ASTR20A:
Introduction to Astrophysics I

Dr. Devontae Baxter

Lecture 1

Thursday, September 25, 2025

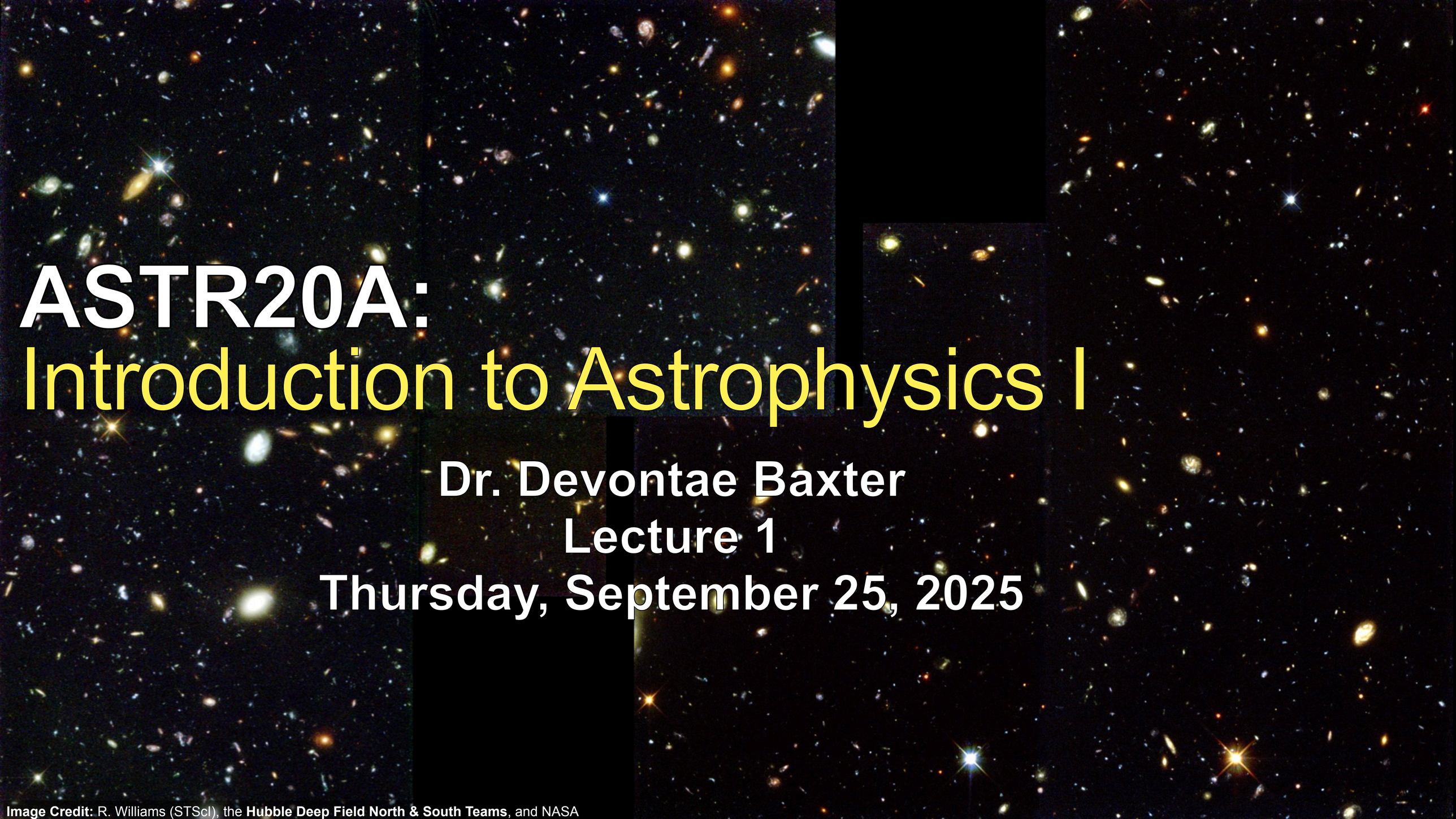


Image Credit: R. Williams (STScI), the **Hubble Deep Field North & South Teams**, and NASA

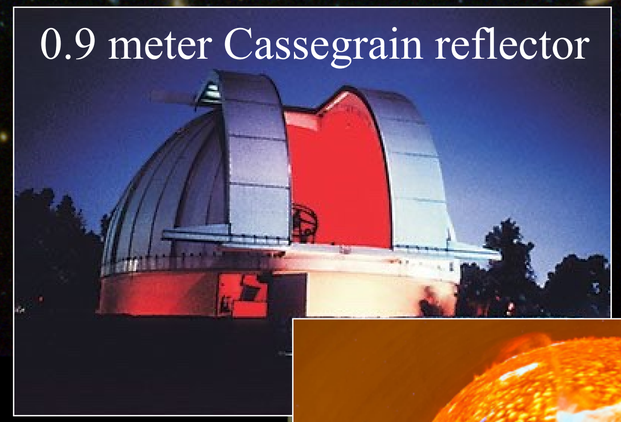

Meet the Professor

About Me | My Journey in Astrophysics

Fernbank Science Center

Hartsfield-Jackson International Airport

ATLANTA
GEORGIA, UNITED STATES



UCIRVINE

IRVINE
CALIFORNIA

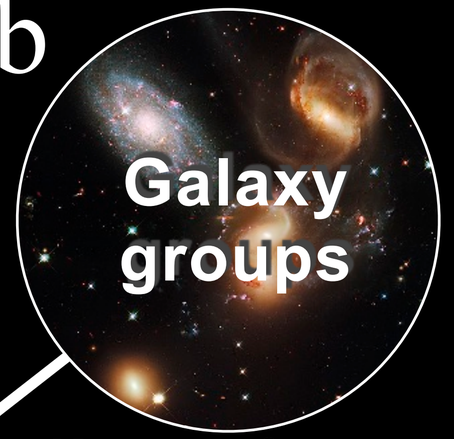
Credit: Fernbank Science Center; NASA, PBS

About Me | My Research

Credit: DESI collaboration

Galaxy Environments Across the Cosmic Web

Distribution of galaxies as measured by the *Dark Energy Spectroscopic Instrument* (DESI) Survey



$N_{\text{galaxies}} \sim$ few – tens

Node

Node

Filament

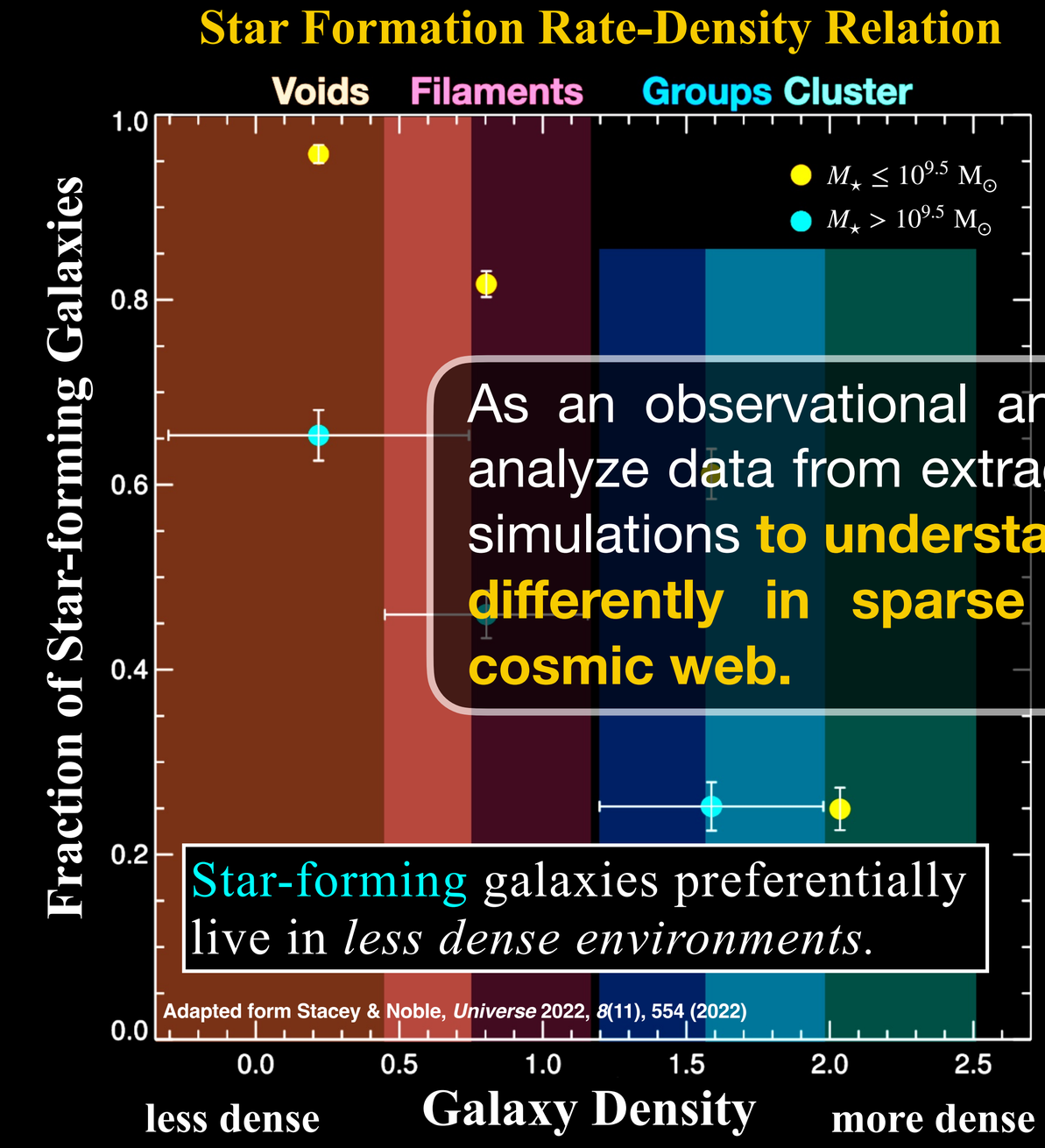
Void

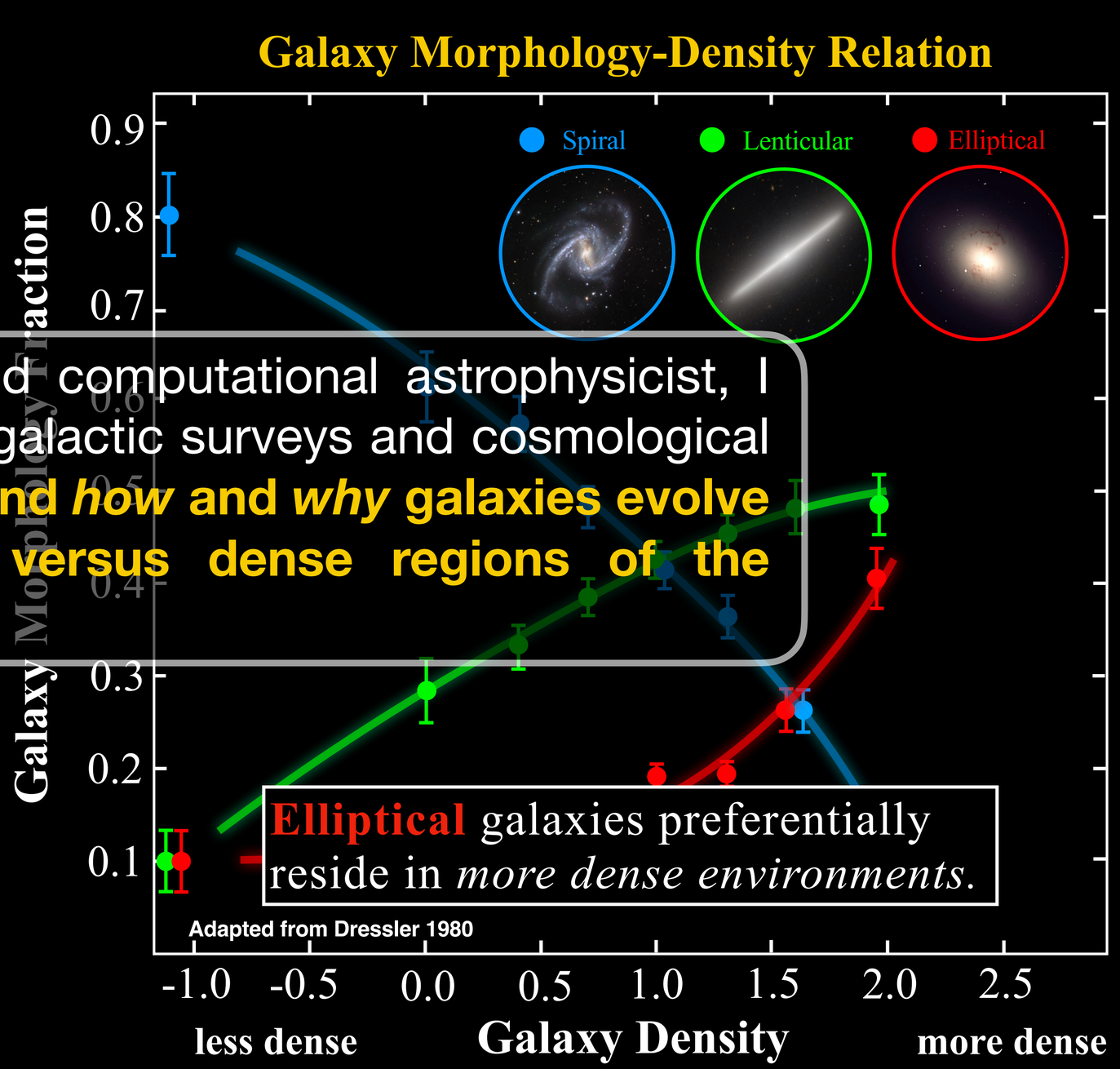
$N_{\text{galaxies}} \sim 100 - 1000$

Cosmic Voids

Earth (Kitt Peak National Observatory)

Divergent Galaxy Evolution Across the Cosmic Web





As an observational and computational astrophysicist, I analyze data from extragalactic surveys and cosmological simulations **to understand *how* and *why* galaxies evolve differently in sparse versus dense regions of the cosmic web.**


Questions?

Course Goals

ASTR 20A - Course Goals

1. This quarter we will be building up your **general knowledge about Astrophysics**.
2. We will discuss the **historical context of discoveries**, and **how technology has changed our understanding of the cosmos.**
3. We will also learn some *essential astronomy*:
    1. **How do things move in the night sky.**
    2. **Fundamentals of the motions of stars and planets.**
    3. **How do we measure distances to stars.**
    4. **How are stars created and how do they evolve.**

Astronomy Research Content Goals

Developing familiarity with basic astronomical concepts and observational methods

Astronomical Coords & Timekeeping

- **Explain sidereal time** and determine if an object is observable at night at a specific location given it's **Right Ascension** and **Declination**.
- **Describe** the differences between **heliocentric** and **galactocentric** coordinates.

Stellar Structure

- **Describe** the **composition of the Sun.**
- **Explain** the **nuclear fusion processes** in the Sun and how they generate energy.

Orbital Mechanics

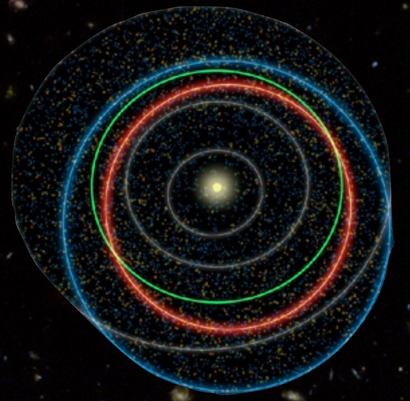
- **Explain Kepler's Laws** and use them to calculate the **orbital period** and **semi-major axis** of a planet or satellite.
- **Calculate** the length of a day on a planet given its **rotational velocity** and **size**.

The Cosmic *Distance Ladder*

- **Explain** the concept of a **parsec**, including its *definition*, *physical meaning*, and role in measuring stellar distances.
- **Apply parallax measurements** to calculate the distances to nearby stars!

Modern Astronomy Research Process Goals

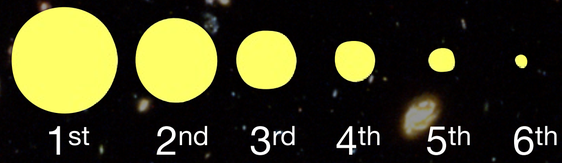
Understanding the Night Sky



Apply knowledge of gravitational and orbital principles to **explain the motion of celestial objects.**

Plan an observing run by determining target visibility from a specific Earth-based observatory.

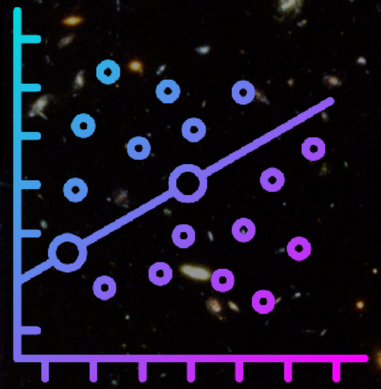
Understand & apply the **magnitude scale** to determine the *brightness* of stars and other celestial objects.



Analyze astronomical objects by **comparing their sizes, distances, and brightness using ratios and scaling.**

Professional Development Goals

Visualizing quantitative information.



Working in a collaborative environment.

Scientific writing & communication.

Programming & data analysis.

Learning Python

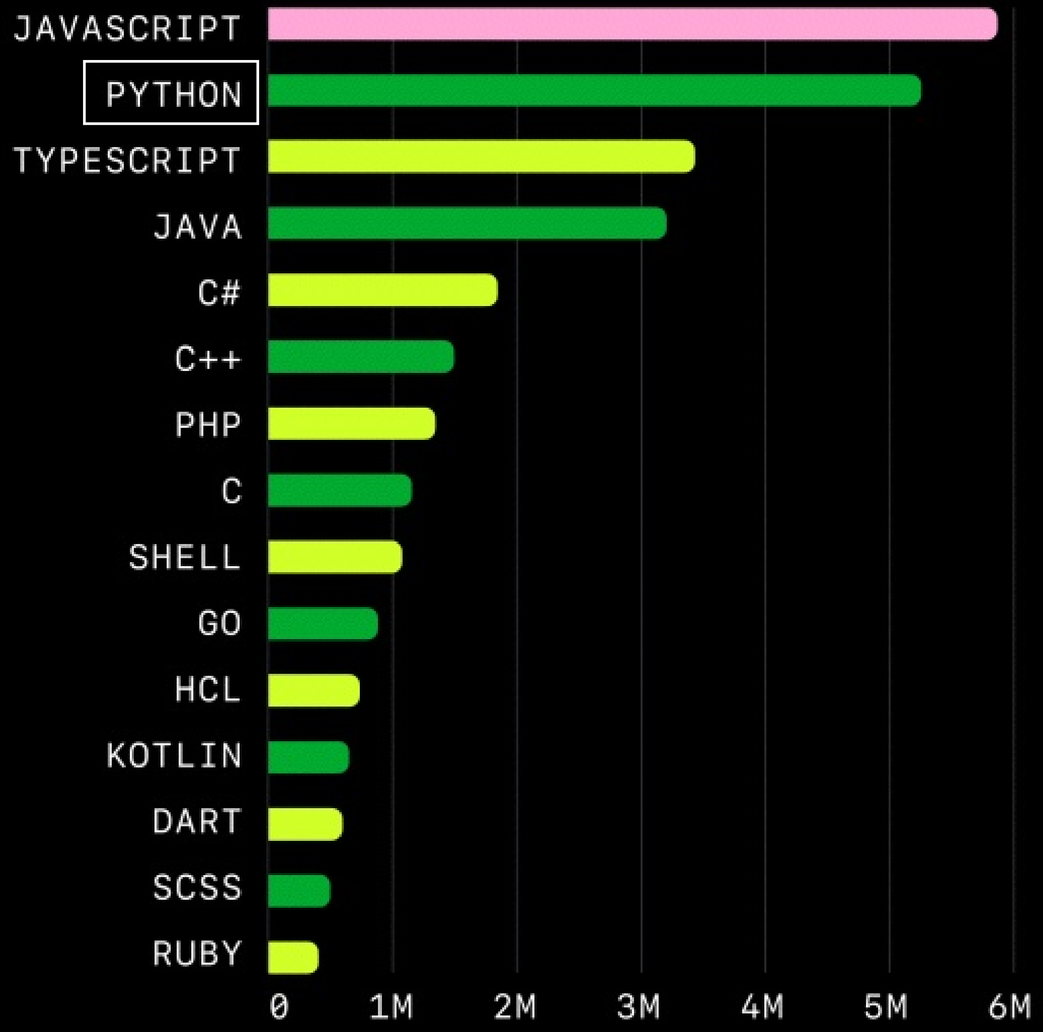
- **In this class, we will be doing a little bit of coding!**
- See course Canvas webpage for a list of Python tutorials and Unix command tutorials
  - **Please review these tutorials, if you haven't programmed in Python before**
- This week Discussion section, the TA will be doing a short introduction to Python and showcasing the JupyterLab interface

JupyterLab (DataHub)

- UCSD JupyterLab can be accessed from *any* computer, including: personal laptops, UCSD computers.
- If you need computer access please let the instructor or TA know.
  - The TA will go over this in the first discussion section

Why Python?

The top languages in 2023 by usage

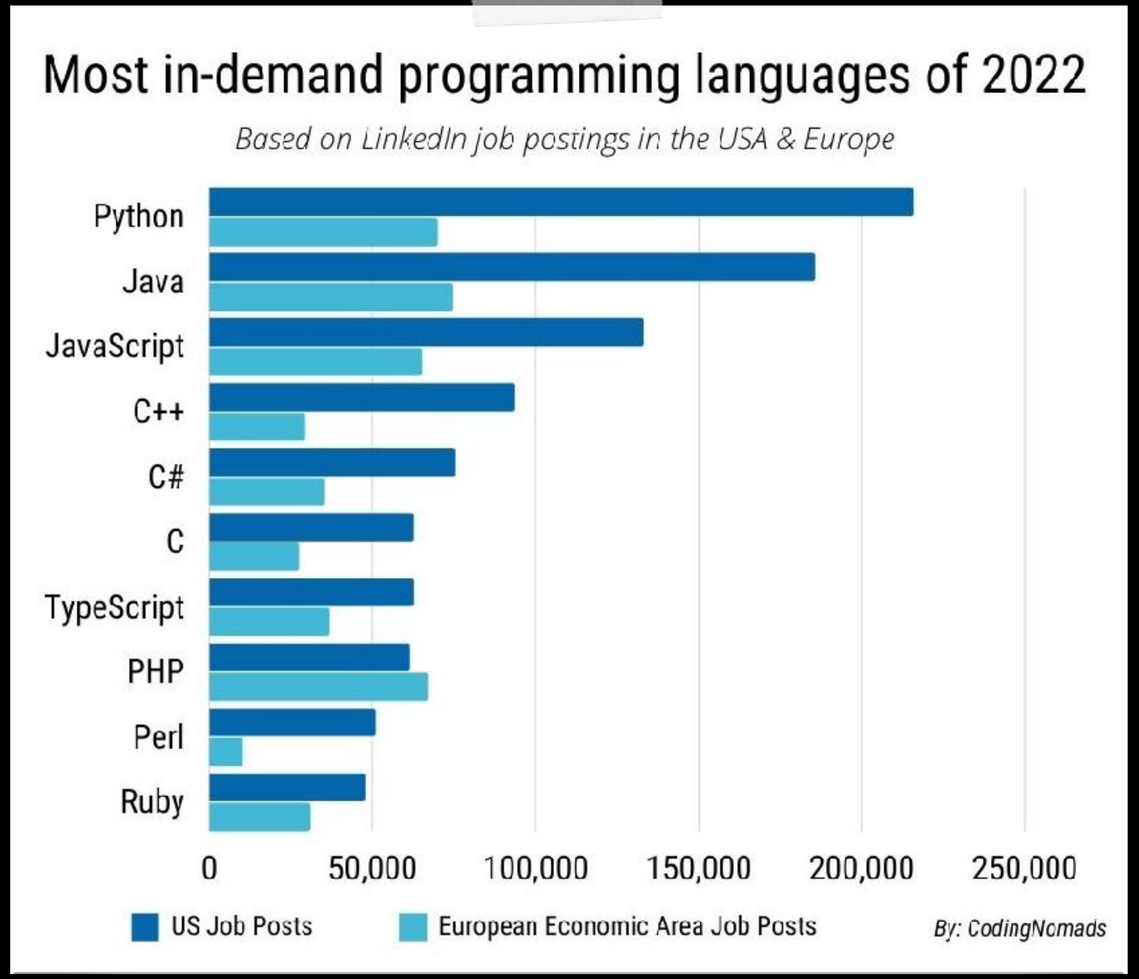


Across all GitHub projects

Python is the 2nd most used code in the world!

Source: https://github.blog/2023-11-08-the-state-of-open-source-and-ai/

Python is consistently among the most in demand language in job postings.



Source: https://codingnomads.co/blog/the-best-programming-languages-to-learn/

- For those interested in developing programming skills for undergraduate research, I recommend applying to the Computational Research Access Network (CRANE) program.
- Learn more at cranephysics.org
- Applications are due **December 5th, 2025 11:59 PM ET**

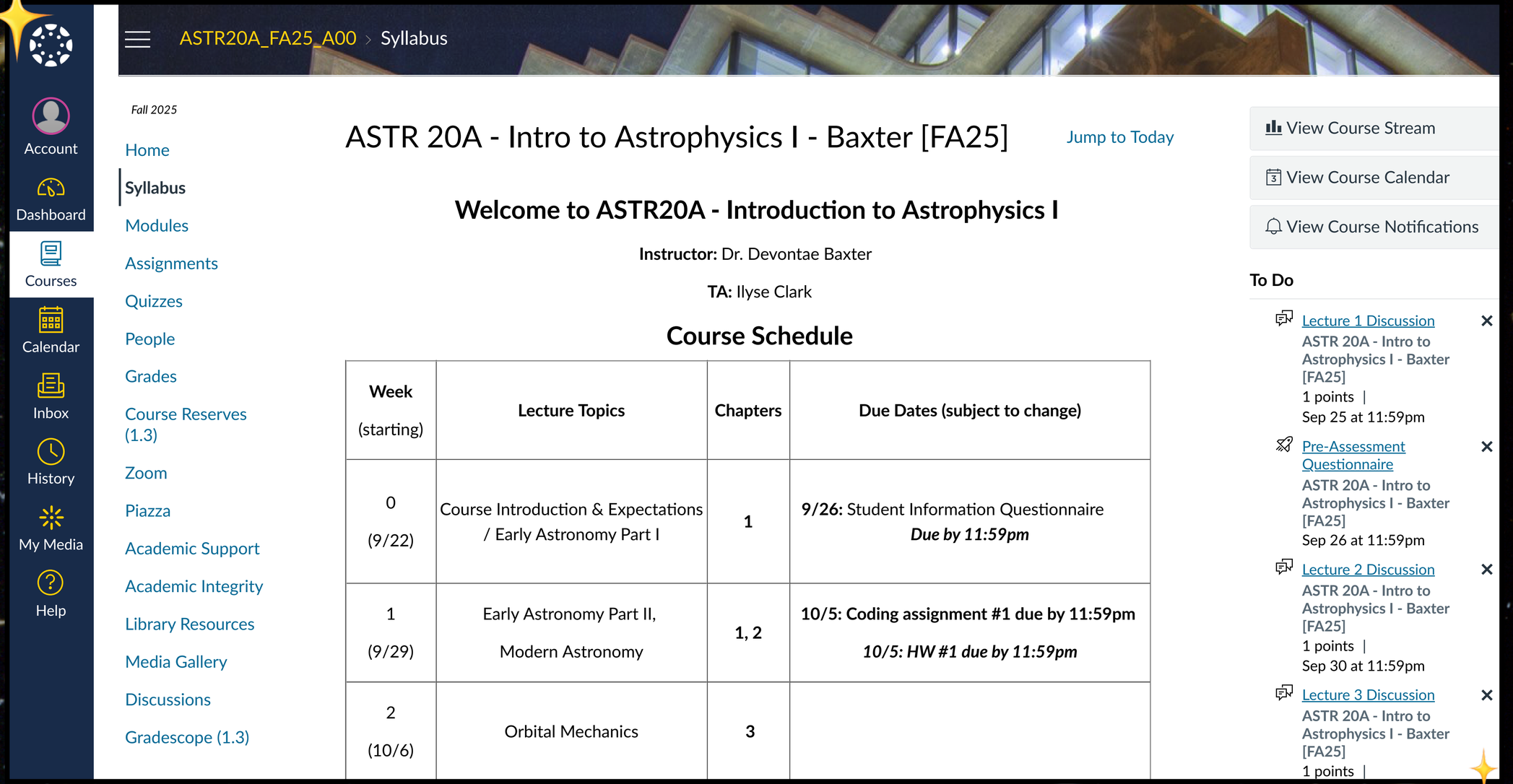

Questions?

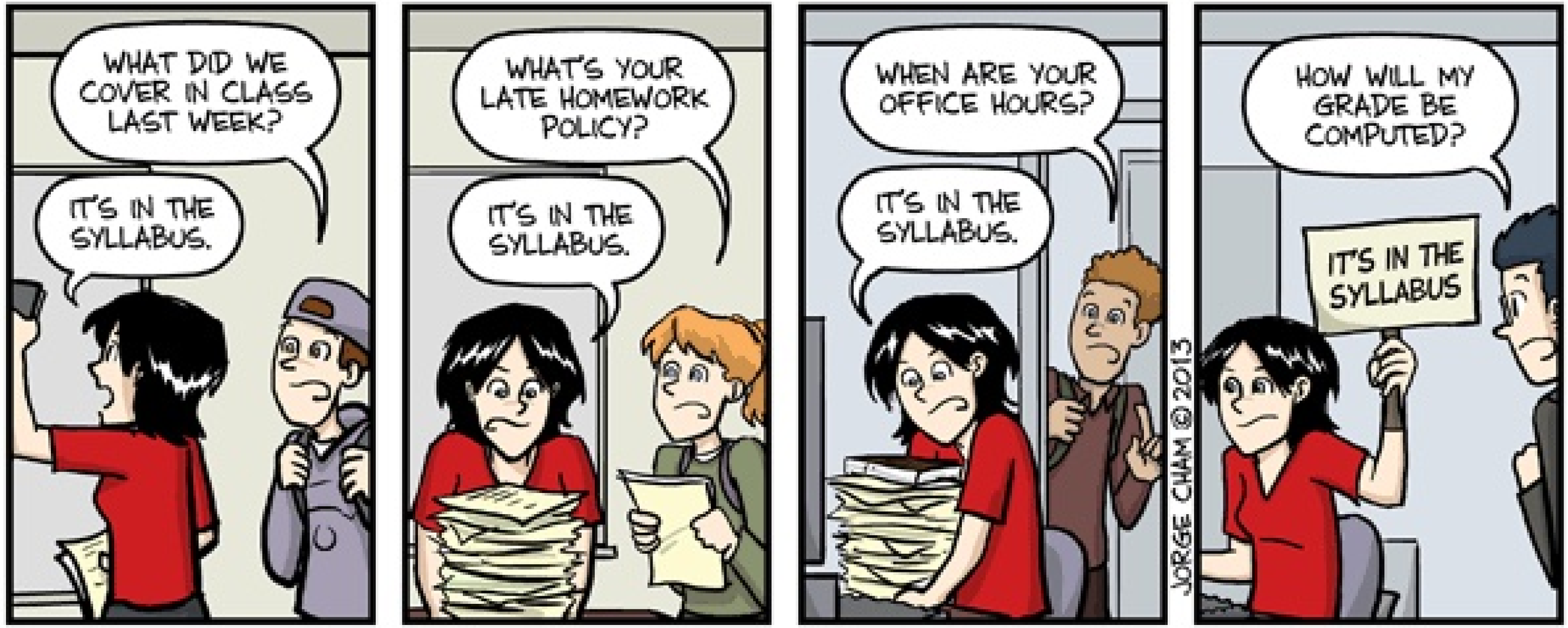

Course Expectations

Our Classroom Philosophy

- **Learning is a process:** Mistakes are part of growth and help deepen understanding.
- **Take intellectual risks:** Embrace curiosity, ask questions, and adopt a *growth mindset.*
- **Collaborate & contribute:** Engage actively; learning is stronger when you work with peers.
- **Respect diverse perspectives:** Listen carefully and value how others think and approach problems.
- **Thoughtful feedback:** Give and receive constructive comments gracefully and respectfully.

Follow ASTR 20A Canvas Webpage





IT'S IN THE SYLLABUS

This message brought to you by every instructor that ever lived.

WWW.PHDCOMICS.COM

Course webpages and platforms

- The course webpage is **Canvas**
  - Files posted, homework assignments, etc.
- For programming the entire class will be using **UC San Diego JupyterLab (datahub.ucsd.edu)**
  - This is where you will learn to program in Python.
- For additional communication we will be using **Piazza** to post questions where the TA, instructor, and your classmates can respond to inquiries.
  - Inappropriate posts or content, online harassment, or cyber bullying will **NOT** be tolerated and will be reported immediately to your college dean and possibly OPHD
    - If you are on the receiving end of such behavior, please let me or the TA know as soon as you can

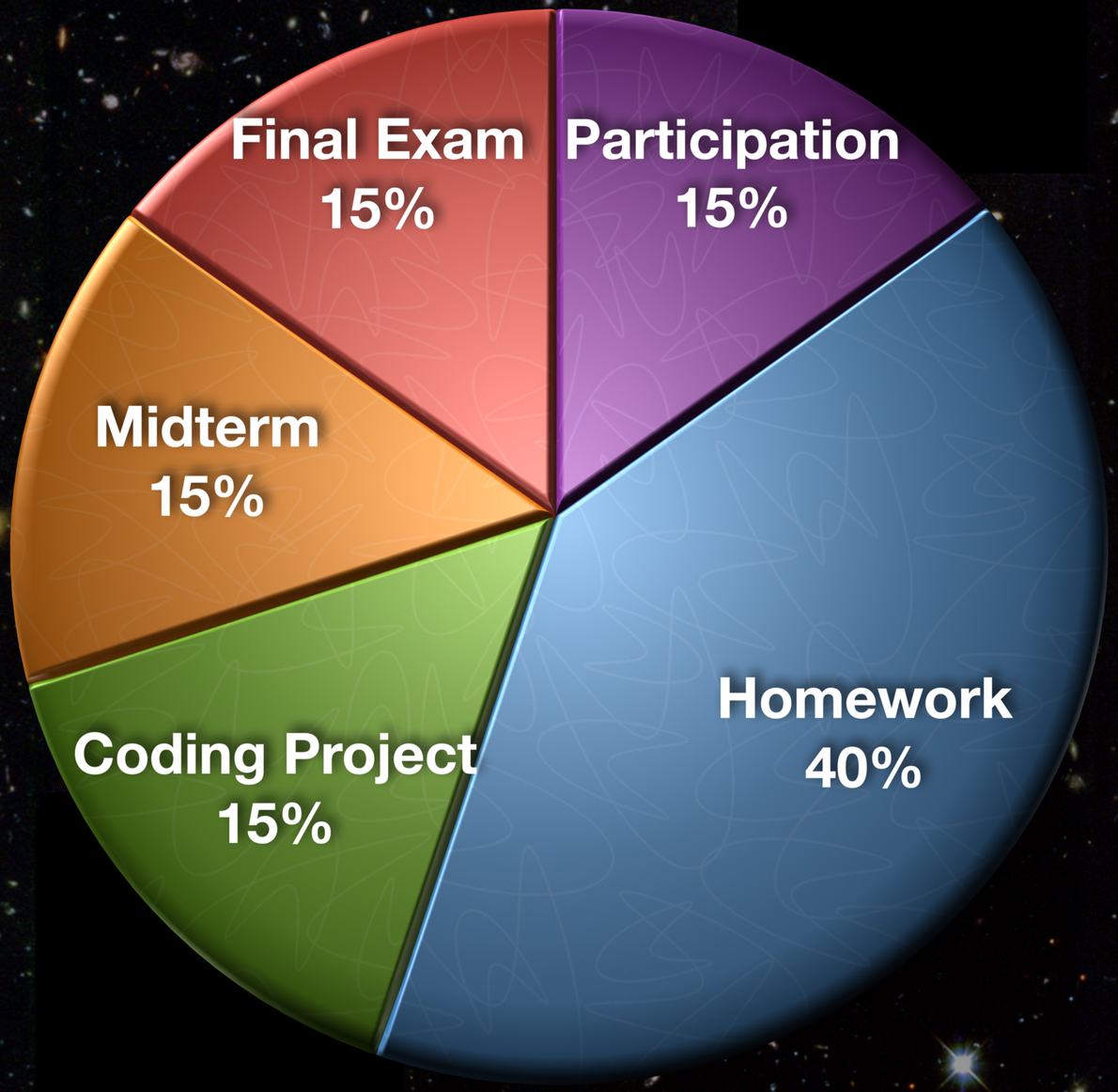
Course Schedule*

Week (starting)	Lecture Topics	Chapters	Due Dates*
0 (9/22)	Course Introduction & Expectations, Early Astronomy Part I	1	**9/26:** Student Information Questionnaire ***Due by 11:59pm***
1 (9/29)	Early Astronomy Part II, Modern Astronomy	1, 2	**10/5: Coding assignment #1 due by 11:59pm** ***10/5: HW #1 due by 11:59pm***
2 (10/6)	Orbital Mechanics	3	
3 (10/13)	Earth-Moon System, Radiation & Matter	4, 5	***10/14: HW #2 due by 11:59pm*** **10/19: Coding assignment #2 due by 11:59pm**
4 (10/20)	Detection of Light, **Midterm Exam I**	6	***10/21: HW #3 due by 11:59pm*** ***10/23: In-class Midterm (through Chapter 5)***
5 (10/27)	The Sun, The Solar System	7, 8	***10/28: HW #4 due by 11:59pm*** **11/2: Coding assignment #3 due by 11:59pm**
6 (11/3)	Earth & Moon, Planets	9, 10	**11/4**: Introduce Coding Project ***11/4: HW #5 due by 11:59pm***
7 (11/10)	*Veterans Day Holiday,* **Midterm Exam II**		***11/13: In-class Midterm (through Chapter 10)*** **11/16: Coding assignment #4 due by 11:59pm**
8 (11/17)	Small Bodies, Exoplanets	11, 12	***11/18: HW #6 due by 11:59pm***
9 (11/24)	Star Properties, *Thanksgiving Holiday,*	13	***11/25: HW #7 due by 11:59pm*** ***11/30: Coding Project Write-up due by 11:59pm***
10 (12/1)	Stellar Atmospheres, Stellar Interiors	14, 15	***12/2: HW #8 due by 11:59pm***
11 (12/8)	**Final Exam**	**Final**	**12/11: In-class Final**

TL;DR: 8 HWs, 3 exams (2 midterms + 1 final), 4 coding assignments, 1 coding project

****subject to change***

Grade Breakdown



†The lowest grade of the two midterms will be excluded in the calculation of your final grade.

Academic Integrity

- All assignments will be vetted by TurnItIn software
- Please take the pledge to exercise academic integrity this quarter
  - https://academicintegrity.ucsd.edu/forms/form-pledge.html
- ***Use generative AI at your peril!***


Questions?


Early Astronomy

Early Astronomy

- Since antiquity humans across various cultures have recognized that **the motion of stars is not random.**

The "Antikythera Mechanism" (200 BCE)

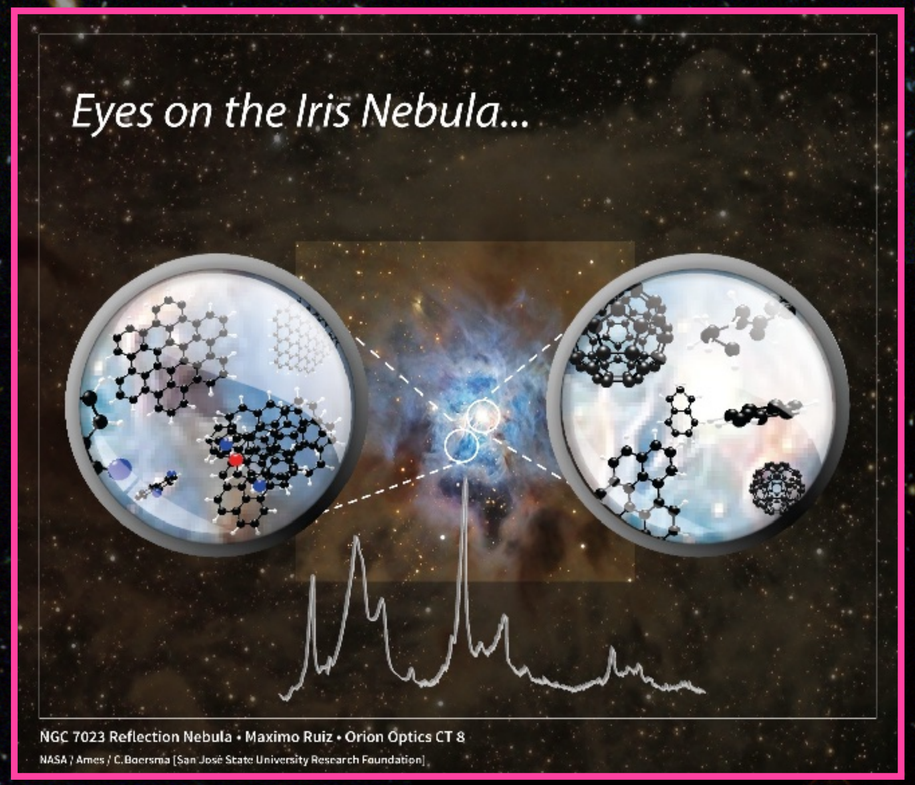
El Caracol Observatory (CE 906)

Cosmic Boards (220 BCE)

- The modern word *"astronomy"* is derived from the Greek word *astron*, meaning "star", and *nomos* meaning "law".

Modern Astronomy

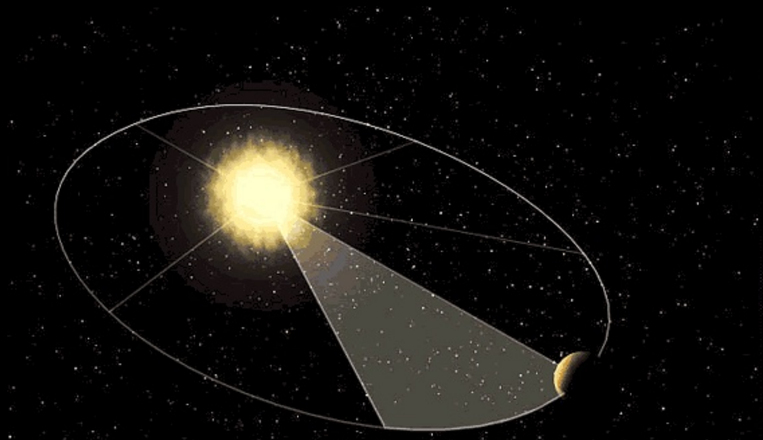
Today, *astronomy* is more than stars and planets, it encompasses everything from tiny dust grains to vast galaxy clusters!



So what is *"astrophysics"*?

The Advent of Astrophysics

The word *“astrophysics”* was invented at the end of the 19th century to **describes how the properties of celestial bodies are related to the underlying laws of physics.**



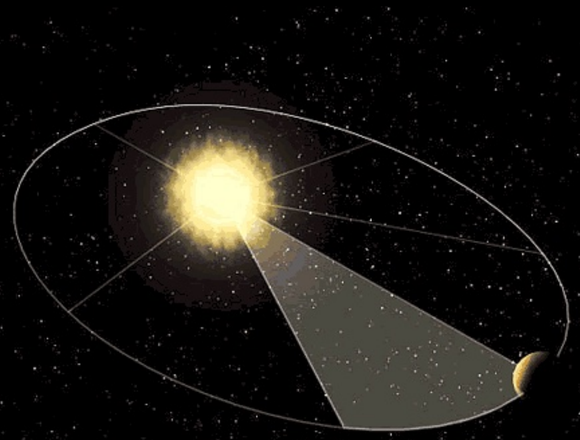
Planetary Motion

Stellar Explosions

Cosmological Redshift

The Advent of Astrophysics

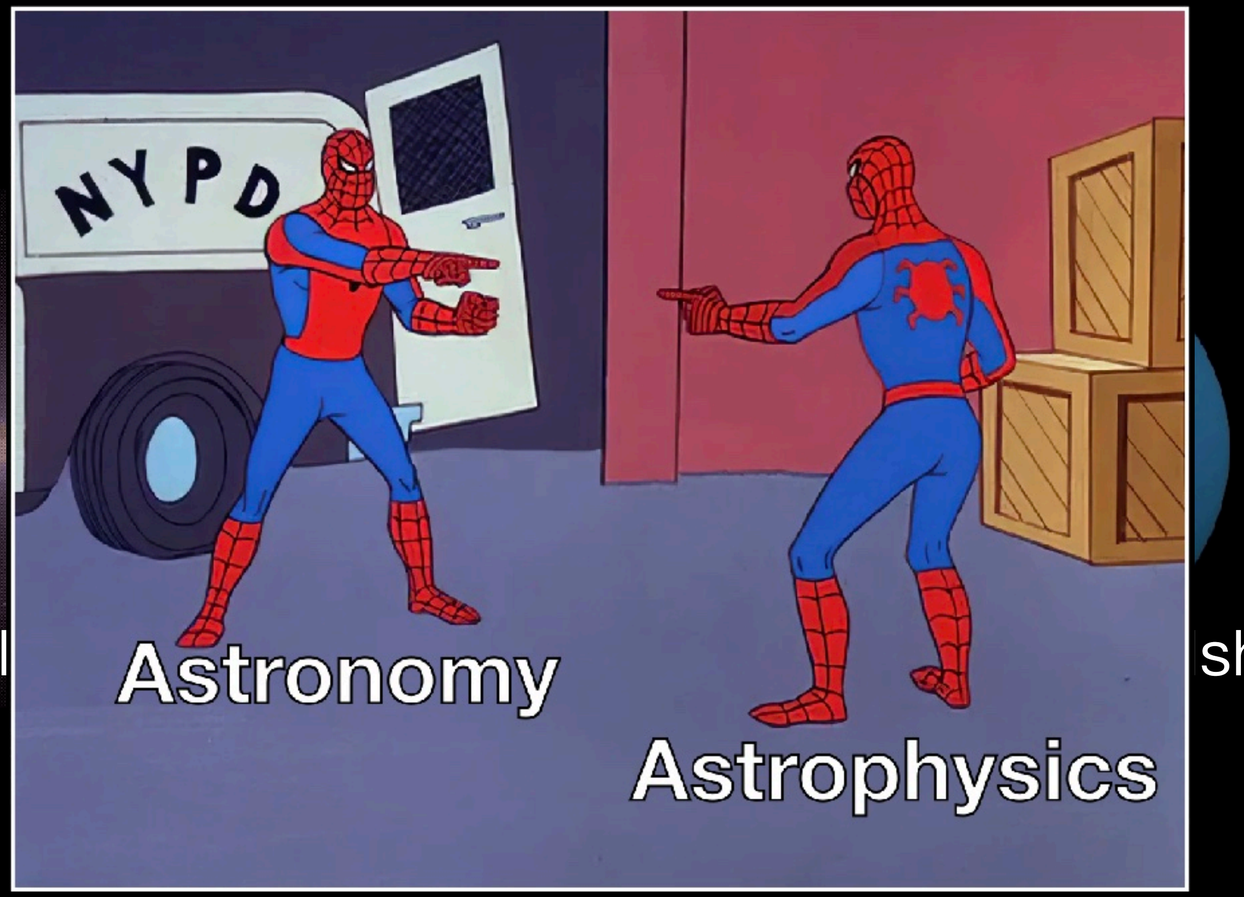
The word *“astrophysics”* was invented at the end of the 19th century to **describes how the properties of celestial bodies are related to the underlying laws of physics.**



Planetary Motion

Illustration

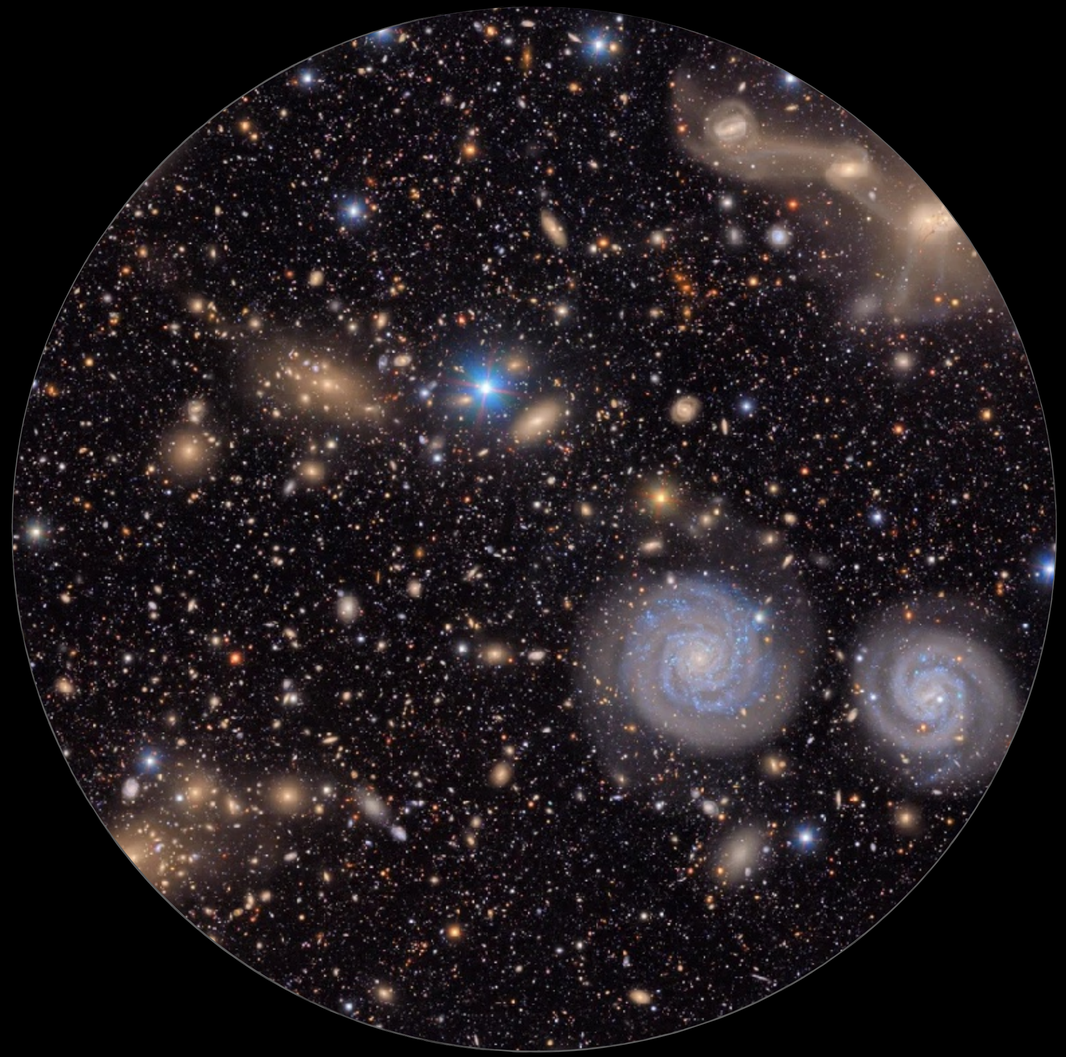
Stel



shift

A Historical Perspective of Astronomy

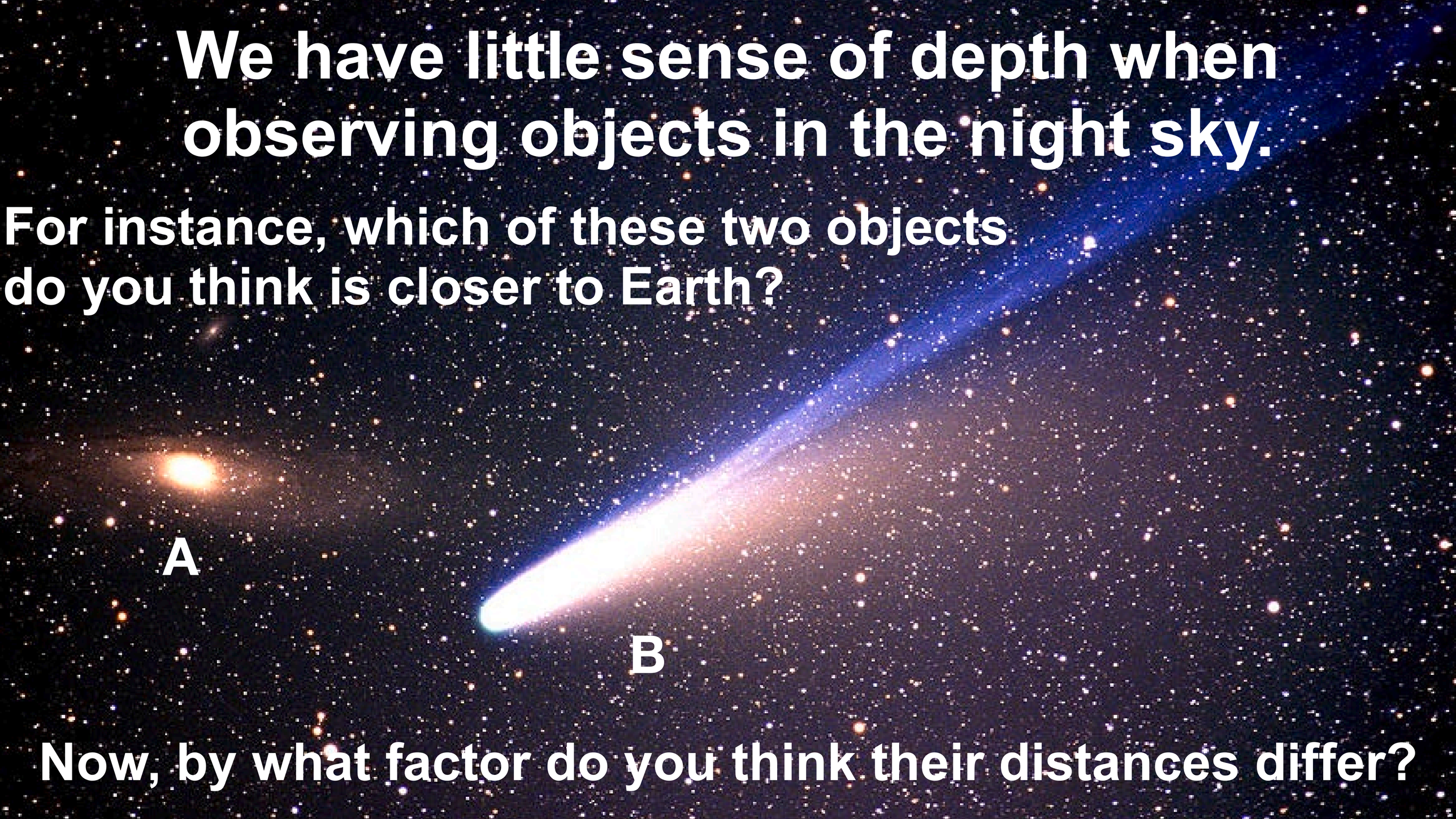
The Nebra sky disk (1600 BCE)



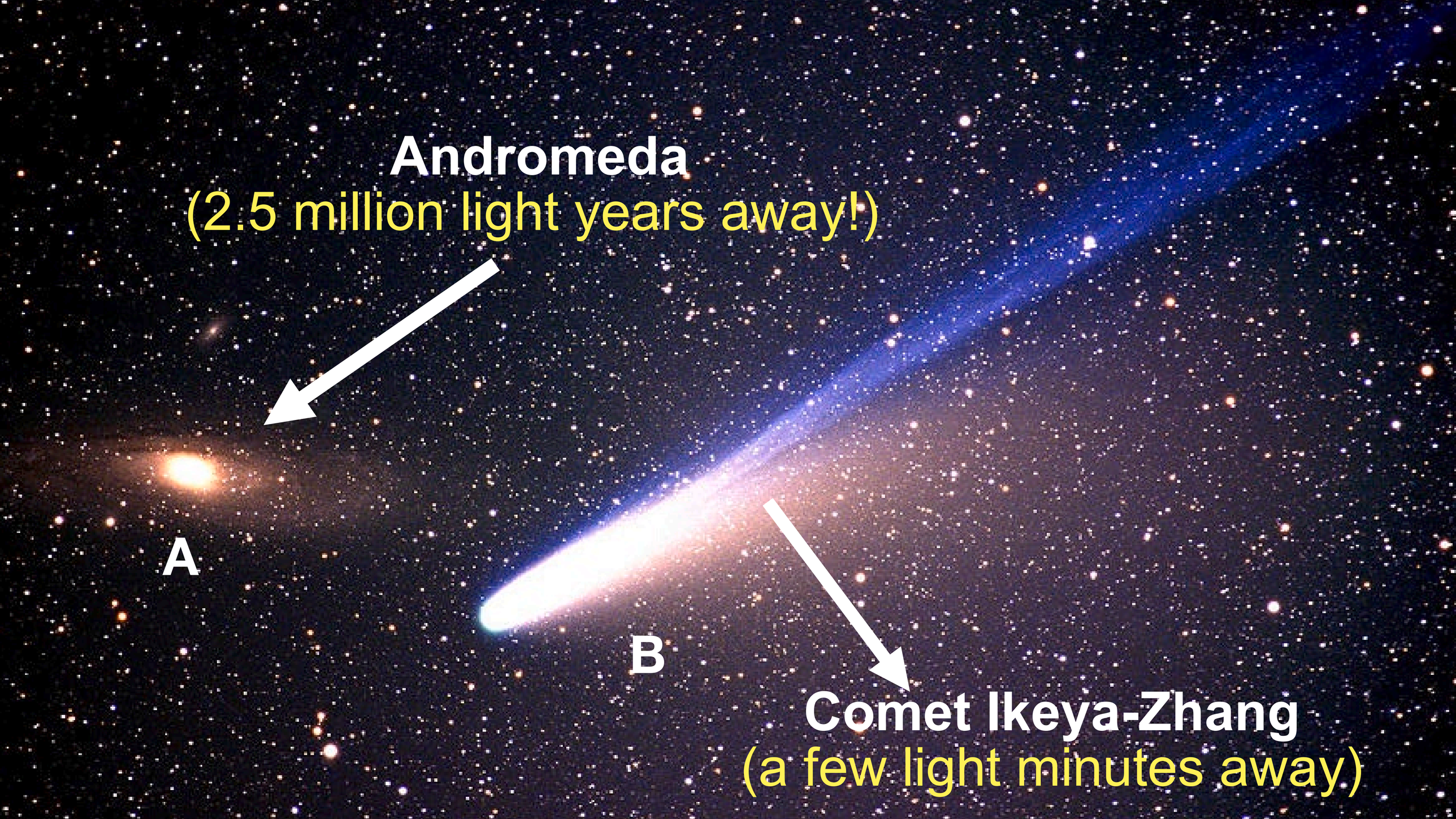
The Virgo Cluster (June, 2025)

We have little sense of depth when observing objects in the night sky.

For instance, which of these two objects do you think is closer to Earth?



Now, by what factor do you think their distances differ?


Andromeda
(2.5 million light years away!)
A
B
Comet Ikeya-Zhang
(a few light minutes away)

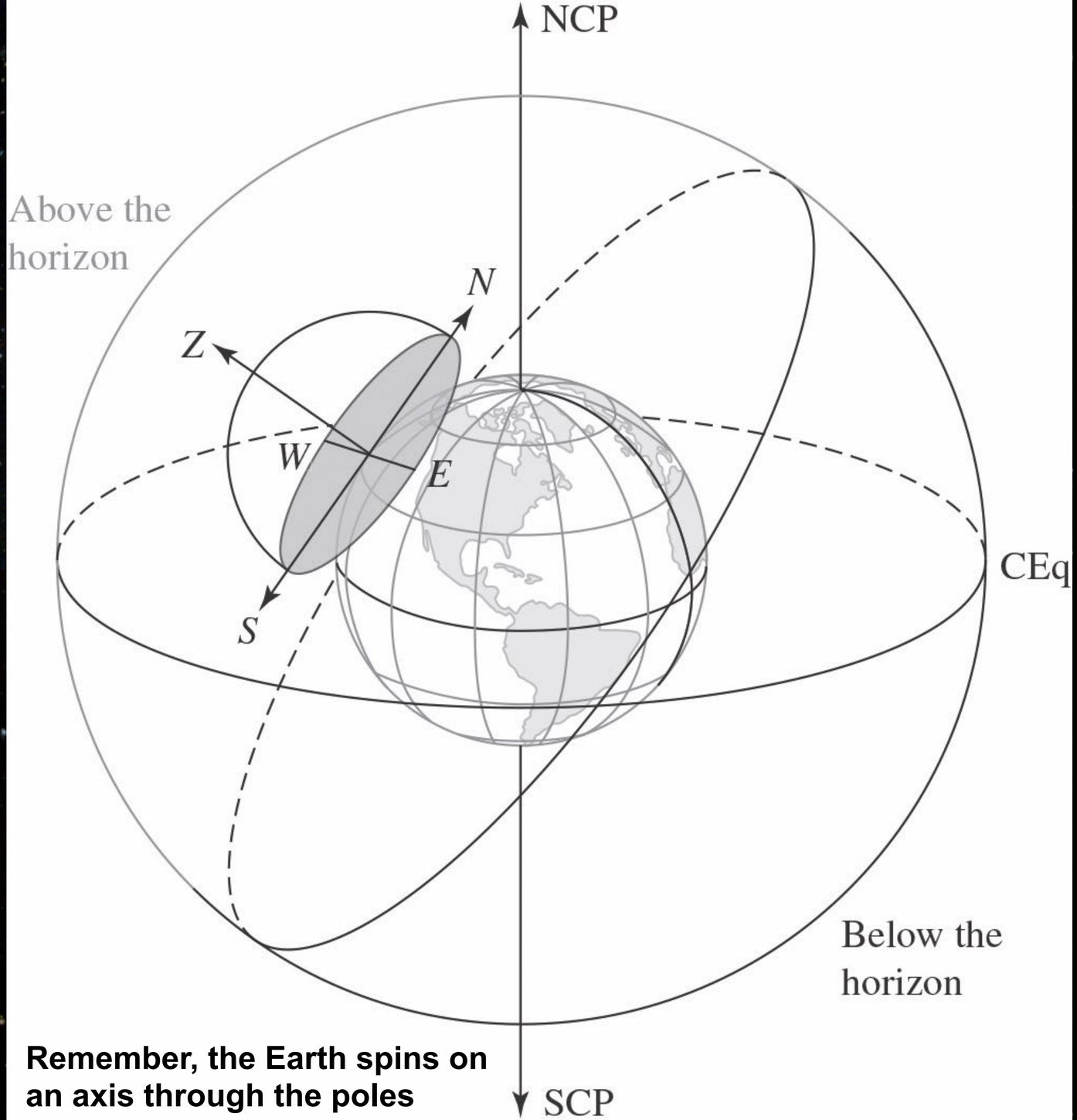
The Celestial Sphere

Definitions

NCP – North Celestial Pole
SCP – South Celestial Pole
CEq – Celestial Equator
Great Circle – Any circle whose center coincides with the sphere's center

In this image, "Z" is the direction directly above our heads – called "zenith"

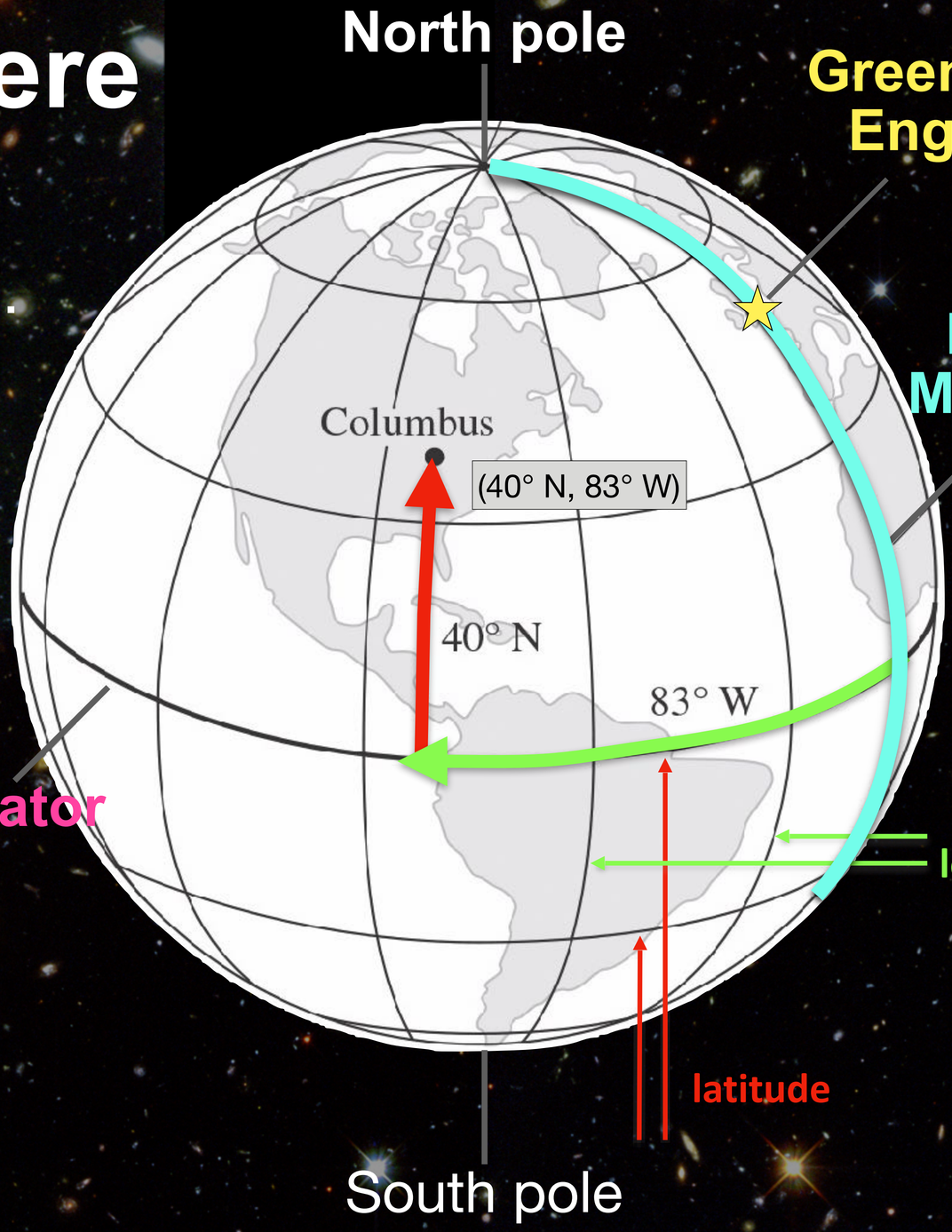
Question: What star does the North Celestial Pole currently point towards?



Remember, the Earth spins on an axis through the poles

Coordinates on a Sphere

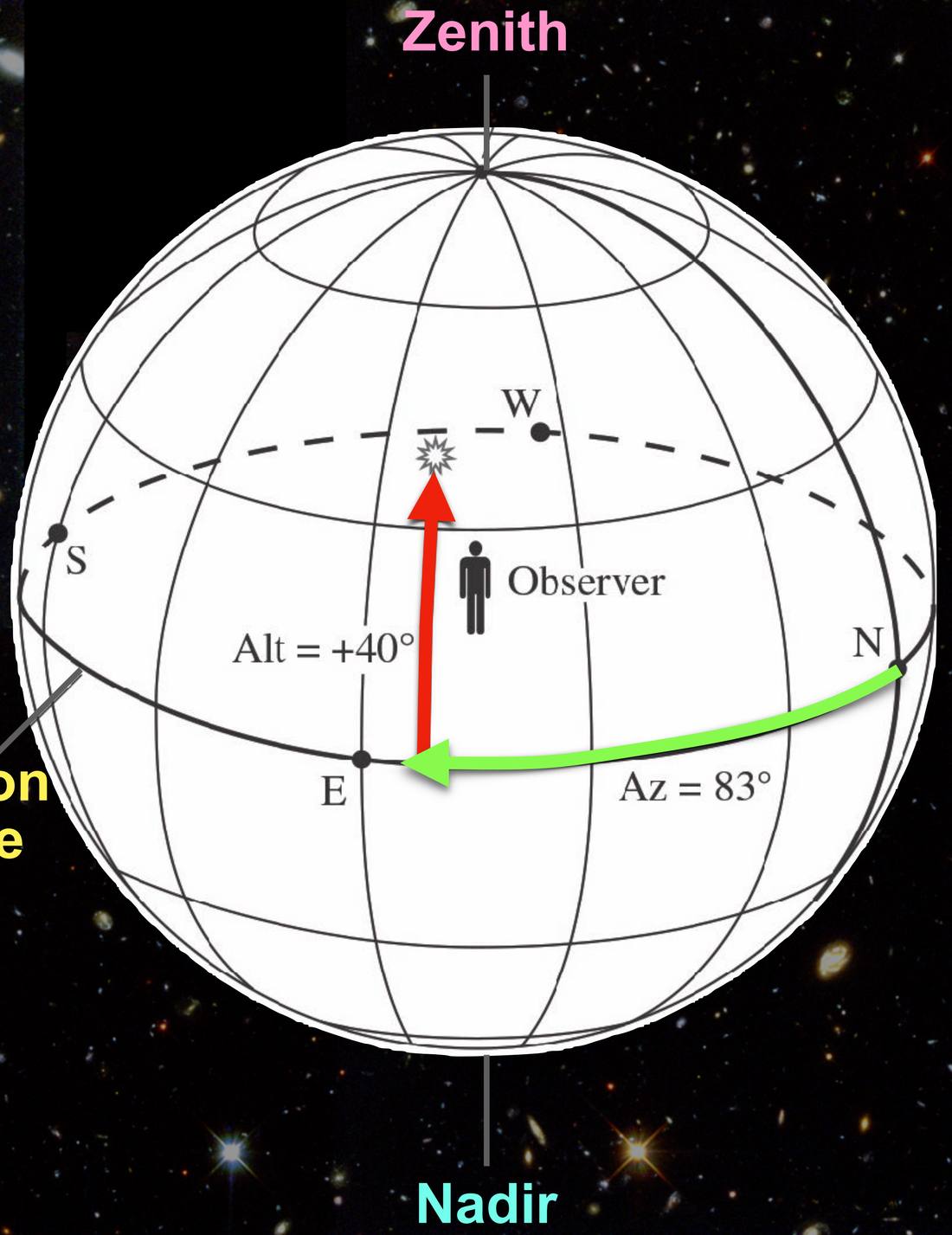
- **Longitude** extends from 0° to 360°, with 0° defined at the "Prime Meridian".
- **Latitude** extends from -90° to +90°, with 0° defined at the Equator.



Coordinates on a Sphere

(observer's frame – *horizontal coord system*)

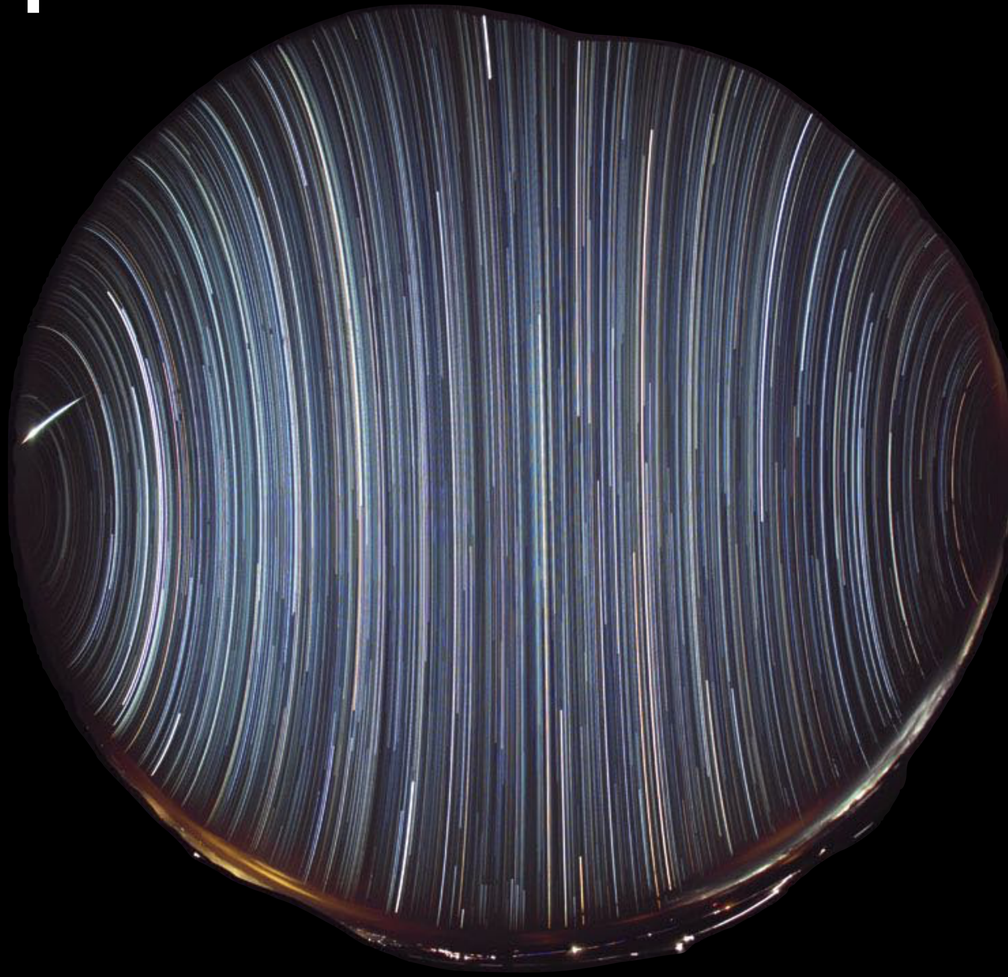
- **Zenith** - the point directly *above* the observer.
- **Nadir** - the point directly *below* the observer.
- **Azimuth** - angle that runs along the Horizon Circle, with the zero-point *typically* taken from due North.
- **Altitude** - angle **above** the *observer's horizon*.



Brain Break – Think-pair-share

1. **Think (2 minutes)**
   I. Take 1-2 minutes to think about the question independently. Feel free to jot down your thoughts or write a brief response.
2. **Pair (4 minutes)**
   I. Pair up in groups of 2-3.
   II. Discuss the topic and identify similarities and differences in what you think. Formulate a single thought that you feel encompasses what you would like to say in the next step (and pick a pair/group representative).
3. **Share (7 minutes)**
   I. Share your group's idea — either volunteer or be chosen randomly.

Brain Break – Think-pair-share



1. *What* are these images depicting?
2. In what ways are these images *similar/different*?
3. *Where* do you think these images were taken from?

Image credit: Stéphane Guisard, Lincoln Harrison

Motions of stars on the sky

The circular path a star follows is called the **“diurnal circle”**

Things that don’t change

1. A star’s *declination*
2. A star’s distance from the *celestial* equator

Question: Over the course of 24 hours (1-day) ***how many degrees*** on the observer’s sphere will a star have moved?

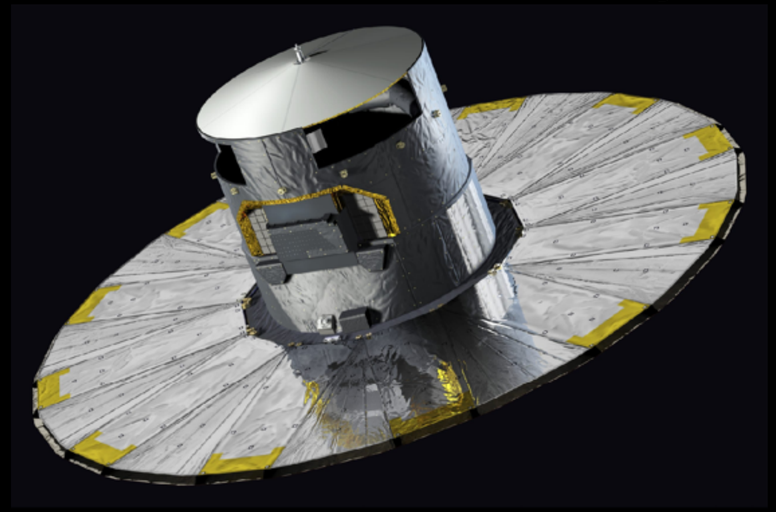
Motions of stars on the sky

For convenience we typically divide the angle into smaller portions, called the **“arcminute”** (′) and the **“arcsecond”** (″).

60 arcminutes = 60′ = 1 degree

60 arcseconds = 60″ = 1 arcminute

Fun Fact: Using the Gaia space-telescope we are able to measure an object’s motion to a precision of 10 *micro*-arcseconds!



Motions of stars on the sky

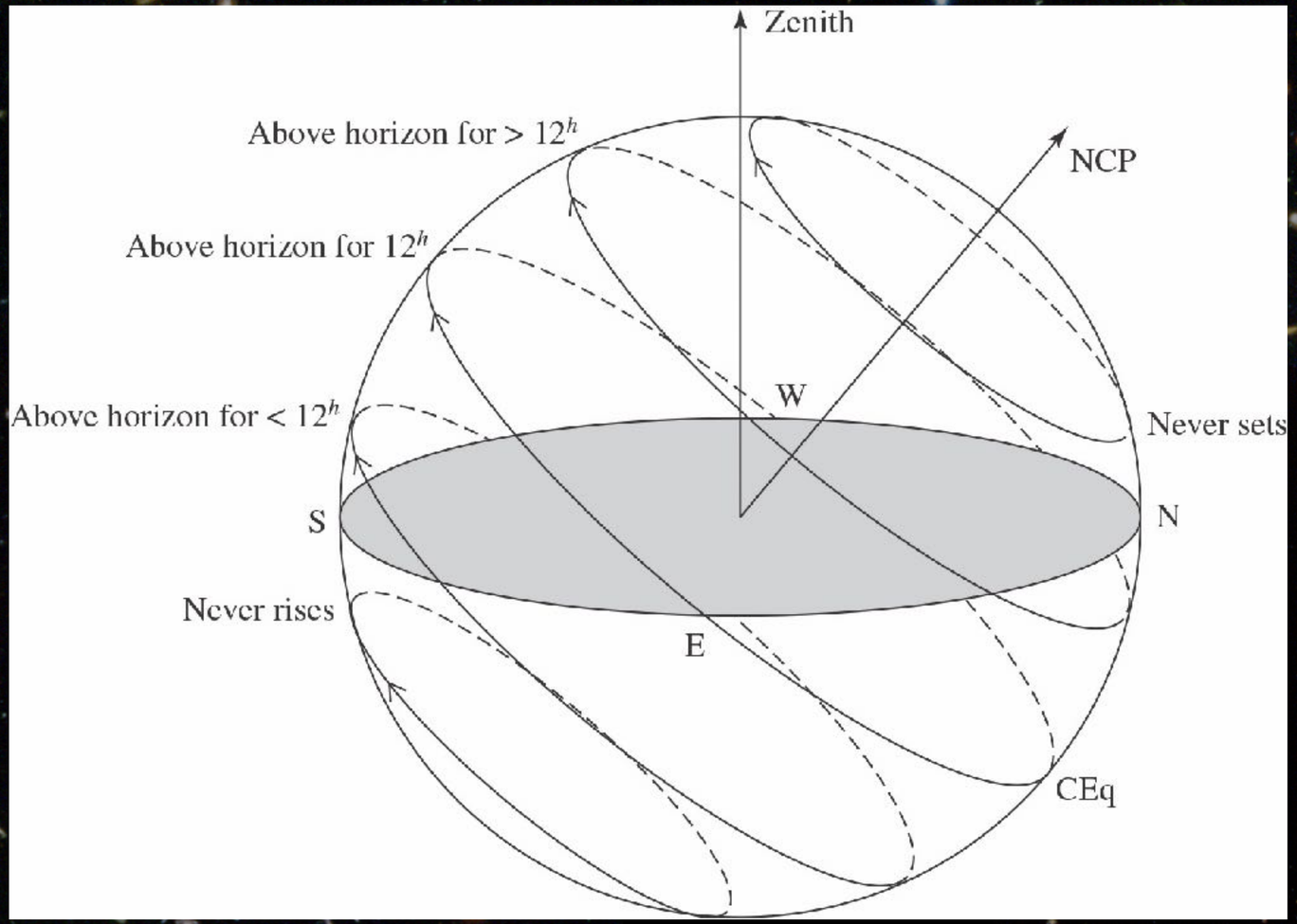
We often refer to the motion of an object using the “hour angle” over the course of a night.

If 360 degrees is equivalent to 24 hours, then **a star moves 15 degrees per hour**

We assign hours, arcminutes, and arcseconds to a star’s position
1 hr = 15 degrees
1 minute = 15’ (arcminutes)
1 second = 15” (arcseconds)

Motions of stars on the sky

"Circumpolar stars" are stars that ***never*** go below the horizon



For an observer at latitude l, the stars that they observe as circumpolar will have declinations δ that satisfy the following conditions:

Northern Hemisphere

$$\delta > 90° - l$$

Southern Hemisphere

$$\delta < -(90° + l)$$

Recall that l is positive above and negative below the equator.


Questions?

Reminders

1. Complete the pre-assessment questionnaire *before* Saturday. It's anonymous and ungraded, so **please be honest.**
2. Attend the discussion section on Monday. Bring your laptop if you can.
3. Don't wait to log into datahub! (You'll hear more about this in discussion section)
4. **Log into Canvas and submit your answer to the discussion question to receive participation credit for today!**