VARIABILITY IN GAS-PHASE CO RESERVOIRS IN MASSIVE YOUNG STELLAR CORES AND BINARIES.

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Introduction: High-resolution observations of young stellar objects (YSOs) are exciting windows into protoplanetary chemistry. Near-infrared observations of carbon monoxide (CO) gas toward YSOs and evaluation of carbon and oxygen isotopes therin have provided insights into protoplanetary processes with implications for the evolution of carbon in the early solar nebula [1-7]. Each YSO observation reveals a snapshot in a ~million-yr timescale of disk evolution; yet, YSOs have also been observed to vary significantly in timescales of months to a few years. For example, infrared fluxes in late-stage solar-type disks show up to 50% variability [8], and 70% of Class I and II YSOs in Orion vary in infrared amplitudes [9]. Structural changes in the inner disk could also influence lightcurve variations in certain YSOs [10], and disk dynamics could lead to photometric variability in within a few years [11]. Our preliminary analysis on abundance variation in CO using archival VLT-CRIRES data revealed that [^{13}CO]/[C^{18}O] ratios for low-mass YSOs could vary significantly (~53% to 63%) [12]. Here we present ongoing results of short-term variability in gas-phase CO toward a range of massive YSOs using high-resolution spectra observed at NASA's IRTF observatory. This study explores a range of environments: solar-type and massive YSO cores, as well as binary pairs – unique targets that inform chemical evolution in systems with stellar multiplicity.

Observations and Methods: CO rovibrational absorption spectra were obtained with NASA's IRTF observatory with the iSHELL instrument at very high spectral resolution (R ~ 80,000, 3.75 km/s) in the *M* bands (υ=1−0, 4.7 μm) for optically thin ^{13}C^{16}O, ^{12}C^{18}O, and ^{12}C^{17}O, *K* bands (υ=2−0, 2.3 μm) for ^{12}C^{16}O, ensuring that all analyzed lines are similarly optically thin. Molecular column densities for each YSO were obtained by fitting spectral lines with a Gaussian and deriving optical depths using the mean line width from the ^{12}C^{18}O or optically thin ^{12}C^{16}O lines. Rotational analyses were used to derive total isotopologue column densities and excitation temperatures using one- or two-temperature models. Repeated epochs were observed at varying intervals to capture a range of windows into variability in CO isotopologue abundances.

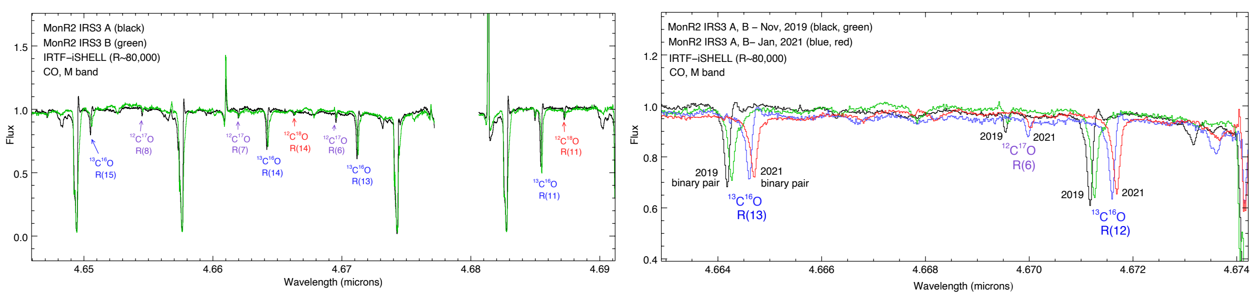

Figure 1. Left: Portion of the 4.7 μm spectra the YSO binary, MonR2 IRS3 (A,B), for the 2019 epoch, showing various isotopolgoue lines. Right: Portion of the 4.7 μm spectra for MonR2IRS3, showing 2019 and 2021 epochs.

Results: Thus far, we find that YSOs show the most variation in ^{13}CO abundance (up to 35%), which manifests in variability in [^{12}CO]/[^{13}CO] up to ~33%, and which may have implications for varying evolutionary pathways for different isotopologues. We have also begun exploring variability within binaries, which has unique value in providing insight into variations within the same epoch as well as between epochs for systems with stellar multiplicity. One such binary is MonR2 IRS3 (Figure 1), also valuable in exploring ^{12}C^{17}O and ^{12}C^{18}O within a multiple system.

Conclusions: Our results thus far suggest that CO reservoirs, in particular ^{13}C^{16}O and its ratios with respect to ^{12}C^{16}O and ^{12}C^{18}O, can vary significantly in abundance over short timescales. These results signify possible inheritance of isotopic heterogeneity from the parent cloud, with relevance to solar nebular models. This ongoing observational study will continue to add statistical significance to these initial findings and include comparisons with stellar multiplicity, and results can be further explored in interdisciplinary work with solar system materials.

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