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Daytime observations of sungrazing comets in Chinese annals

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Abstract. Kreutz sungrazers consist of a handful of major comets and some 400 minor (faint) members found by satellite observations through 2001. Although they can be spectacular visual objects, many must be absent from historical records. Here I show that a dozen or so previously unrecognized sungrazers were probably recorded in Chinese solar observations, and from their brightnesses they must be major group members. The earliest dates from 15 AD, but nearly half were seen in a short period in the 17th century, and there is some evidence that most of the entire ensemble belong to the Kreutz class.

Key words. comets: individual: Kreutz sungrazers – history and philosophy of astronomy

1. Introduction

Sungrazing comets constitute a fascinating group. Most belong to a causally-related class with similar orbits studied in extenso by Kreutz (1888, 1891). They are comets of long period (typically 400–800 yr) with perihelia of no more than a few solar radii (Marsden 1989), and are generally believed to have originated from the break up of a single parent object (Marsden 1967). Although there is a rich body of Chinese observational data on comets stretching back over 2 millennia (BAO 1988), few belong unequivocally to the Kreutz group. However, a number of daytime objects do appear to be plausible candidates.

While investigating Chinese sunspot records (BAO 1988) for an unrelated reason, I was struck by a number of descriptions clearly related to the Sun, but which hardly sounded like sunspots. A typical one can be translated as, “in the Sun a star appears” (or “is seen”). Sunspot records usually read, “in the Sun there is a black spot” (a variety of descriptions can be used instead of “spot”). Although sunspots are often likened to mundane objects (plum, egg, crow, etc.), there is not a single comparison with a star, planet, or other celestial body. There is only one record where a star and sunspot are both mentioned – and it is clear that two separate objects were observed. The Chinese word “star” (*xīng*) for a celestial object is, as in English, quite unambiguous, and has had the same meaning over the entire period of interest here. With an adjective it can mean planet (*xíng xīng* – literally “walking star”), comet (*huì xīng* – “broom star”, or *cháng xīng* – “long star”), etc. It seems very unlikely that the

descriptions in question refer to anything but a compact, bright body near the Sun. What could it be?

A few possibilities can be quickly eliminated. *Planets:* Venus can be seen (just) by naked eye during the day (Ellis 1995); a check shows that it was never closer than 25° to the Sun on the dates of interest. *Bright supernovae:* several have been bright enough to be seen in daylight (Clark & Stephenson 1977), but the a priori probability of a random event appearing close to the Sun is of order 10^{-5} . The chance of observing as many as ten is infinitesimal. *Stars during a solar eclipse:* eclipses were well-known to the Chinese (Ronan 1985; BAO 1988); there were none on the dates in question. *Atmospheric phenomena:* Chinese scholars were also familiar with parhelia, which had been thoroughly described as early as the seventh century (Ronan 1985).

2. Candidate daytime comets?

I believe we are left with only one plausible explanation: the objects recorded by Chinese astronomers were the bright nuclei of sungrazing comets. That such objects can be exceptionally bright is demonstrated by a number of observations from the past two centuries. The “Great September Comet” (1882 II = C/1882 R1) was described as “a blazing star near the sun”, could be seen right up to the solar limb (in broad daylight), and its nucleus was estimated at $m_v < -10$ (Kronk 1984). More recently, Ikeya-Seki (1965 VIII = C/1965 S1) was observed straight through perihelion, could be readily seen at mid-day, and had a similarly spectacular bright nucleus (Marsden 1965; Kronk 1984). Marsden (1989) notes of unseen sungrazers, “...difficult to explain is the absence of daytime records ... within, say, 12 hr of

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Table 1. “Sun stars” from Chinese annals.

No.	Date	Source	Comet?
1	AD 15.3.10–4.7	Chang’an (Xi’an)	15.3? (star)
2	1539.7.15–8.13	Zhejiang	1539.9.12–10.11
3	1564.8.7–9.4	Beijing?	1564.9.5–10.4
4	1625.9.2	Zhejiang	1625.7.4–8.2
5	1630.8.5	Shandong	1630
6	1643.6.16–7.15	Anhui	–
6a	1643	Henan	–
7	1644.3.9–4.6	Hebei	1644.4.7–5.5
8	1647.7.28	Shandong	–
9	1648 summer	Shandong	1648.5.29 (star)
10	1665.8.27	Hubei	1665.8.13 and 1665.8.11–9.8
11	1774	Guangdong	–
12	1792.4.21–5.20	Shandong	–
13	1839.8.14	Guangdong	–
14	1865.7.18	Jiangsu	–

perihelion”. Regular solar observers *ought* to see an occasional sungrazer. In all, from 1800–2000 we know of five daylight comets visible by eye near the Sun (of which three belonged to the Kreutz group), so while unusual, such comets are not unique.

Table 1 lists the 15 occurrences from the compendium, *Chinese Ancient Records of Celestial Phenomena* (BAO 1988) by date, together with other relevant information. Most come from provincial records, so the province is listed. In only six cases is an exact date given. In most of the others, the (lunar) month is indicated, though in one only “summer” is specified, and two mention the year alone. Entries 6 and 6a may refer to the same event – the wording is identical, and the dates are consistent. Entry 7 comes from events described as of “uncertain category”.

In three or four cases (one is slightly ambiguous) the “star” is said to be at the side (*páng*) of the Sun, and two of these (entries 2 and 4) are quite explicit. A translation of the text reads, “daytime star appears at Sun’s side”. Most of the texts, however, simply say a star appeared “in the Sun”, so one might wonder whether they refer to a comet at all, since it would hardly be visible if actually projected on the solar disk. The description of entry 13 is particularly revealing in this respect, as it can be translated: “in the Sun a star appears, its position is the Sun’s side [*páng*]”. In 30% of the entries in Table 1, the location is given as the side. This is rare among sunspots, where only 4% are so described (and only 7% in total have any mention of a location). By implication, there was something unusual about the location of the comets in Table 1; presumably all were seen next to the Sun. From now on I will refer to these objects as *sun-comets*.

There is another striking difference in wording between the comet and sunspot records: all but two of the former are said to “appear” (*jiàn* or *xiàn*), terminology used for only 2% of all sunspots. By the same token, sunspots are regularly compared with birds, fruit, containers, etc.;

this is never done for these comets. While the significance of such textual nuance is unclear, it does serve to contrast the two types of phenomena.

The last column in Table 1 lists comets from the annals (BAO 1988; Kronk 1999) seen within a month of a sun-comet. Given the number of nighttime comets recorded after 1500, most of these objects will be mere chance coincidences. Little or no positional information is given with which to test possible associations further (though in the case of entries 2 and 3, the comet is described as “west” while one would expect an autumn Kreutz sungrazer to be seen in the east). The comet of 1644.4.7–5.5 (entry 7, observed in the month after the appearance of the sun-comet) was seen in the southeast. A southerly location would certainly be expected of a Kreutz member (but in the spring, southwest would seem more likely).

In both AD 15 and 1648, there are records of a star seen at noon (Kronk 1999). The former is from China, and follows a reference to a banquet held during the second month. Kronk describes it as possibly a comet, nova, or even Venus, and the timing could link it with the sun-star of 15.3.10–4.7 (the second lunar month). It is at least a plausible independent sighting of that event. The daytime star sighted in 1648 is also consistent with the sun-comet of that summer. However, it was only reported from London upon the occasion of the birth of the second son of Charles I there. The two comets under entry 10 could refer to the same object. If they are both related to the sun-comet of 27 August 1665, then it must have been seen both before and well-after perihelion. The comet of 1665.8.11–9.8 is mentioned in two different records, which say that it disappeared after “over 60 days” and “2 months”.

Perhaps the most striking fact in Table 1 is the concentration of sightings to the summer months. This is the more remarkable since the summer monsoon generally hampers solar observations (Willis et al. 1980). Figure 1 (upper) shows the months of the 12 dated comets from Table 1, while Fig. 1 (lower) is a similar histogram for sunspots from the Chinese records (BAO 1988). The “summer dip” in the latter may not be entirely due to the obvious cause of thick cloud; it has been suggested that heavy rainfall may wash dust out of the atmosphere, leading to increased solar glare on clear days (while just the opposite, wind-borne dust in the springtime, may account for the March peak, Willis et al. 1980). At such times unaided observations of sunspots would be impossible, although sightings of a bright comet near the Sun would still be feasible (as was the case with Ikeya-Seki in 1965, Marsden 1965). Whatever else it may mean, the difference between Figs. 1 (upper) and (lower) is compelling evidence that the objects described as a “star” differ in some fundamental way from sunspots.

The geometry of the Kreutz comet group orbits is such that they can be seen in darkness during the (northern hemisphere) autumn, winter and spring. In the summer, however, their orbits lie behind the Sun, and indeed only two with perihelia falling between late February and late August have been discovered (Marsden 1989).

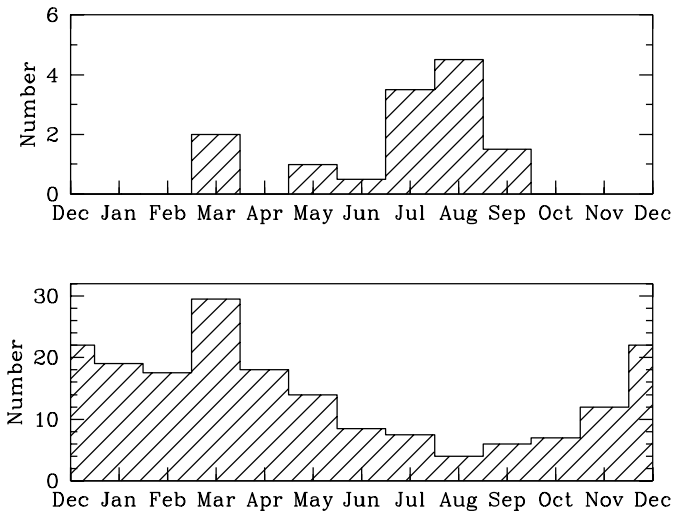


Fig. 1. Histograms showing the annual pattern of recorded solar features over 2 millennia. *Upper:* Those from Table 1 described as “stars” (*xīng*). Where only the (lunar) month is given, its midpoint has been used, but if it straddles two European months, each has been assigned one-half. For the two comets in the sixteenth century, the civil date has been corrected to the Gregorian calendar. *Lower:* Monthly occurrences of the remaining records, all believed to be sunspots.

As Marsden (1967) puts it, such a comet “...at perihelion between mid-May and mid-August will undoubtedly be missed, *unless it can be seen in daylight*” [my italics]. This is circumstantial evidence that most of the objects in Table 1 were Kreutz sungrazers seen just at perihelion. I presume that at other times of the year such objects would have also been seen at night, and the connection “solar star” – comet could have been made. (The Chinese records reveal that the bright Kreutz members 1843 I (=C/1843 D1), probably 1882 II, possibly 1880 I (C/1880 C1) and 1668 (C/1668 E1) as well, were indeed seen by both day and night.) Combined with the aforementioned fact that most daytime comets seen near the Sun have been from the Kreutz group, the evidence in Fig. 1 appears persuasive.

3. Discussion

A substantial number of relatively faint Kreutz sungrazers has been discovered by spacecraft-borne instruments since 1979, suggesting a near-steady flux (though possibly episodic, MacQueen & St. Cyr 1991) of minor debris from this comet group (Marsden 1989). Such objects, at best of brightness $m_v \simeq -4$, appear to be too faint for naked-eye detection. The objects listed in Table 1 (to the extent that they belong to the Kreutz group) are presumably similar to the comets discussed by Marsden (1989; Table IX), while the fainter ones discovered by satellite (including over 350 observed in the past 6 years by SOHO, Biesecker 2002) must be less substantial bodies. In Fig. 2, I show the occurrence of all major objects from 1500 to 2000, including those listed in Table 1, but excluding comets

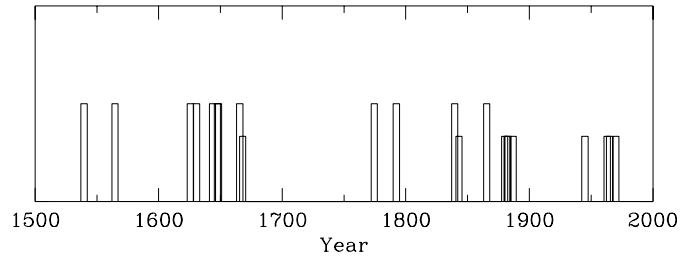


Fig. 2. Bar diagram showing the distribution over five centuries of the ten generally accepted major Kreutz sungrazers (shorter bars), and the sun-comets (Table 1).

in 1689, 1695 and 1702 whose membership is questionable (Marsden 1989).

In addition to previously noted (Marsden 1967, 1989; Sekanina 2000) clusters of Kreutz comets in the nineteenth and twentieth centuries, the new data indicate a third bunch in the seventeenth century, and partially fill in gaps in the sixteenth and eighteenth (the latter noted before, Marsden 1967). It will surprise no one that the temporal distribution in Fig. 2 is significantly different from that expected of random arrivals. However, though it may seem that fewer sun-comets were observed between 1500–1600 and 1700–1800, there were also fewer sunspots recorded (BAO 1988) in both these periods than in the seventeenth century (while the number of reported nighttime objects remained constant). In each century the incidence of sun-comets was about 20% of the sunspots recorded. While we have no way of knowing whether the sunspots observed are indicative of how many sun-comets might have been discovered, it is certainly possible that the rate of (major) Kreutz sungrazers has been fairly constant, if episodic, over the past half millennium.

Sungrazing comets are known to brighten up considerably as they near perihelion, and as noted above some can be quite exceptional. The only information we have about the magnitude of the objects in Table 1 is that they were visible in daylight. What limit can that set on their brightnesses? The brightest of the SOLWIND and Solar Maximum Mission (SMM) comets exceeded $m_v = -4$ (Marsden 1989), yet none were detected from the ground. Daytime comets like C/1927 X1 and 1882 F1 have been observed next to the Sun with a reported (Kronk 1984) magnitude of $m_v \simeq -6$, so it seems likely that the sun-comets were observed with $m_v \lesssim -6$. This makes them brighter than at least half of the Kreutz sungrazers observed from the ground, so most of them should have had substantial nuclear components.

Although the sun-comet records provide no information for orbital determination, they do possibly add to our knowledge of past apparitions of Kreutz group members. Marsden (1989) has sketched an evolutionary scenario which traces the major Kreutz sungrazers back in time, and suggests when some might have split apart. 1882 II and Ikeya-Seki have such well-determined orbits that we can be quite certain that they separated in the

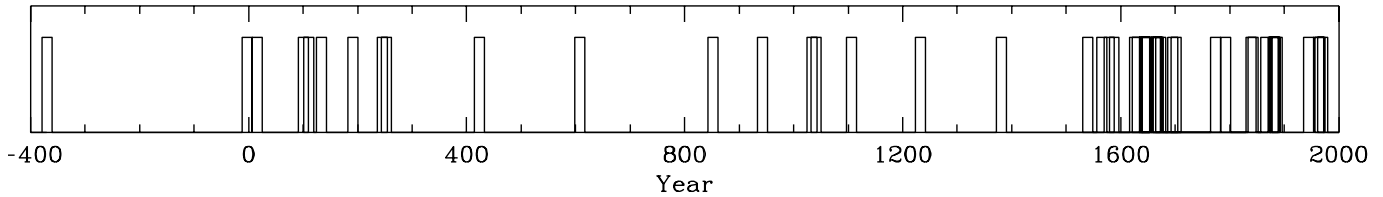


Fig. 3. The distribution of Kreutz sungrazers (Marsden 1989), and candidates from Table 1 and Hasegawa & Nakano (2001). Note that year 0 \equiv 1 BC, $-400 \equiv$ 401 BC.

early twelfth century, and were possibly observed as the comet of 1106. Similarly, 1843 I and 1880 I probably split from a common ancestor (which Marsden dubs “Combo”) in the second half of the fifteenth century, while Combo may have separated from 1963 V (C/1963 R1) (and possibly from the comet of 1668 as well) around 1100. (Here too, the 1106 comet is a possible progenitor.) Furthermore, Marsden identifies two subgroups, on the basis of the longitude of the ascending node Ω and perihelion distance q , with the aforementioned 1882 II and Ikeya-Seki belonging to group II, and those associated with Combo to group I. Most if not all of the minor sungrazers discovered by SOLWIND and SMM can be assigned to group I (Marsden 1989), and the same probably holds for the SOHO objects (Biesecker 2002).

Marsden (1989) discusses how Groups I and II might have evolved away from one another in (physical and parameter) space, from a common origin in the 371 BC comet observed by Aristotle. However, whether this evolutionary scenario is still tenable in the light of the near-steady flux of minor SOHO members may be open to question. If many of the sun-comets (Table 1) and the candidates suggested by Hasegawa & Nakano (2001) were major Kreutz sungrazers, then the picture becomes rather chaotic. Figure 3 summarizes the occurrence of major Kreutz candidates from 371 BC to 1970 AD, showing notable gaps in the pre-Christian era, the 4th, 6th, 7th, 8th, 12th and 15th centuries.

Not only are there no records of nighttime candidates then, but the lack of sun-comet reports in the 4th and 12th centuries may be meaningful. During both periods there were around 30 sunspot reports (BAO 1988), nearly three times the average, a number similar to the seventeenth century (34 records) when six sun-comets were also reported. The negative result for the 12th century in particular may be significant, for the Song Dynasty (960–1279) is generally regarded as a period when science flourished (Ronan 1985). One is inclined to feel that if a daytime comet had appeared, it ought to have been recorded, weather permitting.

Why were solar comets observed only by the Chinese? In fact, they weren’t. Consider the bright “star” seen close to the Sun by the folk of Broughty Ferry, Scotland, on the morning of 21 December 1882 (Botley 1967). Such reports are rare for a variety of reasons, and in this case the date, time and location may be significant. The Sun would have been low in the sky, making it appear more prominent to onlookers, and removing some of its glare.

Local conditions must have also played a role in the Chinese observations, but what they particularly had to their advantage were a long astronomical tradition, trained observers especially attentive to anything abnormal which might signal disharmony in Nature, and perhaps above all an ancient and durable system for registering and preserving observing records. Those records extend back even further than what has been cited above. Consider the following “oracle bone” inscription describing a solar eclipse, dated somewhere between 1353 and 1281 B.C. (Ronan 1985): “three flames ate up the Sun, and a great star was visible”. This has been interpreted as a solar prominence, but while the “three flames” could be features in the Sun’s corona (see, e.g., the image of SOHO-6, Biesecker 2002), it seems not implausible that the “great star” was actually a sungrazing comet. Perhaps even an ancestor of the Kreutz group?

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