Bacterial portraits
Dynamic density shaping of photokinetic *E. coli*
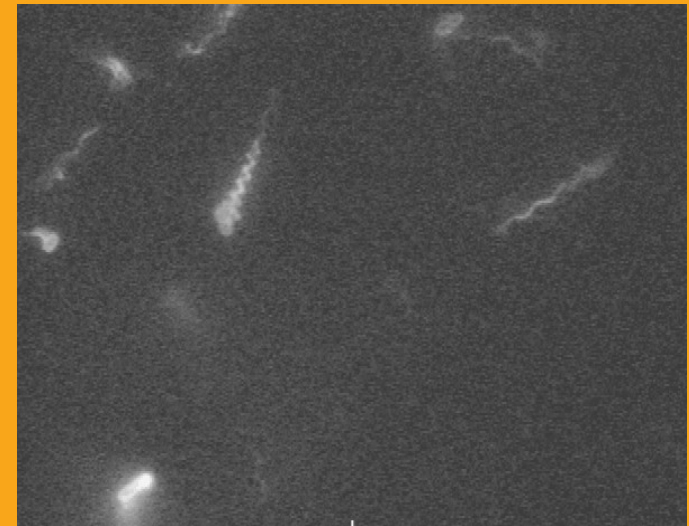
Dario Dell'Arciprete

Outline

1. *E. coli* as active particle & light–controllable speed

2. Experiment on photokinetic cells: density shaping

3. Conclusions

E. coli as active particle

- **Who ?** A bacterium capable of:

  - **Self-propulsion** (motile)

  - **Interaction :** sense environment + compute and respond to stimuli

- *E. coli* **motion :** Propulsion by flagellar motors on body surface. Run-and-tumble dynamics : 1 s straight + 0.1 s tumbling

Turner *et al.* | J Bacteriology | 2000

- **Flagellar motors :** Powered by cellular respiration : O_2 gets in > protons produced > flagellar motor uses protons (proton pump)

How to control speed? Proteorhodopsin

- Proteorhodopsin as a solar panel for the *E. coli* (Béjà *et al.* | Science | 2000)

- Proteorhodopsin as a light–driven proton pump → Protonmotive force ($\Delta V_{membranes}$) → Rotation of molecular motors

Walter *et al.* | PNAS | 2007
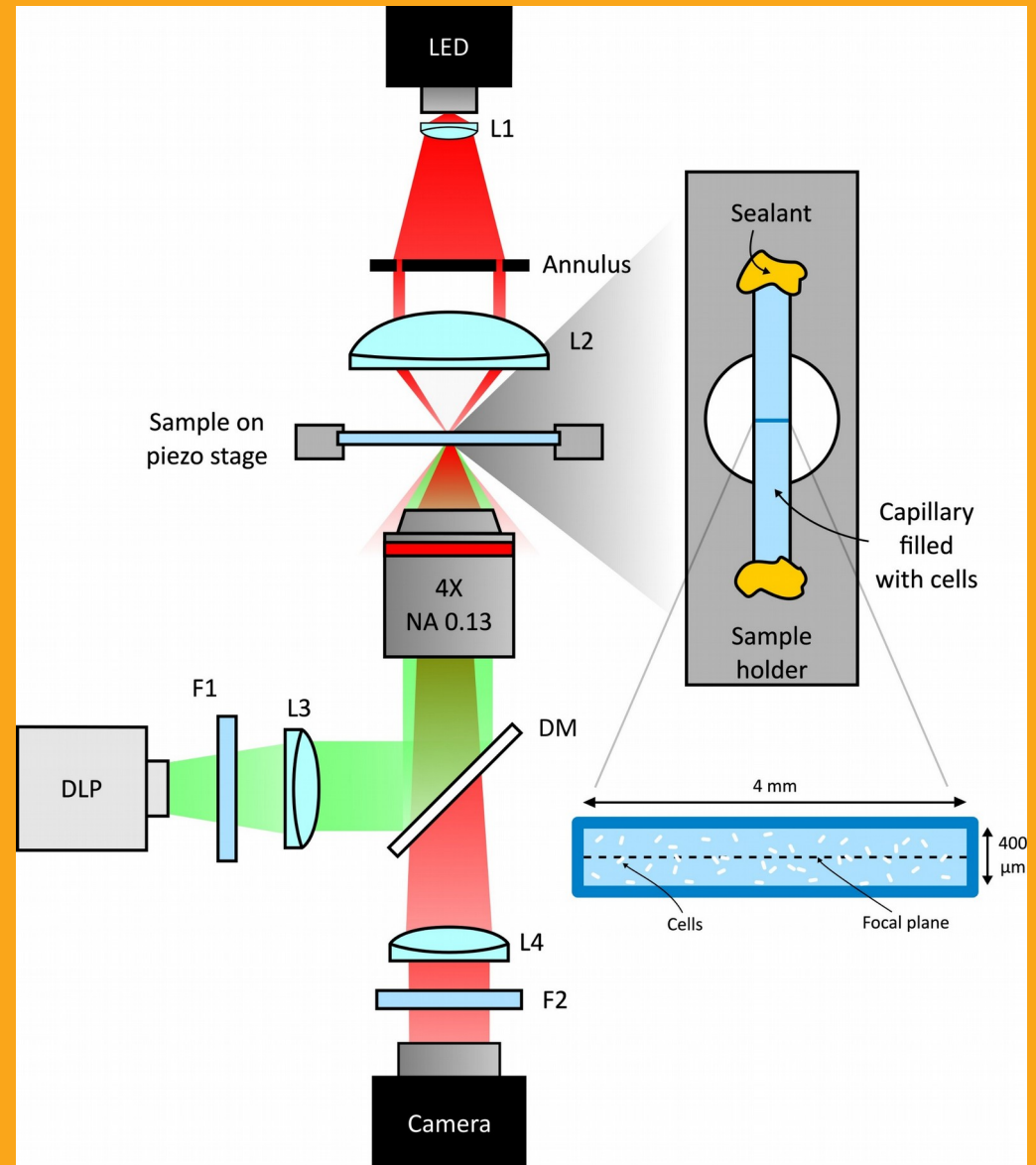
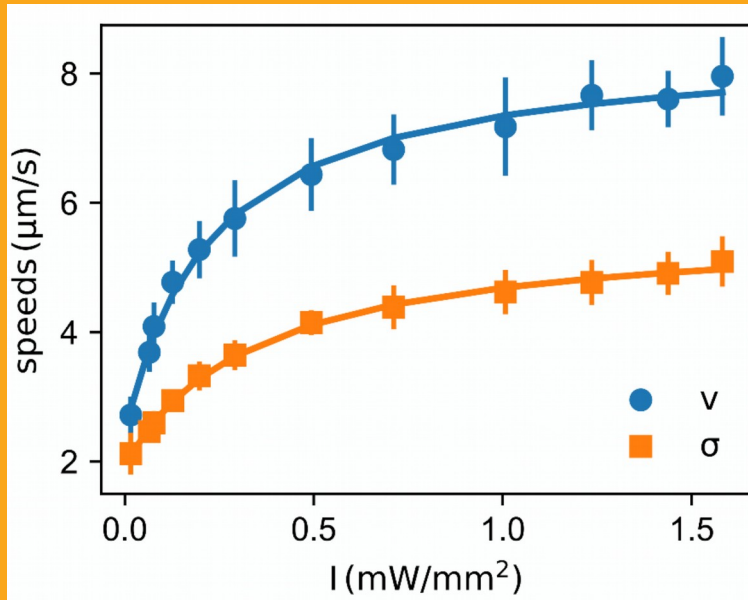- **Control of flagellar motor rotation with light → Control of swimming speed v**

Experiment on photokinetic cells

- Gen. engineered cells: photokinetic *E. coli*

- Digital light projector for light patterns

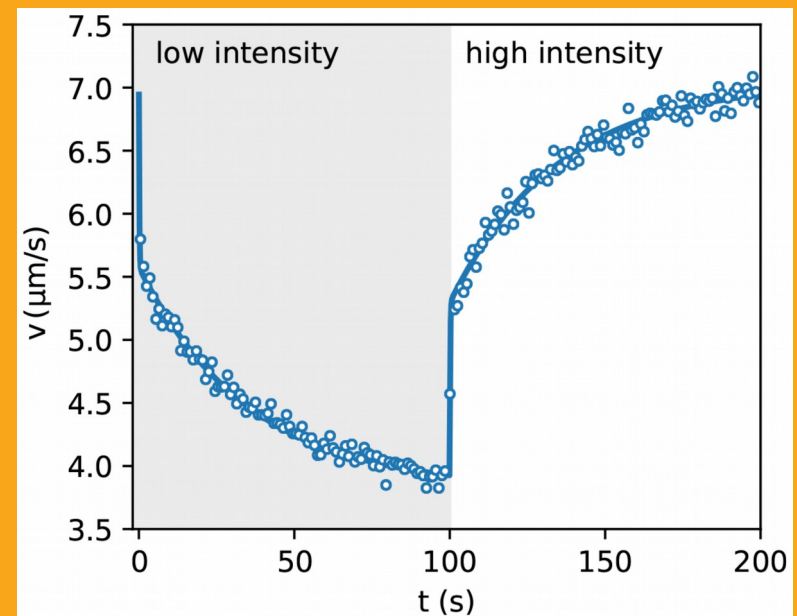- Dark field imaging of 2 mm x 2 mm layer of bacteria
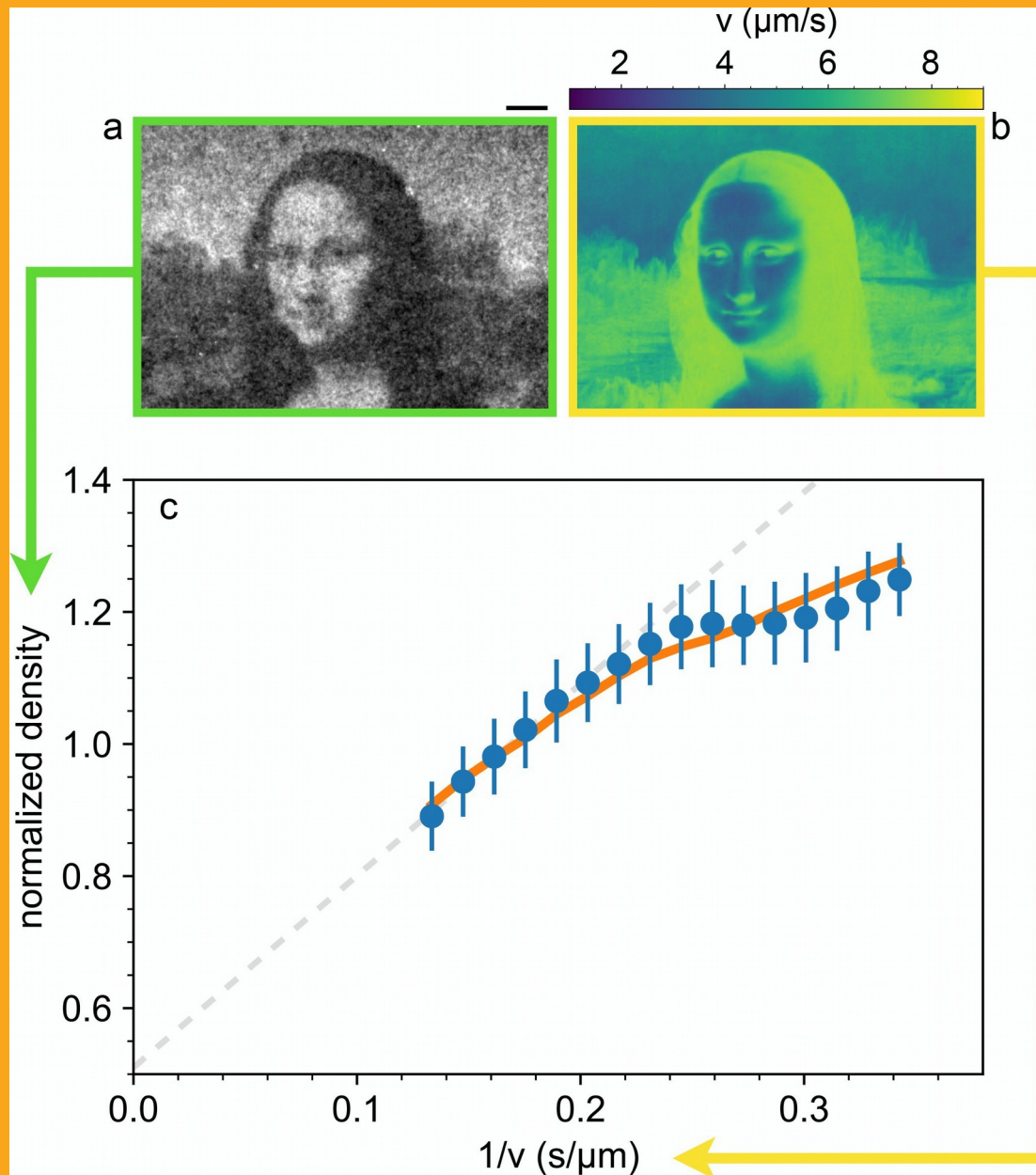
Speed response

On light Intensity

Non linear dependence of speed on light intensity

Non instantaneous change of speed, ca 2 min to reach min and max

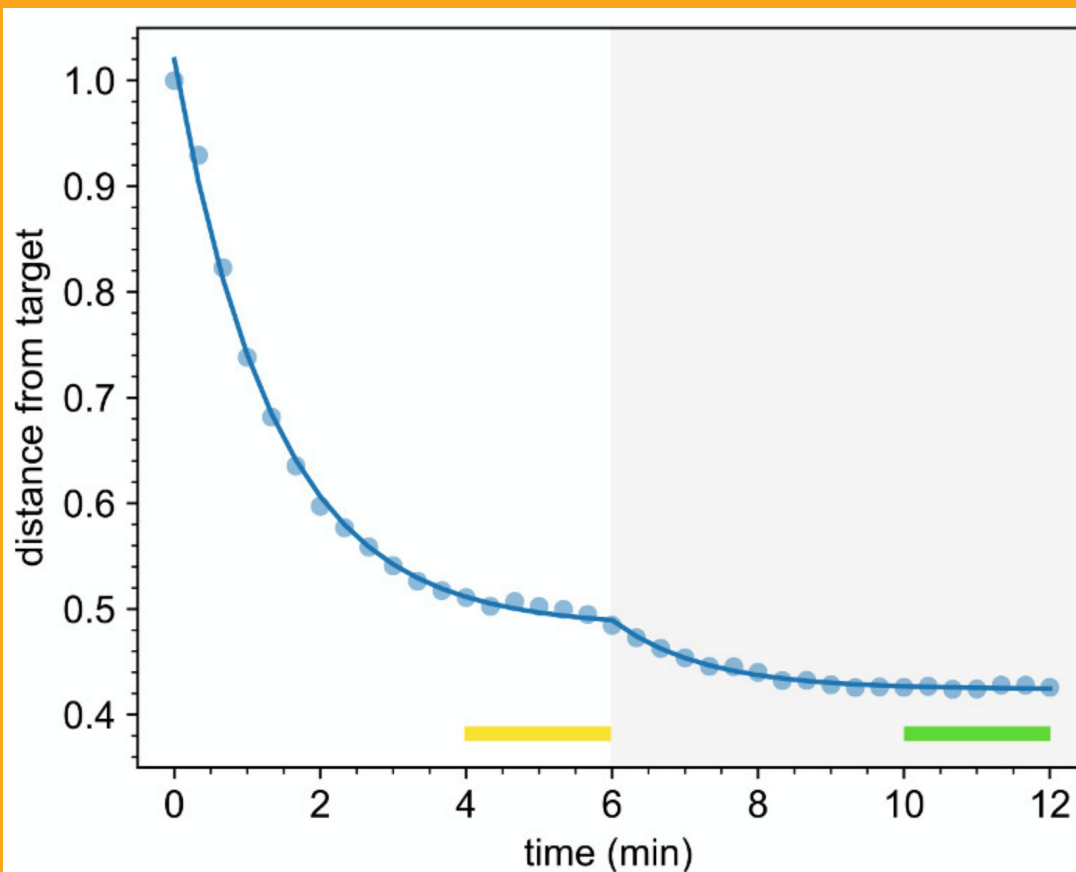On time

Density–speed relation

a

b

c

v (µm/s)

normalized density

1/v (s/µm)

- Models: **ρ(v) as 1/v**
  [Cates *et al.* | A Rev C Mat Phys | 2015]
  (pedestrian walk)

But memory blurs speed map ➙ density map

Possible biological reasons?

- **Stator dynamics?**
  [Tipping *et al.* | J Bacteriology | 2013]

- **ATP synthase: if NO ATP, then steep decrease in velocity**
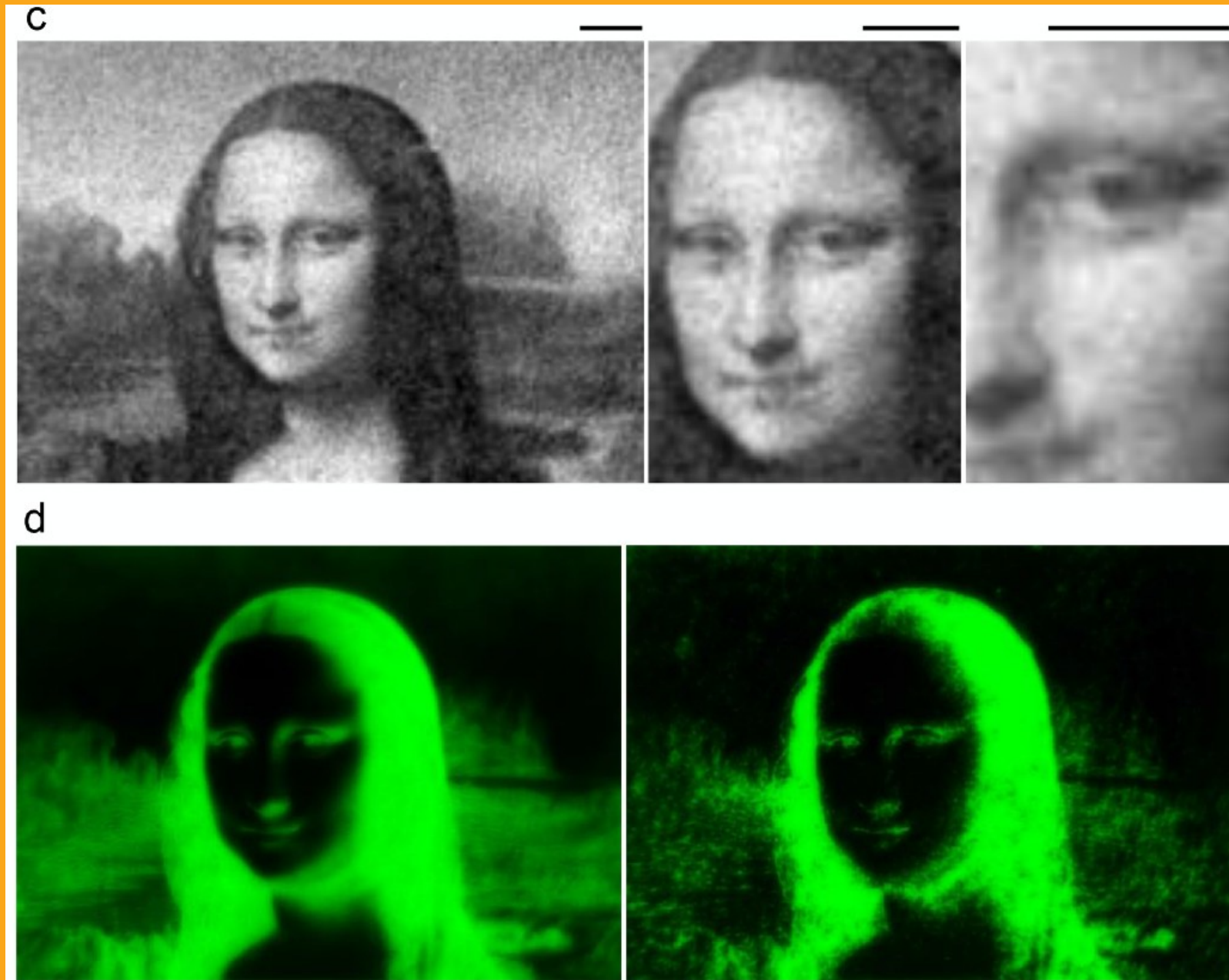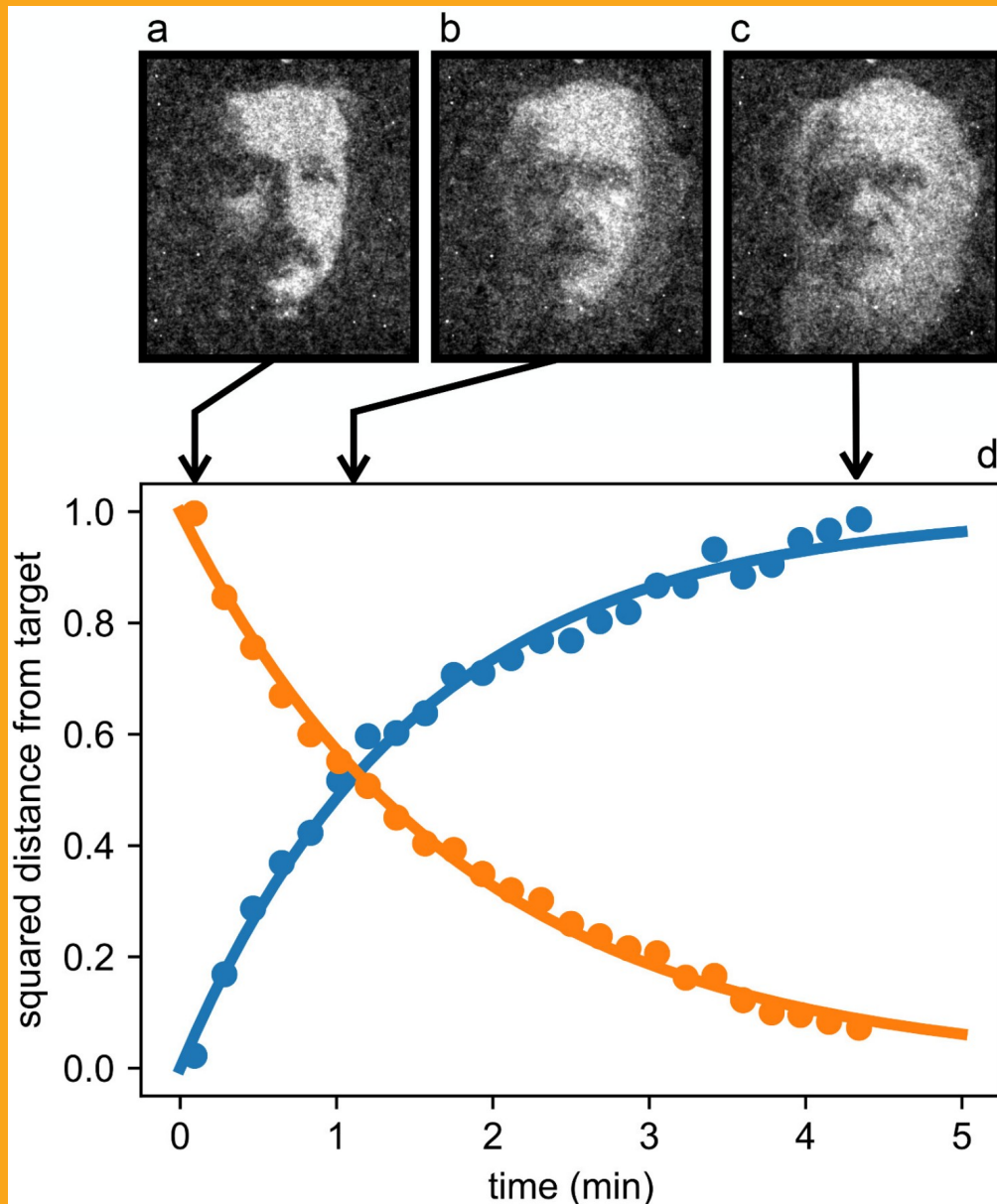 [Arlt *et al.* | Nat Comm | 2018]

Feedback

A bacterial portrait

Morphing : Dynamic reconfigurability

Sum up

- **Density as 1/speed but memory effects** Slow change of speed related to biological factors

- **Feedback :** higher spatial resolution

- **Photokinetic cell collective as active matter** whose **density** can be **shaped accurately, reversibly** and **quickly**

Thank you.

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