2004

Solar 18O/17O and the Setting for Solar Birth

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SOLAR ^{18}O/^{17}O AND THE SETTING FOR SOLAR BIRTH. D. D. Clayton, Clemson University, Clemson SC 29634-0978 (cdonald@clemson.edu)

Introduction: Solar oxygen contains an anomalously high fraction of ^{18}O. I here attribute that excess ^{18}O to the supernova starburst initiated by the merger of a satellite galaxy with the Milky Way. This starburst spawned [1] the mixing line seen in the AGB star compositions whose SiC dust constitutes the observed mainstream SiC grains. The number of starburst AGB stars born in this short time interval excceds that born locally by the steady rate of galactic star birth, so they dominate the SiC grains. Given that, the anomalously large ^{18}O/^{17}O ratio in the sun resulted from these presolar circumstances for the origin of the sun.

Merger Context for Solar Birth: The mainstream SiC presolar stardust grains were produced in galactic AGB stars that were born about 1-2 Gyr prior to solar birth in order to have delivered their AGB-wind grains to the presolar cloud after their 1-1.5 Gyr evolution to the AGB phase. These AGB stars were born with a significant range (25%) of correlated variations in ^{29}Si/^{28}Si and ^{30}Si/^{28}Si. A new physical model [1] for this correlated spread utilizes a burst of star formation induced by the mixing of a low-metallicity gas into the galactic interstellar gas near the solar birth position. Starbursts are common consequences of galactic mergers. Gaseous mixing ensued between the galactic ISM (then of mildly sub-solar metallicity) and the low-metallicity ISM of a dwarf companion galaxy that merged with the Milky Way about 6.5 Gyr ago. Distinct mixtures gave birth to stars having linear correlations among their isotopes, specifically the correlation of ^{29}Si/^{28}Si and ^{30}Si/^{28}Si that has so puzzled interpretation of the mainstream grains. The donor AGB stars were of sub-solar metallicity in this model.

Supernovae of the Starburst: For the SiC grains to have peppered the solar cloud requires that the sun be later born from the same admixed gases. But the sun was not born until 1-2 Gyr after the mixing event began, requiring solar gas to contain not only the AGB ejecta of from starburst but also whatsoever ejecta that can be thermalized from more massive stars that were also spawned by the merger. The sun's metallicity was elevated to solar value by that supernova nucleosynthesis. These stars will include both intermediate-mass red giants and the still more massive supernovae of type II that are responsible for ^{12}C and ^{13}C galactic nucleosynthesis and for ^{18}O and ^{16}O nucleosynthesis. Birth of the sun will therefore be from gas that has had its metallicity (^{16}O, ^{12}C and Si abundances relative to H) increased by that intervening nucleosynthesis and its ^{18}O/^{17}O and ^{12}C/^{13}C ratios altered. Solar Si isotopic ratios were driven downward, positioning the sun near the bottom of the mainstream Si, although Si/H was driven upwarde [1].

^{18}O solar excess from supernovae. The immediate consequence for this paper on oxygen is endowing the sun with greater ^{18}O/^{17}O, because supernovae Type II are prolific producers of ^{18}O and ^{16}O [2] but not of ^{17}O, which may be largely produced in low-mass red giants and in novae. Many of these did not evolve fast enough to contribute their ^{17}O to the solar gas in the interval between the starburst beginning and the solar isolation. The low-mass end AGB C-star mass spectrum will be absent for the same reason; therefore, the physical postulate advanced here is that the solar mainstream grains emerged from AGB C stars having mass greater than those responsible for most of galactic ^{17}O nucleosynthesis. This may then account for the large ^{18}O/^{17}O=5.3 ratio in the sun in contrast to the lower ^{18}O/^{17}O=3.6 ratio in galactic stars and ISM today. In the aeons following solar birth, ejecta mixing from all stars lowered the ^{18}O/^{17}O ratio to the value 3.6 seen in stars today.

Model example. Models [2] show that for supernova less massive than 20Msun, the average ratio of ejecta masses is near ^{18}O/^{17}O=10, about twice the solar ratio, and that, for supernovae of solar metallicity, ^{18}O/^{16}O=0.0041, also about twice the solar ratio. Detailed accounting shows that if the starburst supernovae increased the solar metallicity (^{16}O/H) from its pre-merger value by the factor (1+), the ^{18}O/^{17}O ratio is increased by the factor (1+3.8)/(1+1.9). If the local galactic gaseous metallicity is increased owing to the merger supernovae by the factor =0.5, for example, the ^{18}O/^{17}O ratio is increased by the factor 1.5, accounting for the observed overabundance of ^{18}O in the sun.

Oxygen Isotopes in STARDUST: The most obvious consequence for oxygen of the merger explanation of mainstream SiC grains [1] would be a definite correlation between ^{18}O/^{16}O and ^{17}O/^{16}O with ^{30}Si/^{28}Si in the initial compositions of the AGB stars that were born from the mixing event. In the merger model [1] the companion galaxy's metallicity was perhaps Z=0.2-0.3 relative to solar, so that its interstellar ^{18}O/^{16}O ratio would, owing to galactic chemical evolution [1], lie between 0.3-0.5 of the solar ^{18}O/^{16}O ratio. The analogous initial-composition mixing line for Si is displayed in Fig. 1 of [1]. That figure applies also to oxygen if ^{18}O/^{16}O replaces ^{30}Si/^{28}Si and ^{17}O/^{16}O replaces ^{29}Si/^{28}Si. The substitution of O for Si in that three-isotope figure follows from the precisely secondary nucleosynthesis nature of those neutron-rich isotopes. The model thus anticipates a correlation between ^{18}O/^{16}O and ^{30}Si/^{28}Si in mainstream SiC grains (save for the extent of ^{18}O burnup in the AGB stars [3]). An experimental challenge will be the measurement of the $^{18}O/^{16}O$ isotopic ratios in documented mainstream grains, because the concentration of O in SiC grains is small. A related physical difficulty lies in calculating the extent to which initial ^{18}O in AGB stars was depleted by H burning in their convective envelopes. Although $^{18}O/^{16}O$ in mainstream grains will be difficult to measure, their values will be of great potential scientific benefit.

Oxide stardust. Evidence may be sought from the oxygen isotopes within oxide stardust [3]. Many of the oxides must also arise from merger induced red giants, but not necessarily giants having the same masses as those responsible for the mainstream grains. Figures 5-7 of [3] show that $^{18}O/^{16}O$ ratios in group 1 oxides do indeed scatter about a value near 2/3 of solar, similar to ISM values today. Apparently these oxide-donor red giants formed prior to the continuing starbust nucleosynthesis that, during the next 1.5 Gyr of starburst supernovae, elevated the solar $^{18}O/^{16}O$ ratio to its value 1.5 times greater.

References: [1] Clayton D.D. (2003) *ApJ, 598*, 313-324,; [2] Woosley S.E. and Weaver T.A. (1995) *ApJ Suppl, 101*, 181-236; [3] Nittler L.R., Alexander C.M.O'D., Gao X., Walker R.M. and Zinner E. (1997) *ApJ, 483*, 475-495.