Università degli Studi di Padova

ASTRONOMIA

Course unit English denomination	Adaptive Optics for Astronomy
SS	Fis/05
Teacher in charge (if defined)	Dr. Kalyan Kumar Radhakrishnan Santhakumari (INAF-Osservatorio Astronomico di Padova)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	April 2026
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80 % minimum of presence) ☐ No
Course unit contents	- Atmospheric Turbulence and its Effects - How to remove the effects of turbulence: Classical Adaptive Optics o Wavefront Sensors ▪ Tip-Tilt Sensors ▪ Shack-Hartmann ▪ Pyramid ▪ WFS Curvatures o Deformable Mirrors - Limitations of Classical Adaptive Optics - Laser Stars as References for Wavefront Sensors - Multi-Conjugate Adaptive Optics o Star-Oriented Systems

	o Layer-Oriented Systems - Wavefront Reconstruction o Interaction Matrix o Zonal Reconstruction o Modal Reconstruction
Learning goals	Adaptive optics is an interdisciplinary subject that spans contributions from real-time computing to astronomy to engineering and beyond. This course introduces adaptive optics in astronomy to graduate students.
Teaching methods	Lectures
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	----------
Examination methods (in applicable)	Final oral or written exam (to be defined later)
Suggested readings	ADAPTIVE OPTICS for ASTRONOMICAL TELESCOPES - JOHN W. HARDY - Oxford University Press 1998 Adaptive Optics for Astronomy: Principles, Performance, and Applications – Jacques M. Beckers – ANNUAL REVIEW OF ASTRONOMY AND ASTROPHYSICS Volume 31, 1993 - Additional study materials will be shared with participants during the course.
Additional information	-----------------------------

Course unit English denomination	Astrobiology
SS	Fis/05
Teacher in charge (if defined)	Dr. Michele Maris (INAF, OATS)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	March – april 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80 % minimum of presence) ☐ No
Course unit contents	Astrobiology: introduction, history, definition, links to planetary protection, philosophy/ethics. AB study object: origin, persistence, presence of life in the Universe, its revelation. NASA definition of life. Methodological problems of AB: irreducibility of the development of life to a problem of initial conditions, a single model of known life. Identification of chemophysical and thermodynamic constraints. The functional approach. Limits to the survival of terrestrial life and extension of terrestrial life to other environments (ex: Photosynthesis M Stars, laboratory models for other types of life), biosignatures. Time scale of the development of life on Earth. The building blocks of life and their availability outside the terrestrial environment, prebiotic synthesis (example of formamide), transport of building blocks (Late Heavy Bombardment), chirality problem. Panspermia or local evolution? What evolutionary models? Terrestrial environments as models of extraterrestrial environments. Observational strategy. Searching for H2O, The role of H2O in life: solvent and reagent. Search for potential habitats and biosignatures: within the Solar System Mars, Gas Giant Satellites, Dwarf Planets; and in exoplanets. Once a life

	model ($H2O$ + C) has been established which circumscribe criteria of presence and persistence, the following occur: planetary habitability, galactic habitability, planetary similarity indices (ESI). Planetary Habitability, Climatological models and evolution of the habitability of the planets of the solar system. Habitability of exoplanets. Minimum detectable biomass. Biosignature concept; choice of biosignatures; biosignature detection; significance of the biosignature. Generation of spectroscopic biosignatures in the context of atmospheric models; K-correlation method and row-by-row integration. Limits of observation of spectroscopic biosignatures. Tools for exobiosphere research: JWST, eELT, ARIEL, LIFE.
Learning goals	It is a highly multidisciplinary and interdisciplinary course that teaches to combine concepts of Physics, Biology, Astronomy, Geology and Philosophy
Teaching methods	Classical lectures and exercices
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	-----------
Examination methods (in applicable)	For the examination, students will be required to prepare a short presentation on a topic of their choice related to Astrobiology. Students will be required to make a copy of the presentation available to everyone following the course.
Suggested readings	1. The Astrobiology Primer 3.0 Cady et al. Astrobiology Volume 24, Issue S1 / March 2024 download: https://www.liebertpub.com/toc/ast/24/S1 2. Principles of Planetary Climates R.T.Pierrehumbert Cambridge University Press, 2010, ISBN 978-0-521-86556-2 3. Physics of Life National Academies of Sciences, Engineering, and Medicine 2022, Washington, DC: The National Academies Press.

ISBN 978-0-309-27400-5 | DOI 10.17226/26403
https://nap.nationalacademies.org/catalog/26403/physics-of-life

4. Planetary Astrobiology
   Edits. V. S. Meadows, G. N. Arney, B. E. Schmidt, and D. J. Des Marais
   THE UNIVERSITY OF ARIZONA PRESS, Tucson, 2020
   ISBN 9780816540068 (cloth)
5. Atmospheric Science and Introductory Survey (II edt.)
   J. M. Wallace, P. V. Hobbs
   2006, Elsevier
   ISBN 0-12-732951-X
6. Atmospheric Evolution on Inhabited and Lifeless Worlds
   D. C. Catling, J. F. Kasting
   2017, Cambridge University Press
   ISBN 978-0-521-84412-3

Additional information	---------------------

Course unit English denomination	Astrochemestry
SS	Fis/05
Teacher in charge (if defined)	Dr. Eleonora Bianchi (Center for Excellence, Munich)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	February /march 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80 % minimum of presence) ☐ No
Course unit contents	Introduction to Astrochemistry and overview of chemical processes (gas-phase, surface reactions). Radiative transfer principles and methods. The formation of a Sun-like star and its planetary system, chemistry in the pre-stellar phase.Chemical complexity in the proto-stellar phase and in planet-forming disks. Jets, outflows, chemistry of shocks. The future of astrochemistry: current challenges and future instruments.
Learning goals	To provide essential notions of astro-chemestry, a very multi-disciplinary topic not covered in our academic degrees
Teaching methods	Classical lectures and exercices

Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	----
Examination methods (in applicable)	----
Suggested readings	----
Additional information	----

Course unit English denomination	Astronomical Sites' Characterization
SS	Fis/05
Teacher in charge (if defined)	Prof. Sergio Ortolani (UniPD)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	May 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80 % minimum of presence) ☐ No
Course unit contents	Overview on the limitations of the astronomical observations due to the atmosphere: historical background.The wide scale dynamics of the atmosphere: Hadley and Ferrell cells. Climatic belts, ocean currents, location and characteristics of the main anticyclones. Summary of the atmospheric vertical structure: temperature profiles, inversion layers. Stability and Schwarzschild gradient. Convection in the atmosphere. Reynolds and Richardson numbers. Parameters for the characterization of the astronomical sites. Definitions, parameters priorities. Cloud coverage: definitions. Evaluation techniques from ground and from satellites. Temperature and humidity: evaluation, impact on the astronomical observations. The sky brightness: natural and artificial. The atmospheric turbulence: the development of the seeing and its main characteristics. Climatic variations at short-medium time. Short-time climatic changes (ENSO, NAO, solar activity) and long time (Milankovich cycles, lunar orbit). Evolution of the ozone layer. Specific analysis of the main astronomical sites. Cile: Paranal-La Silla. USA: Mt Graham, Mauna Kea, Antarctic, Dome C – Dome A. Europe: La Palma, italian sites.

Learning goals	Basic notions of ground-based astronomical observation stations and their characterization. Elements of meteorology.
Teaching methods	Classical lectures and exercices
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	-------------------
Examination methods (in applicable)	Short written report
Suggested readings	Power point and class notes available in moodle
Additional information	---

Course unit English denomination	Computational astrophysics
SS	Fis/05
Teacher in charge (if defined)	Elena Lacchin
Teaching Hours	12
Number of ECTS credits allocated	2
Course period	January- February 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	The course focuses on various computational techniques used in astrophysics and will be divided into two main modules. In the first module, the fundamental concepts of the most advanced techniques used in N-body astrophysics simulations will be introduced. Part of the time will be devoted to the implementation of these techniques, comparison between them and the use of NBODY6 for basic tests. The second module will focus on hydrodynamic codes, with the aim of illustrating the main methodologies and different approaches taken in this field. The Ramses hydrodynamic code will also be used to perform simple tests, such as the Sedov test.
Learning goals	Advanced computational techniques and their astrophysical applications

Teaching methods	Lectures and hands-on sessions
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	---------------
Examination methods (in applicable)	---------------------------------
Suggested readings	Slides https://github.com/ramses-organisation/ramses https://github.com/nbodyx/Nbody6ppGPU
Additional information	------------------------------

Course unit English denomination	Exoplanetary Astrophysics
SS	Fis/05
Teacher in charge (if defined)	Prof. Giampaolo Piotto (UniPD)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	June 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80 % minimum of presence) ☐ No
Course unit contents	After almost 30 years since the discovery of the first exoplanet orbiting around a solar type star, we have more than 5500 discovered exoplanets in more than 4000 exoplanetary systems. This research activity had and still has an exponential development, thanks to huge investments that, using numerous astrophysical observational techniques, allow us to not only discover more and more exoplanets, but also to measure their main parameters, to determine their bulk structure as well as to investigate the structure and composition of their atmosphere. The architecture of the exoplanetary systems has revolutionized our ideas on formation and evolution of exoplanets. Within the course, we will present the various detection techniques of exoplanets, the way we can measure their mass and radius, the orbital parameters and the techniques to study their atmospheres. We will discuss present knowledge on exoplanet frequency, how it depends on exoplanet properties, and parameters of their hosting stars. We will present the perspectives of present and future research in this field, both from Earth and Space.
Learning goals	The aim of the course is to present to the students the status of the art of exoplanet search and characterization, as well as provide them with the needed scientific elements to keep updated on future results and perspectives in this Astrophysics research field.
Teaching methods	Classical lectures and exercices
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No

Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	-------------------
Examination methods (in applicable)	Final oral exam
Suggested readings	Power point and class notes available in moodle
Additional information	-----------------------------

Course unit English denomination	Galaxy Formation and Evolution
SS	Fis/05
Teacher in charge (if defined)	Dr. Benedetta Vulcani (INAF, OAPD)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	March 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80 % minimum of presence) ☐ No
Course unit contents	The course aims to provide PhD students in Astronomy with an overview of the main findings regarding the formation and evolution of galaxies. In the first part, various concepts and quantities relevant to the study of galaxies will be introduced, such as the different indicators of the star formation rate, the main characteristics of the galaxies, and the various environments in which galaxies can be located. In the second part, a review of the main findings will be presented, giving an overall view of the state of the art. Galaxies will be characterized both from a global perspective and with spatially resolved data.
Learning goals	Knowledge of the possible evolutionary paths of galaxies at different epochs and in different environments.
Teaching methods	Classical lectures and exercices
Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	--
Examination methods (in applicable)	Presentation of a scientific paper relevant to the topic

Suggested readings	--
Additional information	--

Course unit English denomination	Hands-on Machine Learning with Python
SS	Fis/05
Teacher in charge (if defined)	Dr. Lorenzo Spina (INAF, OAFI)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	January-february 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	Fundamentals of Machine Learning. What is Machine Learning? Types of Machine Learning Systems Main pitfalls of Machine Learning.Preprocessing, Testing and Validating. Working with Real Data Supervised Learning. Performance Measures for Regression and Classification Linear and Polynomial Regression. Gradient Descent.Learning Curves. Regularisation. Support Vector Machines. Decision Trees. Ensemble Learning. Artificial Neural Networks Training Deep Neural Networks. Unsupervised Learning. Dimensionality Reduction. Clustering
Learning goals	Handling of machine learning echniques and their application to astrophysics.
Teaching methods	Classical lectures and exercices

Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Analysis of a dataset of the student's choice using one or more machine learning algorithms covered during the course
Examination methods (in applicable)	“Hands-On Machine Learning with Scikit-Learn, Keras, and Tensorflow”, Aurélien Géron
Suggested readings	--
Additional information	---

Course unit English denomination	Project management in science
SS	Fis/05
Teacher in charge (if defined)	Dr. Maria Bergomi (INAF-OAPD)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	February-March 2026
Course delivery method	☐ In presence ☐ Remotely ☒ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	After a general introduction on Project management, the course will be focused on its theory and application on scientific projects and in scientific research. Real examples of development and project management activities related to the development of ground-based astronomical projects and space-project will be shown and discussed. A class will be dedicated to schedule preparation tips&tricks using a specific SW tool (e.g. Microsoft Project) - General introduction to project management - Project management planning and tools Project Management Plan (PMP), Resource allocation and FTEs, Work Breakdown Structure (WBS), Work Packages (WPs), Product Breakdown Structure (PBS), Product Tree (PT), Cost management, Risk Management, Communication lines and tools, Schedule and Gantt chart

	- Project phases for a scientific instrument and related documentation and tools - Development of a schedule through dedicated software (e.g. Microsoft Project) - Brief introduction to Product Assurance
Learning goals	Learning of different project management techniques, methodologies and keywords, to be applied to small or large scale projects and, more in general, to everyday scientific activities. Learning to be able to respond to requests coming to partecipants of large projects and in the preparation of proposals for projects funding. Learning of the different phases in a scientific project.
Teaching methods	Lectures, possibly work groups
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	-
Examination methods (in applicable)	Examination will focus on question related to the topic covered in the course
Suggested readings	Slides Other material will be given during the course
Additional information	--

Course unit English denomination	Designing multi-sensory public engagement activities
SS	Fis/05
Teacher in charge (if defined)	Dr. Anita Zanella (INAF OAPD)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	March April May 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	The course will be divided in two parts: a theoretical first part and a practical second part. The final exam will follow. Theoretical part: The course will start by discussing what is public engagement and its importance for both researchers and society. The participants will then be presented with different techniques that can be used for engaging the public. They will learn how to design an activity by using one (or more) of these techniques, namely how to transform an initial astronomical concept into an interactive and engaging activity for the public. They will also be presented with the motivations, benefits, and challenges of using multi-sensory approaches. Practical part: The participants will be given a specific astronomical topic (e.g. time) and they will select an age group (e.g. elementary school pupils). They will choose their preferred technique, among the ones presented in the theoretical part of the course, and they will be guided to create their own activity. The activities designed and created by the participants will be presented to the “Festival di Astronomia”, an astronomy festival that is held yearly in Castellaro Lagusello (Mantova), the second weekend of June. The participants in this course will teach selected high-school

	students about the activities that they have designed. The high-school students will then carry out the activities during the festival. Such an approach has proven very successful during the past editions of the festival (www.astronomiacastellaro.oapd.inaf.it) and it has risen the attention of several international organisations and institutes.
Learning goals	- understand what is public engagement - discover the benefits and challenges of using a multi-sensory approach when doing outreach (and research) - learn how to transform a scientific concept into an hands-on, multi-sensory activity for the public and for the schools - learn effective communication techniques - understand the importance of accessibility, equity, and inclusion, and how to achieve them when communicating your research
Teaching methods	Classical lectures and exercices
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	None
Examination methods (in applicable)	Practical
Suggested readings	Slides and bibliography provided by the lecturer
Additional information	None

UNIVERSITÀ DEGLI STUDI DI PADOVA

ASTRONOMIA

Course unit English denomination	Stellar Populations
SS	Fis/05
Teacher in charge (if defined)	Dr. Alessia Moretti (INAF, OAPD)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	May 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	The course aims to provide students of the PhD course in Astronomy with the concepts underlying the study of stellar populations. The course will be divided into two sub-modules: the first dedicated to the analysis of resolved stellar populations, with reference to the stellar evolution of stars with different mass and chemical composition and their distribution in the color-magnitude diagram. A second part of the course will deal with unresolved stellar populations, and how they can be used to interpret the photometric and spectral characteristics of galaxies (colors, spectral indices, SED fitting).
Learning goals	Applications of the Stellar Evolution theory to composite and complex stellar populations.
Teaching methods	Classical lectures and exercices

Course on transversal, interdisciplinary, transdisciplinary skills	☐ Yes ☒ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	
Examination methods (in applicable)	The examination will consist in an oral presentation and discussion of a scientific paper dealing with the contents of the course. The paper needs to be previously approved by the teacher. Further questions on the contents of the course can be made, if needed.
Suggested readings	Slides given by the teacher
Additional information	---------------------------------------

UNIVERSITÀ DEGLI STUDI DI PADOVA

ASTRONOMIA

Course unit English denomination	Writing and Communicating your Science
SS	Fis/05
Teacher in charge (if defined)	Dr. Henri Boffin (ESO, Munich)
Teaching Hours	16
Number of ECTS credits allocated	2
Course period	February 2026
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit contents	Although this is often dismissed, there is no science without communication and no successful scientists without good writing and presentation skills. You can do the best science that exists, if you don't write papers about it – papers that get cited! – and if you don't give presentations that impress people, your science will likely be ignored. Moreover, if you do not write convincing proposals that appeal to non-specialists, you won't get observing time, nor the coveted post-doc position and certainly not the very competitive but needed grants to fund your research. Finally, as a scientist, it is your duty and privilege to communicate your science to the general public, policy makers and the media, and like all the rest, this is something that needs to be learned. The course is structured as follow: How to write convincing and nice papers and proposals How to give stunning presentations How to communicate with the public

Learning goals	This course is not about the publication landscape in astronomy nor about the technical aspects of writing and formatting a paper, but about how to get your message across in the various supports you need to use as a scientist. At the end of the week, you will be able to write more easily convincing papers and give stunning presentations. You will also learn how to deal with various publics.
Teaching methods	Classical lectures and exercices
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	--
Examination methods (if applicable)	--
Suggested readings	Suggestions for follow-up reading will be provided during the course.
Additional information	The students are encouraged to send to the lecturer, prior to the course, a small text with a title, 3 paragraphs and a figure to explain what their PhD project is, or if they prefer, what their Master thesis was about. In addition, if they have one, they should also send the slides of a talk they gave.

UNIVERSITÀ DEGLI STUDI DI PADOVA

ASTRONOMIA

Course unit English denomination	Gravitational Waves
SS	FIS/05
Teacher in charge (if defined)	Daniele Bertacca
Teaching Hours	12
Number of ECTS credits allocated	2
Course period	June/July 2025
Course delivery method	☒ In presence ☐ Remotely ☐ Blended
Language of instruction	English
Mandatory attendance	☒ Yes (80% minimum of presence) ☐ No
Course unit Contents	- Introduction to Gravitational Waves - Definition of Gravitational wavefronts - Linearized theory (in vacuum) - A short introduction to Post-Minkowskian Theory (Weak Field approximation) - Definition of near and wave zone - Short derivation of radiation formulas - Gravitational radiation in the limit of high frequency - Gravitational Waves in curved spacetime - Gravitational Wave energy (stress-energy tensor for gravitational waves) - Gravitational waves from astrophysical sources: general discussion [Gravitational waves from a binary star system] - Geometric optics (shortwave approximation) - Null Vector fields: Geodesic null convergences - Measurement of gravitational-wave polarizations - Gravitational waves as exact solutions of Einstein field equations

	- Brief introduction to the Stochastic Gravitational Wave Background, and its cosmological (e.g. inflation, phase transition) and astrophysical origin.
Learning goals	The field of gravitational wave physics has grown rapidly after the LIGO/Virgo collaboration detected for the first time in 2015 the gravitational waves emitted by the merger of a black hole binary system. Gravitational Waves are emitted not only by the merging of astrophysical compact objects (Black Holes, Neutron Stars, Core Collapse SN, etc) but also from early universe mechanisms, like inflation, phase transitions, etc. In this course we will provide a broad and comprehensive training in both theory and experiments in gravitational wave physics: we will introduce what gravitational waves are, review the main astrophysical and cosmological sources, and how we can model and describe them. At the end of the course, the PhD students will be familiar with the most important concepts of gravitational waves, their main physical properties and their main implications. The tools the students will acquire will allow them to solve problems related to the specific subject of the course, but they will allow the students also to acquire some knowledge to face more general issues, e.g. those which might resemble the same approximation schemes learned during the course.
Teaching methods	Both blackboard and slides will be used
Course on transversal, interdisciplinary, transdisciplinary skills	☒ Yes ☐ No
Available for PhD students from other courses	☒ Yes ☐ No
Prerequisites (not mandatory)	Minimal knowledge of special and general relativity and cosmology
Examination methods (in applicable)	Presentation/talk on a topic presented during the lectures
Suggested readings	Papers and books related to the topic presented during the lectures
Additional information	----------------