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PARTICLES FROM COMET KOHOUTEK DETECTED BY THE MICROMETEOROID EXPERIMENT ON HEOS 2

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INTRODUCTION

The HEOS 2 satellite was launched into a highly eccentric orbit around the earth on January 31, 1972 and re-entered the earth's atmosphere after a successful mission on August 2, 1974. Due to the orbit (apogee: 240 000 km, perigee: 300 - 5000 km) the satellite spent most of the time in the interplanetary region where the influence of the earth's gravitation field is negligible with regard to its effect on interplanetary dust particles.

The micrometeoroid experiment on board measured the mass and the speed of dust particles by the plasma produced during their impact on the sensor. The field of view was a cone with a semi-angle of 60^o. The detector was mounted with the axis of symmetry parallel to the spin axis of the spacecraft. By an active reorientation system the viewing direction of the detector could be turned in any direction perpendicular to the earth-sun line. A detailed description of the detector has been given earlier (Dietzel et al., 1973) (Hoffmann et al., 1975).

About 54 days before the end of the mission the earth and hence the satellite passed through the orbital plane of comet Kohoutek. Prior to this event a study of the orbital mechanics of the earth, the comet and its dust showed that it should be possible within the given attitude constraints of the spacecraft to encounter dust released from the comet.

Particles, ejected from a comet which moves on a parabolic orbit, can be detected by an earth orbiting satellite only during the transit of the earth through the orbital plane of the comet, provided that the comet's node is on or within the earth orbit. In the latter case merely particles with orbits further outwards are able to encounter the earth. This applies to particles subject to the repulsive force of radiation pressure after being released from the comet nucleus. With β denoting the ratio of the force of radiation pressure to that of gravity, particles with an appropriate $\beta > 0$ can encounter the earth orbit. Due to the radiation pressure the particles lag behind the comet and can only be detected if the comet passes its node before the transit of the earth through the orbital plane of the comet. Thus, in principle, solely particles with a specific value of $\beta = \beta_o$ and a specific heliocentric release distance $r_R = r_{Ro}$ are able to encounter the earth.

During the emission process the outstreaming gas from the comet nucleus adds a velocity distribution to the initial speed of the particles given by the comet's speed at the release time. This effect will permit particles from a certain range of heliocentric distances around r_{Ro} and with values of β around β_o to encounter the earth. As demonstrated in figure 1, in the case of comet Kohoutek,

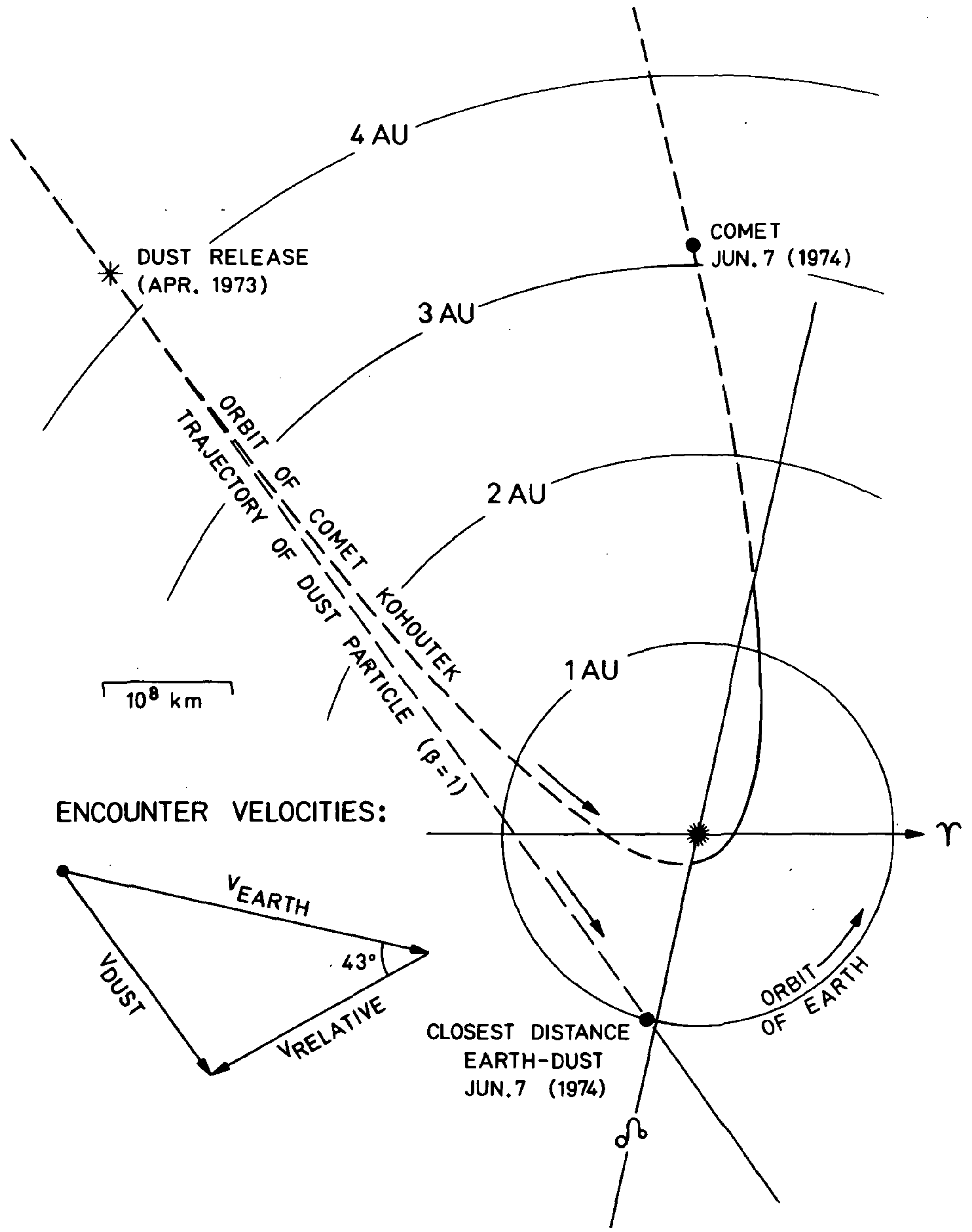


Fig. 1: Trajectory of dust particle ($\beta = 1$) released from comet Kohoutek at a heliocentric distance of $r_R = 4.3$ AU passing the earth close to the comet's line of nodes and velocity diagram during encounte] (to the left).

particles with $\beta \approx 1$ released at a heliocentric distance $r_R \approx 4.3$ AU could encounter the earth. Their heliocentric speed at the release point is approximately 20 km/sec. With $\beta = 1$ the net force acting on the particle is zero, so their speed remains constant and they move on a straight line tangentially to the comet's orbit. Close to their ascending node they are overtaken by the earth. Their geocentric speed is 19 km/sec with the apparent radiant 43° away from the earth's apex towards the sun; hence the best viewing direction of the detector within the given attitude constraints is towards the earth's apex. The particles then would encounter the detector at an angle of incidence of approximately 40° which is well within the detector's field of view.

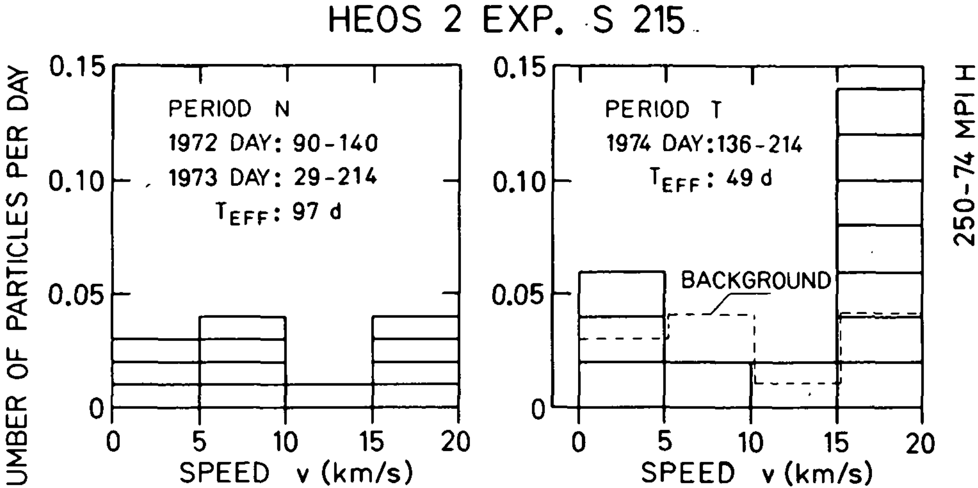
During the transit of the earth through the orbital plane of the comet, the rate of particles with speeds of approximately 19 km/sec should increase compared to the normal rate before and after the transit while viewing towards the earth's apex for particles with $\beta \approx 1$. Since the inclination of the comet's orbit is fairly low ($i = 14.3^{\circ}$) it would be possible to detect these particles for a time-period of approximately two months around the transit.

MEASUREMENTS AND DISCUSSION

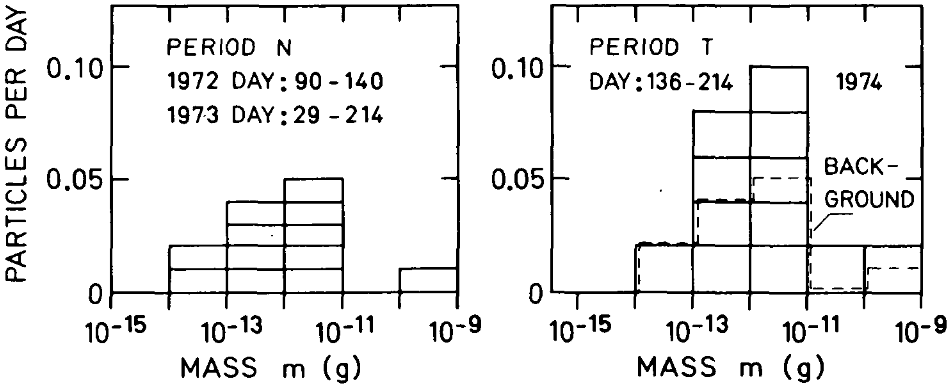
Due to refurbishing of telemetry stations the detector could not be reorientated before May 16, 1974. At that time the rates were already significantly increased, but the remaining period until the mission end was sufficient to observe the decrease of the rate towards the "normal" value. The normal rates were taken from the two periods in 1972 from day 90-140 and in 1973 from day 29-214 when the detector also was viewing towards the earth's apex.

In figure 2a and 2b the average particle rate is shown as a function of the particle speed and mass, respectively, presenting the data from the transit period (period T) on the right and those under normal conditions (period N) on the left part of the figures. The rates refer to the randomly distributed particles with known speed from the interplanetary region (Hoffmann et al., 1975) and the appropriate effective measuring time T_{EFF} taking into account the data coverage.

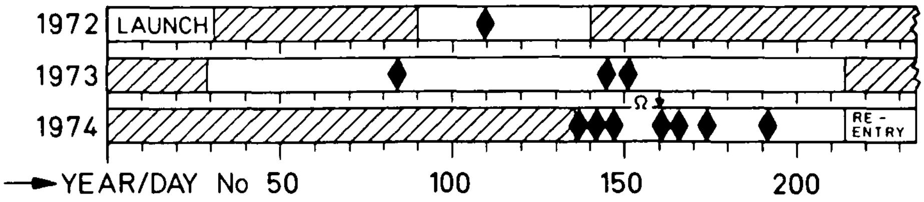
As demonstrated in figure 2a the rates of particles with speeds less than 15 km/sec are equal within the statistical error for both periods, whereas during period T a significant excess of particles is observed in the speed interval from 15-20 km/sec where the cometary particles were expected. Accordingly, in figure 2b during period T the mass distribution raises in the mass range from 10^{-13} to 10^{-11}g over the normal mass distribution (background). In figure 2c both criteria established in figure 2a and 2b have been combined, showing the history



a) SPEED DISTRIBUTION OF APEX PARTICLES



b) MASS DISTRIBUTION OF APEX PARTICLES



c) TEMPORAL DISTRIBUTION OF APEX PARTICLES WITH $15 km/s < v < 20 km/s$ AND $10^{-13} g < m < 10^{-11} g$

Fig. 2: Data from the HEOS 2 micrometeoroid experiment S-215 while facing the earth's apex during the transit of the earth through the orbital plane of comet Kohoutek (period T) and under normal conditions (period N).

exclusively of particles matching the relevant mass and speed intervals. The rate of these "cometary candidates" from period T is higher approximately by a factor of 3.5 than the rate of the background particles from period N. For the sake of completeness it may be mentioned that the rate of these particles during periods when the detector was facing directions different from the earth's apex is of the same magnitude or less than during period N.

Though the number of particles is small, the probability that 7 particles instead of the average of 2 in the relevant speed interval (see fig. 2a) and 9 instead of the average of 4 in the relevant mass interval (see fig. 2b) may be random is approximately 10^{-4}. Therefore, an additional particle source during period T is very likely.

Apart from comet Kohoutek no other sources such as the earth (Bigg and Thompson, 1969), the moon (Alexander et al., 1973; Hoffmann et al., 1975), meteor showers or other comets fulfil all conditions required by the measurements listed below:

a) time interval of enhanced particle rate between May 16 and June 23, 1974 equivalent to ecliptic longitudes from 235°- 273°,

b) mass range of particles: 10^{-13} - 10^{-11}g,

c) speed range of particles: 15 - 20 km/sec

d) apparent radiants of particles: cone around the earth's apex with semi-angle of 60°.

Particles with the required speed, originating in the earth, can be excluded because their trajectories cannot enter the sensor while it is facing the earth's apex. A lunar origin can be ruled out since the same argument holds for 5 out of 7 candidates. Meteor showers as sources are unlikely for two reasons because 1) no increased particle rate has been observed in the preceding year (1973) and 2) the radiants of the showers occuring in the relevant time interval (Daytime Arietids, Daytime ζ Perseids and Daytime β Taurids) do not match the required cone of directions (Whipple and Hawkins, 1959). As the nodes of all major comets (apart from comet Kohoutek) observed in 1973 and 1974 , such as comet Bradfield (1974b) (IAU Circular No. 2636), do not fit in the required interval of ecliptic longitudes or have perihelion distances of more than 1 AU, they cannot supply these particles either. Therefore, the authors believe that the excess of particles during the transit of the earth through the orbital plane of comet Kohoutek is due to dust particles ejected from this comet.

The direct measurements of the individual mass and speed of the particles supply new knowledge about cometary dust which supplements the data derived from photometric studies (Finson and Probstein, 1968, Sekanina and Miller, 1973 and Sekanina, 1975). A direct measurement of cometary dust by a collection experiment during the transit of the earth through the orbit plane of comet Giacobini Zinner has been reported by Hemenway (1973).

INTERPRETATION

For further evaluation of the measured data, orbit calculations have been performed for particles ejected from comet Kohoutek encountering the earth at a time of observation t_O around the date of the earth's transit through the orbital plane of the comet on day 160 in 1974.

Figure 3 shows an instant picture of the particles' positions as a function 1) of the magnitude of β (syndyne) and 2) of the release time t_R (synchrone) and the corresponding heliocentric distance r_R, respectively, at t_O = day 160 (1974). The additional velocity distribution arising from the gas streaming away from the comet nucleus has been neglected in this picture. Due to the additional velocity component Δv, particles with values of β different from 1.00 have a chance to encounter the earth as long as their Δv is sufficient to cover the missing distance to the earth during the time interval $\Delta t = t_O - t_R$. The magnitude of Δv is presented in figure 4. It shows the minimum

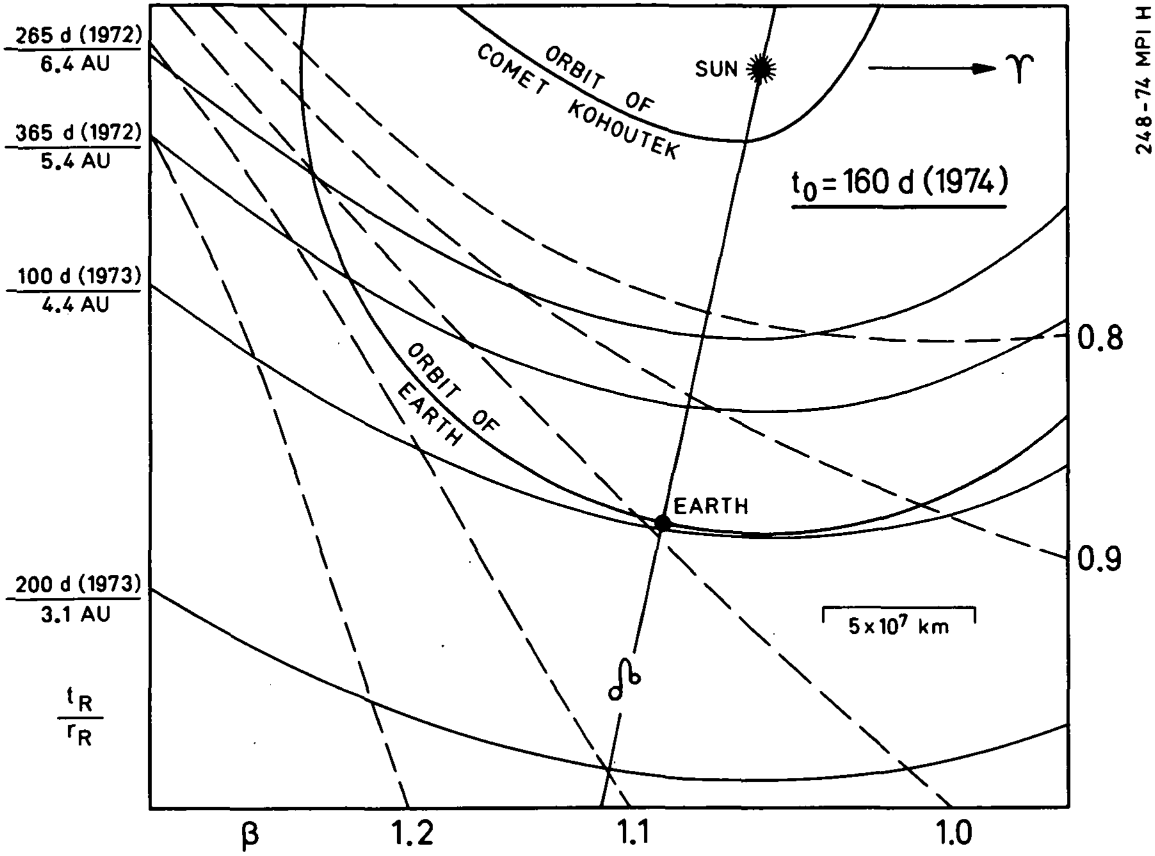


Fig. 3: Position of particles from comet Kohoutek for constant values of 1) β (syndyne: broken lines) and 2) release times t_R (synchrone: solid lines) or the corresponding heliocentric distances r_R during the transit of the earth through the orbital plane of the comet at t_0 = day 160, 1974.

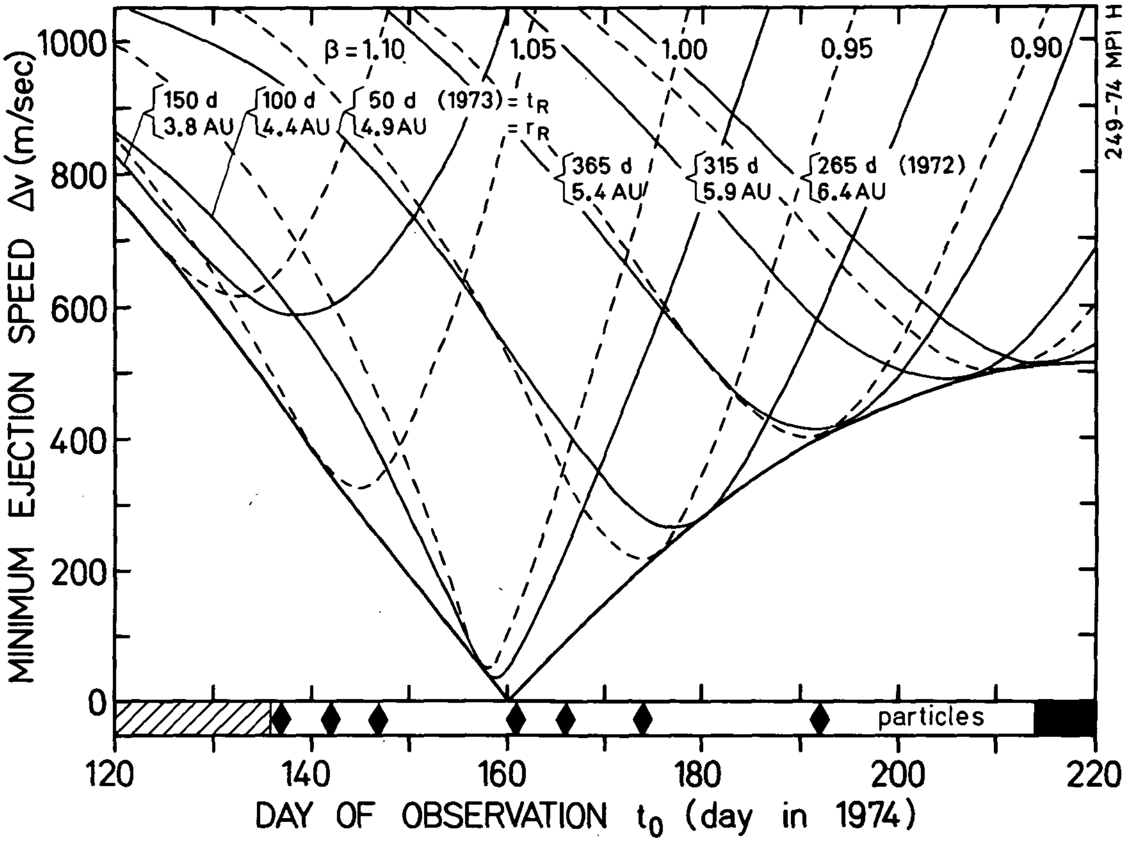


Fig. 4: Minimum ejection speed Δv for constant values of 1) β (broken lines), 2) release times t_R or the corresponding heliocentric distances r_R (solid lines) and envelope (fat line) as a function of the observation time t_0 and temporal distribution of the cometary particles.

ejection speed Δv required to reach the earth as a function of the time of observation t_0 and the parameters β and r_R or t_R. The envelope (fat line) indicates the absolute minimum speed at the various days of observation. Using the time history of the candidates (on the bottom of the figure) ejection speeds can be derived.

If the candidate from day 192 (1974) is a descendent of comet Kohoutek it must have been released with $\Delta v \geqslant 400$ m/sec. On the other hand, Δv cannot be much larger because otherwise further particles should have also been observed at later times. Particles arriving at the earth at day 137 (1974) must have been released with $\Delta v \geqslant 450$ m/sec. However, in this case Δv may be more than 450 m/sec because the rise of the candidates' rate apparently occurred before day 136 which would require a higher ejection speed. Thus, from figure 4 can be deduced that the parameters of the observed candidates range from $\beta \approx .90$ at $r_R \approx 5.4$ AU with $\Delta v \approx 400$ m/sec to $\beta \approx 1.10$ at $r_R \approx 3.8$ AU and $\Delta v \geqslant 450$ m/sec.

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REFERENCES

Alexander W.M., Arthur C.W., Bohn J.L. and Smith J.C. (1973) "Four Years of Dust Particle Measurements in Cislunar and Selenocentric Space from Lunar Explorer 35 and OGO 3".Space Research XIII, Akademieverlag Berlin, 1035

Bigg E.K. and Thompson W.J. (1969) "Daytime Photograph of a Group of Meteor Trails".Nature 222, 156

Dietzel H., Eichhorn G., Fechtig H., Grün E., Hoffmann H.-J. and Kissel J. (1973) "The HEOS 2 and Helios Micrometeoroid Experiments".J. of Phys. E: Sci. Instrum 6, 209

Finson M.L. and Probstein R.F. (1968) "A Theory of Dust Comets. II Results for Comet Arend-Roland". Astrophys. J. 154, 353

Hemenway C.L. (1973) "Collections of Cosmic Dust" paper presented at "Whipple Memorial Symposium", Cambridge, Massachusetts

Hoffmann H.-J., Fechtig H., Grün E. and Kissel J. (1975) "First Results of the Micrometeoroid Experiment S-215 on the HEOS 2 Satellite". Planet. Space Sci. 23, 215

Sekanina Z. (1975) "Progress in Our Understanding of Cometary Dust Tails".Proceedings of IAU Colloquium No. 25

Sekanina Z. and Miller F.D. (1973) "Comet Bennett 1970 II". Science 179, 565

Whipple F.L. and Hawkins G.S. (1959) "Meteors". Handbuch der Physik, Vol. 52, ed. S. Flügge, Springer-Verlag Berlin, Göttingen, Heidelberg, 519