

Thesis subject proposal

Exploring Fusion Plasmas by combining spectroscopy and Scientific Artificial Intelligence

Thesis supervisor: Mohammed KOUBITI

Laboratory: PIIM, UMR7345 (<http://piim.univ-amu.fr/>)

Email & address: mohammed.koubiti@univ-amu.fr, Centre de St-Jérôme, Marseille, France.

Phone: +33 (0)4 13 94 64 47.

Subject description: Artificial intelligence tools are taking an important place in plasma science [1] and particularly in plasma physics [2-3]. Concerning plasma spectroscopy, several applications of machine-learning can be found including 2D beam emission spectroscopy in the DIII-D tokamak for real-time inference of plasma dynamics [4], neutral helium emission in linear plasma devices to predict plasma parameters using a support vector regression model (SVM) algorithm [5], or a more recent work on the Balmer- β line ($H\beta/D\beta$) in the WEST tokamak [6].

As non-invasive method, emission spectroscopy is widely used for diagnostics of magnetic fusion plasmas. Several parameters are diagnosed, e.g, the densities and temperatures of the electrons and main plasma ions, the impurity densities, and the temperatures and concentrations of the hydrogen isotope neutrals. Concerning hydrogen isotopes, the knowledge of the isotopic ratio $D/(D+T)$ is of great importance since tritium inventory is mandatory in magnetic fusion devices operated with DT mixtures for obvious safety reasons. To infer the hydrogen isotopic ratio, we have built a predictive model based on the application of 1D Convolutional Neural Networks (1D-CNN) algorithms to theoretical Balmer $H\alpha/D\alpha$ line spectra generated for neutral temperatures and magnetic field strengths typical of tokamak edge plasmas composed of HD mixtures [7].

In this thesis, it is proposed to develop predictive models based on different architecture of neural networks for more realistic conditions by considering plasmas composed of HD, DT as well as HDT mixtures but also to apply the models to experimental spectra from different tokamaks. We consider exploring experimental data measured in WEST (HD), JET (DT) through the EUROfusion WPTe involvement. Beyond their usefulness for future fusion devices like ITER, the development of predictive models will not be limited to $H\alpha/D\alpha/T\alpha$ spectra but extended to other emission lines of H isotopes and impurity spectra like tungsten EUV spectra [8] in collaboration with spectroscopists from IRFM CEA or from other groups. The selected candidate will have the task to develop, test and validate computer programs coupling different neural network-based architectures to various emission spectra. Such programs should be more general to be extended to various diagnostics. Python and machine-learning/deep-learning skills as well as fusion plasma knowledges are greatly appreciated.

References

- [1] E. Anirudh *et al*, IEEE Transactions on Plasma Science **51** 1750 (2023)
- [2] C. M. Samuel *et al*, Rev. Sci. Instrum. **92** 043520 (2021)
- [3] B. Dorland, Machine-Learning for Plasma Physics and fusion energy, Journal of Plasma Physics (2022)
- [4] L. Malhorta *et al*, 4th IAEA Technical Meeting on fusion data processing, validation and analysis (2021)
- [5] S. Kajita *et al*, AIP Advances, **10** 025225 (2020)
- [6] G. Ronchi *et al*, JQSRT **318** 108925 (2024)
- [7] N. Saura, M. Koubiti, S. Benkadda, Nucl. Materials Energy, **43** 101935 (2025)
- [8] N. Saura, R. Guirlet, M. Koubiti *et al*, Phys. Plasmas **32** 083901 (2025).