First-Year PhD Report

Rojin Bayati

Supervisor: Prof. Marco Raveri

Research Overview

Nonlinear Corrections and Cosmological Parameter Inference from the CMB: The standard analysis of CMB anisotropies relies predominantly on linear perturbation theory, while nonlinear physical effects become increasingly important at small angular scales (high multipoles). In this research, I characterized the scale at which nonlinear corrections become significant and investigated their impact on cosmological parameter inference. In particular, I quantified the shifts in the inferred cosmological parameters when including multipoles beyond the nonlinear scale, comparing the results with analyses restricted to predominantly linear scales within the ΛCDM model. I further extended this analysis to cosmological models beyond ΛCDM, including massive neutrinos and the $w_0 w_a$ parameterization of dark energy. In these extended models, the inclusion of nonlinear scales resulted in negligible parameter shifts, indicating that their impact on cosmological parameter inference is limited within the considered analysis.

Dark Matter Halo Structure in Dwarf Spheroidal Galaxies: In this research, I collaborated with Prof Paolo Saluccci where we investigated the inner dark matter structure of dwarf spheroidal galaxies, focusing on the core-cusp problem and the possible presence of central compact objects. We compared cored and cuspy dark matter profiles, finding that the Burkert profile provides a significantly better description than the NFW profile for the studied systems. We further examined scaling relations between halo and stellar properties and constrained the possible presence of intermediate-mass black holes and nuclear stellar clusters in their central regions.

Courses and exams

1: **Experimental Methods in Astrophysics** Prof. Filippo Zerbi (PhD course)

2: **Large-Scale Structure Cosmology** Prof. Ravi Sheth (PhD course)

3: **Italian for International Students** Prof. Lorenzo Barbieri (PhD course)

4: **Italian Language and Culture** Prof. Silvano Tosi (PhD course)

5: **Soft Skills: Academic Paper Writing** Prof. Mario Marchese (PhD course) - Exam to be taken

Schools and conferences

1: **Theoretical Aspects of Astroparticle Physics, Cosmology and Gravitation** *(Florence, March 02 - 13, 2026)* The School was aimed at providing introductions on the basic theoretical concepts and main tools to work in the field of Astroparticle Physics, Cosmology and Gravitation. Gravitational waves of astrophysical and cosmological origin, neutrino physics and astronomy, early universe physics, dark matter and dark energy, galactic and extra-galactic cosmic rays and gamma-rays. I attended the lectures and tutored two exercise sessions of "Gravity and theoretical cosmology".

2: **Quadrilateral Cosmology Meetings** *(Genova, Dec. 2026)* Quarterly meetings aimed at keeping the Cosmology research groups from the departments of Genova, Milano, Torino and Parma updated.

3: **Talk by Ravi Sheth** *(Genova, April 2026)* This talk was titles "A standardizable rod for cosmology" and was about how baryon acoustic oscillations in the early universe leave a distinctive signature in the galaxy distribution at later times and therefore can be used to constrain the expansion history of the universe.

4: **Special Seminar by Serena Giardiello** *(Genova, April 15, 2026)* Seminar was about challenges in analyses and simulations of CMB data and modelling them to constrain fundamental physics with unprecedented precision.

Publications

Bayati, R., Salucci, P. (2026). Dark Halos, Intermediate-Mass BH and Nuclear Stellar Clusters in Dwarf Spheroidals. Universe, 12(7), 195. https://doi.org/10.3390/universe12070195

Other Activities

Trip to INAF Merate and MediaLario optics company:

- Visiting 1-meter Zeiss telescope from 1926
- Visiting various labs of telescope maintenance
- Learning and watching the process of manufacturing telescope mirrors and polishing them