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Levi ben Gerson's Preliminary Remarks for a Theory of Planetary Latitudes

Levi ben Gerson (Gersonides, 1288–1344) of Orange, France, was the most original medieval astronomer who wrote in Hebrew; his achievements were at the same level (or higher) than those of his Muslim and Christian contemporaries. One of his goals was to improve on Ptolemy's account of planetary motion and to describe physically real models. His *magnum opus, The Book of Astronomy (Sefer ha-tekunah)*, consists of 136 chapters and forms Book V, Part 1, of Levi's *Wars of the Lord*. But the *Astronomy* survives in manuscripts that are different from those that preserve the other books of Levi's philosophical work.[1] A

1 For a list of the manuscripts of Levi's astronomical works, see B. R. Goldstein, *The Astronomical Tables of Levi ben Gerson* (New Haven, 1974), pp. 74–83; for a list of manuscripts of Levi's *Wars of the Lord*, see C. Sirat, "La tradition manuscrite des *Guerres du Seigneur*," in *Gersonide en son temps: Science et Philosophie médiévale*, ed. G. Dahan (Louvain-Paris, 1992), pp. 301-328. See also B. R. Goldstein, "Levi ben Gerson's Contributions to Astronomy," in *Studies on Gersonides: A Fourteenth-Century Jewish Philosopher-Scientist*, ed. G. Freudenthal (Leiden, 1992), pp. 3–19. For a chronology and references to recent literature, see J. L. Mancha, "Levi ben Gerson's

Latin translation of the *Astronomy* made during Levi's lifetime includes only the first 110 chapters.[2]

Levi's models for planetary longitudes are described in several chapters of his *Astronomy;* they depart from Ptolemy's models, which were widely accepted in the Middle Ages. Even more surprising, however, is that Levi takes issue with Ptolemy's theories of planetary latitude, a topic that received little attention from most medieval astronomers.[3] The alternatives to Ptolemy's latitude theories in the Middle Ages were the Hindu models, represented in tabular form in the zij of al-Khwārizmī (ninth century), and those of Naṣīr al-Dīn al-Ṭūsī (thirteenth century).[4] Levi proposed models for planetary latitudes that are difficult to interpret; in this preliminary account I omit his detailed descriptions of them in chapters 124 and 125. The focus here will be on the chapters that precede and follow the technical discussion, namely, chapters 123, 126, and 127. We offer translations of these chapters together with an edited Hebrew text based on the two extant manuscripts: Paris, Bibliothèque Nationale de France [BNF], MS héb. 724 [P]; and Paris, BNF, MS héb. 725 [Q]. The sentence numbers and paragraph divisions are mine.

In P, there is a table of contents that has the following titles for chapters 123 to 127:[5]

* Chapter 123. In this chapter we will explain that it is impossible for orbs to have poles as this term is generally understood (*lit.* as it is thought), but they are called poles metaphorically (*lit.* according to the extension of language).
* Chapter 124. In this chapter we present some proposals for determining how to complete [the description of] the apparent motion in latitude for the planets from what was assumed for the model (*ha-tekunah*) of the orbs.
* Chapter 125. How to complete the apparent motion in latitude for each of the planets.
* Chapter 126. In this chapter we explain that the observations do not

agree with what follows from Ptolemy's [models] for the motion in latitude of the planets from place to place, even though his parameters for the extrema are correct, except in a few cases where he was forced to treat them according to his principles rather than according to observation.

* Chapter 127. In this chapter we construct the tables for the inclination of the planets.

Chapter 123 is a kind of philosophical introduction to the theory of planetary latitudes. A key expression in it is *qeṭavim remuzim*, here translated "definite poles." This meaning of *ramuz* is otherwise unrecorded and is based on the context.[6] There is a similar passage in book ii of Ptolemy's *Planetary hypotheses* (cf. chap. 123:14, below):

Astronomical Work: Chronology and Christian Context," *Science in Context* 10 (1997): 471–493.

2 J. L. Mancha, "The Latin Translation of Levi ben Gerson's *Astronomy*," in *Studies on Gersonides*, ed. G. Freudenthal, pp. 21–46; G. Dahan, "Les traductions latines médiévales des oeuvres de Gersonide," in *Gersonide*, ed. Dahan, pp. 329–368.

3 For Ptolemy's theories of planetary latitude in the *Almagest* and the *Handy Tables*, see O. Neugebauer, *A History of Ancient Mathematical Astronomy* (Berlin–New York, 1975), pp. 206–226, 1006–1016.

4 E. S. Kennedy and W. Ukashah, "Al-Khwārizmī's Planetary Latitude Tables," *Centaurus* 14 (1969): 86–96; F. J. Ragep, "The Two versions of the Ṭūsī Couple," *Annals of the New York Academy of Sciences* 500 (1987): 329–356.

5 E. Renan and A. Neubauer, "Les écrivains juifs français du XIVe siècle," *Histoire littéraire de la France* (Paris, 1893), 31:351–789, esp. 630–631 (repr. ed. Westmead, 1969).

6 See J. Klatzkin, *Thesaurus philosophicus linguae hebraicae et veteris et recentioris* (New York, 1968), 4:43; for *ramuz*, the closest rendering he offers is "bestimmt," i.e., fixed, determined, ascertained.

> And, in general, if it is difficult to conceive celestial motion without (the aid of) fixed poles (*aqṭāb thābita*), it should be much more difficult to conceive the nature (*māhiyya*) of these poles, and how by their means the concave surface of the surrounding spheres is connected to the convexity (*bi-ḥadabati*) of the surrounded spheres, (and also more difficult to conceive) the thing by virtue of which these poles partake of (the nature of) each one of (those spheres). For if we took (the poles) to be points, then we would be connecting bodies by something incorporeal . . . (trans. A. I. Sabra).[7]

Levi had a copy of the Hebrew translation of Ptolemy's *Planetary hypotheses*;[8] the passages he quotes from it in various places in his *Astronomy* agree with the unique extant manuscript (Paris, BNF, MS héb. 1028). For example, in Levi's *Astronomy*, chap. 29 (P 48a),[9] there is a quotation taken verbatim from the Hebrew version of Ptolemy's *Planetary hypotheses*, book ii (Paris, BNF, MS héb. 1028, f. 75a).[10] In medieval astronomical treatises there are relatively numerous allusions to book i of the *Planetary hypotheses* (in which Ptolemy describes his system of planetary distances and sizes). But the situation is different for book ii: whereas extensive discussions are found in Arabic, there are very few such discussions in Hebrew (or Latin) and none as detailed as those in Levi (as far as I know).[11]

In this passage, the Arabic version of Ptolemy's treatise uses a term for "fixed" (*thābita*) that is translated as *qayyam* in the Hebrew version (Paris, BNF, MS héb. 1028, f. 73b:18), rather than Levi's *ramuz*. In my view, Levi intends something a bit different. His argument is that since a point is an abstract mathematical object, it cannot be the cause of the motion of a physical body. Moreover, the transmission of motion cannot be due to pegs (or protuberances), as is the case for rotating bodies in the sublunary world, because they are inappropriate for celestial bodies. In chap. 45, Levi elaborates this comment while justifying an equant point in a planetary model:

> [P 88a:13; Q 65a:31]. And with this it is clear that there is a complete resolution of these doubts that the celestial bodies do not have poles about which their motion takes place. This is because poles of this description are necessary for the existence of artificial spheres in a given place and for moving them about

7 For the Arabic text, see B. R. Goldstein, "The Arabic Version of Ptolemy's *Planetary Hypotheses*," *Transactions of the American Philosophical Society* (Philadelphia, 1967), NS 57.4, p. 38:20ff. The corresponding passage in the Hebrew version is Paris, BNF, MS héb. 1028, 73b:18–74a:1.

8 G. E. Weil, *La Bibliothèque de Gersonide d'après son catalogue autographe* (Louvain-Paris, 1991), pp. 47, 108 (item 39): *Sippur tenuʿot ha-kokavim ha-nevukim li-Baṭlamyus*. The Arabic text of Ptolemy's *Planetary hypotheses* is notoriously difficult and the Hebrew version is a rather literal translation of it.

9 B. R. Goldstein, "Preliminary Remarks on Levi ben Gerson's Cosmology," in *Creation and the End of Days*, ed. D. Novak and N. Samuelson (Lanham, Md., 1986), pp. 261–276, esp. 273.

10 Cf. R. Glasner, "Gersonides on Simple and Composite Movements," *Studies in the History and Philosophy of Science* 28 (1997): 545–84, esp. p. 568 n. 132.

11 For discussions in Arabic, see, e.g., A. I. Sabra, "Ibn al-Haytham's Treatise: Solution of Difficulties Concerning the Movement of *Iltifāf*," *Journal for the History of Arabic Science* 3 (1979): 388–422. It is often assumed that *On the Configuration of the World* (*Maqāla fī hayʾat al-ʿālam*) by Ibn al-Haytham (d. *c.* 1040) is based on Ptolemy's *Planetary hypotheses*, but Langermann has argued persuasively that this is not true. This treatise was available in medieval Hebrew and Latin versions as well as in the original Arabic. See Y. T. Langermann, *Ibn al-Haytham's* On the Configuration of the World (New York and London, 1990), pp. 11–25 and 34–41.

the poles of that very sphere. [Such poles] protrude and may enter in both bodies, fixed at [opposite] ends of the sphere; or they may be in [one] body at [opposite] ends of the sphere, and these protruding pegs enter the second sphere at both ends. [Such a sphere] needs these poles to maintain its position (*maṣav*) in its motion so that it will not roll (*mitgalgel*) but move only by rotation.[12] But a celestial body has no need of these poles because its existence and the existence of its position is by itself, and its motion is about something inside it. Therefore it is clear that it has no poles except by way of analogy. For if it had poles, their existence would be by necessity (*ᶜal ṣad ha-hekreaḥ*),[13] and this is absurd because the form of these pegs is inappropriate for what is in the heavens. This does not need further explanation for the reader of this book; and Ptolemy in his book, *On the description of the motion of the planets,* argued at length that celestial bodies do not have poles. From this discussion [*lit.* place] all doubts are removed from what we explained concerning the orb that does not move about its center, and it follows from this that the poles of this motion are not at definite (*mugbal*) places on the moving sphere, but their place varies on this sphere at different times. This doubt is resolved by what I say, namely, we do not ascribe poles to the orb except accidentally (*be-miqreh*). Therefore, it [a pole] is not prevented from being at one time opposite one part of the sphere and at another time opposite another part of the sphere. In this way, the doubts that were thought possible concerning what was explained previously about the necessity of an orb that does not move about its center are resolved. [P 88a:30; Q 65b:8]

Levi also alludes to the view he expressed in chap. 29 of his *Astronomy* (and elsewhere), namely, that the surrounded orb is the cause of motion of the orb surrounding it.[14] In that case, he asks, how can the element of fire (the highest of the sublunary elements), which is surrounded by the orb of the Moon, have pegs affixed to it? The same difficulty applies to the lowest orb for each planet because, according to Levi, there is a fluid layer between adjacent sets of planetary orbs.[15] By *ramuz* Levi intended to deal with all these cases. Levi resolved this difficulty by remarking in chap. 123:7 that the planetary orbs are animate, a claim that is repeated in chapter 125: "This motion of a celestial body that does not have definite poles [affixed] to it is possible in so far as [a celestial body] is an animate being, and it has some unusual properties" (P 241a:1-3; Q 212a:31-32).[16] A similar view is also expressed in book ii of Ptolemy's *Planetary hypotheses.*[17]

12 In a philosophical context, *maṣav* corresponds to Latin *situs* (Klatzkin, *Thesaurus*, 2:250) and, indeed, this is the word used in the Latin translation of this passage. According to Ḥasdai Crescas (d. 1412), "[by] position (*maṣav*) is meant the relation of the respective parts of a body to each other and the relation of the body as a whole to other bodies" (H. A. Wolfson, *Crescas' Critique of Aristotle* [Cambridge, Mass., 1929], p. 307); cf. Aristotle, *Topics*, i.9:103b, ed. and trans. E. S. Forster (Cambridge, Mass., 1960), p. 293. Note that P has the preferred reading, *mitgalgal* (roll), whereas Q has *meha-galgal* (from the orb); the letters *he* and *tav* are easily confused. On rolling *versus* rotation, see Aristotle, *On the Heavens*, ii.8:290a, ed. and trans. W. K. C. Guthrie (Cambridge, Mass., 1960), p. 187.

13 See the parallel passage in chap. 123:8, below.

14 Goldstein, "Preliminary Remarks," pp. 269–273.

15 B. R. Goldstein, "Levi ben Gerson's Theory of Planetary Distances," *Centaurus* 29 (1986): 272–313.

16 See also Glasner, "Gersonides on Simple and Composite Movements," pp. 577f.

17 A. I. Sabra, "The Andalusian Revolt against Ptolemaic Astronomy," in *Transformation and Tradition in the Sciences*, ed. E. Mendelsohn (Cambridge, 1984), pp. 134–153, esp. 150 n. 29.

In chap. 126, Levi alludes to his own observations of planetary latitude in chap. 122,[18] although none of them is cited in chapters 124 and 125 as the data that need to be satisfied by the theory. The general idea seems to be that while Ptolemy's data are adequate in most cases, his models to account for them are faulty. Levi notes that in the *Almagest* Ptolemy does not cite dated observations of planetary latitudes, in contrast to his practice for observations of planetary longitudes. He then recommends a practice that is found in the *Almagest*, but not in the section on planetary latitude—observing a planet with the Moon.[19] Levi continues with a remark that his parameter for the maximum latitude of the Moon, $4\frac{1}{2}°$, is different from Ptolemy's value, 5°, and his values for lunar parallax differ from Ptolemy's as well (lunar parallax depends on the distance of the Moon from the Earth at a given moment in time: for Ptolemy this distance varies greatly, whereas for Levi it varies hardly at all). Ptolemy does not cite observations at mid-heaven (the point where the ecliptic intersects the meridian above the horizon) for planetary latitude, but he does use this method for determining his parameter for the lunar latitude.[20] The next difficulty that Levi discusses is that Ptolemy's value for the obliquity of the ecliptic, 23;51°, differs from Levi's own value, 23;33°, by 0;18°. Levi then suggests that Ptolemy's observational instruments introduced errors that were not taken into account, as was already mentioned in chap. 3 of his *Astronomy*. Levi also describes a number of improvements for various astronomical instruments.[21]

In the next section, Levi considers the possibility that Ptolemy's observations depended on the position of a fixed star in order to determine the latitude of a planet. But this method has a problem because, in Levi's view, Ptolemy's positions for the fixed stars were faulty. As evidence, he cites an error of 0;22° in Ptolemy's position of Aldebaran.[22] Levi concludes that the errors can be avoided by the proper use of the instrument he invented, the Staff (later known as the cross-staff), described in the early chapters of his *Astronomy*.[23]

Chapter 127 was to include tables for planetary latitude, but they are not preserved in any extant manuscript. This is most unfortunate, for tables often yield many valuable clues that are not easily extracted from the relatively clumsy way in which mathematical ideas were expressed in words in the Middle Ages.

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Translation

[P 237a:1; Q 209a:1] Chapter 123. [1] The motion in latitude can be imagined, upon initial reflection, only if the poles of the orb of the planet move about other poles so that the planet is sometimes to the north and sometimes to the south; hence we should investigate if it is possibly so for the apparent motions in latitude of the planets. [2] We say that it is already clear from what was explained for the motions of

18 B. R. Goldstein, "A New Set of Fourteenth-Century Planetary Observations," *Proceedings of the American Philosophical Society* 132 (1988): 371–399, esp. 396–398.

19 See, e.g., *Almagest*, x.4; G. J. Toomer, *Ptolemy's Almagest* (New York, 1984), p. 474.

20 See *Almagest*, v.12 (Toomer, pp. 246f).

21 B. R. Goldstein, *The Astronomy of Levi ben Gerson (1288–1344)* (New York, 1985), pp. 27–30, 132–134; for Levi's suggestions on improving the astrolabe, see pp. 82–85 and 162–170.

22 B. R. Goldstein, "Levi ben Gerson's Analysis of Precession," *Journal for the History of Astronomy* 6 (1975): 31–41, esp. 36 and 41. See also J. L. Mancha, "Levi ben Gerson's Star List for 1336," *Aleph* 2 (2002): 31–57.

23 Goldstein, *The Astronomy of Levi ben Gerson*, pp. 51–73, 143–158.

the orbs of the motion in anomaly that it is impossible to assign to the orbs definite poles (*qeṭavim remuzim*) about which these motions take place. [3] This is because, if the motion took place about poles of this description, its center would always be on the diameter that passes from one pole to the other. [4] It would then follow of necessity, if the motion took place about those poles that move about the poles of the lower orb of anomaly, that the center of the motion of the upper orb of anomaly would move about the center of the lower orb of anomaly, and this is contrary to what was explained, for we have shown that the center of the upper orb of the motion in anomaly is necessarily fixed on the diameter of the orb of the apogee. [5] Therefore, it is clear in this respect that it is impossible to assign to these orbs definite poles about which they move.

[6] It is also clear that it is inappropriate to assume that the orbs have poles like the poles of rotating bodies in our [sublunary world], for [the nature of] the heavens precludes protuberances similar to pegs that are needed to maintain their position (*maṣav*), for the shape of the orbs must be perfectly spherical whereas these poles in our [world] require inanimate bodies to maintain their position. [7] But in the case of the celestial bodies, this is not needed since their existence is by itself, for they are neither light nor heavy, as is explained in natural science and, moreover, they are animate and therefore do not need anything like such poles to maintain their position. [8] Further, if the matter were so, their existence in a certain position would be by necessity (*ᶜal ṣad ha-heḵreaḥ*), and this is precluded for these bodies, as will be explained later. [9] In addition, if the matter were assumed to be so, it would be impossible for these protuberances to be on the surrounding orb, for it moves with the motion of the orb surrounded by it. [10] Therefore, it would follow that they are on the convexity of the surrounded orb, but I will not conjecture how it is possible to put solid protuberances on the convexity of the element of fire [in a way for them] to be poles for the lowest of the lunar orbs.

[11] This argument applies to the lowest orb of every planet, for it is impossible to set solid protuberances on the body that does not maintain its shape [i.e., the celestial fluid] that is below it. [12] If we assume that these poles lie on the very orbs that move [i.e., not on a surrounding or surrounded orb], then they would necessarily be points, for it cannot be imagined that a part of a rotating sphere does not move. [13] This would imply that a body depends on something that has no existence except by itself, and this is absurd. [14] Therefore, it is clear that it is impossible to assign definite poles for these orbs about which this motion takes place, and Ptolemy was forced to agree that the orbs do not have poles of this description, as he mentioned in his book, *On the description of the motion of the fixed* [sic] *stars.*[24] [End chap. 123]

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[P 244a:5; Q 214b:33] Chapter 126. [1] You should understand from the observations of the motion in latitude that we mentioned, which are undoubtedly true, that the matter of the inclinations of the planets is not as Ptolemy assumed; nevertheless, the arrangement of their inclination conforms approximately to what Ptolemy decided. [2] I think that Ptolemy was unsure of the amount of the inclination in some places for the following reasons. [3] Among them is that one of best ways to attain this knowledge is [to observe] the Moon with each of the planets, for in this way the latitude [of the Moon] relative to that planet is known [Q 215a] by observation. [4] Since the apparent latitude of the Moon is known, so is the latitude of that planet. [5] It is already clear from our remarks, without any doubt, that Ptolemy determined neither the true latitude of the Moon nor the true values for [lunar] parallax, for

24 The reference is clearly to the *Planetary hypotheses*, even though both manuscripts have "fixed stars" (*ha-kokavim ha-qayyamim*) instead of the expected "planets" (*ha-kokavim ha-nevukim*).

his principles closed the door before him and kept him from finding the truth in this matter. [6] Therefore it is clear that this is probably what led him to infer from many of his observations that the latitudes of the planets seen together with the Moon differ from what they [truly] are. [7] One of his ways for attaining this knowledge was based on finding the altitude of the planet when it is at mid-heaven for, if the altitude of the degree at which it is located on the orb of zodiac at mid-heaven is known, then the amount of its inclination is also known, because it is the difference between these altitudes. [8] But this also falls [into the category of] uncertainty because Ptolemy did not determine the true altitude of the orb of the zodiac, for he considered its inclination to the equator to be greater than the proper amount by 0;18°, and [also] because of the uncertainty in the position of the planet in longitude on the orb of the zodiac. [9] This is because if he determined this by observations made with the instrument that he mentioned in the *Almagest*, he would not have escaped error for many reasons, as we mentioned at the beginning of the book.

[10] And if he determined this by calculation derived from his model, there would be a deviation from the truth concerning the position of the planet in longitude for, as we explained in our preceding remarks, taking the altitude of the planet at night may well lead to an error that does not disappear, for many reasons. [11] Among them [i.e., the reasons for error] is that one way to attain this knowledge is to observe this planet with one of the fixed stars at the same longitude. [12] If the latitude of this planet relative to a fixed star is known, the latitude of the planet relative to the orb of the zodiac is also known, for the latitude of the fixed star is known. [13] It is clear that this observation will not yield the truth unless the latitude and longitude of the fixed star relative to the orb of the zodiac are already known. [14] But for some of the fixed stars it is already clear to us that Ptolemy did not determine their true positions in longitude and latitude relative to the orb of the zodiac, as is the case for Aldebaran for which we found

an uncertainty of 0;22° in its longitude, and similarly for its latitude although the amount of its deviation from the truth is not yet precisely known to us. [15] You may also determine that there is some uncertainty in the latitudes of the planets in general by using the instrument we made, namely, the Staff, to observe a planet with a fixed star when they are close to one another. [16] But if you compute the latitudes according to the computations of Ptolemy, significant errors will enter your computations [P 244b] due to the [erroneous] position of the planet in longitude. [17] You should determine this by observing some planet/star with another planet/star so that the effect of the error in the latitudes of the planets/stars will not be perceived in the motion in longitude, as we stipulated concerning the way to use this instrument. [18] In this way the uncertainty in the planetary latitudes first became evident to us, and for this [reason] we stipulated most of what we stipulated for the way to use this instrument. [19] We decided to mention this to you in advance in order that you would not be surprised that these models that we assumed for the inclinations of the planets do not agree with all that follows from Ptolemy's models, for he was led to them by his principles, not by sensory observation. [End chap. 126]

[P 244a:7; Q 215a:26] Chapter 127. [1] But how to construct tables for computing the motion in latitude according to the models that we mentioned ... [a long gap follows—most of two pages in P, and most of 4 pages in Q; just before the beginning of chap. 128 there is a short poem that Levi composed in praise of God for helping him to describe the planetary models.]

ספר התכונה לר׳ לוי בן גרשום

[פ 237א, ק 209א] **הפרק המאה ועשרים ושלשה.**[1] [1] ולפי שתנועת הרחב לא תצוייר בתחלת המחשבה אלא כשיתנועעו קטבי גלגל הכוכב סביב קטבים אחרים ולזה יהיה הכוכב פעם לפאת צפון ופעם לפאת דרום הנה ראוי שנעיין אם הוא אפשר שיהיה כן באלו התנועות הנראות ברחב לכוכבים.[2] [2] ונאמר שכבר התבאר[3] ממה שהתבאר מאלו התנועות אשר לגלגלי תנועת[4] החלוף שאי אפשר שיונחו קטבים רמוזים באלו הגלגלים עליהם תהיינה אלו התנועות. [3] וזה כי מפני שמרכז התנועה כשהיתה על קטבים בזה התאר הוא תמיד על הקוטר ההולך מאחד מהקטבים אל האחר. [4] הנה היה מחויב אם היתה התנועה על אותם[5] הקטבים המתנועעים סביב קטבי גלגל תנועת[6] החלוף השפל {שיהיה מרכז תנועת גלגל החלוף העליון[7] מתנועע סביב מרכז גלגל החלוף השפל}[8] וזה חלוף מה שהתבאר מזה[9] וזה שכבר התבאר חיוב היות מרכז גלגל תנועת החלוף העליון קיים על קוטר אופן הגובה. [5] ולזה הוא מבואר מזה הצד שאי אפשר שיונחו באלו הגלגלים קטבים רמוזים עליהם תהיה תנועתם.

[6] וגם כן הנה הוא מבואר שאין ראוי שיונחו בגלגלים קטבים כדמות הקטבים אשר יונחו למתנועעים בסבוב אשר אצלינו כי אין ראוי שיהיה בשמים תוספות בולטות בדמות[10] יתדות עליהם יתקיים מצבם לפי שתמונת הגלגלים ראוי שתהיה שלמת הכדוריות עם שאלו הקטבים יצטרכו לגשמים אשר אצלינו הבלתי בעלי נפש לקיים מצבם. [7] ואולם בגרמים השמימיים לא יצטרך זה לפי שקיומם הוא בעצמם כי אינם לא קלים ולא כבדים כמו שהתבאר בטבעיות ועוד שהם בעלי נפש ולזה לא[11] יצטרכו לדמיון אלו הקטבים לשמר מצבם. [8] וגם כן הנה[12] אם היה הענין כן הנה יהיה קיומם במצב שהם בו על צד ההכרח וזה

1 פ: הקכ״ג (וכדומה לכל הפרקים).

2 פ: לרוב הכוכבים.

3 ק: יתבאר.

4 פ: תנועות.

5 פ: אותן.

6 פ (למעלה) ק (חסר).

7 פ: השפל.

8 פ (בשולים) וק: שיהיה... השפל.

9 פ (חסר).

10 פ: כדמות.

11 ולזה לא] פ: ולא.

דבר בלתי ראוי באלו הגרמים כמו שיתבאר במה שיבא. [9] ועוד שאם הונח הענין כן הנה הוא בלתי אפשר שתהיינה אלו התוספות בגלגל המקיף כי הוא מתנועע בתנועת המוקף בו. [10] ולזה יחוייב שתהיינה בגבנונית הגלגל המוקף ולא אשער איך יתכן שיונחו תוספות בולטות מקשיות בגבנונית יסוד האש יהיו קטבים לגלגל השפל מגלגלי הירח.

[11] וזה הבטול יקרה בכל גלגל שפל {שבגלגלי כוכב וכוכב[13] כי לא יתכן שיונחו אלו התוספות הבולטות[14] המקשיות בגרם}[15] הבלתי שומר תמונתו אשר תחתיו. [12] ואם הנחנו שיהיו אלו הקטבים בגלגלים המתנועעים בעצמם הנה יחויב שיהיו נקדות כי לא יצוייר שיהיה חלק בכדור המתנועע בסבוב שלא יתנועע. [13] ויחוייב מזה שיתקיים הגשם במה שאין לו מציאות אלא בו וזה בטל. [14] ולזה הוא מבואר שאי אפשר שיונחו לגלגלים קטבים רמוזים[16] עליהם תהיה זאת התנועה וכבר הוכרח גם כן בטלמיוס שיסכים שאין לגלגלים קטבים בזה התאר כבר זכר זה בספרו בספור תנועת הכוכבים הקיימים.

12 פ (חסר).

13 פ: כוכב.

14 פ: בולטות.

15 פ (בשולים) וק: שבגלגלי... גרם.

16 רמוזים] ק: כמו אליהם.

* * *

[פ 244א, ק 214ב] **הפרק המאה ועשרים וששה.** [1] וראוי שתבין ממה שזכרנו ממבטי תנועת הרחב שאין ספק באמתתם שאין הענין בנטיות הכוכבים על האופן שהניח בטלמיוס אבל על כל פנים ימצא הסדור בנטייתם באופן יאות למה שהסכים בו בטלמיוס בקירוב. [2] ואחשב כי נעלם מבטלמיוס שעור נטייתם במקום מקום לסבות. [3] מהם כי אחד מהצדדים אשר תגיע בו זאת הידיעה יותר הוא מפאת הירח כשהיה עם כוכב כוכב והיה מרחבו מהכוכב ההוא ידוע [ק 215א] במבט. [4] וכשיודע מרחב הלבנה הנראה תודע מזה ידיעת[1] מרחב הכוכב ההוא. [5] וכבר התבאר[2] מדברינו במה שאין ספק באמתתו שלא עמד בטלמיוס על אמתת מרחב הירח האמתי ולא על אמתת התחלפות ההבטה כי שרשיו סגרו הדלת בפניו ממצוא האמת בזה. [6] ולזה הוא מבואר שזה היה אפשר שהביאהו ברבים מהמבטים להניח מרחב הכוכבים הנראים עם הירח על זולת מה שהם מהמרחב. [7] ומהם כי אחד מהצדדים

1 פ (הרשמט).

2 ק: נתבאר.

אשר הגיע בו זאת הידיעה הרבה הוא מפני ידיעת גובה הכוכב בהיותו בחצי השמים כי כשתודע גובה המעלה שהוא בה מגלגל המזלות בחצי השמים יודע שעור הנטיה מפני חלוף אלו הגבהים. [8] ובזה גם כן היה נופל מההעלם מפני שלא עמד בטלמיוס על אמתת גובה גלגל המזלות כי הוא היה משים נטייתו מאופן המישור יותר מהראוי כמו י״ח דקים ומפני ההעלם במקום הכוכב בארך מגלגל המזלות. [9] וזה שאם היה נודע לו במבט בכלי שזכר בספר[3] המג׳סטי הנה לא ימלט מהטעות לסבות רבות כמו שזכרנו בראש זה המאמר.

[10] ואם נודע לו לפי החשבון המתחייב מתכונתו הנה יקרה בו נטיה מהאמת במקום הכוכב בארך כמו שהתבאר מדברינו במה שקדם עם שלקיחת גובה הכוכב בלילה הוא ממה שיקרה בו מהטעות מה שלא יעלם לסבות רבות. [11] ומהם כי אחד מהצדדים אשר תגיע בו זאת הידיעה הוא כשיובט זה הכוכב עם אחד מהכוכבים הקיימים השוה לו בארך. [12] וכשיודע מרחב זה הכוכב מהכוכב הקיים יודע מרחבו מאופן המזלות מפני הידיעה במרחב הכוכב הקיים. [13] והוא מבואר שזה המבט לא יתן האמת אם לא יודע תחלה מרחב הכוכב הקיים ומקומו בארך מגלגל המזלות. [14] כבר התבאר לנו בקצת הכוכבים הקיימים שלא עמד בטלמיוס באמתות על מקומם מגלגל המזלות בארך וברחב כמו הענין בעין השור שמצאנו בו מההעלם[4] בארך כמו כ״ב דקים וגם ברחב מצאנו בו מההעלם אלא שלא נתבאר לנו על נכון שעור הנטייה מהאמת בו. [15] וכבר תעמד על מה שיש מההעלם במרחבי הכוכבים בכלל בכלי המקל אשר לנו כאשר תביט בו כוכב רץ עם כוכב קיים והיו קרובים זה לזה. [16] שאתה אם תחשב המרחבים לפי חשבון בטלמיוס יקרה בחשבונך הרבה מהטעות [פ 244ב] במקום הכוכב בארך. [17] וכבר תעמד על זה כשתביט איזה כוכב[5] עם כוכב אחר שלא יתן רושם הטעות במרחבי הכוכבים מה שיורגש בו בחשבון תנועת הארך כמו שהתנינו באופן ההשתמשות בזה הכלי. [18] ומזה הצד נתבאר[6] לנו תחלה ההעלם אשר במרחבי הכוכבים ולזה התנינו רוב מה שהתנינו באופן ההשתמשות בזה הכלי. [19] והנה ראינו להקדים לך זה שלא תפלא אם לא יסכימו אלו התכונות שהנחנו בנטיות הכוכבים לכל מה שיתחייב מתכונת בטלמיוס כי הוא הוכרח בזה מצד שרשיו לא מצד החוש.

הפרק המאה ועשרים ושבעה. [1] ואולם איך יהיה מעשה לוחות חשבון תנועת הרחב לפי התכונות שזכרנו [חלק].

3 ק: מספר

4 ק: מההעלם בו.

5 ק: אז זה הכוכב.

6 פ: התבאר.