The Volatile Chemistry of 103P/Hartley 2 Determined from Ground-based Infrared Measurements During the EPOXI Closest Approach. N. Dello Russo[1], R. J. Vervack Jr.[1], H. A. Weaver[1], C. M. Lisse[1], H. Kawakita[2], H. Kobayashi[2], A. L. Cochran[3], W. M. Harris[4], A. J. McKay[5], and M. A. DiSanti[6]
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Background: Observational evidence supports chemical diversity among the population of observed comets, suggesting differences due to the epoch and location of their formation and subsequent evolution. Significant differences have been measured in the abundances of parent volatiles in comets observed at radio [1, 2] and infrared [3 – 5] wavelengths. A much larger database covered by optical studies also reveals differences in carbon-chain chemistries, with about one-third of the sampled comets classified as depleted in C_2 and C_3 relative to CN and OH [6, 7]. Furthermore, significant differences in carbon-chain chemistry are evident when dynamical classes are compared: more than half of Jupiter-family comets are carbon-chain depleted in contrast to ~ 20% of sampled long-period comets [6 - 8]. More recent observations have increased the narrowband photometry database to about 150 comets [8]. The large optical database hints at the chemical diversity of the early solar system as there is significant heterogeneity of comet composition even in these few measured daughter species, and the compositions of at least some Jupiter-family comets are likely associated with their formation region rather than evolutionary processing.

Although the optical database is comprehensive in the number of comets sampled, it is insufficient for characterizing the parent volatile chemistry of comets because abundances of daughter species in the coma are difficult to link directly to abundances of nucleus ices. Additionally, the few daughter species that can be detected at optical wavelengths are products of only a small fraction of parent volatiles present in nucleus ices. High-resolution infrared spectroscopic studies can begin to properly address this issue by sampling coma species released directly from nucleus ices. Here, we report the volatile chemistry of 103P/Hartley 2 on UT 4 November 2010, the night of closest approach for the EPOXI spacecraft, obtained using high-dispersion ($\lambda/\Delta\lambda$ ~ 28,000) infrared spectroscopy with NIRSPEC at the W. M. Keck Observatory [9] and lower-dispersion ($\lambda/\Delta\lambda$ ~ 2,500) infrared spectroscopy with SpeX at the NASA IRTF [10].

Results: Our data were obtained on the night the EPOXI spacecraft flew through the inner coma of 103P/Hartley 2, placing results of the study directly into the context of the highest quality EPOXI data. In addition, the results presented here also provide critical data needed for the complete interpretation of results obtained by the EPOXI HRI-IR spectrometer. The high spectral resolution of NIRSPEC allows the identification and quantification of coma gas species that cannot be resolved by the HRI-IR instrument, while the broad spectral grasp of the SpeX observations provide a context for both the dust continuum and overall volatile emission from the comet.

Weather conditions at Mauna Kea were clear throughout the night of 04 Nov 2010, with a moderate and relatively constant atmospheric water vapor burden of ~4 pr-mm. NIRSPEC data were obtained using three grating settings over five time intervals. In the first time interval (UT 10:49 – 11:30), a setting sampling H_2O, C_2H_6, CH_3OH, C_2H_2 and NH_3 was used with the slit along the sun-comet line (KL1, 24 minutes on-source, PA = 284°). In the second time interval (UT 11:37 – 12:55), a setting sampling H_2O, C_2H_6, CH_3OH, H_2CO, HCN, C_2H_2 and NH_3 was used with the slit at PA = 284° (KL2, 44 minutes on-source). In the third time interval (UT 13:33 – 14:43), a setting sampling all species in KL2 plus HC_3N was used with the slit at PA = 284° (KL3, 40 minutes on-source). For the fourth time interval (UT 14:50 – 15:17) the KL1 setting was repeated with the slit at PA = 284° (16 minutes on-source). Finally, for the fifth time interval (UT 15:20 – 15:54) the KL1 setting was repeated but the slit PA was rotated to 5° (20 minutes on-source; Fig. 1). Contemporaneous SpeX data were obtained using the LXD mode covering the wavelength range of ~ 1.9 – 4.2 μm. Approximately 96 minutes on-source was obtained with SpeX over the course of the night.

For this work we will emphasize seven main results. (1) Production rates and relative abundances were determined for the following species in 103P/Hartley 2: H_2O, CH_3OH, C_2H_6, C_2H_2, HCN, H_2CO, NH_3 and HC_3N. (2) 103P/Hartley 2 displayed notable short-term variability as preliminary results

suggest the gas production increased significantly between UT 11:00 and 15:00. Relative abundances of species were measured during this time and any short-term variability in the relative abundances of species will be reported. (3) Because we detect individual temperature-dependent ro-vibrational lines with NIRSPEC, a rotational temperature is needed in order to accurately convert line fluxes into production rates. Rotational temperatures in the coma are reported for H_2O, C_2H_6, C_2H_2 and HCN. (4) On UT November 4, the comet was only 0.156 AU from the Earth providing excellent spatial resolution (~ 22 km/pixel) over the 24 arcsecond NIRSPEC slit and the 15 arcsecond SpeX slit. We present the spatial distribution of H_2O, CH_3OH, C_2H_6, C_2H_2, HCN, and dust in the coma of 103P out to roughly 500 km. Comparison of spatial profiles provides clues on how volatiles are associated with each other and how they are released from the nucleus. This will also provide a comparison for the distribution of volatiles seen from EPOXI within the very inner coma as well as daughter species CN, C_2, CH and NH_2 simultaneously measured in a coordinated study obtained with the ARCES echelle spectrometer at Apache Point Observatory [11]. (5) We present dust spectral measurements over the 1.9 – 4.2 μm range, which encompasses the transition from reflected solar light to thermal emission, and an estimated Bond albedo for the dust scattering. (6) The chemistries of comets 103P/Hartley 2 and 73P/Schwassmann Wachmann 3 are compared, as 73P has been classified as carbon-chain [7] and parent volatile depleted [12], whereas 103P has been classified as carbon-chain typical. In addition, observing circumstances were such that spectral datasets for both comets are of very high quality, facilitating chemical comparisons.

References:

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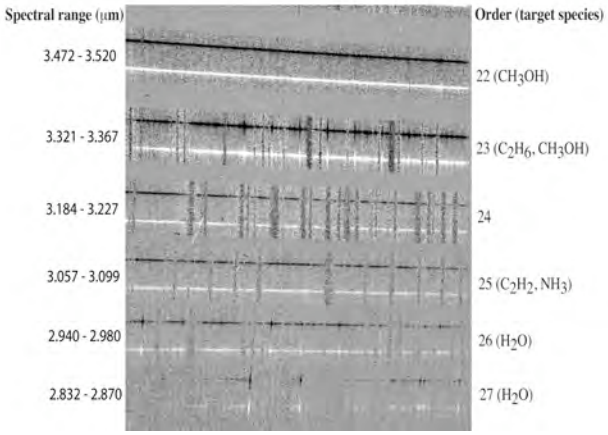

Figure 1 - Spectrum of 103P/Hartley 2 acquired with NIRSPEC on UT 4 November 2010. An unprocessed spatial-spectral difference frame (an A frame is subtracted from a B frame where the B frame was nodded 12 arcseconds along the 24 arcsecond slit) acquired from a single NIRSPEC echelle/cross-disperser setting (KL1, 10 AB pairs equal to 20 minutes on-source). NIRSPEC is a cross-dispersed spectrometer, so multiple orders are covered in a single setting (6 for this setting). The molecular species sampled in each order of this setting are given on the right, while the spectral coverage of each order is given on the left. The spectral coverage of NIRSPEC allows the simultaneous sampling of H_2O with other volatile species. Comet emissions from volatile species are seen on top of the comet dust continuum (the horizontal light and dark bands). Areas of atmospheric opacity are indicated by the vertical strips (atmospheric sky lines) where the continuum flux is interrupted.