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M E T E O R S

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After hearing so many technical descriptions of different high velocity particle experiments, one easily recognizes the paramount importance of sensors for gathering the experimental data on meteoric dust. In contrast the "classical" meteor astronomy and physics is using a less expensive "sensor", the Earth's atmosphere. The interaction of the meteor body with the air has to be recorded and thus our experimental data are just records of the natural phenomenon itself: integral light photographs, spectral photographs, recently also image intensifier photographs and videorecords. The only "active" method is the radar observation of the ionized trail. The close distance of the phenomenon to the observational sites enables one to determine the complete geometrical and dynamical data (heights, distances, velocities); the light recording gives the intensity of the emitted light at individual points of the trajectory, the radar recording gives the ionization intensity. A suitable physical theory is necessary to convert the basic observational data into meteor mass and other parameters. The drag equation yields the "dynamic" mass, the luminosity equation yields the "photometric" mass, and the ablation equation yields the "ablation" mass. For a single meteor, these masses are dependent on parameters defined by the drag coefficient, shape, bulk density, ablation rate and luminous efficiency. Differences in the resulting masses of a meteoroid computed from the different methods at the same trajectory point are good relative measures of the structural and compositional differences. The absolute calibration may be a problem, but laboratory and rocket measurements of the luminous efficiency, calibrations by the Lost City and Pribram fireballs and several other direct and indirect methods can be used.

The most important result in respect to the structure and composition of the meteoroids yielding meteors from +3 to -22 absolute stellar magnitude (masses from 10^{-4} to 10^{8} g) is the detection of several widely different types of the material. Bigger bodies (giving fireballs) can be related to three basic structures (Ceplecha, McCrosky: in preparation for JGR): strong stones (ordinary chondrites), carbonaceous (and "precarbonaceous") chondrites, weak cometary material.

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The cometary material has two distinctly different structures: the classical cometary material (with densities of the order of several tenths of g/cm^3) and the Draconid type material with densities approaching 0.1 g/cm^3. Thus for bodies of quite big dimensions (tens of centimeters to tens of meters), we have observational evidence of greatly different structure: the strongest body could be hardly destroyed by hitting it with a hammer, the weakest body would disappear and only make finger tips dirty after touching. Each of these three structural types of meteoroids participates approximately equally in the whole population of fireball bodies. The number of all fireballs and the corresponding incoming mass within the range of 10^5 to 10^9 grams is enough to explain the enhancement of the atmospheric and surface dust of meteoric origin.

The faint photographic meteors (photographed by Super-Schmidt cameras) contain only material of the cometary group and the carbonaceous group; the ordinary chondrite group is almost missing: few cases of assumed "stones" were used previously by some authors as calibration points and often called "asteroidal" meteors (this is not a good name, because there is no direct evidence for asteroidal origin in contrast to the direct association of individual comets with meteor showers). A huge difference in the penetration ability of two bodies of approximately the same dynamical and geometrical parameters of the trajectory was presented by Ceplecha (Table 2) during this colloquium.

When interpreting our observational results on meteors a decade ago, we started with the wrong, but simple assumption that we are searching for one average structural composition. Thus I would strongly recommend to consider the distribution of meteor particles of any range of sizes (meteoric dust, too) in terms of several different populations statistically superimposed in the experimental data. Nature is not so simple that she prepares just one statistical distribution for our comfort!

The groups of different structure and composition have also different orbits, but the question of their origin is not trivial. There is the direct evidence through showers that the cometary material originates from comets, but also the carbonaceous material seems to be present in some meteor showers with known cometary associations. The statistics of orbits of the carbonaceous material seems to be not much different from the distribution of the ordinary chondritic material and the possibility that the strongest meteoroid constituent is also of cometary origin is still open.

The problem of identification of a cometary orbit with a meteor shower is a well known and established procedure, because the bodies are relatively big, gravitation being the decisive force, and the dispersion time being sufficiently long to preserve the orbital elements until the collision with the Earth. But this does not apply to tiny picogram dust grains observed in space. Kresák (paper of this Coll.) investigated the gravitational, radiative, and destructive effects governing the rate of displacement, dispersion, and removal of interplanetary dust streams. He found drastic effects and he sees no way how a compact dust stream might be maintained over a number of revolutions. The proposed comet-micrometeoroid associations seem to be fictitious and the origin of the observed dust streams should not be connected with distant large bodies such as comets.

The interpretation of the spectral records of meteors would seem to be the most direct way to arrive at the chemical composition. However, the meteor spectra mostly reflect the impact velocity. In case of fireballs, the light is radiated mostly from the very surface of the luminous gas volume, which casts doubts on any abundances of elements determined from meteor spectra. The only exception is the case of the Draconid-type meteors: they start to emit light very high, where the free molecular flow enables us to see all the light produced. The abundances of elements computed for such meteors by Millman correspond roughly to carbonaceous abundances. The future quantitative study of spectra of much fainter meteors (around +3 stellar magnitude), not available today, may give better results on the chemical composition, because of much less importance of the selfabsorption phenomenon. Qualitatively the overwhelming majority of meteor spectra are similar to each other and are roughly independent of the meteoroid structure. A very small percentage (increasing with decreasing brightness) of meteors exhibit spectra without iron lines. Another extreme is formed by a few known spectra containing only iron lines. The best existing spectrum of this type corresponds to a typical cometary meteor (orbit and atmospheric trajectory as well).

Meteors observed by radar are closer to the range of sizes of meteoric dust particles. The observational data are not so accurate as the optical photographic data, but much fainter meteors can be studied independently of weather. The structural variety of these small bodies seems to be not so wide as for the bigger bodies and the "stony" population is missing. But the experimental data are derived from very

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short trajectories under several strongly selective conditions, which put more uncertainity into the results.

The future progress in meteor astronomy and physics depends on several promising space experiments. First, it would be very important to calibrate spectral observations of meteors by producing artificial meteors from a suitable orbiting station. The UV spectra of natural meteors (and artificial meteors as well) are not accessible from the ground due to the absorption in the lower part of the earth's atmosphere. Observations of UV spectra from an orbiting space station is one of the important experiments in the near future. The calibration of radar observations by artificial faint meteors fired with rather high velocity from an orbiting station would enable more reliable interpretations of natural meteors observed by radar. The recording technique should at least partly turn to electronic systems giving videorecords, which could be directly processed by a computer.

The main task of all such experiments and observations is the study of different meteoroid populations and their relative importance among all bodies within a given range of sizes. Inter-corporating all results into one frame, we will arrive at the complete picture of interlocking populations over a huge range of meteoroid masses.

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