

Are moonlets hidden among the clumps in Saturn’s innermost ring?

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Abstract

Saturn’s D68 ringlet is the rings’ innermost narrow feature. Four clumps that appeared in D68 around 2014 remained evenly spaced about 30 degrees apart and moved very slowly relative to each other [1], which is reminiscent of the stationary configurations of co-orbital nearly equal-mass satellites [2]. We therefore explore the possibility that the source bodies for these four clumps are in such a co-orbital configuration. The spacing between the clumps is somewhat smaller than one would expect for a configuration of just four moons, and changing the mass ratios is unable to fix this. We therefore consider whether an unseen fifth object could account for the discrepancies in the angular separations and allow the system to reach stationarity [3]. We constrain the range of possible longitudes for a fifth co-orbital object, as well as the mass ratios of the five objects for the specified longitudes.

1. Background: Four long-lived bright clumps in the D ring

A narrow ringlet referred to as D68 lies near the inner edge of Saturn’s D ring, about 67,630 km from Saturn’s center. From its discovery in Voyager images [4] through much of the Cassini mission, investigation of D68 focused on its radial profile and phase angle properties [5]. Later studies brought attention to its longitudinal brightness variations [6]. In 2014–15, four bright clumps (designated T, M, L, and LL; see Figure 1) formed and remained relatively evenly spaced with small longitudinal variations about mean separations of 26, 32, and 29 degrees [1], which is reminiscent of the stable solution for four equal-mass co-orbital bodies [2, 3]. Here we explore this possibility in more detail.

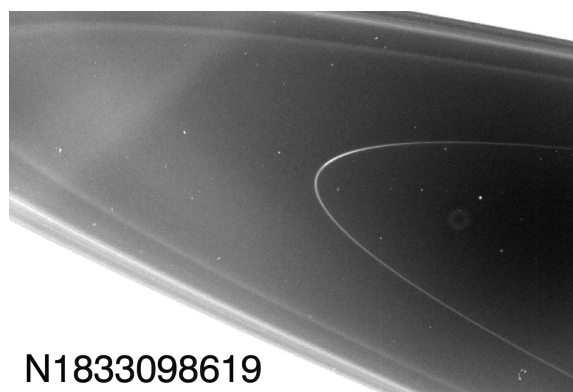


Figure 1: This image, taken on 2 February 2016, shows one of the bright clumps in the D68 ringlet. D68 is the narrow ring near the center of the image. The bright feature is located near the ansa. [1]

2. Lack of solutions with four co-orbiting bodies

Modeling the system as four point-mass bodies in orbit around Saturn, we initially place them at the longitudes of the stable stationary configuration for equal-mass bodies: 41.5, 37.4, and 41.5 degrees [2]. Varying the masses, however, is unable to allow the system to evolve to the angular separations of the D68 clumps. In fact, looking for solutions numerically using the equations of motion [3], the only solutions for the approximate angular separations found in the D68 ringlet involve negative masses. Thus, there does not exist a physical solution for mass ratios of the four clumps.

3. Solutions exist with five co-orbiting bodies

We therefore consider whether there could be an unseen fifth object, whose mass could enable the angular separations we observe between the four known

clumps. We explore the approximately 270-degree span of longitudes ahead of Clump LL and behind Clump T. Using the same equations of motion [3], we find physically realistic solutions in two regions, one about 30 degrees ahead of Clump LL and one about 30 degrees behind Clump T. These regions each span about 30 degrees in longitude and are mapped out in Figure 2.

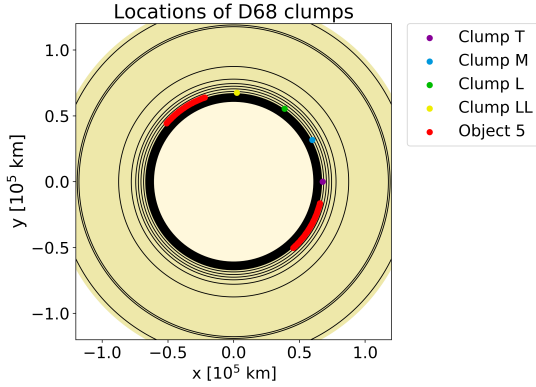


Figure 2: This view of the Saturn system from above shows the locations of the D68 clumps as well as initial predictions for possible locations of a fifth object.

References

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