Module guide

Contents

1 Introduction

This guide explains:

- the aims of S385 *Cosmology and the distant Universe*
- what topics you will study
- how you will study them
- how you will be assessed
- how to get help where needed.

Module aims

The module aims to provide an in-depth and contemporary introduction to the subjects of cosmology and the astrophysics of the distant Universe. Cosmology is the science of modelling the Universe on the largest scales and investigating its evolution over time. Over the course of the module you will develop the mathematical and physical tools of cosmology and will explore how a rich diversity of astronomical observations are used to test cosmological models and to learn about the early Universe. In the second part of the module you will develop your knowledge of key astrophysical processes operating both on the scale of individual particle interactions and of entire galaxies through investigation of a range of phenomena of the distant Universe, including the earliest galaxies, black-hole jets and gravitational lensing.

Python activities in S385

Cosmology is one of the most challenging areas of astrophysics to study because it is intrinsically a very abstract topic, involving many concepts that are far removed from everyday life and that can be highly counterintuitive. For this reason the module includes five, week-long, practical activities in which you will explore key module concepts in a hands-on way, using the Python programming language (or hereafter 'Python', for short). As well as helping you to understand the module material to a deeper level, these activities aim to provide experience of what it means to *do* cosmology and to give you an opportunity to develop your coding skills as a key part of a modern physicist's problem-solving toolkit.

Assumed prior knowledge

S385 is designed as part of the Physics and Astronomy qualifications at The Open University (OU), including R51, Q64 (Astronomy and Planetary Sciences) and M06. It is a Level 3 module in terms of its complexity and should ordinarily be studied at Stage 3 of a suitable qualification pathway. For more information about qualifications, visit the Physics, astronomy and planetary science website.

The module materials assume the level of mathematics and physics knowledge provided by Stage 2 modules for relevant qualifications, namely:

- either *Astronomy* (S284) or *Physics: from classical to quantum* (S217)
- *Mathematical methods* (MST224) or equivalent (e.g. MST210)
- *Remote experiments in physics and space* (SXPS288).

The module is also expected to be of interest to students on Q77 (Mathematics and Physics). If you have not completed SXPS288, you should have a good level of computing ability, and if not familiar with Python we strongly recommend you undertake some Python preparation, such as via the self-study material on the Programming for Physical Sciences site.

We recommend you use the 'Are You Ready For?' diagnostic quiz to assess your preparation for this module.

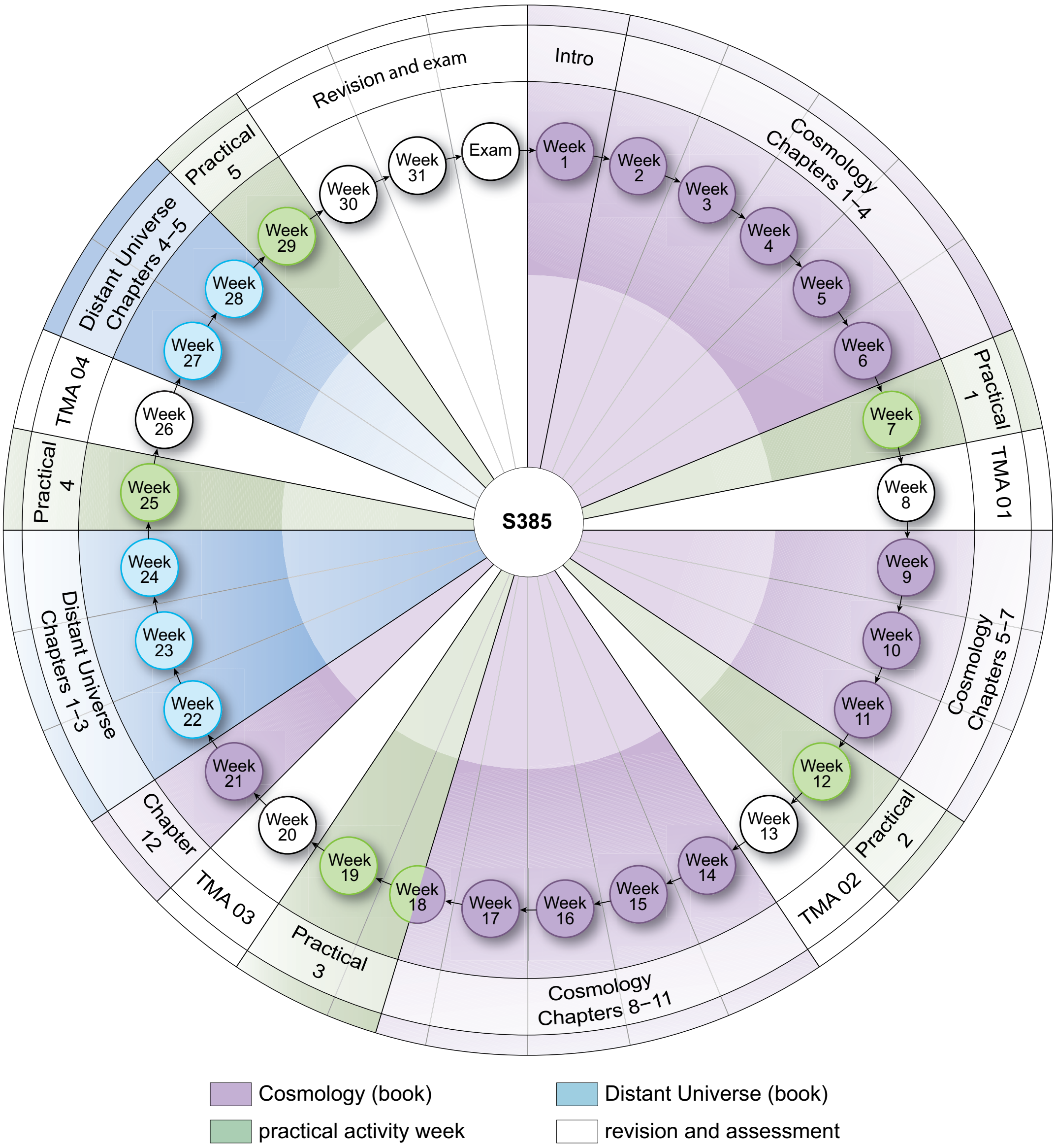
Note

It is important that you read through this guide fully and thoroughly to give you the best possible chance of a satisfying study experience and of successfully completing the module.

2 Module overview

The module website is structured to provide you with a week-by-week study plan. Each week of study will involve one main learning activity, which will be either reading a book chapter, carrying out a computer-based practical activity or preparing to submit an assessment. Additional resources, such as videos and quizzes, will supplement these primary activities.

The module has two main parts: ‘Cosmology’ (comprising around two-thirds of the content and study time) and ‘Distant Universe’ (comprising around one-third of the content and study time). The S385 module map provides a concise overview of the module structure to help you plan ahead (see the click-to-expand image below).



3 Studying S385

3.1 What you will study

The first part of the module (‘Cosmology’, Weeks 2–21) provides a thorough introduction to modern cosmology. This part begins with an overview of current understanding to provide context for the more specialised topics that follow. You’ll then explore the basic concepts and mathematical language of special and general relativity, learning how these underpin our ability to describe the geometry of the Universe. You’ll be introduced to the metric describing the geometry of the Universe and the Friedmann equations that describe its expansion. You’ll learn how a small set of cosmological parameters define spacetime’s past and future evolution, then explore the key observational evidence supporting the current model and how observations measure these fundamental parameters. In later weeks, you’ll follow a history of the Universe from the earliest particle interactions to the formation of structure via gravitational collapse and, eventually, the birth of stars and galaxies. Three Python-based practical activities support the ‘Cosmology’ part of the module, providing hands-on experience of working with cosmological models and observations.

The second part of the module (‘Distant Universe’, Weeks 22–30) consists of a series of in-depth study topics in extragalactic astrophysics, linked to each other and to ‘Cosmology’ by themes of relativity and the interaction of matter and radiation. You’ll examine how we find and study the first galaxies and learn about their impact on their surroundings. You’ll then consider how to use the technique of gravitational lensing – the bending of light by massive objects – to learn about distant galaxies and more nearby objects. You’ll also learn about the Universe’s most massive structures: galaxy clusters. Finally, the module introduces the topic of high-energy astrophysics; you’ll learn about observations and models of two extreme phenomena: jets from supermassive black holes and gamma-ray bursts. Across all of these topics you will explore themes of physics on small scales (particle interactions) and large scales (galaxy evolution). Two further Python-based practical activities support the ‘Distant Universe’ part of the module.

3.2 Study resources and support

The main resources you will use as part of your study include the module website, the module books, video material, tutorials and tutor support. Below, each is discussed in turn.

Module website

The module website is structured as a week-by-week study planner, so you should use this site to plan what to study each week. The website also indicates when you need to start and complete assignments.

Each week you are expected to carry out both *module-directed* and *student-led* work. The website section for each week provides a short summary of your main module-led learning activity for the week, which will be either reading and working through a book chapter, carrying out a practical activity, or preparing and submitting a tutor-marked assignment (TMA).

In book-focused weeks you should aim to spend around 6.5 hours on reading, completing the associated exercises and watching any linked video material. You should aim to spend around a further 3.5 hours on self-directed study. Spending time on student-directed learning is as important as module-directed learning, but you are invited to tailor the specific tasks to your study needs. You could also watch a video to help you understand a tricky concept, or you could read some material that allows you to practise the skill of applying your knowledge to an unfamiliar situation. You may wish to re-read a previously studied book chapter.

In practical activity weeks you should aim to spend around 4 hours reading and following activity instructions. You should aim to spend a further 6 hours in self-directed learning, which could include trying out changes to parameters or code sections, revisiting the module material linked to the activity, engaging with material to support your Python skills development (e.g. videos), seeking support from your tutor or fellow students if needed, or perhaps helping another student with questions on a forum.

Books

Three books are provided that comprise the core teaching material for S385:

- *Cosmology Part 1*
- *Cosmology Part 2*
- *The Distant Universe*.

Cosmology Part 1 and *Part 2* provides a comprehensive introduction to cosmology, including geometrical descriptions of spacetime, cosmological models and key parameters, how observational evidence is used to test cosmological models and measure their parameters, the physics of the early Universe, and the formation of large-scale structure, stars and galaxies.

The Distant Universe explores a series of environments and phenomena of the distant Universe, including cosmic dawn, gravitational lensing, galaxy clusters, black-hole jets and gamma-ray bursts. Across these topics, the book aims to build understanding of the interaction of matter and radiation and applications of relativity, in the wider context of how galaxies evolve over time.

Each book chapter includes a series of worked examples and exercises to enable you to put your learning into practice and develop your astrophysical problem-solving skills. A table of useful constants, as well as Python commands that can be used to retrieve their values, is provided on the inside back cover of the module books, for use with exercises and assessment questions.

Videos

A series of short ‘Explainer’ videos are provided to supplement your learning of tricky module concepts.

A series of ‘Python Skills’ videos introduce the use of Python for cosmology and astrophysics, demonstrate a toolkit of useful routines and packages, and provide walkthroughs of coding examples.

Tutorials and tutor support

Throughout your module studies you will get help and support from your assigned module tutor, who will:

- mark your TMAs and provide detailed feedback to help you improve your future work
- guide you to additional learning resources
- provide individual guidance, whether for general study skills or specific module content

- facilitate online discussions between your fellow students in the dedicated module and tutor group forums
- run online tutorials throughout the module.

You will also be able to attend module-wide tutorials that may be led by another tutor. Where possible, recordings of online tutorials will be made available to you. While these tutorials won't be compulsory to complete the module, you're strongly encouraged to take part.

You will also have access to a Python specialist tutor who will provide support and guidance related to the practical activities via Python forums and 'office hours' in which interactive support can be provided.

Forums

You will have access to several module forums to discuss topics and questions that arise during your study with other students and tutors. Two dedicated Python forums are provided, one public to all students on the module and one private (with conversations visible only to you and the Python tutors). We encourage you to post Python questions in the public forum because many problems that arise are likely to be common to multiple students, which means others can benefit from the conversation and fellow students may be able to provide help. However, the private forum is also available to ensure everyone can access support where needed.

Additional resources

In some study weeks we provide links to small sections of Stage 2 Astronomy and Physics material that cover topics we assume most students have previously studied, as a useful reminder or background information. Other additional resources, such as links to external material, are provided where relevant.

3.3 Computer requirements

For the Python-based practical activities in S385 you will need to be able to read, edit and run Jupyter Notebooks that we will provide. The recommended route for doing this is via your web browser, using the OU's Open Computing Lab (OCL) interface. This avoids the need to install any software on your local machine. It is strongly recommended that you check you are able to use this interface during the module introduction week, so as to be ready for the first activities.

There are alternative ways to run the Python activities, one of which is by installing the Anaconda Python distribution on your own computer. You may have used Anaconda in other modules, and it will be possible to run the S385 activities this way; however, we strongly recommend you use the OCL interface rather than Anaconda if possible, because – in addition to being simpler to use – one S385 activity requires a fairly large external Python module that may be difficult to install and/or slow to run locally, depending on your computer set-up. We may only be able to offer limited support for running this activity via Anaconda.

3.4 Skills development and employability

The skills you will develop in this module provide a foundation from which you can progress to more advanced work in cosmology and astrophysics. The transferable skills you will gain are equally important for tasks in many types of analytical work and employment. In particular, Python coding is very widely used across many industries and so is a valued skillset. You can log the skills you learn and track your progress towards your study goals using the OU's FutureYOU tool. For more information on the opportunities and skills provided by studying physics and astrophysics, visit the Science skills and careers website. For further guidance, you can contact Careers and Employability Services, including booking an individual careers consultation.

3.5 Getting help

If you need help with studying the module, you can contact your tutor or ask a question on the module forums. For more general help, queries and advice, you can contact your Student Support Team (SST) via the Contact the OU website.

4 Assessment

S385 includes several assessments that contribute to your module result; Table 1 explains how they are weighted.

Table 1 Assessment weightings

Assessment	Weighting (%)
TMA 01	5
TMA 02	5
TMA 03	15
TMA 04	5
Exam	70

All four TMAs are designed both to provide formative opportunities for you to practise and develop your skills and understanding, and to assess your progress against the module learning outcomes.

TMAs 01, 02 and 04

These assignments provide crucial opportunities for practising your problem-solving skills and obtaining feedback on your understanding of the course material. Each of these TMAs includes several exam-style questions as well as some questions to demonstrate your engagement with the preceding practical activity week and a reflection on your Python skills development. Marks for all questions contribute to your final module result, so it is important to complete and submit all of the TMAs.

TMA 03 (Practical Cosmology investigation)

TMA 03 involves writing a scientific report that describes work carried out as part of the third week-long Practical Cosmology activity. This assignment assesses your ability to communicate scientific information and ideas and to apply computing skills effectively in the context of cosmology.

Note

TMA 03 is an important assessment worth 15 per cent of your final module result. You must plan ahead for TMA 03 to ensure you have completed the 'Practical Cosmology 3' activity in time to produce your report. Engaging fully with the Python activities earlier in the module is essential to prepare for 'Practical Cosmology 3'.

If you foresee any accessibility difficulties in carrying out the Python-based practical activities, please contact the module team at an early stage to discuss alternative activities for this assessment.

Examination

The majority of your learning in S385 is assessed by a final remote exam of 3 hours (plus a contingency period for assembling your answers and uploading your finished work).

Note

While working on the exam you will have access to all module resources and any other external resources, including the internet. However, you should not rely on being able to look up any material of substance – there simply will not be enough time!

The exam is designed to test your conceptual understanding of cosmology and extragalactic astronomy, and your ability to express these concepts quantitatively in mathematical form, apply them to unfamiliar situations and solve problems in this context. The only way to do this successfully is to come to the exam well prepared, having done plenty of revision and practice.

General information on remote exams is available in the Exam arrangements handbook.

Submitting assessments

For information about special circumstances relating to TMA submission, please see the Assessment Policies.

Information on how to scan, photograph or otherwise capture your answers and submit them is given on the Student guidance for preparing and submitting TMAs page of the Mathematics and statistics website.

Plagiarism

Each assessment includes a plagiarism warning. Make sure you read and understand this warning.

Please note that you are required to complete all assessment elements individually and without help from others.

5 Module learning outcomes

The module learning outcomes for S385 are given in Table 2 together with their assessment method(s).

Table 2 Module learning outcomes and assessment methods

Outcome	Description	Assessment method
Knowledge and understanding		
KU1	The fundamental concepts, principles and terminology of cosmology, the physics of the early Universe and the formation of structure leading to the first stars and galaxies.	Exam and TMAs 01, 02
KU2	The primary observational evidence underpinning modern cosmological models, its limitations and the resulting uncertainty in our understanding of the Universe.	Exam and TMAs 01, 02
KU3	The behaviour and properties of astrophysical objects and phenomena of the distant Universe revealed by current research in high-energy astrophysics and extragalactic astronomy.	Exam and TMA 04
Cognitive skills		
CS1	Devise and sustain arguments on the basis of conceptual understanding of cosmology and extragalactic astrophysics.	Exam and all TMAs
CS2	Critically analyse and synthesise scientific information and data presented in a variety of ways including texts, tables, graphs, diagrams, equations and mathematical derivations.	Exam and all TMAs
CS3	Apply the methods and techniques of the discipline, including calculus, physics and coding, to solve problems in familiar and unfamiliar contexts in cosmology and extragalactic astrophysics.	Exam and all TMAs
Key skills		
KS1	Communicate scientific information, arguments and ideas in cosmology and extragalactic astronomy accurately and effectively using written and numerical descriptions.	This outcome is covered by all the assessments including the exam. It is a particular focus for TMA 03

KS2	Select and apply quantitative and computing skills to model physical systems and to analyse and interpret astrophysical data.	Exam and TMA 03
Practical and professional skills		
PPS1	Reflect critically on feedback and achievements in order to identify goals that will continue to develop your personal and professional skills.	TMAs 01, 02, 04
PPS2	Plan and organise tasks effectively in order to meet deadlines and identified goals.	Exam and all TMAs

6 Accessibility

To aid accessibility, the majority of module materials are available in multiple formats. This includes the content and editable code for the Python activities designed to help you learn the concepts described in the module books.

Please see the Accessibility guide for detailed descriptions of the accessibility provisions in this module. If you use assistive technology for computer-based work, we encourage you to consider approaches for working with Python code at an early stage and to contact the module team via your tutor or the SST if you experience difficulties with this.

OU Library Services also provides accessibility support, which can be sought by contacting the Library Helpdesk.

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8 Next steps

This guide has provided an overview of the most important elements of S385. You may wish to refer back to it during the module if you are ever unclear about the purpose of any of the module elements and how they relate to the overall module structure.

We hope you are excited to start your journey in studying cosmology and the distant Universe. It will undoubtedly be challenging, but we hope also truly fascinating and inspiring! Before you start, we again strongly encourage you to engage thoroughly with the preparation and diagnostic material provided under the Week 1 heading on the module website. To study cosmology and astrophysics it is essential to have a strong grounding in mathematics and physics; you should ensure you have these foundations in place so as to have the best possible chance of success and enjoyment of the module.

Good luck with your studies!

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