FRACTIONATION THROUGH PHOTODESORPTION OF $^{12}\text{C}\text{O}^{13}\text{C}\text{O}$ INTERSTELLAR ICE ANALOGUES. Lucas R. Smith1, Robert D. Lewis1, Murthy S. Gudipati2, Rachel L. Smith3,4, 1Appalachian State University, Department of Physics & Astronomy, 525 Rivers Street, Boone, NC, 28608 (smithlr2@appstate.edu; lewisrd@appstate.edu), 2Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California (Murthy.Gudipati@jpl.nasa.gov), 3North Carolina Museum of Natural Sciences, Raleigh NC (rachel.smith@naturalsciences.org).

**Introduction:** Understanding carbon inheritance in the early solar nebula is important toward building a comprehensive picture of planet formation and prebiotic chemistry, and constraining models of the astrophysical environment in the early solar system. As a precursor to prebiotic molecules and complex organics, carbon monoxide (CO) is an important tracer of carbon chemistry in protoplanetary systems, and can further inform an understanding of the discrepancy between $^{12}\text{C}/^{13}\text{C}$ of the solar system ($\sim 87$ [1]) and the interstellar medium ($\sim 62$ to $69$ [2,3]). Recent high-resolution astronomical observations toward low-mass young stellar objects (YSOs) have revealed an unexpected heterogeneity in the gas-phase ($^{12}\text{C}^{16}\text{O}/[^{13}\text{C}^{16}\text{O}]$) abundance ratios, with possible influence from the CO ice reservoir on the gas-phase ratios [4] (Figure 1). One explanation for the high gas-phase $[^{12}\text{C}^{16}\text{O}]/[^{13}\text{C}^{16}\text{O}]$ observed toward some YSOs could be preferential photodesorption of $^{12}\text{CO}$ compared to $^{13}\text{CO}$ from the ice to the gas phase in these same objects, which in turn could be explained by differences in the zero-point energies (ZPEs) between $^{12}\text{CO}$ ($1081.6$ cm$^{-1}$) and $^{13}\text{CO}$ ($1057.7$ cm$^{-1}$) [5]. This hypothesis is further supported by findings of photochemical $^{13}\text{CO}$ enrichment in $^{12}\text{CO}_{2}/^{13}\text{CO}_{2}$ ice mixtures [6]. Photodesorption is an important astrophysical process in clouds containing dense clumps of icy material in a high UV flux [7,8] environment, and has been shown to be an important driver in the chemistry of protoplanetary ices [6-8]. Here we present our early experimental findings suggesting preferential photodesorption of $^{12}\text{CO}$ from CO ice mixtures, which could help drive higher than expected gas-phase ratios in certain YSOs.

**Methods:** Photodesorption experiments on $^{12}\text{CO}^{13}\text{CO}$ ice mixtures in interstellar ice analogues were performed in the Ice Spectroscopy Laboratory at the Jet Propulsion Laboratory. The experimental setup (collectively called the Himalaya) consists of a high-vacuum cryogenic system capable of reaching near-astrophysical conditions (10 to 35 K and $10^{-7}$ to $10^{-9}$ mbar). An initial 4:1 ratio of $[^{12}\text{CO}]/[^{13}\text{CO}]$ was produced by mixing ultra-high purity gas-phase $^{12}\text{CO}$ and $^{13}\text{CO}$, and subjecting them to a two-step decontamination process to freeze out contaminant molecules through use of LN$_2$ traps. Ice samples were produced by depositing the mixed CO gas at 20 K for 30 minutes at a total pressure of $\sim 5 \times 10^{-8}$ mbar. Temperature of the ice was changed at a rate of 0.5 K/min to selected temperatures (10 K, 15 K, 20 K, and 25 K) below the measured sublimation points of $^{12}\text{CO}$ (29.9 K) and $^{13}\text{CO}$ (29.0 K) [9]. Residual gas in the chamber was measured in pressure versus time (PVT) at one-second intervals with a quadrupole mass spectrometer (QMS) equipped with a high-sensitivity electron multiplier to increase precision down to $10^{-14}$ mbar. A Nicolet 6700 Fourier transform infrared (FTIR) spectrometer was used to measure single-beam transmission spectra of ice at ten-minute intervals (Figure 2). All measurements were taken through a 45-minute equilibration to the end of the irradiation of the ice, and a return to background pressure levels. The ice was irradiated using a Hydrogen-discharge lamp with predominantly the Lyman-$\alpha$ line, and a broadband at $\sim 160$ nm from emission of H$_2$, to simulate protostellar emission. Each irradiation trial lasted from 5 to 12 hours. PVT background data were subtracted from the irradiation trials for both isotopologues, and the initial $^{12}\text{CO}$ levels were normalized to $^{13}\text{CO}$. Fast Fourier transform (FFT) smoothing was applied to decrease noise in the PVT and improve data processing. Partial pressure was used as a measure of fractionation. Final $[^{12}\text{CO}]/[^{13}\text{CO}]$ ratios were derived by dividing the par-
mixtures, supporting the hypothesis that ZPE differences between the isotopologues could lead to high $[^{12}\text{CO}]/[^{13}\text{CO}]$ in the gas phase. This finding could help explain the unusual $[^{12}\text{CO}]/[^{13}\text{CO}]$ heterogeneity observed toward a range of YSOs in the Galaxy. This ongoing study will include quantification of column densities from partial pressures and precise error estimates from the measurements. Further, experiments will be repeated with a $[^{12}\text{CO}]/[^{13}\text{CO}]$ ice ratio at 1:4 (inverted compared to the present ratio) to validate these results. Astrophysically-relevant mixtures of $^{12}$CO-$^{13}$CO ices with CO$_2$ and H$_2$O will also be explored to further investigate CO fractionation in astrophysical regimes. These results are being applied to computer models as part of this project of exploring carbon evolution in protoplanetary systems.

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