Université de Paris

PhD position in "Data Intensive Astroparticle Physics"

Astroparticule et Cosmologie (APC)

Data Intelligence Institute of Paris (diiP)

Call for expressions of interest

The University of Paris calls for applications for a PhD position in Data Intensive Astroparticle Physics to work under the supervision of Prof. Yvonne Becherini. The candidate will develop a new analysis scheme for Imaging Atmospheric Cherenkov Telescopes (IACTs), implemented for ground-based detection of (E>50 GeV) cosmic gamma-rays [1] using Deep Learning techniques [2]. The new analysis strategy is expected to be faster and more sensitive than previous analysis schemes and will be used to analyse data from extragalactic sources, especially from those sources whose detection and characterization require long observing times. The analysis scheme will be developed in the framework of the HESS project [3], and will also be tested with CTA simulations, and possibly, first data [4]. The research project will benefit both from the Astroparticule et Cosmologie laboratory (APC) and from the Data Intelligence Institute of Paris (diiP) environments.

Subject field of the position: Physics with specialization in Data Intensive Astroparticle Physics
Placement: University of Paris, Astroparticule et Cosmologie laboratory (APC) and Data Intelligence Institute of Paris (diiP)
Extent: 100%
Duration of appointment: 3 years
Research project title: Deep Learning for Imaging Atmospheric Cherenkov Telescopes, with a focus on faint extragalactic sources
Data access: HESS simulations and data, CTA simulations, and possibly, first data
Doctoral school: STEP'UP (Earth and Environment Science and Physics of the Universe in Paris)

Context and Goal of the research project

Astroparticle physics is a sub-branch of Physics dealing with the understanding of the Universe through the detection of gamma rays, neutrinos, gravitational waves and cosmic rays. The thesis will be developed in the field of gamma-ray astronomy, and particularly in the HESS and CTA Imaging Atmospheric Cherenkov Telescopes. The data analysis chain for IACTs consists of several CPU-consuming steps: signals detected in the cameras need to be calibrated, atmospheric shower parameters need to be reconstructed, then a final selection of the gamma-ray event candidates is made with different analysis cuts following different approaches, see [5] [6] [7]. Usually, the reconstruction procedure is carried out on all calibrated events seen in the cameras, though the rate of detected events is dominated by the cosmic ray background. The research project proposes a new way of handling the dataflow: instead of reconstructing all signals seen in the telescopes and then selecting the candidate gamma-ray events, we will instead concentrate on the probable gamma-ray candidate signals from the beginning, through the selection of the gamma-ray-like images in the telescopes before the reconstruction process through a classification procedure. A successful implementation of the project will translate to a significant saving of computing time, to speed up the entire analysis procedure, and will significantly reduce the amount of real data to be analysed. Speeding up the analysis procedure will be particularly important for faint gamma-ray sources requiring a long observation time. The method to be implemented for this purpose is called FIBER ("FIlter Before Event Reconstruction") and is based on Deep Learning techniques. The new analysis procedure is expected to be more sensitive than the existing methods, and will be applied to HESS extragalactic faint source datasets (as for instance Cen A, NGC 253, high-redshift blazars), to have a deeper understanding of their VHE emission. A publication on the FIBER method is expected, as well as several HESS publications using the new analysis procedure. A publication on the application of the method to CTA is also to be expected. The possibility of using Deep Learning for calibration purposes will be investigated, but will not constitute the core of the project.

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Description of Group/Laboratory/Supervision

This PhD thesis will be supervised by Yvonne Becherini, Professor at the University of Paris, and will take place within the High-Energy Astrophysics (AHE) group of the AstroParticule and Cosmologie Laboratory (APC) and the Data Intelligence Institute of Paris (diiP). The APC is an ideal laboratory for carrying out such a research project, as the lab participates and therefore has access to the data of several VHE observatories. The diiP is the ideal research centre for knowledge exchange on data-intensive aspects. The PhD student will become a member of the HESS and of the CTA collaborations.

Proposed work

- Deep Learning for IACTs, with a focus on faint extragalactic sources
- Active participation in proposals for, and decisions on HESS observation campaigns
- Analysis based on Python/C++ programming
- Writing of scientific articles
- Oral presentations at national and international workshops/conferences

Duties

- Attend doctoral school courses for a total of 15 Academic credits, more information may be found at this address: https://ed560.ed.univ-paris-diderot.fr/en/rules-for-training/
- Work on the research subject proposed in this document
- Regularly presentations of intermediate research results to the supervisor
- Active participation in the HESS and CTA Collaborations, with responsibility to be undertaken on a technical aspect of data analysis and/or data calibration
- Work in close collaboration with the other project members in an interdisciplinary research environment as well as with domain experts
- Presentation and publishing of intermediate results in conference proceedings
- Presentation and publishing of more mature results in journal articles
- Preparation of the thesis manuscript
- Participation to the annual “Congrès des Doctorants”

Training and skills required

- Master in Astronomy and Astrophysics or Master in Astroparticle Physics
- Ability to work in a team
- Python/C++ programming
- Good command of English

Acquired skills

Various skills acquired and developed during this PhD thesis will be valuable and transferable to other fields: data analysis at different wavelengths, numerical simulations, data processing, data analysis, machine learning, writing of articles and of observation proposals, teamwork, oral presentations at national and international workshops and conferences.

Assessment criteria

The selection of candidates is made with regard to the applicant’s ability to successfully complete and benefit from their studies at the graduate level. The assessment takes into account academic skills documented in scientific works, especially focused on the quality of the essays at the undergraduate level, any advanced work and other scientific or scholarly works. The assessment also takes into account breadth and composition of the undergraduate degree.

The successful candidate has excellent analytical and problem-solving skills, and is a committed researcher with a drive for excellence. Prior research experience concerning the subject is a significant advantage. Excellent written and oral communication skills in English are essential to

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publish and present results at international conferences and in international journals. Advanced skills in computing are a key requirement, as all activities are carried out in Linux/Unix environments and using the Python programming language. Interpersonal skills and flexibility are of key importance since the work is done in a research group.

Required documents

Send a cover letter, a CV, links to the Master thesis and previous works, and contact information of two referees to yvonne.becherini@apc.in2p3.fr, before February 13, 2022.

References

[1] "Ground-based Gamma-Ray Astronomy: an Introduction", Giuseppe Di Sciascio 2019 *J. Phys.: Conf. Ser.* 1263 012003

[2] "Deep Learning based Algorithms in Astroparticle Physics", M. Erdmann, J. Glombitza, Journal of Physics Conference Series 1525(1):012112

[3] The HESS project, all publications

[4] B.S. Acharya, I. Agudo, I. Al Samarai, R. Alfaro, J. Alfaro, et al., Science with the Cherenkov Telescope Array. 2019.

[5] "A new analysis strategy for detection of faint gamma-ray sources with Imaging Atmospheric Cherenkov Telescopes", Y. Becherini et al., Astroparticle Physics Volume 34, Issue 12, July 2011, Pages 858-870, (2011)

[6] "A Monte Carlo Template based analysis for Air-Cherenkov Arrays", R. D. Parsons and J.A. Hinton, Astroparticle Physics 56, 26-34

[7] "A high performance likelihood reconstruction of gamma-rays for Imaging Atmospheric Cherenkov Telescopes", M. De Naurois & L. Rolland, Volume 32, Issue 5, December 2009, Pages 231-252