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Modelling Saturn ring temperature changes at equinox

L. Spilker (1), C. Ferrari (2), R. Morishima (1)
(1) Jet Propulsion Laboratory/Caltech, Pasadena, CA, USA, (2) CEA Saclay/Univ. Paris 7, France

Abstract

The Cassini Composite infrared spectrometer (CIRS) retrieved the equinox temperatures of both sides of Saturn's main rings as the sun traversed from the south to north side of the rings. At equinox the rings are edge-on as seen from the sun and essentially edge-on (maximum ring opening of only about 2.5 degrees) as seen from Earth, so it is not possible to measure the main ring temperatures from Earth.

At equinox the ring temperatures are essentially the same on the lit and unlit sides of the rings. To first order the temperatures are independent of phase angle demonstrating that the primary heat source is Saturn thermal and visible radiation. The ring temperatures at equinox were: C ring, 55-75 K; B ring, 45-60 K; Cassini Division, 45 – 58 K; and A ring, 43 – 52 K.

1. Introduction

CIRS has acquired a wide-ranging set of thermal measurements of Saturn's main rings (A, B, C and Cassini Division) at solar elevations from zero to 24 degrees. The equinox geometry is unique because Saturn heating dominates, contrasted to earlier in the mission when the primary heat source is visible-wavelength energy from the sun. When the sun is the dominant heat source the ring temperature varies between the lit and unlit sides of the A and B rings. As the solar elevation decreased the last few degrees, the ring temperatures on the lit and unlit sides of the rings decreased in a non-linear fashion to the coldest temperatures observed to date.

2. CIRS Equinox Observations

CIRS scanned the rings radially at different local hour angles a few days around equinox. Prior to equinox the sun was shining on the south side of the rings. The solar elevation angle |B'| varied between -0.00007° and 0.036° in this data set and the phase angle ranged from 30° to 147°.

Earlier in the mission, when the sun was the dominant heat source, the temperature of the lit rings decreased with increasing phase angle and the ring temperature in the shadow was less then the ring temperature at noon. At equinox the temperature does not decrease with increasing phase angle and the temperature at noon is no longer greater than the temperature in the shadow.

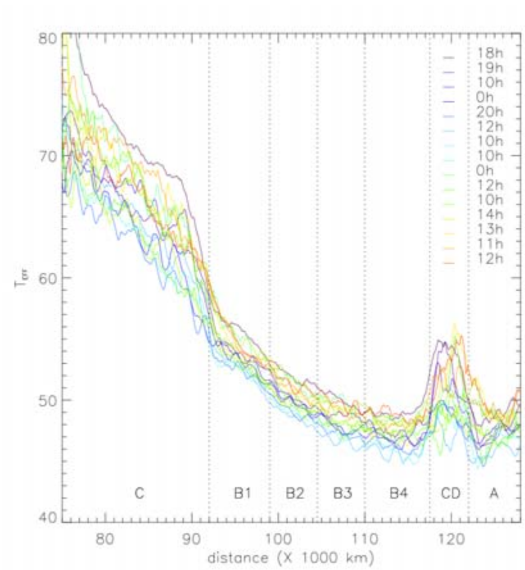

Figure 1. Temperature vs. ring Radius: Midnight (0 local time) is in Saturn's shadow and noon (12 local time) is in the direction of the sun.

Temperatures depend on local time, especially in the C ring which is the closest to the Saturn heating source. They are increasing as the S/C is able to better observe the sub-Saturn point on particles.

3. Models of ring equinox temperatures

The observed averaged radial profile of ring temperature can be used as is in ring thermal models to model the Saturn heating contribution and/or test the ability of different models to reproduce it .

3.1 Multilayer model

We use a multilayer model developed by Morishima et al. [1, 2]. This model is based on classical radiative transfer, which assumes vertical thickness of a ring is much larger than the particle size. It takes into account heat transport due to particle motion in the vertical and azimuth directions and assumes a bimodal size distribution of small-rapidly spinning particles and large non-spinning Lambert particles, which are called fast and slow rotators, respectively. Figure 2 shows equinox temperature as a function of saturnocentric radius compared to model estimates.

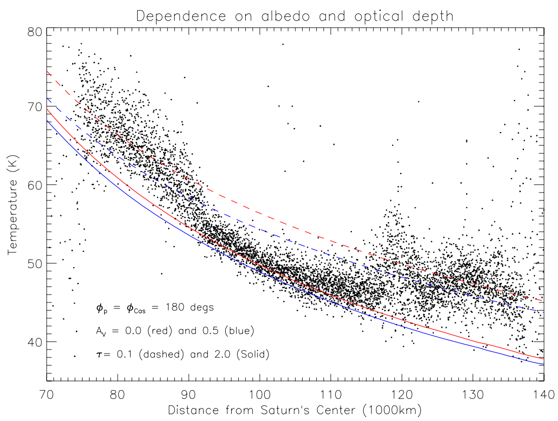

Figure 2: Equinox temperatures vs. saturnocentric radius. The optical depth is 0.1 (dashed curves) and 2.0 (solid curves), and the bolometric albedo is 0.0 (red curves) and 0.5 (blue curves). All particles are assumed to be isothermal fast rotators with local time = 180° and spacecraft elevation = 20°. Black dots are ring temperatures measured in days of year 223-225.

3.2 Slab model

The average infrared emitted flux at equinox can also be fitted to that of a ring slab of ring particles with size R, Bond albedo A emitting through a surface $f\pi R^2$ [3]. The ring optical depth τ is varying with distance according to the latest measurements. The fit shown in Figure 3 is for f=2.99±0.02, i.e. quasi-isothermal particles, and a Bond albedo A=0.30±0.02 for the C and CD rings, assuming Bond albedos of 0.5 and 0.6 for the A and B rings respectively.

4. Summary and Conclusions

The main rings cooled to their lowest temperatures measured to date. At equinox the primary heat sources for the rings are Saturn thermal and visible energy. Temperatures are almost identical for similar geometries on the north and south sides of the rings. Current models are able to reproduce ring temperatures under Saturn heating only. More work is needed to understand their longitudinal variations.

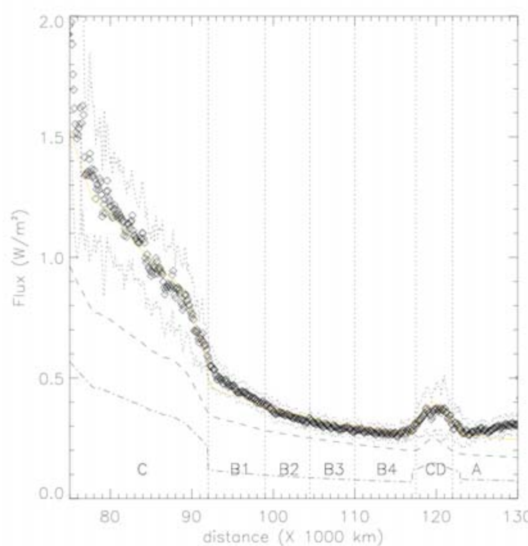

Figure 3: Average equinox ring infrared flux (diamond) and 1σ-deviation (dot), slab model (yellow line), Saturn infrared contribution (dashed line), Saturn visible contribution (dot-dashed).

Acknowledgements

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References

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