**HYDROGEN FLUENCE CALCULATED FROM GENESIS COLLECTORS.** E. C. Koeman-Shields[1], G. R. Huss[1], R. C. Ogliore[2], A. J. G. Jurewicz[3], D. S. Burnett[4], K. Nagashiima[1], and C. T. Olinger[5], [1]HIGP, University of Hawaiʻi at Mānoa, 1680 East-West Road, Honolulu, HI 96822 (ekoeman@higp.hawaii.edu), [2]Dept. of Physics, Washington University in St. Louis, One Brookings Drive, St. Louis, MO 63130, [3]SESE, Arizona State University, Tempe, AZ 85287-1404, [4]Div. of Geol. and Planet. Sci., MC 100-23, Caltech, Pasadena, CA 91125, [5]Applied Modern Physics, Los Alamos National Laboratory, Los Alamos, NM 98544.

**Introduction:** Data for H fluence in diamond-on-silicon (DOS) collectors from the Genesis Mission is presented in this study. While measuring H fluence was not an original goal of the mission, an accurate and precise measurement of the H accompanying the other elements in the Genesis collectors can provide "ground truth" for models of elemental fractionation during acceleration of solar wind. The H fluence also potentially permits a sample-based estimate of solar metallicity. This study builds off of over 5 years of work on H data [1] and provides the most accurate and complete H fluence values to date.

**Experimental Methods:** DOS collector chips were chosen because the material should be less subject to diffusive loss of H than other collector materials. Samples of all four solar wind regimes [2] were requested in order to determine if elemental/H ratios vary due to the nature of the acceleration from the Sun. The four chips allocated to us were: 1) #60628 from the B/C bulk solar wind array, 2) #60631 from the high-speed (Coronal Hole) H array, 3) #60431 from the low-speed (Interstream) L array, and 4) #60625 from the Coronal-Mass-Ejection E array. Because sensitivity factors and instrumental mass fractionation vary within ~2 mm of the edges of a sample or sample holder, all collector chips were at least 5 mm across.

The measurements were standardized by H implants. While implants were spatially homogeneous, the actual implanted amounts were not known to acceptable precision. To resolve this issue, several types of materials were prepared with a standard dose of hydrogen in a single radiation. These included a "blank" DOS chip, two Si chips, our flight samples of the B/C and H arrays, and two apatite grains with well determined H concentrations similar to the expected level of the solar wind (Crystal Lode and Lake Baikal apatites with water contents measured by [3]). We implanted these materials at Kroko, Inc., with a nominal H fluence of $6\times10^{15}$ atoms per cm$^2$ and an energy of 30 keV, significantly higher than the ~1 keV energy of the solar wind. This allows the standard implant to be inserted below and separate from the solar wind (Fig. 2).

The Genesis collectors and standards were measured by ion microprobe in depth-profiling mode using the Cameca ims 1280 ion microprobe at the University of Hawaiʻi at Mānoa. Depth profiles were measured from the apatite grains (Fig. 1), DOS standard material,

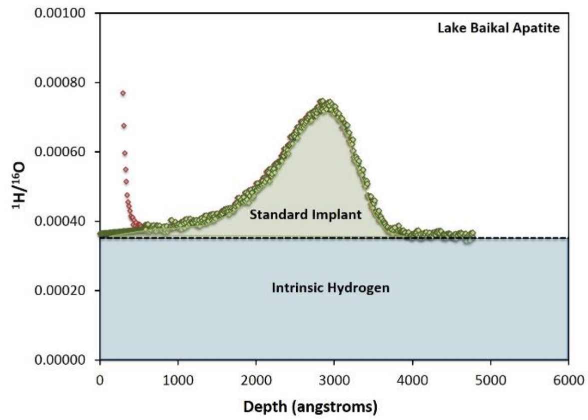


Fig. 1: Depth profile for Lake Baikal Apatite Standard containing 0.20 wt% water. The red diamonds show the original depth profile. The green line shows the implant profile corrected for surface H. The horizontal dashed line and blue box signifies intrinsic H.

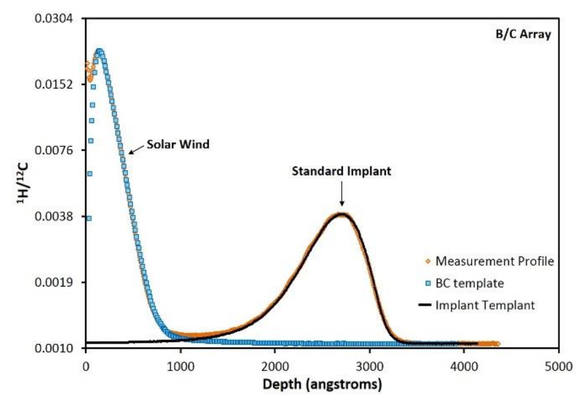


Fig. 2: Depth profile for BC array sample containing the same H implant as shown in Fig. 1. The solar wind and standard implant are noticeably defined. The correction for the shallow part of the profile is discussed in the text.

and the standard-implanted B/C arrays and H arrays. The intrinsic H in the apatite gives a constant signal that can be well measured below the implant. After integrating the area under the measured profile and that for the intrinsic H (blue rectangle in Fig. 1), the intrinsic H can be subtracted from the total signal to give the integrated value of the implant. The ratio of the integrated implant H to intrinsic H multiplied by the independently measured H content of the apatite calibrates the implant. The total implant fluence was determined to be $5.65\times10^{15}$ $cm^{-2}$, approximately 10% lower than the nominal fluence. The measured profiles of the irradiated B/C and H array were deconvolved using templates for the solar-wind and standard-implant profiles (Fig. 2). The templates were scaled to the measured profile and were then integrated to give the relative amounts of H in the solar wind and standard implant. In order to correct for transient ion yield effects and surface H in the few cycles of the ion probe measurements, the shallow portions of the solar wind templates come from a SRIM calculation (Fig 2). The H fluence in the solar wind was then calculated from the solar-wind/standard-implant ratio multiplied by the calibrated H fluence in the implant.

The Genesis L- and E- array collectors were also measured, although they had not been irradiated. The fluence values were determined by comparing the integrated solar wind profiles from these collectors with the integrated profiles of the standard implant (calibrated by the apatites) in the blank DOS. Our fluence numbers include a correction for backscattered atoms based on SRIM simulations.

Following the measurements, all ion probe pits were imaged in a scanning electron microscope to check for pit anomalies. Crater depths were measured using an Alpha Step 200 profilometer at Arizona State University. The accuracy of this instrument using our procedure has been tested recently by comparing pit depths measured at ASU to those measured on the same samples by a different instrument located at NIST. The average pit-depth difference was less than 1% for pits similar to those measured here.

**Results and Discussion:** Table 1 summarizes our best estimates of the solar wind H fluences in the four solar wind regimes. An error of ±10% (2σ) is associated with these values. The error is dominated by the uncertainty in the H content of the standard apatite. Measurements are reproducible to better than ±5%. Table 1 also lists H fluence values collected from the Genesis Ion Monitor [3]. Our values are lower by 5-25%, and the differences are currently not understood. Ion Monitor values have maximum uncertainty of ±20% (2σ) [4]. Our measurements appear to be well calibrated, but we have not been able to confirm whether the DOS collectors quantitatively retained H.

Table 1: Hydrogen fluence values ($H/cm^2$)

| Regime | Solar Wind Collectors | Genesis Ion Monitor | Ratio |
|---|---|---|---|
| Bulk SW (B/C) | $1.69x10^{16}$ | $2.06x10^{16}$ | 0.819 |
| Interstream (L) | $0.68x10^{16}$ | $0.92x10^{16}$ | 0.737 |
| Coronal Hole (H) | $0.53x10^{16}$ | $0.64x10^{16}$ | 0.825 |
| CME (E) | $0.45x10^{16}$ | $0.47x10^{16}$ | 0.951 |

Reliable H fluences for the four solar wind regimes in the Genesis collectors provide basic information that can be used to elucidate the mechanism(s) that accelerate the solar wind from the Sun's surface. For example, elements are fractionated according to their first ionization potential (FIP) during solar wind acceleration [e.g., 5]. There appears to be a step in this fractionation for energetic particles, with elements having higher FIP than Si being depleted relative to those with lower FIP. The FIP that corresponds to this step changes as a function of solar wind energy, and the step is not as obvious for the lower-energy interstream wind. H has a relatively high ionization potential (~13.6 eV), similar to O, and can be on the higher or lower plateau depending on solar wind energy. Thus, the H abundance and the O/H ratio can be used to evaluate this fractionation as a function of energy.

A reliable H abundance may also permit a direct determination of the Ne abundance in the solar wind. Fig. 3 plots $^{20}Ne/^{4}He$ against $^{1}H/^{4}He$ for the solar wind regimes. Extrapolating a line fit to the data to the solar $^{1}H/^{4}He$ ratio (1/0.083) give the $^{20}Ne/^{4}He$ ratio in the Sun, which in turn gives a $^{20}Ne/^{1}H$ ratio of $\sim1.17\times10^{-4}$, slightly larger than the $\sim7\times10^{-5}$ estimated by [6].

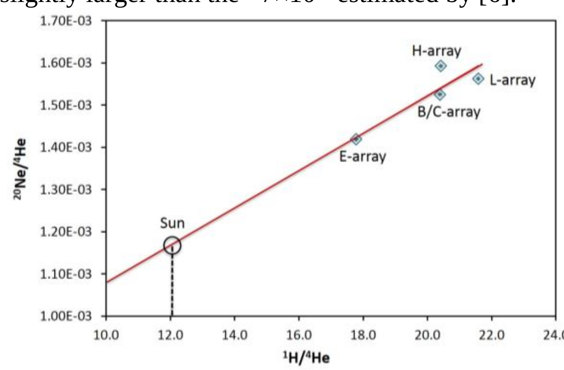


Fig 3: Regression of Genesis data to estimate solar N abundance. Noble gas data from [7].

**References:** [1]Huss G. R., Ogliore R. C., Jurewicz A. J. G., Burnett D. S., and Nagashiima K. (2015) *LPS XLVI*, Abstract #2557. [2]Burnett D. S. (2013) Meteoritics & Planet. Sci. 48, 2351-2370. [3]McCubbin F. M., Hauri E., Elardo S. M., Vander Kaaden K. E., Wang J. and Shearer C. K., Jr. (2012) Geology 40, 683-686. [4]Reisenfeld D. B., Wiens R. C., Barraclough B. L., Steinberg J. T., Neugebauer M., Raines J., and Zurbuchen T. H. (2013) Space Sci. Rev. 175, 125-164. [5]Bochsler P. (2000) Rev. Geophys. 38, 247-266. [6]Asplund M. et al. (2009) Ann Rev. of Aston. Astrophysics. 47, 481-522. [7]Heber V. et al. (2013) Astrophys. J. 759, 121-133. Supported by NASA Grants NNX09AC32G and NNS14AF25G to GRH.