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Numerical Simulations of Chariklo's Ring Confinement with a Moon

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Abstract

Ring systems around small bodies are a relatively new and intriguing field of study. We use numerical simulations of the Chariklo system, including a moon, to study the evolution of the rings. Here we specifically investigate the effect of different moon masses and ring optical depths on the size of Chariklo's inner ring. Perturbations from the moon can produce a ring that is confined to a few km in width, similar to that observed.

1. Introduction

The discovery of rings around the centaur Chariklo in 2013 [1] and the proposed ring system around the similarly-sized centaur Chiron [2] have raised questions about how such ring systems form and evolve. These systems are on a significantly smaller scale than the previously-known rings around the giant planets. Notably, the rings are very narrow. Possible methods for confinement of narrow rings include apse alignment due to self gravity, like that observed at Uranus [3], contributions from non-sphericity of the nucleus [4–5], and shepherding satellites. Here we explore the effect on ring material from a single Chariklo satellite.

2. Simulations

Following the process in [6], N-body simulations are performed for spherical, water ice particles moving past a nearby moon. Material can be confined into rings as a result of collisional damping of the satellite wakes. In the simulations presented here, the moon is located in the 4:5 resonance *interior* to the rings. From previous work [7–8], we expect a similar confinement effect for an exterior satellite. We elect to use the interior case because the effect can also be considered similar to that from a mass anomaly on the surface. We assume moon masses between 1–6 x 10^{13} kg (approximately a few km in diameter, which is below the threshold for direct detection). The ring material is initially in Gaussian density profiles, centered on the locations of the observed rings. The ring particles are 3–10 m in radius, with a power law size distribution. Self gravity is included. The observed optical depths for Chariklo's rings are approximately τ=0.4 (inner ring) and τ=0.06 (outer ring) [1]. Here, we assume that a significant portion of the optical depth is due to small particles and dust, which are too light to have an effect in the simulation. For the larger particles in our simulations, we thus consider a fraction (1/10 or 1/5) of the observed optical depth.

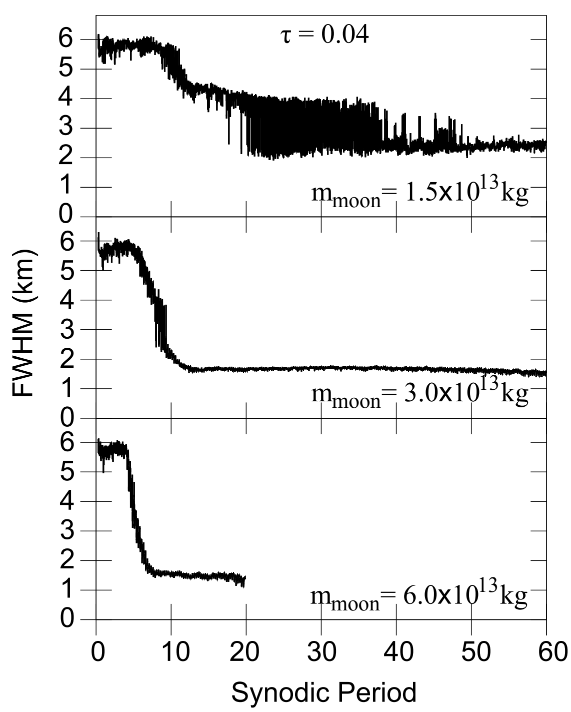

Figure 1: The FWHM of the inner ring over time, as a function of the size of the moon, for an optically thin simulation. The ring has optical depth of approximately one-tenth that observed. The material is confined fairly quickly to a few km in width, given a reasonable moon mass.

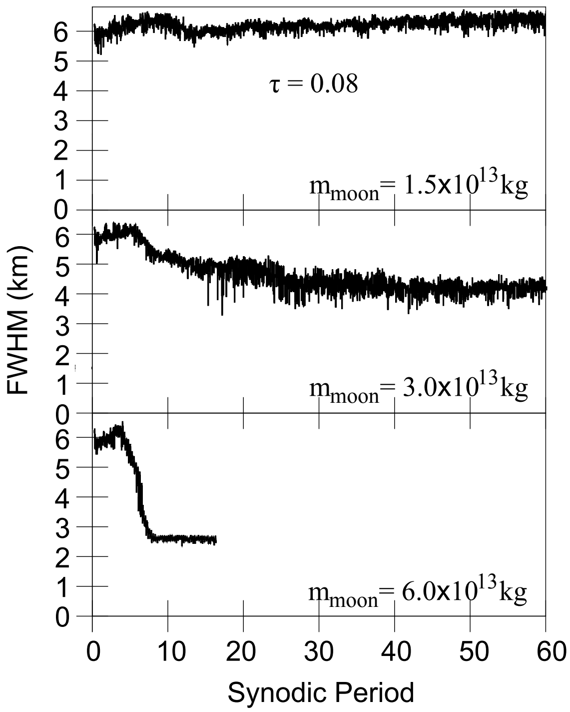

Figure 2: The FWHM of the inner ring over time, as a function of the size of the moon, for a more optically thick simulation. The ring has optical depth of approximately one-fifth that observed. Compared to Fig. 1, a more massive moon is required to confine the material and the resulting ring is wider.

3. Results

The evolution of the full-width at half-maximum (FWHM) of the simulated inner ring is shown in Figs. 1 and 2, for three different satellite masses. Fig. 1 assumes a lower optical depth for the ring material of τ=0.04 and Fig. 2 assumes τ=0.08. A ring of similar width to that observed at Chariklo (a few km) can be produced by this mechanism. The width of the rings scales inversely with the mass of the moon: more massive satellites produce tighter confinement. In both cases, if the moon is not massive enough, the material is never confined. The higher optical depth requires a more massive moon to produce ring confinement, and the rings that are produced are wider than those at lower optical depth.

4. Summary and Conclusions

We have carried out numerical simulations to investigate the evolution of Chariklo's ring system, in the presence of a small moon. Here we present initial results for the size of a simulated inner ring while exploring the phase space of satellite mass and model ring optical depth. A ring of a few km in width, similar to the size observed for Chariklo's inner ring, can be produced with reasonable parameters. The simulations are ongoing, and we will present updated results as well as comparisons with data from stellar occultations observations.

Acknowledgements

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