Joshua Williamson

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Introduction

My name is Joshua Williamson, I am a 3rd year PhD researcher at University College London. I was born in Brisbane, Australia and raised in Cornwall, England. I have spent most of my academic life based in London. My current research interests are in cosmology, statistical methods and artificial intelligence. My PhD is in the Astrophysics department and the Center for Doctoral Training in Data-Intensive Science (CDT-DIS). The CDT-DIS engages its researchers in interdisciplinary projects in industrial applications. My research interests outside of academia are cybersecurity, art and music.

Education

BSc **King's College London**, Physics — Sept. 2015 to May 2018

- **First class honours degree**, with an 80% C-score.
- **The Nikon prize**, awarded for the best performance from a single or joint honours degree student in the third year physics project.
- **Inflationary models: A critical study (2018)**, this project uses the cosmic microwave background data from the Planck satellite to put new constraints on models of inflation. The outcome found that a number of inflationary models are ruled out with statistical significance.

MSc **Imperial College London**, Advanced Mechanical Engineering — Sept. 2019 to Sept. 2020

- **Masters award with distinction in Advanced Mechanical Engineering**, with an 75% C-score.
- **Plume-Surface Interactions for Propulsive Planetary Landing (2019)**, this project confronts the challenges faced by heavy payload planetary landers in the final seconds of their entry, decent and landing phase. The violent fluid-dynamical effects from the descent thruster's plume interacting with the planetary surface has the potential to cause a catastrophic instability to its planned flight path. The result of this project was a high-performance numerical hydro-dynamical flow solver which could model these interactions for various lander design configurations and planetary properties.

MPhil **University College London**, Department of Astrophysics and CDT-DIS — Sept. 2021 to Mar. 2024

- **Masters level courses attended**, Responsible Innovation For Researchers, Research Software Engineering, Introduction to Deep Learning, Proba-

bilistic and Unsupervised Learning, Supervised Learning, Applied Machine Learning, High-Performance computing, Advanced Quantum Field theory and Statistical Data Analysis.

PhD **University College London**, Department of Astrophysics and CDT-DIS — Sept. 2021 to Pres.

- **Supervisors**, Prof. Ofer Lahav, Dr. Niall Jeffrey and Prof. Marta Betke
- **Chair of journal review meetings**, Jan. 2024- Pres.
- **Research** My PhD research is based in cosmology, statistical methods and machine learning. My PhD is focused on using simulation-based inference and machine learning techniques on data from galaxy surveys to constrain cosomolgy. I use this simulation based methodology to further explore viable models of the galaxy-dark matter relation, known as galaxy biasing, and alternative models of gravity. A lot of my work involves developing neural network architectures for cosmology applications and using large scale distributed computing.

Scientific Consortiums

The Dark Energy Survey (DES), Academic Member — Jan. 2022 to Pres.

- **Summary**, DES is a stage-III photometric galaxy survey providing both maps of galaxies; from galaxy clustering, and dark matter; from weak lensing measurements. I work in a number of groups on a number of projects which can be summarized in the publications section.
- **Working groups**, Mass Mapping, Simulations, Beyond 2-Point, Large Scale Structure and Weak Lensing.

The Dark Energy Spectroscopic Instrument (DESI), Academic Member — Jan. 2022 to Pres.

- **Summary**, DESI is a stage-IV spectroscopic galaxy survey creating the most extensive 3D map of galaxies in our universe to date. I work in the C3-Clusters group using gravitational redshift as a probe to constrain alternative theories of gravity.
- **Working Groups**, C3, C3-Cluster, Bright Galaxy Survey.

Experience

NCC group, cybersecurity research project — Jan. 2022 to April. 2022

- **the Extreme Fuzzing Machine**, The goal of this project was to leverage machine learning to improve software vulnerability detection capabilities, known as fuzz testing. I based the tool from a promising framework coming from an extensive review of the fuzz testing literature. The framework used a basic GPU accelerated neural network as a surrogate model to approximate the structure of the program under test. This approach guides the fuzzer's mutation strategy with gradients of the model. The bulk of the performance improvements came from implementing extreme learning machine ensembles as the surrogate model. The outcome of the project saw a large jump in performance compared to the currently used fuzzing tools. This was attributed to the orders of magnitude decrease in training time, to sub-second rates that was possible on a single CPU. Compared to the relatively slow training on an entire GPU at the rate of minutes of the original framework. This gave both an enormous scalability advantage and offered more frequent retraining to guide the fuzzer. The extreme learning machines ensemble was also proven to be more accurate at modelling the program than its GPU dependent predecessor neural network. In every test the fuzzer had an increase in found paths and more potential bugs. From this, the tool was developed into a production version program to be deployed with minimal user knowledge or input on consumer hardware. **github repository**

Conferences

Dark Energy Survey Collaboration Meeting, Portsmouth, United Kingdom — Feb. 2023

Future Cosmology, Corsica, France — April. 2023

Natural Sciences Machine Learning Network meetup: Explainable AI (XAI), Canterbury, United Kingdom — July. 2023

Dark Energy Spectroscopic Instrument Collaboration Meeting, Durham, United Kingdom — July. 2023

Debating the Potential of Machine Learning in Astronomical Surveys, Paris, France — Nov. 2023

Simulation-Based Inference in Astrophysics, the Royal Astronomical Society, London, United Kingdom — Nov. 2023

Simulation-Based Inference for Galaxy Evolution, Bristol, United Kingdom — April. 2024

Challenging the standard cosmological model, The Royal Society, London, United Kingdom — April. 2024

Statistical Challenges in 21st Century Cosmology, Chania, Greece — May. 2024

Dark Energy Survey Collaboration Meeting, Barcelona, Spain — May. 2024

Dark Energy Spectroscopic Instument Collaboration Meeting, Marseille, France — May. 2024

Invited talks

The Extreme Fuzzing Machine, UCL Data-Intensive Science and Industry Meeting, London, United Kingdom — May. 2022

AI-driven Misinformation as a Global Threat to Democracy, UCL CDTea Seminars, London, United Kingdom — Feb. 2024

Simulation Based-Inference made simple, UCL CDTea Seminars, London, United Kingdom — May. 2022

Field-level galaxy biasing from DES Y3 weak lensing mass & galaxy maps, The Dark Energy Survey Collaboration Meeeting, Barcelona, Spain — May. 2022

Galaxy biasing from Simulation-Based inference in the Dark Energy Survey, UCL Cosmology and ExGal seminar series, London, United Kingdom — May. 2022

Computing Workshops

NERSC N-Ways to GPU Programming Bootcamp, Virtual — April. 2023

Oracle cloud computing training, UCL, London, United Kingdom — Jan. 2023

AWS cloud computing training, UCL, London, United Kingdom — Feb. 2022

Publications

Dark Energy Survey Year 3 results: simulation-based cosmological inference with wavelet harmonics, scattering transforms, and moments of weak lensing mass maps II. Cosmological results — 17 May. 2024

M. Gatti, G. Campailla, N. Jeffrey, L. Whiteway, A. Porredon, J. Prat, ***J. Williamson***, et al.

arXiv:2405.10881

Dark Energy Survey Year 3 results: likelihood-free, simulation-based wCDM inference with neural compression of weak-lensing map statistics — 4 March. 2024

N. Jeffrey, L. Whiteway, M. Gatti, ***J. Williamson***, et al.

arXiv:2403.02314

Dark Energy Survey Year 3 results: simulation-based cosmological inference with wavelet harmonics, scattering transforms, and moments of weak lensing mass maps I: validation on simulations 4 Nov. 2023

M. Gatti, N. Jeffrey, L. Whiteway, ***J. Williamson***, et al.

arXiv:2310.17557

Technologies

Languages: C++, C, Fortran, Python, JAX, Tensorflow, PyTorch, CUDA, Assembly and Slurm

High-Performace Computing Clusters: Cori (NERSC), Perlmutter (NERSC), Splinter (UCL), Hypatia (UCL) and Kathleen (UCL)

Cloud Computing: AWS, Oracle

Creative projects

Exhibition: It's the sea gone with the sun, Almanac gallery, London, United Kingdom Nov. 2023 to Dec. 2023

- ***Sound***: 'Merging', a 35 minute soundtrack based on the sample of merging binary black holes.

Publication: The sound of a memory, Book, Ekaterina Bazhenova Aug. 2024

- ***Image***: 'gw191220', in collaboration with artist Maria Gorodeckaya, a general relativity realistic black hole is ray traced with several of her screen prints as her observable universe.