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Makemake: A truly exotic TNO!

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Abstract

Makemake is a truely exotic TNO: Its thermal spectral energy distribution is very different from all other objects in our sample of nearly 140 trans-Neptunian objects observed with *Herschel* as part of the key programme "TNOs are Cool! A Survey of the trans-Neptunian Region". We present the our results on (136472) Makemake from thermophysical model studies of all *Spitzer* and *Herschel* observations combined.

1. Introduction

Makemake is one of the highest albedo targets known to date [1] [2] and it has the strongest absorption bands from methane ice in the entire solar system [3] [4] [5] [6]. Spectral analysis of Makemake's surface revealed that methane must be present in the form of large grains at least one centimetre in size [5]. No satellite has been discovered so far [7] and it has only a very shallow lightcurve [8] pointing to a rotation period of 7.7 hours.

The thermal measurements indicate a surface with two different regions of very different albedos [1] [2]: a dominating large region with $p_V > 0.78$ and a much smaller, hotter region with $p_V < 0.12$.

The lack of a strong visible (or thermal) lightcurve, combined with the thermal evidence for two terrains with very different albedos, indicates that we are probably viewing Makemake in a nearly pole-on orientation at this time.

2. Observational data

We present all existing thermal measurements from *Spitzer* and *Herschel* (published and new data), covering a wavelength range from 24-500 μm and 5 different observing epochs (2005-2011). The thermal data cover the full thermal spectral energy distribution with about half of the data taken before opposition and half after opposition. The *Herschel* data are part of a large key project on "TNOs are Cool! A survey of the Transneptunian region" [9].

3. Results

Makemake's thermal emission spectrum is very different from all other large TNOs. It cannot be explained by simple (TNO adjusted) NEATM solutions nor by sophisticated, single-albedo TPM solutions. An acceptable fit to the far-IR data beyond 100 μm underestimates the 24 μm data by at least a factor of 2-3. Reasonable fits to the 24 and 70 μm data overestimate the far-IR fluxes by far. Stansberry et al. (2008) [1] already noted that fitting the 24 and 70 μm data with simple thermal models failed and they could not determine a plausible beaming parameter. The best solutions at long wavelength point towards an extremely high albedo target with a geometric albedo very close to 1.0, while the *Spitzer* 24 μm data would also be in agreement with albedos below 80%, but require a diameter larger than 1500 km.

We started an extensive TPM study with the goal to explain all thermal measurements of (136472) Makemake. We considered different orientations for the spin-axis, a wide range of thermal inertias, and different flavours of two-terrain models. We also allowed for variations in the phase integral and introduced a wavelength-dependent emissivity with very low values at the longest wavelengths.

We present and discuss the results of our thermophysical model studies and illustrate the influence of the various model input parameters. The results of our

analysis will also be relevant for the interpretation of thermal emission measurements of other large TNOs.

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