2-years PostDoctoral position — Turbulent Dynamos Reduced-Order Modeling via Machine learning — (MilaDy ANR) (H/F)

LISN, Campus universitaire Université Paris-Saclay, 91405 Orsay, France

Contact Pr. UPS C. Nore (caroline.nore@lisn.fr) & DR CNRS D. Lucor (didier.lucor@lisn.fr)

Mission At the LISN CNRS laboratory, on the Université Paris-Saclay (UPS) campus, we recruit a Researcher for a 24-month fixed-term position within the framework of the ANR MilaDy project. The successful candidate will work on the analysis of data produced by large-scale numerical simulations of magnetic and velocity fields related to two experiments investigating magnetic field generation via the dynamo effect (DyE). He/she will collaborate closely with colleagues from the Lagrange Laboratory (Nice) and CEREA (ENPC, EDF R&D).

Context Magnetohydrodynamics (MHD) science studies the interaction between electrically conducting fluids and electromagnetic fields. The DyE explains the origin of magnetic fields in such fluids: an initial magnetic field is amplified by a conducting flow. This phenomenon, which is rare in liquid metals, occurs only in 3D turbulent regimes at low magnetic Prandtl number (Pm). Several experiments have successfully reproduced this effect in Riga, Karlsruhe, and Cadarache. The German DRESDYN project (HZDR, Germany) currently aims to generate a dynamo in a precessing cylinder, but its success remains uncertain.

These dynamos exhibit highly complex dynamics, including magnetic field reversals, intermittent phases, and burst-like events, which are difficult to reproduce numerically. Full modeling of the dynamo effect is hindered by the nonlinear coupling between the Navier-Stokes and magnetic induction equations, making Direct Numerical Simulations (DNS) extremely expensive and typically restricted to Pm~1 regimes.

To overcome these limitations, Reduced-Order Models (ROMs) can be developed to capture and better understand the essential dynamics at a significantly lower computational cost. Machine Learning (ML) provides novel approaches for constructing efficient and predictive ROMs.

Scientific objectives and methods This position has two main objectives:
— analyze magnetic field reversals and dynamo burst phenomena by developing parametric reduced-order models (pROMs) with enhanced physical interpretability, enabling the identification of key mechanisms and the reproduction of the dynamics observed in numerical simulations.
— optimize the DRESDYN experiment using pROMs by adjusting physical parameters (precession, rotation, geometry) to explore the viability of the dynamo effect at reduced computational cost.
The targeted methods must overcome current limitations of pROMs for MHD systems, namely their lack of interpretability and poor extrapolation capability, by combining classical linear

spectral approaches with nonlinear deep-learning-based methods, such as autoencoders and variational autoencoders (vAEs), in order to ensure more explainable, physically consistent, and robust models outside the training domain.

For nonlinear pROMs based on latent representations, physics-informed (v)AEs will be considered, through explicit regression of latent variables with key physical parameters, temporal or parametric contrastive learning, or the incorporation of physical invariants. These approaches will provide projections of multiple attractors in latent space and facilitate the identification of invariant manifolds, bifurcation points, and transition pathways.
After this compression phase, a physics-constrained reduced dynamics will be learned in the latent space, parameterized by the flow control parameters, in order to robustly predict, generalize, and interpret MHD regimes, their transitions, and rare events.

Recurrent Neural Networks will be adapted, such for instance as Long Short-Term Memory networks for limited datasets, or transformer-based models for complex turbulent regimes with large datasets.

Skills and Qualifications The candidate should demonstrate a strong multidisciplinary background, with solid knowledge in fluid dynamics and/or MHD, experience in scientific data analysis and/or reduced-order modeling, and a strong interest in machine learning applied to dynamical systems, as well as good scientific programming skills.

The candidate must hold a PhD in fluid mechanics, applied mathematics, or machine learning.

Working Environment Based on the Université Paris-Saclay campus, the researcher will work at LISN within an interdisciplinary research environment fostering strong interactions between physicists, mechanicians, and machine learning specialists, with access to high-performance computing resources and advanced simulation databases.

This position falls within a domain subject to the protection of scientific and technical potential (PPST) and therefore requires, in accordance with regulations, prior authorization from the competent authority of the French Ministry of Higher Education and Research (MESR) before the post-doctoral researcher can take up the position.

Practical information Duration: 24 months.
Location: LISN, Campus universitaire, Orsay.
Salary: Between €3,131.32 and €3,569.85 gross per month, depending on experience.

Application Send a single PDF (CV + short motivation letter + list of papers + letter(s) of recommandation)
email subject: [Application – MilaDy post-doc, your name], feel free to write in English/French.

References

Bousquet, R., Nore, C., Lucor, D., 2025. AutoEncoders latent space interpretability in the light of Proper Orthogonal Decomposition: machine learning of periodically forced fluid flows, Computer Physics Communications, vol. 315, 109728

Bousquet, R., Chaffard, O., Creff, M., Lucor, D., Nore, C. 2024. Large scale analysis of three-dimensional turbulent von Kármán swirling flows, Physics of Fluids, 36, 105133

Yang R, Schmid PJ. 2025 Complex-network modeling of reversal events in two-dimensional turbulent thermal convection. Journal of Fluid Mechanics. 1011:A30.