ASTR3110

Data Science Techniques in Astrophysics

Session 1, Special circumstances 2021

Department of Physics and Astronomy

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Notice

As part of Phase 3 of our return to campus plan, most units will now run tutorials, seminars and other small group activities on campus, and most will keep an online version available to those students unable to return or those who choose to continue their studies online.

To check the availability of face-to-face activities for your unit, please go to timetable viewer. To check detailed information on unit assessments visit your unit's iLearn space or consult your unit convenor.

General Information

Unit convenor and teaching staff Unit Convenor, lecturer, lab demonstrator. Matt Owers matt.owers@mq.edu.au 7 Wally's Walk, rm 2.703 By appointment Lecturer Christian Schwab christian.schwab@mq.edu.au 7 Wally's Walk, rm 2.202 By appointment Lab demonstrator Lee Spitler lee.spitler@mq.edu.au 7 Wally's Walk, room 2.605 By appointment
Credit points 10
Prerequisites PHYS202 or PHYS2020
Corequisites
Co-badged status

Unit description

We are in the 'golden age' of astronomy: powerful new telescopes are giving us exciting new visions of the Universe. For example, radio telescopes are uncovering hidden structures in our own Milky Way galaxy and space telescopes are revealing exotic planets orbiting alien stars. However, analysing the flood of data from new instruments has been compared to 'drinking from a firehose' - impossible for individuals to do unassisted. Scientists increasingly rely on intelligent algorithms and robust statistical analysis to make new discoveries in astronomical 'big data'. In this unit, students will learn about the astrophysics of the Milky Way galaxy and the hot topic of extra-solar planets - both fields where advanced analysis techniques are making a significant impact. Students will hone their data analysis skills during labs, where they will use machine learning, Bayesian statistics, and data-mining techniques to analyse cutting-edge astronomy data sets linked to the lecture material. The techniques learned here are broadly applicable to a wide range of problems outside of astronomy and this unit will equip students to be pioneers of the information age.

Important Academic Dates

Information about important academic dates including deadlines for withdrawing from units are available at https://students.mq.edu.au/important-dates

Learning Outcomes

On successful completion of this unit, you will be able to:

ULO2: describe and explain the main detection techniques for extrasolar planets, including their main observational biases and limitations.

ULO1: demonstrate knowledge of the detailed structure and formation history of the Milky Way galaxy.

ULO3: compare theoretical models to real data and quantify significance and likelihood.

ULO4: design and write python code to apply statistical techniques to analysing and interpreting astronomical data sets.

ULO5: visualise data, identify biases and describe key properties.

ULO6: apply machine learning techniques to identify structure and patterns in data, and interpret their significance.

General Assessment Information

Unit workload

The 'estimated time on task' for each assessment item is an estimate of the *additional* time needed to complete each assessment outside of all scheduled learning activities. These estimates assume that you actively engage with all scheduled learning activities *and* spend an additional 12 hours of self-led study during the session.

Hurdle tasks

The final examination is a hurdle requirement. You must obtain a mark of at least 40% in the final exam to be eligible to pass the unit. If your mark in the final examination is between 30% and 39% inclusive, you may be a given a second and final chance to attain the required level of performance; the mark awarded for the second exam towards your final unit mark will be capped at 40%, and you will be allowed to sit the second exam only if this mark would be sufficient to pass the unit overall.

Supplementary examinations

If you receive special consideration for the final exam, a supplementary exam will be scheduled after the end of the normal exam period. By making a special consideration application for the final exam you are declaring yourself available for a resit during the supplementary examination period and will not be eligible for a second special consideration approval based on pre-existing commitments. Please ensure you are familiar with the policy prior to submitting an application. Approved applicants will receive an individual notification one week prior to the exam with the exact date and time of their supplementary examination.

If you are given a second opportunity to sit the final examination as a result of failing to meet the minimum mark required, you will be offered that chance during the same supplementary examination period and will be notified of the exact day and time after the publication of final results for the unit.

Late assessment policy

The non-examination assessment components should be submitted via iLearn by the due date and time.

The penalty for late submission is deduction of 5% of the possible mark for that item for each 24 hour period (or part) overdue. Assessments will not be accepted for marking if submitted more than 1 week past the due date. Extensions to the due dates for assignments, practical assessments, and project will only be considered if requested with valid reason prior to the due date.

Students anticipating or experiencing difficulties in meeting a deadline should discuss this with one of the lecturers in the first instance, ideally ahead of the deadline, if at all possible. Students should also be familiar with the University's provisions for Special Considerations.

Assessment Tasks

Name	Weighting	Hurdle	Due
Lab reports	50%	No	Weeks 7, 10, 13
Problem sets	20%	No	Weeks 4, 7, 10, 12
Final exam	30%	Yes	Session 1 exam period.

Lab reports

Assessment Type [1]: Lab report
Indicative Time on Task [2]: 20 hours
Due: **Weeks 7, 10, 13**
Weighting: **50%**

A report for each of the three computational projects.

On successful completion you will be able to:

- design and write python code to apply statistical techniques to analysing and interpreting astronomical data sets.
- visualise data, identify biases and describe key properties.
- apply machine learning techniques to identify structure and patterns in data, and interpret their significance.

Problem sets

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 20 hours
Due: **Weeks 4, 7, 10, 12**
Weighting: **20%**

A series of assignments throughout the semester.

On successful completion you will be able to:

- describe and explain the main detection techniques for extrasolar planets, including their main observational biases and limitations.
- demonstrate knowledge of the detailed structure and formation history of the Milky Way galaxy.
- compare theoretical models to real data and quantify significance and likelihood.

Final exam

Assessment Type [1]: Examination
Indicative Time on Task [2]: 20 hours
Due: **Session 1 exam period.**
Weighting: **30%**

This is a hurdle assessment task (see assessment policy for more information on hurdle assessment tasks)

Examination in the university exam period, covering all content from the unit.

On successful completion you will be able to:

- describe and explain the main detection techniques for extrasolar planets, including their main observational biases and limitations.
- demonstrate knowledge of the detailed structure and formation history of the Milky Way galaxy.
- compare theoretical models to real data and quantify significance and likelihood.

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[1] If you need help with your assignment, please contact:

- the academic teaching staff in your unit for guidance in understanding or completing this type of assessment
- the Learning Skills Unit for academic skills support.

[2] Indicative time-on-task is an estimate of the time required for completion of the assessment task and is subject to individual variation

Delivery and Resources

Your lecturers in this course are Matt Owers and Christian Schwab. Each week, there will be 2 hours of online content provided on echo, as well as one hour of lectorial-type demonstrations conducted via Zoom. The 2 hours of lectures will cover astronomy content related to the Milky Way galaxy (Matt Owers) and extra-solar planets (Christian Schwab), while the one hour lectorials will cover techniques used to extract information from datasets (Matt Owers).

The lab sessions run from **Week 4-12** via Zoom, and will involve a series of computer labs completed using Python Notebooks within the Google Colab environment. **Note that labs start in Week 4.** Matt Owers and Lee Spitler will be your lab demonstrators.

Resources will be provided on iLearn. There is no required text, although the Milky Way Galaxy component will primarily draw content from the book "Galaxies in the Universe: An Introduction" 2nd Ed. by Sparke and Gallagher, supplemented by material from "An Introduction to Modern Astrophysics" 2nd Ed. by Carroll and Ostlie and "Galactic Astronomy" by Binney and Merrifield. Useful resources for the data science part of the course are the books "Statistics, Data Mining, and Machine Learning in Astronomy: A Practical Python Guide for the Analysis of Survey Data" by Ivezic *et al.* and "Hands-On Machine Learning with Scikit-Learn, Keras, and Tensorflow" by Geron.

Unit Schedule

Week	Lecture material (Matt/Christian)	Lectorial material (Matt)	Computer Labs (Matt/Lee)
1	Introduction, basic astro (Matt)	Probability and Statistics	N/A
2	Distance measurements & introduction to GAIA (Matt)	Manipulating, visualising and cleaning data (Pandas)	N/A
3	Demographics of stars and stellar populations (Matt)	Fitting a model to data: simple regression, maximum likelihood (MCMC)	N/A
4	Structure and components of MW part I (Matt)	Modelling data: Bayesian reasoning and samplers (Nested Sampling), advanced regression.	Lab 1: Line Fitting and the Period-Luminosity relation.
5	Structure and components of the MQ part II	Exploring structure in data: visualisation, PCA	Lab 1: Line Fitting and the Period-Luminosity relation.
6	Kinematics of the Milky Way (Matt)	Exploring structure in data: KNN & tSne	Lab 1: Line Fitting and the Period-Luminosity relation.
7	Orbital Dynamics within the Milky Way (Matt)	Exploring structure in data: GMMs	Lab 2: Determining star cluster membership using Gaia data.
8	Formation and evolution of the Milky Way and local group (Matt)	Classification: decision trees and random forest	Lab 2: Determining star cluster membership using Gaia data.
9	Introduction to Exoplanets (Christian)	Artificial neural networks	Lab 2: Determining star cluster membership using Gaia data.
10	Detection of Exoplanets (Christian)	Convolutional neural networks	Lab 3: Deep Learning to classify Galactic objects.
11	Demographics of Exoplanets (Christian)	Time-series analysis	Lab 3: Deep Learning to classify Galactic objects.
12	Exoplanet atmospheres (Christian)	Revision	Lab 3: Deep Learning to classify Galactic objects.
13	Revision (Matt/Christian)		N/A

N.B.: This schedule is flexible and subject to change.

Policies and Procedures

Macquarie University policies and procedures are accessible from Policy Central (https://policies.mq.edu.au). Students should be aware of the following policies in particular with regard to Learning and Teaching:

- Academic Appeals Policy
- Academic Integrity Policy

- Academic Progression Policy
- Assessment Policy
- Fitness to Practice Procedure
- Grade Appeal Policy
- Complaint Management Procedure for Students and Members of the Public
- Special Consideration Policy

Students seeking more policy resources can visit Student Policies (https://students.mq.edu.au/support/study/policies). It is your one-stop-shop for the key policies you need to know about throughout your undergraduate student journey.

To find other policies relating to Teaching and Learning, visit Policy Central (https://policies.mq.edu.au) and use the search tool.

Student Code of Conduct

Macquarie University students have a responsibility to be familiar with the Student Code of Conduct: https://students.mq.edu.au/admin/other-resources/student-conduct

Results

Results published on platform other than eStudent, (eg. iLearn, Coursera etc.) or released directly by your Unit Convenor, are not confirmed as they are subject to final approval by the University. Once approved, final results will be sent to your student email address and will be made available in eStudent. For more information visit ask.mq.edu.au or if you are a Global MBA student contact globalmba.support@mq.edu.au

Student Support

Macquarie University provides a range of support services for students. For details, visit http://students.mq.edu.au/support/

Learning Skills

Learning Skills (mq.edu.au/learningskills) provides academic writing resources and study strategies to help you improve your marks and take control of your study.

- Getting help with your assignment
- Workshops
- StudyWise
- Academic Integrity Module

The Library provides online and face to face support to help you find and use relevant information resources.

- Subject and Research Guides
- Ask a Librarian

Student Enquiry Service

For all student enquiries, visit Student Connect at ask.mq.edu.au

If you are a Global MBA student contact globalmba.support@mq.edu.au

Equity Support

Students with a disability are encouraged to contact the Disability Service who can provide appropriate help with any issues that arise during their studies.

IT Help

For help with University computer systems and technology, visit http://www.mq.edu.au/about_us/offices_and_units/information_technology/help/.

When using the University's IT, you must adhere to the Acceptable Use of IT Resources Policy. The policy applies to all who connect to the MQ network including students.

Changes from Previous Offering

Matt has taken over the lectorial material form Cormac Purcell. Lee Spitler came on board to help with the computational labs.