EPSC Abstracts
Vol. 13, EPSC-DPS2019-1217-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Fine Scale Temperature Mapping of Saturn's Rings at the Shadow Boundary with Cassini CIRS

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1. Introduction

On 29 November 2016 Cassini flew past Titan for the 126th time. This encounter sent the spacecraft on a trajectory carrying it within 10,000 kilometers of Saturn's F ring. The subsequent Titan flyby of 22 April 2017 dropped the spacecraft's periapse location between Saturn's cloud tops and the planet's D ring. This geometry has proven beneficial for high-resolution rings studies because of both Cassini's proximity to the rings and the spacecraft's high elevation angle above the rings, which reduces the foreshortening that tends to degrade resolution in the ring plane. We report here on high spatial resolution observations made by Cassini's Composite Infrared Spectrometer (CIRS) of Saturn's main rings, specifically the B ring, during the F-ring and proximal orbits.

2. The CIRS Instrument

CIRS was a composite interferometer: a polarizing interferometer which covers the far infrared and a conventional Michelson interferometer that records photons at shorter wavelengths. Incoming infrared radiation incident on these interferometers was recorded by three separate detectors. These three infrared detectors covered a combined spectral range of 10 to 1400 cm^{-1} (1 mm down to 7 μm). We focus herein on data from Focal Plane 3 (FP3), which covers the 600 to 1100 cm^{-1} range (16 μm to 9 μm) [3]. (Focal Plane 1 spanned the 600 to 1100 cm^{-1} range (1 mm to 16 μm) and Focal Plane 4 (FP4) – 1100 to 1400 cm^{-1} range (9 μm to 7 μm) – handled the shortest wavelengths. The apodized spectral resolution could be commanded between 0.5 and 15 cm^{-1} [2].

The variable spectral resolution of the instrument was set to 15 cm^{-1} during the observations described herein. FP3 is not as well-suited to measuring ring temperatures as was Focal Plane 1 (FP1), but FP3 provided spatial resolution at scales over an order of magnitude finer than FP1. Whereas the circular FP1 field of view spanned 3.9 mrad, the ten square pixels at the focus of FP3 were 0.273 mrad along each side [2]. Thus, it is possible to map out thermal variations at finer scales with FP3 at the expense of accuracy in the retrieved temperatures.

3. Motivation

Determining how thermal inertia varies across the rings provides clues as to how physical properties of the rings, such as particle composition and regolith porosity, vary in the Saturn system. The thermal budget of the rings is dominated by the solar radiation absorbed by its constituent particles. When ring particles enter Saturn's shadow this source of energy is abruptly cut off. As such, Saturn's shadow provides a useful tool for probing the rings. Ferrari et al. [3] related an observed quadrupole asymmetry in CIRS azimuthal scans of the A ring to the well-known wake structures in that ring. They used that data to constrain the parameters in the wake model of Hedman *et al.* [4]. Morishima *et al.* [5] incorporated such a model into their thermal ring model to explain azimuthal temperature variations.

Such studies have all focused on broad trends in the temperature response to Saturn's shadow and have relied upon FP1 data. These azimuthal scans covered tens of degrees in ring longitude and are well-suited to constraining general ring properties. Other studies have shown that the rings' thermal behavior is complex and partly driven by their overall structure [1], [6]. While the post-eclipse temperature drop in Saturn's rings generally follows an exponential curve [3], [5], no detailed studies of the rings' immediate thermal response to being eclipsed have been done, as typical azimuthal FP1 scans do not have sufficient spatial resolution. Characterizing the details of the thermal response – thermal lag, any non-exponential behavior – has the potential to yield further insights into the nature of Saturn's rings.

4. Observations

To characterize the detailed, localized thermal response of the rings to passage into Saturn's shadow is and determine whether any transients could be resolved with a shorter scan at finer spatial resolution, we oriented the FP3 field of view azimuthally along the rings at two distinct radial locations in the B rings on revs 282 and 283. These observations consist of multiple stares at the rings to build up as long of an azimuthal temperature profile as allowed. The rev 282 observation targeted the center of the B3 region, at 107,500 km from Saturn; the rev 283 observation (see Fig. 1) was targeted at the center of the B1 region, at 96,000 km from Saturn.

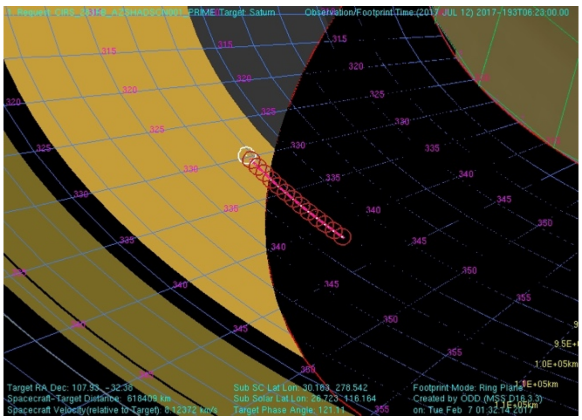

Figure 1: This schematic of the CIRS_283RB_AZSHADSCN001_PRIME observation shows the coverage across the boundary of Saturn's shadow. FP3 footprints are in pink; complementary coverage with FP1 is indicated by the red, circular fields of view. The geometry of the rev 282 observation is similar.

Each observation yielded thousands of mid-infrared spectra. For the rev 282 observation, the radial resolution achieved ranged from 240 to 300 km per pixel. Azimuthal resolution per pixel was between 0.17 and 0.19 degrees of longitude. The rev 283 observation was similar, having radial resolutions between 200 and 275 km and a longitudinal resolution between 0.20 and 0.22 degrees per pixel. Each azimuthal scan starts a couple of degrees on the dawn side of the ingress shadow boundary (*i.e.* where the ring is still illuminated) and extends another ten degrees into Saturn's shadow. In each case, a complementary scan with FP1 covering the same territory was implemented.

5. Summary

Two azimuthal scans of two distinct B ring regions were implemented with the CIRS instrument during the final months of the Cassini mission. Unlike other published observations to date, these azimuthal scans used CIRS' mid-infrared detector to achieve finer spatial resolution than ever before. These observations will allow us to determine the detailed response of the ring as its constituent particles cross into Saturn's shadow. We will report on these observations and the inferences they have for Saturn's B ring and the models that describe it.

Acknowledgements

This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA. Copyright 2019 California Institute of Technology. Government sponsorship acknowledged.

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