Syllabus for Phys 595/495: Theoretical Astrophysics

Fall 2017

Lectures: Tuesdays/Thursdays 12:30–13:50; CCIS L1-029

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— All three offices are on north side of CCIS — .

Office hours: We will have no formal office hours. Instead, we will be happy to meet you at most times; email the appropriate instructor to arrange an appointment, or ask us after class.

Website: https://eclass.srv.ualberta.ca/my/
Look for "PHYS 495/ 595 Fa17 - Theoretical Astrophysics"
Homework, along with other useful information, will be regularly posted to eClass.

Course Description:
This course will consist of three related topics (hereafter, components) in theoretical astrophysics. Each topic will account for approximately one-third of the course, and will be led by a different instructor.

- **Radiative Processes: RP** (Heinke) – This component discusses the processes by which radiation is generated in and propagates through astrophysical systems. Since nearly every astrophysical observation is electromagnetic in nature, it also represents the key physics for understanding data.
- **Astrophysical Fluids: AF** (Ivanova) – Astrophysical fluids span a wider range of physical conditions than are found in terrestrial applications. This component will present an introduction to the hydrodynamic equations and numerical methods used to solve those systems.
- **Approximation Methods: AM** (Sivakoff) – This course component will provide generic problem-solving skills, including the development of prototype solutions to unfamiliar problems (using e.g. dimensional analysis), and estimating the importance of different physical effects in various physical systems. These skills are essential for identifying relevant processes and effective solution strategies in research situations.

Course Prerequisites: Background in electromagnetism, special relativity, quantum mechanics, and (preferably) statistical mechanics, at the undergraduate level. A student should be very comfortable with calculus, and have some basic programming skills. Astrophysical knowledge is optional, but useful.

Required Course Textbooks and Equipment: None

Recommended Course Textbooks: Each component of the course has different recommended textbooks; please see later sections of this outline.

Additional Course Fees: None

Disclaimer: Any typographical errors in this Course Outline are subject to change and will be announced in class. The date of the final examination is set by the Registrar and takes precedence over the final examination date reported in this Course Outline.

Tentative Lecture Schedule:

Sep 5	Intro — AF / RP / AM	Sep 7::	AF-1
Sep 12:	AM-1	Sep 14::	AF-2
Sep 19:	AM-2	Sep 21::	AM-3
Sep 26:	RP-1	Sep 28::	AF-3
Oct 3:	AM-4	Oct 5::	AF-4
Oct 10:	RP-2	Oct 12::	AF-5
Oct 17:	AM-5	Oct 19::	AF-6
Oct 24:	RP-3	Oct 26::	AF-7
Oct 31:	RP-4	Nov 2::	AF-8
Nov 7:	AM-6	Nov 9::	AM-7
Nov 21:	RP-5	Nov 23::	RP-6
Nov 28:	RP-7	Nov 30::	RP-8
Dec 5:	AM-8	Dec 7::	AM-9

Pre-set Assignment Deadlines:

Oct 12:	AF- Oral Presentation topics are given out	(In class)
Oct 31:	RP-Term Project Choice Deadline	(In class)
Nov 2:	AF - Oral Presentation	(In class)
Dec 7:	AM-Oral Exam	(In-class[a])
Dec 8:	RP-Term Project Written Report	(In class)
Dec 15:	RP-Term Project Presentations	(During Final Exam[b], 14:00)

[a]: These exams will occur in the final class, or by appointment with the instructor in the last two weeks of class or first week of the final exam period.

[b]: These presentations will occur on the date reserved for this classs final exam, or on another date agreed to by all students.

Grading: Each of the three course components will contribute to $1/3$ of the final grade (see Grading Assignment). Specific due dates will be listed in the course schedule below. The table below indicates the grade category weights for each course component.

RP	Homework	50%
	Term Project - Written	30%
	Term Project - Oral	20%
AF	Homework	70%
	Oral Presentation	30%
AM	Class Participation	30%
	Homework	30%
	Oral Exam	40%

Grade Assignment: All grade categories of the course are individually capped at 100%. Grades are assigned separately for each of the three course components. Within each component, percentage grades will be calculated using the weights given above. The component percentage is then used to assign a component letter grade/GPA, where grade boundaries will be decided based on the instructor's expectations and judgement. Where possible natural grade boundaries will be used. The final course grade will be an average of the three component's GPAs, and reassigned a corresponding total course letter grade.

Academic Integrity:

"The University of Alberta is committed to the highest standards of academic integrity and honesty. Students are expected to be familiar with these standards regarding academic honesty and to uphold the policies of the University in this respect. Students are particularly urged to familiarize themselves with the provisions of the Code of Student Behaviour (online at www.governance.ualberta.ca) and avoid any behaviour which could potentially result in suspicions of cheating, plagiarism, misrepresentation of facts and/or participation in an offence. Academic dishonesty is a serious offence and can result in suspension or expulsion from the University"

All forms of dishonesty are unacceptable at the University. Any offence will be reported to the Associate Dean of Science who will determine the disciplinary action to be taken. Cheating, plagiarism and misrepresentation of facts are serious offences. Anyone who engages in these practices will receive at *minimum* a grade of zero for the assignment, paper or exam in question and no opportunity will be given to replace the grade or redistribute the weights. As well, in the Faculty of Science the sanction for cheating on any examination will include a **disciplinary failing grade** (NO EXCEPTIONS) and senior students should expect a period of suspension or expulsion from the University of Alberta.

Students are encouraged to discuss assignments with their classmates, friends, family, etc. If students choose to work together on homework, they must submit their own work for grading. Direct copying of another's work is plagiarism.

Students Eligible For Accessibility-Related Accommodations:
(students registered with Student Accessibility Services - SAS)

Eligible students have both rights and responsibilities with regard to accessibility-related accommodations. Consequently, scheduling exam accommodations in accordance with SAS deadlines and procedures is essential. Please note adherence to procedures and deadlines is required for U of A to provide accommodations. Contact SAS (www.ssds.ualberta.ca) for further information.

Please note: Students registered with SAS who will be using accommodations in the classroom or the lab, or who will be writing exams through SAS, are required to provide a "Letter of Accommodation" to the instructor as soon as possible. Students are encouraged to make an appointment with the instructor to discuss any required accommodations, ideally within the first two weeks of class.

Academic Support:

As adults, students are expected to take more responsibility for their own education. If a student needs additional assistance in developing strategies for better time management, study skills or examination skills, keeping up with the material, or adjusting to university learning, then they need to seek help themselves. Sources of help include: the instructor, Isaac Isaac (the Physics Undergraduate Advisor, CCIS 4-185), and the Student Success Centre (2-300 Students' Union Building).

More details for each component of the class is presented on the following pages:

Policy about course outlines can be found in §23.4(2) of the University Calendar.

Radiative Processes (Heinke)

Recommended Texts:

We have several recommended texts: Gabriele Ghisellini's "Radiative Processes in High Energy Astrophysics", and "High Energy Astrophysics" by Thierry Courvoisier, are freely available as PDFs via the U of A Library (https://www.library.ualberta.ca). Alternative texts include the classic "Radiative Processes in Astrophysics", by Rybicki & Lightman, or Bradt's excellent "Astrophysics Processes". Andrew Cumming's notes (http://www.physics.mcgill.ca/~cumming/teaching/642/phys642_all_notes.pdf) are also useful.

Tentative topics (as time permits):

1. Fundamentals of radiative transfer. Equation of radiative transfer, optical depth, thermal radiation, the nature of absorption and emission lines.
2. Radiation from free electrons: radiation from moving charges, and from relativistic particles.
3. Bremsstrahlung radiation.
4. Synchrotron radiation.
5. Compton scattering.

Homework:

Several homework problem sets will be assigned over the term.

Term Projects:

Term projects involve literature research on a significant question in astrophysics that is not covered in detail in our course, but related to the physics discussed. The topic should be chosen by Oct. 31. It will involve a written report explaining the question, the relevant physics, and the current state of research in the area, of not more than 10 pages of text (not counting figures or references). It will also include a presentation to the class, up to 15 minutes long.

Astrophysical Fluids (Ivanova)

Recommended Texts:

This component of the course will make use of freely available online books and lectures notes by: Anderson "Computational Fluid Dynamics", Landau and Lifshitz "Hydrodynamics", Zingale "Introduction to Computational Astrophysical Hydrodynamic", and Dullemond (online lecture notes)

Tentative topics (as time permits):

1. Classification of partial differential equations (PDEs).
2. Derivation of governing equations of fluid dynamics: conservation and non-conservation forms of Navier-Stokes equations and Euler equations. Bernoulli's principle.
3. Intro in sound waves, discontinuities, shocks, Sedov-Taylor expansion (blast wave).
4. Numerical methods: grids, grid-based numerical methods for advection and Euler equation, Riemann solvers. Standard tests for hydrodynamical codes.
5. Briefly on fluid instabilities
6. Brief review of other types of codes: Smoothed Particle Hydrodynamics (SPH), spectral method, particle-in-cell.

Homework:

The homework will be in 3 parts. Some homework will be analytical, and some homework will require you to write a code to test or demonstrate a phenomenon discussed in class. The score for homework will be proportional to the number of earned points to the number of points available in all given homeworks.

For all homework that requires you to write code, the languages that you can use include C, C++, Fortran or Python. Your code must be self-contained. No use of programming platforms like Mathematica, Matlab, etc., is permitted. No use of Numerical Recipes or similar packages that can be called from C, etc. is permitted. In Python, you may use the matplotlib package for plotting and the numpy package to (only!) create arrays. Your code, plots and discussion/analysis of code's outcomes are to be submitted via email.

Oral Presentation:

You will need to learn in detail about one hydrodynamical code that you will be assigned, and present about that code in class, describing specific requested details. More details will be provided on eClass.

Approximation Methods (Sivakoff)

Recommended Texts:

This component of the course will integrate material from several books and online resources. There is a freely available PDF version of Goldreich, Mahajan, and Phinney "Order-of-Magnitude Physics at http://www.inference.org.uk/sanjoy/oom/book-letter.pdf, with updated chapters at http://www.inference.org.uk/sanjoy/mit/. Other useful books (but one's you need not run out and buy are): Harte "Consider a Cylindrical Cow", Harte "Consider a Spherical Cow", Mahajan "Street-Fighting Mathematics", Santos "How Many Licks", Swartz "Back-of-the-Envelope Physics", and Weinstein and Adam "Guesstimation".

Tentative topics (as time permits):

1. Dimensional Analysis and Scaling.
2. Mathematical Shortcuts.
3. General Order of Magnitude Problems.
4. Order of Magnitude Problems in Physics and Astrophysics.
5. Identifying Large and Small Effects.
6. Solutions by Analogy.

Please note that these topics will often be presented in an integrated fashion. We will spend most of the time solving problems together in class.

Class Participation:

Class participation is a vital part of this course component. All students will be evaluated on their participation in each lecture as a student, with students being allowed to miss a single lecture. Starting in the second lecture of this component, PHYS 495 and PHYS 595 students will also lead the class through 1 and 2 problems over the course of the semester, respectively. These problems should take $\sim$ 10–15 minutes for the class to solve. This leadership must involve getting the class to participate in solving the problem. Problems and solutions must be approved by the instructor ahead of time.

Homework:

Several homework problem sets will be assigned over the term.

Oral Exam:

An important part of this course is preparing student's for oral examinations (answering questions during conference talks, degree candidacy exams, degree defenses, etc...) Every student will individually be given a private 30-minute oral exam with the instructor (and whenever possible a second instructor to act as an observer). The exams will involve the student solving a number of problems using the techniques learned in this course component. These exams will occur during the last scheduled class, or by appointment with the instructor in the last two weeks of class or first week of the final exam period. PHYS 495 students will have first priority on scheduling these exams.