FORMATION OF THE SUN IN A STELLAR CLUSTER; CAIs AS LARGE PRESOLAR GRAINS

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Introduction: It is widely accepted that most stars form inlarge clusters [1]. If this is how the Sun formed, it requires a very different approach to understanding the isotopic record in meteorites compared to formation of the Sun in isolation. We now know that the different groups (or clans) of chondrites tend to have different compositions (e.g., of O, Cr, Ti, Ru, Mo). These clearly indicate that the solar nebula did not form by a rapid collapse that produced enough convection to homogenize the isotopes. It appears necessary that the nebula formed from different parcels of material that accreted sequentially with limited amounts of mixing with the earlier accreted materials.

Age and isotopic difference between CAIs and chondrules: The chronometric system based on $^{26}Al/^{26}Mg$ (assuming uniform $^{26}Al/^{27}Al$ initial ratios) gives small age differences among chondrules from different chondrite groups and a 2 Ma age difference between CAIs and chondrules. It has long been recognized that this requires very special conditions to preserve the CAIs in space for 2 Ma. Chondrules (espcially high-FeO chondrules) preserve many relict grains from previous generations of chondrules even though the duration of chondrule formation appears to have been relatively short (<100 ka) at each chondrite location. The same rate of destruction for 2 Ma would have destroyed most CAIs. Aother problem is that, although CAIs are found in all the chondrite groups and are especially abundant in CV chondrites, the isotopic compositions of elements in CAIs are different from those in all bulk chondrites [2] and from the Earth, Moon and Mars. One solution to this is to form the CAIs close to another star and eject them towards the Sun via one of their polar jets [3].

Transport with polar jets: In large clusters of stars forming in molecular clouds, the distance between stars is typically about 10^4 AU. A particle (or planet) in orbit at this distance around a solar-mass star will have a period of 1 Ma. This is thus a reasonable estimate of the time required to transit from one star in the cluster to the next, and is similar to the ^{26}Al-based time difference between CAIs and chondrules.

A key question is the efficiency of transporting refractory condensates from one star to another. A simple assumption is that the stars are close-packed, and thus have six nearest neighbors. Each star has two polar jets, and the probability is 1/6 that one of these is pointed closer to the Sun than to one of its neighbors. The evolution of planetary systems is thought to take about 1 Ma; if we assume that the Sun is average, about half the neighboring stars will have progressed through the jetting stage ahead of the Sun, and thus be a potential source of exotic materials to the solar nebula, while the other stars are lagging behind and were not sources, How much exotic material could be arriving at the Sun comes down the the question of how big the older star (aimed at the Sun) is and what fraction of its mass is lost through polar jets.

Heterogeneities in the molecular cloud: If the CAIs are indeed exotic materials that did not form in the solar system then we cann ot make the assumption that they formed from materials having the same initial 26/27 ratio as the Solar Nebula. It this case, we do not have a constraint on the difference in formation times between CAIs and chondrules. With the exception of FUN CAIs, it is plausible that CAIs all formed all formed at about the same time from a source in which the 26/27 ratio was relatively uniform. However, the CAIs don't have to be fresh steller products. They might just be coarse materials in dusty parcels in the cloud. They were more abundant in the precursor materials of the CV chondrites, and that is why they are more abundant in CV chondrites and also why CV chondrites have higher mean refractory lithophile abundances than other chondrite groups.

Implications: If this approach is correct, it creates problems for some establishment views. It implies that the chondrules may have formed much earlier in the history of the Sun, and that the 2-Ma gap between the formation of CAIs and chondrules cannot be used to constrain models of the formation of the solar system.. It takes away the importance of the agreement between the megaSIMS $\Delta^{17}O$ value [4] and CAIs, and reopens the discussion of why the composition of the Sun can be so different from that of the inner planets [5].

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