



Design, contrôle et stratégie de vol bio-inspirés pour des drones plus performants

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SkyWin & Aerospace Valley

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Inspiration from nature

Feathers and wings....



emerged as an asset toward survival 140 million years ago

Inspiration from nature

A bit too much to the letter



100 years later...

Survival of the fittest



But still... could be smarter

smarter → lighter → more efficient

Embodied intelligence

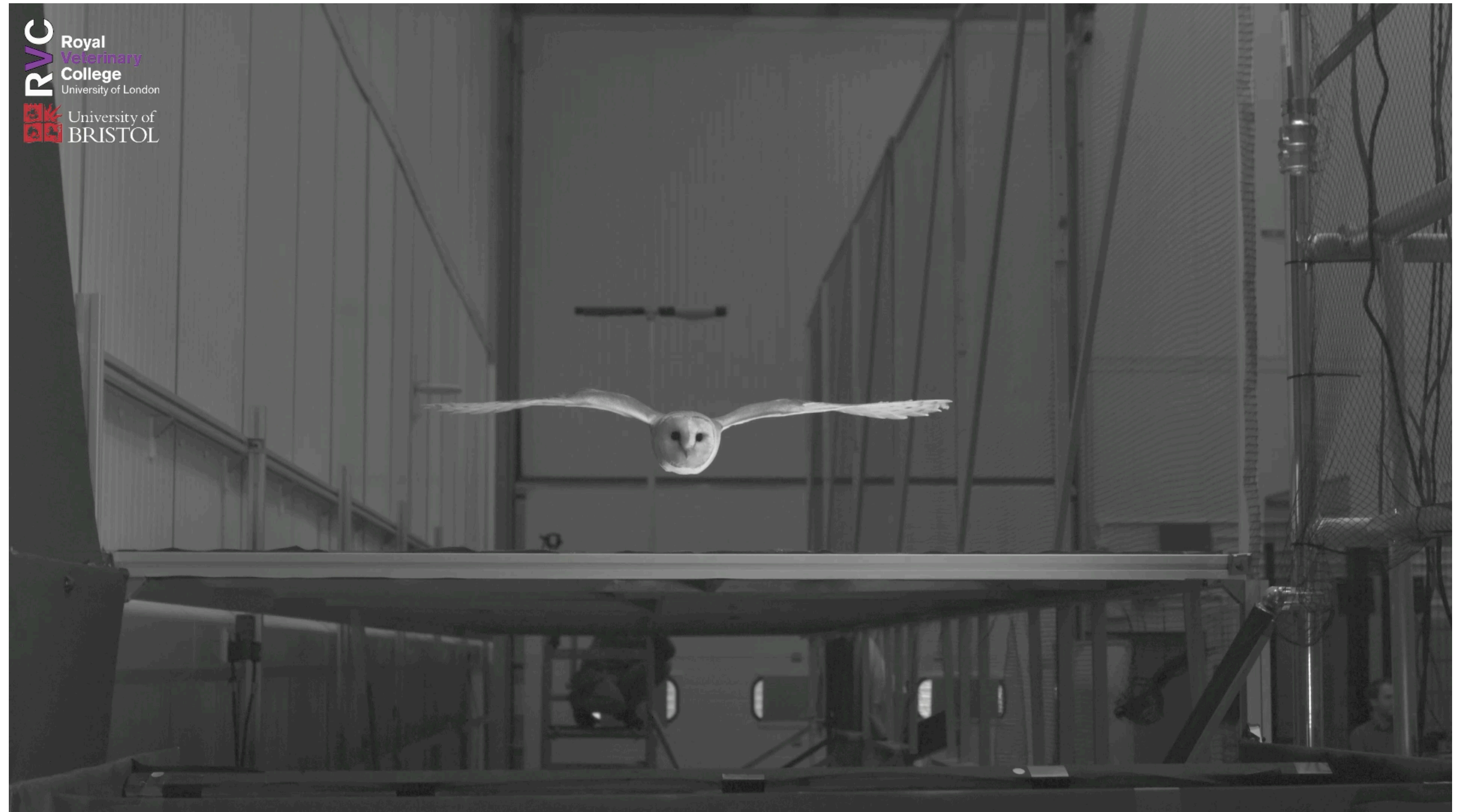
An owl and a gust...

Reaction time **faster**
than reflex arc!?

→ Initial mechanism is
passive, based on
compliance

Avian wing

- **Sensor-rich**
- **Morphing** planform
- **Controllable** compliance
- Feathers **collocate**
actuation and sensing



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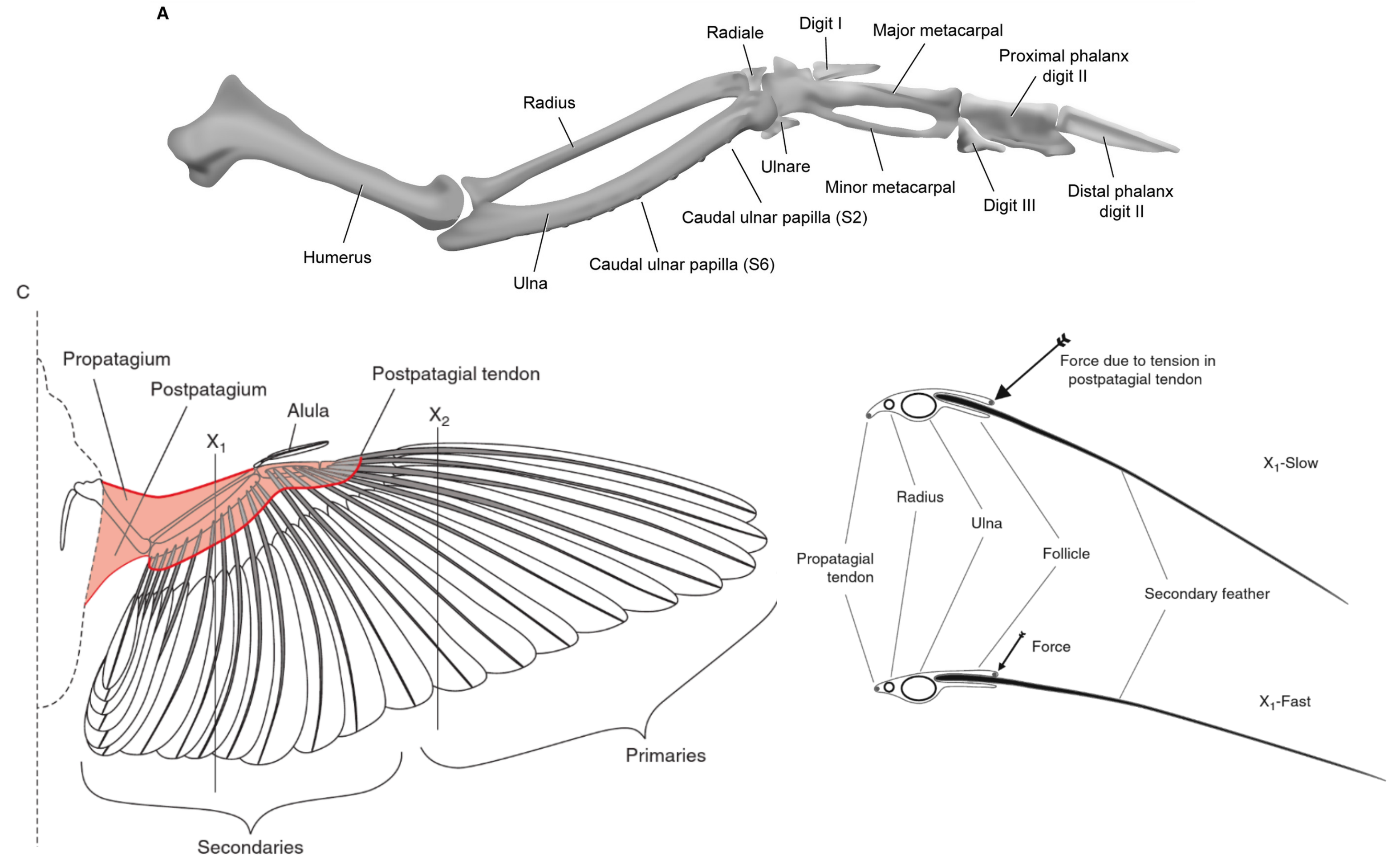
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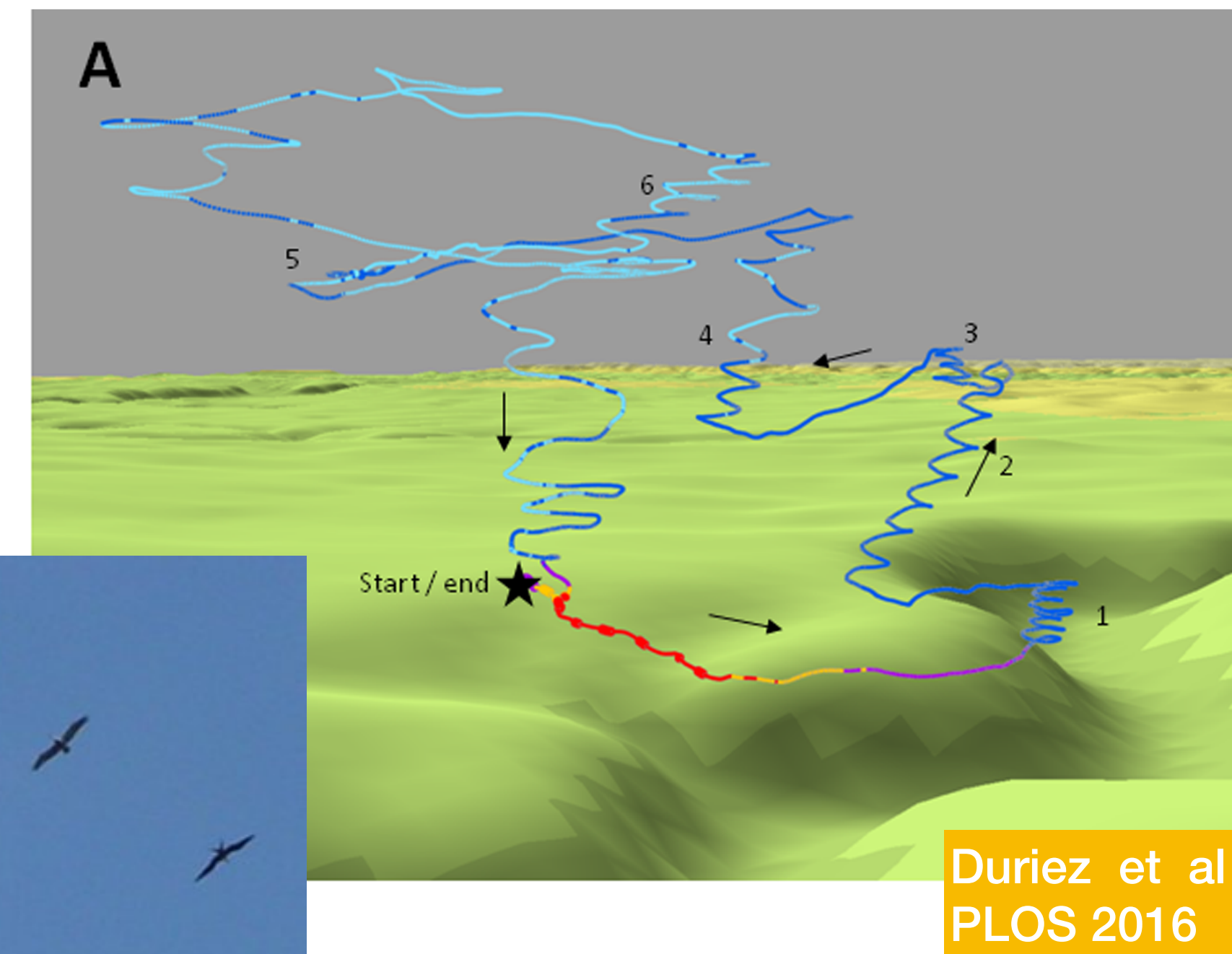
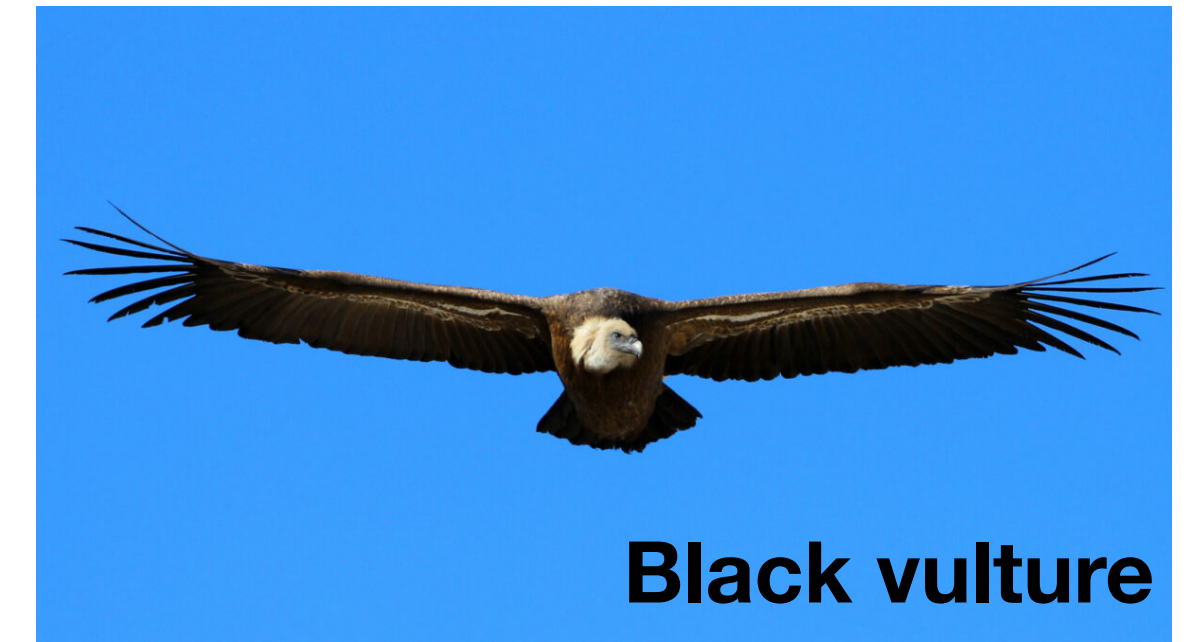


Higher level intelligence

Unlike (most) aircraft, birds rarely fly in a straight line...
especially birds of prey, like vultures

Disturbances are...
information about surrounding
flow that can be **leveraged**

- ➔ Exploitation of atmospheric flow structures (thermals, ridge lift, ...)
- ➔ Flight strategy: thermalling and cruise phases
- ➔ Risk management



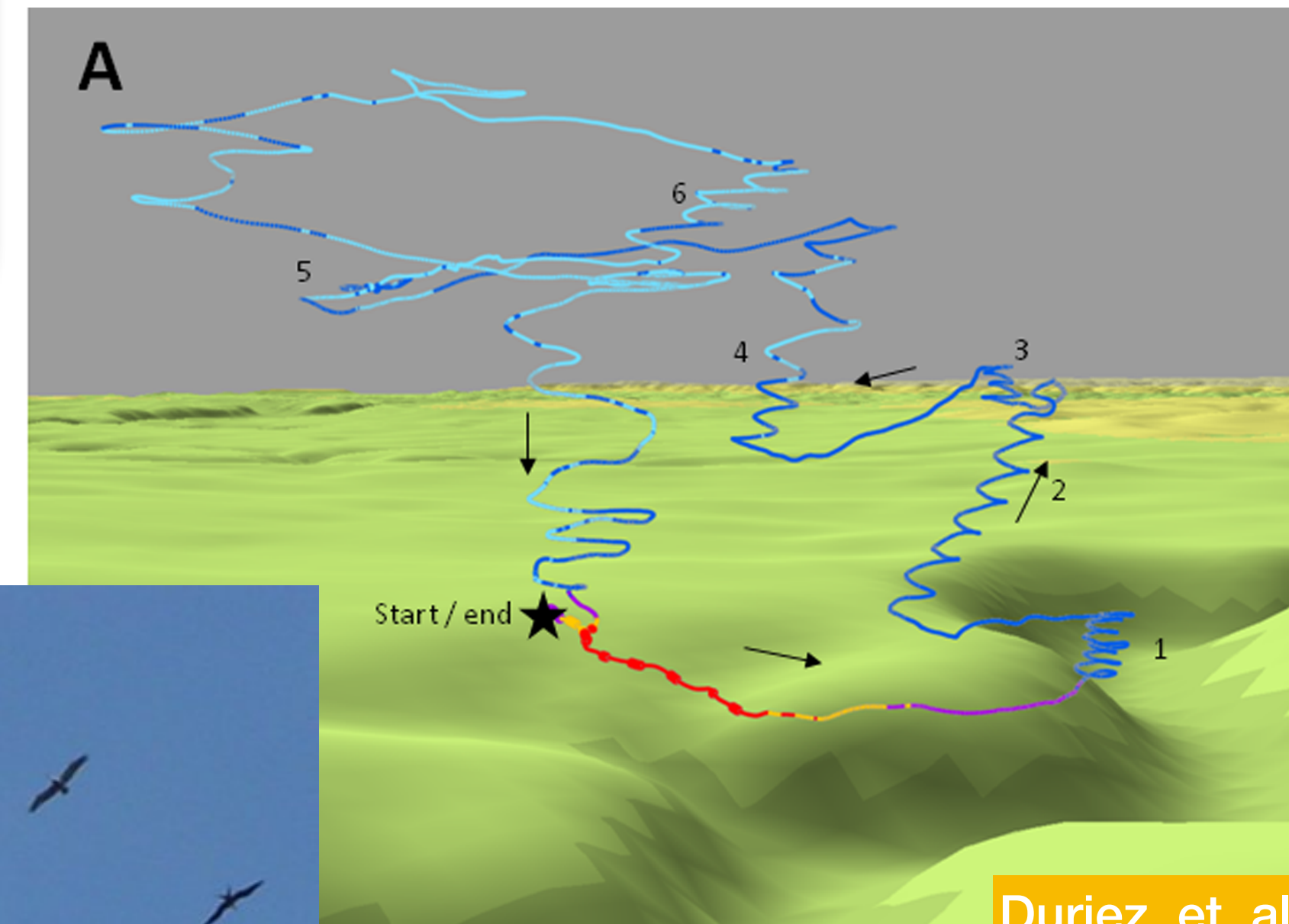
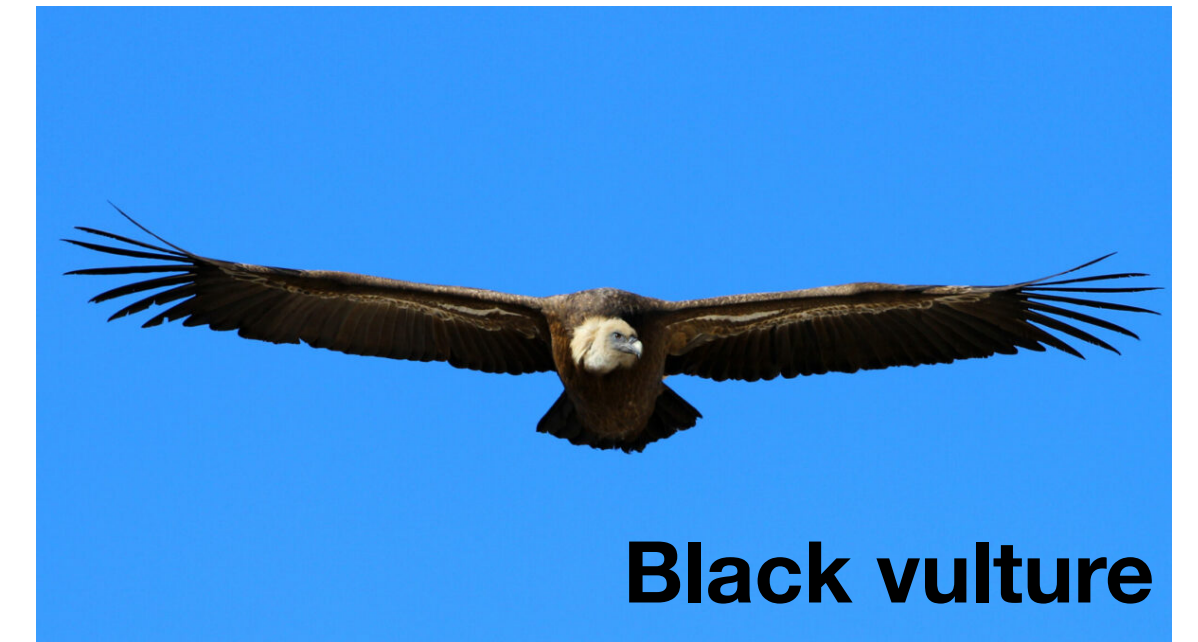
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Man-made flight controllers
mitigate disturbances
but **do not learn** from them

- ➔ Exploitation of atmospheric flow structures (thermals, ridge lift, ...)
- ➔ Flight strategy: thermalling and cruise phases
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Duriez et al
PLOS 2016



Vulture inspiration

Glider pilots know some vulture tricks

- but ...
- Stiff planform without sensory capability
 - Limitations of human proprioception
 - Soaring/gliding for general air traffic?

➔ UAV-based services = an opportunity

➔ Autonomous flight = reverse-engineering of flight cognitive processes and strategies



Credit: P. Chatelain 2022

Formation flight

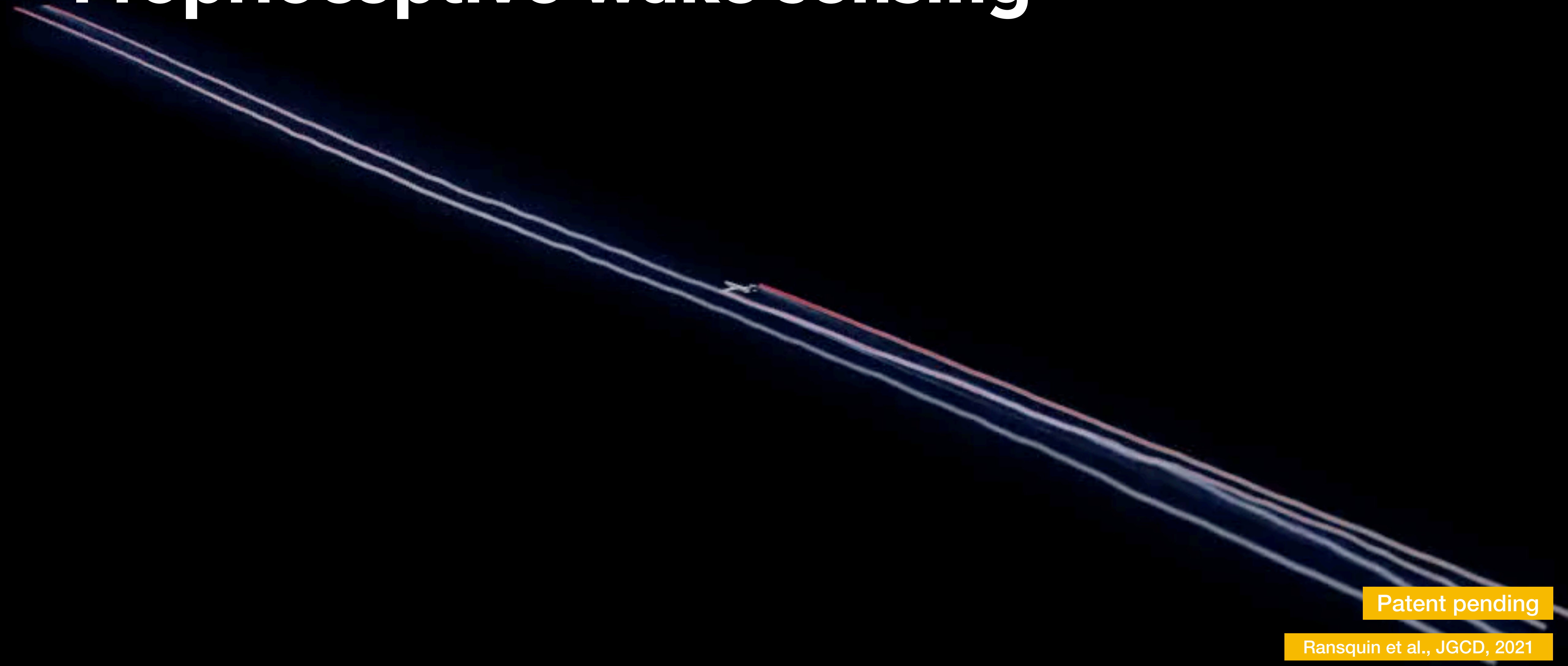
Another bio-inspired flow exploitation strategy



Wake energy retrieval through extended formations → Fuel savings ~10%

- Maintain optimal lateral position
- Sense and track the wake vortices

Proprioceptive wake sensing



Volume rendering of $\|\omega\|$

Patent pending

Ransquin et al., JGCD, 2021

Caprace et al., AIAA Forum, 2019

Hemati et al., JGCD, 2014

Proprioceptive wake sensing

10...100 b

Patent pending

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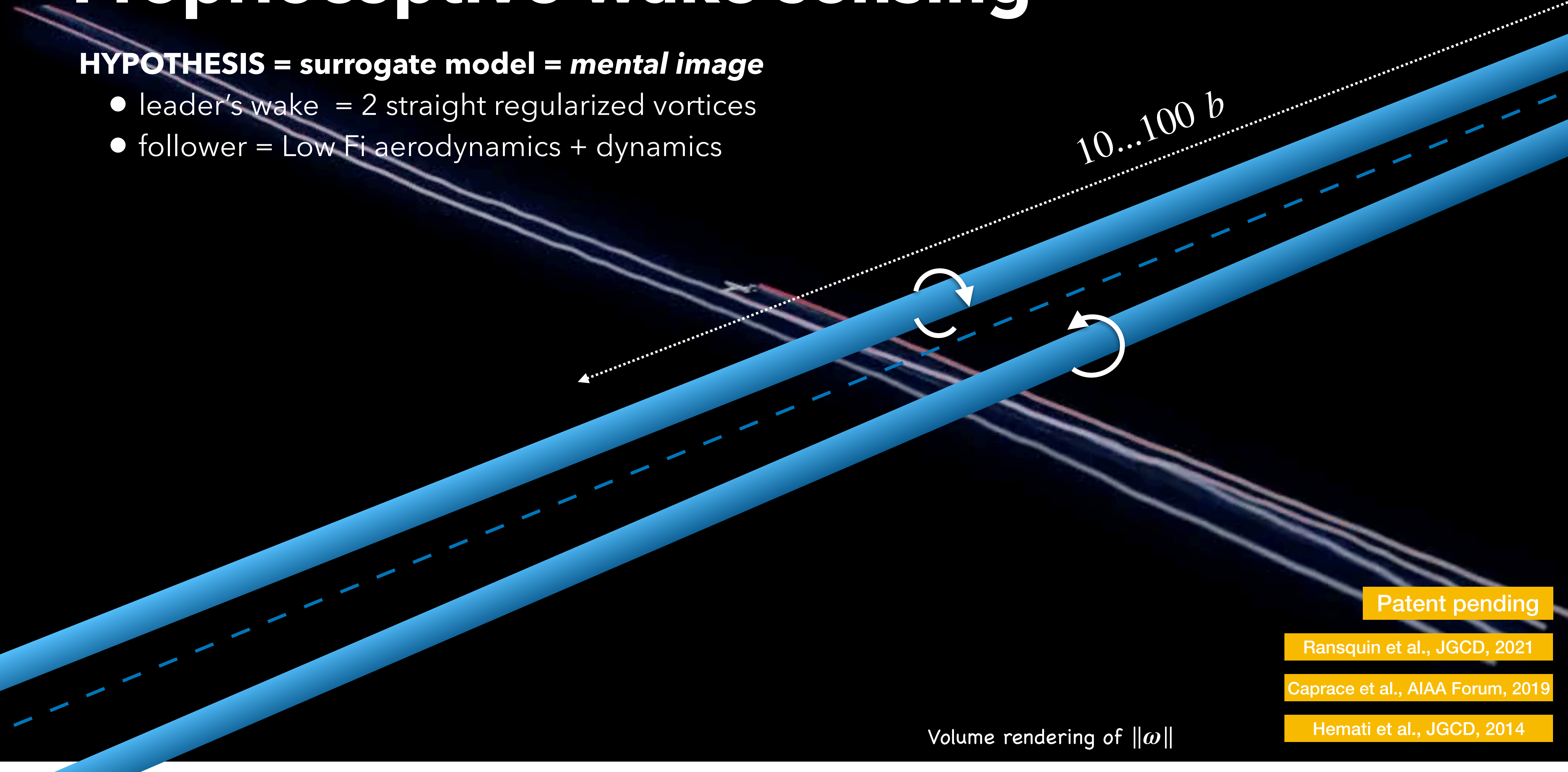
Hemati et al., JGCD, 2014

Volume rendering of $\|\omega\|$

Proprioceptive wake sensing

HYPOTHESIS = surrogate model = *mental image*

- leader's wake = 2 straight regularized vortices
- follower = Low Fi aerodynamics + dynamics



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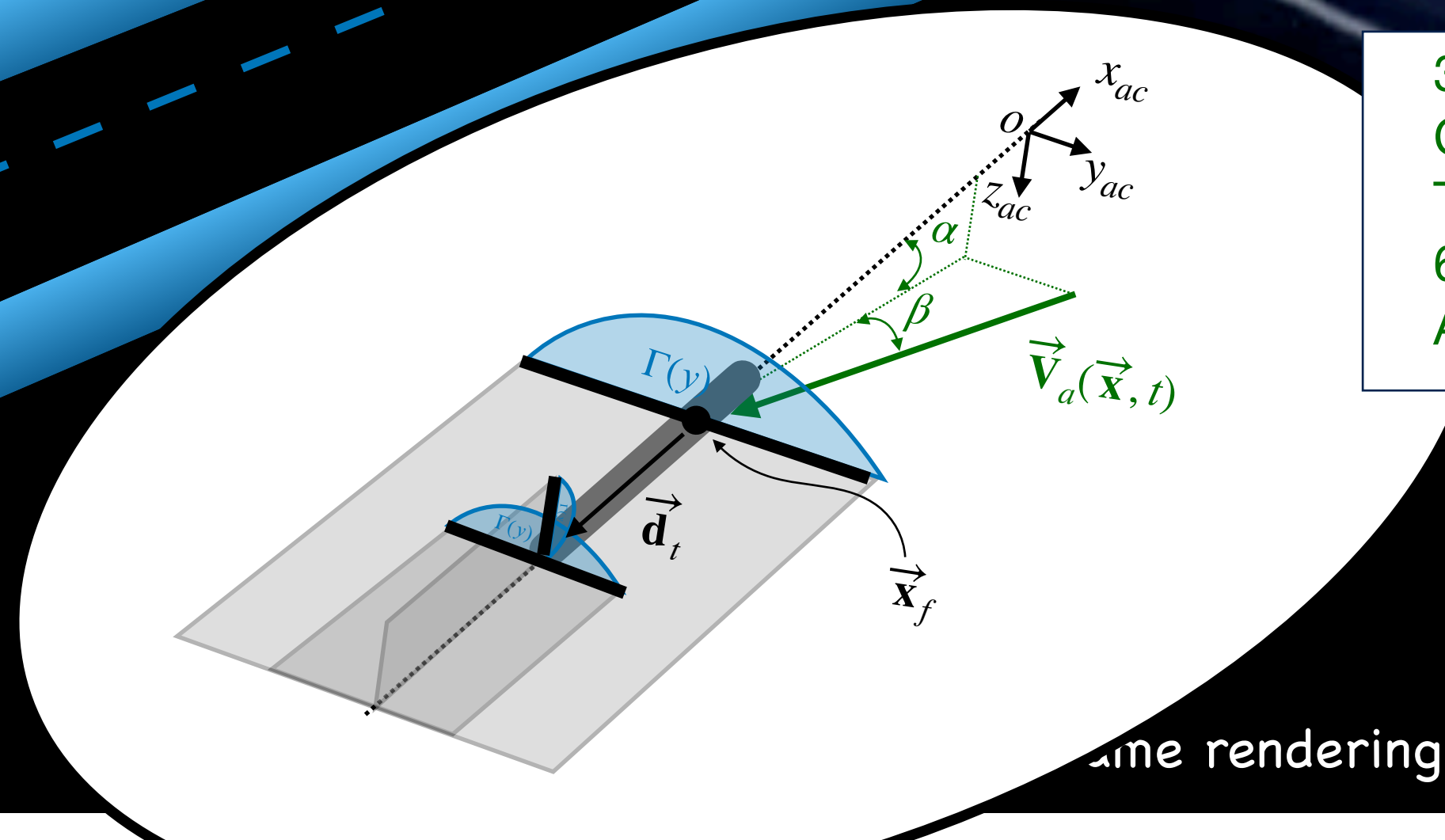
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3 Prandtl Lifting Lines
Control surfaces
Throttle
6 d.o.f. dynamics
Autopilot

Patent pending

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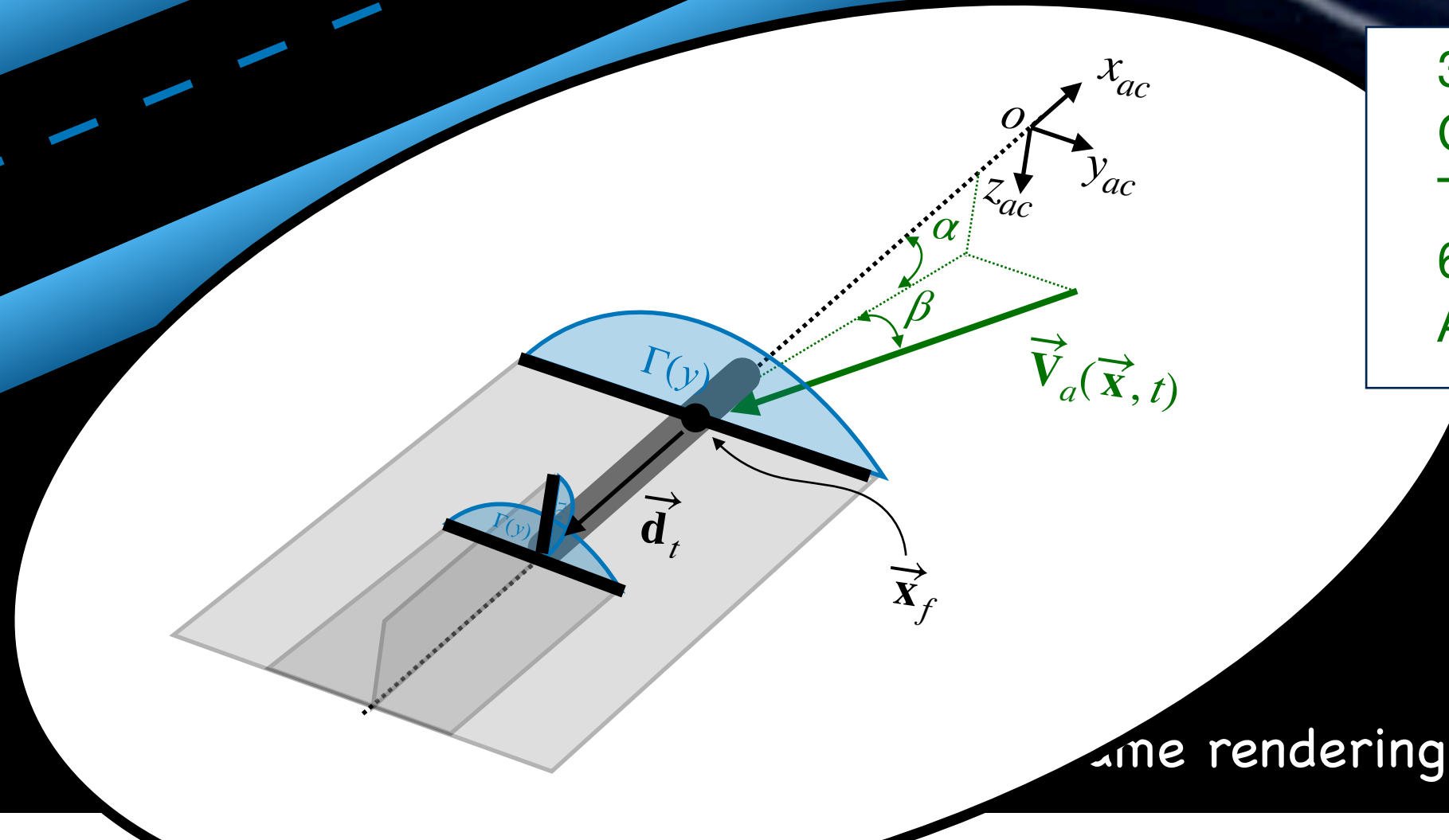
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SENSING = follower's measurements = *proprioception*

- own dynamics (as available from INS)
- angles of incidence and sideslip
- control surface deflections



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Same rendering of $\|w\|$

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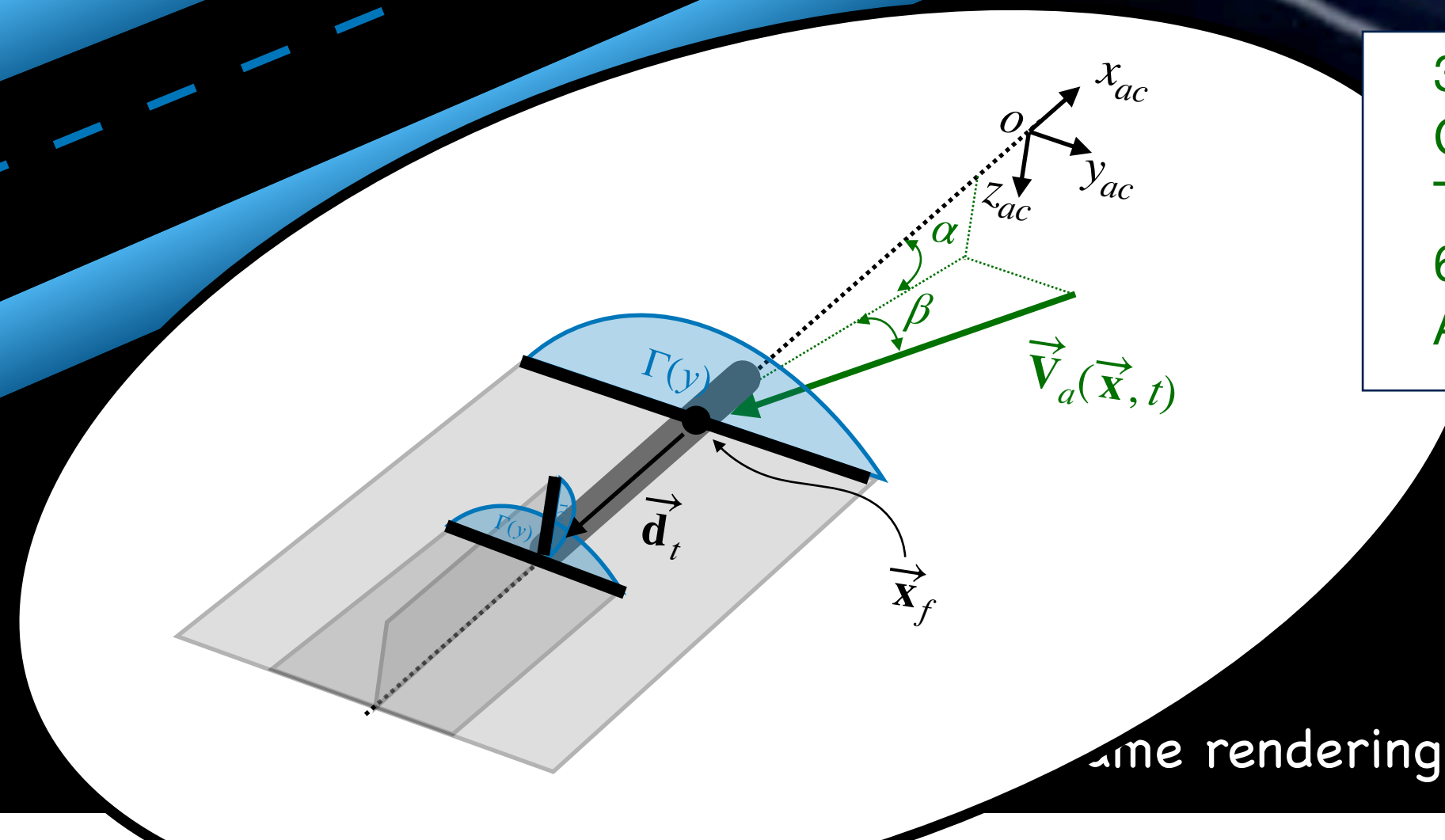
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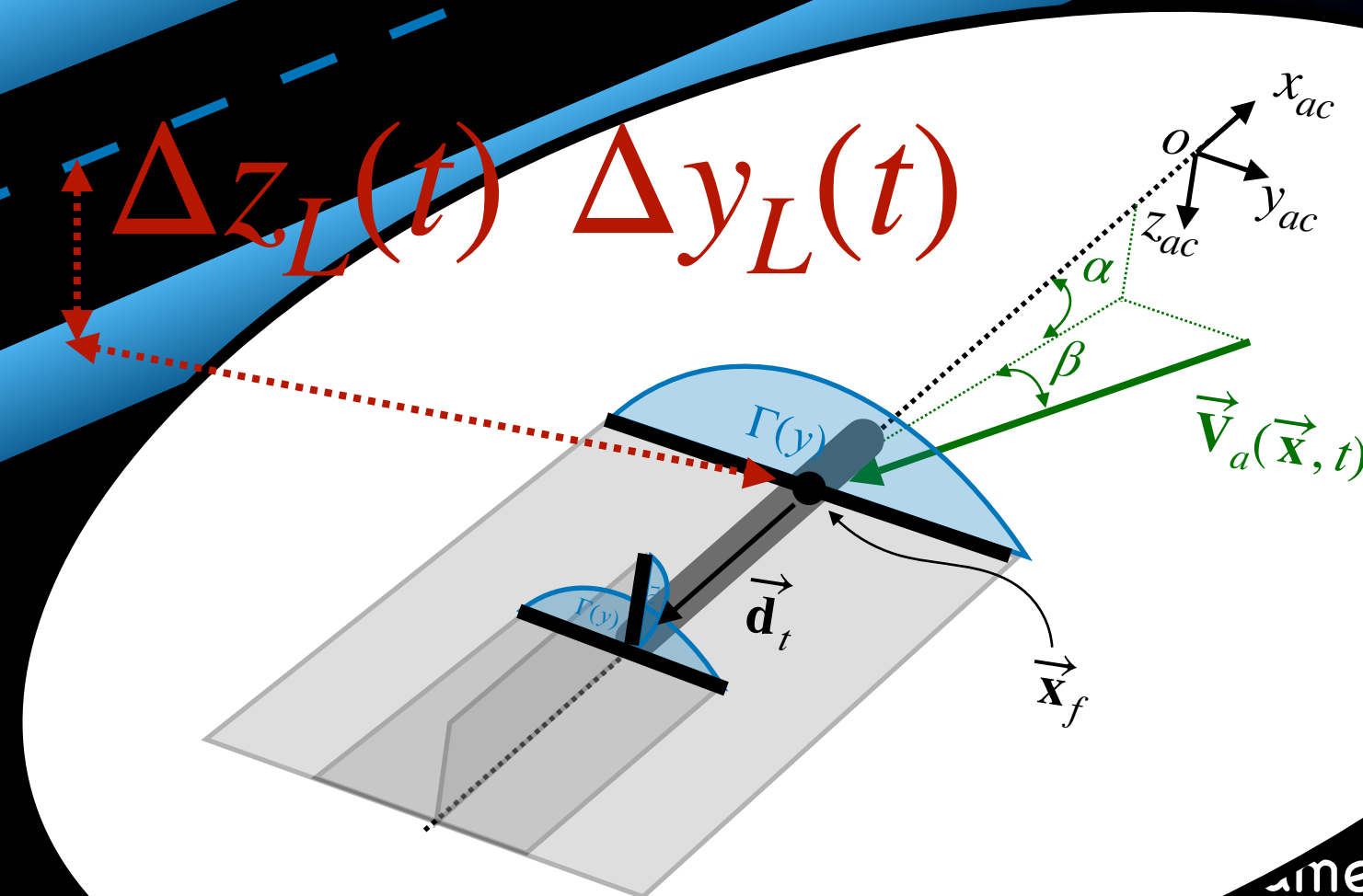
And estimation (data assimilation)

- relative position
- wake characteristics

$10 \dots 100 b$

b_0
 Γ_0

$\Delta z_L(t)$ $\Delta y_L(t)$



3 Prandtl Lifting Lines
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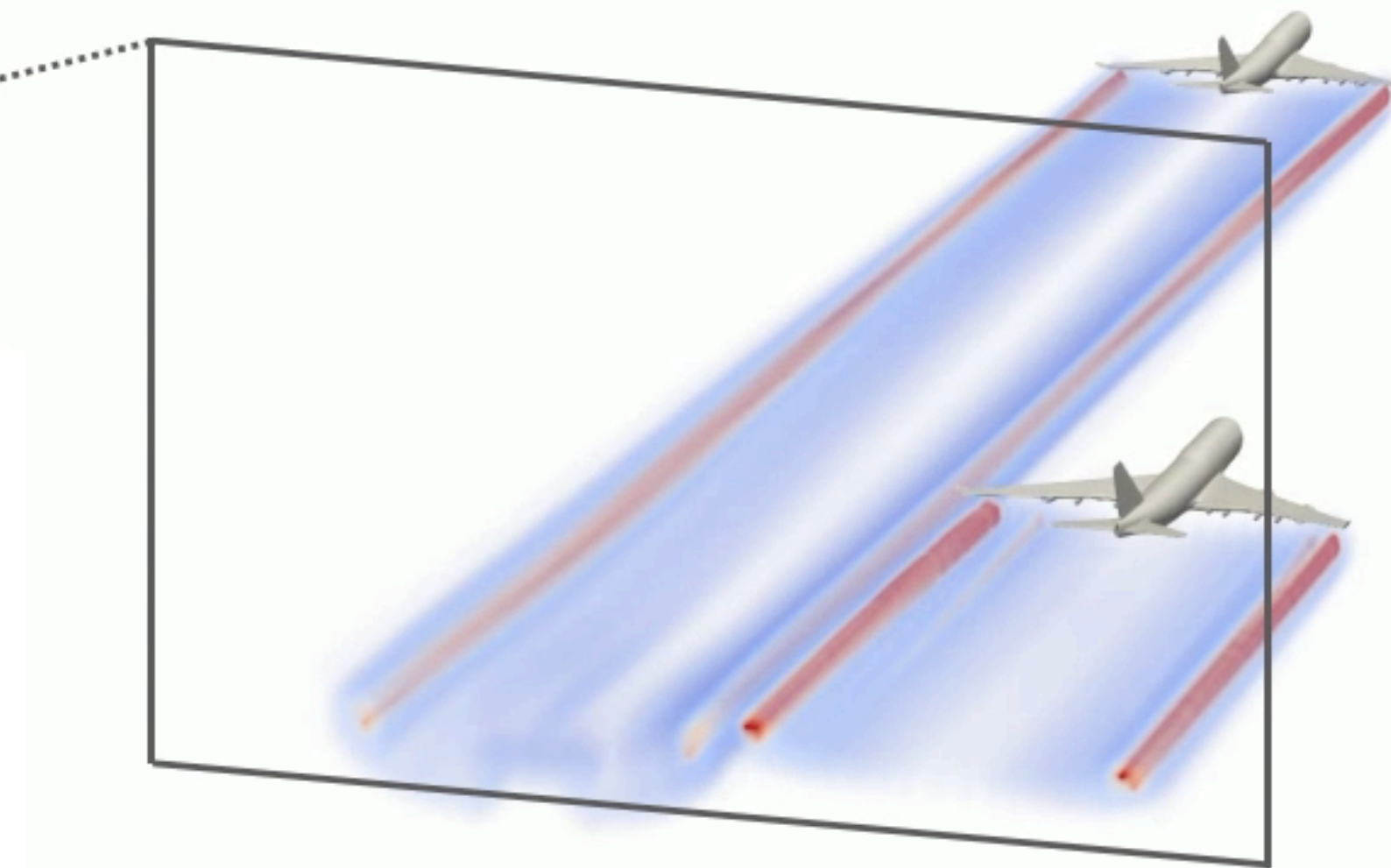
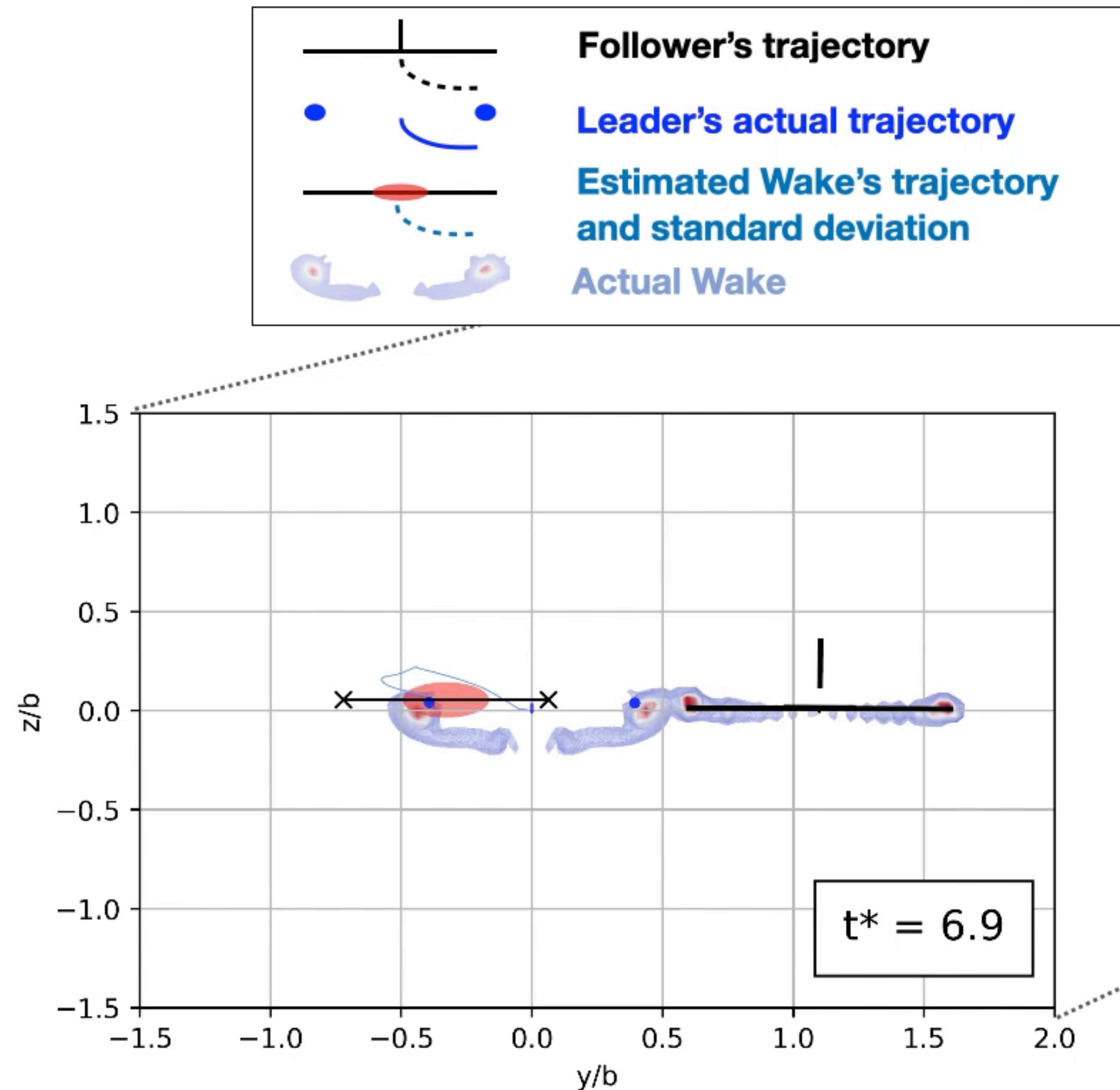
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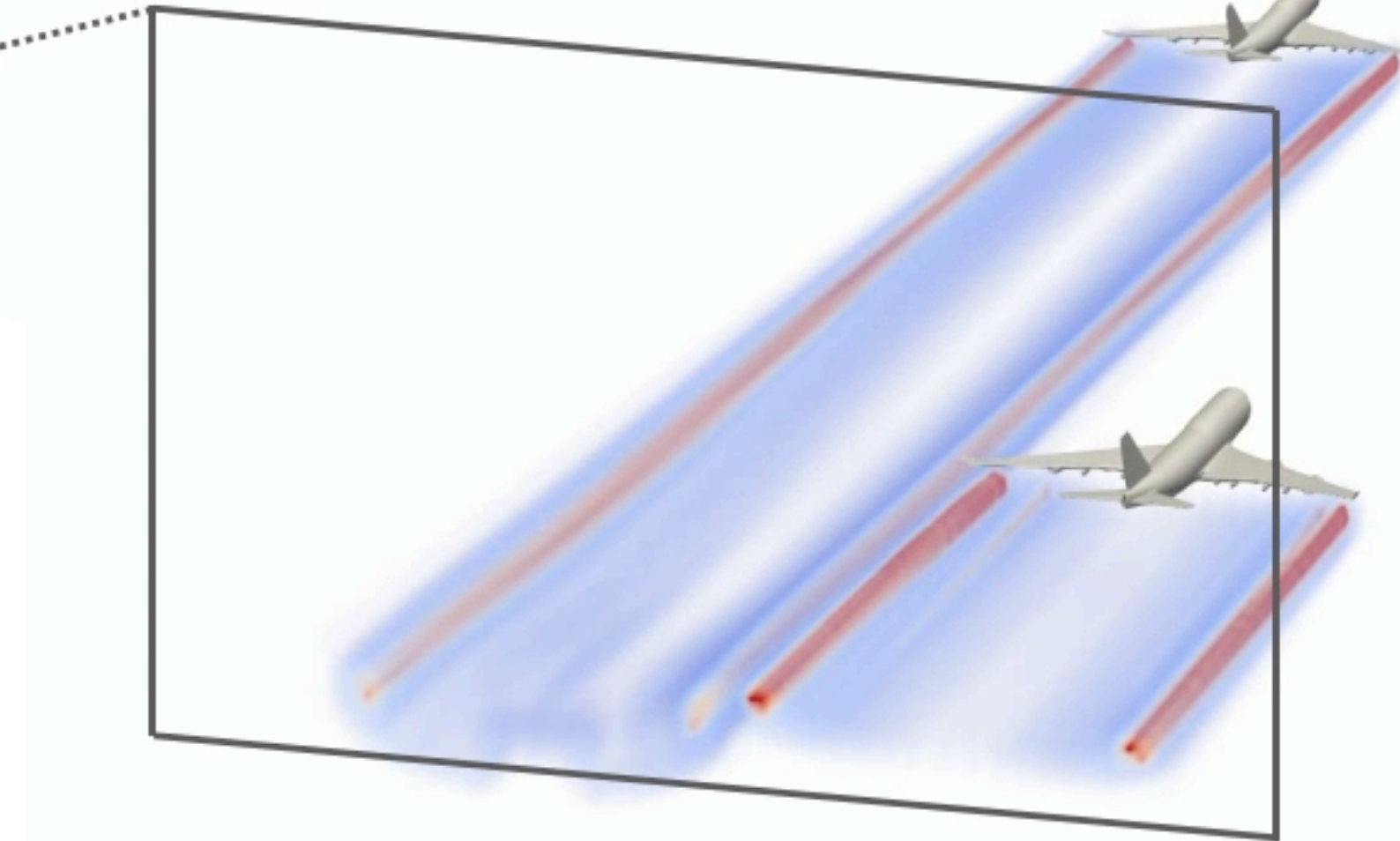
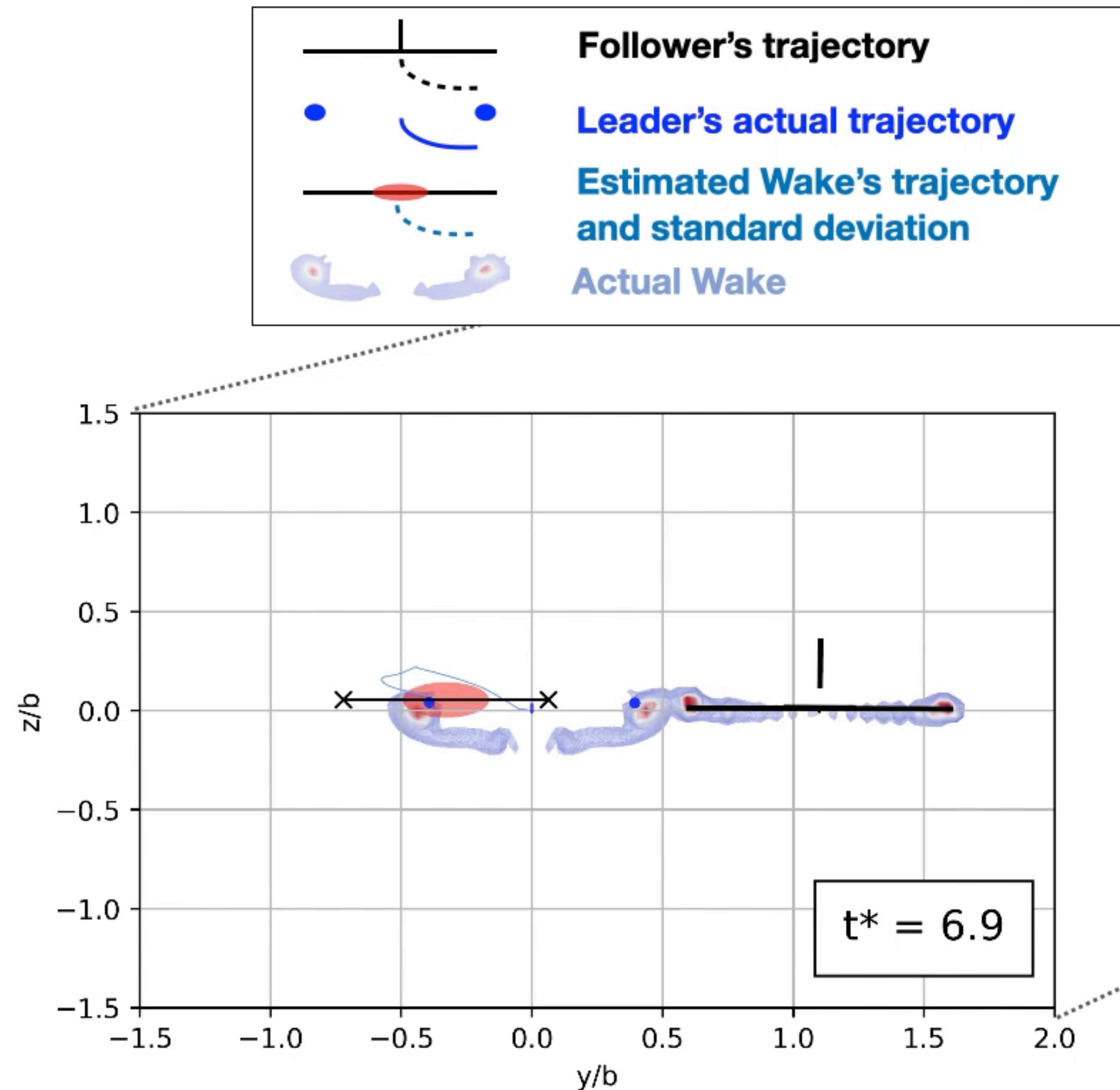
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...and exploitation



...and exploitation



➔ **Fuel savings: 15%**

Take-home messages

Identification and reproduction of **principles** rather than *naïve* mimicry

Bio-inspiration most fertile when biologists and engineers meet

➔ Still a lot to uncover!



Embodied intelligence



Airbus AlbatrossONE

Behavioral intelligence



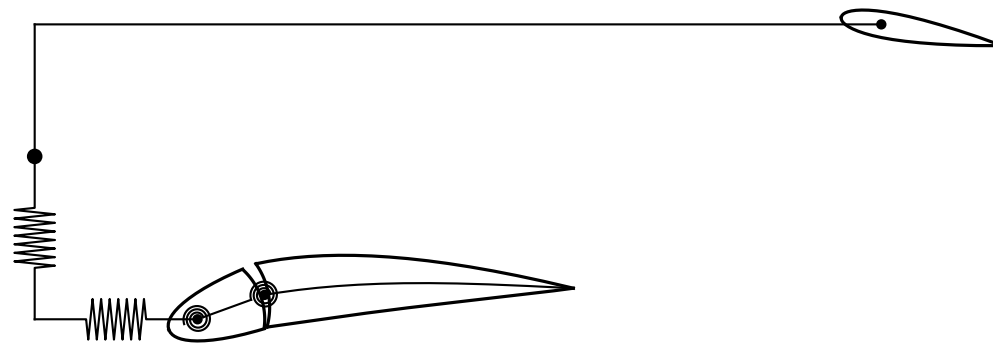
SESAR JU GEESE

Bio-inspired UAVs

Tackling flow control at two distinct spatio-temporal scales

Embodied intelligence

→ Compliant platform



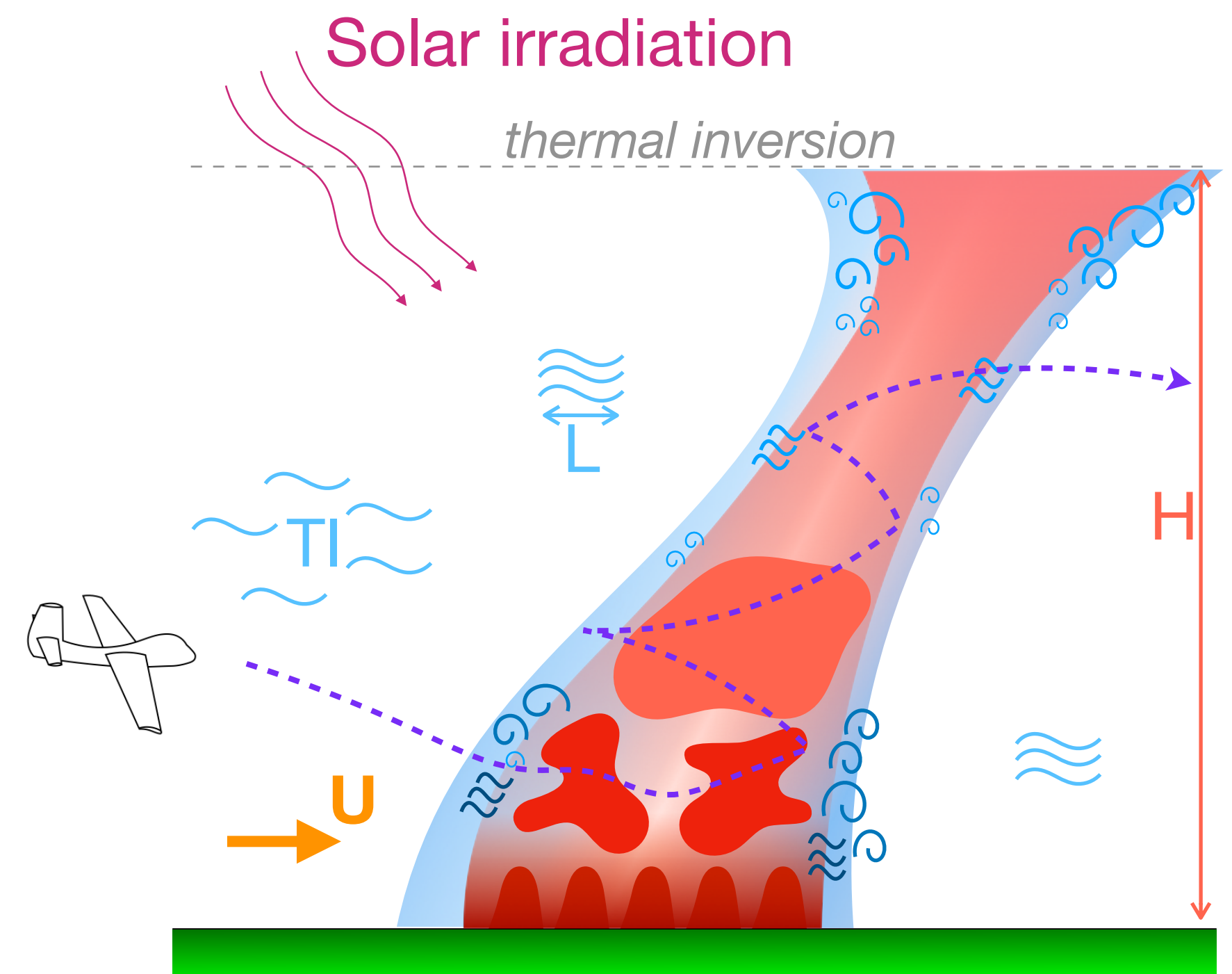
→ Wing-as-a-sensor

→ Fast-time efficient flow control
for disturbance rejection

Strategy

→ Atmosphere-exploiting navigation

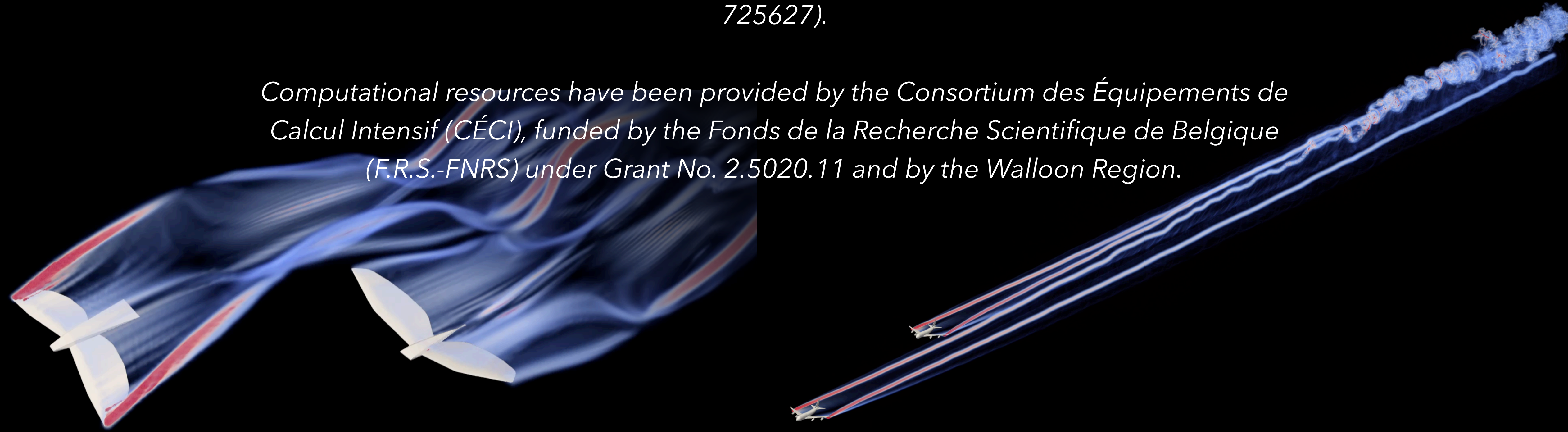
→ Formation flight



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- Ignace Ransquin, Matthieu Duponcheel and Philippe Chatelain. Dynamics of the Wake Vortices of a Two-aircraft Formation, Hazard Assessment at Large Distances and Sensitivity Analysis. AIAA Paper, SCITECH 2022 Forum, p. AIAA 2022-1198
- European Patent Application 20188776.7
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