

# ASTRONOMY 320 – SPRING 2008

## “Theoretical Astrophysics”

### I. Instructors

Prof. Eve Ostriker

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### II. Class Meetings

Lecture:

Tu Th 2:00-3:15

CSS 2428

Discussion:

W 3:00-3:50

CSS 0201

### III. Textbook

Required: *The Physical Universe*, by Frank H. Shu. Published by University Science Books, ISBN 0-935702-05-9

### IV. Course Pre-requisites

To take this course, you should have previously completed ASTR121. You should also have completed either PHYS273, or PHYS270 and 271. With permission of the instructor, some prerequisites may be waived.

### V. Course Assignments and Grading

Homework	40%
Midterm exam	25%
Final exam	35%

Homework will be assigned approximately once a week, due the following week, and must be turned in at the *beginning of class*. If, for whatever reason, the University is officially closed on the due date for an assignment, the due date will be moved to the next lecture. Points will not be given for any “extra credit projects.” It is important to complete all the regular assignments to get the most you can out of the course!

Students who are ill or have another valid excuse must explain the circumstances to the instructor *before* due date of an assignment, and then complete the work within the following week, in order to get full credit. Students who are unable to take an exam due to illness or other valid emergency must contact the instructor *before* the time of the exam, in order to be permitted to make it up. Any illnesses or emergencies need to be properly documented.

## VI. Academic Integrity

University regulations regarding academic integrity apply to all work performed for credit in this course. Particulars of the University's Code of Academic Integrity are printed in the Undergraduate Catalog, and a description of what constitutes academic dishonesty is also given in the on-line Schedule of Classes. In brief, the Code requires that you must never engage in acts of academic dishonesty at any time. Acts of academic dishonesty include cheating, fabrication, plagiarism, or helping another person to do any of these things.

The rules regarding academic integrity apply to homeworks as well as to exams. As a part of these rules, you must give credit to any book (including the course textbook), published article, or web page that you use in completing a particular assignment. These rules also apply to unpublished sources of information. In particular, *students are encouraged to discuss assignments and other class material with each other, but every student must personally work out and write up his or her own solutions to the homework problems.*

According to University policy, all students are expected to write by hand and sign on examinations, papers, or other academic assignments not specifically exempted by the instructor the following Honor Pledge:

*I pledge on my honor that I have not given or received any unauthorized assistance on this assignment/examination.*

## VII. Course Web Page

<http://www.astro.umd.edu/~ostriker/ASTR320>

## VIII. Course Outline (tentative)

### A. Gravity

- Jan. 29** – Introduction to class; Newton's Laws of motion; conservation of momentum; Newton's law of gravitation
- Jan. 31** – Definition of one-body problem; cylindrical coordinates; conservation laws and constants of motion (energy, angular momentum); solution of one-body equation
- Feb. 5** – One body problem *cont.*: classification and shapes of orbits (elliptical, hyperbolic, parabolic); terminology for bound orbits (semi-major and -minor axes, eccentricity); relations of Newton's solution to Kepler's Laws
- Feb. 7** – One body problem *cont.*: epicyclic approximation analysis; definition of two-body problem
- Feb. 12** – Two-body problem *cont.*: relation of two-body problem to one-body solution (reduced mass and CM); application to binary systems
- Feb. 14** – Two-body problem *cont.*: observables of binary systems; types of binaries; extrasolar planets

- Feb. 19** – Three- and two-plus-one- body-problems: equations in rotating frame; effective potential; Coriolis and centrifugal forces; Lagrange points; stability of equilibria
- Feb. 21** – Three- and two-plus-one- body-problems *cont.*: Roche radius; tidal problem; trojan satellites; hierarchical systems; chaos
- Feb. 26** – N-body systems: virial theorem; potential and kinetic energies of stellar systems; application to analysis of star clusters, galaxies, galaxy clusters
- Feb. 28** – N-body systems *cont.* - evolution of collisionless systems: cosmological collapse and virialization; violent relaxation
- Mar. 4** – N-body systems *cont.* - two-body relaxation; dynamical friction; dynamical evolution
- Mar. 6** – N-body systems *cont.* - galactic dynamics: Gauss’s law and galactic potential/density pairs; families of galactic orbits; precession; relation of orbits to galactic structure

*B. Gas physics*

- Mar. 11** – Macroscopic properties of gases and thermodynamics
- Mar. 13** – *Midterm Exam (Covers Part “A”)*
- SPRING BREAK** – Mar. 17-21
- Mar. 25** – Microscopic properties of gases and statistical mechanics: Maxwell- Boltzmann distribution function; ideal gas properties - density, temperature, pressure, energy density, heat capacity
- Mar. 27** – Relation between thermodynamics and statistics; generalized Boltzmann law; interpretation of temperature and entropy
- Apr. 1** – Thermal radiation – pressure, energy density, temperature; radiation law
- Apr. 3** – Cosmological expansion – Friedmann equation; solutions for radiation-, matter-, cosmological constant- dominated universe
- Apr. 8** – Stages of evolution of the Universe; thermal evolution; decoupling
- Apr. 10** – Hydrostatic equilibria: stellar and planetary atmospheres; galactic and circumstellar disks; interstellar clouds; stellar and planetary interiors
- Apr. 15** – Hydrostatic equilibria *cont.*; Waves and instabilities: buoyancy and convection in stars
- Apr. 17** – Waves and instabilities *cont.*: jeans instability and gravitational collapse

*C. Quantum processes*

- Apr. 22** – Quantum principles: historical review; the Schroedinger equation and wavefunctions
- Apr. 24** – Momentum and energy operators; quantum particle in a box: eigenfunctions and counting states

**Apr. 29** – Fermions and Bosons; Fermi-Dirac and Bose-Einstein statistics; Fermion and Boson gases

**May 1** – Electron degeneracy; the Chandrasekhar mass; white dwarfs and neutron stars

#### *D. Model synthesis*

**May 6** – The Hertzsprung-Russell diagram, principles of stellar structure

**May 8** – Stellar energy sources: nuclear reactions, coulomb barrier

**May 13** – Interaction of matter and radiation; diffusive processes; hydrostatic equilibrium; explaining the main sequence mass/luminosity/effective temperature relations

**May 19** – *Final Exam (10:30AM-12:30PM)*

### **IX. Course Description**

Modern astronomy has its roots firmly grounded in the fundamental principles of physics (classical and modern), and correspondingly, many branches of physics as we know them today trace their origins to the search for universal physical laws to explain natural phenomena discovered and analyzed by astronomers.

The goal of theoretical astrophysics is to provide physical and conceptual understanding of the diverse systems that represent our universe. Introductory astronomy courses are often organized by scale (planets, stars, galaxies, and the universe...), and observational astronomy courses are often organized by wavelength because of detector technology. To emphasize the different approach needed for developing a theoretical framework, this course is organized into themes of governing physical processes. For each of three main themes (gravitational physics, gas physics, and quantum physics), we will start with fundamental principles, and then discuss applications in various astronomical contexts. We will also discuss systems in which several physical processes interact synergistically, and demonstrate how astrophysical theories are developed by successive model refinements and confrontations with data. We will show how application of simple physical laws can explain the observed properties of an astounding range of astronomical objects!

An important aspect of this course will be to use astrophysical examples to develop flexible problem-solving skills: how to approach questions when you don't know in advance what tools you need to solve them, and how to exercise quality control by being your own critic.

*This course is intended for astronomy or physics majors or other students with strong physical science background.*