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B ring gray ghosts in Cassini UVIS occultations

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Abstract

After 6 years of Cassini mission the UVIS instrument recorded more than hundred stellar occultations by Saturn's rings. Most of the observed occultations have excellent true spatial resolution (combined radial and azimuthal) on the order of dozen meters. One single A ring occultation (β Persei Rev 116) has been recored with unprecedented true resolution of 3 meters.

In this paper we show results of a new analysis of the smallest scale ring structure. Comparing single occultation measurement of optical depth at t_0 with the next sample $t_0 + \Delta t$ (typically separated by dozen meters or less in the ring plane) we build a map of transition probabilities of the ring structure. This allows us to view the ring structure as a probabilistic Markov system and examine (quasi) absorbing probabilistic states.

The A ring occultations are the most straightforward to interpret and are consistent with previous papers. The ring is composed of two absorbing states corresponding to nearly opaque wake and transparent gap. In other words the ring material is constantly flipping between being nearly opaque and transparent. The transition between these two states is gradual (on the order of few counts). It is important to note that there is no qualitative difference between results inferred from occultations with coarser resolution (dozen meters) and one single high-resolution occultation ($<$ 3m).

The C ring occultations show only one absorbing state, which is consistent with the absence of self-gravity structure. However there is also a very small, but finite, probability of the ring to be transparent or nearly transparent. Such state lasts at most few counts and the ring returns to the nominal absorbing state of moderate optical depth. In other words, the ring is boringly homogeneous for most of the time, except that it shows rare narrow gaps (at most few dozen meters in length). Such gaps have been dubbed ghosts, and we find that they are rather continuous in their appearance from fully transparent to partially transparent.

The B ring results are the most puzzling. Following the published papers the B ring was expected to be qualitatively similar to the A ring with classical opaque self-gravity wakes and nearly transparent gaps. Which would then imply two absorbing states. Contrary to this expectations we found only a single absorbing state of very high optical depth ($\tau > 4$). In addition to this one absorbing state, the ring shows occasional brief transitions to states of relatively lower optical depth (τ of 1 or 2). We dubbed these lower optical depths as "gray ghosts". However, the ring very quickly (few dozen meters) returns to the nominal absorbing state of very high optical depth. The second absorbing state, or nearly transparent gaps as expected from the classical picture of B ring, is completely absent. In other words, B ring is mostly in a high optical depth state ($\tau > 4$) and occasionally flips for a very short period of time to gray ghosts of relatively lower optical depth (τ of 1 or 2). Transparent gaps are completely missing. The ephemeral gray ghosts are too infrequent to be playing the role of the expected transparent gaps.

Although B ring is sampled only at 10m resolution so far, the qualitative agreement of A ring occultations at 10m and below 3m rather suggests that the found image of B ring will not change as we obtain higher resolution B ring occultations later in Cassini mission.

Up to now not a single published N-body simulation of the B ring matches our observations. However, we note a tendency that simulations with smaller surface density show fewer low optical depth regions, thus coming closer to the observed UVIS results.