NEW $^{12}CO/^{13}CO$ OBSERVATIONS IN YOUNG STELLAR OBJECTS AND MOLECULAR CLOUDS: IMPLICATIONS FOR $^{12}C/^{13}C$ IN THE EARLY SOLAR NEBULA

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Introduction: The $^{12}C/^{13}C$ ratio in the solar system is ~ 86 – 89, derived from solar photospheric models [1] and bulk solar system materials [2, 3, 4], respectively. These values are higher than measurements from carbon-bearing molecules in the local interstellar medium (ISM), which range between ~ 62 – 69, as determined from nearby molecular clouds [4, 5, 6]. Galactic chemical evolution models have been used to explain this apparent discrepancy [6, 7]; these models assume that the solar system $^{12}C/^{13}C$ ratio reflects the local ISM ~ 4.6 Gya, and similarly that $^{12}C/^{13}C$ abundance ratios in young stellar objects (YSOs) observed today should represent their local clouds.

Observations: We present several new observations of CO isotopologues toward low-mass YSOs in the local star-forming regions, Corona Australis, Ophiuchus, Vela, Taurus, and Orion. These data were obtained at very high resolution (R=95,000) using the CRIRES spectrograph on the Very Large Telescope; a small, initial subset of these data has been reported [8, 9]. Here we report isotopic results from a robust set of observations of protostellar material representing circumstellar disks, envelopes, and dense foreground cloud gas. Isotope ratios were derived from the column densities obtained directly from the resolved, optically thin line profiles of the observed CO isotopologues.

Results/discussion: We find $^{12}CO/^{13}CO$ abundance ratios ranging from 84 – 158, with all objects showing significantly higher ratios than the local ISM, indicating that YSOs in both early and later stages of evolution show signs of significant isotopic variability from the ambient parent clouds. The spread in $^{12}CO/^{13}CO$ in the Ophiuchus cloud sources also indicates that heterogeneity in molecular clouds may be significant for understanding chemical fractionation in YSOs. We see evidence for CO self-shielding in the oxygen isotopes in several objects, and CO photolysis may partly explain these high $^{12}CO/^{13}CO$ ratios.

Conclusions: We find high $^{12}CO/^{13}CO$ toward several protostellar objects and two Ophiuchus foreground clouds. Our results suggest that Galactic chemical evolution models may be insufficient for explaining the solar system-ISM $^{12}CO/^{13}CO$ discrepancy, and that cloud heterogeneity may be an important factor in understanding early solar system chemistry.

References: [1] Scott P. C. et al. 2006. *Astronomy and Astrophysics* 456: 675-688. [2] Coplen T. B. et al. 2002. *Pure and Applied Chemistry* 74: 1987-2017. [3] Clayton D. D. and Nittler L. R. 2004. *Annual Review of Astronomy and Astrophysics* 42: 39-78. [4] Wilson T. L. 1999. *Reports on Progress in Physics* 62: 143-185. [5] Langer W. D. and Penzias A. A. 1993. *The Astrophysical Journal* 408: 539-547. [6] Milam S. N. et al. 2005. *The Astrophysical Journal* 634: 1126-1132. [7] Prantzos N. et al. 1996. *Astronomy and Astrophysics* 309: 760-774. [8] Smith R. L. et al. 2009. *The Astrophysical Journal* 701: 163-175. [9] Smith R. L. et al. 2010. Abstract #2254. 41st Lunar & Planetary Science Conference.