Course unit English denomination	Dark Matter
SS	PHYS-02/A - fisica teorica delle interazioni fondamentali, modelli, metodi matematici e applicazioni
Teacher in charge	Francesco D'Eramo, Marco Peloso Edoardo Vitagliano
Teaching Hours	24
Number of ECTS credits allocated	3
Course period	March - June 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (50% minimum of presence) ☐ No
Course unit contents	In the last few decades, there has been growing evidence for the existence of dark matter. This course introduces motivated dark matter paradigms that drive most current theoretical and experimental research activities. The lectures are aimed at Ph.D. students working on theoretical and/or experimental aspects of particle and astroparticle physics. The offer is tailored to meet their needs and their backgrounds. - Mod. A: Concise introduction to hot Big Bang cosmology and the thermal history of the Universe. We will first review the observational evidence for the current particle content of the Universe, including various complementary pieces of evidence for dark matter. Starting from basic knowledge of particle physics and statistical mechanics, it is possible to infer from these observations the behavior and properties of the universe when its age was much younger than just one second. These properties can be well understood only within the framework of cosmic inflation. We will review the simplest realizations of inflation and the reheating process that leads to the formation of a dominant thermal bath from the inflaton decays. We will show how it is possible during reheating to produce dark matter particles that are too weakly coupled to thermalize. - Mod. B: Thermal freeze-out paradigm. First, we will discuss hot dark matter and we will explain why it is not viable. Standard model neutrinos belong to

	this class, and they can only be a sub component. We will then investigate cold dark matter and review the motivation for weakly interacting massive particles (WIMPs). These particles reach thermal equilibrium with the bath at early times and therefore their couplings to standard model particles are a potential probe to test WIMP models. We will review experimental searches for WIMPs (also known as "Smash it-break it-shake it") and these include experiments at particle colliders, detection of cosmic rays by Earth- or satellite-based telescopes, and underground experiments searching for elastic scattering. - Mod. C: Feebly interacting particles (FIPs), which are both dark matter candidates and can solve additional open questions in particle physics; the QCD axion as a solution to the strong CP problem is a prominent example. We will describe the "Smash it-break it-shake it" searches in the axion case. Among other probes, we will focus on astrophysical searches for FIPs, their production in stars and transients (supernovae and neutron star mergers), and the observables associated with their production. We will discuss laboratory searches and some of the most promising new ideas in the direct detection of these elusive particles.
Learning goals	This course aims to introduce Ph.D. students to one of the most urgent questions to answer in fundamental physics: the one about the particle identity of dark matter. The target audience includes students working on both theoretical and experimental particle and astroparticle physics. The objectives of this course are to learn the observational evidence for dark matter, particle physics frameworks motivated from the top down, and their experimental tests.
Teaching methods	This course will consist of lecture-based instruction delivered through Blackboard, with students encouraged to actively engage during class
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (if applicable)	The exam will be a seminar on a topic chosen by the student during which lecturers will evaluate the comprehension of the topic itself and the entire program of the course.

Suggested readings

Additional information

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