Global attractor and asymptotic dynamics in the Kuramoto model for coupled noisy phase oscillators

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We study the dynamics of the large N limit of the Kuramoto model of coupled phase oscillators, subject to white noise. We introduce the notion of shadow inertial manifold and we prove their existence for this model, supporting the fact that the long term dynamics of this model is finite dimensional. Following this, we prove that the global attractor of this model takes one of two forms. When coupling strength is below a critical value, the global attractor is a single equilibrium point corresponding to an incoherent state. Conversely, when coupling strength is beyond this critical value, the global attractor is a two-dimensional disk composed of radial trajectories connecting a saddle equilibrium (the incoherent state) to an invariant closed curve of locally stable equilibria (partially synchronized state). Our analysis hinges, on the one hand, upon sharp existence and uniqueness results and their consequence for the existence of a global attractor, and, on the other hand, on the study of the dynamics in the vicinity of the incoherent and synchronized equilibria. We prove in particular non-linear stability of each synchronized equilibrium, and normal hyperbolicity of the set of such equilibria. We explore mathematically and numerically several properties of the global attractor, in particular we discuss the limit of this attractor as noise intensity decreases to zero.

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