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Methanol ice on Kuiper Belt objects 2007 OR_{10} and Salacia: Implications for formation and dynamical evolution

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Abstract

Kuiper Belt Objects (KBOs) and Centaurs are effective tracers of Solar System formation and evolution. We present low-resolution, near-infrared spectra of the scattered disk object (225088) 2007 OR_{10} and the hot classical KBO (120347) Salacia obtained with IRTF/SpeX in Prism mode. We identify H_2O absorption features on both objects and an additional feature at 2.27 μm that we interpret as being due to methanol. The presence of methanol and H_2O can possibly explain the observed surface properties of 2007 OR_{10}, but it is more difficult to reconcile methanol on Salacia because of its neutral-colored surface.

1 Introduction

The properties of the Solar System's different minor body populations, such as the Centaurs and KBOs, provide valuable information on the formation and dynamical evolution of the entire Solar System. The orbital parameters and size of the population indicate which dynamical processes were important early in Solar System history while surface properties reveal the composition of different regions of the solar nebula. Surface properties include broadband colors and composition, which are linked. Two general varieties of surface are observed among the Centaurs and KBOs: low albedo/neutral color (dark/neutral) and high albedo/red color (bright/red) ([1], [2]). Theoretical work suggests these colors are the result of initial surface composition and are not altered during later periods of dynamical evolution: irradiation of H_2O and CO_2 on objects that formed closer to the Sun creates a dark/neutral surface while irradiation of CH_3OH (methanol) creates a bright/red surface [3]. Methanol was previously identified on the Centaur Pholus [4] and the KBO 2002 VE_{95} [5], two bright/red objects. However, dark/red and bright/neutral surfaces are also observed [1], albeit in lower numbers, that cannot be explained by the simple model of [3].

2 Observations

In this work we obtained near-infrared (0.7-2.5 μm) spectra of the large, faint KBOs (225088) 2007 OR_{10} and (120347) Salacia at NASA's Infrared Telescope Facility using the SpeX instrument in low-resolution (R$\sim$75) Prism mode. Observations of 2007 OR_{10} on October 15, 16 and November 3, 2015, and Salacia on November 2, 4, 2015, yielded 8.3 and 6.9 hours of time-on-target, respectively. 2007 OR_{10} is a scattered disk object currently $\sim$87 AU from the Sun and had a V magnitude of 22.0 at the time of the observations. It is a dark/red object [6] with an albedo of $0.089\pm^{0.031}_{0.009}$ [7]. Salacia is a hot classical KBO $\sim$45 AU from the Sun and had a V magnitude of 20.6 at the time of the observations. Salacia is a dark/neutral object with an albedo of 0.044$\pm$0.004 [8] and a B-R color of 1.067$\pm$0.115 [9].

3 Analysis

The KBO spectra were reduced with Spextool [10] and combined spectra were created for both objects (Figures 1 & 2). A model consisting of spectral slope and y-offset components and an H_2O ice spectrum was fit to each combined spectrum using a least-squares fitting algorithm. We also calculated the reduced χ^2 taking into account 3 free parameters.

4 Results & discussion

As seen in Figures 1 & 2, H_2O ice is present on both KBOs, at least in the amorphous phase since the spectral resolution and SNR are not adequate enough to

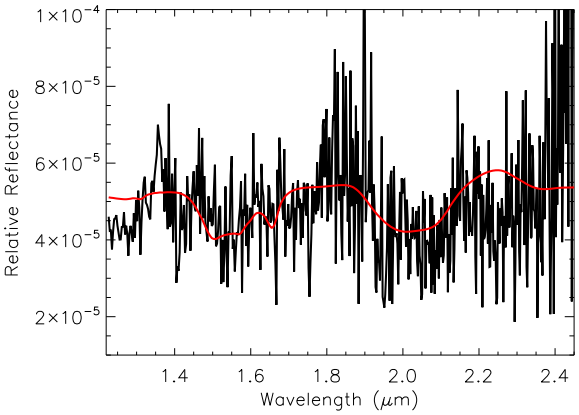

Figure 1: Near-infrared spectrum of scattered disk object (225088) 2007 OR_{10} from 1.4-2.45 μm. The data are in black with an H_2O model overplotted in red. $\chi^2_{\rm reduced}$=2.52

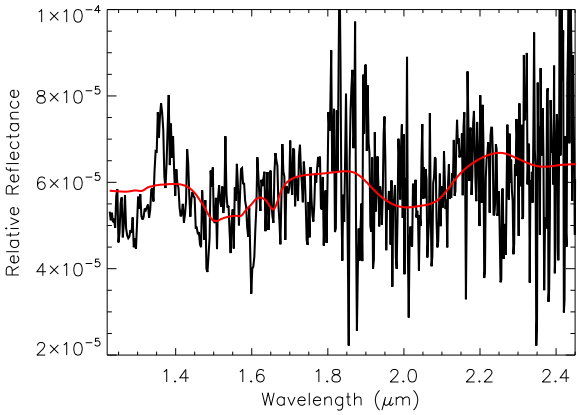

Figure 2: Near-infrared spectrum of hot classical KBO (120347) Salacia from 1.4-2.45 μm. The data are in black with an H_2O model overplotted in red. $\chi^2_{\rm reduced}$=1.79

make an identification of the 1.65 μm crystalline H_2O feature. Since $\chi^2_{\rm reduced}>1$, H_2O is not the only component. This is partially due to the bad fit at shorter wavelengths and the residual noise from the telluric correction between $\sim$1.8-1.9 μm, but is also due to the additional absorption feature observed near 2.27 μm that is not fit by the H_2O ice model. Based on previous work ([4], [5]), we interpret this feature as due to methanol and/or its irradiation products. The same feature was previously observed in the spectrum of Salacia but was not discussed [11].

The presence of methanol on the surfaces of 2007 OR_{10} (dark/red) and Salacia (dark/neutral) does not agree with the simple model of [3]. Methanol and its irradiation products, based on laboratory experiments, are expected to result in a bright/red surface. On 2007 OR_{10}, it is possible that irradiation of H_2O is responsible for the darker surface, but the dark/neutral surface of Salacia is harder to reconcile with the presence of methanol. Salacia may have formed in a transition region where the resulting color was not dominated by a single surface component, as expected for methanol and the bright/red KBOs. Some other species was likely present on the surface of Salacia early in Solar System history. Further laboratory work is needed to identify potential species that would result in surfaces like Salacia's. Additional spectral observations of dark/neutral KBOs are needed to quantify the number of Salacia-like objects.

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