EPSC Abstracts
Vol. 5, EPSC2010-505, 2010
European Planetary Science Congress 2010
© Author(s) 2010

The thermal lightcurve of Kuiper belt object Haumea

P. Lacerda (1), E. Lellouch (2), C. Kiss (3), T.G. Müller (4), O. Groussin (5), P. Santos-Sanz (2) and the Herschel "TNO are cool" Key Programme team
(1) Newton Fellow of the Royal Society, Queen's University Belfast, UK, p.lacerda@qub.ac.uk (2) Observatoire de Paris, France, (3) Konkoly Observatory, Hungary, (4) MPE, Germany, (5) Laboratoire d'Astrophysique de Marseille, France

Abstract

We report *Herschel*/PACS 100/160 μm observations of the fast-rotating KBO Haumea. Our data show a definite 100 μm thermal lightcurve which varies by a factor of $\sim$2 and is positively correlated with the optical lightcurve. The correlation confirms that the bulk optical and thermal variability are due to shape effects. A 160 μm lightcurve is marginally detected. Radiometric fits to the mean *Herschel* and *Spitzer* fluxes indicate an equivalent diametre $D\sim$1300 km and a geometric albedo $0.70 < p_V < 0.75$. These values agree with previous inferences from the optical lightcurve and support the hydrostatic equilibrium hypothesis, placing Haumea in the dwarf-planet class. The large variablity at 100 μm suggests that the object has a high projected a/b axis ratio ($\sim$1.3) and low thermal inertia, as well as possible spatially variable infrared beaming. This may signal the presence of fine regolith on the surface, with a lunar-type photometric behaviour. The thermal data are of insufficient quality to clearly detect the effects of a dark surface spot.

1. Introduction

KBO Haumea spins remarkably fast, with period $P = 3.9$ hr [1]. Its rotational lightcurve varies by $\Delta m = 0.29 \pm 0.02$ mag [2] and is double-peaked suggesting that it is caused by a shape effect. Haumea's large mass (4×10^{21} kg [3]) and fast rotation likely act together to deform its shape into a triaxial ellipsoid, close to that predicted by the theory of hydrostatic equilibrium. Based on that assumption, a number of physical properties have been derived for Haumea. A bulk density $\rho \sim 2.6$ g/cm^{-3} was obtained from fitting Haumea's lightcurve with an equator-on, Jacobi ellipsoid model [4]. The mass, density and shape imply approximate physical semi-axes $a = 1000$ km, $b = 800$ km, and $c = 500$ km [1]. Finally, the size and the optical flux yield a high geometric albedo $p_V\sim$0.60 to 0.75, consistent with the water-ice surface [5]. Although plausible, the idea that Haumea has a triaxial shape that balances internal pressure, and centripetal and gravitational accelerations is based on indirect evidence. Our observations were designed in part to address this issue and reveal the nature of Haumea.

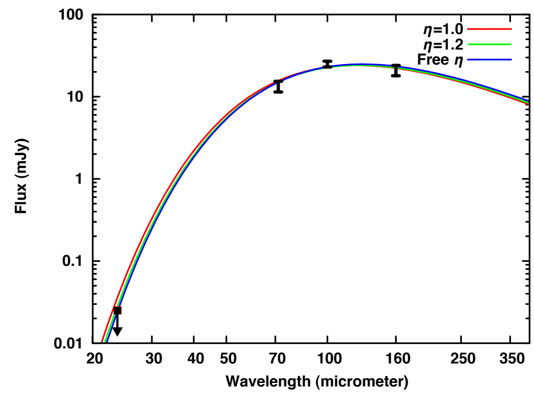

Figure 1: Thermal flux from Haumea as measured by *Spitzer* (24 & 70 μm) and *Herschel*/PACS (100 & 160 μm). Model fits using NEATM with fixed η (η = 1.0 and η = 1.2) and free η (best fit η = 1.38) are shown.

2. Observations

Haumea was monitored using the *Herschel* PACS photometer [6, 7] using the 100/160 μm mode for 3.36 hr on 2009 Dec 23, and then for 0.67 hr on Dec 25 to verify the target flux against a different sky background. The data were reduced and calibrated using *Herschel*-specific software and the total 440 individual observations were binned into 20-min blocks for the 100 μm data and into 40-min blocks at 160 μm to boost *SNR*. The thermal fluxes were extracted using standard aperture photometry. More info can be found in [8].

3. Radiometric diametre & albedo

We performed radiometric modelling of the mean *Spitzer* [9] and *Herschel* fluxes (Table 1) using the Near-Earth Asteroid Thermal Model (NEATM; [10]). The free parametres are the mean radiometric diametre

Table 1: Mean thermal fluxes (in mJy) from Haumea.

Spitzer		*Herschel*	
24 μm	70 μm	100 μm	160 μm
< 0.025	13.4 ± 2.0	25 ± 2	21 ± 3

Table 2: Radiometric model fits.

η	D (km)	p_V	χ^2
1.0 (fixed)	1230 ± 18	0.810 ± 0.024	1.14
1.2 (fixed)	1276 ± 20	0.752 ± 0.024	1.08
1.38 ± 0.71	1324 ± 167	0.698 ± 0.189	1.06

D, the geometric albedo p_V, and the beaming parametre η. The latter may be fixed, if known from a sample of similar objects. We used a mean $H_V = 0.425$ mag and adopted a phase integral $q = 0.7$, intermediate between those estimated for Pluto (0.8) and Charon (0.6) [11]. The emissivity was set to $\epsilon = 0.9$. We considered three cases: $\eta = 1$, $\eta = 1.2$ [9], and free η. Table 2 gives the radiometric solution for the three cases, and Fig. 1 shows the associated fits.

4. Thermal lightcurve

Figure 2 shows the 100/160 μm thermal lightcurves of Haumea plotted against time. The thermal data are overplotted on the optical lightcurve to show the positive correlation between the two. This correlation validates the idea that both the optical and thermal fluxes are modulated by the elongated shape of Haumea. The 100 μm flux varies appreciably, from $\sim$18 to 35 mJy. This indicates a large axis ratio $a/b \sim 1.3$ and, together with the optical Δm points to a weakly limb-darkened, lunar-like surface. The thermal lightcurve of Haumea is reasonably (but not uniquely) fit by a triaxial ellipsoid with semi-axes $961 \times 768 \times 499$ km, mean albedo $p_v = 0.71$ and a spatially variable $0.52 < \eta < 1.15$. The low η indicates low thermal inertia. Our best-fit triaxial solutions, albedos and densities closely match [1, 2, 4], lending support to the hydrostatic equilibrium hypothesis. The dark surface spot proposed by [2] should be warmer than the rest of the surface, and thus the fainter part of the optical lightcurve should appear brighter in thermal emission. This is observed for the lightcurve minima but the maxima show the opposite behaviour. Hence, our thermal data do not unambiguously support the presence of a spot.

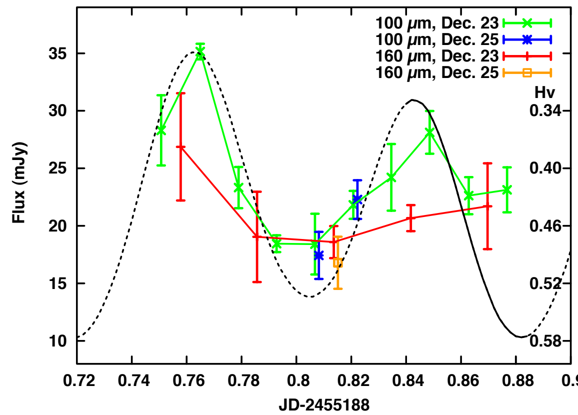

Figure 2: Thermal lightcurves of Haumea at 100 μm (green) and 160 μm (red) in mJy versus Julian date. The Dec 25 data, rephased to Dec 23, demonstrate the robustness of our flux calibration. A black dotted line shows the visible lightcurve (H_V, 2nd y-axis); the solid part marks the region affected by the dark spot model proposed in [2].

5. Conclusions

We use *Herschel*/PACS data (100/160 μm) to measure the size and albedo of Haumea. We find an equivalent diameter $D{\sim}1300$ km and a geometric albedo $0.70 < p_V < 0.75$. When taken together, the optical and thermal lightcurves seem inconsistent with a compact water-ice surface at $\sim$40 K. Instead, the data suggest that Haumea is covered in loose regolith with poor thermal conductivity. New data to be obtained in June 2010 should clarify some of the issues raised here.

References

[1] Rabinowitz, D. L., et al. 2006, ApJ, 639, 1238

[2] Lacerda, P., Jewitt, D., & Peixinho, N. 2008, AJ, 135, 1749

[3] Ragozzine, D., & Brown, M. E. 2009, AJ, 137, 4766

[4] Lacerda, P., & Jewitt, D. C. 2007, AJ, 133, 1393

[5] Trujillo, C. A., 2007, ApJ, 655, 1172

[6] Poglitsch, A. et al. 2010, in press.

[7] Pilbratt, G. et al. 2010, in press.

[8] Lellouch, E. et al. 2010, A&A, in press.

[9] Stansberry, J., et al. 2008, in: The Solar System Beyond Neptune, University of Arizona press, pp. 161.

[10] Harris, A. W., Davies, J. K., & Green, S. F. 1998, Icarus, 135, 441

[11] Lellouch, E. et al. 2000 Icarus, 147, 220