

# The Cosmology Distinction Course in NSW

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**Abstract:** The Cosmology Distinction Course is a new one-year course to be introduced for Year 12 candidates in the 1994 Higher School Certificate examinations in NSW. It is one of three challenging courses of study that will enrich the HSC for talented students who accelerate and complete part of the HSC one year early. The courses will be taught through distance learning and will include residential seminars. They will be implemented on behalf of the Board of Studies by Charles Sturt University and the University of New England.

The Cosmology Course is organised into nine modules of course work covering historical and social aspects of cosmology, observational techniques, key observations and the various models developed—Newtonian, de Sitter, Friedmann, Lemaitre, steady-state, quasi-steady-state and big bang. Assessment will be through assignments, exams and a major project.

As the first Distinction Course in a scientific area, the Cosmology Course represents an exciting and important educational initiative that needs the cooperation of NSW astronomers and, in return, promises to benefit the astronomical and general scientific community in Australia.

## 1. Introduction

In the State of New South Wales, the Board of Studies has responsibility for courses and standards in both private and State schools through primary and secondary levels. The trend in recent years for a greater proportion of students to stay until the final Year 12 and receive a Higher School Certificate means that this exam, formerly regarded as a matriculating qualification for university entrance, now has a much wider scope. It is possible to spread the study and examinations over several years, perhaps combining part-time study and a job. New courses are being introduced to challenge both higher and lower ranges of abilities.

The Cosmology Distinction Course is one of three HSC Distinction Courses which will be introduced for appropriate accelerating students in Year 12 1994. The other courses are Comparative Literature and Philosophy. All three represent a new concept in secondary education, not just in NSW, but in Australia. Rather than being extensions of traditional HSC subjects, the Distinction Courses provide a broader, challenging study for highly gifted students in topics suited to one of the Key Learning Areas, but spanning a range of university courses. They are aimed at the students in the top five per cent of candidates sitting the HSC and are designed to enrich them and encourage excellence. The courses have been developed from the outset by the Board and the universities to be broadly based HSC courses approximating to the level of understanding expected in first-year university study. A conscious decision was made not to develop narrow courses in traditional HSC subjects beyond 3- or 4-unit level. Nor was it intended that these courses be substitutes for any first-year university courses in content or approach. Nonetheless, the work should be rigorous and of considerable depth.

The Cosmology Course includes elements of history, sociology, and mathematics, as well as physics and astronomy. It is designed as a challenging, high-level introduction to some of the most recent techniques and imaginative theories in modern science. Students undertaking the course will be expected to develop a broad understanding across all these areas.

## 2. Criteria for Study

The Distinction Courses are offered to students who accelerate in the highest level of one or more HSC subjects and sit an HSC exam a year early—ahead of their age cohort at the end of Year 11. A good pass in one of these subjects is required, generally at 3-unit level, but 4-unit in Mathematics or one of the full 2-unit courses in Physics, Chemistry, Biology or Geology will qualify. The student should achieve a result that would place them within (or close to) the top five per cent of that course's candidature.

A crucial requirement by the Board of Studies is that there be no prerequisite subject for any Distinction Course. This means that the Board encourages any student who accelerated in, say, Latin or Modern History to undertake the Cosmology Course provided they did well in their exam. This provision obviously imposes some limitations on the course design, particularly with respect to assumed knowledge and mathematical ability. While it is likely that the majority of intending candidates for Cosmology will accelerate in HSC Science or Mathematics, there will be specific, supplementary notes to guide those who do not have this background.

### 3. Advantages of Studying a Distinction Course

Distinction Courses provide the opportunity for a type of study that HSC students have hitherto not experienced. Students are presented with a broader perspective than in the traditional subjects—each Distinction Course spans much of the curriculum. Study of these courses will allow the most talented students to exercise their minds in the pursuit of knowledge and understanding in a field of far greater scope than they have previously encountered, and in a less structured learning situation.

In addition to any intrinsic worth of the course, it is crucial that those involved—students, parents and teachers—are convinced about the practical value and rewards of studying a Distinction Course. A key element here will be the extent to which such study will help a student qualify for tertiary study in highly competitive areas such as medicine or law. A Distinction Course will give a student marks in a 2-unit HSC subject which could contribute to the Tertiary Entrance Rank (TER) for university entrance. Given that students have already accelerated in at least one subject (2–4 units) and do a further 11 units in their Year-12, the Distinction Course is an addition to the usual HSC work load and they will present 13–15 units from which their TER can be drawn. The HSC scaling procedures take into account the quality of the students undertaking any particular course so that the high calibre of the Distinction Course candidature will ensure a favourable scaling factor for the TER of each student.

A further inducement for capable students to undertake a Distinction Course is that several universities have agreed to give recognition to the courses within their own degree structures. A successful pass may be recognised as a credit of a full first-year course, or as a qualification for Advanced Student status. The level of recognition varies between institutions and degree courses but all universities are keen to attract such able students.

### 4. Development of the Course

Planning for the Cosmology Distinction Course began early in 1992 when the Board of Studies

invited Dr Roy Allen, a former Secretary of the ASA, to suggest a course in astronomy. This was quickly expanded into the far broader intellectual challenge of cosmology, and a group of six university astronomers was recruited to write a syllabus.

All secondary schools in NSW were advised in April 1992 of the concept of Distinction Courses, and experienced teachers were asked to register interest in any of the nine courses then being developed—Comparative Literature, the Information Revolution, History and Philosophy of Science, Arts and Design, Modelling and Simulation, Physiology of Human Movement, Philosophy, Australian Archaeology, and Cosmology. Two teachers were selected to join each Syllabus Writing Team.

In August 1992 the Board sent each draft syllabus for comment to selected professional advisors. For Cosmology, the Astronomical Society of Australia provided the ideal group. In 1991 the ASA had set up the Australian Astronomical Directors and Heads Committee under the President, David Allen, which included nine professors across Australia and the directors of the AAO and ATNF. These advisors gave encouragement to the syllabus writing group and many critical suggestions that have been incorporated in the course.

In October the nine courses were considered by the Board of Studies Curriculum Committee, and submitted to the Minister for Education. The Minister approved three courses for introduction in 1994, and recommended that the other six be reconsidered for 1996.

In January 1993 the Syllabus Writing Teams became Course Committees with some changes in members, most notably the addition of Instructional Designers and Course Coordinators appointed from either Charles Sturt University (CSU) or the University of New England (UNE). Both these universities have many years of experience in distance learning and will deliver the Distinction Courses for the Board of Studies.

In March 1993 the Course Outlines for the three approved courses Philosophy, Comparative Literature and Cosmology were issued as a booklet (Lambert 1993) to all universities and secondary schools in NSW and the ACT, with an invitation to comment either as an organisation or as an individual. These responses helped in the development of the delivery of the courses and support for teachers and mentors in the schools.

At present (July 1993) the detailed text for each module, background readings, exercises, assignments and exam questions are being written, revised by the Instructional Designer, and approved by the Course Committee. The first group of students will receive its material in November this year. We ask Members of the ASA to cooperate with and encourage these pioneers in a challenging course.

## 5. Aims of the Course

The Cosmology Distinction Course aims to provide students with a perception of the structure of the universe on the broadest scale. A number of cosmological models, both historical and contemporary, will be examined in the context of the prevailing culture and scientific knowledge. The influence of these models on human thinking will be assessed.

There will be considerable emphasis on the observational techniques used in studying the universe and on the models which arise from various interpretations of the data. Students who complete this course should possess skills in evaluating data, understanding theoretical models and interpreting them logically.

## 6. Course Structure

In common with the other Distinction Courses, the Cosmology Course is a 2-unit subject designed to be studied at school but delivered by a university. The course should occupy 120–140 hours of a student's in-school time, starting in the last part of Year 11. Students will be expected to spend additional time reading, studying and doing research or assignments. They will be required to attend two 2–3 day residential seminars (funded by the Board of Studies). A mentor teacher may offer supervision in the school, but the progress and coordination of the course will be administered, in this case, by CSU at Bathurst Campus.

The Cosmology Distinction Course includes three components of study. The first, coursework using two reference books (Harrison 1981 and Silk 1989), is arranged into nine modules, each requiring on average about three weeks of study. Student progress will be monitored through eight assignments, three of which will each contribute 10% towards assessment. These assignments will include problem calculations, analysis of data and essays.

The second component is an individual research project undertaken on any aspect of Cosmology for about 10 weeks. A diversity of interest will be encouraged and each student will choose their topic after discussion with course supervisors.

The third component is the interaction and lectures at two seminars to be held at UNE. The first will take place after module 2, and is intended to help students settle into the course and meet supervisors, fellow students and research astronomers. At the second seminar, held in about week 20 of the course, students will obtain approval of the research topic for their major project.

There will be two written exams, conducted under supervision, that may be clearly seen as the candidate's unassisted effort. These are together worth 40% of the course assessment. The remaining 30% assessment is for the major project, to be completed and submitted to the Board early in the

final term of Year 12 and before the usual HSC exams begin.

## 7. The Nine Modules—Overview

Each module is summarised here, listing key concepts and headings.

### (1) *The Scale of the Known Universe*

What is cosmology? The “art of creating world pictures” relies on our knowledge of the physical nature of the universe. To introduce this universe we briefly undertake a journey from the very large to the very small—from the background glow revealed by the COBE satellite, to clusters of galaxies and individual galaxies, stars, planets like Earth, and on down to animals, viruses, atoms, hadrons and finally to the quarks and other subatomic particles that ultimately make up the universe.

### (2) *The Contents of the Universe*

What is in the universe? What observational techniques are available to us and how reliable are the results? How do we investigate matter—gas, dust, molecules, stars, galaxies and black holes—by observing with gamma, X-ray, optical, radio, meteor technologies?

### (3) *Development of Cosmological Ideas*

Modern cosmology is based on a scientific view of the world. Historical cosmologies—ranging from Australian Aboriginals' dreamtime to the Ptolemaic geocentric universe—were based on different prevailing ideas. We present the older cosmological ideas and introduce some fundamental principles which assert that there are no special places, or perhaps times, in the universe. The anthropic principle says that the observer is a necessary part of what is observed, thus, perhaps, explaining why the universe today is finely balanced in a way that allows life like us to have developed. An alternative explanation of these same facts might be called the theistic principle, invoking design by a Creator. We study the effects on our society of research into the origin of life, evolution and intelligence, biology in space and the search for extraterrestrial intelligence.

### (4) *Space and Time*

Einstein's special and general theories of relativity present conceptually challenging ideas of space-time such as the curvature of space, and the possibilities of interstellar travel. There are several competing theories which differ in detail. Was Einstein right? We present some of the modern tests which clearly say yes!

### (5) *Expansion and Observed Redshifts*

The prediction of the expansion of the universe was almost simultaneous with the discovery of the recession of galaxies. The expansion, shown with analogies such as the rubber sheet two-dimensional model, remains a serious misconception in modern cosmology. Redshift, the change in the observed wavelength of light, may arise from velocity (Doppler) effects, gravitational fields and cosmic expansion. The difference is crucial to interpreting the observations, deriving the scale size of the universe, and arriving at a cosmological model.

### (6) *Further Key Observations*

There are several critical observations in modern astronomy on which our current theories of cosmology are based. Ultimately these observations must provide the test of any theory. The most crucial of these concern the abundance of elements in the universe, the 3 K background radiation and the anisotropy found by the COBE satellite. Others concern the large-scale structure in the distribution of galaxies and the existence of dark matter, whose presence is deduced from observed motions of the stars and galaxies. The reliability of some of these observations has been questioned. Reference to recent work is crucial.

### (7) *What are the Models?*

We discuss the models that might describe the physical universe as we know it today. We attempt an even-handed treatment (despite almost universal acceptance of the big bang model) in an attempt to emphasise the importance of dissenting views. We have the static Newtonian universe, the steady-state universe, or the de Sitter, Friedmann and Friedmann-Lemaître universes. Recently, interest has been renewed in the role of Einstein's cosmological constant (the Lambda force) in the models. Radical alternatives are the new quasi-steady-state model and the plasma cosmology where there may be no expansion at all!

### (8) *The Big Bang*

We study the 'standard model' big bang which is (arguably) supported by the key observations mentioned earlier. However, there are many variations on the idea of the big bang which differ in detail and might be tested observationally. Most of the models have a standard history, which is after the first fraction of a second, described by the various 'ages' of a big bang universe—the times characterised by radiation, leptons, hadrons and quarks (earlier) and matter (now). The idea of 'inflation' is an important addition of recent years which seems

to persuasively explain many otherwise perplexing aspects of the standard model. We consider the grand unified theories; fundamental particles; dark matter; oscillating models and the 'big crunch'. This module examines the observational evidence for and against the big bang.

### (9) *Where to now?*

We conclude with a survey of current problems; the validity of the big bang model; the value of the Hubble constant, which describes the rate of expansion; the age of the stars. There are problems with the creation of matter and the creation of the universe. The density of the universe governs its fate and appears to be very close to the critical value for which gravity ultimately just stops our outward expansion, but will expansion continue or will we be faced by a future 'big crunch'? What is the density of the universe and where is the dark matter required? Was the universe born and what will be its ultimate fate? Will it bounce from one period of expansion and contraction to the next? Will it suffer an ultimate 'heat death'? With these questions the scientific nature of modern scientific cosmology returns to philosophical and theological concerns.

This module will be updated each year to consider current research problems, recent observations and new technology: there should be results from the Hubble Space Telescope, the Keck Telescope, gravity wave and neutrino detectors. We will monitor developments in associated fields like particle physics, space missions and computer simulations.

## 8. Resources and Residentials

As the course is designed to be taught by distance education and at no cost to individual schools, all essential material—course notes, selected readings and assignment tasks—will be provided to each student. Given the pace of developments in cosmology, students will be supplied with reprints from journals such as *Sky and Telescope* and *New Scientist* in addition to the wide range of books now available in the university library.

The residentials are intended to give the students contact with research scientists working in astronomy and cosmology. The choice of UNE for the Cosmology seminars has the geographical advantage that visits may be made to both the Anglo-Australian Observatory near Coonabarabran and the Australia Telescope Compact Array near Narrabri.

## 9. Benefits and Costs to the Astronomical Community

The Cosmology Course has potential for great benefit to the scientific community in Australia and particularly to the physics and astronomy groups.

By exposing our most talented secondary students to challenging work close to current research, this course should provide an awareness of the processes, the excitement and the vigour involved. There is potential to stimulate students and motivate the study of physics at tertiary level. These Distinction students would be valuable recruits to any institution and to science in general.

Success of the course, and hence the subsequent benefits, will depend in large part on the goodwill and enthusiasm of the astronomical community. The participation of active research astronomers in the residential seminars is highly desirable. Good display materials from our astronomical institutions will be essential.

Given the innovative and challenging nature of these new Distinction Courses, the Cosmology

Distinction Course Committee hopes to receive constructive criticism of this initiative. The Board of Studies wishes to encourage academic excellence among the many gifted young adults in the NSW school system.

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Manuscript received 16 August,  
accepted 13 September 1993