Telescope detects rare form of nitrogen in comet ISON

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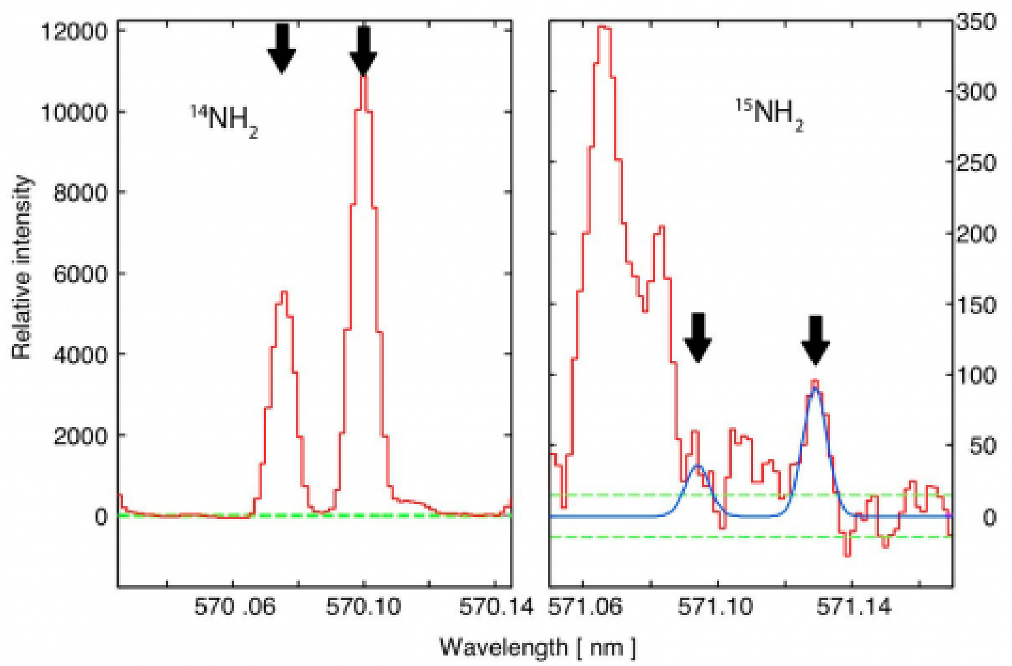


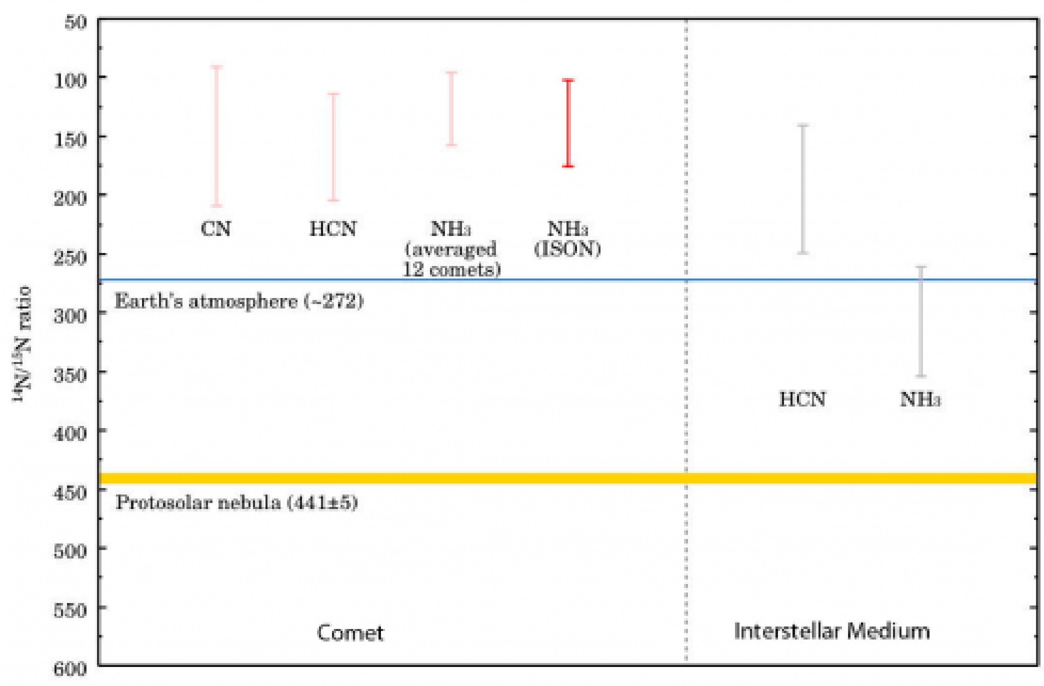
Close-up of spectra of NH2 emission lines (of the same transitions for both 14NH2 and 15NH2) in Comet ISON, showing the difference in wavelengths and relative intensity between the isotopes. The red and green-dashed lines indicate the observed spectrum. The blue line indicates 15NH2, clearly detected for the first time. Credit: NAOJ

A team of astronomers, led by Ph.D. candidate Yoshiharu Shinnaka and Professor Hideyo Kawakita, both from Kyoto Sangyo University, successfully observed the Comet ISON during its bright outburst in the middle of November 2013. Subaru Telescope's High Dispersion Spectrograph (HDS) detected two forms of nitrogen—$^{14}NH_2$ and $^{15}NH_2$—in the comet. This is the first time that astronomers have reported a clear detection of the relatively rare isotope 15NH2 in a single comet and also measured the relative abundance of two different forms of nitrogen ("nitrogen isotopic ratio") of cometary ammonia (NH3) (Figure 1). Their results support the hypothesis that there were two distinct reservoirs of nitrogen in the massive, dense cloud ("solar nebula") from which our solar system may have formed and evolved.

Why did the team focus on studying these different forms of nitrogen in the comet? Comets are relatively small solar system objects composed of ice and dust, which formed 4.6 billion years ago in the solar nebula when our solar system was in its infancy. Because they usually reside in cold regions far from the Sun, e.g., the Kuiper belt and Oort cloud, they probably preserve information about the physical and chemical conditions in the early solar system. Different forms and abundances of the same molecule provide information about their source and evolution. Were they from a stellar nursery (a primordial interstellar cloud) or from a distinctive cloud (solar nebula) that may have formed our solar system's star, the Sun? Scientists do not yet understand very well how cometary molecules separate into isotopes with different abundances. Isotopes of nitrogen from ammonia (NH_3) may hold the key.

Ammonia (NH_3) is a particularly important molecule, because it is the most abundant nitrogen-bearing volatile (a substance that vaporizes) in cometary ice and one of the simplest molecules in an amino group ($^{-}NH_2$) closely related to life. This means that these different forms of nitrogen could link the components of interstellar space to life on Earth as we know it.

Since ammonia is the major carrier of nitrogen in a comet, it is necessary to clear it from the relative abundance of its isotopes to understand how $^{15}NH_2$ separates in cometary molecules. However, the direct detection of cometary ammonia is difficult, and there are only a few reports of its clear detection. Therefore, the team concentrated on studying the form of NH_2 developed after the ammonia was broken down by the light ("photodissociation") in the cometary coma. The team was fortunate to observe the comet as it neared the Sun, when its icy composition was evaporating. They were also fortunate that NH_2, a derivative of ammonia (NH3), is easy to observe in the optical wavelength, and the relative abundance of nitrogen isotopes of cometary ammonia is probably close to that of NH_2.



Comparison of nitrogen isotopic ratios obtained from comets (left) and molecular cloud core (right). The blue line indicates the ratio of nitrogen isotopes in the Earth's atmosphere while the wider, yellow line indicates that of the protosolar nebula. The figure shows that the nitrogen isotopic ratios obtained from cometary molecules are similar to each other while those of HCN (hydrogen cyanide) and HN3 (ammonia) in the molecular cloud core are different. Credit: NAOJ

The team used Subaru Telescope's HDS to successfully observe Comet ISON on November 15th and 16th (UT), when the comet had its bright outburst that began on November 14th. The observation clearly detected 15NH2 from Comet ISON, and the team inferred that the ratio of cometary ammonia of $^{14}N/^{15}N$ (139 ± 38) is consistent with the average ($^{14}N/^{15}N$ ~ 130) of that from the spectra of 12 other comets. In other words, Comet ISON is typical in its relative abundance of $^{14}N/^{15}N$ in cometary ammonia.

These findings support the hypothesis that there were two distinct reservoirs of nitrogen in the solar nebula: 1) primordial N_2 gas having a protosolar value of $^{14}N/^{15}N = 441 \pm 5$, and 2) less volatile and probably solid molecules having a ratio of about $^{14}N/^{15}N$ ~ 150 in the solar nebula. In the case of a dense molecular cloud core, the isotopic ratio of hydrogen cyanide (HCN) is similar to that of comets while its ratio in ammonia is different from its cometary value (Figure 2).

This may mean that the ammonia formed in an environment of a low temperature dust surface, not in the gas of the molecular cloud. Laboratory experiments show that various complex molecules can form on the surface of low temperature dust. If the ammonia molecule formed on the low temperature dust surface, the cometary nucleus could contain a complex molecule that relates to the origin of life, in addition to the ammonia. If this is so, it raises the possibility that the comet brought these materials to Earth.

In the future, the team would like to increase the sample of comets for which nitrogen isotopic ratios of cometary ammonia have been determined. They would also like to carry out laboratory measurements of $^{15}NH_2$ to obtain more precise isotopic ratios. On a larger scale, the team hopes to investigate the origin of Comet ISON and the mechanisms that triggered its outburst so that we can better understand the evolution of the solar system.

More information: Shinnaka, Y., Kawakita, H., Kobayashi, H., Nagashima, M., & Boice, D.C. 2014 "14NH2/15NH2 ratio in Comet C/2010 S1 (ISON) observed during its Outburst in November 2013)" *Astrophysical Journal Letters*, V 782, L106.

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