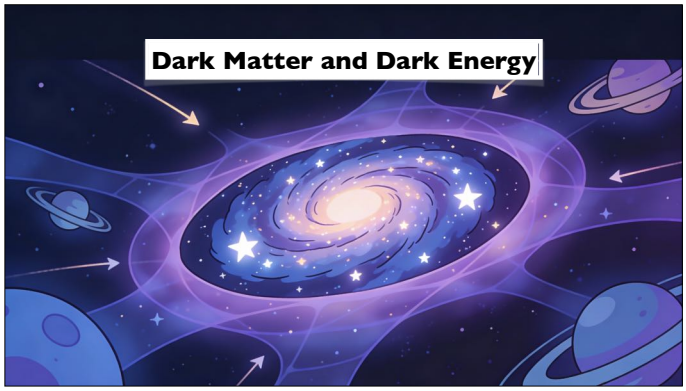
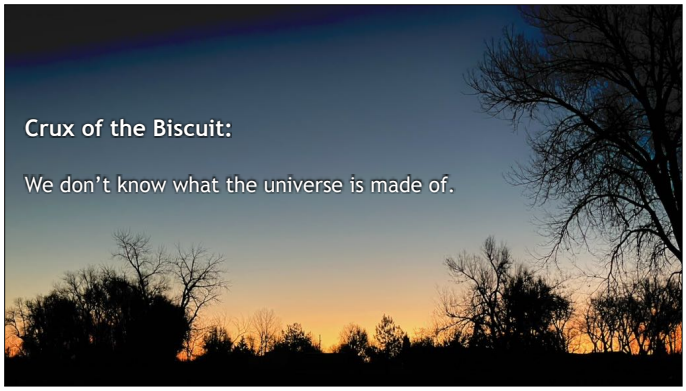
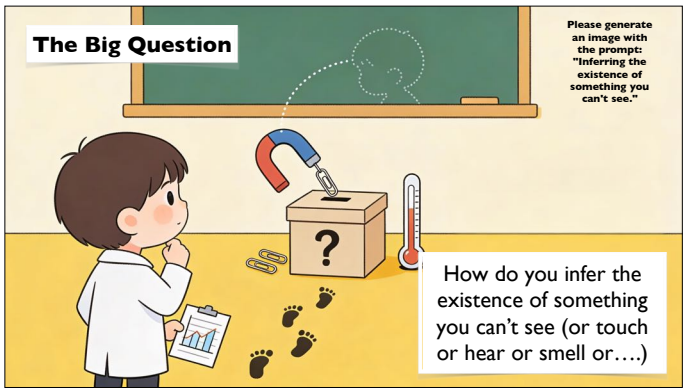
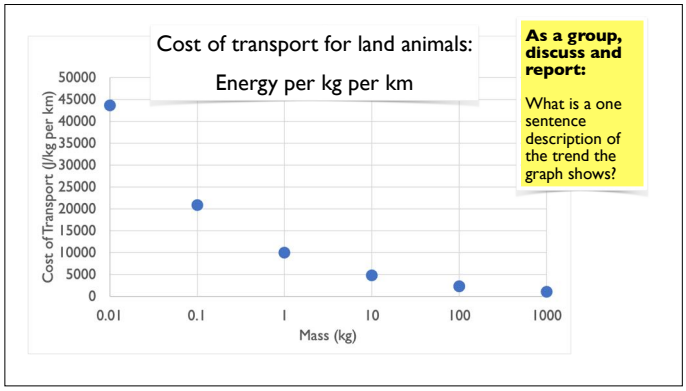
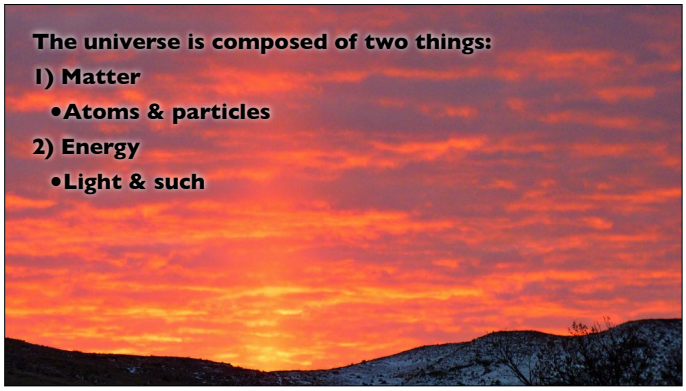

Dark Matter and Dark Energy

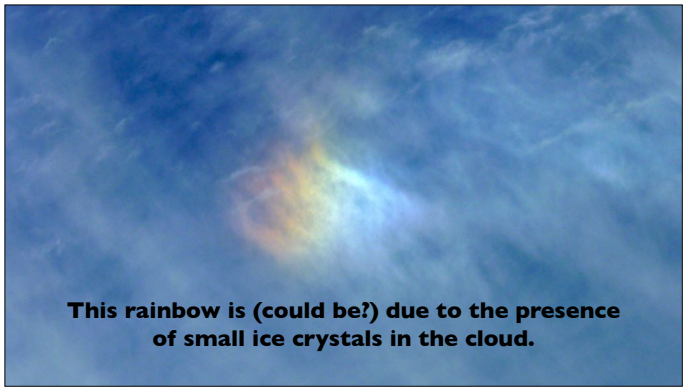

Crux of the Biscuit:
We don't know what the universe is made of.

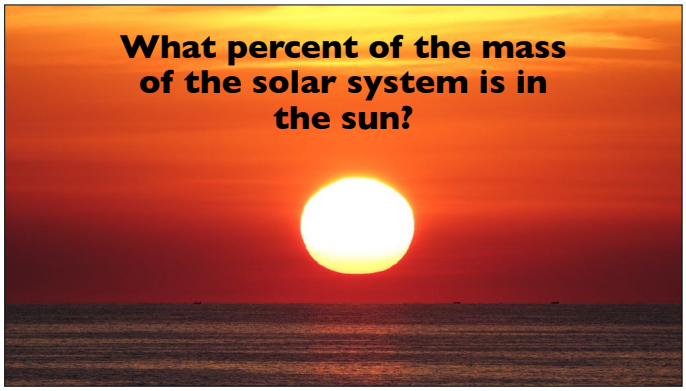

The Big Question
Please generate an image with the prompt: "Inferring the existence of something you can't see."
How do you infer the existence of something you can't see (or touch or hear or smell or….)


As a group, discuss and report:
How do you know there is something on the paper?
How do you know that something is coming from the flashlight?
I need an image that represents invisible ink.

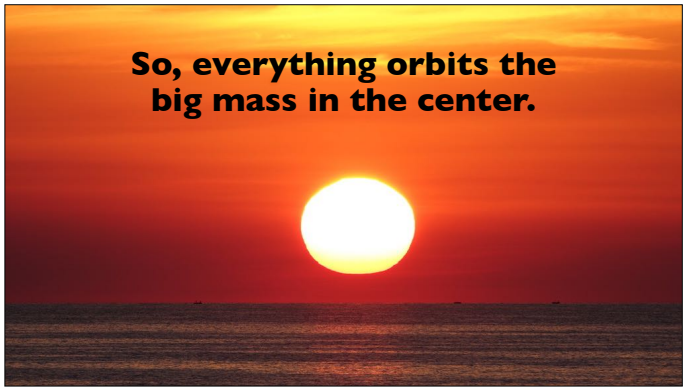

Cost of transport for land animals:
Energy per kg per km
Cost of Transport (J/kg per km)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0.01
0.1
1
10
100
1000
Mass (kg)
As a group, discuss and report:
What is a one sentence description of the trend the graph shows?


The universe is composed of two things:
1) Matter
•Atoms & particles
2) Energy
•Light & such

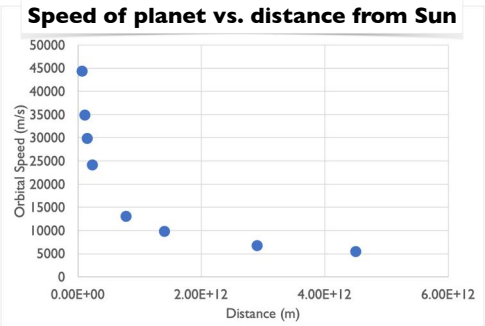

This rainbow is (could be?) due to the presence of small ice crystals in the cloud.


What percent of the mass of the solar system is in the sun?

So, everything orbits the big mass in the center.

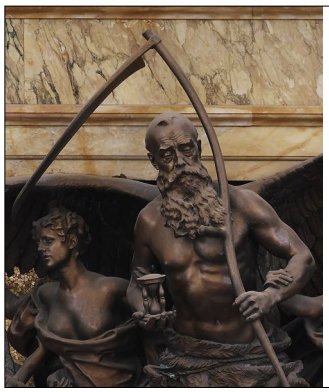


Speed of planet vs. distance from Sun



As a group, discuss and report:

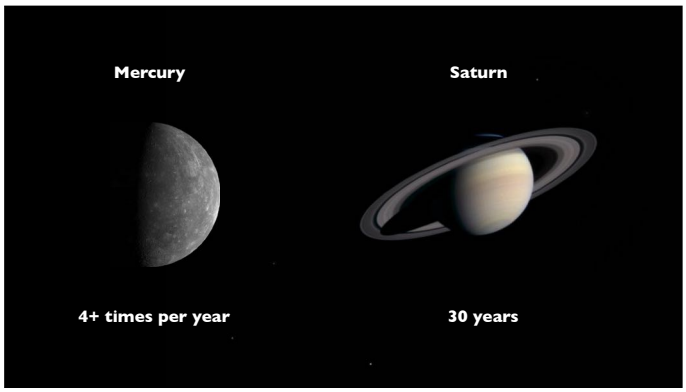
What is a one sentence description of the trend the graph shows?



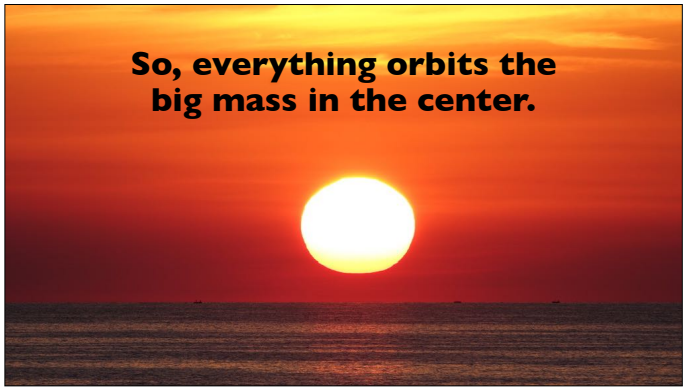
Irrelevant Aside

Father Time has an hourglass, of course.

But why is he carrying a scythe?



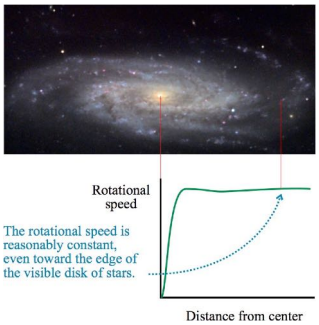
So, everything orbits the big mass in the center.



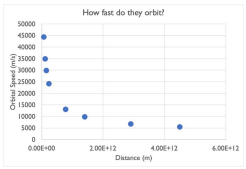
It's kinda like that with galaxies too.

Remember: You Can Use the Doppler Effect to Measure How Fast Things Are Moving

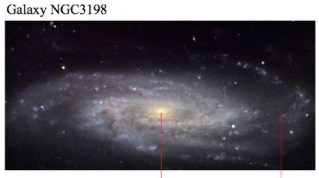
Galactic rotation curves

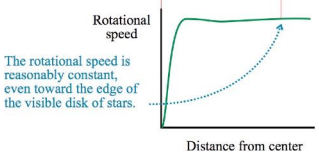


Things Are Orbiting Faster Than They Should.



Galaxy NGC3198

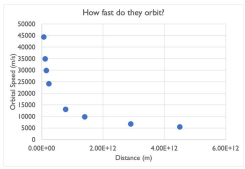




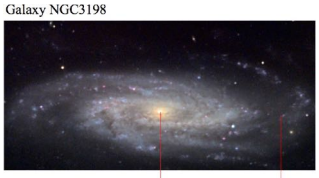
Question

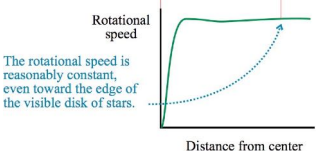
With your group, discuss:

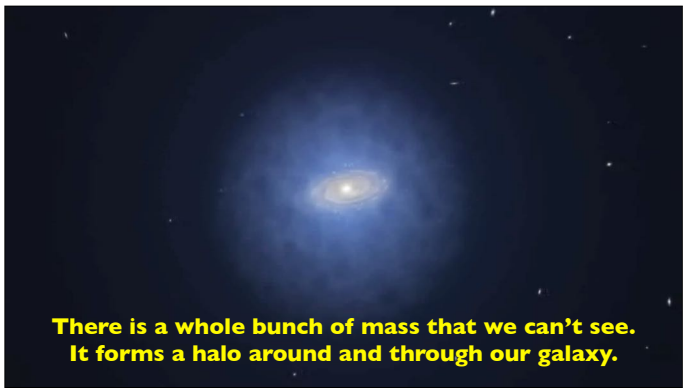
What can we infer from this?



Galaxy NGC3198







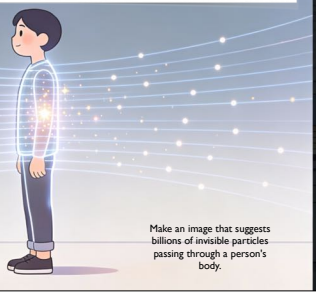
There is a whole bunch of mass that we can't see.
It forms a halo around and through our galaxy.

It's got gravity.
So it's **matter**.
We can't see it.
So it's **dark**.

It's not just dark....

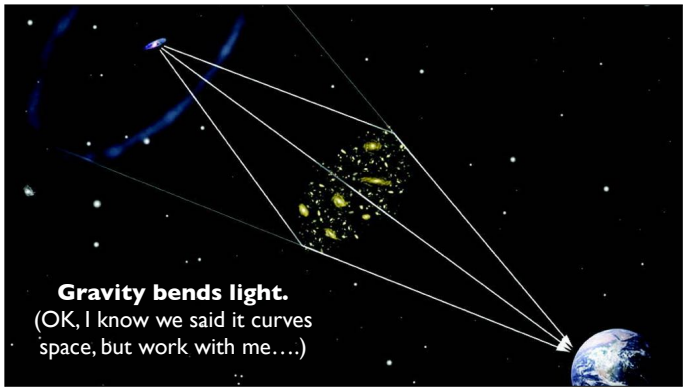
Force	What it does	Regular matter	Neutrinos	Dark matter
Strong Nuclear Force	Binds nuclei together	Yes	No	No
Weak Nuclear Force	At work in the nucleus	Yes	Yes	No?
Electromagnetic force	Making atoms work, making light work, making biology work....	Yes	No	No
Gravity	Universal attractive force	Yes	Yes	Yes

It has very weak interactions with regular matter.



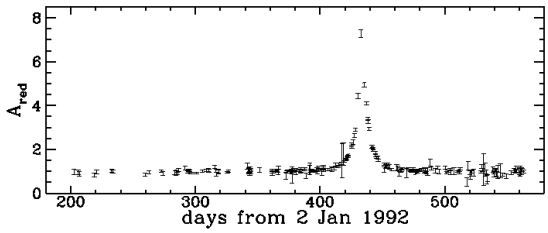
It's likely that **billions** of particles of dark matter pass through your body every second.

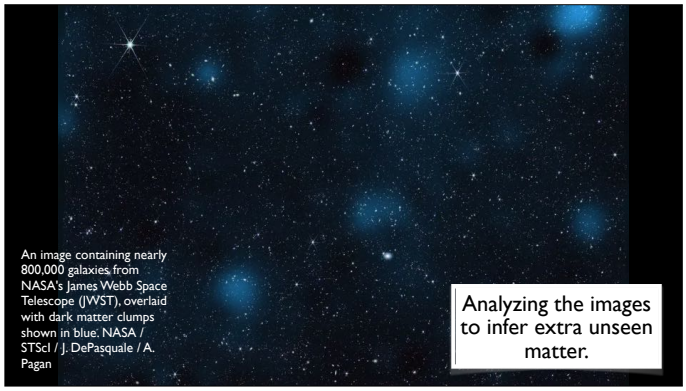
Make an image that suggests billions of invisible particles passing through a person's body.



Gravity bends light.
(OK, I know we said it curves space, but work with me....)

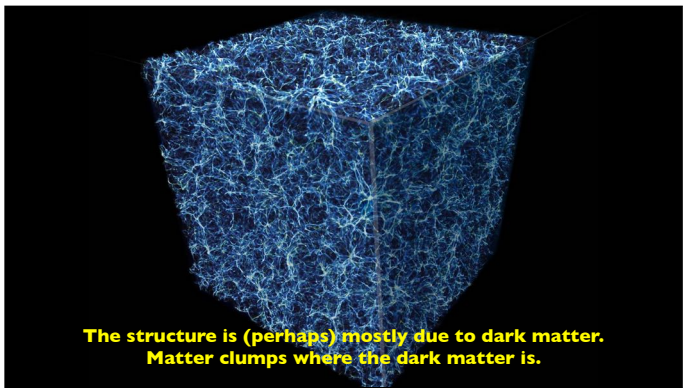
Sudden brightening of stars





An image containing nearly 800,000 galaxies from NASA's James Webb Space Telescope (JWST), overlaid with dark matter clumps shown in blue. NASA / STScI / J. DePasquale / A. Pagan

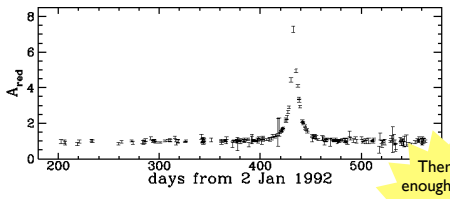
Analyzing the images to infer extra unseen matter.



The structure is (perhaps) mostly due to dark matter.
Matter clumps where the dark matter is.

Two competing theories:
MACHOs: Massive Compact Halo Objects
WIMPs: Weakly Interacting Massive Particles

Sudden increase in brightness of stars



There is not enough of this to account for all of the dark matter that must be there.

I lied.

Beta-minus decay

$$^{14}_{6}\mathrm{C} \Rightarrow {}^{14}_{7}\mathrm{N} + \mathrm{e}^{-} + \bar{\nu}_{\mathrm{e}}$$

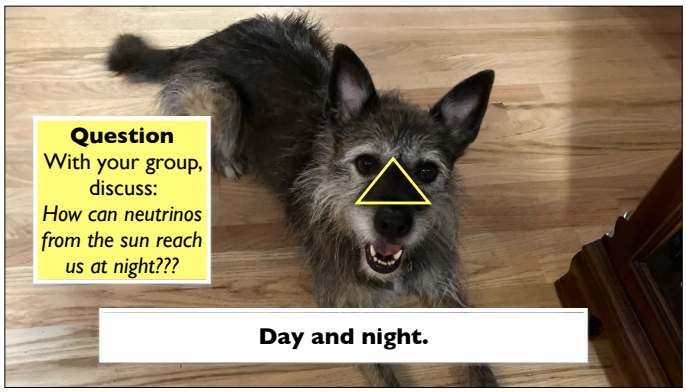
Beta-plus decay

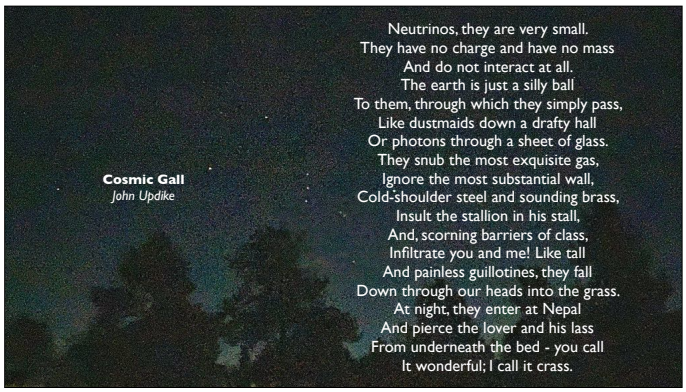
$$^{18}_{9}\mathrm{F} \Rightarrow {}^{18}_{8}\mathrm{O} + \mathrm{e}^{+} + \nu_{\mathrm{e}}$$

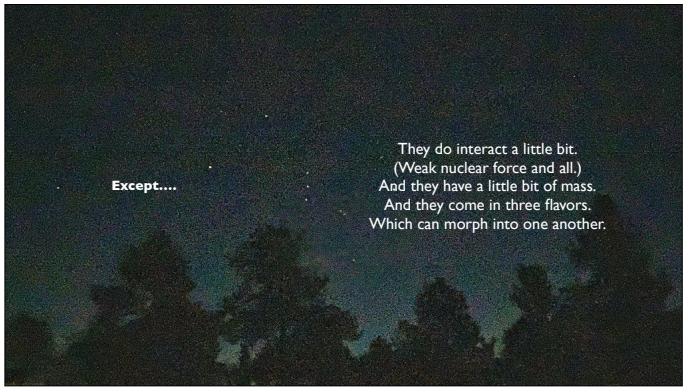
Neutrinos are also produced in the fusion reactions in the sun's center.

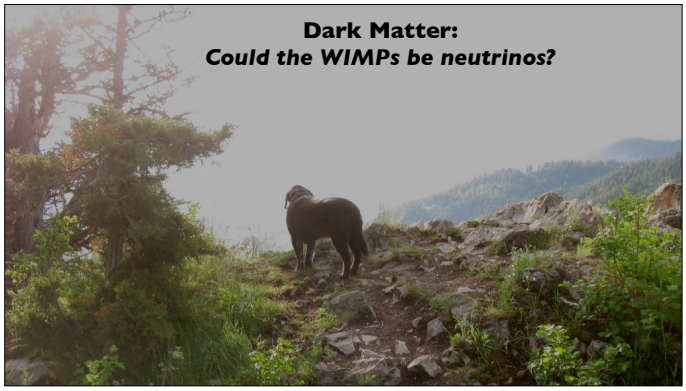
First stage in the process of turning hydrogen into helium:

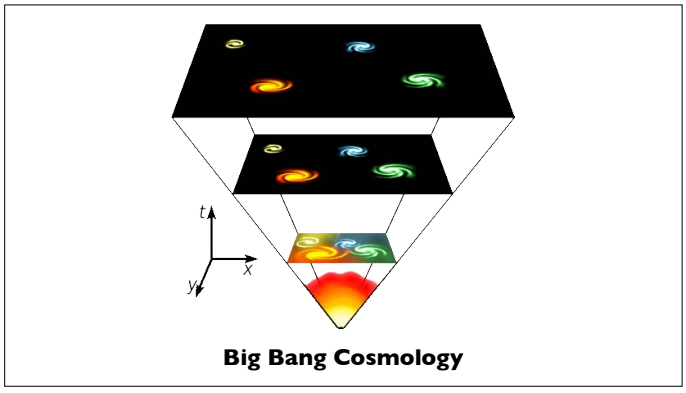
$$ {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \Rightarrow {}^{2}_{1}\mathrm{H} + \mathrm{e}^{+} + \nu_{\mathrm{e}} $$

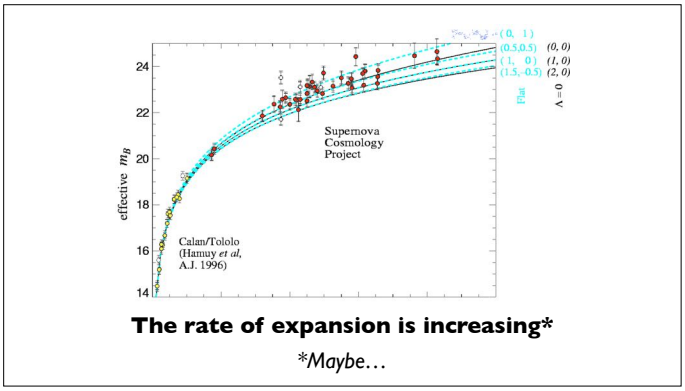






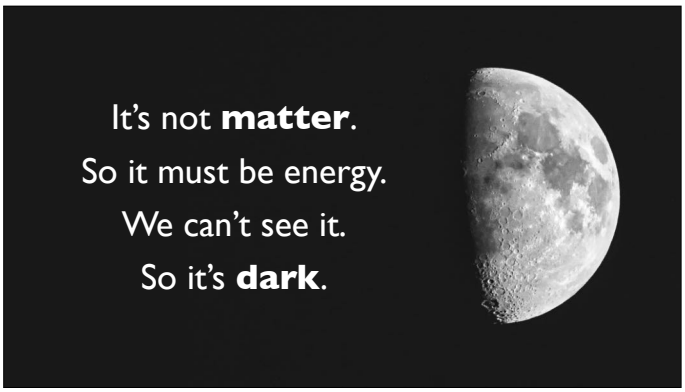


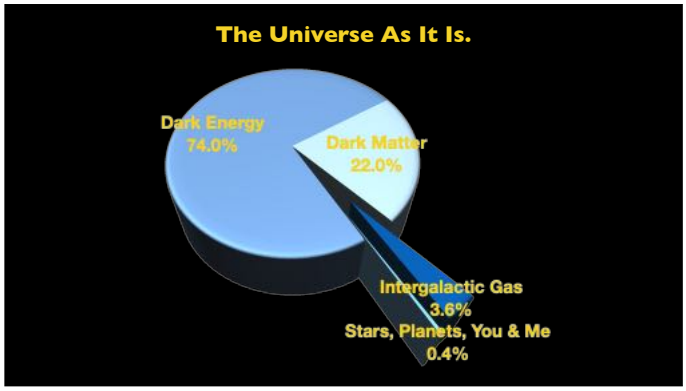


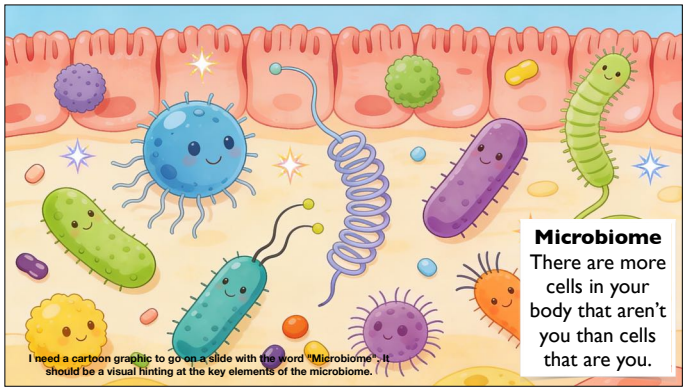


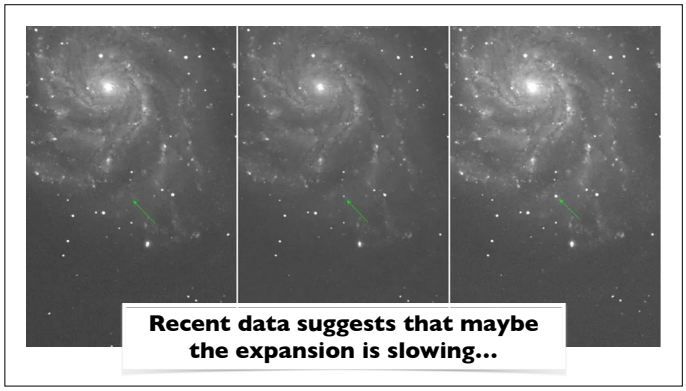
The rate of expansion is increasing*

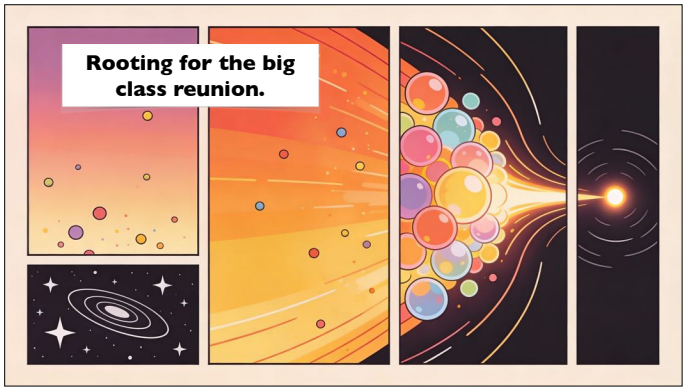
**Maybe…*








Recent data suggests that maybe the expansion is slowing...


Rooting for the big class reunion.


Next Week: Time & Other Mysteries