# *Author's response for* Transient Attracting Profiles in the Great Pacific Garbage Patch

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**Preface**

We thank the referees for their careful summary of our research project and for their helpful comments on our paper. In the following, we provide a detailed point-by-point response to all referee comments and specify all changes in the revised manuscript. Our response to a referee comment is structured in three steps: (1) *comment* from the referee, (2) author's *reply*, (3) author's *changes* in the manuscript. In addition, we provide a marked-up manuscript version showing the changes made using the latexdiff command. This version is the reference for line numbers in the following replies.

## 1 Replies to referee 1

### 1.1 Mesoscale velocity data

*comment*

**The mesoscale currents used for the analysis are likely only marginally applicable for predicting the small-scale distribution of garbage on a day-to-day basis and thus would only marginally help in any real cleanup efforts, which is the main motivation that the authors give for this work. I am not convinced that TRAPs and their statistics would be unchanged if the submesoscale flow features were resolved. This should be clearly explained, so as not to overstate the usability of TRAPs for real garbage cleanup.**

*reply*

We appreciate the comment and agree that in the manuscript, we should highlight that different statistics may result for TRAPs computed from submesoscale velocities. It is also true that we do not obtain any fine details from the altimetry data used here, but if submesoscale flow features would alter the motion of a drifter over a few days, we would see it in our drifter experiment. We could think of it as retaining an aggregate effect of submesoscale motion, which is the relevant effect for our purposes and the time scales we are interested in. Further, we will briefly describe a potential application of mesoscale TRAPs in combination with vessel-based methods to detect debris and submesoscale flow features in the surroundings of a cleanup operation.

*changes*

We address this with the changes made in lines 560 - 580, 582 - 595 and line 18.

### 1.2 Parameter choices

*comment*

**There are several subjective choices that likely affect the statistical results. First, limiting traps to 1 deg arclength seems both arbitrary and unnecessary. I don't think it is necessary to put any limit on TRAPs lengths. It would be better to identify the full extent of a TRAP line length and analyze its statistics.**

*reply*

Higher thresholds for TRAP lengths automatically lead to less distinction between nearby structures. A stop condition for the integration of a TRAP curve like the 30 % attraction strength criterion introduced by Serra et al. (2020) is necessary to obtain distinguishable TRAPs instead of infinitely long tangents to a subset of the eigenvector field $\boldsymbol{e}_2(\boldsymbol{x}, t)$. This cutoff criterion makes sense physically because the attraction of nearby parcels becomes negligible as distance increases away from the core. We will illustrate this in a new Fig. S1 in the Supplementary Material where TRAPs are cut off wherever the attraction strength falls below 30 % of the core attraction, in panel (a), and where no such stop condition applies, in panel (b). Considering the profiles in panel (a), we acknowledge that a second length condition like the 1 degree arclength might then be redundant. However, our statistics refer to the position and attraction of the TRAP *core*, and the main diagnostics of the paper do not depend on TRAP length. There are only two definitions that are dependent on TRAP length:

1. the radius of the vorticity curve parameterisation: without a maximal arclength of 1 degree, one would have to define an upper limit for the radius to capture the vorticity field sufficiently close to the TRAP core

2. the rotation angle for the composite maps of drifter velocities in the vicinity of TRAPs: without a maximal arclength of 1 degree, one would have to define for every drifter-TRAP pair the part of the TRAP curve that needs to align with the zonal axis, such that the rotation of all drifter trajectories allows to identify patterns in a composite map (or apply another mapping)

We consider the choice of 1 degree arclength acceptable for our purposes since our conclusions are insensitive to this choice. But we also recommend dropping this second condition in future studies.

*changes*

We address this with the changes made in lines 162 - 170.

We complement this by inserting the new Fig. S1 in the Supplementary Material.

*comment*

**Second, a 75 km radius was used for the pairing of drifters and TRAPs. Again, this seems like an arbitrary and unnecessary choice. It would be better to define the area of influence for each TRAP around the local minimum, perform statistical analysis of the basin of influence, and use the basin of influence for pairing with drifters.**

*reply*

In the readme 'Drifter-TRAP pair detection' within the repository of the pair algorithm we state:

> 75 kilometres is roughly about 1.5 times the average speed radius of mesoscale eddy detections in this region which we consult from The altimetric Mesoscale Eddy Trajectory Atlas (META3.2 DT) provided by AVISO+ et al. (2022).

This seemed a reasonable search radius to us, considering that we look for drifter movement in the periphery of eddies. We acknowledge that this choice seems arbitrary and explain our further motivation for it. We have run this algorithm for different values of the search radius $r$ ranging from 50 km to 300 km. 86 % of all drifter days occur within 75 km distance to their closest TRAP core. The mean distance and its standard deviation of drogued drifters to their closest TRAP core are $\overline{d} \approx (51 \pm 25)$ km, for undrogued ones it results in $\overline{d} \approx (49 \pm 24)$ km. The mean distance between TRAP cores is around $\overline{d} \approx (78 \pm 29)$ km. We will provide a new Fig. S3 in the Supplementary Material that shows the respective distributions of distances between drifter positions and their closest TRAP core, as well as between TRAP core positions and their closest, neighbouring TRAP core. Panel (b) emphasises that the vast majority of drifter positions is within a radius of 75 km. Beyond this limit, data is insufficient to derive more conclusions than the ones shown in Figure 10 of the manuscript.

For the 14 % of drifter days beyond the 75 km limit, we observe a significant increase in the number of one-day pairings. If drifters are really attracted in a far distance, it is likely that they meet other structures along the way, which terminates the pairing algorithm. Such a one-day 'retention' becomes arguable considering the temporal resolution of the data as well as the distance to the actual structure. Short-term pairings with distant drifters can also occur when a TRAP attracts a distant drifter but dissipates during the drifter's approach. To address this, we also tested a search radius based on the remaining lifetime of a TRAP, which reduced the number of short-term pairings but did not lead to any remarkable insights. With these aspects and the coarse resolution of our data in mind, it seemed straightforward and reasonable to us to apply a 75 km threshold from the beginning.

Our pair algorithm searches for the closest TRAP around a drifter, and therefore, its detection is insensitive to the individual attraction strength or impact range of surrounding TRAPs. As a consequence, drifters may be located within the impact range of one TRAP but will be assigned to another TRAP if the latter is closer, even if the drifter is beyond its impact range. This could lead to a short-term pairing with the closer TRAP and an underestimated retention time with the impacting TRAP, towards which the drifter will be eventually attracted. Therefore, considering the actual impact range of a TRAP could improve the accuracy of retention times and motion patterns of drifters around TRAPs. The definition of a dynamic impact range would be a valuable contribution to the TRAPs concept and would also benefit its operational application. We are currently not aware of a mathematical definition for an objective 'basin of attraction' that is compatible with the concept. However, basins of attraction are a known concept from dynamical systems theory, e.g. see Strogatz (2014); Heitzig et al. (2016); Menck et al. (2013). We also think that the eigenvalue fields $s_i(\boldsymbol{x}, t)$ and eigenvector fields $\boldsymbol{e}_i(\boldsymbol{x}, t)$ contain more information that can be used for such a definition.

This endeavour opens a variety of theoretical questions which would be better placed in a separate research project. Our observational study can serve as an example of motivation. The approach we use is sufficient to show the aggregate effect of TRAPs on drifters and to provide a first estimate of the retention times that drifters can spend around a TRAP.

*changes*

We address this with the changes made in lines 256 - 275.
We complement this by inserting the new Fig. S3 in the Supplementary Material.

### 1.3 Drifter retention

*comment*

**The authors seem to suggest that drifters (and other floating objects like garbage) are more likely to be found near TRAPs than in other regions of the flow. However, I don't think there is any confirmation of this claim in the paper. It would be interesting to compare the statistics for the drifters occurrences and retention times within TRAPs to that within the mesoscale eddies and maybe even for a random subset of regions of comparable size and spatial distribution.**

*reply*

We would like to clarify that we are not looking for encounter probabilities of drifters around TRAPs in comparison to other regions of the flow. Rather, we are looking for regions of confluence and separation where drifters and floating objects will aggregate, even if temporarily, due to the hyperbolic structures that TRAPs identify. It would be worthwhile to study the likelihood of drifters to be found near TRAPs. We did investigate drifter times spent around TRAPs and within mesoscale eddies. In line 434 of the initial version of the manuscript, we mention this aspect and point to Fig. S3 in the initial Supplementary Material, where we present the time series of drifter days identified around both structures. We acknowledge that this part needs more clarification and will improve the description in the conclusions of the revised version.

*changes*

We address this by correcting an unfortunate word choice in line 427.

We address this with the changes made in lines 481 - 482 and 523 - 532.

Fig. S3 in the Supplementary Material of the initial manuscript becomes the new Fig. S5 in the Supplementary Material of the revised version.

## 2 Replies to referee 2

### 2.1 Temporal continuity of TRAPs

*comment*

**The most important issue to address is the temporal continuity of TRAPs. TRAPs by definition, are features that arise in the instantaneous velocity field, and the Serra et al. (2020) paper describes TRAPs as *'short-term attractors'*, and that *'TRAPs necessarily persist over short times'*, with an example of a TRAP existing for several hours. They used a high-spatial resolution HF Radar dataset, along with a high-resolution MIT-MSEAS forecast model with hourly output. Their focus was, of course, on the timescale of hours due to the search and rescue nature of their paper.**

**Lifetimes of TRAPs in this manuscript are in the timescale of days to almost a year long, and it's not clear to me how spatially proximate detections of TRAPs at consecutive timesteps necessarily determine that these TRAPs are the same object. TRAPs are, by definition, instantaneous features that *'necessarily persist over short times'* (Serra et al. (2020)). They could emerge, persist for hours, and later die, all within a day.**

**Can the authors provide more evidence on why TRAPs can be tracked on timescales of days (and months), when they may not exist for more than, as I understand, a few hours? Could successive TRAP identifications simply be older TRAPs decaying and newer TRAPs emerging? The comparison with drifter-TRAP pairs shows typical retention times of just a few days, with the largest retention time being 46 days, far shorter than the longest lifetime of a tracked TRAP. As it stands, I don't think there is enough in the manuscript to make that connection, and additional justification is needed.**

*reply*

We appreciate the comment and agree that this is an important aspect that needs clarification. The theory behind TRAPs guarantees their existence for short periods but says nothing about their existence at larger timescales. When Serra et al. (2020) mention that TRAPs 'necessarily persist over short times', they are not implying they cannot persist for longer periods. Serra et al. (2020) chose a period of six hours, which is a reasonable choice for a "short" timescale (relative to typical oceanic timescales) and, importantly, a critical timescale for search and rescue operations. However, the lifespan of a TRAP depends on the oceanic structures that give rise to the hyperbolic-type Lagrangian motion that TRAPs are designed to identify. Indeed, Serra and Haller (2016) show different types of OECSs, including TRAPs, computed from altimetry data, that last at least six days. In our paper, we show that TRAPs are closely related to vorticity patterns in general and eddy-like features in particular. Thus, we do not find it surprising that mesoscale TRAPs would have lifetimes comparable to those mesoscale features, typically measured in months and not days.

We note that our drifter-TRAP pair results are observations of the hyperbolic-type Lagrangian motion induced by TRAPs, and therefore, a confirmation of the persistence of TRAPs over periods considerably longer than a few hours. We know from our drifter-TRAP statistics that, over about a week, drifters are attracted normally to a TRAP, to then accelerate and leave the TRAP in a tangential direction. Given that the drifter and altimetry datasets are independent oceanic observations, we have shown that TRAPs often persist for at least a week. However, due to the relatively quick transport time of a drifter in the vicinity of a TRAP, it should be expected that a TRAP's lifetime can be considerably longer than a week. Hence, the fact that we observe small drifter retention times is not at odds with long TRAP lifetimes. Importantly, we note that the behaviour of drifters in the vicinity of TRAPs that are forming or decaying is clearly distinct from the hyperbolic behaviour that is observed in drifters when TRAPs neither form nor decay. Thus, the trajectories of drifters in the vicinity of TRAPs prove that we are following the same TRAP and that we are not following different TRAPs that form and decay quickly at similar locations.

An independent example of satellite-observed TRAPs that persist for at least a week while inducing independently-observed tracer deformation can be found in Duran et al. (2021).

Moreover, our study shows from large datasets that TRAPs persist over periods considerably longer than the short period for which they are mathematically guaranteed to exist. We explicitly state this result in a new paragraph of the revised manuscript.

*changes*
We address this with the changes made in lines 98 - 108 and 545 - 558.

### 2.2 Additional mathematical rigour

*comment*
**Section 2.1 Transient Attracting Profiles. This section would benefit from a more thorough description of the theory of TRAPs. In particular, additional rigour in the mathematics is required to make the method more readable to users. As I understand, $s_i = s_i(\boldsymbol{x}, t)$ are, in fact, eigenvalue fields, and $\boldsymbol{e}_i = \boldsymbol{e}_i(\boldsymbol{x}, t)$ are eigenvector fields. The manuscript then describes $\boldsymbol{e}_1$-lines and $\boldsymbol{e}_2$-lines, along with local minima of $s_1$ and local maxima of $s_2$ , which from the current description of $s_i$ and $\boldsymbol{e}_i$ don't make sense. This section (and later sections) would benefit from more careful notation and rigour.**

*reply*
We acknowledge that our mathematical description of the concept requires more clarification. We will also differentiate more carefully between field quantities $\mathbf{S}(\boldsymbol{x}, t)$, $s_i(\boldsymbol{x}, t)$ and $\boldsymbol{e}_i(\boldsymbol{x}, t)$ and local quantities $\mathbf{S}$, $s_i$ and $\boldsymbol{e}_i$ throughout the rest of the manuscript.

*changes*

We address this with the changes made in lines 126 - 156, in the caption of Fig. 2 line 158, in the caption of Fig. 3 line 242, in the caption of Fig. 6 in line 377, in the caption of Fig. A2 line 606, in row 3 of Table B1 line 607 and in Table B2 line 607.

### 2.3 Spatial analysis of TRAP trajectories

*comment*

**Section 3.1 Spatial distribution of TRAPs. I like the spatial analysis, however I think it is hampered by the same problem that spatial analyses using Lagrangian approaches have. Specifically, that trajectories of TRAPs (like Lagrangian particles) that start outside of the domain and later enter the domain (or TRAPs that start in the domain and shortly exit the domain), will be undersampled throughout their true lifetimes, and necessarily have shorter lifetimes (on average) than those that start and remain in the domain throughout their entire lifetimes. Given the size of the domain, the timescales of the largest TRAP lifetimes, and the 20-year duration of the dataset, can the authors comment on any bias this might have on the analysis?**

*reply*

We acknowledge that this effect occurs within our tracking procedure. We also consider it important to clarify any bias on our lifetime statistics since our analysis depends on TRAP lifetime. We find that only 5.4 % of detected trajectories are adjacent to the limits of our study domain and period, and therefore, could be susceptible to an underestimation of trajectory length. However, this set of potentially biased trajectories has no impact on our lifetime statistics. We highlight this in the revised description of our tracking algorithm, and we point the reader to a detailed explanation together with a new Fig. S8 and Table S2 within the new Section S3 of the Supplementary Material.

*changes*

We address this with the changes made in lines 190 - 195.

We complement this by inserting the new Section S3, including a new Fig. S8 and a new Table S2, in the Supplementary Material.

### 2.4 Minor comments

*comment*

**Overall, the manuscript would benefit from additional editing, for language and grammar, as some parts of the manuscript are a little hard to follow.**

*reply*

We apply many minor revisions to improve spelling and grammar or to meet the quality standards of OS. We call these minor revisions because they aim to enhance the easiness of reading and understanding our paper without changing the meaning of the original content. Some of these revisions imply a rewording of sentences or paragraphs.

*changes*

The correction for spelling and grammar involves a large number of minor changes throughout the entire manuscript, which we don't list here for brevity.

*comment*

**The abstract contains notation ($\overline{\Lambda}$, and $\overline{\varphi}$) which are somewhat confusing if not explained, I would stick to more plain language.**

*reply*

We agree and will use plain language for the abstract.

*changes*

We address this with the changes made in lines 15 - 16 and 20 - 21.

*comment*

**Throughout the manuscript, the authors describe 'attractive regions' in the flow. To be consistent with typical dynamical systems literature, these should be described as 'attracting regions', 'attractors', or 'regions of high attraction'.**

*reply*

We agree and will change the term "attractive" to "attracting" except for the terms "attractive properties of TRAPs" and "increasingly attractive TRAPs", where "attractive" seems to be the less ambiguous choice.

*changes*

We address this with the changes made in lines 7 - 8, 12, 29, 66 - 67, 138, 244 and 294.

*comment*

**Line 73, the authors mention 'inevitable errors'. Can they expand on what these errors are? Inevitable in the sense of those that Serra et al. (2020) mention with numerical integration schemes, or other errors?**

*reply*

We mean inevitable errors in the sense of those described in Serra et al. (2020).

*changes*

We address this with the changes made in lines 78 - 79.

*comment*

**In Section 2.2-2.6, the authors use a maximal arclength of 1°, a search area of $\epsilon$ = 0.25° (which corresponds to the model resolution), and a maximal drifter-TRAP pair distance of 75km. These choices seem a little arbitrary, can the authors comment on why they chose these parameters? Could one, for instance, choose a drifter-TRAP pair distance that is related to the TRAP attraction rate? Weak TRAPs may not influence debris 75km away, but strong TRAPs can?**

*reply regarding 1° TRAP length and 75 km search radius*

We have received similar comments from referee 1. For a statement on the 1° maximal arclength and the 75 km search radius, we would like to point referee 2 to *Section 1.2: Parameter choices* in our response to referee 1. The idea to dynamically relate the search distance for drifter-TRAP pairs to the TRAP attraction rate is similar to the other referee's suggestion of defining a 'basin of influence' around a TRAP. We also discuss this point in our replies to referee 1.

*reply regarding the choice of $\epsilon$*

We already motivated our choice of $\epsilon = 0.25°$ in the documentation of our tracking algorithm (Kunz, 2024). We now also include a new section in the Supplementary Material where the choice is motivated and explained in detail. We will refer to this new section in the description of our tracking algorithm within the revised manuscript.

*changes regarding 1° TRAP length and 75 km search radius*

We address this with the changes made in lines 162 - 170 and 256 - 275.

We complement this by inserting the new Figs. S1 and S3 in the Supplementary Material.

*changes regarding the choice of $\epsilon$*

We address this with the changes made in lines 186 - 189.

We complement this by inserting the new Section S2, including the new Fig. S7 and Table S1, in the Supplementary Material.

*comment*

**The authors use a 0.25° spatial resolution velocity dataset, which is quite coarse for operational purposes. Would the authors expect similar results (and similar statistics) when using a higher resolution velocity field (e.g. 0.1° eddy-resolving,**

**or even higher submesoscale resolving velocity fields more commonly used for operational purposes)?**

*reply*

Within the manuscript, we should highlight that different statistics can be expected for TRAPs computed from submesoscale velocities. We have received similar comments from referee 1, and we would like to point referee 2 to *Section 1.1: Mesoscale velocity data* in our response to referee 1. There, we describe important editions to the manuscript.

*changes*

We address this with the changes made in lines 560 - 580, 582 - 595 and line 18.

*comment*

**In the discussion around Figure 4, can the authors give further explanation for why the locations of the strongest average attraction rate, number of TRAP trajectories, and largest average TRAP lifetimes don't correlate well? Could this be hampered by the major point above (point 3)?**

*reply*

At first sight, the different patterns in Fig. 4 do not correlate well, but they all seem connected by the generation and propagation of mesoscale eddies. We acknowledge that this result requires more explanation, which we will provide in the revised manuscript. In addition, we note that the different spatial distributions we see in Fig. 4 do not result from TRAPs that enter or leave the domain. We demonstrate in Section S3 of the Supplementary Material that the 5.4 % potentially spurious trajectories do not affect the main findings of our paper and, therefore, are not expected to have a visible impact on our spatial histograms. Moreover, panel (a) in Fig. 4 cannot be affected by this problem since it is only based on instantaneous TRAP detections. Panel (c) can neither be affected because it counts the number of TRAP trajectories, which would remain constant for a truncation of trajectories at the domain boundaries. If panel (c) was hampered by the underestimation of lifetimes for entering or leaving TRAPs, we should see some signal of high average TRAP lifetimes $\overline{\Lambda}$ around the northeast-southwest diagonal of the domain since TRAPs are propagating westward and towards the equator. $\overline{\Lambda}$ would then decrease on both sides of this diagonal, but we do not observe any sign of such a pattern.

*changes*

We address this with the changes made in lines 317 - 322.

*comment*

**On lines 425-426, the authors say the computations of OECSs and TRAPs are 'instantaneous'. Do the authors mean these computations are on 'instantaneous datasets'?**

*reply*

We confirm that we mean these computations are made on Eulerian snapshots of velocity.

*changes*

We address this with the changes made in lines 499 - 500.

*comment*

**The paragraph on line 428 describes a debate in the community on whether mesoscale eddies accumulate and transport material, whether the transport by an eddy is largely outside of the eddy core, and whether objective methods exist that identify the periphery of an eddy. This discussion point is missing some references, and would be further enhanced with comments on the following articles which describe the transport by both the eddy core and the periphery of an eddy core:**

**Early et al. (2011) (using relative vorticity in an idealised flow),**
**Froyland et al. (2015) (using finite-time coherent sets from a transfer operator),**
**Denes et al. (2022) (using finite-time coherent sets from a dynamic Laplace operator).**

*reply*

We appreciate the suggestion of these articles and will include them in our paragraph on material accumulation and transport by mesoscale eddies (note that the subsequent paragraph will also be modified as described in *Section 1.3: Drifter retention* of our reply to referee 1).

*changes*

We address this with the changes made in lines 504 - 521.

*comment*

**The manuscript suggests that the TRAP approach is useful to marine debris cleanup operators, but the analysis is mostly statistical, analysing a large set of TRAP trajectories. A nice-to-have would be a description of how operators may use the TRAP approach in their cleanup operations.**

*reply*

We will use the second last paragraph to briefly describe a potential application of mesoscale TRAPs in combination with vessel-based methods that can help to detect debris and submesoscale flow features in the surroundings of a cleanup operation.

*changes*

We address this with the changes made in lines 582 - 595.

*comment*

**The manuscript would benefit from more discussion around the potential applications of the TRAP-tracking approach, mentioned in the very last line of the manuscript (lines 470-471). The current main application mentioned is marine pollution cleanup, but a broader description of the applications (by expanding the very last line of the conclusion) may benefit a broader audience.**

*reply*

We agree and will provide a broader description of potential applications in the final paragraph of the revised manuscript.

*changes*

We address this with the changes made in lines 597 - 605.

*comment*

**A couple of spelling issues:**

1. **Line 153, 'programme' should be 'program'.**
2. **Line 164, 'Mesoscalle' should be 'Mesoscale'.**
3. **Line 265, 'view' should be 'few'.**
4. **Line 304, 'frequenlty' should be 'frequently'.**
5. **Line 436, 'approx.' can just be 'approximately'.**

*reply*

We appreciate the advice and will correct the spelling issues 2 - 5 in the manuscript. The first issue arises from our writing in British English.

*changes*

We address this with the changes made in lines 205 - 206, 325, 366, 337, 380, 392 - 393 and 525.

## 3 Other revisions to be mentioned for disclosure

*changes*

We replace the application example "identification of foraging hotspots" with "oil spill containment" in lines 25 - 26 and 35 since it might benefit a larger community.

*changes*

We apply the same corrections as for the short summary in lines 29 - 36 for the version on the article page:

> TRansient Attracting Profiles (TRAPs) indicate the most attracting regions of the flow and have the potential to facilitate offshore cleanups in the Great Pacific Garbage Patch. We study the characteristics of TRAPs and the prospects for predicting debris transport from a mesoscale permitting dataset. Our findings show the relevance of TRAP lifetime estimations to an operational application and our TRAPs tracking algorithm may benefit even more challenges that are related to the search at sea.

*changes*

To strengthen the point we make, we add one more reference in line 62.

*changes*

We abbreviate the description of the computation of TRAP propagation speeds by simply using the common term "centred difference" in lines 196 - 199.

*changes*

We considered the comparison to propagation speeds computed by "taking the full distance travelled by a TRAP and dividing it by the respective lifetime" in lines 199 - 203 somewhat misplaced after reading it another time. Instead, we decided to briefly emphasise that velocities cannot be computed at the formation and decay of a TRAP and how this can be estimated alternatively.

*changes*

We remove the sentence in lines 252 - 253 since it repeats the start of the section.

*changes*

In the caption of Fig. 8 in line 423, we clarify from which reference group we derive the distributions in panel (b).

*changes*

To keep it consistent with other numbers using a comma instead of a dot we correct the numbers in line 425 and column 7 of Table 1.

*changes*

We correct an unfortunate word choice in lines 452 - 453. "Chaotic" here is probably not a good choice because in the literature of trajectories and hyperbolic motion it has a specific meaning, a meaning that happens to be opposite to what we wish to convey.

*changes*

In lines 616 - 617, we apply the same terms for the individual contributions of each author to prevent a biased impression by different wording. We added a last phrase for the contributions to the revision of the manuscript in line 618.

*changes*

In lines 622 - 623, we thank the referees for their careful review and comments, and we state the usage of the AI tools that LK has used for assistance in English writing, especially for improving the spelling and grammar of the revised manuscript.

*changes*

We note that in the revised manuscript, all references now comply with the formal requirements given by OS.

## References


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