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PhD Cycle: 36
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RESEARCH PROJECT: Investigating the Dark Energy properties combining primary cosmological probes: Galaxy Clustering and Weak Gravitational Lensing

The currently "concordance" cosmological model describes a flat universe, composed mainly by "Dark Energy" (≈ 69%) and "Dark Matter" (≈ 26%). Cosmological constant Λ, given by the equation of state $w=p/\rho=-1$ and Cold Dark Matter, made by particles like Weakly Interacting Massive Particles (WIMPS), are respectively the two natural choices which define the standard ΛCDM model. The main aim of this PhD project is to investigate the properties of these dark forms, by using different cosmological probes.

Focusing on small scale limit of the ΛCDM model and in continuity with my master thesis, I have used the semi-analytic model presented by Menci et al. (2018) to investigate how the introduction of Warm Dark Matter particles (WDM, with mass of the order of keV) affects the initial power spectrum P(k), with macroscopic consequences on early galaxy formation and Reionization process. In particular, free-streaming of WDM particles reduces the number density of low mass halos and faint galaxies, with implications on the UV Luminosity Function. The lower quantity of ionizing photons results in a delay in the reheating of neutral hydrogen; we have studied this aspect with respect to some recent observational results. For each cosmology, we have found an upper limit to f_{esc}, the escape fraction of ionizing photons, which guarantees the completion of the process at $z<6.7$. We also quantified the impact of different sources on Reionization, finding that, in CDM case, the bulk of ionizing photons is produced by galaxies with $M_{UV}>-20$ and halos with $M<10^{10.5}\ M_{sun}$, while in WDM scenarios we obtain a shift towards brighter sources. Future observational results, related to the high-z neutral hydrogen fraction and to the electron scattering optical depth measurement, could represent interesting tools in order to set constraints on the WDM particle mass. My results in the field are summarized in the paper Romanello et al. (2021), published by MDPI Universe on 29/09/2021.

The PhD project exploits also two main cosmological probes: Galaxy Clustering and Weak Gravitational Lensing. One of the most powerful tools of modern cosmology is the analysis of two-point correlation function, which measures the excess number of pairs of galaxies, as a function of separation, when compared to a random distribution. During this PhD year, I learned how to measure the two-point correlation function in different ways (real and redshift space, monopole and other multipoles etc.), which are available in the already existing codes for galaxy clustering, in CosmoBolognaLib (Marulli et al. (2016) arXiv:1511.00012v2).

The simplest of these point process statistics is the angular 2-point correlation function. Its advantage is that we can derive the clustering signal from photometric surveys alone, which allows us to probe both larger areas and higher redshifts, with respect to spectroscopic catalogs. Photometric redshift measurements allow us to perform also tomographic studies, which are closer to a full 3D reconstruction. Starting from the Athena (a code for second-order correlation functions estimation) results, I have implemented a new algorithm, for the measurement of the angular power spectrum, which is a projection of the 3D spatial power spectrum P(k).

In the next future we are planning:

1. the implementation of new likelihood modules, to model angular clustering, and the comparison between angular and 3D clustering. We will work with KiDS-DR4/DR5, and with Euclid Flagship mock galaxy catalogs, within the Euclid Consortium Galaxy Clustering Science Working Group, in order to calibrate the cosmological analysis pipelines of the survey;
2. the implementation of new algorithms to compute cosmic shear and galaxy-galaxy lensing, and of likelihood modules, to model weak lensing statistics;
3. to analyze the effect of WDM in cosmic shear and clustering, testing new codes on both simulations and KiDS data. In particular, the weak lensing power spectrum can eventually rule out low mass WDM particles;
4. a cosmological analysis on available data to estimate the parameters of ΛCDM model, as Ω_m and σ_8, or new cosmological constraints on the Dark Energy equation of state, the Dark Matter content, and on the initial power spectrum normalisation parameter.

WORKSHOPS, CONFERENCES & MEETINGS

- 18/11/2020-20/11/2020 Beyond Planck Release Conference
- 16/12/2020 Eduardo Banados. Quasars in the Epoch of Reionization
- 13/01/2021 GGI Tea Breaks. M. Kamionkowski. Is the Lambda-CDM model in trouble?

- 29/01/2021 M. Viceconti. How to write a scientific paper.
- 05/02/2021 M. Viceconti. How to give a scientific presentation
- 12/02/2021 M. Viceconti. What is a model?

- 15/02/2021-17/02/2021 4° Meeting Nazionale Collaborazione Euclid
- 25/03/2021 Italian workshop on MOSAIC
- 16/04/2021 Quid Ultra Seminar. J. Silk. The future of Cosmology
- 28/04/2021 GGI Tea Breaks. M. Lisanti. Galactic Archaeology and the Search for Dark Matter
- 14/06/2021-17/06/2021 SAZERAC 2 (Summer All-Zoom Epoch of Reionization Astronomy Conference)
- 22/06/2021 Quid Ultra Seminar. P. Madau. The dark and luminous side of structure formation

+47 other seminars (Phd Weekly, INAF-OAS and IRA)

My talks:

- 16/06/2021 Weekly PhD. Seminar
- 01/10/2021 Final year PhD talk
- 10/11/2021 (Planned). Invitation to *Universe* Special Webinaire keV Warm Dark Matter in Agreement with Observations in Tribute to Hector de Vega.

PhD SCHOOLS

12/07/2021-23/07/2021 International Summer School on the Interstellar Medium

of Galaxies, from the Epoch of Reionization to the Milky Way

INTERNAL COURSES

- 30/11/2020-02/12/2020 The interstellar medium
- 19/04/2021-23/04/2021 Gamma Ray Bursts: from observations to physical properties
- 5,6,7,10,12 and 14/05/2021, Writing, talking and presenting Science

ISA LECTURES

- 19/01/2021 S. Valenti. Extreme events: how to describe and predict them using mathematical theories
- 26/01/2021 M. Marcia. RNA: Biological Functions and Therapeutic Potential

PUBBLICATIONS

Romanello, M.; Menci, N.; Castellano, M. The Epoch of Reionization in Warm Dark Matter Scenarios. *Universe* **2021**, *7*, 365. https://www.mdpi.com/2218-1997/7/10/365