ASTR320 Theoretical Astrophysics Spring 2021

Prof: Massimo Ricotti

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Office: Physical Sciences Complex (PSC) Room-1156
Prof. office hours: TBD

Lectures: Tuesday and Thursday, 11am-12.15pm on zoom and lecture recordings online

Join Zoom Meeting:
https://umd.zoom.us/j/93148527977?pwd=TzRCNDNEQUhBa1N2dm80VGJ3MG9CUT09

Meeting ID: 931 4852 7977
Passcode: 437723

Discussion section (Harrison Agrusa): Wednesday 1.00-1.50pm
First discussion section: Wed Feb 3rd
Harrison's office hours: TBD

Course description

Modern astronomy has its roots firmly grounded in the fundamental principles of physics (both classical and quantum). Furthermore, 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 as a whole) and observational astronomy courses are often organized by wavelength because of the different technologies. To emphasize the different approach needed for developing a theoretical framework, this course is organized into themes of governing physical principles. For each of the three main themes (gravity, gas physics and quantum physics), we start with fundamental principles and then discuss applications in various astronomical contexts. We will also discuss systems in which several principles interact synergistically and demonstrate how astrophysical theories are developed by successive model refinements and confrontation with data. We will show how application of simple physical laws can explain the observed properties of an astounding range of astronomical objects!

I will assume a basic knowledge of astronomical concepts (up to the ASTR120, ASTR121 level) as well as basic physics (up to the PHYS270, PHYS271, PHYS273 level)

The course website is at
http://www.astro.umd.edu/~ricotti/NEWWEB/teaching/ASTR320_21.html

Texts

No textbooks are required for this class. I will use my own class notes that will be available for download on ELMS (folder "detailed notes", and summary notes for part A, part B, and Part C). Since the course is organized by topics, there are no textbooks that follow the structure of this course. You can find some of the topics that will be covered in introductory astrophysics texts. Two of them, on which you may find some useful material are the following:

- Astrophysics for Physicists, by Arnab Rai Choudhuri, (Cambridge University Press, 2010) ISBN-13: 978-0521815536
- Astrophysics in a Nutshell, by Dan Maoz, (Princeton University Press, 2007) ISBN-13: 978-0691125848

These books are merely listed for your convenience, but you do not need to buy either of them. In addition a lot of useful material can be found on the web, including Wikipedia. However, keep in mind that some of the derivations or homework you will be exposed to in this class, are meant to introduce you to research in astrophysics and problem solving, so you will not find all the answers on books or on the web.

Course expectations

Special arrangements for Online teaching:

This course is mostly math based, hence it involves equations and derivations. For this reason I do not use power point presentations but the blackboard. In order to do this online I use zoom connected to an iPad. I use the detailed notes, go over them and make annotations.

The first classes will be synchronous to get to know each other. Depending on the class preference I am willing to switch to asynchronous classes, posting the lectures on ELMS and using the class time as discussion session/office hour (basically a flipped class). This arrangement worked well in Spring 2020 when we started the lockdown. We will discuss this option the first week of classes. In case we go ahead with a flipped class, here is how it will work:
1) I will ask you to read from the detailed notes on ELMS before watching the lecture. I will make available videos of the lectures on ELMS, typically three or four 15mins-20min long videos per lecture. I will be using zoom on my laptop and an iPad for showing math derivations (because using the stylus pen it's easier).
2) I will post on ELMS weekly quizzes (due by the end of the day on Friday) to check whether you are studying the material and watching the videos. These will count toward the participation grade. You can retake the quiz a large number of times and the highest score is registered, hence you will be able to get full credit for each quiz you complete.
3) HW will be as usual: posted on ELMS and the solutions (in pdf) will be submitted on ELMS or by email.

4) Discussion session will be in the form of an exercise to do with the help of Harrison (who will have zoom office hours). Harrison will let you know more details about his setup.
5) In case we adopt asynchronous lectures, I plan on having open zoom sessions during class time for discussion and answer questions on the lectures, quiz or homework.
6) We will have a midterm and final exam. The format of the final is not yet decided, but most likely will have the same format as the midterm exam. An alternative option we can discuss is term projects in groups of about 5.

Preparation: I expect you to be prepared to work. We will be covering some fascinating but challenging concepts - you will understand this material much more easily if you preview the recommended reading material ahead of time, as well as giving it a more careful read after the lecture. You also should review your class notes sometime before the next lecture to make sure everything is clear.

Study Habits: Study wisely and ask for help if you need it. It is better to keep up with the material on a daily basis than cram the night before the exam. I encourage you to chat about problems with your friends and classmates – you will learn a huge amount from trying to explain confusing issues to each other. ***However, please keep in mind that all graded materials, including class-assignments and home-works, must be your own thoughts in your own words.***

Grading

Grade will be based on homework, participation, one midterm exam and a final exam according to the following weights:

Online participation/Quizzes	25%
Homework	25%
Midterm exam	25%
Final exam/project	25%

Letter grades will be assigned guided by the following scheme.

A+	100% - 97%
A	96.9% - 93%
A-	92.9% - 90%
B+	89.9% - 87%
B	86.9% - 83%
B-	82.9% - 80%
C+	79.9% - 77%
C	76.9% - 73%
C-	72.9% - 70%
D+	69.9% - 67%
D	66.9% - 63%
D-	62.9% - 60%

F	less than 60%

I may adjust the precise grade boundaries to obtain a fair distribution of final grades, but I will only adjust the above-mentioned grade boundaries downwards (i.e. the above-mentioned grade boundaries are the "guaranteed" boundaries and any curving will only be to your advantage).

Online Quizzes

The 25% of your grade will be calculated based on your online participation, which will depend on completing the weekly quizzes and discussion exercises. Both quizzes and discussion exercises will give you full points if you complete them, partial or zero points if you work partially on them or do not work on them at all.

Exams

There will be one in-class midterm examination on the Thursday 11-Mar-2021 during class time. I will proctor the exam on zoom. During class time you will work on the exam, you will scan it or take a picture of it, and upload it on ELMS or send me the pdf. This will be a traditional exam as given in previous years on which you will work individually, but consultation of books and notes is allowed. Samples of previous midterm exams with solutions will be available on ELMS.

The midterm exam is a "**major scheduled grading event**" and is covered by the relevant rules for excused absence. If you are not able to take an exam due to illness or other legitimate reasons, you must make every reasonable attempt to contact me on or before the day of the exam either by email or voice mail. In addition, you must provide documentation detailing the reason for your absence. *A self-signed note is insufficient*. A make up exam must be taken promptly. I will give at most one make-up exam.

As per the University schedule, the final exam for this course will be held on Thursday 13-May-2021. The final exam will cover all material not covered in the Midterm exam (roughly the material discussed in class after the Midterm exam). I will create an exam in pdf (not a Quiz, something similar to a Homework). Samples of previous final exams with solutions will be available on ELMS. On May 13th, with some time limit (2 hours + 15 min to allow extra time to upload the solution), you will work on the final exam, you will scan it or take a picture of it, and upload it on ELMS or send me the pdf. This will be a traditional exam as given in previous years on which you will work individually, but consultation of books and notes is allowed. I will be proctoring the exam during the official exam hour, but if you cannot make that time slot you will be allowed to work on the exam at a different time during the exam day. Again, the final exam is a "**major scheduled grading event**" and is covered by the relevant rules for excused absence (see above).

Homework

Homework will be handed out approximately once every two weeks and will generally be due the following week. I expect that there will be 5 assignments during the semester. The due date will be clearly stated on the homework. On the due date, homework should be submitted online on ELMS or by email. Late homework will be accepted for a few days after the due-date and will be subjected to a penalty of up to 30%. Once the solution sets are handed out, late homework cannot be accepted. If you have a valid emergency that prevents you from making a homework deadline, you should make all reasonable efforts to contact me before the due date telling me the nature of the emergency. Please document all such emergencies; *a self-signed note is sufficient provided that it contains a statement that (1) the information is true and correct and (2) providing false information is prohibited under the Code of Student Conduct.*

Academic Integrity

The University's policies and rules on academic integrity are laid out in this document: http://www.president.umd.edu/policies/docs/III-100A.pdf. In essence, you must never engage in acts of academic dishonesty at any time. Acts of academic dishonest include cheating, fabrication, plagiarism, or helping any other person to do any of these things.

These rules apply to homework and quizzes as well as exams. As a part of these rules, you must give credit to any published article or webpage that you have used to help you with a particular assignment. The University takes these issues extremely seriously, as do I.

Preliminary course outline

	GRAVITY
Jan 26	1 - Introduction; Recap of Newton's laws and the conservation of momentum
Jan 28	2 - Newtonian gravity
Feb 2	3 - One body problem - conservation laws and constants of motion
Feb 4	4 - One body problem - solving the equation of motion
Feb 9	5 - One body problem - derivation of Kepler's Laws
Feb 11	6 - One body problem - cont
Feb 16	7 - Two-body problems and binary systems
Feb 18	8 - In class exercise: LOS velocity and mass function
Feb 23	9 - Two + one (restricted three) body problem - Lagrange points
Feb 25	10 - Two + one (restricted three) body problem - effective potential
Mar 2	11 - In class exercise: Lagrange L3
Mar 4	12 - N-body dynamics - the virial theorem
Mar 9	13 - N-body dynamics - applications of the virial theorem
Mar 11	MIDTERM (in class)
Mar 16	**SPRING BREAK**
Mar 18	**SPRING BREAK**
Mar 23	14 - N-body dynamics - two body relaxation
	GAS PHYSICS
Mar 25	15 - Pressure and the concept of hydrostatic equilibrium
Mar 30	16 - Atmospheres in an external gravitational field

Apr 1	17 - Self-gravitating atmospheres
Apr 6	18 - Introduction to thermodynamics and statistical mechanics
Apr 8	19 - Statistical mechanics of ideal gas
Apr 13	20 - Radiation gases
Apr 15	21 - Radiation gases (cont) and applications to Cosmology
Apr 20	22 – Brief introduction to hydrodynamics
	QUANTUM PHYSICS
Apr 22	23 - The Bohr model of the atom
Apr 27	24 - Particle wave duality and particle in a box
Apr 29	25 - Fermions and bosons; Fermi-Dirac & Bose-Einstein statistics
May 4	26 - Degeneracy pressure and while dwarf
May 6	27 - Type-1a supernovae and neutron stars
May 11	28 - Review
May 13th	Final exam