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ASTRONOMY AND ASTROLOGY IN THE WORKS OF ABRAHAM IBN EZRA*

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Abraham ibn Ezra the Spaniard (d. 1167) was a prolific scholar, deeply familiar with Arabic sources. He wrote in Hebrew on a variety of subjects and is perhaps best known for his Biblical commentaries.[1] He also devoted much of his attention to astronomy and astrology; yet, surprisingly, the most comprehensive study of his efforts in these disciplines is still the article published many years ago by Millás.[2] To be sure, an article on Ibn Ezra appeared in the *Dictionary of Scientific Biography*, but the author's ignorance of the research done by Millás (among others) makes it largely devoid of value.[3] It is therefore most welcome that a fine study of Ibn Ezra's astrology in the context of the history of Jewish thought has recently appeared, and this article is intended to complement it.[4]

Ibn Ezra was one of the foremost transmitters of Arabic scientific knowledge to the West: his works were widely copied in Hebrew and translated into a number of European languages. Moreover, his writings preserve valuable information concerning Islamic astronomical works that are no longer extant, and

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[1] See, for example, U. Simon, *Four Approaches to the Book of Psalms from Saadiah Gaon to Abraham ibn Ezra* (Albany, 1991), which has a useful bibliography; for biographical details and a discussion of Ibn Ezra's non-conformist attitudes, see A. Graboïs, "Le non-conformisme intellectuel au XII[e] siècle: Pierre Abélard et Abraham ibn Ezra," in M. Yardeni (ed.), *Modernité et non-conformisme en France à travers les âges* (Leiden, 1983), pp. 3-13.

[2] J. M. Millás Vallicrosa, "El magisterio astronómico de Abraham ibn Ezra en la Europa latina," in *Estudios sobre historia de la ciencia española* (Barcelona, 1949), pp. 289-347.

[3] M. Levey, "Abraham ibn Ezra," in *Dictionary of Scientific Biography*, vol. IV (1971), pp. 502-3.

[4] See Y. T. Langermann, "Some astrological themes in the thought of Abraham ibn Ezra," in I. Twersky and J. M. Harris (eds.), *Rabbi Abraham ibn Ezra: Studies in the Writings of a Twelfth-Century Jewish Polymath* (Cambridge, Mass., 1993), pp. 28-85.

for this reason they have been helpful in a number of reconstructions of early Islamic astronomy. The treatment of Ibn Ezra's endeavors in astronomy and astrology are scattered in many books and articles written since Millás's pioneering essay of 1949, and our goal will be to present a summary of this recent literature.

Some of his astrological treatises were translated into French by a certain Hagin le Juif (1273) at the request of Henry Bate of Mechelen who then translated the French into Latin (1281); other medieval Latin translations from the French also survive.[5] On the basis of the Latin versions, Ibn Ezra was considered an authority on astrology by many medieval Christian scholars, and his works were particularly influential after their publication in 1485 and 1507.[6] There is also an extant medieval Catalan version of Ibn Ezra's *Book of Nativities*, and another (lost) Catalan version seems to have served as the basis for a Latin translation in 1448.[7]

It has long been known that Ibn Ezra was responsible for the availability of a great deal of Arabic science in Hebrew and Latin: here we will only give a few examples to illustrate the way he transmitted the results of his predecessors and had an impact on his successors writing in Hebrew and Latin. We will limit our discussion to (1) Ibn Ezra's translations of treatises that are no longer extant in the original Arabic, (2) his own works that provide information about Arabic astronomy that is otherwise poorly preserved (if at all), (3) astrological doctrines known from no source prior to him, (4) astrological doctrines for which he was cited as an authority by later Hebrew and Latin authors, (5) his linguistic innovations in scientific terminology, and (6) his role in establishing a Hebrew tradition of star lists.

1.

Ibn Ezra translated some Arabic works into Hebrew that do not survive in the original, notably, Ibn al-Muthannā's *Commentary*

[5] R. Levy, *The Beginning of Wisdom: An Astrological Treatise by Abraham ibn Ezra* (Baltimore, 1939), p. 14.

[6] R. Levy, *The Astrological Works of Abraham ibn Ezra* (Baltimore, 1927), pp. 62 ff; L. Thorndike, *A History of Magic and Experimental Science* (New York, 1923), vol. II, pp. 926-30.

[7] Levy, *Astrological Works*, pp. 51-3.

on the Astronomical Tables of al-Khwārizmī and Māshā'allāh's *Book of Eclipses*.[8] Al-Khwārizmī's treatise (early 9th century) is a very important witness for the early stages of Islamic astronomy in the late 8th and early 9th centuries. But the problems concerning the history of this treatise are considerable because the original Arabic only survives in a Latin translation by Adelard of Bath (early 12th century) of an Arabic version made in Spain by Maslama al-Majrīṭī (ca. 1000). Moreover, Ibn al-Muthannā's *Commentary* (10th century) is lost in the original Arabic and only survives in Hebrew and in Latin. Finally, there are two Hebrew versions of this commentary: the one by Ibn Ezra which is short and incomplete, and another longer one which is anonymous.[9]

Since Ibn al-Muthannā's *Commentary* was composed prior to the Majrīṭī version, it gives us some access to the original form of al-Khwārizmī's tables. So, for example, the original tables were arranged for the Persian calendar whereas the surviving version is arranged for the Arabic (or Hijra) calendar.[10] Moreover, in analyzing the tables for planetary latitude in the published Latin version of al-Khwārizmī's tables, it was noticed that al-Khwārizmī had followed the Hindu procedure for the most part, but one set of entries had values about double the expected ones. The explanation was found by looking at the commentaries on these tables by Ibn al-Muthannā and a certain Ibn Masrūr which describe the procedure underlying the computed entries.[11]

In the introduction to his translation of Ibn al-Muthannā's *Commentary*, Ibn Ezra describes the early stages of astronomy among the Arabs as follows:

> In ancient days, neither wisdom nor religion was found among the Arabs who dwell in tents, until the author of the Koran arose and gave them a new religion from his heart. After him came wise men who composed many books on their religious law until there arose a great king of the Arabs whose name

[8] B. R. Goldstein, *Ibn al-Muthannâ's Commentary on the Astronomical Tables of al-Khwârizmî* (New Haven, 1967); *id.*, "The book on eclipses of Masha'allah," *Physis*, 6 (1964): 205-13.

[9] For the discovery of a second copy of the anonymous version, see B. R. Goldstein, "The Hebrew astronomical tradition: New sources," *Isis*, 72 (1981): 237-51, esp. p. 250.

[10] Goldstein, *Muth.*, p. 191.

[11] E. S. Kennedy and W. Ukashah, "Al-Khwārizmī's planetary latitude tables," *Centaurus*, 14 (1969): 86-96.

was al-Ṣaffāḥ [*read:* al-Saffāḥ]. He heard that in India there were many sciences, and so he ordered that a wise man be sought, fluent in both Arabic and the language of India, who might translate one of the books of their wisdom for him. He thought some mishap might befall the translator because profane sciences were still unknown in Islam. They had only the Koran and wise traditions which they received from Muḥammad. He was told by certain people that there was a very distinguished book concerning counsels for government in the manner of fables from the mouths of dumb animals and that it contained many illustrations pleasing to the eye of the reader. The name of the book is *Kalila wa-Dimna*, which means the lion and the bull, and it is so called because they are spoken of in the first chapter. [Al-Saffāḥ] fasted from that day in the hope that the angel of dreams might appear and permit the book to be translated for him into Arabic. Then in a dream he saw what he had hoped for. So he sent for a Jew who knew both languages and ordered him to translate the book, for he feared that if an Arab were to translate the book, he might die. When he saw how wonderful the book was, for so it truly is, he yearned for more knowledge of the sciences of India, as may be seen. He gave great wealth to the Jew who translated that book so that he might travel to the city of Arin on the equator under the signs of Aries and Libra, where day is equal to night throughout the year, neither shorter nor longer, thinking, "perhaps he will succeed in bringing one of their wise men to the king." So the Jew went and indulged in many subterfuges after which, for a large sum, one of the wise men of Arin agreed to go to the king. The Jew swore to him that he would detain him for only one year and that he would return him to his home. The scholar, whose name was Kanaka, was brought to the king, and he taught the Arabs the basis of numbers, i.e., the nine numerals. Then, from this scholar, with the Jew as Arabic-Indian interpreter, a scholar named Jacob b. Sharah translated a book containing the tables of the seven planets, all the procedures for the earth, the rising times of the zodiacal signs, the declination and the ascending degree of the ecliptic, the arrangement of the astrological houses, knowledge of the upper stars, and eclipses of the luminaries. But there is no mention in his book of the reasoning in all these matters: only facts are given as matters of tradition.[12]

Ibn Ezra's report may tell us more about the way scientific texts were translated in Spain than the method used in Baghdad in the late eighth century. David Pingree has collected the fragments that describe the arrival of Hindu astronomy in Baghdad, and the story is less dramatic than Ibn Ezra's version; moreover, nothing is said about the participation of Jews in this transmission. At the time of the caliph al-Manṣūr (754-775), the successor to al-Saffāḥ (750-754), a Sanskrit astronomical work was brought to Baghdad by a member of an embassy from Sind

[12] Goldstein, *Muth.*, pp. 147-8.

(in India). The arrival of this embassy was probably in A.H. 154 (= 771) or 156 (= 773). It has been argued that the Andalusian identification of the member of the embassy as Kanaka, the astrologer of Hārūn al-Rashīd (786-809), is unjustified.[13] Ibn Ezra's Jacob b. Sharah is presumably a corrupt form of Ya'qūb ibn Ṭāriq who wrote a zīj based on the *Sindhind* that al-Fazārī had translated from Sanskrit. According to the account of Ibn al-Adamī, as quoted by al-Qifṭī and by Ṣā'id al-Andalusī, we learn that "al-Manṣūr ordered the translation of this book [i.e., the Sanskrit astronomical treatise] into Arabic, and that there should be written from it a book that Arabs might use as a basis for the motions of the planets. Muḥammad ibn Ibrāhīm al-Fazārī was put in charge of this; and he made of it a book which the astronomers called *al-Sindhind al-kabīr*."[14] It is also noteworthy that Ibn Ezra generally avoids polemics in his description of Islam, e.g., referring to the *ḥadīth* as "wise traditions." But his characterization of Islam as a new religion that the author of Koran "gave them ... from his heart" (i.e., invented) would be rejected by all Muslims, and has the style of Rabbinite polemics against the Karaites, a Jewish sectarian movement.[15] His allusion to an early translation of *Kalila wa-Dimna* is more or less correct, for Ibn al-Muqaffa' translated that work from Pehlevi into Arabic ca. 762, i.e., there was a Persian intermediary stage between the Indian text and the Arabic version that Ibn Ezra seems not to have been aware of.

Later in his introduction, Ibn Ezra lists a number of prominent Arab astronomers whose works he consulted, including: Yaḥyā ibn Abī Manṣūr (d. ca. 832), Ḥabash al-Ḥāsib (d. ca. 874), Thābit ibn Qurra (d. 901), al-Battānī (d. 929), Ibn al-A'lam (d. 985), 'Abd al-Raḥmān al-Ṣūfī (d. 986), and Ibrāhīm al-Zarqāllu (fl. 1080).[16] He states that "there is no difference between Ptolemy's rules for planetary motion and those of the Hindu

[13] D. Pingree, "The fragments of the works of Ya'qūb ibn Ṭāriq," *Journal of Near Eastern Studies*, 27 (1969): 97-125, esp. p. 98; *id.*, "The fragments of the works of al-Fazārī," *Journal of Near Eastern Studies*, 29 (1970): 103-23.

[14] Pingree, "al-Fazārī," p. 106.

[15] I am most grateful to Dr. Langermann for bringing this argument to my attention.

[16] Goldstein, *Muth.*, p. 150; cf. J. M. Millás Vallicrosa, *El libro de los fundamentos de las Tablas astronómicas de R. Abraham ibn Ezra* (Madrid/Barcelona, 1947), p. 76, where a similar list, with the notable addition of Ibn Yūnus (d. 1009), is to be found; E. S. Kennedy, *A Survey of Islamic Astronomical Tables*, Transactions of the American Philosophical Society, vol. 46.2 (Philadelphia, 1956).

scholar, except in a few places"[17]; in this respect he agreed with Ibn al-Muthannā who also wished to harmonize Greek and Hindu astronomy, but the fundamental differences between these two modes of doing astronomy eluded both scholars.

The Hebrew versions of Ibn al-Muthannā's commentary have been very useful for interpreting a set of canons for tables with Toledo as the meridian preserved in a Latin manuscript, Oxford, Merton College, 259.[18] One section of this manuscript follows quite closely the canons of the Khwārizmī tables as reported by Ibn al-Muthannā, but the Latin author probably had access to them from a different source.

Māshā'allāh's *Book of Eclipses* is an astrological work that includes a discussion of the natures of the zodiacal signs as well as of an astrological theory of world history. Ibn Ezra clearly indicates in various treatises that he accepted the astrological theory of world history based on conjunctions of Saturn and Jupiter that played an important role in the works of Māshā'allāh (d. 815), among others. Here we are told:

> Māshā'allāh said that a conjunction of the planets indicates the future in general. Note when outer planets are in conjunction with inner planets. This is an indication of good if the benevolent planets are strong in the horoscopic diagram. But if the malevolent planets are strong, it is an indication of evil. Note that if the malevolent planets are in conjunction in [some] zodiacal sign, it is an indication of evil according to [the nature of that] zodiacal sign. If they are in conjunction in an aquatic sign, it is an indication of destructive rain, and similarly in other zodiacal signs. ... Māshā'allāh said that great events occur on account of the conjunction of the outer planets because they are slow-moving. ... A great conjunction is an indication of the rising of prophets and seers ... .[19]

In a previous passage, Ibn Ezra translated what Māshā'allāh had to say about the natures of the zodiacal signs: one way of defining their nature is to associate a set of three zodiacal signs with one of the elements (fire, water, earth, air); a second way is to consider that male zodiacal signs are hot, and female are cold; and a third way is to associate the zodiacal signs with the seasons such that four of them are variable (for in them the

[17] Goldstein, *Muth.*, p. 149.

[18] This text has been analyzed in F. S. Pedersen, "Alkhwarizmi's astronomical rules: Yet another Latin version," *Cahiers de l'Institut du moyen-âge grec et latin*, Université de Copenhague, 62 (1992): 31-75.

[19] Goldstein, "Masha'allah," p. 211.

seasons change), four are strong (for in them the season becomes strong), and four are temperate (for in them the season becomes mixed).[20]

In this translation of Māshā'allāh's text an analogy is drawn between heavenly influences on the terrestrial realm and the attraction of iron by a magnet: thus, astrological influences were understood to be in the category of physical phenomena. The only earlier cosmological reference to magnetism I have found appears in a Hindu text of the sixth century by Varāha Mihira.[21]

2.

Ibn Ezra also wrote a work, *De rationibus tabularum* (extant only in Latin) which, according to Millás, he composed in Latin; however, it is perhaps more likely that Ibn Ezra composed this text in Hebrew and that the Latin is simply an anonymous translation.[22] This text includes many paraphrases drawn from Ibn Ezra's translation of Ibn al-Muthannā's treatise. For example, the treatment of trigonometry in *De rationibus tabularum* is explicitly based on an Indian tradition reported in Ibn al-Muthannā's treatise: "*Nunc verba Avenmucenne ponemus de cordis que dixit in expositione tabularum racionis Alcauresmi secundum indos*"[23]; which is paralleled in Ibn Ezra's translation of Ibn al-Muthannā's *Commentary*: "In this book we will follow the Hindu procedure [in matters of trigonometry]."[24] The discussions that follow are remarkably similar to one another. This Latin treatise also seems to contain the earliest occurrence of the term *almanac* whose ultimate origin is unknown.[25]

A table of "the sine of the hours," appended to a treatise on the astrolabe by al-Khwārizmī has recently generated some interest: on the basis, in part, of a passage in Ibn al-Muthannā's commentary, this table can now be safely attributed to al-

[20] *Ibid.*, p. 209.

[21] *Ibid.*, p. 206; cf. D. Pingree, "The Indian and Pseudo-Indian passages in Greek and Latin astronomical and astrological texts," *Viator*, 7 (1976):141-95, esp. p. 150.

[22] Millás, *Tablas*, p. 19; J. D. North, *Richard of Wallingford*, 3 vols. (Oxford, 1976), vol. II, p. 266.

[23] Millás, *Tablas*, p. 130.

[24] Goldstein, *Muth.*, p. 176.

[25] Millás, *Tablas*, p. 119; for details, see F. S. Benjamin, Jr., and G. J. Toomer, *Campanus of Novara and Medieval Planetary Theory* (Madison, 1971), p. 375.

Khwārizmī, and from it an underlying sine table can be reconstructed.[26] The table is based on a simple formula for computing the solar altitude at a given time if the noon solar altitude on that day is known (the time is measured in seasonal hours from sunrise). The formula is preserved in Ibn al-Muthannā's commentary and in Ibn Ezra's *De rationibus tabularum*.[27] Ibn Ezra's translation of Ibn al-Muthannā's commentary is incomplete, and the relevant section of that commentary is preserved in the anonymous Hebrew version but not in Ibn Ezra's version; the parallel passage in Ibn Ezra's other work suggests that the incompleteness of this translation is merely a function of the defectiveness of the only extant manuscript.

Many of al-Khwārizmī's astronomical rules derive from Brahmagupta's *Brāhmasphuṭasiddhānta* (= *BSS*, composed in 628). So, for example, we are given the rules for finding the apparent sizes of the Sun, the Moon, and the Earth's shadow based on the daily progress (called *bhukti* in Sanskrit from which comes the word *buht* or *elbuht* in the Latin version of al-Khwārizmī's tables).[28] These rules are described in Ibn al-Muthannā's commentary as well as in Ibn Ezra's *De rationibus tabularum*, and derive from *BSS* 4.4.[29] Again, the relevant passage is found in the anonymous Hebrew translation of Ibn al-Muthannā's commentary and in Ibn Ezra's *De rationibus tabularum*. For the computation of eclipses according to al-Khwārizmī, the Latin version of al-Majrīṭī's recension does not preserve the rules as well as Ibn al-Muthannā's commentary and Ibn Ezra's *De rationibus tabularum:* again, these passages are "remarkably similar" to those in chapter 4 of the *BSS*.[30]

Ibn Ezra's explicit reliance on lost works of al-Zarqāllu was most helpful for determining the latter's solar theory which was reconstructed from many references to it, including notices by Ibn Ezra.[31] As has long been recognized, this is the first such

[26] J. Hogendijk, "Al-Khwārizmī's table of the 'sine of the hours' and the underlying sine table," *Historia Scientiarum*, 42 (1991): 1-12.

[27] Goldstein, *Muth.*, p. 82, cf. pp. 207 f; Millás, *Tablas*, pp. 157 f: Hogendijk, "Sine table," does not refer to this latter passage.

[28] See O. Neugebauer, *The Astronomical Tables of al-Khwārizmī* (Copenhagen, 1962), p. 57.

[29] Goldstein, *Muth.*, pp. 104 ff, cf. pp. 229 f; Millás, *Tablas*, p. 166; Pingree, "Indian and Pseudo-Indian passages," p. 164.

[30] Pingree, "Indian and Pseudo-Indian passages," p. 165.

[31] G. J. Toomer, "The solar theory of az-Zarqâl: A history of errors," *Centaurus*, 14 (1969): 306-36.

theory to take into account the proper motion of the solar apogee, but many of the details were not adequately understood. Ibn Ezra clearly states that al-Zarqāllu distinguished three senses of the term "year" (tropical, sidereal, and anomalistic), and he preserves the best evidence for the value al-Zarqāllu assigned to the tropical year.[32]

3.

Some years ago I published a translation of the heading for an astronomical table in a Munich Hebrew manuscript: "Table of the arc for the hour for terrestrial latitude 44° according to the place of the Sun in the zodiac composed [with the aid of] the tables of the scholar Rabbi Levi ben Gerson, from which the [astrological] houses may be constructed and the aspects computed according to Ibn Ezra's method."[33] While the impact of Ibn Ezra's work on Levi ben Gerson (d. 1344), one of the foremost astronomers of the fourteenth century, is stated explicitly, this passage seemed to have no particular significance at the time I found it. However, John North has argued that Abraham ibn Ezra was the earliest scholar to record one of the seven methods for the setting up of the astrological houses. Although it is possible that Ibn Ezra was the inventor of this system, it may have been introduced by an unknown earlier scholar and merely reported by him.[34] On the basis of North's calculations, it was then possible to demonstrate that Levi computed the astrological houses for his prognostication of 1345 according to Ibn Ezra's method.[35]

4.

Levi ben Gerson's discussion of the consequences of the Saturn-Jupiter conjunction to take place in 1345 depended very heavily

[32] Millás, *Tablas*, pp. 79-83; cited in Toomer, "Solar theory," pp. 317 ff.

[33] B. R. Goldstein, *The Astronomical Tables of Levi ben Gerson* (New Haven, 1974), p. 81.

[34] J. D. North, *Horoscopes and History* (London, 1986), p. 25.

[35] B. R. Goldstein and D. Pingree, *Levi ben Gerson's Prognostication for the Conjunction of 1345*, Transactions of the American Philosophical Society, vol. 80.6 (Philadelphia, 1990), p. 6.

on Ibn Ezra's astrological doctrines even though this is not specifically acknowledged. Levi's text was retrospectively interpreted as foretelling the Black Death which spread through Europe not long after his own death, but there is no evidence to suggest he had this in mind. This prognostication was translated from Hebrew into Latin with the help of Levi's brother shortly after he died, and the Latin contains information missing in the unique Hebrew copy. Levi's principal source for the astrological theory of conjunctions was Ibn Ezra's *Book of the World*. For example, Ibn Ezra stated, following the view of Māshā'allāh, that one must investigate the positions of the planets at the conjunction and opposition of the Sun and the Moon prior to the vernal equinox of the year in which the conjunction of Jupiter and Saturn is to take place, and Levi complied with this instruction.[36] In another passage Levi says that the third astrological house indicates religion, although it is normally indicated by the ninth house. Again, Levi has followed the view of Ibn Ezra, using the same Hebrew term for religion (*emuna*).[37]

It is possible that Levi ben Gerson derived some of his astrological views from the Provençal philosopher, Levi ben Abraham ben Ḥayyim (ca. 1275), who paraphrased Ibn Ezra's astrological doctrines in his encyclopedic work, *Livyat Ḥen*, and expressed interest in the significance of the conjunction of 1345.[38] In one of the passages in Levi's prognostication preserved only in Latin, we learn that Pope Benedict XII (1334-1342), then resident in Avignon, consulted Levi concerning the astrological significance of a comet seen in 1339.[39]

Shortly after Levi's death in April 1344, a Latin astronomer, Johannes de Muris, was summoned to Avignon by Pope Clement VI (1342-1352) who wished to consult him on matters of astronomy and astrology. Johannes then wrote a prognostication based on the forthcoming conjunction of 1345 in which Abraham ibn Ezra is cited by name along with Māshā'allāh and other astrological authorities.[40] In it Johannes claimed that the

[36] Goldstein and Pingree, *Prognostication*, p. 46.

[37] *Ibid.*; cf. Levy, *The Beginning of Wisdom*, Heb. text, p. xli.

[38] G. Freudenthal, "Sur la partie astronomique du *Liwyat Ḥen* de Lévi ben Abraham ben Ḥayyim," *Revue des études juives*, 98 (1989): 103-12; Goldstein and Pingree, *Prognostication*, p. 3.

[39] Goldstein and Pingree, *Prognostication*, p. 32.

[40] *Ibid.*, pp. 35-9.

Jews "expect the Messiah before a conjunction of Saturn and Jupiter recurs, which will be within 10 years, rather than at another time,"[41] i.e., the Jews expect the Messiah in 1355. In fact, all the Jewish texts of the time indicate 1358 as the date for the Messiah; Levi had mentioned in his prognostication that a righteous (gentile) king would arise in 1355, but in his commentary on *Daniel* he agreed with the prevailing Jewish view that the Messiah will come in 1358.

As we learn from a Hebrew treatise composed in the 12th century by Abraham Bar Ḥiyya, messianic speculation based on the conjunction of 1345 long preceded the event. According to Boudet, this tradition of astrological eschatology based on Saturn-Jupiter conjunctions was appropriated (and reinterpreted) by scholars in Latin Christendom beginning in the mid-14th century and was still going strong in the 16th century.[42] Among the notable proponents of this theory was Pierre d'Ailly (d. 1420) who associated the coming of the Antichrist with a Saturn-Jupiter conjunction on the one hand, and the speculations of Hildegard on the other.

5.

Since Ibn Ezra was one of the first scholars to write on scientific subjects in Hebrew, he had to invent or adapt many Hebrew terms to represent the technical terminology of Arabic. Some of his coinages were widely accepted by later Hebrew authors, while many others were not. For example, Ibn Ezra applied the biblical term *muṣaq* (cf. Job 36:16) for the center of a circle, whereas most later writers used *merkaz* (from the Arabic: *markaz*).[43] Yet, Ibn Ezra introduced the term *yaiba* (= Ar. *jaib*) for sine, rather than consistently adopting a Hebrew word as others did.[44] In other cases, however, Ibn Ezra maintained earlier expressions rather than accept innovations. For example, he kept the Talmudic term *alakson* that originally meant the

[41] *Ibid.*, p. 37.

[42] J.-P. Boudet, "Simon de Phares et les rapports entre astrologie et prophétie à la fin du moyen âge," *Mélanges de l'École Française de Rome*, 102 (1990): 617-48.

[43] Cf. G. B. Sarfatti, *Mathematical Terminology in Hebrew Scientific Literature of the Middle Ages* [in Hebrew and English] (Jerusalem, 1968), p. 145.

[44] Goldstein, *Muth.*, Hebrew section, pp. 126 ff; cf. Millás, *Tablas*, pp. 130 ff, where the term *algeib* is used for sine in the Latin version of Ibn Ezra's text.

diagonal of a rectangle and used it for the diameter of a circle, whereas others (as early as Abraham Bar Ḥiyya) adapted the Arabic term *quṭr* which became *qoṭer* in Hebrew.[45]

6.

In his work on the astrolabe, entitled *Keli ha-neḥoshet* ("the instrument of brass"), Ibn Ezra includes a star list. There are two extant versions of Ibn Ezra's treatise, one dated 1146 which gives information on 36 stars, and one dated 1148 which gives information on only 23 of these 36 stars. Ibn Ezra's list has been shown to be closely related to one ascribed to al-Zarqāllu, even though Ibn Ezra does not give any indication of its origin.[46] The only other Hebrew star list that survives from the 12th century was compiled by Abraham Bar Ḥiyya of Barcelona who depended on al-Battānī's star catalogue.[47]

The Hebrew names for the stars in Ibn Ezra's list are closely related to their Arabic names, both of which are given: e.g., for γ Ori, the Arabic is *mankib al-jabbār al-aysar,* and the Hebrew is *shekhem ha-gibbor ha-semoli* (both the Hebrew and Arabic names mean: "the left shoulder of Orion"). Note that the biblical term for Orion, *kesil* (cf. Amos 5:8), has been replaced by *gibbor*, which in the Bible means "strong man" or "warrior" (cf. I Sam. 14:52). The star names were subject to corruption, most egregiously in the following example: the Hebrew name for α Hya is given in the manuscripts as "the red (*ha-adom*) that is in the neck of the victor," and the corrēsponding Arabic name for this star is given as "the rose (*al-ward*) that is in the neck of the courageous." But Ibn Ezra's Arabic term, *al-ward,* is a corruption of *al-fard* (the solitary). The final stage of corruption occurred in the printed ed. of 1845 where the Hebrew *ha-adom* has been further corrupted to *ha-arus* (the betrothed). In other words, by a series of textual errors we have moved from "solitary" in Arabic to "betrothed" in Hebrew!

[45] Sarfatti, *Mathematical Terminology*, pp. 77, 136; Goldstein, *Muth.*, Hebrew section, pp. 136-7.

[46] B. R. Goldstein, "Star lists in Hebrew," *Centaurus*, 28 (1985): 185-208, esp. pp. 196-7.

[47] Goldstein, "Star lists," p. 188; for additional star lists in Hebrew, see K. Fischer, P. Kunitzsch, and Y. T. Langermann, "The Hebrew astronomical Codex MS. Sassoon 823," *Jewish Quarterly Review*, 78 (1988): 253-92; and B. R. Goldstein and J. Chabás, "Ibn al-Kammād's star list," *Centaurus* (in press).

The stellar coordinates are the same in both versions of Ibn Ezra's treatise, but for textual corruptions in the manuscript tradition. Moreover, the stellar longitudes in this list are derived from an Arabic version of the star catalogue in the *Almagest* (rather than from the Greek original), as can be seen from an analysis of the "errors" in them.[48] This star list was clearly intended to aid an astrolabe maker and there are five extant astrolabes inscribed in Hebrew that seem to have been produced before the modern era (none of them is dated or signed). But the stars marked on these astrolabes are not always the same, and in no case do they agree with a list known from literary sources.[49]

In sum, Abraham ibn Ezra was more important as a transmitter of knowledge he obtained from Arabic sources than as an original scientific thinker, and through his efforts Arabic science reached medieval European Jews and Christians who were unable to read Arabic texts directly.

[48] Goldstein, "Star lists," p. 197.

[49] B. R. Goldstein, "The Hebrew astrolabe in the Adler Planetarium," *Journal of Near Eastern Studies*, 35 (1976): 251-60; B. R. Goldstein and G. Saliba, "A Hispano-Arabic astrolabe with Hebrew star names," *Annali dell'Istituto e Museo di Storia della Scienza di Firenze*, 8 (1983): 19-29; F. Maddison, "Description of a unique Judaeo-Arabic astrolabe," in *Christie's Sale Catalogue:* "Important Judaica 15 December 1988" (Amsterdam, 1988), pp. 88-95.