Aberration angles of comet Bradfield 1987 XXIX plasma tail

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Abstract. A set of thirteen large-scale exposures of comet Bradfield 1987 XXIX taken between 1987 November 8 and December 25 is evaluated. The observations were obtained with the 63/85/187 cm Maksutov telescope of the Klet' Observatory. The studied plasma tail with visible plasma rays, kinks, and disconnection events on some exposures extends out of the field of the plates. Therefore, the tail must have been longer than 1.75°. The dust antitail on the best exposures is as long as 0.5°.

For this period the solar wind velocity is determined from the aberration angle of the plasma tail in the comet's environment. The determined value of the solar wind velocity is compared with the satellite data recorded near the Earth.

Key words: comet — Bradfield XXIX — plasma tail — solar wind

1. Introduction

The long-periodic comet Bradfield 1987 XXIX had, at the first observed return, a visible plasma tail. The comet was observed within 1987 August 11 and 1988 April 13. We have used a set of thirteen large-scales exposures of the comet Bradfield 1987 XXIX (Table 1) to study the solar wind in the comet's environment.

The plates were exposured between 1987 November 8 and December 26 with the Maksutov 630/850/1870 mm telescope of the Klet' Observatory, Czech Republic, on the plates ORWO ZU-21. The exposure time of the plates was between 10 and 40 minutes (see Table 1).

2. Comet motion

The long-periodic comet Bradfield 1987 XXIX moves in an elliptical orbit with an eccentricity 0.994736 in a plane with an inclination of 34.08820°. The peri-

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Table 1. Observations of comet Bradfield 1987 XXIX.

No.	Exposure		Exposure time	Observer
	1987		min	
1	November	8.71754	10	A. Mrkos
2	November	15.74236	30	A. Mrkos
3	November	25.73773	14	A. Mrkos
4	December	8.70794	20	A. Mrkos
5	December	11.72432	20	Z. Vávrová
6	December	12.73264	20	Z. Vávrová
7	December	14.70920	20	A. Mrkos
8	December	14.73264	20	Z. Vávrová
9	December	15.77419	20	A. Mrkos
10	December	22.82351	31	A. Mrkos
11	December	23.71289	30	A. Mrkos
12	December	23.74653	40	Z. Vávrová
13	December	25.70867	12	A. Mrkos

helion of the orbit is 26.22° above the ecliptic plane, 0.87 AU from the Sun. The comet passed it on 1987 November 7.27 ET (Marsden and Williams, 1992).

The relative positions of the comet, Sun, and the Earth between November 8 and December 26 1987 are shown in Figure 1. The comet was 26.95–36.71° above the ecliptic, 0.87–1.22 AU from the Sun, and 1.05–0.83 AU from the Earth. At this heliocentric distances the comet latitudes correspond to positions 0.39–0.64 AU above the ecliptic, 269.68–353.83° in the ecliptical longitude. The phase angle Sun—comet—Earth had values 50.45–82.24°, the Earth's longitude 45.76–93.37°.

Within the investigated period, i. e. 1987 November 8 and December 26, the positional parameters of the comet, Sun, and Earth varied as listed in Table 2.

3. Plasma tail

On all thirteen plates taken between November 8 and December 26, the plasma tail is well developed, and clearly visible. Its length varies from 1.00° to 1.75°, due to different exposure times and atmospheric conditions during the observational period. The plasma tail is not equally well structured on all plates, and almost on all images is "obscured" by a diffuse component of a dust tail.

There are only four pictures (November 15, December 8, and December 23) where the plasma tail is well structured, with typical plasma rays, and some kinks or condensations. On the exposure of November 15, the ion tail is very narrow, clearly separated from the dust tail, and extends up to 1.75° far from the head. In a distance about 0.25° beyond the coma, the plasma tail is somehow twisted. The better exposure is of December 8, where the tail extends out the field of the plate, so it should be longer than 1.75°. On this picture one could

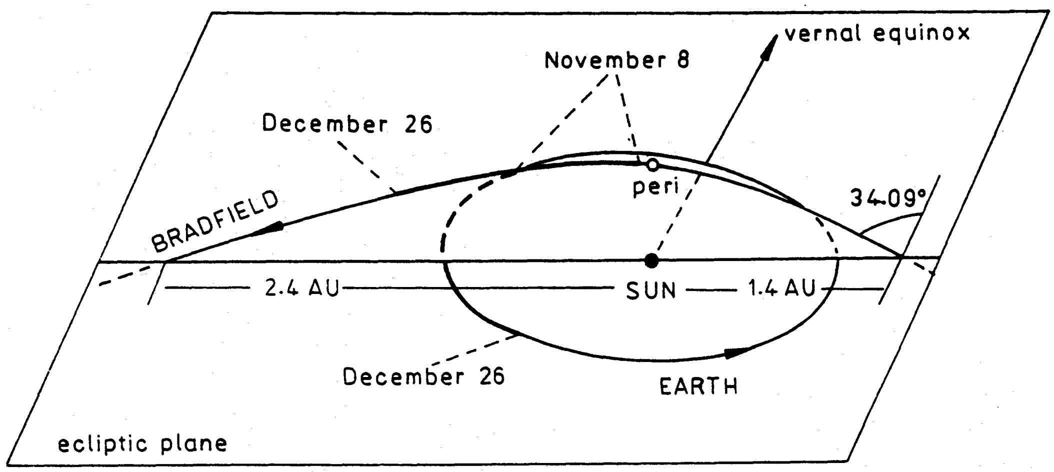

Figure 1. Relative position of comet Bradfield 1987 XXIX, the Sun, and the Earth between 1987 November 8 and December 26.

detect some indication of a disconnection event, in a distance about 0.75° beyond the head, and also several plasma rays.

The best defined ion tail is on two exposures of December 23, with its length about 1.5°, and clearly observed rays and twisted structures.

It could be noted that the dust antitail is well developed on both pictures, reaching of the length up to 0.5°. This antitail, but not so prominent, is detected also on the plates taken on December 15 and December 22. On the last exposure of December 25 the plasma tail is only 1.2° long, but it separated in two parts.

4. Solar wind and plasma tail

The deviation of an axis of the comet plasma tail from the radius vector comet—Sun, the so-called aberration angle, is due to the mutual interaction of the tail's plasma with the solar wind flow, the value of which is proportional to the wind velocity. This problem, together with the related topics, like the motion of the plasma kinks or condensations, disconnection events, and many others are discussed in several papers, e. g. Brandt (1969), Jokers and Lüst (1973), Niedner *et al.* (1978), Tarashchuk (1974), Saito *et al.* (1986a, 1986b), Watanabe *et al.* (1986, 1987), or in many lectures, presented at symposia or colloquia devoted to the cometary research.

It is impossible to figure out the solar wind velocity vector from the measurements of the tail aberration angle alone. A possibility to solve this problem in its simplified model is to assume a purely radial solar wind flow. In the first aproximation it means that the tangential component of the solar wind is zero. Knowing the radial velocity component of the solar wind one could estimate a minimum value of its tangential component. The velocity of the plasma tail ions, carried along the lines of force of the Solar and interplanetar magnetic

Table 2. Positional parameters of the comet, Sun, and Earth. Distances are in AU and angles in degrees.

Exposure 1987 Nov/Dec (UT)	8.717	8.708	14.709	22.824	25.709
Distance comet–Sun	0.869	1.039	1.099	1.189	1.223
Distance comet–Earth	1.045	0.829	0.826	0.853	0.871
Distance Earth–Sun	0.991	0.985	0.984	0.984	0.984
Distance comet–ecliptic plane	0.394	0.620	0.642	0.640	0.630
Angle Sun–Earth–comet	50.446	69.275	74.196	80.324	82.249
Angle Sun–comet–Earth	61.554	62.459	59.487	54.668	52.866
Right anomaly of comet	2.469	47.742	54.575	62.635	65.208
Ecliptical longitude of comet	269.684	319.304	332.065	348.492	353.830
Ecliptical latitude of comet	26.953	36.710	35.755	32.546	31.016
Ecliptical longitude of Earth	45.763	76.068	82.167	90.429	93.369

Table 3. Solar wind flow velocity between 1987 November 8 and December 25. Ecliptical longitude 269–354°, latitude 27–37°, heliocentric distance 1.0–0.8 AU. Designations of velocities: *r* - radial, *t* - tangencial.

No.	Date middle of exposition UT	Aberration angle	Solar wind flow velocity minimum radial		minimum tangential	
			t = 0	r = 100	r = 200	r = 500
	1987 Nov/Dec	deg	$km\ s^{-1}$	$km\ s^{-1}$	$km\ s^{-1}$	$km\ s^{-1}$
1	8.718	2.6	483	15.3−	11.3−	0.7+
2	15.742	2.3	466	13.4−	9.7−	1.3+
3	25.738	1.9	432	10.0−	7.0−	2.0+
4	8.707	2.0	226	3.9−	0.8−	8.5+
5	11.724	2.2	167	2.2−	1.1+	11.2+
6	12.733	2.4	143	1.6−	2.1+	13.0+
7	14.709	2.3	122	0.7−	2.7+	13.1+
8	14.732	2.3	121	0.7−	2.7+	13.1+
9	15.774	2.0	117	0.5−	2.5+	11.4+
10	22.824	1.2	105	2.0+	3.7+	8.5+
11	23.713	1.1	137	2.3+	3.8+	8.5+
12	23.747	1.2	131	2.4+	4.1+	9.2+
13	25.709	2.2	121	4.0+	7.1+	16.2+

field, does not correspond to the solar wind velocity, because the velocity of ions is reduced by the kinetic energy required to carry away the dust particles (Tarashchuk, 1974). Therefore, the solar wind velocities calculated from the measurements of aberration angles using the formulae of Jockers *et al.* (1972), listed in Table 3, should be considered as their minimum estimates.

The last three columns in Table 3 give the minimum value of the tangential component of the solar wind speed under the assumption that the radial velocity component is 100 $\mathrm{km\,s^{-1}}$, 200 $\mathrm{km\,s^{-1}}$, and 500 $\mathrm{km\,s^{-1}}$, respectively. As it was mentioned above, this is only the minimum value, because the deviation angle of the solar wind velocity vector from the comet's orbital plane is unknown. The tabulated values of the tangential velocity component are marked + if the aberration angle is increased by the tangential velocity component of the solar wind, and − in the opposite case. As seen from Table 2, the values of the radial velocity decrease from about 480 $\mathrm{km\,s^{-1}}$ to 100 $\mathrm{km\,s^{-1}}$ with the increasing ecliptical latitude of the comet, and moving away from the Sun. The secondary maximum of the solar wind speed 137 $\mathrm{km\,s^{-1}}$, around of December 23, deduced from the measured aberration angles, could be explained either by the instantaneous variation of the real solar wind, or more probably, by our not precise measurements of the aberration angles.

The quantities used to determine the solar wind velocity – equatorial coordinates of the Sun and the comet, ecliptical longitude and cometocentric coordinates of the Earth, the comet's orbital velocity components, equatorial spherical coordinates, and tabulated values - were calculated using our own computer programs. The coordinates of the comet were calculated using the orbital elements as determined by Kobayashi (1989). The radial direction from the Sun to the comet was determined by the method of the great circle crossing the Sun and the comet (Dobrovolskij, 1966).

To determine the aberration angle from the plates, the coordinate frame of the exposures was provided by 206 reference stars from the Smithsonian Astrophysical Observatory Star Catalogue, with due correction for their proper motion.

5. Solar wind and inteplanetary magnetic field

In the course of the investigated period, November 8 – December 26, the comet moved in the region up to 0.642 AU above the ecliptic, in ecliptical longitudes from 269° to 353°, and at heliocentric distances from 0.87 AU up to 1.2 AU. The magnetic interplanetary field parameters within this period are plotted in Figure 2. They are taken from data collected by the IMP-8 satellite (King, 1989), which operates at a distance of 30–40 Earth radii from the Earth.

Comparison of data in Table 2 with those in Figure 2 shows that there is strong correlation between the total interplanetary magnetic field magnitude (and also satellite data of the solar wind velocity) and derived radial component of the solar wind velocity within the whole observing period. But at least our measurements performed before December 11 fit the satellite data quite reasonably.

Between December 12 and December 17 we have four observations, exposures of December 12.733, 14.709, 14.733, and December 15.774. Unfortunately, we have no satellite data available for this period and it is not possible to correlate

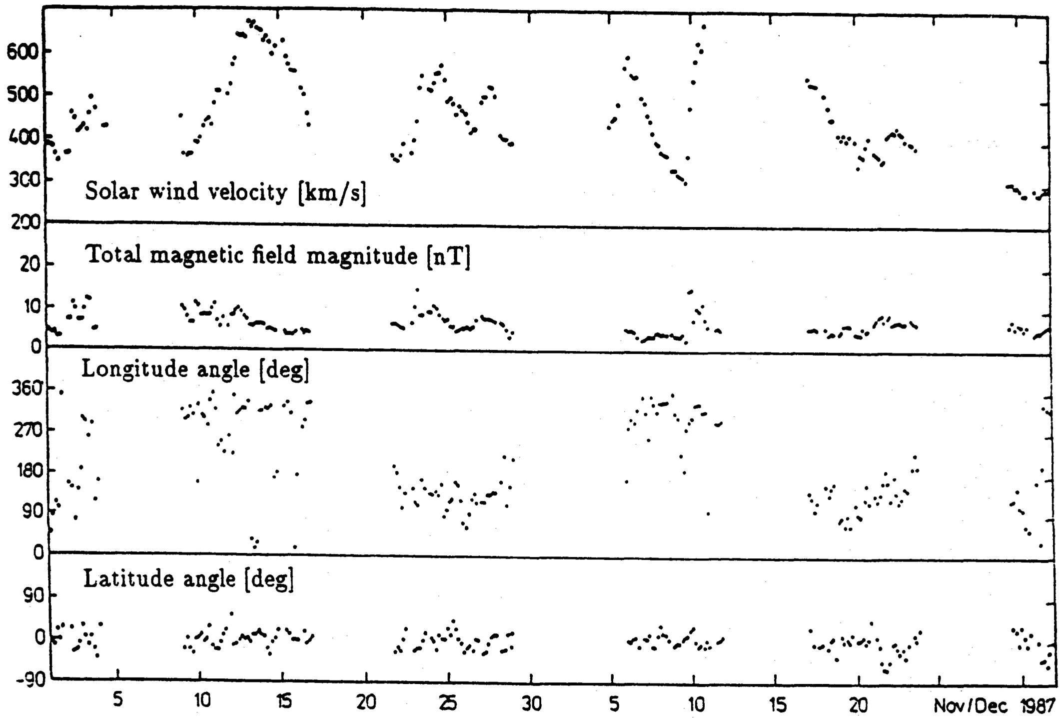

Figure 2. The satellite (IMP–8 spacecraft) solar wind and magnetic field data.

the satellite observations with our measurements. Nevertheless, at the end of our observational period one can see a certain (or slight) correlation between the satellite and our measurements, taking into account the fact that the comet was moving far above ecliptic and away from the Sun, too.

It is generally agreed that there is a strong interaction between the solar wind and the cometary plasma. Yet, the details of this coupling still remain rather obscure and are the subject of discussion (Mendis and Houpis, 1982; Mingchan and Puzhang, 1986; Saito and Oki, 1989).

6. Conclusions

All thirteen large-scale exposures of the Comet Bradfield 1987 XXIX taken between November 8 and December 26 reveal the distinct plasma tail, the length of which varied from 1.00° to 1.75° in dependence on the exposure time, and the current conditions of observation. Within this period the estimates of minimum values of the radial component of the solar wind velocity, as determined from the aberration angles of the ion tail, were in the range of 483 $km\,s^{-1}$ and 105 $km\,s^{-1}$.

The corresponding minimum values of the tangential components for the same period varied between 15.3 $km\,s^{-1}$ and 0.5 $km\,s^{-1}$, 11.3 $km\,s^{-1}$ and 0.8 $km\,s^{-1}$, and 16.2 $km\,s^{-1}$ and 0.7 $km\,s^{-1}$, under the assumption that the radial velocity component was 100 km s^{-1}, 200 km s^{-1}, and 500 km s^{-1}, respectively. These values were determined for the region 0.4–0.6 AU above the ecliptic plane, in the longitude interval 270–350°, in the distance 0.9–1.2 AU from the Sun. There are some indications (with a help of some image processing) that around November 25, the comet probably passed through a magnetic sector boundary of the interplanetary magnetic field.

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References

Brandt, J.: 1966, *Mèm. Soc. Roy. Sci. Liège* **XXII/1**, 309

Dobrovoľskij, O.V.: 1966, *Komety*, Nauka, Moskva

Jockers, K., Lüst, R., Nowak, Th.: 1972, *Astron. Astrophys.* **21**, 199

Jockers, K., Lüst, R.: 1973, *Astron. Astrophys.* **26**, 113

King, J.H.: 1989, *Interplanetary Medium Data Book — Supplement 4*, NASA, Greenbelt, Maryland

Kobayashi, T.: 1989, *Minor Planet Circ.* , No. 14903

Marsden, B.G., Williams, G.V.: 1992, *Catalogue of Cometary Orbits*, Minor Planet Center IAU, Cambridge, Massachusetts

Mendis, D.A., Houpis, H.L.F.: 1982, *Rev. Geophys. and Space Phys.* **20**, 885

Mingchan, W., Puzhang, Q.: 1986, in *Exploration of Halley's comet*, eds.: B. Battrick , E.J. Rolfe and R. Reinhard, ESA SP–250, Vol. III, Noordwijk, The Netherlands, 123

Niedner, M.B.Jr., Rothe, E.D., Brant, J.C.: 1978, *Apj* **221**, 1014

Saito, T., Oki, T.: 1989, *Proc. Res. Inst. Atmospher.* **36**, 27

Saito, T., Saito, K.: 1986a, in *Exploration of Halley's comet*, eds.: B. Battrick , E.J. Rolfe and R. Reinhard, ESA SP–250, Vol. I, Noordwijk, The Netherlands, 135

Saito, T., Yumoto, K., Hirao, K., Nakagawa, T., Saito, K.: 1986b, in *Exploration of Halley's comet*, eds.: B. Battrick , E.J. Rolfe and R. Reinhard, ESA SP–250, Vol. I, Noordwijk, The Netherlands, 129

Tarashchuk, V.P.: 1974, *Astrometriya i Astrofizika* **21**, 62

Watanabe, J., Takatou, N., Kawakami, H., Tomita, T., Kinoshita, H., Nakamura, T., Kozai, Y.: 1986, in *Exploration of Halley's comet*, eds.: B. Battrick , E.J. Rolfe and R. Reinhard, ESA SP–250, Vol. III, Noordwijk, The Netherlands, 119

Watanabe, J., Kawakami, H., Tomita, K., Takagishi, K., Kinoshita, H., Nakamura, T., Kozai, Y.: 1987, in *Symposium on the Diversity and Similarity of Comets*, eds.: E.J. Rolfe and B. Battrick, ESA SP–278, Noordwijk, The Netherlands, 657