europass Curriculum vitae

PERSONAL INFORMATION

Mateusz Kapusta

+48 530 510 849

mr.kapusta@student.uw.edu.pl

https://wesenheit.github.io/

www.github.com/Wesenheit

ORCID 0009-0005-6812-5605

Date of birth 14 July 2001 | Nationality Polish

SUMMARY

I am a Master's student, currently studying at the Faculty of Physics, University of Warsaw. I completed my Bachelor's thesis under the supervision of Przemysław Mróz at the Warsaw University Observatory. I graduated from the college of Inter-Faculty Individual Studies, where I divided my time between the Faculty of Physics (FUW) and Faculty of Mathematics, Informatics and Mechanics (MIMUW). I am passionate about the interdisciplinary research, where physical/astronomical problems can be approach from mathematical/computational perspective. Especially interested in Bayesian Modelling and High Performance Computing. During my studies I had an opportunity to work on different aspects of Astrophysics, ranging from observational projects to theoretical ones. In my free time I like exploring machine learning based methods applied in the field of Natural Sciences, solving problems across different disciplines from Bioinformatics to Astronomy.

WORK EXPERIENCE

April 2024 - present

Student research assistant, Nicolaus Copernicus Astronomical Center

Working under the supervision of Krzysztof Nalewajko (NCAC).

Project in cooperation with Bart Ripperda (CITA, Toronto) and Alexander Philippov (University of Maryland).

Project is planned to be presented in the Master's thesis.

- Working with extreme resolution magnetohydrodynamical (MHD) simulations created with H-AMR code.
- Studying stability of astrophysical jets launched from black holes.
- Investigating influence of magnetic flux eruptions, associated with Magnetically Arrested Discs (MAD), on the properties of the jet.

November 2022 - present

Student research assistant at Astronomical Observatory

Student position in grant 2021/41/B/ST9/00252, working under the supervision of Przemysław Mróz.

- Performing MCMC modelling of microlensing events discovered as the part of 4th phase of the OGLE project.
- Investigating Free Floating Planet (FFP) microlensing event OGLE-2023-BLG-0524. Working on theoretical modelling, analyzing legacy Hubble Space Telescope (HST) photometry, performing detectability simulations in order to verify FFP hypothesis. Project involves a significant data-related part including Bayesian modelling, working with real PSF-s and more.
- Research resulted in 4th-author publication in ApJS, currently preparing first author publication about the OGLE-2023-BLG-0524 event.

November 2023 - present

Research project within the field of Deep Learning

Working on deep learning model aimed to speed up MCMC inference of Spectral Energy Distribution (SED) fitting (written in PyTorch). Project is centered on the analysis of the photometric data to determine physical parameters of stars (temperature, metalicty, reddening, etc.). Python-based PyTorch framework has been used to implement the networks.

- Designed and coded a deep neural network based on the transformer architecture, allowing one to process any number of photometric measurements.
- Implemented a neural network for Neural Posterior Estimation (NPE, based on the Masked Autoregressive Flow model) to estimate the posterior of Bayesian model.
- Project resulted in two posters presented on international machine learning conferences (ML in PL 2024 and GHOST 2024).

November 2024 - present

Research project at the Astronomical Observatory, University of Warsaw

Developing GPU-accelerated, mutli-node special-relativistic hydrodynamical code (writen in Julia). Code utilizes the Riemann solver and allows for various reconstuction methods (Minmod, Weno-Z, PPM). Project is done under the supervision of prof. Tomasz Bulik.

- Writing custom CUDA kernels to maximize the performance on Ampere-based Nvidia GPUs.
- Profiling the code with respect to different bandwidths (computational - memory - communication).
- Checking the performance of different reconstruction methods, trying to pinpoint most suitable algorithm for given GPU architecture.
- Project is being developed with the help of EuroHPC development access computing grant EHPC-DEV-2025D02-085 on the Leonardo BOOSTER, where I am a Co-PI.

July 2022 - July 2023

Bachelor's Thesis at Warsaw University Astronomical Observatory

Working under the supervision of Przemysław Mróz on the data analysis from the OGLE survey to search for dormant black hole candidates.

- Analysing OGLE data using the method introduced in Gomel et al. 2021.
- Designing Python based MCMC code to assemble spectral energy distribution (SED) for candidate objects.
- Inference of the parameters of binaries using the OGLE and Gaia DR3 data, searching for compact companion stars.
- Project resulted in first-author paper accepted in Acta Astronomica.

July 2022 - October 2022

Intern at Nicolaus Copernicus Astronomical Center

Project: "Measuring the structure of relativistic jets in numerical simulation results" under the supervision of Krzysztof Nalewajko (NCAC) and Agnieszka Janiuk (CFT PAN).

- Worked with results from HARM MHD code to study the structure of magnetically arrested discs.
- Developed a few Python routines to search for magnetic reconnection and other interesting magnetic phenomena.
- Work accomplished during the internship resulted in second-author publication submitted to Astronomy & Astrophysics (in revision).

July 2021 - October 2023

Intern at Nicolaus Copernicus Astronomical Center

Project: "Energy of a Strange Quark Star" under the supervision of Fatemeh Kayanikhoo, M. Cemeljic and J. Zdunik

- Worked with LORENE library to study the structure of relativistic strange quark stars, ported part of functions to work with C++17 standard and MPI multithread environment.
- Developed Python code to calculate the external energy of a star contained in a magnetic field.
- Developed multi-threaded C++ code to calculate the equation of state of the magnetized strange matter.

EDUCATION AND TRAINING

2023-2025(expected)

Master of Science in Astrophysics

Faculty of Physics, University of Warsaw, Poland

Thesis: TBD

Supervisor: Krzysztof Nalewajko (email: knalew@camk.edu.pl)

Major: Astronomy

2020-2023

Bachelor of Science in Astrophysics

College of Inter-faculty Studies in Mathematics and Natural Sciences, University of Warsaw, Poland. My studies were divided between the Faculty of Physics and Faculty of Mathematics, Informatics and Mechanics.

Thesis: **Search for dormant black holes in the OGLE data**

Grade: 4.96/5 (2-5 scale, 5 is the highest), graduated with distinctions

Supervisor: Przemysław Mróz (email: pmroz@astrouw.edu.pl)

Major: Astronomy

Minor: Mathematics, Computer Science

PERSONAL SKILLS

Mother tongue: Polish

English - C1 (103 TOEFL)

German - B1

PUBLICATIONS

- K. Nalewajko, **M. Kapusta**, A. Janiuk "Chaotic Magnetic Disconnections Trigger Flux Eruptions in Accretion Flows Channeled onto Magnetically Saturated Kerr Black Holes" Accepted in Astronomy & Astrophysics [arXiv:2410.08280]
- P. Mróz, A. Udalski, M. Szymański, **M. Kapusta**, et al. "Microlensing Optical Depth and Event Rate toward the Large Magellanic Cloud Based on 20 yr of OGLE Observations" ApJS, 273, 4 (2024) [arXiv:2403.02398]
- **M. Kapusta**, P. Mróz. "The search for Dormant Black Holes in the OGLE data" 2023, Acta Astron., 73, 197 [arXiv:2401.11293]

TALKS & POSTERS

- **M. Kapusta**, K. Nalewajko, B. Ripperda, A. Philippov "3D geometry and magnetic connections of the erupting black-hole jet", oral presentation at the conference "Feeling the pull and the pulse of relativistic magnetospheres", Les Houches April 2025.
- **M. Kapusta** "Extreme resolution GRMHD simulations of Astrophysical jets", presentation at 10th Symposium for Young Researchers, presentation awarded with distinctions (September 2024, Warsaw)
- **M. Kapusta** "Iris-ML: Neural Posterior Estimation for the Spectral Energy Distribution fitting." poster at ML in PL 2024 machine learning conference (November 2024, Warsaw).

AWARDS & SCHOLARSHIPS

- Gold medal at 2021 University Physics Competition (as part of the team representing Faculty of Physics)
- Silver medal at the 1st Global e-Competition on Astronomy and Astrophysics (in place of 14th International Olympiad on Astronomy and Astrophysics), 2020
- Bronze medal at 13th International Olympiad on Astronomy and Astrophysics, 2019 Hungary
- Winner of 62th and 63th Polish Astronomy Olympiad for high school students
- Finalist of 67th and 69th (11th place) Polish Physics Olympiad for high school students
- Finalist of 70th Polish Mathematical Olympiad for high school students
- Minister of Education's scholarship in the year 2018/2019, 2019/2020
- Rector's scholarship in the academic year 2020/2021, 2021/2022, 2022/2023, 2023/2024, 2024/2025

OUTREACH

- Jury at the international math competition Naboj (March, 2025)
- Jury at the international math competition Naboj (March, 2024)
- Judge at the 16th International Olympiad on Astronomy and Astrophysics (August, 2023)
- Jury at the international math competition Naboj (March, 2023)

COMPUTER SKILLS

Languages & Software:

Computer languages:

- Python - advanced
- C/C++ - advanced
- Julia - advanced
- Fortran - intermediate
- Rust - intermediate

Additional computer-related skills:

- Advanced knowledge of Linux OS
- Bayesian modeling using emcee, Pyro/NumPyro, PyMC, blackjax and Tensorflow Probability
- 3D visualizations with Paraview and Mayavi
- Parallel programming using MPI/OMP, GPGPU programming in CUDA
- Low-level programming using Python C API
- Deep learning experience using PyTorch, Tensorflow, Jax
- Low-level parallelism using SIMD
- Experience with astronomical Python libraries like Astropy, Astroquery, PyVO