The evolution of volatile production in C/2009 P1 (Garradd) during its 2011-2012 apparition

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Comets are likely to be the most pristine objects in our Solar System. They provide a record of the physical and chemical conditions in the protosolar nebula between about 5 and 40 au during the epoch when the distinct cometary populations were being assembled (Festou et al. 2004; Jewitt 2004; Mumma & Charnley 2011). Cometary nuclei today reside in (at least) two distinct reservoirs, the Oort Cloud (OC) and the Kuiper Belt (KB). Past observations have shown that comets appear to contain a mixture of products from both interstellar and nebular chemistries and could also have been important for initiating prebiotic chemistry on the early Earth (Ehrenfreund & Charnley 2000). Although there are some differences, the volatile composition of cometary ices is generally similar to the inventory of molecules detected in the ices and gas of dense molecular clouds. Given the gradient in physical conditions expected across the proto-Solar nebula, chemical diversity in the comet population is to be expected. Here we report an analysis of long-term ground-based radio observations towards comet C/2009 P1 (Garradd).

Comet C/2009 P1 Garradd is an OC comet that reached perihelion (at heliocentric distance R_h = 1.55 au) in late December 2011 and had its closest approach to the Earth on 5 March 2012. Like C/1995 O1 (Hale-Bopp) at 7.2 au, Garradd exhibited unusual activity at large R_h (8.68 au), displaying a 15" diameter circular coma (IAUC 9062). It is well known that some comets exhibit volatile activity at large heliocentric distances, where water ice cannot sublime efficiently. Infrared (IRTF/CSHELL, Keck 2/NIRSPEC, and VLT/CRIRES) spectroscopy of Garradd showed clear CO (R1 & R2) emission near λ = 4.7 µm (2150 cm^{-1}), as well as a suite of molecules (e.g., $C_2H_6, CH_4, CH_3OH, H_2CO, HCN, C_2H_2, NH_3$) that were also detected near or beyond R_h = 2 au (Villanueva et al. 2012; Paganini et al. 2012; DiSanti et al. 2014).

We monitored the abundance of parent volatiles in Garradd at multiple epochs around the time of its closest approach to the Earth, using multiple facilities: the Arizona Radio Observatory's 12-m telescope, Kitt Peak, the SubMillimeter Telescope, the James Clerk Maxwell Telescope, and the Greenbank 100-m telescope (GBT), covering wavelengths of 20 cm, 3 cm, and 0.8–3 mm. Observations were taken between 28 December 2011 (R_h = 1.55 au, Δ = 1.97 au) and 28 November 2012 (R_h = 4.27 au, Δ = 4.26 au). GBT monitored OH as a proxy for H_2O activity, while the other facilities were used to study the primary volatiles (e.g., $CH_3OH, H_2CO, HCN, HNC, CS, CO$).

The full analysis of these data, including the determination of the rotational temperatures, abundances, and the variation of given species with time, will be presented. Also, comparisons with other comets will be shown in order to constrain the chemical history on comets and add to the statistics for a taxonomic classification of these objects.

References: DiSanti, M. A. et al. 2014, Icarus 228, 167; Ehrenfreund, P. & Charnley, S. B. 2000, ARA&A, 38, 427; Festou, M. C. et al. 2004, A brief conceptual history of cometary science, ed. Festou, M. C., Keller, H. U., & Weaver, H. A., 3–16; Jewitt, D. C. 2004, From cradle to grave: the rise and demise of the comets, ed. G. W. Kronk, 659–676; Mumma, M. J. & Charnley, S. B 2011, ARA&A, 49, 471; Paganini, L. et al. 2012, ApJ, 748, L13; Villanueva, G. L. et al. 2012, Icarus, 220, 291