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Temperature variations of Saturn rings with viewing geometries from Prime to Equinox Cassini missions

E. A. Déau (1), L. J. Spilker (1), R. Morishima (1), S. Brooks (1), S. Pilorz (2), N. Altobelli (3) and the Cassini/CIRS Team
(1) Jet Propulsion Laboratory/NASA, Pasadena, CA, USA (2) SETI Institute 189 Bernardo Avenue, Suite 100 Mountain View CA 94043, USA (3) ESTEC/ESA Keplerlaan 3, Noordwijk Holland (estelle.deau@jpl.nasa.gov / Fax: +818-393-4495)

Abstract

After more than six years in orbit around Saturn, the Cassini Composite Infrared Spectrometer (CIRS) has acquired an extensive set of measurements of Saturn's main rings (A, B, C and Cassini Division) in the thermal infrared. Temperatures were retrieved for the lit and unlit rings over a variety of ring geometries that include phase angle, solar and spacecraft elevations and local time. We show that some of these parameters (solar and spacecraft elevations, phase angle) play a role in the temperature variations in the first order, while the others (ring and particle local time) produce second order effects. The results of this comparison will be presented.

1. Introduction

From our extensive set of infrared spectra (see an example in Fig.1) of Saturn's rings, temperatures (in Kelvin) were retrieved from simple blackbody fit [1].

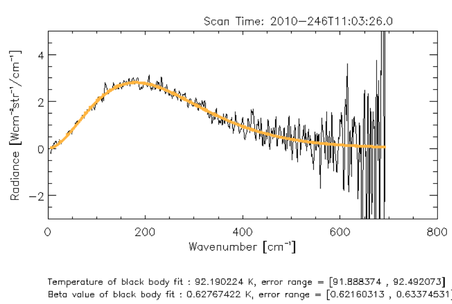

Figure 1: Example of CIRS thermal spectra and blackbody fit in order to obtain the effective temperature.

The temperatures for the lit and unlit rings cover a variety of ring geometries that include solar phase angle, spacecraft elevation and local hour angle. Temperatures were also retrieved at solar elevations |B'| ranging from 24 degrees to zero degrees at equinox. The equinox geometry is unique because Saturn heating dominates, contrasted to earlier in the prime mission when the preponderant heat source was the visible-wavelength solar energy. When the sun is the dominant heat source the ring temperature varies between the lit and unlit sides of the rings.

2. Temperature variations

2.1 with the solar elevation B'

When the CIRS temperatures are represented as a function of the solar elevation |B'|, a clear increase of T with |B'| is noticed. The rings are coldest at equinox when |B'|=0°. For a fixed value of solar elevation, one can see secondary effects caused by the spacecraft elevation and the phase angle (see also [2]). Only the B ring clearly exhibits a huge discrepancy between lit and unlit side data. The discrepancy is moderate for the A ring and not significant for the C ring.

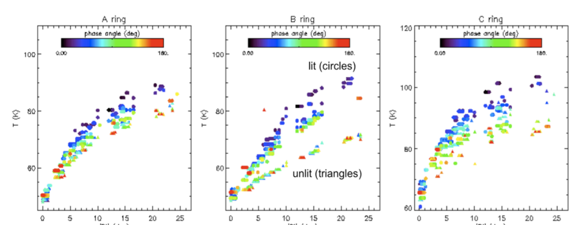

Figure 2 : Temperature vs solar elevation |B'| for the A, B and C rings.

2.2 with the solar local time

The variations of temperature with solar local time show very strong effects for the C ring for both lit and unlit sides. This is not the case for the B ring, where the time curves are flat for the unlit side. The phase angle explains well the scattering of the data for a fixed solar elevation.

2.3 with the particle local time

Another relevant geometrical parameter can be defined as the local time seen by a single particle in the rings: the particle local time. This value has been introduced to add information to the phase angle, which is unsigned. For the C ring, the temperature increases with particle local time up to 180° and then decreases with unlit side data. Similar variation is noted for the B ring, but only for the lit side data. For the unlit side, there are no temperature variations with particle local time for the thickest part of B ring.

2.4 with the phase angle

The thermal phase curves were already studied by [3,4] and exhibit a shape similar to optical phase curves. Near zero phase, a broad thermal surge can be observed. While lit and unlit C ring phase curves are well superimposed, B ring lit phase curves remain flat, contrary to the lit phase curves (see Fig. 3).

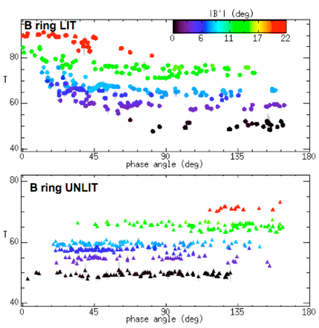

Figure 3: Temperature vs phase angle for the B ring. (Circles symbols correspond to lit side while triangle correspond to unlit side)

2.5 with the spacecraft elevation B

Most of the differences seen when observing the temperature as a function of the solar elevation, solar and particle local times and phase angle are due to the sign of the spacecraft elevation B (see Fig. 4).

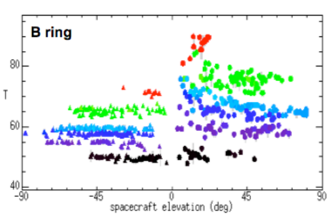

Figure 4: Temperature vs spacecraft elevation for the B ring. (Circles correspond to lit side while triangles denote to unlit side).

For the lit face, the vertical temperature gradient in the B or C ring implies that: at low phase angles, temperature decreases with increasing spacecraft elevation; at high phase angles, temperature increases with increasing spacecraft elevation. For the unlit side, it is the same thing for the C ring while in the B ring, no variation is noticed with spacecraft elevation.

3. Comparison with thermal model

To better understand these various thermal behaviors, we compare the CIRS observations to a thermal model developed by Morishima et al. [5,6]. This model depends on ring parameters such as optical depth, scale height ratio, fraction of fast rotators, and on regolith parameters such as particle albedo, emissivity and thermal inertia. The model, in part because of its high number of free parameters, fits the thermal data well. In this model, ring temperatures usually decrease with increasing spacecraft elevation, as cooler particles shadowed by other particles can be seen at high elevation, and CIRS observations show the same sense. However, other effects such as the wakes and the finite volume filling factor of a ring (not yet implemented), also depend on the spacecraft elevation, and can play an important role.

5. Summary and Conclusions

Ring temperatures decrease with decreasing solar elevation for any observational geometry. To first order, the largest temperature changes on the lit face of the rings are driven by variations in phase angle while differences in temperature with changing spacecraft elevation and local time are a secondary effect. Phase curves of ring temperature for a small range of solar elevation typically show about a 5K scatter for any given solar elevation. Some of this intrinsic scatter is a function of solar local time, particle local time and spacecraft elevation, and we are studying the ring temperature changes as a function of these parameters as well.

Acknowledgements

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