

SOLAR WIND XENON COMPOSITION MEASURED IN SILICON COLLECTOR TARGETS FROM THE GENESIS MISSION. S. A. Crowther and J. D. Gilmour, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester, M13 9PL, UK (sarah.crowther@manchester.ac.uk).

Introduction: Noble gases are key tracers of volatile evolution in the solar system, and precise and accurate knowledge of their original solar compositions is vital to our understanding of the formation and evolution of the solar system. But data relating to the solar noble gas elemental and isotopic composition are scarce. The most reliable available data for krypton and xenon have resulted from measurements of solar wind implanted in the lunar regolith [1, 2].

Xenon, which has 9 isotopes, is of particular interest among the noble gases. Neither the isotopic composition of the Earth's atmosphere nor that of Q-Xe, the major planetary component trapped in meteorites [3], can be directly derived from solar wind xenon by linear mass fractionation alone [4]. The xenon trapped in meteorites is best described as fractionated solar wind xenon, mixed with variable amounts of (presolar) HL-Xe and ^{129}Xe from ^{129}I decay [5]. After correcting for mass-dependent fractionation, atmospheric xenon shows excesses in ^{129}Xe and $^{131-136}\text{Xe}$ relative to solar wind xenon. It is generally accepted that excess ^{129}Xe is derived from decay of ^{129}I , but the excesses in $^{131-136}\text{Xe}$ are more difficult to understand. The required ratios cannot be obtained from addition of spontaneous fission products from ^{244}Pu and ^{238}U to mass fractionated solar wind xenon as measured in the lunar regolith, and it has been suggested that the Earth's atmosphere may require a reservoir distinct from the well-mixed solar system (U-Xe – [6]).

NASA's Genesis mission directly sampled the present-day solar wind, and aims to provide isotopic and elemental compositions for most of the periodic table. Measuring the elemental and isotopic compositions of the noble gases is one of the highest priority scientific objectives of the mission [7]. Our work focuses on measuring the concentration and isotopic composition of solar wind xenon in silicon targets from the bulk collector array, using the RELAX mass spectrometer [8, 9].

Gas Extraction Techniques: After flight and recovery, it is expected that the collector targets contain both xenon implanted from the solar wind (to an expected depth of 100 nm [7]) and xenon intrinsic to the material incorporated on formation – sample blank. An ideal sample extraction technique would combine quantitative extraction of implanted solar wind xenon from flight samples with sample blanks that were both small fractions of the implanted solar wind component and reproducible, allowing reliable blank corrections to be made to flight samples. We have previously investi-

gated both heating and ablation techniques to extract the implanted solar wind [10, 11].

Our preferred method for extracting the implanted solar wind is full sample uv laser ablation (Nd:YAG, 355 nm, ~350 mJ). The laser beam ablates the whole surface of (roughly) square samples ~3-4 mm in dimension without the need to raster over the surface – it is expected that around 10^5 atoms of ^{132}Xe will have been implanted into such a sample – a comparable number to our calibration aliquot. Detailed analysis of the variation in xenon concentration with depth in flight and non-flight samples has shown that 30 laser shots are the minimum required to guarantee quantitative extraction of implanted solar wind xenon. In order to extract the implanted solar wind in as few analyses as possible, and thus minimize instrument blank, our preferred protocol involves analysis of gas released by a single laser shot (to release any surface adsorbed contamination), followed by analysis of gas extracted by 30 consecutive laser shots, $I+30$. To date 9 flight and 12 non-flight samples have been analysed in this manner.

Results and Discussion: The blank xenon intrinsic to the collector material, as measured in the non-flight samples, is consistent with air, within error, but the concentration varies by a factor of ~20.

Variations in xenon concentration are also observed among flight samples. For flight samples, measured isotope ratios correlate with the reciprocal of measured concentration (e.g. Figure 1) suggesting variable concentration blank xenon as identified in the non-flight samples mixes with a uniform concentration component implanted from the solar wind. Mixing lines indicate that the latter is enriched in the lighter isotopes and depleted in the heavier isotopes relative to air.

Extracting a definitive solar wind composition from mixing lines such as that shown in Figure 1 requires knowledge of the concentration of solar wind xenon. We have investigated whether xenon content at depth in the sample correlates with the blank observed closer to the surface in the region where solar wind is implanted so that it might be used to make a blank correction. In 8 non-flight samples the extraction protocol described above was followed by a further series of extractions (4×30 shot extractions followed by 1×150 shot extraction), and it was found that the xenon content of the first “solar wind region” extraction correlated with the total released from the subsequent

“deep xenon” extractions. However, similar analyses of 5 flight samples showed no evidence that a similar correlation had been modified solely by implantation of solar-wind xenon into the region sampled by our standard extraction protocol; some of the flight samples appear to have too much “deep” xenon relative to the amount of xenon extracted in the first 31 shots. We conclude that deep xenon cannot be used to make a blank correction to that released from the solar-wind region.

An alternate method of estimating a blank correction is to study the distribution of the xenon concentrations in both the flight and non-flight samples. Cumulative error functions and variable kernel density estimation both estimate the concentration of the implanted solar wind to be $\sim 1.2 \times 10^6$ ($\pm \sim 10\%$) atoms $^{132}\text{Xe cm}^{-2}$. This is somewhat higher than the pre-flight estimate [7], but consistent with the value reported by Heber *et al.* [12]. A more precise concentration of the implanted solar wind has been reported by Vogel *et al.* as $1.21(7) \times 10^6$ atoms $^{132}\text{Xe cm}^{-2}$ [13]. This value is also consistent with our estimates, and can be applied to our ratio vs. concentration correlation to determine the solar wind xenon isotope ratios. Preliminary ratios for the major isotopes are plotted in Figure 2, as delta values relative to the solar wind measured in the young lunar regolith [1, 2].

These measured ratios appear to exhibit fractionation relative to the solar wind as measured in the young lunar regolith by 3.1 ± 1.6 ‰ per amu favouring the heavy isotopes. However, a similar effect may result if the concentration adopted is inappropriate – a slightly lower concentration of solar wind (corresponding to an underestimate of the blank) would lead to a derived composition consistent with that measured in the young lunar regolith. This will be clarified as further samples are analysed.

References: [1] Pepin, R. O. et al. (1995) *GCA*, 59, 4997-5022. [2] Wieler, R. and Baur, H. (1994) *Meteoritics*, 29, 570-580. [3] Busemann, H. et al. (2000) *Meteoritics & Planet. Sci.*, 35, 949-973. [4] Wiens, R. C. et al. (2004) *EPSL*, 222, 697-712. [5] Gilmour, J. D. (2010) *GCA*, 74, 380-393. [6] Pepin, R. O. (2000) *Space Sci. Rev.*, 92, 371-395. [7] Burnett, D. S. et al. (2003) *Space Sci. Rev.*, 105, 509-534. [8] Gilmour, J. D. et al. (1994) *Rev. Sci. Instrum.*, 65, 617-625. [9] Crowther, S. A. et al. (2008) *J. Anal. Atom. Spectrom.*, 23, 938-947. [10] Crowther, S. A. and Gilmour, J. D. (2008) *Meteoritics & Planetary Sci.*, 43, 5236. [11] Crowther, S.A. and Gilmour, J.D. (2010) *Meteoritics & Planetary Sci.* 73, 5335. [12] Heber, V.S. et al. (2009) *GCA*, 73, 7414-7432. [13] Vogel, N. (2010) Personal Communication.

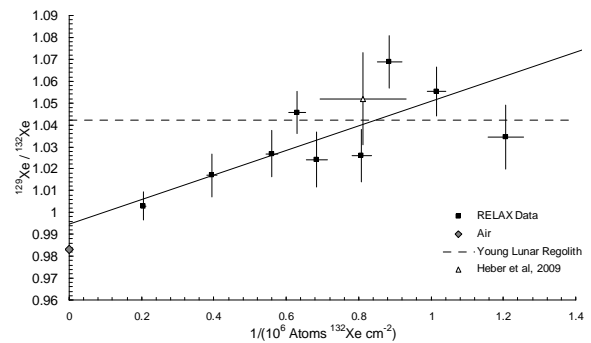


Figure 1. Measured $^{129}\text{Xe}/^{132}\text{Xe}$ ratios plotted as a function of the inverse of the ^{132}Xe concentration for 9 flight samples. Data trend towards the atmospheric ratio as the xenon concentration increases, consistent with a uniform concentration implanted solar wind component mixing with a variable concentration (atmospheric) blank component. The solar wind $^{129}\text{Xe}/^{132}\text{Xe}$ ratio measured in the young lunar regolith [1, 2], and the Genesis $^{129}\text{Xe}/^{132}\text{Xe}$ ratio and ^{132}Xe concentration reported by Heber *et al.* [12] are also plotted for reference.

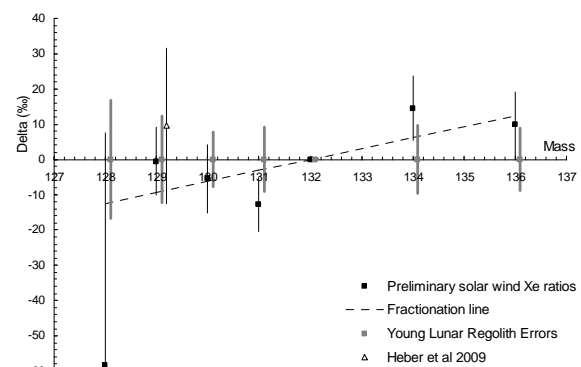


Figure 2. Preliminary Genesis xenon isotope ratios, plotted as delta values relative to the solar wind ratios measured in the young lunar regolith [1, 2]. These ratios have been calculated using the solar wind concentration of $1.21(7) \times 10^6$ atoms $^{132}\text{Xe cm}^{-2}$ determined by Vogel *et al.* [13] and correlations similar to that shown in Figure 1. The large error on the ^{128}Xe measurement is due to interference from an isobaric hydrocarbon. The precision of the solar wind ratio measured in the young lunar regolith is displayed, and the Genesis $^{129}\text{Xe}/^{132}\text{Xe}$ ratio reported by Heber *et al.* [12] is plotted for reference.

Acknowledgements: S.A. Crowther would like to thank N.A. Sheldon for introducing her to the intricacies of variable kernel density estimation.