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Stellar C/O: Effects on Habitability of Exoplanet Systems

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Abstract

In this talk we assess how differences in the composition of exoplanet host stars might affect the availability of water in their systems, particularly the role of carbon and oxygen abundances. Water, one of the key chemical ingredients for habitability, may be in short supply in carbon-rich, oxygen-poor systems even if planets exist in the 'habitable zone'.

1. Introduction

The 'habitable zone' in the solar system is generally defined as the region around the Sun where liquid water can in principle exist on the surface of a planet-sized body given suitable atmospheric pressure – e.g. the Earth. In discussing exoplanet systems, the definition of the habitable zone has also to take into account the host star's history, size and luminosity as well. However, a key factor in assessing the habitability of exoplanets within the zone in a given system is not well constrained – the availability of significant amounts of water in the planetesimal building blocks from which the planets in the system were formed.

2. Role of C/O ratio in determining H_2O availability

For the solar system, C/O = 0.55 is particularly important in determining the refractory (silicate and metal) to volatile ice ratio expected in material condensed beyond the snow line [1],[2]. Our analysis of published compositions for a set of exoplanet host stars [3] showed that the amount of condensed water ice in those systems might range from as much as 50% by mass for sub-solar C/O = 0.35 to less than a few percent for super-solar C/O = 0.7 (Figure 1). For even higher C/O values (> 0.8), there is essentially no oxygen available for water if the major carbon gas phase in the nebula is CO, while in the inner nebula carbides might be a major refractory species, replacing oxides [2], [4].

A recent analysis [5] of a much larger stellar composition data set for 974 FGK stars [6] using similar techniques allows us to assess the possible range of water ice abundance in the circumstellar accretion disks of these 'solar-type' stars (of which 72 were known to have one or more planets as of 2011). Figure 2 shows the range of stellar C/O in a subset (457 stars) of this stellar database with reported C, O, Ni, and Fe abundances. The resulting computed water ice fraction and refractory (silicate + metal) fraction as a function of C/O are shown in Figure 3. Although some of the most extreme (>1) C/O values have been questioned, these results strongly suggest that while many exoplanet systems may have water volatile inventories similar to the Solar System or even more water-rich, many, perhaps 50% or more might well be very dry compared to our system.

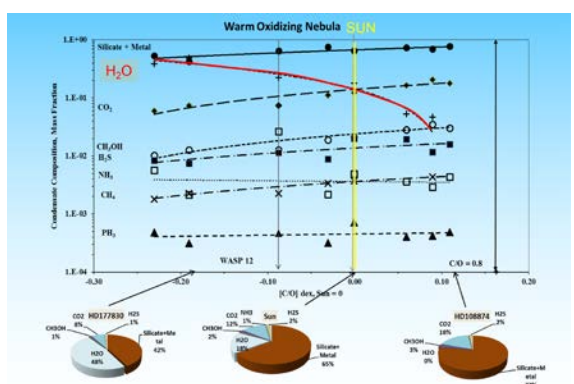

Figure 1: Mass fraction of condensates for exoplanet host stars with varying C/O, in dex (Solar value =0), after [3]

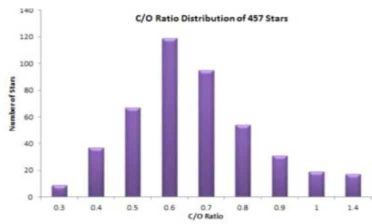

Figure 1.1. *The distribution of carbon-to-oxygen ratio among 457 stars given by Petigura and Marcy (2011), based on the adaption of the solar data from Asplund et al. (2009).*

Figure 2: From [5]

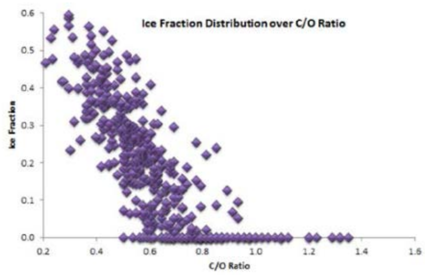

Figure 1.2. *The distribution of water ice fraction over total material available, on the basis of carbon-to-oxygen ratio of parent stars. Results are derived from the data provided by Petigura and Marcy (2011).*

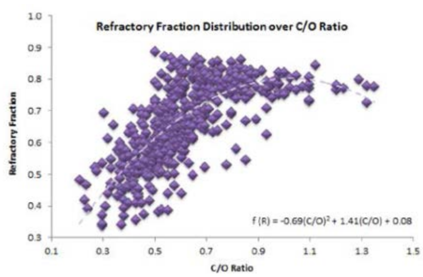

Figure 1.3. *The distribution of refractory (silicate and metallic) fraction over total material available, on the basis of carbon-to-oxygen ratio of the parent stars. Results are derived from the data provided by Petigura and Marcy (2011).*

Figure 3 a (above), b (below) from [5]

3. Summary and Conclusions

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 stars' C/O in the circumstellar nebula. As more and more exoplanets are discovered and characterized, we suggest that stellar composition studies of host stars are a useful way to assess the availability of water in their habitable zones.

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