

RESEARCH PROFILE

I am a computational physicist and applied mathematician with a background in medical physics and electrical engineering. My doctoral work develops numerical methods for physical systems governed by partial differential equations, and pipelines that turn sparse, noisy instrument data into quantitative physical images and maps. Across three projects the unifying thread is the same: building forward models of a physical system and the computational machinery to solve them, or to invert them against real measurements, at scale, on national high-performance computing systems, with extensive use of GPU-accelerated codes. I have large interest in predictive modeling of complex systems - numerical PDE forward models, inverse problems and reconstruction, Bayesian inference, and machine learning - with growing focus on biological and neural dynamics.

EDUCATION

- **University of Rhode Island, US** 2023 – present
PhD Physics (computational and theoretical physics)
 - Presidential Fellow.
 - Graduate Assistant, Institute for Artificial Intelligence and Computational Research.
 - Research on relativistic plasma simulations and numerical modeling of black hole environments.
 - Extensive use of GPU-accelerated computing and national HPC systems (Unity, Perlmutter, Polaris, Aurora).
- **University of Szczecin, Poland** 2020 – 2022
Master's degree, Physics (medical physics)
 - Thesis: Probability distributions of event fluxes observed within sky surveys by sampling experiments in space. Conducted at the Space Research Centre, PAS – Laboratory for Solar Physics and Astrophysics.
- **West Pomeranian University of Technology, Poland** 2018 – 2022
Engineering degree, Automation and Robotics (control theory)
 - Thesis: Robust attitude control system for an Earth observation satellite. Conducted at the Space Research Centre, PAS – Laboratory of Space Mechatronics and Robotics.
- **University of Szczecin, Poland** 2017 – 2020
Bachelor's degree, Physics (medical physics)
 - Thesis research conducted at the Max Planck Institute for Plasma Physics on divertor heat flux measurements in Wendelstein 7-X stellarator experiments.

RESEARCH AND EMPLOYMENT

- **Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS)** 2027
Fellow – Visual Computing Group (H. Pfister); offered, deferred to June 2027 Cambridge, US
 - Appointed Fellow to work on DSL (domain specific language) for visualization for connectomics.
- **University of Rhode Island, US** 2023 – present
PhD Researcher
 - Develop numerical infrastructure for dynamical spacetime simulations, including extending existing numerical methods.
 - Contribute code to the collaborative simulation framework used by the research group (C/C++/Python), enabling future large-scale dynamical spacetime simulations.
 - Run and test simulations on national HPC systems (Unity, Perlmutter, Polaris, Aurora) using GPU-accelerated frameworks.
 - Perform numerical analysis of simulated observables relevant to black hole imaging and Event Horizon Telescope pipelines.

- **Flatiron Institute – Center for Computational Astrophysics** 2024 – present
Guest Researcher New York, US
 – Guest researcher at the Center for Computational Astrophysics.
 – Participated in the Flatiron CCA Summer School: *The Landscape of Astronomical Transients*.
- **Space Research Centre, Polish Academy of Sciences** 2021 – 2023
Physicist – Laboratory for Solar Physics and Astrophysics Warsaw, Poland
 – Contributed to the GLOWS instrument science pipeline for NASA’s IMAP mission.
 – Developed CAPRA, a HEALPix-native computational pipeline for reconstructing full-sky flux maps from spacecraft event-counting data (IBEX / IMAP).
 – Implemented reconstruction algorithms and scalable data analysis pipelines.
 – Designed Python-based visualization and coordinate transformation tools for heliospheric sky maps.
- **Wolfram Research** 2022 – 2023
Consultant in Algorithms R&D department (Astronomy Intern) Champaign, US
 – Developed Mathematica and C routines for orbital mechanics calculations using VSOP87 ephemerides and SPICE kernels.
 – Implemented algorithms for Hohmann transfers and orbital maneuver calculations validated in NASA GMAT simulations.
- **Creotech Instruments S.A** 2021 – 2022
Attitude and Orbit Control Systems Engineer Warsaw, Poland
 – Contributed to satellite missions including POLON, EagleEye and PIAST.
 – Designed and analyzed satellite attitude control algorithms using Matlab and GMAT.
 – Developed Python-based data pipelines and software tools for spacecraft operations.
- **Max Planck Institute for Plasma Physics** 2019
Physics Intern Greifswald, Germany
 – Developed Python algorithms to analyze thermographic measurements from the Wendelstein 7-X stellarator divertors.
 – Investigated the effect of plasma-induced impurity deposition on infrared diagnostic measurements.

PUBLICATIONS AND RESEARCH PROJECTS

- **A Structure-Preserving Finite-Volume Framework for the Coupled Einstein-Euler System** Developed a strictly flux-conservative finite-volume framework for the two-way coupled Einstein-Euler system, built on a new first-order hyperbolic formulation of Einstein’s equations and providing its first coupling to matter. Well-balanced to machine precision (Tolman-Oppenheimer-Volkoff equilibria), admissibility- and hyperbolicity-preserving, with IMEX integration and constraint damping across disparate time scales; demonstrates long-time neutron-star equilibrium, controlled collapse to a black hole, stable post-horizon evolution, and stellar-core collapse. (Manuscript in preparation.)
- **On the observational distinguishability of the Kerr and Kerr-Hayward metrics to EHT** Implemented Kerr-Hayward spacetime into GRMHD and polarized radiative transfer workflows, extending the Event Horizon Telescope analysis pipeline to test a singularity-resolving modification of Kerr. Large-scale simulations show that Kerr-Hayward preserves key image and polarization observables and is functionally indistinguishable from Kerr under current EHT constraints. *Physical Review D* **114**, 023008 (2026). <https://arxiv.org/abs/2604.06128>
- **Capra: Scalable HEALPix-Native Intensity Reconstruction for High-Resolution IMAP Analyses** Developed a HEALPix-native pipeline for reconstructing all-sky flux maps from IBEX and IMAP event-counting data, including flux distribution, convergence studies, and validation of invariance under coordinate transformations. Implemented thread-based parallelization with near-linear scaling and bounded memory usage, enabling efficient high-resolution reconstruction for future IMAP datasets. <https://arxiv.org/abs/2608.25134>. Code DOI: 10.5281/zenodo.20584912
- **Attitude Control of an Earth Observation Satellite with a Solar Panel** Proceedings of the XXI 2022
 Polish Control Conference. Applying general regulation theory to satellite attitude control, tested on a numerical example using Matlab simulations. Paper DOI: https://doi.org/10.1007/978-3-031-35170-9_37

- School investigating discrete spacetime structures and naked singularities within the Wolfram Physics Project framework. Project available: <https://community.wolfram.com/groups/-/m/t/2575710>.

Research Software and Code Contributions

- **Numerical Relativity / GRMHD Simulation Infrastructure** Develop numerical infrastructure for dynamical spacetime simulations based on new formulations of Einstein's equations. Contribute to a collaborative research codebase enabling coupled spacetime-fluid simulations for relativistic plasma systems, available at: <https://github.com/ammahakim/gkeyll>
- **Capra Reconstruction Pipeline** Designed and implemented a HEALPix-native computational pipeline for reconstructing all-sky flux maps from spacecraft event-counting data (IBEX / IMAP). DOI: 10.5281/zenodo.20584912
- **Scientific Computing and Simulation Workflows** Develop simulation tools and numerical analysis pipelines in C/C++/Fortran and Python for astrophysical modeling, high-performance computing workflows, and data analysis. Example projects code repositories: <https://github.com/nikolabukowiecka/GRMHDspace>, DOI: 10.5281/zenodo.20594260

Scientific Computing and Software

- **High Performance Computing** Experience running GPU-accelerated simulations on national supercomputing systems including Unity, Perlmutter (NERSC), Polaris and Aurora (Argonne Leadership Computing Facility), and Sophia cluster. Familiar with CUDA-based computing and currently learning translation of CUDA workflows to HIP and OpenCL.
- **Programming Languages** Python, C, C++, Fortran, C#, JavaScript, TypeScript, HTML/CSS, Visual Basic.
- **Scientific Computing** CUDA GPU computing, numerical simulations, parallel computing, statistical data analysis, HEALPix sky map reconstruction, scientific data pipelines, HPC.
- **Machine Learning and Data** PyTorch, scikit-learn, TensorFlow; NumPy, SciPy, pandas, Matplotlib; OpenCV, Astropy.
- **Statistical and Predictive Modeling** Bayesian inference and Monte Carlo / MCMC sampling, statistical data analysis, system identification, Kalman filtering / state estimation, time-series analysis, dimensionality reduction (PCA).
- **Software** Mathematica, Matlab (Simulink, Model Predictive Control, System Identification, App Designer, PDE Modeler), Octave, ROS, Gazebo, AutoCAD, Docker, Linux HPC environments.

Collaborations, Honors, and Activities

- **Genspace New York / Open Plant** Designing an automated plant-growth incubator and exploring agent-driven experimental workflows for autonomous biology experiments (autonomous lab).
- **Event Horizon Telescope Collaboration** Member of the collaboration through ongoing black hole simulation and modeling work connected to EHT analysis.
- **Wolfram Summer School Mentor** Mentored graduate and undergraduate research projects in discrete spacetime modeling and computational physics.
- **Undergraduate Research Mentorship** Mentoring an undergraduate student project in computational research (University of Rhode Island).
- **Polish Astrobiology Society** Board member and conference organizer for Life and Space conferences (2022–2023).
- **UMass–URI Gravity Research Consortium** Research collaboration on topics including black holes, gravitational waves, multi-messenger astrophysics, and quantum gravity.
- **Huawei “Seeds for the Future” Program** Laureate of Huawei's selective program with certified 2021 coursework in AI, cloud computing, and 5G technologies.
- **Intel “New Technologies for Women”** Recipient of scholarship and mentoring program focused 2020 on emerging technologies.