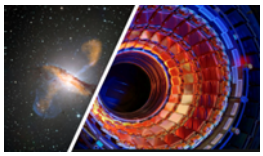


PhD course of National Interest in Technologies for Fundamental Research in Physics and Astrophysics

Annual report

Name and surname: Neeraj Yadav
Cycle and a.a.: 39th, 2024-2025
Supervisor: Dr. Stefano Bagnasco

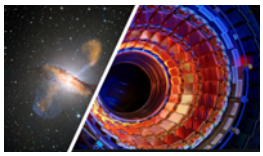
• Research activity carried out during the year

Describe the aim of the project (very briefly), discuss the research activity carried out during the year mentioning the difficulties encountered until now and the actions taken to face them. 1 page max in total.

I am working on two projects: Studying biases in the Inspiral-Merger-Ringdown consistency test and Comparison and Evaluation of scientific workflow management tools. With the objective of developing interdisciplinary expertise bridging advanced computing and GW astronomy, it all fits well with "Advanced computing systems for Gravitational wave research" which is the research topic of my PhD**.**

In the first project, I am a part of the TGR (Testing GR) group of the Ligo-Virgo-Kagra(LVK) collaboration. The aim of this study is to explore the biases in the Inspiral-Merger-Ringdown consistency test. It checks whether the inspiral and merger-ringdown parts of the GW signal from a BBH coalescence are mutually consistent with each other under the assumption that the sources are described by GR. The whole study can be broken into 3 steps. In the 1st step which involves creation of the injection file and 2nd step which involves processing that file, I mainly struggled with imposing the physical conditions in terms of code and the eventual errors I faced and resolved. For e.g. I used bilby (a Bayesian inference library) in which I had to make myself informed about different built-in functions, which error is caused by which function/logic in the bilby library. Basically, reading the documentation; resolving. In the 3rd step, which involves submitting analysis jobs to HT condor(a high-throughput computing software), I had a difficult start. Understanding the workings of HT condor, its different components, writing .ini files. Then, understanding and resolving the error encountered during the parameter estimation jobs. I have had help from my group members in both the coding and physics side of things. Currently, we are in the last phase of this work, and we expect that most of the work will be done by the end of this year.

In the second project, the aim is to assess a selection of scientific workflow management tools providing the Einstein Telescope collaboration with options should it decide to adopt one. Such a tool is a specialized software system designed to automate, manage, and track complex scientific computational processes, often referred to as workflows or pipelines. After careful consideration, I decided 4 such tools: Snakemake, Nextflow, Pegasus and REANA. I based this selection considering things like core functionality, user experience and how widely it is already used amongst other things. Since I have never worked with any of such tool in the past, it was both challenging and exciting. As a practical use case, I along with my supervisor decided to codify everything that I did manually in the IMRCT study in these tools. I handled all the difficulties I faced in Snakemake and Nextflow by myself going through the user documentation and searches on the web. But for Pegasus, I had to contact the



Pegasus help channel on Slack. Presently, I have the workflow ready in all the 4 tools. Recently, I succeeded in getting computing resources at CNAF, Bologna. Now, I will run large scale jobs to see how each handle things, artificially introduce problems to find the fault tolerance, error handling and debugging capacity of these tools.

- **List of attended courses and passed exams**

1. Advanced Scientific Computing in MATLAB (4 CFU)
2. Deep Networks and Structured Learning (2 CFU)
3. Machine Learning for Physics (3 CFU)
4. Soft Skills: How to Deliver Effective Presentations (3 CFU)

- **List of attended conferences, workshops and schools, with mention of the presented talks**

Conferences attended:

1. Einstein Telescope symposium XIV, May 6th to 10th 2024, Maastricht, Netherlands
2. XV Einstein Telescope Symposium, 26-30 May, 2025, Bologna, Italy

Schools attended:

1. SOSC 2024 Sixth International School on Open Science Cloud, Dec 2 – 6, 2024. University of Bologna, Department of Physics and Astronomy
2. CINECA Summer HPC School for Heterogeneous Computing 2025, June 30th to July 11th, 2025

Therefore, I have fulfilled all the "Educational Obligations of the PhD student" as mentioned in PhD TFPA: Regulations for training activities.

- **List of published papers/proceedings**

  None

- **Thesis title (even temporary): Systematic Biases in the IMR Consistency Test and Evaluating Workflow Systems for Scalable Gravitational Wave Data Analysis**

Date: 23/09/2025 **Signature**

Seen, the supervisor