Canadian Association of Physicists

Association canadienne des physiciens et physiciennes

Contribution ID: **3419** Type: **Invited Speaker / Conférencier(ère) invité(e)**

(I) Dynamical mean-field theory: from ecosystems to reaction networks

Monday, 6 June 2022 10:45 (30 minutes)

Both natural ecosystems and biochemical reaction networks involve populations of heterogeneous agents whose cooperative and competitive interactions lead to a rich dynamics of species' abundances, albeit at vastly different scales. The maintenance of diversity in large ecosystems is a longstanding puzzle, towards which recent progress has been made by the derivation of dynamical mean-field theories of random models. In particular, it has recently been shown that these random models have a chaotic phase in which abundances display wild fluctuations. When modest spatial structure is included, these fluctuations are stabilized and diversity is maintained. If and how these phenomena have parallels in biochemical reaction networks is currently unknown, but is of obvious interest since life requires cooperation among a large number of molecular species, and the origin of life is hotly debated. To connect these phenomena, in this work we find a reaction network whose large-scale behavior precisely recovers the random Lotka-Volterra model considered recently. This clarifies the assumptions necessary to obtain a reduced large-scale description, and shows how the noise must be approximated to recover the previous mean-field theories. Then, we show how local detailed balance and the positivity of reaction rates, which are key physical requirements of chemical reaction networks, provide obstructions towards the construction of an associated dynamical mean-field theory of biochemical reaction networks. We outline prospects and challenges for the future, and argue for a synthetic approach to a physical theory of the origin of life.

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Session Classification: M1-8 Statistical physics and biology (DCMMP) | Physique statistique et biologie (DPMCM)

Track Classification: Technical Sessions / Sessions techniques: Condensed Matter and Materials Physics / Physique de la matière condensée et matériaux (DCMMP-DPMCM)