

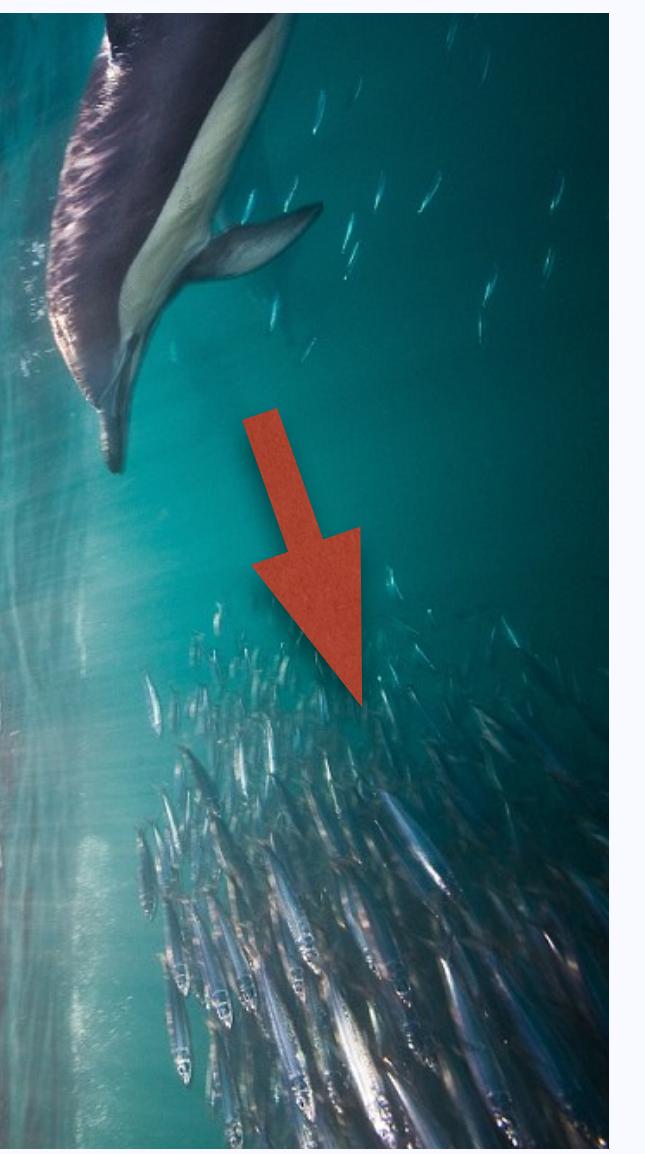
# Limitations on Information Dissemination via Noisy Communication and Implications to Animal Group Behavior

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## Central questions in biology

- How do biological entities process information?
- What is the impact of **noise** on computation?



## Example

**Estimate a direction away from a predator**  
(some fish see directly, some others see others running away)

A. Korman, E. Greenwald, O. Feinerman, [PLOS Comp. 2014]

## Error correction is difficult in stochastic environments

- Small message size: Redundancy at the price of small vocabulary
- Repeatedly talking to the same agent: Difficult

## Noisy PULL model

At each round, each agent independently selects one agent u.a.r and receives an noisy sample of its messages

### The noise criterion

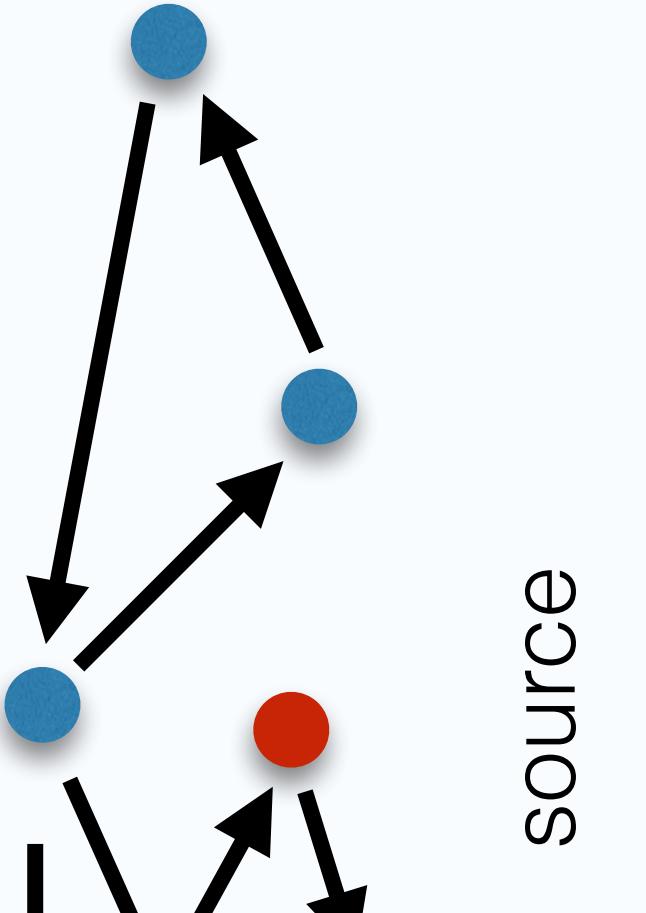
Any message can turn into any other message with prob  $> \delta$

### Rumor spreading problem

Converge on the opinion of the source

### Liberal computational assumptions

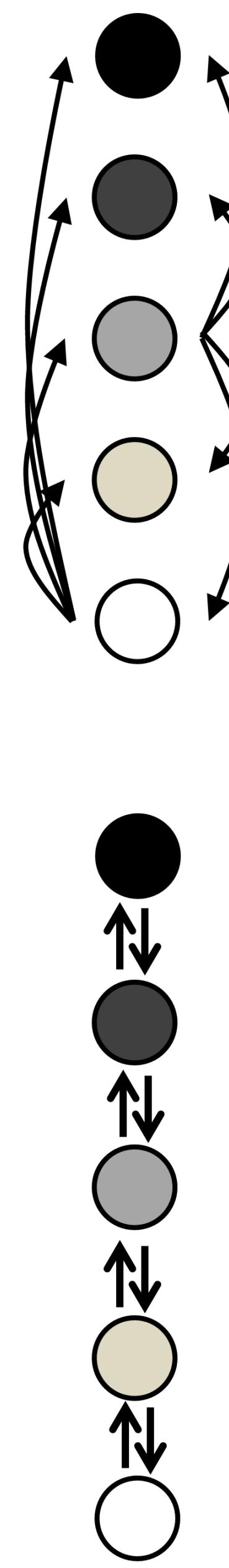
Full Synchronization, Infinite computational power, Shared randomness, Unique identities



## Theorem

No rumor spreading protocol can converge faster than  $\Omega(n\delta)$  steps

**non-uniform noise**



Algorithm:



## No Fast Solution

**First step in the proof: Reduce to Broadcast-PULL**

In each time step, the scheduler selects one agent u.a.r and all agents receive the same noisy sample of it message

### Lemma

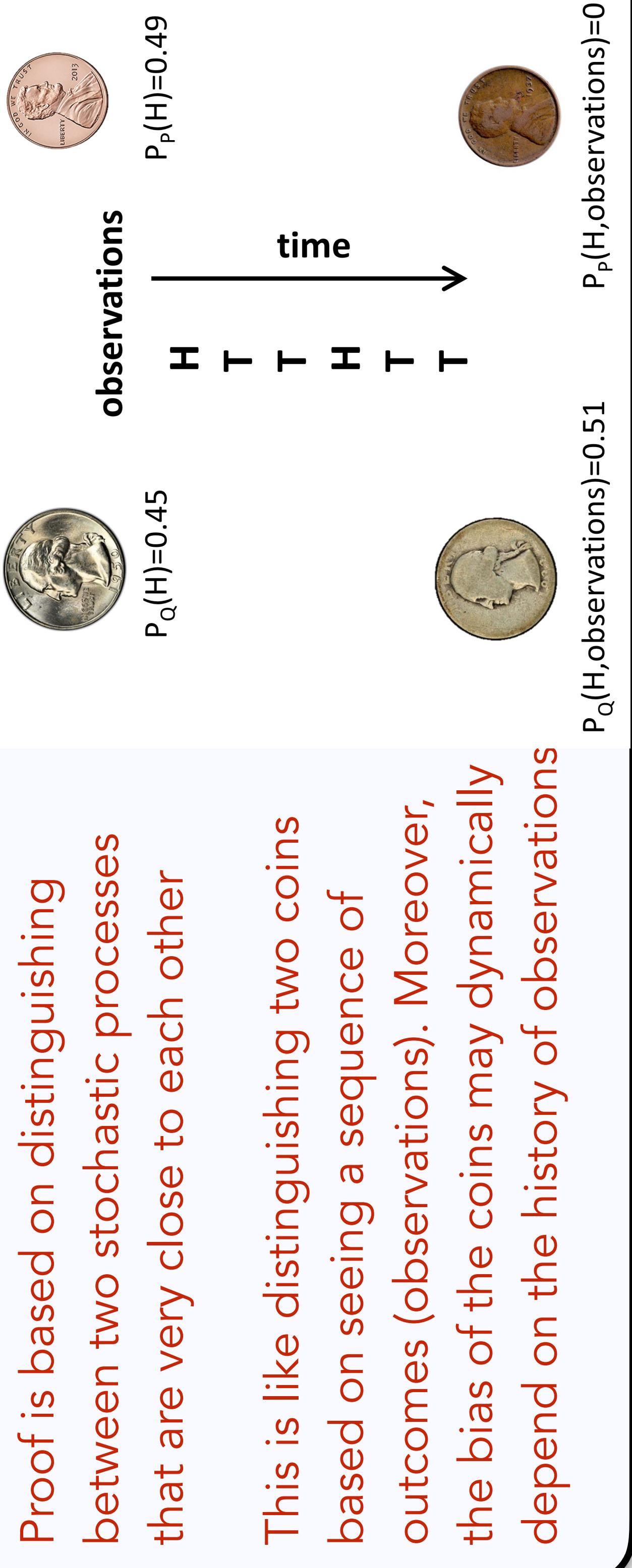
Any protocol in PULL can be simulated in Broadcast-PULL yielding a multiplicative factor of n to the running time

**Proof sketch**

- Divide time into rounds of n steps each
- In step i of a round, only agent i receives the observation
- At the end of the round, each agent updates its message

**Theorem**

No rumor spreading protocol in Broadcast-PULL can converge in less than  $\Omega(n^2\delta)$  teps



## Exponential separation between PUSH and PULL

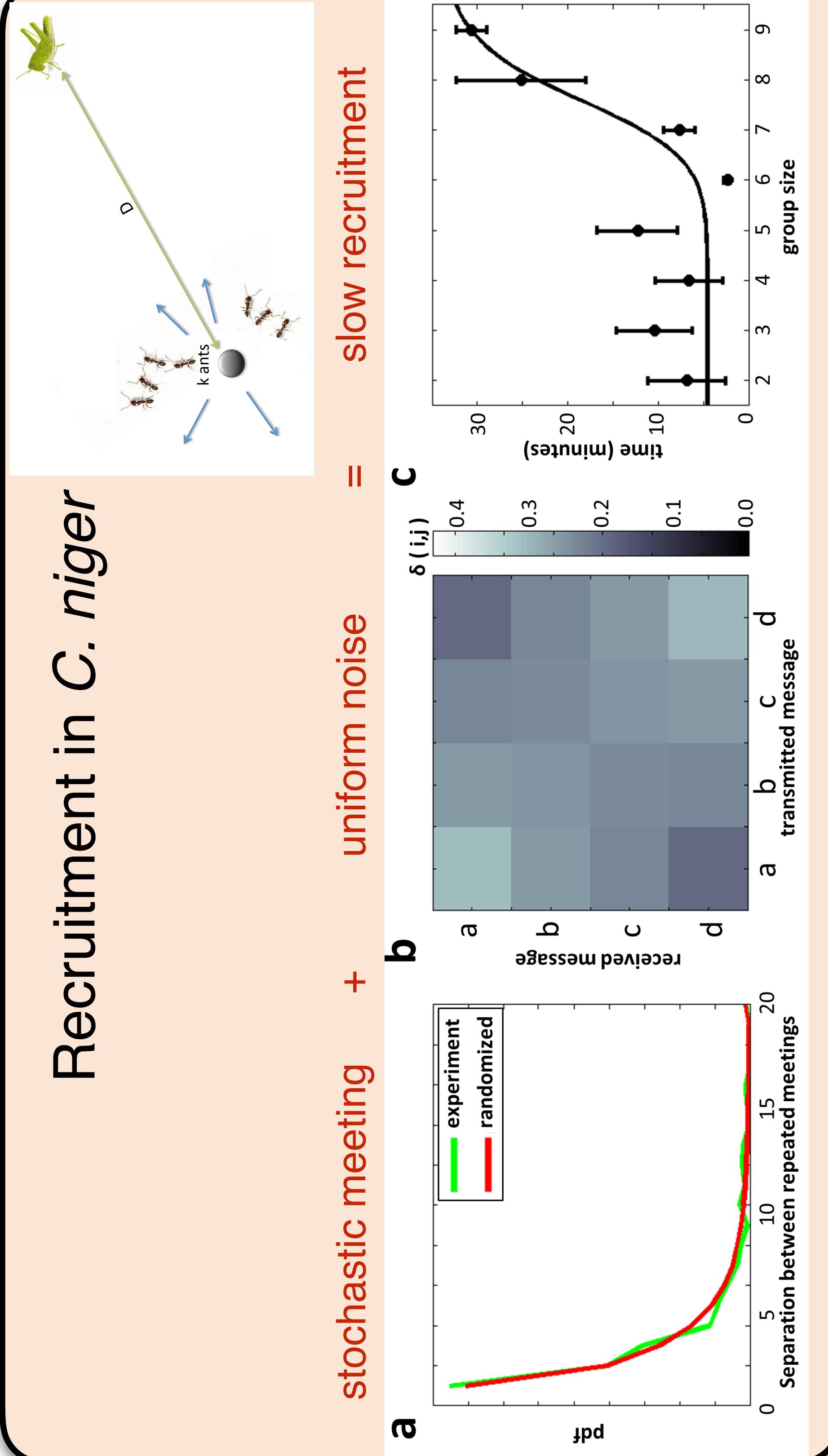
In the noisy push you can solve the problem in logarithmic time!

Ofer Feinerman, Bernhard Haeupler, and Amos Korman [PODC 2014]

## Biological implications

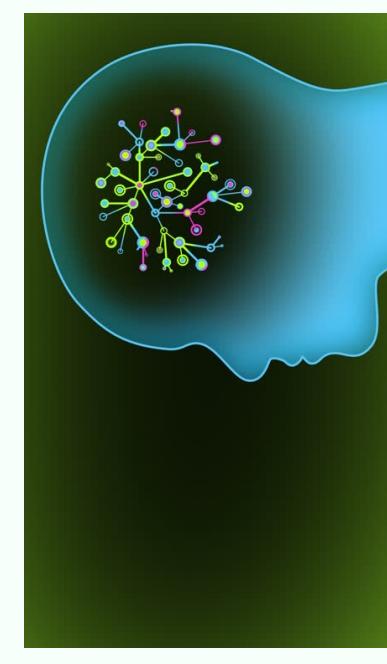
- **Fast rumor spread is possible only if:**
  - you have stable structure, or
  - noise is non-uniform

## Very slow rumor spread

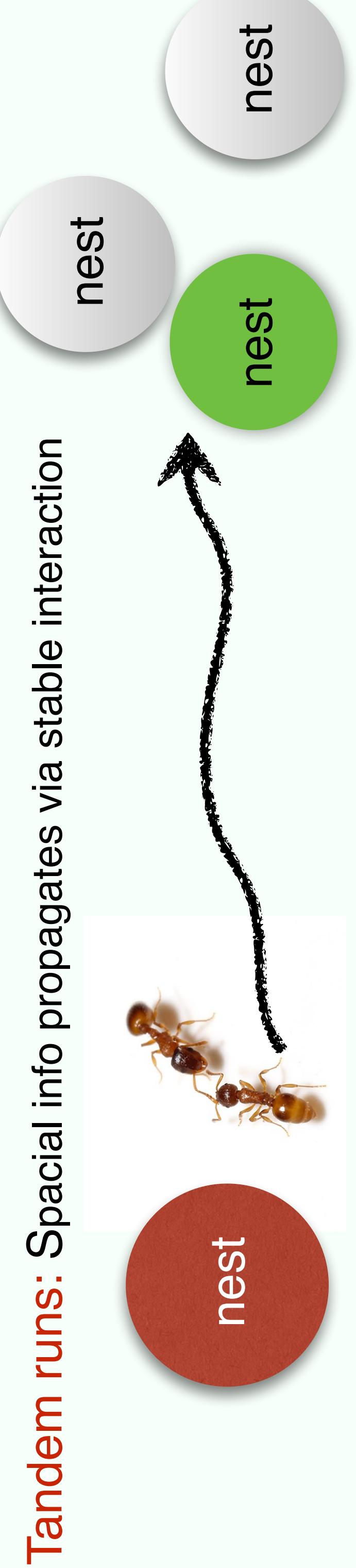


## Strategies to overcome noise

## Examples for info spread via stable connectivity



**The brain:** Stable structure = fast rumor spread



## Non-uniform noise



**Alarming in ants**  
smell of alarm is distinct!

Increased order within a flock  
of birds increases the speed of info spread