ASTR 541: (Diffuse Matter in Space Not Limited to) The Interstellar Medium
cross-listed as ASTR 497B

Fall 2022
Instructor: Jessica Werk; jwerk@uw.edu
Class Meetings: MW 1:30 - 2:50 PM
PAA 214
Web pages: Canvas Page Link and Slack Workspace Link, at the astr-541-497-ism-2022 channel
Required Text Book: *The Physics of the Interstellar and Intergalactic Medium* by Bruce Draine (< 70$ on Amazon; I have also posted an "unauthorized" full PDF on Canvas)

Student Hours and Schedule Notes

Dedicated times: I will generally try to keep 3:00pm - 4:00pm on both MW (the hour following our regular class meeting times) open for questions in my office or on Zoom if you like (inquire about a link if needed). I am happy to arrange additional times for 1-1 meetings, please just get in touch with me to request a meeting time.
Important Dates : I will be out of town on October 5, October 24, and November 23. There will be no official in-class problem solving sessions on these days. During those weeks, we'll do abbreviated weekly problems, which will be due as usual at the end of the week, and you are welcome and encouraged to meet without me for collaborative problem solving if necessary.

Course Description

This course covers the important physical processes that occur in diffuse plasma (e.g. the ISM and IGM), which constitutes >80% of the baryonic matter in the Universe. We will examine the major phases of interstellar and intergalactic matter, and the cycle of mass and energy between these phases. The low densities found in interstellar space make it distinct from any other physical regime we are accustomed to thinking about. For this reason, studying the ISM poses a wonderfully unique and challenging problem.

The official motto for this course is **"Flexibility and Understanding."** That is, every deadline is flexible*, attendance in weekly problem-solving meetings is optional, and I will do my best to make sure every student in this course succeeds at their own pace. I will post all course materials, including assignments, to the canvas page. I only ask that you do your best to participate, keep up and engage with the material. In addition, this class has a dedicated Slack workspace where students can discuss weekly problems, lectures, form study groups, and more.

"Lectures," Assignments and Grading Policies

Every week, I will ask students to watch, asynchronously, between 2-4 approximately 20-minutes-long videos (typically < 1.5 hours total per week) that are a combination of recorded whiteboard presentations and slide presentations. All are posted on YouTube and will be linked in Canvas "Pages" every week; the available, default closed captioning is pretty good. There will be supplemental readings from Draine's book and, on occasion, from other sources (scanned and uploaded as PDFs) to accompany each short video. Every Monday by noon, after having had the previous week to watch the course content presentations and finish the readings, I will require the submission of a short, straightforward canvas quiz that will cover the material in the previous weeks' videos. The canvas quizzes will consist of three short-answer questions (i.e. multiple choice, fill-in-the-blank, order of magnitude), designed simply to ensure that students are keeping up with the posted content.

Specifically, even if you only watch the videos one time, you can expect to get 100% on every quiz. That is, in the videos themselves, I'll basically explicitly give you the answers to the quiz questions; you just have to be paying enough attention to jot them down.

Every week, we will work collaboratively on 1-2 problems during class. On Fridays by 11:59pm Pacific time, I will ask students to turn in their work and notes on these problems electronically via Canvas (scanned PDFs, photos of papers, latex-generated files, Word documents, Python notebooks and many other formats are all acceptable – it just has to be something you can upload to Canvas, or if that somehow fails, email to me as an attachment). I will generously grade your problem solving work, and grade primarily based on effort rather than the objective "correctness" of an answer (although correct answers are appreciated). **Specifically, if you turn in your work on the problems, and it represents a reasonable effort, you can expect to get 100% on every problem write-up**. In most cases, if you attend class, *the problems will not require work outside of class times* and you need only to upload a scan of your in-class notes. For this reason, it will probably make sense for you to bring a computer and/or a calculator to class – anything you need to solve quantitative/analytical problems. Let me know if this is not possible for you and I'll arrange a loaner laptop. For students who cannot attend class, I encourage you to use Slack to work collaboratively; sometimes you learn more by explaining a problem to someone else so don't be shy in helping out classmates! There is only one thing I intend to be strict about: **Every student must submit their own work on the problems, and if you worked extensively with one person in particular, please identify that person in your submitted work. I do not want to see any identical digital documents uploaded to canvas for a given problem. It is important to me that everyone actually makes an effort to learn.**

The short, weekly quizzes will be worth 30% of your grade in this course, and the problems will be worth 30% of your grade in this course.

Lastly, there will be one final project, in a format of your choosing, worth 40% of your course grade. Topics and final formats will ideally be chosen by mid-November, and student choices will be submitted via canvas as an assignment for prompt feedback and approval. One idea is to prepare and record a short video presentation (this worked well in 2020). For example, you may prepare a very brief presentation (e.g. $\sim$ 15 minutes; $\sim$ 10-15 original slides) on a pre-approved ISM/IGM subject of your choosing. Another idea is to write a short paper. You may instead elect to submit a single-spaced 3-4-page review article on a pre-approved ISM/IGM subject that includes at least 2 figures (roughly 1000 - 1500 words). I am open to different formats for the final, but they must be discussed with me and arranged in advance. The deadline for submitting the project is late night December 13th. There is otherwise NO final exam for this class. The final oral presentations, papers, (or interpretive dances) will be worth 40% of your grade.

Mastery in this course is achieved by obtaining a score of 70% or better on the material described above.
* While all deadlines are flexible, please keep in mind that **I must** submit grades by December 21 at 5:00pm.

Topics Covered (not exhaustive)

Thermodynamics and Statistical Mechanics, Radiative Processes, Ionization Balance, Collisions, Atomic Energy Levels and Spectroscopic Notation, Nebular Emission and HII Regions, Absorption Lines, Ionized gas, Neutral Atomic Gas and the 21cm Line, Molecular Gas Diagnostics, and Dust

Resources

The primary textbook for this course is Bruce Draine's book *The Physics of the Interstellar and Intergalactic Medium*, widely-viewed as the definitive ISM textbook. You will find it useful as I will draw much of the video lecture material from it. I will also provide you with supplementary reading material from this book every week that will enhance the video lecture material. Below, I've compiled links to detailed notes online, along with a list of textbooks covering the ISM and IGM (with bonus commentary). Additionally, I will post on canvas scans of relevant book excerpts and/or chapters if they are particularly useful/relevant to a topic.

Textbooks

There are a number of textbooks on the ISM and diffuse gas that may prove useful.

Recent

Draine "*Physics of the Interstellar and Intergalactic Medium*" – If you can only purchase one book, it should be this one. It is excellent.

Tielens "*The Physics and Chemistry of the Interstellar Medium*" – Xander Tielens is a major dust pundit, so texts covers dust extensively (possibly at the expense of other topics).

Dopita & Sutherland "*Astrophysics of the Diffuse Universe*" – Written by two experts on photoionization regions, so will be strongest on that topic. The first edition was riddled with typos, but later editions are rumored to be much better.

Dyson & Williams "*The Physics of the Insterstellar Medium*" – A good source of general explanations, if lacking in many of the details of the relevant physics. A good resource if you need to back away from the math and check your physical intuition.

Ho, van den Bosch, & White "*Galaxy Formation and Evolution*'" – Although not officially a text about the ISM, this book contains some very nice brief write-ups about major ISM processes.

Classic References

Spitzer "*Physical Processes in the Interstellar Medium*" – much older text, but a standard reference. All the physics is in there, but since it's old (1978) it will not have much on what we've learned in the IR. It's also very, very dense reading.

Osterbrock & Ferland "*Astrophysics of Gaseous Nebulae and Active Galactic Nuclei*" – another classic, updated in 2005. A good place to find tables of useful numbers.

Rybicki "*Radiative Processes in Astrophysics*" – Another classic in the field. Fairly brief, and not comprehensive for what will be covered in the course, but an excellent reference for radiative transfer. May be required in other courses.

Shu "*The Physics of Astrophysics Volume I: Radiation*" – Extremely comprehensive, including all the detailed quantum mechanics. Not an easy book to learn from, but an excellent source for details after you've mastered the basics. Excellent resource if you wind up pursuing a more theoretical thesis. More recent than others in this category, and much broader than just the ISM.

Online Resources

1. ASTR 871 Link: A set of reasonably-complete notes from Richard Pogge at OSU. The notes have been distilled from hand-written notes he compiled while teaching Astronomy 871, Physics of the Interstellar Medium, during 4 quarters between 1993 and 1999, and recently revived for teaching it again during Autumn Quarter 2008.

2. Draine Book Notes: Bruce Draine's Web page provides a list of errata to his textbook and a collection of exercises for the ambitious.

3. Blake Notes: An exhaustive set of notes on spectroscopy by Geoffrey Blake. An excellent resource for all the quantum mechanical details of various spectral features.