

AST 235

Astronomy: Stars, Galaxies, and
Cosmology

Assistant Prof. Alicia Aarnio

Spring 2019

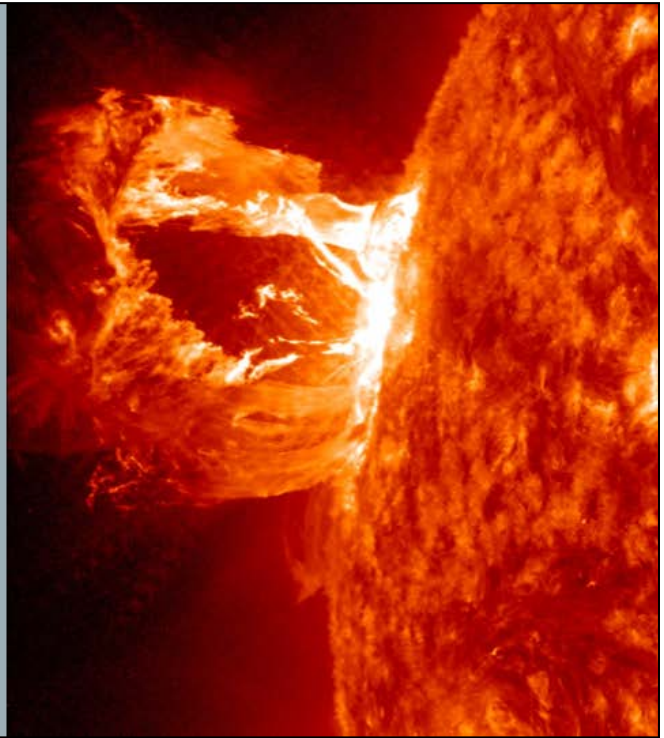
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Welcome!

Astronomy 235: Stars,
Galaxies, and
Cosmology

Professor: Alicia Aarnio

Teaching assistant:
Lindsay House
(l_house@uncg.edu)



Please fill out/return student info forms!

- Entirely voluntary
- Just for me
- I'll shred at semester's end

Name (as appears on UNCG roster)	Alicia Aarnio
Preferred name/phonetic spelling (what would you like me to call you?)	Prof./Dr. Aarnio (<u>ar</u> -nee-oh) Dr. A.
Correct pronouns	She/her/hers
What do you most want to learn about this semester?	The sun/space weather
Is there anything about you it would help me to know? How can I make class inclusive of you?	<p>Examples:</p> <ul style="list-style-type: none"> • Please avoid flashing animations/warn the class first, I get migraines • A mid-class brief stand/move around break would be helpful • Being called on in class causes severe anxiety • I need to eat a snack bar during this hour for blood sugar reasons, sorry if I crinkle during lecture

Please fill out and return to Prof. Aarnio at the end of the first class you attend. This is only for Prof. A., will be stored securely, not shared with anyone for any reason, and shredded at the end of the semester for your privacy.

Today in science...

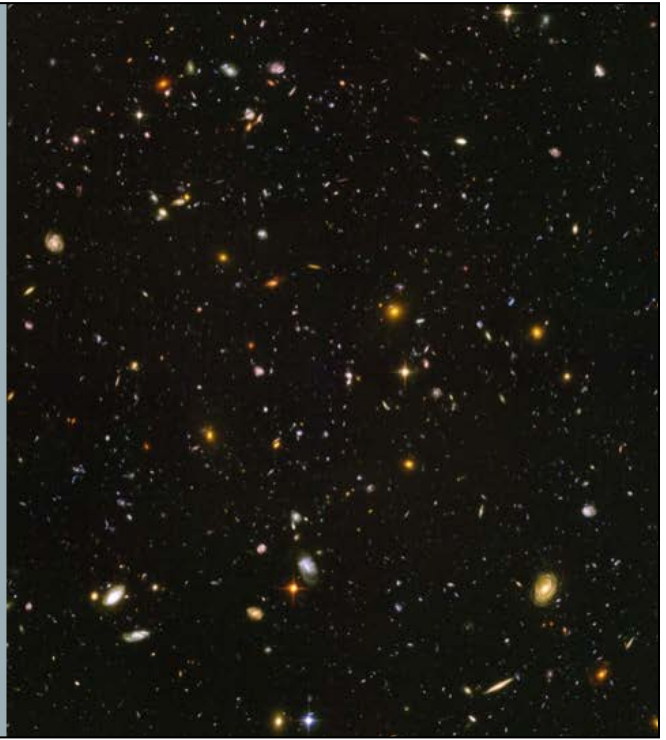
- Discovery!
- Pair of stars orbiting each other
- Disk orbiting the stars...
 - ...perpendicular to where we'd expect it to be!



<https://www.nature.com/articles/s41550-018-0667-x>

Big-picture introduction

Science, astronomy, and
why we do what we do



https://www.nasa.gov/vision/universe/starsgalaxies/hubble_UDF.html

What is science?

- Science is: “the intellectual and practical activity encompassing the systematic study of the structure and behavior of the physical and natural world through **observation** and **experiment**.”
- *Repeatability is paramount!*

STAND BACK



**I'M GOING TO TRY
SCIENCE**

Xkcd.com

Five simple rules for science



~_(\ツ)_/~

1. **Question authority.** No idea is true just because someone says so, including me.
2. **Think for yourself.** Question yourself. Don't believe anything just because you want to. Believing something doesn't make it so.
3. **Test ideas by the evidence gained from observation and experiment.** If a favorite idea fails a well-designed test, it's wrong. Get over it.
4. **Follow the evidence where it leads.** If you have no evidence, reserve judgement.
5. **Remember: you could be wrong.** Even the best scientists have been wrong about some things. Scientists are human.

<div>Icons made by Freepik
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title="Flaticon">www.flaticon.com is licensed by <a
href="http://creativecommons.org/licenses/by/3.0/"
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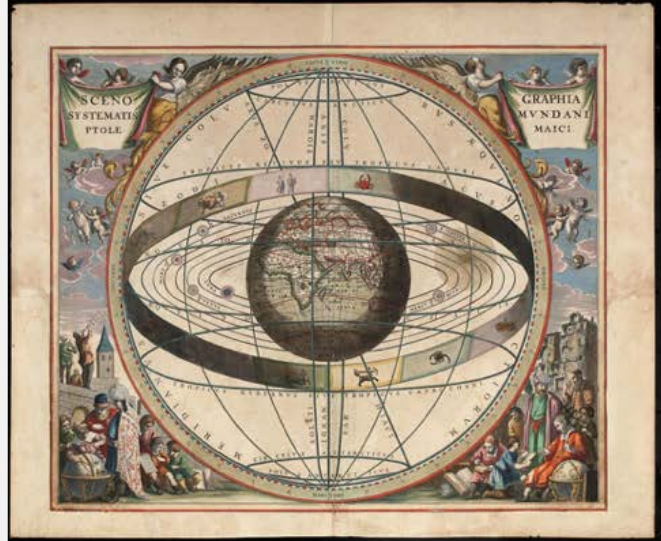
What is astronomy?

- **Astro-** (greek, ἄστρον) “celestial body” + **-nomy** (from Greek *nomia*, law; denoting a specified area of knowledge or the laws governing it)
 - Prefixes you’ll see: astro-, helio-, geo-, extra-, exo-, cosmo- ...
- Astronomy is a natural science that studies the Universe, its constituents, and their “hows” (how they exist, evolve, interact, etc)
- Astronomy is a sub-field of **physics**, applying physics to understand celestial objects
- In the last century, astronomy began using help from chemistry, geology, biology, etc... shift from phenomenology to physical approaches

What is astronomy?

Careful with words!

- **Astronomy** vs **astrology**
- **Cosmology** vs **cosmetology**



<https://www.skyandtelescope.com/astronomy-resources/whats-difference-astrology-vs-astronomy/>

What is astronomy?

- Astronomy is not: stargazing, studying the history of constellations and/or the zodiac
- What do astronomers do?
 - Research
 - Observing
 - Theory
 - Teach
 - Operate telescopes and instruments
 - What do I do?



Very often we're "bad astronomers" and can't tell you what's in the sky right now..

Image is me, standing under a 6.5m (21.3 feet) telescope
(<http://obs.carnegiescience.edu/Magellan>)

My research focuses on young stars

- Evolution of young, Sun-like stars
 - How did the Sun evolve to be the star we see today?
 - How was the early Sun different, and how could that impact planet formation?
 - What does the young Sun tell us about the Sun today, and its future?
- Young, more massive stars
 - How do they interact with their environs?
 - Can you scale up young Suns to describe them?
 - How are they different from young Suns?

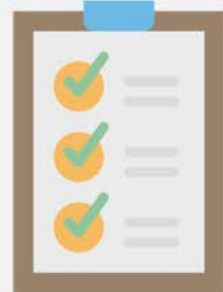


Why is astronomy important?

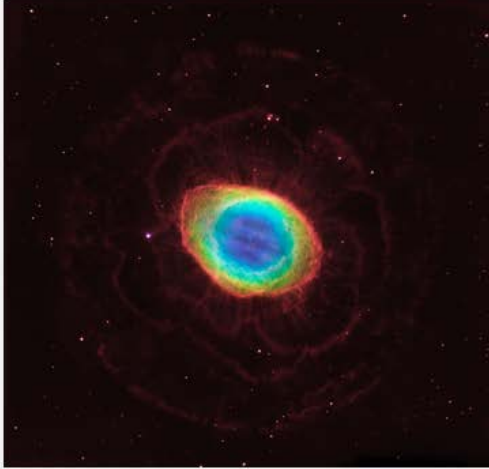
- Historical, practical, and existential/philosophical reasons
- One of the earliest sciences developed!
 - Calendar systems
 - Navigation
- Can be broad applications for astronomical discoveries
 - Energy sources (nuclear fusion)
 - Development of materials and advances in instrumentation
- Search for intelligent life in the universe
- Satisfies fundamental curiosity, can be awe-inspiring

Reasons to take this course

- Studying astronomy...
 - Is challenging, but rewarding
 - Provides a way to develop scientific literacy
 - Might introduce you to a lifelong interest
 - Gets you acquainted with the frontiers of modern astronomy
 - Explores new learning methods and critical thinking
 - Makes you feel small (but in a good way)
 - Will impress your friends/family! (just kidding. They'll ask you about their horoscopes.)



What do you like about this image?



- The colors
- The shape
- All the details and fine structure you can see
- History- it took a long time for that light to get to us!
- Makes me feel small
- What is it?
 - The Ring Nebula! By-product of the death of a star slightly more massive than the Sun.

https://www.nasa.gov/mission_pages/hubble/science/ring-nebula.html

Have you ever wondered...?

Have you ever wondered...



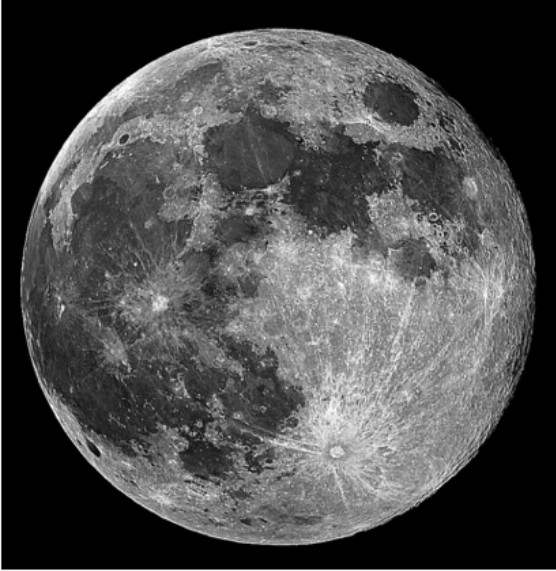
...how to navigate using the stars?

<http://astropixels.com/startrails/arches87/AST87-208.html>

Ancient Polynesian navigators used only the stars to boat between islands:

<http://www.pbs.org/wgbh/nova/ancient/polynesia-genius-navigators.html>

Have you ever wondered...

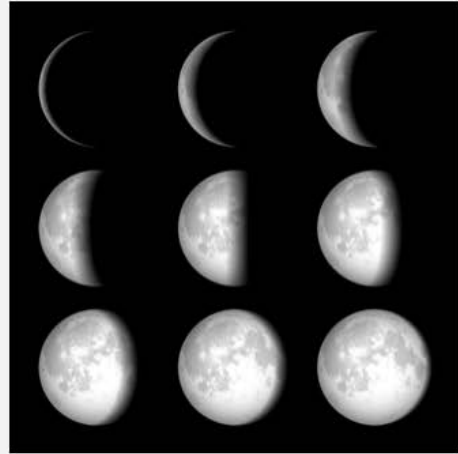


...why we always see the same side of the Moon?



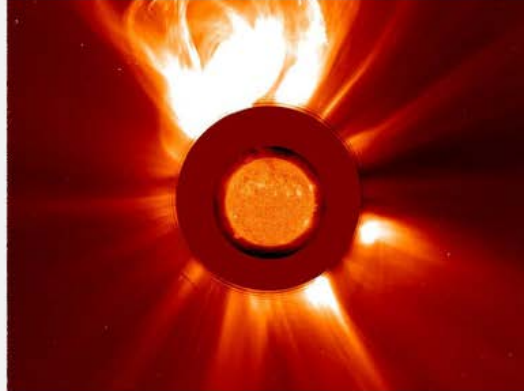
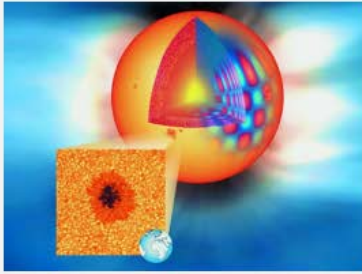
Have you ever wondered...

What causes the seasons?



...and the phases of the Moon?

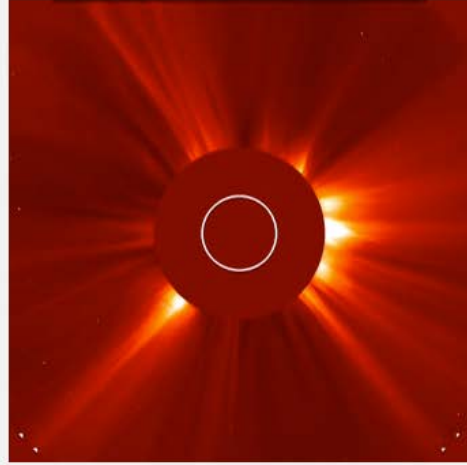
Have you ever wondered...



...why the Sun shines? Where its energy comes from?

<http://www.mps.mpg.de/solar-physics/sun-heliosphere-basics>

Have you ever wondered...



...how and why does the Sun erupt? How could that impact the Earth?

<https://sohowww.nascom.nasa.gov/gallery/movies.html>

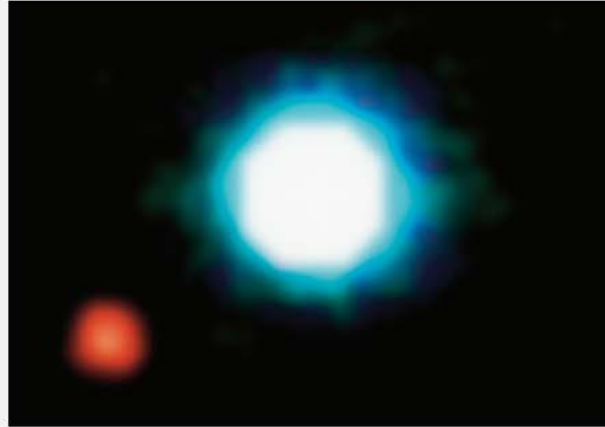
Have you ever wondered...



...why Pluto was "demoted?"

<http://pluto.jhuapl.edu>

Have you ever wondered...



...how we can measure the temperature of places we've never been?

<https://www.eso.org/public/italy/news/eso0515/>

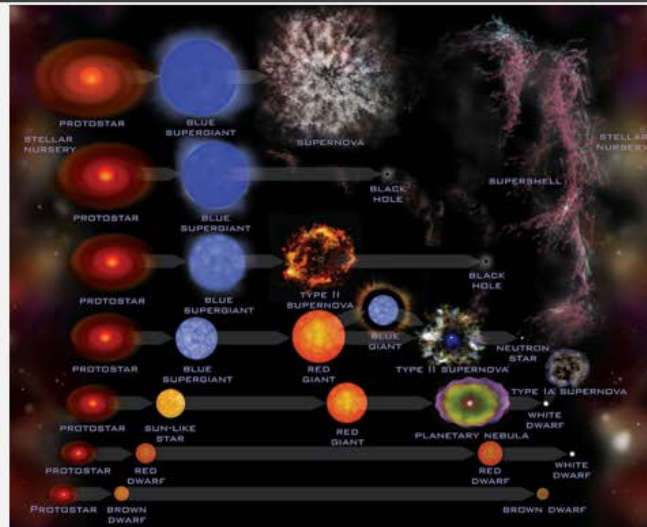
Have you ever wondered...



...how stars are born? If they have families?

https://www.nasa.gov/multimedia/imagegallery/image_feature_768.html

Have you ever wondered...



...how stars evolve, and what happens to them when they die?

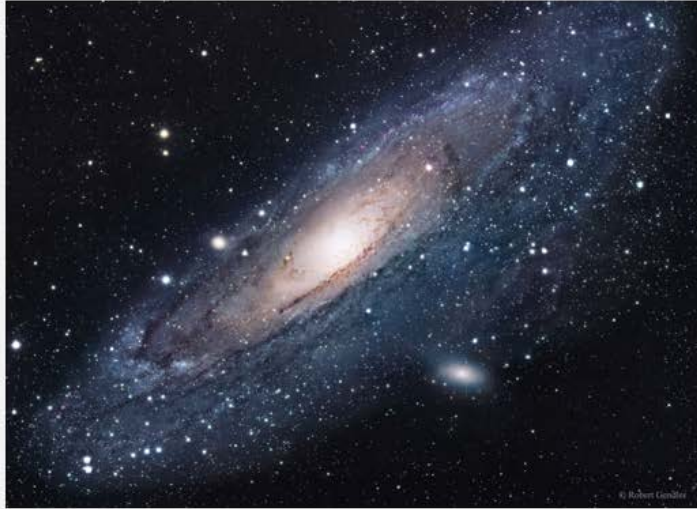
<https://twitter.com/AntonioParis/status/1028418299514810368>

Have you ever wondered...



...how common Earth-like planets are in our galaxy?

Have you ever wondered...



...what galaxies are, how many stars they hold, how they're born and evolve?

<https://apod.nasa.gov/apod/ap150830.html>

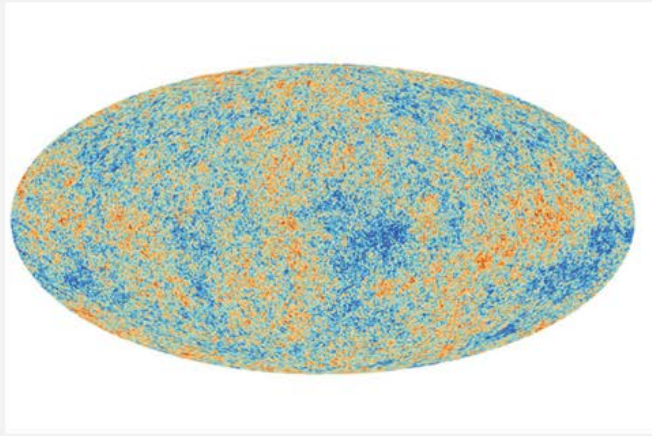
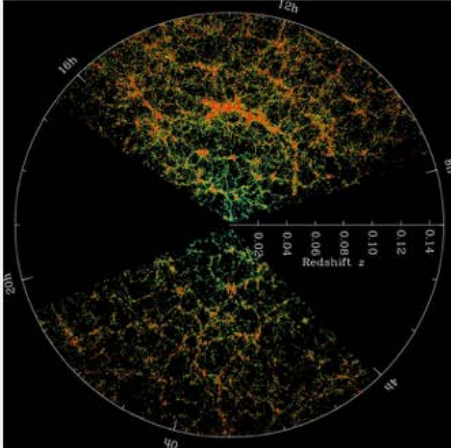
Have you ever wondered...



...if galaxies move? And if they ever run into each other?

<https://apod.nasa.gov/apod/ap180523.html>

Have you ever wondered...



...what the structure of the Universe is?

https://www.e-education.psu.edu/astro801/content/110_p6.html

<https://www.space.com/33892-cosmic-microwave-background.html>

Have you ever wondered...



...whether life could survive on other planets?

No reference link, it's Toy Story.

We will cover these topics and more in AST 235:

- Night sky motion
- Fundamental laws of Physics
- Telescopes
- The Sun/solar activity
- Properties of stars
- Stellar life cycles
- The Milky Way and variety of galaxies
- Distance scales in the Universe
- Dark matter, dark energy, the Big Bang
- Life in the Universe, exoplanets



<https://www.nasa.gov/image-feature/the-pillars-of-creation>

<https://apod.nasa.gov/apod/ap071118.html>

<https://blog.nationalgeographic.org/2014/01/23/star-studded-timelapse-video-from-chiles-high-desert-2/>

http://hubblesite.org/video/999/image_tours

<https://apod.nasa.gov/apod/ap170917.html>

Wondering if you should take this class?

- If you're in the room, you belong here!
- No pre-requisites, no prior knowledge needed: as you are in your seat right now, this class is for you
- Whatever your major, I hope to find connections between what you're passionate about and astronomy
- This room is a community, and we'll all learn together: if one of us is failing, we're all failing.



Course Goals

- Introduce fundamentals of the scientific method: what science is, how it is done, and who does it
 - Integration with arts and other disciplines
 - “Hidden figure” highlights throughout semester
- Learn, understand, and be able to explain basic concepts of modern physics and astronomy, including:
 - Conservation of energy
 - Radiation from celestial objects
 - Tidal interaction and consequences



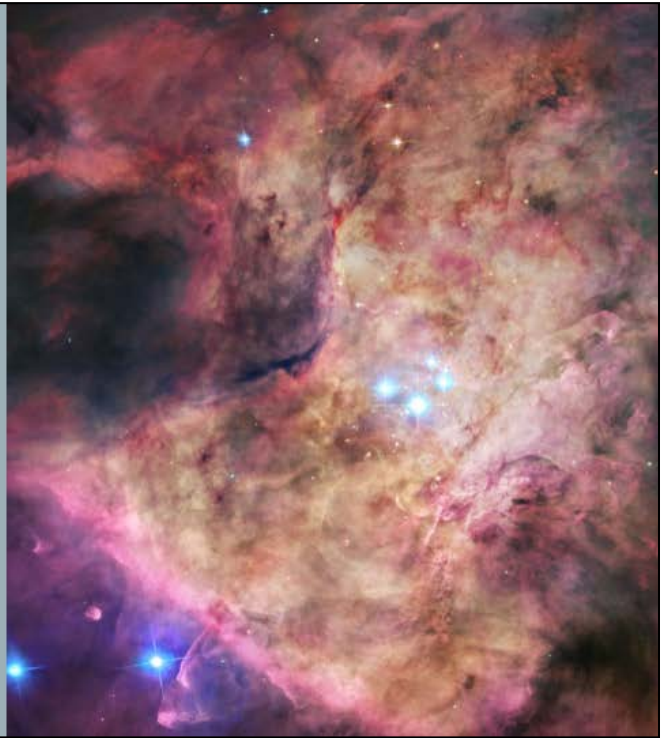
Course Goals

- Be able to explain phenomena we observe in the Universe:
 - Evolution of stars
 - Expansion of the universe
 - Life in the Universe as we understand it (where to find, which conditions allow life)
- Give you tools to engage with current astronomy news (e.g., Space.com, popular science articles, NASA press releases, etc) even after course is over
- Find ways to engage your passion, whatever it may be, with astronomy



Logistics

How will this course
work?



<https://apod.nasa.gov/apod/ap180805.html>

General Information

The course will consist of:

- Lectures + online homework + online labs
- Regular in-class “quizzes” (clickers)
- 1 planetarium visit
- 3 exams (2 mid-term + 1 final)



Textbook: The Cosmic Perspective: Stars, Galaxies, and Cosmology, Eighth Edition, Bennett/Donahue/Schneider/Voit. Don't worry about strange page numbering! Buy the bundle with the 'access code,' that is for..

MasteringAstronomy: homework website

General Information

Course material on Canvas: <https://canvas.uncg.edu>

Material also posted on my course website: <http://aliciaaarnio.solar/stellar/ast235.html>

Most online labs require free software [Stellarium](#); installed on Physics lab computers, Petty 308

- Technical problems with clickers should be addressed to the Office of the Department of Physics and Astronomy in room 321
- Problems with the online course component (MasteringAstronomy) should be solved with the website tech support via email or phone

General Information

- Clicker quizzes:
 - Full credit for attempting
 - Won't announce in advance
 - Will drop lowest 2 at end of the semester



- Extra credit opportunities:
 - Visit the Three College Observatory
 - Do an extra online homework
 - Special bonus project: send me a 2 page original write-up (with references!) of recent astronomy news or a topic that interests you, I'll grade it in place of 1 homework



<https://physics.uncg.edu/tco/>

Expectations

What I expect/we expect from each other:

- Please come to class and participate
- Read in preparation for class
- Bring questions and curiosity
- (Try to) Leave outside stuff outside the door
- Abide by the UNCG academic integrity policy
- Communicate with me
- Work together: be kind and engage with your peers constructively

What you can expect from me:

- Respect and consideration: **this is your class!** I'm here for you.
- Prompt communication/responsiveness
- Clear and careful presentation of the material
- Clear communication of requirements and expectations
- The tools you need to succeed in this course
- Accessible course materials
- Openness to constructive feedback

Throughout the course, I will ask you to fill out comment forms: what am I doing well, what could I improve

Course Structure

- Overview: the Universe and History of Astronomy – 5 lectures
- Basic Laws of Physics & Applications– 5 lectures
- The Sun – 3 lectures
- Study of Stars – 6 lectures
- Study of Galaxies – 6 lectures
- Exoplanets – 1 lecture
- Life in the Universe – 1 lecture



<https://www.google.com/doodles/seven-earth-size-exoplanets-discovered>

How to Study

- We will explain observed phenomena on the basis of currently understood laws of physics
- Every phenomenon is associated with a concept/law:
 - Concept/law – a proven or suggested statement that describes a relevant object, system, or process
 - Concepts can have multiple applications

Example:

- Phenomenon: Motion of planets around stars, motion of stars in galaxies
- Concept: Law of Gravitation
- Application: Weight on planets and stars, details of motion of double stars

Earlier, I noted that astronomy shifted from phenomenological to physical..

Prep for success!

- Read textbook sections in advance of class (see lecture schedule for planned topics)
- Notice concepts and laws of nature used to explain the material
- In your notebook, make a digest of all the laws of nature we study and link them to the relevant phenomena
- Notice basic facts supporting these explanations
- Read all the Mathematical Insight boxes which introduce how to apply the concepts and laws
- Try to answer questions in the end of the Chapter
- Come to class knowing what we are going to talk about

Important Features

Numbers in Astronomy (using scientific notation):

- 1 billion = 1,000,000,000 = 10^9

Basic Units (System International or SI):

- Mass – 1 kg (kilogram)
- Time – 1 s (second)
- Distance – 1 m (meter)

Unit conversion:

- kilometers (1 km = 1000 m)
- centimeters (1 cm = 0.01 m = 10^{-2} m)

Speed of Light (c):

- $c = 300,000 \text{ km/s} = 3 \times 10^8 \text{ m/s} = 3 \times 10^8 \text{ m s}^{-1}$

Help with math – textbook pages A-4 to A-9



<http://www.thesuntoday.org/missions/sdo/>

Special Units Used in Astronomy

Astronomical Unit (au)

- Average distance between the Earth and the Sun
- 1 au = 150 billion meters = 1.5×10^{11} m

Light year (LY)

- The distance the light travels during 1 year
- 1 LY = speed \times time = $c \times t =$
 $(3 \times 10^5 \text{ km/s}) \times (365.24 \text{ days}) \times (24 \text{ hours}) \times (60 \text{ minutes}) \times (60 \text{ s}) = 9.46 \text{ trillion km} =$
 $9.46 \times 10^{12} \text{ km} \approx 63,000 \text{ au}$

Parsec (pc)

- 1 pc = 3.26 LY (will be introduced later)



Recently, the International Astronomical Union voted to abbreviate Astronomical Unit with lower case au instead of AU. I'm not sure why, but the community has adopted it, so if you see a mix of lower and upper case au, that's why! Au, capital A lower case u, is the abbreviation for the element gold.

A Few Other Things

- My office is in Petty, 3rd floor, room 332
- Office hours are Tuesday, Wednesday, and Thursday, 3-4pm
 - Appointments not required, but helps to let me know if you're coming!
 - <https://profaarnio.youcanbook.me>
- I'll be monitoring the class' Slack channel, <https://join.slack.com/t/ast235s2019/signup>
- @AliciaAarnio on twitter
- Email anaarnio@uncg.edu

Questions for me?