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Colors of Eclipses in Medieval Hebrew Astronomical Tables

Medieval Jewish scholars devoted a great deal of attention to positional astronomy and produced many sets of tables for finding the positions of planets, and the times and magnitudes of solar and lunar eclipses.¹ A few astronomers also displayed an interest in issues of physical astronomy, such as the phases of Venus and the brightness of Mars.² But another aspect of physical astronomy, the colors of eclipses, has received relatively little attention in the secondary literature. The tables for the colors of eclipses found in medieval texts seem to represent a literary tradition, for no appeal is made to observations to confirm any

¹ See: D. A. King and J. Samsó, with a contribution by B. R. Goldstein, "Astronomical Handbooks and Tables from the Islamic World (750–1900): an Interim Report," *Su-hayl* 2 (2001): 9–105, esp. pp. 65–69; J. Chabás and B. R. Goldstein, *Astronomy in the Iberian Peninsula: Abraham Zacut and the Transition from Manuscript to Print*. (Philadelphia, 2000) [= Transactions of the American Philosophical Society, vol. 90.2], pp. 49–52.

² See: B. R. Goldstein, "The Pre-Telescopic Treatment of the Phases and Apparent Size of Venus," *Journal for the History of Astronomy* 27 (1996): 1–12; idem, "Levi ben Gerson and the Brightness of Mars," *Journal for the History of Astronomy* 27 (1996): 297–300.

of their entries.³ From a modern point of view, there should not be a table for colors of solar eclipses; for lunar eclipses, the modern theory bears little relationship to the medieval table (for the modern scale of colors for lunar eclipses, see Appendix A).⁴ Although the entries in the medieval tables do not conform to modern data, this tradition may well have affected the perception of reality by those who accepted it.

The tradition of ascribing colors to eclipses goes back to the Babylonians, but there is no evidence of tables for this purpose before the medieval Islamic period.⁵ The basis for a table for lunar eclipses is probably to be found in Indian astronomy, where one finds brief discussions of the colors of lunar eclipses, which depend on the magnitude of the eclipse.⁶ It is likely that the earliest tables for colors of eclipses were incorporated in the lost astronomical tables of al-Khwārizmī (ca. 830), which depended on Indian sources.⁷ But despite the difficulties in establishing the precise circumstances of early Muslim consideration of colors of eclipses, Jewish interest in these tables clearly derived from the medieval Arabic astronomical literature.

In the East, colors of eclipses were listed as early as the first half of the ninth century, not only by al-Khwārizmī, but also by his contemporary Yaḥyā ibn abī Maṣṣūr.⁸ In Spain, the tradition of assigning colors to eclipses can be seen in the Tables of Ibn al-Kammād⁹ (early twelfth century), in the Tables of Barcelona¹⁰ (fourteenth century), which depended on them, as well as in the canons to the Castilian Alfonsine Tables¹¹ (thirteenth century). A description of such a table also appears in a set of canons to the Toledan Tables¹² in Latin (late twelfth century).

This article focuses on four tables whose entries are in Hebrew characters, including some with entries in Arabic written in Hebrew characters. For purposes of comparison, one widely diffused table, in Latin, is also presented. The four tables are as follows:¹³

Table A: There are three sources for this table: Vatican, MS Heb. 379, f. 13b [Va]; Vatican, MS Heb. 379, f. 194b [Vb]; and

- ³ For records of eclipse observations by medieval Muslim astronomers, see: S. S. Said and F. R. Stephenson, "Solar and Lunar Eclipse Measurements by Medieval Muslim Astronomers, I: Background," *Journal for the History of Astronomy* 27 (1996): 259–273; eidem, "Solar and Lunar Eclipse Measurements by Muslim Astronomers, II: Observations," *Journal for the History of Astronomy* 28 (1997): 29–48; F. R. Stephenson and S. S. Said, "Records of Lunar Eclipses in Medieval Arabic Chronicles," *Bulletin of the School of Oriental and African Studies* 60 (1997): 1–34.
- ⁴ For discussion of the modern theory, see M. Minnaert, *The Nature of Light & Colour in the Open Air* (New York, [1940]/1954), pp. 295–296.
- ⁵ For a brief survey of this tradition, see J. Chabás and B. R. Goldstein, *The Alfonsine Tables of Toledo* (Dordrecht, 2003), p. 196.
- ⁶ See, e.g., *Sūrya Siddhānta*, vi.23, in E. Burgess, *The Sūrya Siddhānta: A Text-Book of Hindu Astronomy*, translated by E. Burgess, edited by P. Gangooly, with an Introduction by P. Sengupta (Delhi, [1860]/1997), p. 185; W. Petri, "Colours of Lunar Eclipses According to Indian Tradition," *Indian Journal of History of Science* 3 (1968): 91–98.
- ⁷ See also D. Pingree, "The Indian and Pseudo-Indian Passages in Greek and Latin Astronomical and Astrological Texts," *Viator* 7 (1976): 141–195, esp. p. 166.
- ⁸ Benno van Dalen called my attention to two lists of colors of eclipses in a recension of Yaḥyā's *al-Zīj al-Mumtaḥan* (Escorial, MS Ar. 927, ff. 8r and 87v; a facsimile edition of this manuscript was published in 1986 by the Institut für Geschichte der arabisch-islamischen Wissenschaften an der Johann Wolfgang Goethe Universität at Frankfurt am Main). These two lists, which are almost identical, belong to the same tradition as the others discussed in this paper.
- ⁹ This text is extant only in Latin: see J. Chabás and B. R. Goldstein, "Andalusian Astronomy: *al-Zīj al-Muqtābis* of Ibn al-Kammād," *Archive for History of Exact Sciences* 48 (1994): 1–41, esp. p. 19.
- ¹⁰ This text, with its tables, is extant in Hebrew and Catalan: see J. M. Millás, *Las Tablas Astronómicas del Rey Don Pedro el Ceremonioso* (Madrid and Barcelona, 1962), p. 238; and J. Chabás, "Astronomía andalusí en Cataluña: Las Tablas de Barcelona," in J. Casuellas and J. Samsó, eds., *Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet* (Barcelona, 1996), pp. 477–525, esp. pp. 512–514. There is also a Latin

Paris, Bibliothèque nationale de France, MS héb. 1069, f. 169b [P]. Of special interest is that this table gives both Hebrew and Arabic terms for the colors. In Va this table for the colors of eclipses is included among the tables of Isaac al-Ḥadib (or al-Aḥḍab), a refugee from Spain who arrived in Sicily in 1396.¹⁴ However, some copies of al-Ḥadib's tables do not include this one.¹⁵ Vb is found among the Tables of Barcelona (as is **B**); its terminology differs slightly from that of Va by using עיני הלקיות for "colors of eclipses" (as in **B**).

Table B: This table is found in two manuscripts: Vatican MS Heb. 356, f. 64b [Vc]; and Philadelphia, University of Pennsylvania, Schoenberg, MS ljs 057, p. 191 (formerly: London, Sassoon, MS 823) [S]. This table for colors of eclipses is included in the Tables of Barcelona by Jacob Corsino (fourteenth century), which are extant in Hebrew, Latin, and Catalan versions.

Table C: This table is preserved in one manuscript: Madrid, Biblioteca Nacional, MS 23078, f. 97a (formerly: London, Beth Din, MS Heb. 135) [M].¹⁶ It is included in the unique copy of the tables of Juan Gil of Burgos (fourteenth century), preserved in a Hebrew translation.

Table D: This table is preserved in three manuscripts—Arabic written in Hebrew characters—all of them associated with the tables of al-Fārisī (thirteenth century): London, British Library, MS Or. 4104, f. 115a [L]; Berlin, Staatsbibliothek, MS Or. Qu. 682 (Cat. Steinschneider, MS 230), f. 77b [B]; and Jerusalem, Rabbi Qafiḥ, MS 16, f. 88a [J].¹⁷ The three manuscripts agree so closely that I have not noted the variants. Al-Fārisī was a Yemenite Muslim astronomer whose works were cited by Jewish scholars in Yemen.¹⁸ The tables for colors of eclipses in al-Fārisī's original Arabic text are found in Cambridge, University Library, MS Gg. 3.27, f. 117r [Ca] and in an

anonymous recension thereof, ca. 1400 (in the same manuscript, f. 50r). There are a few variants for solar eclipses, but none for lunar eclipses.¹⁹ The table for the colors of lunar eclipses on f. 50r has the argument as the lunar latitude at 5-minute intervals from 5 to 55 and for 63 (presumably a

version of the introduction, but no tables: see E. Poulle, "A propos des tables astronomiques de Pierre d'Aragon," *Revista da Faculdade de Ciências de Coimbra* 39 (1966): 5–15, esp. p. 5; reprinted in idem, *Astronomie planétaire au Moyen Age latin* (Aldershot, 1996), Essay II.

¹¹ Chabás and Goldstein, *Alfonsine Tables*, p. 197.

¹² F. S. Pedersen, *The Toledan Tables: A Review of the Manuscripts and Textual Versions with an Edition* (Copenhagen, 2002), pp. 652–653.

¹³ The first manuscript cited for each table serves as the base text; variants that appear in other manuscripts are indicated in notes.

¹⁴ See B. R. Goldstein, "Descriptions of Astronomical Instruments in Hebrew," in D. A. King and G. Saliba, eds., *Essays in Honor of E. S. Kennedy, Annals of the New York Academy of Sciences* 500 (1987): 105–41, esp. pp. 106–107, 128.

¹⁵ See, e.g., British Library, MS Add. 26,921, ff. 45–59.

¹⁶ A stamp, "Jews' College, London," appears on f. 1a; this manuscript has sometimes been considered to be in its collection.

¹⁷ See: Y. T. Langermann, "Arabic Writings in Hebrew Manuscripts: A Preliminary Relisting," *Arabic Sciences and Philosophy* 6 (1996): 137–160, esp. p. 147; M. Steinschneider, "Schriften der Araber in hebräischen Handschriften," *Zeitschrift der Deutschen Morgenländischen Gesellschaft* 47 (1893): 335–384, esp. 355–357. I am grateful to Tzvi Langermann for calling my attention to manuscripts B and J.

¹⁸ See: D. A. King, *Mathematical Astronomy in Medieval Yemen: A Bibliographical Survey* (Malibu, 1983), pp. 23–26; Y. T. Langermann, *The Jews of Yemen and the Exact Sciences* (Hebrew) (Jerusalem, 1987), pp. 25–26, 37.

¹⁹ For ease of comparison, I have transliterated a few terms that appear in this Arabic manuscript into Hebrew characters.

copyist's error for 60), but the entries are identical for each pair, beginning with 5 and 10.

In addition to these four, Tzvi Langermann had called my attention to two other versions of this table in Hebrew, which I have not transcribed:

Table E: This table is preserved in one manuscript: Paris, Bibliothèque nationale de France, MS héb. 1045, f. 74a [Q]. Here the colors of eclipses, in Hebrew only, are presented as part of an anonymous set of tables. The terminology in the headings differs from those in the other Hebrew versions: לוח לקורות החמה והלבנה (Table for solar and lunar eclipses); הריחוק מהתנן (elongation from the [lunar] node); חלקי רחב ללבנה (minutes of latitude for the Moon).

Table F: This table is preserved in one manuscript: Vatican, MS Heb. 498, f. 61a (numbered p. 64 of the tables) [Vd]. Here the colors of eclipses, in Hebrew only, are included in a set of astronomical tables by Solomon Franco (fourteenth century).²⁰ The headings for solar and lunar eclipses have been interchanged. Of special interest is that “blue” is called כחולה (solar eclipse, row 10), a term that occurs in none of the other Hebrew tables.

The Latin table is:

Table G: This table appears, with a few variants, in two early printed editions of the Alfonsine Tables: E. Ratdolt, ed., *Tabulae astronomice illustrissimi Alfonsij regis castelle* (Venice, 1483), f. 18v [R]; and P. Liechtenstein, ed., *Tabulae Astronomice Divi Alfonsi Regis Romanorum et Castelle* (Venice, 1518–1521), f. 116v [Li].²¹

Despite their differences, all the tables in Hebrew characters, as well as the *editio princeps* of the Alfonsine Tables, reflect the same tradition.

To help understand these tables, the general requirements for an eclipse are illustrated in Figure 1. The path of the Sun (S)—circle ASD—is called the ecliptic. The Sun moves in the direction of the arrow. The Moon (M) moves in the same direction as the Sun on a path inclined to the ecliptic by about 5° ; this path intersects the ecliptic at two points called the ascending node (A) and the descending node (D). The nodes move slowly in the direction contrary to the direction of solar motion. (If the nodes did not move, eclipses would always take place on the same day of the year.) A solar eclipse can take place only when the Sun and the Moon are near the same node; the solar elongation from the node is shown here as arc AS; the corresponding lunar latitude, measured on a great circle perpendicular to the ecliptic, is shown as arc SM. Points S and M are said to be in conjunction; if the conjunction of the Sun and the Moon takes place too far from the node, no eclipse occurs because the bodies of the Sun and the Moon, as seen from the Earth, do not overlap. For a lunar eclipse to take place, the Sun and the Moon have to be near opposite nodes. In this case, S is 180° from the Sun and is the center of the shadow. (At the time of a lunar eclipse, the Sun, the Earth, and the Moon are aligned, and the shadow cast by the Earth is seen on the Moon.) Then AS is the elongation of the shadow and SM is the lunar latitude at the time of the eclipse. The tables use the

²⁰ For the identification of this manuscript, see Y. T. Langermann, "Two Astronomical Treatises by Solomon Franco," *Kiryat Sefer* 59 (1984): 637–638 [in Hebrew].

²¹ In the Hebrew translation (ca. 1460) of the Latin version of the Alfonsine Tables by Moses ben Abraham of Nîmes, there are tables with headings for the colors of eclipses but no entries in them: see Munich, MS Heb. 126, f. 111b. The headings in this manuscript are *לוח מצבעי לקות חמה* and *לוח מצבעי לקות לבנה*, which seem to be literal (and unidiomatic) translations of the Latin.

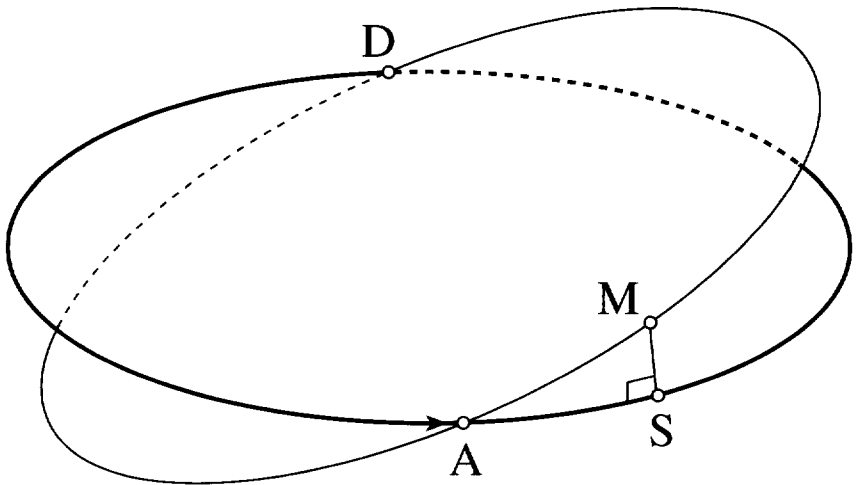


Fig. 1. Requirements for Solar and Lunar Eclipses

elongation (in degrees) of the Sun from a node as the argument for a solar eclipse, and the lunar latitude (in minutes) as the argument for a lunar eclipse. The magnitude of an eclipse is measured in “digits,” where one digit is one-twelfth of the diameter of the eclipsed body.

Table A

The entries in this table are entirely in Hebrew characters: one column gives the colors in Hebrew, the other in Arabic. For ease of reading, the tables for solar and lunar eclipses have been separated and rearranged slightly (see Fig. 2: a facsimile of the table as it appears in MS Va, f. 13b). In this table (and in **B**) there is no Hebrew word for “gray” (Arabic: *أشهب*); instead, the phrase “black tending towards white” is employed. This can be compared with **E**, which has *מטפר* for “earthy [color]”

(solar eclipse, row 5) and מעופר בהיר for “clear, earthy [color]” (solar eclipse, row 6); and with F, which uses עפורית צלולה for “limpid, earthy [color]” (solar eclipse, row 5): all apparently referring to shades of gray.

Arabic terms in standard form are: ביאץ, אביץ (white); בצרה (green); חמרה (red); זרקה (blue); אסוד (black); אשהב (gray); אצפר, צפרה (yellow); אגבר (murky or dusty); and אכחל (kohl [= black]). The same term is not always spelled consistently in different entries.²²

לוח השנים לתקופת המצרים והירישים

שנת הירישים	שנת המצרים	שנת הירישים	שנת המצרים
א	גדול השחוקה	שנה לאסוד	שנה לאסוד
ב	גדול השחוקה	אסוד אצל	גדול השחוקה
ג	עבור אדמות	אגבר בצורה	אסוד בצורה
ד	עבור צהי כוכ	אגבר בצורה	אסוד ברקוק
ה	שחור נעק ללון	אשהב	אסוד בצורה
ו	שחור נעק ללון	אשהב	אסוד בצורה
ז	שחור נעק ללון	אשהב	אסוד בצורה
ח	שחור נעק ללון	אשהב	אסוד בצורה
ט	שחור נעק ללון	אסוד ברקוק	אגבר
י	שחור נעק ללון	אסוד ברקוק	אסוד בצורה
יא	שחור נעק ללון	אצפר	אסוד בצורה
יב	שחור נעק ללון	אצפר	אסוד בצורה

Fig. 2. Va: Vatican, MS Heb. 379, f. 13b (upper left only). Photo courtesy of the Biblioteca Apostolica Vaticana

Table of the Colors of Solar and Lunar Eclipses
 לוח הגונים ללקיות השמיים והירחיים

[I: Colors of Solar Eclipses]

	[Hebrew]	[Arabic]
Elongation of the Sun from the [lunar] node [a] מרחק השמש מהקשר	Color of solar eclipses גון הלקיות השמיים	
1	great blackness גדול השחרות	great blackness שדיד שלאסואד [b]
2	great blackness גדול השחרות	black, kohl אסוד אכחל [c]
3	reddish murkiness עכור אדמוני [d]	murky with red אגבר בחמרה
4	murky with yellowness עכור בצהיבות	murky with yellow אגבר בצופרה [e]
5	black tending towards white, pure שחור נוטה ללובן זך [f]	gray אשהב [g]
6	black tending towards white שחור נוטה ללובן [f]	gray אשהב [h]
7	black tending towards white שחור נוטה ללובן [i]	gray אשהב [h]
8	black tending towards white שחור נוטה ללובן [i]	gray אשהב [j]
9	black tending towards bluish שחור נוטה לתכליתי [k]	black with blue אסוד בזרוקה [l]
10	black tending towards bluish שחור נוטה לתכליתי [m]	black with blue אסוד בזרוקה [n]
11	yellow tending towards bluish צהוב {שחור} נוטה לתכליתי [o]	yellow אצפר
12	yellow tending towards white צהוב נוטה ללובן [p]	yellow with white אצפר בביוצה [q]

- a. For קשר as “lunar node,” see B. R. Goldstein, *Ibn al-Muthannā’s Commentary on the Astronomical Tables of al-Khwārizmī* (New Haven, 1967), p. 325, line 8 [Hebrew], corresponding to p. 120, line 27 [English]; cf. **B** and **G**. P: אצבעות קיטר החמה (digits of the solar diameter). In *Almagest* VI.8, the magnitude of solar eclipses is measured in digits from 0 to 12.²³
- b. Vb: שדיד אלסואד.
- c. P: במתל[ה] (the same as above; lit. “like it”).
- d. P: עבור אדומי.
- e. P: אגבר אשהב.
- f. P: שחור ללובן.
- g. P: אסוד אלאביץ (black, white); Vb: blank.
- h. P: איצא (also, i.e., “ditto”).
- i. P: ג[ם] כ[ן] (also, i.e., “ditto”).
- j. P: איצא; Vb: blank.
- k. P: שחור ללובן תבלתי.
- l. Vb: blank.
- m. P: כמיהו (the same as above; lit. “like it”).
- n. P: איצא; Vb: blank.
- o. Va: שחור (crossed out and replaced by צהוב); P and Vb: צהוב.
- p. P: צהוב ללובן.
- q. P: אצפר לאביץ; Vb: אצפר אלביוצה.

²² Long and short vowels are not properly distinguished, e.g., in the table for lunar eclipses, row 20, כַּרְרָה should be כֶּרְרָה. In some cases, the *waw* (for *ū*) has been misplaced; e.g., in the table for solar eclipses, rows 9 and 10, זורקה should be זורקה (for זורקה). In Hebrew, a *waw* indicating a short *u* would be considered *plene* spelling.

²³ G. J. Toomer, *Ptolemy’s Almagest* (New York and Berlin, 1984), p. 306.

[II: Colors of Lunar Eclipses]

	[Hebrew]	[Arabic]
[a]	Color of lunar eclipses גון הלקיות הירחיים	
10	great blackness גדול השחרות	great blackness שדיד אלסואד
20	black with greenness שחור בירוקות	black with green [b] אסוד בכוצרה
30	black with redness שחור באדמימות	black with red [c] אסוד בחומרה
40	black with yellowness שחור בעהיבות	black with yellow [d] אסואד בצופרה
50	black with murkiness שחור בעכירות	murky [e] אגבר
60	black tending towards white [f] שחור נוטה ללבן	gray [g] {שחור} אשהב

- a. No heading in Va and Vb; P: דקי מרחב [הירח] (minutes of [lunar] latitude). Another column in P (not shown) is headed: אצבעות קוטר הירח (digits of the lunar diameter), with entries from 1 to 24. In *Almagest* VI.8 the magnitude of lunar eclipses is measured in digits from 0 to 21 (plus “entire”).²⁴ In the Tables of Levi ben Gerson (d. 1344), the magnitude of lunar eclipses is measured in digits from 0 to about 24 (the maximum is 23;59 when the Sun is at perigee and 24;24 when the Sun is at apogee).²⁵
- b. P: אסוד פאכצ'ר (black then green)
- c. P: אסוד פאחמר (black then red).
- d. P: אסוד פאצפר (black then yellow).
- e. P: אסוד אגבר.
- f. P: שחור ללבן.
- g. Va: שחור (crossed out and replaced by אשהב); P: אסוד לאביץ (black towards white); Vb: אשהב.

Table B

Hebrew only. As we learn from A, the expression “black tending towards white” means “gray.”

Colors [a] of solar and lunar eclipses at eclipse-middle
עיני הלקויות השמשיים והירחיים בעת אמצע הלקות

Elongation of the Sun from the node	Colors of solar eclipses	
מרחק השמש מהקשר	עיני הלקויות השמשיים	
1	גדול השחרות	great blackness
2	גדול השחרות	great blackness
3	עבור אדמומי [b]	reddish murky
4	עבור בצדיבות	murky with yellowness
5	שחור נוטה ללובן	black tending towards white
6	שחור נוטה ללובן	black tending towards white
7	שחור נוטה ללובן	black tending towards white
8	שחור נוטה ללובן	black tending towards white
9	שחור נוטה ללובן תכליתי	black tending towards bluish white
10	שחור נוטה ללובן תכליתי	black tending towards bluish white
11	צהוב	yellow
12	צהוב נוטה ללובן	yellow tending to white

- a. For עין meaning “color,” see J. Klatzkin, *Thesaurus Philosophicus Linguae Hebraicae* (New York, 1968), 3:130.
b. S: עבור באדמימות (murky with reddishness).

²⁴ Ibid., *Almagest*, p. 307.

²⁵ See B. R. Goldstein, *The Astronomical Tables of Levi ben Gerson* (New Haven, 1974), pp. 123–128, 208–209.

Minutes of lunar latitude דקי מרחב הירח	Colors of lunar eclipses עיני הלקיות הירחיים	
10	גדול השחרות	great blackness
20	שחור בירקות	black with greenness
30	שחור באדמימות	black with reddishness
40	[a] שחור ב[צהיב]ות	black with yellowness
50	שחור בעכירות	black with murkiness
60	שחור נוטה ללבן	black tending towards white
90 [b]	שחור נוטה ללבן	black tending towards white

- a. S: שחור בצהיבות (black with yellowness).
b. This row is also in S. Cf. G (below): the variant in Li has a different color.

Table C

Hebrew only.

Table for the colors [a] of solar eclipses
לוח מראי לקיות השמש

Elongation from the tail or the head מרחק מהזנב או הראש [b]	Colors of solar eclipses מראי לקיות השמש	
1	שחור	black
2	ירוק	green
3	צהוב	yellow
4	אדמדם	reddish
5	שחור מאד	black, red
6	שחור אדום	very black
7	שחור	black
8	שחור אדום	black, red
9	אדום	red

10	צהוב	yellow
11	ירוק	green
12	שחור	black

- a. For מראה meaning “color,” see Klatzkin, *Thesaurus*, 2:274.
- b. This reading is uncertain because of the poor quality of the film available to me. *Tail* and *head* refer to the lunar descending and ascending nodes, respectively.

Table for the colors of lunar eclipses
לוח מראי לקיות הירח

Lunar latitude רוחב הירח	Colors of lunar eclipses מראי לקיות הירח	
0	שחורה מאד	very black
10	שחורה ירקוקה	greenish black
20	שחורה ירוקה	black, green
30	שחורה אדומה	reddish black
40	שחרחרת	blackish
50	שחרחרת	blackish

Table D

Arabic in Hebrew characters.

Colors of eclipses
אלואן אלכסופאת

Colors of solar eclipses
אלואן אלכסופאת אלשמסייה

Degree of the solar elongation from the head or the tail [a] דרג בעד אלשמס מן אלראס או אלדנב [b]	L		Variants in Ca
1	שדיד אלסואד	great blackness	אסוד שדיד [c] אלסואד
2	אסוד כאחל	black, kohl	[d] אסוד אלכחל
3	אגבר בחמרה	murky with red	
4	אגבר בצפרה	murky with yellow	
5	אגבר צאפי	murky, clear	
6	אגבר אשהב	murky, gray	
7	אשהב	gray	
8	אשהב	gray	
9	אשהב	gray	
10	אשהב בזרקה	gray with blue	
11	אצפר	yellow	
12	אצפר אלי ביאץ	yellow [tending] to white	

- a. *Head* and *tail* refer to the lunar ascending and descending nodes, respectively.

- b. Ca 50r: בעד אלשמט מן אלגוהר (elongation of the Sun from the [lunar] node). Ca 117r: אלבעד מן אלגוהר (elongation from the [lunar] node).
 c. Ca 50r. Ca 117r = L.
 d. Ca 50r and 117r.

Lunar latitude ערץ אלקר	Colors of lunar eclipses אלואן אלכסופאת אלקררייה [a]	
10	אסד שדיד אלסואד	black, great blackness
20	אסד בכצרה	black with green
30	אסד בחמרה	black with red
40	אסד בצפרה	black with yellow
50	אגבר	murky
60	אשהב	gray

- a. [אלכסופאת Ca 50r and 117r: אלכסופאת (lunar eclipses).

Table G

Latin.

Table of colors of solar eclipses
Tabella de coloribus eclipsis solis

(°)	Elongation from the [lunar] node	
g	<i>longitudinis a nodo</i>	
1	<i>nigrum pressum</i>	black, deep
2	<i>nigrum obscurum</i>	black, dark
3	<i>fuscum in rubore</i>	murky with red
4	<i>fuscum in croceo</i>	murky with yellow
5	<i>fuscum clarum</i> [a]	murky, clear [a]
6	<i>fuscum rubeum</i>	murky, red
7	<i>ruffum</i>	ruddy
8	<i>ruffum</i>	ruddy
9	<i>rubeum</i> [b] <i>glaucum</i> [c]	red, bluish-gray [c]
10	<i>ruffum</i> [d] <i>glaucum</i>	ruddy, bluish-gray
11	<i>croceum</i>	yellow
12	<i>croceum album</i>	yellow, whitish

- a. Cf. **D**: “murky, clear”; **F**: “earthy, limpid.”
- b. Li: *ruffum*.
- c. In medieval Latin *glaucus* has a range of meanings: the primary meaning is “blue” or “bluish-gray,” but in some contexts it designates “green” or “greenish-gray.”²⁶
- d. Li: *rubeum*.

[Table of] colors of lunar eclipses
De coloribus eclipsis lune [a]

ab	1	in 10	<i>nigrum pressum</i>	black, deep
a	10	in 20	<i>nigra cum viriditate & aureo</i>	black with green and golden
a	20	in 30	<i>nigrum subrubeum</i>	black, reddish
a	30	in 40	<i>glauco</i> [b] <i>cum pallore</i> [c]	bluish-gray with pallor [c]
a	40	in 50	<i>pallida & grisea</i>	pale and gray
a	30 [d]	in 60	<i>grisea cum albedine</i>	gray with whiteness

- a. Li has the heading: *Tabella de coloribus Eclipsium Lune*; and a subheading: *m[in.] Latitudinis*. The arguments in Li are simply 10, 20, ..., 60, 90, and the entry for 90 is *ruffum* (ruddy).
- b. Li: *glaucum*. The form *glauco* is inappropriate here and is normalized in Li to *glaucum*. Based on comparable texts in Latin, Arabic, and Hebrew, one would expect *nigra* (black).²⁷
- c. The Arabic term for *yellow* can also mean “pallor.”
- d. Read: 50 (instead of: 30).

Summary

Tables 1 and 2 present a synoptic view of the entries in these tables (somewhat simplified). Judging from **A**, which gives both Arabic and Hebrew terms (and from **D**, which gives only Arabic terms), a paraphrase was used to render “gray” in Hebrew; in Tables 1 and 2 I have just used “gray” rather than the paraphrase found in **A** and **B**. For solar eclipses it is clear that **C** represents a tradition that is somewhat different from the other texts: the entries for 7 to 12 are very nearly those for 1 to 6, in reverse order. The term *glaucum* for arguments 9 and 10 in

²⁶ See J. André, *Étude sur les termes de couleur dans la langue latine* (Paris, 1949), pp. 162, 175–178, 275.

²⁷ See, e.g., Table A; Pedersen, *Toledan Tables*, pp. 652–653.

G has been translated “bluish-gray” to conform with the corresponding entries in **A**, **B**, **D**, and **F**. For lunar eclipses, some entries in **C** differ from the corresponding entries in the other texts. It is clear, however, that all the tables for the colors of eclipses ultimately derive from a single source.

Table 1. Colors of Solar Eclipses

	A	B	C	D	G
1	great blackness	great blackness	black	great blackness	black
2	great blackness	great blackness	green	black	black
3	reddish murkiness	reddish murky	yellow	murky with red	murky with red
4	murky with yellowness	murky with yellowness	reddish	murky with yellow	murky with yellow
5	gray	gray	black, red	murky, clear	murky, clear
6	gray	gray	very black	murky, gray	murky, red
7	gray	gray	black	gray	ruddy
8	gray	gray	black, red	gray	ruddy
9	black towards bluish	black towards bluish	red	gray	red [a], bluish-gray
10	black towards bluish	black towards bluish white	yellow	gray with blue	ruddy [a], bluish-gray
11	yellow	yellow	green	yellow	yellow
12	yellow with white	yellow with white	black	yellow with white	yellow, whitish

- a. Judging from **A** and **B**, perhaps this is a mistake for “black,” or possibly “gray” (as in **D**).

Table 2. Colors of Lunar Eclipses

	A	B	C [a]	D	G [b]
10	great blackness	great blackness	greenish black	great blackness	black, deep
20	black with greenness	black with greenness	black, green	black with green	black with green and golden
30	black with redness	black with redness	reddish black	black with red	black, reddish
40	black with yellowness	black with yellowness	blackish	black with yellow	bluish-gray [c] with pallor
50	murky	black with murkiness	blackish	murky	pale and gray
60	gray	gray	—	gray	gray with white
90	—	gray	—	—	ruddy [d]

- a. **C** has entries for rows for 0 to 50 instead of the usual rows for 10 to 60; the entry for the row for 0 is “very black.”
- b. **G** has arguments at the left in the form “from ... to”
- c. Perhaps a mistake for “black.”
- d. In **L**; no entry in **R**.

Appendix A: Danjon's color scale²⁸

L = 0	Very dark eclipse. Moon almost invisible, especially at mid-totality.
L = 1	Dark eclipse, gray or brownish in coloration. Details distinguishable only with difficulty.
L = 2	Deep red or rust-colored eclipse. Very dark central shadow, while outer edge of umbra is relatively bright.
L = 3	Brick-red eclipse. Umbral shadow usually has a bright or yellow rim.
L = 4	Very bright copper-red or orange eclipse. Umbral shadow has a bluish, very bright rim.

Appendix B: Ibn al-Muthannā

An anonymous Hebrew translation of Ibn al-Muthannā's *Commentary on the Astronomical Tables of al-Khwārizmī* (not extant in the original Arabic) provides the evidence that al-Khwārizmī presented a table for lunar eclipses. This text also offers a theory of the colors of eclipses:²⁹

The colors [גוני] of lunar eclipses that he [al-Khwārizmī] mentioned are composite colors, but the essence of their nature is the color [white] that brings about the other colors; namely, by acting on blackness [שחורות], which is affected by whiteness [ליבן] as an opposite. For whiteness is light and its opposite, darkness, is blackness. When they [white and black] are mixed, many colors result. Thus, when whiteness is mixed [בשנתרכב]³⁰ with something else, viz. a little blackness, yellowness [ירוקות] results. ... If this yellowness is mixed with some murky light

[אור עכור], then redness [ארמימות] is obtained, ... and if [this yellowness] is mixed with pure blackness then greenness with the color of leek [ירוקות בעץ כרתן] results. For this reason, at sunset the horizon appears to be red, as is the case for walls that the light of the Sun still reaches. It is possible that this greenness [ירוקות] depends on the amount mixed with the yellowness [ירוקות] resulting from the white and [*lit.* or] the black.

It is unfortunate that in this text *yellow* and *green* are represented by the same word. The terminology is clarified in Ibn Ezra's paraphrase of Ibn al-Muthannā's text, which survives in Latin:³¹

De coloribus eclipsis: Sciendum colores compositos ex nigro et albo, albedo vero clara, nigredo obscura, si vero parum nigredinis albo misceatur croceus fit. ... fit rubeum. ... viridim fit.

...

Here we see different words for yellow [*croceus*] and green [*viridis*]. Note that Ibn Ezra has "colors of eclipses" rather than colors of lunar eclipses.

The theory of color formation reported by Ibn al-Muthannā was not associated solely with eclipse theory; rather, it was part of the Platonic and Aristotelian traditions that had entered Arabic philosophy.³²

²⁸ A. Danjon, "Relation entre l'éclairement de la lune éclipsee et l'activité solaire," *Bulletin de la Société Astronomique de France* 35 (1921): 261–265, esp. p. 262.

²⁹ Goldstein, *Muthannā*, p. 327 [Hebrew].

³⁰ With Oxford, Bodleian Library, MS Michael 400, f. 68v.

³¹ J. M. Millás, *El libro de los fundamentos de las Tablas astronómicas de R. Abraham Ibn Ezra* (Madrid and Barcelona, 1947), p. 167.

There is no reason to believe that al-Khwārizmī accepted this theory of mixtures, since he was generally responding to a Hindu astronomical tradition in which the colors of eclipses were discussed without reference to any theory to account for them.

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³² See, e.g., Plato, *Timaeus*, 68b–c [F. M. Cornford, *Plato's Timaeus* (New York and London, 1959), pp. 80–81]; see also Goldstein, *Muthannā*, p. 234.