Abstract Details

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Title: (NL1/SP19, invited) Nonlinear dynamics of a turbulent wave in fluids and plasmas

Abstract:

In a nonlinear wave system we find that a crisis-induced transition to spatiotemporal chaos involves two critical dynamic events . The first event is a collision of the orbit to an embedded saddle point, which triggers onset of the crisis; the second one displays as a critical transition of the state of a mode phase, which destroys spatial regularity of the wave. Here, the saddle point is a steady wave with saddle instability, and the collision is actually a "pattern resonance" of the realized wave with this virtual saddle steady wave (SSW). In the reference frame moving in its group velocity the SSW is a fixed point (saddle point) in the Fourier space, so abundant dynamic phenomena of the nonlinear wave are attributed to variations of perturbation wave (PW) to the SSW. In this moving frame a PW can be transformed into coupled oscillators, whose motion is affected by the SSW as if the latter is a potential. In general coupled nonlinear oscillators have a tendency to establish various types of phase synchronizations. Likewise, despite after the crisis the wave looks very turbulent, the PW oscillators are self-organized to a special kind of synchronization, namely, on-off collective imperfect phase synchronization (CIS) . In "on" stages the mode phases, at least those with long wavelengths, adjust themselves to an imperfect synchronization, in the meantime, the mode amplitudes reach maximum almost simultaneously giving rise to a burst in the total wave energy; in "off" stages slips may occur between the phases and the wave energy fluctuates in a lower level. We define a function describing the correlation behavior between a few mode phases of long wavelengths, the correlation function shows a sharp spike whenever a burst appears in the wave energy, and the interspikes have a power law distribution. The embedded saddle point plays an important role even in the turbulent state after the crisis. Owing to the saddle point the synchronization becomes imperfect, similar to what happens in coupled Lorenz oscillators. However, this is not the unique cause for the on-off CIS. The state transition of the PW master mode phase in the second event as mentioned above is also significant for the on-off CIS. We emphasize that our model system is of practically interesting, which is based on an equation derived from shallow water wave in fluids and drift-wave in magnetized plasmas respectively. The present results may provide an explanation for energy bursts observed in many practical systems, e.g. in solar flares.

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