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Millimetric thermal emission from the two faces of Iapetus

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1. Introduction

Saturn's icy satellites, which are in synchronous rotation around Saturn, often have a different albedo on their leading and trailing sides, which interact differently with their orbital environment and, in particular, with Saturn's dusty rings. This is especially true for Iapetus, which presents the largest albedo dichotomy in the Solar System. Indeed, a dark material covers the leading side as it travels through the diffuse Phoebe ring [1], and thermal segregation further enhances the resulting albedo contrast [2]. This dichotomy, obvious in the visible, has also been observed by the Cassini spacecraft in the far-infrared with the Composite Infrared Spectrometer (CIRS, 7 µm–1 mm) [3] and at 2.2 cm with Cassini Radar/Radiometer [4].

Ries (2012) partially bridged the gap between CIRS and Cassini radiometry by observing Iapetus' two faces at wavelengths varying from 3 to 10.8 mm [5]. He observed that, while the trailing is less emissive than the leading side, it also shows a large absorption feature likely centered near 3 mm. He attributed this feature to diffuse scattering by 1–2-mm ice particles, based on the semi-empirical Microwave Emission Model for Layered Snowpacks (MEMLS) [6], developed for and tested on snow on Earth. He predicted that observations below 3 mm should show a progressive drop of the emissivity with wavelength.

To complete the missing part of Iapetus' microwave spectrum, we observed the two faces of Iapetus at 1.2 and 2.0 mm using the New IRAM (Institut de RadioAstronomie Millimétrique) Kids Array (NIKA2) mounted on the IRAM-30 m telescope. On Iapetus' trailing side, we confirm the prediction of Ries (2012). On the leading side, however, we find that the brightness temperature is much lower at 1.2 and 2.0 mm than observed at 3 mm by Ries (2012).

2. Methods

Using the NIKA2 millimetric camera, we imaged a field of view centered on Saturn and extending to slightly beyond the position of Iapetus, 200" to 500" away from Saturn depending on the date (e.g., Fig. 1). While secondary calibrators were observed before or after each Iapetus observation, it is preferable to calibrate the data on Titan. Indeed, its spectrum is better known (<5% uncertainty), and more importantly it is observed at the same time and under the same atmospheric conditions as Iapetus. However, the measurement of both Titan's and Iapetus's flux density is complicated by the proximity of Saturn, which is over 10 000 times brighter than Iapetus (Fig. 1). Simply subtracting the beam pattern convolved with Saturn is not straightforward as it changes with multiple parameters such as time, elevation, and atmospheric conditions. Thus our best results are obtained when both Titan and Iapetus are near maximum elongation.

3. Preliminary results

Given weather and telescope scheduling constraints, we were able to observe Iapetus' leading (March 2019), trailing (Feb. 2019) and anti-Saturn/trailing (May 2018) sides. For our preliminary analysis, we simply averaged all daily 2-hour-long observations and derived the brightness temperature of Iapetus from the measured flux density, after calibration on Titan.

Table 1: Iapetus's brightness temperatures

Date	Longitude (°E)	1.2-mm T_b (K)	2.0-mm T_b (K)
28 May 2018	203	65±7	69±3
29 May 2018	208	62±8	60±4
14 Feb 2019	305	63±14	55±4
15 Feb 2019	310	63±12	58±4
12 Mar 2019	61	72±5	81±3
20 Mar 2019	96	71±9	76±4
21 Mar 2019	101	74±7	82±4

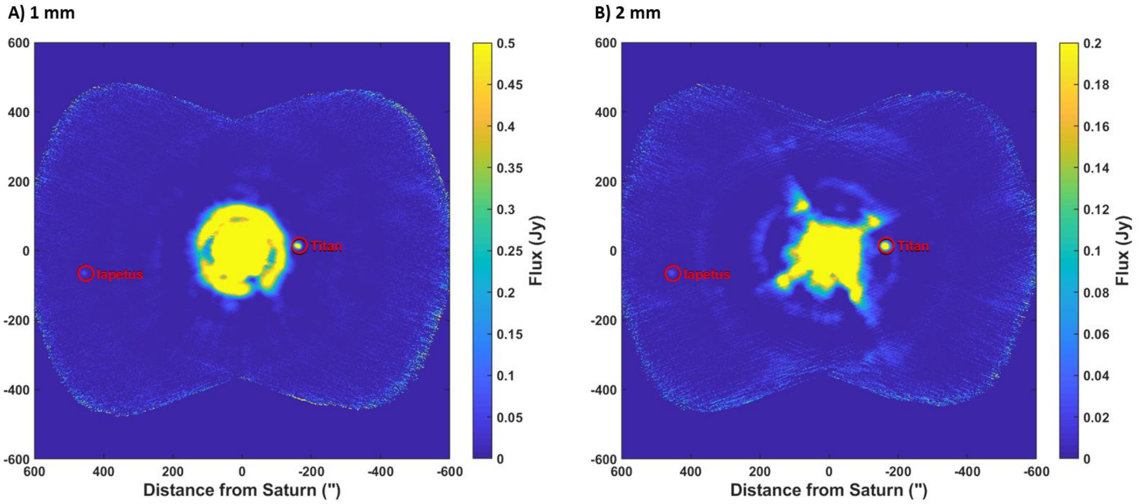

Figure 1: NIKA2 images of the Saturn system on March 21, 2019, averaged over all 2.5 hours of observations. A) 1 mm data. B) 2 mm data. The colorbar is scaled so that both Titan and Iapetus are visible, and their positions are circled in red. Both images are dominated by the beam pattern convolved with Saturn. At this date, Iapetus was near maximum elongation and showed its leading hemisphere to Earth.

4. Interpretations

We plot our 1.2- and 2.0-mm brightness temperatures in Fig. 2, with those found by Ries (2012), Hagen et al. (2014) [7] and Le Gall et al. (2014). Our 1.2-mm results are within error of the 1.3-mm data of Hagen et al. (2014). On the trailing side, the observed brightness temperatures follow the trend predicted by Ries (2012), slowly decreasing with wavelength. This is consistent with the interpretation of diffuse scattering by 1–2-mm ice particles on this hemisphere which has a composition dominated by water ice.

On the leading side, we find that the brightness temperature peaks at 3 mm. This may indicate that the subsurface properties change very quickly with depth in the top few cm. The layers sensed at 1 mm may be less emissive (because of a higher porosity and/or a higher concentration in volatiles) than the deeper layers probed at 2 mm.

Further analysis will include comparison with a thermal model to calculate the effective temperature, and therefore the emissivity, of Iapetus's hemispheres. We will also use the MEMLS model using the new data to further constrain grain size on the trailing side. We are running an observation campaign to complete Iapetus's microwave spectrum using JVLA and ALMA.

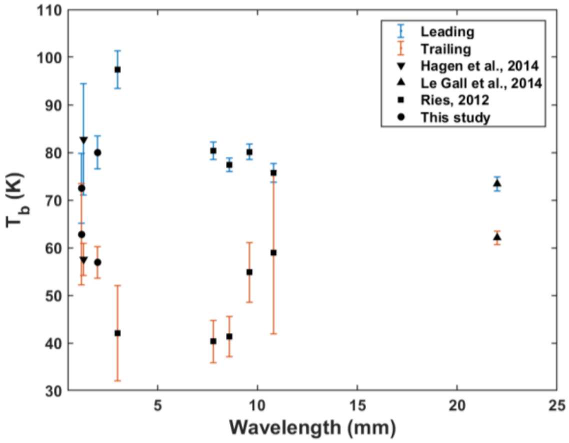

Figure 2: Updated brightness temperatures of Iapetus' leading and trailing sides.

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