Francesco Pio Ramunno

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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

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

- Build the Near-Eath Objects database regarding their physical and chemical properties making automatic scripts for future data.
- Deploy machine learning algorithms (Random Forest, Decision Trees, XGBoost) to highlight correlations between the physical properties of asteroids and their orbital parameters and predict their physical composition by the orbit increasing the prediction accuracy of more than 100 % with respect to the classical analysis.

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

- Perform the morphological analysis on wavelet filtered maps and raw data coming from the XMM-Newton telescope and show data using wavelet techinques it is possible to have a more accurate measurements on the morphological parametrs of more than 30% compared to the analysis performed on raw data.

SKILLS

IT Languages	Python, Matlab, IDL
Lanuages	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

PROJECTS AND PUBLICATIONS

Super Resolution for Solar Data – *Ongoing Project*

- Apply novel super resolution algorithms to the magnetograms coming from the HMI instrument to upscale them by 4x in pixel space. We do this for being able to reconstruct the data after compression for transferring but also generations and to push the limits of the spatial resolution of the telescope,
- We develop a new Latent Denoising Diffusion Model approach predicting the residual difference between the down-sampled and original data and compare it with several baseline models, reaching state of the art result in terms of SSIM, LPIPS, PSNR and a series of physics metrics,
- We test this model to super-resolve the data from the MDI telescope which have natively 2"/pixel spatial resolution to upscale them and match the HMI spatial resolution of 0.5"/pixel. The results in terms of physics metrics and computer science metrics improve the previous deterministic models.
- We implement a novel technique in the Fourier space to truly test if the model can detect features smaller than 2" in the MDI data.

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

- We introduce a novel method to predict the evolution of the solar line-of-sight (LoS) magnetogram using image-to-image translation with Denoising Diffusion Probabilistic Models (DDPMs)
- The results indicate that DDPMs are effective in maintaining the structural integrity, the dynamic range of solar magnetic fields, the magnetic flux and other physical features such as the size of the active regions, surpassing traditional persistence models, also in flaring situation.
- One of the fundamental results is the possibility to obtain an uncertainty map for each prediction to see where the model struggles the most and connect it with the physics. The most difficult region is the Polarity Inversion Line, which is the most varying region during an eruptive events in the Sun.
- Finally we test our model auto-regressively and predict the day after based on the previous prediction and find its limitation after 4 days. In future work we want to tackle this limitation and introduce different types of information in input to improve the model.

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

- Use Denoising Diffusion Models to generate images as obtained by the SDO space telescope with a condition on their energetic content in terms of x-ray,
- After proven the physics validity of the generated images, we use them to augment lower represented classes (the more energetic) and train a classifier with the generated image as data augmentation, increasing the prediction accuracy of more than 50%, using the TSS and the HSS as score 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