

*Selective Appropriation: Jewish Scholars and Lunar Crescent Visibility Prediction in the Ottoman Empire*¹

ROBERT G. MORRISON

Bowdoin College

rgmorrison@bowdoin.edu

ABSTRACT: Steinschneider and Zonta have documented the numerous translations of Arabic texts into Hebrew. Goldstein has found that Jewish scholars transcribed a text of late medieval astronomy, Ibn al-Shāṭir's *zīj* (Ar. *al-Zīj al-jadīd*), into Hebrew characters. Jewish scholars knew of important theories of late medieval Islamic astronomy, such as the Tūsī-Couple, even when the original text was never translated or transcribed into Hebrew characters. Less studied but fascinating episodes of exchange between Muslim and Jewish scholars occurred in the Ottoman Empire during the reigns of Mehmet the Conqueror and his son and successor Bayezit II. During the reign of Mehmet, Moses b. Elijah Galeano produced a Hebrew version of Jaghmīnī's *al-Mulakhkhaṣ fī al-hay'a al-basīṭa*. During the reign of Bayezit, Moses b. Judah Galeano (a.k.a. Mūsā Jālīnūs) learned of the theoretical astronomy of Ibn al-Shāṭir. But there were times when Jewish scholars in Ottoman lands did not appropriate methods from available Islamic texts. The focus of this article is on a few such cases involving lunar crescent visibility prediction. Though the level of astronomy at Mehmet and Bayezit II's court was high, the methods of lunar crescent visibility prediction found in Jewish texts yielded results that were as useful as those found through the methods available in Islamic texts.

KEYWORDS: Ottoman Empire, Lunar Crescent, 'Alī Qushjī, Naṣīr al-Dīn Tūsī, astronomy, *Zīj-i Ulugh Beg*, Maimonides, Karaite Jews.

Apropiació selectiva: autors jueus i prediccions de visibilitat del creixent lunar a l'imperi otomà.

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RESUM: Steinschneider i Zonta han documentat nombroses traduccions de textos àrabs a l'hebreu. Goldstein ha descobert que autors jueus van transcriure un text astronòmic medieval, el *zīj* d'Ibn al-Shāṭir, en caràcters hebreus. Autors jueus coneixien teories importants de l'astronomia tardomedieval, com el parell de Ṭūsī, fins i tot quan el text original no havia estat traduït. Episodis menys estudiats d'intercanvi entre estudiosos musulmans i jueus van tenir lloc en els regnats de Mehmet el conqueridor i el seu fill i successor Bayezid. En el regnat de Mehmet, Moses b. Elijah Galeano (Mūsā Jālīnūs) va estudiar la teoria astronòmica d'Ibn al-Shāṭir, però a vegades els autors jueus no s'apropriaven del material disponible als textos islàmics. Aquest article explora alguns d'aquests casos. Encara que el grau de sofisticació de l'astronomia a les corts de Mehmet i Bayezid era elevat, els mètodes de predicció de la visibilitat del creixent lunar als textos jueus resulten ser tan precisos com els dels textos islàmics.

PARAULES CLAU: Imperi otomà, creixent lunar, 'Alī Qushjī, Naṣīr al-Dīn Ṭūsī, astronomia, *Zīj-i Ulugh Beg*, Maimònides, jueus caraites.

Jewish scholars such as Māshā'allāh (d. ca. 810–25 CE),² Sahl b. Bishr al-Isrā'īlī (d. ca. 845), and Sanad (or Sind) b. 'Alī (fl. ca. 830) were early participants in the scientific enterprise in Islamic societies.³ Thus, it is not surprising that pre-modern Jewish scholars made productive use of Islamic scientific texts before and after the efflorescence of Hebrew as a scientific language in the 11th century. Moritz Steinschneider and Mauro Zonta have documented numerous translations of Arabic scientific texts into Hebrew in their bio-bibliographical research, but translation was not always necessary for intellectual exchange to occur between Jewish and Muslim scholars.⁴ Jewish scholars composed scientific texts in Arabic

2. All dates are CE unless otherwise noted.

3. Robert MORRISON, «Science (Medieval)», in *Encyclopaedia of Jews in the Islamic World*, ed. Norman Stillman, 5 vols. (Leiden: Brill, 2010), 4:270–3, at 270.

4. See, e. g. Moritz STEINSCHNEIDER, *Die hebräischen Übersetzungen des Mittelalters und die Juden als Dolmetscher* (Berlin: Kommissionsverlag des Bibliographischen Bureaus, 1893); Steinschneider, *Mathematik bei den Juden* (Hildesheim: G. Olms, 1964); and Mauro ZONTA, «Medieval Hebrew Translations of Philosophical and Scientific Texts: A Chronological Table», in *Science in Medieval Jewish Cultures*, ed. by Gad Freudenthal (Cambridge and New York: Cambridge University Press, 2011), 17–73.

into the 15th century⁵ and also transcribed Arabic scientific texts, such as Ibn al-Shāṭir's (d. 1375) *al-Zīj al-jadīd* (The New Astronomical Handbook with Tables), into Hebrew characters.⁶ Transcription was not always necessary either. Jewish scholars learned of important theories of late medieval Islamic astronomy, such as the Ṭūsī-Couple, through Hebrew texts even when the original text was never translated into Hebrew.⁷ This interest of Jewish scholars in Islamic texts, whether or not translation from Arabic occurred, reflects the continuing prestige of Islamic science in Jewish cultures. Given that Jewish scholars of science were open to the contributions of Muslim scholars, it is worth investigating cases in which Jewish scholars, despite access to Islamic sources, did not appropriate material from those sources.⁸ This article focuses on cases in which Jewish scholars did not adopt methods of lunar crescent visibility prediction found in Islamic texts to which they had access.

These cases occurred during a less studied but fascinating period of exchange between Muslim and Jewish scholars in Istanbul during the reigns of Mehmet the Conqueror (r. 1444–6 and 1451–81) and his son and successor Bayezit II (r. 1481–1512). There was translation from Persian and Arabic into Hebrew by Romaniot Jews, the Jews of Asia Minor and the Eastern Mediterranean. For example, there was an anonymous Hebrew translation of the tables from *Zīj-i Ulugh Beg* (The *Zīj* of Ulugh Beg; completed in 1438–9) and of Abū l-Ḥasan Kushyār's (fl. 10th–11th c.) *Uṣūl ḥisāb al-Hind* (Principles of Hindu Reckoning) by Shalom 'Anabī (fl. ca. 1450–60).⁹ There were also Hebrew versions, but not translations, of Islamic scientific texts. For example, during the reign of Mehmet, Moses b. Elijah Galeano produced a Hebrew version of Jaghmīnī's *al-Mulakkhaṣ fī al-hay'a al-basīṭa* (Epitome of Simple Theoretical Astronomy; composed 1205–6

5. Morrison, «Science», 271–2.

6. Bernard R. GOLDSTEIN, «The Survival of Arabic Science in Hebrew», *Journal for the History of Arabic Science* 3 (1979): 31–9, at 38.

7. On Jewish scholars' knowledge of the Ṭūsī-Couple, see F. Jamil RAGEP, «From Tūn to Toruń: The Twists and Turns of the Ṭūsī-Couple», in *Before Copernicus: The Cultures and Contexts of Scientific Learning in the Fifteenth Century*, ed. Rivka FELDHAY and F. Jamil RAGEP (Montreal and Kingston: McGill-Queens University Press, 2017), 161–97, at 177 and 182. The Ṭūsī-Couple was not ascribed to Ṭūsī by Jewish scholars.

8. On the openness of Jewish scholars to non-Jewish sources, see Gad FREUDENTHAL, «Introduction: The History of Science in Medieval Jewish Cultures: *Toward a Definition of the Agenda*», in Freudenthal, *Science*, 1–10, at 9.

9. Zonta, «Medieval Hebrew Translations», 66 ('Anabī) and 72 (Ulugh Beg).

CE) while relying on an oral informant.¹⁰ There was also exchange without comprehensive translation. Rabbi Elijah Mizrahi (d. 1526) produced a Hebrew commentary on the *Almagest* in which he referenced Greek manuscripts of the *Almagest* as well as Arabic translations in order to provide alternative readings for the Hebrew translation of Jacob Anatoli (d. 1256).¹¹ During the reign of Bayezit, Moses b. Judah Galeano (a.k.a. Mūsā Jālīnūs; d. after 1542) learned of the theoretical astronomy of Ibn al-Shāṭir (d. 1375) without reproducing or paraphrasing specific passages from *Nihāyat al-Sūl* (The Final Inquiry), Ibn al-Shāṭir's major work on theoretical astronomy.¹² Clearly, there were relatively few barriers to scientific exchange and the level of astronomy at Mehmet and Bayezit II's courts was high.

Even in this context of plentiful intellectual exchange, appropriation of the results of exchange was not a given. The methods of calculating whether the lunar crescent would be visible found in texts by Jewish scholars in the Ottoman Empire were viable. Through a comparison and contrast of methods to predict lunar crescent visibility available in the Ottoman Empire in the 15th and early 16th centuries, I will contend that the relative sophistication of the methods available in Hebrew scientific texts can explain why we do not read in Hebrew scientific texts composed in the 15th and early 16th centuries in the Ottoman Empire of the methods found in contemporary Islamic texts.

MORDEKAI KUMAṬIANO (D. <1487) AND ISLAMIC ASTRONOMY

Mordekai Kumaṭiano (d. <1487) is the first Romaniot Jewish scholar working in the Ottoman Empire whom I will discuss. Kumaṭiano became the leading rabbi of Istanbul which earned him a place at the Ottoman court. Jewish scholars from

10. Robert MORRISON, «The Role of Oral Transmission for Astronomy Among Romaniot Jews», in *Texts in Transit*, ed. by Y. Tzvi LANGERMANN and Robert MORRISON (University Park: Pennsylvania State University Press, 2016), 10–28.

11. Y. Tzvi LANGERMANN, «Science in the Jewish Communities of the Byzantine Cultural Orbit», in *Science*, ed. by Freudenthal, 438–53, at 447.

12. Y. Tzvi LANGERMANN, «A Compendium of Renaissance Science: Ta'alumot ḥokma by Moshe Galeano», *Aleph: Historical Studies in Science and Judaism* 7 (2007): 283–318, at 290–1. See, also, Robert MORRISON, «A Scholarly Intermediary between the Ottoman Empire and Renaissance Europe», *Isis* 105 (2014): 32–57.

Asia Minor such as Kumaṭiano spoke Greek and wrote in Hebrew.¹³ There is specific evidence of his connections to Ottoman scholars. Kumaṭiano donated an astronomical instrument to an Ottoman judge early in his career,¹⁴ and a manuscript of his Hebrew commentary on Maimonides' (d. 1204) *The Guide of the Perplexed* exists in the Topkapı Library.¹⁵

Early in his career, Kumaṭiano wrote on mathematical astronomy. In 1425–6, before Mehmet's ascension to the throne, Kumaṭiano composed *Commentary on the Persian Tables* (Heb. *Peirush luḥot Paras*) in which he argued that the tables derived from the *zīj*es produced by the Persians, and which were translated into Greek mostly by Gregory Chioniades (d. c. 1320), contained tables and methods that improved upon the Ptolemaic tables and methods favored by Byzantine Christian scholars.¹⁶ Kumaṭiano referred to the Hebrew translation by Solomon b. Elijah (a.k.a. Sharbiṭ ha-zahab, fl. 1374–86) of the 1347 *Persian Syntaxis*, a compendium of Persian *zīj*es in Greek translation compiled by George Chrysococès.¹⁷ Sharbiṭ ha-zahab was a calque for Chrysococès. It is possible that Chrysococès depended solely on Ṭūsī's *Zīj-i Ilkhānī*, which was the view of Raymond Mercier,¹⁸ or that Chrysococès also relied on *al-Zīj al-Sanjarī* and *al-Zīj al-'Alā'ī* and perhaps other texts that Chioniades did not translate. David Pingree and his student Joseph Leichter took the latter position.¹⁹ Kumaṭiano's reference to Chrysococès' tables as just one set of tables

13. See Jean-Christophe ATTIAS, *Le commentaire biblique: Mordekhai Komtino ou l'herméneutique du dialogue* (Paris: Éditions du Cerf, 1991), 32–3 for Kumaṭiano's use of Greek, Arabic, and Romance (*la'az*) terms in his biblical commentary.

14. Mordeḳai KUMAṬIANO, *Tīqqūn klī ṣafīḥa*, Munich MS Hebrew 36 (IMHM 1166), 173b. This text was probably composed on the 17th of Tvet in 5223, or July 14, 1463.

15. Julian RABY, «Mehmed the Conqueror's Greek Scriptorium», *Dumbarton Oaks Papers* 37 (1983): 15–34, at 17–18. The manuscript is Istanbul, Topkapı Library, MS III Ahmet 53.

16. Mordeḳai KUMAṬIANO, *Peirush Luḥot Paras*, Paris BnF MS Hébreu 1085, 15b.

17. On Solomon ben Elijah Sharbit ha-Zahab, see Philippe GARDETTE, «Judæo-Provençal Astronomy in Byzantium and Russia», *Byzantinoslavica* 63 (2005):195–209, at 196. On George Chrysococès, see Anne TIHON and Raymond MERCIER: *Georges Gémiste Pléthon: Manuel d'Astronomie* (Louvain-la-Neuve, 1998), 253.

18. Raymond MERCIER, «The Greek "Persian Syntaxis" and the Zīj-i Ilkhānī», *Archives Internationales d'histoire des Sciences* 34 (1984): 35–60, at 37.

19. David PINGREE, «In Defence of Gregory Chioniades», 437–8. See also Joseph Gerard LEICHTER, «The Zīj as-Sanjarī of Gregory Chioniades: Text, Translation and Greek to Arabic Glossary», (Ph.D. Dissertation, Brown University, 2004), 9. Chioniades mentioned in his translation of

among others meant that Kumaṭiano had other means of access to Islamic tables.²⁰ Kumaṭiano did not produce his own tables.

There is additional evidence that Kumaṭiano consulted Islamic tables through avenues other than the Hebrew translations of Chrysococès' *Persian Syntaxis*.²¹ Kumaṭiano included in his commentary instructions on how to compute the appearance (Heb. *gilluy*) of the five planets and referred to a table of the appearance of the planets.²² But there was no such table in the Hebrew version of the *Persian Syntaxis*.²³ Such a table, however, is found in *Zīj-i Ilkhānī* and *al-Zīj al-Sanjarī*.²⁴ Thus, in order to compose his commentary, Kumaṭiano most likely consulted Islamic sources through channels other than the Hebrew translation of the *Persian Syntaxis*. And even if Kumaṭiano's immediate source for information about how to compute the appearance of planets was not Islamic, the contents of Kumaṭiano's commentary still were not governed entirely by the contents of the base text, namely the Hebrew version of the *Persian Syntaxis*. Given this evidence of Kumaṭiano's willingness to bring in sources unmentioned by the author of the base text, it is significant that Kumaṭiano did not include in his commentary a section on how to determine lunar crescent visibility, a topic outlined in the same chapter of *Zīj-i Ilkhānī* in which the appearance of the planets was discussed and elsewhere in *al-Zīj al-'Alā'ī* and *al-Zīj al-Sanjarī*.²⁵ Lunar crescent visibility pre-

al-Zīj al-'Alā'ī the existence of a translation of *Zīj-i Ilkhānī*. See David PINGREE, *The Astronomical Works of Gregory Chionides*, vol. 1, *The Zīj al-'Alā'ī*, part one (Amsterdam: J. C. Gieben, Éditeur, 1985), 158–9.

20. KUMAṬIANO, *Peirush luḥot Paras*, Paris BnF Hébreu 1085, 16b. He wrote, «If you want to know this from the tables of Chrysococès (Heb. *Ḳorshoqōqī*)».

21. There is inconclusive evidence that Kumaṭiano read Arabic.

22. KUMAṬIANO, *Peirush*, 31b.

23. See SHARBIT HA-ZAHAB, *Luḥot*, Paris BnF Hébreu 1042, 80b-81a. This is the location in the base text where Kumaṭiano inserted the section on determining the visibility of the five planets. Paris BnF Hébreu 1042 is the unique MS of the Hebrew translation of the Persian Tables.

24. LEICHTER, «The *Zīj as-Sanjarī*», 142. For more on determining the visibility of planets in *al-Zīj al-Sanjarī*, see 56r. For the edited text from *Zīj-i Ilkhānī*, see Hamid-Reza GIAHI-YAZDI, «Naṣīr al-Dīn al-Ṭūsī on Lunar Crescent Visibility and an Analysis with Modern Altitude-Azimuth Criteria», *Suhayl* 3 (2002–3): 231–43, at 242–3.

25. David PINGREE, *The Astronomical Works of Gregory Chionides*, vol. 1, *The Zīj al-'Alā'ī*, part one (Amsterdam: J. C. Gieben, Éditeur, 1985), 177–83. On the method for calculating the visibility of the lunar crescent in *Zīj-i Ilkhānī*, see GIAHI-YAZDI, «Naṣīr al-Dīn al-Ṭūsī», 231–43. For *al-Zīj al-Sanjarī*, see LEICHTER, «The *Zīj as-Sanjarī*», 132–44.

diction does not arise in the Hebrew translation of the *Persian Syntaxis*. It is hard to know why information is missing from the commentary, but the absence of such a section in the base text cannot be a sufficient reason on its own. I will now argue that there would have been little advantage for Kumaṣiano to include the various methods for calculating the visibility of the lunar crescent found in *Zīj-i Ilkhānī*, *al-Zīj al-Sanjārī*, and *al-Zīj al-ʿAlāʾī*.²⁶

Because Kumaṣiano composed a commentary on Maimonides' *Guide* and a commentary on his *Millot ha-higgayon* (The Terminology of Logic; the Hebrew translation of *Maqāla fī Ṣināʾat al-manṭiq*) and because two of Kumaṣiano's students commended Maimonides' method,²⁷ we can speculate that Kumaṣiano followed or modified the method for lunar crescent visibility prediction that Maimonides presented in the *Mishneh Torah* even though Kumaṣiano never provided a method for predicting the visibility of the new lunar crescent in any text he wrote.²⁸ We will investigate how Maimonides' method for predicting the visibility of the lunar crescent compares to the methods described in the Islamic sources, especially that of *Zīj-i Ilkhānī*, that were likely available to Kumaṣiano when he wrote his *Commentary on the Persian Tables*. I will first outline the Islamic methods available to Kumaṣiano before turning to Maimonides' approach.

According to Ṭūsī, predicting lunar crescent visibility involved (Figure One) comparing the elongation ($\Delta\lambda$), the distance on the ecliptic between the sun and the moon, and the arc of vision, which derived from an arc (S) on the celestial equator that Ṭūsī called the adjusted elongation, with certain limits of visibility. Determining the elongation of the luminaries at sunset was a matter of computing the true lunar and solar positions at sunset after the 29th day of the previous month. Then, Ṭūsī considered the measure of HF, the arc on the ecliptic between the moon's true position and the point on the ecliptic that sets with the moon. HF would be added to the elongation if the moon was north of the ecliptic, as shown in the figure, or subtracted if the moon was south of the ecliptic. The adjusted elongation (Pers. *bu'd-i mu'addal*), i. e. the arc of vision, was the difference in

26. See PINGREE, *Astronomical Works*, 1:7–8 for how the original of *al-Zīj al-ʿAlāʾī*, like all six of the *zīj*es by al-Fahhād, is no longer extant.

27. Robert MORRISON, «Tables for Computing Lunar Crescent Visibility in *Adderet Eliyahu*», *SCIAMVS* 20 (2019): 157–201, at 158.

28. See MAIMONIDES, *On the Sanctification of the New Moon*, trans. by Solomon GANDZ, intro. by Julian OBERMANN, and comm. by Otto NEUGEBAUER (New Haven and London: Yale University Press, 1956).

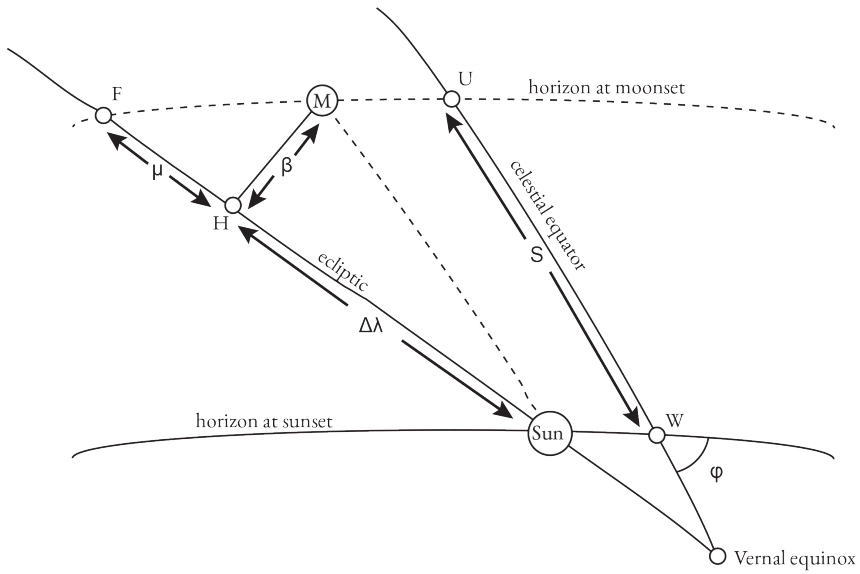


FIGURE from H.R. Giahi Yazdi «Nasir al-Dīn al-Tūsī on lunar crescent visibility», *Suḥayl* (2002–3)

setting times of the sun and the lunar longitude $\pm HF$. Rather than compute HF directly, Tūsī approximated the arc as $3/5$ of the moon's latitude. Finally, he presented criteria for the visibility of the lunar crescent based on the ecliptic elongation and the arc of vision:

If the adjusted elongation is between 10° and 12° , and the ecliptical elongation is greater than 10° , the thin crescent can be observed. Otherwise, it is not visible, unless the adjusted elongation amounts to 12° or more. If the adjusted elongation is between 12 and 14° , the crescent will be observed moderate(ly). If it is between 14° and 16° , the crescent will be bright. If it is between 16° and 18° , the crescent will be visible.²⁹

Al-Zīj al-'Alā'ī, produced by al-Fahhād (fl. ca. 1176), was another *zīj* that was translated into Greek and which may have been available to Chrysococcès when he composed the *Persian Syntaxis*. According to *al-Zīj al-'Alā'ī*, one did the fol-

29. Giahi-Yazdi, «Naṣīr al-Dīn al-Tūsī», 233–4.

lowing to predict when the new crescent would be visible.³⁰ First, one found the true longitude of the luminaries at sunset on the 29th day of the previous month. Second, the setting times of the true positions of the luminaries at sunset the setting on the 29th day of the month were compared. The difference between the setting times was called the hours of setting. Third, half of the lunar latitude was added to the hours of setting if the Moon was north of the ecliptic. If the Moon was south of the ecliptic, half of the latitude was subtracted from the hours of setting. The result was called the arc of vision.³¹ If the arc was greater than 12° , the Moon would be visible. If the arc were between 11 and 12° , the Moon would be faintly visible only if the Moon was north of the ecliptic. If the arc of vision were 11° or less, the Moon would not be visible. The primary differences between the methods of Ṭūsī and of al-Fahhād are the different coefficients by which the lunar latitude was multiplied before being added to or subtracted from the ecliptic elongation, and the broader range of conditions for visibility that Ṭūsī provided. Giahī Yazdī explained how Ṭūsī arrived at the approximation of $3/5$ the lunar latitude.³² Ṭūsī's method represented a conceptual advance over al-Fahhād's because Ṭūsī identified the geometric significance of arc HF. Yet compared to later scholars who calculated HF, Ṭūsī forfeited precision by approximating arc HF. The rest of his method was adopted by, inter alia, the authors of *Zīj-i Ulugh Beg* (composed 1438–9) and Ghiyāth al-Dīn Jamshīd al-Kāshī (d. 1429).³³

We find in both manuscripts of the full Arabic original of *al-Zīj al-Sanjārī*, compiled after 1118,³⁴ as well as in the Greek translation which was based on al-Khāzinī's 1130 abridgment, a method for calculating arc HF, which al-Khāzinī called the equation. My translation of the Arabic text reads:

The fifth chapter on knowing the degree with which the moon sets. If it [the moon] does not have a latitude, then it sets with the degree in which it is. And if it has a vis-

30. PINGREE, *The Astronomical Works* 1, 1:177–83. The entire paragraph draws on these pages. The Arabic original of *al-Zīj al-'Alā'ī* is no longer extant.

31. The Greek text preserves a transcription of the Persian *qaws-i ru'ya* (i. e. arc of vision). See Pingree, *The Astronomical Works* 1, 1:177–8.

32. Giahī-Yazdī, «Naṣīr al-Dīn al-Ṭūsī», 234.

33. *Ibid.*, 231–2.

34. Mohammed ABATTOUY, «Khāzinī: Abū al-Faṭḥ 'Abd al-Raḥmān al-Khāzinī (Abū Maṣū' 'Abd al-Raḥmān, 'Abd al-Raḥmān Maṣū'ir)», in *The Biographical Encyclopedia of Astronomers*, Springer Reference, ed. by Thomas Hockey et al. (New York: Springer, 2007), 629–30.

ible latitude, then we multiply the sine of its visible latitude by the sine of the latitude of the visible climate. We divide the product by the sine of the complement of the latitude of the visible climate and the sine of the equation emerges.³⁵

The complement of the latitude of the visible climate is the angle the ecliptic makes with the local horizon on a certain day. Then, unlike Ṭūsī, Khāzinī used the setting time of the moon to compute the arc of light which was one of four arcs for determining whether the lunar crescent would be visible.³⁶ There was no trace of Khāzinī’s more elaborate method for predicting lunar crescent visibility in any writing by or available to Jewish scholars in Istanbul in the 15th and 16th centuries, including the Hebrew translation of the *Persian Syntaxis* by Sharbit ha-zahab.

For reasons I have already mentioned, the method of lunar crescent visibility prediction found in Maimonides’ *Mishneh Torah* was almost certainly known to

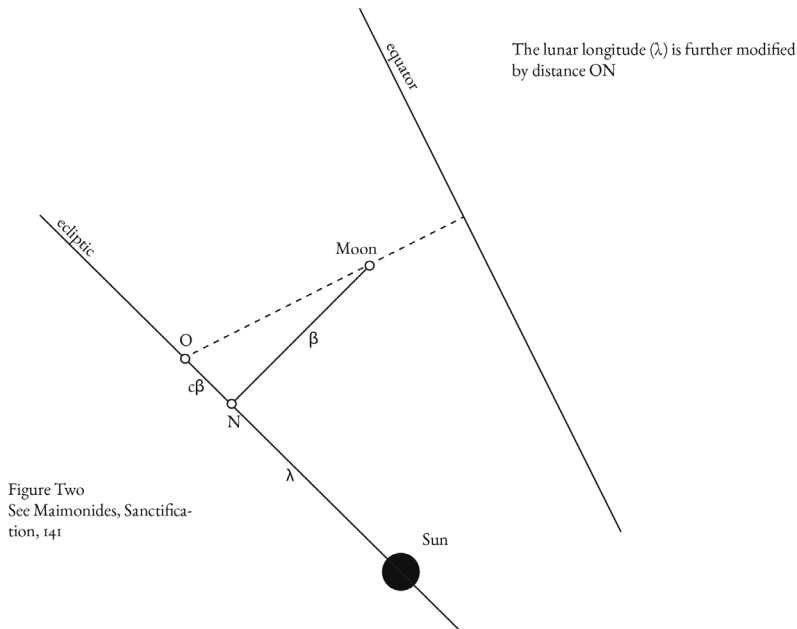


Figure Two
See Maimonides, Sanctification, 141

35. AL-KHĀZINĪ, *al-Zīj al-Sanjarī*, MS Vatican Ar. 761, 86v. Cf. LEICHTER, «The *Zīj* as-Sanjarī», 134 for an English translation of the Greek.

36. Hamid-REZA GIAHI YAZDI, «Al-Khāzinī’s Complex Tables for Determining Lunar Crescent Visibility», *Suhayl* 9 (2009–10): 149–84, at 155.

This modification helped account for the difference between the setting time of the true moon and the setting time of the point on the ecliptic that sets with the moon.⁴⁰ Neugebauer has demonstrated geometrically that the difference between the setting times of B and C in figure three is $\beta \tan \phi / \cos \alpha$, when α is the variable angle at the intersection of the celestial equator and the ecliptic at a given latitude, and β is the lunar latitude corrected for parallax.⁴¹ This is because BAS is $90 - \phi$, the complement of the latitude, and NSA = $90 + \phi + \alpha$. Then, angles NOB and OBA are known. Because distance NMOon is β , OMOon and other sides of the parallelogram, including CB, can be found. Since α varies from 0° to 24° , $\cos \alpha$ varies from 1 to .91. Because the tangent of the latitude of Jerusalem is .62, $2/3$ is the average of values for $\tan \phi / \cos \alpha$ that range from .62 to .7. Maimonides' approximation of the quota of the geographical latitude worked well for predictions of the visibility of the lunar crescent in Jerusalem.

Once the difference in setting times, i. e. the arc of vision, was computed, Maimonides compared the arc of vision and the elongation using certain conditions. If the sum of the modified arc of vision and the original elongation is ≥ 22 or if the arc of vision > 14 , then the crescent will be visible. If the arc of vision $\leq 9^\circ$, then the crescent will always be invisible. In intervening cases, the crescent might be visible.⁴² Compared to Ṭūsī's method from *Zij-i Ilkhānī*, Maimonides' method permitted a greater range of modifications of the arc of vision. It is important to have recapitulated Maimonides' method because the Romaniot authors, who were Kumaṭiano's students, and who proposed a method of predicting lunar crescent visibility, cited Maimonides and borrowed important parts of his method.

If Kumaṭiano relied on the method of Maimonides, he could have (though may not have) improved his results by using tables for the motions of the luminaries that were more recent than the tables of al-Battānī (d. 929), which Maimonides and Kumaṭiano's students used.⁴³ He almost certainly would have used his own correction of the mistaken method for determining the true syzygy, here the true conjunc-

40. See Maimonides, *Sanctification*, 142 (Neugebauer's commentary).

41. Maimonides, *Sanctification*, 143 (Neugebauer's commentary).

42. Maimonides, *Sanctification*, 71–2. Maimonides gave specific examples of those intermediate cases.

43. Morrison, «Tables», 159 for the dependence of Bashyatchi and Afendopolo on the tables of al-Battānī in *Adderet Eliyahu*.

tion of the Sun and Moon, found in the *Persian Syntaxis*.⁴⁴ Computing the true syzygy was critical for deciding whether, at sunset, there was a chance of seeing the new crescent. According to the Persian *zīj*es available to the Byzantines in Greek translation, e. g. *Zīj-i Ilkhānī*, the difference in time between a mean and true syzygy should be calculated as follows: $t = \Delta\lambda/\Delta v$ (i. e. the difference of the lunar and solar positions divided by the difference in their velocities). Ptolemy calculated the difference as follows: $t = 13/12 * \Delta\lambda/v\textcircled{C}$. Chrysococcès, though, combined these two equations in a way that could introduce an error of as much as 30 minutes: $t = 13/12 \Delta\lambda/\Delta v$. This error was reproduced in the Hebrew translation by Sharbiṭ ha-zahab. As Tihon has found, Kumaṭiano's correction of the method for determining the syzygy eliminated the imprecisions of the method of Chrysococcès.⁴⁵

While one might think that methods due to astronomers who worked at the Marāgha Observatory would out-perform updates of Ptolemy's tables and Ptolemaic methods, Chrysococcès' slip-up with the method of syzygy computation clouded matters and spawned a debate. Byzantine Christian astronomers concluded that eclipse calculations with Ptolemy's Handy Tables and methods were more accurate.⁴⁶ Kumaṭiano's correction of Chrysococcès' error is additional evidence that Kumaṭiano must have had access to the correct contents of Islamic *zīj*es. Thus, Kumaṭiano could have improved lunar crescent visibility predictions by combining the method for determining the true syzygy found in the Persian tables with the rest of Maimonides' method for determining the arc of vision and limits of visibility of the crescent. Despite Kumaṭiano's access to and adoption of other contents of Islamic *zīj*es, Maimonides' method for lunar crescent prediction may have sufficed.

LUNAR CRESCENT VISIBILITY PREDICTION IN *ADDERET ELIYAHU*

The next Jewish scholars who wrote on lunar crescent visibility calculations were two students of Kumaṭiano, Elijah Bashyatchi (d. 1490) and his student and brother-in-law Caleb Afendopolo (d. 1525). Because Bashyatchi and Afendopolo came from a community of Jews known as Karaites who had historically preferred

44. See SHARBIṬ HA-ZAHAB, *Luhot*, 45b for how the Hebrew translation reflected Chrysococcès' mistranslation.

45. Anne TIHON, «L'Astronomie Byzantine à l'Aube de la Renaissance», *Byzantion* 66, 1 (1996): 244–80, at 246.

46. Tihon, «L'Astronomie Byzantine», 249.

sighting the crescent to calculating when it would be visible, a brief recapitulation of religious debates over the value of lunar crescent calculation is in order. Both Muslim and Jewish communities debated the merits of calculating when the new lunar crescent might be visible. In Islamic law, there is disagreement over whether one can depend on calculations of the visibility of the new moon or whether sighting is necessary.⁴⁷ Sometimes calculations were used to determine the day to attempt a sighting of the new moon.⁴⁸ Calendar calculations were also a controversial matter among Jews. Rabbanite Jews such as Kumaṣiano, held, following the Talmud, that calculations could be used to help determine the time of the potential visibility of the new moon. According to the Rabbanites, the potential visibility of the crescent mattered more than an actual sighting of the crescent. Cloudy skies would not disrupt the calendar. Karaites are the opponents of Rabbanite Jews. They traditionally believed that the new moon must be sighted and that the calculations of the calendar as detailed in the Talmud carried no legal weight. As there was a notable Karaite community in Asia Minor, computations of lunar crescent visibility would have been an area of discussion between Kumaṣiano and Karaites.

Yet Bashyatchi and Afendopolo composed tables for computing lunar crescent visibility. The tables are found near the beginning of their compendium of Jewish law, *Adderet Eliyahu* (The Cloak/Mantle of Elijah). Those tables, along with Bashyatchi and Afendopolo's instructions for their use, have been published.⁴⁹ Their willingness, as Karaites, to use calculation to determine whether the lunar crescent would be visible was a sea change. Bashyatchi and Afendopolo modified the method for predicting the visibility of the lunar crescent found in Maimonides' *Mishneh Torah*. For example, Bashyatchi and Afendopolo computed the

47. Mohammad ILYAS, «Visibility of the New Moon: Astronomical Predictability (sic!)», *Journal of the Malaysian Branch of the Royal Asiatic Society* 51, 2 (1978): 58–68. See also Mohammad ILYAS, «Lunar Crescent Visibility Criterion and Islamic Calendar», *Quarterly Journal of the Royal Astronomical Society* 35 (1994): 425–461. For a summary of the classical positions of Sunnīs, Ithnā-‘asharī Shī‘īs, and Ismā‘īlīs on the permissibility of calculating the visibility of the new lunar crescent, see J. SCHACHT and R. ETTINGHAUSEN, «Hilāl», in *Encyclopaedia of Islam*, Second Edition, ed. P. Bearman, Th. Bianquis, C.E. Bosworth, E. van Donzel, W.P. Heinrichs. See also David KING, «Ru'yat al-Hilāl», in *Encyclopaedia of Islam*, Second Edition, Edited by: P. Bearman, Th. Bianquis, C.E. Bosworth, E. van Donzel, W.P. Heinrichs.

48. *Ibid.*, 59.

49. Morrison, «Tables».

syzygy following the method found in the Islamic *zīj*es available to Kumaṭiano, including *Zīj-i Ilkhānī*, and which Kumaṭiano defended in his *Commentary on the Persian Tables*. As such, they improved on Maimonides' method of determining the true syzygy which was adapted from Battānī.⁵⁰ Bashyatchi and Afendopolo's tables for the solar and lunar motions still depend on those of Battānī but Bashyatchi and Afendopolo did provide better tables for the parallax of the lunar latitude and longitude.⁵¹ Even though Bashyatchi and Afendopolo adopted the method of determining the true syzygy found in some Persian tables (e.g. the *Zīj-i Ilkhānī*), they did not adopt Ṭūsī's method for calculating the arc of vision.

Rather, their method for computing the arc of vision was closer to that of Maimonides. They began by finding the ecliptic elongation, the arc on the ecliptic between the sun and the moon at sunset. Like Maimonides, Bashyatchi and Afendopolo stated that one should modify the elongation by projecting the moon's right ascension onto the ecliptic (Point O in Figure Two). To approximate the measure of the arc that is between the moon's ecliptic longitude and the ecliptic projection of the moon's right ascension, they provided a coefficient similar to the one tabulated in Maimonides' *Mishneh Torah*. The values of that coefficient (c in Figure Two) ranged from 0 to $2/5$, as in the *Mishneh Torah*, though there were more entries in the table found in *Adderet Eliyahu* because each value for the coefficient corresponded to a smaller range of degrees within each zodiacal sign.⁵² As Maimonides did, Bashyatchi and Afendopolo multiplied the moon's latitude, corrected for parallax, by the coefficient to yield a deviation. One added the deviation to the longitude if the moon was north of the ecliptic and subtracted the deviation if the moon was south of the ecliptic. The result was an elongation based on the ecliptic projection of the moon's right ascension, not the moon's ecliptic longitude. Next, they took the difference in the setting times of the luminaries, based on the modified lunar longitude, to yield an initial value for the arc of vision. They then modified the resulting arc of vision by the quota of geographical latitude, just as Maimonides did. Like Maimonides, they approximated the quota of the visible latitude as $2/3$ of the lunar latitude, corrected for parallax. After modifying the arc of vision by the quota of the visible latitude, they compared the elongation with the arc of vision against certain limits of visibility that

50. Morrison, «Tables», 166.

51. Morrison, «Tables», 195.

52. Morrison, «Tables», 195 (Table I).

were not the same as those found in the *Mishneh Torah*.⁵³ Thus, two of Afendopolo and Bashyatchi's modifications of the method of Maimonides for computing the arc of vision, namely their proposal of new limits of visibility as well as the smaller ranges for each of the fractions by which they multiplied the lunar latitude, constitute evidence that their method was not simply copied from the *Mishneh Torah*; perhaps they tried out their own method.

Because Rabbanite Jews in the Diaspora celebrate a second day of holidays, originally to account for delays in communicating the sighting of the new moon in Jerusalem, Maimonides would not have been concerned with calculating the visibility of the lunar crescent at other locales. Karaites did not add a second day to their holidays because their calendar depended on the local sighting of the new moon. Thus, Bashyatchi and Afendopolo provided parallax tables for other latitudes: 30°, 45° and Istanbul (latitude = 41°). The authors of *Adderet Eliyahu* must have intended that their tables be used for calculation of the visibility of the new lunar crescent in multiple locations other than Jerusalem (latitude = 31°) even though they did not modify Maimonides' approximation of the quota of the visible latitude for latitudes other than Jerusalem.

It is possible that Afendopolo and Bashyatchi knew of the method for calculating lunar crescent visibility found in *Zīj-i Ulugh Beg*, also known as *Zīj-i Jadīd-i Sulṭānī* or *Zīj-i Gūrgānī*. Steinschneider wrote that Bashyatchi knew of the tables of Ulugh Beg (d. 1449),⁵⁴ and that Bashyatchi cited Ulugh Beg's tables.⁵⁵ This *zīj* was composed at the observatory in Samarqand in 1438–9, after the composition of Kumaṭiano's *Commentary on the Persian Tables* but well before the composition of *Adderet Eliyahu*. The Samarqand observatory was founded in 1420 under the direction of Ulugh Beg and attracted luminaries such as Ghiyāth al-Dīn Jamshīd al-Kāshī (d. 1429) and 'Alī al-Qushjī (d. 1474). Kāshī, then Qādī Zādah al-Rūmī (d. after 1440), and, finally, Qushjī directed the observational program. Manuscript copies of *Zīj-i Ulugh Beg* proliferated.

The principal difference between the method found in *Zīj-i Ilkhānī* and that found in *Zīj-i Ulugh Beg* is that the authors of *Zīj-i Ulugh Beg* calculated arc HF (see Figure One), which they termed the equation of setting (*ta'dīl-i ghurūb*), and

53. Morrison, «Tables», 173.

54. Moritz STEINSCHNEIDER, *Mathematik bei den Juden* (Hildesheim: G. Olms, 1964), 196.

55. Moritz STEINSCHNEIDER, «Mathematik bei den Juden», in *Abhandlungen zur Geschichte der Mathematik* 8–9 (1899): 471–83, at 475. I have not been able to locate a reference to Ulugh Beg in *Adderet Eliyahu*, but *Adderet Eliyahu* is a long text.

provided separate tables for the values of arc HF at latitudes 25° , 30° , 35° , and 40° . In these tables, there are entries of the measure of arc HF for lunar latitudes one through five in the horizontal side. In the vertical columns, there are entries for the zodiacal sign in which the moon is found. The maximum equation of setting is $10;32^\circ$, which occurs when the lunar latitude is 5° in the sign of Libra. This maximum value is quite different from Ṭūsī's corresponding approximation of three degrees (i. e. $3/5$ of the maximum lunar latitude of 5°). Because Ṭūsī and the authors of *Zīj-i Ulugh Beg* shared the other steps in computing the arc of vision, Ṭūsī's decision not to calculate HF affected the correspondence of his predictions with those produced by the authors of *Zīj-i Ulugh Beg*. The authors of *Zīj-i Ulugh Beg* did not mention the detailed method found in *al-Zīj al-Sanjārī*. Thus, if those astronomers did not know of Khāzinī's method or considered it to be needlessly detailed, then there was no reason to believe that Kumaṭiano, Bashyatchi, and Afendopolo would have thought any differently.

Like Ṭūsī and the authors of *Zīj-i Ulugh Beg*, Bashyatchi and Afendopolo furnished a table of conditions for whether a lunar crescent would be visible.⁵⁶ One column has the elongation and the other column has the arc of vision, i. e. the modified difference in setting times. If both conditions are met, then the crescent is visible. Interestingly, their table of conditions had more significant digits than Maimonides' or, in fact, those found in *Zīj-i Ulugh Beg*. The authors of *Zīj-i Ulugh Beg* calculated HF while Bashyatchi and Afendopolo approximated it. The fact that Bashyatchi and Afendopolo provided their own values for the limits of visibility means that they believed that their method was good enough.

COMPARISON OF THE METHODS FOR LUNAR CRESCENT VISIBILITY CALCULATION

The geometrical foundations of the methods found in *Zīj-i Ilkhānī*, *Adderet Eliyahu*, and *Zīj-i Ulugh Beg* were the same. The tables for HF, the equation of setting, in *Zīj-i Ulugh Beg* contrast with the approximation found in *Adderet Eliyahu*, which was in turn a more detailed approximation than that found in *Zīj-i Ilkhānī*. To answer the question of the effect of these varying levels of exactitude, in Table One, I compare the deviations of the arcs of visibility found with the methods of Ṭūsī on one hand

56. Morrison, «Tables», 173.

and Bashyatchi and Afendopolo on the other hand from the arcs of visibility found with the method of the authors of *Zīj-i Ulugh Beg* when the moon has a latitude of 2° and a latitude of 5° . In general, Bashyatchi/Afendopolo's method yields arcs of visibility that are closer to those computed with the method found in *Zīj-i Ulugh Beg* than the arcs of visibility computed with the method found in *Zīj-i Ilkhānī*.

Degrees of lunar longitude	$\Delta T_{\text{ūsī}} @ \beta=2^\circ$	$\Delta A_{\text{dderet}} @ \beta=2^\circ$	$\Delta T_{\text{ūsī}} @ \beta=5^\circ$	$\Delta A_{\text{dderet}} @ \beta=5^\circ$
0°	0°	0°	0°	0°
10°	$-.56^\circ$	-1.48°	-1.39°	-3.7°
20°	$-.51^\circ$	-1.64°	-1.26°	-3.1°
30°	$-.42^\circ$	-1.53°	-1.04°	-2.84°
40°	$-.29^\circ$	$-.79^\circ$	$-.72^\circ$	-1.93°
50°	$-.12^\circ$	$-.45^\circ$	$-.3^\circ$	-1.11°
60°	$.085^\circ$	$-.22^\circ$	$.23^\circ$	$-.54^\circ$
70°	$.34^\circ$	$.31^\circ$	$.86^\circ$	1.18°
80°	$.63^\circ$	$.64^\circ$	1.59°	1.76°
90°	$.95^\circ$	$.92^\circ$	2.41°	2.24°
100°	1.31°	1.05°	3.3°	2.53°
110°	1.67°	1.05°	4.22°	1.97°
120°	2.04°	$.88^\circ$	5.13°	1.94°
130°	2.38°	$.85^\circ$	5.98°	1.82°
140°	2.69°	$.66^\circ$	6.73°	1.6°
150°	2.94°	$.67^\circ$	7.32°	1.66°
160°	3.12°	$.61^\circ$	7.68°	1.5°
170°	3.18°	$.62^\circ$	6.45°	$.47^\circ$

TABLE 1: Comparing the arc of vision computed by Tūsī and Bashyatchi and Afendopolo with that computed by the method found in *Zīj-i Ulugh Beg*

Even though the method found in *Adderet Eliyahu* yielded an arc of vision that was generally closer to that computed according to the method found in *Zīj-i Ulugh Beg*, the difference between the arc computed by Bashyatchi and Afendopolo and the arc computed according to the method found in *Zīj-i Ulugh Beg* would be perceptible. Also, the maximum deviations are found at different lunar longitudes. When the lunar longitude is between 0° and 70° , the method found in *Zīj-i Ilkhānī* yields values closer to the values produced by the method found in

Zīj-i Ulugh Beg. But at other latitudes the deviations of values produced with the method found in *Zīj-i Ulugh Beg* are much greater than the deviations of the values produced with the method found in *Adderet Eliyahu*. It is possible that the complexity of the prediction, coupled with the fact that the new moon would have to fall after the 30th day of the preceding month if it did not fall after the 29th day, lowered the stakes of a modest deviation from the values calculated according to the method found in *Zīj-i Ulugh Beg*.

LESS EXACTING METHODS FOUND IN COMMENTARIES

Commentaries on *Zīj-i Ulugh Beg* and *Adderet Eliyahu* inform us about the reception of the methods for lunar crescent prediction found in each *zīj*. An important commentary on *Zīj-i Ulugh Beg* was composed in Persian by ‘Alī Qushjī, who became a prominent astronomer at the court of Sultan Mehmed the Conqueror.⁵⁷ The authors of *Zīj-i Ulugh Beg* provided tables for the equation of setting, i. e. arc HF (in Figure One), without explaining how the tables were computed. Qushjī explained how it was possible to compute the equation of setting at any latitude once the latitude of the visible clime is known.

In addition, Qushjī’s commentary contains evidence that less precise methods of determining lunar crescent visibility were being used. Qushjī wrote, «Through experience (*tajriba*) and testing they have made known that if one takes 2/3 of an hour from the setting of the sun, with the moon [still] above the earth, and [if] the distance between the positions of the luminaries is greater than ten degrees, then it is possible to see the crescent. Two thirds of an hour is ten equatorial degrees».⁵⁸ Then he said that modifying the longitude by three fifths of the latitude (i. e. Ṭūsī’s method) yielded a nearer approximation (*bi-taqrīb nazdīktar ast*).⁵⁹ Hence, Qushjī implied that other scholars were not using the tables of the equation of setting found in *Zīj-i Ulugh Beg* and were also not approximating the arc of vision as closely as Ṭūsī instructed.

57. İhsa FAZLIOĞLU, «‘Alā’ al-Dīn ‘Alī ibn Muḥammad al-Qushjī», in *The Biographical Encyclopedia of Astronomers, Springer Reference*, ed. by Thomas Hockey et al. (New York: Springer, 2007), 946–8.

58. ‘Alī QUSHJĪ, *Sharḥ-i Zīj Sulṭānī*, Philadelphia, University of Pennsylvania MS Schoenberg 400, 384r.

59. Idem.

Joseph Tishbi (fl. 16th cent. in the Ottoman Empire), who authored a commentary on *Adderet Eliyahu*, did not modify the method of the calculation of the difference in setting times found in the base text. In a sample calculation in a commentary, Tishbi retained the approximation of the quota of the local latitude as $2/3$ of the moon's latitude.⁶⁰ Tishbi also provided, in his comments on Chapter Thirty, the theoretical justification for *nelizat ha-ma'agal* (the deviation of the circle),⁶¹ i. e. the modification of the lunar ecliptic longitude by the ecliptic projection of the moon's right ascension, which Maimonides, Bashyatchi, and Afendopolo undertook.

What about the practice of astronomy by other Jewish scholars? The tables (but not the canons) of *Zīj-i Ulugh Beg* were available in an anonymous Hebrew translation.⁶² A rabbi, Abraham ben Yom Tov Yerushalmi, who was in Istanbul in 1510, referred to that translation in a prayer book he composed.⁶³ Goldstein has argued that Yerushalmi, in a separate text, that seemed to be instructions (canons) for using tables, evinced knowledge of the Hebrew translation of *Zīj-i Ulugh Beg*.⁶⁴ In those canons, Yerushalmi proposed a method of lunar crescent visibility prediction that was less tedious than the one found in *Adderet Eliyahu* and the *Mishneh Torah*.

Yerushalmi said to begin by taking the true positions of the sun and moon at nightfall.⁶⁵ He wrote:

If you want to know if it is possible that the moon be seen in the night following the moment of the conjunction, i.e. in the black night, in the majority of months, or in the second black night sometimes, then, at the least, know what is between the true posi-

60. Joseph TISHBI, *Peirush Adderet Eliyahu*, MS St. Petersburg, IOS A96, 54b. For biographical information on Joseph Tishbi, see Abraham DANON, «The Karaites in European Turkey. Contributions to Their History Based Chiefly on Unpublished Documents», *The Jewish Quarterly Review* n.s. 15, 3 (1925): 285–360, at 326–7. Danon located two different people with the same name, both from the sixteenth century.

61. Tishbi, *Peirush*, 52b.

62. Paris MS BnF Hébreu 1091.

63. Bernard R. GOLDSTEIN, «Astronomy in Hebrew in Istanbul: Abraham ben Yom Tov Yerushalmi (fl. 1510)», *Aleph: Historical Studies in Science and Judaism* 20, 1 (2020): 303–7, at 305.

64. Goldstein, «Astronomy in Hebrew», 306. Goldstein pointed to striking overlaps in technical terminology.

65. Though Yerushalmi did not provide specifics, nightfall was probably the end of twilight. See Morrison, «Tables», 167–9.

tions of the sun and the moon at a third of an hour of the black night which is the night of visibility in most cases.

Know also the latitude of the moon and picture it according to what has preceded and enter the true position of the moon in the table of the visibility of the moon from above and the latitude of the moon from the side in the sought horizon. Take the common number between them and it is the distance between the sun and the moon at that time appropriate for the beginning of the visibility. Thus, if what is between the position of the sun and the moon at that time is equal to what you took by way of the table or more than it, the moon will be seen. If not, then it will not be seen.⁶⁶

The advantage of the table that Yerushalmi described is that the user does not need to calculate the arc of vision. Instead, one enters the lunar longitude from above and the lunar latitude from the side and one finds the ecliptic elongation necessary for the new moon to be seen. Since the measure of the minimum arc of vision necessary for lunar crescent visibility, according to Yerushalmi, varied according to the lunar longitude and latitude, the author of the table would have determined the minimum arc of vision necessary that corresponds to a given elongation. The absence of the table from the available manuscript of Yerushalmi's text makes further comment difficult because comparing the precision of Yerushalmi's methods with the precision of the method found in *Zij-i Ulugh Beg* would depend on knowing the number of entries.

Yerushalmi, in the next paragraph, discussed an extreme case in which he may have implied that the crescent needs to be sighted. He explained that if the arc of vision found in the table exceeds the elongation, measured 20 minutes after sunset, by an amount less than the daily elongation on the black night, then the new crescent would be visible the following evening. He adds that if the arc of vision found in the table exceeds the elongation at sunset by more than the daily elongation, it is possible that the new crescent will not be visible even at sunset the following evening: «And if not, you judge that it will not be seen even in the black night nor in the night after it».⁶⁷ The implication may be that a lunar month has no more than 30 days even if the crescent cannot be sighted.

66. Abraham b. Yom Ṭoḇ YERUSHALMI, *Ebronot*, JTSA 5516, 6b. My translation.

67. *Idem*. My translation.

CONCLUSION

Two conclusions follow. First, given that Bashyatchi and Afendopolo's conditions for determining visibility from the elongation and the arc of vision differ from those found in *Zīj-i Ilkhānī* and *Zīj-i Ulugh Beg*, they must have been confident in their method. My geometric analysis has shown that both Maimonides' method and the modification of that method found in *Adderet Eliyahu* are relatively sophisticated and yield values for the arc of vision close to those predicted with the methods found in Islamic texts available to Romaniot Jewish scholars in the 15th and 16th centuries in the Ottoman Empire. That comparison may explain why Kumaṭiano, Bashyatchi, and Afendopolo did not adopt Islamic methods for lunar crescent determination. It is also possible that Kumaṭiano, Bashyatchi, and Afendopolo did not believe that Islamic sources were applicable to a question of Jewish law. Second, we find in Yerushalmi's text evidence that easier methods which were known to be more approximate were being sought out by Jewish astronomers.⁶⁸ In the commentaries on *Adderet Eliyahu* and *Zīj-i Ulugh Beg*, there is additional evidence that ease of use was important to the historical actors. Neither the Ottoman Muslim astronomers nor the Romaniot Jewish scholars I have studied referred to al-Khāzinī's method. Hence, this absence, along with the continuing interest in approximate methods of determining lunar crescent visibility, indicate that there were limits on the value of improved precision.

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68. Cf. Alex JONES, «The Adaptation of Babylonian Methods in Greek Numerical Astronomy», *Isis* 82, 3 (1991): 440–53, at 448–9 on how Hipparchus borrowed Babylonian methods that did not derive from Hipparchus' theoretical models because the Babylonian methods yielded predictions that were sufficiently accurate.

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