EXOPLANET HABITABILITY: SMALL VARIATIONS IN STELLAR C/O CAN HAVE BIG EFFECTS.
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Introduction: The C/O ratio in a circumstellar planet forming disk is particularly important in determining the refractory (silicate and metal) to volatile ice ratio in material condensed beyond the snow line [1, 2], and therefore the availability of water in the system's planetesimal building blocks. Galactic Chemical Evolution (GCE) models show that C and O abundances in the ISM and stars should vary with both time and galactic location ([1,3]). Surveys of stellar composition, including stars hosting planets, report stellar C/O values ranging from sub-solar (<0.55) to 1.0 or greater. There has been much discussion of the extremely C-rich (C/O > 1) cases, partially because these can lead to possible exotic carbon chemistry in the refractory phases of terrestrial planets in these systems . However, due to the difficult nature of the spectroscopic observations and reduction required, doubt has been expressed concerning the reliability of some of the extreme C-rich compositions reported (e.g. [4]). We discuss here the effects on water availability of even modest variations in C/O abundance from 'solar' values.

Discussion:

The compositional effect of changes in C/O values is illustrated by the history of estimates of 'solar' C/O and their effects on interpretation of icy body densities in our own solar system.

The prevalence in the outer solar system of icy satellites with mass fractions of ~50% water ice was first predicted and explained quantitatively in a series of papers by John Lewis (e.g. [5]) based on the estimates of solar C/O available at that time (0.6: [6]). Accurate density measurements from Voyager data for satellites of Jupiter, Saturn, Uranus and Neptune generally confirmed this picture. However, downward revisions of estimates of C/O during this period (to 0.43, [7]) created problems for modeling denser icy satellites such as Triton.

More recently several new solar C/O estimates have reported higher values again (e.g. 0.55: [8]). The difference in estimated water ice mass fraction for such relatively modest changes in C/O are significant for modeling the water ice content of planetesimals formed beyond the snow line in a CO rich nebula (e.g. ~22% water ice for the current best solar value versus ~52% for the 1989 estimates).

The effects of stellar C/O on water abundance in exoplanetary systems are apparent in calculations using a set of stars with a range of measured C/O abundances. The volatile ice content of planetesimals in these systems varies significantly with C/O, controlled primarily by the availability of O for H_2O ice condensation. Systems with C/O less than the solar value (C/O = 0.55) should have very water ice rich planetesimals, while water ice mass fraction decreases rapidly with increasing C/O until only ices of CO and CO_2 are left in significant proportions for values >~0.7 (see Figure 1)[9].

Conclusion:

These results have implications for assessing the habitability of exoplanets since they constrain the amount of water available beyond the snow line for dynamical delivery to inner planets, depending on the host star's C/O in the circumstellar nebula. Even modest variations in C/O can have dramatic effects, as noted above. We suggest that an important element in assessing habitability for exoplanet systems is establishing more reliable methods of measuring C and O abundances in these systems.

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References:

[1] Gaidos E. J. (2000) *Icarus* 145, 637.
[2] Wong M. H. et al. (2008) in Oxygen in the Solar System, G.J. MacPherson, Editor 2008, Mineralogical Society of America: Chantilly, VA, 241.
[3] Nieva and Przybilla (2012)A&A 539, A14.
[4] Fortney, J. J. (2012) ApJ, 747, L27.
[5] Lewis J. S. (1971) *Icarus* **15**(2), 174-185.
[6] Cameron AGW (1981) *In:* Essays in Nuclear Astrophysics. Barns CA, Clayton DD, Schramm DN (eds) Cambridge University Press, New York, p 23
[7] Anders E, Grevesse N (1989) Geochim Cosmochim Acta 53:197-214.
[8] Asplund, M et. al 2009, ARA&A, 47, 481.
[9] Johnson T. V. et al. (2012) *Astrophys. J*. 757(2), 192.

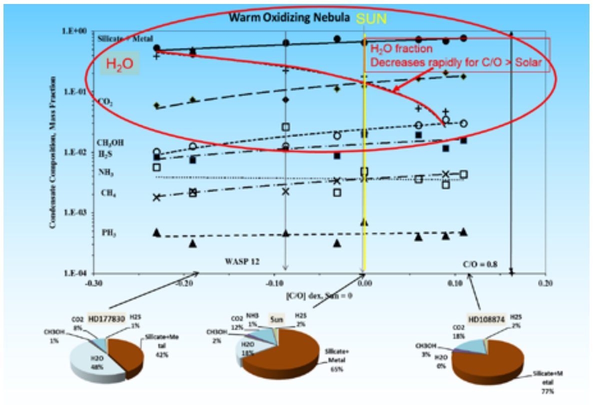

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Figure 1: Expected planetesimal compositions beyond the snow line for condensates in circumstellar nebulae with varying C/O compositions.