SOLAR NEBULA COMPOSITION BASED ON SOLAR WIND DATA. D.S. Burnett[1], Y. Guan[1], V.S. Heber[2], R Hervig[3], G.R. Huss[4], A.J.G. Jurewicz[3], E.C. Koeman-Shields[4], J.M. Laming[5], K.D. McKeegan[2], L. Nittler[6], D. Reisenfeld[7], K.D. Rieck[8], J. Wang[6], R.C. Wiens[8], D.S. Woolum[9] [1]Geological, Planetary Sciences, Caltech, Pasadena CA, 91125, burnett@gps.caltech.edu [2]Earth, Planetary Sciences UCLA, Los Angeles CA, 90095. [3]SESE, ASU, Tempe, AZ, 85287. [4]HIGP, University of Hawai‘i at Mānoa, 1680 East-West Road, Honolulu, HI 96822. [5]NRL Washington D.C., 20375. [6]DTM, CIW, Washington D.C. 20015. [7]Physics, U. Montana, Missoula, MT, 59812. [8]Space and Remote Sensing (ISR-2), LANL, Los Alamos NM, 87545. [9]Physics, CSUF, Fullerton CA 92831.

Introduction: A major question for planetary science is whether or not planetary objects formed from a nebula of uniform composition. Small isotopic variations for many elements are now known but could represent irregular distributions of presolar grains in a uniform nebula, the composition which is preserved in the solar photosphere. Either to test the uniform nebula assumption or to build on it to understand the origins of inner solar system materials, accurate solar abundances are needed. Because of analytical accuracy, the composition of CI chondrites is a widely accepted proxy for solar abundances; however, the *validity* of CI abundances can only be established by comparison with actual solar photospheric composition. This validation must be carried out separately for each element because of the petrographic complexity of CI chondrites, e.g. U is very heterogeneously distributed in CI chondrites [1], probably due to the mobility of high U valence states in an oxidizing aqueous environment. The most direct comparison for CI abundances is with spectroscopic photospheric abundances; new data for most elements based on 3D photospheric models with carefully evaluated errors are available [2], but these are at least 7% (1 sigma). Solar composition can be obtained from Genesis solar-wind analyses with a correction for elemental fractionation during solar wind formation [3]. Genesis solar abundances are potentially more accurate, especially as some elements may need little or no correction (discussed below). Data reported here are from SIMS analyses, mostly by backside depth profiling [4] or from noble gas mass spectrometry.

Results: Pre-Genesis observations of solar energetic particles (MeV ions), the solar corona, and solar wind indicate that solar wind elemental abundances have fractionations relative to the photosphere that correlate with first ionization potential (FIP). **Fig. 1** shows Mg-normalized Genesis bulk solar wind abundances relative to the photosphere [2] vs FIP (1 sigma errors). Data sources and status: KNa [5], final; CaAlCr [6], implant calibration needed; FeMg revised from [7] final, CNO revised from [8], final; KrXe [9] final; H [10], nearly final. There are no true photospheric abundances for noble gases; photospheric Kr and Xe are interpolated from CI abundance curves; adopted solar He is from helioseismology. Error bars on Fig. 1 are relative errors (i.e., Mg error not included), but include errors from both Genesis and photospheric abundances.

A major issue is whether there is a flat pattern for low (<9 eV) FIP elements, as suggested by pre-Genesis observations; this would indicate that low FIP elements are unfractionated and that solar wind abundances equal photospheric abundances. Within errors, Genesis data are consistent with a flat low FIP pattern, but they are also consistent with a monotonic increasing fractionation picking up the trend from the high FIP (11-15 eV) elements. The importance of the K abundance (lowest FIP) is clear. Taking present data at face value a flat pattern is favored.

Solar wind composition data from the ACE mission are available from 1998. Inspired by Genesis, the ACE data have been reprocessed [11] yielding more precise solar wind abundances (**Fig. 2** from Reisenfeld for the Genesis period). For clarity, element labels and 1 sigma error bars are for ACE data. The ACE Fe/Mg is 1 sigma higher than Genesis, but agreement is overall good.

The solar wind arises from release of plasma trapped in closed magnetic field loops in the solar corona. “Low speed” solar wind arises for regions of high densities of closed field lines; a fundamentally different high speed solar wind regime originates from “coronal holes”, large regions of open field lines. FIP-correlated fractionations associated with the injection of plasma into the loops have been calculated by Laming [12]. Separate calculations are made for the high and low speed regimes; a weighted average gives the bulk solar wind composition **(Fig. 3).** The two models on Fig. 3 give a reasonable description of the Genesis data. The short dash curve includes a mass-dependent term which reproduces the observed sense of isotope fractionation [3] and is preferred. When Genesis data are available for the low and high speed regimes [3] separate comparisons with theory will be possible.

Fig. 1 is the fundamental comparison, but a comparison of SW and CI chondrite abundances for low FIP elements, as shown in is useful (**Fig. 4)**. For comparison with earlier figures, Fig. 4 uses the same y axis scale. The use of CI chondrites as the reference compositon significantly reduces error bars, but also results in a significantly flatter pattern. It is possibly premature, but Fig. 4 suggests that SW abundances can be used to validate CI chondrite abundances with significantly improved accuracy at least for the elements shown.

Conclusions: Most elements have FIP < 9eV. To ascertain the extent of low FIP element fractionation, we need to have a few precise spectroscopic photospheric abundances to determine a trend. A flat trend would be convenient, but any well-defined trend is sufficient to correct SW data to true solar abundances. Much remains to be done, especially comparisons with Genesis regime data, but work to date strongly suggests that SW can be used to derive accurate solar abundances for low FIP elements, and/or to validate CI chondrites as source of solar abundances, with realistic errors of ±10%.

The Genesis-inspired improvements in spacecraft instrument SW compositions and in FIP-fractionation theory have obvious benefits for solar and heliospheric physics, but they also benefit planetary science. Improved instrument SW data have better time and speed resolution which can check for solar cycle time scale variations. Improved theories of FIP fractionation will be the basis of larger corrections required for high FIP elements with the ultimate possibility of using Genesis data to resolve the differences in solar metallicity helioseismology and spectroscopic photospheric abundances.

References: [1] Rocholl A., and Jochum K. P. *EPSL* 117, 2651993. [2] e.g., Scott P., et al., *Astronomy & Astrophysics* 573, A25, 2015. [3] Burnett D., *Meteoritics and Planetary Science* 48**,** 2351, 2013. [4] Heber V, et al. *Chem. Geology 390*, 61 2014. [5] Rieck K, *thesis* ASU 2016; LPSC 2016, #2922. [6] Heber V, et al., *LPSC 2014,* #1203. [7] Jurewicz A. et al. *LPSC 2011*, #1917. [8] Heber V et al *LPSC 2013,* #2540. [9] Meshik A, et al., *Geochim,Cosmochim* 127**,** 326. [10] Koeman-Shields E C, et al., *LPSC 2016*, #2800 [11] Shearer P, et al., *Ap J* 789, 60, 2014. [12] Laming J.M., *Living Reviews in Solar Physics* 12**,** 2, 2015.

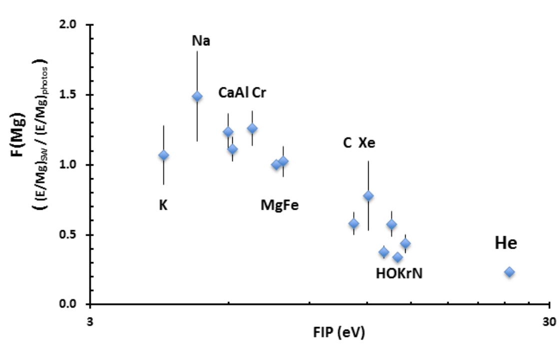


Fig. 1: Genesis Solar wind compositional data as a function of First Ionization Potential (FIP).

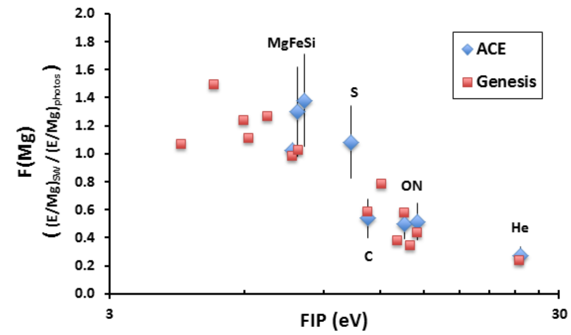


Fig. 2: Recently reprocessed ACE data (Reisenfeld).

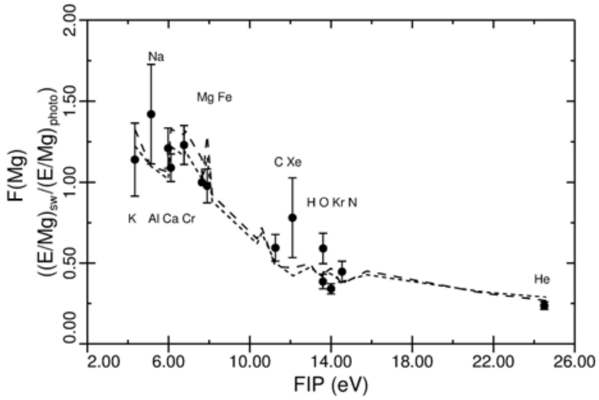
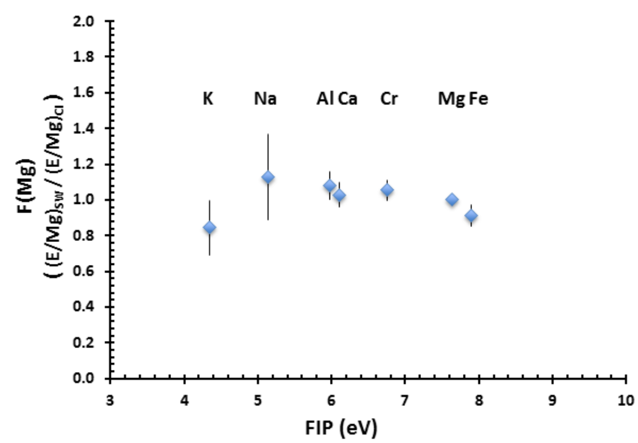


Fig. 3: Theoretical FIP fractionation (Laming). Mass dependence in short dash curve produces isotope fractionation.



Fig, 4: Genesis solar wind compositional data compared with chondritic values for FIP<10.