Light scattering by dust particles in the innermost coma of comet 67P/Churyumov–Gerasimenko: synthetic images from numerical simulations in comparison with Rosetta OSIRIS data

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During two years, from August 2014 – September 2016, ESA's Rosetta spacecraft followed comet 67P/Churyumov–Gerasimenko (hereafter 67P) along its orbit and collected a vast amount of data about both the nucleus and the innermost coma with a large set of scientific instruments.

Dust in the innermost coma of 67P is visible through sunlight scattered by dust particles, which was caught on the images of Rosetta's scientific Optical, Spectroscopic, and Infrared Remote Imaging System (OSIRIS) cameras [1]. The dust in the innermost coma is dragged away from the surface by outgassing from sublimating ices on the nucleus and the motion of the dust is coupled, although in a complex way, to the motion of the gas. The OSIRIS image data set offers therefore the unique opportunity to study global gas and dust dynamics and dust grain properties in the innermost coma of comet 67P through sunlight scattered in the coma itself. However, the inverse problem of determining the properties of scattering particles just by the field of scattered light is extremely challenging and complicated to solve unambiguously. Our approach is to numerically model the gas and dust dynamics in the coma around the comet in full 3D and then apply a Mie scattering model to produce synthetic images that can be directly compared to the original data from OSIRIS observations [2]. In our computer model we simulate the dynamic behaviour of 40 discrete dust size bins and weight our results according to a power law function of the type $n(r_d) \sim r_d^{-b}$, with n being the number density, r_d the radius of the dust particles and b the power law exponent determining the steepness of the particle size distribution. Our simulated dust sizes range between $r_d = 8$ nm – 0.3 mm corresponding to size parameters of $0.08 < x < 3265$ ($x = 2\pi r_d/\lambda$, with λ being the wavelength of the incident light). This method allows us to test different combinations of input parameters, governing for example the particle size distribution, to determine the most probable set of parameters that best describe the observations.

To study the dynamical behaviour of gas and dust in the innermost coma of 67P we analyse azimuthally averaged pixel column brightnesses with increasing distance from the nucleus, the so-called "azimuthal average profiles" [3]. The column brightness from scattered light by dust particles in the coma is proportional to the integrated number density along the camera line-of-sight for an optically thin coma. Deviations of real data results from simplified model predictions of dust number densities are therefore a direct sign for additional physical processes engaged in the dynamical behaviour of gas and dust not accounted for in the model and hence an interesting field of research.

In our recent studies we have focused on the possibility to explain deviations from simulation results to OSIRIS data especially prominent on the night side of the coma with the presence of large particles. Large particles can be captured in gravitationally bound orbits or on long ballistic trajectories around the nucleus and have been observed in the vicinity of 67P (e.g., [4]). Here we explore how to incorporate large particle scattering in our model and study its effects on the azimuthal average profile in combination with the simulated main bulk of the dust coma that is scattering sunlight in the Mie regime.

In this talk we will portray how we use numerical simulation of gas and dust dynamics combined with a Mie particle scattering model to calculate synthetic images in spectral radiance which can be compared directly to OSIRIS images. We will also shortly discuss our latest results regarding the deviations between simulated data and observations and explain our findings and the implications thereof.

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