Supernova SN 1006 in two historic Yemeni reports

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We present two Arabic texts of historic observations of supernova SN 1006 from Yemen as reported by al-Yamānī and Ibn al-Dayba’a (14th to 16th century AD). An English translation of the report of the latter was given before (Stephenson & Green 2002), but the original Arabic text was not yet published. In addition, we present for the first time the earlier report, also from Yemen, namely by al-Yamānī in its original Arabic and with our English translation. It is quite obvious that the report by Ibn al-Dayba’a is based on the report by al-Yamānī (or a common source), but the earlier report by al-Yamānī is more detailed and in better (Arabic) language. We discuss in detail the dating of these observations. The most striking difference to other reports about SN 1006 is the apparent early discovery in Yemen in the evening of 15th of Rajab of the year 396h (i.e. AD 1006 Apr 17 ± 2 on the Julian calendar), as reported by both al-Yamānī and Ibn al-Dayba’a, i.e. ∼ 1.5 weeks earlier than the otherwise earliest known reports. We also briefly discuss other information from the Yemeni reports on brightness, light curve, duration of visibility, location, stationarity, and color.

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1 Introduction: Supernova SN 1006

Historic observations of supernovae (SN) are useful for identification and age dating of SN remnants (SNR) and neutron stars. There were some ten such SNe observed in the last two millenia, all from China, three from Europe, and two from Arabia (see Stephenson & Green 2002, henceforth SG02).

The previously known Arabic reports about SN 1006 present a lot of detailed information (Goldstein 1965): From the ecliptic longitude of the SN as given by Ḥāʾil ibn Ġirdān (and an error bar from Ḥāʾil ibn Ġirdān’s assumed measurement precision) together with the declination limit from a St. Gallen observation of this SN (Goldstein 1965) and the Chinese right ascension range (from Chinese lunar lodge), it was possible to constrain the location of the SN and to identify the SNR (Stephenson et al. 1977, SG02).

Arabic scholars – following Aristotle – considered transient celestial events (including comets as well as variable and new stars) as being located in the Earth atmosphere like meteors, because Aristotle considered true stars to be eternal and constant. In his report, Ḥāʾil ibn Ġirdān used the Arabic words athar and nayzak, which can both mean something like spectacle, e.g. a very bright star (Goldstein 1965). The word athar can also mean trace, possibly something like a persistence effect in the eye due to the strong brightness and/or strong scintillation. There is also one Arabic report about SN 1054 (Brecher et al. 1978): Ibn Abi Usaybi’ā (historian who lived AD 1203-1270 in Damascus, Syria) quoting Ibn Butlān (a physician, who lived AD 1038-1075 in Baghdad, Iraq) wrote about the athar kawkab as the star leaving traces or spectacle star (Brecher et al. 1978); kawkab can mean star or celestial object in a general sense including planet (while najm can only mean star). Regarding the translation of athar, Brecher et al. (1978) write: ... a novel astronomical or meteorological phenomenon ... characterised by its transient, explosive or spectacular appearance. Apparent star, phenomenon or spectacle might be equally viable translations. The word nayzak was previously and otherwise used for comets, as they also appear to be new and transient celestial objects, so that the new star of 1006 was long regarded as comet instead of a SN (Goldstein 1965). See Kunitzsch (1995) for a review on the Arabic words used for stars and transient celestial objects.

While the other Arabic and east Asian observations of SN 1006 all were obtained between the geographic latitudes of 30° and 35° north, we discuss here an additional observation from Ṣan’ā‘, the capital of Yemen, i.e. at 15.3° north. We present for the first time the Arabic text plus a translation to English from al-Yamānī and then, also for the first time, the original Arabic text from Ibn al-Dayba’a (Sect. 2), both with text variants. Then, we date the observation by converting from the Islamic calendar to the Julian calendar (Sect. 3). Finally, we discuss briefly the other information contained in the Yemeni reports (Sect. 4), and conclude with a summary (Sect. 5). An English translation of one of the two texts was first presented in SG02 quoting private communication with one of us (WR).
2 Arabic text about SN 1006 from Yemen

The two original Arabic texts are shown in Figs. 1-3.

The first (earlier) text is a small excerpt from the book entitled Bahjat al-Zaman ft tārīkh al-Yaman written by Abū Muhammad (Abū l-Mahāsin) ʿAbdalbāghi b. ʿAbdalmajīd b. ʿAbdallāh ʿAjjaddin b. Abī l-Maʿāli Muthannā b. Ahmad b. Muhammad b. ʿIsā b. Yūsuf al-Yamānī al-Makhzūmī al-Qurashi al-ʿAdānī al-Shāhī (for short: al-Yamānī), he died in AD 1342. We use the edition of al-Hubaishi & al-Sanabānī (1988), see Fig. 1 for the text about SN 1006.

Our English translation of this text is as follows (with a text variant given in square brackets, see Fig. 1):

On the night of mid-Rajab (or: 15th of Rajab), in the year 396h, a star appeared from the east at half an hour after sunset. It was four times as large as Venus. [It was as large as Venus and rose several times after sunset.] It was not circular, but nearer to an oblong. At its ends, there were lines like fingers. It showed a great turbulence as though it was seen in disturbed water. Its light rays were similar to sunlight. It appeared in the zodiacal sign of Libra in Scorpio and remained unchanged like that. In the night of mid-Ramadān, its light started to decrease and gradually faded away.

The 2nd (later) text is a small excerpt from the book entitled Kitāb Qurrat al-ʿayn fī akhbār al-Yaman al-maimūn about the history of Yemen, written by Abū ʿAbdallāh ʿAbdoralāḥmān ibn ʿAlī ibn Muḥammad ibn ʿUmar ibn ʿAlī ibn Yūṣuf Wāǧījāḥidān al-Shaybānī al-Zabīdī ibn al-Daybā (for short: Ibn al-Daybā), who was born on AD 1461 Oct 8 in Zhīb, Yemen, worked as a teacher and chronicler at the main mosque of Zhīb, Yemen, and died in AD 1537 Dec 21, also in Zhīb, Yemen, i.e. he lived and wrote about five centuries after SN 1006 (see Brockelmann 1949, Sellheim 1976, the latter being a translation of the auto-biography of Ibn al-Daybā).

We used manuscript number 416 from the Wadad Center for indexing and edited books; this manuscript is a copy written in AD 1680; see Figs. 2 & 3 for the text about SN 1006. There is also an edition of Ibn al-Daybā’s work Qurrat al-ʿayn by al-Akwāʾa al-Hiwwālī as publication of the Hiwwāli Yamānī Library (Ṣanʿāʾ, Yemen); the two texts are almost identical – with one exception: For the text by Ibn al-Daybā in our manuscript (Fig. 2) the word shuʾb is missing, which is present in both the printed edition of the work of Ibn al-Daybā by al-Akwāʾa al-Hiwwālī (Fig 3) and also in the printed edition of the work of al-Yamānī by al-Hubaishi & al-Sanabānī (1988), Fig. 1. The word shuʾb means branches or lines; the meaning of the text does not change significantly with or without this word.

An English translation of this text is as follows (as in SG02); the translation of the word shuʾb (for lines) from the edition of al-Akwāʾa al-Hiwwālī (Fig 3) is given in square brackets below, it is missing in our manuscript (Fig. 2):

In the year 396h, on the night of mid-Rajab, a star like Venus appeared. It regularly rose half an hour after sunset. It was not round, but rather was elongated; at its edges were [lines like] fingers. It showed great turbulence as though (reflected) in disturbed water. Its light rays were similar to the rays of the Sun. It appeared in the location of al-Ghafir in the sign of Libra. It remained unchanged until the night of mid-Ramadān. Then, its light diminished and it gradually faded away.

In manuscript number 416 as consulted by us, see Fig. 2, there is also a comment or headline about this new star at the left margin saying (Fig. 2):

the appearance of a great ranking star

which may have been written by the original author or a copying scribe.

Neither of the two texts was written by the observer, but they are histories written several hundred years after the SN. For both texts, we have to assume that the manuscripts known today are copies of copies of copies etc. The fact that they are otherwise very similar shows that the later text (written between AD 1461 and 1537) is probably derived from the earlier text (written before AD 1342) or its source.

Let us now discuss the differences of the two texts:

- Ibn al-Daybā: On the night of mid-Rajab, in the year 396h, a star appeared ...
- Ibn al-Daybā: In the year 396h, on the night of mid-Rajab, a star like Venus appeared.
- al-Yamānī: It was four times as large as Venus.
- Ibn al-Daybā: a star like Venus appeared, i.e. the latter left out the factor four (text variant of al-Yamānī also without that factor, but then in less good Arabic).
- al-Yamānī: a star appeared from the east at half an hour after sunset.
- Ibn al-Daybā: It regularly rose half an hour after sunset, i.e. leaving out the direction and adding regularly.
- al-Yamānī: It appeared in the zodiacal sign of Libra in Scorpio.
- Ibn al-Daybā: It appeared in the location of al-Ghafir in the sign of Libra, i.e. al-Ghafir instead of Scorpio.
- al-Yamānī: It appeared ... and remained unchanged like that. In the night of mid-Ramadān, its light started to decrease and gradually faded away.
- Ibn al-Daybā: It remained unchanged until the night of mid-Ramadān. Then, its light diminished and it gradually faded away, i.e. Ibn al-Daybā combined the last sentences from al-Yamānī, but both texts can be interpreted to show stationarity.

The later text by Ibn al-Daybā is shorter and/or less precise than the earlier text from al-Yamānī, e.g. Ibn al-Daybā left out the factor four in the brightness.

Regarding the difference in size or brightness in the two Yemeni reports, it may seem likely at first sight, that the 2nd author just left out the words four times (as large as Venus) and wrote instead a star like Venus. One could consider that
Fig. 1 The Arabic text from the History of Yemen from al-Yamānī, here the report about the year 396h including SN 1006. This is the earlier text no. 1. We also show one small text variant (1), bottom line, as specified in the edition of al-Hubaishi & al-Sanabānī (1988), page 63: The text variant says intafa instead of arba’. These two words are written in a very similar way in Arabic. With the variant intafa (Arabic verb for to rise), the text means It was as large as Venus and rose several times after sunset – while with arba’ (Arabic word for four), it would mean It was four times as large as Venus. The version with arba’ is better Arabic, while the version with intafa would lead to some kind of a duplication: ... a star appeared from the east at half an hour after sunset. It was as large as Venus and rose several times after sunset. The later version of the text by Ibn al-Dayba has just intafa’.

"فلما كان نصف رجب (سنة 396 هجريه) ليلة النصف طلع نجم من الشرق
مثل الزهرة أربع (4) مرات بعد غروب الشمس بنصف ساعة ولما يكن مدوراً بل هو إلى الطول أقرب، وفي أطرافه شعب مثل الأصابع ولما حركة عليه كأنه في ماء يضطرب، ولبه شعاع كشعاع الشمس وكان طلوثه في برج الميزان من العقرب.
وادم كذلك فلما كان ليلة النصف من رمضان نقص نوره ثم اضحلم."

(1) ارتفع

He left out four times, because, e.g., it may have seemed to him to be too much or too bright, but otherwise he left in its light rays were similar to the rays of the Sun, also appearing to be very bright. It is not certain that the 2nd author copied directly from the other (earlier) manuscript that we know today. It is well possible that he copied from an earlier, possibly different source, from which also the 1st report was copied earlier. The difference in this regard appears only in one of the two text variants.

Therefore, it seems possible that the 2nd author, Ibn al-Dayba, did not copy from the text in the very version we call here text no. 1, but that he either copied from an even earlier version of that report, or that he changed some details (e.g. as Venus, instead of four times as large), because he thought to know better from yet another source. However, this possibility appears more speculative. Of course, we cannot exclude that the differences are due to (intentional or unintentional) changes or mistakes made by copying scribes.

The main variant of the first text from al-Yamānī is better Arabic than its minor variant and than the text from Ibn al-Dayba, and it is also more detailed, so that we conclude that the 2nd text is most certainly derived from the first one.

Note that in this text about a new star (SN 1006), the word najm is used for star, while in the previously found Arabic reports about SN 1006 and 1054 the words kawkab (used for star or planet), nayzak (spectacle), and athar are used (atha’ kawkab meaning the star leaving traces or alternatively spectacle star, Brecher et al. 1978).

The reports from Yemen offer new and independent information on SN 1006, which is different from all other known reports, e.g. the apparent early discovery date, the detection half an hour after sunset, and the brightness (4 times as Venus). Hence, the reports are probably original (hence, likely from Yemen), and not copies of reports from other countries.

In the following interpretation, we will of course consider both reports, their differences, and the different text variants.

3 Dating

According to de Blois (2000), the wording nisfī min Rajab means middle of or 15th of Rajab, translated as mid-Rajab in SG02. This wording is not unusual for Arabic, it does mean one particular night (or day) and is not a rough indication of the middle of the month. The dates given in both Yemeni reports (the night of mid-Rajab or 15th of Rajab) and the night of mid-Ramadān or 15th of Ramadān in the year 396h) will now be converted from the Islamic calendar to the Julian calendar.

The calculated Islamic calendar can be converted to the Julian (or Gregorian) calendar by starting the Islamic calendar with year 1h on AD 622 Jul 15/16 then alternating months with 29 or 30 days, and also one leap day in 11 of every 30 years (the synodic month is 29.53 days on average). This is the calculated Islamic calendar, which may well be different from the real calendar used. In particular,

1 The Islamic year 396 hijri (396h) started 396 lunar years after the start of the lunar year in which the Hijra took place, i.e. the emigration of the Islamic Prophet Muhammad from Mecca to Medina, known as Hijra; this era, i.e. the year 1h started on AD 622 Jul 16 (evening of 15th to evening of 16th July) according to most scholars – but it may have been on AD 622 Jul 15 (evening of 14th to evening of 15th July) see, e.g., de Blois (2000); according to NASA GSFC (eclipse.gsfc.nasa.gov/phases/), new moon was on AD 622 Jul 14 (Julian calendar) at 5:26h UT (±2 min, Morrison & Stephenson 2004), so that the crescent new moon was hardly visible in the evening of AD 622 Jul 14, but it was well visible in Mecca, Saudi Arabia, in the evening of AD 622 Jul 15 (Neugebauer 1929).
Fig. 2 A copy of a small part of the History of Yemen from Ibn al-Dayba\textsuperscript{c}, here the report about the year 396\textsuperscript{h} including SN 1006. This is the younger text no. 2. It is taken from manuscript number 416 (written AD 1680) from the Wadod Center for indexing and edited books. An edition of Ibn al-Dayba\textsuperscript{c}’s work Qurrat al-\textsuperscript{u}y\textsuperscript{u}n by al-Akwaa\textsuperscript{a}’ al-Hiw\textsuperscript{a}l\textsuperscript{i} is available as publication of the Hiw\textsuperscript{a}l\textsuperscript{i} Yamani Library (\textsuperscript{S}an\textsuperscript{\textdagger}, Yemen). The relevant text about SN 1006 is indicated by yellow background: It starts before the middle of the 7\textsuperscript{th} line from the bottom with Fa-lamm\textsuperscript{a} k\textsuperscript{a}n\textsuperscript{a}t laylat al-nis. f min Rajab ... (on the night of mid Rajab ...); it ends after the middle of the 4\textsuperscript{th}-to-last line with ... thumma naqasa n\textsuperscript{a}r\textsuperscript{a}hu wa-id. alla ... (then its light diminished and it gradually faded away.). The words at the left margin say z\textsuperscript{u}h\textsuperscript{a}r najm ʿz\textsuperscript{a}m al-sha\textsuperscript{a}n (the appearance of a great ranking star). At the end of the 6\textsuperscript{th} line from the bottom, the last three words read wa\textsuperscript{f}t atr\textsuperscript{a}fhi mithlu, while the same portion in the text of al-Yam\textsuperscript{a}l\textsuperscript{i}, it says wa\textsuperscript{f}t atr\textsuperscript{a}fhi shu\textsuperscript{b} mithlu; the extra word shu\textsuperscript{b} means branches or lines, so that the meaning of these two versions is not really different. See Fig. 3 for the Arabic text re-written by us for better reading. Our translation is given in Sect. 2.

Fig. 3 The Arabic text from the Qurrat al-\textsuperscript{u}y\textsuperscript{u}n by Ibn al-Dayba\textsuperscript{c}, here the report about the year 396\textsuperscript{h} including SN 1006, re-written by us from the edition of al-Akwaa\textsuperscript{a}’ al-Hiw\textsuperscript{a}l\textsuperscript{i}. Please note that the manuscript (Fig. 2) does not have the word shu\textsuperscript{b}, which is present in the edition by al-Akwaa\textsuperscript{a}’ al-Hiw\textsuperscript{a}l\textsuperscript{i}.

the length of the months were not set to be alternating between 29 and 30 days, but the start (and end) of a month was set by observing the crescent new moon. There are two uncertainties in this calculated Islamic calendar: (i) The start of year 1\textsuperscript{h} could have been AD 622 Jul 15/16 or 14/15 (see footnote 1) and (ii) it is not clear a-posteriori when in history a month had an extra day\textsuperscript{2}. Furthermore, the calculated Islamic calendar was not used in history\textsuperscript{3}. In summary, the calculated Islamic calendar can deviate by up to two days (Ginzel 1906, Spuler & Mayr 1961, de Blois 2000).

The start (and end) of a month was not set by some calculated calendar, but by real observations of the crescent on average – six months of 30 days. Due to crescent sighting, the month with one extra day did not necessarily follow the leap day/month rule in the calculated Islamic calendar used in, e.g., Spuler & Mayr (1961).

\textsuperscript{2} Given that the average duration of a synodic month is 29.53 days, one needs one extra day in 11 of each 30 years; the calculated Islamic calendar uses leap days in certain, pre-defined years and months; in reality, we have to expect that, in each period of 30 years, there were 11 months which had an extra day (due to real crescent sighting) – in addition to those 354 days in a pure lunar calendar with – on average – six months of 29 days and –

\textsuperscript{3} al-Bir\textsuperscript{a}n\textsuperscript{i} (AD 973-1048) wrote: the leap years of the Arabs, not that the Arabs ever actually used or use them, but the authors of astronomical tables need them when they construct tables on the basis of the years of the Arabs (quoted after de Blois 2000).
new moon: A month started on the evening, when a new crescent moon was seen (Quran, Sura 2, 189).

However, the sighting of a crescent new moon could have been delayed by one or more days due to, e.g., bad weather, high extinction at low latitude, or difficult landscape. It may also be possible that a month started one day too early due to a false early detection (Doggett & Schaefer 1994, Ilyas 1994). If the weather was overcast for several days, the start of the month can be set later given the age or phase of the moon, also typically to ±2 days. In some cases, however, it is possible to convert from the Islamic calendar to the Julian (or Gregorian) calendar with an accuracy better than ±2 days (i.e., better than with the calculated Islamic calendar), namely when some calibration is known, e.g., the mentioning of an Islamic date together with a weekday, or the observation of a certain astronomical event, that can be dated nowadays with higher accuracy. If the length of a month was fixed to at least 29 days and/or at most 30 days (which is likely, but not certain, de Blois 2000), then a calibration in the next or preceding month might also be sufficient for an accuracy of better than ±2 days. See, e.g., Spuler & Mayr (1961), Spuler (1963), Ilyas (1994), de Blois (2000), Said et al. (1989), and Neuhäuser & Kunitsch (2014) for more details about Muslim calendar rules and calendar conversion.

By converting the date given as night of mid-Rajab or night of 15th of Rajab from the calculated Islamic calendar (Spuler & Mayr 1961) to the Julian calendar, we obtain the night of AD 1006 Apr 17/18 (first detection of SN 1006).

Let us now try to determine the date of the first crescent visibility with a precision of better than ±2 days.

Start of the month Rajab: According to eclipse.gsfc.nasa.gov and Gautschy (2011), new moon (true conjunction of moon and Sun) was on AD 1006 Mar 31 at 23:57h UT (± few min, Morrison & Stephenson 2004), or on Apr 1 at 02:57h in the current time zone of Yemen (3h east of Greenwich), or on Apr 1 at 02:54h at the eastern longitude of Şan‘a′ (44°12′23″E). According to Gautschy (2011), the crescent new moon was then visible not before 16:14h UT (in Babylon, Iraq) on AD 1006 Apr 2 (the crescent can be detected only if the separation between sunset and moonset is sufficient and if the moon is sufficiently high above horizon, see, e.g., Ilyas (1994) and references therein). The crescent probably has been sighted at Şan‘a′ first in the evening of (our) Apr 2 (19° above horizon at sunset). In case of bad weather, an even later sighting is possible. In case of an early (false) detection, the first sighting of the crescent could have been reported (and accepted) for Apr 1.

Given that dates are memorized with respect to the end of a month (de Blois 2000), we also have to consider the end of the month of Rajab: According to eclipse.gsfc.nasa.gov and Gautschy (2011), new moon was on AD 1006 Apr 30 at 9:08h UT (± few min, Morrison & Stephenson 2004), or at 12:08h moon in the current time zone of Yemen, or 12:05h at Şan‘a′. According to Gautschy (2011), the crescent new moon was then visible not before 16:21h UT (for Babylon, Iraq) on AD 1006 May 1. Hence, the first detection of the crescent probably happened on the evening of (our) May 1.

The first day of the new lunar month of Shaʾbān would then run from the evening of May 1 to the evening of May 2 (or maybe from May 2 to 3 in case of bad weather on May 1); in the less likely case of a false early detection of a crescent, the month could have started on Apr 30. While according to de Blois (2000) a wording like mid-Rajab means the 15th of Rajab, all dates since the 15th were given and memorized under the assumption that the month would have a total of 30 days. One could question this by arguing that, after it was noticed that a particular month had only 29 days, one could correct the dating; on the other hand, experienced observers of the moon can deduce the number of remaining days before a new crescent moon could be observable from the currently observed age or phase of the moon anytime during the month. As we will see below due to sightings of SN 1006, the month of Rajab in that year most certainly had 30 days. Furthermore, it may be easy to correctly give the date as middle of the month, because this is near full moon, which is easy to observe and to determine; according to eclipse.gsfc.nasa.gov, full moon was on AD 1006 Apr 16 at 9:35h UT. Note, however, that in a lunar month starting with the first sighting of the crescent (and not with true conjunction), full moon is not exactly in the middle of the month.

Unfortunately, neither al-Yaḥyā nor Ibn al-Daybāʾ mention the weekday of the 15th of Rajab. We can, however, consider other Arabic reports about SN 1006 for a more precise dating of the end of Rajab.

Ibn al-Jawzī reported that SN 1006 was first detected on Friday at the beginning of Shaʾbān – meaning the evening at the start of the 1st of Shaʾbān just after sunset. And Yaḥyā ibn Saʾīd al-Āntākī reported that it was first detected on Saturday, in the evening at the start of the 2nd day of Shaʾbān. Hence, for those two additional Arabic observers, the month of Shaʾbān started on a Friday (1st of Shaʾbān). In the Islamic calendar, a day (like this Friday) started at an evening sunset and ended at the next evening sunset (on the Julian or Gregorian calendar, we regard the time from the first evening sunset to midnight as the previous day, here a Thursday). According to Spuler & Mayr (1961), our May 3 was indeed a Friday in AD 1006. Hence, we can identify the 1st of Shaʾbān on the Islamic calendar with the date AD 1006 May 2/3 (from sunset to sunset) on the Julian calendar. The reports by Ibn al-Jawzī and Yaḥyā ibn Saʾīd al-Āntākī are consistent with each other, i.e., the observers, on whose observations the reports are based, both started the month of Shaʾbān at the evening sunset of AD 1006 May 2. The observer, whose observations are reported by Ibn al-Jawzī, detected both the lunar crescent and SN 1006 for the first time on that evening (hence, 1st of Shaʾbān). For the observer, whose observations are reported by Yaḥyā ibn Saʾīd al-Āntākī, the weather was also clear and fine on the evening of May 2, so that he could detect the crescent – but he did not detect the supernova on that evening.

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Note that the start of the lunar month on the evening of AD 1006 May 2 in Arabia is not in contradiction with the Far Eastern reports about SN 1006, where we can read: *on the 2nd day of the 4th lunar month (May 1)* (China, Song Huijao Jigao) and *on the 2nd (day) of the 4th month (May 1)* (Japan, Meigetsuki) (texts cited and date conversions given are both from SG02), i.e. the lunar month started in China and Japan on Apr 30 (days and dates run from midnight to midnight).

As mentioned above, new moon (conjunction of moon and sun) was on AD 1006 Apr 30 at 9:08h UT. And indeed, the Chinese started the day-count in each (lunar) month with what we call *new moon*, i.e. conjunction of moon and sun, as confirmed by the fact that all of the dates of solar eclipses from (at least) AD 700 to 1200 are dated to the *first day of the month*, see listing in Xu et al. (2000).

According to the calculated Islamic calendar, the 1st of Sha’bân (from evening to evening) was on AD 1006 May 2/3, which is here consistent with the true crescent detection by the Arabic observers. According to Gautschi (2011), the crescent would have been visible on AD 1006 May 1, but we have to conclude that the weather may have been bad on that evening, so that the month started one day later (and SN 1006 was also not detected by those observers on May 1 due to bad weather). Since the month could have started one day earlier than it did, the previous month probably had 30 (instead of 29) days.

Alî ibn Riḍwân observed SN 1006 on AD 1006 Apr 30, without giving explicitly this date, but this dating (and the fact that he had good weather on that date) is not inconsistent with the weather of the other observers discussed above on May 1 and 2.

Let us now assume that the weather was similar (good on May 2 and bad on May 1 evening) for the observer, whose observations are reported by al-Yamâni and Ibn al-Dayba’, so that he also started the month of Sha’bân at the evening sunset of AD 1006 May 2.

If the 15th of Rajab was given with respect to the end of the month under the assumption that it had 30 days (see above, de Blois 2000), then the 15th of Rajab ran from the sunset of AD 1006 Apr 16 to the next sunset on Apr 17.

Above, we had concluded that the possible dates for the evening of the 1st of Rajab were 1 Apr (early false detection) or Apr 2 (best case) or Apr 3 (in case of bad weather on Apr 2). If the month of Rajab ended with the evening sunset of AD 1006 May 2, and if its length was 30 days, then it started on Apr 2 at evening sunset (if its length was 29 days, then it started on Apr 3 at evening sunset).

An additional uncertainty of one more day could be introduced, if a month would last neither 29 nor 30 days; while some scholars argue that this is excluded given an Hadîth[8] others argue that this Hadîth applies only to the month of Ramaḍân and could show evidence that in a few rare cases, a Muslim month did last 31 days (see, e.g., de Blois 2000, according to Schaefer (1993), this can happen in 0.06 % of cases). The most likely dates for the start of the night of the 15th of Rajab remain AD 1006 Apr 16 and 17.

In the evenings of AD 1006 Apr 17 and 18, the moon was below the horizon for a significant time after the rising of SN 1006, so that it should have been possible to have detected SN 1006 since AD 1006 Apr 17, while on the evening of AD 1006 Apr 16, the moon was above the horizon (and also above the location of SN 1006) before SN 1006 rose, so that it would have been less likely to discover it. If the weather was not good enough for the detection of the crescent of AD 1006 Apr 2 at the site of the observer, whose observations are reported by al-Yamâni and Ibn al-Dayba’, but good enough on Apr 3, then the month of Rajab started (for him) on Apr 3, so that on Apr 17 (evening) the 15th of Rajab started.

Al-Yamâni then also mentioned that SN 1006 *a star appeared from the east at half an hour after sunset* (Ibn al-Dayba’: *regularly rose half an hour after sunset*): At the location of Šan’ā’ in Yemen, the apparent rising of SN 1006 (on an assumed perfectly flat horizon) was indeed ∼ 25 to 30 min after apparent sunset around AD 1006 Apr 17. This time difference then decreased until SN 1006 rose at sunset around AD 1006 Apr 23/24. After that date, SN 1006 rose before sunset.

This conclusion is correct for considering *half an hour either as a period of 30 well-defined clock-minutes (as we do today) or as a period of half a sun-dial hour (as done in former times, when the bright day-light time was split into 12 hours of unequal duration), because in mid-April, half a sun-dial hour was only slightly longer than 30 clock-minutes, in particular in a location as south as Yemen.

The considered rise time is also consistent with another historic report, the Mauretanian report said for early May: *(It appeared on the first (day) of Sha’bân, (3)96 mentioned above.) Its first appearance was before sunset, whereupon it faded until night came and it reappeared (SG02), but translated different in Goldstein (1965):* It began to appear in the beginning of Sha’bân (3)96. Its first appearance took place before setting whereupon it went backwards until it rose night[9]

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[8] According to the collection of Hadîth by Bukhârî translated by M. Muhsin Khan (www.searchtruth.com/hadith_books.php), Prophet Muhammad once said: *When you see the crescent (of the month of Ramaḍân), start fasting, and when you see the crescent (of the month of Shawwâl), stop fasting; and if the sky is overcast (and you can’t see it) then regard the crescent (month) of Ramaḍân (as of 30 days).*

[9] Both translations specify that SN 1006 was detected before sunset, i.e. during the late day. There is no such day-time detection reported from the Chinese, Japanese, nor Koreans. The day-time detection from Mauretania may have been facilitated by clean air and/or high altitude (the highest point in today’s Mauretania is the Kediet al-Jill at 915 m, and the highest point in today’s Morocco is the Atlas Mountain with 4,165 m in the north of Morocco). Since the conversion of a Muslim date to a Julian date depends on whether SN 1006 was detected before or after sunset, i.e. before or after the change of the date, we have to clarify the date here: The reported detection on the *first (day) of Sha’bân (or the beginning of Sha’bân)* before sunset would then not necessarily be the evening of AD 1006 May 2, but maybe already May 3 just before sunset, because the first day of Sha’bân ran from the evening of AD 1006 May 2 to the evening of May 3. This consideration would modify the detection date from Mauretania (as given in Goldstein 1965 and SG02) by one day. Detection of SN 1006 before
The fact that the difference between rise time and sunset is fully consistent with the given discovery date (around AD 1006 Apr 17 evening), for a location of Shan‘ā‘y in Yemen, gives quite a high confidence and credibility in the report by Al-Yamānī. It can also be seen as circumstantial evidence that the observations were really done at (or near) Shan‘ā‘y in Yemen.

It may be quite surprising if the observer, who is the original source for the reports of the Yemeni authors, really has observed and detected SN 1006 already several days before the other Arabic observers (e.g. Apr 30 by ʿAlī ibn Ridwān), and all (confirmed) eastern Asian observers (not before May 1), so that this early date was rejected by SG02 as artificial.

However, since Shan‘ā‘y is at 2400 m sea level and since it has a clear horizon towards the south, an observation from here earlier than all other known detections may not appear impossible.

4 Brightness, duration of visibility, lightcurve, location, stationarity, and color

We will now discuss the other information content from the Yemeni reports.

**Brightness.** Al-Yamānī gives it was four times as large as Venus (in the more likely text variant), while Ibn al-Dayba‘ gives a star like Venus. If we interpret this observation as brightness of the new star, than it was (probably) four times brighter than Venus, i.e. 1.5 mag brighter than Venus around that time. Venus was visible in the west increasing in apparent brightness from −2 to −3 mag; in Sep 1006, Venus and SN 1006 came as close as 16° with Venus having an apparent magnitude −4 mag. Alternatively, four times as large as Venus could mean the apparent size instead of the brightness.

**Duration of visibility.** The last sentence of Al-Yamānī is: In the night of mid-Ramāḍān, its light started to decrease and gradually faded away, similar in Ibn al-Dayba‘. According to the calculated Islamic calendar (Spuler & Mayr 1961), the night of mid-Ramāḍān (or 15th of Ramadān) is AD 1006 Jun 15/16. According to eclipse.gsfc.nasa.gov, conjunction between moon and Sun was on AD 1006 May 29 at 19:32h UT, and according to Gautschy (2011), the crescent new moon was not visible (at Babylon, Iraq) before AD 1006 May 31 at 16:45 UT. Hence, the 1st day of Ramadān 396h started probably on the evening of AD 1006 May 31, and the 15th of Ramadān was then AD 1006 June 14/15 (evening to evening). On this day, SN 1006 started to get fainter (in the Yemeni reports), so that the period of visibility is at least two months. According to eclipse.gsfc.nasa.gov, full moon was on AD 1006 June 14 at 7:46h UT (with a partial lunar eclipse visible in Arabia), so that it was relatively easy to date the middle of Ramadān well. Maybe the bright light of the moon in and around that night caused the observer to conclude that SN 1006 was getting fainter.

The last sentences of al-Yamānī (In the night of mid-Ramāḍān, its light started to decrease and gradually faded away), and also even in Ibn al-Dayba‘ (its light diminished and it gradually faded away), both for mid June, do not mean that the Yemeni observations were restricted to those two months from mid-April to mid-June, but rather that the brightness of SN 1006 remained roughly constant until mid-June, and then started to get fainter. ʿAlī ibn Ridwān reported: it ceased all of a sudden in July, i.e. indeed even one month later.

**Lightcurve.** While the more likely text variant in al-Yamānī says that the SN was four times brighter (or larger) than Venus (in mid April 1006), the less likely text variant and Ibn al-Dayba‘ give a different brightness: a star like Venus.

As discussed above, it is not impossible that the (later) report by Ibn al-Dayba‘ regarding the brightness is correct, either because he corrected the other report by al-Yamānī with independent information (or, less likely, that the two values refer to different dates, even though they report the same dates). From the reports by Ibn al-Dayba‘ (a star like Venus) and ʿAlī ibn Ridwān (2.5 or 3 times as large as Venus), we may be able to conclude that SN 1006 was about 1 mag fainter when observed by the source of Ibn al-Dayba‘ than as it was when observed by ʿAlī ibn Ridwān. Given the typical lightcurve of a SN Ia, it increases in brightness for the first 10 to 18 days (before the peak) by 1 to 1.5 mag, and it also decreases by 1 to 1.5 mag in 10-18 days after the peak (Woosley et al. 2007, Gameshalingam et al. 2011). The apparent magnitude and time difference between the two observations reported by Ibn al-Dayba‘ and ʿAlī ibn Ridwān would then be consistent with a SN Ia lightcurve. From this consideration, it remains uncertain as to whether the observation reported by Ibn al-Dayba‘ was 10-18 days before or after the observation reported by ʿAlī ibn Ridwān. It would be fully consistent with a SN Ia lightcurve, if the observation reported by Ibn al-Dayba‘ (e.g. evening of Apr 17) would have been 10-18 days before the one reported by ʿAlī ibn Ridwān (Apr 30). While SN II-P show slower brightness decreases than II-L, the historic data on the lightcurve of SN 1006 are not sufficient to distinguish between SN types. Given that al-Yamānī may report a different brightness for the same date as Ibn al-Dayba‘, the above consideration is highly speculative, even though this difference appears only in one of the two text variants of al-Yamānī. Furthermore, also in the report by ʿAlī ibn Ridwān, the wording 2.5 or 3 times as large as Venus can be interpreted as meaning the apparent size instead of the brightness.

**Location.** Al-Yamānī gives the position as in the zodiacal sign of Libra in Scorpio, while Ibn al-Dayba‘ gives in the location of al-Ghafr in the sign of Libra. The reports

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6 The Jabal al-Nabi Shu‘ayb, the highest mountain in Arabia with 3666 m, is due west-south-west from Shan‘ā‘y, while SN 1006 was rising in the evening in the south-east.
could either refer to the ecliptic longitude of the new star by comparing it to the ecliptic longitude of a constellation or zodiacal sign (like Libra and Scorpio) or a lunar mansion (al-Ghafır), or the reports could give the location of the new star (e.g. meaning in Libra or in Scorpio or in al-Ghafır). The wording Libra in Scorpio can be interpreted in different ways:

Roughly the border between the two (astrological) zodiacal signs, roughly as the area of overlap of the constellations Libra and Scorpio, or the area in Libra with Arabic lunar mansions, that pertain to (and are named after) the constellation of Scorpio, i.e. roughly in the 2nd half of Libra.

In historic Arabic astronomy (and astrology), al-Ghafır (the covering or the hair on the end of the tail of the beast of prey) is the 15th of 28 lunar mansions (as already given in SG02) running from 0° to 12°51’26” within the zodiacal sign of Libra. There are 28 lunar mansions around the ecliptic (one sidereal month lasts 27.3 days). The lunar mansions with their names and borders can be found, e.g., in The Chronology of Ancient Nations by the famous Arab astronomer al-Bīrūnī (AD 973-1048), edited and translated to English by Sachau (1879), as well as in the book called Ghayat al-hākim (Latin Picatrix) about astrology written around AD 1000 (Hartner 1965, Sezgin 1971, Pingree 1986).

Depending on the interpretation, the location given for SN 1006 can be correct: It has an ecliptic longitude as near as the border of the true stellar constellations of Libra and Scorpio as seen around AD 1006, and SN 1006 also has such an ecliptic longitude.

Stationarity. Al-Yamānī wrote: It appeared in the zodiacal sign of Libra in Scorpio and remained unchanged like that. This can be interpreted such as that the object remained unchanged with respect to the stars, i.e. that it did not move with the planets, but with the stars, i.e. that it was stationary.

The Mauretanian report said for early May that SN 1006 moved backwards and ʿAli ibn Rīdwan reported: It remained where it was and it moved daily with its zodiacal sign – probably both meaning that it was staying still relative to the stars.

Color. If the text given by Ibn al-Dayba7 (a star like Venus) would refer to the color of the SN (instead of the brightness), it would have a Venus-like color, i.e. white to yellow. However, the text by Ibn al-Dayba7 is probably just a shortened version of the text by al-Yamānī, who clearly said: it was four times as large as Venus.

5 Summary

We have presented the Arabic texts of the observation of SN 1006 by al-Yamānī and Ibn al-Dayba7 from Yemen. While the English translation of the text from Ibn al-Dayba7 was presented earlier (SG02), the more original text from al-Yamānī is presented here for the first time. We have also discussed their content in comparison with other Arabic and eastern Asian observations.

Brightness (or size or color), duration of visibility (at least two months), stationarity (with respect to the stars), and position are fully consistent with the other Arabic and eastern Asian observations, and of course fully consistent with all what is known about SN 1006, which gives a lot of confidence in the reports. Yet, the most striking difference is the early discovery around AD 1006 Apr 17. The very early sighting in Ṣanʿāʾ, Yemen, might have been facilitated by its large height above sea-level being some 2400 m: Going from such a large height to roughly sea level, where most of the other, later observers were located (e.g. Cairo, Japan, China) can change the atmospheric extinction for object low on the horizon by some 4 mag (e.g. Schaefer 1993). If the brightness of SN 1006 was around -3 mag (like Venus at that time) when observed at the location of Ṣanʿāʾ, Yemen, it would have been ~1 mag at the other sites, so that it might not have been noticed, yet, as new bright star – the limit for serendipitous discovery of a new star on the sky by naked-eye is some 0 to 2 mag according to Clark & Stephenson (1977) and Strom (1994).

It might be possible that the author (al-Yamānī, Ibn al-Dayba7, and/or an earlier author) found in his source only the month, not the date, and that at least one of them thought that he would need to give the date with better precision, i.e. not only the month, but also the day in the month, he then gave night of mid-Rajab as his best guess. (The same consideration can be applied to the last obervational date given (the night of mid-Ramada), as already considered by SG02.) On the other hand, the wording the night of mid-Rajab is quite typical and normal for Arabic dates, and it does mean exactly the 15th of the month (de Blois 2000).

Also, the report that it rose several times half an hour after sunset is fully consistent with AD 1006 Apr 17 (±2 day) for an observation from Yemen, in particular from as high as its capital Ṣanʿāʾ. The otherwise earliest certain observation is on AD 1006 Apr 30 by ʿAli ibn Rīdwan.

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7 sometimes also given as the hair on the end of the lion’s tail, which is, however, misleading, because it is not connected to today’s constellation of Lion (Leo), but to the Arabic constellation/asterism of beast of prey.

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