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3D analysis of spatial resolution of MIRO/Rosetta measurements

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Abstract

Based on a detailed 3D nucleus shape model, illumination conditions and the pointing information of the viewing geometry, we evaluate the relative contribution of water density originating from facets directly inside the MIRO beam as well outside of the beam as a function of distance along the MIRO line-of-sight. In this work we demonstrate that despite the rather small MIRO field-of-view, there is only a small fraction of molecules that originate from facets within the MIRO beam. This results provide insight into why the MIRO measurements cannot directly discriminate active from non-active regions. Furthermore, our results suggest that the beam averaged solar incidence angle, local time and mean normal vectors are not necessary related to molecules released from the surface area within the MIRO beam. Finally, these results also indicate why the 1D spherical Haser model can be applied with relative high success for analyzing the MIRO data (and generally any Rosetta measurements).

1. Introduction

The Microwave Instrument for the Rosetta Orbiter (MIRO) instrument was one of the four remote sensing instruments on board Rosetta (Gulkis et al. 2015). The individual spectral line shapes determined by MIRO carry information about the variation in expansion velocity, temperature structure (especially for optically thick transition), and density profile along the line-of-sight (LOS). Therefore, understanding from where the water molecules inside the MIRO field-of-view originate is crucial for understanding the MIRO derived coma production rates and their relation to the nucleus characteristics.

In this work we considered both the nadir and limb geometry observations to investigate these relationships in order to address the following questions: 1) can MIRO accurately discriminate active from non-active regions on the nucleus (and at which spatial scales), 2) how well local illumination (e.g. local time) evaluated from facets within the beam reflect the most likely source of detected gas molecules in the MIRO beam, and 3) how well can the 1D spherical model represent the 3D nature of the water source distribution on the surface.

2. Modeling

The shape of the 67P nucleus is approximated with a 3D digital terrain model SHAP7 with 125,000 facets (Preusker et al. 2017) with sufficient resolution to obtain accurate information on the distribution of all facets contributing into the MIRO beam for a given viewing geometry at a typical spacecraft distance of 100 km. We assume a collisionless flow starting with illumination driven outgassing at each facet, accounting for topographical obstacles in a geometrical fashion.

In our simulations, grid points along MIRO LOS with distance of 2.5, 5, and 20 km to nucleus surface are studied to investigate the water molecules contributed from different region of nucleus. These grids points are selected on these physical principles to obtain a good understanding how the MIRO measurement is affected differently along the LOS.

3. Simulation Results

Fig. 1 shows the simulation results for a nadir viewing geometry. The MIRO beam is positioned on the small lobe nearly at the terminator (white circle in all panels). The contribution of different facets at grid point at 2.5~km distance from the surface is shown in panel B. It is clear that in this case the contributions are clearly "local", and most of the molecules come from area just around the FOV. However, at 5~km (panel C) and finally at 20~km distance (panel D) the water molecules may come from extended and different regions (significant contributions can even come from the other lobe). The calculated in-beam/out-of-beam ratio of water column density is much smaller than 1%. This is a clear example that much of the water density within the MIRO beam does not originate at the surface facets withing the FOV. It also means that beam averaged illumination angle may not be correlated with the observed column density, hence carries limited useful information.

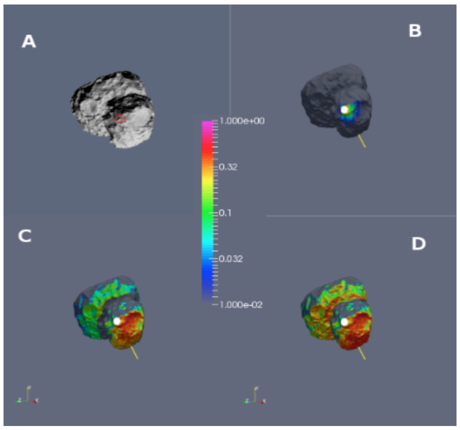

Figure 1: Case 2: illumination condition is shown in panel A). Panels B, C, D show surface distributions of H_2O density originating from different facets into the MIRO LOS at selected grid points 2.5, 5, and 20~km from the surface (respectively).

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