GROUND-BASED CENTIMETER, MILLIMETER, AND SUBMILLIMETER OBSERVATIONS OF COMET 103P/HARTLEY 2. S. N. Milam[1], S. B. Charnley[1], Y. –L. Chuang[2], Y. –J. Kuan[2,3], I. M. Coulson[4], and A. R. Remijan[5], [1]NASA Goddard Space Flight Center, Astrochemistry Laboratory, Code 691.0, 8800 Greenbelt Rd., Greenbelt, MD 20771, USA (email: stefanie.n.milam@nasa.gov), [2]National Taiwan Normal University, 88, Sec. 4, Ting-Chou Rd., Taipei 116, Taiwan, [3]Institute of Astronomy & Astrophysics, Academia Sinica, 1, Sec. 4, Roosevelt Rd., Taipei 106, Taiwan, [4]Joint Astronomy Center, P.O.Box 1104, Keaau, HI 96749, USA.

Introduction: Comets provide important clues to the physical and chemical processes that occurred during the formation and early evolution of the Solar System, and could also have been important for initiating prebiotic chemistry on the early Earth [1]. Comets are comprised of molecular ices, that may be pristine interstellar remnants of Solar System formation, along with high-temperature crystalline silicate dust that is indicative of a more thermally varied history in the protosolar nebula [2]. Comparing abundances of cometary parent volatiles, and isotopic fractionation ratios, to those found in the interstellar medium, in disks around young stars, and between cometary families, is vital to understanding planetary system formation and the processing history experienced by organic matter in the so-called interstellar-comet connection [3].

We have conducted observations, at primarily millimeter and submillimeter wavelengths, where molecular emission is easily resolved, towards comets to determine important cosmogonic quantities, such as the ortho:para ratio and isotope ratios, as well as probe the origin of cometary organics. Comets provide important clues to the processes that occurred during the formation and early evolution of the Solar System. Past observations, as well as laboratory measurements of cometary material obtained from Stardust, have shown that comets appear to contain a mixture of the products from both interstellar and nebular chemistries. A major observational challenge in cometary science is to quantify the extent to which chemical compounds can be linked to either reservoir.

In the classical picture, the long-period comets probably formed in the nebular disk across the giant planet formation region (5-40 AU) with the majority of them originating from the Uranus-Neptune region. They were subsequently scattered out to the Oort Cloud by Jupiter. The short-period comets (also known as ecliptic or Jupiter Family Comets) reside mainly in the Edgeworth-Kuiper belt where they were formed. Given the gradient in physical conditions expected across this region of the nebula, chemical diversity in this comet population is to be expected [4,5]. Their deuterium fractionation (D/H) is a particularly important diagnostic of cometary origins. Prior to 2009, HDO/H_2O had been determined for only three bright comets: Halley, Hyakutake, and Hale-Bopp, yielding a common value of about 3×10^{-4}, about a factor of ten greater than that of the local interstellar medium [6]. As the terrestrial (SMOW) D/H value is 1.5×10^{-4}, this seems to limit the role played by Oort Cloud comets in transporting water to the early Earth. The first measured limit on HDO/H_2O in a JFC, from 3.7μm observations of 8P/Tuttle at the VLT, was reported only recently and is $< 4\times10^{-4}$ [7].

Comet JFC 103P/Hartley 2 has an extremely favorable orbit for ground-based observations, approaching < 0.1AU from Earth, and is a rendezvous target for NASA's Deep Impact Extended Investigation (the DIXI component of the EPOXI space mission [8]). Data obtained for this JFC will provide further constraints on the cometary D/H isotope ratio as well as the formation temperature of the volatile component of this comet, and possibly provide insight to the origin of similar cometary bodies.

Observations: Observations were conducted from four facilities, contributing to the large ground-based consortium organized in support of the EPOXI mission. The Arizona Radio Observatory's 12m telescope, Kitt Peak, AZ, and Submillimeter telescope, Mt. Graham, AZ, as well as the James Clerk Maxwell Telescope, Mauna Kea, HI and the Greenbank 100m telescope, Greenbank, WV, were employed for this study covering 20 cm, 3 cm, and 0.8-3 mm. Data were obtained, collectively, from 12 October 2010 to 5 November 2010. The GBT was the only facility not utilized during the EPOXI flyby by the presenting authors. Data were collected in position switching mode at all facilities with spectral resolutions of dv ~0.05 – 0.6 km/s. Ephemeris were generated from JPL Horizons daily and positional accuracy was monitored approximately every hour by pointing/focusing on nearby planets and/or quasars.

Results and Discussion: About a dozen species were observed throughout this effort of the ground based observing campain for comet 103P/Hartley 2. These include deuterated isotopologues of HCN, H_2CO, and H_2O. Limits of the D/H ratio were obtained, with the best limits derived from DCN yielding a D/H < 0.01. While this value is only an upper limit, it is consistent with other cometary D/H values obtained (e.g. 0.002 in Hale-Bopp [9]), and helps constrain the origin of this particular species in cometary bodies since the interstellar DCN/HCN value is 0.1-0.01 [10].

Additionally, data was obtained for ortho and para-H_2CO towards this comet, in multiple transitions, and simultaneously. These data will be used to obtain the *o/p* ratio for this species and further constrain the formation temperature and environment where these simple organics were formed.

Other species detected or where upper limits were obtained include: CH_3OH, HNC, CS, H_2S, *c*-C_3H_2, SO_2, and OH. Figure 1 shows the detection of multiple transitions of CH_3OH near 157 GHz. Detailed analysis of all these data will help constrain the temperature, abundances, variance or periodicity of a given species, and can be compared to results from other comets, as well as support the data obtained from the EPOXI mission. The full analysis and comparison will be presented.

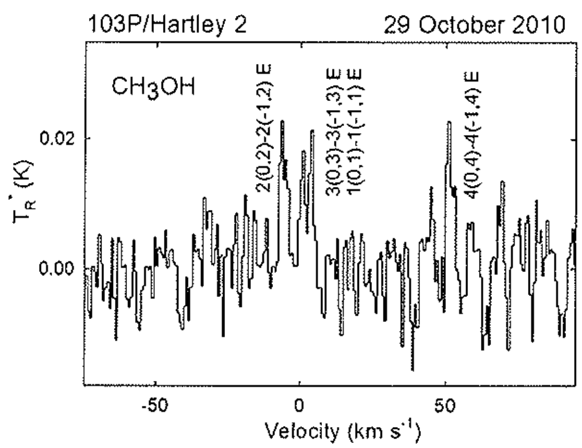

Figure 1: CH_3OH spectra obtained towards comet 103P/Hartley 2 on 29 October 2010 employing the ARO 12m telescope. Data are plotted in 390 kHz resolution and centered at a cometocentric velocity near 157.2 GHz.

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