# Near-infrared Spectroscopic Observations of Comet C/2013 R1 (Lovejoy) by WINERED: CN Red-system Band Emission

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Recently nitrogen isotopic ratios ($^{14}N/^{15}N$ ratios) in various astrophysical objects have been investigated by both observational and theoretical studies. From the viewpoint of chemical evolution in molecular cloud and proto-planetary disk, the high $^{15}N$-fractionation found in those environments together with comets in the Solar System is quite puzzling. Any chemical evolution models cannot explain the observed high $^{15}N$-fractionation of molecules in solid-phase quantitatively, so far.

In the case of CN radical of comets, CN *B*-*X* violet band at ~388 nm has been observed (e.g., [1]). Observational conditions are often not good for a comet which becomes brighter as it approaches the Sun because this band (which is close to UV region) is significantly affected by telluric extinction. In addition, S/N ratios of CN emission spectra would be worth because of the extinction by dust grains in cometary coma.

Here we report high-resolution near-infrared spectra of CN red-system band (*A*-*X*) at ~1.1 $\mu$m [2]. The red-system band is not severely affected by the telluric extinction compared to the violet-system band. We developed the fluorescence excitation model for CN by solar radiation based on modern spectroscopic studies. We applied the fluorescence excitation models for CN to the observed CN spectra of comet C/2013 R1 (Lovejoy). The spectra were taken by the near-infrared high-resolution spectrograph WINERED mounted on the 1.3-m Araki telescope at the Koyama Astronomical Observatory, Kyoto, Japan on 30 November 2013. Our emission model could reproduce the observed CN red-system band of the comet with a linear combination of a pure fluorescence excitation model for the outer coma region and a fully collisional fluorescence excitation model for the inner coma region (see Figure 1). The observed spectrum is consistent within error-bars with the previous estimates of isotopic ratios in comets; $^{12}C/^{13}C$ of ~90 [1] and $^{14}N/^{15}N$ of ~150 [1,3].

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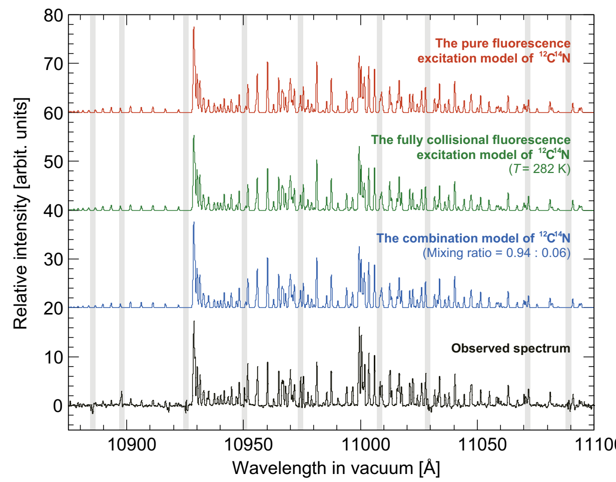


**Figure 1**: Comparison between synthesized and observed spectra of comet Lovejoy in the CN red-system (0-0) band [2]. The top three spectra are the synthesized spectrum of $^{12}C^{14}N$ based on the pure fluorescence excitation model (red), the fully collisional fluorescence excitation model with $T_{rot}$ of 282 K (green), and the synthesized spectrum of $^{12}C^{14}N$ as a linear combination of the fully collisional fluorescence excitation model and the pure fluorescence excitation model with a mixing ratio of 0.94:0.06 (blue) for the observed conditions of comet Lovejoy. The bottom spectrum (black) is observed emission spectra of comet Lovejoy. The gray vertical bars correspond to the regions of OH sky emission lines.

## References

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[3] Shinnaka, Y., et al.: 2016, *MNRAS*, **462**, S195-S209.