

Daniel Muthukrishna

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MIT Kavli Institute, 70 Vassar St, Cambridge, MA 02139, USA

Education

Institute of Astronomy, University of Cambridge

Cambridge, UK

PHD IN ASTROPHYSICS (FOCUSING ON MACHINE LEARNING APPLICATIONS)

Oct. 2017 - Jun. 2021

- **Thesis:** Data-driven Discovery of Transients in the New Era of Time-Domain Astronomy
- **Advisers:** Prof Kaisey Mandel, Prof Gautham Narayan

University of Queensland

Brisbane, Australia

BACHELOR OF SCIENCE, PHYSICS

Mar. 2012 - Dec. 2016

High Distinction Average

University of Queensland

Brisbane, Australia

BACHELOR OF ENGINEERING, ELECTRICAL AND AEROSPACE

Mar. 2012 - Dec. 2016

Awarded 1st Class Honours - High Distinction Average

- **Thesis:** Deep Learning for the Spectral Classification of Supernovae
- **Advisers:** Prof David Parkinson, Dr Brad Tucker

Research and Work Experience

Kavli Institute for Astrophysics, Massachusetts Institute of Technology

Cambridge, MA, USA

POSTDOCTORAL RESEARCHER

Sep. 2021 - Present

- Applying deep learning and statistical models to astronomical time-series data from the Transiting Exoplanet Survey Satellite (TESS).
- Manage a team of five undergraduate research assistants. Assign research projects and supervise them to develop novel astrophysical models with state-of-the-art data analysis and machine learning methods.
- Develop Diffusion Model and Normalizing Flow architectures to model scattered light and noise from space telescope images.
- Develop Convolutional Neural Network and Recurrent architectures to identify extrasolar planets.

Institute of Astronomy, University of Cambridge

Cambridge, UK

PHD CANDIDATE

Oct. 2017 - Jun. 2021

- Developed a real-time anomaly detection framework for identifying unusual and interesting astronomical time-series data using Bayesian models and temporal convolutional neural networks.
- Developed a real-time photometric identification (**RAPID**: <https://astrorapid.readthedocs.io>) algorithm for classifying astronomical time-series in large-scale telescope surveys using recurrent neural networks.
- Published a novel spectroscopic classification tool for supernovae (**DASH**: <https://astrodash.readthedocs.io>) that used CNNs.

University of California, Santa Cruz

Santa Cruz, California, USA

KAVLI STUDENT FELLOW

Jul. 2019 - Aug. 2019

- Used deep neural networks for regression over time-series astronomical data.
- Developed generative models of common astronomical objects and used the model predictions for real-time anomaly detection.

Mount Stromlo Observatory, Australian National University

Canberra, Australia

RESEARCH ASSISTANT

Mar. 2017 - Aug. 2017

- Part of large international Dark Energy Survey collaboration (OzDES) and the SkyMapper Transient Survey Telescope.
- Helped develop software pipeline in the SkyMapper search for Planet 9 and the BBC Stargazing living citizen science project.

Gemini South Observatory

La Serena, Chile

RESEARCH INTERNSHIP

Dec. 2016 - Feb. 2017

- Analysed the internal kinematics of giant star-forming regions in interacting galaxies.
- Developed spectral emission line fitting tool called **FitELP** (<https://fitelp.readthedocs.io/>).

University of Queensland

Brisbane, Australia

RESEARCH ASSISTANT

Jan. 2014 - Feb. 2016

- Analysed cosmological data (Type Ia Supernovae and Baryonic Acoustic Oscillations) with Bayesian statistics. Modelled cosmic acceleration without invoking a theory of gravity by using a Taylor expansion of the scale-factor.

Micreo Limited

Brisbane, Australia

RADIO FREQUENCY ENGINEER

Dec. 2014 - Sep. 2015

- Radio Frequency Engineer at a leading Microwave and Electro-optic engineering company focused on electronic warfare for defence contracts.
- Researched, designed, simulated, and manufactured various Microwave Frequency equipment.
- Tested equipment using Vector Network Analysers, Spectrum Analysers, Oscilloscopes, and soldered components onto Printed Circuit Boards.

Selected Seminars & Conference Presentations

Apr. 2024	University of Washington , Institute for Data-Intensive Research (DiRAC), <i>Invited speaker</i>	Seattle, WA
Nov. 2023	Yale University , Yale Data Science x Astronomy & Astrophysics, <i>Invited speaker</i>	New Haven, CT
Sep. 2023	Harvard University , Center for Astrophysics Seminar, <i>Invited speaker</i>	Pasadena, CA
Mar. 2023	NASA Jet Propulsion Laboratory , Machine Learning and Instrument Autonomy group	Los Angeles, CA, USA
Jan. 2023	American Astronomical Society Meeting , 241st meeting, Contributed	Seattle, WA, USA
May. 2022	ESO Garching , SciOps 2022: Artificial Intelligence for Science in Astronomy, Contributed	Garching, Germany
Mar. 2022	Korea Astronomy and Space Science Institute , Cosmology Seminar Series, <i>Invited speaker</i>	Online
Jun. 2021	Dark Energy Science Collaboration, LSST , Machine Learning Topical Team, <i>Invited speaker</i>	Online
Mar. 2021	Telstra Telecommunications Company , AI ML forum, <i>Invited speaker</i>	Online
Dec. 2020	University of Sheffield , Astronomy Seminar, <i>Invited speaker</i>	Online
Feb. 2020	Stanford University, SLAC National Accelerator Laboratory , AI Seminar Series, <i>Invited</i>	Stanford, CA, USA
Feb. 2020	MIT , Kavli Institute's Brown Bag Lunch Talk Series	Cambridge, MA, USA
Feb. 2020	University of California Berkeley, SETI , Search for Extraterrestrial Intelligence Weekly Meeting	Berkeley, CA, USA
Feb. 2020	Texas A&M University , Astronomical Data Science Workshop, <i>Invited speaker</i>	Texas, USA
Nov. 2019	DESY (Deutsches Elektronen-Synchrotron) , Astroparticle Seminar, <i>Invited speaker</i>	Hamburg, Germany
Aug. 2019	Northwestern University , Hotwiring the transient universe workshop, <i>Invited speaker</i>	Evanston, IL, USA
Jul. 2019	Joint Statistical Meeting , Astrostatistics Best Student Paper Session	Denver, CO, USA
Jun. 2019	Institute of Astronomy, University of Cambridge , Wednesday Seminar	Cambridge, UK
Apr. 2019	Space Telescope Science Institute , Enabling Multi-messenger Astrophysics in the Big Data Era	Baltimore, MD, USA
Mar. 2019	Royal Astronomical Society , Machine Learning and AI applied to Astronomy, Contributed	London, UK
Mar. 2019	University of California, Santa Cruz , Invited Talk to Transient group	Santa Cruz, CA, USA
Jan. 2019	Harvard University , CHASC Topics in Astrostatistics group	Online seminar
Jun. 2018	University of Oxford , Planning for Surprises in the era of Data-Driven Astronomy, Contributed	Oxford, UK
Jul. 2017	Australian National University , Astronomical Society of Australia Annual Meeting, Contributed	Canberra, Australia
Jan. 2017	University of Chile , Machine Learning and transient group	Santiago, Chile

Selected Awards

2021	Paul Murdin Prize , Best Published Journal Paper by an Astronomy PhD Student	University of Cambridge
2019	Kavli Student Fellow , Selected fellow of the Kavli Summer Program in Astrophysics	UC Santa Cruz
2017	Bok Prize Highly Commended , Awarded to top three astronomy Masters theses in Australia	Astronomical Society of Australia
2017	Cambridge Australia Poynton Scholarship , Awarded to top applicants from Australia	Cambridge Trust
2017	President's PhD Scholarship , Awarded to the top applicants across Imperial College	Imperial College
2017	AAO Scholarship , Awarded to top astrophysics graduate students	Australian Astro. Observatory
2016	IEEE Student Thesis Prize , Best Engineering thesis from all undergraduates in Queensland	Institute of Electrical Engineers
2016	GBST Best Software Project , Best software-related thesis at the University of Queensland	GBST and University of Queensland
2016	Gemini Studentship , Two students from Australia selected	Australian Astro. Observatory
2016	Dean's Commendations for High Achievement , Awarded to students with top-ranking GPAs	University of Queensland
2015	RSAA Astronomy Winter School , Four students from Australia and New Zealand were selected	RSAA, Canberra
2014	Micreo Scholarship in Electrical Engineering , Awarded to one student each year in Queensland	University of Queensland
2013	Mpemba Effect Competition , Selected in the top 10 out of 22000 entrants	Royal Society of Chemistry
2012	Students for the Future Award , Awarded to the top 100 engineering students in Queensland	Queensland Resource Council

Skills

Experienced researcher working at the intersection of astronomy and data intensive science. I use deep learning and Bayesian modelling for data-driven astrophysics. I'm enthusiastic about applying novel machine learning methods to new datasets.

Expert Python: Experience with:	Tensorflow, Keras, PyTorch, Numpy, Pandas, Scipy, Scikit-learn, PyMC, Jax. C, C++, Matlab, SQL, HTML, Fortran, IDL, Java
Developer	Developed widely used packages based on convolutional and recurrent neural networks: astrodash https://astrodash.readthedocs.io and astrorapid https://astrorapid.readthedocs.io
Other	Deep learning, Recurrent Neural Networks, Diffusion Models, Normalizing Flows, Transformer Architectures, Time-series modelling, Bayesian statistics, data augmentation, massive observational datasets, data visualisation, multi-collaborator git version control, teaching, supervising students, managing teams in local and international collaborations, electronics design.
Academic Referee	Reviewer for National Science Foundation (NSF) Review panel, NASA's TESS Review Panel, NeurIPS workshops, ICML workshops, AAS (ApJ, A&A), MNRAS, and IEEE Journals.

Teaching Experience

Cambridge Centre for International Research

LECTURER

- Designed and lectured a 13-week lecture series on "Data-driven Astronomy: Machine learning and Statistics for Modern Astronomy".
- Course included probabilities, distributions, central limit theorem, Bayesian modelling, sampling, maximum likelihood estimation, supervised learning, clustering, random forests, support vector machines, and neural networks.

Online

Feb. 2023 - Present

DPMS, Centre for Mathematical Sciences, University of Cambridge

COURSE ORGANISER AND SUMMER LECTURER

- Prepared and lectured an intensive computer training course for Part II and Part III (third and fourth-year undergraduate) students.
- Began with an introduction to Python and shell environments, and extended to big-data analysis, Markov Chain Monte Carlo sampling, solving ODEs, visualising data, and machine learning architectures using scikit-learn and Tensorflow.

Cambridge, UK

Jul. 2018, Jul. 2019

School of Mathematics & Physics and School of Engineering, University of Queensland

UNIVERSITY TUTOR

- Led classes of 20-70 students and graded coursework for higher undergraduate level engineering, physics, and calculus courses.

Brisbane, Australia

Mar. 2013 - Nov. 2016

Mentoring

Joseph Lupo	Computer Science and Electrical Engineering, Senior, paper in prep., Jun. 2023 - Present	MIT
Hali Huang	Computer Science, Junior, paper accepted at NeurIPS workshop, Jun. 2022 - Jan 2024	MIT
Prajna Nair	Astrophysics, Junior, co-authored accepted at NeurIPS workshop, Mar. 2022 - Jan 2024	MIT
Zimi Zhang	Computer Science and Physics, Junior, co-authored accepted at NeurIPS workshop, Jun. 2022 - Jan 2024	MIT
Rithwik Gupta	High school student, paper in review, Mar. 2022 - Present	High School
Miguel Chacon	Computer Science and Physics, Sophomore, Sep. 2022 - Dec. 2023	MIT
Torsha Majumder	Verizon Data Scientist, Masters student, paper in prep, Dec. 2021 - Present	University of Texas
Andrew Jenkins	Electrical Engineering and Computer Science, 3rd year undergraduate, Jun. - Sep. 2022	MIT, Tesla
Saul Balcarcel	Astrophysics, 2nd year undergraduate, Mar. - Jun. 2022	MIT
Anahita Srinivasan	Computer Science, 2nd year undergraduate, Dec. 2021 - May. 2022	MIT
Jaya Chand	Astronomy, 3rd year undergraduate, Jun. - Aug. 2021	University College London

Selected Software Development

PRIMARY CONTRIBUTOR

- RAPID (Real-time Automated Photometric Identification)
 - Documentation:** <https://astrorapid.readthedocs.io>
 - GitHub:** <https://github.com/daniel-muthukrishna/astrorapid>
 - Description: Software package to train a deep learning model to classify astronomical transient time-series (light curves).
- DASH (Deep learning for Automated Supernova and Host classification)
 - Documentation:** <https://astrodash.readthedocs.io>
 - GitHub:** <https://github.com/daniel-muthukrishna/astrodash>
 - Description: Software package to train a deep learning model to classify supernova spectra.
- FitELP (Fit Emission-Line Profiles)
 - Documentation:** <https://fitelp.readthedocs.io/>
 - GitHub:** <https://github.com/daniel-muthukrishna/FitELP>
 - Description: Tool to fit emission lines in echelle or long-slit spectra, and compute kinematic chemical properties.
- COVID-19 Country Comparison
 - Website:** <https://covid19-cases-and-deaths.herokuapp.com/>
 - GitHub:** <https://github.com/daniel-muthukrishna/covid19>
 - Description: Online dashboard that allows users to compare the growth of COVID-19 across different countries.

5. LowHighCovid

Website: <https://lowhighcovid.herokuapp.com/>

GitHub: <https://github.com/nt409/covid-19>

Description: Online dashboard that allows users to implement their own SIR model of COVID-19 growth and compare the effect of different lockdown restrictions on the growth rate. This work was led by a Cambridge Mathematical biologist.

Selected Publications

See [full publication list on ADS](#). Over 1600 citations. H-index: 16.

FIRST THREE AUTHORS

1. Lupo, J., **Muthukrishna, D.**, Vanderspek, R., *Conditional Diffusion models for Correcting Systematic Effects in Astronomical Images from Space Telescopes*. 2024, submitted to the International Conference for Machine Learning's AI for Science Workshop.
2. Gupta, R., **Muthukrishna, D.**, Lochner, M., *A Classifier-Based Approach to Multi-Class Anomaly Detection for Astronomical Transients*. 2024, in review.
3. Huang, H., **Muthukrishna, D.**, Nair, P., Zhang, Z., Fausnaugh, M., Majumder, T., Foley, R., Ricker, G. *Predicting the Age of Astronomical Transients from Real-Time Multivariate Time Series*. 2023, Machine Learning and the Physical Sciences Workshop, Neural Information Processing Systems (NeurIPS) 2023. [[ads](#)]
4. **Muthukrishna, D.**, Mandel, K., Lochner, M., Webb, S., & Narayan, G. *Real-time detection of anomalies in large-scale transient surveys*. 2022, MNRAS, 517, 393. [[ads](#)][[doi](#)]
5. **Muthukrishna, D.**, Mandel, K., Lochner, M., Webb, S., & Narayan, G. *Real-time Detection of Anomalies in Multivariate Time Series of Astronomical Data*. 2021, Machine Learning and the Physical Sciences Workshop, Neural Information Processing Systems (NeurIPS) 2021. [[ads](#)]
6. Webb, S., Lochner, M., **Muthukrishna, D.**, et al., *Unsupervised machine learning for transient discovery in Deeper, Wider, Faster light curves*. 2020, MNRAS, 498, 3077. [[ads](#)][[doi](#)]
7. **Muthukrishna, D.**, Narayan, G., Mandel, K., Biswas, R., & Hložek, R. *RAPID: Early classification of explosive transients using Recurrent Neural Networks*. 2019, PASP, 131, 118002. [[ads](#)][[doi](#)]
8. **Muthukrishna, D.**, Parkinson, D., & Tucker, B. *DASH: Deep Learning for the Automated Spectral Classification of Supernovae and their Hosts*. 2019, ApJ, 885, 85. [[ads](#)][[doi](#)]
9. **Muthukrishna, D.** & Parkinson, D. *A cosmographic analysis of the transition to acceleration using SN-Ia and BAO*. 2016, J. Cosmol. Astropart. Phys, 11, 052. [[ads](#)][[doi](#)]
10. Agarwal, M., et al. (incl **Muthukrishna, D.**) *Applications of Deep Learning to physics workflows*. 2023, submitted. [[arXiv](#)]
11. Huang, H., **Muthukrishna, D.**, Nair, P., Zhang, Z., Majumder, T., Fausnaugh, M., Ricker, G. Foley, R., *Predicting the Age of Astronomical Transients in real-time surveys*. 2023, in prep.

OTHER CO-AUTHOR

13. Tey, E., et al. (incl **Muthukrishna, D.**), *Identifying Exoplanets with Deep Learning. V. Improved Light Curve Classification for TESS Full Frame Image Observations*. 2022, AJ, 165, 95. [[ads](#)][[doi](#)]
14. Fausnaugh, M., et al. (incl **Muthukrishna, D.**), *Four years of Type Ia Supernovae Observed by TESS*. 2022, ApJ, 956, 108. [[ads](#)][[doi](#)]
15. Biswas, E., Ishida, E., et al. (incl **Muthukrishna, D.**), *Enabling the discovery of fast transients: A science module for the Fink broker*. 2022, A&A, 677, A77. [[ads](#)][[doi](#)]
16. Chatterjee, D., Narayan, D., Aleo, P. D., Malanchev, K., **Muthukrishna, D.**, *Electromagnetic Counterpart Identification of Gravitational-wave candidates using deep-learning*. 2021, Accepted in NeurIPS 2021. [[ads](#)]
17. Chatterjee, D., Narayan, D., Aleo, P. D., Malanchev, K., **Muthukrishna, D.**, *El-CID: A filter for Gravitational-wave Electromagnetic Identification*. 2021, MNRAS, 509, 914. [[ads](#)]
18. Hložek, R., et al. (incl **Muthukrishna, D.**), *Results of the Photometric LSST Astronomical Time-series Classification Challenge (PLAsTiCC)*. 2021, submitted to ApJS. [[ads](#)]
19. Jones, D. O., et al. (incl **Muthukrishna, D.**), *The Young Supernova Experiment: Survey Goals, Overview, and Operations*. 2020,

ApJ, 908, 24. [[ads](#)][[doi](#)]

20. Stachie, C., Coughlin, M., Christensen, N. & **Muthukrishna, D.**, *Differentiating the signal from the noise: towards optimal choices of wide field-of-view telescope transient follow-up*. 2019, MNRAS, 497, 1320. [[ads](#)][[doi](#)]
21. Malz, A. I., et al. (incl **Muthukrishna, D.**), *The Photometric LSST Astronomical Time-series Classification Challenge PLAsTiCC: Selection of a Performance Metric for Classification Probabilities Balancing Diverse Science Goals*. 2019, AJ, 158, 171. [[ads](#)][[doi](#)]
22. Campuzano Castro, F., Hagele, G. F., Bosch, G., Firpo, V., Cardaci, M., **Muthukrishna, D.**, Morrell, N. *Chemodynamics in Blue Compact Dwarf galaxies: II Zw 33 and Mrk 600*. 2019, Boletín de la Asociación Argentina de Astronomía, 61A. [[ads](#)][[doi](#)]
23. Kessler, R., et al. (incl **Muthukrishna, D.**), LSST Dark Energy Science Collaboration, Transient and Variable Stars Science Collaboration *Models and Simulations for the Photometric LSST Astronomical Time Series Classification Challenge (PLAsTiCC)*. 2019, PASP, 131, 094501. [[ads](#)][[doi](#)]
24. Kessler, R., et al. (incl **Muthukrishna, D.**), *First cosmology results using Type Ia supernova from the Dark Energy Survey: simulations to correct supernova distance biases*. 2019, MNRAS, 485, 1171. [[ads](#)][[doi](#)]
25. Brout, D., et al. (incl **Muthukrishna, D.**), *First Cosmology Results Using SNe Ia from the Dark Energy Survey: Analysis, Systematic Uncertainties, and Validation*. 2019, ApJ, 874, 150. [[ads](#)][[doi](#)]
26. Abbott, T., et al. (incl **Muthukrishna, D.**), *First Cosmology Results using Type Ia Supernovae from the Dark Energy Survey: Constraints on Cosmological Parameters*. 2019, ApJL, 872, L30. [[ads](#)][[doi](#)]
27. D'Andrea, R., et al. (incl **Muthukrishna, D.**), *First Cosmology Results Using Type Ia Supernovae From the Dark Energy Survey: Survey Overview and Supernova Spectroscopy*. arXiv:1811.09565. [[ads](#)]
28. Campuzano Castro, F., Bosch, G., Hagele, G., Firpo, V., **Muthukrishna, D.**, Cardaci, M. *Estudio en galaxias BCD: Mrk 600 y IIZw 33*. 2018, Boletín de la Asociación Argentina de Astronomía, 60, 148. [[ads](#)]
29. Childress, M., et al. (incl **Muthukrishna, D.**), *OzDES multifibre spectroscopy for the Dark Energy Survey: 3-yr results and first data release*. 2017, MNRAS, 472, 273. [[ads](#)][[doi](#)]

SELECTED WHITE PAPERS, NOTES, AND ASTRONOMICAL TELEGRAMS

30. de Jong, R., et al. (incl **Muthukrishna, D.**), *4MOST: Project overview and information for the First Call for Proposals*. 2019, The Messenger, 175, 3. [[ads](#)][[doi](#)]
31. Allen, G., et al. *Multi-Messenger Astrophysics: Harnessing the Data Revolution*. 2018, arXiv:1807.04780. [[ads](#)]
32. The PLAsTiCC team, et al. *The Photometric LSST Astronomical Time-series Classification Challenge (PLAsTiCC): Data set*. 2018, arXiv:1810.00001. [[ads](#)]
33. **Muthukrishna, D.**, Sharp, R. G., Tucker, B. E., et al., *Classification of 17 DES supernova with OzDES*, *The Astronomer's Telegram*. 2017, ATel, 10759. [[ads](#)]

THESES

34. **Muthukrishna, D.** *Data-driven Discovery of Transients in the New Era of Time-Domain Astronomy*. 2021, PhD Thesis, University of Cambridge. [[Online Thesis](#)][[doi](#)]
35. **Muthukrishna, D.** *Deep Learning for the Spectral Classification of Supernovae*. 2016, Unpublished Honours Thesis, University of Queensland, Brisbane, Australia. [[Online Thesis](#)]
Awarded IEEE General Student Thesis prize for the best Electrical Engineering thesis in Queensland.
Awarded GBST prize for the best software thesis at the University of Queensland.
Awarded Bok Prize Highly Commended for the top three ranked astronomy Honours or Masters theses in Australia.