Meteoroids 2001

Abstracts

Key:
1.1 after the abstract indicates **Talk 1 in Session 1**
PSA-1 indicates **Poster 1 in Poster Session A**
PSB-1 indicates **Poster 1 Poster Session B**

The Detection of the Motion of Radio Meteor Reflection Point of Geminids by HRO
Kouji Ohnishi (Nagano National College of Technology,Japan), Toshiyuki Ishikawa, Shinobu Hattori, Osamu Nishimura, Akiko Miyazawa, Masatoshi Yanagisawa, Makoto Endo, Masaki Kawamura, Toshiyuki Maruyama, Kai Hosayama, Mai Tokunaga, Yoshie Aoki, Yukiko Iijima, Aya Kobayashi (Nagano National College of Technology, Japan), Kimio Maegawa (Fukui National College of Technology) and **Shinsuke Abe** (Institute of Space and Astronautical Science, Japan)
Ham-band Radio Observation (HRO) is one of the observational techniques of the forward scatter observation of meteors. We observe the meteor echo with two-element loop antennas (F/B ratio is 10 dB) at the Nagano National College of Technology (Nagano, JAPAN) using the continuous transmission of beacon signals for meteor observations at 53.750MHz, 50W from Fukui National College of Technology (Sabae, Fukui, JAPAN). To prove that the radio echo is really the echo due to meteor, we construct the Directional Determination System using the paired antennas that can detect the direction roughly where the radio echo come from. The direction of one of this paired antennas was West toward Sabae and the other was East which has proved to be the most sensitive for this research. Using this system, we detected the change of the direction of reflection point of meteor radio signal of Geminids in 2000; from the westward to eastward before and after the culmination of the radiant which is consistent the formula of reflection point of meteors. At the same time, we detected the change of a trend of the Doppler shift of meteor echos. This result is consistent of the meteor wind data of MU Rader of Radio Science Center for Space & Atmosphere (RASC), Kyoto University. **PSB-5**

The Earth Rotation and Revolution Effect of the Daily and Annual Variation of Sporadic Meteor Echo by HRO
Kouji Ohnishi (Nagano National College of Technology ,Japan), Shinobu Hattori, Osamu Nishimura, Toshiyuki Ishikawa, Akiko Miyazawa, Masatoshi Yanagisawa, Makoto Endo, Masaki Kawamura, Toshiyuki Maruyama, Kai Hosayama, Mai Tokunaga, Yoshie Aoki, Yukiko Iijima, Aya Kobayashi (Nagano National College of Technology, Japan), Kimio Maegawa (Fukui National College of Technology, Japan) and **Shinsuke Abe** (Institute of Space and Astronautical Science, Japan)
Ham-band Radio Observation (HRO) is one of the observational techniques of the forward scatter observation of meteors. We started the observation of the daily and annual variation of sporadic meteor echo with paired two-element loop antennas (F/B ratio is 10 dB) at the Nagano National College of Technology (Nagano, JAPAN) using the beacon signals at 53.750MHz, 50W from Fukui National College of Technology (Sabae, Fukui, JAPAN) from Aug.2000. The direction of one of this paired antenna was West toward Sabae and the other was East. This system could be roughly detected the direction of the radio echos. Using this system, we observe the daily variation of sporadic meteor echos; the echo rose from midnight with the peak coming at about 6 a.m. and decreasing to the noon, the peak echos were observed from the West antennas at 4 a.m. and the peak from East antenna was at 10 a.m. This daily variation is interpreted as the effect of the Earth rotation and revolution around the sun. At the conference, we will also discuss the annual variation of sporadic meteor echos. **PSB-6**

Fine Structures within the Leonid Dust Trail: Resonant Filament Model Examined by Optical Video Observations

Hajime Yano (Institute of Space and Astronautical Science, Japan), **Shinsuke Abe** (Institute of Space and Astronautical Science, Japan) Noboru Ebizuka (The Institute of Physical and Chemical Research, Japan) Norimoto Fujino (Science University of Tokyo, Japan) and Jun-ichi Watanabe (National Astronomical Observatory, Japan)

We observed the Leonid meteor showers by real-time video imagery of high definition digital video cameras with image intensifiers (HDTV-II) onboard airborne platforms (Leonid MAC) in 1998 (over the Pacific)-1999 (over the Mediterranean), and NTSC digital video CCD cameras (WATEC) placed at a 2500-m class mountain in the Canary Islands in 2000. HDTV-II and NTSC videos had different limiting magnitudes for meteor detection (e.g., the 8th mag. for HDTV-II with a f1.0 50-mm lens) but both indicated fine structures (in several to a few tens of minutes) of the flux variation within each main peak. Such trends became more evident as the magnitudes of observed Leonids went fainter. Recently Cevolani and Pupilo reported radio observations of the 1999 Leonids from Italian ground stations also found the same as our results. These temporal flux variations seemed to coincide with periods that the Earth crossed the “inhomogeneous” Leonid dust trail, which is composed of the smoothed “background” component and several narrow, “dust filaments” ejected from the parent comet P/Tempel-Tuttle in the last several perihelion passages. Thus, our results directly confirm the resonant cometary dust trail model proposed by McNaught and Asher in 1999, especially in the smaller end of the Leonids. **PSA-24**

Spectroscopic Study of Meteor and Persistent Train

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During the 1999 Leonid, an intensified HDTV camera was used for slitless meteor spectroscopy at visible and near-UV wavelengths in the Leonid Multi-instrument Aircraft Campaign. The HDTV system provided a high dynamic range (digital 10-bit) and a wide field of view of 37 x 21 degrees. Here, we report on the results for several particularly nice spectrum from Leonid and Taurid meteors. Fe/Mg abundance of Taurids is about 2 times higher than that of Leonids. It is possible to build up a hypotheses. A LTE temperature calculated by numerous Fe emission lines below 550 nm is compared with a electronic-vibrational temperature of N2 in the visible (550 — 800 nm). It seems that meteor spectra can be explained well by LTE model. Moreover, stereoscopic observations of one spectroscopic meteor have been accomplished during the Leonid MAC and the real height of emissions were measured. An excellent spectra of a Leonid persistent train was obtained during the 1998 Leonid maximum in Japan by using a grating spectrograph covering 370 — 640 nm wavelength range. Identified Mg, Fe and Na suggests that these atoms are the source of the persistent trains and of long-lived emitters. **4.1**

Orbital Perturbations on Dust Trails: Predicting Meteor Storms

David Asher (Armagh Observatory, UK, and Bisei Spaceguard Center, Japan)

Although the chaotic nature of planet-crossing orbits limits the timescale over which their dynamical evolution can be reliably calculated, a sufficiently accurate initial orbit can at least be followed for some time (e.g., centuries) into the future. When debris is released from a comet during a given return to perihelion, the first stage of its evolution is to stretch gradually into a long, dense, narrow trail of meteoroids and dust. Perturbations on particles in the trail are a function of position along the trail, and position along the trail depends almost entirely on orbital period, particles of shorter/longer period being ahead/behind. Therefore perturbations at all points along the trail, and their consequent effect on the trail’s location, can be reliably calculated until chaotic behaviour sets in (e.g., for some centuries). Since meteor storms occur when the Earth passes near the centre of a trail, where the particle density is very high, this has allowed storms and outbursts to be predicted with great accuracy in the Leonids and many other streams. **2.1**

Features of the Enhanced AMOR: The Advanced Meteor Orbit Radar

W.J. Baggaley (Department of Physics and Astronomy, University of Canterbury, Christchurch, New Zealand)

AMOR is a continuously operating radar facility for measuring the heliocentric orbits and atmospheric parameters of Earth-impacting grains down to sizes of 40 micrometres. The facilty provides a data base of

the order of 10^6 orbits. Recent extensions to the facility including augmented antenna arrays and increased velocity resolution are providing an enhanced system capability. **6.1**

Mapping the Interstellar Dust Flow into the Solar System Using AMOR

Jack Baggaley (Department of Physics and Astronomy, University of Canterbury, Christchurch, New Zealand)

The Advanced Meteor Orbit Radar facility (AMOR) monitors the dynamical properties of meteoroids of sizes down to about 40 micrometres. The orbital data set secured to date contains about 10^6 orbits. The population of inner solar system meteoroids sampled contains a significant proportion of particles that are moving in unbound solar orbits. Maps the far-sun inflow directions of this extra-solar system population show the presence of both a broad interstellar inflow and discrete sources. **11.6**

Combined Visual and Radar Observations. 45 Years Later

O.I. Belkovich (Zelenodolsk Branch of the Kazan State University, Russia) and V.S. Tokhtas'jev (Engelhardt Astronomical Observatory, Russia)

Combined visual and radar observations of Perseids made by B.A. Lindblad at the Onsala Wave Propagation Observatory, Sweden between 1953 and 1961 have been processed taking into account random positions of reflecting points on meteor trails and the modern physical theory. As a result the new more accurate relation of ionization and luminosity coefficients has been found for Perseids meteors. Velocity dependence of this relation was found from the analysis of other data. **PSA-4**

Comparative Analysis of Meteor Shower Observations Processed by Three Different Methods

O.I. Belkovich (1), M.G. Ishmukhametova (2), N.I. Suleimanov (3) and V.S. Tokhtas'jev (3).

(1) Zelenodolsk Branch of the Kazan State University, Russia, (2) Kazan State University, Russia, (3) Engelhardt Astronomical Observatory, Russia

Long-term series of radar and visual observations of Geminids and Quadrantids have been used for the analyses. Processing of radar observations has been made by the two methods: 1) the flux density has been calculated from hourly number of meteors with amplitudes exceeding the radar threshold level, 2) from hourly number of reflections from overdense meteor trails with durations greater than 1 second. The S coefficient of meteoroid mass distribution as a function of the solar longitude has been found from rations of two flux densities. Reduced zenith hourly rates for meteors brighter than +3 magnitude from visual observations of the showers have been found by the method worked out at the Engelhardt Observatory. Profiles of the showers (flux densities or ZHR as functions of the solar longitudes) depends on the minimal registered masses of meteoroids. This fact has given us the opportunity to check as the correctness of the methods of processing of observations so to do independent estimation some parameters of the physical theory of meteors (mass scales of radio and visual meteors). The estimation of the collecting area in visual observations of meteors has been made also. **PSA-5**

Expected Distribution of Interstellar Meteoroids in the Vicinity of the Earth's Orbit

O.I. Belkovich and A.R. Bagautdinova (Zelenodolsk Branch of the Kazan State University, Russia)

One of the hypotheses of origination of interstellar meteoroids is the lost them by planetary systems of the late spectral class stars. In this case the most probable distribution of their velocities relative the local centroid of stars mast be similar to one of the late class stars. This distribution has been found from the catalogue of star ray velocities. The orbital element distributions of interstellar meteoroids in the vicinity of the Earth's orbit and radiant and velocity distributions over the celestial sphere in the heliocentric and geocentric frame of references have been calculated taking into account of meteoroid flux transformation due to the Sun gravitation field and moving the Sun and Earth relatively the local centroid of stars. **PSB-22**

Is the Problem of Sporadic Meteoroids Space Distribution Solving Correct?

O.I. Belkovich (Zelenodolsk Branch of the Kazan State University, Russia)

Nearly all that we know now on the distribution in the interplanetary space of sporadic meteoroids in the mass range from 0.00001 to 100000 g is based mainly on the ground-based meteor observations. We used to think that this problem was solved years ago except for some details. I would say that it is a delusion and I would like to prove that assertion. Firstly. What variable or what variables can represent the distribution of sporadic meteoroids in the vicinity of some point of the space? As a physicist I can say that it is the phase density, i.e. density of particles in the 6-dimensional space of coordinates and velocities as a function of their masses. What corresponds now in the meteor astronomy to this definition? Secondly. All ground-based meteor observations are made on the moving and attracting Earth. Are you sure that so-called astronomical selection taken into account in processing of observed data is correct? Thirdly. Most meteor astronomers like to analyse their own observations and even in case of some differences with the results of other observations they are inclined to explanation of those differences due to the different observed masses of meteoroids. Do you believe them? **10.2**

The Moravka Meteorite Fall: Fireball Trajectory, Orbit and Fragmentation

J. Borovicka, P. Spurny and Z. Ceplecha (Astronomical Institute, Academy of Sciences, 251 65 Ondrejov, Czech Republic)

The Moravka meteorite fall of May 6, 2000, is only the sixth case in history, when the pre-fall trajectory could be determined from instrumental records. A very bright fireball appeared during broad daylight at 11:51:52 UT and was seen by thousands of people. Fortunately, three casual witnesses captured the fireball on video. The fireball was also detected by satellite-based infrared and visible sensors. Sonic booms were recorded by a local seismic network and an infrasound array located in Germany recorded signals from this event. Three ordinary chondrites of type H5-6 and total mass of 634 g were recovered in the vicinity of village Moravka, Czech Republic (18.53E, 49.60N) over a span of 11 km. Much more fragments certainly fell, since one video record shows multiple hierarchical fragmentation to more than hundred pieces. After a careful calibration of the videos, we were able to determine the fireball trajectory with a good precision. The initial velocity was 22.5 km/s and the trajectory slope 20 degrees to horizontal. The most resistant fragment disappeared at an altitude of 21 km when decelerated to 4 km/s. The heliocentric orbit is notable by a high inclination of 32 degrees. Details of fireball dynamics and fragmentation will also be given. **8.1**

Video Spectra of Leonids and Other Meteors

Jiri Borovicka (Astronomical Institute, Academy of Sciences, 251 65 Ondrejov, Czech Republic)

More than thousand Leonid video spectra were obtained during the expeditions in the years 1998-2000. A survey of the spectra with the emphasis to the effect of early release of sodium will be presented. Leonid spectra will be compared to the spectra of other meteor showers obtained with the same instrument at the Ondrejov Observatory. **PSA-20**

ALIS (Auroral Large Imaging System) Used for Optical Observations of the Meteor Impact Process

Urban Brändström (1), Björn Gustavsson (2), Åke Steen (3) and Asta Pellinen-Wannberg (1)

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ALIS is a low-light imaging facility consisting of six remote-controlled stations in northern Sweden. The initial objective of the facility was to study aurora from multiple directions and reconstruct three dimensional distributions of the phenomena with the tomographic inversion method. The stations are located in a 50 km grid. They are equipped with non-intensified, high-performance CCD cameras, with telecentric lens systems and filter-wheels with narrow-band (40 Å) interference filters for auroral emission lines. The field-of-view is 90° x 90° at two stations and 54° x 54°at four stations. Each camera is mounted in a positioning system, enabling ALIS to monitor overlapping fields-of-view. The facility can also be used for real time meteor impact observations. Filters for optically observable meteor constituents such as sodium (5893 Å) and calcium (4227 Å) can be used at two stations, while the others measure the trail impact in white light. When a meteor comes within the common volume its ablation can be observed by making multiple exposures before reading out an image. Exposure times down to 50 ms and frame rates of one image per second are possible. A simulation of how an ablation process of sodium and calcium can be observed with this facility is presented. **PSA-30**

Meteor observations from Israel

Noah Brosch (Wise Observatory, Tel Aviv University, Tel Aviv 69978, Israel)

We observed meteors of the Leonid and other showers with an L-band radar system. In the case of the 1999 Leonids we detected a twin-peaked dheight distribution, where the surprising finding was of a wide peak centered near 250-km altitude. We present a possible mechanism to generate radar returns at such heights. We also describe the development status of a two-station system to observe video meteors, which is planned to operate in the second half of 2001. **2.7**

Astronomical and Physical data for Micrometeoroids Recorded by the ALTAIR Radar

P. Brown (Los Alamos National Laboratory, Los Alamos, New Mexico USA, and Department of Physics and Astronomy, University of Western Ontario, London, Ontario, CANADA), S. Hunt and S. Close (MIT Lincoln Labs)

We present preliminary results of orbital and physical measurements of a selection of meteoroids observed at multiple frequencies by the ALTAIR radar on Kwajalein island in November, 1998. The head echoes observed by ALTAIR allow precise determination of velocities and decelerations, from which both ballistic parameters for individual head echoes and orbits have been measured and will be presented. The ALTAIR radar observes several thousand head-echoes per hour and each head echo has a known trail orientation relative to the beam. Examination of the trail orientations produces an estimate of the effective beam collecting area. This collecting area when taken in conjunction with the observed rate information, allows an independent estimate of the limiting observed mass of meteoroids observed by ALTAIR through comparison with the known sporadic meteoroid flux. The principle function of ALTAIR is as a contributing sensor to the US Space Command satellite-tracking network. ALTAIR is a high-power (5 Mw peak at both frequencies), narrow beam (3° at VHF, 1.2° UHF), 43-m diameter mechanically steered dish. ALTAIR transmits right circular polarized energy and records left circular with a range resolution of 15 m VHF and 7.5 m UHF meters. Azimuth and elevation difference channel data are also measured, which contribute to the accurate determination of target position in three dimensions. The aforementioned characteristics allow ALTAIR to reliably detect a -62 dBsm target in VHF and a 81 dBsm target at UHF at a range of 100 km. Examples of the head echoes observed by ALTAIR and some indications of the likely origin for the population observed by ALTAIR during this campaign will also be discussed. **PSB-9**

Recent Infrasonic Observations of Large Bolides

Peter Brown (Los Alamos National Laboratory, Los Alamos, New Mexico, USA, and Department of Physics and Astronomy University of Western Ontario London, Ontario, Canada), Douglas O. ReVelle and Rod Whittaker (Los Alamos National Laboratory, Los Alamos, New Mexico, USA)

We expect a minimum of several dozen bolides to impact the Earth each year and penetrate low enough in the atmosphere to produce infrasonic waves. These objects have energies from 10-2 kT to many hundreds of kT and many of these are also simultaneously observed by US DoD satellites. Here we present a summary and discussion of more than 15 infrasonically observed bolide events detected since 1996. These data demonstrate the capability of infrasound arrays to reliably locate the source of bolide explosions in the atmosphere at heights of typically 20-30 km and at ranges exceeding 5000km. We find, for example, that a 0.2kT bolide detonation can be detected at ranges of 3300 km under good conditions. Most notable among these recent events is a multi-kt event recorded off the coast of Mexico on 25 Aug, 2000 which was recorded by six infrasound stations and a large (~20 kt) detonation in the South Pacific on 18 Feb, 2000. The modelling and interpretation of some individual events and comparison with other instrumental records of the same bolides will be highlighted. **PSB-14**

The Tagish Lake Meteorite Fall : Interpretation of Physical and Orbital Data

Peter Brown (Los Alamos National Laboratory, Los Alamos, New Mexico, USA, and Department of Physics and Astronomy, University of Western Ontario, London, Ontario, Canada), Douglas O. ReVelle (Los Alamos National Laboratory, Los Alamos, New Mexico, USA) and Alan Hildebrand (Department of Geology and Geophysics, University of Calgary)

The Tagish lake meteorite fell 18 Jan, 2000, at 16:43 UT in Northern British Columbia Canada. Some 500 meteorites were later found on the frozen ice-surface of Tagish Lake. The fireball accompanying the meteorite fall was widely recorded by ground-based photographers/videographers, earth-orbiting satellites, seismic and infrasound sensors. The associated meteorites have proven unique; reflectance spectra from Tagish Lake is the first to match that of D-class asteroids (Hiroi et al., 2001) and the bulk density of TL is the lowest measured for any meteorite at 1.67 g cm-3 (Zolensky, pers comm). Here we will discuss the data relating to the fireball and associated modelling to determine the orbit of TL and probable physical structure. Most notably, the fireball data suggest that TL is intermediate between Type II and III fireballs. Our modelling indicates the initial body had a porosity near 50%. Type III objects are presumed to be related to cometary bodies and suggests that TL and by extension D-asteroids might be intermediate in physical structure between primitive chondritic asteroids and cometary nuclei. **8.6**

Fragmentation and Initial Radius

M. Campbell and J. Jones (University of Western Ontario, London, ON, N6A 3K7 Canada)

The problem of initial radius effects is one of the major obstacles to well-calibrated fluxes from meteor radars. The effects are dependent on the wavelength of the radar used, and will be affected by the dependence of initial radius on height and the density profile of electrons in the ionized trail. Most previous studies have assumed a gaussian profile of electrons in the trail, and have found from multifrequency studies that the initial radius varies more slowly than the mean free path with height. Studies of meteors in the size range detected by most radars show that they are not single bodies, but fragment prior to luminous ablation; fragmentation is potentially a huge effect in the initial radius correction. We present a study of the effects of fragmentation on initial radius using a combination of numerical simulation and data from a multifrequency radar. **3.6**

Ground-based Observations of the Leonids 1999-2000

M.D. Campbell, C. Theijsmeijer, J. Jones (University of Western Ontario, London, ON, N6A 3K7 Canada), R.L. Hawkes (Mount Allison University, Sackville, NB, E4L 1E6 Canada) and P. Brown (Los Alamos National Laboratories Los Alamos, NM 87545 USA)

We present video observations of the 1999 Leonid shower made from Israel and similar observations collected in Spain and New Mexico for the 2000 shower. During the 1999 Leonid storm a total of 233 double-station Leonids were recorded. The mean begin, maximum brightness and end heights are 123.3 ± 0.7 km, 107.3 ± 0.42 km and 95.0 ± 0.56 km respectively for storm Leonids of average mass ~10-6 — 10-7 kg. The peak flux at the time of the 1999 storm was found to be 0.81 ± 0.06 meteoroids km-2 hour-1 brighter than +6.5. using 15 minute binning and 0.99 ± 0.11 meteoroids km-2 hour-1 brighter than +6.5 for 3 minute intervals. The smaller temporal resolution reveals a broad plateau in flux lasting from approximately solar longitude=235.276° — 235.285° (J2000.0). The video mass distribution index over the course of the Leonid storm was found to be constant constant near s=1.75 and near s=1.7 in 2000. The peak time of the storm estimated from 3 minute resolution video counts place the maximum at 235.281°±0.003° (1h55m ± 4m). We do not find evidence for any significant high altitude Leonid population in 1999 at video masses despite biasing one camera pair to an intersection altitude of 160 km. The 2000 shower showed two distinct peaks separated by 24 hours. We recorded a peak video flux of 0.06 meteoroids km-2 hour-1 brighter than +6.5 near solar longitude=236.15° during the 2000 Leonids. We also discuss preliminary radar observations in 2000 which suggests that an earlier peak near solar longitude=235.29 ± 0.02 is much stronger than reported by visual observations and dominates the later visual peak at 236.25 ± 0.02. **PSA-19**

Bolide Fragmentation Processes: Comparisons of Bolide Data against Theoretical Bolide Models

Zdenek Ceplecha (Astronomical Institute, Czech Academy of Sciences, Ondrejov Observatory, Ondrejov, The Czech Republic) and Douglas O. ReVelle (Los Alamos National Laboratory, Los Alamos, NM 87545, USA)

This work is a practical extension and testing of theoretical work also submitted to the Meteoroids2001 conference. We have applied the fragmentation model of ReVelle to the most precise EN and PN fireballs in order to evaluate the shape change parameter, and the fragmentation scale height in comparison to the pressure or density scale heights. If the ratio of the fragmentation scale height to the density scale height is large, we recover the single-body model limit. In the opposite extreme, pancake type fragmentation is possible. This was done in order to determine if, for any of the available very precise bolide observations, a parameter range existed that allowed pancake type catastrophic fragmentation processes to occur. This is

important since a number of workers in the early 1990's identified this behavior as being important for the larger bodies entering the atmosphere in the small ablation limit (Hills and Goda, Chyba, Zahnle and Thomas, etc.). We are currently examining a number of bolides with very precise observations to determine these fundamental properties and will report on our findings at the conference. **8.4**

Bolide Fragmentation Theory with Application to PN and EN fireballs

D.O. ReVelle (1) and **Z. Ceplecha** (2)

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The simple physical concept of the conservation of energy and momentum (single-body theory) was applied to a majority of multi-station photographic observations of bolides assuming that the entry behavior could be successfully described using a constant value of the ablation coefficient (sigma), the shape-density coefficient (K), and allowing for a single sudden gross-fragmentation at one distinct altitude. If the precision of the observational data is better than +/-30 m in distance measured along the bolide trajectory, then about 40% of the events can be explained without any gross-fragmentation, about 40% are explainable with one gross-fragmention point and about 20% have definitely experienced more than one gross-fragmentation point. High values of the derived ablation coefficients from observations speak for nearly continuous fragmentation as being the main mass-loss process for these bodies. If the precision of the observational data is better than +/-15 m as described above, then the assumption of constant sigma and K is no more sustainable. There are not many data available with such a high precision. The complete solution of the problem with sigma and K being functions of time was subsequently derived and applied to 22 PN and EN fireballs each with the needed high precision. The luminous efficiencies, tau, can also be determined from this approach as well. We will present our results on sigma, K, and tau as a function of the many different variables and parameters of the problem for individual bolides during their luminous trajectory and for individual bolide types. **PSB-11**

Relation of Meteoroid Ablation-Classification to Light Curves

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Classification of bolides according to their ablation coefficients allows the recognition of 4 different groups: type I, type II, type IIIA, and type IIIB. (In addition, iron bolides have also been identified by the authors, but from our limited data set, we can not evaluate them using the current effort). The possibility of determining to what type a bolide belongs from just light curve data was examined, and a criterion IT = (1/I)(dI/dt) was earlier proposed. The statistical significance of sorting bolides according to IT was also established. Recently, we have revised our original light-curve classification using ground-based radiometer data taken at the Ondrejov Observatory provided by Sandia National Laboratory (courtesy of Mr. Richard Spalding, operated by Mr. Pavel Spurny) and have determined: a) the originally proposed classification tables published in the Annals of the New York Academy of Sciences (1997) are valid and form the best possibility available at the moment, but they should be utilized only if light curves are the only form of observational data available, b) relevant results can be obtained for values of brightness separated by a time interval, dt, of 0.05 s (if a shorter interval is available, one should adjust the interval by summing all data inside each 0.05-s interval), c) associating a bolide with a single type by using only light-curve data is rarely possible, since only the probability of belonging to one of the 4 types can be determined, d) the ablation coefficient, sigma and the shape-density coefficient, K, cannot be construed as a weighted average and must be taken for each bolide type separately, e) if other precise observational data can be derived (e.g. data on heights and velocities at several points), they are certainly preferable for determining the sigma and K values. The characteristic light curve determined for each of these 4 meteoroid types will be presented. **PSB-10**

Microwave Observations of Molecules in the Earth Atmosphere during a Meteor Shower: The Leonids

Didier Despois et al. (Observatoire de Bordeaux, INSU/CNRS, B.P. 89, F-33270 Floirac, France; e-mail: despois@observ.u-bordeaux.fr)

Meteor showers affect to some extent the chemical composition of the upper atmosphere. We discuss the use of mm/submm wave spectroscopy to study the molecules delivered or produced, some of which may be of importance for prebiotic chemistry. We present radio observations of the HCN line using the CSO radio telescope in Hawaii on Nov. 18/19 1999 ; the night after the second Leonid shower maximum showed unusually low HCN abundances above 45 km altitude, which are only recovered after sunrise. New observations to test the link of the HCN line variation with the meteor shower will be undertaken for 2001 Leonids. **PSA-37**

Components of a New Interplanetary Meteoroid Model

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New populations of interplanetary dust are proposed for the new ESA interplanetary meteoroid model. Formulation of the model and its populations differ from those adopted in earlier meteoroid models and are tied to long-term dynamics of the interplanetary dust. To validate the new model, infrared emission observations with COBE DIRBE instrument, impact counts with the dust detectors aboard Galileo and Ulysses spacecraft, and the radar meteors monitored with AMOR are used. **10.9**

Hypervelocity Impact Effects on Spacecraft

Gerhard Drolshagen (ESA/ESTEC)

Every spacecraft in orbit is exposed to a certain flux of impacting particulates. These impacts occur at typical velocities between a few and some tens of kilometers per second. Submicron and micron sized particles can lead to a degradation of sensitive spacecraft surfaces and equipment, like mirrors, optical sensors and thermal control surfaces. Somewhat larger particles with diameters in the range of tens to hundreds of microns can penetrate outer spacecraft coatings and foils as well as solar cells. Penetration of solar cells can lead to short circuits and subsequently to a degradation of the power supply. Craters resulting from hypervelocity impacts are typically 3-20 times larger (depending on the material and impact parameters) then the impactor. That implies that even submillimeter sized particles can cause problems for sensors and for the future use of impacted surfaces (e.g. sealing, Shuttle windows). In addition to these mechanical effects, every hypervelocity impact creates an impact plasma. Such an impact generated plasma can lead to electromagnetic interference with spacecraft systems and payloads. More importantly, the impact plasma can also trigger a discharge of electrostatically charged dielectric surfaces, releasing a current which is much larger than what would be possible by the impact alone. Millimeter sized particles can penetrate exposed tanks and seriously damage certain equipment. In addition the momentum transfer can lead to attitude problems. Impactors of cm size or larger will typically lead to complete destruction of the impacted spacecraft part. The presentation will give an overview of the hypervelocity impact effects on spacecraft and also briefly address some common protection measures. **9.1**

Persistent Leonid Meteor Trails: Types I and II

J.D. Drummond, S. Milster, B. W. Grime, D. Barnaby (Air Force Research Laboratory), C. S. Gardner, A. Z. Liu, X. Chu (University of Illinois), M. C. Kelley, C. Kruschwitz (Cornell University) and T. J. Kane (Pennsylvania State University)

From our 1998 and 1999 study of Leonid lingering trails, we have identified two types of trails. Type I trails are wide (1 km after a minute) with high diffusion rates (1000 m^2/sec), appear turbid, optically thick, and 'puffy'. Type II trails are narrow (< 100 m), often parallel, with low diffusion rates (10 m^2/sec), appearing optically thin, smooth, and clean. Of the four trails extensively studied, one is Type I only, another is Type II only, and two show both types of trails. Information (especially altitude) from a sodium lidar is used to derive detailed geometric parameters for the trails. For example, diffusion appears to be a function of altitude, with the hyperbolic tangent function describing the transition from low to high rates. A 17 minute video will be shown, and line emission rates, diffusion coefficients, and other data will be given for each. **PSA-23**

Meteor Trail Evolution: Comparison between ALTAIR Radar Observations and Plasma Simulations

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We present the first direct comparisons between plasma simulations and radar observations to explain the the most salient features of non-specular meteor trail echos. The radar observations were obtained during Leonids 1998 with the highly sensitive ALTAIR radar in the Kwajelein Atoll. Plasma simulations demonstrate that meteor trails are unstable to growth of gradient-drift Farley-Buneman (GDFB) waves that become turbulent and generate large B-field aligned irregularities (FAI). These results indicate that the non-specular echos, that can extend between 5-10 km in altitude range, are reflections from plasma instability generated FAI. The simulation results can explain a number of characteristics of these non-specular observations. The observed altitudinal extent of the trail echos. Trail diffusion in the plane perpendicular to B that can be up to an order of magnitude larger than expected from ambipolar diffusion. echos. Additionally, meteor and atmospheric properties including neutral temperature, neutral-ion collision frequency, and meteoric ion mass may be inferred with greater accuracy then previously possible. **7.6**

Comparison of Meteoroid and Space Debris Fluxes to Spacecraft in Earth Orbit

Veronika Ekstrand and Gerard Drolshagen(ESA/ESTEC)

Spacecraft in earth orbit will be impacted by natural meteoroids and man-made space debris particles. The relative ratio depends mainly on the spacecraft orbit and attitude. Predicted number of impacts from different flux models will be presented for particle sizes ranging from microns to cm. For low Earth orbits meteoroid fluxes dominate for sizes between some tens of microns and about 1mm while space debris is more abundant for smaller and larger sizes. The mode differences for a given population indicate the present level of uncertainty. **9.4**

The Effective Diffusion Coefficient of Meteor Trails above 100 km

W.G. Elford (Department of Physics and Mathematical Physics, University of Adelaide, Adelaide 5005, Australia) and M.T. Elford (Atomic and Molecular Physics Labs., Res. School of Physical Sciences and Eng., Australian National University, Canberra, 0200, Australia)

In a recent paper R E Robson [Phys Rev E, 63 (2) 026404, 2001] has set the problem of the diffusion of meteor trails “in the context of mainstream plasma physics”. The outcome is a new expression for the amplitude of the scattered radar signal from an underdense trail, viz.,A(t) = A(0) exp[-4k¬* tDeff] where Deff = Dll sin¬*m sin¬*q + D^(1- sin¬*m sin¬*q) . Dll and D^ are the ambipolar diffusion coefficients parallel and perpendicular to the magnetic field, q is the angle the field makes with the trail, and m is the angle between the wave vector and the normal to the plane of the trail and the field. Further, the two diffusion coefficients are simply related by the expression D^ = Dll (1+r)-1, where r depends on the cyclotron and collision frequencies of the electrons and ions. Using laboratory based data for the values of the parallel diffusion coefficient and the collision frequencies, values of the effective diffusion coefficient have been calculated for radar observations of underdense trails as a function of trail orientation (radiant position) and reflection point heights. Dramatic reduction of the effective diffusion coefficient of high altitude trails (>110 km) occurs when the radar beam is directed orthogonal to the magnetic field. The new values are applied to several sites of meteor radars. **5.4**

Effects of Meteoroid Fragmentation on Radar Observations of Meteor Trails

W.G. Elford and L. Campbell (Department of Physics and Mathematical Physics, University of Adelaide, Adelaide 5005, Australia)

The majority of radar echoes from meteor trails do not show the Fresnel diffraction oscillations expected to occur just after the ablating meteoroid passes the point on the trail where the orthogonal from the radar station intersects the trail. For 50 years this has been attributed to fragmentation of the meteoroid prior to or during the ablation phase. However, direct evidence of fragmentation from radar studies has been almost non-existent. Recently, a breakthrough has occurred on two fronts, (a) observations of amplitude oscillations in down the beam meteor echoes, and (b) deduction of the structure of meteor trails using radio holography. In this paper plausible models to explain the new observations will be presented and applied to the question of the degree of fragmentation required to explain the paucity of Fresnel diffraction oscillations. Also, other new evidence of fragmentation will be presented. **PSB-2**

Observations of the Structure of Meteor Trails at Radio Wavelengths Using Fresnel Holography

W.G. Elford (Department of Physics and Mathematical Physics, University of Adelaide, Adelaide 5005, Australia)

Radar observations of a meteor trail are the temporal variations in the amplitude and phase of the scattered radio signal usually recorded at one site. During the formation of the trail in the radar beam the recorded received signal can be considered as a one-dimensional diffraction pattern produced by a moving source. This diffraction data contains information on the structure of the trail that can be revealed by an appropriate Fresnel Transform. An analytical technique for carrying out this transform of meteor radar data will be described and examples given of the outcomes for a range of typical diffraction data. Inherent in the outcomes are refinements in the value of the speed of the meteoroid, the presence of multiple sources (presumed due to fragmentation) and a measure of the lateral motion of the trail during formation due to wind drift. **6.5**

Radar Meteor Observations at 2 MHz

S. I. Grant and **W.G. Elford** (Department of Physics and Mathematical Physics, University of Adelaide, Adelaide 5005, Australia)

The Buckland Park MF radar (34 S, 138 N), located near Adelaide, Australia has been used for night time meteor observations. Distributions of meteor heights and incoming speeds have been determined from observations over selected periods during 1999 and 2000. Most radar meteor observations are conducted using VHF radars, with the wavelength-dependent meteor echo ceiling limiting observation to heights below about 110 km. In contrast MF radars have the potential to make observations to heights exceeding 140 km, and hence provide information on any high altitude component that contributes to the meteor true height distribution. A significant limiting factor affecting such observations is the presence and strength of the night time E-region. **PSB-3**

Resonance Structure of Meteoroid Streams

V.V. Emel'yanenko (South Ural University, Russia)

The dynamical behaviour of meteoroid streams is studied on the basis of the resonance theory of perturbations. Parameters are calculated for the principal resonance zones near the orbits of the main meteoroid streams. The features of changes in the spatial number density for librating, circulating and stochastic-type motion are described. In the case of librations near centres of resonances, the density of meteoroid streams changes almost periodically, and resonant particles produce compact trails. On the other hand, the stochastic motion of meteoroid streams is similar to that of a diffusion process. The Leonid, Lyrid, Ursid, Perseid and Bootid outbursts as indicators of the described dynamical features are discussed. Recommendations are given for the future observations of the annual meteor showers. **1.7**

Meteor Head Echo Observations Using the Millstone Hill/MIDAS-W UHF Incoherent Scatter Radar System

Philip J. Erickson and Frank D. Lind (Atmospheric Sciences Group, MIT Haystack Observatory)

UHF incoherent scatter radars can study meteor influx into the upper atmosphere through recording so-called meteor head echoes, which result from scattering of the incident wave from structures surrounding an inbound meteor as it ablates in the 80 — 120 km altitude range. The Millstone Hill 440 MHz incoherent scatter radar, with its associated 68 m zenith and 46 m steerable antennas and 2.5 MW peak power transmitter, was used as early as 1962 in observations leading to a seminal series of papers by John Evans describing UHF meteor scattering characteristics. Recently, we have employed the Millstone system, using a prototype wideband data acquisition system (MIDAS-W) and a Barker code transmission scheme similar to work done at EISCAT, in a series of head echo detection experiments during the Leonid meteor showers of November 1999 and November 2000. We describe the capabilities of the MIDAS-W system for meteor research, and present selected results of these Leonid observations along with future plans. **7.5**

Capture of Meteoroids by Aerogel Exposed on the MIR

G. Ferrini and L. Colangeli (Osservatorio Astronomico di Capodimonte, Napoli), P. Palumbo (Istituto Universitario Navale, Napoli), A.J. Westphal (Space Sciences Laboratory, University of California at Berkeley) and J. Borg (Institut d'Astrophysique Spatiale, Université Paris Sud)

The Earth orbit environment is an ideal place for the collection of meteoroids of different origins. The intact capture of these solid particles in space is of special interest for cosmic dust research in order to understand their nature, to assure the complete characterisation of their chemical composition and to determine their orbits and relative contribution to the total flux in the Solar System. Searching for these results, in the last few years a number of experiments were carried out in Low Earth Orbit, many of which onboard the Russian MIR Space Station. The COMET-99 experiment flew on the MIR between November 1998 and April 1999, during Earth encounter with Leonids. With the aim of in situ collection of particles from this meteor stream, a package composed of different dust collectors, belonging to various capture experiments, was exposed to space. Among these collectors, two blocks of silica aerogel provided by the Cosmic Physics Laboratory of Napoli were included. Laboratory analyses on these aerogels show a conspicuous presence of tracks and captured solid particles. Here we present our results on the extraction and analysis of collected grains. **9.3**

On the Atmospheric Dynamics of the Tunguska Cosmic Body (Dedicated to P. Farinella)

L. Foschini (1), Ch. Froeschlé (2), R. Gonczi (2), T.J. Jopek (3), G. Longo (4) and P. Michel (2)
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We studied the available scientific literature on the Tunguska event of 30 June 1908 in order to extract a sample of data from which we calculate the possible parameters of the atmospheric dynamics of the Tunguska Cosmic Body. We perform a comparative analysis by means of some of actual theoretical models and with the help of interplanetary dynamics, to exclude unphysical orbits. From the obtained results, the probability that the TCB was an asteroid is very high. **PSA-34**

The Leonid Meteors Found in Chinese Historical Records

Y. Fujiwara (Nippon Meteor Society)

Beijin Observatory published the compilation of the Chinese historical records of meteor showers and individual fireballs. Since some records of the fireballs indicate the meteor trail with Chinese constellation or bright fixed stars and the directions of the path, we can estimate probable path of the meteor. So we can identify the permanent shower meteor not only the aid of the solar longitude at the meteor apparition but also the its path. In this paper some Leonid meteor records found in Chinese chronicles by using this method are presented. **PSA-21**

TV Observation of the 1998 Giacobinid Meteor Shower in Japan

Y. Fujiwara, M. Ueda, M. Sugimoto and T. Sagayama (Nippon Meteor Society), M. Satake and A. Furoue (Kansai Astronomical Society)

Activity of Giacobinid (Draconid) meteor shower was recognized on October 8th, 1998, in Japan, with multi-station TV observations. 104 Giacobinid meteors have been recorded, and among which precise orbit could be determined for 60 meteors. It is found that the radiant points were concentrated compactly. Furthermore, the beginning heights of Giacobinid meteors are significantly higher than typical TV meteors with similar velocities. **PSA-11**

Probing the Structure of the Interplanetary Dust Cloud Using the AMOR Meteoroid Orbit Radar

David Galligan and Jack Baggaley (University of Canterbury, Christchurch, New Zealand)

During the past five years the University of Canterbury's (New Zealand) Advanced Meteor Orbit Radar (AMOR) has catalogued over half a million high-quality meteoroid orbits. This data set, which is greater in size than the combined total of all previous surveys, provides high resolution information on the structure

of the dust cloud orbiting the Sun. It is important to be able to obtain an astronomically true picture of this dust population for inclusion in interplanetary dust models, as a background to studies of interstellar dust such as that detected recently by W.J. Baggaley, and from a general scientific interest point of view. There are a series of selection effects which must be allowed for in changing from the orbital distributions as observed directly to "true" distributions in space — these effects, and the "corrected" distributions resulting from their removal, will be discussed. **10.3**

Io Revealed in the Jovian Dust Streams

Amara L. Graps (1), Eberhard Gruen (1), Harald Krueger (1), Mihaly Horanyi (2), Håkan Svedhem (3) and the Galileo and Cassini Dust Science Teams
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The Jovian dust streams are high-rate (at least 250 km/s) bursts of submicron-sized particles travelling in the same direction from a source in the Jovian system. The source of the Jovian dust streams is Jupiter's moon, Io, in particular, dust from Io's volcanoes. Charged Io dust, travelling on trajectories from Io's location, is shown to have some particular signatures in real space, in frequency space, inside of Jupiter's magnetosphere, and outside of Jupiter's magnetosphere. The work presented here describes an emerging electrodynamical picture of the Jovian dust streams as they appear inside and outside of the Jupiter environment using data from the Galileo spacecraft in years 1996-2000 and from the Galileo-Cassini December 2000 dust stream measurements. We show that some aspects of the dust stream particles' dynamics in real space can be understood if the particles charges are a varying parameter in the force equation. The Jovian dust stream dynamics in the frequency-transformed Galileo dust measurements show two different signatures, depending whether the dust detector is located outside of the Jovian magnetosphere or inside of the Jovian magnetosphere. This time-frequency analysis is the first direct evidence that Io is the source of the Jovian dust streams. **10.8**

Dust Astronomy

Eberhard Gruen (MPI-Kernphysik, Heidelberg)

Dust particles, like photons, are born at remote sites in space and time, and carry from there information that may not be accessible to direct investigation. From knowledge of the dust particles' birthplace and the particles' bulk properties, we can learn about the remote environment out of which the particles were formed. This approach is called dust astronomy which is carried out by means of dust telescopes on dust observatories in space. Targets for dust telescopes are dust from the local interstellar medium, meteor stream dust, cometary, asteroidal, and lunar dust, and space debris. Dust particles' trajectories are determined by in-situ dust detectors with narrow apertures and by the measurements of the electric charge signals that are induced when the charged grains fly through appropriately configured grid systems. Modern in-situ dust detectors are capable of providing mass, speed, physical and chemical information of dust grains in space. A "dust telescope" can, therefore, be considered as a combination of detectors for dust particle trajectories along with detectors for physical and chemical analysis of dust particles. A state-of-the-art dust telescope will consist of an array of parallel-mounted dust instruments, which share a common impact plane of at least one square meter in size. **11.5**

Porous Flake Meteoroids and the Structure of Small Bodies in the Solar System

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There is significant evidence that comets and even some asteroids preserve in the structure of their materials the physical dimensions of the interstellar dust grains that they were made from. Laboratory simulations of comet material in the form of colloidal grains of a narrow size distribution embedded in water ice produced thin flakes from the process of sublimation. Simple calculations show how the gas pressure below a grain on the surface of a sublimating material increases sharply as the layer of grains grows from a monolayer to becoming two particles thick. This is the probable cause for the formation of thin flakes in the experiment and also on the surface of comets under some circumstances. It probably corresponds to one of several modes of dust and meteoroid production from comets. I will review some evidence for the presence of such flake-like structures among dust and meteoroids. From the external shape of dust aggregates, we will now turn our attention to the internal structure of grain arrangement. I will show how optical grain properties including colour and polarization is evidence for a hierarchy in the arrangement that may be indicative of turbulence in the nebula at the time of aggregation.. **10.1**

Development of a New Reflectron Type TOF Mass Spectrometer for Dust Analysis in Space

Yoshimi Hamabe (1), Sho Sasaki (1), Hideo Ohashi (2), Tohru Kawamura (3), Ken-ichi Nogami 3), Hajime Yano (4), Sunao Hasegawa (4), and Hiromi Shibata (5)
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In order to analyze the elements of dust particles in space, we have been developing a reflectron-type dust TOF-MS (Time-Of-Flight Mass Spectrometer) with a curved electric field. Now we have done performance experiments of our device by impacting hypervelocity microparticles with a Van de Graaff accelerator at HIT (High Fluence Irradiation Facility, University of Tokyo), where carbon particles of 0.3-2.0 micrometer in diameter are accelerated up to 5-20 km/s which is compared to the velocity of dust particles in space. The results showed the device has higher mass resolution than the system with a parallel reflecting region under the same experiment situation by factor 2 or 3. Moreover the TOF spectra showed the higher detection efficiency, and the value was 10 times higher compared to the parallel reflectron TOF-MS. These effective results are considered to be caused by a curved electric field in a reflecting region. **PSB-18**

Millimeter Continuum Observations of Parent Comets of Meteor Storms

Hitoshi Hasegawa (ASTEC, Inc.), Nobuharu Ukita (Nobeyama Radio Observatory) and Ryosuke Nakamura (NASDA)

The 2 millimeter continuum observations of parent comets of meter storms, P/Tempel-Tuttle and P/Giacobini-Zinner, were made with a bolometer array installed on the 45m radio telescope at the Nobeyama Radio Observatory. P/Tempel-Tuttle was observed on January 16, 1998, near its closest approach to the earth, and P/Giacobini-Zinner was observed November 5 and 8, 1998. The maps obtained showed no signal from these comets greater than 12.0 mJy for P/Tempel-Tuttle and 17.4 mJy for P/Giacobini-Zinner (3 sigma). Using the same assumptions in Jewitt and Mathews (1997, AJ, 113, 1145), we estimated that the mass upper limits in the 12 arcsec beam were 7.5E9 kg and 6.2E10 kg for P/Tempel-Tuttle and P/Giacobini-Zinner respectively. We esitimated total mass of these meteor streams form the observed upper limits. The derived total mass upper limits are serveral orders larger than those expected from meteor observations. **1.2**

Parent Objects of Alpha Capricornid Meteor Stream

Ichiro Hasegawa

The complex structures of Alpha Capricornid stream are investigated from about 45 photographic meteors observed during July 8 and September 10. Although there are several subgroups in this stream, it is confirmed that the main parent comet is 45P/Honda-Mrkos-Pajdusakova. 72P/Denning-Fujikawa and 141P/Machholz 2 are likely to be additional parent comets. Near earth objects, (2101)Adonis and (9162)1987 OA are also suggested as the possible parent objects. **1.9**

High Resolution Meteor Light Curve Investigations

R.L. Hawkes, J.E. Bussey, S.L. MacPhee, C.S. Pollock and LW. Taggart (Physics Department, Mount Allison University, Sackville, NB Canada E4L 1E6)

The dustball model of meteoroid structure would be expected to lead to short duration fluctuations on light curves, anomalous decelerations, and possibly light production over a significant spatial region. Traditional approaches to meteor light curve video analysis have not used all of the information which is provided by the CCD video signal. We have employed coincidence and correlation analysis using two spatially separated microchannel plate (Gen III) image intensified CCD observations systems coupled to digital video recording equipment to search for fine scale structure both perpendicular to the line of motion and along the meteor path and attempted deceleration measures. We will describe the digital image analysis approaches, give some model predictions, as well as preliminary results. **3.8**

Sondrestrom ISR Meteor Measurements

C.J. Heinselman and J. Jørgensen (SRI International, 333 Ravenswood Ave, Menlo Park, CA 94025, USA)

Measurements of the meteoric phenomena with the Sondrestrom ISR at 1290 MHz have previously been limited to studies of sporadic E layers and their relationship to infrequent, strong meteor echoes. Recent enhancements to the Sondrestrom data acquisition system have enabled the development of data collection codes better suited to probing the meteor head echo phenomena at this frequency. Initial results will be presented of measurements from recent meteor showers. Future plans will also be discussed for making more routine meteor measurements with the Sondrestrom system. **7.8**

Two-frequency Meteor Observations Using ALTAIR

Stephen Hunt and Sigrid Close (MIT Lincoln Laboratory, 244 Wood Street, Lexington MA, 02173, USA)

We present a sample of radar meteors detected during the November 1998 Leonid shower that were collected using the ARPA Long Range Tracking and Instrumentation Radar (ALTAIR). A total of 29 minutes of VHF data were collected near the peak of the shower, which produced over 900 head echoes; 17 minutes of simultaneous UHF data were collected, which resulted in over 500 head echoes. These data were analyzed to determine frequency-dependent radar cross section and shape characteristics. In addition, the azimuth and elevation data were used to compute the true velocity and deceleration of the head echoes, which produced the result that a meteoroid's deceleration is not constant. Finally, the first head echo that was detected using three frequencies (160 MHz, 422 MHz, 1320 MHz) is discussed.

ALTAIR is a highly sensitive, two-frequency radar that is uniquely suited for detecting meteor head echoes. ALTAIR transmits right circular polarized energy and records both left circular and right circular data, as well as azimuth and elevation difference channel data. These data allow the accurate determination of a target's position, velocity and deceleration. ALTAIR's system sensitivity allows the reliable detection of a -55 dBsm target in VHF and a -75 dBsm target at UHF at a range of 100 km. **7.4**

Arecibo Detection of a "Large" Mass Component in the Ulysses Interstellar Dust Flow

David Meisel (1, 2), **Diego Janches** (2, 3) and John Mathews (2)
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Micrometeoroids detected with the Arecibo UHF radar have hyperbolic heliocentric velocities as well as measurable atmospheric drag decelerations. Thus both orbits and sizes can be inferred. Evidence is presented for the discovery of a large size (10 microns> radius >0.2 micron) component of the Ulysses interstellar particle flow. The mean velocity of these "large" particles is somewhat higher than for the mean of the Ulysses particles themselves, but when the Arecibo particle velocity vectors are transformed to system moving at their average velocity, good coincidence with the Ulysses radiant is found. Larger extrasolar particles (>10 microns radius) have been detected, but they do not correlate well with the Ulysses radiant. **PSB-21**

The Size Distribution of Arecibo ISPs and its Implications

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Extrasolar particles observed at Arecibo and deemed to be true interstellar particles display a lognormal distribution of sizes. The radii also correlate with their original hyperbolic, solar system impact parameters. The upper end of the observed distribution occurs for particles on the order of 10 microns radius, while the lower end of the observed distribution occurs for particles ten times smaller. Such a distribution is characteristic of a "breakage" process (Wadsworth, 1990) and has been shaped by various creation and loss processes during transit from their source regions to the earth. The observed size limits agree quite well with models attempting to explain Ulysses spacecraft observations. **11.7**

Tristatic measurements of meteors using the 930 MHz EISCAT radar system

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We report results from the first tristatic measurements of radar meteors obtained during November 17-18, 1997 and 1998, using the UHF (930 MHz) EISCAT radar system. This system consists of three antennas located in Tromso, Norway (69.6 N; 19.2 E); Kiruna, Sweden (67.9 N; 20.4 E) and Sodankyla, Finland (67.4 N; 26.6 E). Since EISCAT observes mostly head-echoes, a general characteristic of high power/large aperture radars, very precise Doppler velocity determination are possible. In addition using the technique reported here, absolute geocentric meteor velocity and precise radiant information are deduced for those meteors that are detected simultaneously by all three receivers. An overview of the methodology and a summary of the results obtained so far are reported in this work. To the best of our knowledge, these observations represent the first of their kind and prove EISCAT to be a crucial instrument for the study of extraterrestrial particles entering the earth's atmosphere, in particular at very high geocentric latitudes. **7.7**

Leonid Storm Research in the Near Future

P. Jenniskens (SETI Institute, at NASA Ames Research Center)

Recent observations and dynamical models show that the biggest Leonid storms in this season are still to come. In November of 2001 and 2002, Zenith Hourly Rates are predicted to increase to levels above the storm of 1999. And the next storm is not until 2099. Results from the 1999 Leonid storm research were published, recently, in special issues of *Earth, Moon and Planets*, *Meteoritics & Planetary Science*, and *Geophysical Research Letters*. In this presentation, I will summarize some results from key areas of Leonid storm and meteor outburst research to date, elaborate on how those results further other research fields, and discuss in what areas future research might make rapid progress. **PSA-13**

Meteors: A Delivery Mechanism of Organic Matter to the Early Earth

P. Jenniskens (SETI Institute, at NASA Ames Research Center), C.O. Laux, D. Packan and C.H. Krueger (Stanford University), I. Boyd (University of Michigan, Ann Arbor) and O.P. Popova (Institute for Dynamics of the Geospheres RAS, Moscow)

All potential exogenous pre-biotic matter arrived to Earth by way of our atmosphere, where much material was ablated during a luminous phase called "meteors" in rarefied flows of high (up to 270) Mach number. The recent Leonid showers offered a first glimpse into the elusive physical conditions of the ablation process and atmospheric chemistry associated with high-speed meteors, and the possible pathways of survival for meteoric organic compounds and the creation of reduced carbon compounds through aerothermochemistry. In this presentation, I will discuss the role that meteors can have played in delivering organic matter to the early Earth as precursors for the origin of life. **3.3**

The 2000 Ursid Shower Prediction and Observations

P. Jenniskens (SETI Institute, at NASA Ames Research Center) and E. Lyytinen (Finland)

We applied Leonid dynamical models to Halley-type comet 8P/Tuttle and its meteor shower, the Ursids. An outburst was predicted for December 22, 2000, when Earth was to cross the dust trails that originated during the 1392 and 1405 returns. An announcement was made in the IAU circulars and in extended form in WGN, the Journal of IMO. The meteor outburst observed from California using video and photographic techniques. At the same time, five Global-MS-Net stations in Finland, Japan and Belgium counted meteors using forward meteor scatter. We can now confirm the return of the Ursid outburst with a maximum at 8:06±07 UT, December 22nd, when activity peaked at ZHR ~ 90. The Ursid rates were above half peak intensity during 4.2 hours. The relative contribution from both dust trails to the outburst is discussed, as is the relevancy of this for future meteor outburst forecasts. **PSA-3**

A Physical Model of the Sporadic Meteoroid Complex

J. Jones, M. Campbell and S. Nikolova (Department of Physics and Astronomy, University of Western Ontario, London, Ontario, N6A 3K7 Canada)

Almost a half century ago Davies (1957) and Hawkins and Southworth (1958) showed that the directional distribution of the trajectories of sporadic meteoroids is not isotropic. More recently Jones and Brown (1993) showed that there are six main clusters of sporadic meteor radiants for which they determined the mean directions and widths. In this paper we present the results of a model of the evolution of sporadic meteoroid orbits which takes long and short-period comets as the sources of meteoric material and the Poynting-Robertson effect as the dominant mechanism of orbital change. The predicted radiant and orbital distributions are in excellent agreement with observation. It is shown that the inclusion of Steel and Elford's (1985) estimate of the collisional lifetime of meteoroid-sized particles, yields the observed variation of the volume density of the particles with distance from the Sun. **10.4**

Radar-meteor Velocity Determination

J. Jones, K. Ellis and M. Campbell. (Department of Physics and Astronomy, University of Western Ontario, London, ON, N6A 3K7 Canada)

Meteoroid velocities are essential for the calculation of orbits. Most methods for measuring radar-meteor velocities require high signal-to-noise ratios and the question arises whether the process of selecting those meteor echoes suitable for velocity determination introduces bias. For example, are fragmenting meteors discriminated against because their Fresnel oscillations are "washed out"? In this paper we have examined the time-honored "rise-time" method and tried to push it to its limit. Model calculation indicated that an accuracy of 5% should be attainable for signal-to-noise rations of 20 dB. Simultaneous measurements using identical radars operating at 29 MHz and 38 MHz yield an accuracy of about 13% for echoes with signal-to-noise ratios > 6dB. The method allows a velocity determination for every echo. **6.2**

The Computer Model "KAMET": A New Generation

Arkady Karpov, Sergey Tereshin and Joury Abrosimov

In this work , we present the results of the modernization of the computer model "KAMET". "KAMET" contains the following primary software modules: (1) astronomical model of the flux of meteoric material into an atmosphere of the Earth; (2) a block of geometrical aspect equations; (3) the physical model; (4) the electrodynamics model; (5) a block of power equations and (6) an astronomical component of model "KAMET" is based on long-term experimental radar observation which are carried out on the meteoric radar of the Kazan university. Modifiction of the radiotomography input data gives us the possibility of taking into account a thinner structure of meteor flux.

The astronomical model of inflow of meteoric material into the atmosphere of the Earth is expressed by tables of cumulative density of meteor flux. Densities of meteor flux which are higher than a given amount are obtained by analytical recalculation of density above a given threshold of detection as indicated by the experiment. Subsequent calculations are reduced to some characteristic height. It is an approximation with an accuracy that is impossible to evaluate at present.

We offer here a different simulation method which allows one to decide a problem of recalculation without reduction of the data to a characteristic height. The simulation method also allows revision of the tables of meteor flux density for new physical models that may be introduced. **PSA-33**

The Measurement to Ozone Concentration by Kazan Radar Observations

Arkady Karpov, Alexey Naumov, Andrey Konnov, Matvey Krimer

An indirect method of measurement of ozone concentration based on duration of the radar observed radiometeor reflections is presented. A comparative analysis of different processes has been carried out from recombinations — radiative, and dissociative processes to recombinations under triple collisions. The most important role in such processes is dissociative recombination and recombinations with the electronic stabilization.

By means of "KAMET" computer model, we have studied the disintegration of meteoric trails. The modeling of reflection duration was carried out for different mechanisms:

- Without accounting for recombinations;
- With accounting for only dissociative recombinations;
- With accounting for recombinations with electronic stabilization;
- With accounting for both mechanisms;

The model results are compared with experimental durations of meteoric burst observed at a frequency of 32,8 MHZ. **PSA-35**

Thin Space Structure of Meteor Flux Irregularities in Large Meteor Showers in 1986 -1999

A.V. Karpov and E.Z. Yumagulov

Meteoric observations obtained with the radar KGU-M5 (1986 — 2000), have been archived in an Oracle 8 relational database. An advanced statistical method of searching for fine spatial structure of meteoric showers has been applied to the database and information on the distribution of material in the Quadrantid, Geminid and Perseid showers has been obtained.

For the Geminid meteor shower, evidence of grouping was found in 49 % of the intervals of observation (similarly for the Quadrantid and Perseid showers 39% and 63 % were obtained, respectively.). The results also had a dependence on signal level. Groupings were detected (a) in 79 % of cases only at low signal level,

(b) in 17 % of cases the groupings were detected at both high and low levels detection, and (c) in 4 % of cases groupings were found only at high signal levels and they were absent at low levels. The prevalence of groupings observed at low signal levels corresponds qualitatively well to that of a Poisson model of particle distribution. **1.5**

Meteoroid Stream Impacts on the Moon: Information of Duration of Seismograms

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The seismograms of meteoroid stream impacts on the Moon have brought important information about inside structure of the Moon more years ago. This work is a new attempt of using records of “Apollo” seismic network for receiving further information about dynamic processes on the Moon. The Nakamura Catalogue is employed for research of these problems. We have built up some histograms from seismic data of Catalogue. The duration of impact _imp in minutes was a general parameter for our analysis. The impact duration was plotted on the horizontal axe of histogram and sum number of impacts _ni for every impact duration was plotted on its vertical axe. In other words, these histograms are the graphic images of relationships between _ni and _imp. Following kinds of functions_ni=_ni(_imp) are analysed: (1) one impact of a meteoroid per Earth day; (2) two impacts per day; (3) three impacts per day; (4) four-eight impacts per day; functions (1)-(3) have been built up only within 1974 year; function (4) has been built up for every year within 1974-1977 and for their sum also. Preliminary conclusions of processing histograms is as follows: the increase of energy of impact from (1) to (3) moves a maximum of histograms to shorter duration, especially it is evident in the case of 4-8 impacts per day; every histogram contains significant picks which are 58-56; 40; 38; 25; 19-20; 16 minutes, but 6; 10,13 minute picks are existed only for 4-8 imp/day histogram. We expect that physical models for explaining these picks might be discuses in the meeting. **1.3**

Radioseismology as a New Method of Investigations of Meteor Streams on the Moon and Planets

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Radioseismology is based on registration and interpretation of radio emission of seismic origin. Such radioseismic processes occur on the Moon, planets, and asteroids. Non-thermal radio emission of the Moon caused by rock fracturing, seismic activity, and thermal cracking of the regolith was detected during observations of the Moon at the 64 m Kaliazin radio telescope at 13 and 21 cm on July 31, 1999. We observed the Moon on November 16-18, 2000 with the 32 m Ventspils antenna at 25 mm. During the morning of November 17 we registered significant quasiperiodic oscillations of the lunar radio emission starting near 1:44 UT and contining until the end of observations at 7:17 UT. Oscillations were also registered on November 18 starting near 2:28 UT. Intensive oscillations were registered until about 7:00 UT with bottom to peak heights of 5-10 K. The time of maxima of oscillations does not contradict theoretical predictions about the existence of three maxima of the Leonid meteor shower on the Moon. Amplitudes of oscillations were equal to 1-2 K before and after the time of Leonid’s maxima. These results can be explained as the detection of lunar radio emission of seismic origin caused by meteoroid impacts. The implications of the radioseismic method for determination of the intensity of meteor showers on the Moon and planets and the internal structure of the Moon are described. **PSA-16**

Temporal Structure of Meteoroid Stream and Lunar Seismicity According to Nakamura’s Katalog

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Nakamura and Oberst pioneered in receiving data of clustering of meteoroid streams from impact seismograms. As a continuation of their research we have derived some types of temporal series. Two series 1 and 7 years in persistence (1974 and 1969-1977) are the temporal sequences of sum numbers of impacts per unit time (one day, three days). The third series one year in persistence (1974) is the temporal sequence of impact events and time intervals between them according to Catalogue. We adopted that event amplitudes are equal to unit. The duration of these events was obtained from impact seismograms. The forth series with the same persistence (1974) is the temporal sequence of values equal to duration of impacts averaged through day. All series were studied by spectral analysis and as a result, common periodicity for all series and supplementary picks in only two series were obtained. Spectrum of the series (1969-1977) disclosed time picks on Mercury, Venus and Earth orbital periodicity (88; 115; 225; 365, 27.3 days). Comparative analysis of spectra for other series disclosed following periodicity picks: 44; 27; 5,5; 3,7 (for first series 1974 in persistence); 10; 5; 3; 2.5; 2.23 days (for third series); 10; 5; 3,3; 2.5; 2,23 days (for forth series). The 10 and 5-days picks are exceptionally interesting, because magnetic solar storms have the same periodicity. The dust component of meteoroid streams similar to dust plasma probably is modulated by variation of solar magnetic fields. Thin temporal structure of temporal variation of meteoroid streams has the picks which coincide with half-periods of neighbourhood binary star systems (2.2 day — UWCma; 3.6 days — hAql). **PSA-6**

Properties of Interstellar Dust Derived From In-Situ Measurements and Extinction Observations

Hiroshi Kimura and Ingrid Mann

Already since the 1930s observations of the extinction of stellar radiation have revealed the presence of dust in interstellar space. The spectral variation of the interstellar extinction was classically used to infer the size and composition of interstellar dust along the line of sight of observations. Current models also apply measurements of elemental abundances in interstellar space to place constraints on the dust compositions. During the past decade, interstellar dust particles that enter the solar system have been identified with in situ measurements from spacecraft. Analyses of these in-situ data provide information on the properties of dust in the local interstellar cloud, in which the solar system is embedded. In this review, we first discuss problems with current models when compared to the experimental results and laboratory analyses of presolar grains. We present an update on the status of our modeling, in which the properties of interstellar dust are consistent with astronomical observations and in-situ experiments. We finally discuss possibilities for future studies and in-situ measurements. **11.2**

Interstellar Particle Detection and Selection Criteria of the Meteor Streams

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There is a hypothesis on possible exposure of interstellar particles from kinematics discussions. If interstellar meteors are present among the observed meteoroids with hyperbolic orbits, then their heliocentric velocity distribution must correspond to distribution of radial velocities of close stars Thus, heliocentric velocity of interstellar meteoroids equals to 46.6 km/sec. Moreover, a concentration of meteor radiants to the apex of the Sun should be observed for interstellar meteoroids. In the paper there has been examined probable distribution of number of interstellar meteoroids. By appraisals of Belkovich O. I., Potapov I. N., 1985, Kazantsev A. M., 1998, the nor less than 75% of interstellar particles which are observed on the Earth are distributed in the interval from 1 to 1,1. This interval of the eccentricity is typical the eccentricity and for orbits which have become hyperbolic because of errors of their definition. The same the eccentricity will belong to orbits of meteor bodies, which have become hyperbolic because of narrow rapprochement with planets. It is investigated the opportunity of division the observation orbital radiometeor data, with the eccentricity, which exceeds one, according to mechanism of their formation with the goal of search the orbits of interstellar particles. They are adduced the results of search the orbits of interstellar particles by criterions which are based on analysis of orbital elements and on limitations which associates with conditions of observation such particles on the Earth. The eccentricity of 2303 investigated hyperbolic orbits is in the interval from 1 to 2. The approbation of search were made on the different samples from observation material, which volume is more than 7 thousands hyperbolic and about parabolic orbits of unique Kharkiv electronic catalogue 160000 orbits of radiometeors to +12 starry size that were registered in 1972-1978 years. 111 meteoroid hyperbolic orbits with $1<e<2$ were foundduring 21 March, 20 days before and 20 days after this date (data for 1972-1978). Distribution of their parameters is given. It is possible that there is a certain number of interstellar meteoroids. **11.4**

Extreme Beginning Heights for Non-Leonid Meteors

Pavel Koten, Pavel Spurny, Jiri Borovicka and Rostislav Stork (Astronomical Institute, Academy of Science, Ondrejov Observatory, 251 65 Ondrejov, Czech Republic)

Extreme beginning heights up to 200 km were recently discovered for bright Leonid meteors. Here we report results of the search among our double-station video data of other meteor showers. We found two eta-Aquarid and one Perseid meteors with beginning heights up to 150 km and one Lyrid meteor with beginning height above 130 km. Surprisingly, the eta-Aquarids and the Lyrid were not bright enough to be recorded by all-sky photographic cameras. **PSA-10**

Light Curves of Faint Meteors

Pavel Koten and Jiri Borovicka (Astronomical Institute, Academy of Science, Ondrejov Observatory, 251 65 Ondrejov, Czech Republic)

The results of the analysis of light curves of about 250 meteors observed and recorded within the double-station image intensifier observations at the Ondrejov observatory will be presented. Double-station observations allow to compute the meteor trajectory in the Solar system and in the atmosphere as well as to determinate the absolute magnitude of meteor and its mass. Light curves and heights data of all major meteor showers — Lyrids, eta-Aquarids, Perseid, Orionids, Leonids, Geminids as well as many sporadic meteors — were analysed. The differencies between individual showers were found, e.g. Perseids appear to be more compact than Leonids. There is also difference between 1998 and 1999 Leonids. This suggests different composition or structure of parent bodies. Our data show that the beginning heights of Perseids, Orionids and Leonids are weakly dependent on meteor mass, although the dust-ball theory assumes they should be mass independent. **3.5**

Some Features of Digital Kinematic and Photometrical Processing of Faint TV Meteors

Pavlo M. Kozak, Alexander A. Rozhilo and Yury G. Taranukha (Astronomical Observatory of Kyiv Taras Shevchenko National University, Kyiv, Ukraine

Some features of digital kinematic and photometrical processing of TV faint meteors are discussed. For these purpose a computer original program has been worked out. The program uses data, obtained by two TV devices, equipped by izokon TV tubes. Observational images were recorded into videotaperecorder and than digitized with the help of a framegrabber. A precision of measurements of meteor coordinates in the frame is estimated.

The kinematic processing is based on an original method using in general elements of vector analysis and calculates both meteor trajectory parameters in Earth's atmosphere and orbit elements. The errors of the parameters are also computed. Photometrical characteristics of TV systems were investigated. Some experiments for photometrical field correction, spectral sensitivity of TV tube cathode and correction for the motion of a meteor were carried out. The method was approbated on the results of basic observations of meteors for the last years in Kyiv. **PSA-31**

Thermal Explosions of Meteoroids in the Earth's Atmosphere

V.G. Kruchynenko (Astronomical Observatory of Taras Shevchenko Kiev University, Ukraine)

Based on a data analysis about bright flashes of large meteoroids in a terrestrial atmosphere (Tungusskiy, Sichote — Alin, Sterlitamak, Kun'-Urgench etc.) we come to a conclusion, that such thermal explosions happen at the height of maximum deceleration. Such assumption confirms also explosion of Shoemaker-Levy 9 comet in atmosphere of Jove. In this area on a small interval of altitudes (significant less than altitude of a homogeneous atmosphere, therefore explosion can be considered as the point one) the loss of energy by a body on deceleration surpasses energy, which is indispensable for a full evaporation of whole body. At the same time, achievement by a meteoroid of the altitude of maximum deceleration is condition indispensable, but not sufficient that there was a thermal explosion. It is known the meteoroids, which reach the altitude of maximum deceleration, but explosion does not happen. For the analysis of conditions in the field of maximum deceleration the indispensable mathematical model is developed. We also suppose, that at collision of bodies with any environment (water, rock, metal) the explosion of the impacting projectile happens (more correctly: is possible) only on a depth of its maximum deceleration in given environment. **5.3**

The Modal of the Quasi-continuous Fragmentation and its Application to the Analysis of Meteoric Observations

V.L. Kuznetsov and G.G. Novikov (Novgorod State University, Novgorod the Great, Russia)

The amount of data evidencing fragmentation led Levin (1963) to the conclusion that, if fragmentation were not taken into consideration in processing the observations, erroneous results would results. Knowledge of sizes and masses of particles, which separate from a meteor body or on which it is fragmented during moving in atmosphere of the Earth, is of interest for understanding of processes of its interaction with air, and for improvement of our notion idea of a structure of meteor bodies. The new formula, describing an appearance of fragmentation is obtained on the basis of a new mathematical model approach to solution of the task about fragmentation of a meteoric body the quasi-continuous type. The new approach has allowed describing two kind quasi-continuous fragmentation (QCF) of uniform mathematical formula. The limiting case slow QCF is the pure evaporation and the limiting case fast QCF is the flares of meteors in its classical definition are exhibited. The method of the analysis of meteoric observations, introduced in the catalogues containing information about height of maximum of a brightness and values of a brightness at these heights to definition by the parameters QCF are represented. **3.4**

Contemporary Interstellar Meteoroids in the Solar System: In-situ Measurements and Clues on Composition

M. Landgraf (ESA/ESOC, 64293 Darmstadt, Germany)

Meteoroids originating from the local interstellar medium traverse the solar system. This has been proven by in-situ measurements by interplanetary spacecraft as well as by highly sensitive radar measurements. Early attempts to detect interstellar meteoroids using the instruments on board the Pioneer 8 and 9 spacecraft failed. More sensitive detectors on board the joint ESA/NASA mission Ulysses as well as on board the NASA spacecraft Galileo, however, unambiguously detected meteoroids of interstellar origin. This discovery has started efforts to compare the results from the in-situ measurements with highly sophisticated models of interstellar dust properties derived from astronomical absorption and extinction measurements. It was found that, at least locally, is more mass locked up in meteoroids than expected from the astronomical measurements. So far the in situ measurements only allow to derive composition information indirectly via the meteoroid’s dynamics. **11.1**

Clues to the Structure of Micrometeoroids, from Dust Light Scattering Properties

A.Ch. Levasseur-Regourd, E. Hadamcik and V. Haudebourg (Université Paris VI and Service d’Aeronomie, CNRS-IPSL)

Knowing the size distribution and the shape (compact or fluffy) of the dust particles in meteor streams is of major importance, to understand their mechanisms of interaction with the atmosphere and their impacts effects on spacecraft. Some clues are provided through observations of the solar light scattered by cometary and interplanetary dust particles. While their brightness and polarisation phase curves are mostly similar, and indeed characteristic of irregular particles, major differences are noticed (both from remote and in-situ observations) in terms of polarisation levels and polarisation colours. These differences correspond to different formation regions, and also reveal an evolution of the dust morphological properties, linked to fragmentation and evaporation processes. Recent results from computational models and laboratory measurements will be presented, including polarisation phase curves of samples of terrestrial or meteoritic origin, and results of the CODAG experiment, launched from Esrange in May 1999. **10.6**

The IAU Meteor Data Center

B.A. Lindblad (Lund Observatory, Lund, Sweden)

The IAU Meteor Data Center (MDC) in Lund acts as a central depository for meteor orbits obtained by photographic, video and radar techniques. It was started in 1978 at the suggestion of the present author. The photographic data sample now consists of 4580 precisely reduced orbits plus 2401 graphically reduced orbits. The reformatting of the precisely reduced orbits to a standard format has been a major undertaking since each author/station has used a somewhat different format. There is also some overlap between the various catalogues. For details see the IAUMDC Documentation pamphlet.

As of 1 January 2002 the responsibility of operating the MDC will be transferred to the Astronomical Institute of the Slovak Academy of Sciences in Bratislava, Slovakia with Dr. V. Porubcan as the responsible scientist.

Dr. V. Porubcan and co-workers have been involved in various studies of the photographic data-base. They are preparing a new version which is based on the year 2000 equinox (instead of the 1950 equinox used in nearly all of the published catalogues). They have also made extensive studies of the errors in some of the older photographic data. A description of this work is presented in Lindblad, Neslusan, Svoren and Porubcan (2001). **PSA-1**

Visual and Radar Observations of the Perseid Meteor Stream 1953-83

B.A. Lindblad (Lund Observatory, Box 43, SE-221 00 Lund, Sweden)

This paper describes a long term, high-resolution study of the activity of the Perseid meteor stream based on visual and radar observations at the Onsala Space Observatory in Sweden. The data sample consists of 147 visual hourly rates and some 2000 radar hourly rates recorded in mid-August in the period 1953-83. In a previous paper (Lindblad 2000) a high-resolution study of the visual zenithal hourly rates of bright Perseid meteors versus solar longitude was described. The study using a step length of 0.05° in solar longitude, revealed that the Perseid activity curve has a multi-peak structure with at least four separate and well-defined peaks in the activity curve of bright Perseid meteors. In the present paper we analyse more than 2000 radar hourly rates obtained during the same period. Each hourly rate is available in three different echo duration classes. It is well known that the percentage of Perseid meteors is highest amongst the echoes of long duration. We therefore here analyse hourly rate counts of echoes of duration 1.0 sec and longer, corresponding approximately to visual magnitudes of 2.5m and brighter. The activity curve of the Perseid stream based on these bright meteors is studied. The radar data very strongly support the previous visual data indicating several separate and permanent peaks of stream activity. **1.1**

Cosmic Dust and Micro-debris Measurements on Space Station MIR

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Investigation of impact features found on material retrieved from low earth orbit, after exposure to space for a long period of time, has provided us with a great deal of data on the particulate environment, either natural or man-made. Between 1987 and 1997, several detection devices have been deployed outside the Russian MIR space station. The passive sensors are composed primarily of stacked thin metal foils (gold and aluminum). The size of holes or impact craters give information on the size or shape of the impacting particles. In addition, solar cells from a solar array retrieved by a Shuttle-MIR mission have been searched for impact craters. Samples have been retrieved for laboratory analysis and flux of impacting particles has been derived. Comparison with data from LDEF, and HST provides insight in the long-term evolution of small particle population and in the debris environment of a permanently manned station. Between 1987 and 1997, no peculiar enhancement in the population of microdebris in the vicinity of the MIR station was seen. Several samples show evidence of secondary impact cratering: an attempt is made to locate the origin of primary impact sites. For routine monitoring of space environment the method provides a low cost and reliable tool, if the retrieval of material is possible. However, as short-term fluctuations in the flux of particles are not visible with passive experiments, they should benefit from data obtained by active experiments. **9.2**

Cosmic Dust near 1 AU

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Cosmic dust near 1 AU results from the collision evolution of dust produced from comets, asteroids and meteoroids. Moreover, dust particles entering the solar system from interstellar space are detected near the Earth orbit. Knowledge of the size distribution and of the orbital distribution of dust near 1 AU therefore helps to understand the sources of the dust cloud as well as its collision evolution. We discuss the velocity distribution of dust near 1 AU as well as the collision evolution of dust and the production of beta-meteoroids that leave the solar system in hyperbolic orbits. Moreover we discuss the expected flux of interstellar dust and its gravitational focussing. We finally refer to dust measurements of the Mars Dust Counter experiment onboard the Japanese mission Nozomi that works since 1998. Nozomi measurements near Earth have detected particles with masses 10^{-17} kg $< m <$ 10^{-12} kg. The Nozomi measurement planned during the next phase of the mission will provide dust fluxes between about 1 and 1.6 AU. **PSB-20**

Dust and Meteoroids in Extra-solar Planetary Systems

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Basic properties of the evolution of the solar system meteoritic complex are also expected to be important for the evolution of circum-stellar debris disks: Mutual Collisions and Poynting Robertson effect limit the lifetime of dust particles in Keplerian orbits around stars if the density of circum-stellar gas is sufficiently small. While "dense" dust shells such as the shell around Beta-Pic are limited by collision lifetime, mutual collisions get less important for systems with lower dust density. The evolution of dust and meteoroids from their sources can cause, similar to meteor streams, local features in circum-stellar dust shells. We discuss the compatibility of solar system and "extra-solar" conditions for the evolution of planetesimals, meteoroids and dust particles. **11.3**

Meteor Trains as a Probe for Measuring the Dynamics of the Upper Atmosphere

Steven Marsh and Jack Baggaley (University of Canterbury, Christchurch, New Zealand)

The AMOR meteor orbit radar operated in New Zealand has recently been extended to enable wind measurements in the upper mesosphere/lower thermosphere. As a meteoroid encounters the increasing density of the Earth's atmosphere it ablates and leaves a train of ionisation. Radar signals reflected from this atmospherically transported train are Doppler shifted and a line of sight wind measurement can be made. Aside from information about atmospheric dynamics, a correct interpretation of meteoric signatures requires an understanding of the influence of such motions. A dual interferometer enables the wind measurement's height to be determined to within 1 km. Hence a detailed vertical profile of atmospheric motion in the meteor region is obtained. This paper details the meteor radar method of wind measurement. Results presented include a time series analysis of the AMOR winds data. This reveals a strong 12-hr semidiurnal tide as well as occasional planetary wave activity. Evidence suggesting the presence of gravity waves, possibly produced from the local Southern Alps mountain range, breaking in the meteor region will also be given. **PSA-36**

The Role of Large-Aperture V/UHF Radar Meteor Observations in Meteor Science

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Meteor science based solely on "classical" HF/VHF meteor radar observations was characterized by a number of long-standing unresolved issues that have been solved or refined with the advent of radar meteor observations made using high-power, large-aperture V/UHF radars. These radars include those located at Arecibo Observatory, the Jicamarca Radio Observatory, EISCAT, and the MU and ALTAIR radars. Radio science issues successfully addressed with the new observations include the origins of "head-echoes" and anomalous trail-echos. Meteor trails have been found to rapidly B-field align throughout the 80-120 km altitude meteor-zone giving rise to FAI (field-aligned irregularity) scattering. Doppler observations have resolved issues related to the speed-distribution of at least micrometeoroids and micrometeoroid mass fluxes have been found. Additionally, it is becoming clear that assumptions regarding ionization mechanisms for the smallest meteoroids must be reexamined. Finally, we note the planetary astronomy role of these radars in providing vast numbers of micrometeoroid instantaneous orbits. **7.2**

Updated Micrometeoroid Mass Flux Results from Arecibo Meteor Observations

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Radar micrometeor observations at Arecibo Observatory enable direct estimates of the meteoroid mass flux into the upper atmosphere. We report updated mass flux determinations from November 1997/1998 observations that are based on the observed number of meteor events per day in the 300-m diameter Arecibo beam and on particle mass determinations from that fraction of all particles for which deceleration is measured. The average mass of the Arecibo micrometeoroids that manifest observable deceleration is ~0.5 microgram/particle with a resultant annual whole-Earth mass flux of ~2.2¥106 kg/yr over the 10-5-102 microgram mass range. The annual whole-earth mass flux per decade of particle mass is calculated and compared with that of Ceplecha et al. [1998] (3.7¥106 kg/yr) and with that derived by Love and Brownlee [1993] (LB) from small particle impact craters on the orbital Long Duration Exposure Facility (LDEF). We also give the LDEF results as significantly modified using the Arecibo-determined average particle velocity of 50 km/sec-much larger than the effective value of 12 km/sec used by LB. This modification results in a net LDEF mass flux of 1.8¥106 kg/yr-about 7% of their original result. These results may continue to provoke debate. **PSA-32**

The AKM Video Meteor Network

Sirko Molau (International Meteor Organization)

The German Arbeitskreis Meteore (AKM) group has been installing and operating a network of automated image-intensified video cameras since March 1999. It is based on the MetRec meteor detection and analysis software, which allows for efficient video observations with only a minimum of human interaction. It is the first network of video cameras ever that operates on a regular basis and collects large amounts of meteor data in the optical domain throughout the full year. As of spring 2001, the network consists of ten stations. Further stations in Germany and abroad are preparing to join the effort, expanding the AKM network into a global one. All data are compiled into an archive that is freely accessible through the Internet. The video meteor database contains currently more than 24.000 single-station meteor records from about 400 observing nights. The talk will describe the development and current status of the MetRec software including a short demonstration. An overview over the present state of the network will be given. We will describe the structure of the database and illustrate its application. Future plans like the automatic analysis of multi-station video observations and thorough meteor shower analyses will be addressed in the outlook. **4.3**

Constraining Cometary Ejection Models from Meteor Storm Observations

Michael Mueller, Simon F. Green and Neil McBride (Planetary and Space Science Research Institute, Open University, Walton Hall, Milton Keynes, MK7 6AA, UK)

Modelling and observations of the Leonid activity in recent years have shown that maxima in the meteor storm activity can be identified to be due to particles released from the comet during a certain perihelion passage. If the particles originating from a certain perihelion passage can be identified, it is an obvious next question to ask what information can be gained about the ejection process of particles from a cometary nucleus. To address this question we have developed a model which allows calculation of the particle number density in a dust trail physically consistent for arbitrary complex activity distributions of a comet with numerical integration of only relatively few trajectories. The model is applied to the Leonid activity in the year 2000. It is shown that particles of different sizes entering the Earth atmosphere at the same time were released from the comet at different heliocentric distances. Therefore one has to make assumptions about the activity of the comet with heliocentric distance in order to derive the cometary size distribution from an observed meteor size distribution. However, it is shown that lower limits on the ejection velocity of the observed particles can readily be derived. **1.8**

Physics and Chemistry of Meteoroids in the Upper Atmosphere

Edmond Murad (Space Vehicles Directorate, Air Force Research Laboratory, Hanscom AFB, MA 01731, USA)

Meteoroids entering the Earth's atmosphere are frictionally heated by collision with atmospheric gases and begin to ablate at altitudes ranging from 130 to 100 km, depending on their initial velocities, sizes, and densities. An important question in this entry is whether the thermal properties of the meteoroids can reach equilibrium within the transit time of the meteoroids from the point of entry to the point where they are slowed down. If equilibration can occur quickly enough, then evaporation would follow the laws of equilibrium thermodynamics. If not, then time-dependant thermodynamics have to be invoked. Arguments for the former and their implications will be presented during this talk. **3.1**

Meteor Head Echo Observations by the MU Radar and Simultaneous ICCD Camera Observations

Takuji Nakamura (Radio Science Center for Space and Atmosphere, Kyoto University)
Toru Sato and Koji Nishimura (Graduate School of Informatics, Kyoto University)

The MU radar (middle and upper atmospheric radar) is a VHF Doppler radar with a high output power (46.5MHz, 1MW) with a large circular array antenna (8330m^2). This radar has been used for both atmospheric and meteoric studies by receiving meteor tail echoes for over a decade. Recently, we have applied the MU radar for measurement of meteor head echoes and further developed two different techniques for instantaneous measurement of meteor orbits: the sequential beam lobing method and the intereferometric method. The latter is found to be more precise in orbit determination because of rapid variation of radar cross section of head echoes. Precision of this method is estimated to be 0.2 km/s and 0.5 degree for meteor speed and velocity vector direction, respectively. Simultaneous optical observation with an ICCD (image intensified CCD) camera system (sensitive to +9 mag. meteors) was carried out. From 229 minutes observation, 1393 meteors were detected with the radar and 34 meteors were simultaneously recorded by the optical system. Comparative analysis revealed that our radar observation is capable of determining orbit of faint meteors up to +14.8 magnitude. Meteor velocity distribution and mass estimation will also be reported in the paper. **4.5**

Observation of Leonid Activity in 1998 and 1999 with the MU Radar and an All-sky TV Camera

Takuji Nakamura, Sigeru Asakura and Toshitaka Tsuda (Radio Atmospheric Science Center, Kyoto University), Masayoshi Ueda (Nippon Meteor Society) and Jun-ichi Watanabe (National Astronomy Observatory)

The MU (middle and upper atmosphere) radar observed a significant Leonid activity both in 1998 and 1999. A very strong activity with strong and long lasting meteor echoes was observed between 21 UT on Nov. 16 and 02 UT on Nov. 17 (06-11 LT) in 1998. On the other hand, in 1999, a severe outburst with strong but much shorter echoes was detected just around the expected peak time of 2 UT on Nov. 18, 1999 (11 LT). In order to estimate the visual magnitude and mass of the meteors during such shower activity, we carried out an all-sky TV observation with an image intensifier simultaneously. By applying the ionized tail model with attachment process of electrons, radar echo durations are converted to meteor magnitudes. As a result, we conclude that there were plenty of and few fireballs (e.g., brighter meteors with magnitude of -3) in 1998 and 1999. We further discuss about the total mass of meteors during the two outburst cases. **PSA-29**

Comparison among the Keplerian-orbit-diversity Criteria in Major-meteor-shower Separation

L. Neslusan and P.G. Welch

Recently, two new criteria of diversity of Keplerian orbits have been suggested, that by Valsecchi, Jopek, and Froeschle (VJF) in 1999, and orbital-momentum-based (OMB) criterion by Neslusan in 2001. In the presented paper, there is a comparison of how the classic, Southworth-Hawkins (SH) criterion from 1963, and both new criteria behave, when these are used in the separation of several major meteor showers from the photographic IAU MDC database. The cumulative-number-on-threshold-D-dependence method, based on work by Sekanina from the beginning of seventies, is utilized to perform an optimal separation. The quality of separation is evaluated with the help of “background-number-density test” (described here in more detail). No general difference among the particular criteria was found. A relatively worse result is obtained using SH criterion for Perseids. The separation method does not work with the VJF and OMB criteria for the alpha-Capricornids, and with OMB criterion for the Northern as well as Southern delta-Aquarids. **PSA-9**

Lifetimes of Meteoroids in Interplanetary Space: The Effect of Erosive and Catastrophic Collisions

S. Nikolova, J. Jones (Department of Physics and Astronomy, University of Western Ontario, London, Ontario, N6A 3K7 Canada)

There are a number of mechanisms that affect the lifetimes of meteoritic material in interplanetary space. These include Poynting-Robertson effect, Radiation Pressure, Electromagnetic forces and collisions with other meteoritic particles. A physical model of the sporadic meteoroid complex was recently developed by Jones, Campbell and Nikolova. The model considers short and long period comets as primary sources of meteoritic material and Poynting-Roberston effect as dominant mechanism of orbital change. This paper investigates the lifetimes of meteoroids against erosive and catastrophic collisions including the effect of orbital inclination using spatial density distributions obtained by the latter model. **10.5**

About Pulsation Brightness of the Bright Meteors

G. G. Novikov and O.V. Sokolov

On the example of the solution of the model problem it is shown that one of the possoble reasons of pulsation of the brightness of the bright meteors is rotation. Theoretically counted curves of the brightness for the meteoroids, having the cubic and sellipsoid forms qualitatively agree with the observations. **PSA-27**

The Global Monitor of Meteor Streams by Radio Meteor Observation

Hiroshi Ogawa, Shinji Toyomasu, Kimio Maegawa and Koji Ohnishi

In recent years, in Japan, Radio Meteor Observation(RMO) has spreads, and RMO has come to be observed by many observers. Then, to grasp the whole aspect of meteor stream activity accurately, the necessity of unifying the observational data all over the world came out. Then, we tried to correct and integrate them. To consider the error by geographical factor or the observational equipment, the data was divided by average counts previous one week. The 2000 Leonids RMO result at eight sites of the world was unified by this method, and three peaks appeared. This is similar to the result of Visual Observation. In this time, however, it was considered without using the radar equation etc, we could get result as almost same as Visual Observation. Therefore, the more exact result could be obtained if we consider of it. However, it cannot unify easily now, because we have poor information on the various equipment and various geographical conditions. It cannot unify easily at a present stage. Consequently I would like to collect the detailed data of each observational site, and to establish the method of catching meteor stream activity accurately. **PSA-17**

A New Meteor Shower, eta Eridanids

Katsuhito Ohtsuka (Tokyo Meteor Network) and Tomoyasu Tanigawa (Nishinomiya-Nishi High School)

From among approximately 1000 optical meteor data obtained during the past few decades, we discovered a total of 5 (4 probable and 1 possible) meteors which belong to a new meteor shower, eta Eridanids. Several visual and radar observations reinforces the evidence that the eta Eridanids surely exist. We also found out Comet D/1827M1 (Pons-Gambart) and Comet C/1852K1 (Chacornac) as the parent comet candidates. However, the eta Eridanids are rather associated with Comet Chacornac than Comet Pons-Gambart, judging from their orbital similarities. **PSA-8**

On Electrophonic Phenomena

A.Yu. Ol'khovatov (Radio Instrument Industry Research Institute, Moscow, Russia)

During last years an idea that electrophonic sounds are caused by VLF electromagnetic radiation from a bolide's wake is promoted again. The source of the radiation is considered to be "magnetic spagetti relaxation" in a bolide's wake. The most serious problem with the theory is that level of detected VLF disturbances, accompanied a bolide is negligibly small, comparing with needed for hearing VLF radiation. For example, C. Keay experiments revealed lower limit of hearing in order of 160 V/m. It means that a bolide producing electrophonic sounds is to generate in its wake VLF radiation with the power at least in order of 10^{12} W. Nor present theory neither experiments with turbulent ionized wakes predicts such superpowerful VLF radiation. Anyway, if it is realized somehow, it would lead to spectacular effects, for example, to enormous Joule heating of the wake (due to extremely large electric currents) transforming the wake into object as bright (seen from the ground) as at least the Sun. And, of course, this "super-radiation" would produce remarkable global effects — but none of them are known. The presence of "transducers" near an observer can't help the situation, as the needed level to hear their vibrations are even in order of magnitude larger, and anyway, it can't be lowered down many orders of magnitude. A solid confirmation that these estimations are correct is the fact that otherwise people would hear numerours VLF transmitters hundreds miles away! Also there were reports of electrophonic sounds during several Space Shuttle re-entries. The the hypothetical "super-radiation" (if exists) would produce a very remarkable (devastating) effect on the spaceplane. Also, in many electrophonic events the power of aerobraking, i.e. the power deposited by a meteoroid into the atmosphere, which is to be the energy source of the proposed VLF super-radiation was much less that the power of the latter. **8.5**

A Problem of a Meteor Head Echo

A.Yu. Ol'khovatov (Radio Instrument Industry Research Institute, Moscow, Russia)

An unresolved problem of meteor physics is the meteor head echo, i.e. a radar target moving with a meteor velocity. About a decade ago the author has proposed that a head echo is caused by generation of plasma waves in surrounding ionospheric plasma and in meteor's ablation products. The ion beam instability could be a one of sources of the plasma waves, as at the head echo heights a density of ions "sprayed and repelled" by a meteoroid is rather high, and moreover, the ions are weakly trapped by geomagnetic field. Probably these processes at high altitudes were videotaped during the 1998 Leonids campaign. Also maybe coupling with some types of ionospheric waves is important also. This interpretation of a head echo predicts some shift between a meteoroid velocity calculated from its trajectory, and from its Doppler radar return, due to the plasma waves. And it seems that the prediction are being confirmed. Recent radar data indicate some difference between these two velocities. **PSB-8**

Non-specular Meteor Trails: What Does Linear Plasma Theory Teach us about Field-aligned Irregularities?

Meers Oppenheim, Lars Dyrud, Sigrid Close and Stephen Hunt (Center for Space Physics, Boston University)

Radars probing the atmosphere between 75 and 120 km frequently receive echoes from plasma trails left by ablating micron-sized meteors. These echoes have proven useful in characterizing the meteors and in estimating high altitude wind velocities and temperatures. Measurements of non-specular radar echoes and recent plasma simulations demonstrate that field-aligned irregularities develop within meteor trails. This paper analyzes the plasma physics of meteor trail irregularities and compares the results with simulations and observational data. This study helps us better understand the composition of meteor trails and their interactions with the surrounding atmosphere. In particular, we can evaluate: (1) criterion for the onset of the instability as a function of altitude, meteor trail composition and density, and temperature; (2) the nature of the instability and the resulting waves; (3) the range of unstable wavelengths both perpendicular and oblique to the geomagnetic field; and (4) the growth rates at each wavelength. This analysis should enable us to better use meteor radar data to characterize meteors and the upper atmosphere. **5.5**

On the Variable Meteors Parameters

Petr Pecina (Astronomical Institute, Academy of Sciences, Ondrejov Observatory 251 65 Ondrejov, Czech Republic)

The problem of variable shape-density coefficient and ablation parameter is discussed. The two new alternatives to the approaches published so far are proposed. Both alternatives are based on the observed distances flown by a meteoroid considered as a function of time and on the observed light curve again as a function of time. The first alternative deals with the case of isotropic ablation of a body while the second one considers its cross-sectional area to be a general function of time. As a result, the time dependence of both parameters as inferred from the observational data of 5 fireballs, is shown. As a byproduct, there is also presented the exponent in the light efficiency dependence, tau, on velocity (in the power form), for each fireball. **3.7**

Relation between the Optical and Radar Characteristics of Meteors

Petr Pecina, Pavel Koten, Rosta Stork (Petr Pridal Astronomical Institute, Academy of Sciences, Ondrejov Observatory 251 65 Ondrejov, Czech Republic)

Some results on simultaneous TV double station and radar observations of meteors performed in the Czech Republic in 1998 and 1999 are presented. The relation of the magnitude of each TV meteor, in the height corresponding to the radar reflection point, to the radar amplitude or the duration of the echo, is studied. **6.4**

TV and Radar Observation of Meteors

Petr Pecina, Pavel Koten and Rosta Stork (Petr Pridal Astronomical Institute, Academy of Sciences, Ondrejov Observatory, 251 65 Ondrejov, Czech Republic)

The identification of simultaneously observed TV and radar meteors is usually based on time coincidence of both events. The derivation of the range the TV data yields for the radar one in case when the radar station does not coincide with any TV station, is presented. Since also the height of meteor is important quantity we performed the derivation of formulae providing us with the height of the radar reflection point in case when only one TV station observation accompanied by the radar one was made. **PSB-4**

The High Power Large Aperture Radar Method for Meteor Observations

Asta Pellinen-Wannberg (Swedish Institute of Space Physics, Box 812, SE-981 28 Kiruna, Sweden)

The high power large aperture radar meteor method will be presented. It is compared to the classical meteor radar method in terms of working frequency ranges, beam widths, power and radar energy fluxes at meteor altitudes to show their crucial differences. The classical meteor radars are sensitive to perpendicular meteor

trails and are thus perfectly suited for shower meteor observations when orienting the radar beam perpendicular to the radiant direction. By contrast, the large aperture radars, due to their working frequencies and high power, observe the meteoroid-atmosphere interaction at all look-angles. Tristatic measurements from the EISCAT UHF system show that the scattering is isotropic up to angles of 110°. Due to the high sensitivity and narrow beams of these radars they mainly observe the numerous populations of the very small sporadic background particles. Hardly any shower-related increase in fluxes has been observed in the EISCAT Geminid, Perseid and Leonid observations and in the Arecibo Leonid observations. Simultaneously with meteor modes the radars can operate in their usual incoherent scatter modes to observe the electron density variations in the background ionosphere. Thus evolution of sporadic E layers, their average ion composition and their relation to meteor activity can be monitored. **7.1**

The Impact of Extra-terrestrial Dust on the Upper Atmosphere

John Plane (School of Environmental Sciences, University of East Anglia, Norwich, U.K.)

More than 100 tonnes of inter-planetary dust enters the earth's atmosphere each day. Most of this material ablates in the upper esosphere and lower thermosphere, giving rise to a rich diversity of phenomena. For instance, thin layers of metal atoms such as Na, K, Fe and K occur globally at an altitude of about 90 km. These can be observed from the ground by lidar, providing very detailed information about the physics and chemistry of this little explored atmospheric region. Metallic ions in the *E* region are largely responsible for the formation of sporadic *E* layers, which have an important effect on communications and the global electricity circuit. Meteoric debris also slowly recondenses to form dust particles, which may act as condensation nuclei for noctilucent clouds and polar stratospheric clouds which activate the chlorine-catalysed removal of ozone. Metallic dust may also provide catalytic surfaces for reactions such as O + H_2 to form water.

This paper will focus on a number of recent laboratory and modelling studies by the group at Norwich. The experimental work will include: the reactions of FeO, MgO and CaO with atmospheric constituents such as O_3, O_2, CO_2 and H_2O; the reactions of atomic O with FeO, FeO_2 and FeO_3; the reaction between $NaHCO_3$ and H, demonstrating closure of the atmospheric Na cycle; and the photochemistry of sodium species such as NaOH and $NaHCO_3$. The modelling and theoretical work will include: a rigorous test of the proposed ion-molecule mechanism for the formation of sporadic Na layers; a model of metallic species acting as ice particle nuclei; and a new diurnal model of the Na layer which provides *prima facie* evidence for the removal of Na-containing molecules through dust formation. **5.1**

Formation of Disturbed Area around Fast Meteor Body

O.P. Popova, S.N. Sidneva, A.S. Strelkov and V.V. Shuvalov (Institute for Dynamic of Geospheres, Russian Academy of Sciences)

The ablation of meteoroids essentially influences on all processes connected with or initiated by meteoroid entry. Evaporated meteor substance interacts with incoming air flow and forms disturbed area both around and behind the meteor body. There is no yet complete theory of a single high altitude meteor, which could allow to estimate thermodynamical parameters and radiation of formed area by self-consistent way. Air-meteoroid interaction may be described in the frame of particle-beam model which permits to estimate parameters of formed vapor. It includes both gasdynamical and statistical simulations. The solution of Boltzman equation by the Monte Carlo method allows to consider air particles interactions with meteor body and vapor cloud formed around it. The influence of non-elastic processes is estimated and discussed. This technique permits to determine the energy, momentum and mass transfer and consider not only primary particle interaction but also the fate of secondary formed particles. The gasdynamical description is used for vapor cloud formed as the result of ablation, nearby wake evolution, radiation field. **3.2**

Five-year Cooperative Radio Observations of the Leonid Meteoroid Stream by the BLM Radar System

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A survey of results from joint campaigns of the Leonid meteoroid stream observed by the BLM (Bologna-Lecce-Modra) forward scatter system in 1996-2000 is presented. The Leonid radio observations were carried out on November 10-20 each year along two baselines: Bologna-Lecce (Italy) and Bologna-Modra (Slovakia). Trends of long duration echoes and variations of reflection time exhibit a multiple peak activity which is possibly connected with a filamentary structure of the Leonid meteoroid stream. The mass distribution exponents of the Leonid meteoroids in the period of the shower peak activity show significant changes throughout the 5-year observational period, with a higher representation of larger particles mainly in 1998 and 2000, and of relatively smaller particles during the minor meteor storm in 1999. The multiple peak activity and variations of mass exponent in the observed period resulting from forward scatter observations are consistent with the results obtained by other techniques. **2.6**

The Updated Version of the IAU MDC Database of Photographic Meteor Orbits

B. Lindblad (1), L. Neslusan (2), J. Svoren (2) and **V. Porubcan** (3)
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The database of photographic meteor orbits of the IAU Meteor Data Center in Lund has gradually been updated. The version 2001, which has been prepared for publication and which will be released soon, contains complete orbital and geophysical data on 4581 meteors. Several catalogues have been published in some stations and thus a given publication serial number may correspond to several meteors. To remove ambiguity, we now introduce a new meteor identification code consisting of the publication serial number, the author or station code, and the number of the catalogue. The database contains geophysical parameters and orbital elements, which are mutually dependent. Therefore one set can be used to verify the correctness of the other. This verification and appropriate corrections are done. The distribution of database is again planned as two separate files: one with orbital, another with geophysical data. A file containing all data merged and orbits homogenized will be available, too. All the files as well as the appropriate documentation will be placed on a WWW-site to enable their free, public downloading. **PSA-12**

On Periodic Activity Variations during the 1999 Leonid Meteor Storm in Various Data Sets

Jurgen Rendtel (International Meteor Organization, Potsdam, Germany).

Observational data obtained during the 1999 Leonid meteor storm using intensified video cameras as well as meteor radar systems showed significant fluctuations of the activity. Applying a wavelet analysis to the data it is shown that we see quasi-periodic variations with a typical period of 7 minutes. Given the geocentric velocity of the Leonid meteoroids, this hints at structures within the stream at a scale of about 30000 km along the Earth's passage, or about 9000 km vertical to the stream's plane. As the distance between the observing sites at which such fluctuations were recorded is of the order of several 1000 km in N-S and E-W direction, the variations should reflect a characteristic of the stream. Similar observations are only possible during meteor storms in order to collect a sufficient sample within 2 minutes or less. **2.5**

Bolide Fragmentation Modeling

Douglas O. ReVelle (Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA)

In this talk we extend work begun at the Cornell ACM meeting. The shape change parameter is evaluated for conditions when it is negative. For the values of the shape change parameter between 0 and 2/3, ablation, shape change and deceleration can occur. For values < 0, however, large lateral growth of the body occurs. This negative region of the shape change parameter corresponds to the flight regime that was "rediscovered" by Hills and Goda and by Chyba, Zahnle and Thomas in the 1990's and analyzed in detail by Grigoryan in the 1970's. We have determined analytic expressions for the shape change parameter (assuming a constant ablation parameter and constant meteoroid velocity) and for the fragmentation scale height, Hf. We have evaluated Hf assuming that fragmentation was triggered if the stagnation pressure exceeded the body's compressive/tensile strength. If Hf >> H, the density scale height, the single-body approximation is applicable, whereas, if Hf << H, catastrophic, pancake break-up will occur. In the limit with the shape change parameter < 0 with very small ablation, large increases in the frontal cross-sectional area are predicted to occur, but only over a very limited range of conditions. In addition, as the shape change parameter becomes progressively more negative, end heights raise substantially. We also evaluate the effect of a negative shape change parameter on light emission so that a nearly complete, self-consistent model of the bolide phenomena can be formulated. **PSB-12**

Bolide Luminosity Modeling: Comparisons between Uniform Bulk Density and Porous Meteoroid Models

Douglas O. ReVelle (Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA)

We compare predictions of normalized bolide luminosity for two fundamental bolide models, one assuming a uniform bulk density throughout the body and a second which assumes a uniform chondritic composition throughout, but with varying amounts of porosity (assumed to be filled with either water-ice or open space). The second model is based upon the uniformity of spectral observations taken over many years during periods of shower meteors from the extremes of the Geminids to the dustball-like Draconids. The first model utilized is due to ReVelle (1979, 1993) and the second is based upon the porous meteoroid model of ReVelle (1983, 1993). The standard, uniform bulk density, ablation model assumes that the drag and heat transfer area are equivalent in the positive, shape change factor limit. For porous meteoroids however, the heat transfer area can exceed the drag area by increasingly larger amounts as the body's porosity increases. ReVelle (1983) used this approach to show that the bulk density and ablation parameter compositional group identifications of Ceplecha and McCrosky (1976) were essentially correct. When these factors are introduced into the relevant model equations, a set of nearly self-consistent predictive relations are developed which readily allows comparisons to be made of the end-height variations and of the normalized luminous output of the two basic types of meteoroid models. **PSB-13**

Infrasonic Monitoring of the Global Influx Rate of Large Bolides

Douglas O. ReVelle (Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA)

We have utilized recent infrasonic bolide observations to estimate the large bolide influx rate. These infrasonic signals are from the densest, most deeply penetrating objects entering the atmosphere. Undoubtedly, depending on the exact mass range under consideration, the total influx is about a factor of five-ten times greater. This work is a continuation or work shown at the Cornell ACM meeting in 1999 and initiated by Wetherill and ReVelle in the late 1970's using data from AFTAC (Air Force Technical Applications Center, Patrick AFB, Florida). There have been several additional large bolides detected infrasonically since 1999 that are included in our latest evaluation of the global influx rate of large bolides. Some of these have also been detected independently by US DoD Satellites. Thus, in some cases we also have independent estimates of the bolide source energy that can be used for an evaluation of the accuracy of the infrasonic source energy estimate. We have also used statistical counting error procedures to estimate the uncertainty in the influx rate as a function of the source energy, assuming that the source energy estimates are without error. For example, at a source energy of 0.2 kt (1 kt = 4.185 x 10(12) joules), we find a global influx rate and its estimated uncertainty of 28.1 (+/-8.9) bolides per year. **8.3**

Leonid Entry Modeling: Application to the Bolide of November 17, 1999

Douglas O. ReVelle (Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA)

The results of ReVelle (AIAA Aerospace Sciences Conference, Reno, Nevada, January, 2000) are compared against atmospheric observations of the Leonid fireball of 11/17/1999 in northern New Mexico (NM). These included observations at the Phillips Laboratory Starfire Optical Range (USAF facility) near Albuquerque of the so-called "glow-worm" persistent train which could be tracked for ~1 hour, intensified CCD camera records at Placitas, NM, by all-sky video camera records and infrared radiometers at Sandia National Laboartory in Albuquerque as well as by 2 ground observers in the town of Los Alamos. This bolide was also detected infrasonically at Los Alamos National Laboratory at the CTBT, IMS (Comprehensive Test Ban Treaty, International Monitoring System) prototype array by ReVelle and Whitaker (Meteoritics, 2000). We compare model predictions of velocity, mass, blast wave radius, wave frequency, etc. as a function of the initial source energy against the results predicted using the infrasonic wave arrivals and their properties at the ground (amplitude, wave period, duration, etc.) at the observed slant-range from the bolide. The infrasonic signals were analyzed using the basic line source model of ReVelle (1976) and were independently shown to have emanated from a height region near the Mesopause where the bolide explosively ended its visible flight, presumably due to its low material strength. **PSA-15**

Theoretical Entry Modeling of Large Leonid Bolides

Douglas O. ReVelle (Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA)

We have used the entry model of ReVelle (1979) using an energy of ablation/unit mass for vaporization for weak cometary meteoroids of 3.8 MJ/kg (Jessberger et. al., 1988). These model predictions have been combined with the energetics model of ReVelle (1993). The energetics model has been calibrated using the flight data from the Pribram, Lost City and Innisfree meteorites where ReVelle (1980) determined that at the observed end height about 1 % of the kinetic energy of the original body remained. If the above estimate of the value of the energy of vaporization/kg of cometary meteoroids is reduced by a factor of 5, very good agreement is obtained between the theoretical, equilibrium flow, entry model and the observed ablation parameter (0.10-0.21 kg/MJ, personal communication with P. Spurny, 2000) for large, low density, Leonid meteor-fireballs. Predictions of the expected laminar and turbulent convective heat transfer and of the radiative heat transfer coefficients (regardless of the gas cap opacity) are made using entirely analytic expressions that were developed. These expressions allow a prediction of the velocity, the ablation parameter, the percentage mass loss and of the Knudsen number, etc. to be made. In addition, values of the line source, nonlinear blast wave relaxation radius and of the associated infrasonic wave frequencies are also determined. **2.4**

On the Relationship between Asteroids, Fireballs and Meteorites

A.E. Rosaev (FGUP NPC NEDRA, Yaroslavl, Russia)

Best of interest searching for parental bodies for meteors, fireballs and meteorites with well determined orbits. We use two days to study this problem in this work. First way — investigation close orbits by one of number of empirical criteria like criterion Southworth-Hawkins. The second way is to study the orbit intersection statistics. The fireballs of Prairie network and meteorites with well determined orbits was took into account. Obviously, that fireballs and meteorites — an essence of bodies, having potentially unstable orbits and, as an effect, small lifetimes. If take sufficiently natural suggestion on that, that similar objects are form in collisions NEA with each other and with comets, possible expect that crossing the orbits of asteroids and fireballs, or meteorites will indicate us on the most close on a time events of mutual collisions NEA. Really, the distribution nearly intersected orbits in the system NEA-fireball and fireball-fireball show significant non-homogenous. Possible select about 10 areas to concentrations the cross points of orbits of fireballs and NEA. Probably, they correspond to the most recent disastrous events. Results of calculations for meteorites Lost City, Prhibram, Innisfree Peekskill and Tun-guska’s is given. In case of a general conclusion of this work, the hypothesis of an very close relation studied meteorites with NEA put forward. **8.2**

Asteroid (1620) Geographos as a Possible Parent Body for a Meteor Stream

G.O. Ryabova (Research Institute of Applied Mathematics and Mechanics, Tomsk, 634050, Russia. e-mail: astrodep@niipmm.tsu.ru)

The study was undertaken to answer the following questions: when and how particles could escape from the asteroid, could they reach the Earth and could we detect some of them in available meteoroid orbit databases. It was found that the rotational acceleration does not exceeds the gravitational one for all possible rotational states. So the escape of particles from the asteroid apparently took place during a close approach with the Earth (plus tidal forces) or in a collision. Numerous model streams having different schemes and times of ejection were considered. It was obtained that model meteoroid streams ejected with high velocities (up to 1 km/s) can approach the Earth’s orbit twice, once before (February-March) and once after (August) perihelion. There were found 44 correlated meteor orbits (in databases containing > 75000 orbits) from the both showers and a taxon structure was derived for them. The distribution of ejection velocity vectors looks like originated at impact of a catching up small body, but the time of the collision remains unknown. So, with the high probability Geographos is the parent body for a meteor stream, generating twin meteor showers observable at the Earth : Spring and Summer Geographides. **1.10**

Mathematical Model of the Geminid Meteor Stream Formation

G.O. Ryabova (Research Institute of Applied Mathematics and Mechanics, Tomsk, 634050, Russia. e-mail: astrodep@niipmm.tsu.ru)

The Geminid meteoroid stream formation and evolution was studied by the method of nested polynomials. Besides other results the present work puts forward a new theory to explain the secondary maximum of the Geminid rate profile: branches of the stream have been formed due to differences in orbital parameters of particles ejected from the cometary nucleus before and after perihelion. The model stream originated in such a way has a distinguishing feature: the smaller meteoroid mass, the greater the distance between maxima. Their relative positions depend on the stream age. If the stream is young then as meteoroid mass increases the every next pair of maxima appears to be enclosed in the previous one. (Like a Russian doll “matrioshka”). Such is indeed the case of the Geminids. So we have a weighty argument in favour of the cometary past of the asteroid Phaethon (the parent body). A comparison of the model and observed rate profiles allowed to propose a hypothetical scenario of the comet disintegration: greater intensity of dust production before perihelion, significant change of the cometary orbit due to jet forces and ejection of dust in the wide cone directed to the Sun. **PSA-2**

Detection of Interplanetary and Interstellar DUST particles by Mars Dust Counter (MDC) on Board NOZOMI

Sho Sasaki (1), Eduard Igenbergs and Gerd Hofschuster (2), Hideo Ohashi (3), Walter Naumann (4), Ralf Muenzenmayer (5), Eberhard Gruen (6), Yoshimi Hamabe (1), Heinrich Iglseder (7), Georg Farber and Franz Fischer (2), Akira Fujiwara (8), Tohru Kawamura and Ken-ichi Nogami (9), Tadashi Mukai (10), Håkan Svedhem, Gerhard Schwehm and Ingrid Mann (11)

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Mars Dust Counter (MDC) is an impact-ionization dust detector on board the Japanese Mars mission NOZOMI, which was launched on 1998-07-04. It is an improved type of MDC-HITEN and MDC-BREMSAT and has three detection channels (electron, iron, and neutral) to discriminate noise signals from impact signals. The main aim of MDC is to reveal the predicted Martian ring or torus of dust from Phobos and Deimos. On 1998-11-18, NOZOMI encountered the Leonids meteoroid stream. MDC detected two dust impacts, but directional analysis showed that those particles probably did not belong to the Leonids. However, the detected dust number in November 1998 was apparently higher than in other months. Leonids meteoroid stream would have increased the dust population around the Earth, probably though collisions of stream particles with the Moon. NOZOMI orbital plan was changed; Mars insertion was postponed to be on 2004-01-01. Between 1999 and 2003, MDC-NOZOMI continuously measures the dust environment between the Earth's and Martian orbits. By the end of 2000, MDC had detected more than 60 events of dust impact. From the analysis of velocity and direction of particles, those events should include maybe five particles of interstellar origin. **10.7**

Observations on Stratospheric-Mesospheric-Thermospheric Temperatures Using Indian MST Radar and Co-located LIDAR during Leonid Meteor Shower (LMS)

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The temporal and height statistics of the occurrence of meteor trails during the Leonid meteor shower revealed the capability of the Indian MST radar to record large number of meteor trails. The distribution of Radio meteor trails due to Leonid meteor shower in space and time provided a unique opportunity to construct the height profiles of lower thermospheric temperatures and winds with good time and height resolution. There was a four-fold increase in the meteor trails observed during the LMS compared to a typical non-shower day. The temperatures were found to be in excellent continuity with the temperature profiles below the radio meteor region derived from the co-located Nd-Yag LIDAR and extend the maximum height of the temperature profile from the LIDAR to ~110 km. There are however some significant differences between the observed profiles and the CIRA-86 model profiles. The first results on the meteor statistics and neutral temperature are presented and discussed below. **PSA-26**

The Result of 1999 Leonids Daytime Observation in Japan

Hirotaka Serizawa and Masayuki Toda

The large appearance of Leonids was observed in Europe on November 18 in 1999 at the 2:00UT (11:00JST). Then, daytime-meteor was detected some observers in each place, and the number of 40 meteors were detected in 4 hours in Japan. Since globally daytime-meteor observation is rare most people would have doubt about the objectivity of data. Therefore, I tried to identify with each Radio Meteor Observation, in order to acquire the objectivity of data. Consequently, four shooting stars were in accorded with the result of Radio Meteor Observation. Besides, two synchronous meteors were observed by two observers. Therefore, these meteors could be reliable. However, there were few bright (shooting stars>-5 magnitude) which could be observed in Europe in daytime at the same time. For that reason, the question arose in the

luminous intensity of the meteor that we observed. As one of this cause, it can be considered that the meteor luminescence mechanisms differ daytime from night. I would like to call more observers all over the world to carry on meteor observation from now on to collect the data about a daytime-meteor. **PSA-18**

The Discrete Solution of a Quasi-thomography Problem for Construction of the Radiant Distribution of Meteors by Results of Radar Goniometer Measurements

Vladimir Sidorov and Sergey Kalabanov

A new solution of the quasi-tomographic determination of the spatial distribution of the meteoric complex as constructed from radar goniometer data is represented for the first time. A previous solution obtained by O. Belkovich, V.Sidorov and T. Filimonova was based on the assumption of a continuous radiant distribution of sporadic meteors on the celestial sphere. In that theory, the number of unknowns grew quadratically with increase of the angular measurement accuracy. Therefore a stable solution was possible only for the angular measurement accuracy in 10 x 10 deg bins. The new solution is obtained using the hypothesis that there is a discretization in the angular radiant distribution of meteors. It assumes the meteor flux consists, not of an ensemble single meteors, but consists of a system of showers and microshowers with close velocities and close angular grouping. The new method uses a computer optimization of such a radiant distribution on the celestial sphere subject to constraints of the microshower hypothesis, the mirror condition of trail reflection and other independent measurements. The method is implemented on a computer for routine goniometer processing with discrete 2 x 2 deg bins and has been used for determination of meteor shower orbit parameters on one day of radar observation, December 13, 1986. **1.4**

Microswarm Structure of a Meteoric Complex outside of a Plane of an Ecliptic

Vladimir Sidorov, Sergey Kalabanov and Tamara Filimonova (Kazan University)

Earlier we noted that the radiant distribution of sporadic meteors obtained by the radar tomography method shows stable structures of radiants distributed along at particular elongation angles from the apex. In the present activity we have tried to find out (a) how these structures vary in the course of the year, (b) how they are correlated in time, and (c) whether they will be repeated from one year to the next.

Nearly continuous radar observations of the meteors from Kazan during January-April and June-December 1993; during 3 different years in April (1987, 1988 and 1993); and in December (1986-1988) were analysed by a quasi-tomographic method with a bin size of 10 x 10 deg. We have discovered that a toroidal structure dominates February to April. During August to October, on the contrary, a stable minimum is found in the neighbourhoods of ± 90 deg to ecliptic plane. The apparent distributions of meteors at different angles to the cliptic plane during April for different years are very close and mostly break up into three maxima at 75, 90 and 115 deg. The data of December and April were analysed additionally by a discrete quasi-tomographic method with a 2 x 2 deg bin of radiant position. The role of showers and microshowers in the formation of local stable structures in the total radiant distributions of meteors and a small comet origin of some of the observed microshowers is discussed. **PSB-17**

Radar Observations of the 1999 and 2000 Leonid Meteor Storms at Middle Europe and Northern Scandinavia

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Observations of the 1999 and 2000 Leonid meteor storms made with all-sky meteor radars in Middle Europe (54N) and northern Scandinavia (68N) were analyzed in terms of height-dependend meteor rates and entrance velocities. The 1999 Leonid meteor storm is characterised by a major activity peak on November 18 at 2h5m UT with a peak rate of about 1400 meteors/h. In contrast to the 1999 observations, we found three activity maxima for the 2000 Leonid storm. The first peak (170 meteors/h) was observed on November 17, 2000, at 8h15m UT related with the 1932 Leonid dust trail. The second well pronounced maximum (130 meteors/h) was detected on november 18 at 7h25m UT associated with the 1866 Leonid dust trail. The third broad activity event (about 70 meteors/h on average) was found on November 18 between 1h UT and 5h UT related with the 1733 Leonid dust trail. During both years the Leonid storm activity was dominant at altitudes above 98 km. **PSA-25**

Common Ground-based Optical and Radiometric Detections of Fireballs within the Czech Part of the European Fireball Network

Pavel Spurny (Astronomical Institute, Academy of Science, Ondrejov Observatory 251 65 Ondrejov, The Czech Republic) and Richard E. Spalding (Sandia National Laboratories, PO Box 5800, Albuquerque, NM 87185-0978, USA)

Since August 1999 two radiometric systems equiped with optical sensors are operated at two stations of the Czech part of the European fireball network (EN). During this period we have obtained several very detailed lightcurves for bright fireballs recorded also photographically in scope of the EN. First results of this study will be presented. **PSB-15**

The EN310800 Vimperk Fireball: Probable Meteorite Fall of an Athen-type Orbit Meteoroid

Pavel Spurny and Jiri Borovicka (Astronomical Institute, Academy of Science, Ondrejov Observatory 251 65 Ondrejov, The Czech Republic)

We report a detection of an unique fireball photographed at two Czech stations of the European Fireball Network. This slow-moving fireball with initial velocity of only 15 km/s reached the maximum absolute brightness -14 and penetrated down to almost 20 km. The meteorite fall of several pieces of the total mass of several kilograms is highly probable. However, no meteorite has been recovered yet. From one very rough spectral record and also from its behavior in the atmosphere we found that it was stony meteoroid, probably ordinary chondrite. The main exceptionality of this fireball is in its heliocentric orbit, with semimajor axis only 0.8 AU, eccentricity 0.3, aphelion 1.03 AU and inclination 17 degrees. This rare Aten type orbit is only third one in the history of decades-long operation of the European Fireball Network. **PSB-16**

New Type of Radiation of Bright Leonid Meteors above 130 km

Pavel Spurny, Pavel Koten (Astronomical Institute, Academy of Science, Ondrejov Observatory 251 65 Ondrejov, The Czech Republic), Hans Betlem, Klas Jobse and Jaap van't Leven (Dutch Meteor Society, Lederkarper 4, 2318 NB Leiden, The Netherlands)

Precise atmospheric trajectories of very bright Leonid meteors have been determined from the double-station photographic and video observations of Leonid meteors in scope of the ground-based expedition to China during the exceptional so-called "fireball night" of 1998 November 16/17. Whereas beginning heights of photographed meteors are all lower than 130 km, those observed by the all-sky video system or by the even more sensitive LLTV system were recorded up to 200 km for the brightest Leonids meteors. Such high beginnings for meteors have never before been observed. All cases with beginnings recorded by sensitive LLTV systems exhibit comet-like diffuse structures with sizes on the order of kilometers that developed quickly during the meteoroids descent through the atmosphere. For the brightest event with maximum absolute magnitude of -12.5, we observed an arc similar to a solar protuberance and producing a jet detectable several kilometers sideways from the brightest parts of the meteor head, and moving with a velocity over 100 km/s. These jets are common features for all studied very high altitude meteors. When these meteoroids reached 130 km height, their diffuse structures of the radiation quickly transformed to the usual meteor appearance resembling moving droplets, and meteor trains started to develop. Recently we observed similar behavior for two Eta Aquarid, one Perseid and one Lyrid meteors with beginning heights up to 150 km. These meteor phenomena above 130 km were not recognized before our observations, and they cannot be explained by standard ablation theory. **2.2**

Double station TV Meteors and Analysis of their Trajectories

R. Stork, P. Koten, J. Borovicka, P. Spurny and J. Bocek (Astronomical Institute, Academy of Sciences of the Czech Republic, CZ–25165, Ondrejov, Czech Republic)

The TV observation of meteors is performed in Ondrejov since 1990. Together with taking meteor spectra we started also double station observations in the integral light in 1997. The stations are located in Ondrejov and Kunzak, it gives the base distance of 92.5 kilometers. We use camcorders with image intensifier, the diameter of the field of view is about 20 degrees, limiting magnitude about 8 for stars and 6–7 for moving object (meteor). Hundreds of shower and sporadic meteors were recorded, about half of them are double station ones. The selected meteors were measured on digitized records from both stations and their trajectories in the atmosphere and heliocentric orbits were computed. Also K_B parameter [Ceplecha Z. 1988, *Bull. Astron. Inst. Czechosl.* 39, p. 221–236] was computed for meteors and the distribution of shower and non-shower meteors into classes using that criterion will be presented. **4.4**

The Dispersion of the Swarm of Fragments of Large Meteoroids due to Aerodynamic Forces

Yang Su (Beijing Astronomical Observatory and National Astronomical Observatories, Chinese Academy of Sciences, Beijing, 100012)

In order to gain insight into the dispersion of the swarm of fragments due to differential atmospheric pressure across it, I derive an approximate analytic solution to the simple analytic model of lateral spreading of the cylinder-like swarm of fragments in which gravitational acceleration and ablation are neglected. The solution is applicable to the initial fragmentation stage of large meteoroids above several meters in size. Because the spreading of fragments from the initial fragmentation stage defines the primary ellipse of strewn field, this solution is applied to the scatter ellipses of meteorite showers. In comparison to a simple analytic approximation to airburst altitude, my solution demonstrates that the growth of the effective cross-sectional area of the swarm in the initial fragmentation stage is well below the one at airburst altitude. The initial fragmentation stage should never occur at airburst altitude unless the meteoroid begins to break up at an altitude less than 2.8 H and airburst at an even much lower altitude, where H is the scale height of the atmosphere. **5.2**

Dust Measurements in the Geostationary Orbit

Håkan Svedhem and Gerhard Drolshagen (ESA/ESTEC, PB 299, NL-2200AG Noordwijk, The Netherlands; e-mail: h.svedhem@esa.int and gerhard.drolshagen@esa.int) and Eberhard Gruen (MPI f Kernphysik, D-69029 Heidelberg, Germany; e-mail: eberhard.gruen@mpi-hd.mpg.de)

The impact detector GORID, on the Russian Express II satellite has now collected data on Cosmic Dust and Space Debris for more than four years from its geostationary location at first 80 and later 103 deg East. During this time a large number of events have been registered and these are now being analysed and categorised. The yearly average number of certain impacts has varied from 1.7 per day to 3.2 per day. Recent re-calibration of a spare model has resulted in more accurate factors for conversion of the measured parameters into physical parameters as particle mass and velocity. Data sets from one or several full years are used to suppress the possible biases that can result from spatial, temporal and directional variations in the flux and to reduce the statistical errors. During several occasions particles have been detected clustered in time, with up to 30 or more particles within one hour. In addition, at some dates these clusters have been detected at the same times for several consecutive dates. We believe these particles are related to exhaust particles from the solid rocket boosters used for changing the geostationary transfer orbit into a geostationary orbit. For the remaining particles the majority seems to be natural meteoroids. **10.10**

A Fine Structure of Perseid Meteoroid Stream. Method of Indices

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A procedure based only on mathematical statistics is used to study the fine structure of the Perseid stream and its filaments which cannot be reliably separated by iteration methods. Besides the five orbital elements incorporated in the Southworth-Hawkins D-criterion, we also take into account the coordinates of the radiant which belong to the most precisely determined parameters and the geocentric velocity as a significant parameter characteristic for physically related orbits. The basic idea of the procedure is a division of the observed ranges of parameters into a number of equidistant intervals and assignment of indices to a meteor according to the intervals pertinent to its parameters. The meteors with equal indices are considered for mutually related. Since various parameters listed in the catalogue contain various relative errors, it is necessary to use different numbers of intervals in the division of each parameter to obtain a good fit with the real orbital distribution. The relative ratios, approximated by small integers, corresponding to the reciprocal values of the relative errors of parameters, are applied as the basic numbers for the division of the parameters. Our results are compared with the known filaments of the Perseid meteoroid stream discovered by other authors. **PSA-7**

Spectroscopic Analysis of Fine Structures in Leonids

Toshio Tsukamoto (Nagoya university), Shinsuke Abe (Institute of Space and Astronautical Science), Noboru Ebizuka (The Institute of Physical and Chemical Research),

Hajime Yano (Institute of Space and Astronautical Science), Yasuhiro Hirahara (Nagoya university) and Jun-ichi Watanabe (National Astronomical Observatory)

Observations of meteors and the orbital caluculations lead to understanding behavior of cometary dust grains in space. Spectroscopic obserations of meteors enable us to investigate not only the chemical composition of meteors but also the chemical heterogeniety among the meteor dust trails (fine structures) . However, there had not been enough data to understand fine structures in a meteor shower until the 1999 Leonids. 55P/Tempel-Tuttle, the parent comet of the Leonid stream, returns to perihelion every 33 years, generating a new trail of dust each time. During the 1999 Leonid meteor storm, the Earth encountered various trails which allowed us to study the fine structure between those dust trails generated in different perihelion epochs. We report results of those fine structures within the 1999 Leonids. These observations were carried out using Grism as slitless spectrometer with an image intensifier. The images were recorded on NTSC video at a rate of 30 frames per second, with 37.1 x 20.8 deg, FOV. The main peak occurred around 2hUT while sub-peaks stood out around 1h30m, 1h45m, 2h15m, 2h20m, 3h00m UT on 18 November 1999. We examine the temporal spectroscopic differences among those fine structures. **PSA-22**

Results of Double-station TV Obsevations during 1998 and 2000

Masayoshi Ueda (Nippon Meteor Society), Yasunori Fujiwara, Masatoshi Sugimoto (Nippon Meteor Society)

We carried out double-station TV meteor observations during 1998 and 2000. The TV observations could record faint meteors. The radiant positions of Leonid and Taurid meteors was determined. **PSA-28**

Results of Foward-Scatter Radio Observations

Masayoshi Ueda (Nippon Meteor Society) and Kimio Maegawa (Fukui National College of Technology)

Our radio meteor observation uses its own 50W continuous wave beacon on 53.750MHz in 6m amateur band with a broad directivity antenna. The location of transmitter is Fukui, Japan (Longitude 136.18 degrees E, Lattitude +35.93 degrees N). The location of receiver is Osaka, Japan (Longitude 135.64 degrees E, Lattitude +34.53 degrees N). Though the distance between Fukui and Osaka is about 200km, we could detect about 1,500 meteor echoes in no shower day. We report the mean daily variation of meteor rates and The mean annual variation of meteor rates. **PSB-1**

The New Meteorite Radar of the Sodankylä Geophysical Observatory

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At the Sodankylä Geophysical Observatory (67° 22’ N, 26° 38’ E) a new meteorite radar was built during the winter 2000/01. The radar employs a new antenna geometry minimising the directional ambiguities of the received echos. Furthermore, the 8-channel radar does not only sample the received signals but also the transmitted pulses in order to get an accurate picture of their shapes. The transmitted pulses are sampled with all 8 channels allowing for calibration of the receivers on a pulse-to-pulse basis. In June 2001 test operations began. Here we present the new instrument and some first results. **PSB-7**

The Complex of Asteroids, Comets and Meteoroids

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A global structure of the asteroid, comet, and meteoroid complex and its origin is the objective of this paper. The problem of meteoroid-comet-asteroid evolution is considered on the basis of modern studies of small bodies in the Solar system. Along with major planets and their satellites, the Solar system contains small bodies: asteroids, comets, meteoroids and their complexes. The bodies of these complex are in the state of active evolution by perturbing forces, in contrast to the stable systems of major planets and their satellites. Another common feature of the bodies of the complexes is their ability to fall to many parts and to disintegrate. In addition, their orbits pass partly through the same domains of interplanetary space. There are classic the Taurid asteroid complex, the complex of the Halley comet with Aquarid and Orionid streams and many other complexes in the Solar system. In general one complex can include: several comets, several asteroids and several decades of meteor streams. Using one of the largest meteor data banks and the results of calculation of asteroid orbit evolution, new approaches to the search for space bodies that may be the parents' bodies of the meteor streams are formulate. More than 230000 individual orbits of meteoroids with masses exceeding 10-6 g were registered by the meteor automatic radar system (MARS) from January 1972 till December 1978 in Kharkiv. 159787 individual orbits were chosen according to special technique to increase further analysis reliability. The technique for selection of streams and associations from a large sample of individual meteor orbits is used. The investigation were made on the different samples from observation material, which volume is more than 5 thousands minor meteor showers of this unique Kharkiv electronic orbit catalogue. **PSB-19**

Differential Ablation of Meteoroids as Observed by Ground-based Lidars

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We report on an extensive set of new observations of meteor trails by ground-based lidars. The observations are performed with metal resonance lidars which sound the atom densities of Na, K, Fe, Ca, and Ca+ in the altitude range between 80 and 105 km. At the Leibniz-Institute of Atmospheric Physics we have clustered three such lidars at one site for simultaneous common-volume observations of meteor trails. We have also enhanced our lidar observations of meteor trails through co-located observations of meteors by an image-intensified video camera.

The average rate of trail detections is 0.8 meteor trails per hour of lidar observations. The total number of our lidar-observed meteor trails stands at more than 1300. We show through observations and modelling that the capability of any lidar to detect meteor trails is strongly altitude dependent. We estimate that Leonids must have a brightness < +7 m (equivalent photometric mass 0 micro g, diameter 0.35 mm) to become detectable for our lidars.

The most important result of our research is the discovery that lidar-observed meteoroids ablate almost exclusively differentially. Differential ablation shows up in the unexpectedly small number of two- and three-element trails in comparison to that of single-element trails (of 1279 analyzed trails, only 42 trails are two-element trails and 6 are three-element trails) and the lidar-measured ratios of metal abundances in meteor trails (all averages of the various abundance ratios deviate significantly from CI chondritic composition). The preponderance of differential ablation for meteoroids with masses in the milligram-to-gram range could indicate that a very large percentage of all meteoroids desintegrate into many tiny particles in the early part of their atmospheric entry. **4.2**

The Activity Profile of Comet 55P/Tempel-Tuttle in 1998 return: Meteoroid Release Concentration on the Perihelion

J. Watanabe (Nat. Astron. Obs.Japan), H. Fukushima (Nat. Astron. Obs. Japan) and T. Nakamura (Canon Co. Ltd)

It is important to know the activity profile of the parent comets of meteor showers. The activity of the parent comet of the Leonids, 55P/Tempel-Tuttle had never been followed until the recent return in 1998 mainly due to the geometrical difficulty of its orbit relative to the Earth. We carried out a CCD imaging monitor of this comet from January through February in 1998 by using 50-cm telescope of National Astronomical Observatory, Japan. The circular shape of the coma was not changed during this period for the pre-perihelion phase. The photometric measurements of the coma indicated high dependency of the activity on the heliocentric distance, of which the parameter index n is derived as about 10. This large value indicates that the dust release from comet 55P/Tempel-Tuttle is concentrated at around the perihelion passage. **PSA-14**

Interferometric Radar Observations at Widely Separated Locations

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Back-scatter radars have been operated simultaneously and on a continuous basis at Tavistock, near London Canada and near Sao Paulo, Brazil. Each system consists of five separate receiving antennas arranged as two orthogonal 3-element arrays that allows the unambiguous determination of the direction in space of the meteor echo relative to the station location. The antennas used are two-element Yagi type with horizontal elements and pointed vertically upwards to give all round coverage. Aside from the operating frequency, 29.3MHz in Canada and 35.2MHz in Brazil, the systems are identical. Results from these operations during the time of the 1999 Geminids are presented illustrating the similarities and differences arising from the significantly different site coordinates. **6.3**

The Determination of the Ejection Velocity of Meteoroids

I.P. Williams (Faculty of Engineering and Mathematical Sciences, Queen Mary, University of London; e-mail I.P.Williams@qmw.ac.uk)

A knowledge of the ejection velocity of meteoroids from the nucleus of a parent comet is important both for an understanding of processes ongoing in cometary nuclei and the accurate modelling of the evolution of the resulting stream. However, determination of this from the observations of comets tends to be difficult, since observational techniques focus on grains of sizes that are different from meteoroids. Similarly, determination from the study of meteor showers is also difficult because the properties of the observed meteor shower are generally affected by post-ejection evolution through the effects of radiation and planetary perturbations. Thus in order to make deductions regarding the meteoroid ejection velocity from the study of meteor showers, we must a) find a shower that is so young that evolutionary effects are ignorable or b) find a stream where evolution is unimportant or c) we must find a shower that has some special characteristic whose appearance is very sensitive to the ejection velocity. The aim of this talk is to discuss these three options and compare the results so obtained. **1.6**

Prediction and Observations of Leonid Meteor Shower in China

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Recent years, Leonid meteor shower has been paid more attention in China. Observations by both visible and radio have been performed under the organizing of Chinese Leonid Watch. We have observed some interesting phenomena, like the filamentary structure of the shower, the variations of the size distribution of meteoroids and the mass density. In 1998, Chinese and Dutch astronomers in Qinghai firstly observed an activity of very bright fireballs; in Xinxiang, we observed the expected main shower with radar, and the radio peak was as high as 2500 hr-1; in Yunnan, the records indicated that the contour of the peak maximum is asymmetry. An abnormal peak in the ionosphere characteristic value was also detected about 18 hours after the main shower. In 1999 and 2000, the observations were still obtained greatly. From observed differences between the longitude of the ascending node of meteoroids and that of their parent comet, we find this difference depends on the ejection position as well as the ejection velocity. We successfully predicted the Leonids in 1999 and 2000 with a T_{E-C} versus CEOS diagram. We are working on the research of the orbital evolution of the meteoroid stream with the calculation of celestial mechanics. **2.3**

Observations of Field-aligned Irregularities in Meteor Trails Using the MU Radar

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A large number of range-spread trail echoes (RSTE) have been observed using the Kyoto University Middle and Upper (MU) Atmosphere 46.5 MHz Radar. In fact, essentially all the head echoes displaying an along-the-beam velocity component were followed by range spread echoes in the perpendicular-to-B pointing geometry. RSTE’s are typically observed a couple of hundred milliseconds after the passage of the head echo. This indicates the occurrence of plasma instability in meteor trails. In addition, all the spectra are limited within a bandwidth corresponding to a Doppler shift of 320 m/s, suggesting that the two stream instability is absent most of the time. The MU observations show that the model of a smooth meteor trail does not exist in reality. We will present the characteristics of RSTE’s and discuss the implications of the MU observations on meteor science and aeronomy applications. **7.3**