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Observing Saturn's Rings in the Microwave with Cassini

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Abstract

We will present an initial calibration and analysis of microwave radiometry observation of Saturn's rings from the Cassini RADAR. Microwave emission is the ideal waveband for studying the scattering properties of cm-scale ring particles and for constraining the thermal emission from (possibly buried) rocky ring contaminants, which, unlike water ice, behave like blackbodies at cm- wavelengths.

1. Motivation

Passive microwave radiometry obtained from within the Saturn system has several advantages. While occultation observations are necessarily restricted to near-forward scattered light, scattered emission from Saturnshine (an extended source) can be viewed at a wide range of geometries. This varied geometry allows for a robust calculation of the particle size distribution, especially for cm-sized particles. As the sensitivity of radio occultation observations to the particle size distribution is typically limited to meter scale or greater particles [1], the ability to investigate sub-meter particles at a range of locations across the rings is novel. Similarly, the radiometer's inherent ability to constrain the distribution of non-icy contaminants through their microwave emission is especially useful. Despite these advantages, however, this dataset is yet to be analyzed due to the presence of substantial side lobe contributions that complicate the conversion between observed antenna temperature and target brightness temperature. We will present fully processed brightness temperature maps from Cassini radiometry scans obtained between December 2004 and October 2008.

2. Dataset

There are two categories of Cassini radiometry observations of Saturn's rings: low-resolution scans from a distance of ~25 Saturn radii (Figure 1B) and high-resolution scan from 5-8 Saturn radii (Figure 1A). The low-resolution scans were obtained at full linear polarization (repeat scans at 60° increments in polarization), ring opening angles ranging from -6° to 22°, and contain both ansae for asymmetry identification. The high-resolution scans were obtained along specific azimuths in three 60° increments in linear polarization and ring opening angles from 4° to 20°.

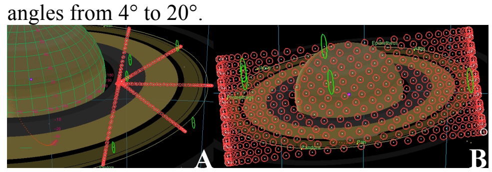

Figure 1 Example of Cassini RADAR high (A) and low (B) resolutions scans Saturn's rings. Red circles represent the size of the main beam while the green ellipses depict polarization.

3. Calibration & Sidelobe Removal

The Cassini RADAR radiometer is ideal for studying the scattering properties of cm-scale ring particles as well as constraining the magnitude of thermal emission generated by non-icy contaminants. However, this dataset is challenging to process—Saturn and its rings are extended targets and, most importantly, each measurement of antenna temperature (T_a) represents the convolution of the microwave brightness temperature (T_b) of the target with the radiometer's gain pattern (G). The gain pattern consists of a near-Gaussian main beam with a FWHM of 0.36° and extensive sidelobes that, on average, drop to -35 dB within 2° of beam center [2]. In order to obtain high-resolution measurements of T_b, the signal contribution from the sidelobes must be removed from each observation. In order to remove the sidelobe contributions, we employed an iterative adaptation of the sidelobe removal algorithms developed for Titan [2] and Saturn [3]. A more complex processing scheme was required because of the order of magnitude difference in brightness between Saturn (T_b~ 150 K) and its rings (T_b~ 15 K). Examples of the output of this processing are presented in Figures 2-4.

6. Initial Results

C-Ring brightness temperatures show the greatest variation with both scattering angle and ring opening angle (Fig. 3). The latter is consistent with the low microwave optical depth (τ ~ 0.2) suggested by RSS occultation experiments [4]. The factor of two brightness variation within the C-Ring, as observed at 22°, is also expected given the variation in cm-scale optical depth across the region [4,5], although it is unclear if this brightness variation can be explained using scattered Saturnshine alone. The C-Ring is also known to have compositional variations [6,7] that may result in a variable thermal emission component to the microwave brightness.

At low ring opening angles, the outer C-Ring shows a substantial reduction in brightness temperature at scattering angles approaching 90° (side scattering). This phenomenon was observed during both the low and high resolution scans and could be indicative of polarization dependence in the particle phase function.

Unlike the C-Ring, the microwave response of the B and A-Rings shows little variation with ring opening angle. This is consistent with their large microwave optical depths [4,8], suggesting that these ring regions are opaque to microwave radiation. The general reduction in microwave flux across the B and A rings is, to first order, consistent with the relative reduction in the solid angle of Saturn as seen from the ring plane. The variation in B-Ring microwave emission with scattering angle at high inclination, however, is surprisingly small and will be a focus of future analysis.

References

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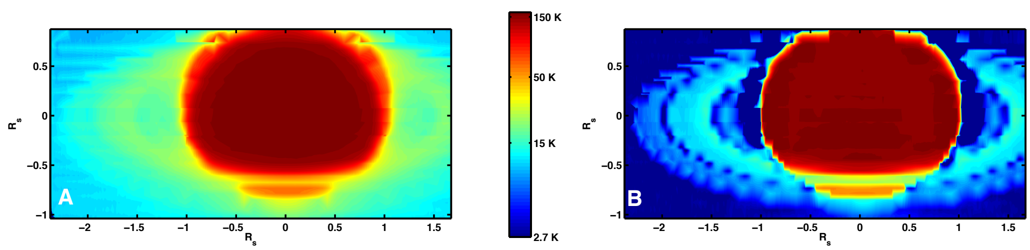

Figure 2: Calibrated antenna temperatures (A) and initially processed brightness temperatures for a low-resolution rings observation obtained on Sep. 12, 2006 at an inclination angle of 22°. Data are gridded in the plane perpendicular to the spacecraft-Saturn line that passes through Saturn's COM. Spatial position is given in units of Saturn radii

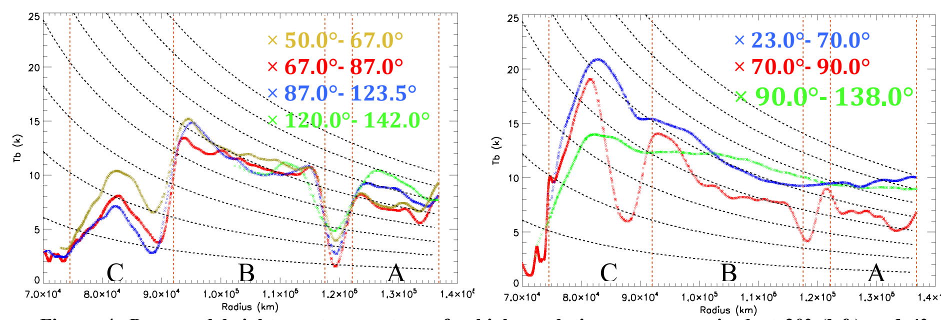

Figure 4: Processed brightness temperatures for high-resolutions scans acquired at 20° (left) and 4° (right) ring opening angles. Colors correspond to the scattering angles ranges of three discernable spoke scans. Black dashed lines represent contours of the incoming microwave flux for Saturn, which decreases with Saturn's solid angle. The positions of the D, C, B, and A ring boundaries are also shown .