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Of Mice and Monodromy: Bifurcation analysis of the circadian-reward system

Humans have tried to predict the behaviour of living systems for at least as long as quadrupedal predators have had sharp teeth. Many aspects of behaviour arise from rhythmic neural activity. Though individual rhythms are highly predictable, their interactions can produce remarkably complex behaviours. Disruptions to these rhythms are widely associated with disease, yet we lack a clear understanding of how changes in their interactions translate into altered behaviour.

Here, we approach this problem through bifurcation theory, asking what can be learned about the dynamics while making minimal assumptions about the interacting system. Taking circadian regulation of the dopamine system as an example, we investigate the generic mechanisms by which stable limit cycles lose stability and give rise to more complex dynamics. We then translate these bifurcations into constraints on Fourier coefficients in harmonic regression, providing a statistical framework for translating between aberrations in observed behaviour and underlying neural regulation.