Peer review „Bayesian Integration of Astrochronology and Radioisotope Geochronology”

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In their manuscript, Trayler et al. introduce a novel R package named *astroBayes*, designed for constructing geologic age-depth models that incorporate both radio-isotopic dates and astrochronologic information. To create such a model for a specific section, the user must provide four key pieces of information:

1. A proxy depth-series containing an **assumed** astronomical imprint. At this stage, user input is minimal, and the choice of proxy and its sampling interval is the primary user consideration.
2. Geochronologic dates for the section (stratigraphic position, age, and uncertainty). This input also does not require additional user intervention/decisions.
3. Target frequencies, represented as a vector of astronomical frequencies that are expected to be imprinted in the proxy depth-series mentioned above. The user's input is essential at this stage and likely influences the results in a considerate manner. The potential impact of this user choice becomes evident in the manuscript: The authors made different target frequency choices for the synthetic data sets (Table 2) and the Bridge Creek dataset (Table 4). The different selections raise concerns regarding whether the authors may be favoring certain results by adjusting these frequencies. Notably, the Bridge Creek dataset uses three obliquity periods, despite two of those obliquity components have significantly lower amplitudes compared to the primary 39-kyr obliquity forcing. It also uses only a single precession period, despite precession being influenced by multiple quasi-periodicities.
4. Layer boundaries, representing stratigraphic positions where sedimentation rate changes are expected based on visual inspection of an evolving power spectrum or sedimentological indicators (e.g., hardgrounds, hiatuses, lithology changes). This piece of information is notably user-dependent.

The manuscript is generally well-written and clear. The authors succeed in conveying the general idea behind the algorithm. However, **throughout the manuscript, the authors overlook two critical questions**: First, it remains unclear as to what extent the age-depth model results are **influenced by the user's selection of layer boundaries** (both the number of boundaries and their stratigraphic positions). Second, the authors do not describe the **behavior of the *astroBayes* model when applied to a pure-noise proxy depth-series**.

To investigate the second question, I ran the *astroBayes* model with a purely random noise signal (autoregressive noise with a rho value of 0.9). Apart from the pure-noise character, other depth-series characteristics were similar to the test “cyclostratigraphy” dataset provided in the R package. It appears that, indeed, for a depth-series without an astronomical signal, the age-depth model produces wider uncertainty bands compared to depth-series with an astronomical signal. Nevertheless, these uncertainty bands remain considerably narrower than the "Bchron sausages" referenced in the authors' Figure 3. Obviously, this is because the assumption of piecewise constant sedimentation rates is inherent to the *astroBayes* model. This obviously remains a questionable assumption to make, and to my taste, this assumption does not fully acknowledge true geologic variability in sedimentation rate and the possibility of cryptic hiatuses anywhere in the section. Hence, to my taste, the uncertainty bands for the “pure noise” series in the Figure below seem somewhat over-optimistic, particularly within the interval between bentonite B and C. I recommend that the authors write a dedicated section in the discussion to address this question, explicitly addressing the assumption of piecewise linear interpolation in-between layer boundaries. This is of paramount importance because the algorithm's user-friendliness can make it highly susceptible to misuse.

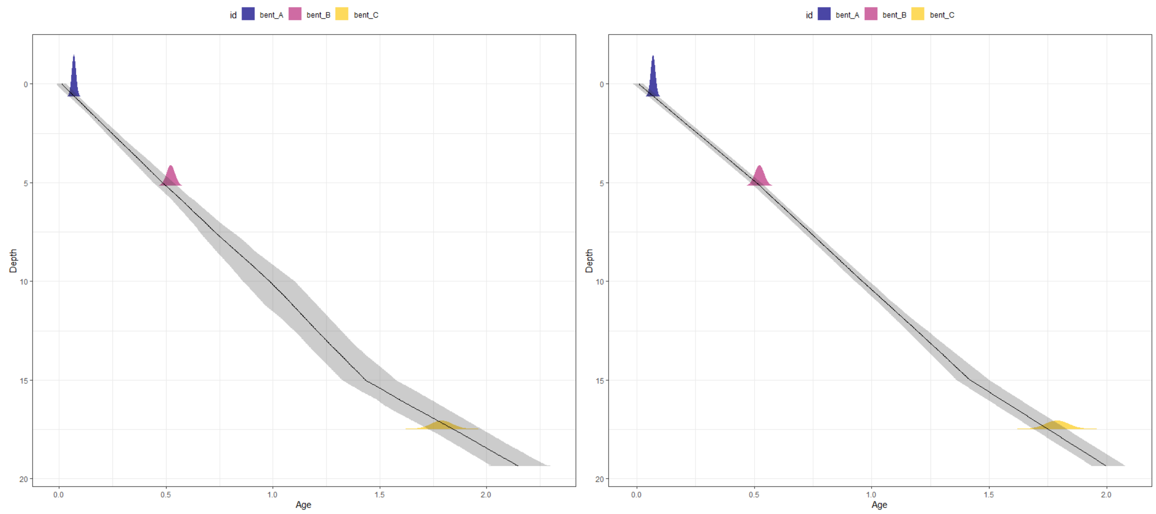

Figure: comparison of astroBayes age-depth model result using a signal without (left) and with (right) astronomical imprint.

I was also wondering how the model performs when there is an outlier radio-isotopic date? From what point onward, will astroBayes ignore this outlier? Answering this question will require some sensitivity runs, I assume.

Minor comments:

- Line 14: Anchoring chronologies CAN rely on radio-isotopic geochronology… but can also rely on other stratigraphic markers (magnetostratigraphic reversals, biostratigraphic datums, event stratigraphic markers). Are there any ideas about how to incorporate stratigraphic uncertainties on such dates into the astroBayes model?
- Line 28: I find the end of the abstract rather weak. The last sentence does not represent the big “take-home” message for the reader of this paper.
- Line 45: I would recommend a consistent use of Ma and ka for “million years ago” and “thousand years ago” (absolute time, ages). Myr and kyr for “million years” and “thousand years” (durations, relative time differences). In any case, there is no consistent use of these abbreviations throughout the manuscript.
- Line 129 - 148: I would move this part to the end of the Introduction, discussing previous attempts to integrate radio-isotopic dates and astrochronologic interpretations.
- Line 73-77: Repetition of information that was already given in the Introduction.
- Line 82: Wrong Berger et al. citation. You probably mean André Berger et al. 198X or 199X.
- Figure 2f: I can’t recognize why the authors drew the horizontal dashed lines (layer boundary positions) at those exact depths. There are no obvious features in the evolutive spectrum that would make me draw them exactly there.
- Line 324 – 325: Not really relevant that future model developments could make the positioning of layers more objective… The required user input in the current version of the algorithm, to me, represents the Achilles heel of your work right now.
- Figure 4: I do not see any points, nor error bars

- Figure 8: Batenburg et al. suggested two tuning options, with an astronomically-tuned age for the C-T boundary of either 93.69 +- 0.15 Ma (Tuning 1) or 94.10 +- 0.15 Ma (Tuning 2).
- Line 396: model → models
- Figure 5: Was the hiatus already known prior to this study? Or was it discovered by astroBayes?
- Figure 6: Which of the two models in Figure 5 are we looking at here? Or is the result in Figure 6 identical for both models in Figure 5?
- Line 466: Case 2 from the Cyclostratigraphic Intercomparison Project was designed by Christian Zeeden, not by Matthias Sinnesael. He should be acknowledged here.