ASTR3110

Data Science Techniques in Astrophysics

Session 1, In person-scheduled-weekday, North Ryde 2023

School of Mathematical and Physical Sciences

Contents

General Information

Unit convenor and teaching staff
Convenor, lecturer, lab demonstrator
Matt Owers
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12 Wally's Walk, rm 510
By appointment.

Lecturer, lab demonstrator
Andrew Hopkins
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Australian Astronomical Optics, Level 1, 105 Delhi Rd, North Ryde 2113
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://www.mq.edu.au/study/calendar-of-dates

Learning Outcomes

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

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

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

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 over the course of the session.

Requirements to Pass this Unit

To pass this unit you must achieve a total mark equal to or greater than 50%, **and obtain a mark of at least 40% in the final exam**, which is a hurdle assessment. 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. The final exam is set as a hurdle task in order to ensure that Unit Learning Outcomes 1 and 2 are fulfilled by the student.

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, typically about 3 to 4 weeks after 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

Unless a Special Consideration request has been submitted and approved, a 5% penalty (of the total possible mark of the task) will be applied for each day a written report or presentation assessment is not submitted, up until the 7th day (including weekends). After the 7th day, a grade of '0' will be awarded even if the assessment is submitted. The submission time for all uploaded assessments is **11:55 pm**. A 1-hour grace period will be provided to students who experience a technical concern.

For any late submission of time-sensitive tasks, such as scheduled tests/exams, performance assessments/presentations, and/or scheduled practical assessments/labs, please apply for Special Consideration.

Assessments where Late Submissions will be accepted

- Lab Reports - YES, Standard Late Penalty applies
- Problem Sets - YES, Standard Late Penalty applies

Special Consideration

The Special Consideration Policy aims to support students who have been impacted by short-term circumstances or events that are serious, unavoidable and significantly disruptive, and which may affect their performance in assessment. If you experience circumstances or events that affect your ability to complete the assessments in this unit on time, please inform the convenor and submit a Special Consideration request through ask.mq.edu.au.

Assessment Tasks

Name	Weighting	Hurdle	Due
Lab reports	50%	No	Weeks TBA
Final exam	30%	Yes	Session 1 exam period.
Problem sets	20%	No	Weeks 3, 8, 12

Lab reports

Assessment Type [1]: Lab report
Indicative Time on Task [2]: 20 hours
Due: **Weeks TBA**
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.

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:

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

Problem sets

Assessment Type [1]: Problem set
Indicative Time on Task [2]: 20 hours
Due: **Weeks 3, 8, 12**
Weighting: **20%**

A series of assignments throughout the semester.

On successful completion you will be able to:

- demonstrate knowledge of the detailed structure and formation history of the Milky Way galaxy.
- describe and explain the main detection techniques for extrasolar planets, including their main observational biases and limitations.
- 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 Writing Centre 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 Andrew Hopkins. Each week, there will be 2 hours of lectures that will be delivered on-campus. There will also be a one hour of lectorial-type demonstration delivered on-campus. The 2 hours of lectures will cover astronomy content related to the Milky Way galaxy (Matt Owers) and extra-solar planets (Andrew Hopkins), while the one hour lectorials will cover techniques used to extract information from datasets (Matt Owers). Both will begin in Week 1 of session, and **in-person attendance is essential for success in this unit.**

The lab sessions run from **Week 3-12** on-campus in the Physics and Astronomy computer lab, and will involve a series of computer labs completed using Python Notebooks within the Google Colab environment. **Note that labs start in Week 3.** Matt Owers and Andrew Hopkins will be your lab demonstrators. **Again, in-person attendance is essential for success the labs.**

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.

Methods of Communication

Communication will be via your **university email** or through **announcements on iLearn**. General queries regarding assessments and/or lecture/lab content should be placed on the iLearn discussion board. Queries of a more personal nature can be sent to the convenor (matt.owers@mq.edu.au) from your university email address.

COVID Information

For the latest information on the University's response to COVID-19, please refer to the Coronavirus infection page on the Macquarie website: https://www.mq.edu.au/about/coronavirus-faqs. Remember to check this page regularly in case the information and requirements change during semester. If there are any changes to this unit in relation to COVID, these will be communicated via iLearn.

Unit Schedule

Week	Lecture material (Matt/ Andrew)	Lectorial material (Matt)	Computer Labs (Matt/Andrew)	
1	Introduction, basic astro (Matt)	Getting started with Google Colab	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.	Lab 1: Line Fitting and the Period-Luminosity relation.	
4	Structure and components of the Milky Way part I (Matt)	Modelling data: Bayesian reasoning and samplers (MCMC).	Lab 1: Line Fitting and the Period-Luminosity relation.	
5	Structure and components of the Milky Way 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 with K-means clustering.	Lab 2: Determining star cluster membership using Gaia data.	
7	Orbital Dynamics within the Milky Way (Matt)	Good Friday	Good Friday	
	Mid-sem	Break		
8	Formation and evolution of the Milky Way and local group (Matt)	Exploring structure in data with Gaussian Mixture Models	Lab 2: Determining star cluster membership using Gaia data.	
9	Introduction to Exoplanets (Andrew)	Classification: decision trees and random forest	Lab 2: Determining star cluster membership using Gaia data.	
10	Detection of Exoplanets (Andrew)	Artificial neural networks	Lab 3: Deep Learning to classify Galactic objects.	
11	Demographics of Exoplanets (Anderew)	Convolutional neural networks	Lab 3: Deep Learning to classify Galactic objects.	
12	Exoplanet atmospheres (Andrew)	Revision	Lab 3: Deep Learning to classify Galactic objects.	
13	Revision (Matt/Andrew)		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
- Assessment Procedure
- Complaints Resolution 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

Academic Integrity

At Macquarie, we believe academic integrity – honesty, respect, trust, responsibility, fairness and courage – is at the core of learning, teaching and research. We recognise that meeting the expectations required to complete your assessments can be challenging. So, we offer you a range of resources and services to help you reach your potential, including free online writing and maths support, academic skills development and wellbeing consultations.

Student Support

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

The Writing Centre

The Writing Centre provides resources to develop your English language proficiency, academic writing, and communication skills.

- Workshops
- Chat with a WriteWISE peer writing leader
- Access StudyWISE
- Upload an assignment to Studiosity
- Complete the 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 Services and Support

Macquarie University offers a range of Student Support Services including:

- IT Support
- Accessibility and disability support with study
- Mental health support
- Safety support to respond to bullying, harassment, sexual harassment and sexual assault
- Social support including information about finances, tenancy and legal issues
- Student Advocacy provides independent advice on MQ policies, procedures, and processes

Student Enquiries

Got a question? Ask us via AskMQ, or contact Service Connect.

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

Andrew Hopkins has joined the teaching staff for the unit.