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Saturn ring temperature changes through equinox

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Abstract

The Cassini Composite infrared spectrometer (CIRS) retrieved the temperatures of Saturn's main rings at solar elevations ranging from 24 degrees to zero degrees at equinox (August 2009) as the sun traversed from the south to north side of the rings. Over this broad range of solar elevation the CIRS data show that the ring temperatures vary as much as 29K- 38K for the A ring, 22K-34K for the B ring and 18K-23K for the C ring. Interestingly the unlit sides of the rings show a similar decrease in temperature with the decreasing solar elevation.

1. Introduction

The Cassini Composite infrared spectrometer (CIRS) retrieved the temperatures of Saturn's main rings at equinox for the first time, 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.

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.

2. Ring Temperatures with Decreasing Solar Elevation

On the lit side of Saturn's rings the ring temperatures steadily decrease with decreasing solar elevation (Figure 1). The thermal structure evident in the middle of the B ring in the red, green and light blue curves diminishes as well (black square). In the B ring there is a good correlation between optical depth and temperature [1, 5]. The C ring and Cassini Division, with lower albedos, are warmer than the A and B rings.

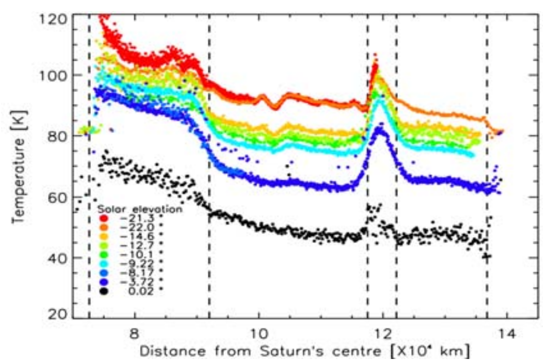

Figure 1: Radial scans of ring temperature with decreasing solar elevation: Nine radial scans at solar elevations ranging from -21.3 degrees to 0.02 degrees are plotted. The scatter in the data points is indicative of the error in the measurements.

3. Modeling CIRS Equinox Data

3.1 Radiative Transfer Multilayer Model

Cassini stellar occultation measurements [2] suggest that the thickness of the rings is on the order of 10 m, comparable to the size of the largest particles. Therefore, the rings resemble a monolayer for the largest particles and may be represented by multilayers for the small particles that spread more extensively in the vertical direction. Dynamical models support this picture [3].

A new thermal model [4] has been developed which takes into account the following effects:
i. The equation of classical radiative transfer is solved directly for both visible and infrared light

using a plane-parallel approximation (no wakes).

ii. The vertical heterogeneity of spin frequencies of ring particles is taken into account. Two particles sizes are considered; non-spinning large, Lamberian particles and small, rapidly rotating isothermalparticles. The scale height ratio is 3.

iii. Heat transport due to vertical and azimuthal particle motion is taken into account.

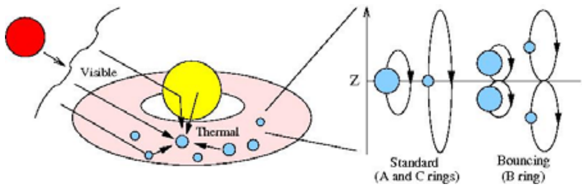

Figure 2. Diagram of Multilayer Model: Left side: The radiation sources for the radiative transfer calculation include the sun, Saturn visible and thermal and radiation, and mutual heating between particles. Right side: The vertical displacement between the large Lambertian and small isothermal particles is indicated. For the A and C rings particles move between the north and south sides of the rings as they orbit Saturn. For the B ring the particles bounce at the midplane because of the large optical depth in the B ring.

3.2 Model Results at Equinox

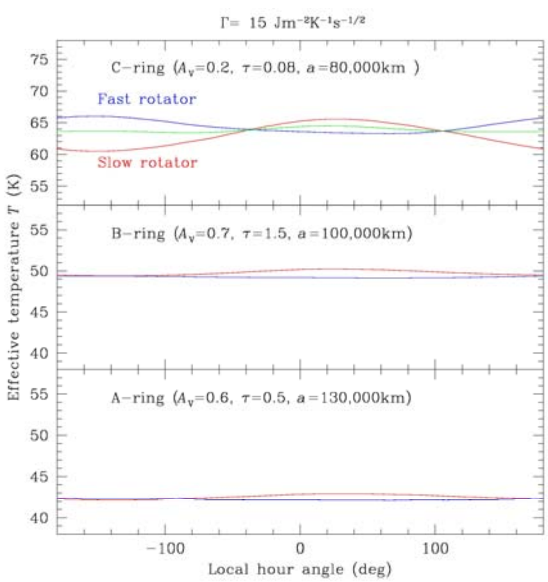

Figure 3. Radiative transfer model without solar input: Model temperatures for the C ring (top), B ring (middle) and A ring (bottom) are shown for 3 separate cases, from 100% fast rotations (blue) to 100% slow rotators (red) to a mix of 50% slow and 50% fast rotators (green) assuming a thermal inertia of 15 $Jm^{-2}K^{-1}s^{-1/2}$.

The radiative transfer multilayer model was applied to the equinox data by setting the solar contribution to zero. Model curves for the C, B and A rings are shown in Figure 3. In the A and B rings the curves show only a small dependence of temperature with local time.

4. Conclusions

The main rings cooled to their lowest temperatures measured to date. At equinox the solar input is very small and 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. 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. The thermal model by Morishima et al. [4] is able to reproduce most of the equinox temperatures observed by CIRS with the exception of the A ring where the model temperatures are cooler than the observed temperatures. One explanation may be the presence of gravitational wakes throughout the A ring.

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References

[1] Spilker, L. et al. (2006) PSS 54, 1167- 1176.
[2] Colwell, J. et al. (2006) GRL 33, L07201.
[3] Morishima, and H. Salo, H. (2006) Icarus 181, 272-291.
[4] Morishima, R. et al. (2009) Icarus 201-2, p. 634-654.
[5] Flandes, A. et al., (2010) PSS, in press.