OBSERVATIONS OF COMET C/2012 S1 (ISON): THE RISE AND FALL OF A GREAT COMET. S.N. Milam[1], I.M. Coulson[2], J. Keane[3], A.J. Remijan[4], A. Gicquel[1,5], G.L. Villanueva[1,5], M.A. Cordiner[1,5], T. Riesen[3], S.B. Charnley[1], M.A. DiSanti[1], Y.J. Kuan[6], K. Meech[3], B. Yang[3] and M.J. Mumma[1], [1]NASA Goddard Space Flight Center, Goddard Center for Astrobiology, 8800 Greenbelt Rd, Greenbelt, MD 20771, stefanie.n.milam@nasa.gov, [2]Joint Astronomy Center, P.O.Box 1104, Keaau, HI 96749, USA, [3]University of Hawaii, Institute for Astronomy 2680 Woodlawn Drive, Honolulu, HI 96822, [4]National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903, [5]Catholic University of America, University Heights, Washington, DC 20064, [6]Institute of Astronomy & Astrophysics, Academia Sinica, 1, Sec. 4, Roosevelt Rd., Taipei 106, Taiwan.

Introduction: Comets are primarily located in two distinct regions of the solar system the Oort cloud and the Kuiper Belt.. Short period comets (<200 years) include comets in Halley-type orbits that come from the Oort cloud. The Kupier Belt is the source of Jupiter family comets [1]. Theoretical models have shown that giant planet migration can have a profound effect on the populations of the Oort Cloud and Kuiper Belt (the 'Nice' model, Gomes et al. 2005; Tsiganis et al. 2005). More recently, Levison et al. (2010) showed that the Oort Cloud comets could have been captured from other stars in the Sun's birth cluster. This may lead to compositional characteristics within these reservoirs that are quite different from those expected based on the classical picture (DiSanti & Mumma 2008). Given the gradient in physical conditions expected across the nebula, chemical variation in the comet population is to be expected, as has been inferred for both JFCs [3] and Oort Cloud comets [4; Milam et al. 2014, submitted].

There is seemingly a chemical diversity amongst comets and hence characterizing these differences between the distinct comet populations will contain important clues to the origins and formation of our solar system. Previous work [3,4,5] has revealed a range of abundances of parent species (from "organics-poor" to "organics-rich") with respect to water among comets, however the statistics are still poorly constrained and interpretations of the observed compositional diversity are uncertain. The potential chemical richness of an individual comet was amply demonstrated by long term monitoring of comet Hale-Bopp [8].

The long-period comet, C/2012 S1 (ISON) – by some dubbed the "Comet of the Century" — provided an exceptional opportunity to characterize a comet in this way. The species targeted in our ground-based campaign are well studied in a number of comets and reveal details regarding volatile content, physical parameters (temperature, outflow velocity), and chemistry. By incorporating results from various observational techniques, including single-dish and interferometric radio observations, and IR spectroscopy, one can gain much better insight into the abundances, production rates, distributions, kinematics and formation mechanisms of molecules in these objects [6,7].

Comet ISON was originally expected to be exceptionally bright in the visible (M_v ~ -13) at perihelion, leading NASA to dedicate all facilities to an organized campaign to monitor ISON throughout its passage. However, in the weeks prior to perihelion ISON was not as active as originally predicted. The comet reached perihelion at 0.0124 AU on November 28 (after a number of small outburst events) where it disintegrated completely. Our team contributed coordinated observations from 5 facilities (over 170 hours), including some of the only observations from the ground at perihelion.

Observations: We conducted observations from four facilities (we never triggered the ToO observations on SOFIA due to poor gas production rates): the James Clerk Maxwell Telescope, Mauna Kea, HI, the Greenbank 100m telescope, Greenbank, WV, the Atacama Pathfinder Experiment, Chile, and the Atacama Large Millimeter/sub-millimeter Array in Chile (see abstract by M. Cordiner et al.). Data were obtained, from August 2013 through Nov. 28 (perihelion). Observations were conducted at high spectral resolutions (*dv* ~0.05 – 0.6 km/s) and included monitoring campaigns of both dust and gas (primary volatiles and OH). Ephemerides were generated from JPL Horizons daily, until it was no longer updated due to lack of optical observations the week of perihelion, and positional accuracy was monitored approximately every hour by pointing/focusing on nearby planets and/or quasars.

Preliminary Results: Our dataset includes detections from the beginning of October through perihelion and includes observations of HCN (multiple transitions), OH, and continuum images. Data obtained from ALMA will be reported elsewhere (Cordiner et al., this meeting). Throughout our campaign we were scheduled during at least one outburst event and monitored the variation in flux on 15-18 November 2013 with APEX and the GBT. Data obtained through perihelion were only acquired with SCUBA-2 on the JCMT. Preliminary analyses of these observations suggest the detection of either a large scale fragmentation event and/or the comet's disruption. Figure 1 shows images obtained on Nov 23 and at the end of Nov 27 (UT). The lower image can be compared with images obtained with NASA's STEREO and SOHO spacecraft when the comet entered their FOV. The SCUBA-2 data show a nice, spherically symmetric dust coma that becomes elongated and diffuse on the day of perihelion.

Our full dataset and results will be presented and compared with those of other investigations conducted during the comet's approach to the sun and its demise.

Acknowledgements: We thank the staff of the JCMT for their support during the course of our months-long observing campaigns, and particularly during the week of perihelion. The experience of Telescope Systems Specialist Jim Hoge during that week was particularly valuable. We also gratefully acknowledge the Time Allocation Committees of JCMT - the UKTAG, the International TAC , and the University of Hawaii TAC – for their support of long-term cometary science on JCMT, despite the frequent disappointments of individual targets. These particular data were taken for programs m13bi07 and m13bh32a. The National Radio Astronomy Observatory Robert C. Byrd Green Bank Telescope (GBT) is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc. Data was collected under program GBT13B-200. This work includes data from program 092.F-9321(A), that were acquired with the Atacama Pathfinder Experiment (APEX). APEX is a collaboration between the Max-Planck-Institut fur Radioastronomie, the European Southern Observatory, and the Onsala Space Observatory.

References: [1] Jewitt, D. 2004, in Comets II, M. C. Festou, H. U. Keller, and H. A. Weaver (eds.), University of Arizona Press, Tucson, 745 pp., p.659-676, [2] Weissman, P. 1999, SSRv, 90, 301, [3] Crovisier, J. et al. 2009, P&SS, 57, 1162, [4] Mumma, M. et al. 2003, Adv. Sp. Res. 31, No. 12, 2563:2575; DiSanti, M. & Mumma, M.J. 2008, Space Sci. Rev.,138, 127, [5] Mumma, M. J. Charnley, S. B. 2011. Annual Review of Astronomy and Astrophysics, 49:471-524., [6] DiSanti, M.A.et al. 2009. Icarus, 203:589-598, [7] Meech, K. J. et al. 2011. ApJ, 734, article id. L1, [8] Biver N., et al 1996, Science 275, 1915.

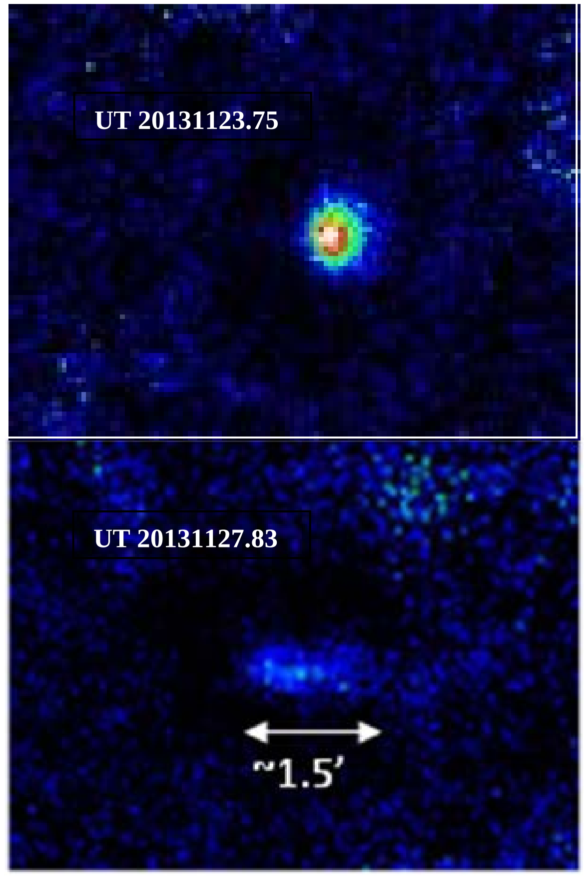

Figure 1: 850 mm continuum images obtained at the JCMT with SCUBA-2 on UT 20131123.75 (Nov. 23.75, Top) and UT 20131127.83 (Nov. 27.83, Bottom) towards comet C/2012 S1 (ISON). The comet was ~0.31 AU and 0.1 AU from the Sun, respectively. The images were collected in 30 min integrations each with an approximate 14 arc-min FOV (Note: the image above is cropped). The peak flux is ~100mJy, denoted by white in the top image (both on the same color scale).