

# Caden Phillips

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MPhys Astrophysics student at the University of Liverpool, specialising in neutron star structure, gravitational wave modelling, and computational astrophysics. Experienced in Fisher matrix investigation, tidal deformability modelling, TOV solver analysis, hybrid EoS construction, and rapidly rotating neutron star simulations using RNS and LORENE. Experienced in Python and scientific computing for data analysis and simulation.

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## Education

### **University of Liverpool**

*Expected 2027*

MPhys Astrophysics

Academic Advisor: Dr. Christopher Copperwheat

*Projected: 2:1*

**Selected Modules:** Computational Modelling, Relativity and Cosmology, Advanced Observational Astrophysics, Physics of Galaxies, Physics of Planets

## Research Experience

### **Physics Internship, Institute of Nuclear Physics (IFJ PAN), Kraków, Poland**

*July–August 2025*

*Supervisor: Dr. David Álvarez Castillo*

*Project: Physical Inputs for Simulations of Gravitational Wave Emissions from Compact Stars within the Einstein Telescope Detection Range*

- Applied a Fisher Information Matrix framework to estimate tidal deformability uncertainties and assess their propagation in binary neutron star systems.
- Developed and implemented a Tolman–Oppenheimer–Volkoff (TOV) solver to compute mass–radius and tidal deformability relations for hybrid equations of state.
- Processed a dataset of 62 hybrid equations of state, generating M–R and  $\Lambda$ –M curves ( 400 stellar configurations per EoS) and analysing stable and unstable branches.
- Compared model predictions with GW170817 50% and 90% credible regions to assess equation-of-state viability.
- Presented project results jointly with a fellow intern at the IFJ PAN Summer Internship Symposium 2025.

*Full internship report: PDF.*

### **Teide Observatory, Tenerife, Spain**

*June 2025*

*Supervisor: Dr. Daniel Harman*

*Project: Week-long field work at Teide Observatory*

- Conducted observations using the 0.8 m IAC-80 telescope, as well as a Celestron C14 Edge HD system with a QHY-163M/C CMOS detector.
- Calibrated and reduced multi-band CCD data to construct composite images and Hertzsprung–Russell diagrams.

**Independent Study – Rotating Neutron Star Modelling**  
*Self-directed follow-up research after IFJ PAN internship*

*Autumn 2025–Winter 2025*

- Investigated the effects of stellar spin on neutron star structure, extending previous TOV-based models which neglect rotation.
- Used **RNS** and **LORENE** frameworks to model rapidly rotating neutron stars under different equations of state.
- Developed a **C++ program** to automate RNS and LORENE runs for a single tabulated EoS, exploring how rotational frequency affects mass, radius, and relativistic stability limits.

**Independent Study – High-Energy Astrophysics Data Analysis (HEASARC/NICER)** *Winter 2025–ongoing*  
*Self-directed observational analysis project*

- Developed a **Python-based pipeline** integrating **HEASoft** tools via **Bash** to automatically download and organise archival **NICER** X-ray observations from the **HEASARC** database.
- Automated event filtering and calibration prior to light-curve extraction using scripted **XSELECT** workflows across multiple ObsIDs.
- Produced calibrated X-ray light curves and diagnostic plots to enable time-domain comparison of source variability across multiple observing epochs.

## Technical Skills

- **Programming:** Python (NumPy, SciPy, Matplotlib, Astropy), C++, Bash
- **Tools & Software:** RNS, LORENE, Jupyter, ROOT, Git, LaTeX, HEASoft
- **Scientific Methods:** TOV and hybrid EoS modelling, Fisher matrix estimation, numerical ODE solvers, gravitational wave parameter inference
- **Languages:** English (native), Portuguese (conversational)

## Research Outputs

- **Project Presentation:** “*Gravitational Wave Emissions from Compact Stars within the Einstein Telescope Detection Range*,” presented at the IFJ PAN Summer Internship Symposium 2025 (slides).
- **Internship Report:** “*Physical Inputs for Simulations of Gravitational Wave Emissions from Compact Stars within the Einstein Telescope Detection Range*,” Institute of Nuclear Physics (IFJ PAN), Kraków, 2025.

## Awards & Achievements

- Awarded competitive summer internship placement at IFJ PAN (Poland) through PHYS309 Internship Module.

## Memberships

- Associate Member, Institute of Physics (IOP) *since 2023*

## Interests

Astrophysics (compact objects, neutron stars, gravitational waves); astrophotography; hiking.

*References available upon request.*