Samuel David Tootle

University of Idaho – Department of Physics
875 Perimeter Dr., MS 0903, Moscow, Idaho, 83844
Email: sdtootle@uidaho.edu

Education:

01/2023 **Doctor of philosophy in the natural sciences**
Goethe Universität - Frankfurt am Main, Germany
Thesis Title: *Probing extreme configurations in binary compact object mergers*
Advisor: Prof. Luciano Rezzolla, Grade: Magna cum laude

09/2019 **Master of Science (Physics) with a Minor in Informatics**
Goethe Universität - Frankfurt am Main, Germany
Thesis Title: *Improved General Relativistic Initial Data for Compact Object Binaries*
Advisor: Prof. Luciano Rezzolla

05/2009 **Bachelor of Science (Applied Physics)**
Michigan Technological University - Houghton, MI
Research Project: *Application of optical waveguides to enable automation in construction equipment safety*

05/2004 **Associate of Arts and Science (Computer Network Services)**
West Shore Community College - Scottville, MI

Research Interests:

- **Theoretical Astrophysics:** General Relativity, Relativistic Astrophysics, Black Holes, Neutron Stars, Compact Binary Coalescence, Gravitational Waves, Multi-messenger Astrophysics, Dense Matter Equation of State
- **Computational Physics:** Numerical Relativity, Sustainable Computing, High-Performance Computing, Code Generation, Open-Source Development
- **Community Resources:**
    - I am the lead developer and maintainer of FUKA, an open-source suite of initial data codes which has enabled forty scientific publications by scientists across North America, Europe, and Asia.
    - I am the lead developer of NRPyGPU, a CUDA extension to the NRPy code generation framework, which enables the generation of optimized numerical relativity applications for CUDA-enabled GPUs.

Research Appointments:

10/2023 – Present University of Idaho - Moscow, Idaho, USA

Postdoctoral Researcher: *Led the sustainable numerical relativity initiative for the BlackHoles@Home project*

02/2023 – 10/2023 Goethe Universität - Frankfurt am Main, Germany

Postdoctoral Researcher: *Multi-messenger signatures of black hole-neutron star binaries; Led development efforts towards exascale frameworks*

Scholarship Accomplishments:

10/2019 — 01/2023 **PhD Scholarship**, *Goethe Universität, Frankfurt*

10/2017 — 09/2019 **Scholarship**, *Deutschland Stipendium*
Competitive scholarship based on academic and professional excellence.

Teaching Experience:

10/2021 — 03/2022 *Institute for Theoretical Physics, Frankfurt* - **Instructor**

Advanced General Relativity - Practical

10/2021 — 03/2022 *Institute for Theoretical Physics, Frankfurt* - **Instructor**

Introduction to Programming for Physicists - Practical

10/2020 — 03/2021 *Institute for Theoretical Physics, Frankfurt* - **Instructor**

Introduction to Programming for Physicists - Practical

04/2019 — 09/2020 *Institute for Theoretical Physics, Frankfurt* - **Instructor**

Numerical Methods in Physics - Practical

09/2008 — 12/2008 *Department of Physics, Michigan Technological University* - **Instructor**
Electronics Laboratory

09/2008 — 12/2008 *Department of Physics, Michigan Technological University* - **Instructor**
Introductory Physics Laboratory I

Mentoring Experience:

I have had the privilege to collaborate and mentor a diverse set of undergraduate and graduate students as they pursue their academic and professional goals.

University of Idaho

10/2023 – present *Terrance Pierre Jacques (Graduate Advisor: Zach Etienne)*
Relativistic Hydrodynamics

10/2023 – present *David Boyer (Graduate Advisor: Zach Etienne)*
Neutron star physics

10/2023 – present *Thiago Assumpção (Graduate Advisor: Zach Etienne)*
Binary black hole initial data

Goethe University

Undergraduates:

10/2021 – 04/2022 *Sinan Altiparmak (Undergraduate Advisor: Luciano Rezzolla*

Graduates:

10/2021 – present *Carlo Musolino (Graduate Advisor: Luciano Rezzolla):*
Relativistic radiation hydrodynamic simulations

10/2021 – present *Harry Ng (Graduate Advisor: Luciano Rezzolla):*
Relativistic radiation hydrodynamic simulations

10/2021 – present *Konrad Topolski (Graduate Advisor: Luciano Rezzolla):*
Phenomenology of compact object mergers

10/2021 – 10/2023 *Marie Cassing (Graduate Advisor: Luciano Rezzolla):*
Differential rotation profiles of binary neutron star remnants

09/2021 – 09/2022 *David Hyun-Jin Leemüller (Graduate Advisor: Luciano Rezzolla):*
Conformally curved initial data construction

10/2018 – 03/2020 *Frederike Kubandt (Graduate Advisor: Luciano Rezzolla)*
Efficient, multi-code simulations

Publications

16. **S. D. Tootle,** L. Werneck, *T. Assumpcao, T. P. Jacques, Z. B. Etienne: Accelerating Numerical Relativity with Code Generation: CUDA-enabled Hyperbolic Relaxation; (submitted, January 2025)*
Contribution: I developed all the code extensions, performed all the analysis, and wrote the manuscript.

15. T. P. Jacques, S. Cupp, L. Werneck, **S. D. Tootle,** M. Hamilton, Z. Etienne: *GRoovy: A General Relativistic Hydrodynamics Code for Dynamical Spacetimes with Curvilinear Coordinates, Tabulated Equations of State, and Neutrino Physics; arxiv: 2412.03659 (submitted, December, 2024)*

Contribution: I led the development and integration of FUKA initial data into GRoovy to enable the study of rotating neutron star solutions.

14. H. Ng, C. Musolino, **S. D. Tootle**, L. Rezzolla: *Accurate muonic interactions in neutron-star mergers and impact on heavy-element nucleosynthesis, arxiv: 2411.19178 (submitted, November, 2024)*
Contribution: I performed all analysis related to outflow mass, distribution and composition. I also computed the projected r-process nucleosynthesis abundances and wrote the related sections in the manuscript.

13. K. Topolski, **S. D. Tootle,** L. Rezzolla: *Black hole - neutron star binaries with high spins and large mass asymmetries: II. Properties of dynamical simulations; arxiv: 2409.06777 (submitted, September, 2024)*
Contribution: I mentored K. Topolski on designing and performing highly complex compact object simulations and analysis. I also contributed significantly to the manuscript and proposed a novel disruption criteria.

12. K. Topolski, **S. D. Tootle,** L. Rezzolla: *Black hole - neutron star binaries with high spins and large mass asymmetries: I. Properties of quasi-equilibrium sequences; arxiv: 2409.06767 (submitted September, 2024)*
Contribution: I worked for two years to develop the FUKA solver that made this work possible. I also mentored K. Topolski extensively on initial data construction, spectral methods, and the physical interpretation of such extreme datasets.

11. M. Chabanov, A. Cruz-Osorio, C. Ecker, C. Meringolo, C. Musolino, L. Rezzolla, **S. D. Tootle**, K. Topolski: *Microphysical Aspects of Binary Neutron Star Mergers; DOI: 10.1007/978-3-031-46870-4_2; (2024)*
Contribution: I was a lead author on the allocation proposal that funded this project. Additionally, I contributed significantly to the scientific results which were published in refs 6 & 4 below.

10. H. Ng, J. Jian, C. Musolino, C. Ecker, **S. D. Tootle**, L. Rezzolla: *Hybrid approach to long-term binary neutron-star simulations; DOI: 10.1103/PhysRevD.109.064061 (2024)*
Contribution: I wrote and generated the head-on collision initial data that was used for one of the code tests.

9. K. Topolski, **S. D. Tootle**, L.Rezzolla: *Post-merger Gravitational-wave Signal from Neutron-star Binaries: A New Look at an Old Problem; ApJ, DOI:10.3847/1538-4357/ad0152 (2024)*
Contribution: I mentored K. Topolski on gravitational wave extraction and analysis as well as provided waveform data from numerical simulations I had performed.

8. M. Chabanov, **S. D. Tootle**, E.R. Most, L. Rezzolla: *Crustal magnetic fields do not lead to magnetar-strength amplifications in binary neutron-star mergers*; *ApJL, DOI: 10.3847/2041-8213/acbbc5 (2023)*
Contribution: Mentored M. Chabanov on initial data construction with FUKA and provided insights into the analysis of gravitational waves from numerical simulations.

7. T. Demircik, C. Ecker, M. Järvinen, L. Rezzolla, **S. Tootle**, K. Topolski: *Exploring the Phase Diagram of V-QCD with Neutron Star Merger Simulations; DOI: 10.1051/epjconf/202227407006 (2022)*
Contribution: This proceeding was based largely on Ref. 6 below.

6. **S. D. Tootle**, C. Ecker, K. Topolski, T. Demircik, M. Järvinen, L. Rezzolla: *Quark formation and phenomenology in binary neutron-star mergers using V-QCD; DOI: 10.21468/SciPostPhys.13.5.109 (2022)*
Contribution: I performed all numerical simulations, a large portion of the data analysis, and wrote a significant portion of the manuscript.

5. L. J. Papenfort, E.R. Most, **S. D. Tootle**, L. Rezzolla: *Impact of extreme spins and mass ratios on the post-merger observables of high-mass binary neutron stars; DOI: 10.1093/mnras/stac964 (2022)*

Contribution: I co-developed the FUKA codes that made this work possible and assisted with drafting the manuscript.

4. **S. D. Tootle**, L. J. Papenfort, E. R. Most, L. Rezzolla: *Quasi-universal behaviour of the threshold mass in unequal-mass, spinning binary neutron-star mergers; ApJL, DOI: 10.3847/2041-8213/ac350d (2021)*
Contribution: I independently performed more than 400 numerical simulations to obtain this novel result.

3. L. J. Papenfort, **S. D. Tootle**, P. Grandclément, E.R. Most, L. Rezzolla: *New public code for initial data of unequal-mass, spinning compact-object binaries; 10.1103/PhysRevD.104.024057 (2021)*
Contribution: I co-developed this early version of FUKA with L. J. Papenfort where we both equally contributed to the construction of the code, the analysis, and drafting the manuscript.

2. E. R. Most, L. J. Papenfort, **S. D. Tootle**, L. Rezzolla: *On accretion disks formed in MHD simulations of black hole-neutron star mergers with accurate microphysics; DOI: 10.1093/mnras/stab1824 (2021)*
Contribution: This work was enabled by the FUKA code. I assisted with initial data generation and revising the manuscript

1. E. R. Most, L. J. Papenfort, **S. D. Tootle**, L. Rezzolla: *Fast Ejecta as a Potential Way to Distinguish Black Holes from Neutron Stars in High-mass Gravitational-wave Events; ApJ, DOI: 10.3847/1538-4357/abf0a5 (2021)*
Contribution: This work was enabled by the FUKA code. I assisted with initial data generation and revising the manuscript.

Grants and Contracts Awarded:

Pending NSF proposal 2450507: *DESC: Type 1: Toward a sustainable future for numerical relativity and scientific computing;* Principal Investigators: Zach Etienne, Hari Sundar
Contribution: I developed the GPU proof of concept and led drafting the proposal.

Invited Colloquia and Seminars:

07/2024 *FUKA: Binary initial data in extreme conditions* - Albert Einstein Institute; Potsdam, Germany

09/2023 *Extreme binary neutron star mergers* – University of Idaho seminar series

02/2023 *Probing extreme configurations in binary compact object mergers* - Perimeter institute

Conferences and Workshops

07/2023 *FUKA initial data* - Lecture and Tutorial - North America Einstein Toolkit Meeting 2023 (invited speaker)

04/2023 *FUKA initial data* - Lecture and Tutorial - European Einstein Toolkit Meeting 2023 (invited speaker)

07/2022 *FUKA: A public code for initial data of unequal-mass, spinning compact-object binaries* - Frontiers in Numerical Relativity 2022

06/2022 *FUKAv2 - Howto: Generate a proper initial guess for near-extremal binary compact object initial data* - North American Einstein Toolkit School 2022

05/2022 *Quasi-universal behaviour of the threshold mass in unequal-mass, spinning binary neutron-star mergers* - PHAROS 2022

07/2021 *Introduction to FUKA Initial Data* - North American Einstein Toolkit School 2021 (virtual)

Non-Academic Professional Experience:

07/2009 — 10/2017 United States Department of State - Clearance Held: TS

Position: **Management Officer**

- Provided regional training and support in addition to leading a small team and managing local program requirements

Position: **Information Management Technical Specialist**

- Conduct data recovery, network implementation, and troubleshooting of client and server systems

Position: **Engineer**

- Led new programs in the field of optics to support Embassy security programs

Service:

10/2018 – present FUKA: Lead developer

10/2023 – present NRPy: Lead developer of NRPyGPU, contributor to base NRPy functionality

02/2023 – present EinsteinToolkit: Scientific tool contributor

10/2024 University of Idaho Homecoming: Department of Physics outreach booth volunteer

Referee: COMPHY-D

Professional Societies:

2024 – present American Physical Society

2003 – present Phi Theta Kappa

Professional Development:

12/2024 **Creating an Inclusive and Supportive Learning Environment**; ACUE (virtual)

07/2021 **Node-Level Performance Engineering;** *HLRS,* Stuttgart (virtual)

4-day course on HPC optimizations based on node architecture

05/2021 **Shared memory parallelization with OpenMP;** *VSC,* Vienna (virtual)
2-day course on OpenMP implementation in C++ and Fortran

11/2019 **Advanced C++ with Focus on Software Engineering;** *HLRS*, Stuttgart

5-day course on modern C++ features and software design paradigms

04/2019 **Parallelization with MPI and OpenMP;** *HLRS,* Stuttgart
3-day introductory course on MPI and OpenMP in C++ and Fortran

Professional Skills

Computational Frameworks:

Einstein Toolkit

Visualization:
Matplotlib, VisIT, Kuibit

Tools:

Git, Github, Bitbucket

Codes:

Lead Developer: *FUKA, NRPyGPU*

Contributor: *KADATH, Kuibit, Einstein Toolkit, NRPy*

Programming Languages:
C++17, C, Python, Fortran 2008,
MySQL, PHP, BASH script

Programming paradigms:

MPI, OpenMP, CUDA

High Performance Computing:
Use of multiple Tier-0 HPC computing facilities in Germany including *Supermuc-ng* (LRZ, Munich) and *HAWK* (HLRS, Stuttgart) for numerical relativity simulations. Helped write multiple proposals and reports to obtain and document compute time in excess of **150 million core-hours**. To date, I have utilized over **60 million core-hours** in support of my research.