Posters

Detecting Early Warning Signals for Critical Transitions in Astrophysical Systems

Poster

Devraj Pawar

R. J. College, Ghatkopar, Mumbai, India

Complex systems often undergo changes affected by various factors and their effects sometimes result in the transition the system from one stable state to another stable state. For many systems, it is possible to detect early-warning signals before this critical transition. Astrophysical systems are dynamic systems that evolve due to the various perennial physical processes within as well as with their interactions with other systems and also with the medium around them. Such astrophysical systems can exist for varying time spans in certain states, each characterized by a specific pattern of behavior indicated by its spectrum and variable luminosity. The evolution from one state to the other may can be sudden as seen in gamma ray bursts and supernovae events or it may be gradual as in the case of neutron star or black hole X-ray binaries. These states often correspond to different ranges or combinations of control parameter values whose information is embedded in the lightcurves of these systems. Control parameters play a crucial role in defining the system's states and how they evolve over time and sometimes a small change in a control parameter(s) causes the system to shift abruptly from one state to another, this is called a critical transition [1]. For example, in X-ray binaries the energy output across the energy spectrum can change by a few orders of magnitude [2] during outbursts and the system exhibits well defined states based on spectral and temporal characteristics [3]. Often such critical transitions are preceded by changes in the system's behaviour which can be the "early warning signals" to such transitions. The changes seen may be indicators of critical changes in the system as seen in the recent historic dimming of Betelgeuse [4]. Lightcurves of astrophysical systems show variability characterized by various parameters, however variability which will lead to critical changes will have different parameter values which can be calculated using Multifractal analysis and Recurrence Network Analysis. Predicting the outbursts of such transient systems based on lightcurves from monitoring instruments is an important aspect to study the evolution of their complex dynamics as well as to plan observations. We have tried to detect Early Warning Signals in lightcurves from transient X-ray binaries and discuss the results.

References

[1] Robert C Hilborn et al. Chaos and nonlinear dynamics: an introduction for scientists and engineers. Oxford University Press, 2000.

[2] Walter Lewin and Michiel van der Klis. Compact Stellar X-ray Sources. 2010.

[3] Pablo Reig, T Belloni, and M Van Der Klis. Does grs 1915+ 105 exhibit "canonical" black-hole states? Astronomy & Astrophysics, 412(1):229–233, 2003.

[4] Sandip V George, Sneha Kachhara, Ranjeev Misra, and Gouri Ambika. Early warning signals indicate a critical transition in betelgeuse. Astronomy & Astrophysics, 640:L21, 2020.