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About human activity, long-term memory, and Gibrat's law

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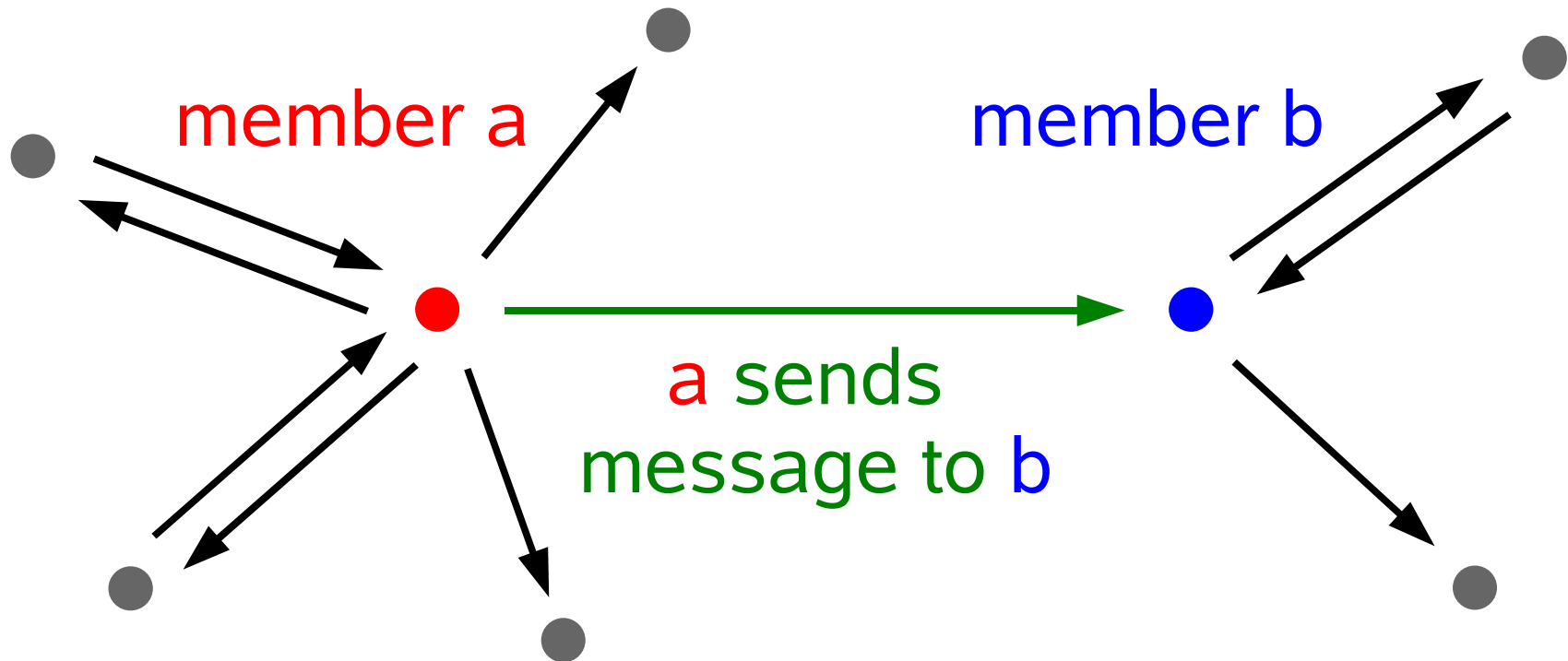
APS March Meeting 2009

Pittsburgh; room 303

March 19, 2009; 9:36 am – 9:48 am

Motivation

online community: members sending messages



either following an existing link $m_a \rightarrow m_a + 1$
or creating a new one $k_a^{\text{out}} \rightarrow k_a^{\text{out}} + 1$
=> growth process

Outline

1. online community data
2. growth process
3. temporal correlations
4. missing link
5. conclusions

Online community data

online community 1 (OC1):

- 80,000 members
- 12.5 million messages
- 63 days

online community 2 (OC2):

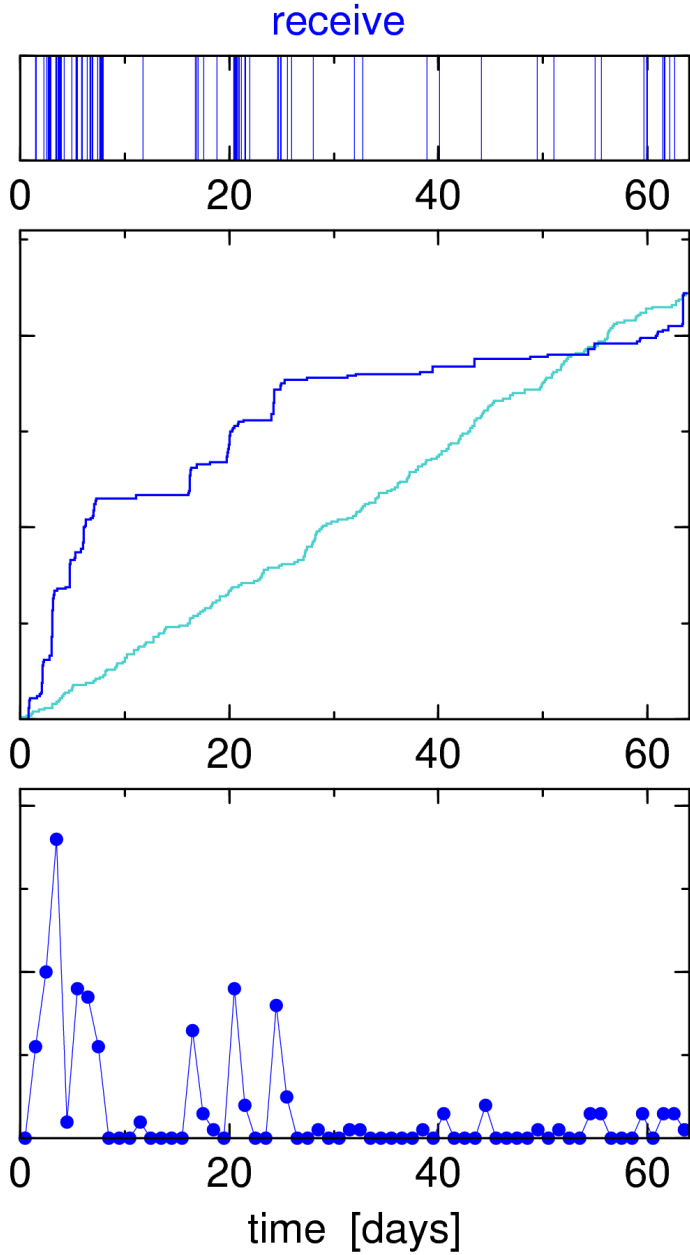
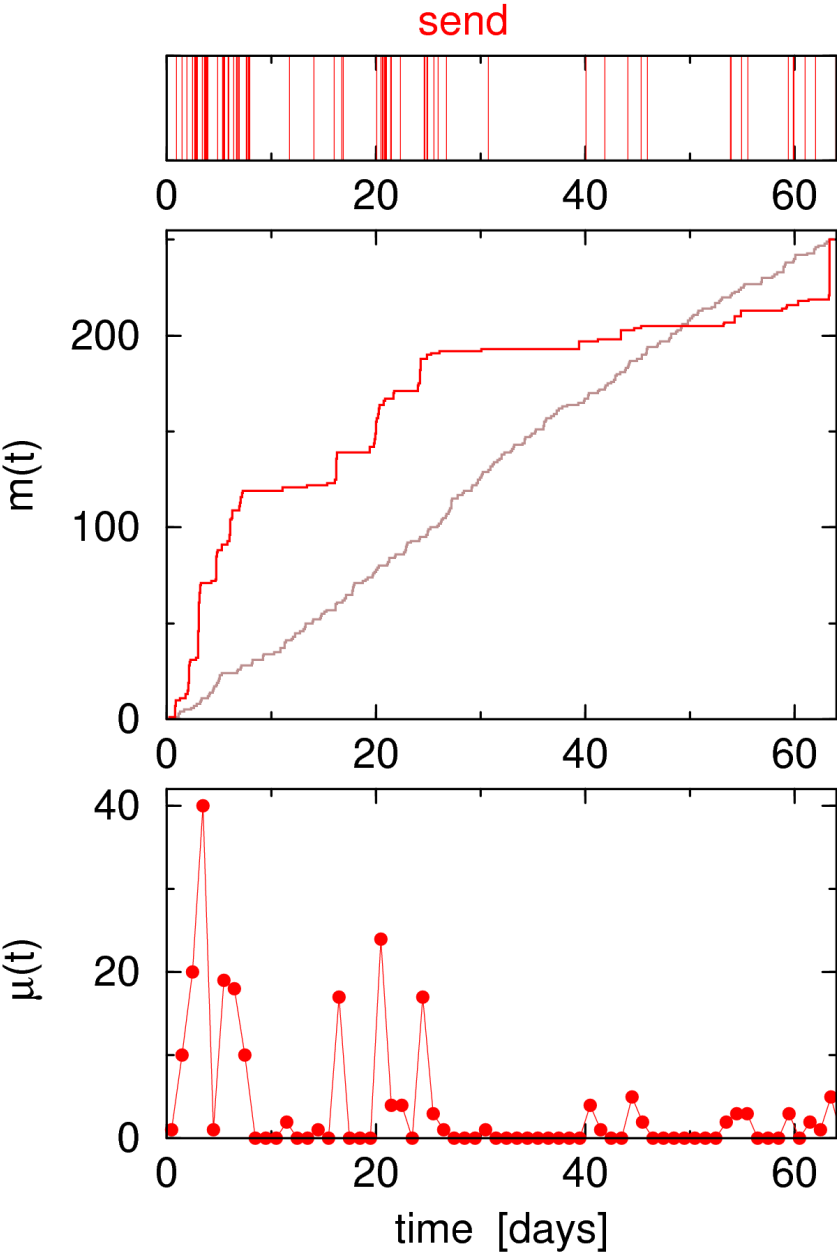
- 30,000 members
- 500,000 messages
- 492 days

both are dating-communities

also used for social interaction in general

completely anonymous

Typical activity (OC1)



Growth process

for each member:

cumulative number of messages $m(t)$

logarithmic growth rate $r = \ln \frac{m_1}{m_0}$

between two time-steps t_0, t_1

two quantities:

conditional average growth $\langle r(m_0) \rangle = \langle r | m_0 \rangle$

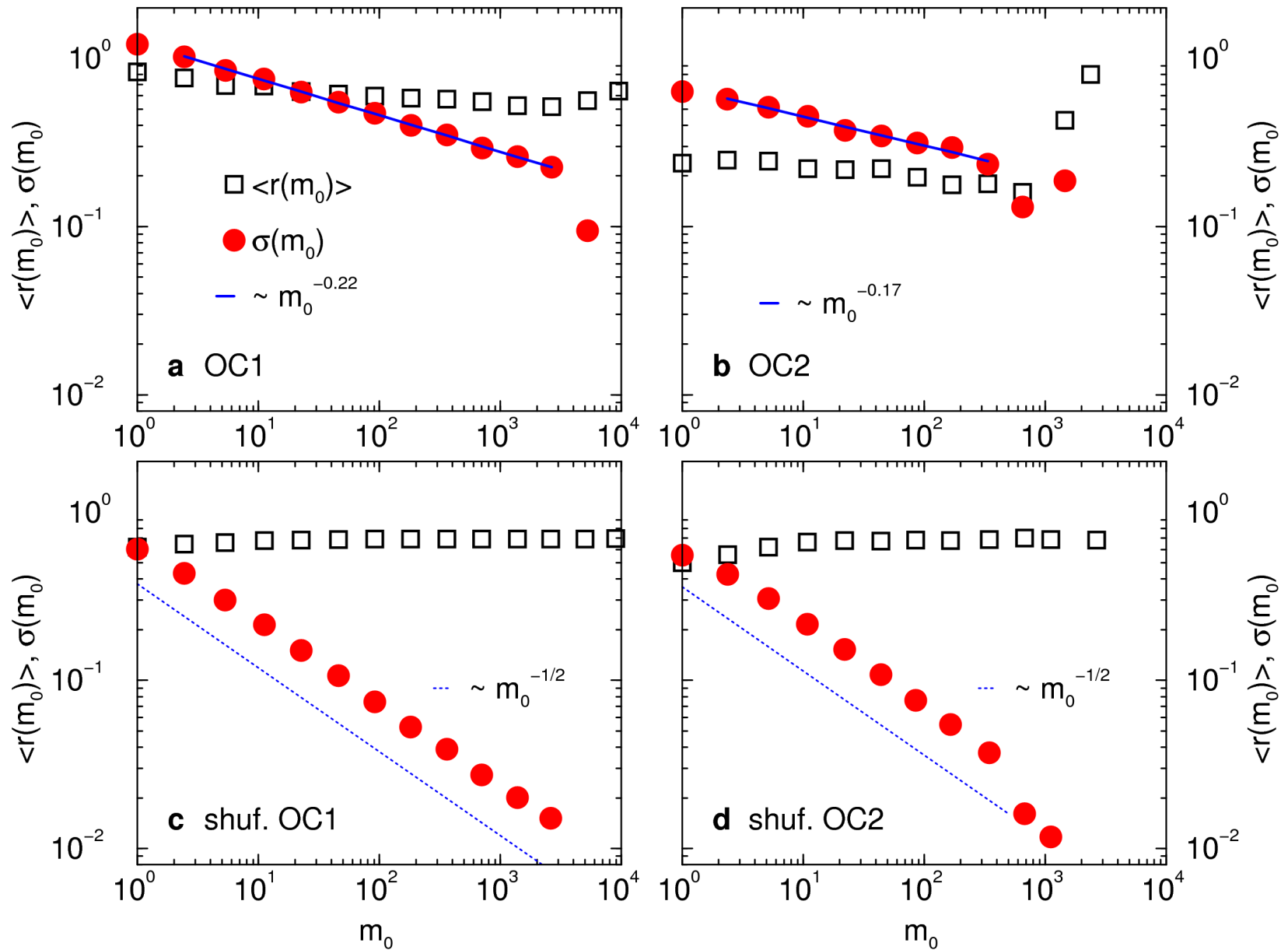
cond. standard deviation $\sigma(m_0) = \sigma(r | m_0)$

see e.g. M.H.R. Stanley et al., nature, 1996.

Analogy to other data, such as city growth

- (1) The members of a community represent a **population** similar to the population of a country.
- (2) The number of members fluctuates and typically grows **analogous** to the number of cities of a country.
- (3) The activity or number of links of individuals **fluctuates** and **grows** similar to the size of cities.

Growth process: results



Growth process: results

$$\sigma(m_0) \sim m_0^{-\beta}$$

$$\text{OC1: } \beta_{\text{OC1}} = 0.22 \pm 0.01$$

$$\text{OC2: } \beta_{\text{OC1}} = 0.17 \pm 0.03$$

$$\text{shuffled: } \beta_{\text{rnd}} = 1/2$$

Gibrat's law of proportionate growth

multiplicative process

to explain broad distributions (log-normal)

involves assumption: $\langle r(m_0) \rangle = \text{const.}$

$$\sigma(m_0) = \text{const.}$$

$$\Rightarrow \beta_G = 0$$

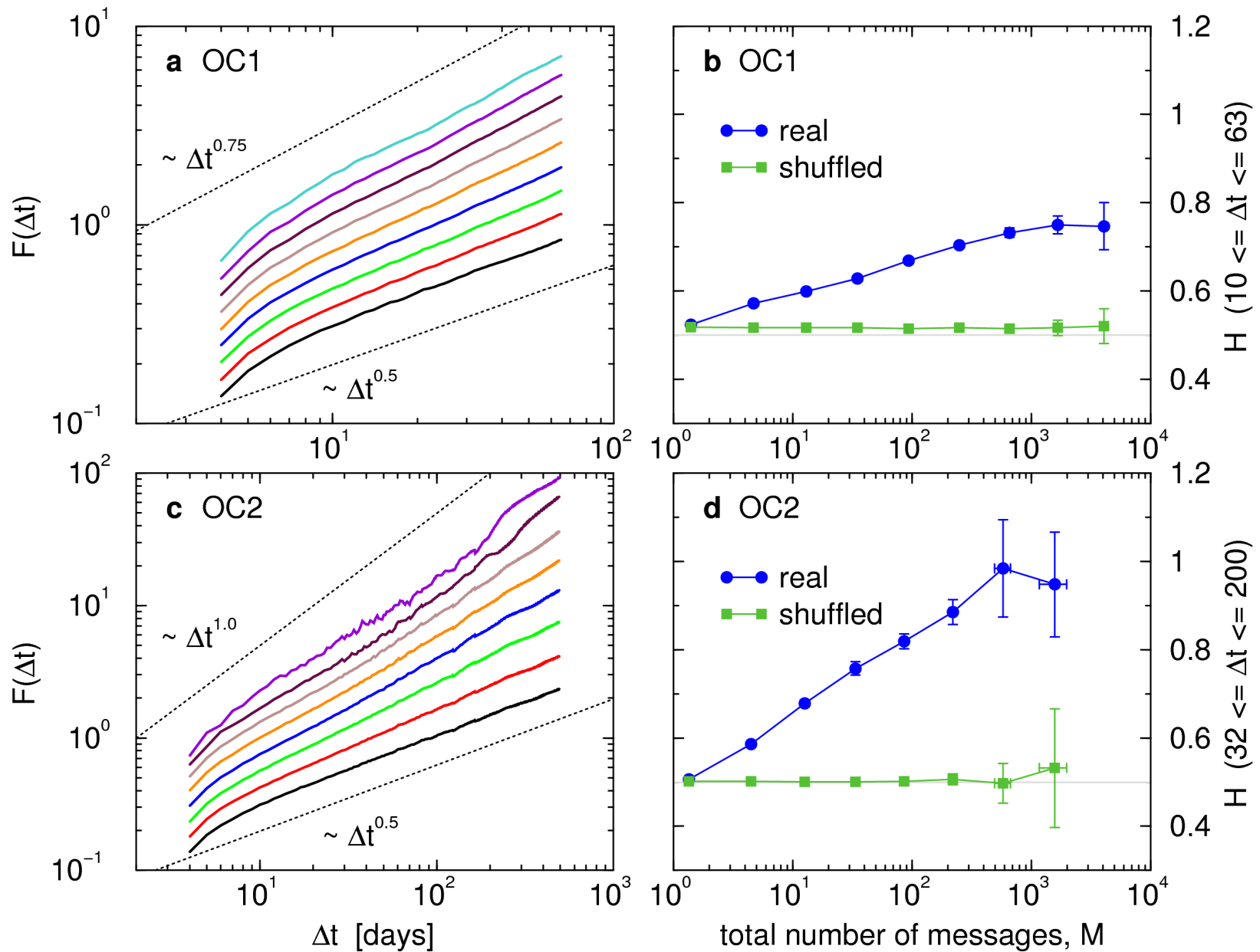
Temporal correlations

- **shuffling** destroys temporal correlations, leading to $\beta_{\text{rnd}} = 1/2$
- this suggests $\beta \approx 0.2$ might be due to **temporal correlations**
- we use Detrended Fluctuation Analysis (DFA) to **quantify long-term correlations** in the activity (messages per day): $\mu(t)$

fluctuation function: $F(\Delta t) \sim (\Delta t)^H$

$$1/2 < H < 1 \quad \Rightarrow \text{lrc}$$

Temporal correlations: results



Missing link

derivation leads to:

$$\beta = 1 - H$$

accordingly:

$$\beta \approx 0.2 \Rightarrow H \approx 0.8$$

OCs

$$\beta_{\text{rnd}} = 1/2 \Rightarrow H_{\text{rnd}} = 1/2$$

shuffled

$$\beta_{\text{G}} = 0 \Rightarrow H_{\text{G}} = 1$$

Gibrat's law

Conclusions

1. **human activity** sending messages is long-term correlated

2. scaling in growth $\sigma(m_0) \sim m_0^{-\beta}$ is due to **long-term correlations**

=> this may also be the case for **other data**

paper submitted to PNAS: Rybski *et al.*

Thank you for your attention