NORTHERN ARIZONA UNIVERSITY

College of the Environment,
Forestry, and Natural Sciences

Department of Astronomy and Planetary Science
AST 391 — Astrophysics: Stars
Fall 2023

Course Information

- Meeting Times & Location: TTh 2:20 — 3:35 pm, Rm 321, Bldg 19
- Credit: 3 credit hours
- Instructor: Dr. Lisa Chien
- Email: Lisa.Chien@nau.edu
- Office Location: Blgd. 19, Rm. 225C
- Office Hours: MW 11:00 am — 12:00 pm and Thu 12:30 — 1:30 pm
- Grader: Max Hood (mnh284@nau.edu)

Course Prerequisites

AST 280 and PHY 263 (also PHY 265 preferred)

Course Description and Student Learning Objectives

This is an upper-level undergraduate course in stellar astrophysics, which is generally divided into two parts: the outsides of stars (*stellar atmospheres*) and the insides of stars (*stellar interiors*). The atmosphere component contains an introduction to stellar spectra, line formation, radiative transfer, which is useful in all areas of astrophysics. If time permits, related topics such as *stellar evolution, star formation, brown dwarfs* will also be discussed. This will be a lecture course that includes group activities and small quizzes, reading assignments, homework of writing small codes and using programs to plot and interpreting the results of those programs, and exams.

At the end of this course, you should be able to:
SLO1. Explain the key concepts of stellar properties, atmospheres, and interiors;
SLO2. Derive and/or apply fundamental equations that describe stellar phenomenon;
SLO3. Write, or use, programs to explore and illustrate some of the key diagrams, and interpret the output to demonstrate physical principles and phenomenon;
SLO4. Explore and analyze real/theoretical stellar data, synthesize with course content, and derive scientific results or conclusions, individually or in a small group;
SLO5. Create simple Concept Maps or diagrams to express, or relate to, complicated physical properties of stars, as a practice of better and effective science communication, individually or in a small group;
SLO6. Practice a professional and intelligent conversation, with confidence and sincerity, to an invited guest speaker. (I will try my best to invite guest astronomers to class.)

Textbook and Materials

- ***An Introduction to Modern Astrophysics***, 2nd ed. by Carroll and Ostlie (*a.k.a.* BOB)
- ***Foundations of Astrophysics***, by Ryden and Perterson (only Chapter 15, will be provided)
- **Calculator**

- **Laptop** or an accessible computer
- **Programming/graphing software** of your choice (free! See https://in.nau.edu/its/software/)— **Microsoft Excel, MATLAB, Mathematica,** Python, etc.
- **Free online plotting software** of your choice (less preferred)— Desmos, Symbolab, Wolfram Alpha

Evaluation & Grading System

Absences	Effect on grade
0 — 3	None
4 — 6	Lowered by 5%
≥ 7	Lowered by 10%

Assessment	Points
Homework	**175**
Activity	**140**
Final Exam	**65**
Midterm Exam	**60**
Reading Quiz	**60**
Total	**500**

Grade	Points
A	450 or more
B	400 — 449
C	350 — 399
D	300 — 349
F	0 — 299

i) **Homework:**

Homework can be submitted in-person or online on Canvas. If you choose to submit online, please write them on papers and take high-resolutions pictures, or turn them into PDFs, for submission. Please submit only .jpg, .png, or .pdf files (no .fig). For programming homework, please make your codes readable in .pdf files as well. No homework points will be dropped.

- **Receive full credit for computing problems:** you need to turn in both your plots and code. Any plots must have 1) *a title,* 2) *axes labeled with units,* and 3) *legends if needed*. Your code needs to be *commented*. At the very least, the comments should include your name and the date, and what units each variable is carrying.
- **Late assignments:** they will be accepted only with my *previous* permission. I know this is a hard time, and I will be very accommodating, but you have to work hard too. Please keep active and constant communication with me to let me know any extensions you need. As long as you want to do the work, I will give you the credit!
- **Work with classmates:** I encourage you to work with other students on the assignments, but you must turn in your work ***in your own words,*** including **any programming/plotting codes** you wrote (see Academic Integrity Policy below). Homework that is copied or suspiciously similar will receive a zero for *all students* involved.
- **Receive makeup points:** You are allowed to correct answers that you got wrong in each homework **within a week** and get **half** of the missing points back! But again, you must work on your own!
- This is the biggest part of your grade, so please **expect constant assignments and dues, and heavy workload during the semester**. If you have not taken a class that covers the basics (PHY 265, PHY 321 etc), I welcome you to work with me when you have difficulties.

ii) **Activity:**

Almost every week we will have an in-person in class Activity. There are 15 Activities total, 12 Group Activities, either small or large, with the use of in-class materials, Google Slides and Google Sheets, and 3 individual activities on Canvas. Most Activities are 10 points, two are 5 points and so total is 140 points. No Activity points will be dropped.

- **Absence:** Missing class will significantly affect your grade and participation in these activities (see policy

above). Documented illness and institutional excuses will be accepted. You must reach out to Dr. Chien yourself and make up the activities on your own before the next class to receive full points.

- **Bring your laptop to class**, please.
- **Participation: I *ask* that you participate in-class at least once every class (ask a question, answer a question, make some intelligent, sensible noises, etc)**, and I will keep track of that to make sure that everyone is participating and at the same pace. When we have guest speakers, please also try your best to interact and ask questions.

iii) **Reading quizzes:**

All Reading Quizzes are administered and submitted online on Canvas. No reading quiz points will be dropped.

- **Get prepared:** This course requires A LOT OF physics and math, so in order to keep up with the class, **I strongly urge you to read the textbook, especially before the class**. Coming to class prepared is crucial since many of in-class exercises depend on your reading background.
- **After each chapter:** In order to guarantee that you do the reading, there will be **a reading quiz *every time we finish a chapter (actual dates to be announced in class).*** The quizzes are open-book and solely based on the textbook (in any format you have) during the reading quizzes. You will only have 20 **minutes** to finish it, so you need to know where your materials are.
- **Sections not taught:** You can skip the sections that are not covered in the class, and I will not test you what is not discussed in the class.

iv) **Exams:**

Both Midterm and Final Exams will be administered and submitted online on Canvas. You can enter your answers directly on Canvas, or write them on papers and take high-resolutions pictures, or turn them into PDF, JPG or PNG files, for submission.

Exams will consist of both qualitative and quantitative questions. Makeup exams are not given except with official excuses. You must provide documentation and arrange with me before the exam. **Exams will be open-book/open-notes style,** however you are NOT allowed to access search engines (and I will know because if you can google answers, I can google your answers too). Any plagiarism will be 0 points for the entire Exam.

Tentative Schedule

Week	Dates	Text	Topic
1-2	8/29, 8/31, 9/5, 9/7	Ch3	Class introduction & The continuous spectrum of light
3-4	9/12, 9/14, 9/19, 9/21	Ch5&3.6	The interaction of light and matter & The color index
5-7	9/26, 9/28, 10/3, 10/5, 10/10, 10/12	Ch7.1-7.3	Binary systems & stellar parameters
MIDTERM DUE 10/22, Sun, 11:59pm: Ch 3, 5 and 7			
8-10	10/17, 10/19, 10/24, 10/26, 10/31, 11/2	Ch8	The classification of stellar spectra
11-13	11/7, 11/9, 11/14, 11/16, 11/21	Ch9	Stellar atmospheres
14-15	11/28, 11/30, 12/5, 12/7	Ch 15 in R&P	Stellar Interior (in Ryden & Peterson)
16	**FINAL EXAM DUE 12/14: Ch 8, 9 and 15 in R&P**		

NACE Career Readiness Competencies

The National Association of Colleges and Employers (NACE), the leading source of information on

the employment of the college educated, have identified eight Career Readiness Competencies (CRC), a foundation from which to demonstrate requisite core competencies that broadly prepare the college educated for success in the workplace and lifelong career management. In this course, several of the CRCs are identified to be aligned to the assignments:

- **Career & Self-Development**: Proactively develop oneself and one's career through continual personal and professional learning; awareness of one's strengths and weaknesses
- **Communication**: Clearly and effectively exchange information, ideas, facts, and perspectives with personals inside and outside of an organization
- **Critical Thinking**: Identify and respond to needs based upon an understanding of situational context and logical analysis of relevant information
- **Equity & Inclusion**: Demonstrate the awareness, attitude, knowledge, and skills required to equitably engage and include people from different local and global cultures.
- **Professionalism**: Knowing work environments differ greatly understand and demonstrate effective work habits, and act in the interest of the larger community and workplace
- **Teamwork**: Build and maintain collaborative relationships to work effectively toward common goals, while appreciating diverse viewpoints and shared responsibilities
- **Technology**: Understand and leverage technologies ethically to enhance efficiencies, complete tasks, and accomplish goals

All assignments are designed to develop your **Career & Self-Development** and **Professionalism**. Below are tables of detail assignments, along with the aligned SLOs and additional CRCs.

Homework

	SLO	CRC	Question 1		Question 2		Question 3		Points
Ch3 HW1	**1, 2**	Critical Thinking	Solar irradiance	4	Magnitude and flux	6			10
Ch3 HW2	**1, 2, 3**	• Critical Thinking • Technology	Blackbody curves	11	Rayleigh-Jeans law	12	Wien's displacement law	5	28
Ch5&3.6 HW1	**1, 2**	Critical Thinking	Electronic transitions	8	Series limits	6			14
Ch7 HW1	**1, 2, 4**	Critical Thinking	Mass, luminosity, and radius determination of Sirius A & B	17					17
Ch7 HW2	**1, 2, 4**	Critical Thinking	Mass determination of zeta the binary	10					10
Ch7 HW3	**1, 2, 3, 4**	• Critical Thinking • Technology	Eclipsing Binary Simulator	28					28
Ch8 HW1	**1, 2, 3**	• Critical Thinking • Technology	Maxwell-Boltzmann distribution	13	Boltzmann Equation	14			27
Ch8 HW2	**1, 2, 3, 4**	• Critical Thinking • Technology	He I Partial ionization zone in a pure He atmosphere	15	Balmer absorption strongest in A-type stars at T = 9900 K	6	**Extra Credits**: He II partial ionization zone in a pure He atmosphere	(7)	21
Ch9 HW1	**1, 2, 3, 4**	• Critical Thinking • Technology	Curve of growth and abundance of elements, Part II	20					20
***Coding and plots required.**									**175**

Activity

	SLO	CRC	Activity	Method	Group Size	Points
Ch3	1, 5	• Communication • Critical Thinking • Equity & Inclusion • Teamwork	#1: Stellar Properties Concept Map	Hands-on	Extra Large	10
	1, 5	Critical Thinking	#2: Star Map	Canvas	(Individual)	10
	1, 2	Critical Thinking	#3: Parallax Exercise	Hands-on & Canvas	(Individual)	10
	1, 2	Critical Thinking	#4: Blackbody Radiation of You	Canvas	(Individual)	10
Ch5&3.6	1, 2, 4, 5	• Communication • Critical Thinking • Teamwork • Technology	#5: Color-Color Diagram	Google Slides	Small	10
Ch7	1, 5	• Communication • Critical Thinking • Teamwork • Technology	#6: Mass of Spectroscopic Binaries	Google Slides	Small	10
	1, 5	• Communication • Critical Thinking • Teamwork • Technology	#7: Light Curves of Eclipsing Binaries	Google Slides	Small	10
Ch8	1, 4, 5	• Communication • Critical Thinking • Teamwork • Technology	#8: Hydrogen Atom's Electron Orbitals	Google Slides	Small	10
	1, 2, 5	• Communication • Teamwork • Technology	#9: Mini H-R Diagram	Google Slides	Large	5
Ch9	1	Critical Thinking	#10: Stellar Temperatures	Canvas	(Individual)	10
	1, 5	• Communication • Critical Thinking • (Creativity) • Teamwork • Technology	#11: Photon-Particle Interactions	Google Slides	Small	10
	1, 2, 4, 5	• Critical Thinking • Teamwork • Technology	#12: Curve of Growth & Abundance of Elements, Part I	Google Slides	Small	5
Ch15	1, 2, 5	• Communication • Critical Thinking • Teamwork • Technology	#13: Modeling Stellar Interior, Part I	Google Slides	Small	10
	1, 2, 5	• Communication • Critical Thinking • Teamwork • Technology	#14: Modeling Stellar Interior, Part II	Google Slides & Sheets	Small	10
	1, 2, 5	• Communication • Critical Thinking • Teamwork • Technology	#15: Modeling Stellar Interior, Part III	Google Slides & Sheets	Small	10
						140

Reading Quiz

	SLO	CRC	Points
Ch3	1, 2, 4	Critical Thinking	10
Ch5&3.6	1, 4	(Self-evaluation)	14
Ch7	1, 2, 4, 5	Critical Thinking	13
Ch8	1, 4	(Self-evaluation)	8
Ch9	1	(Self-evaluation)	15
			60

Brief Learning Guide

🌟 Be diligent, proactive, and ask questions 🌟

Stellar astronomy is a very much ongoing research, especially when applying to extrasolar planet studies, and it is an excellent field to apply fundamental physics. The materials are not hard but require diligent learning and practice, which will in turn repay you with lots of fun and accomplishment. Many difficulties may rise simply due to not knowing some *jargons* (definitions, symbols, names etc). But as long as you are patient and willing to learn, you can be an excellent stellar astronomer as well!

🌟 Think big and accept approximations 🌟

One of the reasons that I love astronomy is because even though it is not as precise as physics, it turns physics into *beautiful objects* such as stars, galaxies, and even dark matter. Much of astronomy is empirical or based on observations, and observations can be limited due to technology or natural conditions. So even in stellar astronomy, one of the most well-studied fields in astronomy, our knowledge of stars can still be evolving. We also approximate many calculations and you have to accept that. Astronomy is not like physics or chemistry, or math, where we can find precise equations and rules to describe everything we see.

🌟 Keep making progress and know where to find your resources 🌟

The Universe is so big (like a puzzle) and there is no reason to believe that I know *everything*. I will do my best to guide you through stellar studies, and provide you ways to resources, but at times we may have to learn about new observations or theories together. Please feel free to share and participate, and do not worry about making mistakes. We all learn and advance from making mistakes.

Respect for Diversity

It is my intent that students from all diverse backgrounds and perspectives be well served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that students bring to this class be viewed as a resource, strength and benefit. It is my intent to present materials and activities that are respectful of diversity: gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture. Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally or for other students or student groups. In addition, if any of our class meetings conflict with your religious events, please let me know so that we can make arrangements for you. I am NAU Safe Zone certified.

University Policies

- Academic Integrity Policy: Simply two words— no tolerance. *All students* involved will receive zero points on that assignment or exam. If cheating/plagiarism continue, you will receive an F in the class and the Dean's office will be notified.
- See Need to miss a class? page from NAU Dean of Students for official guide on what to do.