

Internship proposal

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Thesis possibility after intership: Yes

Statistical physics of ecosystems with structured interactions

In recent years, there has been a growing interest in trying to understand the dynamics of large, highly diverse, ecosystems from the point of view of statistical physics [1, 2]. Simple high-dimensional models with random interactions between species and/or environment/resources have been proposed, many of which exhibit a rich phenomenology characterized by distinct dynamical phases and corresponding phase transitions [3, 4]. The biological relevance of the phase diagram thus obtained has been highlighted in recent controlled experiments on bacterial populations [5].

In this internship, we would like to investigate what happens to these dynamical phases and transitions when the commonly assumed structureless random interactions are replaced by more structured ones. To do this we will first investigate the phenomenology of the models via numerical simulations. Next, at the analytical level, describing the corresponding phase diagram will require the use of dynamical mean field theory, a powerful and pervasive method to study high-dimensional dynamical systems (such as neural networks, ecosystems, glasses...), carefully extended so as to treat these structured interactions.

References

- [1] Wenping Cui, Robert Marsland III, and Pankaj Mehta. Les houches lectures on community ecology: From niche theory to statistical mechanics. *ArXiv*, pages arXiv–2403, 2024.
- [2] Ada Altieri and Silvia De Monte. Unveiling complexity: Statistical physics approaches to ecological communities. *Europhysics Letters*, 150(5):51002, 2025.
- [3] Guy Bunin. Ecological communities with lotka-volterra dynamics. *Physical Review E*, 95(4):042414, 2017.
- [4] Thibaut Arnoulx de Pirey and Guy Bunin. Many-species ecological fluctuations as a jump process from the brink of extinction. *Physical Review X*, 14(1):011037, 2024.
- [5] Jiliang Hu, Daniel R Amor, Matthieu Barbier, Guy Bunin, and Jeff Gore. Emergent phases of ecological diversity and dynamics mapped in microcosms. *Science*, 378(6615):85–89, 2022.