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Effects of an additional shepherding moon on the mu-ring and Mab

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Abstract

In 2006, Showalter and Lissauer [1] announced the discovery of an outer ring system around Uranus, composed of the nu-ring and the mu-ring (Fig. 1). Their discovery was made using Hubble Space Telescope (HST) observations. Follow-up observations by the Keck telescope revealed the nu-ring to be spectrally red, like other dusty rings in our solar system (e.g., Jupiters rings and Saturn's G-ring). The mu-ring however appears blue - an unusual color implying a predominance of (sub)micron-sized particles [2]. As the dynamic lifetime of dust grains is shorter than the age of our Solar System, there must be a source of continuous replenishment. A small moon Mab, centered in the mu-ring, was also discovered [1]. Current hypothesis is that Mab serves as the source of the material for the mu-ring. An explanation for the presence of only (sub)micron-sized material has not been determined, however this is thought to be tied to the dynamics governing the interaction between the dusty mu-ring and the moon Mab.

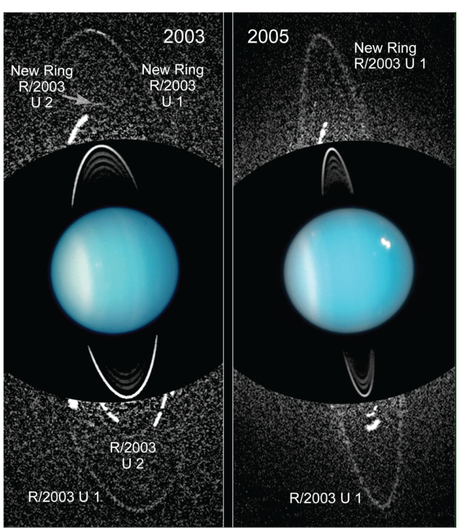

Figure 1: Uranian outer ring system imaged by the Hubble Space Telescope [1].

Showalter and Lissauer (2006) show that the orbit of Mab is not well understood. They derived its orbital position from both the Voyager flyby data (1986) and HST data (2003-2006). They compared the observed positions with an orbital model that includes the J_2 gravitational flattening of Uranus. Although this model works well for nine other Uranian moons, for Mab the fitting errors are six times larger. This indicates that we are currently overlooking an essential part of the dynamics that determine the orbit of Mab. Is there an unknown body in the Uranian system that affects Mab's orbit?

The mu-ring is a faint belt of dust approximately 10,000 km wide that shows a peak in brightness near the orbit of Mab. The only other blue ring in our Solar System is Saturn's E-ring, which is generated by the moon Enceladus. This enigmatic moon was imaged in detail by the Cassini spacecraft, revealing a system of linear troughs, or 'tiger-stripes', on Enceladus' south pole. Cassini also discovered hot spots on these stripes, from which plumes of gas and dust emanate. Numerical calculations show that these plumes are the main source of the material in Saturn's E-ring, and that they populate the ring with tiny particles [3], [4].

Although the color of the Uranian mu-ring is similar to that of Saturn's E-ring, its generation process must be very different, since Mab is assumed to be much too small (10-20 km in size) to be volcanically active [2]. It is more likely that the mu-ring is generated via (micro)-meteorite impacts on Mab, analogous to the formation of Jupiter's rings [5]. However, Jupiter's rings are red, i.e., the particle size distribution includes both macroscopic and microscopic particles. If the mu-ring is formed via impacts, somehow macroscopic particles 'disappear', and only (sub)micron-sized material survives. Before the Cassini spacecraft discovered volcanic activity on Enceladus, it was hypothesized that (micro-)meteorite impacts on Enceladus, combined with the effects of Poynting-Robertson drag, J_2 gravity flattening, and electromagnetic forces conspire to ensure that only (sub)micron-sized dust 'survives' in this system. Perhaps similar forces act in the Uranus system?

Even if this is the case, however, this does not explain what happens to macroscopic material. A possible hypothesis is that the larger particles accrete some-

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where in the system, for instance on Mab or on other ring particles. Charnoz et al. (2007) suggested accretion on moons for the Pan and Atlas moons in the Saturnian system, which appear to have equatorial bulges. Could a similar mechanism apply to the larger particles that would be generated by meteorite impacts on Mab?

In this study, we took a first step towards answering these questions by considering the effects of a hypothetical shepherding moon in the vicinity of Mab on both the motion of Mab and the mu-ring. We analyzed different configurations and assessed whether the second moon can induce chaotic motion of Mab. We compared this against astrometric data of the motion of Mab and assessed the likely mass of the second moon and its distance of separation with respect to Mab. We also investigated if the chaotic motion of Mab and the introduction of a new moon caused any dynamical effects on the mu-ring.

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