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Iapetus's SED from 3-11 mm

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Abstract

Several observations were made of Saturn's moon Iapetus using the NRAO Green Bank Telescope (GBT) using the MUSTANG W-band (3.3mm) bolometer and the Ka-band (7.5-11mm) CCB instrument in order to constrain its spectral energy distribution (SED). Observations show a severe decrement in brightness temperature at some wavelengths, but the location of the decrement shifts depending on the sub-observer longitude.

1. Introduction

While the optical surface of Iapetus has been extensively studied and mapped, the thermal surface has not. Snapshots of the thermal surface have been previously obtained by Cassini (Howett et al., 2010), but these snapshots are of limited utility in determining a thermal light-curve for Iapetus because there have only been two fly-bys of Iapetus which were very short compared to the orbital and rotation period of Iapetus (80 days). Due to Iapetus's long rotation period, the thermal skin depth is of the order a few meters, and thus substantially deeper than the depths probed by high-frequency radio observations. Thus a thermal light-curve should be obtainable from the ground using radio telescopes.

2. Data Acquisition

We use the Green Bank Telescope to obtain continuum observations of Iapetus at six different locations in Iapetus' orbit/rotation using the Caltech Continuum Backend (CCB) instrument, which simultaneously measures flux density in four evenly-spaced bands covering 26.5-40 GHz (11.3-7.5 mm). At elongation (i.e. when either the leading or trailing side is directly facing Earth), we also obtained observations with the MUSTANG instsrument, a bolometer array operating at 90 GHz (3.3 mm) on the GBT.

The CCB observations were challenging because of the brightness contrast between Saturn and Iapetus combined with the large beamsize (22"). As a result, additional off-source data were acquired in order to make sure our detections were not influenced by sidelobes crossing Saturn. We observed the bright quasar 3C286 on every night to use as our calibrator and occasionally observed an additional calibrator to ensure that our calibration was accurate. No problems with sidelobes or calibrators were detected.

3. Results

Some of our results are shown in Figure 1 showing brightness temperature vs. wavelength for the leading and trailing hemispheres. The expected surface temperature for Iapetus is about 100K. Brightness temperatures are used for comparison since they are distance-independent and provide a direct comparison relative to a blackbody. The trailing SED shows a profound minima centered around 8.5 mm on the trailing side.

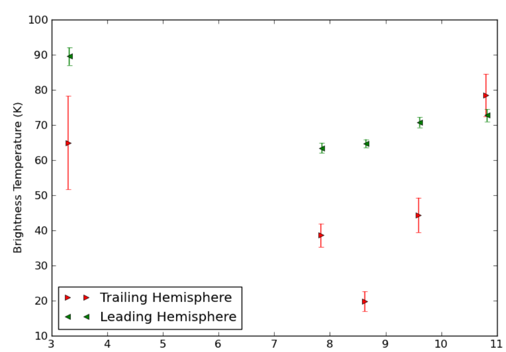

Figure 1: This figure shows the observed SED of Iapetus for the leading and trailing hemispheres.

The cause of this trough may be due to scattering off of $\sim$650μm sized particles. The extreme depth of the trough may be due to a highly porous material on the trailing side. However, this scattering effect is stronger than previously observed scattering effects seen in terrestrial snow and ice formations (Mätzler, 1994), asteroids (Redman et al., 1992), or even in other icy satellites such as Enceladus (Ostro et al., 2006) or Europa (Muhleman and Berge, 1991).

The leading hemisphere does not appear to show any strong scattering effects. However, the observed brightness temperature at Ka-band is consistent with a thermal depth effect, but with substantially higher than normal transparency transparency (500 λ vs a more typical 20 λ (Mitchell and de Pater, 1994). This deeper penetration depth could be accounted for with fairly pure water ice.

Some observations at intermediate phases show a rise in brightness temperature in the middle of the Ka-band ($\sim$9 mm) and a dropoff to either side of the peak. This pattern may indicate the presence of multiple populations of scatterers.

Plain thermal lightcurve effects can be ruled out in all cases as thermal variation is expected to be less than 20K peak to trough based on previous thermal models from the Cassini spacecraft (Howett et al., 2010). Furthermore, normal surface thermal variations should not show a strong wavelength dependence.

Iapetus is well-known for its stark albedo dichotomy in the optical, but these observations reveal that its millimeter and centimeter wave emission show just as much variation.

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