Effect of Phase Lag Parameter on the Swarmalator Dynamics

Poster

Rakshita Sharma and D. V. Senthilkumar

School of Physics, Indian Institute of Science Education and Research Thiruvananthapuram, Kerala, India

Swarmalators are a unique class of systems that integrate both synchronization and swarming. Synchronization is a process by which individual oscillators adjust their internal state to achieve a unified behavior, often seen in phenomena like metronomes ticking in unison or fireflies flashing together. Swarming refers to the collective movement of individuals within a group, leading to coordinated motion without a central leader, as observed in flocks of birds or schools of fish. Swarmalators are oscillators that simultaneously exhibit coordinated motion and synchronization of their intrinsic behaviors like internal phases, resulting in complex spatiotemporal pattern formation. Such systems are accurately modeled by coupled differential equations involving spatial dynamics and phase dynamics. In our study, we investigate the impact of introducing a phase lag factor in the phase dynamics to include asymmetric effects. Our analysis revealed that the inclusion of the phase lag results in significant change to the space-phase order and kinetic energy of the swarmalator system. In the two-parameter space, where the evolution of collective states can be observed, we demonstrate the regions exhibiting high correlation between space and phase enlarges, while the regions with no correlation diminish in size. This indicates that higher phase lag enhances the system's space-phase order. Additionally, the nature of the transition of space-phase order parameter with varying coupling strength from a non-zero value to zero undergoes a significant transformation as the phase lag increases. For a phase lag of zero, the phase diagram exhibits a continuous transition. However, as the phase lag is increased to $\pi/6$ and $\pi/3$, this transition becomes abrupt, signifying a first-order transition which results in hysteresis in the system. Bistability in distorted active phase waves and static async is observed. Additionally, a new collective state termed as distorted active phase wave has been identified. For positive coupling strengths and higher values of phase lag, a chimera state is also observed.

References

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