Werkgroep Meteoren

jointly organized
IMC 2025

IMO

44th International Meteor Conference

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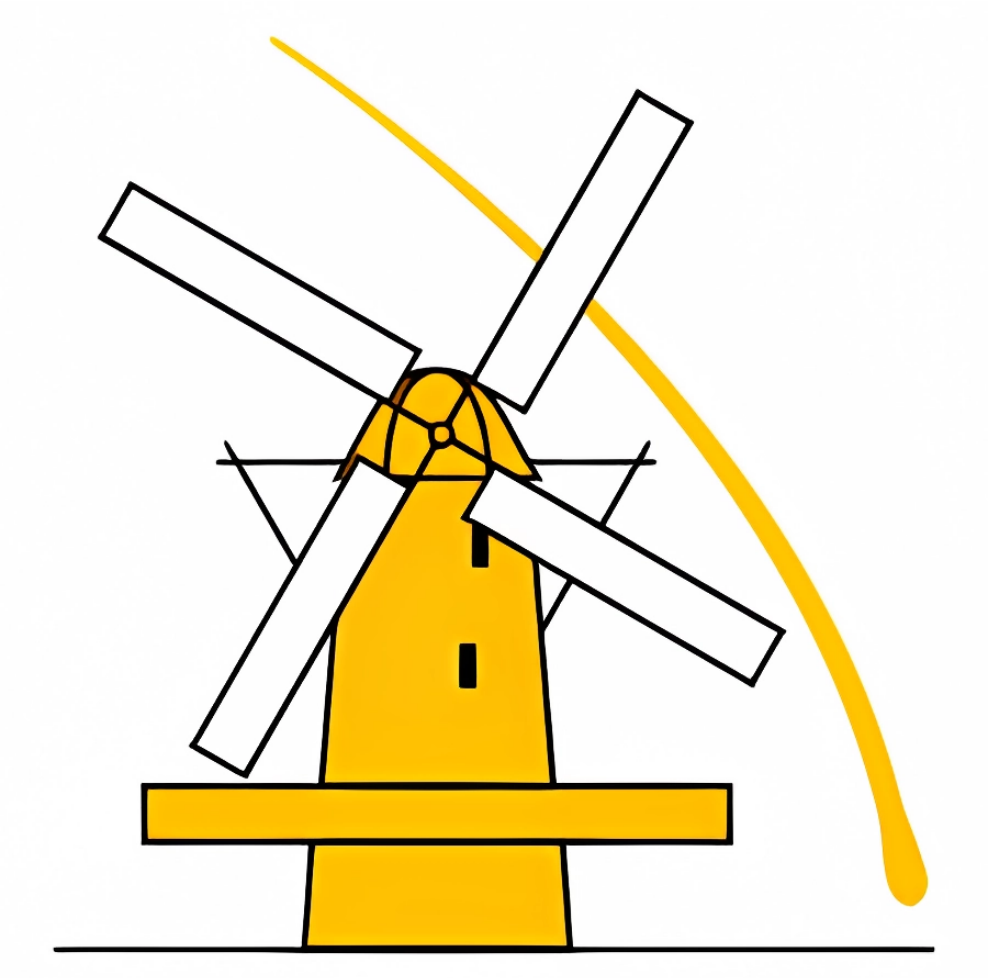

Stayokay Hostel Soest, Soest,
Netherlands

Contents

1 Dust in the Universe

1.1 *20:00* – 20:55 Invited talk: The curious case of transits by giant disks of dust

Matthew Kenworthy

Watching hundreds of millions of stars over two decades has detected thousands of exoplanets by the transit method: the star dims slightly for a few hours as the orbiting planet blocks a small part of the star's light. We also see many other odd astronomical events with stranger light curves - over the past decade, complex eclipses that last from weeks to months or even years suggest stranger objects: giant ring systems that hundreds of times larger than Saturn's rings, colliding planets and their debris, and even tilted disks around binary stars.

In this talk I'll show some of the more impressive light curves, and what they tell us about planets and moons in formation around them, and what we can expect to find in the upcoming years.

1.2 *20:55* – 21:15 Invited talk: Material from the DART impact on asteroid Dimorphos can reach Earth (online)

Paul Wiegert

In 2022, NASA's DART spacecraft intentionally collided with the asteroid Dimorphos to test methods for deflecting potentially hazardous space objects. The impact created a crater and ejected debris, some of which may eventually reach Earth due to the asteroid system's relatively close orbit—it passes about 6 million kilometers from Earth. These particles could be observed as meteors in the Earth's atmosphere. This event might mark the first time human-made meteoroids reach Earth, offering insights into how human activity on asteroids could influence the space environment and pose risks to spacecraft. This talk will discuss how much debris will arrive at the Earth and when.

2 Meteoroid Streams

2.1 *09:00* – 09:20 Why Geminids are a comet stream (online)

G. O. Ryabova

In this talk I'll try to explain what structural parameters of the stream indicate its cometary origin and what observational data confirm this. We will also discuss data that appear to contradict this hypothesis.

2.2 *09:20* – 09:30 Beginning heights and meteoroid composition: A comparative study of ORI, ETA, STA, and NTA (online)

Chih-Ming Lin, I-Ching Yang

We present a statistical analysis of the beginning height distributions of four meteor showers – Orionids (ORI), Eta Aquariids (ETA), Southern Taurids (STA), and Northern Taurids (NTA) – using 15 years of video data from the SonotaCo Network Members. Gaussian fitting and normality tests based on skewness and excess kurtosis reveal that most distributions are approximately normal, though some deviations are observed. Notably, meteor showers sharing the same parent body exhibit highly consistent average beginning heights: ORI and ETA (Comet Halley) peak around $110.9\ \mathrm{km}$, while STA and NTA (Comet Encke) peak near $94.6\ \mathrm{km}$. These results indicate that the beginning height is strongly influenced by meteoroid composition and origin. Our findings demonstrate that the mean beginning height is strongly governed by meteoroid composition, reflecting the thermal properties inherited from parent body origin. This suggests beginning height as a viable diagnostic for compositional classification of meteor showers.

2.3 *09:30* – 09:45 916 meteor showers: investigating their reality and implications to the near-Earth environment.

Aishabibi Ashimbekova, Jeremie Vaubaillon

The International Astronomical Union (IAU) lists 916 meteor showers, raising questions about their reality given current models of the Solar System. This ongoing study evaluates whether known near-Earth objects—specifically near-Earth and Earth-crossing comets, near-Earth asteroids, and active asteroids—can plausibly account for these showers based on their orbital dynamics, dust production capabilities, and residence times. By examining the physical and dynamical properties of these bodies, we aim to determine their capacity to generate and sustain the observed meteor activity. Our findings will refine our understanding of meteor shower origins and contribute to broader comprehension of the dynamics and interactions within the near-Earth environment.

2.4 *09:45* – 10:00 Reassessing meteor showers in IAU MDC: Identifying duplicates and the need for reclassification

R. Rudawska, L. Neslusan, T. Jopek, M. Hajdukova, S. Durisova

As observations increase, classifying showers has become more complex, with most lacking dynamical studies. Classification is often case-dependent, and no universal convention exists. When Earth intersects a meteoroid stream, crossing at both nodes can result in two meteor showers. Over time, planetary perturbations may create a filamentary structure, leading to multiple showers from the same parent body. Conversely, a single shower can originate from several parent bodies, and non-gravitational effects also play a role in shower characteristics. Authors submitting data to the IAU Meteor Data Centre (IAU MDC) use their own criteria to determine whether a shower is a new discovery or matches an existing one, leading to duplicates in the official IAU list in some cases. Our analysis of 835 showers found seven duplicates, 43 needing reclassification, and 11 requiring status updates, along with 11 showers with mixed solutions. Proposed corrections will be submitted for approval by the IAU F1 Working Group and included in an updated MDC list.

2.5 *10:30* – 10:47 A single-station 2002 Leonid meteor cluster

Pavel Koten, David Čapek, Bernd Gährken, , Jeremie Vaubaillon

On 19 November 2002, a very fast and compact meteor cluster was captured by a video camera located near Calar Alto. The cluster consisted of nine meteors observed close to the radiant of the Leonid meteor shower. Their atmospheric trajectories were reconstructed based on the assumption of the Leonid shower membership. The formation mechanism is deduced using mutual positions of the meteors and their photometric masses.

2.6 *10:47* – 11:04 Lyrid meteor shower observed by the European Fireball Network

Lukáš Shrbený, Pavel Spurný, Jiří Borovička

Our photographic cameras observed several dozens of fireballs belonging to the Lyrid meteor shower in last couple of years. Lyrids come from comet C/1861 G1 Thatcher and are fast meteors in the Earth's atmosphere so their trajectories are short, which means that the initial velocity is determined with less accuracy. Therefore, our video camera records were also used to more accurately determine the initial velocity. We determined physical properties of observed Lyrids and compared them to other showers. Lyrids are similar in ablation abilities to Perseids, alfa Monocerotids and September epsilon Perseids. On the other hand, their beginning heights are distributed around a constant value, which is the same behaviour as in the case of more fragile meteoroids of the Leonid meteor shower. We also performed modeling of Lyrids with the longest observed atmospheric trajectories by the semiempirical fragmentation model.

2.7 *11:04* – 11:21 Determination of physical properties of eta Virginids from AMOS all-sky meteor observations

Tomáš Vörös, Juraj Tóth

The eta Virginid meteor shower exhibits an increase in activity every four years. The expected heightened activity in 2025 was observed by AMOS all-sky cameras which recorded tens of eta Virginids. Using standard procedures, we calculated their orbits, and obtained the light curves and deceleration curves of each meteor. Then, we utilised the model of meteoroid erosion to model the atmospheric flight of eta Virginids. The most interesting result is their high bulk density – the average for analysed meteors was more than 1800 kg m^3. Thereby we show that eta Virginids are very likely of asteroidal origin. This has already been noticed by other authors by means of the classical PE parameter, but now we have added another piece of evidence via complex modelling of atmospheric flight.

2.8 *11:21* – 11:32 Origins of the Kappa-Cygnid Meteor Shower: Investigating through Orbital Comparisons and Dynamical Simulations within a Chaotic Environment

Gabriel Borderes Motta, Jiří Borovička

The Kappa-Cygnid meteor shower currently lacks a clearly identified parent body. The chaotic nature of the meteoroid orbits complicates efforts to determine its origin. In this study, we address this issue by using different approaches. We analyzed a resonant region associated with a subset of the stream's meteors. We investigated the capability of this resonance to retain, become populated with, and disperse meteoroids. We explored the hypothesis that comet 21P/Giacobini–Zinner may have given rise to the formation of the Kappa-Cygnid stream in the past. To explore this, we performed backward numerical integration of the comet's orbit to identify epochs of close orbital similarity to the meteoroid stream. Subsequently, we simulated meteoroid ejections and tracked the long-term dynamical evolution of the stream. The results of these simulations are presented and discussed in detail.

2.9 *11:32* – 11:49 Dynamical history of Kappa-Cygnid and August Draconid meteoroids

Filip Hlobik, Jeremie Vaubaillon

August Draconids and Cygnids are two established meteor showers with large radiants close to each other in the August night sky. Some authors consider them a single Cygnid-Draconid complex, while others classify them as separate meteor showers. In this conference talk, we will present our ongoing work on the orbital evolution of Cygnid and August Draconid meteoroids from two nearby radiant groups. Our goal is to assess whether a dynamical connection exists between the two meteoroid streams, or if their radiant similarity is purely coincidental. To achieve this, we performed numerical integrations using the REBOUND integration package including non-gravitational radi-

ation forces. For each simulated meteoroid orbit, we generated 10,000 clone particles in four different size bins (ranging from 10 to 10^2) and integrated the system for 1,000 years into the past. Preliminary results do not show a high likelihood of a dynamical link between the two meteoroid streams. Both the Cygnid and August Draconid orbits are influenced mostly by close encounters with Jupiter, and 5:3J and 9:4J mean motion resonances, respectively.

2.10 *11:49* – 12:00 Improving meteor shower characterization from radio meteor counts in a multi-observer network

S. Calders, J. De Keyser, H. Lamy, K. Kolenberg

Retrieving trajectory and velocity of individual meteors using radio forward scatter techniques is a complex problem and in practice requires a large number of receiving stations (at least 6 but usually more, Balis et al. 2023 and 2025). As a result, data from a single or a small number of stations are not enough to say whether a detected meteor belongs to a shower or is part of the sporadic background. This means that any separation between shower activity and background must be done statistically, by analyzing changes in count rates over time and correlating them with known shower profiles. To accurately study meteor showers using radio forward scatter, it's important to correct for sporadic meteors and differences in how each station observes them. Effects such as antenna sensitivity and the position of the radiant can strongly influence what each observer detects. We use a method that models both the sporadic and the meteor shower signal, building on earlier work by (Steyaert et al., 2006), and improve it to work with data from multiple stations at once. Our approach fits the observed meteor count rates using simple assumptions about shower shape and sporadic meteor behavior. It also ensures that the model makes physical sense, e.g. by setting the sensitivity to zero when the radiant is below the horizon. Using observations of the Geminids and sigma Hydrids from two radio stations in December 2019, we show how this method helps separate the actual shower activity from the sporadic background, even when the stations have different equipment. The results show good agreement with the observed counts and produce realistic values for the peak time and duration of the showers. Differences in background levels and sensitivity between stations also highlight the importance of understanding local observation conditions. While the technique still relies on good-quality data and reasonable assumptions, it offers a practical tool for extracting meteor shower properties from count rate data in a multi-observer network, supporting both professional research and coordinated observations by experienced amateur observers. The method might also be applicable to visual or video observations, although this remains to be tested.

References: Balis, J., Lamy, H., Anciaux, M., Jehin, E., 2023. Reconstructing Meteoroid Trajectories Using Forward Scatter Radio Observations From the BRAMS Network. Radio Science 58, e2023RS007697. https://doi.org/10.1029/2023RS007697 Balis, J., Lamy, H., Anciaux, M., Jehin, E., De Keyser, J., Kastinen, D., Brown, P. Enhanced meteoroid trajectory and speed reconstruction using a forward scatter radio network: pre-t0 phase technique and uncertainty analysis, submitted to Radio Science.

Steyaert, C., Brower, J., Verbelen, F., 2006. A numerical method to aid in the combined determination of stream activity and Observability Function.

3 Meteor-Related Software and Hardware

3.1 *13:30* – 14:00 Machine learning in meteor science: A review

Simon Anghel

Advances in machine learning (ML) are rapidly reshaping how we detect, classify, and interpret meteors. This review synthesizeskey developments from fireball networks and radar surveys to space-based sensors across three domains: Meteor detection, Data reduction/filtering, and other applications. Alongside these advances, we highlight current challenges such as limited labeled data and performance testing. Together, these trends signal a move toward fully autonomous, meteor-monitoring systems within the next decade.

3.2 *14:00* – 14:11 Updates on AllBert EinStein: creating a fireball with an artificial meteoroid

Michael Frühauf, Detlef Koschny, Luca Mansel, Zijin Shao, Vidisha Baviskar

The AllBert EinStein project aims to advance the study of meteors and fireballs through the observation of a controlled re-entry of one or more artificial meteoroids. A precisely characterized artificial object will be deployed into space and then intentionally re-entered into Earth's atmosphere to undergo ablation. The resulting optical emission and its spectral composition will be recorded during an airborne observation campaign. These measurements will be used to determine the photometric luminous efficacy—a key parameter quantifying the conversion efficiency of kinetic energy into optical radiation—and to validate laboratory experiments and numerical models. Due to the system's simple mechanical, thermal, and electrical design and the short mission duration, the technical entry threshold is low, enabling a rapid and cost-effective development. This presentation will provide the latest status update of the project, including the current design and risk assessment.

3.3 *14:11* – 14:22 Improving meteor candidate filtering in Global Meteor Network pipeline

Dino Gržinić

Global Meteor Network uses a machine learning model to filter out false meteor detections from its pipeline. Although the model has a satisfying level of accuracy, it can always be improved. Therefore, an improved model for meteor detection filtering using a small Convolutional Neural Network (CNN) is presented.

3.4 *14:22* – 14:33 MeteorLog - Mobile app for streamlining visual meteor observations

Dino Gržinić

Visual meteor observation is a crucial component of amateur and professional astronomical research, but recording and formatting this data for submission to IMO can be tedious and error-prone. MeteorLog is a mobile application developed in Flutter that simplifies this process by guiding users through observation sessions and automatically generating IMO-compliant CSV reports. The app allows observers to input session parameters and log sightings in real time with a non-distracting dark-themed interface. Observational data (including magnitude, source shower, and observer details) is compiled and saved in structured CSV files that are ready for upload. This talk will present the motivation, features, and technical challenges behind the development of MeteorLog, as well as its potential to enhance citizen science.

3.5 *14:33* – 14:44 Project MERLIN - MEteoR Lightcurve INvestigation

Roman Piffl

Today, information about meteors can be found in databases that contain the results of observations from several local or global observation networks. However, these data, apart from absolute brightness, do not contain any data from which the physical nature of the bodies that burned up in the atmosphere could be determined. Therefore, I set up a project to obtain additional information from the original data of the recorded meteors - the dependence of the height, time, speed and brightness of the observed disappearance of bodies in the atmosphere.

3.6 *14:44* – 15:00 Meteor Detection based on Forward Scattering with SDR and the BRAMS Beacon (online)

Maximilian Bundscherer, Thomas Schmitt, Benjamin Blaga, Thomas Müller, Thomas Lauterbach

This study presents our implementation and evaluation of a Meteor detection system based on Forward Scattering, utilizing Software-Defined Radio (SDR) and the Belgian Radio Meteor Stations (BRAMS) Beacon. We implemented two detection approaches that combine signal processing and computer vision methods. To evaluate our approaches, we recorded data from three different receiving stations in Germany. A subset of these data was manually labeled to allow an objective evaluation. Furthermore, we provide a public live stream of our SDR receiver along with open access to our implementations to assist in future Meteor detection research.

4 Radio Meteor Work

4.1 *15:30* – 15:40 Radio Meteor Workshop: Summary

H. Lamy participants of the radio workshop

During this short presentation, we will present a summary of the presentations given during the radio workshop and highlights the main new results and outcomes of the discussions.

4.2 *15:40* – 15:54 Determining the speed of a meteor using the phase of the Fourier spectrum : application to BRAMS data

H. Lamy, J. Balis

BRAMS (Belgian RAdio Meteor Stations) is a network using forward scatter of radio waves on ionized meteor trails to detect and characterize meteoroids. It is made of a dedicated transmitter and of 50 receiving stations located in or near Belgium. The transmitter emits a circularly polarized CW radio wave with no modulation at a frequency of 49.97 MHz. One of the receiving stations is an interferometer using the Jones configuration. Since there is no information available on the range traveled by the radio wave, the only data that can be used to reconstruct the meteoroid trajectory and speed is the time delays measured between the time t0 of appearance of the meteor echo at various receiving stations (assuming specularity of the reflection). The problem is ill-posed since a small error on the measurement of t0 (of the order of a few ms) can lead to a strong error on the reconstruction (Balis et al., 2023). Therefore there is a need for additional constraints that can come e.g. from pre-t0 phase measurements at some of the stations. Indeed, in Balis et al. (2025), it is shown that these measurements systematically improve the reconstruction, sometimes by an order of magnitude. Here, we study another possibility to constrain the speed of the meteoroid by looking at phases computed using the Fourier transform (FT) of the meteor echo. This method was proposed for back scattering meteor radars by Korotyshkin (2024) but is applied here for the first time to a forward scatter system using BRAMS data. The method will be explained in detail, emphasizing the modifications we introduce due to the forward scatter geometry on one hand, and the fact that BRAMS transmits a CW signal instead of pulses on the other hand. The advantage of the method is to increase the signal-to-noise ratio by combining samples from the entire meteor echo. Hence, in principle, it can be applied to fainter meteor echoes. We present preliminary tests on BRAMS data with the aim in the future to incorporate the constraints put on the meteoroid speed into our trajectory solver. References : • Balis, J. et al., Reconstructing Meteoroid Trajectories Using Forward Scatter Radio Observations From the BRAMS Network, Radio Science, 58, 2023. https://doi.org/10.1029/2023RS007697 • Balis, J. et al., Enhanced meteoroid trajectory and speed reconstruction using a forward scatter radio network: pre-t0 phase technique and uncertainty analysis, sub-

mitted to Radio Science, 2025 • Korotyshkin, D., Radio meteor velocity estimation based on the Fourier transform, Advances in Space Research 74, 4134-4145, 2024. https://doi.org/10.1016/j.asr.2024.06.080

4.3 *15:54* – 16:09 Anomalous long duration communication meteor scatter echoes at 432MHz

Bill Ward

Meteor ionisation is used by radio hams as a means of forward scatter communications. Meteor scatter at UHF frequencies is not well defined and a difficult challenge. During the Perseid meteor shower maximum 2024, several recordings were made lasting 10's of seconds.

4.4 *16:09* – 16:18 Solving the "epsilon" mystery

Christian Steyaert

Non-specular reflections caused by FAI (field aligned irregularities) give rise to specific signatures in forward scatter observations. The subject is known for a longer time in the geophysical area, but less in the astronomical world. We try to make the connection between the radar observations and the geophysical models developed to explain them and the long lasting echoes recorded by simple forward scatter observations.

4.5 *16:18* – 16:32 Simultaneous forward scatter observations of two beacons during March 2025

Johan Bogaerts, Christian Steyaert

During March 2025, the month with the lowest meteor activity, the two Belgian beacons were observed simultaneously. The purpose was the comparison of the hourly activity, corresponding to the sporadic background in the absence of showers. The power output of both beacons was confirmed to be constant during the whole month. The daily activity pattern of the two transmitters shows an unexpected and not fully understood correlation.

4.6 *16:32* – 16:47 BRAMS interferometer calibration survey

J. S. Laur, H. Lamy, M. Anciaux, J. Balis

Interferometric calibration is crucial for advancing meteor trajectory reconstruction and atmospheric wind speed estimation. This work presents a detailed calibration survey of the BRAMS (Belgian RAdio Meteor Stations) interferometer system in Humain, leveraging both drone-based transmitters and commercial aircraft ADS-B signals as reference sources. For the drone flights, the transmitter distance was near the edge of the radiative near-field far-field region, hence the analysis required to account for non-planar wavefronts. Calibration follows the self-calibration methodology established by Valentic

[1] to model and correct phase offsets arising from hardware effects, and software signal processing steps. We performed a detailed analysis of the hardware signal path to identify and account for phase differences introduced by the system components, such as variations in cable lengths and accurate antenna positions, before calculating the calibration offsets. Valentic's method was extended to account for the non-coplanarity of the antennas and is compared to Jacobs' [2] model. By systematically comparing measured interferometric phases to theoretical expectations, we derive phase corrections for each antenna pair to address the random initial phase differences present each time the receivers are powered on. The inclusion of ADS-B data from passing aircraft enables regular and automated calibration checks throughout the year, providing a practical means to monitor the long-term stability, and health status of the BRAMS interferometer. Our results show that this calibration approach significantly reduces systematic phase errors and improves angular accuracy for Angle-of-Arrival (AoA) determinations. The established calibration survey is a prerequisite for meteor trajectory determination and underpins future developments in wind estimation using interferometric data from the BRAMS network. This calibration survey is being applied to the recently installed second interferometer at ECOTRON.

[1] T. A. Valentic, J. P. Avery, S. K. Avery and R. C. Livingston, "Self-survey calibration of meteor radar antenna arrays," in IEEE Transactions on Geoscience and Remote Sensing, vol. 35, no. 3, pp. 524-531, May 1997, doi: 10.1109/36.581960. [2] Jacobs, E. and Ralston, E. "Ambiguity Resolution in Interferometry." IEEE Transactions on Aerospace and Electronic Systems AES-17 (1981): 766-780.

4.7 *16:47* – 17:01 Improved meteoroid trajectory and speed reconstruction with BRAMS: pre-t0 phase and uncertainty analysis

Joachim Balis, Hervé Lamy, Michel Anciaux, Emmanuel Jehin, Johan De Keyser, Daniel Kastinen, Peter G. Brown

This study presents a significant advancement in reconstructing meteoroid trajectories and speeds using the Belgian RAdio Meteor Stations (BRAMS) forward scatter radio network. We introduce an improved method based on a novel extension of the pre-t0 phase technique, initially developed for backscatter radars, and adapt it for continuous wave forward scatter systems. This approach leverages phase information recorded before the meteoroid reaches the specular reflection point t0 to enhance speed estimations. Furthermore, we combine this newly determined pre-t0 speed with time-of-flight measurements to reduce uncertainties in the reconstructed meteoroid paths and velocities. The robustness of our method is assessed using Markov Chain Monte Carlo techniques and validated against optical observations from the CAMS-BeNeLux network.

4.8 *17:01* – 17:15 Modeling meteor scatter propagation with GNU Radio

Martínez Picar, Antonio

GNU Radio is a powerful open-source toolkit widely used for developing software-defined radio (SDR) and real-time signal processing systems. This study explores its capabilities for simulating radio meteor echoes, highlighting its effectiveness as both a scientific analysis platform and an educational resource.

5 Ongoing Meteor Work, Miscellaneous

5.1 *08:45* – 09:15 To catch a falling star: The search for cosmic dust on Earth

Guido Jonker, Tim Schipper, Daphne Lagendijk, Steven Goderis, Jeroen van der Lubbe, Wim van Westrenen

Cosmic dust particles originate from a wide variety of solar system and interstellar objects. During deceleration in the atmosphere, micrometeors leave a trail of superheated plasma. Particles that survive atmospheric entry can be retrieved on the Earth's surface as micrometeorites. Within this study, classical methods for their recovery from a variety of sediments have been significantly improved by using a sequence of mineral separation techniques based on particle shape, density, and magnetic susceptibility. Over 5000 micrometeorites from various sites have been texturally and geochemically characterized, enabling comparison of their statistical properties. Together with oxygen isotopic data, the spatially and temporally varying nature of the collections provides new insights into the composition and characteristics of the cosmic dust flux to Earth from several million years ago until present. The steady flux of micrometeorites and their global distribution allow for retrieval from every geographical location, including rooftops in inhabited areas. Citizen scientists subsequently play an important role in the collection and study of micrometeorites. Micrometeorites are predominantly sourced from carbonaceous chondritic parent bodies, including unknown sources not identified among meteorite collections, and thus represent a valuable reservoir to study the chemical diversity and evolution of the solar system.

5.2 *09:15* – 09:37 Almost a fireball: Asteroid 2024 YR4

Detlef Koschny

Asteroid 2024 YR4 was estimated to impact the Earth with a probability of ¿1 % in Jan 2025. This triggered the international notification systems. The impact probability rose up to about 3 %. After about one month, it went down to 0. Thus, this object could have become a very bright fireball - in Dec 2032. This presentation will tell the story of this object as seen by the author.

5.3 *09:37* – 09:59 Re-entry of space debris and the meteor community

Daniel Kastinen, Juha Vierinen, Johan Kero

New measurements show that about 10% of the aerosol particles in the stratosphere contain metals and other material that originated from the re-entry of space debris. It is predicted that in the coming decades, with the advent of mega-constellations, that we might come close to the natural meteoric input of metals into the atmosphere with re-

entries. Currently, most studies into re-entries focus on the larger satellites and rocket stages. However, there is also a massive amount of smaller pieces of space derbies that re-enter every day all over the Earth. As well as an large increase in the re-entry of short-lived satellites, such as those part of the Starlink constellation. Addressing this issue is a new and emerging research topic. It turns out there are many knowledge gaps with respect to these re-entries. This is where the meteor community overlaps with this new field: we have the instrumentation, the global coverage, the observational methods, the ablation models, and so on. They need to be adapted to the unique trajectories and compositions of re-entries, but we probably already have a wealth of data on the subject by serendipity.

5.4 *09:59* – 10:15 Recent planetary defence activities at ESA's Planetary Defence Office

F. Ocaña

ESA's Planetary Defence Office is a specialised division within the Agency's Space Safety Programme dedicated to protecting Earth from asteroid threats. The Office has as goals, among others, to become aware of the current and future position of NEOs relative to our planet, and to estimate the likelihood of their potential impact. This presentation focuses on the Office activities, especially those related to meteors and on the understanding of NEOs as parent bodies of meteoroids. The presentation will discuss the observations performed by us, using our telescope network and the search and tracking of out-of-atmosphere meteoroids. I will present also the systems involved in the monitoring of these imminent impactors, and all the mitigation activities, related to understanding the risk in case an impact may happen. Apart from space missions, we have 3 AMS all-sky cameras monitoring nighttime sky, we are working on an algorithm to exploit Meteosat MTG-LI fireball data, we will restart the lunar impact flashes monitoring and support the LUMIO mission.

6 Video Meteor Work

6.1 *10:45* – 11:07 AMOS global meteor network: Status and results

Juraj Toth, Pavol Matlovic, Leonard Kornos, Tomas Paulech, Pavol Zigo, Martin Balaz, Tomas Voros, Maria Paprskarova, Filip Hlobik, Adriana Pisarcikova, Veronika Pazderova, Jaroslav Simon

AMOS (All-Sky Meteor Orbit System) is an automated, intensified meteor detection system operating in both the Northern and Southern Hemispheres, monitoring meteor activity 24/7 in the optical range up to +4 magnitude, mainly in mid range of meteor brightness from -3 to +2 magnitude. We present the current status of network of 17 all-sky and 17 spectral stations. The system was invented and developed by Comenius University in Bratislava to detect and characterize weak meteor showers and to provide comprehensive information about the dynamical and physical nature of meteoroids in the millimeter to decimeter size range worldwide. AMOS operates in collaboration with several institutions, including the IAC (Canary Islands), SpaceObs and Paniri Caur Observatory (Chile), the University of Hawaii and SMA, Curtin University in Perth, and the Cederberg and Rogge Cloof Observatories in South Africa, and recently a new spectrograph installed in partnership with the Vatican Observatory in Arizona. We present results of notable meteor showers, special meteor events as meteor clusters, and case studies aimed at the detailed dynamical and physical characterization of selected meteors with achondritic signs, including analysis of their spectral properties.

6.2 *11:07* – 11:18 Event-based camera for meteor sciences

J. Vaubaillon, L. Acin, A. Ashimbekova, M. Guennoun, C. Simon-Chane, A. Histace

Event-based camera have the potential to detect low-light object with a time resolved frequency higher than 1 KHz. We explore the potential for meteor sciences.

6.3 *11:18* – 11:45 What have AllSky7 and the Gartner Hype Cycle in common?

Sirko Molau

The lecture will introduce recent hardware improvements to the AllSky7 system.

7 Meteor spectroscopy and meteor physics and dynamics

7.1 *10:00* – 10:10 Meteor Spectroscopy Workshop: Summary

Meteor Spectroscopy Workshop: Summary

7.2 *10:10* – 10:30 A fragmentation and differential ablation model for simulating dynamics and light emission of meteoroids

Mgr. Mária Paprskárová; prof. RNDr. Juraj Tóth, PhD.

Meteoroids during their atmospheric passage interact with the surrounding air. It causes them to decelerate and heat up, leading to ablation and often fragmentation. Mass loss through both processes changes the dynamics of the body, and affects the amount of light emitted. Videos capturing the behaviour of a meteor allow us to infer the composition and inner structure of the body. Our approach is to model the atmospheric flight of a meteoroid adjusting several parameters to gain a fit as close as possible to the observation. We focus on the shape of the light curves (brightness over time) that indicates the changes in ablation rate, break-up times, size and amount of produced fragments. We use a model combining fragmentation and differential ablation for our simulations, examining the connection between fragmentation and differential ablation. We will present our current results for several cases showing the signs of one or both.

7.3 *10:30* – 10:45 Unveiling meteoroid properties through dynamic nested sampling: A probabilistic approach to optical meteor data

Maximilian Vovk, Peter Brown, Denis Vida

Meteoroids pose a significant impact hazard to satellites, necessitating precise inference of their physical properties. Traditional fragmentation models rely on deterministic fitting, often neglecting uncertainty quantification. We present Dynamic Nested Sampling, a probabilistic inversion method that rigorously explores parameter uncertainties, enabling robust constraints on meteoroid physical characteristics.

Our approach is built upon the erosion fragmentation model of Borovička et al. (2007), which describes meteoroid mass loss via micrometer-sized grain ejection. By applying this method to high-resolution optical meteor observations from Electron Multiplying CCD (EMCCD) cameras and the Canadian Automated Meteor Observatory (CAMO) mirror-tracking system, we infer key meteoroid properties (including bulk density) while simultaneously quantifying uncertainties. The datasets span a diverse range of meteoroids observed with EMCCD cameras (limiting magnitude +7, resolution 50 m per pixel, 32 FPS) and CAMO (6 m per pixel, 100 FPS), capturing detailed morphological evolution during atmospheric entry.

Our preliminary results demonstrate that measurement precision fundamentally constrains inversion accuracy, revealing intrinsic limits imposed by meteoroid morphology as resolved by CAMO. This framework paves the way for improved meteoroid risk assessments, offering a statistically rigorous tool for modeling meteoroid physical characteristics.

7.4 *11:15* – 11:35 A new mechnism of meteor persistent trails II

Nagatoshi Nogami, Shinsuke Abe

More quantitative talk than last year one. My abstract will give before IMC.

7.5 *11:35* – 11:55 Compositional analysis of meteorite ablation spectra using radiative transfer model

Adriana Pisarčíková, Jiří Borovička, Pavol Matlovič

We present results from the compositional analysis of high-resolution Echelle spectra from 22 meteorite samples exposed to laboratory-simulated atmospheric entry conditions. These spectra, acquired during plasma wind tunnel experiments at the Institute of Space Systems, University of Stuttgart, simulate the low-velocity entry of asteroidal meteoroids. We applied a radiative transfer model, considering local thermal equilibrium and self-absorption, to estimate the plasma temperature and relative elemental abundances (Fe, Mg, Cr, Mn, Si, Na, Ni, Li, and H) from these spectra. The findings are compared to laboratory-measured bulk compositions of the meteorites, enabling, for the first time, validation of the radiative transfer model on spectra of meteorites with known composition. This work provides reference data for more accurate interpretation of the composition of asteroidal meteoroids from meteor spectra.

Posters

Multi instrument detection and study of tau Taurid fireball over Hungary in 2024

Cs. Szárnya, J. Vinkó, L. Deme, V. Barta et al.

We present the results from measuring a very bright tau Taurid fireball, detected with optical cameras, an ionosonde and infrasound detectors located in the Western part of Hungary in 2024.

The spatial flux of Earth's present-day meteorite falls

C. Kadir, A.R.D. Smedley, G.W. Evatt, A.J. King, K.H. Joy

The flux of meteorites that fall through the Earth's atmosphere can be quantified using data from fireball monitoring networks, allowing fall flux estimates to be obtained. In 2020, Evatt et al. used data from NASA's Center for Near Earth Object Studies (CNEOS) spanning from April 1988 to June 2018 to investigate whether a latitudinal variation in fall frequencies exists. Compelling evidence was found to suggest that the flux follows a model outlined by Evatt et al., as opposed to being isotropic.

Motivation for this work: Investigations into the latitudinal variation of meteorite fall frequencies have multiple applications. The latitudinal model proposed by Evatt et al. and further validated in this study has beneficial applications in quantifying threats to specific regions on Earth due to large impactors. Namely, Evatt et al. suggests that the equatorial regions have a 12% greater risk of larger impactors than if the flux across all latitudes were isotropic. Orbital analysis is crucial, especially when dark-flight analysis of observed fireballs yields successful sample recovery, since it allows analysis of collected meteorite samples to provide information on the celestial objects from where the meteorites originate.

New approach: This work now expands on the results of Evatt et al., using recent CNEOS data to investigate the validity of the latitudinal variation model. We find that the latitudinal variation model proposed by Evatt et al. is a good fit to this new expanded dataset, particularly at the Earth's poles. Analysis of the orbital inclinations calculated from fireballs recorded by the FRIPON camera network further validates the proof used for this mathematical model.

Development of slitless optical spectrograph for meteor spectroscopy

J. Vinkó, A. Igaz, N. O. Szabó and K. Sarneczky

We present details of the development of the optical spectrograph consisting of a Sony Alpha 7 III camera and visible transmission grating of 600 groove density.

A quick bibliographical review of D-criteria

Ariane Courtot, Patrick Shober, Jérémie Vaubaillon

A quick bibliographical review of D-criteria

Centennary of the 1925 Ellemeet diogenite impact

S.J. de Vet

On 28 August 1925 two fragments of asteroid Vesta impacted near the town of Serooskerke, within the Ellemeet municipality in the Netherlands. In 2025 a century after the impact we will look back at the event with a historical reconstruction of the impact; the (re)discovery of the impact locations; and present work using 3D models of the surviving meteorite fragments.

Set-up of the IMC's Spectroscopy Workshop

J. Zender, A. Pisarcikova, G.J. Netjes

The workshop on meteor spectroscopy has been held in the morning of the IMC start. In the poster, we sketch out the main goals and the implementation details of this workshop.

Mapping meteorite colours using Munsell colour charts and multi-colour sensors

S.J. de Vet

Descriptions of meteorite colours often use qualitative descriptors that are difficult to correlate with calibrated colour references. Reported colours of meteorites and their crusts are controlled by the minerals and the reworking of these mineral sources by melting and mixing during ablation, which forms the fusion crust. After impact, exposure to the terrestrial environment causes chemical weathering, which can induce e.g. colour mottling and iron staining. This means that the gamut of meteorite colours is potentially diverse and it can help infer and convey relevant geochemical and alteration characteristics. Accurate and easy communication of meteorite colours may thus contribute to a more effective colour-based geological description. Several colour description systems are readily used for such applications in soil science, while smartphone-controlled spectrophotometers now offer affordable sensor-based measurements. At IMC 2025 we will set-up a citizen-science experiment and invite participants to assess colors of meteorite fusion crusts that we will compare to instrument measurements and evaluate their effectiveness.

The Budel rooftop micrometeorite collection

Guido Jonker

Each day roughly 100 tons of cosmic dust enter Earth's atmosphere of which only 10% reaches the surface as micrometeorites. As a result of variable parent body characteristics and melting and recrystallization in the atmosphere, micrometeorites display a large variety of compositions and textures. For decades, they have been collected in remote and pristine areas. In recent years, micrometeorites have been successfully retrieved from rooftops in densely populated areas. The Budel micrometeorite collection is the largest urban collection from a single rooftop with over 1000 cosmic spherules collected using improved mineral separation techniques. An oxygen isotopic study of 80 Budel cosmic spherules has given new insights into the composition and characteristics of the modern-day flux of cosmic dust to Earth.

Estimating Orbital Parameters from Meteor Head Echoes

Juha Vierinen, Jorge L. Chau, Nico Pfeffer, Daniel Kastinen, Ralph Latteck, Marius Zecha, Toralf Renkwitz, Devin Huyghebaert, Johan Kero, Masaki Tsutsumi, Koji Nishimura, Taishi Hashimoto, Kazuhiko Mushiake, Kaoru Sato

Meteor head echoes can be utilized to estimate the three-dimensional trajectories of micrometeoroids as they enter the Earth's atmosphere. These trajectories, in turn, enable investigations into the statistical distributions of orbital parameters and masses of the Earth-crossing meteoroid population. Currently, two large and complementary meteor head echo surveys are being conducted using High-Power Large-Aperture (HPLA) radars: MAARSY (Middle Atmosphere ALOMAR Radar System) and PANSY (Program of the Antarctic Syowa MST/IS Radar). MAARSY is located at 69°N in the Northern Hemisphere, while PANSY is situated at 69°S in the Southern Hemisphere. Between 2016 and 2024, MAARSY recorded approximately 1.6 million high-quality meteor events, whereas PANSY has collected around one million good-quality detections since January 2025. To accurately interpret the estimated orbital and mass parameters, it is essential to quantify the associated uncertainties. This includes accounting for atmospheric drag, unmodeled mass loss, and the propagation of orbits when correcting for the influence of Earth's gravity. This study evaluates the uncertainties in derived orbital parameters for both radar systems and applies a consistent methodology to analyze their respective meteor catalogues. Additionally, it presents representative examples of the resulting distributions of orbital elements.

An Analysis of Forward Scatter Radio Meteoroid Head Echoes Using Video Meteor Trails

Mike German

Radio meteoroid head echoes and video camera meteor trails are combined to investigate the geometric aspects of the observability factor. Radio and video measure-

ments from August 2024 are compared. The geographical spread of detected meteoroids is shown. Radio detection numbers are much lower than camera numbers. The Hayfield-GRAVES geometry seems to favour Perseids steam over meteors from Sporadic sources although other physical factors may have influenced this result.

Demos

Micrometeorites demo

Guido Jonker

Micrometeorites demo

Meteorite impact demo

Felix Bettonvil

Meteorite impact demo

Color checker demo: Assessing meteorite color properties

Sebastiaan J. de Vet

What colour is that meteorite? Join our experiment at IMC 2025 to assess colours of meteorites. We need your help testing user-based colour description systems, which we will compare to instrument measurements to evaluate the effectiveness. You will determine the colour of a few fusion-crusted meteorite using a colour chart book, fill in the online form with your findings and answer a few questions. Its as easy as that!