Crystalline water ice on the satellite of the trans-Neptunian object 2003 EL61

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Abstract

We report the near-infrared observations of the binary TNO system 2003 EL61(ref. 1) , which reveal that crystalline water ice is present not only on the primary but also on the satellite whose diameter is about 300-500 km. The presence of crystalline water ice indicates that the ice has been heated over 100 K, which is substantially higher than the equilibrium temperature at their heliocentric distance. The 2003 EL61 system was possibly formed by a collisional impact. During that event, the satellite was formed by accretion of the impact debris(ref. 1-3). Water ice was crystallized by heating from the impact.

Object 2003 EL61 is one of the largest known TNOs with such small satellite. Its total mass is 4.2x10ˆ21 kg and satellite to mass ratio is about1/100 assuming the satellite and the primary has the same albedo and density(ref. 1). The diameter of the primary and the satellite will be 1700 km and 380 km if the density is 1.5x10ˆ3 kg m-3.

We observed 2003 EL61 during the commissioning run for the IRCS at Nasmyth focus of the Subaru telescope on UT 2006 Jan. 15. The spectrograph covers wavelength range from 1.44 um to 2.54 um simultaneously. The object had heliocentric distance 51.2 AU and phase angle 1.08 deg. The separation of the satellite was 1.0 arcsec.

The spectra of the primary and the satellite are similar (Fig. 1). The broad absorption features near 1.5 um and 2.0 um indicate absorption of water ice, and relatively narrow absorption band at 1.65 um specifies that the ice is crystalline. The absorption depth of the satellite is little deeper than that of the primary. No other absorption features, including ammonia hydrate, are seen with high confidence level.

The similarity between the spectra of the primary and the satellite suggests that the surface material have experienced the similar thermal history. Since the 2003 EL61 is a binary system, it can be considered that the satellite is the product of an impact event that formed 2003 EL61 as a binary system(ref. 1,3). In case that crystalline water ice was not there but amorphous ice was there, impact energy by collision can make the amorphous ice crystalline. Successive accretion of the debris and tidal evolution were also the cause of heating.

Although only three binaries have been observed with good spectra (Pluto system, 2003 EL61, and 2003 UB313, two of them (Pluto system and 2003 EL61) shows crystalline water ice. Spectra of single TNOs with good signal-to-noise ratio also shows crystalline water ice (Quaoar) or methane ice layer (2005 FY9)18. Considering that a high fraction of TNOs are binaries and there must be more single TNOs that experienced collisional impacts but failed to form binaries, high fraction of observable bright TNOs might have experienced high temperature state, at least up to 100 K. Some of the short period comets might have also heated because they are thought to be fragments of TNOs.

Jewitt and Luu estimated the timescale of destruction of crystalline water ice by energetic particle radiation, and found that it is very short (about 10ˆ7 y). If this estimate is true, the surface of the primary and the satellite must be fresh, and the satellite forming impact or possible resurfacing process has occurred recently.

References

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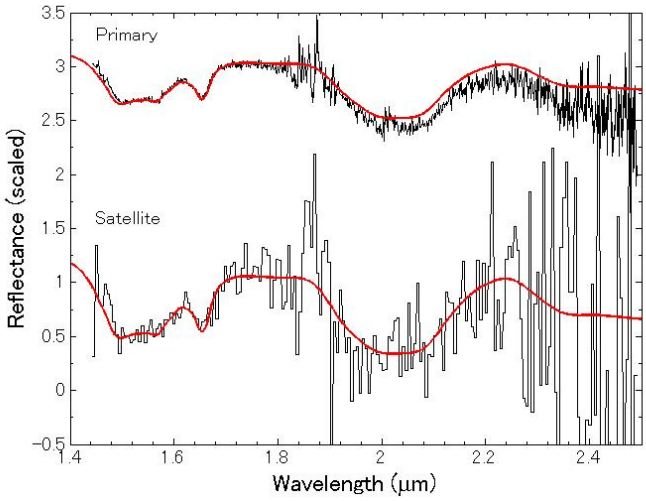
Fig. 1 Reflection spectra of 2003 EL61 primary and its satellite (black line) compared with model reflectance spectra of crystalline water ice(red line). The model spectra were scaled to match the observed spectra. The satellite spectrum fits well to that of pure crystalline water ice whereas the primary does not, suggesting more contaminants on the primary.


Primary
Satellite
Reflectance (scaled)
Wavelength (μm)
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
1.4
1.6
1.8
2
2.2
2.4