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Indirect evidences of the ring system around Chariklo

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Abstract

In this work we show from photometric and spectroscopic observations, that the variability of the absolute magnitude and spectral ice feature in Chariklo spectra observed in different years and even the disappearance of the band can be explained by the aspect angle of a system of rings around (10199) Chariklo. Using X-Shooter at VLT we obtained a new reflectance spectra and we show that the water ice spectral feature was again visible in 2013, in accordance with the ring configuration. Here we also show that past absolute photometry of Chariklo and new photometry that we obtained in 2013 can be explained by a ring of particles whose opening angle change as a function of time. Finally, we modelled the spectra taken over time and our own and obtained an estimation of the concentration of materials on the surface and rings of Chariklo.

1. Introduction

Chariklo, which appears to be the largest object in the centaurs population with a diameter of 248±18 km [1][2] has never shown any traces of cometary activity. A vast photometric monitoring along a large time span has been made since its discovery in 1997, trying to identify possible outbursts, but no such potential outbursts have been identified thus far. Using the Herschel Space Observatory on August 2010 [1] found a very dark surface for Chariklo (2.5 < p_V < 4.5%). That work also used a thermo-physical model to exclude the pole-on solution at the time of Herschel observations. On June 3rd 2013, a stellar occultation of an R=12.4 magnitude star by Chariklo was predicted [3] and observed thanks to a large observational campaign. The discovery of a ring system around Chariklo has been reported from those observations [4]. The multi-chord stellar occultation revealed the presence of two dense rings around Chariklo, with widths of about 7 and 4 km, optical depths of 0.4 and 0.06, and orbital radii of 391 and 405 km, respectively. On the other hand, several independent spectroscopic studies of Chariklo reported the detection of water ice absorption bands located at 1.5 and 2.0 μm (e.g. [5][6]). Later on, observations with higher S/N ratio have shown different spectral behaviour [7][8] and no absorption band could be detected at the same spectral region.

2. New observational data

With the intention to obtain new values for the absolute magnitude of Chariklo, photometric observations were made with different telescopes in 2013. Also, as was mentioned, a reflectance spectrum in the vis+nir range was obtained with the X-Shoother at VLT. We obtained a reflectance spectrum of Chariklo ranging from 0.35 m to 2.3 μm using the X-Shooter spectrograph located in the Cassegrain focus of unit 2 at the VLT. X-Shooter is an echelle spectrograph that can simultaneously record all the vis+nir spectral range.

3. Analysis of the photometric data

To make an interpretation of the photometry compiled by [9] and our new photometry during 2013, we built a model of the reflected light by the main body and a model of the reflected light by the rings. The nominal shape used is an ellipsoid whose projected shape matches that observed in the stellar occultation. Using the pole determination and size estimated from the stellar occultations in Chariklo, we applied the equations presented in [10] to obtain the evolution of absolute magnitude during time, presented in figure 1.

4. Analysis of the spectral data

The spectrum of Chariklo taken in 2013 shows a red slope in the visible of 9.375%/1000Å from 0.55 to 0.75 μm. This slope is typically related with the presence of complex organics on the surface of the body. Band depths (%) were computed by defining a linear continuum between 1.75 and 2.2 μm and then measuring the reflectance at 2.0 μm relative to the one at 1.75 μm.

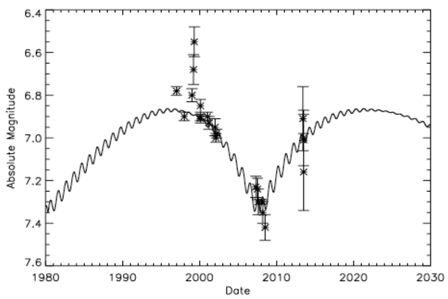

Figure 1: Variation of the H_V during time. Data taken from [9] and our own observations. The solid curve represents the model. It is fitted to the data, assuming the ring pole position mentioned in the text (λ=138, β=28). We assume that Chariklo's rotation axis is aligned with ring pole.

We used the Shkuratov theory [11] to generate a Collection of synthetic spectra that reproduce the overall shape of the spectrum of the whole system: Chariklo and rings. The first spectrum that we modelled was that from [7] acquired in 2007. We did some tests to reproduce the shape of the spectrum with materials that are typically found on the surface of centaurs and trans-Neptunian objects: water ice, complex organics, amorphous olivine, and amorphous pyroxene with different content of magnesium and iron, and amorphous carbon. In a second step we modelled the new spectrum presented in this work.

5. Results and conclusions

One of the main results is that using the spin axis orientation we can understand the behaviour of the absolute magnitude of Chariklo.

From the spectrum acquired in 2007, when almost all the light is scattered by Chariklo's surface, our best models all discard the presence of water ice on the surface of the Centaur[11]. They also show that this surface is composed of a mixture of amorphous silicates (30%), red-complex organics (10%) and amorphous carbon (60%). The second main result is the fact that we can model all the other spectra with a canonical composition for the continuum linearly combined with a canonical composition for the rings, but changing their relative contributions by means of the aspect angle of the system.

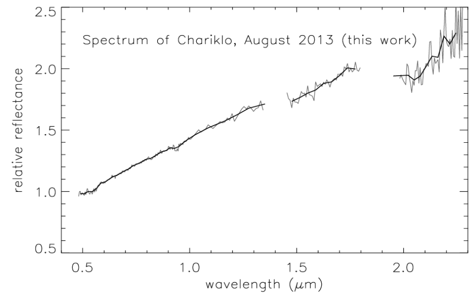

Figure 2: Reflectance spectra of Chariklo obtained in August 2013 using the X-Shooter at VLT.

The rings can contain up to a 20% of water ice (with a size particle of ~ 80 μm) and fits the bands in the three spectra with very different shape, from the very shallow in the spectrum from 2008 (aspect angle = 83º) to the deeper in the spectrum of 2013 (aspect angle = 58º).

6. References

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