Large particles in cosmic dust

Ludmilla Kolokolova[1], Johannes Markkanen[2], Daniel Mackowski[3], Oleksandra Ivanova[4], Vera Rosenbush[5]

[1]University of Maryland, USA, [2]Institut für Geophysik und Extraterrestrische Physik, TU Braunschweig, Germany, [3]Auburn University, AL, USA, [4]Astronomical Institute of the Slovak Academy of Sciences, Slovakia, [5]Main Astronomical Observatory of the National Academy of Sciences of Ukraine, Kyiv, Ukraine

Recent observations of different dusty objects (disks, comets, active asteroids) show an abundance of dust particles in the size range of hundreds of microns and even millimeters. Evidence of this is in situ data for comets and asteroids; also, they show unusual photometric and polarimetric properties, specifically, their phase curves are very different from those considered typical for cosmic dust. Laboratory measurements of large particles (Munoz et al., Astroph. J. Suppl. Ser., 247, 19, 2020) showed that the unusual phase curves can be characteristics of mm-size particles. However, the most popular computational techniques that model light scattering by dust particles (e.g., T-matrix, DDA) are not capable to simulate the photopolarimetric properties of particles of size larger than 10-20 microns as the computations for such particles are too demanding to the computer resources and cannot be handled even with modern supercomputer clusters.

In this presentation, we consider new techniques recently developed to model light scattering by large particles to overcome the computational problems. Specifically, we describe a multi-sphere superposition method for large-scale systems based on an accelerated T-matrix algorithm (Mackowski and Kolokolova, JQSRT, 287, 108221, 2022) and its results that allow seeing some regularities in light scattering by large aggregates depending on their material, number, and size of spheres. We will also introduce the Fast superposition T-matrix method (FaSTMM) which uses the fast multipole method (FMM) to speed up the superposition T-matrix solution (Markkanen and Yuffa, JQSRT, 189, 181, 2017). The FMM forms monomer groups hierarchically and computes electromagnetic interactions between the separate groups at each level of the hierarchy. FaSTMM code is available at https://wiki.helsinki.fi/display/PSR/. FaSTMM was successfully used to model large dust particles in the coma of comet 67P/Churyumov-Gerasimenko and could successfully reproduce its unusual photometric phase curve (Markkanen and Agarwal, Astron. Astrophys. 631, A164, 2019). It also successfully reproduces the photometric and polarimetric phase curves observed for the disk HR 4796a (Arriaga et al. Astron. J., 160.2, 2020).

We will present photopolarimetric observations of comet C/2014 B1 (Schwartz) at 9.6 au and show that the FaSTMM simulations of its polarization, color, and their change within the coma require particles of size up to several millimeters.