Course unit English denomination	Observational Multimessenger Astrophysics
Teacher in charge (if defined)	Elisa Prandini Elisa Bernardini Livia Conti Chiara Sirignano
Teaching Hours	24 hours
Number of ECTS credits allocated	3 credits
Course period	02/2025 - 06/2025
Course delivery method	■ **In presence** ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	■ **Yes (50% minimum of presence)** ☐ No
Course unit contents	The course aims to provide solid knowledge of the main open questions driving current experimental research in astroparticle and gravitational wave physics, using an original, transversal approach: the multimessenger view. It explores interconnected topics, with a common focus on the experimental aspects of current research in the field. The course introduces key concepts, including the sources and properties of cosmic particles and of gravitational waves, as well as the properties of dark matter and dark energy. The challenge of detecting cosmic messengers forms the core of this course, offering a broad overview of the complex experimental techniques employed by the current generation of instruments, such as MAGIC, IceCube, Baikal, KM3NeT, LIGO, Virgo, Euclid and Roman Space telescopes. Recent experimental results on cosmic messengers (gamma-rays, neutrinos, gravitational waves), as well as dark matter and dark energy surveys, are reviewed in detail, with special emphasis on the experimental aspects and constraints. Finally, future experimental perspectives are outlined and contextualized in terms of the expected advancements in our understanding of the multimessenger universe.
Learning goals	• Evaluate different astrophysical environments as sources of astroparticles • Explain the main mechanisms of production and propagation of gamma rays, neutrinos, gravitational waves, and possible dark matter candidates • Assess qualitatively and quantitatively the various methodologies for detecting cosmic messengers • Identify the main features of next-generation detectors and their impact on the current observational landscape • Explain the main experimental techniques applied in large galaxy surveys. • Critically assess some recent experimental results
Teaching methods	The activities include classroom lectures using digital support, with the use of slides. Some lessons will be supplemented with audio-visual material.
Course on transversal, interdisciplinary, transdisciplinary skills	■ **Yes** ☐ No
Available for PhD students from other courses	■ **Yes** ☐ No
Prerequisites (not mandatory)	Basic knowledge of the theory of special relativity, elementary particle physics and their interactions, and nuclear physics is requested.

Examination methods (in applicable)	The final exam consists of the discussion of two articles, selected and presented by the student, covering various topics addressed during the course. The articles, agreed upon in advance with the lecturers, must explore the connections between different areas of research. The exam also includes some questions on all the topics covered throughout the course.
Suggested readings	• Thomas K. Gaisser, Ralph Engel, Elisa Resconi, Cosmic Rays and Particle Physics, Cambridge Uni. Press (2016), old book: https://galileodiscovery.unipd.it/permalink/39UPD_INST/prmo4k/alma990000040660206046 • Maurizio Spurio, Particle and Astrophysics, Springer (2015), Galileo discovery link: https://galileodiscovery.unipd.it/permalink/39UPD_INST/prmo4k/alma990024057240206046 • Felix A. Aharonian, Very high energy Cosmic Gamma Radiation (2004) https://galileodiscovery.unipd.it/permalink/39UPD_INST/prmo4k/alma990013728970206046 • De Angelis, Pimenta, An Introduction to Particle and Astroparticle Physics, Springer (2018), https://galileodiscovery.unipd.it/permalink/39UPD_INST/prmo4k/alma990031884740206046 • Scott Dodelson, Fabian Schmidt, Modern Cosmology, Elsevier (2020) https://galileodiscovery.unipd.it/permalink/39UPD_INST/prmo4k/alma990008568700206046 • Bond, C., Brown, D., Freise, A. *et al.* Interferometer techniques for gravitational-wave detection. *Living Rev Relativ* **19**, 3 (2016). https://doi.org/10.1007/s41114-016-0002-8 • Abbott, B.P. et al., “Prospects for observing and localizing gravitational-wave transients with Advanced LIGO, Advanced Virgo and KAGRA”, Living Rev Relativ 23, 3 (2020), https://doi.org/10.1007/s41114-020-00026-9
Additional information	The course is divided into the following four modules: - The High-Energy Universe (E. Prandini) - Astrophysical Neutrinos (E. Bernardini) - Gravitational Waves (L. Conti) - Experimental Aspects of Dark Matter and Energy Surveys (C. Sirignano)