Alexander Deich

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Education

University of Illinois at Urbana-Champaign September 2019 – Present
Ph.D candidate, physics *Urbana-Champaign, IL*

Montana State University September 2018 – May 2019
Graduate student in physics, transferred with research group to UIUC *Bozeman, MT*

Reed College September 2012 – May 2016
B.A. in physics *Portland, OR*

Senior thesis: *Particle Dynamics in a Time-Dependent Kerr Geometry*

Lead Author Papers

- *Lyapunov Exponents to Test General Relativity*,
  Deich, Yunes, Gammie, (in preprint) 2023 PDF
- *Accuracy of the slow-rotation approximation for black holes in modified gravity*,
  Cano & **Deich**, Yunes, (in preprint) 2023 PDF
- *Chaos in Quadratic Gravity*,
  Deich, Cárdenas-Avendaño, Yunes, PRD 2021 PDF
- *Automating the* Swift *Scheduling Pipeline*,
  Deich, Gropp, LaPorte, Tohuvavohu, SPIE 2018

Research Experience

Lyapunov Exponents to Test General Relativity July 2023
University of Illinois at Urbana-Champaign *Urbana-Champaign, IL*

- Developed a theory-agnostic framework for calculating Lyapunov exponents for null geodesics.
- Applied this method to the dCS and sGB theories of gravity to establish accuracy requirements for VLBI observations.
- Published as lead author

Accuracy of the slow-rotation approximation for black holes in modified gravity April 2023
University of Illinois at Urbana-Champaign *Urbana-Champaign, IL*

- Calculated eight different observables for metrics in two theories of gravity, dCS and sGB at very high expansion orders in spin.
- Developed a technique for performing the calculations perturbatively, in a way which minimized the accumulated numerical noise
- Published as co-lead author

Chaos in Quadratic Gravity November 2021
University of Illinois at Urbana-Champaign *Urbana-Champaign, IL*

- Implemented a parallelized high-order numerical integrator (RKF-7(8)) with a bisection method for extremely high-precision calculation of Poincaré surfaces of section to investigate the symmetries of timelike geodesics in quadratic theories of gravity.
- Deployed this code on a high-performance computing cluster
- Published as lead author

Science Planning September 2017 – August 2018

Swift *Gamma-Ray Burst Explorer* *State College, PA*

- Constructed observation timelines for the *Swift* spacecraft which balance on-board resource restrictions such as momentum wheel buildup, passive temperature control, and target visibility.
- Independently engaged in research with *Swift* (see "Presentations" section below)
- Designed and ran simulations to optimize the spacecraft response procedure to LIGO signals

Automating the *Swift* Scheduling Pipeline September 2017 – August 2018

Swift *Gamma-Ray Burst Explorer* *State College, PA*

- As a member of the Science Operations Team (SOT) at *Swift*, I was part of a 3-person team automating the observation scheduling
- The automation initiative is a comprehensive overhaul of the scheduling process consisting of a Python-based collection of programs which interface with the main MySQL observation database and construct observation timelines with no human input.
- My contributions include: constructing a temperature prediction and optimization module, modeling momentum buildup with TensorFlow, writing documentation for these, and designing large-scale code structure.

Off-axis emmission of short GRB's July 2016 – August 2017

Oregon State University *Corvallis, OR*

- Built an analysis package in Python for investigating the physics of gamma-ray bursts.
- Designed an extensive simulation code which integrates a GRB fireball to produce the expected lightcurve for arbitrary wavelength, fireball energy, lorentz factor, and fireball structure.
- The simulation code, whose documentation is available on GitHub, is very extensible and has found applications elsewhere.
- Co-authored a paper on this work.

Metallicity and Extinction in Andromeda June 2014 – August 2015

University of Utah *Salt Lake City, UT*

- Designed data fits to derive reddening values and metallicity from wide-field Hubble data of young stars in the Andromeda galaxy to look for a gradient in metallicity across the galaxy.
- Wrote a tool which allowed the user to interact with large data sets graphically. The user can select regions of data, and plot or perform analysis on those data. The documentation is available on GitHub.
- Performed Monte Carlo simulations of stellar populations of various ages, which we used to refine the parameters of our data.
- Presented the project at the 2015 meeting of AAS in Seattle, Washington, where it was a finalist for the Chambliss Award for Undergraduate Research.

Research Presentations

Lyapunov Exponents in Modified Gravity, **Alex Deich**, Nicolás Yunes, Charles Gammie
APS April 2023

Chaos in Quadratic Gravity, **Alex Deich**, Alejandro Cárdenas-Avendaño, Nicolás Yunes
APS April 2022

Automating the *Swift* Scheduling Pipeline, **Alex Deich**
SPIE Astronomical Telescopes + Instrumentation 2018

Probing the Stability of Compact Objects with X-ray Reflection Spectroscopy, **Alex Deich**
AAS 2018

Calculating the Cocoon Energy of Short GRBs, **Alex Deich**, Davide Lazzati
Oregon State University 2016

Particle Dynamics in a Time-Dependent Kerr Geometry, **Alex Deich**
Reed College thesis defense 2016

PHAT Youths: Determining Metallicity for Hot Young Stars in M31, **Alex Deich**
AAS 2015

Photometric Analysis of Clusters in the Vista Variables in the Via Lactea (VVV)
AAS 2014

Workshops Given

Lyapunov Exponents: How to Calculate Them, How to Use Them
UIUC, 2022

Fast Scientific Computing with Python
UIUC, 2021– 2022

Introduction to BASH
UIUC, 2021

Introduction to High-Performance Computing
UIUC, 2021

Outreach

WYSE Summer Camp Leader
UIUC Physics Department, 2023

How Do Spacecraft Work?
Talk given to Urbana-Champaign Astronomy On Tap, 2022

The Atoms in Your Body: How they got there, where they're going
Talk given to Urbana-Champaign Astronomy On Tap, 2021

Visiting Expert in 4th and 5th grade classrooms at South Side and Westview Elementary schools
Champaign, IL, 2021 – 2022

Invited Guest Expert on the *Comparing Notes* podcast
2021

Awards & Honors

Excellence in Teaching
University of Illinois at Urbana-Champaign *2022*

Chambliss Award for Undergraduate Research
American Astronomical Society *2014*

Classes taught

Quantum Mechanics (instructor)
University of Illinois at Urbana-Champaign *2022*

Statistical & Thermal Mechanics (instructor)
University of Illinois at Urbana-Champaign *2022*

Special Topics in Physics - Post-Newtonian Theory (grader)
University of Illinois at Urbana-Champaign *2021*

Introductory Mechanics (instructor)
University of Illinois at Urbana-Champaign *2020*

Electricity & Magnetism (instructor)
University of Illinois at Urbana-Champaign *2019*

Introductory Mechanics (instructor)
Montana State University *2019*

Introductory Mechanics (instructor)
Montana State University *2018*

Classical Mechanics (grader)
Reed College *2016*

Specialized Skills

Programming Languages: Scientific Python, C/C++, Mathematica, bash/csh/zsh
Packages and Environments: NumPy, Pandas, SciPy, PyMC, TensorFlow, manim, SLURM, PBS, AWS
Numerical methods and techniques:

- High-precision numerical integration with several high-order methods, including DP6 and RKF7(8), and implementation and validation of these.
- Numerical optimization, including stochastic gradient descent, conjugate gradient descent, and MCMC.
- Deploying code on large-scale high performance computing clusters, for both CPUs and GPUs.

Mathematical techniques:

- Measures of instability and chaos, including numerical and analytic calculation of Lyapunov exponents, as well as high-precision calculation of Poincaré surfaces of section
- Ray tracing in a generally relativistic context, including initial condition calculation and determination of the black hole shadow
- Perturbatively calculating black hole observables, including quantities like quasinormal modes, as well as orbital parameters on the ISCO and photon ring.