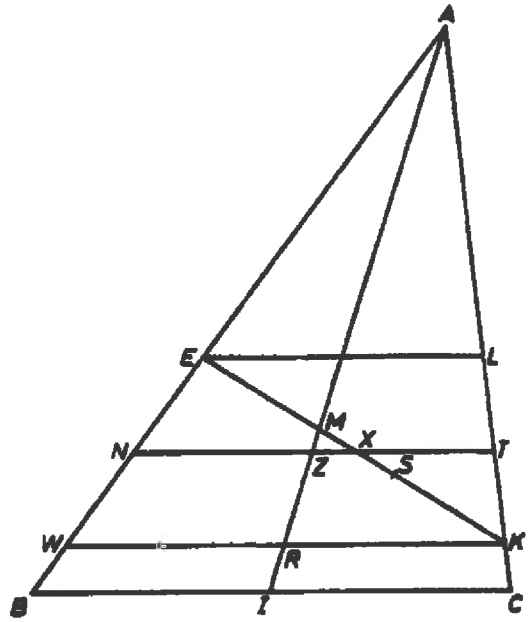
Post-Galilean Scientists Who Came to Prominence in the Years Between Descartes' and Newton's *Principia*s

In England

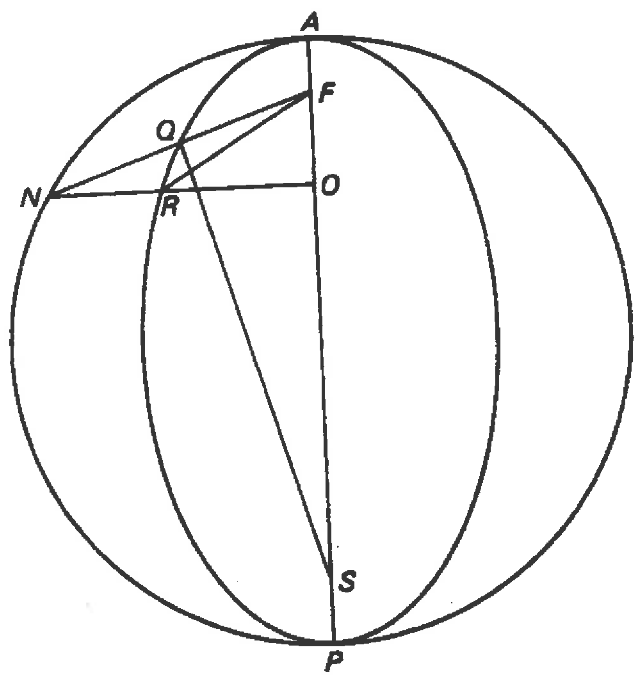
Wallis	**(1616-1703)**
Ward	**(1617-1689)**
Horrocks	**(1618-1641)**
Wing	**(1619-1689)**
Mercator	**(1619-1687)**
Streete	**(1622-1689)**
Boyle	**(1627-1691)**
Wren	**(1632-1723)**
Hooke	**(1635-1702)**
J. Gregory	**(1638-1675)**
Newton	**(1642-1727)**
Flamsteed	**(1646-1719)**
Halley	**(1656-1743)**

On the Continent

Borelli	**(1608-1679)**
Hevelius	**(1611-1687)**
Picard	**(1620-1683)**
Mariotte	**(1620-1684)**
Rohault	**(1620-1672)**
Auzout	**(1622-1691)**
Pascal	**(1623-1662)**
Cassini	**(1625-1712)**
Huygens	**(1629-1695)**
Richer	**(1630-1696)**
Campani	**(1635-1715)**
de la Hire	**(1640-1718)**
Rømer	**(1644-1710)**
Leibniz	**(1646-1716)**



Boulliau's Cone - 1645

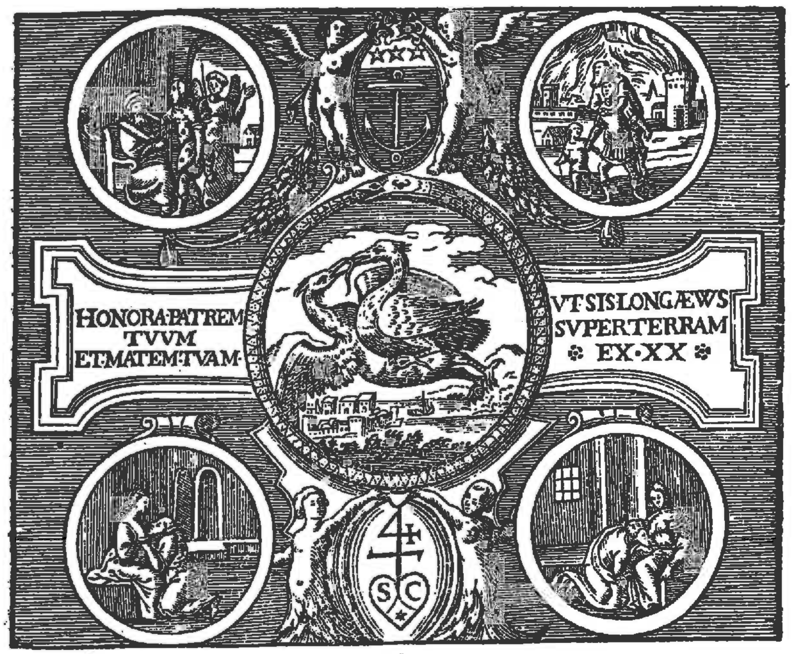


Boulliau's 1657 Method for Obtaining True Anomaly from Mean Anomaly

ISMAELIS
BVLLIALDI
ASTRONOMIÆ
PHILOLAICÆ FVNDAMENTA
clarius explicata, & asserta.

ADVERSVS

Clarissimi Viri SETHI WARDI *Oxoniensis Professoris impugnationem.*



PARISIIS,
Apud SEBASTIANVM CRAMOISY, Regis & Reginæ Architypographi,
ET
GABRIELEM CRAMOISY, viâ Iacobæâ, sub Ciconiis.

M. DC. LVII.
CVM PRIVILEGIO REGIS.

HARMONICON COELESTE:

OR,

The Cœleſtiall Harmony of the

VISIBLE WORLD:

CONTEINING,

An abſolute and entire Piece of

ASTRONOMIE.

WHEREIN

Is ſuccinctly handled the *Trigonometricall* Part, generally Propounded, and particularly Applyed in all Queſtions tending to the *DIURNALL MOTION*.

Eſpecially reſpecting, and truly ſubſervient to the main Doctrine of the Second Motions of the *Luminaries* and the other *Planets*: Together with their Affections as ECLIPSES, &c.

Grounded upon the moſt *Rationall Hypotheſis* yet Conſtituted, and compared with the beſt Obſervations that are Extant, eſpecially thoſe of TYCHO BRAHE, and other more Modern *OBSERVATORS*.

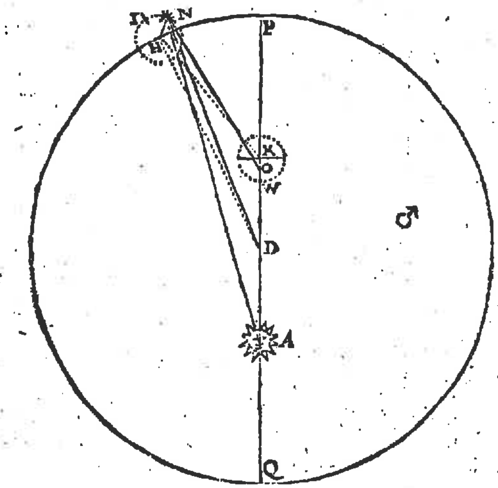
Fitted to the *Meridian* of the moſt Famous and Ancient *Metropolis* LONDON, and principally intended for our Engliſh Nation, and commended as uſefull to all *Schelers*, *Aſtronomers*, *Aſtrologers*, *Divines*, *Phyſitians*, *Hiſtoriographers*, *Politicians*, and *Poets*, &c.

By VINCENT WING. *Philomathemat.*

Quum reſpicio Cœlos tuos, opus digitorum tuorum; Lunam & Stellas quas ſtatuiſti: quid eſt mortalis, quòd memor ſis ejus? aut filius hominis, quòd viſites eum? Pſal. 8.4,5.

LONDON:
Printed by ROBERT LEYBOURN, for the Company of STATIONERS, 1651.

Firſt Figure of Mars.



In this Diagram I number the Anomalie of ♂ from P to H 6d 7′ 40″, whoſe Complement 173d 52′ 20″, is the angle D X H, which given with the Side D H 152040, and the Side D X 14105, the angle D H X will be 34′ 3″.

Side D H 152040,			5,181958
Sine of the angle D X H 173d 52′ 20″;			9,028352
Side D X 14105,			4,149373
Sine of the angle D H X 34′ 3″:			7,995767
Simple Anomalie P X H,	6d	7′	40″
Angle D H X Subſtr.		34	3
Anomalie æquated P D H.	5	33	37
Motion of the Epicycle I H N.	11	7	14

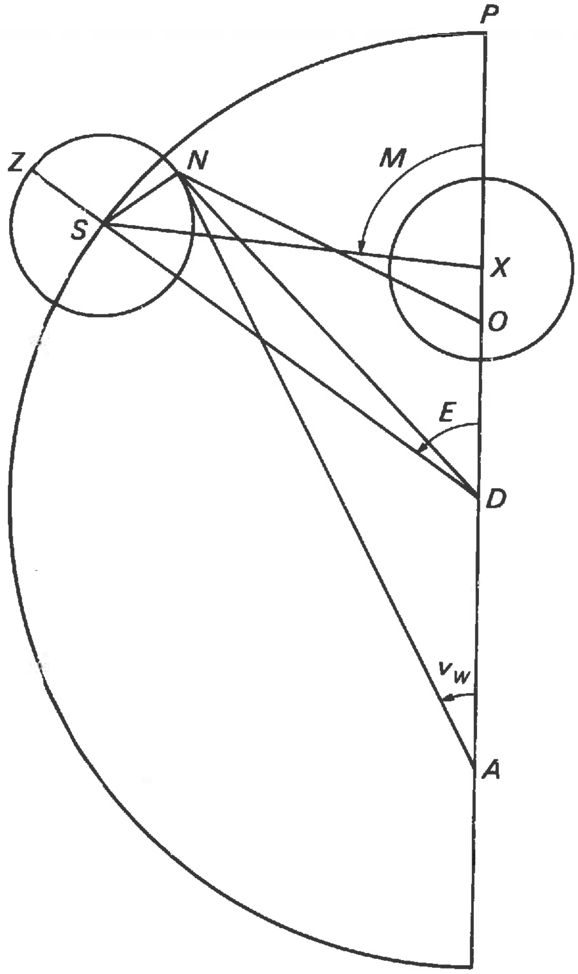
In the Triangle D H N.

Summe of D H and D N 152500,	5,183270
Difference 151580;	5,180642
Tangent of 5d 33′ 37″,	8,988343
Tangent of 5 31 37:	8,985715
Aggregate 11 5 14. *viz.* Angle H N D,	
Difference 2 0 *viz.* Angle H D N,	
Sine of the angle H N D 11d 5′ 14″,	9,283985
Side D H 152040;	5,181958
Sine of the angle D H N 168d 52′ 46″,	9,285274
Side D N 152492:	5,183247

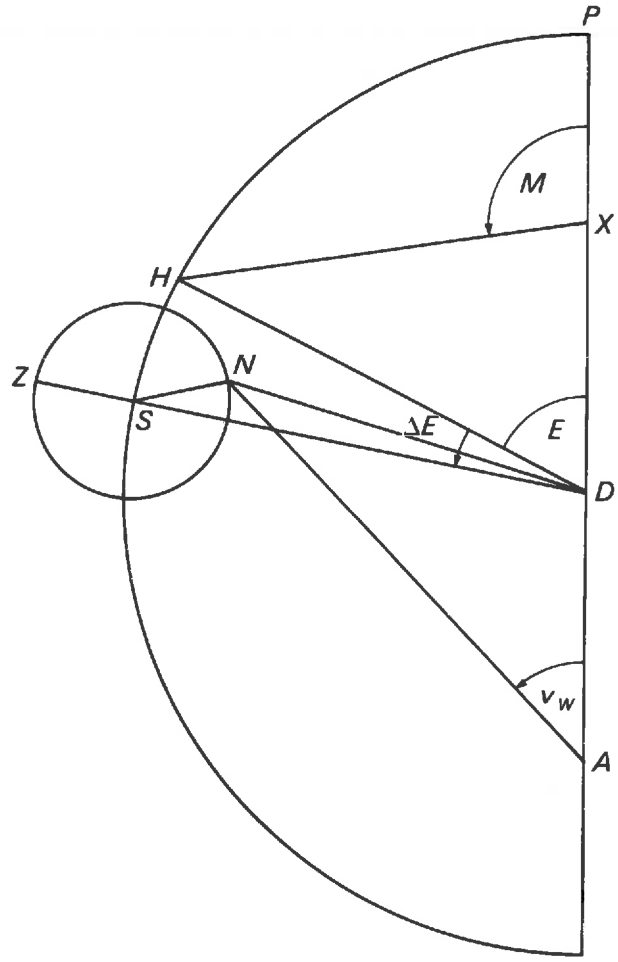
	D	′	″
Anomalie æquated P D H.	5	33	37
Angle H D N Subſtr.		2	0
Anomalie Co-æquated P D N.	5	31	37.

In the former Diagram ♂ is Supra-Diacentron, therefore I number the motion of the Epicycle 11d 7′ 14″ in the nether part of the Equant from X to O, then I ſay,

As



10.6. Vincent Wing's procedure, in his *Harmonicon coeleste* of 1651, for deriving true anomaly (v_W) from mean anomaly (M).



10.7. Wing's improved procedure, in his *Astronomia instaurata* of 1656 and his *Astronomia Britannica* of 1669, for deriving true anomaly (v_W) from mean anomaly (M).

newly devised by the Authour, wherein is plainly and succinctly delivered . . . how to calculate the Motions of all the Planets Trigonometrically, wherein I much dissent from all other Authours that have treated hereof in other Languages, and have delivered the same more methodically for practice, than any hath done before me . . . .

Wing's new procedure is in fact a modification of Boulliau's. In Figure 10.6 the ellipse is produced by an epicycle of radius $\frac{1}{4}e^2$ moving on a circle of radius $1-\frac{1}{4}e^2$; M is the mean anomaly, and E the "equated anomaly", determined by the relation $\sin(M-E)=e \sin M/(1-\frac{1}{4}e^2)$. The angle ZSN of epicyclic motion is $2E$. The eccentricity $DX=AD=e$ is varied by subtracting a sinusoidal term $XO=\frac{1}{4}e^2 \sin 2E$, and the total equation of centre is given by $\angle OND + \angle DNA$. The resulting true anomaly v_W can be shown to differ from the Keplerian value by

$$v_K - v_W = \tfrac{1}{4}e^2 \sin 2M - \tfrac{1}{4}e^2 \sin M \sin 2M - 2e^3 \sin M + \tfrac{8}{3}e^3 \sin^3 M - \tfrac{1}{2}e^3 \sin^4 M.$$

In the case of Mars, this error rises to 5′ in the second quadrant of anomaly.

By the time Wing published his *Astronomia instaurata* in 1656, he had detected the error in this theory by comparing it with acronychal observations of Mars. Moreover, he had found a way of eliminating most of this error; it consisted in adding to the angle E a correction term equal to $k \sin 2E$, where k was to be determined empirically. The value of k should be about $\frac{1}{2}e^2$; in the case of Mars, Wing in his calculation takes it to be 14′ 55″ $\approx \frac{1}{2}e^2 + \frac{2}{3}e^4$. The new theory, which is also that of the *Astronomia Britannica* of 1669, is represented in Figure 10.7. Once again the radius DS of the deferent is $\frac{1}{2}(1+\sqrt{(1-e^2)}) \approx 1-\frac{1}{4}e^2-\frac{1}{16}e^4$, so that the radius SN of the epicycle is $\frac{1}{4}e^2+\frac{1}{16}e^4$, while, with $\angle PDH=E$, $\angle HDS=(\frac{1}{2}e^2+\frac{2}{3}e^4) \sin 2E$; and the

ASTRONOMIA BRITANNICA:

IN QUA

Per Novam, Concinnioremq; Methodum, hi quinq; Tractatus traduntur.

I. *LOGISTICA ASTRONOMICA*, quæ continet Doctrinam Fractionum Astronomicarum integram, tùm in Numeris Naturalibus, tùm Artificialibus.

II. *TRIGONOMETRIA*, seu Doctrina Triangulorum, (Analytica & Practica) quæ comprehendit Dimensionem omnium Trigonorum, tàm Planorum, quàm Sphæricorum, cujus ope, Dimensiones Cœli, Terræ, universiq; Mundi Orbis (modo mirabili) dignoscantur.

III. *DOCTRINA SPHÆRICA*, quæ exhibet Longitudines, Latitudines, Declinationes, Ascensiones, Ortus, Occasus, Intercapedines, Parallaxesq; singulorum Planetarum ad cujuslibet Sphæræ positum, & quo pacto Figuræ Cœlestes erigi possint.

IV. *THEORIA PLANETARUM*, quæ Novâ, accuratâq; Methodo super Hypothesi *Copernicanâ*, veros Motus & Configurationes omnium Planetarum computare docet.

V. *TABULÆ NOVÆ ASTRONOMICÆ*, ex quibus Singulorum Planetarum Motus, & Luminarium Eclipses, mirâ promptitudine colligantur.

Congruentes cum Observationibus accuratissimis Nobilis *TYCHONIS BRAHÆI.*

Cui accessit Observationum Astronomicarum *Synopsis Compendiaria*, ex quâ *Astronomiæ Britannicæ* certitudo affatim elucescit.

Opus exoptatum, non modò Astronomis, Astrologis, sed & Theologis, Historiographis, Nautis, Medicis & Poetis, perutile & jucundum.

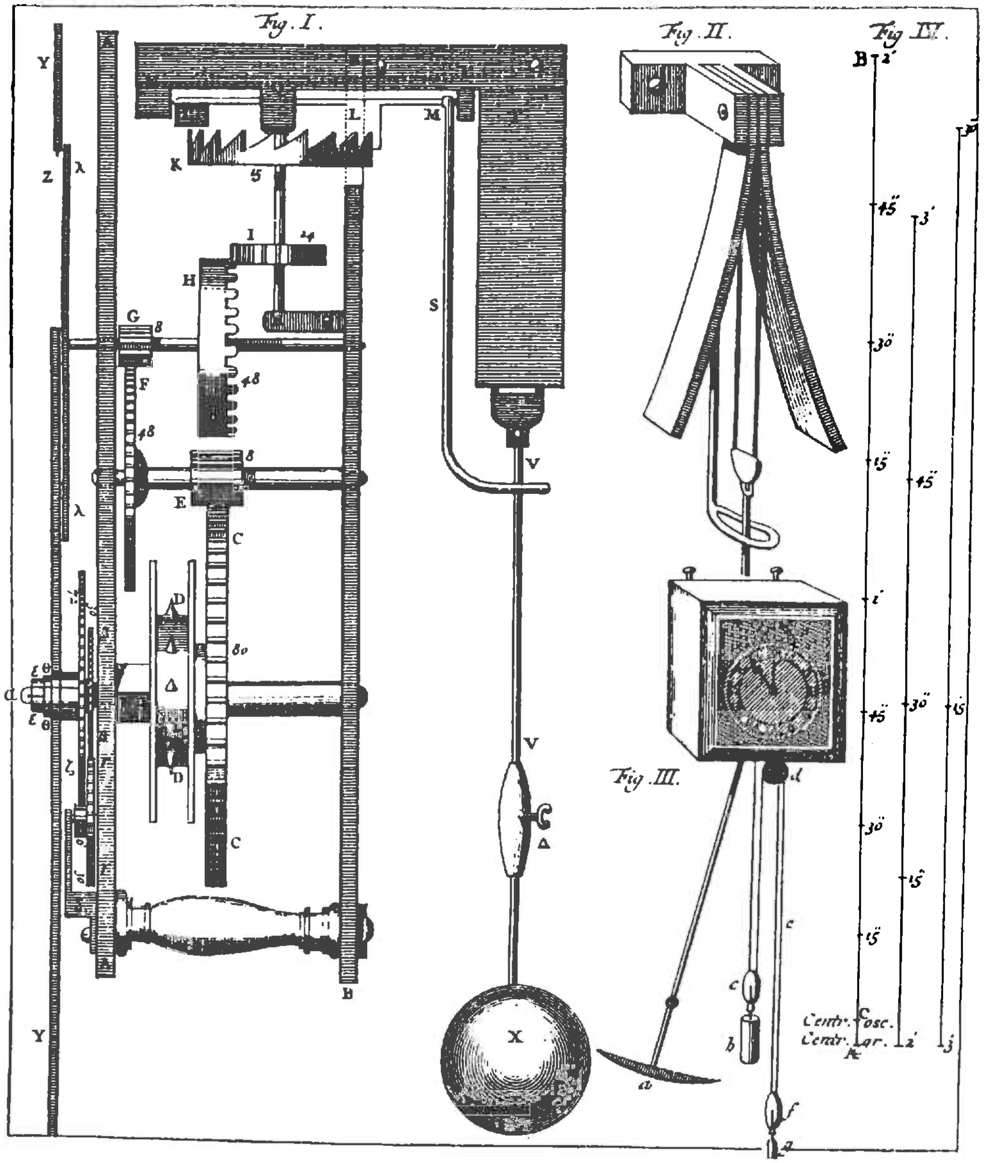
Cui additur Postscriptum de *Refractione.*

Authore *VINCENTIO WING*, Mathem.

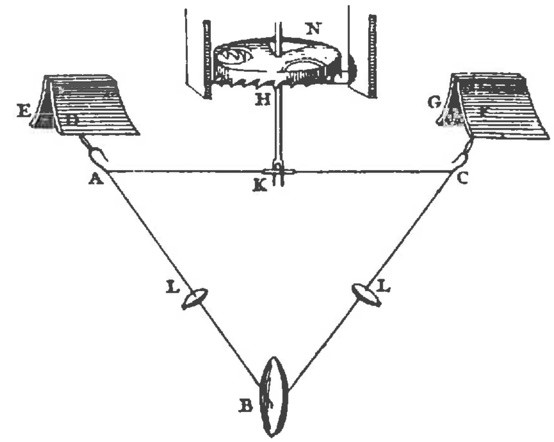
LONDINI,

Typis *Johannis Macock*, Impensis *Georgii Sawbridge*, prostantq; venales apud locum vulgò Clerkenwel-Green dictum. 1669.

[Fig. 1: I, II, III, IV]

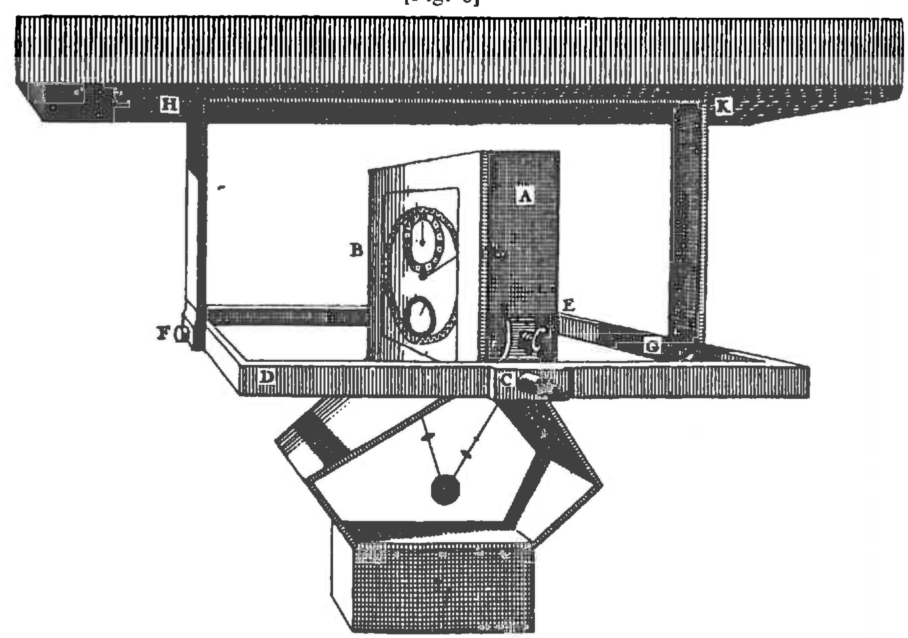


[Fig. 5]



ment the clock maintains a perpendicular position no matter what the inclination of the ship is. Also the axis C, together with the one opposite it, are so located that they correspond in a straight line to the points of suspension of the pendulum just described. From this it follows that the oscilla-

[Fig. 6]



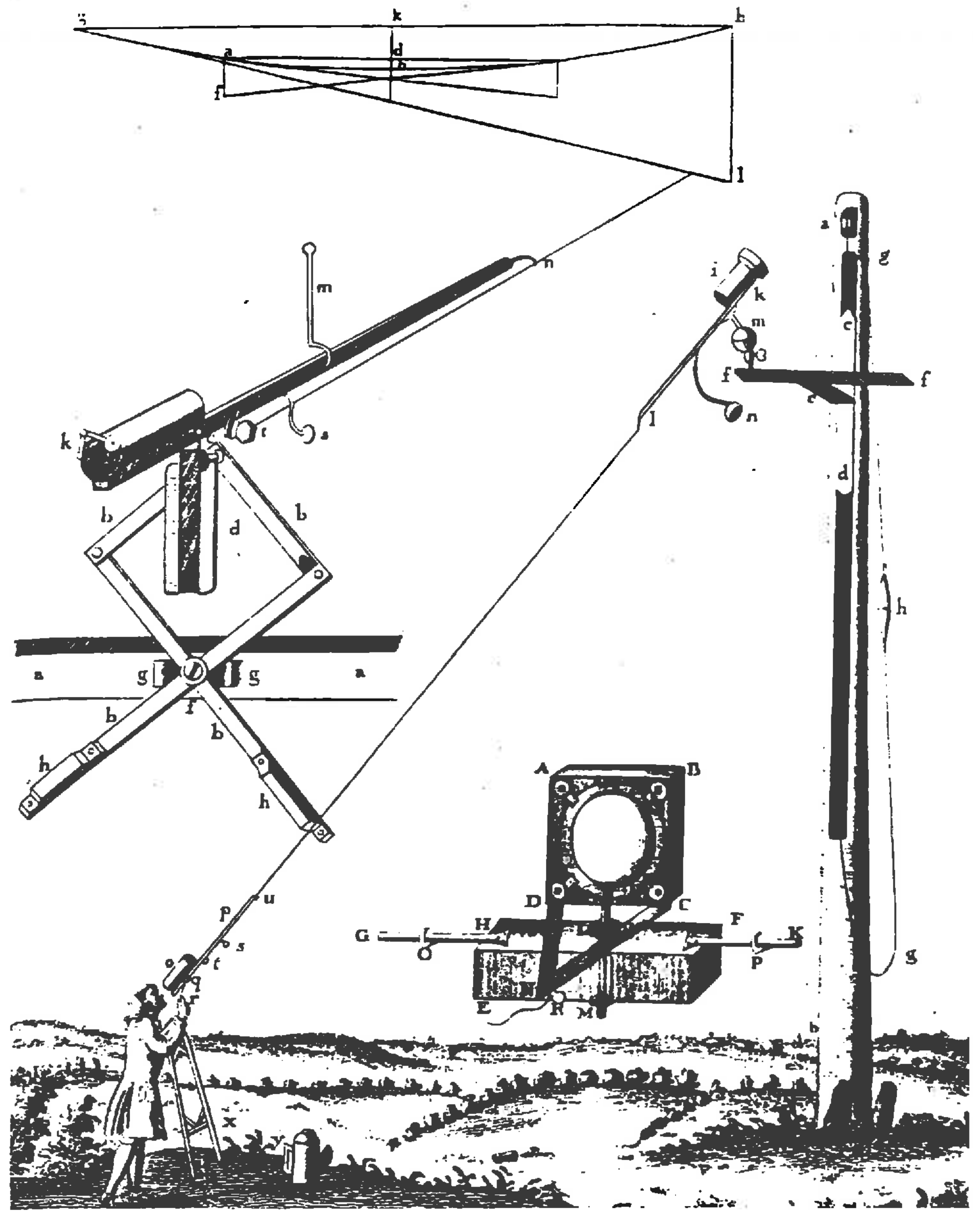


Fig. 25—Huygens' aerial telescope

(Science Museum, London. British Crown copyright)

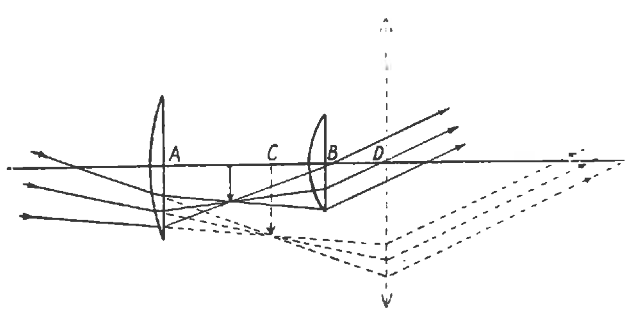
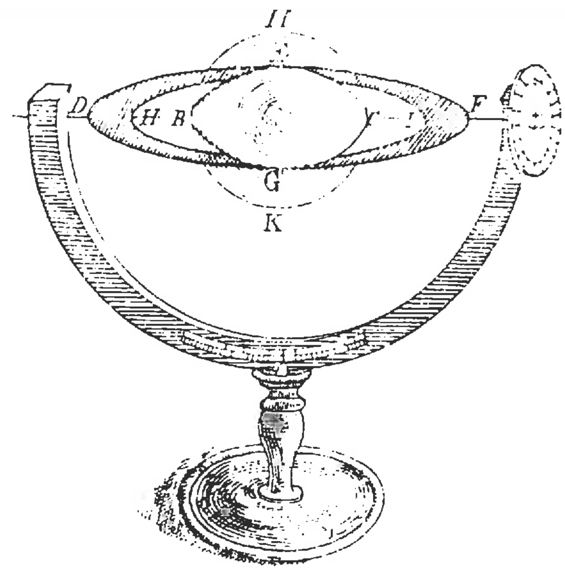


Fig. 26—Huygens' eyepiece

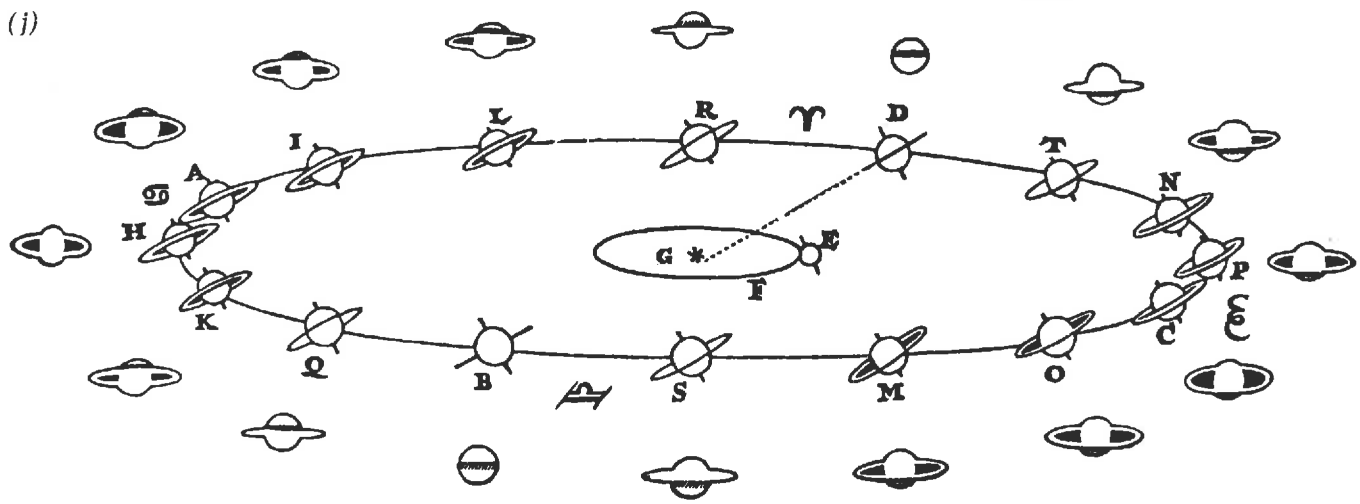
A Field-lens
B Eye-lens
D Position of single lens giving the same magnification
CD Focal length of equivalent lens

(*i*) and (*j*) When Saturn again appeared edgewise, in the mid-1650s, astronomers were formulating fully-fledged theories to explain the planet's strange appearances. Christopher Wren (*i, right*) in 1657 supposed that an infinitely thin elliptical 'corona' was attached to the planet, while the entire formation rotated or librated around its long axis. In 1656 Christiaan Huygens (*j, below*) supposed that the planet "is surrounded by a thin flat ring which does not touch him anywhere and is inclined to the ecliptic". The thickness of Huygens's ring was not negligible.

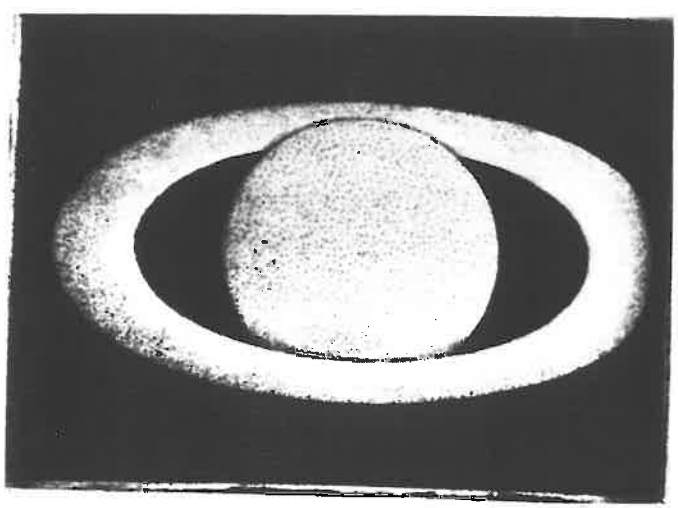
(*i*)



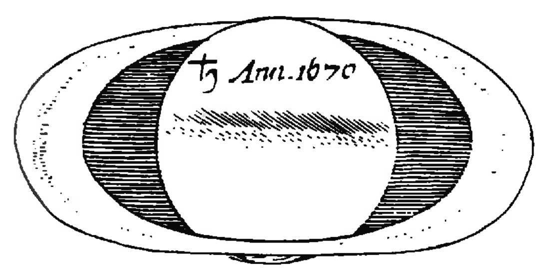
(*j*)



(*k*)



(*l*)



(*k*) Between 1660 and 1675 the ring theory (as well as better telescopes) led to the discoveries of shadow effects that in turn confirmed the theory, as is shown here in the 1664 observation by Giuseppe Campani.

(*l*) Finally, in 1675, Gian Domenico Cassini discovered that the ring had a gap in it.

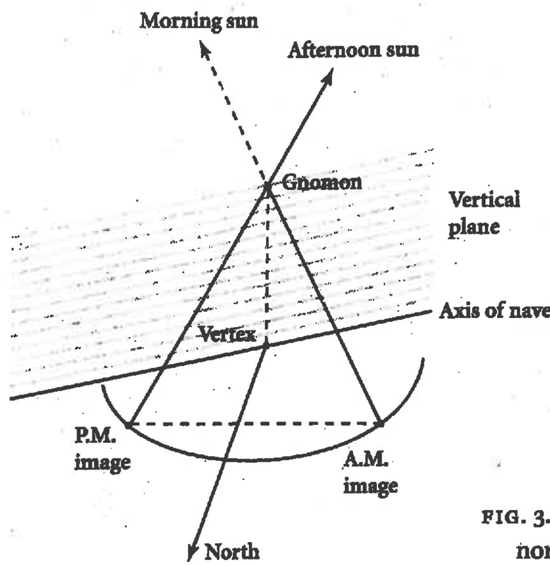


FIG. 3.3. Method of determining north-south line by the sun.

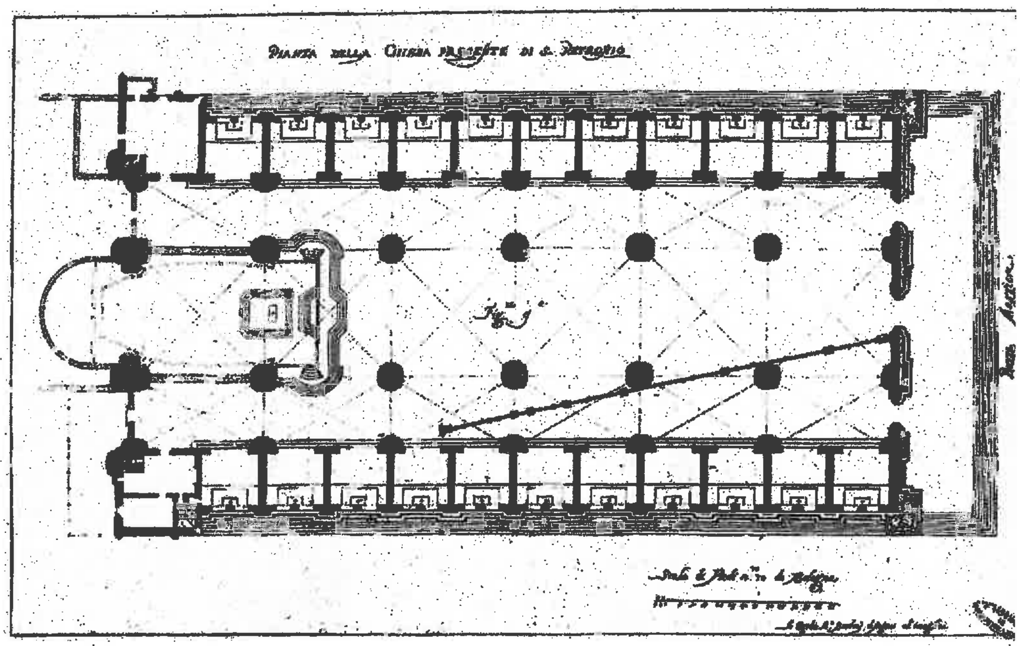


FIG. 3.4. Floor plan of San Petronio showing the *meridiana* just clearing the pillars. From Cassini, *Meridiana* (1695).

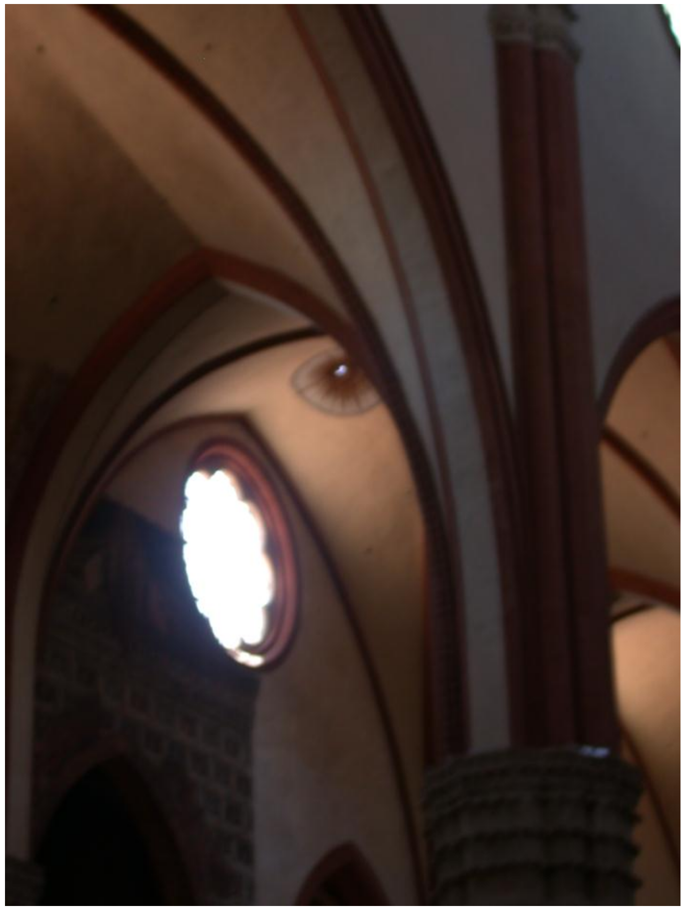
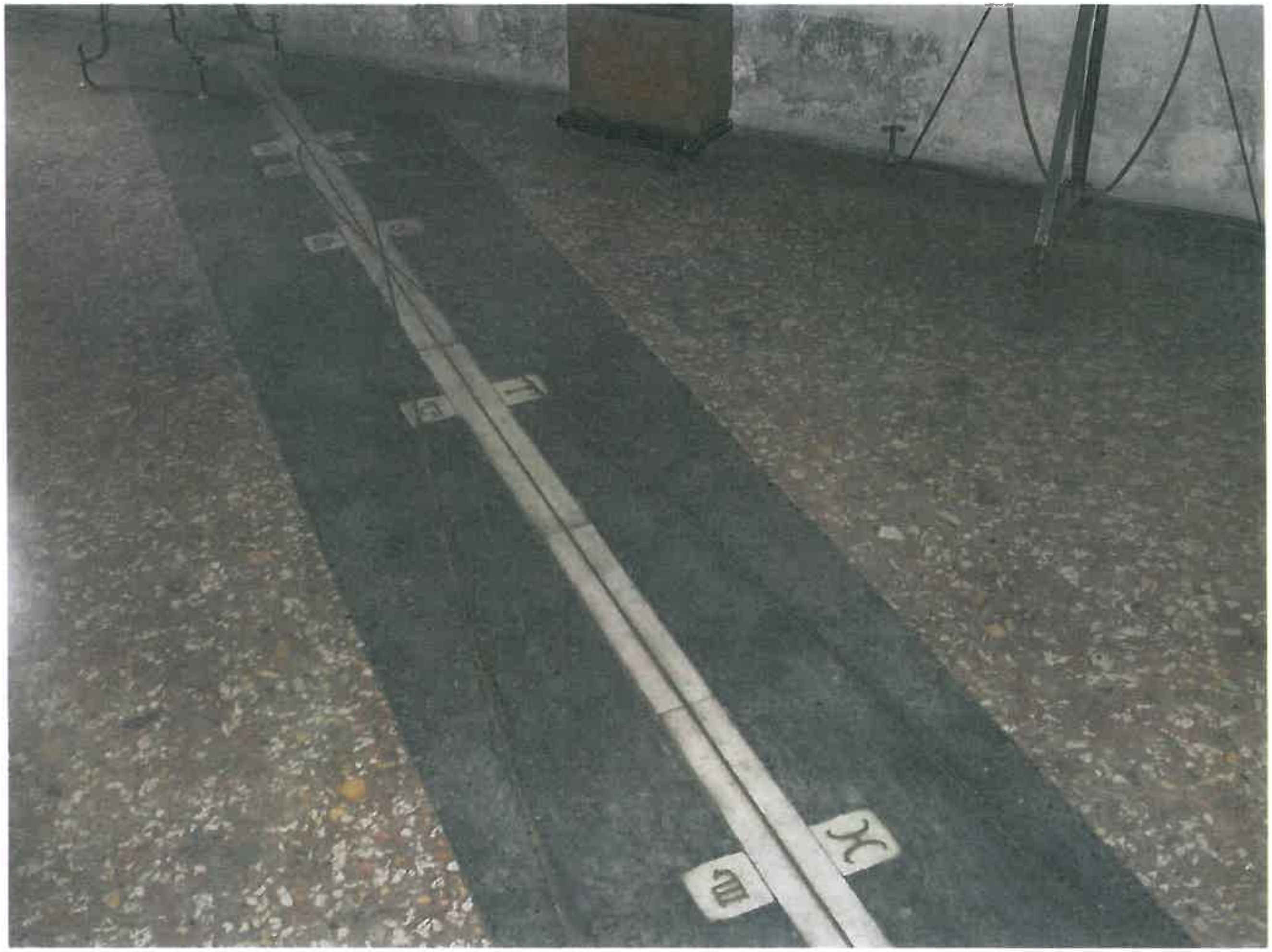


PLATE 3. San Petronio, Bologna, interior. The *meridiana* touches the piers on the left. From Bellosi et al., *Basilica* (1983).

PLATE 4. The sun on the *meridiana* of San Petronio. From Heilbron, in Shea, *Scienze*, 2 (1992), 349.




26
27
28
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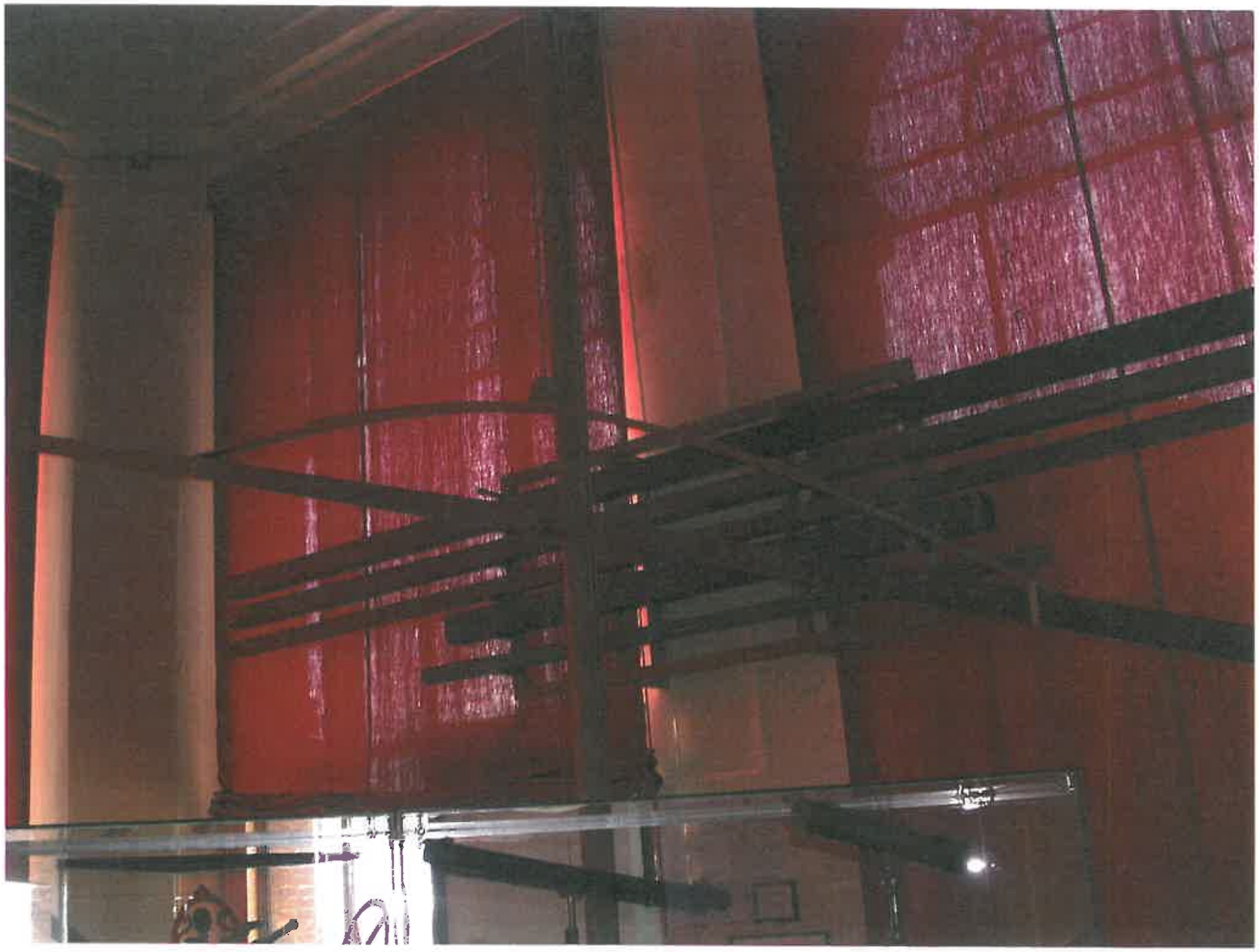
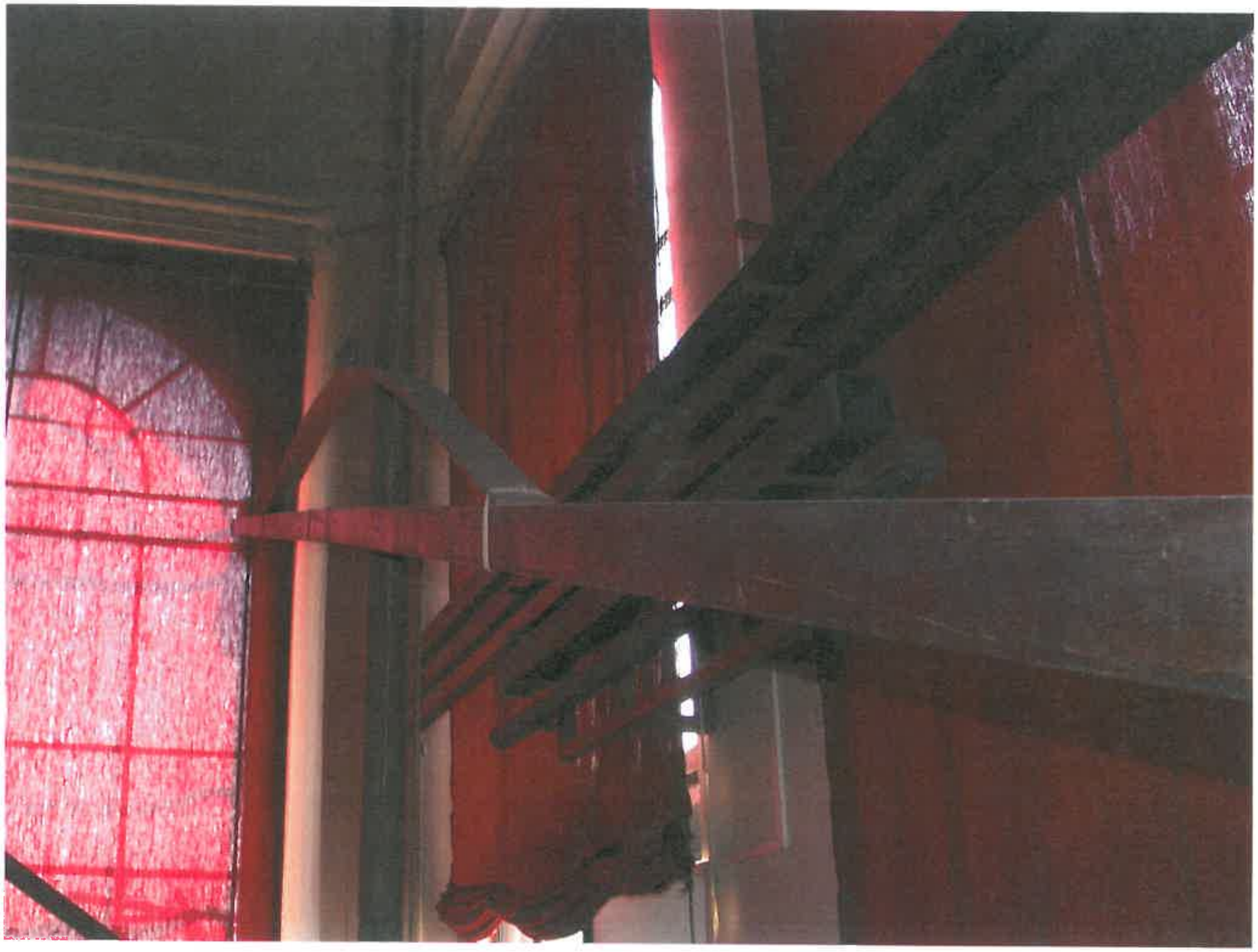




Aſtronomia Carolina.

A NEW

THEORIE

OF THE

Cœleſtial Motions.

Compoſed according to the Beſt Obſervations and moſt Rational Grounds of Art.

Yet far more Eaſie, Expedite and Perſpicuous than any before Extant.

WITH

Exact and moſt Eaſie Tables thereunto, and Precepts for the Calculation of Eclipſes, &c.

By THOMAS STREETE, Student in *Aſtronomy* and *Mathematicks*.

LONDON,
Printed for *Lodowick Lloyd*, and are to be ſold at his Shop at the Caſtle in *Cornhil*, 1661.

The old supposition of solid orbs to support and carry the planets, I count scarce worth the mentioning; the Earth we see hath no such orb, and nature itself with all observations of the true motions of secondary planets and of comets plainly demonstrating the impossibility of any such thing.

Nor shall I here mention any of those many and gross absurdities, which will necessarily follow in all such systems, as attribute to the Sun or fixed stars any of the Earth's natural motions.

But farther to clear the truth from all seeming contradictions; whereas we see that all corporeal substances appertaining to this our earthly globe do (proportionably to their quantities) tend downward towards the Earth's center; let us observe that this comes to pass by the natural magnetic power of the Earth, attracting its parts, a property common to every one of the planets, whereby (according to the Creator's will) they become compact bodies, and do retain their constant form; the Sun also and fixed stars (though of a different principle) having the like retentive faculty:

And that the air, the clouds, a bird flying, a stone falling from any height, an arrow or bullet shot or driven any way, and all things else within the sphere of the Earth's activity (whether otherwise moved or not) do naturally and exactly follow her annual diurnal motion, for that we the Earth's inhabitants cannot possibly perceive or be made sensible thereof, any other way then by such real demonstrations as are here given; we shall exemplify this in the planets *Jupiter* and *Saturn*, whole attendants (at a far larger distance) do not only keep their constant revolutions about them, but together with them about the Sun; the like doth our Moon about the Earth, and both about the Sun. So that by the impulse and universal consent of nature (whether accidental motions be annexed or not) all things so near the Earth do precisely keep the same motion with it.

Streete, *Astronomia Carolina*, p. 11

Table 10.1 *Orbital elements of the planets adopted by seventeenth-century authors, compared with Newcomb's values for 1600*

	Eccentricity	Aphelion	Mean distance
Mercury			
Newcomb (for 1600)	0.205 55	251°14′ 9″	0.387 10
Kepler (K−N)	+0.004 50	+ 1°35′49″	+0.000 98
Boulliau (B−N)	+0.004 52	+ 23′38″	−0.001 25
Wing 1651 (W−N)	+0.004 85	+ 1°34′ 6″	−0.000 70
Wing 1669 (W−N)	+0.004 84	− 7′54″	−0.001 10
Streete (S−N)	+0.000 34	− 31″	0
Venus			
Newcomb (for 1600)	0.006 97	305°55′51″	0.723 33
Kepler (K−N)	−0.000 05	− 4°41′29″	+0.000 80
Boulliau (B−N)	+0.000 87	− 32′46″	+0.000 65
Wing 1651 (W−N)	−0.000 05	+ 32′41″	−0.000 26
Wing 1669 (W−N)	+0.000 36	− 6°55′41″	+0.000 74
Streete (S−N)	+0.000 18	− 3°22′50″	0
Earth			
Newcomb (for 1600)	0.016 88	276° 4′ 2″	1.000 00
Kepler (K−N)	+0.001 12	− 19′54″	0
Boulliau (B−N)	+0.000 96	− 28′38″	0
Wing 1651 (W−N)	+0.000 99	− 20′34″	0
Wing 1669 (W−N)	+0.001 00	− 20′34″	0
Streete (S−N)	+0.000 44	+ 21′26″	0
Mars			
Newcomb (for 1600)	0.093 04	148°41′58″	1.523 69
Kepler (K−N)	−0.000 39	+ 17′56″	−0.000 19
Boulliau (B−N)	−0.000 65	+ 17′54″	−0.000 19
Wing 1651 (W−N)	−0.000 55	+ 18′ 2″	+0.001 31
Wing 1669 (W−N)	−0.000 39	+ 15′ 4″	−0.000 02
Streete (S−N)	−0.000 50	+ 6′24″	0
Jupiter			
Newcomb (for 1600)	0.047 84	187°53′27″	5.202 7
Kepler (K−N)	+0.000 38	− 1° 1′26″	−0.002 7
Boulliau (B−N)	+0.000 72	+ 7′55″	+0.010 5
Wing 1651 (W−N)	+0.000 46	+ 53″	+0.020 5
Wing 1669 (W−N)	+0.000 01	− 8′20″	+0.013 3
Streete (S−N)	+0.000 32	− 27′25″	−0.001 6
Saturn			
Newcomb (for 1600)	0.056 93	265°13′24″	9.546
Kepler (K−N)	0	− 15′48″	−0.036
Boulliau (B−N)	+0.000 81	+ 46′22″	−0.004
Wing 1651 (W−N)	+0.000 56	+ 46′36″	−0.013
Wing 1669 (W−N)	+0.000 56	+ 56′36″	−0.013
Streete (S−N)	+0.000 42	+ 53′49″	−0.008

NICOLAI MERCATORIS
Holsati, è Soc. Reg.
INSTITUTIONUM
ASTRONOMICARUM
LIBRI DUO,
DE MOTU
ASTRORUM
COMMUNI & PROPRIO,
Secundum HYPOTHESES Veterum
& Recentiorum præcipuas;
DEQUE
Hypotheseon ex observatis constructione:
CUM
TABULIS TYCHONIANIS
Solaribus, Lunaribus, Lunæ-Solaribus,
Et *RUDOLPHINIS* Solis, Fixarum,
Et Quinque Errantium;
Earumque Usu Præceptis & Exemplis commonstrato.
QUIBUS ACCEDIT
APPENDIX
De iis, quæ Novissimis temporibus
Cœlitus innotuerunt.

LONDINI,
Typis *Gulielmi Godbid*, sumtibus *Samuelis Simpson*
Bibliopolæ Cantabrigiensis. 1676.

HYPOTHESIS ASTRONOMICA NOVA,

Et *Consensus* ejus cum Observationibus.

ARGUMENTUM LIBRI:

Capita hujus Libri sunt tria,

CAPUT I

Exponens Hypothesin Novam.

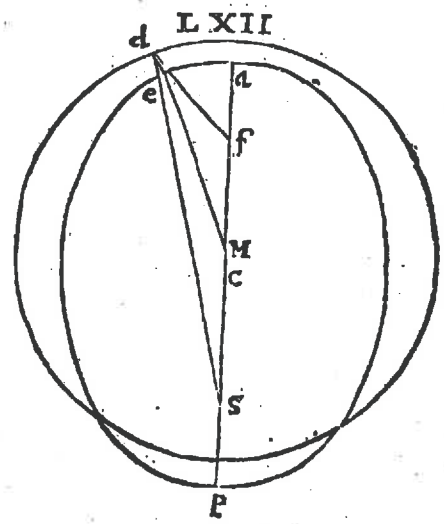
SUppono, Terræ motum circa axem suum esse æquabilem, h. e. revolutionem cujusque meridiani ad quamlibet fixam æqualibus semper temporum intervallis absolvi, quocunque tandem in loco Orbitæ suæ Tellus versetur. Quæ Suppositio licet nova non sit, attamen, cùm aliter censuerit non nemo, & nihilominus

minus revolutio diurna unà cum differentia motûs annui veri & medii constituat elementum unum æquationis temporis (nam alterum est differentia longitudinis & Ascensionis rectæ Terræ:) indicandum fuit, quid nam hoc loco sectandum duxerim.

2. Præcessionem Æquinoctiorum non aliam usurpabo nunc quidem quàm *Keplerus*, nimirum 51" in annos singulos, ut observationes ab illo in Commentario de Stella Martis traditas, & præcessione æquinoctiorum, quantâ diximus, affectas quamproximè exhibeam absque molestâ reductione, non ignarus interim, fieri posse, ut motus Æquinoctiorum paulò aliter se habeat.

3. Aphelia & Nodos Planetarum eundem perpetuò sub fixis locum obtinere, vel quod idem valet, non alio quàm Præcessionis æquinoctiorum motu cieri putemus.

4. In adjecto Schemate LXII. sit S Sol, *f* Focus superior,



c centrum ellipseos, *m* punctum sectionis divinæ, quo scil. distantia focorum *sf* secundùm extremam & mediam rationem secatur: Sitque idem centrum circuli descripti radio *md* æquali *ca* vel *cp* semidiametro maximæ Ellipseos. *a* aphelium, *p* perihelium, *afd* anomalia media, *asd* anomalia coæquata, *fds* prosthaphæresis, *e* erro sive Planeta, *se* distantia Planetæ à Sole.

5. Determinatio linearum:

	In Sole	*In Marte*
ca vel *md*	10000000	15236900
sf	344477	2835800
sm	212898	1752621
mf	131578	1083179

Mercator, 1676

KEPLER -- 1609

Tempus	Locus ☉	Solis a Terra distantia	Martis a Sole distantia	Martis eccentricus in ecliptica	Locus computatus	Locus observatus	Differentia	Latitudo
								Bor.
1582. 23 Nove. H. 16. 0	11°. 41' ♐	98345	158852	0°. 42'. 11'' ♋	26. 40. 0 ♋	26. 38. 30 ♋	1'. 30'' +	2. 49
26 Dece. H. 8. 30	15. 4 ♑	98226	162104	16. 7. 18 ♋	17. 44. 19 ♋	17. 40. 30 ♋	3. 49 +	4. 7
30 Dece. H. 8. 10	19. 9 ♑	98252	162443	17. 56. 32 ♋	16. 6. 20 ♋	16. 0. 30 ♋	5. 50 +	4. 8
1583. 26 Janua. H. 6. 15	16. 33 ♒	98624	164421	0. 6. 24 ♌	8. 17. 57 ♋	8. 20. 30 ♋	2. 33 —	2. 52
1584. 21 Dece. H. 14. 0	10. 16 ♑	98207	164907	3. 51. 45 ♌	1. 14. 34 ♍	1. 13. 30 ♍	1. 4 +	3. 31
1585. 24 Janua. H. 9. 0	14. 53 ♒	98595	166210	18. 47. 8 ♌	24. 3. 58 ♌	24. 7. 30 ♌	3. 32 —	4. 31
4 Febr. H. 6. 40	26. 10 ♒	98830	166400	23. 33. 41 ♌	19. 43. 52 ♌	19. 47. 0 ♌	3. 8 —	4. 28
12 Mart. H. 10. 30	2. 16 ♈	99858	166170	9. 23. 14 ♍	11. 43. 31 ♌	11. 46. 0 ♌	2. 29 —	3. 22
1587. 25 Janua. H. 17. 0	16. 1 ♒	98611	166232	8. 13. 40 ♍	4. 41. 50 ♎	4. 42. 0 ♎	0. 10 —	3. 26
4 Mart. H. 13. 24	24. 0 ♓	99595	164737	24. 56. 50 ♍	26. 24. 41 ♍	26. 25. 40 ♍	0. 59 —	3. 38
10 Mart. H. 11. 30	29. 52 ♓	99780	164382	27. 35. 54 ♍	24. 5. 15 ♍	24. 5. 15 ♍	0. 0	3. 29
21 April. H. 9. 30	10. 48 ♉	101010	161027	16. 44. 51 ♎	15. 49. 50 ♍	15. 48. 20 ♍	1. 30 +	1. 48
1589. 8 Mart. H. 16. 24	28. 36 ♓	99736	161000	16. 55. 14 ♎	12. 14. 7 ♏	12. 16. 50 ♏	2. 43 —	2. 4
13 April. H. 11. 15	3. 38 ♉	100810	157141	4. 1. 50 ♏	4. 45. 0 ♏	4. 43. 20 ♏	1. 40 +	1. 10
15 April. H. 12. 5	5. 36 ♉	100866	156900	5. 1. 41 ♏	3. 58. 57 ♏	3. 58. 20 ♏	0. 37 +	1. 4
6 Maji. H. 11. 20	25. 49 ♉	101366	154326	15. 30. 36 ♏	27. 8. 17 ♎	27. 7. 20 ♎	0. 57 +	0. 7
								Aust.
1591. 13 Maji. H. 14. 0	2. 10 ♊	101467	147891	12. 7. 38 ♐	2. 15. 36 ♑	2. 20. 0 ♑	4. 24 —	2. 25
6 Junii H. 12. 20	24. 59 ♊	101769	144981	25. 38. 48 ♐	27. 11. 45 ♐	27. 15. 0 ♐	3. 15 —	3. 55
10 Junii H. 11. 50	28. 47 ♊	101789	144526	27. 56. 49 ♐	25. 57. 57 ♐	26. 2. 36 ♐	4. 39 —	4. 8
28 Junii H. 10. 24	15. 51 ♋	101770	142608	8. 29. 32 ♑	21. 4. 21 ♐	21. 10. 0 ♐	5. 39 —	4. 45
1593. 21 Julii H. 14. 0	8. 26 ♌	101498	138376	20. 1. 38 ♒	17. 43. 14 ♓	17. 45. 45 ♓	2. 31 —	5. 46
22 Aug. H. 12. 20	9. 11 ♍	100761	138463	10. 15. 25 ♓	13. 9. 39 ♓	13. 10. 15 ♓	0. 36 —	6. 7
29 Aug. H. 10. 20	11. 54 ♍	100562	138682	14. 37. 15 ♓	11. 11. 41 ♓	11. 14. 0 ♓	2. 19 —	5. 52
3 Octo. H. 8. 0	20. 15 ♎	99500	140697	6. 19. 39 ♈	7. 49. 54 ♓	7. 50. 10 ♓	0. 16 —	3. 17
1595. 17 Sept. H. 16. 45	4. 18 ♎	99990	143222	22. 49. 19 ♈	26. 5. 45 ♉	26. 7. 12 ♉	1. 27 —	1. 42
27 Octo. H. 12. 20	13. 59 ♏	98851	147890	15. 35. 38 ♉	18. 50. 46 ♉	18. 51. 15 ♉	0. 29 —	0. 6
								Bor.
3 Nove. H. 12. 0	21. 2 ♏	98694	148773	19. 26. 33 ♉	16. 18. 33 ♉	16. 18. 30 ♉	0. 3 +	0. 17
18 Dece. H. 8. 0	6. 43 ♑	98200	154539	13. 2. 29 ♊	11. 39. 1 ♉	11. 40. 0 ♉	0. 59 —	1. 40

BOULLIAU -- 1657

Loca 28. Martis à Tychone obseruata à Keplero in Commentarijs de Stella Martis assumpta, hic iuxta Tabulas Philolaïcas & iuxta hypothesim supra restitutam secundum longitudinem computata.

	Anni.	Menses.	D. H. ′	Locus ☉ Medius. S. g. ′. ″.	Anomalia ☉ Media. S. g. ′. ″.
1	1582.	Nouemb.	23. 16. 0	♐. 12. 30. 12	5. 7. 11. 53
2		Decemb.	26. 8. 30	♑. 14. 43. 41	6. 9. 25. 8
3		Decemb.	30. 8. 10	♑. 18. 39. 25	6. 13. 20. 52
4	1583.	Ianuar.	26. 6. 15	♒. 15. 11. 7	7. 9. 52. 38
5	1584.	Decemb.	21. 14. 0	♑. 10. 32. 0	6. 5. 11. 45
6	1585.	Ianuar.	24. 9. 0	♒. 13. 50. 25	7. 8. 30. 5
7		Februar.	4. 6. 40	♒. 24. 35. 11	7. 19. 14. 49
8		Martij.	12. 10. 30	♈. 0. 13. 37	8. 24. 53. 10
9	1587.	Ianuar.	25. 17. 0	♒. 14. 40. 34	7. 9. 18. 22
10		Martij.	4. 13. 24	♓. 21. 58. 58	8. 16. 36. 40
11		Martij.	10. 11. 30	♓. 27. 49. 7	8. 22. 26. 48
12		Aprilis.	21. 9. 30	♉. 9. 8. 2	10. 3. 45. 36
13	1589.	Martij.	8. 16. 24	♓. 26. 33. 24	8. 21. 9. 11
14		Aprilis.	13. 11. 15	♉. 1. 49. 42	9. 26. 25. 24
15		Aprilis.	15. 12. 5	♉. 3. 50. 2	9. 28. 25. 44
16		Maij.	6. 11. 20	♉. 24. 30. 5	10. 19. 5. 45
17	1591.	Maij.	13. 14. 0	♊. 1. 1. 58	10. 25. 35. 41
18		Iunij.	6. 12. 20	♊. 24. 37. 12	11. 19. 10. 51
19		Iunij.	10. 11. 50	♊. 28. 32. 32	11. 23. 6. 11
20		Iunij.	28. 10. 24	♋. 16. 13. 28	0. 10. 47. 4
21	1593.	Iulij.	21. 14. 0	♌. 9. 33. 1	1. 4. 4. 59
22		Augusti.	22. 12. 20	♍. 11. 1. 21	2. 5. 32. 54
23		Augusti.	29. 10. 20	♍. 17. 50. 23	2. 12. 21. 55
24		Octobris.	3. 8. 0	♎. 22. 14. 31	3. 16. 45. 58
25	1595.	Septemb.	17. 16. 45	♎. 6. 21. 12	3. 0. 50. 47
26		Octobr.	27. 12. 20	♏. 15. 35. 51	4. 10. 5. 22
27		Nouembr.	3. 12. 0	♏. 22. 29. 0	4. 16. 58. 30
28		Decembr.	18. 8. 0	♑. 6. 40. 34	6. 1. 9. 56

	Locus ♂ Computatus. S.	g.	′.	″.	Locus ♂ obseruatus. S.	g.	′.	″.	Differentia. ′.	″.
1	♋.	26.	40.	13	♋.	26.	38.	30	-- 1.	43
2	♋.	17.	39.	22	♋.	17.	40.	30	† 1.	8
3	♋.	16.	2.	7	♋.	16.	0.	30	-- 1.	37
4	♋.	8.	18.	40	♋.	8.	20.	30	† 1.	50
5	♍.	1.	14.	46	♍.	1.	13.	30	-- 1.	16
6	♌.	24.	6.	3	♌.	24.	7.	30	† 1.	27
7	♌.	19.	46.	33	♌.	19.	47.	0	† 0.	27
8	♌.	11.	44.	47	♌.	11.	46.	0	† 1.	13
9	♎.	4.	43.	49	♎.	4.	42.	0	-- 1.	49
10	♍.	26.	26.	53	♍.	26.	25.	40	-- 1.	13
11	♍.	24.	7.	33	♍.	24.	5.	15	-- 2.	18
12	♍.	15.	47.	21	♍.	15.	48.	20	-- 0.	59
13	♏.	12.	15.	3	♏.	12.	16.	50	† 1.	47
14	♏.	4.	45.	58	♏.	4.	43.	20	-- 2.	38
15	♏.	4.	0.	40	♏.	3.	58.	20	-- 2.	20
16	♎.	27.	11.	3	♎.	27.	7.	20	-- 3.	43
17	♑.	2.	21.	7	♑.	2.	20.	0	-- 1.	7
18	♐.	27.	16.	47	♐.	27.	15.	0.	-- 1.	47
19	♐.	26.	7.	34	♐.	26.	2.	36	-- 4.	58
20	♐.	21.	15.	33	♐.	21.	10.	0	-- 5.	33
21	♓.	17.	43.	23	♓.	17.	45.	45	† 2.	22
22	♓.	13.	12.	57	♓.	13.	10.	15	-- 2.	42
23	♓.	11.	15.	11	♓.	11.	14.	0	-- 1.	11
24	♓.	7.	47.	50	♓.	7.	50.	10	† 2.	20
25	♉.	26.	8.	49	♉.	26.	7.	12	-- 1.	37
26	♉.	18.	49.	16	♉.	18.	51.	15	† 1.	59
27	♉.	16.	15.	47	♉.	16.	18.	30	† 2.	43
28	♉.	11.	41.	43	♉.	11.	40.	0	-- 1.	43

STREETE -- 1661

♂ Extra situm *Acronychium. Tycho.*

Anno Mens. D. H.	Loc. ☉ verus s. °. '. "	Anom. ♂ med. s. °. '. "	Loc. ♂ Comput. s. °. '. "	Loc. ♂ Observ. s. °. '. "	Differ. '. "
1582. Nov. 23. 15. 7	7. 14. 20. 12	9. 22. 48. 56	2. 29. 17. 45	2. 29. 16. 53	− 0. 52
Dec. 26. 7. 44	8. 17. 40. 26	10. 9. 56. 51	2. 20. 15. 18	2. 20. 18. 49	+ 3. 31
Dec. 30. 7. 25	8. 21. 44. 23	10. 12. 2. 12	2. 18. 39. 24	2. 18. 38. 48	− 0. 36
1583. Ian. 26. 5. 30	9. 19. 6. 5	10. 26. 8. 37	2. 10. 57. 4	2. 10. 58. 45	+ 1. 41
1584. Dec. 21. 13. 13	8. 13. 18. 14	11. 0. 30. 59	4. 3. 51. 36	4. 3. 50. 7	− 1. 29
1585. Ian. 24. 8. 15	9. 17. 41. 14	11. 18. 13. 31	3. 26. 43. 1	3. 26. 44. 3	+ 1. 2
Feb. 4. 5. 53	9. 28. 42. 6	11. 23. 56. 15	3. 22. 24. 31	3. 22. 23. 31	− 1. 0
Mar. 12. 9. 31	11. 4. 47. 45	0. 12. 52. 56	3. 14. 21. 14	3. 14. 22. 26	+ 1. 12
1587. Jan. 25. 16. 15	9. 18. 31. 7	0. 11. 28. 9	5. 7. 19. 46	5. 7. 16. 50	− 2. 56
Mar. 4. 12. 28	10. 26. 29. 9	1. 1. 17. 59	4. 29. 4. 1	4. 29. 0. 25	− 3. 36
Mar. 10. 10. 32	11. 2. 21. 15	1. 4. 14. 6	4. 26. 45. 30	4. 26. 40. 0	− 5. 30
Apr. 21. 8. 24	0. 13. 19. 44	1. 26. 21. 52	4. 18. 25. 12	4. 18. 22. 59	− 2. 13
1589. Mar. 8. 15. 37	11. 1. 3. 38	1. 26. 31. 49	6. 14. 53. 11	6. 14. 49. 53	− 3. 18
Apr. 13. 10. 9	0. 6. 7. 32	2. 15. 16. 48	6. 7. 18. 21	6. 7. 16. 18	− 2. 3
Apr. 15. 10. 59	0. 8. 5. 53	2. 16. 20. 46	6. 6. 33. 26	6. 6. 31. 17	− 2. 9
Maij. 6. 10. 15	0. 28. 19. 15	2. 27. 20. 6	5. 29. 41. 58	5. 29. 40. 14	− 1. 44
1591. Maij. 13. 12. 57	1. 4. 39. 1	3. 23. 36. 27	8. 4. 46. 13	8. 4. 51. 11	+ 4. 58
Jun. 6. 11. 27	1. 27. 30. 30	4. 6. 9. 5	7. 29. 43. 24	7. 29. 46. 8	+ 2. 44
Jun. 10. 10. 59	2. 1. 18. 0	4. 8. 14. 14	7. 28. 30. 18	7. 28. 33. 44	+ 3. 26
Jun. 28. 9. 41	2. 18. 23. 27	4. 17. 38. 30	7. 23. 40. 29	7. 23. 41. 5	+ 0. 36
1593. Jul. 21. 13. 24	3. 10. 57. 46	5. 22. 50. 41	10. 20. 11. 3	10. 20. 15. 4	+ 4. 1
Aug. 22. 11. 44	4. 11. 43. 50	6. 9. 34. 40	10. 15. 34. 38	10. 15. 39. 30	+ 4. 52
Aug. 29. 9. 42	4. 18. 27. 25	6. 13. 12. 4	10. 13. 40. 20	10. 13. 43. 14	+ 2. 54
Oct. 3. 7. 11	5. 22. 48. 33	7. 1. 29. 15	10. 10. 15. 41	10. 10. 19. 20	+ 3. 39
1595. Sept. 17. 16. 1	5. 6. 49. 41	7. 15. 50. 30	0. 28. 31. 35	0. 28. 34. 42	+ 3. 7
Oct. 27. 11. 26	6. 16. 30. 4	8. 6. 42. 10	0. 21. 15. 41	0. 21. 18. 38	+ 1. 57
Nov. 3. 11. 6	6. 23. 32. 59	3. 10. 21. 51	0. 18. 43. 32	0. 18. 45. 53	+ 2. 21
Dec. 18. 7. 12	8. 9. 9. 20	9. 3. 51. 36	0. 14. 7. 21	0. 14. 7. 17	− 0. 4

WING -- 1669

Synopſis tredecim aliorum locorum Martis, *tàm ex Obſervatione Acronychiâ in verâ* Solis *oppoſitione, quam Calculo ad eadem tempora, juxta* Aſtronomiam Britannicam.

Tredecim aliæ fulſiones ♂ Acronychiæ.

Ecce mirabilis conſenſus Calculi cum obſervationibus.

Tempus Uraniburgi Anni	Men.	D.	H.	M.	Long. obſer. Sig.	Gr.	′	″	Longit. media. S.	gr.	′	″	Ano. Med. S.	gr.	′	″	Longit. Supp. S.	gr.	′	″	Dif. ′	″	
1582.	Dec.	28	4	0	♋	16	54	30	3	9	28	19	10	10	53	8	♋	16	53	46	0	44	—
1585.	Jan.	30	19	15	♌	21	35	10	4	20	11	41	11	21	34	0	♌	21	35	41	0	31	+
1587.	Mart.	6	7	20	♍	25	42	0	5	0	50	53	1	2	10	38	♍	25	43	7	1	7	+
1589.	April	14	6	20	♏	4	23	0	7	14	21	37	2	15	38	48	♏	4	25	26	2	26	+
1591.	Jun.	8	7	45	♐	26	42	0	9	5	47	10	4	7	1	44	♐	26	41	38	0	22	—
1593.	Aug.	25	17	30	♓	12	16	0	11	9	58	18	6	11	10	12	♓	12	18	11	2	11	+
1595.	Oct.	31	0	40	♉	17	30	40	1	7	17	17	8	8	26	32	♉	17	32	32	1	52	+
1597.	Dec.	13	16	0	♋	2	27	0	2	23	15	10	9	24	21	49	♋	2	25	29	1	31	—
1600.	Jan.	18	14	0	♌	8	37	0	4	4	38	49	11	5	42	56	♌	8	35	26	1	34	—
1602.	Febr.	20	14	14	♍	12	26	0	5	15	2	30	0	16	4	5	♍	12	24	32	1	28	—
1604.	Mart.	28	16	20	♎	18	36	10	6	27	2	56	1	28	1	58	♎	18	36	30	0	20	+
1608.	Julii.	24	2	0	♒	11	10	0	10	14	14	33	5	15	8	20	♒	11	10	28	0	28	+
1610.	Oct.	8	16	50	♈	25	30	0	0	16	58	17		17	49	7	♈	25	28	37	1	23	—

39′ 47″, Anomalia Sig. 10. gr. 21 8′ 39″. Nodus Bor. Sig. 1 gr. 16 33′ 10″, unde elicitur locus *Martis* à *Sole* ad Eclipticam reductus in gr. 25 53′ 43″, & diſtantia ♂ à ☉ curtata 163745.

Quoniam in Triangulo A S g, habentur duo latera A g 163745. A S 99015, cum angulo g A S gr. 77 31′ 47″, (qui eſt Complementum Anomaliæ Orbis ad gr. 180.) dabitur ergò angulus A S g gr. 68 17′ 23″, & angulus A g S, gr. 34 10′ 49″, cum latere S g 172089. Si igitur motui Martis ex Sole in Ecliptica, addatur hic angulus Parallaxis Orbis annui A g S, prodibit longitudo *Martis* ex *Terrâ* in gr. 0 4′ 32″ ♍, obſervationi proximè conſentiens.

Obſervat. T. B. 1586.

8. Eodem anno 1586. die 15 *Decembris*, Hor. 18 30′, Nobilis *Tycho Brahæus* obſervavit *Martem Uraniburgi* in gr. 26 6′ 24″ ♍. cum lat 2° 35′ B.

Quo tempore verus Solis locus erat in gr. 4 16′ 39″ ♑, & diſtantia Terræ à Sole 98220, Martis medius motus Sig. 4. gr. 18 38′ 32″, Anomalia Sig. 11. 19 gr. 58′ 33″, Mars ergò ex Sole apparebat in gr. 20 18′ 11″ ♌, diſtantia ♂ à ☉ exiſtente 166213. Poſtremò ex locis ♂ & ☉ invenitur Anomalia Orbis Sig. 4. gr. 13 58′ 28″, cujus Complementum ad 6. Signa, gr. 46 1′ 32″, eſt angulus ♂ A ♊.

In Triangulo igitur obliquangulo ♂ A ♊ dantur latera A ♊ 166213, A ♂ 98220. cum angulo comprehenſo ♊ A ♂ gr. 46 1′ 32″, ergò datur Parallaxis Orbis Telluris A ♊ ♂ gr. 35 47′ 51″. Adde hanc ad locum ♂ Heliocentricum, gr. 20 18′ 11″ ♌, & habebis locum verum ♂ ex Terrâ in gr. 26 6′ 2″ ♍, Calculus itaq; noſter cum obſervatione adamuſſim congruit.

Obſervat. T. B. 1591.

9. Anno Chriſti 1591. die 13 *Maii*, Hor. 14. *Tycho Brahæus* obſervavit *Martem* in gr. 2 20′ ♑, quo tempore, verus locus Solis fuit in gr. 2 9′ 16″ ♊, & Diſtantia Terræ à Sole 101490.

Medius motus Martis erat Sig. 8 gr. 22 17′ 47″, Anomalia Sig. 3. gr. 23 32′ 26″. Proſthaphæreſis gr. 10 8′ 55″ ſubtrahenda, locus ergò *Martis* ex *Sole* oſtenditur in gr. 12 8′ 52″ ♐, in Eclipticâ autem in gr. 12 8′ 9″ ♐, unde Angulus Anomaliæ Orbis reperitur gr. 9 58′ 53″, quo dato, cum lateribus A ♈ 147874. & A H 101490, innoteſcit Angulus Elongationis A H ♈ gr. 149 51′ 36″, & Angulus Parallaxeos Orbis Telluris A ♈ H gr. 20 9′ 30″, ideoq; verus locus ♂ Geocentricus ſit in gr. 2 17′ 39″ ♑, obſervationi proximè conſentiens.

Obſervat. T. B. 1591.

10. Eodem quoq; anno 1591. die 28 *Junii*, Hor. 10 24′ *Uraniburgi*, obſervatus eſt *Mars* in gr. 21 10′ ♐, quo tempore verus locus Solis erat in gr. 15 51′ 19″ ♋, & Diſtantia Terræ à Sole 101767.

Medius locus *Martis* tunc tenebat gr. 16 19′ 31″ ♑, ſed viſus à Sole in Eclipticâ gr. 8 30′ 7″ ♑, quocirca ſi è loco Solis vero ſubtrahatur locus Martis ex Sole verus, remanet angulus Anomaliæ Orbis annui gr. 7 21′ 12″.

In Triangulo A Z L dantur bina latera A Z 142569, A L 101767, unà cum angulo ab iiſdem comprehenſo gr. Z A L gr. 7 21′ 12″, idcircò juxta Triangulorum analyſin, inveniuntur anguli A L Z gr. 155 16′ 36″, A Z L gr. 17 22′ 12″. cum latere Z L 43628. Ablato autem angulo A Z L ex loco *Martis* ex *Sole*, relinquitur locus ♂ Geocentricus in gr. 21 7′ 55″ ♐, obſervationi quamproximè conveniens.

Obſervat. T. B. 1593.

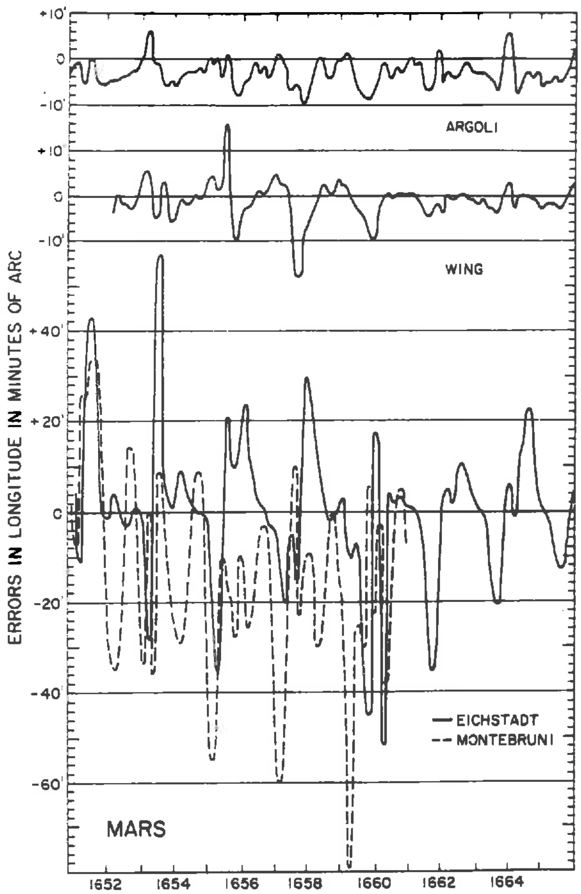
11. Anno 1593. die 21 *Julii*, horis à meridie 14. videbatur ♂ *Uraniburgi* in gr. 17 45′ 45″ ♓, quo tempore Sol vero ſuo motu erat in gr. 8 26′ 6″ ♌, & Diſtantia Terræ à Sole 101500.

Medius motus Martis erat Sig. 10. gr. 21 33′ 10″, Anomalia Sig. 5. gr. 22 45′ 11″, hinc dabitur Proſthaphæreſis gr. 1 30′ 47″ auferenda, locus

MERCATOR -- 1676

Loca Martis extra situm Acronychium 28, commentario de *Uraniburgi observata & à* Keplero *in Marte relata.*

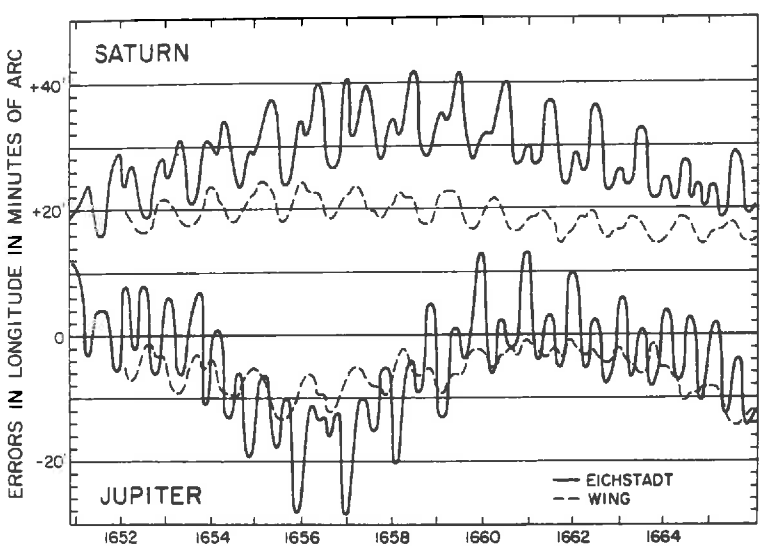
					Verus locus Solis.				Anom med. ♂				Loc. ♂ comput.				Loc. ♂ observ.				Differ.	
Ann.	Mens.	dì.	hor.	m	Sig.	grad.	min.	sec.	Sig.	gr.	min.	sec.	Sig.	gr.	min.	sec.	Sig.	gr.	min.	sec.	Min.	sec.
1582	Novembris	23	10	00	♐	11	41	25	09	22	51	48	♋	26	40	13	♋	26	38	30	01	43 −
	Decembris	26	08	30	♑	15	02	20	10	09	59	54	♋	17	38	57	♋	17	40	30	01	33 +
	Decembris	30	08	10	♑	19	05	59	10	12	05	17	♋	16	03	15	♋	16	00	30	02	45 −
1583	Januarii	26	06	15	♒	16	28	04	10	26	11	50	♋	08	22	40	♋	08	20	30	02	10 −
1584	Decembris	21	14	00	♑	10	41	41	11	00	34	01	♍	01	15	17	♍	01	13	30	01	47 −
1585	Januarii	24	09	00	♒	15	04	43	11	18	16	44	♌	24	09	43	♌	24	07	30	02	13 −
	Februarii	04	06	40	♒	26	05	42	11	23	59	31	♌	19	47	30	♌	19	47	00	00	30 −
	Martii	12	10	30	♈	02	11	25	00	12	56	17	♌	11	45	37	♌	11	46	00	00	23 +
1587	Januarii	25	17	00	♒	15	56	13	00	11	31	22	♎	04	42	25	♎	04	42	00	00	25 −
	Martii	04	13	24	♓	23	54	00	01	01	21	19	♍	26	26	03	♍	26	25	40	00	23 −
1587	Martii	10	11	30	♓	29	46	28	01	04	27	27	♍	24	05	56	♍	24	05	15	00	41 −
	Aprilis	21	09	30	♉	10	45	09	01	26	25	09	♍	15	51	45	♍	15	48	20	03	25 −
1589	Martii	08	16	24	♓	28	30	17	01	26	35	10	♏	12	15	17	♏	12	16	50	01	33 +
	Aprilis	13	11	15	♉	03	34	45	02	15	20	06	♏	04	43	11	♏	04	43	20	00	09 +
	Aprilis	15	12	05	♉	05	33	17	02	16	24	04	♏	03	59	04	♏	03	58	20	00	44 −
1589	Maii	06	11	20	♉	25	46	15	02	27	23	19	♎	27	10	15	♎	27	07	20	02	55 −
1591	Maii	13	14	00	♊	02	08	03	03	23	39	39	♑	02	18	51	♑	02	20	00	01	09 +
	Junii	06	12	20	♊	24	59	38	04	06	12	09	♐	27	11	45	♐	27	15	00	03	15 +
	Junii	10	11	50	♊	28	47	11	04	08	17	17	♐	25	58	40	♐	26	02	36	03	56 +
	Junii	28	10	24	♋	15	51	44	04	17	41	26	♐	21	07	20	♐	21	10	00	02	40 +
1593	Julii	21	14	00	♌	08	28	13	05	22	53	30	♓	17	45	01	♓	17	45	45	00	44 +
	Augusti	22	12	20	♍	09	14	54	06	09	37	21	♓	13	08	26	♓	13	10	15	01	49 +
	Augusti	29	10	20	♍	15	57	52	06	13	14	44	♓	11	15	05	♓	11	14	00	01	05 −
	Octobris	03	08	00	♎	20	19	42	07	01	31	55	♓	07	46	06	♉	07	50	10	04	04 +
1595	Septembris	17	16	45	♎	04	22	26	07	15	53	09	♉	26	08	38	♉	26	07	12	01	26 −
1595	Octobris	27	12	20	♏	14	02	39	08	06	44	54	♉	18	47	49	♉	18	51	15	03	26 +
	Novembris	03	12	00	♏	21	05	17	08	10	24	36	♉	16	16	28	♉	16	18	30	02	02 +
	Decembris	18	08	00	♑	06	42	10	09	03	54	36	♉	11	40	22	♉	11	40	00	00	22 −



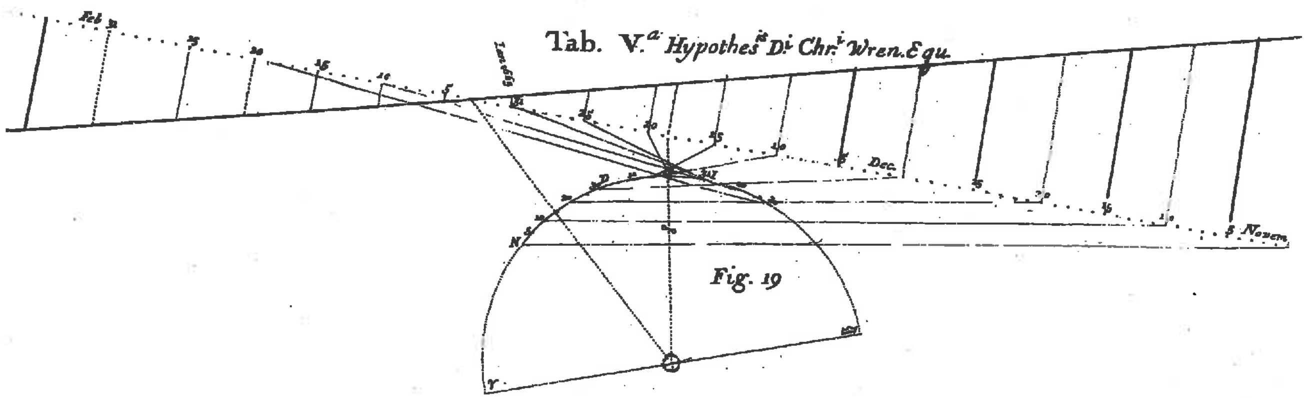
Graph 1

Accuracy of ephemerides during the seventeenth century The graphs of this and the following two pages, prepared by Owen Gingerich and Barbara Welther, plot the errors in a number of planetary ephemerides published during the seventeenth century. The accuracy of the ephemerides depended both on the accuracy of the tables or the theory from which they were derived, and on the accuracy with which the derivation was carried out.

Of the ephemerides whose error-plots are given in Graphs 1 and 2, those of Andreas Argoli (1570–1657) ran from 1621 to the end of the century, and were based on his own *Secundorum mobilium tabulae* (Padua, 1634), apparently adapted from Kepler's *Rudolphine Tables*. Those of Lorenz Eichstadt (1596–1660) were a continuation of the ephemerides begun by Kepler; but Eichstadt's calculations from Kepler's tables appear to have been very inaccurate. Francisco Montebruni (*fl.* mid-seventeenth century) based his ephemerides on the tables of Philippe van Lansberge, published in 1632. Vincent Wing used his own tables for calculating ephemerides, shifting in the late 1650s from those of the *Harmonicon coeleste* to the more accurate tables of the *Astronomia instaurata*.



Graph 2



12.3. Wren's 'theory' of cometary motion, applied to the comet of 1664–65. The semicircle represents the orbit of the Earth, the continuous straight line the path of the comet, and the dotted straight line its projection onto the plane of the ecliptic.

Fellows of the Royal Society of London

The list of fellows given below is only those scientists elected Fellows of the Royal Society whose biographies appear in the MacTutor History of Mathematics Archive, together with some present day mathematicians. The list also gives their date of their election to the Society.

1663 - 1749

William Brouncker 1663
Robert Boyle 1663
John Wilkins 1663
Isaac Barrow 1663
Robert Hooke 1663
William Neile 1663
John Pell 1663
John Wallis 1663
Christopher Wren 1663
Christiaan Huygens 1663
Nicolaus Mercator 1666
Ismael Boulliau 1667
John Collins 1667
James Gregory 1668
Isaac Newton 1672
Jean D Cassini 1672
Gottfried W von Leibniz 1673
Renatus F Sluze 1674
Jonas Moore 1674
John Flamsteed 1676
Edmond Halley 1678
Denis Papin 1682
Joseph Raphson 1689
David Gregory 1692
Vincenzo Viviani 1696
Abraham de Moivre 1697
Jacques Cassini 1698
John Keill 1700
John Arbuthnot 1704
Guido Grandi 1709
Giovanni Poleni 1710
John Craig 1711
William Jones 1711
Roger Cotes 1711
Brook Taylor 1712
Johann Bernoulli 1712
Nicolaus (I) Bernoulli 1714
Pierre Varignon 1714
Willem Jakob 'sGravesande 1715
Pierre R de Montmort 1715
John Hadley 1717
Thomas F de Lagny 1718
Colin Maclaurin 1719
Giulio Fagnano 1723
Edmund Stone 1725
James Stirling 1726
Benjamin Robins 1727
Samuel Clarke 1728
Pierre L M de Maupertuis 1728
Joseph Privat de Molières 1729
Louis B Castel 1730
Bernard le B de Fontenelle 1733
Johann G Doppelmayr 1733
Alexis C Clairaut 1737
Johann A Segner 1738
Georges L L Buffon 1740
Thomas Bayes 1742
Giovanni F M S Castillon 1745
Thomas Simpson 1745
Leonard Euler 1747
Charles M de La Condamine 1748
Jean le R d'Alembert 1748
Gabriel Cramer 1749

PHILOSOPHICAL *TRANSACTIONS.*

Munday, March 6. 166$\frac{4}{5}$.

The Contents.

An Introduction to this Tract. An Accompt of the Improvement of Optick Glaſſes *at* Rome. *Of the Obſervation made in* England, *of a Spot in one of the Belts of the Planet* Jupiter. *Of the motion of the late* Comet *prædicted. The Heads of many New Obſervations and Experiments, in order to an Experimental* Hiſtory of Cold; *together with ſome* Thermometrical *Diſcourſes and Experiments. A Relation of a very odd Monſtrous* Calf. *Of a peculiar* Lead-Ore *in* Germany, *very uſeful for Eſſays. Of an* Hungarian Bolus, *of the ſame effect with the* Bolus Armenus. *Of the New* American *Whale-fiſhing about the* Bermudas. *A Narative concerning the ſucceſs of the* Pendulum-watches *at Sea for the* Longitudes; *and the Grant of a* Patent *thereupon. A Catalogue of the Philoſophical Books publiſht by* Monſieur de Fermat, *Counſellour at* Tholouſe, *lately dead.*

The Introduction.

WHereas there is nothing more neceſſary for promoting the improvement of Philoſophical Matters, than the communicating to ſuch, as apply their Studies and Endeavours that way, ſuch things as are diſcovered or put in practiſe by others; it is therefore thought fit to employ the *Preſs*, as the moſt proper way to gratifie thoſe, whoſe engagement in ſuch Studies, and delight in the advancement of Learning and profitable Diſcoveries, doth entitle them to the knowledge of what this Kingdom, or other parts of the World, do, from time to time, afford, as well of the progreſs of the Studies, Labours, and attempts of the Curious and learned in things of this kind, as of their compleat Diſcoveries and performances: To the end, that ſuch Productions being clearly and truly communicated, deſires after ſolid and uſefull knowledge may be further entertained, ingenious Endeavours and Undertakings cheriſhed, and thoſe, addicted to and converſant in ſuch matters, may be invited and encouraged to ſearch, try, and find out new things, impart their knowledge to one another, and contribute what they can to the Grand deſign of improving Natural knowledge, and perfecting all *Philoſophical Arts*, and *Sciences*. All for the Glory of God, the Honour and Advantage of theſe Kingdoms, and the Univerſal Good of Mankind.

An Accompt of the improvement of Optick Glaſſes.

There came lately from *Paris* a Relation, concerning the Improvement of *Optick Glaſſes*, not long ſince attempted at *Rome* by Signor *Giuſeppe Campani*, and by him diſcourſed of, in a Book, Entituled, *Ragguaglio di nuove Oſſervationi*, lately printed in the ſaid City, but not yet tranſmitted into theſe parts; wherein theſe following particulars, according to the Intelligence, which was ſent hither, are contained.

The *Firſt* regardeth the excellency of the long *Teleſcopes*, made by the ſaid *Campani*, who pretends to have found a way to work great *Optick Glaſſes* with a Turne-tool, without any Mould: And whereas hitherto it hath been found by Experience, that *ſmall* Glaſſes are in proportion better to ſee with, upon the Earth, than the *great* ones; that Author affirms, that his are equally good for the Earth, and for making Obſervations in the Heavens. Beſides, he uſeth three Eye-Glaſſes for his great *Teleſcopes*, without finding any *Iris*, or ſuch Rain-bow colours, as do uſually appear in ordinary Glaſſes, and prove an impediment to Obſervations.

The *Second*, concerns the *Circle of Saturn*, in which he hath obſerved nothing, but what confirms Monſieur *Chriſtian Huygens de Zulichem* his Syſteme of that Planet, publiſhed by that worthy Gentleman in the year, 1659.

The

The *Third*, reſpects *Jupiter*, wherein *Campani* affirms he hath obſerved by the goodneſs of his Glaſſes, certain *protuberancies* and *inequalities*, much greater than thoſe that have been ſeen therein hitherto. He addeth, that he is now obſerving, whether thoſe ſallies in the ſaid *Planet* do not change their ſcituation, which if they ſhould be found to do, he judgeth, that *Jupiter* might then be ſaid to turn upon his *Axe*; which, in his opinion, would ſerve much to confirm the opinion of *Copernicus*. Beſides this, he affirms, he hath remarked in the *Belts* of *Jupiter*, the ſhaddows of his *ſatellites*, and followed them, and at length ſeen them emerge out of his Disk.

A Spot in one of the Belts of Jupiter.

The Ingenious Mr. *Hook* did, ſome moneths ſince, intimate to a friend of his, that he had, with an excellent twelve foot Teleſcope, obſerved, ſome days before, he than ſpoke of it, (*videl.* on the ninth of *May*, 1664. about 9 of the clock at night) a ſmall Spot in the biggeſt of the 3 obſcurer *Belts* of *Jupiter*, and that, obſerving it from time to time, he found, that within 2 hours after, the ſaid Spot had moved from Eaſt to Weſt, about half the length of the Diameter of *Jupiter*.

The Motion of the late Comet prædicted.

There was lately ſent to one of the *Secretaries* of the *Royal Society* a Packet, containing ſome Copies of a Printed Paper, Entituled, The *Ephemerides* of the *Comet*, made by the ſame Perſon, that ſent it, called *Monſieur Auzout*, a *French* Gentleman of no ordinary Merit and Learning, who deſired, that a couple of them might be recommended to the ſaid *Society*, and one to their *Preſident*, and another to his Highneſs Prince *Rupert*, and the reſt to ſome other Perſons, nominated by him in a Letter that accompanied this preſent, and known abroad for their ſingular abilities and knowledge in Philoſophical Matters. The end of the Communication of this Paper was, That, the motion of the *Comet*, that hath lately appeared, having been prædicted by the ſaid *Monſieur Au-*

Vertue for cuttings, lameneſs, *&c.* the part affected being anointed therewith. One thing more he related, not to be omitted, which is, that having told, that the time of catching theſe Fiſhes was from the beginning of *March,* to the end of *May*, after which time they appeared no more in that part of the Sea: he did, when asked, whither they then retired, give this Anſwer, That it was thought, they went into the Weed-beds of the Gulf of *Florida*, it having been obſerved, that upon their Fins and Tails they have ſtore of Clams or Barnacles, upon which, he ſaid, Rock-weed or Sea-tangle did grow a hand long; many of them having been taken of them, of the bigneſs of great Oyſter-ſhels, and hung upon the Governour of *Bermudas* his Pales.

A Narrative concerning the ſucceſs of Pendulum-Watches at Sea for the Longitudes.

The Relation lately made by Major *Holmes*, concerning the ſucceſs of the *Pendulum-Watches* at Sea (two whereof were committed to his Care and Obſervation in his laſt voyage to *Guiny* by ſome of our Eminent *Virtuoſi*, and Grand Promoters of Navigation) is as followeth;

The ſaid *Major* having left that Coaſt, and being come to the Iſle of St. *Thomas* under the *Line*, accompanied with four Veſſels, having there adjuſted his Watches, put to Sea, and ſailed Weſtward, ſeven or eight hundred Leagues, without changing his courſe; after which, finding the Wind favourable, he ſteered towards the Coaſt of *Africk*, North-North-Eaſt. But having ſailed upon that *Line* a matter of two or three hundred Leagues, the Maſters of the other Ships, under his Conduct, apprehending that they ſhould want Water, before they could reach that Coaſt, did propoſe to him to ſteer their Courſe to the *Barbadoes*, to ſupply themſelves with Water there. Whereupon the ſaid Major, having called the Maſter and Pilots together, and cauſed them to produce their Journals and Calculations, it was found, that thoſe Pilots did differ in their reckonings from that of the Major, one of them eighty Leagues, another about an hundred, and the third, more; but the Major judging by his *Pendulum-Watches*, that they were only ſome thirty Leagues diſtant from

the

the Iſle of *Fuego*, which is one of the Iſles of *Cape Verde*, and that they might reach it next day, and having a great confidence in the ſaid Watches, reſolved to ſteer their Courſe thither, and having given order ſo to do, they got the very next day about Noon a ſight of the ſaid Iſle of *Fuego*, finding themſelves to ſail directly upon it, and ſo arrived at it that Afternoon, as he had ſaid. Theſe Watches having been firſt Invented by the Excellent Monſieur *Chriſtian Hugens* of *Zulichem*, and fitted to go at Sea, by the Right Honourable, the Earl of *Kincardin*, both Fellows of the *Royal Society*, are now brought by a New addition to a wonderful perfection. The ſaid Monſieur *Hugens*, having been informed of the ſucceſs of the Experiment, made by *Major Holmes*, wrought to a friend at *Paris* a Letter to this effect;

Major *Holmes* at his return, hath made a relation concerning the uſefulneſs of *Pendulums*, which ſurpaſſeth my expectation: I did not imagine that the Watches of this firſt Structure would ſucceed ſo well, and I had reſerved my main hopes for the New ones. But ſeeing that thoſe have already ſerved ſo ſucceſsfully, and that the other are yet more juſt and exact, I have the more reaſon to believe, that the Invention of *Longitudes* will come to its perfection. In the mean time I ſhall tell you; that the *States* did receive my Propoſition, when I deſired of them a Patent for theſe new Watches, and the recompenſe ſet a-part for the invention in caſe of ſucceſs; and that without any difficulty they have granted my requeſt, commanding me to bring one of theſe Watches into their Aſſembly, to explicate unto them the Invention, and the application thereof to the *Longitudes*; which I have done to their contentment. I have this week publiſhed, that the ſaid Watches ſhall be expoſed to ſale, together with an Information neceſſary to uſe them at Sea: and thus I have broken the Ice. The ſame Objection, that hath been made in your parts againſt the exactneſs of theſe *Pendulums*, hath alſo been made here; to wit, that though they ſhould agree together, they might fail both of them, by reaſon that the Air at one time might be thicker, than at another. But I have anſwered, that this difference, if there be any, will not be at all perceived in the *Penduls*, ſeeing that the continuall Obſervations, made in Winter from day to day, until Summer, have ſhewed me that

they

they have always agreed with the Sun. As to the Printing of the *Figure* of my New Watch, I ſhall defer that yet a while: but it ſhall in time appear with all the Demonſtrations thereof, together with a *Treatiſe* of *Pendulums*, written by me ſome days ſince, which is of a very ſubtile Speculation.

The Character, lately publiſhed beyond the Seas, of an Eminent Perſon, not long ſince dead at Tholouſe, *where he was a Councellor of Parliament.*

It is the deſervedly famous *Monſieur de Fermat*, who was, (ſaith the Author of the Letter) one of the moſt Excellent Men of this Age, a *Genius* ſo univerſal, and of ſo vaſt an extent, that if very knowing and learned Men had not given teſtimony of his extraordinary merit, what with truth can be ſaid of him, would hardly be believed. He entertained a conſtant correſpondence with many of the moſt Illuſtrious Mathematicians of *Europe*, and did excel in all the parts of Mathematical Science: a Teſtimony whereof he hath left behind him in the following Books.

A Method for the Quadrature of *Parabola's* of all degrees.

A Book *De Maximis & Minimis*, which ſerveth not only for the determination of Problems of *Plains* and *Solids*, but alſo for the invention of *Tangents* and *Curve Lines*, and of the *Centres* of Gravity in Solids; and likewiſe for Numerical Queſtions.

An Introduction to the Doctrine of *Plains* and *Solids*, which is an *Analytical* Treatiſe, concerning the ſolution of *Plains* and *Solids*, which had been ſeen (as the Advertiſer affirms) before Monſieur *Des Cartes* had publiſh'd any thing upon this Subject.

A Treatiſe *De Contactibus Sphæricis*, where he hath demonſtrated in *Solids*, what Mr. *Viet*, Maſter of Requeſts, had but demonſtrated in *Plains*.

Another Treatiſe, wherein he eſtabliſheth and demonſtrateth the two Books of *Apollonius Pergæus*, of *Plains*.

And a General Method for the dimenſion of *Curve Lines*, &c. Beſides, having a perfect knowledge in Antiquity, he was conſulted from all parts upon the difficulties that did emerge therein: he hath explained abundance of obſcure places, that are found

By the Council of the Royal Society of *London* for Improving of Natural Knowledge.

Ordered, *That the Book written by* Robert Hooke, *M. A. Fellow of this Society, Entituled*, Micrographia, or some Physiological Descriptions of Minute Bodies, made by Magnifying Glasses, with Observations and Inquiries thereupon, *Be printed by* John Martyn, *and* James Allestry, *Printers to the said Society.*

Novem. 23.
1664.

Brouncker. *P. R. S.*

MICROGRAPHIA:

OR SOME

Physiological Descriptions

OF

MINUTE BODIES

MADE BY

MAGNIFYING GLASSES.

WITH

Observations and Inquiries thereupon.

By *R. HOOKE*, Fellow of the Royal Society.

Non possis oculo quantum contendere Linceus,
Non tamen idcirco contemnas Lippus inungi. Horat. Ep. lib. 1.

LONDON, Printed by *Jo. Martyn*, and *Ja. Allestry*, Printers to the Royal Society, and are to be sold at their Shop at the *Bell* in S. *Paul's* Church-yard. M DC LX V.

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HIA.

s and dryings, as the parts
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r to work upon those sub-
m.

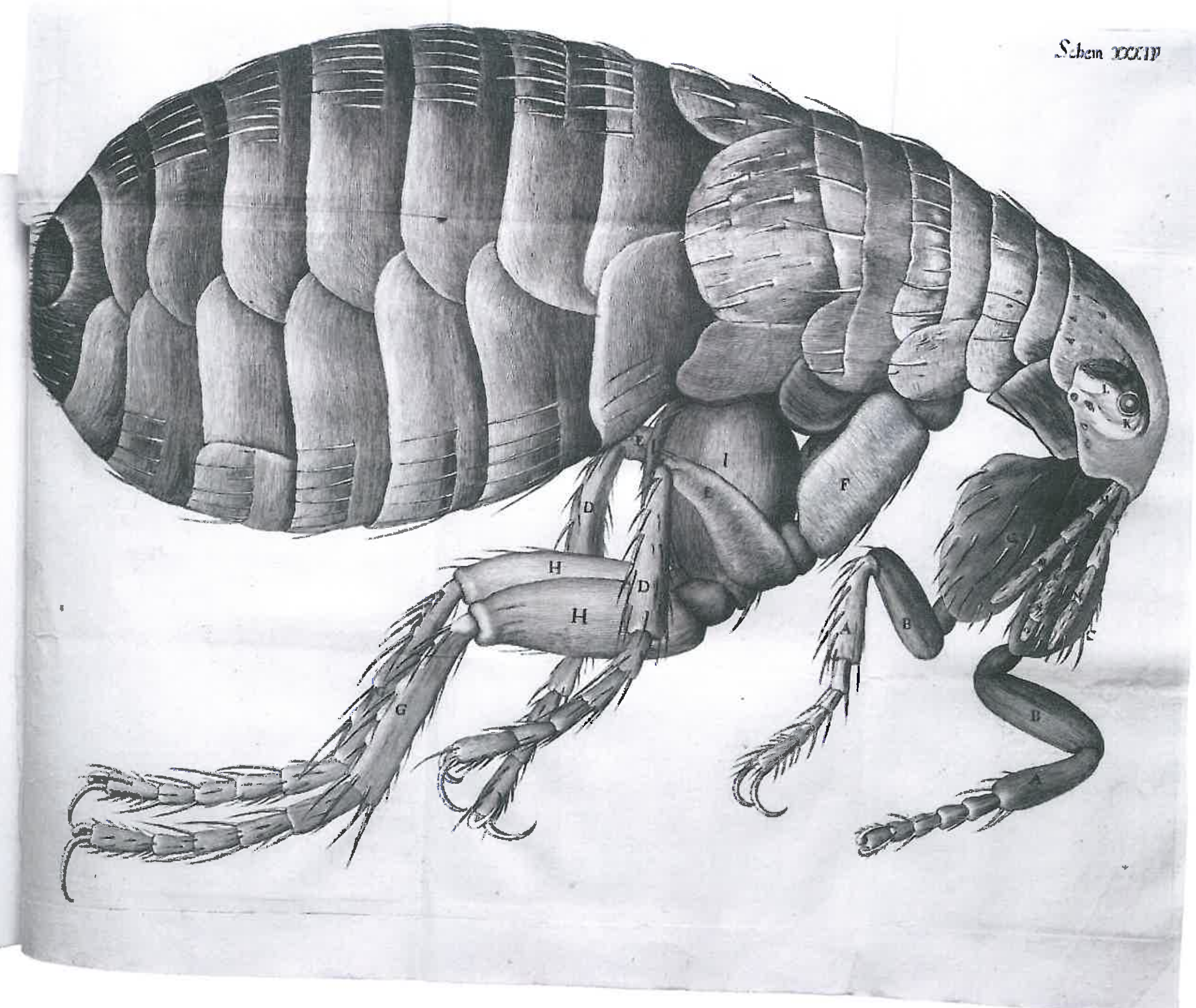
of Saw-dust or chips this
Time) conveys into its in-
the excellent contrivance
continually nourished and
onsets, and fomented by the
e most admirable fabrick of
wasting of that fire, to be
more materials to augment
the principal end of all the

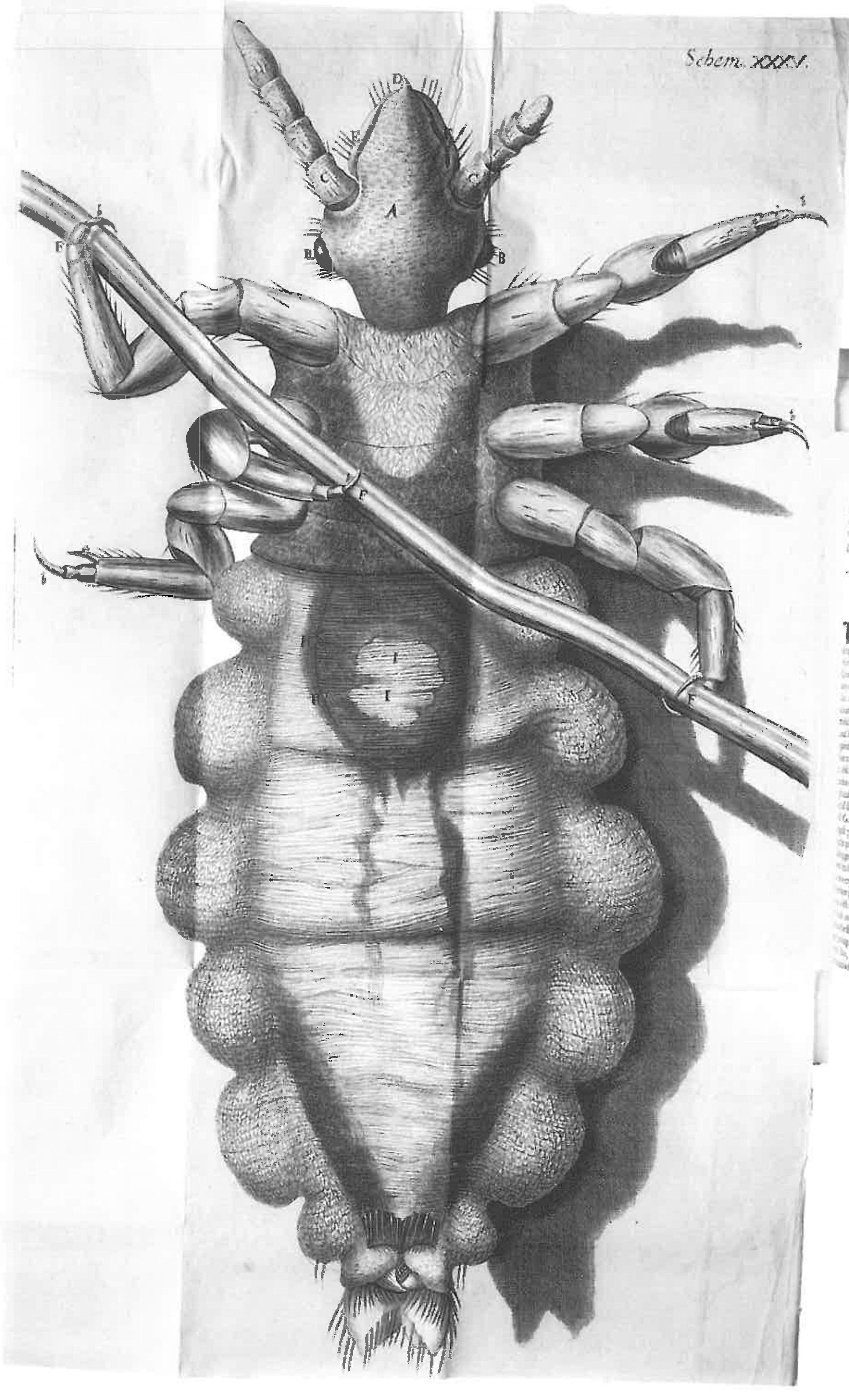
a Flea.

ture, had it no other rela-
cription.

make no greater discoveries
ous contrivance of its leggs
ery plainly manifested, such
as any thing like it; for the
e fold these short one with-
m out to their whole length,
e 34. Scheme, lies within B,
each other; but the parts
D without E, and E with-
e hinder leggs, G. H and I,
a double jointed Ruler, or
e six leggs he clitches up al-
ll out, and thereby exerts

manifests it to be all over
de Armour, neatly jointed,
pp'd almost like Porcupine's
head is on either side beau-
behind each of which also
s to move to and fro a cer-
m hairs, which probably may
tween the two fore-leggs, he
smelless, M M, which have
d other creatures; between
D, that seems to consist of a
tube,

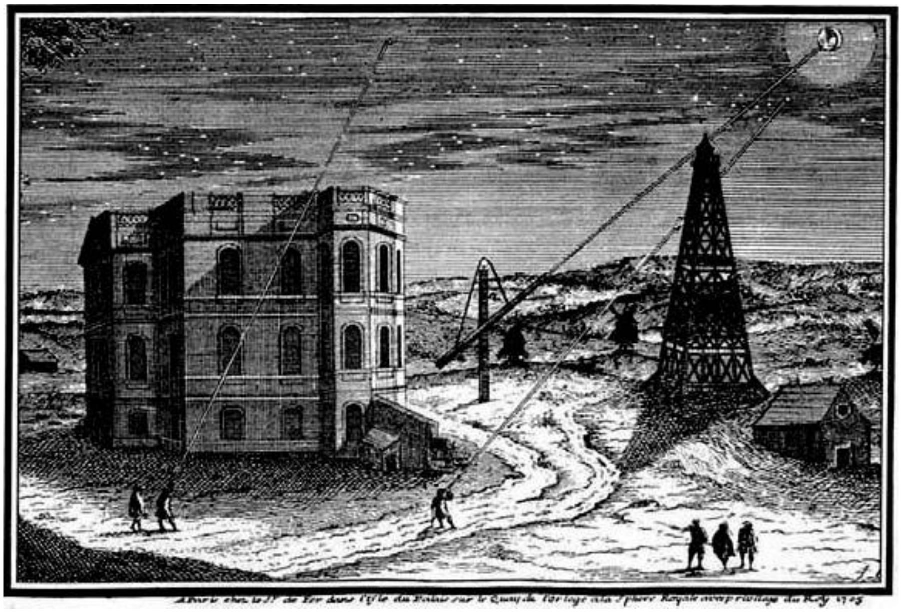




MICROGRAP

Royal Academy of Paris, 1666

Auzout – astronomy
Bourdelin – chemistry
Buot – geometry
Duclas – chemistry
Duhamel – anatomy
Frénicle de Bessy – geometry
Gayant – anatomy
Huygens – geometry
La Chambre – physics
Marchant – botanist
Mariotte – physics
Niquet – geometry
Perrault – physics
Picard – astronomy
Richer – astronomy
Roberval -- geometry



A Discovery of two New Planets *about* Saturn, *made in the Royal Parisian Observatory by Signor* Cassini, *Fellow of both the Royal Societys, of* England *and* France; *English't out of French.*

I.

A Discovery of 10 small Fixt Stars, and of one New Planet, first.

ABout the end of *October* 1671. Saturn pass'd close by *Four* small Fix't Stars, visible only by a Telescope, within the *sinus* of the Water of *Aquarius*, which *Rheita* once took for New Satellits of Jupiter, calling them *Urban-octavians*; but which *Hevelius* (who called them *Vladislavians*) shew'd to be some of the common Fix't Stars, that may every day be seen by a Telescope any where in the Heavens.

This Passage of Saturn gave us occasion to discover in the same place, within the space of 10 minuts, by a Telescope of 17 feet, made by *Campani*, *Eleven* other smaller Stars, one of which, by its particular motion, shew'd it self to be a true *Planet*: which we found by comparing it not only to Saturn and his Ordinary Satellit, discovered 1655 by Mr. *Hugens*, but also to other Fix't Stars, and particularly to three, marked *a*, *b*, *d*, in the First *Table*, where, to avoid a long explication of our first Observations, we have described the way of Saturn, and

See Tab. I. *Fig.* II.

Royal Academy Expeditions

Picard to Denmark, 1671

Determine precise longitude and latitude of Hven

Obtain a copy of register of Tycho's observations

{Discovers anomalous "motion" of northern stars

Brings young Roemer back to Paris Academy}

Richer to Cayenne, 1672-73

Determine precise obliquity of the ecliptic

Determine precise times of equinoxes

Determine parallaxes of Mars, Venus, Sun

Record motions and parallaxes of Moon

Record motions of Mercury

Record positions of south-hemisphere stars

Determine precise longitude and latitude of Cayenne

{Finds clock around 2½ minutes slow per day

Finds one-second pendulum 1¼ lines shorter, i.e. gravity around 0.35% weaker at Cayenne}

PHILOSOPHICAL
TRANSACTIONS.

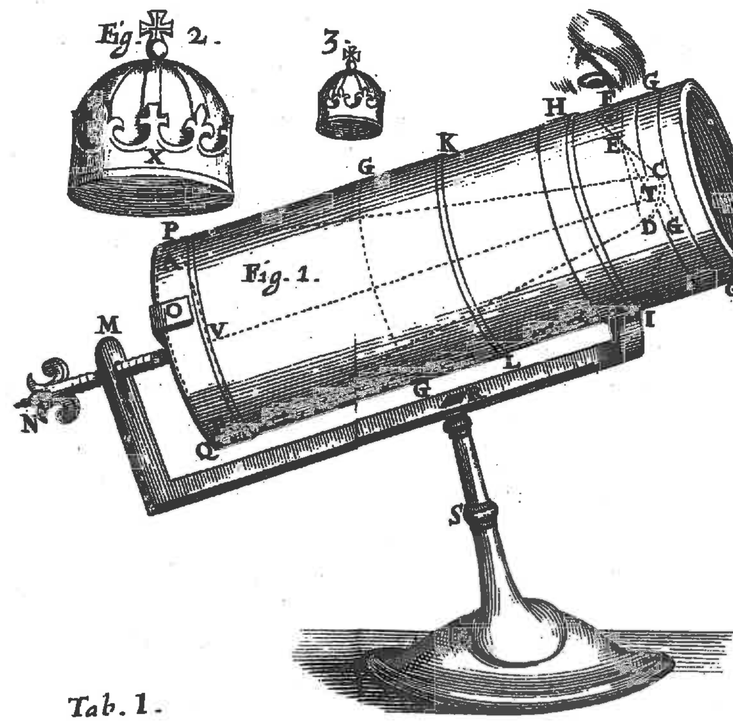
February 19. 16$\frac{71}{72}$.

A Letter of Mr. Isaac Newton, *Professor of the Mathematicks in the University of Cambridge; containing his New Theory about* Light *and* Colors: *sent by the Author to the Publisher from Cambridge, Febr. 6. 16$\frac{71}{72}$; in order to be communicated to the* R. Society.

An Accompt of a New Catadioptrical Telescope invented by Mr. Newton, *Fellow of the* R.Society, *and Professor of the Mathematiques in the University of Cambridge.*

THis Excellent Mathematician having given us, in the Transactions of *February* last, an account of the cause, which induced him to think upon *Reflecting* Telescopes, instead of *Refracting* ones, hath thereupon presented the Curious World with an *Essay* of what may be performed by such Telescopes; by which it is found, that Telescopical Tubes may be considerably shortned without prejudice to their magnifying effect.

This new instrument is composed of two Metallin *speculum's*, the one Concave, (instead of an Object-glass) the other Plain; and also of a small plano-convex Eye-Glass.



Tab. 1.

A Demonſtration concerning the Motion of Light, *communicated from* Paris, *in the* Journal des Scavans, *and here made Engliſh.*

PHiloſophers have been labouring for many years to decide by ſome Experience, whether the action of Light be conveyed in an inſtance to diſtant places, or whether it requireth time. M. *Romer* of the *R. Academy* of the Sciences hath deviſed a way, taken from the Obſervations of the firſt Satellit of *Jupiter*, by which he demonſtrates, that for the diſtance of about 3000 leagues, ſuch as is very near the bigneſs of the Diameter of the Earth, Light needs not one ſecond of time.

Let (in *Fig.* 11.) A be the *Sun*, B *Jupiter*, C the firſt Satellit of *Jupiter*, which enters into the ſhadow of *Jupiter*, to come out of it at D; and let EFGHKL be the *Earth* placed at divers diſtances from *Jupiter*.

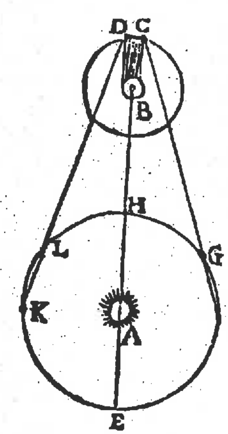
Now, ſuppoſe the *Earth*, being in L towards the ſecond Quadrature of *Jupiter*, hath ſeen the firſt Satellit at the time of its emerſion or iſſuing out of the ſhadow in D; and that about $42\frac{1}{2}$ hours after, (*vid.* after one revolution of this Satellit,) the *Earth* being in K, do ſee it returned in D; it is manifeſt, that if the Light require time to traverſe the interval LK, the Satellit will be ſeen returned later in D, than it would have been if the Earth had remained in L, ſo that the revolution of this Satellit being thus obſerved by the Emerſions, will be retarded by ſo much time, as the Light ſhall have taken in paſſing from L to K, and that, on the contrary, in the other Quadrature FG, where the *Earth* by approaching goes to meet the Light, the revolutions of the Immerſions will appear to be ſhortned by ſo much, as thoſe of the Emerſions had appeared to be lengthned. And becauſe in $42\frac{1}{2}$ hours, which this Satellit very near takes to make one revolution, the diſtance between the *Earth* and *Jupiter* in both the Quadratures varies at leaſt 210 Diameters of the *Earth*, it follows, that if for the account of every Diameter of the *Earth* there were required a ſecond of time, the Light would take $3\frac{1}{2}$ minutes for each of the intervals GF, KL; which would cauſe near half a quarter of an hour between two revolutions of the firſt Satellit, one obſerved in FG, and the other in KL, whereas there is not obſerved any ſenſible difference.

Yet

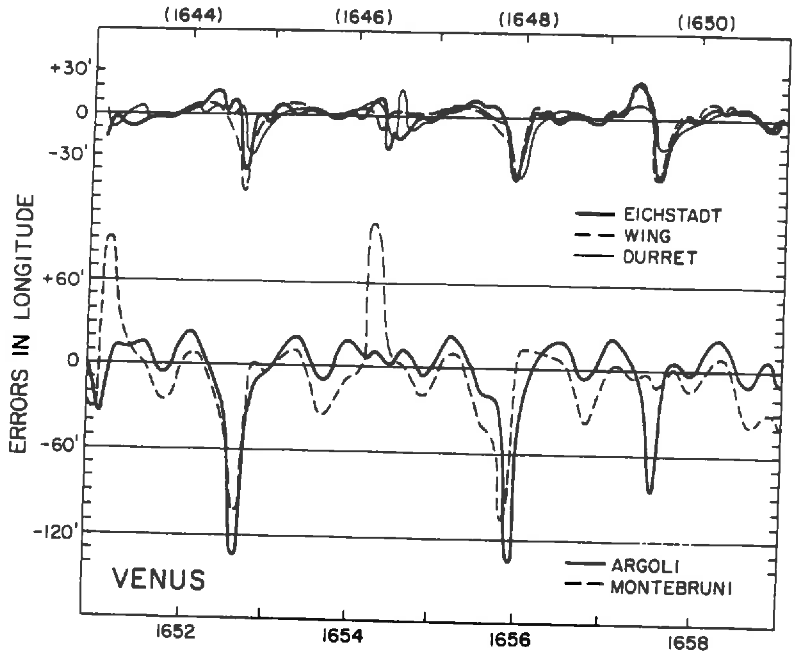
Yet doth it not follow hence, that Light demands no time. For, after M. *Romer* had examin'd the thing more nearly, he found, that what was not ſenſible in two revolutions, became very conſiderable in many being taken together, and that, for example, forty revolutions obſerved on the ſide F, might be ſenſibly ſhorter, than forty others obſerved in any place of the Zodiack where *Jupiter* may be met with; and that in proportion of twenty two for the whole interval of H E, which is the double of the interval that is from hence to the Sun.

The neceſſity of this new Equation of the retardment of Light, is eſtabliſhed by all the obſervations that have been made in the *R. Academy*, and in the *Obſervatory*, for the ſpace of eight years, and it hath been lately confirmed by the Emerſion of the firſt Satellit obſerved at *Paris* the 9th of *November* laſt at 5 a Clock, 35′ 45″. at Night, 10 minutes later than it was to be expected, by deducing it from thoſe that had been obſerved in the Month of *Auguſt*, when the *Earth* was much nearer to *Jupiter*: Which M. *Romer* had predicted to the ſaid Academy from the beginning of *September*.

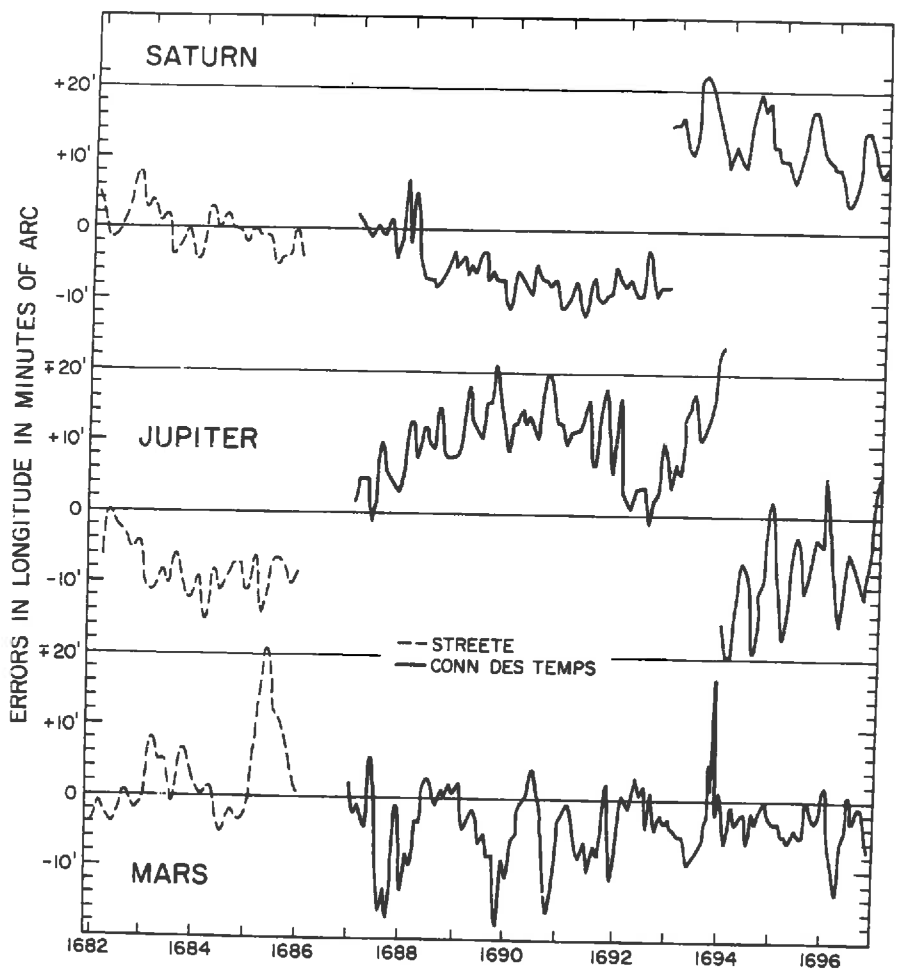
But to remove all doubt, that this inequality is cauſed by the retardment of the Light, he demonſtrates, that it cannot come from any excentricity, or any other cauſe of thoſe that are commonly alledged to explicate the irregularities of the *Moon* and the other Planets; though he be well aware, that the firſt Satellit of *Jupiter* was excentrick, and that, beſides, his revolutions were advanced or retarded according as *Jupiter* did approach to or recede from the Sun, as alſo that the revolutions of the *primum mobile* were unequal; yet ſaith he, theſe three laſt cauſes of inequality do not hinder the firſt from being manifeſt.



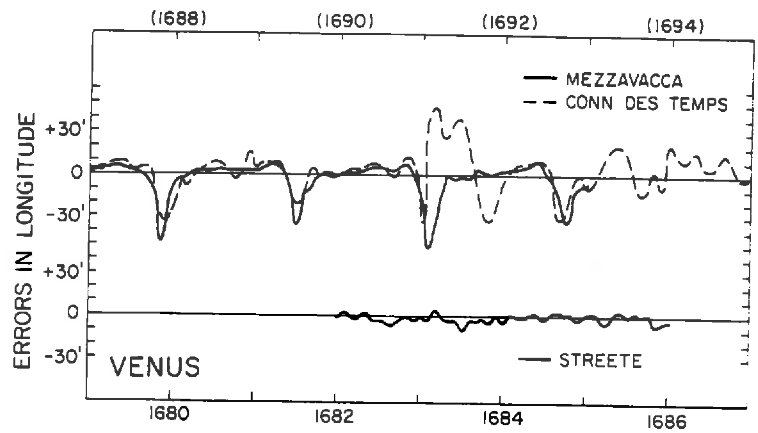
Greenwich Observatory



Graph 3



Graph 4



Graph 5

In Graph 3, which shows errors in ephemerides of Venus, it is noteworthy that Durret's positions match those of Eichstadt and Wing very closely; they have apparently been determined from almost the same elements and theory. The errors in the Venusian ephemerides of Argoli and Montebruni are three to four times larger, and so have been plotted separately.

In Graph 4 Streete's almanacs of 1682–85 are compared, for the superior planets, with the *Connaissance des temps*, begun in 1679 by the Paris Academy of Sciences. The errors in both are considerable, even for Mars which, unlike Jupiter and Saturn, is not subject to sizeable long-term perturbations.

Graph 5 compares the Venusian ephemerides of Streete, the *Connaissance des temps*, and Flaminio Mezzavacca (d. 1704), who appears to have copied at least some of his positions from the ephemerides of Argoli. Streete's superior accuracy is evident; it is due in part to the superior solar theory he inherited from Horrocks, and in part to his employing Kepler's third law to determine the mean solar distance of Venus – a practice that derives from Horrocks.

	ORBITAL TRAJECTORY	LOCATION VS. TIME	MEAN DIST. FROM SUN
KEPLER	ellipse	area rule	from observations
BOULLIAU	ellipse	a geometric construction	from observations
HORROCKS	ellipse	area rule	via 3/2 power rule
STREETE	ellipse	Boulliau's construction	via 3/2 power rule
WING	ellipse	oscillating equant -------------- a geometric construction	from observations
MERCATOR	ellipse	a geometric construction	from observations

Table 1. Seven Comparably Accurate Ways of Calculating Planetary Orbits as of 1680 – All Known to Newton

Open Questions in Astronomy, 1679

1. Which of the several more or less comparably accurate yet still discrepant orbital calculation procedures is to be preferred?

2. Does Kepler's or any other of these procedures amount to anything more than just a transient approximation to the true motions, as Descartes would have them?

3. What is the nature and source of the comparatively large discrepancies exhibited by Jupiter and Saturn?

4. What are the proper corrections to observations for parallax and atmospheric refraction?

5. Is the speed of light really finite and, if so, what corrections to observations are needed to adjust for it?

6. What is the motion of the Moon and why is it so much more complicated than e.g. those of Jupiter's satellites?

7. What are comets and what trajectories do they describe as they pass through the planetary system?

8. Does the strength of surface gravity really vary from one place to another and, if so, according to what rule?

9. Are the planets being carried around by vortices and, if not, then what retains them in orbits that are at least roughly elliptical?

10. What, if anything, should be made of the seeming fact that the centrifugal *conatus* of the planets varies in an inverse-square ratio with mean distance from the Sun?

In 1674 Hooke had put forward three hypotheses at the end of his <u>An Attempt to Prove the Motion of the Earth</u>:

- "That all celestial bodies whatsoever have an attraction or gravitating power towards their own centers, whereby they attract not only their own parts, and keep them from flying from them, as we observe the Earth to do, but that they do also attract all the other celestial bodies that are within the sphere of their activity; and consequently that not only the Sun and Moon have an influence upon the body and motion of the Earth, and the Earth upon them, but that Mercury, also Venus, Mars, Saturn, and Jupiter by their attractive powers, have a considerable influence upon its motion as in the same manner the corresponding attractive power of the Earth hath a considerable influence upon every one of their motions also."

- "That all bodies whatsoever that are put into a direct and simple motion, will so continue to move forward in a straight line, till they are by some other effectual powers deflected and bent into a motion, describing a circle, ellipse, or some other more compounded curved line."

- "That these attractive powers are so much the more powerful in operating, by how much the nearer the body wrought is to their own centers."

"Now what these several degrees are I have not yet experimentally verified; but it is a notion which, if fully prosecuted as it ought to be, will mightily assist the astronomer to reduce all the celestial motions to a certain rule, which I doubt will never be done true without it. He that understands the nature of the circular pendulum and circular motion, will easily understand the whole ground of this principle, and will know where to find direction in nature for the true stating thereof. This I only hint at at present to such as have ability and opportunity of prosecuting this inquiry, and are not wanting of industry for observing and calculating, wishing heartily such may be found, having myself many other things in hand which I would first complete and therefore cannot so well attend it. But this I durst promise the undertaker, that he will find all the great motions of the world to be influenced by this principle, and that the true understanding thereof will be the true perfection of astronomy." (Gunther, viii, pp.27-28)