Rotationally resolved spectroscopy of the dwarf planet (136472) Makemake

V. Lorenzi[1], N. Pinilla-Alonso[2], and J. Licandro[3,4]

[1]Fundación Galileo Galilei -INAF, Spain
[2]Department of Earth and Planetary Sciences, University of Tennessee, USA
[3]Instituto de Astrofísica de Canarias, Spain
[4]Departamento de Astrofísica, Universidad de La Laguna, Tenerife, Spain

Icy dwarf planets are transneptunian objects large and cold enough to retain large amounts of volatiles on their surfaces, which is of particular interest for the understanding of the origin and evolution of the Solar System. Two of them, Pluto and Eris, are very similar. They are of comparable dimensions and present similar spectral characteristics, with methane-ice bands dominating the visible and near-infrared spectra, and a red slope in the visible, suggesting the presence of complex organic materials on the surface (Licandro et al. 2006a). But there are also some significant differences: whereas Pluto has an observed global atmosphere (composed mainly of N_2 but also of CH_4, e.g., Lellouch et al. 2009), for Eris, there is no evidence of the presence of an atmosphere. No N_2 (main component of the surface of Pluto) or CO have been detected on the surface of Eris, even if their presence is inferred (Licandro et al. 2006a), and there is no evidence for surface variability (Alvarez-Candal et al. 2011), which has been widely studied for Pluto (e.g., Buie et al. 2010; Grundy et al. 2013). Moreover, the albedo of Eris ($p_v = 0.96$, Buratti et al. 2003) is higher than Pluto's ($p_v = 0.52$, Sicardy et al, 2011). All this seems to indicate that Eris, with a more eccentric orbit and a distance to the Sun varying between 35 and 97 au, could be an iced Pluto whose atmosphere has collapsed on the surface covering it with ices of higher albedo and giving it its homogeneous appearance.

Makemake, another dwarf planet, seems to be a intermediate case between the other two: it moves at a heliocentric distance between 38.5 and 53 au, it has an intermediate albedo ($p_v = 0.77$, Ortiz et al. 2012), and like Pluto and Eris, it has a reddish spectrum with strong methane-ice absorption bands (Licandro et al. 2006b). Furthermore, some surface heterogeneity related with volatile transport has been suggested. Thermal observations (Stansberry et al. 2008; Lim et al. 2010) point at the existence of two different surfaces, with associated albedos between 0.07 and 0.84. This was recently reinforced by the observation of an occultation of a star by Makemake that hints at the presence of a transient atmosphere. Volatile transport would be supported by surface heterogeneity (Ortiz et al. 2012).

If this is the case, the abundance of super volatiles (N_2 and CO) versus CH_4 on the surface of Makemake should be different from that on the surfaces of Eris and Pluto. Furthermore, these ices would be distributed heterogeneously over the surface of the dwarf planet.

In this work, we present new visible spectra of Makemake (0.35–0.54 µm and 0.7–1.0 µm) obtained with the medium-resolution spectrograph ISIS at the WHT telescope, La Palma, Spain. The observations were carried out over a 5.4-h time interval, covering ∼70 % of the rotational period (7.7 h; Thirouin et al. 2010). These data were combined in three averaged spectra. For these three spectra, we study the center of the bands of methane ice, their depth and the slope of the overall continuum, which is indicative of non-ice component such as complex organic materials.

Here we present the results of this analysis. It shows that the centers of the bands are shifted with respect to the theoretical positions calculated in the laboratory, indicating that the CH_4 is in solid solution with another volatile. We also discuss if these shifts are different for the three different phases, which would be indicative of surface heterogeneity. We will also show the results of extending the same analysis in a systematic way to other spectra collected from the literature to search for secular variation.

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