22. METEORS AND METEORITES (MÉTÉORES ET MÉTÉORITES)

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INTRODUCTION

The content and format of this report differ from previous reports of the Commission. Limits of space, the absence of draft reports, and the long interval between preparation and publication have had their influence in the past; the present changes were motivated by the General Secretary. He has argued convincingly that critical reviews are of much greater value than reports that are primarily bibliographic. To achieve this goal, the subject matter has been divided into six topics, each assigned to a particular author. The reports of the Meteorite Committee and the Cosmic Dust Committee follow. The President has acted as editor and assumes responsibility for any omissions. The various authors thank those members who responded to the request for information and suggestions.

Space limits have curtailed the number of references and influenced the reference system. Whenever possible, *Astronomy and Astrophysics Abstract* numbers are given in the text. Other references are given at the end of each section, except for articles appearing in an IAU Symposium and certain IAU Colloquia:

Symp. **45**, 'The Motion, Evolution of Orbits and Origin of Comets', ed. by G. A. Chebotarev, E. I. Kazimirchak-Polonskaya, and B. G. Marsden. D. Reidel Publ. Co., Dordrecht (1972).
Colloq. **12**, 'Physical Studies of Minor Planets', ed. by T. Gehrels. NASA SP-267, Washington, D. C. (1971).
Colloq. **13**, 'The Evolutionary and Physical Problems of Meteoroids,' ed. by C. L. Hemenway, A. F. Cook, and P. M. Millman. NASA SP-319, Washington, D. C. (in press).
Colloq. **22**, 'Astéroids – Comèts – Matière Météorique'. Nice, 1972 (in preparation).

PHOTOGRAPHIC METEORS

R. E. McCrosky

The emphasis in direct meteor photography has turned to the bright fireballs. The European All-Sky Network in Czechoslovakia and Germany and the Prairie Network in the U.S.A. have now been joined by a twelve-station array in Canada under the direction of Halliday (05.105.101). The Canadian Network became fully operational in August 1971 and has recorded about 200 multistation fireballs. The European Network photographs nearly 50 objects brighter than −6 mag. per year, and the Prairie Network about 300 such objects each year from more than one station. A common aim of these efforts is the recovery of meteorites for which orbits are known and for which the interactions with the atmosphere are observed. The observation of a few meteorites may be sufficient to detect an observational parameter that separates these bodies from meteors produced by other kinds of material. If this is so, the orbital statistics of meteorites would be greatly improved by the inclusion of data from objects that cannot be recovered either because of their small size or for other reasons.

The rate of meteorite recovery is well below earlier expectations. Since 1970, the various networks initiated ground searches for ten suspected meteorites. In three cases, the expected terminal mass was large enough, and the impact terrain suitable, for recovery. However, only one fall, Lost City

(05.105.081), was recovered. The distribution of the four recovered fragments with respect to their shapes and sizes did not correspond to that expected from the simple application of aerodynamic laws for spherical bodies. It is apparent from this, and indirectly from the other negative results, that impact-point predictions may be seriously in error because of aerodynamic lift or other effects impossible to account for *before* the body geometry is known. The recovery of a large sample of photographed meteorites will be possible only if a much larger search effort is made than is usual now. Impact-prediction errors are probably two or three times those anticipated earlier, and the area requiring search is thus five to ten times larger.

It also appears now that the body geometry is at least partially responsible for the difficulty in separating stony meteorites from other meteoritic material solely by means of optical observations. McCrosky and Ceplecha (04.104.027) analyzed the existing trajectory and photometry data of fireballs and concluded that if meteoroids did not depart seriously from sphericity, then either the great majority of fireballs were produced by a material much less dense than meteorites or the luminous efficiency used to estimate the meteoroid mass had been seriously underestimated. The Lost City observations confirmed that the luminous efficiency derived for smaller bodies was reasonably accurate for this fireball. However, the mass of the largest recovered fragment was more than five times that deduced from the observed deceleration. This discrepancy was initially explained by the rather highly flattened shape of the meteorite. Since the meteorite was an 'oriented' object (i.e., a fixed stagnation point is apparent on the leading surface), it was claimed that the fundamental aerodynamic parameter, the ratio of mass to frontal area, could be specified and that this quantity was consistent with the observed deceleration. This interpretation needs revision in the light of recent wind-tunnel tests made on a model of the meteorite. The object is not stable with the observed stagnation point along the direction of flight, and the conclusions based on this assumption were therefore unwarranted. The stable orientation, in fact, is not in a direction that maximizes the frontal area but rather in a direction that should have caused the body to decelerate at about the same rate as a sphere of the same mass. (The usual statement that stable supersonic flight occurs in the maximum drag orientation is true only for symmetrical bodies. The first condition for stability is that there be no torques acting.) Nevertheless, it can hardly be denied that the pronounced nose of the meteorite was, at one time rather late in the trajectory, at the stagnation point. This would have been possible if the meteoroid had lost an edge piece that gave the main fragment an even flatter shape than had been initially proposed. It is apparent that if one must contend with a wide variety of shapes, and with perhaps predominately flattened shapes, the past procedures for determining which meteoroids are high density may be of limited value.

Baldwin and Shaffer (06.104.001) have introduced a model of meteoroid fragmentation that attempts to explain anomalously high decelerations by pressure fragmentation of the bodies. They have considered both ordinary chondrites and carbonaceous chondrites. Studies of terrestrial rocks have given a relationship for the effective crushing strength as a function of size. Larger objects are fragmented more easily than smaller ones. The same law, augmented by some new strength tests on bronzite meteorites, is assumed to apply to the dynamic pressure-crushing of meteoroids. However, it is recognized that meteorites frequently disintegrate high in the atmosphere, where the loads can only exceed the presumed tensile strengths, and it has been necessary to include in the model an unverified relationship governing this initial breakup. Despite this weakness, the general modeling procedure should be useful.

Another mechanism to produce gross fragmentation of bodies that may deserve further study relates to the 'de-spin' forces on a rotating body as it penetrates deeper into the atmosphere. At some time complete rotation ceases and the body undergoes an oscillation of decreasing amplitude and increasing frequency. The effect is vividly seen in a few meteors showing regular light variations at about 100 Hz. The body may fail under bending loads applied to locally weak areas of the meteoroid. Upon fragmentation the individual pieces may in certain circumstances undergo a new rotational damping process that permits further fragmentation.

The possibility is remote that one can specify a detailed fragmentation process for bodies of unknown shape, poorly known mass, and very uncertain structure. The last factor is particularly troublesome since all meteorites have been filtered during atmospheric entry and only the more durable masses are available for structural studies. Stony meteorites, in space, may have substantial structural weaknesses produced by collision processes, according to Gault and Wedekind (02.105. 167). Optical observations may still be required to investigate structural differences. As an immediate goal, one would like to be able to distinguish between ordinary chondrites and carbonaceous chondrites, both because the known physical differences of these two materials make it seem likely that a separation is possible from optical observations and, more importantly, because the orbital distributions of these two kinds of meteoroids may suggest important differences in their origin.

The increased number of fireball observations now verifies an earlier suggestion that there exists a distinct class of large objects that show remarkably high end heights as compared to other meteors of comparable brightness and velocity. The high-altitude events penetrate no more than 1% of the atmosphere traversed by more usual meteors. Their orbits universally have aphelia in the vicinity of Jupiter and probably are associated with short-period comets. Similar orbits are comparatively rare among other fireballs. It is inconceivable that the high-altitude meteors ever produced a meteorite, and even the carbonaceous chondrites must be searched for among bodies of greater strength or lower ablation coefficients (McIntosh, 04.104.038).

A new form of meteor study has been recently proposed: meteor sound observations, as discussed theoretically by Tsikuzin (02.003.121) and amplified by Revelle and Bartman (1972). The latter propose to make acoustical records of large meteoroids in the atmosphere, including some objects that may be observed photographically by the Prairie Network.

REFERENCE

Revelle, D. O., Bartman, F. L. 1972, Rep. No. 010816-1-T, University of Michigan College of Engineering.

RADAR METEORS

R. B. Southworth

This Section primarily reports on progress in understanding physical processes in the ionized column left by the moving meteoroid. There have been substantial accomplishments here, but there has not been time for meteor radar workers to integrate all the results into a coherent theory. Furthermore, it is likely that there is more to learn, particularly about the mass dependence of several parameters.

Fragmentation in faint radar meteors has been inferred from details of the Fresnel diffraction patterns. At Kharkov, division into two fragments of comparable size was observed, as well as irregularities in the ionization curve interpretable as flares (06.104.023). At Havana (U.S.A.), disappearance or reduced amplitude of the later oscillations of the Fresnel patterns showed that a substantial fraction of the meteors had fragmented into at least several pieces, which were spread up to a few hundred meters along the ionized column. It is to be expected that the fragments must then also be spread across the ionized column; to radar apparatus this has the appearance of a larger initial radius for fragmented meteors. The Havana-Sidell simultaneous radar-television observations (Cook *et al.*, *Coll.* **13**) confirm the effect in the following way. From the shape of the light curve, roughly half the meteors observed by both radar and television could be recognized as fragmenting, and the radar return at some or all stations from these fragmenting meteors was anomalously low compared to the optical brightness.

Dissociative recombination of electrons with O_2^+ and N_2^+ has been inferred from the Havana observations (Southworth, *Coll.*, **13**), using analysis of the Fresnel patterns and the distribution of height vs apparent radar magnitude. Recombination occurs in the first few milliseconds after formation of a sufficiently dense ionized column – i.e., a column with sufficiently large electron line density and sufficiently small initial radius. Recombination places a lower bound on observable heights; this lower bound is higher for bright meteors and lower for faint meteors. Since slow