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The ring system of the Centaur Object (10199) Chariklo

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Abstract

Observations of a stellar occultation on 03 June 2013, led to the discovery of the first ring system ever detected around a small Solar System object, the Centaur (10199) Chariklo [1]. The object is about 125 km in radius and is in an unstable orbit between Saturn and Uranus. The system is composed by two narrow and dense rings, separated by an empty gap.Their current configuration may be explained by the presence of putative kilometre-sized satellites. By means of the shepherd mechanism, it can confine and open the gap between the rings, otherwise they would spread out in few thousand years. From 1997 to 2008 the Chariklo system showed a strange behaviour. It dimmed by 0.5 in absolute magnitude and the water ice band in its spectrum, formerly observed, could not be detected in 2008. This can be simply explained by the rings orientation, which were seen edge-on 2008. Photometric and spectroscopic observations made in 2013, had shown an increasing of brightness and the detection of the water ice band. New stellar occultations by the Chariklo system have been observed along the year, allowing better understanding of the system.

1. Introduction

Planetary rings were known around the four giant planets of our Solar System. During a stellar occultation [2] on 03 June 2013, observed from sites in Chile, Brazil, Uruguay and Argentina a new ring system was found. It is orbiting the Centaur object (10199) Chariklo, the biggest object of its class with an equivalent radius of 124 $\pm$ 9 km [3], in an unstable orbit between Saturn and Uranus. It may be a former trans-Neptunian object that has been scattered, by gravitational perturbations from Uranus, to its current location less than 10 Myr ago [4]. The ring system was detected from seven different sites, while the main body was detected from three of them.

2. Rings detections

2.1. Two narrow rings

Observations made at European Southern Observatory at La Silla / Chile, with the Danish 1.54 m telescope, were acquired with a rate of 10 images per second. This high speed photometry resolved the two closely-spaced, narrow and dense rings that compose the system. They are denoted 2013C1R and 2013C2R (C1R and C2R for short). They are fitted by two sharp-edge rings with average radial widths in the ring plane of $W_{\mathrm{C1R}} = 6.6$ km and $W_{C2R} = 3.4$ km, and normal optical depths of $\tau_{N,C1R} = 0.38$ and $\tau_{N,C2R} = 0.06$, respectively. No material ($\tau_{gap} < 0.004$) is detected on the 8.7 km gap.

2.2. Big picture

A total of 13 secondary events were observed from 7 different sites. The two rings were generally not resolved, but their depths provide a measure of the integrated flux loss of the events, which depends on the local geometry of the occultation in the plane of the sky. They are satisfactorily explained by two flat and azimuthally homogeneous rings, on a circular orbit around Chariklo (Fig. 1), with radii of 391 km, for C1R, and 405 km, for C2R. From the fit we obtain two possible pole positions. As justified below, our preferred pole position has equatorial J2000 coordinates $\alpha_p = 151.30 \pm 0.49$ and $\delta_p = 41.48 \pm 0.21$.

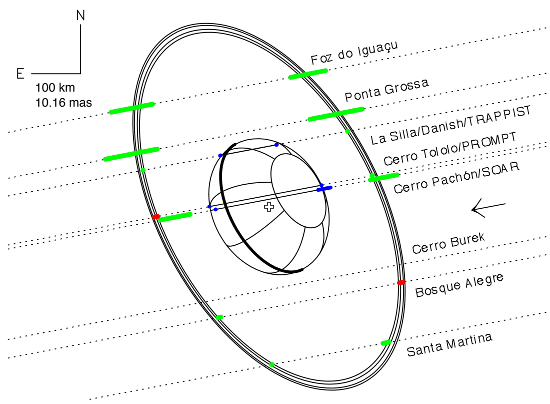

Figure 1: Chariklo's ring system geometry as observed from seven different sites on 03 June 2013, see [1].

3. Analysis

3.1. Ring structure

By analogy with the surface density of Saturn's A ring, and the rings of Uranus, we estimate that the mass of C1R is equivalent to that of an icy body with a radius of roughly one km, whereas C2R corresponds to a body of half that size. An unperturbed ring several kilometres in width and of thickness of few meters would spread in a few thousand years, owing to interparticle collisions. Thus, the rings are either very young or actively confined. Kilometre-sized shepherd satellites can confine the rings and create the gap.

3.2. Photometric and spectroscopic variations

Our preferred pole position implies that the rings were seen edge-on in 2008. This is a natural explanation for the brightness and spectral variations observed from 1997 to 2008. During this period, the Chariklo system's absolute magnitude dimmed by a factor of 1.75 [5], so we estimate the ring reflectivity to be $I/F < 0.05$. During the same period the 2 μm water-ice band and the spectral slope below 0.55 μm gradually disappeared [6], so we infer that they are partially composed of water ice. Observations made in 2013 show that the system has brightened since 2008, and that the water-ice band is detectable again, supporting our interpretation.

4. Origin Scenarios

We can think of several origin scenarios, all relying on the formation of a debris disk that was afterwards confined into the rings by the largest fragments, or pre-existing satellites, acting as shepherds for the smaller material: (i) a smooth collision that excavated icy material from Chariklo; (ii) a rotational disruption that led to a formation of a debris disc; (iii) a collision of two pre-existing satellites; (iv) a satellite that migrated inwards and got disrupted by tidal forces; (v) a debris disk fed by cometary-like activity, although no cometary activity was ever observed on Chariklo. Dynamical studies are needed to determine which is the most reliable scenario.

5. Future

As stellar occultations are the only technique, at present, that allows the study of the rings' structures in details, we continue to monitor such events. The rings were already detected in 3 new occultations this year. New data will allow confirmation of the ring pole position, monitoring of the ring stability and, possibly, studies of the system in finer detail.

References

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