Advances in the modeling of ecological communities: a theoretical physics approach

Francesco Ferraro
University of Padova
National Biodiversity Future Center

Biodiversity PhD Day - 4 June 2024

Advances in the modeling of ecological communities: a theoretical physics approach

Francesco Ferraro
University of Padova
National Biodiversity Future Center

Biodiversity PhD Day - 4 June 2024

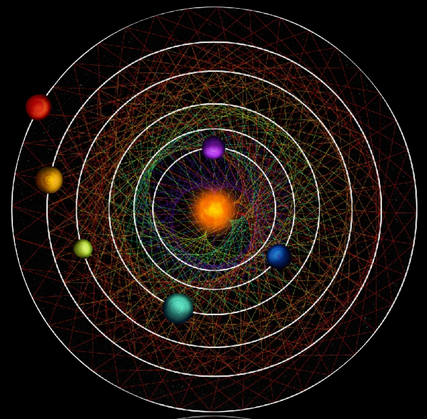
What does physics have to do with ecology?

The grand goal of physics: uncover laws and explain regularities

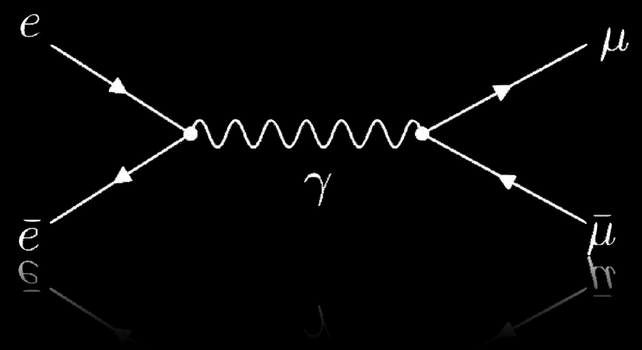
Regularities appear in two kind of systems

very few objects interacting

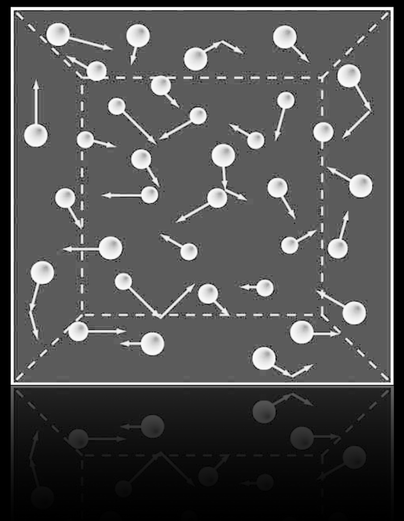
many, many objects interacting



solar system



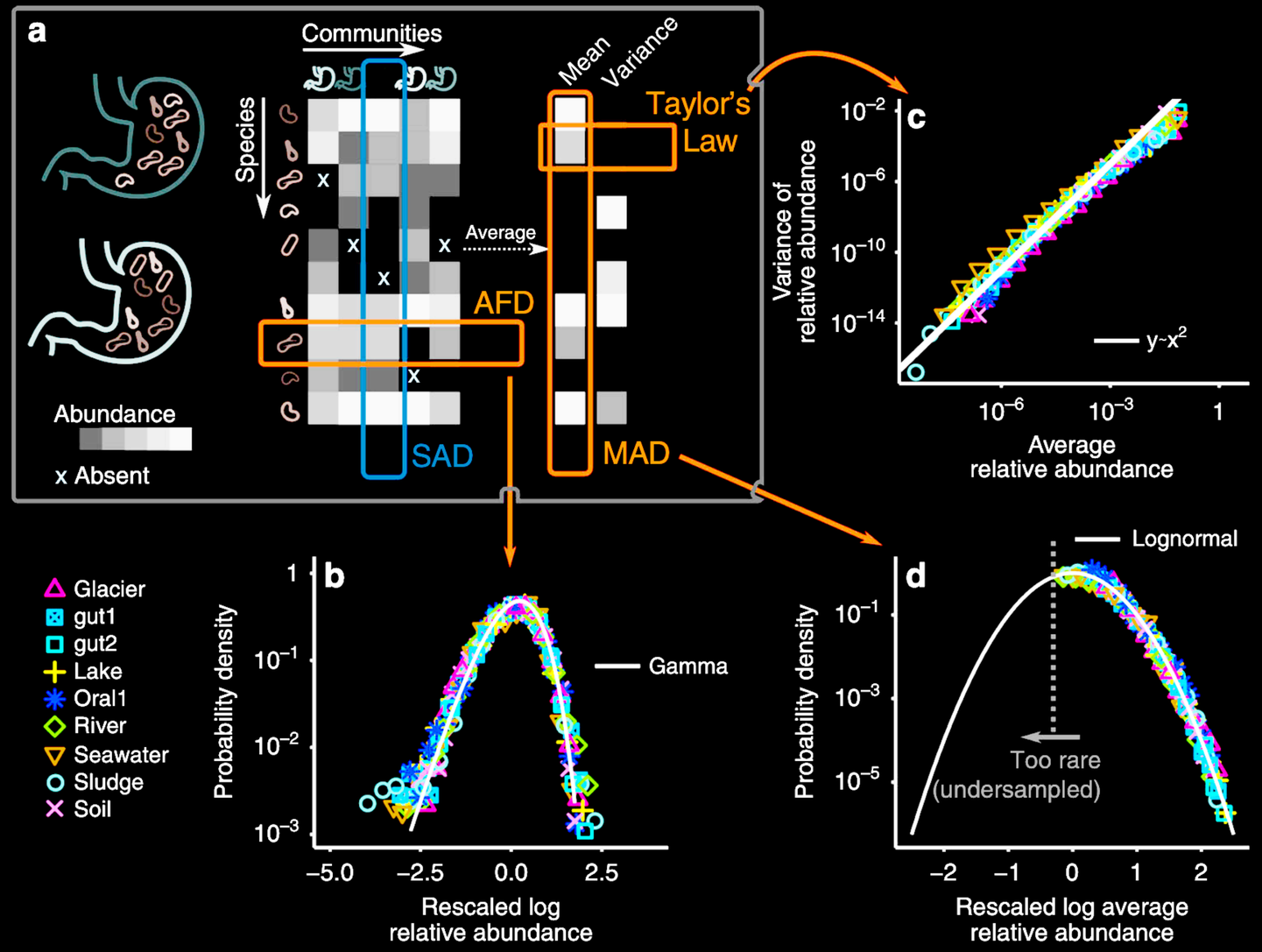
particle physics



gases

flocks

Ecological communities have regularities



J. Grilli (2020)

Why model ecological communities?

- Uncover principles and laws
- Explain regularities
- Understand monitoring data
- Make predictions
- Enable their control

A taste of our work

A classical result on stability of ecological communities

- Take a community at equilibrium
- Perturb it slightly: if it returns to equilibrium it is *stable,* if not it is *unstable*
- Robert May (Nature, 1972) showed that a community is stable only if

$$\sigma^2 SC < 1$$

where σ diversity, S number of species, C connectance

- Contrast with ecological intuition and observations is known as *complexity-stability paradox* (still unresolved 50 years later!)

The fundamental model

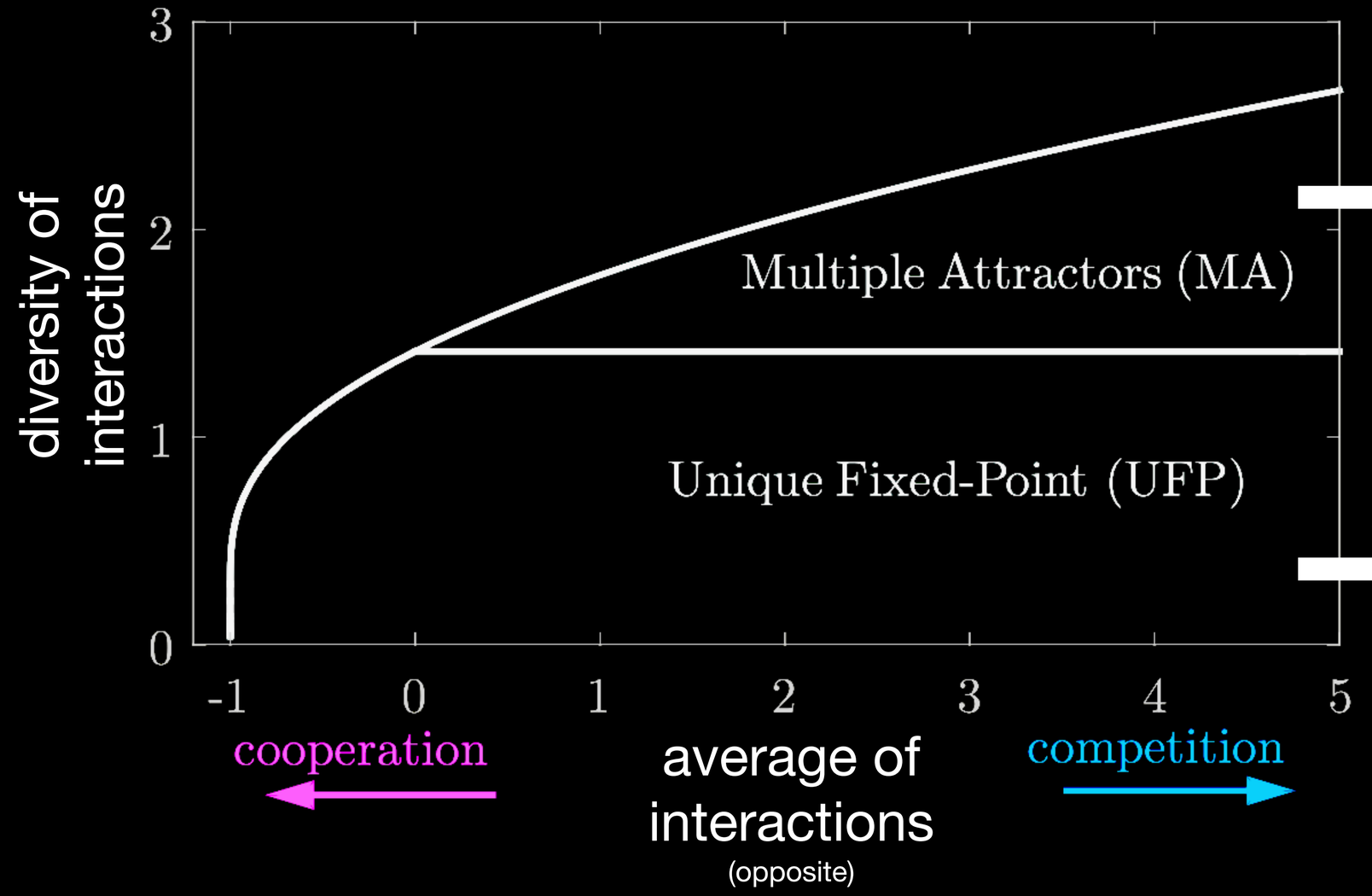
Lotka-Volterra differential equations of community ecology

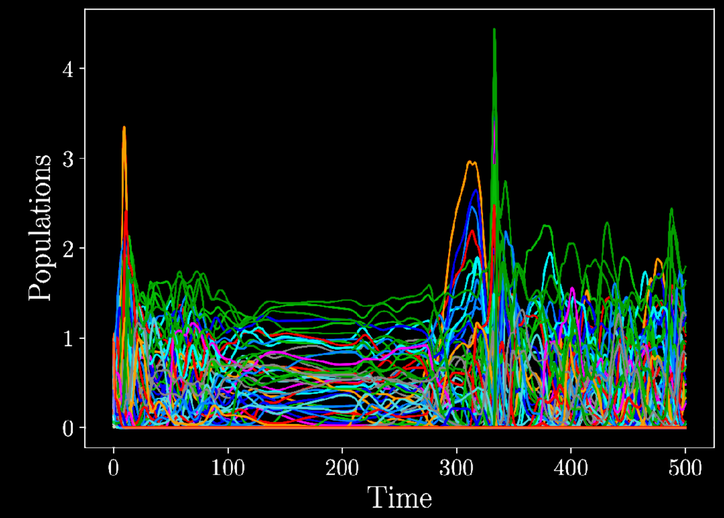
$$\frac{dN_i}{dt} = g_i N_i$$

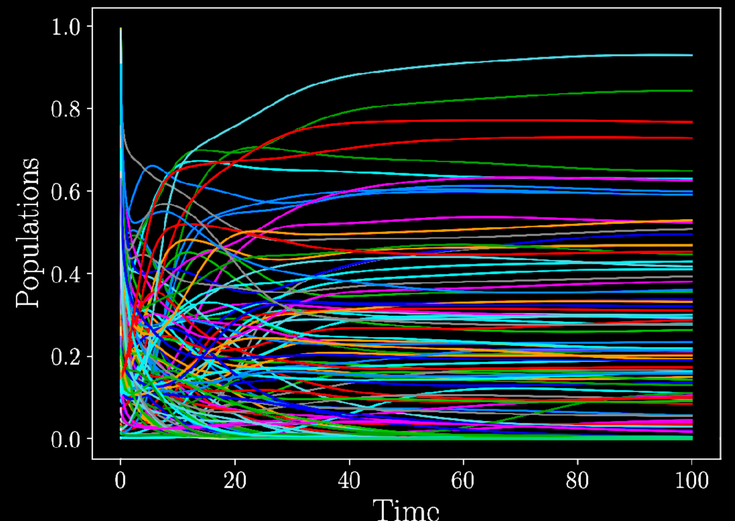
$$g_i = 1 - N_i + \sum_{j \neq i} \alpha_{ij} N_j$$

The fundamental model

Lotka-Volterra differential equations of community ecology



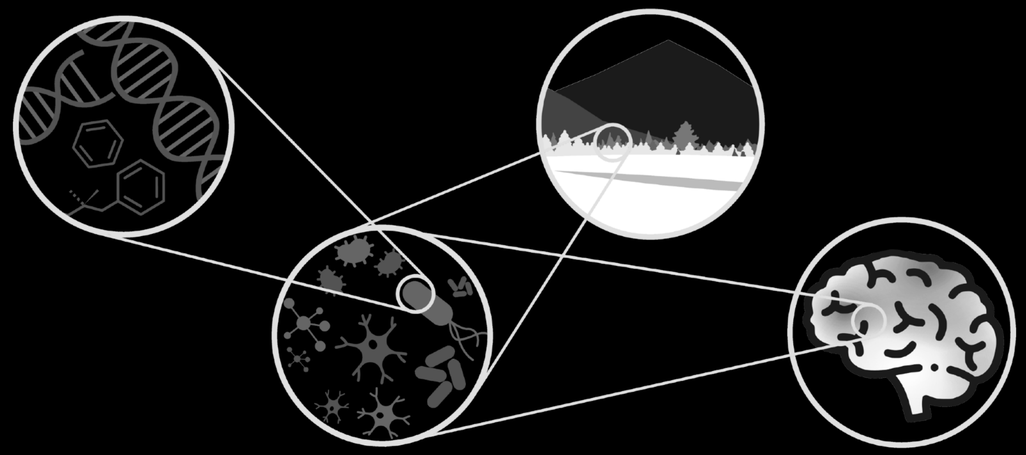




Our advances

- Dynamical interaction strategies between species give rise to more realistic macroecological patterns
- Delayed interactions induce persistent and synchronized oscillations in species abundances
- An explanation on the origin of some non-universal macroecological patterns
- More work in progress to bridge theory and experimental data from bacteria, forests and plankton
- Check Alice Doimo poster on metapopulation models for a flavor of our work!

Laboratory of
Interdisciplinary
Physics



To conclude

- Communities are the simplest level of collective organization in ecosystems
- Ideas and tools from theoretical physics can be used to study them
- Does this interest you?
  - very happy to talk in more detail!
  - my group is eager to collaborate, especially in connection with data
  - my specialties: mathematical modeling, simulations, data analysis

Thank you for your attention!

Francesco Ferraro
francesco.ferraro.4@phd.unipd.it

Biodiversity PhD Day - 4 June 2024