

Collective « fields »
in physics and sociology –
Spatio-temporal vote turnout patterns
With Ch. Borghesi

“From micro-rules to macro-behaviour” (Schelling)

- Inferring the behaviour of large assemblies from the behaviour of its elementary constituents is **THE** fundamental problem in physics, material sciences, biology, sociology, traffic flow, economics, and sociology.

- A notoriously hard problem

- Traditional Macro: Homogeneous, non-interacting, rational agents, Aka « The representative agent »

- But heterogeneities and interactions can lead to totally unexpected phenomena: **micro and macro behaviour need not coincide**

◁ Crises are expected to require large aggregate shocks, when in fact small local shocks could trigger large systemic effects

“From micro-rules to macro-behaviour”

Statistical physics has developed in last 100 years precisely to understand the micro-macro link:

- **When interactions are absent or *small enough***, the system as a whole reflects the properties of individual atoms (i.e. the RA)
- **When interactions reach a threshold**, one may observe a **phase transition** where the macro-properties are totally different from those of individual atoms, and often unexpected and **hard to guess**, e.g.:
 - ◁ Rigidity and jamming, magnetism, super-fluidity/-conductivity
 - ◁ The segregation phenomenon in Schelling’s model, even when agents are OK with 50-50 mix, etc. etc.



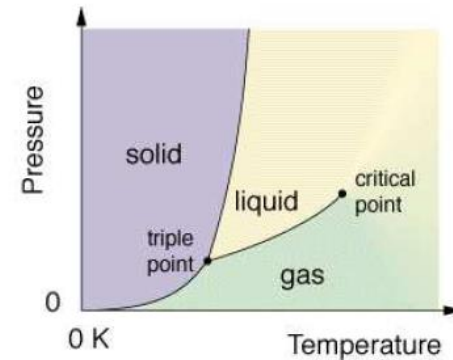
Water at 272K and 274K
!!!

“Broken symmetry” and collective fields

Take a solid, made of the very same atoms as the liquid/gas.

What makes it so different?

Is “rigidity” that trivial?

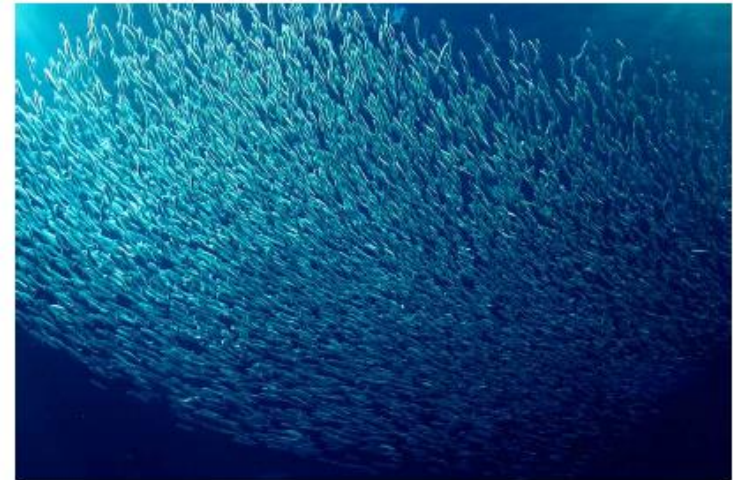


Rigidity: “action at a distance” and memory:

- Atoms “know” what happens far away
- Atoms remember where they should sit, even when each one of them is free to move and *does indeed move*

What makes this possible is the existence, in the “symmetry broken” phase, of a collective field created by the atoms, but not belonging to any of them, and possibly surviving all of them

An example of “collective memory”: bird flocks



Starlings (A. Cavagna et al.) and fish schools

Each bird has a only very vague idea of the direction to follow, but if interaction (imitation) is strong enough, the flock will fly in the « right » direction, thanks to the appearance of a *collective* « direction field », robust to error and noise

In search of collective fields in human behaviour

Empirical study of vote turnout statistics:

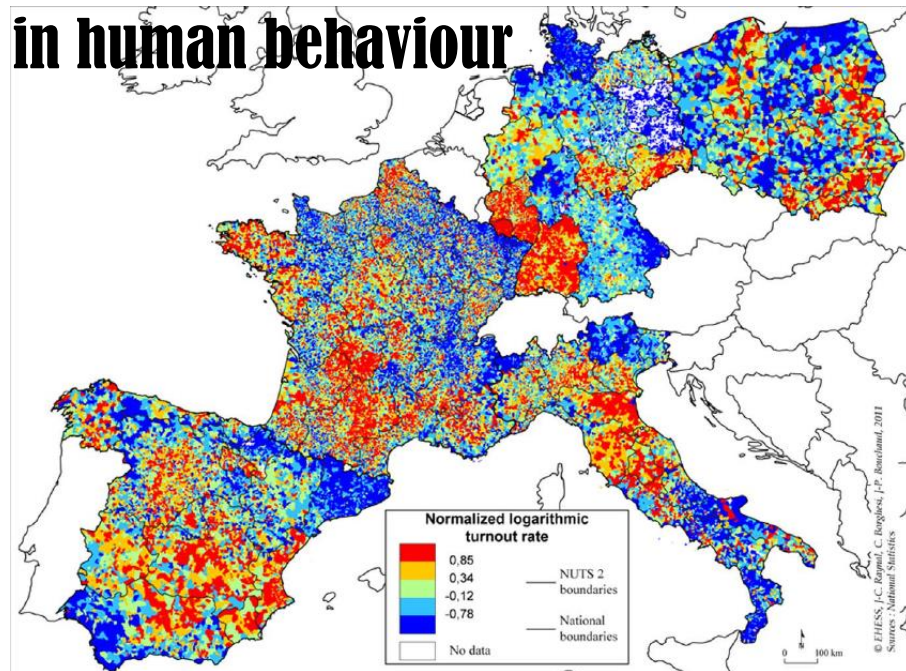
- Many elections in many countries
 - Spatially resolved at the level of cities or even “bureau de vote”
 - Different elections but a unique question:
how many people did participate?
 - “Natural experiments”: different types of elections (P,L,E,M)/
Same elections but different countries/evolution over 20 years of the electoral body, etc.
-
- 77 elections, from 11 different countries.
 - 22 from France (36000 municipalities in mainland France) from 1992 to 2010
 - 13 from Austria (2400 municipalities), 11 from Poland (2500 municipalities),
7 from Germany (12000 municipalities)
 - Canada (5), Spain (4), Italy (4), Romania (4), Mexico (3), Switzerland (3), Czech Republic (1)

In search of collective fields in human behaviour

$$\pi = N_+ / N \in [0, 1]$$

$$\tau := \ln \left(\frac{\pi}{1 - \pi} \right)$$

European elections 2004



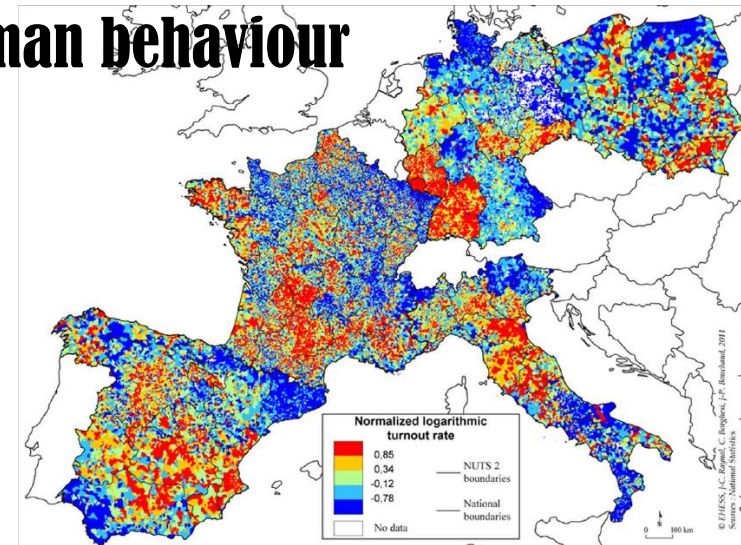
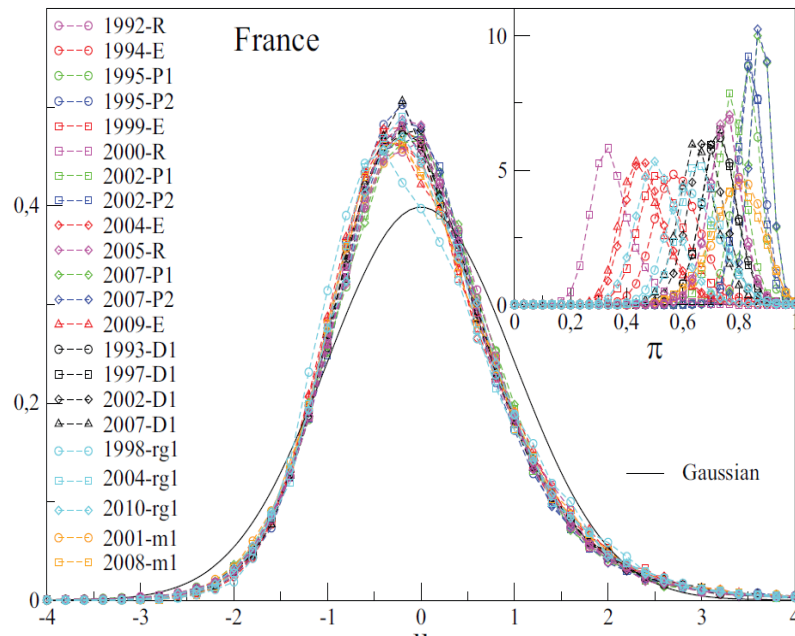
A striking result in turnout statistics:

- The average turnout rate is election/country dependent
- But the spatial and temporal fluctuations around the average are **long range correlated** and **reveal some universal regularity**
- The fact that there are strong and permanent patterns in regional voting habits (and political choices) is long known, but we have tried to make these observations *quantitative*.

In search of collective fields in human behaviour

$$\tau := \ln\left(\frac{\pi}{1-\pi}\right)$$

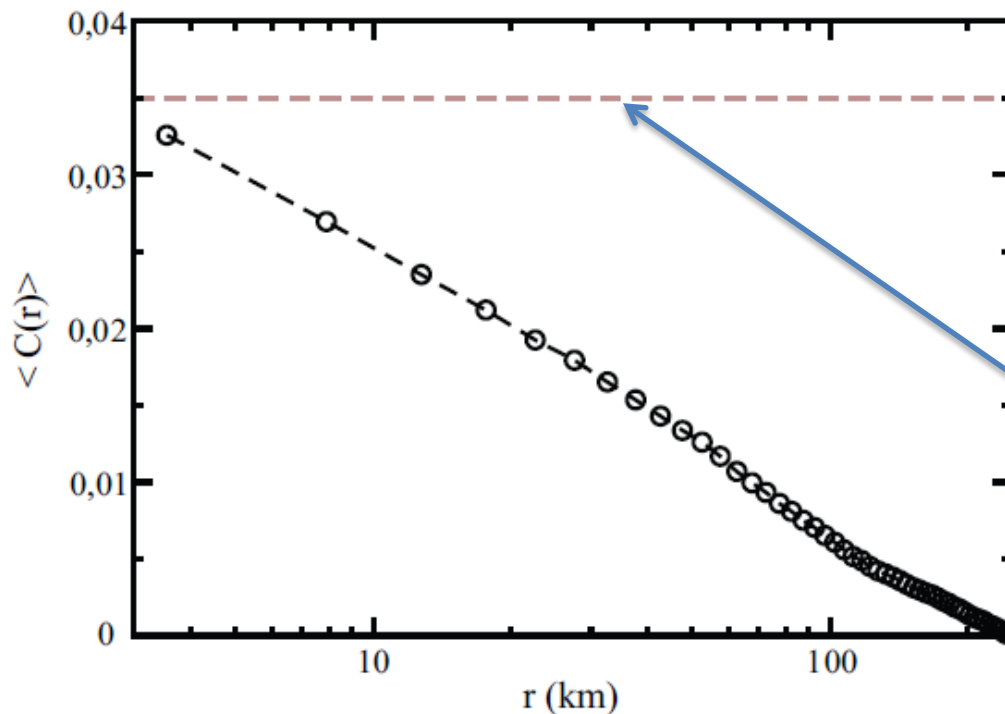
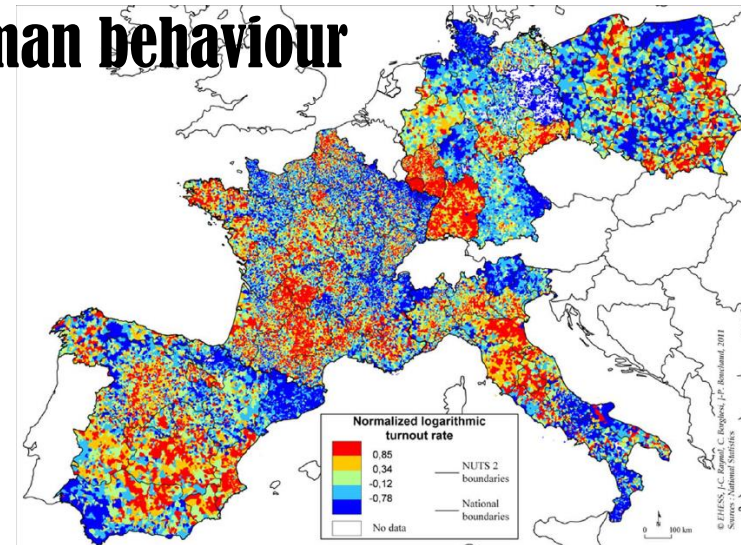
A (nearly) universal distribution of LTR:



$$u = \frac{\tau - \langle \tau \rangle}{\sigma}$$

In search of collective fields in human behaviour

More strikingly, the spatial turnout pattern has *characteristic, logarithmic (long range) correlations*



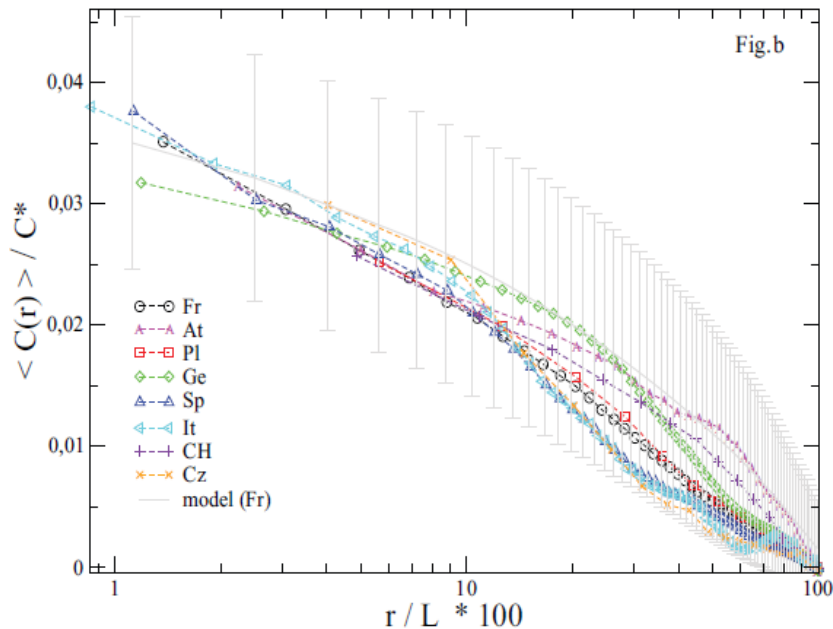
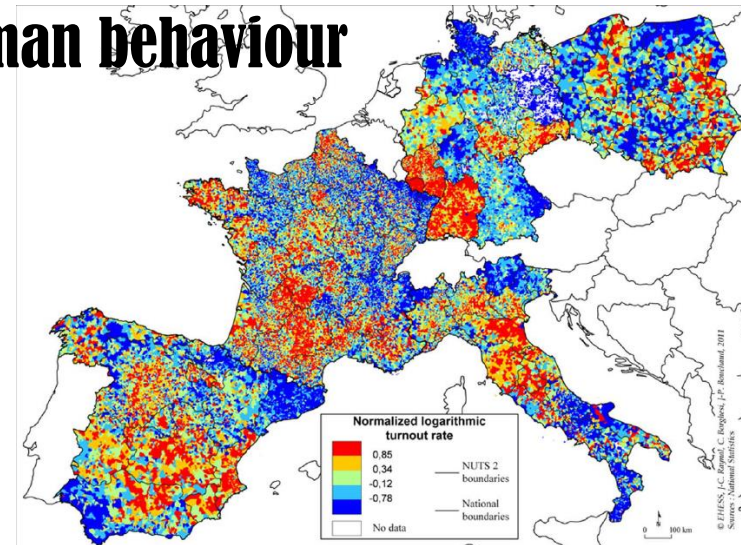
$$C(\vec{r}) = \langle \tau'(\vec{R} + \vec{r}) \tau'(\vec{R}) \rangle \approx -C_0 \ln \frac{r}{L}$$

Note this level line

300 km: a fraction of the size of the country

In search of collective fields in human behaviour

More strikingly, the spatial turnout pattern has *characteristic, logarithmic (long range) correlations* & (approximately) universal across countries



$$C(\vec{r}) = \langle \tau'(\vec{R} + \vec{r}) \tau'(\vec{R}) \rangle \approx -C_0 \ln \frac{r}{L}$$

In search of collective fields in human behaviour

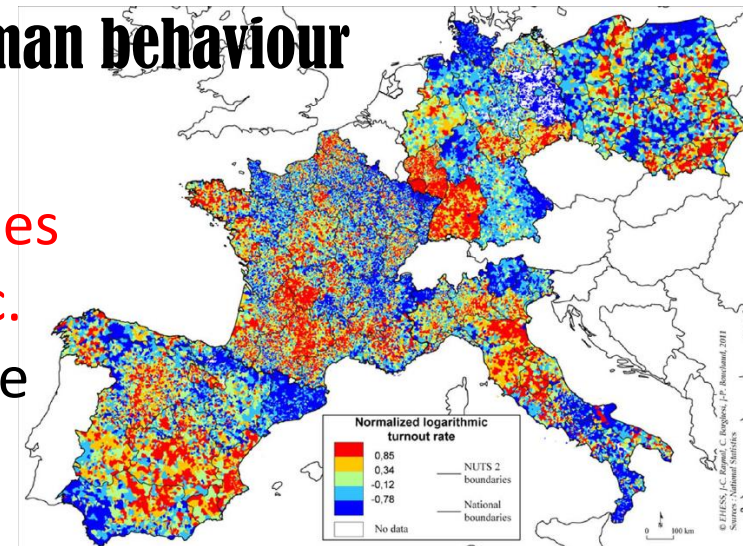
Our idea to explain these regularities:

There exists a “cultural field” $\phi(\mathbf{r})$ that encodes regional biases in intentions, convictions, etc.

(for example to vote or not to vote, or to vote for the left or right, to respect or not speed limitations, etc.)

These (subject specific) cultural fields transcend individuals while being shaped, shared, transported and transformed by them.

They should exist *independently of any election*, or any other occasions where a decision has to be made. These events merely provide an instantaneous snapshot of the opinion or of the behaviour of individuals, which are in part influenced by these fields



In search of collective fields in human behaviour

Getting more formal I:

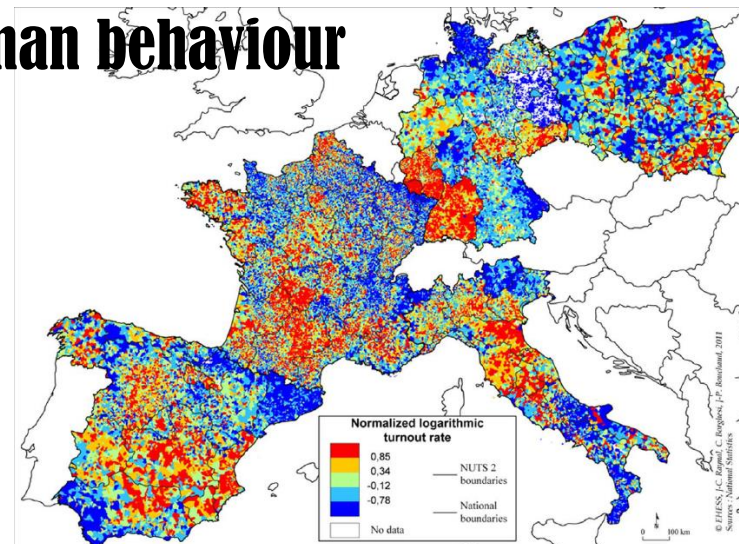
- Factors influencing each (potential) voter

$$\varphi_i(t) = \epsilon_i(t) + \phi(\vec{R}_a, t) + \mu_a(t)$$

↑
Idiosyncratic
(individual)

↑
« Cultural » field
(spatially correlated)

↑
Idiosyncratic (city)
No spatial correlations



- **Logistic model** in decision theory → turnout proba. $p = \frac{1}{1 + \exp(-\frac{\phi + \mu + \Phi_{th}}{\Sigma})}$

→ LTR for cities of size N:

$$\tau = \ln\left(\frac{\pi}{1 - \pi}\right) \approx \beta \cdot (\phi + \mu + \Phi_{th}) + \sqrt{\frac{h}{Np(1 - p)}} \xi$$

In search of collective fields in human behaviour

Getting more formal II:

- Dynamics of the cultural field:**

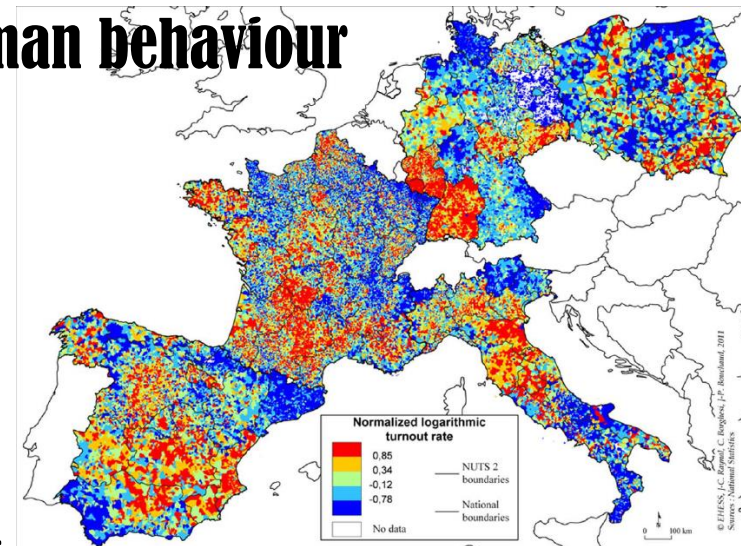
The cultural field is encoded, shared and locally transported by individuals, but also evolves due to random shocks (in space and time) – ex: closing down of a large factory, local political figure

$$\left. \frac{\partial \phi(\mathbf{R}_\alpha, t)}{\partial t} \right|_{\text{infl.}} = \sum_{\beta} \Gamma_{\alpha\beta} [\phi(\mathbf{R}_\beta, t) - \phi(\mathbf{R}_\alpha, t)] + \text{noise}$$

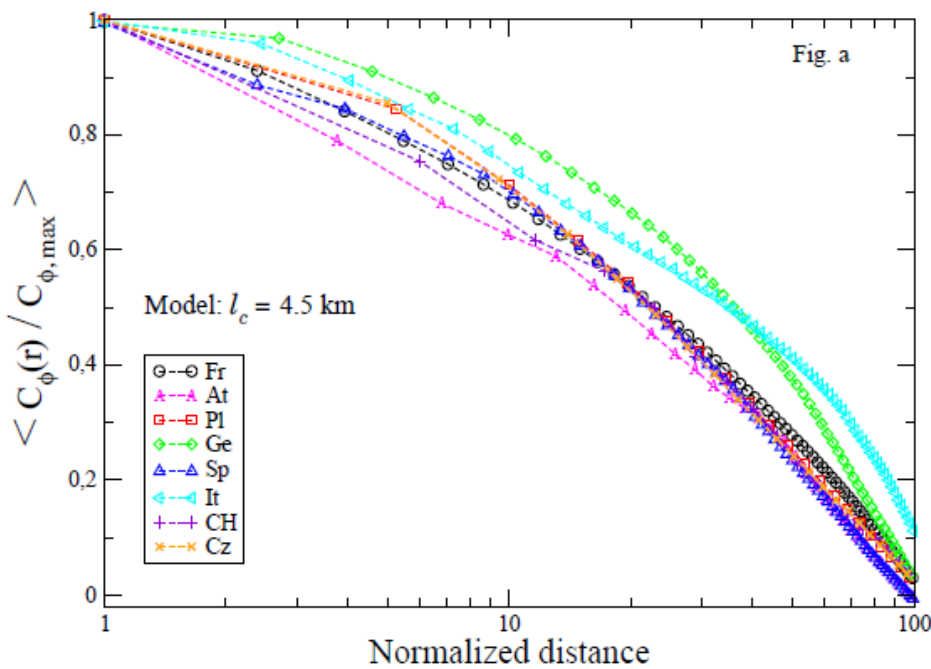
(See also: Schweitzer & Holyst)

→ Random diffusion equation which naturally leads to logarithmically behaving correlations:

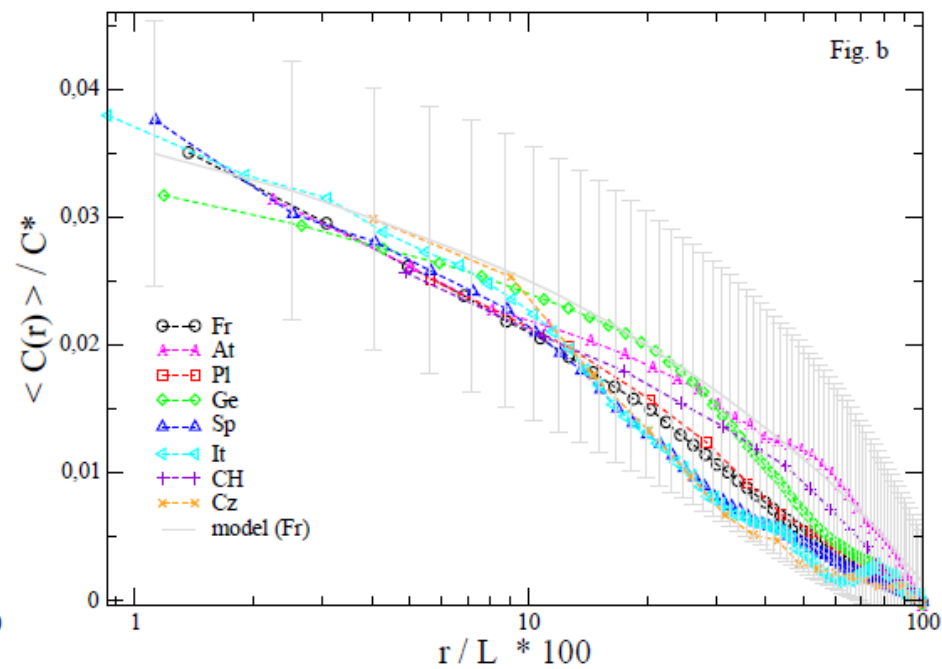
$$C(\vec{r}) = \langle \tau'(\vec{R} + \vec{r}) \tau'(\vec{R}) \rangle \approx -C_0 \ln \frac{r}{L}$$



Comparison between numerical simulations of the diffusive model and empirical data



Simulations with exact location of cities

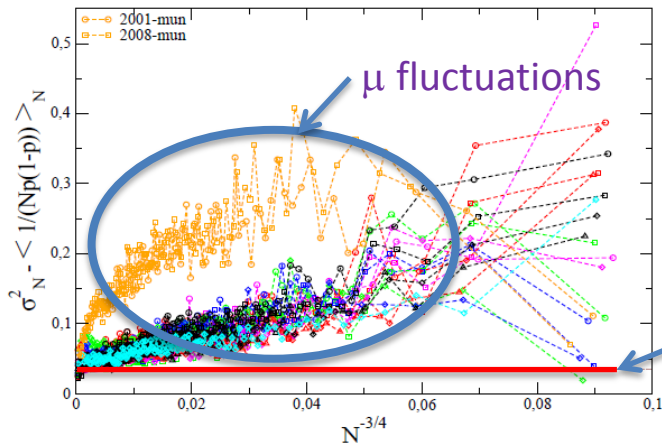


Empirical data and model (grey)

In search of collective fields in human behaviour

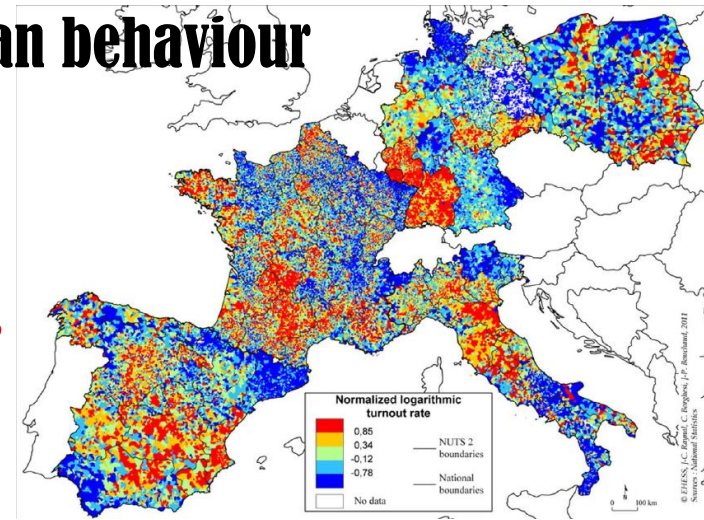
Two further cross checks:

→ Independent estimate of the ϕ fluctuations



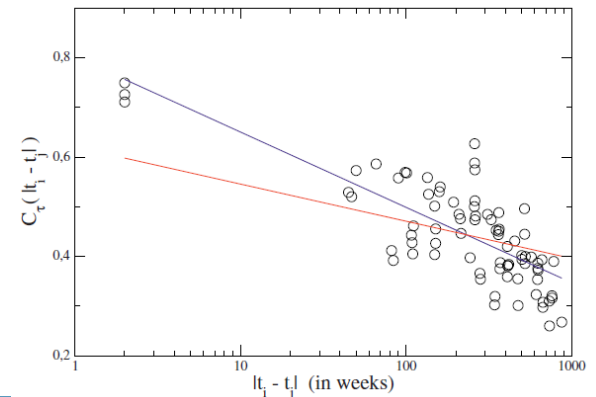
Turnout fluctuations as a function of city size (note the $-3/4$ power)

Predicted level from $C(r)$, election independent!



→ Temporal correlations of the cultural field predicted by the model

$$C_\phi(t) = \frac{\langle \phi(\mathbf{R}, t) \phi(\mathbf{R}, 0) \rangle}{\langle \phi(\mathbf{R}, t)^2 \rangle} \approx -\frac{\Lambda^2}{2} \ln \frac{t}{T_{eq}}$$

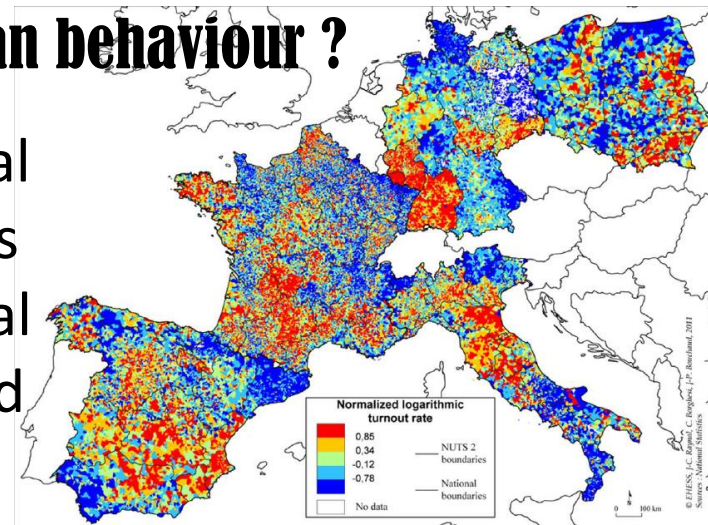


Conclusion: collective fields in human behaviour ?

Our theory based on the existence of a cultural field that obeys a *random diffusion equation* is in *quantitative agreement* with many empirical observations, for a wide range of elections and countries.

This cultural field allows one to account for the spatial and temporal persistence of regional patterns – beyond the individuals who live there (death or immigration)

Cultural fields should also affect other behavioral biases, such as social or consumptions habits: more empirical data (for example from supermarkets) showing (?) a logarithmic behaviour would be decisive



Other collective phenomena, with direct interactions

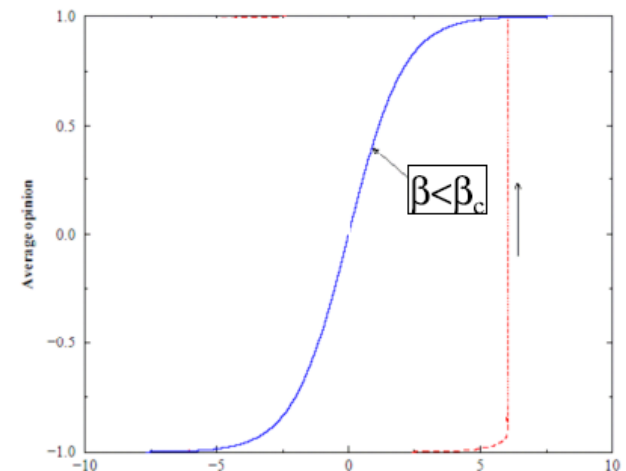
The cultural field is persistent in time, and different from (but akin to) collective phenomena induced by **direct interaction/imitation**

Example: binary decision (buy/sell, trust/distrust, clap/stop clapping, etc.) with

- Heterogeneous individual propensities
- Global information/price level/technology/zeitgeist
- Instantaneous social pressure, imitation

Depending on imitation strength:

- Smooth behaviour
(merely reflects the heterogeneity of the population)
- **Spontaneous discontinuities**
(crises/trust evaporation, etc)



« Crises and collective effects in socio-economic systems: simple models and challenges », J Stat Phys 2013