CHAPTER XVII.

The Transit of Venus over the Sun:

OR

AN ASTRONOMICAL TREATISE

ON

THE CELEBRATED CONJUNCTION

OF

VENUS AND THE SUN

ON THE 24th of NOVEMBER 1639.

By JEREMIAH HORROX.

CHAPTER I.

The occasion, excellence and utility of the Observation.

Soon after the commencement of my astronomical studies, and whilst preparing for practical observation, I computed the Ephemerides of several years, from the continuous tables of Lansberg. Having followed up the task with unceasing perseverance, and having arrived at the point of its completion, the very erroneous calculation of these tables, then detected, convinced me that an astronomer might be engaged upon a better work. Accordingly I broke off the useless computation, and resolved for the future with my own eyes to observe the positions of the stars in the heavens; but lest so many hours spent on Lansberg should be entirely thrown away, I made use of my Ephemerides in ascertaining the positions of the distant planets, so that I was enabled to predict their conjunctions, their appulses to the fixed stars, and many other extraordinary phenomena. Delighted for the time with such a foretaste of the science, I took great pains carefully to prepare myself for further observation.

Whilst thus engaged, I received my first intimation of this remarkable conjunction of Venus with the Sun; and I regard it as a very fortunate occurrence, inasmuch as about the beginning of October 1639, it induced me, in expectation of so grand a spectacle, to observe with increased attention. I pardon, in the meantime, the miserable arrogance of the Belgian astronomer, who has overloaded his useless tables with such unmerited praise, and cease to lament the misapplication of my own time, deeming it a sufficient reward that I was thereby led to consider, and to foresee, the appearance of Venus in the Sun. But on the other hand, may Lansberg forgive me that I hesitated to trust him in an observation of such importance; and, from having been so often deceived by his pretension to universal accuracy, that I disregarded the general reception of his tables. Besides, I thought it my duty to consult other calculations, especially those of Rudoiphi, which Hortensius has vainly laboured to depreciate. Daily experience indeed convinces me that what Lansberg says (whether with less modesty or truth I know not) of his own tables may be affirmed with propriety of Kepler's, namely, that they are superior to all others.

"Quantum lenta solent inter viburna cupressi."

The more accurate calculations of Rudolphi very much confirmed my expectations; and I rejoiced exceedingly in the hope of seeing Venus, the rarity of whose appearance in conjunction with the Sun, had induced me to pay less attention to the more common phenomena of the same kind visible in the planet Mercury; for though hitherto these phenomena have been observed on one occasion only, the science of astronomy holds out to us the assurance that they will, even in our time, frequently appear.

But lest a vain exultation should deceive me, and to prevent the chance of disappointment, I not only determined diligently to watch the important spectacle myself but exhorted others whom, I knew to be fond of astronomy to follow my example; in order that the testimony of several persons, if it should so happen, might the more effectually promote the attainment of truth; and because by observing in different places, our purpose would be less likely to be defeated by the accidental interposition of the clouds, or any fortuitous impediment.

The chance of a clouded atmosphere caused me much anxiety, for Jupiter and Mercury were in conjunction with the Sun almost at the same time as Venus. This remarkable assemblage of the planets, (as if they were desirous of beholding, in common with ourselves, the wonders of the heavens, and of adding to the splendour of the scene), seemed to forebode great severity of weather Mercury, whose conjunction with the Sun is invariably attended with storm and tempest, was especially to be feared. In this apprehension I coincide with the opinion of the astrologers, because it is confirmed by experience; but in other respects I cannot help despising their more than puerile vanities.

I have thought it right, independently of the remarks upon the planets which I have elsewhere made, to publish a separate treatise upon this observation, on account of its great practical utility and excellence above all others, which I trust I may be permitted to set forth without being accused of ostentation.

In the first place, I found that it was well suited to correct the mean motion of Venus, on account of two advantages, which other observations do not possess.

The one consists in the difficulty, which might be occasioned by the parallax of the orbit, or the second equation, being removed from this observation. I speak in accordance with the opinion of Copernicus, whom alone I shall follow in his general hypotheses. The conjunction placing the bodies of the sun, of the earth, and of the planet herself in one line has removed all possibility of deception from a spectacle, which in other positions presents difficulties scarcely possible to overcome.

The other advantage results from the proximity of Venus to the earth, and her convenient situation as respects the sun; whence it happens that one minute in her longitude alters her apparent situation nearly three minutes. If therefore on the other hand, we can observe her apparent place within a minute, it is clear that we shall ascertain her real longitude in her orbit within the third part of a minute; whereas when the planet is in other situations, a whole degree scarcely affects the apparent place of her longitude, especially in her greatest distances from the sun, when observations of her are most frequently and correctly made; moreover both these and other observations plainly prove that the mean motion of Venus, has never yet been determined by astronomers with sufficient accuracy.

In the second place, no other observation shews so correctly the longitude of the node of Venus, for the telescope which I employed on this occasion is much more accurate than those gene rally used. Neither have I depended altogether upon the latitude of the fixed stars, with regard to which there might be some doubt, but have calculated from the sun itself, which is always necessarily fixed in the Ecliptic. Moreover there is an additional circumstance in the very great visible inclination of the orbit, by which, the apparent latitude being rapidly changed, the distance of Venus from the node is more minutely ascertained; one minute of observed latitude determining the longitude of the node to the tenth part of a degree; upon this point, however, it is right to add that modern astronomers are divided.

But especially would I call the attention of the reader to the surprising minuteness of Venus' apparent diameter; even though Gassendi has already bespoken the admiration of astronomers, by pointing out a similar peculiarity with respect to Mercury; and though I am not the first to notice this circumstance, I can at all events confirm it. By another and a very striking proof it will be seen how much we are liable, in estimating the diameters of the planets, to be deceived by their refraction.

Influenced by these reasons, and following the example of Gassendi, I have drawn up an account of this extraordinary sight, trusting that it will not prove less pleasing to astronomers to contemplate Venus than Mercury, though she be wrapt in the close embraces of the sun;

Vinclisque nova ratione paratis
Admisisse Deos.

Hail! Then, ye eyes that penetrate the inmost recesses of the heavens, and gazing upon the bosom of the sun with your sight-assisting tube, have dared to point out the spots on that eternal luminary! And thou too, illustrous Gassendi, above all others, hail! Thou who, first and only, didst depict Hermes' changeful orb in hidden congress with the sun. Well hast thou restored the fallen credit of our ancestors, and triumphed o'er the inconstant Wanderer. Behold thyself, thrice celebrated man! associated with me, if I may venture so to speak, in a like good fortune. Contemplate, I repeat, this most extraordinary phenomenon, never in our time to be seen again! The planet Venus drawn from her seclusion, modestly delineating on the sun, without disguise, her real magnitude, whilst her disc, at other times so lovely, is here obscured in melancholy gloom; in short, constrained to reveal to us those important truths, which Mercury, on a former occasion, confided to thee.

How admirably are their destinies appointed! How wisely have the decrees of Providence ordered the several purposes of their creation! Thou, a profound Divine, hast honored the patron of wisdom and learning; whilst I, whose youthful days are scarce complete, have chosen for my theme the Queen of love, veiled by the shade of Phœbus' light!

CHAPTER II.

Account of the Observation.

Whilst I was meditating in what manner I should commence my observation of the planet Venus so as effectually to realize my expectations, the recent and admirable invention of time telescope afforded me the greatest delight, on account of its singular excellence and superior accuracy above all other instruments. For although the method which Kepler recommends in his treatise on Optics, of observing the diameter and eclipses of the sun through a plain aperture without the aid of glasses, is very ingenious, and in his opinion, on account of its freedom from refraction, preferable to the telescope; yet I was unable to make use of it, even if I had wished to do so, inasmuch as it does not shew the sun's image exactly, nor with sufficient distinctness, unless the distance from the aperture be very great, which the smallness of my apartment would not allow. Moreover I was afraid to risk the chance of losing the observation; a misfortune which happened to Schickard, and Mogling, the astronomer to the Prince of Hesse, as Gassendi tells us in his Mercury*:* for they, expecting to find the diameter of Mercury greater than it was reasonable to anticipate, made use of so large an aperture that it was impossible to distinguish the planet at all, as Schickard himself has clearly proved; and even though Venus gave promise of a larger diameter, and thereby in some measure lessened this apprehension, and I was able to adapt the aperture to my own convenience, yet in an observation that could never be repeated, I preferred encountering groundless fears to the certainty of disappointment. Besides, I possessed a telescope of my own of such power as to shew even the smallest spots upon the sun, and to enable me to make the most accurate division of his disc; one which, in all my observations, I have found to represent objects with the greatest truth. This kind of instrument therefore I consider ought always to be preferred in such experiments. As soon as its usefulness became known to me I eulogized it in the following lines:

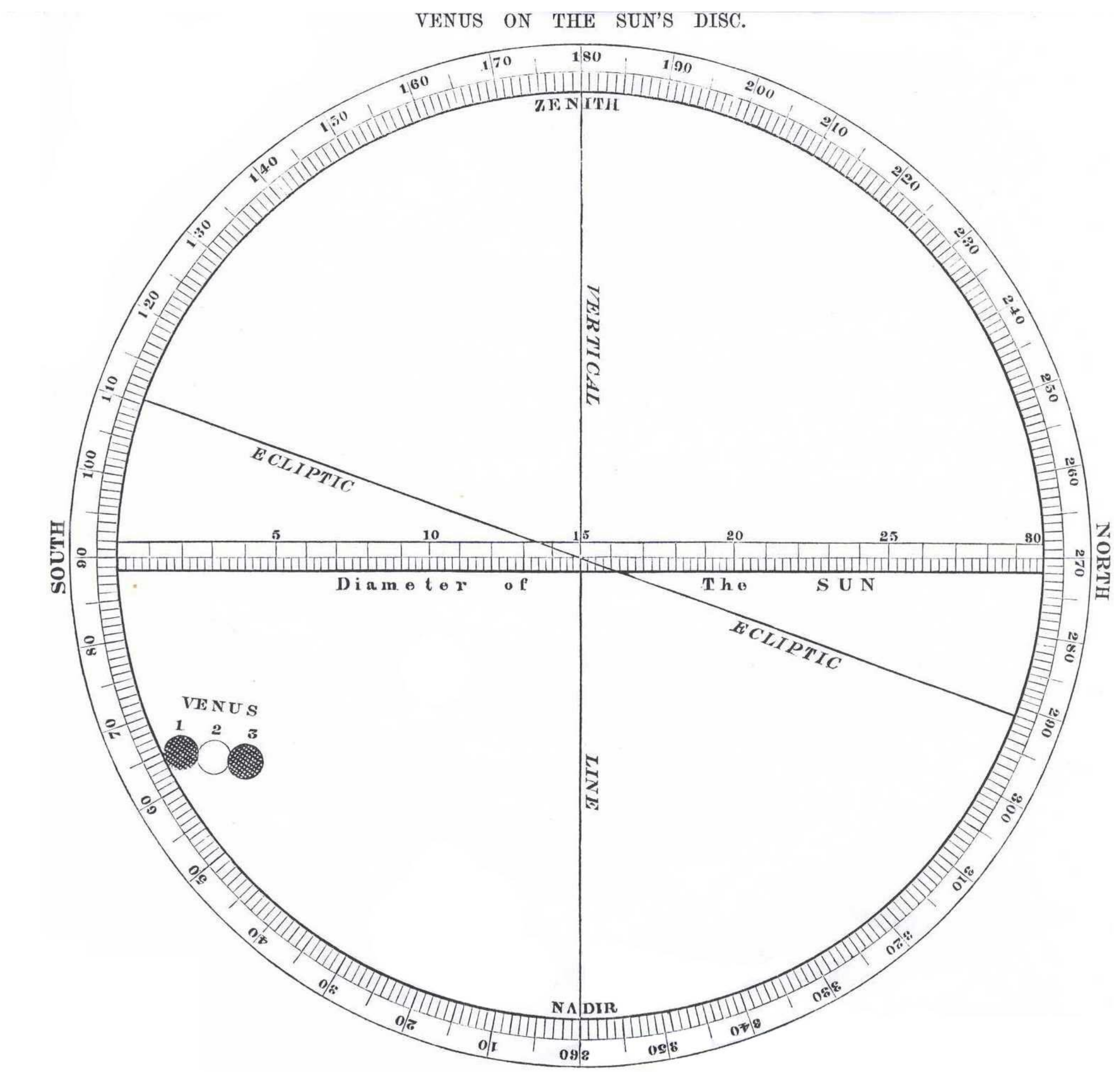
> Divine the hand which to Urania's power
> Triumphant raised the trophy, which on man
> Hath first bestowed the wondrous tube by art
> Invented, and in noble daring taught
> His mortal eyes to scan the furthest heavens.
> Whether lie seek the solar path to trace,
> Or watch the nightly wanderings of
> Whilst at her fullest splendour, no such guide
> From Jove was ever sent, no aid like this
> In brightest light such mysteries to display;

Nor longer now shall man with straining eye
In vain attempt to seize the stars. Blest with this
Thou shalt draw down the moon from heaven, and give
Our earth to the celestial spheres, and fix
Each orb in its own ordered place to run
Its course sublime in strict analogy.
For whilst thou see’st the lunar disc display
Such rocks and ocean-depths unfathomable,
What powers prevent thy sight of world’s celestial
From tracing all their semblance to this earth?
This hand divine, right bold Copernicus,
Supplies fresh arms to vindicate thy cause,
Supporting thee who dared to make the worlds
Revolve by laws unchangeable, it clothes
The hosts of heaven with earthly forms, and bids
The earth itself to claim the second place
Below the sun, a rival to the stars
That hold their stations in the realms of space.
Forbidding more the senseless crowd to rule
O’er minds whose high-aspiring thoughts shall soon
Surpass the utmost bounds of ancient lore,
Its powers disperse the troop that know no rule
But texts too vainly taught by him who gave
Such lasting honors to Stagira’s name;
They tear to shreds a thousand fancied laws
That truth deface like spots upon the sun,
And send the tomes that else might lead astray
A fitting present to the moths and worms.
This prying tube too shews fair Venus’ form
Clad in the vestments of her borrowed light,

While the unworthy fraud her crescent horn
Betrays. Though bosomed in the solar beams
And by their blaze o'erpowered, it brings to view
Hermes and Venus from concealed retreats;
With daring gaze it penetrates the veil
Which shrouds the mighty ruler of the skies,
And searches all his secret laws. 0! power
Alone that rivalest Promethean deed!
Lo, the sure guide to truth's ingenuous sons!
Where'er the zeal of youth shall scan the heavens,
0 may they cherish thee above the blind
Conceits of men, and the wild sea of error
Learning the marvels of this mighty Tube!

Having attentively examined Venus with my instrument, I described on a sheet of paper a circle, whose diameter was nearly equal to six inches, the narrowness of the apartment not permitting me conveniently to use a larger size. This however admitted of a sufficiently accurate division; nor could the arc of a quadrant be apportioned more exactly, even with a radius of fifty feet, which is as great an one as any astronomer has divided; and it is in my opinion far more convenient than a larger, for although it represents the sun's image less, yet it depicts it more clearly and steadily. I divided the circumference of this circle into 360° in the usual manner, and its diameter into thirty equal parts, which gives about as many minutes as are equivalent to the sun's apparent diameter:

Each of these thirty parts was again divided into four equal portions, making in all one hundred and twenty; and these, if necessary, may be more minutely subdivided; the rest I left to ocular computation, which, in such small sections, is quite as certain as any mechanical division. Suppose then each of these thirty parts to be divided into 60", according to the practice of astronomers. When the time of the observation approached, I retired to my apartment, and having closed the windows against the light, I directed my telescope, previously adjusted to a focus, through the aperture towards the sun and received his rays at right angles upon the paper



already mentioned. The sun's image exactly filled the circle, and I watched carefully and unceasingly for any dark body that might enter upon the disc of light.

Although the corrected computation of Venus' motions which I had before prepared, and on the accuracy of which I implicitly relied, forbad me to expect anything before three o'clock in the afternoon of the 24th; yet since, according to the calculations of most astronomers, the conjunction should take place sooner, by some even on the 23rd, I was unwilling to depend entirely on my own opinion which was not sufficiently confirmed, lest by too much self-confidence I might endanger the observation. Anxiously intent therefore on the undertaking through the greater part of the 23rd, and the whole of the 24th, I omitted no available opportunity of observing her ingress. I watched carefully on the 24th from sunrise to nine o'clock, and from a little before ten until noon, and at one in the afternoon, being called away in the intervals by business of the highest importance, which, for these ornamental pursuits, I could not with propriety neglect. But during all this time I saw nothing in the sun except a small and common spot, consisting as it were of three points at a distance from the centre towards the left, which I noticed on the preceding and following days. This evidently had nothing to do with Venus. About fifteen minutes past three in the afternoon, when I was again at liberty to continue my labors, the clouds, as if by divine interposition, were entirely dispersed, and I was once more invited to the grateful task of repeating my observations. I then beheld a most agreeable spectacle, the object of my sanguine wishes, a spot of unusual magnitude and of a perfectly circular shape, which had already fully entered upon the sun's disc on the left, so that the limbs of the Sun and Venus precisely coincided, forming an angle of contact. Not doubting that this was really the shadow of the planet, I immediately applied myself sedulously to observe it.

In the first place, with respect to the inclination, the line of the diameter of the circle being perpendicular to the horizon, although its plane was somewhat inclined on account of the Sun's altitude, I found that the shadow of Venus at the aforesaid hour, namely fifteen minutes past three, had entered the Sun's disc about 62^{o} 30', certainly between 60^{o} and 65^{o}, from the top towards the right. This was the appearance in the dark apartment; therefore out of doors beneath the open sky, according to the law of optics, the contrary would be the case, and Venus would be below the centre of the sun, distant 62° 30’ from the lower limb, or the nadir, as the Arabians term it. The inclination remained to all appearance the same until sunset, when the observation was concluded.

In the second place, the distance between the centres of Venus and the Sun I found, by three observations, to be as follows

The Hour.			Distance of the Centres.
At	3.15	**by the clock**.	14’ 24”
,,	3 . 35	,,	13’ 30”
,,	3 .45	,,	13’ 0”
,,	3 . 50 the apparent sunset.		

The true setting being 3.45 and the apparent about 5 minutes later, the difference being caused by refraction. The clock therefore was sufficiently correct.

In the third place, I found after careful and repeated observation, that the diameter of Venus, as her shadow was depicted on the paper, was larger indeed than the thirtieth part of the solar diameter, though not more so than the sixth, or at the utmost the fifth, of such a part Therefore let the diameter of the Sun be to the diameter of Venus as 30’ to 1’ 12”. Certainly her diameter never equalled 1’ 30”, scarcely perhaps 1’ 20”, and this was evident as well when the planet was near the Sun’s limb, as when far distant from it.

This observation was made in an obscure village where I have long been in the habit of observing, about fifteen miles to the north of Liverpool, the latitude of which I believe to be 53° 20’, although by the common maps it is stated at 54° 12’, therefore the latitude of the village will be 53° 35’, and the longitude of both 22° 30’ from the Fortunate Islands, now called the Canaries. This is 14° 15’ to the west of Uraniburg in Denmark, the longitude of which is stated by

Brahe', a native of the place, to be 36^{o} 45' from these Islands.

This is all I could observe respecting this celebrated conjunction, during the short time the Sun remained in the horizon: for although Venus continued on his disc for several hours, she was not visible to me longer than half-an-hour, on account of his so quickly setting. Nevertheless, all the observations, which could possibly be made in, so short a time, I was enabled, by Divine Providence, to complete so effectually that I could scarcely have wished for a more extended period. The inclination was the only point upon which I failed to attain the utmost precision; for, owing to the rapid motion of the Sun, it was difficult to observe with certainty to a single degree, and I frankly confess, that I neither did nor could ascertain it. But all the rest is sufficiently accurate, and as exact as I could desire.

CHAPTER III.

What others observed, or might have observed, of this Conjunction.

WHEN first I began to attend to this Conjunction, I not only determined myself to watch diligently an appearance so important, but invited others also whom I knew to be interested in astronomy to do the same, in order that the testimony of many observers, should it so happen, might more firmly establish the truth; and especially because, if observations were made in different places, our expectations would be 'less likely to be frustrated by a cloudy sky or any other obstacle. I wrote therefore immediately to my most esteemed friend William Crabtree, a person who has few superiors in mathematical learning, inviting him to be present at this Uranian banquet, if the weather permitted; and my letter, which arrived in good time, found him ready to oblige me; he therefore carefully prepared for the observation, in a manner similar to that which has been mentioned. But the sky was very unfavorable, being obscured during the greater part of the day with thick clouds; and as he was unable to obtain a view of the Sun, he despaired of making an observation, and resolved to take no further trouble in the matter. But a little before sunset, namely about thirty-five minutes past three, certainly between thirty and forty minutes after three, the Sun bursting forth from behind the clouds, he at once began to observe, and was gratified by beholding the pleasing spectacle of Venus upon the Sun's disc. Rapt in contemplation, he stood for some time motionless, scarcely trusting his own senses, through excess of joy; for we astronomers have as it were a womanish disposition, and are overjoyed with trifles and such small matters as scarcely make an impression upon others; a susceptibility which those who will may deride with impunity, even in my own presence, and, if it gratify them, I too will join in the merriment. One thing I request: let no severe Cato be seriously offended with our follies; for, to speak poetically, what young man on earth would not, like ourselves, fondly admire Venus in conjunction with the Sun, "pulchritudinem divitiis conjunctam"? But to return, he from his ecstasy, and I from my digression. In a little while, the clouds again obscured the face of the Sun, so that he could observe nothing more than that Venus was certainly on the disc at the time. What he actually saw in so short a space was as follows:

In the apartment, Venus occupied the right side of the Sun, being higher than its centre, and therefore in the heavens lower and on the left. She was distant at the aforesaid hour, namely thirty-five minutes past three, a sufficiently appreciable space from the Sun's left limb; but Crabtree's opportunity was so limited that he was not able to observe very minutely either the distance itself; or the inclination of the planet. As well as he could guess by his eye, and to the best of his recollection, he drew upon paper the situation of Venus, which I found to differ little or nothing from my own observation; nor indeed did he err more than Apelles himself might have done in making so rapid a sketch. He found the diameter of Venus to be seven parts, that of the

Sun being two hundred, which, according to my calculations, gives about 1’ 3”.

This observation was made near Manchester, called by Antoninus *Mancunium* or *Manucium,* the latitude of which Mr. Crabtree makes 53^{o} 24’, and the common tables 45^{o} 15’; the longitude 23^{o} 15’, or three minutes of time to the east of Liverpool, from which it is distant twenty-four miles.

I wrote also of the expected transit to my younger brother, who then resided at Liverpool, hoping that he would exert himself on the occasion. This indeed he did, but it was in vain; for on the 24th, the sky was overcast, and he was unable to see anything, although he watched very carefully. He examined the Sun again on the following day, which was somewhat clearer; but with no better success, Venus having already completed her transit.

I hope to be excused for not informing other of my friends of the expected phenomenon, but most of them care little for trifles of this kind, preferring rather their hawks and hounds, to say no worse; and although England is not without votaries of astronomy, with some of whom I am acquainted, I was unable to convey to them the agreeable tidings, having myself had so little notice. If others, without being warned by me, have witnessed the transit, I shall not envy their good fortune, but rather rejoice, and congratulate them on their diligence. Nor will I withhold my praise from any who may hereafter confirm my observations by their own, or correct them by anything more exact. Let us then briefly consider what assistance may be expected from others.

In the space of half-an-hour, Venus advanced towards the centre of the Sun a distance of 1’ 24”; of course, therefore, in twenty-six minutes she had travelled to the extent of her own diameter, namely 1’12”; that is, as much as, at the first observation at fifteen minutes past three, the antecedent limb of Venus had passed over the Sun’s limb; therefore forty-nine minutes past two was the commencement of her eclipse.

At Uraniburg, where there was formerly an observatory under Tycho, this would be forty-six minutes past three, but the Sun set there at half-past three, which is sixteen minutes before the commencement of the eclipse; therefore nothing could have been observed, even should astronomy not have perished with its patron, and some should be yet remaining who, having leisure for the pursuit, sustain the ancient credit of Uraniburg.

At Goesa, in Zealand, where Lansberg lately flourished, it commenced at fourteen minutes past three, and the Sun set at fifty-five minutes past three, consequently it might have been seen there. But no one excepting Lansberg and his friend Hortensius, both of whom I hear are dead, would trouble themselves about the matter; nor is it probable that, if living, they would be willing to acknowledge a phenomenon which would convict their much-vaunted tables of gross inaccuracy.

At Hesse Cassel the eclipse began at thirty-three minutes past three, the Sun set at fifty-five minutes past three. Providentially, Mr. Mögling would be prepared for the conjunction with his telescope, or at least with a tube furnished with a narrower aperture than that which was formerly used in observing Mercury; if indeed there is sufficient leisure in Germany to attend to subjects of so trivial a nature to the neglect of more important affairs.

At Paris, where Gassendi observed the conjunction of Mercury with the Sun, the transit was to be seen a little later than with us; for the first entry of Venus upon the Sun's disc took place at six minutes past three, whilst the true time of sunset was eight minutes past four, and the apparent at twelve minutes past four, therefore Venus was visible in the Sun for more than an hour. Hence we shall consider Gassendi very fortunate if he have found her no less accessible than Mercury; and that neither unfavorable weather nor inadvertence, of which it would be wrong to accuse so celebrated an astronomer, deprived him of the opportunity.

In short, Venus was visible in the Sun throughout nearly the whole of Italy, France, and Spain; but in none of those countries during the entire continuance of the transit.

But America!

0 fortunatos nimium bona Si sua norint!

Venus! What riches dost thou squander on unworthy regions, which attempt to repay such favors with gold, the paltry product of their mines. Let these barbarians keep their precious metals to themselves, the incentives to evil, which we are content to do without. These rude people would indeed ask from us too much should they deprive us of those celestial riches, the use of which they are not able to comprehend. But let us cease this complaint, 0 Venus! and attend to thee ere thou dost depart.

"Way beauteous Queen desert thy votaries here?
Ah! Why from. Europe hide that face divine,
Most meet to be admired? On distant climes
Why scatter riches? Or such splendid sights
Why waste on those who cannot prize their value?
Where dost thou madly hasten? Oh! Return:
Such barbarous lands can never duly hail
The purer brightness of thy virgin light.
Or rather here remain: secure from harm,
Thy bed we'll strew with all the fairest flowers;
Refresh thy frame, by labors seldom tried,
Too much oppressed; and let that gentle form
Recline in safety on the friendly couch.
But ah! thou fliest! And torn from civil life,
The savage grasp of wild untutored man
Holds thee imprisoned in its rude embrace.
Thou fliest, and we shall never see thee more,

While heaven unpitying scarcely would permit
The rich enjoyment of thy parting smile.
Oh! Then farewell thou beauteous Queen! Thy sway
May soften nations yet untamed, whose breasts
Bereft of native fury then shall learn
The milder virtues. We with anxious mind
Follow thy latest footsteps here, and far
As thought can carry us; my labors now
Bedeck the monument for future times
Which thou at parting left us. Thy return
Posterity shall witness; years must roll
Away, but then at length the splendid sight
Again shall greet our distant children's eyes."

Chapter IV

It is proved that the spot observed in the Sun's disc was really Venus.

THE most skilful astronomers in their observation of Mercury have been frequently deceived; firstly, those, who in the time of Charlemagne, on the 16th of April in the year 807, believed that the transit of Mercury over the Sun continued eight days: secondly, Averrhoes, who says in the *Ptolemaic Paraphrase,* that he recollected to have seen something of a darkish appearance, and subsequently found by the numbers that the conjunction of Mercury and the Sun had been predicted; he flourished about the year 1160 of the christian era: thirdly, Kepler himself the most learned astronomer that ever lived, was greatly deceived on the 18th of May 1607. All these having seen spots on the Sun's disc, an appearance not understood in those days, rashly concluded them to be the planet Mercury; but they were evidently misled, as circumstances afterwards proved.

Are we then similarly deceived, and do we mistake an ordinary spot for

Venus?

Verily since this may be doubted, as well by sonic who arc unacquainted with the heavens except from books, as by others who are learned and practical astronomers; and lest our labor should be in vain, it may be worth while, before further prosecuting the enquiry, to prove in a satisfactory manner that the planet Venus was the actual cause of this appearance.

Firstly, perchance there may be some who believe that neither Venus nor Mercury could ever be seen in the Sun, although they might be upon his disc; such, for instance, as suppose that all the heavenly bodies shine with their own light, and are neither opaque nor cast a shadow like the Earth and Moon.

Secondly, others who, trusting to the astronomical tables which they imagine as accurate as their authors describe them to be, easily give way to the same opinion, and deny that any real transit took place on either the hour or the day we have specified; nor will they allow themselves to be persuaded that tables, boasting so confidently of their own accuracy, could possibly err to the extent of a whole day, or miscalculate the situation of Venus by several degrees.

But, thirdly, they will be the most astonished who, having contemplated this beautiful planet, which on a clear evening they think may even vie with the Moon, shall learn from us her surprising minuteness; and when they are told that the common opinion of astronomers makes the diameter of Venus equal to two-fifths of that of the Sun, that is, ten times greater than we have actually found it, they may possibly conclude that we have been deceived by an ordinary spot, and blinded by the desire of dignifying it with the name of Venus.

Let others fear such a conclusion: for myself what I saw with my own eyes in the heavens, supplied me with sufficient evidence of the certainty of the observation, almost all the circumstances of which I had predicted to my friends; and I silently congratulate myself that my correction of the motion of Venus, which I had not before sufficiently appreciated, has been confirmed beyond my utmost hopes. In order to satisfy the doubts of others I make the following remarks: -

Firstly, there is no occasion for any one to be misled because Venus was deprived of that native light which many erroneously attribute to the planets; for, by satisfactory arguments to be found elsewhere, it is quite clear that the bodies of those planets are obscure and derive their light exclusively from the Sun.

Secondly, I should be more ready to commend those who employ their skill in computing Ephemerides, if, instead of servilely receiving the report of others, they would trust something to their own eyes. Indeed no one who has eyes and who diligently avails himself of his opportunities can be said to be so destitute of astronomical instruments that he cannot observe many things in the heavens, the knowledge of which, acquired with so little trouble, would conduce greatly to the advancement of the science. And although even the best of the common tables may err, this observation alone clearly shews that there are no others which can supply their defects; nor will these tables even impugn its accuracy, as they are less at variance with it than with each other.

Thirdly, they who are so astonished at the minuteness of the diameter of Venus should rather be surprised at those astronomers whose carelessly-formed opinions have assigned such monstrous proportions to the planets; for I will prove that the diameter of Venus ought not to seem greater than we in reality have found it. But however much less it may be than the dimension usually attributed to it by astronomers, it has nevertheless far exceeded the size of any spot, which I have observed. Schickard indeed remarks, that “the solar spots sometimes appear so large that they are visible through an opening in a darkened apartment; and that, from a small aperture in a wine cellar, on the 6th of July, 1629, he had observed such an one which was broader and darker than any that had come under his notice, having a peduncle in the shape of a pear.” But these spots are rarely seen so large, indeed I have never yet witnessed any to be compared with this shadow of Venus, the common ones scarcely equalling half-a-minute, except when many are seen together so as to increase their bulk.

But even if this spot of ours agreed with the common ones in magnitude, yet we can shew, by other and more certain proofs, how it may be distinguished from them. I have noticed particularly three remarkable points of dissimilarity, of which the first two are probable distinctions, and the third a certain one.

First, as to figure. The figure of this body was a perfect sphere, such as is usually attributed to the planets, to the eternal bodies of the universe, and to Venus herself. But the common spots, which are nothing more than smoky exhalations, or, as one may say, solar nebulosities, consisting of fluid matter easily dispersed, are rarely found to assume a spherical form, but are of an irregular shapeless figure, and may be aptly compared with the terrestrial clouds. Moreover those spots which when seen upon the centre of the Sun appear large and spacious, when upon his limb or near the edge are compressed into a lengthened figure, and are exceedingly subtile. This proves that they do not possess a spherical or globose shape, but one extenuated and diffusely spread, and therefore that they are not stars as some imagine. Ours then is no common spot, since it retains unchanged the same spherical figure and magnitude as exactly when in the circumference of the Sun as when far distant from it.

Second, as to color. Since the ordinary spots, or solar nebulosities, are of rarer and less dense matter, scarcely darker than that of thick smoke, they cannot be said entirely to exclude the light of the Sun, but rather to transmit its rays more faintly; they are therefore seldom, if ever, perfectly black, but are more frequently a darkish kind of color mixed with light, especially round their edges which no doubt are more rare than the centre. But this beautiful shadow of Venus clearly shewed that it proceeded from an opaque and very dense body resembling the planets; for even the Moon in a solar eclipse does not cast a shadow denser, in proportion to its magnitude, than the one which I have observed from this spot.

Thirdly, and lastly. I found a remarkable difference between the motion of this shadow and that of the common spots upon the sun; so that, if other arguments were insufficient, this fact of itself proves most clearly and incontestably that it was a very unusual one, and occasioned by Venus alone. Moreover, the common spots are close to the surface of the sun and are carried round with him, performing a revolution in the space of a month, providing any of them happen to last so long. Wherefore at the beginning and end of their appearance, while passing round the receding edge of the Sun, they seem to move at so slow a rate that a day or two scarcely changes their position, their approach to or departure from our sight being as it were, in a right line. But that which we observed, passed with a rapid and uniform motion over the edge of the Sun, traversing the twentieth part of his diameter in half-an-hour, which the common spots have never done in two whole days.

Perhaps I have argued this point at greater length than it really merits; not because I thought that an astronomer would entertain a doubt as to these spots, which are visible, almost daily upon the Sun's disc, but that I might have an opportunity of explaining their nature and peculiarities.

For I know that there are some who make it their business to deny with the most obstinate and reckless malevolence the truth of our discoveries, and who contend that these solar spots are not temporary and fleeting vapours, but real planets and durable bodies; lest forsooth the dogma of the Peripatetics, respecting the incorruptibility of the heavens, should be impugned, which our doctrine beyond all question effectually opposes. Indeed the common spots are so different in their nature from the stars that, even in the centre of the Sun, they are frequently observed to be engendered, to increase, to diminish and to die away; of which any candid enquirer may easily convince himself. But it is in vain to speak of these things to those who will not hear, and who prefer their Aristotle, or to speak more plainly, their own unreasonable prejudices to the clearest demonstration. It is much easier to teach the ignorant than those who will not learn.

Let such men make the most of their wilful blindness, and delight in their fables; let them keep to their worthy instructor, under whose mantle they may safely retire! I envy not their ignoble dreams. At least, when astronomers meet with an observation similar to ours, let them know how to distinguish Mercury or Venus from the common spots upon the Sun.

CHAPTER V.

An Examination of the apparent Longitude and Latitude of Venus from the Sun.

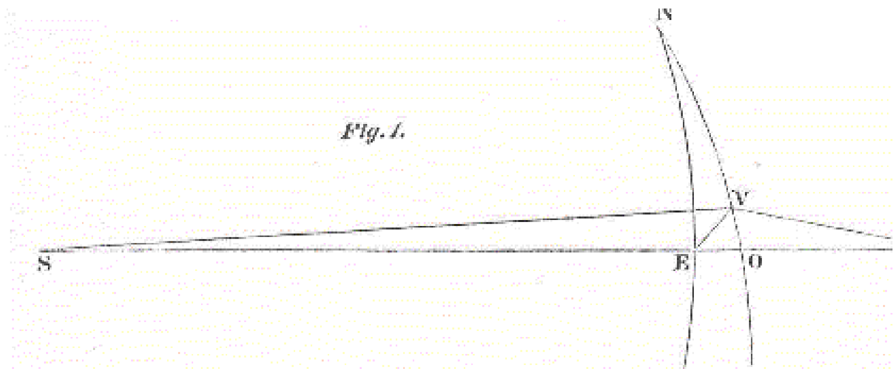
A PLAIN statement of the observation having now been made, and the truth of it, proved, it remains for us to explain of what advantage it may be to astronomy. In the first place, the apparent longitude and latitude of Venus from the Sun's centre are to be computed; and, with this view, we annex an estimate of the distance of their centres, and of the inclination.

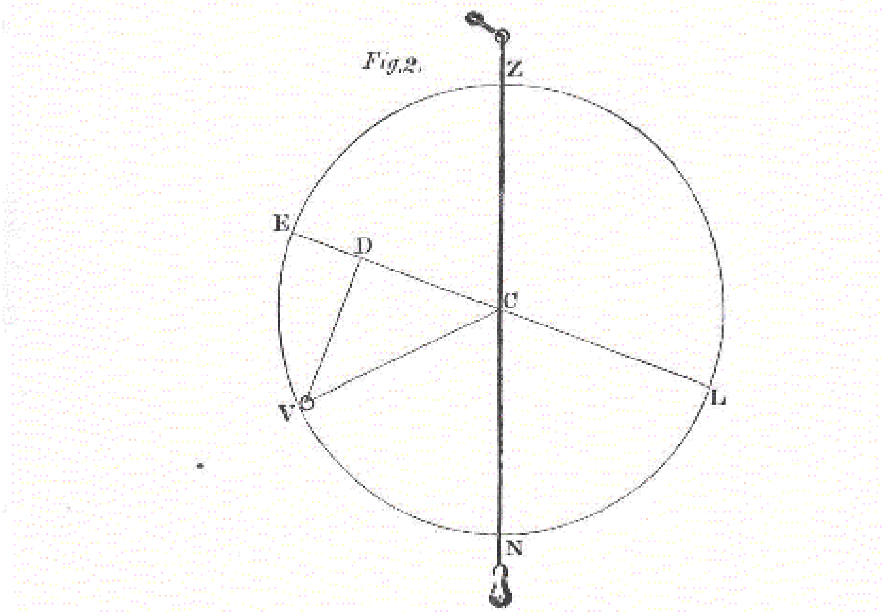
But before proceeding, let us ascertain the Sun's apparent diameter; for this will be our surest guide in computing the distance between their centres. On this point astronomers differ considerably: it was according to

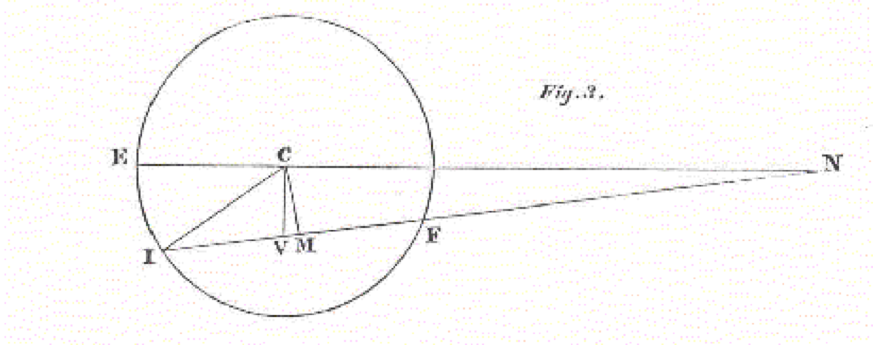
Kepler …………………………………………………………………31' 1"
Tycho and Longomontanus ……………………………………………31' 54"
Lansberg ………………………………………………………………35' 50"

a very important difference, certainly, and one not easily reconcileable with the laws of astronomical science. For the present, however, I will not advert to these inaccuracies; but leave them for fuller consideration at a future time, and proceed to other matters. Let us then assume the diameter of the Sun to be 31' 30", which is nearly the mean of Kepler and Tycho, an estimate which I adopt, not from regard to the idle adage "*medio tutissimus ibis*," but because I have found it, from my own repeated observations, to be very close to the truth.

My circle having only thirty divisions, the distances before given will have to be reduced into minutes and seconds, of which the Sun's diameter will be 31' 30", as the following table will satisfactorily explain:







By the Clock.	The Distances of the Centres.
3.15	15' 17"
3.35	14' 10"
3.45	13' 39"

From these distances, together with a constant inclination of 62^{o} 30', the longitude and latitude of Venus from the centre of the Sun was demonstrated, as is shown in the foregoing figure No. 2 in the plate, representing her true situation on his disc, at her first entrance.

Let C be the Sun's centre, V Venus, E C L the Ecliptic, Z C N the Vertical, Z the Zenith, N the Nadir, C V the Distance of the Centres, D C the Difference of Longitude, D V the Difference of Latitude; the angle V C N the Inclination, N C L the Parallactic Angle or the Inclination of the Ecliptic to the Vertical, E C V the Inclination of the circle through the centres to the Ecliptic.

The Parallactic Angle N C L is computed by the doctrine of spheres; the altitude of Culmination and the Sun's distance from it, together with the Meridian Angle, being given by a well-known method. To this is added the observed Inclination V C N; and thus it forms the angle V C L whose complement to a semi-circle is the inclination of a circle through the centres to the Ecliptic E C V. This being given, it will be as the radius is to the distance of the centres C V, so the line of the angle E C V is to the difference of the latitude D V: and so the sine of the complement is to the difference of the longitude D C. All of which, in the three observations, are carefully deduced in the following manner:

					D.	M.
The true situation of the sun……………………………					12	24
The right ascension…………………………………….					250	55
The altitude of the Equator………………………………					36	25
From these is given						
The Hour	3.15		3.35		3.45	
The Culminating degree………………	27	34	2	23	4	48
The Meridian angle……………………	78	37	76	54	7	6 4
The altitude of the Culmination………	15	43	16	45	17	18
The distance of the sun from the culmination…………………	45	10	49	59	52	24
Therefore the angle N C L……………	70	56	68	53	67	55
To which V C N being add……………	62	30	62	30	62	30
Gives the angle V C L ………………	133	26	131	23	130	25
Answers	**M.**	**S.**	**M.**	**S.**	**M.**	**S.**
To the compliment of which E C V…	46	34	48	37	49	35
The distance from the centre V C….	15	7	14	10	13`	39
The difference in longitude D C……	10	24	9	22	8	51
The difference in latitude D V………	10	58	10	38	10	24

And thus are found the three distances of Venus from the Sun, with respect to her longitude and latitude.

In noting the observation, it is however obvious that the Inclination is uncertain to one or two degrees. Lest therefore it should be thought that any great mistake with respect to the situation of Venus might arise from this error, I will here show how little is left in doubt. Imagine then that I have erred 5^{o}, and that the first hour of observing is 3 15'.

	D.	M.
The inclination V C N……………………………………..	67	30
The angle V C L will be…………………………………..	138	26
To the complement ofwhich ECV………………………	41	34
Answers	**M.**	**S.**
The distance of thecentres C V ………………………..	15	4
The difference of longitude D C…………………………	11	19
The difference of latitude D V……………………………	10	2
The error therefore will be		
In longitude………………………………………………..	0	55
In latitude………………………………………………….	0	56

It is clear therefore that an error of 5^{o} in the Inclination would not alter Venus' situation, either in its longitude or latitude one minute, which is very little. But I believe that I have not erred 5^{o}; therefore, the apparent situation of Venus being satisfactorily ascertained, I shall proceed.

CHAPTER VI.

The alteration of the apparent into the true situation of Venus.

I BEHELD Venus, during the transit, not from the centre but from the surface of the earth; therefore I observed her apparent and not her true situation. Her true situation, which chiefly concerns us, is only to be obtained by the correction of the parallaxes, into which subject I now proceed to enquire.

The hypotheses of all astronomers make the parallax of Venus in so near an approach to the earth sufficiently apparent; but this I shall leave to be further considered in a separate treatise, and in the meantime retain my own opinion.

After much and repeated consideration, I find the mean distance of the Sun to be equal at least to 15,000 semi-diameters of the earth. This paradox, as it may seem, differs greatly from the commonly received opinion; nevertheless I trust elsewhere to substantiate its correctness. Let us now ascertain, from this distance of the Sun, the distance and parallax of Venus.

According to observation, it was as the following calculation shews, chap. 14: —

The distance between the Sun and the Earth……………………………	98409
The distance between the Sun and Venus…………………………………	72000
Therefore the distance between the earth and Venus……………………..	26409
Of which the mean distance of the Sun . . ………………………………..	100000
But of semi-diameters this observation supposes…………………………	15000
And the distance of the Earth from Venus. …………………………………..	3962

Venus therefore was distant from us just so many semi-diameters of the Earth; to which distance belongs—

	M.	S.
The horizontal parallax of Venus……………………………………………	0	52
from which the parallax of the Sun being subtracted……………………...	0	14
Gives the parallax of Venus from the Sun…………………………………	0	38

Indeed so small a parallax will effect only a trifling alteration and if we were to take no notice of it, the inconvenience would not be much felt; but since we have leisure let us remove even these slight objections from our scrupulous opponents. It is not more trouble to apply the parallax than to investigate it.

It is a problem sufficiently well known that the parallax of the altitude of Venus, which differs nothing from the horizontal on account of the inconsiderable altitude of the Sun, is extended in length and breadth; given therefore the parallactic angle which I before computed in each of the observations, and the following parallaxes are obtained

The Hour.	of the Longitude.	of the Latitude.
3.15	0’ 13”	0’ 36”
3.35	0’ 14”	0’ 35”
3.45	0’ 14”	0’ 35”

Venus was with the Sun in the western quarter of the Zodiac, in longitude more east than the centre of the Sun, in latitude more south, therefore the parallax diminishes the apparent longitude from the Sun and increases the latitude; hence, in order that both may be true, we must add in the one case and subtract in the other, which being done, the true difference is given.

The Hour.	**Of the Longitude.**	**Of the Latitude.**
3.15	10’ 37”	10’ 22”
3.35	9’36”	10’ 3”
3.45	9’ 5,”	9’ 49",

CHAPTER VII.

An Inquiry into the Time and Place of the True Conjunction of Venus and the Sun.

I was not able to observe Venus at the actual point of her conjunction with the centre of the Sun, for both had set before she arrived there. But as the chief utility of the observation depends upon a knowledge of the true conjunction, I will therefore represent it from those facts, which I was fortunate enough to observe.

The diurnal motion according to the calculation:

	D.	M.	S.
The direct motion of the Sun…………………………	1	1	2
The retrograde motion of Venus…………………….		36	38
Therefore that of Venus from the Sun was…………	1	37	40

The differences of longitude which we have found are next to be divided by this diurnal motion of Venus from the Sun, that the time may be obtained which is to be added to the moment of the observation, in order to give the true hour of the conjunction, in this manner:

	M.	S.	M.	S.	M.	S.
The difference of longitude……………………	10	37	9	36	9	5
Gives the hours………………………………	2	36 $\frac{1}{2}$	2	21 $\frac{1}{2}$	2	14
Add the hour of observation…………………..	3	15	3	35	3	45
which makes the hour ofconjunction…………	5	51 $\frac{1}{2}$	5	56 $\frac{1}{2}$	5	59

The moment of the conjunction, which from all the observations ought to be exactly the same, shews a difference of 7 $\frac{1}{2}$.’, a small variation which the impartial reader will easily excuse. The medium between the extremes may be retained with safety, and thus ascertained will be 5.55,.

To obtain the true longitude at this moment, the Sun’s situation is to be computed, the situation of Venus being apparently the same, but in reality the contrary. Therefore from my calculation—

	D.	M.	S.
The true situation of the Sun is……………………………………..	12	29	35
And that of Venus will be……………………………………………….		29	35

So far for the longitude. But as the situation of Venus is at length clearly known, and the latitude is made evident, it is necessary to ascertain it also at the hour of conjunction.

The diurnal variation of the latitude of Venus is assumed from calculation to be 15’ 40”; and because the latitude was south around the northern node, it therefore decreased, as this observation likewise shews. The diurnal variation of the latitude must therefore be divided into the hours and minutes in which the true conjunction followed the observation, and the quotient added to the observed latitude in this manner:

	D.	M.	D.	M.	D.	M.
In hours……………………………………..	2	40	2	20	2	10
The latitude decreases……………………	1	44	1	31	1	25
The observed latitude…………………….	10	22	10	3	9	49
Therefore at the hour of conjunction…….	8	38	8	32	8	24

The first observation differs from the third 0’ 14”, which is of no importance; but if, as before, we take the mean, the latitude will be ascertained at the hour of conjunction to be 8’ 31” south.

Chapter VIII

Vie Demonstration of the Node of Venus.

It will conduce much to the improvement of astronomy if the node of Venus be shown; therefore to demonstrate this from what is already discovered, let S in the foregoing figure No. 1 in the plate represent the Sun; T the Earth; V Venus; E N the portion of the Ecliptic; 0 V N part of the orbit of Venus; N the Northern Node; E N V the inclination of the orbit of Venus to the Ecliptic, which on the authority of Kepler I assume to be 3^{o} 22’; E T V the apparent angle of the latitude of Venus on the Earth 8’ 31” from observation; S E the distance between the Sun and Venus; T E the distance between the Earth and Venus. From these the distance of the node E N from the place of the conjunction is thus computed:

1st. In the plane triangle T E V

The right angle T E V is given **D. M. S.**

With the angle ETV………………………………………………………..0 8 31

And with the side T E………………………………………………… 26409

D. M. S.

Therefore the side E V………………………………………………0 0 65

2nd. In the plane S E V

The right angle S E V is given

And the side S E…………………………………………………………..72000

With the side E V…………………………………………………… 0 0 65

Therefore the angle E S V (or the arc E V)………………………… 0 0 37

3rd. In the spherical triangle N E V

The right angle at E is given

The arc E V…………………………………………………….. 0 3 7

And the angle E N V…………………………………………… 3 22 0

Therefore the arc N E………………………………………….. 0 53 10

Let the place of the conj unction be added to this II………….. 12 29 35

Which makes the longitude of the node . . ………II…………… 13 22 45

But the node of Venus is according to

Kepler……………………………………………..II…………… 13 31 13

Longomontanus . . ………………… ……….…..II…………… 14 32 6

Lansberg…………………………………………..II…………… 11 52 4

I cannot pass over, without astonishment, this difference of opinion, so much to be regretted among astronomers of such celebrity; nor is the result unimportant, so great is the discrepancy, for it changes the latitude of Venus in this position nearly half a degree; and although elsewhere in more remote distances, the variation may not be so perceptible, yet it never disappears so completely as not to be a great reflection upon our astronomers who err to such an extent; and the more so as from other observations now extant, they might so much better agree among themselves. Lansberg, who aggravates his fault by foolish boasting, is one of those chiefly to blame; nor is Longomontanus, who possessed to so little purpose the observations of his friend Tycho, much more excusable; but here as elsewhere, the ingenious Kepler errs least of all.

CHAPTER IX.

The beginning, middle, and end of the Transit are skewn.

WE have already spoken of the hour of the true conjunction in respect of the ecliptic, but as that was not the middle of the transit, nor was there shewn in it the nearest distance of the centres, it may perhaps be agreeable to some, though it is not otherwise of much use, to assign the true middle, together with the beginning and end, of so unusual and wonderful a conjunction. For this purpose, let a figure be drawn, such as No. 3 in the preceding plate, and let C be the Sun's centre N the Northern node; E C N the ecliptic; I N the orbit of Venus; I the beginning of the transit; M the middle; F the end; V the true conjunction in respect to the ecliptic; C V the latitude of Venus at its true conjunction; C M the least distance of the centres in the middle of the transit; C N the distance of the node from the place of the true conjunction; E N I the visible inclination of the orbit of Venus to the ecliptic. From these the periods of incidence M I and I M F are thus computed:

1st.—In the triangle V C N the rightangle

	D.	M.	S.
VCN is given			
The side C N (chap. 8)	0	53	10
The side C V (chap. 7)	0	8	31
Therefore the angle C N V	9	6	0
And to this V C M is equal, whence moreover the right angle V M C is given with the			
Side C V	0	8	31
Therefore the side V M	0	1	21
And the side CM	0	5	24

2nd.—The diurnal motion of Venus from the Sun which I before used is less than in her proper orbit. To find this in the triangle V C N.

Let the right angle V C N be given.

The diurnal motion in the Ecliptic C N	1	37	40
With the angle C N V	9	6	0
Therefore the diurnal motion in her orbit V N	1	38	55
By this let V M be divided	0	1	21
The horary periods are	0	19	30
Which must be added to the moment of the true conjunction	5	55	0
That the middle of the eclipse may be found	6	14	30

3rd.—For the periods of incidence in the triangle I M C the right angle at M is given.

With the side C M	0	8	24
And the sum of the semi-diameters of the Sun and Venus C I	0	16	23
Therefore the periods of incidence I M	0	14	4
Divided into the diurnal motion	1	38	55
Give the time of incidence	3	25	0

In a similar manner they are computed by the difference of the semi-diameters as in a total eclipse of the moon.

The periods of half the eclipse	0	12	34

The time of half the eclipse…………………………………………...3		3	0
Therefore the first ingress will be ………………………Hour…...2		49	30
The total ingress…………………………………………………….3		11	30
The middle…………………………………………………………...6		14	30
The first egress……………………………………………………...9		17	30
The total egress……………………………………………………..9		39	30

CHAPTER X.

An Examination of the Calculations of Astronomers
Respecting the foregoing.

THE value of this observation, in correcting the motion of Venus, has already been explained. We must next ascertain how the facts, which are deduced from it, agree with the calculations of astronomers. This inquiry will doubtless shew the usefulness of the observation to the practical student; especially as it will appear that even the best astronomers have not only disagreed among themselves, but have considerably deviated from the truth.

There are four astronomers from whose tables Ephemerides are at this time chiefly computed, into whose respective merits, as there is some difference of opinion, it may be well carefully to inquire.

1ST. Copernicus who compiled the new, or rather the renewed, hypotheses, and the laws of the sidereal motions, in six books of Revolutions, from which Erasmus Reinhold afterwards constructed the Prutenic tables; and from these, Origanus, Maginus, and others derived their Ephemerides which are still extant, and are chiefly used in our prognostics, though now the Prutenic calculation is held in less esteem.

2ND. Longomontanus, the disciple of Tycho Brahé, and as it were the heir of his discoveries, who, in his Danish astronomy, treading faithfully in the footsteps of his master, brought to a conclusion those things which Tycho was by death prevented from finishing.

3RD. The sagacious Kepler, who formerly assisted Tycho in his calculations, was afterwards astronomer to three Emperors, and happily effected the renovation of the science by the publication of the Rudolphian tables, to which his other writings may be considered a prelude.

4TH. Lastly, Lansberg, who undervalued the labors of his predecessors, and with much assurance endeavoured to substitute his own perpetual tables of the celestial motions, loading them to satiety with the praises of himself and others.

I will give the calculations of these four men, in order that it may appear who has best explained the difficulties respecting Venus, and who, in other respects, is most safely to be trusted. This observation is well suited to the purpose; for the calculation may answer tolerably well in very great distances from the Sun, though it is otherwise erroneous: greater accuracy is necessary in the inferior conjunction; and unless the calculation be, as it were, held together, it will betray gaping chinks, and the smallest error will be detected. It also happens, though why do not know, that whatever is faulty in the hypotheses of the astronomers shews itself principally here, the errors being in this instance accumulated, and not compensating one another as is sometimes the case.

But I shall be content to set forth the calculation from their tables alone, and will not weary myself nor my readers with any geometrical delineation of hypotheses or superfluous computations of triangles; for there is no need of such nicety in refuting gross errors, neither is it necessary to waste paper in a prolix display of circles or in a description of hypotheses, which are incorrect in their very form.

Come then, ye renowned astronomers of our own times! Behold here a noble reward, — Venus promises Urania, fairer than any Helen, to him who shall happily win her.

CHAPTER XI.

The Calculations of Copernicus

I shall commence with the incomparable Copernicus, the successful reviver of what Gellibrand calls the "noble hypothesis of the motion of the Earth," whom all the lovers of astronomy have hitherto followed, and will doubtless continue to do. Having long contemplated and admired a philosophy so sublime and so worthy of a Christian, I thus expressed my aversion to the puerile fictions of the pagan Ptolemy: -

Why should'st thou try, 0 Ptolemy, to pass
Thy narrow-bounded world for aught divine?
Why should thy poor machine presume to claim
A noble maker? Can a narrow space
Call for eternal hands? Will thy mansion
Suit great Jove? or can he from such a seat
Prepare his lightnings for the trembling earth?
Fair are the gods you frame forsooth! nor vain
Would be their fears if giant hands assailed them.
Such little world were well the infant sport
Of Jove in darker times; such toys in truth
His cradle might befit, nor would the work
In after years have e'er been perfected,
When harlot smiles restrained his riper powers.
These are your fancied gods, your paltry dreams;
And worthy them is all you raise around;

The temples that you build are amply large,
Thy heavens are suited to a Jove like thine.
Are such the auspices by which you rule
Your world? No longer I deplore the earth
That stands begirt with solid adamant;
Such walls repel unholy deities,
And keep the nations pure. How wisely doth it
Court repose far from the stars where it would
Have to mingle in degrading commerce,
And find, not heaven, but realms replete with crime.
Calm urge thy chariot through the starry sphere,
O Phœbus! crowds oppressed with wino can bear
No tumult. Now the banquets of the gods
Are spread by one, a youth, whose limbs betray
His steps, whose head in whirling motions lost
Can never mix the cup with steady hand.
Yet spare thyself thy labor wisely cease,
And while the sober deities recover
Their sounder senses, let thy jaded steeds
Renew their strength with nectar and ambrosia.
No trifling task it is to hurl at once
So many gods and stars in uniform
Gyration. Then let those whose little sum
Of learning reaches but to tell the tale
Their fathers told before, whose every word
Deals in absurdities unworthy heaven,
Rival each other to applaud this fable.
But a sublimer throne is thine, and awe
Ineffable awaits thy lightning's course,
Thou God of truth whose certain laws direct

The starry spheres, whilst all the powers above
Admire and tremble; the projected Earth
Rolling along its planetary path
Hath learned to hail thy triumph; and this ago
Enables mortal eyes in thy great works
To view thee nearer, and with nobler thought
To trace the stars whose order proves them thine.
In vain the Sun his fiery steeds would urge,
In vain restrain them, or attempt to guide
Their rapid course within the laws of fate.
The Earth performs their task, and by each day's
Revolving saves to all the distant stars
The useless labor of unceasing motion.
The clouds which once obscured our mental sight
Are gone for ever; great Copernicus,
Sent from above, lays open to our view
The arduous secrets of wide heaven's domain.
Turn hither then your grateful steps, for here
Are wondrous mysteries that you may learn,
Open to all whom, freed from baser thoughts,
The love of truth impels, and whom no cry
Of vulgar men can scare from what is right,
Nor fear oppress, O child of ignorance!
Nor fabling oracles once deemed divine.

It was sufficient for Copernicus to have laid so good a foundation, we must pardon him if, his sublime understanding being perplexed by some few inaccurate and fallacious observations, he failed in rearing the superstructure; for he neither discovered the true form of motion, nor did lie ascertain the numbers with precision, being too much devoted to the circles and equality of the ancients, as appears from this observation which I thus calculate from his tables, assuming the difference between the meridian of Frueburg and our own to be 1° 30’.

Of THE SUN.	**SEX**	**DEG**	**MIN**	**SEC.**
Simple equable motion (æqualis simplex).	3	44	14	29
The simple anomaly of the Equinoxes	2	58	40	46
The prosthaphœresis of the centre to be added	0	10	53	
The proportional parts (scrupula proportionalia)			0	0
The mean anomaly of the Sun		2	31	53
16				
The coequate anomaly (anomalia coequata)	2	32	4	9
The prosthaphœresis of the orbit to be subtracted		0	53	12
Therefore the true simple motion of the Sun	3	43	21	17
Or Venus.				
The apogee	0	48	20	0
The anomaly of the centre	2	55	54	29
The prosthaphœresis of the centre to be subtracted		0	8	43
The proportional parts (scrupula proportionalia)			59	53
The eccentric longitude	3	44	5	46
The mean anomaly of the orbit	2	58	48	7
The equate anomaly of the orbit	2	58	56	50
The prosthaphœresis of the orbit to be added		2	50	20
Therefore the situation of Venus by the fixed stars	3	46	56	6
The south latitude		0	21	30

In the latitude there is a small error, not indeed more than 13’; but in the longitude there is a very considerable one, for Venus, who was actually in conjunction with the Sun, was distant from it, according to this calculation, 3° 34’ 49”, and as her diurnal motion from the Sun is 1° 37’ 40”, they were in conjunction the day after, at four minutes and forty-seven seconds past two.

Therefore it is not on account of Mercury alone that Schickard may pity the vanity and unskilfulness of the astrologers who, putting forward their tables as true, trifle with the fate of posterity. Venus does not smile upon their absurdities:

What good luck is destined for me? What sort of a wife? The inconstant Mercury is propitious, will not Venus, whom the astrologers conciliate by such well-contrived calculations, be so likewise? I perceive that I must apply for other assistance than the scheme of my nativity affords which, so far from telling my fortune, does not even indicate what is already revealed. Are the astrologers then, who are so profoundly ignorant in certainties, to be credited in doubtful matters?

I have computed the situations of Venus and the Sun from the fixed stars, because we are here seeking their distances only; but if you should desire the longitude from the true equinox, add to their situation, with reference to the fixed stars, the true precession of the equinoxes 28° 27' 23", and you will obtain it.

CHAPTER XII.

The Calculation of Lansberg.

LANSBERG, a true disciple of Copernicus, follows him very closely; indeed his numbers only differ slightly respecting some of the planets; but his formula of the hypotheses scarcely varies from that of his master. His astronomy is therefore nothing more than a second edition of the Prutenic tables. In some things perhaps he is a little more elaborate; but, in most, certainly more faulty than his original. Nevertheless he earnestly recommends his immortal fame to posterity; and, under a pompous title, offers his tables as compiled from and agreeing with all sorts of observations, without fear of detection. Let him not be angry if we should prefer, rather than himself those whom he so superciliously condemns: and that it may be known with what justice he so confidently boasts of his own labors, let him explain, in his own words, that most accurate calculation which he has made the subject of so many encomiums.

From the commencement of the Christian era to the time of this observation there are 1638 full Julian years, 10 months, 23 days, 5 hours, and 55 minutes, under the meridian of Liverpool; under that of. Goesa 6 hours and 20 minutes apparent time, or when properly corrected 6 hours and 4 minutes, this is, in Sexagence dierum, 2'" 46" 16', 46 days, 15' 1O",* by which the following motions are given.

	SEX	DEG	MIN	SEC
OF THE EQUINOXES.				
The anomaly	5	58	32	51
The prosthaphtæresis to be added.			12	30
OF THE SUN.				
The mean motion (motus medius)	4	13	3	38

* As the general reader may not understand this mode of calculation, it may be well to state that Horrox takes it from Lansberg who adopts, for the arrangement of his tables, what he called Sexagena dierurn. According to his method, 60 days make a sexagena prima, 60 times 60 or 3600 days a sexagena secunda, and so on. Hence, in
Conformity with a calculation which he gives, we have:-

	3a	2a	Ia	Dies
1600 Julian years	2	42	20	0
38 do. Do		3	51	19
The ten first months of a common year (1639 was not bissextile), or $\frac{304}{60}$			5	4
Additional days in November . . .				23
	2	46	16	46

of time calculated in sexagence ascending; together with 15' 10" of scrupula descending.

	SEX.	DEG	MIN	SEC
The anomaly of the centre	3	16	48	7
The prosthaphæresis of the centre to be added		1	42	50
The proportional parts (scrupula proportionalia)			1	20
The mean motion of the apogee	1	35	54	49
The equate motion of the apogee	1	37	37	39
The true anomaly of the orbit	2	35	25	59
The prosthaphæresis of the orbit to be subtracted		0	51	47

The mean motion of the Sun from the true Equinox……..…	4	13	16	8
Therefore the Sun was in ……………………………………	4	12	24	21
Of Venus.				
The mean motion of the apogee………………………………	1	31	47	11
The anomaly of the centre……………………………………..	2	41	16	27
The prosthaphæresis of the centre to be subtracted……….		0	39	9
The proportional parts (scrupula proportionalia)…………..			58	12
The longitude of the centre……………………………………	4	12	24	29
The mean anomaly of the orbit………………………………..	2	59	50	31
The equate anomaly of the orbit………………………………	3	0	29	40
The prosthaphæresis of the orbit to be subtracted …………		1	19	52
Therefore the longitude of Venus from the mean Equinox...	4	11	4	37
From the true Equinox………………………………………	≠	11	17	7
The mean motion of the northern node…………..………	1	11	43	34
The distance of Venus from the northern node……………..	3	0	40	55
Therefore the north latitude of Venus………………………..		0	10	45

The observation shews Venus in conjunction with the Sun; this calculation separates them 1^{o} 7' 14".

Therefore the conjunction by computation was earlier by 16 hours 31 minutes.

The observation decreases the latitude south, while the calculation increases it as much north. Hence the studious may perceive how little these perpetual tables, which their author so loudly praises, are to be relied upon; certainly a little more modesty would have been more consistent with their pretentions than so many undeserved compliments, which among prudent people have the effect of lessening rather than of increasing confidence.

No one who is disposed to favor Lansberg must be blamed; the diameter and parallax are, in his opinion, assumed to be different from these statements. But, if we should follow him in the longitude, both causes, and in the latitude the former, would increase the error.

CHAPTER XIII

The Calculation. Of Longomontanus.

IT may perhaps be some consolation to the admirers of the Lansbergian astronomy, if there are any, to learn that the followers of Tycho, disowned by their master and to whom Hortensius, the advocate of Lansberg, strenuously denies the merit of having perfectly restored the science of astronomy, (see Preface to Lansberg's Motion of the Earth), labor under a similar or even a greater error; and, lest I should seem to envy them the miserable satisfaction "habuisse socios," I will edify their dull souls by convicting Longomontanus, Tycho's disciple and his too faithful follower in all things whether true or false, of a most palpable blunder. His calculation is thus:

To the current year of our Lord 1639, 24th day of November 5 hours 55 minutes at Liverpool; or 6 hours 52 minutes by apparent time, and 6 hours 46 minutes by mean time at Uraniburg these motions are given.

The anomaly…………………………………………………	3	20	30	28
The prosthaphæresis to be added…………………………..			9	36
OF THE SUN				
The equable motion (motus æqualis)………………………	4	13	9	13
The apogee……………………………………………………	1	36	15	14
The anomaly of the orbit………………………………………	2	36	53	59
The prosthaphæresis of the orbit to be subtracted…………		0	49	46
The mean motion from the true equinox……………………	4	13	18	49
Therefore the Sun's situation………………………………	≠	12	29	3

OF VENUS.

The apogee……………………………………………………	1	30	22	30
The anomaly of the eccentric………………………………	..2	42	46	43
The prosthaphæresis of the eccentric to be subtracted…...		0	33	5
The proportional parts (scrupula proportionalia)……………			58	30
The eccentric longitude………………………………………	.4	12	36	8
The mean anomaly of the orbit………………………………	3	0	20	55
The equate anomaly of the orbit……………………………	.0	54	0	3
The prosthaphæresis of the orbit to be subtracted		2	28	37
Therefore the longitude of Venus from the mean Equinox……………………………………………………	..4	10	7	31
From the true equinox…………………………………	...≠	10	17	7
The mean motion of the northern node…………………	1	14	22	30
The distance of Venus from the northern node…………	...2	58	13	38
Therefore the south latitude……………………………		0	7	40

The latitude is sufficiently correct, but the longitude errs 2° 11' 56", and hence it is one day, eight hours, and twenty-five minutes too little. In the latitude, therefore, he is more correct than Lansberg, but in the longitude he is almost twice as much at fault; nevertheless I do not wish it to be thought, from this one instance, that Lansberg's tables are superior to his in other matters, for I have often proved that Longomontanus is more correct as to the three superior planets, and also with respect to the moon.

CHAPTER XIV.

The Calculation of Kepler.

BUT I leave these patrons of circles and equality, these artificers of an useless labyrinth, and their hypotheses which are faulty in their construction and incapable of amendment. For although the measures of the eccentricities of the orbits, together with the mean motions, might be corrected so as to resemble this and other observations; yet as the stars are governed by different laws from those which they have invented, it is impossible by a complication of such circles to bring about an entire agreement with appearances.

I hasten therefore to that prince of astronomers, Kepler, to whose discoveries alone, all who understand the science will allow that we owe more than to those of any other person. I venerate with the greatest honour and admiration his sublime and enviably happy genius; and if necessary, I would defend with my best efforts the Uranian citadel of the noble hero who has so much surpassed his fellows, nor shall any one while I live, violate his ashes with impunity. His death was an event that must ever have happened too soon; the science of astronomy received the lamentable intelligence whilst left iii the hands of a few trifling professors who had kept themselves concealed like owls until the brightness of his sun had set.

Who, mighty shade, shall sing thy praises? who,
Worthy so great a task, shall reach the stars?
Who now shall chant thy fate? The modem seers
Portend that heaven’s disturbed by monsters which
Are unintelligible to mankind;
Perchance in pity thou dost still protect
The weaker minds of those whom thy decease
Hath robbed of nature’s best interpreter.
Since such a guide is lost, what other now,
Deserving to succeed, can take the reins?
Or should the stars rebel, who can restore
Them to their course, and bind with closer ties
Their wandering ways? 0! thou alone couldst take
The arduous guidance and shake the strong rein

To urge along the slothful retinue;
By thee restrained, the vulgar crowd
Dared not to climb the sacred car of heaven.
No devious course could cause thy thoughts to wander
In perplexity; fictitious circles
Could not enthral thy loftier genius;
But thy mind, intent on the sublime, with
Faithful hand traced the motions which the God
Of nature hath decreed. While yet the power
Was thine to guide their way, true to thy rules
Each planet in its ordered path revolved,
And all rejoiced to follow in thy train.
But now deprived of thee science declines,
Sinking in antiquated errors; all
The stars are hurled as madness may devise,
And heaven's deformed by senseless violence!
Unhappy Germany! though torn by wars,
The sword alone will not effect thy ruin;
A heavier curse conspires to bring about
Thy mind's destruction. 'Tis this encourages
Hortensius to insult Pelides' dust;
By this the pompons Belgian, bolder grown,
Imposes on the world Perpetual Tables,
And spurns the embers which a powerful flame
Has sadly left; nor does he even fear
Lest his bold thefts should imply be detected,
Now that great Kepler's numbered with the dead.
Chaos is come again, the world's unhinged,
All things, in thee o'erpowered by fate, betray
The noblest art to trifling sycophants.

Kepler's Rudolphian tables give the following calculation of the observation, the time having been before reduced and settled by Longomontanus.

Of THE SUN.	**SEL**	**DEO**	**MIN**	***SEC***
The equable motion (motus æqualis)………………………	4	13	18	7
The apogee…………………………………………………	1	36	24	5
The mean anomaly…………………………………………	2	36	54	2
The equation to be subtracted…………………………….		0	49	32
Therefore the Sun's situation…………………………….	≠	12	28	35
The distance between the Earth and theSun……………	9	8	35	0

	SEX.	DEG.	MIN.	SEC.
The equable motion……………………………………………	1	13	19	2
The aphelion……………………………………………………	5	2	4	57
The mean anomaly…………………………………………….	2	11	14	5
The equation to be subtracted………………………………..	2	10	36	4
Therefore the eccentric longitude……………………………	1	12	42	58
Reduced to the ecliptic……………………………………..……	1	12	43	4
The distance between the Sun and Venus…………………			72084	
The anomaly of the commutation……………………………	3	0	14	29
The prosthaphæresis of the orbit to be subtracted………..		0	39	43
Therefore the apparent situation of Venus…………………	≠	11	48	52
The northern node……………………………………………	1	13	31	13
The distance of Venus from the northern node…………….	5	59	11	45
Therefore the south latitude……………………….………….		0	7	45

In the longitude there is an error of 39' 43", which is as much as the prosthaphæresis of the orbit, and gives 9 hours 46 minutes, by which quantity the conjunction was earlier.

In the latitude, the calculation is only slightly defective. Hence it is clear that Kepler's tables represent the situation of Venus in the Sun the most correctly of all, and in this respect at least, are to be preferred. I have also found them better in various ways, both from my own observations and from those of others.

CHAPTER XV

Correction of the Motions according to Rudolphl.

SINCE the error which I discovered in the Rudolphian tables is so great, it may not be amiss to shew how the calculation may be amended in order to agree with this and other observations. I quite agree in the form of Kepler's hypotheses, and gladly receive both his annual and diurnal motion of the earth. I am of opinion also that these motions do not arise from complicated fictions of useless circles, but from natural and magnetic causes, and that they are owing to the rotation of the Sun on its axis. He knows but little of astronomy who is ignorant that the figure of the orbit is elliptical; that its centre is the body of the Sun, and not a fictitious point near it: that the motion of the planet is really unequal; that the whole apparent inequality does not proceed from its eccentricity alone; and finally, that the inclination of all the orbits to the ecliptic is not influenced by the annual motion, but is fixed and constant. No one, we repeat, who denies such facts is sufficiently acquainted with astronomical observations. They are all fully demonstrated by Kepler, and I have found them, by subsequent examination, to be strictly true; but with the view of attaining greater perfection in the theory constructed upon these principles and in the quantity of the mean motions and eccentricities of the orbits, I have attempted to correct the motions of the Sun and Venus in the following manner; an undertaking which could not be displeasing to Kepler himself; as he frankly confessed that these matters were not yet thoroughly explored.

I. OF THE SUN.

1. The mean motion of the Sun, as to its periodical quantity, is correctly

determined by Kepler, but it seems to me that one minute should be subtracted from its roots; the places of the fixed stars however ought not on that account to be diminished, as Longomontanus has hastily concluded.

2. The apogee is right in all respects.

3. The eccentricity, which he makes 1800 with a radius of 100,000, I make, for many reasons, only 1735. Therefore the greatest equation will be, according to me, 1^{o} 59' 18"; whereas according to him it is 2^{o} 3' 46"; and herein lies Kepler's principal error which has betrayed him into many others, as I shall shew at another opportunity.

4. The last correction, which I shall make, relates to the triple method of equalizing the natural days in the astronomical or Emperic demonstration of Tycho, and in the physical one of Kepler. The correction of the lunar motion requires this, and the diminished eccentricity of the Sun explains the difficulty in which Kepler was so deeply involved; but more of this in its proper place, God willing.

II.OF VENUS.

1. I find the mean motion of Venus much slower than Kepler makes it, namely about 18' in a hundred years; but in the beginning of the present year, 1640, 9' 20" should be subtracted, and hence arises the chief cause of the great discrepancy in the calculation of Rudolphi concerning this observation.

2. The aphelion, in this age, remains at 5^{o} in; and the observations of our predecessors seem to allow it scarcely any, or at least, an exceedingly slow motion. Hence it is clear why those who refer the eccentricities of the planets to the centre of the great orbit of the Earth, find the eccentricity of Venus less at this day than what Ptolemy has recorded; for he added, during the advance of the apogee, the moveable centre of the orbit of the Earth to the fixed centre of the orbit of Venus.

3. The true eccentricity is 750, and the semi-diameter of the eccentric of Venus 100,000; therefore its greatest equation is 51' 34", whereas according

to Kepler, the former is 692, and the latter 47’ 36”.

4. The radius of the orbit of Venus is to the orbit of the Earth as 72,333, not 72,414 as he fixed it, to 100,000.

5. It has already been demonstrated that
8’ 30” are to be subtracted from the northern node, from the beginning of the year 1640, which may also be done hereafter in other ages.

6. The inclination of the orbit to the ecliptic appears slightly to exceed the calculation of Kepler. he has fixed it at 3^{o} 22’ whilst I make it 3^{o} 24’; but certainly it is not so much as 3^{o} 30’, as Lansberg and Longomontanus suppose

I partly began these corrections of the Rudolphian tables before the transit of Venus, from other observations; and afterwards considerably amended them by further experiment8 very carefully instituted. I have also brought this calculation, otherwise tolerably exact, to coincide even in the minutest particulars with our observation, in the following manner:-

Of THE SUN

	SEX.	DEG.	MIN.	SEC.
The equable motion (motus æqualis)………………………	4	13	17	22
The apogee……………………………………………………	1	36	24	5
The mean anomaly…………………………………………...	2	36	35	17
The equation to be subtracted……………………………….			47	47
Therefore the situation of the sun…………………………...	≠	12	29	35
The distance between the Sun and the Earth……………….				98409

OF VENUS

	SEX.	DEG.	MIN.	SEC.
The equable motion (motus æqualis)………………………	1	13	10	16
The aphelion…………………………………………………...	5	5	0	0
The mean anomaly……………………………………………	2	8	10	16
The equation to be subtracted…………………………………			40	47
Therefore the eccentric longitude……………………………	1	12	29	29
Reduced to the ecliptic……………………………………...	1	12	29	35
The distance between the Sun and Venus…………………..				72000

The northern node……………………………………………	1	13	22	25
Distance of Venus from the northern node………………….	5	59	6	44
Therefore the south latitude…………………………………			8	31

You see here that, agreeably to our expectation, Venus was exactly conjoined with the centre of the Sun; therefore there is no anomaly of the commutation, nor prosthaphœresis of the orbit. You also see that the latitude and other particulars exactly agree with the observation; this result indeed might easily be obtained from a single example, but it would be tedious, and foreign to the subject in hand, to shew what might happen in other circumstances. I ask therefore that credit may be given to my bare word for the present; and, with God's permission, by further collating and condensing my proofs, I will cause Venus to arise from this sea of error, to come forth, wrapt in the chain of numbers, more beautifully than she did from the arms of Vulcan, and to learn a modesty unprecedented in her former deportment; nor, as heretofore, shall she wander in wanton lasciviousness, evading and despising the care of her guardians whose councils have been so little attended to, as we have already plainly seen:

CHAPTER XVI.

On the diameter of Venus.

CONGRATULATE us, Gassendi, on clearing from suspicion your observation of Mercury, and let astronomers cease to wonder at the surprising smallness of the least of the planets, now they find that the one which seemed the largest and brightest scarcely exceeds it. Mercury may well bear his loss since Venus sustains a greater.

I observed the diameter of Venus (Chap. I.) to be 1' 12", the Sun being 30'; therefore the latter being 31' 30", the true diameter of the former is 1' 16". My friend Mr. Crabtree's observation agrees with this calculation: I am sure she did not appear greater; if there is any error, it is in an excess. There is no reason why any one should doubt the truth of the observation; unless indeed he is unacquainted with the telescope, or influenced by the knavery of the Peripatetic, or suspects our honesty; and I shall not stay to argue either with those who have not seen this instrument or who mistrust its fidelity, for it is vain to contend with ignorance and self-will. Permit me to remind any who may suspect our good faith, how easy it would be to investigate the subject for themselves, and how little it would serve our purpose to distort truth by falsehood.

Let us then examine the opinions of others, in order that it may appear with what degree of accuracy astronomers have hitherto estimated the magnitudes of the stars.

1. Tycho Brahé, in whom most men place confidence in such matters, makes the diameter of Venus 3' 15" in her mean distance from the Earth. But the distance of Venus from the Earth according to our observation was 26,409, and the mean distance of Venus or the Sun from the Earth 100,000 as was before shewn; therefore Venus, who from the distance of 100,000 appears to be 3' 15", at the distance of only 26,409 will be 12' 18". But this is far from the truth, being nearly ten times as much as in the observation.

2. Philip Lansberg, who boasts so authoritatively of his Uranometria, makes the diameter of Venus in her mean distance 3' 0"; therefore at the distance before-mentioned, it would be 11' 21". This is very far from the mark, being nine times greater than in truth it should be.

3. From the tables of Rudolphi, according to the precepts of Kepler, the diameter of Venus, by our observation, is computed to be 6' 51"; his is the nearest approach to the truth, as is generally the case with Kepler, but still it is five times or more in excess.

Copernicus and Longomontanus say nothing of the diameters of the five primary planets; but the ancients, Alphraganus and Albategnius, differ very little from Tycho and Lansberg.

Since therefore the observed diameter of Venus differed so considerably from what has been assigned by the whole school of astronomy, it may perchance be doubted whether some optical deception has not caused it to appear small; for Schickard, an excellent mathematician and professor of Hebrew and astronomy in the university of Tubingen, supposed that such was the case with respect to the Mercury of Gassendi, the minuteness of which caused equal astonishment. The reasons why he supposed Mercury in the Sun to be diminished below the truth, as they apply equally to Venus, I shall briefly subjoin, and with the author's permission, examine; for I observe that some sensible men acquiesce in his opinion, and, from not having sufficiently considered the subject, at once take for granted that which connects, upon any grounds, new appearances with old opinions.

1. He takes his first argument from the diffusion of the solar light. "You know," says he "it is the nature of this light to spread and diffuse itself on all sides, hence it necessarily follows that opaque bodies in the immediate neighbourhood are somewhat divided and cut away. You may see this in a familiar experiment which I have often tried by candle-light among my winter amusements; if you cause a short stick to be held out at a short distance, you will find that as you stand apart from it, it will appear to be serrated on both sides where the light crosses it, as if it were cut and ragged."

2. He argues from the opticians Alhazen the Arabian, and Vitellio, the Sarmatian, who shew that the base of' the shadow is less than the hemisphere of its body, if the illuminating sphere be greater than that which is illuminated; whence be assumes as certain that "nothing could be seen of Mercury or Venus in the Sun, except what was turned away from its light and placed in the shade; and that this must be less than half; since the illuminated part is greater than half; therefore Mercury, and consequently Venus, appear to be small."

3. He gives another reason which he confesses to be only probable: "If it be right to reason from the analogy of the moon to other planets, we must believe that they are not all obscure, but have opaque parts in the middle, or nuclei,

whilst externally they are covered with a kind of transparent coating like a mirror, the one part representing the metallic foil and the other the glass which reflects the rays that fall upon it; for when the moon approaches the stars, she seems to envelope them as they draw near and to admit them somewhat within her luminous periphery; on the contrary, when they are receding, she seems to restore them to sight before they touch her border. Maestlinus noticed this in the cases of Mars and of the heart of the Scorpion, in the year 1595 (*Disput. de pass. plan. Thes.* 148) whence he inferred that they are surrounded by a kind of transparent air. But I leave this for more mature experience".

With your leave, most learned Schickard, I must entirely differ from you in this particular, for I do not believe that either your Mercury or our Venus were at all less than the true measurement requires; nor are they in the heavens different from what they appear to us in the Sun, unless that the radiations might interfere and increase their visible magnitude in the day time, though this would not affect bodies seen upon the Sun's disc. You will therefore allow me to prefer the simple truth to your arguments, which I think may be easily confuted.

1. I readily admit that there is a remarkable, and indeed an almost incredible, diffusion of light when we gaze upon it with the naked eye; and I wish that astronomers would sufficiently bear this in mind, and that they would not allow the false rays of the planets and fixed stars to deceive them by making the true magnitude of Venus and Mercury seen in the Sun to appear so astonishingowing to this delusion. Contiguous opaque bodies are certainly divided and cut away, when beheld by the naked eye, but not otherwise: but your experiment of the stick seen in the candle-light, although it may be true, does not appear to have any reference to the point at issue: for the reason why the light of the candle diminishes the magnitude of the stick is because its rays are refracted and amplified by the moisture of the beholder's eye; but if you look upon the shadow of the stick upon the wall it will not be at all less than the

stick itself, unless the light be larger than the object and the shadow be diminished at a certain distance according to a geometrical law. But we observed the shadows of Mercury and Venus depicted in the light of the Sun, through the telescope by which the rays are so modified as to be easily endured by the eyes. Indeed if we had tried to observe the planets in the Sun with the naked eye, I can readily conceive that we should not have been able to see them at all; for the diminutive bodies of Mercury and Venus would have been entirely concealed from our view, owing to the powerful light of the Sun being so oppressive. But in a darkened view, the affair is very different; and there is no reason to fear the light of the Sun diffusing itself more than is legitimate or cutting off the contiguous opaque bodies beyond what is proportionate.

We have a much better experiment when the moon eclipses the Sun. The naked eye always estimates the eclipse less than the truth, as may be proved by many examples; but the telescope exhibits the exact quantity, both of the eclipse and of the lunar diameter. I lately proved this in the eclipse of the Sun on the 22nd of May 1639; and Gasendi observed the same thing in a similar eclipse on the 11th of May 1621, when the diameter of the moon appeared by no means less than as observed at other times. Although the moon when at her full seems to be enlarged beyond her proper size, yet this is a deception, which does not occur in an eclipse of the Sun. Moreover you yourself know the absurdity of the dogma for reducing the semi-diameter of the new moons, which Tycho, and after him Longomontanus sought to put upon us. Why then, let me ask, do you maintain that so zealously in Mercury which you properly reject as untenable in relation to the moon?

2. Let it be conceded to you that the Sun illuminates more than half of the bodies of Mercury and Venus, and hence, since those bodies are precisely spherical, that they are less than half in the shade: now in your turn you must allow that that which, on this account, is slightly diminished, is diminished still further from a prior cause which deceives the eye in a most remarkable

manner. The amount is indeed so small that it is scarcely worth naming; but, lest the uninformed should be misled, I will explain how it arises: The diameter of the Sun, as seen from the Earth, at the distance of 98,409 parts, appeared to be 31’ 30”, and from Venus at the distance of 72,000 to be 43’ 3”; but the diameter of Venus from the Sun appears 0’ 28”, therefore the angle of the cone of the shadow of Venus will be 42’ 35”, which, being subtracted from the semi-circle, leaves the circumference of the shadow 179^0 17’ 25”, the half of which 89^0 38’ $42\frac{1}{2}$”, 999,980,820, is the sine to the radius 1 ,000,000,000, and the apparent diameter of Venus is 1’ 16” to the true which is 1’ 16” 0”’ 5””. But after all of what consequence is a trifling difference which does not exceed 5””’? Or how can the prior cause, which is of itself of no importance, be deemed to increase a discrepancy, which is so small?

But since it pleases you to debate so ingeniously, I will reply with a similar subtlety. I deny that the Sun illuminates more than one half, or that the planet appears less to us from any such reason; on the contrary, he illuminates less than the half; and so far are we from seeing the illuminated portion of the hemisphere, that we cannot discern the whole of that which is obscure, the dark part being greater than the portion which is irradiated:
for I have no doubt that the bodies of all the planets, and especially of Venus on account of her strong reflection, are mountainous and uneven like the moon and the Earth. These mountains therefore will obstruct the rays of the Sun so that they cannot extend beyond the half; indeed they will not reach over more than the half of the mountains which intervene on every side, and obstruct the rays of light towards the even ground.
This is the case as regards the Earth where the Sun frequently conceals himself behind the mountains before he reaches his true setting; and these mountains terminate our view so that it does not extend as far as to the middle; accordingly the apparent magnitude would be increased rather than diminished thereby. But these are trifles,

3. What you advance in the third place is by no means proved, nor do you

certainly state, such is your modesty, that the light of the Sun is reflected from the moon and planets as from a looking-glass. The idea is less common than ridiculous, for the least part of a spherical glass reflects the light of the Sun, though all surrounding objects should remain in obscurity. It is true that, on account of its great distance, the particle cannot be seen, but if it could, it would appear to be circular like the Sun; for the same reason, the moon never appears forked; indeed the object would become invisible. See a dissertation on this question by that acute astronomer *Galileo* in his *Cosmic System*.

Moreover the lunar mountains seen through the telescope plainly shew, from the very dark shadow which they cast, that the external surface of the moon is not transparent. Hence it is evident that her exterior matter is not less opaque than that of our Earth: nor do you consider that to entertain a contrary option is tacitly to confirm the Tychonian diminution of the moon in solar eclipses, which you elsewhere condemn as absurd.

I have not the least doubt but that the moon is surrounded by a kind of transparent air; nor do I think otherwise of the rest of the planets whose radiation is, on that account, very likely to be augmented. For the same reason the moon may seem to envelope the stars before they actually reach her edge, especially if she be seen with the naked eye, and the star is in contact with her lucid margin; but if you view her with the telescope covering the stars with a dark shade, you will perceive that, as they approach her edge, they very suddenly vanish. William Crabtree and I observed this most clearly in the conjunction of the moon and Pleiades on the evening of the 19th of March in the year 1637. These circumstances therefore do not by any means increase the magnitudes of Venus or Mercury.

Although Mercury rising from the horizon at Aix in Provence, together with Arcturus, on the 10th of October 1621, appeared equal to it in the eyes of Gassendi, yet this is no disparagement to the observation of the transit. For albeit that star is commonly estimated 2’, it is nevertheless very properly taken by you to be much less than 1’. Galileo found, by a singular method of observation, that the diameter of a fixed star of the first magnitude was not greater than 5”; and if the fixed stars did not shine by their own light, they would perhaps appear to be much less: the telescope, by which they are so much more distinctly seen, represents them as mere points, as was evident in the conjunction of the moon with the Pleiades; for as soon as the moon covered the bodies of the stars, their false rays immediately vanished, whereas if these had proceeded from the bodies of the stars themselves, they would have subsided gradually and not suddenly.

I greatly wonder that all astronomers should have been so much deceived in computing the diameters of the planets, which they make five or six, and in some instances even nine or ten times as great as they ought to be. I think however that I understand the cause of the error, which is that they have not taken these adventitious rays into consideration. Still it surprises me that they should all have been so negligent as not to perceive a deception so remarkable as to be detected even by the naked eye. For I have often observed both Venus and Jupiter, during the day, when the Sun’s altitude was some degrees, to be so minute that they could scarcely be discerned, and I have, in imagination, compared their diameters with those of the Sun and moon; but they seemed to delay all computation, and not to equal one-hundredth part of the diameter of the former luminary, whereas the common opinion supposes them to be a tenth or even a sixth or fifth. Galileo notices this error in estimating the diameters of the planets and fixed stars, and gives a method of measuring them even without the aid of a telescope, which I have frequently tried with respect to Venus, and by which, although I may not have ascertained the truth very accurately, I have discovered the greatness of the common error.

On the 7th of January in the present year 1640, the Sun being risen and diminishing the rays of Venus by his own light, an iron needle whose diameter was 8 parts at a distance of 4300 covered the planet Venus; therefore the diameter was 0' 38".

On the 29th of January in the same year, a needle of 5 parts covered Venus at the distance of 383; therefore the diameter was 0' 27".

In these observations I looked through a small opening made with a fine needle in a piece of card; by which method alone, even on a dark night, the diameters of the planets appear to be wonderfully reduced: so that, unless you are very strong-sighted, you can scarcely discover either the planets or the fixed stars which deceive the naked eye from their rays being so entirely cut off by the narrow opening.

For these reasons, I have no doubt that the diameter of Venus in the Sun appeared its proper size, and did not differ one second from the truth.

CHAPTER XVII

Of the Diameters of the rest of the Planets, of the Proportion of the Celestial Spheres, and of the Parallax, of the Sun.

I SHALL here say something which may tend to throw light upon the dimensions of the stars, and upon the horizontal parallax of the Sun, a matter of the greatest importance, and one which has keen the subject of much fruitless speculation; but I will not speak dogmatically, nor, as I may say, "ex cathedrâ," but rather for the sake of promoting discussion, and with the view of examining other men's opinions.

John Kepler, the prince of astronomers, speaking of the relative proportion of the planets (*Astr. Cop*. page 484), thinks it "quite agreeable to, nature that the order of their magnitudes and of their spheres should be the same; that is to say, that of the six primary planets, Mercury should be the least, and Saturn the largest, inasmuch as the former moves in the smallest, and the latter in the largest orbit."

"But as the dimensions of their bodies may be regarded as threefold, either according to their diameters, their superficies, or their bulk," he is doubtful which should be preferred. He thinks the first proportion "to be beyond question contrary to original reasons, as well as to the observations made on the diameters by means of the Belgian telescope." He advocates the second, because the original reasons are preferable; whilst Remus Quietanus, a man well versed in practical observations, defends the third; and with him Kepler at length agrees, retaining this proportion in the Rudolphian tables. But as this was not found to be entirely satisfactory, he sought a proportion in the density of the matter, whereby the bodies of equal magnitude may differ in weight, and vice versâ.

To give my opinion upon the subject, I am persuaded that the proportion of the globes and orbits of the planets is the most accurate and certain, for such would appear the most agreeable to the Divine Nature which formed all things by weight and measurement, and as Plato says, "æternam exercet geometriam." Moreover the proportion that obtains between the periods of the motions of the planets and the semi-diameters of the orbits is most exact, as Kepler, who discovered it, very justly remarks, and as I have accurately proved by repeated observation. Indeed there is not an error even of a single second. Since therefore it is true that the Sun by its attractive power regulates the motions of the six primary planets, I cannot conceive how it could adapt that power so perfectly to their several distances, unless those moveable globes themselves were similarly proportioned. In short, a well-conducted inspection of the diameters clearly warrants the same conclusion; neither is it necessary with Kepler to have recourse to material density.

What then, you will ask, is the proportion of these orbits and bodies? I reply, that it is the first one which has reference to the diameters, and which Kepler and others very inconsiderately reject; and this proportion is more acceptable from its suitableness, and has been more corroborated by my own observation than that of either superficies or bulk.

For what, I ask, can be more absurd than to compare the semi-diameter of the orbit with the superficies or magnitude of the planet, rather than with its semi-diameter? It is as though we were to compare the head of one person with the foot of another, or as the poet says

“Humano capiti cervicem pictor equinam Jungere si velit, et varias inducere plumas
Undique collatis membris.”

But on the other band, what can be more appropriate than that the diameters of the orbit and of the planet should be proportioned to one another? According to this relation, both their superficies and magnitudes should be similarly proportioned. If Peter be twice as tall (altior) as John, it is not necessary in order to preserve the proportion, that his head be twice as great, (majus) nor twice the superficies, but twice as thick (crassius); and the matter will stand thus: as the body of Peter is to the body of John, so is the head of Peter to the head of John, in whatever proportion, whether of thickness, (crassitudinis,) or of superficies or bulk (corpulantiœ); and so it is with regard to the spheres. For, because Saturn is nearly ten times taller (altior) than the Earth, he will not therefore be ten times greater, (major,) nor have a superficies ten times larger; but inasmuch as they are spheres, the orbital diameter of Saturn will contain ten times that of the Earth. Indeed any proportion may be calculated in this manner; for as the diameter, superficies, or bulk of the sphere of Saturn is to the diameter, superficies, or bulk of the sphere of the Earth, so is the diameter, superficies, or bulk of the globe of Saturn to the diameter, superficies, or bulk of the globe of the Earth; and so it is with regard to the rest.

But let us pass on to notices the observations upon which they chiefly rely who reject these arbitrary proportions as vain. It is clear from the example of Venus that experience is entirely against the proportion of Kepler; and this is also evident from Gassendi's observation of the planet Mercury, the diameter of which he found to be scarcely equal to the third part of a minute, although Kepler's calculation extends it to three minutes. The same is the case with reference to Mars whose diameter, according to Kepler's rules, is sometimes increased beyond six minutes whereas, in reality, it never equalled two: and Kepler himself confesses that when Mars was nearest the Earth, he did not appear much larger than Jupiter which he estimates at only fifty seconds. He errs less, scarcely at all, with regard to Saturn and Jupiter.

But Kepler writes that the proportion of the diameters is without doubt disproved by observation. I reply that he created a shadow, which prevented him from seeing clearly. It is true that observation is opposed to it, if his parallax of the Sun, which is of one minute, is to be taken; but I see no necessity for adopting such a parallax, nor do I acknowledge the propriety of his original speculations, much less of his other arguments. Such reasoning is absurd, and like begging the question; the true proportion of the orbits and globes should be sought from observation. In this way the apparent semi-diameter of the Earth, or parallax of the Sun, may be concluded; and if this is borne out by observation the thing is finished.

I say therefore that the diameter of any primary planet, distant from the Sun 15,000 of its own semi-diameters, must appear in the Sun near 0' 28" in mean distance. This seems to be consistent with nature; and I will shew in the case of each of the planets that it is not contrary to observation.

1. I will begin with Venus whose diameter I have observed most accurately; and, in her cone junction with the Sun, found to be 1' 16", she being, at the time, distant from the Earth 26,409 parts. In her mean distance

therefore of 72,333 from the Sun, it appears to be nearly 0’ 28”.

2. The observation, which Gassendi made on the 28th of October 1631, proves almost the same thing with respect to Mercury: he found that his diameter in the Sun scarcely equalled twenty seconds. The Rudolphian calculation makes the distance of Mercury from the Earth 67,525; therefore, in his mean distance from the Sun which that calculation states to be 38,806, Mercury will be nearly equal to 0’ 34”, which approaches closely to 0’ 28”, a quantity that is given precisely if four seconds be taken from the observation, as indeed his words seem to intimate. thus these two planets preserve their proportion in a remarkable manner, nor do I believe that the rest would differ if they could be observed as carefully; but since we have not the like advantage with regard to them, we must pass on to other methods.

3. Remus and Kepler suppose that Saturn never exceeded thirty seconds, a conjecture which I conceive to be very near the truth, as this planet does not differ perceptibly in respect of distance or diameter. At ten o’clock on the evening of the 6th of September 1639, Saturn appeared as if joined in longitude to a little star placed by Tycho’s catalogue in 2^0 ν ϑ, and he is further said to have appeared at the back of a star of the fifth magnitude, and rather towards the west. The distance compared with the diameter of the moon, was thought to be seven or eight minutes; and upon comparing it afterwards with the diameter of Saturn, I was unable, owing to the great variation, to form a precise estimate; it was however greater than 8 to 1, and less than 16 to 1; Saturn therefore rather exceeded half-a-minute, but did not equal a whole

minute. All this was ascertained by means of a telescope.

4. Kepler supposes (Astr. Cop. page 485) that Jupiter covers about fifty seconds by twilight. My proportion gives thirty-seven; the difference is not very great, and may be explained by Jupiter's brightness which increases his appearance. I have often compared Jupiter with Venus, which may be done with certainty, as they shine so equally. On the morning of the 25th February 1640, I thought him rather less; on the 2nd March, I thought him equal or perhaps rather larger; on the 6th, I thought him evidently larger. The diameter of Venus, at that time, was 0' 24", according to my estimate; and that of Jupiter about the same quantity. I do not suppose that this calculation is so accurate that a fault of a few seconds may not have arisen in it, either from the variable altitude of the planets, or from the degree of clearness of the diurnal light; but the conjecture is sufficiently satisfactory to my own mind, since it is clear that Jupiter does not differ perceptibly from the proportion of the other planets.

5. The planet Mars loses by comparison with the rest; and certainly does not exceed the assigned proportion. I suppose this is owing to his light being so remarkably obscure, for none of the planets sheds a feebler glow, or diffuses fewer rays. In the beginning of the month of March 1640, Mars appeared much less than Jupiter, though they were in reality equal. He emits however a stronger ray by twilight when he is nearest to the Earth, and sometimes appears so immensely large that he is mistaken by the inexperienced for a new star; on this latter occasion he seems nearly equal to two minutes, a quantity which perhaps he reaches; there is however some doubt upon this point, inasmuch as no other planet, Jupiter and Venus not excepted, actually attains this dimension, though apparently they do not fall far short of it. But there is no need of hesitation when others extend the diameter

to six or seven minutes; the proportion here given is at all events probable, and would doubtless agree very well with our observations, if we could make them with sufficient accuracy. It is, without controversy, much more correct than the opinions put forward by others, which are sometimes many minutes in excess of the truth, as may be seen by referring to the instances of Venus and Mars.

6. Since therefore it is certain that the diameters of the five primary planets, in mean distance, appear from the Sun 0’ 28”, and that none of them deviate from this rule, tell me, ye followers of Copernicus, for I esteem not the opinions of others, tell me what prevents our fixing the diameter of the Earth at the same measurement, the parallax of the Sun being nearly 0’ 14” at a distance, in round numbers, of 15000 of the Earth’s semi-diameters? Certainly, if the Earth agree with the rest as to motion, if the proportion of its orbit to that of the rest be so exact, it is ridiculous to suppose that it should differ so remarkably in the proportion of its diameter. For it is incredible that of the six primary planets the diameter of one should be as much as 2’, or as others make it 6’, whilst all the rest should not exceed 0’ 28”. I have not within reach the opinions of other astronomers; but every one must believe what he sees for himself, and to me such a parallax seems absurd.

But it may be replied that this is merely a probable conjecture, and has not the force of demonstration; and further that so immense a distance is unbelievable, inasmuch as it exceeds, by ten times or more, the opinions hitherto received which so many excellent astronomers have geometrically demonstrated from their observations on eclipses. But I answer:

1. I do not put forth this conjecture as an absolute demonstration, but rather as being highly probable, and having as much weight as many others, which are carefully received in astronomy. Who, for instance, will prove to me that all the stars are spherical bodies? This has long been known to be true as to the Earth and moon, and has been very recently ascertained as to the Sun and Venus, and the fact that such is the case with them obliges us to suppose, although it cannot be demonstrated by experiments, that it is so with Jupiter

and Saturn, &c.; at all events they are not planes as they appear to be to us. Kepler rightly concluded that the figure of the orbits of all the planets is elliptical; and though this cannot be verified with respect to Venus and the Earth, on account of their small eccentricity, it is sufficient that observations do not disprove in their case that form which is required in the case of others, and it is enough that no good reason can be alleged why we should not assign to the Earth the same proportion which all other planets possess.

2. It has lately been shewn, from the diameter of Venus, how little importance is to be attached to the common opinion of astronomers respecting the Sun's parallax; for though the planet was so long open to observation, and her diameter could have been measured by so many different methods, it is fixed, by common consent, at least ten times as great as it ought to be. What fear then of innovation can arise from my stating that the same thing has happened in respect of the diameter of the Earth, the appearance of which in the Sun no one ever saw, and the investigation of which is most difficult, and has not hitherto been properly undertaken?

3. Moreover if any one has clearly demonstrated from observation a greater parallax, and does not find mine to be in all respects confirmed, I am willing to reject it as a false speculation. I know how loudly some speak of the distance of the Sun as demonstrated from the centre of the Earth; but they are triflers, seeking for vain glory, and trying to impose fallacies upon the credulous , instead of bringing forward actual proof.

I had intended to offer a more extended treatise on the Sun's parallax; but as the subject appears foreign to our present purpose, and cannot be dismissed with a few incomplete arguments, I prefer discussing it in a separate treatise, "De syderum dimensione" which I have in hand. In this work, I examine the opinions and views of others; I fully explain the diagram of Hipparchus by which the Sun's parallax is usually demonstrated, and I subjoin sundry new speculations; I also shew that the hypotheses of no astronomer, Ptolemy not excepted, nor even Lansberg who boasts so loudly of his knowledge of this subject, answer to that diagram, but that Kepler alone properly understood it; I shew in fact that the hypotheses of all astronomers make the Sun's parallax either absolutely nothing, or so small