LIFETIME OF METEOR STREAMS ASSOCIATED WITH COMET HALLEY

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ABSTRACT. Critical examination of the orbital parameters of particles ejected from comet Halley rejects the low age hypotheses for meteor showers associ- ated with the comet. The diffusion of the orbits of large particles is too slow for explaining the observed structural features of the stream. The mass-loss process as derived from space observations compared with the mass of the stream of particles deduced from flux data lead to comet lifetimes of the order of 10^5 years.

1. INTRODUCTION

After the perihelion passage of Halley's comet in 1986 series of articles occurred discussing the past orbital history of this comet and its meteor streams. Weissman (1987) has concluded in agreement with Hajduk (1985) and Hughes (1985) that the age of the comet in the inner solar system can be placed between 1800 and 2500 revolutions ago. Olsson-Steel (1987) studying the probability of the encounter of the comet with Jupiter came to similar conclusion that there is less than 50 % chance that during 2×10^5 years there have been no close planetary encounters which have substantially altered the orbit of the comet. On the other hand McIntosh and Jones (1988) and Jones et al. (1989) modelling the orbital motion of test particles suggest that structural features observed in meteor streams associated with comet Halley may be explained as a consequence of particle diffusion in much shorter time corresponding to about 300 revolutions. Carusi et al. (1987) analysing Halley type comets in general, indicate these active lifetimes as mostly longer than 300 revolutions. For P/Halley they do not exclude capture by Jupiter 150 revolutions ago. Numerical simulations by Chirikov and Vecheslavov (1989) on the other hand show that the sojourn time of comet Halley within the solar system crucially depends on weak nongravitational forces acting upon the comet near the Sun and that it may reach values of 10^5 revolutions or 10^7 years. The present paper, based on the mass-loss rates determined by spaceprobes and on the derived parameters of the comet and its stream sets limits for the possible orbital and physical history of the comet and of the stream.

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2. STREAM STRUCTURES AS AGEING CRITERION

The cloud of particles released from a comet during its perihelion passage creates, in time, a narrow band along the comet orbit. The non-homogeneous initial velocity distribution of ejecta, the spectrum of perturbations along the orbit with rapid motion of nodes, ($\Delta\Omega$ = 1 deg/rev) can create concentrations of particle orbits in a broad belt. McIntosh and Jones (1988) and Jones et al. (1989) suggest that stream filaments are caused by relatively fresh ejecta, requiring only tens of revolutions. Similarly one may conclude that many such filaments should exist within the whole broad stream as a consequence of the variation of orbital parameters of the comet. If we suppose that the observed maxima in meteor rates correspond to the increased particle flux within such filaments, then the existence of these features along the broad interval of solar longitudes, especially larger than 209°, 47° in both showers respectively, cannot be explained by ejecta from the present libration cycle of the comet orbit, starting with $\omega = 47°$, or $\Omega = -18°$ respectively, as defined by Kozai (1979): Firstly, because the nodes of the comet orbit are too far from the mentioned positions on the Earth's orbit, and secondly, because the ejection velocities, considered in paper by McIntosh and Jones (1988) are overestimated for a given mass. They are based on Whipple's formula (Whipple 1951) but contradict to numerous observations (Hajduk and Hajduková 1989). However, it does mean that the observed activity peaks within the showers may well be caused by the superposition of short-term and long-term processes of the spread ejecta. This also explains the gradual shifts in solar longitude of sec-ondary peaks in consecutive returns of the shower and the relatively smooth average activity from superposed returns. We can conclude, therefore, that filamentary stream structure does not necessarily correspond to a young age. The main criterion of ageing remains the total width of the stream (not to be confused with the shower width in solar longitude, as it depends on the part of the stream intersecting Earth's orbit), which can be used as a measure for the slow gradual orbital diffusion process of the particles supplied in the series of perihelion passages of the comet. The width of the P/Halley streams, extending over 14 degrees in solar longitude, with observable particle masses well over 10^{-3} kg requires at least a few libration cycles of the comet, which implies that the age of the stream is of the order of 10^{3} revolutions. The age of the parent body may be determined in different ways. Hajduk (1985) and Hughes (1985) obtained the same age for P/Halley from different parameters, although both took into account the comet's mass production rate and its change with time. However, as shown by Kresák (1985) and Hughes (1988), both the time scale and irregularity of the systemat-ic decrease of comet brightness and the instrumental and selection ef- fects involved make it difficult to determine the long-term smooth de- pendence of the comet's mass production on the decreasing comet's size.

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3. COMETARY DUST-LOSS RATE AND THE PARTICLE FLUX WITHIN THE STREAM AS AGEING CRITERIA

On the basis of data from space probes and ground based observations we have constructed, in Figure 1, limits for different possibilities of the evolution of the comet and its stream of particles. The total mass-loss rate of the comet from different spaceborne experiments give a mean value of about 1.5×10^{11} kg in the last apparition (Whipple 1986). Adopting the critical remarks to the analyses of the gas/dust ratios with the substantial contribution of large dust particles (Crifo 1987, Hajduk 1987) the mass of particles forming the stream does not differ substantially from the mass-loss ratio. The mass-loss process of the comet is, of course, changing considerably with the comet's age. When we postulate that the mass production of the comet changes proportionally to its surface $(R_o/R)^2$ we obtain the dependence of the mass-loss on the number of revolutions. In Figure 1 is the mass-loss curve of cometary dust ΔM_{cd} constructed for Kozai's cycles (Kozai 1979)

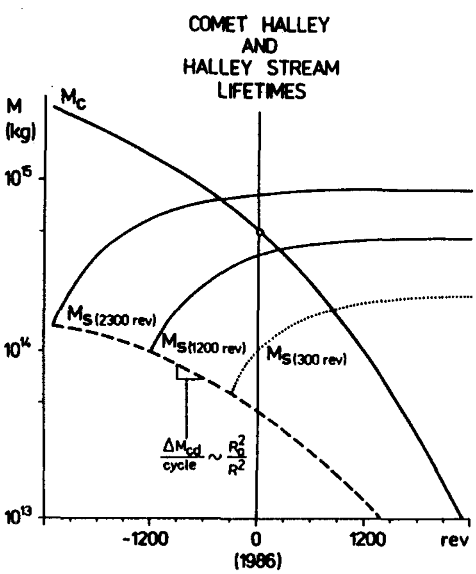

Figure 1.
Evolutionary diagram for the mass of the comet (M) and its stream (M) for different capture times. Dotted curve corresponds to the mass-loss of cometary dust in 300 revolution cycles.

of 300 revolutions. In similar way is expressed the change of the mass of the comet. The present mass is uncertain due to very different views concerning the density of the nucleus. We take here the mass of the nucleus M = 5×10^{14} kg. The same value was derived from meteor flux data (Hajduk 1982) for the present mass of the whole Halley stream. The mass of the stream M depends, naturally, on the time of the beginning of the stream formation. The M curves in Figure 1 show the mass cumulated in the stream from the beginnings of this process 2300, 1200 and 300 revolutions ago respectively. Because of some uncertainty in the derived values we can slightly shift these evolutionary curves; however, the shift of the beginning of the stream forming process (which is equivalent to the time of the capture of the comet in the inner solar system) over 2300 revolutions or below 1200 revolutions appears problematic, as unprobably high or unprobably low values of the particle flux and mass-loss rates would be required. This argument, in connection with that one, following from the formation of the total width of the stream, makes the statements like "Halley's comet is quite young" (Maddox 1989) more than questionable.

REFERENCES

Carusi, A., L. Kresák, E. Perozzi, and G.B. Valsecchi (1987). Long-term resonances and orbital evolution of Halley-type comets. 10th Europ. Reg. Astron. Meeting 2, 29-32.

Chirikov, B.V. and V.V. Vecheslavov (1989). Chaotic dynamics of comet Halley. Astron. Astrophys. 221, 146-154.

Crifo, J.F. (1987). Are cometary dust mass loss rates deduced from optical emissions reliable? 10th Europ. Reg. Astron. Meeting 2, 59-66.

Hajduk, A. (1982). The total mass and structure of the meteor stream associated with comet Halley. Sun and Planetary System (eds. W. Fricke and G. Teleki), D. Reidel; 335-336.

Hajduk, A. (1985). The past orbit of comet Halley and its meteor stream. IAU Coll. No. 83, 399-404, Reidel, Dordrecht.

Hajduk, A. (1987). Dust production of comet Halley with account of large particles contribution. 10th Europ. Reg. Astron. Meeting 2, 177-178.

Hajduk, A. and M. Hajduková (1989). From the formation of meteor streams up to their decay. Asteroids, Comets, Meteors III , Uppsala Univ., pp. 531-534.

Hughes, D.W. (1985). The size, mass, mass-loss and age of Halley's comet. Mon. Not. R. Astron. Soc. 213, 103-109.

Hughes, D.W. (1988). Cometary magnitude distribution and the ratio between the numbers of long- and short-period comets. Icarus 73, 149-162.

Jones, J., B.A. McIntosh and R.L. Hawkes (1989). Mon. Not. R. Astron. Soc. 238, 179- .

Kozai, Y. (1979). Secular perturbations of asteroids and comets. In: Dynamic of the Solar System, IAU Symp. No. 81, 231-237, Reidel, Dordrecht..

Kresák, L. (1985). The aging and lifetimes of comets. In: Dynamics of Comets: Their Origin and Evolution, IAU Coll. No. 83, 279-302, Reidel, Dordrecht.

Maddox, J. (1989). Halley's comet is quite young. Nature 339, 95.

McIntosh, B.A. and J. Jones (1988). The Halley comet meteor stream. Mon. Not. R. Astron. Soc. 235, 673-694.

Olsson-Steel, D. (1987). The dynamical lifetime of comet P/Halley. Astron. Astrophys. 187, 909-912.

Weissman, P.R. (1987). How typical is Halley's comet? ESA SP-278, 31-36.

Whipple, F.L. (1951). A comet model. Astrophys. J. 113, 464.

Whipple, F.L. (1986). The cometary nucleus: current concepts. ESA SP-250, II, 281-288.