We greatly appreciate the thoughtful discussion comments from Klaudia Kuiper, an expert on Ar geochronology who has worked extensively on questions of precision and statistics in the field. The review is reprinted in its entirety in italics with author responses shown by indentation where appropriate. Some comments were also addressed in the response to the Wielandt review.

Interactive comment on "The Isotopx NGX and the ATONA Faraday Amplifiers" by Stephen E. Cox et al.

Klaudia Kuiper k.f.kuiper@vu.nl

Received and published: 13 March 2020

General comments This article describes the performance of a new patented type of capacitive transimpendence amplifier (CTIA) for noble gas mass spectrometry. Due to trade secrets the exact working of this amplifier is not described, only its performance is tested and compared to other commonly used amplifier technology. This seems to be a new step in amplifier development and although not fully disclosed, this is an development that likely will be implemented by several labs in the next 5 years or so. I therefore consider this paper worth publishing, because it is relevant for the community to judge the possible advantages and disadvantages of this new CTIA. The papers is well written clearly describes the experiments and tests that have been performed.

Specific comments and technical issues

Line 38 "as those are that are" → remove "are"

> We have corrected this typo.

Line 63 "through small leaks". What do you consider small leaks?

> We have changed the word "small" to "undetectable" to clarify that we mean small inputs of gas that are too small to be considered problematic and would not be detected through leak checking.

Line 77-80: What about 37 beam. This is also a very small beam on e.g. young sanidine grains (can now possible be addressed with ATONA).

> Sanidine will have very low 37Ar; the size of this beam will still be far too small to measure precisely with the ATONA. This is especially true for young sanidine, which typically undergoes very short irradiation. The other side of this coin is that the correction is so small that the precision we obtain is acceptable. It is certainly true that we are measuring 37Ar more precisely on the NGX with ATONA than on previous instruments.

Line 96-97: Not fully clear, can you give examples of approaches you are thinking of (even tough not fully tested)?

We have added an example of a measurement approach that will be possible with the production version of the ATONA hardware (it is not possible with the protoype version we used here).

Line 130-131: Can you provide used equations and calculations in appendix?

We have added the equation to the appendix.

Line 142: modify to "approximately 8.5×10-13 moles of 40Ar per aliquot"

We have clarified that the amount of Ar is calculated per aliquot.

Line 146-149: Can you quantify? What signals did you expect based on your approximations and based on GLO? What is the 40Ar content in your GLO standard? And I'll assume you mean APIS with the manometrically calibrated volume. Can you add an estimate of your system's sensitivity?*

I think the original wording of this section makes it sound like something more complicated is happening here. The standard used in this paper was prepared without first doing a manometric volume calibration for the machined pipette, so the point of this section is just to say that the precise size of this particular standard is known from a comparison to properly volume-calibrated air standard in a different tank. APIS is not involved. The calculated sensitivity was also compared favorably to GLO in the course of normal analyses on several occasions, but this is not used as part of the primary calibration and is not particularly important, so I have removed this remark for clarity. Hopefully the changes in the manuscript make all of this more clear. The sensitivity of the mass spectrometer is described elsewhere in the paper.

Line 152: Can you add for clarity 100% (8.5×10-13 moles 40Ar), 37.7 % (x moles 40Ar) etc

Yes, we have added this information.

Line 211: "our lab standard" which is?

The original wording in the paper is very confusing. The lab standard is the afore-mentioned air standard. The other air standard is the air standard that is part of the APIS. We have clarified this in the manuscript.

Line 213-214: "so a direct comparison of measured ratios is not possible" Comparison with what?

We have added "between labs." The original purpose of the APIS experiment was to allow mass spectrometers to be compared after measuring exactly the same gas. While the comparison is still useful, the noticeable amount of air contamination over time requires that the ratios first be corrected before comparison.

Line 224-225: "gain bias of the amplifiers is significantly more stable than both RTIAs and electron multipliers" This paper does not really provide data for comparison of gains for RTIAs and ATONA. Only gain data of ATONA are shown.

This is a fair point. We have changed this to focus on noise levels and to clarify the comparison to the ion-counting multiplier. The preliminary data we cite from TIMS instruments (Szymanowski and Schoene, 2019) will show more clearly that the gain stability of the ATONA is superior to existing RTIAs. In our case, we do not have an independent electronic calibration on the prototype unit, and the stability of the signal is limited by the noble gas mass spectrometer ion source rather than by drift in the amplifiers.

Figure 1: add the unit between brackets to the Y-axis title (e.g. cps). In caption it is mentioned that Faraday data are reported in Volts, in line 110-111 it is stated that you convert back to beam current for easier comparison.

This figure shows the output as displayed in the current version of the pychron software, which is not how we present the data elsewhere in the paper. For this reason, we clarify the display units in the caption.

Figure 3 and text line 112-115: can you add your calculations / formulas used for RTIA noise to the appendix. Inset is really small and hard to read (especially when printed)

The formula has been added to the appendix. I am also adding the full version of the inset figure to the appendix because I do not think it merits another figure in the paper and the template restricts the size of the figures, so it is difficult to make the inset more readable.

Figure 5: Is 40Ar/38Ar the t0 intensity of 40Ar air minus t0 intensity of 40Ar blank divided by the t0 intensity of 38Ar air minus t0 intensity of 38Ar blanks? How many blanks are run? In the legend there are only circle symbols, in the figure also squares. The way data are plotted suggests that Xact and ATONA measurements are bracketed. Can you first plot the Xact 100% data, followed by ATONA 100% data etc.?

We have expanded the description of the measurement scheme in the caption and changed the figure as suggested. Thank you for catching the error in the legend.

Figure 6. Maybe a matter of reader preference, but I prefer to see the 10 different analyses of one beam size plotted combined instead of interspersed. Now I find it difficult to see that variation within 10 similar experiments. And we are looking at ratios of blank corrected time zero intensities of 40 and 36? Inset is again rather small.

The figures have been changed, and information requested added to the caption.

Figure 7. The ARGUS RTIA data are from NMGRL? And are the measured with m/e36 on a Faraday with RTIA or multiplier? Colors of shaded lines are similar, not clear what they are showing.

I added a reference to the paper section that describes the comparison datasets, which I think are too extensive to put in this already-lengthy caption. The shaded lines are an attempt to guide the eye to the many different groups of data points in the figure, and I have clarified this in the caption. I recognize that this figure is busy and that they are hard to distinguish, but I think making them bolder would obscure the more-important data points themselves.

Figure 8: in caption it is indicated that smaller aliquots are on the left, and larger on the right. Can you indicate different areas in the figure which are the 0.1cc, the 0.2cc aliquots etc. The NMGRL Argus measurements are with 40Ar on H2 with 10ˆ12 Ohm amplifier and 36 on L2 with 10ˆ13 Ohm amplifier? Do Argus data with 40Ar on H1 with 10ˆ12 or 10ˆ13 Ohm amplifier and 36Ar on L3 multiplier also exist? And if yes, how do they compare? Did NMGRL perform exactly the same experiment with 3 aliquots per pipette volume? And if not, what are the criteria to select these 3 data points?

The experimental protocol was (as close as possible) to identical during the APIS experiments, which hopefully will be published eventually. I have added this information to the caption. This represents the complete dataset. The requested clarification has been added to the figure.

Table 1: what is the ± in the header row? 1SD? What is the 1-σ at the bottom of the table: the standard deviation of the ten measurements? Can you also report the mean (or the weighted mean)?

I have clarified the latter points and added a note in the caption stating that uncertainties are 1-sigma standard deviation.

Figure A1: I don't like the interspersed way of plotting. Also with all the colors that look rather similar it is difficult to see what is what.

This has been changed.

Figure A2: what is exactly plotted on the Y axis? Why not signal divided by average AX signal? Then the intercalibration factors mentioned in caption are immediately clear. And what is plotted on the X-axis? Why are there no data of aliquots 817, 820 etc. What is the beam size used for this intercalibration, is a baseline correction needed? And I'll assume data are regressed to time zero using a linear fit? What is the settling time, maybe worth mentioning, because a similar approach using RTIAs will take longer

This is exactly what is being done, only then the data are shown using delta units because the ratios are so close to unity. This is unclear, so I have changed the figure to simply show the ratios. The aliquot numbers represent extraction numbers from the air pipette, and the missing aliquot numbers were standards that were measured in typical multicollection mode in between intercalibration measurements. This is not meaningful outside of the lab and has been removed. The beam size is the full air standard described elsewhere; this has been clarified, along with details of the measurement scheme.