

Loxias, seu de obliquitate solis diatriba

[Loxias, or a Treatise on the Obliquity of the Sun]

(1626)

by Govaert Wendelen (Godefridus Wendelinus, 1580–1667)

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

Loxias ("the oblique one," an epithet of Apollo) is Govaert Wendelen's treatise on the obliquity of the ecliptic, the angle between the Sun's annual path and the celestial equator. Reviewing ancient, medieval and contemporary determinations, Wendelen argued that the obliquity is not fixed and proposed a rule for its variation over time. The work is an early landmark in the long debate over whether, and how, the obliquity changes.

A NOTE ON THE TRANSLATION PROCESS

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

A note on the references. A scriptural or bibliographic reference given in brackets or parentheses is, in most cases, an **editorial identification of an allusion rather than a citation printed in the source**. Books of this kind quote and weave scripture constantly without naming it, and the identification is supplied here as a convenience to the reader. Where the source does print a reference of its own, it is given as printed. **An identified allusion is not evidence that the author cited that passage** — look at the original before resting an argument on one.

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.

ACKNOWLEDGEMENTS

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

Notation and abbreviations

A few conventions have been applied uniformly throughout this translation, so that one quantity is always written one way. They change how a value is *written*, never what it is; where the printed source and this translation differ in notation, the source's own form is recorded in the editorial apparatus.

Numerals are Arabic, even where the source sets Roman ones. Roman numerals are kept only in headings, running headers and signatures, which are transcribed as printed.

Dates are given as year, month, day — *1572 November 11*. Dates are Julian, as the source gives them, and have not been converted to the Gregorian calendar.

Angles are written with the conventional signs — $23^{\circ} 27' 30''$. Early modern astronomy divides the degree sexagesimally and often runs to places for which modern writing has no common symbol; the orders used in this book are:

sign	order	the source's term
$^{\circ}$	degrees	<i>partes, gradus</i>
$'$	minutes of arc	<i>scrupula prima, minuta</i>
$''$	seconds of arc	<i>scrupula secunda</i>

Where a table in the source spreads one quantity across separate columns for degrees, minutes and seconds, those columns have been joined into a single column and the value written whole. Where a value runs to thirds and beyond, the columns are kept, since there the columns are the notation.

[Non-book page: the digitizer's notice, not part of the 1626 book.]

[Non-book page: front cover of the binding, plain paper, carrying later library shelf-labels and stickers only; no printed text of the book.]

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[Non-book page: blank leaf; scattered specks and a crease line at the lower left.]

GODEFRIDI WENDELINI [Govaert Wendelen] **BELGÆ, I. V. DOCT. LOXIAS SEV DE OBLIQVITATE SOLIS** *Diatriba*

GOVAERT WENDELEN OF THE LOW COUNTRIES, DOCTOR OF BOTH LAWS

LOXIAS OR ON THE OBLIQUITY OF THE SUN

A Treatise

In which the declination of the zodiac from the equator [Zodiaci ab Æquatore Declinatio], unknown until now, is at last brought to light and entered in its own table [Canon]; and by which, as Pliny the Elder says, THE DOORS OF THINGS ARE OPENED.

Diagram. The printer's device: an oval medallion in a strapwork cartouche with grotesque masks at top and bottom. Within the medallion a rampant lion stands on rough ground under a hatched sky, its forepaws resting on an oval shield. The shield carries a cross-shaped merchant's mark above the letters H and V, each in a small circle, with a further mark below them [?]. The motto runs round the medallion's border.

- Border, upper left: "RVIT SVA"
- Border, upper right: "VIS CONSILI"
- Border, right: "EXPERTS"
- Border, lower left (set reversed in the ring): "MOLE"
- Shield, centre: letters "H" and "V" beneath a cross-shaped mark; a mark below them unresolved [?]

The motto reads, in order: "Force without judgement collapses under its own weight" [VIS CONSILI EXPERS MOLE RVIT SVA].

ANTWERP At the house of Hieronymus Verdussen 1626 [M. DC. XXVI.]

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ILLVSTRISSIMO / AC / REVERENDISSIMO / D. IOANNI FRANCISCO / EX COMITIBVS GVIDIIS / A BALNEO / ARCHIEPISCOPO PATRACENSI / NVNCIO APOSTOLICO, CVM FACVLTA TE / LEGATI À LATERE PER BELGIVM

To the Most Illustrious and Most Reverend Lord Giovanni Francesco [Ioanni Francisco], of the Counts Guidi di Bagno [ex Comitibus Guidiis a Balneo],

Archbishop of Patras, Apostolic Nuncio with the faculty of a legate *a latere* throughout the Low Countries [BELGIVM],

Godefridus Wendelinus / LOXIAM / Dedicat, Confecratque.

Govaert Wendelen dedicates and consecrates his *Loxias*.

Most Illustrious and Most Reverend Lord: you have embraced me with a kindness freely given, and so made me a debtor for great favours. I credit this to the nature of your birth, but even more to your own personal gifts, through which you have come to count your ancestors and their portraits [auos atque imagines] among secondary things.

And may you be blessed in this distinction, most excellent man [Vir Præfantisime]. By it you have shown yourself equal to the French and Belgian legations, and lately also to unravelling difficult affairs; and you have shown yourself higher than legations — fit not so much to undertake them as to bestow them: that is, worthy of the sacred Purple. But no stars promise you the Purple more surely than these qualities do.

You yourself are your own heaven and your own horoscope. Your virtues — always great, always splendid — are bright and more decisive stars, and I too have now begun to feel their influences, and to feel them as wholesome. So, held under so great an obligation by kindnesses that keep me in pledge — an obligation to be acknowledged both in words and in deeds — I look for a way to redeem the pledge [lutionem].

Let others, indeed, proclaim the rare praises found in you with rare encomia: those whose swan-like voice, ringing out from the citadels of Pallas, is carried by their wings to the heavens. My own eloquence, being in straits, looks about for support from a gift (and is not giving, too, a part of talent?).

For while elsewhere praise comes all too easily, in your case nothing is ever enough. For that very reason I have preferred to offer a gift: because, since its whole measure and worth come from the spirit (and mine is truly vast in this respect), it makes even water offered from the hollow of the hand [aquam de vola] acceptable to great kings.

Nor is this boldness, drawn from that example, without a sponsor. I am persuaded to dare it by a most distinguished and excellent man: if I did not believe him, Probity and Learning would publicly arraign me; if I did not obey him, they would also condemn me for Ingratitude.

That man is ANDREAS TREVISIVS [Andreas Trevisius], physician of the chamber [Medicus à Cubiculo] to the Most Serene Princes of the Low Countries, and physician also to my fortunes — my Maecenas, I say. Until now he has supported me, raised me up and lifted me, entangled as I am in a most difficult lawsuit over the defence of sacred rights [sacrorum tuendorum] before the most distinguished Council of Brabant [Brabantiae Senatu]; so that I look down on Fortune from on high, and despise her even when she threatens.

And so, having often before urged me in words to publish the several things I have, now, see, he presses me with deeds. He thought it would not be enough for me to be kept busy unless I also made a name for myself by writing [nifi

[criptione quoque diftingar], and that I should labour to bring this forth at least for your name.

Since, therefore, there is neither an excuse to serve as a pretext, nor any delay left open to me without my being pressed for it. And so, in order to dedicate reverently what I publish first, I chose to publish first the work which, for its illustrious subject, I judged fit to be inscribed to YOUR MOST REVEREND AND MOST ILLUSTRIOUS TITLE.

That work is the OBLIQUITY OF THE SUN, or the λόξωσις [Greek: loxōsis, "obliquity"] of the zodiac. In the very fountain of light it has until now remained obscure, and yet in that very obscurity it is luminously manifest; it has long been sought by so many outstanding masters [artificibus], and has remained unknown through so many centuries. From remotest antiquity down to our own day it has been seen to decrease continually, and yet no one has been able to learn by what Limit it is bounded and within what Confines it holds that Limit — that is, how far it ranges at its widest on the one side, and how tightly it is held in on the other. So it has compelled astronomers to tremble [trepidare] for the whole of their discipline: you might even say that the motion of Trepidation took its name from this.

Certainly this subject has worn out the minds of all mathematicians up to now, who have confessed their ignorance. And although knowledge of it has been sought with the unceasing prayers of those who long for it (since it is from here, in the end, that the completion of astronomy must take its starting point), no one to this day has dared to treat it without at once losing heart, as in a hopeless matter; and the oracle of all who have ever touched it has been: HANDS OFF THE PANEL [MANVM DE TABVLA].

Their despair might well have warned me of the danger that the very effort of labour would stifle whatever reputation I might be bringing to birth (if I was in labour with any). But since I am certain that in the whole matter I have grasped nothing rashly, I hurry — meaning to take counsel for the common good, and also to bring help — to the very place from which others flee in terror, and I cry: HANDS TO THE TABLES [MANVM AD TABVLAS].

Indeed I say it twice over: HANDS TO THE TABLES! For the knowledge of this matter is not single, and it blesses us more than once over. From it come the true parallax of the Sun [Parallaxis Solis], its certain eccentricity, and its ascertained magnitude; from it the accurate measure of the year; from it the obliquity and motion of the fixed stars; from it the completion of the Moon and of the remaining planets. From it, finally, there rises the light and rule of the ages — I mean the norm for establishing chronology, and the soul of histories.

HANDS TO THE TABLES, then — and namely to those which I shall shortly publish, the ISABELLINE tables [ISABELLINAS], which embrace the whole slipping course of time [æui labinam] with constant certainty. Just as by their help there is hope of finding longitudes and of perfecting the art of navigation, so with their support the CHAOS OF TIMES [CHAOS TEMPORVM] and the darkness of the ages is dispelled; a CHRONOLOGICAL

CONSUMMATION [APOTELESMA CHRONICVM] is brought forth; and whatever has tormented inquiring minds with so many quarrels and disagreements, from the Creation of the World to our own times, is calmed and peace is made.

All these things I worked out long ago by lamplight. Yet although the lavish generosity of the excellent TREVISIUS (as I said) urges them on, they do not dare to see the light unless this Lamp of the world goes before them. They cannot set out on the straight road unless they first see this tottering obliquity of the light that goes ahead of them corrected, with COUNT GUIDI enlisted as companion [adfcito COMITE GVIDIO].

Taking a good omen for myself from this name, therefore, I have set about dedicating this writing to YOU, MOST ILLUSTRIOUS AND MOST REVEREND LORD. Indeed, from this Beginning [Principio] I have, as it were, already dedicated whatever I am going to publish, since all things are contained in their Beginnings; and TO HAVE PLEASED the learned will be the Beginning of everything.

It is long since I first carried away this hope from You, a prelate learned as few are [docto in paucis Præfule], this hope, good and sure. And so, since you yourself have chosen to hope well of me, I repay hope with hope.

Indeed, since you too seemed to have such confidence as to judge my Deluge [Diluuium meum] worthy to be read by the Most Holy Lord himself, I too dare to be confident. Therefore (may it turn out well) I begin from here this confident writing under your august augury, on the August Calends, at august Brussels, in the house of TREVISIUS [in ædibus TREVISIANIS].

In the year after the Creation of the World 5594

After the restoration [Apocatastafin] that followed the end of the Flood 3937

In the year of the 601st Olympiad [OLYMPIADIS DCI.], still its first year;

From the Birth of CHRIST, the natal or Bethlehem reckoning [Genitali feu Bethleemitico], 1630, which is 1631 of the Incarnation;

From His Birth by the census, or Nazareth reckoning [Cenfuali feu Nazarethano], 1626 [M. DC. XXVI.]

Greetings, my reader, lover of learning [MI LECTOR PHILOMATHES SALVE.]

Since I have now won this much from your goodwill, that you will turn your eyes to these pages, I have obtained a commendation for the subject I pursue here; and the writing, which I undertook precisely so that you would read it, I shall have accomplished if you read it. Yet I shall take your goodwill as given to this field of study, not to my writing. And if anything in that writing goes wrong, I promise that you will be in no way more forgiving [placabilior te nihil polliceor] — out of regard for the honour of the profession.

And indeed I may seem to have gone wrong where I weigh Eratosthenes' opinion on the Sun's distance from the Earth. Following the annotations to

Ptolemy's *Great Syntaxis* [magnam Syntaxin] in the Basel edition, I set it down at 308 myriads of stades, where in Plutarch (mutilated at this point, but filled out from elsewhere) you read only 78 myriads. Indeed, in the division I take those 308 myriads as tenfold, so as to derive from them exactly 366 semidiameters of the Earth from here to the Sun. A bold deed, you will say, and a great overconfidence in criticism. But since Eratosthenes' assertion had already made the globe of the Sun twenty-seven times larger than the Earth when the two are compared, and Pliny too had drawn the matter in this direction, this reasoning, and what needed correcting, suggested themselves of their own accord.

To weave such grammatical quibbles [Grammaticas ... tricas] into a continuous treatise was no business of a mathematician. I want you warned of this once and for all, so that you do not look in vain for trifles in the other works I am going to publish.¹

As for the authors I cite from manuscript — I know you would prefer this [malle te scio] — they are the *Astrolabe* of Messala [Astrolabium Messalæ], part of Eben mezuphi, and an Anonymous. I came upon them here and there twenty years ago and placed them, along with many other good ones [cum alijs bonis ab multis]², in the library of the most distinguished André Arnaud [ANDREÆ ARNAVDI], lord of Mira-Vallis [Miræ-Vallis Toparchæ] and governor of Forum Elucororum (they call it Forcalcarium [Forcalquier]). There they are. I wanted you to know this — and to fare well.

On the Discovery of the Reverend Master Govaert Wendelen [GODEFRIDI WENDELINI], of Herk [Hercani], Pastor of the Bethasii [Bethasiorum Paistoris]

Phaethon bent the Sun aslant along pathless ways, and from this was born labour for every astronomer. Wendelen [VENDELINVS] would not suffer that reproach [inuidiam]: so that so many ages need not toil, he teaches the road to run more truly.

Antonius Piperus, Licentiate in Sacred Theology [S. T. L.], parish priest of Tienen [Plebanus Thenenſis].

Epigram on the *Loxias* of the Reverend and Most Learned Master Govaert Wendelen, Polymath [IN LOXIAM ... D. GODEFRIDI WENDELINI Polyhifitoris EPIGRAMMA.]

The path of Phoebus, his wandering track, undiscovered and obstructed until now, surveyed with diligence and keen care, lays itself wholly open to you, Wendelen. And now that the doors of things stand open for all to see, Apollo

¹a handwritten mark stands over the printed word "Grammaticas" in this copy.

²the printed "ab" does not construe and is left untranslated; a later hand has struck it through in this copy

owes you this thanks: that, his circuit of fixed extent laid open, he may at last cease to be called Loxias.

I. Casperius Gevartius [Jan Caspar Gevaerts], jurisconsult [I. C.], and Clerk [Ab Actis] to the Senate and People of Antwerp [S. P. Q. Antuerp].

Loxias Off the Road, and the Traveller [LOXIAS IN AVIO, ET VIATOR.]

L. Which way? Where to? By what road does the way lead? Alfonso [Alphonse], Copernicus, Tycho, the path you showed me does not lead aright.

V. Phoebus, you have wandered enough [fat errrafti] [recte: errafti]. From now on a BROTHER gives you, as director of your oblique track, a COMPANION, GUIDIUS [COMITEM GVIDIVM].

Nicolaus Wendelinus [VWendelinus] of Herk [Hercanus], to the Master, his brother [Domino Fratri suo P].

To the Babblers [AD BATTOLOGOS.]

Keep far away, you crowd of twice-cooked-cabbage eaters [Crambes comedonum turba recoctæ], whose tasteless food swells in the mouth; who say the same things so often that they burst their sides. What has been said — let it be enough to have said it once. Whoever you are who seek to become known, reveal what is unknown: to know only what the common crowd knows is ignorance.

Iohannes Acanthius B[?]thasius [B.thasius], to the Master, his most deserving brother [D. Fratri suo Opt. mer].

GOVAERT WENDELEN'S
LOXIAS, OR ON THE
OBLIQUITY OF THE SUN
[GODEFRIDI WENDELINI
LOXIAS SEV DE OBLIQVITATE
SOLIS.]

Chapter One [CAPVT PRIMVM.]

THE OBSERVATIONS OF THE AUTHORS [OBSERVATIONES AUCTORUM.]

"He who first noticed the obliquity of the zodiac [Obliquitatem Zodiaci] opened the doors of things," says Pliny. He who marked out the limit of the obliquity entered them, say I. And he who will determine the bounds of that limit — to him Posterity will award the palm in astronomy.

But while all the practitioners of every age apply themselves to investigating these matters, they have at length accomplished this much

that we should understand this obliquity to be inconstant, and should grasp its limits and bounds [Terminosque, & Confinia], by the following arguments.

Eratosthenes of Cyrene [Eratosthenes Cyrenæus], 204 years before Christ, observing the greatest and least altitude of the Sun above the horizon at the time of each solstice, found the distance between the two tropics to be 11 parts of which the whole circle is 83 — that is, roughly $47^{\circ} 42' 40''$. He took half of this as the obliquity: $23^{\circ} 51' 20''$.

Hipparchus agreed entirely with Eratosthenes, about 130 years before Christ.

Ptolemy [Ptolemæus], 140 years after Christ, asserted the same declination of the zodiac from the equator.

al-Battānī the Arab, in the year 882 from Christ, found the interval between the two tropics to be $47^{\circ} 10'$, and made the greatest obliquity $23^{\circ} 35'$.

Arzachel [al-Zarqālī] the Spaniard [Arzachel Hispanus], 190 years later, in the year of Christ 1072, found $23^{\circ} 34'$.

Almæon Almanioris, nearly 70 years after Arzachel — that is, in 1142 — detected $23^{\circ} 33' 30''$.

Prophatius the Jew [Jacob ben Makhir ibn Tibbon], 160 years after Almæon, found in the year 1300 roughly $23^{\circ} 32'$.

Purbachius [Georg von Peurbach], around the year 1460, observed at Nuremberg

the interval of the tropics at $46^{\circ} 56'$, from which he gave the obliquity $23^{\circ} 28'$.

Domenico Maria Novara [Dominicus Maria], the teacher of Copernicus [præceptor Copernici], judged the obliquity at Bologna in the year 1461 to be $23^{\circ} 29'$.

Bernhard Walther [Bernardus Walterus], at Nuremberg, through the year 1480 and the following years, held with Peurbach that it was $23^{\circ} 28'$.

Johannes Werner [Ioannes Wernerus], at Nuremberg, through the year 1514, pronounced [?] it $23^{\circ} 28' 30''$.

Nicolaus Copernicus, at Frombork [Fruenburgi] in Prussia [Borussia], in the year 1525 gives $23^{\circ} 28' 40''$.

William, Landgrave of Hesse [Wilhelm IV of Hesse-Kassel], measured $23^{\circ} 30'$ at Kassel [Cassellis] in the year 1564.

Tycho Brahe, on the island of Hven in Denmark [in Huenna Insula Daniæ], in the year 1587 and the following years, asserted $23^{\circ} 31' 30''$.

I myself, at Forcalquier [Forcalcarij], a town of Provincia Narbonensis, in the year 1609 and the three following years, had the interval of the two tropics as $47^{\circ} 1\frac{2}{5}'$. From this I found the greatest obliquity of the zodiac to be $23^{\circ} 30' 40''$, noted fairly accurately by gnomonic methods [per Gnomonicas rationes] on very large surfaces [in vastis spacijs].

It is clear, therefore, that from Eratosthenes all the way to Peurbach a continuous decrease was observed, over 1660 years; but from Peurbach up to my own observation there seems now to have been an increase, now again a decrease, in a quite in-

constant manner. Something must lie hidden in this that deceived the observers — quite apart from the fact that error is detected in the authors themselves.

For look: from Eratosthenes to al-Battānī, over 1080 years, the decrease is $16'$. So from al-Battānī to Prophatius, over 420 years, it ought proportionally to have been $6\frac{1}{4}'$; and yet it is only $3'$. Before and after Prophatius, therefore, the decreases became gradually smaller, as if they took place on the diameter of some small circle, according to the ratio of the sines [iuxta rationem sinuum].

It follows that in equal times unequal decreases took place: greater in the time of al-Battānī than in Arzachel's, greater under Arzachel than under Almæon, and finally greater under Almæon than under Peurbach. This too, then, must be held: that the 190 years from al-Battānī to Arzachel produced no less decrease (indeed even more) than the 230 years from Arzachel to Prophatius. The obliquity of al-Battānī will therefore in truth have been $23^{\circ} 36'$, not $35'$. Once this is corrected, there is certainly a remarkable agreement among these observations, which accord with one another proportionally — so that from this alone it is evident what needed correcting.

From al-Battānī to Prophatius the analogy proves that the obliquity [Greek: λόξωσιν] is still decreasing, and the evidence of the eyes shows this to be true. For it has been established, and

demonstrated to me, that from the year 1580 to 1612 the obliquity of the Sun decreased so much that, at a place by some cliffs where the summer Sun, both rising and setting, used long ago to graze the rocks, it no longer reaches that far, but falls noticeably short of the mark [metam declinet] for those watching from the same spot. I myself also detected this, from the year 1604 to 1612 — rather dimly, it is true, but detected it nonetheless.

So far, then, the obliquity has been decreasing; and it is clear that Peurbach and the other practitioners down to my own time agree neither among themselves nor with the truth. Tycho noticed two causes of this; I add a third, and I count these three as the reasons why not only the latest observations but the earlier ones too, and at the same time other matters not yet either noticed or published, have made the treatment of this subject hopeless. They are: refractions, parallaxes, and the latitude of Alexandria. Once these are known, we shall at last, God willing [cum bono Deo], find the solar obliquity — that is, the key of the science of the stars [Clauem sideralis scientiæ], sought in vain by everyone. And first let us look at refractions.

Chapter II [CAPVT II.]

SOLAR REFRACTIONS [REFRACTIONES SOLARES.]

A coin or a pebble lying at the bottom of a bucket cannot be seen if you step back a little from it;

pour in water, and it will now even be thought to float on the surface. This seeing of a thing outside its own true place is called refraction [Refractio], the name being taken from a stick: if you plunge one partly into water, it appears broken [fractus]. The opticians pursue the explanation of this phenomenon [Greek: φαινομένου (phainomenou, "of the phenomenon")].

The air here, which covers us entirely like a flood, does to the Sun, the Moon and the stars just what the water does to the coin: it shows them to our sight outside their true position, and displays them higher than they really are — so much so that the Sun, in the morning before it has risen and in the evening after it has set, appears above the horizon whole, in its full size.

Tycho recorded the greatest refractions at the horizon: for the Sun 34', for the Moon 33', for the stars 30', decreasing at once from there, so that the refractions of the stars cease at an altitude of 20°; those of the Sun and Moon, however, he holds to reach as far as 45° of altitude, as can be seen from his tables [Tabellis].

But just as the air produces these effects, so its constitution, which is not the same always and everywhere, produces refractions now of one size and now of another, often varying even in the same place and on the same day by a sudden change. It is therefore less surprising that practitioners [artificibus]

in different parts of the world do not detect the same values. I myself, in the Provincia Narbonensis, found the horizontal refraction of the stars almost the same as Tycho did in Denmark, and not reaching beyond 18° of

altitude — so I observed. As far as I could make out, however, the solar and lunar refractions also vanish entirely there. How I tracked this down will be set out more fully elsewhere.

Therefore neither in Provence [in Prouincia], nor in Spain, and much less in Syria, Arabia or Egypt, do the refractions of the winter solstice stand in the way of observing the Sun. In Germany the case is quite different: there the winter Sun is raised scarcely 17° , scarcely 15° , scarcely 13° above the horizon, and undergoes refractions of a good many minutes. As a result, the space between the two tropics becomes that much shorter, and so the obliquities of the Sun come out narrower.

Since those practitioners did not notice this, and did not even suspect it, it is no wonder that they went wrong — though theirs is an error that has now ceased to deceive us. The second error therefore follows: on account of parallaxes not well understood, even great men, indeed the very leaders of leaders, went astray. Let us see, then, what we ought to think about these parallaxes.

Chapter III [CAPVT III.]

PARALLAXES OF THE SUN [PARALLAXES SOLIS.]

If we had established how far the Sun stands from the Earth, then on determining the size of the solar parallax

no labour would be needed. As it is, however, since it cannot be established in any other way, we must labour to determine that distance.

This is not the place to recount everything that various authors have held on this matter. I shall bring forward here three opinions of the most distinguished authors, and for this reason: that I must make use of them in investigating the obliquity of the Sun, and they are to be tested against the authors' observations.

Eratosthenes of Cyrene [Eratosthenes Cyrenæus], a mathematician and a truly outstanding philosopher, asserted that the Sun is twenty-seven times larger than the whole Earth, on the testimony of Macrobius [teste Macrobio]. Theodoret, bishop of Cyrrhus [Theodoretus Cyrensis Episcopus], in books 1 and 4 of his *Curationes Graecanicae* [Curationum Græcanicarum], attributes this same opinion to Anaximander and Anaximenes as well. Eratosthenes therefore held that the diameter of the Sun is to the diameter of the Earth as 3 to 1. And since he was well aware that the Sun subtends about $30'$ — that is, that it is distant from us about 120 of its own diameters — he concluded that it is distant from us 360 terrestrial diameters in all; or, as Pliny the Elder indicates (book 2, chapter 23), twelve times as far as the Moon is from us, which comes to the same thing. For antiquity believed that the Moon is distant from us exactly 30

terrestrial diameters, and that it therefore completes its circuit in thirty days; from which, by an analogical

reasoning, it was agreed to believe that the Sun, which accomplishes its year twelve times more slowly, is distant at a twelvefold interval — or rather, since it completes its circuit in 365 days, that it is distant 365 terrestrial diameters.

Twin to this is what I read elsewhere: that by Eratosthenes' determination the Sun is distant from us 3080000 stadia, which yields very nearly the same interval. For they divided the whole perimeter of the Earth into 360 parts, and took a third portion of this circle, namely 120 parts, for the diameter — just as Ptolemy too, in the chords of arcs [subtensis arcuum], or, as they call them, sines, makes the whole sine [totum sinum] 60 degrees. Eratosthenes therefore assessed the diameter of the Earth at 120 parts [Greek: πλατικῶς (platikōs, "roughly, in round figures")]. But he gave each degree 700 stadia, as is established from Strabo, Pliny the Elder, Macrobius and others; so he made the whole diameter of the Earth 84000 stadia — just as Dionysiodorus [Dionysodorus] wrote that half of this, 42000 stadia, lies from the centre of the Earth to its convex surface, on the testimony of Pliny (book 2, last chapter). Dividing the stadia of the solar distance by these stadia of the terrestrial diameter, then, we find that 366 diameters of the Earth come out from here to the Sun — the very numbers that Pliny gives (book 2, chapter 23). So from this too Eratosthenes' meaning is understood.

According to these reckonings, therefore, the greatest parallax of the Sun for Eratosthenes is about 5' — which I wish to be noted above all.

Aristarchus of Samos, seeing that the Moon has no light of its own but is lit by the Sun, observed as closely as he could at how many degrees' distance from the Sun it made its dichotomy [Greek: διχοτομίαν (dichotomian, "bisection" — the Moon seen exactly half-lit)] and appeared exactly halved. He judged that this happened whenever it stood 87 degrees from the Sun. From this it followed, by geometrical demonstrations, that the Sun is nineteen times as far from the Earth as the Moon is from us. Now the Moon is 60 terrestrial semidiameters away, or somewhat more; he therefore judged the Sun to be removed from us to 1140 semidiameters, or perhaps even 1200 — in line with Ptolemy's effort to persuade us that he himself established this very figure from the size of the Earth's shadow and from eclipses, a figure he drew by conjecture from the nineteen-year cycle.

This opinion, by which the Sun is asserted to be nineteen times more remote from us than the Moon, was at once followed with broad assent by Hipparchus, Ptolemy, and all the practitioners [artifices] who have followed down to our own age, with no difference — or certainly a slight one, scarcely worth reporting — producing any divergence among the authors. So their consensus is one: the greatest parallax of the Sun is fully 3', and the diameter of the Earth is to the diameter of the Sun as 2 to 11; from which the Sun is believed to be 167 times the size of the whole Earth [167. partibus maior totâ Terrâ].

At last, after the telescope had been invented, I —

— intent, diligently and stubbornly, on investigating these matters and on observing the quadratures of the Moon, clearly observed, both often on other occasions and notably on 1625 March 15, and again in this very year on the Kalends of June [Calendis Iunij], that the lunar dichotomy occurs at an apparent distance from the Sun of 89 degrees, no less; and I found plainly that the Sun is sixty times as far from us as the Moon is removed from here. There are therefore fully 3460 terrestrial semidiameters from here to the Sun — 1730 diameters, I say, or somewhat more. And since the winter Sun is 108 of its own diameters away from us and the summer Sun 112 (as I found repeatedly and consistently in Provincia Narbonensis from the year 1605 to the year 1612, by letting the Sun into large buildings through an aperture, with the aperture bounded and taken into the computation), it appears that the diameter of the Sun is to the diameter of the Earth as 16 to 1, precisely enough. From this I pronounce the Sun 4096 times larger than the whole Earth [maiores totâ Tellure, partibus 4096.], whatever others may write or think. The greatest parallax, however, I determine to be scarcely one minute — which I shall also confirm in its proper place by many other solid and apodictic demonstrations, through observations both my own and other people's.

This greatest solar parallax of one minute, which I am to confirm elsewhere with careful attention, Kepler too has recently begun to endorse —

first, in the *Commentary on the Star of Mars* [Commentario de Stella Martis], where he admits a parallax for Mars (which, as is established, is twice as great as the Sun's) of scarcely two minutes; from which he is forced to admit scarcely a single minute in the Sun. Again, in his recent *Ephemerides*, by clearly attesting that he acknowledges only a single minute, he has now cast his vote for me most openly.

Let it stand, then, as what is drawn out of this dissertation: that against the solar obliquity, as observed at any given time, there must be set (unless we are content to be deceived) either the parallaxes of Eratosthenes, of about 5'; or the Ptolemaic ones, of 3' in all; or finally our own, the true ones, of only 1'. Once these are applied, and afterwards corrected, we shall have more certain observations and a smoother road for investigating the obliquity — provided, however, that we have the third item, I mean the latitude of Alexandria, well established. Something must now be said about it.

Chapter IV [CAPVT IV.]

THE LATITUDE OF ALEXANDRIA [ALEXANDRIÆ LATITUDO.]

Alexandria, the storehouse of the most ancient observations, is reported by Ptolemy, in book 5 of the *Great Syntaxis* [Greek: τῆς μεγάλης συντάξεως (tēs megalēs syntaxeōs, "of the Great Syntaxis", Ptolemy's work known as the *Almagest*)], to stand off from the equator in latitude by about 30° 58'; or, as he noted in his *Geography* —

his own *Geography* [in *Geographia sua*], roughly [Greek: πλατικῶς (*platikōs*, "roughly, in round figures")], 31 degrees in all. All practitioners up to now have followed this assertion of his. What error, and how great, has arisen from it in astronomical matters we shall say later; here let us examine briefly how far this assertion is in error.

With what instruments Ptolemy derived this latitude of Alexandria from the heavens is not obscure to anyone who reads both his *Geography* and the ancient authors. For we find that such things used to be sought, in former times, by gnomons and by the ratios of the shadows to their style — witness, if nothing else, the last chapter of book 6 of Pliny the Elder, who extols this Greek discovery as one "of the most exquisite subtlety" [*exquisitissimæ subtilitatis inuentionem*]; and it is certain, even from Strabo, that the whole enterprise of the ancient practitioners proceeded by this one route. For that very reason it must necessarily have gone somewhat astray.

For since the Sun pours out its light not from its centre alone but from its whole body or disc, however great that is, it certainly makes the shadows of gnomons shorter by as much as the uppermost edge of its luminous limb is known to stand from its centre — that is, by about 15 minutes [15. *præter propter*]. By those whole 15 minutes, I say, the shadows of gnomons are cut short, and they indicate places nearer the equator.

Therefore Alexandria will no longer be distant from the equinoctial by 30° 58', but, with those 15 minutes added, its latitude will be about 31° 13' [gr. 31. min. 13. *admodum*], or not much less — if it is any less at all.

Indeed, I noticed long ago that it is not only the latitude of Alexandria that should be corrected in this way. When I hold Ptolemy's faulty records [*vitiosas ... denotationes*] of other notable places to this standard as well, I find that they agree very closely indeed with their true position.

And lest I seem to rely on conjecture alone, here is the most trustworthy testimony from antiquity itself — witnesses, I say, beyond all exception: Eratosthenes and Hipparchus, praised by Strabo not once, nor on a single occasion. These authors, the parents as it were of mathematics [*Matheseos velut parentes*], state again and again that 700 stadia must be reckoned to each degree, and that the perimeter of the whole Earth is encompassed by 252000 stadia, as may be seen in Pliny the Elder, Macrobius, Martianus [*Marcianum*], and who not? Now they count 21800 stadia from the equator to Alexandria, on the testimony of Strabo, and that repeatedly. Therefore they hold that Alexandria is distant from the equator by about 31° 8' 35" [gradibus 31. min. 8. sec. 35. *prope modum*]. So they now seem to come very close to the quantity that we found by the gnomonic correction of the shadows [*per Gnomonicam vmbrarum correctionem*], with a difference of only 4 minutes, which is imperceptible.

And indeed, that these things were not put forward without grounds by the great

Eratosthenes and the great Hipparchus, you may gather from the fact that they determined the distances of the fixed stars from the pole very accurately.

It is certainly Eratosthenes' finding that the last star of Cynosura [ultima stella Cynosuræ] was found to be $12^{\circ} 24'$ from the pole, and on that author's authority Hipparchus asserted the same, as Ptolemy testifies in book 1, chapter 7 of the *Geography* [teste Ptolem. lib. i. cap. 7. Geographiæ]. But those practitioners could not have hunted down this distance from the pole except from the star's lowest and highest altitude above the horizon. They therefore cannot have been ignorant of the elevation of the pole, and so the latitude of Alexandria cannot have escaped them either. Since they set it at about $31^{\circ} 9'$ [grad. 31. min. 9. ferme], let us take it as certain that this value is either the true one or very close to the truth.

However, if we choose to strike a middle course between that correction of mine and this assertion of theirs, we shall say that the latitude of Alexandria should be set, accurately enough, at $31^{\circ} 10'$ [gradus 31. min. 10.]. For we shall not stray from the truth if we adopt this as the proper value in what follows — since other considerations also draw us here.

Bartholomæus Crescentius [Bartolomeo Crescenzo], papal mechanician [Pontificius Mechanicus] (engineers, as they call them [Ingeniarios vocant]), complained in his *Nautica Mediterranea* that the geographical tables of the ancients teem with errors and lead the common run of seafarers into the gravest mistakes; and he has drawn up [elabo-] for us a chart [Tabulam] of the Mediterranean Sea, most accurate and most thoroughly corrected. He undertook this, as he says, at great expense and at very frequent risk to his life and liberty, in order to correct the errors of the ancients by his own efforts and with suitable instruments, and to bring to light things hitherto either doubtful or unknown. This Crescenzo, then, places the northern promontory of the island of Pharos [insulæ Phari promontorium boreale] at $31^{\circ} 15'$ of latitude. Now it is established — even on the testimony of the Alexandrian Chronicle [Alexandrinum Chronicon] — that Pharos (a town and a Roman colony, today Castelletto) lies 4 thousand paces [4. millibus passuum] from Alexandria; and, by the agreement of Bellonius [Pierre Belon] and of the coastal charts [Tabularum littoralium], that headland [Greek: ἀκρωτήριον (akrōtērion, "promontory, headland")] is 5 Italian miles in all [milliaria Italica 5. omnino] from the nearest walls of the city of Alexandria. Surely, then, the latitude of Alexandria must be left at $31^{\circ} 10'$, and so what we conjectured before is now demonstrated.

The same Crescenzo, on folio 177, admits that Alexandria is no longer found at the latitude of 31° at which Ptolemy placed it, but that there is a considerable difference; and he even tries to give the reason for it: "Because," he says, "the mainland has perhaps grown out into the sea itself, through the alluvium of the river Nile, which pushes its shores forward" [Quoniam (inquit) forsitan continens excreuerit in ipsum mare, propter alluvionem fluminis Nili, littora sua promouentis]. But this reason is beside the point and unworthy of Crescenzo. For the shore at Alexandria is not sandy; and even granting that it could be pushed forward in this way, the walls of Alexandria have certainly

never moved from their place. It is nearer the truth that the faulty one is Ptolemy's latitude, and that this is why so marked a discrepancy is found.

Moreover, I too have been informed by various sailors and merchants (who did this for me) that the harbour of Alexandria has a latitude of $31^{\circ} 12'$ or $10'$ [graduum 31. min. 12. vel 10.] — so precisely that the latitude of Alexandria itself is the one I stated, $31^{\circ} 10'$. This we shall assume as certain and beyond doubt for what is to be said.

Chapter V [CAPVT V.]

THE OBSERVATIONS CORRECTED [OBSERVATIONES EMENDATÆ.]

Having prepared what pertained to the treatment of this arduous business, let us now see what help we get from the observations made at one time and another by industrious practitioners — but observations nonetheless diligently corrected and weighed, as we said should be done, and moreover enlarged with others hitherto unknown.

[Margin: I.] Those who first cultivated astronomy [Astrologiam] among the Greeks divided the whole circle into 60 parts and reported that eight of these are intercepted between the two tropics, according to Hyginus. Now this was Thales of Miletus [Thales Milesius]. It is established from Laertius [Laërtio] and others that he first brought these studies into Greece, and also that he predicted an eclipse of the Sun, which occurred in the fourth year of the 48th Olympiad [Olympiadis XLVIII. anno quarto], as Pliny the Elder and Solinus write. The same Thales also wrote on the equinoxes and the solstices; and he was in fact the man who defined the interval between the tropics — in his own parts, as I said, eight, which make a full 48 of ours. Consequently the obliquity of the zodiac from the equator was precisely 24° . This was in the year of the world 3384 by our restored chronology [anno Mundi ex restitutione nostra 3384.], which was 584 years before our common era.

Messalla [Māshā'allāh] too may vouch that this obliquity of 24° was once observed. In his *Astrolabe* (in manuscript; I have not seen the printed edition), discussing the obliquity of the Sun as gradually diminished, he records these very 24 degrees of greatest declination as handed down by the Indians. This is certainly worth noting, since Philostratus too, in his *Sophists* [in Sophistis], acknowledges the Indians as astronomers [Astrologos] not to be despised, and older even than the Chaldaeans and Egyptians. But Messalla records no date for this observation. Let us therefore take it as certain that in the age of Thales, in the year I mentioned, 3384, the obliquity was observed to be fully 24° ; and that this was around Miletus and Lydia, at a latitude of about 36° , where the distance of the summer Sun from the zenith was 12° — from which the parallax of the Sun is found to be $12''$ — while the distance of the winter tropic from the zenith was 60° .

with a parallax of $52''$. The excess of the one parallax over the other [Excessus ergo Parallaxeon] is therefore $40''$, and the apparent separation of the tropics

must be reduced by this amount, so that their true distance from each other was $47^{\circ} 59' 20''$; and hence the obliquity [λόξωσις] of the Sun from the equator was fully $23^{\circ} 29' 40''^3$, as the calculations show.

[Margin: II.] After Thales of Miletus, once 380 years had passed — that is, in the 143rd Olympiad [per Olympiadem CXLIII.] — Eratosthenes, from the highest and lowest altitudes of the Sun, found the interval between the tropics to be greater than $47^{\circ} 40'$ but less than $47^{\circ} 45'$, on the testimony of Ptolemy. Since, however, he assumed very large parallaxes, nothing prevents the interval from having appeared to him even above $47^{\circ} 45'$, so that, once his parallaxes were subtracted, he declared it to be below $47^{\circ} 45'$. In reality, therefore, the separation of the tropics was then no less than $47^{\circ} 45'$, and the greatest declination of the Sun came to $23^{\circ} 52' 30''$. This was about the year of the world 3764, that is, about 204 years before our era. So Eratosthenes, splitting the difference between $47^{\circ} 40'$ and $40^{\circ} 45'$ [recte: $47^{\circ} 45'$], fixed it at about $47^{\circ} 42' 30''$; and, reducing these to prime numbers [ad numeros primos], he laid down that the interval of the tropics stands to the circumference of a great circle as 11 to 83, as can be seen in Ptolemy.

[Margin: III.] Hipparchus of Nicaea in Bithynia, Eratosthenes succeeded, and retained those same prime numbers, 11 and 83 — no doubt because his observations persuaded him of it. And since in the 50th year of the third Callippic period, which was the year 3840 from Adam, he settled permanently on the island of Rhodes, devoted himself wholly to writing and applied himself to taking observations, let it be granted that at that time too this interval of the tropics, $47^{\circ} 42' 40''$, was noted in the sky. Hipparchus, however, neglected parallaxes, on the testimony of Ptolemy. Therefore (as we did with the observation of Thales), if we correct these figures by our parallaxes, which at the latitude of Rhodes come to about $40''$, the true distance of the two tropics will remain at about $47^{\circ} 42'$, and hence the greatest declination of the Sun at fully $23^{\circ} 51'$.

After Eratosthenes and Hipparchus the obliquity of the Sun decreased more and more, and quite evidently so within a few years. This I gather from Pliny the Elder, book 36, chapter 10, where he relates that the obelisk set up at Rome in the Campus Martius served as a gnomon; that the mathematician Manlius added a gilded ball to its apex, so that the shadow would gather in upon itself at the ball's top; that a pavement was laid out according to the obelisk's height, so that the shadow at the sixth hour on the day of the winter solstice [Brumæ confecto die, sextâ horâ] would equal it; and that, along rulings of bronze inlaid in it, the shadow would decrease by degrees day by day and then grow again. This was done years before Pliny — about 90 of them. And when Pliny was writing these things, the observation of the longest shadows had already failed to agree for 30 years. Thus not even for sixty years — the span from Manlius to Pliny's youth — had the shadows stayed the same; rather, they had

³half of the $47^{\circ} 59' 20''$ stated in the same sentence is $23^{\circ} 59' 40''$; the page prints "23. 29. 40."

decreased so far that some thought the obelisk had become somewhat twisted, and others that it had settled, and so no longer cast shadows as long as it used to at the winter solstice. Yet foundations had been laid against settling, in proportion to the height of the mass set upon them; and the shadows were found to have changed not on that one obelisk alone but in other places too. From this there arose at the time a twofold opinion about this phenomenon [φαινομένῳ (phainomenōi, "phenomenon")]: "either," he says, "through a discordant course of the Sun itself and some change in the heavens, or through the whole Earth being displaced somewhat from its centre" [siue (inquit) Solis ipsius dissono cursu, & coeli aliquâ ratione mutato, siue Vniuersâ tellure aliquid à centro suo dimotâ.].

Indeed, if we suppose that the Earth inclines ever so slightly either to the south or to the north, the ancient solstitial shadow-marks will change not a little — such as those in the well at Syene, in the observatory of Eudoxus, in the temple of Serapis, on the Roman obelisk, and very many on countless sundials [in Sciatericis infinitis] everywhere. Indeed, since people at that time saw them change even within their own lifetime, they could suspect nothing else than that this was happening because the Earth had been displaced from its centre.

Since, then, the shortening of the shadows became so noticeable within 60 years, how great shall we judge it

Certainly not less than one minute. Accordingly, reason proves that in the nearly three hundred years from Hipparchus to Ptolemy the obliquity decreased by about five minutes, so that under Ptolemy it was about $23^{\circ} 46'$, and not (as he tells us) the same as under Hipparchus. For he himself — see — confirms my assertion as follows.

[Margin: IV.] The fifth book of the *Great Syntaxis* [magnæ Syntaxeōs], which teaches how to track down the distance of the Moon from the Earth by the parallaxic rules, reports that the Moon, at dichotomy [Greek: διχότομον (dichotomon, "halved" — the Moon at half phase)], stood in the colure of the summer tropic and was carried as far as possible toward the north. Its apparent distance from the zenith of Alexandria was 2 degrees and an eighth of one — that is, $2^{\circ} 7' 30''$; but once the sighting is corrected for parallax, the true distance by which the Moon stood from the Alexandrian zenith comes to $2^{\circ} 5' 25''$. At that time, moreover, the Moon was $5^{\circ} 17' 45''$ from the ecliptic, the Sun's path (as it usually is even today). The distance of the tropic from the Alexandrian zenith was therefore at that time $7^{\circ} 23' 10''$. But Alexandria is distant from the equator, as we have said, $31^{\circ} 10'$. It follows, therefore, that the Sun's greatest declination was then $23^{\circ} 46' 50''$, or perhaps somewhat less. And in what year Ptolemy (or Theon, Ptolemy's contemporary) made these observations is not difficult to work out. It is neces-

-sary, then, that this happened precisely when the Dragon's Head [Caput Draconis] stood near the vernal equinox, and, with the Sun placed at the same point, the Moon was in quadrature, near the very colure of the summer solstice. This took place in the year 126 of our common reckoning, which is the year

of the world 4094. In that year, therefore, the Sun's obliquity is found to be about $23^{\circ} 46' 50''$, just as I had already conjectured a little earlier.

[Margin: V.] Pappus of Alexandria, in Book 6 of the *Mathematical Collections*, proposition 35, affirms that in his time the diameter of the summer tropic had the same ratio to the diameter of the sphere as 529 has to 629, square to square [quam habent 529. quadratum, ad quadratum 629.]; and that the line drawn from the centre of the sphere to the centre of the tropic is to the semidiameter of the tropic as 10 is to 23. From this twofold statement of these proportions, therefore, it is evident that the distance of the SUMMER TROPIC from the equator observed at that time was precisely $23^{\circ} 30'$ — about what is found today. And yet not even long after Pappus was the obliquity [λόξωσις] so small; and in the 255 years between Ptolemy and Pappus so great and so sudden a change in the obliquity could not have happened. What are we to say here? Pappus himself answers in a word, in that what he reports is an observation made at the SUMMER TROPIC. He noted, that is, how far the Sun at the summer solstice declined from the zenith of Ale-

-xandria, which, following Ptolemy, he believed to be distant from the equator precisely $30^{\circ} 58'$, as we have already shown; and he found the degrees I mentioned, $23^{\circ} 30'$. But since the equator is a full 12 minutes farther from the Alexandrian zenith — $31^{\circ} 10'$, as we demonstrated above — that tropic was assuredly $23^{\circ} 42'$ in all from the equator. And since the Sun stood $7^{\circ} 30'$ from the zenith, our parallax adds $7''$, so that in Pappus's century the true obliquity was $23^{\circ} 42' 7''$. This period was about the year of Christ 400, since Pappus succeeded Theon, as is clear from the *Commentaries on Ptolemy*; and the year of the world indicated is about 4368.

[Margin: VI.] An ancient Arab, Eben-Mezuphi, once fell into my hands — a writer who bestowed a few, but golden, records for the investigation of the truth. He reports that in the year of the Hegira [Alhigeræ] 210, in the city of Baghdad [Bagdet], with *many learned men* assembled, the interval between the two tropics was observed to be $47^{\circ} 13'$, and that once the parallax [diuerfitate aspectus] was removed it was judged to be $47^{\circ} 10'$; from which the obliquity of the zodiac was determined as $23^{\circ} 35'$. This is the very obliquity that al-Battānī published in the same century; Messalla in the *Astrolabe* [in Astrolabio], and Alfraganus [al-Farghānī] with him, also recorded it, adding that it was obtained under King Ioannes [Ioanne Rege] — or was it a caliph? In weighing this observation

against our parallaxes, the interval must have been only $47^{\circ} 12' 20''$; and so the true declination is understood to have been $23^{\circ} 36' 10''$ in the Christian year 827, which was the year of the world 4795 — the time when, as the *Catalogue of the Caliphs* also reports, that King Ioannes lived.

[Margin: VII.] al-Battānī, in chapter 4, found (as he says) that the Sun's greatest summer altitude was distant from the zenith of Aracta [ar-Raqqa] $12^{\circ} 26'$, and the winter one $59^{\circ} 36'$; from which he gives the difference as 47°

10⁴. But (as far as I can see) he followed in the footsteps of the Caliph Ioannes and subtracted Ptolemaic parallaxes from the sighting. Hence the difference as observed and seen must have been about 47° 12'; and limiting this by our parallaxes, we found 47° 11' 20". Therefore the Sun's greatest declination must then have been 23° 35' 40", and that around the year of Christ 882, that is, of the world 4850.

[Margin: IIX.] Eben-Mezuphi, in the Yazdegerdian year [anno Iezdagirdico] 325, found 47° 10½', nearly, between the two tropics. Since he says "nearly" [*fermè*], he means it to be understood as even less than the half; let it be, then, 10 minutes and 20 seconds. Therefore the sighting, corrected by our parallaxes, will give an interval of 47° 9' 40", and the obliquity of the zodiac will come out at 23° 34' 50" in all, and that around the year of Christ 957, which was the year of the world 4925.

[Margin: IX.] Arzachel the Moor [Arzachel Maurus; al-Zarqālī], 190 years after al-Battānī, noted that the Sun's declination did not exceed 23° 34'. Correcting this by our parallaxes, as in

Spain, I see that it should be set at about 23° 33' 40"; and that in our year 1072, which was the year 5040 from the founding of the world.

[Margin: X.] Almæon, likewise a Moor, 70 years later found the declination to be 23° 33' 30"; corrected by our parallaxes, this becomes 23° 33' 10", for our year 1142, which was the year of the world 5110.

[Margin: XI.] Prophatius the Jew [Prophatius Iudæus], 160 years later or even more, asserted a declination of 23° 32'. Examining it by our parallaxes, I find that it was at least 23° 31' 40", wherever, or whenever, he lived. He is thought, however, to have lived around our year 1300, that is, the year of the world 5268; others reckon him a full 20 years later.

[Margin: XII.] A certain anonymous observer, in the year 1364 in Provence [in Prouincia], recorded the interval between the two tropics as found to be 47° 3½'. Limited by our parallaxes, this comes out at 47° 2' 50". The obliquity of the Sun was therefore at that time 23° 31' 25", in that year of ours, which was the year of the world 5332.

[Margin: XIII.] Bernardus Walterus [Bernhard Walther], a citizen of Nuremberg, found in the year 1476, by the Ptolemaic rules, the chord of the Sun's distance from the zenith [Chordam Solis distantis à Vertice] to be 44890 — certain, as he writes — and he represents it as the same in the following years too. The Sun was therefore apparently distant from Walther's zenith by 25° 56' 26", but in truth, by our parallaxes, by 25° 56' exactly; and that at Nuremberg, whose latitude is established to be 49° 27'. Yet the ob-

-servatory, where he was living at the time, was distant from the equator about 49° 26' 55", as I clearly find from his equinoctial chords weighed against

⁴the 4 is only partly inked on the leaf; its bar and stem survive

the true motion of the Sun (which I hold to be most exact, and indeed everlasting). The interval of the solar obliquity from the equator was therefore $23^{\circ} 30' 55''$ in all, and that in the year which was the year of the world 5444.

[Margin: XIV.] Tycho Brahe, in the year 1587, recorded the greatest visible summer declination as $23^{\circ} 29' 55''$ in all; and, adding that Ptolemaic parallax of his, $1' 35''$, he pronounced the obliquity to be $23^{\circ} 31' 30''$ — the value everyone now follows on account of the authority of so great a man. By our parallaxes, however, it rises only to $23^{\circ} 30' 27''$, and that in the year 5555 from the founding of the world.

[Margin: XV.] I myself, through the year 1609 and the three following, in Narbonese Gaul [in Gallia Narbonensi] at a latitude of $43^{\circ} 54'$ most exactly, found the Sun's summer declination to be $23^{\circ} 30' 5''$, quite accurately; and, adding the parallax, I obtained $23^{\circ} 30' 25''$. That was the year of the world 5577. So much for the observations.

Chapter VI [CAPVT VI.]

THE APOCATASTASIS OF THE OBLIQUITIES [OBLIQUITATUM APOCATASTASIS.]

I come now to what is the subject of the disputation undertaken: that it may at last be known how great

the greatest and how great the least obliquity is, and (what follows from this) its apocatastasis [periodic restoration].

To attempt the matter by geometrical demonstrations — since no one has yet noticed the increase — is something all who have contemplated these things cry *Manum de tabula* ["hands off the panel"] against. To be admitted into these inner recesses with the mechanical help of sines and numbers, trying the approach first one way and then another until a door is found that receives us glad and exultant, is already a great deal. Having long attempted everything on this motion with various hypotheses, I at last found that the whole matter stands as these propositions state.

Proposition I [Propositio Prima.]

The least obliquity of the Sun is $23^{\circ} 30'$ in all.

Proposition II [Propositio Secunda.]

The greatest obliquity of the Sun is $24^{\circ} 30'$.

Proposition III [Propositio Tertia.]

The mean obliquity of the Sun is 24° exactly.

Proposition IV [Propositio Quarta.]

The libration [Libramentum] of the increasing and decreasing obliquity takes place as if on the diameter of a small circle [Circellus] whose centre lies on the solstitial colure, 24° exactly from the equator; its semidiameter is $30'$.

Proposition V [Propositio Quinta.]

The apocatastasis of the libration is completed in 9840 tropical years.

Proposition VI [Propositio Sexta.]

The least obliquity will occur in the year of Christ 1860, which will be the year 5828 from Adam.

Postulate [Postulatum.]

Let the beginning of the anomaly of this libration be set at the point of least obliquity, namely in the year 1860 already mentioned, and likewise 9840 years before it, or as many after.

Table of the Motions of the Anomaly of the Obliquity [TABVLA MOTVVM ANOMALIÆ OBLIQVITATIS.]

Years	Motion	Years	Motion	Years	Motion	Years	Motion
1	0° 2' 12"	10	0° 21' 57"	100	3° 39' 31"	1000	36° 35' 7"
2	0° 4' 23"	[?]0	0° 43' 54"	200	7° 19' 2"	2000	73° 10' 15"
3	0° 6' 35"	3[?]	1° 5' 51"	300	10° 58' 32"	3000	109° 45' 22"
4	0° 8' 47"	40	1° 27' 48"	400	14° 38' 3"	4000	146° 20' 30"
5	0° 10' 59"	50	1° 49' 45"	500	18° 17' 34"	5000	182° 55' 37"
6	0° 13' 10"	60	2° 11' 43"	600	21° 57' 5"	6000	219° 30' 45"
7	0° 15' 22"	70	2° 33' 40"	700	25° 36' 35"	7000	256° 5' 52"
8	0° 17' 34"	80	2° 55' 37"	800	29° 16' 6"	8000	292° 41' 20"
9	0° 19' 45"	90	3° 17' 34"	900	32° 55' 37"	9000	329° 16' 7"
10	0° 21' 57"	100	3° 39' 31"	1000	36° 35' 7"	10000	5° 51' 15"

Epochs or Roots of the Anomalies, and from them the Obliquities [Anomaliarum EPOCHÆ feu Radices & hinc OBLIQVITATES.]

Epoch	Anomaly	Obliquity
Of the founding of the world [ORBIS CONDITI]	146° 46' 50"	24° 25' 6"
Of the Flood, at its end [DILVVII definentis]	207° 25' 0"	24° 26' 37"
Of the Olympiads [OLYMPIADVM]	263° 35' 0"	24° 3' 21"
Of Jesus Christ [CHRISTI IESV]	291° 56' 30"	23° 48' 48"

With these things thus established, let us bring the observations to the reckoning.

Under the authors [SVB AVC- TORIBVS]	Year of the World [ANNO Mundi]	^s	Year of Christ [Christi]	Anomaly [Anoma- lia Gr. M.]	Obliquity computed [OBLIQVITAS Supputata G. M. S.]	Obliquity observed [Obseru- ata]	Difference in seconds [Differentia Secund.]
Thales of Miletus [Thale Milesio]	3384	before [ANTE]	584	270° 35'	23° 59' 41"	40	1 plus
Eratos- thenes [Eratos- thene]	3764		204	284° 30'	23° 52' 30"	30	0
Hip- parchus [Hippar- cho]	3840		128	287° 16'	23° 51' 6"	0	6 plus
Ptolemy [Ptolemæo]	4094		126	296° 33'	23° 46' 35"	50	15 minus
Pappus of Alexandria [Pappo Alex.]	4368	after Christ [POST CHRISTVM]	400	306° 35'	23° 42' 6"	7	1 minus
Ioan. Calipha.	4795		827	322° 12'	23° 36' 18"	10	8 plus
al-Battānī [Albateg- nio]	4850		882	324° 12'	23° 35' 40"	40	0
Eben- Mezuphi	4925		957	326° 58'	23° 34' 51"	50	1 plus
Arzachel [Arzachele]	5040		1072	331° 9'	23° 33' 43"	40	3 plus
Almaeon [Almæone]	5110		1142	333° 44'	23° 33' 6"	10	4 minus
Prophatius [Propha- tio]	5268		1300	339° 9'	23° 31' 58"	40	18 plus
an anony- mous author [Anonymo]	5332		1364	341° 51'	23° 31' 30"	25	5 plus
Walther [VValtero]	5444		1476	345° 57'	23° 30' 54"	55	1 minus
Tycho [Tychone]	5555		1587	350° 1'	23° 30' 28"	27	1 plus
Wendelen [VVen- delino]	5577		1609	350° 49'	23° 30' 24"	25	1 minus

It is clear, then, how accurately our hypothesis, as comprised in the six propositions above, answers to the observations of these two thousand two hundred years. For it achieves this with such closeness that the calculations nowhere stray by a sixth part of one minute; often they agree even to the very seconds [secunda scrupula], which might seem little short of a prodigy. For what is short by a quarter [of a minute] in Ptolemy is in excess in Prophatius; and anyone who weighs for himself how much allowance must be made for the slippery method and practice of observing will marvel that there is not even more wavering than this.

For the rest, just as on this account I shall win favour with the posterity that will follow us, as I trust; so, if any hidden error still lurks — especially in defining and more accurately establishing the period of the orbit [orbis periodici tempore] — I leave it to that posterity to correct after ten thousand years.

CAPVT VII.

COROLLARIES OF THIS DOCTRINE [COROLLARIA HUIUS DOCTRINÆ]

From this most laborious, but also most accurate, inquiry there follow for me some very fine corollaries.

First: from the reliability of the calculations, which agree with the observations of the authors, it is evident that from Thales to Walther (to say nothing of myself), over the 2060 intervening years, the solar obliquity [Greek: λόξωσιν (loxōsin, "obliquity")] decreased continuously, and indeed proportionally. It therefore necessarily follows that under Tycho the obliquity was none other than one still decreasing, and had not begun to increase anew, as he supposed.

Second: it also follows that the Tychonic parallaxes, which argue for an increase, are erroneous, and must therefore be taken much smaller. Thus, when Tycho added 1' 35" to the apparent summer declination of 23° 29' 55", so that the whole declination came to 23° 31' 30", he should have applied only 32" — that is, one third of the Ptolemaic parallax he had assumed [Parallaxeos Ptolemaicæ] — so as to make 23° 30' 27".

Third: it is clear that no solar parallaxes, however and from wherever they are drawn, keep faith with the calculations except Kepler's [Keplerianas] and mine. Indeed, since these do so, no others need be sought; and the Sun's greatest parallax is therefore rightly and correctly set at one minute only. So it is no longer the obliquities that are confirmed from the parallaxes, but our parallaxes that are confirmed from the obliquities once understood, and sealed, as it were, with a sacred seal.

⁵Before
/ after
Christ
— no
head
printed

Fourth: once the Tychonic parallaxes are cut back, it is certain that his solar refractions too must be shortened.

Finally, these things once understood will be the PRINCIPLE [PRINCIP-IVM] of investigating the solar eccentricity, of correcting the prosthaphaereses, of the motion of the fixed stars, of the length of the year [Annuae quantitatis], of the lunar hypotheses, and of all the planetary revolutions.

APPROBATIO.

This little book, entitled *Loxias, or On the Obliquity of the Sun*, composed by the Reverend Lord Govaert Wendelen [Godefridum VVendelinum] and treating its matter most carefully, is worthy to see the light, especially since it contains nothing contrary to the Faith or to good morals. Given at Antwerp, this 9th of August 1626.

Zegerus van Hontsum, Licentiate in Sacred Theology [S. T. Licent.], Penitentiary of Antwerp, and also Censor of Books.

TABLE OF THE SOLAR OBLIQUITIES [TABVLA SOLAR-IVM OBLIQVITATVM:]

[Margin: (set vertically along the left edge of the table) Degrees of the anomaly of the solar obliquities, extended through the whole circle [Gradus Anomaliae Obliquitatum Solarium expanfi per totum Circulum:]]

Obliquity [g. Anom.m. f.]		Anom.	Anom.	Obliquity [g. m. f.]		Obliquity [g. Anom.m. f.]		Anom.
1	23° 30' 0"	359	31	23° 34' 17"	329	61	23° 45' 27"	299
2	23° 30' 1"	358	32	23° 34' 34"	328	62	23° 45' 55"	298
3	23° 30' 2"	357	33	23° 34' 51"	327	63	23° 46' 23"	297
4	23° 30' 4"	356	34	23° 35' 8"	326	64	23° 46' 51"	296
5	23° 30' 7"	355	35	23° 35' 26"	325	65	23° 47' 19"	295
6	23° 30' 10"	354	36	23° 35' 44"	324	66	23° 47' 48"	294
7	23° 30' 13"	353	37	23° 36' 3"	323	67	23° 48' 17"	293
8	23° 30' 17"	352	38 [recte: 38]	23° 36' 22"	322	68	23° 48' 46"	292
9	23° 30' 22"	351	39	23° 36' 41"	321	69	23° 49' 15"	291
10	23° 30' 27"	350	40	23° 37' 1"	320	70	23° 49' 45"	290
11	23° 30' 33"	[?]49	41	23° 37' 21"	319	71	23° 50' 15"	289
12	23° 20' [recte: 30'] 39"	[?]48	42	23° 37' 42"	318	72	23° 50' 44"	288
13	23° 30' 46"	347	43	23° 38' 3"	317	73	23° 51' 14"	287
14	23° 30' 5[?]2"	346	44	23° 38' 25"	316	74	23° 51' 44"	286
15	23° 31' 1"	345	45	23° 38' 47"	315	75	23° 52' 15"	285
16	23° 31' 9"	344	46	23° 39' 9"	314	76	23° 52' 45"	284
17	23° 31' 18"	343	47	23° 39' 32"	313	77	23° 53' 16"	283
18	23° 31' 28"	342	48	23° 39' 55"	312	78	23° 53' 46"	282
19	23° 31' 38"	341	49	23° 40' 19"	311	79	23° 54' 17"	281
20	23° 31' 49"	340	50	23° 40' 43"	310	80	23° 54' 48"	280

Obliquity [g. Anom.m. f.]			Obliquity [g. m. f.]			Obliquity [g. Anom.m. f.]		
Anom.		Anom.	Anom.		Anom.	Anom.		Anom.
21	23° 32' 0"	339	51	23° 41' 7"	309	81	23° 55' 19"	279
22	23° 32' 11"	338	52	23° 41' 32"	308	82	23° 55' 50"	278
23	23° 32' 23"	337	53	23° 41' 57"	307	83	23° 56' 21"	277
24	23° 32' 36"	336 ⁶	54	13° [recte: 23°] 42' 22"	306	84	23° 56' 52"	276
25	23° 32' 49"	335 [recte: 335]	55	23° 42' 47"	305	85	23° 57' 23"	275
26	23° 33' 2"	334	56	23° 43' 13"	304	86	23° 57' 54"	274
27	23° 33' 16"	333	57	23° 43' 39"	303	87	23° 58' 26"	273
28	23° 33' 30"	332	58	23° 44' 6"	302	88	23° 58' 57"	272
29	23° 33' 45"	331	59	23° 44' 33"	301	89	23° 59' 28"	271
30	23° 34' 1"	330	60	23° 45' 0"	300	90	24° 0' 0"	270

PER SINGVLOS GRADVS ANOMALIÆ.

[Table of the Solar Obliquities,] for each degree of anomaly — continued from the facing page.

Obliquity (g. Anom.m. s.)			Obliquity (g. Anom.m. s.)			Obliquity (g. Anom.m. s.)		
Anom.		Anom.	Anom.		Anom.	Anom.		Anom.
91	24° 0' 32"	269	121	24° 15' 27"	239	151	24° 26' 15"	209
92	24° 1' 3"	268	122	24° 15' 54"	238	152	24° 26' 30"	208
93	24° 1' 34"	267	123	24° 16' 21"	237	153	24° 26' 44"	207
94	24° 2' 6"	266	124	24° 16' 47"	[?]36	154	24° 26' 58"	206
95	24° 2' 37"	265	125	24° 17' 13"	235	155	24° 27' 11"	205
96	24° 3' 8"	264	126	24° 17' 38"	234	156	24° 27' 24"	204
97	24° 3' 39"	263	127	24° 18' 3"	233	157	24° 27' 37"	203
98	24° 4' 10"	292 [recte: 262]	128	24° 18' 28"	232	158	24° 27' 49"	202
99	24° 4' 41"	261	129	24° 18' 53"	231	159	24° 28' 0"	201
100	24° 5' 12"	260	130	24° 19' 17"	230	160	24° 28' 11"	200
101	24° 5' 43"	259	131	24° 19' 41"	229	161	24° 28' 22"	199
102	24° 6' 14"	258	132	24° 20' 5"	228	162	24° 28' 32"	198
103	24° 6' 44"	257	133	24° 20' 28"	227	163	24° 28' 42"	197
104	24° 7' 15"	256	134	24° 20' 51"	226	164	24° 28' 51"	196
105	24° 7' 45"	255	135	24° 21' 13"	225	165	24° 28' 59"	195
106	24° 8' 16"	254	136	24° 21' 35"	224	166	24° 29' 7"	194
107	24° 8' 46"	253	137	24° 21' 57"	223	167	24° 29' 14"	193
108	24° 9' 16"	252	138	24° 22' 18"	222	168	24° 29' 21"	192
109	24° 9' 45"	251	139	24° 22' 39"	221	169	24° 29' 27"	191
110	24° 10' 15"	250	140	24° 22' 59"	220	170	24° 29' 33"	190
111	24° 10' 45"	249	141	24° 23' 19"	219	171	24° 29' 38"	189
112	24° 11' 14"	248	142	24° 23' 38"	218	172	24° 29' 42"	188
113	24° 11' 43"	247	143	24° 23' 57"	217	173	24° 29' 47"	187

⁶first figure damaged on the leaf; its upper part is that of a 3

Obliquity (g. Anom.m. s.)			Obliquity (g. Anom.m. s.)			Obliquity (g. Anom.m. s.)		
Anom.		Anom.	Anom.		Anom.	Anom.		Anom.
114	24° 12' 12"	246	144	24° 24' 16"	216	174	24° 29' 50"	186
115	24° 12' 41"	245	145	24° 24' 34"	115 [recte: 215]	175	24° 29' 53"	185
116	24° 13' 9"	244	146	24° 24' 52"	214	176	24° 29' 56"	184
117	24° 13' 37"	243	147	24° 25' 9"	213	177	24° 29' 58"	183
118	24° 14' 5"	242	148	24° 25' 28"	212	178	24° 29' 59"	182
119	24° 14' 33"	241	149	24° 25' 43"	211	179	24° 30' 0"	181
120	24° 15' 0"	240	150	24° 25' 59"	210	180	24° 30' 0"	180

VSVS TABVLÆ.

Use of the Table

This table is easy to use, and its use is plain at first sight. For I work out, for a given time, the anomaly of the Sun's obliquity from the table set out on fol. 29. With the anomaly found, I enter the column of anomaly numbers; and once the one I am looking for turns up, I at once have the degrees noted against it, with the corresponding minutes and seconds — and that is the obliquity for the given time. An example:

I want to know how great the obliquity of the Sun was in the time of Moses, in the year of the world 2454.

	Anomaly
<i>Radix annorum mundi est</i> [The root of the years of the world is]	146° 45' [recte: 46'] 50"
Motus Anomalie 2000 annis [Motion of the anomaly in 2000 years]	73° 10' 15"
Anom. annorum 400 est [Anomaly of 400 years is]	14° 38' 3"
Anom. annorum 50 est [Anomaly of 50 years is]	1° 49' 45"
Denique Anom. ann. 4 est [Finally, anomaly of 4 years is]	0° 8' 47"
<i>Summa annorum</i> [Sum of the years] 2454	<i>Anom.</i> 236° 33' 40"

With this anomaly now found (which lies between 236 and 237), I enter the table; and after interpolating by proportional parts, I declare that the greatest obliquity of the Sun was then about 24° 16' 33".

I should also like to track down the greatest obliquity in the time of the astronomer Timocharis, in the year 3675.

	Years	Anomaly
<i>Radix annorum mundi est</i> [The root of the years of the world is]		146° 46' 50"
Pro annis [For years]	3000 funt [are]	109° 45' 22"
Pro annis	600 funt	21° 57' 5"
Pro annis	70 funt	2° 33' 40"
Pro annis	5 funt	0° 10' 59"

	Years	Anomaly
<i>Summa Annorum</i> [Sum of the years] 3675	<i>dat Anom.</i> [gives the anomaly]	281° 13' 56"

The obliquity in the time of Timocharis was therefore exactly 23° 54' 12". And in fact the observations that Ptolemy reports in Book VII, chapter III, prove it to have been just that great, as will become clear in our lunar work [in *Lunaribus nostris*]; and the remarkable fruit of this discussion will then come to light.

Finally, to obtain the obliquity for this present year of ours, 1626, I investigate it [?] this way.

	Years	Anomaly
<i>Radix Chrifti eft.</i> [The root of Christ is]		291° 56' 30"
Pro annis [For years]	1000 funt [are]	36° 35' 7"
Pro annis	600 funt	21° 57' 5"
Pro annis	20 funt	0° 43' 54"
Pro annis	6. funt	0° 13' 10"
<i>Summa Anorum.</i> [Sum of the years]	1626,	351° 25' 46"

Since, then, the anomaly is greater than 351 and less than 352, I find by proportional parts that this year's obliquity is precisely 23° 30' 20". And so, by this method, the obliquities can be investigated for any given time. For the present, let this much be said about them.

FINIS. [The End.]

[Greek: ΤΟ ΝΟΗΣΑΙ ΚΑΙΡΟΣ ΑΡΙΣΤΟΣ / ΚΑΙ ΤΟ ΔΙΔΑΞΑΣ[?]ΑΙ ΕΙΔΟΤΙ ΠΑΙΤΕΡΟΝ (to noēsai kairos aristos / kai to didaxas[?]ai eidoti raiteron — "In understanding, due measure is best; and to teach [?] is easier for one who knows")]

Pind. in Olymp. [Pindar, in the *Olympians*.]

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Blank page (no printed matter; scattered specks only).

Blank page (no printed matter; scattered specks and a stain along the lower outer corner only).

Back cover (no printed matter): bare board with a paper label at the upper outer corner carrying a few handwritten characters [Illegible: handwritten label, not part of the printed book], and a second small label at the foot of the spine edge.