

# 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 - GPA: 6.7/7

### University of Queensland

Brisbane, Australia

BACHELOR OF ENGINEERING, ELECTRICAL AND AEROSPACE

Mar. 2012 - Dec. 2016

Awarded 1st Class Honours - High Distinction Average - GPA: 6.5/7

- **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.

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

## Selected Awards

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

## 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.

## 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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### Miguel Chacon

MIT

COMPUTER SCIENCE, SOPHOMORE

Jun. 2022 - Present

- Developed a semi-supervised classification algorithm using a neural network variational autoencoder and random forest to classify multi-channel time-series data with a small amount of labeled data.

### Hali Huang

MIT

COMPUTER SCIENCE, SOPHOMORE

Jun. 2022 - Present

- Paper in preparation on the development of a probabilistic recurrent neural network to predict the epoch time of transients from the Transiting Exoplanet Survey Satellite (TESS) and Zwicky Transient Facility (ZTF) data.

### Zimi Zhang

MIT

COMPUTER SCIENCE AND PHYSICS, SOPHOMORE

Jun. 2022 - Present

- Modelling multi-channel light curves using a 2D Gaussian Process over time and wavelength. Using model for data augmentation to help train the other student's machine learning algorithms.

### Prajna Nair

MIT

ASTROPHYSICS, SOPHOMORE

Mar. 2022 - Present

- Paper in preparation with Hali Huang on the development of a Bayesian parametric model of early-time observations of supernovae to accurately predict the epoch time.

### Torsha Majumder

University of Texas, Verizon

DATA SCIENTIST, PROSPECTIVE PHD

Dec. 2021 - Present

- Paper in preparation on the development of unsupervised learning algorithms to identify anomalies in supernovae data from the TESS and ZTF.

### Andrew Jenkins

MIT, Tesla

ELECTRICAL ENGINEERING AND COMPUTER SCIENCE, JUNIOR

Jun. - Sep. 2022

- Developed a semi-supervised classification algorithm using a neural network variational autoencoder and random forest to classify transient light curves with a small number of labelled data. This work is being continued by Miguel Chacon, a 2nd year computer science undergraduate at MIT.

### Saul Balcarcel

MIT

ASTROPHYSICS, SOPHOMORE

Mar. - Jun. 2022

- Searched the TESS TOI catalog for multi-planet systems using a Bayesian model of Transit Time Variations in TESS light curves.

### Anahita Srinivasan

MIT

COMPUTER SCIENCE, SOPHOMORE

Dec. 2021 - May. 2022

- Used unsupervised machine learning using a neural network autoencoder and HDBSCAN to search for anomalies in the TESS TOI catalog.

### Jaya Chand

University College London

ASTRONOMY, 3RD YEAR UNDERGRADUATE

Jun. - Aug. 2021

- Developed a convolutional neural network to identify the redshift of supernova spectra from the Dark Energy Survey.

## 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](#).

### FIRST THREE AUTHORS

1. **Muthukrishna, D.**, Huang, H., Zhang, Z., Nair, P., Majumder, T., Fausnaugh, M., Ricker, G. Foley, R., *Predicting the Age of Astronomical Transients from Real-Time Multivariate Time Series with Bayesian Uncertainty Quantification*. 2023, International Conference for Machine Learning (ICML 2023), submitted.
2. **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](#)]
3. **Muthukrishna, D.**, Mandel, K., Lochner, M., Webb, S., & Narayan, G. *Real-time Detection of Anomalies in Multivariate Time Series of Astronomical Data*. 2021, NeurIPS 2021. [[ads](#)]
4. 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](#)]
5. **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](#)]
6. **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](#)]
7. **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](#)]
8. Agarwal, M., et al. (incl **Muthukrishna, D.**) *Applications of Deep Learning to physics workflows*. 2023, submitted.
9. 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.
10. Majumder, T., **Muthukrishna, D.**, Huang, H., Fausnaugh, M., Ricker, G., *Anomaly detection and unsupervised classification of transients in TESS and ZTF*. 2023, in prep.
11. **Muthukrishna, D.**, Chacon, M., Zhang, Z., Jenkins, A., Huang, H., Fausnaugh, M., Ricker, G., *Semi-supervised classification of transients in real-time transient surveys*. 2023, in prep.

### OTHER CO-AUTHOR

12. Tey, E., et al. (incl **Muthukrishna, D.**), *Identifying Exoplanets with Deep Learning. V. Improved Light Curve Classification for TESS Full Frame Image Observations*. 2022, accepted for publication in ApJ.
13. Fausnaugh, M., et al. (incl **Muthukrishna, D.**), *Four years of Type Ia Supernovae Observed by TESS*. 2022, submitted to ApJ.
14. Biswas, E., Ishida, E., et al. (incl **Muthukrishna, D.**), *Enabling the discovery of fast transients: A science module for the Fink broker*. 2022, submitted to A&A.
15. 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](#)]
16. Chatterjee, D., Narayan, D., Aleo, P. D., Malanchev, K., **Muthukrishna, D.**, *El-CID: A filter for Gravitational-wave Electromag-*

*netic Identification*. 2021, MNRAS, 509, 914. [ads]

17. Hložek, R., et al. (incl **Muthukrishna, D.**), *Results of the Photometric LSST Astronomical Time-series Classification Challenge (PLAsTiCC)*. 2021, submitted to ApJS. [ads]
18. Jones, D. O., et al. (incl **Muthukrishna, D.**), *The Young Supernova Experiment: Survey Goals, Overview, and Operations*. 2020, ApJ, 908, 24. [ads][doi]
19. 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]
20. 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]
21. 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]
22. 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]
23. 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]
24. 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]
25. 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]
26. 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]
27. Campuzano Castro, F., Bosch, G., Hagele, G., Firpo, V., **Muthukrishna, D.**, Cardaci, M. *Estudio en galaxias BCD: Mrk 600 y II Zw 33*. 2018, Boletín de la Asociación Argentina de Astronomía, 60, 148. [ads]
28. 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

27. 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]
28. Allen, G., et al. *Multi-Messenger Astrophysics: Harnessing the Data Revolution*. 2018, arXiv:1807.04780. [ads]
29. The PLAsTiCC team, et al. *The Photometric LSST Astronomical Time-series Classification Challenge (PLAsTiCC): Data set*. 2018, arXiv:1810.00001. [ads]
30. **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

31. **Muthukrishna, D.** *Data-driven Discovery of Transients in the New Era of Time-Domain Astronomy*. 2021, PhD Thesis, University of Cambridge. [Online Thesis][doi]
32. **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.