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Tycho Brahe, Abū Maᶜshar, and the *comet beyond Venus* (ninth century A.D.)

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Abstract

From his observations of the A.D. 1572 supernova and the A.D. 1577 comet, Tycho Brahe concluded that such transient celestial objects are outside the Earth's atmosphere, and he quoted the ninth century A.D. Persian astrologer and astronomer Abū Maᶜshar: *Dixit Albumasar, Cometa supra Venerem visus fuit*; i.e., the latter had reported much earlier that comets were seen beyond Venus. However, even from a more detailed Latin translation, the observations and logic behind Abū Maᶜshar's conclusion were not understandable. We present here the original Arabic text (manuscript Ankara, Saib 199) together with our translation and interpretation: Abū Maᶜshar reported that he had observed Venus in (or projected onto) the tail of a comet and concluded that the comet was behind Venus because he had observed the extinction of Venus due to the cometary tail to be negligible (*light of Venus was unimpaired*). He then concluded that the comet would be located behind Venus. He also mentioned that others had observed Jupiter and Saturn in cometary tails, so that those comets would even be located beyond those two outer planets – *in the sphere of the stars*. The dates of the

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observed close conjunctions were not mentioned; using known orbital elements for a few comets, we found a few close conjunctions between comets and planets from A.D. 770 to 868, but we cannot be sure regarding which conjunctions were reported. While the argument of Abū Maᶜshar is not correct (as cometary tails are optically thin), the conclusion – namely that comets are outside the Earth's atmosphere and beyond the moon – is correct. This may have helped Tycho Brahe to come to his revolutionary conclusion.

Keywords
Abu Mashar, al-kayd, comets, Tycho Brahe

Introduction

According to Aristotle's *Meteorology* (Book I, Chapter 6–7, 342 b 25 to 345 a 7), comets were long thought to be atmospheric phenomena. Tycho Brahe's work about the comet of A.D. 1577 is usually considered to be the first to show convincingly that comets are located outside the Earth's atmosphere, even beyond the Moon and among the planets.[1] Tycho Brahe, commenting on the classification of the (super-)nova of 1572 as a comet by Adam Ursinus, wrote that he does not want to discuss the astrological meaning of the nova but quoted Abū Maᶜshar indirectly through Adam Ursinus (A.D. 1524–1590) and Jerome Cardanus (A.D. 1501–1576):

> Id solummodo, quod in fine sui Scripti ex Aphorismo quodam Cardani (qui sic habet) citat: *Dixit Albumasar, Cometa supra Venerem visus fuit; non igitur in Elementari Regione est, contra Philosophum.*[2]

We translate this into English as follows:

> Just this, that he [Adam Ursinus], at the end of his work, quotes from a certain sentence of Cardanus (which is written there as follows): Albumasar said: A comet was seen above Venus; it is therefore not in the sphere of the [four] elements, contrary to the philosopher.

The citation was taken literally from Adam Ursinus, who took it from Jerome Cardanus (who has *cometes* instead of *cometa*); there is no additional information available in those two works.

The quoted scholar called by his Latin name *Albumasar* is the Persian astronomer and astrologer Abū Maᶜshar, his full name is *Abū Maᶜshar Jaᶜfar b. Muḥammad b. ᶜUmar al-Balkhī*.[3] He was born on A.D. 787 10 August (171 Hijra) in Balkh, Khurāsān[4] (now in Iran), he died on A.D. 886 9 March (272 Hijra).[5] Abū Maᶜshar lived mostly in Baghdad (Iraq) and started studying astronomy when he was already 47 years old – motivated by his colleague al-Kindī.[6] Abū Maᶜshar is mainly known for his astrological works, e.g. the *Introduction* (to astrology), translated to Latin by Johannes Hispalensis[7] (John of Seville) and then quoted very often, but he has also written about astronomical observations, e.g. in a *Zīj*, a list of stars and their parameters.[8] Aristotle's *Meteorology*

was translated into Arabic in the second half of the eighth century A.D.,[9] so that it was probably known to Abū Maᶜshar.

Given the short quotation from Tycho Brahe, it is necessary to find the original Arabic text, on which the quotation (through Cardanus) is based, in order to understand how Abū Maᶜshar, seven centuries before Tycho Brahe, concluded that comets are outside the Earth's atmosphere, even beyond Venus. While a Latin translation of the relevant text by Abū Maᶜshar is available, the logic behind his argument was not clear.[10]

We will present first the problem, namely, that the original Arabic text, upon which the Latin translation and the quotation by Tycho Brahe are based, was not yet used to understand how Abū Maᶜshar came to his conclusion (section "The problem: which Arabic work and text was quoted by Tycho Brahe?"). Then, we present the relevant Arabic original text together with our English translation (section "The solution: the original Arabic text of *Albumasar in Sadan*") and discuss the astronomical interpretation of the text (section "Astronomical interpretation of the Arabic text and Abū Maᶜshar's observation"). In section "Planet–comet conjunctions A.D. 750 to 886," we calculate and consider which comet–planet conjunctions Abū Maᶜshar and his colleagues may have observed, also taking into account historic Chinese and European observations. Finally, in section "Summary," we conclude with a summary.

The problem: which Arabic work and text was quoted by Tycho Brahe?

Goldstein[11] already tried to trace the quotation by Tycho Brahe (A.D. 1577) through Cardanus (A.D. 1547) as far back as possible. He quoted a work by Fortunio Licetus (A.D. 1577–1657)[12] as follows:

> The well-known Jerome Cardanus … unanimously affirm that among the Arabs who cultivated astronomy were … Albumazar, who in the year of the Lord 844 observed a comet above the orb of Venus that was certainly larger than Venus. The parallax of the comet was found to be perceptible. Parallax was determined by those astronomers with a most accurate ruler which indicated the altitude of stars.[13]

As found by Thorndike,[14] this quotation probably goes back to the following text in a Latin translation of a work by Abū Maᶜshar's student Shādhān often called *Albumasar in Sadan*. We cite here from the Latin MS Erfurt Amplon, Q.352 folios, 11v–17r (probably thirteenth/fourteenth century A.D.), which was consulted by us but not by Thorndike (folio 15r, from line 13 onwards):

> Dixit Albumasar: Dicunt quidam et ipse Aristoteles quod cometae consistunt in celo in sphera ignium et nihil ex ipsis fit in celo et quia celum non suscipit aliquam passionem. Sed erraverunt omnes circa talem opinionem. Ego enim ipsis oculis vidi cometam super Venerem et sciebam quod cometa erat supra Venerem, quia non immutabat colorem ipsius. Et dixerunt mihi multi, quod ipsi viderunt cometam supra Iovem et alii viderunt supra Saturnum (with a notice in the right margin saying: "de cometis").

This is fully consistent with Thorndike's translation of other Latin manuscripts (MSS):

> Abū Maᶜshar said: The philosophers say, and Aristotle himself, that comets are in the sky in the sphere of fire, and that nothing of them is formed in the heavens, and that the heavens undergo no alteration. But they all have erred in this opinion. For I saw with my own eyes a comet beyond Venus, and I knew that the comet was above Venus, because its colour was not affected. And many have told me that they have seen a comet beyond Jupiter and sometimes beyond Saturn.[15]

Federici Vescovini[16] published an edition of the Latin texts of this work, where the text of the relevant paragraph above is fully consistent with the translation by Thorndike[17] and as given above. Thorndike[18] commented this paragraph as a "remarkable antedating of the views of Tycho Brahe" and wrote in the introduction about the work that "it correctly represents comets as celestial phenomena, more distant from the Earth than the planet Venus, or even Jupiter and Saturn."[19]

Apparently, neither Goldstein[20] nor Thorndike[21] consulted any original Arabic MS of the work connected with Abū Maᶜshar often called in Latin *Albumasar in Sadan* or *Mudhākarāt*[22] (which means "Discussions"), Thorndike[23] consulted two Latin MSS from the fourteenth and fifteenth century A.D., namely Bodleian, Oxford, UK, MS Laud. and Misc. 594 and BnF, Paris, France, MS 7302. One of the titles of the Arabic work is *Kitāb Abī Maᶜshar fī asrār ᶜilm al-nujūm*[24] (which means *Book (by) Abū Maᶜshar on the secrets of the science of the stars*); it was written by his student Shādhān b. Baḥr and consists mainly of answers by Abū Maᶜshar to questions by Shādhān and maybe other students on astronomical and astrological topics. Not much is known about that student, *Abū Saᶜīd Shādhān b. Baḥr* (for short: Shādhān), an Iranian name, once called *al-Kirmānī*, i.e., a native of the Kirmān province (but not the town Kirmān).[25] Translations of Latin translations are available in parts in English[26] and in full in Italian.[27]

The available Latin translations are shortened and incomplete and may possibly be based on a Greek or Hebrew translation of the original Arabic.[28] The Greek text survived as Codex Angelicus 29 from the fourteenth century A.D.[29] and, in parts, as Codex Vaticanus graecus 1056, which both contain the relevant paragraph:[30]

> Εἶπον τῷ Ἀπομάσαρ· λέγουσιν οἱ φιλόσοφοι καὶ αὐτὸς ὁ Ἀριστοτέλης ὅτι οἱ κομῆται τοῦ οὐρανοῦ συνίστανται ἐν τῇ τοῦ πυρὸς σφαίρᾳ καὶ οὐδὲ εἷς αὐτῶν ἐν τῷ οὐρανῷ γίνεται καὶ ὅτι ἀνεπίδεκτος ὁ οὐρανός ἐστι τινος πάθους· ἀλλ ἐσφάλησε πάντη περὶ τὴν τοιαύτην δόξαν, ἐγὼ γὰρ οἰκείοις ὀφθαλμοῖς εἶδον κομήτην ἄνωθεν τῆς Ἀφροδίτης καὶ ἔγνων ὅτι „εἴδομεν κομήτην ἄνωθεν τοῦ Διὸς καὶ ἕτερον ἄνωθεν τοῦ Κρόνου". (folio. 51v)[31]

Our English translation is as follows:

> I said to Albumasar: "The philosophers argue and Aristotle himself, that the comets of the heaven come together in the sphere of fire and that not anyone of them is formed in the heaven and that the heaven cannot accept any event. But all erred in that regard, because I saw with my own eyes a comet beyond Venus and I learnt that >we saw a comet beyond Jupiter and another one beyond Saturn<."

As we can see, the text here is said to originate from Shādhān, the student, and not from Abū Maᶜshar. He quotes that "*we saw*" comets beyond Jupiter and Saturn. By

comparison with the Arabic text in MS Ankara, we will see below that this Greek translation is incomplete. The text was translated from Arabic to Greek in about A.D. 1000.[32]

From the texts quoted above by both Licetus (*parallax ... perceptible*) and the Latin translation of *Albumasar in Sadan* (*its colour was not affected*), it cannot be understood how Abū Maᶜshar concluded that comets are located beyond Venus. Hartner wrote about Thorndike's translation as follows: "… l'interpréter comme le résultat de véritables observations, c'est-à-dire de déterminations des parallaxes variables d'une ou de plusieurs comètes … mais de la couleur non affectée ou altérée de la comète."[33] Then, Federici Vescovini wrote, "Ancora Abū Maᶜshar: … perché egli stesso ha visto una cometa sopra Venere ed egli sapeva che era sopra Venere perché non mutava il colore di quel pianeta" but again only from a Latin translation.[34] Parallaxes are not known to have been measured by Arabs or others in the ninth century A.D.; and inside the solar system, one cannot conclude on the distance from a colour because extinction effects are negligible here. While Hartner concluded that the whole discussion by Abū Maᶜshar has only an astrological sense, so that the citation by Tycho Brahe would be a misunderstanding,[35] Dunlop remarked that "before leaving the question it seemed desirable to recover if possible Abū Maᶜshar's original Arabic."[36]

The solution: the original Arabic text of *Albumasar in Sadan*

The quotation given above is from the work *Albumasar in Sadan.* There are 10 Arabic MSS of this work listed,[37] the oldest one is located in Ankara, Turkey, namely MS Ankara Saib 199 (folios 1a to 26a) dated to the sixth century Hijra[38] (twelfth century A.D.), which should be the complete MS. We have consulted that MS.

MS Saib 199 also includes the work *Kitāb fī dalāʾil al-qirānāt wa-l-kusūfāt* by al-Battānī (dated seventh century Hijra,[39] on "conjunctions") and a work ascribed to *Kanaka al-Hindī* ("Kanaka, the Indian") also on conjunctions. All three texts are also available as microfilm and hardcopy in the library of the *Institut für Geschichte der Arabisch-Islamischen Wissenschaften*, Frankfurt am Main, Germany. Neither the date of the copy nor the name or place of the copyist is mentioned in the MS. From the fact that one of the three texts was later dated to the sixth century and one to the seventh century, we conclude that MS Saib 199 is from the sixth or seventh century Hijra (twelfth/thirteenth century A.D.). It is then only slightly younger than the Latin MS Erfurt mentioned above.

We have also consulted MS Paris 6680 (folios 1–25) from the twelfth century Hijra, which is, however, a different work, it was listed as *possibly being Albumasar in Sadan*.[40] We would also like to note that the relevant parts were previously not found in the Arabic MS Cambridge no. 1028 Gg. 3.19 (folios 1–20a, 767 Hijra).[41] Both MS Esat 1967 in Istanbul's Süleymaniye Library and MS Cairo Ṭalᶜat mīqāt 157 are different works.[42] Pingree[43] consulted three MSS: Huntington 546 in the Bodleian Library, Oxford, the above-mentioned MSS Cambridge no. 1028 Gg. 3.19, and Ankara Saib 199, and concluded that only the latter is complete; he compared it to two Greek versions[44] and the Latin edition by Federici Vescovini,[45] but Pingree neither cited the Arabic text nor gave a translation.[46] We have then also consulted the MS Teheran Millī 1634/10, but it was a different work by Abū Maᶜshar. We have also tried to consult the MS in the Teheran

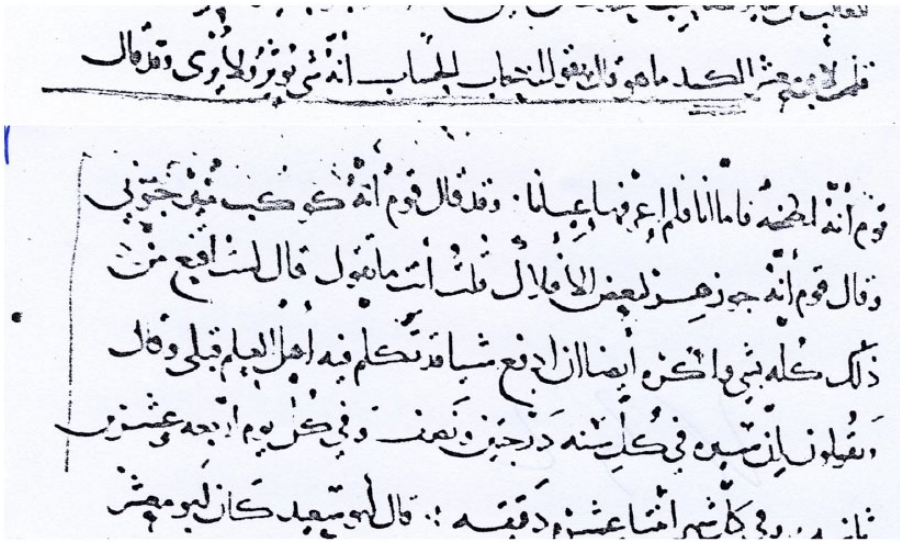

Figure 1. First part of the Arabic text from Abū Maᶜshar, MS Ankara Saib 199, bottom part of folio 15b at the top (top line) and then the top part of folio 16a at the bottom (bottom 5 lines). This is the first part of the Arabic text given in Latin transcription and as English translation in our text. Abū Maᶜshar is asked about *al-kayd* and gives several different possibilities.

Khunjī library but were told that it was dislocated to an unspecified location outside Iran. Hence, of the 10 MSS listed by Sezgin,[47] at least four are different works, one disappeared (Khunjī), and two are incomplete regarding our paragraphs (Oxford and Cambridge). We stress that, among the Arabic MSS, only Ankara Saib 199 includes the relevant passages about the comet observation studied here but that all or most of the Latin MSS (and at least one Greek MS, see above) do include these passages; in addition, there are a few more Arabic MSS, which we could not consult.

Sezgin did not only find the MS Ankara Saib 199, but he also noticed the two relevant paragraphs in the Arabic text by stating,

> Astronomiehistorisch gesehen ist sehr aufschlussreich – wie L. Thorndike und W. Hartner gezeigt haben –, dass sich Tycho Brahe (gestützt auf ein Zitat von Cardano) bei seiner außerordentlich wichtigen Theorie, dass die Kometen sich im Universum frei bewegen … auf *Abū Maᶜshar* beruft … Wie ich es z. Zt. übersehe, scheint der lateinische Text eine ziemlich freie Kombination von zwei Stellen des arabischen Originals zu sein.[48]

Hence, Sezgin already noticed that the Latin text is a free combination of two paragraphs in the Arabic original; he then gives the Arabic text in Latin transcription in his footnote 4 on pages 156 and 157.

We here present the edition of the relevant passages of the Arabic text of *Albumasar in Sadan* as taken from MS Saib 199 folios 15b–16a, the original Arabic text is shown here in Figure 1 (differences to Sezgin's edition are mentioned below, our comments or additions are in square brackets) and reads as follows:

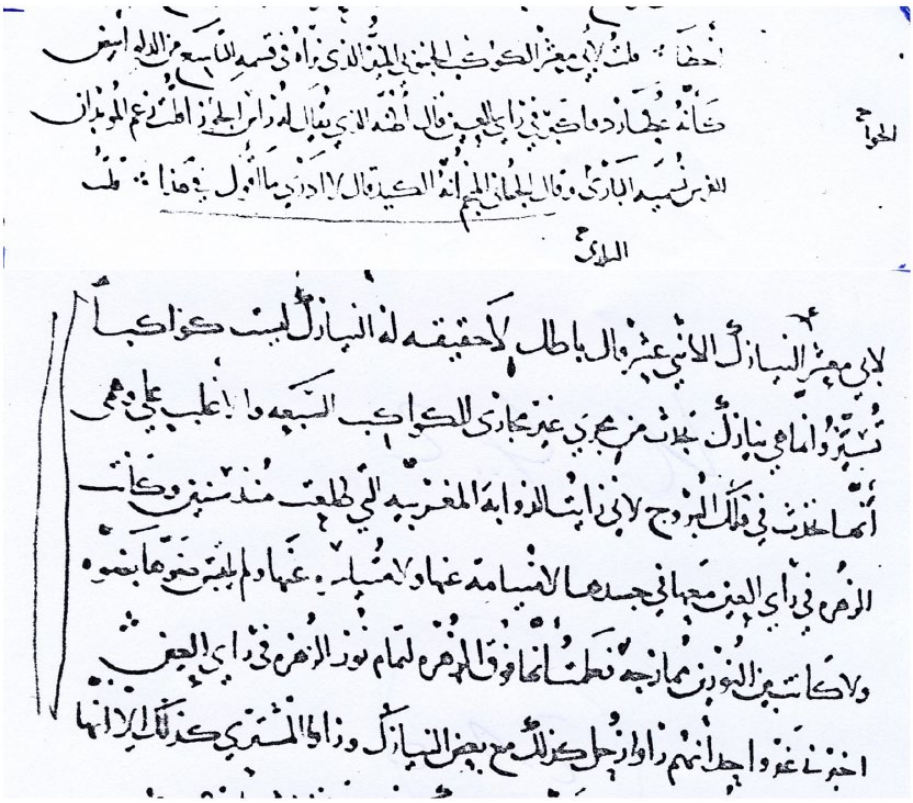

Figure 2. Second part of the Arabic text from Abū Maᶜshar, MS Ankara Saib 199, bottom part of folio 20b at the top (top three lines plus one word) and then the top part of folio 21a at the bottom (bottom 6 lines). This is the second part of the Arabic text given in Latin transcription and as English translation in our text. Abū Maᶜshar explains here his observation of Venus in the tail of a comet and concludes that the comet is behind Venus.

Qultu li-Abī Maᶜshar: al-kayd ma huwa? Qāla yaqūlu aṣḥāb al-ḥisāb innahu shay′ yu′aththiru wa-lā yurā, wa-qad qāla qawm innahu laṭkhatun (a), fa-ammā anā fa-lam aᶜrifhā ᶜiyānan, wa-qad qāla qawm innahu kawkab munīr janūbī, wa-qāla qawm innahu jawzahr li-baᶜḍ al-aflāk; qultu anta ma taqūlu? Qāla lastu aqnaᶜu min dhālika kullihi bi-shay′ wa-akrahu ayḍan an adfaᶜa shay′an qad takallama fīhi ahl al-ᶜilm qablī. Wa-qāla wa-yaqūlūna inna sayrahu fī kulli sana darajatān [MS: darajatayn] wa-niṣf wa-fī kull yawm arbaᶜ wa-ᶜishrūna [MS: arbaᶜa wa-ᶜishrīna] thāniya wa-fī kull shahr ithnatā ᶜashrata daqīqa.

(a) Sezgin has *la-najmatun* (“(just) a star”).[49]

Then, we continue with MS Ankara Saib 199 folios 20b–21a (original in Figure 2):

Qultu li-Abī Maᶜshar: al-kawkab al-janūbī al-munīr alladhī narāhu fī qismat al-tāsiᶜ min al-dalw abyaḍ ka-annahu ᶜuṭārid wa-akbar fī ra′y al-ᶜain. Qāla: aẓunnuhu alladhī yuqālu lahu ra′s al-jawzā′. Qultu zaᶜama l-mūbadh anna al-Furs tusammīhi al-bārī [until here not given in

Sezgin]; wa-qāla l-Jayyānī al-munajjim innahu al-kayd. Qāla [Abū Maᶜshar]: lā adrī mā aqūlu fī hādhā. Qultu li-Abī Maᶜshar: al-nayāzik al-ithnā [MS: al-ithnay] ᶜashar. Qāla: bāṭil, lā ḥaqīqata lahu; al-nayāzik laysat kawākib tusayyaru wa-innamā hiya nayāzik taḥduthu min majran ghayr majārī l-kawākib al-sabᶜa wa-l-aghlab ᶜalā wahmī annahā (b) taḥduthu fī falak al-burūj, li-annī ra´aytu al-dhu´āba al-maghribīya allatī ṭalaᶜat mundhu sinīna wa-kānat al-zuhara (c) fī ra´y al-ᶜayn maᶜahā fi jasadihā lā … ᶜanhā (d), wa-lā … ᶜanhā (e) wa-lam (f) yaltabis ḍaw´uhā bi-ḍaw´ihi (g) wa-lā kānat min [or: bayna?] al-nūrayn mumāzaja fa-ᶜalimtu annahā fawqa l-zuhara li-tamām nūr al-zuhara fī ra´y al-ᶜayn; akhbaranī ghayr wāḥid annahum ra´aw zuḥal ka-dhālika maᶜa baᶜḍ al-nayāzik wa-ra´aw al-mushtarī ka-dhālika.

Sezgin has (b) *innamā*, (c) *al-zuhra*, (d) *mutabāyina* (?) *īyāhā*, (e) *mutasāyira* (?) *lahā*, (f) *wa-lā*, (g) *bi-ḍaw´ihā*; we are not sure what is written at the location given as "(?)" in Sezgin and "…" by us. The two uncertain words *mutabāyina* and *mutasāyira* are both participles, both followed by the preposition *ᶜanhā.* In our translation, we follow Sezgin's reading, except the prepositions, which we both give as "from it" for *ᶜanhā.*

Our translation of these two paragraphs is as follows (our comments and additions in square brackets):

I [Shādhān] said to Abū Maᶜshar: What is *al-kayd*? He [Abū Maᶜshar] said: The scientific astronomers say it is something which produces traces [*yu´aththiru*], but cannot be seen. People have said, it was a [nebulous] spot. But I have not seen it with my own eyes. Some people have argued, it would be a bright southern star; and [other] people have said, it would be the node [*jawzahr*] of certain spheres [like the lunar nodes[50]]. I [Shādhān] said: And what do you [Abū Maᶜshar] say? He [Abū Maᶜshar] said: I am not happy with any of those; and I also do not like to dismiss what scholars before me have said. And he [Abū Maᶜshar] said: They say, it would move every year by two and a half degrees and every day by 24 seconds and every month by 12 minutes. (Saib 199, folios 15b–16a)

I said to Abū Maᶜshar: The bright southern star that we see in the section of the ninth [house?] in Aquarius is white as if it were Mercury or larger when seen with the eye. He [Abū Maᶜshar] said: I think it is the one that is called the "Head of Orion." I [Shādhān] said: The Mobad [Zoroastric priest] said that the Persians call it *al-bārī*. And the astronomer/astrologer al-Jayyānī said: This is *al-kayd*. He [Abū Maᶜshar] said: I do not know, what I should say on that. I [Shādhān] said to Abū Maᶜshar: [They are] the twelve *nayāzik* [comets]. He [Abū Maᶜshar] said: Nonsense, that is not correct; the *nayāzik* [plural of *nayzak*] are not celestial objects [or: planets] that orbit [in normal spheres like the planets, *kawākib tusayyaru*], moreover they are celestial objects that are formed [or: happen/occur/come to exist] in an orbit [or: path] different from the orbits [or: paths/courses] of the seven planets. It appears to me most probable that they are formed [or: occur] in the zodiacal sphere, because I have seen the western [or: evening] comet [*al-dhu´āba*, for: lock of hair], which appeared years ago, and for the eye Venus was standing near it in its body [*fī jasadihā*], not distinguishable from it and not moving away from it, and its [Venus'] light did not mix with its [the comet's] light, and there was no blending between the two lights [or: light sources]. Hence, I could conclude that it [the comet] stood above [or: beyond/behind] Venus, because the light of Venus was unimpaired for the eye. More than one told me that they saw Saturn in a similar manner with certain *nayāzik* [comets], and also Jupiter. (Saib 199, folios 20b–21a)

After the end of the second part just cited, the text continues describing the astrological consequences of a comet or *nayzak*, that they are stronger the larger (brighter) the *nayzak* is, etc.

Some parts of this second paragraph are quite similar to Thorndike's English translation[51] of a Latin translation of *Albumasar in Sadan*, see section "The problem: which Arabic work and text was quoted by Tycho Brahe?," even though shortened and slightly altered (e.g. *Aristotle* instead of the *scholars before me*, or *colour* instead of *light*), so that it was hard to understand, while our translation of the original Arabic can readily be understood. The connection between the two paragraphs is given by the fact that both discuss the nature of *al-kayd.*

Let us first comment on some rare words and names in the text.

The word *al-kayd* has an Indian origin, namely from the Sanskrit name *Ketu* for the descending node of the lunar orbit, depicted often as the tail of a dragon, whose head is *Rāhu*, the ascending node;[52] those lunar nodes were early considered as the locations where lunar and solar eclipses can happen. This particular meaning of *al-kayd* was not supported by Abū Maᶜshar. However, the angular velocity given at the end of the first paragraph (2.5° per year) is not the correct angular velocity of the lunar nodes (18.6 years), but 144 years. Given the description of *ketu* as the *tail* of a dragon, the object was later considered to be a star with tail (Indian *dhūmaketu* for *smoke-ketu*), i.e., a comet and, then, to be a negative portent given its irregular appearance.[53] This is then probably also the reason, why Abū Maᶜshar discussed comets, when he was asked again for *al-kayd* (see 2nd paragraph cited above). The previously earliest mention of *al-kayd* in an Arabic text in Ibn Hibintā's *al-Mughnī* written in A.D. 829: *al-kayd* "is one of the stars with tail; it appears once every hundred years and travels retrogradely, like the lunar nodes …"[54] The period given above for the lunar nodes (2.5° per year, or 144 years) is roughly twice the orbital period of comet 1P/Halley.

In the second sentence of the first paragraph, Abū Maᶜshar quotes the opinion of other people, maybe scholars, on what *al-kayd* maybe, namely, a [*nebulous*] *spot* (*laṭkhatun*). The next possibility of *al-kayd* given (*some people have argued, it would be a bright southern star* and that *scientific astronomers say it is something which produces traces* [*yuʿaththiru*]), may point to a (super-)nova, as the Arabic *athar* has been used for supernovae, e.g. SN 1006,[55] but in an astrological context, it can also mean *portent* or *trace* or *effect*. Another possibility given (*the nodes of certain spheres*) seems to be the correct one, given the origin of the word *al-kayd*, but it was not favoured by Abū Maᶜshar. In the second paragraph, Shādhān considered that *al-kayd* would be identical to (one of) *the twelve nayāzik*, which was not supported by Abū Maᶜshar.

The discussion in the second paragraph leads us back to *al-kayd*: Shādhān mentions a *bright southern star* in the sign of *Aquarius*, brighter than Mercury. Abū Maᶜshar identifies it with the star called *The Head of Orion*, while Shādhān mentions that the Persians called it *al-bārī* (a corrupt middle-Persian name; later, the Persian *al-bār* was used for α Aur). We would like to point out that the star called *The Head of Orion* in Ptolemy's star catalogue is very faint (*λ Orionis* with 4th magnitude). It is possible that the connection to the discussion about *al-kayd* (maybe a nebulous spot as one possibility given) is due to the fact that Ptolemy describes the star discussed above as *nebulous* (λ Ori forms a small triangle with ϕ^1 und ϕ^2 Ori, which can appear unresolved and then like a nebulous spot, today known as a star-forming gas cloud), while Shādhān describes the star as being as white as or larger than Mercury, maybe referring to a whitish extended nebula.

The word *nayzak* (pl. *nayāzik*) can stand for 1 of the 12 original Greek types of comets, but it is of Persian origin and means *spear* – the comet *looking like a spear*,[56] or it can stand for *comet(s)* in general, or – even more general – for *transient celestial object(s)* or *guest star(s)*.[57] Abū Maᶜshar also used *al-dhuʾāba* for the comet (*lock of hair*) in the text above. We translated the word *kawākib* in the second text as *celestial objects*, as it can mean either *stars* or *planets*.

It is not clear, who the astronomer or astrologer *al-Jayyānī* is, he is mentioned at the beginning of the second paragraph. The name could point to *Jaen*, a Spanish town, but it is highly doubtful whether an astronomer from Arab Spain (al-Andalus, Arabic from A.D. 711 to 1492) would have been known to Abū Maᶜshar in Baghdad, Iraq, already in his lifetime (he died A.D. 886 at an age of roughly 100 lunar years) or to his student Shādhān. There is no Spanish astronomer or other Spanish person known with this name. If the person would not be contemporary with Abū Maᶜshar and/or Shādhān, one would have to consider whether this part of the text was added later by a copyist.

There is, however, a person known as *al-Jayhānī*, who lived in Persia from around A.D. 900 to at least A.D. 978; he was known to be interested mostly in geography but also in astronomy; as a vizier, he invited foreign scholars to ask them about their countries and astronomy, e.g. the local altitude of Polaris; one of his known friends was Abū Zayd al-Balkhī,[58] from Balkh like Abū Maᶜshar – hence a possible connection between *al-Jayhānī* (or al-Jayyānī?) and Abū Maᶜshar. According to Miguel, the reports about the person named *al-Jayhānī* refer to two different persons, father and son,[59] so that the father may have lived already in the ninth century A.D., contemporary with Abū Maᶜshar. The two names (*al-Jayhānī* and *al-Jayyānī*) differ only by one letter; while it maybe unlikely for a copyist to mix up these two Arabic letters (*h* instead of *y*) because they look quite different in the Arabic script, the two names still sound similar, so that either a copyist (mis)wrote while the MS was read to him or the name was wrong from the very beginning (heard and/or written wrong by Shādhān).

We conclude that Abū Maᶜshar's arguments were not understandable from the Latin translations, which may have been translations from an incomplete and altered Greek or Hebrew translation of the original Arabic. Pingree numbered the relevant paragraph (the second paragraph as given in Arabic and English) with no. 106 for MS Saib 199, but did not give the Arabic text nor an English translation;[60] he also noticed that this paragraph was partly present in the two Greek MSS and in Federici Vescovini's edition of the Latin MSS.[61]

Astronomical interpretation of the Arabic text and Abū Maᶜshar's observation

One could question whether the relevant paragraphs are indeed from Abū Maᶜshar or Shādhān, or whether they may have been added later. Abū Maᶜshar has otherwise followed Aristotle, but here he corrects him (comets to be supralunar) but also adds *I also do not like to dismiss what scholars before me have said*. While MS Ankara is from the twelfth century A.D., we do see the same content (comet behind Venus) in the older Greek translation (and also in all Latin translations). Hence, it is quite well possible that this observation (and conclusion) was indeed obtained by Abū Maᶜshar or Shādhān himself,

i.e. in the ninth century A.D. Even if the two relevant paragraphs would have been added to the MS later (between the ninth and twelfth century A.D.), MS Ankara is the oldest known Arabic text saying that comets are outside the Earth's atmosphere.

In the last part of the second paragraph as cited above (section "The solution: the original Arabic text of *Albumasar in Sadan*"), Abū Maᶜshar explains his observation: Abū Maᶜshar had observed (*years ago*) a *western* (evening) *comet*. Venus was seen in close conjunction with a comet; actually, Venus was apparently seen as projected onto the comet's tail (*Venus was standing near it in its body*). Venus and the comet apparently did not move relative to each other from night to night (*not moving away from it*). Both Venus and the comet were clearly seen as different objects (*its light did not mix with its light and there was no blending between the two lights*). There is no mention of colour contrary to the English translation[62] of a (wrong) Latin translation of this work. Abū Maᶜshar then also explains that other colleagues have made similar observations of comets with both Jupiter and Saturn (*more than one told me that they saw Saturn in a similar manner with certain comets and also Jupiter*).

Then, the interpretation of Abū Maᶜshar is as follows: "I could conclude that it [the comet] stood above of Venus, because the light of Venus was unimpaired for the eye."

Hence, Abū Maᶜshar observed Venus in (or actually projected onto) the tail of a comet. With the wording the *light of Venus was unimpaired*, Abū Maᶜshar probably meant that Venus was seen with the same brightness while in (projected onto) the cometary tail as before and/or afterwards, so that the (presumable or expected) extinction due to the cometary tail (if Venus would be behind the tail) was negligible. He then concluded that Venus would be in front of the comet – otherwise, the light of Venus would have been partly absorbed. Since other astronomers also observed Jupiter and Saturn in (projected onto) cometary tails, Abū Maᶜshar concluded that comets are beyond (above/behind) the planets, in particular outside the Earth's atmosphere and outside the sphere of the Moon.

He says specifically as follows:

> Comets (*nayāzik*) are not celestial objects that orbit in normal spheres, but they are celestial objects that are formed [or: occur] in an orbit different from the orbits of the seven planets. It appears to me most probable that they are formed [or: occur] in the zodiacal sphere.

It is clear that Abū Maᶜshar considered comets to have distances larger than the planets. He places their orbits and distances to the stars in the sphere of the Zodiac, the sphere of the fixed stars. While the conclusion drawn by Abū Maᶜshar, that comets are not sublunar, is correct, his argument is not correct: Cometary tails are optically thin, so that more distant planets and stars can be seen *unimpaired* through them.

Abū Maᶜshar may have known that sometimes (also normal fixed) stars are seen in (behind) cometary tails, but that the brightness of those stars would also not be affected, so that he would need to conclude that those comets are behind those stars. And indeed, he placed comets in the sphere of stars.

Stars (and planets) with very small angular separation near a bright cometary head (whether projected onto the tail or not) may not be visible anymore; this is then not due to extinction but due to the large brightness difference – a problem of dynamic range: not only brightness difference and not only separation. The closer *and* fainter a faint object

(like a background star) to the bright (foreground) comet (head), the more difficult it is to detect the fainter object. Maybe this is what was observed by Abū Maᶜshar: He may have noticed that a (faint) star was not detectable anymore while in close conjunction with the brightest parts of a comet (head), while Venus (being brighter than all stars) remained *unimpaired* even in close conjunction to a comet (head). Even in this case, his argument would not be correct: From a very close conjunction of Venus (even if remaining *unimpaired*) and a comet, one cannot conclude that the comet is behind Venus. The problem of dynamic range applies to both background and foreground objects.

Planet–comet conjunctions A.D. 750 to 886

We can now consider which comet might have been observed by Abū Maᶜshar in close conjunction with Venus – and which comets might have been observed by the other astronomers in close conjunction with Jupiter and Saturn. Since the observers may have misidentified the planet(s), we consider all planets visible for the naked eye.

Let us first discuss which time period to consider: Abū Maᶜshar himself died A.D. 886 9 March (272 Hijra). He also mentioned that other astronomers had seen Jupiter and Saturn in close conjunction with a comet, but he does not specify the times nor names of those astronomers. They could have been his teachers, e.g. al-Kindī, whose work is mostly lost. The earliest possible time of observation may therefore probably not be before roughly A.D. 750, when Arabs started to translate Greek texts and to study astronomy. Therefore, we consider the period from A.D. 750 to 886.

The most prominent comet with a known orbit and with sufficient precision for many centuries, including the time from about A.D. 750 to 886, is 1P/Halley,[63] so that we can compare its orbit with the planetary positions during the relevant time. For comet 109P/Swift-Tuttle, the orbit is not sufficiently well known for the eighth and ninth centuries A.D.

We used *Cartes du Ciel* V3.10 and *The Sky* V6.0 to calculate the ephemeris to compare the orbit of 1P/Halley[64] with the planets for its perihelion passages in A.D. 760 and 836/837. We list in Table 1 possible conjunctions between planets and comets for 1P/Halley and other comets. The values given for comets (brightness, tail length, and separation from the planets) can only be very rough estimates because of unknown cometary and solar activity at those times; brightness and tail length are given for average solar and cometary activity according to *Cartes du Ciel*.

Planetary conjunctions with 1P/Halley

On A.D. 836 19 December (see Figure 3), the head of 1P/Halley and Jupiter were very close to each other; the tail of comet 1P/Halley would have a length of ~2° according to *Cartes du Ciel* (Table 1) but should have been quite faint some 2.5 months before perihelion. Given the uncertainties in the orbit,[65] one cannot be sure about the position of 1P/Halley relative to Jupiter. The Chinese astronomers started to observe 1P/Halley on A.D. 837 22 March,[66] and also in an indirect report from al-Kindī, there are no earlier observations mentioned.[67] It is still possible that records about such earlier observations are missing. It would have been possible to discover the comet very close to the bright planet Jupiter on A.D. 836 19 December just because of its close separation from Jupiter.

Table 1. Close conjunctions between comets and planets A.D. 750–907.

Date A.D.	Comet	Magnitude	Tail/deg	Planet	Magnitude	Separation	Figure
770, 28 April	C/770 K1	~4.5	~2	Mars	2	~7°	5d
836, 19 December	1P/Halley	~5–6	~2	Jupiter	−2	Maybe <1°	3
837, 14 January	1P/Halley	~5	~5	Venus	−4	~2°	5a
837, 7 April	1P/Halley	~−1	~48–80	Mars	1	~4°	4
837, 7 April	1P/Halley	~−1	~48–80	Saturn	0	~77°	4
852 March/April	Ho no. 297	<6	~50	Jupiter	−2	Also in Vir/Cnc Japan	
857 September/October	Ho no. 299	<6	~3	Jupiter	−2	In Oph/Sgr near Sco	
864 April/May	X/864 H1	<6	~3	Venus	−4	In Tau near Aries	
868 January	Ho no. 302			Venus?	−4	"trespassed"	Korea
868, 27 January	C/868 B1	~3	~24	Mars	1	Maybe < 1°	5b
868, 27 March	C/868 B1	~7	~1.5	Mercury	1	~1°	5c
868, 27 March	C/868 B1	~7	~1.5	Venus	−4	~1°	5c
907, 9 April	Ho no. 322	<6	~30	Venus	−4	"trespassed"	Japan

Apparent brightness (in magnitudes), tail length (in degrees) and separation between comets and planets are rough estimates from *Cartes du Ciel* for average solar and cometary activity. The large tail length given for A.D. 837 7 April and 852 were observed in China; see text.

Let us consider whether comet 1P/Halley was bright enough on 19 December: The apparent brightness m (in magnitudes, or mag) of a comet as observed from Earth can be calculated by

$$m=M+5\log(d)+2.5n\log(r)$$

with absolute brightness M at 1 au, distance d in au between Earth and comet (well known due to the orbit), activity parameter n depending on solar and cometary activity (n = 2 for pure reflection), and distance r in au between comet and Sun. For the absolute brightness, values between 3.7 and 5.5 magnitude have been suggested for 1P/Halley, and for the activity parameter, values from 2.70 to 5.15 have been proposed.[68] For these ranges of parameters and the known orbit, we can estimate the apparent brightness of 1P/Halley for A.D. 836 19 December to be between 5.6 and 7.9 magnitude (3σ range being 4 to 10 magnitude), hence, possibly detectable (even if only due to its proximity to Jupiter). The Chinese have detected 1P/Halley until A.D. 837 28 April,[69] and indeed, for all six parameter combinations suggested, 1P/Halley would have been brighter than 6 magnitude at the end of A.D. 837 April. In addition, even if the brightness according to above equation for typical values would indicate that the comet would have been too faint for naked eye detection, it is always possible that the comet was in a period of higher activity than normal at that time, which often happens after the perihelion passage.

Furthermore, there was a conjunction of 1P/Halley with Mars on A.D. 837 7 April, Mars being some 4° away from the comet (Figure 4); at this time, the comet was indeed observed by both the Chinese[70] as well as al-Kindī,[71] but the planet is not mentioned in their reports.

Around A.D. 837 7 April, Saturn may also have been located on the tail of 1P/Halley, even with a separation of almost 80° (Figure 4): The Chinese reported for A.D. 837 7

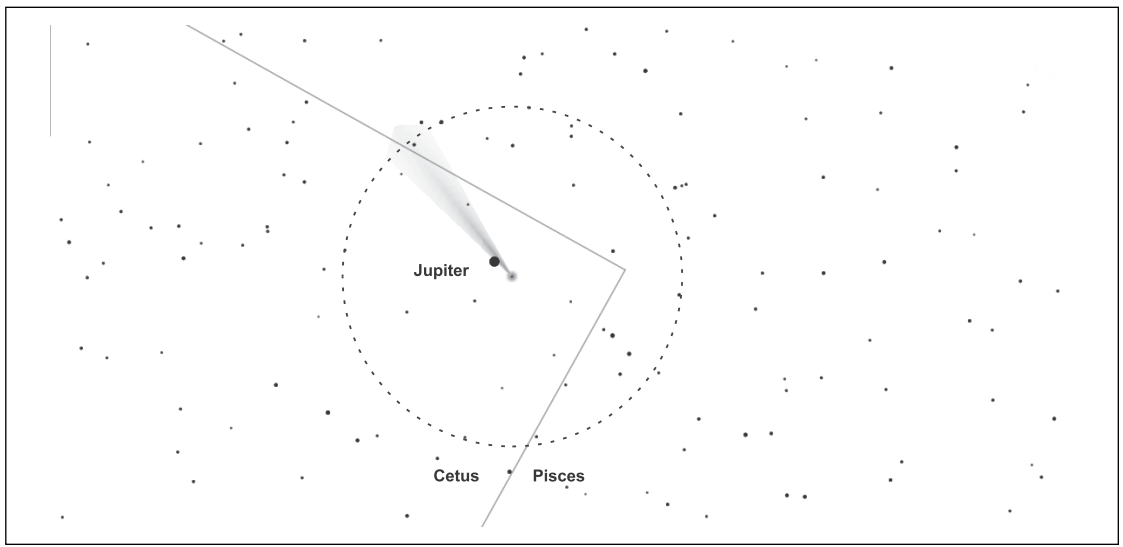

Figure 3. Comet 1P/Halley (with tail) and planet Jupiter (black dot) as seen from Baghdad, Iraq, on the evening of A.D. 836 19 December at 4 p.m. UT.
The dotted circle indicates the 1σ uncertainty on the cometary position given the uncertainty of its orbital elements for the A.D. 837 perihelion. We also indicate the border between the constellations of Cetus (left) and Pisces (right). The comet may have been visible for the naked eye being as bright as about 4 magnitudes within 3σ or even brighter if more active than normal at that time (see text), some 46° above the horizon in the south-west. Planet Jupiter may have been seen in or projected into the comet tail. The tail has a length of about 2° here and points away from the Sun, which is 24° below the horizon. Positions, brightness, and comet tail length were calculated with *Cartes du Ciel*. This may have been the situation reported by Abū Maᶜshar to have been observed by others regarding Jupiter.

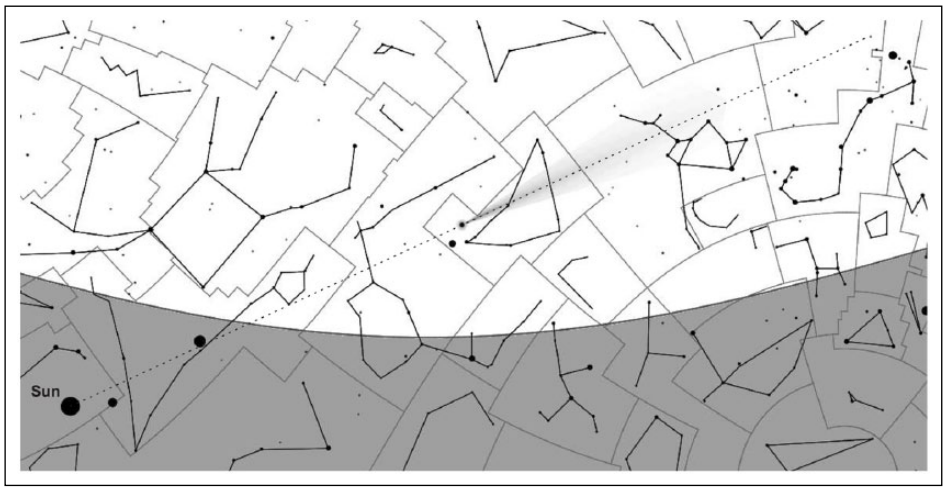

Figure 4. Comet 1P/Halley (in the centre with tail towards the upper right), Mars (black circle in the centre to the lower left of 1P/Halley), Saturn (black circle in the upper right corner), as well as the Sun (in the lower left below the horizon, dark shaded area) as seen from Baghdad, Iraq, in the night of A.D. 837 6/7 April (shown here for 1 a.m. UT).
The comet tail is directed away from the Sun towards Saturn as observed by both the Chinese and al-Kindī. Given the orbital uncertainty of comet 1P/Halley (15° for 1σ uncertainty), planet Mars (separation 4°) may have been seen in or projected into the comet tail. The tail has a length of about 48° here and points away from the Sun, which is 20° below the horizon. Positions, brightness, and comet tail length were calculated with *Cartes du Ciel* for average cometary and solar activity. However, since the Chinese reported a tail length of 80° for a few days after 7 April, cometary and/or solar activity may have been larger than average at this time, so that the comet was brighter and the tail was longer. Given that Saturn is located at a separation of about 77° from 1P/Halley but on the projected (extrapolated) tail (which had a length of 80° according to the Chinese), it may have been observed *in* the tail. This may have been the situation reported by Abū Maᶜshar to have been observed by others regarding Saturn.

April a tail of "two zhang long and three chi wide" (20° long and 3° wide), and a few days later, the tail was even eight zhang long (80°).[72] The fact that the tail does not appear that long in Figure 4 is due to the fact that the software used, *Cartes du Ciel*, assumes average solar and cometary activity. We have seen above, that there is evidence for larger than average values for solar and/or cometary activity given the detection on A.D. 837 28 April. Furthermore, it was shown that also solar activity was larger than average in the years of A.D. 836 and 837 (and also around A.D. 760, the previous perihelion), seen by strongly enhanced auroral activity and a drop in radiocarbon.[73] Hence, it is well possible that 1P/Halley was brighter than average and that its tail was longer than average, consistent with the historical reported tail length (80°), so that Saturn may have been located just inside (actually projected behind) the tail, close to the faint end of the tail.

The fact that the tail was observed to be much longer than expected for average solar and cometary activity maybe considered additional evidence for strong solar (or cometary) activity at that time.

We could also find some additional conjunctions of Venus with 1P/Halley on A.D. 760 2 March and 12 June and on A.D. 837 14 January. Since Abū Maᶜshar mentioned that he

had observed such a conjunction (with Venus) himself, he could not have meant those in A.D. 760. At the conjunction on A.D. 837 14 January (Figure 5(a)), comet 1P/Halley was at about 1.6 au distance from Earth and Venus at 1.0 au, so that indeed, the comet was behind Venus – as Abū Maᶜshar may have thought.

We can otherwise exclude close conjunctions with the planets and 1P/Halley for the period studied. The conjunctions reported by Abū Maᶜshar may of course be related to other comets, not 1P/Halley.

Planetary conjunctions with other comets

There is an observation of a conjunction between a planet identified as Venus and a comet reported in Korea in the Chronicle of Silla for A.D. 867/868, i.e. within the lifetime of Abū Maᶜshar: "During the 12th month of the seventh year of Kyongum Wang [A.D. 867 30 December to 868 28 January] a guest star trespassed against Venus" (Sanguk Sagi 11/5).[75]

The above date (A.D. 867/868) would then also be quite close to the A.D. 866 19 April passage of *al-kayd* as descending lunar node through the vernal point[76] – possibly the reason why Abū Maᶜshar combined the comet–Venus conjunction with *al-kayd* in his memory. However, in that month (A.D. 868 January), Venus was visible in the east in the early morning around −4 magnitude, while Abū Maᶜshar reported to have seen Venus in close conjunction with a western (evening) comet (*al-dhuʾāba al-maghribīya*). (In the quotation by Licetus[77] as given in section "The problem: which Arabic work and text was quoted by Tycho Brahe?" the year A.D. 844 was given for the observation by Abū Maᶜshar. In the text of Abū Maᶜshar himself, however, there is no indication for this year (*years ago*). While it is possible that the text, on which the Latin translation consulted by Licetus is based, is different from Ankara Saib 199, it was noted before that there was a strong confusion about the year of this (or some other nova or comet) observation.[78]) It is, however, possible that both the Koreans and Abū Maᶜshar misidentified the planet as Venus but actually observed a different planet close to a comet.

There are three more comets with known orbital solutions only for one particular perihelion passage between A.D. 750 and 886, namely, C/770 K1, C/817 C1, and C/868 B1.[79] We have compared their orbits with the positions of the planets, too. According to the orbital solution of the comet of A.D. 868,[80] the planet Mars (at an apparent brightness of about 1 magnitude) may have been near the comet (brightness 3 magnitude for typical activity, n = 4) on A.D. 868 27 January (Figure 5(b)), located in the evening in the west, around 16° altitude during the closest approach (but note that the orbit is uncertain to a few degrees). It may still be true that Venus was close to a comet between A.D. 867 30 December to 868 28 January, as reported in Korea, even though the orbital solution[81] does not support this report because it is well possible that the reports about the comet of A.D. 868 are actually about two different comets (see Note 74). Alternatively, it is also possible that the Koreans have thought or reported that it was Venus, but in fact it was Mars. Maybe, the same error was committed by Abū Maᶜshar (reporting a western, evening comet).

Venus and Mercury were close to the previous comet of A.D. 868 on A.D. 868 27 March, both separated from the comet by only about 1°, but this was at an altitude of only

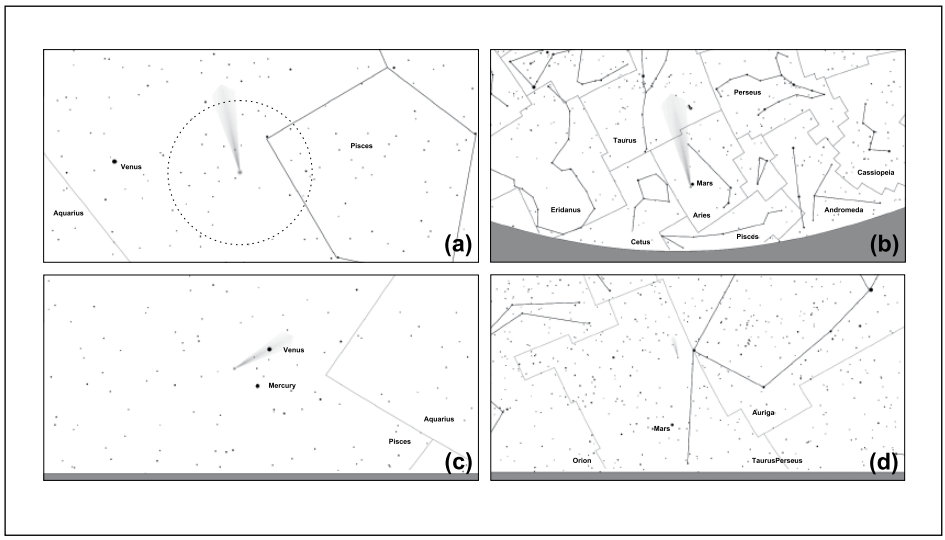

Figure 5. (a) Top left: Comet 1P/Halley and Venus as seen from Baghdad, Iraq, on A.D. 837 14 January at 4:20 p.m. UT in the west (dotted circle as in Figure 4). Given the uncertainty, Venus may possibly have been visible inside the comet tail within 2σ. The Sun was 24° below the horizon, the Moon was above the horizon, and comet 1P/Halley was about 16° above the horizon at a brightness of about 5 magnitude. This may have been the situation Abū Maᶜshar has observed himself regarding Venus in the tail of a western comet. (b) Top right: Comet C/868 B1 and Mars as seen from Baghdad, Iraq, on A.D. 868 27 January at 7 p.m. UT in the west: The cometary position was calculated with the orbital elements given for the A.D. 868 perihelion in Kronk (1999).[74] Mars has been visible inside the comet tail. The Sun was 55° below the horizon and the comet was about 16° above the western horizon at a brightness of ~ 3 magnitude with a tail length of about 24°. This may have been the situation Abū Maᶜshar has observed himself regarding Venus in the tail of a western comet, but he would have misidentified Mars as Venus. (c) Bottom left: Comet C/868 B1 together with Venus and Mercury as seen from Baghdad, Iraq, on A.D. 868 27 March at 2 a.m. UT in the east: The cometary position was calculated with the orbital elements given for the A.D. 868 perihelion in Kronk (1999) (see Note 74). The Sun was 12° below horizon and the comet was only about 2.5° above the horizon at a brightness of only about 7 magnitude (or brighter if more active) with a tail length of about 1.5°. Given the low altitude, it is dubious whether this conjunction was observed. Given that the comet brightness and tail length are calculated only for average solar activity, Venus (or even Mercury) may or may not have been visible inside the comet tail. This may have been the situation Abū Maᶜshar has observed himself regarding Venus in the tail of a comet, but the comet–Venus conjunction plotted here was in the east, while Abū Maᶜshar reported it for the west. (d) Bottom right: Comet C/770 K1 (faint object with tail in the centre) and Mars as seen from Baghdad, Iraq, on A.D. 770 28 April at 4:45 p.m. UT in the west. The cometary position was calculated with the orbital elements given for the A.D. 770 perihelion in Kronk (1999) (see Note 74). The Sun was 13° below the horizon and the comet was about 11° above the horizon at a brightness of about 4.5 magnitude with a tail length of about 2°. Given that the comet brightness and tail length are calculated only for average solar activity, and that the comet position is somewhat uncertain, Mars may possibly have been visible inside the comet tail. This may possibly have been one of the situations Abū Maᶜshar has reported for other observers, who may have misidentified Mars with either Jupiter or Saturn.

about 2.5°, the comet may have been invisible at m = 7 magnitude for typical activity, and the conjunction was in the east (Figure 5(c)). Again, we cannot exclude that the comet had a larger activity than normal around that date. It could be that the Korean report cited above, which connects the comet of A.D. 868 with Venus, is just misdated (to A.D. 868 January) but really refers to the close conjunction on 27 March. At this conjunction, the comet was at about 1.44 au distance from Earth and Venus at about 1.44 au, so that indeed, the comet may have been located slightly behind Venus.

A few more possibilities are listed in Table 1.

Summary

From the fact that Venus was seen in the tail of a comet, Abū Maᶜshar concluded that the comet was located behind Venus – obviously (incorrectly) considering the comet tail to be optically thick. While some part of the conclusion is correct (that comets are outside the Earth's atmosphere and behind the moon), the argument itself is not justified because cometary tails are optically thin. Due to similar observations with Jupiter and Saturn, he concluded that comets are located in the sphere of the stars. This was seen as a clear contradiction with Aristotle's *Meteorology*. Abū Maᶜshar said, "*I am not happy with any of those*" (opinions of other people), while in the English translation of a Latin translation we find, "The philosophers say, and Aristotle himself, that comets are in the sky in the sphere of fire … But they all have erred in this opinion."

The conclusion in *Albumasar in Sadan* (late ninth century A.D.), to place comets beyond Venus, clearly antedates the same conclusion by Tycho Brahe (for the comet of A.D. 1577) some seven centuries later – and Tycho Brahe quotes Abū Maᶜshar for his much earlier finding.

While we cannot be sure which planet–comet conjunctions were observed and mentioned by Abū Maᶜshar, we found a few good candidates, namely conjunctions of 1P/Halley with Jupiter (Halley possibly visible) and Saturn (near the end of a very long tail) in A.D. 836/837, as well as a possible conjunction of comet C/868 B1 with Mars, where planet Mars was misidentified as Venus in Korea and maybe also by Abū Maᶜshar.

Even though the argument made by Abū Maᶜshar is not justified, it is nevertheless highly important to note that he considered this possibility – contrary to the common interpretation of Aristotle. This is but one more example where Arabic scholars did not only use and translate Greek texts but where they also questioned them. It may well have helped Tycho Brahe much later to come to a similar result.

Like Tycho Brahe, Abū Maᶜshar may have seen the problem that comets appear to cross the planetary spheres. Contrary to Tycho Brahe, Abū Maᶜshar solves this problem by placing the comets behind the planets, among the stars. This solution may have been motivated by the observation of Saturn (the most distant planet know at that time) in the tail of a comet, so that it was concluded (incorrectly) that the comet was behind Saturn, and/or by another observation that also the light of star(s) remained unimpaired when in close conjunction with a comet. However, comets behind Jupiter and Saturn cannot be detected by the naked eye.

These further conclusions were not known to Tycho Brahe, who just quotes Adam Ursinus following Cardanus: "Albumasar said: A comet was seen above Venus; it is

therefore not in the sphere of the [four] elements." This was consistent with the findings of Tycho, who concluded that comets are not sublunar. If he would have known that *Abū Maᶜshar* had placed comets outside the solar system, as specified in the Arabic text, he might not have quoted him, but that part of the quotation was lost during the transmission through Latin.

After the relevant quotation (*Albumasar said, "A comet was seen above Venus"*), Tycho Brahe then continues as follows (translated by us):

> This statement, I think, was brought up suitably in that citation, and he [Ursinus] correctly reminds us that some basics of the oldest astronomers on these matters should be reconsidered and be compared more carefully with this phenomenon [new star of 1572]. If he [Ursinus] would have done so, he would not have listed this star [of 1572] as comet. Nevertheless, if he [Ursinus] thinks, that this opinion of Albumasar is superior to that of Aristotle, and if he thinks that all comets belong to the sky [supralunar], and if he has therefore considered this new star [of 1572] to be in that heavenly zone [outside the solar system] (which he did not do publicly), then he deserves patience for unsuitably listing this [supernova 1572] as comet.

Likewise, we can state as follows: If Abū Maᶜshar thinks that all comets belong to the sky [supralunar], and if this has helped Tycho Brahe some 700 years later to come to a similar conclusion, then he deserves patience for unsuitably considering a comet tail as intransparent.

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