MACHINE LEARNING FOR ASTROPHYSICS
2ND EDITION CATANIA, 8-12 JULY, 2024

Contribution ID: **242** Type: **not specified**

Inferring stellar parameters and their uncertainties from high-resolution spectroscopy using conditional Invertible Neural Networks

Wednesday, 10 July 2024 11:20 (5 minutes)

Next generation instruments are prompting a revolutionary surge in collecting a wide variety of data, with an unprecedented advancement in our understanding of the Universe. The stellar community is actively adapting to this transformative era, trying to maximise the information obtainable from observational data, in particular stellar spectra. The next generation of multi-object spectrographs and surveys (e.g., SDSS-V: Kollmeier et al. 2017; WEAVE: Jin et al. 2023; MOONS: Gonzalez et al. 2020 and 4MOST: de Jong et al. 2019) have started or will soon start to observe a number of stars more than an order of magnitude larger than the previous ones. The significant shift in data volume requires the development of novel, fast, and precise codes to preprocess the huge flux of data collected every night and to analyse it in a quick but reliable manner, e.g., through supervised machine learning algorithms, such as Neural Networks inference. These algorithms are characterized by enhanced speed, improved precision at lower resolutions [Wang et al., 2023, Guiglion et al., 2024], and reduced dependence on a priori knowledge of physics due to their data-driven nature. Therefore, they are progressively gaining traction within the astrophysical community. However, not all applications of these algorithms succeed in providing the uncertainties on derived parameters [e.g. Huertas-Company and Lanusse, 2023], given the vast number of hyper-parameters, thereby precluding conventional Bayesian analyses.

In this talk, I will introduce OssicoNN, a neural network expressly devised to address new challenges associated with the determination of stellar parameters. At its core, lies the application of the conditional Inversible Neural Network (cINN), an elegant framework developed by Ardizzone et al. [2019]. Utilizing the flux uncertainty present in the spectra and the properties of cINN, OssicoNN offers an estimation of the overall uncertainty derived during in the inference process, encompassing both the epistemic error associated with the neural network and the aleatoric error intrinsic to the data. I will demonstrate with OssicoNN, the high-performances of a cINN trained on stellar observational data, specifically the GIRAFFE dataset of the Gaia-ESO Survey, to derive effective temperature, surface gravity, metallicity, and various elemental abundances (Aluminum, Magnesium, Calcium, Nickel, Titanium, and Silicon) from stellar spectra.

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Session Classification: FlashTalks