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NEAR-INFRARED SPECTROSCOPY OF THE BRIGHT KUIPER BELT OBJECT 2000 EB173

Michael E. Brown,[1] Geoffrey A. Blake, and Jacqueline E. Kessler
Division of Geological and Planetary Sciences, California Institute of Technology, MS 170-25,
Pasadena, CA 91125; mbrown@gps.caltech.edu, gab@gps.caltech.edu, kessler@gps.caltech.edu
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ABSTRACT

We have obtained a near-infrared spectrum of the bright Kuiper Belt object 2000 EB173; the spectrum appears featureless. The spectrum has a sufficient signal-to-noise ratio to rule out the 1.5 and 2.0 μm absorption from water ice even at the low level seen in the Centaur Chariklo. In addition, we can rule out a 2.3 μm absorption at the level seen in the Centaur Pholus.

Subject headings: infrared: solar system — Kuiper Belt objects — minor planets, asteroids

1. INTRODUCTION

Kuiper Belt objects (KBOs) are thought to be the least-processed remnants of the early solar nebula. They have suffered less solar heating and UV bombardment than any other objects in the solar system. Nonetheless, their surfaces may be far from pristine; in the past 4.5 billion years, they have been subjected to multiple collisions, to cosmic-ray bombardment, and possibly to other processes. The composition of the surface of a KBO will therefore reflect both the initial composition of the object and its history.

Near-infrared spectroscopy is the best-suited method of remotely determining the surface composition of KBOs (Brown & Cruikshank 1997). In general, however, KBOs have been too faint for us to obtain high-quality infrared spectra, so little is known about these compositions. Recently, however, several spectra of some of the brighter KBOs have been reported. The spectrum of 1993 SC (with a current maximum V magnitude of 22.2) has a low signal-to-noise ratio but has been interpreted as having absorptions that are due to hydrocarbons (Brown et al. 1997); the spectrum of 1996 TL66 ($V = 20.7$) appears featureless at a moderate signal-to-noise ratio (Luu & Jewitt 1998), while that of 1996 TO66 ($V = 20.9$) has clear absorptions due to water ice (Brown, Cruikshank, & Pendleton 1999). No discernible patterns have yet appeared. Continued progress requires continued spectroscopy, but KBOs bright enough to obtain adequate spectra are rare.

The KBO 2000 EB173 was discovered in 2000 March and has a reported maximum V magnitude of ~19.9 (Rabinowitz 2000), almost a full magnitude brighter than the previous brightest-studied KBO. At discovery, 2000 EB173 had a heliocentric distance of only 30 AU, closer than most other known KBOs; thus, its unusual brightness is caused by a combination of a closer perihelion and either a large size (600 km diameter for an assumed albedo of 4%) or a high albedo. The brightness of the KBO makes it an excellent target for near-infrared spectroscopy.

2. OBSERVATIONS

Observations of the KBO 2000 EB173 were obtained in 2000 June 18, 19, and 20 using NIRC, the facility near-infrared camera at the Keck telescope (Matthews & Soifer 1994). These observations were made close to the quadrature of the object, so the motion of the object with respect to the background stars was only 0″.75 hr^{-1}. To identify 2000 EB173 positively, we first imaged the predicted location of the object on June 18. We then imaged the same field on June 19 and found a single object that had moved in the predicted speed and direction over 24 hr. With the telescope guiding at the predicted rate of the object, we then placed the object into the 0″.52-wide slit and inserted the 120 line mm^{-1} grism and an H- through K-band order-sorting filter into the light path, allowing us to collect a spectrum in first order from 1.4 to 2.5 μm at a resolution of approximately $\lambda/\Delta\lambda = 100$. Total integration time was 1800 s on June 18 and 2700 s on June 19. The spectra were obtained by positioning the object in the center of the long slit, integrating for 180 s, and then offsetting the telescope 5″ and 10″ north and then south and obtaining similar exposures. A calibration spectrum of SAO 11973, a nearby G5 V star, was obtained at a similar range of air masses. Data reduction was performed identically to the procedure described in Brown (2000).

3. DISCUSSION

The spectrum of 2000 EB173 shows no evidence of any spectral features (Fig. 1). Water ice, which is currently the most commonly detected material on outer solar system surfaces, has absorptions at 1.5 and 2.0 μm (Fig. 2). To quantify upper limits to possible absorptions due to water ice, we construct simple models of surfaces covered with mixtures of water ice and a dark, spectrally featureless material. For water ice, we calculate the spectrum from the laboratory optical constants of Grundy & Schmitt (1998), assuming grain sizes of 10 μm and temperatures of 50 K. Hapke theory (Hapke 1981) is used to transform the optical constants to a reflectance spectrum. We model the dark component as a featureless but possibly slightly red or blue continuum. We then vary the slope of the neutral component and the amount of water ice in order to determine the maximum depth of water ice absorption that could be present in the spectrum. We define the water ice absorption depth of these models as the fractional absorption that is due to only water ice at 2.0 μm compared with the continuum at 1.8 μm. Any slope to the featureless material is removed before the calculation of absorption depth is made. For 2000 EB173, we find that the maximum water ice absorption that the data will allow is ~7%.

The only other spectral feature clearly observed in a KBO or Centaur is an absorption feature found in the Centaur Pholus at 2.3 μm (Fig. 2), which has been interpreted as being caused by methanol ice or photolytic products of methanol (Cruikshank et al. 1998). To determine the maximum amount of

[1] Alfred P. Sloan Research Fellow.

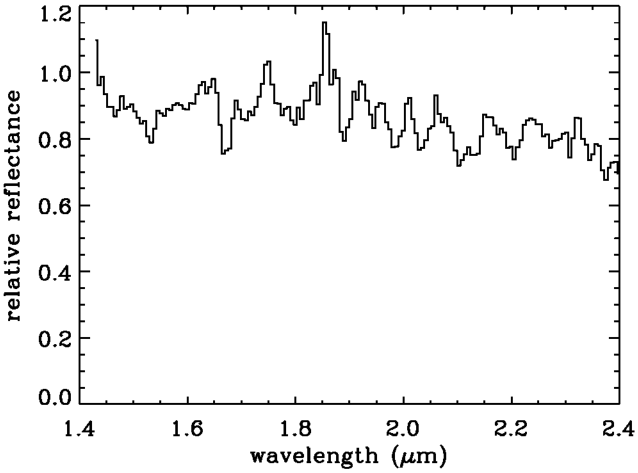

FIG. 1.—Reflectance spectrum of 2000 EB173. The spectrum has been scaled to a value of 1.0 at 1.85 μm.

2.3 μm absorption that could be present on 2000 EB173, we create similar spectral models using the spectrum of Pholus as the template for the 2.3 μm absorption. We find that 2000 EB173 could have at most a 5% absorption in the 2.3 μm feature, compared with the 20% absorption present on Pholus.

We have constructed similar models for all trans-Neptunian objects with measured spectra (Fig. 3). The upper limit (or measured) 2.0 and 2.3 μm absorption depth is shown in Table 1. The spectrum of 1993 SC has been smoothed to a resolution significantly lower than that of the other objects, so judging the final significance of the features is difficult. We find that while the weak absorption in 2000 EB173 that is due to water ice or to methanol cannot be ruled out from these spectra, the level of absorption is below that found in the Centaurs Chariklo and Pholus. Water ice at the level of Chariklo cannot be ruled out in any of the other KBOs, while a 2.3 μm absorption at the level of Pholus is ruled out in 1996 TL66 but not in 1996 TO66.

The featureless spectrum of 2000 EB173 has several implications. First, since no ice absorptions are detected, the object is possibly quite dark, implying that it is likely one of the largest of the known KBOs. Second, the lack of any 2.3 μm absorption (and the similar lack of such an absorption on 1996 TL66) suggests that the 2.3 μm absorption on Pholus cannot simply be explained by Pholus being freshly arrived from the Kuiper Belt compared with other Centaurs; at least some ob-

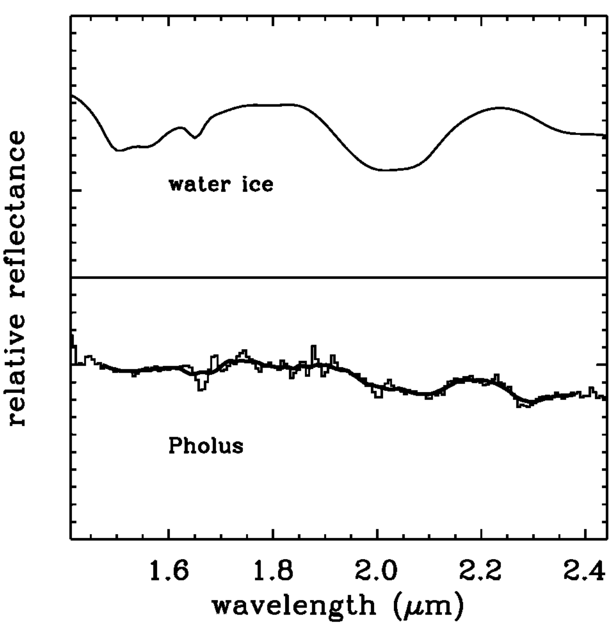

FIG. 2.—Spectra demonstrating two observed components of outer solar system spectra. Water ice is present on many outer solar system bodies. The upper spectrum shows a reflectance spectrum of crystalline water with a 10 μm grain size. The lower spectrum shows the Centaur Pholus (Brown 2000), which has 2.3 μm absorptions interpreted as being due to methanol ice (Cruikshank et al. 1998). The thick solid line shows the smoothed spectrum that was used as a template for spectral modeling.

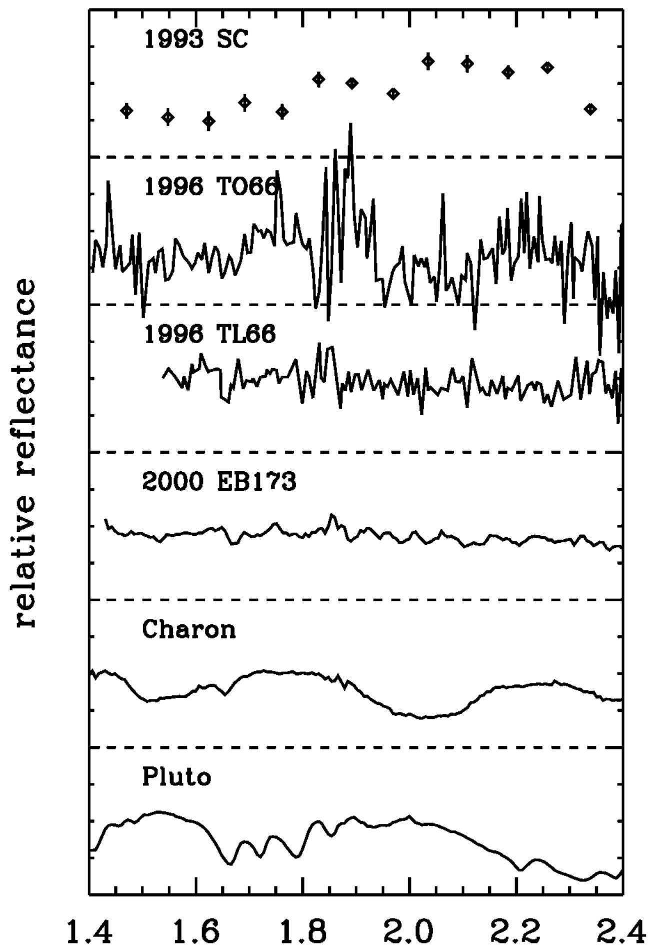

FIG. 3.—Comparison of all reported spectra of trans-Neptunian objects. All spectra were obtained with the same instrument at the Keck telescope, although by three different observing groups (for references, see Table 1). The signature of water ice is more clearly observed in 1996 TO66 in a smoothed spectrum shown in Brown et al. (1999)

TABLE 1
ABSORPTION FEATURES ON TRANS-NEPTUNIAN OBJECTS AND CENTAURS

Object	$A_{2.0}$	$A_{2.3}$	Class	Reference
2000 EB173	<7	<5	KBO	This work
1996 TO66	60	<25	KBO	Brown et al. 1999
1996 TL66	<15	<15	KBO	Luu & Jewitt 1998
1993 SC	<25?	50?	KBO	Brown et al. 1997
Charon	60	<5	Satellite	Brown & Calvin 2000
Pluto	<10?	70	Planet	Brown & Calvin 2000
Pholus	13	20	Centaur	Brown 2000
Chariklo	10	<5	Centaur	Brown & Koresko 1998

jects still in the Kuiper Belt clearly also lack this feature. Third, the visible colors appear unrelated to the infrared spectral properties: the visible colors of 1996 TO66 and 1996 TL66 are almost identical (Tegler & Romanishin 1998), but their spectra differ greatly, while the visible colors of 1996 TL66 and 2000 EB173 (Rabinowitz 2000) differ, but their spectra appear equally bland.

The differences in KBO physical properties remain unexplained. Significantly more photometric and spectroscopic observations will possibly be required before a large enough sample exists so that patterns begin to emerge. With the discovery of 2000 EB173, the hope of a brighter population of KBOs that will be more amenable to detailed study appears promising.

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