*Univerza v Novi Gorici*
*Fakulteta za naravoslovje*

*University of Nova Gorica*
*School of Science*

| **UČNI NAČRT PREDMETA / COURSE SYLLABUS** | |
|---|---|
| **Predmet:** | Astrofizika zvezd II |
| **Course name:** | Stellar astrophysics II |

| **Študijski program in stopnja**<br>**Study program and level** | **Študijska smer**<br>**Study field** | **Letnik**<br>**Academic year** | **Semester**<br>**Semester** |
|---|---|---|---|
| Fizika in Astrofizika I. stopnja | / | 3 | 1 |
| Physics and Astrophysics I. level | / | 3 | 1 |

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|---|---|
| **Vrsta predmeta / Course type** | izbirni / elective |
| **Univerzitetna koda predmeta / University course code:** | 1FAF21 |

| **Predavanja**<br>**Lectures** | **Seminar**<br>**Seminar** | **Sem. vaje**<br>**Tutorial** | **Lab. vaje**<br>**Lab. work** | **Teren. vaje**<br>**Field work** | **Samost. delo**<br>**Indiv. work** | **ECTS** |
|---|---|---|---|---|---|---|
| 30 | / | 30 | / | / | 120 | 6 |

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| **Nosilec predmeta / Lecturer:** | prof. dr. Andreja Gomboc | |
| **Jeziki /**<br>**Languages:** | **Predavanja / Lectures:** | slovenščina / English |
| | **Vaje / Tutorial:** | slovenščina / English |

| **Pogoji za opravljanje študijskih obveznosti:** | **Prerequisits:** |
|---|---|
| Vpis v tekoče študijsko leto. Opravljen izpit iz Astrofizike zvezd I.<br>Za študente v okviru študentskih izmenjav bo izpolnjevanje pogojev preverila Študijska komisija FN. | Enrollment into the current study year. Completed exam in Stellar Astrophysics I.<br>For the exchange students, meeting of the course prerequisites will be checked by the Study committee of the school. |

| **Vsebina:** | **Syllabus outline:** |
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| - **Osnovne predpostavke** pri fizikalnem opisu zvezd, časovne skale, hidrostatično ravnovesje, virialni teorem, proizvodnja, transport in ohranitev energije.<br><br>- **Lastnosti snovi v zvezdah**: enačbe stanja (idealni plin, fotonski plin, mešanica idealnih plinov in fotonskega plina, degenerirana snov, snov pri visokih temperaturah). Atomska stanja in njihova zasedenost, Sahova enačba, stopnja ionizacije, depresija kontinuuma. | - **Basic assumptions** in stellar description, timescales, hydrostatic equilibrium, virial theorem, energy production, transport and conservation.<br><br>- **Properties of matter in stars**: equations of state (ideal gas, photon gas, mixture of ideal and photon gases, denegerate matter, matter at high temperatures). Atomic levels, Saha equation, ionization degree, depression of continuum.<br><br>- **Rates of nuclear reactions in stars**. |

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|---|---|
| - **Hitrost jedrskih reakcij v zvezdah**.<br><br>- **Mehanizmi prenosa energije v zvezdah**: sevanje, konvekcija in pogoj za konvekcijo, kondukcija.<br><br>- **Prenos energije s sevanjem**:<br><br>Masni absorpcijski koeficient, Rosselandovo povprečje, odvisnost neprozornosti od temperature, Thomsonovo sipanje, Kramersov zakon.<br><br>Enačba sevalnega prenosa energije in nekatere njene rešitve. Optično redki in optično gosti sevalci, transport v približku lokalnega termodinamskega ravnovesja, nastanek in lastnosti spektralnih črt v atmosferah zvezd, razširitev spektralnih črt zaradi temperature, načela nedoločenosti, trkov; ekvivalentna širina črt, krivulja rasti.<br><br>- **Enačbe zvezdne strukture in robni pogoji**: Eulerjev in Lagrangev opis; lokalno termodinamsko ravnovesje; lokalna in globalna ohranitev energije; efektivna temperatura; primeri reševanja enačb zvezdne strukture: UV ravnina, homologni modeli, politropni modeli in degenerirana snov, masne limite. Stabilnost zvezd.<br><br>- **Razvoj zvezd po glavni veji**: Hayashijeva linija, vžig helija, končna stanja zvezd: bele pritlikavke, nevtronske zvezde in črne luknje.<br><br>- **Rotacija zvezd**: von Zeipel teorem in vpliv rotacije na zvezdo.<br><br>- **Osnove astrofizike plazme**: osnovni opis in enačbe: kontinuitetna enačba, enačba gibanja, energijska enačba, indukcijska enačba.<br><br>- **Alfvenov teorem** o zamrznitvi magnetnega pretoka, Sončeve pege in magnetno polje v Soncu. | - **Mechanisms of energy transfer in stars**: radiation, convection and condition for convection, conduction.<br><br>- **Radiative energy transfer**:<br>Mass absorption coefficient, Rosseland mean, dependence of the opacity on temperature, Thomson scattering, Kramers' law.<br><br>Radiative transfer equation and examples of solution. Optical depth, transport in local thermodynamical equilibrium approximation, formation and properties of spectral lines in stellar atmospheres, broadening of spectral lines due to temperature, uncertainty principle, collisions; equivalent width of lines, curve of growth.<br><br>- **Equations of stellar structure and boundary conditions**: Euler and Lagrange description; local thermodynamical equilibrium; local and global energy conservation; effective temperature, examples of stellar structure equations solutions: UV plane, homologous models, polytropic models and degenerate matter, mass limits. Stability of stars.<br><br>- **Stellar evolution after the main sequence**: Hayashi line, helium ignition, final states: white dwarfs, neutron stars and black holes.<br><br>- **Stellar rotation**: von Zeipel theorem and influence of rotation on a star;<br><br>- **Basics of plasma astrophysics**: basic description and equations: the continuity equation, equation of motion, energy equation, induction equation.<br><br>- **Alfven theorem** on frozen flux, Sunspots and Solar magnetic field. |

| **Temeljni literatura in viri / Basic readings:** |
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| 1. A.R. Choudhuri: Astrophysics for Physicists, Cambridge University Press 2010.<br><br>2. D. Prialnik: An Introduction to the Theory of Stellar Structure and Evolution, Cambridge University Press 2010.<br><br>3. R. Kippenhahn, A. Weigert, A. Weiss: Stellar Structure and Evolution, Spinger, 2012. |

| **Cilji in kompetence:** | **Objectives and competences:** |
|---|---|
| - razširjeno poznavanje astrofizikalnih konceptov pri opisu strukture zvezd in astrofizikalne plazme | - advanced knowledge of astrophysical concepts in description of stellar structure and astrophysical plasma |

| **Predvideni študijski rezultati:** | **Intended learning outcomes:** |
|---|---|
| Študenti bodo osvojili pojme in koncepte:<br><br>- opis strukture in procesov v zvezdah<br>- astrofiziko plazme | The students will learn:<br><br>- description of stellar structure and processes<br>- plasma astrophysics |

| **Metode poučevanja in učenja:** | **Learning and teaching methods:** |
|---|---|
| - predavanja<br>- računske vaje | - lectures<br>- tutorial |

| **Načini ocenjevanja:** | **Utež / Weight (%)** | **Assessment:** |
|---|---|---|
| - kolokviji, pisni izpit<br>- ustni izpit | 50<br>50 | - written tests, writen exam<br>- oral exam |

| **Reference nosilca / references of the course principal:** |
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| Prof. dr. Andreja Gomboc se raziskovalno ukvarja z izbruhi sevanja gama, plimskim raztrganjem zvezd v bližini masivnih črnih lukenj, elektromagnetnimi dvojniki dogodkov gravitacijskih valov in relativističnim modeliranjem dinamike sistema satelitov. Doslej je objavila 90 znanstvenih člankov v mednarodnih referiranih revijah, vključno s 3 članki reviji *Nature*, 2 v *Science* in 1 v *Nature Astronomy*.<br><br>Prof. Dr. Andreja Gomboc is active in research of gamma-ray bursts, tidal distruption of stars by massive black holes, electromagnetic counterparts of gravitational wave events and relativistic modelling of a satellite system. She has published 90 scientific papers in international refereed journals including 3 papers in *Nature*, 2 in *Science* and 1 in *Nature Astronomy*.<br><br>Izbrane objave /selected publications:<br><br>1. S. Covino et al. (incl. A. Gomboc). The unpolarized macronova associated with the gravitational wave event GW 170817. Nature Astronomy, 1: 791-794, 2017. |

2. K. Wiersema et al. (incl. A. Gomboc). Circular polarization in the optical afterglow of GRB 121024A. Nature, 509: 201-204, 2014.

3. A. Maselli et al. (incl. A. Gomboc). GRB 130427A: A Nearby Ordinary Monster. Science, 343: 48-51, 2014.

4. J. Japelj, et al. and A. Gomboc. Phenomenology of Reverse-Shock Emission in the Optical Afterglows of Gamma Ray Bursts. The Astrophysical Journal, 785: Issue 2, article id. 84, 22 pp., 2014.

5. C. Mundell et al. (incl. A. Gomboc). Highly Ordered Magnetic Field from GRB 120308A. Nature, 504, 119-121, 2013.

6. A. Gomboc. Unveiling the secrets of gamma ray bursts. Contemporary Physics 53: 339-355, 2012.

7. J. Japelj and A. Gomboc. Detectability of GRB Optical Afterglows with Gaia Satellite. Publications of the Astronomical Society of the Pacific, 123: 1034-1043, 2011.