

# Surfing on protein waves: proteophoresis as a mechanism for bacterial genome partitioning

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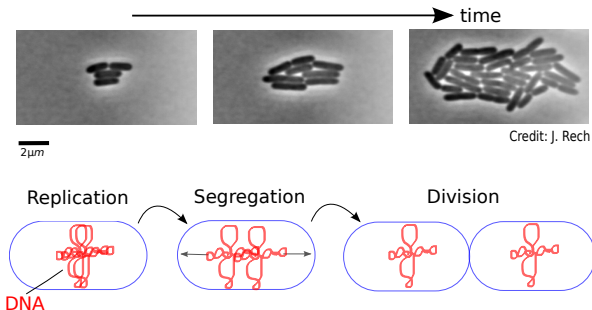
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*American Physical Society – March Meeting*  
Boston, USA  
4-8 March 2019

# Outline

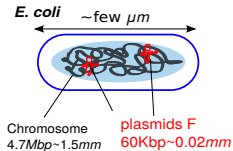
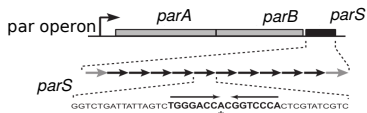
- 1 Bacterial DNA segregation: the ParABS system
- 2 Dynamics: complexes surfing on protein waves

# Segregation of bacterial DNA



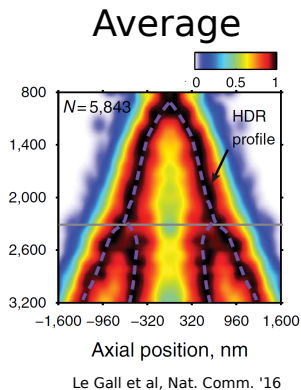
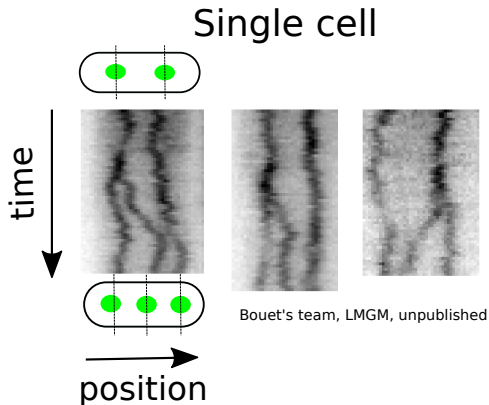
How is the bacterial genome segregated ?

# The ParABS operon

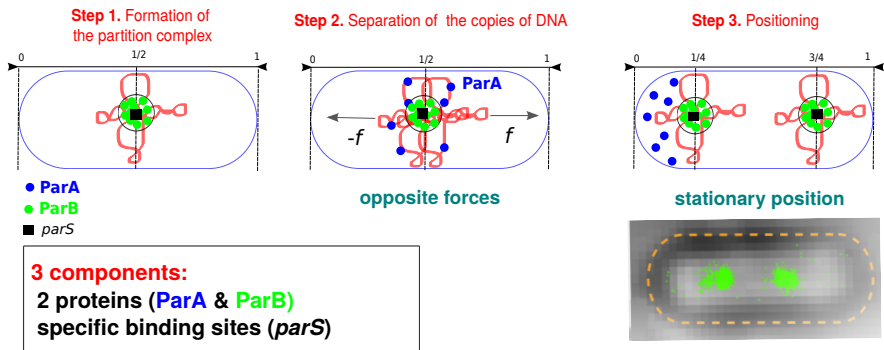


- ParA: “motor” protein (ATPase, Walker-type)
- ParB: binding protein (specific or non-specific binding)
- *parS*: centromere-like DNA sequence

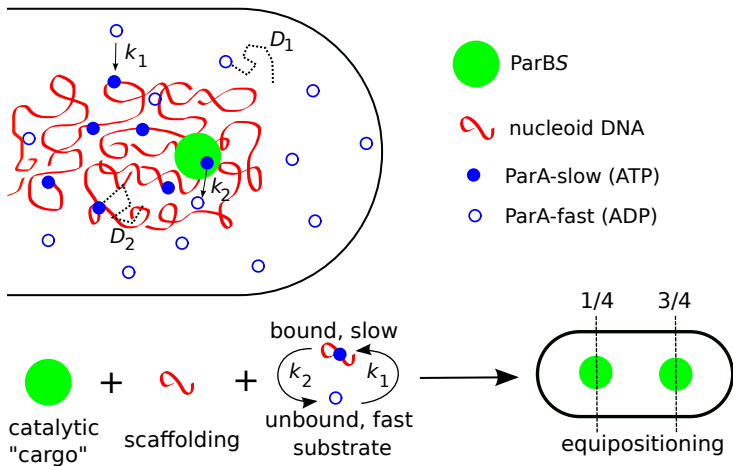
## Bacterial DNA segregation: experimental facts



# How does ParABS work ?



## Bacterial DNA segregation: interactions of ParABS



# Dynamical steps: Reaction-Diffusion equations

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

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

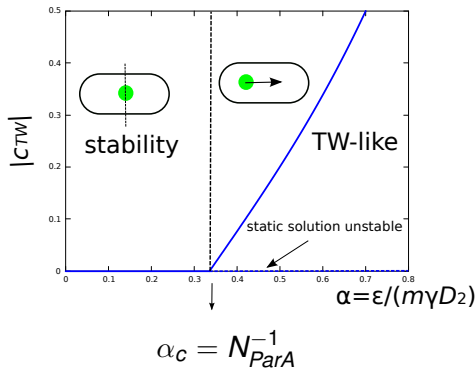
$$m\gamma \frac{d\mathbf{r}_i}{dt}(t) = \varepsilon \int_V \nabla v(\mathbf{r}', t) S(\mathbf{r}' - \mathbf{r}_i(t)) d^3\mathbf{r}'$$

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

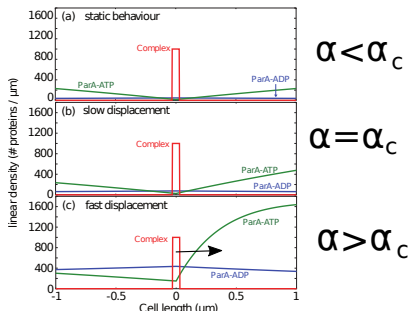


# Dynamical instability

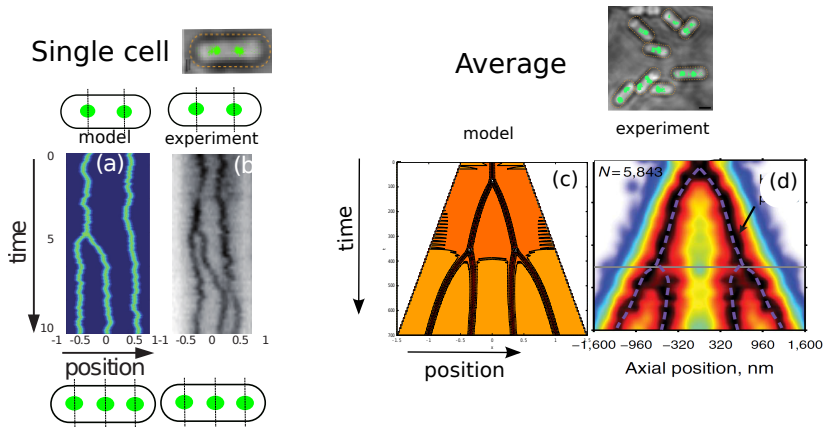
Threshold of dynamical stability obtained with Traveling Waves (TW) *ansatz*:  
 $u(x, t) = u(\xi); v(x, t) = v(\xi)$ , where  $\xi = x - c_{TW} t$



## Quasistatic hypothesis: calculation of the profiles



## Comparison with experiments



# Summary

- **Minimal reaction-diffusion** system:  
→ sufficient to explain segregation and positioning in ParABS
- Non-linear coupling between ParBS and ParA densities:  
→ **Self-consistent description of the 3 protein species**
- Analytical analysis:  
→ **dynamical transition (stable/unstable regime)**

JCW, Dorignac J., Lorman V., Rech J., Bouet J.-Y., Nollmann M., Palmeri J., Parmeggiani A. & Geniet F., *Surfing on protein waves: proteophoresis as a mechanism for bacterial genome partitioning*, *Phys. Rev. Lett.* **119**, 028101.

arXiv:1702.07372 [q-bio.SC]

## Physical modeling

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## Molecular biology

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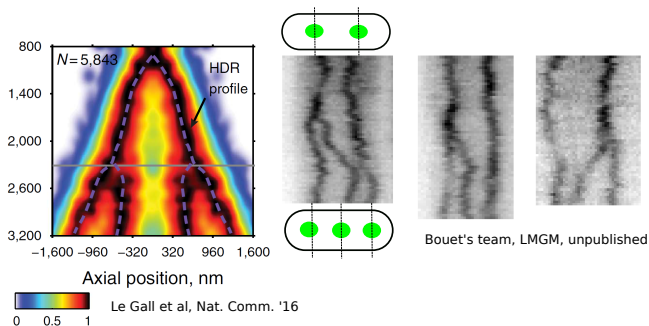
## Super-resolution microscopy

D. Cattoni  
A. Le Gall  
M. Nollmann

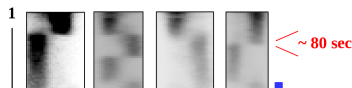


## Bacterial DNA segregation: experimental facts

## Equipositioning of the complexes



## Oscillations of ParA



# Screening length

