MICHAEL ASTWOOD

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RESEARCH INTERESTS

Applied Differential Geometry, Mathematical Physics and Biophysics, and Fluid Mechanics.

EDUCATION

University of Waterloo, Waterloo, Canada *September 2017 - June 2021*
Honours Bachelor of Science (BSc), Mathematical Physics
Specialization in Astrophysics. Minor in Pure Mathematics.
Completed graduate level courses in Quantum Theory and Differential Geometry

Westwood Collegiate, Winnipeg, Canada *September 2013 - June 2017*
International Baccalaureate Diploma

EXPERIENCE

Research Assistant - Full Time *May 2020 - September 2020*
University of Waterloo Department of Applied Mathematics. Supervised by Dr. Henry Shum
Research in microscale fluid mechanics. Geometric control theory for particles and filaments in fluid, with applications to microswimmers and transport systems.

Research Assistant - Part Time *September 2019 - Present*
Perimeter Institute for Theoretical Physics. Supervised by Dr. William Donnelly
Investigated BRST quantization for the Free Gross-Taylor String, and related systems. Progressing towards developing a BRST-complex model of the particle on a sphere with constraints, with the goal of developing a BRST interpretation of the Jacobi Triple-product formula for the partition function of the desired system (and furthermore interpreting the Gross-Taylor string as a BRST complex). Work has involved readings in topological field theory, gauge theory, and constrained Hamiltonian dynamics. Presented research for the UWaterloo Physics club seminar series.

Research Assistant - Full Time *May 2019 - September 2019*
University of Waterloo Department of Applied Mathematics. Supervised by Dr. Brian Ingalls
Performed research in model based Optimal Experimental Design theory. The work involved investigating optimal designs for dynamical systems with bifurcations, particularly models appearing in systems biology. Investigation used MatLab to develop optimization algorithms for use in the regression analysis of the model, as well as for use in developing criteria for the success of the theoretical experimental design. Theoretical work in stochastic processes, statistical likelihood theory, and optimization was required. This resulted in the development of a software package for performing experimental design on nonlinear and bifurcated systems.

Mathematics and Modelling Team Lead *February 2018 - Present*
University of Waterloo iGEM Synthetic Biology Team
Mentored and organized student lead research group in synthetic biology (the application of engineering to genetics and molecular biology). Projects involve extensive modelling of molecular systems with ordinary and partial differential equations as well as discrete and stochastic models. Software tools are developed in order to implement models in practice.

CONFERENCE POSTERS

An Optimal Experimental Design Software Package for Nonlinear Models in Biology (Co-Author) — SIAM Optimization 2020

Engineering Herbicide Tolerance in Rhizobia — BioTEC 2019, iGEM 2019

Characterization of Optimal Experimental Designs and Parameter Estimation Methods for a Genetic Toggle Switch — CUMC 2019

Dynamic Optogenetic Control of Co-Cultures — iGEM 2018

PROJECTS

Simulating Quantum Field Fluctuations *March 2020 - April 2020*

Quantum Field Theory for Cosmology Final Project

Derived mode decomposition for quantum field configurations in flat and FRW spacetimes. Found probability distributions of field configurations in Fourier space using the Schrodinger functional equation. Implemented probability distributions in python and simulated particle creation and field fluctuations in expanding spacetimes.

Advanced Quantum Theory *May 2019 - March 2020*

LU Hannover Lecture Series

Independent study of Tobias Osborne's Advanced Quantum Theory course at LU Hannover. The course covers the quantum theory of many particles, including the Fock formalism, condensed matter field theory, and scattering theory.

Engineering Herbicide Tolerance in Rhizobia *February 2019 - December 2019*

University of Waterloo iGEM

Developed partial differential equation models for the flow, uptake, and degradation of herbicides in soy bean roots. Coupled Navier-Stokes flow to a large transport-reaction equation in order to predict efficiency of a molecular system in preventing nitrogen metabolism in Rhizobia.

Geonomaly *November 2019*

Canadian Space Agency SpaceApps Challenge

Lead team through the SpaceApps 2019 hackathon. Developed an algorithm for finding anomalous results in geomagnetic data taken from the GO-Canada magnetic observatories across Canada. The algorithm involves de-noising signals via the Hilbert-Huang transform and then comparing signals across time windows through a Short-Time Fourier transform.

Impact of Accretion Disks on Stellar Structure *March 2018 - April 2018*

Stellar Astrophysics Final Project

Implemented RK45 (Fehlberg) integrator with the multiple direct shooting method in order to solve the equations of stellar structure for various stars along the main sequence. Introduced modified luminosity relation in order to investigate the effect of an accretion disk on the structure of a star.

Dynamic Optogenetic Control of Co-Cultures *February 2018 - December 2018*

University of Waterloo iGEM

Developed model-predictive control system for optimizing the proportion of two separate bacterial cultures in an interacting colony system in real time. Implemented this system using APIMonitor's GEKKO suite in python. Also investigated the use of PID control systems in literature for use in similar optogenetic systems.

TALKS AND SEMINARS

Quantization, Constrained Systems, and BRST Formalism *March 2020*
Presented for University of Waterloo Physics Club Seminar Series

Engineering Herbicide Tolerance in Rhizobia *October 2019*
Presented at iGEM 2019, oGEM 2019
Presented partial differential equation model of herbicide uptake in soy-bean roots, and chemical-kinetic model of herbicide degradation.

All About Tensors *October 2019*
Presented for University of Waterloo Physics Club Seminar Series
Review of vector spaces. The Dual Space. Tensors as multilinear maps. Tensor product spaces. Coordinate representations of tensors.

Optimal Experimental Design for a Genetic Toggle Switch *August 2019*
Presented to University of Waterloo Department of Applied Mathematics
Presented summer research results.

Analysis in Physics *July 2019*
Presented for University of Waterloo Physics Club Seminar Series
Norms and completeness. Hilbert spaces in physics. Operator norms and boundedness. Trace-class operators.

Geometry in Physics *May 2019*
Presented for University of Waterloo Physics Club Seminar Series
Introduction to manifolds. Differential forms and vector fields. Examples of smooth manifolds in physics.

Dynamic Optogenetic Control of Co-Cultures *October 2018*
Presented at iGEM 2018
Presented model predictive control suite for dynamical control of an interacting bacterial colony with two separate populations.

TECHNICAL SKILLS

Programming Languages	MatLab, Python, C♯, Java, JavaScript, C++
Software & Tools	MS Office, FeNiCS, FireDrake, NumPy, SciPy, Gekko
	CasADI, MatLab Optimization Suite, Pandas, XML, HTML, CSS
	NodeJS, Cheerio, Express, Request, DiscordJS, jQuery, XNA
Graphic Design	LaTeX, Adobe Illustrator Photoshop and inDesign, InkScape

NOTABLE COURSEWORK

PMATH 965: Topics in Geometry and Topology (Gauge Theory)	*Winter 2020*
PHYS 785: Quantum Field Theory for Cosmology	*Winter 2020*
PHYS 701: Quantum Mechanics	*Fall 2019*
PMATH 465/665: Smooth Manifolds	*Fall 2019*

VOLUNTEER EXPERIENCE

President; Vice President; Media Officer; Editor; Librarian *September 2017 - Present*
University of Waterloo Physics Club
Developed, budgeted, and ran multitudes of student events at the University of Waterloo targeting hundreds of science students. As the seminar coordinator and librarian, personally gave seminars on topics in physics and mathematics, and began a now traditional weekly student seminar series for physics students at UW. Managed the executive team and delegated roles for 8 months as the Vice President and President. As media officer and editor, created posters and designed graphics and articles for the physics student newspaper *Dark Matter*.

Science Ambassador *September 2018 - Present*
University of Waterloo
One of three representatives of the Mathematical Physics program at UWaterloo. Represents the program at the university open house events throughout the year, and gives tours to visitors to the university. A primary point of contact for students wishing to learn about the program before applying to university.

Third Year Class Representative *September 2019 - April 2020*
University of Waterloo
Representative of the third year Mathematical Physics students at UWaterloo to the Department of Physics and Astronomy.

Director *May 2018 - September 2018*
Physics Interconnected
Developed survey system, matched candidates, and designed graphics for UW's physics student mentoring program. The idea of physics interconnected is to match upper year mentors with first year students with the goal of spreading and enriching the physics community at UWaterloo.

Creative Director *May 2018 - September 2018*
University of Waterloo Science Society
Designed graphics for the Science Society, including posters, logos, and pamphlets distributed to over 1000 first year science students during orientation.

Upper Tier Orientation Leader *September 2018*
University of Waterloo
Trained in Standard First Aid, CPR Level C, and AED usage for role. Assisted new students on campus by providing information, instructions, and directions.

AWARDS AND HONOURS

Dean's List *January 2020*
University of Waterloo - Recurring Award
National Champion *November 2019*
Canadian Space Agency SpaceApps Challenge
Undergraduate Student Research Award *May 2019*
National Science and Engineering Research Council - Monetary Value $ 9000
Entrance Scholarship *September 2017*
University of Waterloo - Monetary Value $ 1000
Top 10 in Province *May 2017*
Canadian Association of Physicists High School Prize Exam