Francesco Pio Ramunno

+41 0782578180 | frarampio@gmail.com | fpramunno.github.io | github.com/fpramunno/ | linkedin.com/in/francesco-pio-ramunno-a03a20158/

EDUCATION

University of Geneva (Switzerland) and Fachhochschule Nordwestschweiz FHNW, *PhD in Deep Learning and Astrophysics* | Zurich, Switzerland — 2022-Ongoing

University of Rome Tor Vergata, *MS in Astrophysics and Space Science* | Rome, Italy — Final Mark: 110 / 110 with honours — 2020-2022

Università degli studi della Basilicata, *Bachelor in Mathematics* | Potenza, Italy — Final Mark: 110 / 110 with honours — 2017-2020

WORK EXPERIENCE

Polymathic AI (Simons Foundation), *AI Foundation Models for Science Intern* | New York City (NY), USA — March 2025 - Aug 2025

- Develop a foundation model for the Sun using data coming from the NASA SDO mission. The data are mostly images in different wavelengths and the goal is to predict the evolution of the magnetic field of the Sun,
- Develop and train CV/AI algorithm/models on image-to-image translation, image prediction and video prediction for understanding the evolution of the magnetic field of the Sun using score based diffusion models.
- The main difficulties are data related since the images are totally different from usual natural images and their ranges span from -5000 to 5000, so we address it using a specific transformation which should be reversible because we want after the prediction to come back into the physics space and do actual science, in such a way the model is not only used as visualization tool but also as a scientific tool for physics modelling.

European Space Agency (ESA), *Data Science and Machine Learning Intern* | Frascati, RM (Italy) — March 2022 - Aug 2022

- Developed an automated pipeline for building a Near-Earth Objects database, capturing their physical and chemical properties for future data integration.
- Implemented machine learning algorithms (Random Forest, Decision Trees, XGBoost) to analyze correlations between asteroids' physical properties and orbital parameters. Achieved a more than 100% improvement in prediction accuracy for physical composition compared to traditional analysis methods.

University of Rome Tor Vergata, *Data Science Intern* | Rome (Italy) — March 2021 - Aug 2021

- Conducted morphological analysis on wavelet-filtered maps and raw data from the XMM-Newton telescope. Demonstrated that wavelet techniques improve the accuracy of morphological parameter measurements by over 30% compared to analyses using raw data.

SKILLS

IT Languages	Python, Matlab, IDL
Languages	Italian (Native), English (C2/Professional proficiency), German (A1/Basic proficiency)
Software	Linux, Tensorflow, Pytorch, Keras, Docker, OpenCV, Slurm, Pandas, Jax, Scikit-learn, Jupyter Notebook, Numpy
ML skills	Generative AI, Image generation, uncertainty quantification, transformer, classification, prediction, super resolution, image segmentation, image to image translation, video generation, diffusion model, sde

PROJECTS AND PUBLICATIONS

Generative Simulations of The Solar Corona Evolution With Denoising Diffusion: Proof of Concept – *Submit to A&A* – Second author

- Developed a novel application of Denoising Diffusion Probabilistic Models (DDPMs) to simulate future solar corona evolution by generating 12-hour video forecasts from 12-hour input observations. This approach incorporates spatio-temporal convolutions and attention mechanisms to predict dynamic solar events with stochastic reliability.
- Introduced a light UNet backbone with 2D+1D convolutional layers to reduce computational complexity while enhancing spatio-temporal pattern learning. Self-attention mechanisms in the bottleneck further improve the model's ability to capture solar dynamics.
- Created a specialized dataset of Solar Dynamic Observatory (SDO) observations focusing on active regions within ± 230 arcsec from the solar disk center, aligned, exposure-normalized, and downsampled for computational efficiency. Multi-wavelength input (94Å, 193Å, and 211Å) is used for diverse coronal dynamics.
- Assessed the model's video outputs using traditional metrics like PSNR, SSIM, and LPIPS, alongside space weather-related metrics such as flux dynamics, maximum peak flux, and fluence, demonstrating alignment with ground truth.
- Generated probabilistic simulations that not only reconstruct complex magnetic and coronal dynamics but also provide uncertainty estimates for events like solar flares, facilitating interpretable space weather forecasting.
- Highlighted the potential to improve temporal resolution and spatial coverage for operational solar forecasting, paving the way for advanced applications in solar physics and space weather predictions.

Enhancing Image Resolution of Solar Magnetograms: A Latent Diffusion Model Approach
– *Submit to A&A* – First author

- Applied novel super-resolution algorithms to magnetograms from the HMI instrument, achieving 4x pixel-space upscaling. This work enhances data reconstruction post-compression for transfer and generation purposes while pushing the telescope's spatial resolution limits.
- Developed a new Latent Denoising Diffusion Model to predict residual differences between downsampled and original data. Achieved state-of-the-art results compared to baseline models across metrics such as SSIM, LPIPS, PSNR, and various physics-based evaluations.
- Tested the model on MDI telescope data with a native spatial resolution of 2"/pixel, successfully upscaling it to match the HMI resolution of 0.5"/pixel. Demonstrated significant improvements over previous deterministic models in both physics and computer science metrics.
- Implemented a novel Fourier-space technique to evaluate the model's ability to detect features smaller than 2" in MDI data.

A machine learning approach for computing solar flare locations in X-rays on-board Solar Orbiter/STIX – *Paper at the ESA SPAICE conference* – Co-author

- The paper presents a machine learning approach using a multi-layer perceptron (MLP) to compute the (x, y) coordinates of solar flare locations from data captured by the Coarse Flare Locator (CFL) on the STIX instrument aboard the Solar Orbiter,
- A neural network was trained on CFL observations with post-training quantization to enable integer arithmetic, making it suitable for onboard computations with limited hardware resources,
- The proposed MLP outperforms the current CFL algorithm in accuracy while requiring fewer parameters, with predictions showing a mean distance of 97 arcseconds compared to 280 arcseconds for the existing method,
- The technique improves onboard flare location estimation, enabling better coordination between instruments and timely ground-based analysis for space weather events. Future work includes refining the model and extending its applicability to wider datasets

Magnetogram-to-Magnetogram: Generative Forecasting of Solar Evolution – *Paper at the ESA SPAICE conference* – First author

- Introduced a novel approach for predicting the evolution of solar line-of-sight (LoS) magnetograms using image-to-image translation with Denoising Diffusion Probabilistic Models (DDPMs).
- Demonstrated that DDPMs effectively preserve structural integrity, dynamic range of solar magnetic fields, magnetic flux, and physical features such as active region sizes, outperforming traditional persistence models, even in flaring scenarios.
- Highlighted the ability to generate uncertainty maps for each prediction, identifying regions where the model struggles the most. The most challenging area is the Polarity Inversion Line, which is highly dynamic during solar eruptive events.
- Tested the model in an auto-regressive manner to predict daily evolution up to four days. Identified limitations after four days and outlined plans to address these by incorporating additional input data in future work.

Solar synthetic imaging: Introducing DDPM on SDO/AIA data – *Paper on A&A Journal* – First author

- Applied Denoising Diffusion Models to generate images resembling those captured by the SDO space telescope, conditioned on their energetic content in terms of X-ray emission.
- Validated the physical reliability of the generated images using cluster metrics and the Fréchet Inception Distance (FID) with both CLIP and IV3 encoders. Further tested their similarity by training a classifier on original data and evaluating it on simulated data.
- Augmented underrepresented classes (higher energy events) using the generated images to train a classifier. Achieved over a 50% improvement in prediction accuracy, evaluated using True Skill Statistics (TSS) and Heidke Skill Score (HSS) metrics.

Conferences

International Workshop on Machine Learning and Computer Vision in Heliophysics, Sofia, Bulgaria, 19-21 April, 2023	Oral presentation
European Space Weather Week, Toulouse, France, 20-24 November, 2023	Oral presentation
American Geophysical Union, San Francisco, USA, 11-15 December, 2023	Oral presentation
ESA SPAICE Conference, European Centre for Space Applications and Telecommunications (ECSAT), UK, 17 – 19 September 2024	Oral presentation
European Space Weather Week, Coimbra, Portugal, 4-8 November, 2024	Oral presentation
American Geophysical Union, Washington D.C., USA, 9-13 December, 2024	Oral presentation