

# The Importance of Observation

and other unfortunate issues in modern  
physics

# Scientific method is used daily



Say your car is overheating, how would you try to fix it?

# Scientific method

**Observation:** Engine is overheating....

**Hypothesis:** It must be the fan!

**Experiment:** Check to see if fan is working

**Accept/Reject Hypothesis:** Did it work? If not  
form new hypothesis

# Induction vs deduction

Inductive reasoning goes from specific to general

Example:

- Most of my Egyptians friends have brown eyes
- Therefore most Egyptians have brown eyes

Deductive reasoning goes from general to specific

Example:

- All people breathe oxygen
- Tarek is a person and therefore he breathes oxygen

Do we use inductive or deductive reasoning in science?

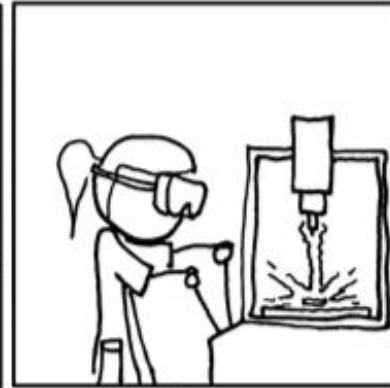
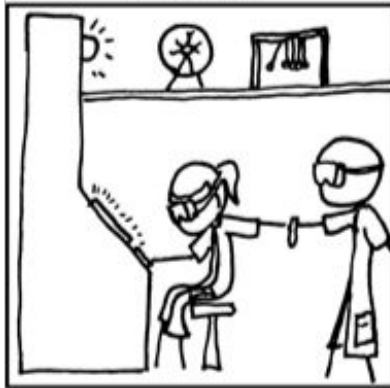
# Empirical Falsification

**Theory:** Everytime the engine overheats, it is due to a broken fan.

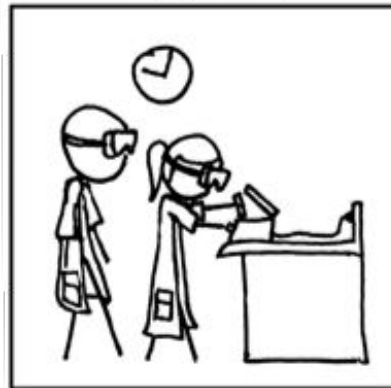
Can this theory be proven true?



# MOVIE SCIENCE MONTAGE



# ACTUAL SCIENCE MONTAGE



# Germ Theory

In the 1860s, two competing beliefs:

1. Biological cells can be spontaneously generated

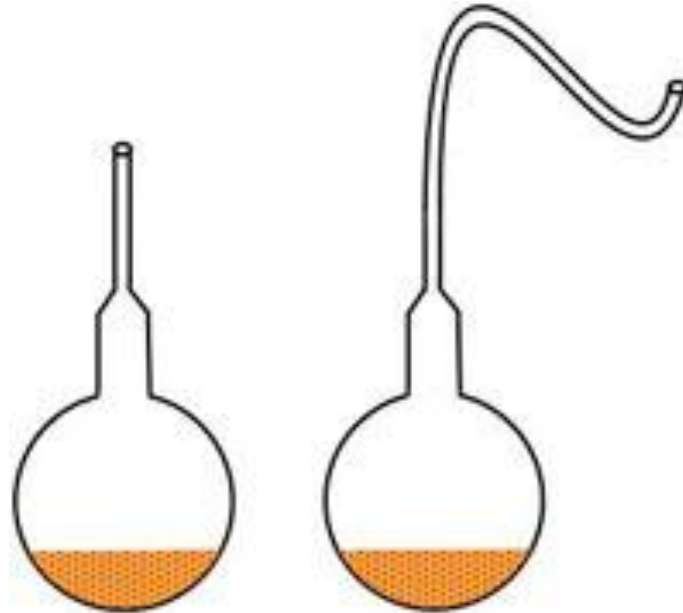
-or-

2. Biological cells come from other cells

Both theories were used to explain why food and drink rots or spoils

# Pasteur's experiment

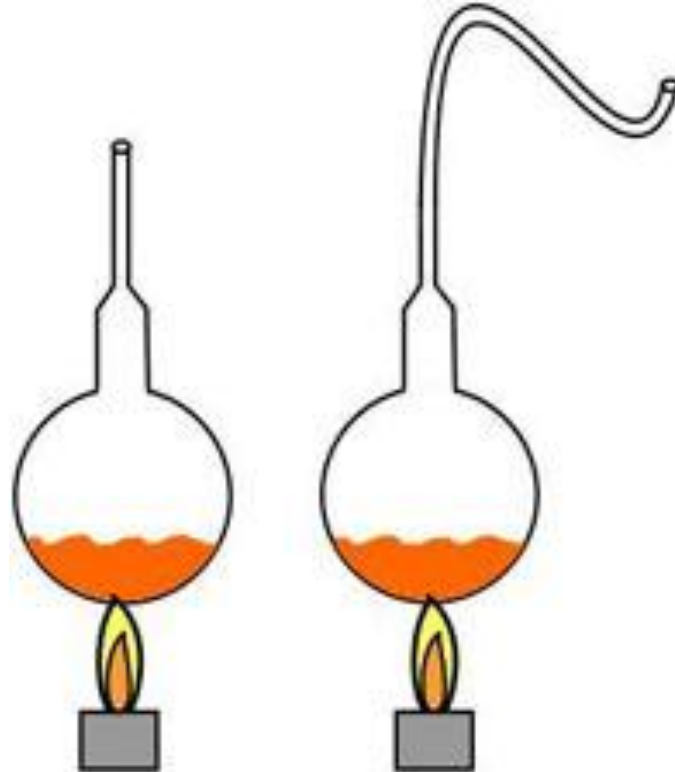
1. Prepare two different containers with chicken broth





# Pasteur's experiment

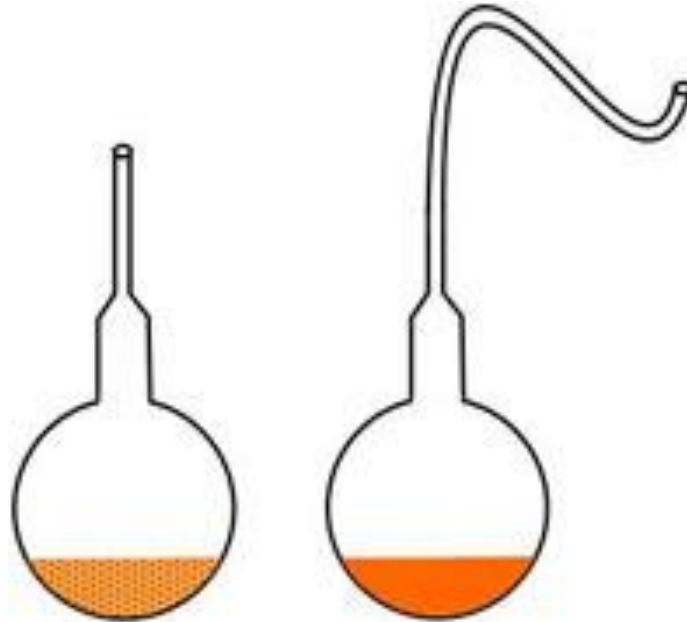
2. Boil the chicken broth to kill all living organisms inside.



# Pasteur's experiment

3. Let the broth sit for many weeks

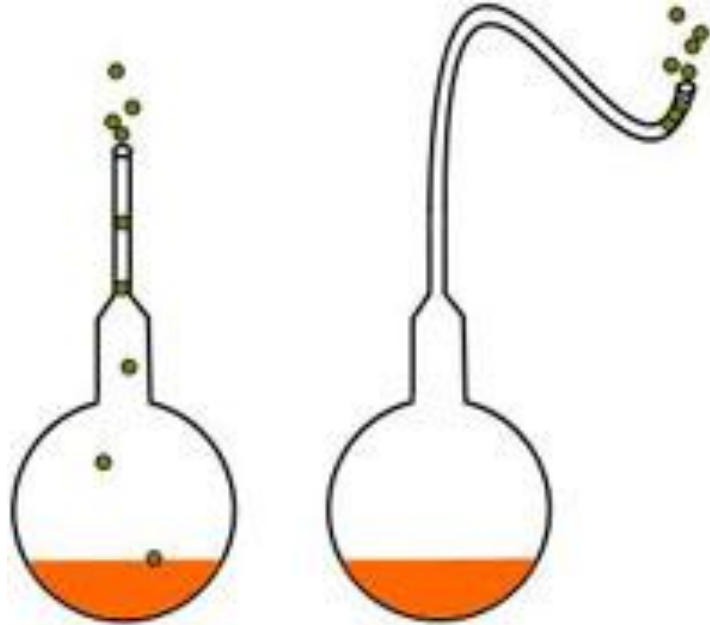
Result: the broth in the straight neck flask became cloudy and spoiled



# Pasteur's experiment

Pasteur was able to falsify the theory of spontaneous generation in favor that the germs had to come from elsewhere.

Notice the need for a **control** sample to compare with, and notice that this experiment can be **repeated** to test its accuracy



WHEN YOU SEE A CLAIM THAT A  
COMMON DRUG OR VITAMIN "KILLS  
CANCER CELLS IN A PETRI DISH,"

KEEP IN MIND:



SO DOES A HANDGUN.

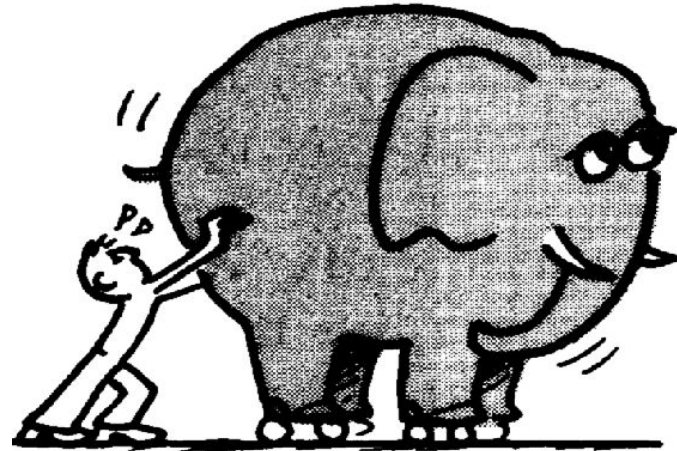
# Physics

The study of the fundamental laws of nature. It is meant to explain how objects move and behave as a result of their interactions.

# Theories of motion + Physical Laws

1. **First Law:** An object at rest or at constant velocity remains in its state of motion unless acted upon by external forces.
2. **Second Law:** The total force acting on an object can be measured by multiplying its (mass) x (acceleration) = (Force). (See Picture)
3. **Third Law:** If object A exerts a force on object B, then object B exerts an equal and opposite force on object A. (This is why it hurts to slap someone!)

## Newton's Second Law of Motion



# Gravitational force

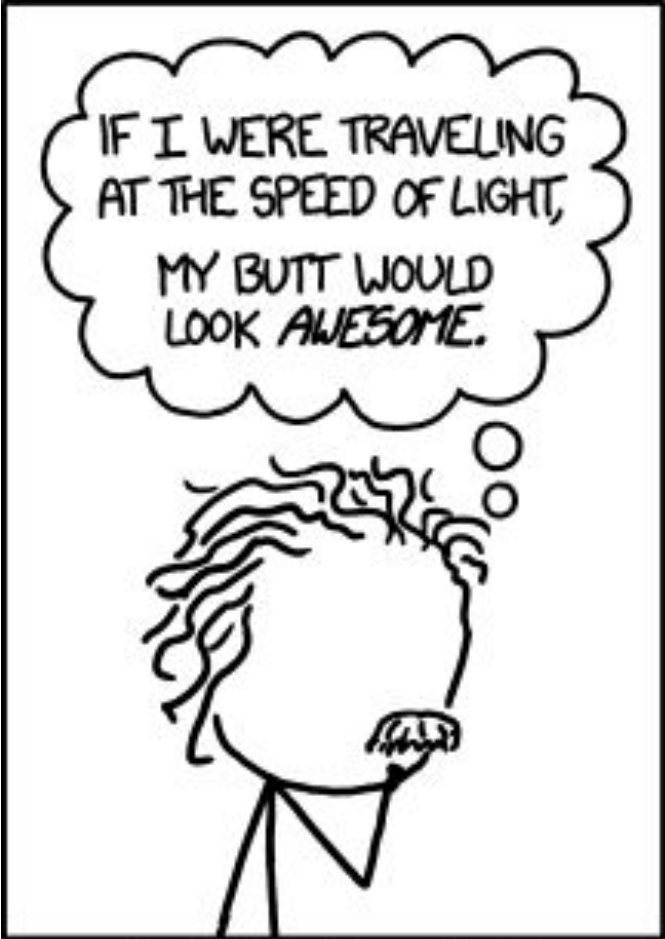


Newton's theory of gravity:

$$F \sim (\text{Mass of Earth}) \times (\text{Mass of Moon}) / (\text{Distance})^2$$

Describes the orbits of solar system planets almost perfectly.

Is it a good theory and is it falsifiable?

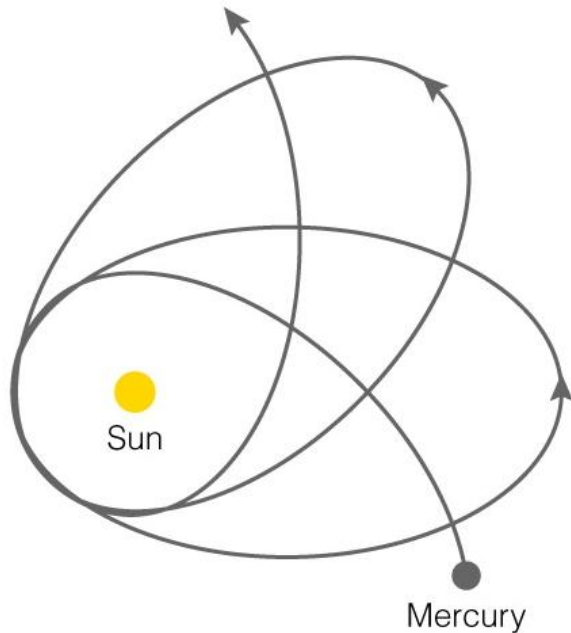


IF I WERE TRAVELING  
AT THE SPEED OF LIGHT,  
MY BUTT WOULD  
LOOK AWESOME.

EINSTEIN WAS FAMED  
FOR HIS GEDANKEDANK.



# Problems with Newton's Law



Note: The amount of precession with each orbit is highly exaggerated in this picture.

- Gravity travels instantaneously
- Newton's law doesn't explain what it is that carries the law of gravity (**gravitational waves**)
- Newton's law can not account for the precession of Mercury's perihelion (**A direct falsification of Newton's law**)
- Einstein's theory remedies this, but it too is incomplete



Further tests of Einstein's theory include the indirect measurement of gravitational waves using pulsar binaries

I'M CURRENTLY CONDUCTING  
AN EXPERIMENT WHICH  
MAY PROVE EINSTEIN WRONG!

OOH, EXCITING!

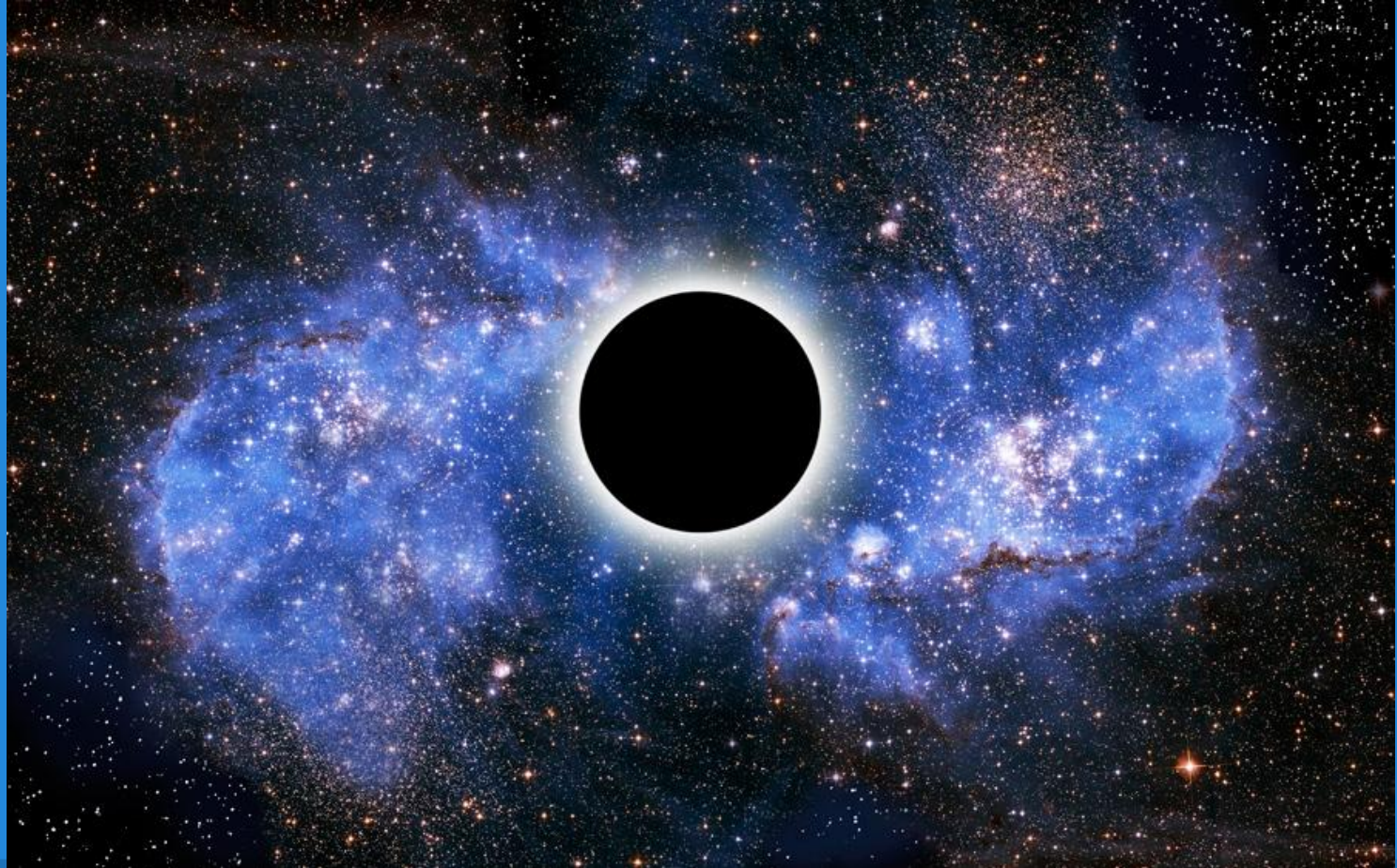


1947:

IT'S IMPOSSIBLE  
TO FIND A GOOD  
SANDWICH  
IN THIS TOWN.



**Physics at the boundary of questions we're allowed to ask**

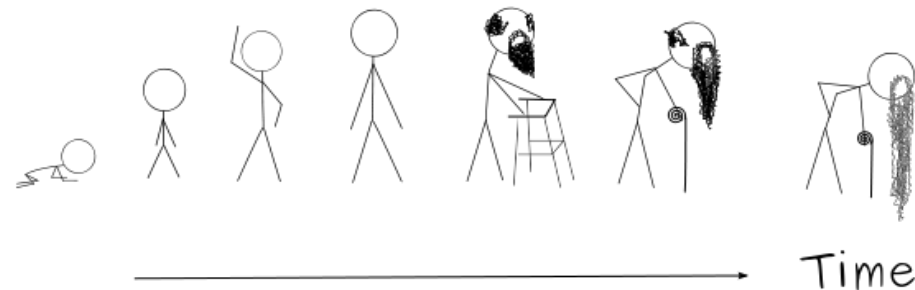


Einstein's theory of general relativity predicts the existence of black holes, but what goes on inside of them? **Is the answer to this question falsifiable?**

outside a black hole

According to Einstein's equations:

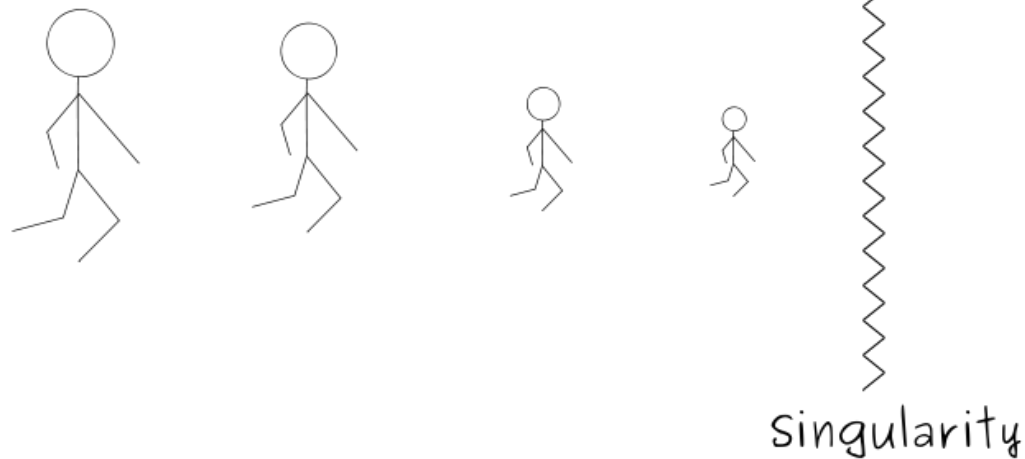
$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} .$$

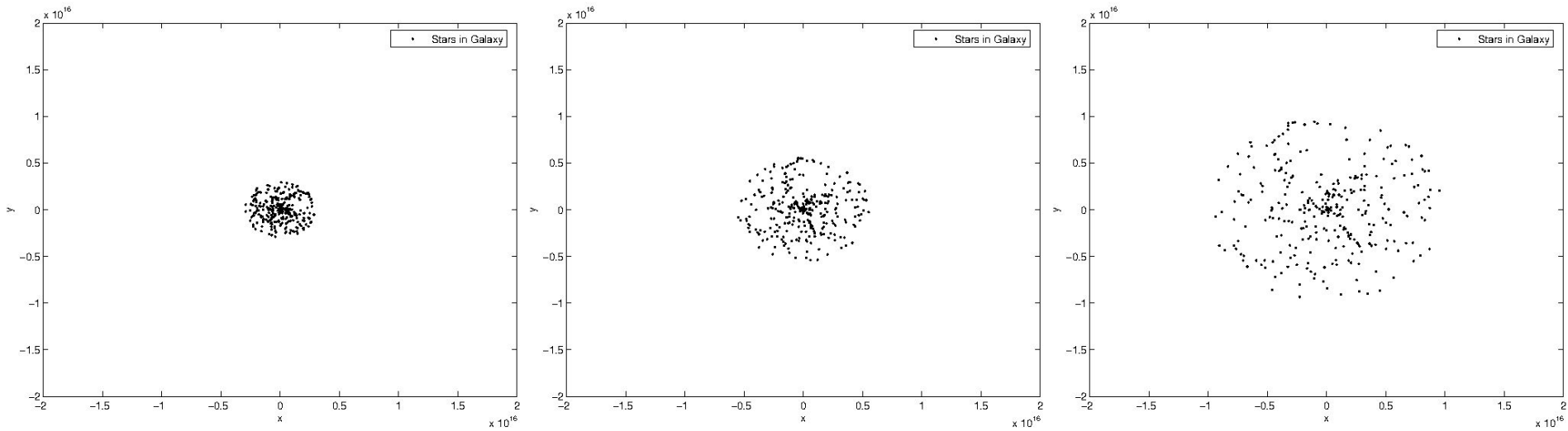


**black holes** are objects with an **event horizon** which acts like door you can only cross once.

There is a **singularity** at the center, and inside the black hole **time and space swap meaning**

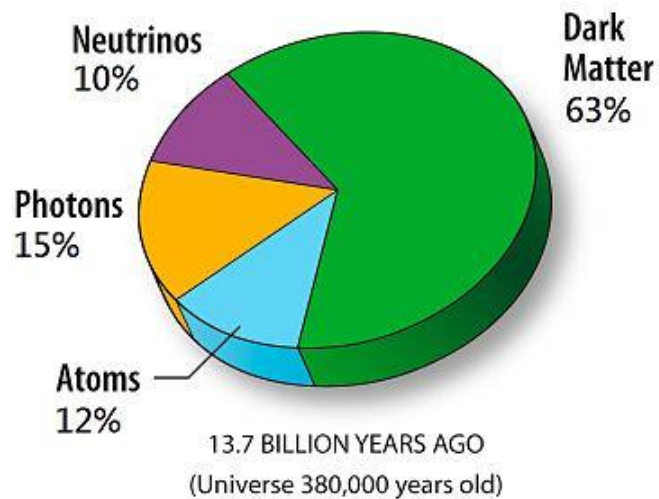
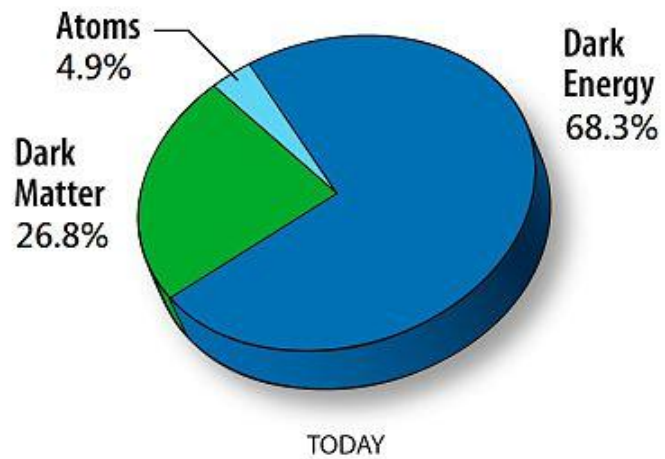
Inside a black hole





We have observed stars moving in galaxies, and they move faster than expected. This is a simulation of stars moving at their observed speeds in a galaxy. **What keeps them together?**







# From what we know about DM....

It doesn't interact with any known particles except via gravitationally.

How can we learn more about it?

## STRING THEORY SUMMARIZED:

I JUST HAD AN AWESOME IDEA.  
SUPPOSE ALL MATTER AND ENERGY  
IS MADE OF TINY, VIBRATING "STRINGS."

OKAY. WHAT WOULD  
THAT IMPLY?

I DUNNO.



