Oxygen isotope anomalies of the Sun and the original environment of the Solar system

J.-E. Lee, [1] E. A. Bergin, [2] and J. R. Lyons [3]

[1] *Department of Astronomy and Space Science/ Sejong University, Korea*
[2] *Department of Astronomy/ The University of Michigan, USA*
[3] *Department of Earth and Space Sciences/ University of California, USA*

Most stars form in clusters [1] even though our star, the Sun, seems alone at present with the closest stellar neighbor at 1.3 pc. It is not certain, however, whether the Sun formed in a cluster or in isolation. Some memory of the environment where the Sun formed might exist within the remnants of the formation of the Solar System. In this regard, primitive meteorites, interplanetary dust particles, and comets have been considered as the best sources to search for memory of conditions prior to and during formation, since they escaped from significant physical and chemical processing and therefore may preserve some relic of interstellar material. For instance, the inferred presence of short-lived radionuclides, especially ^{60}Fe, in meteorites [2] suggests that the Sun formed near a massive star, which went through the core collapse of a supernova and provided the radionuclide to the solar nebula [3] or to the proto-solar molecular cloud [4]. This possibility of the Sun formation in proximity to massive stars is also supported by the prominent dearth of objects beyond the semi-major axes of the Kuiper Belt, which might be caused by the dynamical truncation though stellar encounters [5][6] or by the external photoevaporation [7].

If the Sun formed in a cluster, as described above, the ultraviolet radiation field around the proto-Sun would have been enhanced by 4 to 5 orders of magnitude compared to the standard local interstellar radiation field. Therefore, this enhanced radiation environment must have also left some evidences in chemistry affected by photolysis. It has been discovered that oxygen isotopes in calcium aluminum rich inclusions (CAIs) embedded in primitive meteorites had different ratios from those seen in terrestrial rocks [8], where the oxygen isotopic fractionation depends on mass. Recent theories suggest this mass-independent fractionation recorded in meteorites can be understood as a result from the isotopic-selective photodissociation of CO, either in the Solar Nebula [9][10] or parent cloud [11]. The photodissociation of CO is strongly coupled with the strength of the far-ultraviolet (FUV) radiation field as well as the CO column density. The studying of oxygen isotope ratios in the Solar system, therefore, will place strong constraints on its formation environment.

The oxygen isotope composition of the Sun is central to understanding the oxygen isotope evolution of the Solar system as recorded in meteorites. Recent preliminary Genesis results [12] of the direct Solar wind measurements show that the Solar oxygen isotope ratios are similar to the initial bulk values ($\delta^{18,17}_{SMOW}$ = -50 permil), i.e., isotopically light compared to the Standard Mean Ocean Water (SMOW). However, the Solar wind isotope measurements in lunar metal grains have yielded dramatically different results; $\delta^{18,17}_{SMOW}$ = -50 permil in one case [13] and $\delta^{18,17}_{SMOW}$ = +50 permil in the other [14].

Based on the CO self-shielding model in a collapsing low mass star forming cloud, we have showed that the Solar oxygen isotopic anomalies could vary depending on the strength of the surrounding radiation field (G_0) when the Sun formed [15]. When constrained by oxygen isotope anomalies measured in meteorites, comets, and the Solar wind (Genesis), our model independently suggests that the Sun formed in the vicinity of massive stars, which is consistent with other evidences such as short-lived radionuclides and the dynamical properties of planets and Kuiper Belt objects.

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