

# Physics 521: Astrophysics

Fall 2021

PRELIMINARY

3 Credits

Lectures: MW, 4:05pm-5:25pm

ERP 114

**Instructor:** Prof. Robert Rutledge. Email: Use myCourses to contact me by email.

**Teaching Assistants:** Sabrina Berger and Nirmalya Brahma. Email: Use myCourses to contact Teaching Assistants by email.

**Office Hours:** Office Hours can be scheduled at the site <http://rutledge.simplybook.me> (fast) or by email (slower).

**Prerequisites:** The course is open to MSc/Phd students, and students enrolled in a U3 Honors physics program, or permission of the instructor. Students are assumed to have mastered physics at an undergraduate level, including quantum mechanics, statistical mechanics, electromagnetism, and particle physics. We will draw from the derivations and conclusions of each of these areas. Students are also assumed to be capable in at least one computer language (C, Fortran, Python) which will permit them to make iterative calculations, and produce 2-dimensional plots.

## Course Content

This is a survey course on astrophysics, explained largely from an observer's perspective. We will cover tools in the astronomer's toolbox: statistics, mathematical (Fourier) methods, computer methods and tools, instrumentation, research resources. We will cover stellar astrophysics, including: stellar properties, structure and evolution; stellar endpoints (white dwarfs, neutron stars, and black holes). Related topics include gamma-ray bursts, supernovae, super nova remnants, X-ray binaries. We will cover galaxies (structure, kinematics, evolution, and distribution). Active galactic nuclei (AGN). Introductory cosmology – including inflation, structure formation, and the cosmic microwave background.

At the end of this course, students will know about the objects which populate the universe, be able to discuss and explain their properties and behavior verbally and mathematically using the language of modern astronomy and astrophysics, using undergraduate-level physics. A focus will be on recognizing and executing the canonical analytic problems in astrophysics. The course should be seen as preparation for graduate-level astrophysics research.

## Instructional Method

The course is centered around the lectures, reading assignments, repetitive proofs. Up to six homework assignments will draw from the lectures and reading assignments, and guide students learning in preparation for the skills practicum, which are a demonstration of student skills in each subject area.

## Course Materials

- **Required Textbook:** *An Introduction to Modern Astrophysics*, Bradley W. Carroll and Dale A. Ostlie (Addison-Wesley; 2nd Edition, 2017) ISBN: 1108422160. 1359 pages. There will be weekly assigned reading from this text, and assigned homework problems from this text. Digital editions is the recommended version.

Reading assignments (always in Carroll and Ostlie – CO). There is a total of 925 pages of assigned readings, which is an average of 66 pages per week. Students should read ahead, and come to lectures prepared to discuss the assigned readings. Here is a general outline.

- Week 1 (Sept 6): Statistics
- Week 2 (Sept 13): Chapter 1-5. (139 pages). The Celestial Sphere, Celestial Mechanics, The Continuous Spectrum of Light. The Theory of Special Relativity. The Interaction of Light and Matter.
- Week 3 (Sept 20): (cont)
- Week 4 (Sept 27): Ch 6 (Telescopes, 38 pages), Ch 7 (Binary Stars, 22 pages)
- Week 5 (Oct 4): Ch 8-10 (147 pages). The Classification of Stellar Spectra. Stellar Atmospheres. The Interiors of Stars.
- Week 6 (Oct 11): (cont)
- Week 7 (Oct 18): Ch 12-13 (85 pages). The Interstellar Medium and Star Formation. Main Sequence and Post-Main-Sequence Stellar Evolution.
- Week 8 (Oct 25): Ch 15-17 (90 pages). The Fate of Massive Stars. The Degenerate Remnants of Stars. General Relativity and Black Holes.
- Week 9 (Nov 1): (cont)

- Week 10 (Nov 8): Ch 24-25 (126 pages). The Milky Way Galaxy. The Nature of Galaxies.
- Week 11 (Nov 15): (cont).
- Week 12 (Nov 22: Ch 26-27 (85 pages). Galactic Evolution. The Structure of the Universe.
- Week 13 (Nov 29 (final week)): Ch 28-29 (145 pages) Active Galaxies. Cosmology.
- Extra: Ch 30 (45 pages). The Early Universe.

## Administration

### Grading:

**Textbook Reading Notes, 25%.** Handwritten reading notes, turned in by full chapter (i.e. Ch 7, Ch 8, etc). Grading will be on conciseness, completeness of subject matter (that is, covers all the assigned material), usability, and legibility. In answer to the question "how concise", for the required textbook CO, a minimum of approximately 1 page of notes per 10 pages of assigned reading is expected. Notes must be taken from a careful reading of the required textbook; in particular, *copying notes from any source other than the textbook, such as other students' notes, is expressly forbidden*. DEADLINES: Soft deadline, is the assigned week of reading. Hard deadline, after which no submissions will be accepted, is the final day of lectures.

**Repetition Proofs, 25%.** Handwritten proofs, assigned approximately weekly from among proofs given during video presentations, from the textbook, or otherwise provided. There will be no more than 10 assigned throughout the term. Each proof must be written 3 times, by hand, as a form of re-enforcement. Alternatively, there are two options, either one of which will be accepted in stead of the repetition proof: (1) a handwritten, narrative description of the proof; (2) a video recording of the student, verbally explaining the proof. Additional information is provided on the proof assignments. DEADLINES: Soft deadline, is 7 days after assignment. Hard deadline, after which no submissions will be accepted, is the final day of lectures.

**Homework exercises, 0%.** The homework exercises, assigned approximately every other week, are meant to guide studying in preparation for skills practicum. Homework will be graded on a "+" (Meaning, good completion), "check", (acceptable completion), or "-" (poor completion). If all homework is completed with a "+", with at most one "check", the final course grade will be bumped up by half a mark (a C+

becomes a B-; a A- becomes an A). Solutions will be made available. DEADLINES: Hard deadline is 7 days after assignment.

**Skills Practicum/Exams - 2x 15% for 30% total.** These are more intense, skill-demonstrating tests. One will occur during mid-terms; a second, during Finals Period. The format will be determined at least 14 days prior to the start time of the midterm, and 14 days prior to the final day of lectures, for the final exam. Students unable to complete the first Skills Practicum mid-term, may opt to have all 30% of this grade due to the second during Finals Period.

**End-of-Month Self-Reflection, 10%.** A form will be provided, for a self-reflection/assessment exercise, due at midnight on the final calendar day of each month. Students will reflect on their progress in the course materials, their learning progress, and a representation of their grade for the past month, and cumulative course grade, based on their self-reflection. Assessment of the self-reflection is based on its accuracy – that is, the student accurately reflects only their contributions to their learning for the past month – and not on their course grade (i.e. a student, who reflects that they have earned a 'C' based on their learning in the past month, can be assessed with an 'A' for that self-reflection. Likewise, a student who reflects that they have earned an 'A' for the past month, but does not adequately support that in their self-reflection, can be assessed a 'C'). DEADLINES: Hard deadlines are 11:59pm Sept 30, Oct 31, Nov 30.

**Participation, 10%.** Presence and verbal participation with constructive contribution during video-lectures, during video-lecture breakout periods, and other course-related synchronous interaction. Participation includes, but is not limited to: constructive questions, commentary, answering to other course participant's questions, meeting soft deadlines for written work, engaging in back-and-forth constructive discussion with other course participants in class texts, or myCourses. Students will be asked to describe their course participation in the End-of-Month Self-Reflection.

## Addendum

**Equipment.** To participate in this course, you will need to be able to handwrite work, then make a color digital photocopy and submit it on myCourses as PDF. These capabilities require hardware and networking, which it is the student's responsibility to secure access to, including: a) broadband internet; b) internet-capable camera and microphone; c) capability to photograph handwritten work (homework, skills practicum, textbook reading notes, repetition proofs), convert to color PDF, and submit using myCourses. "Scanner" software on a smartphone can accomplish this. So can the scanners available on-campus, as "copiers".

**Disabilities.** Students who will be unable to participate in any aspect of the course due to an ongoing or temporary disability are encouraged to immediately contact the professor to arrange for an accommodation. Students are encouraged to avail themselves of the services of the Office for Students with Disabilities at <http://mcgill.ca/osd>.

**Video Appearances.** Although exceptions may occur during the term, course participants will not generally be required to appear on video, to participate in this course. Audio communication - via internet or phone-in connection - should almost always be sufficient, for both listening, and speaking, during course-related activity. An example of an exception, is when the instructor needs to confirm the identity of the participant.

**Deadlines.** Students are strongly advised to maintain the discipline of meeting the soft deadlines provided for graded, written work (Reading Notes, Repetition Proofs). Doing so, will insure students are prepared to maximally benefit from contemporaneous lectures and course topical work. Failure to do so will likely decrease students' educational goals. The hard deadline is provided to offer the maximum possible flexibility allowed under University guidelines for due dates for written, graded work, but the instructor recommends students employ the hardline only under extenuating circumstances. What constitutes extenuating circumstances is left to the discretion of the student, and the student may employ the hard deadline without any additional permission from the instructor.

**Honor Code:** Students enrolled in the class must enforce the following Honor Code for all activities related to this class: "I will not take unfair advantage of any other member of the McGill community."

**Academic Integrity:** McGill University and the instructor value academic integrity. Therefore, all students must understand the meaning and consequences of cheating, plagiarism and other academic offenses under the Code of Student Conduct and Disciplinary Procedures (see [www.mcgill.ca/integrity](http://www.mcgill.ca/integrity) for more information).

**Practical Application of Academic Integrity Policies, with regards to Homework:** Students are expected to have executed their homework individually. Nonetheless, students may consult verbally with other students. For example, you may work in groups while working on your homework.