PHD PROGRAMME IN PHYSICS, ASTROPHYSICS, AND APPLIED PHYSICS
UNIVERSITÀ DEGLI STUDI DI MILANO
PhD Cicle 41 (2025-2026)

All lectures will be given in English.

Course title	Advanced topics in astrophysics and plasma physics - Observations of the Cosmic Microwave Background
Teacher in charge of the course	Bersanelli Marco
List of the teachers of the course	Bersanelli Marco, University of Milan, marco.bersanelli@unimi.it
Training objectives	• Provide an overview of the main experimental challenges involved in observations of the Cosmic Microwave Background (CMB) appropriate for a PhD student working out his/her research in a generic area of physics or astrophysics. • Describe the specific strategies in measurements of the CMB frequency spectrum, temperature anisotropies and polarization, and highlight their scientific impact. • Provide an overview of the current state-of-the-art and of future perspectives of CMB experiments. • Stimulate an interactive discussion with and among the students during the lectures and, where possible, identify interconnections with the research subject of each student.
Prerequisites	• There is no specific prerequisite other than being engaged in a research project at the level of a PhD student in Physics or Astrophysics. • For students with a specific background in CMB science, some more technical content will be provided. They will be also invited to contribute more actively to the discussions.
Detailed course program	• General definitions: flux density, antenna temperature, beam pattern. Discovery of the CMB and early observations • Measurements of the CMB frequency spectrum. Scientific motivations: blackbody spectrum and spectral distortions. Absolute calibration. Atmospheric contribution and Galactic foregrounds in absolute measurements. South Pole experiment, COBE/FIRAS. Total power and differential receivers. Radiometer equation. Systematic effects in absolute measurements: instability, straylight, atmospheric residuals, galactic foregrounds. State of the art and future perspectives. • Measurements of CMB anisotropies. Scientific motivations: origin of cosmic structures, measurement of cosmological parameters. Angular power spectrum, cosmic variance. CMB dipole. COBE/DMR, large and small scale anisotropies. Foregrounds for CMB anisotropies: dust, synchrotron, free-free, point sources. Dicke-switched radiometers, pseudo-correlation radiometers. Bolometric receivers. Cryogenic systems for CMB. Angular resolution and optical systems for CMB experiments. Ground based, balloon and space experiments. WMAP and Planck. • Measurements of CMB polarization. Motivations: cosmological parameters, probing inflation through B-modes. Experimental challenges in CMB polarization measurements. Galactic and extragalactic polarized foregrounds. CMB polarization from WMAP and Planck. State-of-the-art and future perspectives: large detector arrays from ground (Atacama, South Pole) and from space (LiteBIRD mission).
Examination modalities	The exam consists of a presentation by the student focusing on a topic treated in the course, previously agreed with the lecturer, followed by a general discussion. Students are encouraged to identify, if possible, connections (in content or methodology) between the topics discussed in the course and their own research area.

Preliminary schedule	The course is typically delivered in the second or third week of April. However, the timing can be agreed with the students depending on everyone's schedule. Course enrolment deadline: December 27, 2025.