Early Solids in Planetary Systems: Effects of Stellar Composition on Silicates and Ices in Planetesimals.

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Introduction: Stellar abundances of exoplanet host stars exhibit significant variations from solar in solid forming elements, both refractory and volatile (e.g [1]). The C/O ratio is particularly important in determining the refractory (silicate and metal) to volatile ice ratio in material condensed beyond the snow line [2, 3]. Given the observed range in stellar C/O in exoplanet host stars, condensates might range from more water and volatile rich than solar system objects to volatile poor and silicate/metal rich [4]. In addition, for more carbon-rich stars (C/O >~0.8) refractory material in the inner part of the systems might be dominated by carbides rather than silicates [2, 5]. We estimate the composition of volatile and refractory material in extrasolar planetesimals using a set of stars with a wide range of measured C/O abundances and compare them with early solar system materials.

Table 1 Stars used and C/O abundances

Star	C/O	[C/O]
HD19994	0.32	-0.23
HD177830	0.35	-0.19
HD213240	0.51	-0.03
Sun	0.55	0.00
Gl777A	0.63	0.06
HD72659	0.68	0.09
HD108874	0.71	0.11
55Cnc	0.81	0.17
HD17051	1.02	0.27
HD27442	1.10	0.30
HD4203	1.51	0.44
WASP 12	0.45	-0.09

Data and Calculations: Stellar abundances for exoplanet host stars used are from [6-9]. Table 1 lists the stars and their measured C/O ratios. Abundances of Si, Fe, Ni and S were also reported for most stars. Solar values of S were used if not reported and solar P was assumed for the volatile ice calculations. The amount of silicate ($MgSiO_3$) and metal (FeO, FeS, Ni) in the refractory condensates was determined as described in [3]. The remaining O in the gas phase H_2O and CO and the stellar composition values were then used to calculate the volatile ice condensation chemistry beyond the snow line in the circumstellar nebula following [10]. The composition of the resulting silicate/metal and ice condensates as function of C/O ratio is shown in Figure 1 for an 'cool', oxidizing nebula with a midplane temperature as low as 20K, where CO ice and clathrate become important (depending on clathration efficiency – 100% assumed here). Figure 2 shows the same for a 'warm' oxidizing nebula with temperature ~50K.

Discussion: Figure 1 demonstrates that 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; [C/O] = 0 dex) 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 warmer nebula conditions (T>~50K), Figure 2 shows that condensates become increasingly silicate and metal rich, with some CO_2 ice until C/O ~ 0.8, where the silicate plus metal mass fraction is ~ 1. The C/O ratio for 55Cnc is close to this limit and planets in that system may have been enriched with silicate/metal rich, volatile poor, planetesimals. For larger C/O ratios, the system would become more reducing, with CH_4 becoming the major carbon-bearing gas and possibly including C as solid hydrocarbons in the condensates.

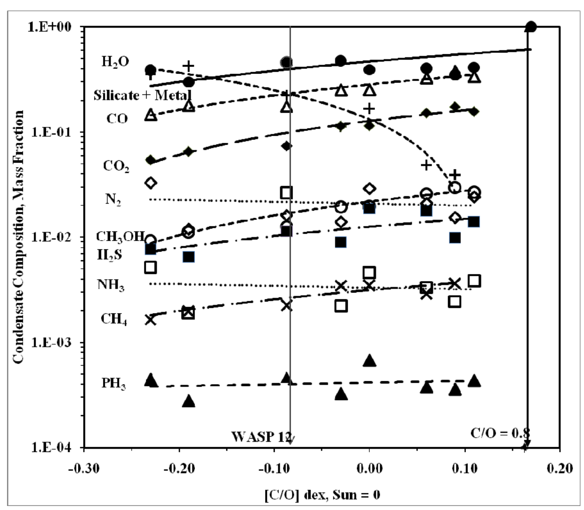

Figure 1 Composition vs [C/O] – cool oxidizing nebula

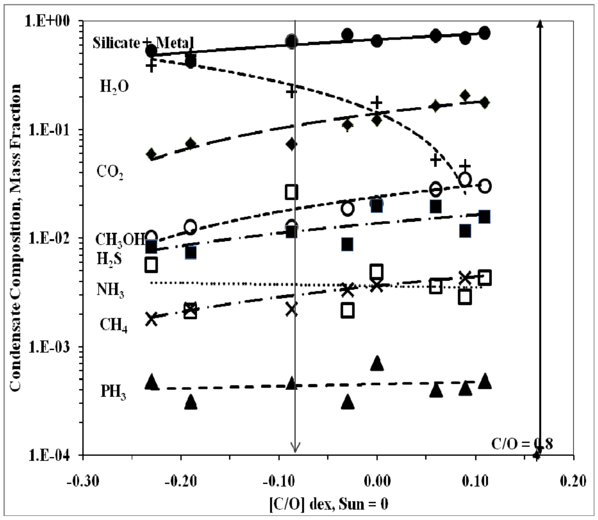

Figure 2 Composition vs [C/O] – warm oxidizing nebula

WASP12b: WASP 12b, a transiting hot Jupiter has been reported to have an atmospheric C/O > 1 [11]. In this case the composition of the planet seems not to reflect the stellar composition, which has a sub-solar C/O (light grey line in Fig.1 and 2). Planetesimals with the compositions shown in Fig. 1 for this star cannot easily explain this C/O enhancement, suggesting that either O is sequestered in the planet or the nebula C/O in the planet forming region was depleted in O (or enriched in C) compared with the stellar value [12].

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