Measuring the Size of a Small, Frost World

Observing from three different sites a very rare occultation of a star by Pluto's satellite Charon, astronomers were able to determine with great accuracy its radius and density. They also put strong constraints on the existence of an atmosphere around Charon.

Since its discovery in 1978, Charon and Pluto have appeared to form a double planet, rather than a planet-satellite couple. Actually, Charon is about twice as small as Pluto in size, and about eight times less massive. However, there have been considerable discussions concerning the precise radii of Pluto and Charon, as well as about the presence of a tenuous atmosphere around Charon.

In August 2004, Australian amateur astronomer *Dave Herald* predicted that the 15-magnitude star UCAC2 26257135 should be occulted by Charon on 11 July 2005. The occultation would be observable from some parts of South America, including Cerro Paranal, in the northern Atacama Desert, the location of ESO's Very Large Telescope (VLT).

Stellar occultations have proved to be powerful tools to both measure sizes - at km-level accuracy, i.e. a factor ten better than what is feasible with other techniques - and detect very tenuous atmosphere - at microbar levels or less. Unfortunately, in the case of Charon, such occultations are extremely rare, owing to the very small angular diameter of the satellite on the sky: 55 milli-arcsec, i.e. the size of a one Euro coin observed from 100 km away!

This explains why only one occultation by Charon was ever observed before 2005, namely on 7 April 1980 by Alistair Walker, from the South Africa Astronomical Observatory.

Similarly, only in 1985, 1988 and 2002 could astronomers observe stellar occultations by Pluto. Quite surprisingly, the 2002 event showed that Pluto's atmospheric pressure had increased by a factor of two in four years (ESO Press Photo 21/02).

"*Several factors, however, have boosted our odds for witnessing occultations of Charon,*" said *Bruno Sicardy*, from Paris Observatory (France) and lead author of the paper reporting the results. "*First, larger telescopes now give access to fainter stars, thus multiplying the candidates for occultations. Secondly, stellar catalogues have become much more precise, allowing us to do better predictions. And, finally, the Pluto-Charon system is presently crossing the Milky Way, thereby increasing the odds of an occultation.*"

The July 2005 event was eventually observed from Paranal with Yepun, the fourth Unit Telescope of the VLT, equipped with the adaptive optics instrument NACO, as well as with the 0.5m "Campo Catino Austral Telescope" at San Pedro de Atacama (Chile), and with the 2.15m "Jorge Sahade" telescope at Cerro El Leoncito (Argentina).

An accurate timing of the occultation seen at the three sites provides the most accurate measurement of Charon's size: its radius is found to be 603.6 km, with an error of the order of 5 km.

This accuracy now allows astronomers to pin Charon's density down to 1.71 that of water, indicative of an icy body with about slightly more than half of rocks. **Quite remarkably, Charon's density is now measured with much more precision than Pluto's.**

Thanks to these observations, Sicardy and his collaborators could determine that if an tenuous atmosphere exists on Charon, linking it to the freezing -220 degrees centigrade or so surface, its pressure has to be less than one tenth of a millionth that at the surface of the Earth, or 0.1 microbar, assuming that it is constituted entirely of nitrogen.

A similar upper limit is derived for a gas like carbon monoxide. This is more than a factor one hundred smaller than Pluto's surface pressure, which is estimated to be in the range 10-15 microbars.

"*Comparing Pluto and Charon, we seem to cross a borderline between bodies which may have bound atmospheres – like Pluto – and airless bodies like Charon*", said *Olivier Hainaut*, from ESO and member of the team.

The observations also indicate that methane ice, if present, should be restricted to very cold regions of the surface. Similarly, nitrogen ice would be confined at best to high northern latitudes or permanently shadowed regions of Charon.

As Pluto and its satellite sweep across the Milky Way, observations of more occultations will be tempted from the ground, while NASA's Pluto-Kuiper Belt Mission, to be launched in January 2006, will be traveling towards the planet, that it should reach in July 2015.

A report of these results is to be published in the January 5, 2006 issue of Nature ("*Charon's size and upper limit on its atmosphere from a stellar occultation*", by B. Sicardy, A. Bellucci, E. Gendron, F. Lacombe, S. Lacour, J. Lecacheux, E. Lellouch, S. Renner, S. Pau, F. Roques, T. Widemann, F. Colas, F. Vachier, N. Ageorges, O. Hainaut, O. Marco, W. Beisker, E. Hummel, C. Feinstein, H. Levato, A. Maury, E. Frappa, B. Gaillard, M. Lavayssière, M. Di Sora, F. Mallia, G. Masi, R. Behrend, F. Carrier, O. Mousis, P. Rousselot, A. Alvarez-Candal, D. Lazzaro, C. Veiga, A.H. Andrei, M. Assafin, D.N. da Silva Neto, R. Vieira Martins, C. Jacques, E. Pimentel, D. Weaver, J.-F Lecampion, F. Doncel, T. Momiyama, and G. Tancredi).

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High resolution images are available at http://www.eso.org/outreach/press-rel/pr-2006/phot-02-06.html

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ESO is the European Organisation for Astronomical Research in the Southern Hemisphere. Whilst the Headquarters are located in Garching near Munich, Germany, ESO operates three observational sites in the Chilean Atacama desert. The Very Large Telescope (VLT) is located on Paranal, a 2 600m high mountain south of Antofagasta. At La Silla, 600 km north of Santiago de Chile at 2 400m altitude, ESO operates several medium-sized optical telescopes. The third site is the 5 000m high Llano de Chajnantor, near San Pedro de Atacama. Here a new submillimetre telescope (APEX) is in operation, and a giant array of 12-m submillimetre antennas (ALMA) is under development. Over 1 600 proposals are made each year for the use of the ESO telescopes.

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