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Density and Interior of Binary Jovian-Trojan Asteroids: The (624) Hektor Case

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Abstract

Using Keck AO observations and a dynamical model, we have derived a stable and primordial mutual orbit for (624) Hektor. Its average density is similar to (617) Patroclus, but its composition could be different. We conclude that Hektor may be a captured TNO.

1. Introduction

The Jupiter-Trojan asteroid population remains significantly unexplored despite its importance in constraining the early history of the Solar System. To date, only two multiple Jupiter-Trojan asteroid systems have been imaged directly using adaptive Optics (AO) Systems on 8-10m class telescopes: (617) Patroclus-Menoetius (in L5), a similarly-sized binary composed of two D~100 km components [1,2] and (624) Hektor (in L4), a large D_{eq}~200 km primary which possesses a 10-15 km satellite [3]. Additional binary candidates (L5 2006BC56 and (29314) Eurydamas) have been suggested by [4] based on their large lightcurve range and long rotational periods. Finally, a secondary event observed in 2012 during an occultation by (911) Agamemnon implies that the L4 Trojan possesses a 4km satellite orbiting very close to its primary (~280 km in projected distance) [5]. We focus this work on the Trojan asteroids (624) Hektor for which we have derived the mutual orbit and compare our result with (617) Patroclus-Menoetius.

2. Observations

From July 2006 to November 2011 we collected twelve observations of (624) Hektor with the Keck II AO system and its near-IR camera in Kc band. In July 2006 we used the LGS AO data to reveal the presence of the satellite. In 2007-2011 thanks to an improved Keck AO system, we recorded data in NGS AO mode to confirm the presence of the satellite shown in Figure 1. Because of its large contrast (ΔK=7.2 mag) and small separation (0.2-0.4 arcsec), the marginal detection of the satellite complicated the analysis of the data compared with binary main-belt asteroid observations (e.g. [6])

3. Shape and Mutual Orbit

Combining our resolved AO observations with lightcurves from the literature (since 1957) and recent observations data plus successful occultation data we derived an accurate shape model and pole solution of Hektor's primary. The primary (D_{eq}=256 ± 12 km) is most likely made of two joined components of $D_{eq}(1)$~ 220 km and $D_{eq}(2)$ ~ 183 km (Fig. 2). Using the astrometric positions of Hektor's moon as inputs parameters for the Genoide-ANIS fitting algorithm [7], we derived a dynamical model of the system, which also includes estimates for the size and quadrupole moment (J_2) of Hektor's primary. The best-fitted orbit is very different from any other binary asteroid orbits seen so far [e.g 6]. It has an eccentricity of ~0.3 and an inclination to the primary equator of ~57 degrees. The dynamical size (D_{eq}~224 ± 36 km) and J_2 = 0.15 ± 0.04 are in agreement with a slightly differentiated and elongated primary. We studied the long-term dynamics stability of the orbit and found that the perturbations are dominated by Hektor's oblateness. The orbit is stable over 1E6 years and the effect of the tides is negligible. We concluded that this orbit has been unchanged and most likely the primordial one.

3. Interior and Composition

We have derived an average density of 1.0±0.2 g/cm^3 for Hektor's system, very close to the density inferred for Patroclus [1,2]. Visible albedo (p_v) and emissivity features in the mid-IR [7,2] are identical for both Trojan asteroids, which seems to imply a similar composition. Their vis/NIR reflectance spectra [9] are however different, both featureless, but with Patroclus being significantly less red than Hektor.

Thermal modeling of these asteroids after [10] shows that their interior temperature is never high enough to produce creep-driven compaction. However, because Hektor is larger, the pressure is sufficient for the compaction of a mixture of ice and rocks to proceed below 75 km depth. We derive a grain density for Hektor of 2.0± 0.2 g/cm^3, similar to Triton and Pluto, and a grain density of 1.6±0.4 g/cm3 for Patroclus, similar to giant planet satellites (e.g., Ganymede, Amalthea).

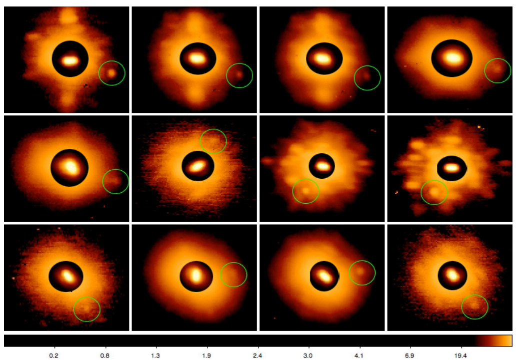

Figure 1: Twelve Keck AO observations of (624) Hektor. The green circles indicate the position of the 15km-satellite. The central areas show Hektor's primary which is resolved 55 mas< D_{ann}< 70 mas.

4. Conclusion

Our recent W.M. Keck AO observations confirm that Hektor possesses a 12±3 km satellite and that the primary is strongly elongated and most likely bilobated. The mutual orbit of the satellite is exotic, but primordial since stable over a long period of time. Even if Hektor and Patroclus have the same average density, their difference in size translates into different grain density estimates, although the uncertainty on Patroclus' bulk density is too large to support definitive conclusions. The contrast in Vis/NIR reflectance does suggest different compositions, hence formation in different areas of the solar system before capture. Hektor could be a captured TNO following the scenario described by [11]. In contrast, Patroclus could be a representative from the early Jupiter-Saturn planetesimal reservoir.

This work highlights the importance of a dedicated mission to explore the Jupiter-Trojan swarms, a unique place in the solar system where we could sample the remnants of the formation of gas giant planets and test early Solar system dynamics models.

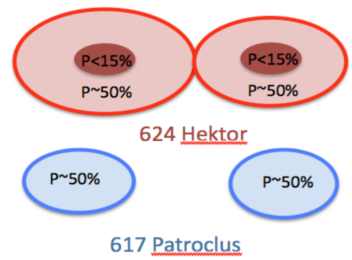

Figure 2: Sketch of Hektor and Patroclus' interiors.

Acknowledgements

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