A search for additional volatile ices on dwarf planet (136472) Makemake

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Abstract

The spectrum of dwarf planet Makemake is dominated by volatile CH$_4$ absorption, preventing direct identification of the other volatiles N$_2$ and CO. A new absorption feature at 2.238 µm was recently identified in the lab as being due to N$_2$ and CO in solution, with near-equal amounts producing the strongest absorption. We observed Makemake with the twin LUCI spectrographs at the LBT in order to search for the 2.238 µm feature.

1. Introduction

The surface compositions of Kuiper Belt Objects (KBOs) provide clues about the environment in which these objects formed, their original and current inventories of volatile ices, the ongoing chemical and physical processes at work on these bodies, and the potential to support atmospheres. Volatile ice species, those with high enough sublimation pressures at typical KBO surface temperatures (~40 K), are CH$_4$, N$_2$, and CO [1]. Over the age of the solar system, volatile ices should be lost from the surfaces of smaller, warmer bodies while larger, colder bodies retain them [2,3]. Only a handful of objects, including Pluto and the captured KBO Triton, should (and do) retain volatile ices on their surfaces. Understanding the exact physical and orbital circumstances that result in retention of volatiles is a key question in KBO studies.

The dwarf planet (136472) Makemake represents the perfect opportunity to test volatile retention theories in the Kuiper Belt. According to [2], Makemake is within the transition region for retention of volatile ices. Methane is definitively identified in the spectrum of Makemake, but due to the strength of these CH$_4$ absorption features [e.g., 4] direct detection of the N$_2$ and CO features at 2.15 µm and 2.35 µm, respectively, is not feasible. Previous work reported an indirect detection of N$_2$ due to the shift in the central wavelengths of multiple CH$_4$ features [e.g., 5]. No previous investigations have attempted to identify CO on Makemake due to the prior lack of observable features.

Recent work by [6] identified a new absorption band at 2.238 µm that indicates the presence of both N$_2$ and CO ice and was detected in the near-infrared spectrum of Triton (Fig. 1). This band is unusual in that it is strongest when these two ice species are in solution in equal amounts, but is not present for pure N$_2$ or pure CO. On the only outer solar system bodies with direct detections of N$_2$ ice, Pluto and Triton, CO is present as well, identified by the
2.35 µm absorption feature [e.g., 7,8]. These species also show peak abundances at similar longitudes, suggesting that N$_2$ and CO may frequently co-exist on icy surfaces [8,9].

2. Observations

Near-infrared spectra of Makemake were obtained on March 30 and April 1, 2019, in order to search for the 2.238 µm absorption feature. These spectra were obtained with the twin LBT Near Infrared Spectroscopic Utility with Camera and Integral Field Unit for Extragalactic Research (LUCIFER) instruments at the Large Binocular Telescope (LBT) [10]. These instruments, typically referred to as LUCI1 and LUCI2, operate in parallel, one for each primary of the LBT. The spectra were obtained at a resolving power of ~6700 over the wavelength range 2.05-2.37 µm using the 210_µzJHK grating, the N1.8 camera, and the 0.5” slit. Total time on-target was 2 hours each for LUCI1 and LUCI2.

3. Results

We present the reduced, corrected, and combined spectrum of Makemake between 2.05-2.37 µm. The presence or absence of the 2.238 µm N$_2$:CO feature, and its implications for Makemake’s surface evolution and potential for an atmosphere at closer heliocentric distances, will be discussed.

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References


