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Imaging of Saturn's main rings during the Cassini Ring-Grazing Orbits and Grand Finale

Matthew S. Tiscareno (1) for the Cassini Imaging Team
(1) Carl Sagan Center for the Study of Life in the Universe, SETI Institute, Mountain View CA, USA (matt@seti.org)

Abstract

In its two-part end-of-mission maneuvers, the Cassini has obtained and (as of this writing) continues to obtain the sharpest and highest-fidelity images ever taken of Saturn's rings. Among the results we can report so far are 1) radial variations in the degree of visible "clumpiness" in the ring, 2) a particle-size distribution for small "propellers," yielding insights into the history and dynamics of the ring's largest particles, 3) close-range flybys of three large "propellers," obtaining new details of how the unseen moons disturb and interact with the ring in which they are embedded, and 4) expanded data on the size, frequency, and spectral properties of impact ejecta clouds in the rings.

We will report on our ongoing analysis of these new images.

1. Introduction

Cassini is ending its spectacular 13-year mission at Saturn with a two-part farewell. From December 2016 to April 2017, the spacecraft executed 20 near-polar orbits that passed just outside the outer edge of the main rings; these "Ring-Grazing Orbits" (RGOs) provided the mission's best viewing of the A and F rings, the Cassini Division, and the outer B ring. From April to September 2017, the spacecraft is executing 22 near-polar orbits that pass between the innermost D ring and the planet's clouds; this "Grand Finale" (GF) provides the mission's best viewing of the C and D rings and the inner B ring.

2. Clumpy Belts

Clumpy structure called "straw" was previously observed in parts of the main rings [1], especially in the troughs of density waves and in other locations where ring material has recently been released from compression. RGO images show this structure with greater clarity, which will enable measurement of the structure and comparison with numerical simulations.

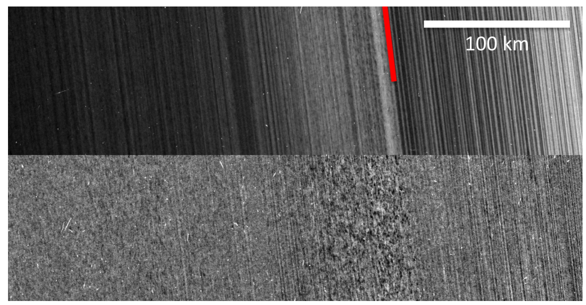

Figure 1: Cassini image of strong radial structure in the inner A ring. The upper panel shows the plain image, while the lower panel shows a contiguous portion of the same image after application of a filter that removes the radial structure so that compact structure is more visible. The red line marks a boundary between two characters of radial structure.

More surprisingly, RGO images reveal similar clumpy belts in regions that (to our knowledge) have *not* recently undergone compression, such as the inner A ring (Fig. 1). This region is thought to be subject to self-excited modes called "viscous overstability" [2], though it is not yet clear whether the clumpy belts are correlated with the occurrence of VO.

3. Flocks of Propellers

A "propeller" is a local disturbance in the ring created by an embedded moon [3, 4, 5]. Cassini has observed two classes of propellers: small propellers that swarm in the "Propeller Belts" of the mid-A ring (discussed in this section), and giant propellers whose individual orbits can be tracked in the outer A ring (discussed in the following section).

The original discovery of propellers in the Propeller Belts [3] used four images taken from unusually close range during Cassini's maneuver to initially put itself into Saturn orbit in 2004. The propellers discovered in those images were smaller than those seen later in the mission in the same location [4, 5], and a clear connection between the different size populations has

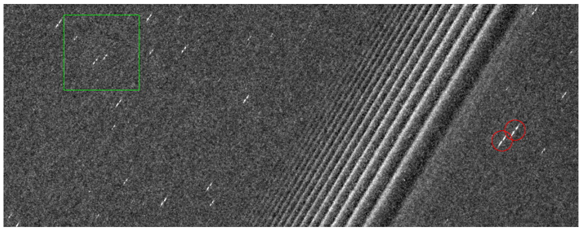

Figure 2: Cassini image of propellers and a density wave in the mid-A ring. The green square indicates the approximate size of the original propeller discovery images [3], and the propellers within the green square are approximately the size of the discovery propellers. The red circles indicate larger propellers nearby.

not previously been established. RGO images (e.g., Fig. 2) show, for the first time, a wide range of sizes in the Propeller Belts, putting the SOI propellers in context.

4. Propeller Close-ups

The orbits of giant propellers have been tracked for the past decade, tracing the effect that the ring has upon them [6]. In the RGOs, close-up views of selected propeller shed light on their effects upon the ring.

We will present maps of of the propeller structures, with enhanced ability to convert brightness to optical depth and surface density due to information from both the lit and unlit sides of the rings (Fig. 3). The images contain more complex structure than is predicted by simple models, which we will describe, and for which we will comment on likely explanations.

5. Impact Ejecta Clouds

Being a large and delicate system, Saturn's rings function as a detector of the planetary environment. The population of decimeter-to-meter-sized meteoroids in Saturn's vicinity was estimated from images of impact ejecta clouds in the rings [7]. RGO images increase the number of detected IECs by a factor of several. Also, spectral information from color filters may constrain the particle-size distribution of the ejecta, thus constraining the fracture properties of ring material.

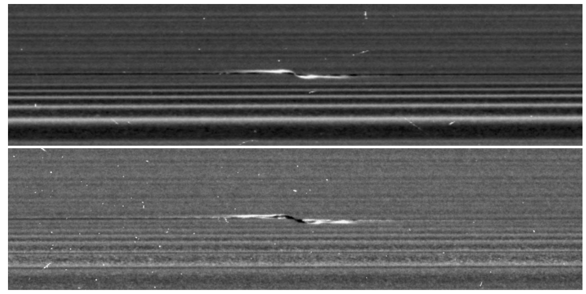

Figure 3: The propeller "Santos-Dumont," viewed on the lit side (top) and unlit side (bottom) of the rings. On the lit side, the rings look darker where there is less material to reflect sunlight. On the unlit side, some regions look darker because there is less material, but other regions look dark because there is so much material that the ring becomes opaque. For example, in the unlit-side view, the broad, dark band through the middle of the propeller seems to be a combination of both empty and opaque regions.

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