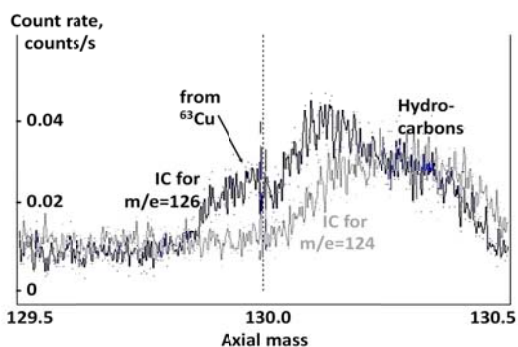


**ISOTOPIC COMPOSITION OF SOLAR WIND XENON CAPTURED BY GENESIS: VERIFICATION AND POSSIBLE IMPLICATION FOR INDIGENOUS LUNAR XENON.** A. Meshik<sup>1</sup>, O. Pravdivtseva<sup>1</sup>, and D. Burnett<sup>2</sup>. <sup>1</sup>Physics Department and McDonnell Center for Space Sciences, Washington University, 1 Brookings Drive, Saint Louis, MO 63130 ([ameshik@physics.wustl.edu](mailto:ameshik@physics.wustl.edu)), <sup>2</sup>MC 100-23, California Institute of Technology, Pasadena, CA 91125.

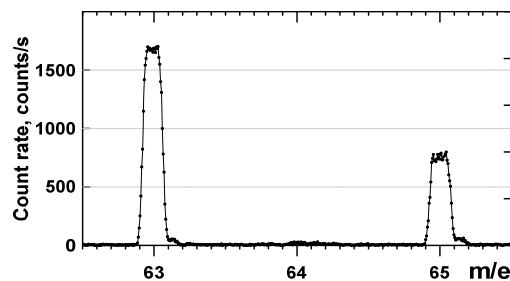
**Introduction:** The goal of this study is to explore the differences in the composition of heavy noble gases between contemporary Solar Wind (SW) captured by Genesis NASA mission and SW accumulated in the lunar regolith over millions of years.

**Experimental:** During 853-day SW exposure at L1 point, 1 cm<sup>2</sup> of Genesis collectors captured  $\sim 1.2 \times 10^6$  atoms of the most abundant <sup>132</sup>Xe [1], and only  $\sim 4000$  atoms of the least abundant <sup>126</sup>Xe and <sup>124</sup>Xe. With Xe sensitivity (4850 at/count/s) of the multi-collector (8-multipliers) Noblesse mass-spectrometer designated for noble gas analyses of Genesis samples the count rate of <sup>124,126</sup>Xe retrieved from 1 cm<sup>2</sup> is  $\sim 1$  count/s. Evidently, for such low count rate instrumental background and multiplier noise (dark current) are needed to be taken into account. In this work we present the evaluation of the dark current, hydrocarbon contribution, and previously overlooked contribution of the <sup>63</sup>Cu change of charge effect to the <sup>126</sup>Xe count rate. Figure 1 shows a background count rate for m/e = 124 and 126 integrated overnight in the mass spectrometer continuously pumped by ion pump to ensure the absence of Xe.



**Figure 1.** Multi-collection of background signals (no Xe) with m/e = 124 and 126. Signals from only two ion collectors (ICs) are recorded. Outputs from other six ICs are not shown for clarity. X-axis corresponds to the axial ion beam (m/e=130). The noise (dark counts) for both ICs is  $\sim 0.01$  cps, the hydrocarbons are  $\sim 0.03$  cps. There is  $\sim 0.025$  cps peak likely from change of charge effect on <sup>63</sup>Cu<sup>+</sup>. This peak is partially resolved from the hydrocarbon peak, but cannot be separated from <sup>126</sup>Xe, since the resolution of  $\sim 3000$  is needed. The vertical dotted line is where the actual measurements are taken.

During the isotopic analyses the ubiquitous hydrocarbons were resolved from Xe peaks using a “pseudo-high resolution” mode (measuring on the shoulder of the peaks superposition, as shown by the vertical dotted line in Fig 1). This mode works fine for <sup>124</sup>Xe, but at m/e=126 the <sup>126</sup>Xe peak is contaminated by some unresolvable contribution seemingly due to the change of charge of <sup>63</sup>Cu. Copper is a common material in high vacuum systems. A small fraction of doubly charged <sup>63</sup>Cu<sup>++</sup> ions can pick up an electron from the source defining slits or from ion-atom collisions between ion-source and magnet. Then they become singly charged <sup>63</sup>Cu<sup>+</sup> ions with double energy, thus following the same trajectory as <sup>126</sup>Xe<sup>+</sup>. The copper mass spectrum is shown in Figure 2. Due to change of charge effect <sup>63</sup>Cu will also produce unresolvable interference with <sup>130</sup>Xe, but it is negligible compared to <sup>130</sup>Xe, much more abundant than <sup>126</sup>Xe.



**Figure 2.** Mass spectrum of Cu. The peak heights are nearly constant in both static and dynamic operation (with or without pumping) but strongly depend on the electron trap current, suggesting that the main source of Cu is likely the W-filament itself. The installation of the filament from different W manufacturer may verify our suspicion.

During our latest Xe analyses the change of charge effect has been taken into account. We also estimated that in our early SW-Xe analyses this effect did not significantly change the <sup>126</sup>Xe SW abundance. However an unaccounted contribution of <sup>63</sup>Cu could explain some larger than statistically expected variations of <sup>126</sup>Xe often observed in Xe isotopic measurements.

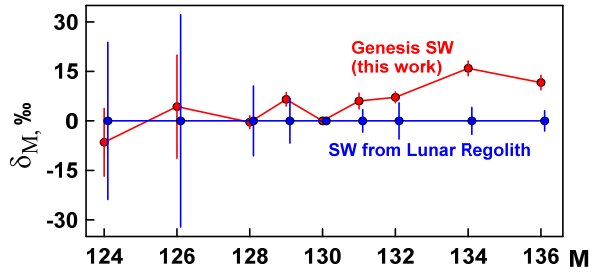
Since the first complete SW-Xe isotope measurements [1] we continue to refine Xe analyses and to improve the statistics. The right column in Table 1 includes our latest analyses and represents the best current estimate of contemporary SW-Xe collected by

Genesis mission. This SW-Xe composition is compared with the SW-Xe composition in lunar regolith [2] in Figure 3.

**Table 1.** Solar Wind Xe normalized to  $^{130}\text{Xe}$ . While the isotopic composition does not change significantly, the uncertainties ( $1\sigma$ ) become smaller.

year	2014 [1]	2015 [3]	2018 [4]
$^{136}\text{Xe}$	1.819 (6)	1.822 (5)	1.818 (4)
$^{134}\text{Xe}$	2.237 (7)	2.244 (6)	2.242 (5)
$^{132}\text{Xe}$	6.061 (15)	6.068 (11)	6.063 (10)
$^{131}\text{Xe}$	5.004 (14)	5.010 (12)	5.010 (12)
$^{129}\text{Xe}$	6.306 (16)	6.314 (13)	6.314 (13)
$^{128}\text{Xe}$	0.510 (2)	0.511 (2)	0.510 (1)
$^{126}\text{Xe}$	0.0252 (6)	0.0255 (4)	0.0256 (4)
$^{124}\text{Xe}$	0.0298 (4)	0.0297 (4)	0.0292 (3)

**Implication for indigenous lunar Xe.** Isotopic composition of contemporary SW-Xe captured by Genesis mission is statistically different in  $^{136,134}\text{Xe}$  from SW-Xe implanted into lunar regolith [2].



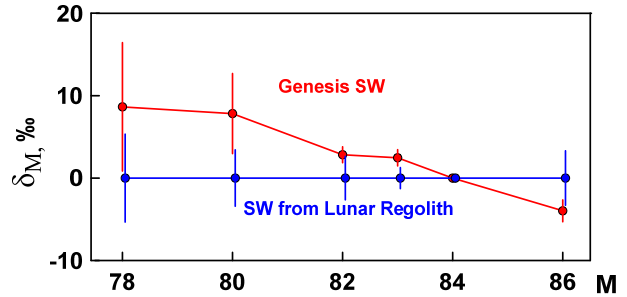
**Figure 3.** Xe composition of contemporary SW captured by Genesis as a permil deviation from SW accumulated in lunar regolith [2]. The errors ( $1\sigma$ ) are not propagated to the delta plot, but shown individually for each composition.

This difference may appear as a result of slight mass-dependent Xe fractionation, but in this case Kr isotopes should be fractionated to a higher degree and in the same direction, which is not the case (Figure 4).

The Kr fractionation (Figure 4) suggests that the light isotopes must have been preferentially lost from the regolith.  $^{84}\text{Kr}/^{132}\text{Xe}$  in lunar soils varies from 4.7 to 9.0 [5], while in the Genesis collectors it is  $9.55 \pm 0.16$  [1], indicating diffusional Kr losses favoring the more mobile light isotopes. This effect is likely to be enhanced by the depth-dependent fractionation in constant velocity implantation, coupled with surface erosion. Lunar surfaces quickly saturate under SW bom-

bardment. Solar protons, if retained, would exceed the lattice atoms after 1,000 years, enhancing surface sloughing. Deeper (heavier) isotopes will be enriched as the surface erodes.

The difference between SW-Xe captured by Genesis and SW-Xe implanted into the lunar regolith might reflect temporary variations of SW-Xe composition. But, once again, there is no evidence for such variations in SW-Kr.



**Figure 4.** Kr in contemporary SW captured by Genesis is slightly fractionated from SW-Kr accumulated in lunar regolith [2].

Therefore the apparent  $^{136,134}\text{Xe}$  depletion in lunar regolith reported here, as well as similar observations in some lunar anorthosites [6, 7], may represent the indigenous lunar Xe seemingly resulted from addition of hypothetical U-Xe [8] possibly carried by cometary material [9]. Alternatively the observed difference could be attributed to the implantation of the early Earth's atmosphere into the lunar crust [10]. The analyses of samples from the back side of the Moon would be crucial for understanding the origin of indigenous lunar Xe.

To further explore the difference between SW-Xe delivered by Genesis and by Apollo missions we need to return to analyses of SW implanted into extraterrestrial regolith which are currently less precise than analyses of Genesis SW-targets.

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