INVESTIGATING PROTOSTELLAR CARBON RESERVOIRS WITH HIGH-RESOLUTION SPECTROSCOPY TOWARD MASSIVE YOUNG STELLAR OBJECTS.

R.L. Smith[1,2], G.A. Blake[3], A.C.A. Boogert[4], K.M. Pontoppidan[5], and A.C. Lockwood[3]. [1]NC Museum of Natural Sciences, [2]Appalachian State University. rachel.smith@naturalsciences.org. [3]California Institute of Technology, Division of Geological and Planetary Sciences. [4]SOFIA/USRA, NASA Ames. [5]Space Telescope Science Institute.

Introduction: Near-IR observations of CO isotopologues taken at high spectral resolution toward young stellar objcts (YSOs) enable valuable comparisons between YSOs and solar system material, as well as robust evaluation of early protoplanetry chemical reservoirs [1-7]. Recent observations toward low-mass, solar-type YSOs revealed signatures consistent with CO self-shielding [2-4], as well as significant heterogeneity in $[^{12}C^{16}O]/[^{13}C^{16}O]_{Gas}$, which may in part be due to interplay between CO ice and gas [3,4,6,7]. Toward expanding this investigation of early protostellar phenomena to include a range of environments, we present new observations toward massive, luminous YSOs with varying CO ice abundances along a single line-of-sight. These data are part of our ongoing study of carbon reservoirs beyond our solar neighborhood (R_{GC} ~ 8 kpc).

Observations and Methods: Thus far, we have obtained fundamental ($\upsilon = 1 - 0$) and first overtone ($\upsilon = 2 - 0$) CO rovibrational absorption spectra toward nine massive YSOs using Keck-NIRSPEC at high resolution (R=25,000). Spectra were reduced with a customized IDL pipeline. Doppler broadening, integrated gas temperatures, and total molecular column densities were determined with curves-of-growth and rotational analyses. A subset of preliminary results was recently reported [7].

Results: Thus far, two massive targets, AFGL 2136 (R_{GC}~6.1 kpc) and NGC 7538 IRS9 (R_{GC}~9.4 kpc), have been completely analyzed. Doppler broading values are ~ 8 km/s (AFLG 2136) and 3.5 km/s (NGC 7538), with cold $[^{12}C^{16}O]/[^{13}C^{16}O]_{Gas}$ of 59+/−8 and 74+/−3, respectively, which are within expectations from a Galactic $^{12}C/^{13}C$ gradient [8]. Lower cold $[^{12}C^{16}O]/[^{13}C^{16}O]_{Gas}$ than $[^{12}CO_2][^{13}CO_2]_{Solid}$ [8] suggest that CO_2 may not originate from a CO reservoir as previously assumed [9]. The warm $[^{12}CO]/[^{13}CO]_{Gas}$ for AFGL 2136 is 124+/−22, suggesting that both high- and low-mass YSOs [2,3,4] may have higher $[^{12}CO]/[^{13}CO]_{Gas}$ in warm vs. cold gas. Signatures consistent with CO ice-gas interplay were found toward the massive YSOs, following a similar trend in the low-mass sample [3,4,7].

Conclusions: New observations toward two massive YSOs suggest generally less dispersion in $[^{12}C^{16}O]/[^{13}C^{16}O]_{Gas}$ toward high- vs. low-mass YSOs, while interactions between CO ice and gas may be similarly affecting the $[^{12}C^{16}O]/[^{13}C^{16}O]_{Gas}$ in both high- and low-mass YSOs. Our new data further indicate that CO_2 may not originate from CO. This ongoing investigation of a range of massive, luminous YSOs will provide a robust suite of observations leading to a statistically significant evaluation of key protoplanetary chemical reservoirs in the Galaxy.

References: [1] Brittain S.D. et al. 2005. *ApJ 626*: 283-291. [2] Smith R.L. et al.. 2009. *ApJ 701*: 163-179. [3] Smith R. L. et al. *ApJ*, submitted. [4] Smith R. L. et al. 2013. #2698, *44th LPSC*. [5] Pontoppidan K. M. 2006. *A&A 453*, L47-L50. [6] Young E.D. and Schauble E.A. 2011. *42nd LPSC*. [7] Smith R.L. et al. 2014., #2653, *45th LPSC*. [8] Boogert A.C.A. et al. 2000. *A&A 353*, 349-362. [9] van Dishoeck E.F. et al. 1996. *A&A 315*, L349-352.