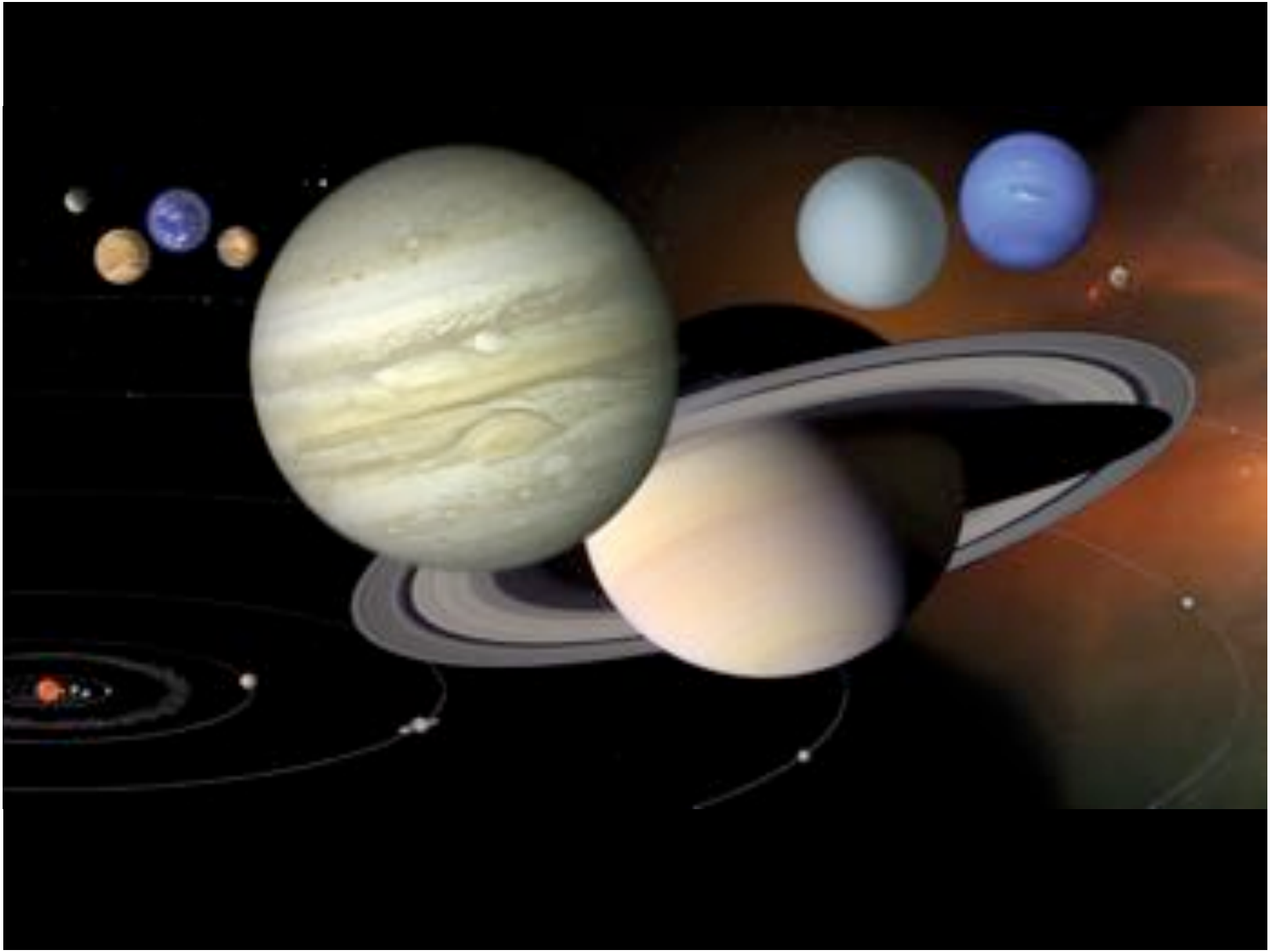


Dark Matter & Cosmology

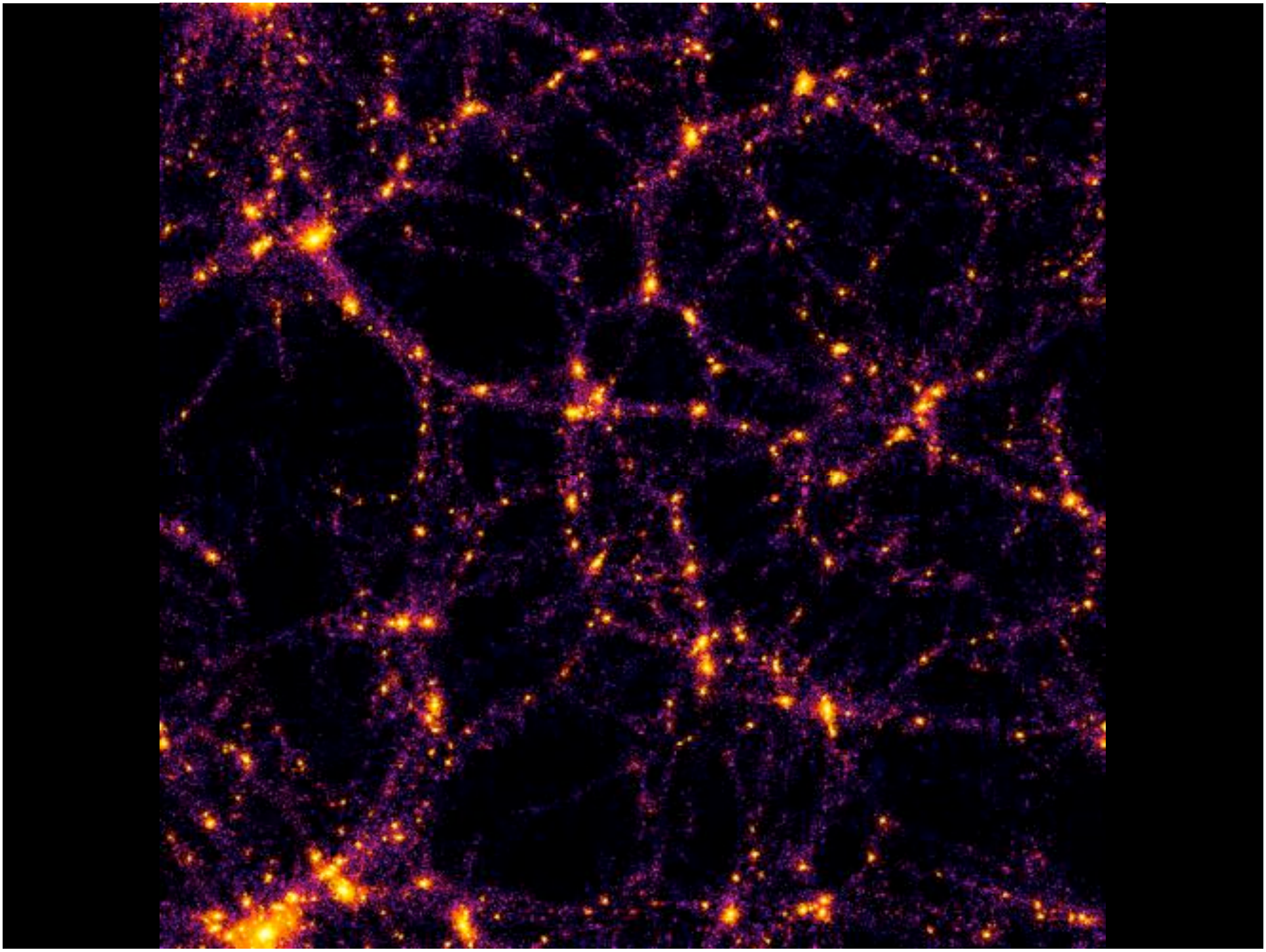
Jes Ford

PhD Student at UBC





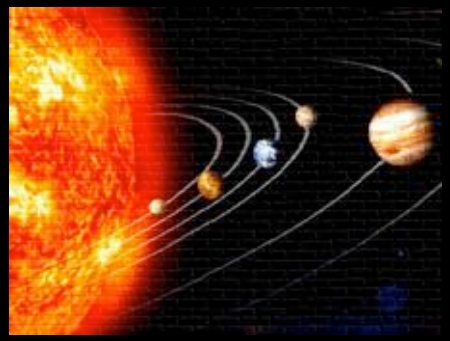
The Night Sky



Sizes in the Universe

~ 1 m

~ 10^7 m



~ 10^{13} m

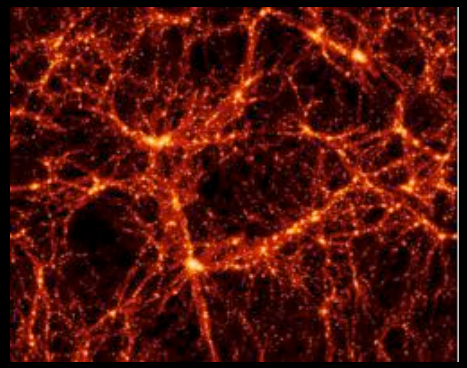
~ 500 light minutes

~ 10^{21} m

~ 100,000 light years

~ 10^{23} m

~ 10 million light years



> 10^{24} m

> 100 million light years

Flythrough the Universe

What is Dark Matter?

- We don't know what it is…
- What we know:
  - Its invisible
  - It has a lot of gravity
  - It is all around us

- Gravitational Lensing is one way to measure it

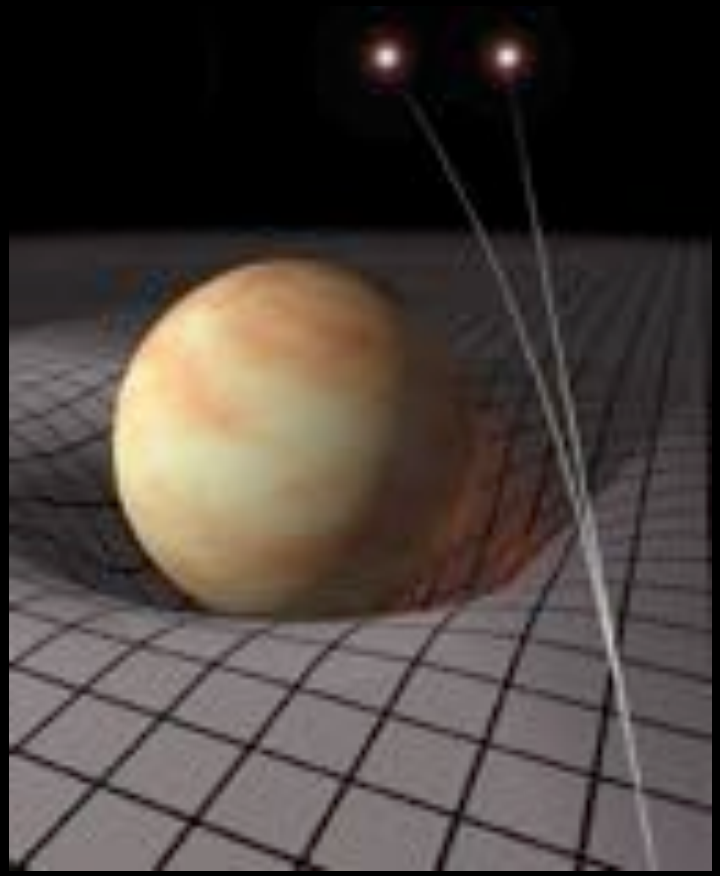
What is Gravitational Lensing?

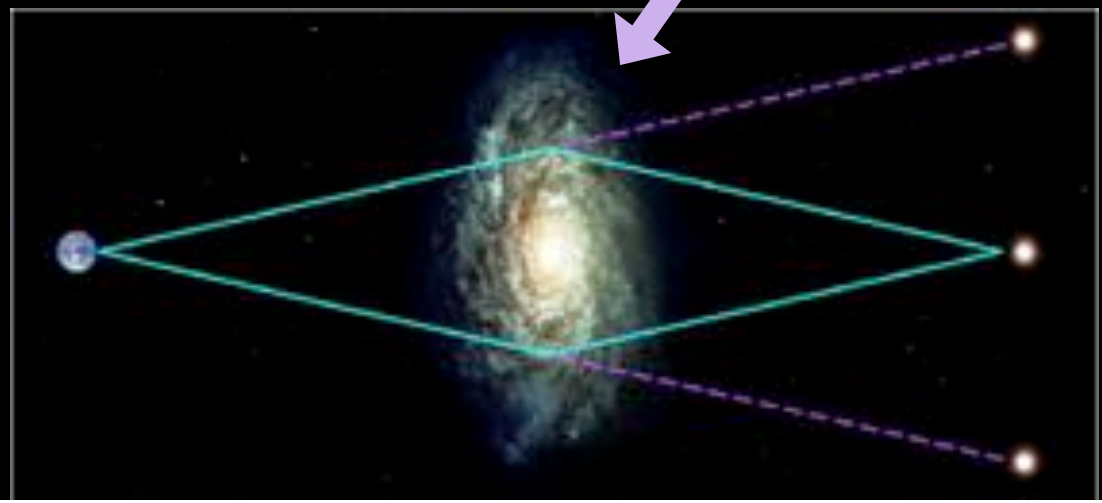
What is Gravitational Lensing?

Its an optical illusion!

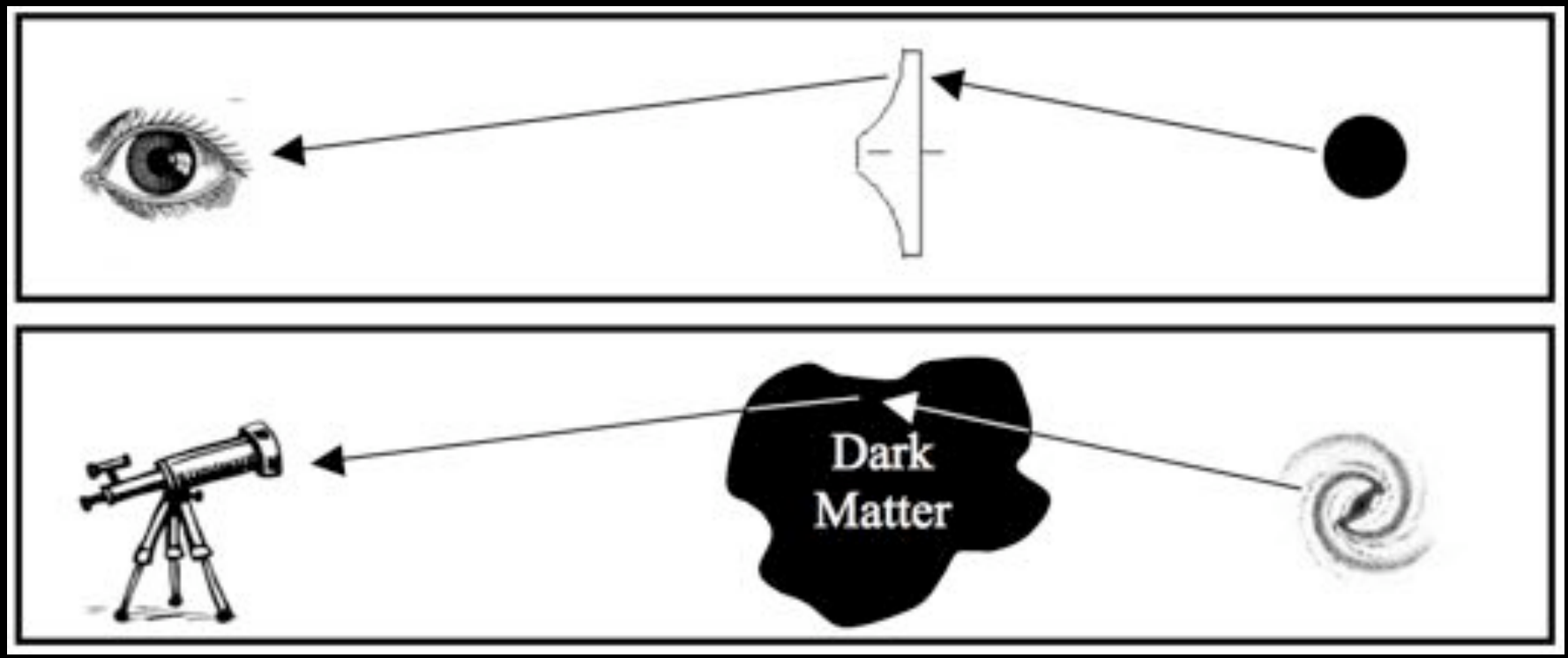
A distant background galaxy appears different than it really is…

The light traveling to us has been bent by gravity.

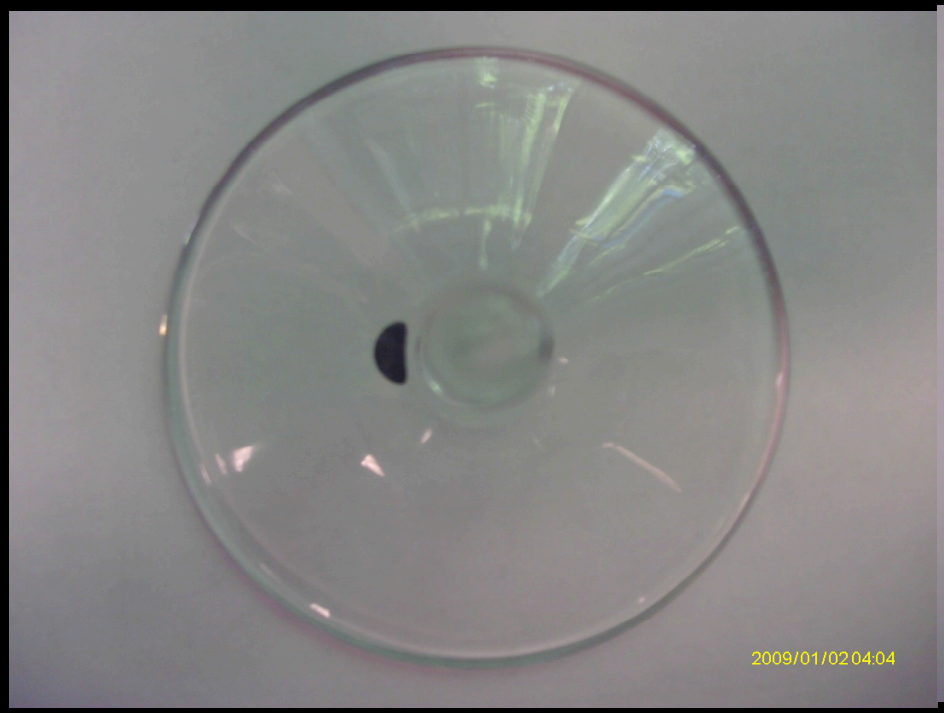


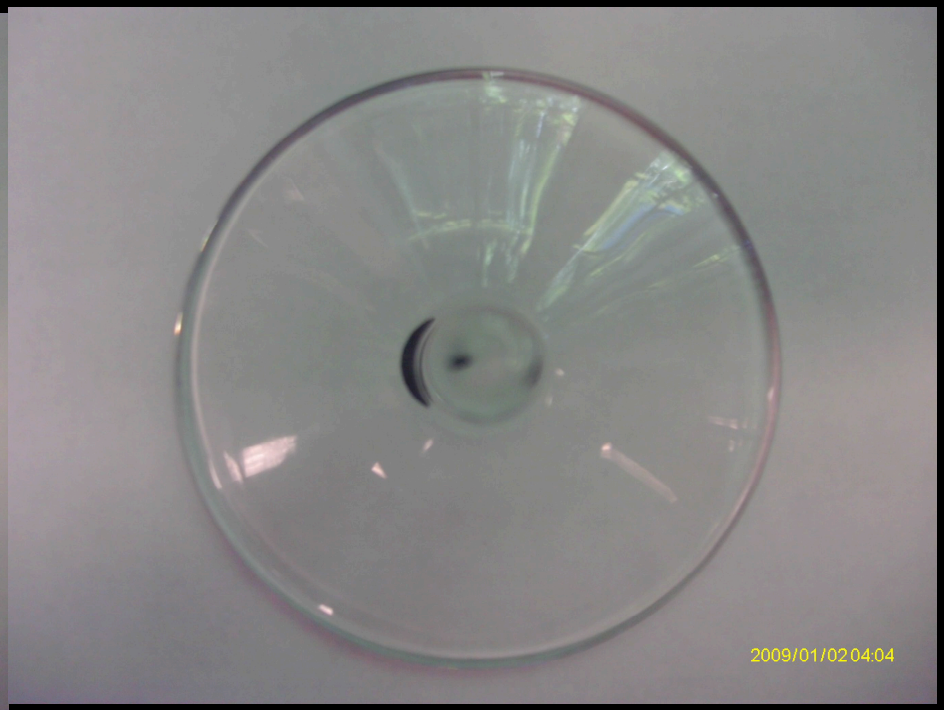


Gravitational Lensing Activity



Gravitational Lensing Activity

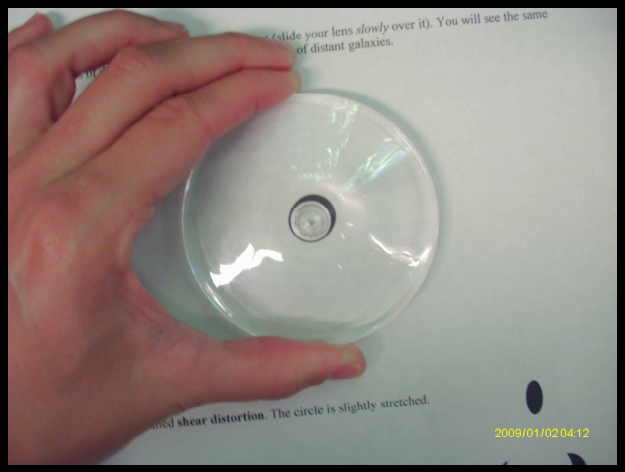


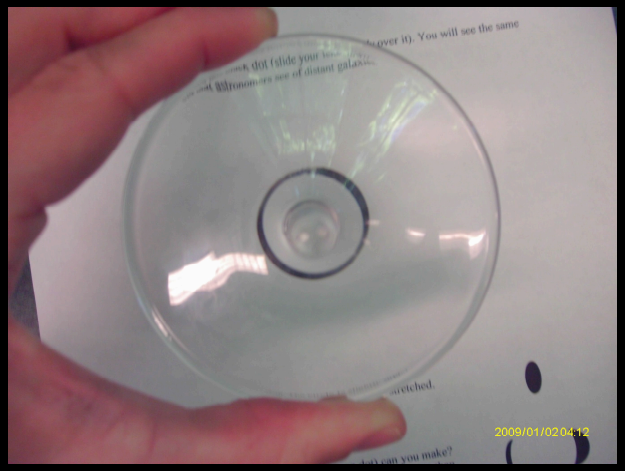


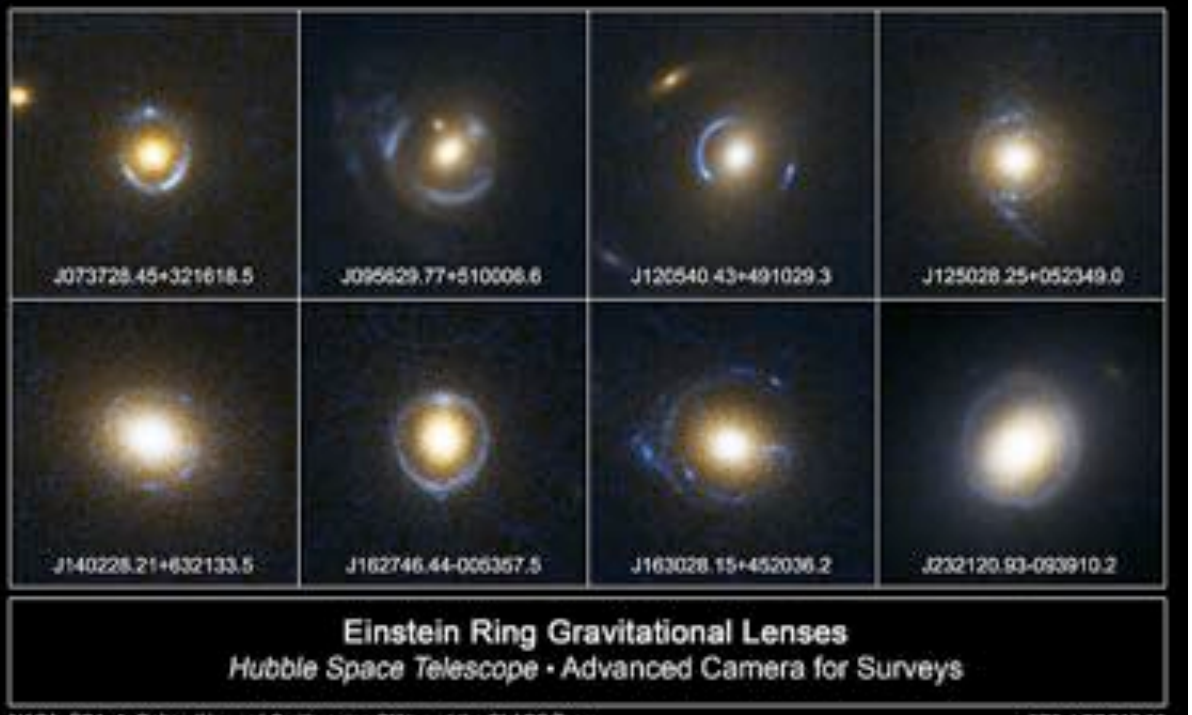
How does a black hole create optical illusions?

Multiple Images: Einstein Crosses

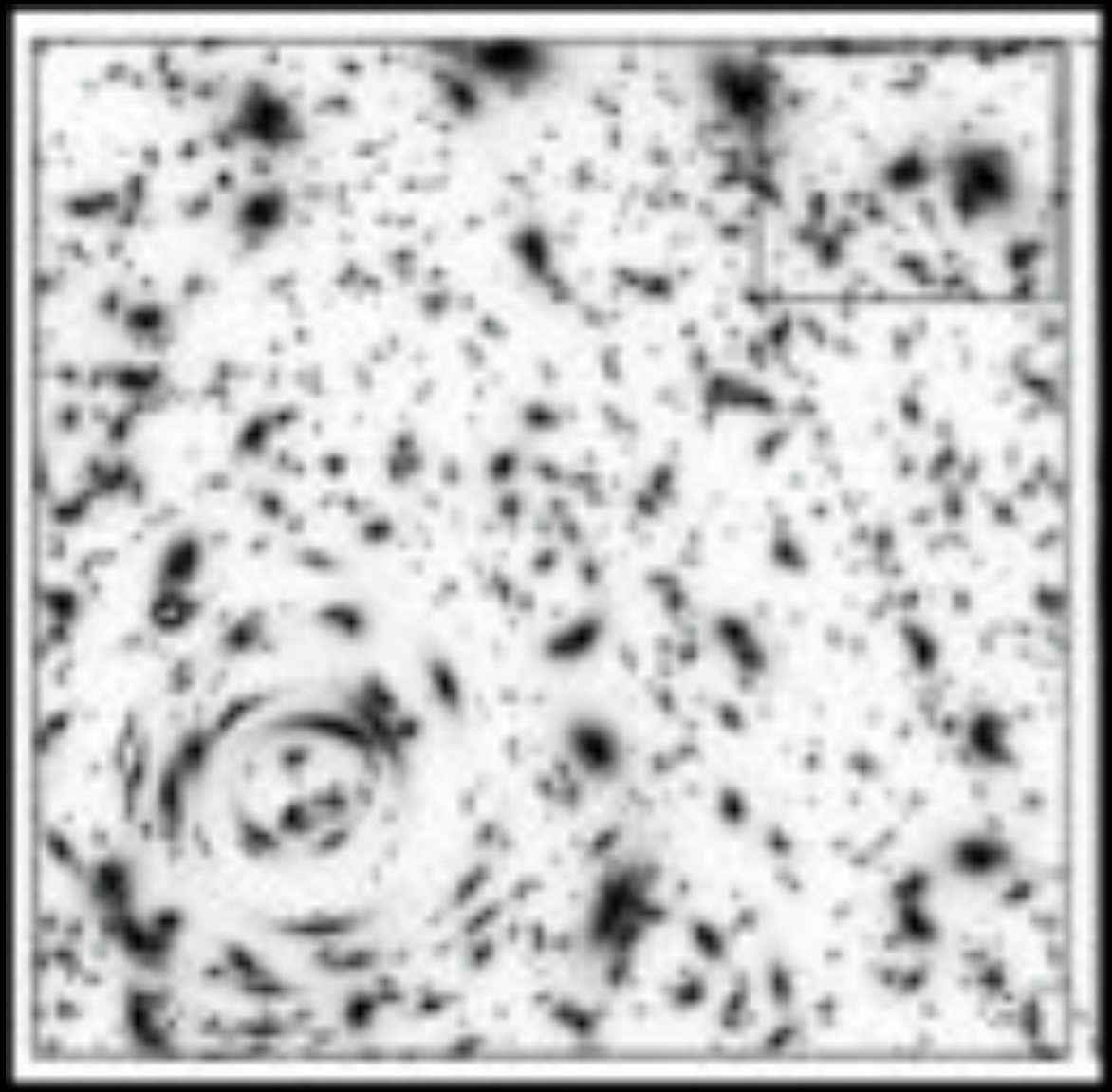
Einstein Rings







Find the gravitational lens



Find the gravitational lens

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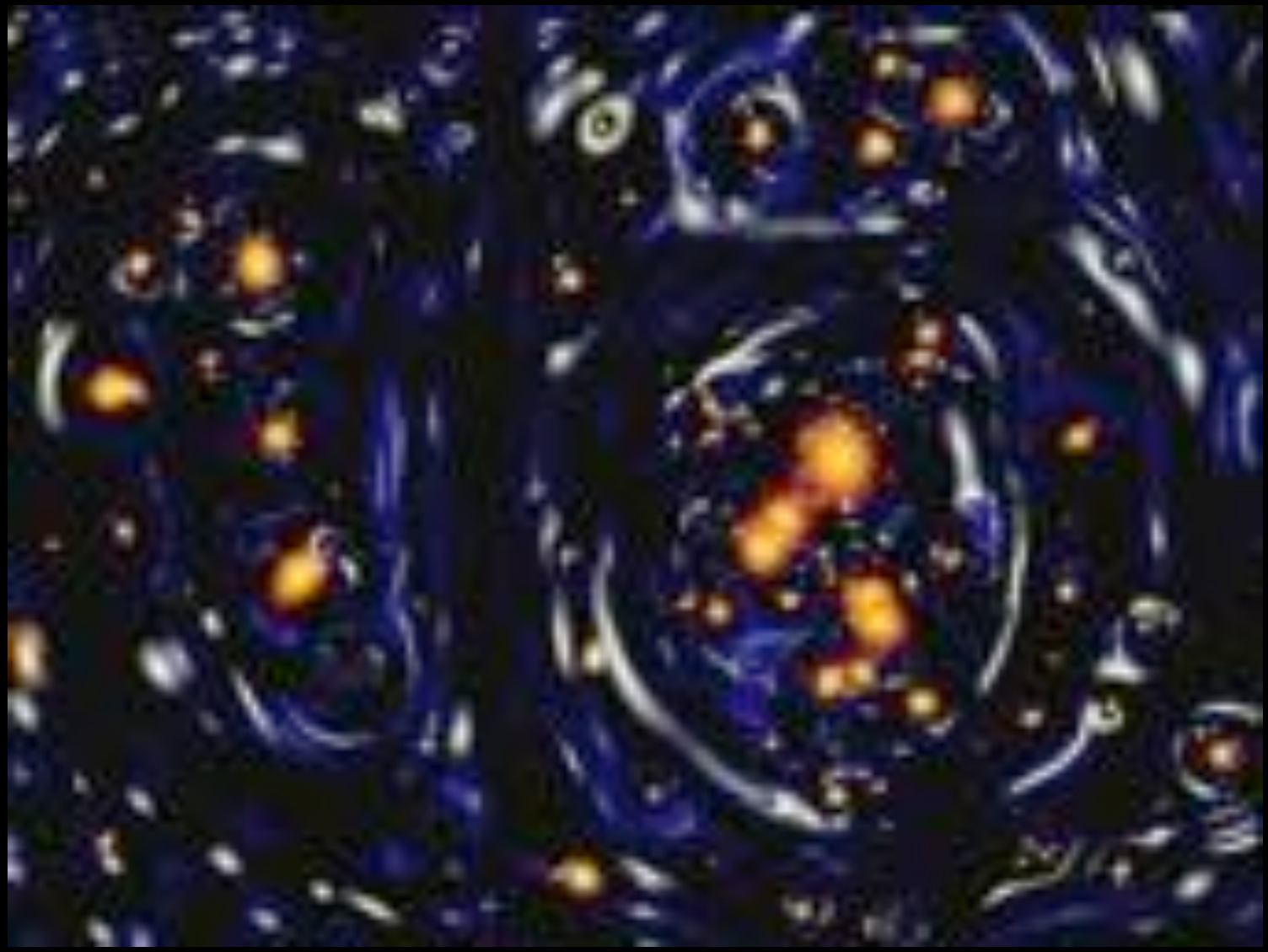

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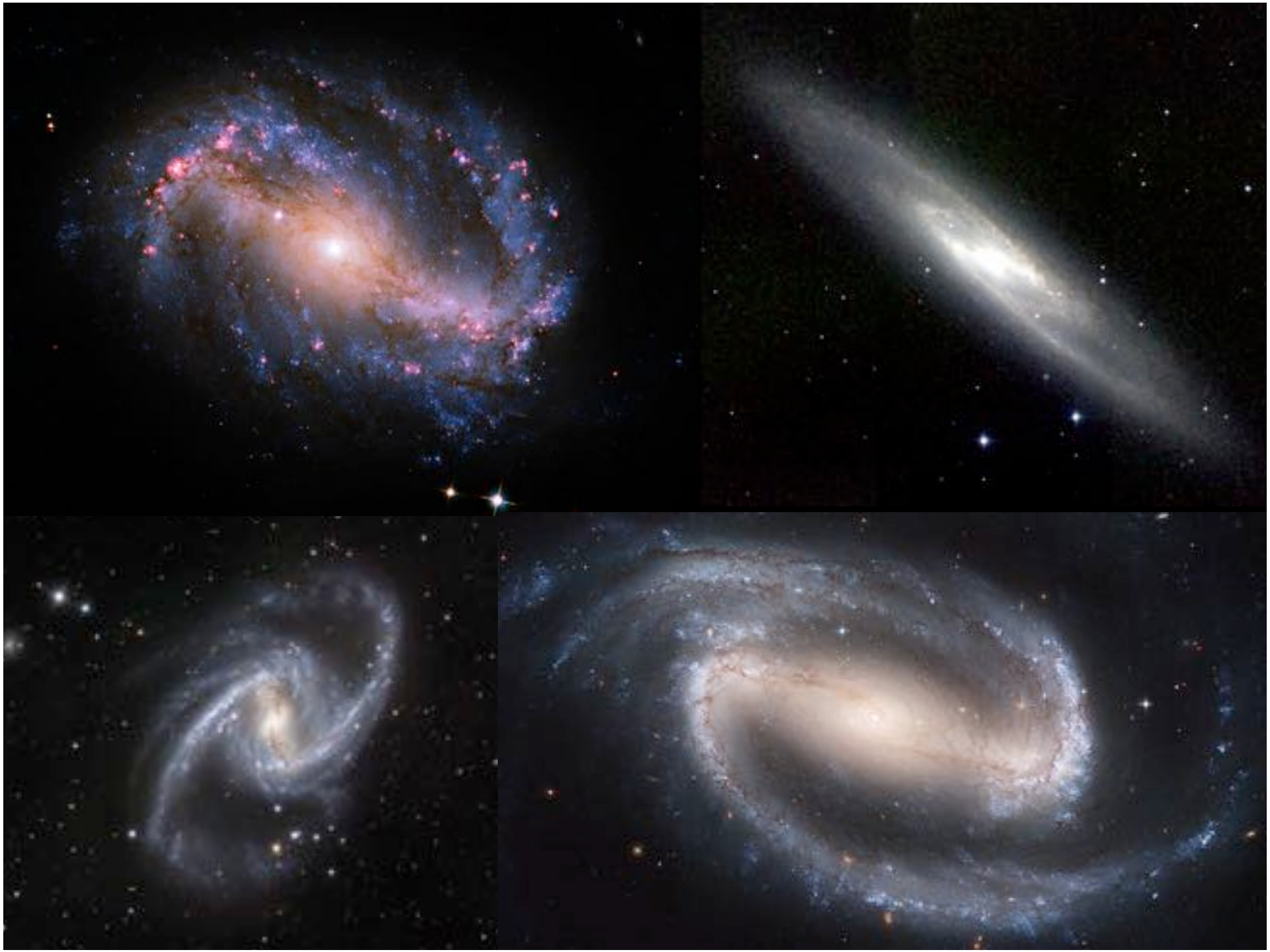
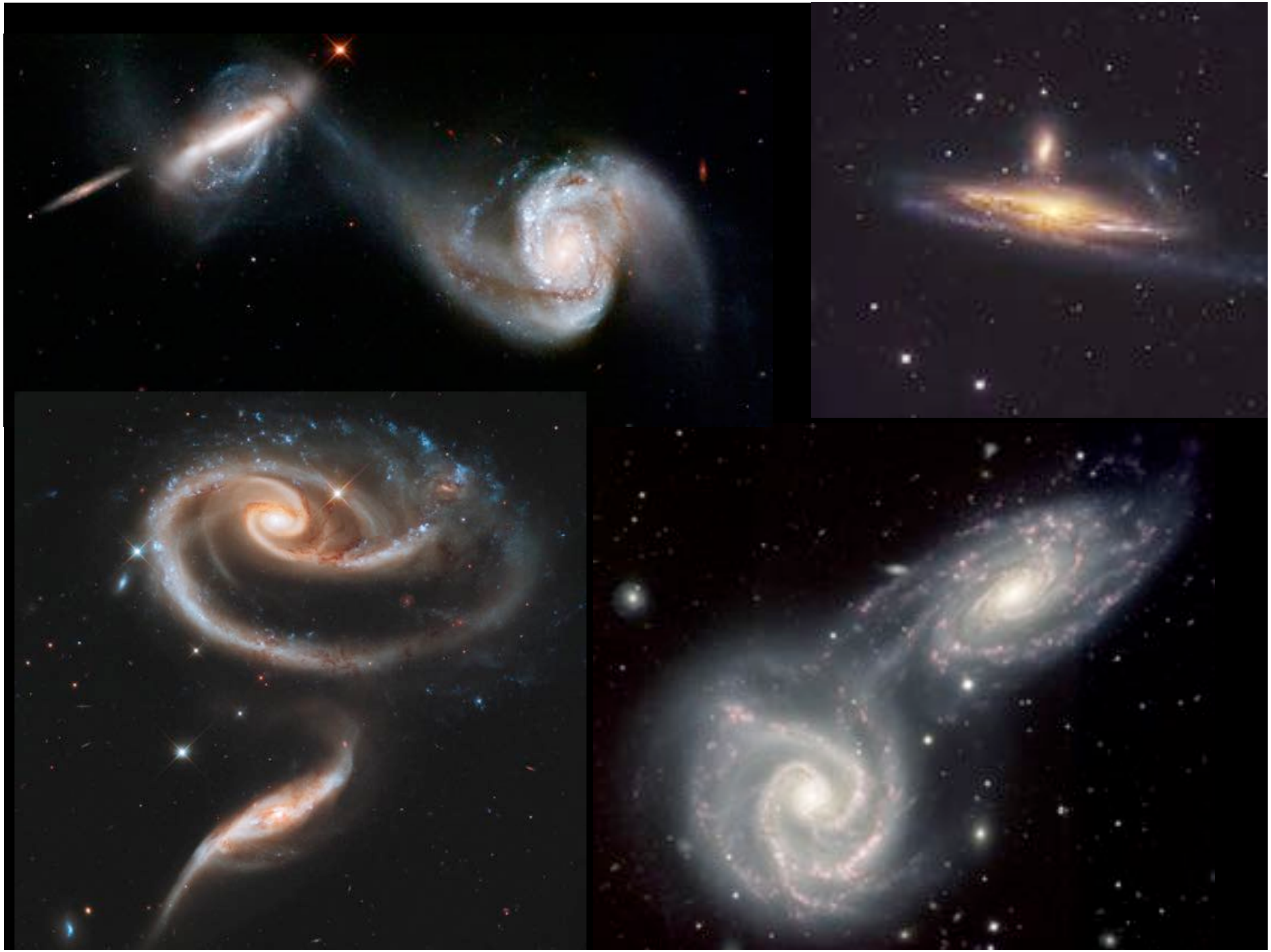
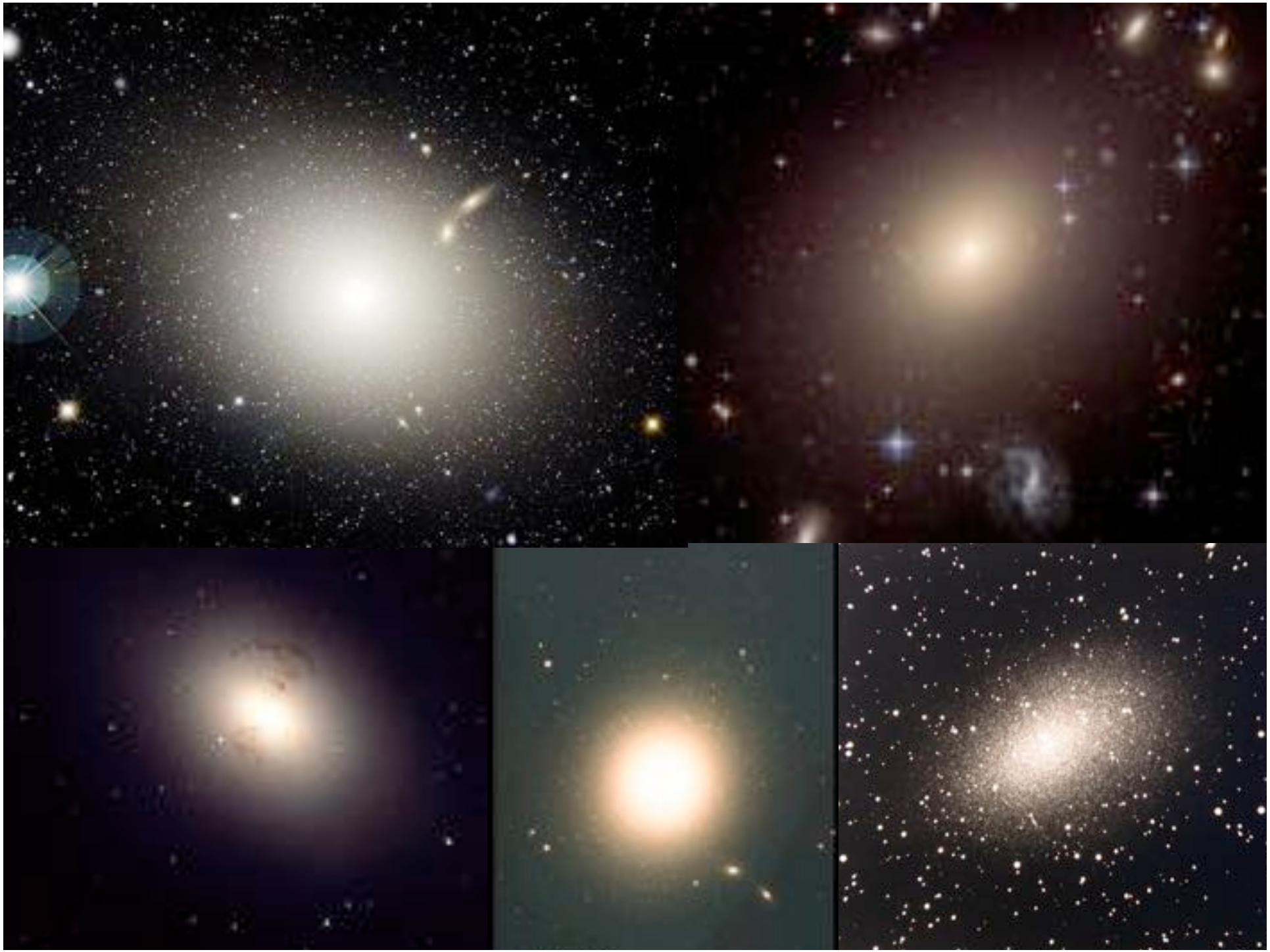




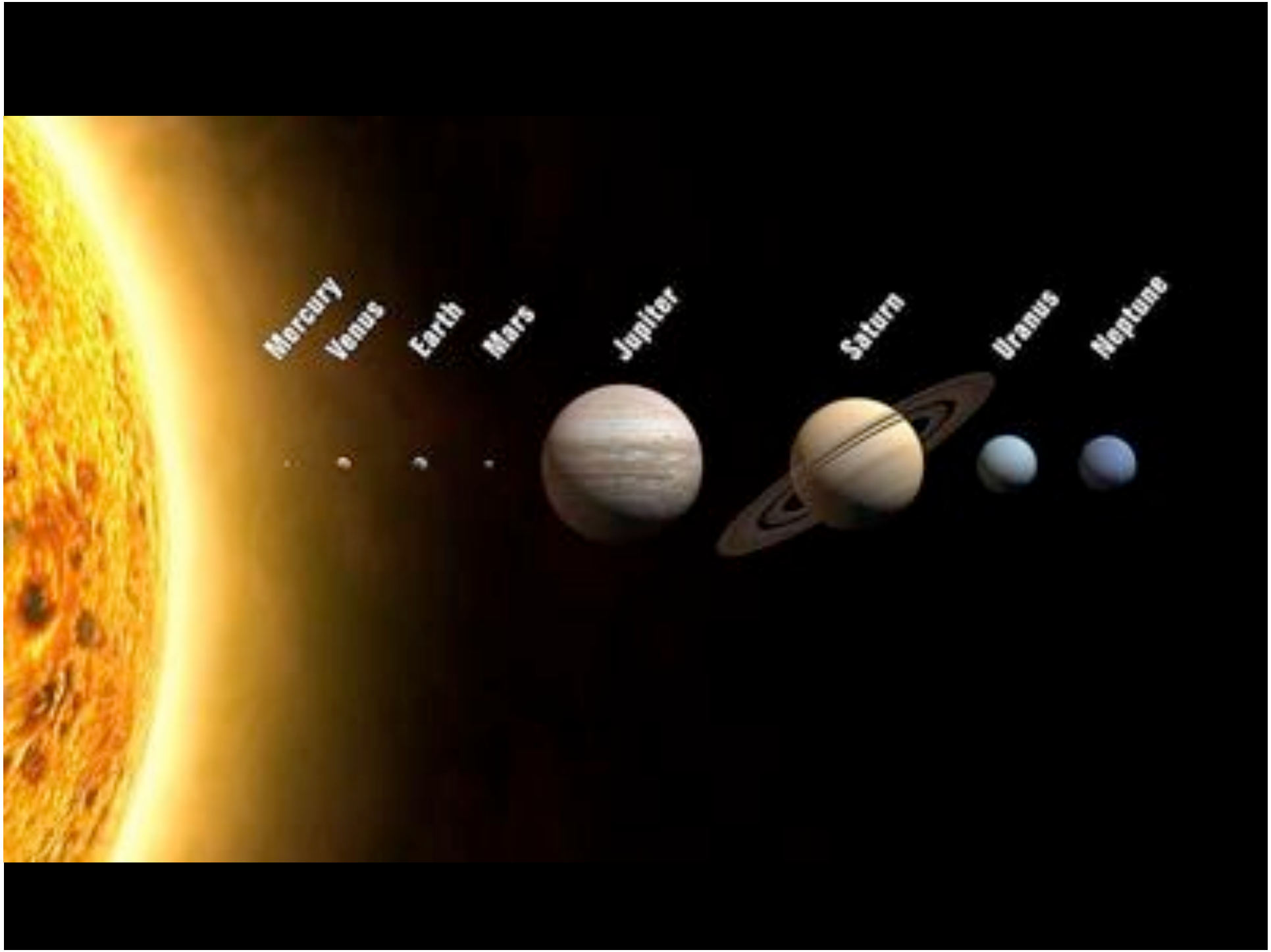


Friday: Galaxies

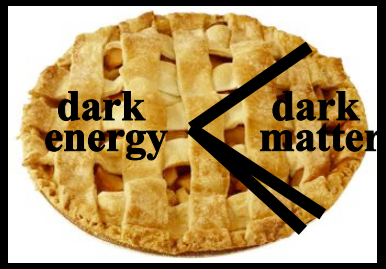
- **Remember:** what makes up a galaxy? What are some different types of galaxies?

- **Friday:** we will help real scientists to classify different types of galaxies, and record any unusual findings in real astronomical images of the universe.

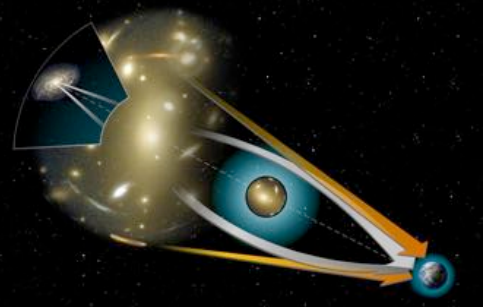
Extra Slides


Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune

Things to take away



The biggest mysteries in physics & astronomy are Dark Matter and Dark Energy.



One way we can study Dark Matter is by using Gravitational Lensing.

Gravitational Lensing is just an optical illusion when light is bent by something very massive.

Life as a scientist is very rewarding!
Challenges, problem-solving, creativity, traveling…

Observations

Space versus Ground…

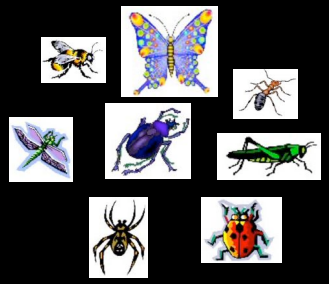
Hubble Space Telescope

Canada-France-Hawaii Telescope

Magnification

Analogy: **Bug Counting**

The number of insects you detect depends on the strength of your magnifying glass.



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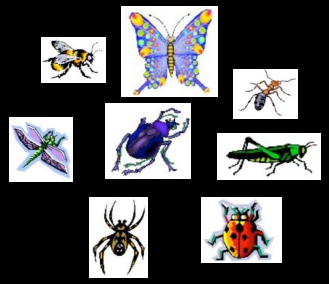
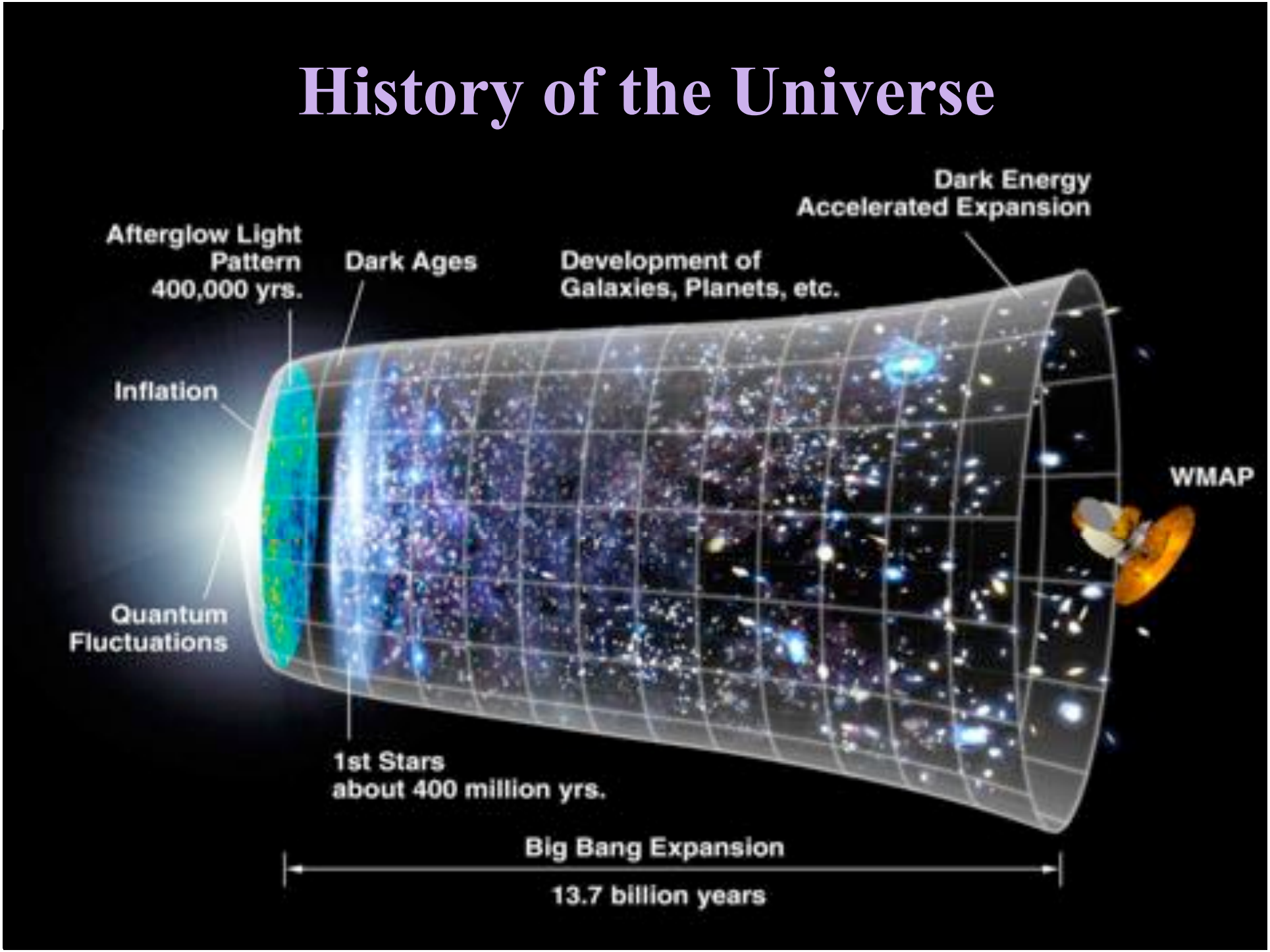
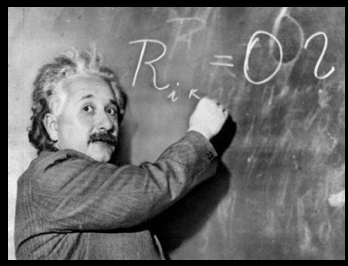


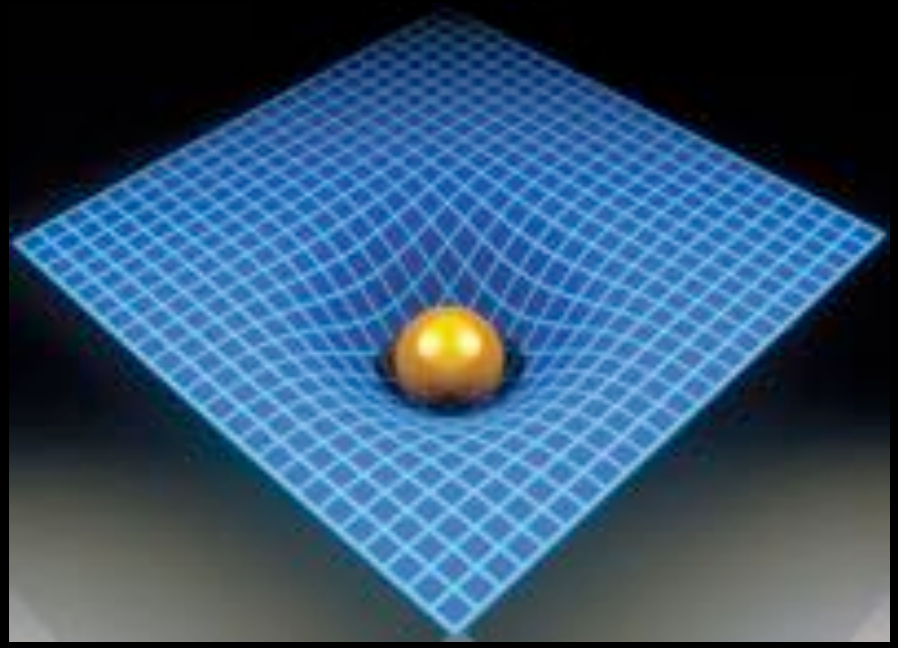
The same will be true for counting galaxies behind a *gravitational* lens.

History of the Universe

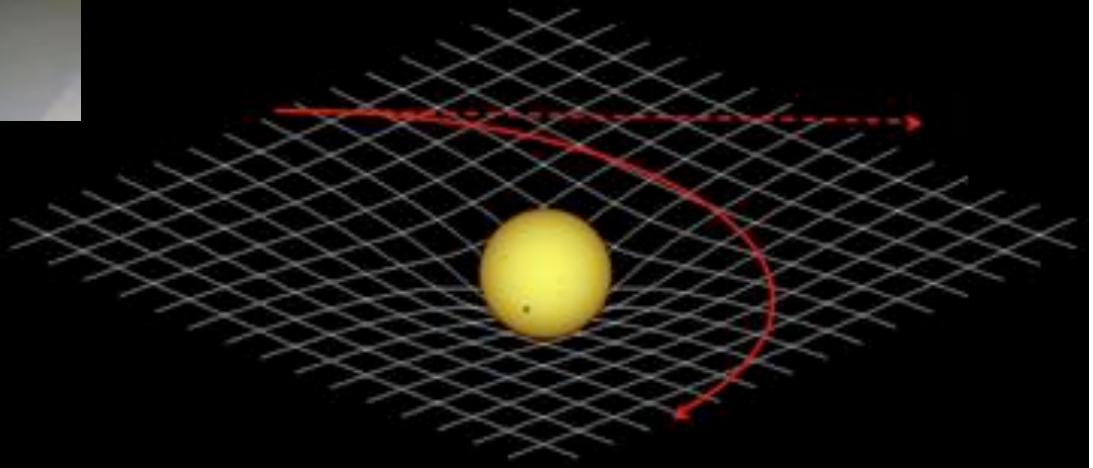


General Relativity





Einstein's theory of gravity:
Space-time is warped by the presence of mass.



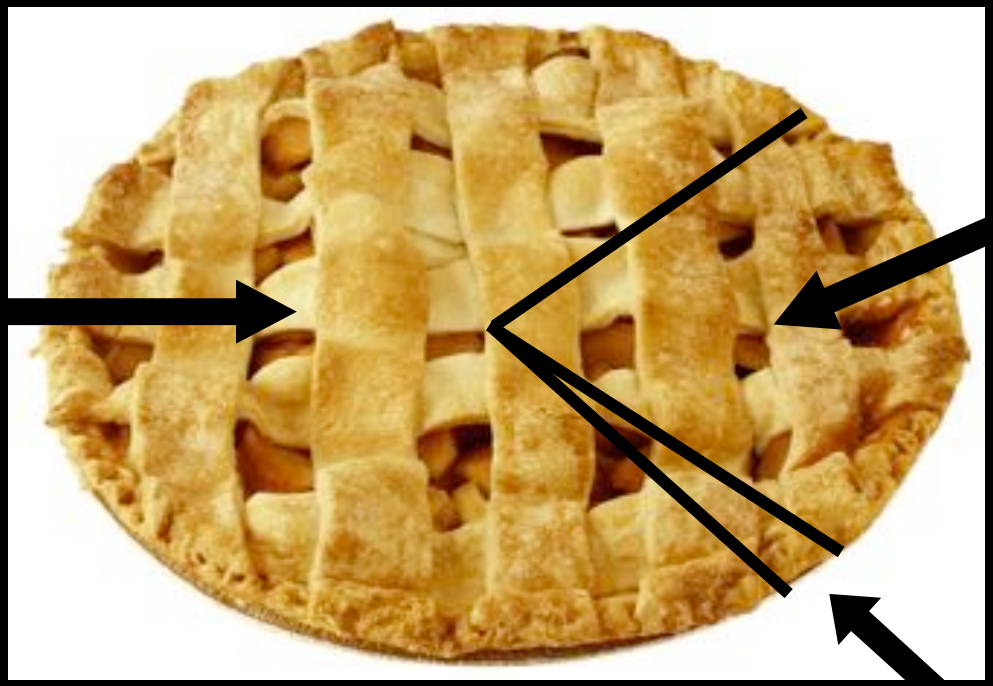
2D Analogy: **bowling ball on a trampoline**

Pie chart of the entire Universe

~ 74%

Dark Energy

causing the universe's expansion to speed up



~ 22%

Dark Matter

cold, heavy, invisible stuff

only ~ 4% **Normal Stuff**

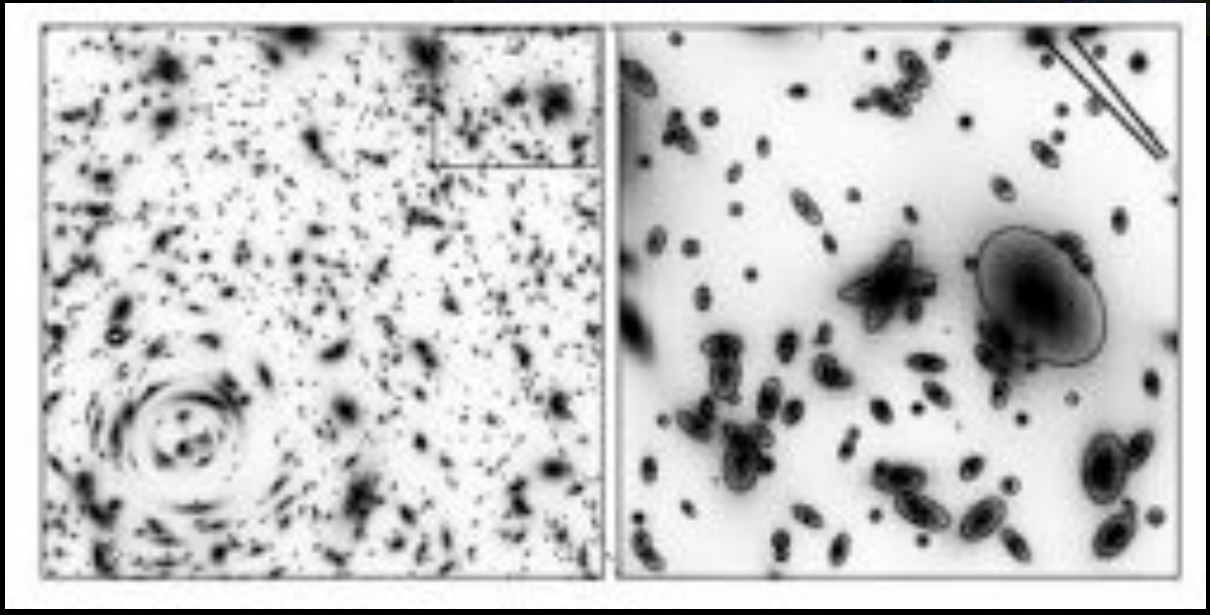
everything around us made of atoms, all things in the universe that we can actually see and interact with

Evidence for Dark Matter

It all has to do with gravity…

- Galaxies rotate too fast
- Clusters of galaxies orbit their centre-of-mass too fast
- Structure Formation: we couldn't even exist without it!
- Gravitational Lensing

Flavours of Lensing



Strong Lensing

arcs, multiple images,
big distortions you can *see*

Weak Lensing

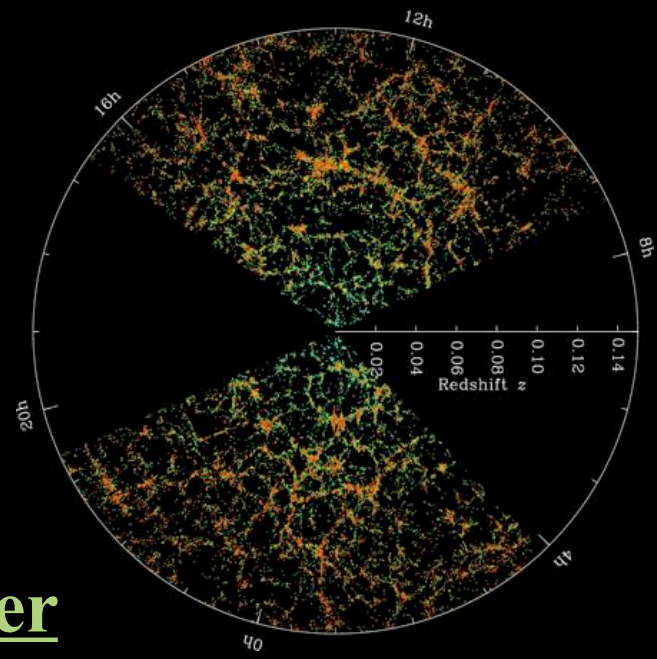
shapes are slightly
stretched out, distorted

Micro Lensing can detect less massive compact objects like black holes, planets, MACHOs

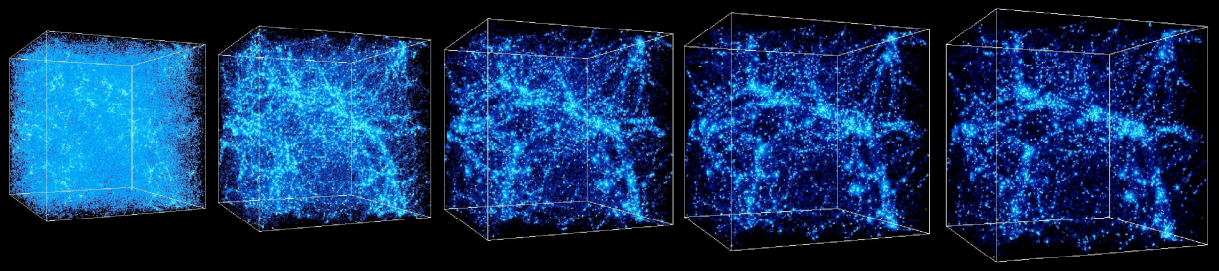
The biggest stuff in the universe

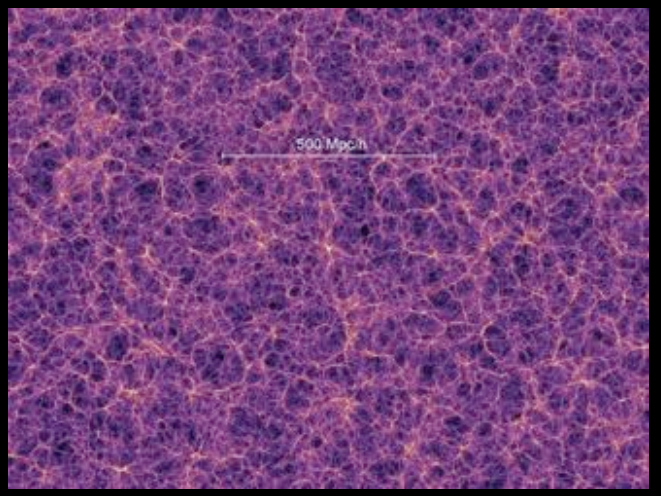
- **Cosmology**

  shows that galaxies are clumped together like a giant web, or huge foamy bubbles



- **Most of this stuff is Dark Matter**





- ***check out on youtube:*** Millenium Simulation Flythrough