

Active control of jet flows using advanced flow diagnostics

Supervisors:

Prof. Stefano Discetti

Prof. Marco Raiola

Candidate:

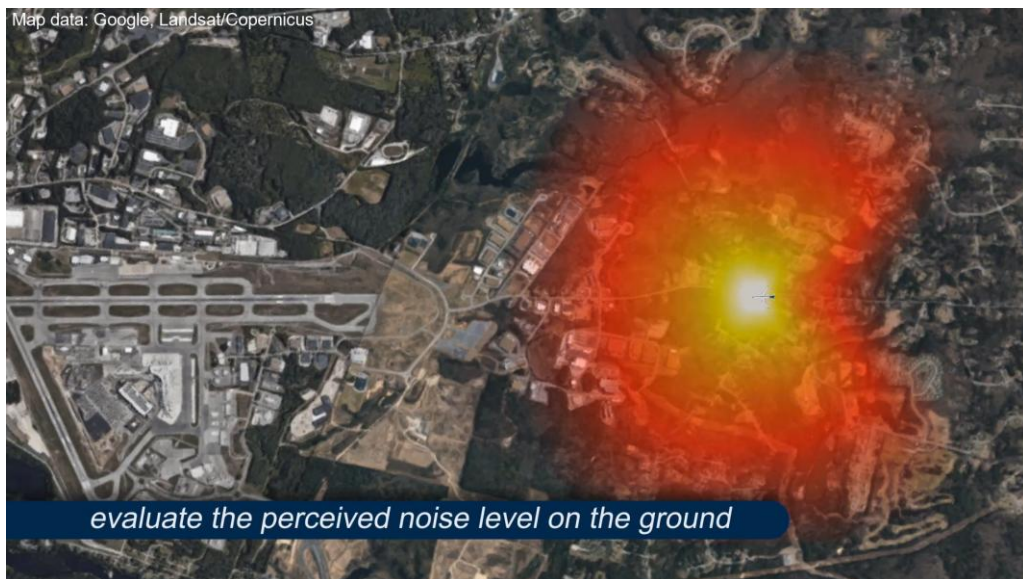
Luca Franceschelli

Doctoral Meetings
02/06/2026

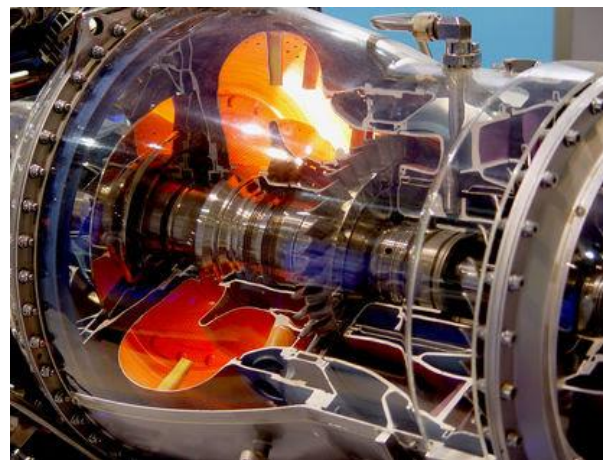


Jet Flows

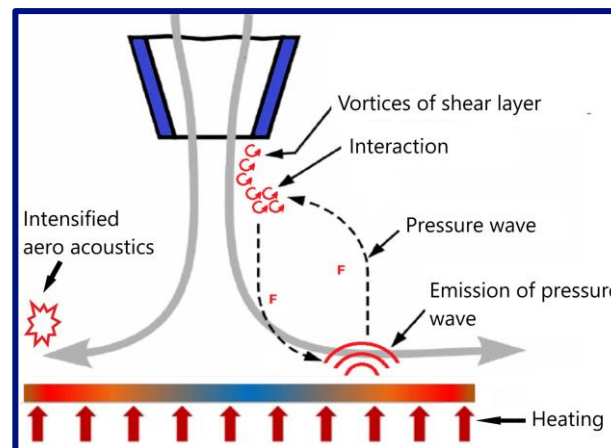
- Jet flows are everywhere in nature and industrial applications
- The problem is that turbulence makes them **noisy**, **inefficient**, and **difficult to control**
- Can we actively shape them for:



Noise reduction and
propulsive efficiency



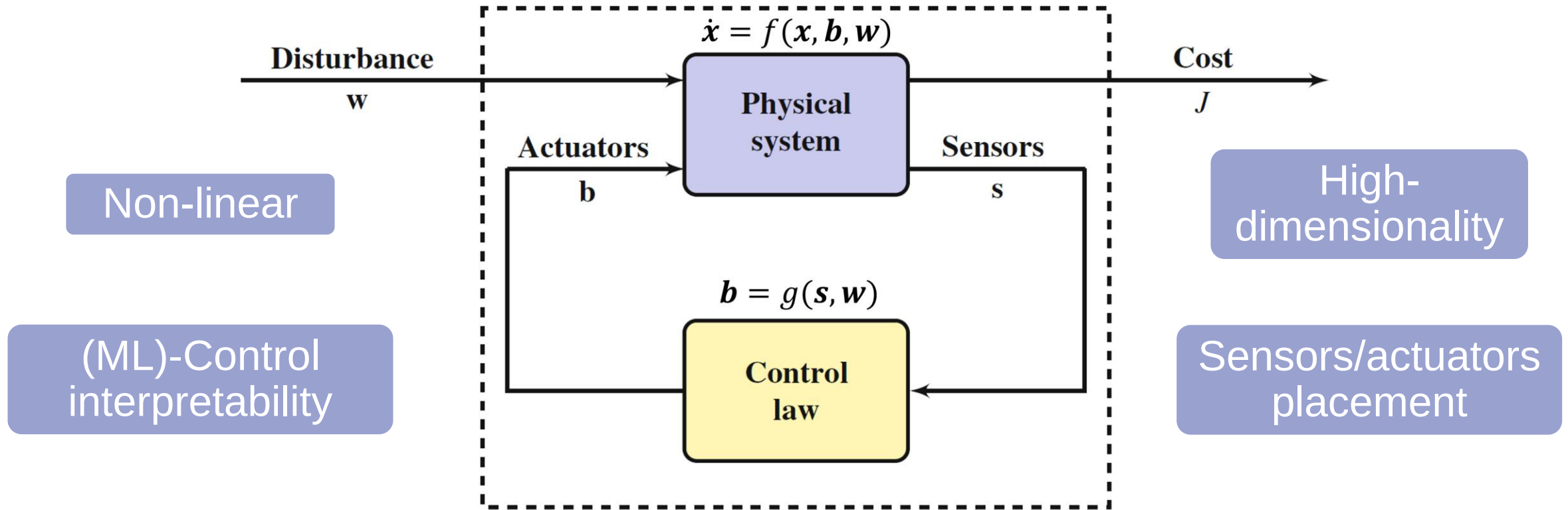
Optimize mixing in
combustion chambers



Cooling and
industrial processes

and more ...

My PhD: build a system to sense and control turbulent jets



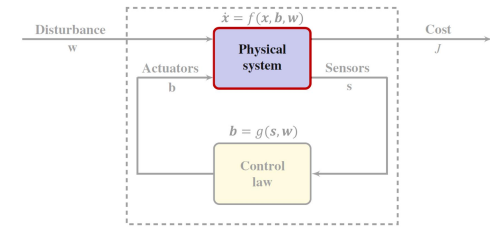
- Design and implement an experimental framework for active jet-flow control
- Extract interpretable control solutions
- Develop of imaging technique for in-the-loop implementations



“Machine learning control-taming nonlinear dynamics and turbulence”, Duriez T et al. (2017)

Physical System: jet-flow facility and anechoic chamber

Reproduce free-field environment in the lab



Acoustic

No reverberation ✓

*Results presented at AIAA
Aeroacoustics Conference,
Rome 4th-7th June 2024*

Implementation of a Jet Collector and Dissipation Cavity into a
Closed Anechoic Chamber for jet noise studies

Ricardo Moreno* and Luca Franceschelli†
Universidad Carlos III de Madrid, Leganés, Madrid, 28911, Spain

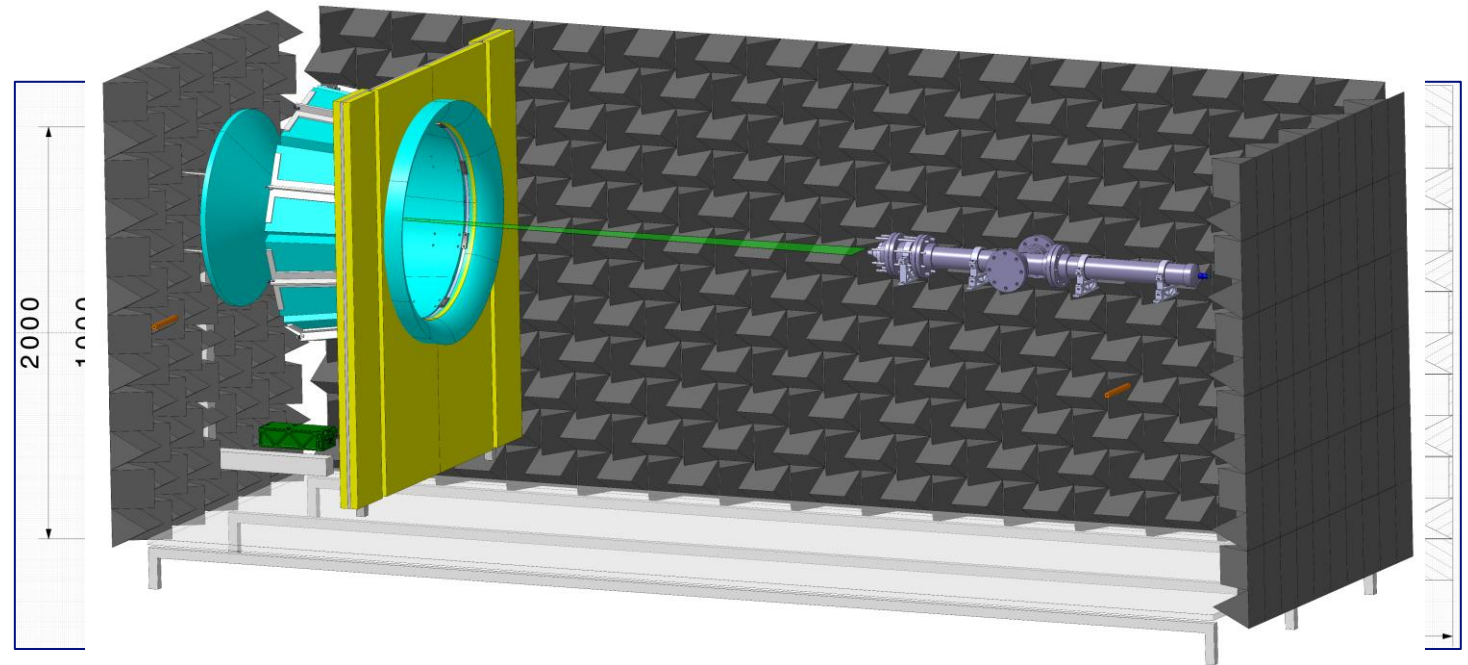
Daniel de la Prida‡
Technical University of Madrid, Madrid, Madrid, 28031, Spain

Luis A. Azpicueta-Ruiz§ and Marco Raiola¶
Universidad Carlos III de Madrid, Leganés, Madrid, 28911, Spain

Fluidic

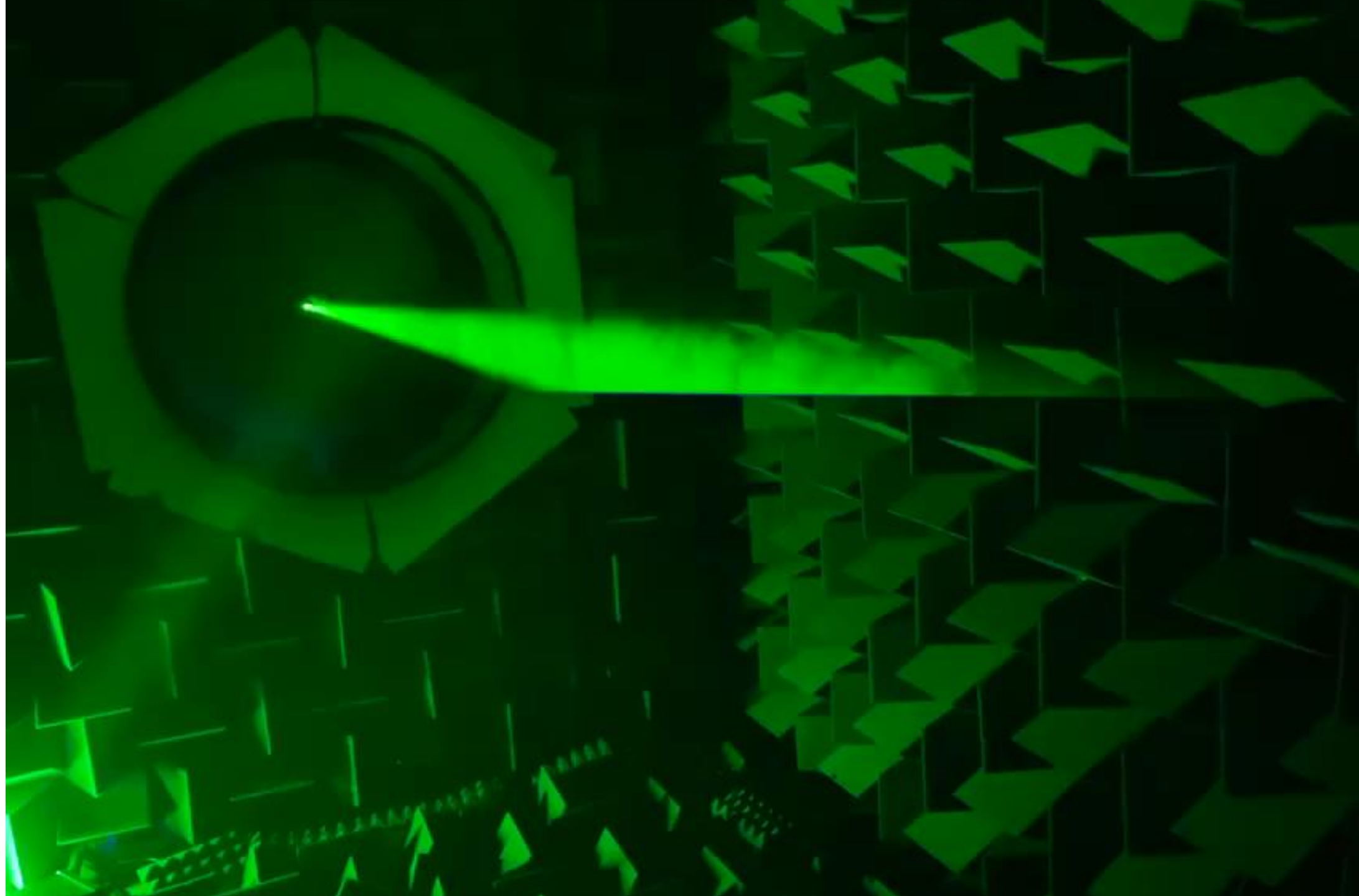
No Flow recirculation ✓

- Flow dissipation via secondary room

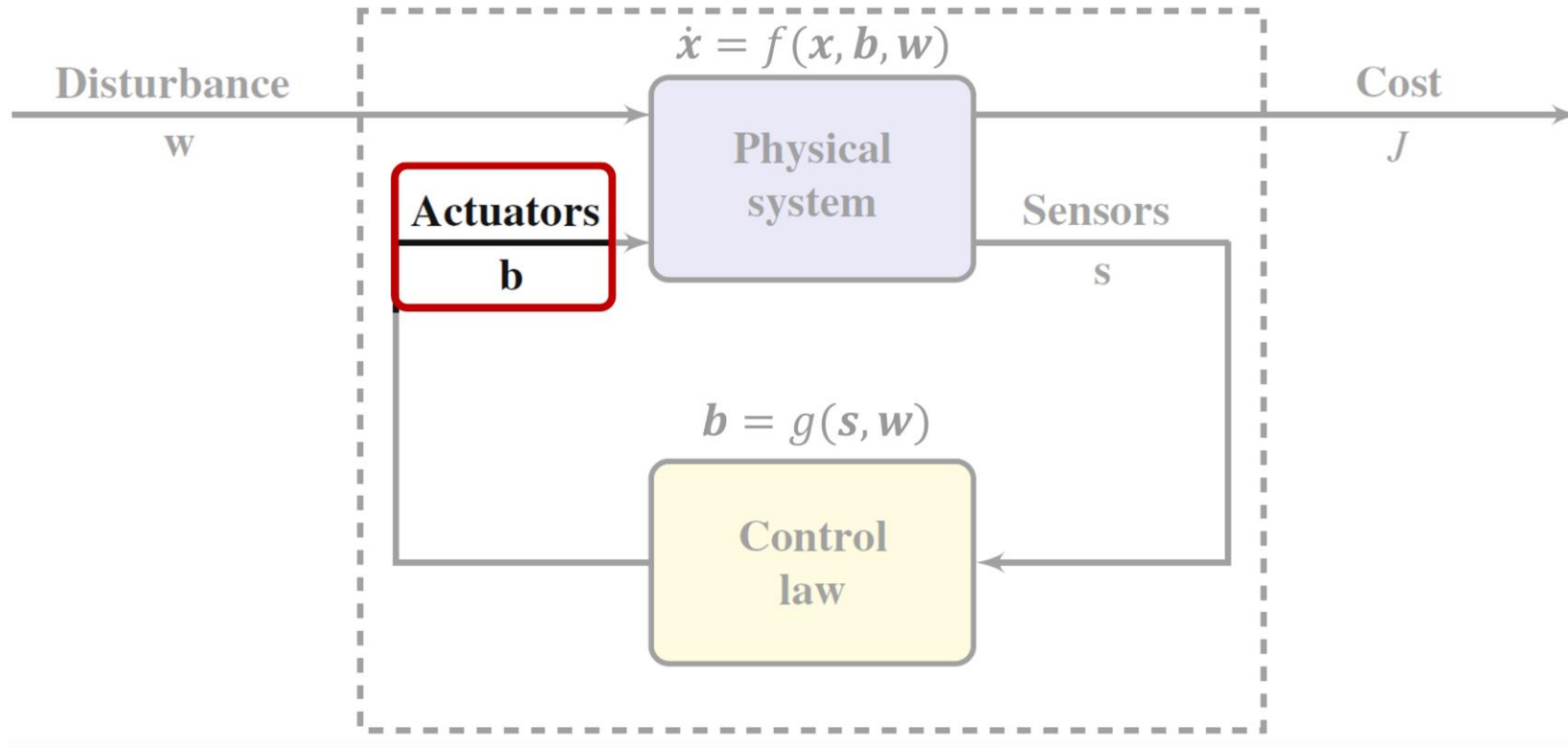


Merino-Martinez, R. et al., “Aeroacoustic design and characterization of the 3D-printed, open-jet, anechoic wind tunnel of Delft University of Technology”, 2020

Ahuja, K. K., “Designing Clean Jet-Noise Facilities and Making Accurate Jet-Noise Measurements”, 2003

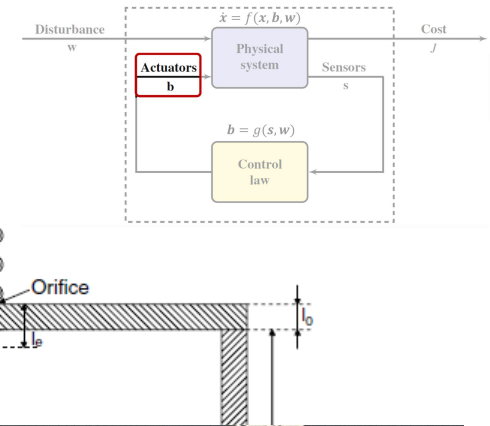
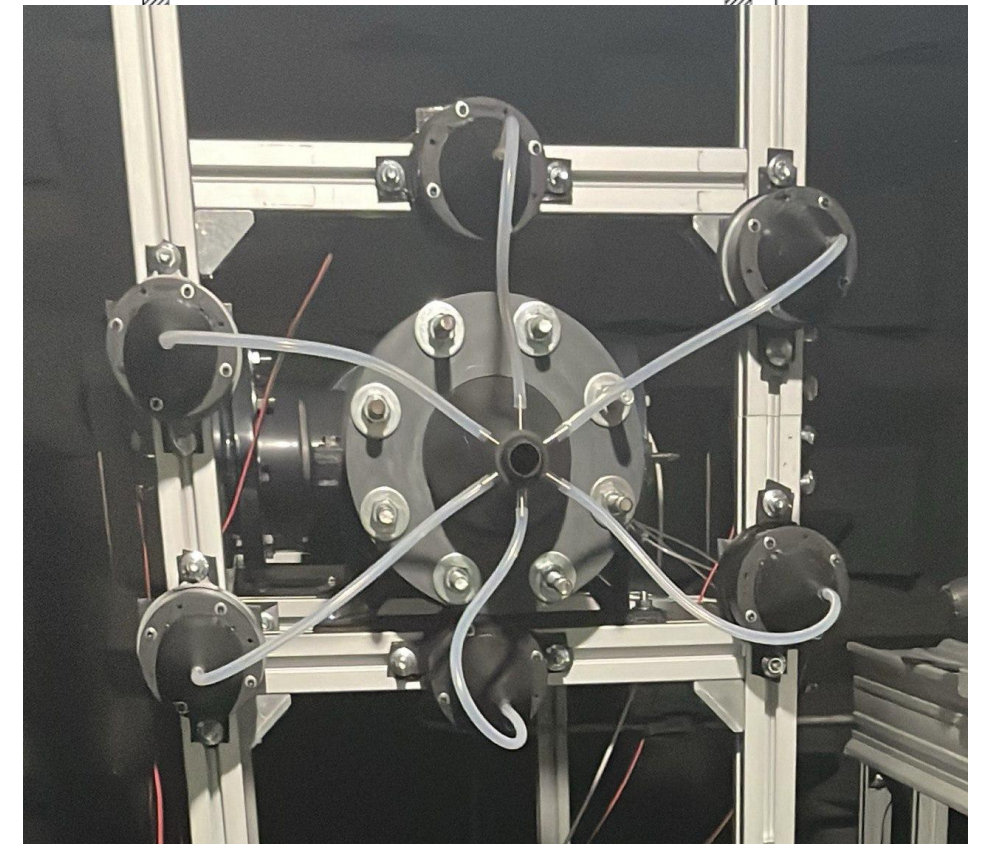
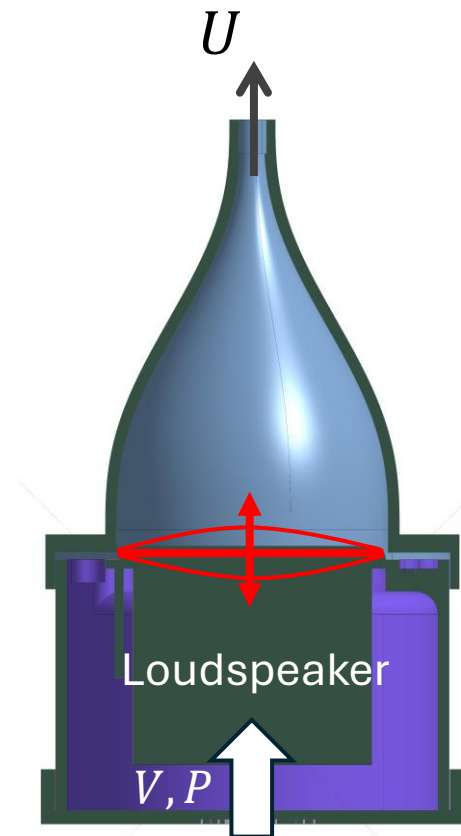
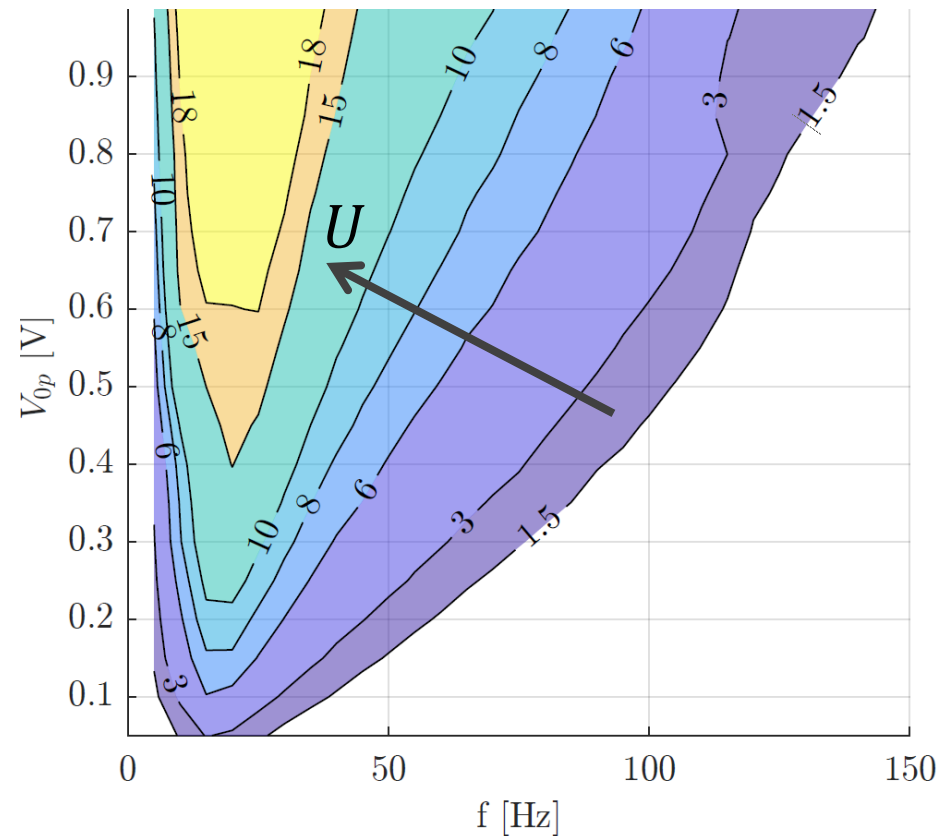


Actuation Design

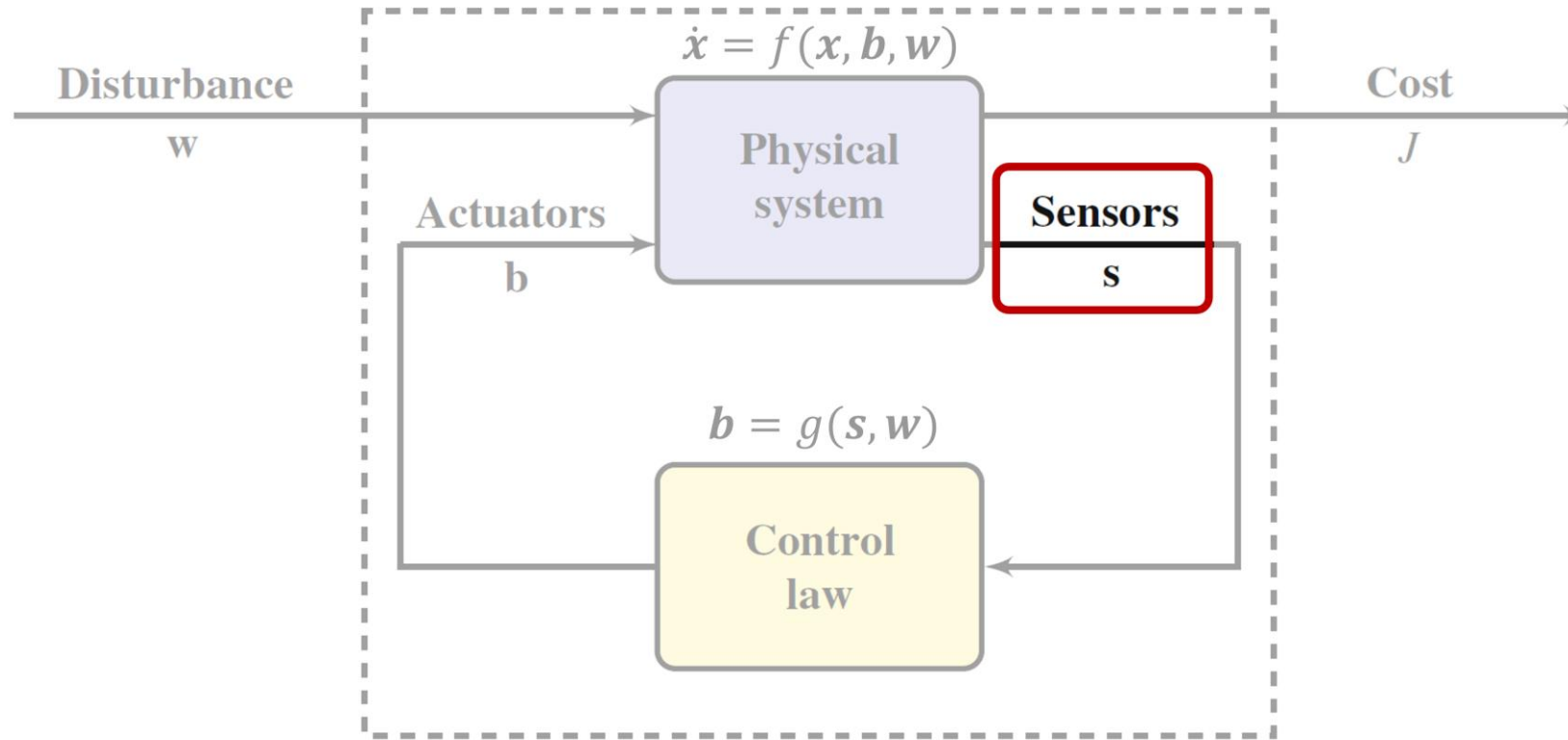


Synthetic jet actuators

- Zero net mass flow actuation
- No external air supply required
- Compact, cost-effective and easily integrated

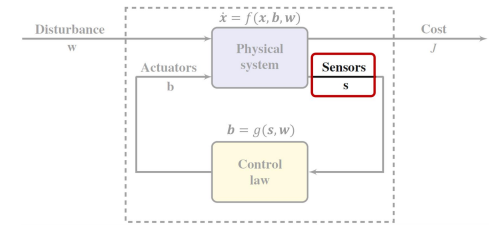
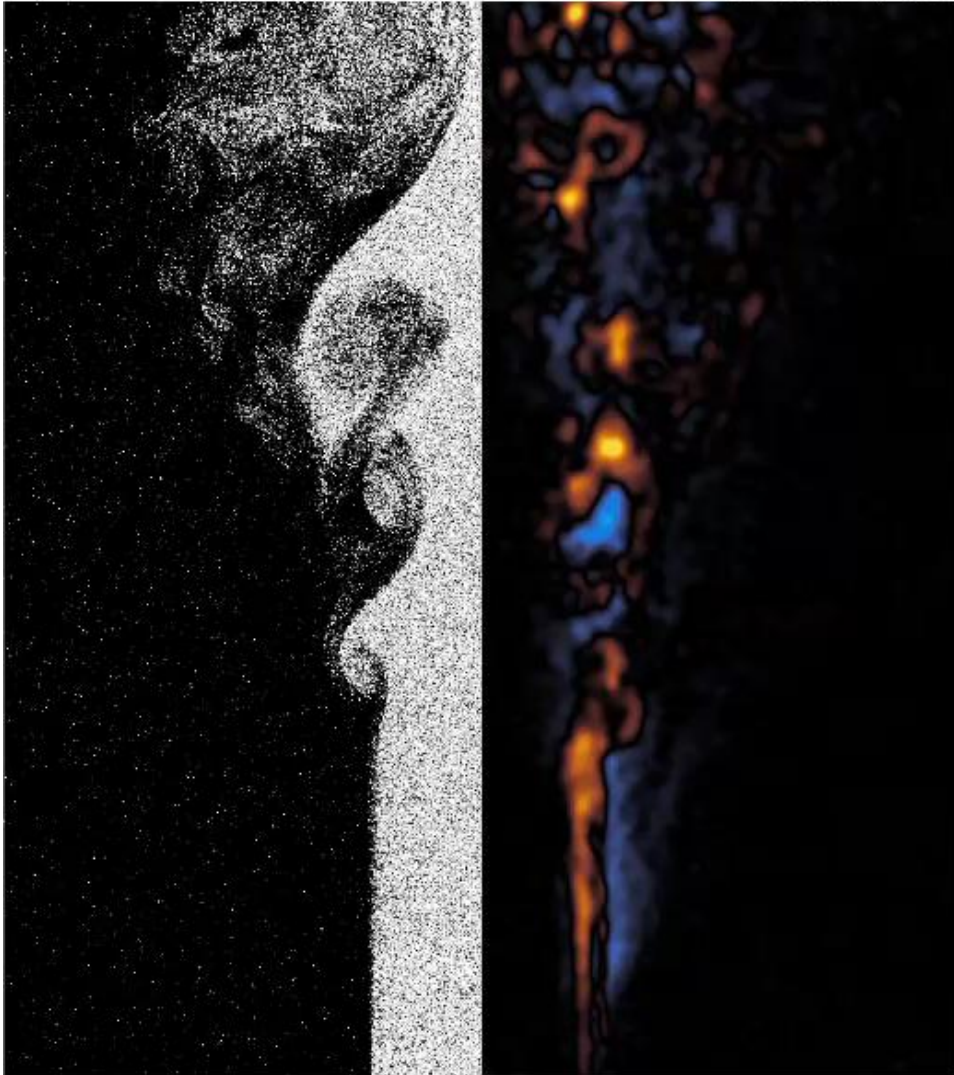


Close the loop: how to “sense” the flow



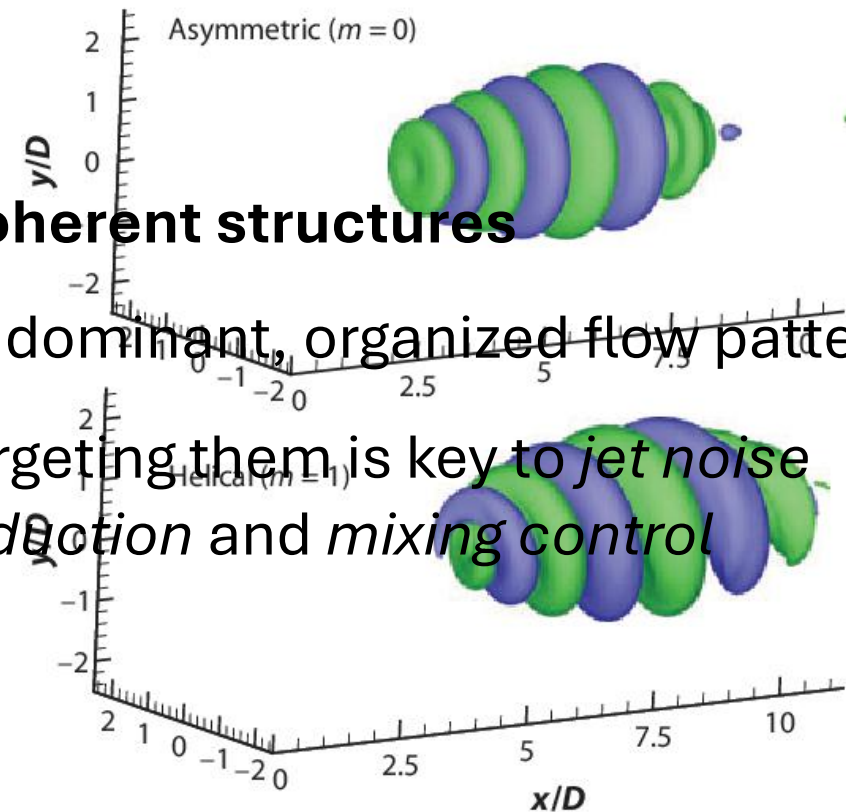
What do we want to control?

$$f_{act} = 0 - St = 0.000$$



Most energetic structures in a jet

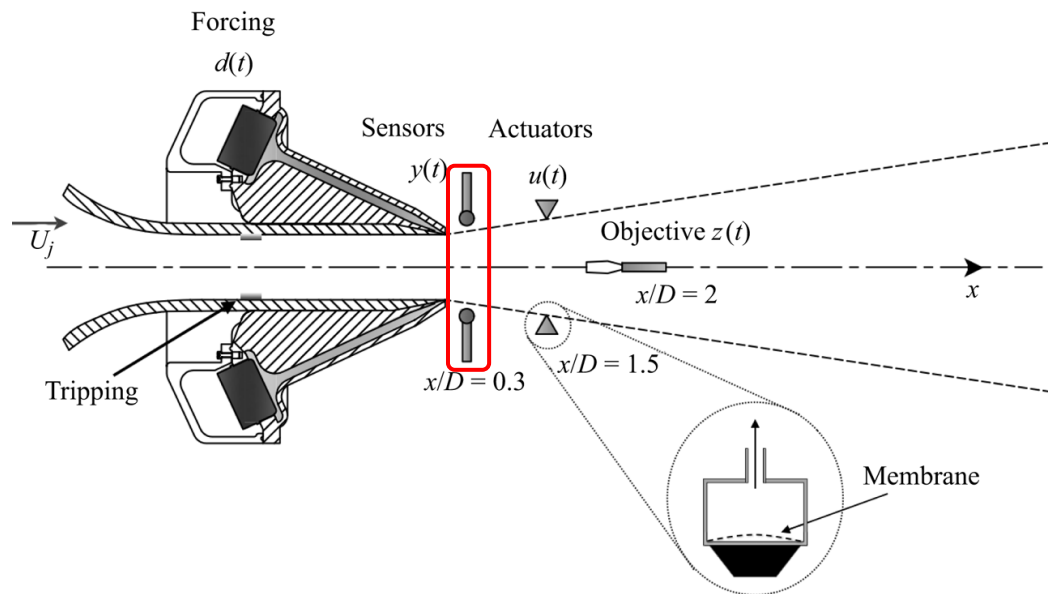
- **Coherent structures**
 - dominant, organized flow patterns
- Targeting them is key to *jet noise reduction* and *mixing control*



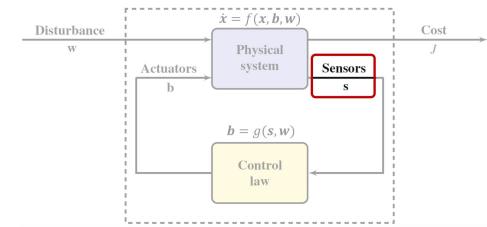
Jordan P, Colonius T, "Wave Packets and Turbulent Jet Noise", 2013

What do we want to control?

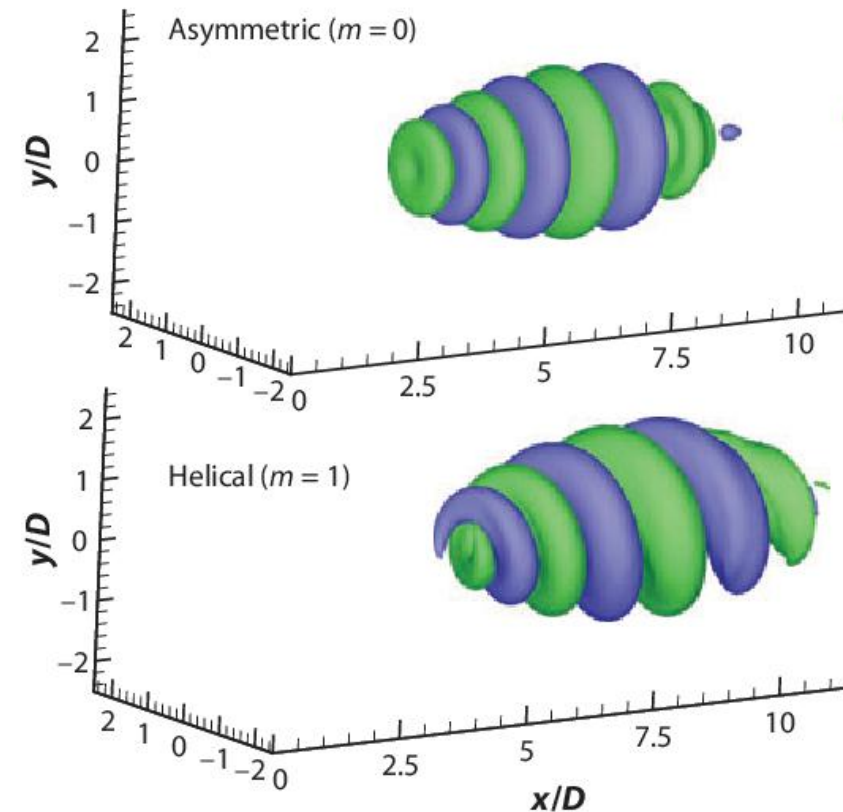
 Audiffred et al., “Reactive experimental control of turbulent jets”, 2024



Can we infer the most relevant flow structures from few a distributed probes?



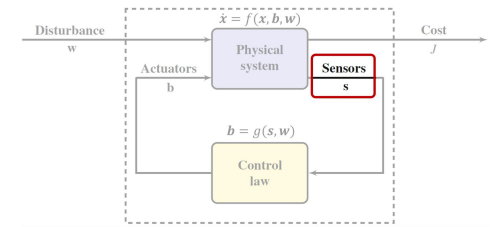
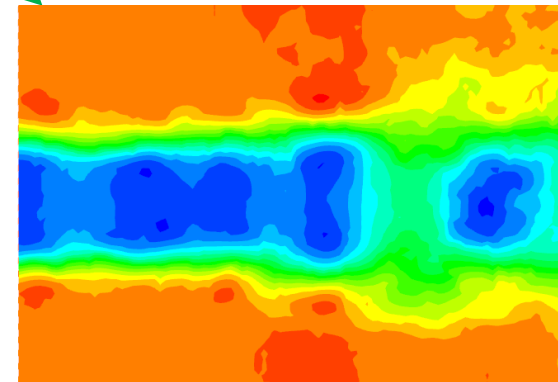
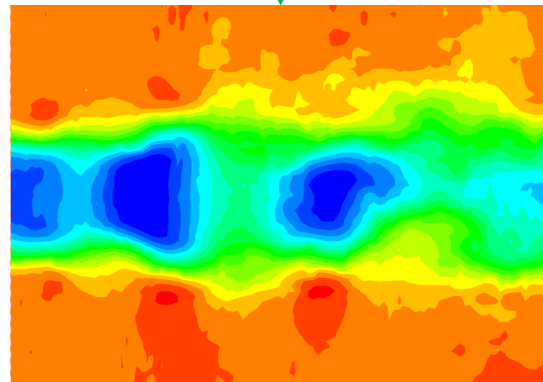
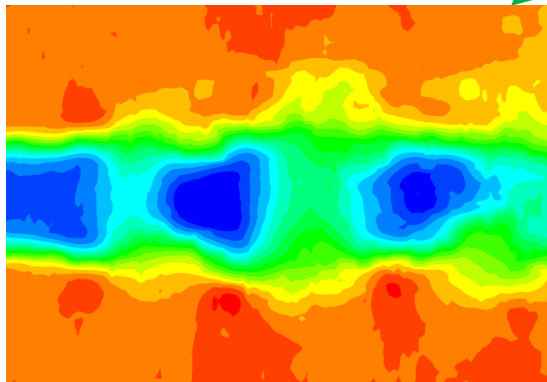
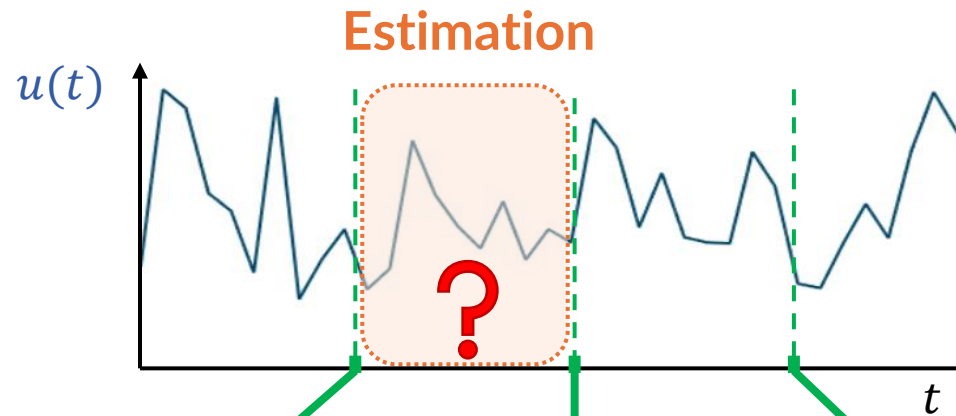
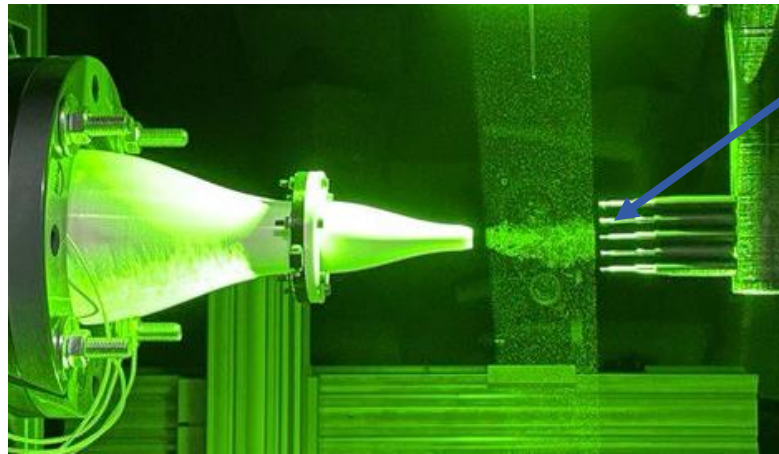
Most energetic structures in a jet



 Jordan P, Colonius T, “Wave Packets and Turbulent Jet Noise”, 2013

Flow Field Estimation from probes

- ✓ Fast response probes → ~~Point-wise measurement~~, high temporal resolution
- ✓ Snapshot PIV → Instantaneous Flow-field, ~~no temporal resolution~~



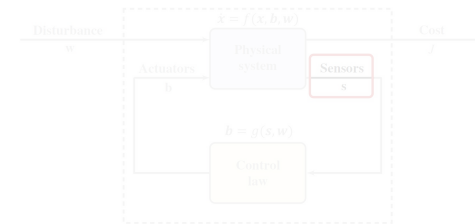
Enhance
time resolution



Flow sensing via EPOD – 8 Virtual Microphones

Case – Water jet flow

Reality...



Correlation matrix probes-PIV



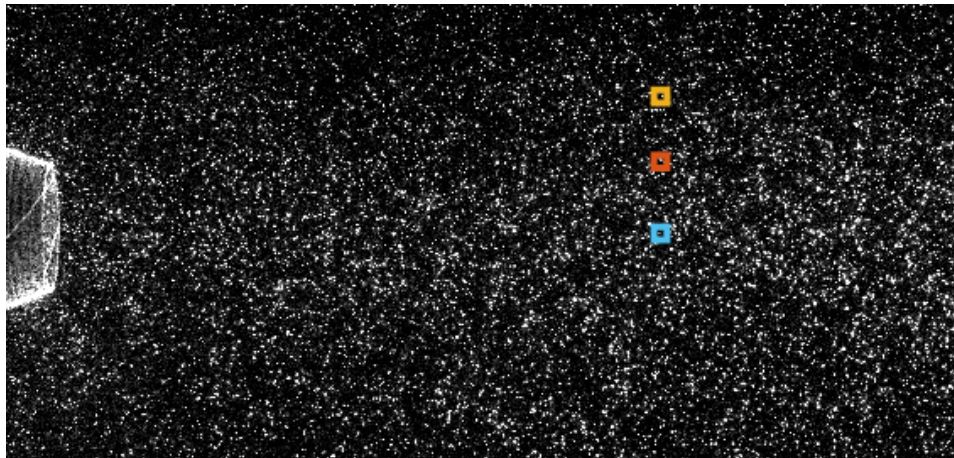
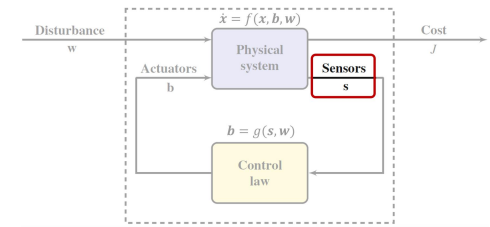
Why not use imaging velocimetry for sensing?

Failed flow-field reconstruction



Can we use PIV as a sensor?

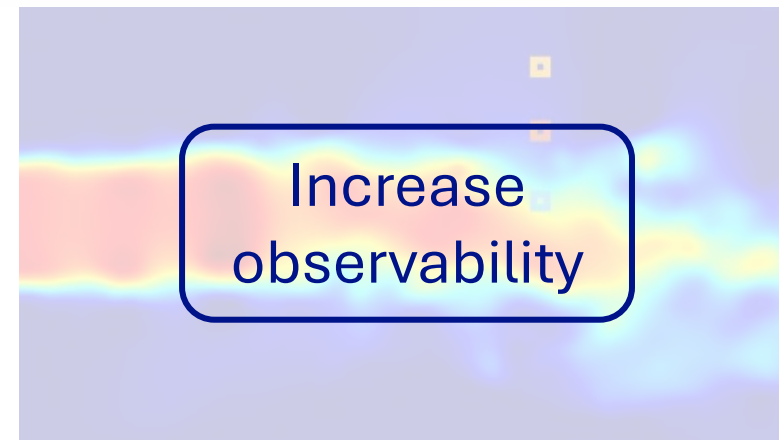
- Point-wise sensors usually implemented: microphones, hot-wires, ...
- PIV sees the flow well — but **not** fast enough for control
- Bottleneck: image acquisition process, data rate, cost



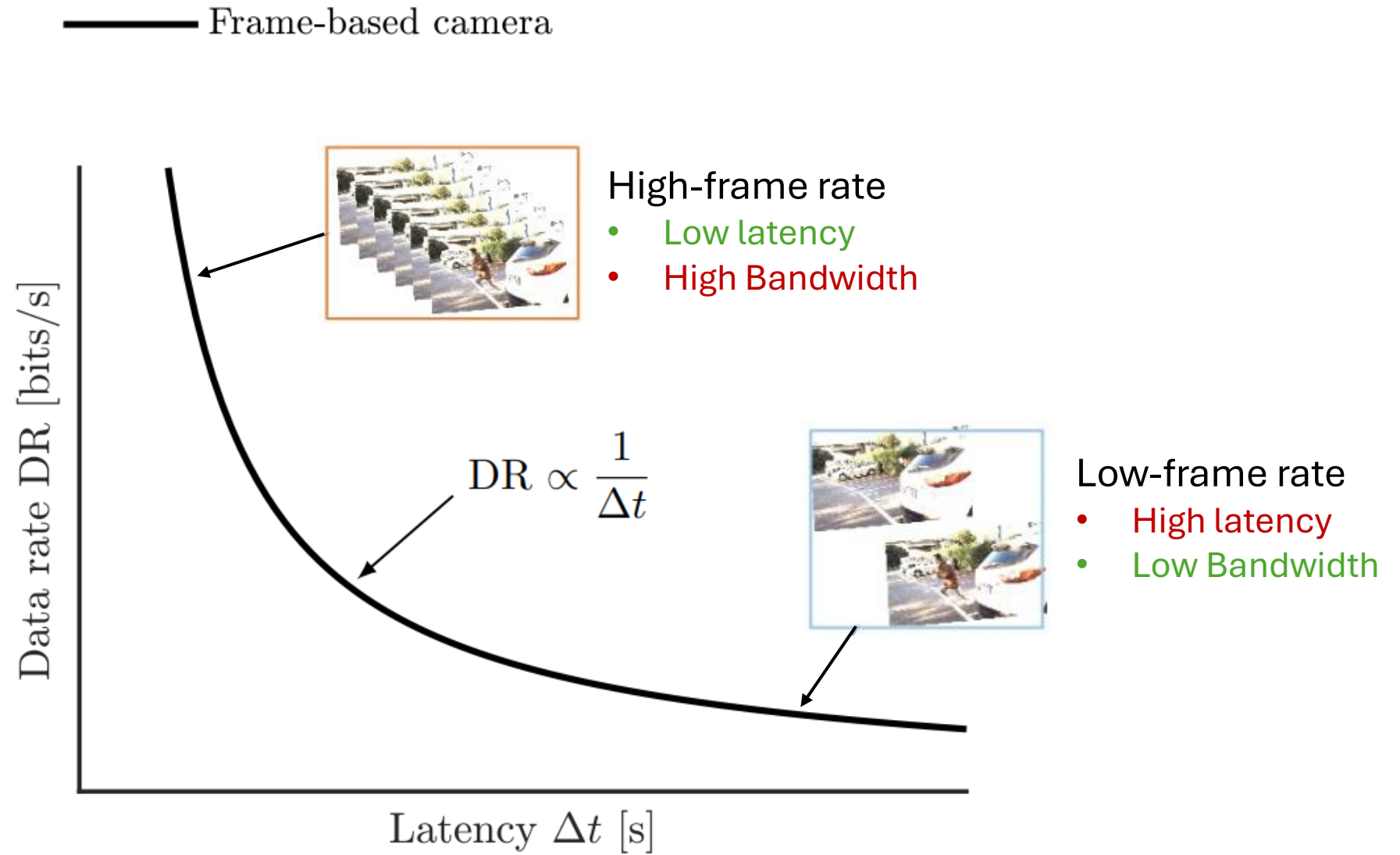
v



t

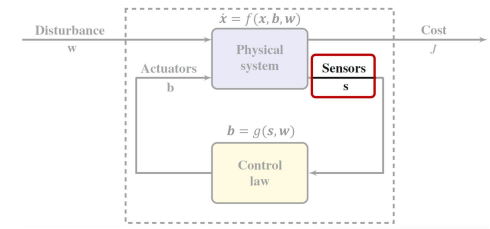
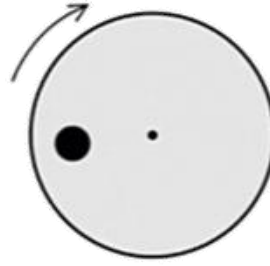


The Latency-Bandwidth trade-off

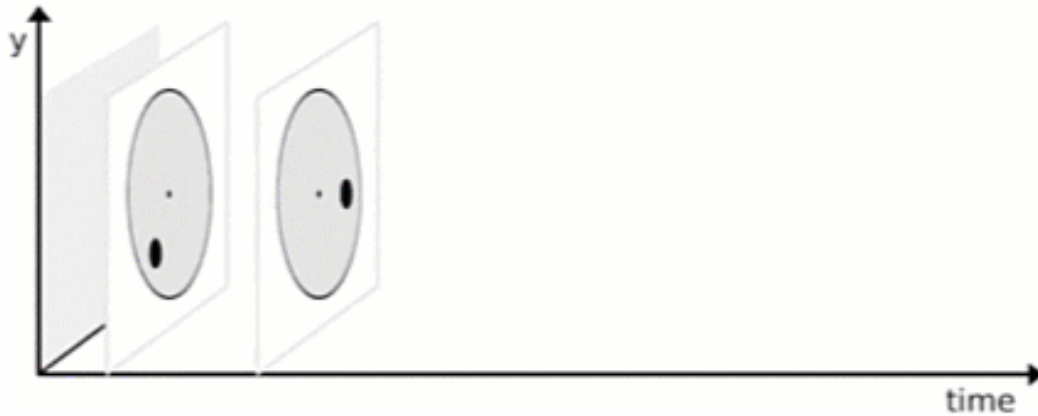


Gehrig & Scaramuzza (2024) Nature

Event-based vision (EBV)



Frame-based



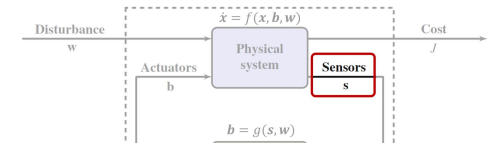
- Generates sequential frames
- Clock-driven $\rightarrow$ pre-defined frame-rate
- User-defined exposure time
- Synchronous read-out of the sensor

Neuromorphic camera

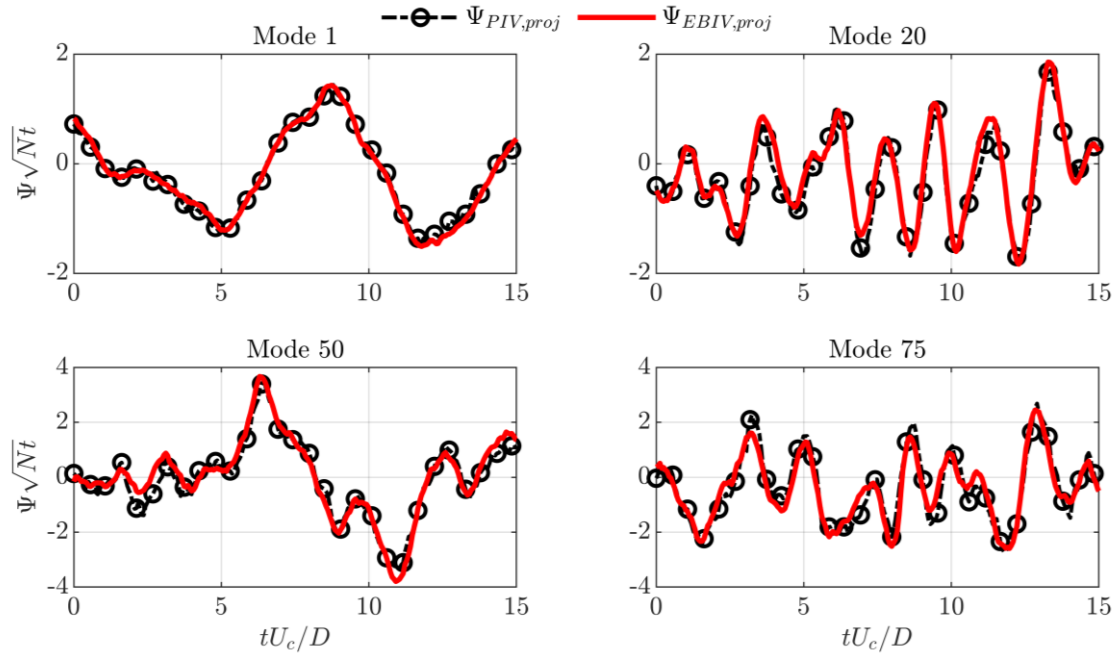


- **Continuous** data-stream from pixels
- **Adaptive** scene-driven sampling rate
- **Sparse data**
- **Logarithmic sensitivity** $\rightarrow$ High dynamic range

Event-based Imaging Velocimetry (EBIV) as a sensor flow control



Comparison EBIV with Conventional PIV



2) EBV camera

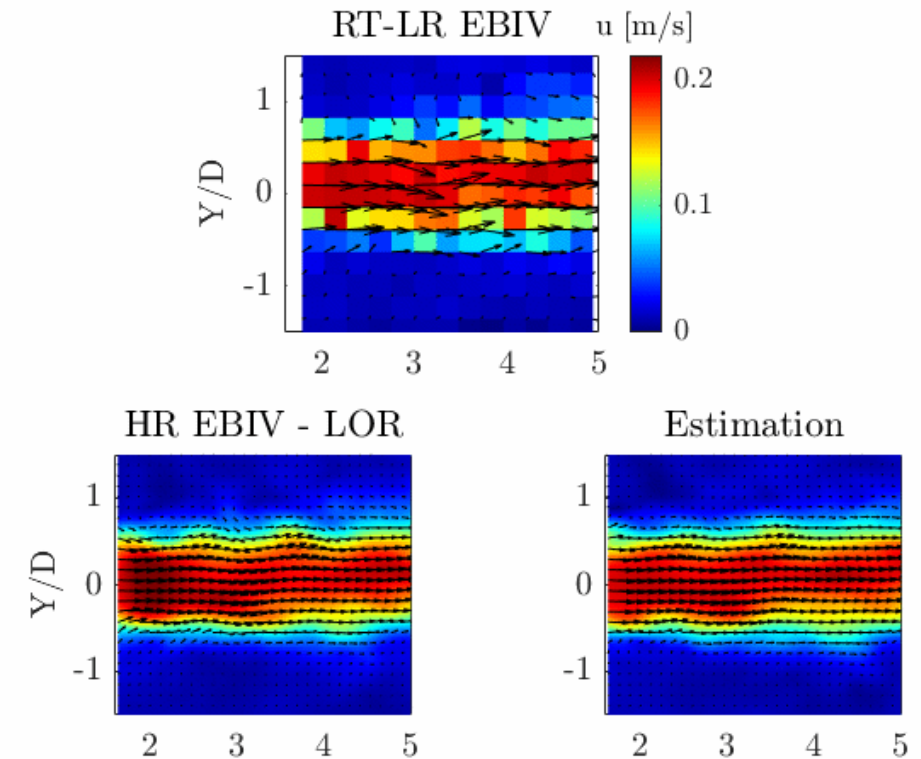
~ 1'000€

3) High-speed camera

~ 200'000€

EBIV is capable of correctly identifying the dynamics of flow structure...

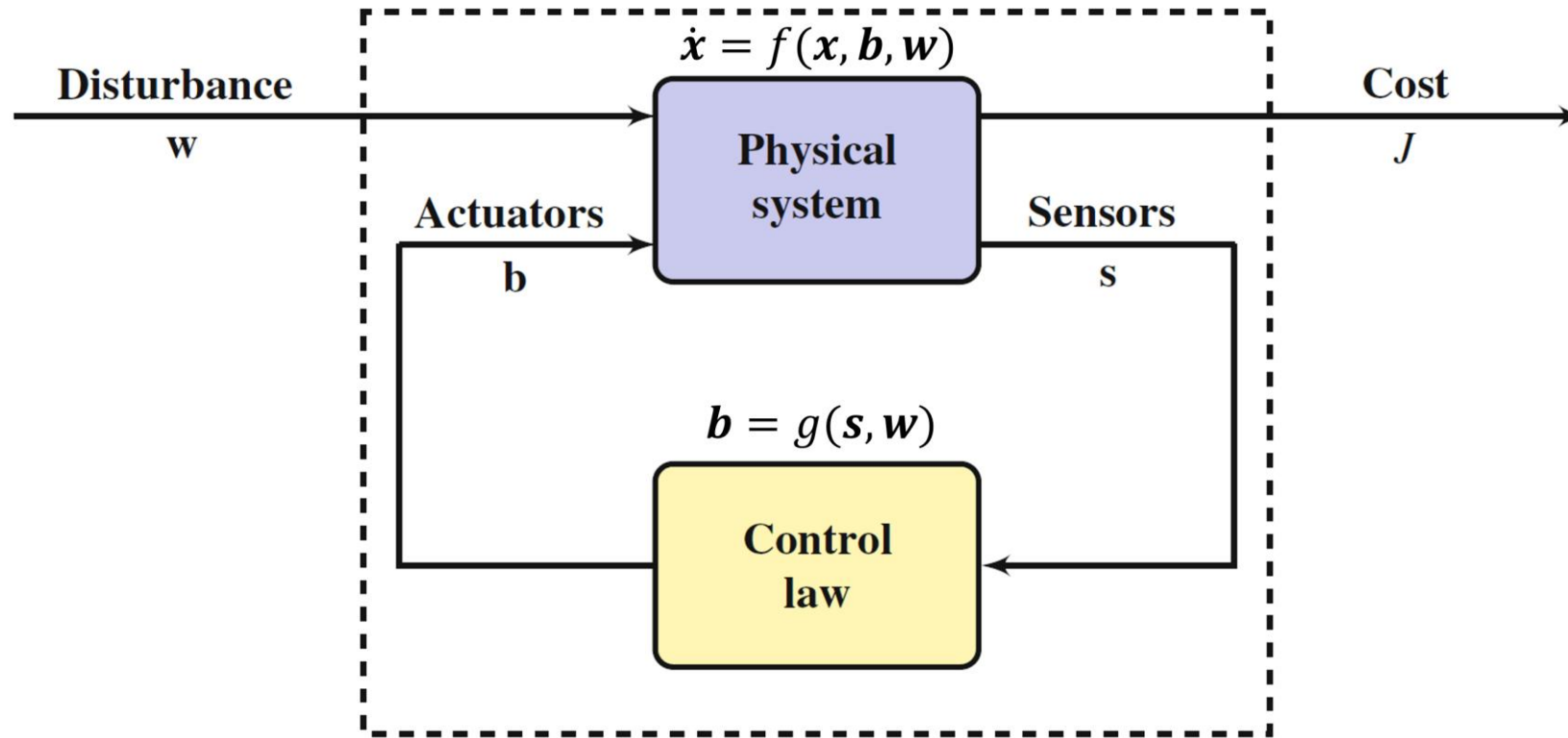
Real-time high-resolution measurements



...accurately and in real-time*

*data-efficient way

Flow control time



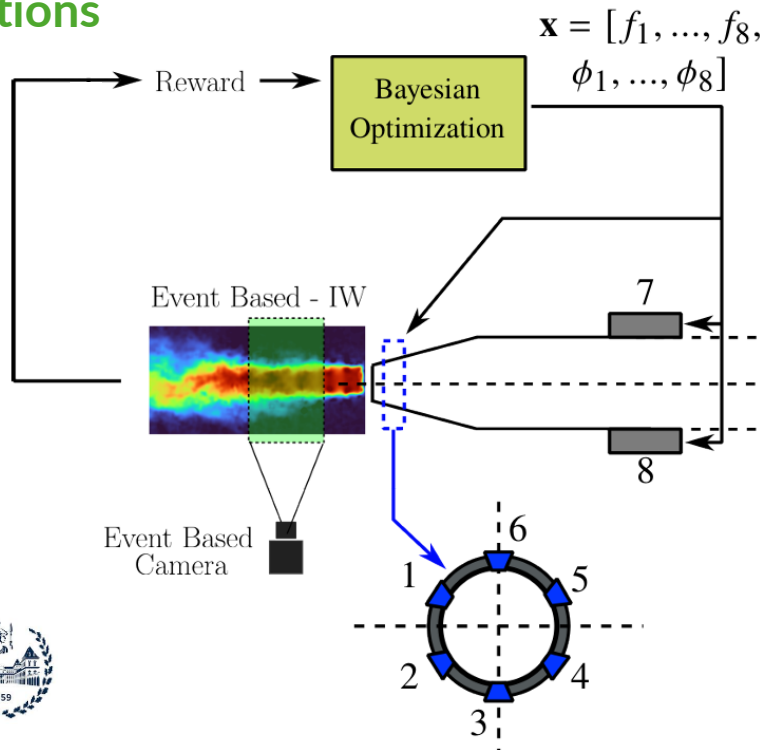
Implementation of EBIV in the control loop

Open-Loop Optimization



The “guide”

- EBIV as **data-rich/efficient** reward estimator
- Guiding optimization through **complex cost functions**

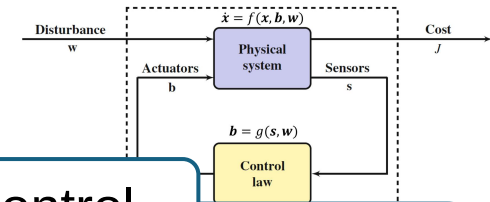
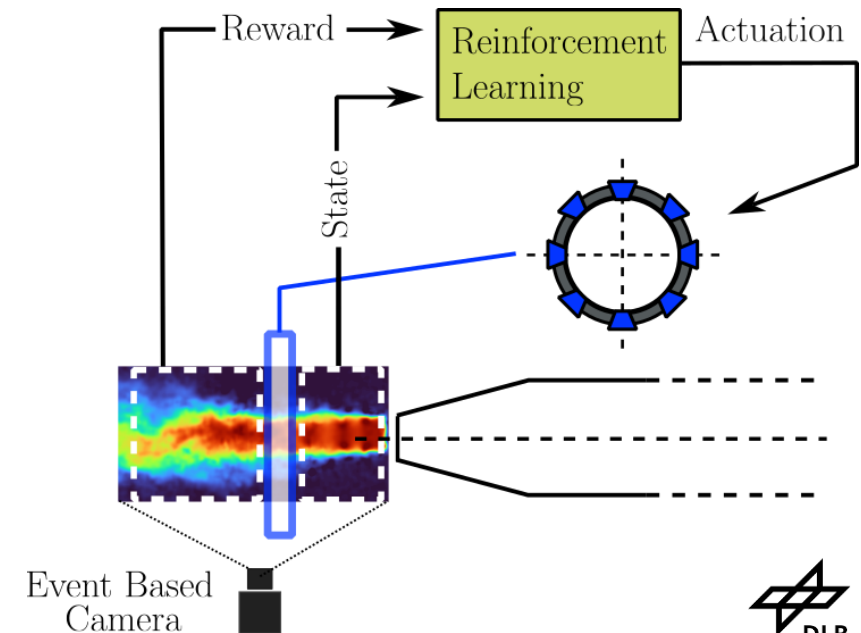


Closed-Loop Control

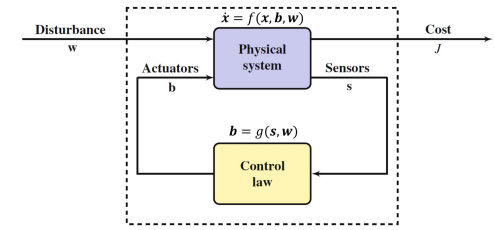


The “sensor”

- Real-time EBIV as **state** estimator
- Field of view is split into **state** and **reward** regions



Implementation of EBIV in the control loop

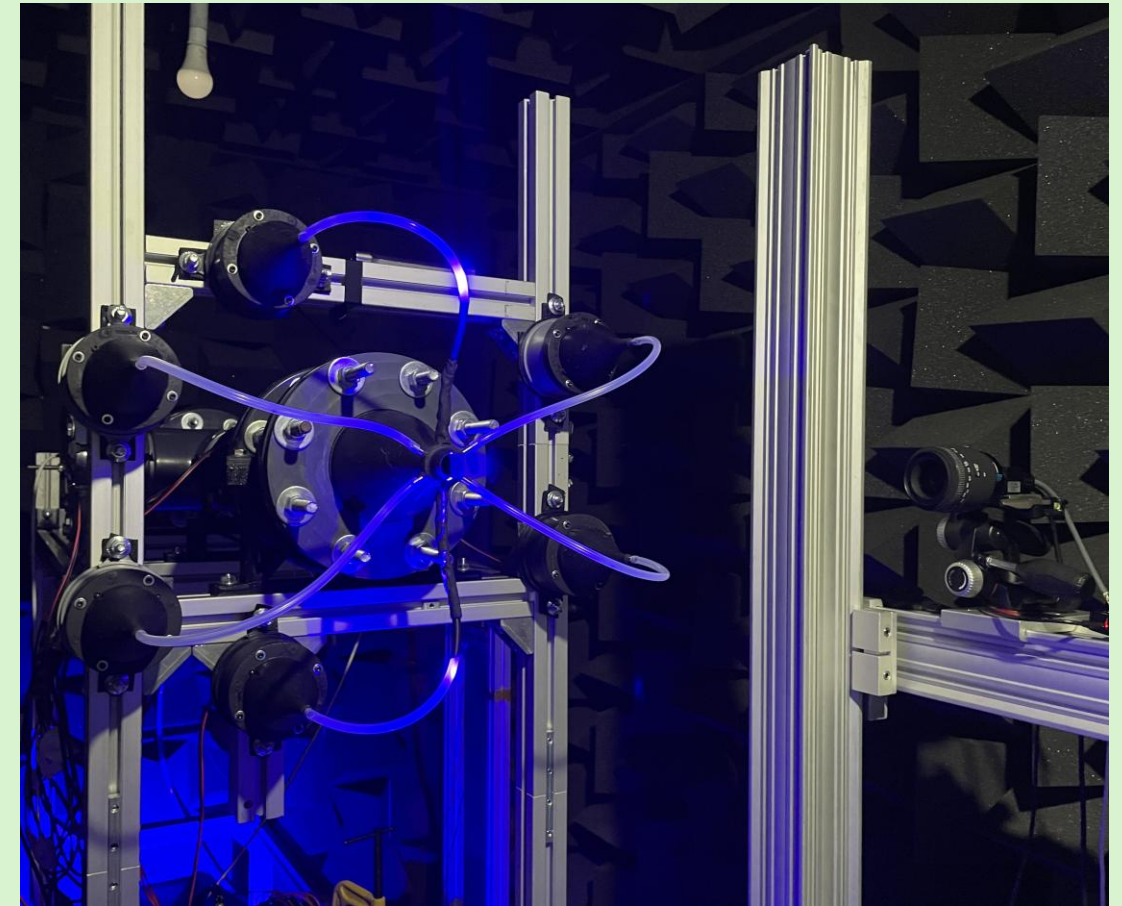
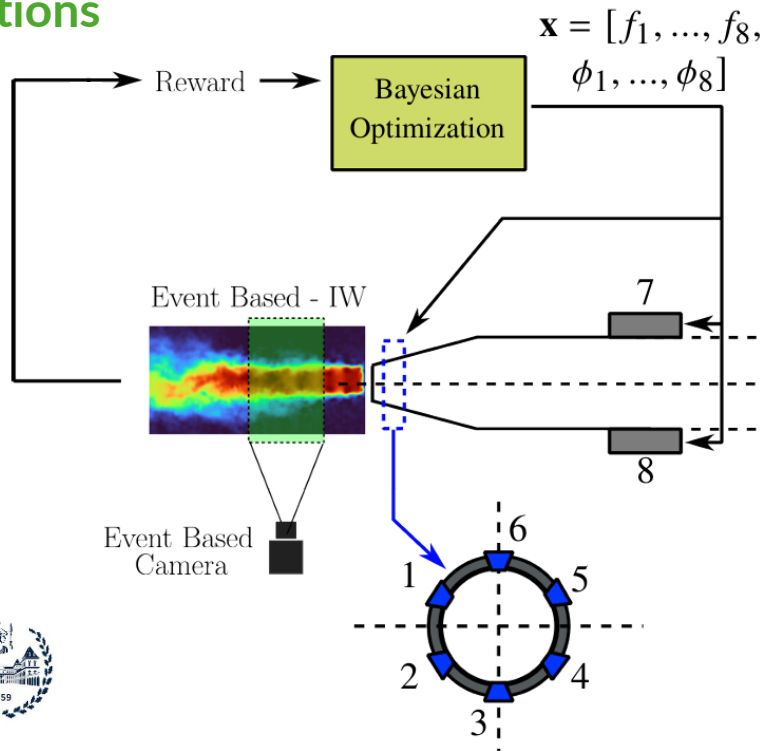


Open-Loop Optimization

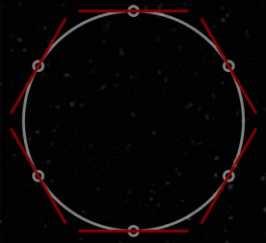


The "guide"

- EBIV as **data-rich/efficient** reward estimator
- Guiding optimization through **complex cost functions**



Uncontrolled



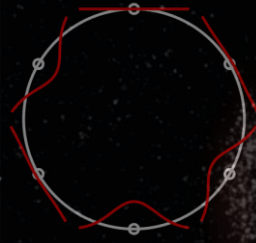
Run 8



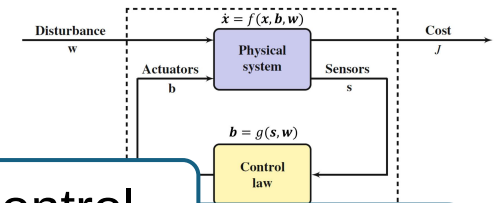
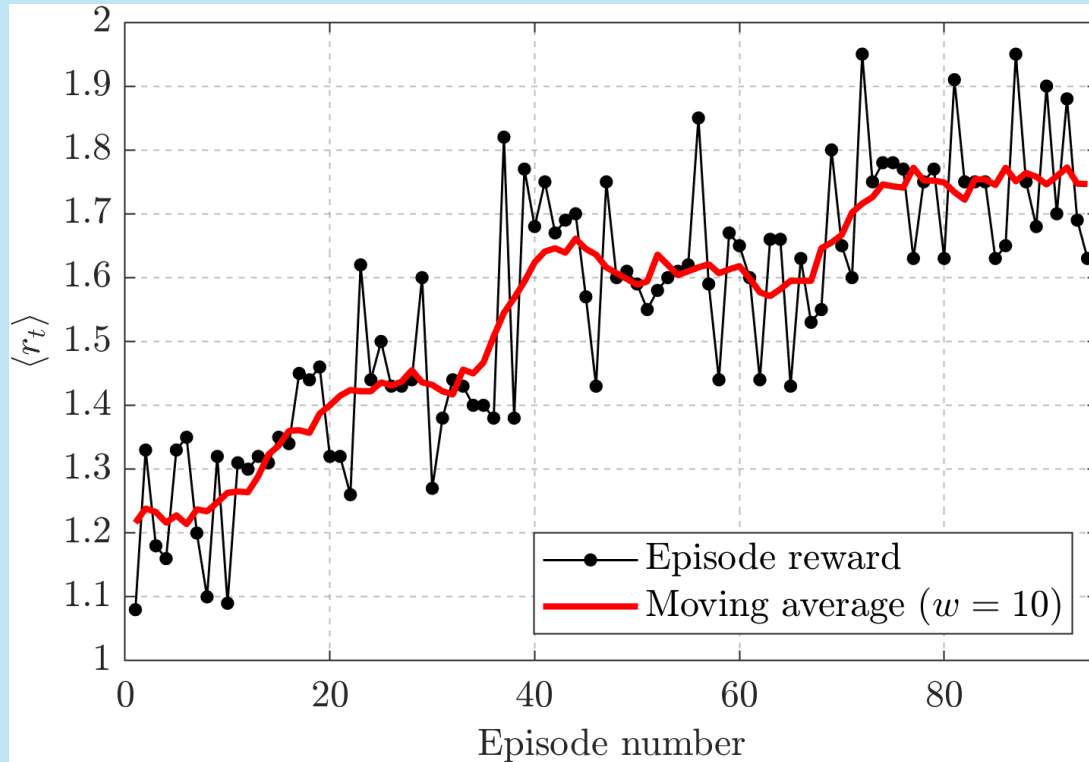
Run 34



Run 437



Implementation of EBIV in the control loop

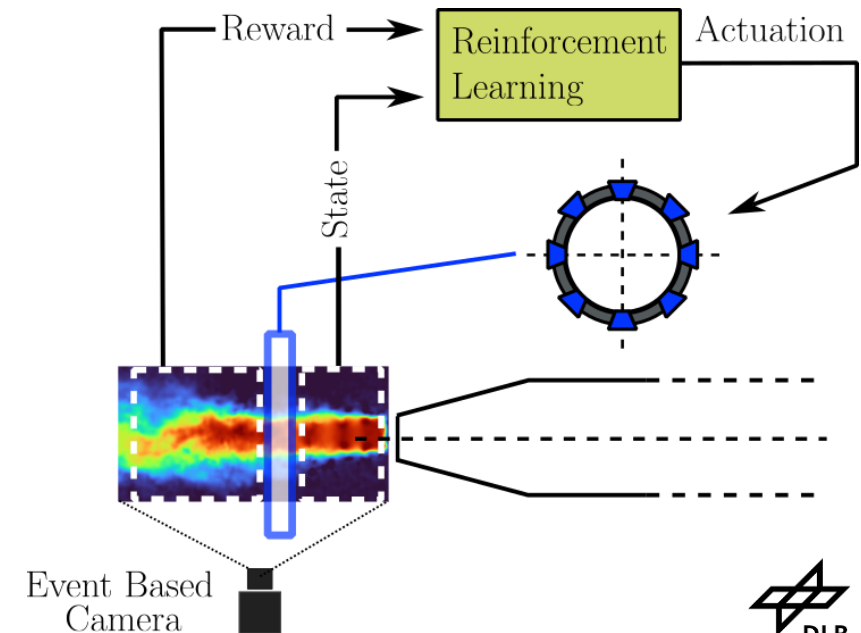


Closed-Loop Control



The "sensor"

- Real-time EBIV as **state** estimator
- Field of view is split into **state** and **reward** regions



June 2026
Join PoC RT-Flow

Timeline

October
2022

Year IV

-  EBIV for high-speed flows
-  Jet-flow closed loop control
- ☐ Writing, writing, writing.... 

Research stay at PoliTo under the supervision of Prof. Cafiero (Sept–Dec 2025)

Year III

- ☒ rt-EBIV for closed-loop control
-  Jet-flow optimization using imaging-based reward
-  Actuation manifold of a controlled jet
- ☒ event-based sensing for flow control

Year II

- ☒ Upgraded jet facility and characterization
- ☒ Implementation of flow actuation
- ☒ Evaluation of event-based imaging for real-time PIV

Year I

- ☒ Preliminary jet facility
-  Flow estimation via EPOD

Outcomes

Journal Paper

- Franceschelli, L., Willert, C. E., Raiola, M., & Discetti, S. (2025). *An assessment of event-based imaging velocimetry for efficient estimation of low-dimensional coordinates in turbulent flows*. Experimental Thermal and Fluid Science;
- Franceschelli, L., Amico, E., Willert, C. E., Raiola, M., Cafiero, G., & Discetti, S. (2026). *Real-Time Estimation of High-Resolution Flow Fields and Reduced-Order Coordinates from Event-Based Imaging Velocimetry*. arXiv preprint arXiv:2605.04186.
- Willert, C., Franceschelli, L., Amico, E., Raiola, M., Cafiero, G., & Discetti, S. (2026). *Real-time event-based particle image velocimetry for active flow control*. In Journal of Physics: Conference Series (Vol. 3173, No. 1, p. 012001). IOP Publishing.

Conference papers

- “Jet flow feature estimation with snapshot PIV and fast probes”, presented at ISPIV15 (San Diego, 19th – 21st June 2023), iTi-X (Bertinoro, 24th – 26th July 2023) and ETC18 (Valencia, 4th – 6th Sept 2023)
- “Implementation of a Jet Collector and Dissipation Cavity into a Closed Anechoic Chamber for jet noise studies”, presented at AIAA Aeroacoustics (Rome, 4th – 7th June 2024)
- “An assessment of event-based imaging velocimetry for dimensionality reduction in turbulent flows”, presented at LXLASER (Lisbon, 8th – 11th July 2024)
- “Identification of an actuation manifold for open-loop control of subsonic jet noise with acoustic-based excitation”, presented at Forum Acousticum Euronoise (Malaga, 23rd – 26th June 2025), ISPIV26 (Tokyo, 26th – 28th June 2025), Flucome (Delft, 2025)
- “Event-based imaging velocimetry for jet flow control”, presented at ISPIV16 (Tokyo, 26th – 28th June 2025) and Flucome (Delft, 4th – 7th November 2025)
- “A POD-based spatial resolution enhancement method for real-time event-based imaging velocimetry”, presented at ISFV21 (Tokyo, 21st – 25th June 2025)
- “Jet coherent structures prediction using the MxArray and neural-network-based mapping”, presented at BeBeC2026 (Berlin, June 1st -2nd 2026)
- “Real-Time Event-Based Imaging Velocimetry for Closed-Loop Jet Control”, presented at LXLaser-22 (Lisbon, 29th June – 2nd July 2026)
- “Jet mixing optimization using Event-Based Imaging Velocimetry”, presented at LXLaser-22 (Lisbon, 29th June – 2nd July 2026)

Thank you for your attention!



This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No 949085).