



UČNI NAČRT PREDMETA / COURSE SYLLABUS

Predmet:	Eksperimentalne metode in detektorji v astrofiziki visokih energij
Course name:	Experimental methods and detectors in high energy astrophysics

Študijski program in stopnja Study program and level	Študijska smer Study field	Letnik Academic year	Semester Semester
Fizika in Astrofizika II. stopnja	Astrofizika	2	/
Physics and Astrophysics II. level	Astrophysics	2	/

Vrsta predmeta / Course type	obvezni / mandatory
Univerzitetna koda predmeta / University course code:	2FAF11

Predavanja Lectures	Seminar Seminar	Sem. vaje Tutorial	Lab. vaje Lab. work	Teren. vaje Field work	Samost. delo Indiv. work	ECTS
40	/	20	/	/	210	9

Nosilec predmeta / Lecturer:	doc. dr. Sergey Vorobyev	
Jeziki / Languages:	Predavanja / Lectures:	slovenščina / English
	Vaje / Tutorial:	slovenščina / English

Pogoji za opravljanje študijskih obveznosti: Prerequisites:

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Vsebina:	Syllabus outline:
<p>- Detektorji delcev na balonih (CREAM) in satelitih (AMS-02, Fermi-LAT). Sledenje, kalorimetrija, identifikacija delcev. Parametri in rezultati.</p> <p>- Plazovi sekundarnih delcev. Elektromagnetni in hadronski plazovi. Hadronske interakcije. Naravni kalorimetri (zrak, led, ...) in njihove lastnosti.</p> <p>- Detektorji kozmičnih žarkov. Pierre Auger, CTA, HiRes, Cascade-GRANDE. Talni detektorji. Detektorji fluorescence. Hibridno odkrivanje. Rezultati ob smereh prihoda, energijskem spektru, delčni sestave. R&D odkrivanja z uporabo radijskih valovih.</p>	<p>- Particle detector experiments on balloons (CREAM) and satellites (AMS-02, Fermi-LAT). Tracking, calorimetry, particle identification. Performances and results.</p> <p>- Cosmic ray showers. Electromagnetic and hadronic cascades. Hadronic interactions. Media used for calorimetry (air, ice, etc.) and their performances.</p> <p>- Cosmic ray detectors. Pierre Auger, Telescope Array, HiRes, Cascade-GRANDE. Surface detectors. Fluorescence detectors. Hybrid detection. Results on arrival directions, energy spectrum, composition. R&D on radio detection.</p>



<p>- Detektorji gama žarkov visokih energij. Teleskopi za zaznavanje Čerenkove svetlobe v atmosferi (IACTs). Polja IACT: H.E.S.S., MAGIC, VERITAS. Učinkovitost in rezultati. Izvori gama žarkov. Cherenkov Telescope Array: postavitve, pričakovani parametri, cilji.</p> <p>- Drugi tipi detektorjev VHE gama žarkov. Rezultati (Milagro, ARGO, HAWC) in perspektive (LHAASO, HiScore).</p> <p>- Detektorji astrofizikalnih VHE nevtrinov. Nevtrinski oscilacije. Nevtrinski teleskop IceCube.</p> <p>- Detektorji gravitacijskih valov. Interferometri. LIGO, VIRGO.</p> <p>- Večglasniški pristopi, sinergije, omrežja.</p>	<p>- Very-high energy (VHE) gamma-ray detectors. Imaging air Cherenkov telescopes (IACTs). Existing IACT arrays (H.E.S.S., MAGIC, VERITAS), performances and results. Galactic and extragalactic sources. Cherenkov Telescope Array, layout, design, performances and goals.</p> <p>- Non-imaging VHE gamma-ray detectors, results (Milagro, ARGO, HAWC).</p> <p>- Detectors of VHE astrophysical neutrinos. Neutrino oscillations. Neutrino telescope IceCube.</p> <p>- Detectors of gravitational waves. Interferometers. LIGO, VIRGO.</p> <p>- Multi-messenger synergies and networks.</p>
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Temeljni literatura in viri / Basic readings:

- K. Kleinknecht, *Detectors for particle radiation*, Cambridge University Press, 1986.
- T. Stanev, *High energy cosmic rays*, Springer, 2009.
- T. K. Gaisser, *Cosmic rays and particle physics*, Cambridge University Press, 1990.
- M. S. Longair, *High energy astrophysics*, Cambridge University Press, 2011.
- Pierre Auger Collaboration, *Properties and performance of the prototype instrument for the Pierre Auger Observatory*, NIM A523 (2004), pages 50-95.
- CTA Consortium, *Design concepts for the Cherenkov Telescope Array CTA : an advanced facility for ground-based high-energy gamma-ray astronomy*, Exp. astronomy, 32 (2013), pages 193-316.
- K. Louedec, *Atmospheric effects in astroparticle physics experiments and the challenge of ever greater precision in measurements*, Astropart. Physics, 60 (2015), 54-71.
- T. K. Gaisser and Francis Halzen, *IceCube*, Ann. Rev. of Nucl. & Part. Sci, 64 (2014) 101.
- K. Riles, *Gravitational Waves: Sources, Detectors and Searches*, PPNP 68 (2013) 1-54.

Cilji in kompetence:

- osvojitve metod opazovanja in identifikacije kozmičnih delcev, ter analize in interpretacije podatkov v poskusih na področju astrofizike osnovnih delcev;
- priprava študentov za uspešno vključitev v eksperimentalne skupine, ki delujejo na sedanjih poskusih ali pripravljajo bodoče eksperimente.

Objectives and competences:

- knowledge of particle detection and identification methods, data analysis and interpretation in astroparticle physics experiments;
- elaboration of students' ability to successfully integrate the experimental teams working on the current detectors or preparing the future ones.



Predvideni študijski rezultati:	Intended learning outcomes:
<p>Študenti bodo osvojili pojme in koncepte:</p> <ul style="list-style-type: none"> - vire sistematičnih napak in ključnih parametrov (občutljivost, razpon energij, energijska in kotna ločljivost, sprejemljivost, ciklus itd.) sodobnih poskusov na področju astrofizike osnovnih delcev, omejitve teh poskusov ter metode in tehnike izboljšanja karakteristik detektorjev; - oceno kvalitete meritev in interpretacije podatkov sodobnih poskusov v astrofiziki osnovnih delcev. 	<p>Students will learn:</p> <ul style="list-style-type: none"> - how to identify typical sources of systematic errors and assess key performances (sensitivity, energy range, energy and angular resolutions, acceptance, duty cycle etc.) of astroparticle physics experiments, their current limitations, and the methods and techniques of improvement of the detector characteristics; - how to assess the measurements and interpret the results in modern astroparticle physics experiments.

Metode poučevanja in učenja:	Learning and teaching methods:
<ul style="list-style-type: none"> - predavanja - študentske predstavitve - skupinsko delo 	<ul style="list-style-type: none"> - lectures - student presentations - team work

Načini ocenjevanja:	Utež / Weight (%)	Assessment:
<ul style="list-style-type: none"> - seminarska naloga - predstavitev 	<p>50</p> <p>50</p>	<ul style="list-style-type: none"> - written report - oral presentation

Reference nosilca / references of the course principal:
<p>Dr. Sergey Vorobyev je docent za področje fizike na Univerzi v Novi Gorici. Dr. Sergey Vorobyev is assistant professor of physics at the University of Nova Gorica.</p> <p>Njegova raziskovalna dejavnost je povezana z eksperimentalno fiziko kozmičnih žarkov in astronomijo gama žarkov zelo visokih energij.</p> <p>Izbrane objave / selected publications:</p> <p>Pierre Auger Collaboration, AAB, A., VOROBIOV, Serguei, et al., Observation of a large-scale anisotropy in the arrival directions of cosmic rays above 8×10^{18} eV. <i>Science</i>, ISSN 0036-8075, sep. 2017, vol. 357, iss. 6357, str. 1266-1270, ilustr., doi: 10.1126/science.aan4338. [COBISS.SI-ID 4921595].</p> <p>SCHWANKE, U., VOROBIOV, Serguei, et al., A versatile digital camera trigger for telescopes in the Cherenkov Telescope Array. <i>Nuclear instruments and methods in physics research. Section A</i>, ISSN 0168-9002, 2015, vol. 782, str. 92-103, doi: 10.1016/j.nima.2015.01.096. [COBISS.SI-ID 3758075].</p> <p>CTA Consortium, ACTIS, M., VOROBIOV, Serguei, et al. Design concepts for the Cherenkov</p>

Telescope Array CTA : an advanced facility for ground-based high-energy gamma-ray astronomy. *Experimental astronomy, Astrophysics and space science*, ISSN 0922-6435, 2013, vol. 32, no. 3, str. 193-316, doi: 10.1007/s10686-011-9247-0. [COBISS.SI-ID 3234555].

VOROBIOV, Serguei, et al., **NECTAr : new electronics for the Cherenkov Telescope Array.** *Nuclear instruments and methods in physics research A*, ISSN 0168-9002, vol. 639, no. 1, 2011, str. 62, doi: [10.1016/j.nima.2010.08.112](https://doi.org/10.1016/j.nima.2010.08.112). [COBISS.SI-ID [3233787](https://www.cobiss.si/id/3233787)].

H.E.S.S. Collaboration, ABRAMOWSKI, A., VOROBIOV, Serguei, et al. **Search for a dark matter annihilation signal from the galactic center halo with H.E.S.S.** *Physical review letters*, ISSN 0031-9007. [Print ed.], apr. 2011, vol. 106, 161301-1-161301-5, doi:10.1103/PhysRevLett.106.161301. [COBISS.SI-ID 3232251].

VOROBIOV, Serguei, HUSSAIN, Mustafa, VEBERIČ, Darko. **Studies of UHECR propagation in the galactic magnetic field.** V: CAPDEVIELLE, Jean-Noël (ur.), ENGEL, Ralph (ur.), PATTISON, Bryan (ur.). *ISVHECRI 2008 : proceedings of the XV International Symposium on Very High Energy Cosmic Ray Interactions*, Paris, France, 1-6 September 2008, (Nuclear physics B, Proceedings supplement, ISSN 0920-5632, Vol. 196). Amsterdam: Elsevier, 2009, vol. 196, str. 203-206. [COBISS.SI-ID 1305083].

ABRAHAM, J., VOROBIOV, Serguei, et al., AUGER Collaboration. **Correlation of the highest-energy cosmic rays with nearby extragalactic objects.** *Science*, ISSN 0036-8075, 9. nov. 2007, let. 318, str. 938-943. [COBISS.SI-ID [775419](https://www.cobiss.si/id/775419)]

DJANNATI-ATAI, A., VOROBIOV, Serguei, et al. **Detection of the BL Lac Object IES 1426+428 in the very high energy gamma-ray band by the CAT telescope from 1998-2000.** *Astronomy & astrophysics*, ISSN 0004-6361, 2002, let. 391, št. 3, str. L25-L28. [COBISS.SI-ID [564731](https://www.cobiss.si/id/564731)].