

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

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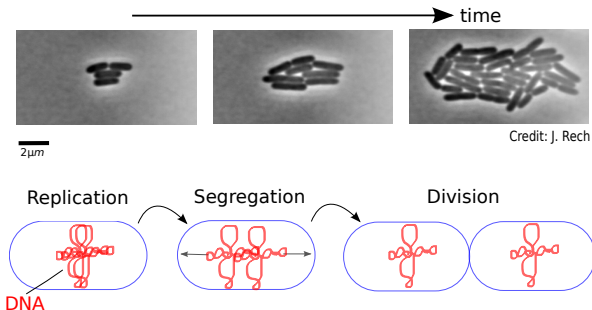
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The Biology and Physics of Bacterial Chromosome Organisation 2018
Leiden, The Netherlands
4-6 June 2018

Outline

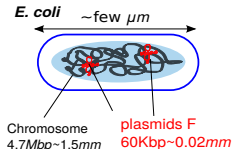
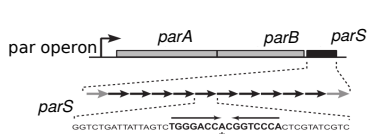
- 1 Bacterial DNA segregation: the system ParABS
- 2 Dynamics: complexes surfing on protein waves

Segregation of bacterial DNA



How is the bacterial genome segregated ?

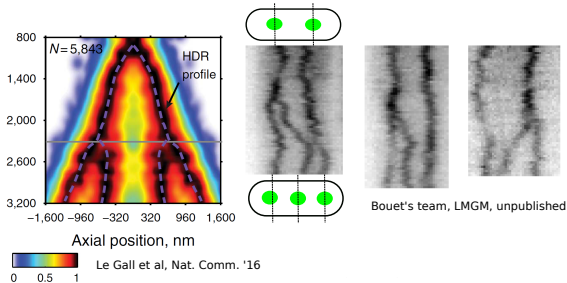
The ParABS operon



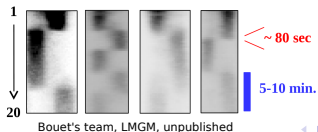
- ParA: “motor” protein (ATPase, Walker-type)
- ParB: binding protein (specific or non-specific binding)
- *parS*: centromere-like DNA sequence

Bacterial DNA segregation: experimental facts

Equipositioning of the complexes

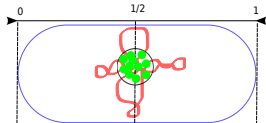


Oscillations of ParA



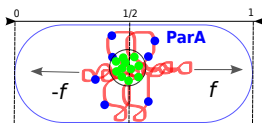
How does ParABS work ?

Step 1. Formation of the partition complex



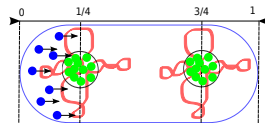
- ParA
- ParB

Step 2. Separation of the copies of DNA



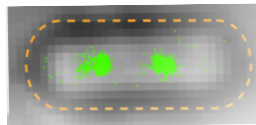
opposite forces

Step 3. Positioning

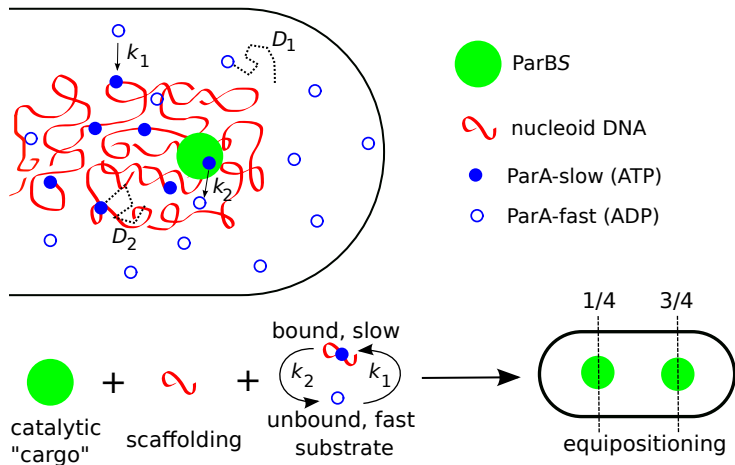


oscillations of ParA

3 components:
 2 proteins (ParA & ParB)
 specific binding sites (*parS*)



Bacterial DNA segregation: interactions of ParABS



Dynamical steps: Reaction-Diffusion equations

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

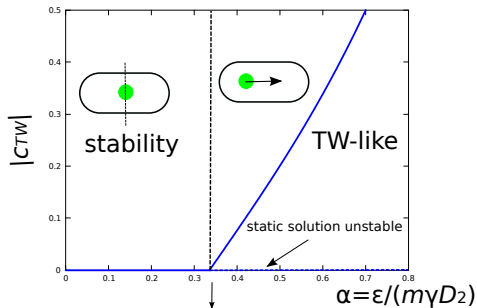
$$\text{ParA-slow: } \frac{\partial v}{\partial t} = D_2 \Delta v + k_1 u(\mathbf{r}, t) - k_2 v(\mathbf{r}, t) \sum_i S(\mathbf{r} - \mathbf{r}_i(t))$$

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

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

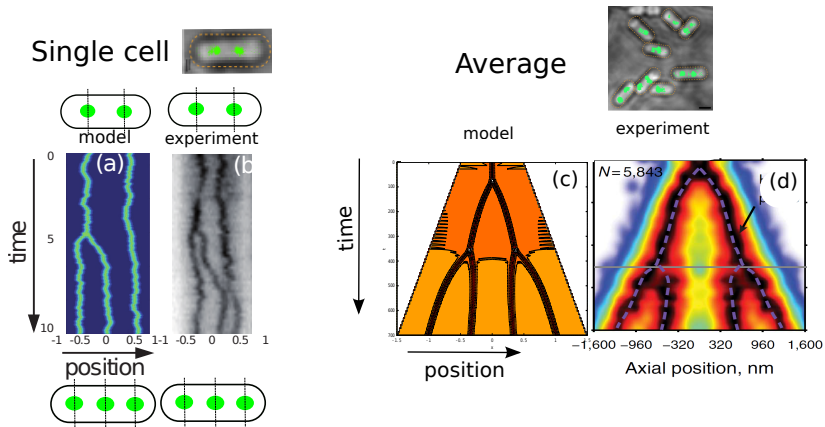
Dynamical instability

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



$$\alpha_c = (\sigma C_0)^{-1}$$

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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