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Saturn ring temperature variations near equinox with Cassini CIRS

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Abstract

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

At equinox the ring temperatures are almost the same on the lit and unlit sides of the rings. To first order the temperatures are independent of ring local time and 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 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 [1]. 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.

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.

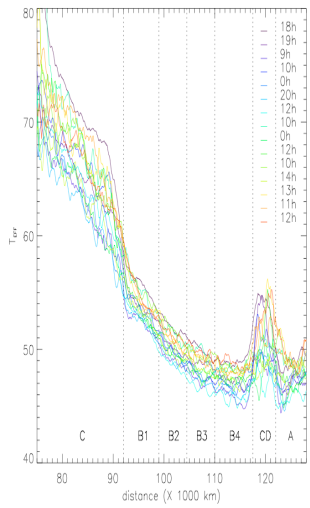

Figure 1. . Temperature vs. ring Radius: Midnight (0 local time) is in Saturn's shadow and noon (12 local time) is in the direction of the sun. Five sets of observations were taken close to equinox.

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 (Fig. 1).

To first order, at equinox the temperatures are independent of ring local time. The noon scan temperatures are very similar to the midnight scan temperatures taken in Saturn's shadow clearly demonstrating that with the sun edge on to the rings the primary heat source on the main rings is Saturn visible and thermal radiation.

2. 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. The model takes into account heat transport due to particle motion in the vertical and azimuth directions. The model assumes, instead of an actual continuous size distribution, a bimodal size distribution consisting of small-rapidly spinning particles having spherically symmetric thermal structure 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. All particles are assumed to be fast rotators, and two different albedos, $A_V = 0.0$ (red curves) and 0.5 (blue curves), and two different optical depths, $\tau = 0.1$ (dashed curves) and 2.0 (solid curves) are used.

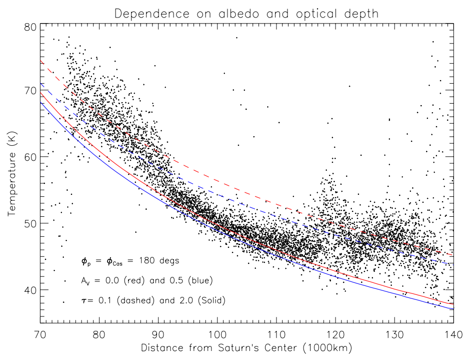

Figure 2: Equinox temperature vs. Saturnocentric radius. The optical depth is 0.1 (dashed curves) and 2.0 (solid curves), and the bolometric albedo is 0.0 (red curves) and 0.5 (blue curves). In model calculations, all particles are assumed to be isothermal fast rotators with phase angle = 180° and B = 20°. Black dots are ring temperatures measured in days of year 223-225.

The temperatures decrease with increasing τ. When τ is small enough, the thermal emission from both hemispheres of Saturn heat up ring particles. When τ is large enough, only one hemisphere of Saturn directly heats up ring particles. The dependence of temperature on bolometric albedo is weak. The heat source in visible light at equinox is sunlight reflected by Saturn and scattered light. The flux in the visible varies with local hour angle and has its maximum at the noon. When the visible flux is averaged over the orbital period, it is one order of magnitude smaller than the thermal flux, which is the summation of the thermal flux from Saturn and the mutual heating flux.

3. Summary and 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, with the thermal energy dominating over the 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.

Acknowledgements

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