A Scholarly Intermediary between the Ottoman Empire and Renaissance Europe

*By Robert Morrison**

ABSTRACT

This essay studies Moses Galeano, a Jewish scholar with ties to Crete and the Ottoman Sultan's court, who traveled to the Veneto around 1500. After describing Galeano's intellectual milieu, it focuses, first, on circumstantial evidence that he transmitted information central to the rise of Renaissance astronomy. Galeano knew of theories that strongly resemble portions of astronomy texts written by Giovanni Battista Amico and Girolamo Fracastoro at Padua a few decades later. He also knew about theories pioneered by the Damascene Ibn al-Shāṭir (d. 1375) that strongly resemble portions of Copernicus's work. Next, the article turns to concrete evidence showing that Galeano was part of a network of Jewish scholars who did have contact with Christian scholars in Europe. The essay concludes that, while it is impossible to prove that Galeano had direct contact with Copernicus, he most likely had contact with some European astronomer(s) in the Veneto.

FOR SEVERAL DECADES, historians of astronomy have been aware of circumstantial evidence that Nicholas Copernicus (1473–1543) drew, without acknowledgment, on the achievements of the astronomers of Islamic civilization, particularly Ibn al-Shāṭir (d. 1375).[1] Noel Swerdlow and Otto Neugebauer, in their 1984 book *Mathematical Astron-*

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I would like to thank the three anonymous referees for *Isis* as well as Jamil Ragep (McGill University) and Tzvi Langermann (Bar Ilan University) for their advice and encouragement at various stages of this project. This essay is based on talks I gave in 2011 at the University of Washington and at the History of Science Society annual meeting.

[1] Early studies include Victor Roberts, "The Solar and Lunar Theory of Ibn al-Shāṭir: A Pre-Copernican Copernican Model," *Isis*, 1957, *40*:428–432; E. S. Kennedy and Roberts, "The Planetary Theory of Ibn al-Shāṭir," *ibid.*, 1959, *50*:227–235; and Otto Neugebauer, *The Exact Sciences in Antiquity* (Providence, R.I.: Brown Univ. Press, 1957; rpt., New York: Dover, 1969), pp. 202–205. These results and some subsequent findings are presented in Neugebauer and Noel Swerdlow, *Mathematical Astronomy in Copernicus's "De Revolutionibus,"* 2 vols. (New York: Springer, 1984), Vol. 1, pp. 41–64. The most important recent studies—which include more direct historical evidence for transmission—are George Saliba, *Islamic Science and the Making of the European Renaissance* (Cambridge, Mass.: MIT Press, 2007), pp. 193–232; and F. Jamil Ragep, "Copernicus and His Islamic Predecessors: Some Historical Remarks," *History of Science*, 2007, *45*:65–81.

Isis, 2014, 105:32–57

0021-1753/2014/10501-0002$10.00

omy in Copernicus's "De Revolutionibus," saw Copernicus as the last astronomer in the tradition of the astronomy of the Marāgha Observatory in northwest Iran.[2] Recently, F. J. Ragep has found that the work of ʻAlī Qushjī (d. 1474), an astronomer in the Ottoman Empire, was relevant for understanding Copernicus's transformation of a geocentric system into a heliocentric one.[3] As a start to explaining the numerous, overwhelming similarities between Copernicus's work and that of the Islamic world, Neugebauer and Swerdlow proposed a Greek transmission of Naṣīr al-Dīn Ṭūsī's (d. 1274) lunar model via Gregory Chioniades.[4] Beginning in the 1990s, George Saliba found substantial evidence of transmission of scientific manuscripts from the Islamic world to Renaissance Europe in the mid-sixteenth century, including Guillaume Postel's (1510–1581) copy of Ṭūsī's *Tadhkira*. Although Copernicus did acknowledge some astronomers from the Islamic world, none of them was later than al-Biṭrūjī (fl. ca. 1200).[5] Copernicus mentioned Biṭrūjī once in *De revolutionibus*, regarding the placement of Venus and Mercury with respect to the sun.[6] But since there is a consensus that Copernicus relied on the work of Regiomontanus (d. 1476), though he did not actually mention Regiomontanus by name, the issue of other uncited sources for Copernicus's work remains.[7]

When exploring why the findings of Saliba, Neugebauer, E. S. Kennedy, and Swerdlow have not had much of an impact on the research of historians of European science, Ragep has noted that historians of science have found Copernicus's most important innovation to be the heliocentric arrangement, a hypothesis absent in the work of the astronomers of the Islamic world.[8] But while there is no evidence of any astronomer in Islamic civilization

[2] Neugebauer and Swerdlow, *Mathematical Astronomy in Copernicus's "De Revolutionibus,"* Vol. 1, pp. 47, 295. For a survey of the achievements of the astronomers of Islamic societies see George Saliba, "The Astronomical Tradition of Maragha: A Historical Survey and Prospects for Future Research," *Arabic Sciences and Philosophy*, 1991, *1*:67–99.

[3] F. Jamil Ragep, "ʻAlī Qushjī and Regiomontanus: Eccentric Transformations and Copernican Revolutions," *Journal for the History of Astronomy*, 2005, *36*:359–371. This final point of similarity is significant because, while no Islamic astronomer proposed a heliocentric cosmos, the mathematical accuracy of Copernicus's heliocentric system would have been unattainable without the mathematical transformation enabled by Qushjī's demonstration of the equivalence of the epicyclic and eccentric hypotheses for retrograde motion.

[4] The evidence for this claim first appeared in Otto Neugebauer, *History of Ancient Mathematical Astronomy* (New York: Springer, 1975), pp. 11, 1035, 1456 (for a reproduction of the relevant MS folio).

[5] Saliba, *Islamic Science and the Making of the European Renaissance* (cit. n. 1), pp. 217–218. Biṭrūjī's *On the Principles of Astronomy* was available in Europe in a Latin translation attributable to Michael the Scot (d. 1217). For the Latin translation of Biṭrūjī's *Kitāb al-Hay'a* see Abū Isḥāq Nūr al-Dīn al-Biṭrūjī, "*De Motibus Celorum": Critical Edition of the Latin Translation of Michael Scot*, ed. Francis J. Carmody (Berkeley: Univ. California Press, 1952). Goldstein's translation (with commentary) of the Arabic original took account of the Hebrew translation: Al-Biṭrūjī, *On the Principles of Astronomy*, trans. Bernard Goldstein, 2 vols. (New Haven, Conn.: Yale Univ. Press, 1971).

[6] Edward Rosen, "Copernicus and Al-Bitruji," *Centaurus*, 1961, *7*:152–156, on p. 152, rpt. in Rosen, *Copernicus and His Successors*, ed. Erna Hilfstein (London: Hambledon, 2003), pp. 41–45.

[7] Noel Swerdlow concluded that there were five main sources for Copernicus's work: Peurbach's *Theoricae novae planetarum*, Peurbach and Regiomontanus's *Epitome of the Almagest*, the *Alphonsine Tables*, the *Almagest*, and the work of the astronomers of Islamic societies, whom he referred to as the Marāgha astronomers. See Noel Swerdlow, "The Derivation and First Draft of Copernicus's Planetary Theory: A Translation of the *Commentariolus* with Commentary," *Proceedings of the American Philosophical Society*, 1973, *117*:423–512, esp. pp. 425–426.

[8] Ragep, "Copernicus and His Islamic Predecessors" (cit. n. 1), p. 69. Robert Westman's recent *The Copernican Question* (Berkeley: Univ. California Press, 2011), while covering a lot of ground, does not discuss how Copernicus would have become acquainted with or have discovered independently Ibn al-Shāṭir's models. Westman cites Neugebauer and Swerdlow's argument "for the virtual identity" of Copernicus's and Ibn al-Shāṭir's models without further discussion: *ibid.*, p. 531 n 136. For another recent explanation of the origins of Copernicus's heliocentric hypothesis see Bernard R. Goldstein, "Copernicus and the Origin of His Heliocentric System," *J. Hist. Astron.*, 2002, *33*:219–235.

proposing a heliocentric astronomy, discussions of a rotating earth did exist.[9] And Qushjī's (d. 1474) proof of the possibility of transformation of epicyclic models to eccentric models in the models of the lower planets has been recognized by Owen Gingerich as relevant to the history of the heliocentric arrangement.[10] Ragep, for his part, has recently argued that developments in the conception of the discipline of *'ilm al-hay'a* (astronomy) reassessed the relationship of mathematical astronomy to Peripatetic philosophy and should be seen as part of the conceptual background of Copernicus's work. This essay will show that the range of circumstantial connections between the theoretical astronomy of the Islamic world and Renaissance astronomy extends beyond the appearance of the innovations of astronomers of the Islamic world in Copernicus's work. Then, the article will describe a network of scholars that not only accounts for this wider range of circumstantial connections, but also expands our understanding of the specific context for Copernicus's work.[11] Searching for cross-cultural points of contact to explain the circumstantial evidence has the potential to tell us more about the rise of Renaissance astronomy in general and about the dimensions of Copernicus's work that have less to do with the science of the Islamic world.

In the past decade there has been significant research detailing scientific and cultural exchanges between Europe and the Islamic world beginning in the mid-sixteenth century.[12] Though research into contacts between Renaissance Europe and the Islamic world does focus on a wide range of communities, Jewish communities may be a particularly promising direction of research.[13] The persecution and then final expulsion of the Jews from Spain in 1492 both further dispersed and created connections among these transnational communities, rendering them a conduit for scientific knowledge.[14] For instance, members of an Ibn Naḥmias family went from Castille to Albania, and then to Salonika, before moving to Venice by the 1600s. Members of that family also established the earliest printing press in the Ottoman Empire, by the end of the fifteenth century, probably in 1493.[15] In fields such as medicine and philosophy, Jewish communities of the Iberian

[9] On Islamic discussions of a rotating earth see F. Jamil Ragep, "Ṭūsī and Copernicus: The Earth's Motion in Context," *Science in Context*, 2001, *14*:145–163.

[10] See Owen Gingerich, "Islamic Science and the Making of the European Renaissance (review)," *Journal of Interdisciplinary History*, 2008, *39*:310–111, on p. 311. Gingerich wrote, apropos Qushjī's demonstration, "At present, there appears only one small avenue where a specific geometrical insight from the Islamic world might have given an indispensable impetus toward the radical heliocentric rearrangement."

[11] Ragep, "Copernicus and His Islamic Predecessors" (cit. n. 1), p. 72. Ragep has called for more attention to be paid to Copernicus's context: "What seems to be overlooked by those who advocate a reinvention by Copernicus and/or his contemporaries of the mathematical models previously used by Islamic astronomers is the lack of an historical context for those models within European astronomy" (*ibid*., p. 70).

[12] George Saliba, "Arabic Science in Sixteenth-Century Europe: Guillaume Postel (1510–1581) and Arabic Astronomy," *Suhayl*, 2007, *7*:115–164. See also Eric R. Dursteler, *Venetians in Constantinople: Nation, Identity, and Coexistence in the Early Modern Mediterranean* (Baltimore: Johns Hopkins Univ. Press, 2006).

[13] See, e.g., Rivka Feldhay and F. Jamil Ragep, eds., *Before Copernicus: Cultures and Contexts of Scientific Learning in the Fifteenth Century* (forthcoming). On the role of Middle Eastern Christians as scholarly intermediaries see George Saliba, *Rethinking the Roots of Modern Science: Arabic Scientific Manuscripts in European Libraries* (Washington, D.C.: Georgetown Univ., Center for Contemporary Arabic Studies, 1999).

[14] Bernard Goldstein has written of astronomy as a "neutral zone." See Bernard R. Goldstein, "Astronomy as a 'Neutral Zone': Inter-religious Cooperation in Medieval Spain," *Medieval Encounters*, 2009, *15*:159–174. An older study that remains important is Moritz Steinschneider, *Die Hebräischen Übersetzungen des Mittelalters und die Juden als Dolmetscher* (Berlin, 1893; rpt., Graz: Akademische Druck- u. Verlagsanstalt, 1956).

[15] Regarding the Ibn Naḥmias family see Abdelkader Modena, *Medici e chirurghi ebrei dottorati e licenziati nell'Università di Padova dal 1617 al 1816* (Bologna: Forni, 1967), p. 49: "Nella prima metà del '600 una famiglia Namias si trova stabilita a Venezia. Il medico Abram Namias fu scolaro dello Studio nel 1645, ma pare si sia laureato altrove. . . . Nel 1645 furono pure scolari dell'Università artista Joseph ed Isach Namias." On their

Peninsula, Italy, Greece, and the Ottoman Empire all contributed to the transmission of knowledge from the Islamic world to Renaissance Europe.[16] In particular, we know that Jews were a means of communication between the Republic of Venice and the Ottoman Empire following the Ottoman conquest of Constantinople in 1453.[17] As non-Muslims, Jews could be connected to the Ottoman Empire without Europeans perceiving them to be associated with Europe's most significant enemy; hence, Jews were more viable colleagues for European scholars. As negative portrayals of the Ottomans were politically motivated, not due to intellectual disdain, Europeans' interest in scientific and philosophical texts from the Islamic world continued unabated.[18]

The subject of this essay is Moses Galeano, who wrote in Arabic under the name Mūsā Jālīnūs, a potential transmitter of scientific information between the Ottoman Empire and the Veneto, primarily between 1497 and 1502.[19] Galeano brought with him knowledge of scientific theories that appeared not only in Copernicus's work, but also in the homocentric astronomy (where each celestial body maintained a fixed distance from a static earth) of Giovanni Battista Amico (d. 1538) and Girolamo Fracastoro (d. 1553), two other astronomers writing at the University of Padua. The question of Galeano's contact with Christian scholars during his time in the Veneto is significant because Copernicus spent time (1501–1503) at the University of Padua studying medicine.[20] And Galeano's knowl-

printing establishment see A. K. Offenberg, "The First Printed Book Produced at Constantinople," *Studia Rosenthaliana*, 1969, *3*:96–112.

[16] See Y. Tzvi Langermann, "Science in the Jewish Communities of the Byzantine Cultural Orbit: New Perspectives," in *Science in the Medieval Jewish Communities*, ed. Gad Freudenthal (Cambridge: Cambridge Univ. Press, 2012), pp. 438–453. See also Langermann's and Goldstein's survey articles cited *ibid*., note 18.

[17] Kenneth M. Setton, *The Papacy and the Levant, 1204–1571*, 4 vols. (Philadelphia: American Philosophical Society, 1976–1984), Vol. 2, p. 296. In a covert attempt at negotiations to stall further Ottoman military advances, the Venetian Senate sent David Mavrogonato, a Jew, to Istanbul in 1469. See David Jacoby, "Un agent juif au service de Venise: David Mavrogonato de Candie," *Bollettino dell' Istituto Ellenico di Studi Bizantini e Post-Bizantini*, 1972, *9*:68–96, esp. p. 72.

[18] Margaret Meserve, *Empires of Islam in Renaissance Historical Thought* (Cambridge, Mass.: Harvard Univ. Press, 2008), p. 117. On astronomy as a cross-cultural meeting ground in a slightly earlier period see Bernard Goldstein, "Astronomy in the Medieval Spanish Jewish Community," in *Between Demonstration and Imagination: Essays in the History of Science and Philosophy Presented to John D. North*, ed. Lodi Nauta and Arjo Vanderjagt (Leiden: Brill, 1999), pp. 225–241. See also Y. Tzvi Langermann, "Science in the Jewish Communities of the Iberian Peninsula," in *The Jews and the Sciences in the Middle Ages* (Aldershot: Ashgate, 1999), pp. 2–54. On the cultural dynamics between European Christians and Muslims see Nancy Bisaha, *Creating East and West: Renaissance Humanists and the Ottoman Turks* (Philadelphia: Univ. Pennsylvania Press, 2004), p. 172. Bisaha remarks that "it is important to remember that many humanists transferred their disdain for the Turks to other Islamic peoples—the conflict of West versus East was not limited to the Turks alone." For a slightly different view see Meserve, *Empires of Islam in Renaissance Historical Thought*, p. 208: "European historians had revised their estimates of almost every Asiatic empire (whether Persian, Arab, Turk, or Mongol) once it ceased to pose a threat to Christian interests or once a new and more aggressive dynasty rose to replace it."

[19] Y. Tzvi Langermann, "A Compendium of Renaissance Science: *Ta'alumot ḥoḵma* by Moshe Galeano," *Aleph: Historical Studies in Science and Judaism*, 2007, *7*:283–318 (hereafter cited as **Langermann, "Compendium of Renaissance Science"**), p. 296; this recent article is very important for the present essay. Earlier scholarship on Galeano includes Juan Vernet, *Estudios sobre historia de la ciencia medieval* (Barcelona: Bellaterra, 1979), pp. 333–351; and José Chabás and Bernard Goldstein, *Astronomy in the Iberian Peninsula: Abraham Zacut and the Transition from Manuscript to Print* (*Transactions of the American Philosophical Society*, 90) (Philadelphia: American Philosophical Society, 2000), pp. 163, 170. See also Langermann, "Medicine, Mechanics, and Magic from Moses ben Judah Galeano's *Ta'alumot ḥoḵma*," *Aleph*, 2009, *9*:353–377; and Robert Morrison, "An Astronomical Treatise by Mūsā Jālīnūs alias Moses Galeano," *ibid.*, 2011, *10*:315–353.

[20] On Fracastoro and Amico see Mario di Bono, "Copernicus, Amico, Fracastoro, and Ṭūsī's Device: Observations on the Use and Transmission of a Model," *J. Hist. Astron.*, 1995, *26*:133–154. See also Enrico Peruzzi, *La nave di Ermete: La cosmologia di Girolamo Fracastoro* (Florence: Olschki, 1995). Regarding Copernicus's time at Padua see André Goddu, "Nicholas Copernicus," in *Complete Dictionary of Scientific Biography*, ed. Charles Coulston Gillispie *et al.* (Detroit: Scribner's, 2008), pp. 176–182, esp. p. 177.

edge of and preference for homocentric astronomy broadens the investigation of his role as an intermediary beyond a possible connection with the work of Copernicus.[21] Galeano's Hebrew and Arabic writings increase the circumstantial evidence for his having had contact with Christian scholars in the Veneto. The circumstantial evidence extends beyond the parallels between Copernicus and the astronomers of Islamic societies, to include the homocentric astronomy that appeared in the work of other astronomers at the University of Padua. Galeano also turns out to be part of a network of scholars who *did* have contact with Christians in Europe. Further investigation of the possibility of his connections with the University of Padua is important because there was a long history of Jews studying in the Faculty of Medicine, which included philosophy, at that university, which graduated its first Jewish physician in 1409. In 1501, the Polish legate to Rome reported that he knew "of six Jews of Polish origin who were attending the university under assumed names." Beyond the long-standing presence of Jews at the University of Padua, there was, as well, a significant Jewish community in the city. In 1508, Elijah Capsali (d. 1555), the Chief Rabbi of Candia, came to Padua to study at the yeshiva there.[22] Unfortunately, the War of the Cambrai, which took place between 1508 and 1516 and cut short Capsali's time in Padua, means that the archives of the University of Padua are thin for precisely the period in which we are interested.

Galeano also spent a significant amount of time in Istanbul, the capital of the Ottoman Empire, and named Elijah Mizraḥi (d. 1526), the Chief Rabbi of Istanbul in the early 1500s, as a teacher. In a major work in Hebrew, *Ta'alumot ḥokma* [*Puzzles of Wisdom*], composed around 1500, Galeano described events at the court of the Ottoman Sultan Bayezit II (r. 1481–1512). In a different text, one that favored homocentric models for astronomy, he likened the order of the planets to the way people sit before the Sultan.[23] The latter text is now found in the Ahmet III collection of the Topkapi Library, the personal library of Sultan Ahmet III (r. 1703–1730). While Galeano's presence at the Sultan's court is noteworthy, his was not a unique case, as he was not the only Jew associated with scientific activity at the court of Bayezit II. Ilyās ibn Ibrāhīm al-Yahūdī (d. after 1512), known as 'Abd al-Salām al-Muhtadī or 'Abd al-Salām al-Daftarī after his conversion to Islam, came from Andalus to the court of Bayezit II and wrote a text in Hebrew about how to use an astronomical instrument that he invented, known as al-Dābid.[24] Then he translated the text into Arabic at the Sultan's request in 1502. Also under Bayezit II, the court physicians were members of the Hamon family, originally of Granada, and were caught up in court intrigue.[25] Even half a century earlier, Sultan

[21] Regarding Galeano's views on homocentric astronomy see Langermann, "Compendium of Renaissance Science," pp. 290–292. See also Morrison, "Astronomical Treatise by Mūsā Jālīnūs alias Moses Galeano" (cit. n. 19). Presuming that Galeano actually thought that the epicyclic and eccentric hypotheses were problematic, then this Arabic treatise by Galeano (writing as Jālīnūs) is more evidence that the alternative would have been homocentric astronomy.

[22] Isaac Barzilay, *Yoseph Shlomo Delmedigo, Yashar of Candia: His Life, Works, and Times* (Leiden: Brill, 1973), pp. 35 (quotation), 36. In note 2, one finds that there were Jewish students studying at the University of Padua in 1501 under assumed names.

[23] Langermann, "Compendium of Renaissance Science," pp. 287 (regarding the Chief Rabbi), 287–289 (*Puzzles of Wisdom*); and Morrison, "Astronomical Treatise by Mūsā Jālīnūs alias Moses Galeano" (cit. n. 19), p. 401 (ordering of the planets akin to people sitting before the Sultan).

[24] I would like to thank Jamil Ragep and İhsan Fazlıoğlu for bringing Ilyās al-Yahūdī to my attention. My information about him comes from Ekmeleddin İhsanoğlu *et al.*, eds., *Osmanlı Astronomi Literatürü Tarihi*, 2 vols. (Istanbul: İslâm Tarih, Sanat ve Kültür Araştırma Merkezi, 1997), Vol. 1, pp. 71–73.

[25] Elli Kohen, *History of the Turkish Jews and Sephardim: Memories of a Past Golden Age* (Lanham, Md.: Univ. Press America, 2007), p. 27: "A rumor, perhaps originating in the apocryphal stories about Mehmed II's

Mehmet the Conqueror's (d. 1481) personal physician was Jewish, named Yacub (i.e., Jacob) Pasha. We have a *firmān* from 1452 from Mehmet the Conqueror that exempted Jacob and his offspring from the payment of many different taxes.[26] Jacob was originally from Gaeta, a city in central Italy; hence he was also seen by the Venetians as a possible opening to the Sultan.[27]

Jews held positions of parallel importance at the papal court. Jacob ben Immanuel (Bonet da Lattes), originally of Provence, became the personal physician of Pope Alexander VI (d. 1503), who was probably pope during Galeano's visit to Italy. Jacob ben Immanuel dedicated to the pope an astronomical instrument known as Gemma's rings and wrote an astrological prognostication for Rome, which he dedicated to Cardinals Valentiani and Borgia, as well as annual astrological prognostications from 1493 to 1498. He also studied at Pisa with Giovanni de Medici, the future Leo X. Jacob ben Immanuel eventually became the Chief Rabbi of Rome, indicating that his associations with the papal court did not entail a corresponding loss of contact with his coreligionists. His influence was such that Johann Reuchlin (d. 1522), a Christian Hebraist interested in the Qabbalah, called on him in 1513 to intervene on his behalf in a dispute.[28]

Jewish scholars in the Ottoman Empire in the generation before Galeano evinced an interest and skill in astronomy that brought them into contact with Muslims and Christians. Mordechai Comtino (d. before 1487), who was Elijah Mizraḥi's teacher, attained a level of proficiency with astronomical instruments that brought him to the attention of a *kadiasker*, an Ottoman chief military judge.[29] Comtino donated an instrument to that judge. Comtino's *Commentary on the Persian Tables* was addressed to a Christian critic, indicating that, even by Comtino's lifetime, astronomy was a space for exchange among Jews (including between Karaites and Rabbanites), Christians, and Muslims in the Ottoman Empire.[30] Astronomy's position as a locus of contact between religious communities

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Galenus, Hekim Yakub, attributed to the Elder Hamon a leading role in the poisoning of Bayezit II, masterminded by his son Selim."

[26] Abraham Galanté, *Documents officiels turcs concernant les juifs de Turquie* (Istanbul: Haim, Rozio, 1931), pp. 194–295. On Jacob's position as a *wazīr* (minister), Galanté cited *Achik Pacha Zadé Tarihi* (Constantinople, 1916), pp. 191–192. See also Kohen, *History of the Turkish Jews and Sephardim*, p. 158, where there is a quotation from a document that referred to Yacub Pasha as the Galen and Hippocrates of his time.

[27] Setton, *Papacy and the Levant, 1204*–1571 (cit. n. 17), Vol. 2, p. 296.

[28] Regarding Gemma's rings see *Annuli astronomici pereum compositi super astrologiam utilitas* (Rome, 1493). A description of these rings frequently appeared in print, in the early 1500s, together with an edition of Sacrobosco's *De sphaera*; see http://ghtc.ifi.unicamp.br/Sacrobosco/SB1534b.htm. On the astrological prognostication for Rome see Moritz Steinschneider, "Die mathematischer Wissenschaften bei den Juden, 1441–1500," *Bibliotheca Mathematica*, 1901, *3*:58–76, esp. p. 72; on the annual prognostications see Daniel Carpi, "Bonet Lattes," in *Encyclopaedia Judaica*, ed. Michael Berenbaum and Fred Skolnik, 22 vols., 2nd ed. (Detroit: Macmillan Reference, 2007), Vol. 12, pp. 518–519 (this reference work can also be accessed through the Gale Virtual Reference Library). On Jacob ben Immanuel's studies with Giovanni de Medici see Anna Esposito and Micaela Procaccia, "Un astrologo e i suoi prognostici: Bonnet de Lattes a Roma alla fine del quattrocento," *Materia Giudaica*, 2002, *7*:97–104, http://www.enzobarilla.eu/ospiti/bonetto%20de%20lattes%20-%20un%20astrologo%20e%20i%20suoi%20prognostici.pdf. Regarding the episode where Reuchlin sought his intervention see Carpi, "Bonet Lattes," p. 518.

[29] Mordechai Comtino, *Tiqqun kᵉli ṣafiḥa*, Munich Hebrew MS 36 (Institute for Microfilmed Hebrew Manuscripts [hereafter **IMHM**] 1166), fol. 173b. This text was probably composed on the 17th of Tevet in 5223, or 14 July 1463.

[30] Philippe Gardette, "Judaeo-Provençal Astronomy in Byzantium and Russia," *Byzantinoslavica*, 2005, *63*:195–209, esp. p. 202. Gardette gives the name as Eliezer Khomatiano, but see Ephraim Kupfer, "Mordecai ben Eliezer Comtino," in *Encyclopaedia Judaica*, ed. Berenbaum and Skolnik (cit. n. 28), Vol. 5, pp. 132–133. Comtino's (a Rabbanite) belief that science was important for an understanding of Scripture led to a rapprochement with Karaites. See Jean-Christophe Attias, "Intellectual Leadership: Rabbanite–Karaite Relations in Constantinople as Seen through the Works and Activity of Mordekhai Comtino in the Fifteenth Century," in

had a history.[31] Mizraḥi eventually attained currency in Europe, as his *Compendium of Mathematics* was published in Basel in 1546 in Hebrew with Latin annotations by Oswald Schreckenfuchs and Sebastian Münster. He also wrote a commentary on the *Almagest* in which he attempted to emend the text of the Hebrew translation through references to Arabic and Greek manuscripts of the text.[32] Mizraḥi's knowledge of these languages and his position as leader of the Jewish community, not to mention his ability to gain access to the manuscripts, are all strong indications that his relatively advanced study of astronomy involved contact with Muslims and Christians, albeit in Istanbul, not in Italy.

Given Galeano's presence at the Sultan's court, it would follow that he had contact with Muslims. From Galeano's own account in *Puzzles of Wisdom*, we know that he traveled to Venice between 1497 and 1502 and visited the famous printer Gerson Soncino (d. 1534). Unfortunately, Galeano did not mention any other contacts he made during that trip. Because Galeano knew of recent developments in the field of theoretical astronomy that would have been of interest to scholars such as Copernicus, Amico, and Fracastoro, the likelihood of his contact with Christian scholars in Europe is worth researching further. Indeed, by the time Galeano returned from the Veneto to Istanbul he knew enough Latin to translate the canons of the *Almanach Perpetuum* from Latin into Arabic for the Ottoman chief military judge.[33]

WHAT WAS THE ASTRONOMY THAT GALEANO DESCRIBED IN *PUZZLES OF WISDOM*?

In a key passage of *Puzzles of Wisdom*, first studied by Tzvi Langermann in an excellent 2007 article, Galeano described the challenges of astronomy and four types of solutions to those problems:

> An example from astronomy. . . . It is [of the same type] as the example from medicine that we have just mentioned, i.e., a confusion between what is essential and what is accidental. But it is also to confuse separation and combination. Indeed, the configuration has been established—and it is the truth—that the heavenly bodies, and every heavenly motion, trace equal arcs on their orbs in equal times. This is true, even though we observe with our instruments that it is not so. Confusion is caused in this way because it does not follow that the same rule which applies to each motion individually must [also] hold when they combine together. Indeed, from the combination of uniform equal motions that are traced out, there results an unequal motion that is not uniform; I mean that the star will not traverse equal arcs in equal times.
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> This may occur (a) from the compounding of motions of uniform direction, models, and centers, as we maintain, along with "the man [whose theory] shook [the world]" and *The Light of the World* of R. Joseph ibn Ya'ish; or (b) from varying centers, models, and directions of the motions, according to the principles of Ptolemy; or (c) from varying centers, directions of motion [and] models on the epicycle alone, according to the astronomy of Ibn al-Shāṭir; or (d)

Ottoman and Turkish Jewry: Community and Leadership, ed. Aron Rodrigue (Bloomington: Indiana Univ. Press, 1992), pp. 67–86, esp. p. 77.

[31] See, e.g., Goldstein, "Astronomy in the Medieval Spanish Jewish Community" (cit. n. 18); and Langermann, "Science in the Jewish Communities of the Iberian Peninsula" (cit. n. 18).

[32] Elijah Mizraḥi, *Compendium arithmetices: Decerptum ex libro Arithmeticarum institutionum magistri Eliae Orientalis*, commentary by Oswald Schreckenfuchs and Sebastian Münster (Basel, 1546; rpt., Jerusalem: Maqor, 1970). Münster's dedication to the readers noted his preexisting interest in Abraham Bar Hiyya's *Sepẹr Ṣurat ha-Areṣ*, a text on which he also commented in Latin. For more on Mizraḥi's commentary on the *Almagest* see Langermann, "Science in the Jewish Communities of the Byzantine Cultural Orbit" (cit. n. 16), pp. 446–449.

[33] Langermann, "Compendium of Renaissance Science," p. 295 (visit with Soncino in Venice); and Julio Samsó, "Abraham Zacut and José Vizinho's *Almanach Perpetuum* in Arabic (16th–19th C.)," *Centaurus*, 2004, *46*:82–97, esp. p. 83.

> from varying the models, directions, and centers, but by means of eccentrics alone, as in the new astronomy of Gersonides, of blessed memory.[34]

In the first paragraph, Galeano explained the real challenge of theoretical astronomy, which was to account, using combinations of uniform motions, for the planets' observed nonuniform motions. In the second paragraph, he listed the four dominant approaches to representing the planets' nonuniform motions with combinations of uniformly rotating orbs. There are three main things of interest in this list. The first is the fact that Galeano was aware of the astronomy of Ibn al-Shāṭir (d. 1375), an astronomer from Damascus who worked as a mosque timekeeper (*muwaqqit*). Ibn al-Shāṭir's text *Nihāyat al-sūl fī taṣḥīḥ al-uṣūl* [*The Ultimate Quest in the Rectification of the Hypotheses/Principles*] has been understood to build on the work of the astronomers affiliated with the Marāgha Observatory, such as Ṭūsī and Quṭb al-Dīn Shīrāzī (d. 1311). Scholars have noted strong, striking parallels with the models of Ibn al-Shāṭir (d. 1375) in Copernicus's work.[35] Copernicus's and Ibn al-Shāṭir's models for the moon were identical. The models for the planets differed primarily in that Copernicus's were heliocentric while Ibn al-Shāṭir's were geocentric; otherwise they were mathematically equivalent. Though Galeano was the first Jewish scholar to mention Ibn al-Shāṭir's important theoretical advances, another figure roughly contemporary with Galeano, Abraham Zacut (d. 1515), produced a copy of Ibn al-Shāṭir's *al-Zīj al-Jadīd* [*The New Astronomical Handbook with Tables*] in Hebrew characters.[36] Most important, Galeano is the first person we know of with knowledge (not to mention understanding) of Ibn al-Shāṭir's theoretical astronomy to be in the Veneto when Copernicus was.[37] Hebrew notations on the Qonya manuscript of Mu'ayyad al-Dīn al-'Urḍī's (d. 1259) *Kitāb al-Hay'a*, an innovative text produced by another astronomer affiliated with the Marāgha Observatory, elements of which were crucial for Copernicus's *De revolutionibus*, is further evidence that Jews in the Ottoman Empire were able to gain access to high-level texts of Islamic astronomy.[38] Because Galeano recorded events at the court of Bayezit II (d. 1512) in *Puzzles of Wisdom*, we have 1512 as a *terminus ante quem* for his presence at the court, the likely source for his knowledge of Ibn al-Shāṭir; Langermann's dating of the composition of *Puzzles of Wisdom* to circa 1500 meant that Galeano probably knew about Ibn al-Shāṭir's astronomy *before* he traveled to Italy.[39]

The second item of interest is that models of homocentric orbs were Galeano's

[34] Langermann, "Compendium of Renaissance Science," p. 291 (this is Langermann's translation). On Gersonides' astronomy see Bernard R. Goldstein, *The Astronomy of Levi ben Gerson (1288–1344)* (New York: Springer, 1985). See also Goldstein, "Levi ben Gerson's Contributions to Astronomy," in *Studies on Gersonides, a Fourteenth-Century Jewish Philosopher-Scientist*, ed. Gad Freudenthal (Leiden: Brill, 1992), pp. 3–19.

[35] The first publication to point out the connection was Roberts, "Solar and Lunar Theory of Ibn ash-Shāṭir" (cit. n. 1), p. 428: "What is of most interest, however, is that his lunar theory, except for trivial differences in parameters, is identical with that of Copernicus (1473–1543)." See also Kennedy and Roberts, "Planetary Theory of Ibn al-Shāṭir" (cit. n. 1), p. 227. For a summary of the parallels between Copernicus and Islamic astronomers, parallels that cannot be explained only by independent discovery, see Saliba, *Islamic Science and the Making of the European Renaissance* (cit. n. 1), pp. 196–209.

[36] See Ibn al-Shāṭir, *al-Zīj al-Jadīd*, Jewish Theological Seminary of America MS 2580 Acc. 0191 (IMHM 28833). See also Bernard Goldstein, "The Survival of Arabic Astronomy in Hebrew," *Journal for the History of Arabic Science*, 1979, *3*:31–39.

[37] Langermann, "Compendium of Renaissance Science," p. 290.

[38] George Saliba, ed., *The Astronomical Work of Mu'ayyad al-Dīn al-'Urḍī: A Thirteenth Century Reform of Ptolemaic Astronomy, Kitāb al-Hay'ah* (Beirut: Center for Arab World Unity Studies, 1990), pp. 11–13. On the connection between 'Urḍī and Copernicus see Saliba, *Islamic Science and the Making of the European Renaissance* (cit. n. 1), pp. 202–204.

[39] Langermann, "Compendium of Renaissance Science," p. 287.

preferred ("as we maintain") solution to the problem of representing the planets' nonuniform motions with combinations of uniformly rotating orbs. He referred to two astronomers who devised these models. The first was "the man who shook the world" (Hebrew: *ha-mar'ish*)—that is, Biṭrūjī, the most famous exponent of astronomical models composed of homocentric orbs.[40] *The Light of the World*, the second reference to homocentric astronomy, was a text from circa 1400 that aimed to improve on Biṭrūjī's astronomy, particularly in terms of predictive accuracy.[41] This text (*Nūr al-'ālam*) was originally composed in Judeo-Arabic and existed as well in a Hebrew recension (*Or ha-'olam*) that differed from and expanded on the Judeo-Arabic original in certain places.[42] Though the author of *The Light of the World* was Joseph Ibn Joseph Ibn Naḥmias and not R. Joseph Ibn Ya'ish, as Galeano stated, Langermann presumed that Galeano *was* referring to Ibn Naḥmias's *The Light of the World* and not to some other text. A study of Galeano's Arabic composition, entitled *Dhikr ba'ḍ al-maḥallāt* (*sic*—this should read *muḥālāt*) [*An Account of Some of the Impossibilities*], has found significant overlaps with the content of Ibn Naḥmias's *The Light of the World*.[43] In fact, the fourth chapter of *An Account of Some of the Impossibilities* follows the text of *The Light of the World* verbatim. Hence, we have every reason to conclude, as Langermann presumed, that Galeano was very familiar with the models of both Biṭrūjī's *On the Principles of Astronomy* and Ibn Naḥmias's *The Light of the World*.[44] While the question of what Copernicus learned from the astronomy of the Islamic world has attracted a great deal of attention, the question of what other astronomers at the University of Padua might have learned from the astronomy of the Islamic world (most immediately the Ottoman Empire), including models of homocentric orbs, is relevant if we are to understand the extent and wider context of communication facilitated by figures such as Galeano.

THE CONTEXT OF MOSES GALEANO'S ASTRONOMY

The third way in which Galeano's summary of the approaches to the underlying theoretical problem of astronomy is noteworthy is that the style of his discussions of astronomy in *Puzzles of Wisdom*, in which he surveyed the options for accounting for the planets' nonuniform motions with combinations of uniformly rotating orbs, had a context in the Hebrew scientific texts of the period. In this section I will elucidate that context. There were clear parallels between *Puzzles of Wisdom* and three Hebrew astronomy texts from the last two decades of the fifteenth century. The first such text was Eliyahu al-Fājī's *Miḵtaḇ Eliyahu* [*Elijah's Letter*].[45] The author was probably from the Ottoman Empire, as

[40] *Ibid.*, p. 292. A likely contemporary of Galeano, Elijah al-Fājī, used the same Hebrew epithet (*ha-mar'ish*) to refer to Biṭrūjī.

[41] On *The Light of the World* see Robert Morrison, "The Solar Theory of Joseph Ibn Nahmias," *Arab. Sci. Phil.*, 2005, *15*:57–108; and Morrison, "Andalusian Responses to Ptolemy in Hebrew," in *Precious Treasures from Hebrew and Arabic*, ed. Jonathan Decter and Michael Rand (Piscataway, N.J.: Gorgias, 2007), pp. 69–86. I am currently preparing an edition and translation, with commentary, of *The Light of the World*.

[42] An initial exploration of some of these expansions can be found in Morrison, "Andalusian Responses to Ptolemy in Hebrew."

[43] Morrison, "Astronomical Treatise by Mūsā Jālīnūs alias Moses Galeano" (cit. n. 19), pp. 385, 386–388.

[44] One of the few surviving manuscripts of Biṭrūjī's *Kitāb al-Hay'a* is in the Topkapi Palace Library, in the same codex (MS Ahmet III 3302) as Mūsā Jālīnūs's *Dhikr ba'ḍ al-maḥallāt*. Both texts misspell Biṭrūjī as Biṭrūghī.

[45] Eliyahu al-Fājī, *Miḵtaḇ Eliyahu*, BM 1017 Add. 15454 (IMHM 4939), 114 fols. I base my dating of this text to around 1500 on Steinschneider's statement in "Die mathematischer Wissenschaften bei den Juden, 1441–1500" (cit. n. 28), p. 73.

his responsa (Hebrew: *teshuḇot*—answers to questions of Jewish law) appeared in a collection of responsa from Turkey and Palestine.[46] Al-Fājī posed the same question (how to represent nonuniform motions with uniformly rotating orbs) about astronomy that Galeano did; the three approaches he mentioned as answers were those of Ptolemy, *ha-Mar'ish* (probably Biṭrūjī), and Gersonides (1288–1344).[47] These were three of the four that Galeano mentioned in *Puzzles of Wisdom*. Astronomers were not able to demonstrate through a proof (*moḇet*) which of the three was true.[48] While al-Fājī did not present Ibn al-Shāṭir's approach, he did refer to an attempt to account for celestial motions with epicycles alone—which *was* what distinguished that approach.[49] One can see how Ibn al-Shāṭir's exclusion of the eccentric lent a certain symmetry to the other three approaches, as Gersonides' models were characterized by the exclusion of the epicycle, Ibn al-Shāṭir's models by the exclusion of the eccentric, Biṭrūjī's (and Ibn Naḥmias's) by the exclusion of both, and Ptolemy's by the inclusion of both.[50] Thus, al-Fājī provides a context for Galeano's interest in Ibn Naḥmias (as an improvement on Biṭrūjī) and in Ibn al-Shāṭir (as an astronomy that excluded eccentrics, which would lend a symmetry to Gersonides' theories that excluded epicycles).

Al-Fājī's work also gave a nuanced response to Gersonides' implication that only his models met the standard of predictive and retrodictive accuracy while also being consistent with Aristotle's philosophy.[51] Al-Fājī wrote that he based his solar model on the eccentric not because the eccentric was true in an absolute sense, nor because the eccentric involved fewer orbs than the epicycle, but because only Biṭrūjī rejected the eccentric and Gersonides, in al-Fājī's view, conclusively refuted (*biṭṭel*) Biṭrūjī in book 5 of *The Wars of the Lord*. Al-Fājī pointed out that astronomers would, for example, propose (*nani'aḥ*) that the sun's yearly west-to-east motion could be accounted for, via geometric demonstrations (*moḇtim handasiyim*) with an epicycle, along with all of the observed variations in its motion.[52] But, al-Fājī noted, there was no geometrical demonstration for why the sun had to have a model based on the eccentric hypothesis, as all of the observed phenomena could flow just as easily from a model based on the epicycle. The phenomena could also flow from another model that was as yet unknown.

Isaac ben Samuel Abū al-Khayr's 1497 commentary on Farghānī's *Elements of Astronomy* argued, as al-Fājī's *Mikṯaḇ Eliyahu* had, that none of the available schemes of physical models for celestial motions was necessarily true. Abū al-Khayr was expelled from Spain in 1492 and settled in Padua, where he composed the commentary. Again like al-Fājī, he criticized the relationship between Ptolemy's theoretical proposal (*hanaḥah*) and his geometrical proofs. Abū al-Khayr commented that Ptolemy's hypotheses served only to rationalize or account for the observations; Ptolemy's observations did not necessitate the hypotheses that he devised. Thus the proofs in the *Almagest* were deficient

[46] See Jewish Theological Seminary of America Rab. 1429 (IMHM 43432). Margoliouth's catalogue of Hebrew and Samaritan manuscripts identified al-Fājī with the Elijah ben David al-Fājī who signed a teshuvah (i.e., a responsum) for Elijah Mizraḥi in 1518.

[47] Al-Fājī, *Mikṯaḇ Eliyahu* (cit. n. 45), fol. 2b. See also Langermann, "Compendium of Renaissance Science," pp. 290–291.

[48] Al-Fājī, *Mikṯaḇ Eliyahu*, fol. 2b. The entire paragraph draws on this folio.

[49] Langermann, "Compendium of Renaissance Science," p. 295 n 17, mentioned this reference in *Mikṯaḇ Eliyahu*.

[50] Langermann, "Compendium of Renaissance Science," p. 291, made this observation with regard to Galeano.

[51] Al-Fājī, *Mikṯaḇ Eliyahu* (cit. n. 45), fol. 3b. On Gersonides' position see Goldstein, *Astronomy of Levi Ben Gerson (1288–1344)* (cit. n. 34), pp. 22–23.

[52] Al-Fājī, *Mikṯaḇ Eliyahu*, fol. 2a. The entire paragraph draws on this folio.

(*ḥaserim*) in that they showed neither that the heavens must be arrayed in the way that Ptolemy proposed nor that they could not be arrayed in a different way. Since Gersonides proposed models without epicycles for the planets, which was the opposite of Ptolemy's astronomy, Abū al-Khayr concluded that "the human intellect had not yet arrived at the knowledge of the true situation of the stars in their orbs in the heavens."[53] Like al-Fājī, Abū al-Khayr used Gersonides as a way to show that certain models could not be true. Al-Fājī was not arguing that Gersonides' models represented the best or final answer as to the structure of the heavens. Both scholars, as well, used the contingency of Ptolemy's models as a way to criticize his demonstrations, though they accepted Ptolemy's models as the default for the purposes of calculations.[54] Both scholars provide an intellectual context for *Puzzles of Wisdom*'s presentation of interchangeable alternative models for celestial motions. The case of Abū al-Khayr indicates that there was a Jewish astronomer in Padua (in addition to the Christian astronomers to whom we shall turn in the next section) who would have been interested in what Galeano had to say.

The third text that contributes to our knowledge of Galeano's intellectual context is a commentary on the *Almagest* (St. Petersburg Oriental Institute MS C128) attributed to Elijah Mizraḥi, Galeano's teacher.[55] There is evidence to accept the attribution of the commentary to Mizraḥi. Another manuscript (St. Petersburg Oriental Institute MS D33), containing a 1478 copy of Jacob Anatoli's *Almagest* translation, includes marginalia attributable to Mizraḥi (and Comtino); these marginalia indicate that Mizraḥi actually did comment on the *Almagest*.[56] One of those marginal comments has Mizraḥi correcting Anatoli's text on the basis of the Greek *Almagest*.[57] That comment is fascinating because it means that Mizraḥi must have become aware of how the Greek version had something to offer beyond what was found in the Arabic and Hebrew versions. Moreover, the *Almagest* commentary attributed to Mizraḥi also contained corrections of the Hebrew translation on the basis of the Greek version; accepting the attribution of an *Almagest* commentary to Mizraḥi seems safe.[58] The *Almagest* commentary attributed to Mizraḥi had numerous references to an Arabic version of the *Almagest*, as well as to the writings of Ibn Rushd (Averroes; d. 1198) and Jābir ibn Aflaḥ (twelfth century) on the *Almagest*, reflecting the depth in which Mizraḥi and his students probed Anatoli's translation of the Arabic.[59] Finally, Mizraḥi's *Almagest* commentary provides evidence that 1500 was the

[53] Yiṣḥaq ben Samuel Abū al-Khayr, *Perush al-Fargani*, Bodleian Neubauer 2015 (IMHM 19300), fols. 2a–2b (here and throughout the essay, translations into English are mine unless otherwise indicated). The quotation from fol. 2b reads, in Hebrew: "'Adayyin lo higi'a ha-seḵel ha-enoshi li-yeda' amitat maṣaḇ ha-koḵaḇim ba-galgalim."

[54] As far as I am aware, this line of argument is absent in the astronomy of Islamic societies.

[55] This text (Elijah Mizraḥi, *Perush Sep̄er al-Magisṭi*) is available in MS St. Petersburg, Oriental Institute C 128 (IMHM 69356).

[56] Ptolemy, *al-Magisṭi*, trans. Jacob Anatoly, MS St. Petersburg, Oriental Institute MS D33 (IMHM 69609); see, e.g., fols. 10b, 11a, 11b, 26a, 42a, for marginal comments from Mizraḥi.

[57] *Ibid.*, fol. 86b. For more on Mizraḥi's references to other manuscripts see Langermann, "Science in the Jewish Communities of the Byzantine Cultural Orbit" (cit. n. 16), p. 447. More generally, Anne Tihon has written, "The fifteenth century was a period of intense intellectual exchanges, which left their traces in manuscripts, so that one finds notes in Latin or Hebrew in Greek astronomical manuscripts of the period." See Anne Tihon, "The Astronomy of George Gemistus Plethon," *J. Hist. Astron.*, 1998, *29*:109–116, on p. 116.

[58] Langermann, "Science in the Jewish Communities of the Byzantine Cultural Orbit," p. 446, has accepted the attribution of the *Almagest* commentary to Mizraḥi.

[59] Mizraḥi, *Perush Sep̄er al-Magisṭi* (cit. n. 55), fols. 85v, 86v, 89v (for references to the Arabic *Almagest*). On fol. 86r, Mizraḥi compared two Hebrew versions of the *Almagest*. Comparisons with other texts of the *Almagest* served to clarify perceived corruptions in the available text. On Mizraḥi's references to Ibn Rushd and Jābir ibn Aflaḥ's writings see Langermann, "Science in the Jewish Communities of the Byzantine Cultural

approximate date of composition for *Puzzles of Wisdom*, with only tinkering occurring during the next few decades. When discussing homocentric astronomy, Mizraḥi referred not only to Biṭrūjī but also to those who followed him.[60] That had to have been a reference to Ibn Naḥmias, because the only known improvement on Biṭrūjī was Ibn Naḥmias's *The Light of the World*. Thus, if Mizraḥi knew about Ibn Naḥmias by the time he wrote his *Almagest* commentary, it is likely that Galeano would have known about Ibn Naḥmias by the time he traveled to Venice.

An important feature of Mizraḥi's *Almagest* commentary is the text's reference to two aspects of Ptolemy's geometric models as *sep̱aqot* (doubts).[61] The commentary simply acknowledged that two great doubts were possible (*yitḥayyaḇu sh^{e}nei sep̱aqot g^{e}dolot*). The first of these was how a single point could move with two motions in the same instant. The second doubt was that the Ptolemaic lunar model brought the epicycle noticeably closer to and farther from the earth.[62] Mizraḥi explained that the response to the second doubt would be to allow a change in the measure of the anomaly (*w^e-yigdal w^e-yiqṭan shi'ur he-ḥillup̱ ha-qoreh mi-ṣad galgal ha-haqqap̱ah*). This solution to the doubt entailed introducing another problem akin to that of the prosneusis, Ptolemy's determination that the motion of the lunar epicycle was uniform with respect to an imaginary point.[63] One indication that Mizraḥi had considered this consequence, the epicycle's irregular motion, to require extra explanation was that he wrote, apropos his figure for the lunar model: "The motion of the deferent should always be about point G, even though its [the epicycle's] mover is line AB which goes out from the center of the Earth. And it is *impossible* (emphasis mine; Hebrew: *'i ep̱shari*) that they be pictured (*she-yiṣuyyaru*) except by way of repelling (*mi-ṣad ha-d^{e}ḥiyyah*)." He stressed that one needed to think of the line as the mover, not the endpoint where the line terminated in the orb, pushing the circumference of the deferent. Mizraḥi added that the potential distortion in the observed motion of the epicycle was addressed with a correction or equation (*tiqqun*).[64] He proposed a new explanation in order to retain the predictive accuracy of the Ptolemaic lunar model.

Mizraḥi has expressed both doubts in ways that pay more attention to the physical structure of the orbs than to the philosophical ramifications of orbs' nonuniform motions. Gersonides, too, had used observational evidence to argue against the epicycle and to dismiss Ptolemy, whose theories could not account for the apparent size of the moon or planetary distances.[65] Gersonides was, nevertheless, aware of the equant problem, though neither Galeano nor his contemporaries referenced his critique.[66] It is possible that

Orbit," p. 447. Langermann notes that Mizraḥi had misgivings about Andalusian (i.e., homocentric) astronomy. See also Mizraḥi, *Perush Seper al-Magisṭi*, fol. 21v.

[60] Langermann, "Compendium of Renaissance Science," p. 285; and Langermann, "Science in the Jewish Communities of the Byzantine Cultural Orbit," p. 447.

[61] See al-Ḥasan Ibn al-Haytham, *al-Shukūk 'alā Baṭlamyūs*, ed. A. I. Sabra and Nabil Shehaby (Cairo: Maṭba'at dār al-kutub, 1971), for the Arabic discussion of doubts (*shukūk*) about Ptolemy.

[62] Mizraḥi, *Perush Seper al-Magisṭi* (cit. n. 55), fols. 163r–v, 164r. See also Langermann, "Science in the Jewish Communities of the Byzantine Cultural Orbit" (cit. n. 16), pp. 447–448.

[63] Mizraḥi, *Perush Seper al-Magisṭi*, fols. 163v–164r. See also Langermann's discussion in "Science in the Jewish Communities of the Byzantine Cultural Orbit," p. 448. Langermann did not mention Mizraḥi's acknowledgment of the practicability of allowing a variation in the anomaly.

[64] Mizraḥi, *Perush Seper al-Magisṭi*, fol. 164r.

[65] On the relationship between observations and theory in the work of Gersonides and Ibn al-Shāṭir see Bernard Goldstein, "Theory and Observation in Medieval Astronomy," *Isis*, 1972, *63*:39–47, esp. pp. 46–47 (for Ibn al-Shāṭir; on Gersonides see pp. 41–42). On observational considerations and Ibn al-Shāṭir's solar model see George Saliba, "Theory and Observation in Islamic Astronomy: The Work of Ibn al-Shāṭir of Damascus," *J. Hist. Astron.*, 1987, *18*:35–43.

[66] José Luis Mancha and Gad Freudenthal, "Levi Ben Gershom's Criticism of Ptolemy's Astronomy," *Aleph*,

Mizraḥi, despite his comment ("it is impossible"), accepted the epicycle's resulting nonuniform motion, though a student (i.e., Galeano) might have seen things differently. While there is little doubt that Galeano's knowledge of astronomy well surpassed that of his teacher Elijah Mizraḥi, Mizraḥi's *Almagest* commentary, as well as the works of Eliyahu al-Fājī and Abū al-Khayr, shows that Galeano was by no means the only Jewish scholar of his era who was thinking critically about theoretical astronomy, either in the Eastern Mediterranean or in Padua (cf. Abū al-Khayr).

HOMOCENTRIC ASTRONOMY AT THE UNIVERSITY OF PADUA

While Copernicus was the astronomer who spent time at the University of Padua who would have been most interested in Ibn al-Shāṭir's astronomy, the homocentric astronomy produced by other astronomers there in the 1500s strongly resembled key details of Ibn Naḥmias's *The Light of the World*. This section explores the work of these astronomers and their predecessors, in order to establish that other figures affiliated with the University of Padua would have been interested in talking to Galeano. Scholarship on homocentric models has found them to be less effective than alternatives involving eccentrics and epicycles in accounting for the planets' varying velocities in longitude.[67] In addition, the key feature of a homocentric, geostatic cosmos was that each celestial body maintained a fixed distance from the earth, so these uniform distances contradicted observations in which the size of the moon, to take one example, was seen to vary.[68] Thus, modern scholars have found it difficult to accept that an outstanding astronomer such as Regiomontanus (d. 1476) could have taken homocentric astronomy seriously, though he does seem to have. Whatever the limits to the predictive accuracy of these models of homocentric orbs were, homocentric astronomy was a *philosophically* coherent way of disagreeing explicitly with Ptolemy.[69] As Michael Shank has noted in seeking to understand Regiomontanus's interest in homocentric astronomy, even if homocentric models could not account for all observations, certain physical problems with Ptolemy remained. Peter Barker has recently identified the criticisms of Averroists (i.e., scholars who favored a

2005, *5*:35–167, esp. pp. 101, 161–164. Ibn Naḥmias's contemporary Profiat Duran (d. 1415) also knew of the equant problem. See Profiat Duran, *Perush al-Majisṭī*, BNF MS 1026 (IMHM 15025), fol. 10a. On Ibn Rushd's own awareness of the equant problem see Juliane Lay, "*L'abrégé de l'Almageste*: Un inédit d'Averroès en version hébraïque," *Arab. Sci. Phil.*, 1996, *6*:23–61, esp. p. 38. Ibn Rushd expressed the equant problem, without actually naming it as such, in physical terms as a supposed intersection of the deferent orb and the orb of the deferent center's mean motion (i.e., the equant orb). See also *ibid.*, pp. 32–33. Lay cites European and Christian astronomers, including George of Trebizond (d. 1486) and Pico, who knew about the *Epitome*, a text that has survived only in Hebrew.

[67] Al-Biṭrūjī, *On the Principles of Astronomy*, trans. Goldstein (cit. n. 5), Vol. 1, pp. 131–140. More fundamentally, see *Almagest* 3.3, in *Ptolemy's Almagest*, trans. G. J. Toomer (London: Duckworth, 1984), p. 141, where Ptolemy entertained the eccentric and epicyclic hypotheses as equivalent ways to account for the observed anomalies in the sun's motions. Ptolemy, therefore, framed the question as one of predictive accuracy, not idealized consistency with Aristotelian philosophy.

[68] Of course, the Ptolemaic lunar model predicted variations in the size of the moon that were not observed.

[69] Regiomontanus became skeptical of eccentrics and epicycles owing to their inability to account for observed changes in the sizes of the planets. See Michael Shank, "Regiomontanus as a Physical Astronomer: Samplings from *The Defence of Theon against George of Trebizond*," *J. Hist. Astron.*, 2007, *38*:325–349, esp. p. 326; see also p. 327, where Shank discusses "the inaugural lecture of his [Regiomontanus's] course on al-Farghānī at the University of Padua in 1464, in which he mentioned wistfully Averroes' unsuccessful efforts to construct a concentric astronomy." See also Shank, "The 'Notes on al-Biṭrūjī' Attributed to Regiomontanus: Second Thoughts," *ibid.*, 1992, *23*:15–30, on p. 15: "And yet, paradoxical though it may seem, Regiomontanus was very interested in the homocentric tradition, in spite of the fact that he was an exceptionally competent mathematical astronomer."

homocentric astronomy) as a reason for the realist portrayal of the orbs in Capuano's (d. ca. 1490) commentary on Georg Peurbach's (d. 1461) *Theoricae novae*, probably written while Capuano taught at Padua. In fact, a 1531 printed edition of Capuano's commentary also included a Latin translation of Biṭrūjī's *On the Principles* and presented that book as Biṭrūjī's own *Theorica*.[70] So while Ibn Naḥmias's interest in homocentric models has led contemporary scholars to be a bit dismissive of his overall scientific acumen, there is ample evidence that serious astronomers at Padua might have been interested in Ibn Naḥmias's homocentric models.[71]

This shared interest is the foundation of the circumstantial evidence for the transmission of Ibn Naḥmias's homocentric astronomy to astronomers at the University of Padua. The story begins with Regiomontanus's homocentric models for the sun and the moon, produced in 1460.[72] Both Regiomontanus and Ibn Naḥmias attempted to address the signal weakness (or challenge) of homocentric astronomies: preserving predictive accuracy without either eccentrics or epicycles. Both astronomers improved on Biṭrūjī by devising ways to use uniformly rotating homocentric orbs to produce linear or nearly linear oscillations. Then, these orbs that produced the oscillations could be combined with another uniformly rotating orb. If the period of the oscillation were calibrated with the period of the uniformly rotating orb, the homocentric models would come much closer to accounting for the sun's observed positions.[73] A key component of both Regiomontanus's and Ibn Naḥmias's models was, as we shall see shortly, a reciprocation mechanism, also known as a slider-crank mechanism, that used a rotation to produce a linear oscillation.[74] In Figure 1, a picture of Regiomontanus's reciprocation mechanism, all motions are taking place on the surface of an orb.[75]

Noel Swerdlow has argued that Regiomontanus could certainly have devised this improvement on Biṭrūjī independently.[76] As the precise form of the reciprocation mech-

[70] Michael Shank, "Regiomontanus on Ptolemy, Physical Orbs, and Astronomical Fictionalism," *Perspectives on Science*, 2002, *10*:179–207, esp. p. 192; and Peter Barker, "The Reality of Peurbach's Orbs: Cosmological Continuity in Fifteenth and Sixteenth Century Astronomy," *Archimedes*, 2011, *27*:7–32, esp. pp. 14, 18 (this essay is part of a special issue of the journal entitled *Change and Continuity in Early Modern Cosmology*, edited by Patrick Boner).

[71] See Gad Freudenthal, "Towards a Distinction between the Two Rabbis Joseph ibn Joseph ibn Naḥmias," *Qiryat Seper*, 1988–1989, *62*:917–919 (in Hebrew). See also the English translation in Freudenthal, *Science in the Medieval Hebrew and Arabic Traditions* (Aldershot: Ashgate, 2005). Freudenthal's position—that Ibn Naḥmias's contributions were not that significant—derived from the way Profiat Duran cited Gersonides' observational proof of the need for eccentric orbs in his (Duran's) response to *The Light of the World*. Duran's assessment of *The Light of the World* was appended to the unique manuscript of the Hebrew recension of *The Light of the World*.

[72] Noel Swerdlow, "Regiomontanus's Concentric-Sphere Models for the Sun and the Moon," *J. Hist. Astron.*, 1999, *30*:1–23, esp. p. 2. José Mancha has argued that Ibn al-Haytham's (eleventh century) homocentric epicycles were transmitted to Europe by the fourteenth century. See José Mancha, "Ibn al-Haytham's Homocentric Epicycles in Latin Astronomical Texts of the Fourteenth and Fifteenth Centuries," *Centaurus*, 1990, *33*:70–89.

[73] I say more about these connections between Ibn Naḥmias's homocentric astronomy and the work of astronomers at Padua in Robert Morrison, "The Position of the Jews as Scientific Intermediaries in the European Renaissance," in *Before Copernicus*, ed. Feldhay and Ragep (cit. n. 13).

[74] Swerdlow, "Regiomontanus's Concentric-Sphere Models for the Sun and the Moon" (cit. n. 72), pp. 14–15. Here Swerdlow commented that the slider-crank mechanism is the key element of Regiomontanus's homocentric models, the element responsible for producing a linear oscillation through the motion of orbs.

[75] Drawing on the original Latin *arcus reciprocationis*, Swerdlow also called Amico's device a reciprocation mechanism, in which the reciprocation of motions between two contiguous orbs effected the oscillation of a point. See Noel Swerdlow, "Aristotelian Planetary Theory in the Renaissance: Giovanni Battista Amico's Homocentric Spheres," *J. Hist. Astron.,* 1972, *3*:36–48, esp. pp. 38–41.

[76] Swerdlow, "Regiomontanus's Concentric-Sphere Models for the Sun and the Moon" (cit. n. 72), p. 4.

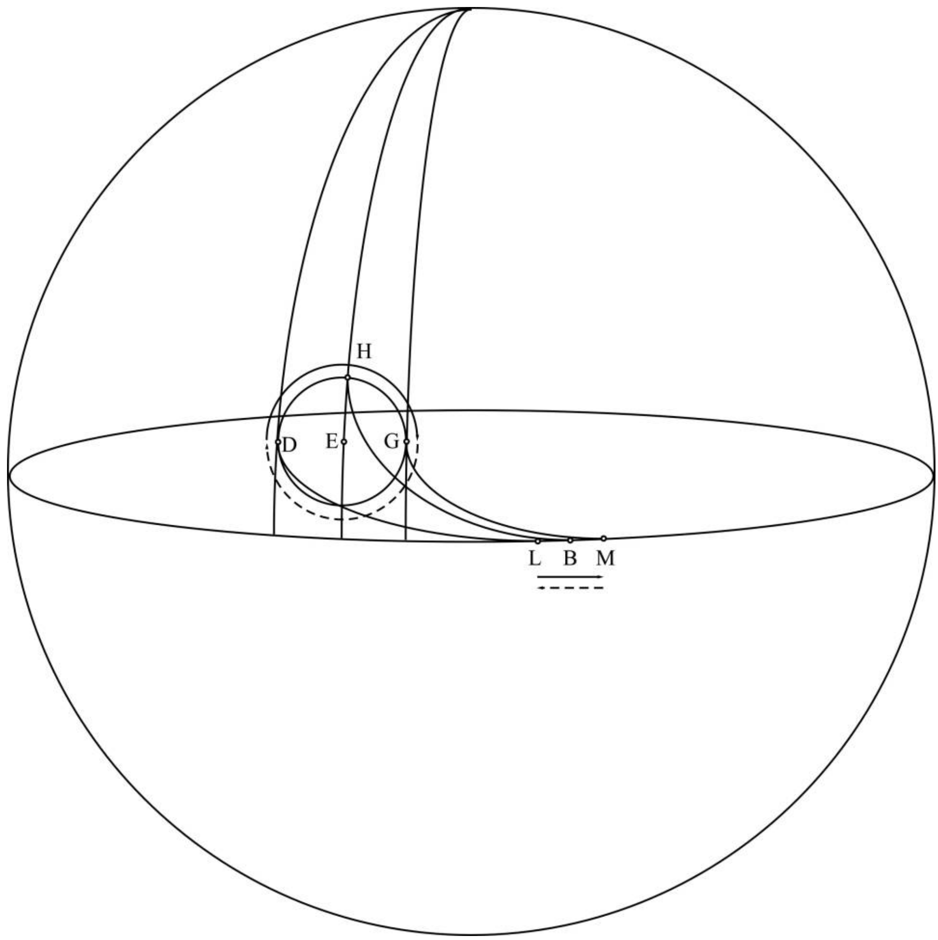

Figure 1. *Regiomontanus's reciprocation mechanism. Based on Noel Swerdlow, "Regiomontanus's Concentric-Sphere Models for the Sun and Moon,"* Journal for the History of Astronomy, *1999,* 30*: 1–23, on p. 7. I gratefully acknowledge the permission of the journal's editor, Michael Hoskin, to reproduce part of the original figure.*

anism proposed by Regiomontanus did not appear in *The Light of the World*, Regiomontanus's innovation might have led to contact between Galeano and later astronomers at Padua in the following way. Jewish astronomers knew of Regiomontanus, as MS Vatican Ebr. 387 included a text from the 1460s on lunar stations, aligned to the longitude of Padua, that was attributed to him.[77] Even if the attribution is spurious, it suggests that Jews in Italy, and perhaps specifically in Padua, who were interested in the sciences were aware of Regiomontanus's achievements. A clear link between developments at Padua in this era and the community of Jewish scholars associated with Candia—for example, Galeano—is the Candiote scholar Elijah Delmedigo, who was actively sought out by Christian scholars

[77] '*Esrim w^e-shmoneh maḥanot ha-l^eb̲anah li-shnat* 1464, Vatican Ebr. 387/4 (IMHM 469). The astrological tables contained in the text were composed for the longitude of Padua. Vatican 379, Parma 2637, and Budapest Kaufmann A 508 contain more extensive Hebrew translations from tables produced by Regiomontanus.

in the 1480s and 1490s.[78] Delmedigo became licensed to teach at a number of Italian universities, including the University of Padua, and spent time in Venice, which controlled Crete during his lifetime. Among his students was Pico della Mirandola (d. 1494).[79]

In his Hebrew commentary on Ibn Rushd's *De substantia orbis*, Delmedigo made, regarding Andalusian critics of Ptolemy, a tantalizing reference to attempts to reform Ptolemaic astronomy.[80]

> All of these [i.e., Ibn Rushd, Ibn Ṭufayl, and Maimonides] said that the roots of natural science contradict what Ptolemy proposes regarding this [i.e., astronomy]. And it [natural science] is true and, without doubt, there are attached to Ptolemy's astronomy enormous gaps (*harḥaqot 'aṣumot*) in his proofs since he did not have completely satisfactory evidence for the epicycle and eccentric he proposed, as Ibn Rushd explained in many places. Even the words of the modern astronomers[81] and their like, who thought to save Ptolemy, necessitate that there be a heavenly body without any function so that there will not be proposed any void with a few of the planets. This body nearly solves the difference, that is to say that a part of it is very thick and that a part is very thin and that it occurs with this that it moves in a way agreeing with the rest of the bodies that are with it until no void occurs nor interpenetration of [celestial] bodies as is known to whomever looks at their words. All of this is a worthless fancy.[82]

This quotation began by citing contemporaries of Ibn Rushd who questioned the existence of epicycles and eccentrics. Then Delmedigo mentioned Ibn Rushd's *Epitome of the* Almagest (*Qiṣṣur al-Magisṭī*), a text in which Ibn Rushd accepted the existence of epicycles and eccentrics and referred to Ibn al-Haytham's *Shukūk 'alā Baṭlamyūs*.[83] Next Delmedigo referred to modern (i.e., post-Ptolemaic) astronomers (*ha-aḥronim w^{e}-dimyoneihem*) who also sought to save Ptolemy and noted that they, too, accepted the existence of the complementary bodies, bodies that prevented the existence of a void between, say, eccentric and parecliptic orbs. At the end of the cited portion, Delmedigo rejected the existence of these bodies, suggesting that he favored a homocentric astronomy.

[78] David Geffen, "Insights into the Life and Thought of Elijah Medigo Based on His Published and Unpublished Works," *Proceedings of the American Academy for Jewish Research*, 1973–1974, *41–42*:69–86, esp. pp. 71–72. Though little is known of Galeano's life, there is evidence that he had a connection to Candia. First, Candia was where he completed *Puzzles of Wisdom*. See Langermann, "Compendium of Renaissance Science," p. 287. Second, there were scholars with the same last name in Candia, probably cousins. See *ibid.*, p. 287; see also Steinschneider, *Die Hebraeischen Übersetzungen des Milttelalters und die Juden als Dolmetscher*, 1956 ed. (cit. n. 14), pp. 595, 578. Third, a prominent rabbi in Istanbul, Moses ben Elijah Capsali (d. ca. 1500), was the cousin of Elijah Capsali, the leader of the Jewish community on Candia. See Abraham David, "Moses ben Elijah Capsali," in *Encyclopaedia Judaica*, ed. Berenbaum and Skolnik (cit. n. 28), Vol. 4, p. 456.

[79] David Bercovy, "La famille Delmedigo," *Revue d'Histoire de la Medecine Hebraique*, 1969, *22*:13–20, esp. p. 14; and Alberto Bartòla, "Eliyahu del Medigo e Giovanni Pico della Mirandola: La testimonianza dei codici vaticani," *Rinascimento*, 1993, N.S., *33*:253–278. Some of the contact between Pico and Delmedigo occurred in Padua (see pp. 259–265).

[80] The classic article on Andalusian critics of Ptolemy is A. I. Sabra, "The Andalusian Revolt against Ptolemaic Astronomy: Averroes and al-Biṭrūjī," in *Transformation and Tradition in the Sciences*, ed. Everett Mendelsohn (Cambridge: Cambridge Univ. Press, 1984), pp. 133–153.

[81] Note, though, that on fol. 74b of the same manuscript Delmedigo referred to Ibn Rushd as one of the *aḥronim* (which can mean any post-antique figure) in philosophy.

[82] Elijah Delmedigo, *Bi'ur Eṣem ha-galgal*, Paris MS Hébreu 968, fol. 49a. This manuscript indicates a composition date of 1485 and a copying date of 1492; see *ibid.*, fol. 74a. For more on the dating of the Hebrew and Latin versions of Delmedigo's commentary on *De substantia orbis* see Bohdan Kieszkowski, "Les rapports entre Elie Del Medigo et Pic de la Mirandole (d'après le ms. lat. 6508 de le Bibliothèque Nationale)," *Rinascimento*, 1964, *4*:41–91, esp. p. 45.

[83] See Lay, "*L'abrégé de l'Almageste*" (cit. n. 66), pp. 47–48 (for the *Shukūk*), 46–48 (for discussion of eccentrics and epicycles).

Clearly, the would-be savers of Ptolemy to whom Delmedigo referred could not have been those, such as Biṭrūjī or Ibn Naḥmias, who, like Delmedigo, favored a homocentric astronomy. It is possible that he was thinking of Ibn al-Haytham or Jābir ibn Aflaḥ, critics of Ptolemy cited in Ibn Rushd's *Qiṣṣur*.[84] Delmedigo's commentary was composed and copied before he returned to Crete around the time of Pico's death in 1494.[85] Given the young age at which Delmedigo left Crete for Italy, it is also possible that the attempts to save Ptolemy to which he referred were something he learned of once in Italy, such as Regiomontanus's better-known nonhomocentric astronomies. Delmedigo might even have been referring to Gersonides. But whatever the identity of the referent of Delmedigo's comment about modern astronomers, we have in Delmedigo a Jewish scholar who was connected to Christians, moved between Crete and the Veneto, and thought that Ptolemy needed to be reformed, probably with homocentric astronomy.

This evidence offered by Delmedigo is important because parts of Ibn Naḥmias's *The Light of the World* responded to the shortcoming of the salient feature of Regiomontanus's homocentric models, the reciprocation mechanism. Swerdlow concluded that the slider-crank mechanism does function geometrically but that there are physical problems with it. In particular, how would the oscillating point know to remain in the ecliptic without some sort of track?[86]

The Hebrew recension of *The Light of the World*, in its expansions on the solar model found in the Judeo-Arabic original, included three proposals for a physical mover that would keep the oscillating point on track. The first two proposals entailed ways to counterbalance the point's displacement from the linear path on which it was supposed to oscillate.[87] For instance, in Figure 2, DGK, the great circle arc upon which K would oscillate, was part of the equator of the second orb the poles of which were T and H. Poles T and H were fixed in a lower orb. K and the point opposite it are fixed in a third orb with pole Z. Z is fixed in a fourth orb that rotates about A. So when pole Z went to point E, K would want to go to X, but the second orb would rotate about poles T and H, fixed in the first orb, to allow K only to go toward G.

As the effect of this second of the first two solutions was to fix the oscillating point in another orb, the author of the Hebrew recension provided a third proposal, which has not been described in earlier scholarship. (See Figure 3.) This proposal allowed the rotation of Z to E to cause an oscillation from K to G, all through the complete (i.e., without the back-and-forth oscillations that characterized the first two proposals) rotations of orbs. The Hebrew recension of *The Light of the World* paid attention to the question of physical movers for these motions, whereas Ibn Naḥmias, in the Judeo-Arabic original, was more interested in locating all the celestial motions on the surface of an orb than he was in questions of how one orb would move another. The dashed lines from P to N and from N to Y, along with my step-by-step description, are there just to help the reader envision

[84] If one were to read "*ha-aḥronim*" ("later ones") with Ibn Rushd as the reference point, it would be odd to refer to Ibn Rushd's predecessors as later or modern astronomers and their like (*ha-aḥronim w^{e}-dimyoneihem*) in the course of a discussion of Ibn Rushd.

[85] On Delmedigo's return to Crete see Jacob Levinger, "Elijah ben Moses Abba Delmedigo," in *Encyclopaedia Judaica*, ed. Berenbaum and Skolnik (cit. n. 28), Vol. 5, pp. 542–543.

[86] Swerdlow, "Regiomontanus's Concentric-Sphere Models for the Sun and the Moon" (cit. n. 72), p. 17: "To expect S to know to remain in the ecliptic while L moves about a circle is to expect a great deal." I thank Swerdlow for reminding me of his articles.

[87] The first two options are discussed more in Morrison, "Andalusian Responses to Ptolemy in Hebrew" (cit. n. 41), p. 83; and Morrison, "Position of the Jews as Scientific Intermediaries in the European Renaissance" (cit. n. 73).

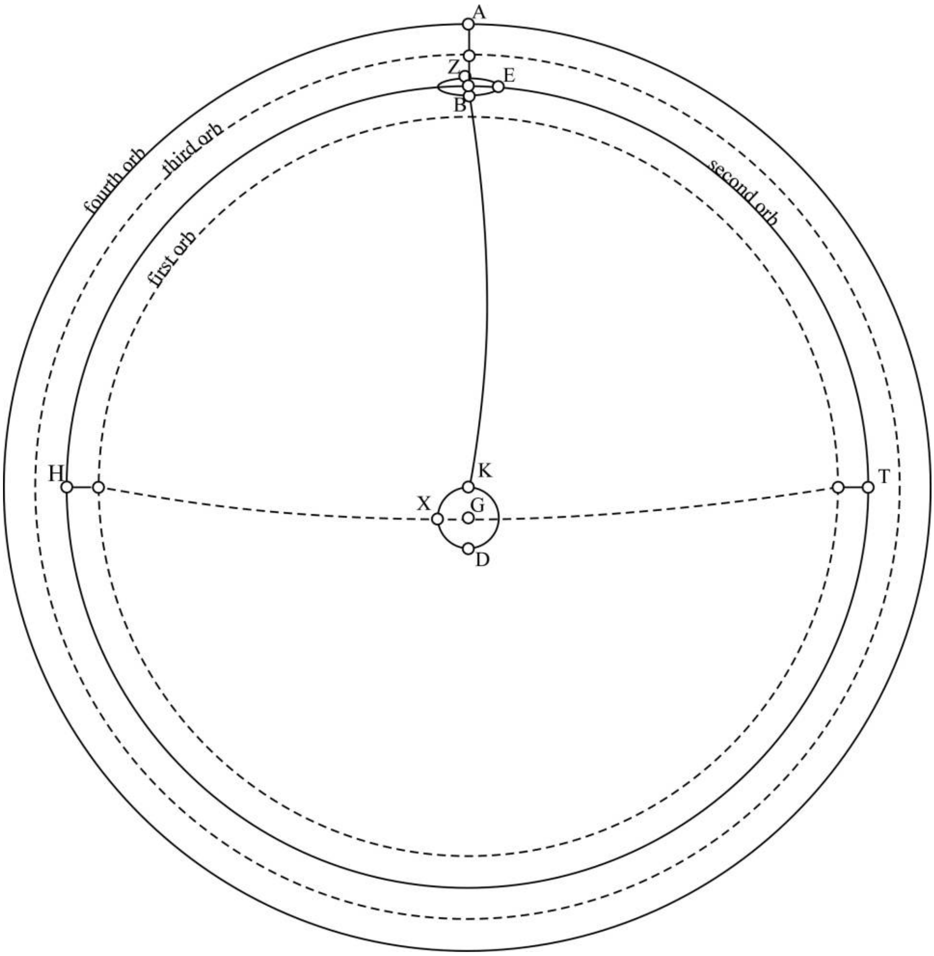

Figure 2. The Light of the World*'s second modification of the reciprocation mechanism. (Drawn by Robert Morrison.)*

how the proposal functions. All of the ensuing motions should, in fact, occur simultaneously. First, pole Z on the first orb rotates about pole A a certain number of degrees, 45 in the figure, to arrive at point P. As a result, the position of point K becomes point N, with a latitude from T equal to arc KY. Then, the second orb whose pole is A rotates about pole Z to bring point K from point N down to point Y.[88]

As the author of the Hebrew recension, perhaps Ibn Naḥmias himself, acknowledged, this solution will not work precisely, because for arc EG to be 90 degrees, the rotation from Z to E cannot be exactly 90 degrees.[89] This solution incorporates a Eudoxan couple:

[88] Ibn Naḥmias, *Or ha-olam*, Bodleian Canon Misc. 334, fols. 116a–115b (the manuscript is numbered backward).

[89] *Ibid.*, fol. 115b.

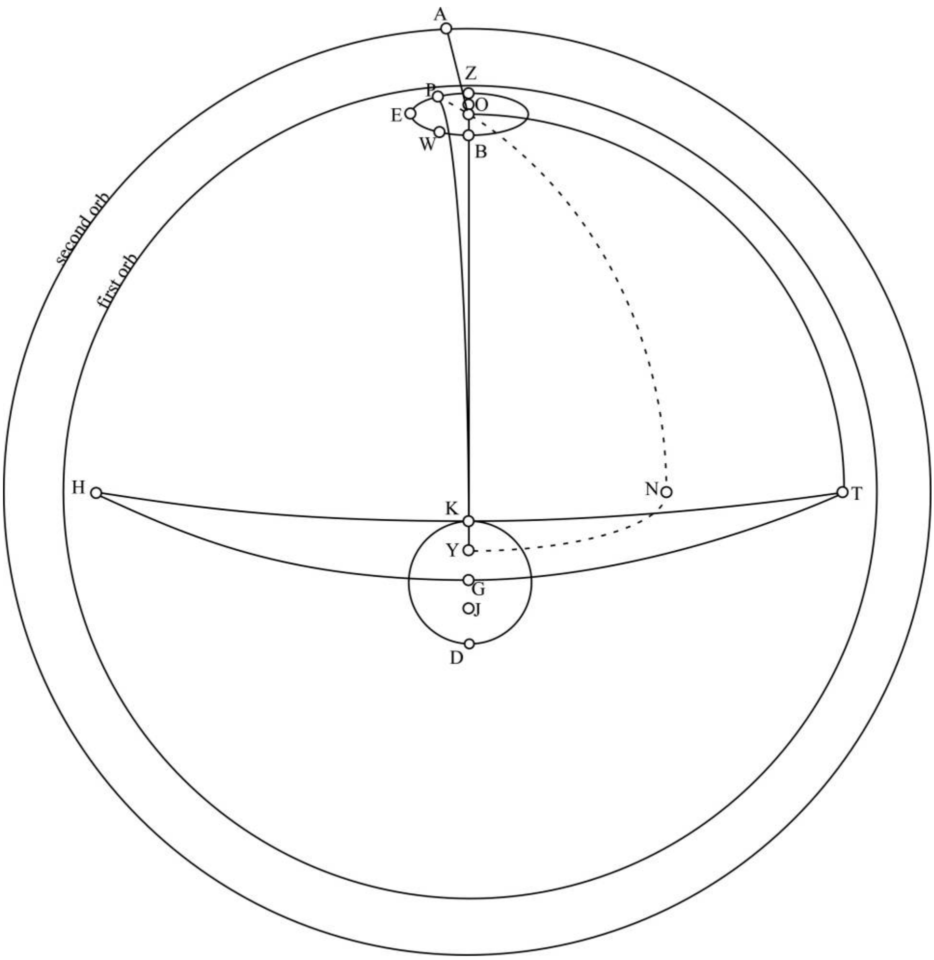

Figure 3. The Light of the World*'s third modification of the reciprocation mechanism. (Drawn by Robert Morrison.)*

one orb encloses another and the pole of the first is inclined to the pole of the second. The two orbs rotate the same amount in opposite directions.[90]

Any attempted solution to a flaw in Regiomontanus's homocentric astronomy would undoubtedly have interested astronomers at the University of Padua in *The Light of the World*. Circumstantial evidence for the actual interest of Padua scholars is the presence of a double-circle device in the text, on homocentric astronomy, of Giovanni Battista Amico

[90] There is no evidence that Ibn Naḥmias knew that this device could be understood as being inspired by Eudoxus's work. Mathematical analysis of this hypothesis can be found in the commentary on my forthcoming edition and translation of *The Light of the World*. For more on Eudoxan couples in the work of Biṭrūjī see J. L. Mancha, "Al-Biṭrūjī's Theory of the Motions of the Fixed Stars," *Archive for History of Exact Sciences*, 2004, *58*:143–182. Mancha pointed out that there was no evidence that Biṭrūjī actually knew that his model incorporated a Eudoxan couple (pp. 157–161).

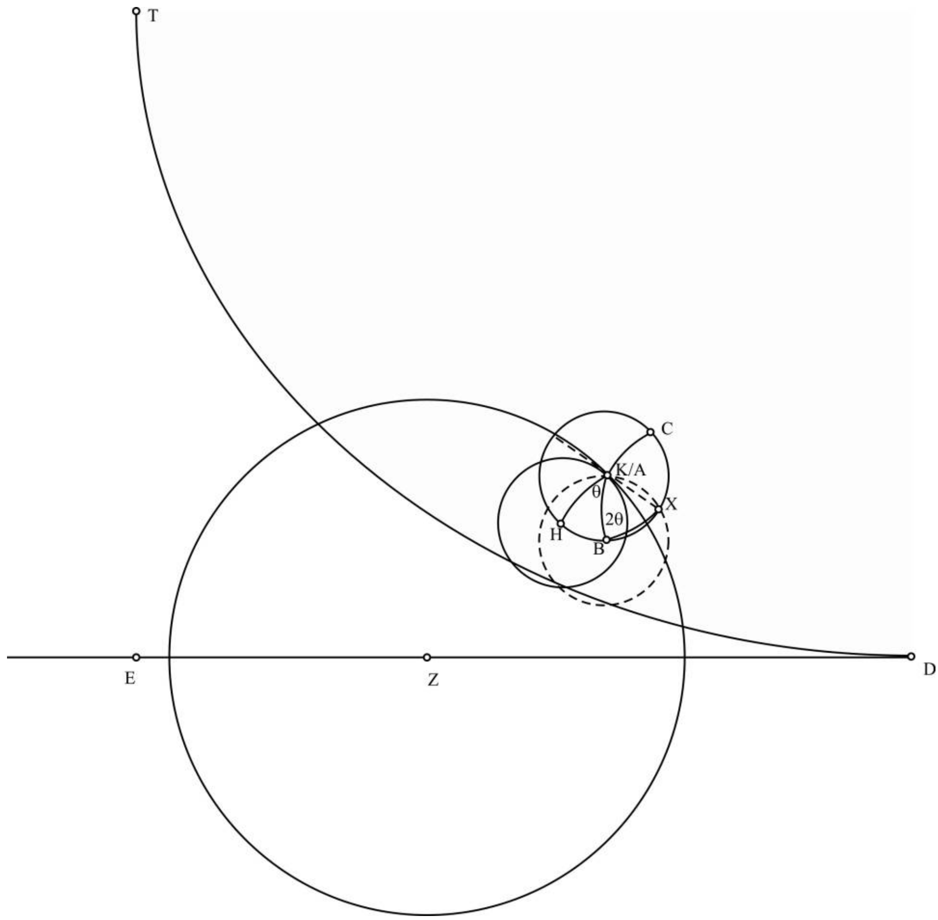

Figure 4. *The double-circle device in* The Light of the World. *(Drawn by Robert Morrison.)*

(d. 1538) who wrote in the 1530s at Padua.[91] The double-circle device was Amico's way of producing a linear oscillation on the surface of concentric orbs. (See Figure 4.)

Amico's double-circle device closely resembled the double-circle device found in Ibn Naḥmias's *The Light of the World*.[92] (See Figure 5.) The double-circle device also strongly resembles an early version of the Ṭūsī couple found in Ṭūsī's recension of the Arabic translations of the *Almagest*.[93] It is highly unlikely that Ibn Naḥmias invented the double-circle device himself, as there is evidence of transmission of mathematics and

[91] Goldstein, *Astronomy of Levi ben Gerson (1288–1344)* (cit. n. 34), p. 14. Goldstein wrote that Amico's criticism of the epicycle may have been inspired by Gersonides. Jews did not attend the University of Padua in large numbers until the end of the sixteenth century. See David Ruderman, "Medicine and Scientific Thought: The World of Tobias Cohen," in *The Jews of Early Modern Venice*, ed. Robert Davis and Benjamin Ravid (Baltimore: Johns Hopkins Univ. Press, 2001), pp. 191–210, esp. p. 191.

[92] There was a double-circle device in the Judeo-Arabic original of *The Light of the World* as well. See Morrison, "Solar Theory of Joseph Ibn Nahmias" (cit. n. 41), pp. 92–98. Unlike the refinements of the reciprocation mechanism found only in the Hebrew recension of *The Light of the World*, the double-circle device was in both versions.

[93] On the rudimentary Ṭūsī couple in *Taḥrīr al-Majisṭī* see George Saliba, "The Role of the *Almagest*

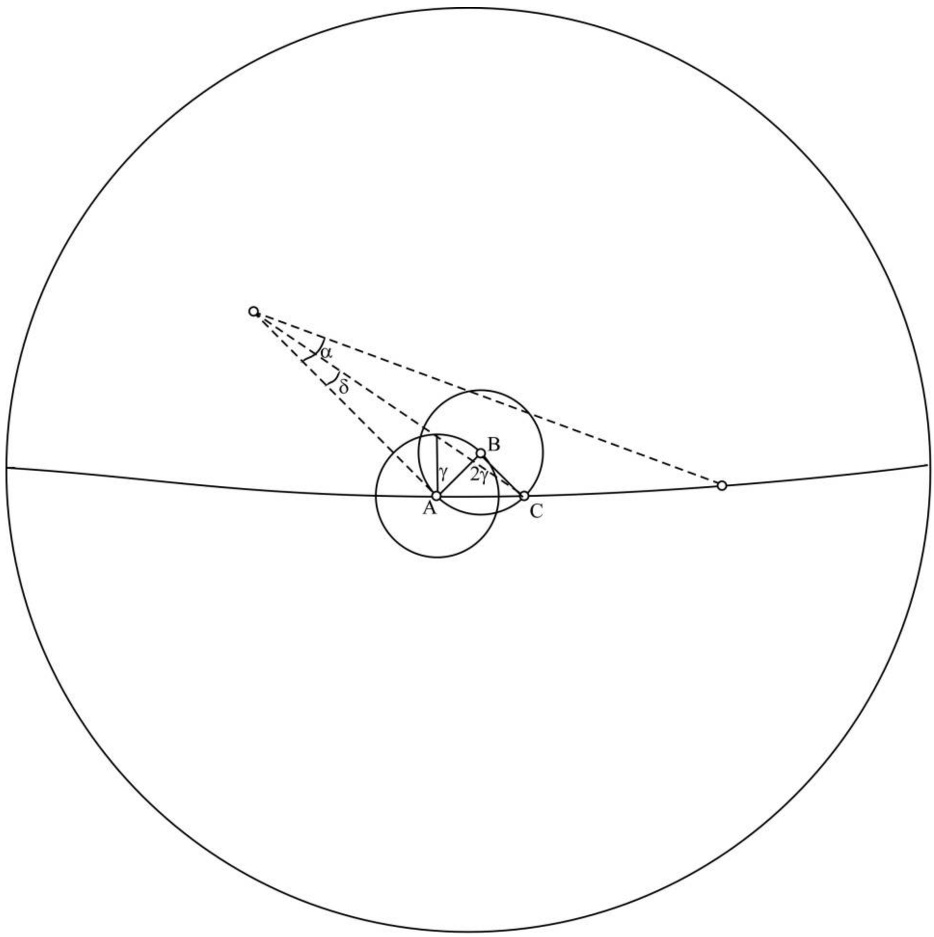

Figure 5. *The double-circle device in Amico's astronomy. From Noel Swerdlow, "Aristotelian Planetary Theory in the Renaissance: Giovanni Battista Amico's Homocentric Spheres,"* Journal for the History of Astronomy, *1972,* 3:*36–48, on p. 41. I gratefully acknowledge the permission of the journal's editor, Michael Hoskin, to reproduce this figure.*

instruments from Marāgha to Andalusia before his lifetime.[94] In the figure, pole H rotates a certain amount about pole A to point B. Then, pole K rotates twice that amount about pole H (at B), moving to point X. The dashed circle is the new location of the circle with its pole now at B. The dashed line running from X through K/A indicated the approximate path of pole K, almost on a great circle arc.

Another astronomer at Padua, Girolamo Fracastoro, was also pursuing a homocentric

Commentaries in Medieval Arabic Astronomy: A Preliminary Survey of Ṭūsī's Redaction of Ptolemy's *Almagest*," *Archives Internationales d'Histoire des Sciences*, 1987, *37*:3–20.

[94] Gersonides (d. 1344) was certainly aware of the Pseudo-Ṭūsī commentary on Euclid's *Elements* and may have been aware of the authentic Ṭūsī commentary as well. See Tony Lévy, "Gersonide, commentateur d'Euclide," in *Studies on Gersonides, a Fourteenth-Century Jewish Philosopher-Scientist*, ed. Freudenthal (cit. n. 34), pp. 83–147, esp. pp. 90–91. On instruments see M. Comes, "The Possible Scientific Exchange between the Courts of Hulaghu of Maragha and Alphonse 10th of Castille," in *Sciences, techniques et instruments dans le monde iranien*, ed. Nasrallah Pourjavady and Živa Vesel (Tehran: Presses Univ. d'Iran, 2004), pp. 29–50.

astronomy in the 1530s; Fracastoro had been an instructor of logic in the Faculty of Medicine at Padua during the period in which Galeano visited the Veneto.[95] Copernicus knew of Fracastoro's work by the time he wrote *De revolutionibus*, though he disagreed with Fracastoro's contention that the problems with the *Almagest* were due to the hypotheses of the epicycle and eccentric.[96]

Swerdlow's study of Amico's *De motibus corporum coelestium* showed that Amico used only double-circle devices to account for the planets' anomalies. Ibn Naḥmias generally used the double-circle device for a slightly different purpose, eliminating a remaining displacement from the zodiac. Nevertheless, at one point in the Hebrew recension, Ibn Naḥmias did propose using only the double-circle device to account for the sun's anomaly.[97] But while Amico's double-circle mechanism does work in the plane, there is a displacement on the surface of an orb, a fact of which Amico was unaware. Ibn Naḥmias, however, was aware of enduring inaccuracies, even after the inclusion of the double-circle device in the solar model.[98] These strong similarities and slight differences could be explained by oral transmission of much of the content of *The Light of the World* but not the whole text.

Another reason why investigating whether Galeano transmitted Ibn Naḥmias's theories to the astronomers at Padua is important is that I have found, in Giulio Bartolocci's (1613–1687) *Bibliotheca magna rabbinica de scriptoribus*, a biobibliographical dictionary of Jewish literature, a report of *The Light of the World* being seen at Padua.[99] Thus the mid-seventeenth century becomes the *terminus ante quem* for the arrival of *The Light of the World* in Padua. Arguing that the similarities between Ibn Naḥmias's and Amico's homocentric astronomies, as well as the similarities between Ibn al-Shāṭir's models and those of Copernicus, were due to independent, parallel discoveries would necessitate that a number of astronomers in Padua who had the same interests as Galeano somehow never came into even distant contact with him. It is difficult to imagine that all the scholars in the Veneto, in the intellectual ferment of the times, and given the prominence of Elijah Delmedigo among Christian Hebraists, would have been unaware of *all the knowledge* that Galeano brought with him. In light of potential contacts of astronomers at Padua with Galeano, Mario di Bono's proposal that the presence of the Ṭūsī couple in Copernicus's

[95] On Fracastoro's appointment as a professor of logic at the University of Padua see *Archivio Antico dell' Università*, Vol. 669, fol. 3r; fol. 1r ff. contains "Professori di Logica in 1° Luogo." On Fracastoro's astronomy see Di Bono, "Copernicus, Amico, Fracastoro, and Ṭūsī's Device" (cit. n. 20), pp. 143–144. See also Peruzzi, *La nave di Ermete* (cit. n. 20).

[96] Miguel Granada and Dario Tessicini, "Copernicus and Fracastoro: The Dedicatory Letters to Pope Paul III, the History of Astronomy, and the Quest for Patronage," *Studies in the History and Philosophy of Science*, 2005, *36*:431–476, esp. pp. 458–464.

[97] Swerdlow, "Aristotelian Planetary Theory in the Renaissance" (cit. n. 75), esp. p. 41; and Ibn Naḥmias, *Or ha-olam* (cit. n. 88), 113b.

[98] Morrison, "Solar Theory of Joseph Ibn Nahmias" (cit. n. 41), p. 98. Naṣīr al-Dīn Ṭūsī was aware of such a displacement with his own slightly different double-circle device. See E. S. Kennedy and George Saliba, "The Spherical Case of the Ṭūsī Couple," *Arab. Sci. Phil.*, 1991, *1*:285–291. The commentary in my edition and translation of *The Light of the World* shows that Ibn Naḥmias's double-circle device was mathematically equivalent to the spherical Ṭūsī couple.

[99] Giulio Bartolocci, *Bibliotheca magna rabbinica de scriptoribus* (Rome: Sacrae Congregationis de Propaganda Fide, 1675–1694), Vol. 4, p. 501. The report came via a certain Petrus Rivier, who was associated with the Collegium Neophytorum (where Bartolocci had also been a professor) and was a convert from Judaism (*ibid.*, p. 228). Petrus Rivier was likely a contemporary of Bartolocci (*ibid.*, p. 229). The Collegium Neophytorum was founded in 1543; see Robert Wilkinson, *Orientalism, Aramaic, and Kabbalah in the Catholic Reformation* (Leiden: Brill, 2007), p. 42.

De revolutionibus may stem from the time he spent at Padua, with its tradition of Averroism, is fascinating.[100]

A SCHOLARLY NETWORK CONNECTING GALEANO TO CHRISTIAN SCHOLARS

The final section of this essay locates Galeano within a network of scholars who transmitted texts between Crete, the Ottoman Empire, and Europe. We will see that Galeano was not an isolated example of a scholarly intermediary. His place in this network of scholars makes it even more probable that he had contact with Christian scholars when he was in the Veneto between 1497 and 1502. Galeano was part of a network of Jewish scholars in Candia, with connections to Istanbul, that sold Hebrew manuscripts in the early 1540s to Ulrich Fugger (d. 1584), perhaps via an agent.[101] Transfer of manuscripts to Fugger may have taken place in Venice as well. The Fuggers, in addition to their wealth, had wide interests and assembled a collection of Hebrew manuscripts in Heidelberg that became part of the Vatican's collection in 1623. For those manuscripts that could not be purchased, Johann Jakob Fugger (1516–1575; a.k.a. Hans Jakob) had Jewish copyists in Venice.[102] The Fugger mercantile network, in the early 1500s, had established connections to both Venice and Padua.[103] Thus Venice, like Padua, Rome, and Florence, became an important site for the Fuggers' book acquisitions in Italy.[104]

The Fuggers' acquisitions in Candia began in 1541. Elijah Capsali was the conduit for 175 Hebrew volumes. Capsali had served as head of the Jewish community as early as 1515 and had represented the Jews before the Venetian authorities.[105] A codex of religious texts, Vatican MS Ebr. 44, was acquired by Fugger from Capsali in Candia in 1541. Vatican MS Ebr. 285, a codex that included primarily texts of *midrash* and *halaḵah*, with several folios on astrology and astronomy, was also acquired by Fugger from Capsali in 1541, probably on Candia.[106] Capsali's life history is one indication that Fugger's (or his agent's) voyage to Candia to buy manuscripts was the result of preexisting relationships. But because Capsali was not the sole vendor, and because the manuscripts were acquired over a period of at least two years, the story involves more than just the sale of Capsali's personal library.

[100] Di Bono, "Copernicus, Amico, Fracastoro, and Ṭūsī's Device" (cit. n. 20), p. 146.

[101] Paul Lehmann, *Eine Geschichte der alten Fuggerbibliotheken*, 2 vols. (Tübingen: Mohr, 1956), Vol. 1, pp. 91–93. Umberto Cassuto noted in *I Manoscritti Palatini ebraici della Biblioteca Apostolica Vaticana e la loro storia* (Vatican City, 1935), pp. 29–30, that the manuscripts were sold for Venetian currency.

[102] David H. Stam, ed., *International Dictionary of Library Histories*, 2 vols. (Chicago: Fitzroy Dearborn, 2001), Vol. 1, p. 202. This information is found in the entry for the history of the Bavarian State Library. Later in his life, Johann Jakob Fugger served as librarian for Albrecht of Bavaria; see Mark Meadow, "Merchants and Marvels: Hans Jacob Fugger and the Origin of the Wunderkammer," in *Merchants and Marvels: Commerce, Science, and Art in Early Modern Europe*, ed. Pamela Smith and Paula Findlen (New York: Routledge, 2002), pp. 182–200, esp. p. 191.

[103] E. Martellozzo Forin, "A Padova col Caiado: Marco Fugger e Pandolfo Rem (1504–8)," *Quaderni per la Storia dell'Università di Padova*, 1971, *4*:76–97. On the Fuggers and Venice see Jacob Strieder, *Jacob Fugger the Rich: Merchant and Banker of Augsburg*, trans. Mildred Hartsough and N. S. B. Gras (New York: Adelphi, 1931), p. 103.

[104] Lehmann, *Eine Geschichte der alten Fuggerbibliotheken* (cit. n. 101), Vol. 1, p. 61. On Ulrich Fugger's connection to Venice see *ibid.*, p. 91.

[105] *Ibid.*, p. 93 (175 Hebrew volumes); and Cecil Roth, "Elijah Capsali," in *Encyclopaedia Judaica*, ed. Berenbaum and Skolnik (cit. n. 28), Vol. 4, pp. 455–456.

[106] Vatican MS Ebr. 44, fol. 3r. See also Benjamin Richler, ed., *Hebrew Manuscripts in the Vatican Library* (Studi e Testi, 458) (Vatican City: Bibilioteca Apostolica Vaticano, 2008), pp. 31, 215. The catalogue explains that Fugger's inscription indicated that Capsali was the head (*contestabile*) of the Jewish community at the time.

An example of an enduring relationship between Christian scholars in Italy and Jewish scholars on Candia begins with Elijah Delmedigo, whom I have already described as one of Pico's teachers and informants and who was also a Latin translator of some of Ibn Rushd's works. A member of the same family, Meyuḥas Delmedigo, sold a corrected and heavily annotated manuscript of Kalonymus b. Kalonymus's (d. after 1328) translation of Averroes' middle commentary on Aristotle's *Physics* to the Fuggers in 1542 in Candia. The manuscript had made its way from the Iberian Peninsula to Candia and, according to one colophon, was studied by Saul b. Moses ha-Kohen Ashkenazi (ca. 1470–1523), concluding in 1520.[107] Elijah Delmedigo's reputation could well have brought the family to the attention of the Fuggers.

Saul b. Moses ha-Kohen Ashkenazi's father, Moses Kohen Ashkenazi, was also known to Christians in Italy. Moses Kohen Ashkenazi composed an astrology text entitled *Urim w^e-Tummim* that was purchased by the Fuggers. The text was produced in the middle decades of the fifteenth century at Candia. This manuscript is particularly good evidence for the continuation of contacts between Jewish scholars in Crete and Christians, because Moses Kohen Ashkenazi had produced horoscopes for a government advisor and a physician, both from the Vittori family in Candia, as well as a prediction for a boy born in Venice in 1454.[108] Given this history of the Ashkenazi family's earlier contacts with Christian scholars, it would be a stretch to claim that the Fuggers learned about the Ashkenazis only upon the purchase of the manuscript in Candia in 1541 or 1542. Also important for this story of transmission is the content of *Urim w^e-Tummim*, as it offers a vigorous justification of astrology, holding that the self-knowledge gained from astrology is, in fact, an aid to fulfilling religious obligations. Astrology was the ultimate goal (*taḵlīt*) of the study of the heavens, and astrological knowledge was a religious duty (a *miṣwah*).[109] The author, Ashkenazi, though he praised the work of Abraham Ibn Ezra (d. ca. 1164–1167), some of which was available in Latin, did not simply rely on authorities. He criticized all previous astrology texts for failing to discuss the conjunctions of the moon with the planets; Ashkenazi filled the lacuna.[110] The purchase of this text is evidence that Pico's condemnation of astrology seems not to have been the final word in Renaissance Europe. Recently, Robert Westman has discussed Copernicus's desire to respond to Pico's criticisms of astrology as a crucial motive for his work in astronomy.[111] Fugger's acquisition of *Urim w^e-Tummim* is, in addition, evidence for an interest of Christian scholars in astrology as an alternative (or accompanying) religious philosophy to Qabbalah, which Pico and others were certainly interested in. Elijah Delmedigo was a known opponent of Pico's views of Qabbalah.[112]

[107] Richler, ed., *Hebrew Manuscripts in the Vatican Library*, p. 292. See also Kalonymus b. Kalonymus, trans., *Bi'ur Ibn Rushd li-Sepẖer ha-sheima' ha-ṭ^{e}ḇa'i*, Vatican MS Ebr. 343, fols. 1v, 134v (studied by Ashkenazi). On Ashkenazi see Jacob Haberman, "Saul ben Moses Ha-Kohen Ashkenazi," in *Encyclopaedia Judaica*, ed. Berenbaum and Skolnik (cit. n. 28), Vol. 2, p. 577.

[108] Moses Kohen Ashkenazi, *Urim w^e-Tummim*, Vatican MS Ebr. 393, fols. 1r, 1v (horoscopes).

[109] *Ibid.*, fol. 137v. On fol. 122r, Ahskenazi wrote that astrology was also a *ta'alumat ḥokhma* (puzzle or mystery of wisdom). See also Langermann, "Science in the Jewish Communities of the Byzantine Cultural Orbit" (cit. n. 16), pp. 449–450.

[110] Ashkenazi, *Urim w^e-Tummim*, fol. 152v ff. Ibn Ezra's writings in Latin were not the same as those in Hebrew. See Renate Smithuis, "Abraham Ibn Ezra's Astrological Works in Hebrew and Latin: New Discoveries and Exhaustive Listing," *Aleph*, 2006, *6*:239–338.

[111] Westman, *Copernican Question* (cit. n. 8), pp. 103–105; see p. 192 for more on Fugger's *mathematicus* Leovitius, who wrote a book defending astrology.

[112] Delmedigo has traditionally been considered to be a rationalist opponent of the Qabbalah and of Pico's attempts to integrate the Qabbalah with Christian theology. But Kalman Bland has argued that Delmedigo's

There is exciting evidence that Galeano was part of this network of scholars that sold manuscripts to the Fuggers. Vatican MS Ebr. 201 contains Qabbalistic commentary on the Torah and was purchased by the Fuggers, though no date of purchase is given.[113] Thus, it may or may not have been purchased during the 1541–1543 trip. The end of the manuscript contains a 1539 statement of sale from Galeano's student Abraham Algazi to Galeano, naming Galeano as a rabbi, physician, and his (Algazi's) teacher.[114] Thus, when the Fuggers' agent came to Candia in 1541 and 1542 to buy manuscripts—including, eventually, this one—it was, as far as we know, in Galeano's possession.[115] There is one potential reason for caution in my reading of the statement of sale. The buyer's name is spelled Agaleano, with an aleph at the beginning. We know from the colophon of *Puzzles of Wisdom* that Galeano completed that text in Candia in 1536. Algazi copied the only surviving manuscript of the text in Candia in 1539.[116] So unless Algazi had another teacher at the same time, who was also a rabbi and a physician (as the statement of sale identifies him as such) with almost the same name, I am comfortable with equating Agaleano and Galeano, as one of the colophons in the manuscript of *Puzzles* spells the last name Agaleano.[117]

It is possible that the book that Galeano bought from Abraham Algazi was not Vatican MS Ebr. 201, but MS Ebr. 202, a jumbled, unbound codex of twenty-one texts. In his 1935 book on the Hebrew manuscripts of the Vatican's Palatine collection, Umberto Cassuto stated, though without citing evidence, that the statement of sale bound in Vatican MS Ebr. 201 actually belonged to Vatican MS Ebr. 202. Cassuto added that much of 201 would still be part of the Fuggers' collection (though not owned by Galeano).[118] I would speculate that since the statement of sale for 201 was on a folio with no other writing, and because the folio had been mostly reattached to the binding, Cassuto presumed that that statement of sale came from 202. An expertly prepared catalogue of the Vatican Hebrew manuscripts, published in 2008, states that folios 239–241 of the manuscript were originally blank.[119] As there is no doubt that folio 239 was originally part of MS 201, because it contains a brief text that began on 238, just below where the Torah commentary ended, so folio 240, with the statement of sale, would have been part of Vatican MS Ebr. 201 all along. I have examined the original manuscripts and do not believe that the ownership statement was pasted onto folio 240, suggesting that Cassuto's concern was misplaced. But even if Cassuto was correct, MS Ebr. 202 still became part of the Fuggers' collection, meaning that the statement of sale is highly significant for assessing the likelihood of Galeano's contact with Christian scholars.[120]

position on the Qabbalah was nuanced and dependent on the audience. See Kalman Bland, "Elijah del Medigo's Averroist Response to the Kabbalahs of Fifteenth-Century Jewry and Pico della Mirandola," *Journal of Jewish Thought and Philosophy*, 1991, *1*:23–53.

113 The manuscript may contain more than one commentary on the Torah. See Cassuto, *I Manoscritti Palatini ebraici della Biblioteca Apostolica Vaticana e la loro storia* (cit. n. 101), p. 25.

114 Vatican MS Ebr. 201, fol. 240v. The colophon reads: "modeh ani eik̲ mak̲arti ha-sep̲er ha-zeh li-mori rabbi he-ḥak̲am ha-shalem ha-rop̲ei . . . Mosheh Agaleano . . . kesep yadu'a b̄ein k̄ebodo u-b̲eini . . . ani Ab̲raham al-Gazi ha-koteib̲ bi-yadi m̄amash."

115 Though the manuscript is part of the Fondo Fuggeriana, there is no statement of sale.

116 Langermann, "Compendium of Renaissance Science," pp. 287, 290. Langermann has described the surviving manuscript of *Ta'alumot Ḥokhmah* as "a professional copy that the author later revised."

117 Moses Galeano, *Ta'alumot ḥokmah*, Cambridge University MS Add. 511.1, fol. 95a.

118 Cassuto, *I Manoscritti Palatini ebraici della Biblioteca Apostolica Vaticana e la loro storia* (cit. n. 101), pp. 36, 25.

119 Richler, ed., *Hebrew Manuscripts in the Vatican Library* (cit. n. 106), p. 140.

120 Cassuto, *I Manoscritti Palatini ebraici della Biblioteca Apostolica Vaticana e la loro storia* (cit. n. 101), p. 36.

CONCLUSION

We have reached several conclusions. First, though a full assessment of the reasons for Christians' interest in these Hebrew manuscripts and an investigation of the full dimensions of the contacts between Christian and Jewish scholars are topics for a longer project, it is clear that the range of texts and ideas transmitted through this network of scholars went well beyond theoretical astronomy. Thus the ideas, and perhaps the texts, of Ibn Naḥmias and Ibn al-Shāṭir were circulating with other ideas and texts, the transmission of which is not contested. Second, the essay has noted many instances of contact between scholars in Europe and the Jewish communities of Crete and Istanbul; Galeano, if he did indeed meet Christian scholars, as the evidence from the statement of sale in Vatican MS Ebr. 201 strongly suggests, was not an isolated case. The only thing about Galeano that was exceptional was the range and depth of his knowledge of non-Ptolemaic astronomy. But even Galeano's exceptional level of knowledge of non-Ptolemaic astronomy, this essay has shown, emerged from the context of Jewish intellectual life in the Eastern Mediterranean. Even a scholar like Elijah Delmedigo, not at all an accomplished astronomer, was aware of the shortcomings of Ptolemy's astronomy.

Third, this article has also provided a context for why Christian astronomers in Renaissance Italy would look to Jewish informants. Broadly speaking, Jews had a history of being sources for Christians in other areas—for example, Qabbalah, astrology, and medicine. And, more specifically, the article has shown that Ibn Naḥmias's work on homocentric astronomy meshed perfectly with that of other scholars at the University of Padua and that a copy of *The Light of the World* was reported to have been at Padua. The possibility of independent (or parallel) discoveries in some of these areas is still arguable, but there may be a limit to how much can be attributed to independent discovery in the face of a plausible path of transmission. André Goddu has written that without a clear path of transmission to explain the parallels between the astronomy of the Islamic world and the work of Renaissance astronomers, including Copernicus, we should entertain other explanations. To account for the overwhelming parallels between Copernicus's models and Ibn al-Shāṭir's, he noted that Sandivogius of Czechel and Albert of Brudzewo proposed double-epicycle models for the moon.[121] But those lunar models were not the same as Ibn al-Shāṭir's and Copernicus's, and there is no explanation of how those double-epicycle lunar models led to planetary models that, with the exception of heliocentrism, were equivalent to Ibn al-Shāṭir's. In contrast, the network of transmission that this article has described would seem to offer a more plausible explanation.

Finally, this essay has acknowledged that the work of European astronomers was the context for the transmission; without the work of Regiomontanus, there would be no reason to presume that astronomers at Padua would be interested in Ibn Naḥmias's ideas. Transmission is not a simple story with clearly defined paths. There is a complex interplay between individuals' insights and networks of transmission. Still, in the case of Moses Galeano, given the context for his scientific interests as well as both circumstantial and direct evidence for his contact with European scholars, it would be difficult to believe that he did not speak to Christian scholars while in the Veneto between 1497 and 1502 and transmit his knowledge of the theories of Ibn Naḥmias and Ibn al-Shāṭir to someone of significance.

[121] André Goddu, *Copernicus and the Aristotelian Tradition: Education, Reading, and Philosophy in Copernicus's Path to Heliocentrism* (Leiden: Brill, 2010), pp. 486, 144.