**NON-RECIPROCAL PHASE TRANSITIONS**

Spontaneous synchronization is at the core of many natural phenomena. Your heartbeat is maintained because cells contract in a synchronous wave; some bird species synchronize their motion into flocks; quantum synchronization is responsible for laser action and superconductivity.

The transition to synchrony, or between states of different patterns of synchrony, is a dynamical phase transition that has much in common with conventional phase transitions of state – for example solid to liquid, or magnetism – but the striking feature of driven dynamical systems is that the components are “active”. Consequently quantum systems with dissipation and decay are described by non-Hermitian Hamiltonians, and active matter can abandon Newton’s third law and have non-reciprocal interactions. This substantially changes the character of many-degree-of-freedom dynamical phase transitions between synchronized steady states and the critical phenomena in their vicinity, since the critical point is an “exceptional point” where eigenvalues become degenerate and eigenvectors coalesce.

We will illustrate this in several different systems – a Bose-Einstein condensate of polaritons, models with cavity mediated interactions, and models of multicomponent active matter such as flocks of birds, generalized Kuramoto models, and Wilson-Cowan models of neural networks. We argue that there is a systematic theory and generalized phase diagram, and corresponding universality behaviors determined by the symmetry of the models.

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1. Fruchart et al., Nature **592**, 363-369 (2021)
2. Hanai et al. Phys.Rev.Lett 122, 185301 (2019)
3. R Hanai, PB Littlewood Physical Review Research **2** (3), 033018 (2020)
4. S Liu, R Hanai, PB Littlewood arXiv:2503.14384
5. R Belyansky, C Weis, R Hanai, PB Littlewood, AA Clerk arXiv:2502.05267
6. J Jachinowski, PB Littlewood arXiv:2507.07960
7. S Shmakov, PB Littlewood Physical Review E 109, 024220 (2024)
8. S Shmakov, G Osipycheva, PB Littlewood Physical Review E 111, 034133 (2025)
9. S Shmakov, PB Littlewood arXiv:2501.14192