How The Universe Got That Way

13 billion years ago (more or less) the universe was born in what is termed the "big bang". It was a hot, dense soup of particles and photons. Now, the universe is a big, cold, largely empty space populated by galaxies, stars, planets—and you and me.

How did it get this way? *And how did we figure this out?*

These are the topics of this course.

As you come in:
- Get a name tent
- Introduce yourself to your neighbors
- Start chatting
- Introduce yourself to me, if you'd like!

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How Class Will Go

The first 10 minutes:	Introductions & chatting
The first hour:	Physics principles
The second hour:	What does this teach us?
The last 10 minutes:	Mysteries and extensions
Anytime:	Questions
Between classes:	Lunch and conversation

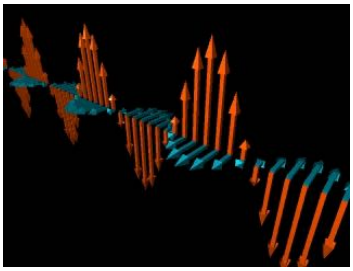
Physics Principles

Electromagnetic Waves

Photon Model

Interactions with Matter

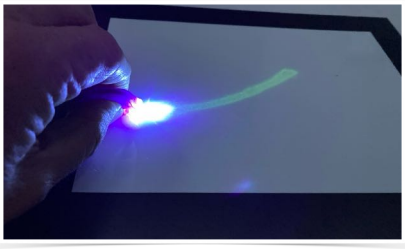
The electromagnetic wave.



An oscillating charge will emit an electromagnetic wave.
It's a wave of electric and magnetic fields.

Interaction of Light With Matter

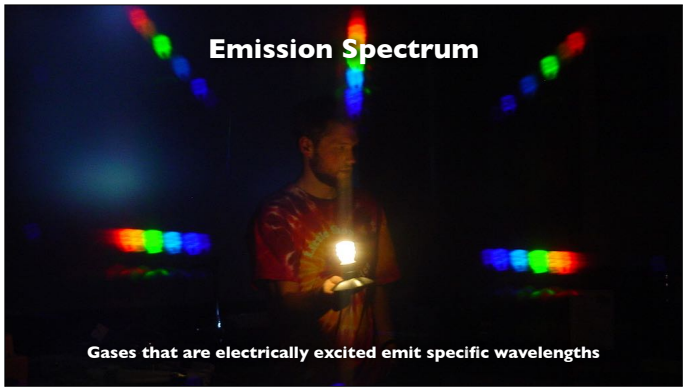
Touch (gently!) different color flashlights to the glow-in-the-dark surface.
Which colors leave trails?



Continuous Spectrum

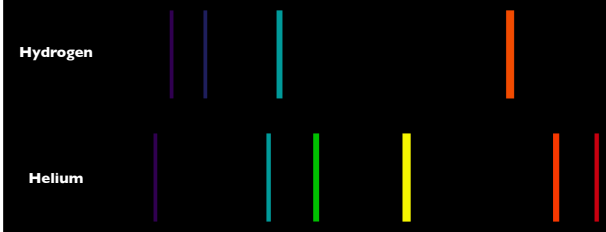
Things that are hot emit a continuous spectrum of light.

Emission Spectrum



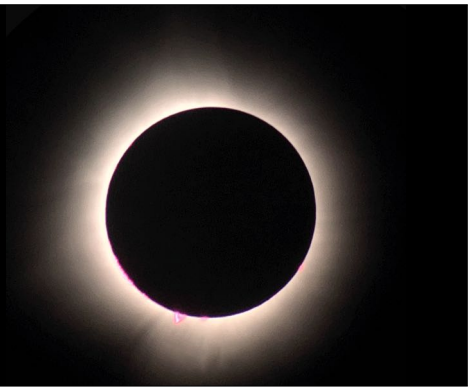
Gases that are electrically excited emit specific wavelengths

Line Spectrum

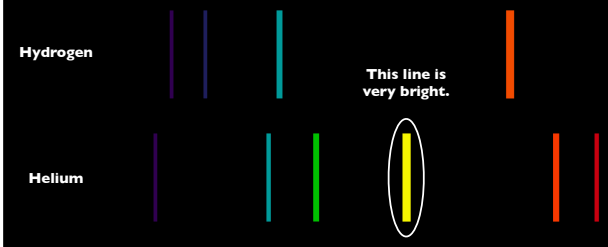


Gases that are electrically excited emit specific wavelengths

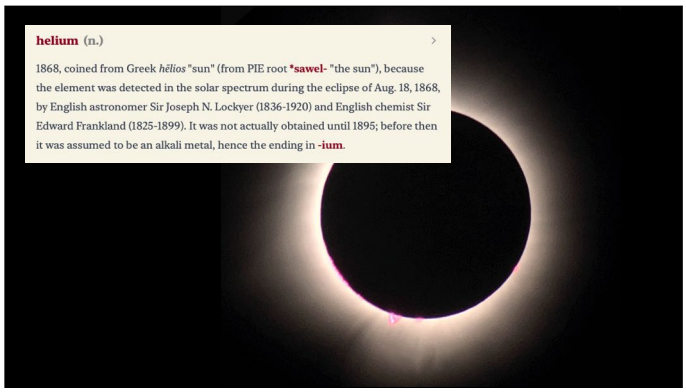
During a solar eclipse, you can see the spectrum of the corona



Line Spectrum



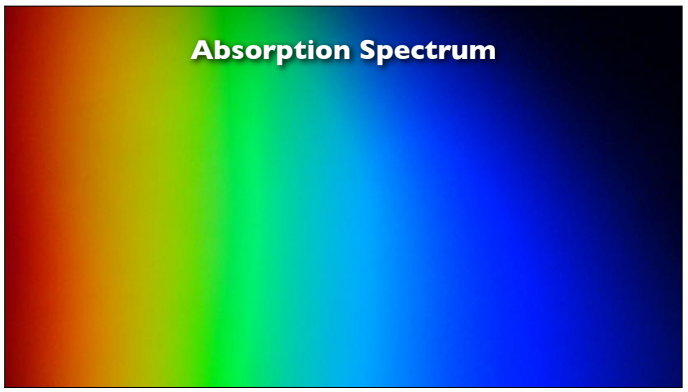
Gases that are electrically excited emit specific wavelengths



helium (n.)

1868, coined from Greek *hēlios* "sun" (from PIE root ***sawel-*** "the sun"), because the element was detected in the solar spectrum during the eclipse of Aug. 18, 1868, by English astronomer Sir Joseph N. Lockyer (1836-1920) and English chemist Sir Edward Frankland (1825-1899). It was not actually obtained until 1895; before then it was assumed to be an alkali metal, hence the ending in **-ium**.

Absorption Spectrum

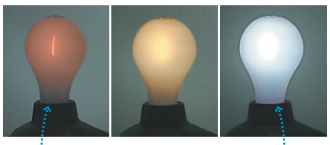


The Electromagnetic Spectrum

Wave	Wavelength	Photon energy
FM Radio	10 feet	½ millionth eV
Microwave	6 inches	8 millionths eV
Thermal Radiation	1/10 of a hair	1/10 eV
Red	10x red blood cell	2 eV
Blue	6x red blood cell	3 eV
Ultraviolet	4x red blood cell	4 eV

As things get warmer, the wavelength of emitted radiation gets shorter.

Increasing filament temperature

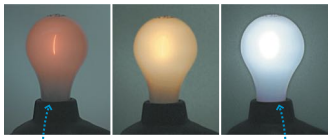


At lower filament temperatures, the bulb is dim and the light is noticeably reddish.

When the filament is hotter, the bulb is brighter and the light is whiter.

Things get brighter and bluer.

Increasing filament temperature



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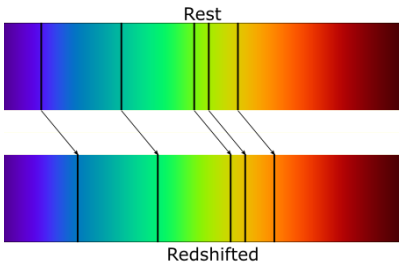
The Doppler Effect

Question

When a source of waves is approaching you, how does this change the wavelength?
When a source of waves is moving away from you, how does this change the wavelength?

Redshifts and Blueshifts



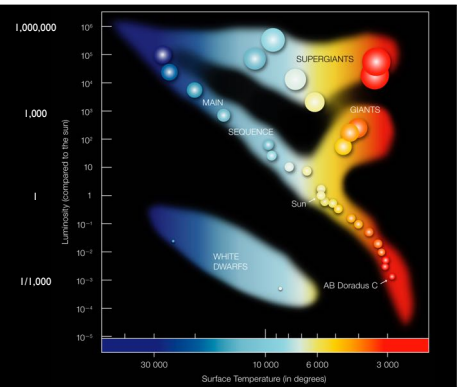
Question

With your group, come up with your best guess:

Of the 100 nearest stars to Earth, how many are visible to the naked eye?

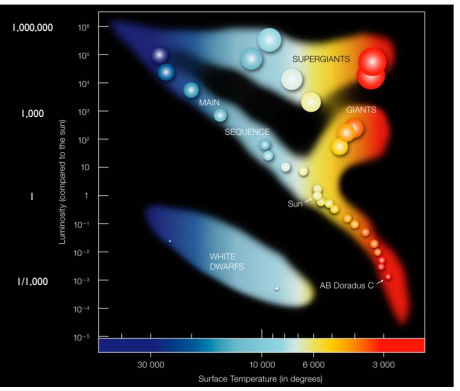
Hertzsprung-Russell Diagram

Hotter means bluer and (generally) means brighter



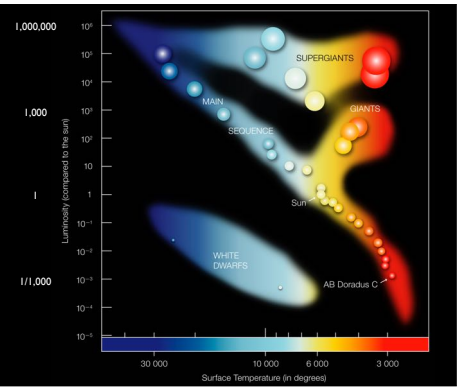
Hertzsprung-Russell Diagram

Question
What other trends do you notice?

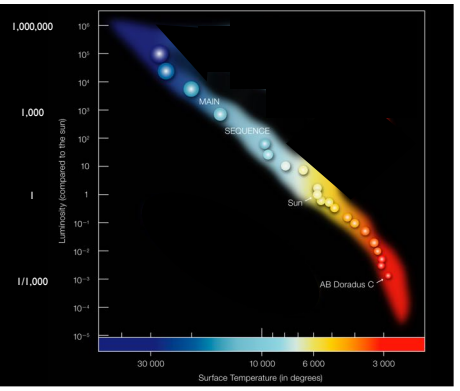


If you know a star's color, you know its brightness.

This lets you figure out how far away it is.

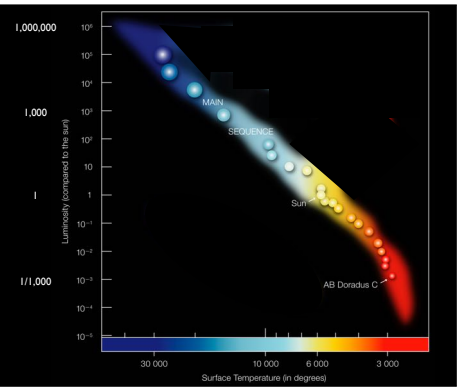


The brightest stars on the main sequence are 100,000,000 times brighter than the dimmest stars.



Question
Which type of star will live longer:

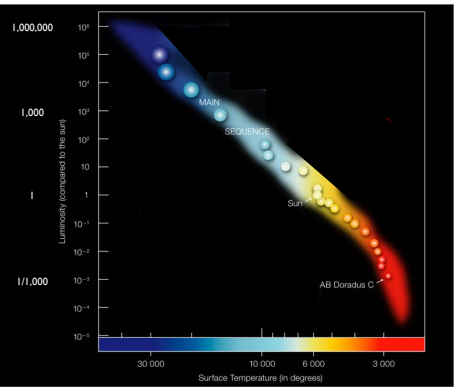
Bright and blue
or
Dim and red



The dim, red stars live longer.

So most of the stars around us are dim and red.

We just can't see them.



The Light-Year

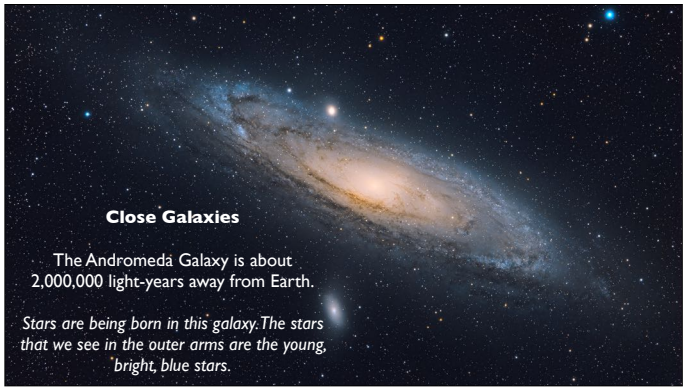
A light-year is a measure of distance, the distance light travels in 1 year.

For perspective:

Light could travel all the way around the Earth 7 times in 1 second.

A globular cluster near the small Magellanic cloud.

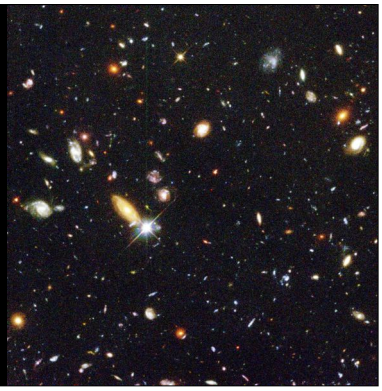
What can you say about the age of the globular cluster?



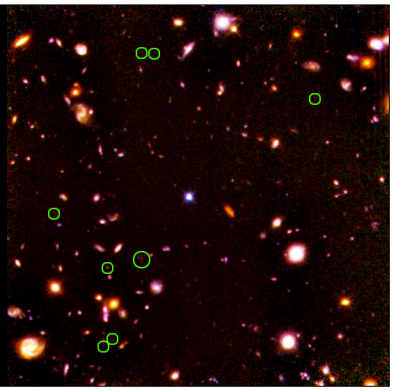
Distant Galaxies

Why are *they* red?

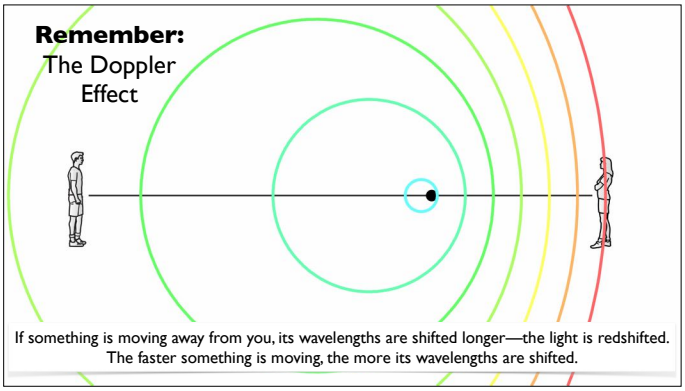
It's not because they are old. The brightest stars in spiral galaxies are the young stars. They should appear blue. But they don't.



Also:
The farther away a galaxy is, the redder it appears.



Remember:
The Doppler Effect

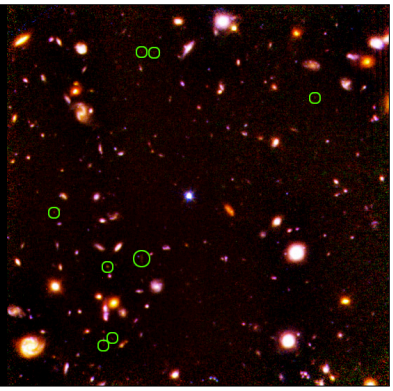


If something is moving away from you, its wavelengths are shifted longer—the light is redshifted. The faster something is moving, the more its wavelengths are shifted.

Question

On the small whiteboards, give a one sentence explanation for this fact:

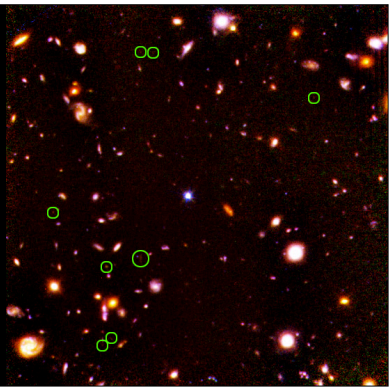
Distant galaxies appear redshifted.
A galaxy twice as far away is redshifted twice as much.



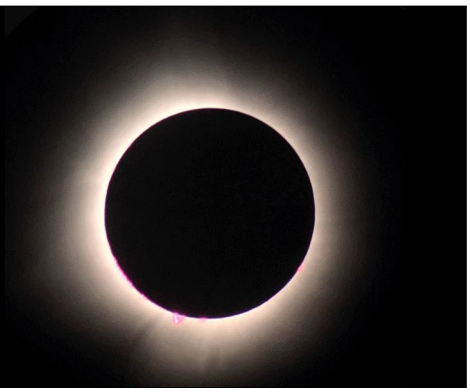
Question

How do we explain this?

We'll come back to this in the 5th week, when we talk about the Big Bang.

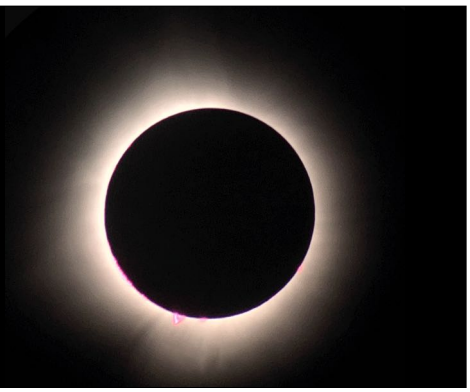


In the spectrum of the sun, you see lines for hydrogen, helium, carbon and many other elements.



But in the spectra of some other stars you only see lines for hydrogen and helium.

Why?



Anywhere you look in space, you can detect radio waves.

Where did they come from?