

# 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

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

## Selected Awards

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

## Skills

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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:** Tensorflow, Keras, Numpy, Pandas, Scipy, Scikit-learn, PyMC3.  
**Experience with:** 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, data augmentation, Bayesian statistics, 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 NeurIPS, ICML, AAS (ApJ, A&A), MNRAS, and IEEE Journals. National Science Foundation review panel

## Teaching Experience

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### Cambridge Centre for International Research

Online

LECTURER

Feb. 2023 - Present

- 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.

### DPMMS, Centre for Mathematical Sciences, University of Cambridge

Cambridge, UK

COURSE ORGANISER AND SUMMER LECTURER

Jul. 2018, Jul. 2019

- 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.

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

Brisbane, Australia

UNIVERSITY TUTOR

Mar. 2013 - Nov. 2016

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

## Mentoring

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

## Selected Software Development

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### PRIMARY CONTRIBUTOR

1. 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).
2. 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.
3. 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.
4. 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

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See [full publication list on ADS](#). Over 1500 citations. H-index: 16.

### FIRST THREE AUTHORS

1. Gupta, R., **Muthukrishna, D.**, Lochner, M., *A Classifier-Based Approach to Multi-Class Anomaly Detection for Astronomical Transients*. 2024, in review.

2. 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](#)]
3. **Muthukrishna, D.**, *Recurrent Neural Networks for Modern Astronomy*. 2023, Invited review article in the *Machine Learning Methods in Modern Astronomy* special edition, Astronomy and Computing (Elsevier), in prep.
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.
12. Lupo, R., **Muthukrishna, D.**, Vanderspek, R., Ricker, G., *Modelling Scattered Light in Space Telescope's with Diffusion Models*. 2024, 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.