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Simulation of the radiance from a cometary nucleus coma. Application to Rosetta-VIRTIS observations of 67P Churyumov-Gerasimenko.

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Abstract

The topic of this work is to describe the simulation we are performing to characterize the radiance from a coma containing dusty and icy grains and gas. This study is in support of the definition of the operations of the VIRTIS (Visible and Infrared Thermal Imaging Spectrometer) instrument, an imaging spectrometer onboard of the Rosetta spacecraft working in the spectral range of 0.25-5 μm. In a later phase the model shall be used to retrieve abundances of grains and gases from the radiance measured by the VIRTIS instrument in the nucleus cometary environment. In fact, in the VIRTIS team we have initiated and effort to simulate the dust radiance using several radiative transfer models (see Blecka et al, this issue).

Introduction

Cometary coma spectra are strongly affected by the processes involving dust and ice grains present in the coma and by their properties. The solar light illuminates the grains that can scatter, absorb and emit radiation. The reflected and the emitted radiation, has been modeled using a Monte-Carlo method realized in the code SCATRD 06.10 (Vasilyev et al., 2006). This code calculate the multiply scattered solar radiation for each wavelength in the VIRTIS spectral range. The code assume a coma in spherical geometry and we can simulate limb observations as well as nadir observations (for various zenith angles). This allows us to understand and define the dust and ice properties of Churymov-Gerasimenko comet in the VIRTIS spectral range computed at different distances from the sun and with different dust grains models (size distribution, composition and vertical distribution). The gases composition, spatial distribution and coma properties have been retrieved from the Inner Coma Environment Simulation tools (ICES) (http://ices.engin.umich.edu/). The synthetic spectra derived are presently used to forecast the signal expected at the instrument and to correctly plan the observations at the comet.

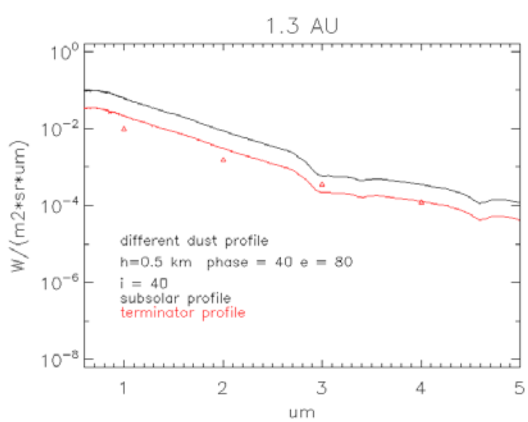
1. Radiative Transfer Model

The synthetic spectra were computed using the subroutine SCATRD_OFOS. This code calculate solar multiple scattering radiation monocromatic intensity in spherical geometry atmosphere specially for observation from orbit. Calculations are mainly based on Monte-Carlo method realized in the code SCATRD 06.10 (Vasilyev et al., 2006). In the current version the thermal radiation, non-LTE, refraction and polarization processes are not implemented. The spectra can be calculated in nadir and limb mode. The input of the code are:

1. The radial distribution of gases and dust as retrieved by ICES tool. We considered two different profiles: at the subsolar point and at the terminator and each profile is retrieved at 1.3 AU (case 1) and 3 AU (case 2)
2. Dust model: the optical parameters were calculated using Mie scattering. The dust is composed by titan tholin (Khare et al., 1993). We use a log normal size distribution with a r_{eff}=3 μm and σ_{eff}=10 μm. The dust density vertical profile is derived by ICES (Table 1) at the subsolar point and at the terminator.
3. Spectral grid: VIRTIS spectral grid
4. Solar Flux: Kurucz solar spectrum
5. Geometry of observations: limb mode

2. Model Results

In this section we show same model results. All spectra are computed in limb mode with a nucleus radius of 2km, a spacecraft distance of 100 km and a tangent altitude (h) above the surface about 0.50 km. Regarding the dust content, Afρ is 100 at 1. 3 AU and 10 at 3 AU (taken from ICES). Figure 1 shows the simulations as obtained with a vertical density profile a the subsolar point and at the terminator at two heliocentric distances. The dust content at the subsolar point is more than the one at the terminator. This behaviour well represents the dust distribution around the surface that is an asymmetric narrow structure elongated toward the sun direction. In the simulation, the radiance increases when the dust content increases, because, in an optically thin coma, the scattering is more efficiently. The red triangles in the figures are the preliminary analytical estimate of coma intensity computed by Fink (Fink and Rubin, 2012). The intensity contribution is derived looking just past the nucleus from a spacecraft orbiting 12 km from the comet center and a line of sight with miss distance of 0.1 km. These intensities actually do not depend on any complex Afρ model calculation. They simply take an Afρ observed from the ground which results in a certain intensity and then scales that to the column density to be observed by Virtis, compared to the column density observed from the ground (Afρ ~ 370 r^{-4} with r= heliocentric distance). The comparison between the simulations and the theoretical values shows a good agreement only in the case at 1.3 AU, but at 3 AU the theoretical values are lower. This is because the dust content can be better defined at 1.3 AU respect to at 3AU and in this last case the dust particle densities in the ICES tool are probably too high.



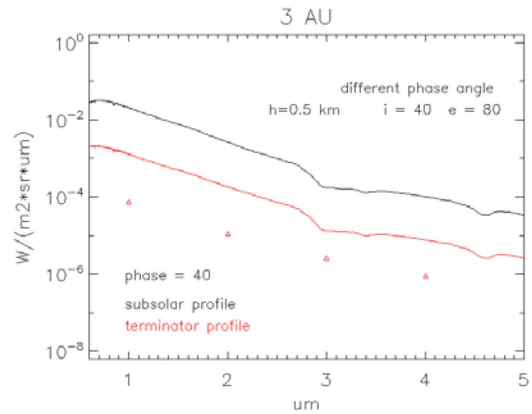


Figure 1: Top panel represents the synthetic spectra computed with two different dust profile retrieved at 1.3 AU. The bottom panel at 3AU

3. Conclusions

The results show that the principal properties that determine the observed spectral shapes are the composition and the grain size. They show, also, a remarkable contribution of the dust coma to the observed radiance: the dust content affects the continuum and increases the radiance in the visible channel. In particular demonstrate that the Afρ is a crucial parameter to characterize the radiance from a coma. The simulated radiances will be fed to the VIRTIS instrument simulator to determine the best operative modes and conditions to quantitatively characterize the dust in the 67P/Churyumov-Gerasimenko coma.

Acknowledgements

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References

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