**The Emergence of Dynamic Order in Autocatalytic Sets.** C. Mathis[1,2] (cole.mathis@asu.edu) and S. I. Walker[1,3,4,5], [1]Beyond Center for Fundamental Concepts in Science, Arizona State University, [2]Department of Physics, Arizona State University, [3]School of Earth and Space Exploration, Arizona State University, [4]ASU-SFI Center for Biosocial Complex Systems, Arizona State University, [5]Blue Marble Space Institute of Science (sara.i.walker@asu.edu)

**Introduction:** Life is a state of matter characterized by a stable pattern of non-equilibrium behavior. While equilibrium thermodynamics has helped elucidate some features of living systems and the environment in which they are embedded [1], key properties of the living state have been left unexplained [2]. It has been proposed that the stability of the living state is derived from its kinetic [3] and autocatalytic features [4], rather than it's thermodynamic ones. Unfortunately, quantative descriptions of this distinct type of stability have not been provided, which has prevented the development of quantative laws of life analogous to thermodynamics in their predictive and explanatory power. I will demonstrate how to use techniques from statistical physics and complex systems science to characterize and quantify the dynamics of autocatalytic systems in order to understand this kinetic stability.

**Autocatalytic Sets:** Metabolism first theories for the origin of life posit that the first life-like entities on Earth were catalytic chemical reaction networks. Autocatalytic sets are often studied in the context of metabolism first theories. Autocatalytic sets (ACS) are chemical reaction networks in which each reaction is catalyzed by the product of another reaction in the set [4]. ACS have been predicted theoretically since the 1980s [4], however they have been notoriously difficult to observe in laboratory settings, until recently [5,6]. Due to their relative simplicity, ACS make an excellent model to investigate potential characterizations and quantifications of kinetic stability. Here I present a kinetic model of ACS in which both the topological and kinetic features can be studied [7].

**Inferring Organization:** In order to understand the organization of ACS, I employ common measures from information theory. For example, the mutual information shared between substrates and catalysts quantifies their correlated behavior. By measuring the mutual information shared by all pairs of molecules, a correlation-based representation of the ACS dynamics can be constructed that extracts the most important dynamic feautres of the underlying chemical reaction network. From this representation it is possible to infer the existence of organization or structure in the dynamics [8]. In this way the relationship between the toplogical properties of ACS and the dynamic consequences can be studied directly.

By quantifying the dynamics in this manner, these techniques can detect organization which is not put in 'by hand.' Therefore this analysis provides new tools to investigate catalytic systems in laboratory setttings, particularly for understanding 'messy chemistries,' in which organization is not easily recognized. This also provides ways of probing the dynamics of autocatalytic networks that could provide insights into their stability and evolvability, which would shed light on non-equilibrium processes as well as the origin of the living state on Earth and elsewhere.

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