WATER ICE ON 24 THEMIS?.

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Background: There is ample evidence for aqueous alteration in carbonaceous chondrites [1]. There is also ample evidence for hydrated/hydroxylated minerals on asteroids, particularly C-class asteroids [2]. The canonical starting condition for the creation of hydrated minerals on carbonaceous chondrite parent bodies is as a mixture of anhydrous silicates and water ice, which then reacted after the ice was melted (via heating by short-lived radiogenic isotopes or other means). Because aqueous alteration is an exothermic reaction, it would drive the melting of more ice, which would allow more reactions to take place, and so on until either the water or the unreacted rock was used up [3].

In the inner asteroid belt and closer to the Sun, ice is not stable at the surfaces of airless bodies. At Jupiter and beyond, it can be stable. Within the outer asteroid belt is a region where ice may be stable near the poles of objects, depending on their obliquities, and can exist in the subsurface [4]. However, up until recently, the general paradigm has been that asteroids are “rocky”, inner-solar system objects and comets are “icy” outer-solar system objects.

A number of recent observations and models have significantly muddied the waters (so to speak). While ice is not found at the surface of Ceres, there is evidence that a large ice ocean is present in its subsurface [5,6], which may also be true of other large C-class asteroids. Recent simulations of dynamics in the early solar system suggest that much of the material in the outer asteroid belt may have been transported from the Kuiper Belt, bringing large amounts of volatiles [7]. Perhaps most striking, a handful of objects in the main asteroid belt have been observed with cometary characteristics. These “main-belt comets” or “activated asteroids” are found as members of the Themis dynamical family near 3.1 AU and are presumed to have their activity driven by sublimation of near-surface ice [8].

Observations: We have observed the asteroid 24 Themis, largest member of the Themis dynamical family, in the 2-4 μm region using the SpeX instrument on the NASA IRTF. Observations were made at 4 apparitions, in 2003, 2005, 2006, and 2008.

Results: Every spectrum shows a reflectance minimum near 3.1 μm, with a band depth of roughly 10%. This band shape is quite different from what is seen in carbonaceous chondrites, and also different from most C-class asteroids, which have monotonically-increasing reflectances from shortward of 2.9 μm to 3.2 μm or beyond.

Interpretation: The spectrum of Themis is consistent with water ice frost on its surface. The particle size indicated by the band depth and width is much less than 1 μm, making qualitative modeling via Hapke theory inappropriate. However, if a linear mix is assumed, the implied surface area for the ice is up to 5%. This is a surprisingly large amount compared to the fraction of cometary surfaces thought to be active.

If confirmed, a finding of water ice on Themis would be the first detection of ice on an asteroidal surface, and the first detection of water *per se* (as opposed to OH) on an asteroidal surface. It also would strengthen the paradigm that cometary activity in Themis family objects is driven by sublimation of ice.

We will present observations of Themis as well as preliminary modeling results. We will also discuss other asteroids for which spectral evidence for ice is present.

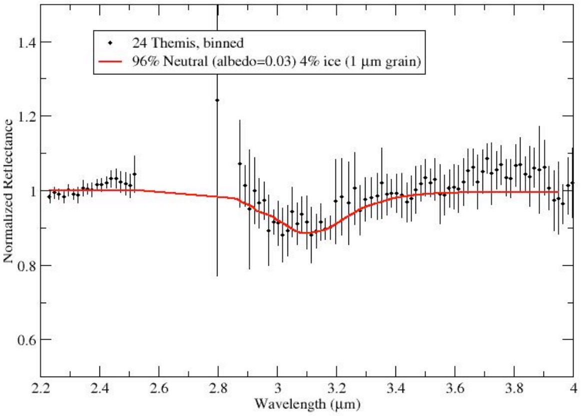

Figure 1: The 2.2-4 μm spectrum of Themis was modeled using a linear mix of a neutral, low-albedo material and a fine-grained water ice frost. While not a unique solution, this model shows the plausibility of ice on Themis’ surface.

References:

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