RICE

Course: ASTR 350
Term: Fall 2021
Zoom: On-line
Class: TTh, 10:50-12:05

Instructor Contact Information

Instructor: Matthew G Baring
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Office Hours: TBD

Course Objectives and Learning Outcomes

This undergraduate course is primarily intended for juniors. It is part of the core curriculum for astrophysics major students at Rice, along with ASTR 360 (Galaxies and Cosmology). Together they provide a year-long grounding in the branch of astrophysics that deals with celestial objects and structures in the nearby and distant Universe, serving as essential preparation for all budding professional astronomers and astrophysicists, particularly those who intend to pursue this field in graduate studies. It is also suited for a wider physics-trained audience who love astronomy.

Objectives: The goal is to provide students with a basic understanding of stars and gaseous nebulae, their classification and their physical structure, and how astronomers acquire observational diagnostics of the physics and chemistry of these cosmic environs. This starts with a study in gravity, planetary orbits and constituents of the solar system. The evolution of stars to the supernova stage is explored, as are the remnants of their eventual explosions, white dwarfs. neutron stars and black holes. Students will learn how to assemble various of pieces of physics from disparate areas of the Rice physics curriculum to bring to bear on a wide selection of astrophysical problems in the Milky Way and beyond. These will include plasma physics, nuclear physics, quantum theory, relativity, gravity and electromagnetism. Students will be taught to think logically and critically about what are reasonable assumptions in models and what are not, how to pose hypotheses and then test them. They will also be taught how to think “laterally” in the sense of connecting seemingly unrelated pieces of information with common threads of physics and astrophysical understanding. Another aim is to use and develop skills from mathematical and computational portions of the Rice undergraduate curriculum in these astrophysical contexts. In addition, the course gives students the opportunity to do a small amount of reading research, and communicate their findings both in a paper and orally to their peers.

Learning Outcomes: By completing the course, students will be in a much better position to assess posed problems, suggest hypotheses for observed phenomena, test their ideas, develop efficient strategies for probing their speculations, and draw conclusions from their investigations. They will receive a modicum of training to communicate their ideas, hypotheses and understanding of select issues to an ensemble of their peers. This is the essence of the research process: think critically, probe, discover, revise one’s perspective, tell the broader community of the results and the path taken to get there, and decide where to go next. Such is invaluable training for an array of professions and potential careers down the line, including industry, business and academia.

Course Logistics Information

This course will be taught primarily on-line; the circumstances governing this have been communicated to the students. Lecture slides will be available to students before each class, and posted on-line. Office Hours will be predominantly virtual, at times suiting the students, though some face-to-face discussions in outdoors environs with safety plus physical-distancing protocols enacted can be workable. Homeworks will be submitted electronically unless otherwise negotiated. Details of various logistics will be communicated via email throughout the course.

REQUIRED TEXTS AND MATERIALS

An Introduction to Modern Astrophysics, by Bradley Carroll and Dale Ostlie (Cambridge)

This provides the basis for much of the course, and is an essential supplement to the lectures. Notes for some course material not contained therein will be provided. It is also normally used for the companion course ASTR 360.

OPTIONAL SUPPORTING TEXTS

Universe, by William Kaufmann, Robert Geller and Roger Freedman (Clancy Marshall)
Astronomy Today, by Eric Chaisson and Steve MacMillan (Pearson)
Introductory Astronomy and Astrophysics, by Michael Zeilik and Elske Smith (Cengage)
Foundations of Astronomy, by Michael Seeds and Dana Blackman (Cengage)
The Physical Universe, by Frank Shu (University Science)

EXAMS AND PAPERS

The course assessment will consist of seven to eight approximately weekly/bi-weekly problem sheets, cumulatively constituting 40% of the total grade, one ***open-book, open notes*** **take-home mid-term exam** during the semester that constitutes 20% of the grade, one **research project** presented as a written paper and a short talk to the class in late October/early November, worth 20% of the grade, and an ***open-book, open notes*** **take-home final exam** at the end of the semester, constituting the remaining 20% of the assessment.

GRADE POLICIES

All parts of the assessment will be graded on a curve, determined commensurately with the overall performance of past students who have taken this course at Rice. This means that present students will not only be measured relative to their peers, but also relative to the long-term body of high-caliber Rice students who have enjoyed the experience of this course.

Late homeworks will automatically receive a **5% reduction in credit**, unless an extension has been negotiated with Prof. Baring. Homeworks that are **4-7 days or more overdue** will be **reduced by 30%** in total credit. Beyond that timeframe, late homeworks will not be graded and score zero. This policy is adopted because (i) it is not fair to other students to have the return of their homeworks on a timeframe that is substantially delayed by inadvertent tardiness by any student, and (ii) it is not fair to impose logistical constraints on Prof. Baring in terms of grading.

Extensions of homework deadlines must be negotiated with Prof. Baring prior to the original deadline, with the student defining good cause for the extension. The negotiated deadline will substitute for the original one in terms of the aforementioned late penalties.

The final exam must be submitted prior to the University-mandated deadline of 5pm on Tuesday, 14th December, the end of Fall Semester, 2021.

Exceptions to these late policies can occur for extenuating circumstances such as student illness, family illness or emergency. In such cases, it is the student's responsibility to let Prof. Baring know (ahead of time, if possible) what is going on so that he is not "in the dark." The student will need to (retroactively) document the circumstances.

Class Attendance

The purpose of the lectures is to impart knowledge distilled to its essentials on the subject matter of the course and in a manner more efficient than is afforded by merely reading textbooks and browsing Web sites; these important out-of-class learning paths are intended to supplement, not replace lectures. A central ingredient of this classroom forum is leveraging the extensive research experience and science connections of the Lecturer, and this is best done by attending on-line lectures. The small average class size underpins an exceptional learning experience that sets Rice apart from many of its peer institutions. **Students should take advantage of this opportunity by habitually attending classes**; their learning curve will be enhanced by such dedication.

Absence Policies

Infrequent absences are not a problem. If a student is noted to be absent for an extended period of time, or frequently, the student must communicate with Prof. Baring the reasons of the absence(s). Such cases normally will degrade the efficacy of learning for the student. Again, if there are extenuating circumstances such as student illness or family illness or emergency, accommodations will be made, and Prof. Baring should be informed.

Rice Honor Code

In this course, all students will be held to the standards of the Rice Honor Code, a code that you pledged to honor when you matriculated at this institution. If you are unfamiliar with the details of this code and how it is administered, you should consult the Honor System Handbook at http://honor.rice.edu/honor-system-handbook/. This handbook outlines the University's expectations for the integrity of your academic work, the procedures for resolving alleged violations of those expectations, and the rights and responsibilities of students and faculty members throughout the process. This integrity is an approach to work and life that we hope students will apply throughout their future careers.

The mid-term and final (take-home) exam questions are not to be discussed at all with other students, faculty or graders, and are subject to the provisions of the Rice Honor Code. Please verify this by **writing the word pledge and your signature on each exam**. Questions specifically about exams should be directed only to Prof. Baring.

Disability Support Services

If you have a documented disability or other condition that may affect academic performance you should: 1) make sure this documentation is on file with Disability Resource Center (Allen Center, Room 111 / adarice@rice.edu / x5841) to determine the accommodations you need; and 2) talk with Prof. Baring to discuss your accommodation needs *during the first two weeks of class*.

Any letter from the DRC to the instructor requesting accommodations for the student should be delivered in the first three weeks of semester, so that Prof. Baring can plan accordingly.

Title IX Responsible Employee Notification

Rice University cares about your wellbeing and safety. Rice encourages any student who has experienced an incident of harassment, pregnancy discrimination, gender discrimination or relationship, sexual, or other forms interpersonal violence to seek support through The SAFE Office. Students should be aware when seeking support on campus that most employees, including myself, as the Instructor, are required by Title IX to disclose all incidents of non-consensual interpersonal behaviors to Title IX professionals on campus who can act to support that student and meet their needs. For more information, please visit the http://safe.rice.edu/ webpage or email titleixsupport@rice.edu .

SYLLABUS

The detailed syllabus below gives the layout of the course material. For further information, such as scheduling, pointers to related chapters in the Required Text, etc., see the ASTR 350 course web pages at http://www.ruf.rice.edu/~baring/astr350/astr350.html/ .

*** With the updated pandemic protocols for the start of the semester, topics so designated will be reading only, unless time permits a formal lecture.

Celestial Mechanics

- Kepler's Laws (1609)
- Conic Sections
- Planetary Orbits
- Newtonian Mechanics
  - Potential and Kinetic Energies
- Binary Orbits
- Derivation of Kepler's Laws
  - Kepler's First Law
  - Kepler's Second Law
  - Kepler's Third Law

Binary Stars, Exoplanets and the Virial Theorem

- Binary Stars
  - Mass Determination Using Visual Binaries
  - Spectroscopic and Eclipsing Binaries
- Extrasolar Planets
- Virial Theorem

Tides, Comets and Asteroids ***

- Tidal Forces
- Comets
- Asteroids

Photometric Concepts and Radiation

- Magnitudes
- Extinction and Reddening
- Blackbody Radiation
  - Wien and Stefan-Boltzmann Laws
  - Planck Spectrum

Radiation Processes and the Quantum Atom

- Continuum Mechanisms
  - Photo-electric Effect
  - Compton Scattering
  - Cyclotron and Synchrotron Radiation
  - Bremsstrahlung Radiation
- Spectral Lines
  - Kirchhoff's Laws
- The Bohr Atom
- Quantum Concepts

Stellar Spectra and Atmospheres

- Spectral Classification
- Atom Excitation: the Boltzmann Equation
- Ionization and the Saha Equation
- The Hertzsprung-Russell Diagram
  - Morgan-Keenan Luminosity Classes
- The Radiation Field and its Pressure
- Stellar Opacity and Radiative Transfer
- Structure of Spectral Lines

Stellar Structure

- Hydrostatic Equilibrium
- Pressure and Equation of State
- Stellar Energy Sources
  - Gravitational Potential
  - Nuclear Timescales
  - Thermonuclear Reaction Rates
  - Thermonuclear Chains
- Stellar Structure

The Sun

- The Solar Interior
  - Solar Neutrino Problem
- The Solar Surface and Exterior
  - The Solar Cycle

Stellar Evolution

- Star Formation
  - Gravitational Collapse: Jeans Criterion
  - Pre-Main Sequence Stars
- Evolution on the Main Sequence
  - The Schönberg-Chandrasekhar Limit
- Late Stages of Stellar Evolution: Massive Stars
- Supernovae, Lightcurves and Radioactive Decay
- Stellar Pulsation: Variable Stars
  - The Physics of Stellar Pulsation

Compact Objects

- White Dwarfs
  - Degenerate Electrons in White Dwarfs
  - Mass-Radius Relation and the Chandrasekhar Limit
  - White Dwarf Cooling
- Neutron Stars
  - Neutron Star Structure
  - Pulsars
- Black Holes

Syllabus Change Policy

This syllabus is only a guide for the course and is subject to change without advanced notice.