**Andrea Sacchi (INAF/IASF-Milano)**

- **Origin of X-ray variability in 2MASX J12571076+2724177**
  2MASX J12571076+2724177 is a galaxy hosting in its center a supermassive black hole that exhibits a quasi-periodic oscillation in its X-ray light curve. The goal of this project, assuming we are observing disc-instability-related phenomena, is to understand the possible origin of this modulation.

- **Multiwavelength properties of TDEs**
  Tidal disruption events (TDEs) occur when the tidal forces of a supermassive black hole disrupt a star. Today, roughly a hundred such sources are known, discovered in different electromagnetic bands. This project aims to collect all of the published multiwavelength properties of known TDEs. This preliminary effort will be key in future population studies of these phenomena.

**Andrea Geminardi (IUSS)**

- **From radio data mayhem to astrophysical signals**
  The study of the Universe in the radio band is performed with the largest telescopes on Earth. The huge amount of data collected and the presence of radio frequency interferences are the main challenges in radio observations. The situation is getting direr and direr with the electromagnetic pollution generated by satellite constellations. The aim of this project is to explore both the best algorithms to mitigate the radio interferences, and the newest approaches to identify genuine astrophysical signals with machine learning techniques.

**Guglielmo Mastroserio (IUSS)**

Black holes (BHs) are among the most fascinating and extreme objects in the universe. However, studying them is notoriously difficult, as they do not emit light—nothing can escape their gravitational pull. Smaller BHs, a few times the mass of our Sun, often form binary systems, where matter from a companion star is drawn in, forming an accretion disk before spiraling into the BH. Larger BHs, ranging from millions to billions of solar masses, are found in the centers of galaxies as part of active galactic nuclei (AGN), where they accrete material from their surroundings.
We study these systems by modeling the accretion process and analyzing the radiation emitted from the innermost regions of their accretion disks. The following projects explore both theoretical and observational aspects of these systems, with the shared goal of uncovering new insights into the behavior of accreting black holes.

Projects:

- **Outburst Alert (technical/coding project)**
  Stellar-mass black holes alternate between long periods of quiescence and bright X-ray outbursts. This project aims to analyze the recurrence patterns of these outbursts across various sources, helping to better understand their duty cycles and the physical mechanisms that trigger them. Additionally, the project involves developing an automated pipeline to detect and alert the scientific community when a source enters an outburst phase, thereby improving coordination for follow-up observations.

- **4U 1543 Spectral-Timing Analysis (observational project)**
  This project focuses on the 2021–2022 outburst of the black hole binary system 4U 1543. Observations were collected using X-ray telescopes (NICER and NuSTAR) and ground-based infrared facilities during the source's return to quiescence. A multi-wavelength spectral-timing analysis of this poorly studied phase may provide valuable insights into the physical processes governing outburst decay.

- **NuSTAR Deadtime Lag Simulation (coding and theoretical project)**
  The Nuclear Spectroscopic Telescope Array Mission (NuSTAR) NASA's hard X-ray observatory, is typically used to analyze the spectral energy distribution of accreting black holes. However, it can also probe rapid variability in these systems. This project investigates the time delays (lags) between different X-ray energy bands, specifically examining how NuSTAR's instrumental deadtime affects these measurements. Simulating and understanding these effects is essential for accurate timing analysis.

- **Reverberation Lag in Accreting BH (observational/modelling project)**
  X-ray emissions from accreting BHs can be split into direct radiation from near the BH and reprocessed radiation from the accretion disk. The time delay between these components, known as reverberation lag, contains information about the disk structure and geometry. This project applies cutting-edge reverberation models to stellar-mass BH data to extract key system parameters and improve our understanding of inner disk dynamics.

- **QPO Timescales in Accreting BH (observational project)**
  Quasi-periodic oscillations (QPOs) are a ubiquitous feature in the X-ray light curves of stellar-mass black holes. These timing signals evolve during outbursts, offering clues about the inner accretion flow. This project aims to compile a comprehensive catalog of QPO timescales across known

sources—gathering published values and analyzing raw data when necessary. The ultimate goal is to identify correlations between QPO properties and system parameters such as black hole mass or inclination.

- **Disk Realignment and Lense Thirring precession (theoretical/simulation project)**
  Quasi periodic oscillations (QPOs, see project above) are thought to be caused by Lense Thirring precession of the inner regions of the accretion disk due to the misalignment between the angular momentum of the disk and the spin of the black hole. These oscillations are observed to persist for hours or even days during outbursts. This project investigates whether such precession can remain stable over these timescales by modeling the disk's realignment process and evaluating the influence of the disk characteristics on this phenomenon.

- **Variability of the Polarised Signal (theoretical/technical project)**
  Recent observations by NASA's Imaging X-ray Polarimetry Explorer (IXPE) have detected polarized X-ray emission from several accreting black hole systems. Since X-ray radiation from these sources is highly variable—and much of this variability is believed to arise from changes in geometry—the degree and angle of polarization are also expected to vary over time. This project aims to assess IXPE's ability to detect such variability in the polarized signal, using innovative analysis techniques and simulations. The goal is to determine under which conditions polarization variability becomes measurable and what physical insights can be gained from it.

- **Swift J2127.4 a long AGN campaign (observational project)**
  Working in progress…

- **Study AGN variability with Gaussian processes (theoretical project)**
  Working in progress…

**Serena Farina (IUSS / IASF-Milano)**

Sviluppo e caratterizzazione di un prototipo di rivelatore ultravioletto per futura strumentazione astronomica.

**Giorgio Galanti (IASF-Milano / UniPV)**

Studi di fisica fondamentale in ambiente astrofisico.

**Luigi Capozza (U. Mainz)**

The P2 experiment aims at a precise determination of the electroweak mixing angle via parity violating electron proton elastic scattering at low momentum transfer. The experiment is right now under construction and is planned to start
taking data within the next three years at the new MESA electron accelerator in Mainz, Germany.

A variety of master thesis topics is available within the P2 project, involving activities which are typical for experimental particle physics, e.g. mounting and characterising detector modules, simulating particle detector response, developing and testing electronic components, developing and building data acquisition systems, developing and implementing experiment control software, etc..

A few examples of current topics are:

- Development and Commissioning of a Helicity Control System for Fast Polarization Switching of the MESA Beam

- Design and Testing of a Detector System for Beam Halo Studies

- Development of a Control System for the P2 Detector System Based on EPICS

- Development of a Modular AI Co-Pilot Architecture for Real-Time Anomaly Detection at the P2 Experiment

- Design and Implementation of a Standardized Interface for AI-driven Slow Control System Diagnostics

Depending on the starting time of the master thesis work and on the inclinations of the applicant, also other topics can be proposed.

Being a relatively small collaboration, P2 offers the rare possibility for students to get in touch with all aspects of a particle physics experiment and acquire a complete in-depth understanding of the involved methods and techniques.

The master thesis activities will mainly take place at the MAMI/MESA facility which is located on campus at the Johannes Gutenberg Mainz University (https://www.uni-mainz.de/en/), an internationally renowned educational institution with more than 30’000 students.