ASTR 2100: Foundations of Astrophysics (fall)

Calendar description: The emphasis of this first course in astrophysics is on directly observable quantities such as the positions and motions of stars and the light they emit. Topics include a review of the celestial sphere, time in astronomy, astronomical catalogues, the two-body problem, dynamics of star clusters, stellar spectra including emission and absorption lines, and the operation of telescopes. Students are assigned observing projects and trained to use the Burke-Gaffney Observatory.

Classes 3 hrs. and telescope observing 1 hr. per week; 1 semester.

Contents

Overview

The course is essentially a follow-on to ASTR 1100 (Introduction Astrophysics), although students who did not take ASTR 1100 can often enter the astronomy stream at ASTR 2100. Some topics covered in ASTR 1100 are repeated here from a first-principles approach (*e.g.*, Kepler's Laws, spherical trigonometry) given the student will have had a full year of university-level physics and calculus. Indeed, this course focusses more on the mathematical and physical tools of astronomy than on particular astronomical phenomena that should have been covered adequately in ASTR 1100.

Prerequisites

ASTR 1100 Introduction to Astrophysics

From ASTR 1100, students will have had an overview of the universe, from the structure of the solar system, to the life cycle of a star, to basic galactic structure, and even some cosmology, allowing the instructor of ASTR 2100 to focus more on the physics of astrophysics: How do we know what we know? Students will have had some experience in the Burke-Gaffney Observatory, though will not have yet conducted any "independent" observing projects.

PHYS 1101 University Physics II

Students come into this course with a full year of Halliday and Resnick-level physics. Thus, a good familiarity of Newton's Laws, free body diagrams, conservation laws, angular momentum and torques, waves and oscillations, the first and second laws of thermodynamics, and Maxwell's equations in integral form can be assumed. Typically, neither fluid mechanics nor Newtonian gravity are covered in any depth.

In addition, many students will have taken PHYS 1500 (Introduction to Modern Physics) and thus will have discussed special relativity and some ideas in elementary quantum mechanics, though this course is not a prerequisite for ASTR 2100.

MATH 1211 Introductory Calculus II

The instructor can take ordinary differentiation and 1-D integration for granted. Concurrent to this course, most students are enrolled in MATH 2301 (linear algebra) and MATH 2311 (Intermediate Calculus II) in which vector calculus is introduced.

Dependent courses

ASTR 2400 Properties of Stars

The instructor of ASTR 2400 will depend upon ASTR 2100 giving the student a quantitative familiarity with concepts such as colour photometry, blackbody radiation, flux and luminosity, magnitudes, luminosity-temperature-radius relation for blackbodies, and the Bohr model of the atom. Students will also see some of these ideas in PHYS 1500 (Introduction to Modern Physics).

Student Outcomes

Students will have seen many of the topics of this course in ASTR 1100 (Introduction to Astrophysics), though at a less rigourous level. The overall aim of ASTR 2100 is to provide students with a foundation in celestial mechanics and light detection in order to gain appreciation of topics covered in advanced astronomy courses. A student completing ASTR 2100 will be able to:

1. understand celestial mechanics, spherical geometry, equatorial coordinate systems, and navigate the sky;
2. derive the Virial Theorem and Kepler's Laws from conservation laws;
3. derive Wien's and the Stefan-Boltzmann Law from Planck's function;

4. understand the formation of spectra, the photon nature of light, and line broadening mechanisms;
5. understand optical/radio telescope designs, optics, detectors, and interferometry;
6. operate the BGO and use a CCD.

Typical problems a student completing ASTR 2100 should be able to solve:

1. Derive the relationship between a planet's synodic and sidereal period for inferior and superior planets.
2. Derive the Rayleigh-Jeans law.
3. Given the temperature, radius and distance to a star, calculate: luminosity, absolute/apparent bolometric magnitudes, radiant flux at star surface and at Earth.
4. Determine the radial, transverse, true velocity of a star from knowing proper motion and distance.
5. Determine what time of year a certain star will be observable from a certain position on Earth.

Curriculum

1. the celestial sphere
2. celestial mechanics
   - elliptical orbits
   - Newtonian mechanics
   - Kepler's Laws
   - Virial theorem
3. continuous spectrum of light
   - parallax
   - magnitudes
   - waves
   - blackbody
   - colours
4. interaction of light and matter
   - spectral lines

  - photons
  - Bohr atom
  - Doppler effect

5. telescopes

  - basic design
  - optical
  - radio
  - multiwavelength

Suggested texts

1. *Fundamental Astronomy* by Karttunen *et al.* (ISBN 3-540-00179-4) is the text recommended for ASTR 1100 (Introduction to Astrophysics). and may be adequate for ASTR 2100 as well. It includes a fairly decent description of spherical astronomy.

2. *An Introduction to Modern Astrophysics* by Carroll and Ostlie (ISBN) This has been used for several years and the course is somewhat structured to follow this text book. Specifically, chapters 1, 2, 3, 5, and 6 are currently covered in ASTR 2100. It does not cover spherical geometry well and previous instructors have had to supplement the text with personal notes. This text is practical if adopted for subsequent advanced courses in ASTR, but is inappropriate for this course alone as its scope is far beyond what this course needs.

Notes to the instructor

1. Few books cover spherical geometry well and supplementary material prepared by the instructor is normally needed. Such notes exist within the department, and the instructor is encouraged to seek out previous instructors of the course for these.

2. Some coordination with the instructor of ASTR 1100 (Introduction to Astrophysics) would be useful to minimise unnecessary overlap and optimise how the two courses dovetail.