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Critical behavior in networks of real neurons

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The patterns of joint activity in a population of retinal ganglion cells encode the complete information about the visual world, and thus place limits on what could be learned about the environment by the brain. We analyze the recorded simultaneous activity of more than a hundred such neurons from an interacting population responding to naturalistic stimuli, at the single spike level, by constructing accurate maximum entropy models for the distribution of network activity states. This – essentially an "inverse spin glass" – construction reveals strong frustration in the pairwise couplings between the neurons that results in a rugged energy landscape with many local extrema; strong collective interactions in subgroups of neurons despite weak individual pairwise correlations; and a joint distribution of activity that has an extremely wide dynamic range characterized by a zipf-like power law, strong deviations from "typicality," and a number of signatures of critical behavior. We hypothesize that this tuning to a critical operating point might be a dynamic property of the system and suggest experiments to test this hypothesis.