ASTRON 0113/0413: Introduction to Astrophysics

Term: Fall 2020
Credits: 3
Prerequisites: MATH 0020 or any MATH greater than or equal to MATH 0031 (Min Grade: C) or MATH PLACEMENT SCORE (61 or greater)
Meeting Time: Tuesdays and Thursdays, 1:15-2:30 PM, 104 Thaw Hall or virtual

Honors section (ASTRON 0413): 4 credits, same meeting times (Tuesday/Thursday 01:15-2:30 PM), plus 12:00-12:50 PM on Tuesdays, 106 Allen Hall or virtual.
Prerequisites for honors section: MATH 0230 or 0235, and PHYS 0110 or 0174 or 0475.

Instructor: Prof. Evan Schneider

eschneider@pitt.edu (email or Canvas is the best way to get in touch with me!)
Office: 304 Allen Hall
Office Hours: Mondays 4:00 - 5:00 PM, Thursdays 4:00 - 5:00 PM

Course Description:

This course is an introduction to astronomy and astrophysics at the beginning undergraduate level, intended for students that are majoring in science or engineering. Broad familiarity with basic physical concepts such as force, energy, momentum, and temperature will be assumed, as well as college level mathematics. Algebra, geometry, and trigonometry will be used extensively throughout the course and will be needed to complete the homework sets and exams. Familiarity with calculus will be very helpful, but it is *not* required for ASTRON113 and will *not* be needed to complete any assignments or exams in this course outside of the honors section.

   This is a self-contained course focusing on astronomical objects that lie beyond the solar system and the nature of the Universe as a whole. The main topics are the properties and life-cycle of stars including their birth, death and the formation of remnants such as black holes and neutron stars, the nature and evolution of galaxies, including exotic objects such as quasars, and the origin and ultimate fate of the Universe (cosmology).

Important note: If you are uncomfortable applying algebra and geometry, or you are not interested in studying astrophysical systems in detail, you may want to consider taking ASTRON 0087, 0088, or 0089, which are not designed for science majors and do not assume mathematical proficiency. Please contact me if you have any questions about your level of preparation. If you read this line, please send me an email with the cutest picture of a baby animal that you can find for extra credit on your first homework assignment.

Course Objectives:

   This course has two primary objectives:

- To provide a basic knowledge of the Universe outside the Solar System, sufficient to prepare students for more advanced astronomy courses.

- To help students gain skills in solving scientific problems, including the use of approximation techniques and other methods of obtaining rough solutions.

Modern astronomy has become a vast field of study encompassing atomic and molecular physics, planetary science, the study of galactic structure, and much more. It would be impossible even to survey the subjects that most practicing astronomers would consider "basic knowledge" in a single semester. Therefore, some choices have to be made. This semester, ASTRON 0113 will cover the following areas: (1) basic problem solving using approximation techniques; (2) the law of gravity, the process that lead to our contemporary understanding of gravity, and its application to physical problems; (3) the fundamental properties of light, and their importance in astronomy (4) basic stellar physics and stellar classification; (5) the structure of galaxies; and (6) the evolution of our entire Universe (cosmology). The solar system is probably the astronomical system most familiar to beginning students and I will address the solar system only briefly in

the first part of the course. This is a course designed for students who plan to continue in the sciences, and the emphasis will be on scientific thinking and problem solving. If there is a particular subject related to astronomical science that you find interesting, please let me know and I will try to cover it as part of the course if there is sufficient interest. In the past, students have requested lectures on black holes, supernovae, planets around stars other than the Sun, searches for extraterrestrial intelligence, space flight, and other subjects. My intention is to make this course as fun and productive as possible.

At the end of the course, you should be able to explain, among other things:

- How we can measure the properties of distant stars and galaxies using observations from the Earth and space.

- Why the Sun shines, and why it will not do so forever.

- How most chemical elements are synthesized in stellar cores through nuclear fusion.

- How the Sun and other stars form and die.

- How the Milky Way Galaxy we live in is similar to (or different from) other galaxies.

- Why we believe many galaxies have black holes at their center.

- What the main constituents of the Universe are, how it began, and what its ultimate fate will be.

Textbook: This course is more detailed than the standard introductory surveys of astronomy for non-science majors such as ASTRON 0087, 0088, or 0089, yet not so advanced that sophisticated mathematical tools (such as calculus) can be brought to bear on astronomical problems. Unfortunately, there is no textbook available that is particularly appropriate for this level. A good option is the openstax Astronomy book by Fraknoi, Morrison, and Wolff, which can be downloaded electronically for free, therefore this is the resource that I recommend you draw upon for conceptual content, however the mathematical level is significantly below that of ASTRON 0113 in most cases. 21st Century Astronomy by Kay, Palen, and Blumenthal (the Stars and Galaxies edition is sufficient) is another very good introductory book that makes only limited use of mathematics and has many excellent illustrations for students who prefer to have a physical reference, but we will cover most topics in more detail than is given in this book. Astrophysics in a Nutshell by Maoz is a great book. It provides an excellent introduction to most of the topics we will cover in this course including Light, Stellar Physics, Galaxies, and Cosmology. However, this book makes heavy use of calculus and therefore is a bit too advanced for ASTRON 0113. Other good textbooks include Universe by Freedman and Kaufmann (some math) and Foundations of Astrophysics by Ryden and Peterson and (more math, including calculus). Homework problems will not be taken from any specific textbook and no specific textbook will be necessary to complete this course. I will highlight the relevant chapter(s) in openstax Astronomy throughout the syllabus, but I recommend Astrophysics in a Nutshell for the more mathematically-inclined (and ASTRON 0413) students.

As there is no textbook for the course, taking good notes during lectures will be of critical importance, regardless of whether you are able to attend lectures synchronously. In addition to lecture recordings, I will post slides from all the lectures on Canvas after each class. Please check Canvas often for updates, and let me know if you have any problems downloading the files. I will not answer questions in office hours about lecture materials if you miss a lecture and have made no effort to obtain the lecture materials through other means first.

Goals: My main goal is to work with students to make this course engaging, interesting, and fun. Do not hesitate to contact me with **any** questions or concerns, either by email or by coming to office hours. I need your feedback in order to improve your learning experience! Please let me know if you have issues with the course material, or you would like me to cover some topic that you are particularly interested in. Of course, I have to abide by University and Department rules and I have to work within the Physics and Astronomy curriculum, so I cannot accommodate all requests, but I will do my best.

Logistics: I will hold regular office hours on Mondays from 4 to 5 PM and Thursdays from 4 to 5 PM in 304 Allen Hall (these times may change during the semester, but will always be up to date on Canvas and any changes would be announced in class). Office hours will be virtual via Zoom until further notice. If you cannot make these times, please contact me and we can arrange to meet at another time. I would encourage you to use me as a resource - the problem sets in this course can be challenging and I want to help you work through them. If you need further help or would prefer to seek help from a tutor, the Department of Physics and Astronomy maintains a Physics Resource Room in 312 Thaw Hall that is staffed by tutors between 9 AM and 5 PM on weekdays throughout the semester. Please take advantage of this service.

Course Topics in Detail:

Below is a rough outline of topics covered in ASTRON 0113, which may be modified according to student interests and pacing as the semester progresses.

- **(1) Aug 20**: Introductory Material; Astronomy as a Science; Order of Magnitude
- **(2) Aug 25**: The Science of Astronomy and Steps Towards the Theory of Gravity
- **(3) Aug 27**: Newton?s Laws and the Universal Law of Gravitation
- **(4) Sep 1**: Energy and Gravitation; PSet 1 due (order of magnitude calculations, basic trig etc)
- **(5) Sep 3**: Conservation Laws and Spaceflight
  Add/drop period ends September 4
- **(6) Sep 8**: Angular Momentum, Introduction to Light; PSet 2 due (basic orbits, Kepler's Laws)
- **(7) Sep 10**: Emission, Absorption, Doppler Effect, Blackbody Radiation
- **(8) Sep 15**: Blackbody Radiation, Telescopes and Basic Optics; Pset 3 due (Newton's gravity, Tides etc)
- **(9) Sep 17**: Intro to Stars and the HR diagram
- **(10) Sep 22**: Stars and the Sun; Pset 4 due (Light as particle/wave, Blackbody radiation)
- **(11) Sep 24**: The Sun
- **(12) Sep 29**: The Interstellar Medium and Star Formation; Pset 5 due (The Sun, HR Diagram)
- **(13) Oct 1**: The Life and Times of a (low-mass) Star
- **(14) Oct 6**: Binary Stars and The Life and Times of a Massive Star; Pset 6 due (The Sun, hydrostatic equilibrium, inverse square law)
- **(15) Oct 8**: Stellar Remnants and Star Clusters
- **(16) Oct 13**: Star Clusters and stellar populations; Pset 7 due (Stellar lifecycles, remnants etc.)
- **(17) Oct 15**: A Historical Introduction to Galaxies in the Universe
- **(18) Oct 20**: What Shapes Galaxies?; Final Project Proposals due)
- **(19) Oct 22**: Mysteries in Galaxies: AGN, Supermassive Black Holes, and Dark Matter
- **(20) Oct 27**: The Milky Way Galaxy and its Structure; Pset 9 due (Galaxies, Dark Matter))
- **(21) Oct 29**: Introduction to Cosmology
- **(22) Nov 3**: Election Day, No class
- **(23) Nov 5**: The Expanding Universe and its Consequences
- **(24) Nov 10**: The Major Predictions of the Big Bang and the Theory of Cosmic Evolution; Final Project Draft due)
- **(25) Nov 12**: The Expanding Universe and its Consequences
- **(26) Nov 17**: Wrapping things up; Pset 10 due (Expanding Universe and Cosmology)
- **(27) Nov 19**: Final Project Presentations
- **(28) Nov 24**: Final Project Presentations
- **(29) Nov 26**: Thanksgiving, No class
- **(30) Dec 1**: Final Projects due

Grading Policy:

There will be approximately ten homework sets due throughout the course of the semester as well as a final project that will be due on Dec. 1. A full 60% of your grade will be based on your performance on the homework sets. The reason for this emphasis on homework sets is to hone your problem solving skills in an environment that mimics what practicing scientists do, where you have ample time and resources to accomplish a given task. If you want to get a high grade in this course, I advise you to set aside enough time to work on the homework assignments - you will need it. I understand that some weeks are busier

than others and will drop your lowest homework score (on an individual homework assignment) from your overall grade calculation. One benefit of this approach is that it will be difficult to do very poorly in this class if you do a good job on the homework assignments. The final project will comprise 25% of your grade, split into three pieces that will be graded separately - a project proposal (5%), a project draft (5%), and the final project itself (15%). The remaining 15% of your grade will consist of participation as demonstrated by lecture quizzes and polls, small group breakouts, and lecture notes. If you are unable to attend a lecture synchronously for any reason, you will still be expected to complete the lecture activities.

Additional Opportunities for Credit: Faculty, students, and postdocs at the University of Pittsburgh are actively involved in ongoing astrophysics research. We have regular research seminars that students are welcome to attend. From time to time you will have the opportunity to attend an astronomy-related presentation and submit a summary of that talk for credit (these are optional and will be counted in your homework grade average). I will discuss possible events during class and will post some on Canvas. If you find an event that you would like to suggest, please let me know!

In all assignments, the focus will be on showing the correct reasoning. **NO CREDIT** will be given for a correct answer without the reasoning being clearly explained. A great deal of the credit for a problem may be given if the reasoning is correct, but the numerical answer is incorrect for one reason or another. To get full credit for a problem, you must give a detailed statement of the problem and a brief but complete explanation of your reasoning. Occasionally, you may find an answer that is obviously incorrect. For example, say you derived the distance to the Sun to be three miles. In such a situation, you can still get partial credit for the problem simply by recognizing that the answer obviously does not make sense and explaining why the answer is manifestly incorrect. **NO CREDIT** will be given for an answer that has incorrect units unless you comment on the fact that your answer is wrong and take a guess where you may have gone wrong. For example, if you expect an answer that should have units of length (inches, meters, miles, etc.) but give an answer of 25 seconds you will get no credit unless you comment on this. Finally, your work must be legible. **NO CREDIT** will be given for work that I find illegible. **NO CREDIT** will be given if I find it difficult to follow the sequence of steps. Your work must flow sequentially from left to right across the page and from the top to the bottom of the page. It is your responsibility, and yours alone, to make sure that your work is legible and orderly. You may discuss problems with others on your homework sets, but the solutions you hand in must be your original work. Homework should be turned in via Canvas by the beginning of class on the day that assignments are due. I will accept emailed assignments, but the due dates / times will be the same regardless of technical difficulties. Late homework will be accepted with the grade reduced by 20% per 24 hours. I will post all solutions to problem sets a week after the due date. Once I have posted a solution set on Canvas, no late credit may be obtained for that assignment.

Attendance:

Given the uncertain nature of the world this semester, attendance in class will not be mandatory and absences will not impact your grade. However, if you miss a class, you are responsible for viewing the lecture recording in Canvas and completing all associated in-class participation assignments, including taking detailed notes. If you are unable to attend classes for a period of a week or more, please email me directly so that we can discuss your situation.

The Department of Physics and Astronomy:

(I will post Canvas announcements with updates to this section if and when in-person activities become available again.)

As students at the University of Pittsburgh, you have access to a Physics and Astronomy Department that is highly recognized and is performing world-class research. The Department of Physics and Astronomy wants you to feel welcome. If you are interested in further study of or research in physics or astronomy please talk to me or any other faculty member.

The Department of Physics and Astronomy provides free assistance for all students. The **Physics Exploration Center** allows students to operate some simple experiments and demonstrations. Within the Exploration Center is the **Physics Help Room**, staffed with TAs who can answer homework related questions, explain basic concepts and help you with the math. This is a free service and you are encouraged to use it. The Physics Exploration Center and the Physics Help Room are both located in Thaw 312, and a detailed schedule is posted here: `http://www.physicsandastronomy.pitt.edu/Savefe_room`. In addition,

tutoring is available through the Academic Support Center (WPU 311). You may also make use of the undergraduate lounge off of the mail room on the second floor of the Old Engineering Hall. This is a good place to meet with classmates to discuss problem sets and course material. You might also meet physics and astronomy majors here that can help you, discuss other classes with you, or inform you about the major program. The Department hosts a doughnut and coffee hour every Wednesday at 4PM, which is designed to encourage discussion. The Astrophysics group within the Department hosts seminars on topics of current interest in astronomy and astrophysics every other Friday at noon. The talks are typically at an advanced level, but eager students can learn a great deal about contemporary astronomy and astrophysics by attending (and can obtain credit for doing so). You can find the talk schedule in the Department web site: `http://www.physicsandastronomy.pitt.edu`.

Academic Integrity:

The integrity of the academic process requires fair and impartial evaluation on the part of faculty and honest academic conduct on the part of students. To this end, students are expected to conduct themselves at a high level of responsibility in the fulfillment of the course of their study. It is the corresponding responsibility of faculty to make clear to students those standards by which students will be evaluated and the resources permissible for use by students during the course of their study and evaluation. The educational process is perceived as a joint faculty-student enterprise which will perforce involve professional judgment by faculty and may involve - without penalty - reasoned exception by students to the data or views offered by faculty.

Cheating/plagiarism will not be tolerated. Students suspected of violating the University of Pittsburgh Policy on Academic Integrity, from the February 1974 Senate Committee on Tenure and Academic Freedom reported to the Senate Council, will be required to participate in the outlined procedural process as initiated by the instructor. A minimum sanction of a zero score for the quiz or exam will be imposed. For details, refer to the University Guidelines on Academic Integrity (`https://provost.pitt.edu/sites/default/files/academic_integrity_guidelines.pdf`).

Diversity and Inclusion:

I consider this class to be a place where you will be treated with respect, and I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, ability - and other visible and non-visible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.

Disabilities:

If you require special accommodations or classroom modifications, please notify both your instructor and Disability Resources and Services by the end of the first week of the term. The office of Disability Resources and services is located in 140 William Pitt Union, (412) 648-7890, drsrecep@pitt.edu, (412-228-5347 [voice or TDD]), and their website is at `http://www.drs.pitt.edu`. If you have a physical, learning, or emotional disability, please let me know as early as you can so that appropriate accommodations can be made.

Syllabus Addendum – Natural Science General Education Requirement

This course fulfills one Dietrich School of Arts and Sciences Natural Science General Education Requirement (GER) as described for the GERs starting Fall 2018 (term 2191). That GER reads as follows: *Three Courses in the Natural Sciences:* These will be courses that introduce students to scientific principles and concepts rather than offering a simple codification of facts in a discipline or a history of a discipline. The courses may be interdisciplinary, and no more than two courses may have the same primary departmental sponsor.

Voting at Pitt

In this presidential election season, eligible student voters and those educating themselves about the election process are encouraged to consult the nonpartisan website Pittvotes.turbovote.org. This site ensures Pitt students and other members of the community always know when elections are happening and have the information they need to vote with confidence. The site also provides election reminders, voter registration, applications for absentee ballots, and more. Please consult Pittvotes.turbovote.org and seek out assistance

from your instructors and peers as you work to learn about and exercise your critically important right to vote. Note that this class will be cancelled on Election Day in order to make it easier for you to vote in person, volunteer as a poll worker, etc.