



ASTR3110

Data Science Techniques in Astrophysics

Session 1, In person-scheduled-weekday, North Ryde 2022

School of Mathematical and Physical Sciences

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General Information

Unit convenor and teaching staff

Unit Convenor, lecturer, lab demonstrator

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By appointment

Lecturer

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Lab demonstrator

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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.

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 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.

Late assessment policy

There is now a General Faculty of Science and Engineering Policy for assessment submission deadlines and late submissions:

Online quizzes, in-class activities, scheduled tests and exams must be undertaken at the time indicated in the unit guide. Should these activities be missed due to illness or misadventure, students may apply for [Special Consideration](#).

All other assessments (e.g., lab reports and assignments) must be submitted by **5:00 pm on their due date**.

Should these assessments be missed due to illness or misadventure, students should apply for Special Consideration.

Late submission are allowed in this unit, and a consistent penalty will be applied for late submissions as follows:

A 12-hour grace period will be given after which the following deductions will be applied to the awarded assessment mark: 12 to 24 hours late = 10% deduction; for each day thereafter, an additional 10% per day or part thereof will be applied until five days beyond the due date. After this time, a mark of zero (0) will be given. For example, an assessment worth 20% is due 5 pm on 1 January. Student A submits the assessment at 1 pm, 3 January. The assessment received a mark of 15/20. A 20% deduction is then applied to the mark of 15, resulting in the loss of three (3) marks. Student A is then awarded a final mark of 12/20.

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.

Assessment Tasks

Name	Weighting	Hurdle	Due
Problem sets	20%	No	Weeks 3, 8, 12
Final exam	30%	Yes	Session 1 exam period.
Lab reports	50%	No	Weeks 7, 10, 13

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.

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.

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.

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 [Christian Schwab](#). Each week, there will be 2 hours of lectures that will be delivered on-campus with echo recordings provided. 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 (Christian Schwab), while the one hour lectorials will cover techniques used to extract information from datasets (Matt Owers).

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 [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 Ivezić *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)	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 MW 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 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 with K-means clustering.	Lab 2: Determining star cluster membership using Gaia data.
7	Orbital Dynamics within the Milky Way (Matt)	Exploring structure in data with Gaussian Mixture Models	Lab 2: Determining star cluster membership using Gaia data.
	Mid-sem	Break	
8	Formation and evolution of the Milky Way and local group (Matt)	Anzac day	Anzac Day
9	Introduction to Exoplanets (Christian)	Classification: decision trees and random forest	Lab 2: Determining star cluster membership using Gaia data.
10	Detection of Exoplanets (Christian)	Artificial neural networks	Lab 3: Deep Learning to classify Galactic objects.
11	Demographics of Exoplanets (Christian)	Convolutional neural networks	Lab 3: Deep Learning to classify Galactic objects.

Week	Lecture material (Matt/Christian)	Lectorial material (Matt)	Computer Labs (Matt/Lee)
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 \(https://policies.mq.edu.au\)](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 \(https://students.mq.edu.au/support/study/policies\)](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 \(https://policies.mq.edu.au\)](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 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.