

## The fluid mechanics of odor transport, sensing and tracking

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### ABSTRACT

How does an agent (e.g., an organism or a robot) find the source of a smell it can barely sense? Olfactory search in turbulence is hard because the signal is sparse, intermittent and carries no direct bearing to the target. In this seminar, I build toward this control problem through the fluid mechanics that shapes the signal. I will start with the problem of odor transport in turbulence. Our computational fluid dynamics results show that swimmers reshape the plume they themselves release: puller-like and pusher-like motion mix and dilute odor differently, producing an 'olfactory shielding' that suppresses detection downstream. Different swimming modes can result in different levels of this shielding, thus providing an evolutionary pressure for certain swimming modes. Capturing odor at a sensor is the next step, and its efficiency depends strongly on the fluid medium. By using direct numerical simulations of odor adsorption in terrestrial and aquatic axolotl olfactory chambers, we show that odor sensing in aquatic media is a fundamentally inefficient process. In the last part, I will discuss the problem of odor tracking in turbulence. We build a reinforcement-learning agent with a minimal olfactory memory that recovers behavior observed in nature. We further show that proprioceptive noise, surprisingly, sharpens Bayesian localization of the source. Together, these results trace odor from emission through capture to search and show that each stage is shaped by fluid mechanics, with implications for biology and autonomous navigation.

### ABOUT THE SPEAKER

Martin James is a postdoctoral researcher at the Machine Learning Genoa Center and the Department of Civil, Chemical and Environmental Engineering, University of Genoa, where he works on fluid dynamics and reinforcement learning for navigation in turbulent flows. He completed his BSc and MSc in Physics from the Indian Institute of Science, Bangalore. He received his PhD in Physics in 2020, conducting his doctoral research at the Max Planck Institute for Dynamics and Self-Organization, supported by the prestigious IMPRS Fellowship. During his PhD, he worked on understanding how turbulence can emerge in active systems at low Reynolds numbers and self-organize into ordered patterns. After his PhD, he did a short research stay at ICTS-TIFR, Bangalore, before moving to Genoa for his postdoctoral position. His research spans turbulence, active matter and machine learning.



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