



$$\left( \varepsilon : \text{person} \frac{7}{n} + \text{person} \right) \times \frac{x}{4} \text{person} \pi^{-1} =$$

$$\left( 4^n + \sqrt{x} \times (\text{person}) + \frac{3}{10} + \text{person} = 5 \right)$$

PABLO JENSEN

# Pourquoi la société ne se laisse pas mettre en équations

$$N \times (\text{person} \text{ person} \text{ person}) = \infty^0$$

$$\left( 8^n + \sqrt{x} \times (\text{person}) + \frac{2}{10} + \text{person} = 6 \right)$$

CNRS

Laboratoire  
de physique

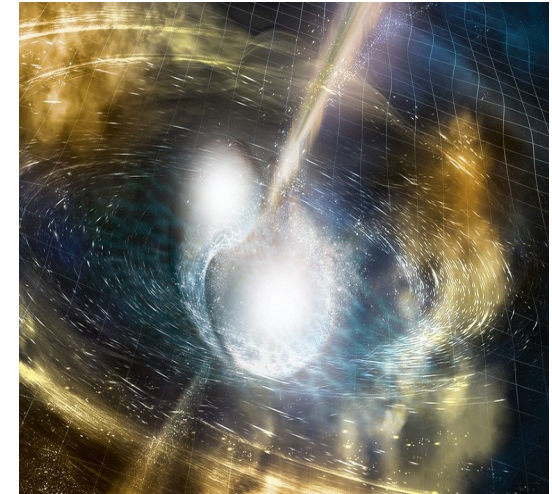




# L'Univers se laisse mettre en équations...

## Newton : gravitation universelle (~ 1680)

- Succès Newton, Einstein...
- Grandeurs **mathématiques** :
  - Planète ~ point (m, r)
  - Force =  $G m m' / r^2$
  - Mouvement ~ force
- Permet de *calculer* trajectoires des planètes + satellites
- Désaccord ? **Prédiction** de planètes inconnues : Neptune !



Collision deux étoiles neutrons, 8/2017

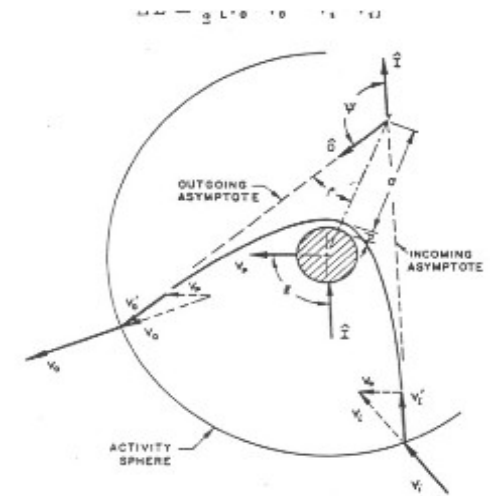


Fig. 1. Encounter hyperbola

Trajectoire Voyager par alignement planètes grâce à effet « fronde »

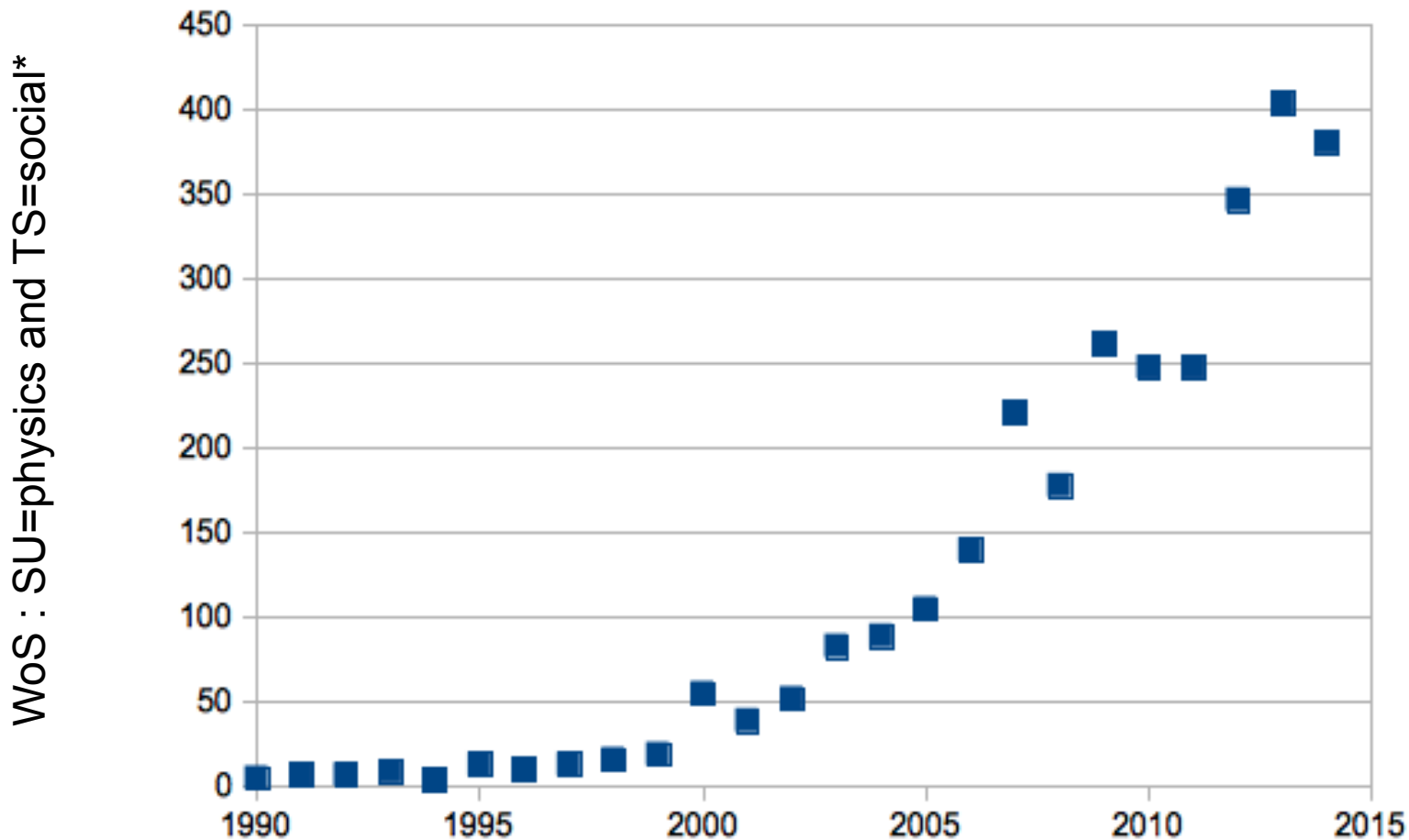
# Temptations of social physics...

*Statistical physics* : explain properties of matter (*macro*) in terms of atomic behaviors (*micro*)

Born in 19<sup>th</sup> century, inspiration from social sciences : data avalanche from centralized states  
→ stable, predictable *average man* (Quételet)  
→ Maxwell perfect gas

Individuals = « social atoms »  $\leftrightarrow$  society ?

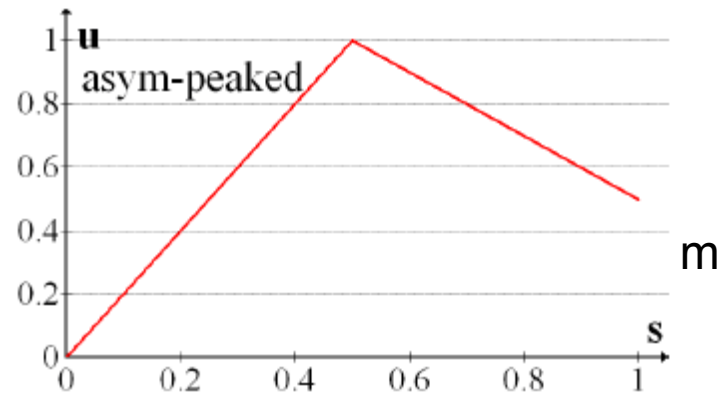
# « Social physics » : a growing subfield



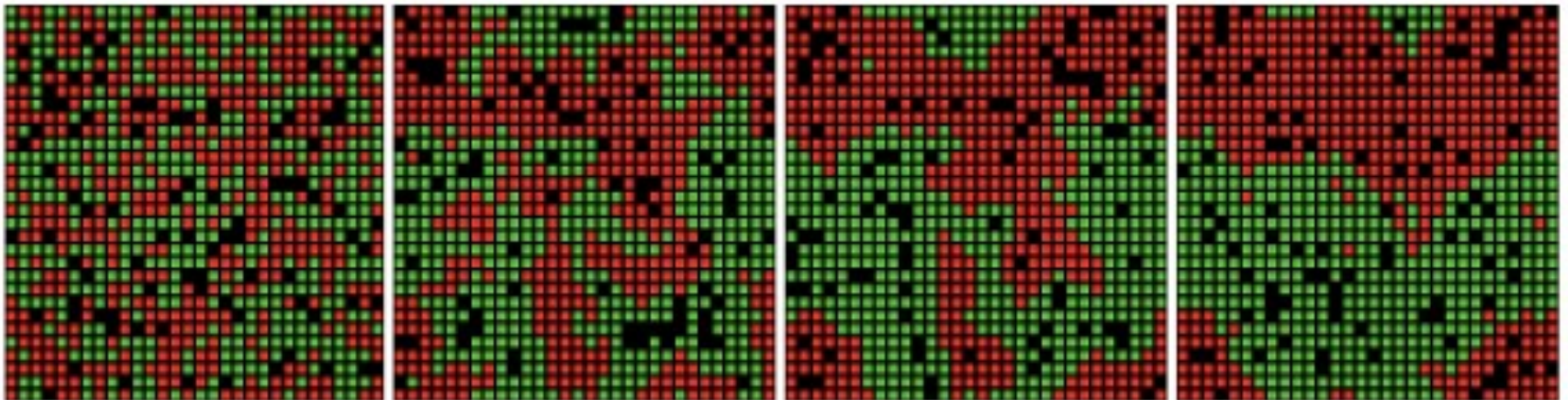
But small ! (nanotube : 11 000 articles in 2008, simulations 100 000 !)

# Modèles simples de ségrégation urbaine (Thomas Schelling, « Nobel » économie 2002)

**satisfaction**



**composition voisinage**



**Dynamique sociale égoïste tend vers... frustration!**

# Statistical physics → analytical solution

*PNAS, 2009*

*Journal of Public Economics, 2012*

- Change continuously between individual and collective dynamics :

$$Pr\{move\} = \frac{1}{1 + e^{-C/T}}$$

- $C = \Delta u + \alpha(\Delta U - \Delta u)$
- $\alpha$  : tax/cooperativity parameter
  - $\alpha = 0 \rightarrow$  “economics”, individual dynamics
  - $\alpha = 1 \rightarrow$  “physics”, collective dynamics
- How to predict the global state for a given utility  $u(\rho)$  ?
- No state function ? !



# Our solution : Link function



- There exists a **global** (state) function  $L(x)$  such that, for each move

$$\Delta u = \Delta L$$

$L$  links micro (individual moves) to macro (state function)!

$$L(x) = \sum_q \sum_{m=1}^{n_q} u(m/H)$$

- $\Pi(x) = \frac{1}{Z} e^{F(x)/T}$ ,  $F(x) = \alpha U(x) + (1 - \alpha)L(x) + TS(x)$

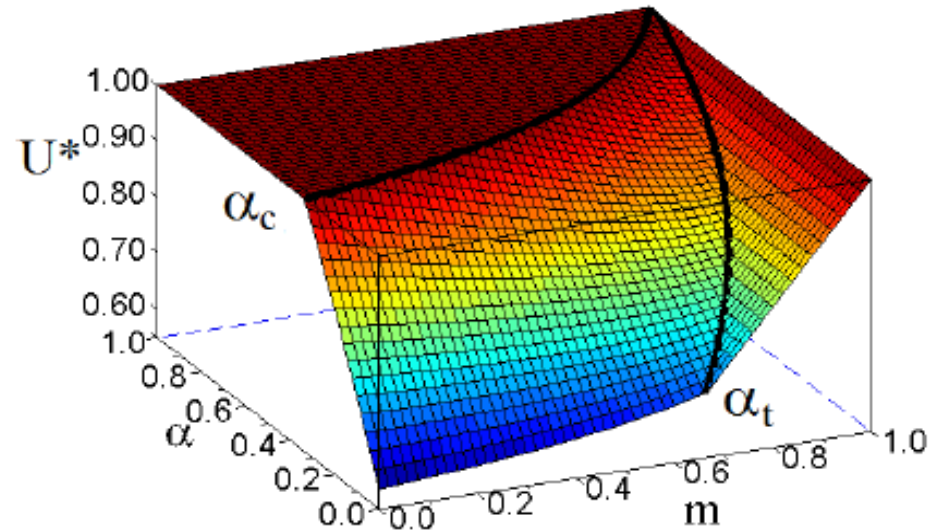
$F(x)$  : Generalized “free collective utility” « Potential »

Resolution :  $H, Q \gg 1$  + standard phase separation methods

Stationary state maximizes  $F(x)$  (not  $U$ !)



# Collective utility - analytical result !



$$U^* = U/U_{\max} = U/(\rho_0 H Q)$$



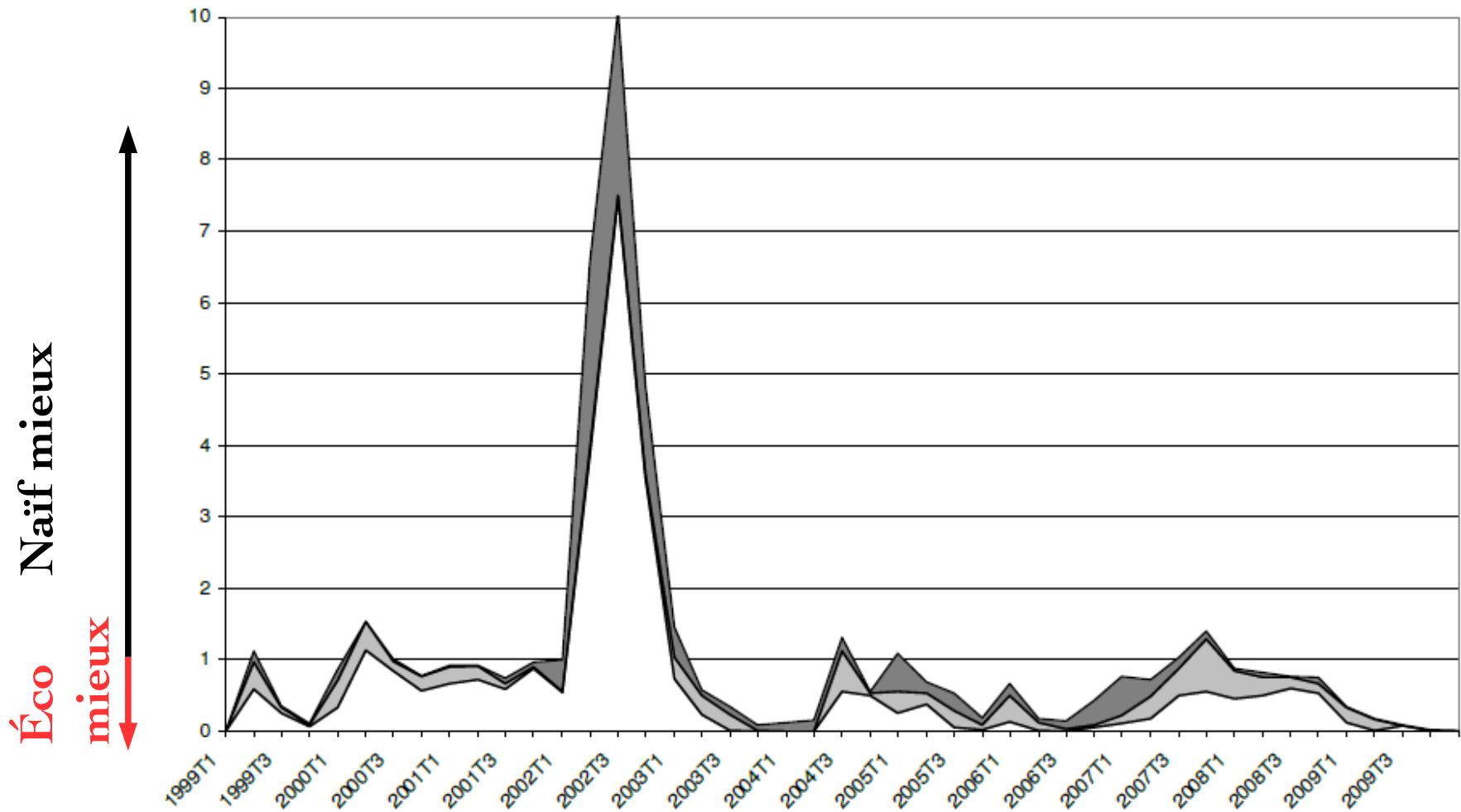
*JP Bouchaud* (review, *J Stat Phys*, 2013) : the most striking example in this review ... is the clear quantitative demonstration [**Grauwin et al**], that the invisible hand can fail at solving simple coordination problems...

**Conceptually ok**, but do we learn anything about the **real** world ?  
Are there trustable models of real social systems ?



# Mettre la société en équations ?

- Prédire la croissance l'année prochaine par:
  - Modèles économiques complexes ou
  - Un modèle naïf: croissance année prochaine = cette année



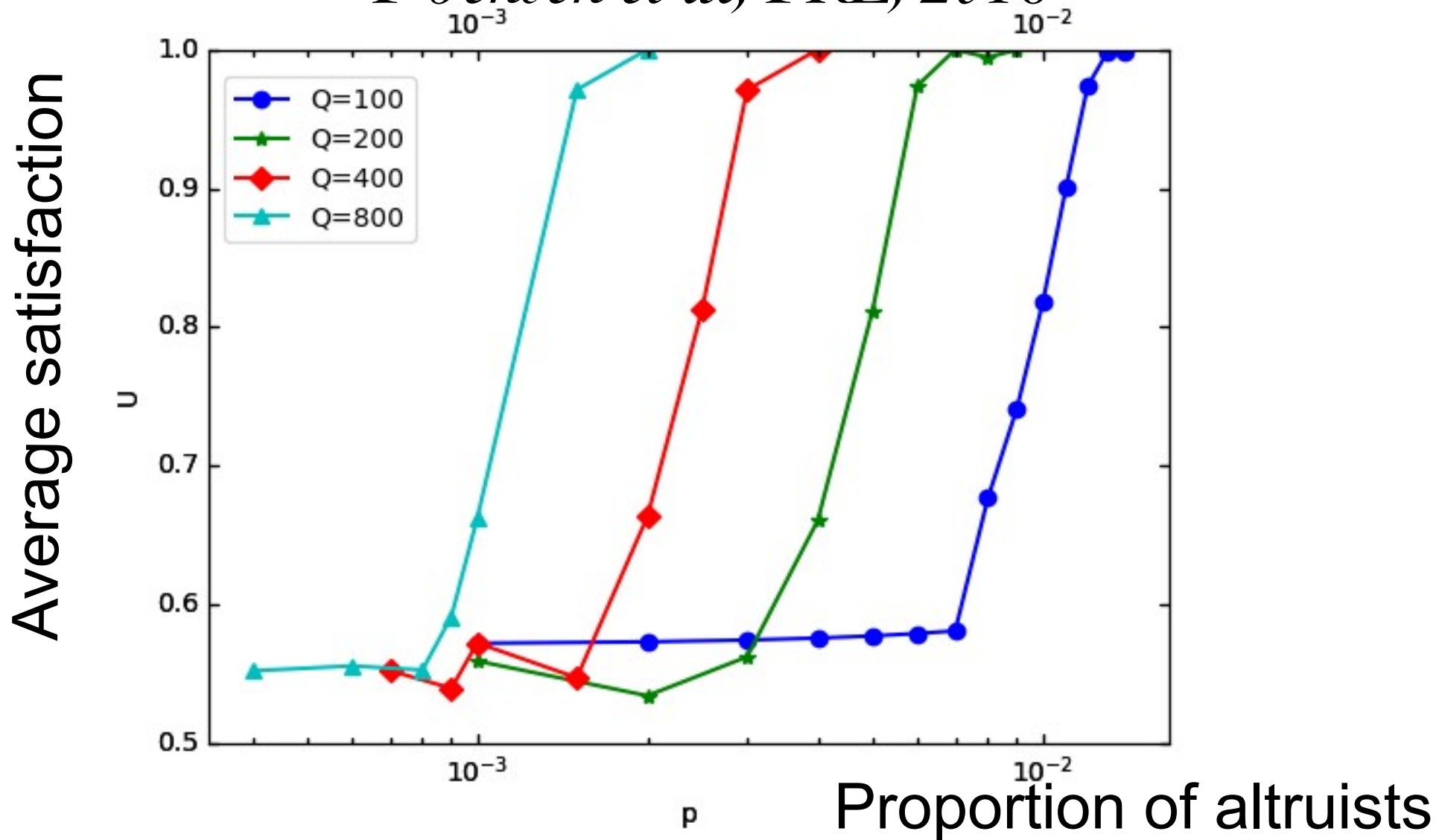
# Why social equations are not trustable

- *Complexity of social causality*
  - Many relevant variables, human heterogeneity, memory...
  - Also in physics (climate models) → analytical method !  
Not so useful in social sciences: complex causality, *no stable capacities, no social atoms, no stable relations* (energy conservation, atoms...) : no dynamical theory!
- *Politics* of modeling
  - Human *reflexivity*, that care about models and may react
  - These problems cannot be solved simply by more data  
→ *Transform* society to model it !

Adding a vanishing fraction of « altruists »  
→ social optimum reached !

Model not robust : « compositional chaos »

*P Jensen et al, PRL, 2018*



# Falling Paper: Navier-Stokes Solutions, Model of Fluid Forces, and Center of Mass Elevation

Umberto Pesavento<sup>1,\*</sup> and Z. Jane Wang<sup>2,†</sup>

<sup>1</sup>*Department of Physics, Cornell University, Ithaca, New York 14853, USA*

<sup>2</sup>*Theoretical and Applied Mechanics, Cornell University, Ithaca, New York 14853, USA*

(Received 28 January 2004; published 27 September 2004)

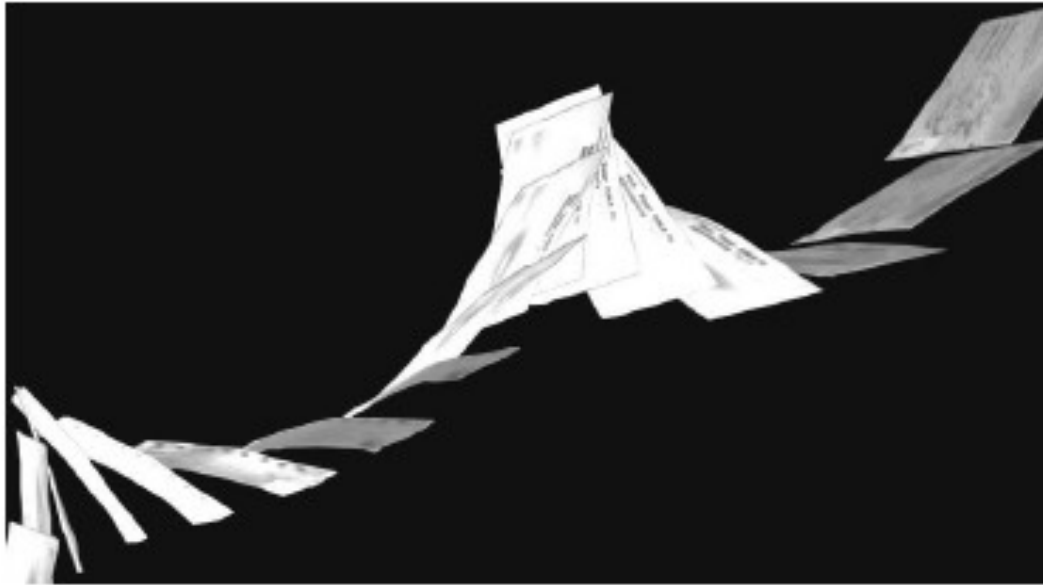


FIG. 1. Rise of a falling journal cover under windless conditions, selected frames from a footage filmed at 300 frames/s.

**contribution gravité**  
 **$s \sim t^2$**



$$F_y = \rho_f u \Gamma - m_{21} u \Omega - m_{22} \dot{v} + (\rho_f - \rho_b) A g \cos \theta + F_y^\nu,$$

# Complexity of social causality

The vanity of rigour in social sciences, N Cartwright

- Stable capacities : in physics, ideal experiments : find effect of a single cause, stable across many situations (mass  $\rightarrow$  fall as  $t^2$ )
- Stability  $\rightarrow$  possible to combine (vector sum...) causes
- If no stable capacity, analytical method / models not very useful, as **effects of every cause depend** on many other assumptions  $\rightarrow$  cannot be extrapolated to the real world
- Models : Akerloff effect of « asymmetry of information ». Many assumptions needed for model : *“There are two types of traders with distinct utility functions, and both types are von Neumann-Morgenstern maximisers of expected utility. Cars’ quality is distributed uniformly between zero and two, goods are infinitely divisible...”*
- Effect of age on unemployment? It depends... If high education, increases, if low education, decreases... Influence of floor on flat value? It depends... elevator or not?

# Qualitative Comparative Analysis

Usual statistical model: INDEPENDENT effect of each variable, "all other things being equal", all other variables except those under immediate consideration are held constant. Example of effect of sex, if differences in average h per sex (effect of sex or h?)

- `glm(promu ~ h + sexe + DS + age06, binomial, data = cand)`

	Estimate	Std. Error	z value	Pr(> z )	
(Intercept)	-23.388034	6.721947	-3.479	0.000503	***
h	0.124536	0.020982	5.935	2.93e-09	***
SexeH	-0.172660	0.224193	-0.770	0.441215	no effect
DSSC	-0.933787	0.331425	-2.817	0.004840	**
DSSDU	-1.286947	0.399792	-3.219	0.001286	**
DSSDV	-0.877375	0.329757	-2.661	0.007799	**
DSSPM	-1.051303	0.351339	-2.992	0.002769	**
age06	0.957918	0.293649	3.262	0.001106	**
age06^2	-0.010372	0.003198	-3.244	0.001180	**

H &gt;&gt; F

F &gt;&gt; H

F &gt;&gt; H

H &gt;&gt; F

profil	impact	âge	sexe	# total	taux promo	# promu
1	0	0	H	17	0,176	3
2	0	0	F	2	0	0
3	0	1	H	58	0,31	18
4	0	1	F	21	0,048	1
5	0	2	H	63	0,127	8
6	0	2	F	14	0,357	5
7	1	0	H	36	0,25	9
8	1	0	F	6	0,167	1
9	1	1	H	142	0,296	42
10	1	1	F	61	0,41	25
11	1	2	H	31	0,355	11
12	1	2	F	7	0,714	5
13	2	0	H	51	0,275	14
14	2	0	F	5	0,2	1
15	2	1	H	53	0,509	27
16	2	1	F	15	0,533	8
17	2	2	H	1	1	1
18	2	2	F	1	0	0

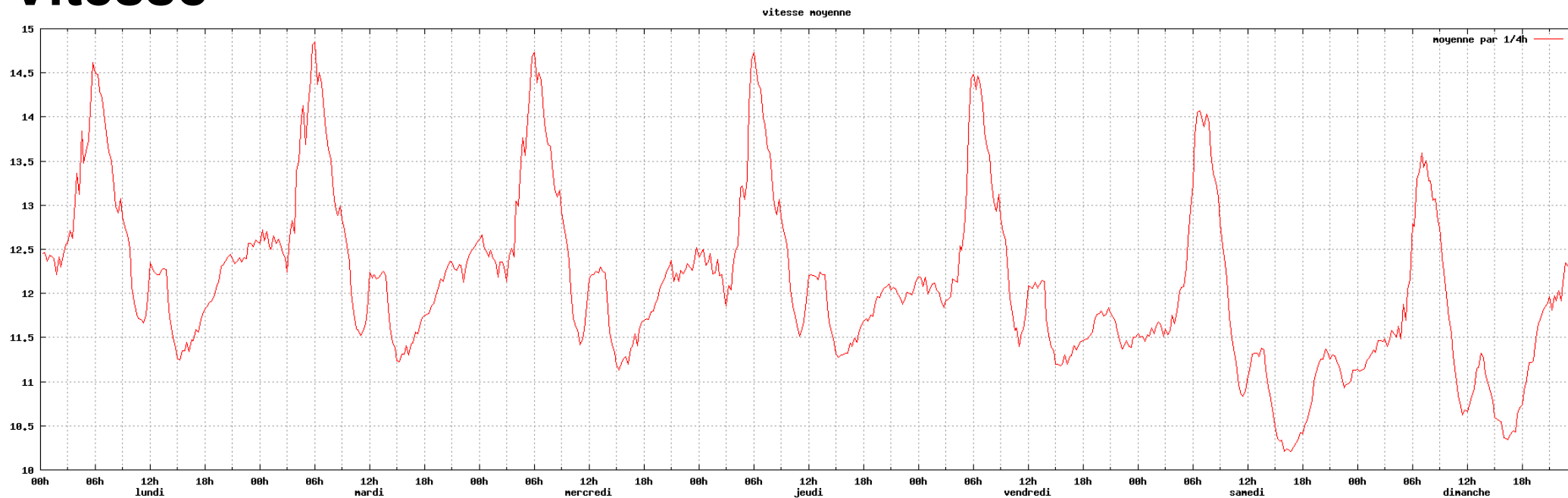
# Exemple d'analyse de données réelles

Utilisation des Velov (Lyon) : 13 millions voyages

*Comparaison distance réelle et théorique :  
environ 30% des Veloveurs prennent  
des sens interdits ou trottoirs...  
(plus le matin en semaine que le week-end)*



## Vitesse



**Jour, heure**



# Big data ?



- Predict tweets *success* ? Retweets?
- D Watts (Microsoft) : all tweets in English in February 2015 (852 millions), 51 millions users, 2 billion retweets
- Message characteristics : some Internet site mentioned ? Hour ? Topic ? User (followers, number of tweets...)
- Random forests on first 3 weeks... → explain 20 % of success variability last week + 20 % using **past success**
- Not better than « tomorrow = today » !

# We are not social atoms

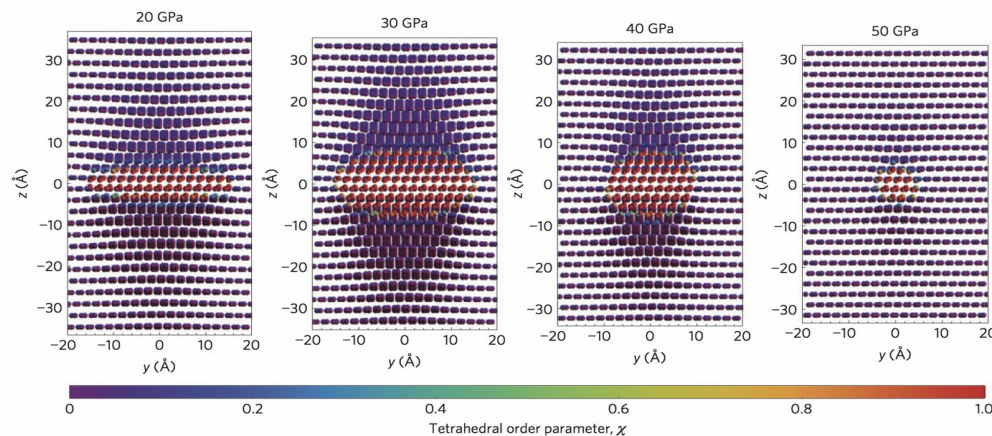
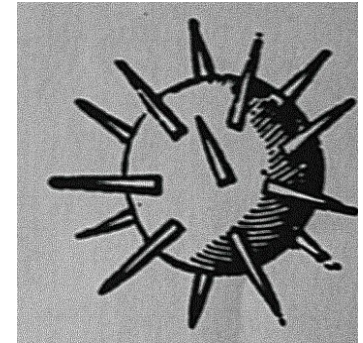
- Quelles relations stables? Théorie classique (micro-) économie: seulement les préférences des agents
- Agents économiques = "**atomes**" sociaux, **définis** par préférences, ou fonction utilité, **stable**

**Action = caractéristiques internes + contexte présent**

**Mauvaise** image des atomes en physique!

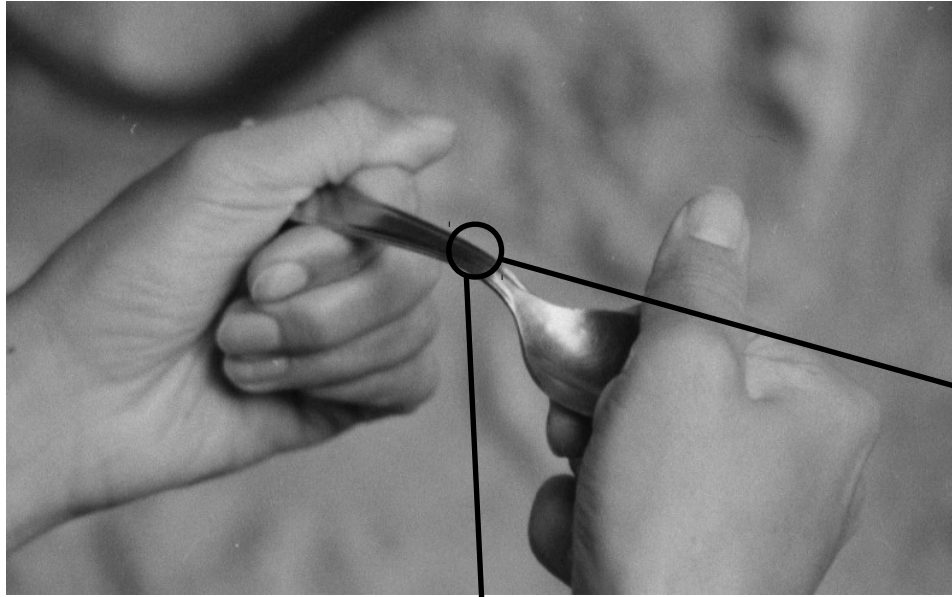
# Atomes en physique

- Quelles caractéristiques internes?
  - *Postulées* pour rendre compte expériences
  - Rayon? Variable! Potentiel empirique? Variable!
- **Atomes pas "atomiques"! Quelles PRATIQUES?**
- Utilise noyau et électrons :
  - incalculable > 10 élec!
  - DFT + réseau de neurones pour graphite - diamant

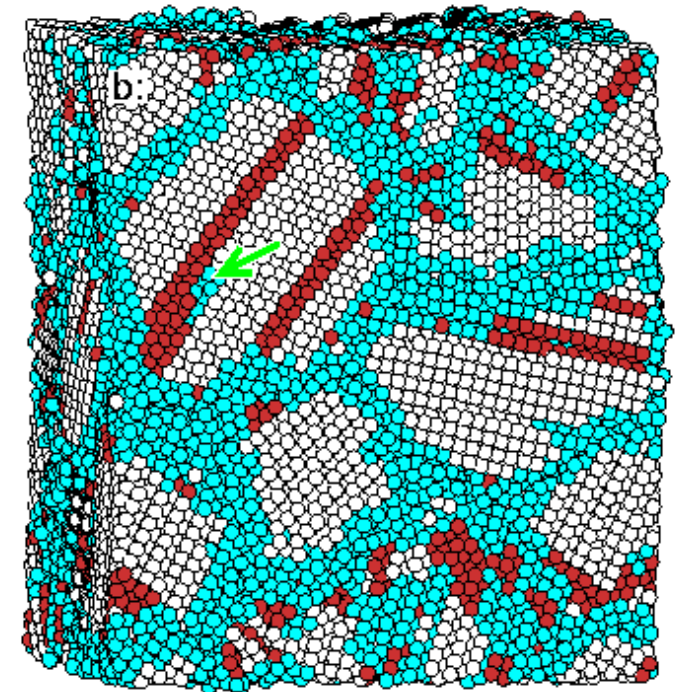
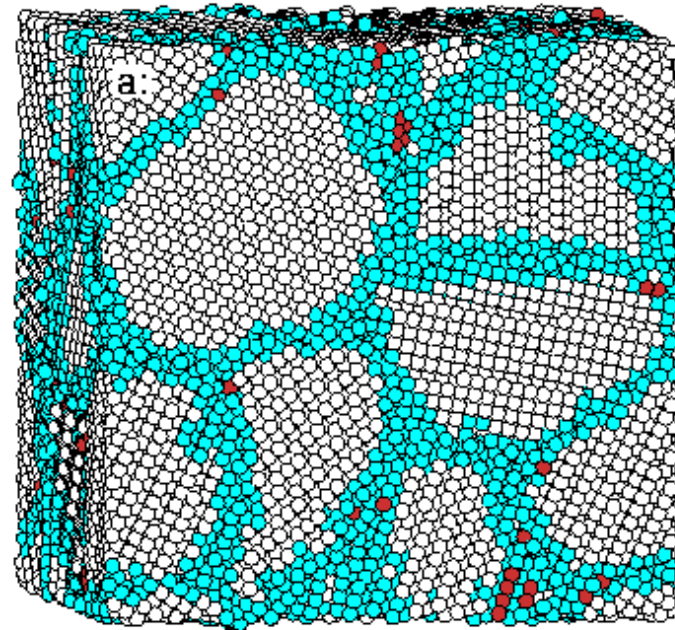


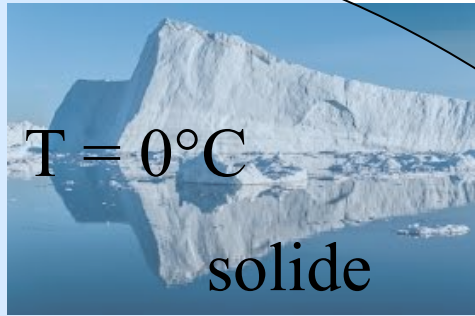
$$\frac{\hbar^2}{2m} \frac{d^2\psi(x)}{dx^2} + (E - V(x))\psi(x) = 0$$

# Comprendre grâce aux atomes ?



**Too complex !**

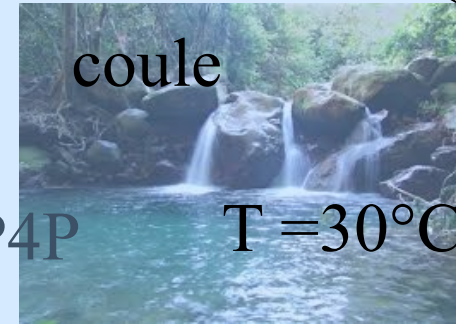




## Expé 1 eau/glace

F = TIP4P

## Expé 2 Eau/liquide



F = TIP4P

T = 30°C

**H<sub>2</sub>O**

F = LJ612

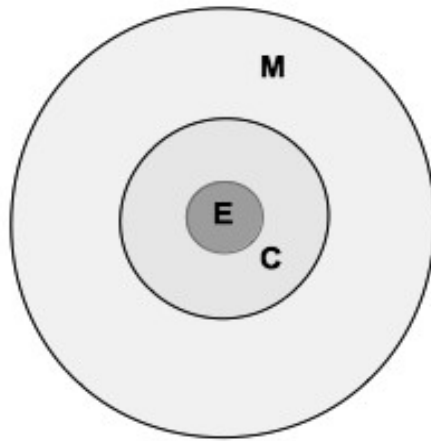
## Expé 3 Eau/vapeur



Atomes **connectent** expériences grâce à stabilité chimique  
→ contrôle (Dewey)

Pas la réalité « profonde » : ~ prix pour objet  
Quelle intersection stable pour les humains ?

# Atomes sociaux ?



E : entité

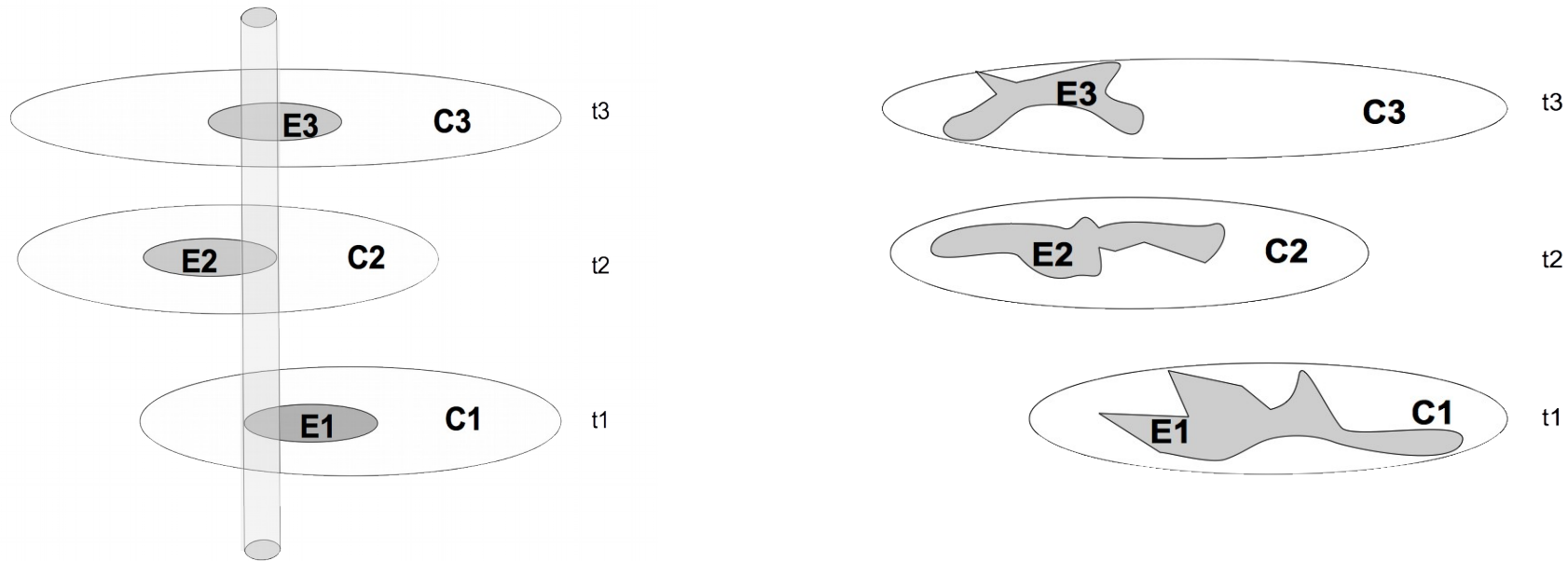
C : contexte

M : monde « externalisé »

Vision essentialiste :

- entités aux bords nets = séparation essence/contexte,
- noyau/essence E explique action

# Atomes sociaux ?



- Trois expériences successives, dans des contextes différents, révèlent des capacités distinctes.
- À gauche, atomes physique, entités naturelles, comportement change mais reste prévisible, centré autour d'un noyau servant d'ancrage pour une essence ( $\epsilon_{\text{noyau}} \gg \epsilon_{\text{électron}}$ ).
- À droite, entités sociales : contours variables selon contexte, ne se laissent pas résumer (pas de  $\epsilon_{\text{interne}} \gg \epsilon_{\text{interaction}}$ ).

# Comment rendre compte, à la fois, de la dynamique et de l'inertie du social?

Physique : permanence des atomes et transformation de leurs configurations.

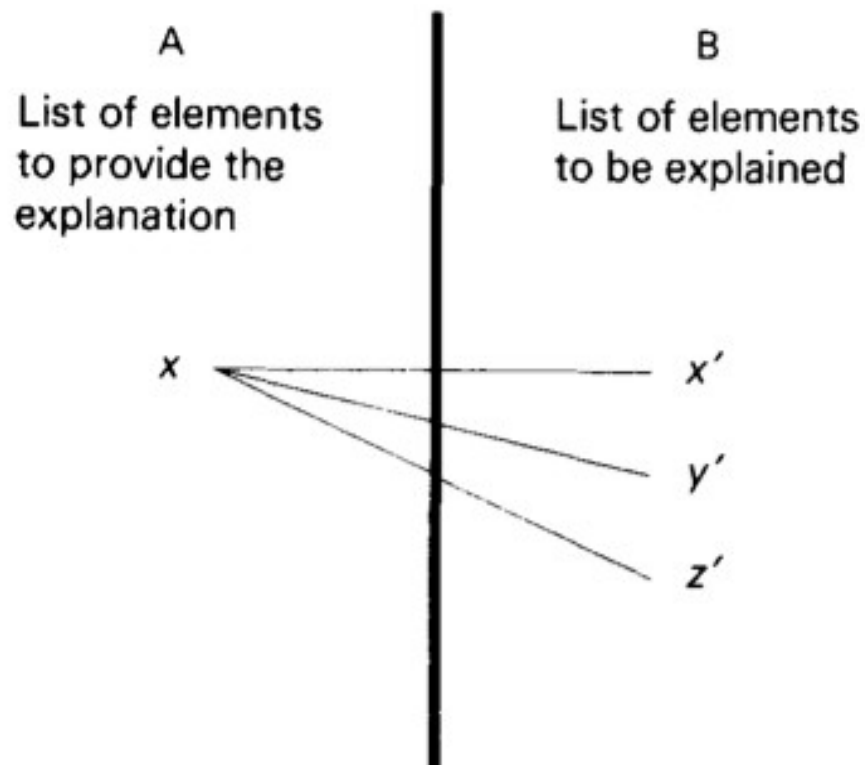
Social: fluide tourbillonnant qu'à ces nettes combinaisons de briques. Au sein de ce fluide en mouvement placide, surgissent d'imprévisibles bouillonnements. Ils forment ici et là des tourbillons qui, tels des individus, possèdent une certaine stabilité, mais ne peuvent se maintenir qu'en évoluant constamment, en interaction forte avec ce fluide toujours mouvant de relations sociales.

1. ...  
2. ...  
3. ...  
4. ...  
5. ...  
6. ...  
7. ...  
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39. ...  
40. ...  
41. ...  
42. ...  
43. ...  
44. ...  
45. ...  
46. ...  
47. ...  
48. ...  
49. ...  
50. ...



# Politics of explanation

- Explanation : some sort of relation between two lists
- When you hold  $x$  in A, you also hold the  $x'$ ,  $y'$ ,  $z'$  in B
- A general definition of power
- Feeling of strength, economy and aesthetic satisfaction



B Latour (1988)

# Politics of explanation

- Trois types :
  - Dédution : tous les éléments de B, y compris ceux non encore connus, peuvent être déduits d'un élément de A : enthousiasme à l'âge classique
  - Corrélation : A = relation entre plusieurs éléments de B (toujours, souvent, significativement...)
  - Description : A = répétition de B, arrangé autrement, histoire, fiction.
- Mais pourquoi expliquer? A quoi, à qui ça sert?

# Politics of explanation

- Explain = control from a **center**, build an *empire* !
  - Stay in B, no need to go to A = practice
  - If in A and not care about B = theory
  - If in A but want to act on B : need of *reliable connection* = *explanation*
- Explanations reinforce centers, reduce B
- Models = external vision, humans= molecules within organism whose brain is elsewhere (Scott)
- Alternative? Texts that help readers understand their practice

# Politics of social models

- Equation  $\leftrightarrow$  empirical stability, otherwise vanity of rigour
- Stability generally obtained by clever, risky *transformation* (taming the tiger)
  - Transform society, taming humans to stabilize ? Done by States for « statistics » (surnames, land registry...)
  - Prices channel our economic choices
  - Maths efficient as « logistics » : center can combine many «homogeneous» situations to build common causes : firearm deaths, pollution, discrimination...
  - Quantitative indicators : which ones? replace or enrich evaluation ?
- Center is no longer State, but GAFAM : stop doing formal models ?