Fa23 - RADIATV PROCS & RADIATV TRANSF (48375)

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AST 380E – Radiative Processes and Transfer

Unique ID: 48375

Fall 2023

MW 2:00 PM – 3:30 PM

Instructor: Prof. John Chisholm

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Help Hours: Mondays 11am - 12 pm or by appointment in PMA 17.212 or on this zoom: https://utexas.zoom.us/my/johnchisholm (https://utexas.zoom.us/my/johnchisholm)

Desired Learning Outcomes

Light is the most important observable in Astronomy. We use light to determine the composition of planetary atmospheres, the structure of stellar photospheres, the chemical abundances of distant galaxies, and the early evolution of the Universe. It cannot be overstated how fundamental light is to the understanding of our Universe as it underpins nearly all of the astronomy sub-disciplines. To understand how the physical properties of light relates to scientific findings, you need to know how light is produced and how light interacts with matter. This is the purpose of this course.

The topic of radiative transfer is perhaps the most physics-based and mathy of all Astronomy course. Radiative Transfer courses have the tendency to be heavily focused on derivations and proofs of equations. There is little that we can do to avoid much of this, but I am trying to approach this from an observer's perspective as much as possible. We will also try to have fun. Please remember to enjoy

Astronomy. There will be math, for sure, but there will also be a strong attempt to ground the math into the core observables that underpin our interpretation of the Universe.

Graduate classes provide the bridge to help you transition from your undergraduate education, where you focused on learning facts that other people discovered, to the skills and knowledge that you will need for the rest of your career (as an astronomer or in some adjacent field). That means that this class will try to understand the production and propagation of light by focusing on some of the important skills the field requires: presenting, coding, and independent critical thinking skills. Therefore, over the course of the semester you will be expected to actively engage in the dialog of the class, independently reveal the astrophysics of radiative transfer, and synthesize the details of radiative processes.

By the end of this course you'll be able to:

1. Understand the basics of the production of radiation and its transfer through matter as a toolbox for your own personal research.
2. Convey complex ideas and findings on the nature of radiative transfer.
3. Demonstrate coding abilities to plot and analyze the propagation of light through matter.
4. Actively engage with your own learning process and shape the community of the class and department.

COURSE LOGISTICS

Meeting Information

We will meet Mondays and Wednesdays from 2-3:20PM in PMA 15.216B. I will record the audio of the class lecture, if requested.

Class Slack

We will be using a Slack Space as our main communication. I will post announcements and homeworks through the Slack, and you will be able to directly message me and the rest of your classmates through it. Please join the Slack space here: **https://join.slack.com/t/ast380e/shared_invite/zt-2151016ue-lhpBl4n0Kkx__SZQsCdEQw (https://join.slack.com/t/ast380e/shared_invite/zt-2151016ue-lhpBl4n0Kkx__SZQsCdEQw)**

When you join, please include your preferred first name, how you pronounce it, your preferred pronouns, and add a pictures of yourself to your profile. Then introduce yourself in the #general channel. In your introduction, please let us know what year you are, what you are working on, and two things that you like to do outside of Astronomy (or two things that you are proud of in general).

It is a free account, so we will only have access to messages sent within the past 90 days. This is pretty close to a full semester, but not quite the whole time.

Canvas

I will use Canvas to host grades and other details about the class, but most of the communication will be through Slack.

Student Help Hours

I am always here to help you. And I genuinely want to help you through anything that you are going through. Research. Class. Outside life. Anything that impacts you at all, I am here to help you. Please, never hesitate to reach out to me with concerns or questions. I promise to listen and rationally think through issues. Communication is vital to the success of this class.

Come chat with me in PMA 17.212. I will make sure to be in my office on Mondays from 11-12, but I am happy to organize a time to discuss anything outside of class.

Course Materials

This course does not have a required textbook. I will do my best to provide notes throughout the semester that are meant to act as a reference for the course material. I will try to post the next week's notes by **Friday at 5 PM** at this **link (https://utexas.box.com/s/41tvzhjds4ibezpwf59anl81lfx19bdn)** (pinned in the #general channel), but extenuating circumstances may arise. Each version of the notes will have the date it was compiled on the first page so you will know if there is an updated version.

Additionally, this is the first time I am putting these notes together and there are sure to be errors in these notes, even if I will try my best to avoid them. As such, please let me know what the errors are, and I will try to improve the notes for future classes.

The reason I am opting for my own notes is that I do not think there is a perfect book on the subject of radiative transfer. Often times, the available books focus on specific proofs and math of an indvidual sub-field. While I think that there is a place and time for that, I don't think they are always the most accessible. Further, many of the students in this class will come from a variety of sub-fields, each with their own jargon and processes for radiative transfer. That means that each individual student will find different books more useful for their individual sub-fields.

I fully acknowledge that the first iteration of these notes might not be perfect and that you might want other resources, but I will try my best. As such throughout my notes I am trying to provide you specific references for each topic. These references are called out in the notes with gold boxes. I will let you decide which of these books your career requires a hard copy of, but many of them are available online through the **University of Texas Library System (https://search.lib.utexas.edu/discovery/search?tab=LibraryCatalog&search_scope=MyInstitution&vid=01UTAU_INST:SEARCH&offset=0)** for free.

1. ***Radiative Processes in Astrophysics,* George B. Rybicki and Alan Lightman.** This is the classic textbook on radiative processes. It's thorough and delves into the physics underpinning radiative transfer without being too sub-field specific. You will see it on many astronomer's bookshelves.

2. ***The Observation and Analysis of Stellar Photospheres,* David Gray.** This is a classic textbook for the characterization of the processes in stellar atmospheres and succinctly covers many of the important radiative transfer issues within this course.
3. ***Physics of the Interstellar and Intergalactic Medium*, Bruce Draine.** This is a comprehensive accounting of many of the radiative processes and radiative transfer of gas between stars. It is a must for extragalactic observers.
4. ***Exoplanet Atmospheres,* Kevin Heng.** This is a new book on the processes underlying exoplanet atmospheres that goes into the radiative properties behind recent advances in exoplanet atmospheres.
5. ***Astrophysics of Gaseous Nebulae and Active Galactic Nuclei,* Donald Osterbrock.** This is the classic book for Radiative Transfer in the Interstellar Medium (e.g. it came way before Draine). It goes through a lot of physical processes that will be relevant for some of the discussion that we talk about in the second half of the semester.
6. ***The Craft of Scientific Presentations,* Michael Alley*.*** This one might seem odd, but bear with me. A core component of any job you will get in the future is how well you are able to present complicated ideas. Throughout the semester we will be evaluating and creating scientific presentations; we need a resource to provide core guidance on what we should be looking for in scientific presentations. This book is not perfect (and it is comically outdated), but it does give some things to think about when you are creating your own science presentations.

Philosophy of Graduate Coursework

Graduate school is very different than undergraduate school. No longer are you there as a sponge of knowledge. Rather, you are the one revolutionizing our understanding of the Universe. How to think through the grandest problems in the entire Universe; how to define, pursue, and obtain your own research questions; and how to eventually synthesize some of the most complex information on the fundamental fabric of the Universe. These are no easy feats. If we all had the inherent skills to do this, there would be no purpose for graduate school.

So what is the purpose of grad school?

A large part of it is to provide you with the hidden curriculum and the mechanic skills of the field. How to write papers and proposals. How to attack a complex physical problem and to reason out a solution. How to obtain future data to answer those science questions. What the fundamental tools are to answer science questions. These are crucial aspects of being a professional scientist that can be extremely nerve-wracking to become comfortable with. Throughout much of the semester I will try to focus on many of these skills to provide you with the experiences to begin to feel comfortable with the crucial components of being a professional astronomer.

1. A large focus of the class content will be on the fundamentals of radiative processes required to understand the physics underpinning your astronomy research.

2. A large focus of the homework assignments will be on short programming and data presentation skills.
3. A large focus of the final project revolves around writing a persuasive argument to obtain telescope time.
4. A large focus of the group work and final project will be on presentation skills and becoming confident communicating science in front of people.
5. A large focus of the oral midterm and the group work will revolve around thinking on your feet.

These are not randomly assigned tasks. These are the core tasks required of any intellectual researcher (inside or outside of the field of Astronomy).

There is perhaps a less tangible role of graduate classes than the direct skills that you get to practice that is more fundamental: Graduate classes are the bridge between curated undergraduate courses and the autonomous and independent thinking required for scientific advancement. By the time you finish graduate school you are no longer the consumer of astronomical information, you are the producer. When you leave here you will be one of the most knowledge people in the world on your subject matter. You will produce novel discoveries and ground-breaking observations. You will revolutionize our understanding of various aspects of science. This transition requires a rewiring of how you view your place in science, and how you think through scientific problems. Graduate classes are meant to ease that transition and enable you to start that process for yourself.

This means that graduate classes, to a large extent, will require a lot of your own personal investment. I strongly believe in you and I am here to help you in any way I can. At the end of your PhD., you will be a renowned autonomous researcher and I hope that our graduate classes can help smooth that transition.

Grading Breakdown

Your total grade for this class will be a combination of four components:

- In class participation and group work (20%)
- Out of class homework assignments (50%)
- Oral Midterm (15%)
- Final McDonald Proposal and Presentation (15%)

Letter grades will be assigned as

A:	94.00 – 100%	**B–:**	79.00 – 82.99%
A–:	91.00 – 93.99%	**C+:**	76.00 – 78.99%
B+:	87.00 – 90.99%	**C:**	0 – 75.99%
B:	83.00 – 86.99%		

Everything will be rounded to the nearest hundredth (0.01%). This means that a 90.993% will receive a B+ and a 90.996% will receive a A-.

As a graduate course and since I personally knowing how fantastic you all are, I fully expect that the grades will not be an issue. As such, I do not expect to assign grades below C. Grades of B- or above are required to remain in good academic standing in the Astronomy program.

An extra note, I will fill out the **Coursework Rubric (https://astronomy.utexas.edu/academics/academic-forms#:~:text=graduate%20course%20instructors)-,pdf,-/%20docx)** for all Astronomy Graduate Students at the end of the semester. This will be used to evaluate students for your progression to PhD Candidacy. If you have any questions about this, please reach out to me or your advisor to discuss the process.

In addition to the numerical percentages listed above, all four components of the course must be completed in order to receive at least a B-. This does not mean that you cannot miss a class or a homework assignment. However, if you do not participate in class, submit the homework assignments, attend your oral mid-term, and submit/present your final project, your maximum grade will be a **C+**.

In class participation (20%)

Actively engaging in the material is a great way to master the subject matter. As such, coming to class prepared to contribute to the discussion is a significant component of this class. Throughout the class I will try to have opportunities to work on problems and questions in class. You can participate on this in small groups of your choice, or, if you would prefer, by yourself. Some of our course content will not allow for extensive group work. As such, the cadence and involvement in group work will vary from class to class. Contributing will look different depending on the class. Sometimes we will work on a problem on a piece of paper or white board. Sometimes it will be actively asking and answering questions. You will receive one participation point (1%) for each class you participate in. While I want participation in the class, please be mindful about dominating the participation in class. This is everyone's opportunity to participate.

The participation grade is not meant to be overly harsh to anyone and it's not meant to be opaque. My intention and hope is that everyone will contribute to the class and everyone will receive the maximum points to the participation grade. If I am worried about your participation, I will likely ask to speak with you before I deduct points. This is because I care about your well-being and I value your contribution to our class.

The astute observer will notice that there are 25 classes, but you only need to obtain 20 participation points for full credit. Obtaining full credit for participation does not mean that you have to attend all lectures. I fully expect you to miss some classes (e.g. observing, conferences, and other important activities are vital to your grad school success). Please send me a message at least a week in advance if you have a planned absence, and we will work something out. If there's an unplanned absence, then please also message me after class and we will work something out as well.

Colloquium Slides: One of the ways that we are going to try to improve our presentation skills is by taking photos on your phone or screenshots of slides during our Tuesday colloquia (or **external--non-UT student--**Seminars). You should upload these slides to the #colloquium-pictures channel on Slack. Please comment on elements of the slides that you find useful, or ways you would improve the slides (be constructive!). Then please discuss within the thread with your classmates about various aspects of the slides. I expect everyone to upload at least one picture this semester and I expect everyone to contribute to the discussion on Slack. We will go over any uploaded slides to start class on Wednesdays. Both the uploaded images and the discussion will count towards Wednesday participation.

Homework Assignments (50%)

There will be six homework assignments (worth a total of 8.3 points per assignment). Each will contribute equally to the final grade. The homeworks are intended to provide you the opportunity to solve some of the big concepts that we discuss in this class yourself. As such, they will largely be Python-based Juypter notebook assignments. If Python is not the language for you, we can work something out, just come talk to me. They will ask you to solve and plot many of the fundamental quantities that we discuss in class, and to use simple methods to better understand the individual content.

Part of the intention of these assignments is for you to focus on ways to successfully present ***your*** science. You are unlikely to plot numerous blackbody functions in your research, but you will likely have to create plots that demonstrates the importance and intricacies of your data. Treat each of these homeworks as a chance for you to practice conveying important scientific findings.

Since a large focus of the assignments will be on successfully conveying science, I will pick one exemplary plot from the submitted homeworks and we will discuss in class what exactly about the plot works effectively. These plots will remain anonymous unless the plot maker wants to reveal their identity. **If you do *not* want your work included in this discussion, please message me before the submission of the first homework.**

The initial dates for the assignments are given in the Table below. If for some reason we move slower through the content than I anticipate, I will let you know in advance that deadlines will be pushed back. I have been intentional about when the assignments are due. I am trying to avoid the middle to end of October when there are quite a few important deadlines. I am trying to avoid having multiple assignments due in a week or having midterms, projects, and assignments due on the same days. I am trying to have the assignments due at least one week after the course content that introduces the content of the assignments.

I will provide you with the assignments at least a week before they are due. If I do not provide you with the assignments a week before they are due, I will move the assignments back. Please print out all Juypter notebooks as a PDF and either email or send me a direct message on Slack with the PDF before class starts on the due date (2PM central time). I will aim to have assignments graded within 2 weeks of you submitting them.

Oral Assessment (15%)

Mid-way through the semester (tentatively October 2nd and 3rd), we will have an oral exam. It will consist of a 15 minute whiteboard discussion with just me and it will occur in PMA 15.216A. We will **not** have an in-person class on this day to accommodate the number of oral exams. I will send out a Google Spreadsheet 1 week before the exam to sign up for a slot that works best for you.

The purpose of this oral exam is to provide you experience with answering questions in front of someone and interacting with the whiteboard. This will hopefully help you when you have to give your 2nd year research presentation, visit other Universities to present your research, or have to pitch your ideas to someone. The idea will be to make you think outside of the box and get you to think on your feet. Throughout my notes, I am adding question boxes in blue that are meant to provide you some practice questions for this exam.

Final Project (15%)

The final project is a 1-page **McDonald Observatory Proposal (https://mcdonald.utexas.edu/for-researchers/observer-tools/telescope-scheduling-policies-procedures/proposal-formats)** . This project is open-ended and does not have to be necessarily scientifically feasible with McDonald Instrumentation. Rather the purpose is to lay out a scientific justification to observe some radiative process we discuss in class and why that radiative process would be scientifically valuable to observe. We will talk about the proposal process on November 6th, and you can come to me to discuss possible science topics. On the last day of class we will then have 5-minute presentations on the importance of your science proposal, with the aim of convincing your classmates of the merit of your proposed science.

Establishing persuasive arguments and conveying a complex science theme are crucial for anything that we do. This is meant to give you practice writing (**no Chatgpt or other generative AI algorithms on the core ideas of the presentation, please**) which is one of the most fundamental skills that you will use in your careers. It will also provide you a final chance make a research presentation.

Acknowledging our land's past

I would like to acknowledge that we are meeting on the Indigenous lands of Turtle Island, the ancestral name for what now is called North America. The University of Texas at Austin and the McDonald Observatory resides on the current and past homes of the Alabama-Coushatta, Caddo, Carrizo/Comecrudo, Coahuiltecan, Comanche, Kickapoo, Lipan Apache, Tonkawa and Ysleta Del Sur Pueblo, and other Indigenous Peoples' communities. I acknowledge the ongoing and past struggle of those who are here or have become a part of these lands and territories in Texas.

Expected behavior

Our pursuit of the understanding of the Universe is a timeless and age-old question. This is a pursuit that everyone should feel comfortable to explore. This means that we aspire to create an environment that is free from bullying, harassment, and micro-aggressions. As such, there will be a **zero-tolerance** policy for this behavior. This is especially true during our group work and discussions. If there is ever an issue please do not hesitate to bring it to my attention. I will pursue it to the fullest extent of University policies. The bottom line: Everyone deserves respect and I expect you to treat everyone with respect.

All employees of Texas universities, including faculty, are required to report to the **Title IX Office (https://titleix.utexas.edu/)** any information regarding incidents of sexual harassment, sexual assault, dating violence, or stalking that is disclosed to them. Texas law requires that all employees who witness or receive information about incidents of this type (including, but not limited to, written forms, applications, one-on-one conversations, class assignments, class discussions, or third-party reports) must report it to the Title IX Coordinator. Before talking with me, or with any faculty or staff member about a Title IX related incident, please remember that I will be required to report this information. If you would like to speak with a case manager, who can provide support, resources, or academic accommodations, in the Title IX Office, please email: **supportandresources@austin.utexas.edu (mailto:supportandresources@austin.utexas.edu)**. Case managers can also provide support, resources, and accommodations for pregnant, nursing, and parenting students.

Further, any indication of academic dishonesty will result in an automatic zero on the assignment. Depending on the situation, I reserve the right to pursue any act of academic dishonesty to the furthest extent of University policy, including but not limited to failure of the class and being reported to Student Judicial Services in the Dean of Students Office. In this case, Judicial services will determine the final penalty.

Above all us, please come to me if there is ever any issues. I am here to help you, and I will do everything I can to enable your success.

Mental Health Resources

Mental health is paramount to everything. Graduate school is a trying time for everyone and I fully understand and empathize that there will be times when we all will struggle with mental health. If you are having specific mental health issues, please keep me informed. You do **not** have to provide me with any information or details, but informing me that you are going through a hard time will help me support you. However, I am not a trained counselor and I highly encourage you to utilize as many resources as you can. The University provides mental health support through the Counseling and Mental Health Center. They have a website (**https://cmhc.utexas.edu/ (https://cmhc.utexas.edu/)**) where you can access confidential virtual counseling services free of charge. There is also a 24-hour crisis hotline (512-471-2255) where you will immediately be put into contact with someone. You have people in your corner, especially me, that are always here to support you.

Disability and Access: Help with accommodations

I am committed to make the pursuit of astronomy accessible to everyone in this class. If there are any particular parts of this class that are challenging for you, please let me know as soon as possible so that I can assist you. I will keep all requests confidential. I am willing to seek out possible solutions that will help you learn best.

Any student with a documented disability who requires academic accommodations should contact **Disabilities and Access (D&A) (https://diversity.utexas.edu/disability/how-to-register-with-ssd/)** and go to **this site (https://utexas.qualtrics.com/jfe/form/SV_8pEFQipZiaQ77St?Q_JFE=qdg)** as soon as possible to request an official letter outlining authorized accommodations. My goal is to do everything that I can to help you learn the material. More information is available on the Services for Students with Disabilities website at **https://diversity.utexas.edu/disability/accommodations-and-services/ (https://diversity.utexas.edu/disability/accommodations-and-services/)**

Course Schedule

This is a goal, probably not a rock solid commitment. I am committed to getting through as much of this material as possible and I would be happy to consider any special topics that you feel like you need for your research.

CLASS NUMBER	DATE	TOPIC	Pre-class Reading
1	M Aug 21st	Introduction and policies	Syllabus
2	W Aug 23rd	Energy, Intensity, Solid Angle	· Section I.1-I.2
3	M Aug 28th	Moments of Intensity	Section I.3
4	W Aug 31st	Absorption and emission of light by matter	Section II.1-II.2
	M Sept. 4th	**NO CLASS Labor Day**	

5	W Sept. 6th	The radiative transfer equation	Section II.3-II.4
6	M Sept. 11th	Life in Thermal Equilibrium: Blackbody Radiation	Section III.1-III.3
7	W Sept. 13th	Atomic Structure, Einstein coefficients, Excitation processes	Section IV
8	M Sept. 18th	Complex Solutions of the Radiative Transfer Equation	Section V **Homework 1 due before class**
9	W Sept. 20th	Electrical Potentials and Charged Particles	Section VI.1
10	M Sept 25th	The Larmor formula and dipoles	Section VI.2-3 **Homework 2 due before class**
11	W Sept 27th	Classical Atom	Section VI.4
12	M Oct. 2nd	Oral Midterm	
13	W Oct. 4th	Scattering	Section VI.5
14	M Oct. 9th	Classical treatment of atoms redux	Section VII.1
15	W Oct. 11th	Quantum Mechanics and single electron atoms	Section VII.2
16	M Oct. 16th	Selection Rules	Section VII.3

			Homework 3 due before class
17	W Oct. 18th	Multi-electron atoms	Section VII.4
	F Oct. 20th	**NSF-GRP deadline -- No class this day!**	
18	M Oct. 23rd	Molecules	Section VII.5
19	W Oct. 25th	**JWST Deadline --** Radiative Transitions	Section VIII.1
20	M Oct 30th	**Bash Fest --** No Class	
21	W Nov 1st	Line Profiles and Curve of Growth	Section VIII.2- VIII.3
22	M Nov 6th	Collisional excitation and the McDonald Observatory	Section VIII.4 **Homework 4 due before class**
23	W Nov 8th	Ionization and recombination	Section VIII.5 - VIII.6
24	M Nov 13th	Dust and polarization	Section IX
25	W Nov 15th	Free-Free radiation	Section X.1-X.2 **Homework 5 due before class**
	Fall Break		

26	M Nov 27th	Synchrotron Radiation	Section X.3
27	W Nov 29th	Bound-free Continuum	Section X.4 **Homework 6 due before class**
28	M Dec 4th	Final Project presentations	**Send me your proposal before the start of class**

Course Summary:

Date	Details	Due