EPSC Abstracts
Vol. 11, EPSC2017-363, 2017
European Planetary Science Congress 2017

Spectroscopy of the dwarf planet Makemake

T. Hromakina (1, 2), D. Perna (2, 3), F. Merlin (2), S. Ieva (3), S. Fornasier (2), I. Belskaya (1) and E. Mazzotta Epifani (3)
(1) Institute of Astronomy, Kharkiv V.N. Karazin National University, Sumska Str. 35, Kharkiv 61022, Ukraine, (2) LESIA – Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, Univ. Paris Diderot, Sorbonne Paris Cité, 5 place Jules Janssen, F-92195 Meudon, France, (3) INAF – Osservatorio Astronomico di Roma, Via Frascati 33, I-00078 Monte Porzio Catone (Roma), Italy

Abstract

Here we present new rotationally resolved visible and near-infrared spectra of the dwarf planet Makemake obtained in the time span 2006–2013. Our spectra show no variation within the errors, suggesting a very homogeneous surface, as well as no secular variations was discovered when comparing our data to that in the literature. The presence of methane diluted in nitrogen is evidenced by the shift of the observed absorption bands with respect to those of pure methane. Spectral modelling results suggest that the addition of methane irradiation products gives better fit to our data compared to that of pure methane ice.

1. Introduction

The spectrum of dwarf planet (136472) Makemake is dominated by the deep absorption bands of methane ice (associated with large grain sizes), that are slightly blue-shifted with respect to those of pure methane, suggesting the latter is the dominant material with a possible partial dilution in nitrogen (cf. [4] and references therein). Additionally, a polarimetric observation of Makemake suggests the presence of a thin low-porosity layer of hoarfrost [1]. Thermal observations of Makemake suggest the presence of a low-albedo spot on an overall high-albedo surface [2]. But the recent discovery of a Makemake's satellite [3] makes plausible to associate the dark material with the surface of the satellite. Noteworthy, the first rotationally resolved spectroscopy of Makemake [4] did not show a reliable variation and keeps Makemake's surface heterogeneity open to discussion.

2. Observations

A total of 12 visible (Figure 1) and 2 near-infrared

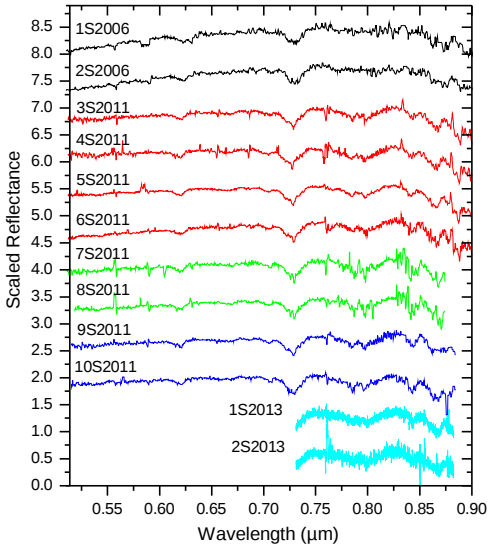

Figure 1: Visible reflectance spectra of Makemake obtained in 2006-2013.

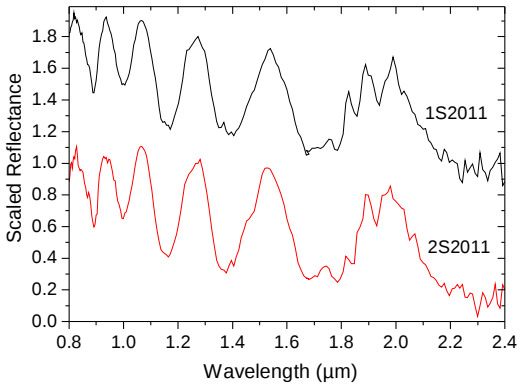

Figure 2: NIR reflectance spectra of Makemake obtained on 28/29 March 2011.

(NIR) (Figure 2) spectra were obtained in 2006–2013 during three observing runs (April 2006, March 2011 and January 2013). All observations were carried out at the 3.6-m TNG telescope (La Palma, Spain), using

the DOLORES instrument for visible observations and the NICS instrument for NIR observations. Data reduction has been performed following the standard procedure using the IRAF software package.

3. Data analysis

The majority of spectra were obtained during the second run in 2011, covering about 80 per cent of the surface of Makemake, providing us with an optimal amount of data to look for any surface variation. To calculate spectral slopes, we normalized our visible spectra at 0.65 μm and fitted the 0.55–0.65 μm region with a linear function. The calculated values of the slope (mean ~9 ± 3 per cent/1000 Å) are consistent with those from the literature and show only minor variations compatible within the errors. This can suggest ether very homogenous surface of Makemake or near pole-on aspect. However, as it was discussed in [3] a nearly edge-on configuration seems to be more preferable.

In order to measure the band shifts we ran a cross-correlation analysis between our spectra and the spectral model of pure methane. We found our average value of the band shifts (−6.2 ± 1.9 Å) to be in good agreement with the previously reported blue-shift of ~−4 Å [4].

To constrain the surface composition of Makemake, we applied Shkuratov spectral model [5]. We consider both large and small methane ice particles, and found that Makemake's surface is dominated by cm-sized methane ice grains (which is rather an indicator of a long path length), while the presence of small ones is limited to a few per cent. Inclusion of tholins and methane irradiation products into our model lowers the RMSD value compared to that of pure methane ice (cf. Figure 3). But given that spectral resolution of our data is too low for direct detection of those products, our final model suggests rather a possibility of the presence of irradiation products on the surface of Makemake, not a unique solution.

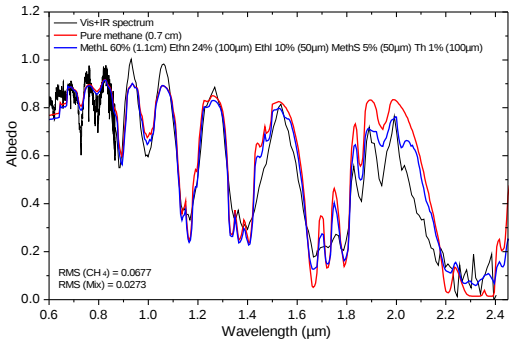

Figure 3: Spectrum of Makemake (black), fitted by a model (blue) of methane ice (Large grains: 60%; Small grains: 5%) plus ethane (24%), ethylene (10%) and Ice tholins (1%). A model of pure methane ice (red) is shown for comparison.

4. Summary and Conclusions

We present new visible and NIR spectral observations of the dwarf planet Makemake, that cover most part of the surface. The obtained spectra are dominated by methane ice absorption bands and are slightly blue-shifted, probably due to a partial dilution of methane in nitrogen. Our data suggest a very homogeneous surface, which is supported by the discovery of a Makemakean moon (to explain previously detected heterogeneities) and probable equator-on configuration. Hence, our data do not support the hypothesis of atmospheric freeze-out and escape episodes with consequent local colour changes. Spectral modelling results suggest that the surface of Makemake is dominated by large cm-sized methane ice grains (or a slab) eventually covered with a thin layer of small particles and possible presence of higher mass alkanes (such as ethane and ethylene).

References

[1] Belskaya, I., et al.: Polarimetry of trans-Neptunian objects (136472) Makemake and (90482) Orcus, A&A, Vol. 547, 101, 2012.

[2] Lim T. L. et al.: "TNOs are Cool": A survey of the trans-Neptunian region III. Thermophysical properties of 90482 Orcus and 136472 Makemake, A&A, Vol. 518, L148, 2010.

[3] Parker, A. H. et al.: Discovery of a Makemakean Moon, AJ, Vol. 825, L9, 2016.

[4] Lorenzi V., Pinilla-Alonso N., and Licandro J.: Rotationally resolved spectroscopy of dwarf planet (136472) Makemake, A&A, Vol. 577, p. 86, 2015.

[5] Shkuratov Yu., et al.: A Model of Spectral Albedo of Particulate Surfaces: Implications for Optical Properties of the Moon, Icarus, Vol. 137, 235, 1999.