ON THE COMPOSITION AND EARLY EVOLUTION OF EXTRASOLAR TERRESTRIAL PLANETS

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Introduction

Conventional solar nebula models on planetary formation suggest that the composition of planets formed around a star strongly depends on the chemistry of the initial molecular cloud. Equilibrium condensation of gases ejected from two different types of novae suggest that (1) systems with a very high dust/gas ratio (10^8 x solar) may develop during cooling of C-O novae and, (2) graphite becomes a stable and abundant mineral at 800 K even when the initial gas C/O ratio is less than unity (O-Ne novae environments). At such high dust/gas ratios, supermassive rocky planets may be formed from C-O novae ejecta at short distances from the central star. On the other hand, substantial amounts of solid carbon in protoplanetary materials may yield to subtantial differences in the primary differentiation of a terrestrial planet. First, a carbide-rich (rather than metallic) core may form. Given that the density of $(Fe,Ni)_xC$ is substantially lower than that of a metallic Fe,Ni alloy, core segregation may happen slowly, due to lower density contrast between metal carbide and silicates, and inefficient core formation is thus possible. This would certainly have strong implications on the development of an intrinsic magnetic field, the efficiency of planetary outgassing and the composition of the (non-captured) atmosphere. Also, immiscible excess carbon may yield to the formation of a graphite-rich crust, with relatively high thermal conductivity, where fast dissipation of internal heat might substantially reduce the time span of geological activity of even large bodies.

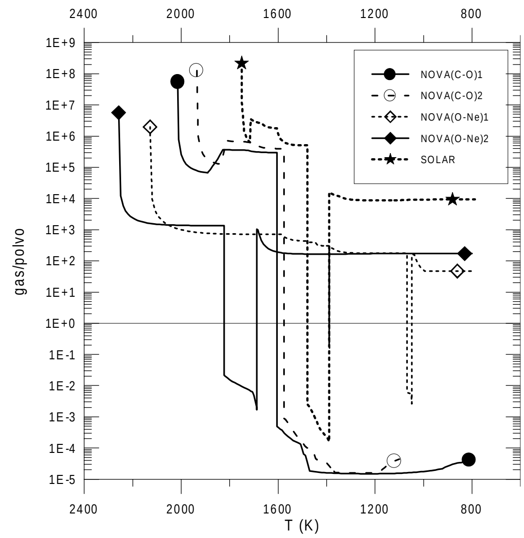
Condensation of novae ejecta

Novae ejecta are a significant contributor to molecular clouds from which protoplanetary systems may form. In this work, equilibrium condensation calculations on four different cases (José and Herranz, 1998) have been carried out, on the basis of previous work showing that such calculations are adequate for the simulation of the composition of terrestrial-like planets (Casanova and Portela, 1996; Valeriano and Casanova, 1997):

1. NOVA (C-O) 1: the chemical composition of the outermost ejected layer where the mass of the white dwarf is 1.15 solar masses, accretion rate is $2x10^{-10}$ solar masses /yr and 50% mixture between the white dwarf core and ejected material.
2. NOVA (C-O) 2: same as NOVA (C-O) 1 but for the closest layer to non-ejected material.
3. NOVA (O-Ne) 1: same as NOVA (C-O) 1 but adopting a Ne-O composition of the white dwarf core.
4. NOVA (O-Ne) 2: same as NOVA (C-O) 2 but adopting a Ne-O composition of the white dwarf core.

The evolution of the gas/dust ratio as a function of temperature is graphically described in Fig. 1.

C-O novae have very similar condensation sequences. the most interesting feature of such sequences is that the gas/dust ratio decreases rapidly at 1600 K, suggesting a high-efficiency condensation event. At temperatures between 1100 and 800 K, the gas ratio is approximately 8 orders of magnitude higher than the solar analog, implying that the residence time for solid materials in the molecular cloud is much higher than in the primitive solar system, yielding to a prolonged accretion and subsequnet possibility of formation of supermassive terrestrial-like planets.



Ne-O novae ejecta show a condensation sequence very similar to the solar case (as far as gas/dust ratios) but significant chemical differences exist, including the preservation of graphite as a stable component at temperatures as low as 800 K with an initial C/O ratio of 0.6. This observation opens new possibilities towards understanding the formation and stability of solid carbon species during planetary formation processes. Specifically, graphite stability of graphite at temperatures as low as 800 K permits reaction between solid carbon and metals (Fe,Ni) to produce matllic carbides. If the planet grows to the extent of developing significant partial melting, a carbide-rich rather than a metallic core will form, leading to less efficient segregation and, ultimately, a planet without a central core. If graphite content exceeds the stoichiometric abundance required for the formation of metallic carbides, excess carbon will "float" to develop a graphite-rich crust.

Reference

José J. and Hernanz M. 1998 *Astrophys. Journal* **494**, 680
Casanova I. and Portela J.C., 1996. *Geogaceta* **20,** 62
Valeriano J. and Casanova I., 1997. *Actas del I Congreso Ibérico de Geoquímica* 624