22. COMMISSION DES METEORES ET METEORITES

(This report, which was received late, is printed out of normal order; the names of the President and Members of this Commission are printed on page 213.)

PROGRESS IN THE STUDY OF METEORS FROM 1958 TO 1960

Data for the present summary were obtained from a number of Commission members and other persons of different countries. Communications, reprints and recommendations were sent by Astapovich, Bakharev, Bogorodsky, Katasev, Kashcheyev, Lubarsky (U.S.S.R.), Chapman, Olivier, R. Thomas, Whipple (U.S.A.), Ceplecha, Guth, Kresak (C.S.S.R.), Baldet, Guigay (France), Hirose, Miyadi (Japan), Millman (Canada), Kaiser (England), Lindblad (Sweden), Nielsen (Denmark), O. Thomas (Austria), de Jager (Netherlands), Carrara (Italy), Venter (South Africa).

I. S. Astapovich (Odessa Observatory, U.S.S.R.), a member of the Commission, prepared for the present report a vast survey of data that appeared for the recent years in the world scientific literature. It is accompanied by a list of 537 references. I thank very much all the above-mentioned persons for their useful collaboration.

METEORS AND THE COSMIC SPACE INVESTIGATION

After 1957 October 4, when the launching of the first Soviet sputnik, artificial satellite of the Earth, took place and investigation of cosmic space began, meteor astronomy undoubtedly entered a new phase of its development. Meteoric matter in cosmic space has a direct effect on the shells of satellites and cosmic rockets. The sudden cessation of signals from satellite $1958\beta_2$, the U.S.S.R. cosmic rocket No. 2, and the "Echo" project satellite was probably caused by their collision with meteoric bodies. The future launching of interplanetary vehicles requires a much more detailed study of the distribution of cosmic matter in space. Such study must now be carried on not only from the Earth's surface, but also directly by means of instruments carried by satellites and cosmic rockets. On the other hand, modern rocket techniques permit the application of cosmic velocities to bodies to make artificial meteors for an experimental check of the theory. Thus, meteor astronomy is being transformed from a purely observational into an experimental branch of science of great practical value, which it never had before. Investigators of meteors must realize the new problems and opportunities of meteor astronomy in this new phase of its development, and direct their activity towards new subjects and methods.

ORGANISATION OF STUDIES

Measurements on rockets and satellites

In the period from 1958 to 1960 the Moscow Institute of Applied Geophysics of the U.S.S.R. Academy of Sciences, the Astrophysical Observatory of the Smithsonian Institute (Cambridge, U.S.A.) and some other scientific institutions organised complex studies of meteoric matter by also using the results of direct measurements on rockets and satellites. This is a totally new direction in the study of meteors and only first results have been published. Of great importance will be a comparison of the data of direct measurements with meteor observations from the Earth's surface.

The IGY-IGC programme

Observations in accordance with the vast programme of meteor studies in the period of the International Geophysical Year—International Geophysical Co-operation (IGY-IGC), started in June 1957, were completed in January 1960. The IGY-IGC programme stimulated con-

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siderably meteor studies. The study of meteors included in the IGY-IGC programme represented a part of the ionospheric investigations (section V) and was mainly aimed to determine the influence of meteors upon the state of the ionosphere, and to measure winds in the upper atmosphere by observing the drift of meteor trains. These observations permitted also to obtain detailed data about meteoric matter in cosmic space—its density near the Earth, the orbits of individual meteoroids and the structure of some great meteor streams. Scientific Institutions of the U.S.S.R., C.S.S.R., Canada, England, U.S.A., Japan, Australia and South Africa took part in the IGY-IGC observations.

Radar, photographic, and visual observations of meteors according to the IGY-IGC programme were carried out in the U.S.S.R. in Ashkhabad (Turkmenian Academy of Sciences), Stalinabad (Tadjik Academy of Sciences), Kazan, Kiev, Odessa (Universities), Kharkov, Tomsk (Polytechnical Institutes) and Simferopol (the All-Union astronomical and geodetical Society). Information about the stations, the observational programmes, and the instruments used have been published (**1-4**). Extensive statistical data of the radar observations show an increased number of meteors on January 15-16, February 14, March 9-15 and other days besides the known dates of large meteoric showers. New data on the structure of meteor streams, the Lyrids in particular, were obtained. The orbits of several hundred meteors, about 1% of which are clearly expressed hyperbolas, were determined by means of radar and photographic methods. Interesting results about the distribution of meteors with magnitude were obtained from over 20 000 visual observations by amateur astronomers from Simferopol, Riazan, Moscow etc. The processing of the radar, photographic and visual meteor observations is realized by the aid of electronic computers. The meteor stations, which have been organized in the U.S.S.R. for the IGY-IGC period, in Vannovsky near Ashkhabad, Tripolje near Kiev, Majaki near Odessa, in Kharkov and Simferopol continue their work at present.

A large net of stations for meteor observations was organized in Canada (**5-9**). Special meteor stations with radar installations, photo-cameras and spectrographs have been built in Springhill near Ottawa, Saskatoon (Saskatchewan), Meanook (Alberta), Baker Lake and Resolute Bay (North-West territories). The latter station, situated at latitude 75°N., was the northernmost point on Earth for meteor observations in the IGY-IGC period.

Over 100 000 visual observations of meteors were collected by P. M. Millman in the National Research Council of Canada in Ottawa from several hundred observing groups. These observations have been tabulated on IBM punched cards. Special IGY radar equipment has operated continuously at the Springhill Meteor Observatory on a frequency 32 mc/sec ($\lambda = 9{\cdot}4$m) and over 3 million meteor radar-echoes have been tabulated on punched cards. A detailed statistical analysis of both the visual and radar observations is now being carried out.

The IGY-IGC programme of meteor observations in Czechoslovakia (C.S.S.R.) represented a part of the ionospheric studies, and was conducted by means of radar equipment on a wavelength of 8 m, and by using both photographic and visual methods. Much attention was paid to the visual telescopic observations. The radar and photographic observations were obtained in Ondřejov, near Prague, by the Astronomical Institute of the Czechoslovakian Academy of Sciences (V. Guth, Z. Ceplecha, Z. Plavecova). Naked-eye visual as well as telescopic observations were obtained by the amateur astronomers in the popular observatories and astronomical circles. Telescopic observations of meteor showers and special programmes of simultaneous telescopic observations were carried out at Skalnaté Pleso under the supervision of L. Kresak (**10**). Within the IGY-IGC period the photographic instruments were appreciably improved, radar was used for the first time, the amateur astronomers collaborated actively with the observatories. Remarkable photographs of the bolide accompanying the fall of the stone chondrite Pribram (Louga) of 1959 April 7, were obtained from 2 places (**11**). Fragments of the

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Pribram meteorite were found near the place calculated from analysis of the photographs. The fragmentation in the atmosphere of the initially-whole large meteoric body is seen on the photographs. An interesting series of telescopic meteor observations in 1958 July-August was obtained by A. Mrkos, the well-known Czechoslovakian "comet hunter", collaborator of the Soviet Antarctic expedition at Mirny at latitude 60°S. This was the southernmost station for meteor observations in the IGY-IGC period.

In England regular operation of the well-equipped Jodrell Bank Station of Manchester University was continued (**12**). Regular statistical radar observations of meteor activity on a wave-length of 4·2 m were made. Theoretical and experimental studies of meteoric problems were carried out by T. Kaiser in Sheffield University (**13**).

In the U.S.A. a radar system on a wave-length of 7·2 m, with a transmitter of 7 Mw (peak-power) and six receivers, was mounted in Havana (Illinois) during the IGY-IGC period. This system permits to obtain the heights and orbits of individual meteors up to 12th magnitude. Its recording capacity is up to 1000 radio-echoes of meteors per hour (**14**). 6287 double photographs of meteors and 192 photographs of persistent meteor trains were obtained by means of Super-Schmidt cameras; among the 413 precise orbits calculated from these photographs only 7 were found to be hyperbolic, but the accuracy of the velocity determinations of these meteors is low (**15**). Heights and intensities of 48 meteor trains were obtained by means of the Super-Schmidt cameras in New Mexico (**16**).

In Australia regular radar observations of meteors up to $+7^{m}\cdot 5$ were continued, aimed to determine their number and to study meteor showers. These studies were continued in Adelaide on a wave-length of 11 m (**17**).

In Japan visual observations of meteors during the IGY-IGC were carried out by many amateur observers in co-operation with the Meteor Center of Canada. The largest group of observers was directed by K. Komaki in Vakajama. Preliminary reports have been issued monthly in mimeograph prints. Meteoric dust was systematically collected. Radio observations were made in the Radio Research Laboratory at Kokubundji, Tokyo.

In South Africa visual naked-eye observations of meteors, and observations by means of small telescopes, were obtained by some amateur astronomers in collaboration with the Meteor Center in Canada (**18**).

In all 8 countries participated in the meteor observations in accordance with the IGY-IGC programme. The complex observations were carried out by means of radar, photographic, and visual methods, and produced both astronomical and geophysical results. Thus was practically realized the International Meteor Year suggested by the Czechoslovakian meteor observers in 1954 as a part of the IGY. Meteor observations according to the IGY-IGC programme have considerably promoted the development of meteor investigations and advanced their level.

There are of course some deficiencies in the work so far done: the inhomogeneity of the observational methods; insufficient and irregular distribution of stations on the Earth's surface; delayed and incomplete reception of the results by the International Data Centers (IDCs). In spite of this, meteor studies in the IGY-IGC period are a successful example of international scientific collaboration, which it would be rational to repeat on a broader and improved scale after a certain time.

Symposia, publications

Scientific conferences and symposia devoted to meteors in 1958–59 took place in the U.S.S.R. and Czechoslovakia. The number of papers on meteor astronomy is still increasing. Monographs in Russian were issued by Astapovich (**19**), Krinov (**23**). Books by Lovell (**21**) and Kaiser (**22**) were translated into Russian. Books by Krinov and Staniukovich (**25**) were in turn translated into English and a book by Levin into German (**24**). The mutual translation of scientific books into Russian, German and English promotes exchange of ideas and general progress in meteor astronomy. The monograph by Öpik, devoted to the physical theory of meteors, was issued in English (**26**). The book by O. Thomas in German (Vienna, Austria) on the orbit calculations of bolides is ready for print (**27**). In the U.S.S.R. have appeared journals "Meteoritika" (Nos. 17, 18 and 19), "Bulletin of the Commission for comets and meteors" of the Astronomical Council of the U.S.S.R. Academy of Sciences (Nos. 2-5). In Canada were regularly published the surveys "Meteor News". Bibliographies appeared in the *Referativny Zhournal*, series of "Astronomy" and "Geophysics" (in Russian); *Astronomisches Jahresbericht* (in German) and *Bulletin Signalétique* (in French). A survey of Soviet meteor bibliographies (1917–57) is appended to the paper by Fedynsky in the book "Astronomy in the U.S.S.R. for 40 years" (Moscow, 1960).

METHODS OF OBSERVATIONS

Direct method of study

Direct methods for the study of meteor particles are already largely developed. Different methods of recording have been applied: crater counts on soft metals, on polished steel; piezo-microphones; photo-electric record of bursts producing by meteoric impacts against plexiglass, or an aluminized luzcite disk; increase of the resistance of the sprayed metal layer 15 Å thick; decrease of the radio-activity of the standard; measurement by means of photo-cells of the amount of light through holes in an opaque plate etc. (**28, 29, 30**).

The present state of techniques in the direct recording of meteor particles permits only with considerable difficulty the comparison of the data obtained by different methods and related to the energy of the particles. The best of the advanced methods can probably record meteoric particles of energies of more than about 10^4 ergs, which corresponds to minimum masses of the order 10^{-9}g and to dimensions of the order 4 microns and larger, at a mean velocity of collision of 40 km sec^{-1}.

The collection of cosmic dust in aerosols permits to obtain mainly the substance formed as a result of the diffusion of the initially-whole meteoric particles in the terrestrial atmosphere. In the IGY-IGC period aerosols had been collected on sticky paper at 62 stations in C.S.S.R., U.S.A., France, Japan and other countries (**31, 32, 33**). Probes were also taken by means of the jet-born equipment at heights from 7 to 16 km (**34**). The Japanese antarctic station in Syova collected dust in 1957–58 from the snow-covered glacier.

Radio-methods

As was mentioned in the survey of the IGY-IGC programme, the first place among other observational methods belongs to the radar method of meteor study. Metre-wave-range radars (4—12 m) were used for the recording of meteor radio-echoes. The reception of radio-echoes from several points provides the possibility of determining the real position and velocity of individual meteors, and permits the determination of their orbits in the solar system. The enormous amount of information is processed by means of automatic digital computers. Since 1959 Italy has joined the countries in which radar observations of meteors are being made (Australia, Canada, C.S.S.R., England, Japan, New Zealand, U.S.A., U.S.S.R.). A radar installation on a wave-length of 7·5 m was mounted in Firenza (**35**). The important problem of the reduction of radar observations of meteors was studied by Kaiser (**36**) and Tsesevich (**37**). In much previous radar work, insufficient attention has been given to the quantitative aspects of these studies. The transmitted power, the receiver sensitivity, the aerial gain, the polar diagram, and other parameters of the instruments require precise control and measurement within the closest possible limits. The aerial should best be located in the equatorial plane to west or east. In this case observations of sporadic meteors can be reduced without the knowledge of the radiant distribution on the celestial sphere, which is otherwise required. Tsesevich suggested the use of a statistical method with the application of spherical functions for the reduction of radar meteor observations.

Photo-electric recording

J. Davis (Jodrell Bank) has made observations of meteors brighter than magnitude +3, using red, blue and green filters in front of photo-multipliers. He finds that fainter meteors are considerably redder than bright ones. Some individual experiments in the U.S.S.R. (Kazan) established the possibility of noting in this way meteors up to 3rd magnitude (Stepanov, Kazan).

Photographic methods

The most precise method for the determination of the meteor real position still remains the photographic one. Super-Schmidt meteor cameras were used in England, in combination with radar observations, and in Canada. However the climatic conditions of the English and Canadian stations permitted to obtain but a small number of photographs. In the U.S.A. operation of these cameras was suspended in 1958, after obtaining very extensive material which is now being processed in the Harvard and Smithsonian observatories under Whipple's direction, and in Japan under Hirose. Meteor patrol equipment with cameras of 1/2·5, $f=25$ cm, and a Kramer system obturator with a movable blade permitting to note the instant of meteor occurrence were operating in the U.S.S.R. (Kiev and Odessa). Meteor patrols of other types have also been mounted in Stalinabad (Tadjik S.S.R.) and Ashkhabad (Turkmen S.S.R.). A 7-camera meteor patrol with an equatorial mounting and a clock mechanism has been operating in Stalinabad since 1958. A second 7-camera fixed equipment is mounted on the other end of the base-line. A high-speed obturator with 143 breaks per second was used in Ashkhabad. The cameras used in Ashkhabad and Stalinabad were the same as in Kiev and Odessa. Over 500 meteors have been photographed by the meteor stations of the U.S.S.R. in 1958–60, and the data are being processed. To hasten the processing Sosnova used automatic digital computers (**38**), and Rosenblum suggested the use of a stereo-comparator (**39**). Kramer proposed to measure photographs in the focal camera plane by means of a phototheodolite, through the objective of the camera. In Ondřejov (C.S.S.R.) a patrol was operated consisting of two groups of cameras with base-line distance of 40·4 km with objective 1/4·5, $f=18$ cm. These cameras cover about a half of the visible hemisphere of the sky. 47 breaks per second are given by the obturator. Meteor flight times are determined in Ondřejov by means of a driven group of 12 cameras on an equatorial mounting. Experiments by means of cameras of long focal-length (1/6, $f=75$ cm) with an obturator in front of the plate, giving 200 breaks per second were also carried out. 88 double-station photographs were obtained by means of cameras with short focal-lengths and 6 by a camera of long focal-length. The data are being processed by means of automatic digital computers (Guth, Ceplecha, Rajchl and others, in co-operation with Davies at Jodrell Bank).

To improve the photographic photometry of meteors, devices with a moving source of light were designed in the U.S.S.R. (**40**, **41**). Photometric reference to the traces of stars mostly provides practically satisfactory results with a fixed camera (**42**).

From special photographic plates obtained with the large Mt. Palomar instrument A. Cook, F. Stienon and G. S. Hawkins (**43**) have obtained more reliable estimates of the width of meteoric trails. According to these measurements the width of one of them was 10 m. The magnitude of the meteor and the width of the track are mutually well correlated. Interesting details about the division of the meteor bodies into small particles in their flight through the atmosphere can be seen on the large-scale photos of the bright fireballs observed in Odessa (U.S.S.R.) and Ondřejov (C.S.S.R.).

Spectra and Colours

Spectrograms of meteors by means of objective prisms and diffraction gratings have been obtained. The main spectrographic data were obtained at the meteor stations in Ashkhabad, Simferopol, Odessa and Stalinabad (U.S.S.R.), Springhill, Ottawa (Canada), and Ondřejov (C.S.S.R.).

By the end of 1960 the total number of meteor spectrograms obtained was 427; 175 of them were received in Canada and 150 in U.S.S.R. (**44**). In Springhill (Canada) photographic meteor spectra are obtained side by side with radar and visual observations of meteors (**45**). Over 30 grating spectrographs are in operation at Meanook, Newbrook and Springhill. These include two spectrographs with quartz optics for ultra-violet studies and two high-dispersion instruments with focal lengths of approximately one metre. The use of a rotating shutter in front of the spectral cameras permits the emission spectra of meteor trains to be obtained (**46**). By means of plates with special emulsions a number of spectrograms in the infra-red were secured (**47**). Two meteor spectra were obtained at the end of 1960, in Ondřejov (C.S.S.R.), by means of the spectral patrol constructed by Rajchl and consisting of the four Tessar cameras ($1/4{\cdot}5, f=360$ mm; $1/3{\cdot}5, f=300$ mm) and diffraction gratings. Dispersion of these spectra is sufficiently high (~ 20 Å/mm) and the number of lines is 99 and 166, respectively. All this increased considerably the information about meteor spectra. Reliable data on atmosphere gas radiation were obtained, in particular the auroral green line λ 5577 was established, O I, namely the forbidden oxygen line (**48, 49, 50**).

A number of papers devoted to the study of the individual spectra of fireballs and bright meteors, the spectrograms of which were obtained in the U.S.S.R., Canada, and C.S.S.R., were published (**51-61**). The first artificial spectra of meteors were obtained by vaporising the powder of meteoric matter by means of a helium shock-wave (**62**).

McCrosky (Smithsonian Astrophysical Observatory, U.S.A.) has constructed, for the Super-Schmidt meteor camera, a full aperture 3-step 20° angle polysterne cast-plastic Fresnel prism. This prism is distinguished by comparatively low optical power, 600 Å/mm dispersion at a minimum deviation of 4750 Å. This prism was successful in its first attempt to obtain the spectrum of a rocket-propelled artificial meteor.

The colour index of meteors was studied by Jacchia (**63**) and Ceplecha (**64**) from the data of parallel photographic and visual observations. Ceplecha concludes that faint meteors are relatively more red than bright meteors, in good agreement with the photo-electric observations made by Davies. A summary of 950 colour determinations of the fireball of 1956 October 6, was given by van Diggelen (**65**).

Magnetic effect of meteors

Electromagnetic phenomena occurring as a result of the penetration of meteoroids in the terrestrial atmosphere can be used for the study of meteors. The effect of magnetic field variation during the flight of meteors was for the first time discovered by Kalashnikov (U.S.S.R.) in 1949, and recorded by means of the fluxmeter (**66**). On the other hand, no magnetic effect could be found by Hawkins (**67**). In 1960 Jenkins and Philippe (Denver, U.S.A.) who made observations on frequencies 1 to 5 cycles per sec by means of instruments with a sensitivity of $1{\cdot}5 \times 10^{-8}$ gauss, confirmed again the presence of meteor magnetic effects (**68**). The radio-emission of meteors is also observed at frequencies of the order of 30 mc (**69**).

Visual observations

In spite of the development of instrumental methods, numerous amateur astronomers continued visual observations of meteors in different countries. Visual observations in combination with instrumental determinations gave interesting results about the luminous energy of meteors, their number, the structure of streams etc. Information about the visual observations of meteors was obtained from Austria, Canada, C.S.S.R., Denmark, Holland, Japan, South Africa, Sweden, U.S.A., and U.S.S.R. Lindblad (**70**) gave a summary of 300 visual observations of the bright fireball of $-6{\cdot}6$ mag. which flew over the southern part of the Scandinavian peninsula on 1954 January 9 (**74**). Olivier on the ground of 294 000 visual observations obtained in 1901–58 published a catalogue of the numbers of meteors for every hour of the night for a whole year. Reduction of these numbers to the standard observer was introduced (**71**). Nielsen prepared for press a catalogue of 1200 fireballs, contining 600 fireballs from the Niessl-Hoffmeister catalogue. Kresak (Slovak Academy of Sciences) communicates about his attempt to organise, in Europe, international observations of Geminids, aimed to determine the dependence of the number of meteors upon the zenith distance of the radiant, undertaken in December 1958, but yielding no result owing to cloudiness at a majority of the stations. There had only been a clear sky at Skalnaté Pleso (C.S.S.R.), where five observers have registered 1312 meteors on 1958 December 12/13. From these observations it was obtained that in the dependence of the number of meteors upon zenith distance ($N_z = N_0 \cos^n z$) the exponent $n \approx 1{\cdot}5$. In September 1958 simultaneous visual observations aimed for the study of systematic and random errors were also made at Skalnaté Pleso by a group of six observers. The total number of visual observations obtained in C.S.S.R. (Praha, Plzeň, Ondřejov, Chlumec, Brno and Skalnaté Pleso) during 1957–59 from 121 observers is 8248.

A group of Dutch observers continued to publish the orbits of fireballs in the journal *De Meteoor*. Collective observations of meteors by amateur-astronomers were conducted in the U.S.S.R. at the sections of the All-Union Astronomic and Geodetic Society in Simferopol, Moscow, Riazan, Riga, Odessa, Kiev, and also by special groups in Ashkhabad and Stalinabad. About 25 000 observations were obtained during 1958–60. The general catalogue of observations and analysis of the results are under preparation. Some results of the many years series of 15 000 observations obtained by I. S. Astapovitch in Ashkhabad have been published (**72**).

Telescopic observations

Telescopic observations of meteors were carried out in Ashkhabad by means of the 30×12 binoculars 'Asemby'. Observations of 1232 telescopic meteors gave the mean hourly number of $3{\cdot}8$ in the zenith, which corresponds to the flux intensity of telescopic meteors $0{\cdot}2$ hours^{-1} km^{-2}. From his observations in Tchardjou (Turkmenian, S.S.R.) of 155 telescopic meteors Stepan deduced 17 radiants (**73**). Telescopic observations were also obtained by Terentjeva in Kiev (**74, 75**). She found that the curve of the meteor numbers decreases close to 10th magnitude. The same was noted by Astapovitch in Odessa in his observations of meteors up to +15th magnitude, by means of the 485 mm (20-inch) reflector. Wide angle 10×80 binoculars and Somet-binoculars of 25×100 were used in C.S.S.R. for telescopic observations. The number of telescopic meteors and their heights (80-100 Km) had been determined. The total number of telescopic meteors recorded by 175 observers in 1957–59 was 8074. In Johannesburg (South Africa) the group of observers of artificial earth satellites used for the observation of meteors up to +8th magnitude, the highspeed 50 mm (2-inch) telescopes of short focal-lengths with the field of 12°5.

PHYSICS OF METEORS

It is now possible to obtain cosmic velocities in laboratories. This caused an essential progress in the physical theory of meteors. The series of lectures read by Öpik in Maryland university (U.S.A.) gives a general idea on the state of this problem three years back (**76**). Recent progress in this domain is described in individual papers on particular problems in meteor physics. The foundations of the physical theory of meteors, developed earlier (Levin, Hoppe), were the subject of discussion (**77, 78, 79**), which shows the necessity of a further essential development of the theory in its present stage.

A successful attempt to produce models of meteoric phenomena was realized by means of firing from the 'Aerobee' rocket, at certain heights and with high velocity (up to 10 km/sec), aluminium bodies, using cumulative charges. On the basis of these and also the laboratory experiments McCrosky calculated the lower limit of the light output of aluminium in meteoric processes (**80**). By comparing theoretically the light output of aluminium with that of meteoric matter, he established the lower limit of this value for meteors, which is close to the later estimates by Öpik and is an order higher than the upper limit estimated by Cook and Whipple (**81**).

Artificial satellites of the earth represent a peculiar model of large meteoric bodies in their entrance into the comparatively dense layers of the atmosphere. Thus, during its fall of 1958 April 14 the U.S.S.R. Sputnik 1957 β shone like a fireball of -10th magnitude. Its luminescense lasted 3·5 mins, in the course of which the satellite passed the distance from New England to the Gulf of Mexico, then burst into a swarm of fragments and fell into the Caribbean Sea (**82**). The luminosity of the protective cone of the first Soviet sputnik could probably be observed early on 1957 November 25, over Finland and Estonia (**83**). Astapovich observed on 1960 December 2 a fireball of -8th magnitude caused by the combustion of the cabin of the third Soviet cosmic ship. Its blast into a swarm of fragments 300 m in diameter occurred over the Black Sea at a height of 35 km.

Zotikov studied the process of formation of regmagliptes by fusing meteoritic matter with supersonic velocity by means of an air current. A velocity of Mach 2·8 was reached as a result of this experiment and the temperature of the meteoritic matter reached 2800 °K (**84**). Laboratory heating of meteorite samples from museums was carried out by Manning for the study of their structure and hardness. He found the ablation velocity of matter from the surface of meteorites constituting 1-2 mm/sec (**85**). Several tons of museum samples of meteorites were used by Rinehart for his ablation studies (**86**).

The mechanism of the formation of a thin film on the surface of meteoric bodies was studied by Lees (**87**). At a definite viscosity of meteorite matter, evaporation is practically absent and only air erosion of the film takes place. The intensity of the erosion decreases with the penetration of meteoric bodies into the lower layers of the atmosphere and their deceleration. At a velocity of 4·66 km/sec the film is absolutely stable and forms the solid crust, characteristic of meteorites.

The origin of the system of shock waves in the flight of meteoric bodies in the atmosphere and the fall of meteorites was investigated by Staniukovich (**88**) and Markstein (**89**). According to Zinman, dissociation of the atmospheric gases takes place after the passage of the shock wave. As a result of the diffusion of dissociated air through the boundary layer there is O and N recombination, which increases the loss of heat and accelerates the ablation of the meteoric body (**90**). Pointing out the contradictions in the physical theory of meteors, Hoppe doubts

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whether it is possible to calculate parameters of the upper atmosphere, according to meteoric data, because of a number of unknown, unobservable, values contained in the equations of the physical theory of meteors. In his opinion, densities of meteoric bodies less than 1 g/cm^3 are unreal (**91**). Baker investigated the flight of meteoric bodies in the transitional region with account to the reaction of molecules tearing from the body, their scattering and screening. He found the accommodation coefficient to constitute 0·7 and not 1, as had been accepted earlier, and calculated a new value of the resistance coefficient for the ultra-sonic interval (**92**). He calculated also the conditions for the capture by the Earth of meteoric bodies and showed that for their transformation into natural satellites of the Earth they must pass tangentially at a height of 106–110 km. There are about 0·2% of such meteoric bodies from the total amount and they fall on the Earth's surface spiralwise. The fireball procession of 1913 February 9 (Canada-Bermuda) probably belonged to this category of meteoric bodies. Verniani found in his studies the deceleration of meteors at the point of maximum evaporation, where it does not depend upon mass and velocity (**93**).

Using extensive experimental material Krinov demonstrated the scattering and erosion of meteoritic matter and showed that in the regions of meteorite falls micro-meteorites totally covered by the crust of fusion can be found (**94**). The fragmentation of meteoric bodies is noted on a number of meteor photographs. The fireball of the Pribram meteorite (C.S.S.R.) of 1959 April 7, photographed at Ondrejov observatory, fractured into seventeen individual bodies at the height of 44—23 km (Ceplecha). McCrosky finds that nearly one-quarter of Super-Schmidt meteor trails display a wake, *i.e.* luminosity within the shutter breaks, mostly among slow meteors. The wake is produced evidently by the swarm of particles with mass of the order of 10^{-5} g, removed from the meteoric body. The occurrence of the luminous tail of meteors can be explained in the same way. The slower the meteor, the more intense is the wake (**95**). Stepan observed in Tchardjou telescopic double and faint multiple meteors (**96**).

From accurate photographic light-curves of 392 meteors Jacchia has determined the height at which each individual meteor first reached 'absolute' magnitude +2·5 (phot.). He finds that the more massive and bright meteors reach such magnitudes at a greater height—a height increase of about 1·5 km/magnitude. Meteors with long orbits, the aphelia of which are 7 A.U. and more, appear 3 km higher than the meteros of the Jupiter-family. The mean fragmentation intensity of the long-orbit meteors is greater than that of the second ones, which is apparently an indication of the different physical properties of these two groups of meteoric bodies (**97**). Cook has shown that high-velocity meteoroids can become screened by their own evaporation (**98**). Millman and Cook found from the spectrograms of very slow meteors that the systematic increase of their luminosity along the path is caused by nitrogen (**99**). Two systems of nitrogen bands (N_2) were discovered in Ashkhabad (U.S.S.R.) in September 1960, by Lubarsky, in the spectrum of a bright fireball of −9th magnitude. The first positive group of nitrogen bands ($N_2$2PG) gives fourteen lines. In the spectrum of this fireball, iron lines (Fe I) and faint calcium lines (H,K) are also present. By evaporising the powder of iron and stone meteorites, Nichols, Watson and Parkinson obtained 237 lines with which many of the lines previously observed in the spectra of meteors are identified (**100**). According to Millman (**46, 221**) and Halliday (**51**) in the trains of meteors, the spectra of which have been separated from the spectra of the corresponding meteors, the matter is in the atomic state and radiates as a strongly decelerated gas. Lines of the lowermost excitation levels of Fe, Ca, Ca II, Na, and Mg are present in the spectra of meteor trains. Millman and Halliday (**47**) summarized the identifications in all known infra-red meteor spectra and listed 15 atomic emission lines in the infra-red due to N I, O I, and Ca II. Halliday found lines of N II, O II, and Sr II in the spectra of bright Perseid meteors (**101**) and identified the auroral green line O I (5577 Å) in the spectra of eight fast meteors (**49**). He also studied the spectrum of an asteroidal meteor fragment (**222**) which is notable for the absence of all lines of Na, Ca, and Mg.

Cook, Hawkins, Stienon and Whipple determined from the meteor photographs obtained by means of the 48-inch Schmidt camera at Mt. Palomar the width of meteor trajectories for meteors of +1st to +4th magnitudes which is of the order of $1 \cdot 3 \pm 0 \cdot 5$ m, and 3 m for the Geminids. One of the 0^m meteors was found to be much wider and was fragmented at the end into three parts, drifting 20 m apart (**102, 103**).

From other studies related to meteor physics should be mentioned: the "boomerang-effect" noticed by Popova for the bright meteor of 1956 November 12 (**104**); the negative result of the attempt to discover polarisation in the radiation of meteors (**105**); finally the determination of heights, duration and intensities of 48 meteor trains photographed with Super-Schmidt cameras in New Mexico, U.S.A. (**106**).

RADIO-PHYSICS OF METEORIC PHENOMENA

The complicated process of meteor ionisation can be going on through the mutual collisions of meteor bodies and the air, photo-ionisation and thermo-ionisation. Different aspects of this process were examined in 1958-60 by a number of authors. Baker points out that the destruction of the meteor body can be compared with atomic diffusion (**107**). Loshchilov applied the theory of atomic collisions to meteoric phenomena and determined the probability of ionization from visual and radio observations (**108, 109**). The latter question was also investigated by Fialko (**110**) and Furman (**111**). In developing Herlofson's theory Weiss found the distribution of the linear density of electrons (α) in a trail (**112**). Flood studied the insufficiently dense trails ($\alpha < 10^{12}$) on super-high frequencies and found that in this case both refraction of radio-waves in the trace and backward scattering take place (**113**).

Kaiser underlines the importance of studying the distribution of ionization along the train. For this purpose the signals from a transmitter should be received by means of several receivers, placed at distances of the order of 1 km between them. Similar observations had already been carried out by Greenhow and Neufeld, who found the linear density in a trail (α) to change strongly at a distance of some kilometres of the path (**114**). In order to investigate the variation of linear electron density, which must theoretically vary with the cosine of the zenith distance of the radiant, Kaiser suggests observations at different heights of the radiant over the horizon and informs that such observations are intended for 1961–2 at Sheffield university. The time of the existence of the ionization train depends upon the turbulence of the upper atmosphere, as had been shown in the paper (**115**). Dokuchaev investigated the distribution of ionized gas in the train at its formation (**116**). Mirtov discussed in his study (**117**) the mechanism of train formation. The resonance effect was repeatedly investigated in radar observations of meteors, as for instance in (**118**). Lazarus and Hawkins completed a theoretical study of meteor ionization to estimate the mass of meteoroids (**119**). They computed the ionizing cross-section of the neutral sodium atom and other elements. Ionization ceased below a threshold velocity of 6 km/sec, which is confirmed by the absence of radio-echoes from satellites during their motion in the upper layers of the atmosphere (**120**). At increasing velocities of meteors from 6 km/sec and higher, the ionizing cross-section increased almost proportionally to the velocity, the ionization curve follows that of the meteor light-curve. The ionization data obtained from radar observations permitted our estimate of the mass of meteoroids, which was found to be 5g for the Geminids of 0^m and 1·7g for the Perseids. These masses tend to confirm the revised Cook and Whipple scale and imply a decrease of 1/40 for the luminous efficiency, from Öpik's early theory, and a decrease of 1/3 from his later estimates. Cook and Hawkins (**121**) have shown that the meteor radar-head echo can be ascribed to ultra-violet radiation from the meteor, as proposed by McKinley and Millman, provided that molecular oxygen is the ionized constituent and that a recombination coefficient of $2 \cdot 10^{-5}$ cm^3 sec^{-1} is adopted for these ions.

The forward scattering of radio-waves by the meteor train, depending upon emission and reception conditions, was investigated by Hines (**122**). The measurement of the radio-echo angle from the meteor was given by Hagfors and Landmurk (**123**). Following Kaiser, Weiss developed the theory of height distribution of meteor radio-echoes. The different peculiarities of radio-wave scattering on meteor trains were studied by the military and scientific institutions of Canada in relation with the Janet scheme (**124-128**). This problem is successfully progressing, which is seen from the fact that the A.R.S. (U.S.A.) is broadcasting on meteor trains, by means of a sharply directed aerial, 2000 words per minute over 1500 km at a frequency of 40 Mc/s and a power of 20 kw.

The observed duration of ionized meteor trains is several orders shorter than the value given by the simple diffusion theory. It must therefore be considered that electron attachment plays a considerable part. According to Manning two trains are produced by the meteor—a neutral and an ionized one. Thus gaseuous-kinetic diffusion is going on at first, and then, after expansion of the trace up to about 14 free-path lengths of the molecules, electron attachment starts and the diffusion becomes ambipolar (**129**). Murray attempted to find the dependence of ambipolar diffusion upon height, but this dependence was found to be rather insignicant (**130**). The studies by Davis and his collaborators are also devoted to the problem of electron adhesion (**131**).

The decrease of the light intensity of meteoric traces had also been studied by Hawkins and Howard on the photographic trail of a bright meteor obtained with the Super-Schmidt camera. The velocity of magnitude variations with time (dM/dt) differs with height, the minimum value being observed at 92 km (**132**). Astapovich noted that one of two similar meteors of the same shower produces a stable and the other a non-stable train, which is explained, according to his opinion, by the inhomogenity of the ionosphere at a height of 100 km and more. Kashcheyev, on the other hand, showed in his studies of meteor radio-echoes that the degree of ionization in the E layer has an insignificant influence upon the duration of the reflection (**133**).

The duration of the reflections must also be connected with atmospheric turbulence, which scatters the trace mechanically. The influence of turbulence upon the height distribution of sporadic meteors is being established by Weiss (**134**). Booker showed the main properties of meteor echoes—the amplitude distribution and fluctuation velocity—to be explained by the turbulence phenomena (**135**). Greenhow evaluates the power of turbulence to be 70 ergs. sec^{-1} per gram of air (**136**). Greenhow and Neufeld studied 100 pairs of meteoric echoes, obtained on two receivers, and found that at heights of 80—100 km turbulence exists with a horizontal scale of 150 km and a vertical scale of 6 km, with a vertical wind gradient of 25 m sec^{-1} km^{-1} (**137**).

METEOR PHENOMENA IN THE ATMOSPHERE

Optical observations of meteor trains are a supplement to the radar information about them. Gulmedov published data on the drift of meteor trains over Tukmenistan (**138**). Gulmedov and Savzukhin in Ashkhabad and Shodijer in Stalinabad obtained photographs of four meteor trains, which are being processed now. Artificial gaseous trains were formed experimentally by means of rockets, which permitted the establishment of diffusion parameters at heights of 128 and 116 km (**139**). Hoffmeister continues to explain the luminous bands in the sky by the intrusion of cosmical dust clouds into the Earth's atmosphere and evaluates their height at 130 km (**140**). Sodium, diffused in the atmosphere at a hight of 85 km, and also diffused calcium, are probably of meteoric origin, their thickness being small—of the order of several km (**141, 142**).

Anfimov arrives at the conclusion, according to photographs of meteors, that the meteor body is not only fusible, but that it also evaporates and diffuses (**143**). This explains the appearance of meteor non-luminous trains and of thin meteoric dust in the upper air. The discussion of Bowen's ideas about the problem of the influence of meteoric dust upon rainfall was continued. The rainfall data of six U.S.S.R. stations were analyzed statistically. The probable period, 31 days, of dust fall was found (**144, 145**). Krivsky and Letfus opposed this point of view (**146**).

ASTRONOMICAL RESULTS

Meteor activity

The number of meteors can be estimated from radar observations in the IGY-IGC period, which are under processing now (**147-154**). Tsesevich gave the theory for the determination of the aerial diagram and of the actual number of meteors, from radar observations (**155**). The activity of sporadic meteors varies according to these data as 1 = 4, being minimum in February and maximum in August. Telescopic observations of meteors in Ashkhabad give a variation in meteor numbers during the year, with the change of amplitude of their number from the autumn to the spring half-year of 1·56 : 1·00. In the southern hemisphere of the Earth the variation of meteors during the year is quite the same as it is observed in the northern hemisphere. König and Olivier published catalogues of meteor activity from visual observations (**156, 157, 158**). The parameter of the luminosity function $\kappa = 1 + 1/N^{m}$, where N^{m}, the number of meteors of magnitude m, was repeatedly established from optical and radar determinations. In Ashkhabad the reduction of the photographs of bright meteors gives, according to Astapovich, $\kappa = 1{\cdot}9$, and from observations with the 30×12 binocular "Assemby" according to Lubarsky $\kappa = 3{\cdot}0$; after some corrections this value is 4·5. From 174 380 radio observations of meteors in Tomsk $\kappa = 2{\cdot}08$ (**159**) and from Kharkov radio observations $\kappa = 2{\cdot}01 \pm 0{\cdot}08$. M. Kresakova investigated the dependence of meteor numbers upon magnitude, for large meteoric showers. She proceeded from the analysis of 48 000 visual observations at Skalnate Pleso and showed in her doctoral thesis that for sporadic meteors irrespectively of solar longitude, $\kappa = 3{\cdot}5$. For the showers, κ is distinctly lower (on average 2·6) and tends to decrease within the telescopic magnitude range. In streams subjected to faint perturbations the bright, large meteoric bodies are concentrated in the nucleus of the shower. In the strongly perturbed streams large meteoric bodies are distributed irregularly. The magnitude separation expected as a result of the influence of the Poynting-Robertson and corpuscular effect is only indicated for the stream of Orionids. Weiss investigates the effect of the group appearance of meteors and arrives at the conclusion that this effect is the result of some physical causes and not of the observational conditions (**160**). The estimate of the total mass of meteoric bodies falling on the Earth constitutes 28·6 million tons per year (Hagel, **161**) according to data obtained from artificial Earth satellites, but according to Soviet determinations (Nazarova) this value seems overestimated. According to Dubin the accretion of meteoric matter constitutes from 13 to 80 thousand tons per day, proceeding from the data obtained by means of artificial Earth satellites (**162**).

It deserves particular mention that from the rocket and satellite data the amount of meteors that fall on the Earth is much greater than had been supposed earlier. According to visual observations from the Earth the most probable total mass of meteors falling on the Earth per year was estimated earlier as a value of the order of 10^3 tons. A value of the order of 10^5-10^6 tons of meteoric matter per year was obtained with the aid of rockets and satellites. This estimate is confirmed by values, which can be calculated on the basis of cosmic dust collection. Thus, Petterson, from observations on the Pacific Islands, supposes a yearly fall on the Earth of 14×10^6 tons of cosmic dust (**172**). On the other hand, proceeding from the analysis of the content of nickel particles in deep-water sediments, the same author considers the amount of meteoric matter, which fell on the Earth in the course of the recent geological period to be

$2 \cdot 4-5 \times 10^3$ tons per year. He also indicates that the fall of meteoric matter on the Earth was going on at least in the course of the total tertiary period, which follows from the findings of iron globules with nickel admixtures in the deep-water deposits (**173**).

Meteoric matter in the solar system

Whipple investigates the problem of the role of solid particles in the solar system (**163**). Fesenkov gives reasons in favour of the point of view expressed by him earlier, that the matter causing zodiacal light is the product of the destruction of comets and asteroids, and is of a dust, and not of an electronic nature (**164, 170**). Walter believes the outer regions of the solar corona to consist of dust particles causing the diffusion of solar rays (**165**). The polarization of the Zodiacal light, indicating the dust nature of particles reflecting solar light was studied by Elsässer and Fesenkov (**166, 167**). Kallman investigated the mass distribution of particles in the meteoric cloud surrounding the Sun (**168**). The part played by the Poynting-Robertson effect in the accumulation of dust particles on the Sun was investigated by Guigay (**169**). Contrary to the Zodiacal light, the Gegenschein may represent, apparently, the gaseous tail of the Earth, as it was for the first time suggested by Astapovich and is confirmed now by the studies of Parijsky and Gindilis (**171**).

The orbits of meteors

A great number of determinations of individual meteor orbits has been obtained in recent years by means of radar. Kashcheyev, Lebedinetz and others determined the mean square error of the velocity determinations (ϵ_v) and of the radiant co-ordinates (ϵ_θ) for different values of the geocentric velocity (V_g), due to the influence of the atmospheric turbulente wind.

V_g	20	40	70	
ϵ_v	$\pm 1 \cdot 2$	$\pm 1 \cdot 1$	$\pm 0 \cdot 3$	km sec^{-1}
ϵ_θ	$\pm 4^\circ 0$	$\pm 2^\circ 7$	$\pm 1^\circ 3$	km sec^{-1}

Determination of the values needed for the calculation of orbits was carried out in Kharkov from three points, located with mutual distances of 7·1 and 4·5 km. The orbits are being calculated according to the known Kleiber scheme by means of digital computers "Ural" (**174**). Fialko at Tomsk also determined the velocities of meteors by means of the radio method (**175**). Proceeding from the study of a large number of orbits of individual meteors Davies and Gill concluded that the orbital eccentricity of individual meteors depends upon their magnitude, *i.e.* their mass (**176**). Many bright sporadic meteors have orbits similar to the orbits of long-period comets. Faint meteors ($7\text{-}8^m$) have orbits of small eccentricities, short-period orbits with periods of the order of one year, which are absent among brighter meteors. Such orbital distribution upon the size of meteorioids can be the consequence of the consecutive combination of the influence of the Poynting-Robertson effect and the attraction of Jupiter.

Jacchia and Whipple obtained precision orbits for 413 Super-Schmidt meteors and analysed these data (**177**). The error in velocity probably does not exceed 0·1% for 173 meteors and 0·4% for 181 others. No hyperbolic meteors have been found among 251 meteors, the velocity of which had been determined with a precision up to 0·2%. Seven hyperbolic orbits from the lower-precision group are unproven. Data by Ceplecha from the photographs of meteors (1955) and by Kashcheyev from radar observations indicate that the existence of meteoroids with hyperbolic orbits is actually probable (**178**).

According to Jacchia and Whipple, the orbital data alone indicate that more than 90%, even more than 99% must be cometary in origin, while the physical data from deceleration and light-curves show no unusual characteristics for the remainder. Lack of an apsidal correlation with Jupiter and a large stream membership (65%) shows that the photographed meteoroids have short life-times of only a few thousand revolutions. Jacchia and Whipple show the possibility of the existence of newly discovered meteoric showers connected with comets (1833 ?, 1947 III, 1826 III??, 1886 I ?, 1858 III Tuttle-Giacobini-Kresak, 1834, 1945 II, 1930 VI, 1770 I Lexell, 1864 II? 1790 I ???, 1779 ??). Hawkins and Southworth find that the majority of radiants, obtained by photography of meteors belong to associations (**179**). They developed the criterion for identifying individual members of weak streams. Radiants of many small showers are scattered on the celestial sphere like the radiants of sporadic meteors. Sporadic meteors represent the last stage in the dissolution of faint showers and with sufficiently precise investigation they could be traced back to well-defined streams and parent comets. Southworth developed a method of studying the dynamical perturbations of the members of a well-defined stream caused by planetary attraction. Ceplecha and Rajchl published photographic determinations of the orbits of 28 meteors, which are considered to be sporadic (**180**). Astapovich shows that many faint meteoric showers known earlier are confirmed photographically (**181**) and that Hawkins in his study (**182**) takes insufficiently into account the observational conditions in his analysis of the catalogues of visual radiants. In Ashkhabad (U.S.S.R.) Proskurina published the continuation of the catalogue of radiants with their geocentrical velocities, found by comparing the physical properties of the meteors from those radiants, with the physical properties of the streams of known geocentrical velocity (**183**). Stepan published the results of his study of the radiants of telescopic meteors (**184, 185**). Some meteoric showers, considered as faint, produced a burst of activity for the investigated period (1958–60). Thus, the α Lyrid shower known earlier produced 450 meteors, 1958 July 15-16, according to visual observations by Martynenko and his group at Simferopol. The active meteoric shower of Phoenicids reaching 100 per hour (1956 December 5) continued to be observed in the southern hemisphere (**186**). Huruhata and Nakamura, who observed the shower from the Japanese expedition ship *Soya* suppose that it is connected with the comet 1819 VI (**187**). The unexpected increase of meteoric activity was also recorded in radar observations as for instance, 1958 March 15, 1959 January 15-16 and February 16 (U.S.S.R.).

From 2529 approximate reductions of the Harvard photographic programme McCrosky and Posen investigated the distribution of orbital parameters (**188**). The mean errors of the determination of the orbital elements are as follows: $i \pm 2°$, $e \pm 0{\cdot}08$; $1/a \pm 0{\cdot}14$ 1/AU; $q \pm 0{\cdot}03$ A.U. They found seven new photographic streams and established their connection with the comets 1739, 1819 IV and 1913 I. Wright finds that the extended great-circle path of radiant motion for meteor showers passes through the Sun's position at the middle of the shower, within the accuracy of the determination (**189**).

Large meteor showers

Quadrantids. The structure of this shower was studied by Kashcheyev, Katasev, and others by means of radar. A large number of small meteoroids are concentrated in the central part of the stream (**190**). Ridley published a summary of English observations of Quadrantids in 1959. Its maximum was noted on 1959 January 3 at 23^h UT (**191**). The active shower of Quadrantids was observed in 1960 visually at Ashkhabad and Odessa and by radar at Kharkov. By using visual observations of Quadrantids for 1838–1954 and Super-Schmidt photographs on 1954 January 3 Hawkins and Southworth found the retrograde motion of the orbital node $-0°{\cdot}6$ for 100 years. Hamid thinks that only a half of this perturbation can be attributed to Jupiter (**192**).

Lyrids. A spontaneous increase in the activity of Lyrids was recorded by means of radar by Kashcheyev, Lebedinetz and others at Kharkov, U.S.S.R. on 1959 April 22-23. An extremely concentrated stream of meteoric particles is present in the Lyrids producing rich showers of short duration at its encounters with the Earth. The density of meteoric matter in the outer zone of the stream is rather insignificant. Wright, Jacchia and Böhm determined the photo-

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graphic ephemeris of the Lyrids radiant. The great circle through the positions of the radiants passes within 6° of the Sun (**193**).

Perseids. Radar observations by Katasev (1960) showed an almost homogeneous structure of the stream in its crosssection. According to telescopic observations by Stepan and others the concentration of small particles in the central part of the Perseids is absent. These data show a comparatively significant age of the stream, the particles of which had been durably influenced by the Pointing-Robertson effect. According to Ridley the radiant of the Perseids is a point from photographic observations. From twenty photographic observations Ceplecha established the change of all elements of the Perseids' orbit with increasing longitude of the Sun (**194**).

Draconids. Evdokimov (Kazan, U.S.S.R.) pre-calculated the Giacobini-Zinner comet perturbations for the next appearance of Draconids in 1959 and reported the results of his calculations at the meeting of the Commission on comets and meteors of the Astronomical Council of the U.S.S.R. Academy of Sciences in September 1959. He pointed out that the central part of the Draconids stream of meteors is displaced by 0·06 A. U. from the Earth's orbit owing to perturbations caused by Jupiter and that the shower must be practically unobservable. The same was concluded by Hasegawa, Japan (**195**). The forecast was confirmed by observations. Radar observations of Draconids were carried out by Nakata in Tokyo on a wave-length of 5·3 m with the aerial directed to the north celestial pole. As with the visual observations in the U.S.S.R. and Japan, the radar patrol of the shower showed the absence of meteors from the Draconids. Meteoric dust was collected at the same time in Norikura (Japan), and the results are being interpreted at present. Katasev investigated the physical parameters of the Draconids and arrived at the conclusion that the particles of this shower are not friable, contrary to the opinion of American investigators (1960).

Monoceratids. According to Kresák this stream with maximum on November 21 is the narrowest one of all streams observed hitherto in more than one apparition. The hourly rate of meteors can reach 3000 in maximum, with naked-eye observations. The association with Comet 1944 I is suggested (**196**).

Geminids. Kashcheyev and Lebedinetz investigated the structure of this shower in 1958. In the central part of the meteoric stream larger meteoroids are present (**197**). Together with Lagutin they determined in 1959 the radar orbits of 298 meteors of this shower (**198**). Analysis of the data obtained has shown that radar permits to obtain orbital elements with practically the same accuracy as photographic observations. Below is given a comparison of the results of determinations of radiant position, geocentric velocity and the orbital elements of Geminids from radar observations by Kashcheyev (1959) and the photographic observations by Whipple (1954). The data are given for the nodal longitude $\Omega = 260°$.

	Radar, 1959 (Kharkov, U.S.S.R.)	Photographic, 1954 (Harvard, U.S.A.)
α	111°36′	111°35′
δ	32°18′	32°25′
V_∞	36·15 km/sec⁻¹	35·95 km/sec⁻¹
a	1·320 A. U.	1·301 A. U.
e	0·8918	0·8924
i	23°· ±	23°·6
q	0·139	0·141
ω	325°9	324°·3

The slight inaccuracy of the radar determination of individual orbits is compensated by their great number. The reception of meteoric radio echoes from heights of 85–95 km results in their practically inappreciable deceleration. Radar and photographic observations of Geminids both established the systematic increase of the elements a and e with increase of the Sun's longitude during the period of visibility of shower.

Ursids. Bakharev (Stalinabad, U.S.S.R.) established the absence of this shower in 1958 December (**199**) but some Ursids were observed at Springhill (Canada) in that year.

Photograph of the Pribram meteorite fall on 1959 *April* 7. Exclusively interesting material was obtained by Ceplecha and other Czechoslovakian scientists, who succeeded in photographing for the first time on 1959 April 7 the flight of a very bright bolide, accompanied by the fall of a meteorite (**200**). The bolide was photographed on ten plates, three of them were taken with the obturator. The trajectory of the bolide has 241 interruptions at a frequency of 48 intervals per sec. The beginning of the trajectory was photographed at a height of 97·8 km, when the meteorite entered into the atmosphere with a velocity of 20·9 km/sec^{-1}. The trajectory was inclined 43° towards the horizon. At a height of 44—23 km the meteorite successivly fractured into 17 individual pieces. The final height of the bolide was 13·3 km. Its brightness increased from $-0{\cdot}6^m$ at the beginning of the exposure to -19^m at a height of 55 km. From the photographs has been calculated the trajectory of the meteorite in the region of its fall, where four pieces of the meteorite, weighing 4·48, 0·80, 0·42 and 0·105 kg have been found. One of these meteorites was found within 12 m from the calculated point of the intersection of the bolide trajectory with the Earth's surface. The Pribram meteorites are chondrites, and they mainly consist of enstatite and olivine with iron and nickel admixtures. Their fusion core is 0·3 mm thick. The connection between the trajectories of the individual pieces of the meteorite on the photographs and their position on the Earth's surface has been established. The meteorite of 4·48 kg must have been the second piece by weight that reached the Earth. The main trajectory probably belongs to a meteorite of 100 kg, which had not yet been found. The orbit of the meteorite is of the minor planet type: $a = 2{\cdot}424$; $e = 0{\cdot}674$; $q = 0{\cdot}790$; $\omega = 241^\circ{\cdot}6$; $i = 10^\circ{\cdot}4$. The preliminary information about the Pribram meteorite is also published in (**201, 202**) and the results in (**203**).

Bright bolides. Van Diggelen and de Jager at Leyden (Netherlands) chanced to determine photo-electrically the brightness of the bolide of 1953 April 17, which was found to be $-13^m \pm 1^m$, the visual estimate being $-13{\cdot}2^m$ (**204**). Kramer published the results of a study of the photographs of the fireball on 1955 May 11. The fracturing of the meteoric body is seen on these photographs (**205**). The radiant of the fireball (248°, -14°) coincides with the radiant found earlier by McIntosh. Its trajectory (107-75 km) is slightly curved and splintered at a height of 92—80 km, the meteoric body apparently fractured into two pieces. Sonic bolides were observed by Hoffmeister on 1957 December 6, (**206**) and by Delnotte on 1958 May 5, (**207**). In connection with the development of optical observations of satellites the number of observations of bright night soundless fireballs has considerably grown. The atmospheric trajectories of the meteorites Staroje Pesjanje of 1933 October 2, and Pervomayski Poselok of 1933 December 26 were studied by Astapovich (**208**).

THE ORIGIN AND EVOLUTION OF METEORS

The opinion that meteors are of double origin is now the most generally held. The majority of them are products of comet destruction, and the remainder originate as a result of asteroid disintegration. Guigay continued his study of eruption mechanism of dust particles by comets and showed that the nucleus of the Arendt-Roland comet 1956*h* emitted a stream of particles with a rather low initial velocity near perihelion (**209, 210**). Baldet discovered that the spectrum of the second tail of the Mrkos comet (1957 *d*) is of continuous nature and must thus be formed by dust particles leaving the comet nucleus, probably the micro-meteorites (**211**). The same

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conclusion was reached by Baldet and Bertaud on the basis of photometric observations of the Mrkos comet (**212**). Kresak investigated the sputtering influence of the solar corpuscular radiation upon the magnitude distribution of meteors. In showers of early origin the amount of faint meteoroids must respectively diminish. This forecast coincides with observational data and gives a better explanation of them than the Poynting-Robertson effect. The progressive destruction of meteor streams by the corpuscular radiation of the Sun can also explain the observed relative abundances, which contradict the supposition about the scattering of showers as a result of planetary perturbations and the dissolution of their matter into the sporadic background (**213**).

The influence of interplanetary magnetic fields upon the formation of the cosmic dust cloud in the solar system was investigated by de Jager, who found the electronic density in the asteroid zone $2{\cdot}5 \times 10^3$ per cm^3, the medium turbulence being determined by a turbulent velocity of the order of 1 km/sec^{-1}. Hence the magnetic field intensity in this zone may reach 7×10^{-5} gauss (about 7 gammas), which must influence the accumulation of dust in this zone (**214**).

Ahnert and Schubart investigated the secular perturbations of the Scorpionids-Sagittarides shower caused by major planets and estimated the age of the shower as being 8000 years (**215**). In connection with such low estimates of the possible age of actual meteoric showers, the historical investigation of meteoric activity from ancient observations becomes very interesting. Such are the investigations by Astapovich of the observations in ancient China (**19**), Imoto and Hasegawa of the historical sources of China, Korea, and Japan (**216**). It is assumed that the existence of large meteoric showers observed in antiquity must be of the order of at least 10^4 years.

The discovery by Hawkins and Southworth of meteoriod orbits with $a <$ 1A. U. and with retrograde motion, inexplicable from the genetic point of view, is of considerable interest (**217**). Tables for calculating the secular perturbations of short-period orbits of meteoric showers were issued by Hamid (**218**). Haug established that the distribution of the parameters of the orbits of small particles with dimensions of 10^{-3} cm contained in the zodiacal light do not differ from the distribution of much larger meteoric bodies of 0·1 cm and larger (**219**). The perturbing influence of the Earth upon the meteor streams, which leads to the scattering of meteoric swarms at their encounter with the Earth and their focusing into anti-radiant direction was investigated by Makovezky (**220**).

RECOMMENDATIONS

1. To study experimentally in laboratories, as also by means of rockets and satellites, the physical parameters entering theoretical and analytical work on meteor investigations, namely:

   a. accommodation coefficients for gases and solids in the range 1 eV - 100 eV;

   b. inelastic excitation and ionization cross-sections for atom-atom collisions;

   c. the macroscopic behaviour of the excitation mechanism (air-density dependence of the luminosity-producing mechanism).

   (Proceedings of Commission 22 of 16 August 1958).

2. To undertake special radio-echo observations of meteor numbers, simultaneously with the recording of micro-meteorites using artificial Earth satellites (AES) (*ibid.*).

3. To realize continuous registration of micro-meteoroid impacts, by means of AES, along th whole orbital ellipse, preferably in a nearly circular orbit of low height and low inclination to the ecliptic, in order to obtain information on the distribution of micrometeoroid orbits in space (L. Kresak).

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4. To record, on AES, impacts with discrimination according to impulse, in order to judge the mass distribution of meteoric bodies and the real amount of interplanetary matter in cosmic space (L. Kresak).

5. To record, on AES, impacts with micro-meteoroids in periods of maximum activity of major meteor showers, desirably with a low orbit of the satellite, and with the pole lying near the plane perpendicular to the direction of the apparent radiant (L. Kresak).

6. To determine, on AES, simultaneously the momentum and energy distribution of the impacts of micro-meteorites, and to extend the range of sizes of the bodies studied (T. Kaiser); to determine separately the mass and velocity of micro-meteorites by means of sputnik and rocket experiments (Zd. Ceplecha).

7. To realize the study of the physical properties of the first suitable bright comet, using direct measurements by means of a cosmic rocket which penetrates to the comet (Zd. Ceplecha).

8. To use meteor trails simply as radar targets of the absorption and magneto-ionic effects in the D-region of the ionosphere (T. Kaiser).

9. To combine photographic, radar and spectral observations of meteors to obtain complete data of individual meteors, mainly with respect to the physical processes of meteor flights (Zd. Ceplecha).

10. To study meteor radar echoes in the atmospheric regions of strong auroral luminosity and ionization, which may reveal new phenomena (S. Chapman).

11. To publish deceleration data for every point on meteor photographs and not only as coefficients of an analytical formula (I. Astapovich).

12. To pay attention to the precise determination of the parameters of meteors with hyperbolic velocities resulting from instrumental data (I. Astapovich).

13. To collect cosmic dust and micro-meteorites from interplanetary space to learn their composition, from, and other properties, including the manner and extent of polarization of light incident on them (S. Chapman).

14. To study the influence of interplanetary dust in promoting recombination of ions and electrons, or atomic combinations and reactions (S. Chapman).

15. To advance participation of investigators in different parts of the Earth in the activity of Commission 22, considering the local nature of meteor phenomena (A. Nielsen).

16. To realize the same programme of simultaneous photographic and radar studies of meteors in different latitudes, for comparative study of the physical parameters of the upper atmosphere (V. Fedynsky).

17. To introduce a systematic programme of meteorite photography with all-sky cameras equipped with rotating shutters and distributed at mutual distances of 100 km (Zd. Ceplecha).

18. To realize a wider distribution of meteor wind equipment to yield the large scale circuation in the 80-100 km region (T. Kaiser).

19. To ensure that amateur astonomers do not become discouraged or indifferent to visual observations of meteors for the determination of the hourly rate and magnitude distribution, and for the study of fireballs and persistent trains (Proceedings of Commission 22 of 18 August 1958).

V. FEDYNSKY
President of the Commission

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