Precise but Off? Do we need improved irradiation procedures and/or new monitors in $^{40}Ar/^{39}Ar$ geochronology?

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With the advent of a new generation of noble gas mass spectrometers the precision of argon isotope measurements has markedly improved, and $^{40}Ar/^{39}Ar$ ages with errors <0.1% (2σ) have been reported [1-2]. High intra-laboratory precision is, in some cases, contrasted by relatively large variations in published ages of fluence monitors (age standards) and, at least in our lab, by an external reproducibility which in several cases exceeds 1%, markedly off the challenging ±0.1% target of the EARTHTIME project.

Experiments show that the external reproducibility of measured ages is mostly controlled by residual fluence gradients during rotational irradiation in Al-discs [3]. In some cases, this variation even *across* a single irradiation disc (~33 mm diameter) might be as high as 2%, not systematically related to the vertical position but obviously caused by the mass and position of co-irradiated material. We also observed that individual splits of a sample, each irradiated with its *own* fluence monitor in the *same* hole, still provide an age variation in the order of 0.4 - 1.0%.

Based on this, it is speculated that neutron scattering and absorption by co-irradiated material might limit the error minimization due to local fluence gradients significant even on a mm-scale. Our results suggest that the type, mass and density of material irradiated for $^{40}Ar/^{39}Ar$ dating, its distribution within the irradiation container as well as sample transfer into and operation conditions of the reactor influence the resulting ages, and might cause some "fractionation" of the $^{39}K(n,p)^{39}Ar$ reaction rates between standards and samples.

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