Copernicus and his Revolutions

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Copernicus quotations, *De revolutionibus* (1543). Translated by Dennis R. Danielson, *The Book of the Cosmos* (Perseus Books Group, 2002).

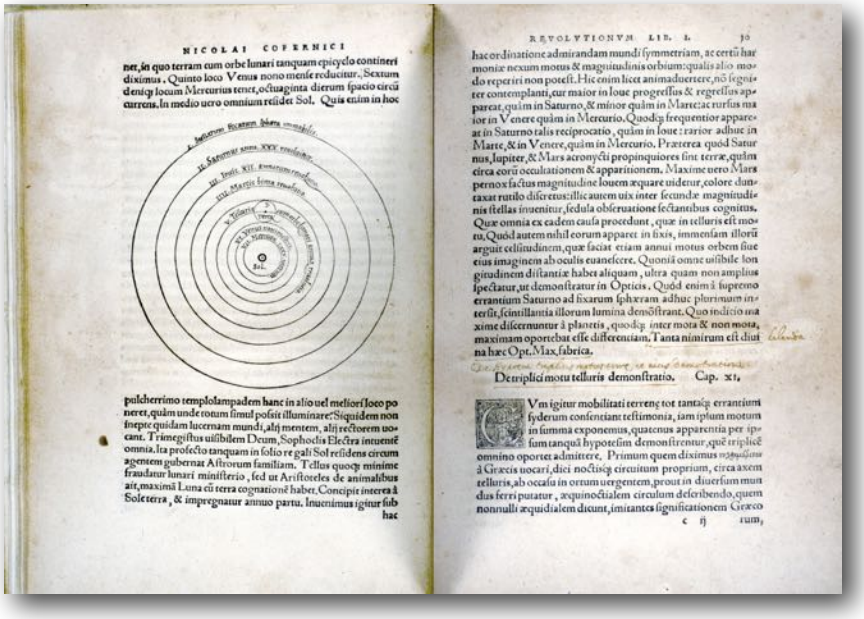
1. Andreas Osiander, anonymous letter "to the reader on the hypotheses of this work": "Since [the astronomer] cannot in any way attain true causes, he will adopt whatever suppositions enable the motions to be calculated.... For hypotheses need not be true nor even probable. On the contrary, if they provide calculations consistent with the observations, that alone is enough.... Different hypotheses are sometimes offered for one and the same motion (for example, either an eccentric or an epicycle model will explain the Sun's motion). The astronomer will adopt whichever hypothesis is easier to grasp.... So as far as hypotheses are concerned, let no one expect anything certain from astronomy... lest he accept as truth ideas conceived for another purpose, and depart from this study a greater fool than when he entered it."
2. Letter from Cardinal Schönberg, 1536: "Some years ago... I began to have a very high regard for you. For I learned that you had not merely mastered the discoveries of the ancient astronomers uncommonly well but had also formulated a new cosmology. In it you maintain that the Earth moves; that the Sun occupies the lowest, and thus the central, place in the universe; that the eighth [starry] heaven remains perpetually motionless and fixed; and that, together with the [four] elements included in its sphere, the Moon... revolves around the Sun in the period of a year. I have also learned that you have written an exposition of this whole system of astronomy, and have computed the planetary motions and set them down in tables, to the greatest admiration of all. Therefore with the utmost earnestness I entreat you, most learned sir, unless I inconvenience you, to communicate this discovery of yours to scholars.... Moreover, I have [given instructions] to have everything copied in your quarters at my expense...."
3. "We are not sufficiently safeguarded to repel an attack and we fear lest the enemy, who is already so near, should besiege us also. Therefore, we humbly appeal to your Holy Majesty to come to our aid as quickly as possible and to support us. For we are completely devoted to Your Majesty, even if we were to perish."
4. "I have preferred dedicating these late-night studies to you, Your Holiness, rather than to anyone else. For even in this very remote corner of the Earth where I live you are considered the highest authority by virtue of your exalted office and your love for all literature, even astronomy."
5. "Perhaps there will be babblers who claim to be judges of astronomy although completely ignorant of the subject and, badly distorting some passage of Scripture to their purpose, will dare to criticize and censure my teaching. I shall not waste time on them; I have only contempt for their unfounded criticism.... Astronomy is written for astronomers."
6. "Therefore, having obtained the opportunity from these sources, I too began to consider the mobility of the Earth."

7. [Astronomers have not] "deduced... the main point, that is, the structure of the universe and the true symmetry of its parts. On the contrary, they have been like someone attempting a portrait by assembling hands, feet, a head and other parts from different sources. These several bits may be well depicted, but they do not fit together to make up a single body. Bearing no genuine relationship to each other, these fragments, joined together, produce a monster rather than a man."

8. "if the motion of the other planets is viewed in relation to the circular motion of the Earth... then... the order and sizes of all the orbs and spheres and heaven itself are so interconnected that in no portion of it can anything be shifted without disrupting the remaining parts and the entire universe."

9. "No one can propose a more fitting first principle than that the magnitude of a planet's sphere is proportionate to its period of revolution." "Thus we discover in this orderly arrangement the marvelous symmetry of the universe and a firm harmonious connection between the motion and the size of the spheres...."

10. "Behold, in the middle of the universe resides the Sun. For who, in this most beautiful Temple, would set this lamp in another or a better place, whence to illumine all things at once? For aptly indeed do some call him the lantern—and others the visible god, and Sophocles' *Electra*, the Watcher of all things. Truly indeed does the Sun, as if seated upon a royal throne, govern his family of planets as they circle about him."



NICOLAI COPERNICI

ner, in quo terram cum orbe lunari tanquam epicyclo contineri diximus. Quinto loco Venus nono mense reducitur. Sextum denicq locum Mercurius tenet, octuaginta dierum spacio circũ currens. In medio uero omnium reſidet Sol. Quis enim in hoc

pulcherrimo templo lampadem hanc in alio uel meliori loco ponaret, quàm unde totum simul possit illuminare? Siquidem non inepte quidam lucernam mundi, alij mentem, alij rectorem uocant. Trimegistus uisibilem Deum, Sophoclis Electra intuentẽ omnia. Ita profecto tanquam in solio re gali Sol residens circum agentem gubernat Astrorum familiam. Tellus quoq minime fraudatur lunari ministerio, sed ut Aristoteles de animalibus ait, maximã Luna cũ terra cognationẽ habet. Concipit interea à Sole terra, & impregnatur annuo partu. Inuenimus igitur sub hac

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hac ordinatione admirandam mundi symmetriam, ac certũ harmoniæ nexum motus & magnitudinis orbium: qualis alio modo reperiri non potest. Hic enim licet animaduertere, nõ segniter contemplanti, cur maior in Ioue progressus & regressus appareat, quàm in Saturno, & minor quàm in Martes: ac rursus maior in Venere quàm in Mercurio. Quodq; frequentior apparet in Saturno talis reciprocatio, quàm in Ioue: rarior adhuc in Marte, & in Venere, quàm in Mercurio. Præterea quòd Saturnus, Iupiter, & Mars acronycti propinquiores sint terræ, quàm circa eorũ occultationem & apparitionem. Maxime uero Mars pernox factus magnitudine louem æquare uidetur, colore duntaxat rutilo discretus: illic autem uix inter secundæ magnitudinis stellas inuenitur, sedula obseruatione sectantibus cognitus. Quæ omnia ex eadem causa procedunt, quæ in telluris est motu. Quòd autem nihil eorum appareat in fixis, immensam illorũ arguit cœlitudinem, quæ faciat etiam annui motus orbem siue eius imaginem ab oculis euanescere. Quoniã omne uisibile longitudinem distantiæ habet aliquam, ultra quam non amplius spectatur, ut demonstratur in Opticis. Quòd enim à supremo errantium Saturno ad fixarum sphæram adhuc plurimum interſit, scintillantia illorum lumina demõstrant. Quo indicio maxime discernuntur à planetis, quodq; inter mota & non mota, maximam oportebat esse differentiam. Tanta nimirum est diuina hæc Opt. Max. fabrica.

De triplici motu telluris demonstratio. Cap. xi.

VM igitur mobilitati terrenę tot tantaq; errantium syderum consentiant testimonia, iam ipsum motum in summa exponemus, quatenus apparentia per ipsum tanquã hypothesim demonstrentur, quę triplicẽ omnino oportet admittere. Primum quem diximus περιφορὰν à Græcis uocari, dici noctisq; circuitum proprium, circa axem telluris, ab occasu in ortum uergentem, prout in diuersum mundus ferri putatur, æquinoctialem circulum describendo, quem nonnulli æquidialem dicunt, imitantes significationem Græco

c ij rum,

11. "This whole matter is difficult, almost paradoxical, and certainly contrary to many people's way of thinking.... God helping me, I shall make these things clearer than sunlight, at least to those not ignorant of the art of astronomy."

12. "We must examine carefully the relationship of the earth to the heavens. Otherwise, in our desire to investigate things of the highest order we may remain ignorant of what is nearest to us, mistakenly attributing things that are earthly to things that are heavenly."

13. "It is like the case spoken of by Virgil's Aeneas: 'We sail forth from the harbor, and lands and cities draw backwards.' For when a ship glides along smoothly, its passengers see its motion reflected by everything outside of the ship and, by contrast, suppose themselves and everything else on board to be motionless. No wonder, then, that the movement of the Earth makes us think the whole universe is turning round."

14. "If the Earth moves [instead of the Sun]... then the risings and settings of the constellations and fixed stars... will appear just as they do. Furthermore, the stations and retrograde motions of the planets will be seen not as their own motions but as earthly motion transmuted into apparent planetary motions."

15. "So vast, without any doubt, is the handiwork of the Almighty Creator."

Resources

This presentation incorporates much material from "Copernicus and His Revolutions," a planetarium show written and produced by Kerry Magruder for the Cosmology and Cultures Project of the OBU Planetarium, August 2005. While today's presentation is organized as if we were paging through the *De rev*, the planetarium show is organized chronologically. The two are complementary; each contains material not in the other. Topics explored in the planetarium show include:

A. Background: Italian Renaissance and Greek emigration; the geocentric universe; university reforms; mathematical devices used in ancient Greek systems; Ptolemaic astronomy; a tradition of geocentric astronomical innovations (Maragha school, Peurbach, Regiomontanus).

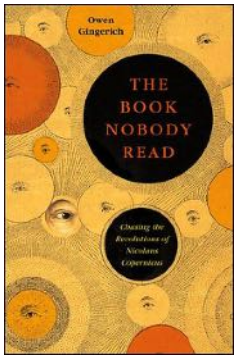
B. Early Life: Childhood in Torun; University of Cracow; University of Bologna (astronomy and law); University of Padua (medicine); University of Ferrara; return to Poland.

C. Publishing: Catholic background (Cardinal Schönberg); Lutheran role (Nuremberg circle: Rheticus, Osiander, Petraeus); Polish circumstances (Bishop Dantiscus, Bishop Giese, Duke Albrecht).

D. *De revolutionibus*: Triple motion of the Earth; dedication to pope; Humanism and ancient texts; role of observations; problem of the equant; the universe as a coherent and integrated system (harmonies between the planetary motions, their order and distances); aesthetic considerations (planetary distances, the dignity of the center, a moving Earth amidst the heavens).

E. Problems for heliocentrism: optical illusions (common sense and the relativity of motion, diurnal and retrograde phenomena); Aristotelian physics; astronomy (absence of stellar parallax, and the problem of planetary satellites); aesthetics (definitions of simplicity and elegance, hierarchy, size).

F. Reception: Osiander's preface; the Wittenberg Interpretation (Erasmus Reinhold); Tycho Brahe; Johann Kepler; early Catholic reception (Offusius and the Paris circle); post-Trent Catholic reception (Galileo); revolution in physics; observational proof; post-Copernican revolution in astronomy (non-circular planetary orbits, fluid heavens, non-hierarchical cosmos; telescope).



Further reading: For a classic interpretation of medieval and Renaissance sensibilities about the cosmos, see C. S. Lewis, *The Discarded Image* (Cambridge, 1994). Many primary sources, accompanied by brief, judicious comments, may be found in Dennis R. Danielson, *The Book of the Cosmos* (Perseus Books, 2002). An introductory survey of mathematical astronomy from antiquity to Copernicus is Michael J. Crowe, *Theories of the World from Antiquity to the Copernican Revolution* (Dover Publications, 2001), which includes excerpts from Ptolemy, Copernicus and Galileo. A more advanced survey text is James Evans, *The History & Practice of Ancient Astronomy* (Oxford, 1998), and the standard study is Otto Neugebauer, *History of Ancient Mathematical Astronomy* (Springer Verlag, 1975, 3 vols). The standard study of Renaissance scholastic cosmology is Edward Grant, *Planets, Stars, and Orbs: The Medieval Cosmos, 1200-1687* (Cambridge, 1996). A representative figure of the Islamicate tradition that influenced Copernicus is introduced in F. Jamil Ragep, *Nasir Al-Din Al-Tusi's Memoir on Astronomy* (Springer, 1993). Owen Gingerich's personal account of his endeavor to examine every surviving copy of *De Revolutionibus* provides a very readable and delightful introduction to Copernicus and his era: Owen Gingerich, *The Book Nobody Read* (Walker & Company, 2004). The scholarly account is Owen Gingerich, *An Annotated Census of Copernicus' De Revolutionibus* (Brill, 2002). For the text of Copernicus' *De Revolutionibus*, excerpts are available in the two works mentioned above by Crowe and Danielson. There is no widely acclaimed English translation of the complete work, but one is Nicholas Copernicus, *On the Revolutions* (Johns Hopkins University Press, 1992). The standard study of Copernicus' mathematical astronomy is Noel M. Swerdlow and Otto Neugebauer, *Mathematical Astronomy in Copernicus's De Revolutionibus* (Springer, 1984). The first part of this work is perhaps the best available biographical account of Copernicus. For additional studies of Copernicus browse recent issues of the *Journal for the History of Astronomy* for articles by the above authors, including Peter Barker and Bernard Goldstein "Patronage and the Production of *De Revolutionibus*"; Dennis Danielson, "Achilles Gasser and the origins of Copernicanism"; Katherine Tredwell, "Early Copernicans"; and Jamil Ragep, "Ali Qushji and Regiomontanus."

Questions for Discussion

1. What two themes evident from the *De rev* are described as relevant to the history of science generally? Do they make sense to you?
2. Why is it problematic to refer to Copernicus as a professional astronomer? What other occupational roles did he have or train for?
3. Were the celestial spheres a common sense idea, capable of explaining a multitude of celestial phenomena?
4. In the ancient Earth-centered system, was the Earth's position a place of privilege?
5. How did the Reformation affect Copernicus and his work? How did publication of the *De rev* reflect cooperation between Catholics and Protestants across sectarian lines?
6. In his dedication to the pope, Copernicus argued that, while some theologians might mistakenly regard his system as contrary to the Bible, his arguments rested on mathematics, and those with no expertise in mathematics should not rush to judge. Is this principle one of the implications of the story of Copernicus?
7. Does this story display characteristics of the Renaissance, such as humanist scholarship or the printing revolution?
8. If Copernicus believed that mathematical methods enabled one to better understand reality, why did Andreas Osiander insert the preface which argued that Copernicus could be interpreted only instrumentally, or hypothetically? Is realism vs. instrumentalism a recurring point of disagreement in science? How did this preface affect the immediate reception of the *De rev*?
9. It is often said that Copernicus refrained from publishing his views until his death because of fear of suppression by the Roman Catholic Church. Discuss the historical evidence pertinent to this claim.
10. It is often said that by removing the Earth from the center of the universe, Copernicus rejected the anthropocentric orientation of the medieval cosmos. Discuss the historical evidence pertinent to this claim.
11. What is retrograde motion of the planets? How does it appear to the eye in the night sky?
12. Evaluate the following explanations for the superiority of Copernican astronomy: (1) The Ptolemaic system was unable accurately to predict the positions of the planets. (2) The Ptolemaic system had no explanation of retrograde motion. (3) The Ptolemaic system was too complex.
13. The geometrical devices of deferent, epicycle, eccentric, and equant, as used in geocentric astronomical models, proved quite versatile and effective in combination to explain astronomical motions in terms of underlying "uniform circular motions." How does Copernicus represent continuity and discontinuity with this ancient and medieval tradition? (Did he use the same geometrical devices? Did he affirm uniform circular motion? Did he accept solid spheres?)
14. Did Copernicus represent an abrupt discontinuity from the religious cultures of the Middle Ages, both Christian and Islamic, to the Scientific Revolution?
15. What advantages did Copernicus point to in favor of his system over that of Ptolemy's?
16. Does Copernicus represent the rejection of medieval anthropocentrism?
17. How does the shift from geocentrism to heliocentrism illustrate the importance of perspective?
18. What compelled Copernicus actually to adopt a heliocentric system? Observations? Simplicity? What does this imply for our understanding of science?
19. What objections posed to Copernicus seem most powerful to you? If you had read the *De rev* in 1543, would you have been persuaded? What if you had read it in 1615? Would you have interpreted it hypothetically? At what point in history would you have been willing to defend it as physically true?
20. What would it be like to live through a time of major change in understanding of the cosmos?
21. Was Copernicus a revolutionary, or a conservative, or both?
22. Did you discover anything new, surprising, or unexpected? What was most meaningful to you?