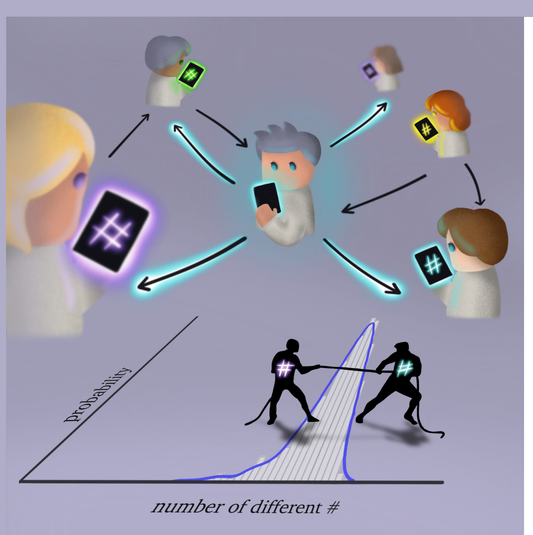
Neutral Theory for competing attention in social networks

Carlos A. Plata[1,2], Emanuele Pigani[1], Sandro Azaele[1], Violeta Calleja-Solanas[3], María J. Palazzi[4], Albert Solé-Ribalta[4,5], Javier Borge-Holthoefer[4], Sandro Meloni[3] and Samir Suweis[1,6,7]

[1]Dipartimento di Fisica "G. Galilei", INFN and University of Padova, Via Marzolo 8, 35151 Padova, Italy [2]Université Paris-Saclay, CNRS, LPTMS, 91405 Orsay, France [3]Institute for Cross-Disciplinary Physics and Complex Systems, CSIC-UIB, 07122 Palma, Spain [4]Internet Interdisciplinary Institute, Universitat Oberta de Catalunya, 08018 Barcelona, Catalonia, Spain [5]URPP Social Networks, University of Zurich, Zurich, Switzerland [6]Padova Neuroscience Center, University of Padova, Via Orus 2/B, 35131 Padova, Italy [7]European Center of Living Technology, Dorsoduro 3911, 30123 Venezia, Italy



Online social networks have significantly changed global communication dynamics. And despite the complexity of such dynamics, we observe **emergent patterns** from hashtag usage. However, going beyond empirical or simulation-based studies and distinguishing fundamental mechanisms at the origin of such patterns are still open problems.

Here, inspired by the neutral theory of ecology, we provide an **analytical formalism** capable of capturing the competition for attention and explaining several emergent patterns of *information ecosystems* within several **networks structures**:

- Persistence distributions of memes
- Number of coexisting memes
- Relative meme attention

We show how our theoretical framework is successful in explaining **real** empirical **data** collected from Twitter.

Why an ecological-inspired approach? There are analogies:

Species competing for resources → Memes competing for attention and users thriving for visibility
Extinction time → Persistence
Biodiversity → Number of coexisting memes
Healthy ecosystem that sustains high biodiversity → Healthy communication which diversity of ideas and no echo chambers

This allows the use of all the machinery developed in theoretical ecology for the study of online human interactions!

Model and formalism

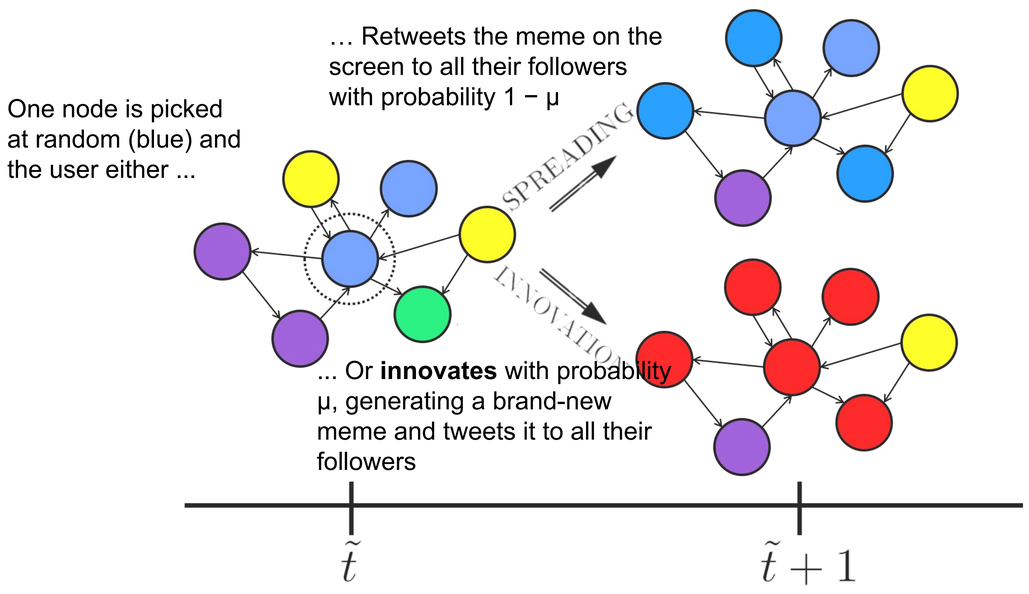
Our information ecosystems are **directed networks** of connected users (nodes) that retweet a single meme (color), solely characterized by its out-degree distribution p_k:

→ Homogeneous → Scale-free (as empirical ones)

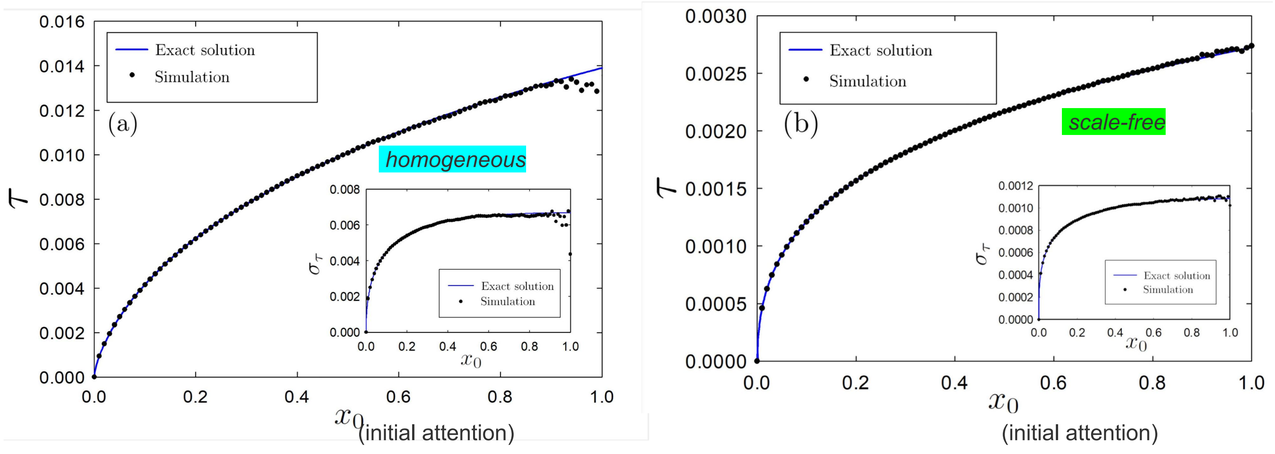
Why a neutral theory? Because it has been proven to be very successful in describing ubiquitous emergent patterns in ecology. Its main assumptions are:

- Every meme is equivalent
- The fate of a meme depends on its topological role in the network and on random demographic effects

With this setting, we can describe the dynamics as a discrete **Markovian process**.



Mean persistence time for attention τ



Or the lifetime of a meme.

The time that a meme persists in the network receiving attention gives insight into the virality of that meme, i.e., the longer it remains "active" the more probable it may go viral.

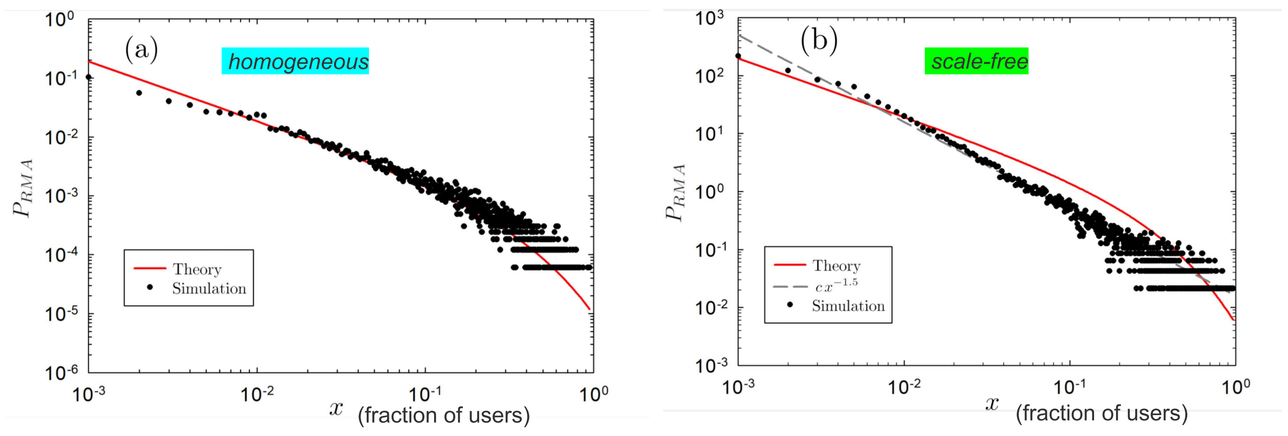
- It directly depends on the innovation rate (μ) and the structure.
- Exact expression obtained using the backward master equation matches numerical simulations.

Diversity: relative meme attention

It allow us to understand how users' attention is distributed among memes.

If the probability P_{RMA} that a meme receives attention from a fraction x of users is fat-tailed, then users' attention is extremely unevenly distributed among tweets, with some meme attracting attention of the majority of users.

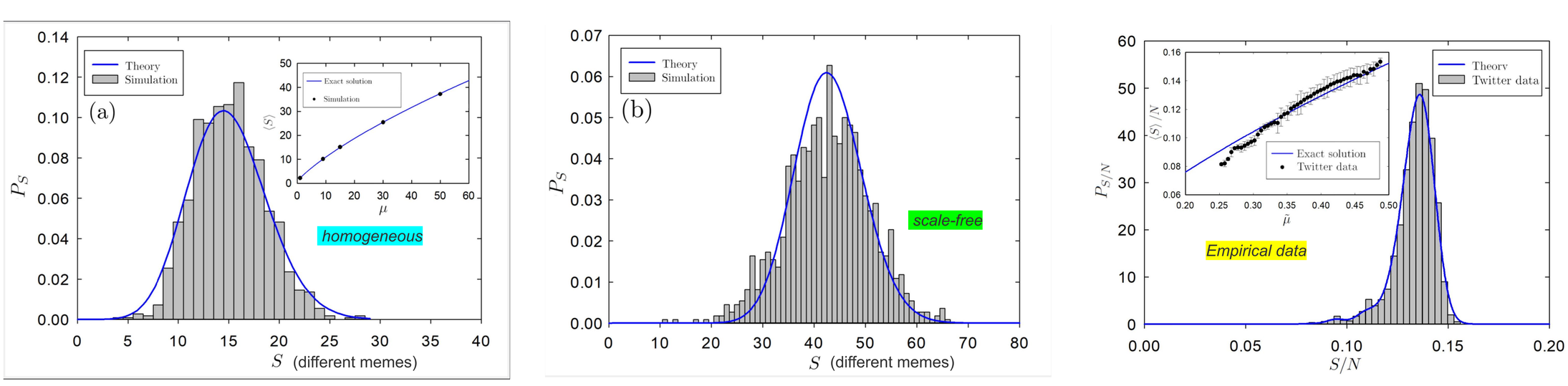
- The outcome of our prediction is a logarithmic-series distribution, rekindling a classical result for the relative species abundance in ecology, i.e., extremely heterogeneous.



Diversity: number of coexisting memes

The capacity of attention of users is finite and affects meme spreading.

- Because of both neutrality and the assumption of a constant innovation rate (μ), it is possible to exactly calculate the probability P_S of having S different memes coexisting: the stationary solution for P_S .In the long time limit, it is a Poisson distribution regardless of the network structure.
- Due to privacy constraints, this pattern is the only one to be tested empirically. Remarkably, given the correlations and possible biases in the data that could contradict the assumptions of our model, there is a good agreement.



This framework provides tractable analytical insight into the roles played by competition and network structure on uantities such as the number of coexisting memes, the distribution of user attention among these memes, and the average persistence time for attention to a meme; and a null model to be tested against different real data.

All these emergent properties have an ecological analogy in natural systems, suggesting that an ecological approach to study information ecosystems can provide an opportunity for understanding the dynamics of online communication networks.

Take a look at the full print here:
Plata, Carlos A., et al. "Neutral theory for competing attention in social networks." *Physical Review Research* 3.1 (2021): 013070.