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THE CYBELE BINARY ASTEROID 121 HERMIONE REVISITED F. Marchis[1,2,3], P. Descamps[3], J. Durech[4], J.P Emery[5], A.W. Harris[6], M. Kaasalainen[7], and J. Berthier[3], [1]SETI Institute, Carl Sagan Center, 515 N. Whisman Road, Mountain view CA 94043, USA, fmarchis@seti.org. [2]UC-Berkeley, Dept of Astronomy, 601 Campbell Hall, Berkeley CA 94720, USA. [3]Institut de Mécanique Céleste et de Calcul des Éphémérides, Observatoire de Paris, France, descamps@imcce.fr. [4]Astronomical Institute, Charles University, Prague, Czech Republic [5]University of Tennessee, Knoxville, USA. [6]DLR, Berlin, Germany. [7]Dept of Mathematics, University of Helsinki, Finland.

Introduction: (121) Hermione is a Cybele group binary asteroid with a km-size moonlet discovered in 2002 [1]. The ~200-km primary was conjectured to be bilobated [2] based on Adaptive Optics (AO) observations. Because of the limited angular resolution of the AO observations (~60 mas) its size and shape were poorly constrained, impacting its bulk density estimate which ranged between 0.8 and 2.0 g/cm^3. From the determination of the orbital characteristics of Hermione's satellite [2] we predicted that the system would be seen in equatorial aspect in June 2007.

Shape of Hermione's primary: We organized a campaign to record with small aperture telescopes the photometric variations a.k.a lightcurve of Hermione's primary in 2007 before and after the asteroid equinox. From the 19 lightcurves recorded, we derived a spin period of 5.55096±0.00015 h and confirmed that Hermione is elongated (Δm=0.60-0.75). Additional AO observations were recorded with the Keck telescope in September 2008. A general nonconvex shape and spin model was constructed by combining the lightcurve and the limb/shadow profil [3]. The final shape model confirmed the bifurcated nature of Hermione's primary [4].

Size of Hermione's primary: The Keck AO system was recently improved and the last observations taken in September 2008 have an angular resolution almost twice that of the previous observations (~35 mas). Combining the shape and pole model with the recent AO images, we derived an equivalent radius R_{eq}= 94±2 km. This radius is ~10% smaller than the IMPS (IRAS) radius of 104.5±2.5 km [5]. However, re-analysis of the IRAS data with the NEATM [6], and correction for the different aspect angles, leads to excellent agreement between the new AO and IMPS sizes. Similarly, taking account of the different aspect angles leads to very good agreement between the new AO size and that derived from Spitzer/IRS observations performed on September 30 2007 (see Fig 1): Using the NEATM model, we derived R_{eff}=82.4 (+4.3 -4.1), p_v=0.078 (-0.016 +0.020) with H=7.31 and a beaming factor η=0.98 (+0.03 -0.01). Using the pole solution, nonconvex shape model, and equivalent size (R_{eq}=94 km) of the primary, we calculated an effective radius of 80.7 km for the time of the Spitzer observations.

Satellite of Hermione: Additional observations of the satellite were recorded using the Very Large Telescope AO system in May 2006 and the Keck telescope in September 2008. The size of the satellite is re-estimated to a diameter of ~32 km. The orbit solution was improved but does not vary significantly from that previously published [2]. The satellite orbits around the primary in 2.5632±0.0021 days describing a circular orbit (e<0.02) with a radius of 747±11 km.

Bulk density of Hermione: Combining the new size estimate and the mass derived using the 3rd Kepler law from the satellite orbit, we derived a bulk density value of 1.4±0.2 g/cm3. Hermione's taxonomic class is C-type with a low albedo making the CI and CM carbonaceous chondrites the best meteoritic analog. With a grain density of 2.1 g/cm^3 [7] we derived a macroporosity of 33±5% for Hermione's interior, very close to the low porosity of rubble. Dryer or Fe-rich carbonaceous meteorites will imply a higher porosity.

Tidal evolution: Dissipation by tides between the satelllite and the primary of a binary asteroid system force the orbital elements to evolve. [8] describe the conditions of stability and evolution of eccentricity and semi-major axis of various binary asteroid systems Using the new bulk density and improved orbital solution, with a rigidity μ = 10^{10} dynes/cm^2 [9] and a dissipation parameter Q=100 [8], we derived a timescale for evolution by tidal interaction of ~20 Myr for 121 Hermione, significantly younger than other C-group binary systems such as 45 Eugenia (>4 Byrs), 87 Sylvia (110 Myrs), or 107 Camilla (920 Myrs) [8,10]. Figure 2 shows that because of the new size measurements of primary and secondary, the Hermione binary system is now above the limit of excitation approximated assuming $Q_s=Q_p$, $k_s=k_p$ and $\rho_s=\rho_p$. Therefore the orbit of the satellite was most likely circularized by the tides.

Conclusion: The combination of AO, photometric and mid-IR observations of the Hermione binary asteroid system is key to deriving accurate insight into the system's components and evolution. We confirmed the bilobated nature of the primary already suggested in [1], derived a low and accurate bulk density implying a rubble-pile interior. Considering an evolution by tidal interaction, the Hermione system seems to be younger than other binary asteroid systems. With (624)

Hektor [11] and (216) Kleopatra [12], (121) Hermione is the third confirmed bifurcated asteroid with a satellite. Spectroscopic studies, combining visible, near-infrared reflectances and mid-IR spectroscopy emissivity spectra could help to better estimate the composition and thus infer an accurate porosity estimate of the asteroid.

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References:

[1] Merline et al. (2002) IAU 7980. [2] Marchis et al. (2005) Icarus 178, 450-464 [3] Kaasalainen (2009), submitted to Inverse Problems and Imaging [4] Descamps et al. (2009) Icarus, submitted [5] Tedesco et al. (2002) AJ 123, 1056-1085 [6] Harris (2008), Icarus, 131, 291[7] Britt and Consolmagno, (2003) Meteor. & Plan. Sc 38, 1161-1180 [8] Marchis et al., (2008) Icarus 195, , 295-316 [9] Yoder (1982) Icarus 49, 327-326. [10] Marchis et al. (2008) 196, 1, 97-118 [11] Marchis et al. (2006) DPS #38, 65.07 [12] Marchis et al., (2008) IAU Circ 8980, Ed. D.W. Green

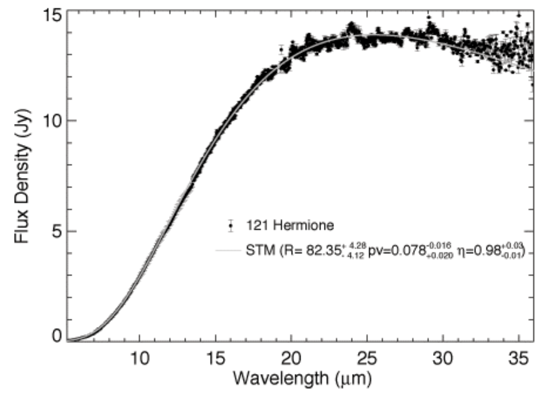

Figure 1: Low- and high-resolution Spitzer/IRS spectra of 121 Hermione taken on September 30 2007 at 23:56 UT. We derived the effective radius, albedo and beaming factor using the NEATM model [6].

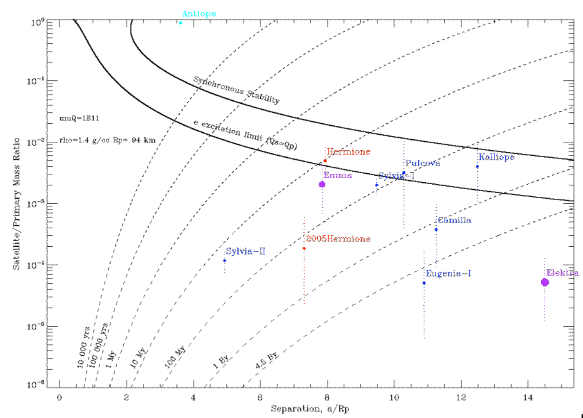

Figure 2: : Evolution of binary asteroid mutual orbits due to tidal dissipation. A binary asteroid system above the synchronous stability line, such as 90 Antiope, does not evolve via tidal interaction. The satellite of a system below the excitation limit curve will have a slightly eccentric orbit, such as we observed for Emma & Elektra [7], due to tidal excitation. Previously derived characteristics of Hermione (labeled 2005Hermione in the figure) from [2] were not in agreement with the model since the satellite orbit is known to be circular. New measurements of the density and size of Hermione's components now place the asteroid slightly above the limit, in agreement with the theory.