Qeios

Peer Review

Review of: "Superexcitability in Chiral Oscillators with Spatial Degrees of Freedom"

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General Overview

I read v2 carefully and had drafted detailed review notes. Before posting them, I noticed that the author had already uploaded v3 with substantial proactive revisions. In particular, the introduction of the macroscopic order parameter S to characterize phase–momentum locking, and the inclusion of a baseline basin analysis for the $N=2$ case in Appendix A, align closely with the main directions I had planned to recommend. These updates significantly improve the manuscript's self-consistency, reproducibility, and narrative clarity.

Building on this strengthened v3, I provide below a concise set of remaining comments aimed at further polishing the current version.

Major Comment

1. Quantitative characterization of multistability diversity via basin measure (extending from $N=2$ to $N>>1$)

I highly appreciate the newly added $N=2$ basin map in Appendix A. It makes the claim of "different basins of attraction under the same parameters" much more robust and provides a clear foundation for the subsequent many-body discussion. Building on this improvement, I recommend extending the same basin-based characterization to the $N>>1$ regime to more strongly support the "attractor diversity and bistability/multistability" emphasized throughout the manuscript. For instance, calculating the basin measure in the $N>>1$ regime would allow one to quantify whether the type-(ii) (topologically classified) state is robust to noise, or instead exhibits a "nucleation-like" accessibility barrier, i.e., it does not emerge spontaneously from generic random initial conditions unless an appropriate seed is provided. Concretely,

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this could be assessed by running large ensembles at a few fixed Δ values in the bistable window, comparing basin measures across (i) random initial conditions, (ii) weakly biased/near-type-(i) initial conditions, and (iii) seeded/near-type-(ii) initial conditions, and repeating the same analysis under a noise-amplitude sweep.

Specifically:

- **Controlled complement to Fig. 5:** If Fig. 5 is intended to illustrate attractor diversity, please consider adding a controlled companion set (panels or summary statistics) at strictly fixed Δ while varying only initial conditions. This would help readers distinguish "differences driven by parameter changes" from "differences due to multistability under the same parameter."
- **Statistics for topological classification:** If topological charge/defect category remains a key basis for classification, it would be very helpful to report the distribution (or occurrence probability) of Q at fixed Δ (rather than only selected snapshots), making the connection between "classification" and "phases/regions" more quantitative.

Minor Comments

1. Mechanistic explanation for the empirical scaling $\Delta_{low}(N) = a/N$

v3 presents the numerical evidence for $\Delta_{low}(N)$ more systematically than v2 (the phase diagram, fitting, and statistics are considerably clearer). If the author aims to further strengthen the physical meaning and testability of this scaling relation, I suggest adding at least one mechanistic explanation (even if heuristic or semi-empirical). It would also help to clarify the operational definition of Δ_{low} (e.g., the threshold where Type-(ii) attractors start to appear versus where they become stably dominant). Reporting uncertainty for the fitted parameters, or providing a minimal control test (e.g., varying density or the interaction-kernel length scale), would make the scaling more convincing.

2. Visual self-consistency of Fig. 2(b) (formerly Fig. 1(b))

Although the interaction rules are explained clearly in the text, Fig. 2(b) itself does not yet visually encode both the positional and orientational components in a fully self-contained way (readers may readily perceive positional repulsion but not the corresponding orientational attraction). I suggest making both positional and orientational interactions visually explicit: e.g., use separate arrow/line styles for positional vs. orientational couplings, add "+ / –" (or "repel/attract") labels next to each channel, and include a small legend clarifying the encoding (same-color vs. opposite-color; positional vs.

orientational). If space allows, a minimal two-row schematic (same-color on top, opposite-color below) can make the complementarity immediately readable.

Declarations

Potential competing interests: No potential competing interests to declare.