

Master Internship (Stage de fin d'étude) 2027

Physics-Constrained Generative AI Modelling of Parametric Dynamical Systems (with potential PhD position)

Context

Understanding and modelling magnetohydrodynamic (MHD) dynamos, in which conducting fluid flows spontaneously generate magnetic fields, remains a major challenge in geophysics and astrophysics. Simulating their multiscale turbulence produces large 3D datasets that are difficult to store, interpret, and reuse for modelling and data assimilation. Moreover, the generated magnetic fields can exhibit strong sensitivity to system parameters and nonlinear dynamical transitions, including abrupt reversals of the magnetic field polarity.

The ANR project Milady aims to bridge this gap by developing machine-learning models that respect the underlying physics of MHD flows. The internship will explore physics-constrained generative models that generate diverse physical fields conditioned on system parameters, incorporating constraints derived from governing equations and boundary conditions. The methods will first be evaluated on simple PDE benchmarks, with potential applications to turbulent dynamo flows.

Objective of the internship

The goal is to design and evaluate physics-constrained generative models for parameter-dependent physical fields in dynamo systems. The resulting generative framework should:

- Respect key physical constraints, including energy balance and divergence-free conditions.
- Encode variations across control parameters (e.g., Reynolds number, magnetic Reynolds number, material properties...).
- Enable robust generation of 3D fields that can serve as input for reduced-order models or data assimilation frameworks developed elsewhere in the project.

Scientific and technical work

The work will include:

- Generative model development: implement and test conditional generative models based on diffusion or flow matching to generate physical fields conditioned on system parameters.
- Parameter conditioning and physical constraints: condition field generation on relevant control parameters and incorporate constraints derived from governing PDEs and boundary conditions through model design, training losses, or sampling procedures
- Physics-informed training and evaluation: first validate methods on simple PDE benchmarks, then evaluate generated MHD fields using statistical and physical consistency metrics (energy spectra, helicity, divergence control, and topology preservation).

Expected outcomes

- A comparative study of physics-constrained generative modelling strategies for parameter-dependent MHD fields.
- A concise technical report and reproducible code integrated into the MilaDy project toolbox.
- Successful candidates will have the opportunity to disseminate their research in leading international journals or top machine learning conferences.
- Depending on the intern's performance, a **fully funded PhD position** within the ANR MilaDy project may be offered.

Profile required

- Master 2 or final-year engineering student in Applied Mathematics, Computer Science, Physics or equivalent.
- Solid skills in Python and machine learning frameworks (PyTorch or equivalent) are necessary.
- Interest in physical modeling, fluid mechanics, or dynamical systems.
- Knowledge of generative AI (e.g., diffusion, flow matching) is not required but would be a strong asset.

Supervision and environment

The internship will mainly take place at CEREa (ENPC / Institut Polytechnique de Paris) under the supervision of Dr. Sibor Cheng (ENPC) and Dr. Didier Lucor (LISN, Université Paris-Saclay) in collaboration with Pr. Caroline Nore (LISN) and Dr. Yannick Ponty (Observatoire de la Côte d'Azur, CNRS) within the MilaDy consortium.

Practical information

- Duration: 5–6 months (starting in spring 2027).
- Location: ENPC, Champs-sur-Marne, with possible remote work up to 1-2 days per week.
- Compensation: standard ENPC internship allowance and transport support.

Application

Send a single PDF (CV + short motivation letter + **Master's transcripts** + at least 2 reference information (e.g., previous supervisor, course teachers), in french or english) to sibo.cheng@enpc.fr, didier.lucor@cnrs.fr, email subject: [Application – MilaDy Internship, *your name*], feel free to write in english or french

References (recommended to read before application)

Wang, S., Dou, Z., Shan, S., Liu, T.R. and Lu, L., 2026. Fundiff: Diffusion models over function spaces for physics-informed generative modeling. *Nature Communications*.

Fukami, K. and Taira, K., 2023. Grasping extreme aerodynamics on a low-dimensional manifold. *Nature Communications*, 14(1), p.6480.

Other References

Bansal, A., Chu, H.M., Schwarzschild, A., Sengupta, R., Goldblum, M., Geiping, J. and Goldstein, T., 2024, May. Universal guidance for diffusion models. In International Conference on Learning Representations

Bastek, J.H., Sun, W. and Kochmann, D., 2025, May. Physics-informed diffusion models. In International Conference on Learning Representations

Solera-Rico et al. (2024) — “ β -Variational autoencoders and transformers for reduced-order modelling of fluid flows” *Nature Communications* 15, 1361 (2024)