# Explorers-and-returners mobility coupled to epidemic spreading

(Work in progress)

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# Background: How do we deal with spreading and mobility?

Metapopulation framework:

- Spatial structure: theoretical or real complex networks
- Mobility dynamics: random walks, gravity, radiation, recurrent, data-driven.

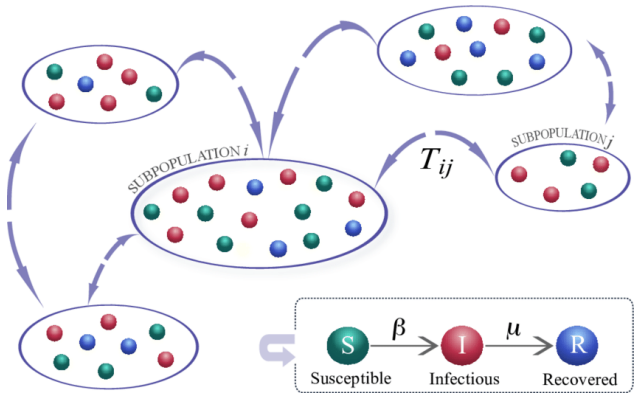


Figure: From Ventura (2022): Metapopulation scheme

It is versatile and fruitful but has limitations:

- Typically assumes coarse-grained & not micro-founded mobility.
- Hampers exploration & conception of fine-grained interventions.

# Motivation: Discoveries in human mobility

Advent of Big Data era allowed for...

Vol 453|5 June 2008|doi:10.1038/nature06958 nature

LETTERS

**Understanding individual human mobility patterns**

Marta C. González[1], César A. Hidalgo[1,2] & Albert-László Barabási[1,2,3]

ARTICLES

PUBLISHED ONLINE: 12 SEPTEMBER 2010 | DOI: 10.1038/NPHYS1760

nature physics

**Modelling the scaling properties of human mobility**

Chaoming Song[1,2†], Tal Koren[1,2†], Pu Wang[1,2†] and Albert-László Barabási[1,2,3★]

- Humans follow simple reproducible patterns.
- RW, CTRW, and Lévy flights are in conflict with empirical results.
- Principles that govern human trajectories: exploration & preferential return (EPR models)

# Returners and explorers dichotomy


ARTICLE

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## Returners and explorers dichotomy in human mobility

Luca Pappalardo[1,2,3,4], Filippo Simini[4,5,6], Salvatore Rinzivillo[1], Dino Pedreschi[1,2], Fosca Giannotti[1] & Albert-László Barabási[3,6,7]

The availability of massive digital traces of human whereabouts has offered a series of novel insights on the quantitative patterns characterizing human mobility. In particular, numerous recent studies have lead to an unexpected consensus: the considerable variability in the characteristic travelled distance of individuals coexists with a high degree of predictability of their future locations. Here we shed light on this surprising coexistence by systematically investigating the impact of recurrent mobility on the characteristic distance travelled by individuals. Using both mobile phone and GPS data, we discover the existence of two distinct classes of individuals: returners and explorers. As existing models of human mobility cannot explain the existence of these two classes, we develop more realistic models able to capture the empirical findings. Finally, we show that returners and explorers play a distinct quantifiable role in spreading phenomena and that a correlation exists between their mobility patterns and social interactions.

- Explorers tend to visit several locations a few times.
- Returners concentrate visits in a few locations (high recurrency).

# Course of action

Aims:

- Couple these agent-based EPR-like mobility models into spatial epidemics modeling.
- Get new insights and try to find control measures that take advantage of this.

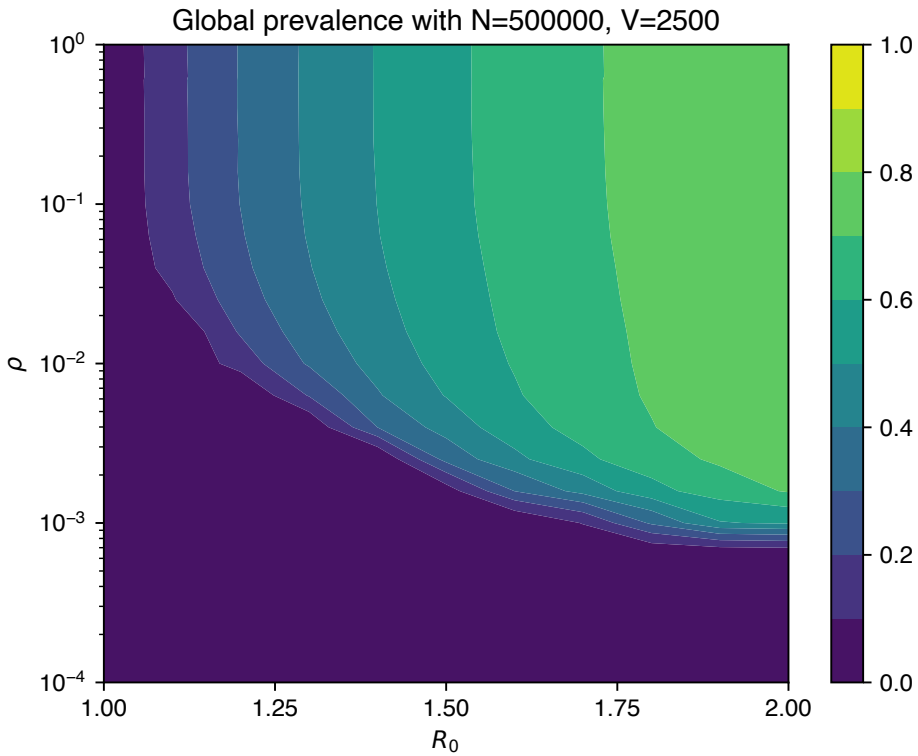
Main questions for now:

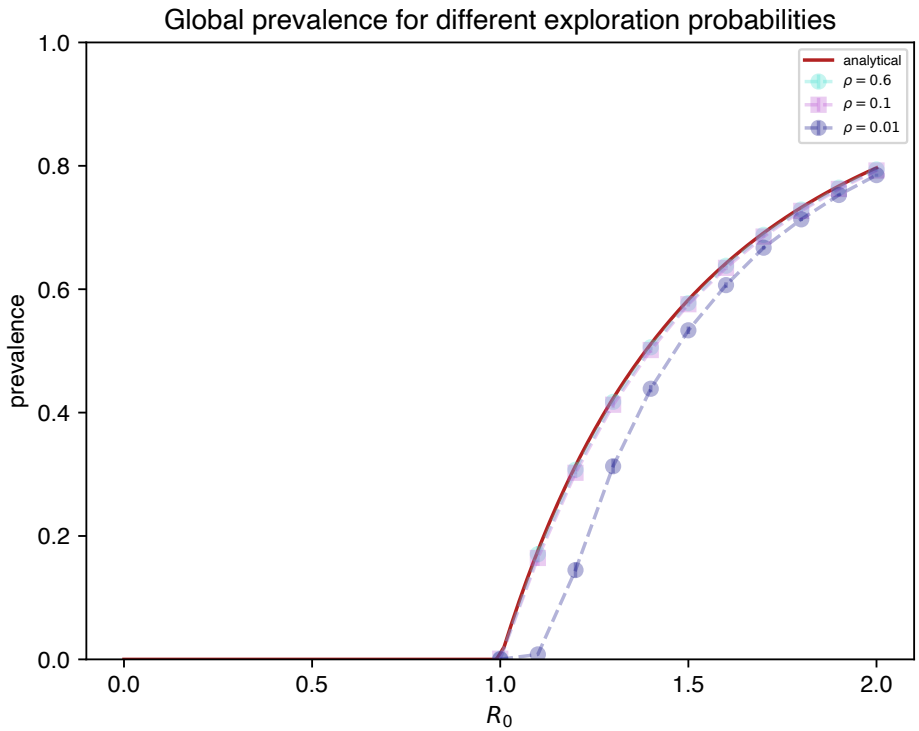
- How is the spreading dynamics affected by these mobility models?
- How are the different mobility profiles impacted by the spreading?

# Our working model

- Spatial structure: regular lattice of locations (with uniform and also heterogeneous attractiveness).
- d-EPR model: At every time step, every agent "decides" whether to explore or return following $P_{\mathrm{exp}} = \rho S^{-\gamma}$.
  - Exploration: mobility gravity law: $P_{ij} \propto \frac{A_i A_j}{r_{ij}^2}$.
  - Return: weighted sampling among already visited locations $\propto f_k / f$.
- Epidemiological model: well-mixed SIR at the location level.

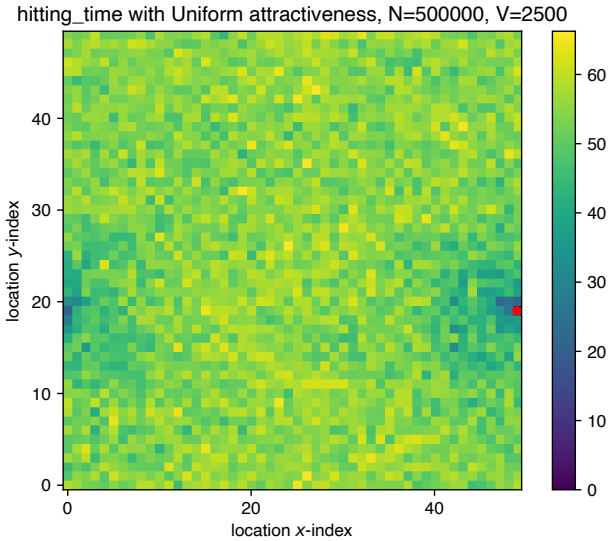
# Preliminary findings: Global behavior

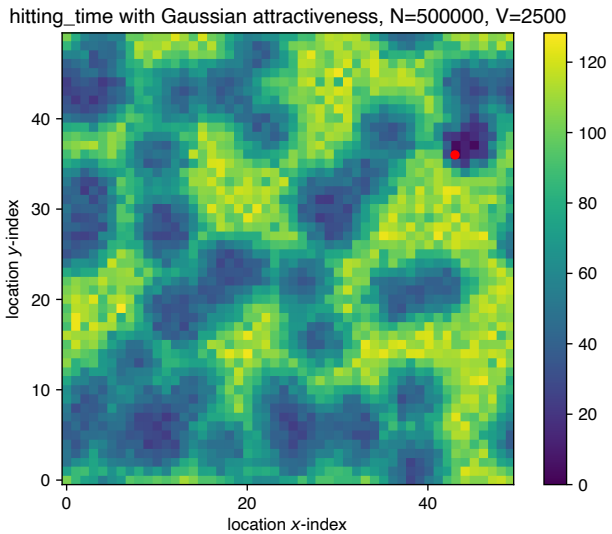


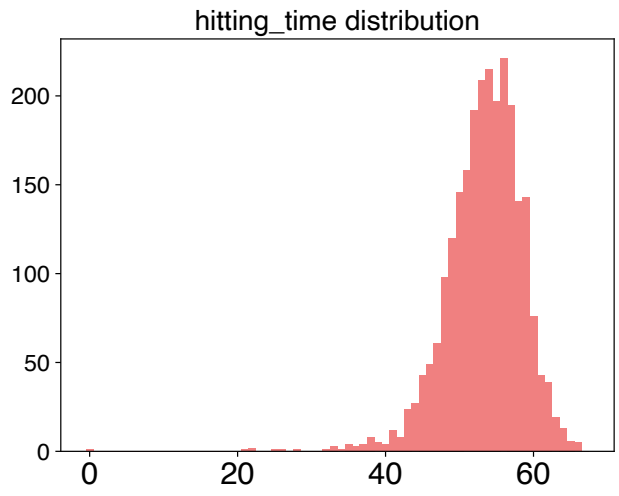



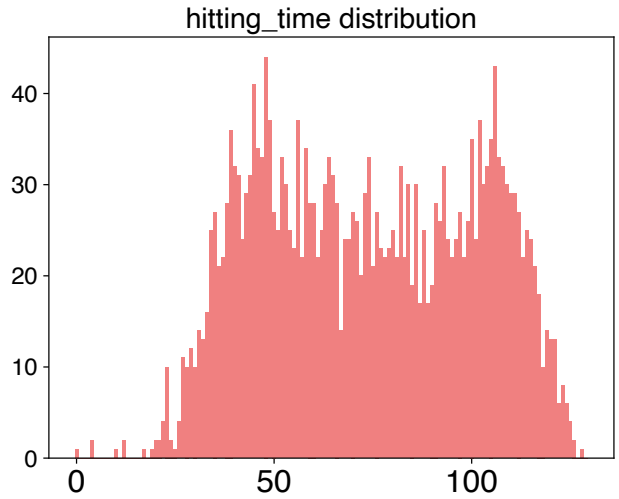

- Sure, decreasing $\rho$ reduces the global prevalence, but the impact is minimal except extremely low values.
- High enough $\rho$: global behavior is much like the classical single population SIR model.

# Preliminary findings: Spatial patterns at location scale

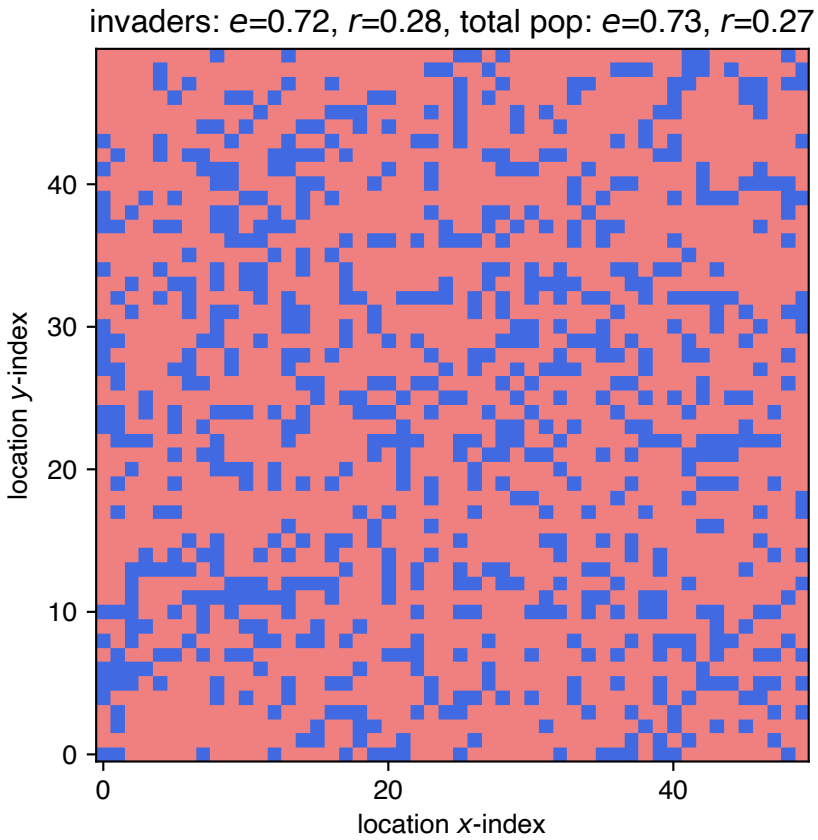


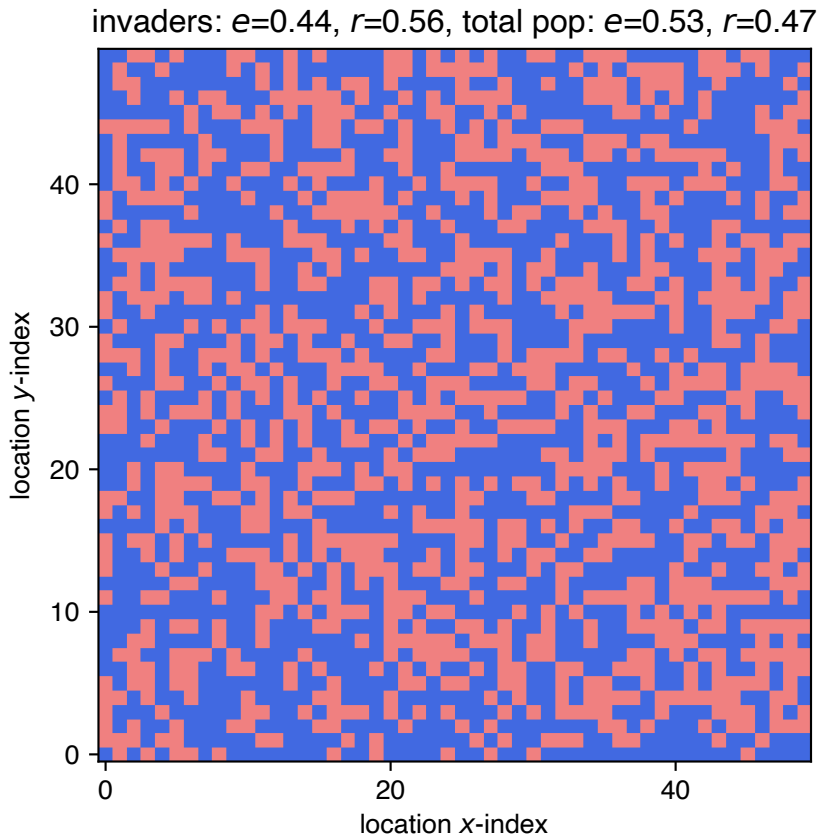



# Preliminary findings: Explorers and Returners




(a) $\rho = 0.6$




(b) $\rho = 0.01$

- Some differences appear related to who invades every location.
- But we have not found a clear relationship yet regarding prevalence. :(

# To be continued...

As a work still under development, lot of things to address now:

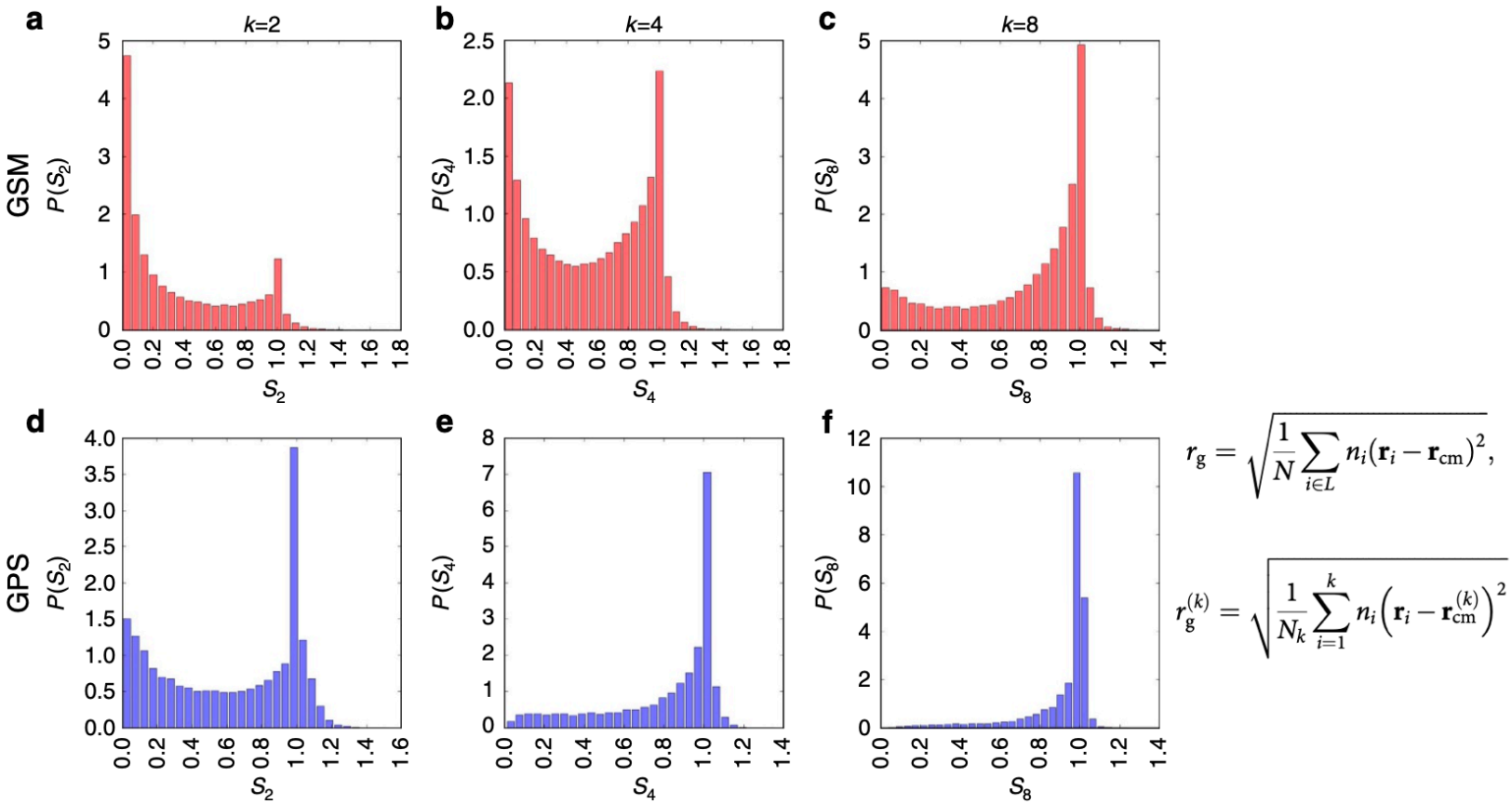
- Conclude the systematic analysis of our toy model and clarify the role that explorers and returners play.
- Move to real urban spaces.

Other potential future work:

- How do these models relate to regular metapopulation models?
- Explore the system behavior under non-pharmaceutical interventions.
- Introduce further sources of heterogeneity and layers of realism.


THANK YOU
FOR YOUR CATTENTION

# Explorers and returners




$$r_g = \sqrt{\frac{1}{N}\sum_{i\in L} n_i(\mathbf{r}_i - \mathbf{r}_{cm})^2},$$

$$r_g^{(k)} = \sqrt{\frac{1}{N_k}\sum_{i=1}^{k} n_i\left(\mathbf{r}_i - \mathbf{r}_{cm}^{(k)}\right)^2}$$

**Figure 4 | The ratio between recurrent and overall mobility.** The distribution $P(s_k)$ of the ratio $s_k = r_g^{(k)}/r_g$ measured on the GSM data for $k = 2, 4, 8$ (**a**–**c**). The peak at $s_k = 0$ corresponds to explorers, while the $s_k = 1$ peak corresponds to returners. For small $k$ in the GSM data, $k$-explorers are more numerous than $k$-returners. As $k$ increases the number of $k$-returners increases and overcomes the number of $k$-explorers. A balance in the population is reached at $k = 4$. (**d**–**f**) The $P(s_k)$ for the GPS data. We again observe two peaks, but the $k$-returners peak, $s_k = 1$, dominates for all $k \geq 2$.