Evolution of fragment-species production in comet C/2012 S1 (ISON) from 1.6 au to 0.4 au

A. McKay[1], A. Cochran[1], N. Dello Russo[2], H. Weaver[2], R. Vervack[2], W. Harris[3], H. Kawakita[4], M. DiSanti[5], N. Chanover[6], and Z. Tsvetanov[7]

[1]University of Texas Austin/McDonald Observatory
[2]Johns Hopkins University Applied Physics Laboratory
[3]Lunar Planetary Laboratory
[4]Kyoto Sangyo University
[5]NASA Goddard Space Flight Center
[6]New Mexico State University
[7]Johns Hopkins University

The chemical composition of cometary ices is among the most primitive in the Solar System. For this reason, studies of cometary composition are important for constraining planetary formation models. Because the best way to characterize the chemical composition of the cometary population as a whole is through remote-sensing spectroscopy of volatiles in the gas phase, it is paramount that the coma physics and chemistry responsible for the observed emissions are understood.

Comet C/2012 S1 (ISON) provided an unprecedented opportunity to study coma physics and chemistry for a sun-grazing comet. Owing to its early discovery, observations of ISON could be planned well in advance of its close perihelion passage at only 2.7 solar radii. Although it did not survive perihelion (and therefore observations of how the comet's composition changed after exposure to the harsh near-Sun environment were not possible), observations of the coma composition evolution with decreasing heliocentric distance were possible throughout the pre-perihelion observing window. We present high-spectral-resolution optical spectroscopy of ISON obtained pre-perihelion in October and November 2013, spanning a heliocentric distance range of 1.6–0.4 au.

We obtained high-resolution optical spectroscopy throughout ISON's pre-perihelion leg using three instruments: HIRESb on the Keck I telescope on Mauna Kea in Hawaii, ARCES on the Apache Point Observatory 3.5-meter telescope in Sunspot, NM, and the 2DCoude on the 2.7-meter Harlan J. Smith Telescope at McDonald Observatory. All these spectrographs provide high spectral resolution (R=30,000–60,000). This enables several avenues of analysis not possible at lower spectral resolution, such as analysis of the forbidden oxygen lines at 5577, 6300, and 6364 Angstroms, and ortho-para ratios in NH_2.

We report detections of many species in our spectral data set, including CN, C_2, C_3, CH, NH_2, [OI], NH, and OH (OH and NH are only detected with HIRES because ARCES and 2DCoude do not extend far enough into the UV to detect these features). Close to the time of peak brightness in early-mid November, we also detected Na, K, and H-alpha. Na and K were detected only when the comet was within 1 au of the Sun, suggesting that sublimating dust grains may be responsible for the release of these metals into the coma. Observations of these metals in comets are rare and determining their abundances can reveal insights into the composition of the silicate dust. The carbon-bearing species (CN, C_2, CH, C_3) experience a large increase in their mixing ratios compared to H_2O with decreasing heliocentric distance, whereas the NH_2/H_2O ratio is fairly constant with heliocentric distance, suggesting a fundamentally different release process for these two groups of species. Analysis of [OI] suggests that the abundance ratio CO_2/H_2O was less than 10 %, making ISON depleted compared to the overall sample of comets with known CO_2 abundances measured within 2.5 au of the Sun. We present comparisons to IR observations of parent molecules and also details of the evolution of the kinetic temperature of the gas with heliocentric distance as revealed by the rotational temperatures of CN and C_2.

Acknowledgements: AJM was supported by the NASA Graduate Student Research Program through grant NNX11AO03H.