CO SELF-SHIELDING BY VARIOUS STELLAR SOURCES. J. R. Lyons[1], [1]Department of Earth & Space Sciences, UCLA, Los Angeles, CA 90095-1567; jimlyons@ucla.edu

Introduction: CO self-shielding models for the CAI mixing line [1] require a stellar far-UV source, either a neighboring large star [2-4], or the central star [1,5]. Because stellar spectra typically have strong wavelength dependence at the wavelengths that CO dissociates (91-108 nm), and because of the highly structured CO spectra, it is necessary to model the resulting isotope signatures from various possible stellar sources. Here, I consider two source stars: TW Hya, a classical T Tauri star, and HD 36981, a large B star (type B5). Both stars have been observed by the FUSE (Far-UV Spectroscopic Explorer) satellite. I also briefly consider the temperature dependence of the expected $\delta^{17}O/\delta^{18}O$ ratio from published molecular cloud shielding functions [6].

TW Hya source star: TW Hya is at a distance of 56 pc and has negligible dust extinction. Observations with FUSE [7] show an FUV spectrum dominated by line emission (e.g., C IV, Si IV, O VI) (Fig. 1), but also a weaker continuum. The FUV features derive from both the accretion shock and disk processes (e.g., excitation of disk H_2)[7].TW Hya is estimated to have an accretion rate of $2x10^{-9}$ M_{solar} yr^{-1}. Using the TW Hya flux and my computed CO isotopic cross sections yields the δ-values shown in Fig. 2. The flux is scaled by the accretion rate to simulate different FUV luminosities. The resulting slopes are ~ 0.90, and a low accretion rate is required. To properly evaluate the central star scenario, a 2-D radiative transfer calculation is needed to account for near-grazing incidence at the disk surface (which will have higher optical depth radiation normally incident to the disk). Allowable accretion rates are higher than implied by Fig. 2.

HD 36981 source star : HD 36981 is a B5 star in the Orion nebula, located at a distance of 409 pc. There is significant dust extinction, which I have not yet corrected for. That means the HD 36981 flux in Fig. 3 is too low by at least a factor ~10, and is significantly reddened. (The flux data will be dereddened in future work.) The spectrum from HD 36981 is dominated by broadband emission and absorption features. Nevertheless, the resulting oxygen isotope slopes (.87-.90) are similar to those obtained using a TW Hya source (Fig. 4).

Temperature dependence of $\delta^{17}O/\delta^{18}O$ ratio using shielding functions: Visser et al. [6] computed shielding functions for all CO isotopologues for various molecular cloud conditions. Their shielding functions for $C^{18}O$ and (especially) $C^{17}O$ are uncertain to a lack of molecular constant data. I have applied those shielding functions to the model of [3] with the nebular gas temperature held at 50 K, but using shielding functions derived for the temperatures shown in Fig. 5. The point is to show that the temperature dependence of the cross sections can yield different 'slopes'. It is interesting that the 20 Kelvin case yields a 1.0 slope, but even at 20 K CO freezeout occurs, precluding significant CO self-shielding.

Conclusions: Given the band structure of the CO absorption spectrum, one would expect that isotope effects during CO self-shielding would depend strongly on the FUV source spectrum. The modeling presented here, using a line-dominated spectrum (TW Hya) and a giant star spectrum dominated by broad features (HD 36981), argues differently . The reason these two spectra yield similar isotopic results is that the continua in the spectra are primarily responsible for CO photodissociation. This is advantageous to the self-shielding theory in terms of 'robustness' of the resulting slope for various FUV sources, but it also makes it more difficult to uniquely identify the FUV source type.

References: [1] Clayton, R. N. (2002) *Nature* 415, 860-861. [2] Yurimoto. H. & Kurimoto, K. (2004) Science 305, 1763-1766. [3] Lyons J. R. & E. D. Young (2005) *Nature* 435, 317-320. [4] Lee et al. (2008) MAPS 43, 1351-1362. [5] Young (2007) EPSL 262, 468-483. [6] Visser, R. et al (2009) A&A 503, 323-343. [7] Herczeg, G. et al. (2002) ApJ 572, 310-325. [8] Eidelsberg, M. et al. (1991) Astron Astrophys S.S. 90, 231-282, [9] Lyons, J. R. (2010) 41th LPSC.

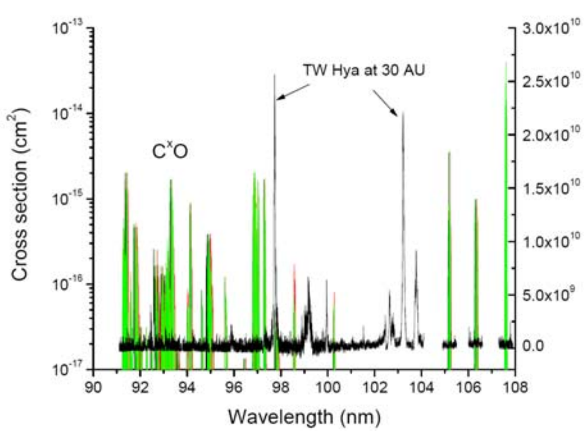

Fig. 1 Computed CO cross sections for $C^{17}O$ (red) and $C^{18}O$ (green), and the photon flux from TW Hya scaled to 30 AU in units of ph cm^{-2} s^{-1} nm^{-1}.

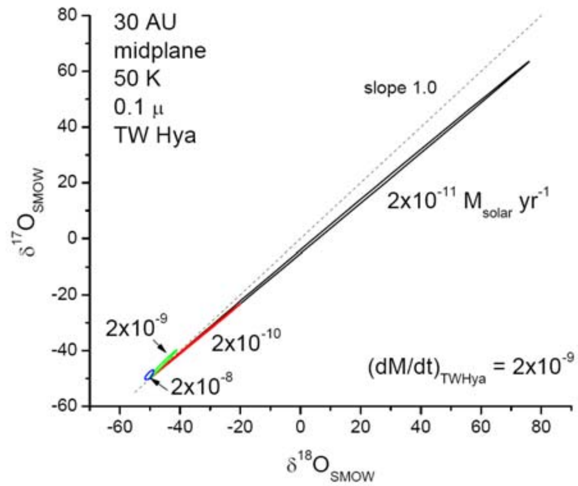

Fig. 2 Three-isotope plot of nebular H_2O for different luminosities of TW Hya (shown as accretion rate in M_{solar} yr^{-1}). Larger luminosities yield smaller δ-values, as seen in [ ].

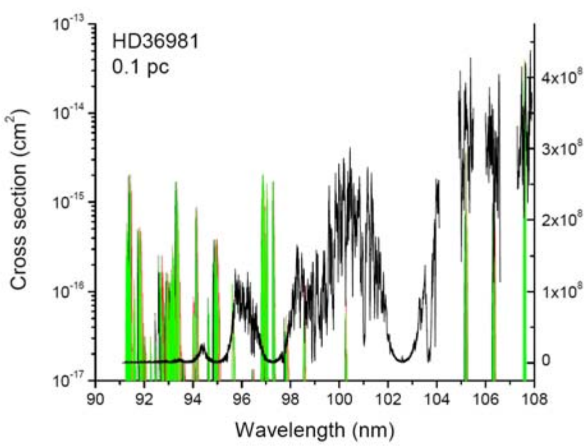

Fig. 3. Computed CO cross sections for $C^{17}O$ (red) and $C^{18}O$ (green), and the photon flux from HD36981 (a B5 star) scaled to 0.1 pc in units of ph cm^{-2} s^{-1} nm^{-1}. Flux uncorrected for extinction and reddening.

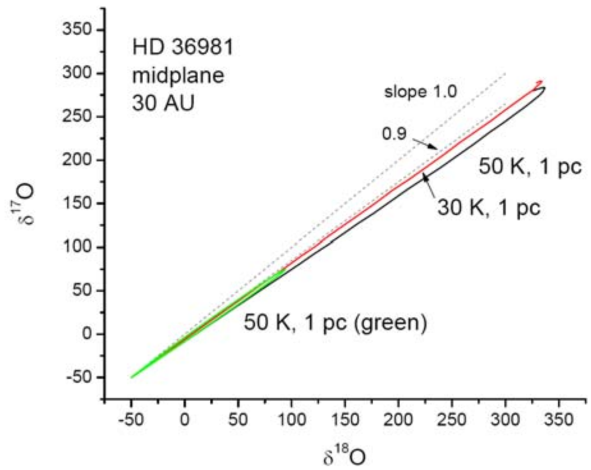

Fig. 4 Three-isotope plot of nebular H_2O for a disk illuminated by HD 36981 at a distance of 1 pc, and for several gas temperatures.

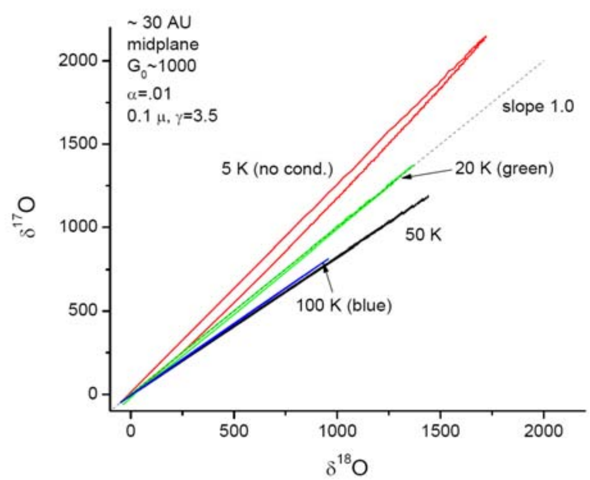

Fig. 5. Temperature dependence of $\delta^{17}O/\delta^{18}O$ ratio from CO self-shielding using shielding functions from Visser et al. [6].