The Cosmos: A Survey of Modern Astronomy
Syllabus

Deep Springs College
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Academic Year 2020-2021, Terms 5 & 6

March 16th, 2021 (the most current version is at brianhill.github.io/astronomy)

Overview

The goal of the discipline of astronomy is to understand the great variety of astronomical observations in terms of the rather few principles of physics. Understanding astronomical observations from physics turns out to be a two-way street. Some of the principles of physics — for example, Newton's Law of Universal Gravitation — were deduced from astronomical observations in combination with laboratory physics experiments.

To do justice to the subject and to the scientific method, the class will use mathematics, but the mathematics will be limited to algebra and trigonometry. Every physics theory that we are confident of, we are confident of precisely because it has been tested quantitatively as well as qualitatively. Theories that are motivated principally by esthetic considerations, or that only give qualitative answers, have generally turned out to be embarrassingly wrong.

The theoretical part of the course will first focus on fundamentals such as the astronomical coordinate system, the motion of objects within our solar system, and the composition of Earth and the other planets. It will then proceed to our understanding of the nearby stars and the rest of our galaxy. At each step along the way we will emphasize not just what is known, but how it has been determined through the interplay of theory and observation.

With these fundamentals, you will be prepared to move farther out into the cosmos, starting with what is known about nearby galaxies, then moving to the evidence for the Big Bang. Near the end of the course, we will get to the complications of the properties of galaxies and the expansion since the Big Bang that can only be explained by dark matter and dark energy.

Hands-On Special Projects

The course will also have a strong hands-on component. Pairs of students will do a significant special project from among the many that are possible with a 130mm refractor, a high-performance CMOS sensor, and research-grade software to control the equipment and analyze data. Possible projects include astrophotography of galaxies and nebulae, imaging of planets, and variable star observation. Data-taking for the special projects will occur mostly during Term 5. Additional data-taking and data analysis will occur at the beginning of Term 6. Presentation of results will occur about 2/3 of the way through Term 6.

Materials

We will rely on the latest edition of a textbook with a fully modern perspective. In a semester-long course with well-prepared students most, but not all, of the textbook can be covered, and the unit outline that follows reflects that:

- *The Cosmos: Astronomy in the New Millennium*, 5th Edition, Jay M. Pasachoff and Alex Filippenko, Cambridge University Press, 2019.

Unit Outline

I. Light, Matter, Energy

Units, Scientific Notation
Light, Frequency, Waves, Color, Matter, Temperature, and Energy
Optics and Telescopes

II. Solar System Motions

The Motions of the Earth, the Moon, and the Planets
The Scale of the Solar System
Kepler's Laws

==== First Midterm ====

Newton's Laws of Motion
Newton's Law of Universal Gravitation

III. The Composition and Properties of Our Solar System and Others

The Rocky Planets
The Gas Giants
Asteroid Belt
Kuiper Belt
Exoplanets

==== Term 5/6 Break ====

IV. Stars and the Galaxy

Hertzsprung-Russell Diagram
Novas, Planetary Nebula, White Dwarfs

==== Second Midterm ====

Supernovas, Neutron Stars, Pulsars, Gravitational Waves
Black Holes

V. Galaxies and the Cosmos

The Milky Way Galaxy and the Magellanic Clouds
Other Galaxies
Active Galactic Nuclei

==== Presentation of Special Project Results ====

The Big Bang

==== Last Midterm (no further exams!) ====

Dark Matter, Dark Energy, and Particle Physics

I have done my absolute best to fit the chapters into our twice-per-week meeting schedule. This was often awkward. The schedule may need adjusting, but I will stick to the three exam dates.

Daily Schedules

- Daily Schedule Term 5 (link to online page)
- Daily Schedule Term 6 (link to online page)

Exams and Grades

As noted in the schedule above, there will be three exams. All three will be "midterms" since none of them are coming at the very end of a term. The dates are: Friday, April 9; Friday, May 21; Friday, June 18. The midterms will be designed to be done in 45 minutes (maximum 60 minutes) so that we can continue developing new material after each of them. The Special Project presentations will be in early June (tentatively, Tuesday, June 8th).

The course will be graded 20% on problem sets (of which there will be at least one every week), 20% on the special project, and 20% on each of the three midterms.

Requirements and Suggestions for Doing Problem Sets and Scientific Reading

Problem sets must be on 8 1/2 x 11 paper, stapled, with name, problem set #, and due date. People that work in pen usually make mistakes and messes. I recommend working in pencil, rubbing out mistakes completely, and recopying work that gets convoluted due to wrong turns. I will supply complete solutions to all problem sets.

When you sit down to do problems, if the problem has a description with no diagram, make your own diagram that captures what is being described as your first step in solving it. When doing problems with values that can be plugged in, keep the variables around. For example, if a problem says $l = 5$ light-years, keep l around. You can plug in 5 light-years (and maybe do some units conversions) at the end.

Scientific texts are generally much denser than non-scientific texts. Definitions are introduced and used precisely. Formulas that have myriad consequences may easily fit on single line. It will often be important not just to read, but to re-read what you are assigned. When the authors make cross-references (to equations, to figures, to results in prior chapters, or to end-of-chapter problems), take time to follow the cross-reference. Pay close attention to diagrams and read the captions until you understand what is being depicted. If a diagram is a graph, pay close attention to what is on the axes.

In order to be able to do problems, it is important to follow the definitions and derivations. In *The Cosmos: Astronomy in the New Millennium,* most of these have been isolated in "Figure it Out" boxes. We will put a lot of effort into understanding these boxes.

If this all sounds daunting, fear not, you can most definitely do it, and to aim for less would not do justice to either astronomy or all your preparation in getting to this point.