

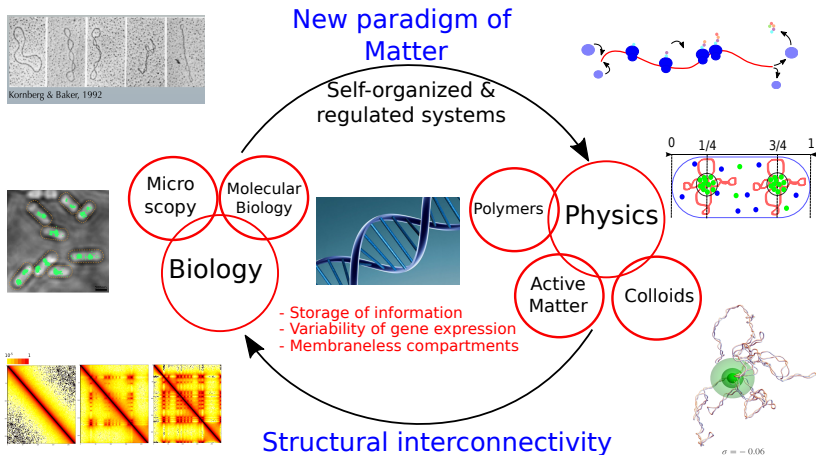
Biophysical modeling of bacterial DNA segregation

Jean-Charles WALTER

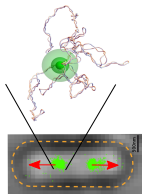
*Laboratoire Charles Coulomb (L2C)
CNRS & Université de Montpellier*

SPLDS22
Pont-à-Mousson, France
May 2022

Physics meets Biology

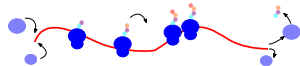


Genomic physics

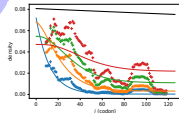


Bacterial DNA
organization
&
segregation

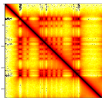
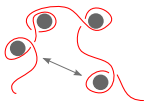
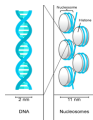
genomic
physics



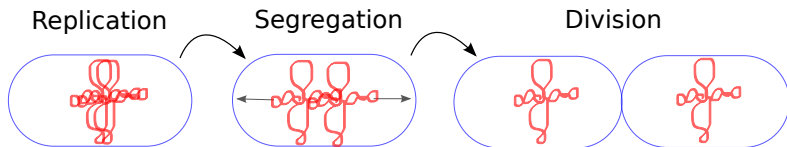
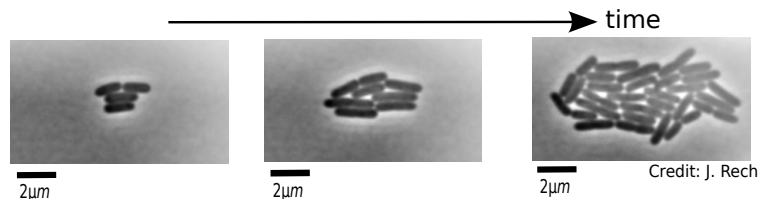
Translation
of
messenger RNA
by ribosomes



Epigenetic
regulation
of eukaryotic
chromatin

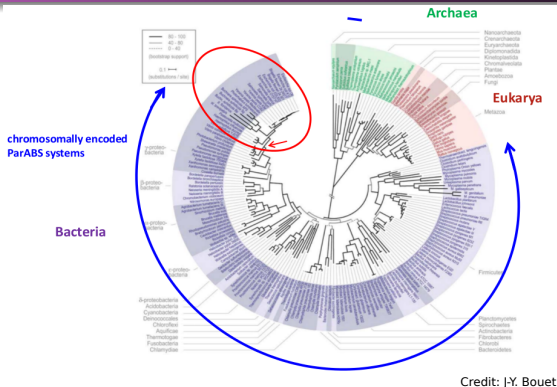


Bacterial DNA segregation



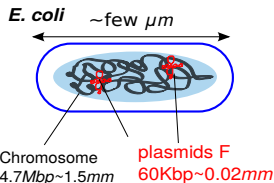
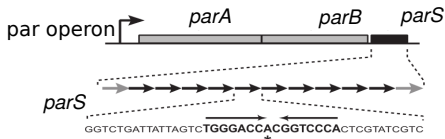
How is the bacterial genome segregated ?

Bacterial DNA segregation: the ParABS system



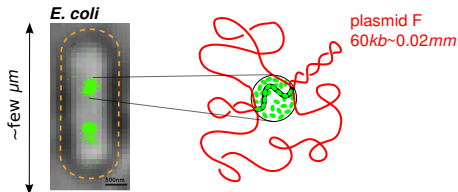
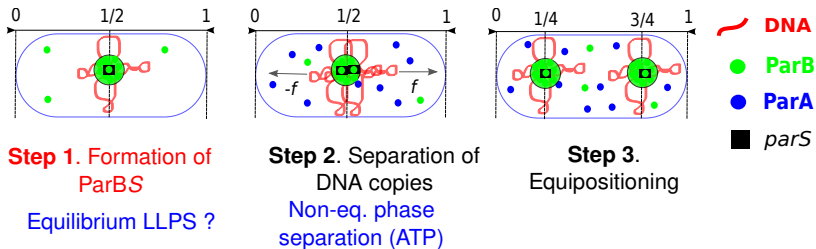
- ParABS is strongly conserved
- Ancient mechanism of liquid-liquid phase separation (**LLPS**)

The ParABS system: the molecular actors

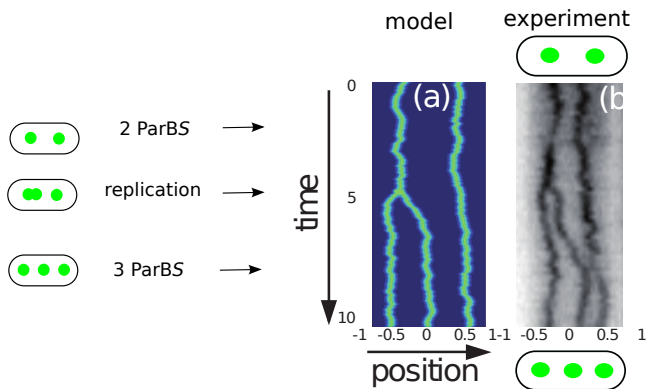


- ParA: “motor” protein (ATPase)
- ParB: binding protein (specific or non-specific binding)
- *parS*: specific DNA sequence

Bacterial DNA segregation: the ParABS system

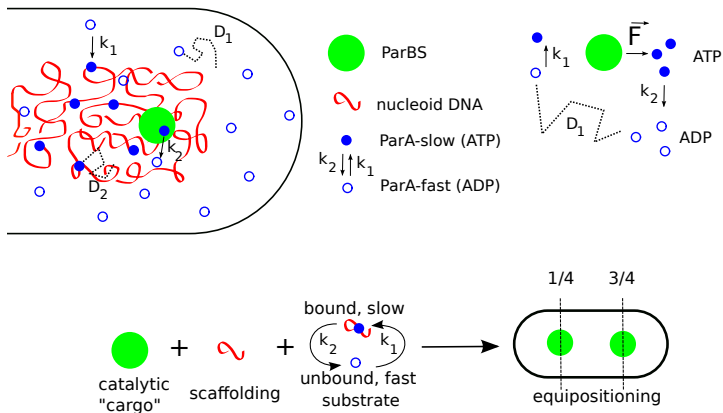


Equipositioning along the cell axis



What are the main physical actors of DNA segregation ?

Reaction-diffusion process: Molecular interactions



Reaction-Diffusion equations

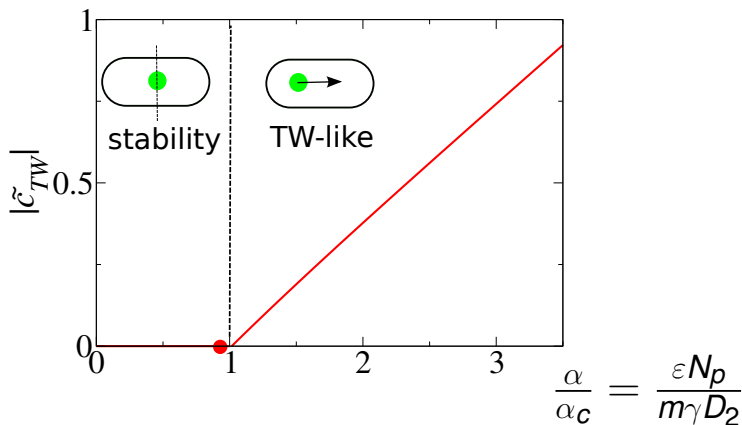
$$\text{ParA-slow (ATP): } \frac{\partial v}{\partial t} = D_2 \Delta v + k_1 u(\mathbf{r}, t) - k_2 v(\mathbf{r}, t) \sum_i S(\mathbf{r} - \mathbf{r}_i(t))$$

$$\text{ParA-fast (ADP): } \frac{\partial u}{\partial t} = D_1 \Delta u - k_1 u(\mathbf{r}, t) + k_2 v(\mathbf{r}, t) \sum_i S(\mathbf{r} - \mathbf{r}_i(t))$$

$$\text{ParBS: } m\gamma \frac{d\mathbf{r}_i}{dt}(t) = \varepsilon \int_V \nabla v(\mathbf{r}', t) S(\mathbf{r}' - \mathbf{r}_i(t)) d^3\mathbf{r}'$$

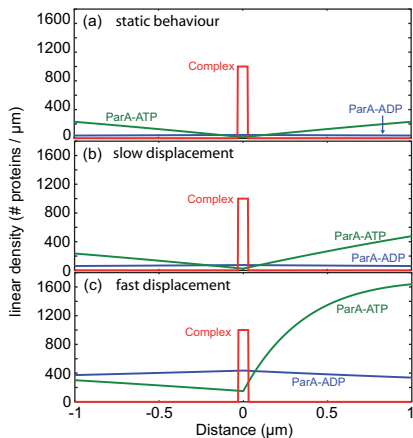
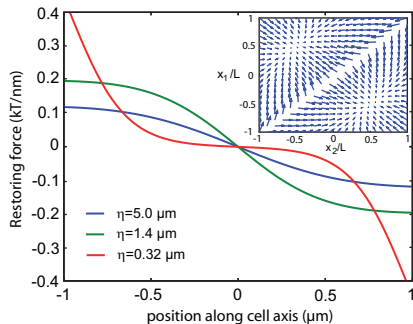
- **Feedback** between the partition complexes and ParA densities
→ Non-linear system with **dynamical instability**

Dynamical instability: bifurcation obtained with Traveling Wave ansatz

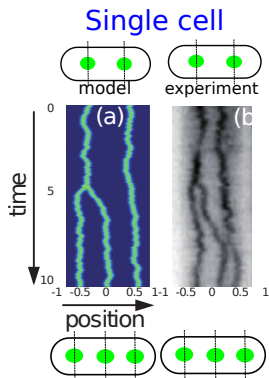


Restoring force & gradient of ParA-ATP

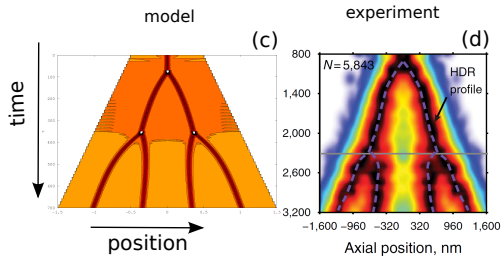
$$\eta = \sqrt{\frac{D_1}{k_1}}$$



Comparison with experiments

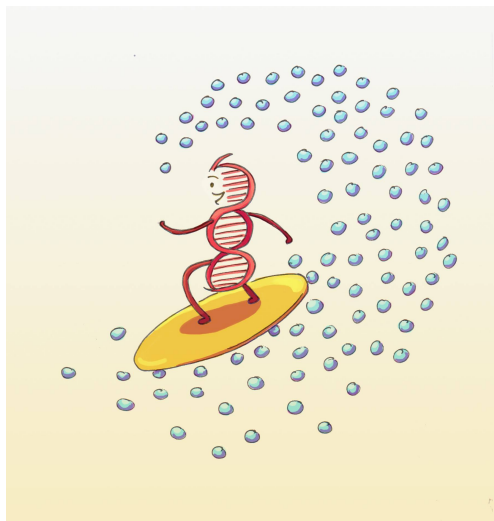


Average

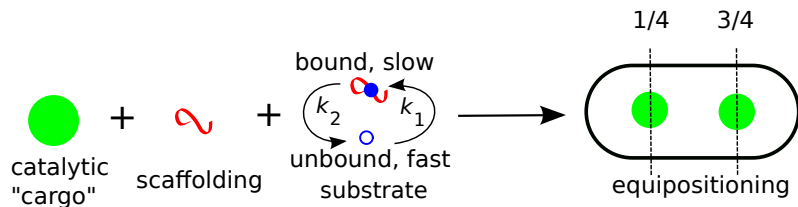


Fluorescence microscopy & Superresolution microscopy

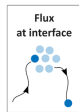
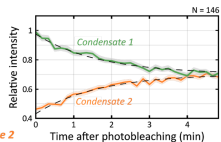
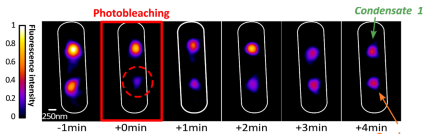
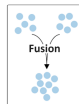
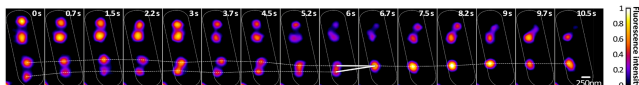
Conclusion



Conclusion



Liquid-like behaviour of ParBS complexes



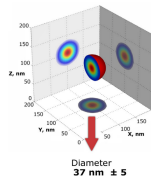
Condensate 2
(photobleached focus)



Baptiste Guilhas
Nollmann's Lab, CBS, Montpellier

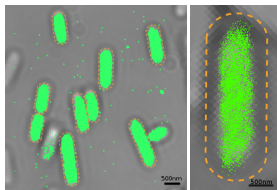


Antoine Le Gall



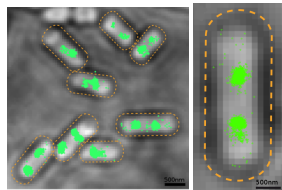
Guilhas, JCW,...Le Gall, Nollmann **ATP-driven separation of liquid phase condensates in bacteria** *Mol. Cell* '20

Liquid-like behaviour of ParBS complexes

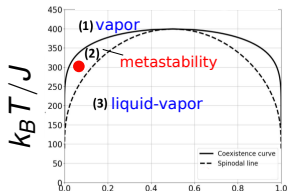
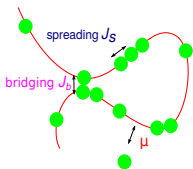


vapor

*specific
binding*
→
ParB/parS



liquid-vapor



Thank you for your attention!

J Dornnac
F Geniet
J Palmeri
A Parmeggiani
N-O Walliser

C Chevalier
G David
P Soudon



Biophysical modeling

A David
A Choquet



Molecular biology



B Guillas
D Cattoni
A Le Gall
M Nollmann



Super resolution
microscopy

Bioinformatics

E Rivals



N Wingreen



C Broedersz



R Diaz-Debaugny
C Mathieu-Demazière
J Rech
J Bouet



Molecular
biology



I Junier
T Lepage



Numerical
Simulations

