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METEORS

-USSR-

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1. The Development of Meteoric Astronomy in the USSR

In the forty years since the Great October Socialist Revolution, the science of meteors, as all of the natural sciences in the Soviet Union, has been developing intensively.

Meteors are defined as cosmic substance in a fragmented and pulverized state. At the present time the study of meteors is attracting the attention both of astronomers and geophysicists. The astronomers study meteoric matter in connection with important problems involved in the structure and evolution of the solar system, as well as the processes of accretion and disintegration of matter within it. In addition to this, astronomy is directing ever greater attention to the dust material in the Galaxy, viewing it along with the masses of interstellar gas either as a destruction product of existing large celestial bodies, or as a possible "matrix medium" for the birth of new universes. The geophysicists look upon meteors as cosmic bodies whose irruption into the upper layers of the earth's atmosphere affords a means of studying the physical properties of these layers, and also of observing air currents at high altitudes.

In addition to all of this, the meteors significantly affect the state of the upper ionized atmospheric layers, while the precipitation of fragments from destroyed meteoric bodies on the earth's surface is continuously increasing the mass of our planet. According to the latest available data, including those obtained with the aid of high altitude rockets and artificial earth satellites, the daily increase in the earth's mass as a result of the precipitation of meteoric matter is on the order of hundreds of tons.

After the launching of the Soviet artificial earth satellites and Soviet cosmic rockets had opened a new era in the history of the human race - the era of space conquest, the meteors are attracting the attention of researchers as a medium in which the motion of artificial earth satellites and interplanetary rockets takes place.

Scientific interest in meteors has grown considerably over the last several decades. This fact explains the progress in the field of meteoric astronomy in many countries, in particular and especially in the USSR.

Up until the middle of the nineteenth century, astronomers tended to regard meteors as a curiosity. The only records of meteoric phenomena having scientific significance were made incidentally in various chronicles and historical writings. In 1832, an amateur astronomer in the city of Kursk by the name of F. Semenov, suggested a hypothesis on the connection with comets of meteors in the Leonid stream, whose abundant appearance was first observed by him in Russia. In 1874-1894, the great Russian astronomer F.A. Bredikhin laid the foundations of our national cometary and meteoric astronomy. He organized meteoric observations at Moscow and Pulkovo, and developed bold and original views as to the disintegration of comets and the formation and evolution of meteoric streams. His works in the field of meteoric astronomy constituted a major contribution not only to Russian, but also to World science. Later, V.K. Tseraskiy, P.K. Shternberg, I.I. Sikora, S.P. Glazenap, G.A. Shayn, S.N. Blazhko, and other scientists worked successfully in the field of meteoric astronomy. These studies prepared the ground for the extensive development of meteoric astronomy in the USSR after the Great October Socialist Revolution.

During the period from 1925 to 1941, research in the field of meteoric astronomy began to develop, sporadically at first, and then ever more systematically at the following Soviet scientific institutions: at the State Astronomical Institute imeni Shternberg, the Institute of Theoretical Geophysics of the USSR Academy of Sciences in Moscow, and at the Leningrad, Tashkent and Stalinabad Observatories. Soviet researchers have gone over to the planned organization of scientific research in meteoric astronomy, developing the theory and methods of observation in a field of astronomy which at that time had not yet reached a high state of development. Amateur observations, which are of a definite scientific significance in meteoric astronomy, were conducted successfully at the All-Union Astronomical-Geodetic

Society.

Scientific ties among Soviet meteor specialists began to develop in 1929, at first in the form of colloquia, and later in the form of conferences on cometary and meteoric astronomy. There were three such conferences prior to the start of the Second World War - in 1935, 1937, and 1939. In 1937, a Commission on Comets and Meteors was created within the framework of the Astronomical Council of the USSR Academy of Sciences; this agency is the co-ordinating center for scientific work being carried on by organizations and individuals in this field. The number of published scientific works on meteors, which appeared largely in the Soviet scientific periodicals, have grown considerably. The representatives of Soviet meteoric astronomy were admitted into the Commission on Meteors (No 22) of the International Astronomical Union. In addition to this, Soviet specialists on meteors have established international scientific ties.

The basic trends of Soviet research on meteoric astronomy prior to 1941 were the following: the thorough development of methods for the visual and photographic observation of meteors (V.A. Mal'tsev, N.N. Sytinskaya, I.S. Astapovich, K.P. Stanuykovich); the development of the theory of meteor penetration into the earth's atmosphere (V.G. Fesenkov, N.M. Shtaude, V.P. Vetchinkin, B.Yu. Levin); the study of the physical properties and air currents in the upper atmospheric layers (I.S. Astapovich, K.P. Stanuykovich, V.V. Fedynskiy); the study of the effects of meteors on the state of the ionosphere (N.A. Ivanov); the study of the astronomical conditions of meteorite precipitation (L.A. Kulik, Ye.L. Krinov); the study of cosmic problems - the structure of meteoric streams, the connection between comets and meteors, and the evolution of meteoric streams (S.V. Orlov, V.A. Mal'tsev, T.V. Vodop'yanova, I.S. Astapovich). It should be realized that this brief list includes only the main research trends and the names of a limited number of scientists.

The war which began in 1941 interfered with the development of meteoric astronomy, as happened in the case of many branches of natural science whose results could not be directly applied in the heroic arms struggle of the Soviet People against the foreign invaders. The war was responsible for the destruction of a number of old astronomical centers and forced the evacuation of some scientists to the East. Meteor specialists G.O. Zateyshchikov, L.A. Kulik, and B.M. Mashbits fought selflessly in the front lines and gave their lives for the victory of the Soviet People. K.A. Voroshilov died of a serious illness while working in one of the defense industries. Soviet scientists will always preserve a warm rememberance for these war victims.

Despite these difficulties and losses, meteoric astronomy in our country continued to develop, since Soviet people believed firmly in the righteousness and final victory of the cause of the Great October Socialist Revolution. During the years of the Second World War, Soviet scientists undertook several new research programs in meteoric astronomy and created new research centers at Ashkhabad and Alma-Ata.

After the end of the Second World War, the development of studies in the field of meteoric astronomy began to move forward at an accelerated pace. In several years, the pre-war level of scientific work in this field was regained, and then exceeded. By the time of the fortieth anniversary of the Great October Socialist Revolution, Soviet meteor scientists along with the entire Soviet scientific community were already engaged in efforts to find the solution to the problem of overtaking and surpassing the level of World science.

Of great importance was the concentration of work at several scientific research institutes, which seriously took up the problems of meteoric astronomy in the post-war years.

In the first place in this connection, one should mention the Stalinabad Observatory, now the Astrophysics Institute of Tadzhik SSR Academy of Sciences. Organized in 1932, the Stalinabad Astronomical Observatory became concerned with the study of meteors as one of its main scientific objectives. In 1938, the first Soviet meteor tracking station was set up at this institution. Over a period of many years, the director of the Observatory, A.V. Solov'yev, devoted a great deal of attention to the organization of work on meteoric astronomy. The meteor study team in Stalinabad (P.B. Babadzhanov, L.A. Katasev, A.K. Sosnova, A.M. Bakharev, V.I. Ivannikov, and others) worked intensely especially in the post-war years. In 1956, the Stalinabad meteor tracking station was considerably improved in accordance with modern requirements. In addition to the construction of a suburban observation station, meteor studies by radar techniques were initiated. As a result of these advances, the Astrophysics Institute of the Tadzhik SSR Academy of Sciences presently occupies a leading position in the field of meteoric astronomy.

Another center for meteor studies was organized at the Physics and Geophysics Institute of the Turkmen SSR Academy of Sciences in Ashkhabad in 1942. A major contribution to the creation and the development of scientific research at this institution was made by I.S. Astapovich. The staff of the Astrophysical Laboratory of the Institute (Ya.F. Sadykov, Kh.D. Gul'medov, V.V. Belous, A.P. Savrukhin, and others) is pursuing many aspects of meteor research by means of visual and radar techniques. At the present time, the staff is beginning to familiarize itself with work at the new observatory constructed in 1957-1958 in the village of Vannovskoye (near Ashkhabad).

Complex meteor studies by photographic and radar methods were initiated in 1957 in the Ukraine. The Odessa University Observatory (V.P. Tsesevich, Ye.N. Kramer, and others) organized the special meteoric station of Mayaki at the mouth of the Dnestr River. The Odessa meteor tracking station was considerably improved during the years 1956-1957. The Kiev University Observatory (A.F. Bogorodskiy, V.P. Konopleva, and others) organized meteor stations at Tripol'ye and Lesniki on the banks of the Dnepr River. The Ukrainian astronomers are devoting the greatest attention to photographic observations of meteors.

Radar methods for meteor studies within the last few years have been developing at the Tomsk Polytechnic Institute (Ye.I. Fialko, E.K. Nemirova, G.S. Zubarev, and others), at the Engel'gardt Observatory (K.V. Kostylev, Yu.A. Loshchilov, Yu.A. Pupyshev, and others), and at the Khar'kov Polytechnic Institute (E.L. Kashcheyev, I.F. Lysenko, B.S. Dudnik, V.F. Chepura, M.F. Lagutin, and others). Especially great successes in this direction have been achieved by the team of researchers at Khar'kov.

The problems of meteor penetration into the earth's atmosphere are being investigated at the Applied Geophysics Institute of the USSR Academy of Sciences (L.A. Katasev, S.M. Poloskov), while the quantitative aspect and distribution of meteoric matter in interplanetary space is being studied at the Earth Physics Institute of the USSR Academy of Sciences (B.Yu. Levin, S.V. Mayeva). The astronomical conditions of the precipitation of large meteorites on the earth are being studied within the scope of the Committee on Meteorites of the USSR Academy of Sciences (V.G. Fesenkov, Ye.L. Krinov, A.A. Yavnel', I.T. Zotkin, and others).

The development of meteoric astronomy in the USSR during the post-war years was also reflected in the level of amateur astronomical observations of meteors. In 1950, a group of young amateur astronomers in Simferopol' created a continuously functioning meteor station; meteoric observations at this facility are systematically carried on by amateurs from the Simferopol' Branch of the All-Union Astronomical-Geodetic Society, as well as by visiting amateurs from the Moscow, Sverdlovsk, Ryazan', and other branches of the Society.

The mutual intercourse of Soviet meteor specialists became more lively during the post-war era. The Commission on Comets and Meteors of the USSR Academy of Sciences Astronomical Council held its plenary sessions IV-VII in 1951 (Kiev), 1952 (Stalinabad), 1955 and 1957 (Odessa). The plenary meetings of the Commission attracted large numbers of participants (up to 100 and more). These conferences aided in the development of general research plans on a nationwide scale, and stimulated the activities of separate scientific institutions in the field of meteoric astronomy. The non-periodic publication of a Bulletin of the Commission on Comets and Meteors was begun in 1956. There was likewise a sharp increase in the number of published works on meteoric astronomy appearing in the periodic press. A number of monographs on meteors was published during the post-war years. The classic works of F.A. Bredikhin were reissued in an edition edited by A.D. Dubyago.

Soviet meteor specialists have considerably expanded their ties with foreign scientists. In 1954, Leningrad was the scene of an International Symposium on the Problems of Cometary and Meteoric Astronomy. Soviet scientists also took part in the International Symposium on Meteors in Manchester (England, 1954), in the International Conference on the Study of Interplanetary Matter at Jena (German Democratic Republic, 1957), and visited the meteor observatory of the National Research Committee in Canada (1957).

Foreign meteor scientists from Czechoslovakia, Bulgaria, the German Democratic Republic, Great Britain, France, the U.S., Canada, Japan, Sweden, Australia, and New Zealand, have visited the Soviet Union in the post-war years, taking part, in particular, in various conferences on meteoritics, the meetings of the Commission on Comets and Meteors, as well as the General Assembly of the International Committee on the International Geophysical Year and the Tenth International Astronomical Congress. Thus, the development of Soviet meteoric astronomy after the war, especially over the very last few years, took place under conditions of ever expanding contact among Soviet and foreign scientists.

2. Research Techniques

Experimental studies of meteors in the USSR are conducted by visual, photographic and radar methods. In addition to this, there have been sporadic attempts made at employing magnetic measurements, the radiation emitted by meteors, and other possibilities in this area.

Visual observations of meteors have been widely employed in the USSR. Of especially great value are the approximately 20,000 observations carried out by I.S. Astapovich and his associates according to a special maximal program under conditions of an almost constantly clear and transparent sky at Ashkhabad (1942-1952). Visual observation errors were studied in the laboratory and directly by means of the observational materials; this permitted the delineation of criteria for the processing of observational results.

Despite the considerable systematic and incidental errors of visual meteor observations, the possibilities of this type of work are extremely varied and have not yet been exhausted even now with the advent of instrumental research techniques. Comparatively simple visual observations in conjunction with instrumental methods afford important supplementary information on meteors. The systematic organization of such observations, including the participation of amateur astronomers, is still a timely endeavor from the scientific standpoint.

Telescopic visual observations of meteors have received considerable development in the USSR, particularly in connection with the wide distribution of short-focusing, single lens-power instruments designed for observing artificial earth satellites. The simple methodology involved in these observations has been described in a number of works. Such observations have given valuable data as to the quantity and altitudes of meteors of 6-9 stellar magnitudes.

The photographing of meteors in the USSR has been going on since 1932, when the first determinations were made of the velocity deceleration of a bright meteor according to a photograph obtained by means of an obturator. In 1938, the first meteor tracking installation consisting of four aggregates with 28 short-focusing cameras each was installed at the Stalinabad Observatory. This installation was used for many years in the systematic photographing of meteors, until its replacement in 1957 with a new and improved facility.

In 1956, the designing bureau of the USSR Ministry of Higher Education and the "Kinap" Factory created under the direction of Ye.N. Kramer a standard tracker, which satisfied modern requirements and featured comparatively simple design and inexpensive optical components. Four such complete trackers had been installed by the start of the International Geophysical Year at the observatories in Odessa, Kiev, and Ashkhabad. Each tracker consists of two fixed aggregates installed at the ends of a 25-40 kilometer base line. Each of the two aggregates in a patrol combination has four single lens-power photographic cameras with F = 1: 2.5, D = 100 millimeters, with automatic plate transport on a film roll, and featuring automatic shutters and printing chronographs for the precise recording of moments of operation with the cameras. One of the aggregates is supplied with an obturator with a variable cross-section vane and precision control mechanism for regulating the speed of obturator rotation.

Methodological problems of meteoric photograph processing are described in the monograph of L.A. Katasev, and also in a number of articles. Many of the results obtained in photographic meteor observations, including photometric studies, have already appeared in print.

Photometric studies of meteoric photographs required the development of techniques for measuring brightness which would take into account the differing velocities of the comparison stars and the meteors. A special facility for the measurement of photometric meteor images on photographic plates was constructed at the Stalinabad Observatory.

Meteor spectrograms are obtained with the aid of short-focusing, low-dispersion prismatic cameras. All of the spectra studied so far belong to the stony class of meteoric particles.

Within recent years, the observation of meteors by radio methods has assumed extremely great importance. One of the outstanding achievements in this area was the application of radar in the observation of the star shower caused by the appearance of the Draconids in 1947; on this occasion, it turned out to be possible to trace the maximum of the phenomenon after sunrise in full daylight.

The study of changes in the state of the atmosphere in connection with the penetration of meteors therein was initiated in the USSR as early as in 1930, continued in 1933 during the Draconid star shower, and went on in the post-war years as well. The activities in this area included the observation of sudden cessations in radio communications and special radio noises during meteor lights, the registration of the loudness of reception at remote radio stations, ionospheric probes, as well as the study of variations in the geomagnetic field.

Radar observations of meteors underwent especially great development during the time of the IGY (International Geophysical Year). Meteoric observations by means of radar according to the IGY program were carried out at the Astronomical Observatory of Kazan' University, the Khar'kov Polytechnic Institute, the Tomsk Polytechnic Institute, the

Astrophysics Institute of the Tadzhik SSR Academy of Sciences, the Physics and Geophysics Institute of the Turkmen SSR Academy of Sciences, the Astronomical Observatory of the University of Kiev, and the Astronomical Observatory of the University of Odessa.

The IGY program on meteoric activity studies included the registration of the number of meteors on fixed wavelengths of 4.2 meters and 8.1 meters, the recordings of the time of meteor appearance, the duration of reflection from meteoric tracks, etc. The observations were carried out on days specified in the IGY international calendar, as well as on supplementary (control) days - once in every 3-4 day period. Measurements according to the IGY program were conducted during the period from 1 July, 1957, through 31 December, 1958.

The number of reflections from meteoric tracks registered on the 4.2 meter wavelength on the equipment used varied from several reflections up to 400-500; the analagous range of variation for the 8.1 and 10 meter wavelengths was from 600-1000 to several thousand. The number of prolonged reflections ($t > 1$ second)differed on various days. In general, the number of such reflections observed on the $\lambda = 4.2$ meter wavelengths was 10-20% of the total number.

Since October, 1957, measurements of the geocentric velocity of meteors by the diffraction technique have been carried out under the direction of B.L. Kashcheyev (Khar'kov). Simultaneous measurements are carried out on the $\lambda = 8.1$ meter wavelength of the angular altitude of the reflecting track (with the aid of reception on two half-wave vibrators located at different altitudes).

By means of radar methods, it is possible to determine an entire number of various perameters of the upper atmosphere: wind velocity, pressure, coefficient of diffusion, the altitude of the homogeneous atmosphere, etc.

Over the last forty years, Soviet meteoric astronomy has developed a varied and extensive complex of investigative techniques. At the present time, instrumental methods are being widely and systematically utilized in the solution of the basic problems of meteoric astronomy.

3. Conditions of Meteorite Precipitation

The study of the cosmic conditions of meteorite precipitation represents a problem which overlaps both meteoritics and astronomy proper. The state of this problem is examined in the article of Ye.L. Krinov included in the present collection. For this reason, we shall limit ourselves to several remarks of a general cosmagonic and geophysical character. The intensity of the pulverization and evaporation of meteoric bodies in the atmosphere is so great, that in all probability only those meteorites which have small initial velocities relative to the earth actually do reach the surface of the earth. The greater part of the mass of a meteorite evaporates during its motion through the atmosphere, so that only an insignificant portion of the original mass actually reaches the earth. While still in the atmosphere, meteorites usually lose their velocity which they had while travelling through space, and fall on the earth with a constant velocity on the order of 100-350 meters per second, depending on their mass and dimensions, and forming small indentations on the earth's surface where one usually finds them. There are individual cases, however, wherein meteoric collisions with the earth's surface took place at velocities of over 4-5 kilometers per second. In such instances, a shock wave radiates out from the center of meteor impact, as from a detonation center, which destroys rock formations over a certain area and transforms them into a highly concentrated gas. The sudden expansion of this gas has an explosive effect tens of times greater than would result, were the falling meteorite to consist of some explosive material, such as TNT (see the article on meteorites). At the point of impact of such a meteorite, there is formed a huge funnel-shaped crater. The destruction resulting from the meteorite is intensified by the shock wave travelling through the air, which propagates with great force along the trajectory of the meteorite's flight.

These considerations are of especially great importance in examining the conditions of flight and impact of the enormous crater-forming Tungus meteorite on 30 June, 1908. A comprehensive description of the fall of this remarkable meteorite was published by I.S. Astapovich and later by Ye.L. Krinov (see the article on meteorites), on the basis of data collected by the expeditions dispatched by the USSR Academy of Sciences under the selfless direction of L.A. Kulik, with the participation of Ye.L. Krinov, V.A. Sytin, and others. The enormous explosive phenomena observed during the fall of the Tungus meteorite, comparable only to the effects of a sudden volcanic eruption, lead one to suppose on the basis of the theory of destructive action by meteoritic impact that the Tungus meteorite itself underwent intensive fragmentation and pulverization.

The latest fall of a large meteorite, which took place on 12 February, 1947, in the Far East, the circumstances surrounding which were almost immediately recorded on motion picture film taken from the air and on the earth, provided an interesting body of factual material on the question of the formation of meteoritic craters.

It would not be out of place at this point to note the drawing together of the two scientific fields of meteoritics and meteoric astronomy which has taken place over the last few years, since this was a natural consequence of the expansion of research in the two fields. Scientists are now firmly establishing the singleness of the origin of the entire family of small bodies in the solar system, as a result of which in the next few years one can expect the development of co-operative studies by geochemists, mineralogists, and astronomers, devoted to meteorites, and may await great achievements in the study of the nature of meteors.

4. Meteors and the Upper Atmosphere

The first attempts made in our country to study the parameters of the upper atmosphere by means of meteoric methods were begun in the 'twenties. The first instrumental observations for the determination of the physical properties of the upper atmospheric layers were employed in 1932. At the present time, photographic methods are systematically used for this purpose.

The physical theory of meteors is of especially great importance in the processing of experimental materials. In the USSR the most comprehensive studies in this area were carried out by B.Yu. Levin.

The physical theory of meteors in the earth's atmosphere, developed by B.Yu. Levin (1939-1941), permits one to form a general picture of phenomena which take place during the motion of meteors through the earth's atmosphere. This theory is based on the analysis of two basic interacting processes - evaporation, and the deceleration of the meteoric body. The air current tears off many of the molecules from the meteor, which form the cap of the latter. The permeability of the evaporated molecular cloud (cap) is subject to considerable changes during the time of the meteor's travel, and this fact complicates calculations of the deceleration. The shielding of the meteor by the cloud of evaporated molecules has to be taken into account from the very point of initial inflagration. The greatest fall in the velocity must take place near the end of the trajectory. The loss of mass by the meteoric body proceeds at a very rapid rate, and even at the smallest possible velocity amounts to 9/10 of the initial mass.

Many problems in the physical theory of meteors require experimental study. Of special importance in this connection are the complex photographic observations of the altitude, velocity and character of radioactive emission of meteors.

The most important types of materials in ascertaining facts of the latter variety are spectrograms. A first-class example of an analysis of the photograph of a meteoric spectrum taken on 12 August, 1907, was provided in 1932 by S.N. Blazhko, who made a careful study of prism distortion and carried out two variations of calculations for the values of the line wavelengths. All of the lines in this spectrum increase in brightness during the second half of the flight. Of the 18 lines, 6 can most probably be identified with calcium lines, while 2 are apparently magnesium lines.

Of great interest is the spectrum of a bright meteor taken on 12 August, 1934. Forty-seven emission lines stand out clearly in the spectrum. The 2 brightest ionized calcium lines appear throughout the path of the meteor, while the rest, belonging to iron, chromium, aluminum, and nickel, are exhibited only toward the end of the trajectory.

Radar observations of meteors also can be used for determining the physical perameters of the upper atmosphere. The determination of the diffusion coefficient for meteoric layers with an electron density not exceeding $D < 10^{12}$ electrons/centimeter^3 may be carried out quite easily. At the same time, the change in the diffusion coefficient with altitude permits one to draw conclusions as to changes in the pressure, and to determine the altitude of the homogeneous atmosphere with a sufficient degree of precision for practical purposes.

Calculations of the diffusion coefficient showed that within a definite altitude range the magnitude of the latter changes exponentially. The greater the velocity of sporadic meteors, the wider this altitude range. The magnitude for the diffusion coefficient, measured by B.L. Kashcheyev (Khar'kov, 1958), turned out to be approximately 1.6 times greater than the value obtained from data received in England and the U.S. This result is fully explicable, if one takes into account the fact that the measurements of pressure by means of rockets at altitudes of 80-100 kilometers showed the pressures to be lower than would follow from the measurements carried out in the U.S. and in England.

The altitude of the homogeneous atmosphere, calculated with the aid of the diffusion coefficient, is equal to 6.8 kilometers for an altitude of about 90 kilometers. The first measurements already showed the presence of periodic components in the changes of the velocity components along the N-S and E-W directions. The period is equal to approximately 12 hours.

The meteoric ionization tracks which are the object of radar observations, also permit rather prolonged visual observations with the aid of telescopes or binoculars. The ionization tracks as they arise have a diameter on the order of several hundred meters. Arising in the rarefied layers of the upper atmosphere at an altitude of about 82-90 kilometers, the ionization tracks spread out at a diffusion rate of no less than 10 meters/second.

They can frequently be seen with the aid of a telescope for 5, or even 10, minutes after the flight of the meteor. The tracks are quickly deformed, collapse into ring-shaped forms or puffs, or else simply diffuse. Drifting along with the high-altitude air currents, the track permits a determination to be made of its direction and velocity. The predominant motion takes place in an easterly direction with a velocity of about 70 meters/second. In the evenings the track motions become more intense and irregular; after midnight, there appears a sharp predominance of directions toward the east and a general drop in the drift velocities.

The change in the character of track motion with solar time was likewise confirmed by I.S. Astapovich. He explains the decreased drift velocity after midnight by the temporary cooling of the upper atmosphere, and connects the track drift peculiarities with the solar component of the daily geomagnetic variation and the course of solar activity. The silvery clouds regularly observed in the Northern Hemisphere in the crepuscular light of the summer sunrise, which are possibly connected with the cosmic clouds of meteoric dust, represent another object for the study of air currents in the upper atmosphere, but at the lower altitude range of 80-83 kilometers. The silvery clouds in general drift with a velocity of the same order as the ionization tracks, but in a westerly direction, that is in a direction opposite to that of the meteoric tracks, and they exhibit a velocity decrease after midnight as well as a change in direction in the course of solar time.

All of this testifies to the presence of a closed circulatory system in the air masses of the upper atmosphere. Taking into account the rotational acceleration of the earth, it might be assumed that in the silvery cloud layer (80-83 kilometers), air massses are displaced under the action of a force directed from the pole to the equator, while at higher altitudes, in the ionization track layer (83-90 kilometers), the masses move in the opposite direction. This system of stratospheric circulation is undoubtedly complicated by the presence of local baric anomalies and, in particular, by the action of photonic pressure, as well as electrical and magnetic forces acting in the rarefied medium of the upper atmosphere on the particles within the ionization tracks and the silvery clouds.

5. The Cosmic Nature of Meteors

The heliocentric velocity of meteors which determines whether or not they belong to the solar system, is determined by the following methods: 1) corresponding observations, visual or photographic; 2) periodic recurrences of elliptic meteoric streams; 3) the method of numerical daily variation; 4) the visible displacement of radiants; 5) the connection between geocentric velocities and the observed altitudes. All of these methods were tested in various projects carried out in the USSR.

V.A. Mal'tsev, using a combination of methods (4) and (5) for determining the velocity and orbital elements of the Geminids, obtained some very interesting results. Ten years in advance of the photographic observations carried out by Whipple in the U.S., Mal'tsev showed that the Geminid stream moves around the Sun along an elliptical orbit, and must be of necessity a periodic stream.

A great deal of attention has been devoted in the USSR to the general study of radiants, systematic catalogs of which were published by V.A. Mal'tsev, N.N. Sytinskaya, A.Sh. Muzafarova, L.G. Yeliseyeva, and others. A calculation of the theoretical cometary radiants and a comparison of them with the meteoric radiants was carried out by K.D. Pokrovskiy and G.A. Shayn, and recently by Ye.N. Kramer; this work was to be of special value to future research. Ye.N. Kramer published a catalog of the 280 cometary radiants which he had calculated, encompassing comets (both elliptic and parabolic) observed up to 1948 inclusively, whose orbits pass at a distance of less than 0.3 astronomical units from the earth's orbit. This work includes data on similar meteoric radiants according to the catalogs of Astapovich, Denning, MacIntosh, Mal'tsev, Sytinskaya, and others, and also gives a survey of methods for finding the points of closest approach of orbits and the calculation of cometary radiants. I.S. Astapovich, having compared his unpublished catalog of meteoric radiants with the catalog of Kramer, discovered that there were 26 streams (including the main active streams) connected with comets.

The problem of the connection between meteoric streams and comets, however, cannot be simply reduced to an identification of orbital elements for both objects. Even Bredikhin held to the concept of a sudden, catastrophic character in the evacuation of meteoric accumulations from comets. This hypothesis obliges one to find points of mutual intersection in the orbits of meteoric streams and comets, suggesting the thought that it was at precisely such points that the dissipation of a large aggregate of small bodies into small accumulations had taken place. In order to achieve this end, it was suggested that studies be made of the distribution of the poles of the orbits being studied over the celestial sphere, located in the case of the intersection of the latter along the lesser circles; another alternative suggested was to use the Tisseran criterion.

S.V. Orlov and T.V. Vodop'yanova pointed to the existence of several comet families having intersecting orbits, which must have been formed as a consequence of the catastrophic disintegration of a primary body at their point of orbital intersection. I.S. Astapovich connects one of these families (comets 1748 II, 1790 III, 1844 II, and 1911 VI) with meteorites and meteorite streams, suggesting that the cosmic catastrophe which produced them took place some time in the middle of the eighteenth century.

One of the basic problems of meteoric astronomy has to do with passing on from the observed picture of meteoric phenomena to concepts as to the true distribution of meteoric matter in cosmic space. B.Yu. Levin worked successfully on this problem, and established that the geocentric velocity of meteors considerably affects the conditions of their visibility. He drew a conclusion on the dominant role of sporadic meteors in interplanetary space and made an estimate of the special density of meteoric matter. This estimate was connected by the author with the positions taken in the cosmagonic theory of O.Yu. Shmidt on the formation of the planetary system.

Finally, the complex of small bodies in the solar system includes the cloud of meteoric dust concentrated near the plane of planetary orbits, and visible from earth as zodiacal light. The photometric studies of zodiacal light carried out over a many year period by V.G. Fesenkov, were generalized by him in a number of works, in which he establishes the connection between zodiacal light and meteors moving along elliptical orbits, and presents the theory of the dynamics involved in the phenomenon (see the article on zodiacal light).

The meteoric matter which produces zodiacal light is periodically renewed as a result of the precipitation of meteoric bodies on the Sun under the influence of its photonic pressure. The new masses of meteoric dust which compensate for this loss testify to the mechanism of planetary disintegration which is taking place in our time. The source of this disintegration consists in the explosive action of cosmic collisions (for example, between meteorites and asteroids, or hard masses of material within cometary cores), that take place at a relative velocity of over 3-4 kilometers/second. At a relative impact velocity of 50 kilometers/second, the mass of the totally destroyed asteroid or meteorite can exceed by a factor of 10,000 the mass of the colliding meteoric body.

Simultaneously with the inevitable fragmentation of blocks of solidified matter in the solar system, that is with the disintegration process, there undoubtedly takes place a reverse process of meteoric matter concentration on the large planets. This process of concentration is aided by the strict regularity of motion characterizing the major portion of the mass of meteoric matter in the solar system moving, like the planets, along regular paths.

Thus, meteoric matter takes an active part in the evolution of the solar system; furthermore, this participation is made manifest in different ways at various stages in the existence of this system and at the different locations within it. There is a necessity for further sufficiently extensive and thorough studies of the nature of meteoric matter and its interaction with large bodies in the solar system. The results of such studies will be of great importance to the expansion of our concept as regards the general features of the process involved in the genesis and development of all bodies in the solar system.

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