MILLIMETER AND SUBMILLIMETER OBSERVATIONS OF COMET 67P/C-G WITH THE MIRO INSTRUMENT.

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Introduction: The Microwave Instrument for the Rosetta Orbiter (MIRO) makes millimeter and submillimeter observations of the nucleus and coma of Rosetta's target comet 67P/Churyumov-Gerasimenko (hereafter referred to as C-G). This presentation summarizes the instrument, its observations, and some of the high-level science objectives we are working towards. Many details will be presented in companion presentations by other team members. See also [1].

MIRO makes continuum measurements at 190 and 563 GHz (1.6 and 0.5 mm) to study the thermal and electrical properties of the nucleus near-surface (depths from ~1 millimeter to 10 centimeters). MIRO also makes spectroscopic measurements of 8 lines near 560 GHz (H_2O, $H_2{}^{17}O$, $H_2{}^{18}O$, CO, NH_3, and three CH_3OH transitions). The abundance, gas velocity, and temperature of those species are measured as functions of time and location.

To interpret its data, the MIRO team has developed sophisticated nucleus and coma models, including the ability to study heat and gas transport within the nucleus and non-LTE processes in the coma. Our goal is to understand the dominant physical processes that create the coupled nucleus-coma system.

In addition to its scientific uses, data from the MIRO instrument is being used operationally to help predict gas drag on the spacecraft while near the comet (necessary to design spacecraft trajectories).

MIRO Goals and Objectives: The highest-level goals of the MIRO instrument are to understand the early phases of Solar System formation and to understand the origin and evolution of comets. Our specific objectives at Comet C-G are:

- Characterize the abundance of major volatile species and key isotopic ratios.
- Study the processes controlling outgassing in the surface layer of the nucleus.
- Study processes controlling the development of the inner coma.
- Globally characterize the nucleus subsurface to depths of a few centimeters.

Spectroscopic Measurements: MIRO has clearly detected water in the coma since 6 June 2014. We have seen the total water production rate increase as the comet approaches the Sun; in early June (3.9 AU from the Sun) it was approximately $1x10^{25}$ molecules/sec, and by early October it was 6x higher (3.3 AU from the Sun). Water production varies both with location on the nucleus and time-of-day, with maximum outgassing rates associated with the "neck" region of the nucleus being illuminated by the Sun. Gas column abundances drop by an order of magnitude as our line-of-sight moves towards un-illuminated regions. Since water production varies with time-of-day, the sublimating ice must be within the layer of the nucleus experiencing diurnal temperature variations. We estimate it to be within a couple centimeters of the surface. At the time of this writing, H_2O and $H_2{}^{18}O$ have been clearly measured by MIRO, with detections of $H_2{}^{17}O$ and CH_3OH. Our analysis of spectral data uses a non-LTE coma model, accounting for the boundary layer at the nucleus, regions dominated by gas collisions, electron collisions, and radiative processes.

Continuum Measurements: MIRO's continuum channels have detected the nucleus since 19 July 2014, and it has been spatially resolved since early August. We clearly see diurnal, seasonal, and vertical temperature variations [2]. Daytime temperatures in our submillimeter channel peak in the early afternoon while millimeter temperatures (sensing ~3x deeper) peak slightly later and with a lower amplitude. This is expected as the thermal wave propagates into the subsurface. Similarly, temperatures in the Northern Hemisphere (summer) are consistently higher than those in the Southern (winter). Initial results are consistent with a very low thermal inertia surface (5 to 40 $J/(K\ m^2\ s^{0.5})$), as expected for a porous, dusty layer. This extremely low inertia---solid rock or ice would have values ~2000---means vertical temperature gradients are also large, with daytime physical temperatures dropping by ~50 K between the surface and 1 cm down. Generally we find the lowest thermal inertia values (< 20) at equatorial and northern latitudes. The higher thermal inertia values are seen at southern latitudes. MIRO has developed a 3-D nucleus thermal/radiative model to assist in observation planning and interpretation of these continuum measurements.

References: [1] Gulkis S. et al. (2015) *Science,* accepted for publication. [2] Keihm S. et al. (2014) *AGU Poster P41C-3946.*

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