ALMA observations of gas and dust in the coma of comet C/2012 S1 (ISON)

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Ground-based studies of cometary comae provide indirect information on the compositions of the nuclear ices, and thus provide insight into the physical and chemical conditions of the early solar nebula. To realize the full potential of gas-phase coma observations as probes of solar-system evolution requires a complete understanding of the gas-release mechanisms. However, previous observations have been unable to ascertain the precise origins of fundamental coma species including H_2CO, HCN, and HNC, and details regarding the possible formation of these species in the coma are not well understood. Here, we present spatially and spectrally-resolved ALMA sub-mm images of the distributions of HCN, HNC, CH_3OH, H_2CO, and dust in the coma of comet C/2012 S1 (ISON), observed during the outburst event on November 15–17 (at r_H = 0.54–0.61 au and Δ = 0.9 au). Our observations reveal an unprecedented level of detail in the distributions of these fundamental coma constituents, and permit accurate measurement of their origins in the coma. Observations were made using ALMA Band 7 in Cycle 1 (Early Science) mode in the frequency range 339–364 GHz, with 25–29 12-m antennae. Weather conditions were excellent, with good atmospheric phase stability and low precipitable water vapor (0.5–0.8 mm at zenith). The spatial resolution was 0.4–0.8" (with maximum recoverable angular scales approx. 5–10"), and the spectral resolution was 0.4 km s^{-1}. The ALMA image cubes show kinematically and spatially-resolved structures in HCN, HNC, CH_3OH, and H_2CO emission. Whereas the CH_3OH and HCN distributions are consistent with release from (or within 100 km of) the nucleus, the H_2CO data indicate coma release from a parent species with scale-length on the order of a few hundred km. The HNC distribution suggests release in clumpy, collimated outflows possibly as a result of the breakdown of a macromolecular/dust precursor. Clear 0.9-mm continuum emission was detected, showing a sharp central peak and extended coma and tail components, consistent with combined thermal emission from dust and the cometary nucleus. Spatial offsets were observed between the gas and dust emission peaks, indicative of differentiated release and/or dynamical effects.

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