Abstract

Synchronization, the phenomenon of matching the rhythms of oscillators upon coupling, is ubiquitous in nature. Until now, one has held the notion that mutually coupled chaotic oscillators synchronize but retain their chaotic behavior like coupled periodic oscillators. The possible alteration of the underlying dynamics of mutually coupled oscillators during synchronization seems to have received less attention. We present experimental evidence of synchronization, wherein the desynchronized coupled chaotic oscillators transition from a state of aperiodic to periodic oscillations as they synchronize.

A turbulent flame combustor is a model, where the synchronization happens between the acoustic oscillations and heat release rate oscillations. We carry out two separate analyses, one in the temporal domain and the other in the spatiotemporal domain. In the temporal analysis, the collective behavior of the spatially extended heat release rate oscillations is captured by summing up the intensity of light emitted from the flame. On the other hand, in the spatiotemporal analysis, we consider the spatial field of heat release rate oscillations as a set of coupled oscillators. The thermoacoustic system transitions from low amplitude chaotic oscillations to large amplitude periodic oscillations with a suitable change in some control parameter.

Our temporal analysis reveals that this transition culminates in a state of generalized synchronization (GS) of the two coupled oscillators, having gone through intermittent phase synchronization (IPS) and phase synchronization (PS). During IPS, the oscillators are periodic in the synchronized phase and harbor aperiodicity in the desynchronized phase. The spatiotemporal analysis demonstrates the desynchronized nature of entire population of oscillators during the chaotic state, and phase synchronized behavior in the periodic state. An interesting feature of the spatiotemporal study resembling a chimera state is observed during intermittency, when the patches of synchronized periodic oscillations and desynchronized aperiodic oscillations coexist simultaneously.

Bio

Dr. R. I. Sujith is Professor in the Department of Aerospace Engineering at the Indian Institute of Technology Madras. He is also a Hans Fischer Senior Fellow of the Institute for Advanced Study (IAS) of the Technical University of Munich, and
was the founding Editor-in-Chief of the *International Journal of Spray and Combustion Dynamics*. He is a recipient of the Alexander Von Humboldt Fellowship, he worked at DLR Göttingen and at the Technical University of Munich. He has won the Young Engineer Award of the Indian National Academy of Engineering, was awarded the Swarnajayanti Fellowship by the Department of Science & Technology, and the Institute Research & Development Award (Mid-career) of IIT Madras. He is a fellow of the Indian National Academy of Engineering and an associate fellow of the AIAA. Sujith works on experimental and theoretical research in combustion instability and is credited with the discovery of non-normality in thermoacoustic interactions and its role in subcritical transition to instability. He is also credited with establishing the route to chaos in thermoacoustic systems and discovered intermittency in thermoacoustic instability. Recent work includes precursor detection for an impending instability, and application of dynamical and complex systems theory to studying transitions.