SOLAR-WIND FE/MG AND A COMPARISON WITH CI CHONDRITES.

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Introduction: Fe and Mg solar-wind (SW) elemental abundances have been measured relative to Fe and Mg implants; these implants, in turn, have been calibrated using RBS and ICPMS, respectively. Previously measured internally-consistent results from silicon (**Si**), Sandia diamond-like carbon (**dlc**) and silicon on sapphire (**SOS**) GENESIS solar-wind collectors have now been anchored. The SW Mg/Fe ratio is below CI but within error of the photosphere.. The role of GENESIS as a proxy for solar Fe/Mg now depends on the extent of fractionation of elements having low First Ionozation Potential (FIP) and First Ionozation Time (FIT), as well as differing amounts of Coulomb Drag (CD).

Solar wind measurements of low FIP elemental abundances are important for three reasons: (1) the basic science value of having more precise knowledge of solar elemental compositions; (2) obtaining a better understanding of fractionation processes (if any) of the low FIP elements between the solar wind and the solar photosphere; and (3) in the case of Fe and Mg, providing precise fluences to serve as references for other elements. Objective (2) must be addressed before ultimate success on (1) can be achieved.

Experimental: We used SIMS (Cameca 6f, 1270, and 7f at ASU, UCLA and Caltech, respectively) to measure the SW depth profiles of Fe and Mg along with a matrix reference element (C or Si) in GENESIS collectors and ion-implanted flight-spare wafers. A "primary" set of implants were independently analyzed by other means to make standard reference materials. That is, the ^{56}Fe implant standard was calibrated with Rutherford Backscattering (RBS) whereas a ^{25}Mg implant was calibrated by comparison with analyses of NIST SRM 617 glass implanted simultaneously. The Mg in our NIST SRM 617 glass was determined using isotope dilution (FSU) on three (~30mg) pieces of the same lot but not implanted. Other Mg implants were intercalibrated relative to the primary implants by SIMS depth profiling.

For Genesis results to be considered accurate, a minimum requirement is that we obtain consistent results independent of collector material (**SOS** and/or **Si,** as well as **dlc**) and of analytical laboratory. Especially for the dlc collectors, this requirement mandated a novel analytical approach, discussed below in Results.

Results: Our original Fe, Mg elemental abundances had high precision for data from a given SIMS session, but significant scatter among sessions. The worst example was abundances derived for Mg in the **dlc** (black points on Fig. 1) on different runs, which varied by up to a factor of 2. Moreover, fluences from **dlc** tended to be systematically higher than those derived from **Si** collectors when externally standardized (within blue bar, Fig. 1). We were able to reduce scat-

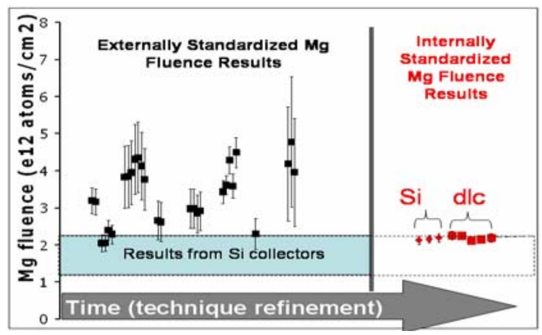

Fig. 1. Mg Fluences, ordered by run date. Blue bar represents the range of 28 analyses of Si collectors; the black data are individual analyses of **dlc** collectors. Both were made relative to external standards. Red points are for analyses standardized internally, by implanting flight samples with ^{25}Mg. Here, fluences from DLC and Si collectors (as marked) agree.

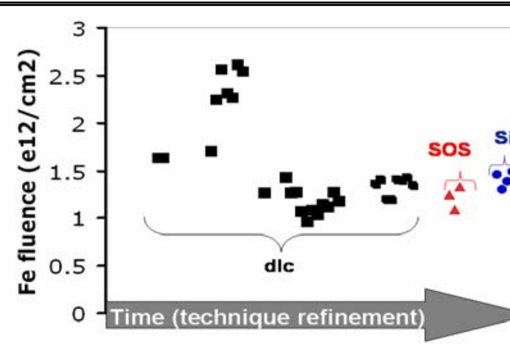

*Fig. 2. Fe Fluences ordered by run date. Tightly controlling analytical procedures gave progressively more consistent results both for the same material and for different materials (**Si**, **SOS**, and **dlc**). Internal standardization was not necessary. Statistical error for individual analyses are about the size of the symbol.*

ter by using only the center hole of a single mount to control sample geometry and by using one SIMS operator in each session. These procedures resulted in precise Fe fluences (Fig. 2). For Mg fluences, *internally* standardizing flight samples was also required to produce convergent results; that is, by implanting samples with ^{25}Mg such that the ^{25}Mg fluence and depth distribution produced negligible cross-contamination with the solar wind.

The internally standardized (red) Mg fluences (Fig.1) show convergence and agreement between externally standardized **Si** and **dlc**. For **Si**, the Mg fluence calculated from the internal standard is similar, although slightly higher, than those inferred from externally standardized analyses. The influence of solar-wind H on the analysis has been shown to be negligible. For the **dlc** collectors, which are amorphous, the internal standardization may have improved precision by eliminating the effect of local structural (e.g., electrical and/or chemical) variations on the calibration.

Figures 1 and 2 shows that our measured SW Mg- and Fe-fluences have converged for different collector materials using both the UCLA and ASU instruments. The data yield a precise Fe fluence of $1.41\pm0.08\times10^{12}$ atoms/cm^2. Using the ^{25}Mg as an internal standard, the data yield a Mg fluence of $2.02\pm0.18\times10^{12}$ atoms/cm^2. The resultant SW Fe/Mg ratio (0.70±0.06, 1 σ) is now accurate as well as precise and is consistent with the (imprecise) photospheric value [1]. This SW value is lower than the Fe/Mg ratio determined from CI chondrites [2] (Fig. 3).

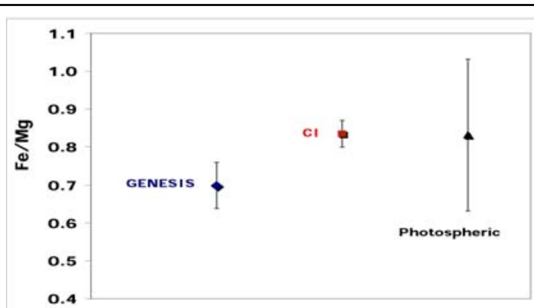

Fig. 3. GENESIS Fe/Mg ratio compared with data from CI chondrites, and photospheric observations. Both chondritic and GENESIS data are consistent with the less accurate photospheric and spacecraft measurements, but not with each other. Are solar-wind lithophiles fractionated during acelleration out of the sun, or is the CI Fe/Mg not quite representative of the solar nebula?

Discussion: The three most commonly discussed mechamisms for fractionation of ions in the solar wind are the inefficient Coulomb Drag (CD, [5]), FIP and FIT [4].

The expected CD fractionation [5] would increase the SW Fe/Mg ratio relative to the photosphere ~3% which is insignificant for our present purposes.

There is currently no evidence for fractionation of elements with FIP<9eV from spacecraft studies [3]. Fe and Mg both have FIP <9eV, at about 8 eV. So, *if* the elemental fractionation of the SW is *uniquely* determined by FIP, our ratio is not fractionated.

Calculations of element transport from the photosphere to the corona do show fractionation based on FIT. The Mg FIT is much less than Fe, thus if FIT is a better indicator, our Fe/Mg data would be subject to fractionation; however, no differences are observed (Fig. 3) supporting lack of fractionation of low FIP elements in the solar wind.

CI abundance comparison The universally-accepted use of CI abundances for average solar composition is ultimately based on the agreement with photospheric abundances, but this use is also limited by the accuracy of the latter, ± 24%, 1σ for Fe/Mg. Moreover, photospheric abudance error estimates have been shown to be unreliable in the past. The Genesis solar wind Fe/Mg ratio is 19% less than the CI ratio, although the Genesis and CI error limits overlap at 2 σ. Re-evaluation of the error limits is ongoing , but the Genesis Fe/Mg is relatively firm. So, there is a distinct possibility that the CI Fe/Mg is high relative to average solar composition (metal/silicate fractionation in CI precursor material?). Alternatively, if CI abundances are really solar to significantly better than 10%, then a FIT enhancement of solar wind Mg relative to Fe of roughly 19% would be indicated.

Looking forward: Higher accuracy of the Genesis Fe/Mg is possible, using other techniques. In addition, Genesis data can be gathered for additional elements (e.g. Ca, Cr, Al, Na) in order to quantify the FIT and FIP models. This future work will further test the possibilities of both CI-solar abundance differences and FIT/FIP elemental fractionations.

References: [1] Asplund M. et al. (2005), in *Cosmic Abundances as records of stellar evolution and nucleosynthesis*, F. N Bash and T. G. Barnes, eds., Proc. Astr. Soc. Pacif. Conf., Austin TX June 17-19 2004; [2] Palme H and Jones (2004) in *Treatise of Geochim.*, A Davis, ed, *3,* 41; [3] Reisenfeld et al. (2007) Space Sci Rev, *130*(1), 79-86; [4] Geiss et al. (1999), Space Sci Rev, *72*, 49. [5] Boschler P. (2000) Rev. of Geophys 38(2) 247-266.

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