PhD project in Computer Science and Engineering

Title of the Project: *"New accelerated and AI-powered transient search pipeline for Current and New Generation Radio Telescopes"*

Supervisor: Dr. Giovanni Naldi (INAF-IRA)

Description of the research project:

The study of astrophysical transient phenomena, such as Fast Radio Bursts (FRBs) and Pulsars, represents one of the key science topics of modern astronomical research. In particular, FRBs are among the most enigmatic and scientifically valuable transients, offering unique probes of the intergalactic medium, compact objects, and cosmology. Due to the large data volumes generated by the search for these events, especially in planned surveys for current and future radio telescopes, data processing and analysis must be conducted in real-time.

This requirement is especially critical at the Northern Cross radio telescope, which is undergoing a major technological upgrade that will significantly increase the number of usable receivers and formed beams. While this upgrade will dramatically expand instantaneous sky coverage and sensitivity, it will also produce a massive increase in data rates and computational load. Processing hundreds of beams in real time poses a critical challenge for existing GPU-based pipelines, demanding careful algorithmic and architectural optimization.

Modern technologies, such as parallel computing architectures, alongside emerging machine and deep learning-based algorithms, offer the suitable tools to tackle this challenge. It is of primary importance to develop innovative search techniques and real-time pipelines able to leverage these resources and maximize the scientific return. Therefore, the aim of this Ph.D. project is to design and implement a new scalable, flexible, GPU-based, real-time transient search pipeline composed of several processing stages, including RFI flagging and mitigation, dedispersion, event detection and classification, as well as data quantisation and persistence.

Building upon the Heimdall pipeline—currently deployed as the core real-time FRB detection engine at the Northern Cross—the project will optimize and extend this framework to enable scalable detection in the upgraded system. The Ph.D. candidate will profile the current pipeline, identify computational bottlenecks, and redesign key components of the dedispersion and candidate-search stages to improve GPU efficiency and memory throughput. Particular emphasis will be placed on multi-beam parallelisation strategies, load balancing across GPU resources, and minimizing latency while preserving detection sensitivity and reliability. This activity will combine astrophysical data analysis with advanced high-performance computing techniques, including CUDA programming, GPU memory management, and real-time streaming architectures.

To achieve this target, the candidate will work with the upgraded Northern Cross Radiotelescope, equipped with a state-of-the-art HPC cluster. The successful outcome will deliver a production-ready transient detection system capable of operating continuously at high data rates, directly enabling a new phase of wide-field FRB science. Crucially, the advanced high-performance computing techniques developed during this work may provide highly scalable and innovative solutions directly applicable to next-generation radio telescopes (e.g., SKA, LOFAR2.0, and CHORD), ensuring a broad, long-term impact on the field. Finally, a long-standing and fruitful collaboration with the University of Malta, the Astronomical Observatory of Cagliari, and the University of Bologna, as well as the recent partnership with the CHORD Collaboration, will constitute the fertile background for the development of this activity.

References:

[1] B. R. Barsdell, et al., “Accelerating incoherent dedispersion”, 2012

[2] D. Agarwal, et al., “FETCH: A deep-learning based classifier for fast transient classification”, 2020

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