Presence of Nonmethane Hydrocarbons on Pluto

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ABSTRACT

We have carried out infrared high-resolution spectroscopy of the Pluto in the L band with the adaptive optics system on the Subaru telescope. The spectrum is dominated by the strong and broad absorption features of methane but includes some additional features. Comparing the spectrum with model calculations, we suggest that absorption features around 3.1, 3.2, and 3.35 μm could be an indication of nonmethane hydrocarbons on Pluto.

This result was just published in The Astrophysical Journal Letters! (Jan. 1 2005 Issue, Vol. 618, L57-L60).

1. INTRODUCTION

Pluto and Edgeworth-Kuiper belt objects (EKBOs)

- EKBOs: remnants of icy planetesimals
- Pluto: the largest objects among EKBOs
- Charon: satellite of Pluto

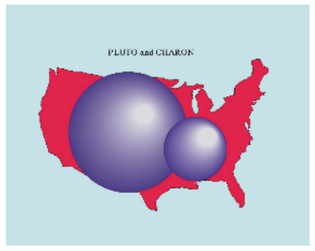


Fig.1 Pluto and the satellite, Charon
(c) University of Colorado

Observation at K band v.s. at L band

- Observation at K band [Cruikshank et al. 1997]
  → surface composition (N_2, CH_4, and CO)
- Observation at L band [Grundy et al. 2002]
  → low-resolution data
- L band: strong and variable telluric extinctions

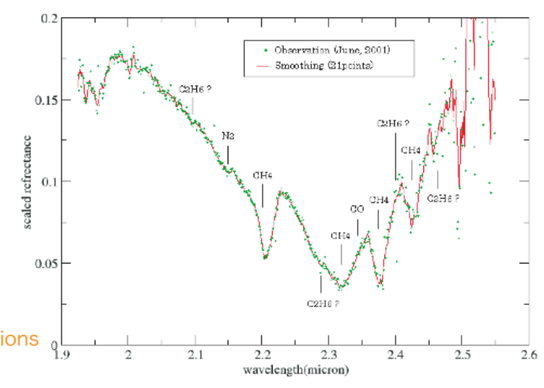


Fig.2 Result of Observation of Pluto at K band

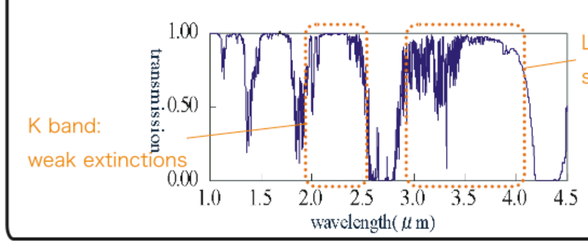
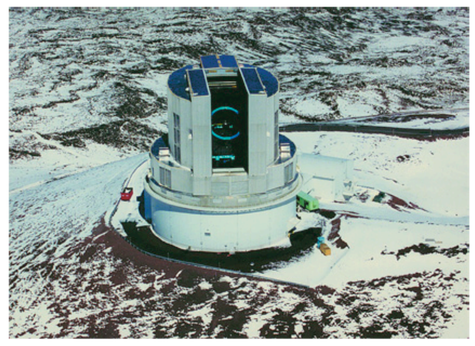


Fig.3 Atmospheric Transmission at Mauna Kea

2. OBSERVATION

An infrared spectroscopic observation of Pluto in the L band by the Subaru telescope with the adaptive optics system

- 2002 May 28 (UT)
- L band: 2.84 - 4.16 μm
- Integration time = 2600 sec
- Using AO system
  → Seeing: 0.3 - 0.4 arcsec
- Separation from Charon = 0.9 arcsec
- Reference star: G3V SAO141540



(c) Subaru telescope

- Pluto was observed within 1.5 hr before/after the standard star.
  → air mass difference < 0.035
- Pluto was clearly separated from Charon with FWHM as 0.4 arcsec.
- Unsertainty in the wavelength calibration is smaller than 0.003 μm.

3. RESULT AND MODEL CALCULATIONS

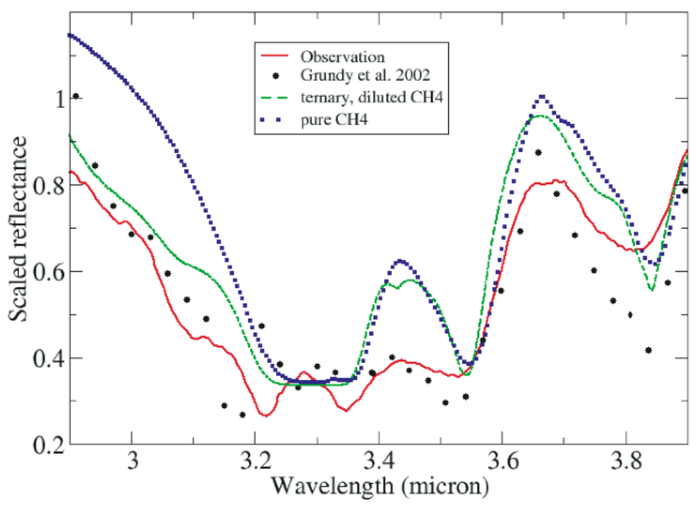


Fig.4 Reflectance spectrum of Pluto along with the previous low-resolution data and synthetic spectra of intimate ternary mixture of N_2-CH_4-CO with mass ratio 1 : 0.01 : 0.002. Data are normalized at 3.58 μm.

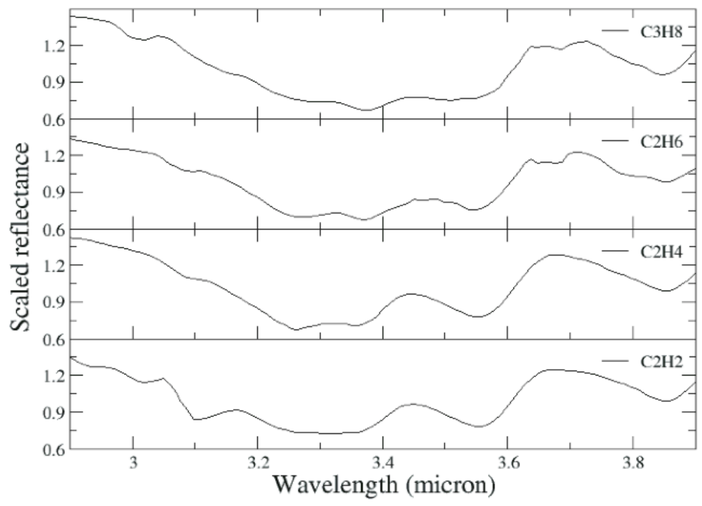


Fig.5 Modeled spectra including nonmethane hydrocarbons as the forth component. The model parameters of the basic ternary mixture are the same as those in Fig.4.

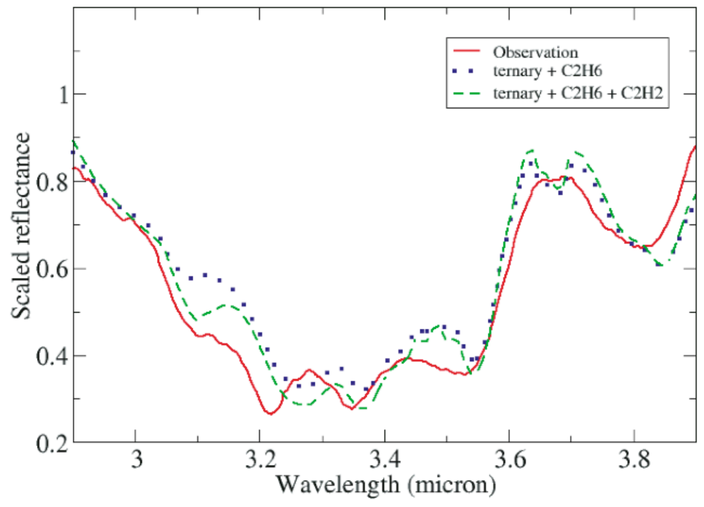


Fig.6 Reflectance spectrum of Pluto with the modeled spectra. The ternary mixture are the same as that in Fig.4. Mass ratio of C_2H_2 : C_2H_6 is 1 : 1 : 10.

- Obtained high-resolution data
- Lower reflectance around 3.45 μm
- Absorptions around 3.1, 3.2, and 3.35 μm
- Considering a diluted CH_4 in N_2
  → reproduce lower reflectance around 3.0 μm

- 3.1 μm: C_2H_2, (HCN)
- 3.2 μm: C_2H_4, C_2H_6
- 3.35 μm: C_2H_4, C_2H_6
- 3.45 μm: C_2H_6, C_3H_8

- diluted hydrocarbons in N_2
  → shift the absorptions to shorter wavelength [Quirico et al. 1999]

The spectrum including C_2H_6 and C_2H_2 as new components in a model calculation matches the observed secturm quite well

4. DISCUSSIONS

Discussion 1. Internal Reservoir

- 500 m thick N_2 layer has been lost from the surface of Pluto since the formation of the Pluto-Charon system. [Krasnopolsky, 1999]

↕

- It is unlikely that such pristine N_2 survived the accretional heating and formed such a thick layer near the surface.

Pluto could have a deep internal reservoir that can produce N_2.

Discussion 2. Lateral Surface Inhomogeneity

- L band: identified C_2H_6 and C_2H_2

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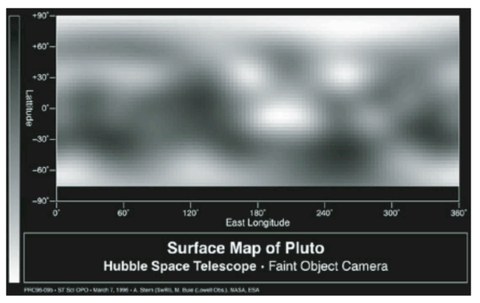
- J, H, K bands: have not identified additional nonmethane hydrocarbons

Concentration of nonmethane hydrocarbons at the uppermost surface of Pluto inhomogeneously.



(c) Habble Space Telescope

Discussion 3. Comparing with Comets

- C_2H_6 / CH_4 ratio is consistent with comae of Oort-cloud, and short-period comets upper limit for interstellar materials
- C_2H_2 / CH_4 ratio is consistent with comae of Oort-cloud comets

C_2H_6 and C_2H_2 could be primordial component.

(c) Asahikawa astronomical club

Disucussion 4. Photochemical Reactions and Irradiations

- Nonmethane hydrocarbons could be secondary products generated from CH_4 by photochemical reactions [Krasnopolsky, 1999]
  cosmic-ray irradiations [Moore and Hudson, 2003]

The relative mass ratio to the parent methane, derived from our observations, could be a key to understanding the gardening process on Pluto, such as the poorly known dust flux and vertical mixing timescale.