20. May 2026

Response to Reviewer 3

85.
This study proposes a quantitative statistical methodology for astronomical time scale calibration and development, designated as AstroComb. The objective of the study is an important one that has broad relevance to the geoscience community. Astrochronology has become a central approach in the calibration of the geological Timescale (GTS 2020: Gradstein et al., 2020), the evaluation of Earth System evolution (Hays et al., 1976; Pälike et al, 2006), and the reconstruction of the history of the Solar System, including Earth-Moon history (Ma et al., 2017; Meyers & Malinverno, 2018). Consequently, improvements in astrochronologic methodologies, especially uncertainty quantification, can result in advancements across multiple domains of geoscience and also astronomy. I'm delighted to see new work on this topic, and to provide feedback.

In evaluating statistical methods such as the one presented in this manuscript, there are three criteria that are essential to consider:

Criteria 1: Does the proposed methodology have a solid theoretical statistical foundation (in other words, is the method theoretically valid)?

Criteria 2: Does the proposed method differ substantially from existing published methods, and does the scholarship recognize the prior related methods?

Criteria 3: Are the concepts of the methodology as described in the manuscript implemented appropriately in the coded software, such that it can correctly accomplish what it proposes to do.

I appreciate that the authors have provided access the AstroComb Matlab code on Zenodo (https://zenodo.org/records/17966228), which permitted a comprehensive evaluation of all three criteria. I will provide a detailed assessment below, but first I present a brief summary. In principle, the methodology looks to have solid statistical foundation (Criteria 1), although there are some crucial details that need to be addressed in the manuscript before this can be fully demonstrated. The proposed method is conceptually similar to a method previously published by Malinverno et al. (2010), which is not referenced in the present manuscript (Criteria 2). An important Innovation of the present study is the evaluation of multi-channel data. Finally, the presentation of the methodology in the manuscript is not yet sufficient to appropriately convey what the AstroComb Matlab code is doing (Criteria 3). Once these issues are addressed, as well as a number of other improvements to the manuscript presentation for the sake of clarity and accuracy, I would recommend acceptance of the manuscript by Geoscientific Model Development, as an appropriate venue for publication.

I hope that the authors find the suggestions in this review helpful, and I would be happy to serve as a referee for a revised version of the manuscript that incorporates the recommendations.

Thank you for the enthusiastic response, helpful review, and constructive comments. We have added references and revised the text accordingly. See details below.

86.

2 The historical context of astrochronologic testing and calibration methods, with respect to the proposed AstroComb methodology.

Below I provide some background on the history of astrochronologic method development – for which there is no thorough up-to-date review available (to my knowledge). I do not expect the authors to incorporate all of this review in their manuscript; it is presented here to communicate to the authors how their proposed method ‘fits’ within the existing methodologies, for appropriate scholarship/citation.

Thank you! Inspired by this, we have revised the introduction to cyclostratigraphic methods. Line 40ff now reads:

Over the past two decades, several classes of inverse astrochronologic methods have been developed to address this problem. Early methods, such as Average Spectral Misfit (ASM) evaluates spectral peaks against astronomical frequencies across sedimentation rates and was later extended to moving-window analysis (eASM; (Meyers and Sageman, 2007)). Bayesian spectral methods later formalized this framework by evaluating the power concentrated in astronomical frequencies relative to a noise model formulated as a likelihood function (Malinverno et al., 2010; Peng et al., 2023; Trayler et al., 2024). Parallel developments introduced time-domain approaches including TimeOpt (Meyers, 2015) and time-variant sinusoidal modeling (Sinnesael et al., 2016; ACE v.1) along with extensions (Sinnesael et al., 2018; Meyers and Malinverno, 2018; Malinverno and Meyers, 2024; Hoang et al., 2025), while correlation-based methods such as COCO and eCOCO evaluated agreement between measured and theoretical power spectra (Li et al., 2018).

87

2.1 SUMMARY: THE FOUR CLASSES OF METHODS

The problem of calibrating and testing cyclostratigraphic records in ‘deep time’, beyond the limits of the theoretical astronomical solutions (approx. 60 Ma; e.g., Laskar et al., 2004; Laskar, 2020), is an important one. There are essentially four classes of inverse approaches that have been proposed to evaluate timescale uncertainty and simultaneously derive an optimal sedimentation rate in such ‘deep time’ cyclostratigraphic data. (Note: there are many other quantitative cyclostratigraphic methods that are not summarized here, but those listed below are inverse methods that constrain timescale simultaneously while evaluating the fit of data to astronomical frequencies, beyond the 60 Ma limit of the theoretical astronomical solutions. They do not require initial assumptions relating a particular bedding cycle to a particular astronomical period.)

CLASS 1: The first type of ‘deep time’ inverse approach for comprehensively evaluating timescale uncertainty in cyclostratigraphic data was developed by Meyers & Sageman (2007), known as “Average Spectral Misfit” or ASM. This approach identifies statistically significant power spectrum peaks in cyclostratigraphic data, and tests the identified frequencies (cycles/meter) against predicted astronomical frequencies (e.g., originally from Berger et al., 1992), using a grid of sedimentation rates to evaluate plausible timescales. The ASM method accounts for resolution limits of the data and astronomical target frequencies, and also provides a Monte Carlo null-hypothesis significance test. The method was adapted to use a moving window (eASM) to allow evaluation of records with unsteady sedimentation rates (Meyers et al., 2012).

CLASS 2: The second type of ‘deep time’ inverse approach for comprehensively evaluating timescale uncertainty in cyclostratigraphic data was developed by Malinverno et al. (2010), and this was the first formal Bayesian inverse method. Instead of identifying the location (frequency) of significant power spectrum peaks (as in ASM), the Malinverno method calculates the power spectrum and evaluates the power concentrated in astronomical frequencies, relative to a noise model (formally, as likelihood). Trayler et al. (2024) adapted the Malinverno et al. (2010) approach, further incorporating radioisotopic constraints (AstroBayes). Another method that explicitly evaluates the concentration of power at astronomical frequencies following calculation of the power spectrum is the ‘power ratio accumulation method’ (Peng et al., 2023).

CLASS 3: The third type of ‘deep time’ inverse method for comprehensively evaluating timescale uncertainty in cyclostratigraphic data was developed by Meyers (2015; TimeOpt), and later adapted and enhanced (Meyers & Malinverno, 2018; Meyers, 2019; Malinverno & Meyers, 2024; Hoang et al., 2025). Below, I present a history of the development of this class of methods.

o Meyers (2015) introduced the regression model framework for astrochronologic testing in the “time domain”, rather than the “frequency domain” (in contrast with CLASSES 1, 2, 4). Meyers & Malinverno (2018; TimeOptMCMC) further developed the approach as a Bayesian inversion methodology “to quantitatively link astronomical theory with geologic observation, allowing a reconstruction of Proterozoic astronomical cycles, fundamental frequencies of the solar system, the precession constant, and the underlying geologic timescale, directly from stratigraphic data.” TimeOptB and TimeOptBMCMC (Malinverno and Meyers, 2024) introduced improvements/enhancements of the original TimeOptMCMC method. All of these methods require relatively stable sedimentation in the analysis interval.

o The TimeOptTemplate and eTimeOpt methods (Meyers, 2019) were designed to evaluate unsteady sedimentation rates within the analysis interval (non-Bayesian), and the AstroGeoFit method (Hoang et al., 2025) introduced a genetic algorithm coupled to the TimeOptMCMC/TimeOptBMCMC Bayesian regression model framework to evaluate unsteady sedimentation histories.

o Note that TimeOpt (Meyers, 2015), TimeOptTemplate (Meyers, 2019), TimeOptB (Malinverno & Meyers, 2024) and AstroGeoFit (Hoang et al., 2024) also provide a nullhypothesis significance test, to help guard against false attribution of observed stratigraphic signals to astronomical forcing.

CLASS 4: The fourth type of ‘deep time’ inverse approach for comprehensively evaluating timescale uncertainty in cyclostratigraphic data was developed by Li et al. (2018; COCO and eCOCO). This method compares the shape of the measured cyclostratigraphic power spectrum to a theoretical astronomical target power spectrum, using a Pearson correlation coefficient, following the calibration of the measured power spectrum across a grid of different plausible timescales (sedimentation rates). The method also provides a Monte Carlo null-hypothesis significance test. I will note that a fundamental challenge in the execution of this approach is the lack of knowledge, a priori, about the appropriate ‘shape’ of the astronomical target spectrum (the relative importance of eccentricity, obliquity and precession components). The other methods listed above (CLASS 1-3) do not have this limitation.

Considering this historical context, the proposed AstroComb method fits into CLASS 2, and is similar in its fundamental concept to the method of Malinverno et al. (2010), which evaluates a range of sedimentation rates and seeks to maximize spectral power (formally, as likelihood) at the astronomical target frequencies. More on that is presented in the review below.

We have revised the introduction and given a more careful introduction to the available methods in Line 40-55.

88
3. An evaluation of the AstroComb methodology
3.2 AstroComb methodology described in the manuscript
- The manuscript presents a description of the AstroComb methodology in Section 2. A key step is the generation of a “synthetic spectrum” (Equation 2), as a function of sedimentation rate (scalar, r), and the amplitude of the astronomical target frequencies (vector, a). With respect to this, the discussion in the manuscript gives an incorrect impression of how the analysis is actually conducted. Evaluation of the Matlab code indicates that Equation 2, in its full form, is not being used to generate the “synthetic spectra” as suggested (lines 164-169), as the amplitudes are not considered (vector, a). Furthermore, there is discussion in the manuscript regarding the shape of the spectral peaks in the synthetic spectra (vector, w), but the shape of spectral peaks is not considered in the “synthetic spectra” generation in the Matlab code. Instead, the code is concerned with sedimentation rate, and its impact on the location of the target astronomical frequencies (step 3.2).

There is an important nuance in reviewer 3’s understanding of AstroComb that we need to correct.

The synthetic spectrum is encoded in 3 mathematical objects: (1) the vector of Milankovic wave-numbers **k**, (2) the vector **w** with the shape of the spectral lines, and (3) the vector **a** of amplitudes of the spectral lines. For each value of the sedimentation rate, we first compute the vector of Milankovic wave-numbers. This vector is convolved with **w** and multiplied with the amplitudes in **a**. The computation of **k** can be found directly in the code (in the function 'computeSedRatePdfs'). The vector with the shape of the spectral line cannot be found directly, because **w** is automatically applied through the specification of the number of samples - including zero padding - used in the spectrum (the more samples, the "broader" the spectral line). The amplitude vector **a** is not input to the computation, but implicitly determined during the process of computing the likelihood. Hence, it is not directly visible in the code. **Importantly, we stress that we are not interested in the amplitudes, only in the wave numbers.**

To clarify this further, we added a sentence to manuscript line 420:

The amplitudes of such periods could be significant, but they are ignored by our algorithm, since we are not interested in the amplitudes, only in the wave number.

89
It is important for the manuscript text to be clearer about what is being done, in terms of how the algorithm is conducting the analysis and evaluating the fit of the “data” to the “model”. For example, there is no indication about the quadratic detrending of the data series in each window, or the spectral background estimation using a sum of 3 decaying exponentials, etc. (see Section 3.1). The methodology description in the manuscript should be sufficient such that the code can, with appropriate expertise and time, be reproduced. In other words, a reader should not be required to consult the code for an accurate description of the essential methodology.

It is important to distinguish between what is belonging to the new methodology presented (and hence necessary for the method to operate according to its principles), and what are minor numerical operations that are replaceable without changing the core methodology. We consider the detrending in data and spectral domains as minor numerical operations that could be replaced, without changing the core method. In our most recent version of AstroComb (revised after submission) we have, in fact, changed the spectral background estimation. The effect was almost invisible, but the computational efficiency higher.

The latest version of the AstroComb algorithm will be curated and made available from this Zenodo website: https://zenodo.org/records/17966228

90

The AstroComb method can be considered an adaptation of the method of Malinverno et al. (2010). Reference to that study, as providing a precedence, is essential. A key innovation of AstroComb is the simultaneous evaluation of multichannel data. The only other instance I know of doing so is in a 2023 GSA conference abstract by Trayler et al. (2023; hfps://gsa.confex.com/gsa/2023AM/meetingapp.cgi/Paper/393427). Thec AstroBayes approach also uses an adaptation of the method of Malinverno et al. (2010).

Citation to Malinverno et al. (2010) is now added in Line 216.

91

When implementing the multichannel approach, it is important to note that covariance of geochemical data is common, while elements also express variable signal/noise. Appropriate treatment of the covariance/likelihoods is typically important when combining multiple datasets. It would be helpful if the authors spoke more to this issue.

The elemental variations can be correlated in two ways: (1) Because the experimental measurements introduce (possibly unavoidable) correlations. We have not incorporated these correlations, because they are unknown to us. (2) Because the elemental variations are generated by the same, underlying sedimentation rate mechanisms. Those correlations are included in our analysis through the forward model.

92

Appropriate determination of the spectral background is critical to the estimation of the probabilities/likelihoods, and this has been a topic of considerable debate in the cyclostratigraphic community (see reviews in Vaughan et al., 2011; Meyers, 2012; Vaughan et al., 2014, Meyers, 2019; Weedon, 2022). I found it interesting that AstroComb uses an L1 fit of the sum of 3 decaying exponentials for the spectral background fivng, as this is not typical in cyclostratigraphy. This may be a valid approach for some data sets, but the fit of the model to the data spectrum background ("spectral continuum") must be validated for the probabilities to be reliable (e.g., see Malinverno and Meyers, 2024).

Agreed. We believe, however, that classical misfit approaches are much more sensitive to the background trend removal than the spectral peak detection method used in our likelihood calculation.

93

Please provide additional theoretical justification for the probability estimation approach (e.g., Equations 4-7), which is used instead of the more typical approach for spectra (e.g., Malinverno et al., 2010).

Additional theoretical justification for the probability estimation approach is now added in line 214ff:

In our computation of the likelihood, data uncertainties are provided by the user as the probability that a peak in the observed spectrum is a Milankovic peak. Existing data-fitting-based methods (Meyers and Sageman (2007); Malinverno et al. (2010), TimeOpt: Meyers (2015), TimeOptMCMC: Meyers and Malinverno (2018); AstroGeoFit: Hoang et al. (2025)) are purely based on misfits between data (elemental records) and synthetic signals (generated from assumed Milankovic periods), but AstroComb is instead aimed at simulating the data uncertainty evaluation carried out by practitioners analyzing observational data. In traditional misfit calculations you not only need experimental uncertainties, but also components of the data that are not modeled by the Milankovic cycles. The latter are significant, but not directly available (for example, The TimeOptMCMC algorithm Meyers and Malinverno (2018) estimate them through a Hierarchical Bayes approach). However, in our approach we are automatically taking alle data uncertainty sources into account, including the practitioner's confidence in identifying spectral peaks.

94
Since AstroComb is a moving window approach, the results are smoothed at the scale of the window size (as is the case with eASM, eTimeOpt and eCOCO); this is like a lowpass filter . Thus, the lack of smoothing claimed in the manuscript text appears overstated (lines 13-15 of abstract).

Yes. Corrected. Line 111ff now reads:

Rather, than assuming a constant or globally smoothed rate model, our approach treats sedimentation as a piecewise continuous process, allowing for abrupt or non-linear changes across the stratigraphic column.

You are right in your statement about the inherent smoothing due to the window size, but there is no further smoothness assumption on the sedimentation rate vs. depth function. Two windows with neighboring center locations are not prevented from giving widely different maximum a posteriori sedimentation rates. This is in contrast to classical least-squares fits that impose smoothness on the solutions.

95.
AstroComb uses an overlapping moving window, while the method of Malinverno et al. (2010; see also AstroBayes of Trayler et al., 2024, which builds on this method) defines the analysis segments, based on an initial assessment of stable stratigraphic intervals. There are advantages to both approaches. Explicitly defining the "layer boundaries", can help to optimize detection using prior stratigraphic knowledge and evaluation, and can guard against overinterpretation. The overlapping window approach can help to resolve shorter term shifts in sedimentation rate variability.

It is tempting to use initial assessment of stable stratigraphic intervals. However, in this way you "use the same data twice", thereby putting additional weight on (part of) the data. This is incompatible with correct uncertainty quantification, because it effectively reduces the error bars on (part of) the data.

96.
Related to the last comment, prior to the application of AstroComb and other such methods, it is important to evaluate bedding stability using time-frequency methods (e.g., spectrogram or evolutive harmonic analysis; Meyers et al., 2001), and to consider the stratigraphic context (including biostratigraphy, available geochronology, etc.), to inform the analysis (e.g., potential hiatus, etc.).

We agree.

97.
The Kullback-Leibler information measure (Equation 13) is an intriguing addition to the methodology. I suspect that it will be unfamiliar to most readers, so it would be helpful to provide discussion of what it means, in a more generally accessible manner. For example, explain what is meant by “information content”.

Yes. See also comment above. We have added a note and reference to the original paper. L205ff now elaborates on the meaning of the KI information measure:

Theoretically, the Kullback-Leibler information measures the expected number of yes/no questions needed to update our state of information from what is given by u(r) (here total ignorance) to what is given by $p_z(r)$ *(here, the posterior distribution).*

98.
A potential challenge for AstroComb and other methods that seek to reconstruct variable sedimentation rates (eASM, eTimeOpt, eCOCO, AstroGeoFit) is that, due to changing signal/noise, one may be inferring astronomical signals through intervals where they are not present. While some methods provide hypothesis testing in an attempt to guard against this, nonetheless, it is not unusual to see intervals with dubiously low signal/noise. It will be important for the authors to speak to this issue, to guide users on when the AstroComb results are reliable. For example, it seems that the Kullback-Leibler information measure is useful for this purpose, but more guidance on this would be helpful .

Kullback-Leibler information is a measure of the reliability of the detection of astronomical signals. We believe that this is now explained in the text where we present the Kullback-Leibler information, and also in the caption of Figure 3.

Reviewer 3's more detailed comments

99
Lines 13-15: As noted above, the sedimentation rates derived from AstroComb are smoothed at the scale of the window. This provides a limit on the resolution of sedimentation rate changes throughout a stratigraphic record, similar to other ‘windowed’ approaches (e.g., eASM, eTimeOpt, eCOCO).

See our comment above.

100
Line 17: The use of the term "astronomical tie points" might be a bit confusing to readers. In principle, the derived "floating time scales" can be anchored to reliable radioisotopic/ biostratigraphic/chemostratigraphic/magnetostratigraphic data. For the last ~60 Ma the theoretical astronomical solutions ("astronomical tie points") also provide a means for anchoring astronomical time scales (given other appropriate constraints, e.g., paleomag data).

Yes. We revised the text to distinguish between geological time and geological age modeling. Line 15ff now reads:

By detecting and statistically constraining Milankovitch cycles preserved in stratigraphic signals, the algorithm seeks a floating age-depth model that reconstricts geological time and can be anchored to deliver absolute ages, where astronomical tie points or radiometrix ages are available.

101
Lines 19-22: As noted earlier in this review, numerous approaches have been previously developed that combine cycle detection and stratigraphic modeling, and the approach here is similar to the method of Malinverno et al. (2010). It is critical to discuss this in the manuscript.

Reference added.

102
Line 20: The claim of "preserving fine-scale depositional variability" is overstated here, as the scale is fundamentally limited by the size of the moving window. For example, the approach cannot resolve precession-scale variability. Note that methods to resolve such "bedding-scale" sedimentation variability have been published (e.g., Schiffelbein and Dorman, 1986; Gamma method of Kominz and Bond, 1990; TimeOptTemplate of Meyers, 2019; Alpha method of Ma et al., 2020).

Yes and no. We clarified in Line 257 the abrupt change is reconstructed well in the synthetic data (no smoothing of sedimentation rate variation along stratigraphy), but the position of where the abrupt shift occurs is uncertain:

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 texttAstroComb algorithm (figure 3). Sedimentation rates are not "smoothened", but the timing of the abrup change appears uncertain.

103
Lines 27: For appropriate scholarship, please add citation(s) for astrochronology as a methodology (e.g., Hinnov, 2013 and references therein).

Reference has been added to Line 27.

104
Lines 28-33. The description here of methods could be improved. Based on the references, I would replace "repetitive spectral features" with "repetitive bedding cycles", and replace "spectral filtering" with "spectral analysis". The passage mentions numerous other methods

(TimeOpt, TimeOptMCMC, AstroGeoFit, eTimeOpt, eCOCO, etc.) all of which are inverse methods that tune to astronomical target frequencies, in some fashion or other. The passage is missing key methodologies, including the one that is most similar to AstroComb, which is Malinverno et al. (2010). See Sec<on 2 of this review for more information.

Corrected. See also comment above A careful introduction to cyclostratigraphic methods is summarized in line 40-55

105
Line 34: Change “Despite sedimentation is” to “Despite the fact that sedimentation is”

Line 58 now reads:
“Sedimentation is an inherently episodic process (Kemp and Sexton, 2014)”

106
Line 45: change “has been” to “was”

This paragraph has been revised and the expression deleted.

107
Lines 34-49. The statements noted here about the challenge of variable sedimentation are indeed key issues that need to be carefully considered. In this regard, the AstroComb method has the same fundamental limitations as many other published moving window methods (e.g., eASM, eTimeOpt, eCOCO).

Agreed. This paragraph has been revised. See lines 40-55.

108
Lines 47-49. For appropriate scholarship, this passage should reference prior work that makes the same claim (see Sec<on 2 of this review).

Agreed. This paragraph has been revised. See lines 40-55.

109
Line 58. As AstroComb is a moving window method, fundamentally it imposes a smoothing (constant sedimentation rate within the analysis window).

Not quite. Recall, the sedimentation rate obtained in a given window is by AstroComb only used to assign a sedimentation rate to the midpoint of the window. It may seem surprising (at first glance, it was to us), but abrupt sedimentation rate change arises when data requires it. See synthetic data.

110
Lines 60-64: As noted earlier, the primary innovation here is the use of multichannel data, while the basic framework builds on the method of Malinverno et al. (2010) (see Sections 2 & 3).

AstroComb innovates both in terms of a new probabilistic formulation and applicability to multi-channel data. See comments above.

111
Lines 77-78: Here, sub-precession scale changes in sedimentation are mentioned with reference to another algorithm that is not yet published ("ProBE4T"; Fernandes et al., 2026). I have not been able to locate ProBE4T online.

We have removed the reference to the unpublished paper by Fernandes et al., 2026.

112
Line 86: remove "here"

Deleted

113
Lines 101-112: This section of the manuscript doesn't sound like a "workflow of AstroComb", but rather a description of the outline of the manuscript.

Section 2.5 describes the AstroComb algorithm and how the code computes it. We added what information is supplied by the user, incl.

Step 2: *(an interval with length, e.g., 2–4 m chosen by the user)*
Step 3: *(the threshold of which is defined by the user),*
Step 5: *Also, an age-depth model is derived when the user defines an age-depth anchor.*

114
Line 111: change "evaluate" to "evaluates"

Corrected.

115
Lines 113-115: The use of multichannel data is a key innovation (the only other instance I know of is in a 2023 GSA conference abstract by Trayler et al. (2023; hfps://gsa.confex.com/gsa/2023AM/meeIngapp.cgi/Paper/393427)

Thanks. This paper is now cited in the introduction

116
Line 121: The manuscript correctly notes that the AstroComb method works "under the assumption that certain stratigraphic signals (e.g., elemental variability) reflect astronomical forcing." Therefore, before interpreting AstroComb results as reliable, it is important to test this assumpIon, which is a key component of many of the published methods (ASM, TimeOpt, TimeOptTemplate, TimeOptB, COCO, AstroGeoFit, etc.). It should be noted in the manuscript that initial hypothesis testing is prudent, before applying AstroComb, and a range of published methods are available to do so.

Indeed, there are several ways to test whether observed periodicities are Milankovitch periods. This is beyond the scope of the current version of the AstroComb algorithm. We have revised the text accordingly. Line 77ff now reads:

The current version of AstroComb is not designed to further validate whether identified Milankovitch periods are indeed driven by insolation variations (e.g. eccentricity-driven amplitude modulations on precession and/or obliquity cycles).

117

Lines 145-146: For the discussion of the distortion of spectra, it would be good to reference past studies that have addressed this, such as Schiffelbein and Dorman (1986), Ripepe and Fischer (1991), Herbert (1994) and Meyers et al. (2001).

The references are now added. Indeed, these papers do address the distortion of spectral peaks.

118

Line 149: Note that there are two components to the theoretical astronomical solutions: the orbital part and rotational component (see Laskar, 2020).

Yes. We know. We are not using the closed-form astronomical solution, but the target astronomical spectrum as described in section 2.3 (line 231ff).

119

Line 166: Change “computed data spectra” to “computed synthetic spectra”

‘data’ is now replaced with the better ‘synthetic’.

120

Equations 4, 5, 7, 8: Please use a different notation for “a”, which has already been used as the vector of amplitudes (Equations 2 and 3).

In equation 2, ‘*a*’ is now replaced with ‘a’.

121

Figure 2: Please indicate the depths on the y-axis.

Corrected.

122

Figure 3: It would be valuable to show a time-frequency analysis (spectrogram, evolutive harmonics analysis) with the same window size. Are the time-frequency results compatible with the AstroComb results?

A comparison between AstroComb and previous methods is now added to figure 7 and 9

123

Lines 264-265 and 337: Change “elements” to “elemental”

Corrected

124
Line 291: Change “beteen” to “between”

Corrected