ELEMENTAL FRACTIONATION PROCESSES IN THE SOLAR WIND REVEALED BY GENESIS SOLAR WIND REGIME SAMPLES.

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Introduction: Solar wind (SW) data can be used to deduce solar abundances. Photospheric abundances obtained by spectroscopy [see compilations by 1, 2] are model-dependent and have relatively high uncertainties. For some important elements, e.g., noble gases, F, and Cl, photospheric abundances were indirectly derived as these elements do not show atomic lines in the photospheric spectrum. However, SW elemental abundances are known to be fractionated from the photospheric composition, and those fractionation processes have to be understood and quantified to infer solar abundances from SW data. Insights into fractionation processes occurring at SW formation can be provided by the composition of SW that emanates from regions in the corona having different ionization states and that exhibit possibly different SW fractionation mechanisms, with the assumption that a homogeneously mixed photosphere is the source of the SW matter.

The Genesis spacecraft collected SW separately from each of the three main SW regimes: fast SW (emanating from coronal holes), slow SW (from above equatorial streamer belts) and SW from coronal mass ejection (CME) events. Additionally, two collector arrays continuously sampled bulk SW [3]. We will present abundances for elements with low first ionization potentials (FIP): Na, Mg, and Al, for the three regimes measured by secondary ion mass spectrometry (SIMS). These data will allow us to extend the observations [4] made for the high-FIP noble gases (Fig. 1) to the low-FIP elements. Mg, Na, and Al were chosen as these elements cover a broad range of ionization potentials in the low-FIP-element region, they are relatively abundant and analyses can be done at low mass resolving power (MRP) for the main isotope by SIMS, thus ensuring a high transmission and thus a large measured signal.

Elemental composition of SW regimes – What do we know from Genesis and *in situ* studies: Heber et al. [4] found that the light elements, He and Ne, are extremely enriched, by 20% and 10%, respectively, in Genesis's CME sample relative to Ar and fast SW (Fig. 1). Coronal mass ejections are violent bursts of magnetically confined plasma. The "storage" of plasma in magnetic loops could lead to extreme elemental fractionation, presumably by gravitational settling [e.g. 5, 6]. It was also observed [4] that all four regimes line up on a straight line in the three element plot in Fig. 1, which might be interpreted as a mixing line between a collection of CMEs as one end member and the fast SW as the other. If this is correct, CMEs could contain the largest portion of mass-fractionated matter generated during the storage of plasma in magnetic loops, whereas the slow SW, originating at least partly from regions above closed magnetic field lines, would still contain some mass fractionated plasma. The fast SW that originates in regions of open magnetic field, would probably not contain matter with any significant mass fractionation.

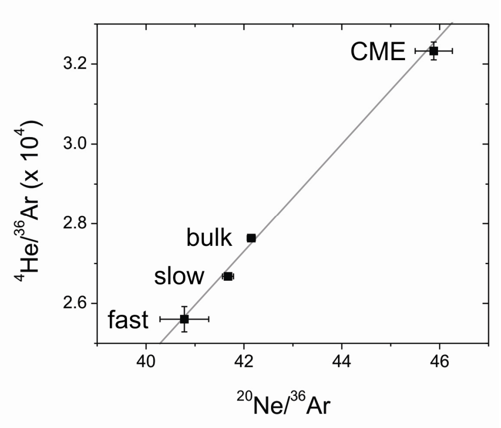

Fig. 1. Noble gas elemental ratios measured in the Genesis regime samples [from 4]. The gray line is the best fit of the data and may represent a mixing line between fast SW and CME matter.

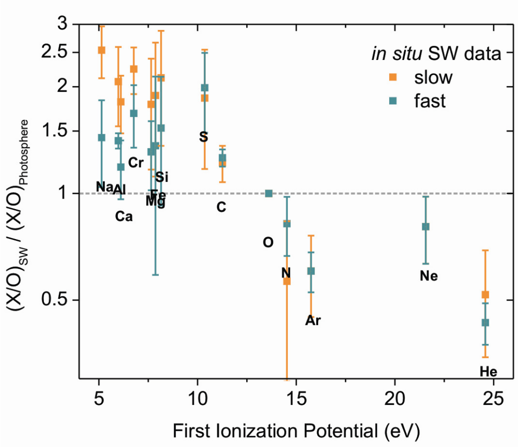

Fig. 2. SW abundances relative to O and photospheric composition [data from 8]. The low FIP elements (FIP<10eV) are more strongly enriched in the slow SW compared to the fast.

A significant issue is whether this enrichment of the light, high-FIP elements in CME is due to gravitational settling in the magnetic loop, or to ionization, or to a combination of both effects. For the former, we would expect for instance an enrichment of the light-mass, low-FIP elements (e.g., Na) relative to Ar in CME relative to fast SW by about 10%, but no measureable effect of Na relative to Ne, because of their similar masses.

The noble gas data from Genesis point further to a small enrichment of He (4%) and Ne (2%) in the slow SW relative to Ar and fast SW [4] (Fig. 1). *In situ* (spacecraft) measurements are too uncertain to show this effect within the high-FIP elements (Fig. 2). *In situ* measurements, however, detected that besides the general low-FIP element enrichment in the SW relative to the photosphere (that is attributed to the atom-ion separation in the upper chromosphere), the slow SW is slightly more FIP-fractionated than the fast SW [e.g., 7, 8] (Fig. 2). This observation lead to the widely accepted hypothesis that the fast SW is the least fractionated SW type [7, 9].

The *in situ* data suggest that Na is 80%, Mg 40%, and Al 50% more enriched in the slow SW than in the fast [8]. An evaluation of the in-flight data of Genesis confirmed that the sample from the Genesis fast SW collector is to 90% pure fast and the slow SW collector to 62% pure slow (+ 34% fast) SW [3]. This suggests that we should see significant differences in the Na, Al, and Mg fluences between the fast and slow SW collectors.

Experimental: A fast SW, slow SW, a CME and a bulk SW Si target were mounted with epoxy on Si substrates and thinned to 1µm thickness by Evans Analytical Group. Samples will be analyzed by backside depth profiling using the Cameca IMS 1270 at UCLA. An O_2^+ primary ion beam with an impact energy of 7keV will be employed to optimize depth resolution, following the analytical procedure that we have previously developed [10]. Fig. 3 shows the ^{24}Mg, ^{27}Al, and ^{40}Ca profiles analyzed in a bulk SW target (NASA code 60968) by backside depth profiling. With this method we are able to almost completely extract the implanted SW for these elements without significant background interference from surface contamination. In Fig. 3, Mg was analyzed with the IMS 1270 at UCLA, whereas Al and Ca were determined with the Cameca 7f-Geo SIMS at CalTech. The total SW implant countrate detected was $5.2\times10^{+5}$ cps for Mg even though a MRP of 3600 was applied. The total countrate for the SW Al implant was $1.8\times10^{+5}$ cps. Because of its higher transmission, we will use the IMS 1270 for all analyses going forward. This and the required only low MRP expects us to obtain a total countrate of several 10^5 cps for the bulk SW Al and Na implant despite their ~10 and ~20 times lower abundances compared to Mg, respectively. The regime samples each contain about one third of the bulk SW fluence (based on noble gases), thus a statistical uncertainty of less than 1% for the integrated fluences can be obtained for each regime analysis.

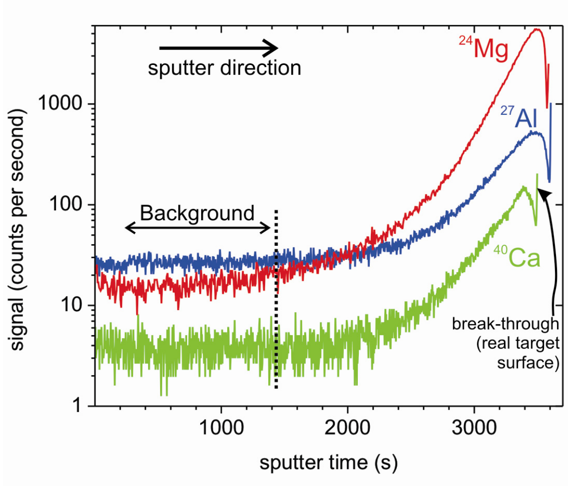

Fig. 3. Mg, Al and Ca bulk SW profiles measured by backside depth profiling by SIMS.

The reproducibility of fluence measurements in artificial implants is between 1-2%, which includes frequent sample changes. To enhance the sensitivity required to detect small compositional difference between the regime samples, we will analyze the samples by standard-sample bracketing with an artificial implant serving as the "standard" and the bulk and regime SW as "samples". With all these measures applied, we are confident that we can reduce the total uncertainties sufficiently to resolve expected differences between the regimes of possibly ~10% between CME and fast SW, and probably few 10s of % for between the fast and slow SW Na, Mg and Al abundances.

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