UNIVERSITY OF CAMBRIDGE

Institute of Continuing Education

Undergraduate Diploma in Astronomy

2016-2017

Course code: 1617DCR605

COURSE SPECIFICATION

University of Cambridge Institute of Continuing Education, Madingley Hall, Cambridge, CB23 8AQ
Tel 01223 746222 www.ice.cam.ac.uk

Welcome to the **Undergraduate Diploma in Astronomy,** a University of Cambridge award offered by the Institute of Continuing Education (ICE). The Certificate is taught and awarded at FHEQ level 5 (i.e. second-year undergraduate level) and attracts 60 credits. The award is completed in one academic year. For further information about academic credit please see our website: http://www.ice.cam.ac.uk/studying-with-us/information-for-students/qualifications-that-we-offer.

The course offers three termly units and a syllabus and reading and resource list for each of these units are included in this course specification.

The overarching aim of the Diploma in Astronomy is to allow students who have successfully completed the existing Certificate in Astronomy, and other students with comparable previous experience, to study the subject to a greater depth and to develop further their understanding of key topics in astronomy. The course aims to:

1. extend students' knowledge of key topics in astronomy by introducing more advanced topics
2. give students a wider perspective and more in-depth understanding of the variety of observed astronomical phenomena (e.g. phenomena associated with binary star systems and their evolution, exoplanets and/or high-energy astrophysical processes).
3. explain why a wide range of approaches are required for tackling different problems in astronomy (e.g. cosmology at early and late times)
4. demonstrate how complementary techniques, including multi-wavelength observations, computer simulations and mathematical techniques, can be used to build self-consistent models of astronomical phenomena.
5. provide opportunities for students to develop practical skills in working with astronomical data and to explore computer simulations.

Teaching staff

Course Director

Dr Judith Croston. Judith is an ICE Teaching Officer and the Academic Director for Physical Science, and also holds a part-time position as Principal Research Fellow at the University of Southampton. She obtained her MSci in Physics with Astrophysics from the University of Bristol, followed by her PhD in the area of extragalactic astrophysics from Bristol in 2004. She has previously worked as a postdoctoral researcher in the Service d'Astrophysique, Commission d'Energie Atomique, Saclay, as an Associate Lecturer with the Open University, and as a Research Fellow at the University of Hertfordshire. She currently leads several international research projects investigating jets from supermassive black holes using ground and space-based astronomical observatories, and is involved in planning for next-generation instruments and observatories.

Tutors:
Dr Matthew Bothwell. Matt is a postdoctoral researcher in the Astrophysics department of the University of Cambridge. He obtained his Master's degree at the University of Southampton, while carrying out research at the Harvard Center of Astrophysics. He then returned to the UK in 2007, completing his PhD at the University of Cambridge in 2011. After a year working as a researcher at the University of Arizona, he returned to Cambridge in 2012. Matt is an observational astronomer, who uses a range of state-of-the-art observing facilities to study the evolution of galaxies across cosmic time.

Dr Hardip Sanghera obtained his PhD from Jodrell Bank, where he studied a class of radio loud active galaxies called Compact Steep Spectrum Radio Sources, where the radio jet is moving through the ISM, and yet may evolve into the typical larger classical radio source. Their study required high/ultra-high resolution observations using radio telescopes arrays e.g. VLA, MERLIN and VLBI, with follow-up observations using ground based optical telescopes, and the space based Hubble Telescope. Following his doctorate, he spent a number of years working at the Joint Institute for VLBI in Europe, in the Netherlands, before moving back to Cambridge, where he currently supporting the ESA space-based Planck observatory, which is mapping the CMB.

After attending school in Philadelphia and London, **Dr Neil Trentham** did his undergraduate degree studying natural sciences specialising in physics at the University of Cambridge. He then did a PhD in astronomy at the University of Hawaii, graduating in 1997. Since then, he has worked at the University of Cambridge as a researcher in extragalactic astronomy and cosmology. He has studied a wide range of objects from Gamma Ray Bursts to low mass galaxies and dark matter. More recently he has become interested in astrobiology and the search for extraterrestrial life.

Dr Ranjan Vilas Vasudevan. Ranjan obtained his BA and M.Sci in 2005 and his PhD in Astronomy in 2009, both at Cambridge, and is currently a postdoctoral researcher at the Institute of Astronomy. Ranjan's research focuses on understanding the total energy created by matter falling onto supermassive black holes (accretion) at the centres of galaxies. This light is intense enough to blow away large quantities of matter and can control the very formation and evolution of galaxies and the stars in them, despite the black holes' small size in comparison to their host galaxies. Ranjan works on gathering data from a number of different observatories to determine this energy in large galaxy catalogues.

Administrative staff

Academic Programme Manager: Linda Fisher, Institute of Continuing Education, University of Cambridge, Madingley Hall, Madingley, Cambridge, CB23 8AQ, 01223 746218, linda.fisher@ice.cam.ac.uk

Programme Administrator: Liz Deacon, Institute of Continuing Education, University of Cambridge, Madingley Hall, Madingley, Cambridge, CB23 8AQ, 01223 746227, liz.deacon@ice.cam.ac.uk

Venue

Madingley Hall is an historic Tudor mansion on the outskirts of Cambridge with one of the finest gardens in the region and will be the venue for your classes unless otherwise specified.

The Hall is situated in the village of Madingley, three miles west of Cambridge with easy access from the M11 and the A14. Full directions are given on our website at www.ice.cam.ac.uk/directions.

Workshops are held at Madingley Hall, which has a variety of teaching rooms ranging from the newly refurbished Courtyard Suite to rooms in the historic Hall. Workshops may be scheduled in different teaching rooms each term.

Contact details of ICE

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Please also refer to the 'information for students' section on ICE's website http://www.ice.cam.ac.uk/studying-with-us/information-for-students and the 2016/17 Student Handbook for award-bearing courses for further information and guidance relating to all aspects of the course including study skills, assignments, assessment and moderation. The Course Information and Help and Guidance section of the ICE VLE will also contain valuable information specific to your course.

Information correct as at 25/04/16

Syllabus for first unit
Michaelmas term 2016

Astronomical techniques across the spectrum

Start date	6 October 2016	**End date**	15 December 2016
Day	Thursday	**Time**	7.15pm-9.15pm
Venue	Madingley Hall, Madingley, Cambridge, CB23 8AQ		
Tutors	Dr Matt Bothwell Dr Ranjan Vasudevan	**No of meetings**	11 evening classes, one Saturday practical session + two optional Saturday half-day activities

Aims
The overall aim of the unit is to give students a broad understanding of the importance of multi-wavelength approaches to astronomy. The range of observational techniques and instrumentation across the electromagnetic spectrum, from radio to gamma-ray astronomy will be explored, and students will develop their knowledge of the astrophysical processes and types of object that dominate the emission we observe in each part of the spectrum. Students will also gain an understanding of the historical development of observing capabilities at different wavelengths, as well as future prospects for new observatories and space missions.

Content
The unit will begin by introducing and revising basic concepts about the electromagnetic spectrum, the types of measurements that astronomers are able to make, the physical processes that produce radiation in astronomical objects and how these relate to conditions of interest, such as temperature and density of gas. After establishing general concepts, the remainder of the course will provide a tour of astronomy across the spectrum, from radio waves through infrared and optical astronomy to X-ray and gamma-ray astronomy. For each part of the spectrum, we will explore the telescope and instrument design needed to make measurements at that wavelength (including past and future technology), and will investigate the types of astronomical objects that dominate the sky when observed at that wavelength. The value of combining knowledge obtained from across the electromagnetic spectrum will be demonstrated via case studies and project work.

Presentation of the unit
The unit will be taught via 11 weekly Thursday evening presentations from 7.15pm until 9.15pm in which the emphasis will be on interactive discussion. There will also be one longer Saturday practical and problem-solving session, and there is also an **optional** Saturday afternoon workshop for students who would like some extra maths practice and/or help.

Teaching methods will include presentations by the tutors, including images, illustrations and video content, supported by regular opportunities for discussion and problem-solving. Case studies will be used to draw together concepts from different parts of the course. Activities making use of the Virtual Learning Environment (VLE) will also be used to support students' learning.

Provisional weekly lecture list

Session	**Date**	**Content**
Lecture 1	06/10/2016	Course introduction & astronomical measurements
Lecture 2	13/10/2016	Radiation across the spectrum: the processes that produce astronomical light
Optional Saturday workshop	15/10/2016 (2pm – 5pm)	Maths skills workshop – optional session for students who would like extra maths practice
Lecture 3	20/10/2016	Radio astronomy (I): measuring the radio sky (history and techniques)
Lecture 4	27/10/2016	Radio astronomy (II): what astronomical objects make up the radio sky?
Optional visit to Mullard Radio Astronomy Observatory	29/10/2016	A visit to the Mullard Radio Astronomy Observatory at Lord's Bridge (near Madingley) to see the historic radio telescopes and current research instruments.
Lecture 5	03/11/2016	From mm waves to the far infrared
Lecture 6	10/11/2016	Infrared astronomy: the cool, the dusty, and the distant Universe
Lecture 7	17/11/2016	IR to optical astronomy: state of the art and future developments
Lecture 8	24/11/2016	Optical (continued) and UV astronomy
Lecture 9	01/12/2016	X-ray astronomy (I): techniques and history
Saturday day-school	3/12/2016 (10am – 4pm)	Practical activities: multi-wavelength astronomy and planning an observing project
Lecture 10	8/12/2016	X-ray astronomy (II): the X-ray sky
Lecture 11	15/12/2016	Gamma-ray astronomy: methods and science at the highest energies

Outcomes

As a result of the unit, within the constraints of the time available, students should be able to:

- demonstrate an understanding of how and why observational techniques differ in different parts of the electromagnetic spectrum;
- explain the types of measurements that can be made at particular wavelengths and how these can be used to determine the physical properties of astronomical objects;
- show an understanding of the advantages and limitations of particular observational techniques and how these are taken into account in designing scientific observing projects;
- demonstrate how measurements from different parts of the spectrum can be combined to solve problems in astronomy and astrophysics;
- engage critically with scientific papers in observational astronomy.

Student assignments

- Students are expected to participate fully in group discussions, and carry out reading and problem exercises at home as directed by the Unit tutors.
- Prepare a written report based on an investigation of how to plan a multi-wavelength observing programme. Instructions and resources will be provided by week 7*[**1500-2000 words**].*

- Prepare and submit a written report about an important observational result in radio, infrared, X-ray or gamma-ray astronomy. A list of topics and associated resources will be provided by the tutor in week 2 *[**1500 – 2000 words**].*

The word limits apply for each assignment separately, giving a total of **3,000-4,000 words** (or equivalent) overall for the unit. **Each assignment is equally weighted 50/50.** These written reports must demonstrate that students are able to fulfil the term's learning outcomes.

All students are expected to upload their assignments into the VLE.

Closing date for the submission of assignments: **Thursday 12 January 2017 by 12:00 (noon) UTC/GMT***
*Co-ordinated Universal Time / Greenwich Mean Time

Reading and resources list

There is no single core textbook for this Unit. The first two books both provide a fairly comprehensive reference for much of the course material, so you may wish to purchase one of them. Chromey's 'To Measure the Sky' provides useful introductory content and focuses on optical astronomy. For students who would like to increase their confidence in mathematical problem solving, we recommend purchasing or finding a library copy of either Fleisch & Kregenow's 'A Student's Guide to the Mathematics of Astronomy', or Jordan's 'Maths for Science', listed below.

Recommended reading:

Astrophysical techniques, 6th ed.	C.R. Kitchin	CRC Press, 2013	ISBN 978-1466513761
Measuring the Universe	G.H. Rieke	Cambridge University Press, 2014	ISBN 978-0521747684
To Measure the Sky	F.R. Chromey	Cambridge University Press, 2-1	ISBN 978-0521747684

General background:

An introduction to modern astrophysics, 2nd ed.	B.W. Carroll & D.A. Ostlie	Pearson Int, 2013	ISBN 978-1292022932
The Multiwavelength Atlas of Galaxies	G. Mackie	Cambridge University Press, 2011	ISBN 978-0511922848

Maths skills:

A Student's Guide to the Mathematics of Astronomy	D. Fleisch & J. Kregenow	Cambridge University Press, 2013	ISBN 978-1107610217
Maths for Science	S. Jordan, S. Ross, P. Murphy	Oxford University Press, 2011	ISBN 978-0199644964

More detailed information on particular topics:

The High-energy Universe: Ultra-high	P. Meszaros	Cambridge University Press,	ISBN 978-0521517003

energy events in Astrophysics and Cosmology	2010

Syllabus for second unit
Lent term 2017

Stellar phenomena

Start date	12 January 2017	**End date**	30 March 2017
Day	Thursday	**Time**	7.15pm-9.15pm
Venue	Madingley Hall, Madingley, Cambridge, CB23 8AQ		
Tutors	Dr Judith Croston Dr Ranjan Vasudevan	**No of meetings**	11 evening classes, one Saturday practical session (no half term break)

Aims
The aim of this unit is to develop students' understanding of the key physical processes affecting stellar evolution, and to explore the physical origins of observational phenomena associated with stars and binary star systems in particular stages of life. From variable stars and flaring activity to pulsars and various types of stellar explosions, students will explore the rich variety of stellar behaviour, and how physical models (and computer simulations) can allow us to understand its causes.

Content
The course begins with a brief review of stellar evolution, before exploring the rich variety of stellar behaviour observed by astronomers. The first part of the course introduces and develops the key physical concepts needed to understand the conditions in which stars can be stable and when and why they show more unusual and dramatic behaviour. These include: the physics of gases and how they behave under different conditions, the evolution of stars in binary systems, and how material from one star can accrete onto a companion and release considerable energy. In the second part of the course, we explore different aspects of observational behaviour and their causes, beginning with variability, flaring activity and periodic behaviour, including pulsars, before moving onto stellar explosions, including supernovae and gamma-ray bursts. Finally we discuss the formation of jets and winds, and how some of the stellar phenomena discussed contribute to the cycle of star formation and chemical enrichment of galaxies.

Presentation of the unit
The unit consists of 11 weekly Monday evening presentations from 7.15pm until 9.15pm in which the emphasis will be on interactive discussion. There will also be one longer Saturday practical and problem-solving session.

Teaching methods will include presentations by the tutor, including images, illustrations and video content, supported by regular opportunities for discussion and problem-solving. Case studies will be used to draw together concepts from different parts of the course. Activities making use of the Virtual Learning Environment (VLE) will also be used to support students' learning.

Provisional weekly lecture list

Session	Date	Content
Lecture 1	12/01/2017	The life cycles of stars: review
Lecture 2	19/01/2017	Stability vs. catastrophe: the structure of stars
Lecture 3	26/01/2017	Inside stars: how gases behave and how changing conditions drive stellar evolution
Lecture 4	02/02/2017	Binary star systems: disrupting stellar evolution
Lecture 5	09/02/2017	Problem solving practice session
Lecture 6	16/02/2017	The power of gravity: accretion onto compact objects
Lecture 7	23/02/2017	The restless sky (I): variability in stars and accreting systems
Lecture 8	02/03/2017	The restless sky (II): periodic behaviour – pulsars and their relatives
Saturday day-school	04/03/2017 (10am – 4pm)	Practical activities and problem-solving
Lecture 9	09/03/2017	The explosive sky (I): supernovae
Lecture 10	16/03/2017	The explosive sky (II): gamma-ray bursts
Lecture 11	23/03/2017	Jets and winds + course summary

Outcomes
As a result of the unit, within the constraints of the time available, students should be able to:

- demonstrate a good understanding of the physical behaviour of gases in stars;
- discuss how timescales of observed behaviour can be used to distinguish between interpretations of their causes;
- explain the main processes that cause stellar variability and explosive behaviour;
- show an increased familiarity with astronomical data and the use of computational methods in astronomy;
- make use of a range of physical concepts to solve problems in stellar astronomy;
- show improved ability to engage critically with scientific papers in astronomy.

Student assignments

- Students are expected to participate fully in group discussions, carry out reading and formative problem exercises at home as directed by the Unit tutors.
- Complete and submit one assessed problem set, which will be provided in week 5
- Prepare and submit a written report about an important result in stellar astronomy. A list of topics and associated resources will be provided by the tutor in week 2 *[**1500 – 2000 words**]*

The written reports must demonstrate that students are able to fulfil the term's learning outcomes. **Each assignment is equally weighted 50/50.**

All choices of assessment topics must be discussed and agreed with the tutor in advance.

All students are expected to upload their assignments into the VLE.

Closing date for the submission of assignments: **Thursday 13 April 2016 by 12:00 (noon) BST* (11:00 UTC)**

*British Summer Time

Reading and resources list

Core text (strongly recommended):

Cosmic catastrophes: Exploding stars, Black Holes and Mapping the Universe	J. Craig Wheeler	Cambridge University Press, 2007	ISBN 978-1107437913

General background:

Stars: a very short introduction	A.R. King	Oxford University Press, 2012	ISBN 978-0199602926
An introduction to the Sun and Stars	S.F. Green & M.H. Jones	Cambridge University Press,	ISBN 978-1107492639
Understanding Variable Stars	J. R. Percy	Cambridge University Press, 2007	ISBN 978-1107403703

More detailed (and mathematical) texts on stellar astrophysics:

The Physics of Stars, 2nd ed.	A.C. Phillips	Wiley & Sons Ltd., 2001	ISBN 471987980
Stellar Evolution and Nucleosynthesis	S.G. Ryan & A.J. Norton	Cambridge University Press	ISBN 978-0199602926
An Introduction to the Theory of Stellar Structure and Evolution	D. Prialnik	Cambridge University Press, 2010	ISBN 9780521866040

Syllabus for third unit
Easter term 2017

The early Universe

Start date	27 April 2017	**End date**	06 July 2017
Day	Thursday	**Time**	7.15pm-9.15pm
Venue	Madingley Hall, Madingley, Cambridge, CB23 8AQ		
Tutors	Dr Hardip Sanghera Dr Neil Trentham	**No of meetings**	11 evening classes, one *Sunday* practical session (no half term break)

Aims
The aim of this unit is to explore how our Universe has evolved, from the Big Bang to the formation of stars and galaxies, via a range of approaches, from the theoretical to the observational. By examining the various stages of the growth of the early Universe, students will develop an understanding of how the physics of the very small (e.g. subatomic particles) and the very large (e.g. clusters of galaxies) are both essential to the study of cosmology.

Content
The unit begins with an overview of the Universe as it is presently understood, before introducing the theoretical underpinnings of our current cosmological models. After considering the key parameters of cosmological models and the implications of particular values, we will explore in more detail the stages of evolution of the Universe, from the radiation-dominated era following the Big Bang to matter domination and the emergence of large-scale structure. The role of both theoretical work and a range of different observations in establishing the currently favoured cosmological model will be examined, and methods for measuring the key cosmological parameters will be discussed. In the later parts of the course, we will consider the formation of structure and the role of dark matter, before finally examining the philosophical implications of cosmology and the possible fate of the Universe, particularly in light of our current understanding of the role of dark energy.

Presentation of the unit
The unit consists of 11 weekly Monday evening presentations from 7.15pm until 9.15 pm in which the emphasis will be on interactive discussion. There will also be one longer Saturday practical and problem-solving session.

Teaching methods will include presentations by the tutor, including images, illustrations and video content, supported by regular opportunities for discussion and problem-solving. Case studies will be used to draw together concepts from different parts of the course. Activities making use of the Virtual Learning Environment (VLE) will also be used to support students' learning.

Provisional weekly lecture list

Session	Date	Content
Lecture 1	27/04/2017	The expanding Universe: an introduction
Lecture 2	04/05/2017	Gravity and geometry: modelling the expanding Universe
Lecture 3	11/05/2017	The key parameters of cosmological models
Lecture 4	18/05/2017	The first few seconds: matter and radiation in the very early Universe
Lecture 5	25/05/2017	The first few minutes: formation of the elements
Lecture 6	01/06/2017	The cosmic microwave background: a snapshot of the early Universe
Lecture 7	08/06/2017	Measuring the parameters of cosmology: what observations tell us
Lecture 8	15/06/2017	The first 100 million years: the dark ages and the formation of the first stars and galaxies
Lecture 9	22/06/2017	Lighting up the Universe: from reionization to the present-day Universe
Sunday day-school	25/06/2017 (10am – 4pm)	Practical activities and problem-solving
Lecture 10	29/06/2017	Dark energy and the accelerating Universe: what of the future?
Lecture 11	06/07/2017	Course summary

Outcomes
As a result of the unit, within the constraints of the time available, students should be able to:

- describe the origins, evolution and possible fate of the Universe;
- demonstrate a basic understanding of mathematical models of the Universe based on the theory of general relativity, and of role played by specific cosmological parameters;
- describe the composition of the Universe and the origin of the chemical elements;
- provide a chronological sequence from the very earliest stages of the Universe, from the origin of matter to the formation of the first stars and galaxies;
- explain how observational methods are used to test cosmological models;
- show improved ability to engage critically with scientific papers in astronomy.

Student assignments

- Students are expected to participate fully in group discussions, carry out reading and formative problem exercises at home as directed by the Unit tutors.
- Complete and submit one assessed problem set, which will be provided in week 5
- Prepare and submit a written report about an important result in cosmology. A list of topics and associated resources will be provided by the tutor in week 2 *[**1500 – 2000 words**]*

The written reports must demonstrate that students are able to fulfil the term's learning outcomes. **Each assignment is equally weighted 50/50.**

All choices of assessment topics must be discussed and agreed with the tutor in advance.

All students are expected to upload their assignments into the VLE.

Closing date for the submission of assignments: **Thursday 27th July 2017 by 12:00 (noon) BST* (11:00 UTC)**

*British Summer Time

Reading and resources list

Recommended reading:

An Introduction to Galaxies and Cosmology	M.H. Jones, R.J.A. Lambourne, S. Serjeant	Cambridge University Press, 2015	ISBN 978-1107492615

General background to the topics covered:

Big Bang	S. Singh	Harper Perennial, 2005	ISBN 978-0007152520
The Little Book of the Big Bang: a Cosmic Primer	C. I. Hogan	Copernicus, 2013	ISBN 978-1461272342
The First Three Minutes	S. Weinberg	Basic Books, 1993	ISBN 978-0465024377
Just Six Numbers	M. Rees	W&N, 2001	ISBN 978-0753810224
A Brief History of Time	S. Hawking	Bantam, 2011	ISBN 978-0857501004
The Infinite Cosmos: Questions from the Frontiers of Cosmology	J. Silk	Oxford University Press, 2008	ISBN 978-0199533619

More advanced reference material:

An Introduction to Modern Cosmology	A. Liddle	Wiley-Blackwell, 2003	ISBN 978-0470848357
Observational Cosmology	S. Serjeant	Cambridge University Press, 2010	ISBN 978-0521157155
Foundations of Modern Cosmology	J.F. Hawley & K.A. Holcomb	Oxford University Press, 2005	ISBN 978-0198530961
Introduction to Cosmology	B. Ryden	Addison-Wesley, 2002	ISBN 978-0805389128
The Early Universe	E. W. Kolb & M S. Turner	Westview Press, 1994	ISBN 978-0201626742

TIMETABLE

Michaelmas 2016
Astronomical techniques across the spectrum

Lecture 1	06/10/16
Lecture 2	13/10/16
Optional Saturday workshop (2 – 5pm)	15/10/16
Lecture 3	20/10/16
Lecture 4	27/10/16
Lecture 5	03/11/16
Lecture 6	10/11/16
Lecture 7	17/11/16
Lecture 8	24/11/16
Lecture 9	01/12/16
Saturday practical class (10am – 4pm)	03/12/16
Lecture 10	08/12/16
Lecture 11	15/12/16

Lent 2017
Stellar Phenomena

Lecture 1	12/01/17
Lecture 2	19/01/17
Lecture 3	26/01/17
Lecture 4	02/02/17
Lecture 5	09/02/17
Lecture 6	16/02/17
Lecture 7	23/02/17
Lecture 8	02/03/17
Saturday practical class (10am – 4pm)	04/03/17
Lecture 9	09/03/17
Lecture 10	16/03/17
Lecture 11	23/03/17

Easter 2017
The Early Universe

Lecture 1	27/04/17
Lecture 2	04/05/17
Lecture 3	11/05/17
Lecture 4	18/05/17
Lecture 5	25/05/17
Lecture 6	01/06/17
Lecture 7	08/06/17
Lecture 8	15/06/17
Lecture 9	22/06/17
Sunday practical class (10am – 4pm)	25/06/17
Lecture 10	29/06/17
Lecture 11	06/07/17

Assignment submission dates are normally 3 weeks after final teaching session of term.

Whilst every effort is made to avoid changes to this programme, published details may be altered without notice at any time. The Institute reserves the right to withdraw or amend any part of this programme without prior notice.

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