EPSC Abstracts
Vol. 9, EPSC2014-633, 2014
European Planetary Science Congress 2014

Propellers in Saturn's rings

M. Sremčević, G. R. Stewart, N. Albers and L.W. Esposito
Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder (Miodrag.Sremcevic@lasp.colorado.edu)

Abstract

Theoretical studies and simulations have demonstrated the effects caused by objects embedded in planetary rings [5, 8]. Even if the objects are too small to be directly observed, each creates a much larger gravitational imprint on the surrounding ring material. These strongly depend on the mass of the object and range from "S" like propeller-shaped structures for about 100m-sized icy bodies to the opening of circumferential gaps as in the case of the embedded moons Pan and Daphnis and their corresponding Encke and Keeler Gaps. Since the beginning of the Cassini mission many of these smaller objects ($\sim$ 100m in size) have been identified in Saturn's A ring through their propeller signature in the images [10, 7, 9, 11]. Furthermore, recent Cassini observations indicate the possible existence of objects embedded even in Saturn's B and C ring [6, 2].

In this paper we present our new results about by now classical A ring propellers and more enigmatic B ring population. Due to the presence of self-gravity wakes the analysis of propeller brightness in ISS images always bears some ambiguity [7, 9] and consequently the exact morphology of propellers is not a settled issue. In 2008 we obtained a fortunate Cassini Ultraviolet Imaging Spectrograph (UVIS) occultation of the largest A ring propeller Bleriot. Utilizing Cassini ISS images we obtain Bleriot orbit and demonstrate that UVIS ζ Persei Rev42 occultation did cut across Bleriot about 100km downstream from the center. The occultation itself shows a prominent partial gap and higher density outer flanking wakes, while their orientation is consistent with a downstream cut. While in the UVIS occultation the partial gap is more prominent than the flanking wakes, the features mostly seen in Bleriot images are actually flanking wakes.

One of the most interesting aspects of the A ring propellers are their wanderings, or longitudinal deviations from a pure circular orbit [11]. We numerically investigated the possibility of simple moon driven librations. We adopted HNbody numerical integrator [4] and checked for possible influence of Saturnian satellites. While we found no significant influence on B ring propellers, some of A ring propellers indeed respond to the satellites (e.g. Earhart and Sikorsky are strongly perturbed by 415:416 and 293:294 mean longitude resonances with Pan). Although it is still not clear whether the identified resonances are solely responsible to the A ring propeller wanderings, this is a significant result which will have to be taken into account when considering other disk driven migration models [3, 1].

While the A ring propellers are not far from the Roche zone limit, propellers within the B ring come as a surprise. Simple expectation has been that the strong shear rate in the inner rings would tear bodies apart, which in turn requires stronger evidence for the B ring propellers. In B ring we discovered 12 propellers in 21 ISS NAC images (both lit and unlit geometry) and we found a propeller signature in UVIS β Centauri Rev96 occultation at r=94,958km. One of the detections (N1504581211, N1550709682, N1550709900, N1550709615 at r=93,801km) is observed at two different epochs indicating a lifetime of at least 1.5 years. Searching for a possible reoccurrence of the β Centauri propeller at r=94,958km, we found a significant feature at a single ISS NAC epoch (N1557847776 ... N1557849576) at r=94,962km. While the geometrical solution has probably 1km uncertainty in both ISS images and in UVIS occultation, the difference in inferred locations is at least 2km. Although it is possible to fit a single orbit, the difference in location is significantly larger compared to the known migrations of A ring propellers [11]. Another detection (N1496890652 at r=96,710km) clearly shows the expected "S" shape, but in general the observed propellers are clearly shorter than A ring counterparts, indicating much stronger viscosity of B ring compared to A ring [8].

The very fortuitous propeller detection in UVIS β Centauri Rev96 occultation at r=94,958km offers insight into the morphology of the discovered objects in B ring. The feature is statistically significant, consists of 6 consequent high counts, and represents a gap with a width of 300m. Similar to the Bleriot occultation

in ζ Persei Rev42, the B ring β Centauri occultation also shows a very prominent gap and a single flanking higher density wake. The significance of the UVIS features was confirmed using statistical T-test. The result from UVIS occultation together with dozen feature detections in ISS NAC images demonstrates beyond reasonable doubt that the presented B ring features are indeed propellers.

References

[1] B. C. Bromley and S. J. Kenyon, *Migration of Small Moons in Saturn's Rings*, ApJ **764** (2013), 192.

[2] J. Colwell, K. Baillie, and L. W. Esposito, *Seeing Ghosts in Saturn's Rings: Ephemeral Gaps in Cassini UVIS Stellar Occultations*, 38th COSPAR Scientific Assembly, vol. 38, 2010, pp. 581–+.

[3] M. Pan, H. Rein, E. Chiang, and S. N. Evans, *Stochastic flights of propellers*, MNRAS **427** (2012), 2788–2796.

[4] K. P. Rauch and D. P. Hamilton, *The HNBody Package for Symplectic Integration of Nearly-Keplerian Systems*, AAS/Division of Dynamical Astronomy Meeting #33, Bulletin of the American Astronomical Society, vol. 34, September 2002, p. 938.

[5] F. Spahn and M. Sremčević, *Density patterns induced by small moonlets in Saturn's rings?*, Astron. Astrophys. **358** (2000), 368–372.

[6] J. N. Spitale and C. C. Porco, *Detection of Free Unstable Modes and Massive Bodies in Saturn's Outer B Ring*, AJ **140** (2010), 1747–1757.

[7] M. Sremčević, J. Schmidt, H. Salo, M. Seiß, F. Spahn, and N. Albers, *A belt of moonlets in Saturn's A ring*, Nature **449** (2007), 1019–1021.

[8] M. Sremčević, F. Spahn, and W. J. Duschl, *Density structures in perturbed thin cold discs*, Mon. Not. R. Astron. Soc. **337** (2002), 1139–1152.

[9] M. S. Tiscareno, J. A. Burns, M. M. Hedman, and C. C. Porco, *The Population of Propellers in Saturn's A Ring*, AJ **135** (2008), 1083–1091.

[10] M. S. Tiscareno, J. A. Burns, M. M. Hedman, C. C. Porco, J. W. Weiss, L. Dones, D. C. Richardson, and C. D. Murray, *100-metre-diameter moonlets in Saturn's A ring from observations of propeller structures*, Nature **440** (2006), 648–650.

[11] M. S. Tiscareno, J. A. Burns, M. Sremčević, K. Beurle, M. M. Hedman, N. J. Cooper, A. J. Milano, M. W. Evans, C. C. Porco, J. N. Spitale, and J. W. Weiss, *Physical Characteristics and Non-Keplerian Orbital Motion of "Propeller" Moons Embedded in Saturn's Rings*, ApJL **718** (2010), L92–L96.