On the **critical signatures** of neural activity

Beg Rohu
Summer School 2021

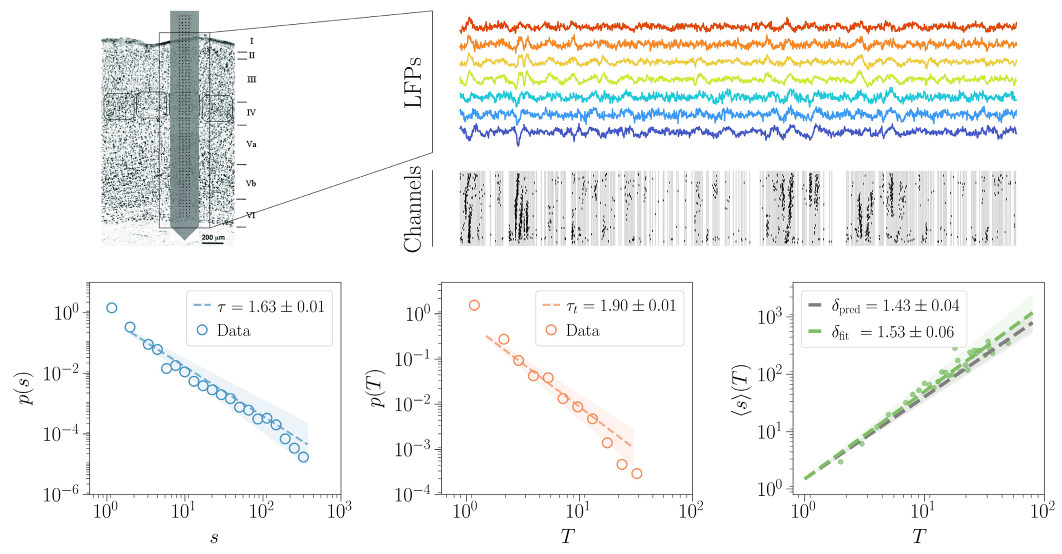
B. Mariani, G. Nicoletti, M. Bisio, M. Maschietto, S. Vassanelli, S. Suweis

arXiv, 2105.05070 (2021)

INTRO

Power-law distributed **neuronal avalanches** are systematically observed in different experimental settings, with varying exponents that obey the **crackling-noise relation**. They are usually associated with the hypothesis that the brain might operate close to a **critical point**...

... but they are compatible with other generative mechanisms. A deeper signature of criticality are instead **long-range correlations**. Through both experimental and theoretical methods, we **disentangle** these different contributions to the critical signatures of neural activity.



We observe power-law distributed avalanches in the LFP signals we obtained from the rat barrel's cortex using state-of-the-art multi-array probes.

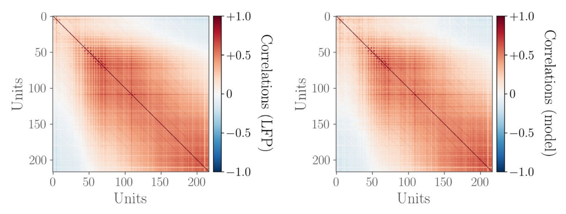
THE MODEL

Our model considers separately the **extrinsic activity**, i.e. a global stochastic modulation due to e.g. thalamic inputs, and the **intrinsic activity**, i.e. the activity due to interactions between population of neurons.

$$\frac{dv_i(t)}{dt} = -\frac{1}{\gamma_i}v_i(t) + \sum_j W_{ij}v_j(t) + \sqrt{\mathcal{D}(t)}\eta_i(t)$$

Intrinsic Activity

We solve the inverse problem for the connectivity matrix to match the correlations of our data.

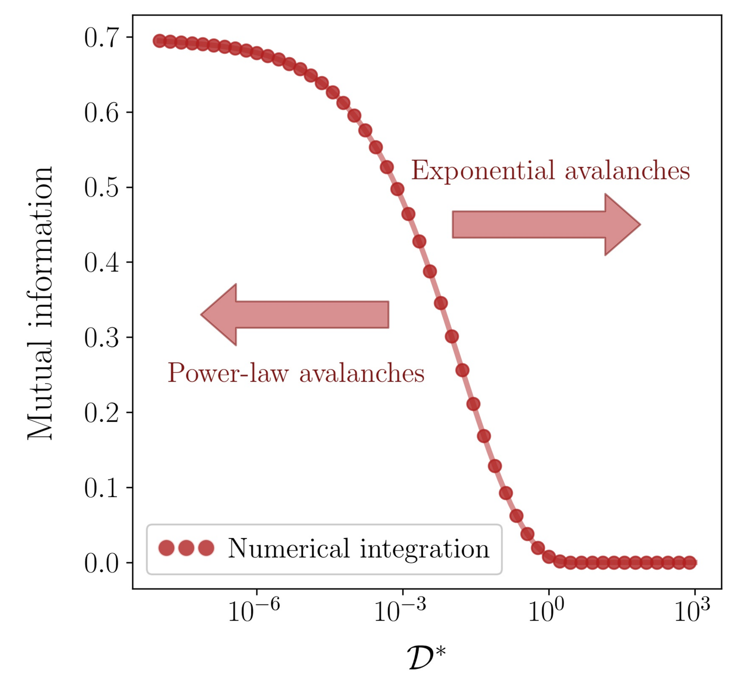


Extrinsic Activity

$\mathcal{D}^*$ is a parameter that controls the mutual information between the units.

$$\mathcal{D}(t) = \begin{cases} \mathcal{D}^* & \text{if} \quad D(t) \le \mathcal{D}^* \\ D(t) & \text{if} \quad D(t) > \mathcal{D}^* \end{cases}$$

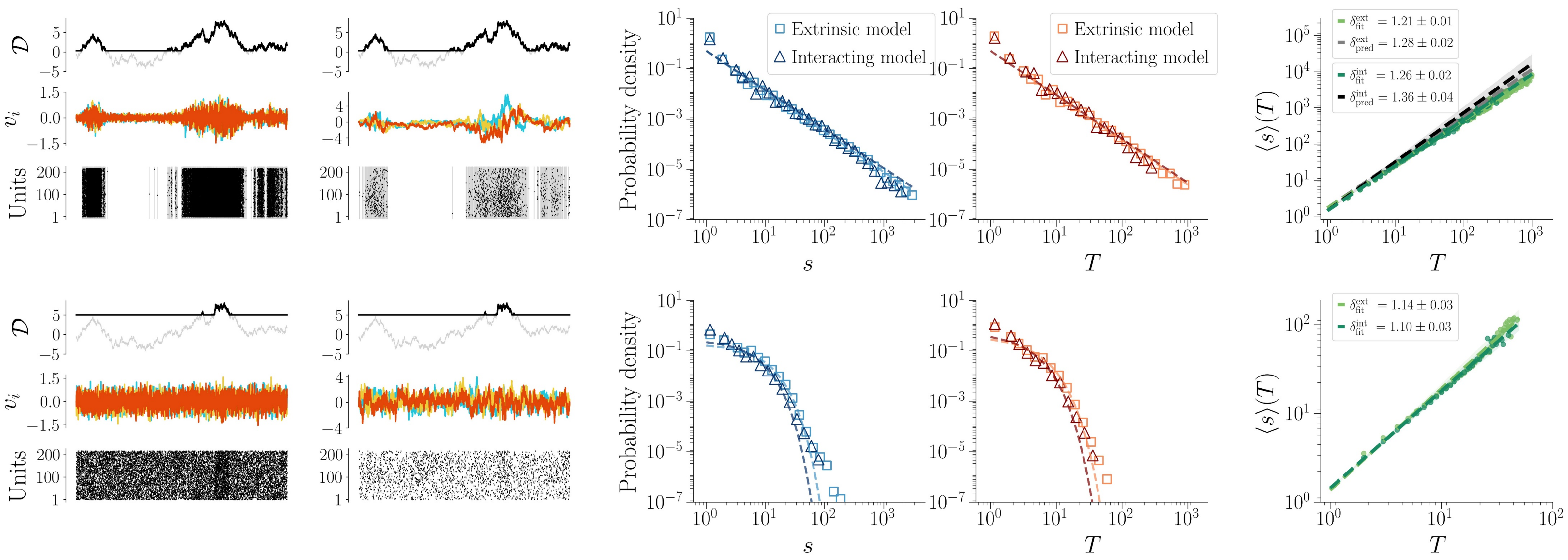
$$\frac{dD(t)}{dt} = -\frac{1}{\gamma_D}D(t) + \sqrt{\theta}\eta_D(t)$$



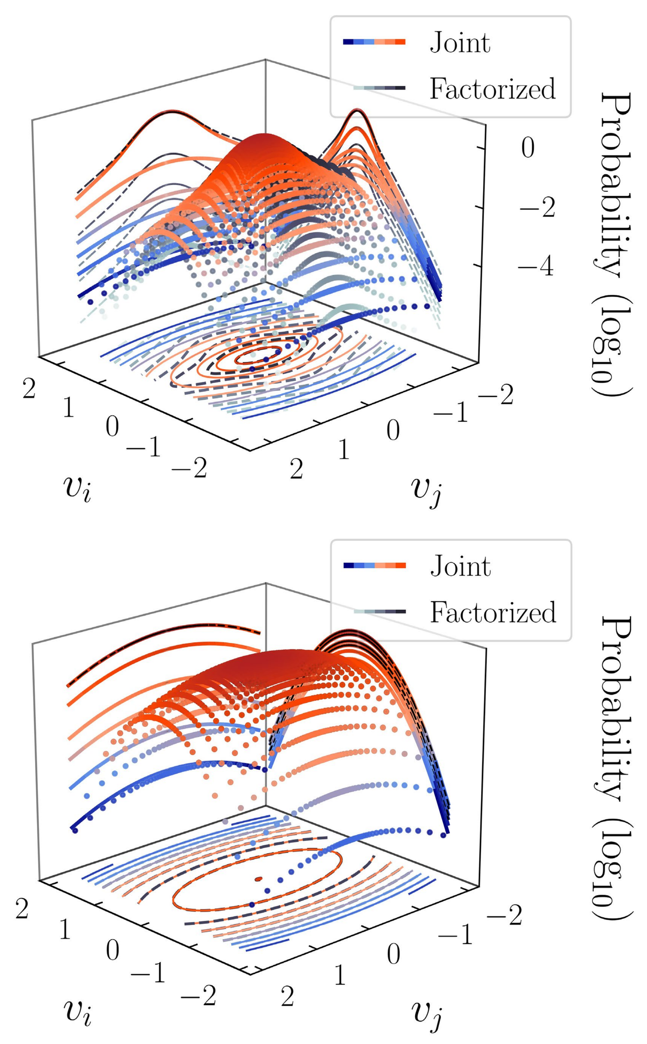
The extrinsic activity alone is enough to induce a mutual information between different units if $\mathcal{D}^*$ is low. The onset of this non-vanishing mutual information is also the onset of power-law distributed avalanches.

THE RESULTS

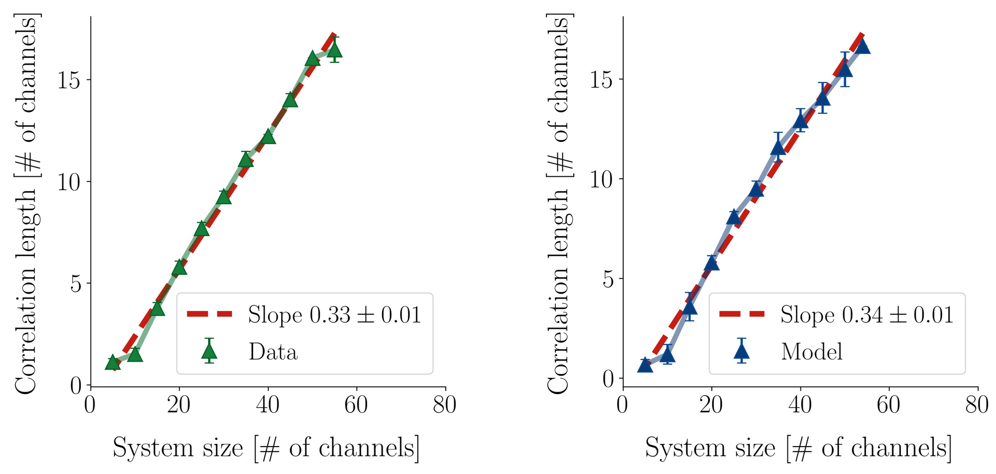
We show that power-law distributed avalanches that satisfy the crackling-noise relationship always appear because of the extrinsic **stochastic modulation**, that induces a **mutual information** among the units.



Due to the conditional-independent nature of the extrinsic activity, we can write exactly the joint-probability distribution and compare it to its factorization at low values of $\mathcal{D}^*$(top), and at high values (bottom).



On the other hand, the **correlation length** of our model and data scales linearly with system size, i.e. long-range correlations are present, because of the **reconstructed interactions**.



Our work sheds a light on which of the observed **critical signatures** in neural activity are fundamental in the understanding of the underlying **interactions**, and what others are simply the result of a **stochastic-induced collective dynamics**.