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Chemical Composition of Comet C/2007 N3 (Lulin) Observed in the Near-infrared Wavelength Region

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Abstract

Oort-cloud comet C/2007 N3 (Lulin) was observed in both L-band and M-band by three different telescopes/instruments atop Mauna Kea; IRTF with CSHELL (R~25,000), Subaru telescope with IRCS (R~15,000), and Keck II telescope with NIRSPEC (R~25,000) during its 2009 apparition. We detected H_2O, HCN, C_2H_2, CH_3OH, CH_4, C_2H_6, and CO and determined mixing ratios of these organic volatiles relative to H_2O. We investigate will chemical variability in the coma of comet Lulin. We also compare our results with the CO mixing ratios determined by the Japanese infrared satellite *AKARI*.

1. Introduction

Comets are thought of as aggregates of planetesimals that were remnants of the early solar system. The process of planetesimal formation is still unclear, so studies on the composition of cometary nuclei are very useful to investigate planetesimal aggregation and chemical processing in the early solar nebula. We report the mixing ratios of comet C/2007 N3 (Lulin) on multiple nights based on near-infrared spectroscopic observations.

2. Observations

We used three different instruments in the 2009 apparition of comet Lulin. CSHELL mounted on the IRTF was used on UT 2009 January 31.6 and February 1.6 with a 1.0" x 30" slit. Although spectral coverage is limited, CSHELL can achieve very high dispersion. We detected H_2O, CH_3OH, CH_4, C_2H_6 and CO with CSHELL. IRCS mounted on the Subaru telescope was used on UT 2009 February 14 – 17 with a 0.27" x 9.5" slit. We used IRCS with AO on all dates except for February 14. We detected H_2O, HCN, C_2H_2, CH_3OH, CH_4, C_2H_6, and CO in three different grating settings during the IRCS run. NIRSPEC mounted on the Keck II telescope was used on UT 2009 March 3.3 with a 0.432" x 24." slit. We detected H_2O, HCN, C_2H_2, CH_3OH, CH_4, and C_2H_6 in two different NIRSPEC grating settings. Observational conditions are summarized in Table 1. The data was processed by the IRAF software package. The acquired spectra include both continuum and gas emission. We extracted gas emission only and examples of extracted, continuum-subtracted spectra are shown in Figures 1 and 2.

Table 1: Summary of observations.

Date 2009 (UT)	Telescope /Instrument	R_h [AU]	Δ [AU]	Δ-dot [km/s]
Jan 31	IRTF/CSHELL	1.255	0.954	-54.3
Feb 1	IRTF/SCHELL	1.260	0.922	-54.2
Feb 14	Subaru/IRCS	1.328	0.546	-42.1
Feb 15	Subaru/IRCS	1.334	0.523	-39.7
Feb 16	Subaru/IRCS	1.340	0.500	-36.7
Feb 17	Subaru/IRCS	1.347	0.480	-33.3
Mar 3	KeckII/NIRSPEC	1.445	0.492	+35.9

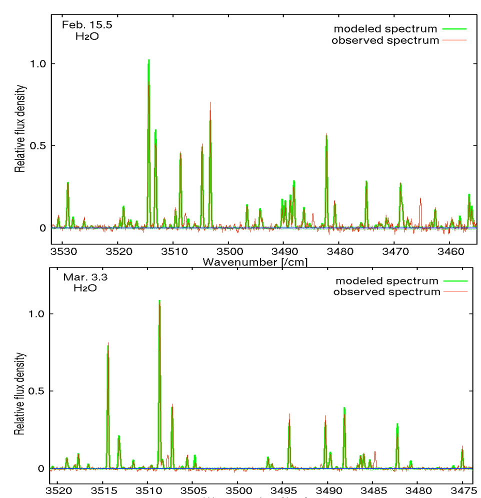

Figure 1: Example spectra of comet C/2007 N3 (Lulin). Here we detected emission lines of H_2O and

OH. The modeled spectra of H_2O are over-plotted for comparison.

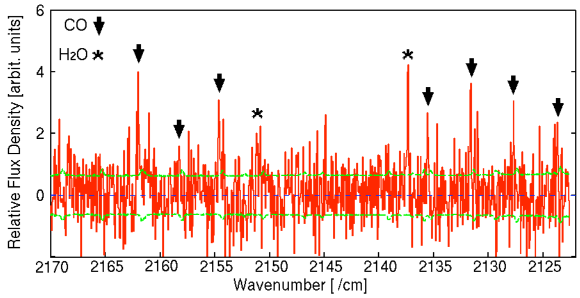

Figure 2: Spectrum of comet C/2007 N3 (Lulin) in M-band on February 15 showing emissions from CO and H_2O. Green traces correspond to +/- 1σ error-levels.

3. Results

We determined mixing ratios of parent volatiles (HCN, C_2H_2, CH_3OH, CH_4, C_2H_6, and CO) with respect to H_2O, and also determined rotational temperatures for H_2O, CH_4 and HCN. We constructed fluorescence excitation models of H_2O, HCN, C_2H_2, CH_4 and CO to calculate the fluorescence efficiencies (g-factors). Our model assumes that (1) molecules are pumped up from the ground vibrational states to the upper vibrational states by the solar radiation field; and (2) the population distributions among the rotational levels in the ground states follow the Boltzmann distribution [1]. We used published g-factors for C_2H_6 and we used an unpublished g-factor for CH_3OH to compare our results with the mixing ratios of other comets directly [1, 2]. We also determined the ratio of nuclear spin isomers for H_2O and CH_4. Preliminary results are summarized in Figure 3 [5].

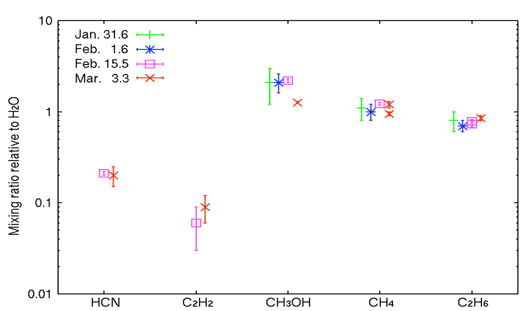

Figure 3: Summary of mixing ratios for comet C/2007 N3 (Lulin). Errorbars correspond to +/- 1σ.

4. Discussion and conclusion

Although mixing ratios of CH_3OH show small variations, they are consistent within 3σ error-levels (Figure 3). Comet Lulin shows no temporal variation in the mixing ratios throughout our observing run. If we assume a rotational period of 42 hours as reported by [1, 3], our observations on January 31.6 and February 1.5 are separated by ~0.6 in a rotational phase. The relative rotational phases on February 15.5 and on March 3.3 are difficult to estimate because of the uncertainty in the rotational period. There is no evidence of chemical heterogeneity within the nucleus of comet Lulin although observations likely occurred during different rotational phases.

The Japanese infrared satellite *AKARI* also observed comet Lulin on March 30 and 31, 2009 [6]. Ootsubo et al. determined an upper limit for the CO mixing ratio in comet Lulin as ~2%. We will compare this result with mixing ratios of CO determined from our data.

References

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