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Comment

Chimera states and reality in brain dynamics
Comment on “Chimera states in neuronal networks: A review” by Majhi et al.

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Chimera represents fascinating mythological figures that show juxtaposition of different body parts of few animals in paintings and structures as known through centuries. In recent times, researchers in dynamical system community have correlated [1] such mythological incongruous figures or structures with coexistence of coherent and incoherent sub-populations in a large ensemble of oscillatory systems. In dynamical networks, such coexisting patterns [1,2] are intriguing since synchrony has been believed to be a stable state [3] in an ensemble of identical oscillators under strong interaction. Contrary to such belief, Kuramoto [2] first showed that a symmetry breaking could happen in a synchronous state in a ring of identical phase oscillators that would lead to coexistence of two coherent and incoherent sub-populations. For this, he proposed a special type of non-local coupling when oscillators are not only coupled to nearest neighbors, but also connected to far away oscillators to form a ring of oscillators and reported coexisting incongruous states, in a ring of phase oscillators, which was later given [1] the fascinating name of chimera. Anyway, it was a strange behavior, in the dynamical sense, as studied both theoretically and numerically, how an ensemble of identical oscillators in a homogeneous synchronous state breaks into two sub-populations with contrasting collective dynamic properties. Since then there has been much progress on existence of chimera states in many paradigmatic model systems, which has been nicely reviewed in the current report by Majhi et al. [4]. Existence of chimera states is not restricted now to networks under nonlocal coupling, it has been shown true for globally coupled networks [5,6] and local nearest neighbor coupling [7] too. In fact, existence of chimera states and clustering states were reported long back by Kaneko [8] in globally coupled map lattice. In chimera states, there exist at least two clusters, one group of oscillators are in coherent motion and another group in incoherent motion. Many other researchers have also claimed [9] that coexistence of two sub-populations in synchronous and asynchronous states in identical and homogeneous networks has been well known and reported by them much earlier before Kuramoto et al. [2] in continuous dynamical model networks as partial synchronization. One such claim is found really true recently [10]. It must be recognized that extensive efforts have been exerted on the origin and mechanisms of chimera only after the work of Kuramoto et al. [2] and Abrams et al. [1]. However, the main question remains unanswered how such chimera states evolve

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and show up in real systems? How chimera states in dynamical systems really explains sleeping mammals' behavior [11] that supposedly make them alert against predator attacks. Another question is raised [13] that chimera states is a transient behavior, which is not easy to identify always from numerical simulations. Some fast electronic experiments confirmed such transient character of chimera states. It also indicated that transient time increases with the size of the network. Later, the chimera was confirmed [14] as a possible stable state even in a small ensemble of oscillators. Of course, neurons are large in numbers in the brain and therefore, the transient time is always very large and one may not really have to be bothered by the transient behavior of chimera, if it is at all true. However, chimera, even in a transient state, may perform useful task in real systems. In this perspective, studies of chimera in neuronal networks is very much relevant in the context of basic understanding, on the one hand and the role of such dynamical features on brain functioning, on the other hand.

Majhi et al. [4] followed a tradition of investigation, from a purely dynamical systems viewpoint, to relate chimera states with unihemispheric sleep of some mammals and birds and bump states. They studied chimera states exhaustively in two paradigmatic neuron models, FitzHugh-Nagumo model and Hindmarsh-Rose model, using mostly nonlocal coupling under chemical and electrical synaptic connections between neurons. They used some well defined quantitative measures to identify chimera states. They extended their earlier work [12] further to include the FitzHugh-Nagumo model, in this work, and in presence of additive uncorrelated gaussian noise in the system and furthermore by introducing delay in communication between the dynamical units. In the mathematical sense, it is a nice approach to understand the origin of chimera in model neuron networks, which they have done successfully. They included the slow-fast Hindmarsh-Rose bursting neuron model to explore chimera states under several coupling schemes, a combination of nonlocal chemical and electrical synapses, nonlocal synaptic delayed coupling and a synaptic gradient coupling. Such studies on model neurons could really lead to our improved understanding on the emergence of chimera states, especially in neuronal networks. Studies of chimera in neuronal network under the presence of noise is a relevant issue, in the context of neuronal dynamics, as also has been explored by them [4]. We wonder, although a symmetry breaking of a homogeneous state into partial synchronization is a fascinating behavior, in mathematical sense, that, in reality, say, neurons are exactly not identical, then a question arises how chimera states would respond to small perturbations in parameters? However, we are still far from simulating a realistic connectivity of neuron; whether non-local network connectivity exists in neuron assembly? Whether the local connectivity is preferred by the neurons? Although chimera in neuronal networks seems mathematically correct, how relevant are they in terms of explaining the behaviors of neurons or more complex brain? We have to be optimistic that such studies may help us explain the unihemispheric sleep in some mammals in the future. Finally, it may be mentioned that, besides investigation on chimera states, the authors revealed an interesting bursting dynamics which has been shown in Fig. 4 in ref. [4], but they have underplayed this in their report. Majhi et al. [4] reported emergence of triangular wave in the case of synaptic gradient coupling when there is seen only imperfect traveling chimera patterns. The triangular wave and square bursting in slow-fast systems are well known in literature [15], however, a mixture of square wave and triangular waves has not been reported so far before the works of this group [4,12], to the best of our knowledge, and it is a novel kind of bursting behavior, which needs further attention to explore their dynamical origin.

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