DOCTORAL STUDIES COURSE UNIT DESCRIPTION

Name of subject	Scientific Field	Faculty	Center/Institute/ Department
Stellar Physics and Evolution (8 ECTS credits)	Physics N 002	Faculty of Physics	Institute of Theoretical Physics and Astronomy
Student's workload	Hours	Student's workload	Hours
Lectures		Consultations	36
Individual study	160	Seminars	4

Course annotation

Stellar structure and evolution: synthesis of theoretical modeling and observations. Equations of hydrodynamics. Discretization of hydrodynamical equations: finite-difference methods; stability of finite-difference methods; numerical diffusion, dispersion and grid resolution limit. Numerical hydrodynamics. Characterization of the radiation field: radiative transfer equation and its solutions; moments of the transfer equation; lambda-operator; diffusion approximation. Interaction between radiation and matter: emission; absorbtion; scattering; photoionization and recombination; astrophysical opacities. Numerical solution of the radiative transfer equation: Feautrier; lambda-operator; ALI methods. Radiative transfer in stellar atmospheres: local thermodynamic equilibrium; grey atmosphere; continuum and spectral line formation; numerical stellar model atmospheres; non-local thermodynamic equilibrium. Methods of spectroscopic analysis of stellar atmospheres. Main codes for stellar atmosphere modeling and spectral line synthesis.

Equation of state of stellar matter. Nuclear reactions in stellar interiors. Energetic equilibrium of stars. Effects of mixing: convection; semiconvection; thermohaline convection; influence of rotation. Hydrodynamical instabilities and transfer processes: diffusion; advection; meridional circulation; rotation- and magnetic field-induced instabilities. Propagation of accoustic waves in stellar interiors. Radial and non-radial stellar pulsations. Methods of asteroseismology.

Formation of stars and evolution to main sequence: pre-stellar phase; protostellar phase, accretion discs; pre-main sequence evolution; formation of rotating and massive stars; formation and evolution of first stars. Main sequence evolution of low-mass stars: hydrogen burning cycles; basic properties of main sequence stars; solar properties and evolution. Post-main sequence evolution of low-mass stars: red giant branch, horizontal branch, asymptotic giant branch; effects of rotation and mixing; nucleosynthesis in asymptotic giant branch stars; planetary nebulae; white dwarfs. Evolution of massive stars: main sequence evolution; effects of rotation and mass loss; WR stars; C, Ne, O, Si burning cycles; nucleosynthesis of chemical elements. Type I and II supernovae, explosive nucleosynthesis. Evolution of zero-metallicity stars. Methods and main codes for numerical modeling of stellar evolution.

List of literature

1. Aerts C., Christensen-Dalsgaard J., Kurtz D.W. Asteroseismology. Springer. 2010. 866 p.
2. Bodenheimer P., Laughlin G.P., Rozyczka M., Yorke H.W. Numerical Methods In Astrophysics. Taylor & Francis. 2007. 352 p.
3. Cassisi S., Salaris M. Old Stellar Populations. Willey-VCH. 2013. 521 p.
4. Hubeny I., Mihalas D. Theory of Stellar Atmospheres. Princeton University Press. 2015. 923 p.

Consulting teachers	Scientific degree	Pedagogical name	Main scientific works published in a scientific field in last 5 year period
Arūnas Kučinskas	Dr.	Prof.	1. Kučinskas, A., Klevas, J., Ludwig, H.-G., Bonifacio, P., Steffen, M., Caffau, E. 2018, Using the CIFIST grid of CO5BOLD model atmospheres to study the effects of stellar granulation on photometric colors. II. The role of convection across the H-R diagram // Astronomy & Astrophysics, 613, A24. 2. Bonifacio, P., Caffau, E., Ludwig, H.-G., Steffen, M., Castelli, F., Gallagher, A., Kučinskas, A., Prakapavičius, D., Cayrel, R., Freytag, B., Plez, B., Homeier, D. 2018, Using the CIFIST grid of CO5BOLD model atmospheres to study the effects of stellar granulation on photometric colors. I. Grids of the 3D corrections in the UBVRI, 2MASS, HIPPARCOS, Gaia and SDSS systems // Astronomy & Astrophysics, 611, A68. 3. Wedemeyer, S., Kučinskas, A., Klevas, J., Ludwig, H.-G. 2017, Three-dimensional hydrodynamical CO5BOLD model atmospheres of red giant stars. VI. First chromosphere model of a late-type giant // Astronomy & Astrophysics, 606, A26. 4. Černiauskas, A., Kučinskas, A., Klevas, J., Prakapavičius, D., Korotin, S., Bonifacio, P., Ludwig, H. -G., Caffau, E., Steffen, M. 2017, Abundances of Na, Mg, and K in the atmospheres of red giant branch stars of Galactic globular cluster 47 Tucanae // Astronomy & Astrophysics, 604, A35 5. Klevas, J., Kučinskas, A., Steffen, M., Caffau, E., Ludwig, H.-G. 2016, Lithium spectral line formation in stellar atmospheres. The impact of convection and NLTE effects // Astronomy & Astrophysics, 586, A156.
Certified during Doctoral Committee session 02/02/2022, protocol No. (7.17 E) 15600-KT-32			
Committee Chairman prof. S. Juršėnas			