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A Portrait of the Centaur 2060 Chiron: new results from groundbased and Herschel observations

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Abstract

The Herschel Open Time Key Program entitled "TNOs are Cool: A survey of the trans-Neptunian region" has been awarded 373 hours to investigate the albedo, size distribution and thermal properties of TNOs and Centaurs [1]. In this work we present the results of the combined SPIRE and PACS instruments observations over 6 bands of the Centaur 2060 Chiron, together with groundbased observations used to constrain its absolute magnitude, to investigate possible cometary activity and its surface composition.
The estimated nuclear H_V magnitude during the Herschel observations is 5.81±0.08, indicating a high flux from the Centaur comparable to that of its activity peak during 1989. Using this H_V value, our Chiron's best size estimation, from NEATM and TPM modelling, is 218±20 km, with an albedo of 16±3 %, a value higher than previous Chiron's albedo estimation. Chiron shows the strongest decrease in the emissivity versus wavelength in the TNOs and Centaurs sample investigated with the PACS and SPIRE instruments.
The results on the cometary activity analysis both in the visual and far infrared images will also be presented.

1. Introduction

Centaurs are a transitional population between TNOs (trans- Neptunian objects) and Jupiter family comets. The median orbital lifetime is 10 Myr [2] and it is proportional to the perihelion distance. Close encounters with planets make Centaurs' orbits short-lived and most of them ($\sim<$ 2/3) will be ejected to interstellar space. Others will be scattered to the inner Solar System ($\sim<$ 1/3) as short period comets, broken apart, colliding with a planet, or become a temporary satellite of a planet. More than 450 Centaurs have been discovered, but the estimated number of Centaurs larger than 1 km in diameter is about 44300 [3]. Chiron was the first Centaur discovered, in 1977. It has shown in the past important cometary activity, and was indeed alternatively labelled as comet 95P/Chiron.

2. Results and discussion

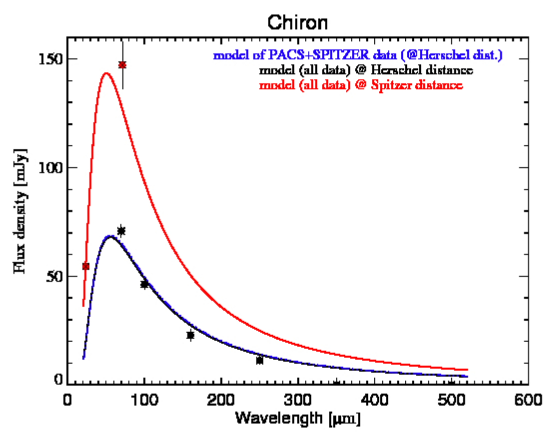

Figure 1: NEATM thermal model of Chiron: model of the MIPS, PACS, and SPIRE data scaled to the heliocentric distance corresponding to the Herschel (black line) and to the Spitzer (red line) observations; blue dashed line: model of the MIPS and PACS data scaled to the heliocentric distance corresponding to the Herschel observations.

Chiron displays considerable variation in its total (nucleus + coma) brightness with time. Belskaya et al. [4], analysing their own data acquired in 2008 and literature data, have found that Chiron's absolute V magnitude was almost constant over the 2004–2008 period, with an H_V value (5.82±0.07) comparable to the one found on 1989, when the object showed a peak of cometary activity.

We got new photometric observations of it in the R filter at the 1.2 m telescope in Calar Alto, Spain on 18 to 24 December 2011, closer to the Herschel observations. The mean value of the seventeen individual observations taken over the seven nights gives an R magnitude R(1,1,α=3) = 5.62$\pm$0.03. Using (V-R)=0.36 and β=0.06 mag/deg [4], we derive an absolute magnitude H$_V$=5.80$\pm$0.04. Considering all measurements over 2004-2011, we adopt H$_V$=5.81$\pm$0.08 for the mean total magnitude of Chiron.

We also re-analysed some deep Chiron images taken in 2007–2008 in the Bessel R filter with the FORS1 instrument at the ESO-VLT telescope. The analysis of those images with the $\sum$Af function [5] allows us to detect a faint evolved coma. Its $Af\rho$ resulted to be 650$\pm$110 cm, constant within errors. Assuming that at the time of the Herschel observation the coma of Chiron had the same Afρ value, the contribution of the coma is less than 10% of the flux of the nucleus. Correcting for this small coma contribution we find that the nuclear H$_V$ magnitude of Chiron was around 5.92$\pm$0.20, where we adopt a conservative error bar to take into account the non-simultaneousness between visual and thermal observations and the errors in the coma contribution estimation.

Nevertheless there is still the possibility that an unresolved evolving coma contributes to Chiron's brightness. In the December 2011 observations we performed, however, the coma, if present, was below our detection limit.

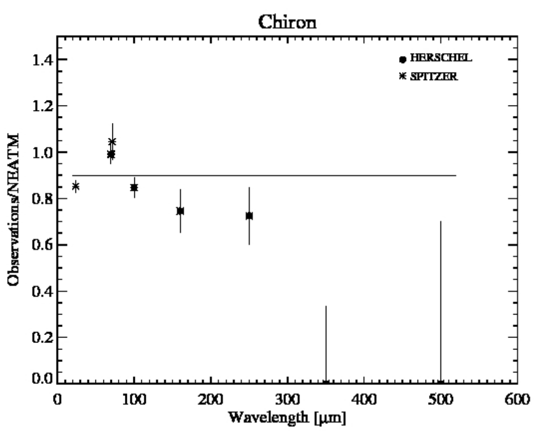

Figure 2: Chiron observed fluxes divided by the NEATM model that best fit the Herschel and Spitzer data.

Chiron was observed with the PACS and SPIRE instrument over 6 bands (centred at 70, 100, 160, 250, 350, and 500 μm) on April 2010. The Herschel data, coupled with the Spitzer-MIPS fluxes at 23.7 and 71.4 μm [6], have been modelled with both NEATM and thermophysical models in order to derive their albedo, diameter and thermal properties.

Assuming H_v=5.92$\pm$0.20 for Chiron nucleus, the NEATM model of the Spitzer-MIPS and Herschel PACS and SPIRE data (Fig. 1) gives a diameter of 215.6$\pm$9.9 km, and a geometric albedo of $16.7^{+3.7}_{-3.0}$ %. Very similar results are obtained from the TPM modelling with a constant emissivity of 0.9. Nevertheless, Chiron shows strong emissivity effects for wavelengths beyond 100 μm (see Fig. 2). We then run a TPM model with wavelength-dependent emissivity derived from the SED of Vesta. This model gives an albedo of 16$\pm$3% and a diameter ranging between 198-238 km for different spin-vector orientations [6].

We interpret the lower emissivity for Chiron for wavelengths $>$ 100 microns to the fact that the sub-mm thermal flux arises from sub-surface layers that are, on the dayside, colder than the surface itself. The steady decrease in the emissivity with wavelength implies that SPIRE radiation most likely probes below the skin depth, and thus is representative of the diurnally-averaged deep temperature, while PACS fluxes in the shorter wavelengths do not probe the deep temperature below the diurnal wave, indicating that the surface is not too transparent.

No coma was detected within our detection limit on the PACS images, from which we derive an upper limit of 0.6–17 kg s^{-1} for the dust production rate. These upper limits are 1-10 times higher than those derived from the optical images relative to the 2007-2008 observations.

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