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.

Acknowledgments: This work was supported by the Dust2Planets ERC-ADG-101053020 project DUST2PLANET. We also thanks Yves Marrocchi (CRPG, Nancy) for the X-ray tomography and the analogs morphology.

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.