The ‘monsters’ of astronomy before Copernicus: Regiomontanus’s criticisms of Ptolemaic modeling in the *Defensio Theonis*

Michael H. Shank

University of Wisconsin-Madison

Best portrait of Johannes Müller von Königsberg = Regiomontanus

from the *Nuremberg Chronicle* (1493) by Hartmann Schedel, who knew him personally

Overview

- Many thanks and Introductory remarks
- Regiomontanus before the *Defensio*
- Introduction to *Defensio*
- Monster language in *Defensio*: sampling
  - Damage of epicycles, eccentrics, and equants to Moon and Mercury among others
  - Fluid heavens monster
  - Partial orbs monster
  - A concentric *Almagest*?
- Regiomontanus reaction to Commentariolus?

Regiomontanus's pre-*Defensio* critiques of received astronomy

- "Letter to Vitez" (1460) **sketches homocentric models** for Sun and Moon

-"Letter to Bianchini" (ca. 1463-64) criticizes large but unseen theoretical variations in area:

Moon: 4x

Mercury: 9x

Venus: 45x

Mars: 51x

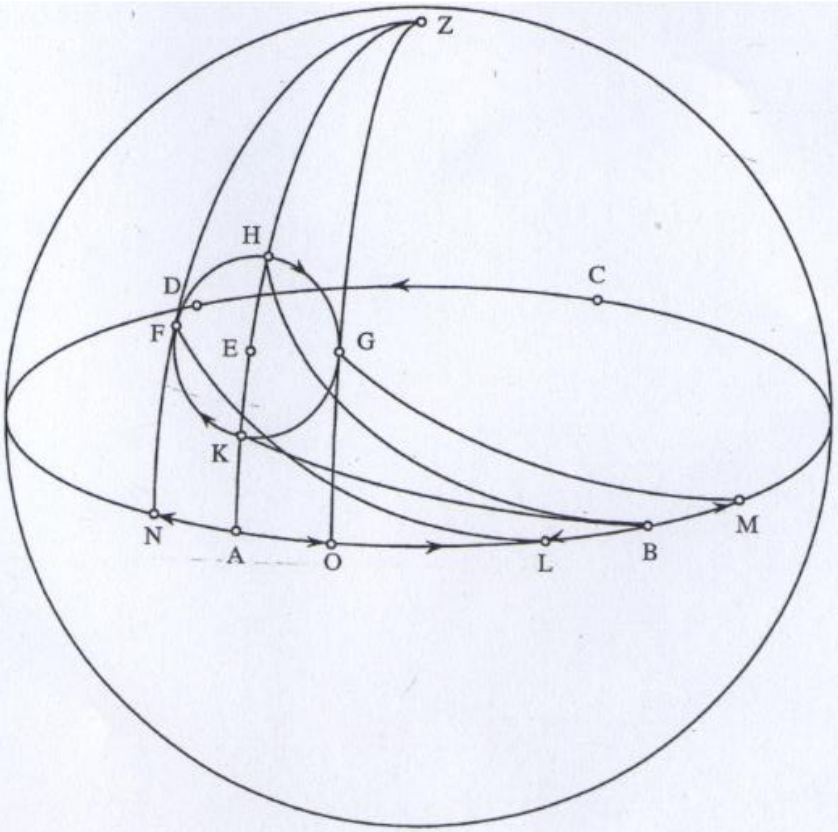


FIG. 1. Theory of the Sun without an eccentric.

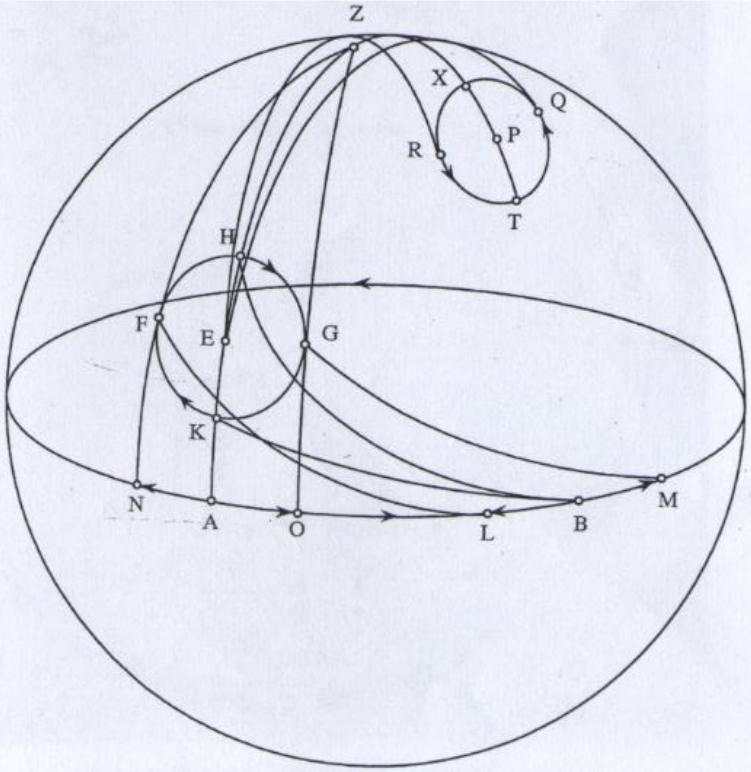
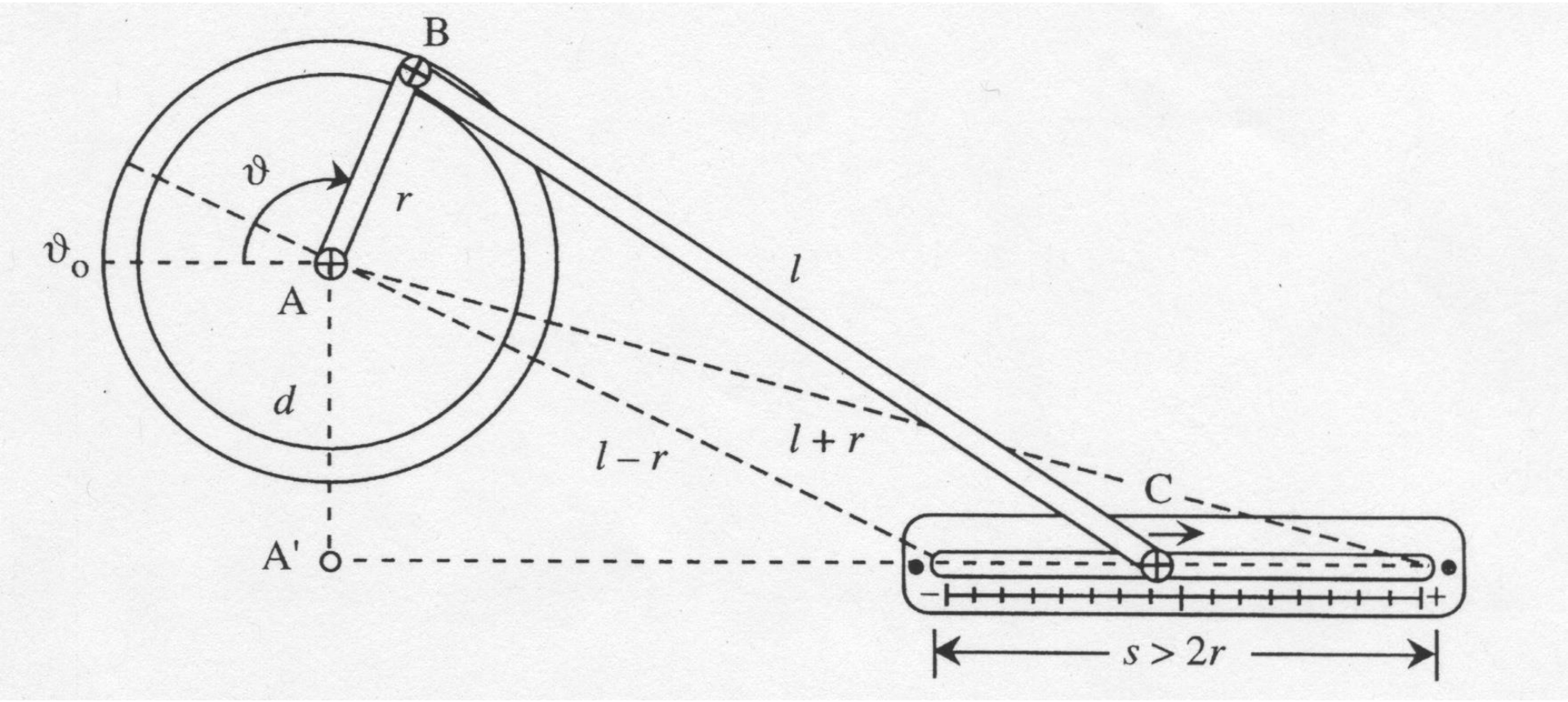
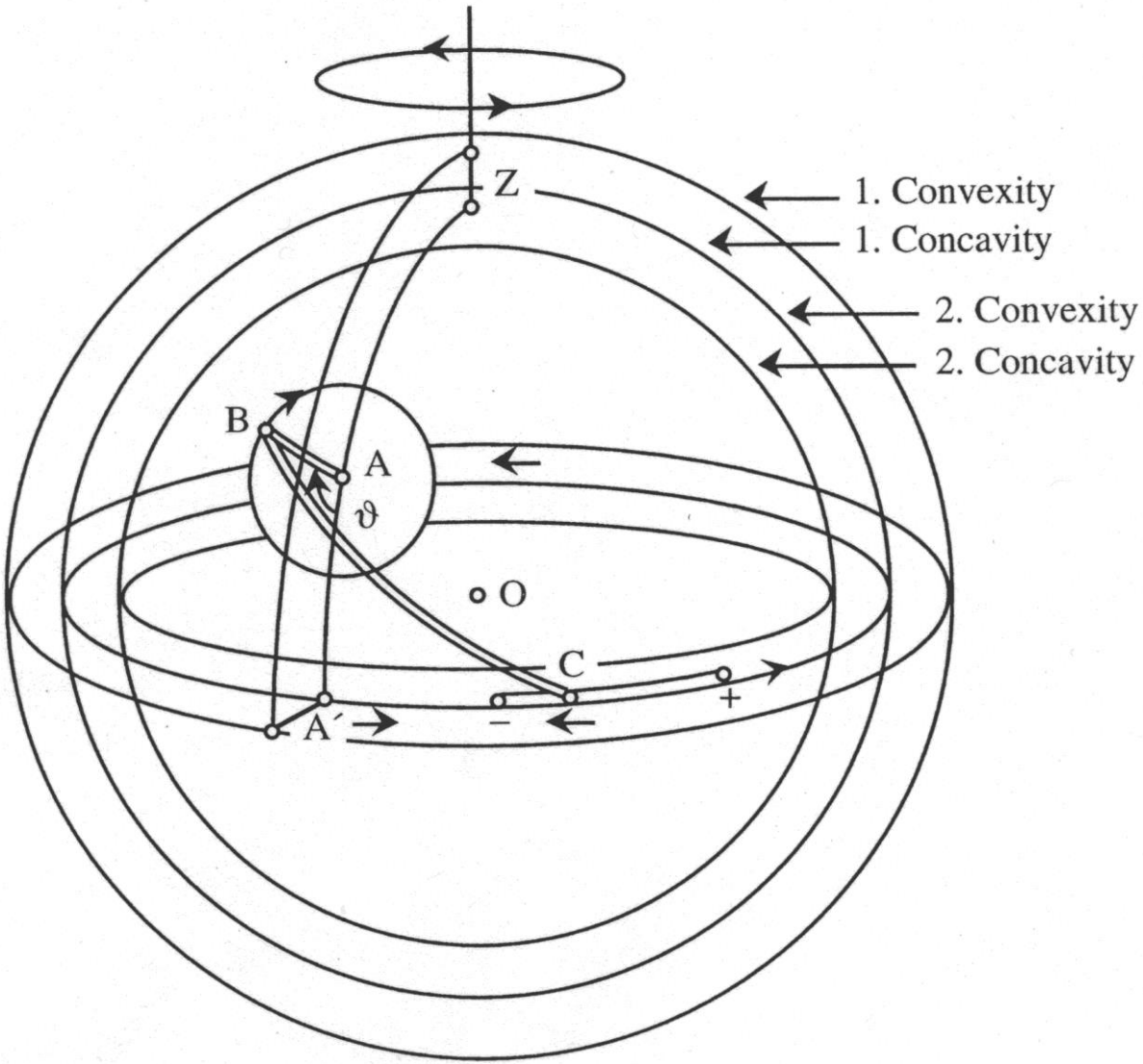


FIG. 2. Theory of the Moon without eccentrics and an epicycle.



Swerdlow's drawing of the "slider-crank" mechanism


Z
1. Convexity
1. Concavity
2. Convexity
2. Concavity
B
A
ϑ
O
C
A´
+
−

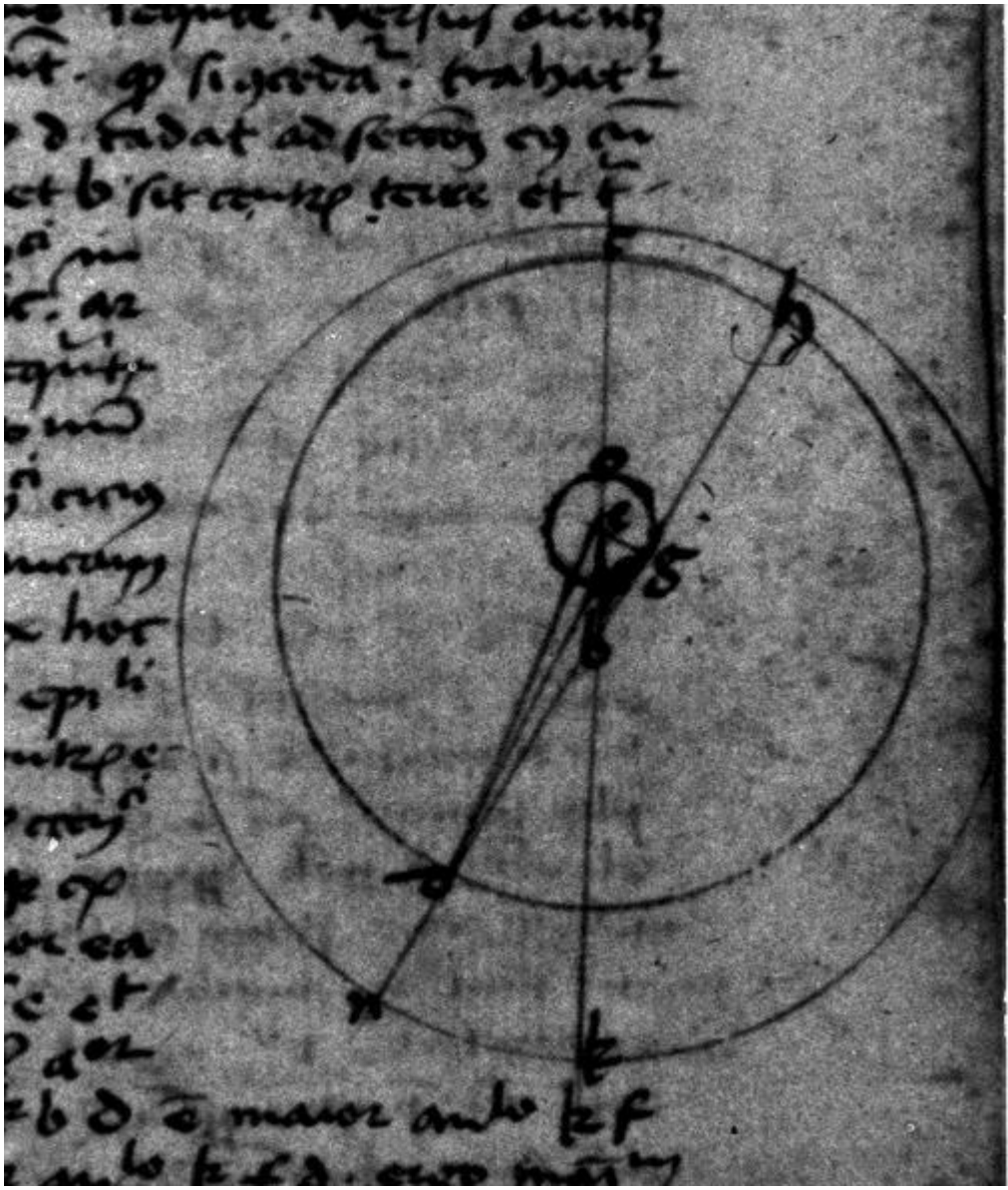
Prelude: *Almagesti minor*

- Rewritten “Euclidization” of *Almagest*
  - Early 13th c.: ***Almagesti minor*** is earliest Latin technical **presentation** of *Almagest* (books 1-6 only) (ed. Henry Zepeda, PAL, v. 1, 2018)
  - Author restructures books 1-6 in **quasi-Euclidean format: propositions with proofs** [*Almagest* does not do so]
- Crucial consequences for 15th-16th c. specialists (Peuerbach, Regiomontanus, Copernicus)—more below

Background of Regiomontanus's critique

- Henry of Langenstein's De reprobatione ecentricorum et epiciclorum (Paris, 1364)
- His own earlier critique of the Theorica planetarum communis on physical grounds:
  - Ptol. lunar theory (4 x area increase) inconsistent with observed size (no change)
  - Critique of theory of Mercury

Regiomontanus's copy of Langenstein's *De reprobatione eccentricorum et epicyclorum* (ÖNB 5203)



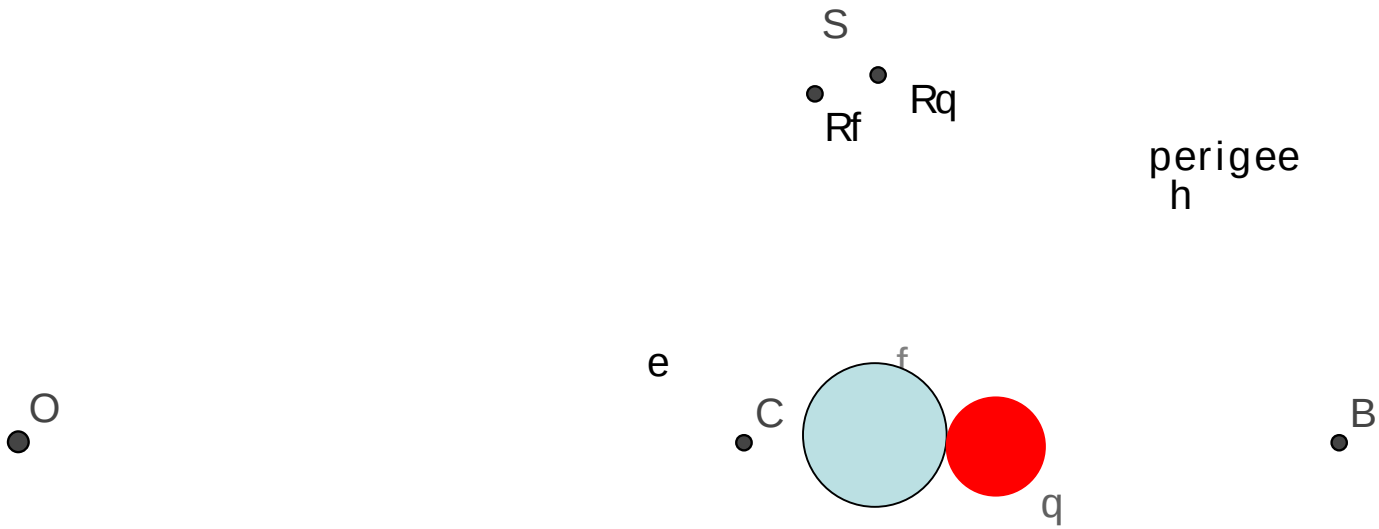
Campanus of Novara's Hyper-detailed schema for computing planetary distances

perigee of planet q's ⇓ center

apogee of ⇑ planet f's center

S = Boundary of contiguous 'physical' spheres ⇒

d



Regiomontanus, *Defensio*, 158r

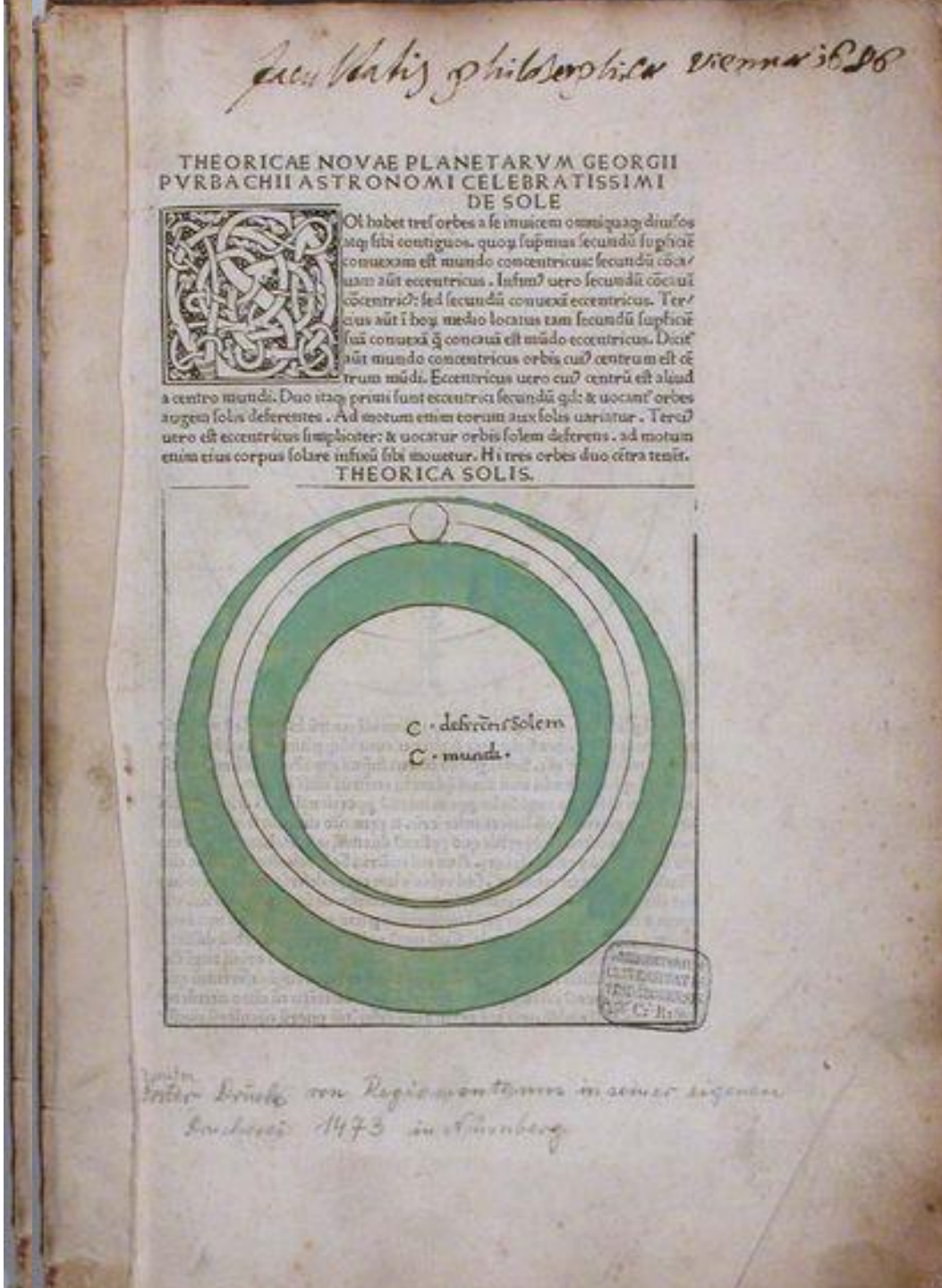
- **“since, whatever their thickness, the orbs of this sort very recently superimposed upon the spheres increase [the thickness] of the celestial region, those who get excited about *climbing the celestial heights on stairs cut out here and there* are effectively laboring in vain.” (book 9)**

Regiomontanus, *Defensio*, 158r

- **Indeed, although individual planets may have [known] eccentric and epicyclic radii and known eccentricities with their individual radii, and [although] the Moon's maximum distance from the universe's center in e.r. has been discovered, nevertheless the conversion of proportions necessary for this work should be kept in check by *so many orbs of unknown thickness inserted here and there.***

Peuerbach,
***Theoricae novae planetarum* (1st ed.)**

written 1454 (Vienna)
printed ca. 1472 by Regiomontanus (Nuremberg)



A commission and an innovation: Vienna, 1460-61

- The Vienna astronomers get “international recognition”
- !460: Visiting Greek Cardinal Bessarion asks Georg Peuerbach to write an **Epitome of the Almagest**
- Request born from **controversy between Bessarion & George of Trebizond, trans. & comm. on *Almagest***
- **Bessarion commissions *Epitome* as an alternative to George’s *Commentary on the Almagest* (1451), which he despises**
- Peuerbach dies (1461) with *Epitome* half finished; Regiomontanus promises to complete it
- With Bessarion, disciple Regiomontanus arrives in Venice San Giorgio Maggiore (561 years ago)

Epitome of the Almagest

- Ca. 1462, Regiomontanus finishes the second half and edits the whole
- **Crucial**! Peuerbach begins the *Epitome* in **imitation of the *Almagesti minor.***
- Format: **numbered propositions and proofs [see H. Zepeda's edition!]**
- **Structure forces Regiomontanus to prove what was not proven in the remaining books of the *Almagest***

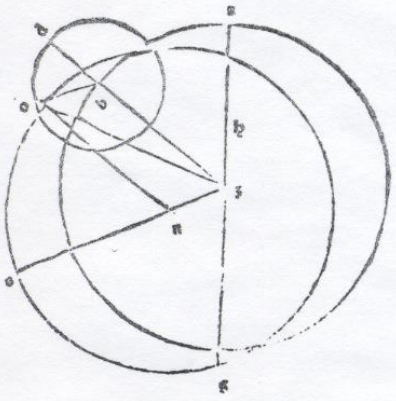
Liber Duodecimus Speculationes Ampliores Circa Paſſionem planetarum diuerſam: Progreſſum videlicet Stationem: & Regreſſum. Variationes nonnullas in longitudinem motus epicyclorũ gratia accidentes lucidiſſime diſcernit.

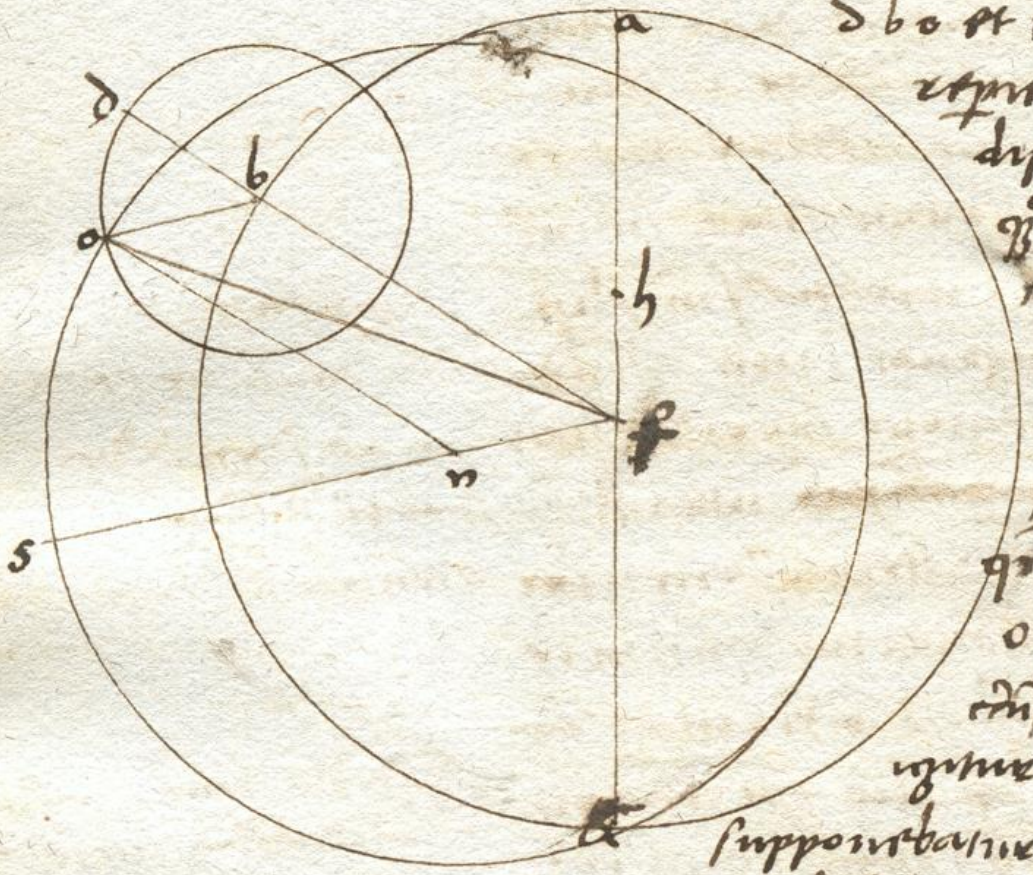
Propoſitio Prima.

Si planetis altioribus vnicã poſueris diuerſitatem: epicyclus in concentrico: aut ecentricus ſine epicyclo eidem ſufficiens erit occaſio.

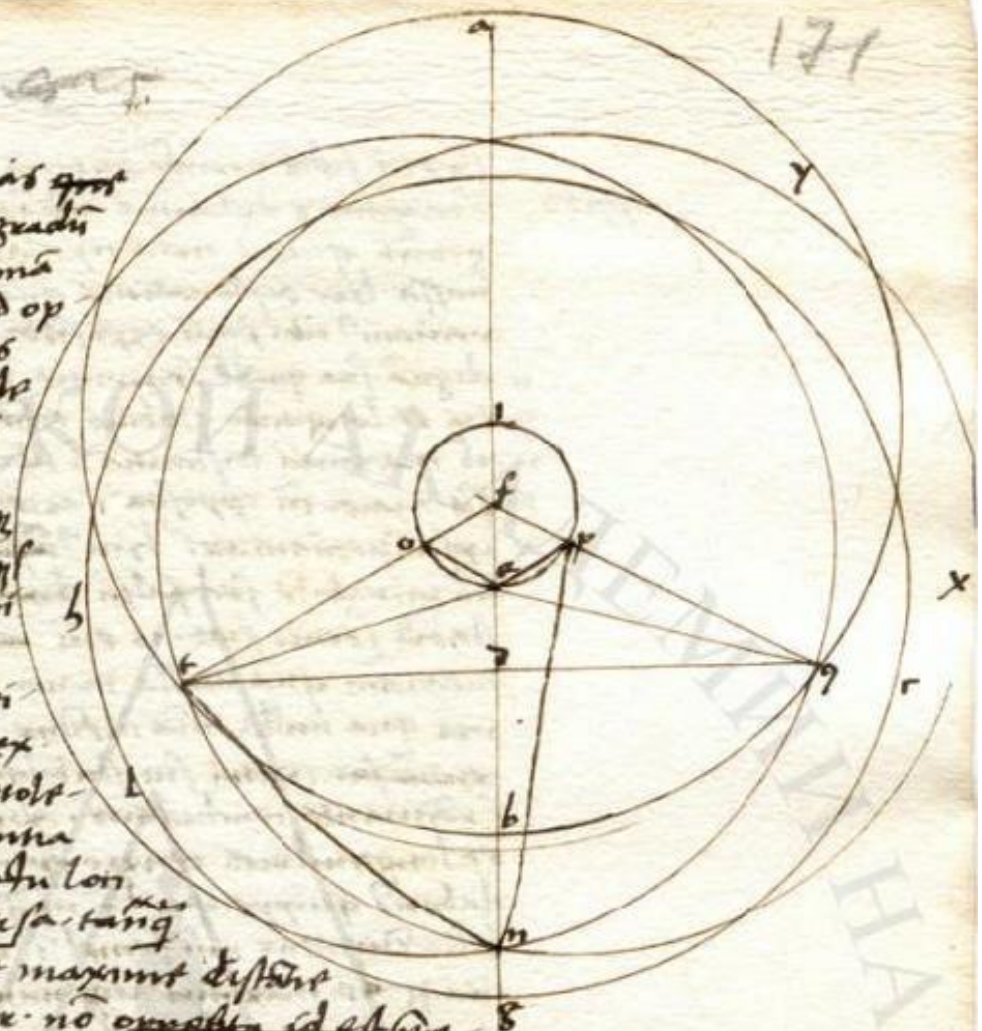
Diuerſitati que ſoli colligata eſt intellige. Ponamus itaq; q motus epicycli in concentrico: & motus planete in epicyclo collecti equent medio motui ſolis: quemadmodũ ſuperius oſtẽſa poſtulant. Ecentrici vo centrũ moueatur ad ſucceſſionẽ ſignorũ eque velociter cum ſole: & planeta ipſe ſimiliter ea velocitate procedat: qua epicyclus in concentrico. Eius quidem medium locum determinet linea a centro mundi ducta equidiſtanter linee exeunti a centro ecentrici per centrum planete. Sit igit circulus mundo concentricus. a. b. g. ſuper centro. z. & ſit punctus. a. in quo fuit centrũ epicycli: dum planeta fuit in auge epicycli: ſcz puncto. b. dũq; ſol medio curſu coniunctus fuit planete: & punctus. h. fuit centrũ ecentrici. Nunc vo epicyclus ſit ſuper puncto. h. & planeta in epicyclo ſuper puncto. o. Ductis igitur lineis. z. h. d. h. o. n. o. z. o. et. z. e. erit angulus. a. z. b. motus medij: & angulus. d. h. o. diuerſitatis ſiue motus medij argumẽti. Sit aũt angulus. a. z. e. medij motus ſolis. hinc in linea. z. e. erit centrum ecentricici: quod ſit. n. Ponamus itaq; primo concentricum & ecentricum equales: et proportionem ſemidiametri concentrici ad ſemidiametrum epicycli equalem proportioni ſemidiametri ecẽtrici ad diſtantiam centrorum. Erit igitur linea. z. h. ſiue. z. n. equalis. h. o. Cum aũt duo anguli. a. z. b. et. d. h. o. equent angulo. a. z. e. ſublato cõmuni. a. z. b. erit angulus. b. z. e. cõlis angulo. d. h. o. quare. z. b. et. n. o. equales & ſibi equidiſtant. Et quia ſunt equales: erunt due linee. due linee. z. n. et. b. o. equidiſtantes. vnde ſuper centro. n. deſcripto cir-

Regiomontanus,
Epitome of
the Almagest
(1462; printed 1496)

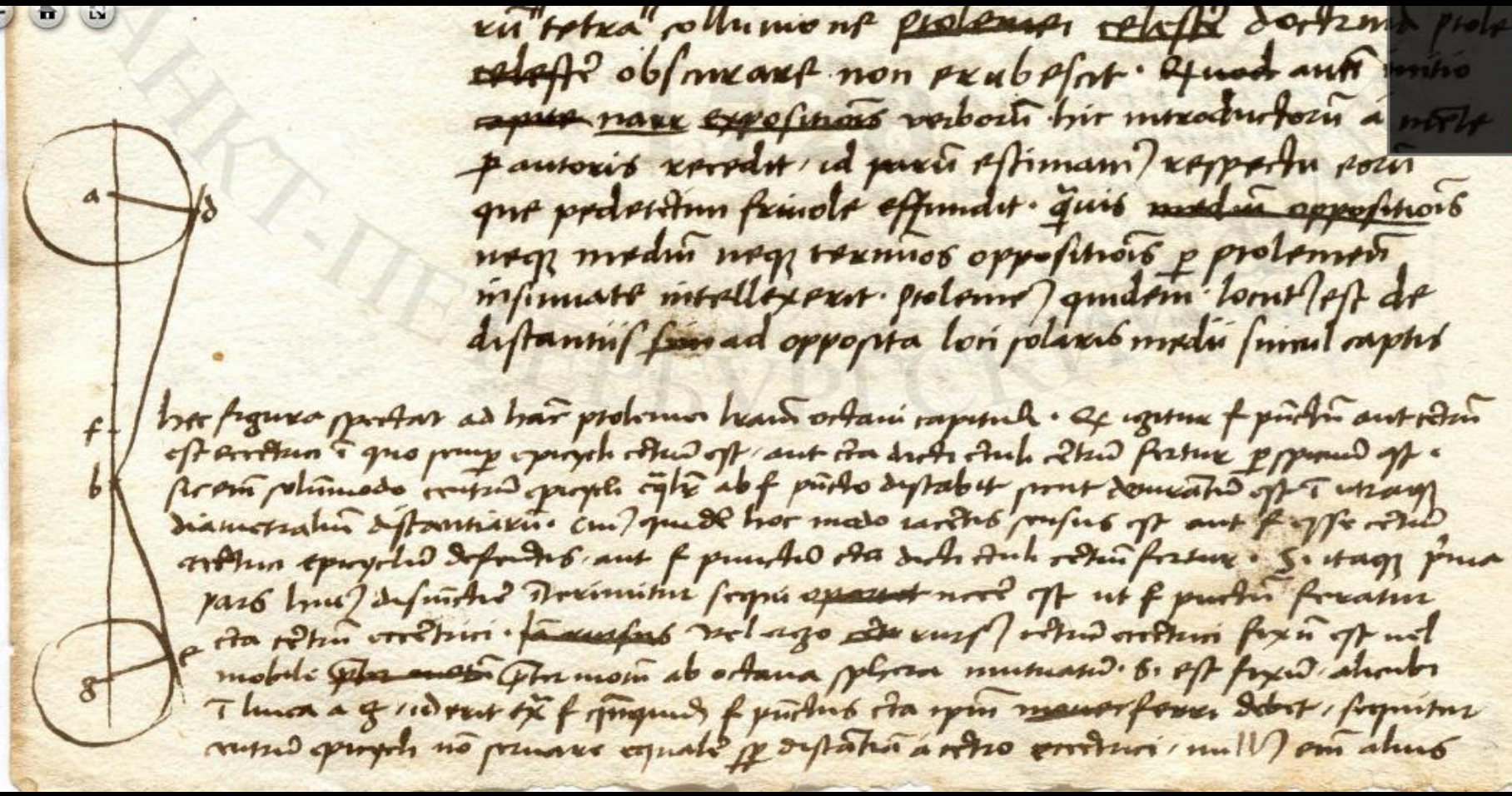



a
d
b
o
h
f
n
s
e

hoc est urbigrā duas distantias ~~quae~~
á medio ~~accidebant~~ sole decimū gradū
obtinente geminorū matutinā
videlicet ac vespertinā ad op
posita loci solaris captas
coniungi do voluit ut inde
constaret quantū totus
epicyclus subtenderet
angulū. huiusmodi namque
q̄sitē angulus vicinitatis atque
remotionis á centro zodiaci
argumentū est. quo enim
maior offenditur eo vi
cinioris terre epicyclū ex
hibet. Sic per opposita ptole
meus intellexit precedentia
et sequentia zodiaci respectu loci
solaris medii amanduersa tanquam
communis termini ad quem maxime distantie
mercuriales referuntur. nō ~~opposita id est~~ prece
dentia et sequentia respectu lineae [illegible]



Regiomontanus, *Defensio*, 170v



Defensio, book 12, 219r

- **Before yours eyes,** you have then that **neither a lunar eccentric nor an epicycle can be tolerated,** because not only **do they not correspond to the Ptolemaic decrees [e.g. *Almagest* 3.3?],** but they also **exhibit poorly the uniformity of motions to be safeguarded by the astronomer.**

Defensio, 219v equant problems

- "But for the period of **Mercury**, he also then demands to explore eccentrics, **if that for the sake of which they were instituted can exhibit a function.** Indeed, since the eccentric deferent, like that of the Moon, is unstable, **the motion and equality that they call equant** [*note distance from the concept!]* is referred to the center of the eccentric;"

Defensio, 219v equant (1)

- "as in the lunar case, **the center of the epicycle, since it is carried uniformly about the other center, of the equant, is shown to move altogether non-uniformly with respect to the eccentric center**; and for that reason, the nonuniform motion is governed by Mercury's eccentric. "

Defensio, 219v
equant (2): mean aux

- "Likewise, since the epicycle gets a uniform degree from its **mean aux, which is unstable**, it is necessary on account of the *fastigium* of the epicycle that the certain and definite planet itself be carried non uniformly, as proven by the straight line extended from the eccentric center through the epicycle center. Recall briefly that **because of the eccentric and epicycle together, the diameter of Mercury can appear variable/different**.

Critique of mean aux and non-uniform motion of the planet in the epicycle

Moon/Merc uniform motion measured from "mean aux;" = **line from equant O to "mean aux" moves**,
(since O is carried around Terra on small crank circle, the mean aux reference point oscillates and planet does not move uniformly about K

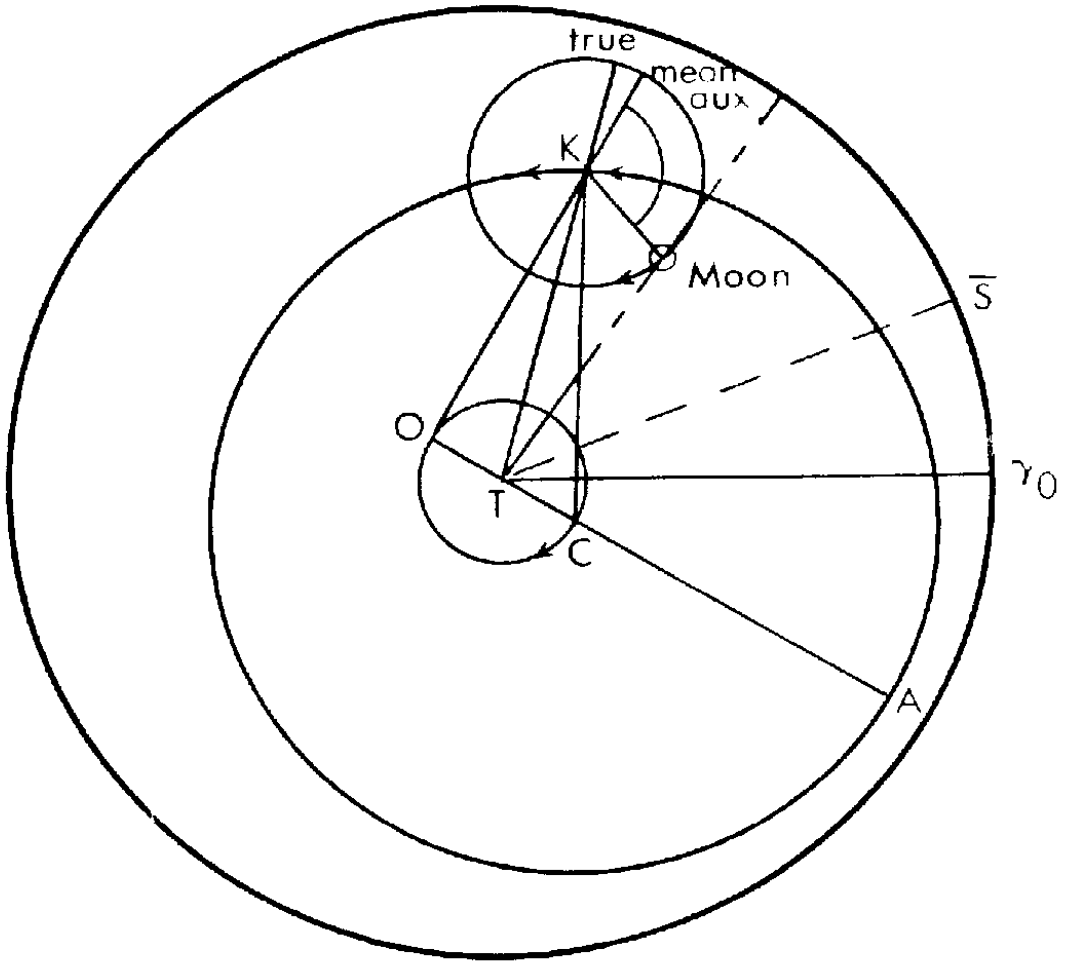


FIG. 3

Defensio, 219v
unseen increase in area

- The greatest distance of **Mercury** that is made up of the two radii of the eccentric and the epicycle together with the tripled eccentricity is 91p 30', where the radius of the eccentric is 60 p; the least distance is 33; 3' of the same parts. These numbers exhibit almost a three-fold proportion [ergo **nine-fold increase in area**]

Defensio, 219v: Latin

- Sed nam tempus Mercurii quoque postulat deinceps eccentricos explorare si cuius gratia instituti sunt officium exhibeant. Verum cum eccentricus deferens eius sicut et lune instabilis sit, motusque \ equalitas / ad centrum eccentrici quem vocant equantem referatur haud aliter quam in negocio lunari ostendetur centrum epicycli cum equaliter in centro \ alieno / equantis feratur, inequaliter ominino penes centrum eccentrici se deferentis moveri; atque idcirco ab eccentrico mercuriali inequalem penitus motum administrari.
- Epicyclus item cum ab auge sua media\ que instabilis est / equalem Mercurio gradum concedat, necesse est \ penes / fastigium epicycli certam atque definitam ac recta quidem ex centro eccentrici per centrum epicycli prodeunte commonstratam inequaliter stellam ipsam ferri . Quod autem propter utrumque simul eccentricum atque epicyclum variam Mercurii diametrum apparere oporteat, breviter commemorabimus.
- Maxima quippe Mercurii distantia que ex duabus semidiametris eccentrici et epicycli una cum eccentricitate triplicata colligitur est 91; 30 qualium semidiameter eccentrici est 60; minima vero distantia 33; 3 similium partium. Hi numeri triplam ferme proportionem suscipiunt;

Defensio, 224v
the fluid heavens monster (1)

- **“For if you think this fifth body is fluid and prone to giving way, this cannot happen unless that part of it which is behind the advancing planet immediately insinuates itself into the place left behind, for <the part> that is lateral, being more distant, is incapable of flowing there, as nature always chooses the shortest path.**

Defensio, 224v
the fluid heavens monster (2)

- "Another part will therefore follow the one replacing at the back, … such that, for **the least movement of a single planet, other things being largely at rest, the entire region of the heavens must become agitated--**unless you oppose this **monster** by means of the rarity of the body from the rear, which also requires that the parts in front **give way**, unless you can concoct condensation."

Defensio, 225r
a Peuerbach monster?

- Pray tell **what exists between solar and Martian eccentrics, when no vacuum.** For if you believe they are **contiguous, you must say that they are concentric to one another, which experience shows to be impossible. But you attempt to surround each with two orbs that have some surfaces eccentric (those touching the planet's deferent), others concentric to the world, so that the planetary spheres are made to fuse concentrically to the world by tenuous orbs. This however advances a species of I know not what monstrosity, that there be in the heavens bodies of such varied thickness, here so skinny, there however swelling greatly by some extraordinary contrivance-- a picture so defective that it could not possibly please nature.**

THEORICAE NOVAE PLANETARVM GEORGII
PVRBACHII ASTRONOMI CELEBRATISSIMI
DE SOLE
non-tangent
C · deferens solem
C · mundi ·
non-tangent

Also in *Defensio*, book 12

Roughly 10-folio section that sketches a homocentric schema for retrograde motion!

This fact did not register during details of transcription (initially from a bad photocopy)…

Too late for this paper but note the program:

Defensio, book 12, 226r-v

“ it is advisable to address some samples of this business cursorily [now], lest we seem to go on a long detour, especially since it is alien to the present profession to hand on/teach [*tradere*] an entire concentric astronomy which with difficulty could someday be completed with a many-parted volume and the greater part of our age [=my later life?] and innumerable observations of the stars necessary for this purpose.

Constantine colossus in Rome

Overview of ‘monster’ sample

- Deep skepticism about the Ptolemaic devices (epicycle, eccentric, equant)
  - Whatever their merits, they produce undetectable distances in Moon, Mercury, Venus, and Mars [also Sun?]
- Goal of a homocentric *Almagest* based on new observations
- Self-conscious about going against the profession

Concluding remarks

- Comments about normal science, crises, esthetics reserved for the audience!
- Instead, let's wonder how Regio-montanus would have reacted to the *Commentariolus* (not *De rev.*)?

They would have agree on several things

- Equant and “mean aux” were problems that had to be fixed!
- No eccentrics!

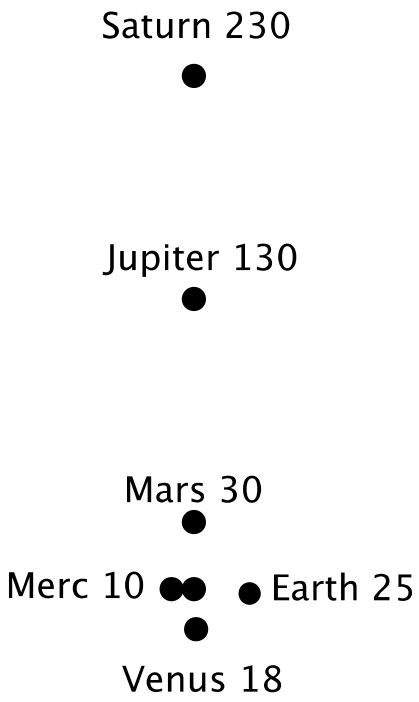
Copernicus, *Commentariolus*,

"Nevertheless, the theories concerning these matters [=epicycles & eccentrics] that have been put forth far and wide by Ptolemy and most others, although they correspond numerically [with appearances], also seemed quite **doubtful**, for these theories were **inadequate unless** they also **envisioned certain equant circles on account of which** it appeared that **the planet never moves with uniform velocity *either* in its deferent sphere *or* with respect to its proper motion. Therefore a theory of this kind seemed neither perfect enough nor sufficiently in accord with reason**."

That said, judging from the *Defensio:*

- Regiomontanus apparently would have hated the *Commentariolus*
- Fundamental diagreement about the tools of astronomy
  - Copernicus adds flawed epicycles!
- Fundamental disagreement about the resulting universe
  - vast tracts of unused space between and beyond the planets

Copernicus's universe +/- to scale



Stars off the chart!

“Ad astronomiam attinere ut non modo calculum apparentibus accommodet, sed et figuras corporum celestium veraciter cum lege motuum edoceat; alias enim fictitiam tradere artem. Equalitatem motuum celestium operepretium tutandam esse.”

Regiomontanus, **Defensio Theonis**, 210v

Epitome of Almagest, 12 second anomaly

- Prop. 1: Regiomontanus proves the equivalence of epicyclic and eccentric models for the superior planets
- Prop. 2: Regiomontanus **proves the opposite of Ptolemy's claim**
  - The two models are also equivalent for the inferior planets
  - No comment about Ptolemy's error

Liber Duodecimus Speculationes Ampliores Circa Paſſionem planetarum diuerſam: Progreſſum videlicet Statio/nem: & Regreſſum. Variationes nonnullas in longitudinem motus epicyclorũ gratia accidentes lucidiſſime diſcernit.

Propoſitio Prima.

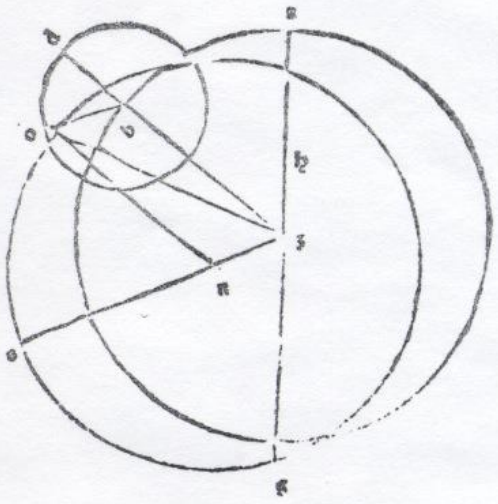
Si planetis altioribus vnicã poſueris diuerſitatem: epicyclus in concentrico: aut ecentricus ſine epicyclo eidem ſufficiens erit occaſio.

¶ Diuerſitati que ſoli colligata eſt intellige. Ponamus itaq; q motus epicycli in concentrico: & motus planete in epicyclo collecti equent medio motui ſolis: quemadmodũ ſuperius oſtẽſa poſtulant. Ecentrici vo centrũ moueatur ad ſucceſſionẽ ſignorũ eque velociter cum ſole: & planeta ipſe ſimiliter ea velocitate procedat: qua epicyclus in concentrico. Eius quidem medium locum determinet linea a centro mundi ducta equidiſtanter linee exeunti a centro ecentrici per centrum planete. ¶ Sit igit circulus mundo concentricus. a.b.g. ſuper centro. z. & ſit punctus. a. in quo fuit centrũ epicycli: dum planeta fuit in auge epicycli: ſcz puncto. d. dũq; ſol medio curſu coniunctus fuit planete: & punctus. h. fuit centrũ ecentrici. Nunc vo epicyclus ſit ſuper puncto. b. & planeta in epicyclo ſuper puncto. o. Ductis igitur lineis. z. b. d. b. o. n. o. z. o. et. z. e. erit angulus. a. z. b. motus medij: & angulus. d. b. o. diuerſitatis ſiue motus medij argumẽti. Sit aũt angulus. a. z. e. medij motus ſolis. hinc in linea. z. e. erit centrum ecentrici: quod ſit. n. Ponamus itaq; primo concentricum & ecentricum equales: et proportionem ſemidiametri concentrici ad ſemidiametrum epicycli equalem proportioni ſemidiametri ecẽtrici ad diſtantiam centrorum. Erit igitur linea. z. h. ſiue. z. n. equalis. b. o. Cum aũt duo anguli. a. z. b. et. d. b. o. equent angulo. a. z. e. ſublato cõmuni. a. z. b. erit angulus. b. z. e. cõlis angulo. d. b. o. quare. z. b. et. n. o. equales & ſibi equidiſtant. Et quia ſunt equales: erunt due linee. due linee. z. n. et. b. o. equidiſtantes. vnde ſuper centro. n. deſcripto cir/

n 4

Regiomontanus—*Epitome of Almagest* [1462] (Venice, 1496), book 12, prop. 1 [& 2]

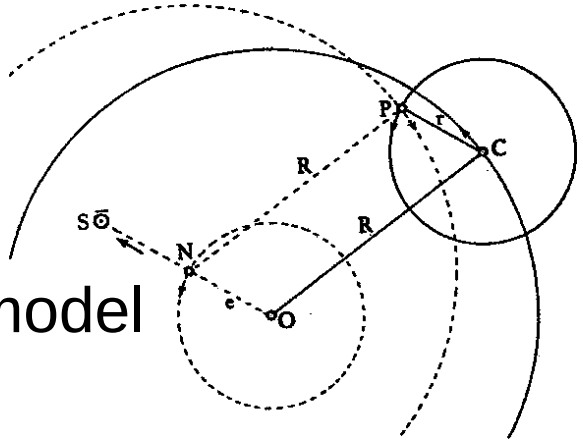
Equivalence of eccentric & epicyclic models for ‘2nd anomaly’ [=retrograde motion]



For retrograde motion of **Superior Planets**

either

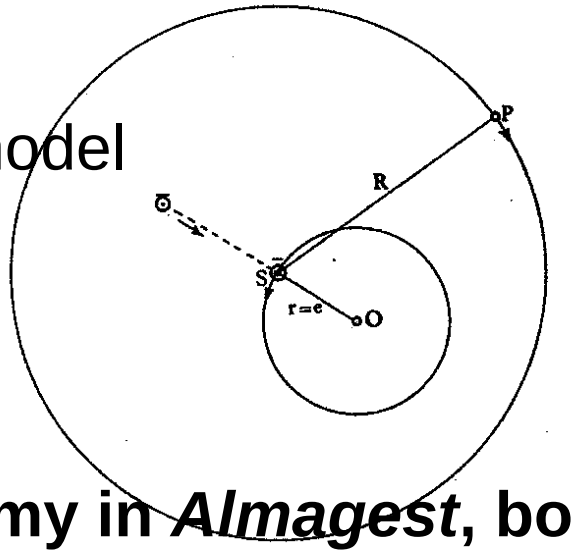
Epicyclic model
(solid)



(a)

or equivalent

(moving) eccentric model



(b)

Fig. 8

Both allowed by Ptolemy in *Almagest*, book 12, chap. 1

Eccentricitas Martis 6583
Epiciclus primus 1492
Epi[cyclus] secundus 494
Jovis ecce[ntricitas] 1917 Epi[cyclus] a 777 b 259
Saturnij ecce[ntricitas] 1083 Epi[cyclus] a 852 b 284
376 Mercurij ecce[ntricitas] 2256 [2259?] Ep[icyclus] a cum b·10·6··/ 100
diversitas diametrj 1151 59 19

"Eccentricities" proportional to Ptolemy's epicycle radii, ergo trans-
mation [Epitome 12]

Orb sizes standardized t
common eccentricity of
25 [into *Commentariolus*]

proportio orbium celestium ad eccentricitatem 25 partium

Martis semidyameter orbis 38 fere Epi[cyclus] a 5 M 34
Epi[cyclus] b M 51
Jovis se[midiameter] 130 M 25·epi[cyclus] a $10\frac{1}{10}$ b $3\frac{11}{30}$
Saturnij Semi[diameter] $230\frac{5}{6}$ epi[cyclus] a $19\frac{41}{60}$ b $6\frac{17}{30}$
Veneris se[midiameter] 18·epi[cyclus]·a·$\frac{3}{4}$ b $\frac{1}{4}$
☿ orbis·9·24·*Epi[cyclus] a 1·44*$\frac{3}{4}$·*1·42*$\frac{3}{4}$·*b 0 34*$\frac{1}{4}$
Ep[icyclus] a·1·$41\frac{1}{4}$/b·0·$33\frac{3}{4}$ coll[igunt?]·1·7·$\frac{1}{2}$/ diversitas diametri 0·29
Semid[iameter] orbis Lune ad ep[icyclum] a $\frac{10}{1\frac{1}{18}}$ epi[cyclus] a ad b $\frac{19}{4}$

$\frac{10}{1\frac{1}{18}}$ $\frac{19}{4}$

“The proportion of the celestial orbs to an eccentricity of 25 parts”

Radius of the orb of Mars nearly 38

Radius of Jupiter 130

Saturn 230

Venus 18

Mercury 9; 24