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ABSTRACT. A set of seventeen large-scale exposures of comet Halley between 1986 April 27 and May 10 is evaluated. The observations were obtained with the 30/150 cm Zeiss astrograph of the Skalnaté Pleso Observatory. The solar wind velocity for this period was determined from the aberration angle of the plasma tail. Its radial component had a minimum value of 60-22 km/s in the comet´s environment: 0.3 AU below the ecliptic plane at a heliocentric distance of 1.7 AU, to the direction 170^{0} of ecliptical longitude. There is a strong correlation between the solar wind velocity and the total interplanetary magnetic field magnitude. The radial velocity component of the solar wind decreased with increasing magnitude of the interplanetary magnetic field.

1. INTRODUCTION

Comet P/Halley ranks among comets which were observed to have a bright plasma tail. During the 1986 apparition a number of disconnection events were observed in its plasma tail, especially near the perihelion. The exposures, evaluated in this paper, are from the middle of the observing period and were taken at European latitudes, after the comet´s perihelion passage.

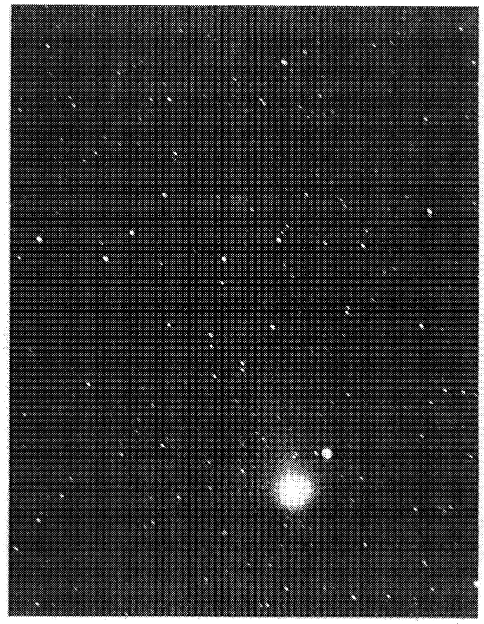

Fig. 1. Comet Halley on May 3.844.

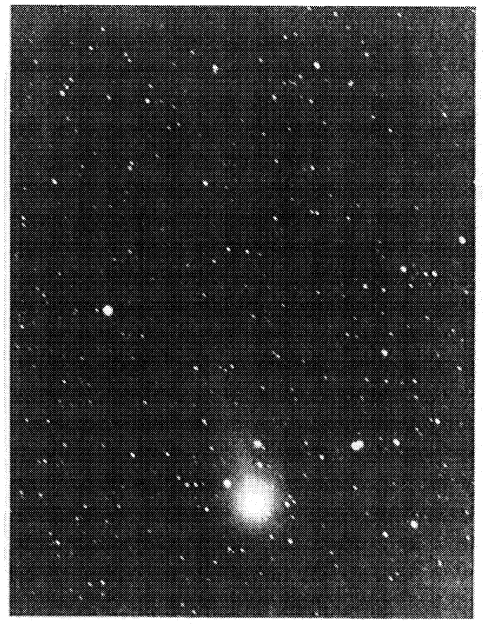

Fig. 2. Comet Halley on May 4.827.

The comet´s brightnees had a decreasing tendency and observing conditions deteriorated from day to day. The plasma tail on the exposures does not show moving plasma kinks or disconnection events. But it is still sufficiently bright and long enough to study its interaction with the interplanetary magnetic field and solar wind flow.

All the seventeen plates investigated were taken between 1986 April 27 and May 10 with the 30/150 cm Zeiss astrograph of the Skalnaté Pleso Observatory of the Astronomical Institute of the Slovak Academy od Sciences.

2. PLASMA TAIL

The investigated plates are pairs of 20-minute exposures from eight nights, and one exposure from one night (Table 1) with the same exposure time. The time interval between exposures on the same night does not exceed one hour.

The plasma tail on these exposures is clearly visible, narrow and up to 2^{0} long. There are no plasma kinks. Disconnection events are missing, too. The coma is the dominant part of these pictures. In spite of the one-hour interval between the exposures on the same night, no motion of the plasma tail drab structures is visible. The tail is diffuse with a little contrast relative to its surroundings.

No better results were obtained on magnified copies of the plates on a gradation film. The reproductions did not provide more than a general view of the tail. They are only suitable for the determination of the plasma tail axis.

3. COMET MOTION GEOMETRY

Comet Halley moves in a plane inclined at 162.24° to the ecliptic plane at ecliptical longitude 58.14°. The perihelion was at 16.45° at a heliocentric distance of 0.59 AU, 0.17 AU north of the ecliptic. The comet passed it on 1986 February 9.46 UT.

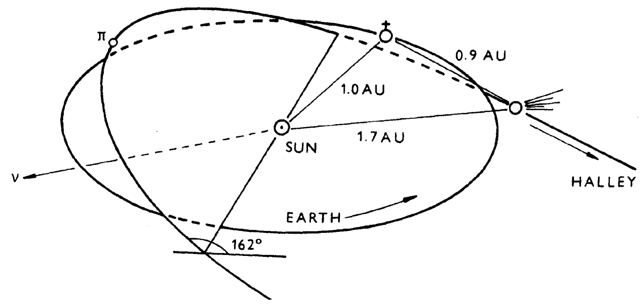

Fig. 3. Relative position of comet Halley, the Sun, and the Earth on May 3.

The relative position of the comet, the Sun, and the Earth on 1986 may 3, i. e. in the middle of the investigated period, is shown in Figure 3. The comet was 11.45° under the ecliptic, 1.67 AU from the Sun and 0.89 AU from the Earth. At this heliocentric distance the comet´s latitude corresponds to position 0.33 AU below the ecliptic, at ecliptical longitude 169.53°. The phase angle Sun-comet--Earth was 29.99°, the Earth´s longitude 223.14°.

Within the investigated period, i. e. 1986 April 27 to May 10, the values of these parameters varied as follows: the comet´s heliocentric distance from 1.59 AU to 1.78 AU, the comet´s geocentric distance from 1.71 AU to 1.11 AU, the comet´s distance south of the ecliptic from 0.30 AU to 0.37 AU, i. e. from -10.87° to -12.02°, the phase angle from 27.12° to 31.31°, the comet´s longitude from 176.81° to 164.83°, and the Earth´s longitude from 217.26° to 229.88°.

4. INTERACTION OF THE PLASMA TAIL WITH THE SOLAR WIND

The possibility to determine the velocity of the solar wind from the deviation of the plasma tail axis from the comet´s radius-vector to the Sun has been discussed in many papers, e. g. Brandt (1969), Jockers and Lüst (1973), Niedner et al. (1978), Tarashchuk (1974). This so-called aberration angle of the plasma tail originates from the interaction of the tail´s plasma with the solar wind flow.

The measured aberration angles between the projection of the Sun-comet radius-vector and the axis of the comet´s plasma tail are listed in Table 1. 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, 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

Table 1. Solar wind flow velocity between 1986 April 27 and May 10.

No.	Date middle of exposition UT	Aberration angle	Solar wind flow velocity		
			minimum radial	minimum tangential	
			tangential = 0	radial = 100	radial = 200
	1986 April/May	deg	km/s	km/s	km/s
1	27.830	11.5	60	3.7	12.9
2	27.889	11.4	60	3.7	12.9
3	1.846	11.8	33	6.8	16.9
4	1.879	11.6	34	6.6	16.6
5	2.824	11.5	30	7.0	17.0
6	2.865	11.3	31	6.8	16.6
7	3.844	11.3	27	7.3	17.2
8	3.885	11.1	27	7.1	16.8
9	4.827	10.5	26	6.9	16.2
10	4.868	10.6	25	7.0	16.4
11	5.835	10.6	22	7.4	16.8
12	5.875	10.4	22	7.2	16.5
13	6.831	8.5	25	5.7	13.3
14	6.870	8.4	26	5.6	13.2
15	7.833	6.8	29	4.4	10.5
16	7.863	6.7	29	4.3	10.3
17	10.845	4.5	29	2.9	7.0

Ecliptical longitude 170^{o}, latitude -12^{o}, heliocentric distance 1.7 AU.

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 1 must be considered as minimu estimates.

The last two columns of Table 1 give the minimum value of the tangential component of the solar wind speed under the assumption that the radial velocity component is 100 km/s and 200 km/s, respectively. 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 quantities used to determine the solar wind velocity - equatorial coordinates of the Sun and the comet, ecliptical longutude 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 comets were calculated using the orbital elements as determined by Landgraf (1986). The radial direction from the Sun to the comet was determined by the method of 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 160 reference stars from the Smithsonian Astrophysical Observatory Star Catalogue, with due correction for their proper motion.

5. SOLAR WIND AND INTERPLANETARY MAGNETIC FIELD

On 1986 April 27 the computed minimum value of the radial solar wind velocity component was 60 km/s (Table 1). Three days later, on May 1, this velocity component dropped to 33 km/s. Within the next four days, from May 2 to May 5, its value decreased from 30 km/s to 22 km/s. On May 6 the value increased to 25-26 km/s, and on the next day to 29 km/s. The same value was also observed on May 10.

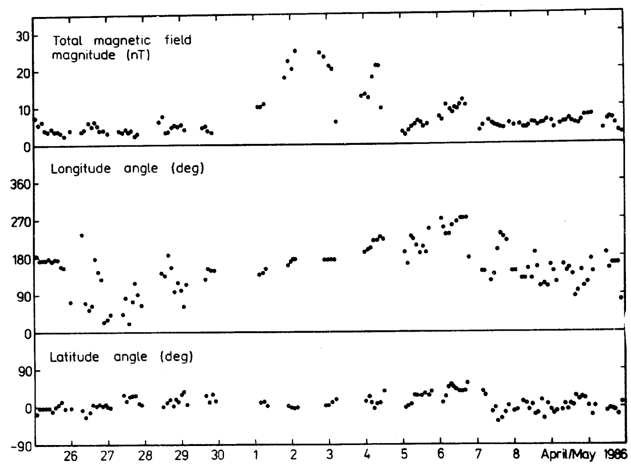

Fig. 4. The satellite interplanetary magnetic field data.

Within this investigated period, the comet moved in a region 0.3 AU below the ecliptic, in ecliptical longitude direction 170^{o}, at heliocentric distance 1.7 AU.

The magnetic interplanetary field parameters within this time interval are plotted in Figure 4. They are from the IMP-8 satellite (Lepping, 1989), which operates at a distance of 30-40 Earth radii from the Earth.

The comparison of these satellite data with our computed values of the solar wind velocity shows a very strong correlation between the total interplanetary magnetic field magnitude and the radial component of the solar wind velocity. On May 1.8, the interplanetary magnetic field magnitude jumped from 10 nT to 18 nT, and on May 1.9 to 20 nT. Between April 27.9 and May 1.8 (unfortunately, we have no observations from April 30), the value of the radial velocity component of the solar wind decreased from 60 km/s to 30 km/s. During the period May 2 to May 5, when the magnetic field magnitude had the maximum value of 30 nT, the radial velocity component of the solar wind decreased from 30 km/s to 22 km/s.

On May 6 the magnetic field magnitude dropped to 10 nT and the radial velocity component increased to 26 km/s. During the following days, May 7 to May 10, the dependence between the magnetic field magnitude and the solar wind velocity was the same. The magnetic field decreased to 5 nT and the radial velocity component of the solar wind increased to 29 km/s.

The negative correlation between the interplanetary magnetic field magnitude and the solar wind velocity was not observed in comet Bennett 1970 II (Zvolánková et al., 1987), and comet West 1976 VI (Zvolánková and Pittich, 1990). The tail evolution in comet Bennett 1970 II observed on March 31, 1970 correlated with an interplanetary shock wave (Jockers and Lüst, 1973), and a very similar cometary event on April 4, 1970, however, does not appear to be correlated to any corresponding solar wind event (Burlaga et al., 1973).

There is general agreement 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

Between 1986 April 27 and May 10 no disconnection events, kinks or rays in the plasma tail of comet Halley were observed. The plasma tail was narrow and its length, as recorded on our exposures, was about 2°.

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, varied between 60 km/s to 22 km/s. During the same period the minimum value of its tangential component varied between 7.4 km/s and 2.9 km/s, or 17.2 km/s and 7.0 km/s, under the assumption that the radial velocity component was 100 km/s and 200 km/s, respectively. These values of the solar wind velocity were determined for the region around 0.3 AU below the ecliptical plane, in the longitude direction 170°, 1.7 AU from the Sun.

There is a very strong negative correlation between the interplanetary magnetic field magnitude and the solar wind velocity: an increase of the magnetic field magnitude is associated with a decrease of the solar wind velocity.

REFERENCES

Brandt, J.C.: 1969, in Nature et Origine des Comètes., Mém. Soc. Roy. Sci. Liège (Ed. P. Swings), 309.

Burlaga, L.F., Rahe, J., Donn, B., Neugebauer, M.: 1973, Solar Phys. **30**, 211.

Dobrovol'skij, O.V.: 1966, in Komety, Nauka, Moskva, p. 31.

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

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

Landgraf, W.: 1986, Minor Planet Circ. IAU 10634.

Lepping, R.P.: 1989, private communication.

Mendis, D.A., Houpis, H.L.F.: 1982, Rev. Geophys. and Space Phys. **20**, 4, 885.

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

Saito, T., Oki T.: 1989, Proc. Res. Inst. Atmospher. **36**, 2, 27.

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

Zvolánková, J., Kubáček, D., Pittich, E.M.: 1987, in Interplanetary Matter (Eds. Z. Ceplecha, P. Pecina), Publ. Astron. Inst. Czechoslov. 87.

Zvolánková, J., Pittich, E.M.: 1990, in Asteroids Comets Meteors III (Eds. C.-I. Lagerkvist, H. Rickman, B.A. Lindblad, M. Lindgren), Uppsala, 479.