their convenient assumption that stars are everywhere born with the same distribution of masses, which they have been loath to do because of the enormous additional uncertainty this would introduce into the models. A more precise determination of the number of dwarf galaxies is obviously crucial — Cowie and co-workers' redshift sample contains only 20 galaxies. But in any case, it seems clear that interesting evolution in the galaxy population has occurred quite recently, contrary to initial expectations. □

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PLANETARY ASTRONOMY

Icy clues to Triton's origins

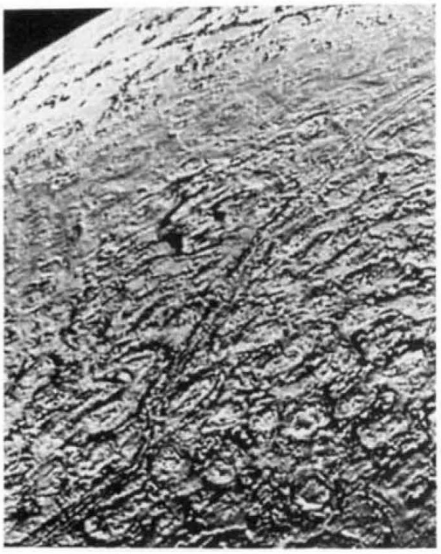
William B. McKinnon

FROZEN carbon monoxide and dioxide have been discovered on Triton, Neptune's largest moon, D. P. Cruickshank (NASA Ames) and colleagues reported at a meeting last month on planetary sciences*. Not only is this the first ever detection of these ices on a moon or planet in the Solar System, but it may bear on the question of whether Triton once followed its own independent orbit about the Sun, only to be captured by its giant partner.

The measurements were made last July at the 3.9-metre United Kingdom Infrared Telescope (UKIRT) on Mauna Kea, Hawaii, using a new spectrometer that is 16,000 times more sensitive than previous detectors. Greatly increased spectral resolution allowed detection of narrow infrared features that were previously considered to be almost impossible to discriminate against the dominant and complex methane absorption bands that Triton presents. Cruickshank and colleagues detected multiple spectral bands for both CO and CO_2 ice, and on more than one night, and the band positions were confirmed with laboratory transmission spectra of solid CO and CO_2 at temperatures comparable to that of Triton's surface (38 K).

These detections are important primarily because they may represent direct cosmochemical proof that Triton was originally captured from solar orbit. CO especially has had the status of a grail species, because it is abundant in star-forming molecular clouds, was ostensibly abundant in the equivalent solar nebula from which the Solar System emerged, and is found (at the few-per-cent level) in comets such as Halley[1,2]. It may also be the dominant heavy gas in Pluto's atmosphere required to explain the planet's June 1988 stellar occultation curve[3]. But CO is not supposed to have been a major constituent of the satellite-building nebulae that once existed around the giant planets, so its detection on Triton (already thought to be Pluto's near twin[4]) is at least consistent with the idea that the satellite has a comet-like composition.

But in finding CO, have Cruickshank and colleagues really found the 'sublimating gun' revealing Triton's origin? Possibly not. Although further detailed analysis is necessary, Cruickshank and co-workers estimate that both CO and CO_2 are only trace components in the surface ice, which is mainly solid nitrogen with a relatively small amount (about 1 per cent) of methane ice[5]. At the trace level, CO could be photochemically derived from CO_2, which may be outgassed from Triton's interior, whatever its origin. And it may be unreasonable to expect much primordial CO at Triton's surface, for Triton may have gone through a protracted episode of extreme heating owing to tidal effects following its capture by Neptune[6,7]. In this case, hydrothermal processing of molten cometary ices or dissolved CHON organics, at the top of Triton's hot rock core, would have largely converted any CO into CO_2 or organic material, depending on the oxidation state of the hydrothermal system[8,9]. In addition, materials as volatile as CO would have formed an atmosphere when Triton's surface temperature was driven up by the heating caused by its tidal interaction with Neptune, and could have been lost through hydrodynamic escape.



A permanent visitor? A Voyager 2 image of Triton, looking across the so-called cantaloupe terrain towards the southern polar cap, which incompletely buries the surface topography. The quasi-circular features at the bottom have a characteristic scale of about 40 km.

Almost incidentally, the new spectral measurements confirm the nitrogen absorption feature detected by Cruickshank and Apt[10] at a wavelength of 2.15 µm. It was the strength of this feature that prompted the widely discussed hypothesis that Triton has oceans made up of liquid nitrogen. Nowadays, it seems safer to suggest that a deep, clear layer of N_2 ice is responsible, as the transparency of solid N_2 rivals that of water ice, and surface nitrogen deposits on Triton should rapidly anneal, on a seasonal timescale[11]. It is also interesting to note that water ice, which is almost certainly the principal ice on Triton and which is inferred to provide the strength necessary to support the satellite's surface topography, cannot be seen in the new high-quality spectra. Apparently it is overwhelmed by optically active methane ice.

What remains to be done is to carefully evaluate the full spectrum, determining what other chemical species may be trapped in Triton's ices. These can then be matched against known cometary volatiles and their plausible photochemical and thermochemical descendants. Pluto will also be observed and its surface CO/N_2 ratio determined, and this will be a key clue to how Pluto's evolution differed from Triton's. Given the power of the new spectrometer, we should look forward to many important discoveries, such as the identification of minor species associated with geologically recent volcanism on Jupiter's Europa and Uranus's Ariel, and perhaps even a fix on what makes up the dark side of Saturn's moon Iapetus. □

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