20. May 2026

Response to Reviewer 1 (Dr Valentin Zuchuat)

Reviewer's comments

4. Autogenic processes and signal shredding.
I recommend the authors to acknowledge autogenic processes and signal shredding explicitly (rivers/deltas, compensational stacking; see commented pdf for references examples). It is also necessary to clarify how AstroComb distinguishes or remains agnostic to these signals vs. orbital forcing. The authors could consider adding a short paragraph in Introduction and returning to it in Discussion. An easy way to start with this is to take some of the text from the “limitations” chapter.

Thank you for this suggestion. We have followed your suggestion and acknowledged autogenic processes and signal shredding explicitly with reference to Paola et al., 2016 and Munnecke et al., 2001

5. I also suggest the authors to avoid the term “geological noise” for non-Milankovitch periods. The preserved signal might not be “noise”, but rather the true expression of the mix of autogenic processes, Milankovitch cycles, and other non-linear effects such as bundling of several cycles. It is also important to justify why AstroComb does not include such periods (lines 311-314).

We have now avoided the term 'geological noise', e.g. line 344 now reads:

“This means that a hypothetical, noise-free Milankovic spectrum will, in general, contain spectral components outside the main Milankovic frequencies Sinnesael et al. (2018).

6. Scope.
Other software are briefly mentioned (l. 31-33). Also this paper remains quite diplomatic about how much better AstoComb is in comparison to these other software, the reader of this manuscript could do with a figure that displays how the different software deal with the same input dataset.

This paper is a presentation of a new method, AstroComb, and a documentation of its correctness and of the new possibilities it presents. We support this by showing its performance on synthetic data with a very large noise level and by comparing results from a geological data set to what has been previously obtained using a more traditional approach. We believe this is sufficient documentation of AstroComb and that further comparisons and scrutiny of other methods should belong in a review paper.

7. The manuscript also only use single elements or several single elements together. A lot of published research (see references in the attached commented pdf) study change in Earth System conditions through the use of elemental-concentration ratios as well as enrichment factors. It could be useful to show how AstoComb responds to elemental-concentration ratios and enrichment factors.

Yes, we agree that it is interesting to investigate how AstroComb responds to elemental-concentration ratios, peak areas and enrichment factors. While we have done a bit of sensitivity testing on this topic, we judge that a larger comparative study will be overwhelming here and instead include it in future work on the algorithm.

8. Finally, it would be beneficial for the manuscript to compare the results from the conformable Alum Shale Formation to other sedimentary-cores XRF scans much more impacted by event beds, hiatus, or vacuity. This would allow the authors to highlight how AstroComb deals with these extreme changes in sediment supply. If this is not possible, please add a short demonstration in addition to your synthetic example, or at least discuss applicability in greater detail. Doing so would allow you to confirm, precise, or disagree with published sedimentation rates of other sedimentary units.

We respectfully disagree with the point raised here. This work presents a new methodology and, as such, we have chosen to limit our exposition to a description of the method, the software, performance on noisy synthetic data, and a comparison of AstroComb analysis of the Faageltofta-2 data with previously published results. Every single geological data set comes with its own challenges and deserves careful discussions, beyond what can be presented in a methods paper.

9. Methods chapter.

I would like the authors to add in the method chapter a paragraph on their XRF data collection workflow: add model, tube type, kV/mA, measurement time, temperature, calibration/normalization, etc. The authors could also cite the paper that generated these data in the first place.

We have mentioned how the data was collected and cited the paper in which it was generates. Line 264 now reads:

To illustrate the application of the multichannel, probabilistic Milankovitch period detector, AstroComb, we analysed high-resolution XRF data from a ~21-meter long interval (67.2520 m - 88.0744 m) of the Fågeltofta-2 drill core through the Alum Shale Formation in southern Sweden obtained by Sørensen et al. (2020). Briefly, the XRF data was collected using an ITRAX core scanner from Cox Laboratories with 30 kV voltage and 50 mA current on a Rh tube. The XRF measurements were collected with a high scanning resolution of 0.2 mm along the core and relatively long exposure time (7 sec/scan), producing signal reported as concentrations for 22 elements, incl. Al2O3, SiO2, S, K2O, CaO, TiO2, V, MnO, Fe2O3, Ni, Cu, Zn, Ge, As, Rb, Sr, Y, Zr, Mo, Ba, Hf, and U. This extensive elemental dataset formed the basis for the spectral analysis.

10. Results and interpretations.

I would suggest to move beyond "visual examples" and describe the results in great details. For instance, the figures displaying the age-model: how does this relate to the sedimentation rates? Where do abrupt changes occur (e.g. line 326); how large are these abrupt changes; over what thickness/time do they occur; what geological interpretations are plausible? Why are some intervals "less Milankovitch" than others in your "information content" curve, tie all of this to core observations and geochemical data

Yes, we have now added an explanation on how the age-models are calculated based on the sedimentation rate probability distribution in the method section. Line 198ff now reads:

From the marginal sedimentation rate distribution

$$p(r) = \int p(r, \mathbf{a})\ da$$

at each stratigraphic position, we can now compute a floating geological time, t, and its uncertainties as a function of depth, z.

$$t(z_0 + N\Delta z) = t_0 + \Delta z \sum_{n=1}^{N} \frac{1}{r_n}\ .$$

We have also explicitly elaborated on how abrupt changes in the sedimentation rates of synthetic data affects the AstroComb results. Line 279ff now reads.

Abrupt changes in the sedimentation rate of about a factor three occur at 70, 74, 81, and 83 m, all of which are accurately captured by the AstroComb algorithm (figure 3). However, the test also illustrates how artifacts (possible, incorrect sedimentation rates) are introduced by the noise, the variability of the true model, and the non-linearity of the problem. Some of these spurious parallel features could potentially be misinterpreted as representing true sedimentation rates. This highlights a key challenge in cyclostratigraphic analyses: a given cycle may be interpreted as corresponding to different target periods, resulting in a multimodal sedimentation-rate probability distribution. Nevertheless, the highest probability remains associated with the true reference model (figure 3).

We also discuss why the KL information content varies for some intervals in the synthetic data. Line 288 ff now reads;

The Kullback-Leibler information content varies along stratigraphic depth with high information content at intervals where the sedimentation rate is constant across the window size (3.3m) and low where the sedimentation rate changes within the window. In any case, we note that the algorithm identifies the correct (true) sedimentation rates despite the high noise level, and that it reconstructs the large discontinuities between layers of constant rates quite well, with lower probability near abrupt sedimentation rate changes.

11.
I would also recommend the authors to have all the figures 3-4-5-6-7 plotted as a one-pager figure together. This will allow for a much easier comparison between the single-element run and the multiple single-element run. Additionally, to tie this comment back to the previous one, please quantify the difference between the to runs, rather than having these results as visual examples. And add the elemental curves used for each runs to these figures. Doing so will allow the authors to expand the discussion to the interpretation of the succession they have studied in great detail.

We have now added the elemental profiles used for each run to the figures.

While figures 3-7 can be plotted on one page, we are concerned about the readability of the details in such a 1-page figure. Therefore, we do not recommend to compress all this into 1 page. We will leave it to the editor to give us advice on this matter.

And finally, we respectfully disagree with the reviewer that our two runs are just "visual examples". These plots are equipped with scales and color bars providing a complete quantification of the results.

12.
Figures and presentation.
I would invite the authors to highlight and indicate more features on their figures: for example, where are the sedimentation rates changing "abruptly", whare are the "spurious features" that "could be interpreted as true sedimentation rate" (l. 289-290), etc.

Yes. We have clarified "spurious" and rewritten the paragraph, so it highlights features observed in figure 3. Line 281ff now reads:

However, the test also illustrates how the probability distribution outside the correct sedimentation rate is not invariable or zero. In fact, artifacts (mathematically possible, but incorrect sedimentation rates) are introduced by the noise, the variability of the true model, window size, and the non-linearity of the problem. Some of these artifacts show up as spurious parallel features that could potentially be misinterpreted as representing true sedimentation rates. This highlights a key challenge in cyclostratigraphic analyses: a given cycle may be interpreted as corresponding to different target periods, resulting in a multimodal sedimentation-rate probability distribution. Nevertheless, the highest probability remains associated with the true reference model

13. I would suggest adding element-curves to Fig. 3-6-10 next to the information content curve, which x-axis need to have a unit or an explanation as to why it doesn't have one. Add proposed sedimentation rate curves on all probability plots, just like you have done on Fig. 10. The authors are also invited to quantify the difference between the two runs.

As also mentioned above, element curves are now added to figures 3, 6 and 10. The information content has no unit[AS1] , see definition in equation (13).

14.
The authors are also invited to combine Fig. 8-9-10 in a one-page figure as well. Please rotate the Fig. 9 to have the depth as a vertical axis, just like all the other figures. Please quantify the impact of "However, the test also shows how artifacts are introduced by the noise, the variability of the true model, and the non-linearity of the problem" (caption of Fig. 10), which are concept that should be discussed in greater detail by the authors, especially with regards to the results of the studied core Fågeltofta-2.

We respectfully disagree here. We are concerned about the readability of the details of the result, if fig. 9 was rotated. Again, we will leave it to the editor to give us advice on this matter.

15. Please check the journal reference formatting, as there seem to be many unnecessary parentheses when multiple references are cited in the text.

Yes. We have corrected (all of?) these..

16. Please chose and stick to "ky", "kyr", or "kyrs" for consistency. Similarly, always call the core Fågeltofta-2, rather than a mix of Fågeltofta-2 or Fågeltofta (e.g. caption of Fig. 2, or l. 304, 326)

Corrected. We now use 'ky' and 'Fågeltofta-2' everywhere.

17. Please use the official chronostratigraphic series name Furongian as opposed to late/upper Cambrian.

We corrected line 280 and note that later Cambrian sometimes refer to Miaolingian-Furongian in a looser sense.