Course: ASTR 360
Term: Spring 2025
Room: Hermann Brown 423
Class: TTh, 1.00-2.15pm

INSTRUCTOR CONTACT INFORMATION

Instructor: Matthew G Baring
Office: Herman Brown 366
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Office Hours: W, 1.30-3.00pm, Herman Brown 223

COURSE OBJECTIVES AND LEARNING OUTCOMES

This undergraduate course is primarily intended for juniors, yet it is often taken by sophomores with sufficient background preparation. It is part of the core curriculum for astrophysics major students at Rice, along with ASTR 350 (Introduction to Astrophysics - Stars). 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 the larger structure of the Universe, its evolution from very early stages to the present, how constituent elements such as galaxies are formed, developed and classified, and also offer an introduction to some of the more exotic cosmic objects such as active galaxies and gamma-ray bursts. It explores how observational data can constrain this understanding, and what physics is needed to comprehend Nature at its most magnificent. 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 larger Universe. 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 via a mini-symposium.

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.

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 350.

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 March/early April, 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 **10% reduction in credit**, unless an extension has been negotiated with Prof. Baring. Homeworks that are **4-7 days or more overdue (i.e. greater than 72 hours)** will be **reduced by 50%** 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 and the Teaching Assistant 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, 6th May, the end of Spring Semester, 2025.

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 habitually attending 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, and Prof. Baring should be informed so that accommodations can be made.

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 take-home mid-term and final 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, 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 360 course web pages at https://www.ruf.rice.edu/~baring/astr360/astr360.html .

Astronomy Concepts

Preliminaries: Stellar Magnitudes
Recap: Blackbody Radiation
Atomic Spectroscopy and the Bohr Model
Preliminaries: Kepler's Laws (1609)
The Hertzsprung-Russell Diagram

The Milky Way

- Historical Models of the Milky Way
- Star Counts and the log N - log S Distribution
- The Morphology of the Galaxy
- Kinematics of the Milky Way
- Galactic Rotation Curve: Evidence for Dark Matter
- The Galactic Center

Normal Galaxies I: Spirals

- The Discovery of Galaxies
- Hubble's Classification of Galaxies
- Spiral Galaxies
  - Tully-Fisher Distances
- Spiral Structure

Normal Galaxies II: Ellipticals

- Elliptical Galaxies
  - Populations of Ellipticals
  - King's Model: Spherical Galaxies
- Galactic Evolution
  - Gravitational Relaxation
  - The Role of Gas Cooling

Cosmic Structures and Distances

- Distance Determination
  - Tully-Fisher Distances
- Hubble's Law
- Supernova Surveys
- Galaxy Clusters
- Large Scale Structure

Active Galaxies

- Global Energetics of Active Galaxies
- Seyferts
- Radio Galaxies
  - Superluminal Motion and Doppler Boosting
  - Shock Acceleration
  - Hot Spots in Radio Lobes
- Blazars and AGN Unification
  - The AGN Unification Scenario
- Quasars
  - The Central region: supermassive black holes

Cosmological Entreé

- Olber's Paradox and Mach's Principle
- The Cosmological Principle
- Cosmochronology
  - Gravitational Instability
  - Nuclear Supply Ages
  - Globular Cluster Constraints
  - White Dwarf Cooling
  - Radio-Isotope Dating

Newtonian Cosmology

Newtonian Expansion/Collapse
Matter-Dominated Universes
  Mathematical Solutions
  Deceleration Parameter

Relativistic Cosmology

Robertson-Walker Metric
Friedmann Equation
Radiation-Significant Cosmologies
The Cosmological Constant

Observational Cosmology

Connecting to the Real World
  Lookback Times
  Flatness Problem
  Angular Diameter Distance
  Luminosity Distance

The Cosmic Background Radiation

Cosmic Microwave Background
  Anticipation and Discovery
COBE, WMPA and Planck Results and Implications
  Acoustic Oscillations: the Robust Cosmic Ruler
  Baryonic Seed Timescale
  WMAP and Planck: the Era of Precision Cosmology
Recombination Era
Redshift of Last Scattering

Big Bang Nucleosynthesis

Primordial Nucleosynthesis
  Neutrino Decoupling
  Neutron Freeze-out
  Deuterium Synthesis
  Helium and Lithium Production

Big Bang Inhomogeneities

Structure Growth: Linear Density Perturbations
  Matter-dominated Epoch
  Radiation-dominated Era
Jeans Instability

The Very Early Universe

The Planck Era
Inflationary Cosmology

Syllabus Change Policy

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