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UNIVERSITÀ
DEGLI STUDI
DI PADOVA

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

Annual report

Name and surname: Maria Bazzicalupo

Cycle and a.a.: 39 , 2024/2025

Supervisor: Lorenzo Busoni

- **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.

My PhD project focuses on the development, implementation, and laboratory characterization of the *CiaoCiao* Wavefront Sensor (WFS), a rotational shearing interferometer proposed within the MORFEO project for the Extremely Large Telescope (ELT). The *CiaoCiao* WFS is designed to sense phase discontinuities across the pupil sectors of the ELT, overcoming a major limitation of conventional Shack–Hartmann sensors, which cannot measure phase jumps across the telescope spiders.

Over the first two years of my PhD, I have concentrated on both the theoretical understanding and the experimental validation of the *CiaoCiao* WFS. After an initial phase dedicated to optical design studies, I set up and optimized the laboratory bench at the Arcetri Astrophysical Observatory, successfully demonstrating the sensor concept with a monochromatic source. With the current setup, we were able to detect phase discontinuities as small as 3 nm between pupil islands over the full capture range at 633 nm.

During the second year, the laboratory activities were expanded significantly. We introduced turbulent conditions into the setup by generating air movements with fans, and we tested the system with different types of light sources to evaluate its robustness under realistic conditions. A further step currently in progress is the integration of an ALPAO 88-actuator



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deformable mirror into the optical bench. This will allow us to introduce known aberrations and turbulence patterns, providing a controlled environment to assess how effectively the CiaoCiao WFS can detect and characterize them.

A main challenge was to create realistic turbulence conditions in the lab. At first we simulated them with air flows, and now with the deformable mirror we want to reproduce them in a more controlled way. In this way is possible to refine the setup and better understand the limits and possibilities of the CiaoCiao WFS. In the project, I am personally responsible for the laboratory optical activities and the development of the data analysis software.

Since May, I have also been conducting a research stay in Canada, collaborating with the Adaptive Optics group of the Herzberg Astronomy and Astrophysics Research Centre (HAA) of the National Research Council Canada (NRC), based in Victoria, BC. Here I have been involved in observational activities and data analysis using the 1.2 m telescope equipped with the adaptive optics bench *REVOLT*. This activity has given me the opportunity to apply and further develop the expertise acquired during the lab-based phase in a real telescope environment. My main focus has been on acquiring and analyzing data for the gain scheduling camera (GSC), which enables a detailed study of the modulation of the pyramid WFS. This work aims to better understand the behavior of the pyramid sensor in the presence of non-common path aberrations and to compute its gain with high precision and mode-specific calibration. For this collaboration, I will stay in Canada until the end of October 2025.



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

- Fundamentals of system engineering and project management for large scientific projects, Prof. Xompero Marco Prof. Runa Antonio Briguglio Pellegrino
- Adaptive Optics for Astronomy, Prof. Arcidiacono Carmelo
- Deep Networks & Structured Learning, Prof. Basili Roberto
- Ottica adattiva per l'astrofisica, Prof. Busoni Lorenzo Prof. Esposito Simone
- Radio and optical interferometry, Prof. Fabrizio Massi Prof. Giovanni Comoretto

Additional Trasversal/Soft Skills Courses:

- The impact of my research: bridging knowledge to people needs - Prof. Davide Ederle -
Dott.ssa Ileana Borrelli , Direttrice Ufficio Terza Missione e Valorizzazione della Ricerca -
Dott.ssa Elena Pavan, Direttrice Ufficio Dottorato di Ricerca
- Public Speaking - Parla con efficacia, ispira con passione - Unismart Unipd (6/11/2025 - 8/11/2025)

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

- The ORP International school Observing with Adaptive Optics at Observatoire de Haute Provence in France from 29th September to 4th October 2024
- AO4ELT - Adaptive Optics for Extremely Large Telescopes 8 - October 27 to 31, 2025 - Viña del Mar, Chile

List of published papers/proceedings

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- **Thesis title (even temporary)**

Sensing phase discontinuities on ELT segmented pupil with a rotational shearing interferometer

Date, 13/09/2025

Signature

María Bazzicalupo

Seen, the supervisor

Lorenzo Buzzani
Gilberto