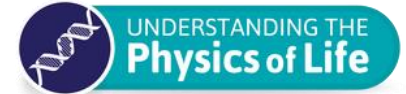


Mesoscopic multiphoton calcium imaging reveals a confluence of overlapping avalanches with varying distance to criticality and distinct roles

IMPERIAL



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Brain Criticality

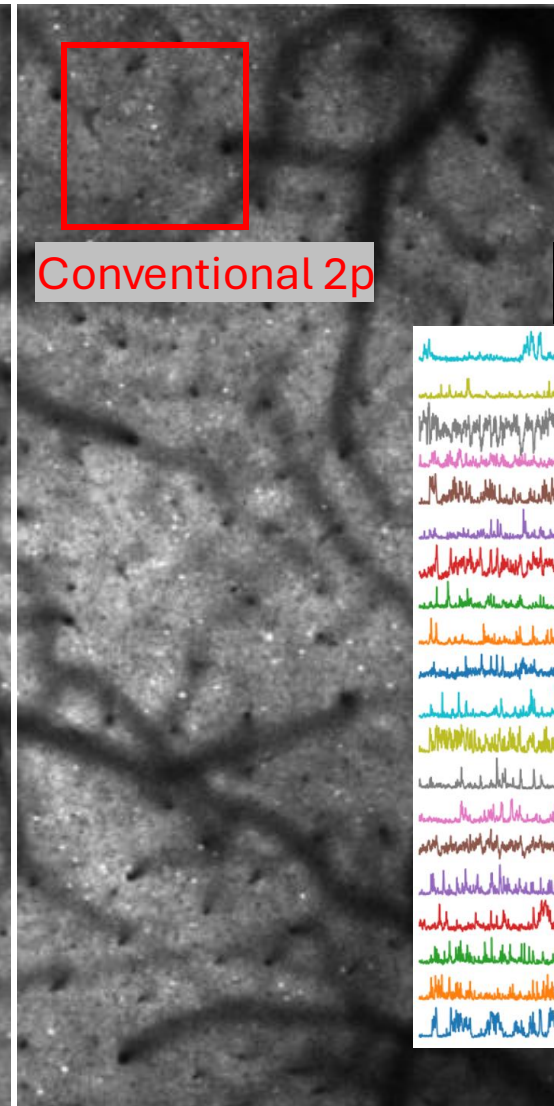
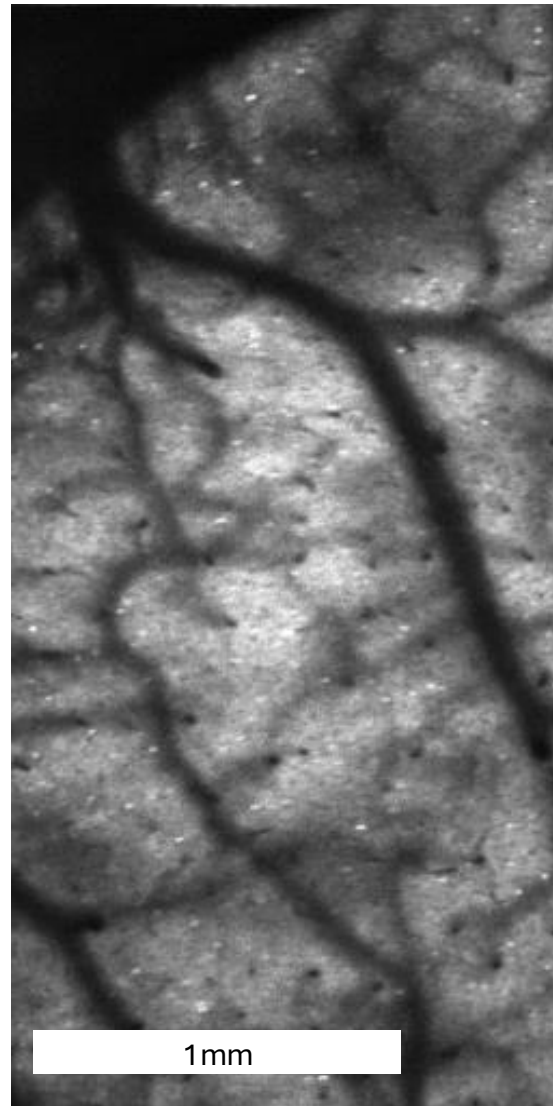
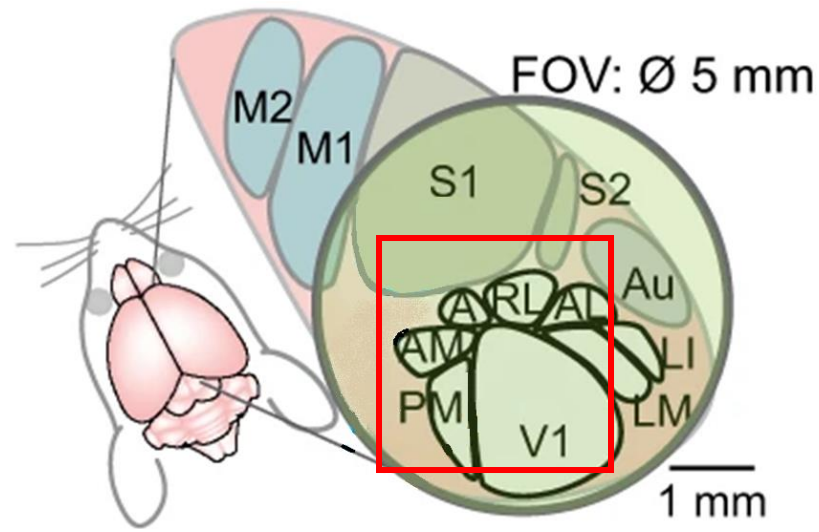
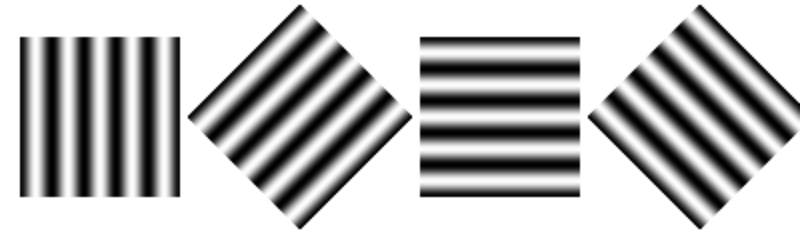
6th November 2024



Mesososcopic multiphoton calcium imaging

Randomised visual stimuli (2Hz)

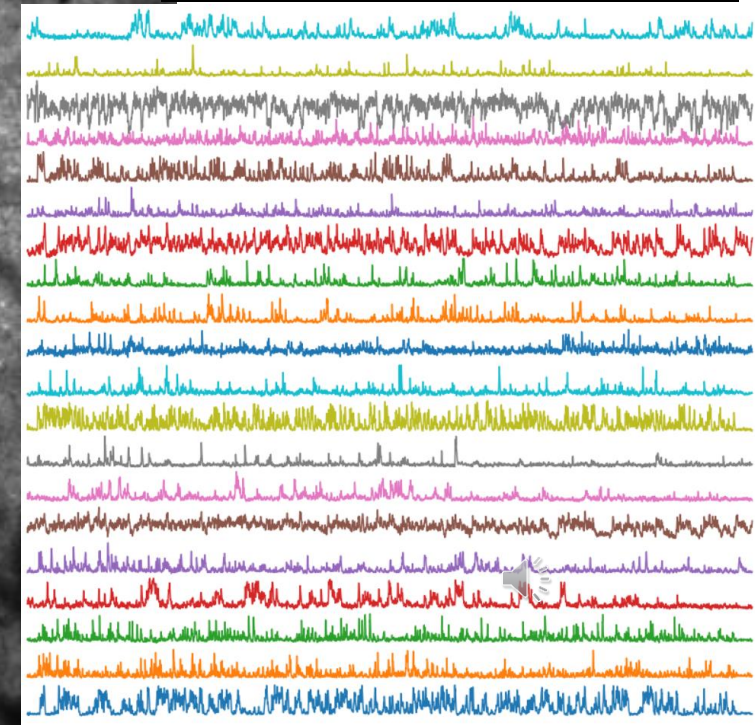
Diesel2p: ~7000 layer 2/3 neurons from a 3x3 mm² field of view at 8Hz



Conventional 2p

Normalised fluorescence

(Collab. with Smith lab, UCSB, imaged by Joseph Canzano)



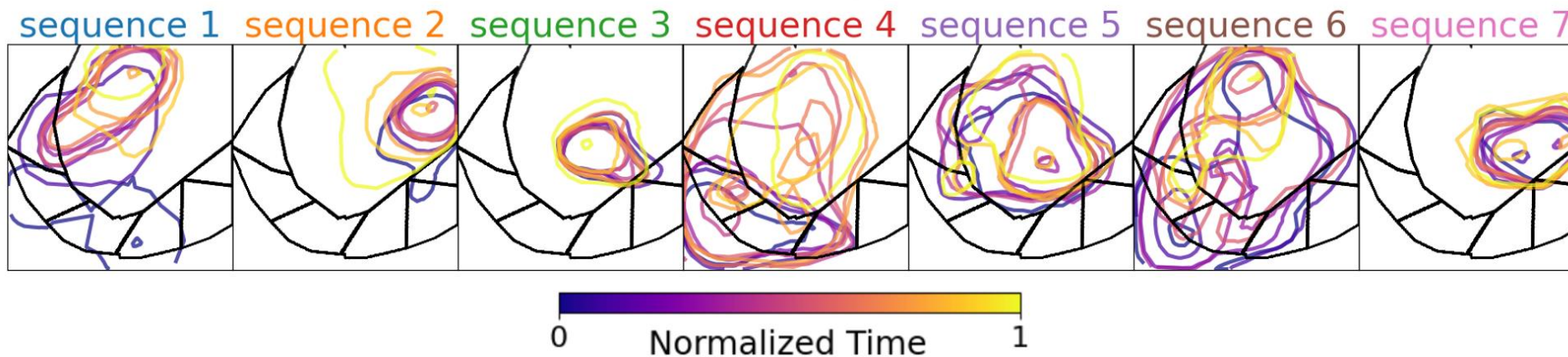
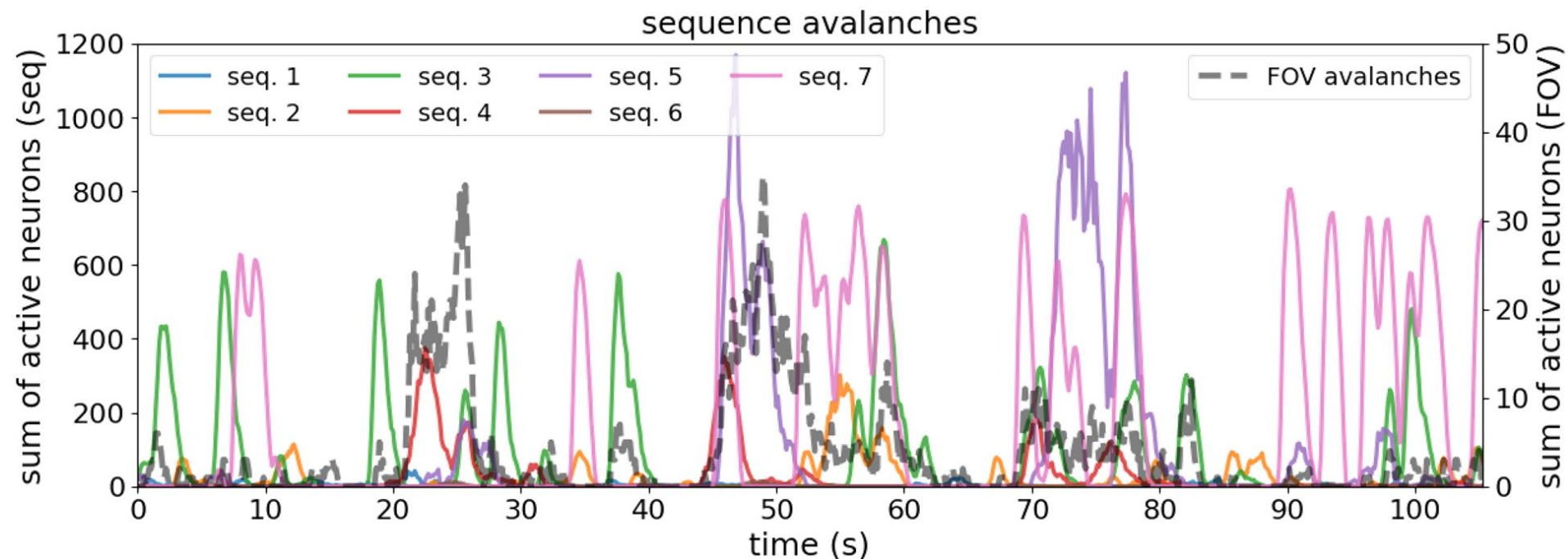
45 minutes

Motor
Somatosensory
Visual
Auditory

Yu, Che-Hang, et al. "Diesel2p mesoscope with dual independent scan engines for flexible capture of dynamics in distributed neural circuitry." Nature communications 12.1 (2021): 6639.

Sequence-avalanches

$H_i * W_i \Rightarrow \text{detection} \Rightarrow \text{sequence-avalanche}_i$



SeqNMF factorizes the neural activity matrix into spatio-temporal sequences of ≤ 1.3 s and their corresponding occurrence timeseries. Convolving both matrices reconstructs overlapping sets of activity from which avalanches are detected.

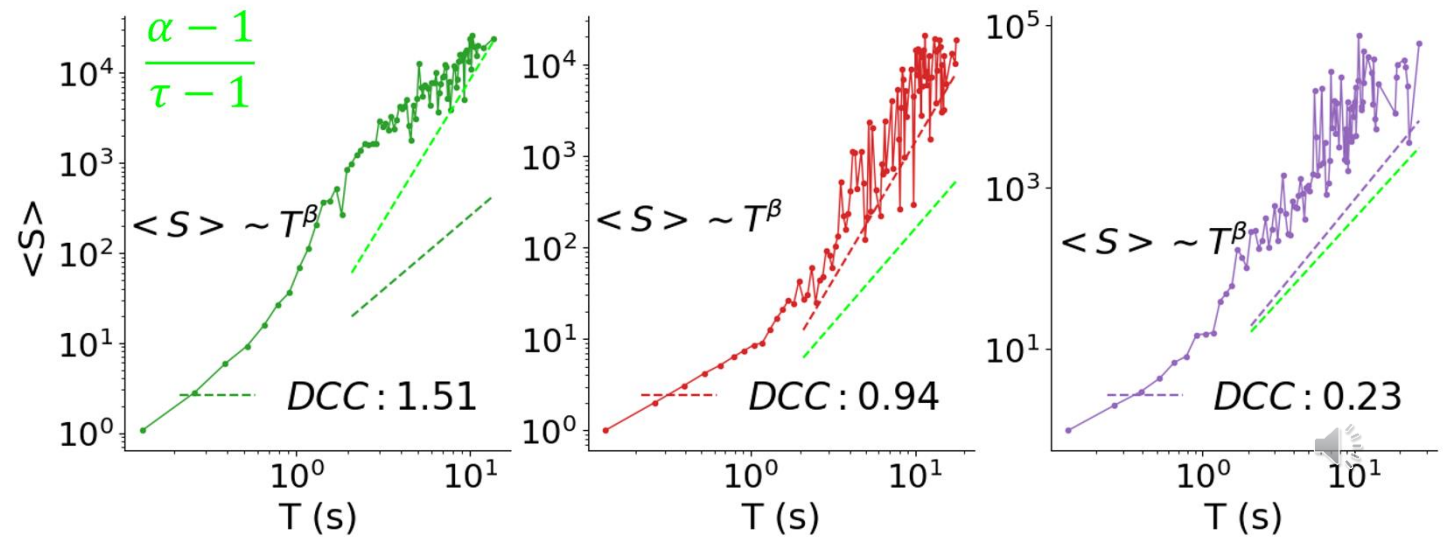
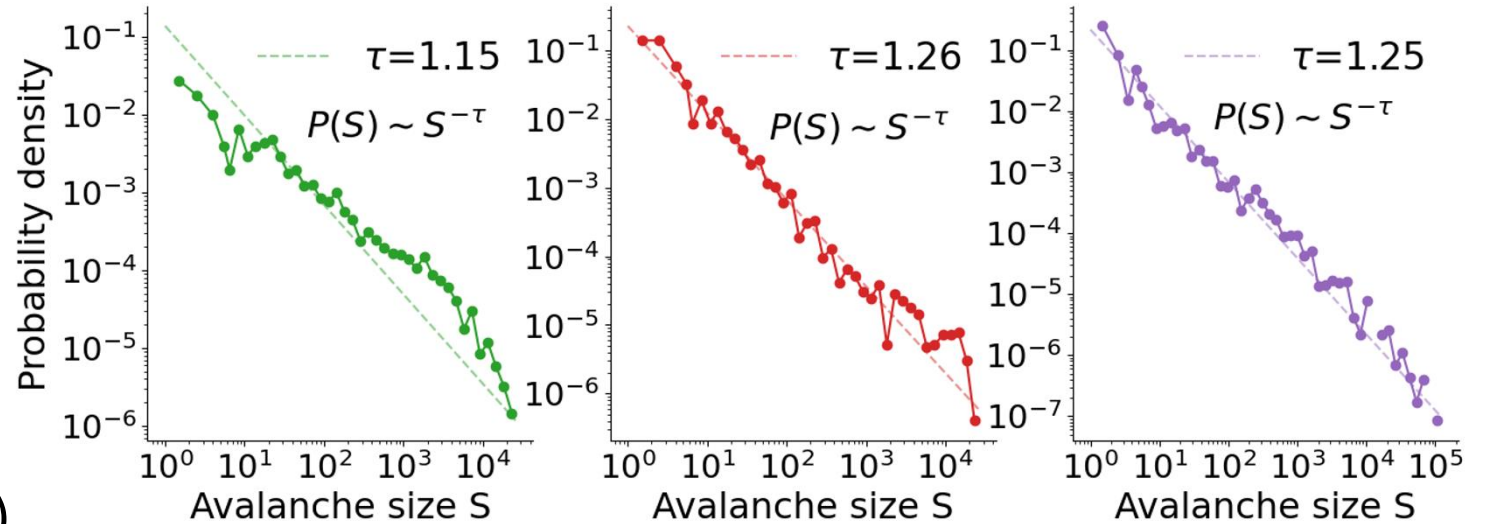


Sequence-avalanches characteristics

The system is close to criticality:

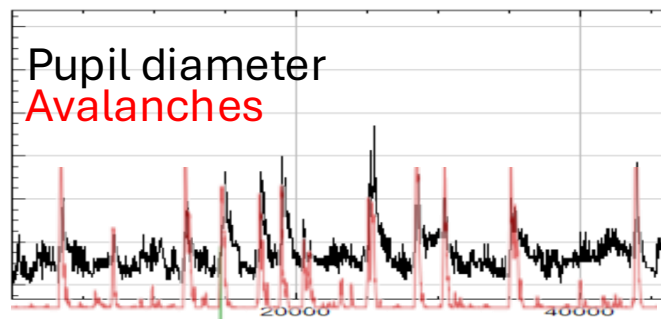
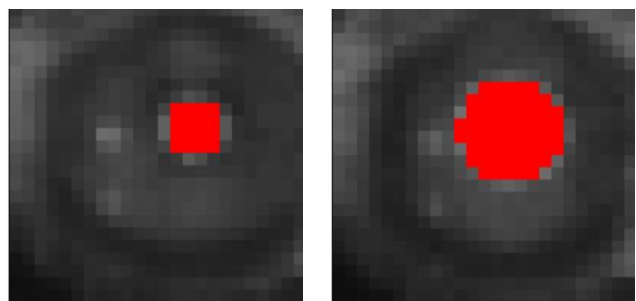
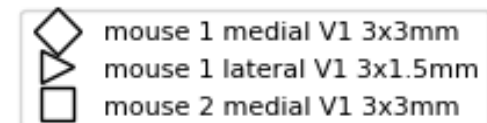
$$\beta_{exp} = \frac{\alpha - 1}{\tau - 1} \text{ (crackling noise dynamics)}$$

Deviation from Criticality Coefficient
(DCC) = $\left| \beta_{exp} - \frac{\alpha - 1}{\tau - 1} \right| \rightarrow 0$

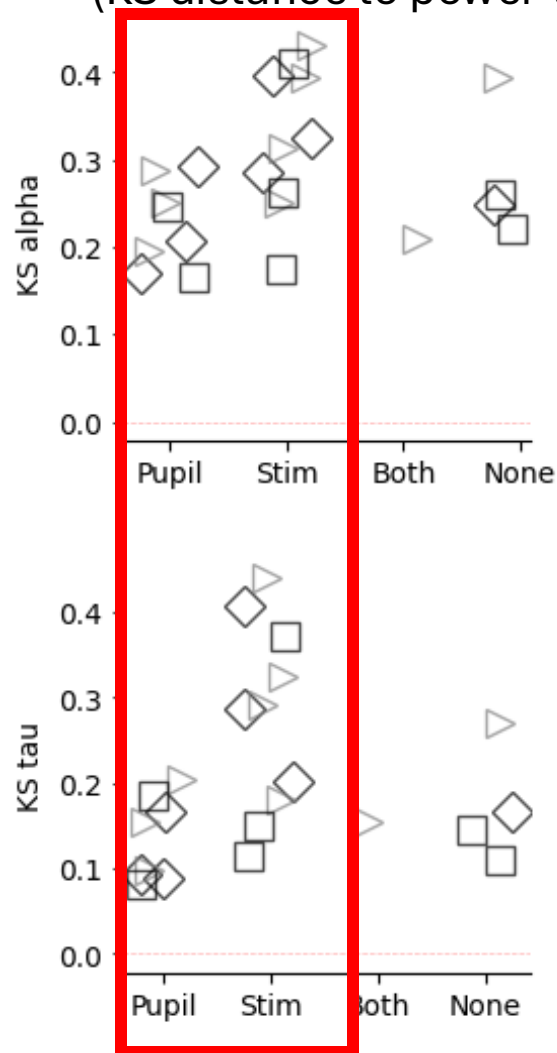


less critical ← → more critical

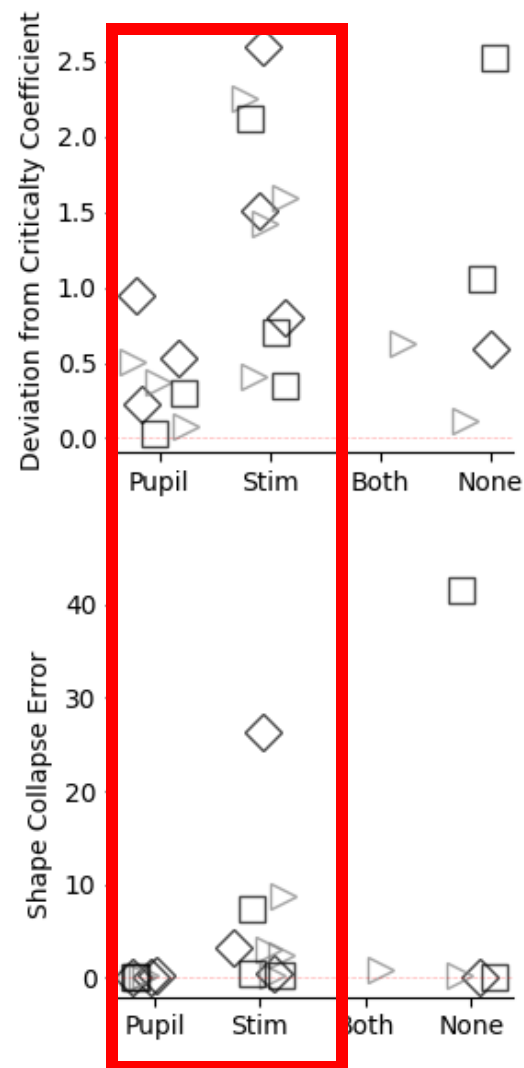
Pupil-avalanches are closer to criticality than stimulus-avalanches



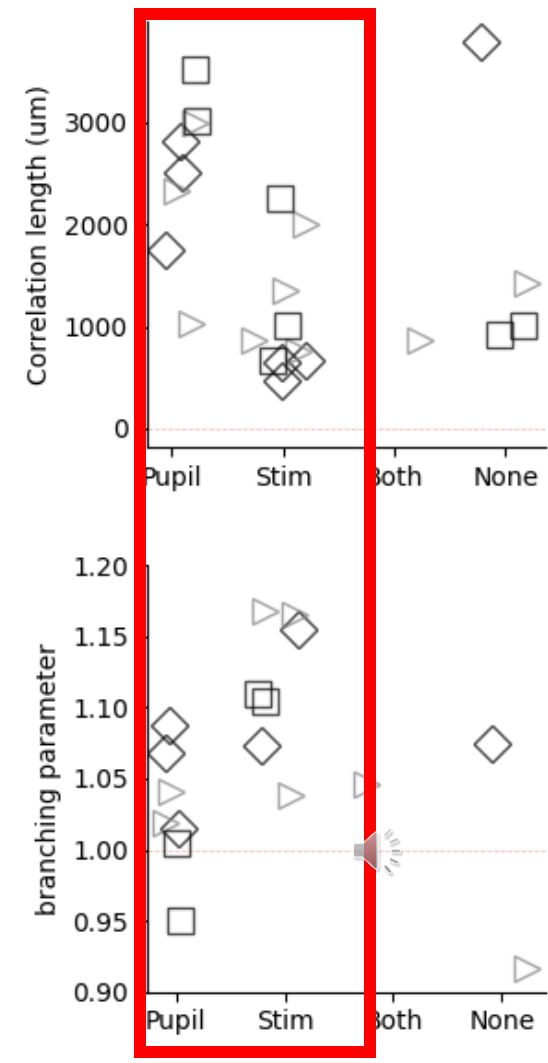
Scale-invariance
(KS distance to power-law)



avalanche metrics



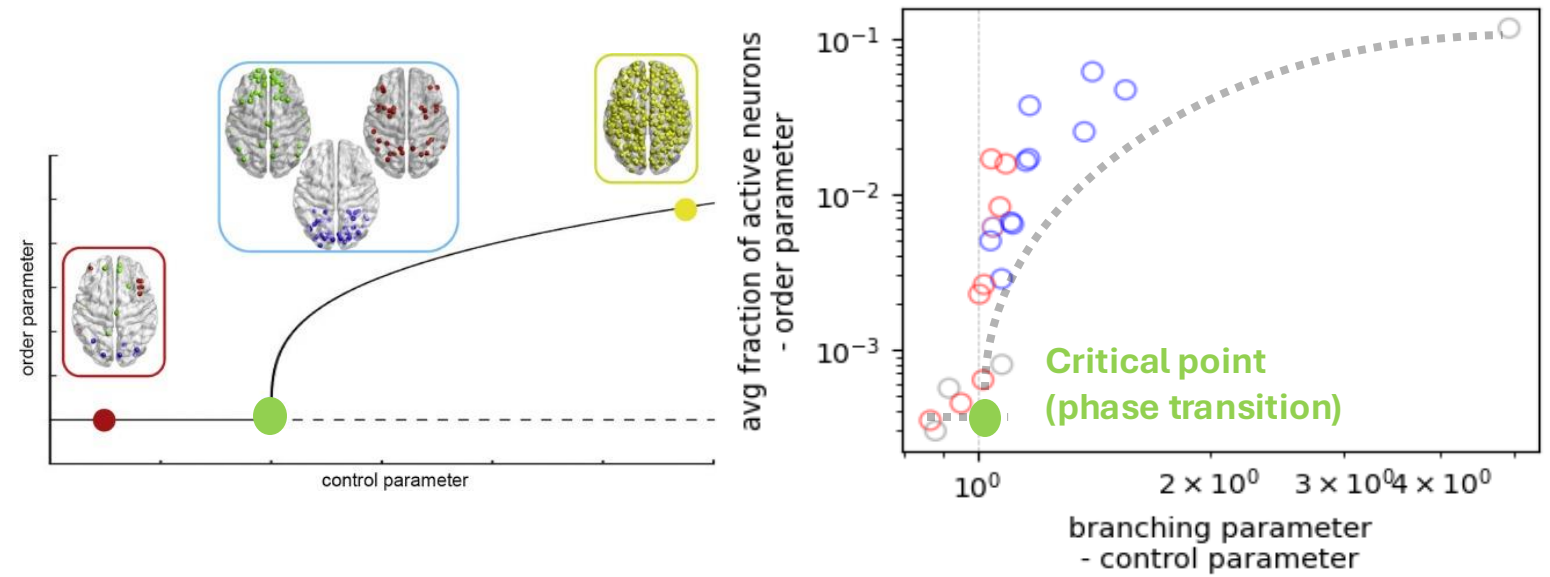
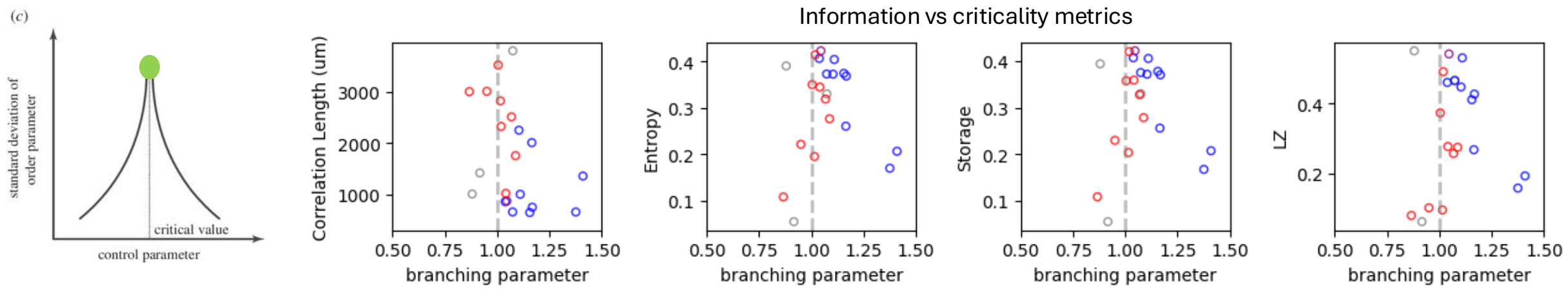
Criticality-enhanced metrics



Distance to the critical point on the phase diagram

Avalanches populate the phase diagram along a phase line at varying distances to criticality

Pupil-avalanches
Stimulus-avalanches
None



Pupil-avalanches are near-critical while stimulus-avalanches tends to be super-critical

Does sensory stimuli drive the system away from criticality and the pupil-activity brings it closer ?

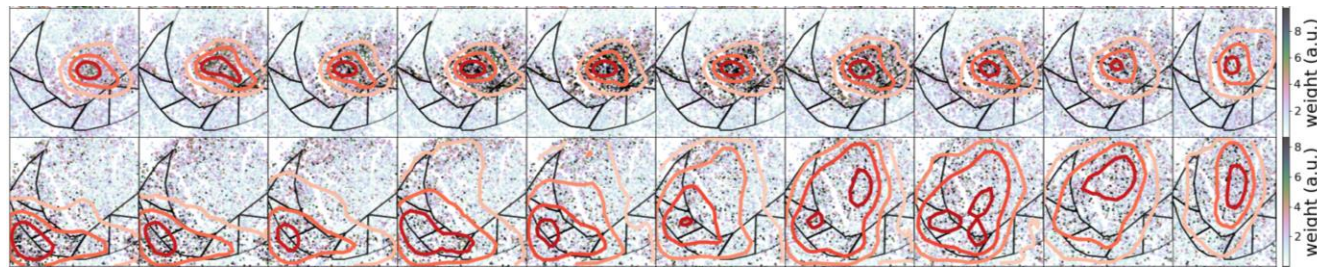
Conclusion

- Mouse visual cortex under stimulation behaves near-criticality
- Sensory-related subprocesses are localised and supercritical
- Pupil-related processes tends to be attracted to the critical point and propagate widely from the somatosensory to visual cortex
- next step: are cognitive subprocess near-critical and how neural circuits implement that ?

spatiotemporal patterns:

- stimulus-related avalanche

- Pupil-related avalanche



scaled time

a **confluence** of avalanches

