

LPT Orsay

Statistical physics group

The statistical physics group at LPT, fall 2016

6 permanent researchers

Martial MAZARS

Jean-Michel CAILLOL

Françoise CORNU

Gatien VERLEY

Henk HILHORST

Cécile APPERT-ROLLAND

2 PhD students

Robert Paul SALAZAR (M. Mazars, joint supervision with Univ. Los Andes - Bogota)

Hadrien VROYLANDT (G. Verley)

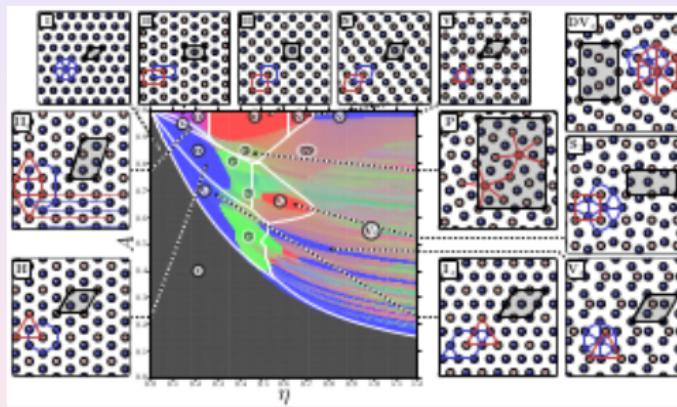
2 retired researchers

Jean-Jacques WEIS DR CNRS

Dominique LEVESQUE DR CNRS

Phase transitions in systems with Long ranged interactions (M. Mazars).

- Phase diagram of asymmetric Wigner bilayers (M. Antlanger, PhD -Thesis, joint supervision with Austria - 12 October 2015)



- Rich Polymorphic Behavior of Wigner Bilayers, M. Antlanger, G. Kahl, M. Mazars, L. Šamaj and E. Trizac
PHYSICAL REVIEW LETTERS, 117, 118002 (2016).

- Melting in 2 dimensional systems. (R. Salazar, PhD - see the talk by Robert)
- The melting of the classical two-dimensional Wigner crystal., M. Mazars, EPL, 110, 26003 (2015).

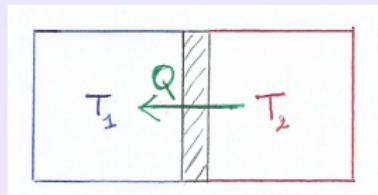
Collaborations: LPTMS (Orsay) ; TU-Wien (AUSTRIA) ; TU-Berlin (GERMANY) ; Slovak Academy of Sciences (SLOVAKIA) : Universidad Los Andes (COLOMBIA).

Theory of liquids

- Critical exponents of the liquid-gas transition for fluids with Coulomb interactions
 - Monte Carlo simulation
 - nonperturbative renormalization
- Phase diagram of lattice ϕ^4 field theory in $d = 3$ and $d = 4$
- Electrostatics on the spheres S_2 and S_3
 - with J.J. Weis and M. Trullson

ex. Fluctuations of exchange heat Q

with M. BAUER and H. HILHORST



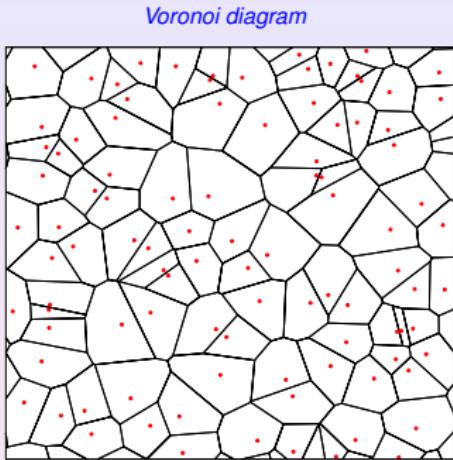
- Fluctuation relation for opposite values Q and $-Q$ of the random heat at a given time τ

$$\frac{P(Q; \tau)}{P(-Q; \tau)} \propto \exp \left[\left(\frac{1}{T_1} - \frac{1}{T_2} \right) Q \right]$$

- Fluctuation relation for random first passage times $\tau_+(Q)$ and $\tau_-(Q)$ by a given heat Q and by its opposite value $-Q$

$$\frac{P(\tau_+(Q))}{P(\tau_-(Q))} \propto \exp \left[\left(\frac{1}{T_1} - \frac{1}{T_2} \right) Q \right]$$

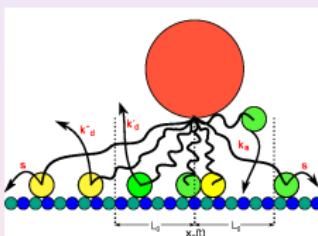
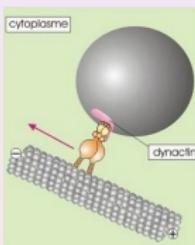
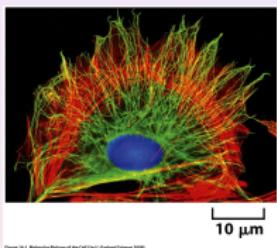
- *Stochastic geometry
in 2D and 2.5D,
2005-2009, 2014-2016*
- *Simplified traffic
models*
 - + C. Appert-Rolland
 - + external coworkers
- Work with F. Cornu



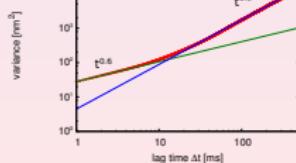
Recent extension:

- *Competition between runners*
- *Nash equilibria*

- Intracellular traffic
- Pedestrian traffic
- Road traffic



©Inria / Photo G. Scagnelli



Prediction

- Easy control
- Counter-intuitive dependence on viscosity, ATP concentration...

Runners
Game theory

Potentiel thermodynamique pour les systèmes hors équilibre

Variables thermo hors-équilibre :

- Courant–Affinité,
- Activité–Barrières d'énergie,
- Occupation–Échappement (non extensif)

Equilibre \Leftrightarrow Hors-equilibre

PRE 2016, 93, 012111

Outlook

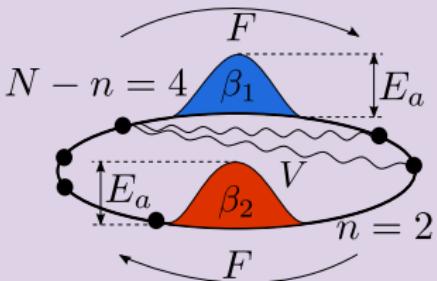
Existe-t-il un potentiel thermodynamique fonction de variables uniquement extensives ?

Fluctuation d'efficacité des petites machines

Machines avec pertes

Modélisation des pertes par un flux de chaleur vers un 3ème thermostat. PRE 2016, 93, 052123

Machines critiques



Statistique de l'efficacité fluctuante

The statistical physics group at LPT

- Participation in the LabEx PALM

(Physique des Atomes, de la Lumière et de la Matière)

- Close relations with: IPhT (CEA-Saclay) and LPTMS

- Seminars of interest for us

- Creation in April 2017 of a seminar "Pedestrians and Crowds"

(LPT-LPTMS)

- Physics-Biology interface seminar

- Stochastic phenomena work group in Saclay

Activités biophysiques

Cécile Appert-Rolland

Laboratoire de Physique Théorique
CNRS / University Paris-Sud / University Paris-Saclay

Transport Modelling

Fluid	Road	Pedestrians	Molecular Motors
Continuous PDEs Conservation of mass and momentum <i>Navier-Stokes</i> ★	Continuous PDEs Conservation of mass + fundamental diag. $j(\rho)$ <i>LWR Model</i> ★	Continuous PDEs Conservation of mass + ... ★	Continuous PDEs Open System → Flux balance
Stochastic Cellular Automata <i>FHP Model</i> ★	Stochastic Cellular Automata <i>Nagel-Schreckenberg</i> ★	Stochastic Cellular Automata <i>Floor Field</i> ★	Stochastic Cellular Automata ★
Kinetic theory $P(v,x,t)$	Kinetic theory $P(v,x,t)$ ★	Kinetic theory $P(v,x,\theta,t)$ ★	
Molecular Dyn. $m \mathbf{a} = \sum \mathbf{f}$	Car-following $\mathbf{a}(\Delta V, \Delta x)$	Ped-following $\mathbf{a}(\Delta V, \Delta x, \theta)$ ★	Molecular Dyn. $m \mathbf{a} = \sum \mathbf{f}$

Collaborations

Local

- Collab. Henk Hilhorst
- ~ 1 Phd or postdoc

National

- PEDIGREE (ANR)
- PERCEFOULE (PALM)

International

Collab. Ludger Santen
(Univ. des Saarlandes,
Germany)

Sem. Biophysique (M.
Lenz, LPTMS)

Sem. Institut Curie

Univ. Paris-Sud



C. Appert-Rolland



Max
Ebbinghaus



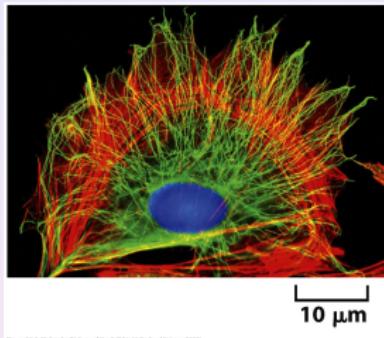
Sarah
Klein

Univ. des
Saarlandes

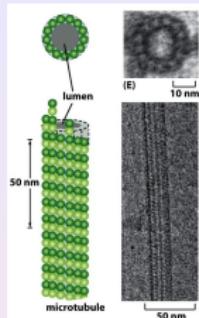


L. Santen

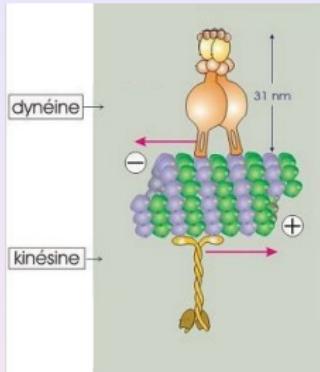
Intracellular transport



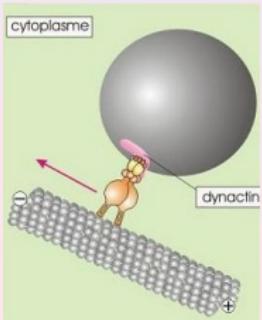
From [Alberts et al, *Molecular Biology of the Cell*, 5th ed. (2008)]



[Modified from
[www.ulysse.u-bordeaux.fr/
atelier/ikramer/
biocell_diffusion](http://www.ulysse.u-bordeaux.fr/atelier/ikramer/biocell_diffusion)]

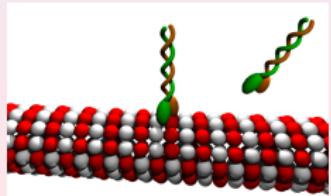


Microtubules are polarized



[From
[www.ulysse.u-bordeaux.fr/
atelier/ikramer/
biocell_diffusion](http://www.ulysse.u-bordeaux.fr/atelier/ikramer/biocell_diffusion)]

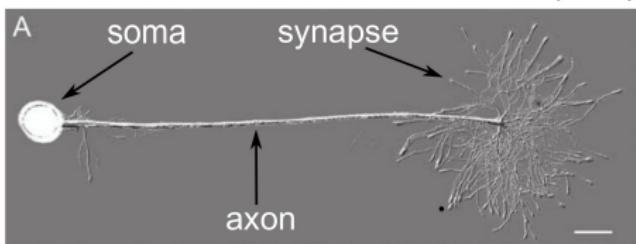
[Modified from a wikipedia
image by Kebes]



Motors can attach and detach

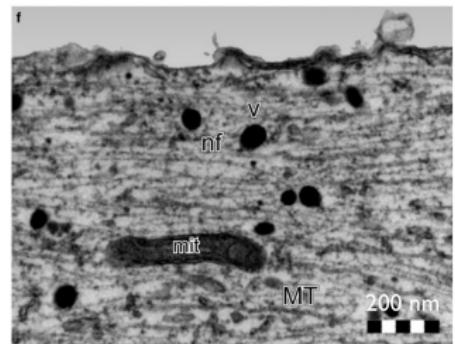
Intra-cellular transport

Shemesh et al., Traffic 9, 458 (2008)



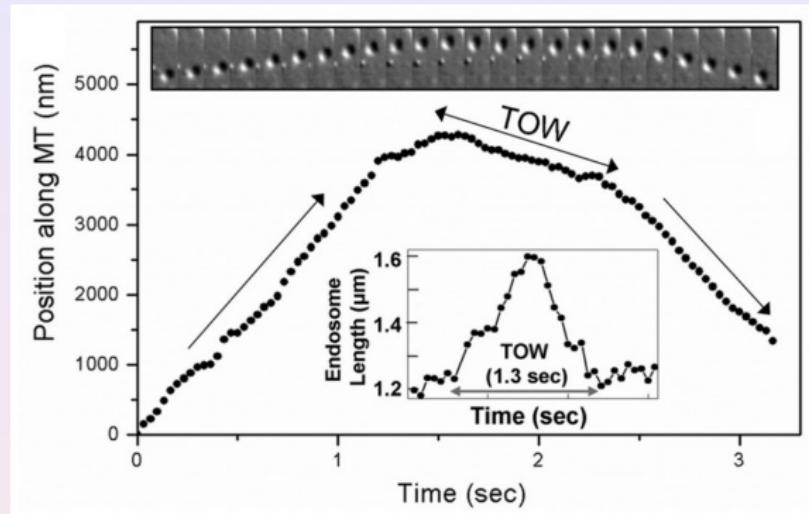
- Particular case: the axon
 - up to 1 m in human beings, a few microns for the diameter
 - crowded environment
- Link with neurodegenerative diseases

v: vesicle
nf: neurofilament
mit: mitochondrion
MT: microtubule



Shemesh & Spira, Acta Neuropathol 120, 209 (2010)

Tug-of-war



Endosome inside
Dictyostelium cells.

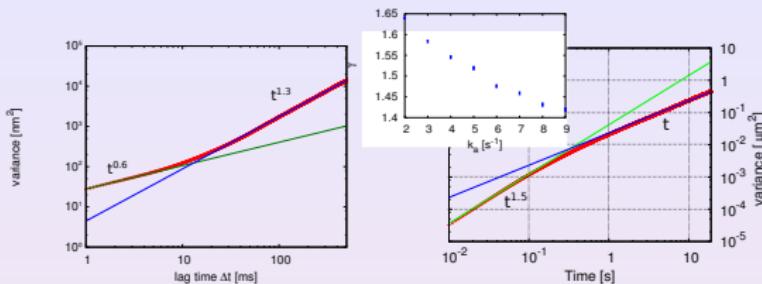
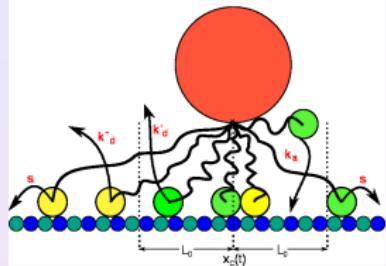
[Soppina et al (2009) PNAS]

Teams of motors

- Can apply stronger forces
- Increases processivity

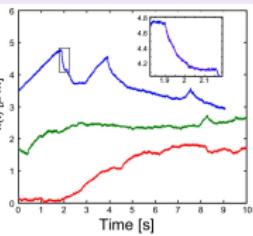


Cargo-motor complexes - Phd Sarah KLEIN



explains experimental observations

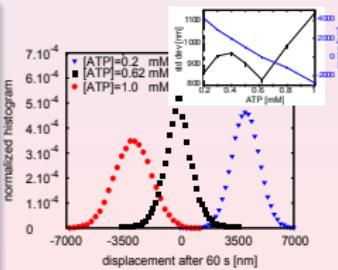
- Anomalous diffusion
- Elastic relaxation



[Kulic et al (2008) PNAS 105, 10011]

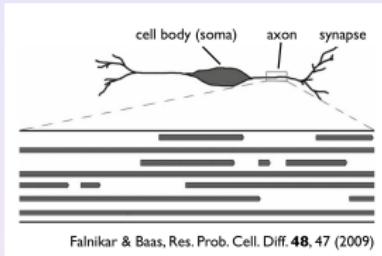
predicts counter-intuitive behavior

- Increase of viscosity can speed-up the cargo
- More ATP can slow down the cargo
- Easy control by an external parameter
- Favorable in crowded areas
- in vitro experiments? (Disc. Stefan Diez - Dresden)



[Klein et al (2014) EPL]

Collective effects in bidirectional intracellular transport

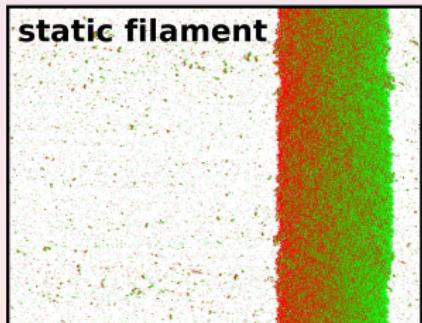


Ingredients

- Two types of complexes going in opposite directions
- Confined diffusion in the surrounding cytoplasm

In general, jams

- No transport in thermodynamic limit
- Offering multiple filaments enhances cluster formation



Equipe Modélisation des Systèmes Biologiques



E. Mandonnet
Médecine des gliomes

Données
cliniques et
biologiques

Analyse des données et modélisation

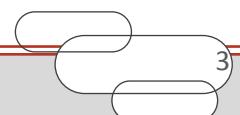
Physique statistique et systèmes dynamiques

M. Badoual
R. Mastrippolito
Biophysique, modélisation

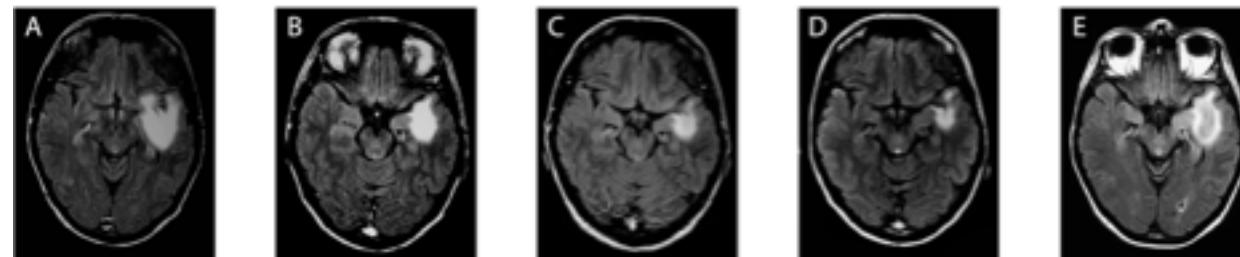
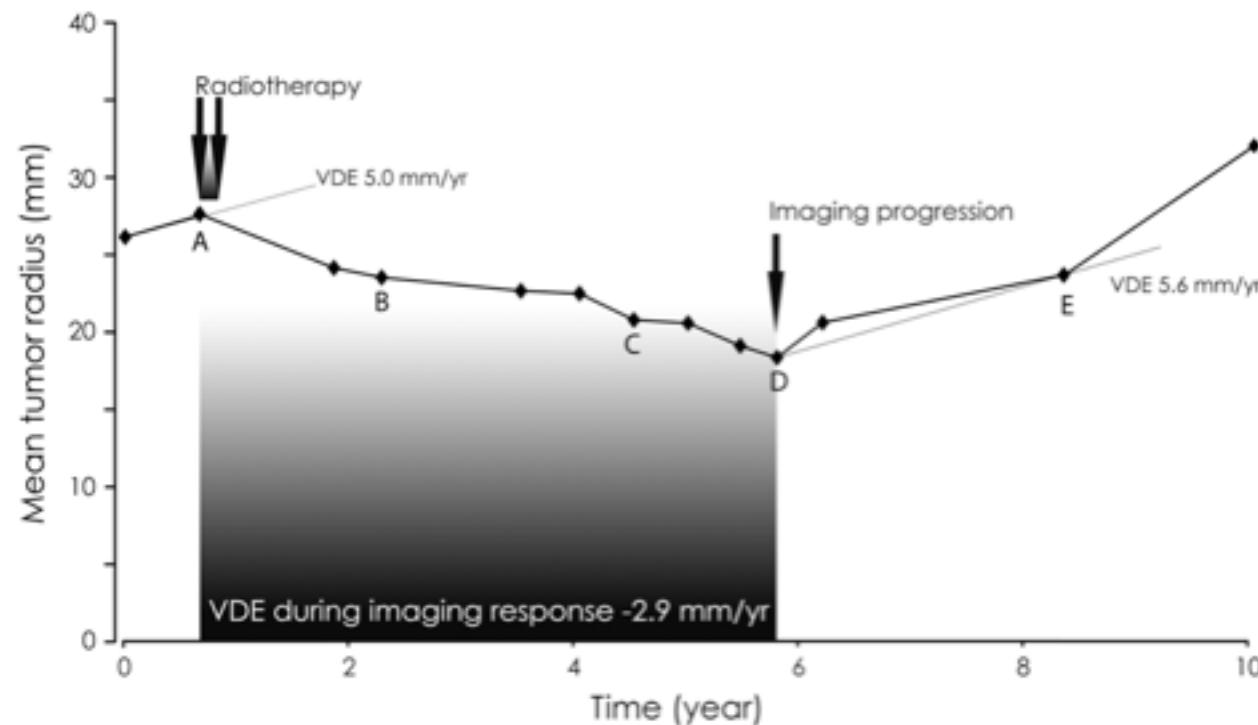
C. Deroulers
Physique statistique

B. Grammaticos
Physique
mathématique

Pluridisciplinarité et complémentarité des membres de l'équipe



Effet de la RT sur les gliomes



Effet de la RT sur les gliomes

Equation for the cell density evolution:

$$\frac{\partial \rho}{\partial t} = D \nabla^2 \rho + \kappa \rho (1 - \rho)$$

ρ : tumor cell density

ξ : edema fraction

κ : proliferation

D : diffusion

λ : edema production

μ : edema clearance

Equation for the edema fraction evolution:

$$\frac{\partial \xi}{\partial t} = \lambda \rho (1 - \xi) - \mu \xi^\nu$$

At the center, when $\rho=1$, ξ reaches its maximum value that verifies:

$$1 - \xi_e = \frac{\lambda}{\mu} \xi_e^\nu$$

Badoual M et al (2014) Oedema-based model for diffuse low-grade gliomas: application to clinical cases under radiotherapy, Cell Prolif., 47, 369-80.

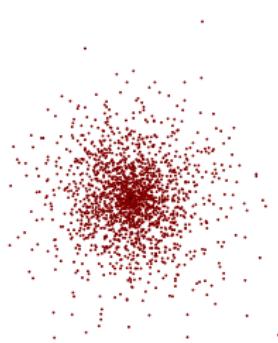
Monte Carlo simulations for migrating (tumour) cells

Initially empty space, source at the centre.

After 10000 time steps:

$$p = 1/2$$

$$p = 1$$



$p = 1/2$ (only exclusion)

$p = 1$ (exclusion +
contact-maintaining interactions)

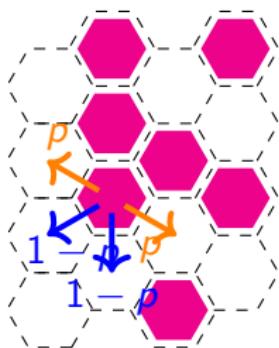


Profile of cell concentration?

Hydrodynamic limit of the stochastic model

Taking into account correlations of positions between nearest neighbours (\approx enhanced mean-field):

Neglect correlations within k -uples of sites with $k \geq 3$ and large-distance correlations \rightarrow

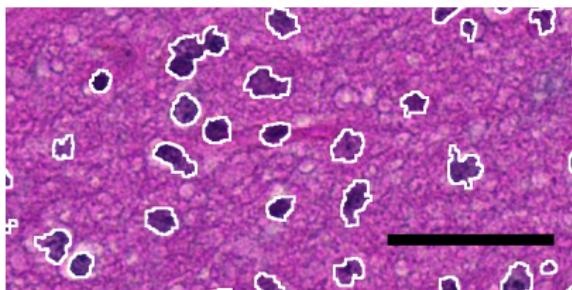


$$\begin{cases} \frac{\partial \rho(\vec{r}, t)}{\partial t} &= \vec{\nabla} \cdot [D(\rho) \vec{\nabla} \rho(\vec{r}, t)] + f(c, \rho) \\ \frac{\partial c(\vec{r}, t)}{\partial t} &= -\alpha c(\vec{r}, t) + g(c, \vec{\nabla} \rho) + \dots \end{cases}$$

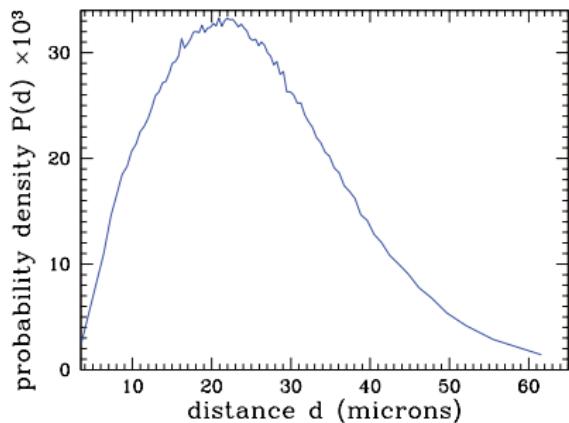
(very schematically)

see G. Ascoli et al. Phys. Rev. E (2013)

In vivo tissues



Bar: 4 μm .



Distribution of the distance
between 154240 dark nuclei and
their nearest neighbour.

CD *et al.*, Diagn Pathol 8 92 (2013)

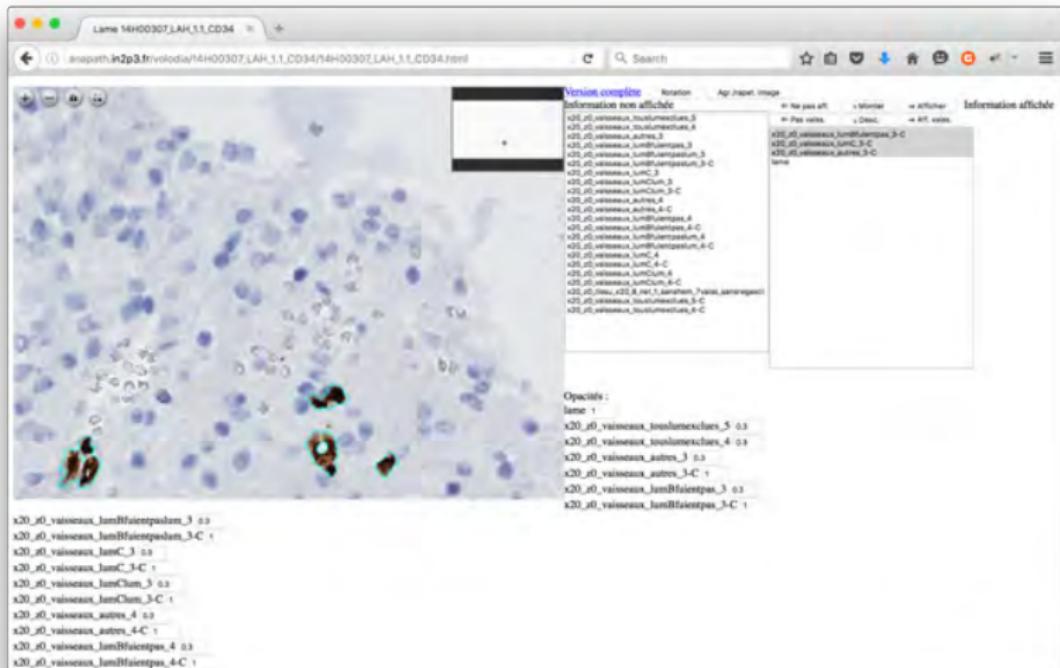
Example session



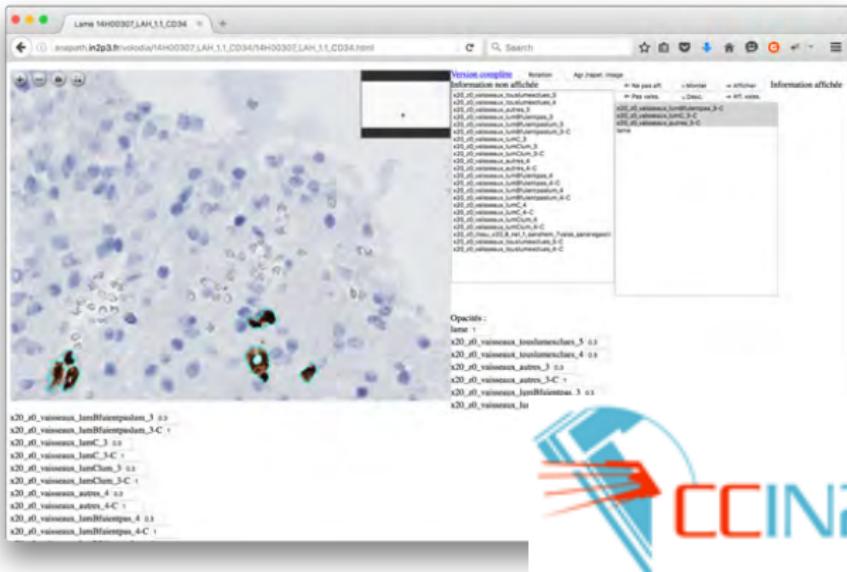
Example session



Example session



Example session



17/21