EVALUATION OF OXYGEN ISOTOPES IN MASSIVE YOUNG STELLAR OBJECTS AND IMPLICATIONS FOR PROTOPLANETARY RESERVOIRS.

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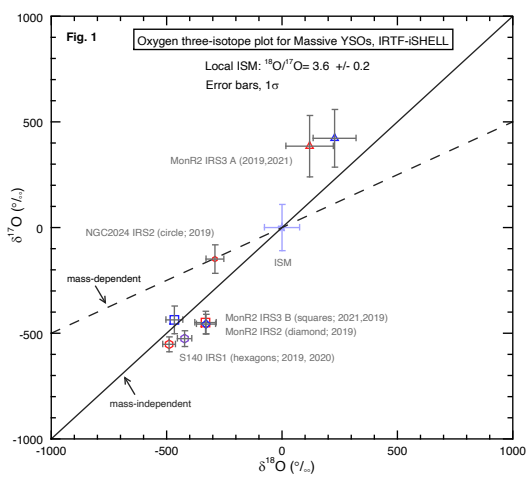
Introduction: Astronomical observations using high-resolution, near-infrared, rovibrational spectroscopy of carbon monoxide (CO) toward young stellar objects (YSOs), and the determination of precise isotope ratios of C and O therein, enable an evaluation of protoplanetary chemistry in a wide range of YSO environments and meaningful comparisons with meteoritical data. Previous work on low-mass/solar-type YSOs has revealed evidence of CO self-shielding in disks [1-3], supernova inheritance in the nebular cloud [4], and CO exchange between ice and gas reservoirs [3]. Massive YSOs (> 8 M_{Sun}) are particularly valuable in that they are extremely bright (~ 10^4 to 10^5 L_{Sun}) and thus observable across a range of distances in the Galaxy. Further, these environments offer insights into nebular chemistry that cannot be probed with their low-mass, dimmer counterparts. Recent work on short-term variabiltiy in [^{12}CO]/[^{13}CO] in massive YSOs has shown support for chemical inheritance from the parent cloud to disk [5,6], and here we expand on this work to include oxygen isotopes within our growing data set of massive YSOs, each with a rich CO spectral forest. These data are particularly relevant to solar nebula models and are windows into a range of protoplanetary environments, most recently including a multiple-star system and isolated core in the same cloud [7].

Observations and Methods: Spectra were obtained with NASA's IRTF observatory using the high-resolution *iSHELL* spectrograph (M band, 4.7 µm: R~88,000; K band, 2.3 µm: R~78,000). Optically thin $^{13}C^{16}O$, $^{12}C^{18}O$, and $^{12}C^{17}O$ were obtained in the M band, and $^{12}C^{16}O$ in K. Spectral lines were fitted with a Gaussian deconvolved from instrumental broadening, and optical depths derived using the mean line widths from $^{12}C^{18}O$ or optically thin $^{12}C^{16}O$ lines. Rotational analyses were used to derive total isotopologue column densities and integrated gas temperatures using one- or two-temperature models, and from these the oxygen isotope ratios were calculated. Repeated epochs were observed at varying intervals to capture a range of windows into variability in CO isotopologue abundances.



Results: Results for oxygen isotopes in the massive YSOs relative to the local ISM ($^{18}O/^{17}O$ ~3.6 [8]) are compiled in **Fig. 1 (left)**. Two targets and component B of the binary MonR2 IRS3 (A,B) show signatures of CO self-shielding (^{16}O-excess relative to ^{18}O and ^{17}O along the mass-independent fractionation line). MonR2IRS3 (A), the binary component with a likely disk [9,10], shows ^{16}O-depletion near the mass-independent line, and a more evolved YSO [11], NCG 2024 IRS2, has moderate ^{16}O-excess along the mass-dependent line. Signatures of self-shielding are also found in the two isolated massive YSOs, MonR2 IRS2 and S140 IRS1, which are thought to have ionizing winds as well as possible disks [12,13]. We do not find a correlation with gas temperatures and self-shielding, with signatures found in cold (MonR2 IRS2; ~21 to 37 K) and warm (MonR2 IRS3B and S140IRS1; 70 to 160 K) gas. Repeat observations are consistent.

Conclusions: Signatures of CO self-shielding are found in one isolated YSO and one binary component evolving within the same parent cloud, MonR2. We see CO self-shielding in two isolated, ionizing massive YSOs with potential disks, and mass-dependent signatures in the more evolved YSO. Together, these results support inheritance of CO self-shielding from the cloud to the disk, with chemical processing as the YSO evolves. These results are consistent with findings of carbon variability [5,6], and together support recent nebular models [14,15]. Our results also indicate that binaries may not evolve along the same chemical pathways, which could affect protoplanetary chemistry within common multiple-star systems. This ongoing study will include new observations and analysis in the coming year, which will add significance to these results.

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