

GRS AS 725 – Gravitational Astrophysics (Spring 2020)

Lectures: Tuesdays & Thursdays, 12:30pm – 1:45pm (CAS Room 320)

Instructor: Prof. Tereasa Brainerd (CAS Room 605, brainerd@bu.edu, 617-353-6646)

Office Hours: Wednesdays 2:00pm to 3:30pm, Fridays 9:00am to 10:30am

and by appointment

Web Homepage: <http://firedrake.bu.edu/AS725/AS725.html>

Grading: Homework (50%), Midterm Examination (20%), Final Examination (30%)

This course will explore a number of astrophysical topics in which gravity plays the dominant role. By and large the topics will be dynamical in nature, but we will cover a few scenarios in which this is not the case. The overarching theme that ties together the different sections of the course is “equations of motion”, including the equation of motion of a photon traveling past a massive body in the universe. There is, unfortunately, no single textbook which addresses all of the material (nor even half of the material!) that will be covered. Instead, related reading material will come from a number of “classic” books that will be placed on reserve in the library. These books will include, but will not be limited to, *Classical Mechanics* by Herbert Goldstein, *Galactic Dynamics* by James Binney & Scott Tremaine, and *Gravitation & Cosmology* by Steven Weinberg. From time to time, written class notes will be used to supplement the texts in the library. If you can afford to do so, it is also recommended that you purchase a copy of Binney & Tremaine’s *Galactic Dynamics* since we will be using it quite a bit, and it’s a standard book that’s good for all astronomers to have on their bookshelves for future reference.

Homework:

Problem sets to be done as homework will be assigned roughly every other week. Homework must be handed in **AT THE START OF CLASS** on the date which it is due. Late homework will not be accepted. Although students are encouraged to discuss potential solutions to the homework problems amongst themselves, students must hand in their own original solutions (i.e., students who simply copy another’s solution will receive grades of zero). In order to be graded, solutions must be **LEGIBLE**; illegible solutions will not be graded and will receive a score of zero. To receive full credit for a problem, students must **SHOW** all of the work; correct final answers which do not clearly follow from correct, complete solutions will receive scores of zero.

Examinations:

All examinations will be closed book. The midterm examination will be held in class at the regular class meeting time, it will be 75 minutes in duration, and it **MUST** be taken in class on the date scheduled. (Actual date of the midterm exam TBD.) The final examination will be 120 minutes in duration and will be held during the University’s final exam period. If you discover that you are too ill to take an exam with the class, you must notify me by telephone or email **prior to** the start of the examination. If you do not do this, you will receive a grade of zero for the examination and will not be given a makeup exam. **All makeup exams will be oral examinations, to be taken in my office by appointment, and they must be completed within 1 week of the missed exam.**

Course Outline

Classical Mechanics:

- generalized coordinates
- Lagrangian & Hamiltonian formalisms
- equations of motion involving central potentials
- gravity as a “force” (Newtonian)
- the 2-body problem (Kepler’s laws; binary stars)
- the restricted 3-body problem

N–body Systems:

- relevant time scales and the process of virialization
- the collisionless Boltzmann equation
- phase space distribution functions
- spherical and triaxial systems (isotropic vs. anisotropic velocity dispersions)
- axisymmetric disk systems and the epicyclic approximation
- dynamical and hydrodynamical mass estimators
- N–body computer simulations

General Relativity Basics:

- the Equivalence Principle
- geodesics, metrics, and the “warping” of spacetime
- radical change in thinking about nature of gravity (not a classical “force”)
- Einstein’s field equations
- the Schwarzschild solution
- “Shapiro” time delay

Gravitational Lensing:

- geometry of a lens system and the non-linear nature of the lens equation
- strong versus weak lensing
- the Einstein radius and conditions for the creation of multiple images and arcs
- geometrical and Shapiro time delays in multiply–imaged systems
- practical applications of gravitational lensing

Classical Theoretical Cosmology:

- the Friedmann–Robertson–Walker metric
- equations of motion for the universe
- the connection between the dynamics of the universe and its geometry in simple universes
- simple spherical collapse models for galaxy formation

Grading Rubric

100% - perfect solution

95% - very minor mathematical errors or the solution is slightly incomplete

80% - problem is set up correctly, the right approach to the solution is demonstrated, but the solution has mathematical errors or is somewhat incomplete

65% - solution demonstrates some understanding of the problem and the path to the solution, but with significant limitations or errors (mathematical or conceptual)

50% - solution demonstrates weak understanding of the problem with little demonstration of the path to the solution

35% - solution demonstrates only minimal understanding of the problem and its solution

0% - solution demonstrates no understanding of the problem, or is left blank