Rock, Dust and Ice: Interpreting Planetary Data

Rocks: Tuesday, March 23, 2021

Click on a presentation title to see the abstract.

Time (Pacific)	Speaker (Affiliation)	Presentation Title
8:00–8:05am		Introduction
8:05–8:30am	Josh Emery (NAU)	Observations of Rocky Solar System Materials at ~3 µm and in the Thermal Infrared
8:30–8:55am	Irina Belskaya (Kharkiv National University)	Probing Surface Properties of Asteroids by Polarimetric Observations
8:55–9:05am	Katherine de Kleer (Caltech)	Electrical Properties of (16) Psyche's Surface from ALMA
9:05–9:15am	10 minute break	
9:15–9:40am	Bastian Gundlach (Technische Universität Braunschweig)	How to Constrain the Physical Properties of Cometary Surfaces?
9:40–10:05am	Alessandro Maturilli (DLR/IFP)	Spectral Laboratory Measurements of Rocks in MIR
10:05–10:15am	**Pre-Recorded Talks Q&A** Biele: Remote Boulder Counting and Thermal IR Temperature Curves Constrain Strength, Microporosity, Thermal Conductivity and Grain Dens Davalos: Values of Internal Scattering Coefficient Obtained from Reflectance Spectra of Meteorites and Minerals Hayne: Thermal Infrared Observations of the Moon from Diviner and L-CIRiS MacLennan: Revisiting (3200) Phaethon's Thermal Inertia Müller: Interpretation of Short-Wavelength Thermal Observations: The Case of Ryugu Ostrowski: Near-Earth Object and Meteorite Physical Properties Online Database Szakáts: SBNAF Database for Thermal Infrared Observations of Small Bodies in the Solar System Valantinas: Colour and Multi-Angular Observations of Martian Slope Streaks	
10:15–10:25am	10 minute break	
10:25am–10:35am	Cailin Gallinger (University of Western Ontario)	Identifying Lunar Crater Ejecta Diversity with LRO Diviner and Multi-Parameter Thermophysical Modelling
10:35am–10:45am	Parvathy Prem (Johns Hopkins Applied Physics Laboratory)	Modeling the Influence of Epiregolith Thermal Gradients on Airless Body Emission Spectra
10:45am–11:35am	Bobby Bus (IRTF), Thomas Müller (MPE, Munich)	Discussion

Rock, Dust and Ice: Interpreting Planetary Data

Ices: Wednesday, March 24, 2021

Click on a Presentation Title to see the abstract.

Time (PDT)	Speaker (Affiliation)	Presentation Title
8:00–8:05am		Introduction
8:05–8:30am	Silvia Protopapa (SWRI)	Characterization of the Ices in the Pluto System through the Synergy of Reflectance Spectroscopy, Photometric Analysis, and Laboratory Measurements
8:30–8:55am	Dale Cruikshank (NASA Ames)	Ices and Organics in the Outer Solar System — Connections to the Solar Nebula and Protoplanetary Disk
8:55–9:05am	Nikolai Kiselev (Crimean Astrophysical Observatory)	Peculiar Polarization of Icy Surfaces: Observations of Jovian Satellite Europa and their Interpretation
9:05–9:15am	10 minute break	
9:15–9:40am	Michael Poston (SWRI)	Testing Trojan Migration in the Lab: Spectra of Weathered Solar System Ices
9:40–10:05am	Perry Gerakines (NASA Goddard)	Mid-Infrared Optical Properties of Ices
10:05–10:10am	**Pre-Recorded Talks Q&A** Roux: Simulating Icy Regolith for Exploration and Resource Development Efforts Schorghofer: Dynamics of Water Adsorption on the Moon and Ceres: Theoretical Predictions Tchernyi: What We Can Say about Ice of the Saturn's Rings Particles	
10:10–10:20am	10 minute break	
10:20am–10:30am	Ludmilla Kolokolova (University of Maryland)	Radiation Scattering by Packed Media: Modeling Icy Layers on Cosmic Bodies
10:30am–10:40am	Patrick D. Tribbett (Northern Arizona University)	Characterizing the Porosity of Astrophysical Icy Surfaces with Near- and Mid-Infrared Spectroscopy
10:40am–11:30am	Stefanie Milam (NASA/GSFC), Will Grundy (Lowell Observatory)	Discussion

Rock, Dust and Ice: Interpreting Planetary Data

Dust: Thursday, March 25, 2021

Click on a Presentation Title to see the abstract.

Time (Pacific)	Speaker (Affiliation)	Presentation Title
8:00–8:05am		Introduction
8:05–8:30am	Chick Woodward (University of Minnesota)	SOFIA Comet Observations — A Window in to Solar System Carbon
8:30–8:55am	Melissa Lane (Fibernetics LLC)	Mid-Infrared Spectral Characteristics of Dust (Minerals and Meteorites) and Their Utility for Interpreting Remote-Sensing Data
8:55–9:05am	Audrey Martin (Northern Arizona University)	Properties and Mineralogy of Trojan Asteroid surfaces — Mid-IR Spectral Effects of Regolith Porosity
9:05–9:15am	10 minute break	
9:15–9:25am	Jessica Arnold (Army Research Lab)	Is the Dust made of Rock, Ice, or Carbon? AU Mic as an Example of the Challenges of Retrieving Debris Disk Dust Properties
9:25–9:50am	Ella Sciamma-O'Brien (NASA Ames)	On the Importance of Producing and Characterizing Laboratory Analogs of Planetary Atmospheric Aerosols, Surface Materials and Cosmic Grains
9:50–10:00am	Antti Penttilä (University of Helsinki)	Rigorous Simulations of Nanophase Iron Space-Weathering Effects on Reflectance Spectra
10:00–10:10am	**Pre-Recorded Talks Q&A** Ahrens: Researching the Planetary Environment with an Interstellar Probe Collins: Using ROCKE-3D General Circulation Model to Reveal Titan's Atmospheric Dynamics Gustafsson: Constraining Asteroid Regolith Grain Size with Hapke Radiative Transfer Modeling Hengst: Multi-Wavelength, Spatial Resolved Modelling of Debris Discs Lietzow: Radiative Transfer of Polarized Radiation for Investigating (Exo)planetary Atmospheres Mutschke: (Sub-)Millimeter Dust Opacities from Laboratory Measurements Yu: Understanding Cloud Formation on Titan	
10:10–10:20am	10 minute break	
10:20am–10:30am	Joseph Roser (SETI Institute, NASA Ames Research Center)	The Laboratory Astrophysics Optical Constants Database
10:30am–11:20am	Dave Jewitt (UCLA), Aigen Li (University of Missouri)	Discussion

Rock, Dust and Ice: Interpreting Planetary Data

Panel Discussions: Friday, March 26, 2021

Click on a Presentation Title to see the abstract.

Time (PDT)	Speaker (Affiliation)	Presentation Title
8:00–8:50am	Arielle Moullet (SOFIA/USRA), Bobby Bus (IRTF)	Data Archives Panel with Gerbs Bauer, Luisa Rebull, Tony Remijan, Robert Szakats, and Meg Schwamb
8:50–9:00am	10 minute break	
9:00–9:50am	Edith Fayolle (JPL), Thomas Müller (MPE, Munich)	Laboratory Databases Panel with Perry Gerakines, Karly Pitman, Will Grundy, Ludmilla Kolokolova, Eric MacLennan, and Joseph Roser
9:50–10:00am	10 minute break	
10:00–10:50am	Maggie McAdam (NASA Ames), Arielle Moullet (SOFIA/USRA)	Models and Codes Panel with Ludmilla Kolokolova, Silvia Protopapa, Geronimo Villanueva, and Jian-Yang-Li

Abstracts: Live Talks

Jessica Arnold (Army Research Lab)

Title: Is the Dust made of Rock, Ice, or Carbon? AU Mic as an Example of the Challenges of Retrieving Debris Disk Dust Properties

Abstract: Debris disks are dusty circumstellar disks analogous to our solar system's Kuiper belt, asteroid belt, and zodiacal cloud. The dust in these disks is produced by the destruction of comets, asteroids, and protoplanets. Understanding the composition of the material within these extrasolar systems may provide insight into the planet formation process, especially in cases where the star also hosts planets. For example, AU Microscopii (AU Mic) hosts both a debris disk and a Neptune-sized planet recently confirmed by Plavchan P. et al (2020) Nature, 582, 497-500.

As debris disks are typically too cold to produce key identifying silicate spectral features in thermal emission near 10 µm, scattered light observations in the VNIR wavelength range are important for making compositional determinations. The edge-on orientation of the AU debris disk means that light scattered at different projected separations from the star will originate from different sets of scattering angles. This allows information about the dust to be extracted from the scattering phase function (SPF), which describes how much light is scattered by the dust as a function of phase angle. AU Mic has been observed to have a blue to neutral color at different projected separations. However, both the SPF and resulting spectral "color" of the disk at various projected separations are function of grain size, shape, and porosity in addition to composition. This means that compositional information can only be extracted if this degeneracy can be broken. Here we examine whether and how assumptions about grain shape affect dust properties retrieved from a data set covering multiple wavelengths and radial distances.

Irina Belskaya (Kharkiv National University)

Title: Probing Surface Properties of Asteroids by Polarimetric Observations

Abstract: Polarimetry is an effective remote sensing tool for studying asteroid surfaces, in particular, for assessing surface albedo and texture, and searching for surface peculiarities. However, the application of the polarimetric technique to study asteroids has not yet been well exploited. This is primarily due to the difficulties in interpreting polarimetric measurements in terms of the physical parameters of asteroid surfaces. So far, the interpretation is mainly based on empirical relationships found in laboratory measurements of meteorites, lunar soil and their structural analogs. As the quantity and quality of asteroid observations increases, it becomes evident that the polarimetric properties of asteroids are more diverse than expected from laboratory data. Comparison of polarimetric properties of asteroids within the same composition class provides complimentary information on their surface nature. The achievements and problems of using polarimetry for studying asteroid surfaces will be discussed.

Dale Cruikshank (NASA Ames)

Title: Ices and Organics in the Outer Solar System — Connections to the Solar Nebula and Protoplanetary Disk

Abstract: Ices of various compositions are characteristic of many planetary bodies, particularly in the outer Solar System. Organic molecules, both simple and complex, are also found on asteroids, planetary satellites, comets, and Kuiper Belt objects (KBOs), some as native material and some as products of photolysis and radiolysis in the space environment. Simple ices (e.g., $CH4$, $H2O$, CO, $CO2$, $N2$, $NH3$, $CH3OH$, HCN) have distinctive and diagnostic absorption bands in accessible regions of the spectrum, particularly 1-5 µm. In contrast, aromatic and aliphatic molecules, and particularly macromolecular complexes have spectral features diagnostic of functional groups but often not of specific compounds. Macromolecular organics characteristically exhibit a range of visible-region colors ranging from yellow to red, while intense processing by UV and charged particles can produce very low albedos. Spectra of KBOs over accessible spectral regions show a few simple ices and a range of color and albedo. Both the ices and the inferred organics are a window on the native materials in the solar nebula in which they formed, and by extension the nascent protoplanetary disk. Protoplanetary disks inherit icy grains from molecular clouds via an infalling protostellar envelope, and eventually icy grains grow large enough to gravitationally settle to the disk midplane, where they are incorporated into planetesimals, producing a vertical chemical gradient. A radial chemical gradient occurs along the disk mid-plane with distance from the newly-forming star as a result of "snowlines" that form according to the sublimation temperatures of different ices. This radial chemical gradient gave rise to Solar System bodies with different compositions, from water-rich comets to methanol-rich KBOs.

Katherine de Kleer (Caltech)

Title: Electrical Properties of (16) Psyche's Surface from ALMA

Abstract: The asteroid (16) Psyche is the target of an upcoming NASA mission and the largest of the M-type asteroids, which have been hypothesized to be the cores of disrupted planetesimals and the parent bodies of the iron meteorites. While recent evidence has collected against a pure metal composition for Psyche, its spectrum and radar properties remain anomalous and indicative of an unusually high metal content. Millimeter observations are sensitive to the thermal and electrical properties of an asteroid surface, and sense the upper few millimeters of the surface in contrast to the greater depths seen by radar. We observed (16) Psyche in thermal emission with the Atacama Large (sub-)Millimeter Array (ALMA) at a resolution of 30 km over 2/3 of its rotation, mapping both the intensity and the polarization of its emission. We model Psyche's millimeter emissivity as a porous mixture of rock and metal, where the latter may take the form of iron sulfides/oxides or alternatively as conducting metallic inclusions. The polarization is interpreted along with past optical and radar polarization measurements to constrain the metal grain size. The collective results are evaluated against candidate surface compositions for (16) Psyche. We note that the interpretation of this and similar datasets would be greatly improved by measurements of the dielectric properties of solid and particulate metal-rock mixtures near 100-300 GHz.

Josh Emery (NAU)

Title: Observations of Rocky Solar System Materials at ~3 μm and in the Thermal Infrared

Abstract: Rock-forming minerals have spectral features that span the electromagnetic spectrum. Visible and near-infrared (VNIR; 0.4 – 2.5 μm) wavelengths have been profitable for characterizing many rocky Solar System bodies, particularly those dominated by the crystalline silicates olivine and pyroxene. VNIR spectra of the majority of asteroids (C-complex, P-, and D-types) and comet nuclei, however, are notoriously difficult to interpret – they contain few diagnostic absorption features. Important constituents of the matrices of carbonaceous chondrite meteorites (the analogs of C-complex asteroids) – phyllosilicates, carbonates, and organics – exhibit strong features in the 2–4 μm spectral region and in the thermal infrared (TIR; 5 – 40 μm). Water in its various forms (OH/H2O in the mineral structure or adsorbed onto grains, H_2O ice), whether native or exogenically sourced, also has strong spectral features at these wavelengths. Fortunately, we have entered an era where high quality (in terms of both sensitivity and spectral resolution) spectral observations are possible in the 2–4 μm region. These observations have revealed substantial compositional heterogeneity among the primitive asteroid classes and promise even deeper insights in the future. TIR spectral observations have revealed emissivity features on a number of asteroids that are diagnostic of surface structure and composition, but those observations also remain difficult to interpret due to a combination of data quality and the complexity of light scattering at those wavelengths. TIR observations also enable thermophysical analyses of surfaces. I will review recent developments in asteroid observations in the 2–4 μm and TIR spectral ranges.

Cailin Gallinger (University of Western Ontario)

Title: Identifying Lunar Crater Ejecta Diversity with LRO Diviner and Multi-Parameter Thermophysical Modelling

Abstract: Impact craters produce a variety of geologic materials when they form, including fragmental ejecta, impact melt, and large boulders. These materials differ in thermal inertia both laterally and with depth, and thus should be distinguishable by their rate of heat loss during the night. Using nighttime surface temperature data derived from observations by the Diviner radiometer onboard NASA's Lunar Reconnaissance Orbiter (LRO), previous investigators have constrained the abundance of meter-scale surface rocks (Bandfield et al., 2011) and the depth-density profile of the lunar regolith (Hayne et al., 2017). We expand on this work by developing a thermal model based on that of Hayne et al. (2017) with two free parameters, that can differentiate between more complex ejecta materials based on their variation in subsurface thermophysical properties. We then apply this model to study the ejecta of several young lunar craters. By mapping the resulting parameters in RGB space, we find that relative differences in color correlate well to distinguishable units viewed in high-resolution LRO narrow-angle camera images. However, we caution that absolute values of model parameters are not uniquely informative, since they are highly dependent on model inputs that are currently poorly constrained. We will discuss the difficulties of extracting quantitative information from thermophysical models of airless bodies in general, and advocate for the importance of relative differences in geological interpretation.

Perry Gerakines (NASA Goddard)

Title: Mid-Infrared Optical Properties of Ices

Abstract: Research in the Cosmic Ice Laboratory at NASA Goddard Space Flight Center centers on the properties of ices relevant to the Solar System and to the cold interstellar medium. This includes studies of physical properties such as density and vapor pressure, and infrared spectroscopic properties such as band strengths and optical constants needed for the interpretation of telescopic observations in the mid-infrared. In order for these data to be useful, the ices must be created under careful conditions of temperature and ice structure (amorphous vs. crystalline). In this talk, I will summarize measurements from our laboratory for ~12 molecules relevant to planetary and interstellar environments, each prepared in amorphous and crystalline forms (where possible). I will also present recent results for ammonium cyanide (NH4CN), an ionic compound (i.e., salt) discovered in the dust surrounding comet 67P/Churyumov-Gerasimenko and a likely source of ammonia (NH3) and HCN gases in the coma of comets.

Bastian Gundlach (Technische Universität Braunschweig)

Title: How to Constrain the Physical Properties of Cometary Surfaces?

Abstract: Comets are believed to be the most pristine objects in the solar system. Studying their physical nature might help us to better understand the formation of our and other planetary systems. However, most remote measurement techniques and instruments on board comet missions can only be used to probe the upper surface layers of comets. Therefore, we need to understand how to interpret the received data. If we can measure the physical properties of the cometary surface material, we are probably able to better constrain the comet and planet formation processes.

In this talk, I will provide an overview of how different formation and evolutionary processes might have influenced the physical properties of the cometary surface layers. Different possibilities to estimate the physical properties of the surface will be discussed in the second part of the talk. Finally, the talk will be concluded by a summary of our current knowledge.

Nikolai Kiselev (Crimean Astrophysical Observatory)

Title: Peculiar Polarization of Icy Surfaces: Observations of Jovian Satellite Europa and Their Interpretation

Abstract: Polarimetry is a powerful technique to study surfaces of solar-system objects, especially at small phase angles were so called negative branch of polarization (NBP) is observed. NBP can have different shape and polarization values for different composition of the surfaces. For rocky surfaces, it has a parabolic shape with a minimum around 10 deg. and inversion point (the angle where polarization changes from negative to positive) around ~20 deg. However, for icy surfaces (satellites of giant planets, cometary nuclei, and TNOs), the NBP becomes very asymmetric, and its minimum shifts to smaller phase angles. The cause of this has been attributed to Coherent Backscattering Effect (CBE), which is known to be very sensitive to the size of particles and porosity of the medium. Recently we have been able to accurately determine the NBP of Jovian satellite Europa. It appeared that Europa's NBP is not bimodal with a deep and narrow and broad and shallow overlapping NPBs (Rosenbush et al. 2015), but has a single very sharp minimum at phase angle <0.5 deg. and inversion point at ~ 6 deg. Such NBP is evidently formed by CBE. We studied wavelength dependence of the Europa's NBP to better characterize the CBE. Using the modeling technique by Muinonen et al. (2015) we estimated the size of icy particles ~20 micron and porosity ~70%. Extending the wavelength range to longer wavelengths, where CBE should be even more pronounced, opens new opportunities to study characteristics of icy surfaces of cosmic bodies.

Ludmilla Kolokolova (University of Maryland, College Park, MD)

Title: Radiation Scattering by Packed Media: Modeling Icy Layers on Cosmic Bodies

Abstract: Retrieval of properties of planetary surfaces from remotely measured spectra often rely on physically realistic yet burdensome exact computer solvers or fast yet empirical models with debatable validity. Efficient and accurate analysis of spectra requires a practical method that still strive to preserve physical legitimacy. With this motivation, we use a technique that is based on a radiative transfer equation enhanced by adding a correction for dense packing effects with the static structure factor. This factor counts on the spatial correlation among densely packed particles that substantially changes their single-scattering properties. The simulations start with calculating light scattering by a single particle; the output of this calculation is corrected for the static structure factor, and then used in a radiative transfer code. The advantage of this approach is that it uses only physical parameters of the particulate surface: size of particles, their refractive index, and filling factor (porosity). Besides, it can be used for particles of any shape and structure. With this technique we modeled the spectra acquired by Cassini's VIMS (Visual and Infrared Mapping Spectrometer) for saturnian icy satellites presenting the surface as a layer of icy particles. We considered particles of three types: spheres (calculated with Mie theory), aggregates (calculated with T-matrix approach), and irregular Gaussian particles (calculated with Sh-matrix approach). The best fit was achieved for small aggregates and compact irregular particles with particle radius 1-2 micron and porosity ~90%. The code is very efficient computationally; it can model 1-4 micron VIMS spectrum in ~5 minutes on a single Dell Precision T7500 desktop.

Melissa Lane (Fibernetics LLC)

Title: Mid-Infrared Spectral Characteristics of Dust (Minerals and Meteorites) and Their Utility for Interpreting Remote-Sensing Data

Abstract: Mid-infrared spectra (5-50 um; 2000 to 200 cm-1) of fine particulates are different from those of coarse particulates and hand samples. As samples decrease in size, their spectra gradually change in appearance. Relative to coarser particulates with strong fundamental features, fine-particulate spectra show decreased depth of fundamental features, increased appearance of volume scattering features, plus a drop in emissivity (increase in reflectivity) at higher frequencies. Dust spectra strongly exhibit this behavior, and with the diminished fundamental bands, other spectral features may need to be used for mineral identification. Furthermore, emissivity spectra are different when acquired under ambient pressure versus vacuum conditions. These spectral characteristics can be used to select the correct spectral library for interpretation of remote-sensing data of planetary and asteroidal targets. Mineral and meteorite spectra (reflectivity, emissivity) will be presented and discussed.

Acknowledgment: This material is based upon work supported by the National Aeronautics and Space Administration through the Solar System Exploration Research Virtual Institute 2016 (SSERVI16) Cooperative Agreement NNH16ZDA001N (TREX).

Audrey Martin (Northern Arizona University)

Title: Properties and Mineralogy of Trojan Asteroid surfaces — Mid-IR Spectral Effects of Regolith Porosity

Abstract: Trojan asteroids are a substantial group of primitive bodies that carry insight into the Solar System as a whole. Asteroid surface composition can be indicative of formation. By constraining non-compositional parameters that affect mid-infrared (MIR; 5-35 mm) spectra, Trojan surface mineralogy can be more accurately interpreted, leading to a deeper understanding of formation. MIR spectra of Trojans exhibit silicate emission features, not unlike a comet comae. To explain this perplexing resemblance, researchers hypothesized that Trojan surfaces may consist of a fine grained, 'fluffy' regolith of silicates (hereafter 'regolith porosity' will refer to how fluffy a regolith is). To understand the MIR spectral region with respect to regolith porosity, and transitively Trojan surfaces, we test the hypothesis: Porosity in regoliths of fine-grained silicates have a systematic and quantifiable effect on the band position, shape, and spectral contrast of MIR spectra.To simulate the effects of regolith porosity, we mixed silicate and KBr powder. Each silicate powder sample was mixed with KBr from 0%-90% with 10% intervals by weight. To control for a grain size, we ground and sieved samples into the following grain sizes: < 20 mm, 20-45 mm, and 45-63 mm. Finally, we measured spectra with a Fourier transform infrared (FTIR) spectrometer in the MIR. Our results show systematic changes of the Christiansen Feature, restrahlen bands, and the broad transparency feature with increased regolith porosity. These results support the hypothesis that regolith porosity has a systematic effect on silicate features in the MIR.

Alessandro Maturilli (DLR/IFP)

Title: Spectral Laboratory Measurements of Rocks in MIR

Abstract: In the last decades orbital spectroscopic observations of planetary surfaces have greatly advanced our understanding of the global distribution of different rock types and their chemical compositions. This vast dataset is complemented in several cases by in situ reflectance spectra from lander missions, which provide more detailed information about the mineralogy of local surface materials and the geological context of the landing sites. Just to cite a recent example, the material analyzed by Yutu-2 at the Chang'E 4 landing site includes not only regolith but also a fragment of rock with a small- to medium grained plutonic texture, that has most likely been excavated by a nearby impact crater. Due to its deep-seated origin, the composition of such a rock fragment is of particular importance for understanding the underlying stratigraphy of the landing site. A reliable quantification of mineral modal abundances from measured reflectance spectra requires the availability of laboratory spectra of comparable samples. However, current spectral databases primarily contain spectra measured on powder samples, while spectra of coarse-grained rock samples are rare. Since reflectance spectra are sensitive to grain size and surface roughness, the available powder spectra might not be sufficient for a quantitative interpretation of measured rock spectra. At the Planetary Spectroscopy Laboratory (PSL) of DLR in Berlin we measured the spectra of rocks in powder and slab format, and of rock building minerals to allow for comparison of spectral features

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Antti Penttilä (University of Helsinki)

Title: Rigorous Simulations of Nanophase Iron Space-Weathering Effects on Reflectance Spectra

Abstract: We present a multi-scale light-scattering model that is capable of simulating the reflectance spectra of a regolith layer. In particular, the model can be applied to a case where the regolith grains have varying amounts of nanophase inclusions due to space weathering of the material. As different simulation tools are employed for different size scales of the target geometry (roughly, nano-, micro-, and millimeter scales), the particle size effects, the surface reflections, and the volume scattering can all be properly accounted for. Our results with olivine grains and nanophase iron inclusions verify the role of the nanoinclusions in the reflectance spectra of space-weathered materials. Together with the simulation results, we give simplified explanations for the space-weathering effects based on light scattering, namely the decrease of albedo, the general increase of the red spectral slope, and the dampening of the spectral bands. We also consider the so-called ultraviolet bluing effect, and show how the change in the spectral slope over the ultraviolet–visual wavelengths is due to the decrease of reflectance in the visual wavelengths rather than the increase of reflectance in the ultraviolet part.

Michael J Poston

Title: Testing Trojan Migration in the Lab: Spectra of Weathered Solar System Ices

Abstract: KISS-funded work simulating a hypothesized history of the Jupiter-Trojan asteroids in the lab and relating back to telescope data. The work focused

on the slope in the visible and near infrared spectral region, but included mid infrared spectroscopy and mass spectrometry, including of the refractory residues. The hypothesis is that bimodal color distributions seen in Trojan ("red" "less-red") and Kuiper belt ("very red" "red") small objects indicate a common composition between the two populations. Specifically, we tested the hypothesis that formation on one side or the other of the H2S ice line - followed by dynamical rearrangement of the solar system - led to each of the colors, with the redder subpopulation of each population containing significant sulfur and the more neutral population lacking it. Lab experiments considered the key difference between the two populations: thermal history. All simulations (H2O, CH3OH, and NH3 - with and without H2S) were formed at 50K then irradiated with energetic electrons. Spectra at the end of the 50K irradiation represented KBOs; continuing the experiments produced Trojan simulants by warming to >120K and further irradiation. The lab results support the hypothesized importance of H2S, but only if Jupiter-Trojan asteroids experienced a relatively warm migration in to 5 AU. Compositional analysis revealed that sulfur, when present, dominated the chemistry.

Parvathy Prem (Johns Hopkins Applied Physics Laboratory)

Title: Modeling the Influence of Epiregolith Thermal Gradients on Airless Body Emission Spectra

Abstract: The low thermal conductivity of regolith on the Moon and other nominally airless bodies can give rise to steep temperature gradients within the epiregolith – the near-surface boundary layer (on the order of hundreds of microns thick) from which remotely measured thermal emission originates. Epiregolith thermal gradients can lead to changes in characteristic spectral features under near-vacuum conditions, complicating interpretations of surface composition and thermophysical properties. Here, we use a Monte Carlo radiative transfer model to investigate the influence of epiregolith thermal gradients on thermal emission spectra for several mineral phases of interest with varying porosity and grain size. Comparing model results to lab measurements allows us to constrain the magnitude of thermal gradients established under lunar-like conditions. We also couple the Monte Carlo model to a one-dimensional heat transfer model in order to compute expected epiregolith thermal gradients at different latitudes over the course of a lunar day. Results are consistent with previous work (Hale and Hapke, 2002) and indicate that lunar epiregolith thermal gradients are steepest at noon, and that regions with similar brightness temperatures may have notably different near-surface temperature profiles.

Silvia Protopapa (SWRI)

Title: Characterization of the Ices in the Pluto System through the Synergy of Reflectance Spectroscopy, Photometric Analysis, and Laboratory Measurements

Abstract: We present an overview of the chemistry, physical properties, state of mixing, and distribution of ices and refractories on the surfaces of Pluto and Charon. This was obtained through the synergy of multi-wavelength and multi-angular spectroscopic observations, detailed radiative transfer modeling, and laboratory measurements. Composition maps of Pluto and Charon provided valuable insight into a suite of different mechanisms at play on the surface of these two objects, from volatile transport to radiation processes and cryovolcanism. The striking spatial heterogeneity on the surface of Pluto results from a variety of geologic and atmospheric processes, including the seasonal transport of nitrogen, methane and carbon monoxide ices, which are volatile at the temperatures prevailing on the surface. Sublimation and redistribution of volatile ices take very different forms on Pluto and on Charon. The majority of Pluto's surface is covered by an optically thick layer of volatiles ices, while the majority of Charon's surface is occupied by a comparatively inert substrate dominated by crystalline water ice, ammonia-bearing species, and at least two darkening materials. We will discuss how our knowledge of Pluto and Charon surface composition has greatly improved in the last four decades and highlight open questions that require further effort in the observational and laboratory fields.

Joseph Roser (SETI Institute, NASA Ames Research Center)

Title: The Laboratory Astrophysics Optical Constants Database

Abstract: The Optical Constants Database (OCdb) is currently under development as part of the Ames Laboratory Astrophysics Directed Work Package (LADWP) ISFM. OCdb is being designed as a publicly accessible, free-to-use, searchable website for accessing and working with optical constants datasets that are necessary for modeling observations of Solar System bodies and exoplanets. Enabling users to make graphical comparisons between datasets, and to search for compositions and wavelength coverage are initial priorities for OCdb development. The OCdb website design will be analogous to its sister database, the NASA Ames PAH IR Spectroscopic Database (https://astrochem.org/pahdb), that is also a part of the LADWP ISFM. OCdb will also accept published, peer-reviewed optical constants datasets contributed by the scientific community.

In addition, OCdb is being designed with a modular Python toolkit of associated offline tools to enable further scientific utilization of the optical constants data. These associated tools will consist of a principal graphical user interface panel that will encapsulate common toolkit tasks such as creating graphs,

loading optical constants data, and saving calculations to file with more complex computing tasks made available through a user-customizable set of modular graphical user interface panels. For example, these specialized tasks could include computing a geometric albedo spectrum or a bidirectional reflectance spectrum from available optical constants data. Modularity and user customization are key aspects of this software design and are intended to encourage contributions to the suite of database tools made by the scientific community.

Ella Sciamma-O'Brien (NASA Ames)

Title: On the Importance of Producing and Characterizing Laboratory Analogs of Planetary Atmospheric Aerosols, Surface Materials and Cosmic Grains

Abstract: Carbonaceous dust and aerosols have been observed in interstellar/circumstellar and planetary environments. Dedicated laboratory experiments have been developed to produce analogs of these solid materials under different experimental conditions (molecular precursors, temperature, pressure, energy source…). These experimental studies are key to investigating the physical and chemical processes that drive the formation of solid particles from gas and solid phase molecular precursors in astrophysical and planetary environments. These experiments also allow the characterization of the physical, optical and chemical properties of the laboratory-generated dust analogs, hence providing critical information that can be used as input parameters in models for the analysis and interpretation of observational data (e.g. optical constants, spectral features, grain morphology).

Here, as an example of these laboratory efforts, we will present various studies that combined (1) experiments performed with the NASA Ames COSmIC facility to produce analogs of Titan's atmospheric aerosols and cosmic grains from gas phase molecular precursors, and (2) the characterization of these analogs with the NASA Ames Optical Constants Facility (OCF) to provide the real and imaginary parts of their refractive indices, n + ik, to the community, from the visible to the far-infrared (0.59–200 µm, 16,950–50 cm−1). We will also discuss the importance of the wavelength and spectral range coverage as well as accuracy of these optical constants, n and k, for their use in radiative transfer, atmospheric and reflectance models.

Patrick D. Tribbett (Northern Arizona University)

Title: Characterizing the Porosity of Astrophysical Icy Surfaces with Near- and Mid-Infrared Spectroscopy

Abstract: Remote sensing spectroscopy is a powerful tool for characterizing extraterrestrial icy surfaces. One crucial physical property of these surfaces is their porosity. Porous water ice is of particular astronomical significance as the pores can trap volatiles, altering the chemical history of the ice. However, direct measurements of surface porosity are exceedingly difficult. These laboratory measurements are usually derived from interference fringe reflectance spectra, which have limited applications within planetary remote sensing. One alternative, indirect measurement of porosity exploits the variation in intermolecular bonding at internal surfaces within porous ice. Some hydrogen bonds do not participate in lattice bonding (dangling bonds), resulting in unique, small near- and mid-infrared spectral features. More interestingly, these features shift with varying chemical environments, providing information about trapped volatiles that test the current capabilities of remote sensing spectroscopy including H2, O2, and N2. These dangling bond features may be important for probing trapped volatile species in addition to the surface ice porosity particularly in the outer solar system, where cold temperatures and lower radiation flux may preserve these dangling bonds. Here, we present new laboratory spectra characterizing these dangling bonds in wavelength regions accessible to remote sensing instruments.

Chick Woodward (University of Minnesota)

Title: SOFIA Comet Observations — A Window in to Solar System Carbon

Abstract: Traces of primordial materials, and their least-processed products, are to be found in the outermost regions of the solar system in the form of ices of volatile materials (H2O, CO2, CO, other rarer species), and more refractory dust grains. Primarily, refractory dust particles are carbonaceous materials and silicates of both crystalline and amorphous forms. This is the realm of comets. Considerable efforts have been expended to characterize the nature of refractory cometary particles and to understand the environment of the early solar system from pebbles to planetesimals to larger bodies. Cometary refractory particles likely are minimally processed over the age of the solar system after incorporation into the nuclei of comets. SOFIA contributes to our understanding of primitive refectory materials through spectroscopic observations of comets from 5.0 to 38 micron where thermal emission from optically thin particles in the coma dominate their spectral energy distribution. We will discuss recent SOFIA observations of four Oort cloud comets that revealed cometary dust carbon-to-silicon (C/Si) atomic ratios much higher than carbonaceous chondrites, suggesting our outer protoplanetary disk, the realm where comets first formed, was rich in carbon. The outer disk being rich in carbon and richer than the inner disk is one of several lines of evidence for a barrier or gap, spawned by Jupiter's formation, that hampered radial mixing and allowed for a radial gradient of carbon in the disk during the epochs of small body and planet formation.

Abstracts: Pre-Recorded Talks

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Tuesday, March 23

Jens Biele (DLR)

Title: Remote Boulder Counting and Thermal IR Temperature Curves Constrain Strength, Microporosity, Thermal Conductivity and Grain Dens

Abstract: In this paper, we summarize the findings and deductions for small asteroid Ryugu from Hayabusa2 remote sensing as well as from MASCOT radiometer (MARA) data. Observations cover the VIS (broadband) and MIR (broadband) wavelength ranges. For a typical rock on Ryugu's surface, we find a thermal inertia of 295±18 Jm-2K-1s-1/2 (Hamm+ 2020), a microporosity of 50 ± 3% (Grott+ 2020, Hamm+, 2020), and assuming a CM composition and thus an inferred specific heat capacity of cp = 890 Jkg-1K-1 (± 10%, at an average temperature of 277 K), we estimate a thermal conductivity of 0.069 ± 0.012 Jm-1K-1 at ~277 K. These estimates are based on MARA surface brightness temperature measurements of an arguably (Biele+ 2019) dust-free boulder at MASCOT's landing site obtained over a full diurnal cycle. Those values are consistent with the TIR instrument's global findings (Okada+ 2020). The main source of uncertainty in the thermal inertia estimate is due to the uncertain surface orientation of the boulder top that determines the insolation power. Including a Digital Terrain Model (DTM) of the observed boulder, embedded in the MASCOT landing site (Scholten+, 2019), into the thermal model could reduce this uncertainty significantly. The very high deduced microporosity lets us reasonably estimate the tensile strength of those abundant "cauliflower rocks" (Jaumann+, 2019), ~200-280 kPa (Grott+, 2019).

Furthermore, also from orbital data (ONC imaging and counting, plus radiometric data for GM), we have estimated the macroporosity of Ryugu, assumed to be a homogeneous rubble pile, based on granular mixing theory and the size-frequency distribution of boulders ranging from ~0.1 m to ~100 m diameter. We find that the macroporosity of Ryugu is very low, 16±3% and that if the underlying homogeneity assumption is true, taken together with Ryugu's bulk density and the average microporosity of its boulders, the average grain density can be estimated as 2.85±0.15 g/cm^3, consistent with the mineralogy of CM meteorites or the ungrouped carbonaceous chondrite Tagish Lake.

It will be exciting to compare these values to actual laboratory measurements of the returned samples (later in 2021). For example, if our values for Ryugu's macroporosity and rock microporosity (and/or grain density) do not agree with what is found from the samples, the assumption of homogeneity might be wrong. This would mean that Ryugu's surface has a significantly different boulder SFD than its interior implying regolith size sorting processes which may result in bulk density variations. Or, simpler, the assumed relationship between rock porosity and thermal conductivity is incorrect.

As for the strength of rock pieces, besides possible size, i.e., scale dependencies and sampling bias (weak pieces tend not to survive the sampling process intact), a higher strength than predicted here would have to be reconciled with the very low thermal conductivity of Ryugu's blocks, which dictates rather small grain-grain neck diameters, that are either sintered, volatile condensates, or salts.

More laboratory data (and theory/simulations) on the thermal conductivity and strength of very porous rocks are urgently needed. To this end, we are currently studying UTPS, a cold pressed Phobos (Asteroid type) simulant (Miyamoto+ 2018) that can be produced with porosities of ~30 to ~50% and is competent, yet weak.

Jorge Alejandro Gonzales Davalos (Grupo de Investigación en Astronomía, Facultad de Ciencias Físicas, Universidad Nacional Mayor de San Marcos)

Title: Values of Internal Scattering Coefficient Obtained from Reflectance Spectra of Meteorites and Minerals

Abstract: In this work was obtained values of the internal scattering coefficient s as a function of the wavelength from measurements of reflectance of a suite of eight particulate samples in the VIS/NIR from RELAB database. First of all, was found the imaginary part of the index of refraction inverting their reflectance spectra using the Hapke's model considering the correction by porosity. For the inverse process was not assuming any a-priori value. The average value obtained for the internal scattering coefficient from the spectra inversion at the center of the first absoption band was 0.0692μm^{-1}, which is in the same order of the value found in the literature for a synthetic sample of silicate glass. Also in this work, values of s were obtained for each particle size range fitting each spectra using the average of the imaginary index of refraction. Better values of s were found in the range 0-0.0963μm^{-1}, correspondent at the range in particle diameter from 37.50 to 310.12μm. For this analysis, it is expected to find a positive correlation between s and D, but for this methodology the majority of the samples have negative or weak correlation, only one sample has a positive correlation. Therefore, we could not state whether there is some correlation between s and D, and more analysis is required.

Paul Hayne (University of Colorado Boulder)

Title: Thermal Infrared Observations of the Moon from Diviner and L-CIRiS

Abstract: Earth's Moon was among the first solar system objects to be observed systematically in the thermal IR (Pettit and Nicholson, 1931), and for decades was the only one from which regolith samples had been collected. Both lunar thermophysical and infrared spectral properties have been studied extensively through remote sensing, in-situ measurements, laboratory measurements, and modeling. At thermal IR wavelengths (~7 - 400 μm) the Diviner radiometer onboard NASA's Lunar Reconnaissance Orbiter spacecraft has systematically mapped lunar surface temperatures (Williams et al., 2017) and derived rock abundance and regolith thermal inertia from multi-wavelength measurements with spatial resolution ~250 m (Bandfield et al., 2011; Hayne et al., 2017). Therefore, the Moon serves as a "ground truth" calibration point for models and observations of airless bodies more broadly. Yet, many of the characteristics of the Moon's thermal IR emission are attributed to small-scale phenomena inferred but not yet directly observed.

In late 2022, NASA will deliver the first thermal imager operating on the Moon's surface, the Lunar Compact Infrared Imaging System (L-CIRiS). Here, we summarize the state-of-the-art thermophysical models for the Moon based on Diviner data, and describe how upcoming L-CIRiS data resolving features < 1 cm will push models toward higher spatial resolution and greater physical realism. We also suggest several modeling benchmarks based on: 1) existing constraints from Diviner data, and 2) testable hypotheses for the L-CIRiS investigation. Studies of the Moon and other airless bodies such as asteroids may benefit from both Diviner and L-CIRiS data. Furthermore, these datasets could be highly complementary to SOFIA observations of the Moon at similar wavelengths.

Eric MacLennan (University of Helsinki)

Title: Revisiting (3200) Phaethon's Thermal Inertia

Abstract: With a perihelion distance of q=0.14 au, the near-Earth asteroid (3200) Phaethon is the largest asteroid with q < 0.3 au. It's repeatedly-observed dust tail at perihelion and orbital similarity to the Gemini meteor stream strongly suggest that it is the primary contributor of meteoroid material to the stream. Phaethon's thermal inertia was previously estimated to be 600 +/- 200 (SI units) by Hanus et al. (2018) using a convex shape model and infrared data collected over three epochs at heliocentric distances ranging from 1.03 to 1.13 au. Using a radar-derived shape model of Phaethon and a larger thermal dataset (including NEOWISE data), we present new estimates of Phaethon's thermal inertia at eight separate epochs at heliocentric distances, ranging from 1.03 to 2.32 au. We demonstrate that Phaethon's thermal inertia is inversely-correlated with heliocentric distance and is lower than the Hanus et al. (2018) estimates at similar heliocentric distances. A function fit to these data show that the thermal inertia dependency on heliocentric distance is stronger than expected when accounting for the temperature-dependence relation of radiative thermal conductivity (e.g., Rozitis et al., 2018). As suggested by Rozitis et al. (2018), we explore the possibility that the observed thermal inertia variation is in part due to depth-dependent regolith properties as a result of changes in the thermal skin depth.

Thomas Müller (Max-Planck-Institut für extraterrestrische Physik)

Title: Interpretation of Short-Wavelength Thermal Observations: The Case of Ryugu

Abstract: Thermalphysical models are widely used to interpret thermal measurements of near-Earth and main-belt asteroids (e.g., Delbo et al. 2015), and in some cases also for icy trans-Neptunian objects (e.g., Müller et al. 2020). The derived radiometric sizes, albedos and thermal properties are reliable when good-quality spin-shape solutions are available and when multi-wavelength thermal measurements are available for different phase angles. However, these techniques are not well tested for cases where the majority of the thermal measurements were taken in the short-wavelength regime below the thermal emission peak, e.g., from warm Spitzer-IRAC, WISE-W1/W2 bands, or ground-based observations up to the M-band around 5 μm.

Müller et al. (2017) analysed a collection of pre-mission thermal measurements of 162173 Ryugu, the Hayabusa-2 target asteroid. The data set was dominated by short-wavelength Spitzer-IRAC data at 3.55 and 4.49 μm, complemented by a Spitzer-IRS spectrum and a few individual data points at longer wavelenghts. The best-fit radiometric size (850-880 m), albedo (0.044-0.050) and thermal inertia (150-300 Jm-2s-0.5K-1) agree very well with in-situ properties (896 m, 0.045, 300+/-100 Jm-2s-0.5K-1; Watanabe et al. 2019; Okada et al. 2020). However, the radiometric solution from 2017 pointed towards a smooth surface. A very low roughness in the TPM setup was required to explain the short- and long-wavelength data simultaneouly. This is in strong contrast to the results derived from the Hayabusa-2! Close-proximity measurements of Ryugu obtained by the visual and infrared instruments of Hayabusa-2 revealed a surface roughness rms of 47° ± 5° (Shimaki et al. 2020), a high value when compared to lunar surface with a rms of surface slopes of 32° (Rozitis et al. 2011; Bandfield et al. 2015). So, what went wrong in the 2017 pre-mission TPM study?

We repeated the analysis of the pre-mission IR measurements of Ryugu but now using the in-situ size, shape, spin (Watanabe et al. 2019) and surface roughness properties (47° ± 5°; Shimaki et al. (2020)). In a first step, we used

a standard constant spectral emissivity of 0.9. This default e=0.90 assumption leads to a best-fit thermal inertia above 1000 Jm-2s-0.5K-1 in the radiometric minimalisation technique (e.g., Alí-Lagoa et al. 2020). In a second approach, we applied a spectral emissivity derived from high-accuracy disk-integrated measurements of the Moon (Müller et al. 2021). The lunar emissivity curve has a minimum value of about 0.7 around 4.5 μm and increasing to values close to 1.0 beyond 13 μm. As a result, we found a very consistent TPM solution for Ryugu for thermal inertias between 150 and 400 Jm-2s-0.5K-1, very close to the published values of about 300 Jm−2s−0.5K−1 (Okada et al. 2020) and 225 ± 45 Jm−2s−0.5K−1 (Shimaki et al. 2020). This example illustrates the importance of realistic spectral emissivity in the context of radiometric studies for short-wavelengh (<10 μm) thermal observations.

Daniel Ostrowski (Bay Area Environmental Research Institute, NASA Ames Research Center)

Title: Near-Earth Object and Meteorite Physical Properties Online Database

Abstract: Information about the physical characteristics of near-Earth objects (NEOs) is needed to model behavior during atmospheric entry, to assess the risk of an impact, and to model possible mitigation techniques. NASA's Asteroid Threat Assessment Project at Ames Research Center has built the Near-Earth Object Properties online database (neoproperties.arc.nasa.gov) that provides an easily accessible repository of aggregated data about the physical properties of near-earth objects and meteorites. The focus of the recorded data is on properties relevant to planetary defense, but can be useful for other planetary science studies. The meteorite data set contains one or more measurements of over 900 meteorites and more than 2300 unique samples. The tabulated physical properties include densities, porosity, acoustic velocity, elastic mechanical properties, electrical resistivity, magnetic susceptibility, and thermal properties. The database includes taxonomies for ~690 NEOs and thermally determined diameters for ~ 2300 NEOs. A literature-based mapping between asteroid taxonomic classes and related meteorite classes (and vice versa) is provided. This consolidated database can be used to support investigations into the properties of single asteroids and their likely meteorite analogs as well as facilitating analyses of the properties of the overall near-Earth asteroid population.

Róbert Szakáts (Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, ELKH)

Title: SBNAF Database for Thermal Infrared Observations of Small Bodies in the Solar System

Abstract: One of the goals of the Small Bodies: Near and Far (SBNAF) project was to create a database for thermal infrared observations of small bodies. We collected published thermal IR measurements for our selected samples of Solar System targets including data from large missions (e.g. catalogues based on Akari, IRAS and WISE observations) and also data from smaller scale and individual reductions (e.g. the Herschel Space Observatory measurements of near-Earth and main belt asteroids). A primary goal of this database is to help scientists working in the field of modeling the thermal emission of small bodies. However, the database has the option to include more data of Solar System small bodies which have been observed at thermal IR wavelengths from space or with ground-based instruments. Researchers who have infrared measurements can submit their published data to us and we can make it available in our database via our webpage, or VO tools.

Adomas Valantinas (Physikalisches Institut, Universität Bern)

Title: Colour and Multi-Angular Observations of Martian Slope Streaks

Abstract: Colour and multi-angular observations can be used to determine properties such as roughness, grain size and relative composition of planetary regoliths. The Colour and Stereo Surface Imaging System (CaSSIS) on board ESA's ExoMars Trace Gas Orbiter (TGO) can observe the Martian surface under various illumination geometries due to the non-Sun-synchronous orbit of TGO. Here, we use these capabilities to observe albedo variations of active mass wasting features on equatorial slopes, known as slope streaks. We detect a sharp increase of brightness relative to surrounding Martian dust in the BLU band (497 nm) under low phase angle observations. Slope streaks may be composed of Martian soil with unique properties that could be affected by opposition surge or coherent backscattering effects. To further investigate these phenomena, we contrast our observations with a Hapke-theory-based model of the spectral reflectance of Martian dust of different grain sizes, and with spectrometry and photo-goniometry measurements of different grain size distributions of a high-fidelity Martian soil analog.

Wednesday, March 24

Vincent Roux (Off Planet Research)

Title: Simulating Icy Regolith for Exploration and Resource Development Efforts

Abstract: Creating icy regolith simulants using cryogenic vapor deposition involves overcoming several challenges while providing several advantages. The ice formed within and upon regolith by this process has a different structure than other formation methods and can produce icy regolith simulants that more closely resemble intended mission destinations. A brief overview of the use of this type of simulant in 2019 to test the capabilities of an engineering version of the Near Infrared Volatile Spectrometer Subsystem (NIRVSS). The ability to produce simulated icy regolith for other worlds will be outlined.

An NSF Phase 1 grant is to improve and expand production to provide these test materials is under way, and input from the community is requested to ensure that the process best meets researcher needs.

Norbert Schorghofer (Planetary Science Institute)

Title: Dynamics of Water Adsorption on the Moon and Ceres: Theoretical Predictions

Abstract: On the airless bodies of the inner solar system, volatile water molecules can be adsorbed on silicate grains at sub-monolayer coverage. They may be found at higher concentration at the winter polar region of Ceres, where an optically thin seasonal water cap has been predicted. The concentration of adsorbed water molecules is also expected to increase with depth, due to a process known as “adsorbate pump”: The decrease of the diurnal temperature amplitude with depth leads to a decrease in the (time-averaged) vapor pressure, which in the long-term is compensated by an increase in adsorbate density. This process can even lead to the sequestration of ice, specifically in sunlit areas close to but outside of lunar cold traps, where the diurnal variation in the surface concentration of H2O water molecules is predicted to be largest.

Vladimir V. Tchernyi (Modern Science Institute, SAIBR)

Title: What We Can Say about Ice of the Saturn’s Rings Particles

Abstract: The Cassini found particles of Saturn’s rings contain 93% ice. Ice in the rings has existed for billions of years. It is hardly possible to create such ice in a laboratory on Earth to simulate its properties. There are two possibilities. We can try to find some types of ice on Earth that can match the environmental parameters in Saturn’s rings. You can also try to understand what properties of ice particles can have from the theory of the origin of Saturn’s rings, if it is consistent with the measurements of the Cassini probe. We know 17 types of ice on Earth. As it turned out, type XI ice has stable parameters at the temperature of the rings. Such ice was discovered in Antarctica, its age estimated as 100 years. It may originate of ordinary ice below -32,8°F. On the other hand, we found that it is possible to construct a theory of the origin of Saturn’s rings if we assume that the ice in the particles of the protoplanetary cloud has diamagnetism. It also turned out that ice XI is diamagnetic. After emerging of Saturn’s magnetic field, all chaotic orbits of the ice particles due to the force of diamagnetic expulsion begin to shift to the magnetic equator plane, where the minimum magnetic energy of the particles is observed. Finally all particles are trapped in a three-dimensional magnetic well.

Thursday, March 25

Caitlin Ahrens (NASA Goddard Space Flight Center)

Title: Researching the Planetary Environment with an Interstellar Probe

Abstract: In 2018, a study originated with the idea of a mission that would be feasible to launch in the 2030s, targeting 1000 AU within 50 years using current technology. While the primary objective of such an Interstellar Probe would be to understand the heliosphere and interstellar medium, this probe offers an excellent opportunity for rock, dust, and ice sciences. In the initial stages of its journey through the solar system, this Interstellar Probe would carry out a wide range of potential observations to study the planetary environment, particularly focusing on dust/ice analysis and planetary science through fly-bys of critical science targets, especially in the trans-Neptunian region. A flyby of a trans-Neptunian dwarf planet, such as Quaoar, would provide further geological, compositional, and geophysical context for Earth-based observations. Aside from in-situ remote sensing techniques, VISIR and dust analyses would also benefit in this region of the solar system to determine (i) dominant ice and dust compositions and potential variations depending on heliocentric distance (e.g., chemical or irradiated products); (ii) collections and identification of PAH-type components; and (iii) solar nebula chemical and mechanical processing, such as collisions. The purpose of our poster is to provide a background of the Interstellar Probe's objectives and possible instrumentation to offer insight on current questions about the planetary environment.

Maxwell Collins (University of Hong Kong)

Title: Using ROCKE-3D General Circulation Model to Reveal Titan's Atmospheric Dynamics

Abstract: The Resolving Orbital and Climate Keys of Earth and Extraterrestrial Environments with Dynamics (ROCKE-3D) is a General Circulation Model adapted from the Goddard Institute for Space Studies ModelE2, which simulates modern and paleo-Earth climate. ROCKE-3D expands upon the base model to include the possibility of modeling extraterrestrial bodies such as Saturn's moon Titan. Previous models of Titan have largely been focused on 1D or 2D radiative-convection models and have neglected large-scale spatial distributions. This model includes spectral input files within Titan's range of received radiation and can be further improved upon, including updated topographical maps and orbital parameters adapted to synchronously rotating bodies (Way et al 2017). Titan's nitrogen-rich atmosphere contains complex organic chemistry key to understanding the origins of life. This, combined with stable surface liquid methane/ethane bodies, creates an environment conducive to crucial prebiotic chemistry. ROCKE-3D contains extensive coupled atmospheric-surface interactions which provide insight into regions of habitability; atmospheric dynamics over long timescales in conjunction with updated topographical input describe essential features in surface deposition of heavy organic material, i.e., polycyclic aromatic hydrocarbons and tholins, given their production region and lifetime. The ROCKE-3D Titan GCM may be used to advise future missions in locations of interest and as an analogue to early Earth and origins of life studies as is identified by similar chemical constituents such as hydrogen cyanide (HCN).

Annika Gustafsson (Northern Arizona University)

Title: Constraining Asteroid Regolith Grain Size with Hapke Radiative Transfer Modeling

Abstract: Radiative transfer models are some of the most widely used tools for compositional analyses of planetary bodies. For the application of silicate rich asteroids, radiative transfer models have been almost exclusively used to derive olivine to pyroxene abundance ratios. However, formulas for deriving mineralogies from visible and near-infrared spectra of asteroids with prominent olivine and pyroxene (1 and 2 micron) absorption bands have been developed (e.g Burbine et al. 2007; Reddy et al. 2011), and the effects of non-compositional parameters (temperature, phase angle, grain size) have been well characterized, allowing for more accurate interpretations of asteroid surface properties (Burbine et al. 2009; Sanchez et al. 2012; Reddy et al. 2012).

The implementation of this technique into the small body field, where it has not yet been fully adopted, will vastly improve our understanding of surface properties in the population of S/Q type asteroids. A benefit of this technique is that it requires far fewer observations than thermal modeling and allows for the observation of much smaller targets using remote-sensing.

We have implemented radiative transfer modeling on visible and near-infrared spectra of unresolved silicate-rich asteroids using Hapke modeling to constrain surface grain sizes. We will discuss our assessment of the limitations of this technique utilizing visible and near-infrared spectra of ordinary chondrite meteorites from the RELAB database.

Shane Hengst (University of Southern Queensland)

Title: Multi-Wavelength, Spatial Resolved Modelling of Debris Discs

Abstract: Debris discs are the dusty aftermath of planet formation processes around main-sequence stars. Debris discs are analogous to the Solar System's debris belts (i.e., the asteroid and Kuiper belts) and studying these objects are one of the few ways to gain insight into the composition of other planetary systems.

Recent observations have suggested that dusty debris discs also have ice and gas components; comparing them with the Solar system can point towards common formation mechanisms for the planetesimals which produce the detectable debris. Modelling of the disc structure and dust grain properties for those discs is often hindered by the absence of any meaningful constraint on the location and spatial extent of the disc. Multi-wavelength, spatially resolved imaging, and mid-infrared spectroscopy, are complementary to the continuum emission to refine the interpretation of these systems. In this talk I will present the results of studies of two debris disc systems resolved by Herschel, summarising the advances in our understanding of their architectures and properties obtained by this analysis. I will highlight ongoing and future work that will leverage the rich data sets available for some systems to provide points of comparison for planet formation processes in the Solar system and around other stars.

Moritz Lietzow (Institute of Theoretical Physics and Astrophysics, Kiel University)

Title: Radiative Transfer of Polarized Radiation for Investigating (Exo)planetary Atmospheres

Abstract: Polarimetry is a powerful tool for determining the properties of planetary atmospheres, surface properties and the planetary environment.

To provide the basis for preparatory studies and the interpretation of dedicated polarization measurements, sophisticated simulation and data analysis tools are required.

For this purpose, we developed a radiative transfer simulation software that contains all relevant continuum polarization mechanisms for the comprehensive analysis of the polarized flux resulting from the scattering in the atmosphere, on the surface, and in the local planetary environment.

Rayleigh scattering by small particles (e.g., gas molecules), Mie scattering by larger particles (e.g., clouds or dust), as well as surface reflections (e.g., by oceans or landmasses) are considered.

The 3D Monte Carlo radiative transfer code POLARIS (Reissl et al. 2016) provides the platform for our simulation software.

In a first case study, we investigate the impact of a circumplanetary ring consisting of micrometer-sized water-ice particles on the net polarization signal (Lietzow et al. 2021).

While the focus is on the characterization of exoplanetary systems with polarization in the optical / near-infrared wavelength region, this tool can also be applied in the context of polarization studies of solar system objects.

Harald Mutschke (Astrophysical Institute and University Observatory, Friedrich Schiller University)

Title: (Sub-)Millimeter Dust Opacities from Laboratory Measurements

Abstract: In this poster, we present measured low-temperature mass absorption coefficients of glassy and crystalline silicates, water ice, and carbonaceous materials in the far-infrared up to millimeter wavelengths. Some of these data have been transformed into complex refractive indices that can be directly used in the modeling of emissivities for thermal radiation of solid matter at low temperatures.

Xinting Yu (University of California Santa Cruz)

Title: Understanding Cloud Formation on Titan

Abstract: Titan's N2-CH4 atmosphere has enabled rich photochemistry to occur in its upper atmosphere. The photochemistry can create simple hydrocarbons and nitriles such as ethane, acetylene, benzene, and hydrogen cyanide. These simple organics are further processed to form complex organic haze particles. Many of the photochemically produced simple organics are condensable in certain altitudes of Titan's atmosphere to form liquid or ice clouds. In order to form sufficient observable clouds, heterogeneous nucleation is needed for efficient cloud growth. On Titan, the haze particles are proposed to be the main heterogeneous cloud condensation nuclei (CCN) for the various cloud species. Previous efforts on studying Titan cloud formation focus on directly measuring methane/ethane adsorption on laboratory-produced Titan haze analogs, "tholin", under cryogenic conditions. However, the viability to form other kinds of clouds remains unknown. We approach this question differently by first measuring the surface energy of tholin through the contact angle method, which then enables us to approach this question theoretically via the wetting theory. By using the measured surface energy of tholin and surface tensions of various organic species of interest, we can calculate contact angles formed between tholin and possible condensates. We find that Titan haze particles are likely good CCN for various cloud condensates on Titan, which suggests that we are expected to see more types of clouds on Titan.