IDENTIFICATION OF SOLID C≡N BEARING ORGANICS ON OUTER SOLAR SYSTEM BODIES

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Using observations by several groups (1-4), including our own observations at the NASA Infrared Telescope Facility, Mauna Kea Observatory), we have identified cyano-group containing molecules in the very dark material of outer solar system bodies. These include the dust of "new" comets, the surfaces of several asteroids of taxonomic spectral class D, the rings of Uranus, and the dark hemisphere of Saturn's satellite S8 Iapetus.

The identification is made through spectroscopic detection of the 2.2 μm overtone of the C≡N stretching fundamental mode, based on comparisons with laboratory spectra of a number of synthesized samples of various organic materials, including kerogens, tholins, and HCN polymers. In the astronomical spectra, the overtone varies in wavelength from 2.2-2.3 μm; the fundamental band near 4.7 μm is presently unobservable for any of these bodies. In the laboratory specimens, the overtone band varies from about 4.5 to 4.9 μm, depending upon the chemical environment in which the cyano group is found.

Organic materials have been predicted on comets and Trojan asteroids as long ago as the 1980 work of Gradie and Veverka (5). Organic materials are often invoked to explain the reddish colors of the more distant dark asteroid classes (6,7). Aside from a single unconfirmed report of the detection of the 3.4 μm C-H stretching mode band on the dark, G-class asteroid 130 Elektra by Cruikshank and Brown in 1987 (8), there is no unambiguous observational evidence for the presence of organics on asteroids and satellites.

We believe this work gives the strongest available direct observational evidence for solid organics on asteroids, satellites, and the Uranian rings, and it accords with the VEGA detection of C≡N bearing solids in emission at 4.44 μm in Comet P/Halley (9,10).

More significantly, for the first time we have a probable common link between the very low albedo materials found on D asteroids, comets, certain satellite surfaces, and the Uranian rings.

There is some evidence that this material is very primitive and appears only in fairly young exposures of unaltered ancient material. Among these lines of evidence:

* The C≡N bond is believed to be easily broken in aqueous alteration processes (which may account for its absence in C and G class dark asteroids, believed to involve aqueously altered carbonaceous materials) (11).

* The C≡N bond is also believed to be easily broken by exposure to cosmic ray particle bombardment (12). This may mean that only fresh exposures of old material display the 2.2 μm band. Strazzulla suggests "carbonization" times of 10^7 y.

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* Our 1990 observations of D class asteroid 368 Haidea show some weak evidence that the 2.2 μm C≡N feature is stronger on one side than another, consistent with a recent large impact feature exposing the material. It is hard to explain longitudinal variations by non-impact processes on relatively small, primitive asteroids.

* The Uranus rings have been estimated dynamically to be only 10^7 to 10^8 years old.

* In our work and that of Bell et al. (2), 25 dark asteroids have been examined for the 2.2 μm feature. It has been found in only 3 asteroids, all D's. Other D's have been examined and the feature not found. Thus, the feature is not equally visible in all D material, which may mean that only pristine D material shows it.

In terrestrial rocks and on Mars, phylosilicate minerals often show absorptions in the 2.2-2.3 μm region. Depending upon the setting, such bands arise from combinations of the OH-bond fundamental stretch with the Al-O-H, Fe-O-H, and/or Mg-O-H fundamental bending modes. With the possible exception of Iapetus, those bodies on which we report the absorption band attributed to C≡N are thought to have no history of aqueous water, particularly in the case of the dark D-type asteroids, whose longer wavelength spectra fail to show the stronger OH band at 2.75 μm or that of H_2O at 2.9 μm (13).

In summary, all of the sites of C≡N detection could be argued to be young exposures of older primitive material. The Uranus rings and the gardened leading hemisphere of S8 Iapetus are young. New comets in particular blow off a cosmic-ray-exposed soil layer to reveal pristine underlying material that has not been exposed to solar heating. And impacts may expose pristine material on some asteroids and not others.

Whatever the mechanics of exposure of the 2.2 μm feature attributed to C≡N-bearing organics, it offers a hitherto-unknown and important link between different classes of dark solar system small bodies.

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