

DOCTORAL STUDIES COURSE UNIT DESCRIPTION

Name of subject	Scientific Field	Faculty	Center/Institute/ Department
Selected Topics in Astrophysics (10 ECTS credits)	Physics N 002	Faculty of Physics	Institute of Theoretical Physics and Astronomy
Student's workload	Hours	Student's workload	Hours
Lectures		Consultations	30
Individual study	200	Seminars	20

Course annotation
I. Modern Instrumental Astrophysics The main focus is on the current era of data-driven observational astrophysics, where major scientific advances are increasingly driven by large surveys and science-ready archives. Students will explore the most modern observational techniques across the electromagnetic spectrum, including precision spectroscopy, wide-field photometry, time-domain monitoring, high-angular-resolution imaging (adaptive optics and interferometry), and high-energy observations. Emphasis is placed on how modern results are obtained in practice, including survey design, observing strategies, archive-based science, and cross-matching of heterogeneous datasets. The module also introduces major ongoing and next-generation facilities and surveys, with particular attention to large spectroscopic programmes such as WEAVE, 4MOST, and SDSS, and to space missions including TESS, PLATO, and JWST, as well as future flagship facilities such as Rubin/LSST, Euclid, Roman, Athena, ARIEL, and the ELT. II. Modern Methods of Stellar and Galactic Astrophysics This part of the course focuses on the astrophysical science enabled by modern high-precision datasets, with emphasis on stellar variability and Galactic archaeology in the era of large statistical samples. Students will explore the principles, methods, and current advances of Galactic archaeology, combining kinematics and detailed chemical abundances to reconstruct the formation history, dynamical structure, and chemical evolution of the Milky Way. Students will examine the physical mechanisms driving stellar variability, including pulsations, rotation, magnetic activity, and binarity, and how these processes are diagnosed using time-domain photometry, asteroseismology, and complementary spectroscopy. Particular attention is given to the most recent theoretical frameworks used to interpret these observations, including state-of-the-art chemodynamical models of galaxy formation and evolution. III. Exoplanets and Gravitational Lensing This part of the course introduces students to the key methods used to detect and study exoplanets, as well as the principles of gravitational lensing. Students will know how transit and radial velocity techniques work, how precision photometry and spectroscopy reveal planetary sizes, masses and atmospheric properties, and how methods such as secondary eclipses, phase curves, and direct imaging provide additional insights. The course covers major exoplanet

missions including TESS, PLATO, JWST, and ARIEL, and how they contribute to planetary detection and atmospheric characterization. Emphasis is placed on how these space missions complement modern ground-based spectroscopy and high angular resolution imaging. Students will be introduced to gravitational lensing across strong, weak, and microlensing regimes. They will learn how microlensing events caused by stars, stellar remnants or free-floating planets reveal distant planetary systems, including cold and wide orbit planets. The module also presents the observing strategies of surveys such as OGLE and MOA, and the expected advances from the Roman Space Telescope.

IV. Extragalactic Astrophysics and Frontiers

This section encompasses the key present-day topics of extragalactic astrophysics, including the early formation and evolution of galaxies and the properties and impact of active galactic nuclei (AGN) on galaxy evolution. Students will learn about the discoveries made by major present-day facilities such as JWST, ALMA and XRISM in the extragalactic domain, including the properties of most distant galaxies, the evolution of star formation rates across the age of the Universe, the motion of gas from intergalactic medium down to the galactic nucleus scales, the formation and properties of AGN, the formation of their outflows and the AGN impact on the host galaxy properties. The module will also investigate modern numerical simulation techniques and their major results, with particular attention to galaxy-scale and cosmological simulations. The students will explore how simulations and observations complement each other in helping us understand the evolution of galaxies and large-scale structure of the Universe over multi-billion-year timescales.

List of literature

Observational astrophysics / P. Lena, F. Lebrun, F. Mignard, 2020 edition
 Astrophysical Techniques Kitchin, C. R., 2020 edition
 The Exoplanet Handbook. Perryman M. Cambridge University Press; 2011.
 Gravitational Lensing. Dodelson S. Cambridge University Press; 2017
 Supermassive Black Holes. King A. Cambridge University Press, 2023

List of additional literature

Subject review papers from Annual Reviews of Astronomy & Astrophysics, New Astronomy Reviews and other subject journals, selected according to the exact topic under investigation.

Subject presentation and method of payoff

Consulting teachers (alphabetically)	Scientific degree	Pedagogical name	Main scientific works published in a scientific field in last 5 year period
Šarūnas Mikolaitis	PhD	Associate professor	1. Tautvaišienė, G., Viscasillas Vázquez, C., Mikolaitis, Š., Stonkutė, E., Minkevičiūtė, R., Drazdauskas, A., & Bagdonas, V., Abundances of neutron-capture elements in thin- and thick-disc stars in the solar neighbourhood, 2021, Astronomy and Astrophysics, 649

			2. Ambrosch, M., Guiglion, G., Mikolaitis, Š., Chiappini, C., Tautvaišienė, G., Nepal, S., Gilmore, G., Randich, S., Bensby, T., Bayo, A., Bergemann, M., Morbidelli, L., Pancino, E., Sacco, G. G., Smiljanic, R., Zaggia, S., Jofré, P., & Jiménez-Esteban, F. M., The Gaia-ESO Survey: Chemical evolution of Mg and Al in the Milky Way with machine learning, 2023, <i>Astronomy and Astrophysics</i>, 672 3. Tautvaišienė, G., Mikolaitis, Š., Drazdauskas, A., Stonkutė, E., Minkevičiūtė, R., Pakštienė, E., Kjeldsen, H., Brogaard, K., Chorniy, Y., von Essen, C., Grundahl, F., Ambrosch, M., Bagdonas, V., Sharma, A., & Viscasillas Vázquez, C., Chemical Composition of Bright Stars in the Northern Hemisphere: Star-Planet Connection, 2022, <i>The Astrophysical Journal Supplement Series</i>, 259 4. Tautvaišienė, G., Drazdauskas, A., Bragaglia, A., Martell, S. L., Pancino, E., Lardo, C., Mikolaitis, Š., Minkevičiūtė, R., Stonkutė, E., Ambrosch, M., Bagdonas, V., Chorniy, Y., Sanna, N., Franciosini, E., Smiljanic, R., Randich, S., Gilmore, G., Bensby, T., Bergemann, M., Gonneau, A., Guiglion, G., Carraro, G., Heiter, U., Korn, A., Magrini, L., Morbidelli, L., & Zaggia, S., Gaia-ESO Survey: Detailed elemental abundances in red giants of the peculiar globular cluster NGC 1851, 2022, <i>Astronomy and Astrophysics</i>, 658 5. Tautvaišienė, G., Drazdauskas, A., Mikolaitis, Š., Minkevičiūtė, R., Stonkutė, E., Randich, S., Bragaglia, A., Magrini, L., Smiljanic, R., Ambrosch, M., Bagdonas, V., Casali, G., Chorniy, Y., & Viscasillas Vázquez, C., Carbon and nitrogen as indicators of stellar evolution and age: A homogeneous sample of 44 open clusters from the Gaia-ESO Survey, 2025, <i>Astronomy and Astrophysics</i>, 703 6. Heiter, U., Lind, K., Bergemann, M., Asplund, M., Mikolaitis, Š., Barklem, P. S., Masseron, T., de Laverny, P., Magrini, L., Edvardsson, B., Jönsson, H., Pickering, J. C., Ryde, N., Bayo Arán, A., Bensby, T., Casey, A. R., Feltzing, S., Jofré, P., Korn, A. J.,
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			Pancino, E., Damiani, F., Lanzafame, A., Lardo, C., Monaco, L., Morbidelli, L., Smiljanic, R., Worley, C., Zaggia, S., Randich, S., & Gilmore, G. F., Atomic data for the Gaia-ESO Survey, 2021, Astronomy and Astrophysics, 645 7. Brogaard, K., Pakštienė, E., Grundahl, F., Mikolaitis, Š., Tautvaišienė, G., Slumstrup, D., Talens, G. J. J., VandenBerg, D. A., Miglio, A., Arentoft, T., Kjeldsen, H., Janulis, R., Drazdauskas, A., Marchini, A., Minkevičiūtė, R., Stonkutė, E., Bagdonas, V., Fredslund Andersen, M., Jessen-Hansen, J., Pallé, P. L., Dorval, P., Snellen, I. A. G., Otten, G. P. P. L., & White, T. R., Properties of the Hyades, the eclipsing binary HD 27130, and the oscillating red giant ϵ Tauri, 2021, Astronomy and Astrophysics, 645
Edita Stonkutė	PhD	Associate professor	1. Wicker, M., Wyrzykowski, Ł., Hundertmark, M., Rybicki, K. A., Zieliński, P., Stonkutė, E., Ihanec, N., Maskoliūnas, M., Bachelet, E., Kruszyńska, K., Dominik, M., Buckley, D. A. H., Gezer, I., Gromadzki, M., Mikołajczyk, P., Kotysz, K., Majumdar, J., Pakštienė, E., Zdanavičius, J., Čepas, V., Jonauskaitė, et al., Gaia20fnr: A binary-lens microlensing event with full orbital motion revealed by four space telescopes, 2026, arXiv e-prints, 2. Bale, B., Tautvaišienė, G., Minkevičiūtė, R., Drazdauskas, A., Mikolaitis, Š., Stonkutė, E., and Ambrosch, M., Chromospherically active stars: Lithium and CNO abundances in northern RS CVn stars, 2025, Astronomy and Astrophysics, 703, A128 3. Sharma, A., Stonkutė, E., Drazdauskas, A., Minkevičiūtė, R., Mikolaitis, Š., Tautvaišienė, G., and Jonauskaitė, U., Chemical composition of planetary hosts: II. Abundances of neutron-capture elements, 2025, Astronomy and Astrophysics, 701, A153 4. Sharma, A., Stonkutė, E., Drazdauska, A., Minkevičiūtė, R., Mikolaitis, Š., Tautvaišienė, G., and Narbuntas, T., Chemical composition of planetary hosts: C, N, and α-element abundances, 2024, Astronomy and Astrophysics,

			5. Maskoliūnas, M., Wyrzykowski, Ł., Howil, K., Mikołajczyk, P. J., Zieliński, P., Kaczmarek, Z., Kruszyńska, K., Jabłońska, M., Zdanavičius, J., Pakštienė, E., Čepas, V., Rybicki, K. A., Janulis, R., Stonkutė, E., et al., Lens Mass Estimate in the Galactic Disk Extreme Parallax Microlensing Event Gaia19dke, 2024, Acta Astronomica, 74, 77 6. Tautvaišienė, G., Mikolaitis, Š., Drazdauskas, A., Stonkutė, E., Minkevičiūtė, R., Pakštienė, E., Kjeldsen, H., Brogaard, K., Chorniy, Y., von Essen, C., Grundahl, F., Ambrosch, M., Bagdonas, V., Sharma, A., and Viscasillas Vázquez, C., Chemical Composition of Bright Stars in the Northern Hemisphere: Star-Planet Connection, 2022, The Astrophysical Journal Supplement Series, 259, 45 7. Randich, S., Gilmore, G., Magrini, L., et al., Stonkute, E., Sutorius, E., Thévenin, F., Tosi, M., Tsantaki, M., Vink, J. S., Wright, N., Wyse, R. F. G., Zoccali, M., Zorec, J., Zucker, D. B., and Walton, N. A., The Gaia-ESO Public Spectroscopic Survey: Implementation, data products, open cluster survey, science, and legacy, 2022, Astronomy and Astrophysics, 666, A121
Kastytis ZubovasKastytis Zubovas	PhD	Associate professor (VU) / Chief researcher (FTMC)	1. M. Tartėnas, K. Zubovas, E. Skuodas. Simple relations from complex outflows: How the M-σ relation emerges in a multi-phase environment. 2026, Astronomy & Astrophysics, 705, A118 2. K. Zubovas, M. Tartėnas. Active galactic nucleus outflows accelerate when they escape the bulge. 2025, Astronomy & Astrophysics, 703, A230 3. K. Zubovas, M. Tartėnas, M. A. Bourne. The complex effect of gas cooling and turbulence on AGN-driven outflow properties. 2024, Astronomy & Astrophysics, 691, A151 4. M. Laužikas, K. Zubovas. Slow and steady does the trick: Slow outflows enhance the fragmentation of molecular clouds. 2024, Astronomy & Astrophysics, 690, A396

			5. K. Zubovas, G. Maskeliūnas. Life after AGN switch off: evolution and properties of fossil galactic outflows. 2023, Monthly Notices of the Royal Astronomical Society, 524, 4819-4840 6. M. Bischetti, F. Fiore, C. Feruglio, V. D'Odorico, N. Arav, T. Costa, K. Zubovas, G. Becker, S. E. I. Bosman, G. Cupani, R. Davies, A.-C. Eilers, E. P. Farina, A. Ferrara, M. Gaspari, C. Mazzucchelli, M. Onoue, E. Piconcelli, M. V. Zanchettin, Y. Zhu. The Fraction and Kinematics of Broad Absorption Line Quasars across Cosmic Time. 2023, The Astrophysical Journal, 952, 44 7. K. Zubovas, J. Bialoperavičius, M. Kazlauskaitė. Determining active galactic nucleus luminosity histories using present-day outflow properties: a neural network-based approach. 2022, Monthly Notices of the Royal Astronomical Society, 515, 1705-1722
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Committee Chairman Prof. Habil. Dr. Jūras Banys			