CTYI Astronomy Spring 2024

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CLASS CHARTER

WHAT IS ASTRONOMY

What do you want to do?

Astronomy is the study of stars, planets, and the universe itself

What we'll do

Here's what you can expect to learn about over the course of the 8 weeks:

1. Introduction to the Universe
2. Our Solar System
3. The Sun and the Stars
4. Galactic Explorations
5. Beyond Our Galaxy
6. Space Exploration and Technology
7. The Search for Extraterrestrial Life

I get pretty bored only doing slides everyday - so we won't. We'll do activities and quizzes. With one *GIANT* quiz at the very end. But because of all the things we can be doing it's very important that **everyone** is cool and nice to each other and us.

BINGO

1.

Introduction to the Universe

Our Cosmic Address

- What does your address look like?
  - 123 Bóthar Buí, Dublin 12, Co. Dublin, Ireland
  - But what if we go even bigger?
    - Europe?
    - Earth?
    - The Solar System?
    - The Milky Way Galaxy?
- The Planet is big, the galaxy is really really big but the universe is...
- REALLY REALLY REALLYYYYYYY BIG
  - As in about 10000000000000000000 times bigger than the Earth

Just how big is the universe?

Brief Introduction to the Solar System

- How many planets are in our Solar System?
  - 8 (not 9)
  - Can anyone name them?
    - Mercury
    - Venus
    - Earth
    - Mars
    - Jupiter
    - Saturn
    - Uranus
    - Neptune
    - Is Pluto a Planet?

How big is our Solar System?

Activity

CLASS CHARTER

1. No Talking when others are talking
2. Hands up to talk
3. Follow Laws
4. No Running Away
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6. Good Chalk
7. Learn Astronomy

2.

Relativity

What is Light?

Special Relativity I

What is Special Relativity?

- Two Assumptions (Postulates)
  - 1) You're never REALLY at rest
  - 2) Everyone agrees on the speed of light no matter what
- 1. Relative Motion
  - Think of yourself standing still - are you still moving?
  - Not a new idea
- 2. Constant Speed of Light
  - If everyone measures the same speed then something is wonky
  - Time and Space works differently for different people?
  - VERY new idea
- Consequences of Special Relativity
  - Mass Energy Equivalence
  - Mass increases with velocity
  - Moving bodies get shorter
  - Moving clocks run slower

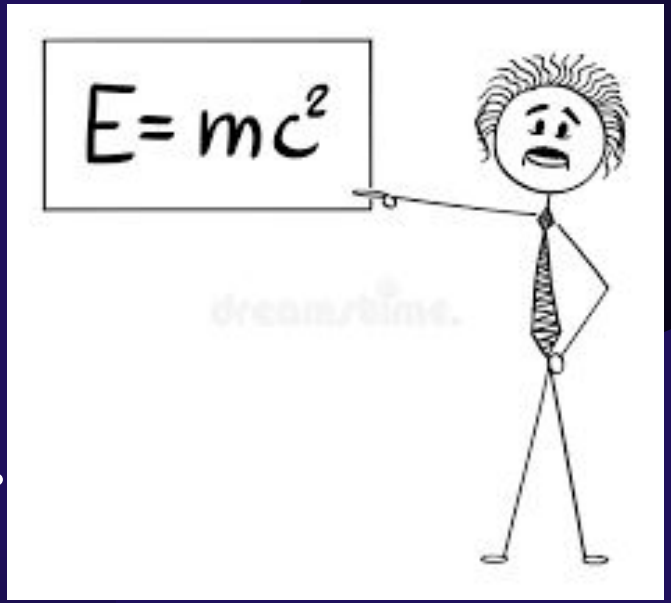
Special Relativity II

Wibbly Wobbly Timey Wimey

- Time Dilation
  - Time Dilation is the effect of someone's experience of time becoming different when they go really fast
- Thought Experiment
  - Someone facing a mirror flicks a torch on
  - Measures how long it takes to travel to the mirror and back
  - Now imagine they do it on a rocket and we can see it too
  - How long does it take in the point of view of the person on the rocket?
  - How long does it take in our point on view?

Special Relativity III

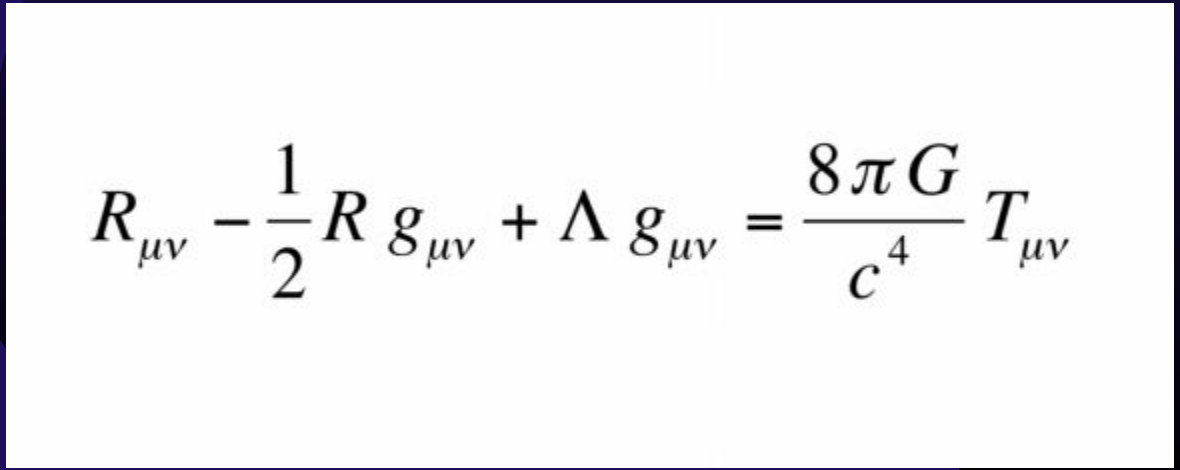
Overview of Special Relativity



- Time is Relative
  - Time is measured differently by different observers
  - Time “slows down” the faster you go
- Space is Relative
  - Space is measured differently by different observers
  - The path of light seems longer to a stationary observer if they’re going at high speeds
- Energy & Mass are different forms of the same thing
  - Mass can be converted into energy
    - And back again
  - Examples of this being used?

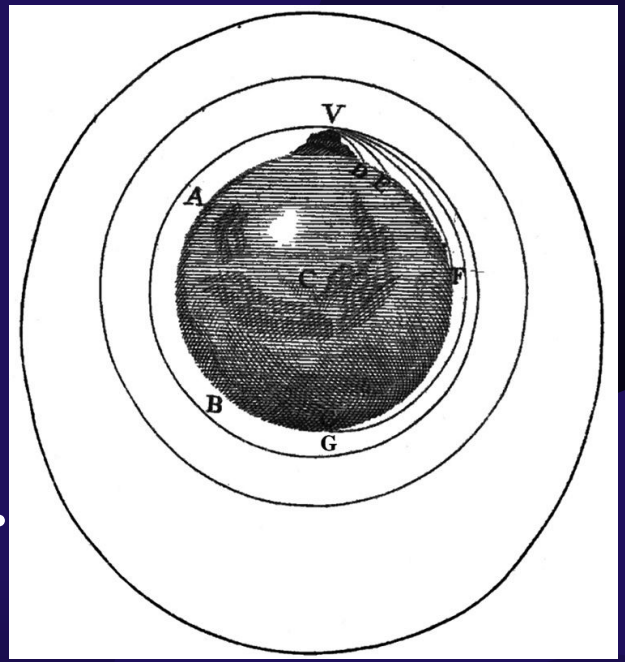
General Relativity 0

Maths Background



General Relativity I

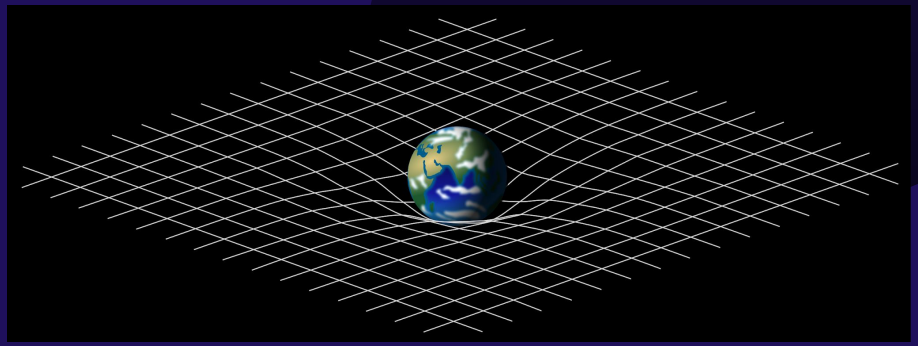
Newton's Gravity



- What is Gravity?
  - Force attracting two masses
- Newton discovers gravity (1687)
  - Strength of force depends on mass and distance between objects
  - Accounts for motion of the Moon and an apple
    - Earth pulls on the Moon and apple
    - Moon and apple both pull Earth
  - Effect of gravity of the Moon on Earth
    - Tides
- Einstein's Idea
  - If you're in freefall - you don't feel gravity
  - From this he figured out that masses would literally bend space

General Relativity II

How straight are straight lines



- Space-time
  - From SR, space and time are connected
    - We have three coordinates for space. What about time?
    - One for time
    - Can describe any event with 3 numbers
  - GR says heavy objects distort space-time
  - Light travels along straight lines
    - Easy to see if space is flat
    - If space is curved?
- Testing GR
  - Star behind the Sun
    - Light bends around the Sun
    - We can see stuff we shouldn't be able to see
  - Time Dilation Pt. 2

General Relativity III

Cas' Favourite GR Visualisation

General Relativity IV

DEMONSTRATION

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3.

The Sun

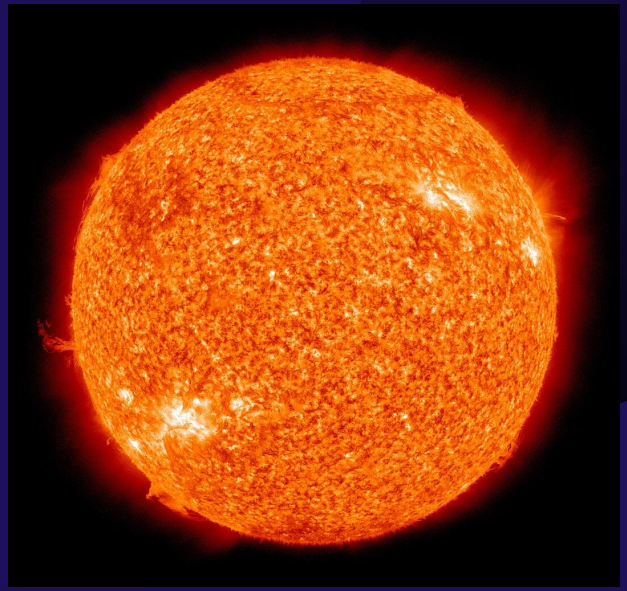
Introduction to Our Sun

Say hi to Lú

- What is our Sun?
  - Name?
    - Sol?
    - Trick question - it doesn't have one
  - What is it made of?
    - Short answer - plasma
    - Long answer - maybe another time
  - How far away is it?
    - 1 AU
      - What is that?
    - 1.496x10^8 km (don't worry if this doesn't make sense, it's just so future Cas remembers - past Cas)

What does the Sun do

For us and against us



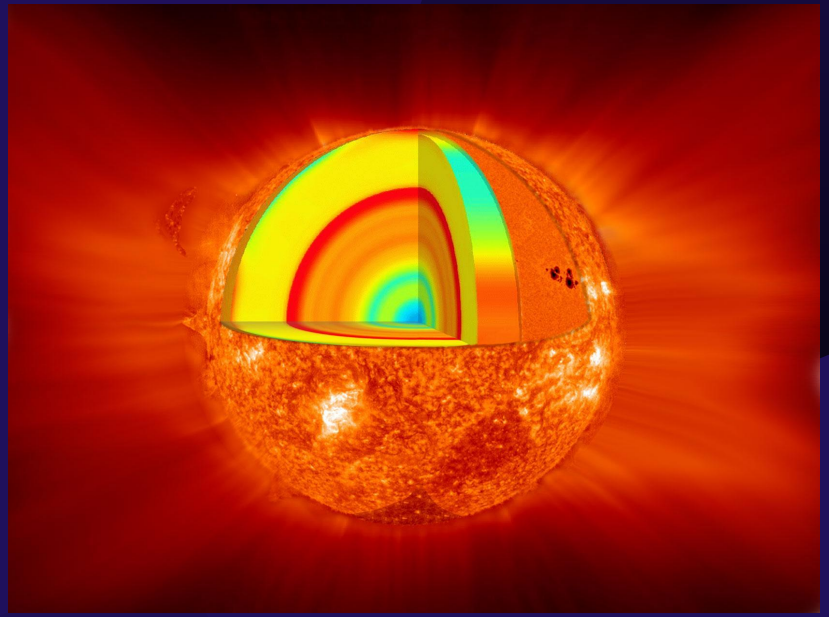
- For us
  - Light (Pretty important)
  - Warmth
  - Solar Energy
    - Used for?
- Against(?) Us
  - Solar Wind
  - Solar Flares

Question

In what way is the Sun like an onion?

The Layers of The Sun

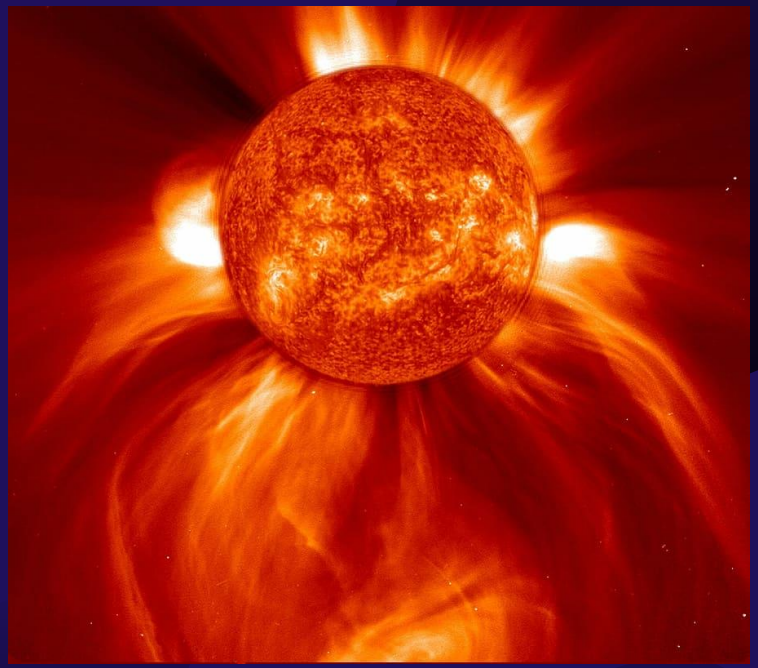
The Sun is a lot like an onion



- The Core
  - It's like the Sun's heart
  - Nuclear fusion turns hydrogen into helium
- Radiative Zone
  - This layer allows energy to travel through it as light and radiation.
- Convective Zone
  - Heat is transferred through the Sun's outer layers via the movement of hot plasma
- Photosphere
  - It’s what we see when we look at the Sun
- Chromosphere
  - It’s responsible for the beautiful color variations we see during solar events
- The Corona
  - Hot and outermost layer.
  - During a solar eclipse, this creates a stunning halo effect around the Sun

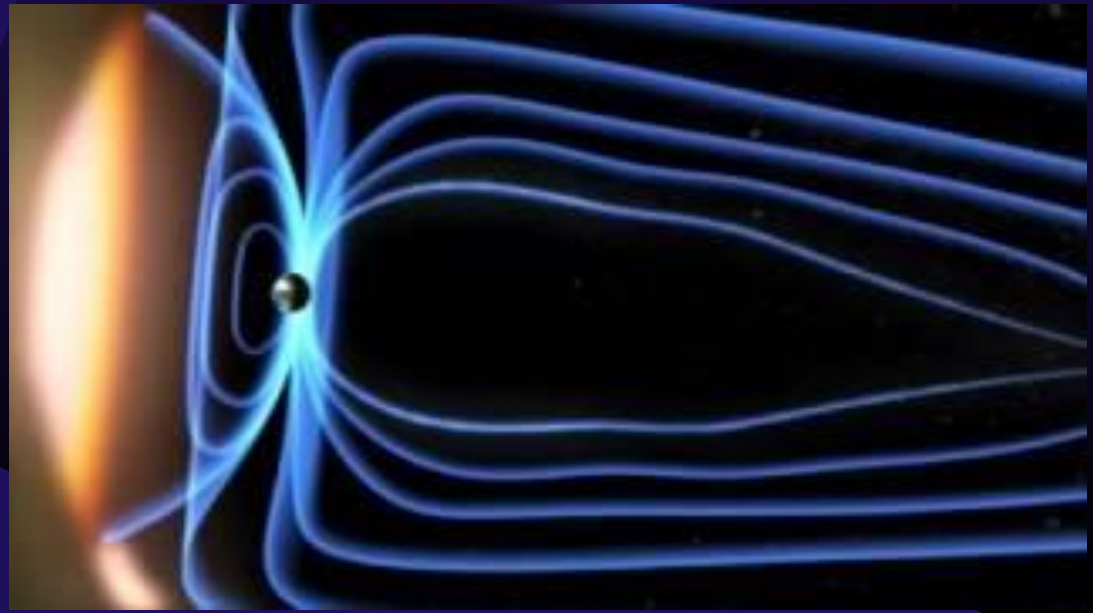
Solar Winds & Flares I

I'd prefer to be in the normal wind



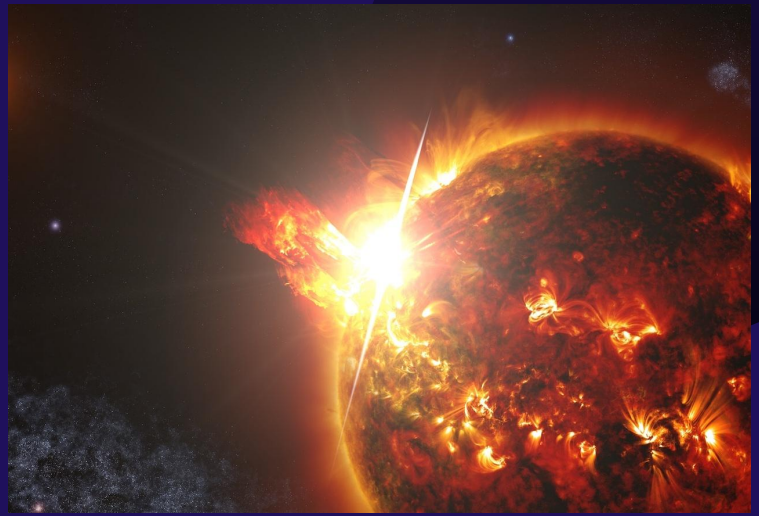
- Solar Wind
  - The Sun emits what are called **charged** particles
    - This just means they are affected by electricity and magnetism
  - These particles are going very fast with a lot of energy
    - If they hit you, it's not gonna be the best
  - Luckily they get deflected by *magnetic fields*
    - Do you know anywhere with a magnetic field?
  - What happens if there's a very very big gust of solar wind?

Solar Winds & Flares II



Solar Winds & Flares III

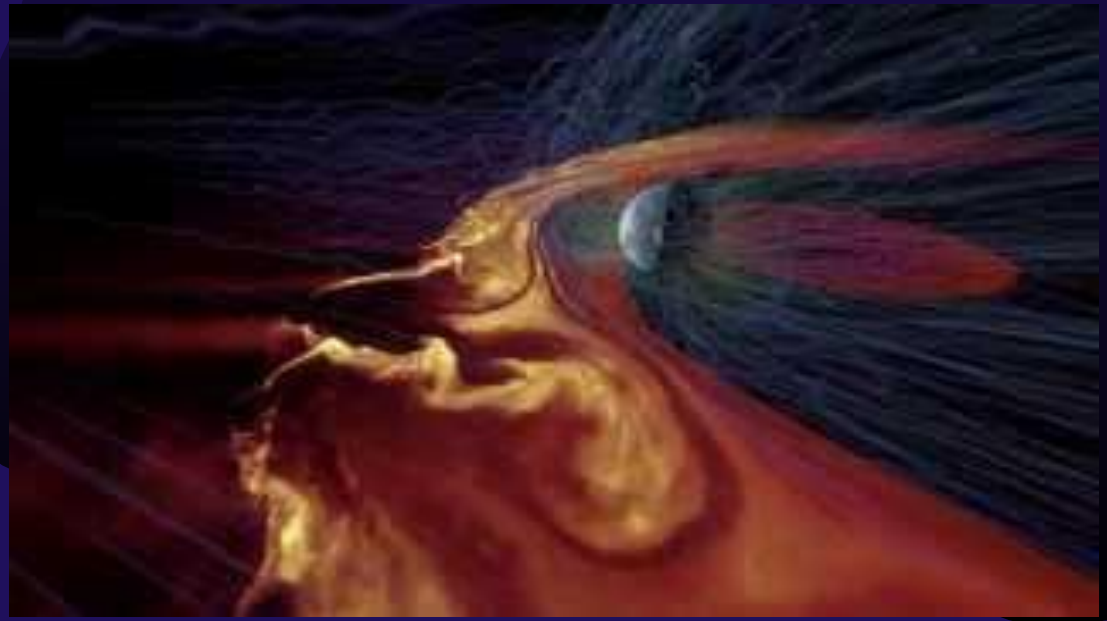
When the Sun flares up



- Solar Flares
  - A really intense emission of light from the Sun's atmosphere
  - Usually occurs with other solar phenomenon
  - Can excite part of the Earth's atmosphere
    - Ultimately messing up how radio waves are transmitted
  - Let's look at some
    - https://www.spaceweatherlive.com/en/solar-activity/solar-flares.html

Solar Winds & Flares IV

We’ll come back to this if we have time



Group Activity

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4.

Galaxies

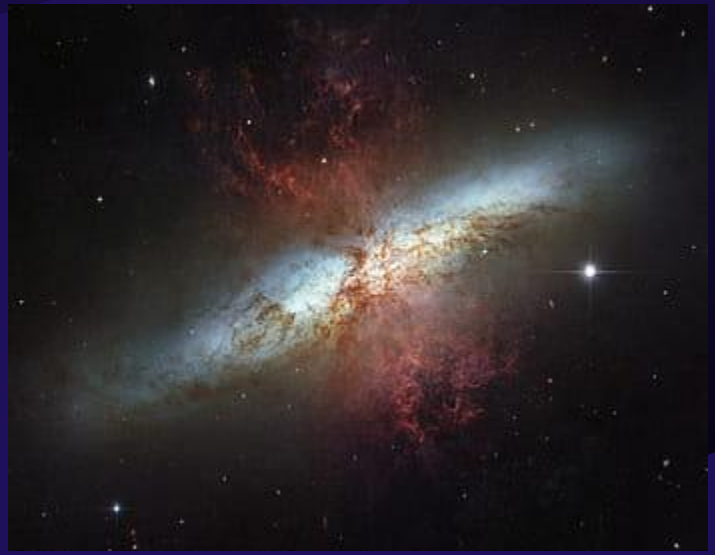
Introduction to Galaxies

- What are galaxies?
  - Composed of billions of stars, dark matter, and gas.
  - Galaxies are found everywhere throughout the universe each with its unique story.
- Types of galaxies
  - Galactic architectures vary.
  - Majestic spiral galaxies, cosmic pinwheels.
  - Elliptical and irregular galaxies.

Types of Galaxies I

- Spiral Galaxies:
  - Big spiral arms.
  - Often host vibrant star formation and young, hot stars.
  - E.g. Milky Way
- Elliptical Galaxies:
  - Cosmic Rugby ball.
  - Predominantly composed of older stars, less dynamic in terms of new star formation.
  - Weird shape from gravitational interactions
- Lenticular Galaxies:
  - Mix of spiral and elliptical

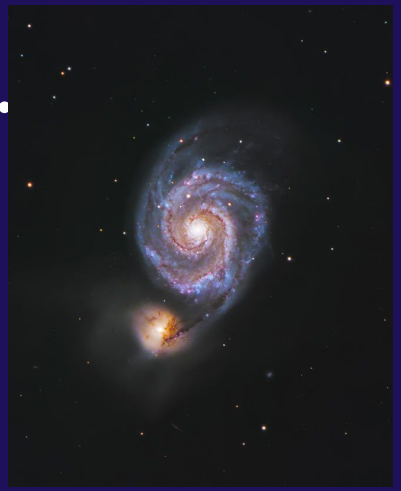
Types of Galaxies II

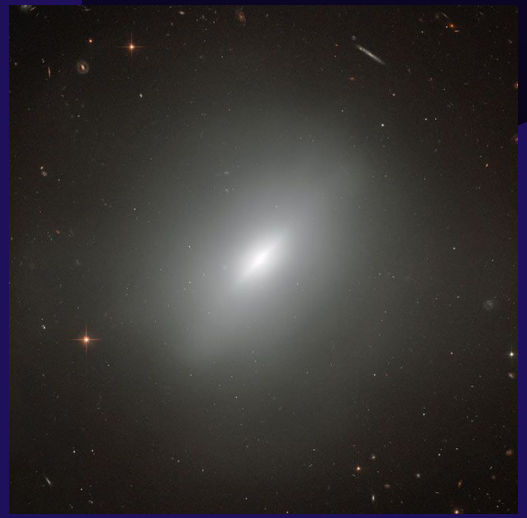


- Irregular Galaxies:
  - No defined shape or structure.
  - Some irregular galaxies emerge from gravitational interactions e.g. mergers.
- Observations of these galaxies provide essential insights into the broader mechanisms driving the evolution of celestial structures.

What type of Galaxy is this?

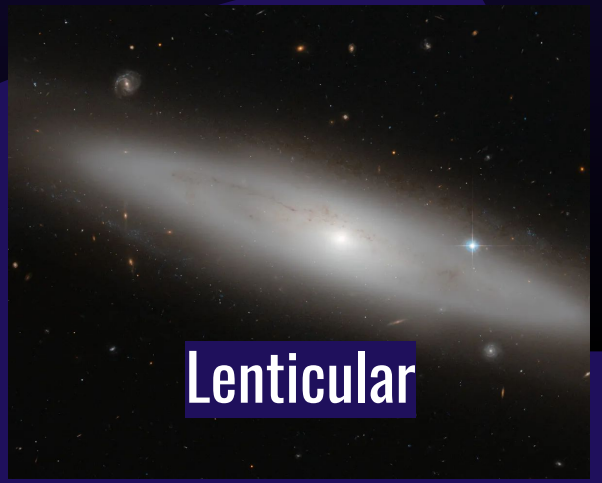
Spiral Galaxy



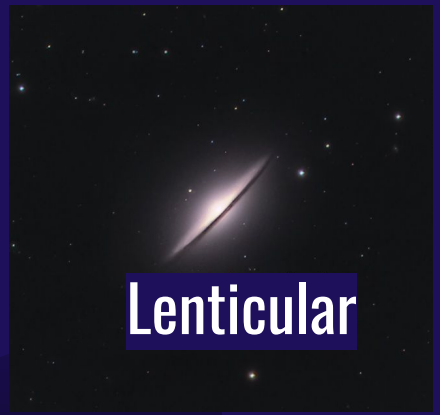



Spiral


Elliptical


Lenticular


Irregular


Lenticular

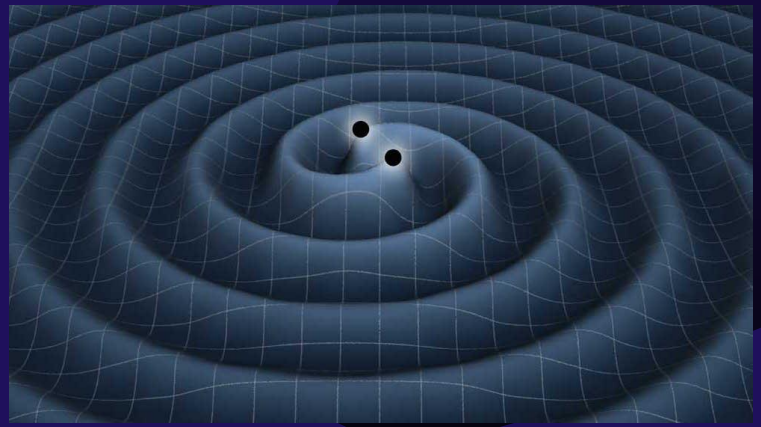

Spiral

CONSIDER

Black Holes I

- Black Holes
  - Formed from the remnants of massive stars undergoing gravitational collapse.
  - Highly dense masses that warp the fabric of space and time
  - Doesn't let anything escape even light
- When do they form?
  - If their mass is above the TOV limit then it will collapse into a black hole
  - Gravitational Collapse makes stars smaller
  - Once its radius gets below the Schwarzschild Radius it becomes a black hole

Black Holes II



- White Holes
  - Theoretical opposites of black holes, expelling matter and light.
  - No observational evidence yet, remains a mystery.
- Gravitational Waves
  - Ripples in spacetime predicted by Einstein.
  - Emitted during cosmic events like black hole mergers.
  - Detected by LIGO and Virgo, opening a new era in astronomy.
    - Detected waves caused by a merger of two black holes (each ~ 30 Solar Masses) about 1.4 billion light years away

BLACK HOLES

Galaxy Clusters

- Galactic Clusters
  - Diverse gatherings of galaxies.
  - Generally bound by gravity
  - Large scale structure (10^14 Solar Masses)
  - Next step are superclusters
- Observational Significance
  - Observations help understand underlying cosmological principles
  - Examples?
- Galaxy Groups
  - One step down from clusters
  - The Milky Way is in the local group

https://vimeo.com/239075970

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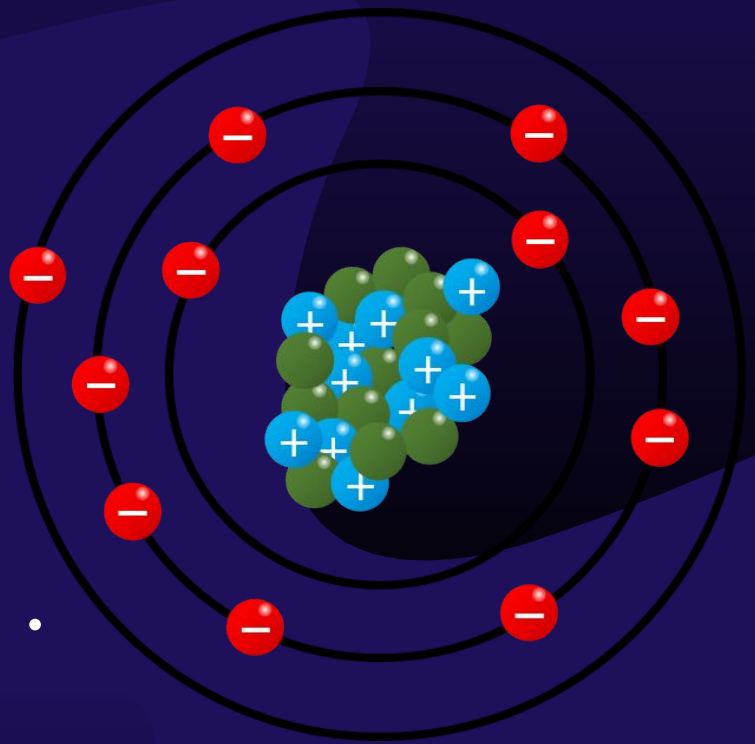
5.
Stellar Evolution...and more

Background Particle-y Stuff

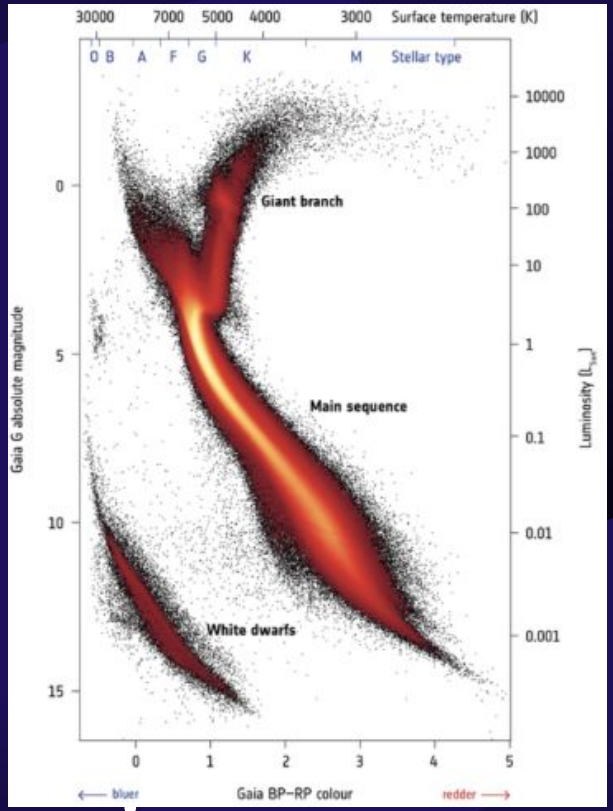


- The Atom
  - For a very long time we thought that the atom was the smallest particle
  - This is wrong.
- What's inside an atom?
  - Protons
  - Electrons
  - Neutrons
  - Protons and Neutrons make up the nucleus (plural nuclei)
- Fermions
  - Type of particle including protons, electrons, neutrons, etc.
  - They don't like being very near each other
  - The force pushing them apart is called **degeneracy pressure**

Nuclear Fusion

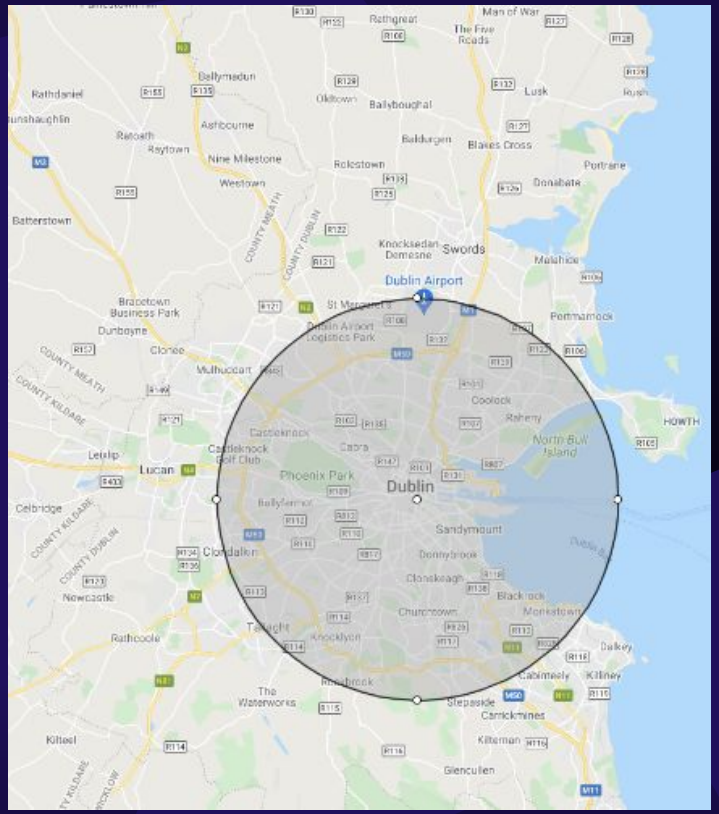
- What is fusion?
  - When lighter nuclei fuse together to make heavier nuclei and produce energy
  - It actually makes a LOT of energy in the form of light and heat
    - This is what makes Stars shine
- Types of Fusions
  - Most common fusion reaction in stars converts hydrogen into helium (called the proton-proton chain)
  - But elements up to Iron are formed through fusion eventually

Stellar Evolution I



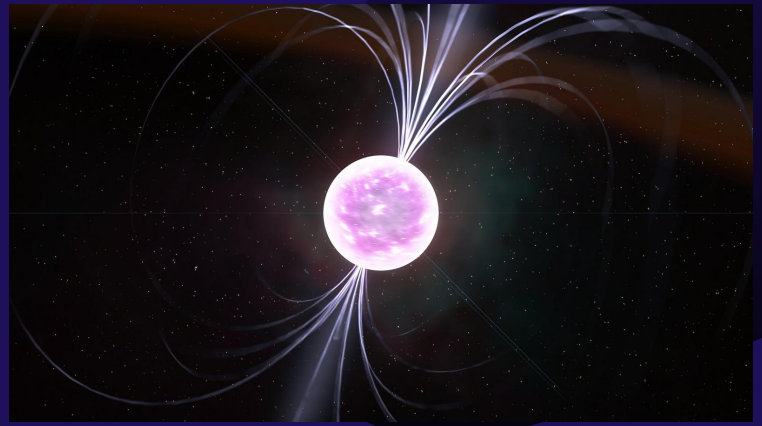
- Birth
  - Stars begin as vast nebulae, clouds of gas and dust.
  - Nebulae collapse under gravity, forming a protostar.
- Main Sequence
  - Protostar becomes a main sequence star.
  - Nuclear fusion in the core balances gravitational forces.
  - Our Sun is currently in this phase.
- Red Giant
  - Depletion of hydrogen leads to expansion into a red giant.
  - Outer layers are expelled, forming a planetary nebula.

Stellar Evolution II



- Supernova
  - Massive stars undergo a dramatic explosion.
  - Outer layers are cast off, creating a brilliant supernova.
- Remnants
  - Fate depends on the star's mass.
  - Low to medium-mass stars become white dwarfs.
  - More massive stars can become neutron stars or collapse into black holes.
- Death
  - Final fate is determined by mass.
  - Smaller stars cool down to become white dwarfs.
  - More massive stars contribute to new stars, form neutron stars, or collapse into black holes.

White Dwarves & Neutron Stars



- White Dwarfs
  - When a low to medium-mass star exhausts its nuclear fuel, it becomes a white dwarf.
  - Gravity compresses the star's core, leaving behind a dense, Earth-sized remnant.
  - White dwarfs are supported by electron degeneracy pressure, resisting further collapse.
- Neutron Stars
  - For more massive stars, the core collapses further, forming a neutron star.
  - This extreme density results in a celestial object composed mainly of neutrons.
  - Neutron stars are supported by neutron degeneracy pressure, preventing further gravitational collapse.

GAME TIME

Pictionary Prompts:

1. Supernova Explosion
2. Nuclear Fusion Process
3. White Dwarf Formation
4. Red Giant Star
5. Black Hole Creation
6. Stellar Nebula
7. Galactic Collision
8. Pulsar Emission
9. Hubble Space Telescope
10. Constellation Formation
11. Dark Matter
12. Andromeda Galaxy
13. Planetary Nebula
14. Solar Flare Activity

Charades Prompts:

1. Mimic a Star's Lifecycle
2. Act Out Nuclear Fusion in a Star
3. Demonstrate the Formation of a Black Hole
4. Show the Emission of Pulsar Beams
5. Imitate the Explosion of a Supernova
6. Portray the Formation of a White Dwarf
7. Act Like a Red Giant Star Expanding
8. Pretend to Be a Hubble Space Telescope Capturing Images
9. Show the Rotation of a Galaxy
10. Illustrate the Movement of Dark Matter in a Galaxy
11. Pretend to Be a Galactic Collision
12. Imitate the Twinkling of Stars in a Constellation
13. Act Out the Birth of a Stellar Nebula
14. Show the Journey of Light Through a Telescope

- Pictionary
- Charades
- Hangman

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6.

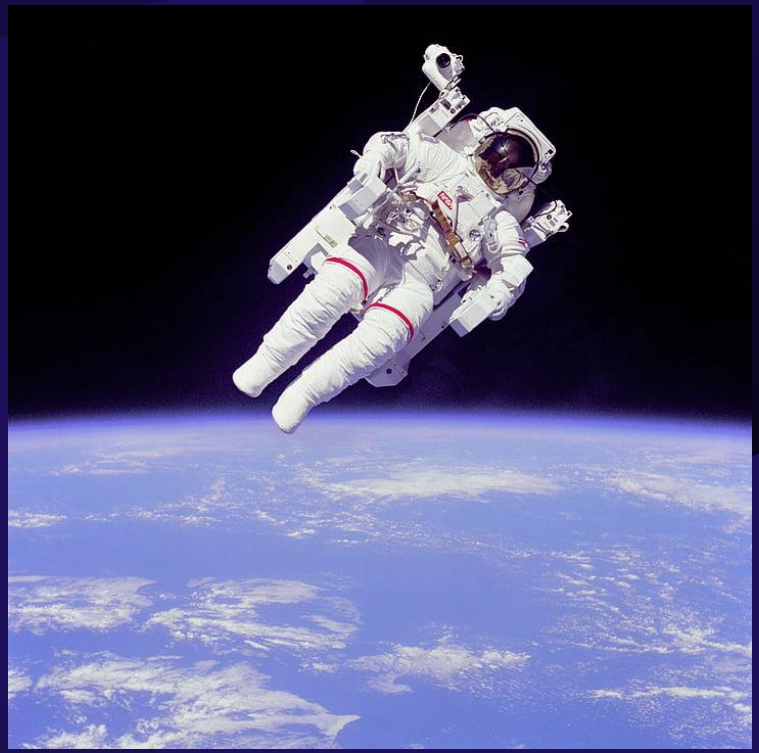
Rockets and SETI

Introduction to Rockets

- Rockets are vehicles designed to travel through space
- They work on the principle of Newton's third law of motion
  - For every action, there is an equal and opposite reaction
- Key components include:
  - The nose cone for aerodynamics
  - Fuselage for payload
  - Fins for stability
  - Engines for propulsion

Rockets 101

Challenges of Space Travel



- Space travel presents unique challenges to human health and technology
- Microgravity
  - Affects the human body
    - How?
  - Requires adaptations for long-duration missions
    - Any ideas?
- Radiation exposure
  - Poses risks to astronauts
  - And to spacecraft electronics
- Life support systems are crucial for sustaining human life in the harsh environment of space

Introduction to SETI

- SETI = Search for Extraterrestrial Intelligence
  - They aim to detect signals from intelligent civilizations beyond Earth
- SETI scientists use radio telescopes
  - They listen for narrow-bandwidth radio signals that could indicate extraterrestrial communication

I-LOFAR

- LOFAR (Low-Frequency Array)
  - Radio telescope network designed to observe cosmic phenomena
  - Works at incredibly low frequencies
  - Consists of thousands of antennas spread across multiple European countries
- I-LOFAR
  - The Irish section of the antenna array
  - Located in Birr (Offaly)
  - Works with SETI by gathering data and bringing people together to work on it

The importance of landing

Activity

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Rapid-Fire Projects

Activity

https://tinyurl.com/ctyiAstro

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8.

Table Quiz (Finale)

Rules

- All questions give equal points
- Any spying will result in all of that round's points lost for the team caught spying (suspected spying will result in taking up only the currently answered questions)
- At most once per round, if ALL teams agree, a hint will be given for one question

Round One

1. Name all the planets and if their name is taken from Greek or Roman mythology

Round Two

1. Who came up with the special theory of relativity?
2. True or False: You appear to be heavier if you're going faster
3. I stay on Earth and my twin travels in a rocket going close to the speed of light. They return when I'm 20 years old. Will they be older or younger than me?
4. Who discovered gravity?

Round Three

1. True or False: The Convective Zone is a layer in the Sun
2. What stops the Sun's solar winds from hitting Earth too much?
3. Name something we use the Sun for
4. What is the name of the Egyptian god of the Sun? (Bonus point if you put down the Irish one too)

Round Four

1. Which Galaxy are we living in?
2. Name the four types of galaxies we covered in class
3. True or false: Black Holes suck in matter and / or light
4. What famous scientist predicted gravitational waves?

Round Five

1. Name ANY of the particles that make up an atom
2. Most energy from the Sun is released via Nuclear _____ ?
3. True or False: White Dwarfs are heavier than Neutron Stars
4. Which of the following is most relevant to the term “planetary nebula”
    a. Red Giant
    b. White Dwarf
    c. Neutron Star

Round Six

1. What component of a rocket has the purpose of propulsion
2. Name a challenge that low-gravity poses to astronauts
3. What does SETI stand for?
4. True or False: Radiation exposure poses a risk to spacecraft

Harder Questions

Worth double points

Round Seven

1. What equation is used to convert energy to mass?
2. According to Einstein, how can we see the light from a star behind a black hole?
3. What is the name of the Irish Sun god?
4. Solar winds are made up from **charged** particles, this means they're affected by which of the following?
    a. Gravity
    b. Electricity
    c. Magnetic Fields

Round Eight

1. True or False: Neutron Stars are kept alive by electron degeneracy pressure
2. Where is I-Lofar?
3. Once a star gets below the Scharzchild Radius it turns into a _____?
4. The Tolmann-Oppenheimer-Volkoff (TOV) limit is relevant to which of the following
    a. Nuclear Fusion
    b. Black Holes
    c. Planetary Motion

Tie Breaker

You have 3 minutes to calculate the following

If you have an answer shout out. First team to get it right wins, if no one has the correct answer by the end of the time then the closest guess wins

Calculate the sum of the first 100 numbers i.e 1+2+3+4+5+...+99+100

Summary

Course Outline

- Course Layout
  - Each class featured a different area of Astronomy (or Astronomy related areas)
  - Every class was split into two (before and after lunch)
  - The first half would cover any needed theory
  - The second would involve applying the theory to some activity

The Course Material

1. Intro to the Universe

- We started off with an introduction to the universe
- We went over what were and weren't planets (looking at you Pluto)
- Also how big the universe actually is

2. Relativity

- I was then peer pressured into covering relativity
- We covered the basic physics behind really fast things (like light)
- As well as the really heavy things (like black holes and stars)

3. The Sun

- We looked at some basic facts about the Sun
- We learned about the make-up of the Sun (raise your hand if you remember why the Sun is basically an Onion)
- We looked at the benefits and dangers around the Sun (e.g.?)

4. Galaxies

- We covered what exactly a galaxy is.
- Then we talked all the different types of galaxies
- We learned about Black Holes and the funky business they come with

The Course Material

5. Stellar Evolution

- We learned about the Atom and a bit of Particle Physics <3
- We learned about what powers stars
- As well as what happens when they no longer can survive

6. Rockets and SETI

- A much more practical class
- We looked at how rockets are designed
- As well as modern day telescopes and what we use them for
- Finally, we made our own parachute based landing crafts to test

7. Rapid-Fire Projects

- For the Penultimate class, we managed to secure laptops for the class
- Groups of ~3 were given the choice to pick from a list of project ideas and we spent most of the class making the slides
- Everyone gathered the courage to come up and talk through what they had learned

8. Finale

- Just this class we did a big group table quiz which everyone no doubt did well in

Certificates

Thank you!

Please let me know if you have any question or feedback (about the course, CTYI, or anything astro!

All materials will be found here:
https://github.com/farrencc/ctyi_astronomy

I'm making notes for everything at the moment which will be ready soon so keep an eye out for changes.
If you forget please feel free to contact me through CTYI