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Approximate Orbits of Ancient and Medieval Comets

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Abstract

This is one of our reports in a continuing series of papers providing orbital elements for ancient and medieval comets recorded in histories. Newly determined orbital elements and calculated paths of comets with translated records are presented for ten comets found in East Asian histories. The distributions of the small perihelion distance and the close geocentric distance of bright naked-eye comets are discussed. Those orbital characteristics given in this paper are fundamentals, and will be useful for further studies of comets.

Key words: Comets: general — Comets: historical records — Comets: individual (Comet 126, Comet 839, Comet 893, Comet 1005, Comet 1266, Comet 1273, Comet 1362, Comet 1430, Comet 1495, Comet 1554) — solar system: general

1. Introduction

During our orbital work on old comets recorded in East Asian histories (Hasegawa 1979; Hasegawa, Nakano 1995, 2001), we found many cometary records which are inadequate for orbit determinations. However, approximate orbital elements can be derived from two positions and a definite path of a comet determined by trial and error.

In this paper, we present newly determined orbits of ten such comets found in historical records. General explanations for the Chinese old calendar systems, Chinese constellations, and related subjects are explained by other authors (Williams 1871; Ho 1962; Kiang 1972), and the units of length used in the astronomical records are also given in table 2 of our paper (Hasegawa, Nakano 2001); therefore, we do not repeat them here. In the present study, the coordinates of stars, the sun, comets, and angular orbital elements are referred to the mean equator and the equinox of the J2000 system.

A summary of ten comets for which the orbital elements were determined in this study are given in table 1. In column 2 of this table, the first and last dates of the observations are given; column 3 lists the sources of the original records using abbreviations of the countries.

The dates of the records used for the orbit determinations are given in column 4, and the calculated times of perihelion passage are listed in column 5. In column 6, the minimum geocentric distances of the comet are given along with dates. The absolute visual magnitudes of the comet, H10, in the last column were derived using the relation

$$H10 = m_1 - 5\log\Delta - 10\log r, \tag{1}$$

where m_1 is the total visual magnitude adopted, about 5, at the last observation (see section 2 of Hasegawa, Nakano 2001); Δ and r are the geocentric and heliocentric distances in astronomical units, respectively.

2. Historical Records and Orbital Elements of Individual Comets

The original records of comets were briefly translated into English, and are presented below. Almost all of these records are given in a compilation of Chinese ancient records of celestial phenomena (Beijing Observatory 1988) as well as in Japanese records (Kanda 1935). Each translation is followed by the original sources and some general catalogues of historical comets. In table 2, derived orbital elements are given for the individual comets, and in table 3, the estimated positions used for the orbit determination as well as the cometary ephemerides are given. Each comet's path in the Chinese constellations is shown in figures 1–10.

No. 1

Comet 126

Chinese On a jia-wu (31) day in the second month of the first year of the Yong-Jian reign-period (126 March 23), a guest star entered Tai-Wei. On the thirteenth day of the second month (126 March 24), a guest star like a comet appeared. It went through Tian-Shi, Geng-He (ϵ Boo), Zhao-Yao (γ Boo), and Tian-Qiang (θ Boo). On the sixteenth day (126 March 27), it entered Zi-Gong (the Northern circumpolar region) and approached Bei-Chen (the North pole). On the seventeenth day (126 March 28), it passed Wen-Chang and Tai-Ling. It then reached between Tian-Chuan and Ji-Shui (λ Per). It first diminished, and then disappeared (Gujin Shu in Hou Han Shu).

Beijing Observatory (1988, p.390); Ho (1962, p.151).

No. 2

Comet 839

Chinese On a gui-you (10) day in the first month of the fourth year of the Kai-Cheng reign-period (839 February 7), a comet appeared in Yu-Lin. On a bing-wu (43) day in the intercalary

Table 1. Comets in historical records treated in this work.

No.	Period of observations	Sources*	Observations	Perihelion passage, T (TT)	Closest distance (Date, AU)	Absolute magnitude (H10)
1	126 Mar 23–28	C	126 Mar 23, 28, and path	126 May 3	Mar 27, 0.03	9.0
2	839 Feb 7–Mar 15	C, J	839 Feb 7, Mar 12, and path	839 Jan 30	Feb 11, 0.70	4.0
3	893 May 6–Jun 11	C	893 May 6, Jun 11, and path	893 Apr 12	May 18, 0.22	6.0
4	1005 Oct 1–14	C	1005 Oct 4, 14, and path	1005 Sep 12	Oct 12, 0.12	9.0
5	1266 Jan 18–Feb 22	J	1266 Jan 20, Feb 7, and path	1266 Jan 26	Jan 31, 0.28	7.0
6	1273 Apr 9–29	C, J	1273 Apr 9, 29, and path	1273 Mar 10	Apr 16, 0.11	8.0
7	1362 Jun 29–Aug 2	C, K, J	1362 Jun 29, Jul 6, and path	1362 Jul 6	Jul 1, 0.54	4.0
8	1430 Nov 14–21	C	1430 Nov 14, 21, and path	1430 Dec 10	Nov 23, 0.08	8.0
9	1495 Jan 7–Feb 20	C	1495 Jan 7, Feb 20	1495 Feb 26	Feb 13, 1.22	2.5
10	1554 Jun 23–Jul 19	C, K	1554 Jun 23, Jul 1, and Jul 3	1554 Jul 24	Jun 30, 0.24	8.0

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

Table 2. Approximate parabolic orbital elements of comets (referred to J2000.0).

No.	Perihelion passage	q (AU)	ω	Ω	i	L^*	B^*
1	126 May 3	0.27	295°	33°	27°	330°	−24°
2	839 Jan 30	0.29	275	122	101	187	−78
3	893 Apr 12	0.79	39	148	7	187	+5
4	1005 Sep 12	0.89	110	242	15	353	+15
5	1266 Jan 26	0.72	5	166	162	162	+2
6	1273 Mar 10	0.70	8	143	6	151	+1
7	1362 Jul 6	1.09	86	17	150	291	+29
8	1430 Dec 10	0.97	218	242	15	99	−9
9	1495 Feb 26	0.38	108	231	48	348	+45
10	1554 Jul 24	0.71	191	147	17	337	−3

* L is the ecliptic longitude and B the latitude of the perihelion.

month (839 March 12), it appeared in Juan-She (Xin Tang Shu Wen Zong Ji).

On a gui-you (10) day (839 February 7), a comet appeared in the west, at the fourteenth degree of the Shi (13th lunar mansion). On the 23rd day in the intercalary month (839 March 12), it was seen north of Juan-She. It lasted for about 33 days. On the night of the 26th day (839 March 15), it disappeared (Jiu Tang Shu Tian Wen Zhi).

On the thirtieth day in the first month (839 February 17), a comet was located south of Shi (13th lunar mansion), and went through Kui, Lou, and Wei (15th, 16th, and 17th lunar mansions) and so on. On the 26th day in the intercalary month (839 March 15), it disappeared (Tang Hui Yao).

Japanese On a hinoe-ne (bing-zi, 13) day in the first month of the sixth year of the Syo-Wa reign-period (839 February 10), a comet was seen in the west, and was about one jyo ($\approx 10°$) in length (Zoku Nihon Koki).

Beijing Observatory (1988, p.411); Williams (1871, p.49); Ho (1962, p.175); Kanda (1935, p.481); Kronk (1999, p.130).

Remarks: The fourteenth degree of the Shi is about at $\alpha = 0^{\mathrm{h}}00^{\mathrm{m}}$ (equinox 2000.0).

No. 3

Comet 893

Chinese On the evening of an yi-you (22) day in the fourth month of the second year of the Jing-Fu reign-period (893 May 6), a comet appeared at Shang-Tai. Its length was over ten

Table 3. Observations and ephemerides of comets.

Date (TT)			Observations α(2000) (h m)	Observations δ (°)	Ephemerides α(2000) (h m)	Ephemerides δ (°)	Δ (AU)	r (AU)	Elongation (°)	Mag	Moon's age
No. 1					Comet 126						
126	Mar	23.5	15 00	+15	14 58	+15.6	0.09	1.09	148	4.2	11
		27.5	···	···	8 56	+78.4	0.03	1.00	81	1.2	15
		28.5	4 00	+50	4 08	+50.1	0.04	0.98	46	1.7	16
		29.5	···	···	3 41	+32.2	0.05	0.96	30	2.5	17
No.2					Comet 839						
839	Feb	7.5	0 00	−15	23 59	−12.9	0.73	0.39	20	−0.8	19
		22.5	···	···	2 00	+27.4	0.85	0.72	54	2.3	5
	Mar	12.5	3 30	+45	3 22	+46.2	1.34	1.10	48	5.0	23
		15.5	···	···	3 32	+47.8	1.43	1.16	54	5.4	26
No.3					Comet 893						
893	May	6.5	9 00	+43	9 00	+42.5	0.28	0.92	63	2.9	16
		18.5	···	···	12 30	+36.9	0.22	1.05	92	2.9	28
		30.5	···	···	14 57	+14.2	0.29	1.20	123	4.1	11
	Jun	11.5	16 00	0	16 00	0.0	0.44	1.36	134	5.5	23
No.4					Comet 1005						
1005	Oct	1.5	···	···	17 10	+45.9	0.17	0.96	73	5.0	25
		4.5	17 30	+55	17 32	+54.7	0.15	0.98	81	4.8	28
		9.5	···	···	19 31	+72.4	0.13	1.02	100	4.6	3
		14.5	1 30	+70	1 24	+70.0	0.13	1.07	124	4.8	8
No.5					Comet 1266						
1266	Jan	20.8	18 13	−26	18 11	−26.1	0.55	0.72	46	4.3	13
	Feb	3.5	···	···	23 23	+15.2	0.31	0.74	30	1.6	26
		7.5	0 45	+24	0 47	+23.8	0.43	0.76	46	4.0	1
		15.5	···	···	2 00	+28.2	0.74	0.83	55	5.5	9
No.6					Comet 1273						
1273	Apr	9.5	5 15	+55	5 16	+55.3	0.15	0.93	54	3.6	20
		16.5	···	···	11 30	+64.8	0.11	1.02	91	3.4	27
		29.5	14 40	+15	14 40	+15.6	0.23	1.20	142	5.6	11
No.7					Comet 1362						
1362	Jun	29.5	20 25	+75	20 24	+74.9	0.55	1.10	83	3.1	7
	Jul	6.5	15 30	+60	15 30	+60.0	0.56	1.09	82	3.1	14
	Aug	2.5	···	···	14 00	+12.7	1.30	1.18	60	5.3	12
No.8					Comet 1430						
1430	Nov	14.5	1 30	+3	1 30	+2.2	0.11	1.06	132	3.5	28
		17.5	···	···	1 43	−9.3	0.09	1.04	126	3.1	1
		21.5	2 00	−30	2 12	−30.5	0.08	1.02	114	2.6	5
		22.5	···	···	2 24	−36.5	0.08	1.01	110	2.6	6
		23.5	···	···	2 37	−42.6	0.08	1.01	106	2.5	7
No.9					Comet 1495						
1495	Jan	6.9	17 20	−25	17 20	−25.1	1.77	1.23	42	4.6	11
		20.9	···	···	18 29	−20.2	1.47	0.96	40	3.2	25
	Feb	19.9	22 05	+5	22 14	+4.1	1.24	0.42	17	−0.8	25
No.10					Comet 1554						
1554	Jun	23.5	12 15	+56	12 15	+56.1	0.26	0.93	64	4.8	23
		26.5	···	···	11 17	+56.6	0.25	0.89	54	4.5	26
		30.5	···	···	9 55	+54.2	0.24	0.84	41	4.2	1
	Jul	1.5	9 35	+53	9 35	+53.0	0.24	0.84	38	4.2	2
		3.5	9 00	+50	9 00	+50.0	0.25	0.82	32	4.1	4
		11.5	···	···	7 29	+35.1	0.29	0.75	20	4.1	12
		19.5	···	···	6 53	+22.9	0.38	0.71	30	4.4	20

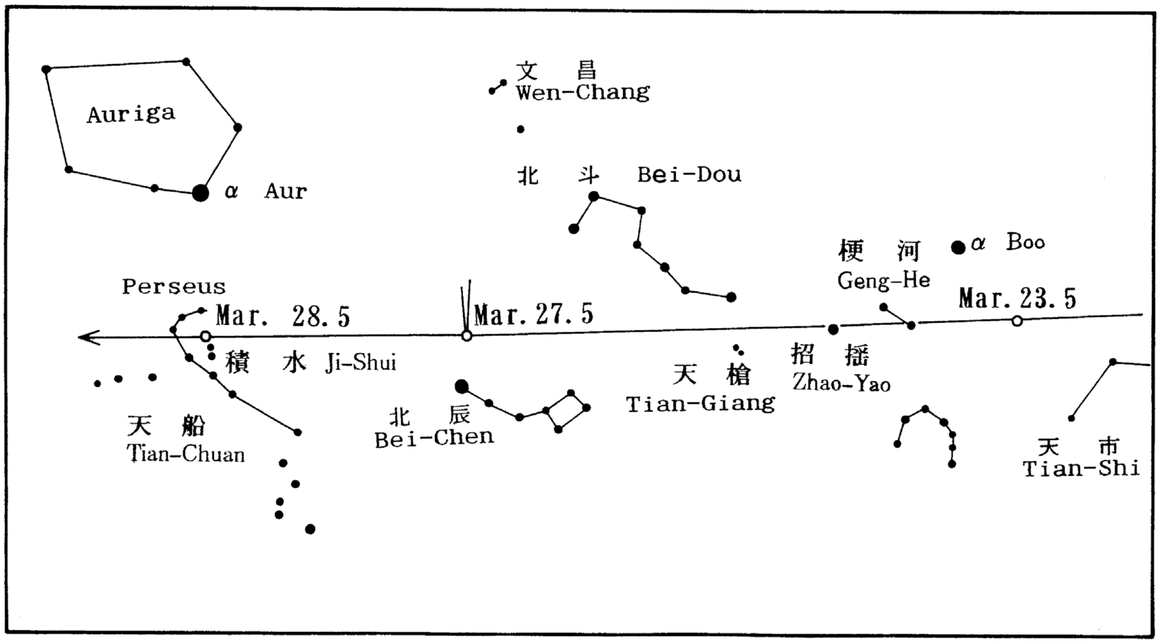

Fig. 1. Calculated path of Comet 126 during 126 March 23 and March 28.

zhangs. It went to the east and entered the Tai-Wei Enclosure, swept Da-Jiao (α Boo) and entered the Tian-Shi Enclosure. After 37 days (893 June 11) its length increased to over twenty zhangs (nearly 180°). When the weather become cloudy, it could not be seen (Xin Tang Shu Tian Wen Zhi).

Beijing Observatory (1988, p.413); Williams (1871, p.51); Ho (1962, p.177); Kronk (1999, p.141).

No. 4

Comet 1005

Chinese On a xin-chou (38) day in the eighth month of the second year of the Jing-De reign-period (1005 October 1), a comet appeared in the Zi-Wei Enclosure (Tzu-Wei-Yuan in figure 4) (Song Shi Zhen Zong Ji).

On a jia-chen (41) day (1005 October 4), a guest star appeared by the side of Tian-Phou in the Zi-Wei Enclosure with rays shooting out like a Fen-Xu (powdered cotton). It gradually entered the Enclosure and went through Yu-Nu and Hua-Gai. After 11 days (1005 October 14) it went out of sight (Song Shi Tian Wen Zhi).

Beijing Observatory (1988, p.416); Ho (1962, p.182); Kronk (1999, p.167).

No. 5

Comet 1266

Japanese On the morning of the eleventh day, a kinoto-i (yi-hai, 12) day, in the twelfth month of the second year of the Bun-Ei reign-period (1266 January 18), a comet was seen in the east. Its ray was over one syaku ($\approx 1°$) in length (Gekinikki).

On the morning of the fourteenth day (1266 January 21), the comet was near Venus. On the evening of the twenty-seventh

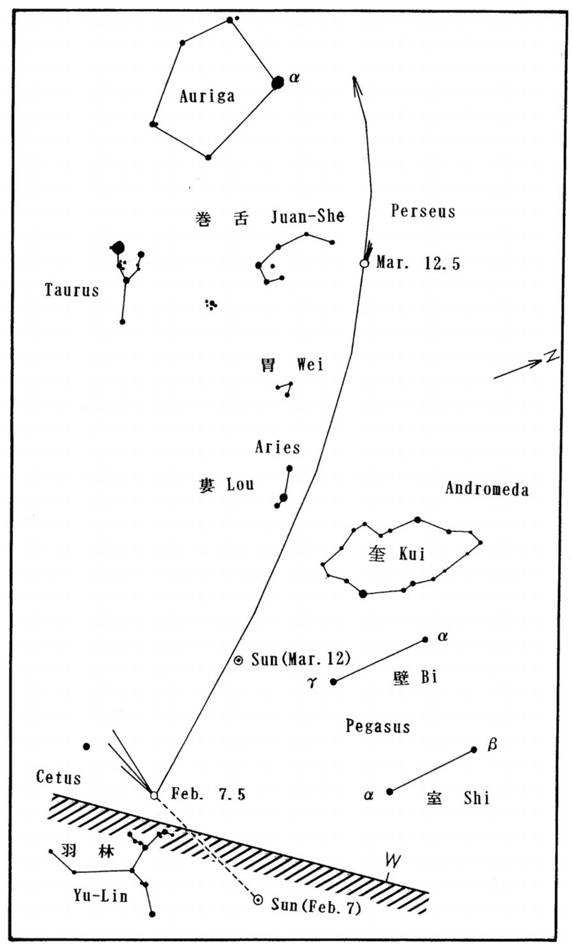

Fig. 2. Calculated path of Comet 839 during 839 February 7 and March 12.

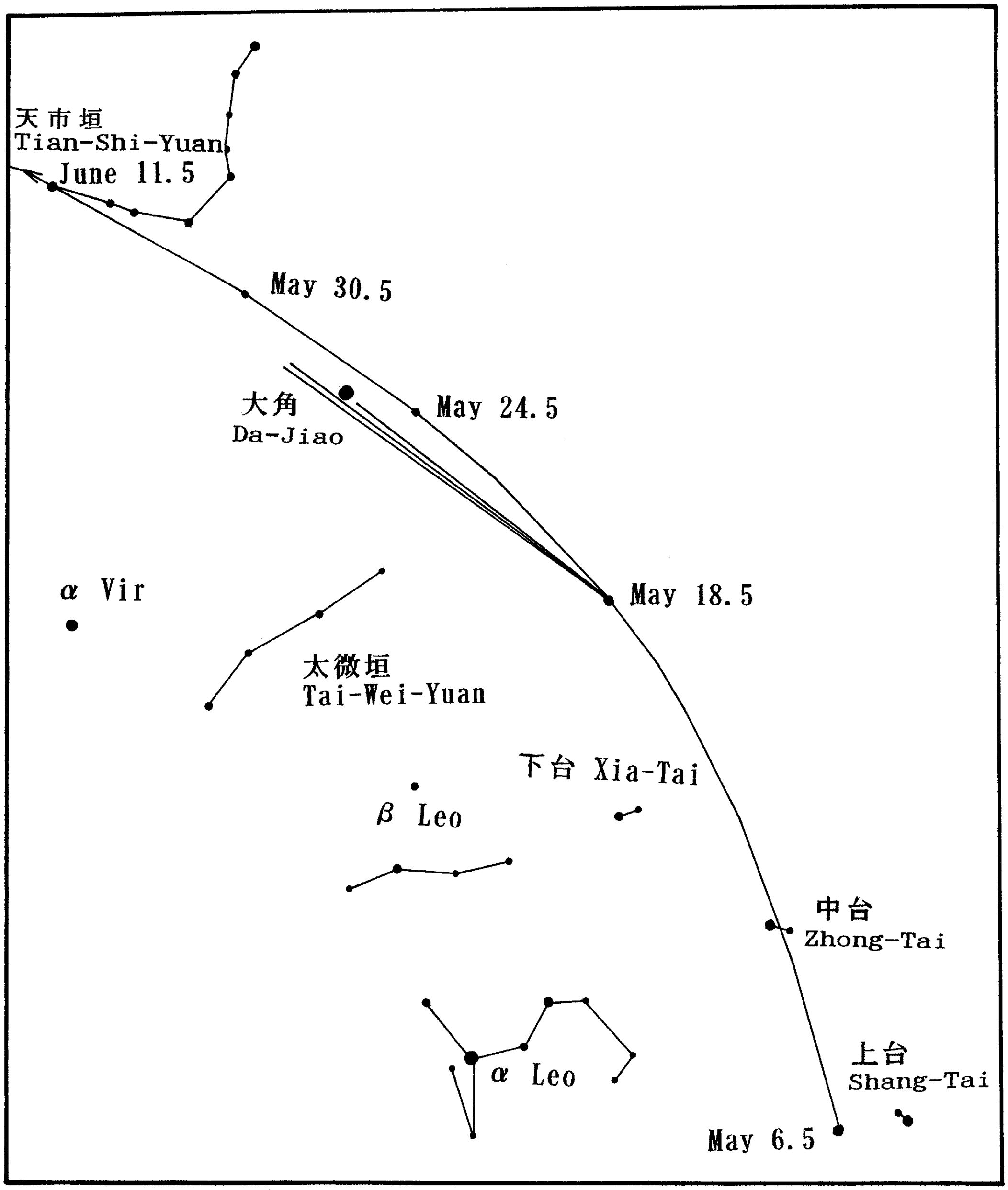

Fig. 3. Calculated path of Comet 893 during 893 May 6 and June 11.

day, a kanoto-u (xin-mao, 28) day (1266 February 3), the comet was seen in the west at Shi (13th lunar mansion). Its ray was two-odd syakus (≈ 2–3°) in length and white in color. On the first day in the first month of the third year, a kinoto-hitsuji (yi-wei, 32) day (1266 February 7), the comet was seen in the west at the eighth degree of the Bi (14 th lunar mansion) (Azumakagami).

In the middle of the first month (about 1266 February 22), the comet was not seen (Zokushi gusyo).

Kanda (1935, pp. 545–547).

Remarks: At 1266 January 20.8 TT, Venus was at $\alpha = 18^{h}13^{m}$, $\delta = -20\overset{\circ}{.}8$, (equinox 2000.0), and the eighth degree of the Bi lunar mansion corresponded to $\alpha = 0^{h}45^{m}$ (equinox 2000.0).

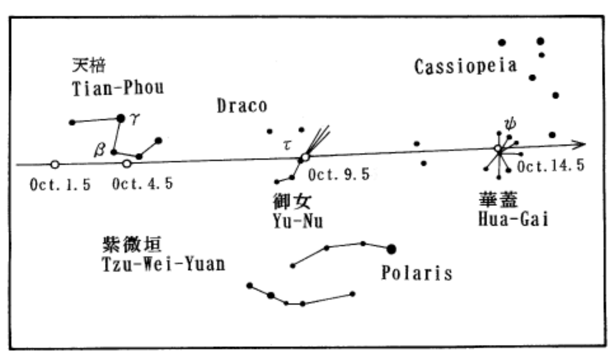

Fig. 4. Calculated path of Comet 1005 during 1005 October 1 and October 14.

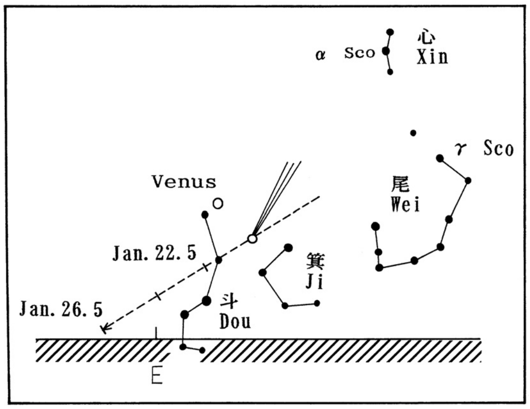

Fig. 5. (a) Calculated path of Comet 1266 during 1266 January 20 and January 26.

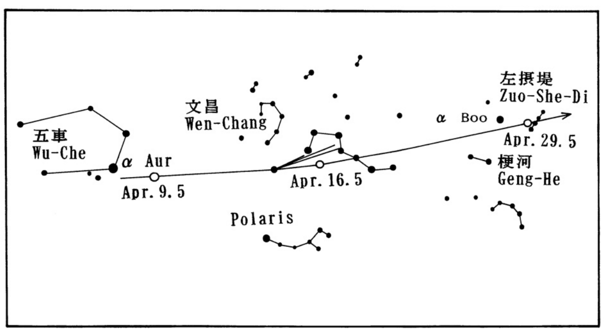

Fig. 6. Calculated Path of Comet 1273 during 1273 April 9 and April 29.

No. 6

Comet 1273

Chinese On a gui-you (10) day in the third month of the tenth year of the Zhi-Yuan reign-period (1273 April 9), a guest star, bluish-white color and like loose cotton, appeared in the range of the Bi (19th lunar mansion) and to the north of Wu-Che. Moving from Wen-Chang it penetrated the Dou-Shao (Big Dipper), passed Geng-He and reached Zuo-She-Di. It lasted about 21 days (1273 April 29) (Yuan Shi).

Japanese On the twenty third day in the third month of the tenth year of the Bun-Ei reign-period (1273 April 12), a guest star appeared in the northwest (Kanda 1935, p.548).

Beijing Observatory (1988, p.422); Ho (1962, p.194); Kronk (1999, p.223).

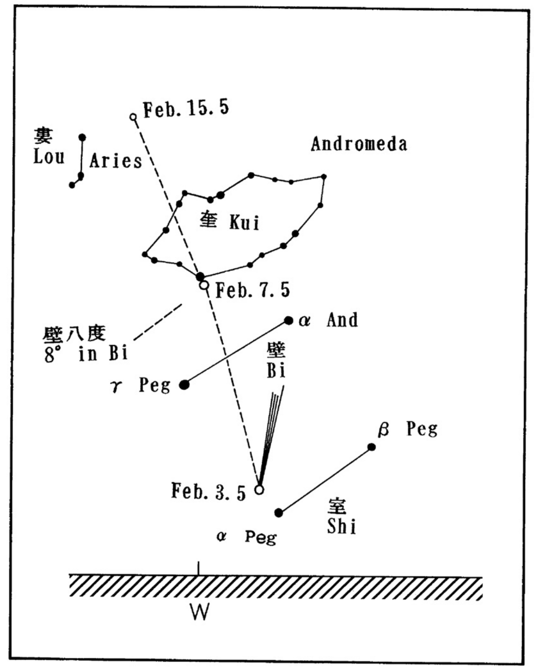

Fig. 5. (b) Calculated path of Comet 1266 during 1266 February 3 and February 15.

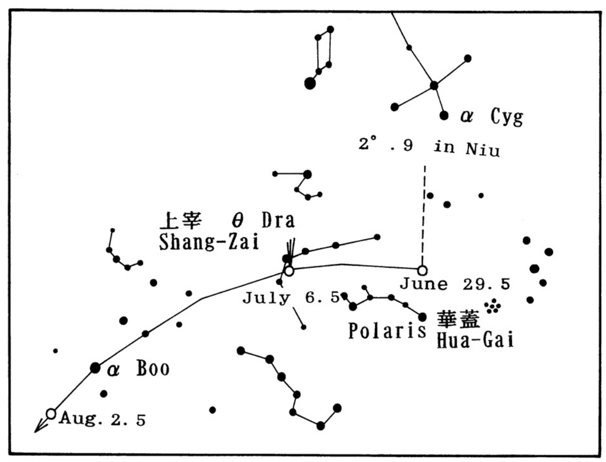

Fig. 7. Calculated path of Comet 1362 during 1362 June 29 and August 2.

Remarks: Bi ranges between $\alpha = 4^{h}28^{m}$ and $\alpha = 5^{h}35^{m}$ (equinox 2000.0).

Comet C/2002 C1 (Ikeya–Zhang) is linked with Comet C/1661 C1, and its previous perihelion passage is considered to be 1273 by S. Nakano (2002, private communication), however, Comet 1273 recorded in Chinese and Japanese histories has not been identified with Comet C/2002 C1.

No. 7

Comet 1362

Chinese On a xin-si (18) day in the sixth month of the 22nd year of the Zhi-Zheng reign-period (1362 June 29), a comet

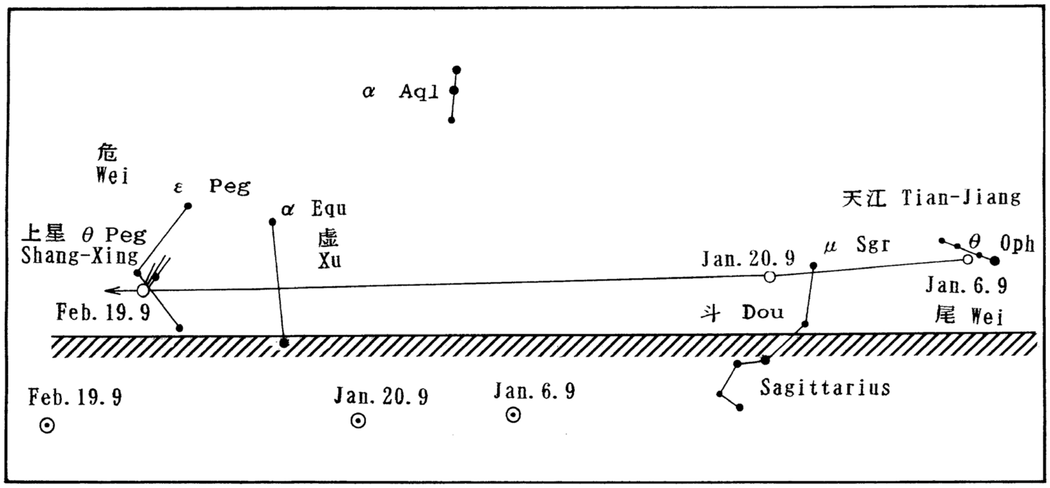

Fig. 9. Calculated path of Comet 1495 during 1495 January 6 and February 19.

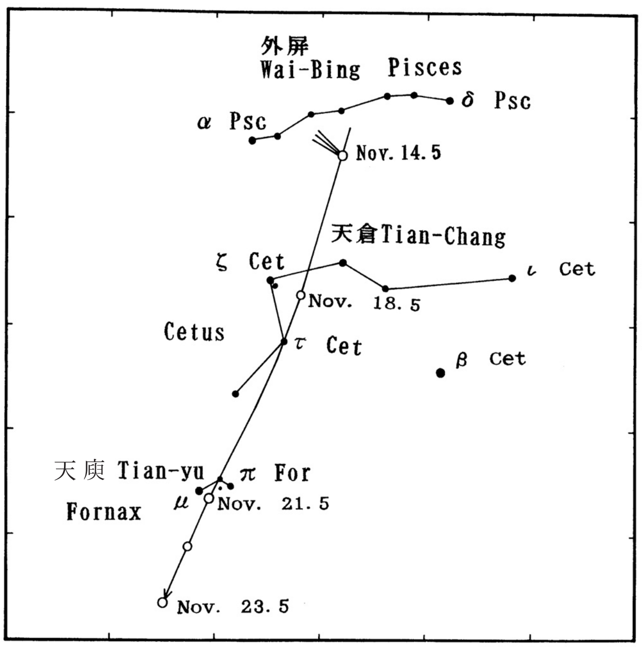

Fig. 8. Calculated path of Comet 1430 during 1430 November 14 and November 23.

appeared in the Zi-Wei Enclosure. Its observed position was at 2.9 degrees in Niu (ninth lunar mansion). It was white and its rays measured over one chi (> 1°) in length and pointed to the southeast. It moved to the southeast. On a wu-zi (25) day (1362 July 6), the rays of the comet swept Shang-Zai (θ Dra). On an yi-mao (52) day in the seventh month (1362 August 2) the comet went out of sight (Yuan Shi).

Korean On a xin-si (18) day in the sixth month of the eleventh year of Kongmin Wang (1362 June 29), a comet was seen in the Zi-Wei Yuan Enclosure below Hua-Gai. It measured about one chi during three days (Koryo-sa).

Ho (1962, p.198).

Japanese In the eighth month of the seventeenth year of the Shyohei reign-period (1362 August 21–September 18), an invocation for a comet was held at a temple (Kacho Yoryaku).

Kanda (1935, p.560); Kronk (1999, p.245).

Remarks: The right ascension at 2.°9 in Niu lunar mansion is $20^{h}25^{m}$, (equinox 2000.0).

No. 8

Comet 1430

Chinese On the night of a bing-shen (33) day in the tenth month of the fifth year of the Xuan-De reign-period (1430 November 14), a pengxing (hairy star) was seen south of Wai-Bing (Pisces). It moved to the southeast. It passed Tian-Chang (Cetus) and Tian-Yu (Fornax). After about eight days (about 1430 November 21), it went out of sight (Ming Shi Tian Wen Zhi).

Beijing Observatory (1988, p.427); Williams (1871, p.89); Ho (1962, p.201); Ho and Ang (1970, p.70); Kronk (1999, p.266).

No. 9

Comet 1495

Chinese Before sunrise, on a bing-yin (3) day in the twelfth month of the seventh year of the Hong-Zhi reign-period (1495 January 7), a guest star appeared beside Tian-Jiang (θ Oph) in Wei (sixth lunar mansion). From a geng-wu (7) day (1495 January 11) to a geng-chen (17) day (1495 January 21), it moved slowly and appeared at Dou (eighth lunar mansion). Before sunrise, on a geng-xu (47) day in the first month of the eighth year (1495 February 20), the guest star entered the Wei (12th lunar mansion) and trespassed on the Shang-Xing (θ Peg) (Ming Kao Zong Shi Lu).

Beijing Observatory (1988, p.432); Ho (1962, p.208); Ho and Ang (1970, p.74); Kronk (1999, p.292).

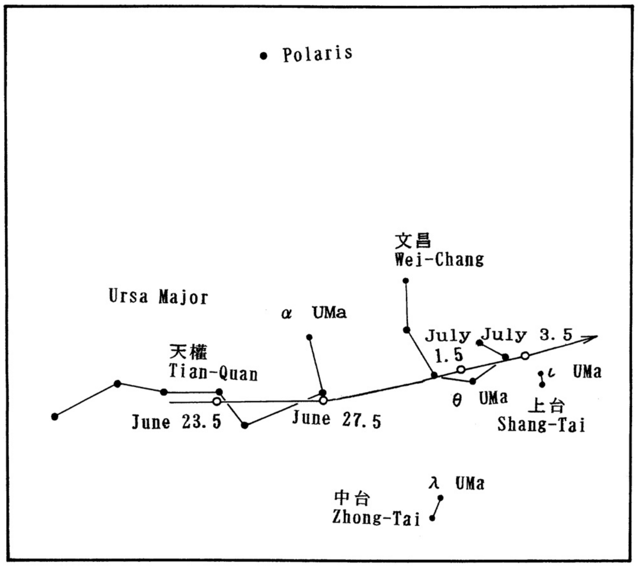

Fig. 10. Calculated path of Comet 1554 during 1554 June 23 and July 3.

Remarks: Ho (1962), Ho and Ang (1970) give an incorrect date as of March 20 for a geng-xu (47) day.

No. 10

Comet 1554

Chinese On the night of a gui-hai (60) day in the fifth month of the 33rd year of the Jia-Jing reign-period (1554 June 23), a comet appeared beside Tian-Quan (δ UMa) in Bei-Dou (the Big Dipper). On the night of a xin-wei (8) day in the sixth month (1554 July 1), it gradually moved to the northwest and trespassed on Wen-Chang. On the night of a yi-chou (2) day (1554 July 19), it went near the horizon and disappeared (Ming Shi Zong Shi Lu).

Beijing Observatory (1988, p.438); Williams (1871, p.83); Ho (1962, p.211); Ho and Ang (1970, p.76); Kronk (1999, p.308).

Korean On the night of a bing-yin (3) day in the fifth month of the ninth year of Myongjong (1554 June 26), a star like comet appeared in the Big Dipper. Its tail length was one cun ($\approx 0\overset{\circ}{.}1$). On a geng-wu (7) day in the sixth month (1554 June 30), the comet was seen between the Big Dipper and Wen-Chang. It was white in color and its tail length was about three or four cuns ($\approx 0\overset{\circ}{.}3$–$0\overset{\circ}{.}4$). At the midnight it was beside the fourth star of Wen-Chang (θ UMa). On a gui-you (10) day (1554 July 3), it was the north of Shang-Tai (ι and κ UMa). During the night of a xin-si (18) day (1554 July 11), it was not seen (Choson Wangjo Sillok).

Sekiguchi (1917, p.85); Kronk (1999, p.308).

3. Remarks and Discussion

Zhou et al. (1997) published their orbit determinations of ancient comets recorded in Chinese histories, and included our ten comets presented here. It seems strange, however, that they have no real results for those ten comets.

Table 4. Distributions of the perihelion distances of bright naked eye comets.

Perihelion distance (AU)	This study	Comets appeared before 1700 (Marsden, Williams 2001)
0.0–0.2	···	12
0.2–0.4	3	16
0.4–0.6	···	18
0.6–0.8	4	20
0.8–1.0	2	15
1.0–1.2	1	6
1.2–1.4	···	···
1.4–1.6	···	1
1.6–1.8	···	1
1.8–2.0	···	···
Total	10	88

Table 5. Distributions of the closest geocentric distance of bright naked-eye comets.

Closest geocentric distance (AU)	Number of comet
0.0–0.1	2
0.1–0.2	2
0.2–0.3	3
0.3–0.4	0
0.4–0.5	0
> 0.5	3
Total	10

The orbital elements for Comet 1491 II = C/1491 B1 (Hasegawa 1979) are to be retracted, because the records of this comet were misunderstood. The orbit for Comet 1491 I = C/1490 Y1 (Hasegawa 1979) has been replaced by that of Hind (1846) in the 12th edition of Catalogue of Cometary Orbits (Marsden, Williams 1997). However, Hasegawa's orbit was determined from six observations and more reliable than Hind's (1846), and this comet is probably the parent object of the Quadrantid meteors in January (see Kronk 1999).

Porter (1952) pointed out that the majority of bright naked-eye comets have their perihelion distances between 0.7 and 1.1 AU; table 4 gives the distributions of the perihelion distances for the ten comets studied in the present work and those for the 88 bright comets observed before 1700 (Marsden, Williams 2001). It is noted that both of the distributions of the perihelion distances in table 4 show their maxima between 0.6 and 0.8 AU.

Seven of the ten bright comets studied here have their closest geocentric distances at less than 0.3 AU. The distribution of the closest distances is given in table 5. Of course, the distribution of the small perihelion distances and close geocentric distance are characteristic of bright naked-eye comets.

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