The chemical composition of comet C/2012 S1 (ISON) between 1.2 au and 0.35 au from the Sun

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Introduction: By virtue of their small size and prolonged storage at large heliocentric distances (R_h), comets remain largely preserved. As a result, their ices encode a record of physical and chemical conditions in the early Solar System [1,2]. The recent apparition of C/2012 S1 (ISON) [3], a dynamically new sun-grazing comet, provided a rare opportunity to both prepare for and subsequently conduct compositional studies to well within 1 au from the Sun.

Observations: We obtained high-resolution spectra (Resolving Power approximately 25,000) of Comet ISON on four dates (UT 2013 Oct. 22, 24, 25, and Nov. 7) using NIRSPEC [4] at Keck 2, and on six dates (Nov. 15 through 19, and Nov. 22) using CSHELL [5] at the NASA InfraRed Telescope Facility (IRTF). Our observations provided a measure of volatile production rates and abundance ratios (relative to H_2O) over a wide range of heliocentric distances (R_h = 1.23–0.35 au). NIRSPEC is cross-dispersed and so allows for simultaneous measure of multiple trace species together with H_2O, thereby avoiding most sources of systematic uncertainty, for example those associated with differences in slit losses and with flux calibration among settings. CSHELL has limited spectral coverage per setting, requiring judicious targeting of specific molecular emissions that (when possible) simultaneously encompass lines of H_2O and/or OH prompt emission, which serves as a proxy for water production provided equivalent OH line g-factors are known [6]. Despite this limitation, the IRTF is unique among ground-based IR observatories in its ability to conduct observations during daytime. This permitted obtaining compositional measurements of Comet ISON to a minimum solar elongation angle of 20 degrees. These will be discussed, and comparisons will be made with previously-reported results from observations with NIRSPEC [7] and HST [8].

Results: A suite of molecules (H_2O, CO, H_2CO, CH_3OH, C_2H_6, C_2H_2, CH_4, HCN, and NH_3) and radicals (OH, NH_2) were targeted and detected. Our serial measurements of production rates permitted a search for potential changes in molecular abundances as Comet ISON approached the Sun. The abundances of certain species (CO, C_2H_6, CH_3OH, CH_4) remained relatively constant with R_h, while others (e.g., H_2CO and HCN) increased in abundance with decreasing R_h, for example, as could result from potential compositional heterogeneity in the nucleus and/or release from increasingly heated grains in the coma.

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