Asymmetric Dust Distributions in Debris Disks and Their Impact on the Direct Imaging of Earth-Mass Exoplanets

Hiroshi Kobayashi[1], Hayato Shimizu[1], and Taro Matsuo[2]

[1]*Department of Physics, Nagoya University*

[2]*Department of Earth and Space Science, The University of Osaka*

Planetary systems often host debris disks. Direct imaging observation has detected giant planets with debris disks. It is expected that Earth-like planets and debris disks will be detected using imaging. We investigate the dust distribution around an Earth-mass planet on a circular orbit at 1 au in a system like the solar system. Dust grains are supplied from a planetesimal belt at 2–3 au and drift inward by the Poynting-Robertson (PR) effect. We computed orbital evolution under stellar radiation pressure, the P-R effect, and planetary gravity. By dividing the disk into radial and azimuthal meshes and summing particle residence times, we reconstructed the steady-state dust density distribution. We find large dust grains form characteristic structures around planets, while small dust forms smooth and structureless disks. Using the results of dust structures, we evaluate the infrared flux of the debris disk relative to the star. We estimate the size distribution of drifting dust grains, which is determined by comparing collisional and drift timescales in planetesimal belts. We obtain disk structures from the integration of five representative sizes. Faint disks are dominated by large grains and have strong asymmetric features that may enhance exoplanet detectability. On the other hand, brighter disks are dominated by smaller grains and obscure planets, but retain weak detectable structures from small-population large grains. Therefore, debris disks may assist the detection of Earth-like planets via direct imaging.

Infrared Emission Spectroscopy of Hot Grains in the Laboratory

Gaël Rouillé[1], Robin Schreyer[1], and Harald Mutschke[1]

[1]*Friedrich Schiller University Jena, Germany*

We recently launched a project that aims to contribute to the characterization of hot dust grains observed in astrophysical objects, in particular hot exozodiacal dust disks (exozodis). Exozodis are frequent (Kral et al. 2017), and they appear to consist of submicron-sized grains (Kirchschlager et al. 2017) that can reach a temperature of 2000 K (Ertel et al. 2018) at the point closest to the central star. The composition and hence the origin of these grains are currently undetermined.

As hot dust is typically revealed by its thermal emission at near- and mid-infrared wavelengths (e.g., Kirchschlager et al. 2017), we intend to obtain the optical constants of relevant materials at high temperatures, up to 1800 K, in the infrared wavelength range. These constants will allow us to compute thermal emission spectra for grains of these materials, taking various geometries and sizes into account, which we will compare to astronomical observation data in order to identify or constrain the nature of hot exozodis.

We can currently measure Fourier-transform infrared (FTIR) thermal emission spectra of grains on a flat substrate heated to temperatures up to 800 K. Initial measurements focused on monolayers of monodisperse SiO_2 glass microspheres (Tamanai et al. 2026), and the study of SiC nanoparticles is underway. We will present our project in detail and report on the first measurements.

References

Ertel, S., Defrère, D., Hinz, P., et al. 2018, Astrophys. J, 155, 194

Kirchschlager, F., Wolf, S., Krivov, A. V., Mutschke, H., & Brunngräber, R. 2017, Mon. Not. R. Astron. Soc. 467, 1614

Kral, Q., Krivov, A. V., Defrère, D., et al. 2017, Astron. Rev., 13, 69

Tamanai, A., Schreyer, R., Mutschke, H., Rouillé, G., & Tominaga, R. T. 2026, in revision, J. Quant. Spectrosc. Radiat. Transfer

Dust polarization observations with ALMA will help us to understand grain growth and magnetic field structure in circumstellar disks for planet formation

Satoshi Ohashi[1]

[1]*The University of Tokyo, Japan*

Grain growth of ~ 0.1 micron sized cosmic dust is the first step toward planet formation in circumstellar disks. Constraining dust sizes observationally is therefore essential for understanding how protoplanetary disks evolve into planetary systems. At millimeter wavelengths, polarization provides a unique probe of dust properties, but its interpretation depends strongly on grain size: relatively small grains can remain aligned with magnetic fields in the same way with interstellar dust, whereas larger grains tend to require other polarization mechanisms, such as self-scattering or aerodynamic alignment.

In this talk, I will discuss how recent ALMA observations are beginning to connect dust evolution and magnetic field structure in planet-forming disks. I will first present our multi-band study of the DG Tau disk, which revealed a geometrically thin and smooth dust disk, evidence for dust enrichment, and a radial variation in grain size, with smaller grains in the inner disk and much larger grains in the outer disk. I will then show how multi-wavelength polarization observations can identify regions where small grains still trace magnetic fields. In the lopsided disk around HD 142527, this approach allowed us to derive the three-dimensional magnetic-field structure and field strength observationally. Finally, I will present our new 2.1 mm polarization results for DG Tau, which reveal a predominantly radial polarization pattern on 10 au scales in the inner disk and a transition to a more azimuthal pattern farther out. If the inner-disk polarization is dominated by magnetically aligned grains, the data suggest a predominantly toroidal magnetic field with non-negligible radial and vertical components. These results demonstrate that ALMA polarization can be used not only to diagnose grain growth and dust evolution, but also to constrain the magnetic environment in which planets begin to form.

The evolution of silicate feature in protoplanetary disks

Batalla-Falcon, Grace A[1]., Cieza, Lucas A.[1], Zhang, Ke[2]
1 Universidad Diego Portales
2 University of Wisconsin-Madison

Silicate dust is a crucial component of protoplanetary disks, and plays an important role in the early stages of planet formation. As disks evolve, the silicate dust is influenced by several processes, such as thermal annealing, coagulation, fragmentation, radial drift and the filtering at the edges of planet-induced gaps and cavities. Here we present JWST-MIRI (5 - to 23 micron) spectra of 30 protoplanetary disks from different nearby molecular clouds. The sample was taken from the ALMA Large Program AGE-PRO and includes objects from three different molecular clouds with different mean ages: the Ophiuchus, Lupus, and Upper Sco clouds. Overall, the targets cover regions with different mean ages (< 1 Myr to 5 Myr) with a relatively narrow range of spectral types (between K6-M3), corresponding to stellar masses from 0.3 to 0.8 Msolar. We present preliminary results showing clear differences in the silicate features with age. In particular, we find the younger Class I sources (still embedded in their natal envelopes) show amorphous silicates in absorption, while the more evolved Class II sources display a variety of crystalline features, similar to the ones present in different types of meteorites. At even later stages of disk evolution, we observe clear evidence for dust filtration in the inner disks of transition objects suspected to harbour giant planets.

DUST IN PROTOPLANETARY DISKS, update from the Dust-to-Planets ERC Project

Francois Ménard[1]

[1] *Univ. Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France*

Young Protoplanetary disks are central to the process of planetary formation. Observationally, planets around main sequence stars are ubiquitous and the case for planets detected during their formation, i.e, still within their parent disk, is growing. The formation of a planet requires the growth of solids (dust) by several orders of magnitudes, from (sub-)micron sizes to kilometer sizes. This is a major problem because disks are short-lived, collisions are expected to shatter pebbles / boulders when they reach decimeter-meter sizes, particles are rapidly drifting inward because of gas drag, etc... The ERC Dust-2-Planets 5-year project is focussing on the very first stage of planet assembly, when small dust is assembling into pebbles and pebbles are concentrating in the disk midplane.

Since my first participation to CosmicDust in 2017 in Tokyo, where I presented an observation-based short review of the properties of dust in protoplanetary disks, instruments on large telescopes have provided a wealth of new and spectacular results on the structure and dust content of protoplanetary disks. Interestingly, the signature of dust scattering are now measured not only in the optical and NIR with better resolution than before, but also at mm wavelengths with ALMA, and now with JWST at mid-infrared wavelengths. In this presentation I will highlight several of the new results obtained with these instruments.

During CosmicDust 12 in Chiba (2019) I presented the proof-of-concept that a MicroWave Analogy (MWA) experiment, located in Marseille, France, could be used to characterize the scattering properties of dust analogs of various shapes. This proof-of-concept was instrumental in obtaining the ERC grant. Since then, the experimental set-up has been upgraded and many more results are available. Very Complex disk particle analogs are "routinely" fabricated by 3D printing, with material carefully tailored to match the complex refractive index of astronomical dust across the relevant frequency ranges (NIR & mm) and chemical compositions (silicates and carbonaceous materials).

The presentation is aimed to be a general summary of the results and progress made as part of ERC Dust-to-Planets. I will first briefly introduce the general background and goals of the project. I will then focus on the recent advances telescopes like JWST have allowed. These include a new method to quantitatively estimate the amount of ices in disks, including the important water ice, from JWST images (PhD work of L. Martinien). Contrarily to spectroscopy-based techniques, our method does not saturate when disks are optically thick. I will also very briefly put in context and show selected results from the PhD work of R. Zerna (3D printing and MWA results) and M. Roumesy (scattering phase functions for a sample of disks). They both presented earlier results of their work at CosmicDust in 2025. Should they also participate to CosmicDust in 2026, I would minimise that part of my presentation accordingly. Finally, I will wrap up by opening towards the future by discussing how these new results can be included in Radiative Transfer models (for comparison with data) and in hydrodynamical simulations that include the evolution of dust to improve our understanding of protoplanetary disk evolution and early planet formation.

Dust properties in planet-forming disks: Insights from observation, scattering phase function and disk color

Maxime Roumesy[1], François Ménard[1], Gaspard Duchêne[1,2], Ryo Tazaki[3]

[1]Univ. Grenoble Alpes, CNRS, IPAG, 38000 Grenoble, France
[2]Astronomy Department, University of California Berkeley, Berkeley CA 94720-3411, USA
[3]Department of Earth Science and Astronomy, The University of Tokyo, Tokyo 153-8902, Japan

Dust grains in protoplanetary disks hold the key to the earliest stages of planet formation, but their physical properties remain poorly constrained. Since grain growth depends on coagulation and fragmentation, determining their size, shape, porosity, and composition is essential. Scattered-light imaging, and in particular the scattering phase function, offers one of the most promising ways to probe dust properties. Motivated by the recent increase in high-resolution disk observations, we developed `DRAGyS`, a new GUI-based Python tool that rapidly and robustly estimates disk geometry and efficiently extracts phase functions. Here, we apply `DRAGyS` to a large sample of VLT/SPHERE observations of ring-shaped protoplanetary disks.

We show that scattering phase functions separate into two distinct categories, revealing differences in dust grain properties. The first category is statistically consistent with porous aggregates larger than a micron, while the second is dominated by compact, submicron-sized particles. This suggests that we are directly probing different stages of dust growth within the disk. However, we also confirm that the scattering phase function alone, in a given disk, is not sufficient to fully break the degeneracies between plausible dust models. To go beyond this limitation, we complement the scattering phase function analysis with disk color derived from multiwavelength observations. We perform radiative transfer simulations to show that disk color carries complementary information on dust properties, with strong sensitivity to grain morphology, porosity, and, in particular, monomer size in aggregate particles. Together, these two measurements provide a more robust framework for interpreting scattered-light observations of protoplanetary disks. By combining scattering phase function and disk-color diagnostics, we open a promising path toward a more reliable characterization of dust growth in planet-forming disks.

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Comparison of the scattering properties of protoplanetary disk dust analogs

Remi Zerna[1], François Ménard[1], Jean-Michel Geffrin[2], Elio Samara[2], Amélie Litman[2], Ryo Tazaki and Alexandre Aguila[3]

[1] *Univ. Grenoble Alpes, CNRS, IPAG, F-38000 Grenoble, France,*

[2] *Aix Marseille Univ, CNRS, Centrale Med, Institut Fresnel, Marseille, France,*

[3] *Department of Earth Science and Astronomy, The University of Tokyo, Tokyo 153-8902, Japan*

[4] *SCALAE Maquette, Saint-Martin-d'Hères, France*

In order to better interpret protoplanetary disk images obtained with ALMA or JWST, it is essential to characterize the scattering properties of the particles composing them. To constrain their morphology, one can rely on analogs from the Solar System. Indeed, fractal particles can be found in the interplanetary medium or on cometary surfaces [1, 2]. One can also consider chondritic meteorites, which contain a matrix together with millimeter-sized chondrules and inclusions formed during the first millions of years of the Solar System [3]. It is reasonable to assume that similar objects exist in the disks we observe, where asteroids and planets are still forming.

In this conference, I will present our study of the scattering properties of several analogs of dust particles, with the aim of assessing whether their morphology can produce an observable signature in images of young disks at NIR or mm wavelengths. A non-destructive method, X-ray tomography, was used to reconstruct the morphology of chondrules in a carbonaceous meteorite. The analogs are then 3D-printed at the centimeter scale using materials whose refractive index is close to that of astrophysical silicates or amorphous carbon. Their scattering properties are measured through microwave analogy facility at the Institut Fresnel, France using the MIMOSA platform, [4]). These measurements are complemented by numerical simulations using the Discrete Dipole Approximation method with the `ADDA` code [5].

For each analog, we measure and compute the Scattering Phase Function (SPF) as well as the Degree of Linear Polarization (DLP) between 3 GHz and 18 GHz (corresponding to size parameters ranging from unity to several tens). I will present a comparison of our results with Mie theory, showing that the SPF of chondrules exhibits a behavior similar to that of spheres with equivalent mass. For the DLP, we observe interesting behaviors for these objects when reproducing their scattering properties for the millimeter wavelengths range, [6]. I will also discuss about non spherical objects, the Gaussian Random Spheres and fractal aggregates made of different materials. Finally, I will discuss the limitations of each method and explain why they complement each other.

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References

[1] S. Messenger, L. P. Keller, A. N. Nguyen, *Dust in the Solar System: Properties and Origins*, Proc. The Life Cycle of Dust in the Universe, PoS(LCDU2013), 040 (2014)

[2] M. S. Bentley et al., *Aggregate dust particles at comet 67P/Churyumov–Gerasimenko*, Nature, 537, 73–75 (2016)

[3] M. Piralla, J. Villeneuve, N. Schnuriger, D. V. Bekaert, Y. Marrocchi, *A unified chronology of dust formation in the early solar system*, Icarus, 394, 115427 (2023)

[4] V. Tobon Valencia et al., *Scattering properties of protoplanetary dust analogs with microwave analogy: aggregates of fractal dimensions from 1.5 to 2.8* A&A 666, A68 (2022)

[5] M. A. Yurkin, V. P. Maltsev, A. G. Hoekstra, *The discrete dipole approximation for simulation of light scattering by particles much larger than the wavelength*, JQSRT, 106, 546–557 (2007)

[6] R. Zerna, F. Ménard, J.-M. Geffrin et al., in prep.

Characterizing the Properties of the DART Dust Ejecta Using 3D Radiative Transfer Modeling

Ludmilla Kolokolova, Yaeji Kim
University of Maryland, College Park, MD, USA

On September 26, 2022, the DART spacecraft impacted Dimorphos, the secondary component of the Didymos binary asteroid system, generating a substantial dust ejecta [1]. The Italian Space Agency's LICIACube, deployed as a follow-up observer, captured this event with its LEIA and LUKE cameras. To characterize the physical properties of the ejecta dust and their temporal variations as observed in post-impact LICIACube images, we have simulated the ejecta plume using the 3D radiative transfer code Hyperion (https://www.hyperion-rt.org/). Hyperion employs the Monte Carlo technique to simulate photon propagation through a scattering medium, accounting for multiple scattering effects. Dust modeling parameters include the single-scattering albedo, brightness and polarization phase functions, and the cross-sectional properties of dust particles, defined by their size and number density. These were modeled assuming a typical S-type asteroid composition for Dimorphos. We adopted a single-scattering albedo of 0.55 and used brightness and polarization phase functions based on laboratory measurements of irregular silicate grains spanning sizes from microns to millimeters [2, 3]. The ejecta plume was modeled as a hollow cone, characterized by impact location, tilt, and opening angle. Our current best-fit model reproduces the LUKE image taken 175 seconds after impact, with a focus on the near-surface region of Dimorphos. Comparison between observed and modeled brightness profiles provides constraints on the dust particle size distribution and number density, as well as their spatial variation. Fitting the observed radiance values across the plume allows us to refine the number density estimates and derive the mass distribution within the plume.

The developed numerical framework can serve as a template for characterizing dust in active asteroids, particularly in optically thick events, enabling constraints on dust size distribution, number density, and mass loss.

[1] Cheng, A.F., et al., 2023, Nature, 616(7957), 457-460.

[2] Munoz, O., et al., 2020, ApJ Suppl. Series, 247,19.

[3] Lolachi, R., et al., 2023, PSJ, 4, 24.

A Theoretical Study on the Dynamic Tensile Strength of Aggregate Dust and Monolithic Dust: Toward a Better Understanding of Ejecta Cloud Formation

Hiroshi Kimura[1], Takaya Okamoto[1], Takayuki Hirai[1], Akiko M. Nakamura[2], Toshihiko Kadono[3], Yukari M. Toyoda[4], Eiichiro Kokubo[4], Yuki Yoshida[5], Sota Arakawa[6], Fumi Yoshida[3,1], Peng K. Hong[7,1], Koji Wada[1], Hiroki Senshu[1], Masanori Kobayashi[1], Tomoko Arai[1], and Takafumi Matsui[1]

[1]*Planetary Exploration Research Center (PERC), Chiba Institute of Technology, Chiba, Japan*

[2]*Kobe University, Kobe, Japan*

[3]*University of Occupational and Environmental Health, Japan, Kitakyusyu, Japan*

[4]*National Astronomical Observatory of Japan, Tokyo, Japan*

[5]*Tohoku University, Sendai, Japan*

[6]*Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, Japan*

[7]*PERSOL CAREER CO., LTD., Tokyo, Japan*

DESTINY$^+$ (Demonstration and Experiment of Space Technology for INterplanetary voYage with Phaethon fLyby and dUst Science) is a mission to flyby (99942) Apophis, (3200) Phaethon, and several other Near-Earth Asteroids (NEAs), equipped with a dust analyzer called DDA (DESTINY$^+$ Dust Analyzer). During each flyby, the DDA will measure the mass, electric charge, velocity, and chemical composition of dust in the so-called ejecta cloud surrounding the NEAs, and during the cruise phase, it will measure those of interplanetary dust and interstellar dust. Since ejecta clouds are formed by continuous bombardments of interplanetary dust onto small airless bodies, one may expect that ejecta clouds are ubiquitously present around NEAs. They are, however, too faint to be observed even by space-borne telescopes and hence in-situ measurements by the DDA will provide an unique opportunity to detect ejecta clouds around NEAs. It is worthwhile noting that the presence of an ejecta cloud has been identified only around Jovian satellites and the Moon by dust detectors onboard Galileo and LADEE to date.

Currently available numerical models of ejecta clouds have been used to predict the detection of ejecta clouds by the DDA, while the models are based on either an empirical law of macroscopic impact experiments or mathematical functions that include numerous variables not governed by physical laws. Therefore, we aim at establishing a theory of ejecta cloud formation that involves mesoscopic physics based on the Johnson–Kendall–Roberts theory of contact mechanics, the Griffith theory of fracture mechanics, and the Weibull theory of flaw statistics. Here, we would like to emphasize that the tensile strength of solid particles is a key physical quantity for a deeper understanding of impact phenomena and ejecta cloud formation. Owing to the hypervelocity impact of interplanetary dust, strain rates have an effect on the tensile strength and hence the formation of ejecta clouds is ruled by the dynamic tensile strength rather than the static tensile strength. In this meeting, we will present a simple theoretical formula that is capable of describing the dynamic tensile strength of solid particles applicable to both aggregates and monoliths with arbitrary porosity, size, composition, and strain rate.

Is the solid carbon depletion in the solar system universal ?

Pantin, E.[1], Lopez, B.[2], Matter, A.[2], Fleury, V.[2], Canas, L.[3], Augereau J.-C. [4], Gonzalez J.-F. [5], Habart, E.[6], and the ANR CYPRESS and C4LIFE consortia members.

[1]Université Paris-Saclay, Université Paris cite, CEA, CNRS AIM, France, [2]Laboratoire Lagrange, Observatoire de la côte d'azur, France, [3]Thales Alenia Space, Sofia-Antipolis, France, [4]IPAG, Université Grenoble-Alpes, Grenoble, France, [3]CRAL, Université Claude Bernard, Lyon, France,[6]IAS, Université Paris-Saclay, France

At the location of the terrestrial planets, solid carbon—although being the fourth most abundant element in the Universe—is depleted by three orders of magnitude compared to cosmic abundances. In contrast, the outer regions of the Solar System appear to be much closer to the cosmic values. This observational fact raises important questions about the habitability of terrestrial planets if they had retained cosmic carbon abundances, as well as about the universality of this carbon depletion phenomenon. To tackle these issues, we have launched two major projects designed to improve our understanding of the origin and implications of this depletion.

We have initiated a project aiming at studying the solid carbon content in the innermost regions (1–20 AU) of protoplanetary disks using the Very Large Telescope Interferometer instrument MATISSE. Its exceptional angular resolution (10 mas) and broad spectral coverage allow us to probe the thermal infrared emission features from C–H bonds in carbon nanoparticles at 3.3, 8.6, 11.3, and 12.7 µm, across the 3–13 µm range. By using this nanoparticle emission as a proxy for solid carbon content, CYPRESS aims to measure the carbon-to-silicon abundance ratio as a function of distance from the central star. Nine bright targets (eight Herbig Ae stars and one T Tauri star) with high signal-to-noise MATISSE data have been selected for this study. This effort is supported by a grant from the French National Research Agency (ANR) under the project CYPRESS, which started in February 2026 and is planned to run for five years.

Recognizing the inherent limitations of ground-based observations, which are restricted to the brightest young stellar objects and to emission bands associated with C–H bonds, we have developed the concept of C4LIFE**.** C4LIFE is a space-based infrared interferometric mission proposed to European Space Agency within the framework of the F3 mission call. In collaboration with Thales Alenia Space, we have developed and submitted a mission concept. This two-year mission would extend the CYPRESS approach to lower-mass stars, down to a sensitivity limit of 1 mJy, while achieving an angular resolution of ~25 mas at 6.2 µm sufficient to resolve the disks at the 2-3 AU scale. A space-based infrared mission would not only enable highly sensitive detection of the C–H emission bands, but also provide simultaneous access to the 6.2 and 7.7 µm C–C bonding emission features, which are inaccessible from the ground. This capability would mitigate biases inherent to ground-based observations, particularly those arising from potentially dehydrogenated particles. Ultimately, such a mission would allow the construction of a statistically robust sample exceeding 200 targets, complete in stellar mass down to spectral type M7.

In this presentation, I will introduce the scientific questions and the observational strategy to tackle them. Some preliminary results from CYPRESS will be shown. A detailed description of the scientific objectives of the C4LIFE mission, currently open to partnerships, will also be given.

A study of the dynamics of the grains of the dust exosphere of Mercury

Alberto Flandes & Harald Krüger

In this work we study the dynamics of the dust grains that build a dust exosphere around Mercury. In a similar way to the atoms and molecules that are part of the exosphere, the grains of the dust exosphere are gravitationally bound to Mercury and mostly follow ballistic trajectories after being released from the surface by hypervelocity impacts ($> 80\ km/s$) of micrometeoroids mainly of cometary origin. We focus on the submicrometric population and consider grains as small as tens of nanometers, given that the smallest (submicrometric) ejecta grains, may be able to achieve the largest ejection speeds. Apart from trying to estimate some properties of the dust exosphere, we try to answer whether instruments like the Mercury Dust Monitor (MDM) on board the Mercury Magnetospheric Orbiter, also known as Mio, would be able to detect some of the grains of the hermean dust exosphere once in orbit around Mercury. Mio, from the Japan Aerospace Exploration Agency (JAXA) is part of the BepiColombo mission, which among its many objectives will study the hermean exosphere after November 2026. In particular, MDM is a piezoelectric (PZT) dust impact instrument that will be dedicated to study the distribution of interplanetary dust at the orbit of Mercury.

In the end, our estimations suggest that MDM could be able to detect grains from the dust exosphere as small as 50nm if their relative speed with respect to MDM is >5 km/s, however, it may easily detect ≥100 nm if their relative speed is ≥1 km/s.

In situ analyses of cometary dust from Rosetta/COSIMA and cometary dust from terrestrial collections

C. Engrand[1], N. Fray[2], A. Conanec[2], I. Sansberro[2], H. Cottin[2], M. Hilchenbach[3†], O. J. Stenzel[3], H. Fischer[3], J. Paquette[4], D. Baklouti[5], C. Briois[6], L. Thirkell[6], A. Bardyn[2,6], J. Rynö[7], J. Silèn[7], K. Hornung[8], J. Duprat[9], E. Dartois[10], J. Rojas[11], L. Bejach[1], J. Mathurin[11], A. Dazzi[11], E. Charon[12], C. Le Guillou[13], H. Leroux[13], S. Bernard[9], L. Delauche[1].

[1]IJCLab, CNRS, Univ. Paris-Saclay, 91405 Orsay Cedex, France. [2]Univ. Paris-Est Créteil, Univ. Paris-Cité, CNRS, LISA, 94010 Créteil, France. [3]Max Planck for Solar System Research, 37077 Göttingen, Germany. [4]NASA-Godard Space Flight Center, Greenbelt, MD 20771, USA. [5]IAS, CNRS, Univ. Paris-Saclay, 91405 Orsay Cedex, France. [6]LPC2E, CNRS, Univ. Orléans, CNES, 45071 Orléans, France. [7]Finnish Meteorological Institute, 00101 Helsinki, Finland. [8]Universität der Bundeswehr München, 85577 Neubiberg, Germany. [9]IMPMC, CNRS, Sorbonne Université, MNHN, 75005 Paris, France. [10]ISMO, CNRS, Univ. Paris-Saclay, 91405 Orsay, France. [11]ICP, CNRS, Univ. Paris-Saclay, 91405 Orsay Cedex, France. [12]CEA, CNRS, Univ. Paris-Saclay, NIMBE 91191 Gif-sur-Yvette, France. [13]UMET, CNRS, Univ. Lille, 59650 Villeneuve d'Ascq, France.

[†]Deceased.

Cometary dust particles hold information on the material present at the time of Solar System formation. The Rosetta mission investigated the structure and composition of comet 67P/Churyumov-Gerasimenko (hereafter 67P) between 2014 and 2016. The Rosetta/COSIMA mass spectrometer [1] collected about 35 000 particles that were ejected from the nucleus of 67P, and analysed about 200 of them. The elemental composition of individual particles was measured for major and some minor elements, and some particles were also analysed after a sputtering sequence, giving access to their sub-surface composition. The 67P cometary dust particles are enriched in carbon compared to the meteoritic CI reference value [2], with a slightly higher H/C ratio and a N/C ratio compatible with the CI value, respectively [3,4]. There is a difference between the sub-surface and the surface compositions, with a solar-like composition in the sub-surface, while some elements (like Mg and Fe) are depleted at the surface of the particles. We suggest that this results from pre-accretion irradiation of the building units of 67P dust particle. Such a pattern is indeed observed at the surface of lunar grains [5] and asteroid samples [6] that are submitted to irradiation from the Sun.

Cometary dust is also present in cosmic dust collections on Earth. Chondritic porous anhydrous IDPs collected in the stratosphere and ultracarbonaceous Antarctic micrometeorites (UCAMMs) are probably of cometary origin [e.g. 7]. Irradiated rims were identified in minerals embedded in inorganic matter in UCAMMs, also suggesting pre-accretion irradiation of these minerals [8]. The organic matter in UCAMMs show several phases with distinct elemental and isotopic compositions, suggesting a formation from several reservoirs [9].

[1] Kissel J. et al, (2007) *Space Sci. Rev.* **128**, 823–867. [2] Bardyn A. et al. (2017) *MNRAS* **469**, S712–S722. [3] Fray N. et al. (2017) *MNRAS* **469**, S506–S516. [4] Isnard R. et al. (2018) *Astron. Astrophys.* **630**, A27. [5] Keller L.P. and McKay D.S. (1997) *Geochim. Cosmochim. Acta* **61**, 2331–2341. [6] Noguchi T. et al. (2014) *Meteoritics Planet. Sci.* **49**, 188–214. [7] Engrand et al. (2024) In: Comets III. Univ. Arizona Press, pp 577–619. [8] Engrand C. et al. (2020) *Lunar Planet. Sci. Conf.* **51**, 2008. [9] Rojas J. et al. (2024) *Nature Astron.* **8**, 1553–1561.

Cometary dust after Rosetta: A team effort

Giovanna Rinaldi[1], Günter Kargl[2], Carsten Güttler[3], Ludmilla Kolokolova[4], Oleksandra Ivanova[5], Olena Shubina[5], Voitko Anhelina[5], Nicholas Attree[6], Yuri Skorov[7], Jurgen Blum[7], Meier Gerwin[7] Christopher Kreuzig[7], Victoria Muthig[7], Jonathan Pfeifer[7], Calvin Knoop[7], Maximilian Timpe[7], Manuela Lippi[8], Johannes Markkanen[7], Zivital Stephan[2], Schuckart Christian[3], Konrad Kossacki[9], Hanni Nora[10], Daniel Muller[10], Cambianica Pamela[11], Nicolas Fray[12], Woitke Peter[2], Richter Jens[7]

[1]IAPS- INAF, Rome, Italy, [2] Space Research Institute (Institut fuer Weltraumforschung), Graz, Austria, [3]Institut für Planetologie, University of Münster, [3]University of Maryland, USA, [4]University of Missouri-Columbia, USA, [5]Astronomical Institute of Slovak Academy of Sciences Stará Lesná, Slovakia,[6] Instituto de Astrofísica de Andalucía, CSIC, Granada, 7IGEP; TU Braunschweig, Germany, Institute for Astronomy, [8]INAF–Osservatorio astrofisico di Arcetri, Firenze, Italy, 10Space Research & Planetary Sciences, Physics Institute, University of Bern, Sidlerstrasse 5, 3012 Bern, Switzerland [11] INAF-OAPd, Padova, Italy, 12Laboratoire Interuniversitaire des Systemes Atmosph ` eriques (LISA), UMR ´ CNRS 7583,

Cometary dust is considered one of the best-preserved remnants of the material present during the formation of the solar system. It contains substances that have not undergone significant alteration, offering valuable clues about the origins of comets and the early solar system.

Due to the importance of cometary dust, the *Rosetta Dust Group* was formed during the Rosetta mission. This team included experts in cometary dust, primarily—but not exclusively—from the Rosetta instrument teams. The group's goal was to advance our understanding of cometary dust science by combining results from multiple Rosetta instruments, ground-based observations, and theoretical studies. Several multi-instrument studies have been published as a result of this collaboration (e.g., Tubiana et al. 2019; Güttler et al. 2019).

Since 2015, a series of dust meetings have been organized to share, compare, and discuss cometary dust research, with the aim of deepening our understanding of comets and their dust. These meetings encourage informal discussions and foster potential collaborative activities.

In this meeting, we will present the results discussed during the most recent dust meeting, held in Graz, Austria on March 2026. The scientific program followed the format of previous workshops, featuring sessions across three main topics: observations, models, and laboratory experiments. The program also included a splinter meeting on “Challenges in dust modeling.”

Origins of dust in JWST-observed primeval galaxies at z~7

Ambra Nanni[1,2], Michael Romano[3,4] Darko Donevski[1,5], Joris Witstok[6,7], Irene Shivaei[8], Michel Fioc[9], Giuliano Lorenzon[1], Denis Burgarella[10] and Prasad Sawant[1]

[1]NCBJ, [2]INAF—Osservatorio Astronomico d'Abruzzo, [3]Max-Planck-Institut für Radioastronomie, [4]INAF—Osservatorio Astronomico di Padova, [5]SISSA, [6]DAWN, [7]Niels Bohr Institute, University of Copenhagen, [8]CAB, [9]Sorbonne Université, [10]LAM

We investigate a sample of star-forming galaxies at z∼7 observed with the James Webb Space Telescope (JWST), focusing on the diversity of their rest-frame ultraviolet spectral properties and, in particular, on the presence of the 2175 Å dust absorption feature. While only a subset of these galaxies exhibits a clear UV bump, its detection provides evidence for the presence of small carbonaceous grains and points to rapid enrichment of the interstellar medium (ISM) at early cosmic times. The aim of this work is to explore the physical conditions and dust production pathways responsible for the emergence of dust grains within the first billion years of cosmic history.

To this end, we analyze galaxies extracted from cosmological IllustrisTNG simulations, post-processed with dust evolution models and radiative transfer calculations. We compare these models with JWST rest-frame UV and optical spectra, and with Atacama Large Millimeter Array (ALMA) observations when available. Our models reproduce several continuum and emission-line diagnostics, including UV slopes, Balmer decrements, dust continuum emission, and [CII] 158μm line fluxes.

We find that the observed dust content, including small carbonaceous grains, can be explained either by efficient dust growth in the ISM combined with low dust condensation efficiencies in Type II supernova ejecta, or by highly efficient dust production in supernovae with limited ISM grain growth. In contrast, dust production dominated solely by asymptotic giant branch (AGB) stars appears insufficient to explain both the observed UV bump and the overall dust content of galaxies at these early epochs.

On the Structure of Supernova Dust Aggregates

Lucas Kolanz[1] and Davide Lazzati[1]

[1] Department of Physics, Oregon State University, Corvallis, OR, USA

Abstract:

Recently the James Webb Space Telescope has observed dust in galaxies out to $z \simeq 8$, and galaxies with considerable metalicity out to $z \simeq 14$. Yet the source of this high redshift dust is not well understood, as the two main dust producers we observe locally become problematic. At these extreme redshifts, Asymptotic Giant Branch stars have not yet had enough time to evolve to a state where they experience a large outflow of material where dust can form. Additionally, dust produced in supernova remnants needs to survive the supernova reverse shock in order to enter into the ISM, but estimates for reverse shock dust destruction remain uncertain and range anywhere from 0-99%.

One key to this problem may be dust aggregates. So far, simulations of reverse shock dust destruction treat dust as single particle grains, since the structure of dust aggregates formed in such an environment has not been directly studied.

To better understand the structure of dust aggregates formed in a supernova remnant we have performed Discrete Element Method simulations of dust coagulation with our code DECCO (Discrete Element Cosmic COllision). In these simulations, we randomly place single grains in a volume with periodic boundary conditions. These grains are then given a thermal velocity in a random direction and the simulation plays out. The simulation ends either when all grains are in a single aggregate, or a certain amount of time has elapsed.

By studying the structures of the final aggregates, this information can inform reverse shock dust destruction simulations and help paint a better picture of how much dust is destroyed.

Grain Formation in Oxygen-Rich AGB Stars

Joseph A. Nuth[1], Frank T. Ferguson[1, 2], Natasha M. Johnson[1], John A. Paquette[1, 2]

[1]NASA's Goddard Space Flight Center, USA, [2]Catholic University, USA,

In theory, the stability of specific minerals can be calculated with reasonable precision in expanding stellar atmospheres provided that the thermodynamic parameters of these solid phases and the chemical composition of the gas are known. Infrared spectroscopic observations of dusty stellar atmospheres can be used to identify the major condensed phases that must be considered in such calculations. Based on this methodology we can predict, to first order, the composition of the dust injected into the interstellar medium from any given star. These results can be misleading.

Unfortunately, grain formation does not occur under equilibrium conditions. Solids form from gas by a kinetically controlled phase transition. Chemical compositions of intermediate phases between the initial gas and the first stable solids are unknown and likely to be highly unstable to both growth and decomposition. In a gas of cosmic composition, the number and complexity of these intermediates is huge and beyond our current ability to model since we not only need the stability of each intermediate but also its reaction rate with each other gas phase constituent.

We have tried to get around these difficulties by conducting a series of experiments. We first measured the conditions under which SiO condensed, then measured the condensation of Mg-SiO and found that the presence of magnesium did not seem to be important for condensation above about 900K. Stephens and Bauer found similar results for the condensation of Fe-SiO. We postulate that nucleation of SiO clusters controls dust condensation in oxygen-rich stars. Analyses of the solids condensed from Fe-Mg-SiO vapors in hydrogen demonstrated that the original grains were either $MgSiO_x$ or $FeSiO_x$ with no $MgFeSiO_x$ condensates, prompting Rietmeijer to suggest that vapor phase growth occurs at metastable eutectic compositions. Mixed $MgFeSiO_x$ only forms via coagulation of fresh condensates followed by Ostwald ripening at high temperatures.

Measuring the rate of spectral evolution of $MgSiO_x$ and $FeSiO_x$ condensates as a function of time and temperature demonstrated that the highly chaotic initial condensates rapidly annealed into more ordered, glassy structures but that the $MgSiO_x$ grains annealed at much lower temperatures than the $FeSiO_x$ condensates. Condensation at metastable eutectics and the much faster annealing of $MgSiO_x$ solids can explain the observation of crystalline forsterite and enstatite dust in some high mass loss rate AGB stars while dust seen in lower mass loss rate stars remains amorphous.

Microgravity experiments have shown that growth of solids from the gas phase is inefficient. For crystalline materials, only a few atoms out of every $\sim10^5$ that hit a surface are incorporated into the growing particle. For more amorphous grains such as SiO_x, the rate may be as high as a few SiO molecules for every 10^3 that hit the surface. In a circumstellar outflow, nearly all of the SiO in the gas becomes incorporated into the dust via one of two processes: formation of stable SiO_x clusters or the growth of these clusters into larger grains. If grain growth were efficient, then once stable SiO_x clusters formed, these would consume the remaining SiO from the gas and form large dust grains. Since growth is inefficient a larger number of stable nuclei form, resulting in a much higher density of very small dust grains. Because the coagulation rate is proportional to the square of the number density, inefficient growth increases the formation rate of dust aggregates in circumstellar outflows and most likely results in the injection of fractal dust into the interstellar medium. This has interesting consequences for subsequent grain processing in the ISM and in protostellar nebulae.

Systematic Constraints on Chemical Compositions of Amorphous Silicate Dust Using New Optical Constants

Hanako Enomoto[1], Aki Takigawa[1]

[1] *The University of Tokyo, Japan*

Amorphous silicate, a major component of circumstellar and interstellar refractory dust, is predominantly formed in asymptotic giant branch (AGB) stars (Henning 2020). Infrared spectroscopic observations of M-type AGB stars show diverse amorphous silicate dust spectra. However, the dust composition of individual stars remains poorly constrained. Previous experiments of amorphous silicate dust analogues have focused on Mg–Si–Fe–O mineral compositions (e.g., Dorschner et al. 1995, Mutschke et al. 1998, Jäger et al. 2003), and one-to-one comparisons between observed spectra and experimental products with specific mineral compositions have been insufficient to explain the observed spectral diversity. Experiments on non-stoichiometric systems including Al and Ca, two major silicate-forming elements after Mg and Fe, are limited. Therefore, the relationships between Al and Ca content, degree of SiO_4 polymerization, and spectral features of amorphous silicate remain poorly understood. As a result, quantitative estimation of dust compositions outside experimentally explored compositional ranges remains difficult. In this study, we experimentally investigated how the chemical composition and internal structure of amorphous silicate dust affect their mid-infrared spectral features by systematically varying Ca/Mg ratios, Al/Si ratios, and degree of SiO_4 polymerization.

Condensation experiments in a Ca–Al–Mg–Si–O system were carried out using the induction thermal plasma (ITP) system (JEOL TP-40020NPS, Kim et al. 2021) to produce dust analogs with systematically varied Al/Si and Ca/Mg ratios based on CI chondritic composition. The products were analyzed by XRD (Rigaku RINT-2100) and EPMA (JEOL JXA-8530F). Absorption and reflectance spectra were measured using FTIR spectrometers (JASCO FT/IR-4200, IRT5200; Thermo Nicolet 6700). We derived optical constants from absorption and reflectance spectra using a Lorentz oscillator model (Enomoto et al. 2026). We also derived optical constants using iterative Kramers–Kronig analysis (Takigawa 2026).

The results provide the first systematic constraints on how Al and Ca abundances and polymerization degree affect the infrared spectra of amorphous silicates in non-stoichiometric regions. The 10 µm peak shifts toward longer wavelengths with depolymerization of the SiO_4 network. In addition, this trend varies with Al/Si ratios (0, 0.08, and 0.5), which can be attributed to the weaker Al–O bond relative to the Si–O bond. In contrast, the 18 µm peak shifts toward shorter wavelengths with decreasing polymerization degree, which may reflect decreases of Si–O–Si bond angles. Furthermore, the 18 µm peak position depends on the Ca/(Ca+Mg) ratio, shifting toward longer wavelengths with increasing Ca content. Our new optical constants of amorphous silicate over a broad compositional range enabled us to identify systematic relationships between Al and Ca content, polymerization degree, and spectral features. These trends provide a framework for constraining dust compositions beyond conventional mineral-based one-to-one comparisons. Using this framework together with physical parameters such as grain size and shape, we constrained the chemical compositions of dust around M-type AGB stars. This approach can also be applied to dust in the interstellar medium and protoplanetary disks.

Carbonaceous Nanoparticles in the ISM?

A.T. Tokunaga[1], W.W. Duley[2]

[1]*University of Hawaii,* [2]*University of Waterloo*

Although the Polycyclic Aromatic Hydrocarbon (PAH) hypothesis remains the most widely assumed explanation for the interstellar infrared emission bands at 3.3, 3.4, 6.2, 7.7, 8.6, 11.3, and 12.7 μm, it is not universally accepted. Laboratory analogs, such as hydrogenated amorphous carbon and soot, offer a compelling alternative explanation because their infrared absorption features align closely with observed interstellar emission bands. These laboratory analogs are insensitive to the way they are produced, for example by condensation of a hydrocarbon plasma, laser ablation of graphite, or combustion. However, the precise composition of the carrier remains elusive due to differences between laboratory and astronomical spectra and the lack of a robust model to explain stochastic emission from solid state carbonaceous nanoparticles.

As a side topic, we will discuss why the spectral energy distribution (SED) should be plotted as $\log(\lambda F_\lambda)$ versus $\log(\lambda)$ [or $\log(\nu F_\nu)$ versus $\log(\lambda)$] instead of $\log(F_\nu)$ versus $\log(\lambda)$. This will improve our understanding of the spectral energy distribution of astronomical objects and the nature of the carrier.

Investigating the Origins of UIR in the ISM: Theoretical Calculations of Imino-Group-Containing PAHs

Sho Fujita[1,2], Masashi Nashimoto[2]

[1]*Tohoku University,* [2]*National Institute of Technology, Niihama College*

Polycyclic aromatic hydrocarbons (PAHs) and PAH-related species have been proposed as candidates for interstellar matter (ISM) responsible for unidentified infrared (UIR) emission. However, since the origin of UIR has not yet been fully identified, it remains important to explore alternative possibilities.

Previous studies have examined nitrogen-containing PAH-related species, such as amino groups and heterocyclic compounds. Given the diversity of nitrogen-containing functional groups, this study compares and analyzes the IR spectra of PAH-related species bearing various nitrogen-containing groups. In particular, this study focuses on PAH-related species containing imino groups (–C=NH), which exhibit trends similar to UIR, and performs analyses using density functional theory (DFT) calculations.

Nitrogen-substituted PAH-related species offer several advantages over PAHs in their vibrational spectra[1),2)]. These include enhanced IR intensity due to the introduction of highly electronegative nitrogen atoms, and the appearance of nitrogen-related vibrational peaks near the major UIR bands at 3.3, 6.2, 7.7, 8.6, 11.2, and 12.7 μm. On the other hand, when an N–H bond is present, as in amino groups, strong N–H stretching vibrations appear at 2.9–3.0 μm; however, such features have not been confirmed in astronomical observations[3)]. This discrepancy suggests the need for a revised model of nitrogen-containing PAHs.

We found that some imino-substituted PAH-related species exhibit spectral features consistent with observational data, particularly at 3.3, 6.2, 7.7, and 8.6 μm. Although these species contain N–H bonds, the IR intensity of the N–H stretching vibration is very weak in the neutral state. These results indicate that imino-substituted PAH-related species can retain the advantages of nitrogen incorporation while avoiding its previously identified drawbacks.

We report a theoretical investigation based on calculated IR spectra, demonstrating the potential of imino-substituted PAH-related species as candidates for UIR-emitting ISM.

References

1) Z. Peeters, et al., 2005, A&A, 432:2
2) B. A. McGuire, et al., 2018, Science, 359:6372
3)A. Vats et al.,2021,PASJ,74:1:161

Testing PAH Emission Models: Constraining Size and Ionization in Reflection Nebulae

Bo Yang and Aigen Li

University of Missouri-Columbia, USA

Polycyclic aromatic hydrocarbon (PAH) molecules exhibit distinct emission bands across various wavelengths in the infrared, revealing their prevalence throughout the Universe. Their excitation is dependent on the spectral shapes or "hardness" of the illuminating starlight. Typical reflection nebulae, of which the central illuminating stars span a wide range of effective temperatures from 3000 to over 20000 K, provide an ideal laboratory for studying the excitation of PAH emission by starlight of various spectral shapes. Focusing on a sample of characteristic reflection nebulae, including vdB 17, vdB 59, vdB 101, and vdB 133, and utilizing the single-photon heating model, we calculate the theoretical PAH emission to explore how PAH properties vary with these different radiation environments. Specifically, we use the major emission features at 6.2, 7.7, and 11.3 micron derived from these model spectra to construct diagnostic band-ratio grids. By placing the observed band ratios in the grids, we can determine the size and charging properties (i.e., ionization fraction) of PAHs and examine how they vary with the local environments. This study sheds light on the nuanced relationship between PAH excitation and starlight spectrum, offering insights into the broader understanding of the physics and chemistry of PAHs in the interstellar medium.

Impact of the dust properties on the photoelectric heating efficiency of the gas, using Spitzer, Herschel and SOFIA observations of the LMC

L. Belloir[1], F. Galliano[1], S. Madden[1], V. Lebouteiller[1], and the LMC+ collaboration

[1] Université Paris-Saclay, Université de Paris, CEA, CNRS, AIM Paris-Saclay, 91191 Gif-sur-Yvette, France

The Large Magellanic Cloud (LMC) provides a unique laboratory to understand the interaction between the interstellar medium (ISM) and massive star formation, in a galaxy with a low metallicity. The LMC's proximity to our Galaxy permits observation of its dusty and gaseous infrared emission at a parsec-scale resolution, thereby enabling study of interstellar properties at the scale of a molecular cloud. The SOFIA Legacy Program (LMC+) [1] has observed the [CII] λ 158 µm and [OIII] λ88 µ m lines in the southern molecular ridge at a resolution of 2.5 pc. These new observations provide access to the dominant cooling lines in the neutral and ionised ISM, enabling investigation of the major heating and cooling mechanisms in the three massive star-forming regions, N158, N159 and N160. In neutral regions, the main mechanism responsible for the gas heating is the photoelectric effect [2]. This process consists in the ejection of an electron from a dust grain after the absorption of a UV photon.

The objective of this work is to combine data acquired by the SAGE [3] survey with Spitzer (3.6 to 70 microns), the HERITAGE [4] survey with Herschel (100 to 250 microns), and new data from SOFIA, with the aim of creating maps of dust properties and constraining the efficiency of the photoelectric heating of the gas in this region. To that end, we have homogenized our multi-wavelength maps to an optimal, common resolution and pixel grid. We took particular care in the estimate of the non-Gaussianity of our uncertainties and their correlations. The spatially-resolved spectral energy distribution of each pixel was then fitted with the hierarchical Bayesian code, HerBIE [5], using the THEMIS dust model [6,7]. Two original aspects are presented in our work. The first one is that the modeling we perform allows us to compare the efficiency of the photoelectric heating to the actual mass of its carriers, and not only to their luminosity. The second one, is that, using ancillary data, we provide a phase decomposition of the [CII] luminosity. Doing so, the efficiency we estimate is less biased by the [CII] linked to other heating mechanism. Our results confirm that the photoelectric heating is dominated by the smallest grains. In addition, the overall efficiency of the heating appears reduced, because of the lower abundance of these grains, relative to the gas, in the LMC.

References

[1] Fischer et al, A&A, 702 (2025)
[2] Kimura, MNRAS, 459 (2015)
[3] Meixner et al, ApJ, 132 (2006)
[4] Meixner et al, ApJ, 146 (2013)
[5] Galliano, MNRAS, 476 (2018)
[6] Jones et al, A&A, 558 (2013)
[7] Jones et al, A&A, 602 (2017)

A flexible view of dust: Attenuation curves, UV bumps, and Lyα escape with JWST - CANUCS and beyond

Vladan Markov

Dust attenuation strongly affects the observed properties of galaxies and remains one of the main uncertainties in interpreting galaxy evolution across cosmic time. Before the James Webb Space Telescope (JWST), constraints on dust attenuation laws in high-redshift galaxies were limited by the lack of rest-frame UV and optical spectroscopy and broad wavelength coverage, leading most studies to rely on local attenuation or extinction templates such as the Calzetti, SMC, or Milky Way laws.

In this talk, I will review recent progress in constraining dust attenuation properties in high-redshift galaxies using JWST observations, with a particular focus on galaxies during the epoch of reionization. Leveraging JWST/NIRSpec and NIRCam observations of galaxies across a broad redshift range ($z \sim 2$–12), we find evidence that dust attenuation curves evolve with cosmic time, becoming systematically flatter toward earlier epochs. We also report the detection of the 2175 Å ultraviolet bump in a galaxy at $z \approx 7.55$, providing evidence for the presence of small carbonaceous dust grains in the early Universe.

I will discuss the observed correlations between attenuation-curve shape, UV-bump strength, and galaxy properties such as V-band attenuation, stellar age, and metallicity, together with their possible physical interpretation in the context of dust production, grain processing, and radiative transfer effects.

Finally, I will present recent spatially resolved JWST studies of the lensed Lyα emitter HCM 6A at $z = 6.5676$, where resolved dust and Lyα maps reveal how feedback-driven multiphase ISM geometries regulate Lyα escape in moderately dusty galaxies during the epoch of reionization.

Probing dust grain properties in low-metallicity galaxies through the sub-mm excess with IRAM-30m/NIKA2

Hye-Jin Park[1], Frédéric Galliano[1]

Unité Mixte de Recherche (UMR) – Astrophysique, Instrumentation, Modélisation (AIM) – CEA Paris-Saclay, Gif-sur-Yvette, France

Dust grain properties, including abundance and size distribution, evolve in response to local interstellar medium (ISM) conditions such as metal content, gas density, and radiation field intensity. How these properties vary across environments, however, remains difficult to constrain, as illustrated by the poorly understood sub-mm excess, which is frequently reported in low-metallicity galaxies, where observed flux densities at long wavelengths significantly exceed predictions from standard dust models. As the physical origin of this excess remains debated, characterising it is critical for accurate dust mass estimates and for constraining how grains evolve with environmental conditions.

In this talk, I will focus on the sub-mm excess in the low-metallicity subsample of the IMEGIN and SEINFELD surveys, which used the IRAM-30m/NIKA2 camera to observe more than 20 nearby galaxies at 1.15 mm and 2 mm. We modelled spatially resolved near-infrared-to-radio spectral energy distribution (SED) using the hierarchical Bayesian SED fitting code HerBIE (Galliano 2018), incorporating the laboratory-based THEMIS dust models (Jones et al. 2017; Ysard et al. 2024). By quantifying the strength of the sub-mm excess and its spatial variation within galaxies, we investigate its dependence on local metallicity, radiation field intensity, and ISM density. These results provide insights into dust grain evolution, specifically how millimetre-wavelength dust opacity and underlying grain properties vary across local ISM environments.

A New Technique for Determining the Dust Masses for Normal Star-forming Galaxies

Aigen Li and Xunzhou Chen

University of Missouri

Dust is crucial in understanding the properties and evolution of galaxies as well as the formation of stars and planets. It controls the absorption and scattering of starlight, which affects the observations of distant objects and the overall structure of galaxies. We present a novel method to estimate the dust masses for normal star-forming galaxies, utilizing the Dale-Helou Phenomenological Model Template Spectra. We derive the dust mass for each spectral template and test this method by comparing the dust masses for real galaxies with that derived from detailed dust models.

The relations between dust intrinsic properties and galaxy global quantities in the nearby Universe

Bogdan Adrian Pastrav[1]

[1]*Institute of Space Science - INFLPR Subsidiary, Romania*

Results of a case study of a sample of low-redshift galaxies are presented, to determine dust temperatures and emissivity indices through a less time-consuming method, and to connect these intrinsic dust properties with global galaxy properties, ISM and star-formation quantities. Dust temperatures (T_d) are determined for two cases - with β_d left free or fixed, based on the corresponding galaxy dust masses independently calculated in our previous work through a self-consistent method, without the need to perform a complete spectral energy distribution (SED) fit of the cold dust emission fluxes. The range and average dust temperatures are found to be consistent within errors with values from other studies. Simultaneously, the dust emissivity indices (β_d) are determined, and their evolution with temperature quantified, to check if the $T_d - \beta_d$ known degeneracy still appears with the current method. It is investigated whether β_d can be predicted from other relation or if it scales with other integrated dust / ISM or star-formation property, which could be used as a proxy. New and observed relations between T_d, β_d, the dust surface density and global / integrated galaxy and star-formation related quantities are presented and analysed in the context of dust/ISM formation and evolution. It is verified which of the star-formation quantities can constitute conclusive tracers of the dust temperature. The differential dust attenuation between nebular and stellar light is determined and its variation with stellar mass and star-formation related quantites is investigated, in comparison with results from other low and high redshift surveys (e.g. PHANGS-HST-JWST, ALPINE-CRISTAL-JWST).
The results and conclusions can be relevant for larger scales studies of low to mid-redshift galaxies from the latest surveys.

Dusty Active Galactic Nuclei from the Nearby Universe to Cosmic Dawn: The Evolving Picture and New Insights in the JWST era

Jianwei Lyu

Steward Observatory, University of Arizona, USA

Dust is a defining component of the active galactic nucleus (AGN) phenomenon, obscuring the accreting supermassive black hole and reprocessing its UV-optical emission into the infrared, where it provides a powerful probe of the structure and physical properties of the obscuring material. Decades of infrared observations from ground- and space-based facilities have established a broad observational framework for understanding dusty AGN through resolved morphology, spectral energy distributions, variability, and spectroscopic diagnostics across a wide range of luminosities and redshifts. Nevertheless, key questions remain regarding the nature of the obscuring structures, the interplay between nuclear and larger-scale dust, and the most deeply buried phases of black hole growth. In this talk, I will review the evolving observational picture of dusty AGN from the local universe to cosmic dawn, focusing on what we have learned about AGN dusty structures and their physical properties. I will also discuss selected new developments from the JWST era, including refined constraints on AGN dust properties, the identification of heavily obscured AGN at high redshift, and the discovery of Little Red Dots in the early universe that may represent extreme environments of rapid black hole growth.

A systematic study on the processing of hydrocarbon dust in various types of galaxies with AKARI and JWST

Hidehiro Kaneda[1], Tsubasa Kondo[1], Eiko Kozaki[1], Risako Katayama[1], Shohei Ono[1], Takuma Kokusho[1], and Shinki Oyabu[2]

[1]Nagoya University, Japan, [2]Tokushima University, Japan

Interstellar polycyclic aromatic hydrocarbon (PAH), or in more general, hydrocarbon dust which contains aromatic and aliphatic components, is known to exhibit numerous outstanding spectral band features in the near- to mid-infrared (IR) wavelength range. For example, Spitzer mid-IR spectroscopy has shown a variety of the PAH emission features for various types of galaxies, which reflects significant changes in the properties of PAHs, such as an ionization state and a size distribution. AKARI near-IR spectroscopy has revealed significant variations in the ratio of the aromatic to the aliphatic hydrocarbon spectral feature in galaxies, indicating structural changes of carbonaceous grains under the harsh interstellar environments. Currently, JWST provides us with detailed spatial distributions of their near- to mid-IR spectral features within a galaxy.

In this presentation, we first review the results of our systematic study with AKARI on the spectral properties of the hydrocarbon dust features at wavelengths of 3.3 to 3.6 microns for about 700 nearby galaxies. Our sample includes not only star-forming galaxies but also active galactic nuclei (AGNs) and even quiescent galaxies such as elliptical galaxies. We find that the flux ratios of the aliphatic to aromatic hydrocarbon feature vary widely from galaxy to galaxy. The results also reveal significant variations in the shape of the aliphatic feature profile and the center wavelength of the aromatic feature. Next, in addition to the AKARI overall results, we present the latest results of our spatially-resolved study with JWST on the aromatic and aliphatic hydrocarbon features for the interacting M51 and the early-type galaxy NGC1052, both of which are found to reveal spatial variations in the parameters characterizing the hydrocarbon dust feature profile.

Based upon those results, we suggest that hydrocarbon dust grains are being processed in various forms under the interstellar environments through photo-dissociation with the intense UV radiation fields associated with massive star formation activity in galaxies or shattering of large carbonaceous grains via mechanical shocks due to AGN outflows or galaxy interactions. In this presentation, combining the AKARI overall results on a large galaxy sample with the JWST detailed results on individual galaxies, we propose a general picture on the processing and evolution of hydrocarbon dust in galaxies, which can consistently explain our observational results with AKARI and JWST.

Near-infrared continuum emission and associated dust features in the Orion Bar

Takashi Onaka[1], Emmanuel Dartois[2], Els Peeters[3], Olivier Berné[4], Emilie Habart[5], Christiaan Boersma[6], Jan Cami[3], Asunción Fuente[7], Javier R. Goicoechea[8], Ozan Lacinbala[2], Yoko Okada[9], Alexander G. G. M. Tielens[10], Dries Van De Putte[3], Francois Boulanger[11], Thomas Pino[2],and Yong Zhang[12]

[1]University of Tokyo, Japan, [2]ISM d'Orsay, France, [3]University of Western Ontario, Canada, [4]IRAP, France, [5]IAS, France, [6]NASA Ames, USA, [7]CSIC-INTA, Spain, [8]CSIC, Spain, [9]University of Cologne, Germany, [10]Leiden University, The Netherlands, [11]ENS, France, [12]Sun Yat-sen University, China

Conspicuous excess emission is present in the near-infrared (NIR) region in various celestial objects, including reflection nebulae, planetary nebulae, and nearby galaxies. However, the spatial distribution and spectral shape of the excess emission remain poorly understood.

Using the three-dimensional spectroscopic data of the Orion Bar taken with the integrated field unit of NIRSpec on JWST from the Early Release Science program "PDRs4All", we study the NIR continuum emission spectroscopically and obtain its spatial distribution relative to the aromatic infrared band (AIB) at 3.3 μm in the Orion Bar proto-typical photo-dissociation region (PDR). After contribution from the foreground ionized gas is subtracted. the observed regions are divided into nine physically distinct regions and an average spectrum is derived for each region. The nine regions, including the ionized gas, atomic PDR, and molecular PDR, clearly show remaining continuum in the region 1–4.5 μm. The continuum at wavelengths longer than 2.7 μm shows good correlations with the 3.3 μm AIB, while the correlation of continuum around 1.2 μm is not significant. We further find that the NIR continuum in the Orion Bar can be approximated by a summation of two blackbodies. The low-temperature component shows a good correlation with the AIB, while the high-temperature component does not.

We discuss possible origins of the NIR continuum, among which recurrent fluorescence from carbon clusters would better explains the observed low-temperature component. In addition, the average spectra show absorption features at 3.0 and 4.27 μm, which are attributed to the water ice and CO_2 ice. The presence of ice species suggests that there must be a contribution from a deeper layer of the PDR along the line-of-sight producing characteristic ice absorption features.

On the evolution of carriers of AIB emission in planet-forming disks

Ryo Tazaki[1]

[1]*The University of Tokyo*

Aromatic infrared band (AIB) emission is a ubiquitous component in the interstellar medium of metal-rich galaxies. Although the exact chemical nature of their carriers is still under debate (e.g., Tokunaga et al. 2026), the carriers of AIBs are likely a class of very small carbonaceous molecules and particles (e.g., Tielens 2005). Such small carbonaceous particles are also expected to be present in planet-forming disks. Although AIBs are commonly detected in disks around Herbig Ae/Be stars, they are much less common in disks around T-Tauri stars (Geers et al. 2006; Seok & Li 2017). This may imply the evolution of AIB carriers in some planet-forming disks. Several factors have been proposed to influence AIB emission in disks around low-mass stars, such as the radiation field (Geers et al. 2006; Visser et al. 2007), photon hardness (Siebenmorgen & Krügel 2009; Lange et al. 2025), particle properties (e.g., PAH size and clustering) (Lange et al. 2021), and vertical mixing (Dullemond et al. 2007). However, these effects have often been investigated under different conditions, and a comprehensive understanding of the AIB carrier's evolution in disks remains elusive.

In this study, we have been developing a disk model that accounts for the interactions between high-energy photons and very small particles, disk radiative transfer, and the subsequent computation of observational quantities, such as SEDs and disk images. Here, as an initial result, we mainly report on the outcomes of interactions between high-energy photons and polycyclic aromatic hydrocarbon (PAH), a potential AIB carrier. Although X-ray photons have previously been suggested to rapidly disrupt large PAH molecules, we show, using the Rice–Ramsperger–Kassel–Marcus (RRKM) theory and stellar X-ray emission models, that X-ray photon absorption by PAH molecules most likely results in the ejection of a photoelectron followed by an Auger electron, and that X-ray photodissociation of PAH containing more than ~ 100 carbon atoms is inefficient. We will discuss implication for the lack of AIB emission in disks around T-Tauri stars.

Rolling friction between dust monomers explored by molecular dynamics simulations

Yuki Yoshida[1], Eiichiro Kokubo[2], Hidekazu Tanaka[1]
[1]Tohoku University, Japan, [2]National Astronomical Observatory of Japan, Japan

Dust is considered to be aggregates composed of submicrometer-sized particles (dust monomers) and it grows by collisional sticking, which has been investigated by using simulations based on the discrete element method (e.g., Wada et al. 2007, 2008, 2009, 2013; Suyama et al. 2008, 2012; Arakawa et al. 2022). Arakawa et al. (2022) investigated the collisions between porous dust aggregates and found that the rolling friction contributed to the energy dissipation during collisions under certain collisional conditions. The rolling friction is modeled by Domink & Tielens (1995), in which the rolling friction is proportional to the critical displacement. However, the value of the critical displacement has not been constrained well. In this study, we aim to clarify the rolling friction by using molecular dynamics simulations.

We performed molecular dynamics simulations, which integrate each atomic motion and analyze the underlying physical processes. We prepared the contacting dust monomers and simulated their rolling motions. The angular velocity of dust monomers decreases with time, and we analyzed the torque acting on them from the temporal evolution of angular velocity. We found that the critical displacement is approximately 0.2 - 0.3 nm. We also found that the torque sometimes changes with rolling due to peeling at the contact surface. This peeling enhances the torque, resulting in a large effective critical displacement. At higher temperatures, the peeling occurs more frequently. Therefore, the rolling friction increases with increasing temperature. Such a peeling phenomenon can be observed in the atomic alignments.

In our presentation, we show these results and discuss their implications for the dust growth.

A theoretical model for the collisional sticking probability of cosmic dust aggregates

Sota Arakawa[1], Haruto Oshiro[2], Yuki Yoshida[3], and Kiwamu Yoshii[4]

[1]*Japan Agency for Marine-Earth Science and Technology, Japan,* [2]*Institute of Science Tokyo, Japan,* [3]*Tohoku University, Japan,* [4]*Tokyo University of Science, Japan*

In protoplanetary disks, pairwise collisional growth of dust aggregates composed of submicron-sized grains is a key process that ultimately leads to planet formation. Understanding collisional outcomes is therefore essential, and the collisional behavior of dust aggregates has been investigated through both laboratory experiments (e.g., Blum & Wurm 2008) and numerical simulations (e.g., Arakawa et al. 2023; Oshiro et al. 2025). Low-velocity collisions can result in bouncing rather than sticking under certain conditions. As bouncing may limit dust growth in protoplanetary disks, quantifying the threshold between sticking and bouncing is crucial for understanding pathways to planet formation.

Here we propose a semi-analytic model for the sticking probability in collisions between spherical dust aggregates. Arakawa et al. (2024) showed that the collisional compression of dust aggregates can be modeled using elastoplastic spheres. Assuming that the energy required to separate two aggregates in contact is governed by a weakest-link model (e.g., Weibull 1939), we derive the sticking probability and the coefficient of restitution as functions of collision velocity, aggregate radius, and volume filling factor. We demonstrate that the model reproduces the numerical results of Oshiro et al. (2025). Furthermore, the model predicts a threshold velocity for bouncing of ~ 0.1–1 m/s for (sub)mm-sized aggregates with volume filling factors of 20%. This prediction is broadly consistent with aggregate sizes and filling factors inferred from astronomical observations (e.g., Ueda et al. 2024). In this presentation, we summarize the essence of the model and discuss several astronomical applications.

Experimental Study on the Coefficient of Restitution and Rotation in Low-Velocity Oblique Impacts of Ice Spheres onto Solid Targets

Yukari M. Toyoda[1,2], Minami Yasui[3], Hiroshi Kimura[4]

[1]Astrobiology Center, Tokyo, Japan, [2]National Astronomical Observatory of Japan, Tokyo, Japan, [3] Kobe University, Kobe, Japan, [4] Planetary Exploration Research Center (PERC), Chiba Institute of Technology, Narashino, Chiba, Japan

In protoplanetary disks, μm-sized dust particles are thought to grow through low-velocity collisions and sticking, forming highly porous aggregates. However, when the aggregates grow to approximately cm size, bouncing may occur because of increasing collision velocity and decreasing porosity. This bouncing can prevent further growth of the aggregates. Understanding low-velocity collisions of aggregates composed of water-ice dust particles is, therefore, important for elucidating the formation process of icy planetesimals beyond the snow line.

Previous laboratory experiments have investigated dust collisions, but low-velocity collision experiments under low-temperature conditions are technically difficult. In particular, the effect of impact angle on collision outcomes has not been sufficiently studied. In this study, we aim to investigate the dependence of the coefficient of restitution and rotational motion on collision velocity and impact angle by conducting low-velocity oblique impact experiments on cm-sized aggregates composed of water-ice dust particles.

As a first step toward this goal, we developed a free-fall oblique impact system and an analysis method using a two-dimensional laser displacement sensor. In this presentation, we report the results of our preliminary experiments using non-porous ice spheres impacting on a granite plate.

The ice spheres were prepared by pouring boiled tap water into silicone molds and freezing them in a freezer at -20°C. A commercially available granite plate with a mirror-polished surface was used as the target plate. The ice spheres were dropped freely onto the granite plate. The impact velocity was controlled by changing the height of the granite plate ($v_i \sim 16$–161 cm s^{-1}). The impact angle was controlled by changing the inclination angle of the granite plate ($\theta_i = 15°, 30°, 45°, 60°, 75°$, and $90°$).

To observe horizontal motion, vertical motion, and rotational motion during oblique impacts, we used a two-dimensional laser displacement sensor with a sampling frequency of 1 or 2 kHz. We measured the sphere's position and the angle of the reference surface over time, both before and after the collision. All experiments were conducted in a cold room at -15°C.

The results show that the coefficient of restitution decreases with increasing impact velocity and impact angle. This suggests that energy dissipation occurred because of crack formation caused by impact stress. In contrast, the tangential coefficient of restitution was approximately 1, suggesting that frictional energy dissipation was negligibly small for collisions between smooth ice spheres and the mirror-polished granite plate.

We also found that the change in angular velocity before and after collisions increases with increasing impact velocity. We attribute this rotational change to the torque induced by a slight misalignment between the geometric center and the center of mass of the sphere.

Development of a Large-Area Dust Detector Using Electric Field Probes for In-situ Measurement of Hypervelocity Micro-Dust Impacts

Masanori Kobayashi[1,2], Osamu Okudaira[2], Kousei Nagasawa[1], Sunao Hasegawa[3]

[1]Chibatech, Japan, [2]Chitec/PERC, Japan,[3]ISAS/JAXA, Japan

Understanding the distribution and physical properties of cosmic dust is crucial for elucidating the growth processes of stars and the evolutionary history of planetary systems. Large micro-dust particles with radii exceeding 10 μm serve as key indicators of these processes. The classical model by Grün et al. (1985) [1] has established the collisional balance of the meteoritic complex, yet the supply processes and distribution of these larger grains remain a subject of ongoing discussion. Accurate modeling of this distribution is also vital for reducing foreground noise in infrared astronomy, as demonstrated by Kelsall et al. (1998) [2]. Furthermore, the detection of large interstellar grains, as discussed by Altobelli et al. (2016) [4], is critical for verifying interstellar material processing and even hypotheses related to panspermia (Wickramasinghe, 2010) [5]. However, due to their low spatial density, conventional detectors often lack the necessary sensing area to collect statistically significant data. To address this, we propose a lightweight, large-area detection method using electric field probes to measure the plasma generated by hypervelocity impacts.

The sensing principle focuses on the phenomenon of impact ionization. When a dust particle impacts a target at hypervelocity, it generates a plasma cloud. The resulting charge separation induces a transient change in the surrounding electric field, which can be captured as a voltage pulse by an antenna-like electric field probe. Unlike traditional metal-target detectors that rely on heavy shielding or specific materials, this method allows for a significant increase in the effective sensing area while maintaining a low mass budget, which is ideal for deep-space exploration missions.

The experimental phase of this research is conducted in collaboration with the Japan Aerospace Exploration Agency (JAXA). Utilizing the two-stage light-gas gun facility at the JAXA Sagamihara Campus, we perform hypervelocity impact experiments in the velocity range of 1 to 7 km/s. By analyzing the characteristics of the induced electric field signals—such as rise time and peak amplitude—we establish a quantitative correlation between the signal profile and the physical parameters of the dust, specifically mass and velocity. Furthermore, these experimental results are integrated with impact ionization models to develop an estimation algorithm capable of extrapolating data to hypervelocity regimes up to 80 km/s, typical of interstellar dust encounters.

The presentation will also discuss the optimization of antenna geometry to enhance detection sensitivity and the implementation of multi-signal discrimination logic to filter out non-dust events, such as cosmic ray showers. This research provides a fundamental engineering basis for the next generation of dust observation instruments, contributing to both space science and the mitigation of risks posed by space debris to orbiting spacecraft.

Atmospheric Entry Dynamics and Textural Evolution of Micrometeorites

Vijay Pratap Singh[1,*], N.G. Rudraswami[2]

[1]WPI-SKCM[2], Hiroshima University, Higashi Hiroshima, Japan
[2]CSIR- National Institute of Oceanography, Goa, India,
*vpsingh@hiroshima-u.ac.jp

An estimated 40,000 tonnes of extraterrestrial dust enter the Earth's atmosphere annually [1]. During atmospheric transit, frictional heating induces severe evaporative and ablative mass loss; consequently, only ~10% of this material survives to reach the surface as micrometeorites [2]. The structural and textural alterations of these particles are strictly controlled by atmospheric entry parameters, specifically entry velocity, entry angle, and size, in conjunction with their precursor composition [3,4].

To evaluate the thermal history of these particles, this study investigated 1,032 cosmic spherules recovered from deep-sea sediments in the Central Indian Ocean Basin. By integrating petrological data with entry heating simulations from the Chemical Ablation Model (CABMOD), the textural evolution of silicate-dominated spherules was analyzed. A systematic classification was implemented, categorizing barred textures into tabular, platy, and radial configurations, and porphyritic textures into equant, skeletal, and chain arrangements [3].

The emergence of these distinct morphologies is governed by the thermodynamic balance between peak heating relative to the precursor liquidus temperature and the subsequent undercooling required for crystallization. Particles heated below the liquidus temperature primarily form scoriaceous or equant porphyritic textures. In contrast, overheating destroys existing nuclei; subsequent undercooling produces barred textures, while extreme overheating yields glassy spherules. Quantitative modeling indicates that particles up to 400 μm entering at an escape velocity of 11 km/s with moderate zenith angles (50°–70°) are likely to form barred textures due to overheating of ~100°C above the liquidus. Steeper entry angles and higher velocities drive extensive melting, favoring glass formation. Furthermore, heating regimes exceeding 2400°C result in >90% ablation, preventing spherule formation entirely. Evaluating these textural modifications provides a reliable framework to determine the precise atmospheric entry conditions of micrometeorites.

References:

[1] Love SG, Brownlee DE (1991) Heating and thermal transformation of micrometeoroids entering the Earth's atmosphere. Icarus 89(1):26–43.

[2] Genge, M. J., Van Ginneken, M., & Suttle, M. D. (2020). Micrometeorites: Insights into the flux, sources and atmospheric entry of extraterrestrial dust at Earth. *Planetary and Space Science*, *187*, 104900.

[3] Singh, V.P., Rudraswami, N.G. (2025) Textural evolution of S-type micrometeorites. *Prog Earth Planet Sci* **12**, 36

[4] Rudraswami NG, Shyam Prasad M, Dey S, Plane JMC, Feng W, Carrillo-Sánchez JD, Fernandes D (2016) Ablation and chemical alteration of cosmic dust particles during entry into the earth's atmosphere. Astrophys J Suppl Ser 227:15.

The prolific dusty laboratories of stellar mergers revealed by JWST

Viraj Karambelkar [1], Mansi Kasliwal [2], Ryan Lau [2], Nadejda Blagorodnova [3], Jacob Jencson [1], Marco Antonio Gomez [3]

[1] *Columbia University, USA,* [2] *Caltech, USA,* [3] *University of Barcelona, Spain*

Luminous Red Novae (LRNe) are a class of extragalactic transient eruptions originating from massive stellar mergers. These eruptions exhibit peak luminosities between those of classical novae and supernovae, low expansion velocities, and a rapid transition to red colors driven by dust formation in their ejecta. LRNe are relatively common, with a volumetric rate $\sim$70% that of the local core-collapse supernovae (CCSNe) rate. Their high occurrence rate and efficient dust production suggest that these stellar mergers could be significant contributors to the cosmic dust budget, potentially helping to explain the unusually dusty galaxies in the early universe.

In this talk, I will present the first mid-infrared observations of extragalactic LRNe obtained with the *James Webb Space Telescope (JWST)* to investigate their dust content. Our sample includes ten LRNe spanning a broad range of progenitor primary masses ($\sim$3–20 $M_\odot$) and observed at post-merger phases between $\sim$3–10 years. Using radiative transfer modeling of their infrared spectral energy distributions, we derive dust masses for each source and estimate that the cumulative dust contribution from LRNe is approximately 25% that of CCSNe. Given the significantly lower ejecta velocities of LRNe ($\sim$100 km s^{-1} versus $\sim$1000 km s^{-1} for CCSNe), their dust is less likely to be destroyed by reverse shocks, potentially making their effective dust yield comparable to or greater than that of CCSNe.

Our observations also show that, at earlier epochs, the mid-IR spectra of mergers are dominated by features from oxygen-rich molecules such as water vapor, CO, and SiO, that transition to strong features of silicate and alumina dust at later epochs. I will describe results from an ongoing *JWST* campaign that aims to trace the molecular-to-dust condensation sequence in real time around a nearby stellar merger. These results demonstrate the importance of stellar mergers as valuable laboratories for studying both the cosmic dust budget and the dust-formation sequence in oxygen-rich environments.

Rapid formation and destruction of dust in the multiphase gas of a simulated starburst

Jonathan A. Jäger,[1] Natalia Lahén,[1] Thorsten Naab[1]

[1]*Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, D-85748 Garching, Germany*

Observations of early Universe galaxies with JWST indicate widespread and rapid formation of dust with diverse properties. We investigate dust formation in the dense interstellar medium (ISM), destruction and expulsion in a high-resolution simulation of a low metallicity merger triggered starburst. The solar mass and sub-parsec resolution simulation resolves the multi-phase ISM and follows the evolution and 'feedback' – stellar winds, HII regions, supernovae, of individual stars. We follow metal species in the gas phase, the solid phase for carbonaceous and silicate dust grains of different sizes as well as the non-steady-state chemical evolution (e.g. neutral, molecular, ionized hydrogen, CO). We find that dust grows in the dense ISM peaking at main star formation phases while gas phase metals are depleted. The onset of stellar feedback from forming star clusters initiates dust destruction by thermal and non-thermal sputtering. The variation in dust-to-gas-ratio between the cold and hot ISM increases strongly, driving considerable differences in attenuation on short time scales. Outflows are multi-phase on kpc scales and significant amounts of dust are expelled. In both formation and destruction processes grain size and grain porosity are relevant factors. For example for H_2-formation, where we utilize the dust mass and dust to gas relative velocity to improve the treatment of H_2-formation on grains surfaces, noticing a strong effect of the grain size distribution, increasing the rate coefficient by over an order of magnitude for our choice of two equal mass grans size bins compared to the previous treatment.
We discuss implications for the interpretation of JWST observations and the impact of early dust formation by supernovae. Our high-fidelity simulations, which are able to resolve the interplay of gas, stars and dust at low metallicities, are valuable tools for understanding dust properties at the early epochs of the Universe.
This work is part of an ongoing effort to implement a detailed dust evolution model in the GRIFFIN project GADGET3 SPH-code. Dust seeding by SNe, AGB stars and stellar winds is in development and the treatment of coagulation and shattering the next planned step.

Grain alignment mechanisms and grain properties in the massive quiescent filament G16.96+0.27 using dust polarization observations from JCMT/POL-2

Saikhom Pravash[1], Thiem Hoang[2], Archana Soam[1], Qi-Lao Gu[3], Tie Liu[3], Pham Ngoc Diep[4], Le Ngoc Tram[5], Nguyen Bich Ngoc[4]

[1]*Indian Institute of Astrophysics, India,* [2]*Korea Astronomy and Space Science Institute, Korea,* [3]*Shanghai Astronomical Observatory, Chinese Academy of Sciences, China,* [4]*Center for Astrophysics and Science Exploration, Vietnam National Space Center, Vietnam,* [5]*Leiden Observatory, Leiden University, Leiden, The Netherlands*

The polarization of starlight and polarized thermal dust emission induced by non-spherical dust grains aligned with the interstellar magnetic field (B-field) provides a powerful tool for tracing the B-field morphologies and strengths in molecular clouds and for constraining the grain properties and their alignment mechanisms. The mechanism behind the alignment of grains to produce polarization is not yet fully clear and act as one of the long-standing problems in astrophysics. However, the leading grain alignment theory is the alignment induced by RAdiative Torques (RATs) known as RAT alignment theory, which is supported by numerous observational studies in diffuse interstellar medium and molecular clouds. The study of the grain alignment mechanism in dense star-forming regions is limited and started only recently with the advancement in far-infrared, submillimeter and millimeter polarimetric instruments. To bring a comprehensive understanding of the grain alignment mechanisms by exploring different environments, a proper study in the dense star-forming regions is highly important. In this work, we investigate the grain alignment mechanisms in a massive, quiescent and filamentary Infrared Dark Cloud G16.96+0.27 using thermal dust polarization observation with JCMT/POL-2 at 850 µm. We observe the so-called phenomenon of polarization hole attributed to the decrease in polarization fraction in the denser regions associated with higher total emission intensity and gas density. We explore for any significant contribution of magnetic field tangling to cause the observed polarization hole. We find that the B-field tangling effect is minimal and the dominant factor to cause the polarization hole is the reduction in grain alignment efficiency in the denser regions, consistent with the RAT alignment mechanism. To test RAT theory, we calculate various quantities describing grain alignment, including minimum size of aligned grains, magnetic and magnetic relaxation parameter, and show that RAT mechanism can explain the observational data. Our study also reveals the potential evidence that the observed high polarization fractions of above 10% in the outer regions of the filament could be explained by the combined effect of the enhanced magnetic relaxation strength and suprathermal rotation of grains by RATs, supporting the magnetically-enhanced RAT (M-RAT) alignment mechanism. To bring a comprehensive analysis, we perform a detailed modeling of thermal dust polarization using DustPOL-py based on M-RAT theory and find that the modeling could successfully reproduce the observational data when maximum grain size is around 0.45 μm accompanied by an increase in the grain axial ratio, along with the consideration of variations in the magnetic field's inclination angle with the line of sight. Our modeling provides implications for anisotropic grain growth in the denser regions of the filament, and also provides insight into the evolution of the 3D B-field morphology over the filament. (This work has been published in ApJS.)

Modeling dust for simulated galaxies at Cosmic Noon

Damle Mitali[1]

[1]*New York University Abu Dhabi, UAE*

The galaxy luminosity function, i.e. the galaxy count per brightness/magnitude bin, is a crucial probe of star formation rate evolution across cosmic times. At Cosmic Noon ($z \sim$ 2-4), galaxies not only have had enough time to accumulate dust, but they also see a peak in their star formation rates. These two aspects together mean that dust present in the star-forming regions of these galaxies can substantially absorb the UV radiation emitted by young and massive stars of this galaxy. Numerical simulations are a great tool to obtain the galaxy luminosity function at various cosmic epochs but the effects of dust have to be delicately and faithfully handled if we want to focus our efforts on galaxies in the Cosmic Noon.

To make this possible, I use data from the HELLO suite of cosmological zoom-in simulations and post-process cosmic dust via the SKIRT radiative transfer code. These simulations contains hundreds of sub-Milky Way and Milky Way mass galaxies between $z \sim$ 2-4. Assuming an observationally motivated dust-to-gas ratio, a dedicated SED library for young stellar populations and a chemical composition for the dust, I model cosmic dust in the simulated galaxies and forward model them through a pipeline to mimic JWST observations. I also study the effects of galactic viewing angle on the dust attenuation and energy balance. Finally, I present some motivation to adopt an updated SED library for young stellar populations that promises to improve the match with observed galaxy colors.

Bursty star formation prevents significant dust survival in radiation-hydrodynamical simulations of the first galaxies

Enrico Garaldi[1,2,3], Filip Popovic[4], Rahul Kannan[4], Aaron Smith[5], Ewald Puchwein[6], Laura Keating[7], Mark Vogelsberger[8,9], Lars Hernquist[10], William McClymont[11,12], Xuejian Shen[8], Naoki Yoshida[13,14,1], Kentaro Nagamine[15,16,1,17,18], Sandro Tacchella[11,12]

[1]Kavli IPMU (WPI), UTIAS, The University of Tokyo, Kashiwa, Chiba 277-8583, Japan, [2]Center for Data-Driven Discovery, Kavli IPMU (WPI), UTIAS, The University of Tokyo, Kashiwa, Chiba 277-8583, Japan, [3]Institute for Fundamental Physics of the Universe, via Beirut 2, 34151 Trieste, Italy, [4]Department of Physics and Astronomy, York University, 4700 Keele Street, Toronto, ON M3J 1P3, Canada, [5]Department of Physics, The University of Texas at Dallas, Richardson, Texas 75080, USA, [6]Leibniz-Institut für Astrophysik Potsdam, An der Sternwarte 16, 14482 Potsdam, Germany, [7]Institute for Astronomy, University of Edinburgh, Blackford Hill, Edinburgh, EH9 3HJ, UK, [8]Department of Physics, Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA, [9]Fachbereich Physik, Philipps Universität Marburg, D-35032 Marburg, Germany, [10]Center for Astrophysics | Harvard & Smithsonian, 60 Garden Street, Cambridge, MA 02138, USA, [11]Kavli Institute for Cosmology, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK, [12]Cavendish Laboratory, University of Cambridge, 19 JJ Thomson Avenue, Cambridge CB3 0HE, UK, [13]Department of Physics, School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan, [14]Research Center for the Early Universe, School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan, [15]Theoretical Astrophysics, Department of Earth and Space Science, The University of Osaka, 1-1 Machikaneyama, Toyonaka, Osaka 560-0043, Japan, [16]Theoretical Joint Research, Forefront Research Center, Graduate School of Science, The University of Osaka, Toyonaka, Osaka 560-0043, Japan, [17]Department of Physics & Astronomy, University of Nevada, Las Vegas, 4505 S. Maryland Pkwy, Las Vegas, NV 89154-4002, USA, [18]Nevada Center for Astrophysics, University of Nevada, Las Vegas, 4505 S. Maryland Pkwy, Las Vegas, NV 89154-4002, USA

Recent JWST observations revealed a much larger number of UV bright galaxies at z> 10 than previously expected. A common explanation is to assume that star formation was much more bursty than assumed in these systems. I will present a systematic analysis of the dust properties in the Thesan-Zoom simulations, the only suite of radiation-hydrodynamical zoom-in simulations that naturally produces bursty star formation histories. Thesan-Zoom self-consistently models a spatially- and time-varying background UV field, a multi-phase ISM, and dust formation, growth, and destruction coupled to radiative transfer.

We find that dust is strongly time-variable and tightly linked to bursty star formation: during starbursts, young stars heat dust, and stellar feedback rapidly destroys and ejects dust from star-forming regions, while in post-burst phases low gas densities suppress efficient regrowth. This cycle yields short-lived IR-bright phases and longer dust-poor phases, naturally producing a correlation between dust temperature and distance from the star-forming main sequence. The predicted attenuation at 1500Å is very low compared to observations, although assuming that unresolved birth-cloud dust can reconcile this measurement without significantly altering global dust scaling relations.

Interestingly, the simulated galaxies reproduce the observed trends of dust-to-gas and dust-to-metal ratios with gas metallicity, while showing a dust deficit at high specific star-formation rates. They also broadly match observed dust temperatures and UV-IR spatial offsets, although their origin is physical dust displacement rather than obscured star formation.

These results imply that bursty star formation is not compatible with large dust masses over a significant fraction of cosmic time, at odds with the popular explanation of bursty star formation as the reason for the large number of UV-bright galaxies observed by JWST. Thus dust provides a sensitive diagnostic of feedback and ISM physics in early galaxies. Our results also have imply that future surveys targeting dust at z>8 (e.g., ALMA-PHOENIX) are key to unveil the physics of the first galaxies.