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Characterising the family of TNO 136108 Haumea

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Brown et al. [1] announced the discovery of the first collisional family in the Trans-Neptunian Region after finding a group of objects with very similar spectral features that could be linked dynamically with 136108 Haumea (2003 EL61). These objects all show the same almost pure water ice spectral signature observed in Haumea, and Brown et al. postulate that the family was formed in a collision with the large and already differentiated proto-Haumea early in the history of the Solar System, leaving the overly dense and fast spinning core with a thin covering of water ice as Haumea and generating a family of pure water ice bodies from the outer layers. Ragozzine & Brown [2] published a list of further potential family members selected on dynamical grounds (including known family members, the list contains 36 objects), but little was known about the surface properties of many of these objects as most are smaller and consequently too faint for the near-infrared spectroscopy that can confirm the presence of water ice on their surfaces.

We began a programme at ESO in 2008 to measure the physical characteristics of these proposed family members with two goals; to confirm the membership of the family for each body by detecting the signature of water ice on the surface and secondly to test the idea that they were composed almost entirely of water ice by placing limits on the density of the bodies. We look for water ice on bodies too small for spectroscopy using optical and near-infrared colours using the ESO instruments EFOSC2 at the NTT and HAWK-I at the VLT. A unique strength of using the new HAWK-I imager is that this instrument contains a medium band filter (CH_4) that covers the water absorption band at 1.5 microns, making the (J-CH_4) colour very sensitive to this absorption feature and therefore a strong indicator of water ice (Fig. 1). We place constraints on the density of the bodies by measuring light-curves (using EFOSC2): The elongation (from the light-curve amplitude) and rotation period then constrain the minimum bulk density of the body, with higher values than 1 g cm^{-3} ruling out a pure water ice composition.

We find that most of the candidates do not have water ice surfaces, based on observations of 22 of the 36 candidates [4] (Table 1). Those that do are clustered in orbital element space near to the proposed collision (Fig. 2), showing that the fragments from the collision did not spread far. The current confirmed members can all be explained by a dispersion velocity of ≤ 125 m s^{-1}, much lower than would be expected for a catastrophic collision with a body of the size of the proto-Haumea. Proposed explanations for this include a grazing impact and merger [5] or a collision with a smaller moon rather than Haumea itself [6], but there is still debate as to the true source of this family of objects.

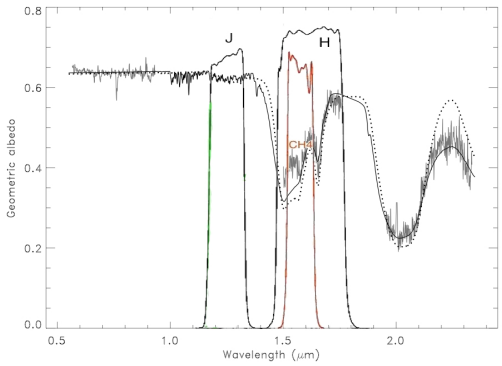

Figure 1: The band-passes of the HAWK-I filters J, H and CH_4 are over-plotted on a SINFONI spectrum of Haumea taken from [3]. It can be seen that using the CH_4 filter as a narrower H_S makes $(J - H_S)$ colours an excellent way to identify the broad water-ice absorption feature at 1.5μm.

Due to the small number of confirmed family members, we cannot place strong constraints on the density of these objects. We present our latest results from this project, including new observations taken in February 2010.

Table 1: Assessment of likely membership (based on water ice detection) for all candidates.

Object		Family?
24835	1995 SM 55	Y
	1996 RQ 20	N
	1996 TR 66	?
19308	1996 TO 66	Y
	1997 RX 9	?
	1998 HL 151	?
181855	1998 WT 31	N
	1999 CD 158	N
40314	1999 KR 16	N
	1999 OH 4	?
	1999 OK 4	?
86047	1999 OY 3	Y
86177	1999 RY 215	N
	2000 CG 105	?
	2000 JG 81	?
	2001 FU 172	N
	2001 QC 298	N
55565	2002 AW 197	N
	2002 GH 32	N
55636	2002 TX 300	Y
136108	Haumea	Y
	2003 HA 57	?
	2003 HX 56	?
120178	2003 OP 32	Y
	2003 QX 91	?
	2003 SQ 317	Y
	2003 TH 58	N
	2003 UZ 117	Y
	2004 PT 107	N
	2004 SB 60	N
	2005 CB 79	Y
136472	Makemake	N
	2005 GE 187	N
145453	2005 RR 43	Y
202421	2005 UQ 513	N

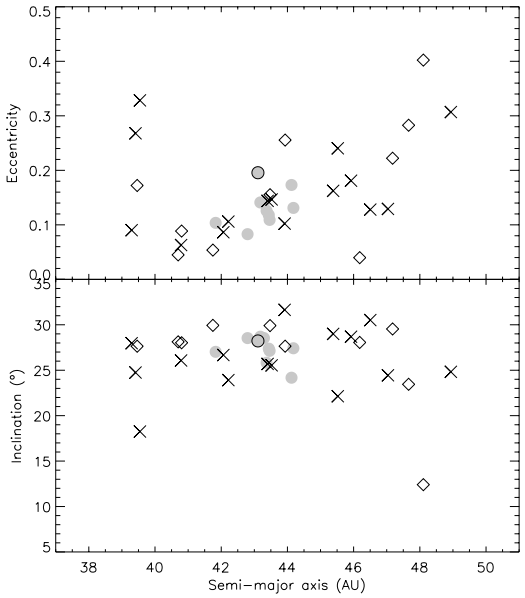

Figure 2: Confirmed family members (grey filled circles), rejected candidates (crosses) and those with unknown surface properties (open diamonds) plotted in terms of the orbital parameters semi-major axis, inclination and eccentricity. Haumea itself is shown as a grey circle with a black outline.

References

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[6] Schlichting, H. & Sari, R. 2009, ApJ, 700, 1242