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# Herschel and IRAM-30m Observations of Comet C/2012 S1 (ISON) at 4.5 AU from the Sun

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The sungrazer comet C/2012 S1 (ISON) (perihelion at $r_h$ = 0.0125 AU from the Sun) was bright and active when discovered in September 2012 at 6.3 AU from the Sun. Our goal was to characterize the distant gaseous and dust activity of this comet, inbound, from observations of H2O, CO and the dust coma in the far-infrared and submillimeter domains. We report observations undertaken with the Herschel Space Observatory (Pilbratt et al, 2010) on 8 & 13 March 2013 ($r_h$ = 4.54–4.47AU) and with the 30m telescope of Institut de Radioastronomie Millimétrique (IRAM) in March and April 2013 ($r_h$ = 4.45–4.18 AU). The HIFI instrument aboard Herschel was used to observe the $H_2O$ $1_{10} - 1_{01}$ line at 557 GHz, whereas images of the dust coma at 70 $\mu$m and 160 $\mu$m were acquired with the PACS instrument. Spectra acquired at the IRAM 30m telescope cover the CO $J$(2–1) line at 230.5 GHz. The spectral observations were analysed with excitation and radiative transfer models (Biver et al., 2007). A model of dust thermal emission taking into account a range of dust sizes is used to analyse the PACS maps, equivalent to that used in Bockelée-Morvan et al., 2010. While $H_2O$ was not detected in our 8 March 2013 observation, we derive a sensitive 3$\sigma$ upper limit of $Q_{\mathrm{H_2O}} < 3.5 \times 10^{26}$ molecules s$^{-1}$ for this date. A marginal 3.2$\sigma$ detection of CO is found, corresponding to a CO production rate of $Q_{\mathrm{CO}}$ = 3.5 $\times$ 10$^{27}$ molecules s$^{-1}$. Later observations of CO (HST) implied that the CO production decreased before increasing with the water turn-on (Weaver et al, 2014). The Herschel PACS measurements show a clear detection of the coma and tail in both the 70 $\mu$m and 160 $\mu$m maps. Under the assumption of a 2-km radius nucleus, we infer dust production rates in the range 10–13 kg s$^{-1}$ or 40–70 kg s$^{-1}$, depending on whether a low or high gaseous activity from the nucleus surface is assumed. We constrain the size distribution of the emitted dust by comparing PACS 70 $\mu$m and 160 $\mu$m data, and considering optical data. Size indices between –4 and –3.6 are suggested. The morphology of the tail observed on 70 $\mu$m images can be explained by the presence of grains with ages older than 60 days.

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