NAU NORTHERN ARIZONA UNIVERSITY

College of the Environment,
Forestry, and Natural Sciences

Department of Astronomy & Planetary Science
Astronomy 392 – Astrophysics: Galaxy and Cosmology
Spring 2024

Course Information

- Meeting Times & Location: TTh 12:45 – 2:00 pm, HLC 4110
- Credit: 3 credit hours
- Instructor: Dr. Lisa Chien
- Email: Lisa.Chien@nau.edu
- Office: Bldg. 19, Rm. 225C
- Office Hours: MW 10 — 11 am
- Grader: Kody Rodman (kr2249@nau.edu), Office Hours: TBA

Email communications preferred first, and please give me 24 hours to reply. We can also set up meetings when I am available.

Course Prerequisites

PHY 263 and AST 280 (PHY 265, PHY 321, and AST 391 preferred)

Course Description & Student Learning Outcomes

This course covers the physical properties of galaxies, including the Milky Way)— galaxy structure, formation, dynamics, and distribution in the universe. The last section of the course covers basic fundamentals of theoretical and observational cosmology. If time permits, related topics such as dark matter and active galactic nuclei will also be discussed. This will be a lecture course that includes group activities and small quizzes, reading assignments, homework for **writing small codes and using programs to plot** and interpret the results of those programs, and exams.

At the end of this course, you should be able to:
SLO1. Analyze the structure of the Milky Way, disk, and elliptical galaxies in scientific forms;
SLO2. Explain the dynamics of disk and elliptical galaxies and matter within;
SLO3. Interpret observational results and deduce into relations in extragalactic astronomy;
SLO4. Derive and interpret the fundamental equations of the Big Bang Cosmology;
SLO5. Describe the large-scale distribution of galaxies and observations supporting the Big Bang Cosmology;
SLO6. Be prepared to comprehensively read professional articles in journals such as *Annual Reviews of Astronomy and Astrophysics*, *Astrophysical Journal*, and *Monthly Notices of the Royal Astronomical Society*.

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

NAU Career Ready Resources

- LinkedIn:
  - CEFNS Career Development www.linkedin.com/in/cefns-career-development-072715233
  - NAU Career Development https://www.linkedin.com/company/nau-career-development/
- Handshake: https://nau.joinhandshake.com/login
- Udemy: Online courses and career searching advice https://in.nau.edu/its/udemy/
  (Log in with your NAU email account and search 'NAU Career Steps')
- O*net Online: Occupation exploration reports https://www.onetonline.org/

Required Materials and Technology

- ***Galaxies in the Universe***, 2nd Ed., by Sparke and Gallagher III, 2014 Cambridge University
- ***An Introduction to Modern Cosmology***, 3rd Ed. by Liddle, 2015 Wiley
- **Calculator**
- **A laptop** or an accessible computer
- **Programming/graphing software** of your choice (free! See https://in.nau.edu/its/software/)— **Microsoft Excel, MATLAB, Python**, Mathematica, etc.
- Free online plotting software of your choice (less preferred)— Desmos, Symbolab, Wolfram Alpha

Evaluation and Grading System

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

Assessment	Points
Homework	**280**
Group Project	**80**
Final Exam	**70**
Midterm Exam	**60**
Total	**500**

Grade	Score
A	448 - 500
B	398 - 447
C	348 - 397
D	298 - 347
F	0 - 346

Assignments & Assessments

All assignments are designed to develop your **Career & Self-Development** and **Professionalism**. The assignments listed below are aligned with identified SLOs and additional CRCs.

i) **Attendance & Participation:** *(SLO 1, 2, 3, 5; Communication, Equity & Inclusion, Professionalism)*

- Attendance is taken every class and you are responsible for signing in. Missing classes will affect your grade according to the policy above. Documented illness and institutional excuses are exempted.
- We will have small group in-class exercises often, many of which will turn into your homework. **It is your responsibility to contact me before the next class and make up the assignment to receive full points.**
- Please bring your calculator and laptop to class whenever you can.
- **I *ask* that you participate in class at least once every class (ask a question, answer a question, make some intelligent noises, etc)**, and I will keep track of that to make sure that everyone is participating and at the same pace. Asking at least one question is especially *recommended* when we have a guest lecturer in the class.

ii) **Reading assignment:**

The first (Ch. 2-3) and the last part (Cosmology) of the materials require a lot of physics and math, so to keep up with the class, **I strongly encourage you to read the assigned material before coming to class**. It is also crucial to come prepared since many of the in-class exercises depend on your reading background. If you have not taken a class that covers some of the basics (PHY 265, 321, and AST 391), come work with me in person when you have difficulties.

iii) **Exercise & Homework:** *(SLO 1 to 5; Communication, Critical Thinking, Teamwork, Technology)*

Homework can be submitted in person or online on Canvas. If you choose to submit them online, please write them on paper and take high-resolution pictures, or turn them into PDFs, for submission. **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. **You have 2 days grace period, and no questions asked!** After the grace period, please keep active and constant communication with me. I will be very accommodating, but you have to work hard too. Once the solutions are posted after grading is finished, you can no longer submit the assignment. *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 some of the basics (PHY 265, PHY 321, AST 391), I welcome you to work with me when you have difficulties.

iv) **Group Project:** *(SLO 6; Communication, Equity & Inclusion, Professionalism, Teamwork, Technology)*

After the midterm exam, you will choose a group of mostly 4 people and finish a project based on the topic of your interest in the *Annual Reviews of Astronomy and Astrophysics, Astrophysical Journal*. Please communicate with me if your group must pick other topics or sources. Your group will make a **one-page outline** with bullets (single line-spacing, figures, and references), to be handed out for your presentation, and a 10 to 15-minute **presentation** during the last week of the semester. We will determine the order the of presentations a week before. A project **report** is also due at the time of your presentation. There will be intermediate deadlines to make sure that you are making sufficient progress. The presentation will be peer evaluated based on the criteria below, and the final score is the averaged score. I will evaluate your group report.

v) **Exam:** *(SLO 1 to 5; Critical Thinking, Technology)*

Both Midterm and Final Exams will be administered and submitted online on Canvas. You can enter your answers directly on Canvas, write them on paper, and take high-resolution 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.

Exercise & Homework

	SLO	CRC	Question 1		Question 2		Question 3		Points
Ch1 HW1	**1**	Critical Thinking	L, T & Magnitudes (Q1 & Q2)	10	Distance Modulus (Q3)	5	Extinction	5	20
Ch2.1 Ex1	**1, 2, 3**	• Communication • Critical Thinking • Teamwork • Technology	Luminosity & Mass Function of Hipparcos Stars	15					15
Ch2.1 Ex2	**1, 2, 3**	• Critical Thinking • Technology	Initial Luminosity Function	5	Star Formation History	5			10
Ch2.2 Ex1	**1, 2, 3**	Critical Thinking	Mass of the SMBH in Our Galaxy	20					20
Ch2.2 Ex2	**1, 2, 3**	• Communication • Critical Thinking • Technology • Teamwork	Magnitude-Color Diagram & Stellar Evolutionary Tracks	10					10
Ch2.3 Ex1	**1, 2, 3**	• Critical Thinking • Technology	One Galactic Year	2	Dark Matter in the Milky Way	12	Galactic Rotational Curve & Dark Matter	11	25
Ch2.4 Ex1	**1**	Critical Thinking	Dust IR Emissions	10	Hydrogen Recombination	10			20
Ch3.1 Ex1	**1, 2**	Critical Thinking	Potential & Density Profiles of a Uniform Sphere	20	Potential Energy of a Plummer Sphere	5			25
Ch3.2 Ex1	**1, 2**	Critical Thinking	Relaxation Times of Galactic Objects	10					10
Ch5.1 Ex1	**1, 3**	• Communication • Critical Thinking • Technology • Teamwork	Galaxy Classification	20					20
Ch5.1 Ex2	**1**	Critical Thinking	Galaxy Surface Brightness	20	Size of a Galaxy	10			30
Ch5.1 Ex3	**1, 3**	Critical Thinking	NGC7331	(10)					(10)
Ch5.5 Ex1	**1, 2**	• Critical Thinking • Technology	Logarithmic Spiral Arms	15	Four-armed Spiral Galaxy	15	Density Wave Theory & Resonances	10	40
Ch6 Ex1	**2**	Critical Thinking	Non-Elliptical Isophote Shapes	10					10
Ex1	**4, 5**	Critical Thinking	Hubble Constant & Distances	3	Wien's Law Revisited	3	CMB Radiation	4	10
Ex2	**4**	Critical Thinking	Einstein's Static Universe	5	Einstein's Cosmological Constant	5	Curvature of a Closed Universe	5	15
Ex3	**4, 5**	Critical Thinking	Expansion of Universe	(10)	Equation of State vs Curvature	(5)			(15)
***Spreadsheet, software, programming, or plots required.**									**280**

Group Project

Rubric	Points
Presentation structure and the orders of materials presented	5
Slides organization (*e.g.*, aesthetic slides, bullet points, organization of slides)	5
Presentation content (*i.e.*, do you learn at least 3 new things from this talk?)	15
Presentation clarity	10
Time management & Presentation style	5
Report structure and organization	15
Report content quality	20
Proper references	5
Total	**80**

Class Tentative Schedule

Week	Dates	Text	Topic
1-2	1/16, 1/18, 1/23, 1/25	Ch1, Ch2.1	Review of stars & Intro to our Milky Way
3-5	1/30, 2/1, 2/6, 2/8, 2/13, 2/15	Ch2.2 - 2.4	The Stars in the Milky Way Galaxy, Galactic Rotation
6-7	2/20, 2/22, 2/27, 2/29	Ch3.1, 3.2	Orbits of the Stars, Two-body Relaxation
8	3/5, 3/7	Ch4	Satellites of Milky Way, the Local Group
MIDTERM Exam Due Fri, 3/8, 11:59pm: Ch 1, 2, 3, 4			
10-11	3/19, 3/21, 3/26	Ch5	Disk Galaxies, Spiral Arms
11-12	3/28, 4/2, 4/4	Ch6	Elliptical Galaxies
13-15	4/9, 4/11, 4/16, 4/18, 4/23, 4/25	Ch1 - 5 in Liddle	Equations and Geometry of the Universe, Simple Cosmological Models, Observational Cosmology
16	4/30, 5/2	**Group Presentations**	
FINAL Exam Due Tue, 5/7, 11:59pm: Ch 5, 6, Cosmology covered			

Brief Learning Guide

🌟 Be diligent, proactive, and ask questions 🌟

Extragalactic/galactic field is a very much ongoing research, and it is an excellent field to apply fundamental physics. The materials are not hard but require patience, which will in turn repay with you 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 extragalactic astronomer as well!

🌟 Think big and accept approximations 🌟

You will find that there are only a few "principles" or "laws" in extragalactic/galactic research; most of the time the best we can do is "formulas" or "relations". This is simply because all the knowledge is empirical, or based on observations, and observations can be limited due to technology or natural conditions. So many times the "relations" can still be evolving, and we approximate many calculations, and so, you have to accept that. In this field, it is not like physics or chemistry or math, where we can find beautiful and precise formulas and rules to describe what 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 to the galaxies and the Universe, and provide you with 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.

Academic Deadlines

- ADD/DROP deadline: Jan 25
- WITHDRAWAL deadline: May 3