Plasma tail of comet P/Brorsen-Metcalf 1989 X

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Abstract. A set of four large-scale exposures of comet P/Brorsen-Metcalf 1989 X between 1989 August 29 and September 3 is evaluated. The observations were obtained with the 40/300 cm Zeiss double astrograph of the International Latitude Station, Kitab, Uzbek Republic. The studied plasma tail is narrow and longer than 3° with visible plasma kinks, rays, and disconnection events.

For this period the solar wind velocity is determined from the aberration angle of the plasma tail. Its radial component had about 210 km/s, tangential component 0.5 km/s, in the comet's environment: 0.5 AU above the ecliptic plane at a heliocentric distance of 0.6 AU, in the direction of 29–49° of the ecliptical longitude.

The three plasma kinks visible on the 1989 August 29 exposures moved from the nucleus at a radial velocity of about 17 km/s and a tangential velocity of about 5 km/s.

Key words: comets – solar wind

1. Introduction

Periodic comet P/Brorsen-Metcalf had, at the last observed return, a visible plasma tail. We have used a set of four large scale exposures of comet P/Brorsen-Metcalf 1989 X (Table 1) to study of the solar wind in the comet's environment, and to determine the motion of the plasma kinks in the tail relative to the comet's nucleus.

The plates were exposed between 1989 August 29 and September 3 with the 40/300 cm Zeiss double astrograph of the International Latitude Station, Kitab, Uzbek Republic. The exposure time of the plate of August 29.029 was twenty

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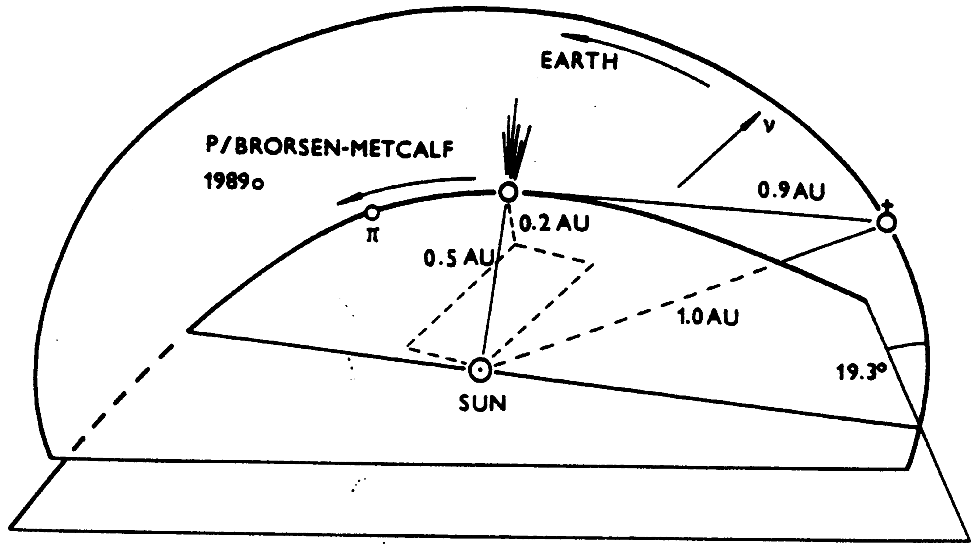

Figure 1. Relative position of comet P/Brorsen-Metcalf 1989 X, the Sun, and the Earth on 1989 August 31.

minutes, of August 29.989 twelve minutes, of August 31.979 thirteen minutes, and of September 3.993 thirty-two minutes.

2. Comet motion

Comet P/Brorsen-Metcalf moves in an elliptical orbit with a large eccentricity in a plane with an inclination of 19.33°. The perihelion of the orbit is 14.77° above the ecliptic plane, 0.48 AU from the Sun. The comet passed it on 1989 September 11.94 ET, nine days after the investigated period.

The relative positions of the comet, Sun, and the Earth on August 31 are shown in Figure 1. The comet was 19.32° above the ecliptic, 0.55 AU from the Sun, and 0.90 AU from the Earth. At this heliocentric distance the comet's latitude corresponds to a position 0.18 AU above the ecliptic, 38.59° in the ecliptical longitude. The phase angle Sun–comet–Earth was 77.85°, the Earth's longitude 338.52°.

Within the investigated period, i. e. 1989 August 29 to September 3, the positional parameters of the comet, Sun, and Earth varied as listed in Table 1.

Table 1. Positional parameters of the comet, Sun, and Earth.

Exposure 1989 Aug/Sep	(UT)	29.029	29.989	31.979	3.993
Distance comet–Sun	(AU)	0.584	0.572	0.547	0.516
Distance comet–Earth	(AU)	0.841	0.859	0.898	0.961
Distance Earth–Sun	(AU)	1.010	1.010	1.009	1.009
Distance comet–ecliptic plane	(AU)	0.190	0.187	0.181	0.169
Angle Sun–Earth–comet	(deg)	39.241	38.262	32.700	30.777
Angle Sun–comet–Earth	(deg)	88.364	97.094	77.847	74.415
Right anomaly of comet	(deg)	−50.644	−47.892	−41.796	−31.560
Ecliptical longitude of comet	(deg)	29.231	32.138	38.593	49.437
Ecliptical latitude of comet	(deg)	18.962	19.123	19.317	19.131
Ecliptical longitude of Earth	(deg)	335.670	336.597	338.523	341.443

3. Plasma tail

The comet was recovered by Helin (1989) at Palomar on 1989 July 4.38 UT as an object of the 15th magnitude with a very symmetric coma, and a slight hint of a tail. One day earlier two very faint pre-recovery images were obtained by Jekabsons (1989) at Perth. On July 13.46 UT a pronounced ion tail was visible, as was a bright nucleus with a well-developed coma (Fink et al., 1989). The total visual magnitude on July 14.44 UT was 8.1 (Morris, 1989a). During the next two months the lenght of the plasma tail increased. The plasma tail on our images between August 29 and September 3 extends out of the field of the plates. Therefore, the tail must have been longer than 3°. The tail was apparently separated into two parts. On the pictures it is possible to see the formation of plasma rays. There are moderate but bright kinks and disturbances.

At the same time a similar lenght of the tail was observed by Keitch (1989) and Keen (1989). On September 4.50 UT the plasma tail was 8° long (Morris, 1989b). This was the longest tail observed at this return of the comet. On September 8.51 UT the tail was only 6° long (Morris, 1989c), and on September 13.51 UT it was very faint and 3° long (Morris, 1989d).

4. Solar wind and plasma tail

The interaction of the tail's plasma with the solar wind causes a deviation of the plasma tail from the Sun–comet radius vector. This so-called aberration angle of the plasma tail has been used to determine of the velocity of the solar wind for the comet's region.

The measured aberration angle between the projection of the Sun–comet radius-vector and the axis of the comet's plasma tail are listed in Table 2. The other columns contain the minimum values of the velocity components of the solar wind. They were calculated from the aberration angles using the formulae of Jockers *et al.* (1972). In this case, the Sun–comet and comet–Earth vectors,

Table 2. Solar wind flow velocity between 1989 August 29 and September 3.

No.	Date middle of exposition UT	Aberration angle	Solar wind flow velocity minimum radial tangential = 0	minimum tangential radial = 200	radial = 300
	1989 Aug/Sep	deg	km/s	km/s	km/s
1	29.029	2.5	212	0.5−	3.8+
2	29.989	2.6	209	0.5−	4.1+
3	31.979	2.7	211	0.5−	4.2+
4	3.993	2.8	215	0.7−	4.1+

Ecliptical longitude 29–49°, latitude 19°, heliocentric distance 0.5 AU.

and the tail axis form a left-handed vectorial system, which was adopted in the formulae.

It is essentially impossible to deduce the solar wind velocity vector from the measurements of the tail aberration angle alone. Therefore, we first assumed that the tangential component of the solar wind velocity was zero. The velocity of the plasma tail ions, carried along by the magnetic field of the solar wind, does not correspond to the solar wind velocity. The velocity of ions is reduced by the kinetic energy required to carry away the dust particles (Tarashchuk, 1974). Therefore, the solar wind velocities listed in Table 2 must be considered as minimum estimates.

The last two columns of Table 2 give the minimum value of the tangential component of the solar wind speed under the assumption that the radial velocity component is 200 km/s and 300 km/s. 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.

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 the tabulated values — were calculated using our own computer programs and a Hewlett-Packard 9830 computer. The coordinates of the comet were calculated using the orbital elements as determined by Yeomans (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 (Dobrovoľskij, 1966).

To determine the aberration angle from the plates, the coordinate frame of the exposures was provided by 137 reference stars from the Smithsonian Astrophysical Observatory Star Catalogue, with due correction for their proper motion.

5. Motion and velocity of kinks

On the two exposures of 1989 August 29 it was possible to locate reliably three plasma details. Their radial and tangential velocities relative to the comet's nucleus were determined from one 23.03 h time interval. All plasma kinks moved from the nucleus with radial velocities of about 17 km/s and with tangential velocities of about 5 km/s (Table 3).

Table 3. Radial and tangential velocities of kinks.

	1989 August 29.029		29.989		$\Delta T = 23.02488h$	
Kink	x	y	x	y	V_r	V_t
	10^6 km	10^5 km	10^6 km	10^5 km	km/s	km/s
1	1.547	0.495	2.887	4.466	16	5
2	1.742	2.226	3.125	6.448	17	5
3	1.861	5.693	3.344	9.675	18	5

The radial V_r and tangential V_t velocity components of the kinks were determined from their cometocentric rectangular coordinates x and y in the comet's orbital plane (Table 3). The x axis points in the Sun–comet direction, the y axis is perpendiculars to x, oriented opposite to the comet's motion. These coordinates were calculated from the cometocentric rectangular coordinates with the same axes orientation in the plate's plane using Stumpff's formulae (1957).

6. Conclusions

Between 1989 August 29 and September 3 disconnection events, kinks and rays in the plasma tail of comet P/Brorsen-Metcalf were observed. The plasma tail was narrow and its length, as recorded on our exposures, was more than 3°.

Within this period the minimum value of the radial component of the solar wind velocity, as determined from the aberration angle of the plasma tail was about 210 km/s. During the same period the minimum value of its tangential component was about 0.5 km/s, or 4.0 km/s, under the assumption that the radial velocity component was 200 km/s and 300 km/s, respectively. These values of the solar wind velocity were determined for the region around 0.2 AU above the ecliptic plane, 29° to 49° in longitude, 0.5 AU from the Sun.

The positions of the three plasma kinks were determined on the two exposures of August 29. They moved from the nucleus at a radial velocity of about 17 km/s, and a tangential velocity of about 5 km/s.

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