Using Atomic Oxygen as a Proxy for CO_2 Production in Comets: Application to Comets 103P/Hartley and C/2009 P1 Garradd Adam J. McKay[1] , Nancy J. Chanover[1], Michael A. DiSanti[2], Jeffrey P. Morgenthaler[3], Anita L. Cochran[4] , Walter M. Harris[5] , and Neil Dello Russo[6] , [1] Astronomy Department, New Mexico State University, 1320 Frenger Mall, Las Cruces, NM 88001, [2]NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD, 20771,[3]Planetary Science Institute, 1700 E. Fort Lowell, Ste 106, Tucson, AZ, 85719 [4]University of Texas at Austin, 1 University Station, Austin, TX, 78712, [5]University of California Davis, 1 Shields Ave. Davis, CA, 95616, and [6]Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel, MD, 20723

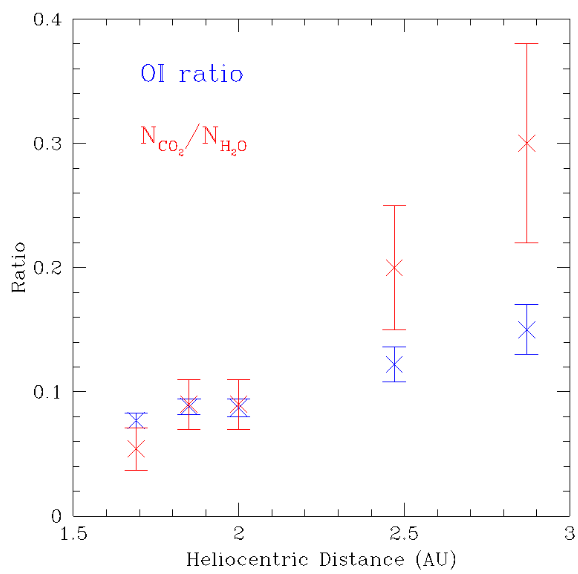
Introduction: H_2O, CO_2, and CO are typically the most abundant ices in cometary nuclei and are therefore considered the primary drivers of their activity. This makes knowledge of the abundances of these ices in comets important for understanding both cometary composition and sublimation behavior. H_2O and CO can be observed directly from the ground, but CO_2 is only observable from space. Therefore, finding an indirect ground-based measurement that can serve as a proxy for CO_2 production is an important goal for studies of cometary composition. Observations of the forbidden lines of atomic oxygen can be employed as this proxy. The flux ratio of the 5577 Å line to the sum of the 6300 and 6364 Å lines (the oxygen line ratio) is considered indicative of whether the parent molecule of the atomic oxygen is H_2O or CO_2/CO [1].

We present analysis of observations of the forbidden oxygen lines in comets 103P/Hartley and C/2009 P1 Garradd and discuss the implications for the use of the forbidden oxygen lines as a proxy for CO_2 abundance in comets.

Observations: We obtained spectra of both comets using the ARCES echelle spectrometer mounted on the Astrophysical Research Consortium 3.5-m telescope at Apache Point Observatory. ARCES has a very large spectral range (3500-10,000 Å) and a spectral resolution of R ~ 31,500. We collected the 103P observations from September-November 2010 and the Garradd observations from June-November 2011, with more observations planned for Spring 2012.

Results: The oxygen line ratios measured for 103P are higher than typically measured for comets near 1 AU from the Sun, suggesting that CO_2 is more abundant in the coma. Using our measured oxygen line ratios to estimate the CO_2/H_2O ratio for 103P results in values that do not agree quantitatively with the DIXI measurements. This may be indicative of an incomplete understanding of some of the detailed physics involved, e.g. photodissociation rates and branching ratios. However, the agreement is sufficient to suggest that the oxygen line ratio is a capable qualitative tool for identifying comets with high CO_2 abundances, like 103P.

We also find evidence for increased CO_2 activity in comet Garradd when it was located at a heliocentric distance of ~ 3 AU. A plot of the measured oxygen line ratio and the inferred CO_2/H_2O ratio vs. heliocentric distance for our Garradd pre-perihelion data is shown in the figure.



Both the oxygen line ratio and the inferred CO_2/H_2O ratio decrease with decreasing heliocentric distance. As the heliocentric distance of the comet decreases, the vaporization rate of H_2O increases faster than that of CO_2 due to the different volatilities for the two ices [2]. This results in a decreasing CO_2/H_2O ratio that can be inferred from the decreasing oxygen line ratio. Others recently reported a similar trend in their measurements with the VLT covering a similar pre-perihelion time period [3].

References: [1] Festou, M.C. and Feldman, P.D. (1981) *Astronomy and Astrophysics*, *103*, 154–159. [2] Meech, K. and Svoren, J. (2004), In: *Comets II*, Tucson, AZ, USA, pp. 317-335. [3] Decock A. et al. (2011) *EPSC-DPS Joint Meeting 2011, page 1126, October 2011*.

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