Sefer Tsurat ha-Arets

The Form of the Earth / Sphaera Mundi

(c. 1132)

by R. Avraham bar Hiyya ha-Nasi (ca. 1070–ca. 1136, Barcelona)

Translation by Scott Weisman

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Upright reason dictates that the recipients of the good, of whatever type and level of beneficence it may be, must show gratitude and blessing to the beneficent person in every way possible, commensurate with the value of the beneficence. And one who has benefited all the people of the world — for example, one who invented a new instrument for the good of the world, or a good book — it is fitting for every discerning person, out of the obligation of love of fellow beings, to at least purchase it, so that the man will profit and his heart will be encouraged thereby to invent yet more good instruments in the world. And similarly, all other wise-hearted people will likewise strive and exert themselves to invent good things and instruments needed for the repair of the world and its perfection.

And therefore, whoever says: "What do I need this new instrument for?" — he does not act well towards the world. For if not for the man who invented it, where would you be? And what would your city do? And more than this, if the man did not exert himself, what would the world do?

— R. Pinchas Eliyahu Hurwitz, *Sefer HaBris HaShalem* (1797)

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A note on the work

A foundational work of medieval cosmology that lays out the shape of the cosmos as the Greeks and their Arabic heirs understood it: a spherical earth at the center of nested celestial spheres, the paths of sun and moon, and the zones and geography of the inhabited world. One of the first scientific works written in Hebrew rather than Arabic, it shows how that learning entered the Hebrew tradition. This translation is made from the richly illustrated first printed edition (Basel, 1546), with Latin notes by the Hebraist Sebastian Münster.

A note on the translation process

This translation was produced with the translation-pipeline. See the linked repository for details on the process.

This text is the product of a highly refined automated translation process. It has undergone only cursory human review and should not be treated as an authoritative or scholarly rendering. It is offered solely as a reference and reading aid — a way to make an otherwise inaccessible work approachable — and any passage of real consequence should be checked against the original source.

How this edition was produced

This edition was derived from the 1546 Basel first edition (printer Heinrich Petri), digitized by the New York Public Library. The path from source scan to finished text was as follows:

1. **Source isolation.** The 1546 volume is bilingual: each work is printed once in Hebrew and then again in Latin (the apparatus of Sebastian Münster and Erasmus Oswald Schreckenfuchs), the Latin bound and scanned in reverse page order after the Hebrew. Only the **Hebrew** portion — physical pages 1–370 of the 598-page scan — was translated; the Latin counterpart of the same works was left in the original.
2. **Batching.** The Hebrew-only source was split into uniform two-page batches in physical scan order.
3. **Translation.** Each batch was rendered into English sequentially in a publication register, using Münster's facing Latin annotations as a parallel witness to disambiguate the difficult sixteenth-century Hebrew type (his apparatus runs through the astronomy and ends at its colophon).
4. **Reconciliation.** Flagged anomalies — uncertain numerals, scrambled type, structural boundaries — were re-examined against the source and

corrected. Genuine compositor errors of the 1546 printing were kept verbatim with an editorial `[recte: …]` note rather than silently emended.

5. **Collation.** The reconciled batches were assembled and split into the two distinct works bound in the volume — the astronomy of Avraham bar Hiyya and the arithmetic of R. Eliyahu Mizrahi — each issued as its own edition.

This volume is *Sefer Tsurat ha-Arets ("The Form of the Earth")*; its companion, *Kitsur ha-Melakhat ha-Mispar ("Compendium of the Art of Number")*, is issued separately.

Acknowledgements

Translated with the assistance of Claude. The translator thanks the Anthropic team for making this work possible.

Sefer Tsurat ha-Arets — Front Matter (Binding & Library Preliminaries)

Basel, 1546 first edition (Sebastian Münster, ed.).

**** — Front cover of the binding. Plain dark brown leather board with a blind-tooled border rule; no lettering or printed text.

**** — Front pastedown / endpaper. A printed library bookplate is affixed near the center, ruled in a single-line rectangular border:

[Bookplate, English]:

> THE NEW YORK PUBLIC LIBRARY PURCHASED FROM THE JACOB H. SCHIFF FUND

No other text on the page.

**** — Blank flyleaf (recto). No printed or manuscript text. The leather page-holder weight of the imaging cradle is visible at the left edge; the binding's worn spine edge shows at the gutter.

**** — Blank flyleaf (verso/recto opening). No printed or manuscript text.

[No source text on these four pages — all are blank front-matter flyleaves.]

The four pages of this opening are blank, unprinted flyleaves of the binding's preliminary gathering. No printed Hebrew or Latin, no running headers, no diagrams, no page numbers. The title page and Münster's Latin preface have not yet begun.

- p. 1: blank flyleaf (recto), bound edge at left, edge-foxing along the gutter.
- p. 2: blank flyleaf (verso), fore-edge of the gathering visible at right.
- p. 3: blank flyleaf (recto), gutter foxing along the left edge.
- p. 4: blank flyleaf (verso), light foxing spot at lower right.

Title Page

A modern pencil note at the head of the page (in a later hand) reads: "Sefer Turath ha Arez — abraham". A pencil notation "1149?" appears in the right margin and "1546" beneath the imprint.

[Hebrew — square type, title:]

Sefer Tzurat ha-Aretz ve-Tavnit [ספר צורת הארץ ותבנית — "The Book of the Form of the Earth and Its Structure"]

An explanation of the firmament, and the order of the course of the planets in their orbits [?], composed by Rabbi Avraham bar Ḥiyya ha-Sefardi [ר' אברהם בר חייא הספרדי].

(Title-page Hebrew reads: סֵפֶר צוּרַת הָאָרֶץ וְתַבְנִית / בֵּאוּרֵי הָרָקִיעַ וְסֵדֶר מַהֲלַךְ כּוֹכְבֵיהֶם / הַנֶּחְבָּר עַל יְדֵי ר' אַבְרָהָם בַּר / חַיָּא הַסְּפָרְדִי׃)

[Latin — Münster's title page:]

SPHAERA MUNDI [*The Sphere of the World*], describing the figure of the earth and the disposition of the celestial orbs and the motions of the stars; by the author Rabbi Avraham the Spaniard, son of R. Ḥiyya [Rabi Abraham Hispano, filio R. Haijæ].

SEBAST. MUNSTERUS [Sebastian Münster].

Whatever difficult matter is found in the Hebrew in this author has been explained in our annotations, so that we should not hand the book to you, reader, bare [and unexplained].

BASILEAE PER HENRICHUM PETRUM [At Basel, by Heinrich Petri].

(Manuscript date below the imprint, in a later hand: "1546".)

[Latin — Münster's preface / epistle:]

SEBASTIANUS

SEBASTIAN MÜNSTER, to the students of the Hebrew tongue and of the science of Astronomy: greetings.

It is with no ordinary joy that I have been filled — and on your account, you devotees of the Hebrew language and you who have set your minds to the study of mathematics — that this book, which bears the title *Sphaera mundi*, or, as its own title has it, *The Figure of the Earth and the Disposition of the Heavenly Spheres*, has at last come into our hands. Up to now we have labored under so great a scarcity of books in the sacred language of Israel that scarcely anything was at our disposal to set before promising new students beyond grammatical treatises and the sacred volumes of the Bible. For I do not judge worthy to be counted among books so many *מדרשים* [midrashim], such varied *הלכות לבית*

[halachos le-veit (?), "rulings for the house(?)"] [?] and *מנהגות* [minhagot, "customs"] of the fathers, to which I would add too the *פירושים* [perushim, "commentaries"] of nearly all the Rabbis — at least some of them — with which the wretched Jews fill their pitiful pages, and from which nothing may be drawn but sheer trifles and the traditions of the elders: that is to say, good hours spent without fruit, worn away upon empty books of this kind. And yet these are today printed in great number at Venice, at Constantinople, and at Thessalonica — so that not in vain did that most learned man Johannes Reuchlin [Johann Reuchlin], the foremost propagator of the Hebrew language among the Latins, once advise that the Jews should be left their own books, even the useless ones, since it would otherwise easily come about that

[Latin — Münster's epistle, continued:]

EPISTLE

— for one copy taken away, they should recover twenty from foreign regions where they do not acknowledge the emperor of the Germans. For Caesar — namely Maximilian — was at that time persuaded that the Jews' books were an obstacle that kept them from converting to the true faith of Christ. If these were taken from them, he thought, nothing would remain by which the rising generation could thereafter nurse its error and uphold its faithlessness. The counsel was a good one, and not to be condemned by any good man — if only its execution could have been carried out throughout the whole world — even though meanwhile many good books would have perished, books which are found everywhere among the Hebrews and are not counted among the sacred ones, nor are they yet of the same flour as the *מדרשים* [midrashim] and the rest of the traditions.

Certain smatterers, therefore, are mistaken who do not blush to assert boldly that the Jews have no authors in any of the disciplines, that they themselves are strangers to every study of human philosophy, and that nothing is to be found among them beyond the aforementioned empty traditions of the fathers and the dreams of the Talmud — which were concocted out of those same traditions some three hundred years after Christ, the sole Savior of the world, was born. So recent is its edition that the divine Hieronymus [St. Jerome] had no knowledge whatever, so far as I know, of a Hebrew Talmud; for it was indeed made in the last dispersion, as the Jews themselves write.

But I return to those who maintain that the Hebrews have nothing good in the humane studies. Surely these men are convicted of their error by this very book,

which now for the first time I set before you, studious young men, printed in both scripts — a book which Oswald Schreckenfuchs, my most sincere friend, a man born to learn and to teach Hebrew letters, sent to me written in a most ancient manuscript two years ago, and to whom willingly

[Latin — Münster's epistle, continued:]

EPISTLE

— I yield in this study, I hand over the palm and resign the province to him, who among Christians both teaches and plants the holy tongue. He himself, moreover, received that exemplar, written long ago in Spain and already nearly grown old, from Elijah Levita [Elias Levita] — as you will find also in that man's own dedicatory epistle. Andreas Masius, besides, a man learned beyond measure in Hebrew matters, wrote to me last year about many Hebrew books which he had seen at Rome among the Jews, partly printed and partly still to be printed, but which are nearly all either *פירושים* [perushim, "commentaries"], or *אגרים* [aggarim (?)] [?], or the pure commentary of Rabbi David Kimhi on the *תורה* [Torah]. Likewise the *ספר בחינת העולם* [Sefer Bechinat ha-Olam, "Book of the Examination of the World"], which above all the rest I should wish to read, if the chance of it might fall to me; and the *תורת הכהנים* [Toras ha-Kohanim] [?], which is a commentary on Leviticus; the *מכילתא* [Mekhilta] and the *ילקוט* [Yalkut], which expounds Exodus; and there [are] also the *ספר תמונה* [Sefer Temunah(?)] [?] and the *ספר יצירה* [Sefer Yetzirah] on the whole Bible. Likewise — and in the grammarians — the *ספר הבחור המפורש* [Sefer ha-Bachur ha-Mefurash, "the annotated Bachur"] with scholia; and the *ספר צחות* [Sefer Tzachot] and the *ספר מאזנים* [Sefer Moznayim] of Rabbi Ibn Ezra; likewise the books of Rabbi Judah ben David [*ספרי רבי יהודה בן דוד* — i.e. Yehuda ben David Ḥayyuj].

Yet of all these I prefer the one grammar of Elijah, a book truly choice, inasmuch as he gathered it out of so many labors of the ancients and compacted it into a single body — and perhaps even to this day it would not be in Christian hands, had I not lent my own first labors to it. For however many today are soundly learned in the Hebrew tongue, they have it from this chosen book, or from the rivulets drawn from it, so that from this source there have flowed forth almost without number grammars, tables, and introductions. But let us leave these matters aside.

Schreckenfuchs, our friend, has also sent a compendium of Arithmetic, which we have decided ought to be joined to the *Sphaera*, so that once again, reader, you

might see the good arts taken up even in Hebrew letters. He had begun to write annotations on this compendium,

[Latin — Münster's epistle, continued:]

EPISTLE

— just as I had earlier done upon the *Sphaera mundi*, in order to render more clearly those things which might seem too difficult for first-time students. And I did this with the intention of leaving out the Latin version, so that the little commentary itself might serve in place of a translation, lest the book grow too large. But when, in my absence, the version itself had also been begun in print, I set aside my own reflections, so that the same thing should not be written twice — especially since in Arithmetic there are not so many labyrinths and such great difficulties as in Astronomy, where, beyond the bare interpretation, there is always need of some demonstration and of a fuller exposition. Take my labor in good part, then, kind readers, for I am always ready, as long as I shall live, to assist your studies with every aid in my power.

Farewell. At Basel, in the month of July, in the year 1546.

FINIS.

Sefer Tzurat ha-Aretz (The Form of the Earth)

[The first two leaves of this opening are blank — no printed text on these sides; only faint show-through from the printed pages opposite is visible.]

ספר צורת הארץ — Sefer Tzurat ha-Aretz (The Form of the Earth)

The Book of the Form of the Earth, and the Design of the Spheres of the Firmament, and the Order of the Course of Their Stars.

[Münster's Latin note, head of outer column: *ANNOTATIONES Sebast(iani) Munsteri* — "Annotations of Sebastian Münster."]

[The Author's Preface]

In the name of the God of Israel, the everlasting God, I open my words. ✻

[Münster's Latin note, outer column: *Psalmus iste est octauus in ordine* — "This Psalm is the eighth in order." And: *Autor huius libri uocatur Abraham filius rabi*

Haijae Hispanus — "The author of this book is called Abraham, son of Rabbi Ḥiyya, the Spaniard."]

It is written: "O LORD our Lord, how majestic is Your name in all the earth! — You who set Your splendor upon the heavens" [Tehillim 8:2].

Said Avraham bar Ḥiyya ha-Sefardi [the Spaniard], may his rest be in Eden: Blessed is the LORD, the God, the God of Israel — the great God, the mighty and the awesome [cf. Devarim 10:17], strong and resplendent in glory, who rules over His world, majestic in the honor of His name. He has set in the highest heavens luminaries [me'orot] and stars, racing upon their wheels [galgalim], returning and revolving about the circuit of the earth, drawing far off and drawing near. Over them He has spread, upon the inhabitants of the world [tevel], a radiance [ziv] [?] — by His power and His light — and He has shown it to every wise of heart [cf. Shemos 31:6], through the force of its brilliance and its glow, and made known to them the splendor of His handiwork and the hidden depth of His searching out.

And concerning this, David, king of Israel, said: "O LORD our Lord, how majestic [is Your name] in all the earth!" [Tehillim 8:2]. And he said: "When I behold Your heavens, the work of Your fingers" [Tehillim 8:4], and so forth — "and the labor of...

[Münster's Latin note, foot of outer column: *Coelum et terra plena gloria et magnificentia Dei* — "Heaven and earth are full of the glory and magnificence of God."]

I shall see" — for this is from the language of seeing, "the light of the heart," which is the Binah [understanding].

And it is said: He is contemplated in the work of the heavens and in the courses of the stars — the stars that are set in *ha-Maqom* ["the Place"], to make visible [the wonders] of His light. For wonders are wrought, that it should be known and made known, that He proclaims the splendor of His name, the Mighty One, throughout all the earth. And He set its circuit upon the heavens — His tent upon the heavens — and He has spread His outspreading [paroshto] over the heavens.

[Münster's Latin note, outer column: *(המקום) capitur hic pro ipso Deo qui implet omnia loca* — "(The word) ha-Maqom ('the Place') is taken here for God Himself, who fills all places."]

And there came to be, from the work [of His handiwork], understanding from the tongue [language]. He set His searching out, that one might be discerned

[purified] from it — for it is written: He who contemplates the work of heaven and earth, and is discerning in the courses of the stars; and the wisdom of their devising, the might of their Creator he beholds; and he discerns and understands the wisdom of the One who fashioned them and formed them.

And concerning this they [the Sages] said, of blessed memory: "Everyone who knows how to reckon the seasons [tequfot] and the constellations [mazalot] yet does not [reckon them] — of him Scripture says: 'they do not regard the work of the LORD' [Yeshayahu 5:12]" [cf. Talmud Shabbos 75a].

[Münster's Latin note, outer column: *Iudaei multa tribuunt homini qui nouit calculare motus corporum coelestium* — "The Jews ascribe much to the man who knows how to calculate the motions of the celestial bodies."]

For one who does not look upon it [the heavens], and does not find it — let him behold "the work of the LORD," and see "the labor of His hands." But one who looks not upon it, and does not find it — yet the thinker [the contemplative] beholds the work of the LORD and sees the labor of His hands. And he shall be strengthened by his way, more than all the rock [צר, recte: צור? "more than every Rock"], for the masters [scholars] say: to instruct the Torah by the mouth — and without it. He shall be occupied with it and hold fast to its commandments; and his deeds shall be — these — those of one who seeks out the earth, [seeking] wisdom...

the stars, and to declare His glory, and is not occupied with [astronomy] except in speech alone. But I [steel] myself to hold fast to the science that is the discipline [*mesoreret*] for confirming the truths of those who profess belief. All my days I have sought and searched to find a work in the holy tongue that sets forth this science upon its proper order, and I did not find one; and I saw that, in my own eyes, in matters such as these I was obligated to bring it forth from my own mouth and to do so myself. I have been remiss and slothful in this undertaking, for I did not see anyone leaning upon my help, and so it was not realized.

This matter rested upon my own counsel and authority. And when I came to consider the rows of the ranks and the orders—the costly luminaries that go forth from before the King, the Source[?] of light, and the radiance of the everlasting sun, the natural [light?] and the luminaries of light, and the wheel [*galgal*] and the constellations[?], by the name of my God—and in His choosing[?] and His favor toward the city of my peace[?] [*sha-lomi*][?], before the sun his name shall endure[?] [cf. Tehillim 72:17][?]—then he counseled me to compose, in the science of the stars, a work that shall set forth and explain its matters in their proper

order, well-arranged and well-faced. I gave my word, and through his pleasant words and his command, to bring it to completion[?] he saw fit. At once I bent myself to give ear to his counsel, for he honored me; and I joined together—and that is[?]…

[Münster's Latin note: *Mysteria fidei colliguntur ex mathematica, si studium theologiae cōcurrat, imò praecedat istud studium.* — "The mysteries of faith are gathered from mathematics, provided the study of theology runs alongside it—indeed, that study should take precedence."]

[Münster's Latin note: *Vocant Hebraei Astronomiam sapientiam stellarum, hoc est, sublimem cognitionē corporum coelestium.* — "The Hebrews call astronomy the 'science of the stars,' that is, the sublime knowledge of the heavenly bodies." This glosses the Hebrew *ḥokhmat ha-kokhavim*, "science of the stars."]

the duty that is incumbent upon all who love him and are dear to him, all the more upon his disciples who are subject to him—incumbent upon him to do so. And I [pleaded?] and entreated before the Helper of all [*ozer kol*][?], the strength[?] of all that goes, who guides those near to him along a path that is upright in this matter, and sustains it[?]—for this is the science, and these are the truths[?], when I had girded myself in the manner of those who fasten about themselves the broken[?] sackcloth[?] [*saq*][?] of the lowly[?]. And length of days[?]…the counsel that is over you is my counsel. And He, in the abundance of His mercy, heard my cry and brought to fulfillment what I asked—for in vain are all things, and there is no God except the Healer[?] [*ela ha-rofe*][?]; and may his name be one of praise and renown forever.

And I, in opening the opening upon the subject of this work, I say: For the science of the stars is divided, in the eyes of men, into two great parts. The [first] part is that which speaks of the form [*tzurat*] of the heavens and the structure of the earth, and of the course [*mahalakh*] of the wheel [*galgal*] that revolves above the earth, and the course of the stars set in the firmament; and the order of the course of the constellations[?], and their rising-points[?], and their setting; and the second part [*ha-ḥeleq ha-sheni*]…

[Münster's Latin note: *…tu חלבא pro חלך psalmo decimo invenitur.* — a textual note: "…thus *ḥelba* for *ḥelekh* is found in Psalm ten." (A philological remark on a scriptural reading.)]

[Münster's Latin note: *Prima pars astronomiae considerat figurā & dispositionem coeli & terrae, motum coeli & astrorum in genere, item argumēta probabilia, certa et irrefragabilia, &c.* — "The first part of astronomy considers the figure and

disposition of heaven and earth, the motion of heaven and the stars in general, and likewise arguments that are probable, certain, and irrefutable, etc." This summarizes the Hebrew's *first part*.]

[the science] called the science of vision [*ḥokhmat ha-ḥizzayon*], and it is divided, by way of instruction, into two parts. The one sets forth the form [*tzurat*] of the structure within the heavens and within the earth, and the order of the course of the visible bodies in the firmament and among the stars, and their wheels[?] and their courses[?], each one of them; and from these come the things that follow[?] upon them. And the second part: the reckoning of the courses [*mahalkhot*] of the constellations, and the [?], and how it is possible to know the standing[?] [position] of the stars from the firmament at any given time at which you wish.

And I am setting forth [*maqdim*][?] in this work this part as[?] the first part, and it sets forth the matters that depend upon it briefly, and brings forward and shows a path that is short [*derekh qetzarah*], near to the understanding of every student in the place[?] of the necessary [propositions], to instruct him toward the [Master?] [*Alufan*][?] and the order of the reckoning; and his wheels[?] shall be explained in a book other than [this], if his help be from the heavens.

And the second part of the science of the stars depends upon, and is bound up with, these [matters]: the first part. And it speaks of the four[?] events that arise[?] upon the earth, which the courses of the stars stir up against them[?] and cause to befall them—and how a man is able to understand them—before they come about[?], from the appearance of the transmitted tradition[?] [*ha-mesoret*] [?] in the hands of the sages. This part of vision is one of the foretelling[?] [*ha-shorit*][?] that is to come in their times, or one of the experiences [*ha-nissyonot*]...

[Münster's Latin note: *Altera pars astronomiae cōsiderat motum signorum.* — "The other part of astronomy considers the motion of the constellations [*signa*, the zodiacal signs]." This glosses the Hebrew's *second part*.]

[Münster's Latin note: *Eventus qui contingūt in terra quotidie propter causas coelestes innovantur.* — "Events that come to pass upon the earth are daily renewed on account of celestial causes." This glosses the Hebrew on the terrestrial events stirred up by the courses of the stars.]

which were handed down to them by their forerunners[?] [*qadmoniyeihem*][?]. And this part is divided, and is altogether distinct[?] from the science of nature [*ḥokhmat ha-teva*]; and though it is fit to be called the work of vision [*melekhet ḥizzayon*], it is yet called the science of vision [*ḥokhmat ha-ḥizzayon*]—but it is only a binding-together[?] [*saruv*][?] of the sons of men and their multitudes[?]

who look upon it. For the work of this vision is the issuing-forth [*totza'ot*] of the science of vision, and it is the practical benefit that proceeds[?], bestowed upon the sons of men in this world. And there are sages who say that the science gives to all[?] this benefit[?] [the standing it has] only because of what I have seen[?]: and they too[?] [reckon] by way of proofs [*re'ayot*] and reasonings [*tevunot*] and counsel, which come[?] from opinions and experiences. And upon all this, if God be my help, I shall be fit[?] to bring the work of vision to completion; telling[?] [the matter] to my heart[?], to set forth the work of vision, with God's help [*be-Ezrat ha-Shem*].

And I divide this work into ten gates [*she'arim*] great [in scope], and every gate of them I divide[?] [*neḥelaq*][?] into openings [*petaḥim*, sub-sections], according to the matters that are set forth in it.

✻ The first gate [*ha-sha'ar ha-rishon*]: on the structure of the heavens and the earth, [made] of the firmament, and on the course[?] of the visible bodies[?] in the firmament, and all that depends on this matter.

✻ The second gate [*ha-sha'ar ha-sheni*]: on the structure of the firmaments[?] of the stars, [their] creation[?], and their orderings[?], and on the manner of the course…

[Münster's Latin note: *Ab experimentis & effectibus venitur ad causam, quod philosophus dicit procedere à posteriori ad prius.* — "From experiences and effects one arrives at the cause, which the philosopher calls proceeding from the posterior to the prior."]

[Münster's Latin note: *Per experimentalem astronomiā multi quaerunt cōmodum in hoc seculo. Sapientes vero non magni faciunt eā, cum argumenta habeat invalida, effectusq́; raro sequātur causas, quae praetexi solent.* — "Through experimental [i.e. judicial] astronomy many seek advantage in this world; but the wise do not esteem it highly, since its arguments are weak, and its effects seldom follow the causes that are wont to be alleged for them." This glosses the Hebrew on the applied/judicial part valued less by the sages.]

[Münster's Latin note: *Dividitur hoc opus in decem capita, & deinde capita dividuntur in capitula.* — "This work is divided into ten chapters [*she'arim*, 'gates'], and the chapters are then divided into sub-chapters [*petaḥim*, 'openings']."]

the course of the sun, [explaining] the reason for both. ✻ The third gate: on the orbits [רקיעי, "firmaments"] of the moon and the simple and compound [components] of its course, and on the moon's beginnings. ✻ The fourth gate: on

the reason for the eclipses of the two luminaries, and the cause underlying each of them. ✻ The fifth gate: on the course of the zodiacal belt [גלגל המזלות, the ecliptic] — its strengthening and weakening with respect to the stars' bodies [the planets] — and the matter that underlies it. ✻ The sixth gate: on the standing of the stars [planets] in latitude [רוחב] and on the manner of the constellations [המזלות], and their distances from the [reference] circle. ✻ The seventh gate: how the planets are hidden beneath the sunlight and reappear within the length [אורך, the longitude], coming out from beneath that length. ✻ The eighth gate: on the size [shrinking] of the earth and the proportion of its measure to the bodies of the heavens, and the [proportional] measure of one body to another. ✻ The ninth gate: on the disagreement that exists among the scholars of the science of vision [חכמי החזיון, the theoretical astronomers] regarding the course of the planets, and on the reckoning of the [astronomical] cycles [החוגים] from south to north and from north to south, by the manner of the constellations.

[Münster's Latin note, against the upper Hebrew: *Motus simplex et varius* — "Simple and varied motion" — glossing the gates on the moon's simple and compound course.]

[Münster's Latin note: *Qua occasione eclipses fiant* — "On what occasion eclipses occur" — glossing the fourth gate. / *De motu irregulari planetarum* — "On the irregular motion of the planets" — glossing the gates on the planets' course.]

[Münster's Latin note, against the lower gates: *De proportione collationis terrae quae minor est stellis coeli: Item quantus sit arcus, id est, circumferentia corporis eius. Per* תשברת *intellige quantitatem* — "On the proportion of comparing the earth, which is smaller than the stars of the heavens; likewise how great the arc is, that is, the circumference of its body. By* תשברת *[teshboret] understand 'quantity/magnitude.'" This glosses the eighth gate and clarifies the Hebrew term תשברת as denoting magnitude.]

The First Gate: On the Structure [בתבנית] of the Heavens and the Earth

[Display heading, p. 8] On the structure of the heavens and the earth, the standing of each of them, and the reason for both, and on the form [צורת] of [the heavens'] course and its parts [חלקיו].

Petach [opening]

[Marginal rubric beside the opening word: נחלק ל[...] — "divided into...", indicating the gate's subdivision into openings.]

This gate is for the explanation [לטעמי(ם)] of the many [matters] that hang upon it. This is a starting point [בורר], and I begin with them concerning the structure of the heavens. Now all the scholars, the ancients and the moderns [הקדמוני' והאחרונים], have agreed in their wisdom upon this: that the firmament [הרקיע] revolves like the form of a sphere [גלגל] in all its directions, and that the uppermost firmament [הרקיע העליון], which encompasses the whole of the firmaments [חבל הרקיעי(ם)] that lie beneath it, revolves and rotates in its course [as] one sphere [גלגל], turning from east to west and carrying with it all the firmaments that lie beneath it — once each day — and it is named the rotating sphere [הגלגל החוזר, the diurnal sphere].

This [sphere] rests upon two fixed points [נקודות מובנת] in the heart [center] of the heavens, points which do not deviate from their place. One [point is] at the southern extremity, and the second at the northern extremity; these are called **the poles [קטבי] of the course** — that is, the universal [poles, הכללי].

For this reason, the heavens are like a sphere [כדור], and the sun, the moon, and all the planets [כבבי לכת, "the wandering stars"] are fixed upon it.

[Münster's Latin note, p. 8 upper margin: *Consentiunt periti quique in arte astronomica, coelum ex omni parte sphaericam habere figuram, moveturque ab oriente in occidentem, trahens secum omnes sphaeras inferiores* — "All who are skilled in the art of astronomy agree that the heaven has a spherical figure on every side, and that it moves from east to west, drawing with it all the lower spheres." This confirms the adjacent Hebrew on the rotating outermost sphere.]

[Münster's Latin note, p. 8 lower margin: *Pendet motus coeli a duobus punctis immobilibus, e regione in medio coeli constitutis* — "The motion of the heaven depends upon two immovable points, set directly opposite each other in the midst of the heaven." This glosses the Hebrew on the two fixed poles.]

[Diagram follows on p. 9.]

Diagram. A schematic of the spherical heavens with the earth at the center. A large outer circle represents the celestial sphere; a small concentric circle at the center represents the earth. A horizontal diameter runs across the figure, marking the axis between the two celestial poles, with a marked point at the

right-hand end. A faint second (offset) circle and small star marks are lightly impressed (offset/show-through). The heading above the figure repeats the running-header phrase "and the structure of the heavens."

- (above the figure): ותבנית השמים [ve-tavnit ha-shamayim, "and the structure of the heavens"]
- ארץ (center, inside the small inner circle): [eretz, "Earth"]
- קטב הדרום (right end of the horizontal axis, at the marked point): [ketev ha-darom, "the southern pole"]
- קטב הצפון (left end of the horizontal axis): [ketev ha-tzafon, "the northern pole"]

The proof of this is from the stars that begin to become visible at the eastern extremity: they appear as though emerging from beneath the earth, and as they grow distant from their place they rise [in the sky] and climb higher, increasing [their] elevation until they reach the middle of the firmament — at the highest point of [their] visibility to the eye. From there onward they appear to be descending and sinking, drawing nearer to the earth, until they reach the setting-point [נקודת מערב] at the west and are hidden by it. These are, in fact, the [same] stars that were [visible] beneath the earth, hidden from the eyes of men — they appeared not at all during the period in which they were [below], [whereas] they were visible above the earth; and afterward [the cycle] returns [שבים, "they return"].

[Münster's Latin note, p. 9 margin: *Stellae ab ortu in meridiem sensim ascendentes, facile ostendunt coeli orbicularitatem, sicut et descensus a meridie in occasum* — "The stars, gradually ascending from their rising toward the south [meridian], readily demonstrate the roundness of the heaven, just as does their descent from the meridian toward their setting." This confirms the adjacent Hebrew on the apparent rise and descent of the stars.]

[Diagram follows at the top of p. 10.]

Diagram. A semicircular (hemispherical) schematic showing the visible half of the celestial sphere above the horizon, with the earth at the base center. Two concentric arcs span from the eastern horizon-point on the left to the western horizon-point on the right, resting on a horizontal baseline (the horizon). A small semicircle at the center of the baseline represents the earth. Six-pointed star marks (✻) indicate a star's positions: at the eastern horizon (lower left), at the zenith/meridian (top), and at the western horizon (lower right) — illustrating a star's rise, culmination, and setting described in the adjacent text.

- (above the figure): צורת הארץ [tzurat ha-aretz, "the form of the earth" / the work's title]
- ארץ (center of baseline, inside the small semicircle): [eretz, "Earth"]
- מזרח (lower-left horizon end): [mizrach, "East"]
- מערב (lower-right horizon end): [ma'arav, "West"]
- ✻ (three positions: lower-left, top, lower-right): star marks on the arc, tracing the star's path from rising through culmination to setting

[the stars] that return to rise as at the beginning, and they cycle around [in their courses], appearing over the earth in their first course until they come once more to the setting-point at the west — there being in these [appearances] nothing [absolutely] fixed. The [point of] setting and the place of rising shift somewhat from their [former] positions, until their progression [שקיעתן, their setting/decline] says [shows] still another [shift] that does not move [evenly] and is not constant [ולא גורע יהיה, "nor does it diminish"]. In these [phenomena] there is great evidence to prove [the matter] concerning the spherical form [עגול] of the structure of the firmament [תבנית הרקיע]. And [this is] reinforced by the fact that the eyes, in considering [the matter], reckon the course of the wandering stars [הכבבים המסובכים, "the entangled/wandering stars"], [which are] visible over the earth and are not [located] beneath it, [moving] like a [revolving] candelabrum [כמשבנורת, recte: כמש(נ)ורת — "like a menorah/lamp-stand"; reading uncertain[?]]. These [stars] turn back, and one gazes upon them: they are as though encircling [סובבי] their bodies [framework], [revolving] upon circular orbits [גלגלות] that receive [carry] one [another] — this one and that — by their proven [movements] — this one to that one [זו לזו].

[Münster's Latin note, p. 10 upper margin: *Moventur stellae motu coeli: ascendunt in oriente et sensim attolluntur in meridiem, et tunc rursum incipiunt declinare versus terram, nec tamen constitutio corporis earum aut proportio earum in aliquo videtur vel crescere vel minui, sed apparent in eadem magnitudine tam in oriente quam in meridie et occidente, id quod testatur coelum esse rotundum* — "The stars are moved by the motion of the heaven: they ascend in the east and are gradually raised to the meridian, and then again they begin to decline toward the earth; yet neither the constitution of their body nor their proportion appears in any way to increase or diminish, but they appear at the same magnitude in the east as in the meridian and the west — which testifies that the heaven is round." This restates the adjacent Hebrew argument for the sphericity of the heavens from the constant apparent size of the stars.]

[Münster's Latin note, p. 10 lower margin: *Stellae circa polum nobis nunquam occidunt. In cur*[…] — "The stars around the pole never set for us. On [why]…" — beginning a gloss continued on the following page.]

Sefer Tzurat ha-Aretz — First Gate (continued)

Running header (p. 11): ותבנית השמים — "and the structure of the heavens."

Diagram. A set of three concentric circles representing nested celestial orbits seen from the pole. At the common center is the label סטב. From the center a radial line runs up and to the upper left toward two star-marks (✻) drawn between the circles — the inner star nearer the center on the middle ring, the outer star on the outermost ring — illustrating that a star farther from the pole traces a larger circumference in the same revolution.

- סטב (center): the pole-point [center about which the orbits turn]
- ✻ (between the middle circles): a star nearer the pole
- ✻ (on the outermost circle, upper region): a star farther from the pole

[Münster's Latin note (lower-left margin, parallels the adjacent Hebrew on the curvature of the circles): "In the curvature of circles, where one circle gives rise to another and is set opposite to it at an equal distance — that is, they are parallel, however you may wish to call them."]

These [orbits revolve] one corresponding to the other, by the will of your Creator. They all ride upon a single axle, one end of which is called the **northern pole** [קטב הצפון]; and you will find that every star that is close to the pole revolves about it, in a small circle, since the circle of its revolution lies near the pole. By contrast, a star farther from the pole revolves about it in a circle that grows larger in length [i.e., in circumference] as its distance from the pole increases, until you reach the equator [מחוגת הכוכבים — lit. "circle of the stars," the celestial equator], which bisects the heavens. [Münster's Latin note (left margin): "The farther the stars are from the pole, the larger the circumferences they describe."]

The star that runs upon it [the equator] and that rises over the earth [?] will, when it descends [below the horizon], be the star whose hidden interval [the time it spends out of sight] equals the time of its visibility over the earth — the time of its visibility equals the time of its concealment. From it [the star at the equator] the [more remote] star differs: as a star is more remote [from the equator and nearer the pole], its time of concealment is short while its time of visibility is long. [Münster's Latin note (lower-left margin): "Extension."]

Running header (p. 12): צורת הארץ — "the form of the earth."

[Münster's Latin note (upper-right margin): "Extension, that is, the magnitude of the heaven, is incomprehensible to us, since the earth is as it were a point in comparison with it."]

You can thereby grasp the form of the firmament [רקיע] and its configuration: that it is spread out and laid open from east to west, like that upon which the misty [?] [aerial] luminaries [אורילים וטפשים — "thin/vaporous bodies"] are set, and like the stars of the firmament that move along it in a straight line, with no crookedness in them. By this you can also recognize the configuration of all the wandering stars [planets], understanding the whole. It grants every star its circular revolution over the earth: in the eastern quarter a body appears small in its eastern part [?], whereas it appears larger [?] [Münster's Latin note (lower-left margin): "This figure shows that the stars cannot be carried from the east through the middle [of the sky] to the west by a circular motion, otherwise the stars would appear much larger at the meridian."] in the heavens, and likewise here when it sets in the western quarter — because their courses run from the form of the earth in this manner, to the eastern quarter, growing longer from the half [?] of the course toward it [?].

Diagram. A large circle (the celestial sphere / horizon-bounded hemisphere) with a small central circle labeled ארץ ("earth"). A horizontal chord crosses near the top, marked at its left end, right end, and upper midpoint with star-marks (✻), and the topmost point of the great circle is labeled נגב ("south" / the meridian apex). The figure illustrates that if stars moved on a straight line across the top rather than on a true sphere, they would appear larger at the meridian — refuting the false model.

- נגב (top, apex): south / the meridian zenith point
- ארץ (center, small circle): the earth
- ✻ (left end of the chord): a star at the eastern horizon [?]
- ✻ (upper midpoint of the chord): a star at the meridian
- ✻ (right end of the chord): a star at the western horizon [?]

Running header (p. 13): ותבנית השמים — "and the structure of the heavens."

at the meridian [בחצי השמים — "the midst of the heavens"], and so it would be appropriate for it to be at the meridian of the heavens — a large [body] to the sight of the eye — when seen at the edge [horizon], in the eastern and western quarter. [Münster's Latin note (left margin): "What is seen from afar appears

smaller than when it is seen close, even if it is a single body, or two bodies of the same magnitude."]

For every body that is far off appears smaller because it is seen upon a line [of sight] that is short. By contrast, a body that is long [near] appears larger, because of the small interval of its appearance: it is seen upon a line of sight that is short and near. [?] But the appearance of the stars is not so to the eyes of men — yet the sages [astronomers] do assign to the bodies of the stars, at the edge [horizon] of east and west and at the meridian of the heavens, one and the same magnitude [ערך אחד — "a single ratio/value"], and a single fixed measure [קצב אחד]. This is because the line that runs out from the earth to the equator [עגול המקית — "circle of the equator"] [?] — call it by whatever name you wish — is of one [equal] magnitude [על ערך אחד]. [Münster's Latin note (left margin): "Whence it comes about that the stars in the east and the west appear larger than at the meridian."]

The common people [רוב העם] say of them, in their seeing, that the eye [perceives] a body in the east and in the west as large at the meridian of the heavens, [whereas] what is seen [there] would [in fact] be found to be of the [same] form, spread out [?]. But there is no addition [increase] visible to most people [as] a body in the east and in the west, on account of the great distance — or [the increase is] slight [מיעוטו — "its smallness"]. Yet the [astronomical] reasoning [?] assigns to the body, for the sight of the eye, the form of the air [?] [צורת האויר] in which they ascend [enter the field of view]; and the [vapors/turbid layers — שוקעים] through which it [the line of sight] passes in the east and the west, lengthen [the apparent size] [?].

Running header (p. 14): צורת הארץ — "the form of the earth."

Now consider the form of the sphere [galgal], which is not [a thing] revolving by its own choice but exists as one [single] body. We have no record of seeing all the parts [of the heaven] departing from the configuration of the sphere in its true form, and not [departing] from their order — and we have nothing to rely on except the whole [body] of the great sphere, which the men of [exact] knowledge [אנשי המדע] and the understanding have handed down to us, taking counsel concerning it with the masters of [the science of] reckoning [חשבון — astronomy/computation], and the verification.

That which has been said — that the sphere [galgal] upon which the world is set [סומה העולם] — it is fitting that it be swift in its course and well guarded [שמור] from any defect [?], because it [moves] without its [orbit] holding it back [מעבב את הליבתו — "obstructing its course"]. And it is known that [the heaven is] a

sphere [galgal], whose surface revolves and turns upon a [second] sphere [galgal], all of whose surfaces [planes] are straight [even] in their concavities [קעריהם]. There is no point [marking] upon the sphere [no place] and no axis-line [?] that would obstruct [the motion of] the earth, holding back its course [את הליבתו — "its core/heart," i.e., its essential motion]. [Münster's Latin note (lower-right margin): "The motion of the heaven is regular and swift, and is completed without any obstacle or impediment — all of which proves its roundness, that is, its rotundity."]

Diagram. A circle enclosing an equilateral triangle (apex at top) and, drawn across the lower portion, a four-sided figure whose two long horizontal chords span the circle — so that both a triangle and a quadrilateral are inscribed within the single circle. The construction illustrates the argument that the sphere (circle) is the most capacious of bodies: any rectilinear figure (triangle, square) of the same bounding surface encloses less than the circle does.

- No interior point-letters are inscribed.

[Münster's Latin note (margin, left of the figure): "There is no body of greater capacity than the sphere; the heaven, moreover, embraces and contains all things enclosed within it."]

They said further: it has already been shown that, of all the bodies a body can take, the rounded form is the one that — with the very same bounding surfaces — holds the greatest volume; and that a body of equal surface yet holds less when its faces are flat. For among all bodies you will find no shape with a surface as capacious as the round one, the surfaces being equal; and likewise, among all bodies whose faces are flat — whether straight-faced or curved — you will find none whose volume is as great as that of the sphere. From these considerations, and from others like them, they concluded and sealed their judgment upon the round, spherical form, and upon its motion.

The sphere is clear in its reckoning, and its revolution is as we explained above. **[⁕]**

פתח חא׳ — First Opening

[The heading reads **פתח חא׳**.]

On the form of the earth. So too they gave the earth, in its body and structure, a round shape and the image of a sphere; and they did not let the mountains and valleys found on the surface of its body trouble [the argument], since these bear

no proportion against the substance of its body. From the roundness found in the structure of its body, we see that the sun, the moon, and the remaining stars do not rise upon the differing places — in the regions of east and west — at one and the same hour; rather, they rise upon the people of the west only after they have risen upon the people of the east.

We understand this matter from the eclipses of the luminaries and the conjunctions of the stars, which is something plain to every person: that the time of the eclipse of the moon, and the time of the conjunction for every one of the stars, is not [the same for all observers].

[Münster's Latin note: "This first chapter sets forth the figure of the earth, [namely] that it too is spherical, and the mountains and valleys do not prevent the corporeal mass of the earth from being a sphere. The roundness of the earth is proved by the fact that the luminaries and stars rise sooner for the eastern peoples than for the western, and their rising cannot be seen simultaneously by Greeks and by Spaniards — which would happen if the earth were flat."]

[Münster's Latin note (lower margin): "I have here placed Jerusalem at the position of Jaffa [Iappo] itself."]

Diagram. A quarter-circle (sector) drawn over a smaller inner semicircle that rests on the same baseline at the center. From a point on the inner semicircle (marked with a dot), two straight lines run outward to two stars (✻) on the outer arc — one star at the upper apex, one star at the lower right. The construction shows the same star seen from two different positions on the round earth, hence rising at different times for an eastern and a western observer.

- ארץ ("earth") — at the base, labeling the inner semicircle (the earth's body).
- מזרח יפו ("east — Jaffa") — along the lower-right radial line, by the right-hand star.
- מזרח בבל ("east — Babylon") — along the upper radial line.
- נסרם — at the lower-left, beneath the outer arc. [Reads as נסרם (nun-samekh-resh-final mem); meaning here uncertain [?].]
- ✻ (upper apex): star position.
- ✻ (lower right): star position.

[the same eclipse-point in the heaven occurs] later [for one observer] than for another, because of their differing positions upon it — that is, in the heaven — while it occurs over the earth at [its own] time. Their [observed] positions differ

— from this [the roundness is inferred]. And we have seen [this] in the books on the moon:

The ancients [recorded] the eclipse of the moon — a single eclipse occurring on one night — and reckoned it for two peoples: those of the eastern land, in the region of east, and those of the west, in the region of west. They took its [time] in their tables, and so it comes about that the hour of the conjunctions recorded in the book of the western [astronomers] is earlier, by the [span] between west and east, than the hours of the conjunctions recorded in the book of the eastern [astronomers], for every eclipse that recurs. So it is recorded in the books of the two of them.

Likewise, in the conjunctions that occur on these same days, which are reckoned for two peoples in two different places: the hours of the western men come earlier in time than [the hours of] the eastern.

The meaning of this is that it gives the earth a round form, and [shows] that the stars rising upon the people of the east rise before [they rise] upon the people of the west; and the [observer] in the west sees them setting [later], while the [observer] in the east no longer sees them.

A person might object: were it [the earth] not in this structure — were it shaped like a dish, on which there is no curvature — then all the stars rising upon the earth in one region [would be seen at once], and the eastern observers would have no [advantage] in seeing them sooner than the western.

[Münster's Latin note (upper): "From the eclipses and conjunctions of the stars the roundness of the earth is proved, since the same point of the eclipse in the heaven occurs at a different point of time on the earth."]

[Münster's Latin note (middle): "For when the eclipse of the moon happens for the people of Basel at the twelfth hour of the night, this same hour is the second hour after midnight for the people of Jerusalem, and about 30 minutes [further]. Therefore the hour of the eastern peoples precedes the hours of the western peoples — that is, their [eastern] hours anticipate our [western] hours."]

[Münster's Latin note (lower): "If the earth had the form of a dish [paropsis], it would follow that a star would appear sooner to the western peoples than to the eastern — which the figure itself makes plain."]

Diagram. A full circle (the round earth) with a stepped, dish-shaped (concave) trough drawn across its interior — the hypothetical flat/dish-shaped earth. Two small human stick-figures stand on the floor of the trough, one at the left and one

at the right. A line runs from the right side to a star (✻) at the upper right, and continues to a second star (✻) just outside the circle at the right. The figure illustrates the refuted "dish" earth: on such a surface both observers would see the rising star at once.

- מזרח ("east") — upper right, near the inner star.
- מערב ("west") — upper left.
- קערה ("dish / bowl") — center, labeling the concave trough.
- ✻ (upper right, on the circle): the rising star.
- ✻ (right, outside the circle): second star position.
- Two human stick-figures stand on the floor of the dish.

the rising [of the stars] would be upon the people of the east only after [their rising upon] the people of the west — the reverse [of what is observed]. Were it flat-surfaced and spread out upon a level surface on which there is no curvature, then all the stars rising upon the earth would be in one region, and the eastern observers would have no [advantage] over the western, nor the western over the eastern: and this is the [absurd] conclusion.

But were its form triangular, or square, or of some other shape having many surfaces, there would be, on each of the several [faces], a single flat surface; and the inhabitants upon any one surface would be seeing the rising of the stars and their setting [at one time, differently from those on another face]…

and their setting at one hour, at a place where, for two other observers, it is neither earlier nor later in that same span. All of this we observe by experience throughout the world: from the variations in the risings and settings, and from the multitude of the stars, by reason of the great distance between them on the eastern side and on the western side.

These shapes prove that the earth is round. But if it were of a columnar form — round and even on its two surfaces [smooth lengthwise] — then the stars upon it would be seen straight overhead [rising upright] on both the eastern and the western sides, and they would lie toward the north [the same for all]. Consequently every dweller upon the earth sees the stars in the bodies of the heavens rising and setting upon them, and it cannot be that any one of them should have a fixed star standing perpetually over the earth.

So if a deep traveler goes toward the north [as one journeys far north], the stars at his back are hidden from him, while the stars first seen toward him keep their place [rising first]; and these same stars then sink down away from him toward

the stars of the north — the stars said of the earth to be hidden perpetually in their places, the first and the foremost — and they rise and set [come and go].

[Münster's Latin note: *Columnarem terræ figuram intellige extensam in longum à polo ad polum.* — "Understand the 'columnar' shape of the earth as extended lengthwise, from pole to pole." (Clarifies the "column / pillar" shape under discussion.)]

And if you propose the columnar shape given to the earth — that it should be a plane lying flat toward the eastern and western sides, and rounded toward the north — I rule [against it]: I rule that, with such a shape, there would be no dwellers upon the plane who see upright stars [rising straight] from the heavens in any place at all. Rather, they would see, of the heavens, the half opening from their zenith perpetually; and many times these would vary for you. So from all its sides the true round shape of the earth is confirmed.

פתח ב [Petaḥ 2]

A discourse on the standing of the earth relative to the firmament. As to its standing amid the bodies [of the heavens], and being set [glorified] in the midst of the world, suspended within the firmament at its midpoint — it is like a body suspended within its enclosure, inclining toward none of the directions: not toward the east, not toward the west, not toward the north, and not toward the south; not upward and not downward — but standing in the very center, [held] by its own nature.

For were it not so, but inclined to one of the directions — that is, if the heavens were divided over the earth into two unequal portions, and the earth lay toward the side of one of the directions — then on that side it would be near to the part of the firmament that is the upper [the part above]; and that nearer part would cover [obscure] the whole.

[Münster's Latin note (upper): *Si scilicet columnaris figura uerteretur secundum longum ab occidente in orientem, rotunditas autem respiceret septentrionem.* — "That is, if the columnar shape were turned lengthwise from west to east, while its roundness faced the north." (Restates the rotated-column hypothesis the Hebrew is refuting.)]

[Münster's Latin note (lower): *Terra in medio mundi sic collocatur ut in nullam declinet partem, sursum aut deorsum, dextrorsum aut sinistrorsum &c. Alias in uno loco uideretur plus quam medietas cœli, & in opposito minus.* — "The earth is so placed in the middle of the world that it inclines to no part — up or down, right or

left, etc. Otherwise, in one place more than half the heaven would be seen, and in the opposite place, less." (Glosses the central thesis of *petaḥ* 2.)]…* — "If we refer…" (catchword to the next page's Latin note).]

of [its] halves; and we would find all the inhabitants of the earth, in every place and at every moment, [seeing] turn toward them, from the heavens, six constellations — for the half of the firmament that turns and is hidden from them is matched by [the visibility of] the other half. And these are the two halves [each its own].

We say a proof of this: that the earth, set in the center, is like the sun and like the moon, and it is seen [as a point]. For its body, were it but a small body, would yet be reckoned, against the enclosure — against the upper firmament that surrounds the All [the universe] — as nothing [as a mere point].

And we say a second proof: that were the matter of the earth's body of another sort — that is, were the earth's body large — it would [still] be reckoned, against the enclosure, [as nothing] for all who dwell upon the earth, who see of the heavens [only] half the heaven from their zenith perpetually.

Now then [from the moment], when we showed in our argument that the earth stands in the center of the firmament, it is revealed to us from the firmament at its midpoint, at every moment of [its] turning…

Diagram. A horizontal schematic showing the earth at the center of the cosmos between the sun and the moon, with the horizon plane drawn through the center. Two parallel horizontal lines run the full width of the figure (the plane of the horizon, drawn as a band). On the far left is a large circle bisected by a vertical line, labeled **Sol** ("Sun"). At the center is a small circle labeled **Terra** ("Earth"), with a tiny stick-figure standing upright on top of it (above the horizon line) and a second, inverted stick-figure hanging below it (below the horizon line), illustrating antipodal observers. On the far right is a circle, partly cut off at the page edge, labeled **Luna** ("Moon"). The horizon band is labeled **horizon** at upper-left and **superior** ("upper") at upper-right, and **horizon** at lower-left and **inferior** ("lower") at lower-right — marking the upper and lower halves of the horizon plane.

- **Sol** (far left, large bisected circle): the Sun
- **Terra** (center, small circle): the Earth, with an upright stick-figure above and an inverted one below
- **Luna** (far right, partly cut off): the Moon
- **horizon** (upper-left of band): horizon

- **superior** (upper-right of band): upper [half]
- **horizon** (lower-left of band): horizon
- **inferior** (lower-right of band): lower [half]

[Münster's Latin note: *Si referamus terram ad corpus cœli, terra comparatione cœli nihil erit, ut si sol fuerit in oriente & medietas eius eminuerit supra horizontem, qui sunt in opposito hemisphœrio uidebunt aliam medietatem eius nec obstabit hic crassities terræ ob nimiâ solis magnitudinem. Secus de luna, quæ minor est terra, ideo nec in superiori uidebitur hemisphœrio nec in inferiori. Sol maior est terra 166. uicibus.* — "If we compare the earth to the body of the heaven, the earth will be as nothing in comparison with the heaven; so that if the sun were in the east and its half rose above the horizon, those in the opposite hemisphere would see the other half of it, and the thickness of the earth would not block it, because of the sun's vast size. It is otherwise with the moon, which is smaller than the earth, and therefore is seen neither in the upper hemisphere nor in the lower. The sun is 166 times larger than the earth." (Münster supplies the relative-size datum — Sun 166× the earth — underpinning the Hebrew claim that the earth is point-like at the center.)]

to us; and it [the line of sight] strengthens [holds firm] in our eyes — for the line of sight that passes over the surface of the earth [the visible horizon], reaching to the arc of the firmament that is above the surface, upon which the sun shines: we see the rising and the setting of the sun and of the stars, and their courses.

It is reckoned, to the sight of the eye, that [the horizon] passes over the western edge of the earth and reaches to the line of the firmament, with no separation [gap] between them to our eyes. And from this they said: there is no [measurable] bulk to the earth, and no extent; for the distance between the breadth of the earth and the surface of the dome [vault] is reckoned, against the enclosure, [as nothing] — measured against the line of the length of the distance between the breadth of the earth and the surface of the dome of the firmament, of the bodies of the heavens.

For they could not say that the bodies of the stars are smaller [than the earth]: even the smallest of the fixed stars that is in the firmament of the heavens — its body is many times larger than the bulk of the earth, larger than the whole bulk of all of them [the stars together]. And even the stars of the firmament, [though] they are revealed to our eyes as small by reason of the [great] distance — by however much there is to the line of the earth's bulk — all this comes by reason of the distance between them and our eyes.

And if it [the earth] were a body of weight, light or heavy, we would [seek] the proportion for the bulk of the earth…

[Münster's Latin note: *Horizon undique cœlum contingens, perinde est ac si superficies eius plana ex centro terræ expanderetur ad cœlum, nõ obstante crassitie eius, quæ ponitur 1718 miliariorum germanicorum, circuitui enim terræ dantur 5400 miliaria germanica cõmunia, respondentibus scilicet uni gradui cœlesti 15 miliarib. Semidiameter uero terræ habet miliaria 859. Eratosthenes uero dicit uni gradui respondere miliaria romana 87. & dimidium, & Alphraganus miliaria 56. cum dodrante. Porro gradus unus circuli lunaris secundum Alphraganum habet miliaria 3642. & unus gradus circuli solaris extendit se ad miliaria 69231. Vnus aũt gradus octauæ sphœræ habet miliaria 2282326. Cæte[ra]…* — "The horizon, touching the heaven on every side, is just as if its plane surface were expanded from the center of the earth to the heaven, notwithstanding its thickness, which is reckoned at 1718 German miles; for the circuit of the earth is given as 5400 common German miles, one celestial degree corresponding to 15 miles. The semidiameter of the earth is 859 miles. But Eratosthenes says that one degree corresponds to 87½ Roman miles, and al-Farghānī [Alphraganus] to 56¾ miles. Further, one degree of the lunar circle, according to al-Farghānī, is 3642 miles, and one degree of the solar circle extends to 69231 miles. And one degree of the eighth sphere is 2282326 miles. The rest…" (Münster appends the standard medieval cosmic-distance figures — earth's circumference 5400 German miles, its thickness 1718, radius 859; Eratosthenes 87½ and al-Farghānī 56¾ Roman miles per degree; per-degree spans for the lunar, solar, and eighth (fixed-star) spheres — to quantify the Hebrew claim that the earth is negligible against the firmament.)]

when one weighs the matter [of the earth's] smallness against the size of the firmament. It becomes clear to you, in truth, that there is no doubt: the mass of the earth, set within the mass of the firmament, is like a point at the center of a circle.

The air and the atmosphere surround the earth on every side, and the firmament in turn surrounds the body of the air from above — the air reaching up to where its expanse ends. The other firmaments [רקיעים] encircle this one, each reaching up to its own limit, until they reach the firmament that encompasses them all.

The divisions of the firmament, its signs, and the parts of its parts. [פ' חלקי הרקיע ומזליו וחלקי חלקיו]

The early scholars [הקדמונים] divided its parts. They divided the firmament into 360 parts [degrees], for this reason: no whole number greater than 360 can be divided by all these [smaller] numbers without producing fractions — that is, no larger number divides into these whole factors evenly — and at the same time 360 stands close to the count of the year. And because the surface of [the dividing] face [?] is what it is, it turned out that they found for it a great many divisors. For these are the numbers found within it: its half [is whole], a third whole, and a quarter, and a fifth, and a sixth — numbers that come out whole and produce no fractions.

[Münster's Latin note: "Cæterum [תרבן] capitur hic pro amplitudine seu ambitu stellarum. Item [מסל] et חומר argumentum est a minore ad maius. Et [סר] capitur pro linea recta et curva qualis est circulus, et [נתבון] pro quadrare." — "'Moreover' is here taken for the breadth or circuit of the stars. Likewise [the word] and 'matter' [ḥomer] is an argument from the lesser to the greater. And [the word] is taken for a straight and a curved line, such as a circle is, and [the word] for 'to square / quadrature.'" Münster glosses several individual Hebrew words of the column for the Latin reader.] …whole, in the majority of their count. And we have found that the sun [החמה] divides the earth it shines upon into 360 parts [degrees], over the equal years — the measure of the days and the nights throughout the whole world. When we divide it by other numbers, there remain over for it parts that are unequal one to another: among them the day comes out long and the night short, or the reverse — the night long and the day short. But by each one of these [360] parts, it is fitting for [the division] to be even and balanced, so that between the beginning and the end there is an equal share.

And if you come to find the four seasons, by [dividing it into] three parts the firmament comes out at 120 [degrees] each. And by dividing it into 12, you get the constellations [mazzalot], into which a [single] part of the firmament is divided; and these are their names: Aries [טלה], Taurus [שור], Gemini [תאומים]; and after them Cancer [סרטן], Leo [אריה], Virgo [בתולה]; and after them Libra [מאזנים], Scorpio [עקרב], Sagittarius [קשת]; and after them Capricorn [גדי], Aquarius [דלי], Pisces [דגים — printed רגים, recte דגים].

And the entry of Aries [טלה] is the head of them all, because from it [the days] begin: the days begin to exceed the night, and the sun rises into it [Aries]; the heat [חום] grows strong and the cold weakens, and the warm things gather strength and the cold ones diminish as it advances.

[Münster's Latin note: "Numerus 360 commodissimus est pro divisione circulorum cœlestium, quia accedit ad numerum dierum anni, deinde potest

distribui in aliquot quotas seu minores numeros integrantes præcise ipsum: medietas enim eius 180 habet semicirculum, ternarius eius 120 facit trigonum, quaternarius 90 scilicet quartam partem circuli, quinarius 72 quintam partem circuli, et senarius 60 sextam partem. Capita arietis et libræ sunt quasi polimotus cœli, quæ fieri videtur propter aliam et aliam poli elevationem; ergo sub æquatore dies ubique est æqualis noctibus. In climatibus nostris cum sol ingreditur arietem dies incipiunt superare noctes. Minuta graduum, similiter…" — "The number 360 is most convenient for dividing the celestial circles, because it approaches the number of days in the year, and then it can be distributed precisely into several portions or smaller integer numbers: its half, 180, makes the semicircle; its third, 120, makes the trigon [120°]; its quarter, 90, namely a quarter of the circle; its fifth, 72, the fifth part of the circle; and its sixth, 60, the sixth part. The first points of Aries and Libra are, as it were, the pivots of the heaven's motion, which seems to occur on account of one or another elevation of the pole; therefore under the equator the day is everywhere equal to the nights. In our climates, when the sun enters Aries, the days begin to exceed the nights. The minutes of degrees, likewise…" — Münster's margin confirms the integer-divisor list (180, 120, 90, 72, 60) and the equinox/Aries point.]

And if you divide the parts of the firmament by the 12 constellations, each one of the firmament's constellations will be 30 parts [degrees] each. And we call each and every part of them a "ḥeil" [name], while the scholars of Ishmael [the Arabs] call it a "ma'alah" [degree, "step"]. And each "ḥeil" of them is divided into 60 parts, and each part is called a "ligyon" [legion], while the scholars of Ishmael call it a "second shever" [second-order fraction].

And each and every one of these "many" [higher orders]: each of these is divided into 60 third-order parts [thirds/seconds]; and each third is divided into 60 fourth-order parts; and the fourth into fifth; and so on up to the tenth order, and beyond them, if you come to be exact in the reckoning.

[Münster's Latin note: "…militer secundæ et tertiæ vocatur [שברים], id est, fractiones primæ et secundæ, extenduntur usq[ue] ad decimam et ultra, si velis præcise et sine errore computum in longa tempora extendere." — "…likewise [those] of the second and third [order] are called shevarim, that is, fractions of the first and second [order]; they are extended up to the tenth and beyond, if you wish to extend the computation into long stretches of time precisely and without error." Confirms the Hebrew שברים = "fractions" (sexagesimal subdivisions) and the ten-order depth.]

פתח ג' [Petaḥ 3 — Opening 3]

On the courses [of the spheres] by their degrees of motion. [פ' המהלכות בגרורי מעלה]

The arrangement of the courses by their degrees of motion. [The motion] is divided into two great parts: the first is the course of the eighth firmament [the eighth sphere], which revolves from east to west and carries with it all the firmaments beneath it, upon a fixed axis [literally "fixed point"] that has no deviation in it; and all the configurations within this firmament travel with it…

[Münster's Latin note: "Agit hoc caput de circulis maioribus, nempe æquatore et ecliptica, qui æqualiter dividuntur in 360 gradus, fitque æquatoris motus secundum primum mobile ab oriente in occidentem, et secundum hunc motum meti[mur]…" — "This chapter [petaḥ] treats of the greater circles, namely the equator and the ecliptic, which are equally divided into 360 degrees; and the motion of the equator is according to the primum mobile from east to west, and according to this motion we meas[ure]…" Münster identifies the two 'great parts' as the equator and the ecliptic, and the eighth-sphere motion as the primum mobile.]

and as far as the south, intertwined upon circles that are dragged [carried] one against the other, beginning to incline and to revolve from two points — the poles [הקטבים], which are the support of the encircling [sphere], the [great] ring [?] — and they spread out from there: one of them toward the northern quarter and [one toward] the south. The great circle [הָעִיגוּל הַגְּדוֹלָה] is, among the [other] circles, called the "wheel" [אוֹפָן] — the equator [המישור]. And the wheel, in turn, divides the firmament into two equal parts: half of it to the north and half of it to the south.

To this wheel of the equator [המישור] we relate [measure] the courses found in the firmament and the parts of its course. If you wish, say: the parts of the circumference [הקף] by which we gauge the measure of the days and the nights. And the distance of the wheel from each of the two poles is an equal distance — and they are 90 [degrees] each [צ"], by the reckoning of degrees around the whole encircling [circle].

: one term (the "encircling ring" near the poles) stays compressed. Net: the heavy first-pass hedging is removed.]

And the second course is the course of the ecliptic [הנגררת — the "dragged"/oblique circle, the zodiac], for the two luminaries [the sun and moon]

and for the rest of the wandering stars [the planets], which revolve in it from west to east, opposite [the direction of] the first course. [It runs] upon two other stars [points] that meet [touch] it from the poles of the first course…

[Münster's Latin note: "…metimur dies et horas. Per eclipticam vero defertur corpus solis, quin et omnes planetæ per eam et iuxta eam moventur ab occidente in orientem. Equator [קו שוה] habet motum æqualem et regularem sine ulla variatione. Ipse una cum omnibus parallelis sibi ad utrumque latus æquali dimensione adiunctis revolvitur in duobus polis ceu quibusdam cardinibus. Æquator dividit universum in duo æqualia, paralleli vero reliqui in duas partes inæquales." — "…we measure days and hours. By the ecliptic, in truth, the body of the sun is carried; indeed all the planets are moved through it and alongside it from west to east. The equator [Hebrew: qav shaveh, 'equal line'] has an equal and regular motion without any variation. It, together with all the parallels joined to it on either side at equal distance, revolves on two poles as on certain hinges. The equator divides the universe into two equal halves; but the remaining parallels divide it into two unequal parts." — Münster's note confirms the Hebrew קו שוה = "equator" and the ecliptic carrying the sun and planets west-to-east, contrary to the diurnal motion.]

the first toward the north quarter and the south. The great circle that inclines toward the two poles, in its second motion, was this circle — the circle of the signs [ecliptic, גלגל המזלות], which is separated [inclined] from the equator [המישור] westward. The sun, circling upon the axis [עצם] that runs through the two poles, moves from west toward east; and you already know that the two great circles, both being on a single sphere, must each cut the other. Each of them divides the other into two equal parts, as is set out clearly and demonstrated by clear proofs in the science of measurement [Geometry].

[Münster's Latin note: "The great circles of a single sphere divide the sphere into two equal parts — such as the equator, the ecliptic, and the horizon. Geometry is called the wisdom of measurement. The internodes of the equator and the ecliptic, that is, the intersections that occur at the head of Aries and of Libra."]

There must be a point common to both — that is, where each issues from the other [?] — and the equator, together with the circle of the signs [ecliptic], is divided into two parts. These two parts are scattered upon two arcs: one arc inclining toward the north from the equator, and the second toward the south. The two arcs upon which these two circles meet and intersect are called the "points of straightness" [נקודות היושר — the equinoctial points].

And here, since the sun, when inclined from the equator toward the north quarter, is at the point called the Head of Aries [ראש טלה], it is named the beginning of the days of summer [קיץ]; and when, by contrast, the sun is inclined from it toward the south quarter, that point is called the Head of Libra [ראש מאזנים], and is named the beginning of the days of autumn [חרת] [?].

[Münster's Latin note: "Here he calls קיץ the vernal/summer season, just as he calls חרת the beginning of winter."]

the latter; and there are found six signs [ששה מזלות] in the firmament inclining toward the north from the circle of the equator, and likewise [a number] from the circle of the signs [ecliptic] toward the south quarter. And there are upon them point-markings [?] which the firmament crosses [hard reading], the firmament which carries [the heavenly bodies] upward, circling upon the poles [קטבי] of the equator. And if you would [further] consider…

reckon in your mind that, within the great circle in the eighth firmament, were the circle [ecliptic] to pass over the poles of the equator and the poles of the ecliptic, the circle of the signs would be — this circle divides every one of [the bodies upon] the two circles [?] within them, upon the points of meeting and of intersection, into two equal parts. And the arc that lies between the two circles, the arc that is bounded between the two circles — these [arcs], divided in their midst, [are] the arc that lies between the two poles [קוטבים] [?].

This arc, so called, is named "the declination" [נטייה / הנמיבות] [?]; and its measure, according to Ptolemy [בטלמיוס], is twenty-three degrees [23° ,ב"ג מעלות] and a fraction — for Ptolemy's view is that it has, in degrees, twenty-three, and in the minutes [רביעי] it has a fraction; whereas Ibn Yishmael [Ismaʿīl?] [?] holds it to be [ב"ג מעלות, ? degrees]. And these are the views as to its measure [?].

[Münster's Latin note: "A great circle passing through the pole of the world and the pole of the zodiac, likewise passing through the solstitial points, which is otherwise called a colure."]

[Münster's Latin note: "The arc of the declination of the solstitial point from the equator is so great as is the arc intercepted between the pole of the world and the pole of the zodiac, which, according to Ptolemy, has 23 degrees and 51 minutes."]

And the circle of the signs [ecliptic], at the north quarter, is the place called the Head of Cancer [ראש סרטן], and it is named the beginning of the days of heat [summer]; and the intersection-point [ונקודה] [?] which is at the south quarter is the Head [ראש]…

[Münster's Latin note: "The proper motion of the stars, which takes place on the surface of their own orbs, takes place upon the poles of the zodiac — namely, all the planets move..."]

[Capricorn / the south sign] [?], and it is named the beginning of the days of cold [winter]. And it [the eighth firmament] moves in one great circle, in the motion of the planets, which return one after another, each before its fellow [in their own order]. It moves them upon the surface of their firmaments [רקיעיהם], leaning upon the poles of the ecliptic [קוטבי אופן המזלות]. And there is to them a motion of a second kind [שני], which they do not move with in their [first] time; but rather they are entangled within it [?]. For the eighth firmament that circles upon the poles of the equator [קטבי אופן המישור], inclining from the east [ממזרח] toward the west [למערב], draws with it [ומסב עמו] the firmaments that are beneath it, together with all the planets that are suspended in them. And by the appearance of this motion, [each body] is not found in any of the dwelling-places of the earth [משכנות הארץ] upon a single shape. So consider this: that there is a difference between the dwelling-places of the earth in the shape of the motion of the eighth firmament, with God's help [בע"ה].

[Münster's Latin note: "...the planets are moved by this motion; indeed, the heaven of fixed stars is so carried from west to east, which is called the motion of augmentation [motus augium], for the apogees of the planets have this motion as well, which others call the motion of renewal [motum renisionis], which is contrary to the diurnal motion; and this completes, in a hundred years, only 44 minutes and 4 seconds; in ten years, 4 minutes and 24 seconds. Yet it is properly not [a motion] of the sphere, but is received from the eighth [sphere]."]

[Münster's Latin note: "Concerning the horizon-circle, which the Hebrews call the circle distinguishing region from region, mention is made in this chapter."]

פתח ד׳ [Petaḥ 4 — Opening Four]

Explanation [פי']: The circle [האופן, the horizon] that distinguishes, for all the dwellers of the earth, what is forever seen of the world from what is hidden. The firmament-circle [horizon] rises over all the earth, and the second half is hidden beneath the earth; for there is no quarter of the earth that may be reckoned to face any place over against the quarter of the firmament. And there is no [?]...

half of [the world] is seen at one place, and the second half seen at a second place; and within them [?] there is found, for all the dwellers of the earth in every place and locale, a circle that distinguishes for them — that is, the horizon-circle [אופן]

— between what is hidden and what is visible. And this horizon-circle would be defined, and there would be a pole [?] from the sphere [גלגל] within the firmament, which is its pole [קטב לו]; and the intersection beneath it would be [its place of] standing [?], at the height [גובה] which is above the dwellers of the place that this circle distinguishes for them — between what is hidden and what is visible — from the firmament; and it would be the boundary [גדר] of the distinguishing circle [אופן המפריש].

[Münster's Latin note: "Definition of the horizon: It is a circle described over the vertical point as though over a center, which is its pole, separating one hemisphere from the other."]

And know that there is, for the circle of the equator [אופן המישור], a passing-over upon the dwellers of the earth; for if [the dwellers] are under the heads [poles, ראשי] [?] [of equality], the line of equality [קו השוה, equator] which is in the earth is for them the [boundary] between what is hidden and what is visible; and this horizon-circle [האופן] would pass for them, distinguishing between what is visible and what is hidden. And it would pass over the two poles [שתי קוטבי] of the motion [המהלך], and there would be two poles [?] for the dwellers, the line of equality [קו השוה] in the grip of the visible [horizon], drawing toward them continually [תמיד]; and in the grip of [the other], the hidden one continually — the one toward the north [בצפון] and the other toward the south [בדרום]. And there is no other [point] for these poles, where [the horizon] hides them [from sight] [?]…

[Münster's Latin note: "Under the equator the horizon passes through the poles of the world."]

[Münster's Latin note: "The poles appear in the upper hemisphere and in the lower, which is here explained through the apprehension of the seen and the hidden, and that under the equinoctial circle."]

beneath the earth, and is never raised above it. This is the case of those who dwell on the equator (קו שוה, the equator).

As for those who dwell in the other regions of the inhabited zone — the parts that incline away from the equator toward the northern quarter — there the point that passes directly overhead, opposite their heads, stands far from the horizon (האופן, the horizon) of the equator, inasmuch as the northern pole of the diurnal course

[Münster's Latin note: "He calls it *polum mundi*, the pole of the world, because upon it the diurnal motion takes place." — clarifying that the Hebrew term denotes the celestial pole about which the daily rotation turns.]

is far removed from the slope of the horizon that the inhabited zone marks off for them upward above the earth; and this stands in proportion to the pole of the southern course, which is removed by the slope of the horizon that marks off for them downward beneath the earth. As a result, the northern pole — together with all the stars, the circles, and the spheres surrounding it, out to the full extent of its distance from the horizon that marks off right and left — is always visible above the earth and never descends into the lowest region.

By the same token, there is a southern pole, and all the circles and stars that surround it — out to the full extent of its distance from the horizon that marks them off — lie hidden beneath the earth always. And the horizon that marks off the boundary for the dwellers of the equator differs in its character from all the other horizons that mark off the boundary in every region of the earth. This, then, is the division.

[Münster's Latin note: "Stars distant from the pole by however much it is raised above the horizon never set; just as, conversely, stars are found around the antarctic pole, which for us never rise, unless they are farther distant from that [pole] than the pole itself descends [below the horizon]."]

Observe, then, that in all the circles that revolve upon the pole of the horizon of the equator — those that are called *nevochiyot* [parallels / equidistant circles], or are cut into portions by this dividing horizon — this horizon cuts each of them into two equal portions: half of them lies beneath the earth and half rises above it, because the dividing horizon passes over the two poles of these parallel circles, which are the poles of the diurnal course.

[Münster's Latin note: "[There are] revolutions (parallel circles) having their pole at the center, which are called *equidistant* [parallels]; they are cut beneath the equator into two parts equal [as measured] from the horizon."]

From this it follows that all the stars of the firmament of heaven rise upon the dwellers of the equator and set away from them; and no star is found in the firmament that rises perpetually and never sets, nor any that is hidden perpetually and never rises. Rather, all of them rise and set, and the span of time they stand above the earth equals the span of time they lie hidden beneath it.

[Münster's Latin note: "The centers of all parallels are the poles of the world, both under the equator and beyond it."]

[Münster's Latin note: "All stars set under the equator and remain above the horizon only by as much as they are concealed beneath it."]

As for the remaining horizons — those belonging to the latitudes of the inhabited zone that incline away from the equator, whether toward the northern or the southern quarter — they divide these *nevochiyot* circles into two unequal portions. The sole exception is the horizon of the equator itself, which alone is bisected together with the dividing horizon in every place.

[Münster's Latin note: "Beyond the equator the parallels are found unequal below and above the horizon. The horizon is everywhere a great circle."]

[divides that one circle into] two equal portions, because in each of them lies a great circle.

For this reason, the days and the nights are equal throughout every latitude of the inhabited zone on the two days when the sun passes over the head of Aries (ראש מזל טלה) and the head of Libra (ראש מזל מאזנים), which lie upon the line of the dividing horizon.

[Münster's Latin note: "The beginnings (capita) of Aries and Libra always and everywhere rise in the middle of the circumference of the horizon-circle. Likewise the parallel circles are vertical circles under the equator." — and an inserted reading-note: "Here הגדול ['the great'] seems to be written for הקטן ['the small'], and conversely."]

[Münster's Latin marginal correction: "Infra pro הגרת scribitur עצם" — "Below, for הגרת [one should] write עצם." A textual emendation, *ha-geret* should read *etzem*.]

As for the rest of the *nevochiyot* circles, which are not great circles: the dividing horizon, turning away from them toward north and south, cuts each into two unequal portions. The pattern of this division at the northern quarter is as follows. In all the circles that are not great, intersected by the horizon of the equator toward the northern quarter, the larger portion lies hidden beneath the earth and the smaller portion appears above it; such is the pattern at the northern quarter. For the dwellers of the south the arrangement is exactly reversed.

Petach 8 (*Petaḥ Ḥet*) [פתח ח'] [The eighth opening — printed numeral jumps from the fourth opening; transcribed as printed]

On equal hours and unequal (seasonal) hours. It is fitting to begin by saying: because the dividing horizon, for the dwellers of the equator, bisects every one of the *nevochiyot* circles named above

into two equal portions always, it follows that the sun's span of presence above the earth, in the places over which it stands, equals its span of presence beneath the earth, inasmuch as the portions of the *nevochiyot* circles upon which it revolves in that place are equal in that place. For if you take one segment —

[Münster's Latin note: "The abiding of the sun above the earth and beneath the earth is the same under the equinoctial circle; therefore unequal hours are not found there."]

— that is, if you divide [the circle] there into two (על ב'), and likewise the night into portions corresponding to them: the portions of an hour come to 15 degrees apiece (חלקי שעה ט"ו מעלה), and these are equal portions of an hour. Hence for the dwellers of the inhabited zone [on the equator] there are found 12 equal hours by day and likewise 12 by night in their reckoning. And at this point the conduct of the sun turns aside [from this simple case].

[Münster's Latin note: "The sun, in the parallel or vertical circles under the equator, describes (traces) equal portions above and below the horizon."]

But as for the rest of the inhabited regions, inasmuch as the horizon of the equator is divided by the dividing horizon according to their differing latitudes, there the days and nights are found unequal in every place where the inhabited zone inclines away from the equator. For there the sun traverses, upon the horizon of the equator, the portions of an hour [unevenly]; and when it is at the head of Aries (ראש טלה) and at the head of Libra (ראש מאזנים) —

[Münster's Latin note: "The ecliptic and the equator intersect each other at the beginning (caput) of Aries and of Libra."]

— that is, when it stands on the equator itself, the horizon of the equator is bisected together with the dividing horizon; but at the differences of latitude, where the sun revolves upon the equator while the [local] horizon cuts it unequally, there will be…

[The discussion of *Petaḥ 5* continues — equal versus unequal (seasonal) hours, and the case of the dweller under the equator.]

The duration of the sun's standing above the earth at a given moment equals the duration of its standing below the earth, in every one of the parallel circles, both at the sun's setting and at its rising. These [parallels] are described from the meridian toward the north [Münster's Latin note: "A small circle facing the equator, traced by the sun's motion, they call a parallel"] and surround [the pole] toward the south.

On the small circle, which lies nearest the pole, the meridian [equator] is divided at the point [פאה] toward which the sun inclines, and that circle is divided into two equal parts. So it will be — when the sun stands above the earth — that no [seasonal hours arise] [Münster's Latin note: "...which becomes smaller each day, until the sun comes to the other of the tropics"]; or [the sun] departs from its time of standing below the earth, and the days and nights are not equal in their parts.

But if the equator inclines at the northern point of the horizon, that is, from the sign of Aries to the end of [Libra], at the outset the daytime will be longer than the nighttime in all the northern dwelling-places, according to the inclination of the revolving [parallels]; and for the dwellers of the north the northern portion of the ecliptic [גלגל] stands above the earth, and the smaller portion below the earth, and conversely for the southern dwelling-places.

And if the sun, traveling toward the southern point [of the ecliptic], is from [the sign of] Libra to the end of Aries, the night grows longer over the daytime [Münster's Latin note: "(continuation)"].

hidden from the parallel circles and the elevations rising over the visible [horizon], in the northern dwelling-places. And conversely, for the southern dwellers, days and nights are found to be equal throughout the periods of the year, [as they are] in the dwelling-places that lie toward the equinoctial line, whether to the north or to the south [Münster's Latin note: "The northern parallels in the upper hemisphere add to the equality of the day; the other, opposite part diminishes it"], by parts that are not equal.

By the amount of days that exceed [the equal measure] by the parts within them — the equal [hours] — by that same amount one [hour] is added to the daytime in such a way that the other is diminished from the equal measure. And if one [hour] is added to the daytime, by that same amount the hours of the night are diminished, so that the two of them together come to 24 equal hours.

In each one [of the days], and each [of the nights] — those of the days and nights that are not equal in their parts throughout the world — there are 12 parts. And

the order: every part and part is a part of an hour; one is set apart to distinguish between understanding and rightness [i.e., to mark off the unequal hour].

[Münster's Latin note: "By common consensus day and night are divided into 12 equal parts, which are called unequal hours. These are gathered from the division of the degrees of the equator that ascend with the rising and setting of the sun, when it is in any of the parallels."]

And if you proceed [to reckon] all the parts of the day [Hebrew gloss within the text: "the degrees that surround the horizon"], the equator rises in degrees from the east until it sets [Hebrew gloss: "(when it sets)"] — by 12, one [degree] producing one rising of the equator, equal [in] the daytime of that [day].

And if you proceed [to reckon] them…

by 15 [ט"ו] degrees rising, one hour after rising, equal in number to the [number of] equal hours in that day. And if you proceed [to reckon] the risings of the unequal hour from 30 [ל'] that remain in degrees, by the number of the risings, the unequal hour rises in the night of that [day].

And if you proceed [to reckon] the number of the equal hours from 24 [ב"ר; astronomically 24 = the hours of day and night] that are the number of the hours of the day and the night, the remainder will be the number of the unequal hours in the night of that day. And likewise: if you proceed [to reckon] the risings of the hour by 2 [ב] in the night from 30 [ל'], you have produced one rising — the unequal hour rises in the day.

And it is found that every day and every night is divided into 12 [לי"ב] unequal hours [שעורות], and every division of them — into 12 [לי"ב] — is divided into equal hours that are added to the 12 hours, [each one] a rising in the day, or diminished [rises] in the night.

[Münster's Latin note: "For example, where the longest day has 16 equal hours, there the unequal hour has 20 degrees, which, subtracted from 30, show the unequal hour of the night to have 10 degrees; the [day-]hour will therefore be smaller than the equal hour by five degrees, just as the unequal hour of the day is larger than the equal hour by five degrees, since 20 degrees correspond to it. Note: 30 degrees make two equal hours; they also make two unequal hours — not of the day nor of the night, but one of the day and one of the night. Therefore, whatever the hour of the night has more than the hour of the day, if it is added to the hour of the day, two equal hours will be constituted. The unequal hours outside the equator are either larger or smaller than the equal hours."]

פתח ו׳ [Petaḥ 6]

On the inhabited part of the earth — the horizon [האופן].

We turn our attention to the regions of the dwelling-place and pass over [to discuss] the place near the eastern point and the western point [Münster's Latin note: "This chapter sets forth that part of the earth which is found to be habitable, namely one..."].

it divides the earth into two equal parts, half of it lying upward and half downward from it. And the horizon, which is the dividing [circle] for the dwellers at the middle of the earth, between the visible [region] and the hidden [region] of the firmament — the equator divides the upper [half] of the earth [Münster's Latin note: "...one quarter, namely, which in this way it teaches us to discern. Let us imagine, under the equator, where the poles of the world lie on the ground, a horizon-circle passing through each pole and intersecting the equator in the east and the west: here it separates the upper hemisphere from the lower; the equator, however, divides the upper hemisphere into two parts, leaving one toward the south and another toward the north."].

[The upper half of the earth] is in sections [divided] toward the north and the south.

And if you raise up [reckon] in the heart of the horizon a circle passing through the two tropics of the sun's course [המתחלך], and at the pole of the horizon the dividing [circle] for the dwellers at the middle of the earth — which is a meridian — at its top will be like the horizon, dividing the upper half [Münster's Latin note: "Let us next imagine a meridian circle passing through the poles of the world and through the vertex, which is the pole of the horizon; and it divides the said two hemispheres into four parts"] in sections toward the east and the west.

And the upper half is divided into 4 [לד'] parts, two of them toward the north and two of them toward the south. And the greater part of the inhabited region of the earth is found in the two geographical sections [התחלקים הגיאוגראפיים?] which are in the upper half [Münster's Latin note: "and it divides the memorized two parts into four parts, and"] — namely a circle, a quarter of the whole.

The detailed account of the inhabited [region] of the earth and its kind, we have already said: that the inhabited [region] of the earth is a kind of granary [גרן] [Münster's Latin note: "and from these only two are said to be inhabited, which are one quarter of the whole earth, namely of the upper hemisphere, and..."], divided into parts.

And the inhabited [region] is divided [extending] in the earth from the end of the east to the end of the west, by twelve hours' [שתים עשרה שעות] [travel].

Petach 6 (continued) — On the inhabited part of the earth

hours, [reckoned] straight, from the midpoint of the equinoctial [risings]. The inhabited region runs from the eastern corner [פאה] toward the northern corner, from the rising-point — namely the 90 risings that lie at the end of the quarter; this is the eastern direction. The rising-sign culminates [מזל מקטיב], and the meridian [המהלך] runs toward the southern corner. From the south the inhabited land widens [מתרחב] toward the southern corner as far as the eastern corner, [a span of] 90 [degrees].

From the equator [מקו השוה] toward the north, the inhabited band extends 66 [?] degrees by their reckoning. From [the southern limit?] onward, settlements can no longer be distinguished, and there is no fixed habitation; for those who dwell within the far south, the heat is so intense that nothing is found there. They divided [the inhabited band], therefore, into seven parts [לז' חלקים], each settled region lying to the north; and each part — each section [חלק] — is an *iqlim* [אקלים, "clime," Greek-derived: κλίμα].

The First Clime [האקלים הראשון]. It begins from the limit of the inhabited band and extends as far as 16 degrees [י"ו] of rising, [measured] from [the equator] toward the northern corner. It runs [long] [מאריך] in its longitude [במרחק]; its longest day is 13 hours [י"ג], [reckoned] straight, and at its shortest [ובקצורו] 11 hours [י"א]. The lands it passes over: it passes over the land of Sheba [שבא], the Jordan [ירדן], and most of the land of the sons of Ḥam [בני חם]; and over the [Nile] outlet [מוצא] it sheds light on Egypt [מצרים], and over the lands which [lie beyond it] right and left, reaching at the western corner the beginning of [the region of] the western Pelishtim [פלשתים, "Philistines"]. [Münster's Latin gloss: Africa.]

The Second Clime [האקלים השני]. It begins from the boundaries [מסות] of the first clime — this being the inhabited band —

[**Münster's Latin (outer column, p. 39),** clarifying the Hebrew:] [Münster's Latin note: …and of the lower [hemisphere]. This quarter is completed [measured out] in its length over 12 hours; that is, when at the easternmost inhabitants it is midday, at the westernmost it is midnight. But in its latitude, this habitable region extends from the equator toward the pole 66 degrees. Ptolemy, however, sets it at only 63 degrees, where he places the parallel passing through Thule. Further, to the 66 degrees we add the distance of Capricorn, and we shall have 90 degrees —

namely a quarter of the circle. There are, however, those who extend the habitable [region] toward the south by 16 degrees [more]; but beyond that there is no fit habitation, on account of the heat.] [Münster's Latin note: The first clime passes through Meroë and has its longest day of [13] hours.]

[**Page 40 (Hebrew column):**]

[the Second Clime] widens from the equator [מקו השוה] as far as 24 [כ"ד] toward the north. Their longest day is 13½ hours [י"ג שעות וחצי], and at its shortest 10½ hours [י' שעות וחצי]. This [region], in the eastern corner, [comprises] most of the land of Ḥorus [חורס — Ḥaurān?] [?], the great river [הנהר הגדול], the Tigris [חדקל / הנסקרא] [?], and [the river] Tzaroq [צרוק] [?]; and it passes over the lands of Ḥordi [חורדי] [?] and Armenia [וארמיה] [?]. The lands this clime passes over: the land of Ishmael [ישמעאל], and Marbar [מרבר] [?] in the land of [Pa'ran / Re'el?] [פארן] [?]; it goes over Misha [מישא] [?], travels [along] the [Salt / Red] Sea [ים סות ים סוף —?] [?], and crosses to the river of Egypt [יאור מצרים — the Nile]; and over the lands which [lie beyond] right and left, reaching at the western corner the beginning of [the region of] Africa [אפריקא].

The Third Clime [האקלים השלישי]. It begins, at the boundary [בגבול] of the second [clime], from a distance of 30 degrees [ל' מעלה] of rising, and [extends?] from the equinoctial line [אופן המישור] toward the northern corner. Its longest day is 14 hours [י"ד]; [and at its shortest…]. The lands this clime passes over: in the eastern corner [it comprises] part [קצת] of the land of the Chinese [הצינים] and the limits [וסות] of Mishbenort [משבנורת] [?], [a city] of Ḥorus [חורס] [?]; it goes out toward the northern corner [to] the land of Egypt [ארץ מצרים] and Alexandria [אלכסנדריא — al-Iskandariyya] and its coastal sea; it crosses through [the region of] Batzra [בצרה — Basra?] [?] and the lands of Shinar [שנער] which are in Babylonia [בבל]; it goes on [along] the Euphrates [פרת], and [the cities of] Damascus [דמשק] and Tyre [צור], and the Holy Temple [בית המקדש — Jerusalem]; and its dwellers [are spread] over the lower [region] [על התחתיים] of the land of Egypt; and Putim [ופוטים — Put, the Libyans] — that [region lies] toward the lands of Africa [אפריקא] in the west.

[**Münster's Latin (outer column, pp. 39–40):**] [Münster's Latin note: …[longest day of] 13 [hours], and a shorter [day of] 11. It passes also through the source [scaturigo] of the Nile, which Ptolemy, however, places beyond the equator.] [Münster's Latin note: Who indeed the western Pelishtim [Philistines] may be, whom he places here in the first clime, is not certain — unless there is an error in the word פל ("Pel-") for בר ("Bar-"), [reading] for פלשתים those who are the western Nigritae [the Black peoples of the west].] [Münster's Latin note: The

second clime passes through the eastern lands, chiefly India and China and their islands, etc. What is meant by "the green sea" [mare viride] is not certain. Our [authorities], however, [hold that] this clime passes through Syene of Ethiopia and not through China of India.] [Münster's Latin note: The third clime embraces part of India, Egypt, Alexandria and its coastal sea, the Holy Land, Babylon. It has also under it Phut and the lands of western Africa…]

[**Page 41 (Hebrew column):**]

in the west, and the region [ומדינת] of Alexandria [אלסירואן — al-Qayrawān?] [?], as far as the western sea [הים המערבי].

The Fourth Clime [האקלים הרביעי]. It begins from the boundary [מתחום] of the third [clime] and extends to 36 degrees [ל"ו מעלה] of rising, [measured] from the equinoctial line [אופן המישור] toward the northern corner. Its longest day is 14 hours [י"ד] [and a half], and at its shortest 9½ hours [ט' שעות וחצי]. It begins, in the east, from [the lands of] Persia [פרס — Paras] and Farghāna [פרגנה — Furghāna]; it goes out toward Ashur [אשור — Assyria] and crosses over the lands of Israel [ישראל] and Antioch [אנטוכיא — Antakya], and the islands of Cyprus [קפרוס — Kupros] and Rhodes [רודוס — Rhodes]; and it goes out in the west toward the land of Tanga [טנגא — Tingitana?] [?] and the western sea [ים המערבי].

The Fifth Clime [האקלים החמישי]. It begins from the boundary [מתחום] of the fourth [clime] and extends to 40 degrees [מ' מעלה] of rising, [measured] from the equinoctial line [אופן המישור] toward the north. Its longest day is 15 hours [ט"ו], [reckoned] straight [ישרות], and at its shortest 9 hours [ט'] [?]. It begins in the east [in the lands of] Gog [גוג] and Magog [ומגוג], crosses toward the northern corner through Persia [פרס / ברסאן] [?]; and its termini [תוצאותיו] reach as far as Rome [רומי] — [Great] Rome [רבתי] [?] — and it goes toward [the lands of] al-Saqlab [אסקלמיא — the Slavs] [?], toward Edom [אדום — Italy/Christendom, per Münster], and toward Faransa [פרנסא — Francia / the province of Narbonensis, per Münster] [?], [and over] all the regions [המחוז] that lie as far as the western sea [הים המערבי].

The Sixth Clime [האקלים הששי]. It begins from the boundary [מתחום] of the fifth [clime] and goes as far as 48 degrees [מ"ח מעלה] of rising, [measured] from the equinoctial line [אופן המישור] northward; its longest day is 15½ hours [ט"ו שעות וחצי], and at its onset [ותחלתו] [it begins], in the east —

[**Münster's Latin (outer column, pp. 40–41):**] [Münster's Latin note: …[a shorter day of] 11. It also passes through the springs [scaturigo] of the Nile, which Ptolemy nevertheless places beyond the equator.] [Münster's Latin note: Who the

western Pelishtim are, whom he here places in the first clime, is not certain, unless there is an error in the word פל ("Pel-") for בר ("Bar-"), [reading] for פלשתים those who are the western Nigritae [Black peoples].] [Münster's Latin note: The second clime passes through the eastern lands, chiefly India and China and its islands, etc. What is understood by the "green sea" is not certain. Our [authorities], however, [say] this clime passes through Syene of Ethiopia and not through China of India.] [Münster's Latin note: The third clime embraces part of India, Egypt, Alexandria and its coastal sea, the Holy Land, Babylon. It also has under it Phut and the lands of western Africa.] [Münster's Latin note (p. 41): The fourth clime passes through Persia or Parthia — [with] samekh changed to teth [a note on a Hebrew spelling variant] — and through Drangiana or Paraponisus. The names of the regions here are obscure or corrupt. From the west this clime passes through Tingitana, the maritime city of Africa. But then Tingitana and Algeria coincide, which are both maritime [cities] in Mauritania.] [Münster's Latin note: The fifth clime passes through the lands of Gog and Magog, who according to the fable of the Jews are [located] beyond the Caspian mountains. Further, as to what land Carsan may be: it is not certain, unless — the letters being transposed — you suppose it should be read "Casdan" (כשדן),]

[**Page 42 (Hebrew column):**]

in the east [the lands of] Gog [גוג] and Magog [ומגוג], and Bukhar [ובוחר — Bukhara?] [?], and all the lands of the Greeks [יונים] and the Romans [רומיים] and Constantinople [קסטנטינא] the great [רבה], and Negsa [נכנסרא — Nicaea?] [?], in all the regions. This [region lies] in Burgundy [ברנכיא — Burgundia?] [?] as far as the western sea [ים מערב] of Oqi'anos [אוקינוס — the Ocean, ὠκεανός].

The Seventh Clime [האקלים השביעי]. It begins from the boundary [מתחום] of the sixth [clime] and extends to 48 degrees and a half [מ"ח מעלה וחצי] of rising, [measured] from the equinoctial line [אופן המישור] northward. Its longest day is 16 hours [י"ו], [reckoned] straight [ישרות], and at its shortest [ותחקצור] [a correspondingly short day]. It begins in the east [in] the lands of the Turks [תרכביי — the Turks?] [?], and these are called [הנקראת] the Esqalavs [אשקלבש — al-Saqlab, "the Slavs"], for all the dwellers of Britannia [ברטנניא — Britain] —

[**Münster's Latin (outer column, pp. 41–42):**] [Münster's Latin note: …"Casdan," that is, Chaldaea — but which has its position in the fourth clime. "Aspanaia" is Spain [Hispania], and "Peransa" [Faransa] seems to be the province of Narbonensis; "Aedom" [Edom] is Italy. The sixth clime in its extremity reaches the Rauraci [the Basel region], likewise the land of Chusar, which seems to be the

outer Scythia, [and] Constantinople and Francia. The seventh clime passes through…]

The seven climes — latitude and day-length

The table below gathers, for each clime, its northern boundary (degrees of rising along the equator), its longest day, and its shortest day, as recovered from the Hebrew column at native resolution and cross-checked against the longest-day scale of the world-map (fig-p42-1) and Münster's Latin margins. The source presents these values inline within each clime's paragraph, not as a ruled table; this is an editorial gathering. Values read with confidence; bracketed items are reconstructed from the regular series where a digit is abraded.

Clime	Northern boundary (latitude)	Longest day	Shortest day
First [הראשון]	16° (י"ו)	13 hrs (י"ג)	11 hrs (י"א)
Second [השני]	24° (כ"ד)	13½ hrs (י"ג וחצי)	10½ hrs (י' וחצי)
Third [השלישי]	30° (ל')	14 hrs (י"ד)	[10]
Fourth [הרביעי]	36° (ל"ו)	14½ hrs (י"ד וחצי)	9½ hrs (ט' וחצי)
Fifth [החמישי]	40° (מ')	15 hrs (ט"ו)	[9]
Sixth [הששי]	48° (מ"ח)	15½ hrs (ט"ו וחצי)	[8½]
Seventh [השביעי]	48½° (מ"ח וחצי)	16 hrs (י"ו)	[8]

Diagram. A circular woodcut occupying the lower-left of the page: the inhabited quarter of the earth shown as a hemisphere within a double-ruled circle, with stylized landmasses (continents and seas hatched with engraver's lines) filling the upper portion and the southern ocean below. A vertical central meridian and a series of horizontal arcs (the parallels bounding the climes) divide the disc. On the **left**, a vertical column of numbers gives the pole-elevation (latitude) values under the Latin label *Eleuatio poli* ("elevation of the pole"); on the **right**, radiating lead-lines key the lowest parallels to the corresponding longest-day values under the label *Dies maximus* ("longest day").

- **Latin label, upper-left of disc:** *Eleuatio poli* [elevation of the pole = latitude in degrees]
- **Left column (latitudes), top to bottom, each keyed by a lead-line to a parallel:**
- 15 & [followed by the "et" (&) ligature; the parallel is also marked ⅓/½ alongside]
- 24 [marked ½ alongside]
- 30 & [with "et" ligature; marked ½ alongside]
- 36
- 40
- 48
- 48 & [with "et" ligature — the lowest/outermost parallel]
- **Right column (Latin: *Dies maximus*, "longest day"), top to bottom, with radiating lead-lines:**
- 13 — *Dies max.* [longest day 13 hours]
- 13 *et dimid.* [13½ hours]
- 14
- 14 *et dimid.* [14½ hours]
- 15
- 15 *et dimid.* [15½ hours]
- **Hebrew label, lower-left, beneath the latitude column:** רבת [rabbat]

[**Münster's Latin (outer column, p. 42), continuing:**] [Münster's Latin note: … per [the seventh clime passes through]…] — text continues onto the following page.

Most of their concerns [livelihoods] derive from the affairs of those who inhabit the rest of the climes. Out to the west, the latitude reaches a point where the inhabited [world] ends at the corner of the north; and the whole western [extent] of the inhabited [world] lies at a latitude of 60 [degrees]. No man crossed beyond it [further than that] in their days — [men] who reported that there is no settlement before it [farther out].

[Münster's Latin note (outer column, p. 43): "Thraces uel Dacos et per Asclabes qui uidetur esse Germani, corrupta uoce אשכנז Askenaſi, qua Germaniæ populos Iudæi significant, niſi malis intelligere Sclauos, id est, Polonos. Britannia maior est Anglia. Homines quando olim explorauerunt terras, non uidentur peruenisse ultra 66. latitudinis gradum." — "Thracians or Dacians, and through the Asclabi (who seem to be Germans, by a corrupt pronunciation אשכנז Ashkenaz, by which

the Jews signify the peoples of Germany — unless you prefer to understand the Slavs, that is, the Poles). Britannia Maior is England. When men in former times explored the lands, they do not appear to have reached beyond the 66th degree of latitude." This clarifies the Hebrew toponyms and the 60° / 66° northern limit of habitation.]

פתח ז' [Petach 7 — Seventh Opening]

The discourse on the standing of the sun over the heads of the inhabitants of the earth.

I have based [the discussion of] this matter on the following principle, and I say: In every inhabited place that lies in the latitude (מרחב) of the head of Cancer (ראש סרטן) [the Tropic of Cancer] upon the horizon (אופן) of the equator (מישור), the sun will be passing over the [point] arc [?] at latitude כ"ג [= 23 degrees] — the elevated arc of the north — at the start of the line of Cancer (שורת סרטן), inclined to the north as far as the entry of the boundary [of] כ"ג [= 23] degrees in the corner of the north. There [at that place], when the sun passes over them, [it is] at the head of Cancer upon the horizon of the equator. The sun will be passing over the arc at latitude [of] the head of [Cancer] — —

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— at the head [of Cancer]. In two places, then, there are two occasions [in the year]. For the arc upon which the sun travels is the one that is the elevated [northern] arc, [reckoned] from the horizon of the equator [at its] shortest [point], measured from [the place] distant from the head of Cancer; and it will be [reckoned] for you [in] two arcs upon the two sides of the head of Cancer — distant from the horizon of the equator — and within the head [of Cancer] is the highest arc from the equator [?].

It thus comes about that there are two arcs in which the sun passes over the head [zenith], at a place [where the latitude] is not less than [some] amount, throughout the whole region, [and] standing over the surface of [the place when] the sun [is at] zenith at midday, on the same day. And when the sun is at degrees [longitudes] that belong to the northern corner, [in] these two arcs it is seen to the north, over the zenith of the men of the place [throughout] the [whole] year — and the shadow (צל) of the [object] standing at midday on that day will fall toward the southern corner. In the rest of the days of the year, [the sun] stands toward [the south] — its shadow, in [terms of] the standings of those who stand at midday, on that day, falls toward the northern corner. And when the sun's

strength diminishes [?], [it] passes over the zenith of the heads of the dwellers, and they return on the two [opposite] days — which is the [day she] travels over them in the manner of the equator: this occurs when she enters the arc of the head of Aries (ראש טלה) and the head of Libra (ראש מאזנים). And there will be no [shadow] for [an object] standing [upright], [when the] shadow [falls] within the whole of midday [i.e. at the meridian], in [their] varied locations [?].

[Münster's Latin note (outer column, p. 44): "Duo puncta uerticalia sunt unus punctus quem sol duplici conficit motu, accedendo scilicet ad tropicum cancri et recedendo ab eo. Idem est iudicium de duobus lateribus tropici, cum unum sit latus. Cum ergo sol est in extrema declinatione, homines qui minorem habent declinationem uident solem uersus aquilonem caditque umbra eorum ad austrum." — "The two zenith points are [really] one point, which the sun reaches by a double motion: namely, by approaching the Tropic of Cancer and by receding from it. The same reasoning applies to the two sides of the tropic, since it is [really] one side. Therefore, when the sun is at its extreme declination, men who have a lesser declination see the sun toward the north, and their shadow falls toward the south." This clarifies the Hebrew on the doubled zenith-passage and the direction of shadows.]

[Printer's page number: 45]

Diagram. A semicircular woodcut: an arch (the dome of the heavens / the horizon-dome) springing from a baseline, enclosing a landscape scene. At the apex of the arch is the sun drawn with a human face and full corona of rays (the sun at the zenith, midday). On the inner left of the arch is a second sun-face with rays, and on the inner right a third sun-face with rays (the sun shown at its eastern and western positions / the doubled passage). Below, centered on the baseline, stands a church building with a steeple and cross atop it, set on a hatched mound of ground; rays from the suns strike toward it, and shadows are cast along the ground to either side. The figure illustrates the preceding discussion of the sun standing over the zenith and the directions in which shadows fall. No lettered labels.

[Münster's Latin note (outer column, p. 45): "Qui habitant sub æquatore habent umbram duplicem in ipso meridie, secundum quod sol digressus fuerit à puncto ipsorum uerticali in austrum uel septentrionem. Quando uero sol est in æquatore habent umbram orientalem et occidentalem, meridie uero nullam habent umbram. Hinc est quod horologia umbratilia illic facillimæ sunt constructionis. Nam stilus parallelicè horizonti erectus proijcit umbras horarias in orientem et occidentem, sicut sequenti figura declarabimus." — "Those who dwell beneath

the equator have a double shadow at midday itself, according to whether the sun has departed from their zenith point toward the south or toward the north. But when the sun is on the equator, they have an eastern and a western shadow, and at midday no shadow at all. Hence shadow-clocks [sundials] are most easily constructed there, for a gnomon set up parallel to the horizon casts its hour-shadows toward east and west, as we shall explain in the following figure." This clarifies the Hebrew on the double shadow and the construction of sundials at the equator.]

According to the standings [positions] of the sun's strength, on the two days — these, and all the days of [the year] — [the sun] will be among the signs [constellations] of the north, going round to the north, [it is] passing over the heads [zeniths], and the shadow falls at midday toward the south. And when it is to the south, among the southern signs, [the sun] is going round to the south, passing over their heads [zeniths], and the shadow falls at midday toward the north. [In] the locations [places] whose latitude is broader than [a span of] =] כ"ג [23 degrees, there is no [time] [when] the sun passes over the zenith at all — except [for them] once a year, that being the day it is at the head of the sign of Cancer (ראש מזל סרטן), which is inclined upon the horizon of the equator. And on the days [signs] of [Aries and Libra] these, [the sun] has no zenith over them at all; the shadow falls within the whole of midday; and as the longitude [distance] of [the sun] increases, and toward the latitude [?], the sun does not pass over the head [zenith] —

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— [the zenith] of those who dwell beneath it [the equator]; and its land is not seen toward the northern corner over the zenith, except [for the time] when [the sun is] at the southern corner — [and] for the whole world the shadow falls toward the northern corner; and toward the southern corner it does not fall toward the south.

In all latitudes deeper [farther] than the strength of the sun in the north — deeper [than that] from passing over the zenith — toward the latitude [?], until the latitude reaches as far as [where] the sun arrives, [the sun] reaches no degrees [longitudes] at the corner of the north, and at the places where it [the sun] is, there is an arc of the zenith of the head, distant [from] the horizon of the equator at a distance of [some] degree [?].

Diagram. A schematic of horizontal lines (representing the parallels / the rising-arcs of the zodiacal signs), drawn from a single vertical line at the left (the axis),

each line running to the right and labeled at its right end with a number. The right-end labels are printed in European Arabic numerals (the same typeface as the page numbers and Münster's "66"), not Hebrew gematria letters. Reading from top to bottom, the lines are numbered: 6, 5, 2, 1, 12, 11, 10, 9, 8, 7. (No "4" or "3" appears in the figure.) A rectangular box (two short vertical strokes joined by horizontals) is drawn spanning the lines labeled 5 / 2 / 1, marking off a group. The caption beneath, at the lower left, reads המזלות [ha-mazalot, "the signs of the zodiac"]. The numbers are ordinal labels of zodiacal signs arranged as a ladder of their rising-arcs.

- Top line: 6
- next: 5
- 2 ך
- 1 ┘ (the box frames the lines labeled 5 / 2 / 1)
- 12
- 11
- 10
- 9
- 8
- 7 (bottom line)

[Münster's Latin note (outer column, p. 46): "Quanto locus aliquis longius declinauerit in septentrionem, tanto sol ad austrum elongat se à zenith eorum. Potest autem elongari ab extremis habitatoribus aquilonis 66. gradibus. Item quanta est eleuatio poli in aliqua regione, tantum declinat ab eo circulus æquinoctialis. Extrema habitatio habet pro zenith polum zodiaci. Et quando polus ille est in uertice capitis, ecliptica iacet præcise in horizonte." — "The farther some place inclines toward the north, the farther the sun removes itself toward the south from their zenith. It can be removed from the northernmost dwellers by 66 degrees. Likewise, however great the elevation of the pole is in a given region, by just that much does the equinoctial circle decline from it. The outermost habitation has the pole of the zodiac for its zenith. And when that pole is at the vertex of the head [the zenith], the ecliptic lies exactly in the horizon." This clarifies the Hebrew on the sun's distance from the zenith with increasing northern latitude and the 66° limit.]

the signs from over the horizon of the equator [קו המישור / qav ha-mishor, the equator]. So too the horizon of the signs [the ecliptic] passes over the points of

intersection — namely, the head of Aries, in the place it begins — and when [the sun] passes it, it will come out [i.e. rise] at that same point.

When the signs revolve over the equator, the dividing horizon at that point will be [such that] the head of Aries falls at the eastern point of intersection, and the head of Libra at the western point of intersection, and the head of Cancer at the northern point of intersection, and the head of Capricorn at the southern point of intersection. They [the points] come out [emerge] from the contact [point] of the dividing horizon.

When the signs are separated [i.e. inclined] from the point of intersection of the head of Aries — that is, the moment the horizon becomes a dividing horizon [an oblique horizon] — it will be divided into two parts. There will then be a part [ḥeleq] following the practice of the two great horizons [the two principal great circles] that meet at the place where the points of intersection [are]. It is by reason of this that the signs set, sinking under the earth one beneath the other; and one horizon — the dividing horizon — [serves] for the rising over the earth of the head of Cancer, [which is] the revolving [rolling] horizon.

[Münster's Latin note: "The head of Capricorn always hides beneath the earth, except when the pole of the zodiac is at the vertex of the head [i.e. at the zenith]; then it reaches as far as the horizontal circle, but does not ascend beyond that circle itself."]

[the head of Capricorn] always hides beneath the earth: it comes in [enters] at its lowest [point]. Yet here we, the inhabitants, find the day long for the hours in which they have no night, at the time the sun lives [is] in the sign of Cancer; and the night long for them by that same [measure of] hours, in which they have no day, on the day the sun lives [is] in the sign of Capricorn.

Consider [also] the place this matter reaches for the inhabitant in the northern quarter [פאת צפון / pe'at tzafon], the matter we mentioned above.

[Münster's Latin note: "Under the antarctic pole the southern signs cannot be seen; therefore the night then lasts so long, until the sun again emerges beyond that depth and renders itself conspicuous among the northern signs."]

As for the places that are deep [low-lying] in the north: there is a measure [qetzev] and a limit to them [a determinate amount], for among the southern signs there are some hidden from them, while [the sun] always appears to them at the edge of its [the sun's] living [path].

The signs always [revolve] toward the north, and on all the days in which the sun travels in the concealed chalakim [degrees/parts], its concealment is not visible at that place; and on all the days of its standing over the chalakim it is not crowned [does not become visible] among them.

The day will be long for them by the count of the days in which the sun travels in the chalakim that are revealed, and the night [long] for them by the count of the days of [the sun's] travel in the chalakim that are concealed — until the long day reaches its limit, [namely] up to six new-moons [ḥodashim, i.e. six months], and the night the same.

and the long night, like them [the long days], up to six [months], as [we have done]. It is enough for us to explain its matter [this matter] — let us return [to the discussion] on another track, with God's help.

פֶּתַח ח׳ — Petach 8 [Opening 8]

Petach 8. On the ascensions [risings] of the signs [maʿalot ha-mazalot] and their setting [u-sheqiʿatan] in every habitation of the earth, [and on] the horizons that divide [distinguish] for the inhabitants of the earth between the visible quarter and the concealed [quarter], by means of the revealed chalakim and the hidden chalakim.

[Münster's Latin note: "This chapter treats of the ascensions and the setting of the signs of the zodiac. First, two kinds of horizontal circles are designated: namely the right [horizon] and the oblique. The right [horizon] makes everywhere, under the equator, right angles with the circle of the equator, since it passes through the poles of the world."]

Among the horizons, [some] stand upon the right horizon [אופן המישור], because they pass over the poles of the equator. These — the dividing horizon — for all the inhabitants [שוכני קו השוה] of the equator halve the day for them, [serving as] the dividing horizon for all the inhabitants of the equator.

These horizons that pass over the poles of the equator divide for [them], because [their path] passes over the poles of the equator. And their difference: those [horizons] that say [reckon] over the equator at a right angle [zawit netzavah], and it will be by reason of [their] inclination from over the ascensions of the signs that revolve over the inhabitants of the equator…

[Münster's Latin note: "Under the equator the horizontal circles are likewise meridian circles with respect to the differing habitations."]

right angles intersect it; that is the practice of their travel and their elevation [their height], for this is the dividing horizon that [stands] over the equator [קו השוה]. The two of them are said [to be] over the right horizon at a right angle, standing [perpendicular]; and it is by reason of an inclination of the signs that the ascensions of the signs [come to stand] over the inhabitants of the equator.

[Münster's Latin note: "The meridian circles stand over the equinoctial — that is, they intersect it at right angles."]

The ascensions [of the signs] are elevated in their travel, for all the inhabitants of the earth — and these are the circles [ofanim] of the ascensions [maʿalot] of those ascensions of the right horizon.

There are among them horizons that incline, which are not crossing over the poles of the equator — but there is a difference between them: their inclination toward the north or toward the south, and there are no ascensions of the signs over the dividing [oblique] horizons distinguishing [these] from their ascensions over the right horizon. But there is between them a great difference, of which the student [of Ptolemy / ha-mitalmed] must take note. And here [we] arrange [the matter of] the ascensions in the right horizon.

The ascensions of the signs ascend over the right horizon evenly [in equal measure], according to its [their] order; [the sun] rises and sets [נצבה / it stands], and it will be by reason of [its] inclination that there will be in the firmament [raqia] the equinoctial [points] — among them toward the north and toward the south, for elevation. And it will be by reason of this that each of the 3 signs [begins] at one of the points of intersection of the right [horizon] — namely the head of Aries, and the head of Libra (these toward the north), and the head of Cancer, and the head of Capricorn — in the north or in the south.

[Münster's Latin note: "Under the equator the motions of the signs are equal — that is, with each single sign there ascend 30 degrees of the equator in the space of two hours; which nevertheless is to be understood of three signs taken together, with which from the horizon to the meridian circle there ascend 90 degrees."]

[Münster's Latin note: "Under the equator the signs ascend straight, and in whatever quarter a sign is found, in that [quarter] the sign ascends and revolves." (Note continues into the catchword "Singu…")]

The arc of the equator that is [traversed] — namely 90 chalakim, whether in the north or in the south — there are ascensions for the 3 signs; the ascensions for them over the right horizon [proceed] by the count [b'mispar]…

[continued from Petach 8 — ascensions over the right horizon]

by the count of their parts that face them, over the right horizon. Among the signs there are found Aries [טלה], Taurus [שור], and the Twins [Gemini, תאומים] — in their ascensions over the right horizon, [reckoned] just as those that face them hold their ascensions; over the right horizon they hold 90° [צ׳], just as those that face them hold [the same] over the right horizon of the signs. So too the rest.

By the same reasoning, the case of Cancer [סרטן] will be like that of Aries [טלה]: at the start they hold 90° [צ׳] in this matter, and likewise Libra [the Scales, מאזנים]. Sagittarius [the Bow, קשת] and within them — their parts are 90° [צ׳] degrees [reckoned] in the equal [equator]. But the four [ד׳] signs that are with them ascend [holding], namely Aries [טלה], Taurus [שור], and Gemini — and the rest. Each one of them turns from the measure of the right [horizon], from the north pole toward the [southern] points [לדרום], as a single point. As they grow more distant, those that are more remote ascend over the right horizon [holding] the longer [arc] by more than [their] ascension. Each one of them holds, over the oblique horizon, the [arc] of the signs.

Over the right horizon they hold **27° [כ"ז] degrees and 50 [חמשים] parts** [27°50′], and there are four [ד׳] signs among them — namely the Twins [Gemini, תאומים], Cancer [סרטן], Sagittarius [the Bow, קשת], and Capricorn [the Kid, גדי] — which are the ones at the two extremities of the [solstitial] distance [המרחק].

[Münster's Latin note (outer column, : "The individual degrees of the ascending signs describe circles upright [right] and equidistant from the equator, and by however many degrees they [the signs] are enclosed, by just so many degrees do they ascend with them over the equator. Single triplicities of signs [groups of three] ascend precisely with **90 degrees** of the equator: thus when the first degree of Aries is on the horizontal line, the first degree of the equator is likewise on the horizon. And when those two points, traveling together, reach the meridian, the first degree of Cancer in the zodiac and the first degree of Cancer in the equator together meet the horizontal circle. But the several individual signs do not each ascend with exactly **30 degrees** of the equator. For of those four signs that begin or end at the equator [the equinoctial signs], those that have the least…"]

the least declination from the equator are enclosed by fewer degrees in the equator than 30. They ascend, each one of them, over the oblique horizon by 30° [ל׳]; but the sum [reckoning] of [the ascension of] each one of them over the right horizon is **32° [ל"ב] degrees and 12 [י"ב] parts** [32°12′], and there remain four [ד׳] signs.

I have said that they face one another — namely Aries [טלה], Taurus [שור], and Gemini and the rest — that hold their ascensions over the oblique horizon, nearer than their ascensions over the right horizon, by some amount. Each one of them holds, over its ascension, on the right horizon, **29° [כ"ט] degrees and 53 [נ"ג] parts** [29°53′], and the reckoning of the ascensions of the signs differs over the planes [aspects] of the [horizon].

The half of the day is, in every habitation of the earth, [equal]; and they are called the ascensions of the signs over the right horizon. By the count of the degrees [chelkei] of the ascensions over the right horizon — which is the number of the parts [degrees] of their [risings] — there is between them no difference [hefresh], by reason of the rising-time of the signs. This is set even [direct] in their ascension over the right horizon, [equal] for the signs whose ascension is reckoned in its own proportion [b'gizro]; and this is the seventh [...].

[New section heading] סדר מעלות המזלות בשאר משבגות [recte:...בשאר משבצות — "The order of the ascensions of the signs in the remaining habitations (dwellings)"]

[Münster's Latin note (outer column, : "...[those that] have the least declination from the equator are enclosed by fewer degrees in the equator than 30. For they ascend with them in the equator by only **27 degrees and 50 minutes** [27°50′]. But the four extreme signs — Gemini, Cancer, Sagittarius, and Capricorn — which stand at an equal distance from the equator and touch the two tropics at the utmost limit of [their] declination, since each is enclosed by 30 degrees in the zodiac, their corresponding ascension in the equator exceeds [30] by some degrees, namely by **two degrees and 12 minutes** [2°12′]. But the four intermediate quadrant signs — Taurus, Leo, Scorpio, Aquarius — have on either side nearly an equal ascension in degrees, falling short by only **six minutes** [6′] in the ascension..."]

over the planes [aspects], that the ascensions of the signs vary from one habitation to another. And [this follows] from one custom [reckoning, minhag] after another, since they are northern signs and southern signs [צפון ורומים — recte דרומים, "south"], by the count of the heads [beginnings] of the signs that are

situated, as I have explained over the right horizon. But some of the ascensions of the northern signs are inclined [נוטי׳] toward the zenith [לרומה] above the heads [beginnings] of the north. And the southern ones [והדרומים] add [more], growing deeper [more inclined], being one beside another; their ascensions are inclined and bent toward their own form [shape].

Their ascension over the oblique horizon falls short [diminishes] from its measure — the [arc] that has risen [שעלה] over the right horizon, or [that which] sets [sinks] over it. And so you will find, in this manner, the ascensions of the signs in degrees [reckoned] over the differing horizons; into parts [chalakim] are the planes [aspects] divided.

These [planes] hold, for two parts [chalakim], an equal [arc]: behold, all six [ו׳] [signs] from the head of Aries [מרא"ש טלה], up to its [end], hold at the start **180° [ק"פ] degrees** in the half of the degrees of the sphere [galgal] of the signs. And the remaining [signs], likewise, hold **180° [ק"פ] degrees**. There will be ascensions, [reckoned] for the six [ו׳] signs, when they emerge wholly over the horizon from these horizons. These are set even [direct] for their ascensions, [reckoned] over the right horizon — except that their ascensions are not [equal] in [their] habitations.

[Foliation marker "ז" below Hebrew column]

[Münster's Latin note (outer column, : "...[in the ascension] of the equator. Moreover, the number or excess of degrees detected in the ascensions is found to be the same in the setting of the opposite signs. We call 'opposite signs' any two signs equally distant from the cardinal points. Signs are also here called 'opposite' when one is distant from the other by the seventh place — as, if you count from Aries [□] to Libra [□], it will be in the seventh place. This seems to mean that, for those settled under the equator, certain signs are toward the north and certain toward the south. But whoever dwells outside the tropic of the northern signs — all the signs decline from their vertex toward the south, and they are submerged; and the southern signs [are] toward the horizon, and they have a different form [aspect] in their ascension from that which they have under the equa[tor]..."]

In these habitations [climates], the matters [proceed] as in the [previous] sections [chapters, פרקים] in their reckoning over the right horizon. But [for] the two signs whose habitations differ — Aries [טלה] at an equal distance toward the north and toward the south — they will be equal in their ascensions over the oblique horizon; and the excess will be [drawn] from their own ascension over the right horizon. The two signs which are [reckoned] in their proportion [b'gizran], being

of [equal] declination from the head [beginning] toward the north — over the oblique horizon their right [ascension] will be like the [arc] in their ascensions over the right horizon, except that they are mixed [set] over their ascensions.

in [their] proportion [b'erek], which differ [are altered], which by their proportion fall short [are diminished] from their ascensions. And there is found, for the [...] signs and for Aries [וטלה], an equal [arc] in their ascensions over the north; and theirs is the deficit in the proportions of [their declination]; the deficit is from their ascensions over the right horizon.

[New paragraph:] The two — the Scales [מאזנים, Libra] — as at the start, are equal in their ascensions over the oblique horizon, yet differing [mixed, ועורבות] over their ascensions; over the right [horizon], in [their] proportion [b'erek], being Aries [שהיה טלה], with parts [regaim, fractions] falling short [missing] from their ascensions, so that their ascension will be [reckoned] when [it is] gathered [collected] wholly in the ascensions over the right horizon — from [the fact] that the excess [תוספת] of one over the other is a seventh [שביעית]; and it will be [reckoned] in the ascension of each one... [text continues]

[Münster's Latin note (outer column, : "...[different] from that which it has under the equator, where the ascension is direct [right]; for the signs either fall short of or exceed that measure which they have under the equator. And if you take together at once the six northern signs and likewise the other six southern signs opposite them — that is, if you divide the [day-]circle into two equal parts — each of them will ascend with half the equator, nor is anything found diminished or in excess in the circle of the signs. But it is otherwise if you weigh each single sign against the equator. This too is detected: that any two signs equally distant from the point of Aries — both toward the north and toward the south — have the same oblique ascension when collated with the equator; for their ascension under the equa[tor]..."]

another [sign] from them under the oblique horizon, [equal] to the chalakim [degrees/parts] of the setting of its counterpart under that [right] horizon.

I shall now make plain to you the matter of the ascensions of the sign of Taurus and the chalakim of the deficiency in their ascensions under the oblique horizon, in proportion to the right horizon. You will find that they exceed in their ascensions over [the value of] their ascensions, in the same proportion by which the opposite of them falls short in its ascensions, like the deficiency [found] there in the ascensions of Taurus and its degrees.

The signs that are equal in their ascensions under the oblique [horizon] — by the [same measure] that their opposites will be; and the signs that are excessive in their ascensions [will be] under the oblique horizon, and the signs that fall short in their ascensions [will be] under the right horizon.

Now Cancer and Leo are equal in their ascensions and exceed [them] over the right [horizon]. And the conduct of each one differs [varies] in its setting, as is the conduct of the count [number] in the former [signs].

There are found, of the four [recte: ד׳, i.e. of the signs] from the head [recte: ר=ראש] of the climes — the signs ascending in the region of the north in chalakim that fall short of the chalakim of their ascensions under the right horizon, and these are called "the deficient (short) ascensions" [קצרות המעלה]. And there are six signs from the head of Cancer to the end of the sign of Sagittarius, ascending in the region of the north in chalakim that exceed over the chalakim of their ascensions under the right horizon; and these are called "the increase of the ascension" [ארבות המעלה].

[Münster's Latin note (p. 35, outer column): "...another. Such that, conversely, two signs equidistant from the beginning of Aries toward the north and toward the south add in their ascensions [by] that proportion by which the opposite of them falls short in its ascensions. Examples are given of Aries and Pisces, of Libra and Virgo. For meanwhile, in the same [degree] by which Aries ascends, [the signs] ascend together with it over the equator [by] 15 degrees only, which are sub-double of 30. When it sets, it keeps the manner of the ascension of the opposite sign — namely Libra. Opposite signs in their ascensions observe a contrary law. And when they are observed more diligently, there is found between [each sign] itself and the equator itself a double proportion in the ascensions. For the addition of the one is the diminution of the other — that is, by however much one sign..."]

the ascension; and everything that you add by these [reckonings] in the north, you will find the signs deficient in their ascension [by that same degree], more or less [than] their ascensions. The deficiency, which is added in their opposites, [grows] by the amount that you reach at the limit [recte: בפאת = at the edge/region] of the north. There, of all the ascensions, you will find the signs and the deficiency [completed], the deficiency adding [recte: חוסיפו] until [it equals] the chalakim, [namely] in half their ascensions; and the increase in the ascensions of the [other] signs is added by the [same] ascension until [it equals] the amount you reach by the full [measure] of their ascensions over the right [horizon].

Now there are six signs deficient in ascension, in that they come in a way that is distinguished [from the others] by the elongation [of the zodiac] when it comes to lie circular [recte: נקפות] upon the horizon, [and stands] of itself; and there will be [some] chalakim taken from them [namely] in the proportion of the six signs of the ascensions that arise — and there will be at the time when this same conduct [obtains], when the signs are distinguished in their own [positions], and there [in that place] the deficiency of the ascensions; and they are distinguished one from the other, and [each] is found.

There arose from [the head of Cancer] six signs; and there is none added to the ascension of the [printed ר׳; recte ד׳=4 or ב׳=2?] signs that are reckoned in the north — [for] there is no measure [variation] at all, nor any difference in the measure in the [given] sign at all. And the rest [of the signs] differ in measure, [namely] the [printed ר׳; recte ד׳=4 or ב׳=2?] signs…

[Münster's Latin note (p. 36, outer column): "…one [sign] adds, by that much the opposite sign diminishes. Signs positioned next to one another are called those which are equidistant either from the beginning of Aries or from the beginning of Libra. These things can be seen to the eye in the material sphere. Opposite signs, moreover, have this exchange, that the ascension of Aries is the setting of Libra, and the ascension of Libra the setting of Aries. For in our region, with the sign of Aries, [the signs] ascend in the equator [by] 15 degrees, and they set with it at setting [by] 40 degrees. With Libra, however, they ascend [by] 40 degrees and set [by] 15 degrees. Likewise the six signs from Aries up to Libra are called deficient in ascensions — namely [those] in the north; and the opposite six signs are called excessive in ascensions, or prolonging the ascension."]

The increase of the ascension holds a part [share], according to the count [number] of the ascension of the equator; and it shall be [when] the length of the day, when it comes, is [reckoned as] some hours [reckoning], and it returns [is reckoned back]. And if there should be a deficiency over the ascension of the signs that are deep [far] in the north, when one reaches over the equator [more], [a portion is] taken from their ascensions — from some part of them, always; and it [comes around] to them from some part of them, always; and there is found the increase that is there [in that place], distinguished — taken from a part of the signs ascending over [the equator], and from a part [of them].

And this [holds] in their settings; but rather the signs are split [divided], rising and reckoned — those reckoned in their settings; and they rise.

Now I, for my part, shall give you an example. Such that even [where] the places that are deep [far] in the north — until the elongation reaches 29 chalakim [כט] and a half — there shall be the sign of Cancer and the Twins [Gemini], they being visible always over the earth; and the remaining five signs [will] rise over the earth and set beneath it; and there will be four of them — Aquarius [דלי] and Pisces [דגים] and Aries and Taurus, ascending in order [גזורים]: Taurus ascends, [then] Aries [טלה]…

[Münster's Latin note (p. 37, outer column): "And the more anyone insinuates [advances] himself into the north, by so much are the deficient signs found to augment their decrement in [their] ascensions, just as, conversely, the excessive signs augment [their] excess. Under the latitude [of] 66 degrees, the signs deficient in ascensions lose all the degrees of ascension; but the sign that is excessive ascends from there, in the degrees of the equator, so that with one zodiacal sign [it] ascends double in the equator. Moreover, when the deficient signs, according to [their] elongation of the equator from the horizon, have come to lie circularly in that same horizon, the two of those circles run together into one circle, according as the pole of the zodiac comes to the angle of the meridian, of the middle of the night, [and] of the east and of the west."]

[At] the beginning, and after it Aries, and after it Pisces, and after it Aquarius [דלי], and they set in Cancer [recte: בסרטן]; Aquarius sets first, and after it Pisces, and after them Aries and Taurus.

[There are] four signs of those that are long [in ascension]: and at the beginning of them are Leo [recte: אריה], and Virgo [בתולה], and Libra [מאזנים], and Scorpio ascending — they being reckoned in their settings, in order.

The remaining signs are split [divided] at the ascension. And if the elongation should reach to 78 [recte: ע"ח] chalakim, there shall be [printed ר׳; recte ד׳=4 or ב׳=2?] signs there — Taurus, the Twins [Gemini], and Cancer, and Leo [אריה] — ascending from the earth always; the signs which are in [the region of] Gemini, and they being reckoned in their settings, [there being] no difference between them; and Aries and the Twins ascend, distinguished from one another; and the rest, and the [other] signs ascend, distinguished.

And [the matter] arises from the reckonings of the appointed [recte: צפון = northern] places, so that you reach the elongation in the north; and there [in that place] there shall be [printed ר׳; recte ד׳=4 or ב׳=2?] signs there in the regions [habitations] of the north — from the horizon, the equator from the head of Aries up to the end of Virgo [recte: בתולה], ascending over the earth always; and the

signs are reckoned in [the region of] Gemini — reckoned always beneath the earth.

[Münster's Latin note (p. 38, outer column): "Finally, [those] signs ascend beyond the horizontal circle, [in the place] where the pole of the zodiac has receded from the vertical point; and by as much as Sagittarius is plunged [beneath], by that whole [measure] Cancer stands out above the horizon. This you will easily picture thus: where the pole of the zodiac is in the zenith, there the ecliptic lies in the horizontal circle; the beginning of Cancer is in the angle of the middle of the night, and the point of Capricorn in the angle of the meridian; and when the pole of the zodiac is moved from the zenith toward the west, the point of Capricorn is plunged from [below] the horizontal circle and ascends, [while] the point of Cancer [moves] gradually toward the east. The 'signs of Nisan' [Münster calls] those six signs which are in that semicircle in which the sign of Aries holds the middle, [the semicircle] into which the sun enters in the month of Nisan."]

and they are deficient signs.

Now, given this elevation of the pole, the distinction is made between the hidden and the revealed: from the firmament and the limit of its course one [sign] rises continually, while another sets. The sphere [galgal] revolves around the height of the heaven, and the half of the signs that always rises upon the earth and revolves over it stands opposite the [other] half, which is always hidden; this half sets as the other rises continually, and the earth itself always turns between the two half-circles.

[Münster's Latin note: ...and they are deficient signs. Moreover, under this elevation of the pole the longer day has 24 hours. Under an elevation of the pole of 69½ degrees, Cancer and Gemini never set below the horizon; but eight signs do rise and set.]

And the revealed [signs]: all the days of their being upon the earth in the northern signs, and all the days of their being in the southern signs, [are passed] in rising and setting upon the earth. The earth shifts — turning now toward one place, now toward another — its half being day and the [other] half night; and from this come the reasons for these [phenomena].

[Münster's Latin note: Under an elevation of the pole of 78 degrees, these four signs — Taurus, Gemini, Cancer, and Leo — never set; and conversely Pisces, Aries, Virgo[?], and Libra [m □ □ □] always remain below the earth. Likewise these four rise and set.]

And those who make this distinction at the northern quarter [of the pole] can grasp the order of the southern quarter, since the signs that revolve at the northern quarter for any given place — reckoned by their degrees, and by the way one reckons the ascensions [ma'alot] — correspond to every part and division of the degrees of the signs.

[Münster's Latin note: Where the pole of the world and the pole of the horizon are one and the same point, there the six northern signs are always above the horizon, just as the opposite six signs — namely the southern ones — are always below the horizon.]

upon the horizon and upon the rest of the horizons the distinction is made; and the reckoning of the [equation of the] day and its parts is expounded in the [diagram/volvelle] within the *Sefer ha-Ḥeshbon* [the *Book of Reckoning*], in the chapters [ha-machalakot, "the divisions"].

[Münster's Latin note: …horizon. There, too, the equator does not differ from the horizontal circle. Under the pole, the whole year is reckoned as one day, which consists of one night and one day; for one half of the year is day, and the other half is night.]

שער השני — Second Gate

It treats of the number of the firmaments and the order of their arrangement; of the orbs of the planets, their structure, and their order; of the order of their motion[?]; and of the course of the Sun [ha-chammah].

Opening [Petaḥ]

The opinion of the philosophers — who have inquired into the foundation of the formation of the heavens and the creation of all things that have come into being in the world — is decreed[?]…

[Münster's Latin note: The wise philosophers agree on nine celestial spheres. Seven they assigned to the planets, the eighth to the fixed stars…]

upon the firmaments of heaven, which are nine firmaments. Seven of them are for the planets [kokhvei lekhet — the wandering stars], the eighth is the firmament of the signs [the sphere of the zodiac], and in it are set all the orbs of the [fixed] stars. The ninth firmament revolves the whole sphere from east to west, [carrying] the two poles that are in the north and the south. There is no star in this firmament — it is bare of any star at all. Yet the wise men gave it [this]

name and understood it as the covering of all the firmaments and their spheres, [moving them] from east to west. This is the opinion of the philosophers.

There are some among them who say there are ten firmaments: the ninth of them is the firmament that bears the signs [zodiac], which conveys the stars from west to east; and the tenth bears them all and revolves them all — moving all the firmaments from east to west. These, then, are ten firmaments. And the [other] sages [reckon] the orbs of their handiwork…

[Münster's Latin note: …to the fixed [stars], and the ninth to the universal motion, which sweeps along with it all the lower spheres and is above the two poles; and there is no star in this heaven — that is, the *primum mobile* — but the glorious God prepared it as a covering for the rest of the heavens.]

[Münster's Latin note: Others, however, posit ten spheres, and they describe the zodiac in the ninth, which indeed drives the stars from west to east; while, conversely, the tenth completes its own motion from east [to west]…]

the orbs which they did not [count] in the eighth[?] firmament [belong to] the ninth firmament; and all [the rest] they placed in the tenth, because no sight of it is revealed to the eye, so they relied upon reasoning concerning the creation, applying themselves to [these matters] with their eyes and their inquiry. And they are reckoned in the heaven as eight elevated firmaments. Within them is the firmament of the signs [zodiac], which covers [the earth]…

[Münster's Latin note: …[from] east into the west. Others deny the said ninth sphere, since they have no ocular experience [of it].]

the rest of the orbs, from east to west; and they agreed that, among the remaining orbs, the upper ones are wholly within the orbit of Saturn[?], and the one below it is within the orbit of the Moon; and adjacent to it, within the orbit of Saturn [♄]; and below it, within the orbit of Mars; and Jupiter [ג', ♃]. These orbs are conducted within the orbit of the Sun [ha-chammah], and the ascensions of the rest of the orbs are conducted accordingly.

And they have divided concerning their orbs: Venus [Nogah] and Mercury [Kokhav] — whether they are conducted in their ascensions above the orbit of the Sun, or below it. All the wise men of the ancients, who hold that these two[?] revolve within the orbit of the Sun, order them within the orbs as follows: that the order of arrangement is Saturn [Shabtai], Jupiter [Tzedeq], Mars [Ma'adim], the Sun [Chammah], Venus [Nogah], Mercury [Kokhav], the Moon [Levanah]; and their mnemonic [siman] is **שצ"ח נכ"ל** [letters as printed: ש — שצ'ח נכ'ל Saturn, צ

Jupiter, ח Sun? / נ Venus, כ Mercury, ל Moon][?] — and so too those who came after them. But there are others who hold a different opinion, and they place Venus [Nogah] and Mercury [Kokhav] above the orbit of the Sun, ordering them thus: Saturn [Shabtai], Jupiter [Tzedeq], Mars [Ma'adim], Venus [Nogah], Mercury [Kokhav], the Sun [Chammah], the Moon [Levanah]; and their mnemonic [siman] is **שצ"מ נכח"ל** [letters as printed: שצ'מ נבח'ל][?]. Yet do not place[?] the order of these two — the orbs that pertain to Venus [Nogah] and Mercury [Kokhav] — as to whether [each] revolves within the orbit of the Sun, since [the Sun]…

[Münster's Latin note: On the location of ♀ [Venus] and ☿ [Mercury] there are diverse opinions among the astronomers. Some place them above the Sun, others below.]

[Münster's Latin note: The reasoning of those who placed □ [Venus] and □ [Mercury] above the Sun:]

and they never obscure the Sun, for at no point do they come between it and the eyes of men as they cling close to it — in the way that the other planets do as they cling close to it.

The proponents of this view said further: these two stars [planets] lie beneath the Sun. They [sometimes] eclipse it [pass across its face], just as the Moon eclipses it at the time of its conjunction; and likewise they eclipse Saturn, Jupiter, and Mars, which are above them.

Yet their reasoning, when you look into it, does not establish what they have set out to show. For the matter [they raise] proves nothing for the city [i.e., settles nothing], since it is possible that the planet that lies above the Sun's firmament is among the other two of these stars that cling close to the Sun, while [the other] is removed from it. They are arranged toward the northern quarter or toward the southern quarter — a great latitude — so that they do not eclipse the Sun, and are not found [in exact conjunction] with it. One may indeed say of any one of them, by [reason of] this arrangement [ʾofen], that it is not near the Sun at the time when they cling close to it; and thereby they are not found to eclipse it, since there are no [shared] paths laid out over it.

And it follows from this that there is no compelling proof…

[Münster's Latin note (outer column, p. 63), upper: "…the Sun, because in conjunctions they never obscure the Sun, as the remaining planets do cover [it]."]

[Münster's Latin note (outer column, p. 63), lower: "The reasoning of those who hold that Venus [□] and Mercury [□] are above the Sun does not compel the

senses to assent, because these two planets, when they are joined to the Sun, always have a latitude from the ecliptic — namely northern or southern — which prevents the star from obscuring the Sun. For in conjunction they are not found in the middle line of the zodiac nor near its boundary. — Tres."]

to accept the words of these men. And I see fit to rely, in the manner [I have described], upon the words of the sages — the ancients [הקרמונים, with resh/dalet ambiguity in the square type; likely הקדמונים, "the ancients"] — who saw fit to place the three planets among the [more] distant stars, [namely those] above the Sun. For all the planets whose distance from us is greater [than the Sun's] are reckoned above it [the Sun], while the planets that are nearer to us — those that are not seen to be borne off [in deep latitude], all those whose distance is the lesser — are beneath the Sun, revolving [there].

That is to say: the three stars whose orbit is lower than [the Sun's] orbit [are reckoned] above it, removed from us; while the [other] stars whose orbit runs above [the Sun's] orbit are below it, [nearer] to us, and over the Earth.

This is the saying of the counsel of the sages.

The foundations of the science [ḥokhmah] are these:

Petach [the new opening begins below]

[Münster's Latin note (outer column, p. 64): "The three superior planets are elongated from the Sun so that they even reach its opposition; but it is not so with Venus [□] and Mercury [□], whose mean motion is the same as the mean motion of the Sun, and therefore [each] is not elongated from the Sun except to the distance of the semidiameter of the epicycle. Likewise, the planets that are above the Sun have a slower motion than the Sun, ⟨and⟩ those below it [have] a swifter [motion]."]

פתח ט׳ — Petach 9 (the Ninth Opening)

The structure of the firmaments [galgalim], how they are arranged in their courses, and what is to be said about them. So, too, is this matter explained, set out at length in the books of the sages — the ancient [הקרמוני, resh/dalet ambiguity; likely הקדמוני, "ancient"] investigators — concerning the formation of all created things.

For the structure of the heavens is, in its entirety, a round form, turning like a wheel [galgal], rolling round; round and straight, and it is not fitting that its being should be of any other form. They explained the reason for this well, with sound

and faithful reasonings, and made clear that of every [possible] motion it is the [circular motion] that endures — for it is the same in every place; its standing does not vary, and it has neither subtraction nor addition. And this is its reason: that it is fitting it should be of one form in every place.

The great sages of the science of vision [ḥokhmat ha-ḥizzayon] set their names to this, and forbade [anyone] to raise an objection against it, on the ground that in every craft there is nothing more wanting [than this principle], and they have no need to seek [further]; nor is it fitting to bring [an objection] against it in their crafts, because it [the round form] is the foundation [that is the source] of every craft — [a foundation drawn] from the wise men, [those] of the great science, by their wisdom.

And when it comes to subtract [account] from the motion of the stars, and to recognize that the swiftest course is the one most fitting for all of them, more than any other among them — by reason of their times they found them sometimes…

[Münster's Latin note (outer column, p. 65), upper: "The heaven is, in every part, perfectly round, nor does any figure other than the spherical befit it — which is proved by probable and firm reasons, and is held today, among the learned astronomers and observers of the stars, as one supreme and most solid foundation."]

[Münster's Latin note (outer column, p. 65), lower: "Since every spherical motion is regular, whence is it that one and the same motion is sometimes found slower and sometimes swifter?"]

tarrying [slowing] in their course; and at times [they are] swift and rapid; and they are not found going in their course at every moment at a uniform rate throughout — which it is proper to account for in their reckoning. So the sages came to consider the structure of the sphere [galgal] by [way of] the form of the revolution, in [each star's] motion. For how can it be that the motion of the star is uniform while it is found going upon its course, and yet sometimes it is found, in its course, [departing] from the straight road? They sought, by the wisdom of geometry [the science of measures], two structures [models], one or the other of which would account for that variation in [each star's] revolution — whether the center [of revolution] be [the center of] the Earth, or whether it be some other; the [observers] surrounding [the question] found that it would [be accounted for] by one of these two models, by [a star's] revolution upon the sphere [galgal] of the star, [whether] a great revolution.

That is: either the sphere [galgal] revolves [carrying] the star, while the track [ʾofen] of its motion is removed from west toward east, the sphere revolving in a uniform circle in every direction, so that it appears, to the eyes of the inhabitants of the Earth, [to differ from] the motion of the Earth by reason of the difference that lies between [the two centers] — for the center of the Earth and the center of its [the star's] revolution differ. For the model in which this occurs is one in which the [Earth's] center is the [center] of revolution upon the two centers.

[The star] appears to the eyes of the sons of men…

[Münster's Latin note (outer column, p. 66), upper: "By the art of geometry they devised a twofold reasoning and a double mode by which that diversity of motion — which arises in a regular body — may be saved. The first is the eccentric. For from the center of a circle a line drawn out to the star carries the star itself round on the circumference of its own great circle, etc. This first reasoning is beautifully explained throughout this whole chapter."]

[Münster's Latin note (outer column, p. 66), lower: "A line drawn out through both centers to the star shows, or represents, that star to men at a twofold distance. One is, namely…"]

[The Latin breaks off ("scili[cet]…") and continues on the following page.]

Sefer Tzurat ha-Aretz — Second Gate, Petach 9 (continued) and Petach 10

namely, upon two distances. If the star is at the point of its sphere [the eccentric] that is nearest to the center of the eccentric circle, it will appear far from the earth — at a great distance — and that is its eccentric apogee (גובה). But if the star is at the point of its sphere whose distance from the center of the eccentric is least, it will appear near to the earth, and that is its eccentric perigee (שפל).

So, by the construction of this star upon the sphere — that is, by its [varying] distance from the center of the eccentric — its motion rises from the apogee toward the perigee, then runs back from the perigee, traversing its course until it reaches the [point of] mean distance between the apogee and the perigee.

[Münster's Latin note: "…namely, it is above the center of the eccentric in the heaven, at the greatest distance from the earth, and is called the *aux* (apogee); the other, which is opposite to it, where the planet approaches the earth as nearly as can be, is called the opposite point of the *aux*, or the lower altitude of the planet.

About the apogee the planet's motion is slower; in the mean longitude (that is, between the apogee and its opposite) it has a moderate and uniform motion; about the opposite of the apogee the planet's motion is swifter than the mean motion."]

When [the star] is at the perigee, its motion runs from the perigee, traversing its course until it reaches the [point of] mean distance between the perigee and the apogee.

You will find that the star, in its form [of motion], moves along its courses [at speeds that] appear unequal: at times you will see it [moving] from the two sides of its apogee, toward east and toward west. In these [respective] ways it traverses, by the rolling of the great sphere, the course of the star — by way [ofen] א, ב, ג, ד and its center ה.

Diagram. A geometric figure of the eccentric model. Two circles are drawn — an outer circle and a smaller inner circle, set slightly off-center within it; they are crossed by a vertical diameter and a horizontal diameter that intersect at the center-point ה. The figure is flanked by the Hebrew direction-words **מערב** ("west," right side as printed) and **מזרח** ("east," left side as printed), marking the horizontal axis as the east–west line. Labeled points:

- א (upper, on the inner circle at top): point alef — the apogee (גובה)
- ב (left of center, on the horizontal axis): point bet
- ה (center, at the intersection of the two diameters): point he — the center
- ר (right of center, on the horizontal axis): point resh
- ז (lower, between center and bottom): point zayin
- ג (lowest, on the inner circle at bottom): point gimel — the perigee (שפל)

[The vertical line runs through the apogee (א) and perigee (ג) — the apogee–perigee line of the eccentric construction discussed in the text; points ז and ג mark the lower (perigee) portion below center ה. The horizontal ב–ר line marks the mean-distance positions to west and east.]

[Text below the diagram, p. 68:]

This is the way [ofen]: that it [the construction] is by the center of the eccentric circle, and by the center of the earth, the points being marked ר ,ז; and the reckoning that passes through the two centers begins from point gimel (ג). Point alef (א) is the apogee at the [point of] elevation, and at the perigee (שפל) [point gimel] at the [point of] depression; while points bet and resh are at the [points of] mean distance, set at the eastern quarter — to which the course runs — and the

[point along] the apogee-quarter at the [point of] mean distance, [namely] point dalet (ד), toward the four quarters: west, and the form of the star.

When [the star] is at the eccentric apogee — point alef — which is [the star] at its greatest distance, that is, that it is seen far from the earth, [the line] from the earth reaching up to the eccentric apogee is long.

And toward the [point of] mean distance from the center of the eccentric — which is the star [seen] at a [certain] distance, far from the earth — by the construction of point gimel it will be at its [nearest] distance from the earth.

[Münster's Latin note: "The figure here added shows where the planet has its greatest distance from the earth, and where it is nearest to the earth. For the semidiameter from the center of the earth to the *aux* (apogee) is much longer than the semidiameter from that same center to the opposite of the *aux*. But the line that is drawn out from the center of the eccentric to the mean longitudes is longer than the shorter and shorter than the longer. When the planet is at the point…"]

the point of mean distance, which is the star at the [point of] mean [distance] from the midpoint [of the eccentric], at the [point of] depression — that is the form of the eccentric. And by the construction [of the line] from point he (ה) to point bet (ב), [the star] appears in its face [as if] near; and at the [point of] mean distance, [the star] being at its two [points of] mean distance, there are two reckonings: the reckoning that goes out from the center of the eccentric — by it [the star] moves evenly; and the reckoning that goes out from the center of the earth.

And [the star] will be at two distinct positions, appearing at one [place] and seen at another: the star appears, by [its] two [points of] mean distance from the center, at one construction along its length, and in being at the other construction it is beneath the apogee-quarter, which appears [different] from the eccentric perigee.

For the eccentric itself, by the construction [the star] goes out, rising to the line of its center — the line of the eccentric — these being upon the form of the ecliptic. By the construction [of the line] ב, ה [bet, he], and the reckoning that is [drawn] toward it from the center of the eccentric — line ח, ב [ḥet, bet] — it will be at a distance, elevated; its height [rumo] in [the matter of] the angles, by its eccentric, [is reckoned] by every measure of the arc which the [triangle] ז, א, ה [zayin, alef, he] encompasses.

And it will be at the [point of] mean distance, [the star] going out toward it from the center of the earth — line ב ,ח [ḥet, bet] — far, elevated; its height [rumo] by the measure of the arc of [triangle] א, ב, ה [alef, bet, he], which encompasses it; and by [the difference of] the angle — the deficit [ḥisra] of [triangle] ז, א, ה [zayin, alef, he] from ב ,ח [ḥet, bet] — by every measure of the arc which [triangle] ז, ב, ה [zayin, bet, he] encompasses it. And it will be at…

[Münster's Latin note: "…where it is, namely, at the *aux* (apogee) or the opposite of the *aux*, it shows the same situation of the planet in the heaven, nor is there any difference of its place from this center or from that. It is otherwise outside these two points, where two different lines show different places in the firmament. For example, the line drawn from *he* to *beth* (where we may suppose the star to be) makes a right angle with the line of the *aux*; but the line from *zain* to *beth* does not make a right angle — it falls short of the prior right angle by the proportion of the triangle *he-beth-zain*. Therefore the motion of the planet in the firmament will be smaller than that motion which the line *he-beth* shows, by the proportion of the triangle *zain-beth-he*; this is what the angle in the firmament, opposite to the angle *he-zain-beth*, shows. That is,…"]

the star [at a place] shorter [nearer], according to its course, to our sight, by every measure that the [triangle] ז, ב, ה [zayin, bet, he] encompasses it.

And if the star is at point resh (ר), its [angular] distance will be from the perigee [mishpal]; its height [rumo] in its sphere [is reckoned] by [the arc] of corner ג, ה, ר [gimel, he, resh], and its distance [marḥaq] from the perigee by corner ג, ה, ר [gimel, he, resh] — by every measure that [the line] ג, ה [gimel, he] is reckoned beyond it, toward the dwellers of the earth, by every measure that the corner [of triangle] ז, ח [zayin, ḥet?] — [no:] that corner ז, ח, ר and ה, ר encompass — and the line ה ר [he, resh] makes a corner.

[Münster's Latin note (margin, p. 70): "…is the arc which that triangle designates in the firmament. Moreover, in the opposite mean longitude the contrary happens: for there the motion is greater than the line *he-daleth* shows, by the addition that the triangle *he-zain-daleth* makes."]

And the star will be set [moving] [?] along its course before our eyes by every measure that the corner [of triangle] ז, ה, ר [zayin, he, resh] [encompasses], [as] it appears; and the star is found to be seen by those who behold it [as] reaching, in its course at the apogee-quarter, its [full] height [rumo], and in its course at the perigee-quarter [a height that is] less. This is the reason [for] the form [of

motion], as the matter has been well-ordered [by Him who set it in order], in [its] varying speeds.

פתח י׳ — Petach 10

The form of the second [model], in the form of the epicycles [ha-girurim — the carried/rolling spheres].

And the reason for the second [model], which the wise men held in the words of their teachers concerning the star's course in the heaven — which is, namely, that the star is found at the center of the eccentric by its construction — is that the star is not at the center of the earth; rather, there is for the star [a separate account], for [its] course is [carried] upon the rolling of the [epicyclic] sphere [galgal]. That is: upon the sphere there is another small sphere [galgal qatan] called the epicyclic sphere [galgal ha-qefet — "the encompassing sphere," i.e. the epicycle].

[Münster's Latin note: "In this chapter is explained another account, according to which the wise men, in their controversy, have tried to save the irregular motion of the stars; and they have found an *epicycle*, that is, a small circle fixed in the extremity of the greater circle, to whose [circumference…]"]

[Petach 10 continues — the epicycle (galgal ha-qefet = epicyclus).]

The epicycle (ha-qefet) is the small circle that rolls upon the circumference of the larger sphere — a small wheel set into a great wheel, on the surface of the deferent. The disk of the epicycle is suspended like a wheel, its half emerging from [the deferent], and its [other] half [lying] within the thickness of the deferent. By this arrangement there comes about the [planet's] motion at its apogee and at its perigee: the place that is its apogee in the path of the epicycle, and the place that is its perigee. And the planet rolls the disk of the epicycle to the place nearest the earth, at the place reckoned as its perigee.

The epicycle rolls the planet from east to west [?] in its course, and its perigee [is reckoned] toward the west. The course at its apogee [?] and at times [?] there comes about this course of the motion at the corner of the apogee — its elevation [rom] — and at times it comes about, in the alternation of their courses [?], at the perigee [shefel]. Its elevation [rom] and its setting [?] are at the apogee, its elevation [?].

[Münster's Latin note (facing column, p. 71): "…by whose motion the planet sometimes recedes far from the earth, sometimes draws near. The center of this small circle is carried regularly around by the deferent orb, but the revolution of

the epicycle, at its own pleasure, adds to and subtracts from this regular motion. It introduces a confusion, such that the planet is found sometimes slow and sometimes swift in its motion. When it moves according to the motion of its own center — which is always toward the east — it is called swift and direct in course; but when it moves contrary to the motion of this center, it is called retrograde and slow in course. The motion at the apogee of the epicycle, in different respects, is slow and swift: slow if it be considered in itself — for then it is far from the earth — swift if it be referred to the motion of the center of the epicycle, which is aided by this motion."]

In this respect the moon resembles the [other] planets. Its body is borne upon the disk of the deferent, at the apogee [reckoned] upon its perigee [?], at the place where its apogee and its perigee, the height [?] and the setting [?], are reckoned [?]. The disk of the epicycle is borne upon the center of the earth [?], and the disk [?] rolls upon its center [?] — at the place reckoned as its perigee [?]; and [the planet] rolls the disk of the epicycle [?], and at the place [?] reckoned [?] toward the apogee of the height [?] — at the place reckoned as the setting of the height [?] — it is known by its place.

Diagram.

A geometric figure of two tangent circles, one above the other, each divided by a vertical diameter and (in the lower circle) a horizontal diameter into quadrants. The upper, smaller circle is the epicycle (galgal ha-qefet); the larger, lower circle is the deferent, with the earth at its center. The two circles touch where the upper rim of the larger circle meets the lower rim of the smaller. The vertical diameter runs through both circles.

- גובת רום ["the height of elevation"] (centered caption printed above the figure): the figure's heading.
- מ (top of the small upper circle): the topmost point of the epicycle.
- גלגל הקפה ["epicycle"] (left interior of the small upper circle): label of the small upper circle.
- א (center of the small upper circle, on the vertical axis): the center of the epicycle.
- ב (lower point of the small circle, on the vertical axis, where it meets the large circle): point ב [bet].
- שפל רום ["setting of the height"] (upper region of the large circle, just below the tangency): the perigee of the apogee zone.
- רום ["height"] (left-upper area of the large circle): apogee.

- ה ד (center of the large circle, on the vertical axis): a two-letter cluster — ה with, to its left, a glyph reading ד [dalet] (possibly ר [resh] — the two are confusable in this type); the center of the deferent / the earth.
- מרכז הארץ ["center of the earth"] (lower-middle quadrant of the large circle): the earth's center.
- א (bottom of the large circle, on the vertical axis): point א [alef], the lowest point.

The place of [the planet's] body, drawn out from the firmament, is the place of the epicycle's apogee and its setting [be-konso]. To go by one of these two [forms] [?] — in the course of the wandering star [?], or shorter [?]. From the course of the epicycle's perigee [?], which is the round figure [?] that differs [?] in [the planet's] course, which is the body's heart [?] — for [the body] emerges from its apogee, borne from its apogee.

[Münster's Latin note (facing column, p. 72): "The same judgment holds for the point opposite the apogee. Further, as to what is added at the end — 'the chariot of Isaac' (for so the old exemplar reads) — I do not understand it, unless you take it as the chariot of triumph. When the planet is at apogee…"]

The perigee of the disk of the epicycle, in such manner, in this configuration there will be — it conducts the earth; and the perigee, in this same manner, it conducts upward. They [the ancients] established it upon the disk of the epicycle toward the apogee, at the place reckoned as the second, at the eastern; and there will be the body's emergence from the perigee of the disk toward the apogee of the planet — by which the perigee of the planet conducts the earth toward the body, upon the place of the disk of the epicycle. If the perigee be such that it conducts the earth toward the apogee at the place reckoned as the fourth, it does not go by the way of the path, as is known. For in [its] course at the perigee there will come about a deficiency in the course of the planet's perigee, in its course at the apogee — its elevation [rom] — and at its course at the perigee — its setting — at the lower point. As we found, the planet emerges from its apogee.

[Münster's Latin note (facing column, p. 73): "…at the apogee or the point opposite the apogee of the epicycle, it is seen precisely through the center of the epicycle, and so it has at that hour the motion of the deferent. But when it departs from one of these points, the planet's motion will be either swifter or slower than the mean motion of the deferent."]

And if [the planet's] body be such [?] that it conducts the earth toward the apogee at the place reckoned as the second [?], in [its] course at the perigee there were

two courses gathered together [?], which differ this from that — and [this is] the [reckoning] of the easterners [?]. The earth in its course is seen to the eye, and it will be in the way [?] of this course of the deviation [?] outwardly, at the corner [?] of the apogee, its elevation [rom], and their setting [?] [are] at the perigees [?]; and afterward [?] therefore from within, as we have explained [?], except in the course of their motions [?], found [?] at the manner [?] the perigee emerges, borne upon [?]...

[Münster's Latin note (facing column, p. 73): "The semidiameter of the epicycle carries round the body of the planet on the circumference of the epicycle. At the apogee of the epicycle it advances the mean motion, and at the point opposite the apogee it diminishes it — just as if the very body of the planet were revolved through a great eccentric circle. Two motions joined together, if they are borne toward one and the same region, are increased — which happens at the apogee of the epicycle, where the motion is more rapid than at another place. But it is slower at..."]

upon one way, at the corner of the apogee of the perigees, to the heart alone. And in the configuration of the disk of the epicycle the planet is found upon two ways: as the star is rolled to revolve in the disk by the disk of its epicycle, in two manners, as you have seen [the figure]. And the planets — for there emerge for them two forms in their course: sometimes it is at the apogee, its elevation [rom], and sometimes at the perigee, its setting, its elevation; and the sages of the craft of observation [astronomy] [drew] near to give them the two forms of configuration that differ this [from that]; and there will be their conditions [?] in their solitude [?] as one emerges — the perigees set upon [?] the disk of the epicycle, upon its course — in the five wandering planets, namely Sh-Tz-M-N-Kh [שצמנ"ך — Saturn (Shabbatai), Jupiter (Tzedek), Mars (Ma'adim), Venus (Nogah), Mercury (Kochav)].

[Münster's Latin note (facing column, p. 74): "...at the point opposite the apogee, where the epicycle moves contrary to the motion of the center of the epicycle. From these and the foregoing statements it is gathered that a planet is slowed in its own motion by reason of the eccentric — namely, when it is found at the apogee point. But if the epicycle too be at the apogee of the eccentric, the star can be impeded in its motion in a twofold way, as is clear from what has already been said. The astronomers posited the epicycle because they saw at the point opposite the apogee a slower motion, which nevertheless ought there to have been swifter; and on this account they made, in the five planets, a composite motion, which is found to be more intricate than in the other planets..."]

upon one way, at the corner of the apogee of the perigees [?], to the heart alone. And in the configuration of the disk of the epicycle, the planet is found upon two ways, as the body is rolled to revolve in the disk by the disk of its epicycle, in two manners. And the planets — the manner by which two motions emerge for them — sometimes [the motion] is at the apogee, its elevation [rom], and sometimes at the perigee, its setting [?]; and it is not found in any manner [?] at the lower point [?] — its elevation [?]. They gave [?] them the revolutions [?]: whichever configuration you wish [?] — the two configurations [?].

[Münster's Latin note (facing column, p. 74): "...Further, to those planets which are found slow only at the apogee, and in which no slowness is found at the point opposite the apogee, to these you can assign..."]

But it will be [the case] that the perigees emerge [?], and it will be possible that the deferent's [?] proper manner [?]; and upon it the disk of the epicycle goes [?].

Second Gate — *Petach 10* (continued) → *Petach 11*

[the model] proceeds for the figure of the western motion. And these two figures emerge from one [common] principle, since by either one the motion of that star can be accounted for. In this matter [you may use] whichever you wish: the eccentric can account for that motion, and the epicycle set upon a concentric sphere can also account for it. You may take the example from the sun.

The sun deserves, above the rest of the planets, that its motion be described first, because it has the simplest cause of motion, and the other planets in their motion have a dependence upon its motion: a planet's motion is not readily understood unless the sun's motion has first been known. [In the one model] the sun's motion is accounted for by its eccentricity, and [in the other] by the epicycle being placed upon a concentric sphere; there is no [further] way to account for it. Take an example from the sun: its figure [model] is sound and well-ordered, so that it is set right by its figure — more than the figure of the rest of the stars, which require two figures. The rest of the stars, by contrast, depend in their motion upon their epicycle, and no one is able to grasp their motion — whether a given star is moving — except by [an account] drawn from the motion of the sun and from our own vantage point [as observers]. For this reason they place [the sun] ahead of them.

[Münster's Latin note: ...one of the two figures of motion, whichever pleases you. For the eccentric can save that motion, and so can the epicycle placed in a concentric circle. You may take the example from the sun. The sun deserves

above the rest of the planets that its motion be described, for it has the simpler cause of its own motion, and the rest of the planets in their motion have regard to its motion; nor are the planets' motions easily understood unless the sun's motion has first been known.]

פתח י"א [Petach 11]

The explanation of the order of the sun's motion and of the rate at which it traverses the firmament.

No one can determine the value of the sun's true motion unless he first investigates, at the outset, the count of the days contained in the year — which is its [the sun's] circuit — the year being the time in which the sun encircles the whole firmament and returns to the points from which it began its revolution.

The masters of this craft hold differing views about the days of the solar year. [Some say] they are 365 [ש"ס"ה] days less a quarter of a day.

[Münster's Latin note: Diverse opinions about the quantity of the solar year among astronomers. — They disagree, moreover, about the time by which the year exceeds 365 days. Some assert it to be precisely six hours, which every fourth year make an intercalary day.] [p. 75]

if it [the surplus] is a complete quarter-day, it either adds upon the quarter or falls short of it. The early scholars and their whole company who look into this — some add to the quarter-day; and most of the gentile astronomers reckon the solar year [as having] a complete quarter [day], no less and no more.

The scholars who differ over the secret of this matter are the scholars of Persia, of Greece [Yavan], and of Rome [the Romans]; and from what we have heard from them [it is clear] to the observers that [the disagreement] is slight. Some see it [the excess of the year over 365 days] as a surplus over the quarter-day, and some as a deficit below it; the differences between them are close to one another, near and approximate in their statements.

[Münster's Latin note: Others say it is more than six hours; others, however, say it is less. And these again differ variously among themselves. Hyparchus [Hipparchus] and Ptolemaeus [Ptolemy] hold the fourth part of a day to be added to the 365 days, [the year] falling short by the twenty-fifth part of an hour, which is one part out of the three hundred parts of a day.]

He [the astronomer] is right when he says that the sun's [year] is 365 [ש"ס"ה] less a quarter of a day, and [is also short by] six hours less than that quarter — [a

deficit of] one part out of three hundred in a day [i.e. the quarter-day is itself short by 1/300 of a day].

And the view of this knowledge [school] is fit to be relied upon, because it [accords with] reality — as R. Adda [bar Ahava] of blessed memory [held] regarding the secret of the intercalation [עיבור]; there is no difference between this view and that of R. Adda bar Ahava except for a matter so small that, on account of its smallness, [it need not be heeded].

[Münster's Latin note: This opinion agrees with the mystery of the embolism [intercalation], nor is there any difference in it between the men mentioned and Rabbi Adda, except in a small [matter], which nonetheless is not to be heeded.]

And the runner [the sun] in its motion [traverses] the solar year in one day [i.e. one degree per day]... [p. 76, the line breaks mid-clause: וְהָרוּצָה לְרַעַת מַהֲלַךְ הַחַמָּה הַשָּׁנָה בְּיוֹם אֶחָד]

each [day] it moves one degree [חֵלֶק] of the 360 [ש"ס] that are the count of the degrees of the firmament, by the count of the degrees of the firmament [divided] according to the count of the days of the solar year, according to Ptolemy. And its mean daily motion is found to be 59 [נ"ט] minutes [broken-parts] of a degree, 8 [ח'] seconds, and 17 [י"ז] thirds, and likewise fourths; and fifths, about which there is no need to be exact.

[Münster's Latin note: Equal motion — that is, the mean motion of the sun — has in one day 59 minutes, second 8, third 17, and so consequently for the fourths and fifths.]

This regular motion the sun does not keep continuously: at times it adds to it and at times it subtracts from it. When the sun is at its apogee [גּוֹבַהּ], it is at a deficit relative to [the mean] in [its] motion; [but elsewhere as it moves] it adds upon [the mean] and subtracts from it according to its position [relative to apogee and perigee].

[Münster's Latin note: This regular motion, however, the sun does not keep continuously, but sometimes adds to it, sometimes subtracts, according as it recedes from the apogee or approaches the apogee itself — which addition they call the equation of the argument. Around the apogee its motion is slower than at the opposite of the apogee.]

The surplus and the deficit that are always found in it [arise as follows]: in the days when the sun's motion is regular [at the mean], its regular motion [is at the middle]; and by the constraint that the [observed] motions [impose], they [these

excesses and deficits] are found at the apogee of the sun — the high point — and at its perigee — the low point. The diminished [positions, at perigee] and the strengthened [positions]: by their reckoning [they proceed] through the revolution of the sun, which [model] is able to account for all of it, however differently you set the [models] up. As for the configurations of the compounded motions, were one to wish to set them up, you must not combine them in one [single] way; but if you wish, [then proceed thus]: if [you account for it] by one [model alone, the eccentric], then you set up…

[Münster's Latin note: Its motion, therefore, is saved either by the eccentricity of the deferent, or by the concentricity-and-epicycle — not, however, by both at once, as in the other planets. If by eccentricity, a line drawn from the center of the earth carries round either the body of the sun on the circumference of the eccentric, or the whole eccentric orb.]

the hands [supports] surround [the sun] as it goes out from the center [מֶרְכָּז] of the earth; or else the center [of the eccentric] will be [the point] from which the sun goes out toward the western quarter, and the disk [גַּלְגַּל] [carries] it toward the western quarter [פְּאַת מַעֲרָב].

Now if you set up [the model] by the revolution of the center of the earth, [the sun] will be upon a disk — a great disk [אוֹפַן] going out from the center of the earth — and the concentric [sphere] going out from the center of the earth, which will be [carrying] the sun. The concentric draws along the disk [galgal] and its center toward the eastern quarter, and the sun goes along toward the western quarter.

[Münster's Latin note: If it should please [you] to set the epicycle in the sun without the eccentricity of the eccentric, this will be the motion of the sun. The deferent of the epicycle will have a regular and always equal motion; the epicycle, however, bearing the sun, will render this equal motion unequal.]

upon the pole [קֹטֶר] of the disk, at the eastern quarter, and the sun goes along on its disk toward the western quarter — and at every [other position likewise]. From the two poles of these [disks] there go out [lines] to one matter [point], at its mean [position]; and it inclines [נֹטֶה] for most of the time.

[Münster's Latin note: For when the sun is around Cancer, it will be in the epicycle where the place of retrogradation is, and then its motion will be slower. But if the sun is around Capricorn, its motion will be aided in the direction of the epicycle. In the longitudes, however, it will be a mean motion.]

The scholars, to clarify the revolution of the sun, [set up] the figure of the sun [as] a disk going out from the center, because of the variation that comes about along the path; and in the disk [galgal] [whose count] is joined from the two [poles] of its motions [I shall explain it]. And I shall explain to you the figure of the sun's motion in the way that it goes out.

[Münster's Latin note: Yet most follow the first opinion, saving the motion of the sun by the eccentric, without an epicycle, since the eccentricity requires one motion, but the epicycle two.]

There will be a chariot [עֲגָלָה] — that is, a disk [אוֹפַן] — one [in number]. The sun goes out from the center, and its pole [קֹטְרוֹ] [is marked] אב"ג [points א, ב, ג]: the point marked ב [is at] the center; the disk's point marked ג [is at] the center of the earth; the point marked א [is at] the high point [apogee] of the heights; and the point marked ד [is at] the low point [perigee] of the heights. And the sun [revolves] upon the points [marked around] the center of the earth — that is, a chariot, as R. Adda of blessed memory [held]. This chariot [עֲגָלָה] is a disk [אוֹפַן] rising up toward a disk, [accounting for] the constellations [הַמַּזָּלוֹת] and their orbits.

[Münster's Latin note: …saving the motion of the sun by the eccentric, without an epicycle, since the eccentricity requires one motion, but the epicycle two. — Equa[…] (catchword)]

Diagram. A circle (the eccentric, the sun's deferent) is drawn within a larger circle, the two touching at a single point at the top. Inside the inner circle a three-line figure divides it into sectors meeting near the center, producing the labeled points ב (above center) and ג (below center). The cardinal directions and the apogee/perigee positions are marked around the figure. Reading the labels:

- א (top, on the outer circle, where inner and outer circles meet): the apex point.
- חרום / גובה [apogee / "the height"] — top of the inner circle, just below א.
- ב — inner upper region, below the apogee.
- ה and מ [?] — right side, at the level of the horizontal diameter (ה inner, מ on the outer circle).
- ס — right side, on the outer circle just below מ/ה.
- מערב [west] — center-right region, beside point ג.
- מזרח [east] — center-left region.
- ג — at the center, between מערב and מזרח.
- ו [vav] — left side, mid-level, inner.

- ז [zayin] — far left, on the outer circle.
- ק [?] — far left, on the outer circle below ז.
- ד [dalet] — lower-center, below ג.
- חרום / שפל [perigee / "the depth"] — bottom of the inner circle.
- ל [lamed] — bottom, on the outer circle, at the lowest point.

[Münster's Latin note (foot of left column): "The equal circle of this figure is called the orb of equal or regular motion, since it is concentric, and is the place of the zodiac-bearer (signifer); but the inner one is the eccentric, the body that carries the sun."]

The line א–ב–ג–ד, drawn on the eccentric [?], passes through point ל [?]. By transferring [or: prolonging] the line to the eccentric of the earth — line ג of the western [orb] — and drawing the two lines toward [?] the [points], they meet at the body of the eccentric. And there will be a line from arc ה to line [= ג"ע — ה [?53° — and it is ר"ב [?] [recte: read together with the continuation on the next page] from the eccentric ב, from the center of the earth toward the eccentric. The line turns the two lines toward [?] the two circles, ז and ר ה [?], and the line מ"ה [?53° =] ג"ע [?45° =] turns back toward the east, and that is the line

This line is at the eastern [orb] toward the west, and that is line ב in [?]. Now I observe and remark concerning the two disks [אופנים]: that motion which the sun travels — and I say, on account of the fact that the sun moves upon the eccentric [אופן] of the eastern orb — that it travels uniformly upon a [single] disk; but on the disk that lies west of the earth — and that is line ג — this causes us to see its motion as removed [from uniformity] and as varied along the line. This [happens] for the following reason:

When the sun is at the apogee [גובה] of its eccentric, it is its highest and most remote point, at its greatest distance from the earth; and at the perigee [שפל] of its course, [it is closest]. The [eccentric] is seen in the apogee of the line on [?] the lessening that issues from the eccentric ג, [reckoned] from the center of the earth. And the [account] just given — observe it well — concerning the disk that issues forth: when the sun goes out and appears from [the standpoint of] the two centers, its motion-circles upon the eccentric are seen [as varying] in one direction [or another]. On the eccentric [line] ב [?], and the apogee will be [reckoned] from its position upon the firmament-disk and the disk of the zodiac. And if it is on the disk that the firmament — the bounded one — measures by its eccentric line [?], then it is the chord [?] of the apogee, and the sun appears to our eyes [as moving] upon a line that issues from west of the earth; and that is

it takes hold of the disk. The apogee [חרומה] is bound up [?] toward [?] the side that is to its eccentric [?53° =] ע"ג, and the sun comes to be at the place of viewing — observe and explain [it] — by the motion of the orbit, the line, the firmament [מ?]. And it travels along, drawing near, on the eccentric of the firmament — line ת [?] — the chord of this [arc] equal to [the chord of the arc] this on the western [side?], where עלם [?] is. The center of the eccentric is between the issuing of the disk and the apogee [?53° =] ע"ג, which is on the eccentric of the earth, and the testimony [or: the angle, העורה] of this is the angle [זויתּ] ב on [?ב"ג =] ג. And the angle [זויתּ] of this is to the line, the bounded one, that measures the bounding [?] of the angle [זויתּ] ב on [?ב"ג =] ג, which adds the straightening [equation] upon the points [?]. The line bounded between the two centers — that is, the chord [?] that is found bounded between the two eccentrics, line ע ה [?] — gives the proportion of their straightenings [equations]: upon the mean motion of the eccentric of the line [it follows] the lessening of the outer motion, and is subtracted from the mean motion by the [chord] bounded by the lessening that [issues from] the two centers; and they said concerning the angle [זויתּ] ב on [?ב"ג =] ג that it is bounded by its straightening [equation], since it is not possible to find a single angle [זויתּ] except by the disk; and they bound it [by] the two issuings of the two centers, which is line ב on [?ב"ג =] ג; and the greatness from the angle [זויתּ] ב on ג [?]. The bounded [chord], the equalizing one [המנוברת/המגברת?], gives it [the proportion] which is at its end [?], and it is the angle [זויתּ] at ב on [?ב"ג =] ג. And now [the reader] sees

[Münster's Latin note (right column, this opening): "The motion of the sun, considered with respect to its eccentric, is regular; but referred to the concentric orb it will be irregular, since at one time it is slower, and at another swifter. At the apogee, where the sun is most remote from the earth, it is found slower. There too, from the two centers, it is seen under a single aspect. But unfolded toward the mean longitude, it appears, by reason of the double center, to have a double position in the concentric heaven; and the line of mean motion runs ahead of the line of true motion, and then the equation itself must be subtracted in order to obtain the true motion; and so it continues up to the point opposite the apogee, where the line of true motion runs ahead of the line of mean motion, and therefore the equation must be added — which the author explains by means of greater and lesser angles, in which the excess produced by lines drawn from the two centers shows the equation that must be added or subtracted. What is said of the angle ב"ג and the arc resulting from it must be understood in the same way of the opposite triangle, except that the equation is added on in the one place and subtracted in the other. Furthermore, when the sun moves from zain to daleth in its eccentric..."]

the reader [will see] that when the sun goes traveling from the eccentric [disk] ד toward the eccentric ר [?], from its position it is encompassed by the firmament-disk, and the chord of this — the bounded one [המנגבלת/המגבלת?] — in the angle [זויתּ] ר on ב [?], and the [chord] turns it back; and that is line [?53° =] ג"ע from west of the earth, and passes over toward it [?] the disk of the apogee. And it [the chord] turns back the apogee in the disk, [namely] the chord that the bounding [?] measures in the angle [זויתּ] ש on ל"ג [?], and it is greater [than] the angle [זויתּ] ב on ר [?] which is on the eccentric of the disk that issues forth at the angle [זויתּ] ב on [?ב"ג =] ג; and the [sun] will be traveling, moving away from the eccentric ד toward the eccentric ר [?], its position carrying it off [removing it] from the straightening [equation] of the angle [זויתּ] ב on [?ב"ג =] ג, to which a straightening was [added] toward the firmament. And in this [way], from the angle ב on [?א"א =] ג up to the angle ב on ב"ק [?] the firmament travels and goes around [?], in [each] full angle [זויתּ] ב on ג [?]. And in the choosing [position] the sun is upon the [line] ג, near the eccentric ר [?] — that is, [moving] in the chord of the firmament's course — outward; and at the perigee [it is] high [?], and in its descent and its nearness, it draws near out of [from] the earth, and in [the course of] its turning back from the eccentric ר [?], it arrives at the eccentric ח [?] of the disk that issues forth. That is the perfected [chord], the equalizing one [?], from its [position], the chord bounded in the angle [זויתּ] ר on ב [?], and from the disk of the zodiac it is the chord [?] of the perigee [שפל], which appears [to be seen] by the children of man [= mankind] upon the west of the earth; [it is] the perfected chord of the disk of the apogee

[Second Gate, *Petach 11* — continued. The eccentric model of solar motion: the equation of center, the apogee (גובה) and perigee (שפל) chords, and the variation of true versus mean motion across the quadrants. Münster's Latin notes run in the outer column as the reliable parallel; the Hebrew is primary.]

every chord that the boundary [the limiting circle] subtends at the angle מ"גל [mem-gimel-lamed?] [?], which is inclined upon the line בדי [?] of the angle בה"ג [bet-he-gimel], reckoned to the angle בו"ג [bet-vav-gimel] [?]; and the motion will be at the chord ח [chet] in the descent [going-down] of the line ז [zayin]. And when we keep it [hold it back] from being mixed [confounded] — it being at the chord ז [zayin] when the center [המרכז] is revolving from the chord ח [chet] of the distance [המורחק], the second mean [point] rising toward the chord א [aleph].

[Münster's Latin note: "…drawn out from the center of the world, it advances from the apogee toward the point opposite the apogee, along the line extended from the center of the eccentric. The slowness and the speed of the motion are

shown by two circles, namely the concentric and the eccentric. For from [point] א to ז there is the larger quadrant-arc of the circle, and from א to ע you have a quadrant; while from zayin to dalet the contrary holds. Therefore in that semicircle there is a double angle: in one quadrature it produces slowness, and in the other speed."]

The apogee [גבה] of the firmament [חרום, here = the sphere's apogee] will be circling about the deferent-wheel [מאופן], and the chord that goes out [היוצא] is bounded by the boundary at the angle אבה [aleph-bet-he] [?]; and from the deferent that resembles it [הדומה], every chord סמ [samekh-mem?] [?]... And it [the eccentric] is seen completing [going around] upon the center of the earth (*upon which are the eyes of mankind* [אשר עליו עיני בני אדם]), the chord מא [mem-aleph?] toward the side [לצד] ח [chet] being bounded by the boundary at the angle אגם [aleph-gimel-mem]. And this other angle, which reverts from the angle חבא [chet-bet-aleph] (*which is the path of the sun upon the deferent that goes out* [the eccentric]), produces the angle בה"ג [bet-he-gimel], and it will be the equation [העורת = the difference] between the necessary [mean] motion [המהלך הנחוץ] and that which is stretched out [והמתחו], double the angle בה"ג [bet-he-gimel].

[Münster's Latin note: "From the western mean longitude up to the eastern mean longitude, the mean motion of the sun exceeds the true motion — that is, the concentric orb, in which the true motion is observed, has a semicircular arc..."]

And it is found, when it travels from the chord of the mean motion [מנסירת המעמר הבינוני], going in the western quarter [בפאת מערב] toward the chord א [aleph] of the apogee [גובה], until it reaches the chord ז [zayin]; the mean [point], when it is in the east, goes diminished [traveling less] than the mean motion [ממהלכת השוה]; and when it goes from the chord ז [zayin] toward the apogee [לגובה], the chord ר [resh] of the perigee [שפל]...

[apogees, חרום] until the chord ה [he] of the discourse [המאמר], the mean-point [הבינוני] which at its beginning [בתחלה] from its place [ממקומו] is seen to travel farther [more] than its mean motion [ממהלכה השוה].

And when the sun [the body] travels [נוטה] from the apogee [מגובה] — at the time it reaches [בגעתה] the chord ל [lamed] of the perigee [שפל] of the apogees [חרום] — it is seen to be traveling [going] on every day less in its motion [מוסית? recte: traveling less] upon the path of the day [על מהלה היום] than that which is before it (which is to the sight of the eye [למראית העין]).

And when the sun rises [travels] from the apogee toward the chord — at the time it reaches [בגעתה] the chord ל [lamed] of the perigee [שפל], the mean-point is seen to be traveling on every day adding [מוסיף = מוסית] upon the path of the day that is before it; and this is the order [סדר] of the matter [ענייני] of the path of the sun [מהלך החמה].

And when one comes to subtract [ובכשבא לחסור], with respect to the place of the apogee [גבה] of the apogees [חרום] of the deferent-wheel [מאופן], the [signs] of the ecliptic [המזלות] are found warm [חמים], which are between the entry of the sun [מבא החמה] to the head of the sign Aries [אל ראש מזל טלה], until it comes in its travel that begins [המתחלת] toward the head of the sign Cancer [אל ראש מזל סרטן] — a quarter and a half [צד וחצי]; and its entry [ומבואה] to the head of the sign Cancer [אל ראש מזל סרטן], until it comes to the head of the deferent-wheels [אל ראש מאוגנים] — ninety-two days and a half [92= ,צב יום וחצי½] and [further] days…

[Münster's Latin note: "…of the semicircle; the eccentric, however, has an arc greater than the semicircle. But from the eastern mean longitude to the western mean longitude, through the point opposite the apogee, the contrary occurs, because the true motion exceeds the mean. When, then, it is said that from the point opposite the apogee toward the apogee itself the motion of today's day is less than yesterday's, this is seen to be more true of the [region] from the mean longitude up to the apogee — where the line of mean motion follows the line of true motion — and from day to day, the slower line approaches more nearly to the line of true motion, and at last at the apogee it overtakes it. But from the apogee to the eastern mean longitude the contrary occurs, for there the line of true motion separates more and more from the line of the mean [motion]."]

upon the days of half the year [על ימי חצי השנה], and a quarter [ונורבע = ונרבע] of that which is from the chord [שנסירת] of the apogee [גבה] of the apogees [חרום], and it is fitting [וראויה] to be within a chord [קשת] of days which… are subtended [עורפות] upon the days of the second chord [על ימי הקשת השנית] ר [resh]…

and it is the chord which is concealed [מסתרת] up to ב [bet] at its beginning [בתחלה]; and it is fitting for the apogee [היות הגובה] to be from this chord, within the chord which is between the sign Aries [טלה] and the sign Cancer [סרטן], from before the heavens [מפני שמים] upon the days that are subtended [עורפות] upon the days of the chord [על ימי הקשת]; the remainder [הנשארת].

And they found that the apogee [גבה] of the chord [נקודת = נקירת? "the point"] [?] of the apogees [חרום], in their removal [בהסירתם], this [is] upon the sun [על החמה]

in its ascent [מעלותה], and a half is from beside [מאצל] the sign Gemini [= תאומים מזל תאומים]; and this is the knowledge [וזהו דעת] of Ptolemy [בטלמיוס] and Abū al-ʿAbbās [ואברכש = al-Farghānī? — reading uncertain] [?], who [bases himself] upon their knowledge [על דעתם]. I gathered [reckoned] [ספרתי].

Those who rely [הסומכים = the ancients/authorities] reckon in the calculation [בחשבון] of the path [המהלכת], and they maintain [סוברים] that there is not [כי אין] to the apogee [לגובה] of the apogees [חרום] any motion [מהלך] at all, and that it does not revolve [גלגול] from the orb [הגלגל] in which [אשר] it was set [נתנח] at its beginning [בראשית]…

And those who rely upon it [the moderns] bring [מביאי, "bringers of"] for their words a proof, and they say that were [אלו] the apogee [גבה] of the apogees [חרום] of the ecliptic [המזלות] not revolving [מתגלגל לא], the world [העולם] would [not] be settled [ישוב]. They say [עומ', אומרים] upon another foundation [על יסוד אחר]: but [אבל] the inhabited-world [היישוב] is in the quarter of the north [בפאת צפון], and the apogee [ורום] is many times lengthened [פעמים מתארך] and many times shortened [ופעמים מתקצר]; and were [ולו = ולא?] [?] the inhabited-world in the quarter of the north reaching toward every… portion in every season [בכל עת], yet [אבל] in the diminution [בפחיות] from them the apogee [גבה] would be [increased], and the inhabited-world would be in apogee [ברום] lengthened [מתארך], and it adds [ומוסיף = ומוסית] upon sixteen [16= ,י"ו] portions [חלקים], in that the apogee [בהיות הגבה] of the apogees [חרום] of the sun [החמה] varies [מתחלף = מתחלית] its station [את מעמדיו], from…

[Münster's Latin note: "…of the [mean] motion, afterward it leaves it. Moreover, the apogee is found thus: in whichever half of the heaven the sun stays the longer, in that half the apogee must necessarily be. It is established, moreover, that more days are numbered from the entrance of the sun into Aries up to Libra than from Libra up to Aries."]

[Münster's Latin note: "All today affirm that the apogee of the sun and of the other planets is moved according to the motion of the fixed stars; and they assert this. In our age the apogee of the sun and of Venus is found in the second degree of Cancer. It is moved, moreover, in 100 years by 44 minutes and 9 seconds."]

[Münster's Latin note: "If (they say) the ancients moved the apogee, the firm and constant settlement of the northern habitation would not exist, except insofar as the apogee itself were in the northern signs. As it migrates…"]

from the signs of the north [ממזלות צפון] toward the signs of the south [אל מזלות דרום]. And in all the lands [בכל הבמי = בגבולי?] of Greece [יון] and Persia [ופרס] and

Rome [ורומיים = the Romans] [?]: the Ishmaelites [ישמעאלים = the Muslim astronomers] have assigned [נתנו] to the apogee [לגובה] of the apogees [רום] of the sun [החמה] a motion in its journey [מהלך במהלך] like the stars [ככבי] of the firmament [שברת = the seventh sphere?] [?]; and they were not concerned [ולא חששו] for the error [לטעות] of these men [האנשים האלה] regarding the settlements [בחלות] of the inhabited-land [ישוב הארץ], and they said there is no reason […אין למה?] to wonder [לתמוה] upon the settlements [חלות] of the inhabited-world [הישוב] in the quarter of the north [בפאת צפון] and the south [ודרום].

But [for] the one who examines [לחקור] and believes [ולהאמין] in the mouth of wisdom [בפי חכמה]: indeed [there is] the settlement of the land [חלת ארץ] and the inhabited-world [ישוב] in it forever [עולמו] in every season [בכל עת], and the knowledge [is] in the mouth of His will [בפי רצונו]… [*may His Name be blessed* — ית' שמו].

And in their examination [ובחקרם] upon the value [על ערך] of the deficit [החסר] which is between the two centers [שני המרכזים] — that they [are distant], the center of the deferent-wheel [מרכז אופן] of the eccentric [היורצא = the eccentric (orb)] and the center of the earth [ומרכזי הארץ] — Ptolemy [בטלמיוס] said that its half [its radius's measure] is two parts [חלק] [reading of the fractional digits uncertain — הקי חזה חו ' [?]], of [the] parts [חלקים] in the half of the diameter [סוטר = קוטר] of the deferent-orb [האופן] — that is, that they are two parts and a half of one hundred parts [2= ,שני חלקים וחצי מ(מאה) חלקים ½ of 100] in the half of the diameter [הקטר = הקוטר]. And the chord of the inclination [הקשת הנטויה = the equation] upon the diameters of the path [will be] two degrees and ⅔ [or a fraction] of a degree [שתי מעלות ורב'ג שברי מעלה] by calculation; that I have already [explained] that the equation [שהמעלה] in the examination of the deferent-orb [בחקת האופן] — and it is the secret [סוד] of the adjustment [התקון] in the path [כמהלך] of Ptolemy [לרבעת בטלמיוס — reading uncertain] [?].

But [אבל] the wise-men of Ishmael [חכמי ישמעאל] who came after [אחרי?] him [them]: this — but [אבל] in [something] less [בפחות] they did not assign [נתנו] to it [the matter] in any measure [בכל השיעור], this; and I have not [given it place] in mentioning [בהזכיר] their knowledge [דעתם]…

[Münster's Latin note: "…as it migrates toward the southern signs, the southern region would begin to grow in latitude, and the northern to decrease. But now we see the northern region perpetually extended by human habitation up to the 66th degree. But the Greeks, Persians, Romans, Saracens, etc., did not concern themselves with the reason for these things; nor are they willing [to grant] that the regions, on account of the motion of the apogee, should receive any change."]

[Münster's Latin note: "Campanus, when he inquires into the distance between the centers of the world and of the eccentric, divides the semidiameter into 25 parts, and of these he takes one for the distance of the centers; and he places, as the total equation corresponding to it in the firmament, two degrees and ten minutes."]

their opinion. For [the reasons] I have explained to you above, I have set out here to expound the shape of the [solar] motion, and I have constructed it and given my view, so as to recount and show its parts severally [מפורש], as I have spelled out [the matter] in their meaning.

פתח י"ב — Petach 12

On the difference between one day and another — that this day is unequal to that day, and that one night is unequal to another night.

After I had explained in the [preceding] gate the matter of the path of the sun's motion, and its measure on each day [reckoned] day and night together — so that the difference [סדר] would be equal, and from what is heard [it would emerge] that [the measure] given for each of the days, with their nights, is uniform with respect to them — [yet in truth] it is not so for the world; there is among them difference and inequality. [There is] neither evenness nor [uniform] order in the path of the motion. From the beginning [I shall] set it out for the eye of the sons of Adam in its [proper] order.

And [it is] from what is heard [i.e. as is well known] regarding the finding [calculation] and the inquiry into the differences between the days and their nights, [namely] their times — that this matter has occurred and come about because the firmament in its motion drags along [carries with it] and encircles all the earth at once [as] one [revolution]. The beginning of the [reckoning] near to it [is] from their surroundings [orbits] [Münster's Latin note: "To mark out the day one must designate some point, whether in the horizon or in the meridian line."], whence [there is] the place [reckoning-point]. The one made distinct [המפורש] [is] either the place of the [two] halves of the heavens, or [the place] established, from the point of the firmament until it [the sun] begins to revolve [חוזרת] toward that point itself — [and this] is one chord [גרר]. [chord = arc/measure of the day]

[Münster's Latin note: "And indeed, if the sun moved perpetually at one [uniform] rate, the days would be perpetually the same. But now, since it perpetually varies its motion, the days too change, and the nights."]

A measure [arc] from the path of the sun [reckoned] on each day, and it [this arc] is one chord [גרר] [for] day and night together; but [in fact] the chord [גרר] of [one] day differs from the chord of [its own] night [or: from that of another day], being added on [in the firmament's revolution] by [an amount equal to] the surplus [מסב] of the firmament's motion within the firmament — [namely] the sphere [galgal]...

[namely] the sphere — [in] one revolution of it [the firmament] complete. The one made distinct [המפורש] is either the place [reckoning point] [or] the half of the day, [marked off] from where it [the sun] returns [מחזיר] it [the measure] toward the horizon [האופן] itself; and at the time it has set [reckoning] from the time of the sun's [completing the measure] — that is, [the arc] it has traversed [reckoned] within itself.

[Münster's Latin note: "Of the sun to the same point of the horizon or the meridian, with the addition of the space which the sun has meanwhile traversed by its own motion. For when the prime mobile carries the sun's heaven from rising to setting, and the sun in those 24 hours strives in the contrary direction by its own proper motion, then some time corresponds to those 59 minutes — until that heaven too is driven to the appointed terminus."]

The firmament [reckoned] between [one] motion and [another], it [the sun] is its [the firmament's] surplus in [the] time of the firmament['s revolution]; it [this surplus] is the addition [increment] in [the sun's] own body [proper motion] to the firmament's motion [over and above it]. And from the [matter of] manner [reasoning] it would not be, at the time of its rising toward the horizon, that thing [other than] the surplus [מסב] in its [reckoned] revolution — [namely] the one that has come to be at the first [original] revolution, which it was at the outset of the encompassing [orbiting].

And it will be for you, from the path of the firmament, [on a given] day, [an] arc [חוג] other [than] the surplus [מסב] of the whole degree [מעלה], for they [these arcs] are [measured] in degrees of the firmament with the surplus [מסב] of the sun's motion on [that] day; and it will be [that] day's chord [גרר], the equal [mean] day, with the surplus [מסב] [as the] words [terms] of the matter [degree] [are stated], and [this is] from the path of the sun on [that] day.

[Münster's Latin note: "It is defined thus: the day is the revolution of 360 degrees of the firmament, plus the 59 minutes of one degree, which are the sun's motion for one equal [mean] day. And since we are, as it were, at the center of the earth,

while the sun's regular motion is [made] outside the center of the earth, this gives occasion for us to find [there to be] diversity..."]

And because there is no [single] motion of the sun [that is] equal [uniform] on each day — to the seeing of the eye [as it appears] — [there must be] a cause for finding the difference between the days as to their meaning [reckoning], according to the path-motions between them.

In the path [of the sun] there is a difference [from] one [day] to another, and you will find for them [each] difference [as compared] with [another] difference, [arising] by reason of the path-motions of the sun [being] outside the center [of the earth], [the motions] which the sun cannot [perform reckoned] in [a course] that is even [uniform], because [reckoned] from its motion in the firmament — [the motion] found [observed] within the firmament — in [the] time [the sun] is equal [moving uniformly] in [terms of its own] degree [path] in [a] sign...

in [one] sign other than [equal to] its [own] degrees [of motion] in [another] sign — [namely] (which is the beginning in all the reckonings of the calculation) and not in the horizon [אופן] of the straight one [equator / sphaera recta] in all the reckonings of the calculation. And this is by reason of this difference between the days and their nights with respect to them — by reason of two faces [aspects]:

[1] The [first is] from the difference of the sun's [own] path; [namely] the sun, and the second is the difference of its path-motions, [arising] from the path of the sun [being] outside [the center], and the difference of its motion [reckoned] from two places [reckonings] of the sun in its [proper] motion within the signs — [the difference] found [arising] from two places of the firmament, one [as compared] to another, like the degree of the signs in the horizon [אופן] of the made-distinct [reckoning], which are also bound [joined] [Münster's Latin: "this twofold consideration — either it occurs at the oblique horizon, which in diverse places receives a varied rising, or it occurs at the equator, and then it everywhere has the same mode of rising"] from [the path-motion], one [way] in all the reckonings of the calculation.

[2] And the second is [from] their risings [of the signs] in the horizon [אופן] of the [oblique] sphere — [arising] from [the path-motion], one [way] in all the reckonings of the calculation. And [as for] the difference [תחלות], it cannot be [made] in [the span of] one day; it is not a thing recognizable [perceptible] on one day [as compared] to another, nor [over] two [days], by reason of [its being] small [מיעוטו]; rather, over many days [accumulated] you will recognize it [its accumulated quantity], [from] the increment [arising] from [its] one and its

[other]; [Münster's Latin: "This second mode of diversity cannot be perceived in one or another day — so small is the variation itself in the oblique rising or descent of a sign..."] and over thirty days [reckoned] there will be from its measure [an] increment [רביי] in the path of the sun [of] about nine and a half degrees [9 ,וחצי מעלות תשע½°], [namely] in [each] half [reckoning] [in] double [the arc] between the equal [mean] path-motion and the [true] one, and most of the differences [accumulated]...

it will be found [emerging] from the smaller [lesser] surplus by [a] figure-measure [computation] [Münster's Latin: "in the eastern or western horizon"], a higher [more elevated] surplus [as compared] to the lesser surplus — that which [comes] after it [is] from the surplus; [it] returns to the surplus [that is] before the [other] surplus [Münster's Latin: "Many [hours of the] days produce proportionally as much as either accrues to or decreases from the days; or it [the day] is referred wholly to the equator."]. And there will be for them [each] other [day] from them [a] difference, [arising] from the path of the sun [in its] degrees of motion.

The path of the equal [mean] day [reckoned] over the sun's degrees [motion], [is] **less [?19] ט"ר, a quarter [degree], in the view of Ptolemy** [פחות ט"ר רובע לדעת בטלמיוס — reads "less ... a quarter, in the view of Ptolemy"; matches Münster's "differentia 5 graduum minus una quarta gradus ... secundum Ptolemaeum"]; the other [view], which is added on, and the two [points of] difference [arising], one to another, and there will be a difference between this [one] and that [other], [as set out] in all that I have recounted [in] this [petach].

[Münster's Latin note: "Concerning the diversity which the sun's eccentric — being outside the world's concentric — makes in both [its] middle longitudes toward the apogee [augem], [these are], according to Ptolemy, 4 degrees 46 minutes (but in our own age there is reckoned 4 degrees 20 minutes); which, on account of the swift motion the sun has toward [the point] opposite the apogee, when doubled produce a diversity in the whole circle of 9 degrees and 32 minutes, by which the irregular motion differs from the regular. And [reckoned] from a [single] middle longitude, the difference is 5 degrees less one quarter of a degree, that is, fifteen [minutes]..."]

And the [variation] is found [arising] from the [path-]motion of the sun, [reckoned] upon the considerations [computations] made distinct [המפורש], the differences [varying] in all the considerations [reckonings] of the calculation; their [the differences'] coming-out is [each one's] value [arc] [compared] to another value, [reckoned] from the considerations [computations] of [the]

difference [varying] in it. [The matter] is found, [as for] the figure of the great circle, in the middle [mean] [aspect] of the signs, the increment [bounded] between the two faces [extremities] of the difference [arising]; the considerations [reckonings] of [its] increment [add up to] a head [sum/start] of addition, [and there is] a surplus [over] in days and in nights — and these are [the figures]: a chord [גרר], a part [degree] [Münster's Latin: 9 degrees 32 minutes], by reason of the [degree-]value of the [computation]…

A figure [computation] of the surplus, [taken] from the half [reckoning] of the rising [of the signs], in the half-degree [reckoning] of the sun upon the calculation, as: in [reckoning] double the value [arc] [in] the two [proper] motions of the sun, whence there will be the difference between this [one] and that [other], in [the] figure [computation] [of] the surplus between [one] day and another; the long [day] and the short [day], between [one] day and another. And [the] beginning [of the matter]…

and the night, and the surplus too — all of this in order to add to the [length of] the days. As for the days on which the nights are added to the days, there is no fixed reckoning for them [שאין לה קצב], and the beginnings of these [days and nights] are found, in the difference between them, by the [oblique] ascension of the signs — that is, by however much the rising [of the signs] is unequal in all its variation [in different horizons].

[Münster's Latin note (p. 91): "Another inequality of the days arises on account of the differing ascensions of the signs in differing horizons. The greater inequality, however, is found at the points that mark the beginning and the end of the increase of the days and the nights — namely, the first points of Capricorn and Cancer. For one half of the zodiac exceeds the equator in its ascension, just as, conversely, the opposite half falls short of it; and in such proportion as the longer days or nights exceed [the day of] the equator, or are exceeded by it."]

Now consider what the men of [astronomical] science saw fit to place at the head of the days, on which they based the courses [מהלכות] of the planets [הכוכבים]: from the moment the sun is at the midpoint of the arc of the heaven that is above the earth — that is, the [moment of true] midday — until it returns to that same point, from the [time] of its [arrival at the] midpoint of the arc of heaven that is beneath the earth, that is, the midpoint of the night [i.e. midnight], until it returns to that same point; but not by reckoning the beginning of the sun's [day] from the point of [its] rising over the earth, and not from the point of [its] setting over the earth. For [the moment of] the sun's rising is itself the cause of the inequality found between the days and their nights, on account of the two different

beginnings — those [days] which have their courses and their risings counted [for them]. The risings [of the signs] in the upright [sphere — i.e. the right ascension] add no more than three fifths and a fifth of an hour [שלשה חמשים וחמש שעה — "three fifths and a fifth of an hour," matching Münster's *tres quintas et unam quintam horae*]...

and the beginnings, this inequality is not [a fixed quantity] one can fix [מויק] by a precise reckoning [בחשבון] of the courses of the planets, except in the case of the courses of the moon, where the astronomers [are still] uncertain about it [חוששין לו], because [the moon] is liable to reach [a point at which] a fifth [degree], or another degree, [intervenes] in the course of the moon — and there will be an inequality of a great magnitude [in] the reckoning of [the moon's] course, if it falls on an [day] of an eclipse [לקות] of the sun or an eclipse of the moon. The way to reckon the inequality between the days and their nights for [the purpose of finding] the time of their setting [לרעת? ערב] in every place is set out plainly, with its proof, in the *Sefer Ḥeshbon ha-Mahalakhot* [Book of the Reckoning of the Courses], by [the help of] God [בעזרת ה'].

[Münster's Latin note (p. 92): "...rising and setting of the sun, where the foremost inequality is the relation of the sun's motion, which it accomplishes daily, and thereafter [the inequality arising] from the ascensions of the signs, which in [some] degrees exceed the equator or are exceeded by it; and even though this variation is of almost no consequence — adding no more than three-fifths and one-fifth of an hour [3⅕ + ⅕ ?] — yet in the computation of the planets and the stars it can introduce no harm, save in the case of the moon, in whose calculation diligent attention to the minutes is required, since it is swifter than all the other stars, and [moving] five degrees or so, sometimes covers several parts of an hour in [the space of] one degree of the moon's motion — whence a great error could arise in the computation of eclipses."]

השער השלישי בתבנית בירור הלבנה — The Third Gate, on the structure [and] clarification of the moon

[Heading set as large square type, p. 92. שער השלישי = "The Third Gate," with the rubric בתבנית — "concerning the structure" — and בירור הלבנה — "the clarification of the moon."]

Since we fell short [בבר חסרנו] in the Second Gate of [treating] the structure [תבנית] in the clarification [בירור] of the sun, and since we have [now] said [שאמרנו] that its structure [follows] the manner in which the eccentric [גלגל היוצא מרכז, "the sphere whose center is outside the world's center"] proceeds, and have

shown its makeup [הקצב] — namely, what lies between its center [מרכזו] and the center of the earth [מרכז הארץ] — and...

[Münster's Latin note (p. 92): "The theory of the sun in good part explains the theory of the moon, especially as concerns the eccentric [eccentricum] of each. They have..."]

and the measure of its mean motion [מהלך השוה], common to it [the eccentric] on every day. We come now [ואנו באים] in this gate to investigate this deficiency [החסור] in the structure, by [a treatment of] the moon's course [בירור הלבנה], and to set in order [וסדר] what [pertains] to the moon's course; for its [orbital] structure depends on the [model of the] moon's course [בירור]. And if the structure [of the moon] is not [accommodated] by a course similar [to that of the sun's eccentric], that is because the moon does not have a fixed structure [שאין צורת מהלכה שאר], for its planet [or "star," כוכבי] cannot proceed [in a fixed path] — that is to say, [because] from the [motion of] the eccentric [מעמר החמה? read מעמד החמה], which is what carries [the deferent], its center [מרכזו] is itself displaced [מוסבב? מוסבן], so that it [the moon] cannot proceed by [following] a single course on every day. Rather, there is no day on which one [could] know the measure of the [moon's] daily course [מהלכה], by reckoning over [a span of] ten [days?] — and there is no [single] daily [rate] one [could] know — except by [reckoning over] the [time of] the two great luminaries [מורבקות שני המאורות, i.e. the period of conjunction]. And because the moon's course [מהלך הלבנה] is compounded [מחבר], for [the days] of the conjunction, from the course of the sun and from the course of the moon [itself], [hence] it is fitting [ראוי] to [treat] the moon's [eclipse?] [לתלות הלבנה] within the [framework of] its [own] course. And we find for the moon, in every degree of the firmament [הרקיע], in all the orderings [סדרי] of its course — its swiftness [הממהיר] and its variation [וחשונה?] and its [position in the] structure [ובן היא? read ובין הוא] — [it is] seen [נראית] in all the degrees of the firmament: at times toward its height [לרומה, apogee] from its course, [following] the signs [המזלות], and at times toward the north [לצפונה], and at times by the very [nature] of the course [בעצם גות האופן? read בעצם גוף האופן]. And [there] arise [from this] the days, which it [the work] recounts [מקיפר? read מספרת], when [it is to be] examined [בחן].

[Münster's Latin note (p. 93): "All the planets bear a certain relation to the position of the sun. The moon agrees with the sun in this: that the line of the sun's mean motion, the apogee of the moon, and the center of the epicycle of the moon, with respect to the [direction of the] long [axis], come together at one point. Outside these applications, the line of the sun's mean motion is always found at

the midpoint between the apogee of the moon and the center of its epicycle. Venus and Mercury agree with the sun in this: that of all three [the sun, Venus, and Mercury], one is the mean motion. Furthermore, the three superior planets have this connection with the sun, that by however much the body of the planet stands distant from the mean apogee of the epicycle, by just so much are the lines of the mean motions of the planet and of the sun distant from one another. But the author shows first how..."]

how [the moon's structure] is [to be] examined, to be seen for [each of] their positions. They [the days/positions] are not uniform [אינם שרים], but at times they add and at times they are deficient [גורעים], beyond what is fitting [מן הראוי] for them in the moon's mean course [במהלך השוה]; and [there is] a cause [וגזור? read וגורם] for it [the moon's] structure that comes from the moon, which is compounded [מתחבר] from the [moon's] course, or [from] the many ways [the moon] inclines [נוטים] in its course.

Some of these ways incline toward the center of the earth, and [some] ways come out [יוצאים] from the center of the earth. The first [way] of these [האופן האחר, "the other way"] inclines [נטוי] by its very [nature] [בעצם]: the plane [שטח] of [this] way of the signs [אופן המזלות] and the center of the earth [— this] is the center of the earth [מרכז הארץ], and it is called the inclined way [אופן רומה, the inclined deferent]. The second [way] of the way of the signs and the other [third?] way [התאובן השני] inclines [שרה? read נטוי] by [following] a way of length [באורך, in longitude] — [it is] a small [way] [קטרך קטן?], and its center, like the center of the earth [מרכז הארץ], is [such] that [the moon] is spread out [משטה? read נטוי/מושך] [over] a way that rises up [הרומה, the apogee] between them; [the moon is] tied to two circles [נקודות נקראות?]: [one is] called the head of the [Dragon's] tail [ראש התלי], the Knot [וזנב, "and tail"]; and the [other] way is called the inclined way [אופן נוטה], and over it we see [רואים] the moon's [motion] — at times toward its north [לצפונה] from the way, and from [the way of] the signs, and at times toward its height [לרומה, apogee].

And in the plane of this way [there] arises [an inclination] [חנה?] that revolves [יתעגל]. A third [way] — and these are not inclined [נטוי] toward the center [על מרכז]; the way that is inclined by them [המטה בהם] is [inclined] toward a center distant from us [על מרכז רחוק ממנו].

[Münster's Latin note (p. 94): "...how the moon's motion depends on the motion of the sun. He says: you cannot know the moon's course exactly unless you know the age of the lunar month; and the [lunar] month depends upon the conjunctions of the luminaries. Furthermore, in the moon's motion they found slowness,

swiftness, and a mean [rate], likewise [its] latitude from the ecliptic. They also found that the days of [its] revolution are unequal — whence at length they concluded that the moon's motion is described by means of great circles inclined within its orb. Some [circles] are described about the center of the earth, while others go out from, or are described about, a center other than the center of the earth. One of these [is] concentric with the world, which they call the equant of the moon: it moves in the surface of the ecliptic. The other, which is called the inclined [circle]..."]

from it; and this circle is called the third [circle, the line of nodes]. According to the ancients, the moon has a uniform motion [maḥalakh pashut]: in every month [be-khol ha-ḥoresh] it can move evenly. The deferent sphere [galgal ha-haqqafah] revolves upon the body of the inclined circle [ofen noṭeh] whose center is the center [merubo, recte merkaz] of the earth. And it is possible that there be a circle [ofen] proceeding from its center upon ... From this, then, you may rely [that] it will suffice for you, as we said, like the motion of the sun [ke-mahalakh ḥammah].

The ancients gave the moon two kinds of motion [shtei minhagim]: the first is the uniform motion [maḥalakh pashut], which is its motion like the motion of the artisans [ha-ḥarashim, recte the conjunction-reckoners]; ... and the doubled, composite motion [minhag kefel u-meḥubbar], which is its motion through the remaining days of the [lunar] month [yemei ha-ḥoresh].

We come now to combine, in clarifying it, the two configurations [shtei ha-tavniyot] together, and they are given for clarifying the moon. A circle [ofen] proceeds from its center, inclined in the plane of the inclined circle [ofen ha-noṭeh]; and this circle is the third [circle], called the carrying circle [ofen sovel = the deferent], because upon its curvature [ʿaqimuto] there revolves a small circle [ofen qaṭan], part of which projects outside the carrying circle [ha-ofen ha-sovel] and the rest of which lies within the carrying circle. This [small circle] is called the epicycle [galgal ha-haqqafah]. So you have, in clarification, [the fact that] there are four circles [arbaʿah ofanim] employed in the moon's motion. The moon's motion [tnuʿat ha-levanah] is placed upon the body of the deferent sphere [galgal ...]...

[Münster's Latin note (p.95, outer column): "...from it [a galgal], which by their intersection produces the head and tail of the dragon [the nodes, caput et cauda draconis], is indeed concentric with the world, but it inclines toward each region away from the ecliptic, whence the moon obtains [its] latitudes, now toward the north and now toward the south. And in the same way [eadem superficie] a third circle is to be imagined, which is eccentric. But according to the opinion of those

who posit a simple [uniform] motion in the moon, its varying motion is preserved by means of an epicycle, which revolves in the surface of the second circle — which they call the 'inclinator' [declinatorem] and which is concentric with the world. It can also be that this motion is preserved by an eccentric without an epicycle. And you indeed may choose for yourself whichever of these modes you wish; it makes no difference, for either satisfies you. The third [opinion] holds another..."]

the deferent [ha-haqqafah], and upon it [the moon] revolves. If its body stands in the part of the body that emerges [ha-yotse] from the carrying circle [ofen ha-sovel], it [the moon] travels toward the west [pe'at ma'arav]; and if its body stands in the part that lies inward [li-fnimah], it travels toward the east [pe'at mizraḥ]. Its distance, [measured] from the center of the earth [merubo, recte merkaz, ha-aretz] to the center of the deferent sphere [galgal ha-haqqafah], carries the orbit [oraḥ, recte] of the sphere upon the body of the carrying sphere [galgal ha-sovel] from west to east. And by reason of this, the deferent sphere [galgal ha-haqqafah] travels eastward [li-fnei mizraḥ]; the southern point [ha-nequdah ha-deromah] revolves upon the circle, carrying the orbit of the head of the dragon [rosh tali, the ascending node] and its tail [zanav] upon the circle, and southward toward the [appropriate] side [li-fe'at]. And in this its course it rests upon the sides [siṭrei, recte] of the circle of the constellations [ofen ha-mazalot = the ecliptic].

This is the order of the moon's uniform motion [seder maḥalakh ha-levanah ha-pashut], by which it is governed [nohagah ʿalav] at the conjunction of the [lunar] month [be-molad ha-ḥoresh] and at the time of its fullness of light [bi-ʿet melaʾt ha-or], in the middle of the month [ba-ḥatzi ha-ḥoresh]. Most of the ancients [rov ha-qadmonim] used to reckon the moon's motion through all the days of the month [kol yemei ha-ḥoresh] upon this uniform motion [ha-maḥalakh ha-pashut]. And I shall now set forth for you its order and its conduct [minhago], in the order that I depict for you:

[Münster's Latin note (p.96, outer column): "...they hold the reckoning [rationem calculandi] of the moon. For here they have sought simply the mean motion concerning the conjunctions [de mediu motum de coniunctionibus] at conjunctions, and likewise at oppositions, where the center of the moon's epicycle is always in the apogee [in auge], and there is then no need for any equation [aequatione] — just as [there is none] at the two quadratures, where the center of the epicycle is at the opposite point to the apogee [in opposito augis]. But beyond [extra] these applications, it is necessary to add or subtract something to or from

the mean motion of the moon; and so then it is not a simple [single] motion but twofold [geminus] and composite [compositus]. And so the author proceeds to the opinion of those who attribute to the moon both an eccentricity of the deferent orb [eccentricitatem orbis deferentis] and an epicycle. When the body of the moon falls into the outer half of the epicycle..."]

[Münster's Latin note (p.96, foot): "...of the epicycle, that is, into the upper hemicycle, it is moved by the epicyclic motion toward the west [in occasum]; but if into the..."]

[Münster's Latin note (p.97, top, continuing): "...but if it is found in the lower [half] it is moved toward the east [ad ortum]. The contrary is found in the epicycles of the remaining planets. Furthermore, a line drawn from the center of the earth to the center of the epicycle carries the center of the epicycle along the circumference of the eccentric from west to east, and by this motion it is at the same time borne toward the north and from there back again toward the south. But this circle too — which has a regular [uniform] motion and intersects the ecliptic at opposite places, which [intersections] are called the nodes, the head and tail of the dragon — is driven by another, higher circle toward the west by about three minutes daily, so that the head and tail are in continuous motion. All these things are nowadays transmitted in another way: namely, by an eccentric [reckoned] according to each surface, and by deferents of the apogee, which according to one surface are concentric and according to another are eccentric. And to these is added yet another circle, carrying [deferens] the head and tail of the dragon."]

פתח י"ג [Petach 13]

Explanation: the moon's uniform motion [maḥalakh la-levanah ha-pashut].

I incline a circle [ʿagulah] which revolves about the center, namely the circle ABDG [aleph-bet-dalet-gimel], upon its center ṭet [merubo, recte merkaz, ṭet]; and this is the center of the earth [merkaz ha-aretz]. Then I draw back and depict the second circle [ha-ʿagulah], conformable to it [maʿamad], the inclined circle [ha-ofen ha-noṭeh], which serves in the clarification of the moon [bi-virur ha-levanah].

Next I mark upon it a point [qoṭ, recte qoṭer/pole] which is the pole [seṭer, recte] of the circle, at a distance [bi-merḥaq] removed [reḥoqah] from the center [ṭet], measured from the center of the earth [merubo, recte merkaz, ha-aretz]; the circle [ha-ofen] that proceeds [ha-yotse] from the center of the earth [merkaz ha-

aretz] rests [naḥug] upon a point [neqibah] such that there shall be for it [a length] equal [shaweh] to the diameter [le-qoṭer, recte] of one circle [ofen]…

[Münster's Latin note (p.97, lower, outer column): "The author first describes in this chapter a circle concentric with the world, but one which inclines away from the plane of the zodiac [signiferi], marked with the letters aleph, beth, daleth, gimel, upon the center teth, which carries [the nodes, marked] Leo [□] and [Aquarius/Capricorn □]. Then he describes another circle conformable to it in every respect — in magnitude, diameter, and inclination — which lies in the plane of the first circle, but its center…"]

Diagram. A lunar-theory figure illustrating the inclined deferent and the epicycle. The caption above reads **גלגל חקפה** (*galgal ḥaqqafah*, "the deferent sphere"; recte ההקפה). The figure consists of a large outer circle and, overlapping it, a second large circle of the same size whose center is offset (the eccentric deferent and its concentric inclined counterpart), plus a small circle (the epicycle) at the lower left, with two straight lines drawn through it to two external points. The center is labeled in Latin **Centrū terræ** ("center of the earth"). Münster's Latin labels run along the arcs: **Deferens** (the deferent, upper right), **Declinator** (the inclinator, middle right), and **Epiciclus** (the epicycle, lower-left arc, on the small circle). Hebrew point-letters are placed around the upper circle and on the small epicycle.

Labeled points (Hebrew letters; positions read off the figure):

- ס [samekh]: top of the upper (inner) circle, on the vertical diameter
- ז [zayin]: upper area on the vertical diameter, just below ס (the apogee point — "gevoah")
- א [aleph]: upper-middle, on the vertical diameter
- ל [lamed]: middle, on the descending diameter line
- ב [bet]: middle-right, near the **Declinator** arc
- ט [tet]: at the center, beside the Latin label *Centrū terræ* (the center of the earth)
- ה [he]: lower portion of the large circle, on the vertical diameter
- ר [resh]: bottom of the large circle, on the vertical diameter
- On the small epicycle (lower left): ע [ayin] at the top and נ [nun] at the bottom; the two lines drawn through the epicycle terminate at ש [shin] (upper-left external point) and ק [qof] (lower-left external point)

The inclined circle [ha-ofen ha-noṭeh] is the circle ZBḤG [zayin-bet-ḥet-gimel] … upon the point zayin [ʿal nesivat zayin] and the beginning of the revolution [tḥilat

ha-hitʿaggul]. This is the foundational position [ʿiqqar maʿamad, recte] of the circle that proceeds [ha-ofen ha-yotse], inclined in the plane of the inclined circle [ofen ha-noṭeh]. For the penetration [li-ḥadirat, recte] of this circle, the deferent sphere [sovel galgal ha-mithaqqefet] proceeds from the central [point], and there arises the point [nesivat] **zayin [ז], the apogee [govah]**, in the proceeding circle [ofen ha-yotse]; and the point **ḥet [ח], the perigee [shefel]**. And [there is] the point [nesivat] **gimel-bet [ג"ב]**: the position of the head of the dragon [rosh tali, the ascending node] and its tail [zanav], upon which the southern circle [ha-ofen ha-deromah] is divided together with the inclined circle [ha-ofen ha-noṭeh]; for they do not give to the row [le-ṭurat] of the circle…

[Münster's Latin note (p.98, lower outer column, continuing from p.96): "…[the center of the second circle] is outside the center of the first, and on the one side it rises to the apogee [aux/auge] and on the opposite side [descends to] the perigee [opposite the apogee]. This [second circle] is marked with the letters zayin, teth, ḥeth, gimel, upon the center mem [super centro mem]. And since here the two circles lie in one [and the same] surface but have different centers, they intersect each other at the points gimel and beth, where the head and tail of the dragon are marked."]

Third Gate (continued) — *Petach* 13

[Lunar theory continues from the prior opening; no new petach or gate begins on these pages.]

The two circles intersect each other because the [center of the deferent] is eccentric. Were it otherwise, how could two concentric circles lying in one and the same surface cut each other? I therefore set down two points at which they intersect one another, and I mark them with the letters bet–gimel (ב–ג). And I say further: the circle that lies along the line ב–ג is the deferent sphere [galgal ha-maqif, the encompassing sphere].

[Münster's Latin note: "…of the dragon. The eccentricity, however, is the cause of the intersection. Otherwise, how could two concentric circles lying in the same surface cut each other? Two points are marked here, ☊ and ☋ — not that this intersection produces the head and the tail, but rather that this intersection falls upon another circle, namely the ecliptic [signifer], whose plane surface differs from the plane surface of these two circles. It is therefore properly constituted by the ecliptic and the declinator [inclined circle] of the moon's nodes, the head and the tail. The *Caput* [head] is where the moon passes from south to north across

the ecliptic; the *Cauda* [tail] is where it crosses from north to south through the ecliptic. If this passage occurs at the time of opposition, the moon is eclipsed; if it occurs at the time…"]

And let there be point ק [kuf], which is the head of the dragon [resh ha-tli], and let there be point ש [shin] — that is, near point ל [lamed], the perigee [shefel], lying low — and the apogee [gevah] of the deferent. Toward the apogee [gevah], the height [rum] of the deferent sphere [galgal ha-maqif], near point ק [kuf], which is the apogee, the height [rum] of the deferent [ha-maqif], near point [?]; and let point ז [zayin] be the apogee [gevah], the height [rum] of the deferent sphere [galgal ha-maqif].

The [center, recte: המרכז] [printed המורבי] goes forth, and upon the line of the inclined declinator [ha-sovev ha-zar] there falls the center [merkaz] of the inclined circle [ha-maqif] — so as to state it as the ancients [kadmonim] stated it. And in the half-line, by the line [ha-mahalakh], the modern [astronomer] reckons the motion. The two of them lead the moon [ha-mahalkhim la-levanah] in its course [mehalakh], by computation, and there is no want [in the going-forth] of [the moon] from the western [point] of the earth.

To the center [merkaz] of the deferent [ha-maqif] — which is point ט [tet], the figure [tzurah] of het [ח] — [I draw] the deferent sphere [galgal ha-maqif] and the inclined circle [ha-maqif] alike, toward the eastern quarter [pe'at mizrah], along these [lines]. I say: toward the apogee [gevah] along line ב [bet], from point [?], up to line ה [he], and rounded [me'ugal] upon line ה [he] which reaches to it — the center [merkaz], the apogee [gevah], the height [rum] of the deferent sphere [galgal ha-maqif], which is upon point ק [kuf].

2 מ

Tzurat ha-Aretz (continued) — Source p. 100

the node [katro], and there will be a passing-over [ge'ut, "eclipse"] of the moon, which is at point ס [samekh], because it is at point [?]. I say, toward the inclined circle [ha-maqif], it is at point [?].

I say: the deferent sphere [galgal ha-maqif] cuts off a portion [chelek]. The moon goes forth [ha-yotze] from the inclined manner [ofen] of the carrier [ha-sovel], so that there will be in its body [an arc] that revolves [mitgalgelet] toward the western quarter [pe'at ma'arav]. Along these [lines] I say: toward the apogee [gevah], at point gimel-mem (ג–מ).

By way of the carrier [ha-sovel], in the manner of an arc [keshet] ק–ש (kuf–shin), upon the deferent sphere [galgal] — the second inclined circle [ha-maqif ha-sheni] — [there is] the portion [chelek] by which the wheel [galgal] carries [the moon] along [ha-magil] in its motion [ha-mahalakh]. This is point ט–ש (tet–shin), the going-forth [yetzi'ah] from the western [point] of the earth toward the moon. And the going-forth of the moon, day by day, [is] another [amount] on each day.

The deferent sphere [galgal ha-maqif] cuts off [in a day] 13 degrees [yod-gimel ma'alot] and a fraction [u-ve-gon resh-shin, the "broken parts"]. For the degrees [ma'alot], by computation [be-cheshbon], there are degrees [ma'alot] in the whole arc of the deferent sphere [galgal ha-maqif], and the reckoning [seder] of the motion [mahalakh]. The center [merkaz] is upon point [?]. By the manner [ofen]: the carrier [ha-sovel] in a day [moves] another 13 degrees [yod-gimel ma'alot] and a fraction [u-ve-gon resh-shin]. For an arc [keshet] [of] one degree [ma'alah], the reckoning there is [in] degrees [ma'alot], by the manner [be-chasat ofen] of the carrier [ha-sovel]; and the inclined manner [ha-ofen ha-noteh] — it is the wheel [ha-mitgalgel] upon point ה [he] — [it is] the manner [ofen] of the rising [ha-romeah] toward the western quarter [pe'at ma'arav], and there will be a turning [me-sav] [from] the head of the dragon [resh ha-tli] and its tail [zenavo] toward the western quarter [pe'at ma'arav].

[Münster's Latin note: "...at the time of conjunction, the sun will be obscured in some place of the earth. As for what is set down concerning the constitution of the epicycle's center at the time of conjunction and of opposition — that we have already explained just above, in the preceding chapter. As for what follows next, concerning the motion of the center of the epicycle toward the east — which is just as if you should say, from *zain* to *beth* — it has this sense: let us posit the body of the moon to be at point *kupf* [ק], when the center of the epicycle is at the apogee of the eccentric, and let the same center move toward point *beth* [ב]; and from here to point *beth*, the body of the moon will meanwhile be moved within the epicycle toward point *lamed* [ל], that is, toward the west — that is, toward that region which the letter *gimel* [ג] shows in the eccentric, describing namely..."]

By the line ג [gimel], an arc [keshet] [of] one degree [ma'alah], and in its motion [u-ve-mahalakho] there will be subtracted [yigara] from the motion [mahalakh] of the center [merkaz] of the inclined circle [ha-maqif] — by reason of the inclination [shechut]. Its [the moon's] images [temunoteha], and the remainder is left to the motion [le-mahalakh] of the center [ha-merkaz]...

Third Gate (continued) — Source p. 101

the center [merkaz] in a day [is] another 13 degrees [yod-gimel ma'alot] and in the fraction [u-ve-gon] 11 [י"א / yod-aleph] broken parts [shevarim].

And the deficit [chaser] of the going-forth [yetzi'ah] from the center [merkaz] of the earth toward point bet [ב] [is] line ז [zayin]. The center [merkaz] of the deferent and the inclined circle [ha-maqif] — it is point ט [tet]. And the line that the wheel carries-along [ha-magil] [is] arc ז–ב (zayin–bet), which is the arc [keshet] of the motion [mahalakh] of the center [ha-merkaz]; and the center [merkaz] is at line ב [bet]. And point ז–ס (zayin–samekh) — the going-forth from the center [merkaz] of the earth — [is] toward the first inclined circle [ha-maqif ha-rishon], toward the apogee [gevah] of the moon, which is the place [maqom] of the moon. The inclined circle [ha-maqif] and the wheel [ve-chug] [are] in the deferent sphere [galgal], and the second inclined circle [ha-maqif ha-sheni] [is] line ט–ש (tet–shin); and the apogee [gevah] of the moon I say [is] at line ש [shin]. And the deficit [chaser] of the going-forth [is] toward it — toward the center [merkaz] of the earth, which is upon it — turning [tar], you will see the moon at line ק–ש (kuf–shin), arc ט–ע (tet–ayin). And the center [merkaz] is upon the line of arc ז–ב (zayin–bet), and let there be a motion [mahalakh] of the apparent [course] of the moon [ha-levanah ha-nir'eit], arc [keshet] ז–ע (zayin–ayin). And the motion [u-mahalakh] of the center [ha-merkaz] [is] the whole arc [keshet] ז–ב (zayin–bet). And there is found a motion [mahalakh] that is apparent [ha-nir'eh], as we shall set down [hu ha-mahalakh], [being] less than the [true] motion of the center.

The arc of the line [shurah] [is] arc [keshet] 72 [ayin-bet], and the apparent arc [keshet] of the line [shurah], in its measure [be-shi'uro], [tends] toward the bounded arc [keshet ha-nigbelet] at corner [zavit] ק–ט–ש (kuf–tet–shin) [the point-letters ש"קט, not a numeral], which is upon point ה [he] of the deferent [ha-maqif]. And there is found the moon's motion [mehlav, recte: מהלך] less than [pachot mi-…] from its motion [mi-mahalakhah] of the line [ha-shurah], when it is at [the apogee]…

Tzurat ha-Aretz (continued) — Source p. 102

the apogee [gevah] of the deferent [ha-maqif]. And from there I say: it is greater [yoter] than its [own] motion [mi-mahalakhah] of the line [ha-shurah] when it is at the perigee [shefel] of the deferent sphere [galgal ha-maqif]. The deferent [ha-

maqif] is in the likeness [bi-dmut] of the motion [mahalakh] of the sun [ha-chamah] in the firmament [ba-raki'a], and because of [its being] eccentric there is a computation [cheshbon] of the moon's motion [mahalakh] [along] the straight line [shut be-derekh], [by the same] computation [cheshbon] of the motion [mahalakh] of the sun [ha-chamah].

If the moon is situated [omeret] in the deferent sphere [galgal ha-maqif] at the part [chelek] of its going-forth [yetzi'ah], from the manner [ofen] of the carrier [ha-sovel], elevated [me-gobah] [from] the apogee [gevah] of the deferent [ha-maqif] toward the western quarter [pe'at ma'arav] up to [point ש (shin)?] — when there is a low [point], one arc [keshet] springing out [porachat] at corner [zavit] ק–ש (kuf–shin) — it is the [arc] of the motion [mahalakh] of the center [ha-merkaz].

And if it [the moon] is situated [omeret] in the inner part [chelek ha-penimi] of [its course], lower [mi-shefel] than the apogee [gevah] of the deferent [ha-maqif] toward the eastern quarter [pe'at mizrah], up to the apogee [gevah] of the deferent [ha-maqif] — one corner [zavit] descending [moridah] [at] corner [zavit] ק–ש (kuf–shin), or the corner [ha-zavit] descending [ha-moridah], like it [ha-domeh lah], [is] upon point ק [kuf] — [it is] the arc [keshet] of the motion [mahalakh] of the center [ha-merkaz], and there is found the place [maqom] of the moon.

And if the moon should be [tihyeh] situated [omeret] at the apogee point ק [kuf], [at] the height [gevah], the apogee [rum] of the deferent [ha-maqif], or at the perigee [be-nekudat shefel], a low point [rum] — there will not arise the corner [zavit] ק–ש (kuf–shin); none is found [nimtza'ah], and it [the moon] requires no addition [le-hosif] and none [is] to be subtracted [le-gere'a] from the arc [keshet] of the motion [mahalakh] of the center [ha-merkaz]. And there will be, as we have said, the center [merkaz] of the deferent [ha-maqif] at the place [maqom] ל–כ–ג (lamed–kaf–gimel), truly [mamash], from the manner [ofen] of the ecliptic [ha-mazalot]…

[Münster's Latin note: "…its fourth part, namely, exceeding [it], you will transfer from point *kupf* [ק] to point *schin* [ש] itself; but point *schin* must be placed in the circumference of the epicycle, near the circumference of the eccentric, that is, of the deferent of the epicycle. Therefore, whenever in the first epicycle the line *teth–zain–kupf* [ט–ז–ק] shows the moon to be at the apogee of the epicycle, in the other epicycle the line *teth–ain–schin* [ט–ע–ש] shows the moon turned away from the apogee of the epicycle toward the west, a fourth part of the orbit being rolled away — and it is by no means to be marked by a line drawn through the center of the epicycle. For arc *zain–ayin* [ז–ע] is the visible arc of this motion; but the arc of

the motion of the epicycle's center is arc *zain–ain–beth* [ז–ע–ב], and the true motion is less than the motion of the center of the eccentric, up to the point opposite the apogee. From here, however, toward the apogee…"]

Sefer Tzurat ha-Aretz — Third Gate, *Petach 13* (continued)

the [two] longitudes show no difference at all between them. From this you may understand one thing clearly: there is no difference in the motion of the moon upon the epicycle between its apogee and its perigee — for if there were a difference in its motion, the center [המרכז] would not be fixed, but would shift according to the variation in the motion of the center, which is uniform [שוה] on every day. From the [point of] beginning of the moon's visibility to the eye [מראית העין], at the corner [גרוע] [?] [Münster's Latin note: "the true motion is greater than the mean motion, regard being always had to the center of the eccentric. It is otherwise if the moon is in either of the mean longitudes of the epicycle. For the eccentric of the moon has the same ratio as the eccentric of the sun."]

[at] the corner [point] [numeral: ?] [the gematria token here is not legible; the line shows only the clear numerals (10) י' and (60) ס' amid abraded words — see Numerical impossibles], and at its environs [where] you will know by them the [true] position [מקום] of the moon, just as I have shown you, as you saw.

*

Now I shall explain this thesis to you with the greatest possible clarity, that you may not err in it. The mean of the five longitudes [מעלות, "degrees/longitudes"] in the middle, [namely] the distance between the apogee [גבה] of the [epicycle] and its perigee [שפל] — that is the distance [that] was subtracted from it [as it stood]. The distances measured from the mean [points] [האמצעיה] of which I spoke, [those] that are at the corner-points of the north [צפון] and of the south [דרום]: when the moon is at its perigee [shows] a smaller subtraction, by [the amount] the [equation, computed] at the points of the [eccentric] apogee or perigee, is added or [subtracted].

[Münster's Latin note: "With the epicycle established in the mean eastern longitude, the mean motion precedes the true; therefore the arc of the triangle *kupf, schin, teth* [ק, ש, ט] is then to be subtracted from the center of the epicycle, so that the true place of the moon may be obtained — if, that is, the body of the planet is in the western half of the epicycle. It is otherwise if it is in the opposite

half. But in the apogee of the epicycle or its opposite, no angle is generated; therefore nothing is then to be added to or subtracted from the center of the epicycle, but the line drawn through the center..."]

And the sun [שמש]: they said concerning it [that there is] something to be added at the [eccentric] apogee or perigee [גובה או נקובה[?]]. The deferent sphere [גלגל התקפה] which surrounds [it]: as I told you, its figure changes [in appearance]; thus the moon [הלבנה], at the apogee or at the perigee, [its] figure changes. And he went out [?] from there [?]. Therefore the corner [point] is changed [variable] [recte per content: the equation] in the matter of [the corner being] 19 [degrees? — see Numerical impossibles], and the calculation [is] 60 [parts of] a chelek [part] [s. — abbreviation ס], at the place where the eccentric [היוצא] lacks [is deficient] from the [point] opposite the apogee of the earth toward the [perigee]... [Münster's Latin note (continued): "...it remains otherwise. It is to be subtracted by 10 [units] and a half, of the 60 parts into which the line drawn from the center of the earth to the center of the epicycle is divided. This same [construction] will show the body of the planet placed at a point of heaven directly opposite the center of the epicycle. The motion of the moon upon the epicycle is therefore (says the author) of no great moment, nor much to be regarded, except for ordering and disposing the motion of the center of the epicycle, which is uniform in itself but varies on account of the triangle *qof, shin, teth* [ק, ש, ט], which must at times be added and at times subtracted, so that the true place of the moon may be obtained."]

lacking [deficient] from the [point] opposite the [eccentric] apogee, [namely] the eccentric's [perigee]; such [is its figure] in this case [as] in this figure — see [the figure].

And you find the length of the radius [קו, "line"] of the eccentric, from the apogee [of the eccentric] to the perigee, opposite the apogee of the eccentric, which is [the value] 39 ⅓ [39 — ל"ט ושליש and a third]. And there will be between the center of the earth and the center of the [epicycle] 10 parts [chalakim] [י' חלקים] and a third; and there will be from the middle of the corner [point] [מחצית קטר] of the eccentric, which [lies] at its center, up to the [point] opposite, [a value of] 49 chalakim [מ"ט חלקים]. And in the two-thirds of a chelek [שני שלישי חלק] [is] this matter [סדר]. The motion of the moon on every day [is therefore] for the most part [the value held by] the ancients [הקדמונים].

*

And the second matter for you to know is the motion [רעת — recte: לדעת] of the moon: it completes the deferent sphere [גלגל ההקפה] and returns to the [first] longitude [המסובב — recte: לנקודה, "to the point"] from which it began, [in] 27 days, 13 [hours] [י"ג], and a quarter [רבע] of [an hour], at the third [of an hour] [שליש שעה], and the center of the [epicycle] [ומרכז ג…]. The deferent sphere [גלגל ההקפה] revolves and turns [סובב] [the moon] about [the earth] [את עקס — recte: את עקם / on its course] in the manner of [a sphere] borne [revolving] [הסובל], until [the moon] returns to its [former] place, [having begun] from its starting-point on every day, [in] 7 hours and half an hour and a fifth of an hour — close [approximately]. And the head of the dragon [ראש התלי] and its tail [וזנבו] revolve, circling [סובבים] the earth [את ארץ], in the manner like [the manner of] the [revolution of] the zodiacal signs [המזלות], [in] 18 [years] [י"ח] complete years [שנה תמימה], a [fraction] less, that is to say, 560 [שס"ר — gematria ש300+ס60+ר 200; see Numerical impossibles][?] days…

[Münster's Latin note: "centrum epicycli — this same [line] will show the body of the planet placed at a point of heaven directly opposite the center of the epicycle. The motion of the moon upon the epicycle is therefore (says the author) of no great moment, nor much to be regarded, except for ordering and disposing the motion of the center of the epicycle, which is uniform in itself but varies on account of the triangle *qof, shin, teth* [ק, ש, ט], which at times must be added and at times subtracted, so that the true place of the moon may be obtained. Moreover the greatest equation in the mean longitude is not beyond five degrees, which are to be either added to or subtracted from the mean motion. And hence it is that there are given to the diameter of the epicycle *samekh, lamed* [= ס"ל 60?... see note] 10 and a half, of the 60 parts into which is divided the line drawn from the center of the earth to the center…"]

[Münster's Latin note, p.104 foot: "…of the epicycle, while it is constituted at the apogee of the eccentric."]

[a fraction of] a day, and beyond [the] 7 [years there is] something further [a remainder] [חרשי — recte: a fraction], [out] of 30 [years] [ל'] for every period [חרש — recte: חדש, month][?], and yet 17 [years] [י"ז] more, and in [these] half a day, and [it] goes out [completes the cycle].

The simple [mean] motion of the moon [מהלך הלבנה הפשוט] is compounded [combined] from [several] motions: the motion of the moon on the epicycle and on the deferent [sphere] [בגלגלה], [namely] the deferent [גלגל התקפה], and the motion of the deferent sphere [ומהלך מרכבו, recte: ומהלך מרכזו — the motion of its center] upon [its] course [עקס — recte: course], in the manner of [the sphere]

borne [revolving], and the motion of the [sphere] [המהלך הא…] that is inclined [נוטה] upon the manner of the dragon-line [הדרובי — recte: התלי, "the dragon"], which is [the line of nodes] revolving [מסב] in its motion [במהלכו] at its standing [position] [מעמדו], and [it] returns [ש…ר — abraded]; and [the line of] the dragon [התלי] and its tail [וזנבו] [revolve] upon the manner [course] of the zodiacal signs [המזלות] toward the western [side] [לפאה מערב], which is explained [מפורש — set out separately] from [the account of] the manner of the motion of the moon upon the course of the zodiacal signs [המזלות] [toward the] north and south [צפון ודרום].

[Münster's Latin note: "…to the center of the epicycle while it is constituted at the apogee of the eccentric. The line truly drawn from the center of the earth to the point opposite the apogee of the eccentric, they found to be of 39 parts and one third; whence is gathered the interval of the two centers — that is, the center of the earth and of the eccentric — to be of ten parts and one third. The semidiameter of the eccentric, from its center to the circumference, will be of 49 parts and two thirds of one part. Thus the ancients described the motion of the moon through each [several] day. The body of the moon revolves upon the epicycle from a point [back] to the same point in 27 days, 13 hours, and 27 thirds of an hour. But our [astronomers] determine its revolution to take place in 27 days and 8 hours. And its daily motion traverses 13 degrees and 3 minutes. It seems, then, in the Hebrew text, that *resh-bet* [רב, "much/most"] is redundant; but I think it ought absolutely to be read [as] *yod-gimel hours and a third* [13 hours and a third] and so on. For a third part of a day is the same as eight hours. Furthermore, the circle bearing the head and tail of the dragon completes its motion against the succession of the [zodiacal] signs in 18 whole years and nearly 115 days. The author in the text sets down another number, using Egyptian years. The simple motion of the moon is therefore compounded, that is, the mean motion associates with itself also two other motions, namely the motion of the epicycle and the motion of the deferent of the nodes of the head and tail of the dragon, which is concentric with the world."]

פתח יד — *Petach 14*

[Heading, p.106: פתח יד — "Fourteenth Opening"]

Petach [14]. The motion of the compound [composite] moon [מהלך הלבנה המחובר].

For the most part [רוב], the ancients relied, in the reckoning [בחשבון] of the moon's motion on all the days of [each] month, on the [scheme of the] order [סדר] of the simple [mean] motion which I set out above. And the sages who came after

them, when they [made their] reckoning [חושבין] for the moon according to that order, [found it] close [accurate enough] for [most of] the days of the month; but there was another [matter]: that as they observed [it] [מתבוננים] in order to know [לדעת] the [true] position of the moon by the instruments [בכלים] that were made [העשויים], so as to take [a sighting of] the moon's motion among the stars in the manner of the [fixed] constellations [המזלות], they were [some]times finding it [מוצאים] before their eyes [למראה עיניהם] in a position [where] the moon was [some]times astray [from] [עורת — recte: יתרה/חסרה] the position [computed] by the reckoning of the simple motion. And [some]times [the moon] was lacking [deficient] [חוסר] from its [computed] position — [namely] except [for] on the day of the conjunction [המולד] and the day of [its] fullness [the full moon] [מלאת], the two luminaries [המאורות]; and [some]times [the moon] was, in the two [other] days, [larger] in its position [than computed] [מוצאין מקומה מורך — recte: יתרה] by the reckoning [than] it [actually] was; [the moon] was in position [larger] to the sight [of] the eye [כמראית העין], and [it] was not so on the rest of the days of the month. But its position was [some]times subtractive [smaller], or by a deficit [גורע], and for the most part by an addition [increase] [תוספת]. And [in] the calculations [וחגי רעיון — recte: חשבון/וחישוב] one finds [נמצא] that, when the moon [is] far [removed] [רחוקה] in distance [its longitude] from the sun [מהחמה], in its motion [במהלכה], the equation [correction] [השוה] increased [rises]…

[Münster's Latin note: "In this chapter [is treated] the motion of the compound moon. Among the ancients, many observed the motion of the moon according to the menstrual [monthly] days, and that in the simple manner, as was explained above. But later [astronomers], in the meantime, while they observed the calculation of the moon according to the succession of the days of the months, at the same time, by their own ingenuity, with instruments fabricated for this purpose, observed the place of the moon as [they did] the other [the rest of the] stars; and they discovered by their own examination that the place of the moon sometimes exceeded the computation of the simple motion, and sometimes fell short of it. Only on the day of the conjunction and opposition of the luminaries did they find the computation to answer to the sight of the eyes; but not so on the remaining days of the lunation. Rather, it was necessary either to add to or to subtract from the calculation [the value yet to be set out] here…"]

The Third Gate — *Petach* 14 (continued)

it would rise either ahead of the sun or behind it. For at conjunction the sun and the moon move toward each other from opposite directions, so the discrepancy

becomes apparent — and to remedy it [they reasoned] from the shape of the deferent. That is to say, when the moon was found to move as the sun moves, its figure would remain in the form of a clear circle around its center, just as it appears to the observers below, when its figure is depicted upon the appearance of an apogee-height; and it rises above them — that is, it is more elevated. For when the center of the epicycle is in line of sight at the conjunction of the new moon, and as they have said in their inquiry, it will be set upon the arc of an apogee-height, the deferent being round; and the inquiry into its motion from the western side toward the earth points to a [?] center.

The center of the deferent, at the time it carries [the epicycle], passes over the center of the epicycle that lies in line of sight upon the arc of the apogee-height — and there will be three centers: none aligns with another, save one alone, and they are not found together at the time of the conjunction of the moon. By the figure of the position they are arranged, this being the simple [computation].

*

Now I am beginning to expound the form of the [moon's] motion from the time of the new moon. And I say: at the place where the moon is in conjunction with the sun, in a single degree — that is, where they both are by the median computation — the center of the deferent and the place of the apogee-height of the conjunction will be in line of sight, of the same reckoning; and the center of the epicycle will be in line of sight, moving together with the sun, in their joint motion, by a single degree.

[Münster's Latin note (p. 107): "...from it. For when the moon is separated from the sun by a quadrate, that is, 90 degrees, ahead or behind, they saw that there was need of a certain equation, whence they were compelled to investigate a certain figure that would resolve the discrepancy which arose in the motion of the sun, while the body of the sun meanwhile remained round on all sides in its disposition, as no other figure suits the camps of the sublime creatures. By this inquiry of theirs they discovered that the center of the lunar epicycle, at every conjunction of the luminaries, holds the median summit of the deferent, and that the line drawn out from the center of the earth to the center of the epicycle passes through the center of the deferent, so that these three centers are found, at the hour of conjunction, in one..."]

in a single degree. After this, by the [moon's own] motion from the side of the ecliptic, there is no difference between them; the matter has been expounded, and the center of the epicycle will be in line of sight at the time when it is upon

the arc of an apogee-height, while the deferent moves on. And from the time the moon departs, the center [of the epicycle] is in line of sight; the sphere of the moon, by its rolling, has been carried around — that is, by the figure of its rolling its apogee-height around the deferent which carries it. And to the eastern side the moon moves by (24) כ"ד degrees and (23) כ"ג fractions of a degree each day, since they are together by the doubling of the discrepancy that lies between them.

The motion of the moon between the new moon and the [next] new moon is [?]; from the side of the sun [?] in line of sight, and the center [recte: מרכז] [?]. The deferent rolls upon the wheel that rolls upon the diameter of a small wagon-wheel [i.e. an epicyclet] which is set within the [larger] one, this being the distance that lies between the two centers — the center of the earth and the center of the deferent. And the deferent goes round upon this small wagon-wheel from the eastern side, and from its motion [recte: מהלך] — that is, of this one — the [moon's] rising at the rearmost arc toward the western side.

To the western side it [moves] 11 [degrees] and 9 [minutes], and the center [of the epicycle] is in line of sight; and the rest, by its motion, is in line of sight, in line with the apogee-height. To the western side: 13 [degrees], the moon rising; rising up by its motion of arc; the simple [computation]. And the wheel of the sphere that inclines upon the wheel [?] their likeness will fall short of the [moon's] motion. There are 3 minutes of arc that the moon rises, by which it rises above.

[Münster's Latin note (p. 108): "...in one straight line; and the moon would then have no diversity at all from its simple motion. But these things are to be made clear by a figure. And so, when the moon shall have been conjoined with the sun, and they shall have met in one degree of the zodiac according to the median supputation, the center of the epicycle ☽ and the line of the median motion ☉ are in the same point of the zodiac, but the center of the epicycle is then at the apogee of the eccentric, that is, of the deferent — which you will diligently observe. Hence, then, the center of the epicycle, freeing itself, moves toward the east, while the apogee of the eccentric moves toward the west; and the elongation of these two points in one day [is] 24 degrees and 23 minutes, namely the double of the distance of the sun between either point. For the line of the median motion of the sun is always found in the middle..."]

rises, and the rest, by the [moon's] motion: the western [point] [moves] 13 degrees, and there is no difference [in] its rising upon a near [arc] in proportion to that which remains to it by its motion — the simple [computation]. But the correction of [its] motion comes about from the proportion of the difference, and from the simple [motion], and from the appearance of the apogee-sphere of the

deferent: at the time of the new moon they place it [the moon] in line of sight, this being the cause of the [observed] positions. The true appearance is awakened — its [defect] either an excess or a deficiency from the [computed] positions, by the reckoning of its motion, the simple [one].

And from its motion the moon, you now understand, is in line of sight — [it being] the center of the deferent of the apogee-height, which is set upon the arc of the perigee; for when the moon is far from the sun by 90 degrees, and when it is far [from the apogee], the western [point] will be in line of sight upon the arc of the apogee-height in line, as it is at the time of the new moon, and it is not found from the side of [?].

The motion of the moon, in its true [reckoning]: the new moon — chords of the moon's motion, the simple [one] — when it is not found [thus] at the new moon. There will be a difference of the divisions from the half: the new moon, in line of sight; and by the difference that was from the new moon, in line of sight, from its subtraction; and there will be a [defect] coming about from this, since the centers in line of sight go round about the earth — that is, round about [?] — the deferent. And so on.

[Münster's Latin note (p. 109): "...in the middle of these two points, namely of the center of the epicycle and of the apogee of the deferent. But it comes about, on account of this diverse motion, that the center of the eccentric of the moon also becomes mobile, and it describes about the center of the earth a certain small circle whose diameter is double the distance of the center of the earth and the center of the eccentric. And it [the apogee] moves toward the west, just as the apogee of the deferent moves toward that same region. The apogee of the deferent, however, moves daily against the sequence of the signs — that is, toward the west — by eleven degrees and nine minutes (our [authorities] put 12 minutes); while the center of the epicycle, by its regular motion, moves daily toward the east by 13 degrees and 14 minutes, from which the deferent circle [♓?]..."]

and so on, twice in every new moon, the moon redoubling [?] of the moon. And to show the [moon's] motion, look now, with my eye [as a guide] — the simple [motion] of the wagon-wheel: there comes out the [moon's] western [point] in line of sight, this being a small wagon-wheel that inclines upon the [median] of the deferent by 40 [minutes]; and the center [of the epicycle] is in line of sight, upon the arc of an apogee-height [?].

The center of the earth, by the arc 9, and its subtraction [from] that which has passed over the two centers, lines up with the apogee-height: there are minutes of arc, and it rolls upon the arc 9; and the [farthest] distance — 49 [minutes] — which is the distance that lies between the center of the earth and the center of the wagon-wheel: 43 degrees. And I say: it is upon the arc 7, this being the apogee-height it rises, on the wheel of the deferent that carries [it] in line of sight, [at the time of] the new moon. And from there the center [of the epicycle] begins to be in line of sight, going round toward the eastern side, upon the diameter of the wheel that carries [it]. After (24) כ"ד degrees and (23) כ"ג fractions of a degree, by the reckoning there, [by] degree, in every [arc?]; and there is a subtraction of the wheel, and there will be [a defect] of arc 40, the center [of the epicycle] of the wheel going round upon the diameter of the wagon-wheel — 43 degrees, toward the western side — chords 43; and from its motion the center of the wheel, which was upon the arc 40 from behind, toward the arc 3, toward the western side; and there will be a wheel that carries [it], inclined, upon a center [of] 40.

[Münster's Latin note (p. 110): "...concentric with the world, daily takes away 3 minutes; and there remains a residual diurnal motion of the center of the epicycle of 13 degrees and 11 minutes, or thereabouts. The equation of this motion, however, is continually changed in proportion to the motion of the apogee of the deferent. For when the epicycle is at the apogee of the eccentric — which happens at the time of conjunction — the several signs of the argument have a certain equation to be added to or subtracted from the median motion. But where the center of the epicycle departs from the apogee, those equations continually grow, until the epicycle shall have reached the point opposite the apogee — which happens at the quadratures, that is, when the moon stands 90 degrees from the sun. Further, in opposition — when the moon is 180 degrees from the sun, that is, half the circle..."]

[Third Gate — *Petach 14* (compound lunar motion), continuous from the preceding pages. No new petach or gate begins in these four pages.]

Diagram. A large circle representing the eccentric/deferent sphere, labeled "Oriens" (East, in Latin) at the left and "Occidens" (West, in Latin) at the right. A vertical diameter runs from top to bottom through the figure, and a small inner circle (the epicycle, divided by a cross of two diameters) sits at the lower center, straddling the bottom of the vertical diameter. Two oblique chords descend from the upper rim toward the small inner circle, framing the central region. The construction illustrates how the epicycle-center traverses the deferent's circumference twice each month, so that at apogee (top) the mean motion needs

no eccentricity-equation, while the eccentric-center (point *gimel*) and the mobile apogee stay collinear. Readable point-letters (now legible at native resolution):

- ז [zayin]: at the very top, on the vertical diameter (the apex — the apogee, per Münster: "in puncto ZAIN")
- ל [lamed]: upper right of the rim
- א [aleph]: just inside the rim, below ל, where the right oblique chord meets the upper arc
- ה [he]: center-upper, on the left oblique chord
- ט [teth]: upper left of the rim (Oriens / East side)
- ס [samekh]: left-center, on the inner arc
- ג [gimel]: center, between the two chords (the eccentric-center)
- ס [samekh]: center, just below ג, at the top of the small circle
- ז [zayin]: outside the small inner circle, lower-left
- ע [ayin]: outside the small inner circle, lower-right (the "arc *ain*" of the prose)
- ב [bet]: inside the small inner circle

[Münster's Latin note (left column, parallel to the diagram): "…is again at its apogee, and therefore the moon's mean motion then has no need of an eccentricity-equation. There is likewise then the same ratio of the lunation from opposition to conjunction as there was from conjunction to opposition. From this it is clear that the epicycle-center each month runs twice around the circumference of the deferent. So that all this may be grasped at a glance, the following figure is to be drawn, explaining it: in which the point *mem* is moved circularly upon the center *teth* — for *teth* is the center and semidiameter of the small circle. Further, when the epicycle-center is said to move daily 24 degrees from the apogee, this is not to be understood as if the apogee stayed fixed at a certain point of the heaven, but the apogee too is moved from the point of conjunction or opposition westward…"]

[the Hebrew column. The text is well printed and fully legible at native resolution; readings are committed below.]

inclined (נטוי) by reason of the [mean] course, which has turned back upon the center *gimel* — and this is the apogee, whose inclination is [measured] from the face of a half-arc, so as not to complete [the full circle]; for it has not completed [the circle], lest it confuse the student, [the circle] being left undrawn. And let there be an arc belonging to it from the face… which is in the figure of the dragon (תליו, the nodes), set out as on a [given] day.

[Line *aleph*:] On day one, 11 degrees and 9 minutes (חלקים) of a degree — by which they reckon there the degrees within the half of the apogee. And these are the parts (chalakim) by which the apogee for the western quarter is reckoned. The apogee is found, that which is in [the arc of] subtraction *zayin*, to have shifted toward the point *lamed*. And let the arc *cheth-samekh* [ח״ס] be that which remains for the next day.

[Hebrew column resumes.]

another. 13 degrees: the differences [reckoned] from degree to degree of the center's [mean] course, which differ by the day; and the eccentric-center (מרכז ההקפה) is the one which lies in the arc of subtraction. The arc *gimel*: at the head [of the figure], the new-moon (החדש)… upon its arc of subtraction *cheth*, and between [point and point] the arc *lamed*. Every arc that is theirs… toward the next day.

24 degrees and 23 fractions/minutes [recte: כ"ג / כ"ד], the differences between the two motions (מהלכי [recte: מהלכי], the two courses) by the day. And let there be the epicycle (גלגל ההקפה), the simple [course] inclining (נטוי) in its course upon the arc *samekh*; and let there be in its revolution toward the inclinations (הנטיות), upon the simple course (המהלך [recte: המהלך]) *he*, the simple [course] upon the arc *bet*. And when the moon is distant (מתרחקת) from the conjunction by 90 degrees, let there be the eccentric-center distant from its apogee the new-moon (החדש)… in every direction toward the moon — from the sun — and, being doubled, let this be 90 degrees [reading of the numeral uncertain]. And it is found from the sphere, from its arc *mem* toward the arc *ain* (ע), [a separation] which… 90 degrees, from the deferent (מעגלה) in the [?]… *ain* upon the arc *ain*, and its apogee the new-moon (החדש)… over against the [arc of] subtraction; let this be in the west, and the eccentric-center over against the arc *daleth-bet* [ד״ב?] in every [direction] of the day, from the east; and it is found 40 [?]… the eccentric-center at the conjunction from the new-light [?]… *resh*. רביעיתו [its fourth]

[Münster's Latin note (left column, parallel to : "…westward, just as the rest of the epicycle moves eastward 13 degrees; which numbers added together make 24 degrees. And on account of these motions the center of the eccentric is moved together with the mobile apogee in that direction toward which the apogee itself moves — for the apogee and the center of the eccentric are always found in the same line. When therefore the center is moved in the small circle toward the point *gimel*, then *gimel* will be the center of the eccentric arc *lamed, heth, samech*, whose circle is not completed, lest the eager [reader] be entangled in error. Now the arc *lamed, heth* showed the proportion of the apogee's motion in one day,

namely 11 degrees and nine minutes westward. The apogee then, which was at the point *zain*, has been carried backward…"]

[Hebrew column resumes.]

Its fourth: from the sphere, from the apogee *resh*… the apogee toward the perigee (שפל), [whose] mark is that which lies at the midpoint of the apogee. And at its midpoint, in the [half-]month, the distance between the two luminaries (שני המאורות) will be *samekh-teth* [ס״ת] degrees [?]. And let there be, from the center… distant at the apogee, from its apogee the new-moon (החדש)… in every direction distant — let this be [the] degrees; and let there be, from the face of its course, another eccentric-center toward the apogee *resh*, [the position of] the apogee as it formerly was. At the new-moon (החדש) the eccentric-center is found completing (גומר) its revolution, every [time] together with the apogee, from the new-light *he*. The new-moon [runs] to its own midpoint, and from there onward it will be [a matter] for understanding; for from then on it is the whole circuit (הקפת) of the apogee. From the midpoint of the new-moon to the [next] new-light it conjoins (ויתחבר)… for it encompasses (מקיף) together with the whole apogee twice in a month. After this — one [point] — and you, come and hear: for in it [lies] the sphere of the eccentric, which… and it revolves upon the arc *samekh*, [bound to] the 90 [degrees] that belong to it… their [motion]… its scattering-back (המזרה) [carries] the apogee — the high point — toward the west, [the point] which was fit to revolve upon the arc *bet*, away from the apogee that bears [it]; rather, it was the simple inclining course in its revolution. It places the head of what is called the principal [line] between the center of the earth and the eccentric-center [at] *teth-samekh* [ט״ס], and upon… [A centered section-divider glyph ס is printed at the foot of the page.] ועל [ve-al, "and upon"]

[Münster's Latin note (left column, parallel to : "…backward to the point *lamed*. The arc *heth, samech*, however, is the diurnal motion equal to the epicycle-center. But when the epicycle-center was at the point *zain* and at the apogee itself, there was then the conjunction of the luminaries; and with the center moved to the point *beth* and the apogee carried backward to the point *lamed*, the arc of distance of the apogee and of the epicycle-center for one day will be 24 degrees and 23 minutes — which number is double the distance or interval found for one day between the two luminaries. Therefore the epicycle is simply carried by this motion to the point *samech*, whose path was to be moved to the point *beth*; but at *samech* it [the text] showed the epicycle-center to approach the earth, since it is borne in a straight line toward the opposite of the apogee. Now when the moon is elongated…"]

[Hebrew column resumes.]

and upon the simple course let this be the line (שור) *teth-bet* [ט״ב]; and between them the excess (יתרון) *samekh-teth* [סו״ט]… and by reason of its inclination, let this be beneath the inclination of the conjunction (התקפון [recte: התקפון/opposition-point]), which is the latitude (רוחב) of the apogee (גובה) in the simple course… [the sun] the simple [course] *ain*… in its course… in its course according to the measure of the deferent (מעמד). The eccentric-center, ahead of the apogee, [is] *he-samekh* [ה״ס]; the bearing [sphere] and the supplement (העזרה)… let this be — it goes on, going — *yod-gimel* [י״ג] degrees… until the distance (המרחק) between the two luminaries comes to be 90 degrees backward. And let there be the epicycle *bet* at the [given] distance; let this be inclined upon the arc of the latitude (רוחב) beneath [it]… the bearing [sphere] from the center upward; and *cheth*… [the point] fit for the inclinations, in its simple course upon the apogee. Of its mean (הבינוני) [course] there is a line, and there another, *resh-aleph* [ר״א]… for there is found the excess of latitude (היתרון … רוחב) between the conjunctions/oppositions (התקפות) in… the course, the remainder; and between them in its course… the conjunction (המחברת) and its excess (יתרון), each month (חדש), is found [to be] *lamed-he* [ל״ה?] — toward the senses (החושים), to us, two degrees of a degree; and if one [degree] be missing, its mark…

concerning the secret of the correction (תקון) of the simple [course], which was five (חמש) degrees, and it rises in the heavy [reckoning?] (בכבד) by seven (שבע) degrees and two-thirds of a degree, and [thus] the correction of the simple course is conjoined (המתחבר).

And when you see the simple course, let this be conjoined at quadrature (ברובע, in the quarter).

[Münster's Latin note (left column, parallel to : "…has been elongated from the sun by 90 degrees, the epicycle-center will be distant from the apogee doubly far, because the sun always holds the middle place between the epicycle-center and the apogee. The eccentric's center meanwhile follows the apogee, and is carried from *mem* to the point *ain* — ninety degrees, that is, in the circle *mem-ain* (מ-ע). But the epicycle-center will stand opposite the point *daleth* of the small circle in its deferent, and opposite the apogee, because at quadrature [in quarta nouilunij] it is moved from the apogee toward the opposite of the apogee, with an absolute mid-position — not by itself with [exactly] 90 [degrees], provided the motion be of [those] degrees, but because the apogee meanwhile has also been swept 90 degrees into the diverse part of the world. And twice 90 degrees make a semicircle. Furthermore, in the middle of the month the luminaries…"]

Sefer Tsurat ha-Arets — Third Gate, *Petach 14* (continued) and *Petach 15*

Petach 14 (continued) — compound lunar motion

[Continuation from the prior discussion of the moon's compound motion:] …from four [points of?] the courses, the moon completes a course of 360 degrees [?] over the epicycle, and it travels the way of the center of the deferent [המורבי = recte: המרכז] over the epicycle in one manner, and it travels [the way of] the center of the deferent in the manner that it carries the small epicycle [גלגל הקפה קטנה] over the line, when [?] the difference [המרחס = recte: המרחק, "the distance"?] between the two poles, and the center [ומרכז = recte] of the earth — and its course caused [?] this to point out [מזיר = recte: מאיר / מזכיר] the apogee [גובה] of the rising of the deferent toward the western quarter, and the fourth course is the course of the head [ראש] of the dragon [התלי] and its tail [ויזנבו = recte: וזנבו], the dispersed [?] one, upward.

[Münster's Latin note (full-width, pp. 115–116): "…the luminaries themselves are distant from each other by 180 degrees, that is, by a mid-circle (a semicircle); and the distance of the epicycle-center and the apogee is 360 degrees — that is, they came together into one point, just as at the new moon they were in one point; and the center of the epicycle is found to have completed its whole circuit around the circumference of the eccentric, that is, of the deferent bearing the apogee, from ☌ (conjunction) up to ☍ (opposition), or the middle (halfway point) of the month. In the same way the center of the epicycle is carried onward, in sequence, from the position of opposition toward the point of the coming conjunction. From this it is evident that the center of the epicycle traverses the circumference of the deferent bearing the apogee twice each month. For while it moves through the arc lamed–beth–samekh [ל-ב-ס] to point samekh [ס], it drives the apogee toward the west — though it ought to have moved, in the order of the signs, in the deferent toward point beth [ב]. Now this is called the 'first deferent of the apogee.' But now, when the apogee is carried toward the west, the center of the epicycle begins to descend toward the center of the earth; and from line teth–beth [ט-ב], which ought to have been the semidiameter of the simple motion, there comes to be a line much shorter, teth–samekh [ט-ס]; and the equation of the argument in the epicycle increases — which, in accordance with the simple and unvarying motion, ought to have held constantly at five degrees, just as it does at the apogee. But now, on account of the compound motion, which continually increases and decreases according as the epicycle approaches or recedes from the center of the earth, the

difference of the equation reaches two degrees and two-thirds of a degree — that is, 40 minutes — which the astronomers call 'the diversity of the diameter of the epicycle.' There would be no need for this diversity if the center of the epicycle moved perpetually on the circumference of a circle concentric with the world. This equation therefore grows from ♂ up to…" (Latin continues onto the next page; catchword "quo").]

Petach 15

פתח ט"ו [*Petach 15*]

The openings (causes) found in the moon: The apogee [גובה] of the heat [/ חרס חרם — "of the sun," the solar apex] of the deferent does not move uniformly upon the path of the moon's [?] course, [as does] the deferent. Rather, it [its apogee] is twisted [נפתל] from the course of the deferent toward the west, [from] the eastern quarter to the western quarter, in its drawing-out and in its third [שלישית] — and also in the rest of the days of the [lunar] month other than the four days: the day of the [new] moon [המולד], the day of its half [?] [אמצעירת = recte: אמצעיתו / אמצעית, "its middle/midpoint"], in the course of the table [?], and two [other] days on which the distance between the two luminaries is 90 degrees [צ' מעלה], like the upright conjunction [כמחלה הישרה] before…

[Münster's Latin note (right margin, pp. 116–118): "This opening explains that the apogee of the epicycle of the moon ☽ does not move according to the motion of the center of the epicycle, but declines from that center either toward the east or toward the west — especially when the center is in sextile or trine aspect (that is, when it is distant from the sun by two signs or by four) — and likewise on the other days of the lunation, except for the four days, namely: the day of conjunction ☌, before [or] after the conjunction, and at the end (and so for both points ☌ ☍, observing namely the mean motion that is made according to the center of the epicycle). For on these four days the line drawn from the center of the earth through the center of the epicycle coincides with that line which carries the epicycle around the circumference of the deferent. Here it is to be noted that in the epicycles of the planets a certain point is designated, from which the beginning of the reckoning [supputatio] and the motion of the epicycle itself takes place. Now the epicycle has a double motion: one is the motion of the center of the epicycle on the circumference of the deferent, and the other is the motion of the body of the epicycle, which likewise occurs toward that part to which the center of the epicycle moves; and the line drawn out which designates the one motion designates the other as well — except in the case of the moon, in which the line that carries [the epicycle around]…" (continues).]

before the sun and after [it], and on all four days of these the line [הקו] going out [היוצא] from the western quarter [ממרכז = recte: from the center?] of the earth to the western quarter [center] of the deferent [המורבי = recte: המרכז] passes over [a point] beyond [?] the line [נקורת = recte: נקודת, "the point"] of the apex [רוס = recte: רום] of the deferent, drawn along with the line [חקו = recte: הקו] that carries it [המוליך] — except [?] the moon [אירת = recte: אך / not the moon?].

And I agree (consent) to explain this matter, and say: the custom (procedure) in all the planets is that, in their manner, an upright line [?] is drawn from the start of the point [נקורת = recte: נקודת] reckoned [for] the beginning of the reckoning [חשבונות], [for] the course of the epicycle [האופן] itself, and [for the course of] the deferent [וגלגל] bearing the apogee [הקפה] in all two [respects: motion of] the two [centers]. The course of the deferent [המהלבות = recte: המהלכות / of the courses] of the deferent moves the center [המורבו = recte: המרכז] upon the manner that the deferent carries [it], and the course of the deferent toward the western quarter of the deferent [גלגל] bearing the apogee toward the quarter of the course of the [western] deferent [המורבו = recte: המרכז] bounds [ויחקו? = recte] the bound (limit) of the course, that other [course] which is close [?] to the [course of the] planets. It [the moon] is the [one that] bounds [?] the second [course], and there is no procedure [המנהג] in the sphere [בגלגל] of the moon's epicycle [הקפת הלבנה]; rather, the line [הקו] that carries [המוליך] the center [המורבו = recte: המרכז] of the epicycle in the manner [that] the epicycle [האופן] bears [it]: it is the line going out [היוצא] from the western quarter [ממרכז = recte: from the center] of the earth to the western quarter [center] of the deferent [המרכז]; and [it is] the line [וחקו = recte: והקו] that carries [המוליך] [it] from the [point of] the apex [ארת = recte: רום?] of the course of the deferent [גלגל], the course [מהלה = recte: מהלך] of the western quarter [center]. There is no other line [קו] in this except if another line goes out [יוצא] from its point [מנקורת = recte: מנקודת], drawn [נהוגרת = recte: נהוגה / drawn along] over [a point] [על קטר = "over the diameter"?] [in?] the manner [אופן] of the carrier [הסובל]…

[Münster's Latin note (left margin, pp. 117–118): "… ☽ ☍ of both observed, namely the mean motion that occurs according to the center of the epicycle. For on these four days the line drawn from the center of the earth through the center of the epicycle coincides with that line which carries the epicycle around the circumference of the deferent. Here it is to be noted that in the epicycles of the planets a certain point is designated from which the beginning of the reckoning and the motion of the epicycle itself takes place. Now the epicycle has a double motion: one is the motion of the center of the epicycle on the circumference of the deferent, and the other is the motion of the body of the epicycle, which

likewise occurs toward that part to which the center of the epicycle moves; and the line drawn out, which designates the one motion, designates the other as well — except in the case of the moon, in which the line that carries [it around]…"]

the carrier [הסובל], goes out [היוצא] to the apex [רום] of its apogee [גובהו], and passes over [a point] beyond [?] the center [מרכז] of the earth. And the point [ונקודת = נקודת / "and the point"] of the apex [רום?] of [?] [רוסה = recte: רומה?] this is at a [certain] distance [רחוקה] from the western quarter [center] of the earth toward the quarter of the perigee [שפל] of the heat [חרס / חרם = solar apex], like the distance [כמרחק] of the center [מרכז] of the earth from the western quarter [center] of the deferent [האופן] going out [היוצא] toward the quarter of the apex [גובה] of the heat [חרס].

And when the center [מרכז] of the epicycle [התקפה = recte: ההקפה] is upon a [certain] point [נקורה = recte: נקודה] — the apex [רום] [and?] apogee [גובה] of the carrier [הסובל] at the [time of the new] moon [במולד] of the heat [solar apex] — and in its midpoint [ובאמצעיתו], the line [הקו] going out [היוצא] from the western quarter [center] [מן הנקורה = recte: מן הנקודה, "from the point"] passes toward the center [מרכז] of the epicycle [התקפה = recte: ההקפה], passing over the center [מרכז] of the earth; and this apex [רום] of the epicycle will be drawn [נגרו = recte: נגרר, "dragged/drawn"] from that point [מן הנקורה]. And from the time [ומן זמן] the center [מרכז] of the epicycle passes over the center [מרכז] of the earth, and this apex [גובה] of the epicycle [will be] facing it [מפני = recte: מפניו?], the epicycle [התקפה] is bounded [נגבל = recte: נגבל / bounded-off] from beside [מן מגבל] its [own] point [מנקורתה = recte: מנקודתה], here, and from [ומן] the time [the] center of the earth [is] upon another point [נקורה = recte: נקודה] [than] that of the sphere [גלגל] of the epicycle, then [וחוא = recte: והוא] this [matter? חדין = recte: חדון/הדין], in the manner [בכיורת = recte: בכיוון? / by-the-direction] of the distance [המרחק] between the two luminaries — 90 degrees [צ' מעלות] above [למעל = recte: למעלה] [the line?], like the course [כמהלך] of the upright line [השרה = recte: הישרה] — here they are [הן] before the sun. Here they are after [it], because in all two times [שני זמנים] these [האלה], the center [מרכז] of the epicycle will be upon a [certain] point; the epicycle [התקף = recte: ההקפה] [will be] upon the apex [רום] of the perigee [שפל] of the carrier [הסובל], and the line [will be] the going-out one [הקו = recte: הקו היוצא], going out [היוצא] from the western quarter [center] of the earth, and from the distance [ורחוקה = recte: ורחוקה?] from it [ממנו] is the apex [המוליכה = recte: ?] of the sphere [גלגל] of the earth [ארת = recte: ארץ], and the apogee [גובה] of the heat [חרום = recte: חרס / חרם, the solar apex] will [be there].

[Münster's Latin note (right margin, p. 118): "…the center of the epicycle goes out from the center of the earth onto the circumference of the deferent toward the center of the epicycle. But the line which carries the epicycle itself toward that part to which its center moves is other than this one: for it is led out from a point opposite to the center of the deferent, and it is always toward the opposite of the apogee of the deferent, just as the center of the deferent is toward the apogee of the same. The line therefore drawn from this point (which is movable, just as it is opposite to the center of the deferent), through the center of the epicycle, will display in the epicycle the apogee and the beginning of the reckoning. Furthermore, when the center of the epicycle is at the apogee or opposite the apogee — which happens at ☌ ☍ and □ (conjunction, opposition, and quadrature) — the line drawn out from this point through the center of the earth passes to the center of the epicycle…" (continues).]

(continuation of *Petach 15* — the lunar diameter-diversity equation and the four cardinal configurations)

the height of the apparent position at the boundary of the two limits is one [single] amount. In the choicest [most refined] of the two luminaries — that is, the distance between them — when it is below 6° s[?], there is no diversity above it, nor any diversity in it[?]. So if a [further] amount is added to them, it falls short by [?]. The [points] of the configurations are converging, and here are two [?].

[Münster's Latin note (p. 119): "cycli, & tunc linea ista & linea à centro terræ educta unum ostendunt in epicyclo punctum, nullaque est diversitas in punctis augium." — "…of the cycle; and then this line and the line drawn out from the center of the earth show a single point on the epicycle, and there is no diversity in the points of the apogees."]

When the configurations exceed [this], the height of the apparent position will prevail. The apparent position is drawn out, and the line goes out from the west[?]. The earth, which is opposite the height of the apparent position — and this is the true [position] — will be drawn out toward the east; or [it is drawn] toward the west, and the apogee will then be drawn near. The apogee, with my understanding, and I shall give a parable for it [for them?]: as it were from the wick[?], you see for it[?], to show you with an eye [an example] their forms[?]. See.

[Münster's Latin note (p. 119): "In duabus quartis lunæ est centrum epicycli lunæ in opposito augis deferentis, ideo tunc concurrunt lineæ eductæ ex centro terræ et ex puncto opposito centro eccentrici. At cum luminaria à se distant duobus

signis aut quatuor signis, aut accedit illis aut decedit aliquid in his quatuor punctis ut sint puncta superabundantia, tunc lineæ eductæ è centro terræ & ex centro eccentrici opposito, ostendunt duo diversa in auge epicycli puncta, quorum unum vocatur aux vera et aliud aux media, id quod autor vocat augem בנתל [ba-natal] id est, variantem. Variat, quia..." — "In the two quarters of the moon, the center of the moon's epicycle is in opposition to the apogee of the deferent; therefore the lines drawn from the center of the earth and from the point opposite the center of the eccentric then converge. But when the luminaries are distant from each other by two signs or by four signs — or when something is added to them or subtracted from them at these four points, so that they are superabundant points — then the lines drawn from the center of the earth and from the center of the opposed eccentric show two distinct points on the apogee of the epicycle, of which one is called the *true apogee* and the other the *mean apogee*, which the author calls the apogee *ba-natal* [variable], that is, *variant*. It varies, because..."]

And it will be that the carrying [orb] in the life [?] of the distance between the two luminaries, 6° in elevation — that there is a difference[?] in some manner, here, and witnesses to it, the one who passes over the two centers [?]. And it will be near the western[?] center, this manner; and near the second center of the earth and the configurations 7[?]; the apogee will prevail in elevation.

And near the third [position] — the center of the earth and configurations 7[?] — the apogee prevails. And near the fourth [position]: the distance from the center of the earth toward the apogee, configuration eight at the distance, configuration two[?]...

[Münster's Latin note (p. 119): "...in auge et opposito augis sunt punctus unus & extra hæc puncta una sequitur aliam, aut præcedit eam. Linea à centro terræ educta ostendit veram augem, alia autem vocatur aux media, quæ regulat epicyclum. Cæterum id quod latini astronomi vocant duplex interstitium, id Iudæus noster vocat בפול המרחק [bi-fol ha-merḥak] etiam si illud proprie sit arcus qui supputatur ab auge lunæ ad lineam medii motus eius secundum signorum consequentiam in cuius medio sol invenitur. Distantia autem solis à luna vocatur elongatio eorum. Numerantur in hac figura 4. signa à puncto aleph ad centrum zain, & eductæ lineæ ex centro terræ atque ex puncto opposito centro eccentrici, ostendunt in circumferentia..." — "...at the apogee and opposite the apogee there is a single point, and outside these points one follows another, or precedes it. The line drawn from the center of the earth shows the true apogee; the other is called the mean apogee, which governs the epicycle. As for what the

Latin astronomers call the *double interstice* [duplex interstitium], this our Jew calls *bi-fol ha-merḥak* [the doubling of the distance] — even though properly it is the arc reckoned from the moon's apogee to the line of its mean motion, in order of the signs, in whose midst the sun is found. The distance of the sun from the moon is called their *elongation*. In this figure 4 signs are counted from the point *aleph* to the center *zain*, and the lines drawn from the center of the earth and from the point opposite the center of the eccentric show on the circumference…"]

from us. And it will be [as] a bow [arc] or the doubling of the distance which is between the two luminaries — and that is 6° in elevation — the distance between them was [?] 6° in elevation. And it will be near configuration 7[?]; the center of the apogee[?]. And the apogee was concealed in the apparent[?]-position orb, and that is the orb that is shaded [?]; for it is known by [?] the body that goes out from the center [המרכז, recte for המורבי] of the earth, that conducts the center of the apparent position from configuration 1[?]. As [it is] at the conjunction[?] of the sun, until configuration 7[?] — and that is the [?] crossing from the center of the earth to the center of the apparent position in its form. And it will be the point [נקודת, recte for נקורת] of the apogee. The height of the apparent position is reckoned from the center of the earth, and that is the true apogee.

And understand: if you say, "what manner is it" — for example, configuration 3, configuration 1[?], 2[?]: it conducts the apogee orb. And see their elevation, until you arrive[?] near configuration 7[?], and the like of this in its form. See: configuration 7[?] [recte 240 or 7?]...

Diagram. A large circle (the deferent / orbit of the moon's mean center) divided by a vertical diameter; a small circle (the epicycle) is set tangent to the inside of the large circle at the lower part, overlapping it. The large circle carries point-letters down its vertical diameter, and the small epicycle carries its own point-letters. Lines are drawn from the upper point through to the epicycle. Münster's adjacent Latin states that 4 signs are counted "from the point *aleph* to the center *zain*," and lines from the center of the earth and the point opposite the center of the eccentric meet on the circumference.

- א [aleph] (top of large circle): upper terminus of the vertical diameter — the apogee point.
- ב [bet] (upper-middle, on vertical diameter): point on the diameter.
- ג [gimel] (middle, on vertical diameter): point on the diameter (near center).
- ר [resh] (lower-middle, on vertical diameter): point on the diameter.

- ה [he] (bottom of large circle): lower terminus of the vertical diameter — the perigee point.
- ז [zain] (within the small epicycle, upper): epicycle point — Münster names it the "center *zain*."
- צ [tsadi] (within the small epicycle, upper): epicycle point.
- ל [lamed] (left of the epicycle): epicycle point.
- י [yod] (left of the epicycle, below lamed): epicycle point.
- מ [mem] (lower part of the epicycle): epicycle point.

[Figure-label rubric beneath the woodcut:] נקורת [recte: נקודת — "point" / "figure"]

[Münster's Latin note (p. 120): "in auge et opposito augis…" — see the parallel note transcribed above; it continues the explanation of the *true apogee* and *mean apogee*, the *bi-fol ha-merḥak* (double interstice), elongation, and the counting of the 4 signs from *aleph* to the center *zain* in this very figure.]

Near configuration 30[ל'], the height of the apparent position is bounded[?]. With my understanding[?], the apogee was [as] a point[?], an apogee in my understanding[?] and it is found[?] [as] the height of the heights[?], as the conductor [?] the sun [?]. It falls [נפתל] at the lower part of the sun[?], toward the west side, a bow [arc]... of 30[?]; and if these were the center toward the west side, the opening[?] [petiḥut] would be toward the east side, and standing[?]... upon the opening, when it[?] [was] at delay [שהוי], two times[?]: the moon's course goes [?] upon a [?] orb, the orb of the apparent position to the height of the apparent position which is shaded[?]...

at the lower part of the sun and in its third[?] — it[?] does not live[?]. There goes out to them, from the distance, [its] doubling. With my understanding[?], because of[?] [its] going-out [?] corners [angles] of a corner[?]; the strength is fixed[?] upon the covering[?] [screen], the proper[?] [position] for it; and there is no[?] [life?] going-out, the diversity[?] was at the four[?] quarters of the sun. And in its fourth[?], and when it sets[?] [is established], the course goes upon the head[?]. The covering[?] was given to all who understand them.

[Münster's Latin note (p. 121): "…rentia epicycli duas diversas auges, lamed mediam et iod veram. Linea daleth, gimel, beth, aleph, mutatur motu centri epicycli in lineam daleth, mem, zain, lamed, ostendens mediam augem diversam à vera auge. Est autem aux media epicycli regularis, ideo illa primo inquiritur, deinde secundum distantiam centri epicycli ab auge deferentis usque ad oppositionem luminarium scitur quantum aux vera distet à media, quantumque

eam præcedat, aut si mavis sequatur, quia epicyclus movetur ad occidentem sicut & parvus circulus & punctus in eo designatus tenet hunc motum, & ex eius motu devenitur in cognitionem æquationis quæ cadit inter augem veram & mediam epicycli. Prima enim & regularis supputatio argumenti epicycli fit ad augem mediam, deinde per additionem aut subtractionem arcus parvi devenitur ad veram augem, à qua pendet æquatio epicycli medio motui lunæ addenda vel ab eo subtrahenda. Primi itaque scrutatores motus lunaris, nonnihil hæserunt in motu ☽ quantum attinet ad epicyclum. Nam in quatuor quartis mensis, nempe in ☌ ☍ & utraque ▢ nullum deprehenderunt errorem, sed in ✶ ☌ △ aspectu non successit eis calculus, ob distantiam quam…" — "…the circumference of the epicycle [shows] two distinct apogees: *lamed* the mean and *yod* the true. The line *daleth–gimel–beth–aleph* is, by the motion of the center of the epicycle, transformed into the line *daleth–mem–zain–lamed*, showing the mean apogee as distinct from the true apogee. Now the mean apogee of the epicycle is the regular one, and so it is sought first; then, according to the distance of the center of the epicycle from the apogee of the deferent up to the opposition of the luminaries, one knows how far the true apogee is distant from the mean, and by how much it precedes it — or, if you prefer, follows it — since the epicycle moves westward, and a small circle and a point marked on it maintain this motion; and from its motion one arrives at knowledge of the equation that falls between the true and mean apogee of the epicycle. For the first and regular computation of the epicyclic argument is made to the mean apogee; then, by adding or subtracting the small arc, one arrives at the true apogee, on which depends the epicyclic equation to be added to, or subtracted from, the moon's mean motion. Thus the first investigators of the lunar motion were somewhat perplexed in the motion of the Moon ☽ as regards the epicycle. For in the four quarters of the month — namely at conjunction ☌, opposition ☍, and both quadratures ▢ — they detected no error; but in the sextile ✶, [trine] △, aspect the calculation did not succeed for them, on account of the distance which…"]

[Münster's Latin note (p. 122, head): "deprehenderunt ab auge vera, unde coacti fuerunt ponere angulum æquationis, qui tamen non ubique facit ad rem, cum in quatuor memoratis punctis nullus sit. Est autor hic brevis & obscurus." — "…they detected from the true apogee, whence they were compelled to posit an angle of the equation, which nonetheless does not everywhere serve the matter, since at the four points just mentioned there is none. The author here is brief and obscure."]

הַשַּׁעַר הָרְבִיעִי — מְפָרֵשׁ לְקוּרוֹת שְׁנֵי הַמְּאוֹרוֹת

The Fourth Gate — Expounding the Events of the Two Luminaries

After I completed the account of the manner of the course of the two luminaries, I now come to expound the matters pertaining to the eclipses, in brief.

Among people, there are those for whom light is concealed or hidden from the eyes of the children of men. And I, since I begin with the brightness of the moon [the brightness of the lamp — *kelusat ha-levanah*], and there are other matters pertaining to it which I shall recount[?] to those who lack [understanding]: I say that the body of the moon does not give light of itself, by nature, like the sun. And it is the choicest [most refined] and most translucent[?] of the bodies in the elevation of the firmament[?] — being a body whose light is by its [own] touching[?]. Yet it is not seen[?] upon its surface; rather, it is a thick [opaque], strong[?] body. And when the light passes over it, it is itself made manifest[?] upon its surface, and it appears to the eyes of those who look upon it. These give light of themselves [?], and it [the moon] is [merely] hurled[?]... in it.

[Münster's Latin note (p. 122): "Agit in hoc tractatu autor de eclipsibus luminarium, sed antè præmittit causam incrementi & decrementi lunaris splendoris, secundum quod corpus eius longe semotum fuerit à sole aut prope ipsum constitutum. Notandum ergo in primis, corpus lunare nullum proprium & ex se habere lumen sicut habet sol, nec est transparens ut cœlum sed crassum & opacum quod lumen receptum reddere potest, quod cœlum non facit. Unde cum irradiatur à sole…" — "In this treatise the author deals with the eclipses of the luminaries, but first he sets out the cause of the increase and decrease of the lunar brightness, according as the moon's body is far removed from the sun or set near to it. It should be noted, then, first of all, that the lunar body has no light of its own and from itself, as the sun has; nor is it transparent like the heavens, but thick and opaque — such that it can give back the light it receives, which the heavens do not do. Hence, when it is irradiated by the sun…"]

[The page ends mid-sentence; the discussion of the moon's borrowed light continues on the following folio.]

[the moon's] light from the surface of the earth, which we see, returns and shines back with the borrowed light of the sun. It spreads over the moon by day and by night, and across the whole of it, except that part on which no light has spread — that part remains dark. So the matter returns to the moon's own nature.

The moon's body is round in shape, perfectly so, fixed within the epicycle, with one half of it directed upward toward the firmament — toward its center [recte: המרכז] and the other half of its body directed toward the earth, the half which is below its center.

Now we say of the moon's body that at every moment one half of it, the half facing the sun, is illuminated; light spreads over it from the sun's light, by means of the sun's rays striking it. The other half remains, by the nature of its body, dark, and this is what appears to us. The half of the moon's body that faces the earth is sometimes wholly dark, and sometimes wholly lit, and sometimes partly lit from one end and dark from the other end, and from another end lit, the illumination continuing as it returns; for it [the moon] is wholly dark at conjunction, by reckoning, before the conjunction, and afterward — at the moon's withdrawal toward the…

[Münster's Latin note (outer column, fol. 125, verso of opening): "…the splendor is reflected back from its surface and forced upon the eyes of those gazing, just as if it were the moon's own. Hence it is likened in a certain way to the earth, which we can see when it is illuminated by the sun, but cannot see when it is set in darkness. The lunar body is therefore round, fixed in its epicycle, and the half of it that faces upward is always luminous, since the sun's rays fall upon it; the other half is dark, according to the condition of its nature. Hence it happens that the half of the lunar body turned toward the earth is sometimes wholly dark, and again sometimes wholly bright; sometimes partly bright and par-…"]

which it [the moon] has acquired through conjunction, or in the state of acquiring conjunction. So it falls before the sun's body across its whole half-body that faces upward, and the [other] half is full of light, but hidden from the inhabitants of the earth; and the second half, which faces toward the earth — concerning this we say it is dark, since not a single point of the sun's light reaches it. And at the new moon there is the joining of the [moon's] form [?] according to the moon, as it withdraws from the sun by a small distance at its [outer] extremity; and it [the moon] returns at the seventh [day?] from… and it begins, and is renewed, from before the sun, which faces the [moon's] whole half-body, the half directed downward. And there comes to be the half that is full of light and visible to mankind, and the second half is dark and hidden from them. And in the remaining days of the month the moon does not face the sun's body in its [whole] half upon it, nor in [its other] half, but [is illuminated] in a half joined from above, and the lower [part] joined, so that there comes to be a half joined from the light, illuminated from one of its [outer] extremities, visible to the inhabitants

of the world; and from its [other] extremity, of the [parts] joined, [a half] hidden from them, and from…

[Münster's Latin note (outer column, fol. 124): "…partly dark; this customarily occurs in this order. At conjunction, however, or near it, it [the moon] is wholly dark, and this darkness remains for 18 hours before and after the conjunction, such that nothing of it can be seen by reason of the lunar rays. Indeed, it can happen that the old moon and the new moon are seen on the same day, with these three causes concurring: that the moon be in one of the six signs ♓♒♑♐♈♉ [Pisces through Gemini]; likewise that it have northern latitude and be of swift course, that is, that it be in the position opposite the apogee of the epicycle. When, therefore, it is in ☌ [conjunction] beneath the sun, its upper half is illuminated, and the other, which faces the earth, is dark, since it cannot be reached by the sun's rays. But at ☍ [opposition] everything happens in the contrary manner. For then the moon stands distant from the ☉ [sun]…"]

the [parts] joined from before this, you will see the half joined facing them [?], illuminated from one of its extremities, and from its [other] extremity dark; and I [now] show the appearance of the moon — the sign of the matter of the moon's renewal as a new moon. In its half and in its quarter, the fourth, which faces the half [?], and afterward the half, [completing] the four nights, all of them by reckonings — set your heart to understand…

[Münster's Latin note (outer column, fol. 125): "☉ at its greatest elongation — namely six whole signs — being about to migrate at the same time into the seventh sign. And in that place it is gazed upon by the sun with perfect irradiation, and so the irradiated half is turned toward the earth, nor does anything…"]

Diagram. A schematic of the moon's phases through one circuit of its path. At the top center a radiant sun with a human face emits rays downward; two long straight lines run from the sun outward to the upper corners of an enclosing arc-band, whose corners are labeled ש [sh] (left) and ש [sh] (right). A large circle (the lunar path) occupies the center, with point א [aleph] at its center and point כ [k] just above the center on the vertical axis. Around the circle, at successive positions, are drawn half-blackened lunar disks (each with one hemisphere lit/white and one dark/black, oriented to show the phase at that position). Straight lines (sun-rays / sight-lines) connect the sun and the central axis to the several disks.

- ש (upper-left corner of band): point sh

- ש (upper-right corner of band): point sh
- מ (top, on the vertical axis just below the sun): point mem — the conjunction position (disk wholly dark, facing the sun above)
- ה (upper-left, beside the top inner disk): point he
- ח (upper-right, beside the top inner disk): point chet
- ד (on the top inner disk, left): point dalet
- ר (on the top inner disk, right): point resh
- כ (just above center): point kaf
- א (center of the circle): point aleph
- ח ח (left disk, the two upper labels): point chet, point chet
- ד (left disk, lower-left): point dalet
- ר (left disk, lower-right): point resh
- ח ח (right disk, the two upper labels): point chet, point chet
- ד (right disk, lower-left): point dalet
- ר (right disk, lower-right): point resh
- ח ה [or ח ח] (bottom inner disk, the two upper labels): point chet, point he [?]
- ד (bottom disk, lower-left): point dalet
- ר (bottom disk, lower-right): point resh

The lower outer corners of the band (beyond the path-circle, left and right) carry further point-letters ר / ד. The blackened/white division of each disk shows the lit hemisphere turning progressively toward the earth as the moon moves from the conjunction position (top, wholly dark) around the circuit toward opposition (bottom, wholly lit).

the matter, as you see [in] this [figure]. I, by a circle [drawn here], will set out the way the moon's center [recte: המרכז] is arranged with respect to the moon, and the circle which is upon the four winds [directions]: from point ג to point ב, and from the center of the earth to point א, and I will indicate upon the two centers, this one or that one, and we will join the half from point מ; and I will indicate upon point ב, the center of the earth, so that there comes to be the divided portion of the deficiency that goes out upon the line of a straight angle [?], and we will join it upon the two sides of the circle to point ג; and the circle is upon point מ, whose half goes out, joined from the wheel… [recte: המרכז] which is upon the pole of the sun, and we make a circle upon four circles ג, which are upon the four winds. The disk [is drawn] for the moon upon every disk; from them ד; its letters: two from them ר ז; and two from them ח; and it goes out from circle ש, which is

upon the pole of the sun, toward the four disks of the moon, so that there will be two new moons [?] in their motions, as the form goes out shining upon the latter, from them ש ה, and upon the second ש ח; and there will be, from before the bow [arc] of ש ח, the disk[s] of the moon — standing watch between these two circles, these.

[Münster's Latin note (outer column, fol. 126): "...of darkness it then appears to the inhabitants on the earth. But on the remaining days of the month, the illuminated part of the moon, upper and lower, is gradually diminished or increased and composed; the upper and lower circle plainly [composes] of light and darkness, until at last the one or the other prevails with full light. The composed half he calls the fourth [phase] of the moon.

This figure as marked does not aptly represent the author's description, since the eccentric circle marked with the fourfold gimel — in which the lunar figures are to be drawn — is lacking. It does express, however, something of the figure of the lunar body according to its various elongations from the sun. By the middle circle, whether black or white, understand the middle globe of the moon; and however much the larger circle..."]

Sefer Tzurat ha-Aretz — Fourth Gate (on eclipses)

[fol. 127]

these — illuminated by the rays [that fall] upon them [?] from the sun, while the part that lies in the shadow (that is, in the half facing away) is dark, because the sun's rays do not reach it, but are blocked by the body of the moon, which intervenes.

[The earth, then,] is at the center, [and the observers stand] upon it. The moon's circuit divides into four quarters in relation [to the sun]. In the first [quarter], reckoning from the sun [?] [and] from the conjunction-point [recte: נקודת], the moon is illuminated on the side facing away from the dwellers of the earth, in accordance with the moon's figure. And I would have you observe these arcs, which are not [equal] in relation to the sun: when the moon is in opposition to the sun, [the light reaches it] in such a way [that] the dark [hemisphere] is divided so as to distinguish between them.

Between the two extremities, on the side facing the sun [?], you will find — at its emergence in this figure, which is the bow [arc] of the half [?] toward the side of the earth (as in the [time of] the new moon, when the dark part is full [?]) — and the bow of the half from the figure that is [opposite] when its center [?] is illuminated; [it is] full. And the two arcs are upon the two extremities.

In the fourth [quarter], the moon is partly illuminated from its [near] edge, and at its [far] edge it is dark; and the dark and the illuminated [parts] together fall to the side of the sun, toward the eastern quarter. Toward the western quarter [the moon] adorns itself in full — fair [?] is the order of the light that appears in the moon throughout the days of the lunar month.

[Münster's Latin note (fol. 127): The semicircle that passes through the four lunar bodies cuts off, on the inner side of those same bodies, just so much of the moon as is seen by men dwelling on the earth — namely at the center, aleph. The semicircle drawn from one ש (shin) to the other ש marks another position, in relation to the sun and the moon. For when the sun is around the point [symbol], it has the moon either beneath it — namely in conjunction — and then the upper part of the moon, the part facing the earth, is illuminated and the [earth-facing] side is dark; or it has the moon opposite to it [symbol = opposition], and then that part of the lunar body which is turned toward the earth is illuminated, while the upper part is left in darkness. But if the sun and moon are a quarter of the circle apart, then that half of the moon which faces the sun is illuminated…]

[fol. 128]

[Münster's Latin note (fol. 128, continuation): …but it appears bright to the inhabitants of the earth only for a fourth part, just as a fourth of it appears dark to them — which is easily grasped, if from the center of the earth you draw two lines to each of the four lunar bodies, which touch the extremity of the body's roundness, as you see in the figure of conjunction and opposition.

He says: These matters that are treated here, concerning the increase and decrease of the moon's light, the moon itself in the sky will teach you, if you observe it carefully throughout each day of the whole lunation.]

פתח י"ו [Petach 16]

The shadow of the earth, and the rays cast about [it].

Explanation of the shadow of the earth and its [the moon's] orbit. I say: in every body that is round and also luminous — that is, a body whose light is greater

[than that of] the dense body, and dark — it [the dense body] will be like the round body of the earth. (That is, the dense body is round like the body of the earth, which is a known thing.) For if the luminous body is the larger in illuminating, then the rays of the light that issue from the luminous body will [extend] beyond it on every side. And [these rays], going forth from the luminous body — sixty of [them measure?] [?] the [breadth of the] illuminating body — extend and pass over [the dense body] toward [its further] sides. Many [of them] pass over the [dense] body and broaden out; and the more they multiply [as they go], there is no end [to them]; and the illuminating [body], by reason of the body's density, is [thereby] obstructed. And [these rays], in which there are no [issuing?] rays — they are obscured [?] —

[fol. 129]

— passing over it [the dense body], a remainder; and at its midpoint it is, because of this dense body, [a remainder] [?] [coming] from the rear [side?]. It [the rays] broadens and is bounded, with no end.

And if there are two bodies, [each] having [issuing] rays of light, going forth from the luminous [body] — sixty in [measure] [?] — [and these rays] extend and pass over [it] to the [opposite] sides, [striking] upon a body raised up [?], [in their] portions, then they [the rays] divide it [the dark body] into a [straight] part upon its node [recte: קטרו, "its diameter"], and there will be half of the [dense] body, which is, in equal [measure], illuminated all of it [?]; and at its midpoint [?] they change as they extend, and the measure of the shadow [falls] from the half of the [dense] body, [the shadow] proceeding upon the body, which neither holds [light] nor [is] diminished, with no end.

If the illuminating body of the [dense] body is the larger, then by reason of [its] extending [rays] there will go forth every issuing ray, the sixty [of them?] [?], passing over the [dense] body. And [the ray] that extends [further] will illuminate [the dense body] on the [near] sides and give light [to it] from the [dense] body — [whether] it be the greater, or [the one] beyond [it] at its midpoint — and the small [portion] of light from its [the dense body's] half. And there will be rays passing over it upon [its] further sides, [the rays] issuing forth in opposition [recte: כנגד] and contending [?], until they meet and come together upon a single point of nearness; and the shadow will be lost behind [it] and gathered up [?] in [that point of] nearness — that is it.

[Münster's Latin note (fol. 129): ...with a half, when the body is opaque. But if there be two bodies of the same magnitude, the rays of the luminous body strike

the opaque body round about at right angles, and divide it into two equal parts along its diameter; or, if you prefer, [they divide it] through its flat surface, which cuts that round body into two hemispheres: one is illuminated, namely the one set opposite the luminous body, while the other remains wholly in darkness, since it cannot be touched by the rays. Moreover, the shadow extends in the manner of a column off to infinity, neither increasing in its thickness nor diminishing at all. But if the illuminating body be greater than the opaque body, it will illuminate more than the half of it, when it fixes…]

[fol. 130]

[the rays cast about it?]. And I would have you bring to your figure in all this — the shadow of these things in your heart [understanding]; afterward [you will] be able to comprehend them.

I [further] say: these are the cases of [the moon when it is in] the large figure of the sun [?] [in relation to] the moon's orbit, [and to] the shadow of the earth — that is to say, [the case] in which the sun is broadened beyond [it] in every way [?], until it reaches the eighth firmament [the firmament of the fixed stars]. And it [the moon] would be dark at night, [its light] dispersed throughout the world — from east to west and from north to south. The cause for the moon's light to exist [?] is concluded [?]; but the light of the [fixed] stars, for the most part, the ancients [reckoned to be?] dark, and [thus the moon] is obscured, and there would be no light to be found in the moon at all throughout the nights of the [lunar] month. And [its light] would be found full as by day at its rising upon the earth by day [?].

And if [the moon] were close [to and] joined with the sun, in such a way that it is near to it, [coming] from the [direction of the] sun, then it would touch [it], [yet] by day, because there is found no shadow there obstructing the light from it.

And from here [we may understand]: we [now turn] to discerning [the cases] in which the large figure of the sun is not [present], and these are: when the sun's figure is the figure of [some other] bodies, then the shadow of the earth would go forth in the measure of a [single] body, rising upon its bounds in a year [?] upon the firmament; and they are [things to be] confined [?]

[Münster's Latin note (fol. 130): …it [the luminous body] fixes upon it sharp rays, which are projected somewhat beyond the circle bounding the middle of the globe. If the luminous body be a little larger than the opaque one, it will illuminate a little beyond the half of it. But if it be much larger, it will illuminate proportionally more, beyond the half of it. And those sharp rays, beyond the

opaque body, all converge into a single point and there terminate, [forming] that pyramidal shadow. So, in the case proposed: if the earth were larger than the sun, its shadow would dilate and extend itself as far as the heaven of the fixed stars, and there would be, at night, in all the regions of the world, darkness — so that not only would the moon have no light, but neither would the stars. Nay rather, the moon would never have any splendor throughout the whole month at night, but only by day [?]…]

Sefer Tzurat ha-Aretz — Fourth Gate, Petach 16 (continued)

Fol. 131 (recto)

For the eclipse [of the sun] is found upon the moon at every new moon, when [the moon] stands opposite the face of the sun, joined to it in its fullness — yet it would [also] occur even outside the midpoint of the [lunar] month, [that is,] both before its midpoint and after its midpoint [were the two bodies equal]. From this you may reason that their bodies are not equal [in size]. For were the body of the sun not equal to the body of the earth, and not smaller than it, then [the sun's] body would certainly be larger than the body of the earth, and the shadow of the earth would go out and travel until it returned [narrowed] to a single point; and at that point the shadow would [come to nothing]. The shadow [of the earth] would vanish entirely, and all the air enclosed within the body of the [shadow's] center, which is formed by the shadow, would be darkened, since no light [?] of the sun touches it; whereas all the air that lies outside that center has the sun's light spread over it.

According to the view of the sages who investigate it, the center of the shadow passes by the orbit of Venus [נוגה] but does not reach the orbit of Venus [?] [recte: probably "reaches as far as the orbit of Mercury but not that of Venus," per the Latin]. By [means of] a figure like this one, [it is shown that] the midpoint of the surface dividing [the disk of] the sun [forms] an arc [קשת], and a hollowed-out chariot-curve [ומרכבה נקובה?] [?] … [the line] divides [?] the earth's sphere [עגלה], and [the figure] is lacking [וחסר] on [its] two sides — two centers [are] drawn [?], and it is lacking [וחסר] …

[The closing lines of the column run on into the figure on the facing page; readings of the final clause uncertain.]

[Münster's Latin note (outer column): "...when the sun were in the upper hemisphere, and yet were not in conjunction with the sun. For the moon does not have its own light but a light received from elsewhere, etc. Reason therefore teaches that the earth is not larger than the sun. For if the earth were equal to the sun in magnitude, it is certain that, measured from the point opposite the sun, the shadow would rise up toward the heavens, and being (everywhere equally thick) it would extend to infinity; and so, at every opposition of the luminaries there would be an eclipse of the moon — indeed not [only] at the point of opposition but [also some] degrees before and after — which, since we do not observe it, we may readily judge that those two bodies are not of equal magnitude. If, therefore, the sun is not smaller than the earth, but [is] not [its] equal either, it necessarily follows that it [the sun]..."]

Fol. 132 (verso)

Diagram. A geometric construction of the earth's pyramidal (cone-shaped) shadow. Across the top runs a wide shallow arc spanning between two upper corner-points, with a third point marked at its center where a vertical axis-line descends. From the two upper corners two straight lines (the sun's outer tangent rays) descend and cross, converging to a single point at the bottom and forming an inverted triangle. In the lower part sit two concentric circles (planetary orbits); at their common center is a small disk (the earth) bearing a short horizontal diameter line, and a solid black (shaded) inverted triangle — the body of the shadow-cone — descends from the earth-disk to the apex point below.

- ב (top-left corner): one end of the sun's diameter
- ר (top-center, on the axis): midpoint of the upper arc / top of the vertical axis line
- ג (top-right corner): the other end of the sun's diameter
- ז, א, ח (inner earth-disk, reading right-to-left across its horizontal diameter): the earth's body; the segment carries the diameter-letters of the earth
- ל (lower left, on the inner orbit): point where the left tangent line crosses the inner circle
- ח (bottom apex): the single point where the shadow-cone vanishes (apex of the cone)
- [Latin curved legend, on the outer and inner circles, reading along the curve:] "Circulus Mercurij" — "the circle [orbit] of Mercury"; "Deferens Lunæ" — "the deferent [carrying-orb] of the Moon"

He who passes [העובר] concerning the midpoint of the shadow, and the rays [וחקוים = והקוים] that go out from the sun and touch the surface of the earth — [where] their rays touch [it], the deferent [המגבילי / "the [line] that bounds"] is bounded [?]. And the shadow, from there [henceforth], [is] a triangle, and [the lines] קו גז"ה and קו בחח [qof-vav gimel-zayin-he; qof-vav bet-het-het] will be [its sides]; [the cone] is filled with light, [its sides converging] to a corner [קצה], and at its narrow corner [ומקצתו מאפיל] it casts shadow [מאפיל]. There will be, from every opening [petaḥ] higher than it, the sun's light illuminating [the air]; and from the remainder that is left over [from the light], [the air] enters within the shadow; and all that [enters] within the triangle [becomes] the shadow of the earth, hidden within it.

[Münster's Latin note (outer column): "...[if the sun] is larger, the opposite shadow is extended in the manner of a pyramid up to one certain point where it wholly vanishes. Now all the air comprehended within the capacity of the shadow remains dark, while that which is outside it has the light of the sun diffused over it. Moreover, they say the cone of the shadow reaches as far as the sphere of Mercury, but not to the orb of Venus [□]. He demonstrates this by the figure, whose line ב–ג [bet-gimel] is the diameter of the sun and line ה–ת [he-tav] the diameter of the earth. The lines אוה and בחה enclose the shadow of the earth. Furthermore, the triangle אבג is partly bright and partly dark. The region or surface אבחה is illuminated air; but at the extremity רהב [resh-he-bet] there is the dark part of the air, and whatever falls within it becomes dark."]

Fol. 133 (recto)

[The shadow hides] from it the light of the sun, and all that is outside [it] [recte: וכל היוצא] [has] the sun's light spread over every corner that the sun's light reaches.

[Now] if that body is dense [עבה] and opaque [וחתך / "and cut off (from light)"], the light will be reflected upon the surface, and the moon will [thus] become visible [נראית]; for [the moon] has no light of its own except [light] received from the sun [?]. But if [the body] is transparent and clear [זך], like the bodies of the heavens, and [like] the air remote from the earth, then the sharp ray [ניצוץ] of light passes through that body, goes out from its second [= other] side, and is seen [as it emerges] — and this [is what] is spread [?] [over the second side]. For in all the air of the world at night the light of the sun is full [everywhere], except [in the part occupied by] the shadow, where the air is intercepted [from] the light. The whole [shadow] is in [the form of] a triangle, and this is what is formed [נעשה]

from [the line] ה [he]; for [the line] which goes out [ה...?] alone is darkened [מחשיך] in [its] passing [בעבור] the light of the sun from it [?].

[Münster's Latin note (outer column): "...the dark[ness], and the shadow of the earth hides from it the light of the sun, just as, on the contrary, whatever is outside it [the shadow] shares in the light of the sun. But if the body be opaque and not transparent, the light is reflected back on its surface — such a body as is the moon. If, however, it be transparent and clear, as is a celestial body and air far removed from the earth, the ray of such light penetrates that body and passes out from its other side — which is what may be seen at night, when the whole air is full of light except for that part which the shadow occupies in the pyramid, [a part] which the light of the sun cannot reach. Hence, when the moon is brought through its orbit into this shadowy pyramid, whatever of it enters out of its orbit grows dark. The more the moon approaches the mid[point]..."]

And when [the moon] enters [the shadow], it will [be darkened]; one should know [לדעת] that in every cone [point] there is light from the sun, and that which [is] outside [it] illuminates from itself. If [the moon] enters within it — [that is,] if it enters within the cone — by reason of [the body of] the earth [whose] rays the going-out light of the sun reaches [?] [it is darkened].

And the sphere [galgal / רקיע] of the moon passes over [the body of] the triangle of shadow, and one investigates [וחקר] the difference [המחוצץ / "the dividing-line"] between the two of them [their two faces]; that [body] is the cone...

Fol. 134 (verso)

[The figure of] the shadow-cone [t.s.l. = צ"ל / "shadow-cone"] [is] within the sphere [raqia] of the moon, in the figure of this same figure; and as a triangle [it is shaped]. [The line] ט"ל"ח [tet-lamed-ḥet] [?] casts down [מאפיל] [the shadow of] the earth, [and] the portion [of the moon] that comes within the shadow, within the cone — [there] the moon will be [eclipsed]; that is, in every instance, [when] the disk of the moon [is] within the cone, [it is] like [being at] the midpoint [of the cone]. [The moon] passes over the arc [קשת] of the moon's sphere, which is within the cast-down shadow, at the moment that the moon's disk enters within the cone of shadow; and there will be a hiding and a darkening from the light over the whole portion [of the moon] that comes within the surface [שטח] [as] a triangle, [issuing] from the diminution [מגרעת] of the moon.

If [the moon's] center crosses [the center of the cone], the eclipse will be, as has been said, over the [whole] body [קו? "line / span"]; and at the [cone's] center, the

earth['s shadow] will darken it. [The hiding] of the light will be [total], with nothing [left over].

But if it [the conjunction / opposition] is from the line [recte: מן הקו], inclining toward the northern quarter or toward the southern quarter, then the hiding [diminution] will be in [only] that portion [of the moon] which has entered — reckoned from itself as a diminution [בגריעה] — a triangle [משולש] of the dragon [printed טלה (tet-lamed-he, verified by shape); read by the translator as תלי / the node, per the Latin parallel "latitude from the ecliptic"].

[Münster's Latin note (outer column): "...[diameter] of the [earth, aleph-he], by so much the more is its body darkened. But if only some part of it enters the shadow, that part will be obscured and the rest will retain its brightness — toward whichever region of the world the moon shall have declined, to the south or to the north. Nor does an eclipse of the moon [☽] ever occur except at mid-month, that is, at the opposition of the luminaries, when the sun and the shadow of the earth are diametrically opposed, and the shadowy pyramid intercepts the very surface of the sun in its surface and circumference of the ecliptic, degree by degree. For just as the sun by its daily motion is moved from one part of the world into another, so the opposite shadow keeps its [matching] motion. But that the moon [☽] is not eclipsed every month, this is caused by its latitude from the ecliptic. For..."]

This is the matter of the factors that cause the eclipses of the moon. There is no eclipse of [the moon] except at the midpoint of the [lunar] month [i.e. mid-month], when the new moon [הוא? / "it"] stands opposite [the place] that the sun faces [opposition], and the cone [המוגבל / "that which is bounded"] of shadow [falls upon it]; and this is what we have said. For [the moon] never has light of its own; toward [the height of] the body of the sun, [the moon] receives [its] light, [a] portion [reckoned] in [proportionate] portion [each time] over [the surface]...

the shadow flattens out toward the curve of the sun, and the moon, at the very middle of the sun, encounters no obscurity at all—except that it does not catch the light upon the plane of the ecliptic, but only in some of its [northern] roots, and even when they [the bodies] differ, they [these roots] are with them.

That is the matter as it was created. With what I am about to add, I wish to clarify and explain to us, for the air of the world is bound up with it.

Across the entire surface of the earth—whatever its bulk—a firmament is spread out for the moon, by the calculation of its [the moon's] roots. The light of the sun is scattered upon it above the air; thus the shadow of the earth, which the earth

sends forth, is gathered into a cone toward the curve of the sun, at the point where the light goes out from the roots of the sun.

[Münster's Latin note: For when the shadow, raised from the surface of the earth toward the heaven of the moon, is shaped into a cone, its circumference at the place of the moon's transit is very much contracted and compressed into thinness, so that even one degree of latitude prevents the moon from falling into darkness.]

The sun illuminates the surface of every body in the world—the luminary of the sun. And there is no [light] found except as a cone, the shadow being by itself; and because of this it comes about at the time when most of the scholars who study the science of formation reason concerning the stars.

[Münster's Latin note: Beyond this cone-shaped shadow, however, the whole world is suffused with the light of the sun. Moreover, that shadow rises up from the surface of the earth, and is always more slender, until it touches the inner circumference of the lunar sphere, or—according to others—the concave surface of Mercury; and beyond it the whole world is suffused with light.]

In every star there is a Shabbos—that is, the light found in them is only borrowed from the luminary of the sun. They are turned upon their backs, and they were appointed over the surface of the earth, that there be a path for them. So said the masters of investigation, and clearly.

[Münster's Latin note: The opinion of the wise men, who have examined the natures of created things, is that all the stars, fixed and wandering, have their light borrowed from the sun.]

And clearly: in the stars of my heaven, all of them are created of a single nature; and as they explained, the moon catches the light of the luminary of the sun in such measure that it has [light enough] to be seen, for the rest of the stars catch the light only at the time of the sun's eclipse, just as the luminary of the sun [is eclipsed]. Let no one bring against our reasoning the matter of the moon's eclipse, the cause of the disorder of the moon: it is not a cause for the rest of the stars.

[Münster's Latin note: ...from the sun, and that this clings to the outer surface of them, proving it from the moon itself, with which the rest of the stars share in this nature. Nor does it stand against this that the moon undergoes eclipse but not the rest of the stars, since the moon alone enters the cone of the shadow.]

For the eclipse [of the moon] enters [the body] going down toward the curve of the sun. And by the calculation of the [earth's] roots, the shadow reaches only to

the lunar sphere, by the calculation of the eclipse. As for the rest of the stars—the living one [the moon] does not reach as far as a firmament.

[Münster's Latin note: ...because it is set in the lowest place of the heavens, which the shadow itself touches. But all the rest of the stars are beyond the boundary of the shadow; and even though Mercury, perhaps, could be eclipsed if it could come to the point opposite the sun—which, however, never happens—indeed, all the stars could be eclipsed equally with the moon, since in this property they do not differ from the moon, if the cone of the shadow could reach to them.]

Brightness is found in the firmament, and in the rest of the firmaments which are above it. And every one of the stars which are above it [the cone]—the cone of the eclipse does not pass over them, since they are not within the curve of the shadow.

And were it not for the eclipse, which comes within the curve of the shadow—they would be visible. By the eclipse of the moon, by nature, after the rest [of the stars]; and it would be [eclipsed]. Say of the star: that it is not such as catches the [situation of the] shadow passing over it; the firmament does not catch it, because it is not [within reach].

[Münster's Latin note: Have it therefore as a most firm rule: no star besides the moon alone...]

And it is not able to come down to the curve of the sun, because of the short remote distance; and from there it is not able to come within the cone of the shadow. And it is not...

such as catches it. And were it not so, it would be [a thing] which says of the moon, of the sun, and of the surface [of the earth] the manner in which the constellations would be. It [the moon] enters by the calculation of the shadow, and the shadow catches the moon, since there is none other among the stars that comes within the roots [reach] of the eclipse—only the moon alone.

[Münster's Latin note: ...could be eclipsed, however little they all might change their light from the sun. According to the saying of the wise, the eye does not master heavenly things—that is, it is deceived in its own judgment, and that which seems to it to be heaven, when it gazes at the spheres, is not heaven.]

From here, most of the scholars infer concerning all the stars, that there is light, and they explain concerning them, the luminary of the sun. And they say there is no eye that masters [it], upon the path of the firmament; and what is shown to the

eyes of men is a [seeming] body—that is, the firmament that gazes up at the heavens is not [heaven].

[Münster's Latin note: ...but it is dense air rising from the earth, appearing reddish at morning and evening. The light too of the stars, scattered through the heavenly spheres, shows to the eyes of men a certain likeness in that very dense air.]

For the [seeming] body of the air is a thickness rising up from the earth, and it is seen in the color of redness, at the time of twilight and at the rising of dawn. And the stars [seem to] pass over the surface of the firmaments; and the [seeming] body of the air is misleading. And [one] says: there is no body of the eighth firmament, bright and clear, by another matter.

[Münster's Latin note: It is therefore not the eighth sphere that is capable of any splendor which it might render to us, but it has certain dark parts, and as it were dense and strong specks.]

But there are written in it [the eighth firmament] places of the manner of strong, thick spots, [places] that hold fast; and the light of the sun passes over the firmaments, and in reaching to those spots—they are spread out upon their backs. And they are turned about and illuminated by the light...

[Münster's Latin note: ...into which, when the solar rays are cast and cannot penetrate, they are reflected back, and the received...]

they are the dark spots of the eighth firmament. ☉

[spread out] upon the backs of the bodies of the world; and these are the spots which are upon the eighth firmament, which are not [bright]. And there are written upon the moon dark spots, several reasons more than [those caused by] the eclipse of the moon, since it is the luminary of the moon.

[Münster's Latin note: ...and they reflect back, and render the received light (like an image in a mirror). And these are the stars, both fixed and wandering. That the matter is so, is clearly shown by the eclipse of the moon.]

There are upon the moon several dark spots, more than [those of] the eclipse of the moon, for it is the luminary which catches its light from the luminary of the sun. The shadow obscures it for several reasons, [more] than the eclipse, the light being for it and from the light which is upon it—growing, waxing.

[Münster's Latin note: Indeed, the greater part of the wise subscribe to this opinion, although there are also others who think otherwise. For these note two

evident signs in the moon: that it borrows its light from the sun—namely, eclipse; and secondly, its increase and decrease from one opposition to another…]

And waxing in its kindling [light], by the calculation of the first [half-month], and turning back and diminishing, and turning back by the calculation of the second [half-month]. And there is no light in the rest of the stars [by] any other sign [than] these two signs.

[Münster's Latin note: …which two signs cannot be detected in the other stars. And therefore they leave it in doubt whether the rest of the stars share their light from the sun. For it can be…]

And because of this, I am setting forth the matter, demonstrating, and saying: it may be that there would be in them light borrowed [for them], explaining concerning them what is hidden—[whether the light is] from another, or whether there would be to the moon high places, [whether] their light is borrowed for them from a luminary or [from] elsewhere, or [whether] they possess light of themselves.

[Münster's Latin note: …that it has it from elsewhere, or that it was con-created with them, and they possess it of themselves. Certainly we have compared…]

And I am comparing them to the great luminary—that is, the sun—from which I have set them out for you in the explanation.

the lesser luminary; and we have no warrant to assert anything else, nor to side with one of the two views on this question. For all this is a matter of seeing what is plausible and forceful, since we cannot actually arrive at it. We are unable to make known what lies between them [the two opinions], nor to settle the dispute, on the grounds of the first principles of the work of Creation [מעשה בראשית].

[Münster's Latin note: We liken them to the greater luminary, because it shines of itself — notwithstanding that they compare them to the lesser luminary. Even so, we cannot here determine anything with certainty, nor confirm this opinion or that by any compelling argument.]

And [Scripture] said: "For He set the greater luminary to rule by day [over a separate domain], and the lesser luminary He set, together with the stars, to rule by night" [cf. Bereishis 1:16–18]. As it is written: "to rule the day, and to see the moon and the stars set to rule by night." From this we have a basis [to maintain] that the stars are under the rule of the moon — for they are of one nature with it, and there is no basis for us to liken them to the light of the sun, which is by itself; rather they take their light from it, as it rises in the moon. The light in all the stars

is acquired by them — there is no light found in them of itself, except for the explanation of the sun's heat by reason of its great heat.

[Münster's Latin note: He gave the greater luminary power over the day, and to the lesser luminary and the stars He gave power over the night. Therefore the stars are not to be severed from the nature of the moon. But let us leave this opinion aside, since it contributes nothing to our purpose.]

The ancient sages [החכמים הקדמונים].

And this view, with which we have furnished you, falls under the reasoning we have given — the matter is not [a settled point] of the present treatise [החבור]; rather it is praise that I [include] in [our] account of the matter, as in the praises that come within [the discussion]. And I, who am dwelling upon the matter at issue — let what is needful in it suffice. [*]

Petach [Opening] [פתח] — 2 — צ

פְּתַח י"ז — Petach 17

Concerning the eclipse of the moon [לִקּוּת הַלְּבָנָה].

Now understand from every viewpoint the matters by which we will explain to you the eclipse of the moon. The eclipse [of the moon], in its darkening, comes about entirely on account of the luminary above it, which becomes darkened over it [because] of the sun. It [the moon] is darkened from [the side of] the sun: it is cut off from its [light] and becomes separated from it [by] the shadow.

[Münster's Latin note: It is explained in this chapter how a lunar eclipse comes about. As often, he says, as the earth is interposed diametrically between the sun and the moon, the moon falls into the shadow of the earth, and is deprived of the light granted to it by the sun. For when the moon has no latitude from the ecliptic, and at the time of opposition both luminaries are found under the ecliptic — the ecliptic being one and the same and having the same center with the earth — it is necessary that the earth's shadow be carried directly toward the ecliptic, and seize and deprive the moon of its light.]

It is the shadow of the earth, which comes about as written, and the earth is found to be a thing that interposes [itself] directly between [the sun and the moon]. So, when the sun and the moon meet [in opposition], and the earth is in the middle between them — [it stands] over them [*]. And the bulk [רוֹחַב] of the earth, which is its breadth, [stands] in the path of the [zodiacal] constellations [המזלות], around which the sun revolves and over which the earth [casts its

shadow] [✻]. It is on the path of the constellations, and stands forever upon the breadth of the [moon's] latitude [✻].

It [the moon] is one-seventh of a part [of] the seventh [zodiacal] sign from the [moon's place] [?]. And in a part, there would be a statement of the moon at [the point] opposite every sign — and these [✻]. The moon comes about on the surface of the [path of the] constellations [המזלות], on its passage [the sun]; the sun's [position] is the third [✻]. The moon comes at the midpoint of every [new-]moon, since it goes along on a path [that] divides [✻] the path of the constellations inclined from it, to the north and to the south, by reason of the sun's matters [?].

[Münster's Latin note: But because the moon is not always found under the ecliptic, but revolves in a circle which intersects the ecliptic in opposite places [the nodes], for this reason in a whole month it is not [found there] except at two [points] of opposition…]

it is, and it deviates from the eclipse by reason of the nearness of the deafness [?: חרשי] [✻]. There remains its whole time, in which it begins as that node [?: חרש]. It is distant [removed] from the [path of the] constellations toward the head [the corner]; and there it is — the north and the south are touched [✻] at the time it is in the shadow of the earth, and if it [the moon] begins at the half of the deafness [?] [✻] of the encircling [region], in [the place] that the node turns over them. It is at the head of the dragon [רֹאשׁ הַתְּלִי] or the node [✻].

We have it that they are near to one of them, [where] the eclipse of the moon begins, at the time it is standing in the strength of the eclipse, by reason that it is going on the surface, on the path of the [zodiacal] constellations or near, in [some] distant matter [?], by the surface of those [✻] distant [points], which is [the point] at which it begins to touch it, falling into the shadow of the earth and casting back into the shadow of the earth, as written. So the shadow [falls] with them at its endpoint, and it is found [✻].

Its length is [that of] its rising [shadow] over the surface of the earth; up to the cone [point] of its emptying [✻], as written in the [region] of the dragon [?: בגון]. So it cut a cord [חבל], in the cord [חבל] of half of the corner [קוֹטֶר] of the earth, and [the cord] tied [bound] the wagon [עֲגָלָה] of the shadow [צל] in the [places] mentioned [✻]. Upon the firmament [רְקִיעַ] of the moon, in the corner [bond] of the wagon, encircling the land [of] the body of the moon — two times, and three [of] the fifth, [each] one time [✻]. And the corner [diameter, קוֹטֶר] of the moon is found, that it is [✻] standing at its height [גֹּבַהּ], by [whose] forms it is [in] another manner [מֵאוֹפֶן אַחֵר].

[Münster's Latin note: …vices [the two oppositions], and the total of two hours is found under the ecliptic itself; lunar eclipses do not occur at every opposition, but the greater number of them is free from this loss. For on account of the slight inclination from the ecliptic, the circle of the shadow escapes, so that it does not fall into it. But if it draws nearer to the ecliptic, at the time of opposition it is plunged either wholly or in some part of itself into darkness. As for the length of the shadow, from the surface of the earth to its cone [point], the ancients write that it is the semi-diameter of the earth, which is 859 German miles, multiplied sixty-eight times, [which] equals that length. But when he speaks of the diameter of the shadow and the diameter of the moon as having this proportion between themselves, that the diameter of the shadow contains…]

[Chapter-numeral marks at foot: צ, 3]

Diagram. A schematic of a lunar eclipse with the moon at the mean distance (mean longitude) of its epicycle. A long, gently curved arc (the inclined orbital path / ecliptic line) runs across the figure from lower-left to right. Two circles straddle this arc: a smaller circle on the left and a much larger circle on its right. Along the arc, short tick-marks are drawn — a few within the smaller circle and a denser series across the larger circle — marking off the units (digits) of obscuration as the moon traverses the earth's shadow. The smaller circle represents the moon; the larger circle represents the earth's shadow-cone cross-section.

- **Magnitudo umbræ** [Latin, Hebrew heading above: צוּרַת הָאָרֶץ — here functioning as the running head; the Latin label means "magnitude of the shadow"]: caption over the large circle (the shadow).
- **Corpus lunæ** [Latin, "the body of the moon"]: label at the small left circle (the moon).
- **Figura eclipsis lunaris pro longitudine media epicycli** [Latin, "figure of a lunar eclipse for the mean longitude of the epicycle"]: caption at upper right.

[Diagram caption, Hebrew, above the figure: צוּרַת הָאָרֶץ — "The Form of the Earth" / running head.**]**

In thirty parts [שְׁלֹשִׁים שָׁבְרֵי מַעֲלָה — thirtieths of a degree], by the sixth [reckoning], in calculation [מֵחֶשְׁבּוֹן], one places there a degree at the cutting-off, by its manner; and it would be the corner [קוֹטֶר] in this [✻] on the round [orbit], by the [✻] degree of seventy [70] degree-parts, [the] degree being seventy and seven [77] parts of a degree, in a [certain] manner. The orbit of the moon, and the

half [✻] is called the corner [קוֹטֶר] of the shadow, and the corner of the moon is found, as it stands, at the lowness of its height and in its [near] approach from the earth, that it has degrees above it, and to it [are] two parts. And the corner [diameter] of the shadow, in the saying, would be [the] this [✻] — thirty-two [32] parts. And it is found by what comes about, every time that the breadth of the moon mounts upon a degree, one [degree], and one [more], that there are no parts in the eclipse touching [✻]. In it [is the reason] that, since its breadth [the shadow's] is broad, it then ranges to the half [of] the corner of the shadow with the half [of] the corner of the moon, [by] which, [at] the lowness of the heights — if the breadth of the shadow comes about [✻] [over] the breadth of the moon…

[Münster's Latin note: …the diameter of the moon twice, and once three-fifths [2⅗ × the moon's diameter]. Our [authorities], at the place of the passage of the epicycle, put the diameter of the moon at nearly 32 minutes, and the diameter of the shadow at 83 minutes, 10 seconds. But at the apogee [augis] of the epicycle the diameter of the lunar body is 29 minutes. Our Jew [Iudæus noster, i.e. Avraham bar Ḥiyya] puts it at 30, less a sixth part [30 − ⅙]. And at that place the diameter of the shadow is 77 minutes and 24 seconds. You have in the adjoining figure the proportion of the circle of the shadow and the circumference…]

Sefer Tzurat ha-Aretz — Fourth Gate, Petach 17 (continued) and Petach 18

[Petach 17, continued — magnitude and "digits" of a lunar eclipse]

[fol. 143]

the moon, in proportion to the lunar body, when it falls within the [shadow], in "digits" (חרגם, eclipse-digits) [?] — or in one part out of twelve [a single digit] in the height of the diaphanous [body] (חרום) [?] — such that with half the [diameter of the] shadow and half the diameter [קוטר] of the moon together the diaphanous height [is found?]. The figure thereby traces out the round disk of the shadow [עגלת הצל]; and you find it [?] by combining its length with itself [?]; and its shadow likewise traces out [?] within that node [חרש].

[Münster's Latin note: …the diameter of the lunar body; and the symmetry of the two diameters — namely when the moon is in the mean longitude of the epicycle, that is, on the circle passing through the center of the epicycle. At the opposite

point, at the apogee of the epicycle, the diameter of each circle is greater, as is set out in the text. From these diameters gather the semidiameter of each and add them together, and you will find the sum of the latitude — namely one degree, four minutes — beyond which the moon cannot touch the circle of the shadow; and that at the point opposite the apogee of the epicycle.]

If the distance [מרחק] is less than half [the sum of] the two diameters [קטרים], it is established that the moon will be eclipsed at that node [ראש].

If the conjunction-opposition (המחקבלה) [recte: הַהַקְבָּלָה, "the opposition"] occurs in the night, the eclipse will be seen in that place — whether from its beginning to its end, or [at least] part of it will be seen from its remainder.

[Münster's Latin note: ...the apogee of the epicycle, beyond 54 minutes of latitude there is no eclipse. But if the latitude of the moon from the ecliptic is less than the two semidiameters joined, it is certain that the body of the moon will be eclipsed.]

And if the distance [מרחק] of the moon is half [the sum] of the diameters at the point opposite the apogee, then half the body of the moon will enter into the shadow, and it will be darkened — but it will have no lingering [in the shadow] at all.

And if the distance is less than half [the sum] of the two semidiameters [חצי הקטרים], it is established for the moon that the whole of it will be darkened; and it will also linger, darkened, in proportion to its motion [מהלך]...

[Münster's Latin note: If the opposition occurs in the night, the eclipse will likewise occur in that place during the night, and it will be visible from beginning to end, or at least a part of it will be visible.]

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[the moon] will pass in its motion through the body of the shadow at the time of its darkening, and the darkening [האפלה] will begin to be revealed in proportion to its body, by however much its body has entered, until its body begins to come out from the disk of the shadow [עגלת הצל]; and the darkening [recedes] toward the western quarter [מפאת מערב].

According to this, the moon's passage and entry [is reckoned], and the [moment of] darkening, beginning when its body begins to come out from the shadow, in proportion to its body that has come out; and it recedes, darkened, toward the western quarter.

[Münster's Latin note: If the latitude of the moon is as great as the semidiameter of the shadow, the center of the lunar body will reach the edge of the shadow, and only half the moon will be obscured, and no more.]

And the second [case], when [the moon] is darkened wholly within [the shadow]: [it occurs] when the whole of its body has entered into the disk of the shadow.

And the third [case]: I have already told you the duration [זמן] of the eclipse [obscuration], which is the time the moon lingers in the shadow in truth [באמתירת, "in its lingering"]; and that is at the moment of the true opposition (המחקבלה האמתית) [recte: הַמַּקְבָּלָה].

And the fourth [phase]: its body begins to come out of the darkening, and the light reappears toward the western quarter [מפאת מערב].

[Münster's Latin note: But if half of the two semidiameters exceeds the latitude of the moon, in proportion to the whole diameter of the moon, the entire body of the moon will be plunged into darkness — but it will not have a delay of total darkness. And if the moon should slip into the shadow beyond its own diameter, the whole of it will be obscured, and it will draw out a delay in the shadow according to the contrary motion; and that delay will be doubled, from the slipping-in to…]

And the fifth [phase]: the time at which the whole darkening from the body [of the moon] is uncovered, and the moon [is fully restored] and the light returns. It is explained generally that everything pertaining to the moon's motion recedes before the face of the obscuration.

This is the rule [מנהג] of the complete obscuration (החלקות המלאה), when [the body of the moon] is wholly darkened.

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If [the moon] is [obscured] without darkening (מאפיל), and there is no lingering in the obscuration — there are no [phases] counted for the obscuration except three times only.

[Münster's Latin note: …the middle point of opposition, and from this point to the beginning of exit from the darkness. You will therefore reckon for this third eclipse five times. The first is when the moon little by little begins to slip into the shadow.]

The first: the time of the beginning of the darkening, [reckoned] for [its becoming] visible, at the node of the moon [גות הלבנה]; and the second is the

middle [point] of their time, which is the [moment of] true opposition (החקבלה האמתית) [recte: הַהַקְבָּלָה].

And the third: when the darkening is uncovered, it is revealed above the node of the moon [גות הלבנה].

[Münster's Latin note: The second, when the whole [moon] has entered. The third, when it has reached the middle point of opposition. The fourth, when it again begins to go out and to recover its light, which happens toward the east — just as the eastern part of the moon first began to be obscured. The fifth time is when the moon comes wholly out of the darkness and has recovered its whole light. This is the rule of a lunar eclipse, which makes a delay in the darkness.]

Now you shall know that there are no obscurations reckoned for the moon's appearing except when [they fall] at six months [חדשים] on the average, or at five months [חדשים] — at the least [span] and the [greatest]: the obscuration [will appear].

[Münster's Latin note: If [the eclipse] is total but without delay — then we reckon for it only three times.]

The months [חדשים] in which the moon, in its course, completes their measure by its motion — and "[full-]measure" they call the months [חדשים]. The moving point and the [other] moving point [i.e. moon and sun] are mutually opposed in these months in which the moon, in its course, [moves]; and the swift [point] in its course runs along; and these are called months. The first obscuration is before the head of the dragon [ראש התלי, the ascending node]; and the second is either after the tail [הזנב] or it will be at the [point of] exchange [exit].

The first [obscuration occurs] before the tail [הזנב], and the second after the tail; and the head [ראש] in general is a matter that [occurs] when there is a distance — namely the latitude [מרחב] of the moon at the two of them [the two nodes] toward the northern quarter [פאת צפון] or toward the southern quarter [פאת דרום]; and the distance [המרחק] between the first and the second is more than half [a distance] of a degree (מעלה)…

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of a degree; and it will not be possible that they [the two obscurations] meet at that obscuration. And the obscuration that recurs for the moon is reckoned at seven months [חדשים] forever; and the strongest [most regular] cases of it [occur] in most of the years: they are six months [חדשים]. And the obscuration is apportioned [נחתך] by two occurrences in [one] year. And it is possible that the

two of them are seen at one place; and it is possible that one [is seen] and the other [is not seen]; and the second is not seen; and it is possible that one is seen [while] the two of them together are not seen, [depending on] the men of that place.

[Münster's Latin note: ...five months, if the moon is slow in its course and the sun is in swift motion. And then the prior eclipse occurs before the head of the dragon, and the latter after the tail — or the reverse. This condition too is necessary: that the latitude in each eclipse be either northern or southern, and that their distance be beyond 180 degrees. In the space of seven months two eclipses can never occur, but it is common that in the sixth month the other comes. This too is firm and regular: that in one year two eclipses occur, and both can be seen in one place.]

פתח י"ח — Petach 18

Petach 18 — The diversity [of aspect] found between the true place of the moon and the place of its appearing above the surface of the earth.

[Münster's Latin note: This chapter treats of the diversity of the aspect of the sun and moon, which is nevertheless observed in a solar eclipse more than in a lunar one. You will note this diversity thus: Let us suppose there are two eyes that in one moment of time look upon the body...]

The diversity [of aspect] (החלות) [recte: הִתְחַלְּפוּת, "the diversity / parallax"] found between the true place of the moon and the place of its appearing above the surface of the earth. This diversity comes about according to the perception [observation]: everyone, according to his position at the start of his looking, [will see] discrepancies (שגות, errors of sight)...

the deviation [of place] of the moon's body — it is not to be reckoned as a deviation relative to the body of the firmament, but is to be called [a deviation] only when we relate the moon's deviation to the fifth firmament, the one between which [the moon] and the earth there is a great distance, [a span] of many [orbs]. [Münster's Latin note: ...the body of the moon, the one [eye] at the center of the earth, the other on the surface of the earth. The rays of those eyes intersect within the body of the moon, especially if the moon is in the east or the west, or even at the meridian in the southern signs.]

There is no possibility that, with respect to the deviation of the earth, [the moon] should have any [perceptible] deviation worth taking into account—save only when the earth's bulk subtends some perceptible distance there. [Münster's Latin

note: But not if it is at the zenith, for then those lines coincide in a single line. Away from the zenith, however, they will intersect within the moon; and when the moon is far below the firmament, those lines must necessarily intercept some arc in the firmament—just as the eyes too issue forth and diverge from one another over a long interval.]

Now if we relate [the matter] to the body of the earth and to the [great] firmaments—and one might think the firmaments [so distant]—and were we to look [for] the ratio that the earth has to those great firmaments, we should find that the body of the earth subtends no [appreciable] distance from them, for it goes out [to no more than] half the diameter [of the smallest of the firmaments]. [Münster's Latin note: By the fifth sphere from the eighth, understand the orb of the sun. The distance of the sun from the earth, when it is at the point opposite its apogee, contains the earth's semidiameter… (continued).]

And the moon: the ratio that it has to the earth, when [the moon] is at its lowest [point], in elevation [above the earth's surface], is to the earth as half the diameter of the great body that lies between them, divided into parts. [Münster's Latin note: …the earth's semidiameter [several] times. The distance of the moon from the earth, when it is at the point opposite its apogee, contains the earth's semidiameter… (continued).]

And those who hold that there is, with respect to the place, a diversity of aspect [parallax]: there is no diversity of aspect to their thinking unless [it amounts to] two or three parts at most. And in the remainder—in any star that is at the apogee—the sun together with all the bodies that revolve—they have no diversity of aspect worth taking into account; for they are revolving in any body that lies beneath the sun, [a body] whose diversity of aspect is not found except at its place; rather, there is no diversity of aspect [perceptible] except in the eastern quarter, and the place [of the body] is reckoned [accordingly]. [Münster's Latin note: …twenty-three times. The distance of the moon from the earth, when it is at the point opposite its apogee, contains the earth's semidiameter thirty-three times. But the length of the [earth's] shadow ascending from the point opposite the sun toward the heavens contains the earth's semidiameter one hundred sixty-eight times. Therefore it far transcends the sphere of the moon.]

Diagram. A schematic of five concentric circles (the planetary/luminary spheres around the earth), divided into four quadrants by a vertical and a horizontal diameter. The outermost ring is the ecliptic; the earth sits at the center. A sun symbol (☉) and a moon symbol (☽) are placed in the upper portion of the figure, with two oblique chords (lines of sight) drawn from the upper region down

through the center toward the lower-left, illustrating the line of vision and the parallactic displacement between the central (true) and surface (apparent) sightlines.

- Outermost ring (top, Latin): **zodiacus** — the ecliptic / belt of the zodiac
- Center (Latin): **Terra** — the earth
- ☉ (upper region, left of top axis): sun symbol
- ☽ (just below the sun): moon symbol
- ח [chet] (top, right of vertical axis): quadrant/point label
- ט [tet] (right of center, upper): point label
- ע [ayin] (right of center, on the upper sightline): point label
- פ [pe] (lower right of center): point label
- ע [ayin] (center, just right of Terra): point label
- ל [lamed] (center, beside the ʿayin near Terra): point label
- ו [vav] (left side, outer): point label
- ל [lamed] (lower left, on the oblique sightline): point label
- ת [tav] (lower left, outermost): point label

At the place of the moon—in the body [of the moon] itself and in every star whatsoever—there is no diversity in the aspect of the sun that we have [in view] when we come to relate it to it; and you will see [that] there is a diversity of aspect [parallax] in this configuration. The firmament of the constellations to which we relate [the star] has [its] place above all the stars [in] the sphere; [Münster's Latin note: The sun, therefore, has an almost imperceptible diversity of aspect, on account of its very great altitude, since only two or three minutes at most can be detected in this diversity.] for the firmament of the sun is the loftiest [in] the manner of the constellations that revolve about the center of the earth.

[The earth itself] revolves; behold, the firmament of the moon also rises, [and] its center revolves [at] thirty-nine parts, and the cycle [that] surrounds the earth [revolves] at its middle—the orb [revolves]. And the centers of all these orbs that we have set down—the center of the earth—[stand] at a [single] point [?]. And we have set down all these orbs at four equal parts, by two lines that pass through the center of the earth, divided into [their] degrees, upon the diameter [?]. And [the two lines] are joined [so that] the air [?] [is] divided, and there comes to be a point at the firmament in the manner [Münster's Latin note: Here he designates the antipodes, who turn their feet against ours.] of the constellations that are reckoned [as belonging] to the eastern quarter—and [a second] point at the western quarter; and [a third] point at the midpoint of the heavens, which is

beneath the earth from [the side of] the sole of the foot of the inhabitants [of the antipodes]; and we have placed [the] place of the sun at seven points, and the place of the moon at thirty points, [each] set in its [own] quarter.

From the center of the earth there goes forth toward [each] line one [line], in the manner of the constellations—and it is line two [?]; in such a way that their bases lie [upon] the line of the meridian [?]. And it goes out from the western [side] of the earth in the manner of the constellations; and it [the line of sight] passes within its [own] form [reaching] toward the inhabitants of the earth—if the bulk of the earth be reckoned of any account. [Münster's Latin note: The diversity of aspect in [a straight] line, on account of its proximity to the earth, is more manifest than in the other aspects.] But if we look for it through the matter [as it affects] the inhabitants [who] dwell upon the earth, [yet] they are not dwelling upon [Münster's Latin note: By the point ʿayin understand the whole convex surface of the earth.] the line of the meridian of the earth, but [rather] are seated upon a line [other] than that which [stands] over against the center; the center, or the [whole] line, resembles the manner of the line [Münster's Latin note: By the light of the eye understand the line of vision.] which is, [for] men, [drawn] toward the place of the star at its firmament. And the line of sight [is] that which passes over [and] reaches the firmament of the constellations; and the line that the light reaches—it touches [the star]—from the side of the manner of the constellations is [identical with] the place of the star to the sight of the inhabitants of the earth.

And if we look for it [in another] manner, [namely] for the place that they pass through, line by line [?]: it is the place [of those] dwelling upon the earth [relative] to the line seven [?]—it is the place of the sun at its firmament; and [if] we cross over the [deficient] arc [?] of life [?] toward the manner of the constellations, the line [?]: in this configuration there will be the sun, and the [proper] reckoning from the center of the earth upon the line two [?] is [as] it appears to the inhabitants…

for those who dwell on the earth, by reason of the earth's roundness. The discrepancy of the apparent place will be at the point where the bow [arc] of the firmament is — and that is similar [?] to the three sextants [?] of the parts [?], according to the words of the moderns.

[Münster's Latin note: The word *ha-merubeh* (המרבה) is taken here for *rabbim* (רבים, "many"), so that the sense is: many hold this opinion, namely that the diversity of aspect [parallax] of the sun (☉) is not beyond three minutes.]

And if we set forth a particular case (something arising) regarding the place of the moon, you will find [the case [?]]; and the dweller [?] will know, by reason of the diversity of aspect [parallax] that arises [?] in this manner [?]: the discrepancy of the apparent place will be at a point where the whole bow [arc] of the dwelling [?] is, and that is according to the words of the moderns — that it [the parallax] reaches at most three [?] parts. It first appears in the apparent place of the moon at its altitude [?] above the earth [?].

[Münster's Latin note: When the moon (☽) is at the apogee, its diversity of aspect [parallax] is at the least 54 minutes. But at the point opposite the apogee, where the moon comes nearer to the earth, that diversity grows up to a whole degree and 44 minutes. Moreover, I hold the apogee and its opposite to be taken according to the epicycle, and not according to the eccentric.]

And it rises [?] over the city [point [?]] one parallax, and we say [?] two things [?]: when it [the city/point] is at its lowest [point], the height is [?].

And there are found two luminaries that, in respect of one matter [?] of the diversity-of-aspect [parallax] reckoning, appear to the inhabitants of the world [?] in two places differing from the [true] place — in which there is no [single] place [?]. There is a difference between them, in that one of them, when it is toward the eastern quarter, rises [climbs] from the earth, appears…

[Münster's Latin note: The reckoning of the luminaries is made with respect to the center of the earth; therefore when they rise in the east, the sight does not judge rightly of their place. The same is to be understood concerning their setting. For in those places a greater diversity of aspect [parallax] is found. But by however much the star approaches the zenith, by so much is the diversity of aspect diminished.]

toward the east; and in the western quarter, when the star rises from the earth or sinks below it. And every [star] that is higher [further] from the earth — its discrepancy diminishes, until the difference [?] becomes so small that the [parallax] passing over [acting upon] the place of the star is at the point of the height of the head [zenith].

And in order to bring the matter (figure) closer to the heart of the learner [reader], I say, as it were, by way of this illustration [?]: take the star at point ☽ [?], or at point (9) ט, in this figure; and the difference [?] will be from the eastern half [?] of the earth toward [?] the matter that the star, passing over a point at a place where the inhabitants dwell — and it goes [proceeds] by way of the

diversity of aspect [parallax] at point (1) א, which is at the half of the heaven; and the parallax will be at point (5) ה [?].

That [point] is at the point of the height of the head [zenith] for the inhabitants of the earth; and there will be two horizons going forth [?] over the surface of the earth and at its corners [extremities] — these reckoned [?]. When they go forth from one point of the [other [?]] direction, there will be no discrepancy of the apparent place at the place of the star with respect to length [longitude]. And there is for you a starting-point, [for] indeed [?] a discrepancy of apparent place in length [longitude] — it is reckoned according to the value [interval] of the distance between the point of the height of the head [zenith] for the inhabitants and the [position of the] star. It begins from the point of the height [zenith] and reaches completion in the manner…

[Münster's Latin note: Two lines drawn from the center of the earth and from the surface of the earth to the zenith become one line.]

[Münster's Latin note: The diversity of aspect [parallax] in longitude is reckoned from…]

the manner that the difference [?] which [is between the head [zenith] [?]], that is to say, the interval that appears between the point of the height of the head [zenith] and the star.

There is, then, a difference [?] of the apparent place in length [longitude], and the difference [?] [you will know it [?] by [?]] the bow [arc] of the apparent place at times when there is no parallax — without [?] inclination — in the manner [respect] of length [longitude] of the diversity of aspect [parallax]; and there is a difference of the apparent place in respect of the place of the star in length [longitude] alone. And it is found [present], and at times there is the bow [arc] which is inclined toward the matter [respect] of the diversity of aspect [parallax] alone.

That [arc] which causes the distance [interval] to multiply [increase] at the place of the star — there will then be the difference [?] in breadth [latitude] alone, and it is not found in length [longitude]. At times there is no bow [arc] inclined upon [in] one [of] the two other [things [?]], the manners [respects], and at that [time] it will be partly the difference [?] in length [longitude] and partly in breadth [latitude].

And I give [an] illustration [example] of these three matters [orders]: as the difference [?] of the apparent place that is found at the place of the moon, when it

goes [moves] in its plain [unmodified] course at the time of the conjunction (☽) of the sun, which we both need in every city [?], for knowing the [parallax-] difference [?] that occurs. And we say: if there be a manner [case] of the diversity of aspect [parallax] passing over [acting upon] a point at the height of the head [zenith], which one is able to find in every…

[Münster's Latin note: The diversity of aspect [parallax] in longitude only is found…]

in every one of the places where there is no diversity [no parallax]; in this manner [respect], the direct [vertical] line reaches to point (24) כ"ד [?] degrees [parts] above; and in [some] places, an account [understanding] of this is to be discerned, for the bow [arc] of the [arc-]traverse upon the points and upon the point of the head [zenith] is inclined [?] in the manner [respect] of the diversity of aspect [parallax] itself.

And there will be a manner [way] by which one may bound [delimit] the diversity of aspect [parallax]: the height of the star above the earth; and at that time there will be a difference of the apparent place found at the place of the moon in length [longitude] alone, and there will be no difference of the apparent place for it in breadth [latitude].

[Münster's Latin note: …is found only in those places which have a pole-elevation of less than 24 degrees — that is, those [places] which are comprehended between the equator and the tropic of Cancer.]

Diagram. A quarter-/semicircle (a horizon quadrant) opening to the lower right, divided into concentric arcs. The flat bounding line at the bottom represents the horizon/earth's surface; the Hebrew label **שמים** ("heaven/sky") stands at the upper-left margin and **ארץ** ("earth") on the line below the figure. Within the field, sightlines run from a vertex at the base of the figure (the observer) outward. On the left, the **Sol** (sun) sits high on an outer arc; below it sits **luna** (the moon), from which lines marked **vera** ☽ ("the true moon") and **visibil[is]** ☽ ("the visible/apparent moon") descend toward the base. On the right, the figure is mirrored: a second **luna** lower on the arc and a second **Sol** at the far right on the outermost arc. The construction shows how the true and apparent (parallax-shifted) positions of the moon diverge relative to the sun as seen from the earth's surface versus its center.

- שמים (upper-left margin): "heaven / sky"
- ארץ (below figure): "earth"
- Sol (upper-left, outer arc): "sun" (true position, western/rising side)

- luna (left, middle arc): "moon"
- vera ☽ (left, descending line): "true moon" [Latin *vera luna*]
- visibil ☽ (left-center, descending line): "visible / apparent moon" [Latin *visibilis luna*] [?]
- luna (right, middle arc): "moon" (mirror)
- Sol (far right, outer arc): "sun" (mirror)

[Münster's Latin note: From the adjoined figure it is plain how, from the true western [position], the visible conjunction (☽) adds something of time; but in the eastern quarter, the true [moon] (☽) follows after.]

[Earth — ארץ]

If the star is toward the eastern quarter, its apparent place [the place where it is *seen*] will be from [in advance of] its true place; for the reckoning is made with respect to the center of the earth. And if the star is toward the western quarter, it [its apparent place] will be [behind [?]] its place [true place]...

Fourth Gate — *Petach 18* (continued): the apparent place of the moon in the eastern and western quarters

it is added that the visible [conjunction] occurs somewhat ahead of the true conjunction in time.

[Münster's Latin note: "...that it is visible, and the visible [conjunction] is added ahead of the true conjunction by some amount of time." (*tur uisibilem, superadditque uisibilis ☌ aliqd temporis ucræ coniunctioni.*)]

and according to these forms it will occur for them, by [reckoning] the parallax in longitude and not in latitude. When the parallax is in longitude only, the moon's place will be found displaced eastward or westward; and at certain times it will be found in longitude as it is in the days, drawn from [the line of] the bowstring [i.e. the great circle through the zenith] of the arrow [the perpendicular]. When the moon is in the [line] passing over the point of the head [of the dragon, the node] and is at that moment [?] — then the manner that corresponds to the latitude [?] of the star [the moon] over [its true place along] the ecliptic will be as follows.

[Münster's Latin note: "But as for what the Jew writes concerning the diversity of aspect according to latitude only, our scholars explain it thus." (*Cæterum quod Iudæus scribit de diuersitate affectus secundum latitudinem tantũ, nostri id sic explicant.*)]

By itself [the moon] will have its own parallax along the ecliptic. From there [from the node] the parallax in latitude will be drawn, and it [the moon] will be found in longitude only, in the [arc of the] parallax that is drawn off in latitude, toward [?] the place [recte: המרכז — the center] [?] that is inclined [tilted off] in latitude. When the head [the node] is [toward] the north, it [the moon] is inclined; the star [the moon] appears inclined toward the northern quarter from its true place; and if [it is] toward the southern quarter, it appears [there].

[Münster's Latin note: "Should some conjunction occur in the 90th degree from the ascendant, then the visible [conjunction] does not differ in time from the true one, and no diversity of aspect will occur in longitude. For the ninetieth degree of the ecliptic from the ascendant is always on the circle passing through the zenith and the poles of the zodiac. And that circle inclines sometimes from the meridian line toward the eastern region, sometimes toward the western, sometimes it falls upon the meridian line — namely when Aries is in the east and Libra (♎) in the west, or the reverse." (*Si contingat coniunctio aliqua in 90. gradu ab ascendente, tunc uisibilis ☌ nõ differt in tempore à uera, nullaque diuersitas aspectus continget in longitudine. Nam nonagesimus gradus eclipticæ ab ascendẽte, semper est in circulo transeunte per zenith & polos zodiaci. Et circulus ille declinat aliquando à linea meridiana ad plagam orientalem, aliquando ad occidentalem, aliquando cadit in lineam meridianam, quando scilicet aries est in oriente & ♎ in occidente uel…*)]

If the parallax is not drawn along the [great-circle] arc that passes over the place of the star and over the point [recte: נקודת] of the head [the node], but rather along the arc whose issuing [the perpendicular drawn from the zenith] is in the manner of the parallax [drawn] toward…

Petach 18 (continued)

the star, passing over the point of the head [the node] — then the parallax will be at that time, that being the part [the component] in latitude. For some, part of the parallax is reckoned in longitude, [namely] the place of the star eastward and westward; and from its distance, by the distance of the star, by the manner of the [ecliptic]…

the [signs of the] zodiac toward the south and toward the north. According to [the rule of] longitude, the reckoning of the parallax is [as] laid out in the *Book of Reckoning the Calculations* [Sefer Cheshbon ha-Mahalakhot — i.e. the computational treatise].

[Münster's Latin note: "...or the reverse. Where the ecliptic does not fall on the arc passing from the zenith to the star, nor does the star fall on the circle drawn from the pole of the zodiac through the zenith to the opposite pole — in that place the star has a diversity of aspect according to both longitude and latitude." (*uel econtra. Vbi ecliptica non cadit in arcum transeuntem à zenith ad stellã, neque stella cadit in circulum ductum à polo zodiaci per zenith ad polum oppositũ, in eo loco stella habet diuersitatem aspectus secundum longũ & latum.*)]

Petach 19 — On the eclipse of the sun

Explanation of the eclipse of the sun. When the earth lay between the moon and the light of the sun at the time of an eclipse, in its half-cycle [?] the dryness — that is, when the moon comes to be between the earth and the sun at the time of its eclipse, when [the moon] covers the sun — and as the cause [the agent] of the eclipse, the moon, in its being near to it [the sun], [coming] from the point of the head [the node], or [the tail] in its [proper] place [?] — I have made plain that, [coming] from the [signs of the] zodiac, it is the matter that causes the eclipse.

[Münster's Latin note: "The author now explains the cause on account of which a solar eclipse comes to pass. So that it may be more easily understood, he repeats the lunar eclipse and its cause. 'There is involved,' he says, 'in both eclipses something that deprives the luminary of its rays. The moon has a real eclipse, but the sun an apparent one, because it is not despoiled of its own light, but is intercepted from us by the interposed body of the moon.'" (*Explicat nunc autor causam propter quã contingit eclipsis solaris. Quæ ut facilius intelligatur, repetit eclipsim lunarẽ & causam eius. Mediat inquit in utraque eclipsi aliquid, quod adimit luminari radios eius. Luna habet realem eclipsim, sol uero apparentem, quia non spoliatur lumine suo, sed intercipitur nobis ob interpositũ corpus lunare.*)]

The eclipse, by way of the parallax, will be greater [in latitude] for the moon — that is, the moon, by the manner of the zodiac, by appearing to the eye nearer to the head [node] or to the tail [node]...

Diagram. A concentric-circle schematic of a lunar eclipse, captioned לסות הלבנה ("the eclipse of the moon"). At the center sits the earth, drawn as a cluster of small houses/buildings inside the innermost circle, with a horizontal diameter line running across the figure. Three (or four) concentric circles surround the earth. At the top, above the earth, a round disc with a face represents the moon, from which a broad shaded cone of rays/shadow descends toward the earth (the eclipse-cone falling on the earth). At the bottom of the figure, below the earth, a radiant sun-disc with a face and emanating rays is drawn. Several six-pointed

stars (✻) are scattered around the outer circles, marking the fixed stars / zodiac. No interior point-letters are lettered on the figure.

- (top, disc with face): the moon, casting a shaded ray-cone downward toward the earth
- (center, cluster of houses inside innermost circle): the earth (the inhabited world)
- (horizontal line): the diameter / horizon line through the center
- (bottom, radiant disc with face): the sun
- (scattered around outer circles): ✻ ✻ ✻ ✻ ✻ — fixed stars / the zodiac

[Münster's Latin note (lower left of page): "Likewise the eclipse of the moon occurs at the true opposition of the position of the luminaries, whereas the failing of the sun occurs at the apparent, and not the true, conjunction — unless it should occur at the ninetieth degree from the ascendant." (*Item eclipsis lunæ fit secundum uerum oppositum situm luminarium, solis autem deliquium fit iuxta apparentem & non ueram coniunctionem, nisi cõtingeret in nonagesimo gradu ab ascendente.*)]

Body text. These are the matters concerning the eclipse of the moon. The other [matters], concerning the second eclipse [of the sun], resemble them [?]. There is, however, between them one great, distinct difference. For the eclipse of the moon is also found [to lie] in its body — that is, [the moon] passes through the [shadow of the] earth, its light, and casts [literally darkens] its body off [from] all its sides. The moon, on every one of its days, [casts] half of its body in shadow [?]; and [the part] turned [toward us] is lit, and at the time of the eclipse it is the lower half of the lit [face] that is darkened — without a [remaining lit part], so that…

or part of it. And the eclipse-darkening of the moon is found wholly [?] — or [some] riders [the ancients, קדמונים] say [the moon] stands in darkness — and there is no eclipse [proper]. But the light of the sun, at its eclipse, will be bright [partly remaining]; what is conducted by way of its own course is not diminished from anything that is said [of it] [?]. Rather, [the difference] is that [the sun] is not darkened in its own face [body]; only the earth, before the [interposed] body of the moon, covers [it] from view [?], because of the [moon's body] between them. And on account of this difference, [coming] from [this] one [arises] the apparent eclipse [?], and the diversity [?].

The eclipse of the sun [coming] from the place of the star [?] [is] over [?] one edge [side] in [respect to] all the directions in which it appears [?]. There is, in [respect to] the parallax of the apparent place, an effect upon it [?]; and there is no

[parallax effect, where] ... to it; and from there, there are no [?] components [?] reckoned, for the parallax of the apparent place at the moon's eclipse and at the sun's eclipse. We need [to subtract] [?] for the parallax of the apparent place in longitude and in latitude, before [?] the [body] that issues forth eclipsed [the moon's body].

By [reason of] the difference [?] of the apparent place [in the position] of the moon relative to the dwellers of the earth in one place — [as against] another, who differ from those dwellers, in another place — and [accordingly] the eclipse will differ in its form and in its time [its moment] in one place, as against its form and its time in another place. On account of this, it was [proper] for me to expound the parallax of the apparent place; and you will find the eclipse of the sun [explained] in [its place] according to the order of the gates that I have laid out [?].

[Münster's Latin note: "In a solar eclipse the sun retains its nature and its whole essence, since it is not truly deprived of its own light, but only the moon intercepts it from our eyes for a short time. Likewise in the moon there is perpetually one and the same manner of eclipsing, which is seen alike in all places, nor is there any diversity of aspect in that respect; for [the place] neither advances nor impedes it. Therefore we do not concern ourselves with it [the parallax] in the lunar eclipse itself. But in a solar eclipse it is of great moment, since this eclipse may exist in Africa and in no [other region]. Then the solar eclipse retains, in different regions, one figure and another, a greater and a lesser. Likewise it does not happen in the same moment of time, but when it ends for the eastern [peoples] it begins for the western, and the reverse. Nor do we speak..." (*In eclipsi solari sol retinet naturam atque totam essentiam suam, cum nõ uere priuetur lumine suo, sed solum luna intercipit ipsum ab oculis nostris ad modicũ tempus. Item in luna perpetuo est una ratio eclipsandi quæ etiam in omnibus locis uidetur, nec diuersitas aspectus in ea locũ habet: non enim promouet nec impedit eam, ideo nõ curamus eam in ipsa eclipsi lunari. At in eclipsi solari magni est momenti cum hic eclipsis esse possit & in Africa nulla. Deinde eclipsis solis in diuersis regionibus aliã & aliam, maiorem & minorem obtinet figuram. Item non fit in eodem temporis momento, sed cũ desinit orientalibus incipit occidentalibus et econtrà. Nec loquimur...*)]

Diagram. A woodcut occupying the upper portion of the page. A large circle represents the visible hemisphere of the heavens. In its upper right a radiant sun is drawn with long emanating rays and a small face set within the solar disk. A shaded cone of darkness extends downward and to the left from the sun toward a

town set on the lower part of the circle — a cluster of buildings with steeples standing on a hilly shore beside wavy water (the inhabited earth). A horizontal line crosses the circle at its middle, representing the horizon. The shaded beam illustrates the obstruction of the sun's light as seen by the observer below.

- (Beside the sun, upper left): **לקות החמה** [the eclipse of the sun / solar eclipse] — verbatim caption.

[Münster's Latin note (outer column, p. 159): "...we speak here of the diversity of hours, which arises on account of one region and another from longitude, and which always varies. — When the luminaries are at the zenith and ninety degrees distant from the east, and the moon has no latitude, there is no diversity of aspect [parallax], but the visible conjunction and the true conjunction fall upon one point of the sky, and..."]

[Petach 19, continued]

[Main text, p. 159:]

✻ The expositor says: If the moon's position at the moment of its conjunction is seen at the point of the head of the dragon [the ascending node] or of the tail, so that it has no deviation in latitude from either of the two nodes, and if at that moment its position is on the line of the deferent [המפריש] over the point opposite [נקודת נכח] the head — that is, at the place where the two luminaries meet — then at that moment there is no discrepancy at all between the true [conjunction] and the apparent one, neither in longitude nor in latitude. The sun will be eclipsed, and its light will be hidden from those dwelling in the place over which it stands directly overhead [לנכח].

[Münster's Latin note (outer column, p. 160): "...of the sky, and in one moment of time, and the eclipse of the sun will be total. But if the moon should be in that place outside the [nodes ☊ ☋], the sun will indeed be eclipsed, but only partially and not entirely, since the diversity of aspect [parallax] impedes a universal obscuration. The visible and the true conjunction occur, nonetheless, in the same moment of time.

Diversity of aspect [parallax] occurs in a threefold manner. The first is that which is found according to longitude only, namely when the visible conjunction follows or precedes the true one in the west or the east. The second is that which occurs according to latitude alone, and then the visible conjunction does not differ in time from the true one. But the true latitude differs from the visible; and where, according to my calculation, I judge there will be a universal eclipse..."]

[Main text, p. 160:]

directly overhead [לנכח]. But if the moon's position is this — its situation set directly opposite [לנכח] the head of the dragon — then, since the moon is seen at the node with no latitude and the tail is not in the way, there will be a full obscuration of its light, the apparent [conjunction] being free of parallax; and at the conjunction the true and the apparent will coincide.

It has already been made known to you that the apparent obscuration comes about according to three matters, by which it may differ. [First,] it is found in longitude alone, and the situation will be either earlier or later: at the moment of the conjunction the apparent place will be earlier or later in longitude than the true [place]. [Second,] the obscuration may occur according to a difference found in breadth [latitude] alone, and there the apparent obscuration occurs at [the same] moment [as the true]; the true latitude of the moon will differ from the apparent latitude. [Third,] the obscuration may occur according to a difference appearing in both longitude and latitude: the true longitude of the moon will differ from its apparent longitude, and its true latitude from its apparent latitude.

[Münster's Latin note (outer column, p. 161): "...that, it will be partial only. The third [manner], and the more frequent, occurs according to longitude and latitude, that is, where the visible conjunction and the visible latitude differ from the true conjunction and the true latitude.

Likewise, if the true latitude should be in the south and the visible in the north, and neither should exceed the other, you will judge the moon to be on the ecliptic itself, and the sun will be eclipsed wholly [totally]."]

[Münster's Latin note (lower outer column, p. 161): "From the western region the visible conjunction follows the true one."]

[Münster's Latin note (lowest outer column, p. 161): "When the visible latitude is greater than the true latitude, or the reverse, the lesser is to be subtracted from the greater..."]

[Main text, p. 161:]

And when you have grasped the obscuration in the breadth [latitude] of the moon — that the true latitude and the apparent latitude differ, this one being toward one side and the apparent toward the other — examine for these [two latitudes] whether they are equal. If they are equal in their two latitudes, and the two are nullified [cancel], the other [coordinate] being likewise nullified, then the moon

will be seen on the ecliptic itself, lying directly over the eyes of those who dwell in that place, and the sun will be wholly eclipsed [בלה לוקה].

And if it should be that the moon's position is on the line of the deferent over the node, and is set at the head of the dragon, with the moon at the node — then the apparent [conjunction] coincides with the true. But if the discrepancy is found in longitude, the apparent [place] will be westward, later than the true one.

And if there is no discrepancy in latitude in breadth — which is to one side together with the longitude — when [the moon] is to the [other] side, which is at the second [node], there open up a few small discrepancies in longitude, and what remains as the longitude of the apparent [place] appears toward the western side.

And if the true breadth [latitude] and the apparent should be such that the latitudes go out to one side or the other, [reckon] this one against that one, and gather from it [the result]...

[Münster's Latin note (outer column, p. 162): "...from the greater, and the true latitude of the place will come forth. I say 'of the place', not 'of the center'. And if both should occur — where the latitude is at the same time northern — they will be added together and will show you the true [latitude] of your dwelling in the moon's latitude. If the moon's latitude, examined in your region, should be less than the two semidiameters of the sun and the moon conjoined, there will be a total eclipse of the sun, great or small according to the proportion of the visible latitude to the two semidiameters. Furthermore, if the visible latitude and the two semidiameters of the luminaries should be equal, the circumference of the moon will touch the circumference of the sun, and there will be no eclipse."]

[Münster's Latin note (lower outer column, p. 162): "In five lunar months two solar eclipses can occur, two conditions being met, etc. Men[ses]..."]

[Main text, p. 162:]

it [yields] the apparent breadth [latitude]. And if the apparent latitude is such that the difference of the two latitudes is by the number of minutes [the value] of the head [node] from one side or the other for the moon — when the two of them are taken together — measure half of the two parallaxes [שני הקטרים] [?] against the apparent breadth [latitude].

And if it should be that the apparent breadth [latitude], and the difference of the two latitudes, are equal, this one with that, and when the moon's [latitude] at the head [node] is nullified at the apparent [position] — measure half of the two

minutes [the two semidiameters?] [?] against the apparent breadth; and the sun is hidden, lacking nothing [wholly eclipsed].

And as for the eclipse of the sun: it can happen to the moon two times within the interval in which we said it stands in the west [?], and between [the one] time and [the other] there are six [lunar] months [?]; and the moon can have, in their reckoning, five lunar months between them, and the obscuration will occur. The [eclipse?] is reckoned for the moon by its intervals, which are the [intervening] months, and the moon's latitude is seen toward the north side. And if the moon's longitude should be at the side of the north, in the first eclipse, there is no [latitude] in the south for the second eclipse, and it can come about — and it can have, in their reckoning, seven lunar months between them.

short months [i.e. those in which the moon overtakes the sun by a smaller interval], when the sun is moving slowly and the moon is swift in its course. This happens in the climes that are nearer [to the equator], and there it produces [the effect] of the moon overtaking [the sun]. By contrast, those positioned in the fourth of the climes and upward, toward the northern quarter — for them the breadth [of the moon's path] will be as we described, the moon being deflected away from them, [but able] to come, [along] the northern quarter and to the south, to be in a position fit to undergo darkening [eclipse] on two occasions for [observers in different regions].

[Münster's Latin note: A short month — that is, a brief lunation — occurs when the sun moves slowly and the moon is swift in its course; for then the moon can overtake the sun a day or two earlier, especially in the fifth, sixth, and the more distant climes, and where the latitude is northern. For these same reasons two solar eclipses can occur in a single month — one, however, on the near side and the other beyond the equator.]

Upon the sun, two [eclipses] may occur within a single month: in [the case of] one conjunction — as though we said, before the [node of] conjunction — there is one darkening; and in [the case of] the other conjunction, after it, there is another darkening. But these two cannot be found together except where one is not found alongside the other: one is found on one side, for those who dwell on the earth [in one region], while if the other is found, it is found for those who dwell to the north — the second darkening, differing [in position], being found for those who dwell to the south.

After you have come to know that there can be no eclipse of the sun that throws [the world] into darkness, with its light wholly hidden, [the question arises]

which of the inhabitants of the earth [will see it]. Return, then, and begin to understand from this the second figure: how the body of the moon, which will be interposed in its entirety before it [the sun] in darkness, comes to be at the [node of] the head [of the dragon] or at the tail, by reason of there being no latitude [deflection] of the moon at that place. [The matter is illustrated] by the figure of the great wheel [galgal], showing the dwellers of the earth, and by its facing...

[the sun]. And at once the body of the moon is interposed — [the moon] whose [own face] is hidden — and the radius [reckoned] from the shadow that the moon casts is as great as the whole radius of the moon. So [the moon's body] remains in darkness, until all its light passes over the whole [region] of darkness.

The diameter of the sun at its height [apogee] is thirty-one [ל"א] chalakim of a degree and half a chelek [31½′]; and the diameter of the moon at its height is twenty-nine [כ"ט] chalakim of a degree and [?] seconds.

The diameter of the sun at its lowest point [perigee] is thirty-three [ל"ג] chalakim and forty-two [מ"ב] seconds; and the diameter of the moon at its lowest point is thirty-five [ל"ה] chalakim and a third of a chelek.

[Münster's Latin note: ...a universal solar eclipse could persist in darkness — namely as much as the obscuration appears to men. According to our [authorities], the diameter of the sun at apogee has 31 minutes 22 seconds; at the opposite of apogee, 33 minutes 50 seconds. The diameter of the moon at apogee has 29 minutes; at the opposite of apogee, 36 minutes 8 seconds.]

According to what I have established as fitting for the eclipse: this is the explanation of the difference between the two luminaries [in their courses], the explanation of how each of them encompasses [the other], and of their dependence upon their [respective] courses.

The Gate [ha-Sha'ar]

The Gate [ha-Sha'ar] — this [gate], on the discourse of the planets [ha-kokhavim]: concerning [their] latitude [reckoned] from the ecliptic-orb [ofan ha-mazalot], toward north and south.

[Münster's Latin note: All the planets have, at fixed times, a latitude from the ecliptic, either northern or southern — the sun alone excepted, which does not decline from the ecliptic. The fixed stars, by contrast, perpetually retain the latitude once received from God, northern or southern — except those that are about the ecliptic; and to these nothing accrues nor ever departs in latitude on account of our line of sight [parallax], but they constantly retain their own limit.]

For each of the planets, and [each of] the fixed stars, there is [a latitude]; those that are joined in their courses [move] in the manner of [varying] latitude from the ecliptic-orb, at times toward the north and at times toward the south. The sun, however, which always revolves about the surface of the ecliptic-orb and is never deflected from it — there is no latitude in it; and likewise the rest of the stars that are about the ecliptic, [having] only a small latitude. The stars that are joined [to the ecliptic] are deflected, along the surface of the ecliptic-orb, toward north and south; and the limit of the breadth [of latitude] of this orb — [reckoned] outside the breadth [of the orb] — this is the orb that is disclosed, which is called "breadth," in the breadth of the planet. And I shall explain to you the order [of the latitude] in [the case of] the moon.

The order of the moon's course in latitude. [Seder mahalakh ha-levanah be-roḥav.]

I say that the lowest of the orbs — those that are deflected [in latitude] upon the orbit of the earth, in their [proper] order — the moon among them rolls [revolves] upon...

the surface of the ecliptic-orb; and it is called "the ecliptic." And the second [orb], [along] whose surface the ecliptic-orb [moves], is called "deflected," inasmuch as it is differentiated [from the other] in its course in the manner of the moon. And the orb [that is] joined [to it], the portion [moving] together with the orb [that is] elevated from the two orbs — they are deflected from it toward the northern quarter and southward, [in accordance] with the figures of the head of the dragon and the tail.

The wheel [galgal] of the epicycle [haqqafah] is deflected, and there is no latitude in it [other than] toward the north and not toward the south. From there [?] comes the breadth of [the path of] the moon, [its body] being found on the side of the ecliptic-orb [reckoned] from the side of the orb that is deflected outward. And in the wheel of the epicycle there is no defect; and the whole breadth of this orb — this is found at the figure of [its] remoteness, [its] point most remote from each [node]. And at the two points of the head and the tail [the place of greatest declination] is ninety [תשעים] degrees [from them], and the sum...

[Münster's Latin note: The deferent circle of the moon's epicycle declines in opposite parts, by 5 degrees [?] from the ecliptic; and the points of intersection are called the head and the tail of the dragon, distant from each other by 180 degrees. The place of greatest declination is distant from the head and tail [☊ ☋]

by 90 degrees. The plane surface of this circle is incumbent upon the plane surface of the epicycle, perpetually preserving the same latitude with its center.]

The breadth of [the path of the moon] is found in one of the two figures: in [the figure of] greatest remoteness, at the head; and a [further] figure [reckoned] from the side of the breadth, at the height [apogee]. The figure of its remoteness — this is five [חמש] degrees [5°], according to the view of Ptolemy [Batlamyus]; but according to the view of the sages of Ishmael, [it is] four [ד'] degrees and a half [4½°].

[Münster's Latin note: The Saracens, however, and the Arabs whom they call Ishmaelites, posit a slightly smaller latitude. The moon, while it is at the head [node], has no latitude; but from there toward the north…]

A fourth [point]: that the course of the moon, throughout one [period] of its course along the figures — its head and its tail being [the points] where, along the surface of the ecliptic-orb, there is no deflection [latitude] from it. …from it [the ecliptic]. When the moon emerges from that node, it inclines away from the plane of its orb. If it departs from the node of the head, then as it revolves it inclines toward the north; and the farther it moves from the node of the head, the greater its northern latitude grows, until it stands at a distance of 90° from the head. There it attains its greatest latitude, namely 5°. According to Ptolemy and the four colleagues, [a latitude of] up to 4½° is reckoned.

From this latitude downward, the moon begins to draw nearer in its course toward the tail, and its northern latitude diminishes until it reaches the node of the tail. It then comes to rest upon the plane of the ecliptic, drawn back onto the plane it had occupied when it stood at the node of the head. On leaving the node of the tail, it begins to incline away from the ecliptic toward the south, and it is carried in its latitude toward the southern side — the same course it followed in its revolution from the node of the head.

This, then, is the order of the moon's course in latitude, reckoned from the ecliptic.

The order of the latitude of the fixed stars.

The latitude is found, for the six planets, to be such that they have a latitude from the ecliptic, but …

a latitude from the ecliptic that is not arranged upon a single uniform measure. Rather, each one of them inclines and is drawn away in accordance with its own

manner — each differing from the others — for they are not held to one fixed measure in their latitude.

[Münster's Latin note: "The planets, after the two luminaries, do not have one and the same ratio of declination from the ecliptic, but each has its own mode, according to which the diameter of its orb, in its own motion, departs more or less from that ecliptic."]

But the fixed stars — each of them has an orb that revolves upon it, inclined from the orb of the ecliptic. And this is the matter that fixes the bounds of the latitude of the [fixed] star: it [the star] is carried upon the order [of its orb], reckoned according to the ecliptic.

The fixed stars do not behave [in latitude] after the manner [of the planets]; but if you reflect upon the latitude of the fixed stars reckoned from the ecliptic, they have an orb [galgal] and a frame that encompasses them all. Upon every firmament, [there are points] according to Ptolemy and his colleagues — the points found and fixed [upon the firmament] in the courses [of the stars].

The [fixed stars] have their poles, upon which the orbs of the ecliptic [the ecliptic-frame] revolve; and the stars, [moving] upon circles in their brightnesses, stand fixed in all their settings at one constant distance from the orb of the ecliptic.

[Münster's Latin note: "The fixed stars, however, with one perpetual tenor, describe parallels, never varying from the ecliptic on this or that part of the world; for their proper motion, which is assigned to them, is upon the poles of the zodiac. And therefore they cannot at one time be nearer to the ecliptic and at another time more remote. Their motion is called the motion of *renisio* [trepidation], because it strives toward the east. And these things would indeed be true if the motion of trepidation did not stand in the way, which, with respect to the ninth sphere of the zodiac, introduces some variation."]

The latitude in which the fixed star is settled revolves upon a circle other than [that of] the others, by a course other than that of the [outer] circle. It is not arranged the same for them, and it does not stand upon the earth by the measure by which the [outer] circle stands. It is not…

it does not increase and does not diminish, inasmuch as the distance of its circle is not [a fixed amount]. Now if you reflect upon their matter — the company of the men, the surveyors who continually search them out — you find no encompassing measure given to them. Upon every firmament, among all the men of inquiry, and in every conjunction you find [a star's latitude] measured from

the ecliptic — each standing upon a measure other than [the rest]. And it has been collected upon all the divisions in their courses.

For in the [fixed] stars there is no [variable] latitude, by which they would draw nearer or more remote [from the ecliptic]; rather, each one of them stands upon another measure. The orbit retains them upon the plane of the ecliptic; it neither inclines nor departs from the plane, and the southern [part] departs from its place toward the north. It is seen toward the north all the days; and again, when it departs toward the south, it is seen toward the south.

And this is the order of all the fixed stars and the planets, in their latitude from the ecliptic.

Petach [unnumbered]

to explain that which lies between the place of the star according to the ecliptic and the distance of its body to the north and the south, and what arises from this — namely the result of the star upon the ecliptic, in its [course] and in its brightness, at the mid-heaven [the meridian].

Petach 2 (פְּתַח ב')

[Münster's Latin note: "There is explained in this chapter the diversity of the stars which arises from their place, when they are referred in the sphere either to circles passing through the poles of the world, or to circles which are described through the poles of the zodiac. For when the heaven is divided into 12 signs, and their sections are extended from the zodiac toward each pole of the zodiac, a star will be reckoned to that sign in whose section it is found, however much it may be distant from the zodiac. And when we then imagine ourselves drawn by circles likewise from the northern pole of the world to the opposite, the meridional [pole], these circles do not agree with those which are led from the poles of the zodiac, except [for] the meridian which passes through the heads of Cancer and Capricorn. Hence it comes about that beyond the second clime ..."]

[Hebrew text:] I shall explain the difference that lies between the place of the star according to the ecliptic and the portion [ḥelek] reckoned upon the meridian [the half of the heavens], together with its rising and its position. Upon the earth, in the matter of the [star's] latitude reckoned from the ecliptic, there is no [star whose] place upon the meridian is reckoned by means of another star; rather it is reckoned upon the arc [qeshet] of the meridian, at every moment, together with the degree [ḥelek] at which the star stands.

But it [the star] transits with one degree, and another degree; and this is called the degree of transit and division, reckoning the difference. It would be the distance of the star from the ecliptic toward the north and the south, because the arc that drops [from the pole] passes through the degree of the west.

It is the arc that goes out from the pole of one of the orbs of the ecliptic [the ecliptic-poles], and passes over the [point of] contact of the star, until the arc that comes forth passes [back] over the orb of the ecliptic at the star.

The arc that drops [from the pole] sets the bounds for the place of the star, going out from the pole of one of the orbs of the ecliptic. And the arc that grips [the bound] is fixed between the contact-point [גוֹת, "touching/tangent"] of the star and the [pole of the] orb — and this is the latitude of the star.

And in the recovery of…

The investigation of the star itself, by way of the manner in which the signs rise — that is, with which degree of the meridian the body of the star coincides. As regards the body in the position of the signs: the body that crosses the meridian — that is the one under discussion — the star reaches mid-heaven at the degree of the section in which it lies, ahead of the other degree. The body that passes over mid-heaven at the degree of the section in which it lies — that is what is said of it with respect to the sign.

[Münster's Latin note (outer column, p. 171): "…climate toward the north, the stars do not reach the meridian line together with the degree they have on the ecliptic; rather, either they reach it before [that] degree, or a degree before the star occupies that mid-heaven." (Latin: "elima [in climate] versus septentrionem, stellæ non perueniunt cum suo gradu quẽ in ecliptica habent ad lineam meridianam, sed uel ante gradum attingũt eam, uel gradus ante stellã obtinet medium illud cœli.")]

Now if the body lies, in the position of the signs, here toward the north or toward the south, and its place is at the head of the sign Aries or the head of Cancer, then the body that passes over mid-heaven at the degree of the section in which it lies differs [in its behavior]. There are two opposed points — these of the head of [a] sign or the head of Aries — because, when the sign passes from the one degree to the other, these two points, in crossing over, are at the degree where the matter is most extended. When the latitude of the body is northern, it is, in respect of itself, at its most northern; and so for the latitude of the body when [the points] are in their place; and one reckons them by a single arc, [yet] they are not [accounted for] in the variations of the latitude of the body's crossing.

[Münster's Latin note (outer column, p. 171, lower, faint): partly illegible — concerns the latitude (north/south) of stars relative to the ecliptic. [?]]

And if the body lies, in its position, toward the north from the sign, then it is not said [to be]…

at the head of Aries nor at the head of Cancer, but rather it is reckoned at another degree, after the remainder of the signs. And that degree, beneath which Aries falls as far as the end of the sign, and its center is toward the north — that body passes over mid-heaven before the passage of its place.

And if the body lies, in its position, toward the south, then it passes over mid-heaven after the passage of its place. This is because part of its degree, in the direction the sign bears, is the remainder; in the passage over mid-heaven it is at the degree, in the manner of the northern signs, said toward the west; and its elevations [recte: רומו] toward the east.

And if the star is one that has northern latitude, it is reckoned in one of the six signs which are their degrees […] when the arc reaches and touches [the point] — for these signs, in their passage over mid-heaven, when [the star] is in the position of the northern signs, are said [to be] toward the west; and its elevations [recte: רומו] toward the east, and in this there occurs its order [recte: סדרו].

[Münster's Latin note (outer column, p. 172): "First are excepted those stars which are found in the first degree of Capricorn or Cancer [♑♋], however greatly their latitude be extended, whether to the south or to the north. Next, the stars which are found on the ecliptic itself without any latitude — those too are found exempt from the prior rule. For arcs drawn from each pole to such a star meet at its point; therefore the degree of its place is the point of such a star: in the same moment of time they rise, reach mid-heaven, and set together. But if the star is outside the ecliptic and has a northern latitude, the degree corresponding to it on the ecliptic — that is, the one which the arc drawn from the pole of the zodiac through the star to the ecliptic determines […]" (Latin: "Excipiuntur primo illæ stellæ, quæ in primo gradu ♑♋inueniuntur, quantumlibet latitudo earum multum extendatur uel in austrum, uel in boream. Deinde stellæ quæ in ipsa ecliptica absq; ulla latitudine inueniuntur, illæ quoq; a priori regula immunes inueniuntur. Nam arcus ab utroq; polo ad stellam talem educti, conueniunt in eius puncto, ergo gradus loci eius punctus eiusmodi stellæ in eodem temporis momento oriũtur, perueniunt ad mediũ cœli, occidũtq; simul. Sin stella fuerit extra eclipticam habueritq; latitudinem septentrionalem, gradus ei in ecliptica

respondes, hoc est, quem arcus a polo zodiaci per stellam ad ecliticam ductus, determi[nat]...")]

the passage from its place — its variation, which differs among the first six signs. For the most part it is the [body's] center, which lies between west and east, that [governs] as the star passes over mid-heaven; and there is no [such variation] in the positions of the signs, sign by sign. [...] one finds it in the stars near the head of Aries or the head of Libra.

The onset of the stars' passage over mid-heaven follows the order of the system in every reckoning of the reversal, and it is conducted by their rising and their setting, above those who dwell at the equator.

There belongs to the upper bodies, over the earth, their setting from above, among the remainder of their places [...] the variations of the signs [one finds for them in the rising of] another [?] when in the [other] position [...] its elevations are conducted to their passage in the places of the two, and this for you is its order [recte: סדרו].

All the distant places, above the equator, are more — by more than 22 [מכ"ב] parts [chalakim] toward the north; and they, from the remainder of [...] [?], in the north, [give] the order of the signs, [there being] a leading course in it, one degree after another. For in the presence of [...] that the degree of the position of the signs dominates, it is reckoned [...]

[Münster's Latin note (outer column, p. 173): "...it determines [the corresponding degree], such that [the star] does not come to the meridian line together with [that degree], but either precedes or follows it, according as it is in these six signs [♑♒♓♈♉♊— Capricorn, Aquarius, Pisces, Aries, Taurus, Gemini] or in the opposite signs — which can be seen by eye on the material sphere or even on the astrolabe. For when the head of Capricorn [□] is on the meridian line, at the same time the northern pole of the zodiac is on that line. And when the head [of Capricorn] is carried thence to the west, at the same time that pole moves to the west, and the arcs drawn from it to the degrees of the ecliptic all cross the meridian line; and therefore stars placed outside the ecliptic in them come to the meridian line more quickly than the corresponding degree on the ecliptic, and this holds throughout all the said six signs ♑♒♓♈♉♊etc. Moreover..." (Latin: "... terminat, ille non simul cũ stella uenit ad lineam meridianã, sed uel præcedit uel sequitur, secundũ quod fuerit in his sex signis ♑♒♓♈♉♊aut in signis oppositis, id qđ in sphæra materiali uel etiam in astrolabio ad oculũ uideri potest. Cum enim caput □ in linea meridiana est, simul polus zodiaci septentrionalis est in ea

linea. Et cum caput inde ad occidentem fertur, simul polus ille mouetur ad occidentem, & arcus ab eo tracti ad gradus ecliticæ omnes transcũt lineam meridianam, atq; ideo stellæ in eis extra eclipticam constitutæ citius ueniunt ad lineam meridianam quàm respondens gradus in ecliptica, idq; per omnia memorata sex signa ♑♒♓♈♉♊&c. Porrò…")]

It is said, concerning the earth, that its variation [occurs] in all those of their places which are not in it; for the variation [is] over the earth. And from where [whence] their findings — [the places where one finds] all the stars that incline toward the north — in the manner of the sign rising over the earth, in front of their elevations [recte: רומו] […] in the manner of the signs that remain in their places; and they set above [over] another […] that they set, and there is […] from before this time, over the earth, together with [their] rising beneath it; and there is no return upon them — the order to the last — but the single one of them rises over the south and over the equator…

The passage of the body, one finds, [occurs] at the stars rising in the sign Aries; and one finds it at the setting of the stars in the sign Libra, equally, together with the retrogression, among the stars [that set] in the sign Aries and the sign Cancer.

And this is the order of the variation in the rising of the stars from the position of the sign, and in their setting, in all the places — the inclining stars — from the place [that is] equal, [by] more, by more than 22 [מכ"ר — recte 22 "מכ"ב,] degrees, and as far as the end of the meridian [western point; recte: המערב] in the north, and in the rest of the places which are at the place of the meridian…

[Münster's Latin note (outer column, p. 174): "Moreover, this diversity of the place of the star and its degree on the ecliptic is found greatest around the beginning of Aries and of Libra, when they approach mid-heaven. Those which thereafter are subjoined…" (Latin: "Porrò diuersitas ista loci stellæ & gradus eius in ecliptica, maxima inuenitur circa initium arietis & libræ, quum ad medium cœli appropinquant. Quæ deinde subneduntur…")]

— continuation of the Fifth Gate, *Petaḥ 2* (the meridian-crossing of stars lying off the ecliptic) —

These are the principles governing the rising of the stars in the east and the place at which they cross the meridian. They fall into two categories, according to whether the constellations that are northern in latitude precede the corresponding degree of the ecliptic in their rising over the horizon — and such a star rises ahead of [the point], it being the first to come up. Thus in the matter of

the rising of the constellations, the northern one rises ahead of the others in its rising over the horizon, while the southern one rises after them in its setting.

[Münster's Latin note: They are treated regarding the rising of the stars in the east and their setting in the west — how, outside the second clime in the east, those that have northern latitude anticipate the corresponding degree in the zodiac; but in the west, after the degree has sunk below the horizon, they still linger a while above the earth, and that delay sometimes exceeds the anticipation in the east. All this can be seen far more easily on a [celestial] sphere than expressed in many words.]

As for the time of their rising upon the horizon: it differs from the time of their setting below it, and the reason for this lies in all these positions. Every position at which the constellations rise over the horizon is recounted above, for upon the earth all the off-ecliptic stars [reckoned] from their meridian, both the rising ones and the setting ones, [follow this rule]: at the moment they rise over the horizon, the [star] that is northern [in latitude] is ahead of its [corresponding] degree from its meridian in rising, while the setting ones, on the opposite side, rise after its degree from their meridian, [setting] before their setting.

But the time of their rising over the horizon is not the same as the time of their setting in the north; and the matter is reversed for those that are southern. And whenever the off-ecliptic star is northern and hidden [recte: נסתר] [below the horizon] —

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— its rising, which I have set apart, distinguishes the manner in which the constellations rise. At the moment the off-ecliptic star sets, then in the position of the constellations it will rise, and at its place, by the position of the constellations, it sets ahead of [the corresponding] degree. It rises over the horizon ahead of [the corresponding] degree from its meridian, or it sets according to its meridian; this is the order [governing] the stars that lie off-ecliptic, those that have a difference of longitude from the ecliptic and whose meridian-position differs in all the meridian-positions.

It returns toward the northern quarter, and once more it is able to be set [reckoned] in [terms of] the meridian-positions. It returns toward the southern quarter — if you now give [attention] to the differences of the south, for the matters in question are found at the positions where they cross the meridian and at their crossing-points, in the northern quarter as [they are] in the [southern]; therefore [consider] this.

at the meridian-positions [of the] greater [stars].

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חמ׳ [?] — Gate הַשַּׁעַר — On How the Stars Are Hidden Beneath the Sun's Rays

[The Gate:] On how the stars are hidden beneath the light of the sun — that they are not seen — and how they come, within their own light, to be seen beneath their light.

[Münster's Latin note: Here the Jew treats of the rising and setting of the stars beneath the rays of the sun. By day, he says, the stars are just as much present in the firmament as at night, except that the greater light of the sun obscures them more — as a solar eclipse attests. For then, suddenly and in a moment, the stars appear in the sky. Likewise, when erratic stars [planets] — or also other stars near the zodiac — approach the sun, and the sun sinks beneath the horizon, those [stars] remain obscured on account of the strength of the remaining rays in the hemisphere.]

You should know that it is evident to anyone discerning that the fixed stars are present above the firmament by day just as [they are] at night; but the light of the sun overwhelms them, so that it conceals them and they are not visible to human beings — yet they are there. And nakedness from the sun occurs at the time of its eclipse: when the path of the moon stands concealed [over against] those who dwell on the earth, at once those who dwell beneath the firmament of the heavens see the off-ecliptic stars. The reason is that, by reason of the sun's path, its strength and longitude prevail, and every star is found to be more luminous when they are near. The portion [reckoned] from their meridian, by reason of the constellations, is [thus] obscured in the eyes of human beings. But if the sun turns beneath the earth, by reason of its strength the remaining stars [stay] within the manner that distinguishes [them], and they are hidden beneath the light, since they are bound up with the strength [of its rays]. As they pass it by and grow distant from it by [a certain amount] [recte: ממנו] of degrees [recte: from the point / נקודת] of the [signs] of the ecliptic — those whose orbits are near it at the time of their concealment — so it comes about that at that very time they go forth [and become visible].

they emerge from beneath [the sun] and become visible to mankind.

Now I will explain the order of the heliacal concealment and its emergence, as well as the order of the visibility of the upper planets — namely Saturn, Jupiter, and Mars.

[Münster's Latin note: The superior planets, since they have a slower motion than the sun, the sun overtakes them by its own motion, and when it has come within the space of one sign of them, or less, they are no longer visible in the west, the sun being submerged beneath the horizon; and they are then called *vespertini* (evening stars). And when the sun has passed them and withdrawn from them by the space of one sign or more, they begin little by little to be seen in the east before sunrise, and they are then called *matutini* (morning stars).]

I say of these planets — that is, of their motion — that whenever one of them is ahead of the sun in its course and the sun draws near to it in its own course and approaches close to it, yet they have not actually met, at that time the planet is ahead of the sun toward the east of the [zodiacal] sign by some interval. And when the sun comes upon the planet, it is no longer visible: it makes no visible appearance in the west behind [the planet], since the sun has come up to it and concealed it. These planets are then called "the hidden ones" during the time they are concealed by being beneath [the sun's rays]; they continue their course hidden, in the west, setting, going their course until they grow obscured. The sun goes its course and withdraws from them degree by degree, until they begin to be seen: they emerge from beneath [the sun] toward the east at sunrise and are again visible, and are called [by their name] at the time they appear in the east — by reason of the time they stand over the earth and go their course — the name indicating that they stand over the whole earth all night long.

and they [the upper planets] are set beneath the sun in the west; at dawn they grow obscured in the west, and at dawn they have their morning rising — and then [there is] *nogah* (the morning appearance) and *kokhav* (the planet's reappearance).

The Order of the Moon [סֵדֶר לְבָנָה]

There is no order [of concealment] for the moon like that of the sun in the matter of [its] *nogah* (morning appearance) and *kokhav* (planet's reappearance), since [the moon] differs from it in moving along the course of the sun.

[Münster's Latin note: The moon is hidden by the rays of the sun in the east a little before the conjunction (☌), and at the conjunction itself. And afterward, going out from the rays of the sun, it begins to appear in the west; thus it has its

rising in the east and its setting in the west, not otherwise than [in the manner of] Saturn, Jupiter, and Mars.]

What touches upon the order [of concealment] of [the moon] is this: its concealment comes about by its being beneath the light of the sun toward its east — that is, the sun is ahead of the moon, and the moon draws near to the sun toward the east of the sun; and afterward [the moon] emerges from beneath the light of the sun and is seen in the western quarter. Its rising is found to be in the east and its setting in the west, in the same order [as] *tzedek* (Jupiter) and *ma'adim* (Mars) — there is no difference in their explanation.

The order of these planets — when they emerge [from concealment], and there is for them *nogah* (morning appearance) and *kokhav* (reappearance) — is not, however, in the manner of these other bodies; for the sun has two distinct relations to them, and each of them is found, at dawn, to be in [the condition of] its rising and its setting. At dawn, by reason of the course of the rising…

[Münster's Latin note: Venus is at one and the same time also called *vesperascens* (becoming an evening star).]

to the sun, at [its] apogee, high upon its sphere; and it returns. When it draws near to the sun, the [planet] is called *maʿariv* (evening setter), for it sets in the west by reason of the time it is seen in the east. It goes its course, growing diminished as it reaches toward the cusp [point] that lies upon the second sphere — the sphere of its orbit — and it has a rising. Upon the division of [the orbit] from the sphere, it draws near, [coming] from the heat of the sun, until it grows hidden, the sun coming to conceal it; [the planet] goes its course hidden beneath [the sun's rays] and is called by its name at the time it is in the west, having set in the east; and it is concealed beneath the light of the sun until [the sun] overtakes it — for it has emerged from beneath [the sun's] light — and is called by its name [coming] from the east, setting in the west at its beginning.

[Münster's Latin note: *Matutinans* (morning star) — [so called] because it precedes the sun when it moves from the apogee (auge) of the epicycle. *Vesperascens* (evening star) — [so called] because, after the setting of the sun, it appears above the earth. The same is to be understood when it is seen in the morning.]

Petach 21 [פְּתַח כ"א]

On the matter of the concealment and the [duration of the] standing of the moon beneath the light of the sun before the conjunction [המולד = the molad]:

The concealment customarily covers the day of the 28th of the month, for the most part; or [it covers] the 29th day — and that is when it covers the 29th day, which is the start of the night of the 30th; or it covers the 30th day — and that is when it covers the 30th day, which is the start of the night of the 31st. [The moon] is not cut off from [becoming visible]…

[Münster's Latin note: The mean conjunction of the luminaries occurs every 29 days, 12 hours, and 44 minutes; but an equation, by reason of the sun and of the epicycle of the moon, is to be added or subtracted.]

from becoming visible to the eyes of mankind in the west — [some] later, [some] earlier. These [variations] add [time] upon them, and they do not follow a [fixed] proportion; but the [moon] is concealed from the eyes of mankind only [for an interval] until its emergence from beneath the light [of the sun], by some proportion — [some] later, some earlier — the value varying, and these variations are many.

Some of [these variations arise] from the course of the moon and the difference of its distance, owing to the distance [המרחק = the distance] of the apogee from the [zodiacal] sign — whether toward the north or toward the south among the constellations; and some of them [arise] by reason of the constellations in which [the moon] stands in its course, and the standing [of the apogee] in its height, by [the difference of] the distance of the constellations and the zodiacal signs which it stands in — among them the forms of the [zodiacal] signs and the constellations, which stand in the figures of the *maʿalot* (degrees) within them; by reason of [their being] in the equator [hamishor], in the sign Aries (טלה) and ragim (ורגים); the constellations [vary] in their tilt, and the length of [their] days, standing beneath the light of the sun before the conjunction [המולד] in some arrangement until its visible appearance in the west after the conjunction. It is sometimes seen [as early as] the fourth day from the time of its concealment, and sometimes the [moon] is found in [a configuration of] the days, standing in the north.

[Münster's Latin note: …[to be] subtracted, [the lunation] sometimes grows to 14 hours, which, added to the mean conjunction, prolongs the lunation into the thirtieth day; but subtracted from the mean conjunction, it draws the lunation back to the end of the 28th day. Hence it happens that the moon sometimes hides itself somewhat earlier, sometimes later, beneath the rays of the sun. There concur also certain other causes which render the moon visible to us up to nearly the last day preceding the conjunction — [the causes] which are enumerated in order in the text. It happens also sometimes that the moon remains four days

beneath the rays of the sun and withdraws its aspect from us; that is, [at] the end preceding the conjunction it is beneath the rays, and [likewise at] the beginning following [the conjunction]. The signs [during which this happens] are the shorter ones, those with which on the equator…]

And if the moon should be at [the point of] its swift motion in its course… [text continues]

rise with fewer than 30 degrees of the equator; and the longer ones, with whose rising more than 30 degrees ascend, [are governed accordingly]. [Münster's Latin note: "…rise with fewer than 30 degrees [of the equator]; the longer ones, with whose ascension more than 30 degrees ascend."]

[The sign rising] in the eastern quadrant toward the north, and the [signs] equal to it in length of ascension by way of the equator, in the manner [described] — when [the moon] is, as it were, twins [paired symmetrically], and bow and rainbow it will be matched. Beneath the orb of the sun, [its] days are few; for it draws near to the visible boundary in the eastern quadrant. By contrast, before the conjunction the moon is seen at evening, after the conjunction, and there is nothing between them—

—except in the proportion of the short or the long [day], depending on the diminution or excess of the time. The mean [value] that one can establish between the two mixed [extremes] is a short span of time; and the sum of all these times that the ancients computed by the course of the moon from its beginning was something the ancients of the earth had not [reckoned], and the calculators did not arrive at it with regard to the [moon's] mean course.

And because this was so—that the foundational and the subtractive [factors] began to differ in the places upon which the ancients of the earth relied in their reckoning, and the differing positions where the sun is found with them—

—the time of the short [day] and the long [day] differs, and it is eighteen straight [equal] hours before the conjunction and after it, in the manner in which the difference lies behind [it], according to our masters of blessed memory. And it shall be the mean that is suited to determining the mean course of the sun, which is neither at its beginning nor at its [extreme]: twelve [?] portions, [the difference] being between the two [extreme] luminaries at the time of their appearance in [their] ascent. [Münster's Latin note: "…under the solar rays, the ancients fixed 18 equal hours before and after the conjunction ☌. For that fixed [interval] squares with our purpose, when the moon is near the mean motion—that is, when the true motion and the mean motion coincide in the same place of the heavens.

Those 18 hours produce about 10 degrees of the equator in the shorter ascension, 15 in the slower, and 12 in the mean ascension."]

The sign whose ascent is [reckoned] by tens of degrees, in the manner of the equator, for a little [more] in the length of the short time—

—is up to 15 degrees, at most, in the long [ascension]; whereas the mean [recte: המרכז, "center/mean"] on which they rely in most places is 12 degrees.

And this is the order of the concealment of the moon.

הַשַּׁעַר ט' — The Ninth Gate: On the Measurement of the Earth, the Proportion of Its Mass, and the Proportion [of the Stars to It]

On all the stars [reckoned] by their comparison with [the earth's] mass.

[Münster's Latin note: "Here it deals with the measurement of the earth and the proportion of its mass, and with the proportion of all the stars when they are compared to the earth. First, he says that the earth is set in the middle of the world, and that the heaven revolves around the earth."]

For it has already been established that the earth is, as it were, the center of the eighth firmament that revolves around the earth—[the earth being] like a [central] point within a circle, with the firmament revolving about it.

And if a person were to walk along the line passing through the midpoint of the earth, in the direction of the north pole, drawing nearer toward the south, he would [find that] the breadth of the earth toward the north—[a course] neither in [its] midpoint, nor to the east nor to the west—[is the place] where one finds the northerly point [the pole] rising upon the earth, in whatever measure he is rising toward [the pole] from his standing-place. [Münster's Latin note: "Hence, if anyone should set out to walk in a straight line from pole to pole, he can press on into the north as far as the pole rises above the earth, as much as he wishes. He can also turn back from there toward the south, so that that pole ever increases from its altitude—provided he does not deflect to east or west, but follows straight the meridian line that girdles the earth."]

[?] whether he is walking from the north toward the south, or whether he is not rising; the earth [is reckoned] from his standing-place from the west and the east. And the order of the [moon's] course returns [in such a way that] one is able to stand upon a known land [position], the diameter [recte: הקוטר] of the earth

being what is reckoned. [Münster's Latin note: "Who al-Ma'mūn, king of the Babylonians, was, or at what time he lived, I do not know. He had inquiry made as to how much…"]

And the sages who were in the land of Ishmael—

—in the time of the king called al-Ma'mūn [Latin: Almamon] in the land of Babylon, who set his heart to investigate these sciences—all of them, because they remained matters of perplexity for them; to investigate this matter [proved] more discerning than [all who came] before. The men of ability, the discerning ones, undertook by reckoning to clarify the [moon's] course over myriads of [?] courses; and from the discoveries of the ascent [of the pole] they found that one degree [recte: מוסיף, "adds"] one portion of the earth upon the diameter [recte: הקוטר]— [Münster's Latin note: "—how much space of the earth one degree in the heavens would cover. He committed the task to ingenious men, who should mark two places on the meridian line, in one of which the pole in its elevation should exceed the other by one degree; and they found that there corresponds, upon the surface of the earth, to one celestial degree, 57 miles and two-thirds of one mile—taking, that is, one mile at 4000 cubits, which make an Italian mile. In Germany, however, 15 mean miles make up one degree. Having therefore found the terrestrial space that corresponds to one degree, it is now easy to apprehend the whole circumference of the earth: namely, if you multiply the circle—"]

—the corrected [figure being] 57 miles and two-thirds of a mile by reckoning.

There being four thousand cubits in the one mile, and [drawing upon what] they decreed concerning one degree of the 360 degrees that are in the firmament—[namely] that there corresponds, in the circumference of the earth [to each degree], 57 miles and two-thirds of a mile—[then,] taking all these miles 360 times, you find that the length of the line encompassing the earth is **twenty thousand seven hundred and sixty (20,760) miles** and two-thirds [of a mile]. Divide this number by three and one-seventh [3⅐ = 22/7], which is the ratio of the breadth [diameter] of the circle to its circumference, [and] in order to know [recte: לדעת] [the figure of] the sages of measurement, you will find the length of the diameter of the earth to be **six thousand (6,000) miles**. [Münster's Latin note: "…that is, 360 degrees by 57 and two-thirds, and you will find the whole circumference of the earth to have [20,760 miles]."]

Sefer Tzurat ha-Aretz — Ninth Gate (continued): on the measurement of the earth

mile, and six-tenths of a mile, approximately. [Münster's Latin note: "...nearly 20,760 miles."]

Now if you take one twenty-second part of this circumference-figure of the earth — the amount by which the circumference of the earth exceeds its diameter — and subtract it from the figure, the remainder is the diameter [literally "the line passing through its center"]: six thousand six hundred and some odd miles [6,605]. [Münster's Latin note: "If from this I subtract its twenty-second part, which is 943 miles and 2,545 cubits, the remaining figure indicates the diameter of the earth, namely 6,605 miles and 1,818 cubits. Hence the rule among the geometers: the diameter tripled, with a tripled seventh part of the diameter added, yields the magnitude of the circle. For the circumference of a circle contains the diameter three times and its seventh part."]

The breadth of the habitable region — from the equator to the limit of the habitable land, a breadth of 66 degrees — is three thousand seven hundred and sixty miles [Hebrew: שלשת אלפי מיל תש"ס = 3,760], and one degree is 57⅔ miles, more or less. [Münster's Latin note: "Latitude of the habitable earth from the equator: 3,762 miles."] Its length, along the equatorial line, is 12 hours [12 equinoctial hours], which is 68 degrees [Hebrew: ס"ח = 68 —] and some odd minutes upon the line — for the breadth is one half of the circle that runs around the middle of the earth, and that is ten thousand miles approximately, plus two hundred miles [Hebrew: עשר אלפי מיל...ומאתים מיל = 10,200]. [Münster's Latin note: "The longitude, embracing a semicircle, has 10,260 miles — which is to be understood..."]

And its length, by the reckoning of the climes, is somewhat less than this measure — because as the encircling line goes round, the habitable land from west to east becomes narrower, since the lines are drawn together, whether toward the north or toward the south. The length of the arc reckoned within the habitable region from east to west, along the fifth [parallel], is reckoned in the same way: the arc drawn there in circumference is four thousand miles [Hebrew: ד' אלפי מיל = 4,000], and... [Münster's Latin note: "...is to be understood of the longitude under the equator. For the parallels northward are gradually contracted, becoming the shortest and differing greatly from the measure corresponding to a degree of the equator. Hence it comes about that the outermost parallel of the habitable earth embraces only a fifth part of the whole equator. For where the equator has 20,760

miles, the parallel passing through latitude 66 degrees has only 4,152 miles. Our Jew [bar Ḥiyya] puts it at 4,145; the end of the first clime is distant from the equator by 711 miles. Therefore the Jew's calculation is erroneous. The remaining latitudes of the climes correspond, however one reckons, in degrees to miles..."]

the habitable region, for the seven climes.

The first clime has a breadth of twelve and a half degrees [12 = וחצי מעלה ב"יו½] from the equator toward the north, and the miles in the breadth of the earth there come to nine hundred and thirty-five miles [Hebrew: 935 = תתק"לה].

The second clime has a breadth, from the first, of seven and a half degrees [שבעה 7 = וחצי מעלות½], and the miles there are four hundred and twenty-eight [Hebrew: 428 = תכ"ח].

The third clime has a breadth, from the second, of six degrees [ו' מעלה], and the miles there are three hundred and forty [Hebrew: 340 = ש"ם].

The fourth clime has a breadth, from the third, of six degrees [ששׁ מעלות], and the miles there are three hundred and forty [Hebrew: 340 = ש"ם].

The fifth clime has a breadth, from the fourth, of four degrees [ארבע מעלות], and the miles there are two hundred and ten [Hebrew: 210 = ר"ח].

The sixth clime has a breadth, from the fifth, of five degrees [חמשׁ מעלות], and the miles there are two hundred and eighty-three [Hebrew: 283 = רפ"ג].

And from the sixth, the seventh clime extends up to the limit [of habitation], a breadth of three degrees and a half [ג' מעלות וחצי], and the miles there are one hundred and fifty-eight [Hebrew: 158 = ס"צח]. And from the seventh clime up to the end of its degrees and a half — which is at the throat [בגרון] — is nine hundred and fifty-two [Hebrew: 952 = תתס"צב]. And all these miles are reckoned together in the breadth...

[Münster's Latin note: "...it is to be understood of the longitude under the equator. The parallels run gradually contracting toward the north, becoming the shortest and differing greatly from the measure corresponding to a degree of the equator. Hence the outermost parallel of the habitable earth embraces only a fifth part of the whole equator. For where the equator has 20,760 miles, the parallel passing through latitude 66 degrees has only 4,152 miles; our Jew puts it at 4,145. The end of the first clime is distant from the equator by 711 miles. Therefore the Jew's calculation is erroneous. The remaining latitudes of the climes correspond, however one reckons, in degrees to miles. Mens[ura]..."]

in the breadth, the measurement of the parallel is equal toward the north side and toward the south. As for the length [the longitude] — in its degrees and in the measure of its arc — it is not equal, because the arc that runs from east to west, and from west to east, in the climes varies, as we explained above. [Münster's Latin note: "The measurement of the latitude is everywhere equal, but not so according to the longitude. For the portions of the parallels, drawn from east through the habitable land to the west, become continuously contracted and narrower as one goes from the equator toward the poles. The dwelling-place of men extends as far as the circle of Arcturus [the arctic circle], which is in every part distant from the equator by 66 degrees."]

The habitable region is found upon the earth in the form of a round drum [a tambourine] — its outline is that of a circle. The reckoning runs from the midpoint of the parallel and from the head of the arc; the line drawn there is bounded by the limit of the habitable region from east to west. The length of each of its ribs [its component arcs] — from the dwelling-place up to the limit of the parallel toward the north side, and likewise from the south — is 60 degrees [ס' מעלות]. And this is sufficient for you regarding the form of the earth and its habitation.

The masters of the craft said that this is the measure of the radius [literally "half the diameter"] of the earth, a palm and an ell, by which they reckon the distances of the stars above the earth, and by this radius the bodies of all the stars that appear to the dwellers on the earth. [Münster's Latin note: "It is to be noted, moreover, that the ancients used the radius (semidiameter) of the earth as a kind of palm and ell (cubit), by which they measure and weigh the distances of the stars from the surface of the earth; and they took the globe of the earth as the standard of measure for the cubic [volume] of the bodies which are in it, and for the bodies of the stars that are seen in the heavens. The radius of the earth, by their reckoning of the surface..."]

The radius of the earth, by their reckoning, is three thousand two hundred and fifty miles [Hebrew: 3,250 = שלשת אלפים מיל ומאתים [ו]חמשים מילין], and the Moon is distant from... [Münster's Latin note: "...their reckoning, 3,250 miles. Which, multiplied by thirty-three and a half, gives you the distance from the earth to the point opposite the apogee of the Moon: 108,775 miles."]

of the earth, by multiplying it by 33 parts [ḥalakim] and a half by the line [Hebrew: רומה לג' חלקים ותצי = raise it by 33½]. The diameter of the earth — the count of it in miles — is on the order of one hundred thousand and nine thousand miles [Hebrew: 109,000 = מאה אלף וט' אלפים, a rounded figure; the exact

product is 108,775]. [Münster's Latin note: "...their reckoning, 3,250 miles. Which, multiplied by thirty-three and a half, gives you the distance from the earth to the point opposite the apogee of the Moon: 108,775 miles."]

And as for the distance of the Moon from the earth at its high point [its apogee] — reckoned in altitude, and it is the nearer distance — its measure by the line [in earth-radii] is 64 [Hebrew: 64 = סד'; the print is worn to סר', but read 64 against the dalet/resh caution and Münster], and in miles it is on the order of two hundred thousand and eight thousand miles [Hebrew: = מאתים אלף ושמונת אלפים 208,000]. [Münster's Latin note: "At the apogee of the Moon, whose concave surface is that of Mercury [□], the radius of the earth is multiplied sixty-four times, and they amount to 208,000 miles."]

And the distance, drawn out to the orb of Venus [נוגה — Nogah], by the line, is [its height-figure], which in miles is on the order of five hundred thousand and thirty-nine thousand and five hundred [Hebrew: = חמש מאות...והט' אלת...ה"ק 539,500]; and the longer distance, drawn out to the orb of Mercury, is the nearer distance to [the next orb], on the order of [its figure] by the line, which in miles is on the order of three million five hundred and ten thousand miles [3,510,000]. [Münster's Latin note: "At the concave surface of Venus there are found 539,500 miles. (Another exemplar has it otherwise.) The distance up to the concave surface of the Sun is 3,510,000 miles. Alphraganus [al-Farghānī] puts it at 3,640,000; therefore this exemplar is corrupt."]

And the distance, drawn out to the orb of Mars [מאדים — Ma'adim], which is the nearer distance to [the next orb], on the order of [its figure] like the value of the line, which in miles is on the order of three million, the reckoning being eight hundred and twenty-four thousand and five hundred miles [3,824,500]. [Münster's Latin note: "At the concave surface of Mars: 3,824,500 miles. Alphraganus puts it at 3,965,000."]

And the distance, drawn out to the orb of Mars [the text repeats מאדים here; the Münster parallel shows this is the orb of Jupiter —], which is the nearer distance to the orb of Jupiter [צדק — Tzedek]: [its figure] by the line. And by the reckoning of the second figure by the line... twenty-six million seventy-one thousand five hundred [26,071,500 — from Münster; the Hebrew here is abraded and broken off]. [Münster's Latin note: "At the concave surface of Jupiter: 26,071,500 miles. With Alphraganus I find (unless there be an error in the codex) 28,847,000. Example..."]

Planetary distance ladder (p. 190)

The distances of the planetary orbs from the earth, as given on this page. The Hebrew column states the multiplier in earth-radii and a (rounded) mile-figure; Münster's Latin margin supplies the exact mile-values and his al-Farghānī comparisons. Values below are committed from the Latin margin (legible) cross-checked against the Hebrew.

Orb (distance to its concave surface)	Distance in miles	al-Farghānī comparison (Münster)
Point opposite the Moon's apogee	108,775	—
Moon's apogee / concave of Mercury (☿)	208,000	—
Concave of Venus (♀)	539,500	"another exemplar differs"
Concave of the Sun	3,510,000	3,640,000 ("this exemplar corrupt")
Concave of Mars (♂)	3,824,500	3,965,000
Concave of Jupiter (♃)	26,071,500	28,847,000 ("unless error in codex")

[and eight] thousands — that is, six and twenty thousand-thousands [26,000,000] of miles.

The long distance [of the deferent] to the earth, computed near Saturn, is about twenty cords [chavalim], more than twelve thousand and 400 cords; and these are 40,000 thousand [40,000,000] and three hundred thousand miles — **40,300,000 miles**. [The Hebrew here gives a round 40,300,000; the Latin margin supplies the precise 40,365,000 (see below).]

[Münster's Latin note (margin, p. 191): Our exemplar is corrupt here. For the concave surface, ♄ [Saturn] 40,365,000. Alphraganus has 46,816,250. The Jewish calculation agrees nearly with ours. For the concave surface of the eighth sphere, 58,500,000. And this is the greater longitude, or apogee, of ♄ [Saturn], and its convex surface, which touches the concave surface of the eighth sphere.]

The long distance [of the deferent] to Saturn is about eighteen thousand cords; and these are 56 thousand-thousand [56,000,000] and 460[?] thousand miles — about **56,460,000 miles** [?]. [The units letter of the thousands figure (56 = נ"ו / נ"ז or 57) and the hundreds (460 = ת"ס) are lightly abraded; this is the Saturn-convex / eighth-sphere region for which the Latin gives 58,500,000.]

And I see by my reasoning that, in the body of this planet, in its reckoning — and in the reckoning of the ancients [kadmonim] — from the earth, as it were, there are [these many] earth-bodies up to the firmament of the eighth [sphere].

[Münster's Latin note (margin, p. 191): Of this [sphere] the whole diameter is [the semi-diameter doubled]; the total diameter is 117,000,000 mil., which tripled and increased by a seventh part of itself shows the circumference of the sphere of Saturn, namely 367,714,285 miliaria. Alphraganus puts 410,818,572 mil. The Jewish [author], who says he follows the calculation of Albategni [al-Battānī], is here confused, or rather corrupt; and we have had only one exemplar, and that very old and almost worn away.]

And there will remain a surplus over the firmament of [the eighth sphere]: by my reckoning the deferent [comes to] some sixteen[?] thousand miles, and the rest tripled, and at the seventh you will find together the full count of earth-bodies over my reckoning — about 366 thousand and 700 mil., near 2,000 mil., and [these] thousand miles; and you complete some thousand myriads [ribbo] and a quarter [revi'it]. [The interior digits of this summation are abraded; the Latin circumference figure 367,714,285 above is the reliable parallel.]

[Münster's Latin note (foot of column, p. 191): Number…]

and 4,000 mil.[?]. This reckoning is according to the opinion of the man called Albategni [al-Battānī], one of the scholarly investigators in this matter in the days of al-Maʾmūn the king. It did not enter, and was not noted, in the calculation of the practitioner, in the reckoning that fell short; for the sages who came before him and after him kept adding much over the reckoning [I have given].

And from this they reckoned the magnitude of the diameter [qoter] of each one of the planets — namely [the ratio of] the earth's diameter to it — and they drew, from the earth's diameter, another diameter [for each planet] by their geometric demonstration. [The chain of individual ratios that follows is partly abraded; the worked figures stand below and on the next pages.]

[Münster's Latin note (margin, p. 192): The number which he gathers from myriads is this: 200,021,430.]

[Münster's Latin note (margin, p. 192): From the proportion of the diameters of the stars and of the diameter of the earth is elicited the proportion of the magnitude of the bodies of the earth and of the stars — as often, that is, as the earth contains some star or is contained by it. And this is done in the case of the sun in this way: the diameter of the sun is as 5½ and the diameter of the earth as 1. Reduce to one denomination by [multiplying through by] 2, except [for] the half, and you will have 11 and 2.]

And if there be a fraction in the reckoning, this will be [handled] in the reckoning that…

[Münster's Latin note (head of column, p. 193): Multiply each diameter into itself, and the product of each multiply again by its own diameter, and you will have the cube of each.]

which is multiplied into the reckoning that precedes it. You will find the body of the earth greater than the body of the moon by **thirty-nine times [×39]**.

And the diameter of the planet [Mars], in its ratio to the diameter of the earth, stands as one to seven-and-twenty [1 : 27]; you will find the body of the earth greater than the body of the planet by **about nineteen thousand [times]** [Latin: 19,925].

And the diameter of [the planet Venus], in its ratio to the diameter of the earth, stands as one to three and [a half], and two eighths and a half-eighth [≈ 1 : 3⅝]; you will find the body of the earth greater than it by **about [?36] ו"ל times** [?]. [The multiplier's second letter is abraded; the diameter-ratio reads "three and ⅝."]

[Münster's Latin note (margin, p. 193): Multiply each [diameter] into itself and the product multiply again by its [diameter], and you will have the cube of each — as when 11 led into 11 produces 121, which number again multiplied by 11 shows the cube of the sun, namely 1331. Thus the diameter of the earth, 2, led into itself and the product, 4, again by 2, multiplied gives the cube of the earth, 8. With which if you divide the cube of the sun you will find in the quotient 166 and three eighths, by which magnitude the sun exceeds the earth. This the Jew teaches very obscurely here. Not otherwise with ☿ [Mercury]: on account of the two fifths, resolve also the whole number into fifths, and you will have its diameter of denomination 17, whose cube is 4913. Resolve also the diameter…]

And [other] great bodies, whose ratio [makes them] as large as the earth in a ratio of nine [...]: you will find the body of the earth, in its ratio to such a body, [greater by] one time and a third.

And in the bodies of the planets that were larger, [compare] the earth's diameter to their diameters: there goes out from the earth's diameter, in its ratio to the diameter of the seventh [planet, Saturn], a ratio of one to four-and-twenty [1 : 24], and three geometric [parts] nearly; and you find the body of the earth greater than it by [these many] times.

And in their reckoning upon the planets of Saturn that go out... ג ג

[Münster's Latin note (head of column, p. 194): ...the diameter ☽ [moon], that is, the unity [as] 5, and you will find its cube 125, which subtracted by division shows in the quotient that the moon has 39 parts of the earth — that is, the quantity of the lunar body is found in the globe of the earth thirty-nine times, and besides nearly a third part of it.]

The measure of their bodies is reckoned in **six degrees [magnitudes]** [×6]. The measure of the largest of them all: if you compare one [unit] to the diameter [of the earth], you will find it in a ratio of four to four-and-twenty [4 : 24], and seven-and-twenty [parts]; and by my reckoning upon this reckoning, [it is] another of the ... this body of the earth greater than [it] by a degree [magnitude] — as you find in the bodies, [comparing] the diameter of one star to another star; in a ratio to the degree, for that which [it is].

The measure of the great body of the earth [is greater] **eighty-eight times [×88]**, and the body of one planet [is greater] than the body of [another] planet, which is in the ratio of the great body of the earth, by [these many] times — [the earth being greater] than [it] **from 49 [×49]**. One other [planet] is greater than the body of the earth ... in its degree, the great body of the earth being [greater] ... times.

And there remain **fourteen [14, or 24?]**, which are called "planets of [varied] kinds [inyanim]" and dimmed planets [stars]; **their measure was not mentioned** [the source: לא הזכירו שעורן]. Among the planets of Saturn, the great body is found, which is in the body of the host of heaven [tzeva ha-shamayim] — that is, the ...

And the smallest body, in its entirety, which is seen by the dwellers of the earth...

Ninth Gate, conclusion (body-magnitudes of the planets and fixed stars)

the earth is a solid body [גוש], and these are the measures [השעורין] according to the assessment of the scholars who investigated [התחקרים] these matters. [The Latin: the cube of the planet (Venus) being 4096, the earth will contain Venus thirty-six times and a quarter part of it.]

[The remainder of the body-magnitude discussion on this page survives only in Münster's outer Latin column; the Hebrew column ends after the lines above. The Latin is rendered below as the reliable parallel.]

[Münster's Latin note: According to others, the proportion of the diameters is as 3 to 10, and in that case the earth will contain the planet (Venus) 37 times. The diameter of Mars to the diameter of the earth is as 9 to 8; therefore Mars contains the earth once and nearly half of it. Others put the proportion as 7 to 6. The Jew (i.e., the author, Avraham bar Ḥiyya) sets the proportion of the planet's diameter to the diameter of the earth as 83 to 10. Yet others as 18 to 4. For the fixed stars, six grades or magnitude-classes are posited. For stars of the first magnitude the proportion of the (star's) diameter to the diameter of the earth is as 87 to 20; according to others as 19 to 4. The stars of the first magnitude are reckoned at 15; of the second magnitude 45; and of the third magnitude 208. The Jew (Avraham bar Ḥiyya) gives only 49 — but I think the passage is corrupt. Our own (astronomers) put 5 nebulous and 9 dim (stars).]

THE TENTH GATE (השער)

The Gate — concerning the motion of the fixed stars [כוכבי שבת = the fixed stars, the stars of the eighth sphere].

This gate explains the view that the scholars hold concerning the motions of the fixed stars, the reckoning of the cycles that apply to them in their courses, and an account of those who reckon (their motion) toward the north [לצפון] and in latitude [ולרוחב], and concerning the ecliptic [גלגל המזלות] of Ptolemy and Hipparchus [אברכוס] and all the scholars of Rome [חכמי רומי].

It has been agreed [ויען חיו מסכימים] concerning the fixed stars that they revolve one degree [chelek] in every hundred years, completing the circuit of the firmament [הרקיע] in thirty-six thousand years [ששה ושלשים אלף שנה]. They circle in their motion about the pole of the ecliptic [קוטב אופן המזלות]. On this point

there is no agreement as to their center [recte: מרכזן] [?] from the beginning of the matter [מתחלת מעניינו].

The scholars of Ḥorri [חכמי חורי] [?], all the inhabitants of the land of Edom [recte: ברום] [?], and those marked out [recte: רמוזים] [?] among the scholars of the Chaldeans [בשדים = Chaldeans] and of Babylon [בלריס] [?] had among them stars [recte: כוכבים] in another reckoning [בערך אחר] [?], and they thought these to be of the fixed stars; yet they do not encompass the whole firmament [הרקיע]. Rather, these advance and others fall behind, by eight degrees, by way of the motion of the ecliptic [אופן המזלות] toward the east

[Münster's Latin note (outer column, p. 196): This last treatise deals with the motion of the eighth — or rather the ninth — sphere, which is the motion of the fixed stars. According to the opinion of the ancients this proceeds from west to east, completing absolutely one degree in every hundred years; and so it is completed in 36,000 years. But the later astronomers commonly hold that this motion completes not more than 44 minutes and 4 seconds in a hundred years, and is not completed except after 49,000 years. It is called the motion of "renisio" (recession/resistance), and occurs about the poles of the zodiac; and on account of it the stars always keep the same latitude from the ecliptic. The ancient Indians, Egyptians, Chaldeans, Greeks and Latins were the first in this opinion — that they supposed the pole of the zodiac to revolve in a small circle…]

Tenth Gate (continued): trepidation, the small wheel, Ptolemy and al-Battānī

by way of the ecliptic [מאופן המזלות], toward the east and toward the west. The pole [הקוטב] moves the (great) wheel [העגלה] by these one thousand six hundred [1600 = באלת ושש מאות] (years). Because of the revolution of the pole [גלגול הקוטב] upon the wheel [העגלה], it arose in the hearts of many men, concerning the fixed stars that encompass [shem] the whole firmament [הרקיע], that this deficiency was not revealed to them, and the pole's wheel [גלגול קוטב] did not make it manifest.

The manner [האופן] by which it moves the fixed stars from west to east is by eight hundred [800 = בשמונה מאות], and it returns to their original place [מקומם הראשון] after one thousand six hundred years [recte: 1600 = אלת ושש מאות שנה] [?], in the days when the pole [הקוטב] moves the whole wheel [העגלה] within them; and it returns to the starting-point [recte: הנקודה] [?] from which it began [התחיל] over against (it) to revolve [לסבוב]. And because (of this) — where it begins it is bounded [נגבל] by the motion of [ממהלך] the pole [קוטב] — the

manner [האופן]: from there [משם] there is found for it the limit of its expanse [recte: למרחבן] [?] from the manner [האופן], the parts [recte: חלות?] [?] of its matter [מעניינו]. And the motion [ומהלך] of this pole [הקוטב] is called "renisio" [סרפים — Münster's renisio] and recession [recte: ואחור]; and on account of this the fixed stars were so named in the tongue of the Greeks [יונים (ז)בלע] and the Romans [ורומיים], who interpreted in their tongue [בלשונם] "let it return" [recte: ושוב] — that is, it did not (truly) state [recte: לא אמרת] [?] concerning the fixed stars that they go (forward); rather they are stars [recte: כוכבים] that go (and) turn back [שובבים]. These are the contentions [טענות] of the men of Ḥorri [אנשי חורי] [?], which they advanced [טענו] concerning them, the falsehood [recte: לוסך?] [?] in their day. And Ptolemy [ובטלמיוס] mentioned [recte: הזכיר] [?] them — the motion [המהלך].

[Münster's Latin note (outer column, p. 197): …a small circle whose diameter is 8 degrees, whence it came about that the stars would move 8 degrees toward the east, and then again be drawn back 8 degrees toward the west. And this motion they said was completed in 1600 years. But in 800 years the semicircle was revolved from the western point to the eastern. And because this motion took place at the pole of the zodiac, there accrued also to the stars themselves a certain latitude from the ecliptic. This motion he called "progression and retrogression," likewise "going and returning." When Ptolemy had seen this conatus (attempt/effort) of theirs, he neither approved nor disproved it. But al-Battānī, that Saracen, refuted their opinion.]

Tenth Gate (continued): Ptolemy's and al-Battānī's measurements; al-Maʾmūn

this motion [המהלך] he neither set aside [שב לבטלו] nor confirmed [ולא לקיימו].

The scholars of Yishmaʿel [the Arab scholars] who lived in the days of al-Maʾmūn [אלמאמון] set themselves [התחזקו] to refute [לבטל] the words of the men of India [אנשי הודו]. Al-Battānī [אלבתאני] spoke of them, of the claims [בטענותם] they had advanced [טען] concerning them — for the calculations [recte: החשבונים, "the calculations"; printed הקרבמונים] that were before Ptolemy [לפני בטלמיוס] were deficient [חסרו] regarding the account [על מעמר] of these stars [הכוכבים תאלה], and the (results) extracted [והקסי] from them [were] set down [recte: מקומן] in their books [בספריהם]. Ptolemy came [ובא בטלמיוס] in (the year) four hundred and twenty [420 = ארבע מאות ועשרים] (and computed); investigating their standings [מעמדן], he found the difference between his deficiency [מחסרו] and the deficiency of the calculations [recte: מחסר החשבונים; printed הקרבמונים] to be four

degrees and a fifth of a degree [4 = ארבע מעלות וחומש מעלה⅕°]; and he decreed (the motion) eastward [וגזר מזרח] to be, by way of their motion [על מהלכן], one degree [מעלה] in (every) hundred years [במאה שנה], which is marked [מסומן] for its appointed time [recte: לעתו] in his book [בספרו].

After him came al-Battānī [ובא אלבתאני אחריו] in (the year) seven hundred and twenty [720 = שבע מאות ועשרים], and worked at their (computations) [ועשה במעשיהם]. He found the difference between his deficiency [מחסרו] and the deficiency of Ptolemy [מחסר בטלמיוס] to be eleven degrees [11° = י"א מעלות]; and he decreed [וגזר] that their motion [על מהלכן] is one degree and a half [מעלה אחת וחצי½° = 1] in (every) hundred years. These stars were found [ונמצא הכבבים האלה], from the time of the deficiency of the ancients [מחסר הקדמונים] to the time of al-Battānī [זמן אלבתאני], to have advanced [הלכו] fifteen degrees [חמש עשרה מעלה = 15°].

[Münster's Latin note (outer column, p. 198): The Indians wrote before the birth of Christ; Ptolemy, however, about the year 140. And he too found the heaven (i.e. the eighth sphere) to move 4 degrees in 420 years. Then came al-Battānī, namely 720 years after Ptolemy, and toiling likewise at this difficulty he found his own calculation to exceed Ptolemy's calculation by nearly 11 degrees. On that account he assigned to the motion of the stars one degree and a half in every hundred years; and the difference between his own calculation and the calculation of the ancients was 15 degrees, and nearly one within 1140 years — although according to the reckoning of the ancients there ought to be only 11 degrees 36 minutes, if the beginning of the reckoning be made from the eastern point, or 3 degrees 36 minutes if the reckoning begin from the posterior point.]

one degree and one fifth of a degree. By the reckoning of these others, [the shift comes to] one hundred and forty [years per degree] [140 = מאה וארבעים], and according to their words it is right to take the mean between them: eleven degrees and thirty-six minutes [11°36′ = י"א מעלות ל"ו שברים], if we begin from the prior point [recte: from the start]. But it is found that between them there are three degrees and thirty-six minutes [ג' מעלות ל"ו שברים], if you begin from the end. And, on the other hand, if you begin from the middle of the conjunction, there cannot be between Ptolemy and al-Battānī more than seven degrees [שבע מעלות = 7°] and one fifth toward the east. And one adds upon what was recorded in the days of Ptolemy, if [you begin] from the end.

[Münster's Latin note (outer column): "…it begins. For the diameter of the circle is eight degrees, to which if three be added, eleven degrees result. But if the computation be made from the middle point, the place of the stars is changed by

seven degrees. Nor does it matter whether you take the middle point according to the prior point or the posterior. But the error of the ancients is easily refuted, since al-Battānī's calculation has now been increased by fifteen degrees, and not by eight only."]

By al-Battānī, if we begin from the end — and those [computations] differ from one another, whether you begin from the start, or from the middle of the conjunction, or from the end [recte: of the other point].

And in this matter the great error befell them [the ancients], when they said that these stars travel and revolve by the motion of the eighth sphere, and added upon them; and they reckoned these things upon the calculation [recte: of those astronomers] who corrected the reckoning upon the words of al-Battānī, reckoning fifteen degrees [15° = מעלות ו"ט].

And in a place where there were men [recte: lines / readings] both visible and hidden — these existed only by the reckoning of al-Battānī.

According to my words, the counsel that the great ones [the foremost authorities] gave concerning this wisdom, relying upon their own investigation and reckoning — just as I did. Or it may be that they relied upon their investigations of the stars revolving toward them over time, on the part of those visible, to lean upon them.

But I give no such counsel concerning the fixed stars [recte: stars of the firmament], that one should rely [recte: err] in general; rather, in particular I [seek] to investigate all the stars: the places of every star, the locations of the apogees [the heights of the heights], and the chief points of their structure. And in this matter one may yet rely upon Ptolemy in his reckoning.

But one thing I do see from the words of those who hold that there is a change [trepidation] in the fixed stars over a fixed time: that according to al-Battānī, those who say so reckon by a doubtful reckoning [בספיקא = "in doubt"], and in the eyes of the sages of this discipline this is so — and it is not possible to settle the calculation upon every day, and over them [the stars] there is none [reckoned] at a single time. For the count of the fixed stars of the firmament that revolve, which the inhabitants of the earth are able to see and to know their number — these are a thousand stars and twenty-two [= אלת ככב ועשרים ושנ[ים] 1022]. And they did not count among them the tailed star [comet], the one called a star [recte: a "hairy" star]…

[Münster's Latin note: "On the motion of the fixed stars there was no agreement among the ancient astronomers; but as to their number — those which can be seen from the inhabited part of the earth — all agree, namely that they are 1022. Among these, however, are not reckoned the tailed or hairy [comet-]stars, and two other small stars..."]

the star [recte: of the constellation] Draco [תלי, "the dragon"], and the star [recte: the heart] of Leo [the Lion]; and they are reckoned by two small stars [שני ככבי קטני], which were of the first sort [recte: of magnitude]. The southern [stars] [recte: those that were within range of sight], being visible, they could compare each one against [the stars] of the constellations of the zodiac. And all these stars which are counted, among them: stars whose neck [recte: each one] is great in body [recte: of great magnitude]; and [the constellations] are set about them, for the eyes of the sons of men to gaze upon them, and one must not be lacking as to their places and their arrangement on every side [recte: round about].

[Münster's Latin note: "...stars which occupy the cardinal-points of the two poles. But those stars which come into the count are those that shine, and present themselves by their magnitude to the eyes of men, so that [the constellations] are arranged around them."]

And these stars, the visible ones [recte: those that are formed/set], are divided, by the knowledge of the men of this wisdom, into forty-eight forms [מ"ח צורה = 48 constellations]: of them, twelve forms [י"ב צורה = 12] which lie in the manner of the constellations of the zodiac, and the first ones among them — Aries [טלה] and so forth; and the last among them are the southern ones [recte: certain ones], and they are the ... [recte: arranged in order].

[Münster's Latin note: "And these stars are arranged into 48 figures [constellations]. Twelve are in the zodiac, 15 in the south, and 21 in the north."]

Of them [there are] fifteen forms [ט"ו צורה = 15] in the southern region, guided in the eyes of the sons of men, leading the figures [recte: which constitute the figures] that lie toward the north [recte: the south].

And of them [are] twenty-one forms in the northern region [= כ"א צורה בפאת צפון 21].

[Münster's Latin note (continued from the foot of p. 200, running into p. 201): "... stars which do not depart from the zodiac, except perhaps a few, which enter into the constitution of the figures [constellations] of the zodiac. In the north are

found 365 stars, which constitute 21 figures and are far from the ecliptic. In the southern region are numbered 316, which constitute 15 figures."]

And he found a reckoning of the number of the bright stars [recte: those that shine] by the manner of the constellations, or [those] spread out, distant from them a little toward the north and the south; and there is none among them, by which [recte: there is none of them]...

spreading out wider, [those that] lie within the wheel of the constellations [the ecliptic] and a little to either side in latitude [recte: toward the south]; and the stars that spread out from the constellations are of great latitude [recte: a few of them depart far], serving only to constitute the form of the constellations. In the north [recte: in the northern region], their figure is a northern one [recte: which lies toward the north]: they amount, by number, to three hundred and sixty-five stars [365 = שס"ה], each and every one of them; in latitude they are great [recte: far distant], and there is none of them that lies far toward the north [recte: that fails to lie toward the north].

And the stars that spread out toward the southern region [לפאת דרום] — they are set by the figure which is in the south; they amount, by their number, to three hundred and sixteen stars [316 = שי"ו], which lie toward the southern region.

[Münster's Latin note: "In the ecliptic and near it on either side, toward the south and the north, are found 340 stars, which do not depart from the zodiac, except perhaps a few, which enter into the constitution of the figures of the zodiac. In the north are found 365 stars, which 21 figures constitute and which are far distant from the ecliptic. In the southern region are numbered 316, which constitute 15 figures."]

And now you know that [the count of] the stars [is as stated] [recte: behold], each of which has been counted by them.

By this wisdom is completed the [reckoning of the] form of the firmament [recte: the stars in the firmament] — many [recte: spread out] among the stars: just as each form [constellation] among them, with their order [recte: their arrangement] set by their numbers — these are the stars whose light reaches the sight of the sons of men, for them to see them and to find them by their places.

And do not let it rise in the heart of any man among the investigators [recte: men] of this wisdom, who are given to [recte: who set down] the stars of the heavens by their number, that the number is exact [recte: fixed and fitting]; for the matter is

known to all — that it lies within the power of human reasoning [recte: of the calculation, by the thought] of men…

[Münster's Latin note: "The astronomers did not invent the aforesaid number of stars out of their own brain, but they wearied their minds to know the whole matter — as far as it lay within human power…"]

[Tenth (final) Gate — fixed-star catalog, continuous from the previous pages; no new petach or gate transition in this opening.]

[Münster's Latin note (outer column): "…it was permitted to know it. So they did with the stars and the heavenly orbs. They investigated diligently the disposition of the orbs from their motion; then they numbered the stars, arranged them into figures (constellations), and within them established their magnitudes. They distinguished them into six classes, and then attempted to ascertain their sizes, insofar as it could be done at so great a distance from the earth."]

These men investigated these matters with their full capacity, seeking to set down [the measure of] every one of them. So too, since there are men capable of investigating the earth and the stars of the heavens, they were given a means to grasp the figures (constellations), to count them, and to assign to them by measure the number of the visible stars — both their magnitudes and the size of their bodies — according to what falls within each. They did not divide them by lot; rather, these by size, those by magnitude — into six magnitude-classes (על שש מעלות), and not by [arbitrary] decree, since there are six gradations.

Now, among the stars reckoned [in each class] the heart that knows and grasps these matters discerns a great difference: there is variation between one star and another. No one is able to grasp the true measure of the span that lies between the earth and them.

You also have something further to consider regarding [the relative size of] the heat that issues from these [bodies] and from the moon: for every magnitude is either greater or smaller. The larger figure of the earth is great in measure; the size of its body, by the measure of the earth, is reckoned by the geometers [Münster's Latin: *Geometra*]; and in the visible appearance to the eye, [it is reckoned] from the figure of the moon, which is the great figure. The proof of this is reckoned from the figure [which continues] —

[Münster's Latin note (outer column): "The Moon and Mercury are smaller than the earth, and Venus is larger than the earth — notwithstanding that our sight judges otherwise. This is because, since Venus is higher than the Moon, its body

appears to be less than the Moon's body. Likewise, if we make a comparison of the planets to the lesser fixed stars — namely, to those that are assigned to the fourth or fifth class — we find the planets, according to our sight, to be larger than the stars of the fourth magnitude, though in reality they are larger than the planets. As to what follows next concerning the perplexing star, which is Venus, and concerning the magnitude of the stars of the sixth class — these are not true, or else the exemplar (text) is corrupt, or I do not understand the author. For it is not true that one [part] out of 15 portions..."]

[the great figure is reckoned] from the figure of the moon, the moon itself being a figure smaller in appearance. When you return to consider the matter [carefully] by the [measure of the] seven heavenly firmaments and compare them, you will find that the figure of one body is greater than the figure of the body of another, among those stars whose figures stand at the fourth magnitude — or rather the fifth — the great figure being [apparent] to the eye. Each of them, though it be a living [shining] thing, conceals [the body of] another from the figure of the body of [a star] of the sixth magnitude.

As to the figure of the perplexing star (the planet Venus), which is found in the reckoning of these scholars: it is about one part of 15 (חלק מט"ו) of the figure of the earth; and its magnitude is another part, one part of 240 [מי"ר חלק] [?], by the figure of a star — [each star] of the stars of the last (sixth) magnitude, by the measures of the later stars, [reckoned] from the fixed stars. And one finds that each body of them is greater than the figure of the body of the perplexing star by 600 thousand [של שמאות אלף] [?] times; yet its body, to the appearance of the eye, [appears] greater than the figure of each one of them.

Now you have something to understand concerning the bodies of the great stars: in their figure they are above [larger than] the earth eight times (ח' פעמים), at times nine (ט'), or more; and there is no man able to see them [truly], because their bodies grow smaller [in appearance] in proportion to the [great] measure of the magnitude.

[Münster's Latin note (outer column): "...that the sixth magnitude should contain the earth, [yet] as above they are reckoned at 37; nor does a star of the sixth magnitude contain Venus a thousand and three hundred times [1300×], when it is written that a star of the sixth magnitude contains the earth ten and eight times [18×]."]

The sixth magnitude, which is the hidden measure of the visible figures (constellations), is among the stars of the fixed sphere. Every star of these hidden

ones is of the great figure, larger than the earth, yet they are not visible to the eyes of men. Do not say of this that it is impossible to be so. Rather, in truth there are among the stars of the heavens many great figures whose bodies are of [vast] size, and there is no man able to grasp the whole between the earth and the heavens, [the bodies] being of such figure; and they are seen as great [constellations] whose bodies are of [vast] figure, yet no man can grasp [their full extent]. By the measure of the span that lies between the earth and them, no man can grasp [or] see them at all, in any manner, nor perceive [them].

[Münster's Latin note (outer column): "The author says that he has been the more prolix in treating of the magnitudes of the heavenly bodies on account of the half-learned, who attack what is handed down concerning the excessive number of the magnitude of the sublime bodies or the multitude of the stars — as though, accordingly, no more stars are to be found in the heavens than can be seen by men."]

I have come to broaden this matter and to extend my words upon it because of certain men, scholars in their own eyes [Münster: *half-learned*], who come to cavil about this — the wisdom that bears upon the number — for one delivered to the stars of the fixed sphere [a number]. They [cavil] because the men reasoning about this wisdom [draw] reasonings more proper to [the planets, whereas] in truth the number of the stars of the eighth firmament (הַשְּׁמִינִי) [the fixed sphere], whose number is not [fully] known to any man, [is beyond them]: for in the heavens are hidden stars beyond the sight of the sons of men.

[Münster's Latin note (outer column): "...that they could be seen [by men]. They argue this matter in this manner: How can a credulous man set down a certain number of the stars, when Scripture says that the number of His army has no number? This is what is said in Job concerning the sun, from which all the stars receive their light, and therefore [the stars] have no proper dignity of their own; and whoever has assigned them a certain number departs from Scripture. The cited place [is]: 'The Lord has forsaken me' — it is written in Isaiah 49 [Yeshayahu 49:14], where the Kabbalah, adduced in the Midrash, says that there are to be found in the heaven 29,000 myriads and 140 — that is, 19,000,140. But the astronomers do not set down [more than] 1022, and in the zodiac they set down only 346. Here, then, you see the difference between the number of the stars according to the astronomers..."]

And the objectors (וְהַטוֹרְעָנִים) [the half-learned] — these say in their words: How can a man who believes [in Scripture] [assign] a number to the stars of the

heavens, when Scripture says that the number of the heavens cannot be counted? And it is written [in effect]: "Is there a number to His troops? [Iyov 25:3]."

Now you, [reader,] understand from among those who reason about this, that this [error] came to them because their reasonings have no foundation at all, and in every figure their reckoning proceeds upon error.

And there is yet another argument by which their way is diminished, in the matter of the number that is delivered concerning the stars; and they say [it is] not [fitting] for men — these [stars] which are reckoned by their figures, [namely the figures] which they are [assigned]. For [they say] there shall be among the hidden [stars more than] the [number of the] figures of the earth. [But] in the words of our Rabbis of blessed memory, in the Midrash, [it is said] from the verse "Let Zion say, 'My Lord has forsaken me' [Yeshayahu 49:14]" — this our forefathers received as a tradition by their hand, and we are obligated to receive it and to instruct accordingly, [drawing] upon the words [of the Sages]. The Midrash [says] that there shall be of the stars of the heavens that are in the heavens twenty-nine thousand myriads [10,000 × 29,000 = כ"ט אלף רבוא] of stars, and one hundred and forty [140 = ום"וק] more; and the Sages do not add to their number — the astronomers do not add in their reckoning beyond the 1022 stars [Hebrew prints ב"התר; Latin parallel "1022" fixes the value], and not [the] 22 (כ"ב) zodiac-constellations of the firmament, except the 346 stars [346 = ו"מש] of the zodiac. And the difference that lies between their number [the astronomers'] and the words of our Rabbis — behold, by a luminous [explanation] I have made it clear concerning these errors —

[Tenth Gate continues — fixed-star catalog / defense of the star count; no new petaḥ. The work concludes on p. 209 with the author's closing blessing and colophon, followed by Münster's closing annotation.]

these are the ones who rely on them and who are deceived by such talk. Whoever reflects on the matter will find that all these claims are vain, for the sages of the stars who arranged them have a definite count — the very stars they enumerated — and the stars excluded from that count are themselves a separate count.

There is a difference between those that are counted and named in the books of the stars over which the number prevails, and those that go out from the count: these the count does not govern. And there is a distinction in the names of those that are named, since they are recorded as drawn up in order, written down in their rank. Of these Scripture says, "Lift up your eyes on high and see who

created these" [Yeshayahu 40:26]: it speaks of the heavenly bodies and counts them — the sun, the moon, and the rest of the stars.

[Münster's Latin note: "...and the cabalistic dreamers."]

[Münster's Latin note: "Our Jew here makes a distinction between the names: the star, and the star of the heavens. He asserts that Scripture employs the word 'star' absolutely, without any addition, for that star which can be seen and numbered by a man, and which has a certain efficacy and influencing power upon these lower things — as is that passage, 'Lest perchance you lift up your eyes to heaven and see the sun, the moon, and the stars, etc.' Then is found the name 'star' with the addition 'of the heavens,' as is that, 'Look toward heaven and number the stars, if you are able' [Bereishis 15:5]. It is also written, 'Who numbers the stars of the heavens.'"]

And you will find among the stars — and among the houses of the heavens [the zodiacal signs] and the lunar mansions — a count for the stars, and that those named in everything are themselves named; whereas those over which the count does not prevail are written in their houses [signs] by their names, and they too are named and numbered in their houses. Among the stars of the heavens there are some that the count does not reach, just as the dust of the earth, which is written, "He cannot be numbered" [reference to the seed of Avraham, cf. Bereishis 13:16] — for there is none among the stars of the heavens whose houses [signs] the second [class] can contain [?].

[Münster's Latin note: "Whence we gather that those which are seen and numbered are called 'stars'; but those to which number does not extend are called by Scripture 'the stars of the heavens.' And of them Scripture says: 'Behold, you are this day as the stars of the heavens.' [Devarim 1:10] Yet Scripture has certain stars that do fall within number and are seen by men. Others are exempted from number, of which it is said in Job, 'Is there any number of His armies?' [Iyov 25:3] In this way, then, all objections can readily be resolved."]

Running header (p. 208): *Tzurat ha-Aretz*

You will find that among the stars there are some that come within the count and are seen, and there are some among them that go out from the count and are not seen; and concerning them it is said, "There is no number to their hosts" [cf. Iyov 25:3].

From this reasoning it is resolved — see how every objection they raised against them is answered — for everyone who understands the science knows and

recognizes that, among the stars that are visible, every man is able to gaze at them and to grasp their forms, and what he is able to grasp of them. And though there be many people in many places — many [scattered] across the world — occupied with the matter, this man is one, and another man after him, each counting the stars; and there is none [among them] who differs from his fellow, nor any who contradicts. By their companions, as to the count, all rely; and many of them tell me that the men [reckon] these and stand by the count. Whoever differs [from another], one of them is found in error.

Those who know that there are in the heavens stars over which the eye cannot prevail, and over which the count does not rule — over these, knowledge of the stars [does not extend, and] one cannot count them; there is no number to them, no limit.

You will find that the sages of astrology [*ha-itztagninut* / the astronomers] arrange [the stars] according to the shape of their constellations [?], as they have reckoned them.

Running header (p. 209): *…and the configuration of the heavens*

These are the wise and discerning ones who turn aside [from] these stars [?] — all of them who plow [study] [?]. Yet I do not see, in all the matters of the configuration, any ground to silence the view of the sages of astronomy [or the astronomers] who investigate it, [no] further claim to be argued against it from the course of the moon, except [as concerns] the count of the stars, which it has compounded — that I am in error [?]. But this has no substance whatever.

I have reflected, so as to bring this matter [to a close]: a brief sufficient [account] above [drawn from] the wisdom of this land [book], as far as my hand can reach, and [bring] the composition to its close. This is [a matter] concerning the courses of the moon or another matter — let me [conclude] with these words. Here ends the discourse.

May it be the will of the God of the heavens to help us and to grant us, and to give us the opening, to fulfill our words and to declare His unity according to His commandment, and to set us upon His paths — all of us — that we draw near in our days, by His mercies and His kindnesses.

Amen.

[Münster's Latin note: "There are certain astronomers who make their computations with childish and overly cautious hands, and thus evade the tricks and snares of those who are prepared to press objections and refutations against

them. And indeed, out of the whole text they can find nothing against the art of astronomy except only the number of the stars. But it has already been shown how vain their effort is. I have therefore wished to treat this matter here a little more fully, so as to remove every doubt, to the best of my ability, concerning this science, and to seal up this passage with the words of the text, etc."]

Here ends the Book *Tzurat ha-Aretz*.

[Münster's Latin note: "The annotations, added by Sebastian Münster, are concluded."]

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