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Effect of stellar composition on the rock/ice composition of condensates in exoplanet systems

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In our solar system, the composition of solid material condensing beyond the ‘snow-line’ (where solar nebula pressure and temperature conditions permit the condensation of water ice) is affected by several major factors. Starting with the ‘solar abundance’ of elements in the nebula, derived from the current solar photospheric abundances, meteorites, and estimates of protosolar values in the early solar nebula, the most important things affecting the composition of the condensates are 1. The carbon and oxygen abundances, $(C/O)_{solar}$ = 0.55 2. The redox state of C (i.e. CO vs. CH_4 rich conditions) and 3. The amount of carbon in solid form. These factors largely determine the refractory to volatile proportions in the expected condensates. For the solar system, we characterize the composition by the fraction of silicates, oxides and metals in the overall condensate, f_{r-m}. Calculated f_{r-m} varies from ∼0.47 to 0.76 in regions of the solar nebula where water is the major condensed volatile and CO and CH_4 are non-condensable (cf. Wong et al., *Oxygen in the Solar System*, G. J. MacPherson, ed, 2008). In colder regions of the nebula, other volatiles, hydrates, clathrates and pure ices such as CO and N_2 add to the condensed volatile fraction depending on the nebula conditions – cf. Mousis et al. ApJ 696, 1348 (2009).

Recent surveys of the stellar abundances of solid forming elements in a sample of exoplanet host stars have shown that there are significant differences from the Sun which affect the expected rock/ice values in condensates in these systems, particularly a wide range of C/O values. We have used the abundances of O, C. Si, S, Fe, and Ni from these surveys to calculate f_{r-m} for condensates in these systems for various conditions, using the methods outlined in Wong et al. The volatile ice compositions have been calculated following the methods described in Mousis et al. ApJ 727 (2011).

The results of our study are that f_{r-m} in these systems may range from ∼0.25 to 1.0. The calculated f_{r-m} values are weakly correlated with the metallicity (Fe/H) but strongly correlated with (C/O), as expected from the solar case. The following cases illustrate the range of possible outcomes: 1. HD17783 (C/O) =0.35 – f_{r-m} from 0.33-0.46 (below the solar range for all redox conditions), with the ice composition ranging from 0.58 H_2O with 0.23 CO (if temperatures permit), for oxidizing conditions to 0.78 H_2O with 0.15 CH_4(for low temperatures) for reducing conditions; 2. HD10887 (C/O) = 0.71 – for the oxidizing case, little O is available for water ice and the condensates are all rock $f_{r-m} =\sim 1$,

until temperatures allow condensation of $CO_2$and CO ices. For the reducing case f_{r-m} is 0.53 and the ices are primarily water and CH_4 (if T permits); 3. HD4203 (C/O) = 1.5 – This high carbon composition results in reducing conditions (all O is taken up by silicates and oxides) and condensates are rocky (f_{r-m} = 0.86) with water ice the major volatile (some methane clathrate possible) until temperatures are low enough for CH_4 ice.

These characteristics may be investigated for extrasolar systems in the future through their impact on the refractory and volatile content of extrasolar planetesimal belts and the amount of heavy element enrichment of extrasolar giant planets (e.g. Mousis et al. 2011).

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