SOLAR ELEMENTAL ABUNDANCES FROM GENESIS COLLECTORS: FE/MG, CONSTRAINING SOLAR-WIND FIP FRACTIONATION, AND COMPARISONS WITH CI CHONDRITES. A. J. G. Jurewicz [1], D. S. Burnett[2] , D. S. Woolum [3], K. D. McKeegan [4], Y. Guan [2] , and R. Hervig [1], [1] Center for Meteorite Studies, Arizona State University, Tempe AZ 85287, [2]Geological and Planetary Sciences, Caltech m/s 100-23, Pasadena CA 91125, [3] Department of Physics, UC Fullerton, Fullerton CA, [3] Earth and Space Sciences m/c GE-75, UCLA, Los Angeles, CA 90095-1567 (contacts: Amy.Jurewicz@asu.edu or burnett@gps.caltech.edu).

Summary: Fe and Mg elemental abundances have been measured, and internally-consistent results from different types of GENESIS solar-wind collectors. The Mg/Fe ratio calculated appears to be significantly different from CI. Moreover, we now have a fuller understanding of analytical issues for GENESIS silicon and Sandia diamond-like carbon array collectors. Other solar-wind elements have also been detected (e.g., Na, Cr, Ca, N, C). Currently, the analytical errors are large, but we are actively trying to increase our measurement precision and accuracy.

Background Solar wind measurements of lithophile elemental abundances are important for three reasons: (1) the basic science value of having more precise solar elemental composition; (2) the value to both GENESIS and solar physics of understanding fractionation processes (if any) of the lithophile 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 and for other laboratories to test analytical procedures. Objective (2) must be addressed before ultimate success on (1) can be achieved.

Experimental: Our procedure is to use SIMS (Cameca 6f, 1270, or 7f at ASU, UCLA or Caltech, respectively) to measure an element of interest along with a matrix reference element (e.g., C, Si) in both a GENESIS collector and ion-implanted flight-like collector materials which serve as standards. Initially, our measured Fe, Mg elemental abundances had high precision, but showed significant scatter. The scatter was especially significant for Mg in the Sandia diamond-like carbon: abundances calculated from different SIMS days varied as much factor of 2; moreover, these fluences tended to be systematically higher than those derived from Si collectors (black and blue points on Figure 2). So, we have made modifications to our analytical procedures in order to eliminate (or at least mitigate) factors contributing systematic error to our abundance measurements.

Our primary change was to mount all samples and standards individually, in our mount's center hole, as we determined that fractionation with position in the SIMS mount was significant.

For Mg -- especially for the amorphous diamond-like carbon -- we needed to go a step further. Data were collected by implanting ^{25}Mg into actual silicon and diamond-like carbon flight samples. These implants were deeper than the solar-wind so that isotopic cross-contamination errors were negligible). We then used the ^{25}Mg as an internal standard.

For both Fe and Mg abundance measurements, our changes have dramatically reduced scatter and produced convergent results (Figures 1, 2).

Why did the internal standardization have such a profound effect on the precision and accuracy of the abundance measurements? The Mg fluence in silicon calculated from the internal standard is similar, although slightly higher, than what had been inferred from externally standardized analyses of Si collectors. Actual flight samples have significant solar-wind hydrogen; so implanting flight samples may have simply addied hydrogen to the matrix. Accordingly, subsequent analytical standards have been implanted with hydrogen. For the amorphous diamond-like carbon collectors, the success of the internal standardization may also eliminated the large scatter because it effectively eliminated the effect of local structural inhomogenieties on the calculated relative sensitivity factors (RSFs).

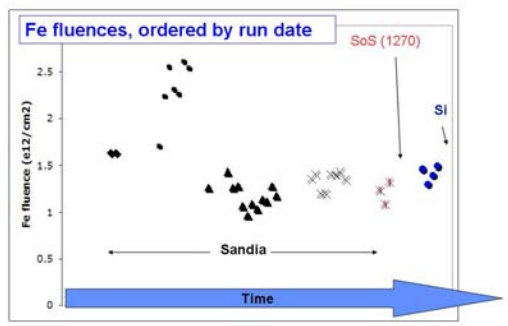

Fig. 1. Fe Fluences ordered by run date. Changing analytical procedures gave progressively more consistent results both for the same material and for different materials (silicon, silicon on sapphire, and Sandia diamond-like carbon). Note: statistical error for individual analyses are about the size of the symbol.

Results: Figure 1 shows that our most recent analyses of the solar-wind Fe-fluence have good agreement for 3 different collector materials with data

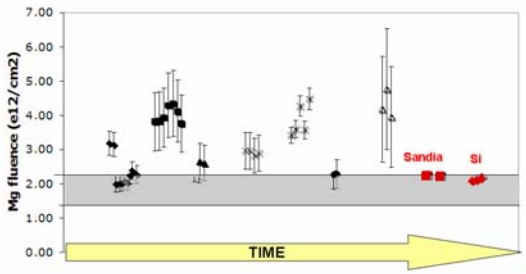

Fig. 2. Mg Fluences, ordered by run date. Externally standardized data for Mg in silicon and Sandia diamond-like carbon are given by the blue bar and dark points, respectively. Sandia externially-standardized data is substantially more variable than silicon data. To mitigate this, 25Mg implanted directly into flight samples was used as an internal standard, resulting in extremely very consistent Mg data. Flight samples added matrix H; internal standardization probably mitigated RSF variations from structural inhomogenieties in the amorphous Sandia.

from both the UCLA and ASU instruments. The data yields a precise Fe fluence of 1.41×10^{12} atoms/cm^2 ($\pm$~5%). Figure 2 shows that by using the ^{25}Mg as an internal standard we have also resolved the discrepancies in Mg abundance (i.e., the red points - most recent analyses). Both materials yield a Mg fluence of 2.15×10^{12} atoms/cm^2 ($\pm$~5%).

The solar wind Fe/Mg ratio (0.66±0.05) we have determined is now reproducible as well as precise. The resulting Fe/Mg ratio is consistent with the photospheric values [1], which have a larger uncertainty (Fig. 3). It appears significantly different from the Fe/Mg ratio determined from CI chondrites [2] (Fig. 3), although final conclusions require assessing possible systematic errors by obtaining independent measurements of the fluences of our implant standards.

Discussion: The significance of the relationships between the GENESIS-, CI-, and photospheric- Fe/Mg requires better understanding of physics of how solar-wind is formed. That is; we need to understand whether or not the lithophile elements have been fractionated by solar-wind formation.

Elements which comprise most of the terrestrial planets have a first ionization potential (FIP) <9eV; Fe and Mg have similar FIP, (about 8 eV). Spacecraft studies [3] have shown that elements FIP >9eV *are* fractionated in the solar wind relative to the solar photosphere. Conversely, there is no evidence for fractionation of elements with FIP<9eV. So, *if* elemental

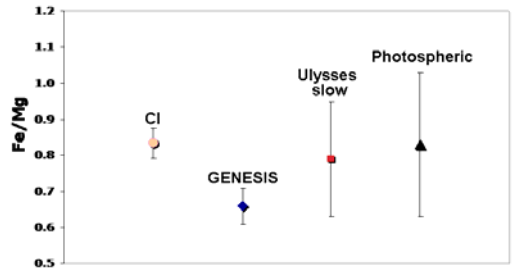

Fig. 3. Comparison of new GENESIS Fe/Mg ratio with data from CI chondrites, spacecraft measurements, and photospheric observations. Both chondritic and GENESIS data are consistent with the less accurate photospheric and spacecraft measurements, but not with each other.

fractionation between the photosphere and solar wind is *uniquely* determined by FIP, our ratio is not fractionated.

However, there is at least one other parameter which could, hypothetically, significantly influence fractionation of lithophile elements during solar-wind formation: first ionization times (FIT, [4]). Model calculations of FIT for Fe and Mg during transport from the photosphere to the corona show differences. If FIT is a better indicator, our Fe/Mg data would be subject to fractionation; however we don't see differences (Fig. 3).

But spacecraft data has relatively large errors compared with the precision that we are achieving analyzing GENESIS collectors (Fig. 3). Thus, (1) the significance of the agreement between the Genesis and photospheric Fe/Mg requires better understanding of the solar physics and (2) measuring additional Genesis elemental fluences to differentiate between FIT and FIP models is needed. Accordingly, methods for accurately measuring Ca, Cr, Na, C, N are being developed.

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.