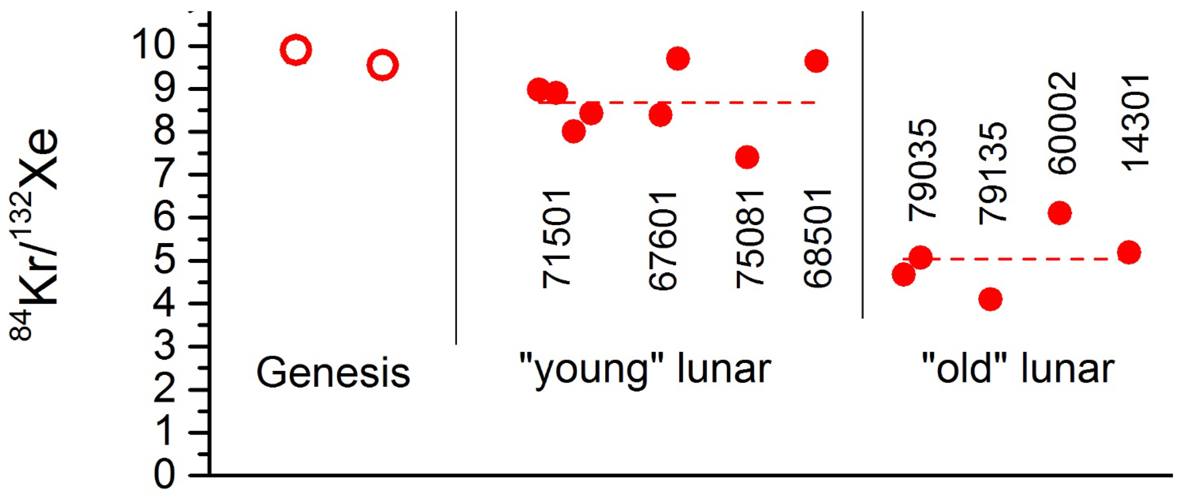
LPSC 2020 #1076

A possible contribution from the ancient terrestrial atmosphere to the trapped Xe inventory of lunar soils - Rainer Wieler[1] & Peter Bochsler[2]

[1]ETH Zürich, Earth Sciences, Zürich, Switzerland; [2]University of Bern, Physikalisches Institut, Bern, Switzerland; wieler@erdw.ethz.ch

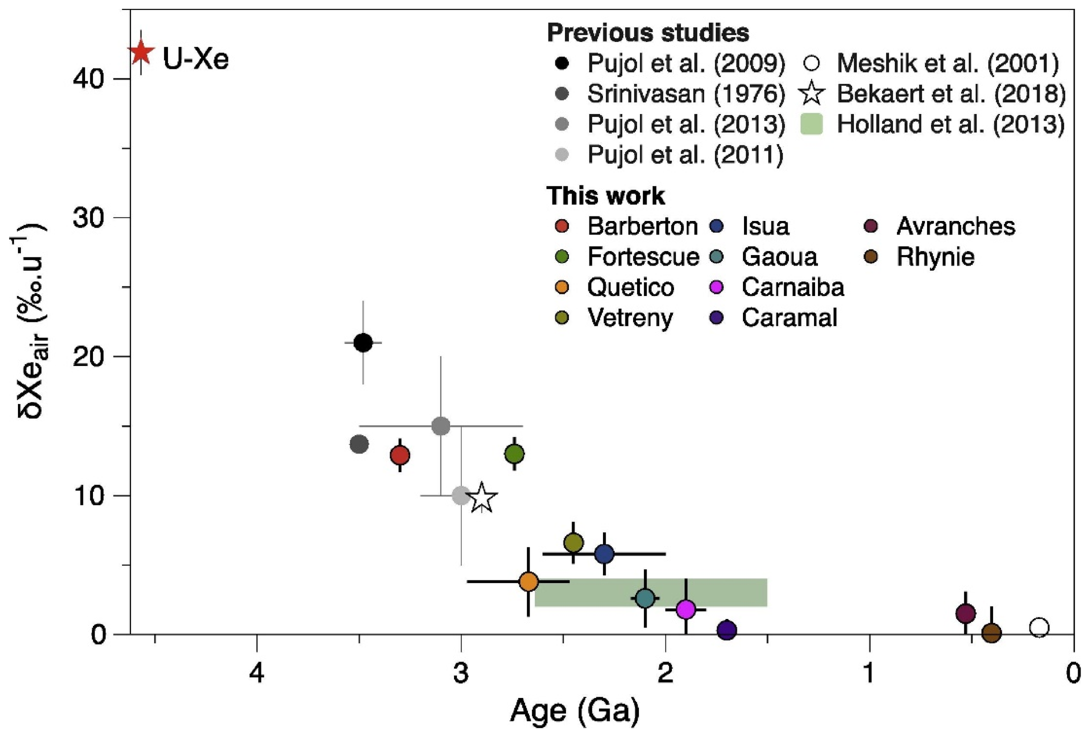
The problem



Lunar regolith samples irradiated billions of years ago ("old") have twice as high Xe/Kr ratios as more recently irradiated samples ("young") [1] and Genesis targets [2, 3].
This was interpreted as indicating a secular decrease of Xe/Kr in the solar wind [4, 5]
However, no viable hypothesis to explain such a secular change has been forwarded.

A possible solution: "Old" lunar samples contain Xe from an "Earth Wind":

- Xe lost from Earth's atmosphere until ~2 Ga ago (Avice et al. [6])
- Loss of Xe from H-rich early atmosphere possible (Zahnle et al. [7])

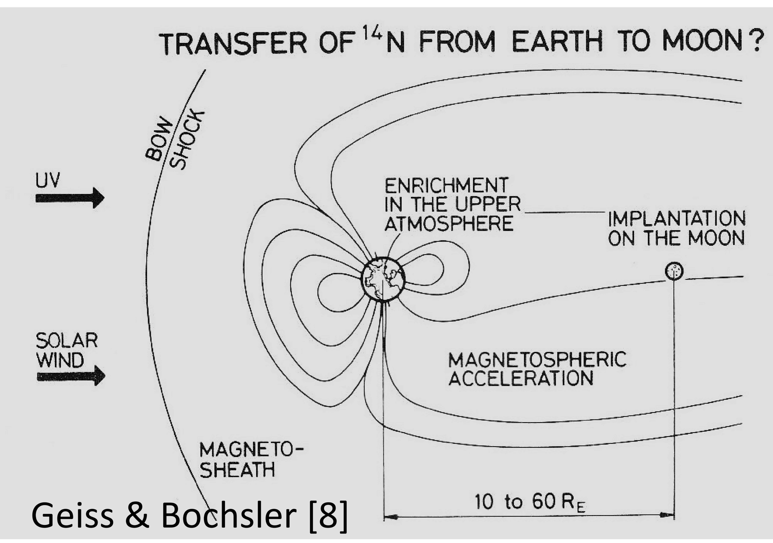


Avice et al: Xe in ancient atmosphere isotopically lighter than today, indicating loss.

Zahnle et al.: Xe efficiently ionized by resonant charge exchange with protons, due to its relatively low FIP. Process would not work for Kr. Only Xe would be lost.

To explain the lunar data, about 50% of the Xe in "old" lunar regolith samples would have to come from such an Earth wind.

Earlier proposed Earth wind contributions



Geiss & Bochsler [8]

Nitrogen: Geiss & Bochsler [8, 9]
Ozima et al. [10]

Oxygen: observed by Kaguya orbiter [11]

The model

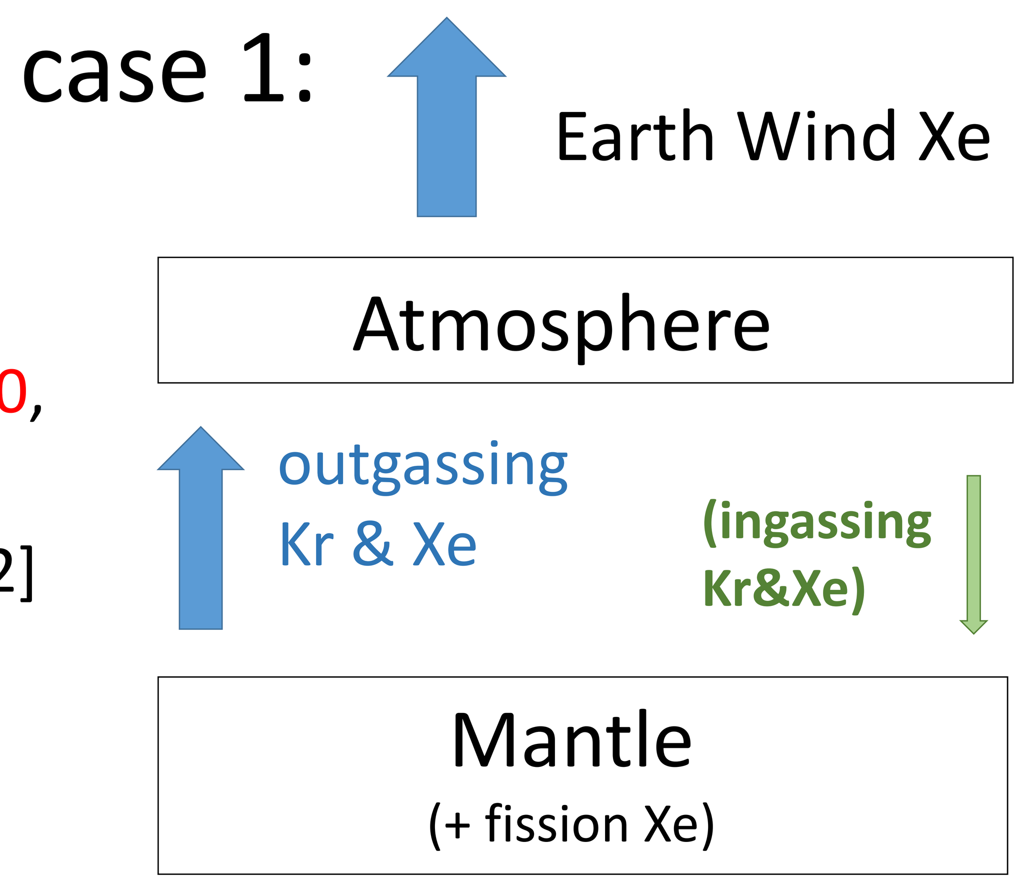
Secular loss of Xe, no loss of Kr [7]

* Case 1: Atmospheric noble gases entirely supplied by exponentially decreasing mantle outgassing, superposed an exponentially decreasing Xe loss according to [7]

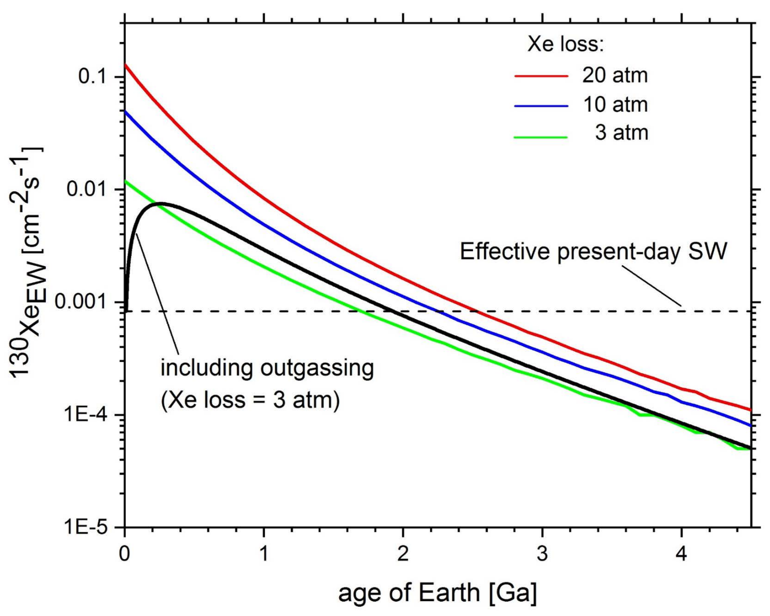
* Case 2: Xe amount in atmosphere at start of loss [7] equals 20, 10, 4 times present day inventory, no outgassing [e. g. 6]

* 1% of original Kr & Xe assumed to remain in mantle today [12]

*Outgassing and loss lead to isotopic fractionation favouring light Xe isotopes, remaining atmospheric Xe becomes isotopically heavier

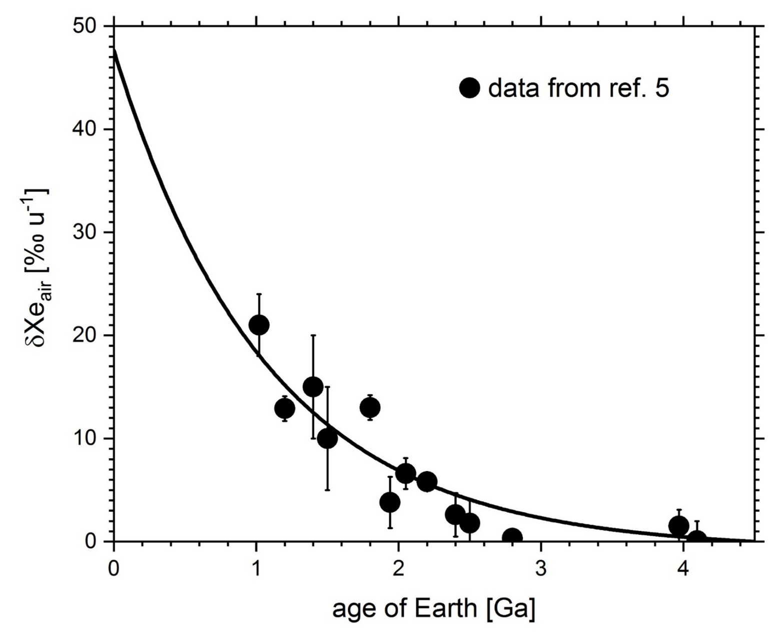


Results



If solar wind flux was same as today, Earth Wind and solar wind Xe fluxes were identical ~2-3 Ga ago.

→ Xe from Earth wind can explain high Xe/Kr in "old" lunar samples



→ case 2: Modelled isotopic fractionation of remaining atmospheric Xe consistent with data from [6]

Conclusions

Earth Wind hypothesis can qualitatively explain the high Xe/Kr ratios in "old" lunar regolith samples (irradiated ~2-3 Ga ago).

The modelled isotopic fractionation of remaining atmospheric Xe is consistent with observed data [6].

Hypothesis is testable with samples from lunar far side, and additional near-side samples with constrained time of solar wind implantation.

Ingassing of atmospheric Xe into the mantle [13] presumably required to explain ~3 times lower Kr/Xe in mantle [12] relative to atmosphere. Model will be extended to study effects of Xe ingassing.

References: **[1]** Wieler R. (2016), Chem. Erde 76, 463 **[2]** Meshik A. P. et al. (2014) GCA 127, 326 **[3]** Vogel N. et al. (2011) GCA 75, 3057 **[4]** Wieler R. & Baur H. (1995) ApJ 453, 987 **[5]** Wieler R. et al., (1996) Nature 384, 46 **[6]** Avice G. et al. (2018) GCA 232, 82 **[7]** Zahnle K. J. et al. (2019) GCA 244, 56 **[8]** Geiss J. & Bochsler P. (1991) in: The Sun in Time, 98 **[9]** Bochsler P. (1994) Adv. Space Res. 14, 161 **[10]** Ozima M. et al. (2005) Nature 436, 655 **[11]** Terada K et al. (2017) Nature Astron. 1:26 **[12]** Ozima M. & Podosek F. A. (2002) Noble Gas Geochemistry 2nd ed., Cambridge Univ. Press **[13]** Mukhopadhyay S. & Parai R. (2019) Annu. Rev. Earth Planet. Sci., 389.