COMETS AND DARK ASTEROIDS: AN UPDATE; William K. Hartmann, Planetary Science Institute, Tucson, AZ 85719, Dale P. Cruikshank and David J. Tholen, University of Hawaii, Honolulu, HI 96822

In last year's abstracts we published a report in which we had examined asteroids previously listed by various authors as suspected extinct comets. We now update that report.

From new spectrophotometric data, we showed that ten out of ten candidate extinct comets are of spectral classes D, P, or C, which are the very low albedo (~0.04) classes of the outer half of the belt and the outer solar system. In a control group of 13 Aten/Apollo/Amor asteroids selected for non-cometary orbits, we found that only one belongs to the low-albedo classes. The rest are moderate-albedo objects characteristic of the inner half of the belt; 8 or 9 of the 13 are of class S (possibly the progenitor class of the most common class of meteorites, the chondrites).

In this data, we found support for our contention of the last few years that comets show spectrophotometric properties similar to those of outer solar system asteroids, especially those of classes D and P, reddish black objects found among the Trojans. We proposed that comets contain very dark carbonaceous dust, often colored by organic compounds, and chemically related to the dust found on asteroid surfaces (and interiors?). The work reported in last year's abstract and the current Icarus paper indicates, at the very least, that the candidate extinct comets are indeed objects from the outer solar system, since that is the only region in which the low-albedo materials appear to be native; it supports the possibility that comets can, once their surface-accessible volatiles are depleted, turn into objects that resemble low-albedo asteroids.

Several new developments support this picture. First, the close encounters with Halley's Comet dramatically confirmed that this is a very dark body. The albedo was measured at 0.04, matching that of the outer solar system asteroid materials. The pre-perihelion colors were red in the infrared, like a D-asteroid, but more neutral in the visible, like a C-asteroid. We have found that comet spectra vary from one comet to another through a range encompassing the similar spectra of D, P, and C asteroids (Tholen et al., in press, Heidelberg symposium). There is some evidence of a color change after perihelion. The space vehicles measured abundant carbon compounds in coma particles, and organic molecules. Pre-Giotto literature attests that the low-albedo, asteroid-like properties were not expected by a number of comet researchers, who proposed much higher albedos as "canonical" expected values.

Second, IRAS albedo measurements became available for a number of asteroids. While we had based our identification of low-albedo class for many of the candidate extinct comets on spectrophotometric properties alone, because albedos were not available for many of them, the new IRAS
albedos permit a test of our classifications. Of the list 23 asteroids mentioned above, IRAS albedos are available for 5, all in the candidate extinct comet group. We had identified all 5 as low-albedo objects, in classes C, P, or D, and the IRAS results confirm our estimates. The IRAS results range 0.03 to 0.07.

For these reasons, we continue to believe that future comet research should focus on comets not as unique objects distinct from asteroids (as has been more or less true since the 1800's), but rather as objects intimately linked to, and probably forming an extension of, outer solar system asteroids. Asteroid spectrophotometry shows a sudden onset of low-albedo, apparently carbonaceous, condensates starting at 2.7 AU in mid-belt and darkening all known interplanetary bodies beyond the outer belt. Comets are probably examples of outer solar system planetesimals, and presumably are colored by these same soils, or a related variant of them that formed at larger distances. Our work, and that of Smith and Vilas (1986, Icarus) emphasizes the trend toward redder colors in interplanetary bodies, as we go from the neutral C's of the outer belt to the very red D's of the Trojans. The colors are believed to result from organic compounds, such as tholins, kerogens, or hydrogen cyanide products, formed in the carbonaceous soils. Comets appear to have a range of colors encompassing this same span, and perhaps are examples of planetesimals ejected into the Oort cloud by different giant planets, each with its own local suite of dark soils and colors. Viewed in this light, comets may comprise a group of varied bodies, with different ice/soil ratios, and varying affinities to outer solar system asteroids. Comet nuclei with volatile-depleted surface layers, in dormant states near their aphelia, might be difficult to distinguish from outer solar system asteroids, even during close flybys.

We are preparing, along with other authors, a study of the spectra of laboratory samples of various candidate materials, which may help in the identifications of the colors and spectral features found in outer solar systems asteroids and comets. We hope this will lead to further understanding about the relation of comets and outer solar system asteroids, and the possible transitions between them.

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