

### U OVOM BROJU. . .

- 4. Dani e-učenja održat će se 20. veljače 2025. na Sveučilišnom Kampusu na Trsatu.
- XVII. Hrvatski simpozij o nastavi fizike održava se 26. — 28. veljače 2025. u Osijeku. Ivani Poljančić Beljan prihvaćeno izlaganje.
- Ivana Poljančić Beljan pozvana je da bude Guest Editor Specijalnog izdanja “Solar Physics: Learn More about the Sun” (Q2).
- Marin Karuza, Tomislav Jurkić i Nenad Kralj sudjelovali u radu Državnog povjerenstva za natjecanja iz fizike.
- Pregled završnih i diplomskih radova izrađenih pod mentorstvom članova Zavoda.
- Čestitka Zavoda za teorijsku fiziku i astrofiziku.

## Četvrti Dani e-učenja

Četvrti Dani e-učenja u organizaciji Povjerenstva za online učenje Sveučilišta u Rijeci održat će se u četvrtak, 20. veljače 2025. na Sveučilišnom Kampusu na Trsatu. Tema i program skupa, kao i svi drugi detalji, objavit će se u siječnju. Mole se zainteresirani da prijave i predstave svoje primjere dobre prakse u obliku 15-minutnog izlaganja.

Zbirkom digitalnih sadržaja za nastavu fizike i prirodoslovlja” prijavila je sa suradnicama Rajkom Jurdanom–Šepić i Natašom Erceg. Simpozij organiziraju Odjel za fiziku Sveučilišta Josipa Jurja Strossmayera u Osijeku, Hrvatsko fizičko društvo, Udruga fizičara Osijek, Fizikalno društvo — Split i Agencija za odgoj i obrazovanje. Ivana Poljančić Beljan, Tomislav Jurkić, Marin Karuza i Klaudija Lončarić recenzirali su prijavljene sažetke.

## XVII. Hrvatski simpozij o nastavi fizike

Ivani Poljančić Beljan prihvaćen je sažetak za sudjelovanje na XVII. Hrvatskom simpoziju o nastavi fizike, koji će se održati 26. — 28. veljače 2025. godine u Osijeku. Izlaganje pod nazivom “Zadovoljstvo budućih učitelja razredne nastave

## SOLAR PHYSICS: LEARN MORE ABOUT THE SUN

Ivana Poljančić Beljan pozvana je da bude Guest Editor Specijalnog izdanja “Solar Physics: Learn More about the Sun” časopisa Applied Sciences. Časopis u 2023. godini ima faktor odjeka 2.5, što ga svrstava u kategoriju Q2 in grupi !Physics, Applied”. Više se može saznati na mrežnoj stranici časopisa: <https://www.mdpi.com/journal/applsci/about>.

## Državno povjerenstvo za natjecanja

Marin Karuza, Tomislav Jurkić i Nenad Kralj sudjelovali su u radu Državnog povjerenstva za natjecanja iz fizike koje je održalo svoj online sastanak. Marin Karuza preuzeo je vodstvo potpovjerenstva za srednje škole i izradu zadataka za 3. i 4. razred srednjih škola. Nenad Kralj i Tomislav Jurkić sudjeluju u izradi zadataka za 3. i 4. razred srednjih škola.

## Završni i diplomski radovi

Za kraj godine, donosimo pregled završnih i diplomskih radova, koji su izrađeni pod mentorstvom članova Zavoda za teorisku fiziku i astrofiziku, a obranjeni su u 2024. godini. Popis je kronološki prema datumu obrane. Čestitamo svim studentima koji su uspješno završili studij u ovoj godini i njihovim mentorima i komentorima.

### Feynmanovi integrali po putevima

MIHAEL BANOŽIĆ

**Naslov rada na engleskom jeziku:** Feynman's path integrals

**Studij:** Sveučilišni diplomski studij Fizika, smjer Astrofizika i fizika elementarnih čestica

**Mentor:** Dr. sc. Tajron Jurić, viši znanstveni suradnik

**Komentor:** Izv. prof. dr. sc. Tomislav Terzić

**Datum obrane:** 5. rujna 2024.

**Rad u repozitoriju:** <urn:nbn:hr:194:046239>

**Sažetak:** U radu istražujemo formalizam Feynmanovih integrala po putevima kao alternativni pristup kvantnoj mehanici (QM). Integral po putevima povezuje klasičnu i kvantnu teoriju kroz princip minimalne akcije. U uvodnom dijelu, pomoću eksperimenta dvostrukog proreza, prikazujemo osnovne kvantne principe kao npr. superpozicija, te uvodimo koncept kvantnih prijelaza kao sumu preko svih mogućih puteva. Nadalje, prikazujemo kako se formalizam integrala po putevima izvodi iz kanonske QM. Bavimo se tehnikama računanja integrala po putevima, detaljno analizirajući Gaussove integrale koji pomažu u izračunavanju propagatora. Dalje, fokusiramo se na konkretne primjere primjene integrala po putevima na fizikalne sisteme poput harmoničkog oscilatora, detaljno prikazujući izračune za propagatore općenitijih lagranžijana. Konačno, istražujemo vezu između integrala po putevima i statističke fizike, objašnjavajući kako se particijske funkcije mogu izračunati pomoću ovog formalizma.

**Ključne riječi:** Feynmanovi integrali po putevima, kvantna mehanika (QM), Gaussovi integrali, harmonički oscilator, statistička fizika.

### Geometry of gauge theories

MARIJA TURK

**Naslov rada na hrvatskom jeziku:** Geometrija baždarnih teorija

**Studij:** Sveučilišni diplomski studij Fizika, smjer Astrofizika i fizika elementarnih čestica

**Mentor:** Dr. sc. natur. Mateo Paulišić

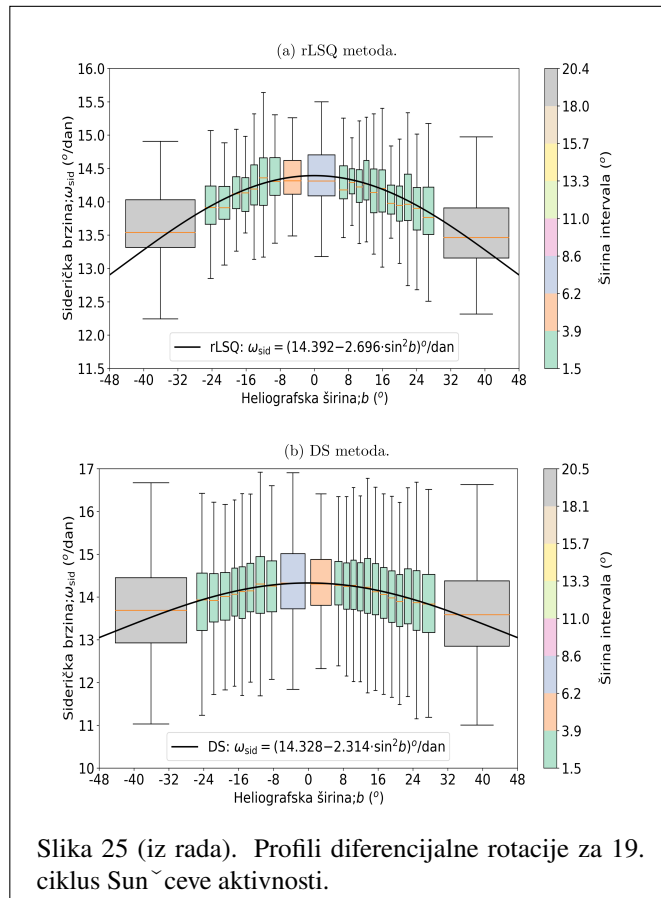
**Datum obrane:** 6. rujna 2024.

**Rad u repozitoriju:** <urn:nbn:hr:194:480070>

**Sažetak:** The goal of this thesis was to mathematically explain concepts from gauge theories. The most emphasis was put on explaining gauge transformations, covariant derivatives, and curvature. The main tools we used for such description were principal fiber bundles and connections. As there exists a lot of background geometry, preparations had to be made before the introduction of those two. Those preparations included an understanding of fiber bundles and Lie groups. Fiber bundles allow for the description of spaces that are not trivial, i.e. those that can be described only locally. Lie groups, on the other hand, were used as a tool for the description of the symmetries we were dealing with. On principal fiber bundles connections were defined as a formal way of comparison that is not well defined in Euclidean geometry. This helped us understand gauge transformations. However, for a full description of covariant derivatives, associated bundles need to be mentioned as they serve as a tool for defining parallel transport map in the context of a vector bundle in which we know how to compare points. This is enough for a formal definition of a covariant derivative, which can be found in both particle physics and general relativity. Curvature relied on no more new concepts as understanding covariant derivative and exterior covariant differentiation was enough for its description. Examples of curvature in gauge theories were given alongside terminology used in these fields as naming conventions differ.

**Ključne riječi:** Gauge theory, Fiber bundles, Principal fiber bundles, Associated bundles, Lie groups.





Članak s proširenom analizom je pripremljen za časopis *Astronomy & Astrophysics* (Q1) te je planirano submitiranje početkom 2025. godine.

## Spinors in classical mechanics

LEO KOVAČIĆ

**Naslov rada na hrvatskom jeziku:** Spinori u Klasičnoj Mehanici

**Studij:** Sveučilišni prijediplomski studij Fizika, smjer Fizika

**Mentor:** Dr. sc. natur. Mateo Paulišić

**Datum obrane:** 10. listopada 2024.

**Rad u repozitoriju:** [urn:nbn:hr:194:045646](https://nbn-resolving.org/urn:nbn:hr:194:045646)

**Sažetak:** Spinors were first mentioned by Elie Cartan (1913) and were introduced in physics by Dirac. Though it is conventionally assumed spinor wave functions are a consequence of quantum weirdness or relativity, and while on closer inspection they can be seen as having topological origin, it can be shown that the fundamental reason for the appearance of spinorial objects in quantum mechanics is purely geometrical. Spinors are naturally described in the language of Clifford algebra which Clifford himself originally intended to be a universal geometric language. To that end, the Kepler problem of classical mechanics is solved in a Newtonian geometric spirit albeit in a modern algebraic formulation, setting the stage for the

formulation of the spinor equation of motion which linearizes and regularizes (removes singularity) the inverse square force equation of motion with universal solutions yielding new applications to perturbation theory. This also leads to new insights and interpretations of quantum mechanical observables, and the geometric nature of fermionic spin 1/2 wave functions.

## Modeling of the Multi-wavelength emission of the blazar S50716+714 during a bright flare

LORENA LULIĆ

**Naslov rada na hrvatskom jeziku:** Modeliranje stanja pojačanog sjaja iz blazara S50716+714

**Studij:** Sveučilišni prijediplomski studij Fizika, smjer Informatika

**Mentor:** Izv. prof. dr. sc. Marina Manganaro

**Datum obrane:** 11. listopada 2024.

**Rad u repozitoriju:** [urn:nbn:hr:194:235922](https://nbn-resolving.org/urn:nbn:hr:194:235922)

**Sažetak:** Nowadays Multiwavelength (MWL) astrophysics (and recently also Multi-messenger) is making immense progress in the understanding of the emission mechanism of several celestial objects. Collecting data from different telescopes observing the same target simultaneously is of paramount importance in the study of galactic and extragalactic sources. The advances in technology are enabling observations of non-thermal radiation produced in multiple objects, such as Active Galactic Nuclei (AGNs), binary systems, supernova remnants, clusters of galaxies, Gamma-ray bursts and also our Galactic Center. Many objects emit photons through the entire electromagnetic spectrum and that is why MWL campaigns are often organized in order to collect as much as possible simultaneous data. In those efforts numerous researchers and observatories collaborate together. In this work, I use two broadband Spectral Energy Distributions (SEDs) of an AGN named S5 0716+714, which is a BL Lac type blazar, during a particular bright flaring activity in 2015 that emitted photons from radio to the very-high-energy (VHE) gamma-rays. In that occasion, a theoretical modelling was applied, which was not entirely successful. Since modelling a broadband dataset is of high importance in order to shed light on the processes behind the broadband emission, I worked with a program named JeT-Set, written in C and python language, which is devoted to modelling and interpretation of SEDs from AGNs and widely used in this field of research. I applied a simple pure leptonic model, the Synchrotron Self Compton (SSC) model to the dataset. My results show that the dataset can not be reproduced by such a model, which was expected. However, it allowed me to learn how to use the code and interpret complex datasets in Multiwavelength astrophysics, and to review the activity of the source in that particular state of activity.

**Ključne riječi:** blazars, AGN, very-high-energy gamma rays, non-thermal, S5 0716+714, BL Lacertae objects.

## Dark matter searches in the globular cluster M15 with the MAGIC telescopes

BRUNO KOVAČ

**Naslov rada na hrvatskom jeziku:** Traganje za tamnom tvari u kuglastom skupu M15 teleskopima MAGIC

**Studij:** Sveučilišni diplomski studij Fizika, smjer Astrofizika i fizika elementarnih čestica

**Mentor:** Izv. prof. dr.sc. Marina Manganaro

**Datum obrane:** 24. listopada 2024.

**Ključne riječi:** dark matter, globular cluster, very-high-energy-astrophysics, MAGIC telescopes, astrophysics, astronomy, M15.

## Nastanak i razvoj protoplanetarnih diskova i protoplaneta

IVAN VIDAK

**Naslov rada na engleskom jeziku:** Formation and evolution of protoplanetary disks and protoplanets

**Studij:** Sveučilišni prijediplomski studij Fizika, smjer Fizika

**Mentor:** Doc. dr. sc. Tomislav Jurkić

**Datum obrane:** 12. studenog 2024.

**Sažetak:** U ovom radu bavimo se nastankom i razvojem protoplanetarnih diskova te procesima koji dovode do formiranja protoplaneta i planetarnih sustava. Protoplanetarni diskovi su rotirajući diskovi plina i prašine koji se formiraju oko mladih zvijezda uslijed gravitacijskog kolapsa molekularnih oblaka. U njima, akrecijom materijala nastaju planetezimali, protoplaneti i konačno planeti. Opisujemo strukturu protoplanetarnih diskova, uključujući radijalnu i vertikalnu raspodjelu temperature i materijala, te razvoj diskova kroz faze do konačnog raspršenja plina i nastanka planetarnog sustava. Također, detaljnije su razmatrani mehanizmi migracije protoplaneta, koagulacija prašine i akrecija, te njihova uloga u nastanku različitih tipova planeta poput plinovitih divova i terestričkih planeta. Rad pruža pregled aktualnih teorijskih modela i opažanja, naglašavajući njihovu važnost u razumijevanju planetarnih sustava.

**Ključne riječi:** protoplaneti, protoplanetarni diskovi, planetezimali, planetarni sustavi, mladi zvjezdani objekti, molekularni oblaci.

## Determination of distance and stellar parameters by Bayes probabilistic inference

TIBOR VESELIN

**Naslov rada na hrvatskom jeziku:** Određivanje udaljenosti i zvjezdanih parametara Bayesovim probabilističkim zaključivanjem

**Studij:** Sveučilišni diplomski studij Fizika, smjer Astrofizika i fizika elementarnih čestica

**Mentor:** Doc. dr. sc. Tomislav Jurkić

**Datum obrane:** 15. studenog 2024.

**Sažetak:** This thesis is devoted to the study of the stellar parameters and determination of stellar distances. For that purpose, the BEAST (The Bayesian Extinction and Stellar Tool) algorithm was used. BEAST is fitting ultraviolet to near-infrared photometric magnitudes to precomputed model grids. This method precisely evaluates parameters such as age, mass, metallicity, and distance by implementing Bayesian inference combined with prior distributions best-suited to the characteristics of the stellar population under study. BEAST integrates synthetic photometry and uses chi-squared fitting techniques that handle observational data from large surveys. This study was focused on globular clusters M92, M13 and NGC 6791 and with the help of BEAST the following parameters were determined: mass, luminosity, surface gravity, radius, temperature, distance, age and metallicity of the stars we studied. We also determined dust parameters: visual extinction and ratio of total to selective extinction. We later compared values from other science papers and values obtained by the BEAST. For M92, BEAST determined the mean distance to be 5.46 kpc. For age, BEAST determined the value of 7.45 Gyr. For visual extinction in magnitude, BEAST got  $A_V = 0.12$  and for ratio of total to selective extinction,  $R_V = 2.76$ . For M13, BEAST determined mean distance to be 5.01 kpc. For age, it determined 7.67 Gyr. For visual extinction in magnitude BEAST got  $A_V = 0.16$  and for ratio of total to selective extinction,  $R_V = 3.49$ . For NGC 6791, BEAST calculated mean distance to be equal to 4.55 kpc, which is an excellent result. In that cluster we analysed SGB and RGB stars, while in other clusters we analysed AGB, RGB and HB stars, so it might be the case that BEAST is doing better estimates for stars in earlier stages of their evolution. For age, BEAST estimated the value of 7.77 Gyr. For visual extinction in magnitude we obtained  $A_V = 0.46$  and for ratio of total to selective extinction,  $R_V = 3.01$ . We have also shown that fixing stellar age does not influence the determination of other stellar and dust parameters, while fixing distance can greatly influence stellar luminosity and radii. BEAST is very effective in dealing with the challenges posed by interstellar dust extinction, which can greatly affect the accuracy of photometric data. The results are not perfect, but they show the effectiveness of Bayesian methods in dealing with complex data in astronomy.

**Ključne riječi:** Stellar parameters, BEAST, Bayes statistics, distance estimation, photometric spectral energy distributions (SED), synthetic photometry, stellar parameters, dust extinction, astronomical surveys, chi-squared fitting.

### IMPRESUM

Zavod za teorijsku fiziku i astrofiziku (ZTFa)

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# LIVE LONG AND PROSPER

Svim dragim studentima, kolegama i suradnicima želimo Sretan Božić i uspješnu 2025. godinu.

Uredništvo Biltena ZTFA

