PASJ: Publ. Astron. Soc. Japan **53**, 931–949, 2001 October 25

Possible Kreutz Sungrazing Comets Found in Historical Records

Ichiro HASEGAWA
Faculty of Socio-Cultural Studies, Otemae University,
2-2-2 Inano, Itami, Hyogo 664-0861
hasegawa@otemae.ac.jp
and
Syuichi NAKANO
Liaison in Japan of the Minor Planet Center,
1-3-19 Takenokuchi, Sumoto, Hyogo 656-0011
snakano@cfa.harvard.edu

(Received 2001 March 12; accepted 2001 August 1)

Abstract

In historical records, twenty four candidates of possible Kreutz sungrazing comets have been found, and their times of perihelion passage estimated. Translated original records of comets with presumed ephemerides are given. Some uncertain candidates are also presented. Although already suggested by Marsden (1967, Astron. Jahresber. 67.9133), our calculations on the motions of comets 1882 R1 and 1965 S1 confirm that the progenitor of these comets is a comet that appeared in 1106; some trials on the linkage of sungrazing comets are discussed.

Key words: comets: general — comets: historical records — comets: sungrazers (Kreutz group)

1. Introduction

A very long, narrow tail pointing in the anti-solar direction with its head appearing near to the sun is a typical scene for a Kreutz sungrazing comet. The appearance of Comet Ikeya–Seki (Comet C/1965 S1 = 1965 VIII) strongly recalled Kreutz's studies of these comets, which appeared in the nineteenth century.

In recent years, using satellite-borne coronagraphs, many small fragments of comets have been detected very close to the sun. Almost all of them are members of the Kreutz group of comets, and we can guess that there may be many records of bright members of this group in historical sources. One of the present authors has presented some candidates found in the historical records in table 5 of his previous work (Hasegawa 1979).

For one member of the Kreutz group of comets, Comet C/1880 C1 (= 1880 I), only the tail was detected to be extending above the western horizon in the evening sky about ten days after the perihelion. The maximum length of the tail was estimated to be 50°. In ancient astronomical sources, there are many records of comets with long tail near the sun. Although most of the orbital elements have not been determined directly from those rough records of cometary positions, we can estimate the time of perihelion passage (T) using the mean orbital elements of the Kreutz group, and the calculated path of its long tail compared with historical records to judge its possible membership.

In the present research, we used the following mean orbital elements for the Kreutz group of comets:

$$\left.\begin{array}{ll} q = 0.00630 \text{ AU} & \omega = 78.^{\circ}7 \\ e = 1.0 & \Omega = 358.^{\circ}7 \\ & i = 143.^{\circ}5 \end{array}\right\} \text{(equinox 2000.0)} \qquad (1)$$

Then, the ecliptic coordinates of the perihelion point are $\lambda = 283^{\circ}$ and $\beta = +36^{\circ}$ (equinox 2000.0), respectively.

2. Estimations of the Time of Perihelion Passage

In ancient Chinese astronomy, the main star, or determinative star, of a Chinese lunar mansion was used to determine the right ascension of a celestial object. From the recorded Chinese lunar mansion where a comet was seen, we can estimate the comet's range of right ascension, because every lunar mansion has its proper range in the right ascension.

Without knowing the comet's declination, we can still estimate its time of perihelion from the above mentioned mean orbital elements, if it is a member of the Kreutz group. By trial and error, both the time of perihelion passage and its uncertainty can be estimated.

Stephenson et al. (1985) noted that Comet 1P/Halley does not reach naked-eye visibility until its apparent magnitude is between 3.5 and 4.0, and Yau et al. (1994) indicated that Comet 109P/Swift–Tuttle did not reach naked-eye visibility until it was brighter than magnitude 3.4. Because the comet's brightness at the time of the last observation might be fainter than 3–4 magnitude, we assume that it was about 5. We can therefore derive its absolute visual magnitude ($H10$) by adopting the following formula for the magnitude:

$$H10 = 5 - 5\log\Delta - 10\log r = 5 - \Delta m \qquad (2)$$

where Δ and r are, respectively, the geocentric and heliocentric distances in astronomical units at the last observation. The estimated values of $H10$ and the time of perihelion passage (T) are given in table 1. In column 3, the duration of the periods of visibility are also given.

Table 1. Possible comets of Kreutz group found in historical records.

No.	First observation	Duration(d)	Perihelion passage(T)	$H10$	Sources*
1	−4 Jan. 26–Feb. 3	> 10	−5 Nov. 25–Dec. 14	2±	C
2	101 Jan. 12	10	100 Nov. 25±5	2±	C
3	110 Jan. 27	···	109 Dec. 22±8	3	C
4	133 Feb. 8	∼ 7	133 Jan. 20±4	5	C
5	191 Oct. 16±15	···	191 Oct. 12(?)	4±	C, K
6	245 Sep. 18	23	245 Oct. 17±3	4	C
7	252 Mar. 24	20	252 Mar. 16±4	4	C
8	423 Feb. 13	20	423 Feb. 7±2	5	C
9	607 Feb. 28	20	607 Feb. 26±1	5	C
10	852 Mar. 14	···	852 Mar. 10±2	5	J, C
11	943 Nov. 5	10	943 Oct. 27±1	6	C, E
12	1034 Sep. 20	33±	1034 Sep. 10±5	3	C, K, J, E
13	1041 Sep. 1	> 90	1041 Aug. 4±4	−1	C, K
14	1106 Feb. 9	> 30	1106 Jan. 26±5	3	K, J, C, E
15	1232 Oct. 17	48±	1232 Oct. 14±2	3	C, J
16	1381 Nov. 17	25	1381 Nov. 3±2	5	K, J, E
17	1579 Oct. 10	12	1579 Sep. 30±4	5	E. C
18	1588 Oct. 24	19	1588 Oct. 16±2	5	C
19	1663 Oct. 31	89	1663 Oct. 15±4	0	C
20	1666 Nov. 20	···	1666 Nov. 10±5	6±	C
21	1668 Mar. 2	29	1668 Feb. 28±1	4	C, K, J, E
22	1673 Mar. 10	30±	1673 Feb. 26±2	3	C
23	1695 Oct. 22	20±	1695 Oct. 24±1	6	C, K
24	1702 Feb. 25	15±	1702 Feb. 13.7±1	5	E, C, K, J

* C, K, J, and E mean that the original records are found in the Chinese, Korean, Japanese, and European histories respectively.

3. Historical Records of Individual Sungrazing Comets

Original records of comets possibly identified as members of the Kreutz group were briefly translated and are presented below. Almost all of these records are given in the Chinese compilation of records (Beijing Observatory 1988) and Japanese ones (Kanda 1935; Ohsaki 1994). However, regarding the Korean records, we must search for them in Korean Annals.

Each translation is followed by a reference to the source. The abbreviations of the original texts used here are listed alphabetically as follows:

BS Bei Shi (History of the Northern Four Dynasties)
CS Chin (Jin) Shi (History of Chin Dynasty)
GJ Guijin-tushu-jicheng (The Great Imperial Encyclopaedia)
HHS Hou Han Shu (History of the Later Han Dynasty)
HS Han Shu Tian Wen Zhi (Book of Astronomy in the History of the Han Dynasty)
JMB Jungbo Munhon Bigo (Supplementary Encyclopaedia of Korea)
JS Jin Shu Tian Wen Zhi (Book of Astronomy in the History of the Jin Dynasty)
JWD Jiu Wu Dai Shi (Old History of the Five Dynasties)
KS Koryo-sa (History of Koryo)
PSS Chronicle of Paekche in the Samguk Sagi (History of Three Korean Kingdoms)
QSG Qing Shi Gao (History of the Qing Dynasty)
SS Song Shi (History of the Song Dynasty)
SShu Song Shu Tian Wen Zhi (Book of Astronomy in the History of the Song Dynasty)
SSS Chronicle of Silla in the Samguk Sagi (History of Three Kingdoms)
Sui Sui Shu (History of the Sui Dynasty)
WS Wei Shu Tian Xiang Zhi (Book of Celestial Phenomena in the History of the Wei Dynasty)
XTS Xin Tang Shu (New History of the Tang Dynasty)

Table 2. Units of length.

Chinese	Japanese	Equivalent degree
cun ≒ 0.03 m	sun ≒ 0.03 m	≒ 0.°1
chi ≒ 10 cuns	syaku ≒ 10 suns	≒ 1°
zhang ≒ 10 chis	jyo ≒ 10 syakus	≒ 10°

The units of length used in these astronomical records are given in table 2. The ratios of chi/degree are discussed by Watanabe (1953) and Kiang (1972). Using the estimated time of perihelion passage (T) given in table 1, the ephemerides for each comet were calculated in table 3. The sixth column of table 3, gives the elongation of the comet from the sun. The calculated paths of the comets are given in the attached figures 1–24. The horizon and the position of the sun shown in

Table 3. Emphemerides of possible Kreutz sungrazing comets.

Date(UT)			α (2000.0)	δ	Δ(AU)	r(AU)	Elongation	Δm	Moon's age
				Comet −4					
−4	Jan.	18.4	4h 17m	−31.°7	1.00	1.40	89°	+1.4	9
		22.4	4 26	−28.1	1.11	1.48	89	+1.9	13
		26.4	4 33	−25.0	1.22	1.56	89	+2.3	17
		30.4	4 40	−22.4	1.33	1.63	88	+2.7	21
	Feb.	3.4	4 46	−20.1	1.44	1.71	87	+3.1	25
		7.4	4 52	−18.2	1.56	1.78	86	+3.5	0
				Comet 101					
101	Jan.	12.4	4 36	−35.3	0.99	1.46	95	+1.6	25
		15.4	4 39	−32.2	1.07	1.52	95	+2.0	28
		18.4	4 42	−29.6	1.14	1.58	95	+2.3	1
		21.4	4 46	−27.2	1.22	1.63	95	+2.6	4
				Comet 110					
110	Jan.	27.4	3 38	−26.7	0.96	1.20	76	+0.7	19
		30.4	3 52	−24.2	1.04	1.27	77	+1.1	22
	Feb.	2.4	4 03	−22.1	1.13	1.33	78	+1.5	25
		5.4	4 13	−20.1	1.21	1.40	78	+1.9	28
				Comet 133					
133	Feb.	8.4	2 21	−17.6	0.88	0.79	49	−1.3	15
		10.4	2 39	−16.6	0.92	0.84	52	−0.9	17
		12.4	2 55	−15.7	0.97	0.89	54	−0.6	19
		14.4	3 10	−14.7	1.02	0.94	56	−0.2	21
		16.4	3 23	−13.8	1.07	0.99	57	+0.1	23
				Comet 191					
191	Oct.	16.8	13 46	−21.5	0.97	0.31	18	−5.2	11
		19.8	13 27	−24.5	0.95	0.43	25	−3.8	14
		22.8	13 10	−27.3	0.93	0.53	32	−2.9	17
		25.8	12 54	−30.0	0.92	0.63	38	−2.2	20
		28.8	12 39	−32.6	0.91	0.72	44	−1.7	23
		31.8	12 23	−35.2	0.90	0.80	50	−1.2	26
				Comet 245					
245	Sep.	17.8	9 34	−16.8	1.26	1.04	53	+0.7	9
		20.8	9 50	−18.1	1.18	0.96	52	+0.2	12
		23.8	10 08	−19.6	1.10	0.89	50	−0.3	15
		26.8	10 30	−21.1	1.02	0.81	47	−0.9	18
		29.8	10 56	−22.6	0.96	0.73	44	−1.5	21
	Oct.	2.8	11 27	−24.0	0.90	0.64	39	−2.2	24
		5.8	12 04	−25.0	0.86	0.55	33	−3.0	27
		8.8	12 46	−25.3	0.83	0.44	26	−4.0	0
		11.8	13 34	−24.4	0.83	0.32	18	−5.3	3
				Comet 252					
252	Mar.	24.4	3 16	+5.4	1.09	0.43	24	−3.4	26
		27.4	3 42	+4.9	1.17	0.54	27	−2.4	0
		30.4	4 04	+4.4	1.25	0.63	30	−1.5	3
	Apr.	2.4	4 22	+4.0	1.33	0.72	32	−0.8	6
		5.4	4 38	+3.7	1.42	0.80	34	−0.2	9
		8.4	4 51	+3.5	1.51	0.88	35	+0.3	12
		11.4	5 04	+3.2	1.59	0.96	35	+0.8	15

Table 3. (Continued)

Date(UT)			α (2000.0)	δ	Δ(AU)	r(AU)	Elongation	Δm	Moon's age
				Comet 423					
423	Feb.	13.4	0 39	−11.0	0.84	0.34	22	−4.6	16
		16.4	1 21	−11.0	0.86	0.49	29	−3.5	19
		19.4	1 57	−10.5	0.90	0.59	36	−2.6	22
		22.4	2 28	−9.8	0.95	0.68	41	−1.8	25
		25.4	2 54	−9.0	1.02	0.76	45	−1.1	28
		28.4	3 16	−8.3	1.09	0.84	48	−0.5	2
	Mar.	3.4	3 35	−7.5	1.17	0.92	50	0.0	5
		6.4	3 52	−6.8	1.25	1.00	51	+0.5	8
				Comet 607					
607	Feb.	28.4	0 40	−1.3	0.92	0.17	9	−7.9	26
	Mar.	3.4	1 28	−1.9	0.92	0.31	18	−5.2	29
		6.4	2 07	−2.1	0.96	0.43	25	−3.7	2
		9.4	2 39	−2.1	1.01	0.54	31	−2.7	5
		12.4	3 06	−2.0	1.08	0.63	35	−1.8	8
		15.4	3 29	−1.8	1.15	0.72	38	−1.1	11
		18.4	3 49	−1.6	1.23	0.80	40	−0.5	14
		21.4	4 06	−1.4	1.31	0.88	42	+0.1	17
				Comet 852					
852	Mar.	14.5	2 00	+2.5	0.97	0.29	17	−5.4	20
		17.5	2 37	+2.1	1.02	0.42	24	−3.8	23
		20.5	3 07	+1.8	1.08	0.52	29	−2.7	26
		23.5	3 32	+1.6	1.15	0.62	32	−1.8	29
		26.5	3 52	+1.5	1.23	0.71	35	−1.1	2
		29.5	4 11	+1.4	1.32	0.79	37	−0.4	5
	Apr.	1.5	4 27	+1.4	1.40	0.87	38	+0.1	8
				Comet 943					
943	Nov.	5.8	14 02	−31.1	0.87	0.48	29	−3.5	5
		8.8	13 43	−34.7	0.84	0.58	36	−2.7	8
		11.8	13 25	−38.3	0.82	0.67	43	−2.2	11
		14.8	13 05	−41.7	0.80	0.76	49	−1.7	14
		17.8	12 43	−45.1	0.78	0.84	55	−1.3	17
		20.8	12 18	−48.2	0.77	0.92	62	−0.9	20
				Comet 1034 = X/1034 S1					
1034	Sep.	20.8	11 17	−10.6	1.20	0.53	26	−2.3	5
		23.8	11 09	−12.3	1.23	0.63	31	−1.6	8
		26.8	11 02	−13.8	1.25	0.72	35	−1.0	11
		29.8	10 56	−15.3	1.27	0.80	39	−0.5	14
	Oct.	2.8	10 50	−16.8	1.29	0.88	43	0.0	17
		5.8	10 44	−18.2	1.30	0.95	47	+0.4	20
		8.8	10 38	−19.5	1.31	1.03	51	+0.7	23
		11.8	10 32	−20.9	1.32	1.10	55	+1.0	26
		14.8	10 26	−22.2	1.33	1.17	58	+1.3	29
		17.8	10 20	−23.4	1.34	1.23	62	+1.5	3
		20.8	10 14	−24.7	1.34	1.30	66	+1.8	6
		23.8	10 07	−25.9	1.34	1.36	69	+2.0	9
				Comet 1041					
1041	Sep.	1.8	9 35	−6.9	1.67	1.03	35	+1.2	3
		9.8	9 33	−9.7	1.75	1.21	42	+2.0	11
		17.8	9 31	−12.4	1.80	1.38	50	+2.7	19

Table 3. (Continued)

Date(UT)			α (2000.0)	δ	Δ(AU)	r(AU)	Elongation	Δm	Moon's age
		25.8	9 27	−14.9	1.83	1.54	57	+3.2	27
	Oct.	3.8	9 22	−17.4	1.86	1.70	65	+3.6	5
		11.8	9 15	−19.8	1.87	1.84	73	+4.0	13
		19.8	9 06	−22.0	1.88	1.98	81	+4.3	21
		27.8	8 54	−24.0	1.89	2.12	89	+4.6	0
	Nov.	4.8	8 40	−25.8	1.90	2.25	97	+4.9	8
		12.8	8 24	−27.2	1.92	2.38	106	+5.2	16
		20.8	8 06	−28.2	1.94	2.50	113	+5.4	24
		28.8	7 47	−28.6	1.99	2.62	120	+5.7	2
				Comet 1106 = X/1106 C1					
1106	Feb.	9.5	1 24	−20.1	0.79	0.65	41	−2.4	4
		13.5	2 10	−18.5	0.85	0.76	48	−1.5	8
		17.5	2 46	−16.5	0.94	0.87	53	−0.8	12
		21.5	3 15	−14.6	1.04	0.97	57	−0.1	16
		25.5	3 39	−12.9	1.14	1.07	59	+0.6	20
	Mar.	1.5	3 58	−11.4	1.25	1.16	61	+1.1	24
		5.5	4 14	−10.0	1.37	1.25	61	+1.6	28
		9.5	4 28	−8.9	1.49	1.33	61	+2.1	2
				Comet 1232					
1232	Oct.	17.8	13 38	−18.8	0.99	0.26	15	−5.8	2
		25.8	12 52	−26.0	0.96	0.56	34	−2.6	10
	Nov.	2.8	12 13	−32.4	0.94	0.80	49	−1.1	18
		10.8	11 31	−38.2	0.92	1.00	63	−0.2	26
		18.8	10 41	−43.0	0.92	1.19	77	+0.6	5
		26.8	9 43	−46.0	0.94	1.36	90	+1.2	13
	Dec.	4.8	8 42	−46.6	0.98	1.52	101	+1.8	21
				Comet 1381 = X/1381 V1					
1381	Nov.	6.8	14 55	−25.7	0.91	0.26	15	−6.0	20
		9.8	14 35	−29.9	0.87	0.39	23	−4.4	23
		12.8	14 17	−33.9	0.83	0.50	30	−3.4	26
		15.8	13 59	−37.9	0.80	0.60	37	−2.7	29
		18.8	13 39	−41.9	0.78	0.69	44	−2.2	2
		21.8	13 17	−45.8	0.76	0.77	51	−1.7	5
		24.8	12 52	−49.6	0.74	0.85	57	−1.3	8
		27.8	12 22	−53.1	0.73	0.93	64	−1.0	11
		30.8	11 47	−56.2	0.72	1.00	70	−0.7	14
	Dec.	2.8	11 20	−57.8	0.72	1.05	74	−0.5	17
				Comet 1579					
1579	Oct.	10.0	12 06	−16.6	1.09	0.50	28	−2.8	19
		13.0	11 55	−18.5	1.10	0.60	33	−2.0	22
		16.0	11 44	−20.4	1.11	0.69	38	−1.4	25
		19.0	11 34	−22.1	1.11	0.78	43	−0.9	28
		22.0	11 25	−23.9	1.12	0.86	48	−0.4	2
				Comet 1588					
1588	Oct.	23.8	12 37	−17.9	1.04	0.43	24	−3.6	4
		26.8	12 23	−20.1	1.04	0.53	30	−2.7	7
		29.8	12 11	−22.2	1.04	0.63	36	−1.9	10
	Nov.	1.8	11 59	−24.2	1.05	0.72	41	−1.4	13
		4.8	11 47	−26.1	1.05	0.80	46	−0.9	16
		7.8	11 36	−28.0	1.05	0.88	51	−0.5	19

Table 3. (Continued)

Date(UT)			α (2000.0)		δ	Δ(AU)	r(AU)	Elongation	Δm	Moon's age
		10.8	11	24	−29.8	1.04	0.95	56	−0.1	22
		13.8	11	13	−31.6	1.04	1.03	61	+0.2	25
						Comet 1663				
1663	Oct.	31.8	11	53	−23.0	1.07	0.72	41	−1.3	1
	Nov.	10.8	11	17	−29.0	1.07	0.98	57	+0.1	11
		20.8	10	38	−34.4	1.07	1.12	72	+1.0	21
		30.8	9	51	−38.5	1.09	1.42	87	+1.7	1
	Dec.	10.8	8	57	−40.7	1.12	1.62	100	+2.3	11
		20.8	8	03	−40.4	1.20	1.81	112	+3.0	21
		30.8	7	15	−37.9	1.31	1.98	119	+3.5	1
	Jan.	9.8	6	40	−34.1	1.46	2.15	123	+4.1	11
		19.8	6	15	−29.9	1.64	2.31	122	+4.7	21
		29.8	5	59	−25.8	1.85	2.47	118	+5.3	2
						Comet 1666				
1666	Nov.	20.8	13	49	−32.3	0.86	0.53	33	−3.1	24
		23.8	13	31	−35.8	0.84	0.63	39	−2.4	27
		26.8	13	12	−39.2	0.82	0.72	46	−1.9	1
		29.8	12	52	−42.5	0.80	0.80	52	−1.5	4
	Dec.	2.8	12	29	−45.7	0.79	0.88	58	−1.1	7
						Comet 1668 = C/1668 E1				
1668	Mar.	2.5	0	03	−8.9	0.86	0.25	13	−6.4	19
		6.5	1	04	−9.6	0.86	0.42	25	−4.2	23
		10.5	1	54	−9.3	0.90	0.55	34	−2.8	27
		14.5	2	36	−8.5	0.97	0.68	40	−1.7	2
		18.5	3	09	−7.6	1.07	0.79	45	−0.9	6
		22.5	3	35	−6.7	1.17	0.90	48	−0.1	10
		26.5	3	57	−5.8	1.28	1.00	50	+0.5	14
		30.5	4	15	−5.1	1.39	1.09	51	+1.1	18
						Comet 1673				
1673	Mar.	10.5	2	01	−9.8	0.91	0.59	36	−2.5	22
		14.5	2	41	−8.9	0.98	0.71	42	−1.5	26
		18.5	3	13	−7.9	1.08	0.82	46	−0.7	0
		22.5	3	39	−7.0	1.18	0.92	49	0.0	4
		26.5	4	00	−6.1	1.29	1.02	51	+0.6	8
		30.5	4	17	−5.3	1.41	1.11	52	+1.2	12
	Apr.	3.5	4	33	−4.7	1.52	1.20	52	+1.7	16
		7.5	4	46	−4.1	1.64	1.29	52	+2.2	20
		11.5	4	58	−3.6	1.76	1.37	52	+2.6	24
						Comet 1695 = C/1695 U1				
1695	Oct.	22.8	13	47	−15.6	0.92	0.12	6	−9.4	15
		26.8	13	32	−16.3	1.01	0.21	12	−6.7	19
		30.8	13	05	−20.0	1.00	0.39	23	−4.1	23
	Nov.	3.8	12	44	−23.2	0.99	0.53	31	−2.8	27
		7.8	12	26	−26.3	0.99	0.66	39	−1.9	1
		11.8	12	08	−29.2	0.98	0.77	46	−1.2	5
		15.8	11	50	−32.1	0.97	0.88	53	−0.6	9
		19.8	11	31	−34.7	0.97	0.98	60	−0.2	13
						Comet 1702 = X/1702 D1=1702a				
1702	Feb.	25.6	1	06	−18.1	0.79	0.57	35	−3.0	28
	Mar.	28.6	1	43	−17.3	0.83	0.66	41	−2.2	2

Table 3. (Continued)

Date(UT)	α (2000.0)	δ	Δ(AU)	r(AU)	Elongation	Δm	Moon's age
3.6	2 16	−16.1	0.88	0.75	47	−1.5	5
6.6	2 43	−14.9	0.94	0.83	51	−0.9	8
9.6	3 06	−13.6	1.02	0.91	54	−0.4	11
12.6	3 26	−12.4	1.09	0.98	56	+0.1	14

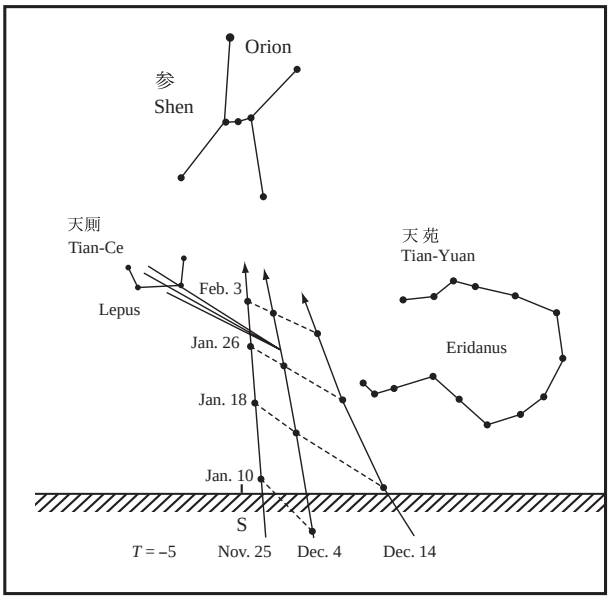

Fig. 1. Calculated path of Comet −4 during −4 Jan. 10 and Feb. 3. Three perihelion times are assumed.

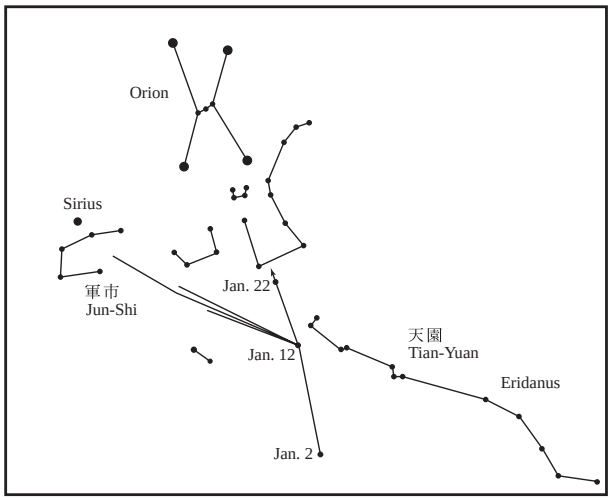

Fig. 2. Calculated path of Comet 101 during 101 Jan. 2 and Jan. 22.

those figures are at the time as the first appearance of the comet. The tails of the comets stretching away to the anti-solar direction are also shown.

Because general explanations for the Chinese date systems, Chinese constellations, and related subjects are given by some authors (Williams 1871; Ho 1962; Kiang 1972), we do not repeat them here.

No. 1 −4 January–February

Chinese During the twelfth month of the first year of the Jian-Ping reign-period (−4 January 10–February 7), a white vapor appeared in the southwest. It reached to the heavens from the ground, and was seen under the Shen (21st lunar mansion), passing through the Tian-Ce (Lepus). It was wide like a bolt of cloth, and ten and odd zhangs in length. It disappeared after about ten days.

HS, vol. 26, p. 1312; Beijing Observatory (1987), p. 387.

No. 2 101 January

Chinese On the night of a gui-you (10) day in the eleventh month of the twelfth year of the Yong-Yuan reign-period (101 January 12), a grayish vapor appeared. Its length was three zhangs. It rose from the northeast of Tian-Yuan (Eridanus), pointing at Jun-Shi (Canis Major). It lasted for ten days (101 January 21).

HHS, Book 11, p. 3237; Beijing Observatory (1987), p. 389; Williams (1871), No. 67, he gives 102 January 7; Ho (1962), No. 87; Kronk (1999), p. 37.

No. 3 110 January

Chinese On a yi-hai (12) day in the twelfth month of the third year of the Yong-Chu reign-periods (110 January 27), a xing-hui (comet) appeared in Tian-Yuan (Eridanus).

HHS, vol. 5, p. 213; Beijing Observatory (1988), p. 389.

In the twelfth month of the third year of the Yong-Chu reign-period (110 January 9–February 6), a hui-xing (comet) rose from the south of Tian-Yuan (Eridanus), pointing to the northeast. Its length was six to seven chis, and was grayish in color.

HHS, vol. 11, p. 3239; Beijing Observatory (1988), p. 389; Williams (1871), No. 68; Ho (1962), No. 9; Kronk (1999), p. 38.

No. 4 133 February

Chinese On a wu-zi (25) day in the intercalary twelfth month of the first year of the Yang-Jia reign-period (133 February 8), a guest star with a white vapor, measuring two chis in width and five zhangs in length, rose at the southwest of the Tian-Yuan (Eridanus).

HHS, vol. 11, p. 3244.

On the night of the seventeenth day, a ji-chou (26), in the intercalary month (133 February 9), a white vapor appeared in the west of the Tian-Yuan (Eridanus). It went over its left leg, entering into the Yu-Jing (β and λ Eridani), and disappeared

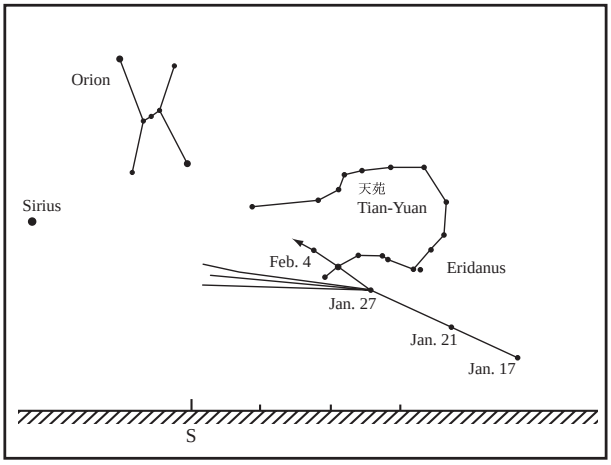

Fig. 3. Calculated path of Comet 110 during 110 Jan. 17 and Feb. 4.

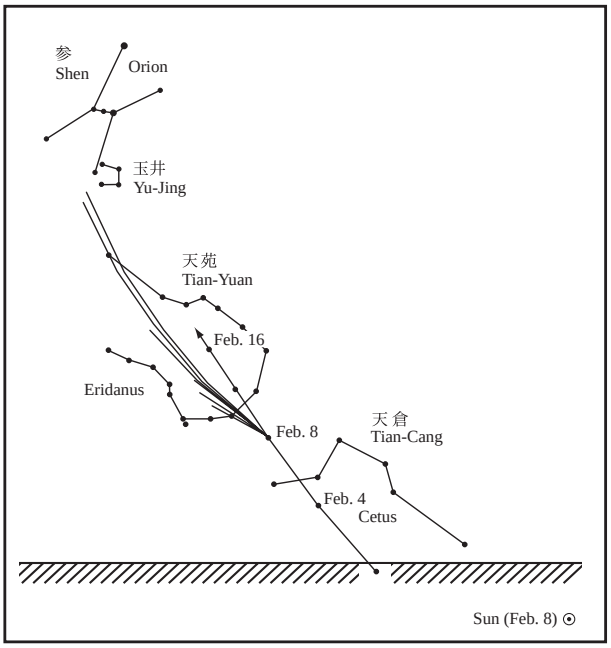

Fig. 4. Calculated path of Comet 133 during 133 Jan. 31 and Feb 16.

after several days.

HHS, vol. 30, p. 1063; Beijing Observatory (1988), p. 390; Ho (1962), No. 99; Hasegawa (1979); Kronk (1999), p. 39.

No. 5 191 October (date uncertain)

Chinese During the ninth month of the second year of the Chu-Ping reign-period (191 October 6–November 4), a chiyou-gi (banner) appeared between the Jiao and the Kang (first and second lunar mansions).

HHS, vol. 9, p. 371.

Korean In the autumn, during the ninth month of the eighth year of Porhyu Wang, a chiyou-gi (banner) appeared between the Jiao and Kang (first and second lunar mansions).

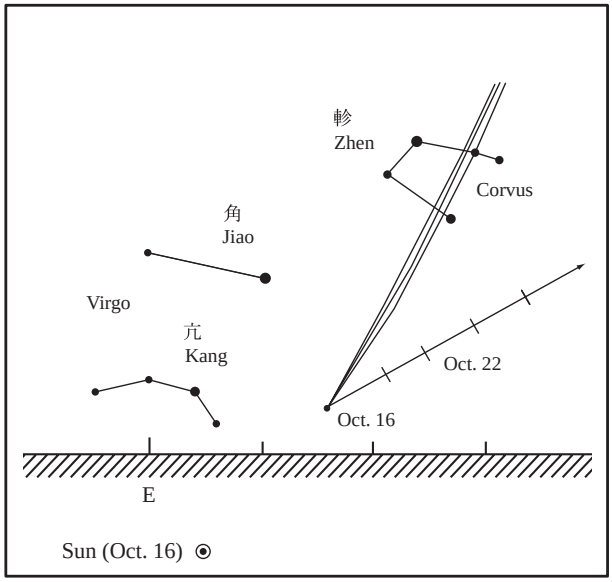

Fig. 5. Calculated path of Comet 191 during 191 Oct. 16 and Oct. 28.

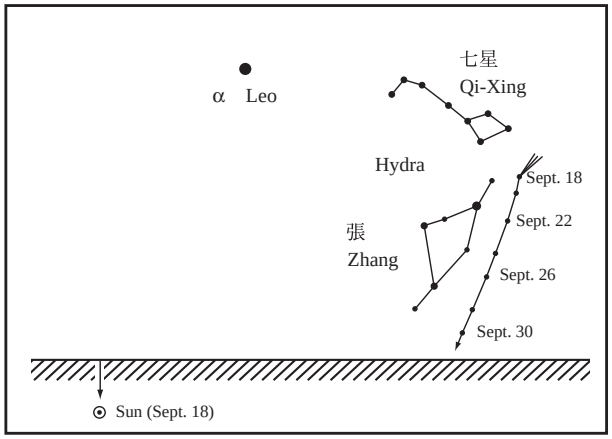

Fig. 6. Calculated path of Comet 245 during 245 Sep. 18 and Sep. 30.

SSS, vol. 2; Sekiguchi (1917), p. 179 and p. 184; Ho (1962), No. 113; Hasegawa (1979); Kronk (1999), p. 45.

No. 6 245 September

Chinese On a wu-wu (55) day in the eighth month of the sixth year of the Zheng-Shi reign-period (245 September 18), a hui-xing (comet) appeared in the Qi-Xing (25th lunar mansion). Its length was two chis, and was white in color. It moved to the Zhang (26th lunar mansion), and disappeared after 23 days (245 October 10).

JS, vol. 13, p. 389; SShu, vol. 23, p. 687; Beijing Observatory (1988), p. 392; Williams (1871), No. 95; Ho (1962), No. 130; Kronk (1999), p. 53.

No. 7 252 March

Chinese On a ding-you (34) day in the second month of the fourth year of the Jia-Ping reign-period (252 March 24), a comet appeared west at the Wei (17th lunar mansion). Its length was five or six zhangs, was white in color, and its beard

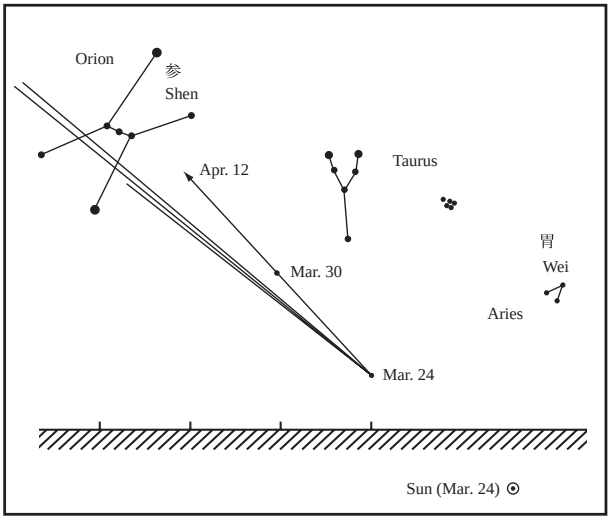

Fig. 7. Calculated path of Comet 252 during 252 Mar. 24 and Apr. 12.

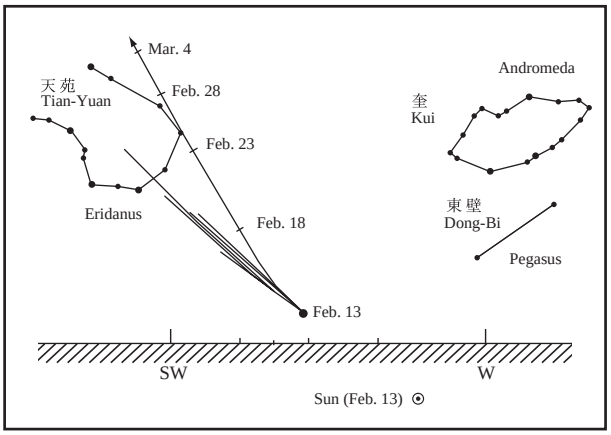

Fig. 8. Calculated path of Comet 423 during 423 Feb. 13 and Mar. 4.

tail pointed to the south and penetrated the Shen (21st lunar mansion). After 20 days (252 April 12), it disappeared.

SShu, vol. 23, p. 689; Beijing Observatory (1988), p. 393, Williams (1871), No. 99; Ho (1962), No. 135; Hasegawa (1979); Kronk (1999), p. 54.

Remarks: The right ascension of this comet on 252 March 24.5 TT is assumed to be 3h 15m and it gives $T = 252$ March 16 ± 4 TT. Because of the full moon, this comet might not have been seen on April 12; however, if the magnitude was 6, the absolute magnitude is estimated to be 5.

No. 8 423 February

Chinese On a yi-mao (52) day in the first month of the first year of the Jing-Ping reign-period (423 February 13), a comet appeared south of the Dong-Bi (14th lunar mansion). It was white and its length was more than two zhangs. It swept Tian-Yuan (Eridanus) and disappeared after 20 days (423 March 4).

SS, vol. 26, p. 745.

In the first month of the eighth year of the Tai-Chang reign-

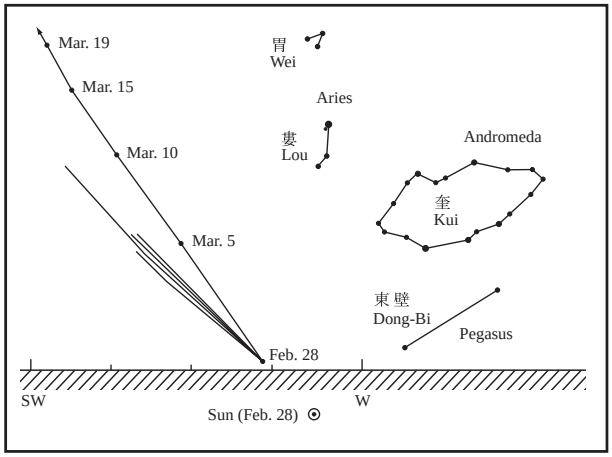

Fig. 9. Calculated path of Comet 607 during 607 Feb. 28 and Mar. 19.

period (423 January 28–February 25), a hui-xing (comet) appeared south of the Kui (15th lunar mansion). It was three zhangs in length and swept the Milky Way in the southeast.

WS, vol. 105, p. 2400; Beijing Observatory (1988), p. 399; Williams (1871), No. 145; Ho (1962), No. 197; Hasegawa (1979); Kronk (1999), p. 78.

No. 9 607 February

Chinese On a bing-zi (13) day in the first month of the third year of the Da-Ye reign-period (607 February 28), a chang-xing (long star) extended across the sky. It appeared in the Dong-Bi (14th lunar mansion), and disappeared after 20 days (607 March 19).

SB, vol. 13, p. 447; Sui, vol. 3, p. 67; Beijing Observatory (1988), p. 403; Ho (1962), No. 237.

No. 10 852 March

Japanese On the evening of a hinoto-mi (ding-si, 54) in the second month of the second year of the Jin-Ju reign-period (852 March 14), a comet appeared in the west. Its length was about five jyos.

Kanda (1935), p. 482; Ho (1962), No. 297.

Chinese During the third month of the sixth year of the Da-Zhong reign-period (852 March–April 22), a comet appeared at the Zui, and then Shen (20 th and 21st lunar mansions).

XTS, vol. 8, p. 249; Beijing Observatory (1988), p. 411; Williams (1871), No. 220, he gives an incorrect date of 851 April; Hsi (1955), No. 49; Ho (1962), No. 297; Hasegawa (1979); Kronk (1999), p. 133

No. 11 943 November

Chinese On the night of a geng-xu (47) day in the tenth month of the eighth year of the Tian-Fu reign-period (943 November 5), a comet appeared in the east, pointing to the west. The length of its tail was one zhang and it was at the ninth degree of the Jiao (first lunar mansion).

JWD, vol. 139, p. 1851.

At the fifth watch of the night (just before sunrise), a comet

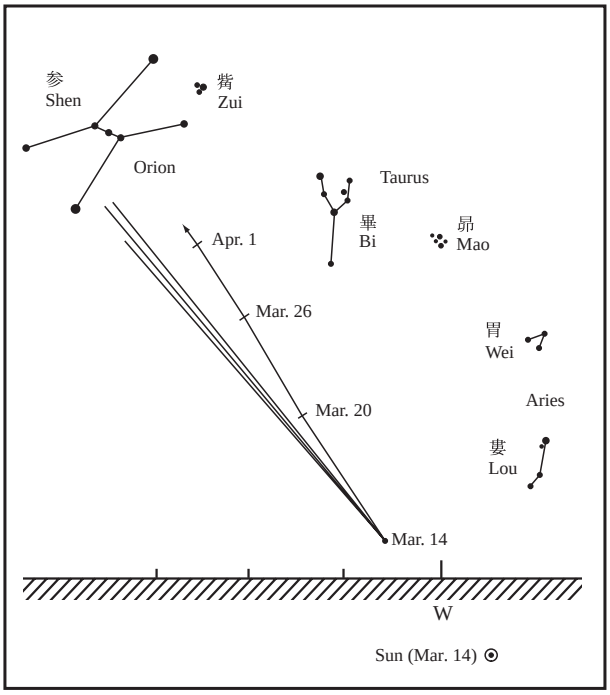

Fig. 10. Calculated path of Comet 852 during 852 Mar. 14 and Apr. 1.

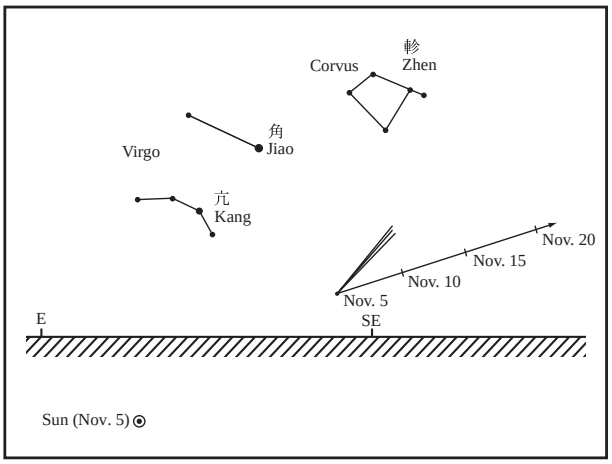

Fig. 11. Calculated path of Comet 943 during 943 Nov. 5 and Nov. 29.

appeared in the east, and it was in the Jiao (first lunar mansion); after ten days (943 November 14) it disappeared.

JWD, vol. 82, p. 1082; Beijing Observatory (1988), p. 415; Williams (1871), No. 237; Ho (1962), No. 336.

European Comets were seen for 14 nights.

Pingre (1783), vol. 1, p. 355; Hasegawa (1979); Kronk (1999), p. 155.

No. 12 1034 September

Chinese On the night of a ren-xu (59) day in the eighth month of the first year of the Jing-Yu reign-period(1034 September 20), a xing-po (comet) appeared at the Zhang and the Yi (26th and 27th lunar mansions). It was seven chis in

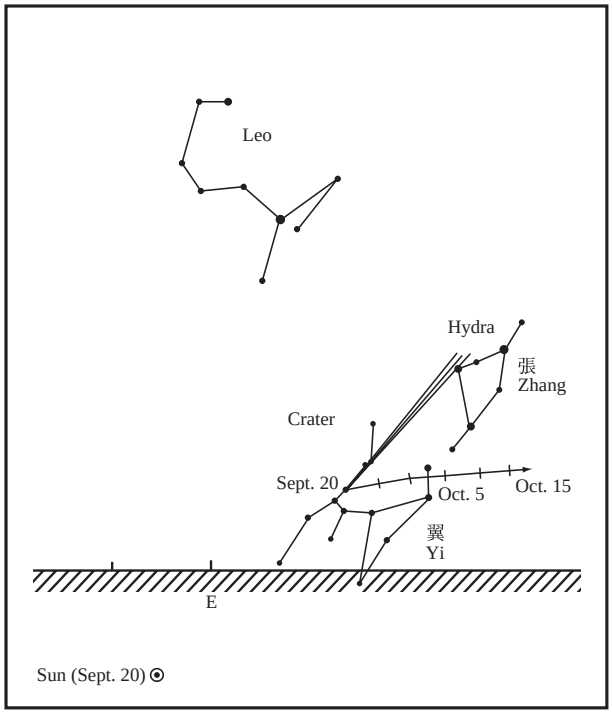

Fig. 12. Calculated path of Comet 1034 during 1034 Sep. 20 and Oct. 15.

length and five cuns in width. After 12 days (1034 October 1) it disappeared.

SS, vol. 56, p. 1227; Beijing Observatory (1988), p. 417; Williams (1871), No. 245; Ho (1962), No. 368.

A blue and yellow white vapor-like comet, measuring seven and some odd chis in length, appeared above the Zhang and Yi (26th and 27th lunar mansions). After about 33 days (1034 October 22) it was not seen.

SS, vol. 60, p. 1309, Beijing Observatory (1988), p. 417.

Korean On a gui-hai (60) day in the eighth month of the third year of the Tokjong (1034 September 21), a white vapor-like comet appeared west of Zhen (28th lunar mansion), pointing to the Zhang (26th lunar mansion). Its length was two and some odd zhangs. After 27 days (1034 October 16), it disappeared.

JMB, vol. 8; Sekiguchi (1917), p. 186:

Japanese On the 13th day in the eighth month of the seventh year of the Chyogen reign-period (1034 September 28), a comet appeared in the east. They said this comet was seen before a great wind (1034 September 24).

Kanda (1935), p. 496.

European A column of fire was seen in the east in September. Its summit was inclined towards the south.

Pingre (1783), vol. 1, p. 370; Hasegawa (1979); Kronk (1999), p. 172.

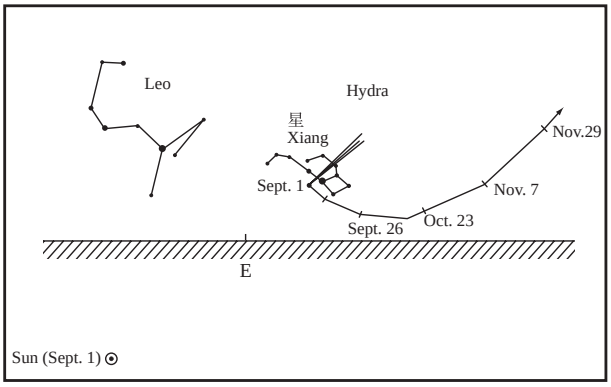

Fig. 13. Calculated path of Comet 1041 during 1041 Sep. 1 and Nov. 29.

No. 13 1041 September

Chinese On the night of a geng-chen (17) day in the eighth month of the first year of the Qing-Li reign-period (1041 September 1), a white vapor appeared in the east. Its length was about ten chis. The comet was in the range of the Xing (25th lunar mansion). On the tenth day (1041 September 8), its length was over one zhang and stretched to the opposition. It was located south of the great star of the Xing (α Hydrae). After 90 and some odd days (1041 November 29), it disappeared.

SS, p. 1309; Beijing Observatory (1988), p. 417.

Korean During the eighth month of the seventh year of the Jingjong (1041 August 30–September 27), a comet was seen in the east. It was about 30 chis in length and after 20 and some odd days it disappeared.

KS, vol. 47, p. 26; Ho (1962), No. 371; Kronk (1999), p. 173.

No. 14 1106 February

Korean On a ding-you (34) day in the first month of the first year of King Yejong (1106 February 9), a comet was seen in the southwest, measuring about ten chis. After a month or so (1106 March 1) it disappeared.

KS, vol. 47, p. 36; Sekiguchi (1917), p. 188; Ho (1962), No. 391; Hasegawa (1979); Kronk (1999), p. 189.

Japanese On the fourth day in the first month of the first year of the Kasyo reign-period (1106 February 9), after sunset, a comet appeared in the southwest. Its rays pointed to the east and trespassed on the space between Tian Cang (Cetus) and Tian Yuan (Eridanus). Its length was ten and some odd zhangs and white in color. On the night of the sixth day (1106 February 11), its brightness gradually diminished and its length was about one zhang. On the night of the seventh day (1106 February 12), it moved far eastward, and its length was about three or four chis. On the night of the eleventh day (1106 February 16), it again went to the east. On the night of the 15th day (1106 February 20), it moved eastward and its length was two and some odd zhangs. On the night of 24th day (1106 March 1), the strange star diminished greatly and after about 30 days(1106 March 10), it disappeared.

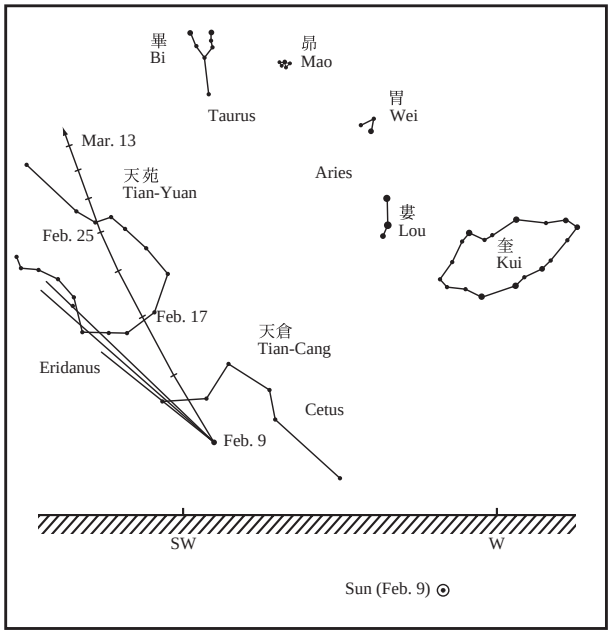

Fig. 14. Calculated path of Comet 1106 during 1106 Feb. 9 and Mar. 13.

Kanda (1935), pp. 501–505; Ho (1962), No. 391; Kronk (1999), p. 189.

Chinese On a wu-xu (35) day in the first month of the fifth year of the Chon-Ning reign-period (1106 February 10), a comet appeared in the west. Its size was like the mouth of a cup, and its rays scattered as if they were broken stars. It was six zhangs in length and three chis in width, and pointed obliquely to the northwest. From the Kui (15th lunar mansion), it penetrated the Lou, the Wei, the Mao, and the Bi (16th, 17th, 18th and 19th lunar mansions), and then it entered into the muddy and disappeared.

SS, p. 1228; Beijing Observatory (1988), p. 419; Williams (1871), No. 253; Ho (1962), No. 391; Kronk (1999), p. 189.

A comet appeared in the west. It stretched across the sky. On a bing-shen (33) day in the third month (1106 April 9), it changed and disappeared.

SS, p. 375; Beijing Observatory (1988), p. 419.

Remarks: This spectacular comet was also recorded in Europe, and Kreutz (1891), suggesting that this was a member of the sungrazing group. Marsden (1989) tried to link this comet with other members of the group, and estimated the perihelion date as 1106 February 5. Hasegawa (1979) suggested 1106 January 30 ± 5; however, after reexaminations, a probable estimation of T = 1106 January 26 TT was derived. With this value of T, the azimuth and the altitude of the comet in Kyoto, then the capital of Japan, at 18h 30m (local time = UT + 9h) on February 9, were calculated to be 230° and 11° respectively. According to Japanese and Korean records, this comet disappeared after about one month, that is to say around March 10. $H10$ is estimated to be 3.

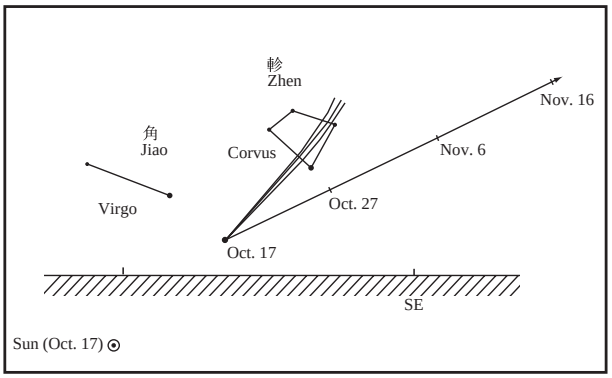

Fig. 15. Calculated path of Comet 1232 during 1232 Oct. 17 and Nov. 16.

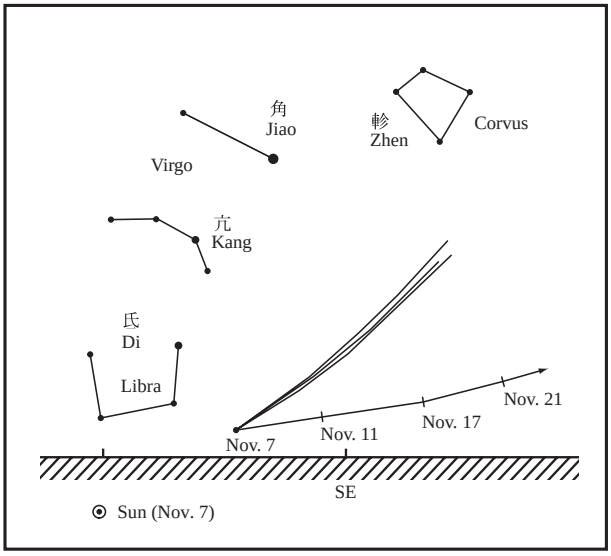

Fig. 16. Calculated path of Comet 1381 during 1381 Nov. 7 and Nov. 21.

No. 15 1232 October

Chinese On a ji-you day (46) in the intercalary ninth month of the first year of the Tian-Xing reign-period (1232 October 17), a comet appeared in the east. It was white and one and some odd zhangs in length, and was bent like an elephant's tusk. It came from the Jiao (first lunar mansion) and went south of the Zhen (28th lunar mansion). On the twelfth day of the month (1232 October 27), its length was two zhangs, and on the 16 th day (1232 October 31), it was not seen under the bright moonlight. At the fifth watch (just before sunrise) on the 27th day (1232 November 11) it appeared again in the southeast and measured about four and some odd zhangs. It began to diminish on the first day of the tenth month (1232 November 14). It lasted about 48 days (1232 December 3).

CS. vol. 29, p. 435; Beijing Observatory (1988), p. 421; Williams (1871), No. 277, Williams gives an incorrect date (1237 September 21); Ho (1962), No. 429.

On a geng-xu (47) day in the intercalary month of the fifth year of the Shao-Ding reign-period (1232 October 18), a comet appeared at the Jiao (first lunar mansion).

SS, p. 797; Beijing Observatory (1988), p. 422; Williams (1871), No. 266.

During the intercalary ninth month of the fifth year of the Shao-Ding reign-period (1232 October 16–November 13), a comet was seen in the east, and on a ji-wei (56) day[1] in the tenth month, it began to disappear.

SS, p. 1229, Beijing Observatory (1988), p. 422; Williams (1971), No. 266.

Japanese On the fourth day, a kanoto-i (hsin-hai, 48) day in the intercalary ninth month of the first year of the Tei-Ei reign-period (1232 October 19), at four o'clock in the morning, a comet appeared in the east, pointing to the southwest. It was two syakus in length and eight suns in width, white and red in colour. On the eighth day, a kinoto-u (yi-mao, 52) day (1232 October 23), it again appeared and increased in the brightness. The length of its tail was two jyos and one syaku or so in width. On the fifth day, a kanoto-mi (hsin-si, 18) day in the tenth month (1232 November 18), its brightness diminished slightly; however, it was seen in the south, pointing to the northwest, and was four jyos in length.

Kanda (1935), pp. 529–531; Ho (1962), No. 429; Hasegawa (1979); Kronk (1999), p. 215.

No. 16 1381 November

Korean On a ren-shen (9) day in the tenth month of the seventh year of the King Sin-u (1381 November 7), a comet appeared in the Di (third lunar mansion). It was one and some odd zhangs in length, and disappeared after 15 days (1381 November 21).

KS, vol. 49, p. 40; Sekiguchi (1917), p. 194; Ho (1962), No. 477.

Japanese In the morning of the 22nd day in the tenth month of the first year of the Eitoku reign-period (1381 November 8), a comet appeared in the east. Its tail was one jyo and five or six syakus in length. During two or three months, around the 15th day of the eleventh month (1381 December 1), it disappeared.

Kanda (1935), pp. 564–565; Hasegawa (1979).

European A comet was seen on the festival of Saint Martin (1381 November 11). It continued for 14 days (1381 November 24).

Pingre (1783), vol. 1, p. 443.

In a Muslim text, in this year a hairy star appeared in the southeast.

Kronk (1999), p. 256.

No. 17 1578 October

European On the 10 th of October (some say on 7) appeared a blazing star in the south, brushing towards the east, which

[1] There is no ji-wei day in the tenth month. If it was a yi-wei (32), it would correspond to 1232 December 2.

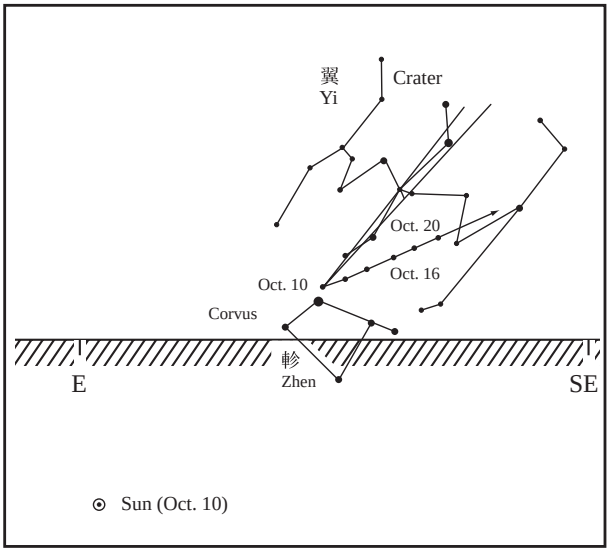

Fig. 17. Calculated path of Comet 1579 during 1579 Oct. 10 and Oct. 20.

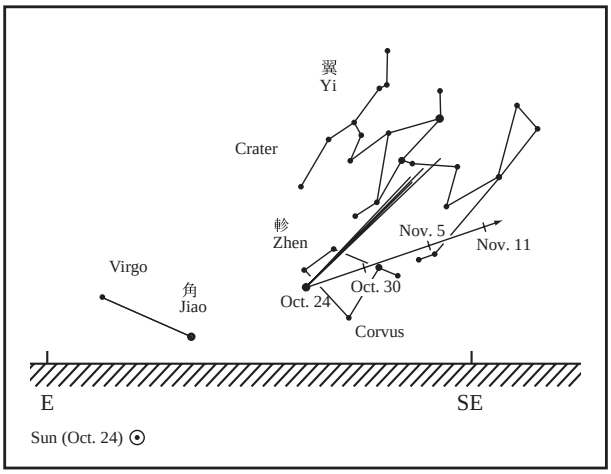

Fig. 18. Calculated path of Comet 1588 during 1588 Oct. 24 and Nov. 11.

was nightly seen to diminish in brightness until the 21st of the same month.

Chambers (1889), p. 584.

Halepo dit, qu'en 1579, on vit a Constantinople une grand comete.

Pingre (1783), vol.1, p. 520; Kronk (1999), p. 320.

Chinese During the ninth month of the seventh year of the Wan-Li reign-period (1579 September 21–October 19), a comet was seen between the Yi and the Zhen (27th and 28th lunar mansions).

Wu Qing Wen Xian, vol. 3, p. 4,

A comet appeared measuring one zhang and or so in length.

Henan Wen-Xiang Xian Zhi, vol. 1, p. 5; Beijing Observatory (1988), p. 446.

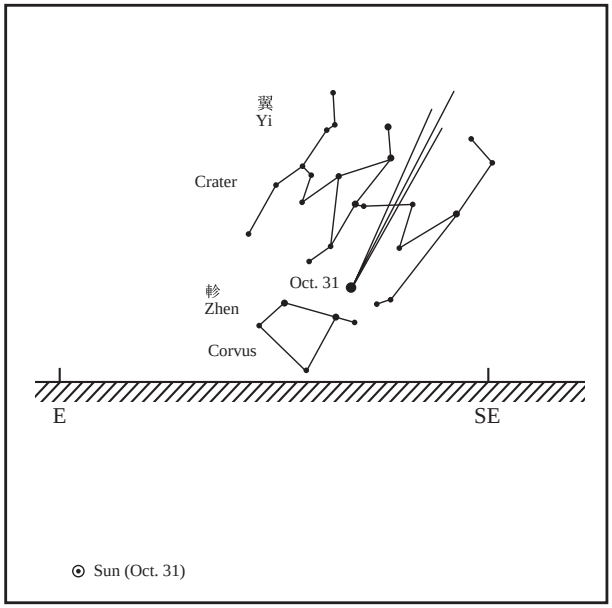

Fig. 19. Calculated path of Comet 1663 on 1663 Oct. 31.

No. 18 1588 October

Chinese On a yi-mao (52) day in the ninth month of the 16th year of the Wan-Li reign-period (1588 October 24), a white vapor appeared in the southeast, measuring two and some odd zhangs in length, and one chi or so in width. Its east side reached the Zhen (28th lunar mansion), and its west side was in the Yi (27th lunar mansion); after 19 days (1588 November 11) it disappeared.

Gui Yang Zhen Kong Zhou Zhi, vol. 22, p. 11; Beijing Observatory (1988), p. 448.

No. 19 1663 October

Chinese On the first day of the tenth month of the second year of the Kang-Xi reign-period (1663 October 31), a comet appeared. It passed through the sky in the eleventh month and on the last day of the twelfth month (1664 January 27) disappeared.

Guang Dong Ya Zhou Zhi, vol. 9, p. 36.

During the tenth month (1663 October 31–November 29), a comet appeared in the range of the Yi and the Zhen (27th and 28th lunar mansions). Its tail was like a broom measuring two and some odd zhangs. In the twelfth month (1663 December 29–1664 January 27) it disappeared.

Haiyang Xian Zhi, p. 10; Beijing Observatory (1988), p. 464.

No. 20 1666 November

Chinese On the night of the 24th day in the tenth month of the fifth year of the Kang-Xi reign-period (1666 November 20), a comet appeared in the southeast. Its length was seven Zhangs and stretched to the center of the sky. It was like a white rainbow stretching to the northwest.

Xin-An Xian Zhi, vol. 11, p. 3; Beijing Observatory (1988), p. 470.

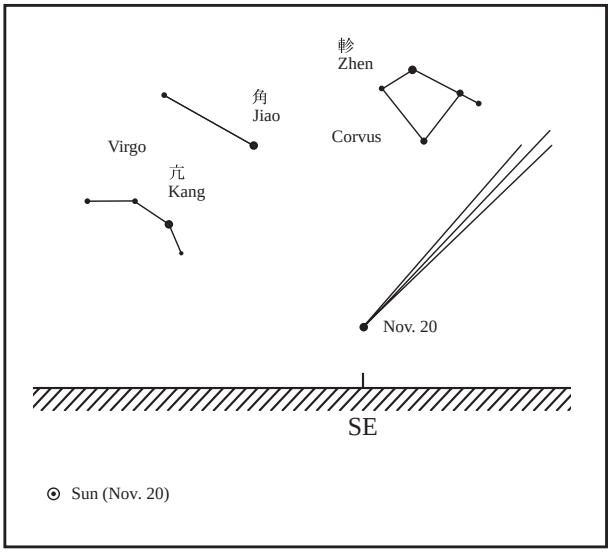

Fig. 20. Calculated path of Comet 1666 on 1666 Nov. 20.

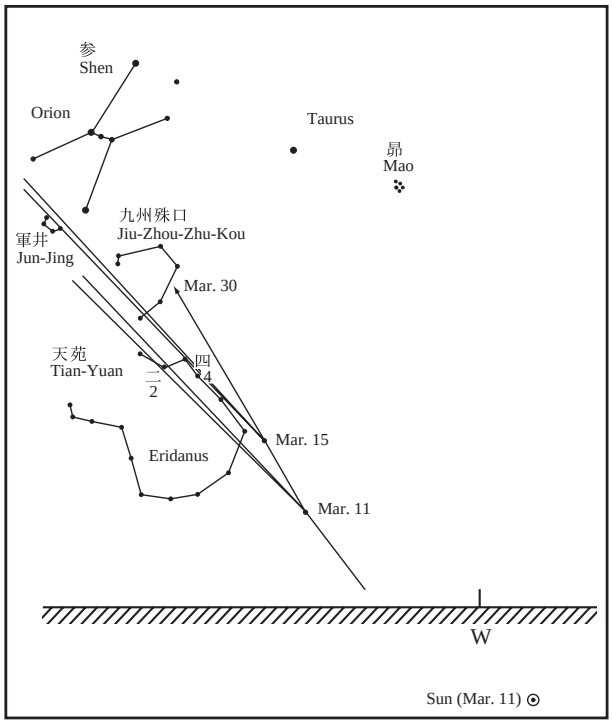

Fig. 21. Calculated path of Comet 1668 during 1668 Mar. 11 and Mar. 30.

No. 21 1668 March

This comet is Comet C/1668 E1 (= Comet 1668). Many records are known in China, Korea, and Japan. In the Korean chronicles, during 1668 March 8 and March 22, everyday observations of the comet were presented. Only brief translations of those records are given below.

Chinese On the night of the 20 th day in the first month of the seventh year of the Kang-Xi reign-period (1668 March 2), a comet appeared in the west. It was some zhangs in length. After several nights it disappeared.

Chao Zhan Fu Zhi, vol. 11, p. 30.

On a yi-hai (12) day in the second month of the seventh year of the Kang-Xi reign-period (1668 March 18), its tail swept the Tian-Yuan (Eridanus), the Jiu-Zhou (eastern part of Eridanus), and the Jun-Jing (Lepus). On a ding-hai (24) day (1668 March 30) it disappeared.

QSG, vol. 39, p. 1468; Ho and Ang (1970), No. 85; Beijing Observatory (1988), pp. 471–472.

Korean On a yi-chou (2) day in the first month of the ninth year of Hyonjong (1668 March 8), a white vapor stood from the west horizon. On the night of a wu-chen (5) day (1668 March 11), a white vapor was seen in the west. It followed the second star of Tian-Yuan (π Eridani), pointing to a star in Jiu-Zhou-Zhu-Kou. On a ren-shen (9) day (1668 March 15), it trespassed the region of Mao (18th lunar mansion) and a fourth star of Tian-Yuan (ε Eridani). Its tail reached a star in the Shen (21st lunar mansion).

Chronicle of Hyonjong, vol. 18, pp. 35–38.

Japanese In the evening of the 27th day in the first month of the eighth year of the Kanbun reign-period (1668 March 9), a white vapor appeared from the west to the east.

Diary of Soko Yamaga, etc.; Ohsaki (1994), p. 451.

European Soon after the sunset on March 5, a bright comet was seen. Pingre (1784) noted the first observation made on March 3 at the Cape of Good Hope. Henderson (1843) computed orbital elements using observations made in Goa, India during March 5 and 21, and suggested a similarity between this comet and C/1843 D1 = Comet 1843 I. Kreutz (1901) also computed an orbit, which is presented in the Catalogue of Cometary Orbits (Marsden, Williams 1999).

Kronk (1999), pp. 361–362.

No. 22 1673 March

Chinese On a gui-si (30) day in the first month[2] of the twelfth year of the Kang-Xi reign-period (1673 March 10), a strange star was seen in the Lou (16th lunar mansion). It was as large as a walnut, white in color and the tail length was one chi and or so, pointing to the east. On a jia-wu (31) day (1673 March 11), it was seen again.

QSG, vol. 39, p. 1468; Ho and Ang (1970), p. 82; Beijing Observatory (1988), p. 475.

In the second month (1673 March 18–April 16), a comet appeared in the west of Zhuanglang. It was one zhang in length and was seen during about one month (until around 1673 April 9).

Gansu Xin Tong Zhi, vol. 2, p. 39; Beijing Observatory (1988), p. 475.

[2] The original record gives the ”second” month, but there is no gui-si (30) day in the second month. It is in the first month.

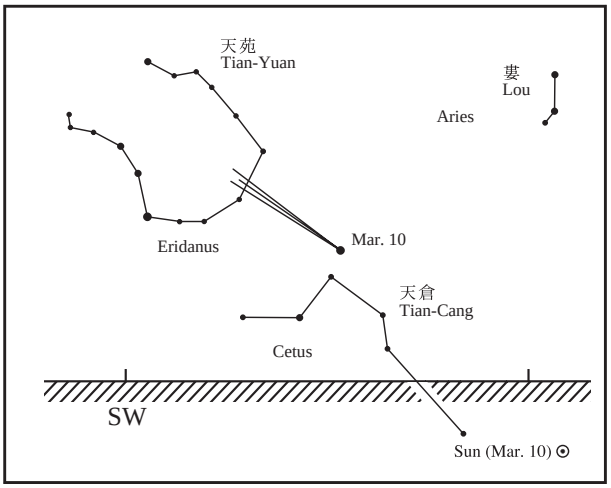

Fig. 22. Calculated path of Comet 1673 on 1673 Mar. 10.

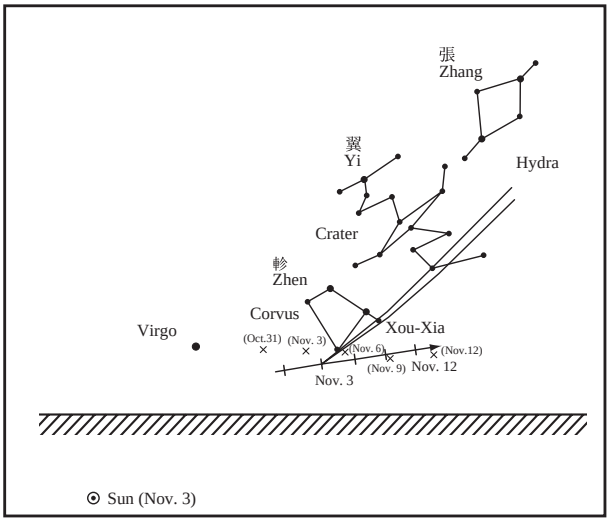

Fig. 23. Calculated path of Comet 1695 during 1695 Oct. 31 and Nov. 12. × denotes the position calculated from Kreutz's orbital elements.

No. 23 1695 November

Korean On a bing-xu (23) day in the ninth month of the 21st year of King Sukchong (1695 November 3), a comet appeared in the east. At night, a white vapor arose from the east. It passed through the Xou-Xia (α Corvi) in the Zhen (28th lunar mansion) and pointed to the Yi (27th lunar mansion). On a ding-hai (24) day in the ninth month (1695 November 4), at night, a white vapor arose from under the Zhen (28th lunar mansion), passed through the star of Xou-Xia (Corvus) and the Yi (27th lunar mansion), and trespassed the Zhang (26th lunar mansion). It looked like a comet. On a ji-chou (26) day (1695 November 6), the white vapor moved to the south of the star of Xou-Xia (Corvus) and trespassed the Zhang (26th lunar mansion). On geng-yin (27) day, the first day in the tenth month (1695 November 7), it moved to the south and became faint. After a few days, it began to disappear.

Yi Wangjo Sillok.

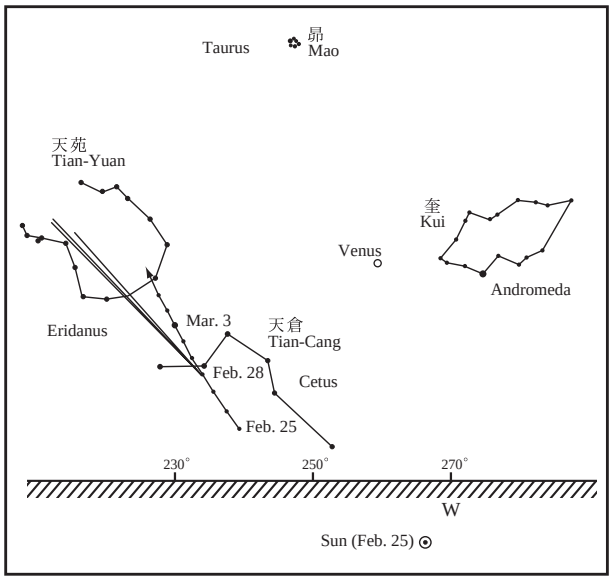

Fig. 24. Calculated daily position of Comet 1702 during 1702 Feb. 25 and Mar. 5.

Chinese After the 15th day in the ninth month of the 34th year of the Kang-Xi reign-Period (after 1695 October 22), at the fifth watch, a comet appeared. It arose from the east, and stretched to the Milky Way. At the first eighth night in the tenth month (1695 November 14), it was still seen.

Hui Cheng Xian Zhi, vol. 18, p. 7; Beijing Observatory (1988), p. 485; Kronk (1999), pp. 381–382.

Remarks: This comet is C/1695 U1 = Comet 1695. Kreutz (1901) and Marsden (1967) doubted that this comet was a member of the Kreutz group; however, we consider that this comet is a possible member of the group. This comet's path, calculated with T = 1695 October 24, is presented in figure 23; its tail passed through the Xou-Xia (Corvus) as described in the Korean record. The positions of the comet calculated from Kreutz's orbital elements (T = 1695 October 23.768) are also given in figure 23 with × marks.

No. 24 1702 February

European Numerous navigators in the southern hemisphere reported seeing a comet between February 20 and March 1 in 1702. On February 28 its tail was 43° long. At 8 pm, at latitude 15°10′ N., and longitude 116°45′ E of Teneriffe, the comet bore south of west 20°30′, altitude 8°40′. It was seen in the evening after the sunset. Maraldi in Rome saw the tail for several days at the end of February and the beginning of March. (Struyck 1753, Vervolg van de Beschryving der Staarts Sternen, p. 50, Amsterdam).

Pingre (1783), vol. 2, p. 37; Chambers (1889), p. 585; Marsden (1967); Kronk (1999), p. 387.

Remarks: The time of observation was 1702 February 28.56 UT, and $\alpha = 1^{\rm h}28\overset{\rm m}{.}5$, $\delta = -17°08'$ (1702.0 equinox), $\alpha = 1^{\rm h}43\overset{\rm m}{.}0$, $\delta = -15°37'$ (2000.0 equinox).

Chinese At you (during 5 and 7 o'clock in the evening) on

the 29th day in the first month of the 41st year of the Kang-Xi reign-period (1702 February 25), a comet was seen.

Wen-Chang Xian Zhi, vol. 9, p. 5.

At you on a jia-yin (51) day in the second month of the 41st year of the Kang-Xi reign-period (1702 February. 28), one line of a white cloud was seen in the southwest. Its length was two and some odd zhangs and one chi or so in width. It penetrated the Tian-Cang (Cetus) and the Tian-Yuan (Eridanus) and entered under the horizon. On ding-si (54) day (1702 March 3), it was three and odd some zhangs.

QSG, vol. 39, p. 1484; Beijing Observatory (1988), p. 485.

Korean On a jia-yin (51) day in the second month of the 28th year of the Sukjong reign-period (1702 February. 28), a white vapor like a comet was seen, and afterwards it appeared every day. On a bing-chen (53) day (1702 March 2), a white vapor was in the west and its root was at the end of the sky in a muddy. On yi-chou (2) day (1702 March 11), it disappeared. Because of very bright moonlight, detailed observations were impossible.

Yi Wangjo Sillok; Sekiguchi (1917), No. 72.

Japanese From the evening of the 29th day in the first month of the 15th year of the Genroku reign-period (1702 February 25), a comet appeared in the west.

Diary of Arai Hakuseki, vol. 1.

In the early evening, from the last quarter in the first month to the first quarter in the second month (1702 February 18–March 6), a white vapor appeared in the southwest. Its root was at the 14th degree of the Kei (15th lunar mansion)[3], or in the Tenso (Cetus), and its end reached to the first degree of the Bo (18th lunar mansion), or in the Tenen (Eridanus).

Tani Jinzan's Jinkiroku, vol. 8; Ohsaki (1994), p. 460.

4. Uncertain Candidates for the Kreutz Group of Comet

In addition, we have some questionable candidates for the Kreutz group of comets. They have no detailed records of positions and directions of motion. Only a short summary of records and remarks are given below.

No. 1 Chinese 838 November 9. During November 9 (Moon's age 18) and 12, a comet with a long tail appeared. It pointed to the southeast star in the Zhen (28th lunar mansion). The comet was above a bright star. On November 21 (Moon's age 1), the comet was in the Wei and the Ji (sixth and seventh lunar mansions), and disappeared on December 28 (Moon's age 8).

Beijing Observatory (1988), pp. 410–411; Ho (1962), No. 292.

Japanese 838 November 12 (Moon's age 21). A long comet appeared in the southeast, and on December 7 (Moon's age 17) it was still seen.

Kanda (1935), p. 480; Ho (1962), No. 292.

Remarks: This comet is X/838 VI (Kronk 1999, p. 128).

No. 2 Japanese 957 March 6 (Moon's age 2). In the night, a white sword star appeared. Its length was one or two jyos.

Kanda (1935), p. 489; Kronk (1999), p. 157.

No. 3 Japanese 961 March 15 (Moon's age 26). A comet-like fire was seen in the southwest.

Kanda (1935), p. 689; Ho (1962), No. 341; Kronk (1999), p. 157.

No. 4 Chinese 1384 September–October. A comet swept the Yi (27th lunar mansion).

GJ, vol. 41, p. 16.

No. 5 Japanese 1399 October 7 (Moon's age 7). A comet appeared in the south.

Kanda (1935), p. 566; Ho (1962), No. 486; Kronk (1999), p. 260.

No. 6 Chinese 1580 October–November. A comet appeared between the Yi and the Zhen (27th and 28th lunar mansions).

Beijing Observatory (1988), p. 445.

No. 7 Chinese 1607 October–November. A comet was seen in the Zhen (28th lunar mansion).

Beijing Observatory (1988), p. 451.

No. 8 Chinese 1611 November 5 (Moon's age 5). A comet was seen in the southeast for about ten days. Its length was three or four zhangs, and disappeared at the sunrise.

Beijing Observatory (1988), p. 452.

No. 9 Chinese 1650 February 26 (Moon's age 25). A white vapor appeared in the west.

Beijing Observatory (1988), p. 463.

No. 10 Chinese 1657 December 7 (Moon's age 2). A comet was seen in the east.

Beijing Observatory (1988), p. 463.

No. 11 Chinese 1676 February 18 (Moon's age 5). A strange white star was seen northeast of Tian-Yuan (Eridanus).

Beijing Observatory (1988), p. 380; Hsi (1955), No. 88; Ho and Ang (1970), No. 87.

European On February 14 (Moon's age 1), Fontenay at Nantes discovered a comet of third magnitude in Eridanus, and saw it on March 9 (Moon's age 16) in Lepus.

Pingre (1784), vol. 2, p. 23; Kronk (1999), p. 364.

Remarks: This comet's recorded positions do not fit with the ephemerides for the Kreutz group.

No. 12 Japanese 1689 December 6 (Moon's age 25). A strange star appeared in the southeast.

[3] Right ascension of the 14 degree of the Kei is 1h 43m (equinox 2000.0).

Table 4. Family of Kreutz group comets, durations, and intervals of their perihelion passage.

Family	Perihelion passages	Duration (Interval) (yr)	Number of comets Table 1	+ Doubt	Corresponding families	Interval (yr)	Number of comets
A	−5	1 (105)	1				
B	100–252	152 (171)	6				
C	423	1 (184)	1				
D	607	1 (231)	1		B, F	782–1006	6, 3
E	838–961	123 (73)	2	3	C, G	809–976	1, 4
F	1034–1106	72 (126)	3		D, H	972–1004	1, 5
G	1232–1399	167 (180)	2	2	E, J	689–864	5, 10
H	1579–1611	32 (39)	2	3	F, K	737–936	3, 8
J	1650–1702	52 (141)	6	4	Mean	878 ± 116	
K	1843–1970	127 (9)	8				
SOLWIND	1979–1984	5 (3)	6				
SMM	1987–1989	2 (7)	10				
SOHO	1996–Present	⋯	many				

Note. In the column of duration, the years of interval of no appearance of comet are given in parentheses, and under table 1+, numbers of the comet observed since 1843 are added.

Ohsaki (1994), p. 458.

Chinese 1689 December 12 (Moon's age 1). A white vapor was seen in the southeast.

Beijing Observatory (1988), p. 484; Kronk (1999), pp. 380–381.

Remarks: This comet may be C/1689 X1 = Comet 1689 (Marsden 1967; Marsden, Williams 1999), but is a doubtful candidate for the Kreutz group.

5. Discussion

Orbital periods are known for only a few of the sungrazing comets. In the Catalogue (Marsden, Williams 1999), eight values of the individual osculating orbital period are given, and are between 513 and 1055 years. The mean value of period becomes 826 ± 172 years. On the other hand, we can also estimate a mean value from historical records of sungrazing comets. Considering that the mean orbital period is about eight hundred years, the Kreutz-group comets are divided arbitrarily into families, as presented in table 4. The number of comets in each family given in column 4 was derived from table 1, Kreutz comets that appeared since 1843 and doubtful comets mentioned in section 4. The comets observed since 1843 are from Marsden and Williams (1999), and make up Family K. Although the division into families is rather arbitrary, the intervals between their appearances are nearly the same as the mean orbital period derived above. In the right part of table 4, the intervals between specific pairs of families are given. The mean value of these intervals, 878 ± 116 years, agrees well with the one mentioned above.

Marsden (1967) has integrated back the motion of the nucleus A of Comet 1965 S1 and obtained that the time of the previous perihelion passage between 1114 and 1116. He suggested the most probable progenitor of this comet was one that appeared in 1106 February. If so, the actual orbital period would be 859 years. Marsden (1967, 1989) also suggested that comets 1882 R1 and 1965 S1 separated from each other at their previous perihelion passages in 1106. We also calculated back the motions of eight comets in Family K. On the assumption that the previous perihelion passage was $T = 1106$ January 26; with each adjusted eccentricity given in table 5, the motions of eight comets in Family K were integrated back to 1106. In our calculations, perturbations by major planets from Mercury through Neptune, Moon, (1) Ceres, (2) Pallas, and (4) Vesta are included. The orbital elements at the epoch in 1106 are given in table 6, showing the coincidence of orbits of comets 1882

Table 5. Adjusted eccentricities for comets in Family K.*

Comet	Epoch or T in ( )	q(AU)	e	Adjusted e	Difference (adjusted $e-e$)
Subgroup I					
1887 B1	(1887 Jan. 11.9)	0.00483	1.0	0.9999470	−0.0000530
1843 D1	(1843 Feb. 27.9)	0.005527	0.999914	0.9999325	+0.0000185
1880 C1	(1880 Jan. 28.1)	0.005494	1.0	0.9999346	−0.0000654
1963 R1	1963 Sep. 8.0	0.005065	0.999946	0.9999437	−0.0000023
Subgroup II					
1970 K1	(1970 May 14.5)	0.008879	1.0	0.9999087	−0.0000913
1882 R1-B	1882 Oct. 2.0	0.007751	0.999907	0.9999103	+0.0000033
1965 S1-B	1965 Oct. 7.0	0.007786	0.999915	0.9999158	+0.0000008
1945 X1	(1945 Dec. 28.0)	0.007516	1.0	0.9999222	−0.0000778

* These comets have the perihelion passage in 1106 (arranged in order of Ω in table 6). As regards the subgroup, refer to Hasegawa (1996), Kresak (1966), and Marsden (1967, 1989). The orbital elements for 1882 R1-B are derived from the longest arc of observations and relativity effects are included. 1965 S1-A is brighter than 1965 S1-B and relativity effects are also included.

Table 6. Orbital elements for comets in Family K at the epoch in 1106 arranged in order of Ω.

Comet in Family K	q(AU)	e	Period (yr)	ω	Ω (2000.0)	I
Epoch = 1106 Jan. 17.0 TT, T = 1106 Jan. 26.0						
Subgroup I						
1887 B1	0.00546	0.9999362	793	83.°301	4.°30	144.°386
1843 D1	0.00541	0.9999344	748	84.571	5.652	144.510
1880 C1	0.00536	0.9999371	786	86.150	7.448	144.717
1963 R1	0.00500	0.9999453	873	86.463	8.105	144.646
Subgroup II						
1970 K1	0.00949	0.9998964	877	62.544	338.577	139.628
1882 R1-B	0.00798	0.9999065	788	68.211	345.818	141.706
1965 S1-B	0.00798	0.9999126	873	68.217	345.823	141.707
1945 X1	0.00840	0.9999065	853	72.243	351.412	141.948

Table 7. Tentative linkages of Kreutz group comets in Family J.

Comet in Family J	T_0	Adjusted e at T_0	$P(0,-1)$ (yr)	T-2	Possible candidate for T-2	$P(-1,-2)$ (yr)
1663	1664 Oct. 15	0.9999238	720	132 Oct. 23	Comet 133	810
1666	1666 Nov. 10	0.9999216	723	128 Aub. 21		
1668	1688 Feb. 28	0.9999226	725	127 Jan. 15		
1673	1673 Feb. 26	0.9999274	730	121 May. 4	Comet 109	834
1695	1695 Oct. 24	0.9999295	752	93 July. 8	Comet 100	843
1702	1702 Feb. 13	0.9999239	759	85 Apr. 25		

Note. $P(0,-1)$ is $T_0 - T$-1(= 943 Oct. 27), and $P(-1,-2)$ is T-1 − T-2 (year of a comet). The mean values of $P(0,-1)$ and $P(-1,-2)$ are 735 ± 16 and 829 ± 17 respectively.

R1 and 1965 S1. Therefore, it seems likely that Comet 1106 is the progenitor of those two comets, as Marsden (1967, 1989) has already suggested. It is also highly probable that the other comets in Family K also separated from Comet 1106 to make two subgroups and many members of the Kreutz group as given in table 6. Comet 1106 and the other two comets in Family F (comets 1034 and 1041) were observed for more than 30 days and were bright enough to be recorded in several countries; however, our trial calculations to link comets 1034 and 1041 with comets in Family K were unsuccessful.

To give one of our trial results, assuming that six comets in Family J originated at the perihelion in 943 (T-1), we calculated back their motions using an adjusted eccentricity and obtained previous perihelion times (T-2), as given in table 7; the possible candidates in Family B are found from table 1 and given in the sixth column of table 7, and derived intervals of the apparition are given in the last column. The mean value of these intervals is 829 ± 17 years. Because the effects of disruption of comet and nongravitational effects were not included, the calculated results given in table 7 are only approximate.

Though we made other trial calculations on the assumption that the comets in Family J were produced from the comet of 852 (No. 10 in table 1), we could not find any appropriate candidates to link between the years 32 and 68. Marsden (1967, 1989) has also given some other suggestions for disruptions to make comets of the Kreutz group. After trying to link various members of the sungrazing comet group, we could not find any other positive relationships. Small sungrazing comets observed very near to the sun by satellite-borne coronagraphs may have been produced by disruptions of larger members of the Kreutz group, for instance the comets in Family F, which appeared about nine hundred years ago. However, those problems are open to further studies.

We thank D. K. Yeomans for a careful reading of the manuscript and useful comments.

References

Beijing Observatory 1988, A Compilation of Chinese Ancient Records of Celestial Phenomena (Nanjing: Jiangsu Sciences and Technology Press) (in Chinese)
Chambers, G. F. 1889, A Handbook of Descriptive and Practical Astronomy, 4th ed. (Oxford: Oxford University Press)
Hasegawa, I. 1966, The Heavens, 47, 31 (in Japanese)
Hasegawa, I. 1979, PASJ, 31, 257
Henderson, T. 1843, Astron. Nachr., 20, 333
Ho, P. Y. 1962, Vistas Astron., 5, 127
Ho, P. Y., & Ang, T. S. 1979, Oriens Extremes, 17, 63
Hsi, T. T. 1955, Smithsonian Contrb. Astrophs., 2, 109
Kanda, S. 1935, Astronomical Materials in Japanese History (Tokyo: Maruzen) (in Japanese)
Kiang, T. 1972, Mem. R. Astron. Soc. 76, 27
Kresak, L. 1966, Bull. Astron. Inst. Czech. 17, 188
Kreutz, H. 1891, Publ. Sternw. Kiel, Heft 6
Kreutz, H. 1901, Ergänzungshefte Astron. Nachr., 1, No. 1
Kronk, G. W. 1999, Cometography, A Catalogue of Comets, vol. 1 (Cambridge: Cambridge University Press)
Marsden, B. G. 1967, AJ, 72, 1170
Marsden, B. G. 1989, AJ, 98, 2306
Marsden, B. G., & Williams, G. V. 1999, Catalogue of Cometary Orbits, 13th ed. (Cambridge, MA: Minor Planets Center, Smithsonian Astrophysical Observatory)
Ohsaki, S. 1994, Astronomical Materials in Modern Japanese History (Tokyo: Hara Shyobo) (in Japanese)
Pingre, A. G. 1783, Cometographie, tom 1 (Paris: L'Imprimerie Royale)
Pingre, A. G. 1784, Cometographie, tom 2 (Paris: L'Imprimerie Royale)
Sekiguchi, R. 1917, Astronomical Herald, 10, 85 (in Japanese)
Stephenson, F. G., Yau, K. K. C., & Hunger, H. 1985, Nature, 314, 587
Watanabe, T. 1953, The Heavens 34, 8 (in Japanese)
Williams, J. 1871, Observations of Comets, from B.C. 611 to A.D. 1640, Extracted from the Chinese Annals (London: Williams and Norgate)
Yau, K., Yeomans, D., & Weissman, P. 1994, MNRAS, 266, 305