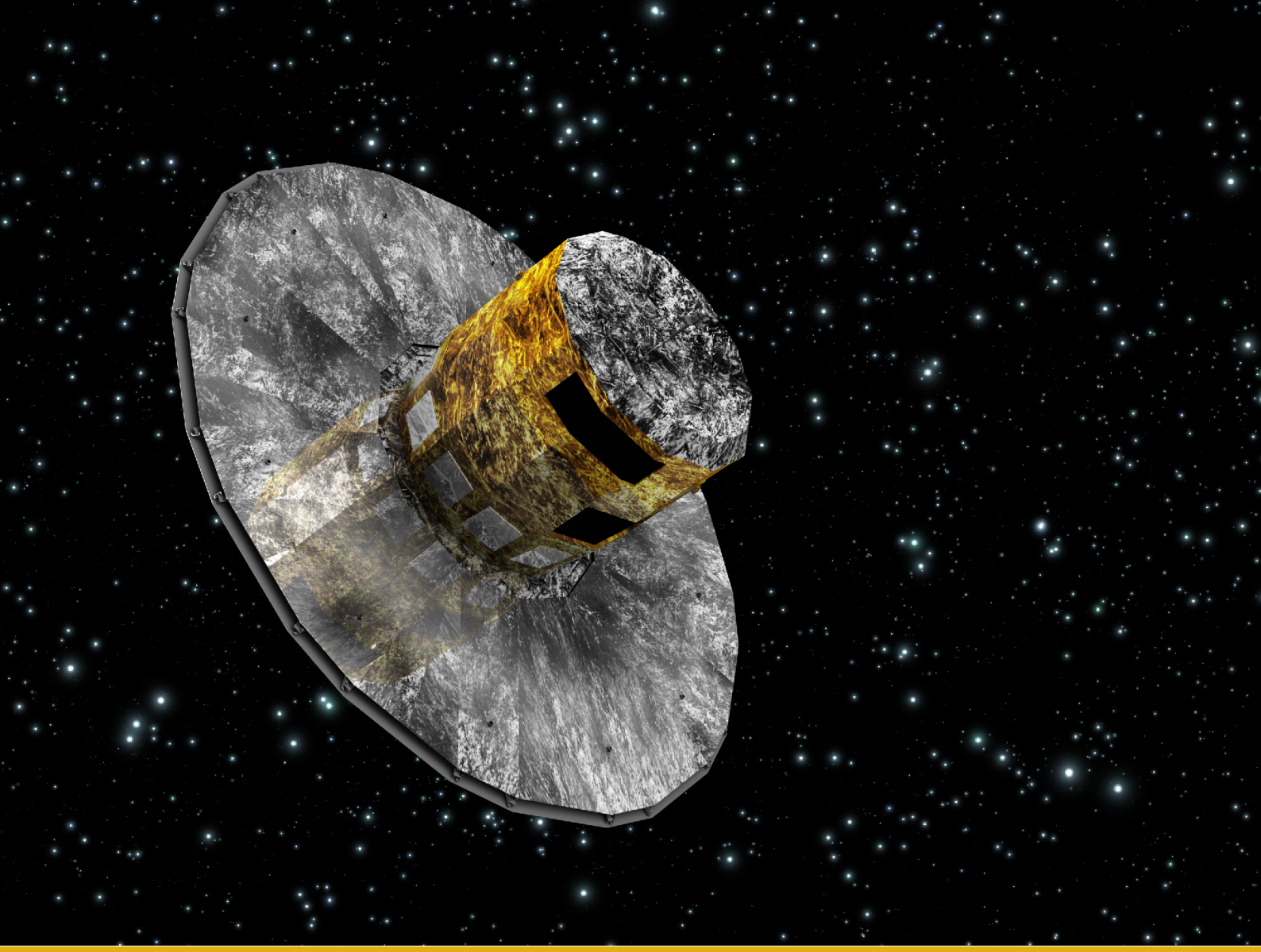

Asteroids And Comets: Revealing the History of the Solar System

Workshop of MW-Gaia COST Action 18104

Working Group 3, Planetary Systems Near and Far

Organized by: Department of Physics, University of Helsinki

Venue: Krapi Conference Center, Tuusula, Finland, and online everywhere

Dates: September 28-29, 2021

1 Scope and organizers

Asteroids and comets are the key to the evolution of the Solar System. These small Solar System objects (SSOs) are being systematically observed, with unprecedented precision in photometry, spectroscopy, and astrometry, by the ESA Gaia Space Mission. The workshop will cover the synergies and challenges in the combination of the Gaia data and data from other sources, that is, from ground-based astronomical observations and space missions to small SSOs. The former include astrometry, occultations, spectroscopy, polarimetry, and photometry, whereas the latter include the high-resolution observations of asteroid Ryugu by the Hayabusa2 mission (JAXA), of asteroid Bennu by the OSIRIS-REx mission (NASA), and of Comet 67P/Churyumov-Gerasimenko by the Rosetta mission (ESA). How Gaia relates to future SSO space missions, such as DART (NASA) and Hera (ESA), Comet Interceptor (ESA), and Destiny+ (JAXA), will be addressed.

The workshop improves the understanding of the physics of small SSOs to draw inferences on their origin and formation. Topics cover, for example, exploitation of the extraordinary accuracy of, first, Gaia astrometry for orbit improvement, navigation to mission targets, and asteroid mass determination, and, second, Gaia photometry for the retrieval of asteroid phase curve parameters, shapes, and rotational characteristics. Tutorial sessions are organized using pre-recorded videos on data analysis techniques in astrometry and photometry, including applications of machine learning techniques to large samples of asteroid data.

Organizers

Scientific Organizing Committee:
Prof. Karri Muinonen (chair), Dr. Anne Virkki, and Dr. Antti Penttilä

Local Organizing Committee:
Dr. Antti Penttilä (chair), Dr. Anne Virkki, Ms. Elizaveta Uvarova, Mr. Mikko Vuori, Mr. Vesa Björn, Prof. Karri Muinonen, Department of Physics, University of Helsinki

Acknowledgements

This workshop was funded by the European Cooperation in Science and Technology (COST) Action 18104, Revealing the Milky Way with Gaia; Academy of Finland project #336546 InSight; and the Department of Physics, University of Helsinki, Finland.

2 Venue

The workshop is organized in a hybrid format with participants attending virtually and on site. Both modes of attendance will involve scientific presentations via Zoom. Mankeliaitta of the Krapi Conference Center (Tuusula, Finland) will serve as the venue for the in-person part, with accommodation at the Onnela premises. For further information, see: https://krapi.fi/en/.

Figure 2.1: The map of the area. The conference venue is in Krapi, near the intersection of Rantatie and Road 145. The accommodation for the in-person participants is located in Onnela.

3 Program

Tuesday, 28 Sep 2021

(Times in EEDT/GMT+3h)

Time	Speaker	Title
08:55	Karri Muinonen	Opening of the workshop
09:00	Paolo Tanga	The role of asteroid observations by Gaia: Preparing the exploitation of the first full-size data release
09:20	Nicholas Moskovitz	Asteroid characterization at Lowell Observatory
09:40	Irina Belskaya	Asteroid magnitude phase curve parameters: accuracy and reliability
10:00	Dagmara Oszkiewicz	Asteroid phase curves using dense differential and sparse relative photometry
10:20	Coffee break	
10:50	Alberto Cellino	Going toward a strengthened multi-disciplinary approach in asteroid science
11:10	Eri Tatsumi	Are Ryugu and Bennu from the same parent body or not?
11:30	Eric McLennan	Asteroid shapes and thermophysical modeling: (3200) Phaethon as a case study
11:50	Tomas Kohout	Comet Interceptor and Hera – Revolutionary planetary mission concepts
12:10	Lunch break	
13:30	Antoine Pommerol	Asteroids and comets: The quest for suitable analogues
13:50	Gorden Videen	Polarized light scattering from regolith simulants
14:10	Maria Gritsevich	In search for the missing link: recovering samples from Small Solar System bodies
14:30	Mikael Granvik	In-situ monitoring of the surface degradation on a near-Sun asteroid
14:50	Coffee break	
15:20	Marco Delbo	Observational constraints to the initial asteroid size distribution: the Gaia perspective
15:40	Federica Spoto	A new weighting scheme to combine Gaia and ground-based observations
16:00	Grigori Fedorets	Searching for asteroid binaries in the wobble of Gaia astrometry
16:20	Lauri Siltala	Asteroid mass determination with Gaia
16:40	Discussion	Gaia data analysis techniques
20:15	Workshop dinner	

Wednesday, 29 Sep 2021

(Times in EEDT/GMT+3h)

Time	Speaker	Title
08:55	Karri Muinonen	Opening of the day 2
09:00	Annika Gustafsson	Revealing Regolith Properties of Asteroids Using Radiative Transfer Modeling
09:20	Joe Masiero	Chasing asteroids in the infrared: NEOWISE and NEO Surveyor
09:40	Xiaobin Wang	Solar System Object data in time-domain photometric surveys
10:00	Karri Muinonen	Asteroid photometric and polarimetric phase curves interpreted using synoptic scattering models
10:20	Coffee break	
10:50	Julia Martikainen	Modeling light scattering by Martian atmospheric dust
11:10	Matthew Berg	Digital Holography: Capabilities and concepts for cometary grain and regolith characterization
11:30	Johannes Markkanen	Thermophysics of dust particles: Implications on cometary activity
11:50	Yuna Kwon	Polarimetric study of the dust environment of comet 67P/ Churyumov-Gerasimenko around the end of its Southern summer
12:10	Lunch break	
13:30	Evgenij Zubko	On the nature of dispersion of linear polarization observed in comets at large phase angles
13:50	Olga Muñoz	Understanding the negative polarization branch of comets and asteroids
14:10	Jürgen Blum	Comets as clues to planetesimal formation
14:30	Coffee break	
15:00	Benoit Carry	The impact of Gaia on the study of asteroid interiors
15:20	Anne Virkki	Characterizing dielectric properties of near-Earth asteroids using radar observations
15:40	Deborah Domingue	Comparing photometric properties of Eros, Itokawa, and Ryugu
16:00	Antti Penttilä	Deep learning tools for asteroid taxonomy with Gaia and other surveys
16:20	Discussion	
17:00	Closing of the Workshop	

4 Abstracts

Asteroid magnitude phase curve parameters: Accuracy and reliability
Irina Belskaya (1), Vasilij Shevchenko (1)
(1) Astronomical Institute of Kharkiv, V. N. Karazin National University, Ukraine

Magnitude phase curves of a large number of asteroids were obtained using sparse photometric data, *e.g.*, from Pan-STARRS1, ATLAS, Gaia. We have compared dedicated measurements of asteroid phase curves with those obtained as a by-product of photometric surveys to reply the following questions: (1) how reliable are the obtained photometric parameters, (2) are there systematic differences in the obtained parameters, and (3) how strong is the correlation of phase slopes and albedos.

Digital holography: Capabilities and concepts for cometary grain and regolith characterization
Matthew Berg (1)
(1) University of Kansas, KA, USA

Digital holography is a versatile contact-free imaging method with unique capabilities. For example, the method has been used to image free-flowing mineral dust and bioaerosol particles in the atmosphere and particles deposited on surfaces. The study of solar system objects (SSOs), such as comets and lunar regolith, with new in situ instrumentation could benefit from holographys imaging capability. We will describe several recently constructed holography instruments used to image small particles and discuss possible approaches for space instrumentation to study SSOs.

Comets as clues to planetesimal formation
Jürgen Blum (1)
(1) Technische Universität Braunschweig, Germany

Due to the enormous data volume delivered by the Rosetta/Philae mission to comet 67P Churyumov-Gerasimenko, we are now in a position to challenge formation and evolution models of planetesimals with empirical evidence. We will show that a gentle gravitational collapse of a pebble cloud leads to observables that match the Rosetta findings. In particular, the low mass density, the overall homogeneity, the ultra-low strength values and the low heat conductivity of comet 67P are in agreement with comets being pebble piles. Moreover, the presence of super-volatiles provides us with constraints on the formation time and maximum size of the cometary precursor planetesimals. Based on Rosetta results and our own work, we will present a plausible formation and evolution scenario from dust to contemporary comets.

The impact of Gaia on the study of asteroid interiors
Benoit Carry (1)
(1) Observatoire de la Cote d'Azur, France

The density is maybe the most fundamental quantity accessible from remote sensing to probe asteroid internal structure, key tracer of their history. Recent instrumental advances have allowed precise shape modeling of the largest asteroids. Unfortunately, the fraction of asteroids with satellites being limited, their mass, hence density, determination relies on long-distance gravitational interaction. I will review current knowledge on asteroid densities and describe how Gaia astrometric survey will have a lasting impact on the subject.

Going toward a strengthened multi-disciplinary approach in asteroid science
Alberto Cellino (1)
(1) INAF - Osservatorio Astrofisico di Torino, Italy

Ground-based polarimetry is making significant progress based on the most recent results of the Calern Asteroid Polarimetric Survey, and to recent VLT observations of NEOs suspected to have a cometary origin. The next data release of Gaia will include, for the first time, asteroid spectroscopic data, in addition to a much increased database of photometric measurements. The studies of the physical properties of asteroids will take profit of the synergy of data obtained using different techniques. We can hope to obtain a combined use of photometric, spectroscopic and polarimetric data to obtain more accurate determination of asteroid surface properties, including geometric albedo and composition. Gaia measurements, combined with polarimetric data, will allow us to obtain a better understanding of objects displaying unusual properties, including Barbarians and F-class asteroids, the latter being promising candidates as bodies characterized by cometary-like surface activity.

Observational constraints to the initial asteroid size distribution: the Gaia perspective.
Marco Delbo (1)
(1) Observatoire de la Cote d'Azur, France

Boosted by the discovery and diversity of exoplanets, modern planetary science focuses on understanding the formation of planets in our Solar System and around other stars. However, the mechanisms by which dust accreted into planetesimals, asteroid sized bodies representing the brick of forming planets, is a tremendous matter of debate in the community. In particular, planetary formation models depend on this initial size function. I will present an innovative observational approach to search for these primordial bodies in the asteroid Main Belt, where they are hidden among all other asteroids.

I will detail how data from the ESA space mission Gaia will help us narrowing this search and how these studies can be used to inform models of planetary formation.

Comparing photometric properties of Eros, Itokawa, and Ryugu
Deborah Domingue (1)
(1) Planetary Science Institute, USA

To date there have been spacecraft missions to S- and C-class asteroids. Images of these objects show that there is much variety in the regolith properties. This presentation reviews and examines the regolith of these objects and the implications for the processing of the surfaces of these solar system bodies.

Searching for asteroid binaries in the wobble of Gaia astrometry
Grigori Fedorets (1)(2), Daniel Hestroffer (3) and the Gaia SSO team
(1) Astrophysics Research Centre, Queen's University Belfast, UK
(2) Department of Physics, University of Helsinki, Finland
(3) IMCCE, Observatoire de Paris, France

The study of asteroid binaries enables the tests of asteroid formation models and deriving mass ratios of binary system components. The ten-milliarcsecond accuracy of along-scan Gaia astrometry facilitates the search for new binary objects among the small objects of the solar system. The search for new binaries will be performed by analysing the displacement of astrometric positions measured by Gaia from the predicted orbital path of the asteroids. The methods developed for unevenly spaced astronomical data, such as the Lomb-Scargle periodogram, will be applied for deriving the rotational period of the binary system. We anticipate applying the derived methods to DR3 data, after which the methodology will be validated by dedicated photometric lightcurve observations of a discovered candidate object.

In-situ monitoring of the surface degradation on a near-Sun asteroid
Mikael Granvik (1)(2)
(1) University of Helsinki, Finland
(2) Luleå University of Technology, Sweden

Icarus is a mission concept designed to record the activity of an asteroid during a close encounter with the Sun. The primary science goal of the mission is to unravel the nontrivial mechanism(s) that destroy asteroids on orbits with small perihelion distances. The Icarus spacecraft and preliminary payload

options have high technology readiness levels and the mission is designed to fit the programmatic and cost constraints of ESA's F class. The Icarus trajectory will be challenging, and discovering candidate mission targets with semimajor axes significantly smaller than 1 au would improve the feasibility of the mission. ESA's Gaia mission is observing at solar elongations where such objects are most likely to be found, and is thus a potential source for suitable targets for the Icarus mission.

In search for the missing link: recovering samples from Small Solar System bodies
Maria Gritsevich (1), Jarmo Moilanen (1)
(1) Finnish Geospatial Research Institute, Finland

It has been estimated that the Solar System has over 150 million asteroids larger than 100 m and a countless amount of smaller ones with the total count of known objects already exceeding 1 million (Moilanen et al. 2021). Comparing these numbers to the number of known meteorites implies that at present our sampling of the Solar system objects is scarce. To bridge this knowledge gap, fireball networks have been set up around the globe. These networks regularly obtain thousands of records of well-observed meteor phenomena, some of which may be classified as a likely meteorite fall (Sansom et al. 2019). A successful recovery of a meteorite from the fireball event requires that the science team can be promptly directed to a well-defined search area. We present an overview of the Finnish contribution to the recovery of meteorites with known origin supported by several success stories built upon adequate representation of the physical processes occurring during their atmospheric flight.

Revealing Regolith Properties of Asteroids Using Radiative Transfer Modeling
Annika Gustafsson (1), Nicholas Moskovitz (2)
(1) Southwest Research Institute, CO, USA (2) Lowell Observatory, AZ, USA

We present a new implementation of Hapke radiative transfer modeling using visible to near-infrared spectroscopy as a means for characterizing and constraining the surface properties of unresolved asteroids. These spectroscopically derived properties are complementary to constraints from thermophysical models of data at longer wavelengths. This spectroscopic approach benefits from observational requirements that are less time intensive and less reliant on specialized instrumentation, and thus has the potential to characterize a large number of near-Earth and Main Belt asteroids. Focusing on spectra of powdered ordinary chondrite meteorites, we have run a large suite of Hapke models to show that when composition is reasonably constrained, our model-derived Hapke grain sizes are consistent with the average physical sieve size of our samples. This approach has direct relevance to the interpretation of both unresolved (ground-based) and resolved (in situ) spectra of airless bodies.

Comet Interceptor and Hera – Revolutionary planetary mission concepts
Tomas Kohout (1)
(1) University of Helsinki, Finland

Within current decade two ESA missions aim to demonstrate new planetary mission concepts. Hera aims to characterize an asteroid kinetic deflection test through monitoring consequences of the DART (NASA) spacecraft impacting binary asteroid Didymos. Hera will carry two small CubeSats with advanced instrumentation (absolute gravimeter, penetrating radar, hyperspectral imager, and dust/volatile detector) in order to increase scientific return through focused close-up observations of the asteroid internal structure and mineralogy at unprecedented resolution. Comet Interceptor consists of three spacecraft performing fly-by of a pristine comet with aim to provide multi-point observations of primitive material from periphery of our Solar System. Both missions aim to demonstrate game-changing technology in order to maximize science return.

Polarimetric study of the dust environment of comet 67P/Churyumov-Gerasimenko around the end of its Southern summer
Yuna Kwon (1)
(1) Technische Universität Braunschweig, Germany

We present the new result obtained from a polarimetric study of the dust of comet 67P/Churyumov-Gerasimenko (67P) using the Very Large Telescope. Three-epoch spectropolarimetric data over 0.4–1.0 micrometres were acquired in a monthly cadence, covering the phase angle range from about 6 to 27 deg. From the data, we investigate the polarimetric and colour behaviours of 67P dust and compare them with other cometary dust in similar observing geometries. Simple modelling was made to constrain the plausible porosity range, and by comparing the Rosetta colour result taken in early 2016, we report the evidence of ice sublimation and the possible amount of ice particles embedded in the dust particles. In this presentation, we discuss the results in the context of the comet evolution and therefrom underscore the potential of polarimetric observations for comets where spacecraft cannot afford to visit.

Asteroid shapes and thermophysical modeling: (3200) Phaethon as a case study
Eric MacLennan (1)
(1) University of Helsinki, Finland

Thermophysical modeling (TPM) analyses rely on shape and spin information of the object being analysed in order to accurately compute the energy budget across the surface. Using data from (3200) Phaethon, the target of the upcoming DESTINY+ mission, I will show the effect that different shape

models can have on the interpretation of TPM modeling. Previous works that used a convex shape model from lightcurve inversion and an assumed spherical shape yielded noticeably different thermal inertia estimates for Phaethon and sizes that are inconsistent with radar observations. Using a detailed, radar-derived shape model I will present diameter and thermal inertia results and highlight the importance of using an accurate shape model in TPM analyses. The implications for asteroids other than Phaethon will also be discussed.

Thermophysics of dust particles: Implications on cometary activity
Johannes Markkanen (1)
(1) Max Planck Institute for Solar System Research, Germany

Thermal properties of dust particles have a major impact on the remote observables of active solar system objects such as comets, active asteroids, and icy moons. Realistic thermophysical models are crucial to better understand the changes in the dust's properties driven by the sublimation of volatile materials and thermally induced particle fragmentation. In this talk, I will present some recent advancements in thermophysical models and their applications to better understand cometary activity. In particular, I will focus on the comet 67P/Churyumov-Gerasimenko using the data from the ESA/Rosetta mission and its relation to the data from the ground-based observations.

Modeling light scattering by Martian atmospheric dust
Julia Martikainen (1)
(1) Instituto de Astrofísica de Andalucía, CSIC. Glorieta de la Astronomía, Spain

Atmospheric dust particles scatter and absorb light and thus play an important role in determining the thermal structure of the Martian atmosphere. However, understanding light scattering by irregular particles is challenging and the scattering function of the Martian dust particles is often obtained by assuming spherical particle shapes. Our aim is to improve the current modeling approach by taking into account non-spherical particle shapes and retrieving the scattering properties of Martian dust analogues measured in the CSIC-IAA COsmic DUst LABoratory (CODULAB, www.iaa.es/scattering).

Chasing asteroids in the infrared: NEOWISE and NEO Surveyor
Joe Masiero (1)
(1) Jet Propulsion Laboratory, California Institute of Technology, USA

Thermal infrared observations are a powerful tool for the discovery and characterization of the small bodies of our Solar system. Asteroids and comets are some of the brightest things in the sky at

mid-infrared wavelengths, and the measurement of their thermal emission let us constrain their sizes, albedos, and their thermophysical properties. I will present an overview of the asteroid and comet studies enabled by the ongoing NEOWISE mission, as well as describe our plans for the next-generation infrared search, NEO Surveyor.

Asteroid characterization at Lowell Observatory
Nicholas Moskovitz (1), Annika Gustafsson (2)
(1) Lowell Observatory, AZ, USA (2) Southwest Research Institute, CO, USA

The ongoing era of big data and large surveys, to which Gaia is a major contributor, poses numerous challenges and opportunities for Solar System research. New tools and synergistic approaches are needed to maximize scientific return from the growing catalog of minor planets and derived physical properties of these bodies. We will present an overview of ongoing efforts at Lowell Observatory to characterize asteroids in the near-Earth object (NEO) population. We will discuss some of the tools developed to facilitate this process, as well as highlighting recent results relevant to the photometric study of NEOs.

Asteroid photometric and polarimetric phase curves interpreted using synoptic scattering models
Karri Muinonen (1)
(1) University of Helsinki, Finland

The photometric and polarimetric phase curves of an asteroid describe, respectively, the dependences of the asteroids disk-integrated brightness and degree of linear polarization on the solar phase angle, the angle between the Sun and the observer as seen from the object. On one hand, a number of different photometric phase curves can be derived from lightcurve observations, such as the sparse lightcurves from the Gaia mission. Lightcurve inversion methods allow for the retrieval of proper photometric phase curves from which the effects due to the asteroids nonspherical shape and due to the illumination and observation geometry, including the rotational phase and pole orientation, have been removed. On the other hand, polarimetric phase curves are rather insensitive to the shape and rotational characteristics of the asteroid. Synoptic scattering modeling, accounting for coherent backscattering and shadowing, will be offered for the photometric and polarimetric phase curves of airless Solar System objects.

Understanding the Negative Polarization Branch of comets and asteroids
Olga Muñoz (1)
(1) Instituto de Astrofísica de Andalucía, CSIC. Glorieta de la Astronomía, Spain

In this talk I will discuss our current efforts to establish a link between the physical properties of cometary/asteroidal analogue dust particles (size, morphology and composition) and the magnitude and position of the negative polarization branch. The study is based on the analysis of experimental degree of linear polarization curves for a selected set of analogue samples. The experimental data are obtained at the IAA Cosmic Dust Laboratory.

Asteroid phase curves using dense differential and sparse relative photometry
Dagmara Oszkiewicz (1)
(1) Institute Astronomical Observatory, Adam Mickiewicz University, Poland

Traditionally asteroid phase curves are derived from dense in time relative or absolute photometry. This kind of targeted observations typically result in high-quality phase curves and are currently available only for about 100 asteroids. On the other hand, sparse in time relative photometry is capable of providing lower quality phase curves for hundreds of thousands asteroids. I will discuss our approach to combine differential ground-based photometry and survey-like sparse measurements to obtain better-quality phase curves for growing number of objects.

Deep learning tools for asteroid taxonomy with Gaia and other surveys
Antti Penttilä (1)
(1) University of Helsinki, Finland

Ongoing and upcoming surveys such as the European Gaia space telescope, Data Release 3 and the final data release (2022 and post-2024), the US Rubin Observatory (LSST, operations starting in 2023) and the European Euclid space mission (launch 2022) will produce unparalleled amount of asteroid spectra or color photometry. However, the spectral ranges or the color filters will be, again, unique to the survey. This enables new possibilities for asteroid taxonomy, but also creates challenges in linking the existing and new systems. We propose neural network classifiers as a tool to provide best possible linking from new observations into existing taxonomic systems when the wavelength range of the spectra does not completely overlap with the taxonomic system.

Asteroids and comets: The quest for suitable analogues
Antoine Pommerol (1)
(1) WP-Physikalisches Institut, University of Bern, Switzerland

Laboratory analogues for asteroids and comets are required for a wide range of experimental investigations. Recent missions have provided new constraints to select suitable samples for this purpose. I will review the numerous challenges and initial successes in procuring material and developing protocols to prepare such analogues. I will also present a selection of results from recent spectro-photometric studies and discuss their implications. Finally, I will discuss the current shortcomings and provide perspectives for future activities in this field.

Asteroid mass determination with Gaia
Lauri Siltala (1)
(1) University of Helsinki, Finland

Gaia Data Release 2 includes milliarcsecond-accuracy astrometry for 14,099 asteroids. The expected scientific applications of this data include asteroid mass estimation via modeling perturbations during asteroid-asteroid encounters and general orbit determination. To demonstrate the impact of Gaia DR2 on the field, I present mass estimates for several large asteroids obtained with a combination of Gaia and Earth-based data and compare the results to those obtained with Earth-based alone. Additionally, we present results for orbit computation for the asteroid (367) Amicitia, previously used as a test case by the Gaia Collaboration, and compare ours to theirs. I detail and discuss the challenges involved in the computations and correct data treatment and conclude with discussion on future prospects beyond DR2.

A new weighting scheme to combine Gaia and ground-based observations
Federica Spoto (1)
(1) Observatoire de la Cote d'Azur, France

Gaia Data Release 2 (April 2018) contained for the first time almost two million ultra-accurate observations of Solar System objects (Gaia Collaboration, Spoto et al. 2018). One of the main goals of having such accurate observations is the possibility of detecting a small non-gravitational perturbation, known as the Yarkovsky effect, in the main belt. Gaia observations alone cover only 18 months, that is why we need to combine them with already available ground-based and space-based astrometry. We worked on a new weighting scheme, which means that we select weights for given observatories that are then used in the orbit determination least-squares fit. That is why having a good weighting scheme is one of the most important parts of the orbit determination process. This new scheme will allow us to reduce to the minimum any manual intervention when we try to combine Gaia and

ground-based observations to measure the Yarkovsky effect in the main belt. The error model is now in use at the Minor Planet Center, where it is has been adapted to deal with different issues in the orbit determination. I will present the technique we have used to create the error model, some applications and future perspectives for Gaia DR3.

The role of asteroid observations by Gaia: preparing the exploitation of the first full-size data release
Paolo Tanga (1)
(1) Observatoire de la Cote d'Azur, France

With the publication of the Data Release 3, the Gaia mission provides to the community the first, major, full-fledged release of asteroid astrometry and spectro-photometry. The most relevant features are the accurate epoch astrometry and photometry for more than 158 000 asteroids, and the average reflectance spectra for about one-third of them. Based on the experience of the much more limited data set of DR2 we will review the impact of the accurate astrometry, with a special focus on its relevance for space missions, and mentioning the difficulties related to its exploitation. We will then discuss the role of the low-resolution spectroscopy by Gaia, in an evolving landscape of current and future large asteroid surveys. The open questions that it can help to clarify, the synergy with other data sets, and its optimal exploitation with modern techniques of data mining will be mentioned.

Are Ryugu and Bennu from the same parent body or not?
Eri Tatsumi (1)
(1) Insituto Astrofísica de Canarias, Spain

Ryugu and Bennu are the sample-return mission target asteroids by JAXA and NASA, respectively. Exogenic materials on the surfaces of both Ryugu and Bennu are found. I will discuss compositional similarity and difference of these exogenic materials. Moreover, we found the regions on Ryugu with materials as blue as Bennus average spectrum. I will discuss the origin of Ryugu and Bennu from the spectroscopic point of view.

Polarized light scattering from regolith simulants
Gorden Videen (1)
(1) Army Research Laboratory, USA

Regolith of small, atmosphereless bodies is highly charged, resulting in an extremely fluffy, structure that is hard to replicate on Earth. Light scattering is dependent on surface porosity, which must be taken into account in remote-sensing studies. Additive manufacturing provides an opportunity to

create highly porous surfaces from which we can measure their light-scattering properties. I will discuss current modeling and experimental efforts aimed at determining the effect of porosity of surfaces composed of different materials on their light-scattering properties. The research supports to the KPLO mission, but is applicable to asteroid studies as well.

Characterizing dielectric properties of near-Earth asteroids using radar observations
Anne Virkki (1)(2)
(1) University of Helsinki, Finland
(2) Finnish Geospatial Research Institute, Finland

Radar delay-Doppler observations provide images of celestial objects with a resolution as fine as 7.5 meters per pixel. I characterized the near-surface dielectric constant of 20 near-Earth asteroids (NEAs) using the disk function analysis. I modeled the radar reflectivity as a function of the incidence angle, θ_i, by a scattering law of the form $R(C+1)\cos^{2C}\theta_i$, where R defines the reflectivity and C is a roughness parameter. The dielectric properties were then used for estimating the regolith mass density near the asteroid surfaces. Only NEAs that appear spheroidal in the delay-Doppler images, are greater than 140 meters, and were observed using the Arecibo S-band (2380 MHz, 12.6 cm) radar were included in this pilot study to understand the connection of radar polarimetry and dielectric properties of NEAs as well as getting clues of their density.

Solar System object data in time-domain photometric surveys
Xiaobin Wang (1), Xiaoyun Xu (2)
(1) Yunnan Observatories, Chinese Academy of Sciences, China
(2) School of Astronomy and Space Science, University of Chinese Academy of Sciences, China

At present, many ground- or space-based photometric time-domain surveys are running to search for new exoplanets or supernovae. Using a Centurion 18 telescope at the Lijiang site of Yunnan Observatories, the time-domain survey for new exoplanets in selected sky regions has been running for 5 years. We established a machine learning method to extract data of Solar System objects (SSOs) in this survey. The photometric and astrometric data of these SSOs are calibrated with the Gaia EDR3 catalogue. The extracted lightcurves of asteroids can be used to derive the shape, spin, and phase function parameters. The dense astrometric measurements of asteroids can be used to improve their orbits.

On the nature of dispersion of linear polarization observed in comets at large phase angles

Evgenij Zubko (1)
(1) Humanitas College, Kyung Hee University, South Korea

When initially unpolarized solar radiation is scattered from a comet, it acquires a partial linear polarization that is quantified with the degree of linear polarization P. Degree of linear polarization is a function of phase angle α. At large phase angles, $\alpha \sim 90^{\circ}$, the strength of the polarimetric response varies greatly from one comet to another. This phenomenon initially was interpreted as a result of the depolarizing effect of cometary gaseous molecules; whereas, a thorough analysis of the entire set of data (spectra, mid-IR thermal emission, and polarization) unambiguously suggests a dusty origin of the polarization dispersion. We will discuss microphysical properties of cometary dust particles causing the polarization dispersion, and their implication in context of evolutionary history of comets.