COMMISSION 22: METEORS AND INTERPLANETARY DUST (METEORES ET LA POUSSIERE INTERPLANETAIRE)

PRESIDENT: P.B.Babadzhanov
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I. INTRODUCTION

As before a number of authors have contributed reviews of their own field. The contributions were editted by the President in order to avoid some overlaps, to reduce the length of the reviews and to add some publications. Reference numbers from "Astronomy and Astrophysics Abstracts" were used when available. In the end of the report a list of references not found in "Abstracts" is given. As editor, the President takes the responsibility for any shortcomings in the report.

The following Proceedings of major meetings and books were published during the last triennium:

"Properties and Interactions of Interplanetary Dust", eds. R.H.Giese and P.Lamy, Reidel, Holland, 1985.

"Asteroids, Comets, Meteors II", Proc. of a meeting held at the Astron. Obs. of Uppsala Univ., June 3-6, 1985, eds. C.I.Lagerkvist, B.A.Lindblad, H.Lundstedt, H.Rickman, 1986.

"Dynamics of Comets: Their Origin and Evolution", eds. A.Carusi and G.B.Valsecchi, Reidel, Holland, 1985.

"Meteors and Their Observations", P.B.Babadzhanov, Nauka, Moskva, 1987 (Russian).

"Meteors, Meteorites, Meteoroids", V.A.Bronshten, Nauka, Moskva, 1987 (Russian).

It is with sorrow that we record the death of a noted meteor astronomer and a member of the Commission Johannes Hoppe.

II. PHOTOGRAPHIC AND TV METEORS — P.B.Babadzhanov

Photographic observations of meteors continued in Dushanbe, Kiev and Odessa. In Dushanbe from July 1984 to December 1986 185 meteors were photographed, 96 of which - from two stations. A catalogue of radiants, velocities and orbital elements for 70 meteors photographed in Kiev during 1967-76 was published by Sherbaum et al. (41.104.027). Kramer et al. (1986) published a catalogue of orbits of meteors photographed in 1953-83 in Odessa. Betlem et al. (40.104.004) have published the results from 18 double-station meteors photographed in 1980-85. Simultaneous TV and radar observations of meteors continued in Dushanbe. For 13 meteors light and ionization curves are found (41.104.037). Jones and Sarma (39.104.008; 39.104.011) published trajectories of 454 double-station meteors in the magnitude range from 0.5 to 8.5 observed with TV system. Jones, Sarma and Ceplecha (39.104.012) have presented the results of a population analysis of meteor beginning heights. Hawkes, Duffy and Jones (42.104.054) and Duffy, Hawkes and Jones (1987) have found a method of obtaining much more information from single-station meteor observations. Hawkes and Jones (1986) have carried out a comprehensive survey of electron-optical techniques used for meteor researches together with the results obtained by these methods. TV ob-

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servations of the Draconid meteor shower were carried out in 1985 by Nagasawa and Kanda (41.104.066). 8 meteors were recorded in total and the shower radiant point was determined as well.

The European EN camera network was in operation during the review period. Fireball phenomena were observed in different countries. Meyer and Steiweeks (42.104.059) described a fireball observed on the 14th of November 1985 in the coast of Lower Saxony. The next day a fragment of a meteorite (chondrite) weighting 43 g was found near Salzwedel (GDR). The summer-autumn fireballs of 1908 observed at middle latitudes of Euroasia have been studied by Anfinogenov and Budaeva (40.104.013) in connection with the Tunguska event. Ognev and Maslenitsyn (42.104.019) presented astronomical and physical data on the fireball observed over the Kirov region of the USSR on 11 September, 1982. An extremely bright fireball was observed on the morning of September 23, 1981 in nearly full daylight in Belgium and also in the Netherland and West Germany during several seconds. Sauval (42.104.068) suggests that the bolid continued its flight without entering the atmosphere. Two exceptional fireballs were widely observed over Alberta in 1985. Folinsbee et al. (42.104.070) has described the Alberta fireballs. Balestrieri and Fontanelli (38.104.015) published a catalogue of fireballs including 257 observations of 1949-82. Rajchl (42.104.021) has discussed the possible causal relation between the overlights of bright fireballs and the occurence of noctilucent clouds in the Northern Hemisphere.

III. RADAR METEORS

C.S.L.Keay

Radar and theoretical studies of the Orionid and Eta-Aquarid meteor showers associated with Halley comet appear now to be in agreement. Cevolani and Hajduk (39.104.049; 40.104.040) presented results supporting the highly elliptical ribbon-like stream structure proposed by McIntosh and Hajduk in 1983 and further refined by Jones and McIntosh (1986). Hajdukova et al. (1986) suggest the presence of two populations of particles in these streams from a reduction observed in the mass index from 2.2 to 1.85 since 1984.

The 1985 return of the Draconid meteor shower associated with Giacobini-Zinner comet was observed by Lindblad (1986) who noticed 0°15 displacement between the stream and comet orbits. The maximum zenithal echo rate of 484 per hour was an order of magnitude less than in 1933 and 1946.

Eighteen years of Geminid observations from Czechoslovakia have been employed by Šimek (40.104.039) to develope a regression method for determining equipment response as well as stream and sporadic meteor information.

Baggaley (39.104.010) has compared seasonal variations in the daily dawn maximum influx of radio-meteors with lower ionospheric irregularities occuring at dawn. Porubčan et al. (1984) report that mean heights and ranges of meteor trails exhibit minima just after sunrise, but could find no relation to the geomagnetic Kp index. Lindblad and Štohl (41.104.022) find mean mid-point heights of 102.2, 93.7 and 95.7 km respectively for Perseid, Delta Aquarid and sporadic meteors.

Comparison of observations at 54, 6 and 2 MHz indicates echo height ceillings of approximately 105, 120 and 140 km respectively, with the number of echoes recorded above 105 km being an order of magnitude greater (Olsson-Steel and Elford, 1986, 1987). This confirms that conventional HF meteor radars seriously underestimate the flux of small meteoroids.

Znojil, Hollan and Šimek (39.104.009) have studied the relation

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between the optical brightness and ionized trail properties of meteors.

As is known the Soviet Union is a sponsor of the International project GLOBMET - Global System of Meteor Investigations - where radar observations are of great importance. Ovezgeldyev et al. (1986) have reported on the GLOBMET tasks and first scientific results. Three papers are dedicated to the method of radar meteor observations. The first paper considers some features of meteor observations when the antennae are directed to the north and south. A different character of diurnal variation of the recorded meteor rate is noted (39.104.033). The second paper (41.036.075) proposes a radar with a rotating aerial to be applied to observations of meteor showers. In the third paper Andrianov (1987) has critically considered the measurements of meteoroid deceleration in the atmosphere by the radio-method.

Physical conditions of radio-wave reflection from ionized meteor trails, diffraction, polarization and resonance phenomena are described in (39.104.045, 048; 40.104.078, 087; 42.104.005;Bayrachenko, 1985).

A great deal of attention has been drawn to the problem of optimum determination of meteor trail parameters according to the amplitude-time characteristics of meteor radio echoes (40.104.038, 075, 085; 42.104.042). From radar observations of more than 100 000 meteors up to $+12^m$ the distribution of heliocentric velocities of sporadic meteoroids is analysed by Voloshchuk et al. (40.104.022). Density distribution maps of radiants of sporadic meteoroids obtained from radar observations in Kazan and at the equator are presented by Pupishev et al. (39.104.042).

The Ottawa (Springhill) 20-kilowatt radar will contribute about 1000 hours of observations of the Eta-Aquarid and Orionid meteor showers. During the intervals in 1986 when the Earth passed through the plane of the Halley comet, the 2-megawatt radar was operated in a search for small particles outside the normal periods of the showers. Results were negative.

It is noted with regret that after thirty years of significant contributions to meteor astronomy, the Springhill Meteor Observatory in Canada was closed in 1987.

IV. METEOR SHOWERS

B.A.Lindblad

During the last triennium observations of the major meteor showers have been carried out by visual, photographic, radar and television techniques. The detection of new meteor showers and/or unexpected recurrences of old showers now largely depends on the efforts of amateur observers. The 1982 Lyrid outburst, the 1985 November Monocerotids and the 1986 Aurigid recurrence were observed by amateur groups. Visual recording by supervised terms of amateur astronomers have been carried out in many countries. For a list of amateur meteor societies and publications see Lindblad (1987a).

General studies of the formation of meteor streams and their subsequent evolution under planetary perturbations have been presented by Emelyanenko (37.104.003, 021; 38.104.006; 40.104.016), Kruchinenko (37.104.039), Karpov et al. (37.104.044), Kramer and Shestaka (38.104.018), Lebedinets (38.104.026; 40.104.076), Fox and Williams (38.104.035), Sukhotin (39.104.018), Katasev and Kulikova (39.104.040), Williams (40.104.041), Froeschle and Scholl (40.104.043), Voloshchuk and Kashcheev (40.104.073), Fox (41.104.010) and Babadzhanov and Obrubov (1986). Gravitational focusing of streams is discussed by Kramer and Shestaka (39.104.037). Šimek (1986) compares the mass index "s" for a number of meteor showers. Lindblad (1987b) lists orbital elements and physical data for 30 major meteoroid streams. Lebedinets (1987) derives density and fragmentation energy for meteoroids from 17 streams. Both authors conclude that the Geminids, Virginids, Delta-Aquarids and Iota-Aquarids are composed of denser meteoroid material than other streams.

A study of meteor streams with orbits inside the Earth's orbit is presented by Simonenko, Terentjeva and Galibina (41.104.007). The concept of a hollow meteor stream is discussed by Jones (40.104.048) and Hughes (41.104.008). Geminid observations by visual observers appear to support this concept (41.104.076). The problem of determining the mean radiant position of more than two meteor trails is analysed by Steyaert (38.104.016). Various selection effects in the observations of meteors are investigated by Andreev (38.104.032), Lebedinets and Manokhina (40.104.026) and Zabolotnikov (40.104.027). Halliday (1987) has described the first known case of a meteorite stream, i.e. two meteorite objects moving in essentially identical orbits. Galibina and Terentjeva (1987) suggest that there is a stream including the Innisfree meteoroid and several fireballs.

Comet-meteor stream associations. Comet-meteor stream associations are discussed by Kulikova (38.104.034), Russell (39.104.023) and Hughes (40.102.047; 41.104.009). Associations between ancient comets and meteor showers are investigated by Kresakova (1986a,b; 1987). A list of theoretical meteor radiants associated with Earth-approaching asteroids and comets is presented by Olsson-Steel (1987a). Radar observations of meteors ascribed to Sugano-Saigusa-Fujikawa comet (1985V) are reported by Šimek and Pečina (38.104.030; 41.104.005). Visual observations 1977-84 of meteors associated with P/Grigg-Skjellerup are reviewed by Lindblad (1986a). The flux of meteoroids in the vicinity of the orbit of Halley comet is investigated by Cevolani and Hajduk (39.104.049) and Hajduk (41.103.638).

Sporadic meteors. The origin of the sporadic meteoroid complex and its contribution to the zodiacal dust cloud is studied by Olsson-Steel (41.104.004). The density distribution of sporadic meteor radiants is discussed by Pupyshev et al. (39.104.029) and Štohl (41.104.019). The theory of determination of the sporadic meteoroid flux is discussed by Pečina (37.104.006) and Bibarsov and Kolmakov (37.104.045). Various selection effects in the observed distribution orbital elements of sporadic meteoroids and the variation of these distributions with heliocentric distance are analysed by Zabolotnikov (37.104.041; 39.104.019; 40.104.004, 010; 41.104.032). The expected distribution of orbital elements of interstellar particles entering the Solar system is investigated by Belkovich and Potapov (40.131.046).

Quadrantids. Long-term radar observations are reported by McIntosh and Šimek (37.104.007), Belkovich et al. (37.104.010) and Isamutdinov (40.104.089). Simultaneous radar observations from several stations are discussed by Simek (42.104.020). The variation of the mass index with date has been studied by Reznikov and Murav'eva (37.104.046) and Isamutdinov (40.104.089).

Theoretical studies of Quadrantid stream evolution have been carried out by Babadzhanov and Obrubov (38.104.012; 39.104.020, 026; 1986), Tkachuk (39.104.002), Froeschle et al. (41.042.012) and Sherbaum (42.104.057). Visual observations of Quadrantids are described by Rendtel et al. (39.104.032).

Lyrids. Radar observations from Ottawa, Ondrejov, Budrio are compared by Porubčan (41.104.011, 068). Budrio radar observations 1983-85 are presented by Porubčan, Cevolani and Formiggini (1986) and the rate profile of the Lyrid shower is delineated. Porubcan and Cevolani (40.104.029) report on a short-lived outburst of Lyrid activity in 1982 as observed by meteor radars.

Extensive visual observations of Lyrid meteors are summarized by Porubčan and Štohl (37.104.019), Betlem (39.104.053), Roggemans (39.104.061) and Wood (39.104.068; 40.104.062). Telescopic observations are described by Jenniskens and Witte (40.104.035).

Eta-Aquarids. Although this meteor stream is ascribed to Halley comet and thus is of current interest surprisingly few observational results have been published. Hajduk and Vana (40.104.028) present a summary of Czechoslovakia radar observations 1969-77. These confirm a previously reported double peak of maximum activity. Australian visual observations in 1984-85 are described by Wood (39.104.067; 41.104.049). Within the framework of the International Halley Watch a number of radar groups (Onrejov, Onsala, Budrio, Ottawa, Dushanbe, Kharkov, Adelaide, Christchurch and elsewhere) have for several years monitored the main period of Eta-Aquarid activity. A preliminary list of participating stations is published (39.104.077). When these results are fully analysed it is expected that our knowledge of the stream and its activity profile will be greatly increased. One problem in studing this stream and its association with P/Halley is the almost complete lack of precise photographic meteoroid orbits on which a computer study of the orbital evolution ultimately should be based.

Delta-Aquarids. Radar visual heights for Delta-Aquarid, Perseid and sporadic meteors are discussed by Lindblad and Štohl (41.104.022).

Perseids. Long-term radar observations of the Perseid shower at Onsala (1953-78) and Ottawa (1958-74) are presented by Lindblad and Šimek (41.104.013) and Šimek and McIntosh (41.104.065). The activity variation with date is studied and the solar longitude of shower maximum is precisely determined. Radar observations 1982-84 in Japan are reported by Maeda (1986).

Zvolankova (39.104.004) presents Skalnate Pleso visual observations for the period 1944-53. Lindblad (41.104.012) presents Onsala visual observations 1953-81. These studies place the Perseid visual maximum slightly later than the radar maximum. The investigations indicate a surprisingly large scatter from year to year in Perseid activity at maximum. Amateur visual observations are discussed by Rendtel et al. (39.104.032), Roggemans (39.104.062; 42.104.005), Palzev (40.104.030), Betlem (40.104.031), Grishchnyuk and Bibnichenko (38.104.033) and Martynenko and Levina (42.104.017). A summary of visual and radar rate profiles is presented by Jenniskens (1986). Perseid meteor counts, heights, magnitudes and spectra are analysed by Russell (39.104.023; 41.104.067).

Taurids. A number of researches are presently undertaking extensive studies of the evolution of the Taurid meteor stream and the relation of this stream to Encke comet and sporadic complex. See papers (42.104.013, 055, 056). The relation of the Taurid stream to Apollo asteroids, the Tunguska object and the Brno meteorite has been discussed by Bailey, Clube and Napier (1986). Visual observations of Taurid meteors are reported by Veltman (1984; 39.104.050).

Draconids. Predictions for a 1985 Giacobinid (Draconid) meteor shower by Yevdokimov (39.103.190) and Yeomans and Brandt (39.103.181) indicated that shower maximum would occur on October 8 between 0.5^h and 13^h10^m. Radar and forward scatter observations showed a short-lived shower with peak activity at 09.35 hrs UT on October 8, 1985 (Lindblad 41.104.003; 1986b; Mason 1986). Radar observations 1985 are reported by Šimek (1986) and Chebotarev (42.104.010). Bronshten (42.104.016) reports on the USSR visual and radar studies. Visual, photographic and TV observations in Japan are described by Koseki (1986), Nagasawa and Kawagoe (1987) and Nagasawa and Kanda (41.104.066). Beech (41.104.061) presents a theoretical discussion of beginning and end heights of Draconid meteors based on photographic observations in 1946. An interesting summary of visual hourly rates recorded during the 1933 and 1946 displays is presented by Veltman and Jenniskens (40.104.034).

Orionids. Radar observations 1981-84 are reported by Hajduk et al. (37.104.005), Belkovich et al. (37.104.010), Cevolani and Hajduk (40.104.040; 1984), Isamutdinov and Chebotarev (41.104.036), Hajdukova et al. (1986), Hajduk et al. (1987) and Milutchenko (1987). Visual observations are presented by Porubčan and Zvolankova (39.104.006), Veltman (39.104.050), Roggemans (39.104.063), Sisonov (41.104.034) and Malysheva and Dubasova (1987). Telescopic observations are reported by Hajduk (42.104.050).

Leonids. Past aparitions of the Leonid shower and the relation to comet Temple-Tuttle are discussed by Kondratyeva and Reznikov (40.104.077) and Williams et al. (41.104.018). The age of the Leonid shower of 1966 is discussed by Kondratyeva (42.104.014).

Monocerotids. The possibility that some ancient fireballs are associated with the present day Monocerotid stream is investigated by Fox and Williams (40.104.047). The analysis of a number of precisely reduced photographic orbits (Lindblad 1987c) shows that the mean Monocerotid orbit agrees exactly with that of Mellish P/comet.

Geminids. Studies of the evolution of the Geminid meteor stream under planetary perturbations have been presented by Ceplecha (37.104.036), Babadzhanov and Obrubov (38.104.012; 1986), Jones and Wheaton (39.104.007), Jones (40.104.048), Hunt, Williams and Fox (40.104.049), Kramer and Shestaka (40.104.076) and Jones and Hawkes (42.104.046). The dispersion of the Geminid stream by radiative effects is discussed by Olsson-Steel (1987b). The spatial structure and age of the stream is investigated by Belkovich (41.104.033), and Kramer and Shestaka (39.104.076; 40.104.001; 42.104.007). Radar observations 1974-76 in Kharkov are presented by Tkachuk (37.104.023). Visual and telescopic recordings are described by Wood (40.104.061), Roggemans (41.104.044) and Jenniskens (39.104.054; 41.104.076). Zvolankova (41.104.069) and Spalding (37.104.012) report on long-term visual observations.

The discovery of an asteroid (3200 Phaethon) moving in the some orbit as the Geminid stream is of great interest. The possible relation to the Geminid stream is studied by Fox, Williams and Hunt (40.104.042) and Hunt, Fox and Williams (41.104.016).

Ursids. Visual observations of the 1984 Ursids are reported by Veltman (39.104.051).

V. METEOR ORBITS

P.B.Babadzhanov

The orbital elements for 454 TV meteors from 0.5 to 8.5 absolute magnitude observed between May 1981 and August 1982 are presented by Jones and Sarma (39.104.011). Both the cometary and asteroidal groups of meteoroids discovered in photographic survey are also given in the TV data. Many of TV meteors have retrograde - orbits with aphelia < 3 A.U. and also a greater fraction of orbits has very small perihelia when compared with Super Schmidt meteors. These features seem to suggest that meteoroid population is in a state of dynamic equilibrium with a source of TV meteoroids reple- s nishing those losses by Jovian perturbations and solar heating.

Orbital elements of 20 photographic meteors were published by Babadzhanov and Getman (40.104.091). Orbital data on about 30 multistation meteors photographed in the Netherlands between 1980 and 1985 are published by Betlem (40.104.005).

Jones and Hawkes (42.104.046) showed that the present duration of the Geminid stream is the result of gravitational perturbations combined with the initial spread in the orbits of the particles ejected from the comet. Jones (42.104.013) on the base of calculation of the evolution of the Taurid stream complex computed the age of the stream to be about 10^5yr.

Fox (41.104.010) calculated the orbital evolution of 53 meteoroid streams and concluded that of the 53 streams observable at present approximately half are no longer in Earth-crossing orbits either one thousand years in the past or the future.

Froeschle and Scholl (41.104.017) investigated the dynamical evolution of the Quadrantid-like meteoroid stream orbiting the Sun in 2/1 mean motion resonance with Jupiter. They concluded that highly inclined streams located in resonance center may give a rise to the formation of arcs.

Babadzhanov and Obrubov (1986) showed that planetary perturbations change strongly the stream shape due to the initial dispersion in orbital elements of meteoroids ejected from the parent body. This causes the streams to become much thicker and produce several couples of showers active in different seasons of the year. For instance, the Geminid stream can produce four showers, and the Quadrantid stream is predicted to produce eight showers.

VI. PHYSICAL THEORY OF METEORS AND FIREBALLS D.O.ReVelle

The work related to meteor modelling has been carried out by Novikov et al. (37.104.001; 38.104.003; 38.104.013; 39.104.024), Kovshun (37.104.013), Kramer et al. (37.104.020), Kalenichenko (38.104.020), Beech (38.104.023; 41.104.061), Jones et al. (39.104.012), Nicol et al. (39.104.001), Novikov and Blokhin (39.104.017), Babadzhanov et al. (39.104.041), Kalenichenko (40.104.008), Bronshten et al. (40.104.017), Lebedinets (40.104.019), Apshtejn and Shevoroshkin (40.104.021), Andreev and Ryabova (40.104.023), Vislaya (40.104.025), Beech (41.104.061), Sekanina (1985) and Fyfe and Hawkes (42.104.069).

Much work has continued on the detailed physical modelling of the meteor phenomena. The efforts of Lebedinets, Babadzhanov and colleagues describe the fragmentation process as being quasi-continuous including deceleration as well. A comparison of the theory and observations has allowed various fragmentation parameters to be derived from the observations. Hawkes and colleagues have worked on the problem of calculating the residual mass remaining after the ablation of very small meteoroids - the classical micrometeorites considered by Whipple in the early 1950's. The goal of this work has been, in addition, to develope a better model of the entry process, to check the grain model of Hawkes and Jones (1975) and to relate the residual mass to the collections of Brownlee and others of this debris. Beech has shown that there is a reasonably good agreement between the theory and observations with the exception that meteors are even more fragile than assumed in the theory of Hawkes and Jones. Kovshun has continued his work on the meteor light generation process and Kalenichenko has considered the light production from the liquid meteoroids. This could have implications for the theory of small water comets impacting in the upper atmosphere following the work of Frank, Sigwarth and Graven. Sekanina (39.103.182) has studied the Draconids in relation to its parent Giacobini-Zinner comet and interpreted the Draconids in terms of the porous meteoroid model of ReVelle rather than the grain model of Hawkes and Jones.

The work related to fireball modelling has been carried out by Pečina and Ceplecha (37.104.009), ReVelle (37.104.026; 1985), Ceplecha (37.105.055; 39.104.056; 40.104.020; 41.104.020; 1985), Ouyang and Heusser (37.105.010), Halliday, Blackwell and Griffin (37.105.194), Gendzwill and Stauffer (38.104.021), Rietmeijer and McInnon (37.105.248), Padevet (37.105.136), Jha (39.105.105), Wetherill (39.105.212; 1986), Kyte and Brownlee (39.105.202), Padevet (39.104.030; 39.104.031), Korobeynikov et al. (39.105.233), Kalenichenko (40.104.018), Halliday (40.104.081), Bronshten (40.104.082), Pilugin and Chernova (41.104.023), Halliday (1985; 1987) and Walberg (1985).

Fireball modelling and observations have proceeded despite the loss of the MORP network from the Canadian Prairie. Data analysis is still continuing with at least one event, the Grand Prairie fireball (February 22, 1984) thought to have dropped about 12 kg to the ground despite an entry velocity of 26.5 km/s. More recently Halliday has shown that the Ridgedale fireball (February 6, 1980) has orbital characteristics identical to those of the Innisfri meteorite and searches for this object have also being planned. In the European Network Ceplecha has continued his work and searches for the Valec fireball although negative has produced some very interesting results. First, this is the deepest penetrating fireball ever photographed. Second, a precise analysis of the terminal portion of the trajectory revealed an ablation coefficient that increased with decreasing height by 20 indicating possible fragmentation. Wetherill has continued to use U.S. Prairie Network data to understand the physical origin of fireballs. In his work he has looked at the behaviour of the fireballs which are in orbits like those of the Geminids. Kalenichenko has also analysed the U.S.Prairie Network fireballs and has considered models for only two types of bodies, one chondritic and the other type which experiences intensive fragmentation. In the series of review papers Ceplecha has attempted to establish interrelations among fireballs, meteors and meteorites.He has also summarized a recent work done on the analysis of fireball trajectories using more realistic atmospheric density profiles as well as one total ablation coefficient for the entire entry. He has compared records from all the major fireball networks in terms of their future research should be done on this subject. These include detailed studies of the fragmentation process, more recoveries of bodies photographed during the entry the atmosphere etc. ReVelle has reconsidered the concept of the end point heights of fireballs in terms of the fireball energetics. He has shown that the end height can be interpreted as the point where the initial kinetic energy of the meteoroids have been reduced down to about 1 to 2 per cent.

Finally, Pilugin and Chernova have considered the optically thick approximation so that the radiative heat exchange during fireball entry can be modelled in terms of the radiant thermal conductivity. The disadvantage of this method is that it can only be used over part of the actual entry path.

Scientific debate still continues over the region and effects produced by the Tunguska event (1908). A related work has continued on this area (37.105.249; 38.105.106; 39.003.023; 39.105.230; 37.105.011; 39.105.231, 232, 234; 40.105.046, 047; 40.102.111).

The paper of Levin and Bronshten (40.105.046) is in effect a rebuttal of the work of Sekanina (34.105.010; 37.105.007) regarding with physical nature of the object that ultimately produced the famous Tunguska event, i.e. ever an asteroidal or cometary parent body to this reviewer it seems probably that the ultimate source was asteroidal (a carbonaceous chondrite) rather than cometary as supposed for many years.

Physical modelling relating to the entry the atmospheres of planets have been carried out by Apshtejn et al. (40.104.015) and Vislaya et al. (40.105.008).

In the work of Wang et al. (38.104.014) and Keay (39.104.025) the so-called anomalies sounds from fireballs are considered. Bibarsov (41.104.063) has considered the production of ozone during the interaction between meteoroids and the atmosphere. Halliday et al. (1985) have considered the possible impacts of meteorites on people and buildings using flux rates derived from the MORP network. Lang and Franaszczuk (1986) have considered the fragmentation process in terms of the fractional concept for the Lowicz meteorite and identify two distinct stages of fragmentation during entry. Finally, Oberst and Nakamura (1987) have reexamined the flux of meteoroids as determined using the lunar seismic data taken during the Apollo program.

VII. METEOR SPECTRA

V.A.Bronshten

Unfortunately, meteor spectra have been poorly investigated during the last triennium. This seems to be surprising that a serious quantitative analysis of meteor spectra should provide the abundance of information being compared with that obtained from the analysis of stellar spectra.

Halliday has studied the spectra of 17 bright meteors of the Orionid shower, photographed within the period from 1958 to 1968. The spectral interval from 3100 to 8700 Å was embraced. The lines of 6 neutral atoms (NI, OI, NaI, MgI, CaI, FeI) and 5 ions (MgII, SiII, CaII, CrII, FeII) were found. The comparison of Orionid spectra with Perseid ones showed a very small difference in the content of the observed elements. This may be accounted for the small difference in compositions of their parent comets. Russell (41.104.067) studied meteor spectra of the Perseids observed in 1977-83. A correlation between spectrum and magnitude of the Perseids was found. Certain spectral characteristics appear correlated with the atmospheric density gradient along the meteor path. Inhomogeneity in the meteoroids may play an additional role in spectral-magnitude relations.

Ovezgeldyev et al. (42.104.064) investigated spectra of meteor trails with electron-optical equipment. Their comparison with the spectra of meteor "heads" showed that spectra of "wakes" and trails are poor with lines and, mainly, contain the lines of lower excitation potentials. An important feature of these spectra is a forbidden green line OI 5577 Å. Probable mechanisms of photochemical and aeronomical reactions causing the emission of the observed lines and bands in meteor trails were considered.

VIII. METEORS AND AERONOMY

W.J.Baggaley

Ablation. Information on the friable structure and desintegration processes of meteoroid dustballs associated with specific showers has been obtained by Beech (38.104.023) using data for characteristic of beginning and end heights, for visual meteor ablation. Models of the residual mass produced by entry of single independent body showed (39.104.001) a strong velocity dependent for the ablation residue and emphasized the small contribution to micrometeorites made by major showers (because of their high velocities). This work was extended (42.104.069) distinguishing large body ablation where grain ejection occurs along the primary optical ionization track, from small meteors where the majority of grains are released above the height of grain evaporation. This dustball model permitted the pre-

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diction of ablation products as a function of meteoroid parameters.

Diffusion. Estimates of the influx of meteoric dust and the mass distribution of the Solar system dust cloud are uncertain because, in an important mass regime (approximately 10^{-5} to 10^{-10} kg) covered by radar meteors, a velocity dependent echo attenuation effect operates. This echo ceilling - due to a large ionization column and rapid plasma diffusion - is important for radars operating in the HF band. To circumvent this observational selection, measurements of radar meteor fluxes have been carried out by Olsson-Steel and Elford (1987) at frequences of 2 MHz and 6 MHz.

Ionospheric effects. The redistribution of metal ions originating from meteoric ablation into lower E-region ionization irregularities by the action of shears in the zonal wind is known to be responsible for the phenomenon of ionospheric E_s. Many factors controlling the processes are not understood and some measure of the time-constants involved may be gained by examining the association between E_s occurrence and the major meteor showers. In a 20-yr survey (38.104.028) no correlation was found, indicating the existence of a large reservoir of meteoric ions with input from shower being only minor. Increases in ionization in the height region of 85 km observed on a VLF ionosonde and by phase anomalies on long distance propagation have been attributed (Vilas Boas et al., 1986) to the Alpha Scorpiids and Geminids. Similary long distance LF propagation effects have been associated (Sarka and De, 1985) with Leonid shower ionization yielding estimates of the effective electron attachment coefficient at 70 km.

Modelling of neutrals and ions. Progress in modelling meteoric M metals and alkalis has continued (Jegou et al. 1985; Kirchhoff 1986) with inclusion of the ablation source function, eddy diffusion, chemistry (including clustering chains), horizontal winds and E fields. Such models have been applied to observed diurnal-seasonal behaviour (Jegou et al. 1984; Granier et al. 1985). Grebowsky and Pharo (1985) demonstrated that mid-latitude nighttime metal ions can be lifted from their ablation region $\sim$100 km to F-region heights (in 30 min) by Pederson drifts produced by poleward electric fields. A review of rocket-born mass spectrometer M^+ measurements has been carried out (Swider 1984) and the data relevant to auroral conditions have yielded estimates of charge transfer rates to M from NO^+. Swider (1986) has demonstrated that simple steady state chemical models are successful in describing the relative composition of neutral Na compounds near the 90 km sodium layer peak without recourse to 1D dynamical models. Above the layer peak ion behaviour as well as transport become important. The large seasonal changes in the sodium layer has been discussed by Swider (1985) in terms of three-body association producing NaO_2.

Measurements of ablated meteoric species. Long-lived Na clouds observed using a tilting photometer (Kirchhoff and Takahashi 1984) and resonance scattering from enhanced Li during the extended arctic twilight (Henriksen et al. 1986) have both been attributed to direct meteoric input. Lidar records of Na layers at 93-101 km associated with E_s showing growth times of only minutes, widths $\sim$1 km and lifetimes of hours have been explained by Zahn et al. (1987) in terms of the release of atoms from sodium bearing dust by auroral electrons - evidence for a reservoir of Na adsorbed onto dust. Rocket mass spectrometer identification of M^+ ions have shown (Kopp et al. 1984) layer having a sharp cut-off below 91 km while flights of concurrent with NLC on meteor shower and non-shower days have produced (Kopp et al. 1985) detailed height profiles showing dominance by Mg^+ and Fe^+ over Na^+, Al^+, Ca^+ with Si^+ behaviour reflecting its different

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chemistry. A variety of meteoric ion compounds MO, MO_2, MOH and hydrates was also determined as well as heavy proton hydrates $H^+(H_2O)_n$ n 12. Such measurements are valuable in not only ion chemistry modelling but also in the importance of the role of ions as nucleation centres for NLC development.

NLC and PMC's. Work has continued in an effort to further our understanding of aeronomy of NLC and PMC development and evolution in the summertime high latitude mesosphere. We still lack data on some of the important microphysical processes. Thomas and McKay (1985) and Roddy (1984) have considered ice growth as well as appropriate crystalline form of ice. We are still not clear as to the identity of the ice nucleation centres; either meteoric dust - coagulated meteor ablation products ('smoke') or the result of metal water cluster ions or proton hydrates growth under supersaturated conditions. Finally, are NLC's and PMC's distinct phenomena?

IX. TEKTITES

C.Koeberl

Tektite research made some progress in the years covered by this report. The close connection between tektites and impact glasses has been further quantified by a number of workers. Recent interest in tektites has focused around the question if tektites producing events are related to other terrestrial events like reversals of the Earth's magnetic field, climatic changes, and extinctions like the one at the end of the Cretaceous. The proceedings of the first International Conference on Natural Glasses (Pye et al., 1984) included a number of papers on tektites and impact glasses as well as studies on the long-term stability and leaching processes of tektite and other glass. Schreiber et al. (1984) presented a thorough study on the redox state of iron in tektites. The first data on fluorine in tektites and impact glasses were reported by Koeberl et al. (1983; 39.105.012) and Moore et al. (1984), showing that fluorine must have been lost in the tektite production process, similar to other halogens and other volatiles.

The so-called Muong Nong type tektites contain large bubbles, are inhomogeneous and layered, much larger than splash-form tektites, and not spherical symmetric or aerodynamically shaped. Muong Nong type tektite iron is present in the +3 state (Koeberl et al., 1984b). The most prominent features of Muong Nong tektites are light and dark layers, and Koeberl (1985) was able to show that the light layers are enriched in almost all elements. Dark layers have higher SiO_2 contents than light layers. Surface structures of Muong type tektites have been studied by Futrell (1986).

Storzer and Müller-Sohnius (1986) have studied the enigmatic high sodium/potassium tektites from the Australasian region. Using K/Ar dating they confirmed earlier studies like the one by Storzer (41.105.148). The age of these tektites seems to be close to 11 million years. Recently some strange glasses similar to the high Na/K tektites have been reported from the Tikal (Guatemala) area (Essene et al., 1987). Among the most important new discoveries is the find of tektite debris in deep sea sediments at Barbados and some deep sea drilling sites (39.105.086; Thein, 1987). Previously tektites were found on land. Tektites are of some age than microtektites but are found in much younger sediments, microtektites are found in sediments of the correct (old) age. Some emphasis has been laid on trace element (Koeberl and Glass, 1986) and isotopic studies (39.105.223) of the new material, and it was shown unambigously that the tektites found in Barbados as well as those recovered from deep sea sediments off the coast of New Jersey are part of the North American strewn

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field. This result is supported by age determinations (Glass et al., 1986). The chemistry of the tektites seems to imply that they are slightly different than the well known bediasites and georgiaites.

The Ries crater - moldavite association has been studied by Horn et al. (1985) using isotope studies. Possible source materials (Middle Miocene sands) for the moldavites have been identified and studied by Engelhardt et al. (1987) and Delano et al. (1986, 1987). A recent review of the geochemistry of tektites and related impact glasses was given by Koeberl (1986b).

Recent studies of the water content of tektites and impact glasses (Koeberl and Beran, 1987) have shown that there is a genetic sequence: Muong Nong tektites contain more water than splash form tektites, in accordance with the other volatiles. The Zhamanshin impact crater, source of several impact glasses and tektite like material (irghizites, Si-rich zhamanshinites) has been subject of recent investigations, like an extensive chemical study by Koeberl and Fredriksson (1986). Irghizites are depleted in volatiles and water if compared to the zhamanshinites, which in turn are very similar to the Muong Nong type tektites and seem to constitute the lower temperature impact glasses. Murali et al. (1987) described a similar genetic sequence of impact materials, leading to tektite like materials at the upper end of the temperature pressure scale, from the Lonar crater in India.

The connection between microtektites, tektites and extinctions is currently being studied at the Eocene-Oligocene boundary, but no conclusive results have been obtained to date (Keller et al., 1987; D'Hondt et al., 1987). The connection between giant impacts and tektites and a soft transition between tektites and impact glasses becomes, however, more and more established.

X. <u>INTERPLANETARY DUST</u> V.N.Lebedinets

<u>Distribution and dynamics</u>. Voloshchuk and Kascheyev (40.104.073; 40.104.006) and Zabolotnikov (42.104.032) have carried out the mathematical simulation of the interplanetary dust distribution in the Solar system. Kascheyev and Kolomiets (39.104.038) and Andreev et al. (1987) found the discrepancy between the observed distribution of hyperbolic radio-meteors and theoretically predicted interstellar particles' orbits. Olsson-Steel (41.104.004) taking into account desintegration of meteor streams due to collisions among meteoroids and planets as well as present concentration of dust in the zodiacal cloud, concluded that 10^4 years ago the amount of meteor streams and their parent comets was essentially greater than at present. From radar observations Longo and Morris (41.081.038) have shown the absence of the Earth's natural satellites with diameters of 5cm (in the orbits with a perigee $q \leq 400$ km) and 40 cm (in the orbits with $q \leq 10\,000$ km) although a great number of fragments of artificial bodies was discovered. Barsukov and Nazarova (1985) from the cosmic dust impact data obtained by space probes, have found that dust particles move around the Sun, Earth and Moon as separate circular systems at certain distances from the centres of gravity. Kapishinskij (40.106.011; 41.106.070) analysing measurement data of space probes concluded that -meteoroids are formed as a result of impacts of larger dust particles.

The series of works consideres the influence of different non-gravitational effects on the motion and desintegration of dust particles. Alfonso (41.106.076) has studied the influence of the Poynting-Robertson effect and deceleration of charged particles in the extraterrestrial plasma. Mendis (1984) calculated the interaction of charged particles with ionosphere. Wallis (1986) and Wallis and Hassen (40.106.026) have shown that the influence of stochastic forces resulted from the fluctuations in surface-charge and interplanetary magnitic field for micron and submicron particles may exceed the influence of the Poynting-Robertson effect and cause the quicker fall of dust particles on the Sun as well as their removal from the Sun. Mukai (40.106.027) notes that the particles with radii less than 0.1 mkm resulted from heterogeneous ice meteoroids after ice sublimation can move in elliptical orbits. Kapisinski (1987) estimated that the erosion of dust particles with radii of 0.5 - 10 mkm under the action of the Solar wind and impact of smaller dust particles can essentialy reduce their lifetimes in comparison with the Poynting-Robertson effect. Steel and Elford (41.106.001) presented the Tables for calculations of the frequency of impacts of dust particles and lifetime of particles of different sizes in different orbits including orbits of 28 meteoroid streams. Grün et al. (39.106.063) calculated the balance of formation and desintegration of particles of different masses at their mutual encounters with account of mass segregation and concentration of dustballs. On the base of lunar crater statistics and data on meteor and zodiacal light observations Grün et al. (1984) calculated the equilibrium distribution of particles with masses up to meteoroids with account of their mutual collisions, the Poynting-Robertson effect and light pressure. Zook et al (40.106.055) have noted that lunar crater statistics can give overestimated values of dust influx because a part of craters is produced by the secondary dust particles ejected during impacts. Analysing the micrometeorite measurements obtained by space probes, Fechtig (39.106.028) concluded that the increase in frequency of impacts by one or two orders in the vicinity of Jupiter and Saturn can not be explained only by the gravitational focusing; this dust was ejected from the planetary satellites and crushed under the action of electrostatic forces. Alexander et al. (39.091.020, 021) estimated the flux density of micrometeorites ejected from surfaces of stone satellites of planets at meteoroid impacts. Fechtig (39.106.028) and Fechtig and Mukai (40.106.014) considered the evolution of Grinberg's particles ejected from a cometary nucleus.

Schiffer (40.106.014) noted that the observed redded zodiacal light in comparison with the solar spectrum can be explained by the roughness of surfaces of particles with diameters exceeding the light wave length. Giovane et al. (1985), Hong (39.106.036), Lamy and Perrin (42.106.001), Maucherat et al. (42.106.009), Sarma and Sommerfeld (1987) investigated the light scattering characteristics of interplanetary dust and the structure of zodiacal dust cloud.

Dermott et al. (38.106.029; 41.106.023) and Sykes and Greenberg (41.106.034) considered characteristics of intensive bands of zodiacal light near the ecliptic discovered from IRAS and showed that they could be formed due to encounters among asteroids. Sykes (41.102.077) indicates that narrow dust streams in the orbits of some comets are formed by the ejections of large dust particles from the cometary nuclei at small velocities. Walker and Aumann (1984) studied the amount of ejected dust from 9 known and 8 recently discovered comets on the base of measurement data obtained by IRAS.

Babadzhanov et al. (40.104.074; 1985) from photographic and radar observations in Dushanbe estimated the flux density of meteoroids with masses of 10^{-3} - 10^{2} g. Blinov et al. (39.106.069) from the measurements of radioactive isotope ^{26}Al in the red clay in the Pacific Ocean estimated the influx of cosmic dust onto the Earth equaled 150 ton/day. LaViolette (40.106.092) according to content of Ir and Ni in the dust filtrate from the ice kern Kemp-Century in the layer aged 19 700- 14 200 yr estimated that the influx of cosmic dust at those times was greater by 1-2 orders than at present.

Physical characteristics and sources. Cosmic experiments "Vega-1", "Vega-2" and "Giotto" allowed to estimate the intensity of dust ejection from the nucleus of Halley comet: according to Sagdeev et al. (1986a) - from 5 to 10 ton/day, according to Vaisberg et al. (41.103.667) - 4 ton/day and McDonnel (41.103.689) - 3.1 ton/day. These values are in satisfactory agreement with Grün's et al. ones (41.103.649) from ground-based observations - 1.5 ton/day. McDonnel et al.(41.103.689) from measurement data obtained by "Giotto" estimated that in the mass range $10^{-17} \leqslant M \leqslant 10^{-5}$ g the observed mass distribution of dust particles is characterized by index 's' equaled 1.66+0.05 (in the coma of Halley comet). Simpson et al. (41.103.669) from measurements at "Vega-1,2" at $M \gg 10^{-13}$ g obtained $s \approx 1.9$. The absence of a cut in mass distribution at $M < 10^{-11}$ g was unexpected for the authors of these experiments. Mazets et al. (41.103.262) suggest that when moving away from the nucleus the fraction of the smallest dust particles increases and this may be accounted for the fragmentation of the larger friable particles. Fragmentation of friable particles was also noted by Storrs et al. (41.103.262) near the nucleus of IRAS-Araci-Alcock comet from ground-based observations.

From ground-based observations of Jacobini-Zinner comet in the visual and IR ranges in August 1985 Tedesco et al. (1986) have estimated the intensity of dust ejection from cometary nucleus equaled 0.8 ton/day at the particle ejection velocity less than 3 m/s.

Krasnopolsky et al. (1986) from spectral observations at "Vega-2" estimated the average density of particles in the Halley comet coma to be 0.35 g/cm^3. Reinhard's (1986) mass-spectrometric investigations at "Giotto" discovered H, C, N, Na, Mg, Si, Ca and Fe in composition of particles. Kissel et al. (41.103.688) obtained that relative to the chondrite composition the dust particles are enriched with H, C, N and O; density of particles is very small. Sagdeev et al.(1986b) and Kissel et al. (41.103.670) from the data of PUMA experiment at "Vega" (mass-spectrometric measurements) obtained that particles are divided into three principle groups: (1) carbonaceous chondrites, (2) carbonaceous chondrites enriched with carbon, nitrogen and sulphur and (3) particles, mainly consisting of hydrogen, carbon and oxygen, and mineral nucleus may be absent in particles.

According to measurements of IR spectra of dust comae of Chernise and Bouel comets, Hoyle et al. (40.103.003) estimated that the coma of Chernise comet contains silicate and organic carbonaceous matter as well as about 10 per cent of ice, and the coma of Bouel comet appears not to contain free ice, but organic matter with hydroxyl. Struzzulla et al. (40.106.015) simulated the influence of solar wind on particles of cometary origin, containing ice, and showed that over the particle lifetime (about 10^6 yr) a strong erosion occurs; carbonaceous chondrite matter is formed from hydrocarbonates and the particle density increases. Morozhenko et al. (1986) from the data of laboratory simulation and polarimetric and spectrophotometric observations of comets identified the ice particles near the cometary nuclei. Frank et al (1986a,b) from UV observations of the Earth from the board of the space probe "De-1" discovered that very small cometary nuclei consisting of snow and ice with masses up to 100 tons and including very fragile dust cloak with masses of order of 1-10 g, enter the atmosphere with a frequency of 20 min^{-1}. This new type of minor bodies of interplanetary environment according to Donahue (1987) should enrich the interplanetary space with hydrogen due to ice sublimation. Geiss et al. (1986) according to data of mass-spectrometric measurements from the board of the space probe discovered in the coma of Giacobini-Zinner ions of Na^+ and Mg^+ which could be resulted only from particles containing frozen solutions of Na and Mg salts. Lebedinets (1987b) from the analysis of heights and decelerations of Super Schmidt meteors noted the existence of such particles among the meteoroids of the Draconid meteoroid stream.

Struzzula (1986) concluded that composition of particles of a cometary origin significally differs from dust composition of a protoplanetary cloud.

Bradley et al. (39.106.042, 065) and Johnson and Lanzerotti (41.106.072) studied nucleous tracks in the stratospheric aerosols and estimated the lifetime of dust particles in the interplanetary space to be 10^4-10^5 yr. Bradley et al. (41.106.009), Reitmeyer (1986) and Zolensky (41.106.015) classified the interplanetary dust particles collected in the stratosphere and for the first time separated porous chondrite agrigates with porosity up to 50 per cent and pieces of glass; the main type is carbonaceous chondrites enriched with volatiles. Schramm et al. (1985) have studied the composition of interplanetary dust according to data obtained by space probe Solar Max Satellite and concluded that in most of cases the composition is close to that of chondrites. Lebedinets (1986, 1987a,b) from the analysis of decelerations and heights of Super Schmidt meteors obtained that all the main types of meteorites as well as dustballs and carbonaceous CO chondrites containing water and other volatiles up to 50 per cent are presented among the meteoroids; the main type of meteoroid is carbonaceous CI chondrites. It is shown that in meteoroid streams such as Taurid, Perseid and Alpha Capricornid (associated with Encke, 1862 III, 1954 III comets) there are iron and stone meteoroids as ordinary chondrites.

Lavrukhina and Mendybaev (1987) on the base of analysis of numerous investigations of chemical, mineral and isotopic compositions of cosmic dust from the stratosphere and oceanic sediments have tried to establish a primary composition of particles from protoplanetary cloud and pecularities of genesis of interplanetary dust.

Lumme and Bowell (39.106.049) according data of photometric and polarimetric observations of zodiacal light have estimated the optical characteristics of dust particles from zodiacal cloud and concluded that particles are resulted from encounters among asteroids. Agafonova and Drobyshevski (39.099.042; 40.098.010; 1985) investigated the possibility of the formation of minor bodies in the Solar system as a result of the explosion of ice shells of giant planets' satellites.

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P.B.Babadzhanov

President of the Comission

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