UCT Honours MAM4001W/AST4007W 2025 - Course Title: **COSMOLOGY**

Course Lecturer: Dr Álvaro DE LA CRUZ-DOMBRIZ (UCT Cosmology & Gravity group)
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Consultation times: by appointment. Languages of consultation: English, Spanish, French.

Course credits: 20
Lecturer contact hours: 24
Tutorial/practical hours: 6

1) Course overview:
Rationale: This course brings students up to date with the basic concepts and key results in current cosmology within the context of the Standard Concordance Cosmological LCDM Model. The focus is on building physical understanding and making links to modern observations where possible.

Outline: The course begins with a very quick overview of the accelerating universe model (LCDM), from the Big Bang and Inflation to the current era of Dark Energy. Then we discuss cosmic times, distances, masses and densities and their standard units in order to develop familiarity with the scales of cosmology.

We use basic ideas of Special Relativity to describe the past light-cone of the observer, and thus derive the comoving, angular diameter and luminosity distances. This leads to qualitative descriptions of baryon acoustic oscillation scale and supernova cosmology. It also lays the basis to analyse number counts in galaxy surveys and volumes on the past light-cone.

Then we shall study the thermal history of the Universe, specifying the intercourse between the concepts of particle annihilation and cosmological expansion.

Subsequently, we shall present the standard formulas for the so-called cosmological perturbation theory. First by addressing the rudiments on how fluctuations originate and then grow to generate the cosmic microwave background (CMB) anisotropies and large-scale structures; then we shall introduce the perturbations in density, velocity and metric potential. Second, we shall rigorously calculate the perturbed Einstein field equations: the evolution of density, velocity and curvature perturbations in the radiation, matter and Dark Energy eras (how modes evolve from Inflation; transfer functions; the effect of Dark Energy; analytical and numerical solutions).

Finally, we shall address two important ingredients of the LCDM model: the Inflationary paradigm and different models therein which can explain the observations; and the physics and theoretical consequences of the so-called Cosmic Microwave Background (CMB).

Students are assisted to write their own basic Python/Mathematica/Maple codes to compute cosmological distances and solve basic equations, etc.

2) Course breakdown/syllabus:

1. *Introduction* **[2 hours] * Chapters 1 and 2 of the notes**
   - Overview of the LCDM model, from Inflation to Dark Energy
   - Cosmic scales: times, lengths, masses and densities in astronomical units

2. *Observations in Cosmology - Cosmological distances* **[8 hours]**
   *** Chapters 3 and 4 of the notes**
   - The past lightcone of the observer (using Special Relativity locally)
   - Derivation of the formulae for comoving, angular diameter and luminosity distances
   - Angular sizes and the BAO as 'standard ruler'
   - Supernovae as 'standard candles'

3. *Observations in Cosmology - Galaxy surveys* **[4 hours]**
   *** Chapter 5 of the notes**
   - Number counts
   - Volumes on the past lightcone

4. *Thermal History of the Universe* **[TBC hours]**
   - Subtopics TBA

5. *Theory of Cosmological Perturbations* **[TBC hours]**
   *** Chapter 6 of the notes**
   - Subtopics TBA

6. *Inflationary Models* **[TBC hours]**
   - Subtopics TBA

7. *Cosmic Microwave Background* **[TBC hours]**
   - Subtopics TBA

3) Resources:
Most of lectures slides and notes will be provided.

4) Recommended texts:
- *Introduction to Cosmology*, B Ryden (Cambridge UP 2006)
https://assa.saao.ac.za/wp-content/uploads/sites/23/2018/08/Ryden_IntroCosmo.pdf
- *Modern Cosmology,* S. Dodelson (Elsevier 2003)
- *Primordial Cosmology,* P. Peter and J.-P. Uzan, (Oxford Graduate Texts 2009)
- *Cosmology,* E. Harrison (Cambridge UP, 2000)
- *Cosmological Inflation and Large Scale Structure,* A. R. Liddle and D.H. Lyth (Cambridge UP 2000)
- *The Early Universe,* E. Kolb and M. Turner (Addison-Wesley, 1994)

Online resources (operational links on Jul 17 2025)
https://www.damtp.cam.ac.uk/user/tong/cosmo.html
https://www.damtp.cam.ac.uk/user/examples/3R2La.pdf

5) Breakdown of practicals/tutorials:
Every second week (two hours) we will have a discussion/tutorial session. Tutorials start on Tuesday 5th August 2025 at 14h00.

Tutor: Mr Tshepo MATHIBELA <MTHTSH098@myuct.ac.za>
Consultation times: by appointment. Languages of consultation: English, IsiNdebele, Sepedi and IsiZulu.

Tutorials will cover:

(a) analytical calculations to solve problems set in lectures and in tutorial sheets;

(b) Python/Mathematica/Maple codes to compute distances and solve differential equations.

6) Assessment
Final exam: 40%
Hand-in Problems: 60%
* There will be a mid-semester class test.