

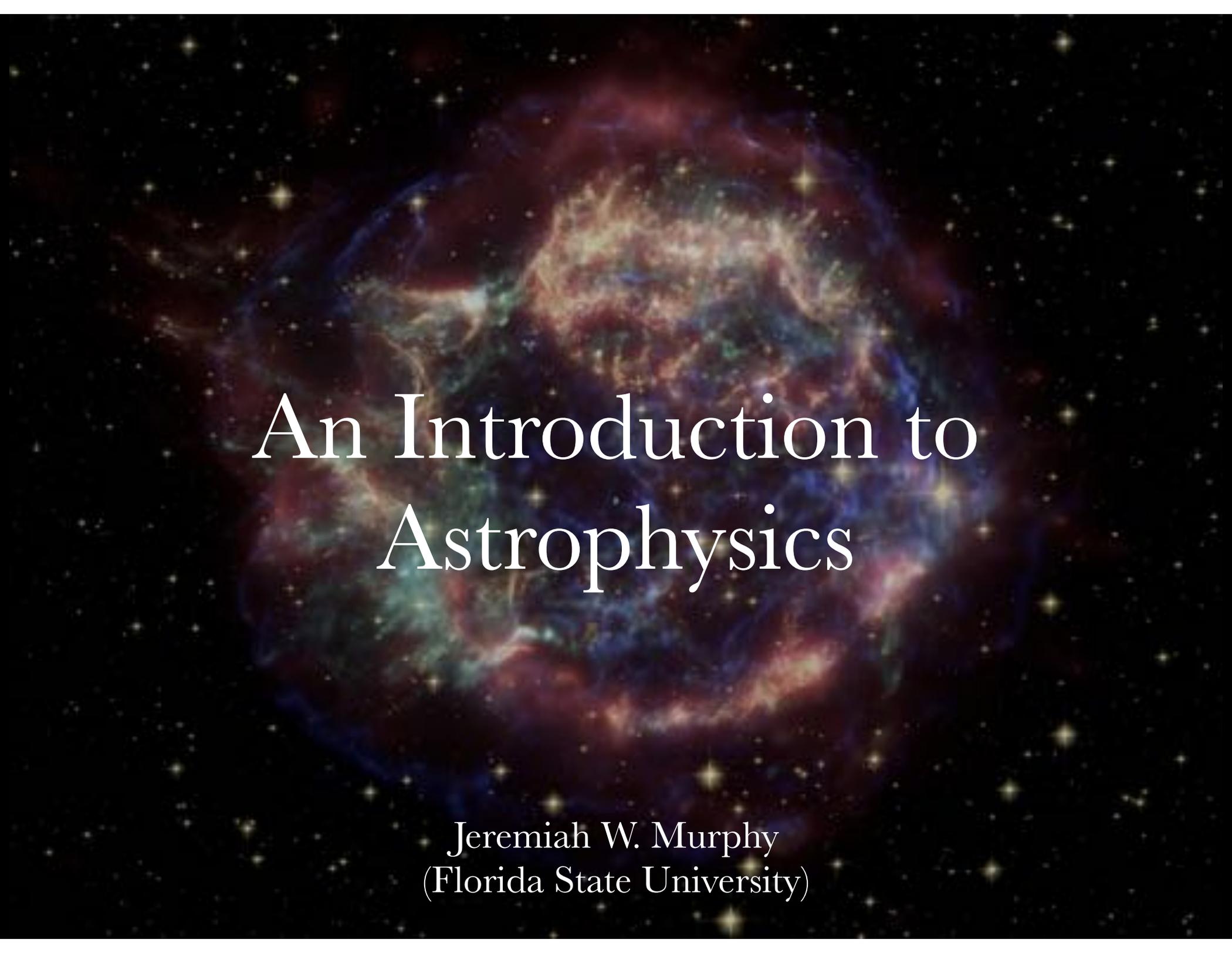


Jeremiah W. Murphy (FSU Physics)



@curiousmiah

Latest Astrophysics News, etc.



An Introduction to Astrophysics

Jeremiah W. Murphy
(Florida State University)

An Introduction to the Universe...in the 60 minutes

Hold on



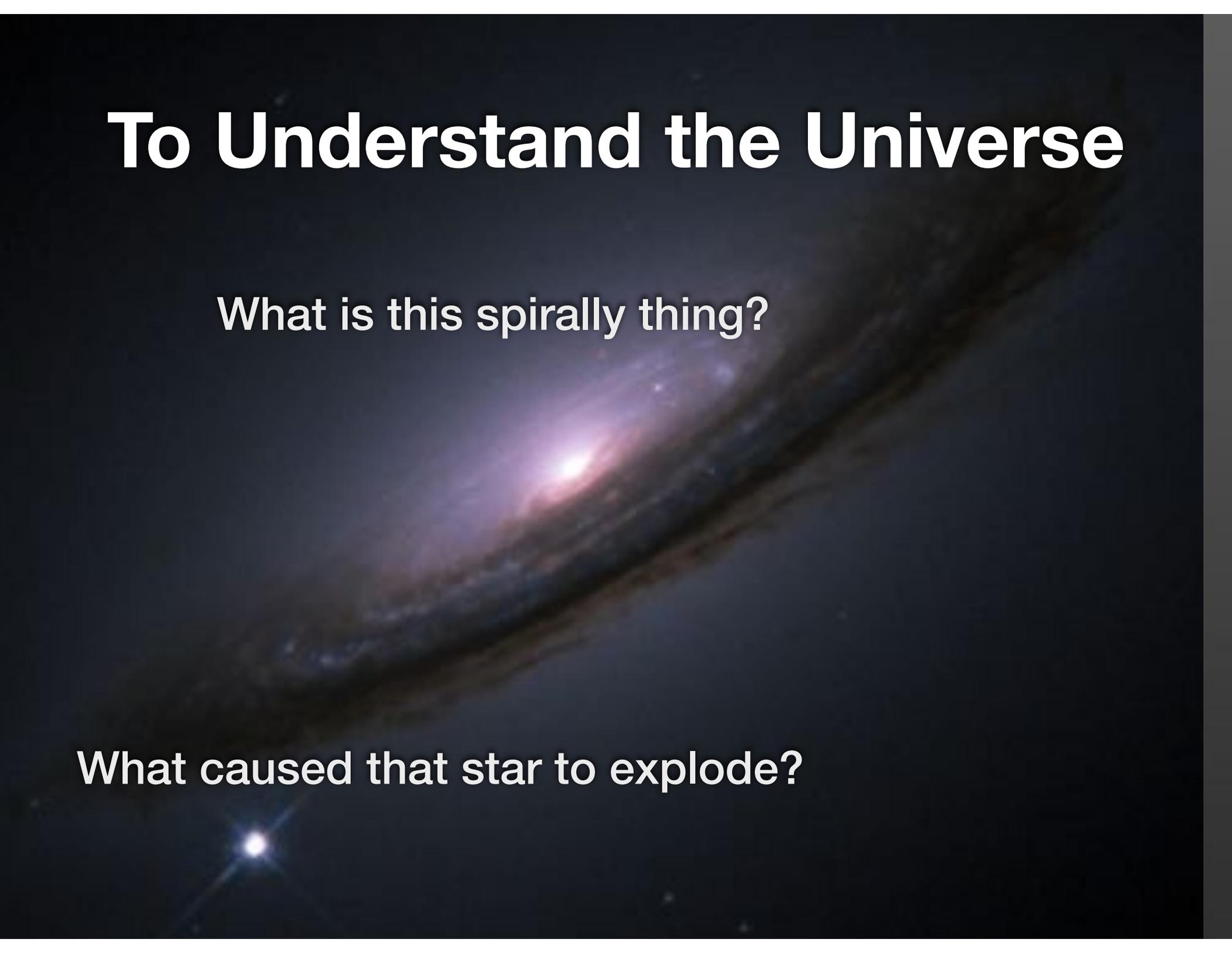
Why Astronomy?



Embrace your
passionately curious inner
child



To Understand the Universe

The background of the slide is a dark, deep blue space. In the center, there is a bright, glowing spiral galaxy, likely the Whirlpool Galaxy, with a prominent central core. The galaxy's arms are composed of numerous stars and dust, creating a complex, swirling pattern. In the lower-left quadrant, there is a single, bright white star with a noticeable diffraction pattern, suggesting it is a nearby star. The overall scene is a vast, cosmic landscape.

What is this spirally thing?

What caused that star to explode?

To Understand the Universe

How old is the Earth?



How did the Earth form?

Why does the Moon look different than the Earth?





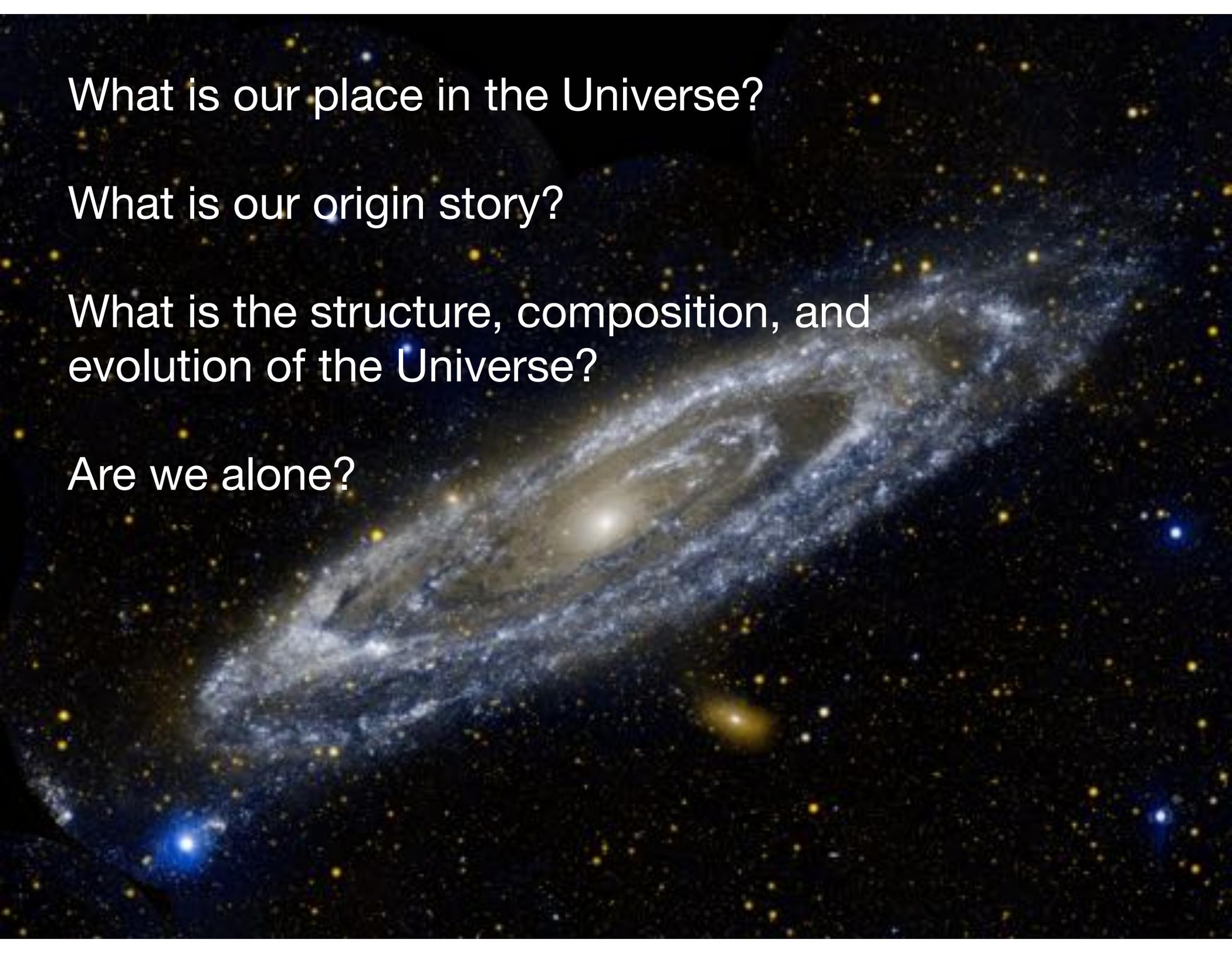
**Ask Some of the Most
Profound Questions**

What is our place in the Universe?

What is our origin story?

What is the structure, composition, and evolution of the Universe?

Are we alone?



When you ask profound questions,
you reach for the stars, and do
amazing things



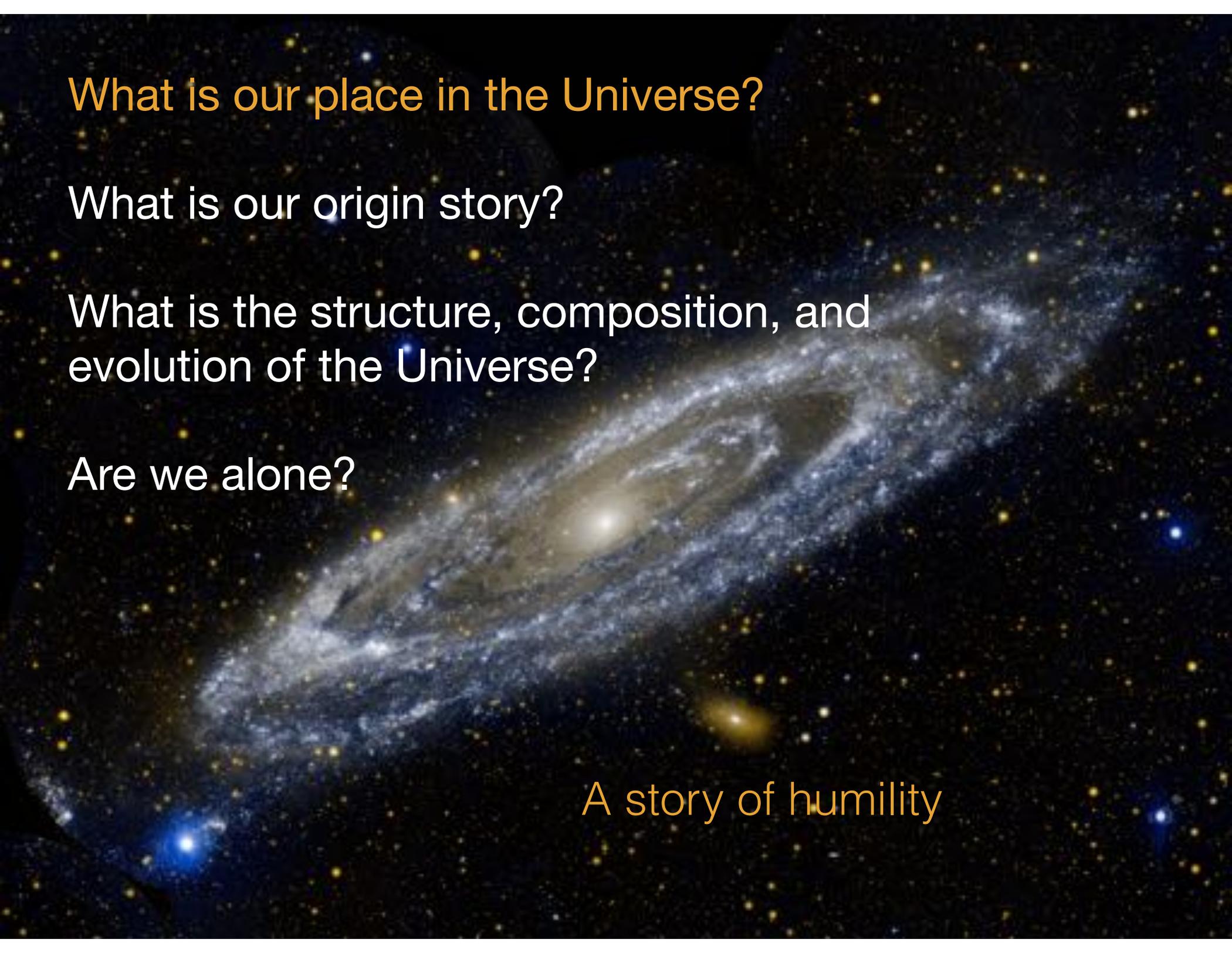
What is our place in the Universe?

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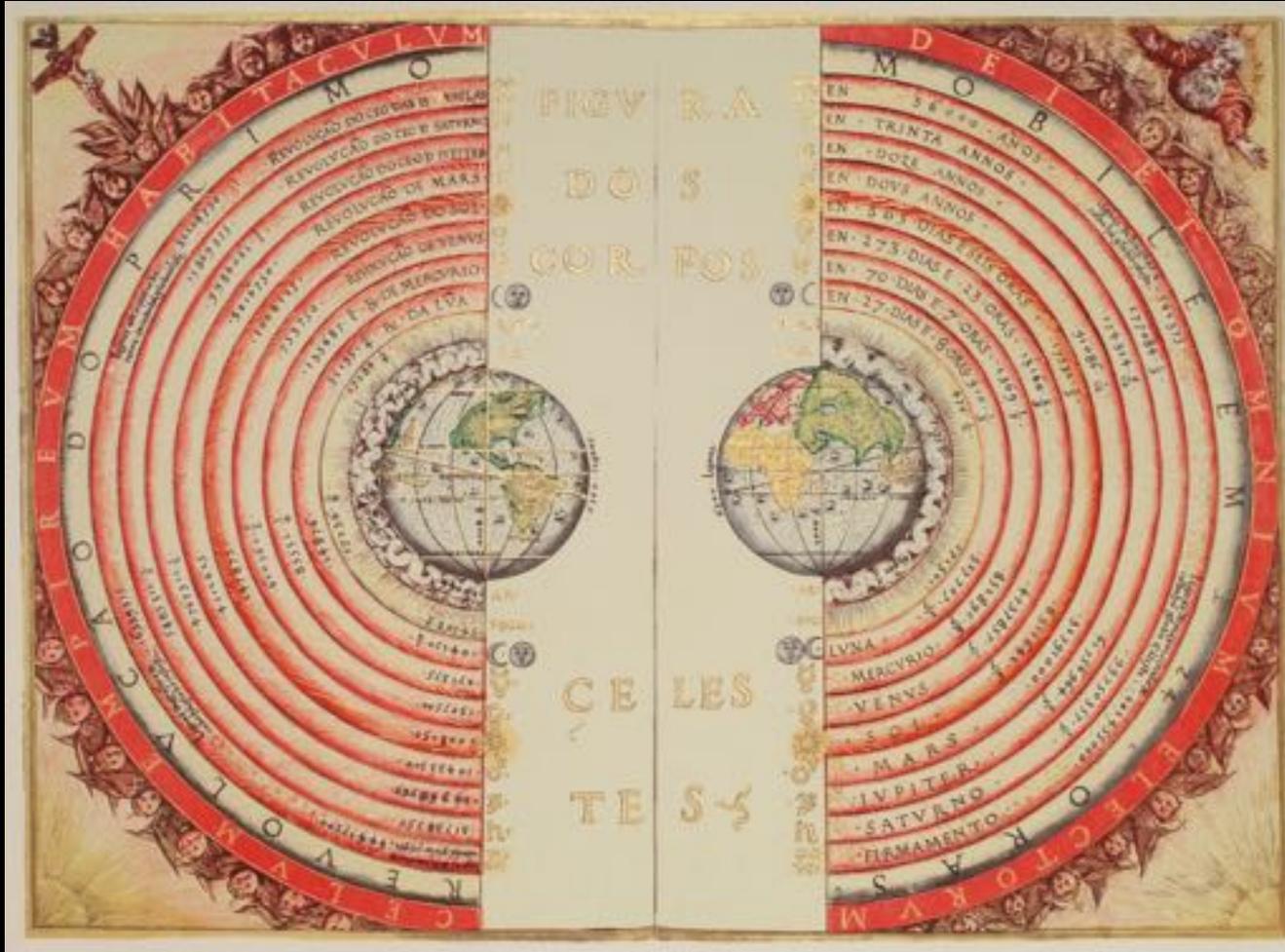
A story of humility



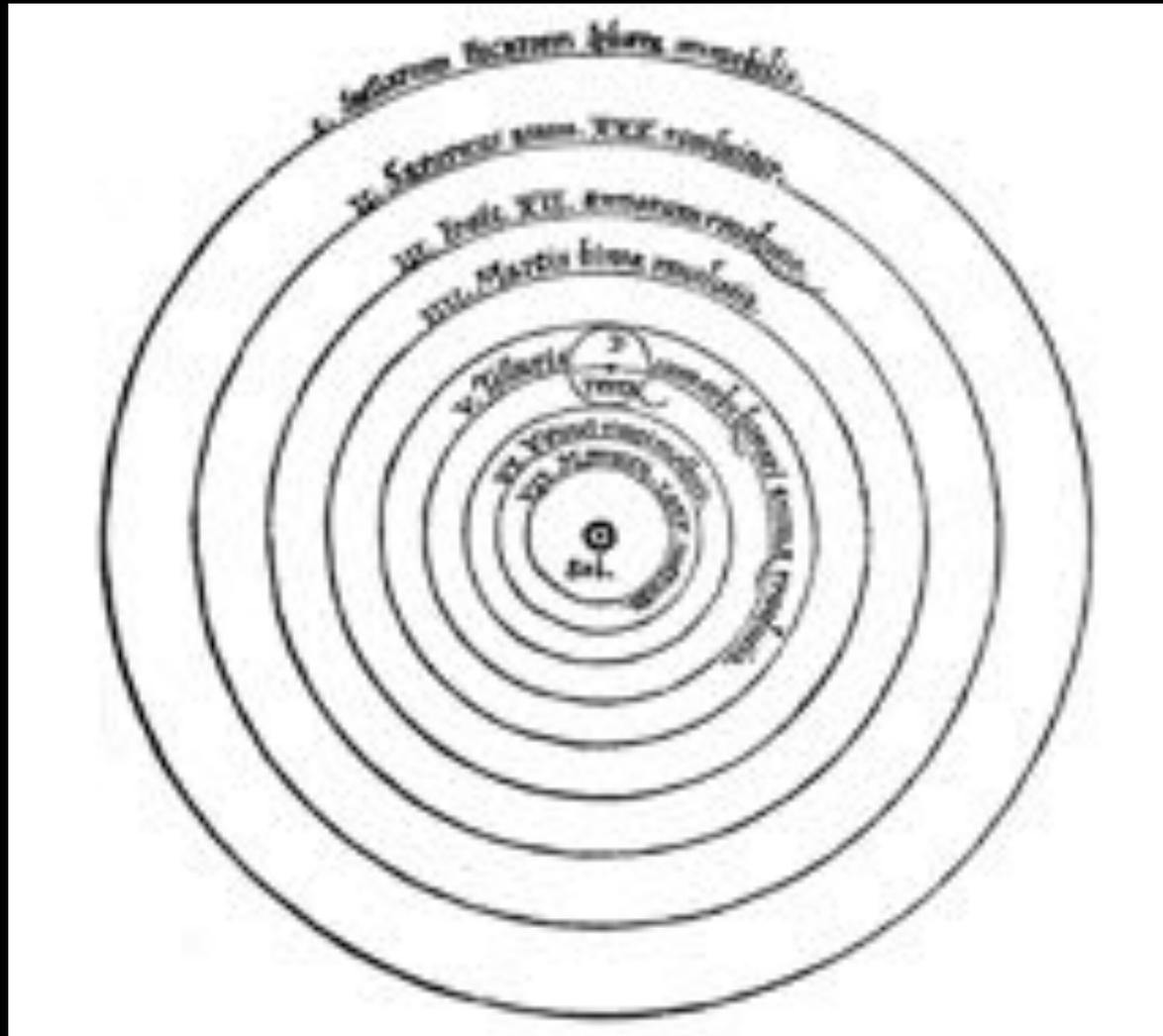
Your Place in the Universe



Ptolemaic: Geocentric Model

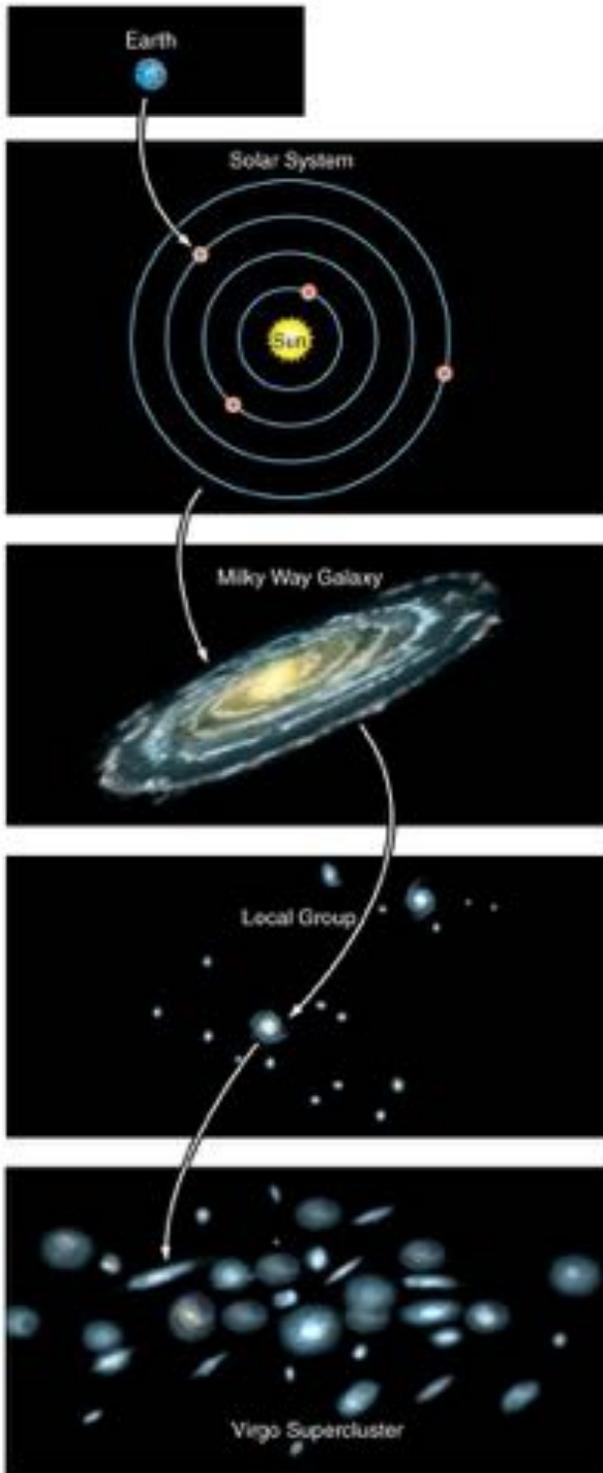


Bartolomeu Velho 1568



Copernican Universe (1543)





Your Place in the Universe

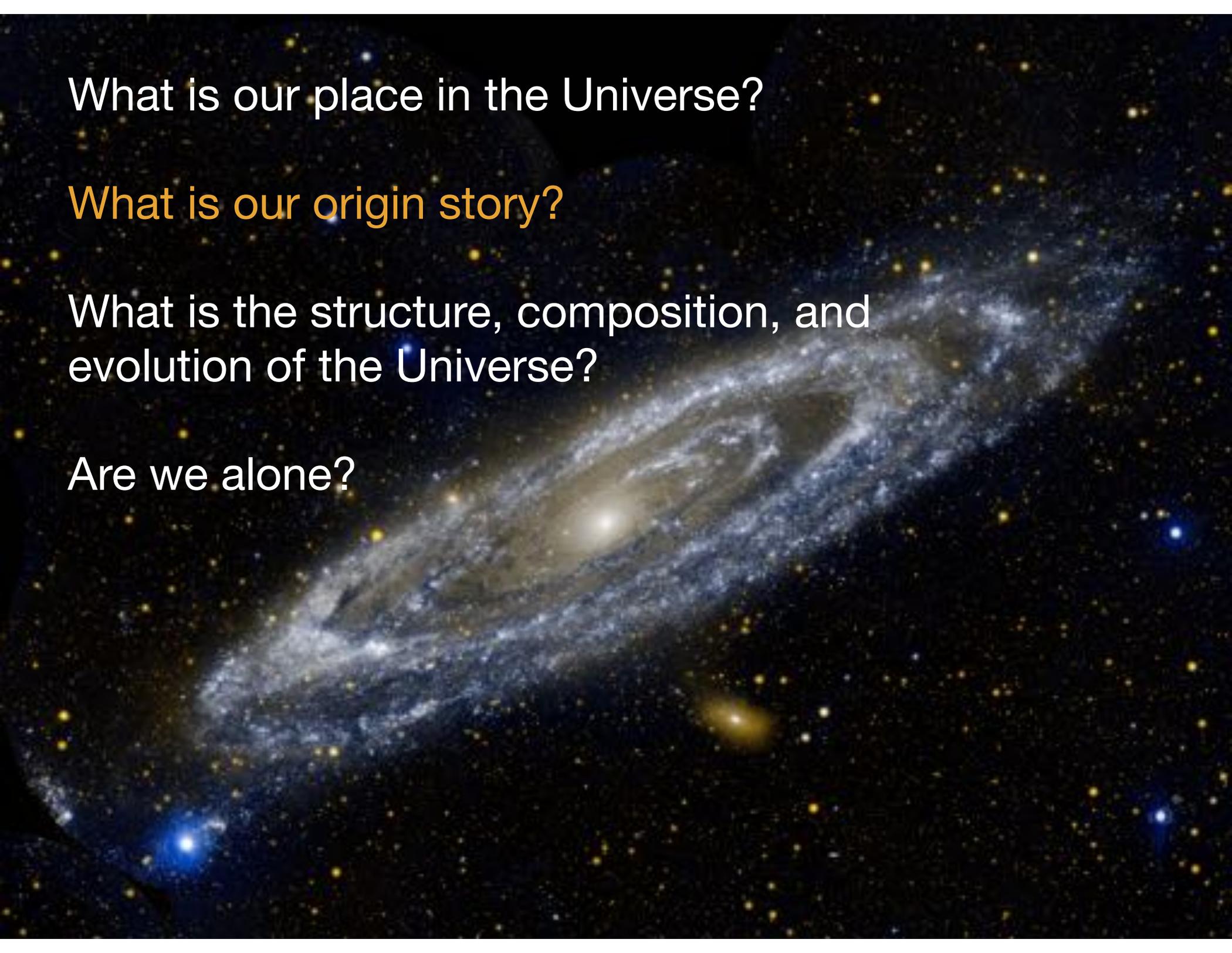


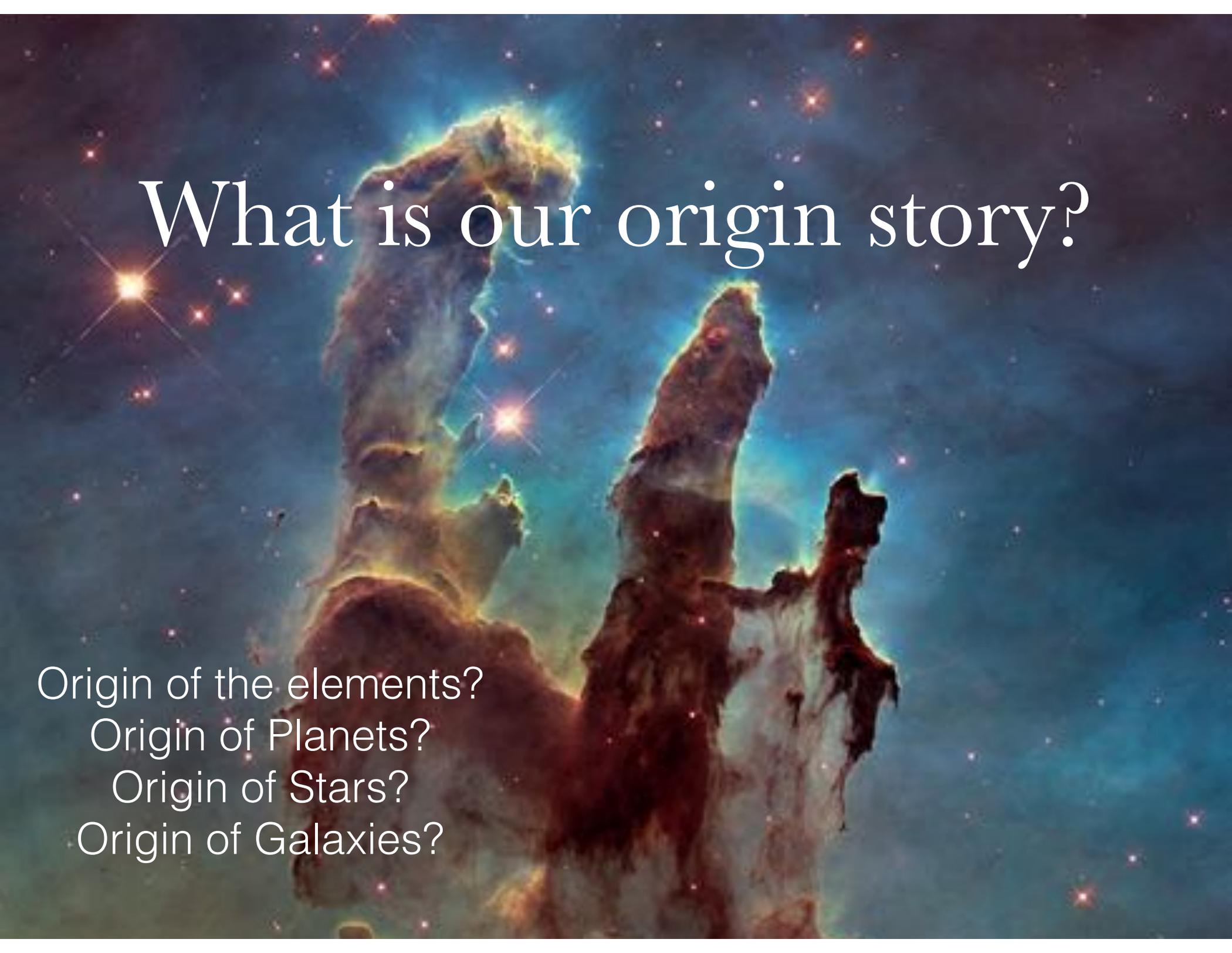
What is our place in the Universe?

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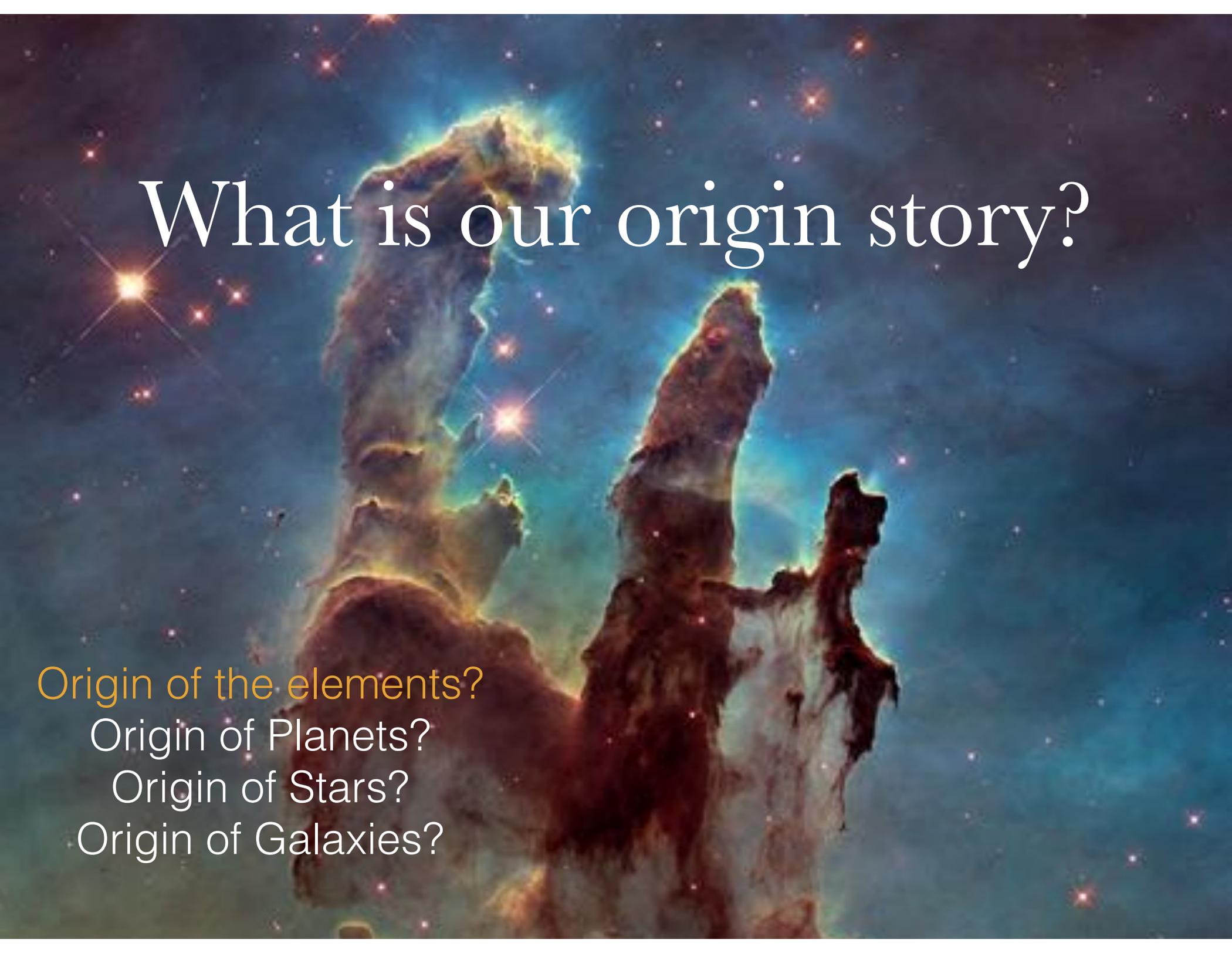
What is our origin story?

Origin of the elements?

Origin of Planets?

Origin of Stars?

Origin of Galaxies?



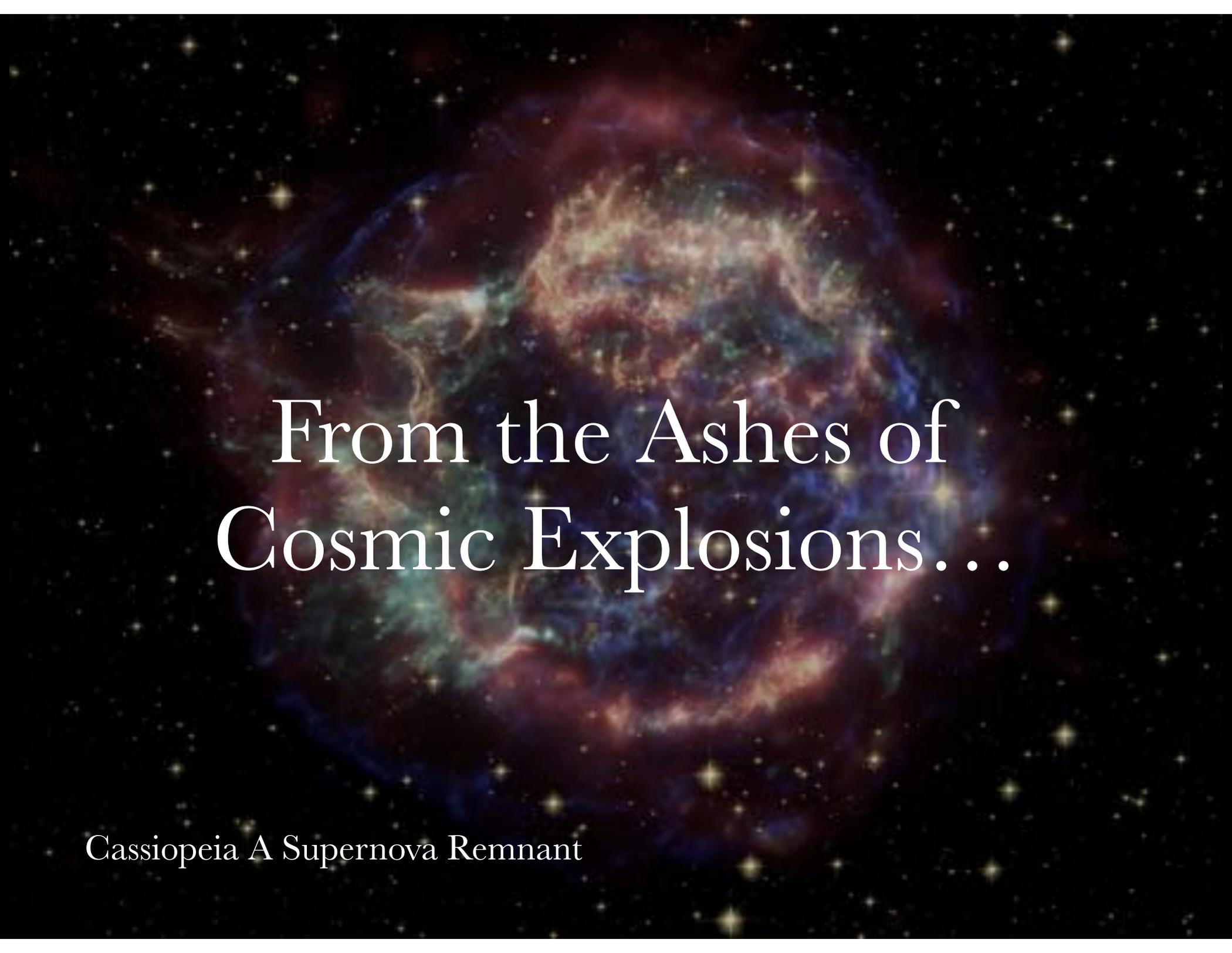
What is our origin story?

Origin of the elements?

Origin of Planets?

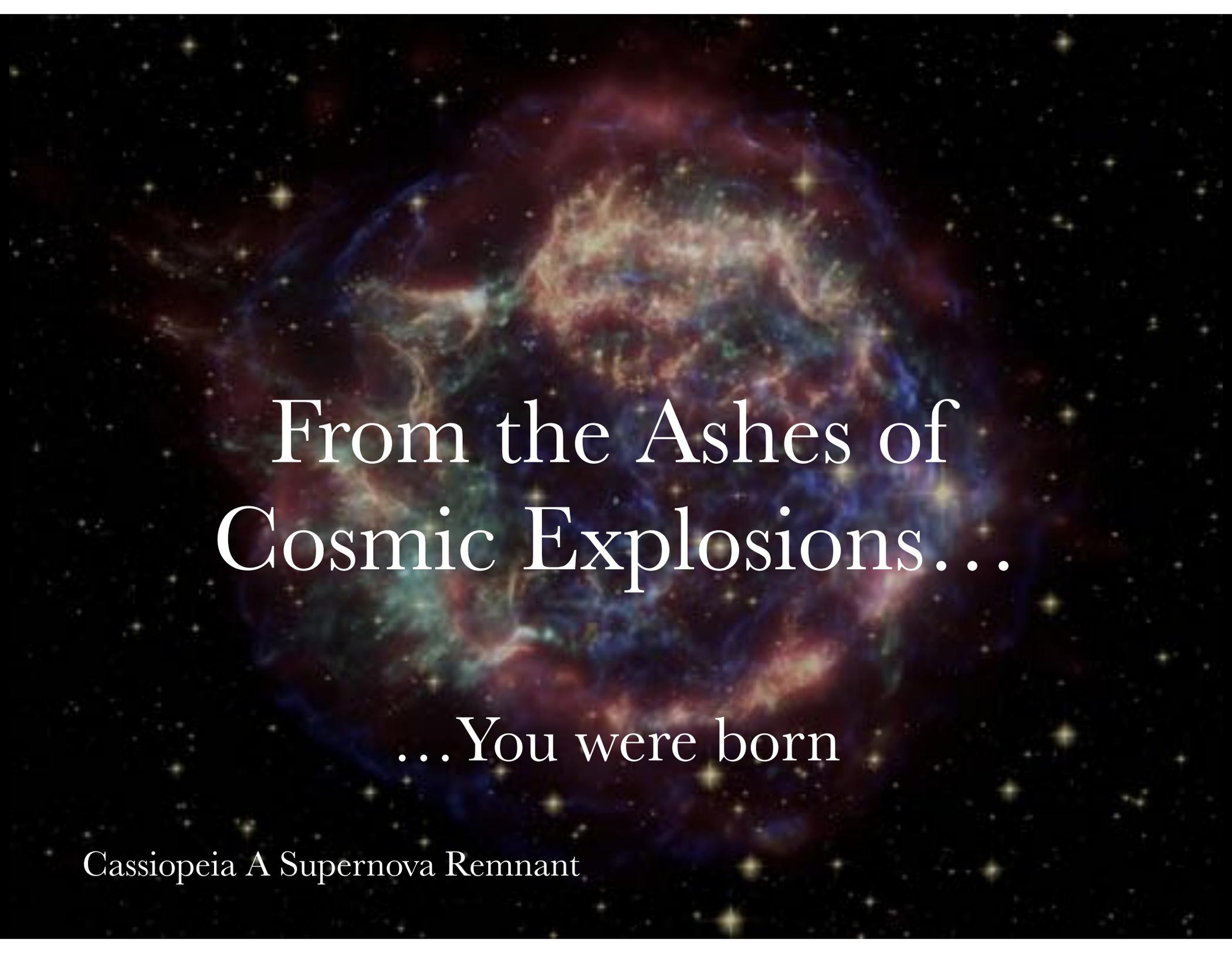
Origin of Stars?

Origin of Galaxies?

A vibrant, multi-colored supernova remnant (SNR) in the constellation Cassiopeia. The remnant is a large, roughly spherical shell of gas and dust, glowing with a mix of red, blue, green, and yellow. It is set against a dark background filled with numerous bright, yellow and white stars. The text "From the Ashes of Cosmic Explosions..." is overlaid in the center in a white, serif font.

From the Ashes of Cosmic Explosions...

Cassiopeia A Supernova Remnant

A vibrant, multi-colored supernova remnant (SNR) in the constellation Cassiopeia. The remnant is a complex, expanding shell of gas and dust, primarily in shades of blue, purple, and red, with some green and yellow highlights. It is set against a dark, star-filled background. The text is overlaid on the central part of the remnant.

From the Ashes of
Cosmic Explosions...

...You were born

Cassiopeia A Supernova Remnant

Luna's
What is ~~our~~ origin story?





Supernova(e)

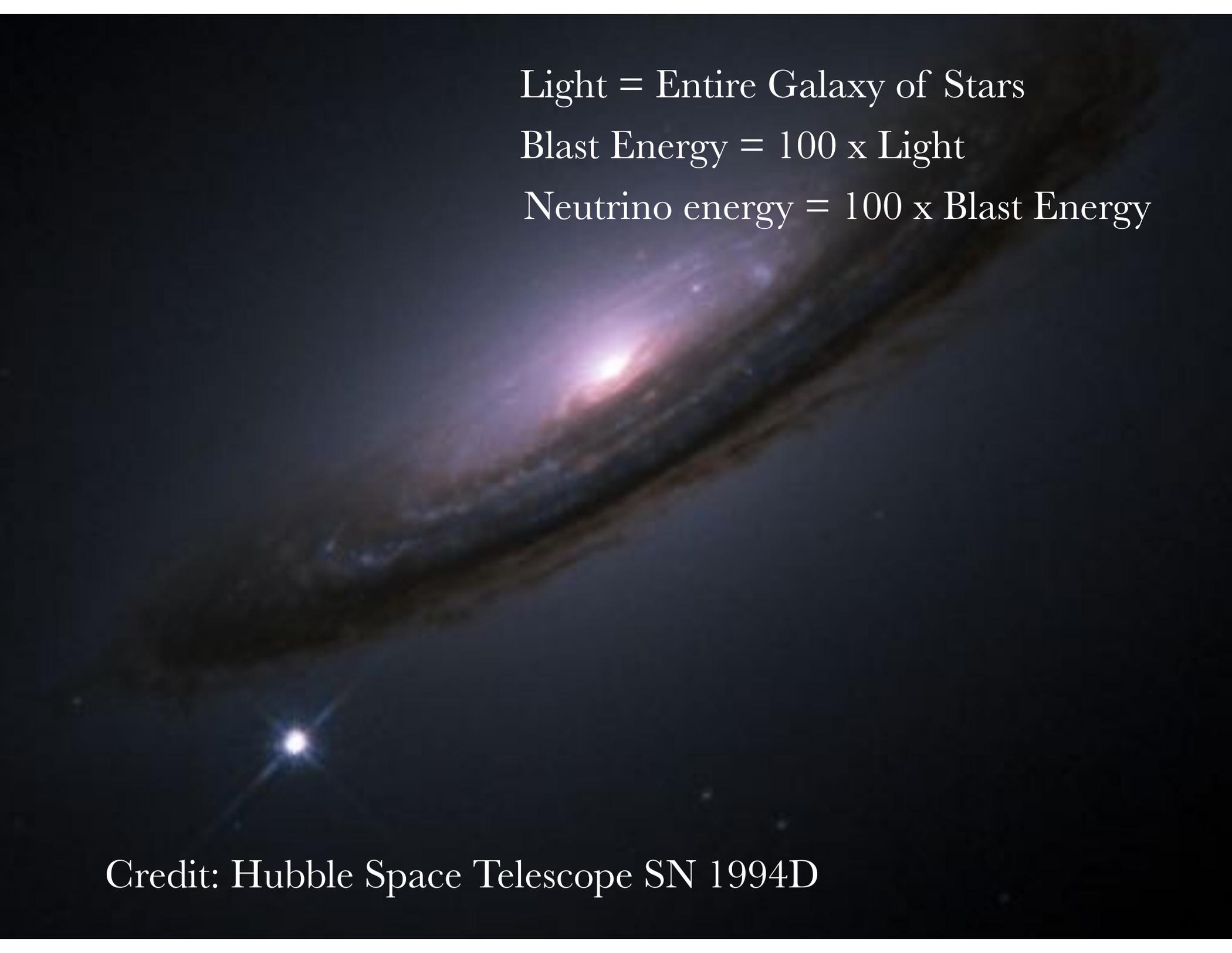


Supernova?

Supernovae: Stellar Explosions



SN 1987A



Light = Entire Galaxy of Stars

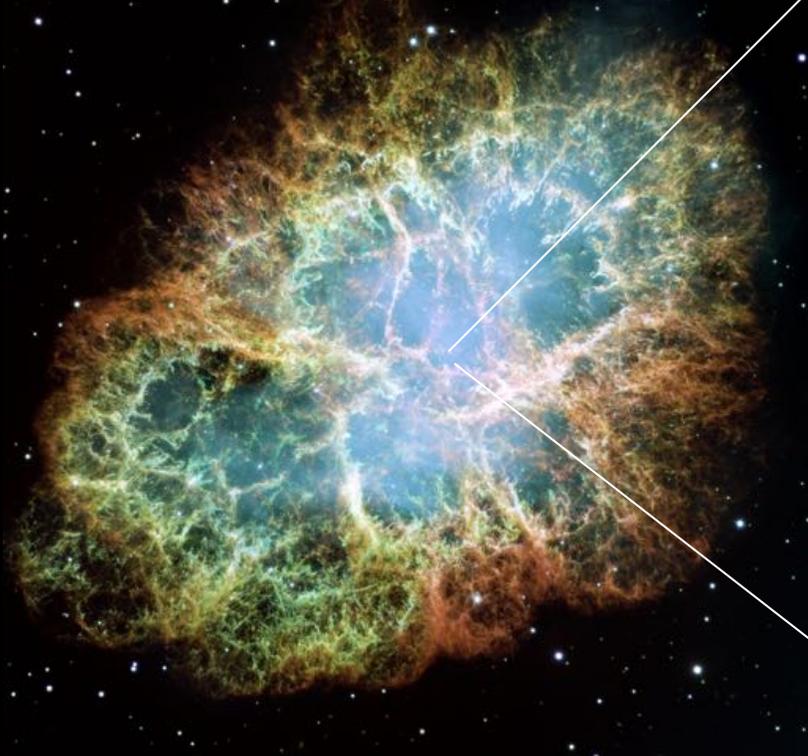
Blast Energy = 100 x Light

Neutrino energy = 100 x Blast Energy

Credit: Hubble Space Telescope SN 1994D

Herald the Birth of Neutron Stars & Black Holes

Crab Nebula



Crab Pulsar

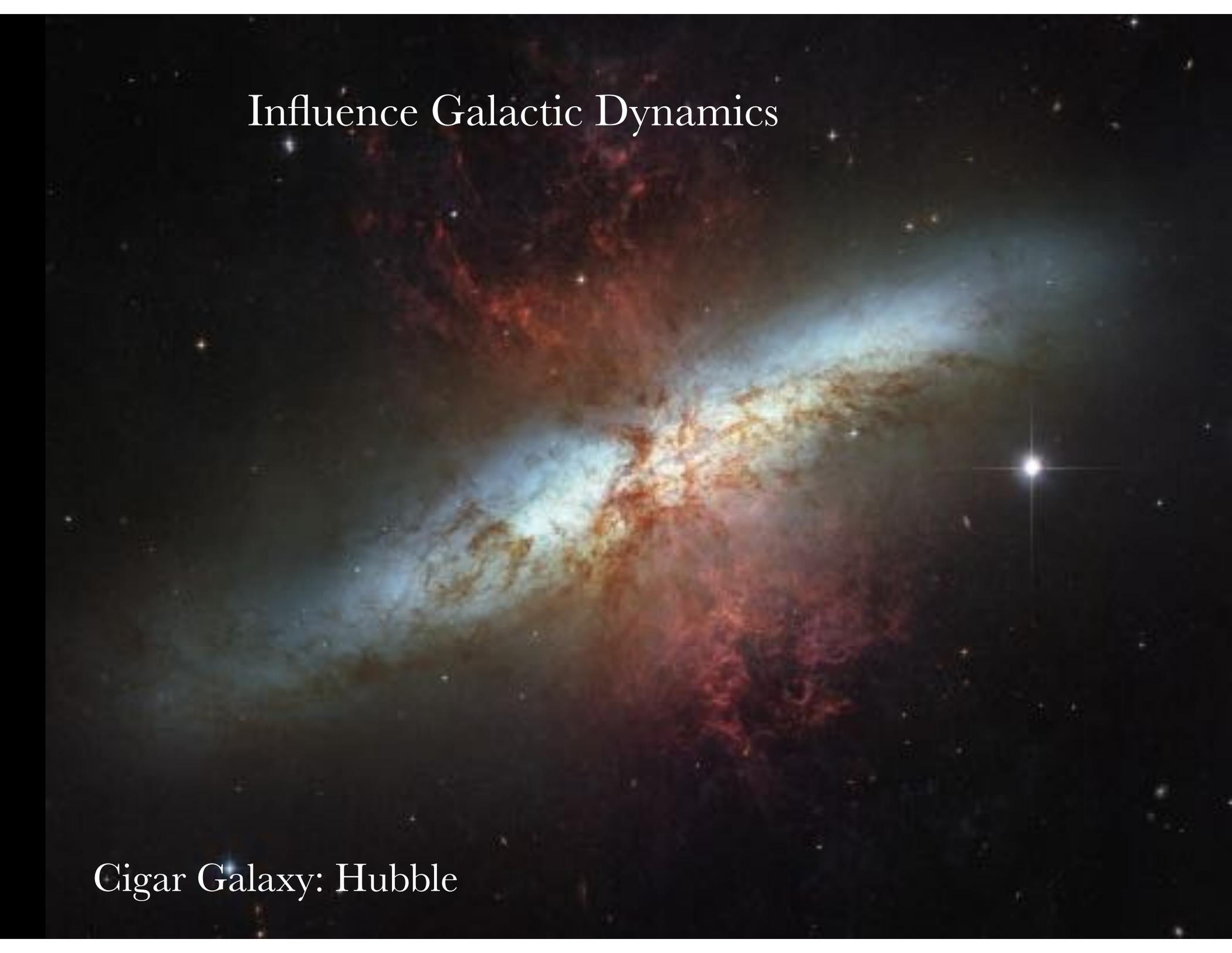


Trigger Further
Star Formation



Influence Galactic Dynamics

Cigar Galaxy: Hubble



Nucleosynthesis

Periodic Table of the Elements

Legend:

- Solids
- Liquids
- Gases
- Artificially Prepared

Example: Iron (Fe)

Atomic Number: 26

Symbol: Fe

Name: Iron

Atomic Weight: 55.845

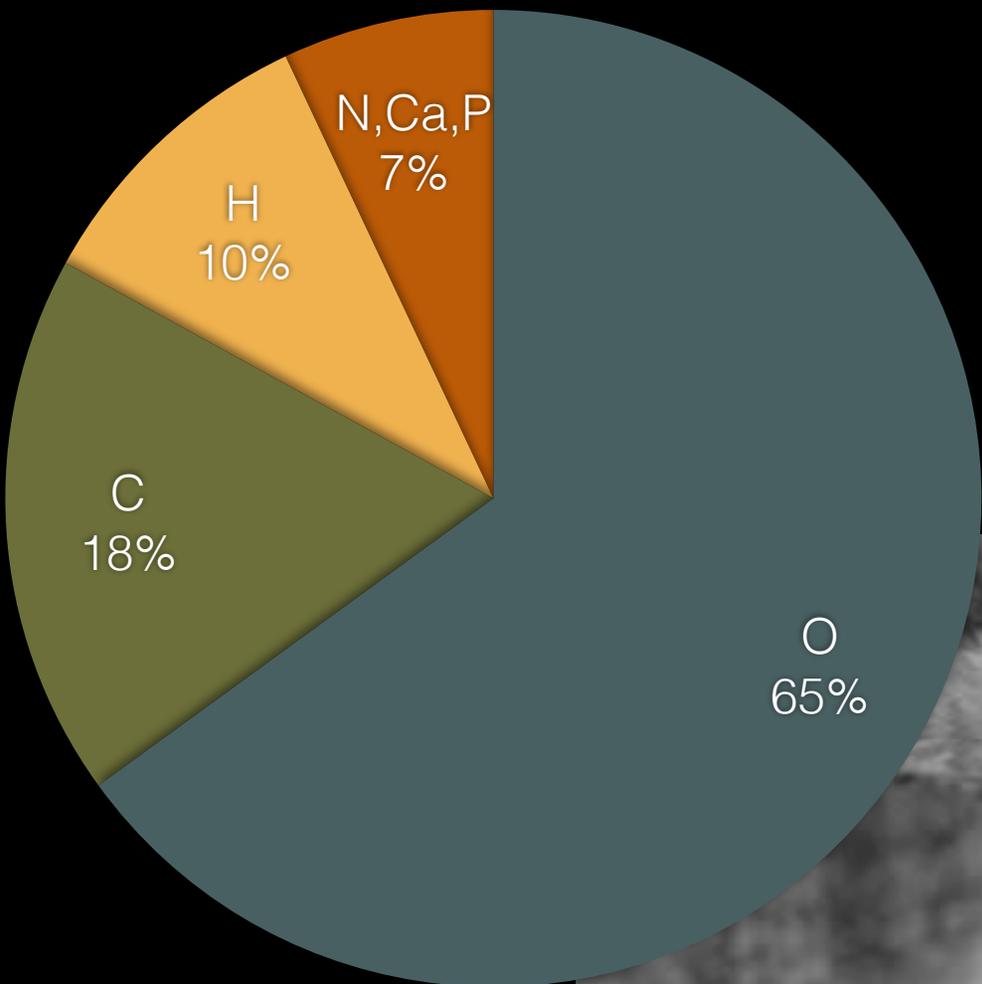
PERIOD	GROUP IA												GROUPS IIIB to VIIIB						GROUP VIII	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
1	H Hydrogen 1.00794																			He Helium 4.00260
2	Li Lithium 6.941	Be Beryllium 9.01218													B Boron 10.811	C Carbon 12.0107	N Nitrogen 14.00674	O Oxygen 15.9994	F Fluorine 18.99840	Ne Neon 20.1797
3	Na Sodium 22.98977	Mg Magnesium 24.3050													Al Aluminum 26.98154	Si Silicon 28.0855	P Phosphorus 30.97376	S Sulfur 32.066	Cl Chlorine 35.4527	Ar Argon 39.948
4	K Potassium 39.0983	Ca Calcium 40.078	Sc Scandium 44.95591	Ti Titanium 47.887	V Vanadium 50.9415	Cr Chromium 51.9961	Mn Manganese 54.93802	Fe Iron 55.845	Co Cobalt 58.93320	Ni Nickel 58.6934	Cu Copper 63.546	Zn Zinc 65.39	Ga Gallium 69.723	Ge Germanium 72.61	As Arsenic 74.92160	Se Selenium 78.96	Br Bromine 79.904	Kr Krypton 83.80		
5	Rb Rubidium 85.4678	Sr Strontium 87.62	Y Yttrium 88.90585	Zr Zirconium 91.224	Nb Niobium 92.90638	Mo Molybdenum 95.94	Tc Technetium (98)	Ru Ruthenium 101.07	Rh Rhodium 102.90550	Pd Palladium 106.42	Ag Silver 107.8682	Cd Cadmium 112.411	In Indium 114.818	Sn Tin 118.710	Sb Antimony 121.760	Te Tellurium 127.60	I Iodine 126.90447	Xe Xenon 131.29		
6	Cs Cesium 132.90545	Ba Barium 137.327		Hf Hafnium 178.49	Ta Tantalum 180.9479	W Tungsten 183.84	Re Rhenium 186.207	Os Osmium 190.23	Ir Iridium 192.222	Pt Platinum 195.078	Au Gold 196.96655	Hg Mercury 200.59	Tl Thallium 204.3833	Pb Lead 207.2	Bi Bismuth 208.98038	Po Polonium (209)	At Astatine (210)	Rn Radon (222)		
7	Fr Francium (223)	Ra Radium (226)		Rf Rutherfordium (261)	Db Dubnium (262)	Sg Seaborgium (263)	Bh Bohrium (264)	Hs Hassium (265)	Mt Meitnerium (266)	Uun Ununium (267)	Uuu Ununium (271)	Uub Ununium (272)								
			La Lanthanum 138.9055	Ce Cerium 140.116	Pr Praseodymium 140.90768	Nd Neodymium 144.24	Pm Promethium (145)	Sm Samarium 150.36	Eu Europium 151.964	Gd Gadolinium 157.25	Tb Terbium 158.92524	Dy Dysprosium 162.50	Ho Holmium 164.93032	Er Erbium 167.26	Tm Thulium 168.93421	Yb Ytterbium 173.04	Lu Lutetium 174.967			
			Ac Actinium (227)	Th Thorium 232.0381	Pa Protactinium 231.03688	U Uranium 238.0289	Np Neptunium (237)	Pu Plutonium (244)	Am Americium (243)	Cm Curium (247)	Bk Berkelium (247)	Cf Californium (251)	Es Einsteinium (252)	Fm Fermium (257)	Md Mendelevium (258)	No Nobelium (259)	Lr Lawrencium (262)			

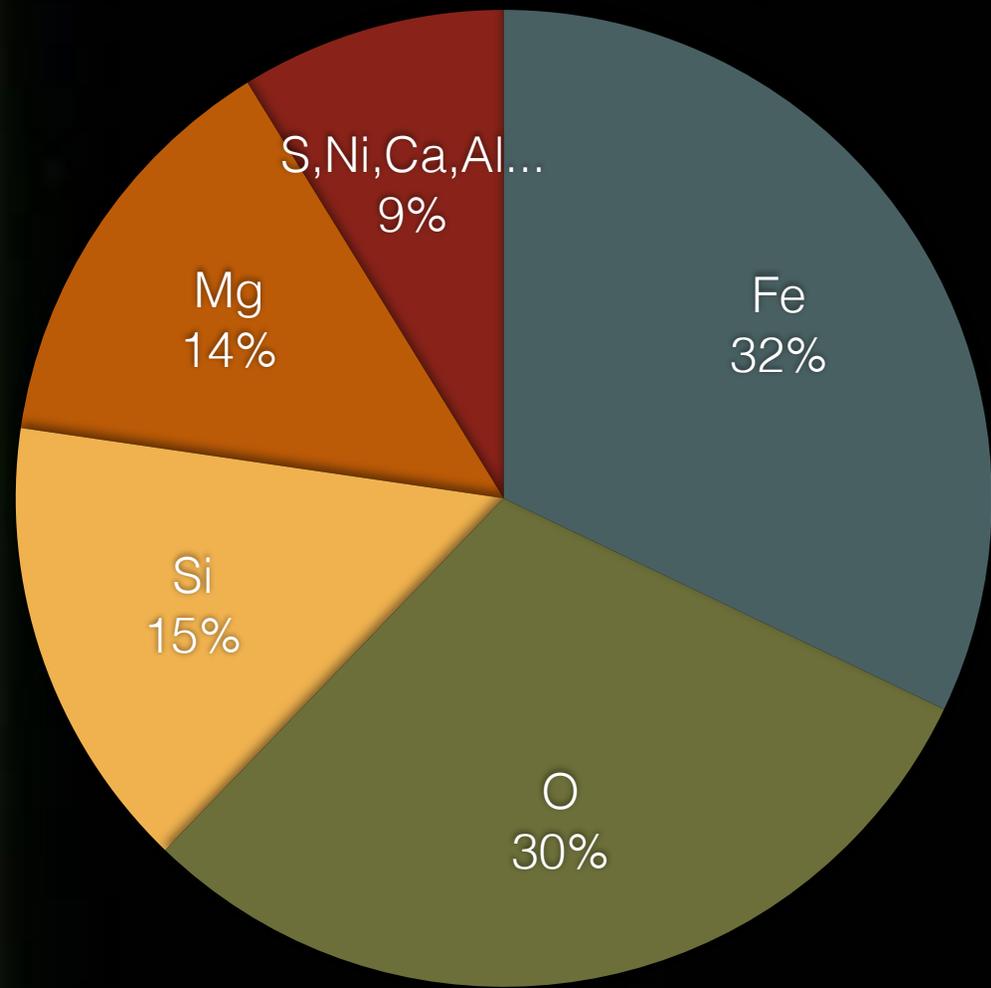
Fe and above produced in supernovae



Luna's
What is ~~our~~ origin story?



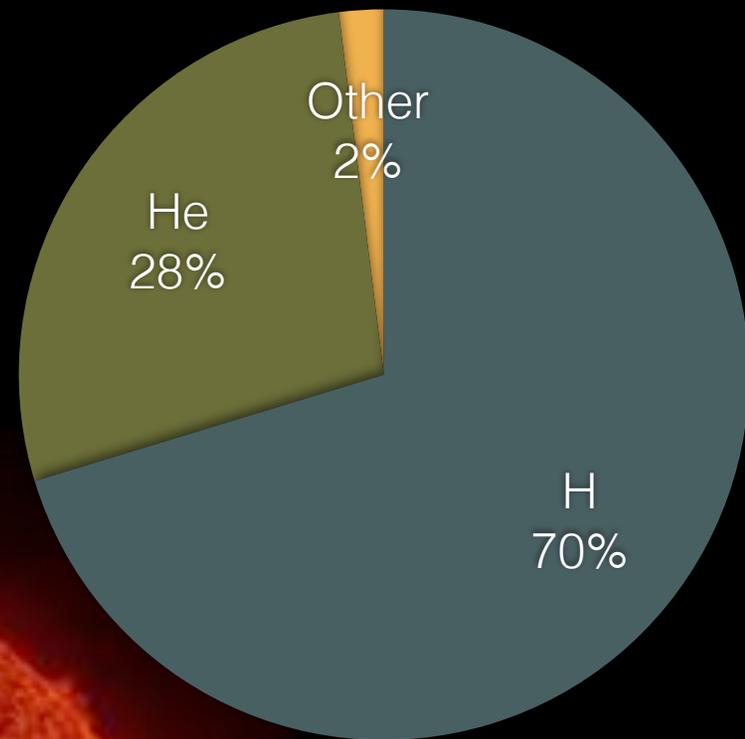




Luna is here



Luna orbits this star



Luna's
What is ~~our~~ origin story?



Origin of the elements?

Periodic Table of the Elements

☐ Solids

☐ Liquids

☐ Gases

☐ Artificially Prepared

Atomic Number: 26

Symbol: Fe

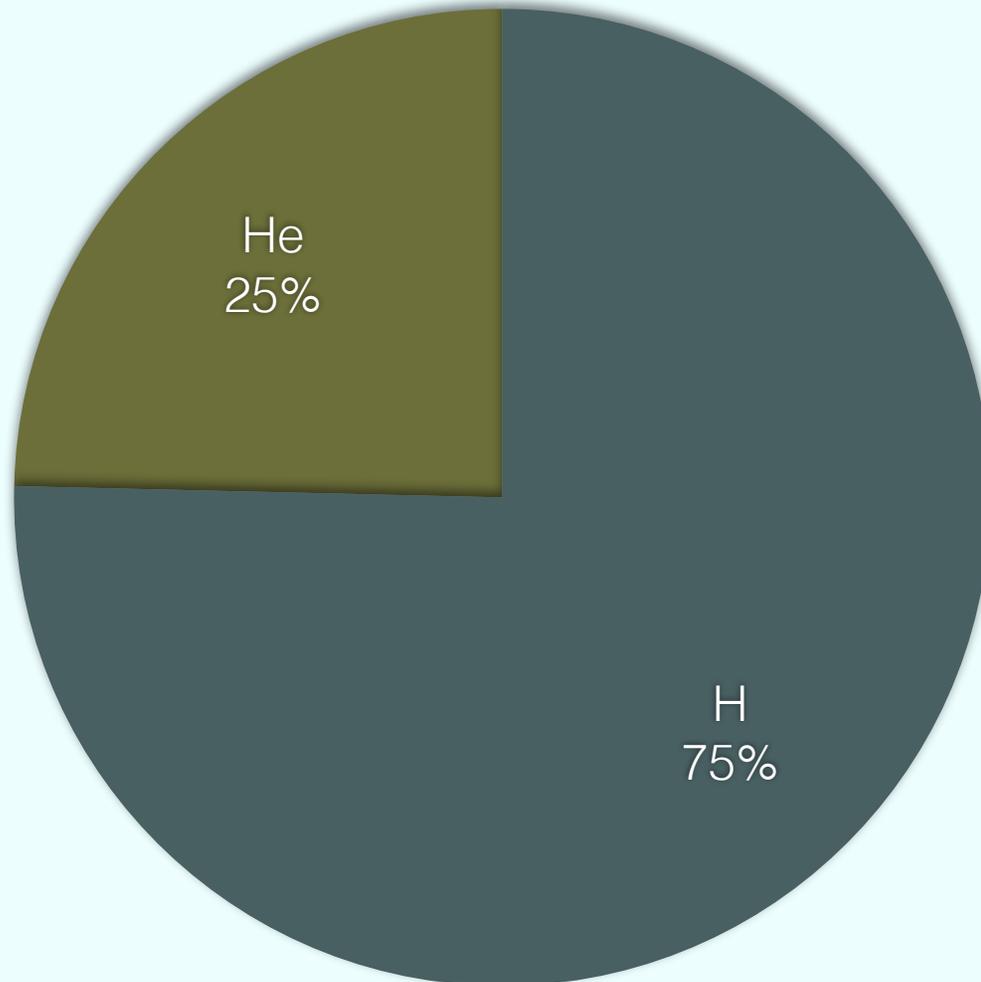
Name: Hydrogen

Atomic Weight: 1.0079

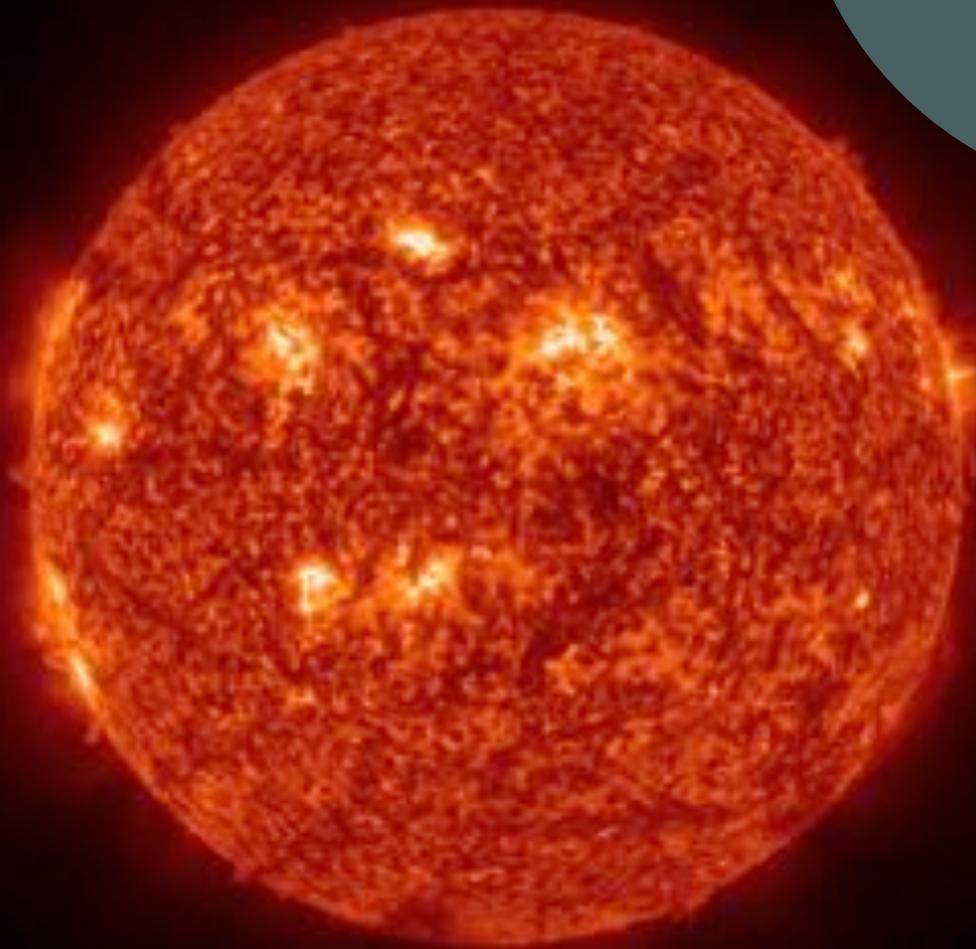
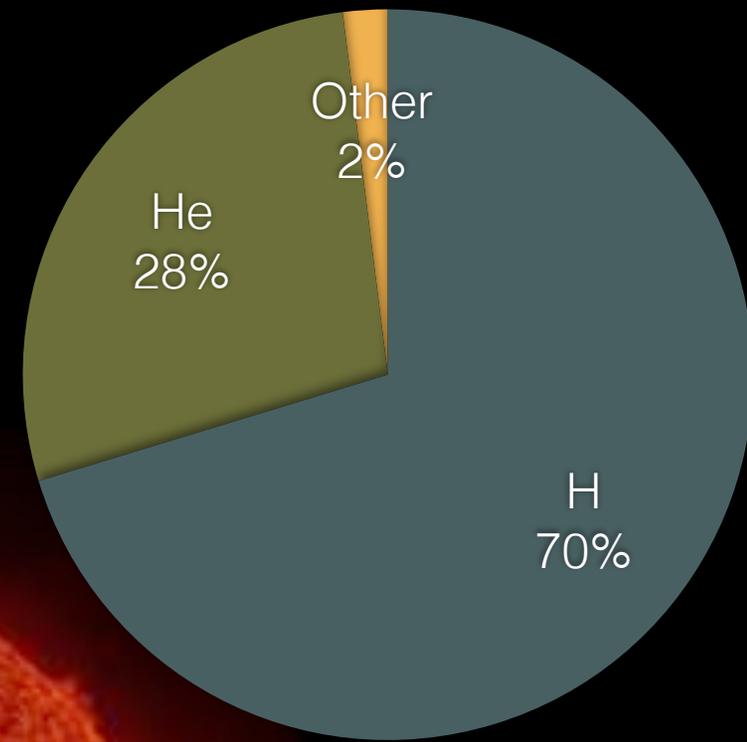
GROUP		PERIOD																VIII													
IA		IIA		III A										IIIB	IVB	VB	VIB	VIIB	VIII	II											
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Big Bang!

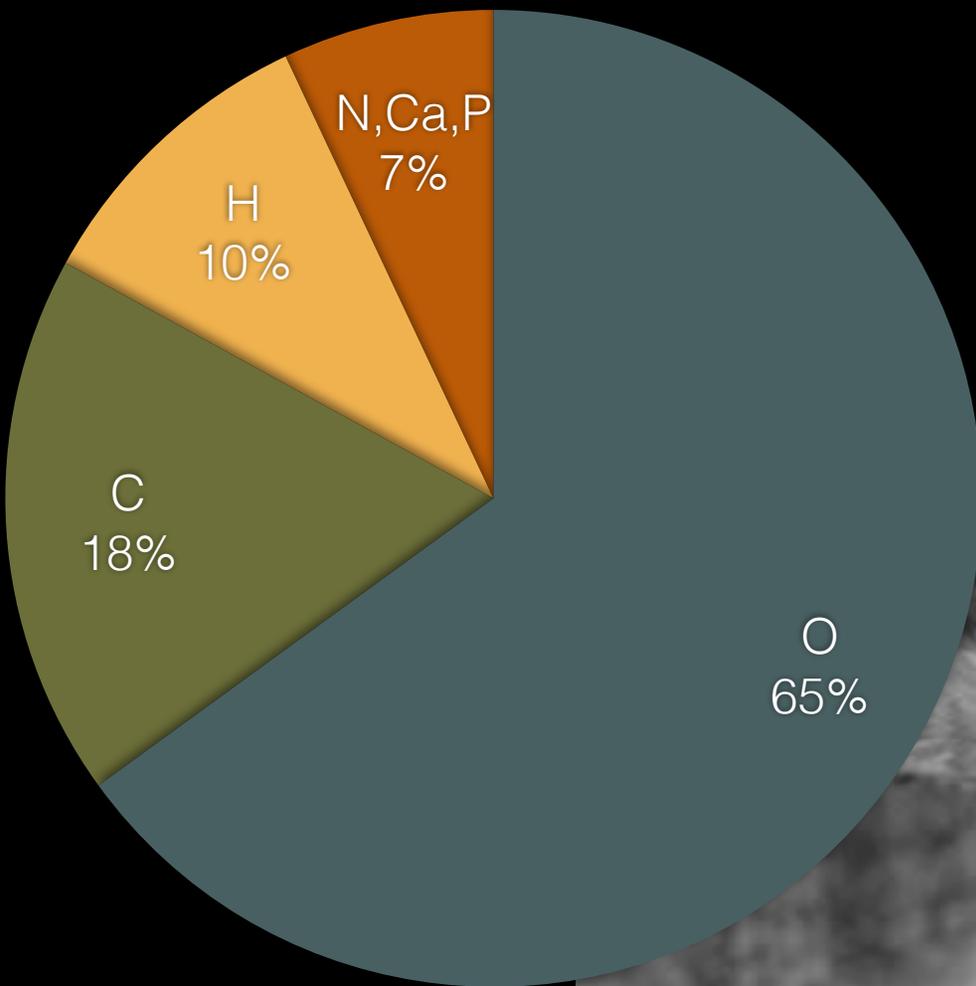
Big Bang!



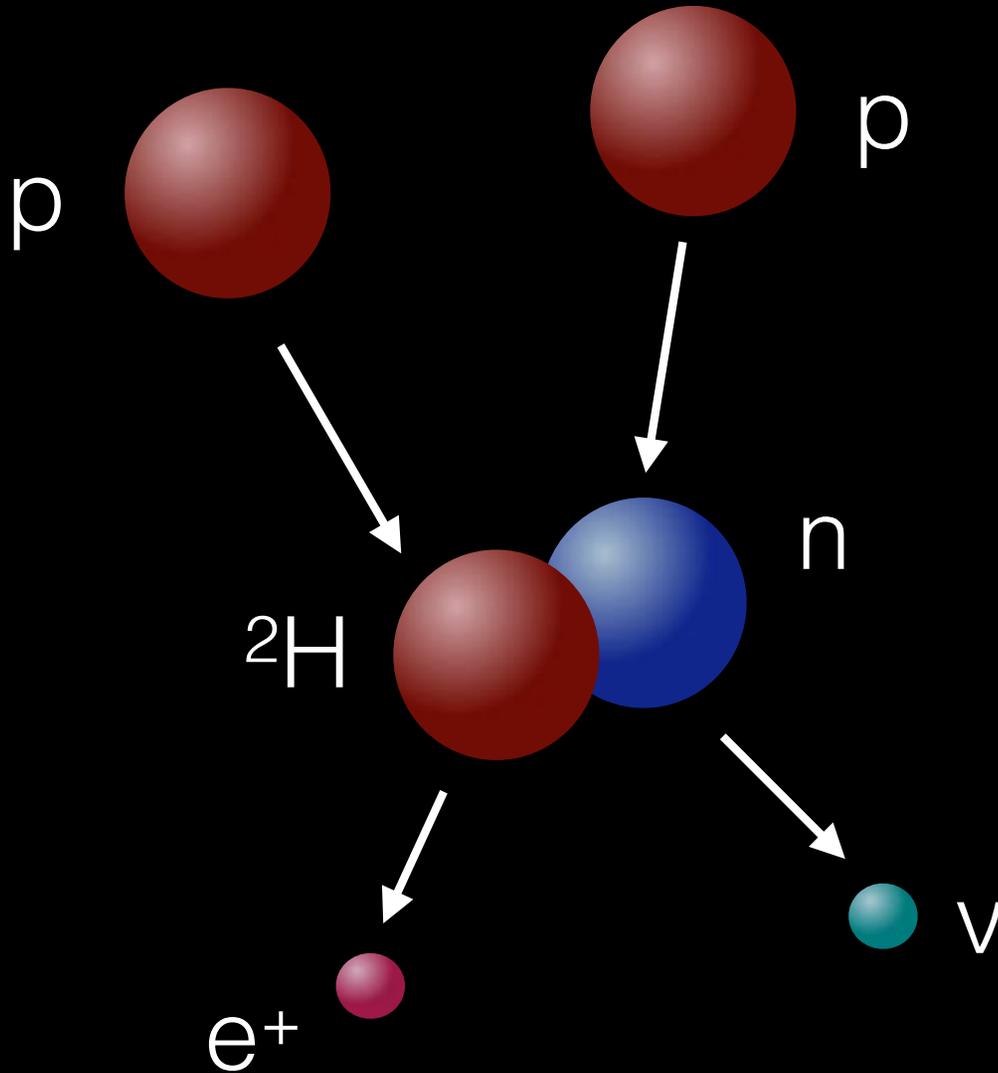
Primordial Abundance



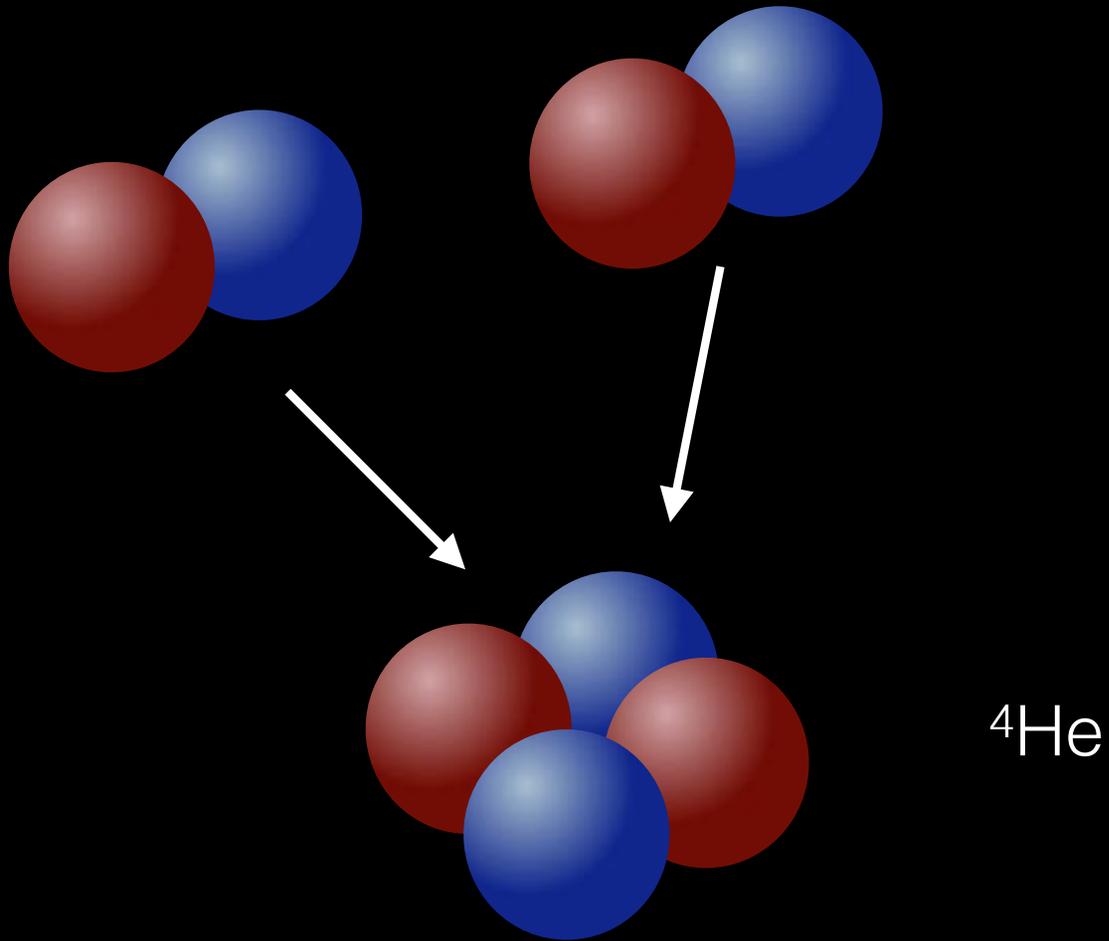
...and Luna?



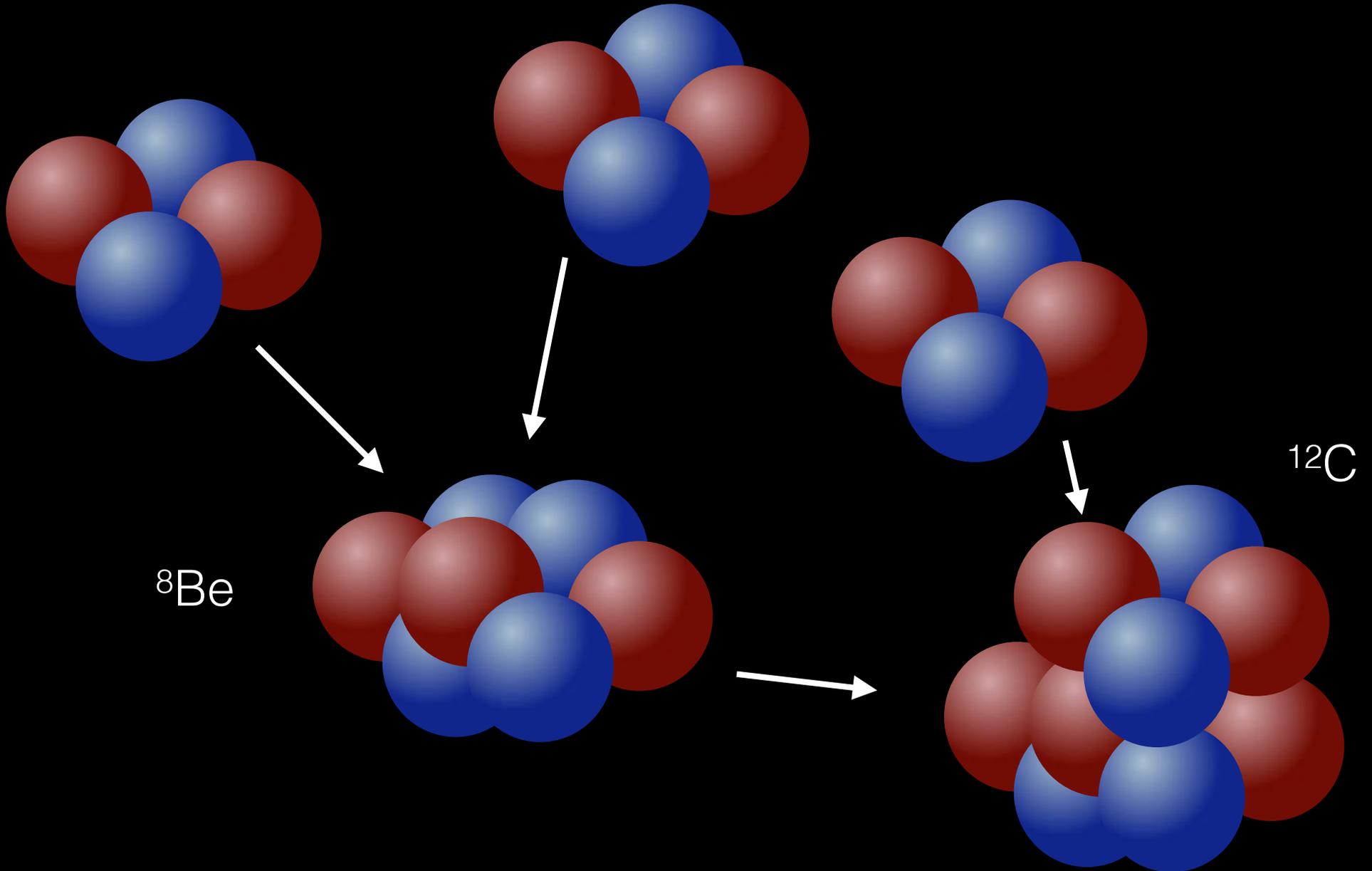
Nuclear Fusion Think Legos!



Nuclear Fusion Think Legos!

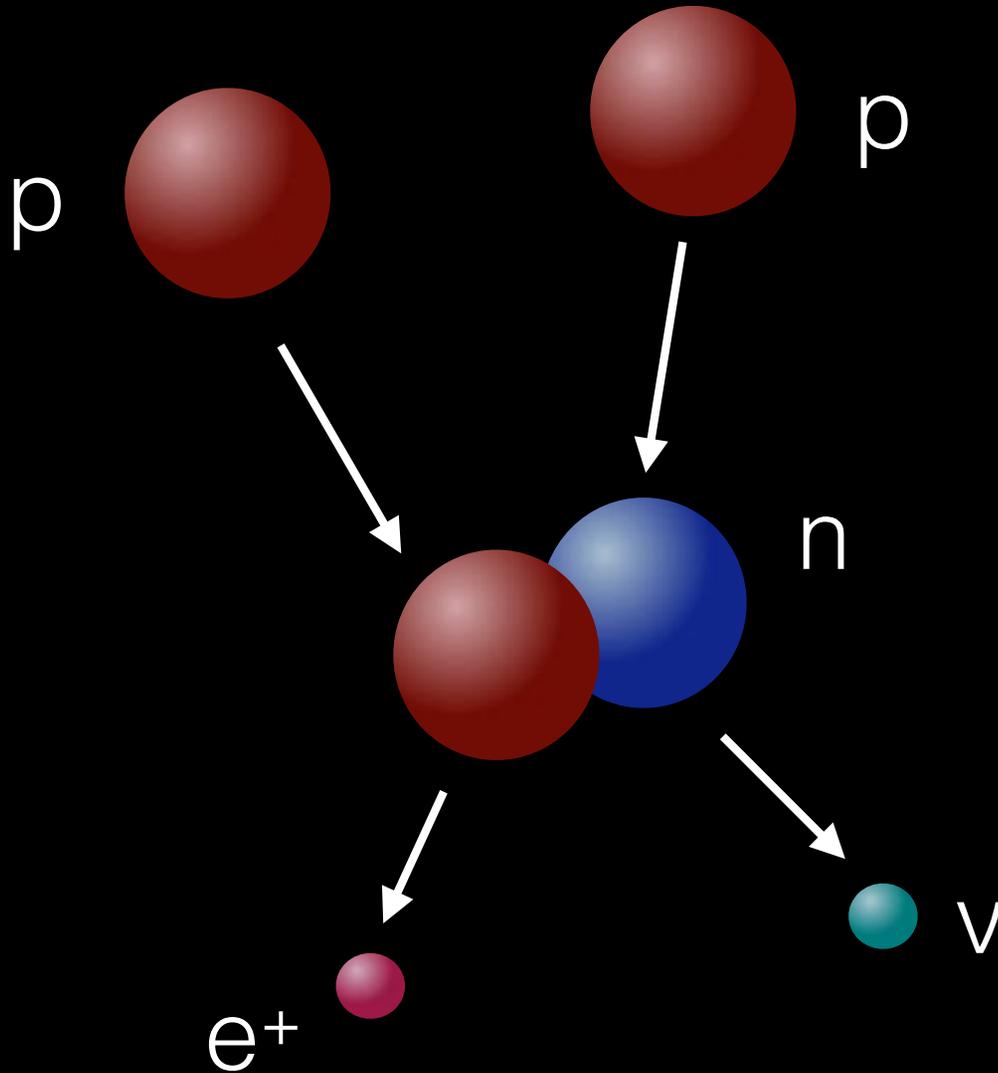


Nuclear Fusion Think Legos!



Where does fusion
happen?

ElectroStatic Repulsion
Strong Force Attraction
(Really Hard)



Hot & Dense
Environments

A Fusion Reactor



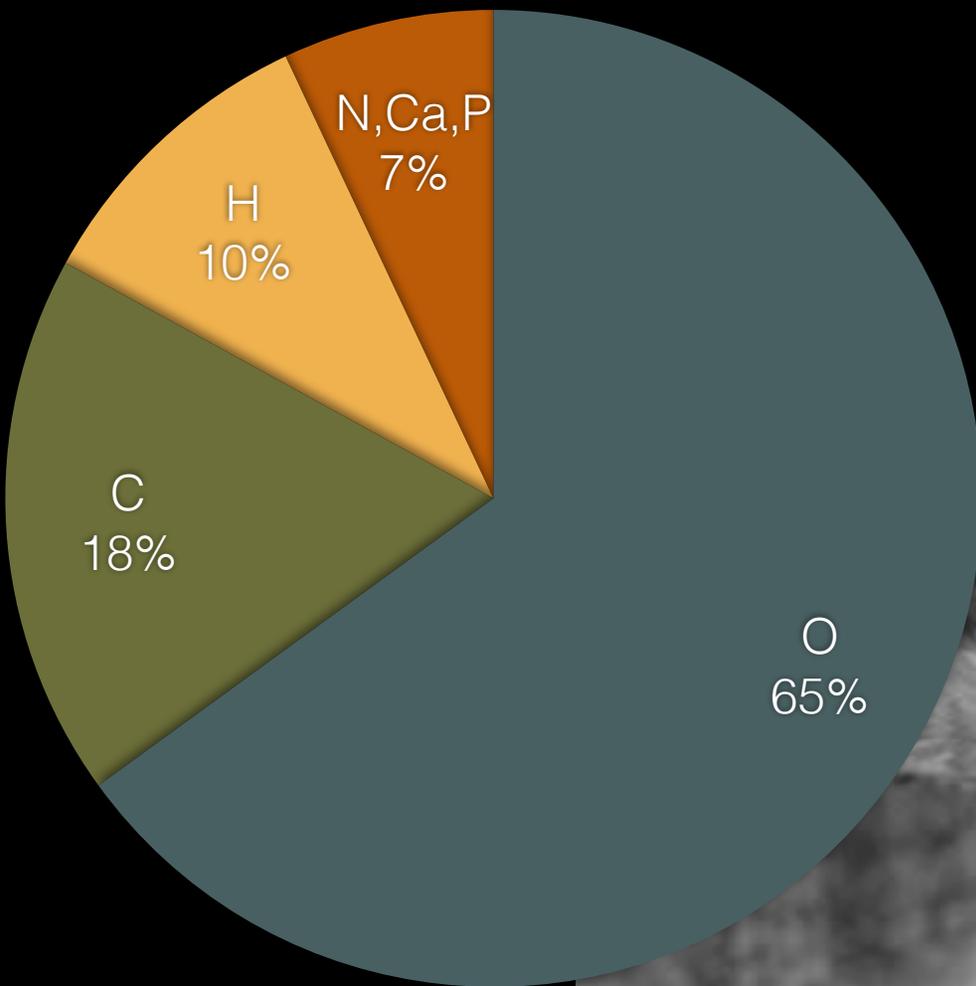
2017 Dec 31 16:00:12

A Fusion Reactor Hydrogen to Helium



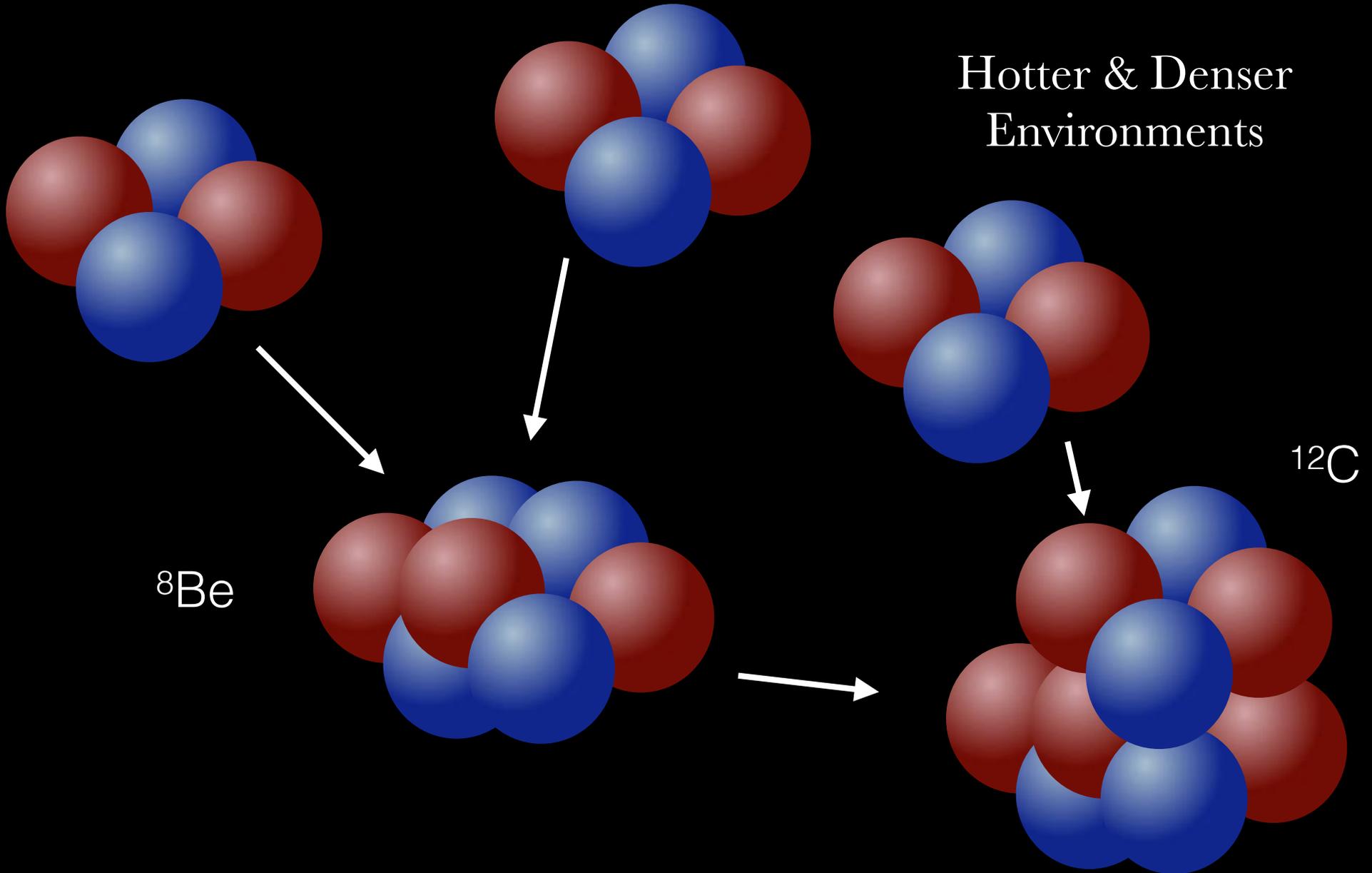
2017 Dec 31 16:00:12

...and Luna?



Even Harder

Hotter & Denser
Environments



Well...more massive stars
keep going

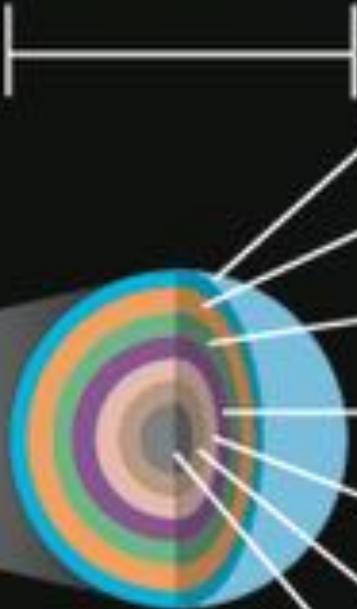
1.6 billion kilometers

About 10,000 km



A supergiant star

Jupiter's orbit



Central regions of a supergiant star

Hydrogen-fusing shell

Helium-fusing shell

Carbon-fusing shell

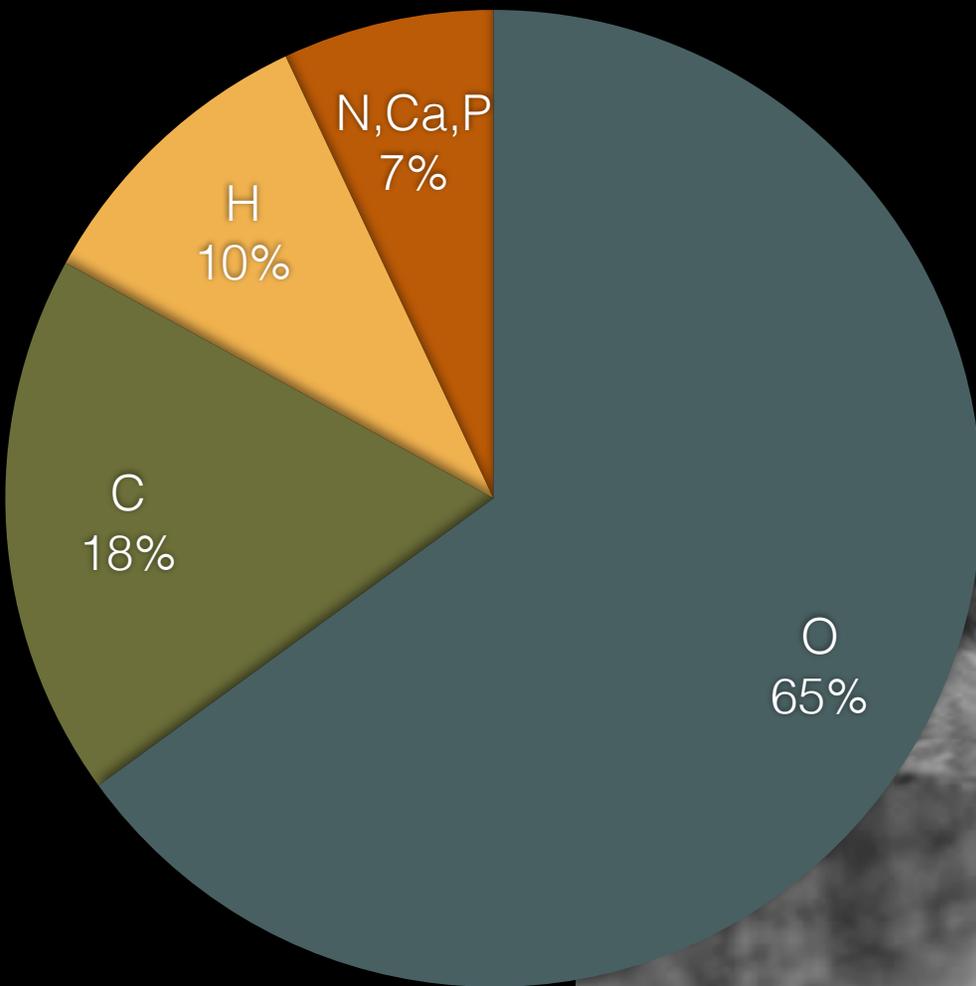
Neon-fusing shell

Oxygen-fusing shell

Silicon-fusing shell

Iron core (no fusion)

Elements need to come out of stars





Supernova(e)



What causes explosion?

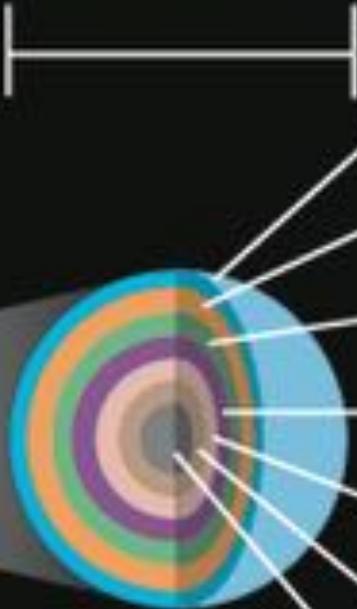
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Jupiter's orbit



Central regions of a supergiant star

Hydrogen-fusing shell

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Carbon-fusing shell

Neon-fusing shell

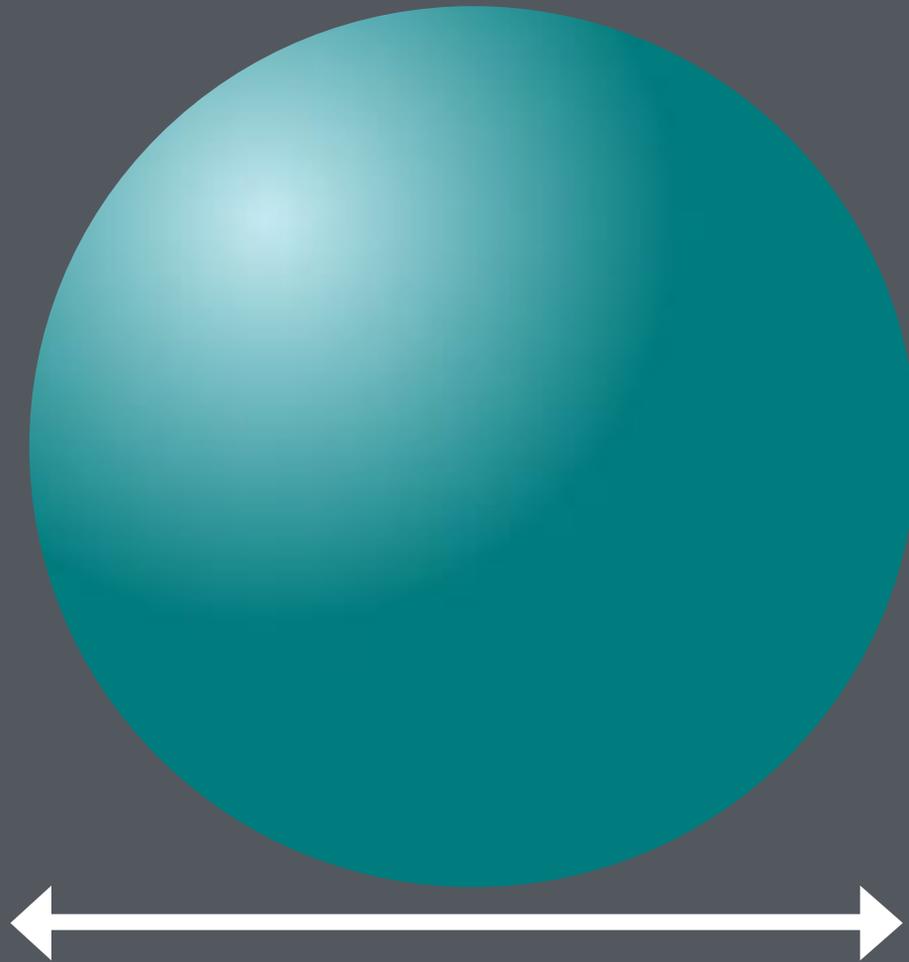
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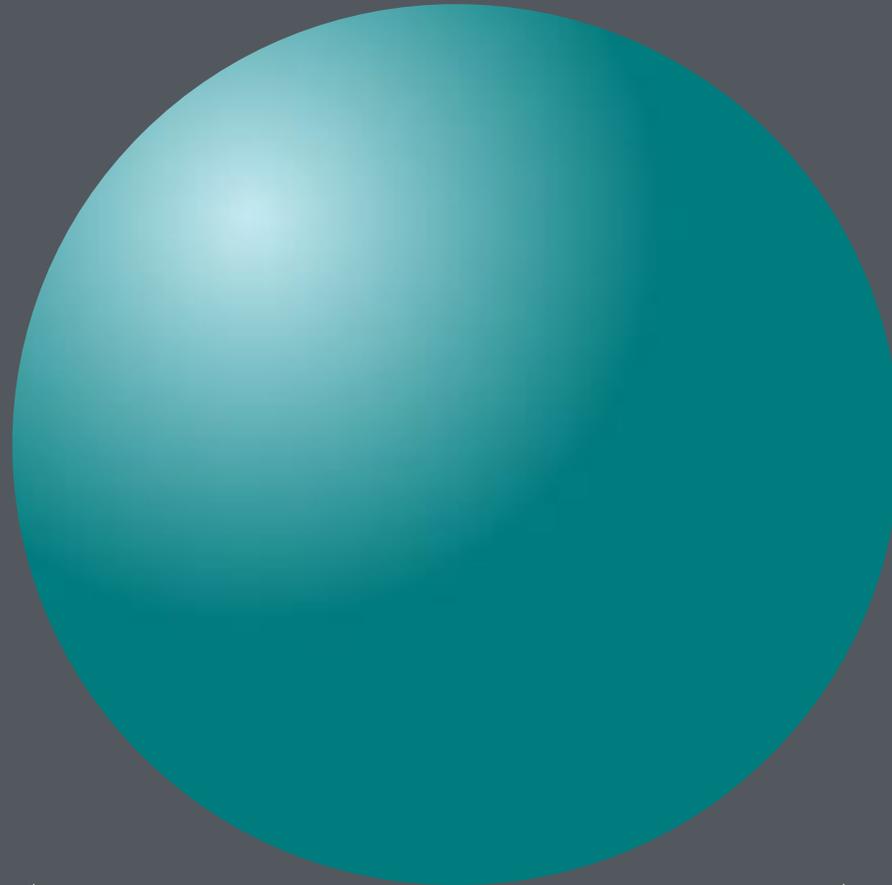
Fe Core

1.4 Mass of Sun



1000s of kms

Fe Core



1.4 Mass of Sun
Collapse 0.1s



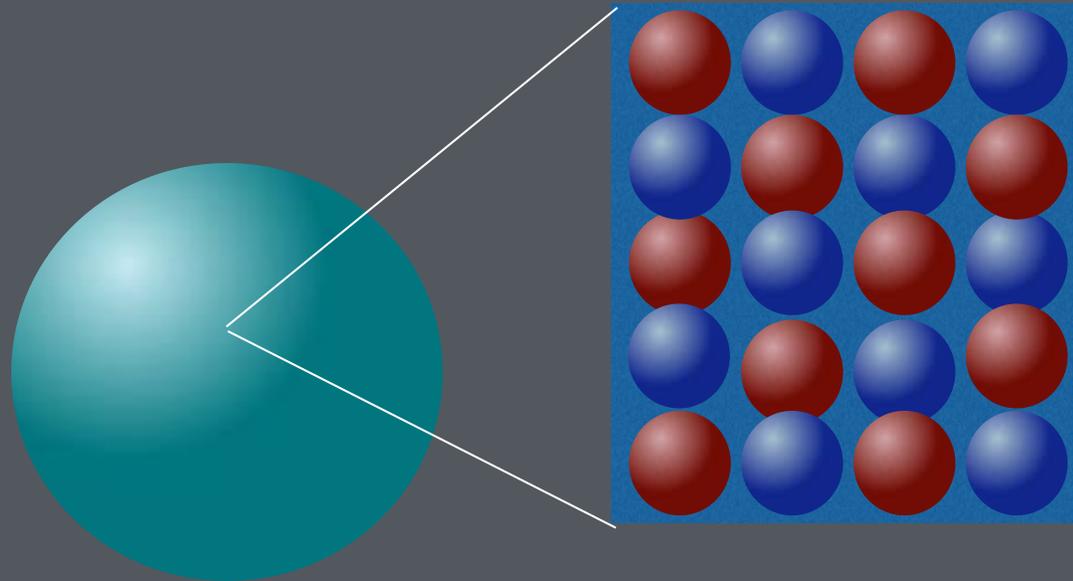
1000s of kms

Neutron Star



10s of kms

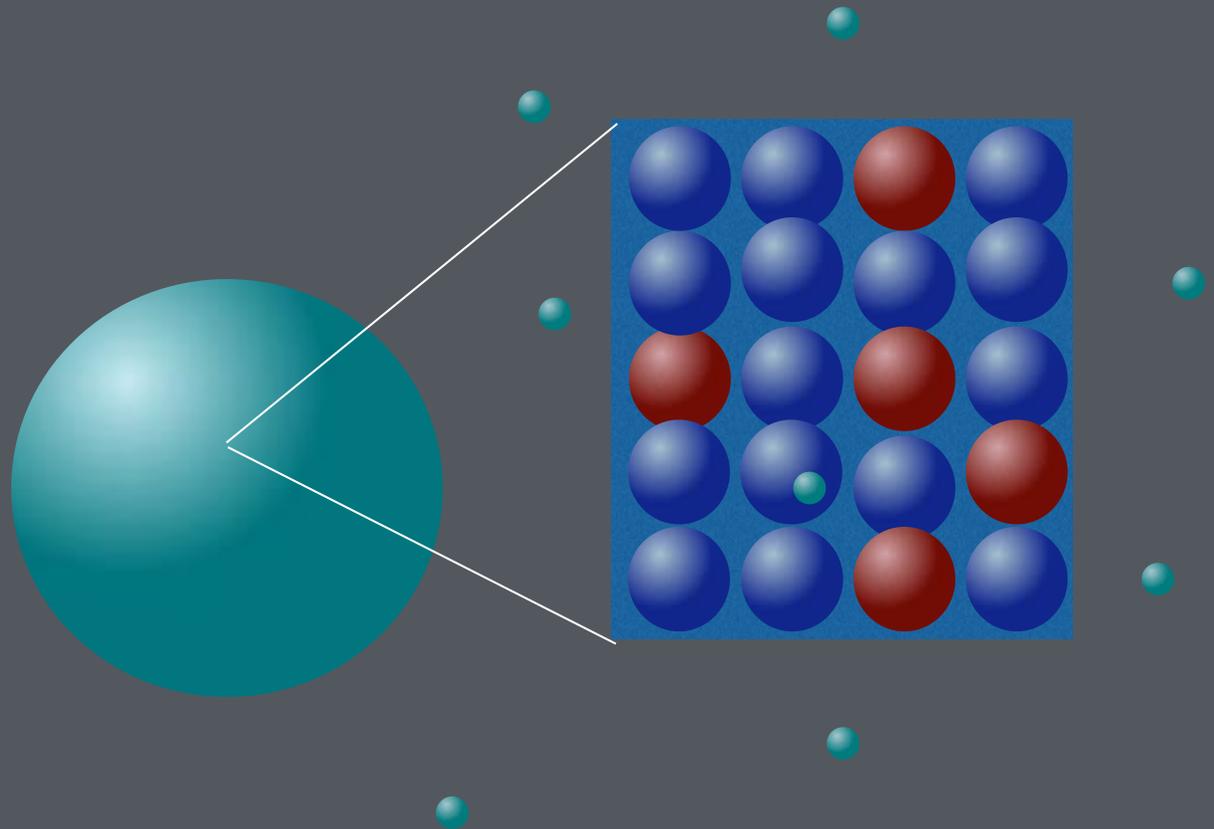
Neutron Star



Denser than the
nucleus of an atom

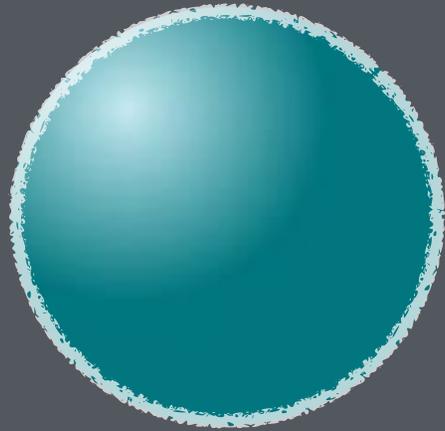
↔
10s of kms

Neutron Star



10s of kms

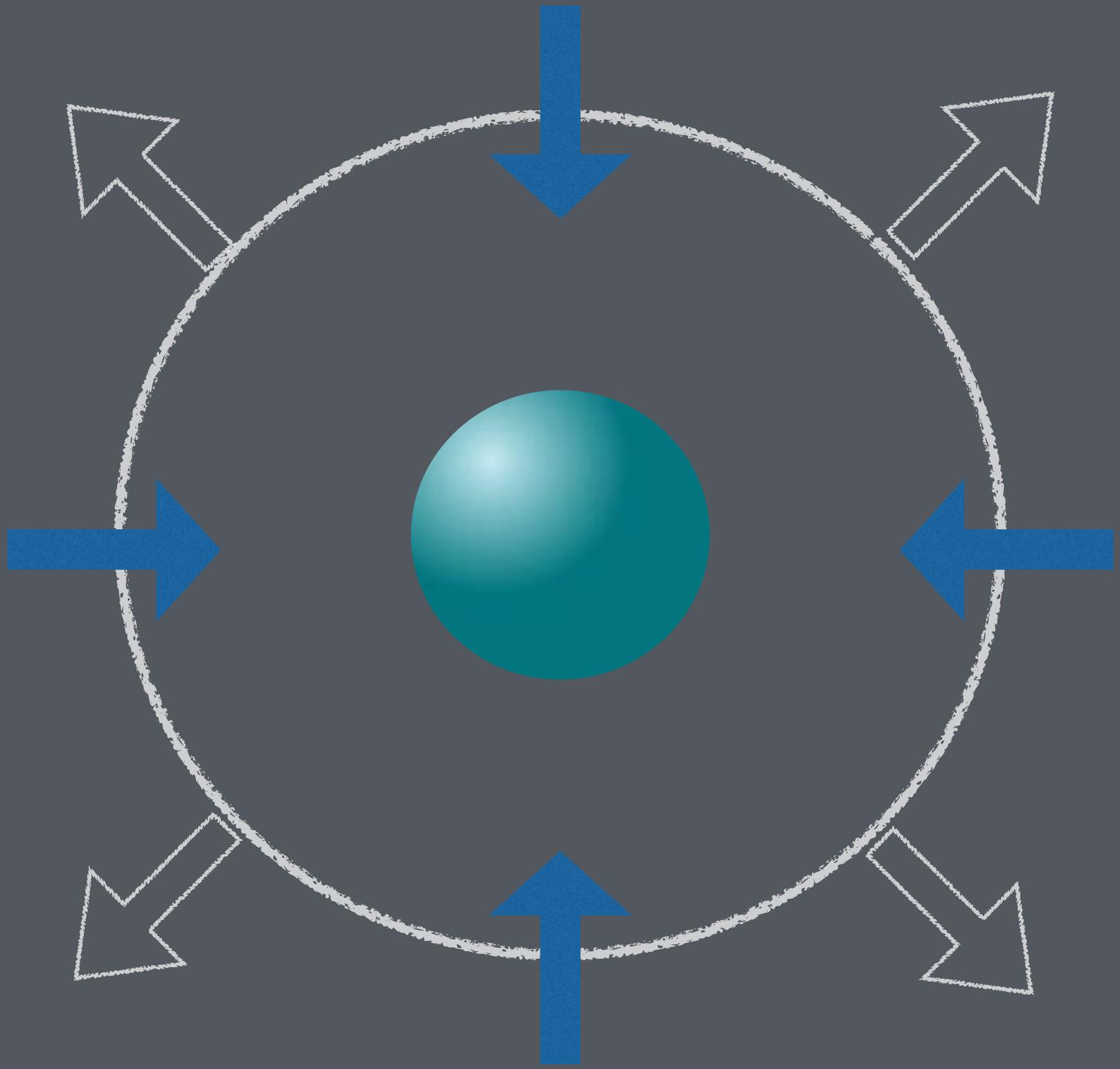
Core Stiffens Launches Blast Wave

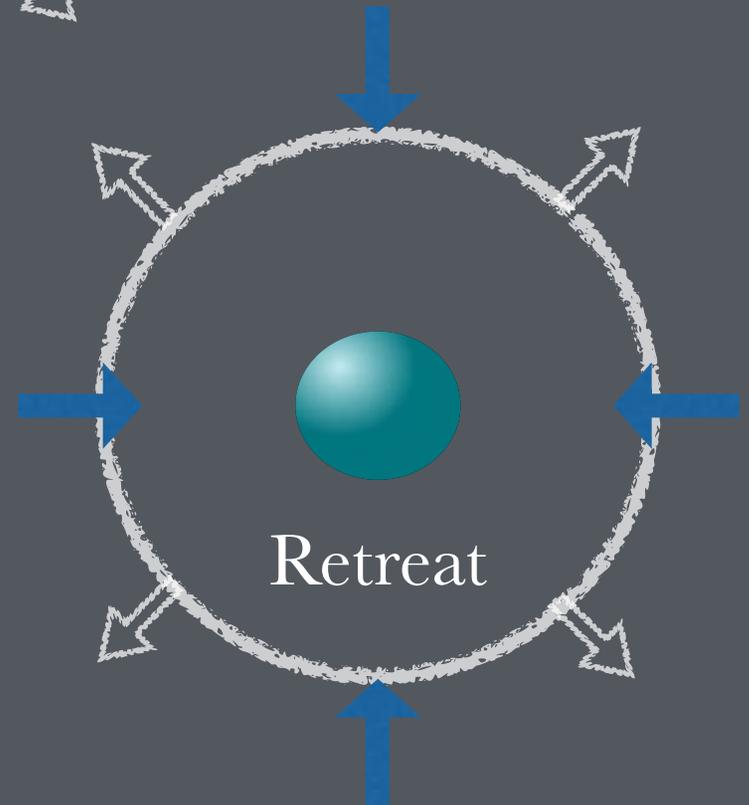
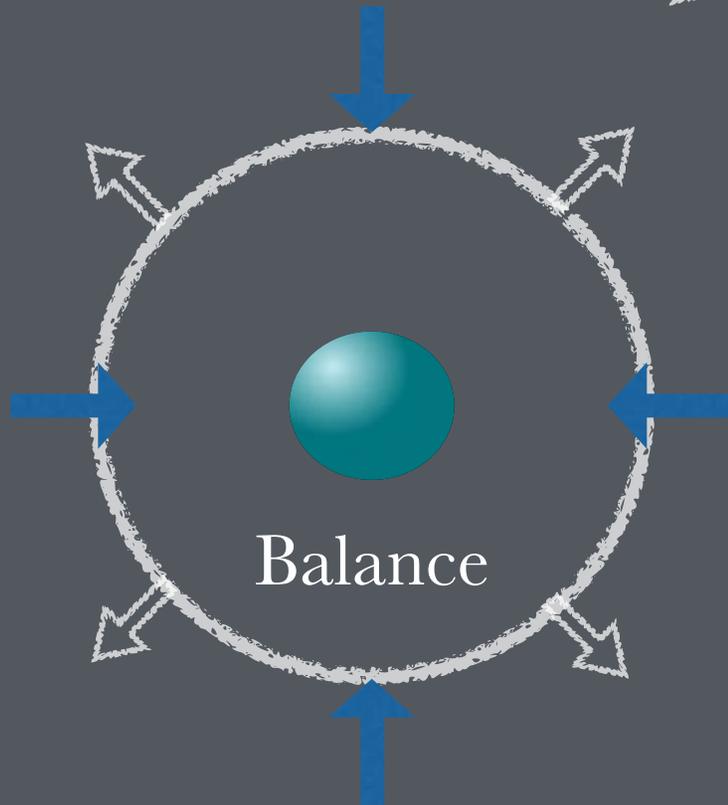
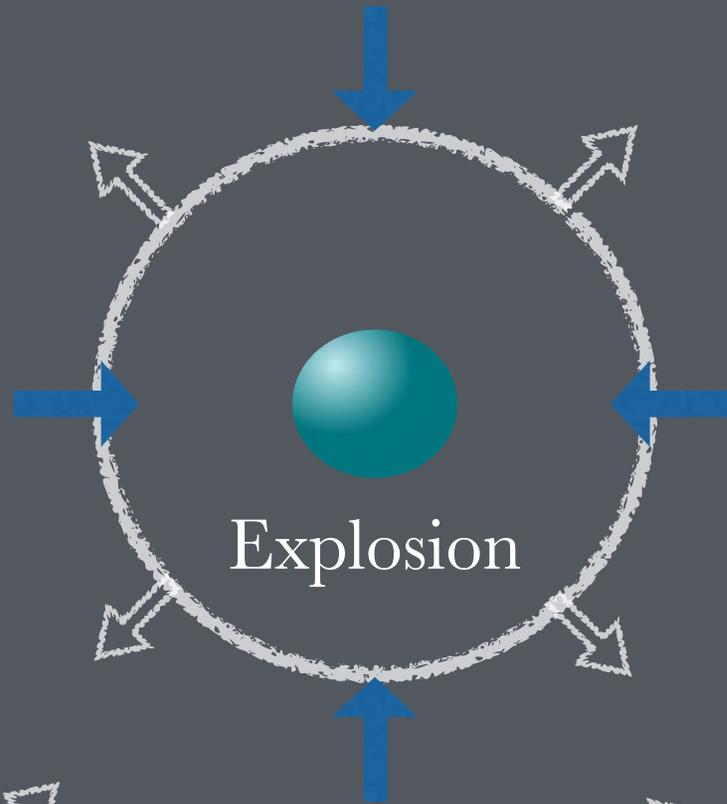


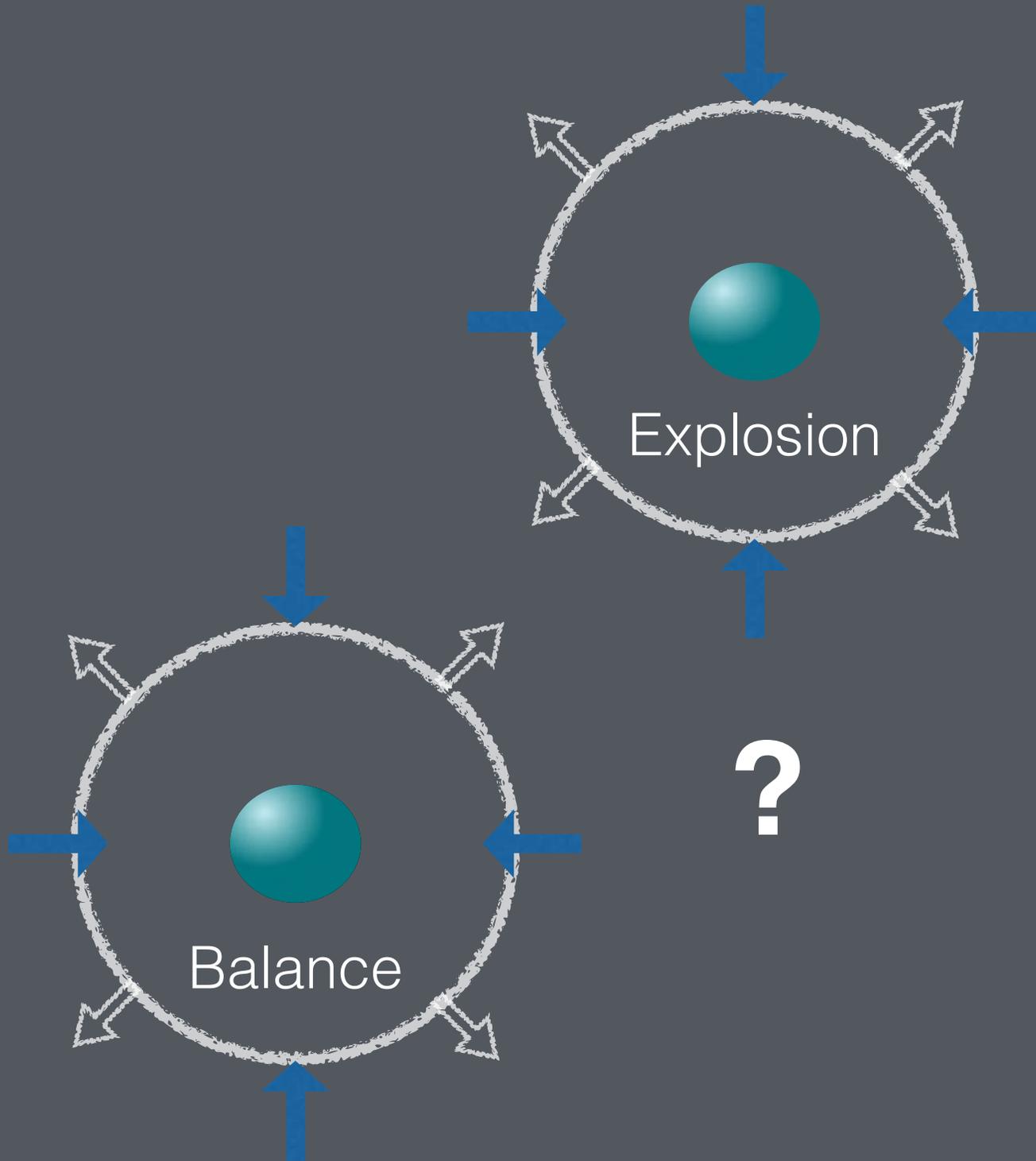
Supernova

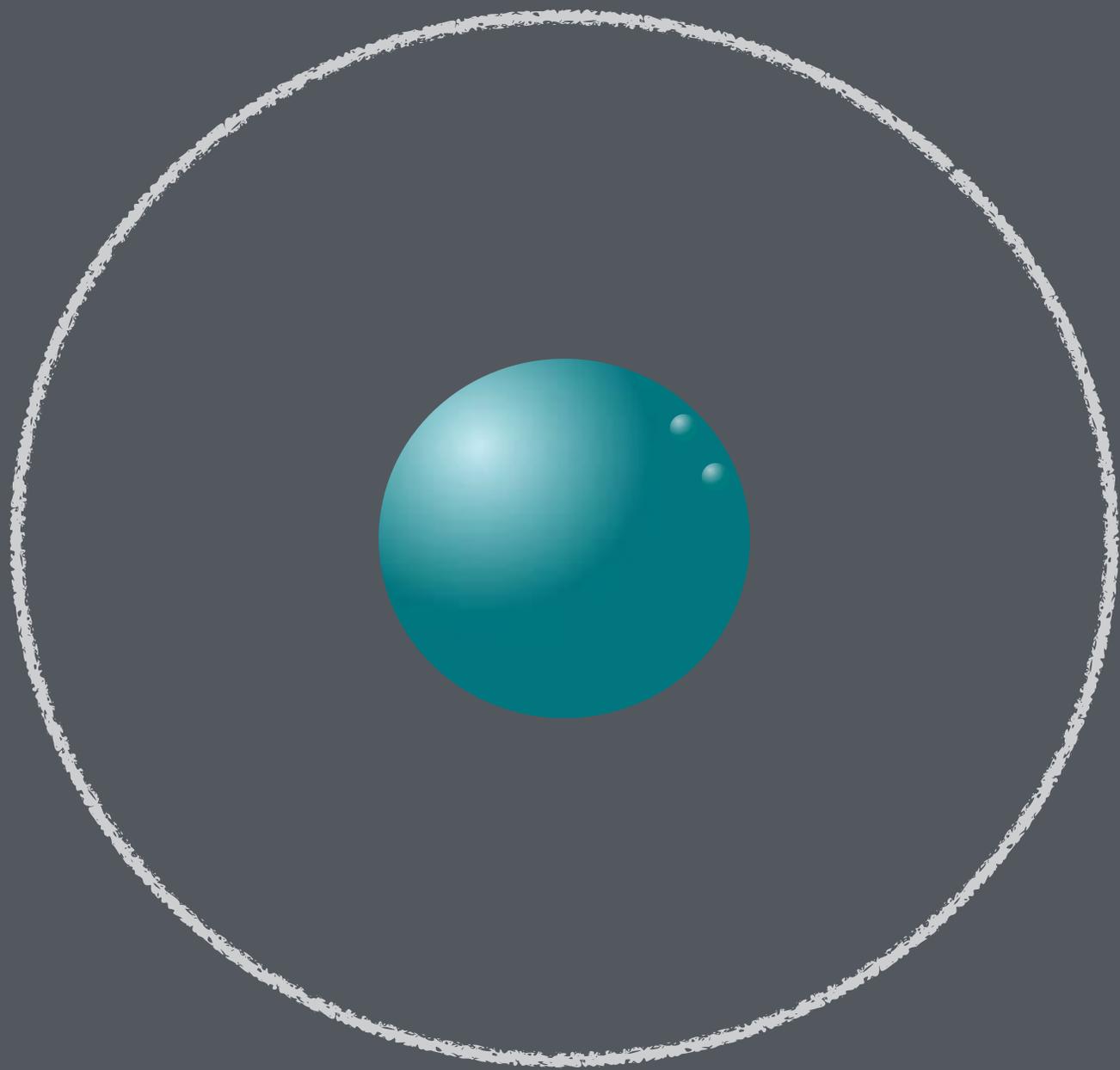


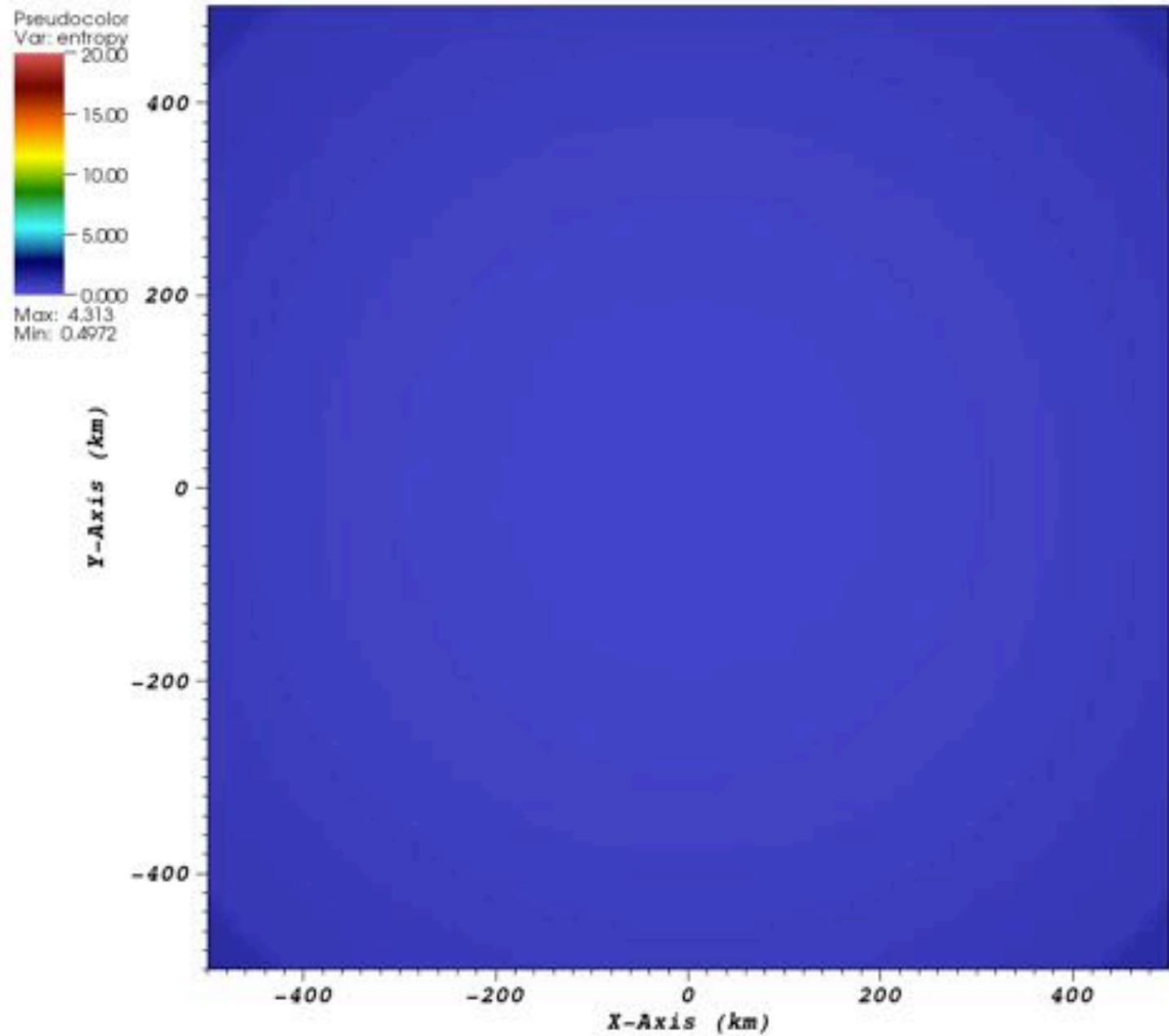
But wait!











Time = -0.2600 s after bounce



Credit: David De Martin (<http://www.skyfactory.org>),
ESA/ESO/NASA FITS Liberator & Digitized Sky Survey

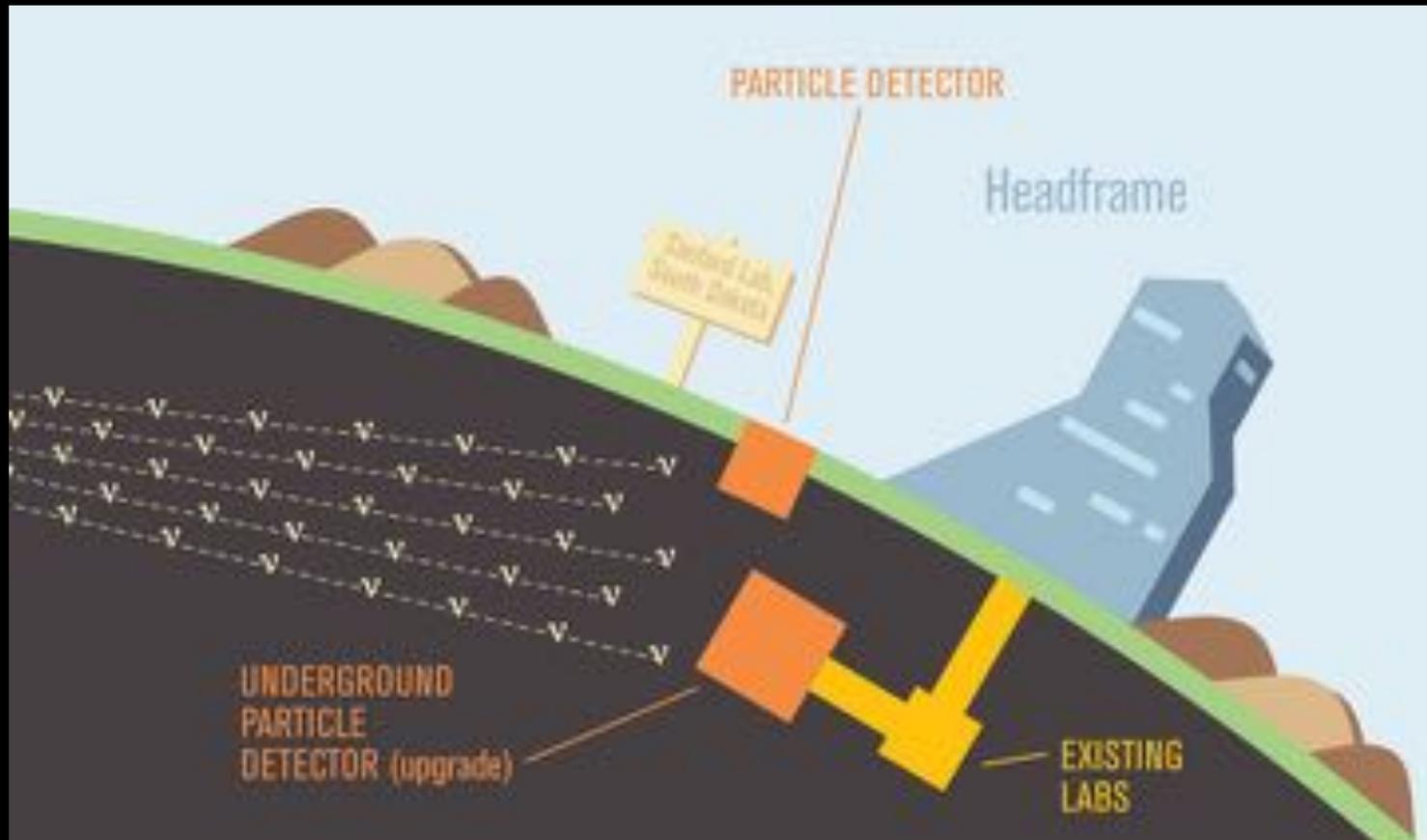
Theory

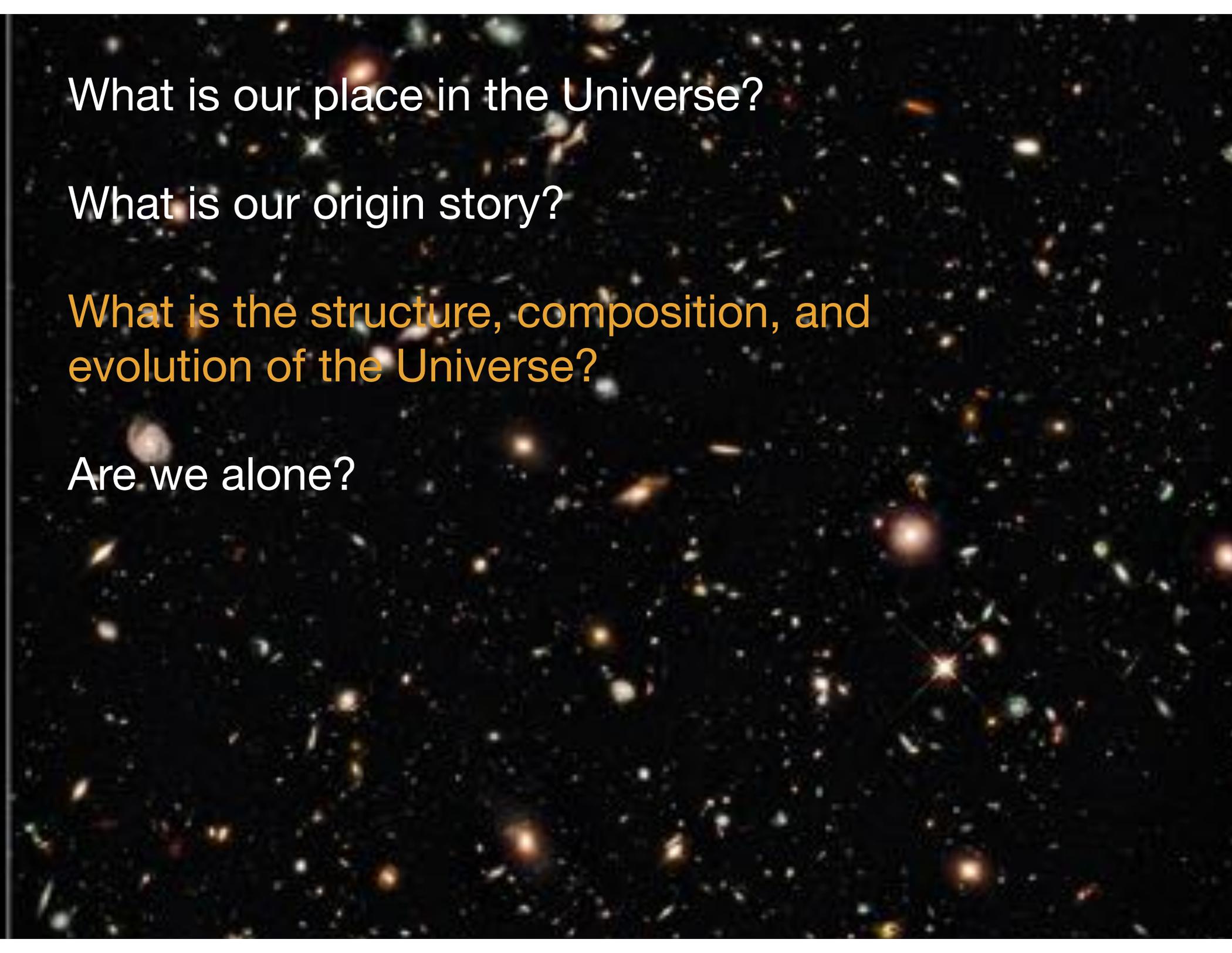
Predict

Observe



Neutrino Detector



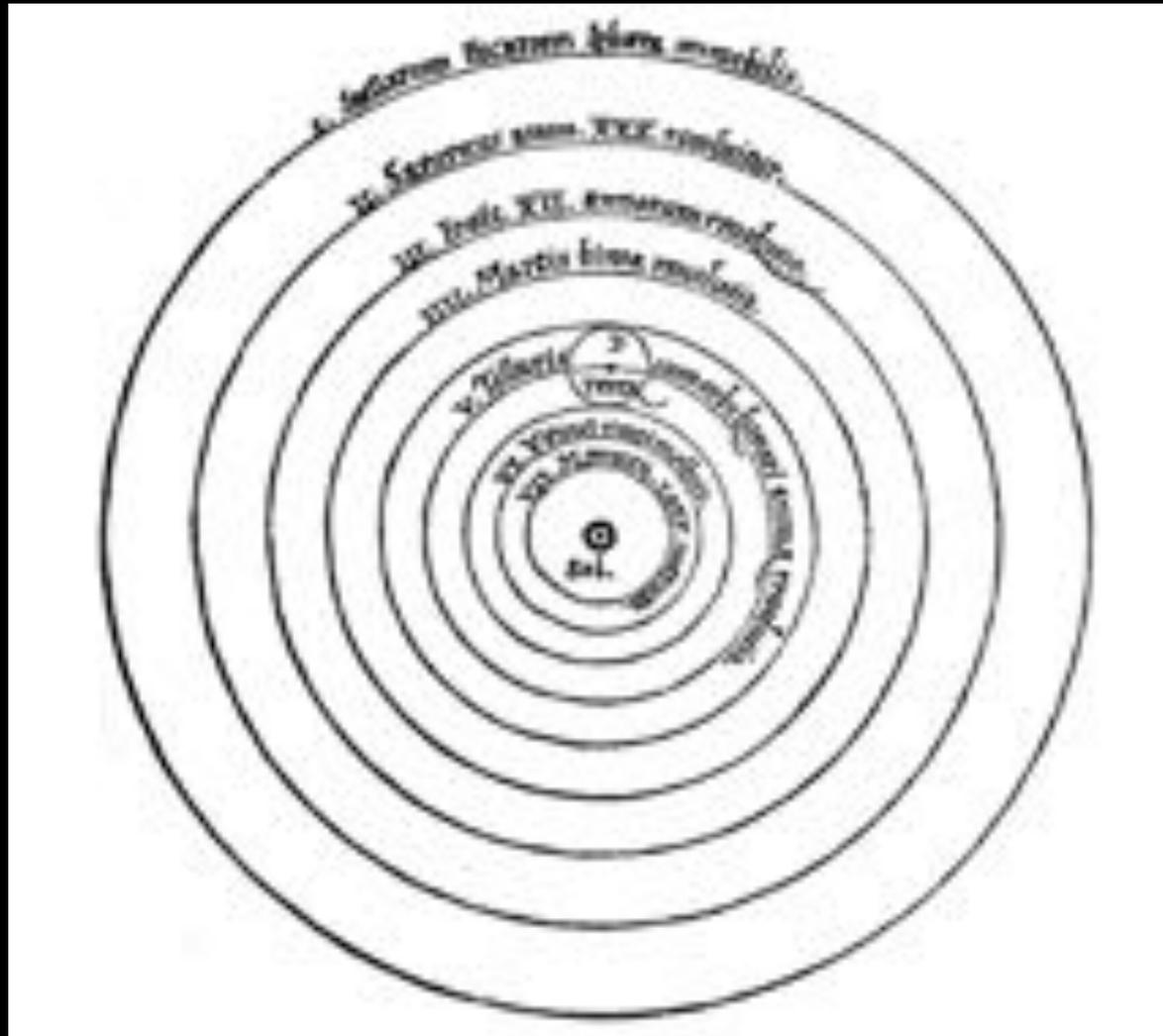


What is our place in the Universe?

What is our origin story?

What is the structure, composition, and evolution of the Universe?

Are we alone?



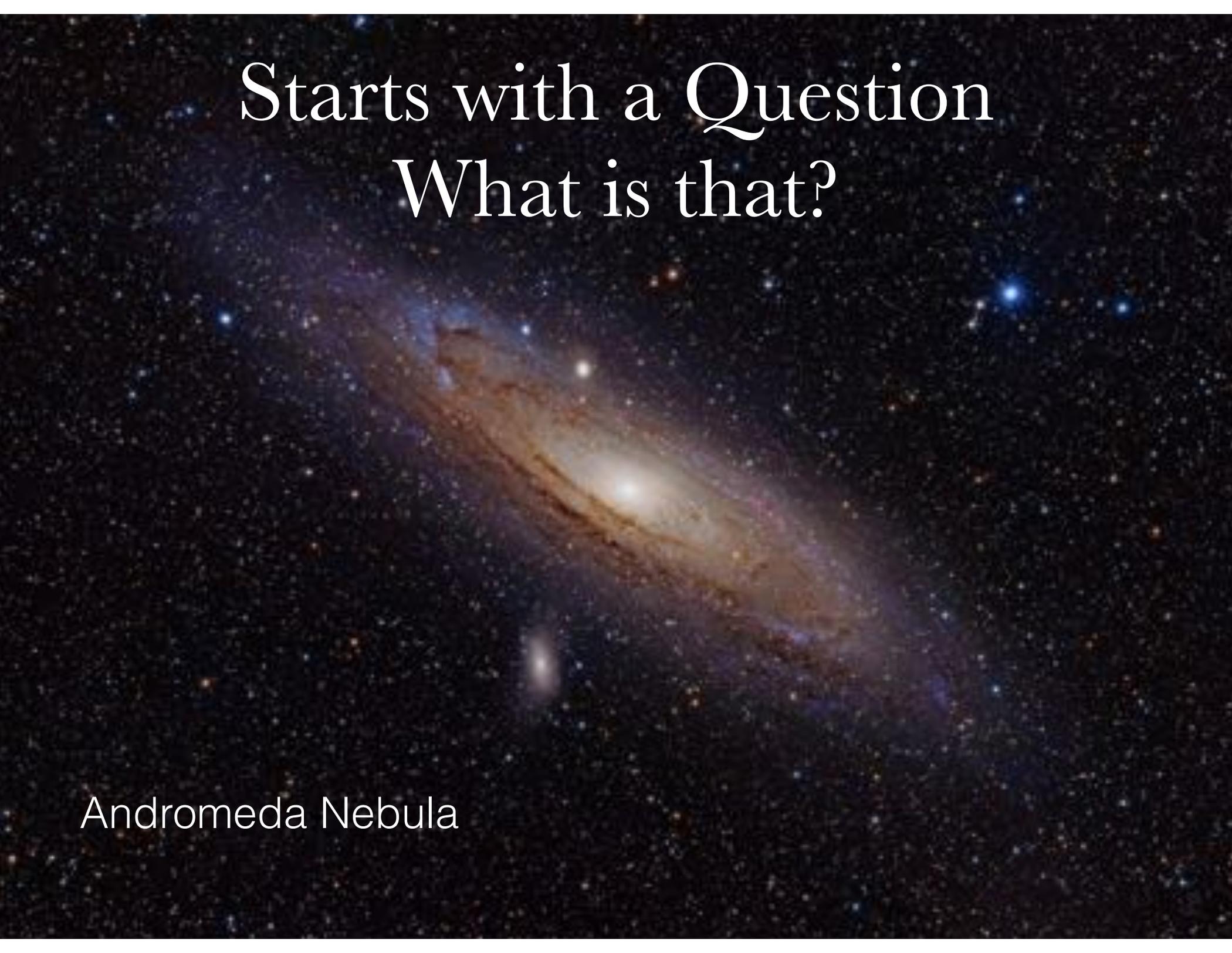
Copernican Universe (1543)



A story of humility.
How did we get there?

Starts with a Question
What is that?

Andromeda Nebula



Look up...what do you see?



NIGHTSCAPEPHOTOS.COM

Look up...what do you see?



All Sky Image, credit: Nick Risinger

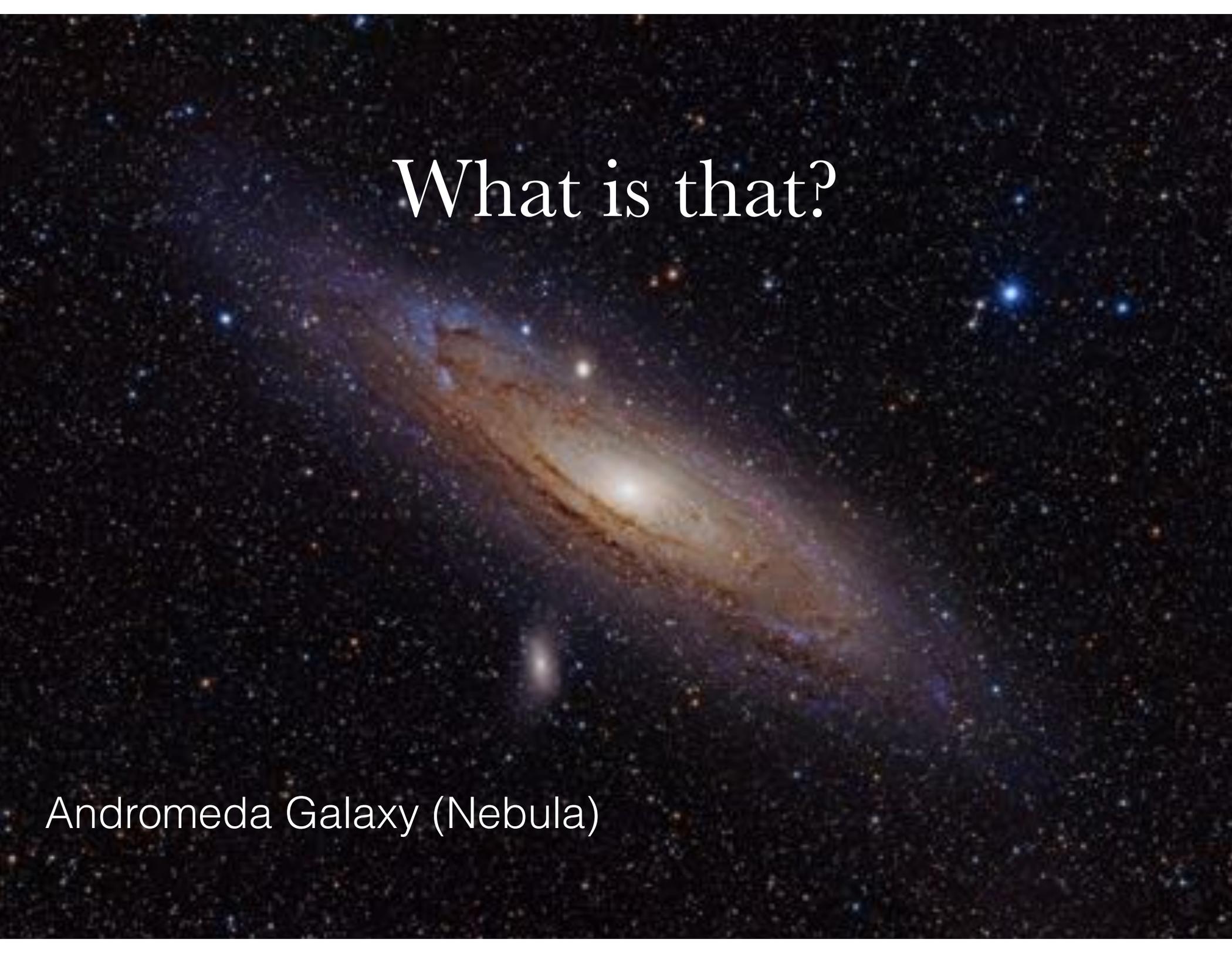
Is this all there is to our
Universe?



All Sky Image, credit: Nick Risinger

What is that?

Andromeda Galaxy (Nebula)



How far away is that?

Andromeda Galaxy (Nebula)

Need a “Yard stick”



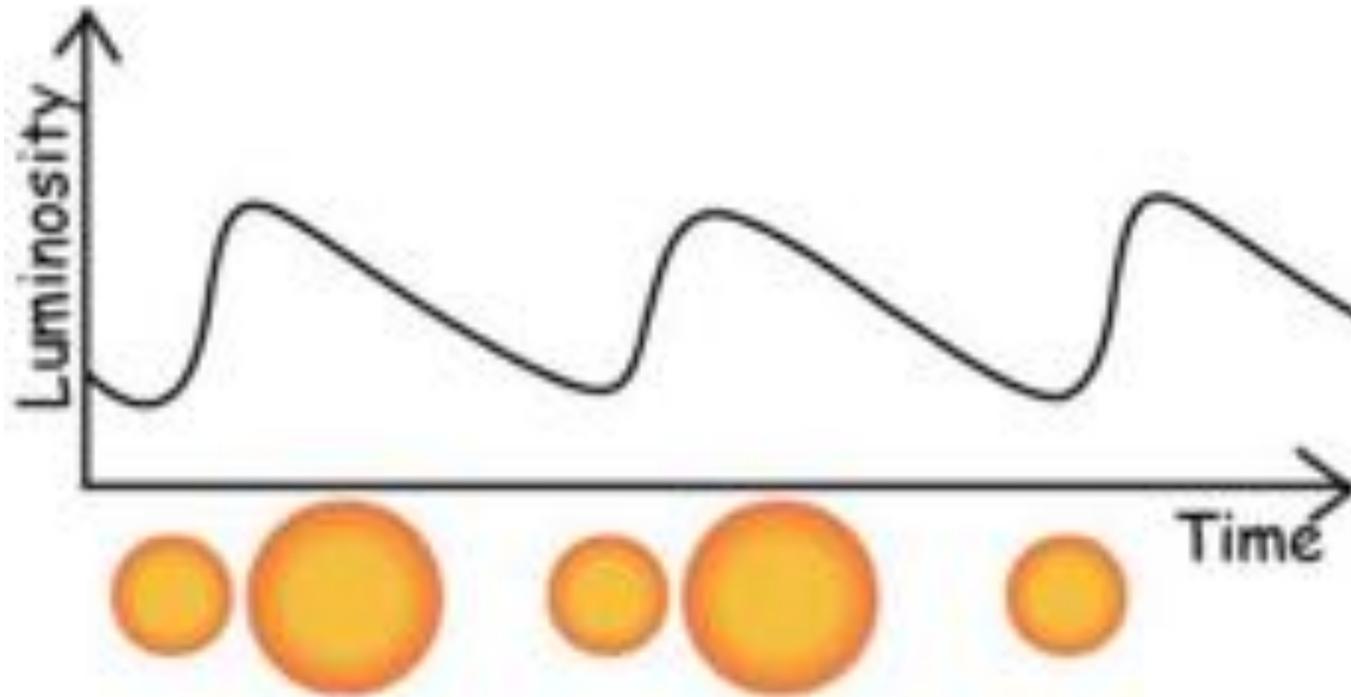
Standard Candle



Henrietta Swan Leavitt

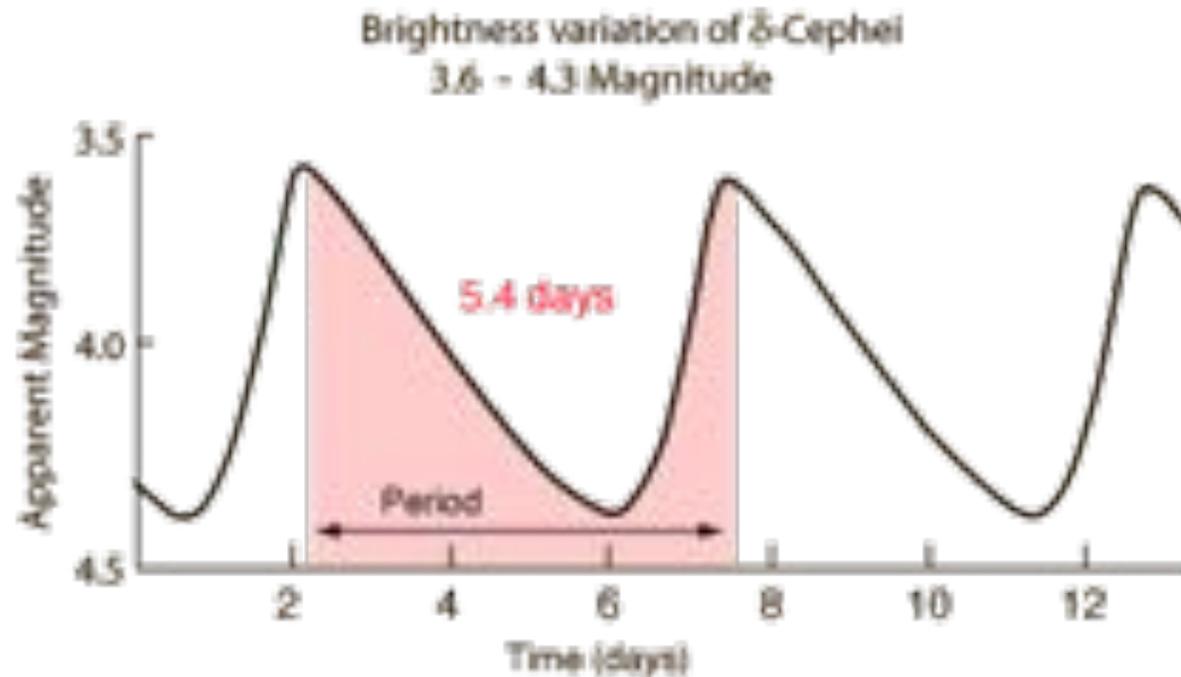


Standard Candle: Cepheid Variables



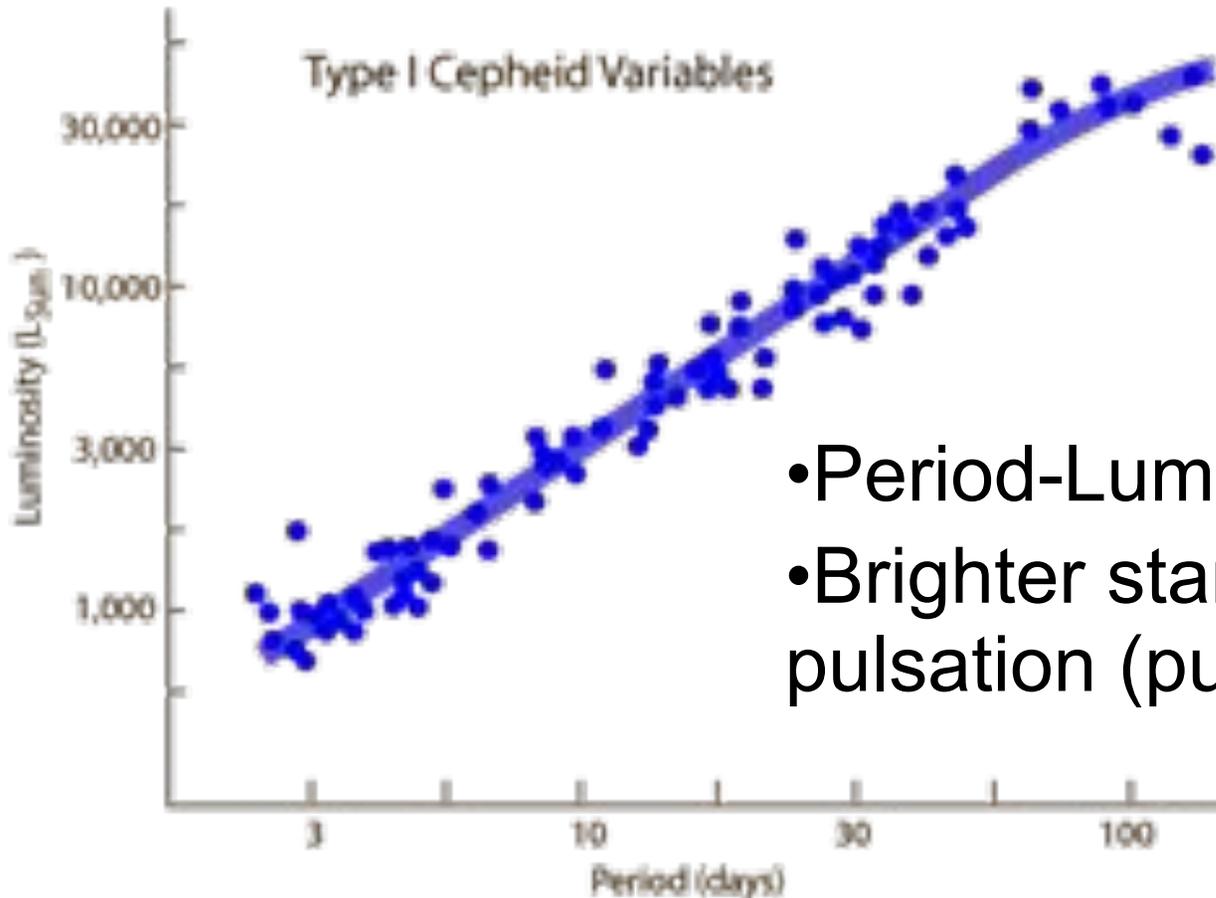
- Cepheid-type stars pulsate
- When bigger they are also brighter
- Have a very regular period of pulsation

Standard Candle: Cepheid Variables



- Cepheid-type stars pulsate
- When bigger they are also brighter
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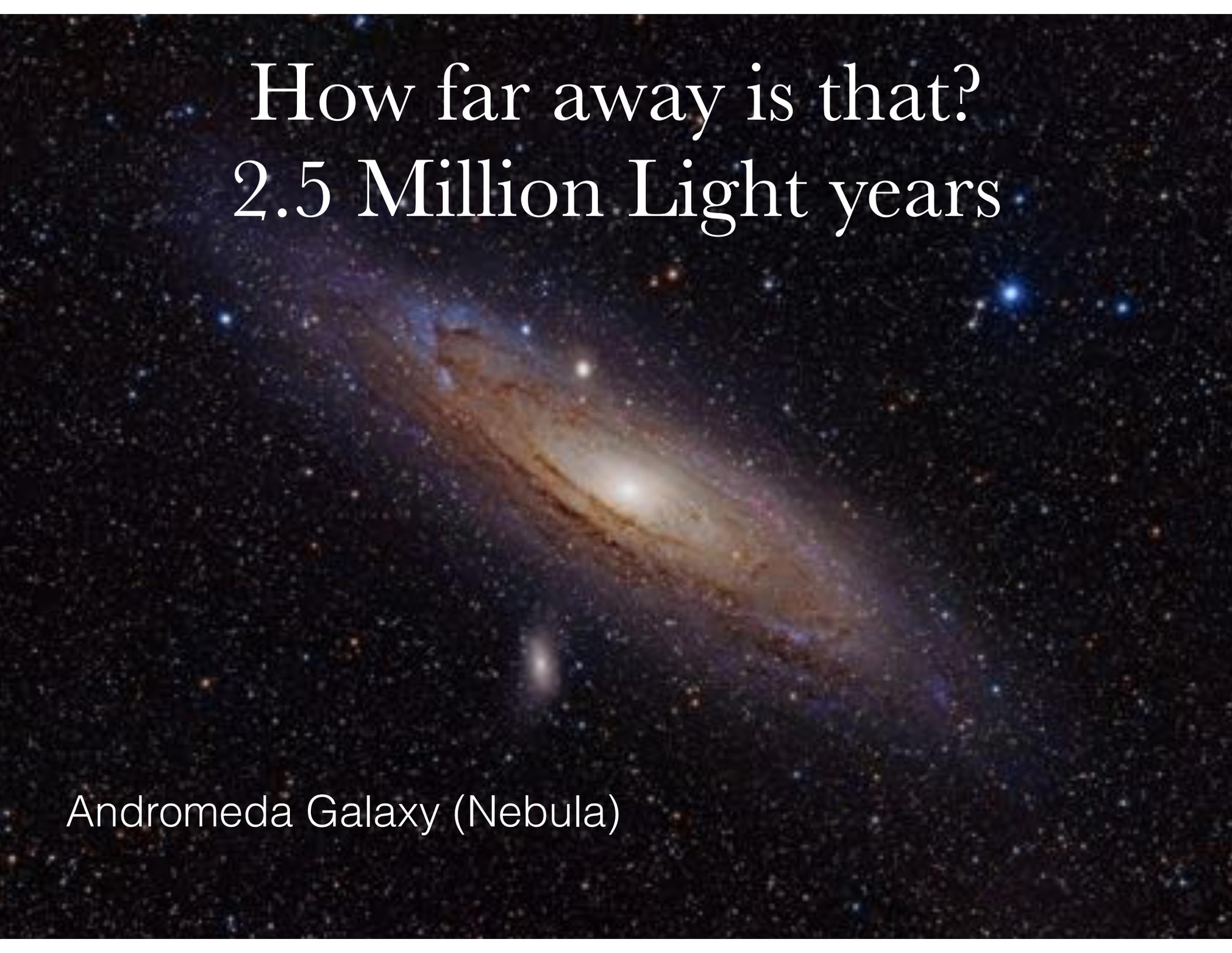
Standard Candle: Cepheid Variables



- Period-Luminosity Relationship
- Brighter stars = longer period pulsation (pulsate slower)

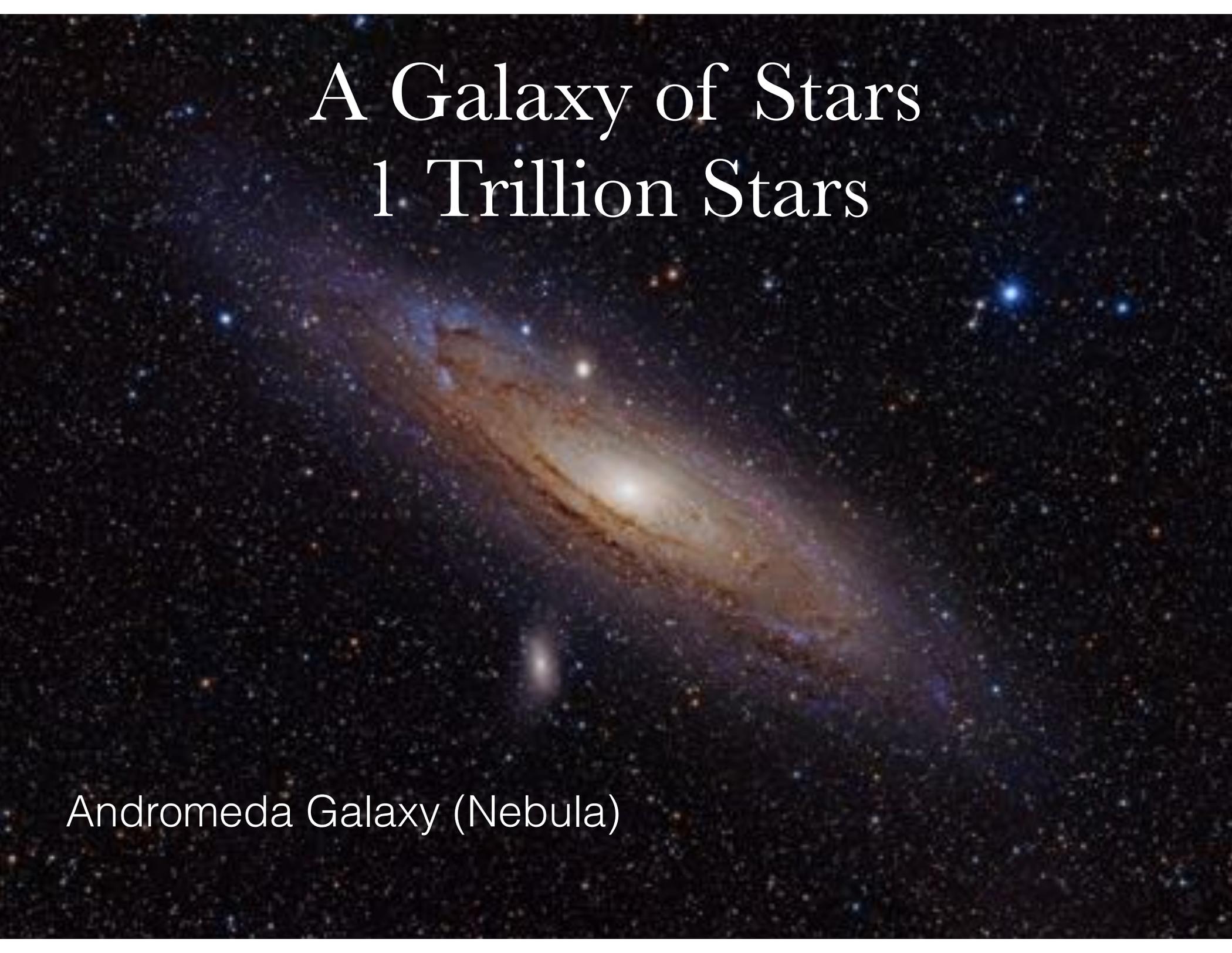
How far away is that?
2.5 Million Light years

Andromeda Galaxy (Nebula)



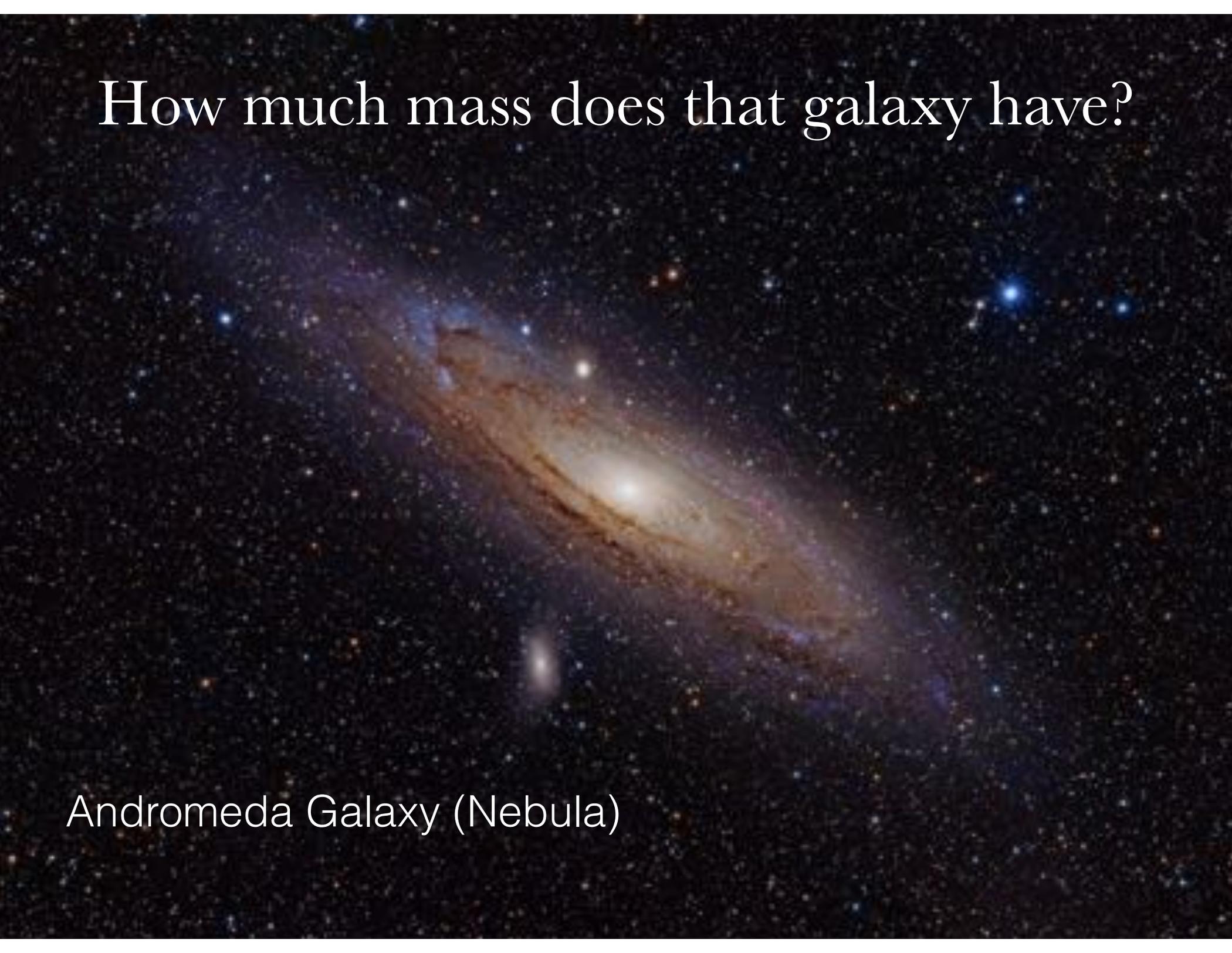
A Galaxy of Stars 1 Trillion Stars

Andromeda Galaxy (Nebula)

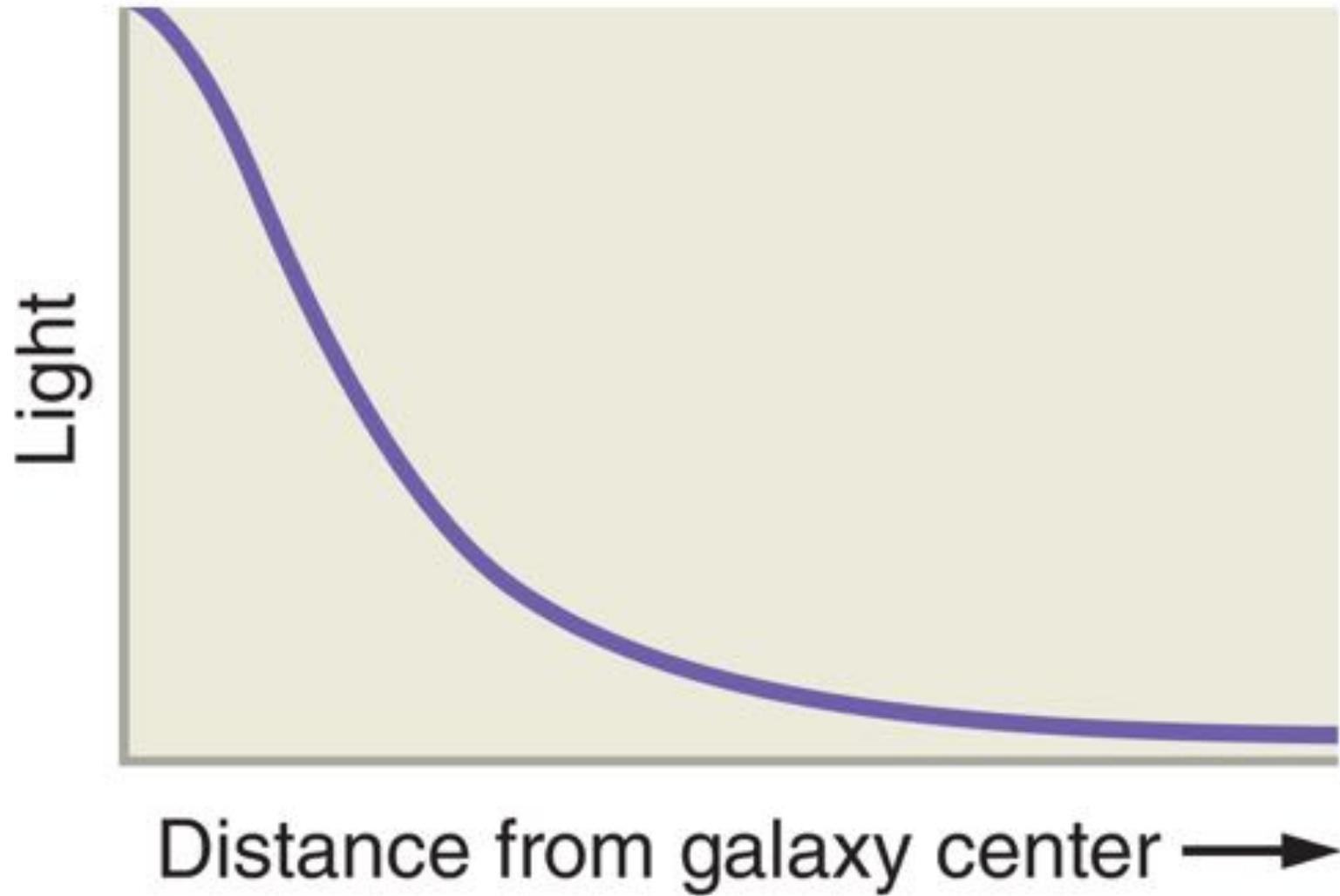


How much mass does that galaxy have?

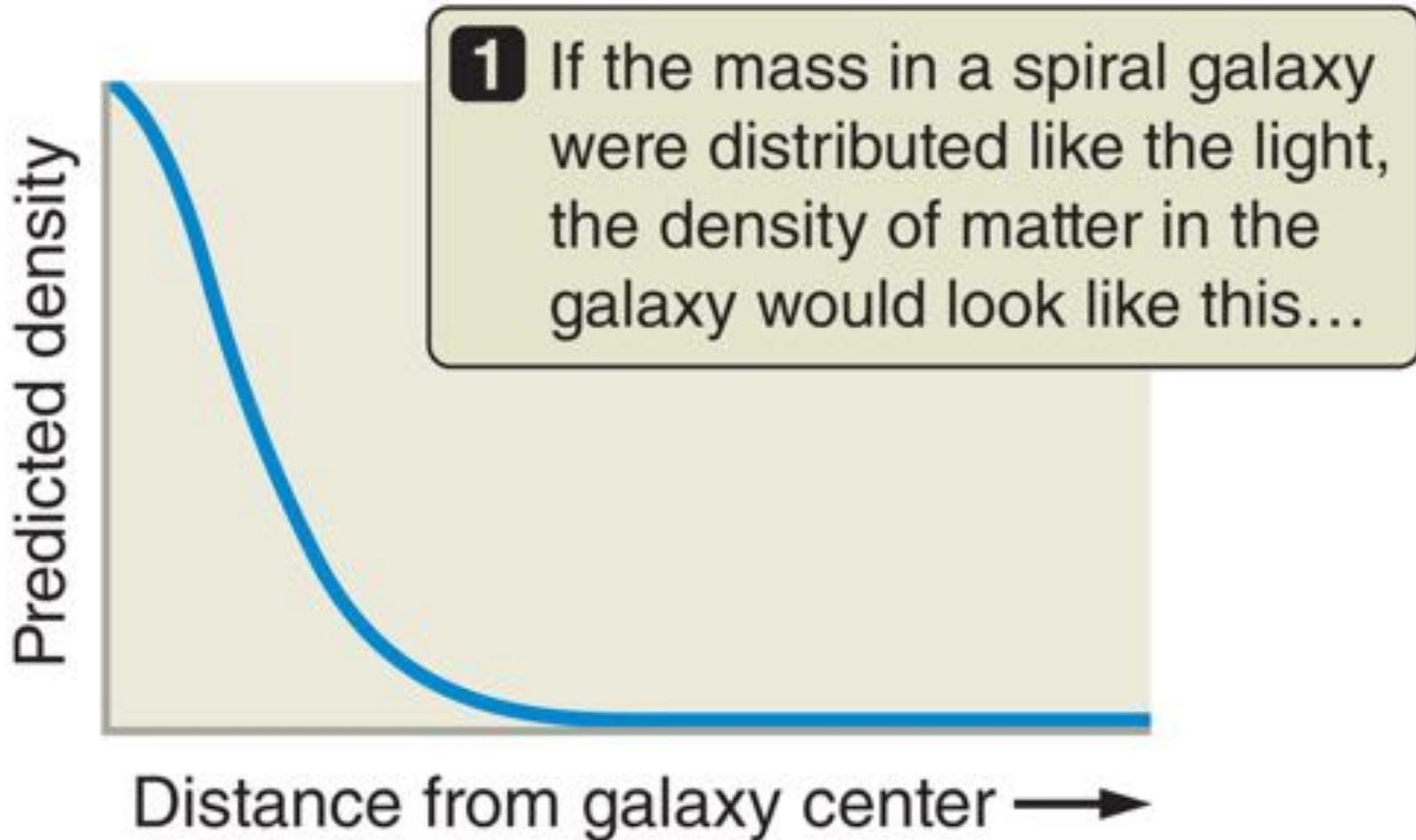
Andromeda Galaxy (Nebula)



Measuring Mass in Galaxies

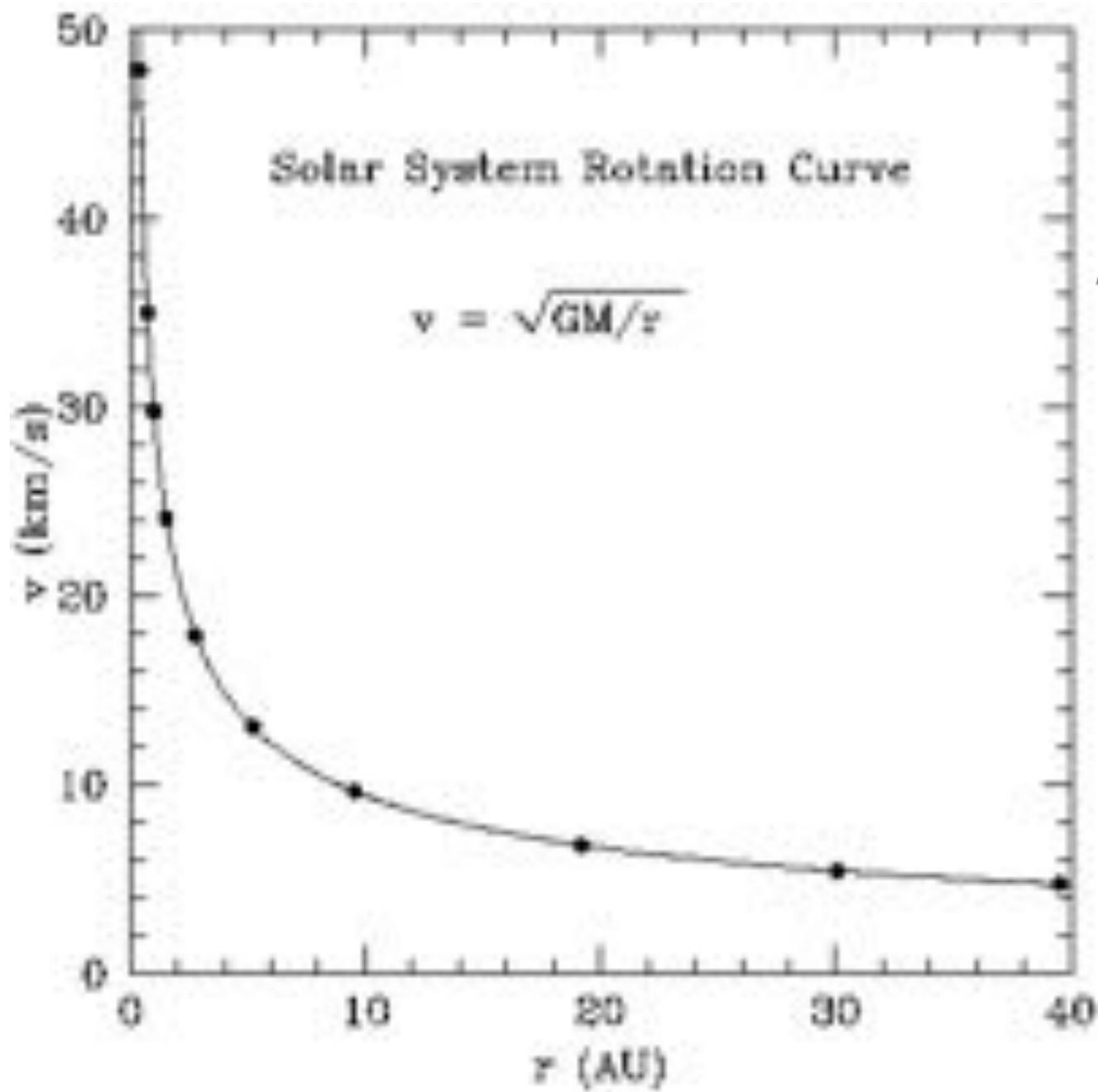


Measuring Mass in Galaxies



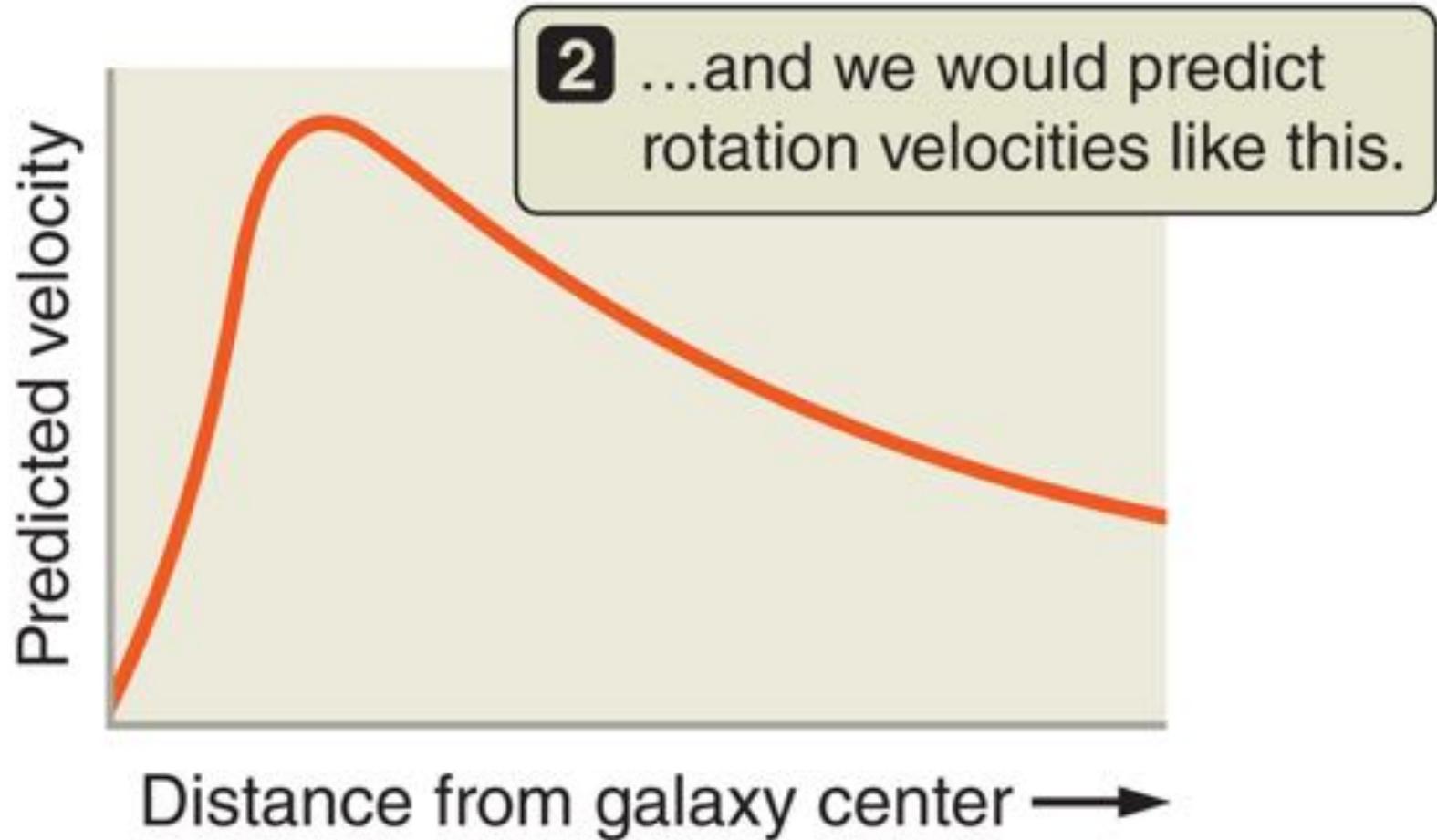
Measuring Mass in Galaxies

$$v_{\text{orbit}} = \sqrt{\frac{GM}{r}}$$

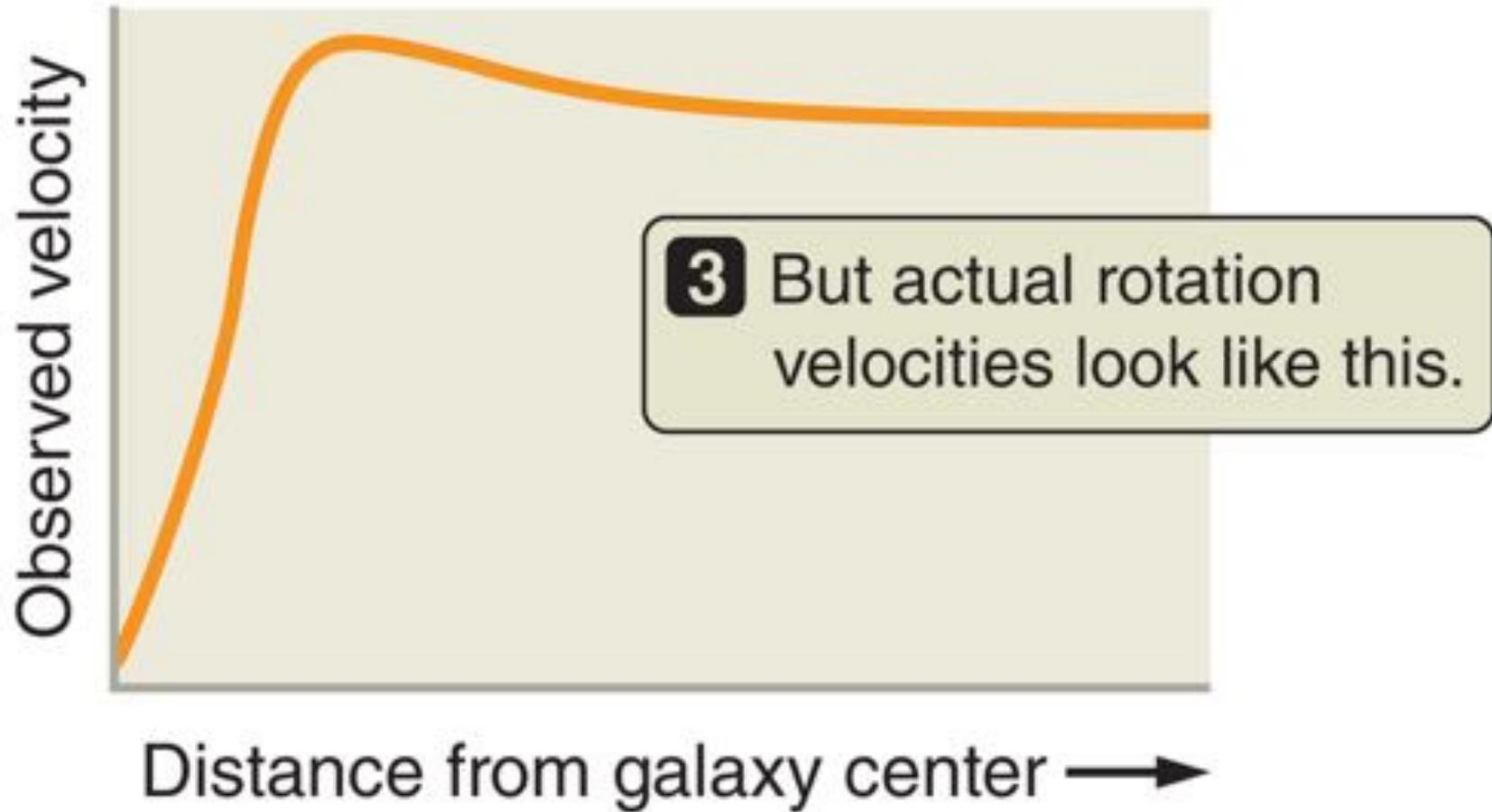


$$v_{\text{orbit}} = \sqrt{\frac{GM}{r}}$$

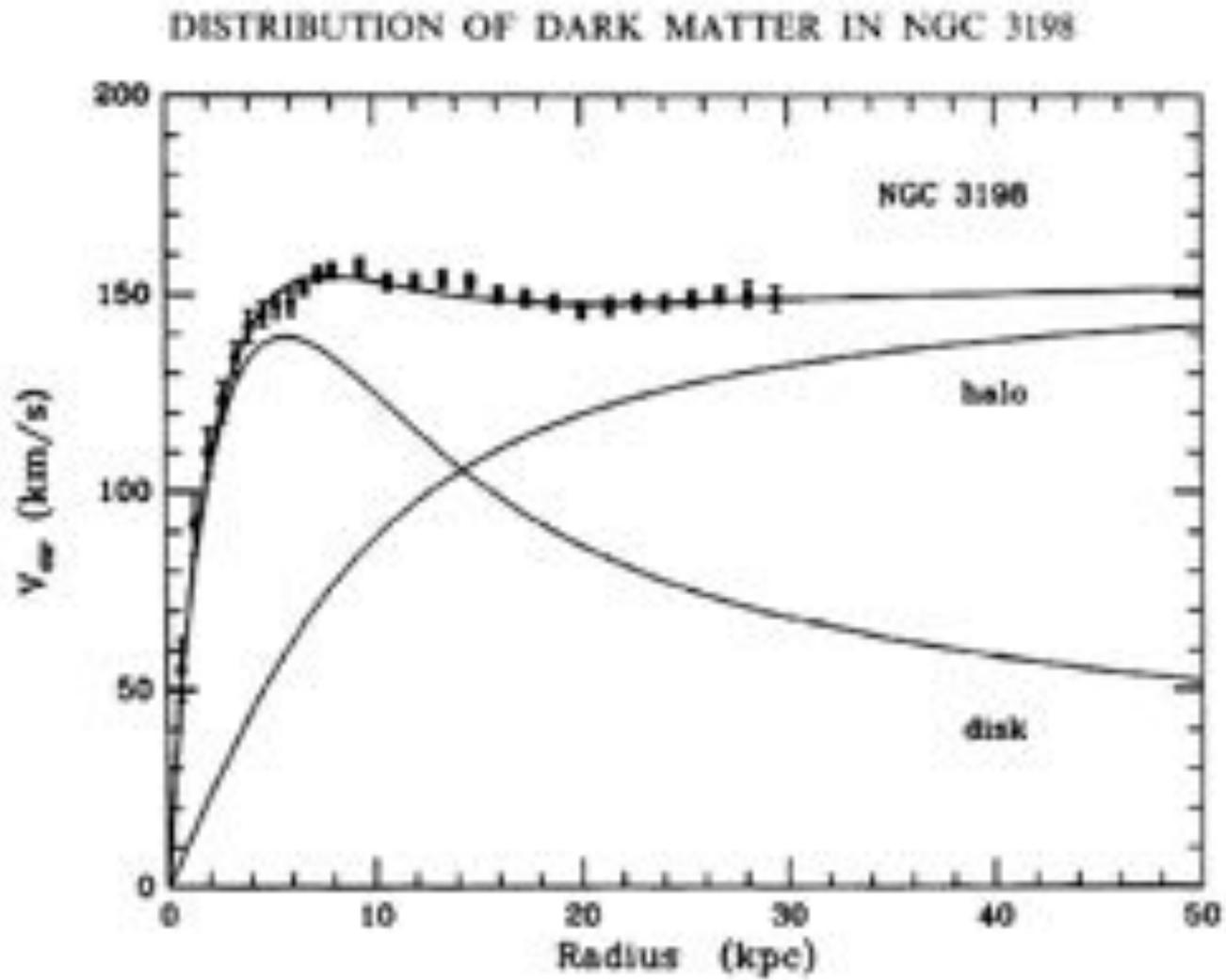
Measuring Mass in Galaxies



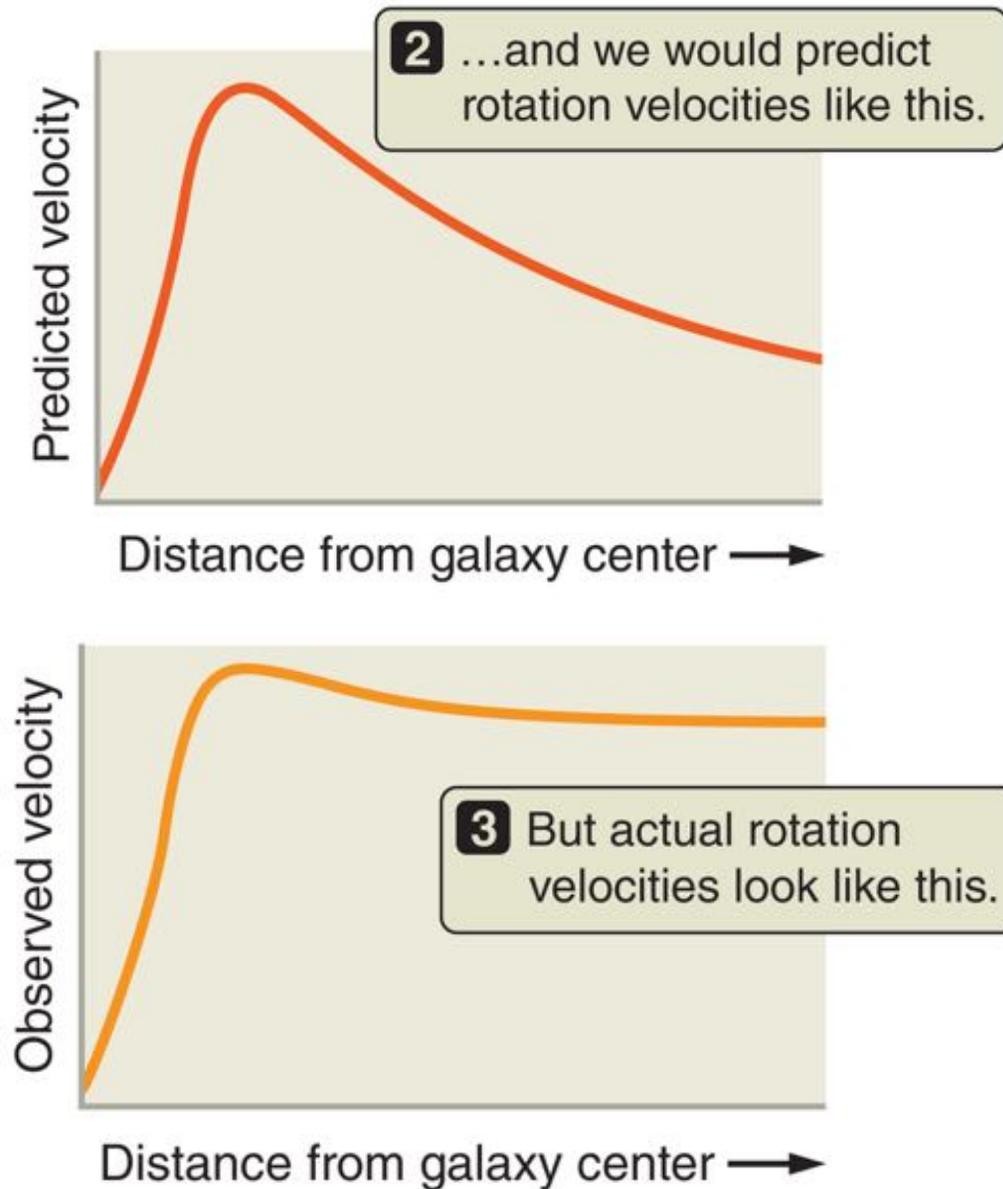
Measuring Mass in Galaxies



Measuring Mass in Galaxies



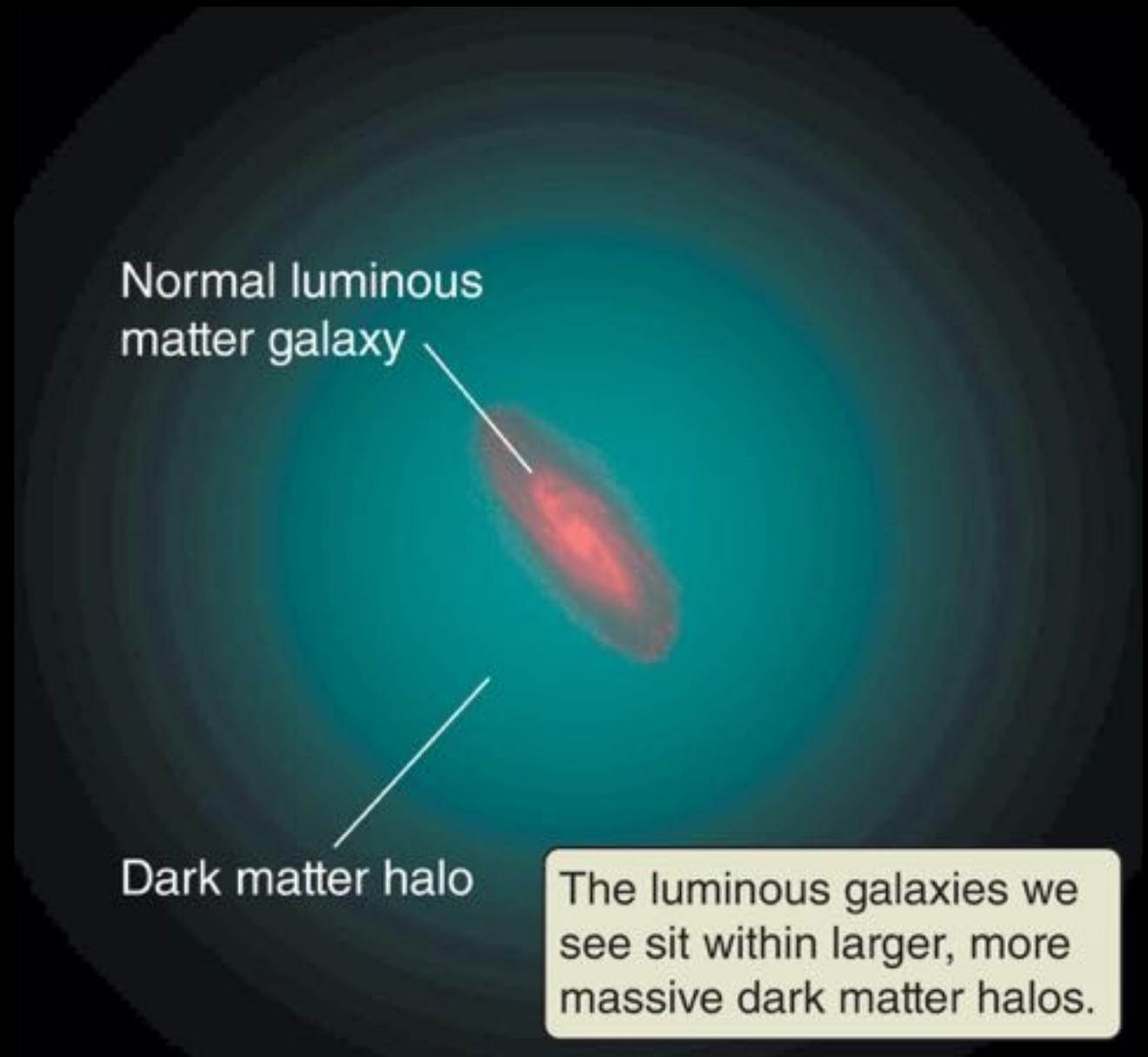
Measuring Mass in Galaxies



- The orbital motions of stars in galaxies is much higher than can be explained by matter inferred from light
- Extra matter that we can't see.

Dark Matter

Dark Matter



As much as 95% of the mass of a spiral galaxy is dark matter.

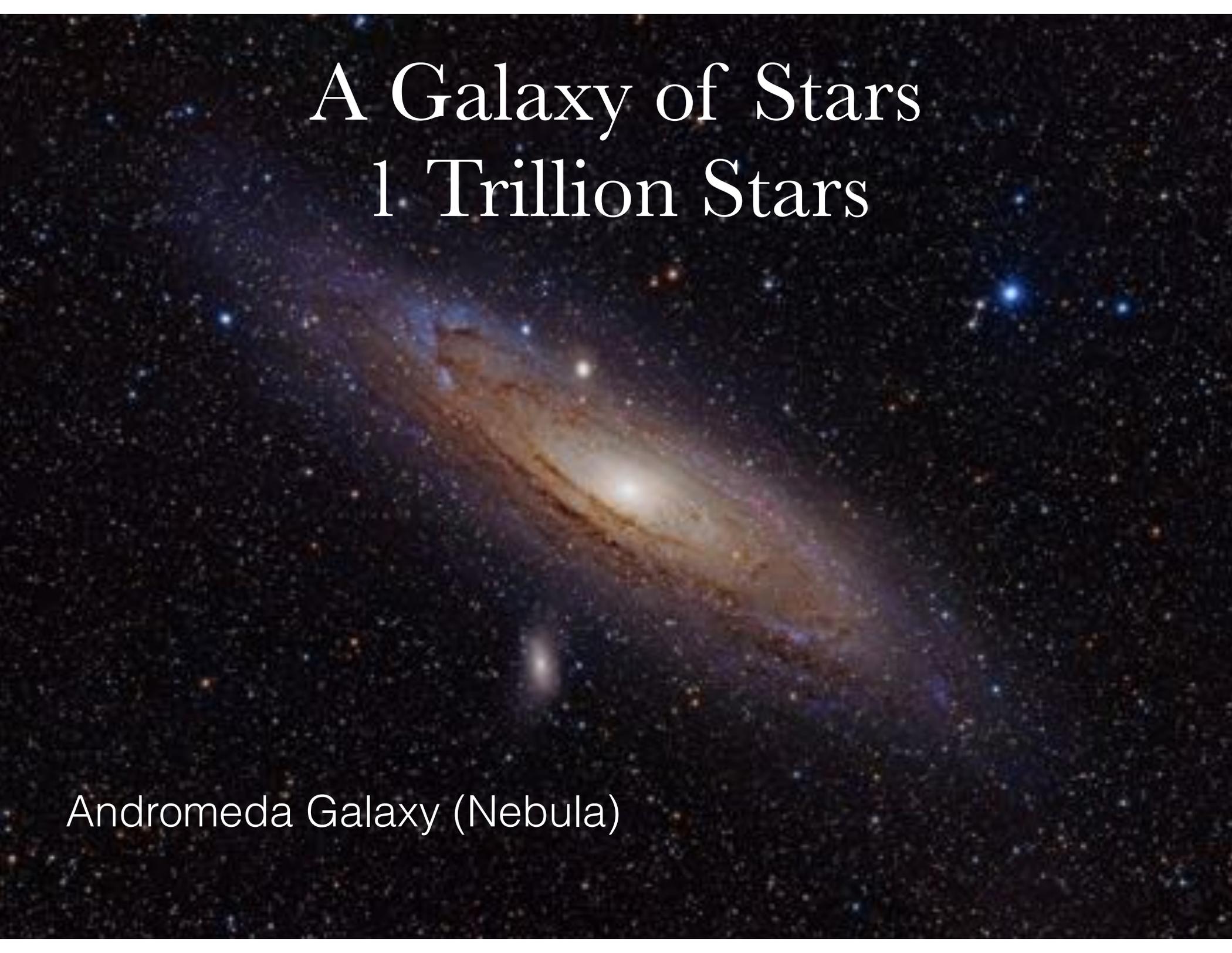
What is Dark Matter?

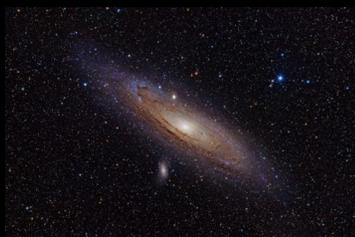
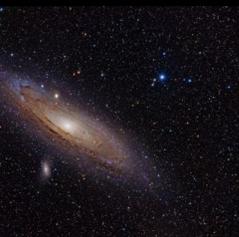
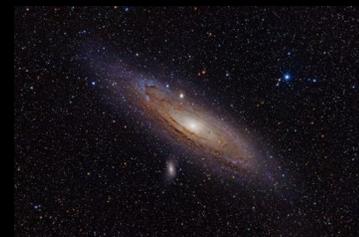
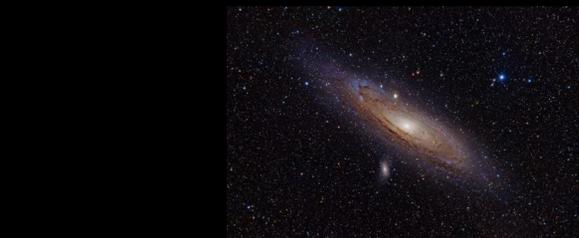
Andromeda Galaxy (Nebula)



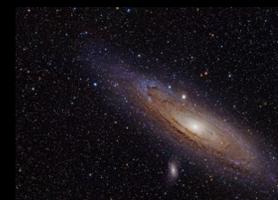
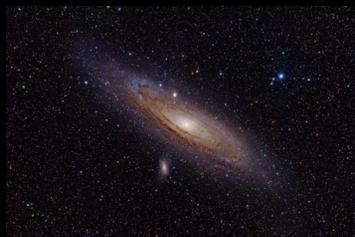
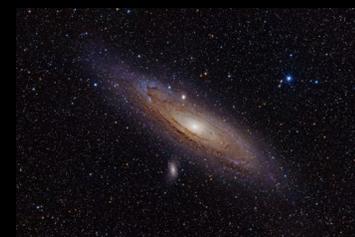
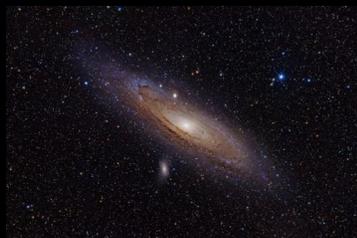
A Galaxy of Stars 1 Trillion Stars

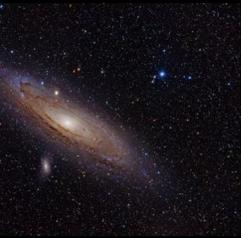
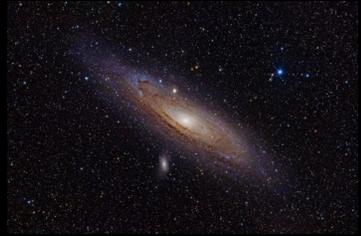
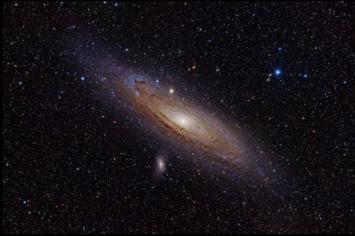
Andromeda Galaxy (Nebula)



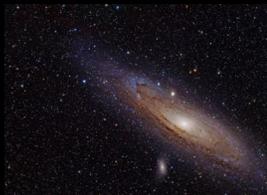
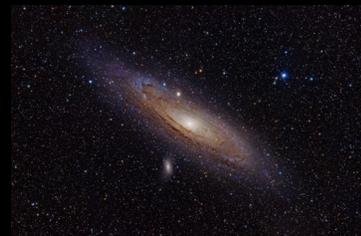
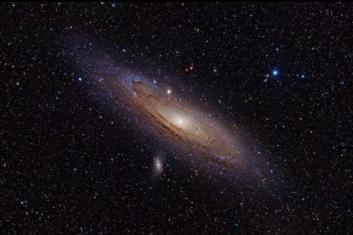


You are here

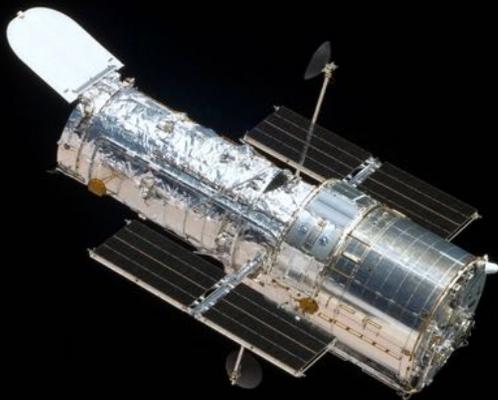




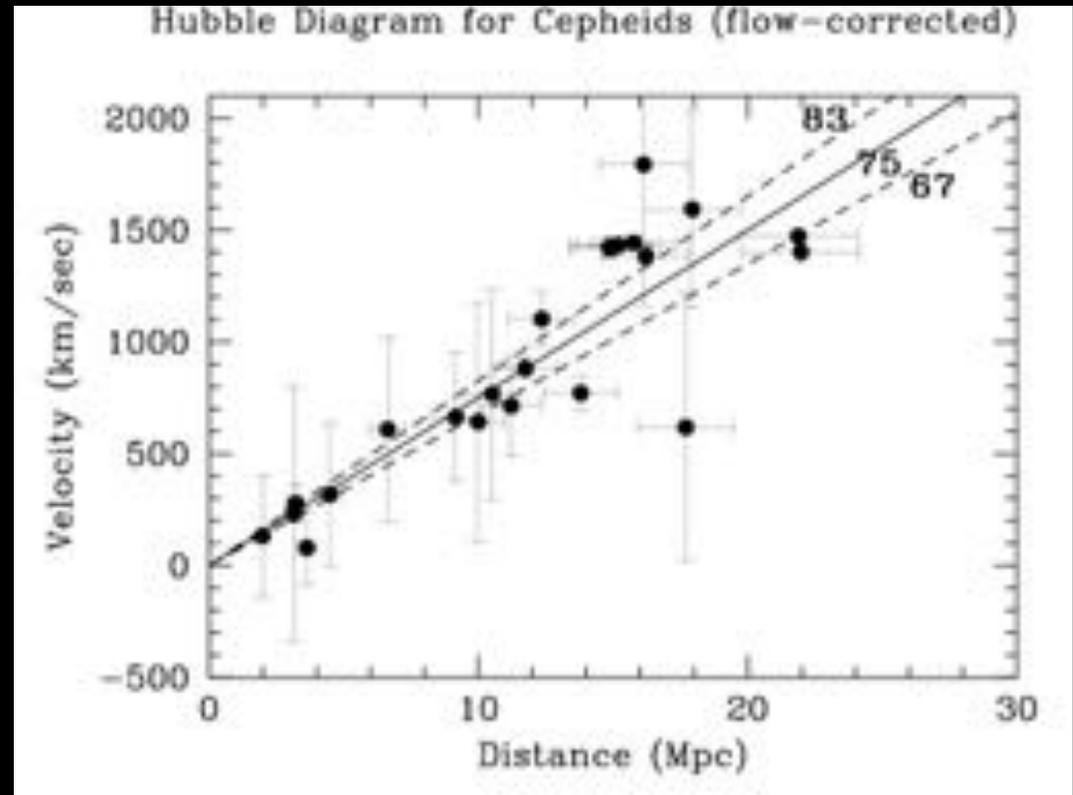
You are here



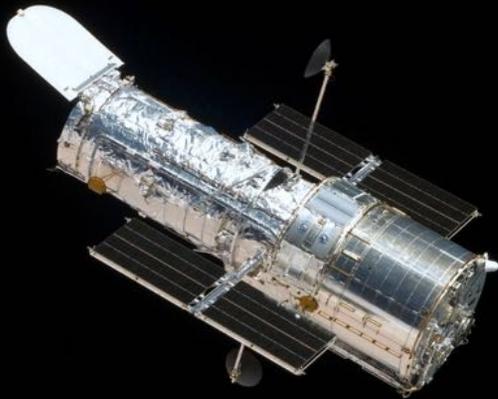
Galaxies are moving away



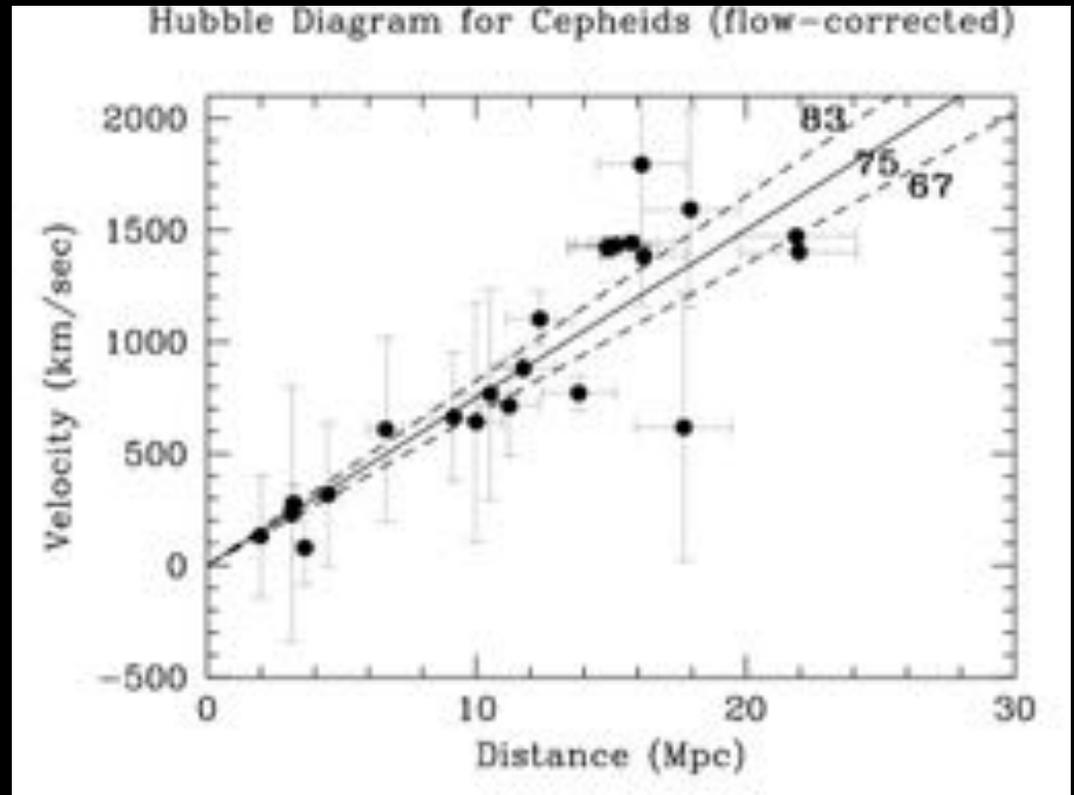
Hubble Telescope:
Key Project

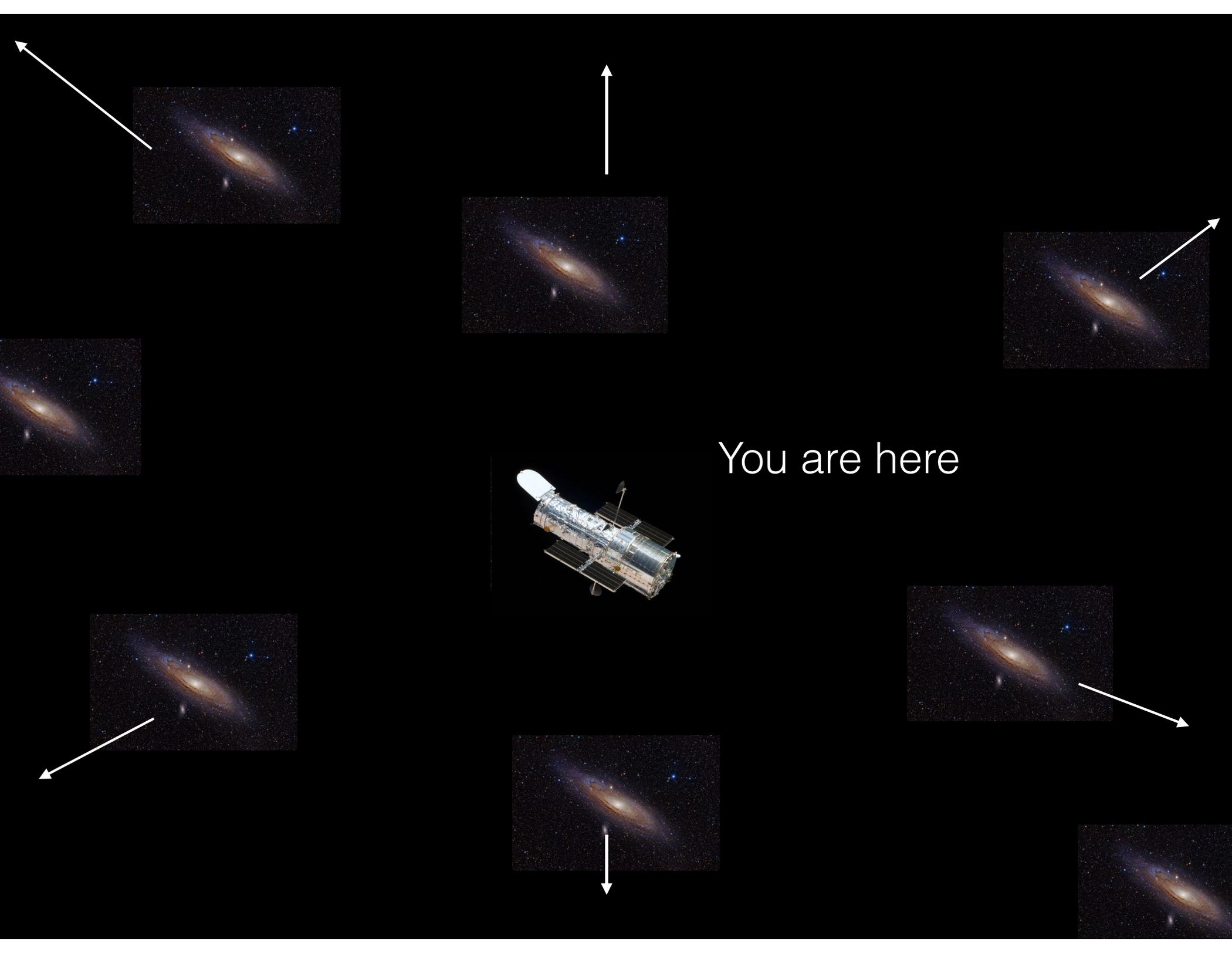


What does this mean?



Hubble Telescope:
Key Project



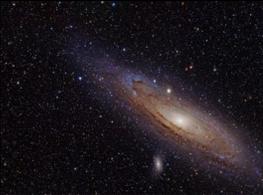
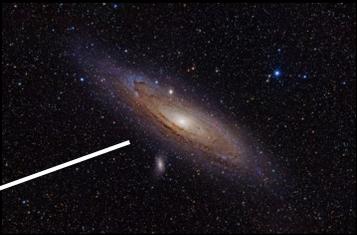
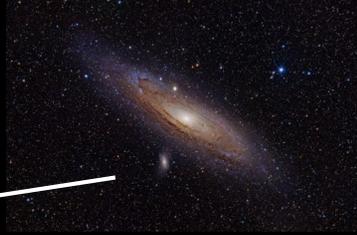
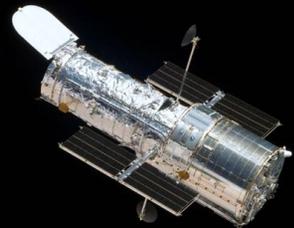
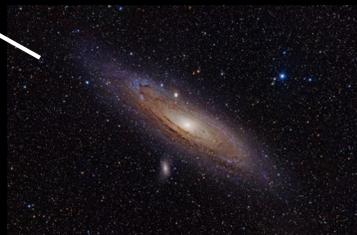
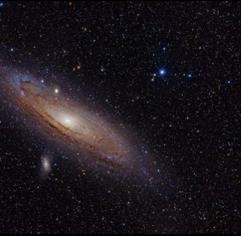
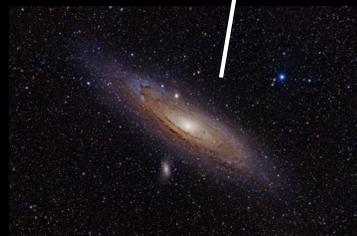
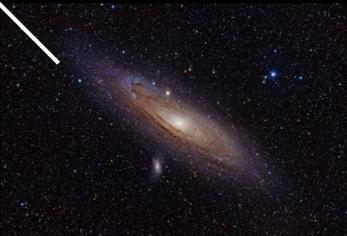
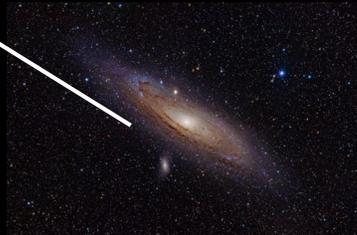


You are here

Are we at the center of the
Universe?

History cautions us to have
humility

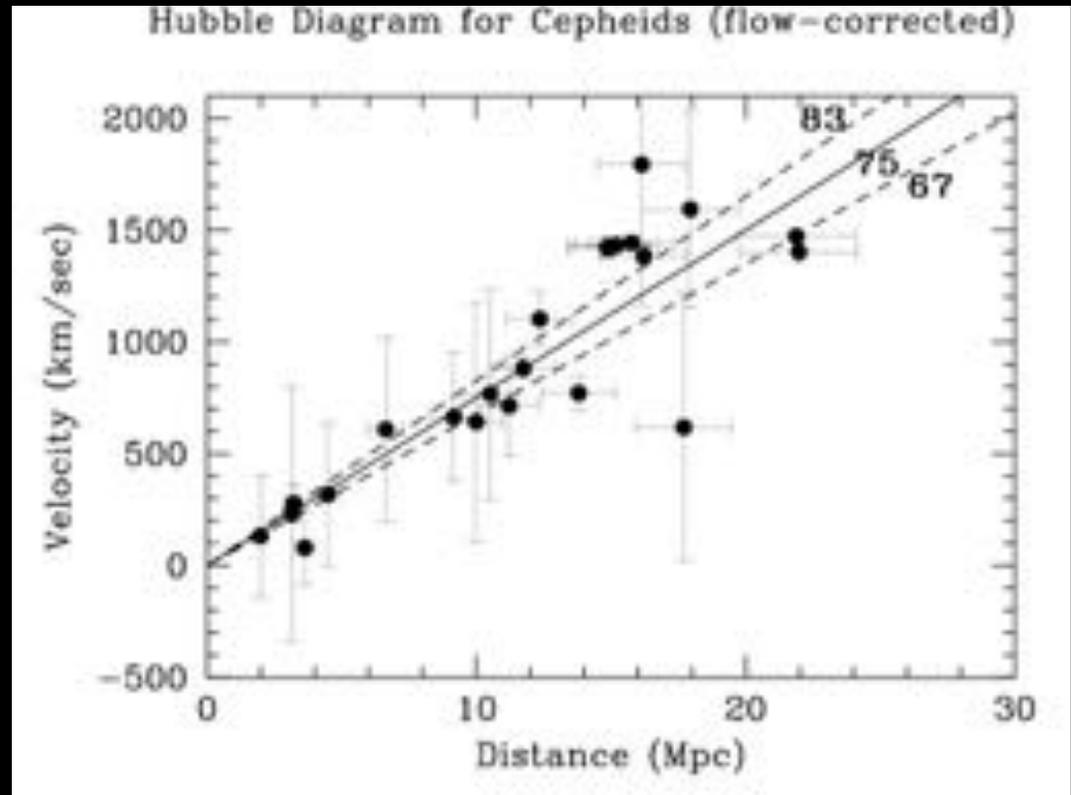
Uniformly expanding Universe



The Universe is Expanding



Hubble Telescope:
Key Project



Rewind

You are here



Big Bang!

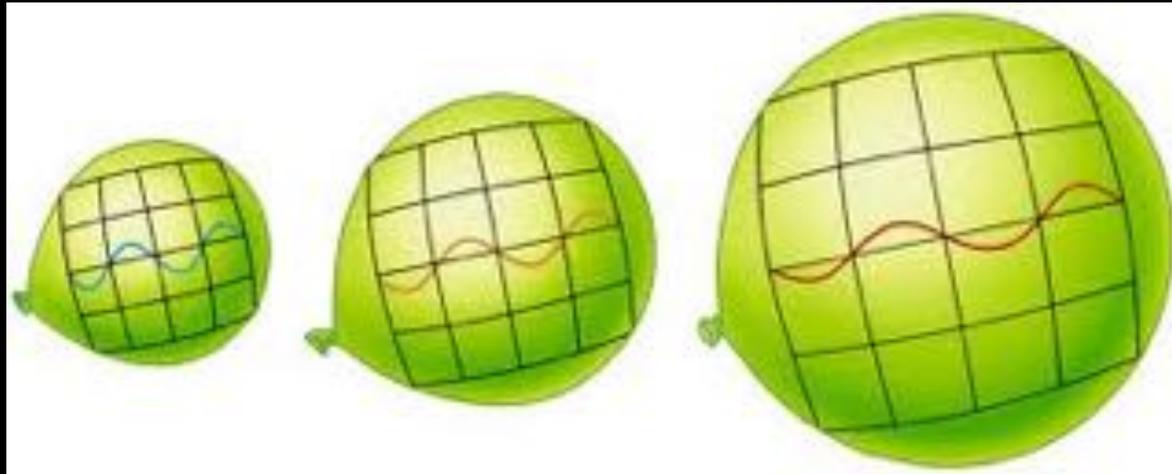
Hot and Dense

Entire Universe was Glowing
(13.7 billion years ago)

Where's the glow now?



General Theory of Relativity



Redshift (z)

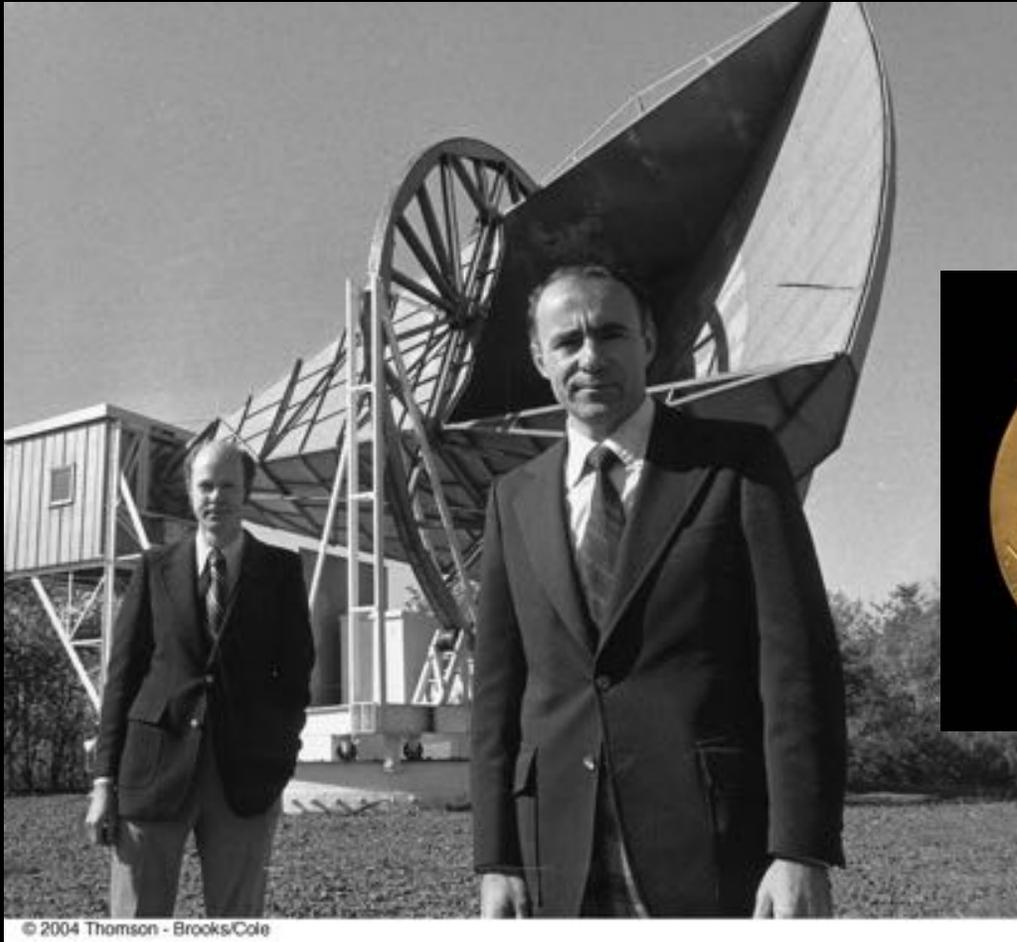
Hot Glow

Universe Expands

Expands 1,100

In the Microwave Today
Cosmic Microwave Background
(CMB)

Nobel Prize #1



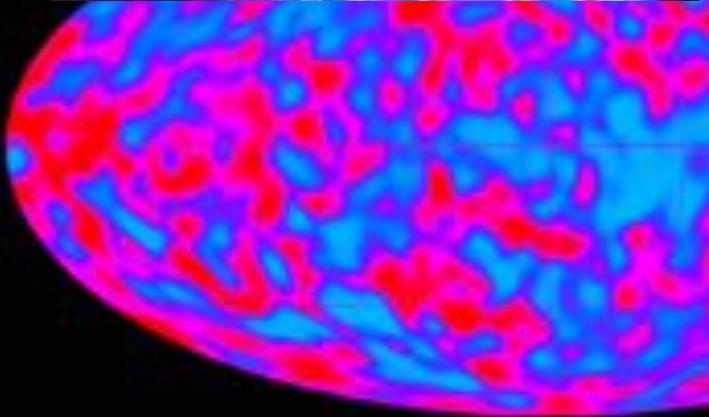
© 2004 Thomson - Brooks/Cole



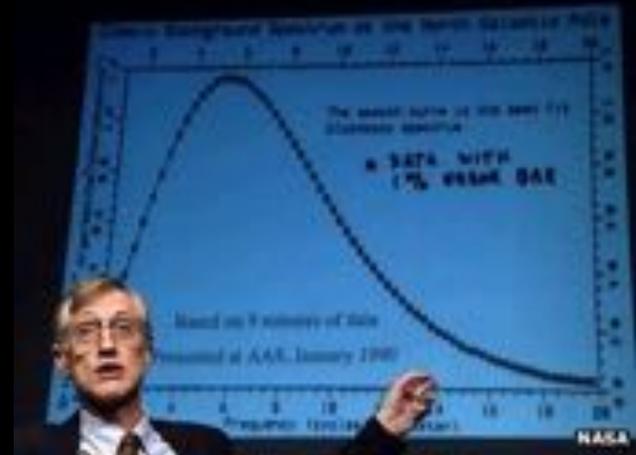
Penzias & Wilson

Nobel Prize #2

COBE



Smoot



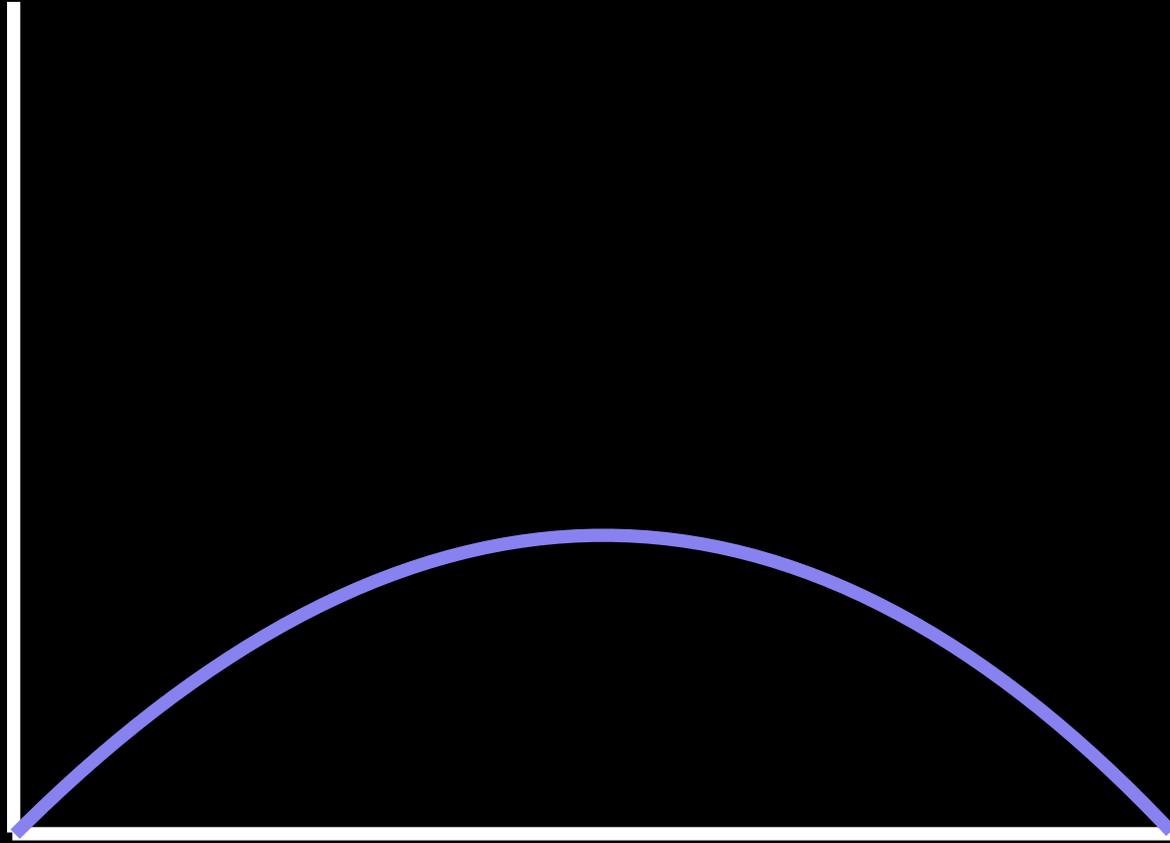
Mather

Universe is Expanding
Past?
Future?

Big bang kick vs. gravity

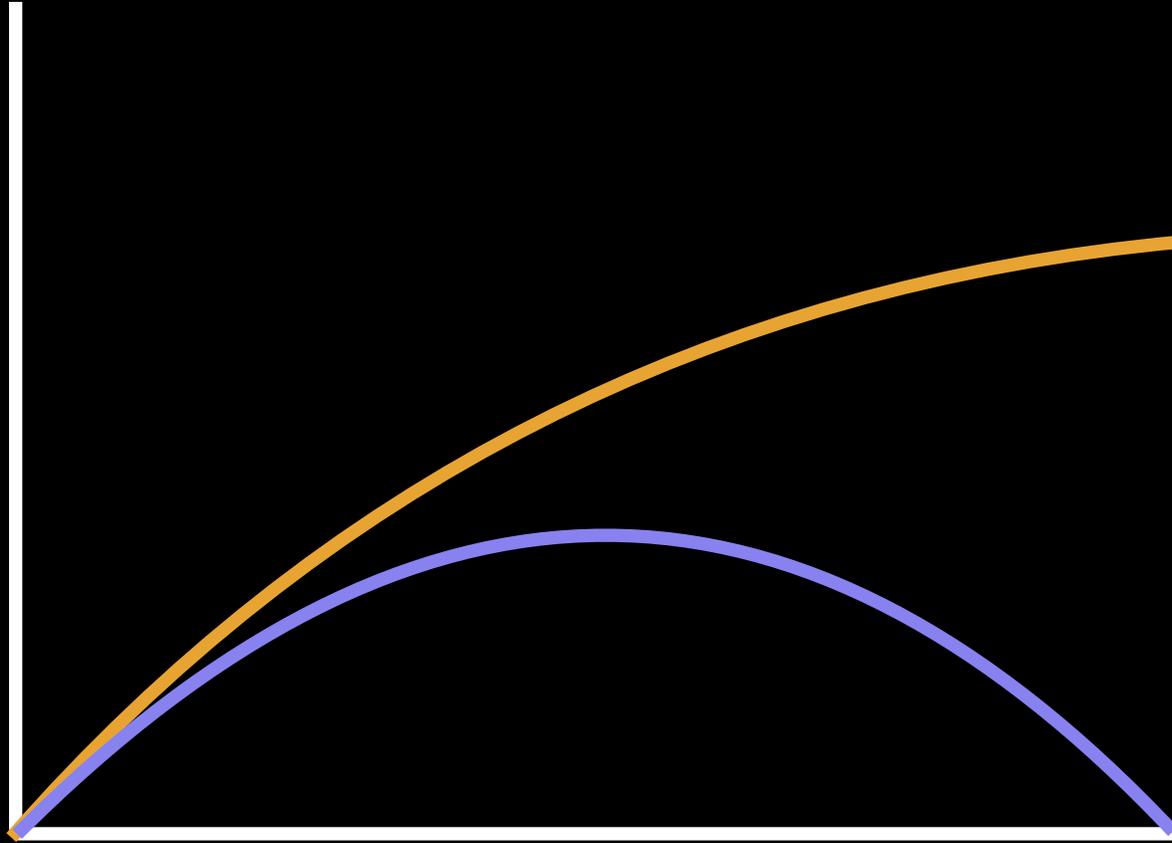


Relative Scale of Universe



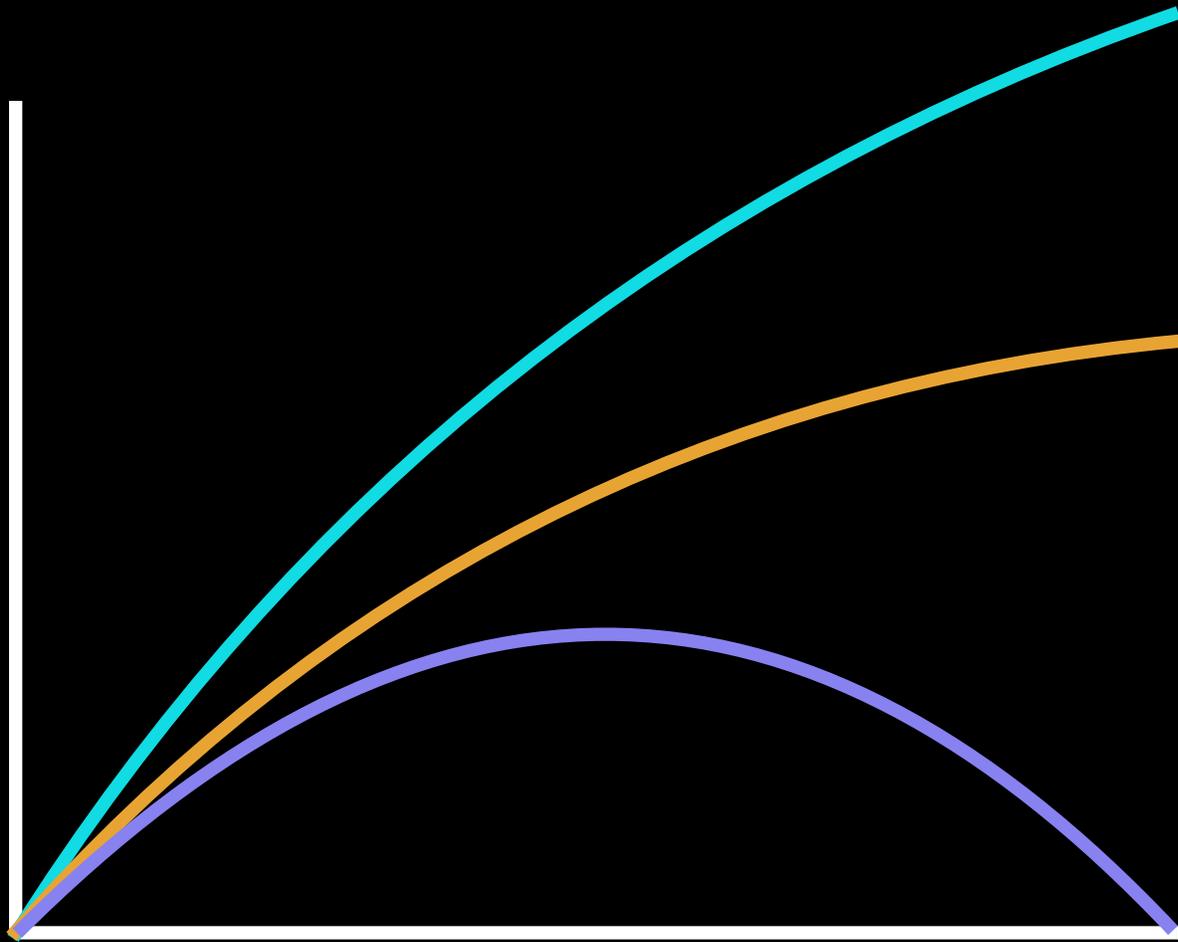
Time

Relative Scale of Universe



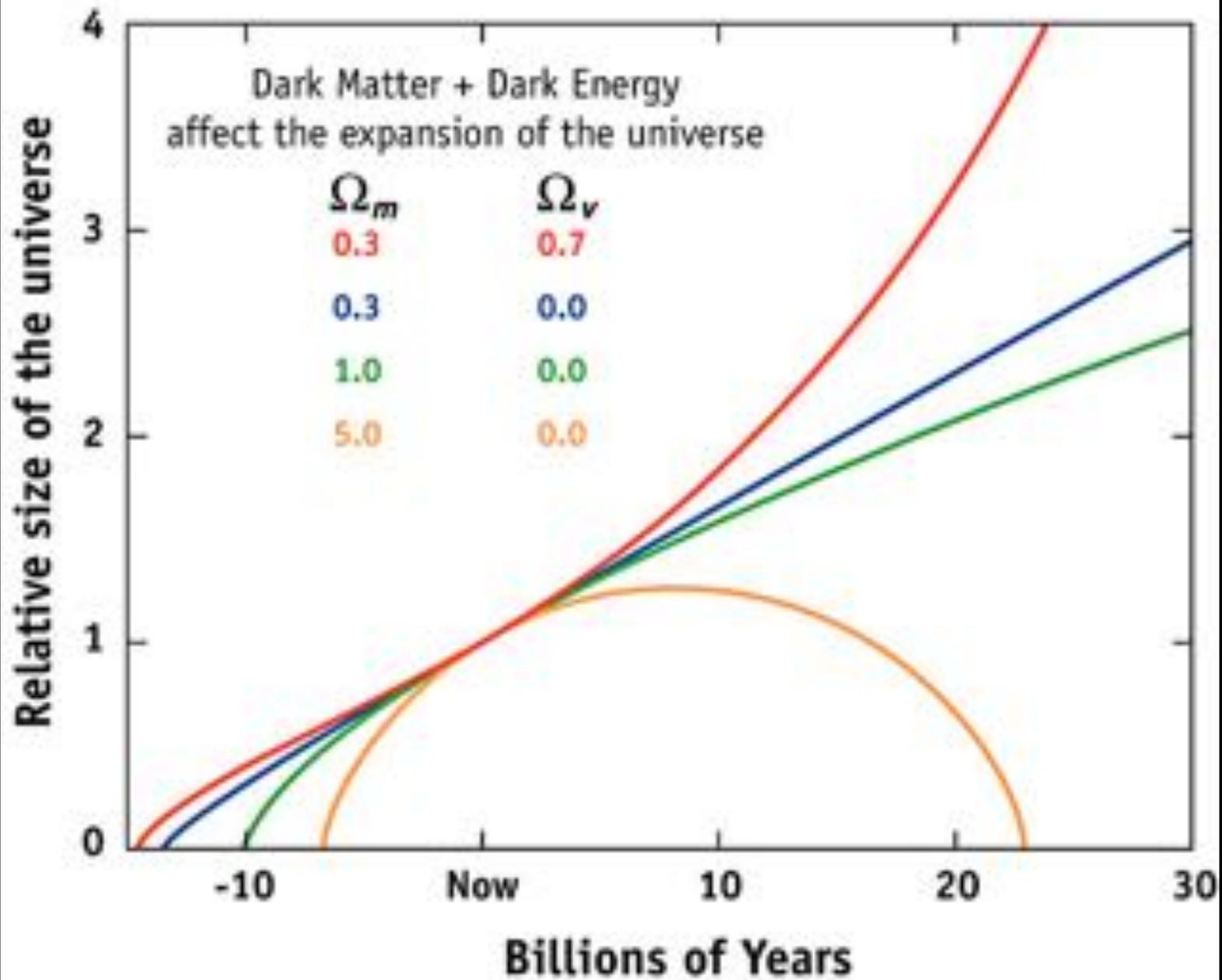
Time

Relative Scale of Universe

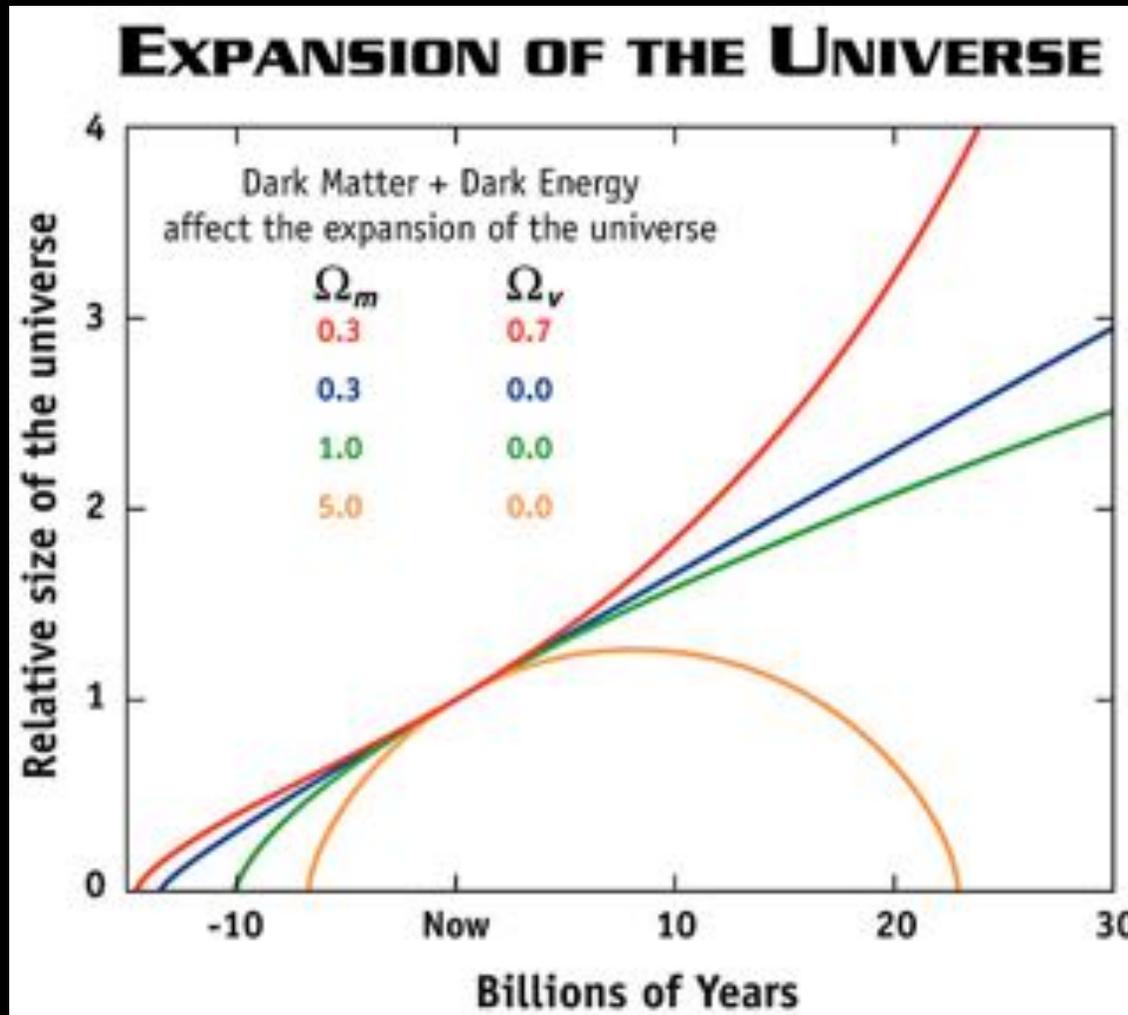


Time

EXPANSION OF THE UNIVERSE



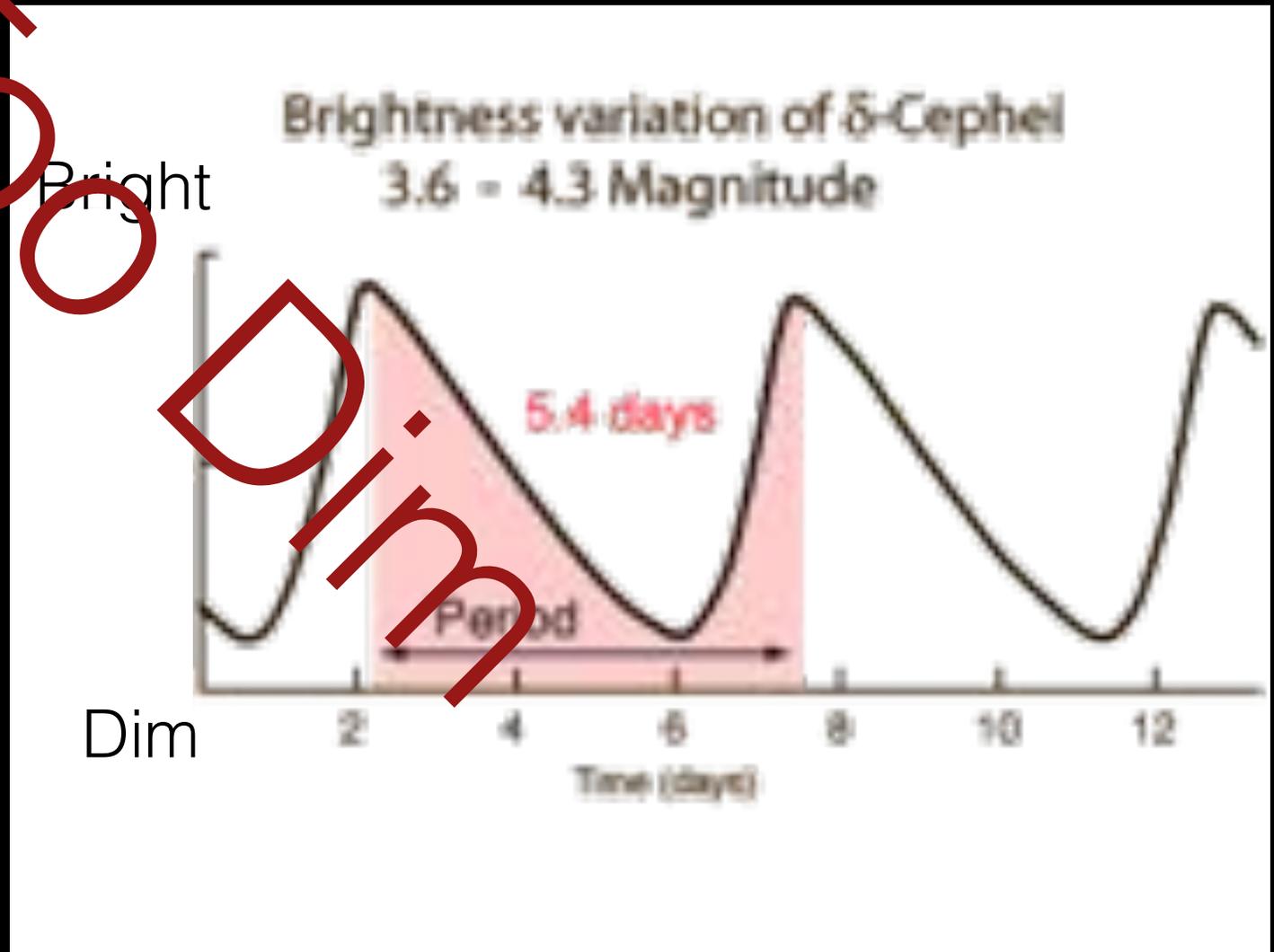
We need a time machine



Farther away
is further back in time

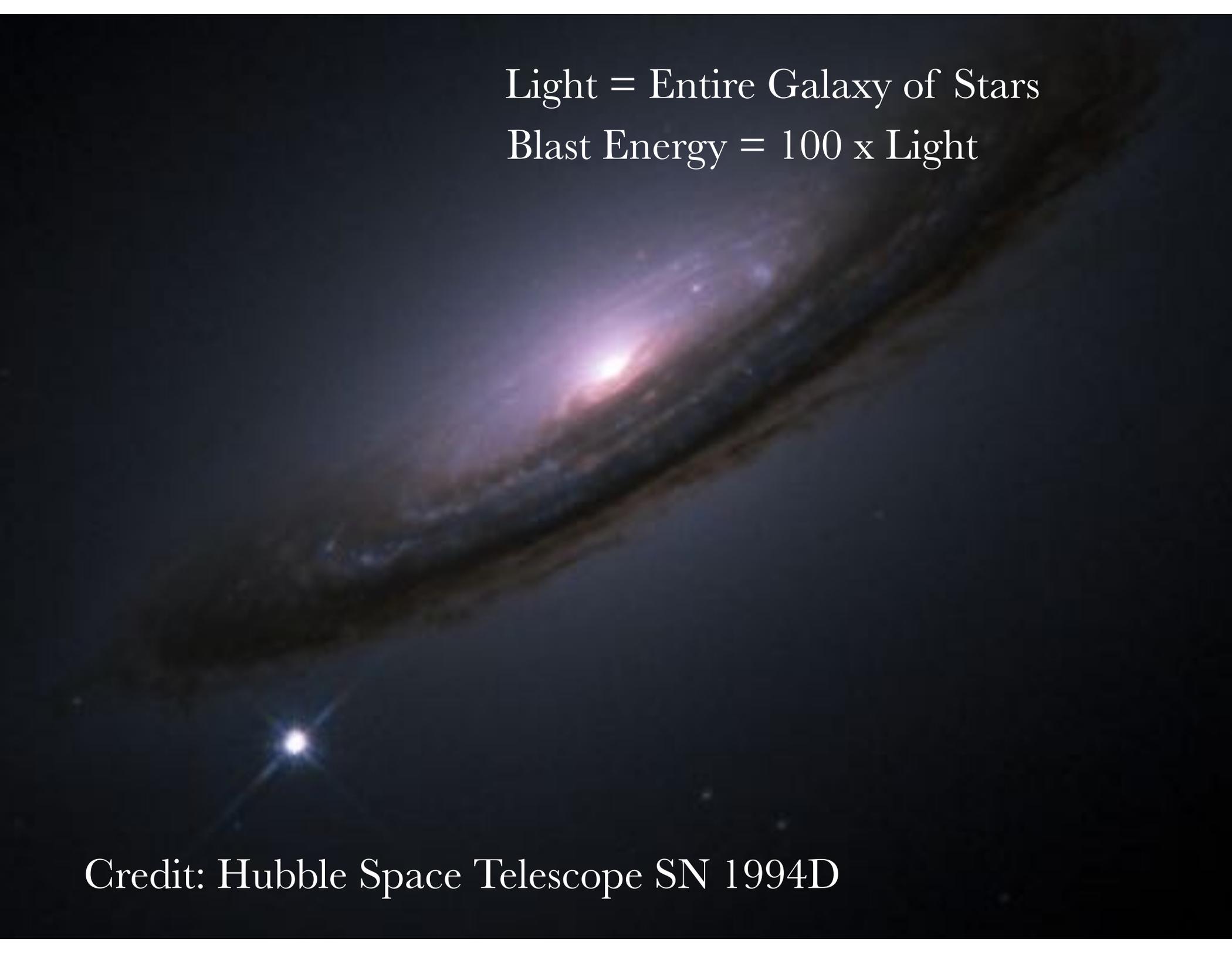
We need to look at the Hubble
diagram for far away galaxies

Cepheid Pulsating Stars

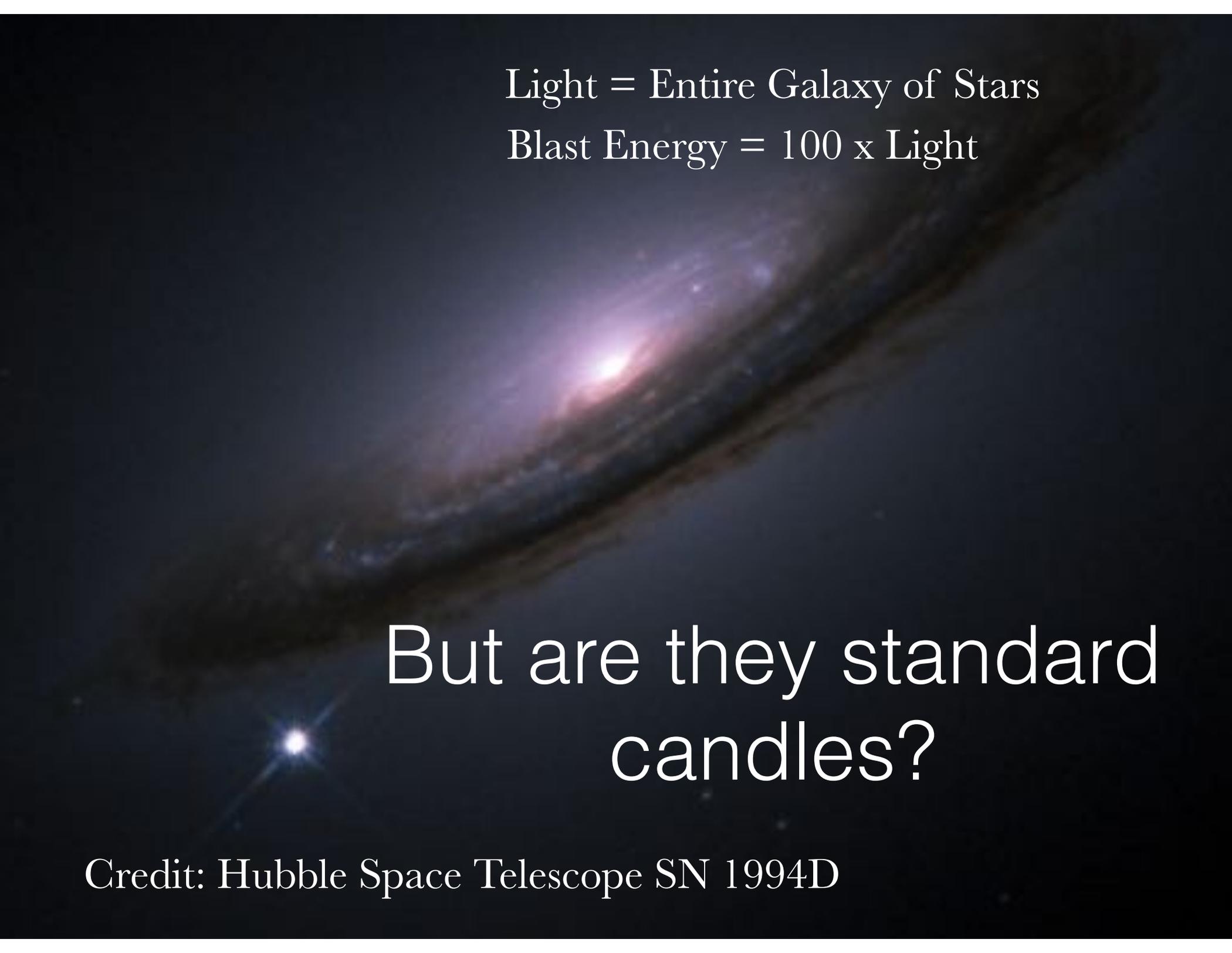


Need a much brighter
standard candle

Light = Entire Galaxy of Stars
Blast Energy = 100 x Light

A photograph of a galaxy, likely SN 1994D, showing a bright central core and a prominent bright star in the foreground. The galaxy is tilted and shows a clear spiral structure. The foreground star is very bright and has a four-pointed diffraction pattern.

Credit: Hubble Space Telescope SN 1994D



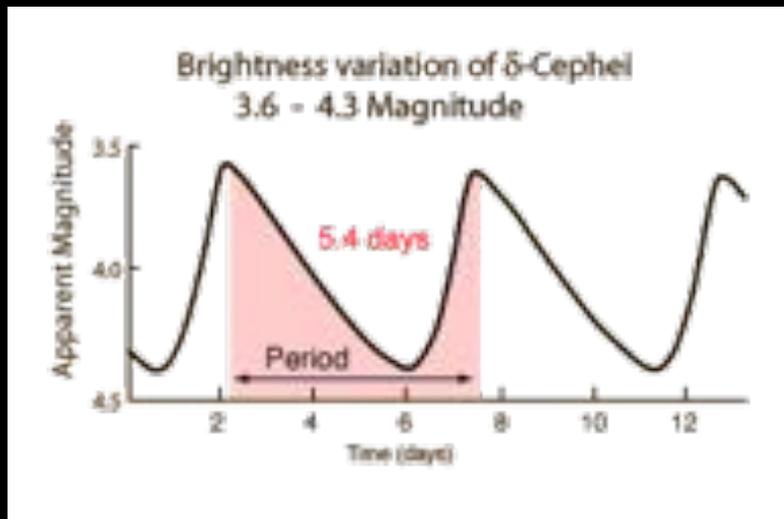
Light = Entire Galaxy of Stars

Blast Energy = 100 x Light

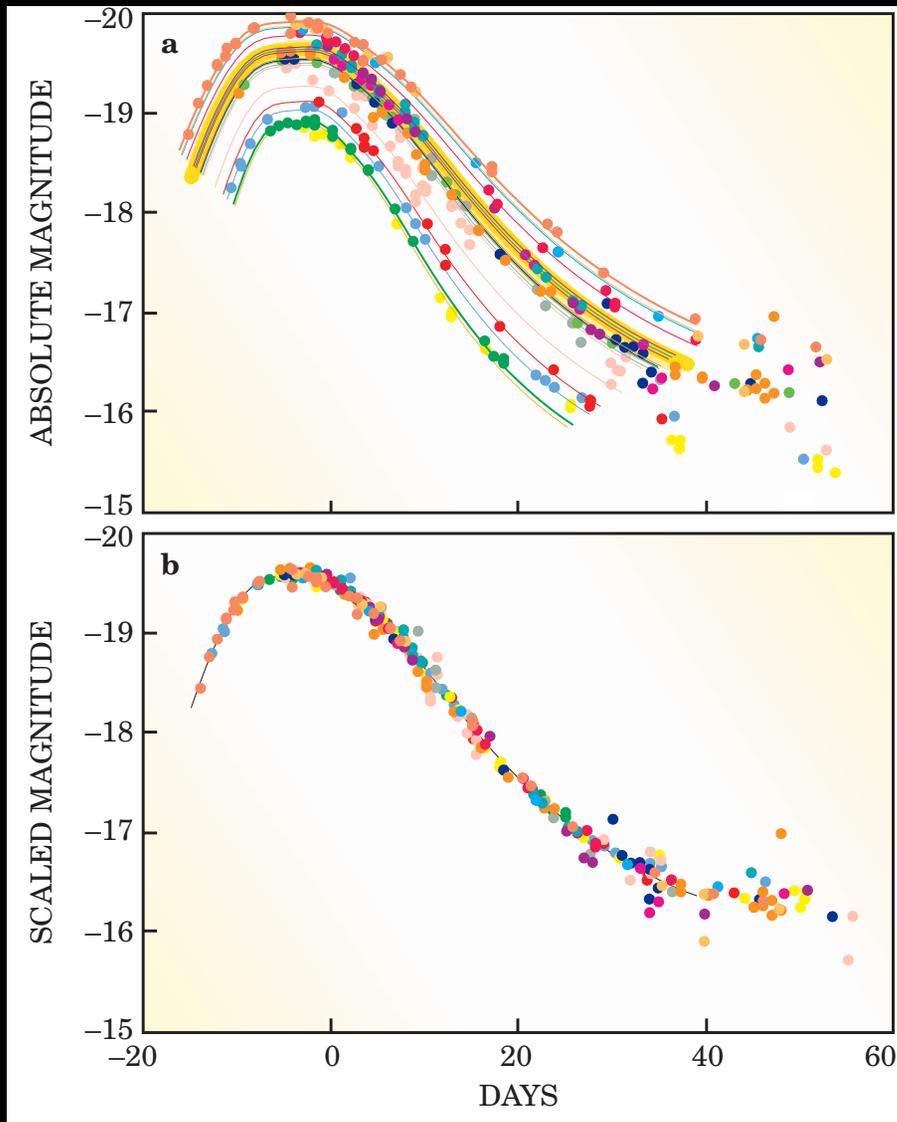
But are they standard
candles?

Credit: Hubble Space Telescope SN 1994D

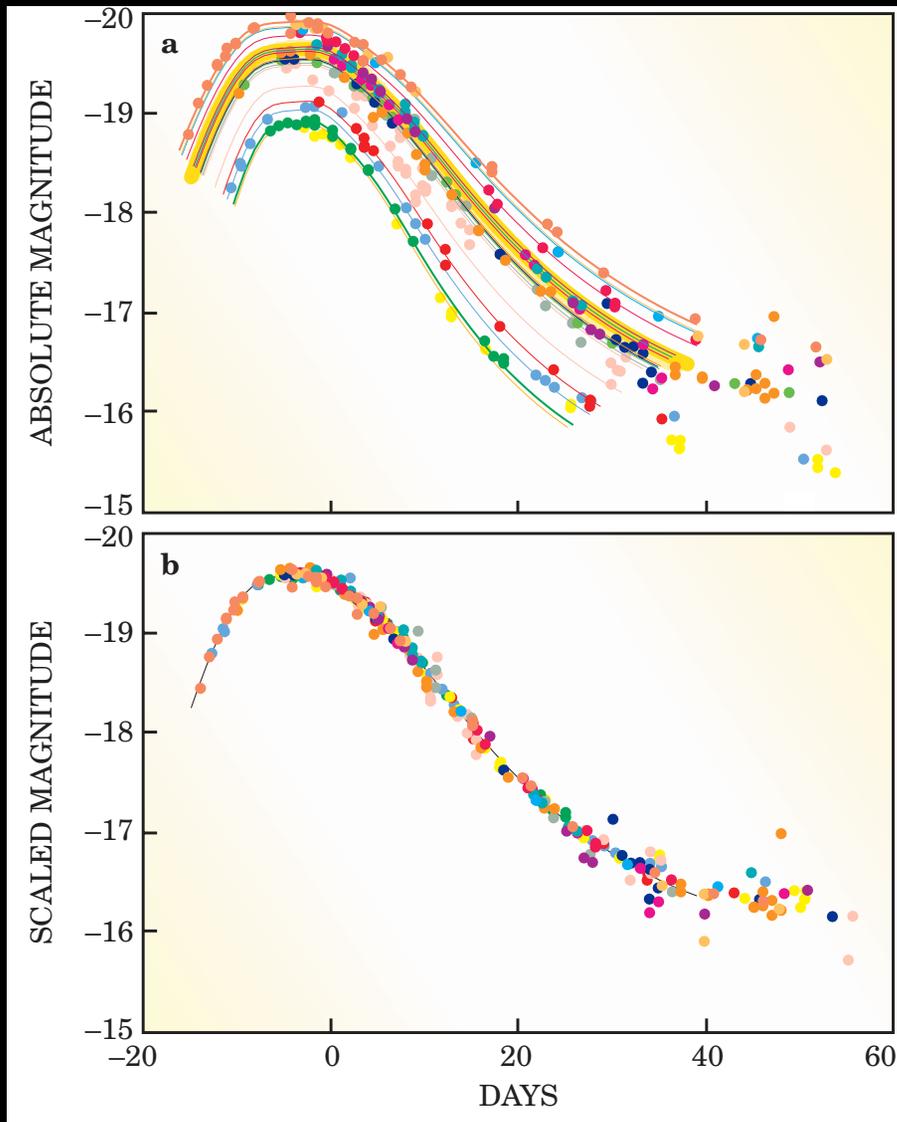
Distance Ladder



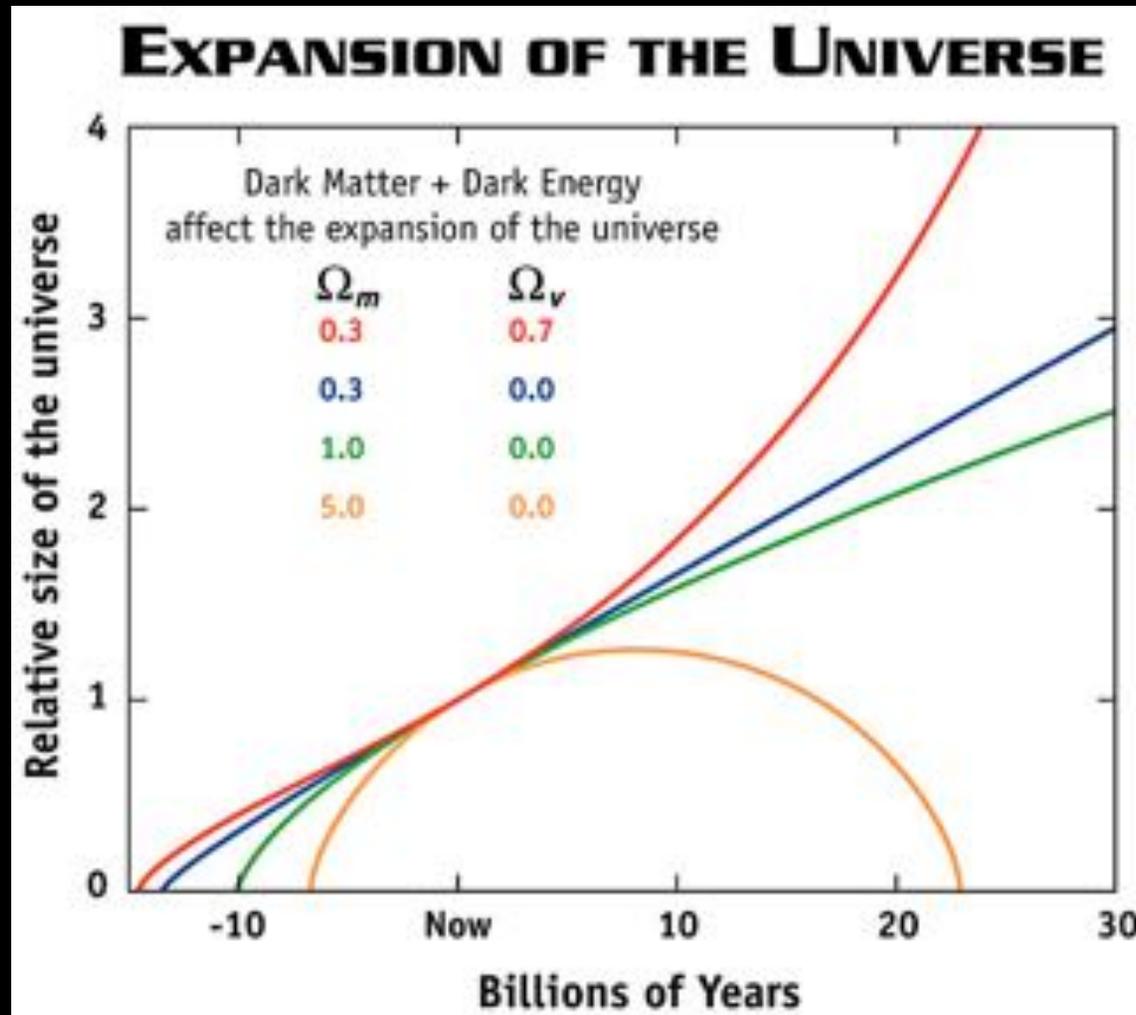
Standard Candle...sort of



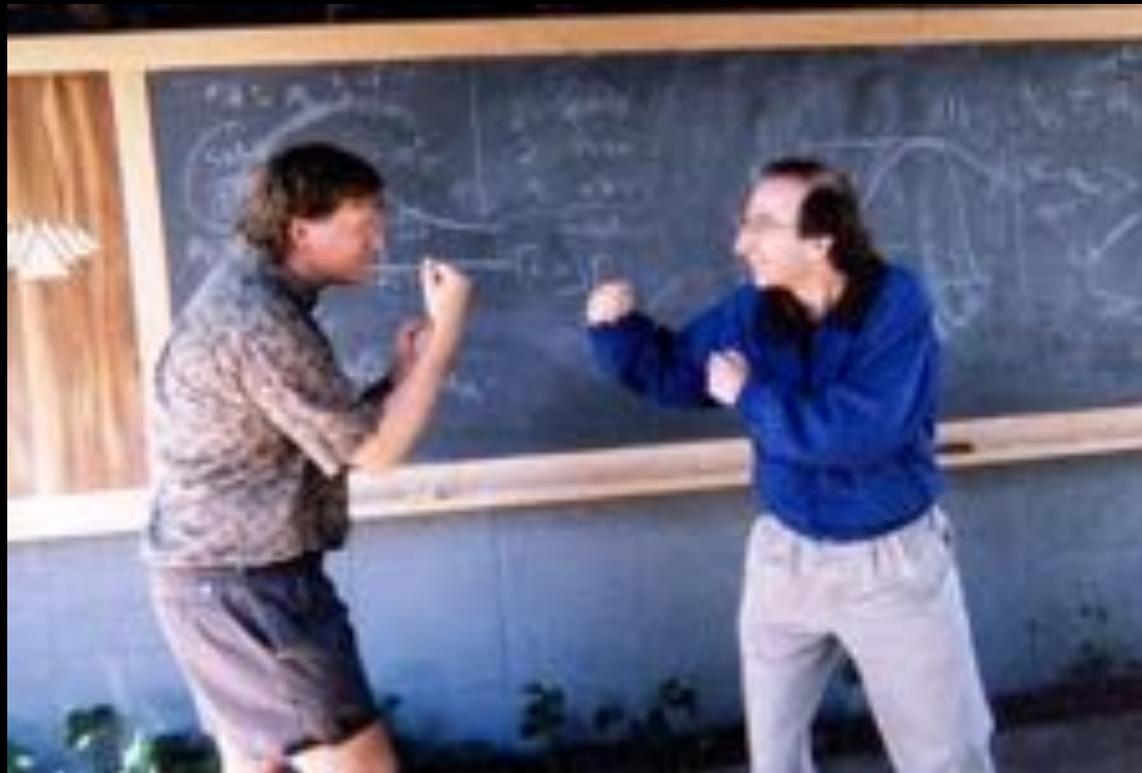
Why?



Which Evolutionary Track are we on?

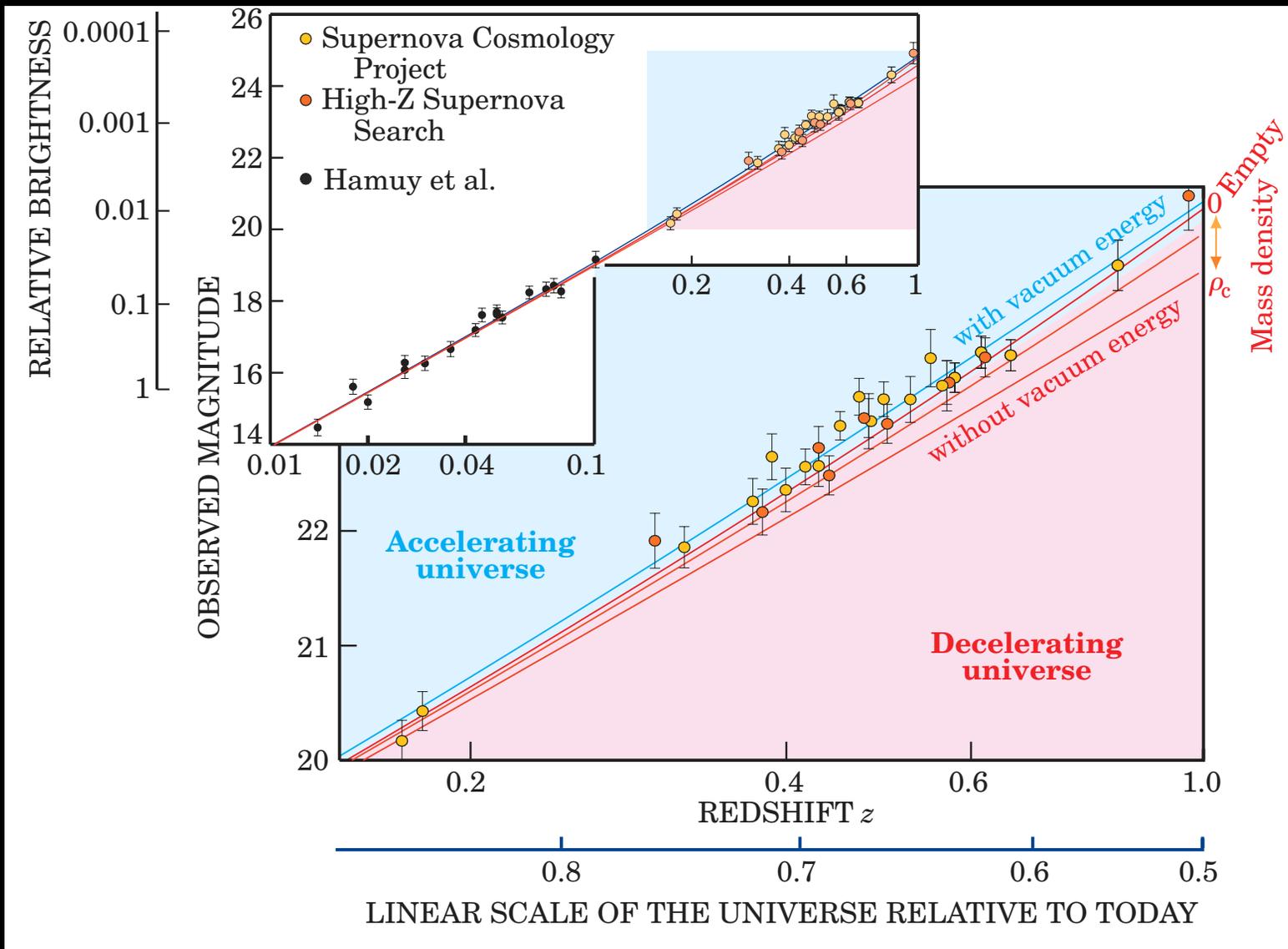


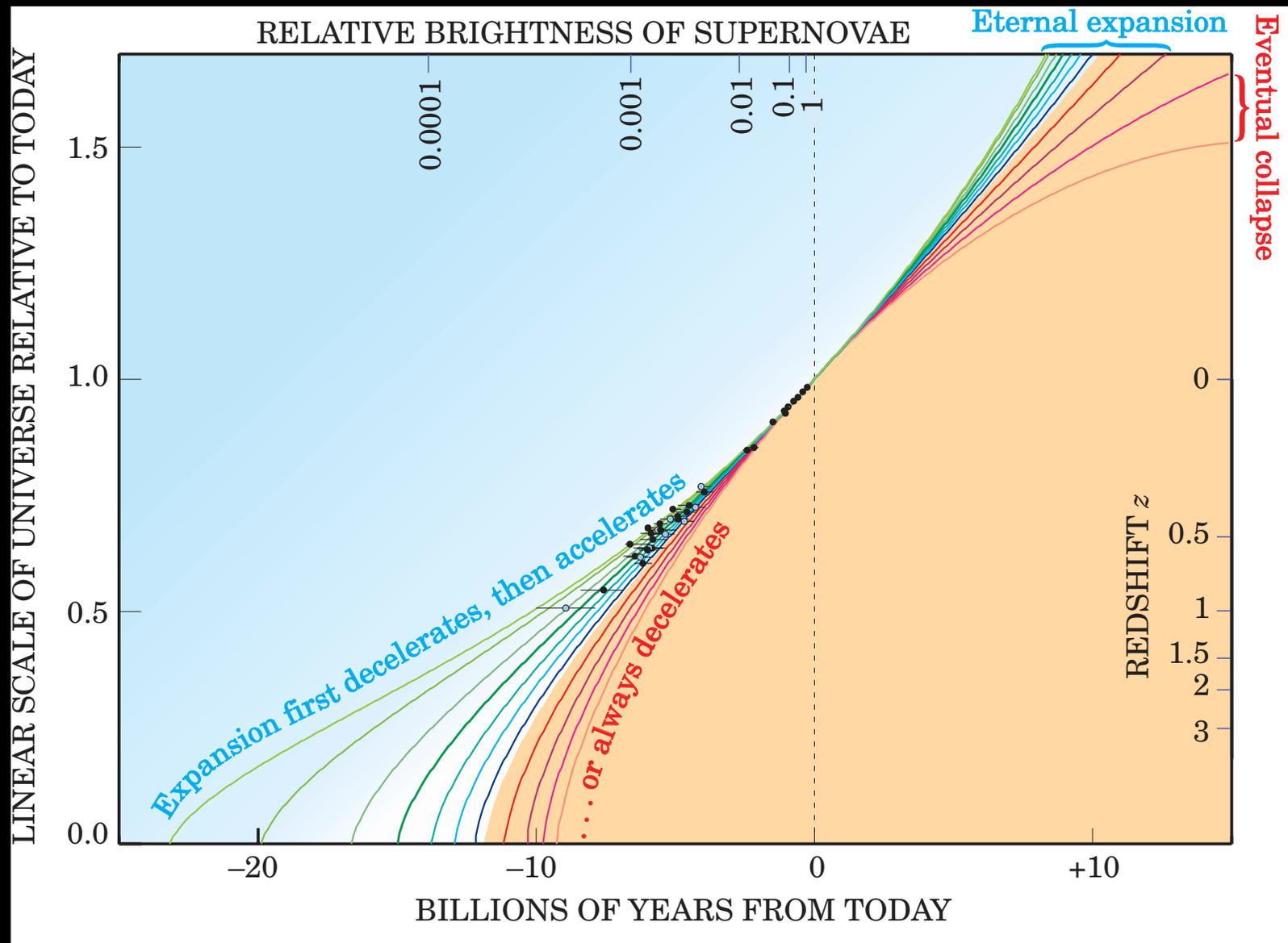
Two teams



Came to an amazing answer!





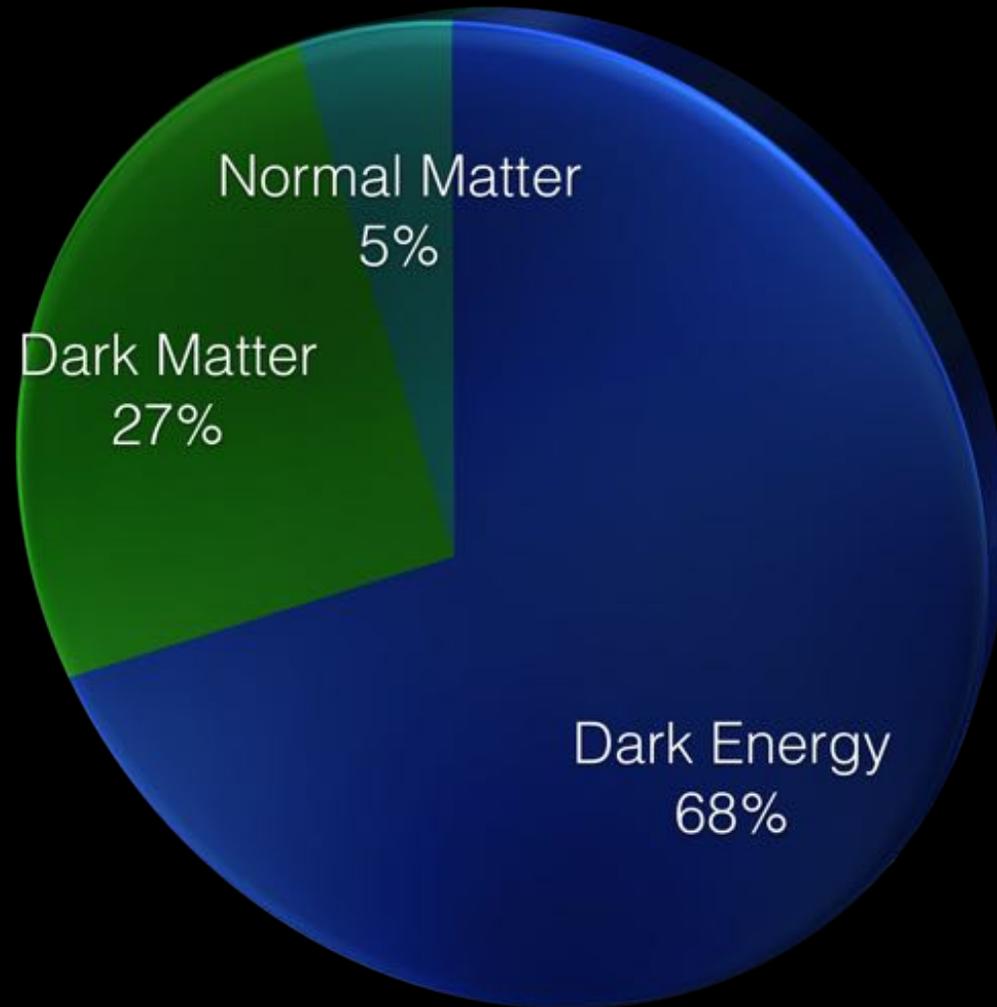


The Universe is not decelerating.
It's accelerating!

What?!!

Something is pushing the Universe apart
...Dark Energy?

We Live in a Strange Universe



Nobel Prize #3



Are we alone?



Image by Cassini Spacecraft
from Saturn

Earth



Are we alone?

My Prediction: In the next 50 years, we'll have some sort of answer to this question.

Earth



Are we alone?

Life in the Universe

Earth



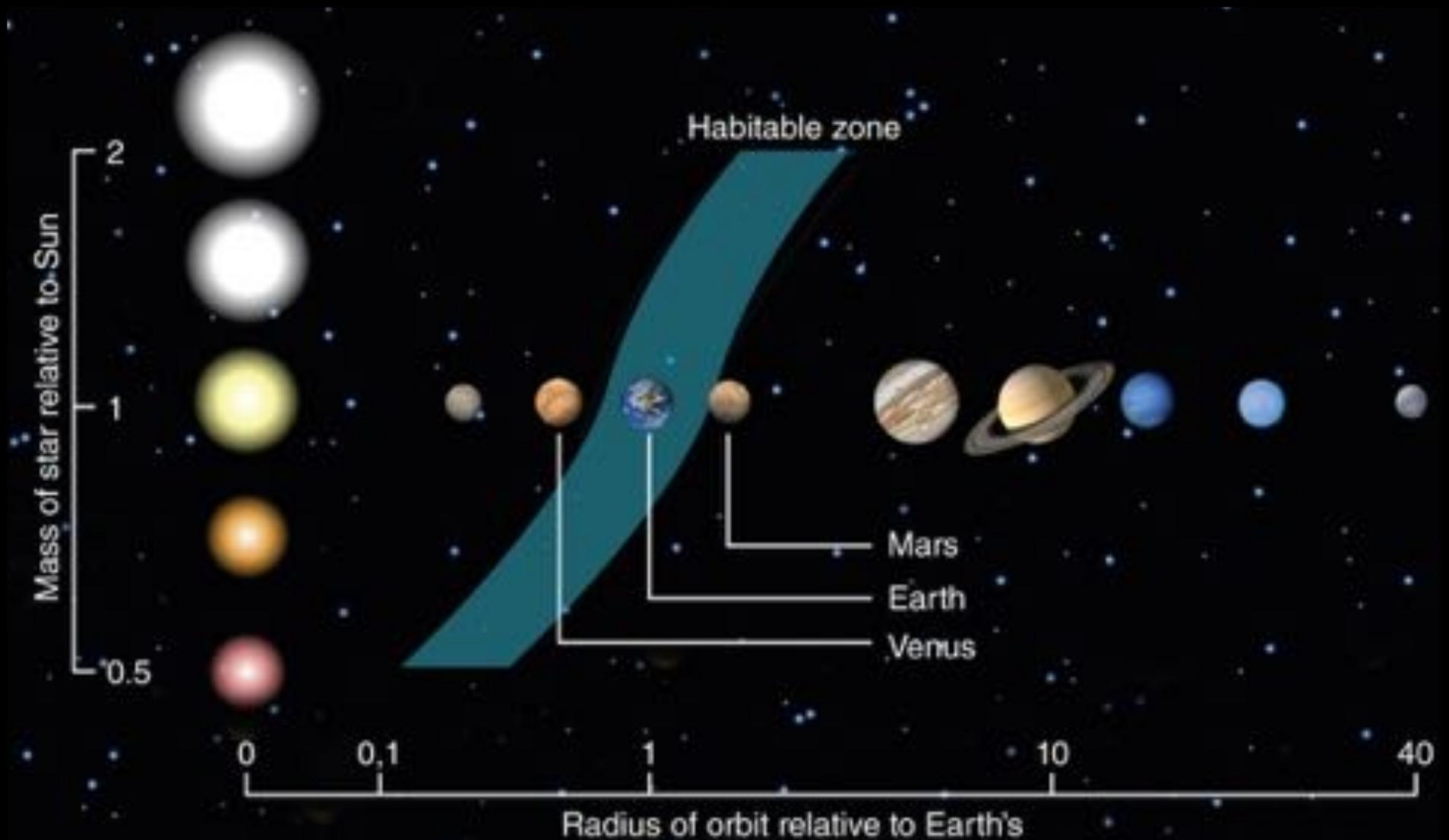
**The one place that we know of
that has life**



Where else might we find microbial life?



Habitable Zones



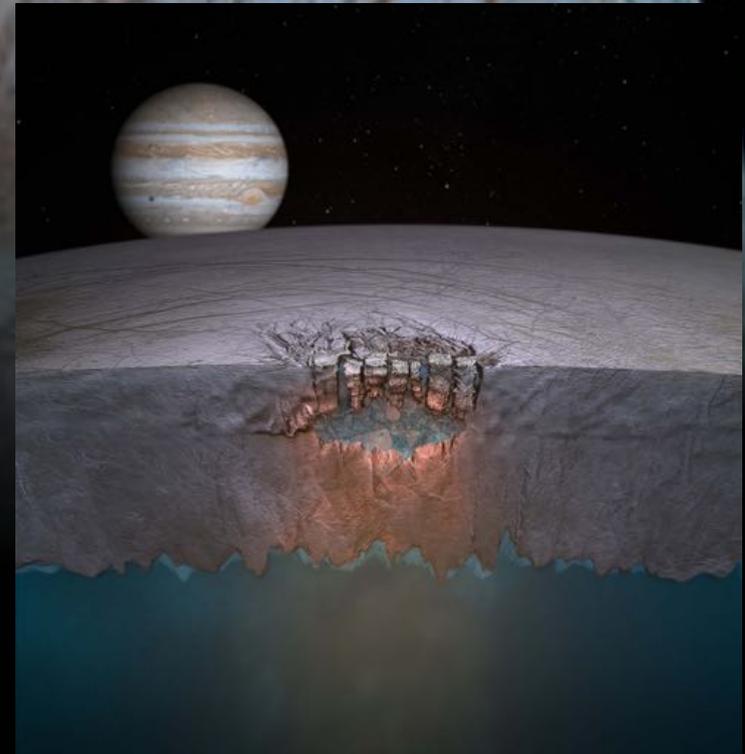
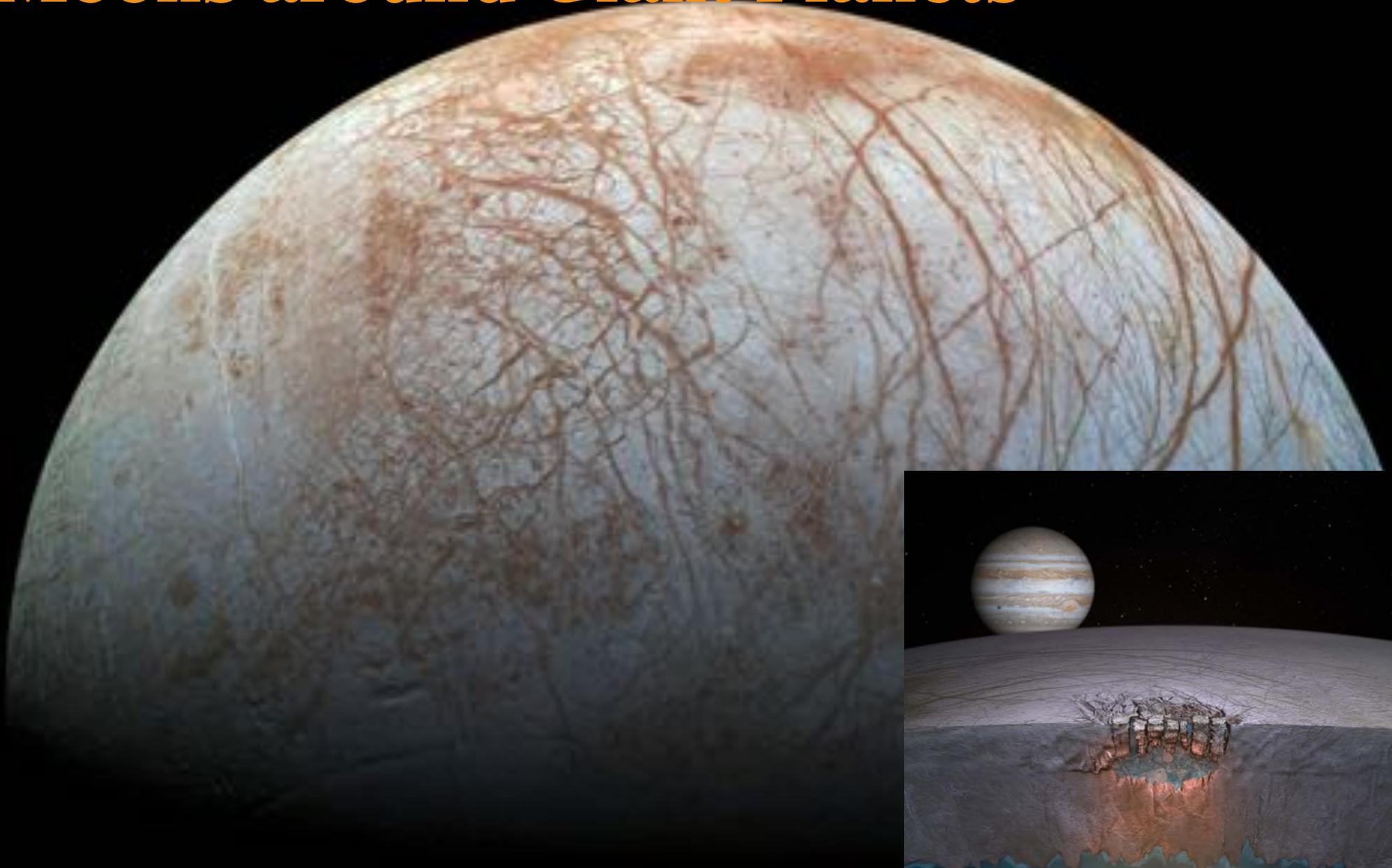
Presence of Liquid water?

Subterranean Mars



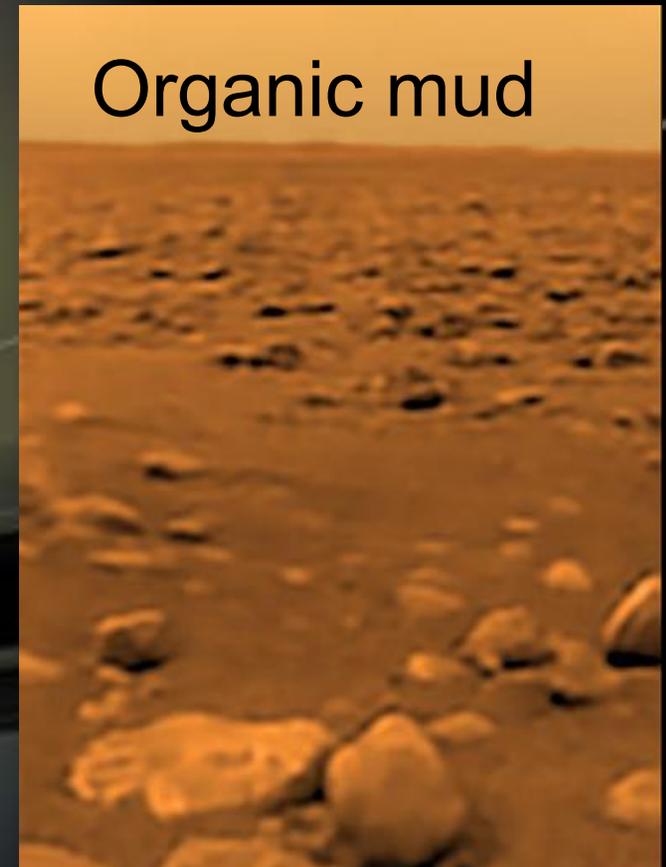
Mars likely has water beneath the surface.

Moons around Giant Planets



Europa likely has a liquid ocean

Moons around Giant Planets



Titan has lots and lots of organic compounds, but maybe not enough energy to support life.

Is Life out there?

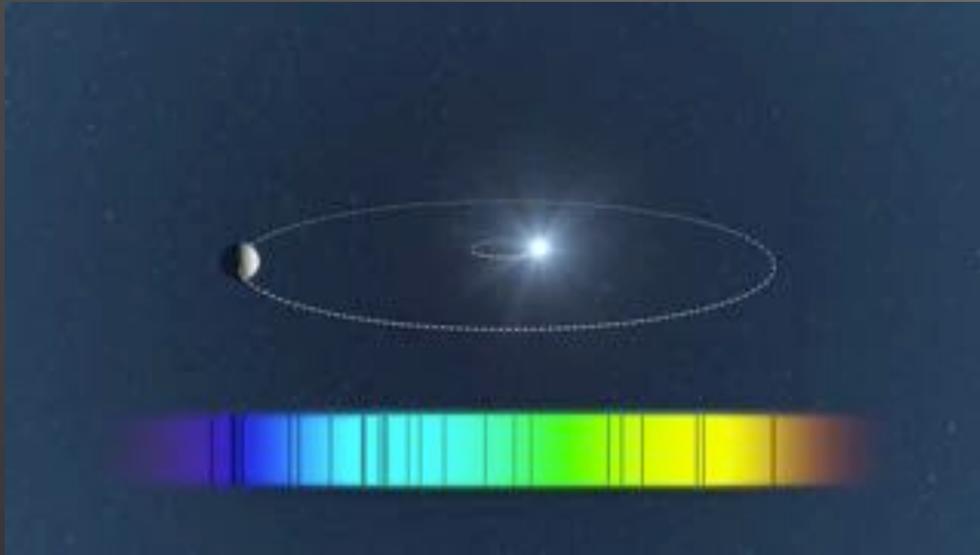


Fraction of stars with planets

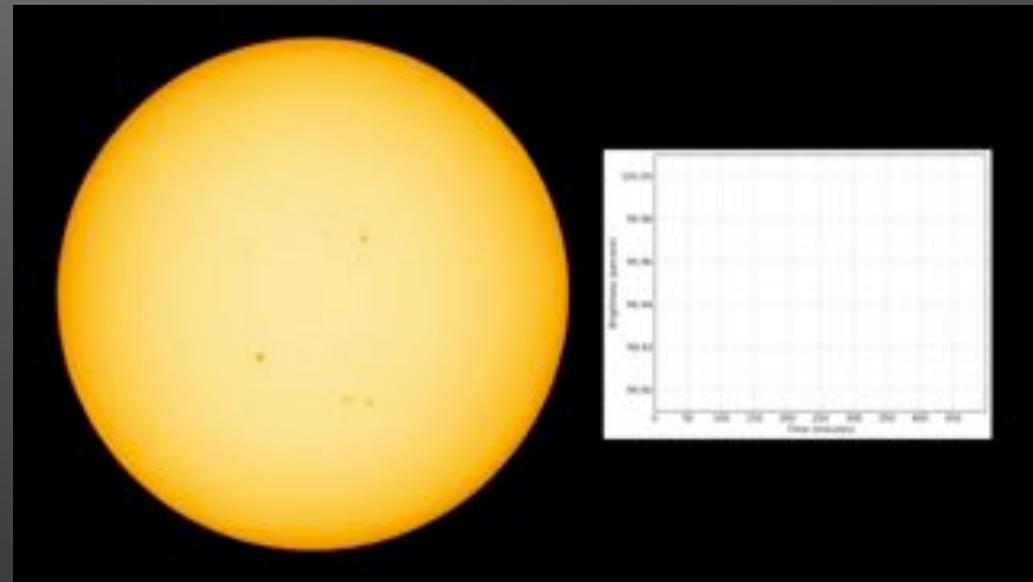
**How do we find the planets around
other stars?**

Exoplanet Hunting

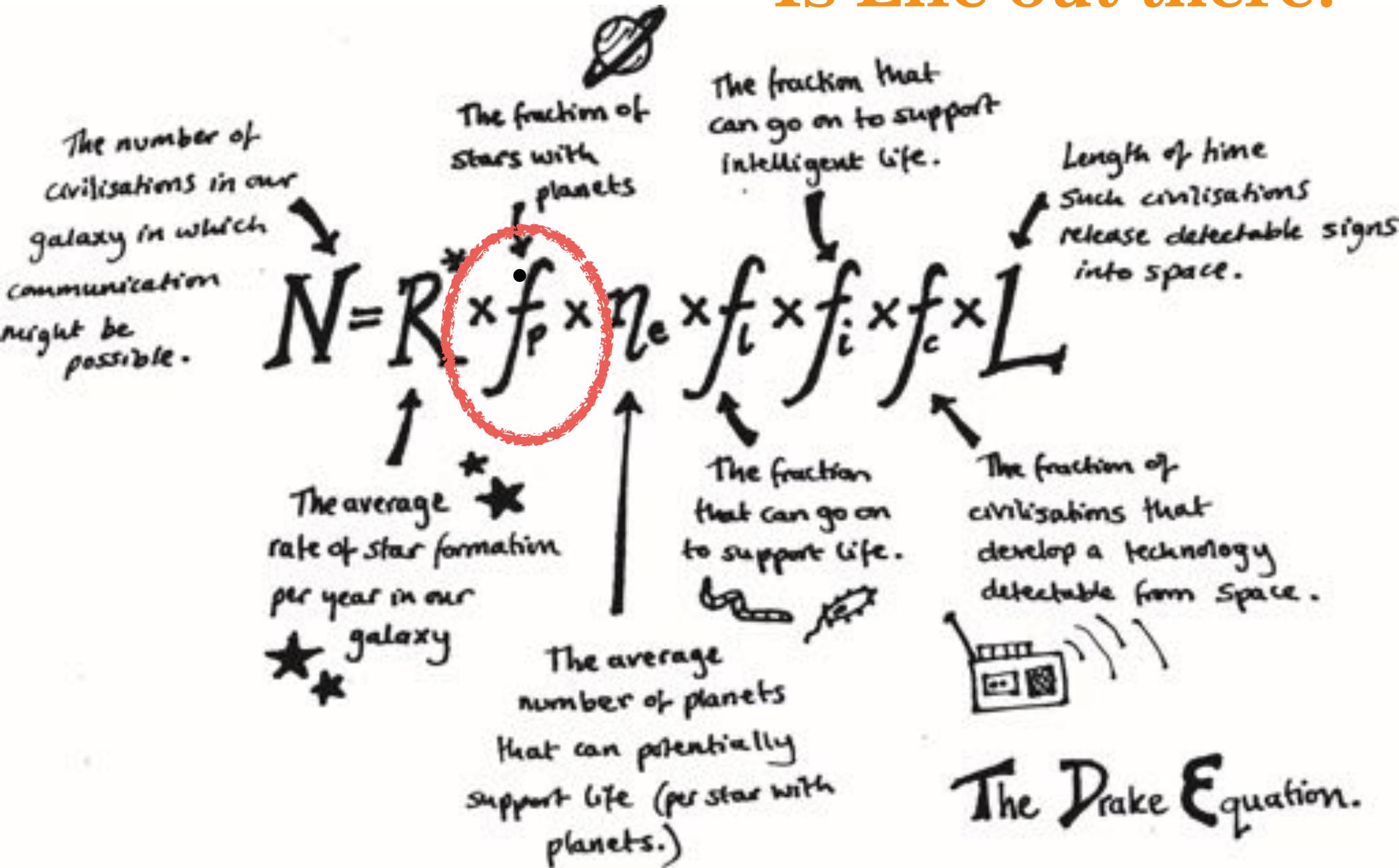
Radial Velocity or
Doppler Method



Transit Method

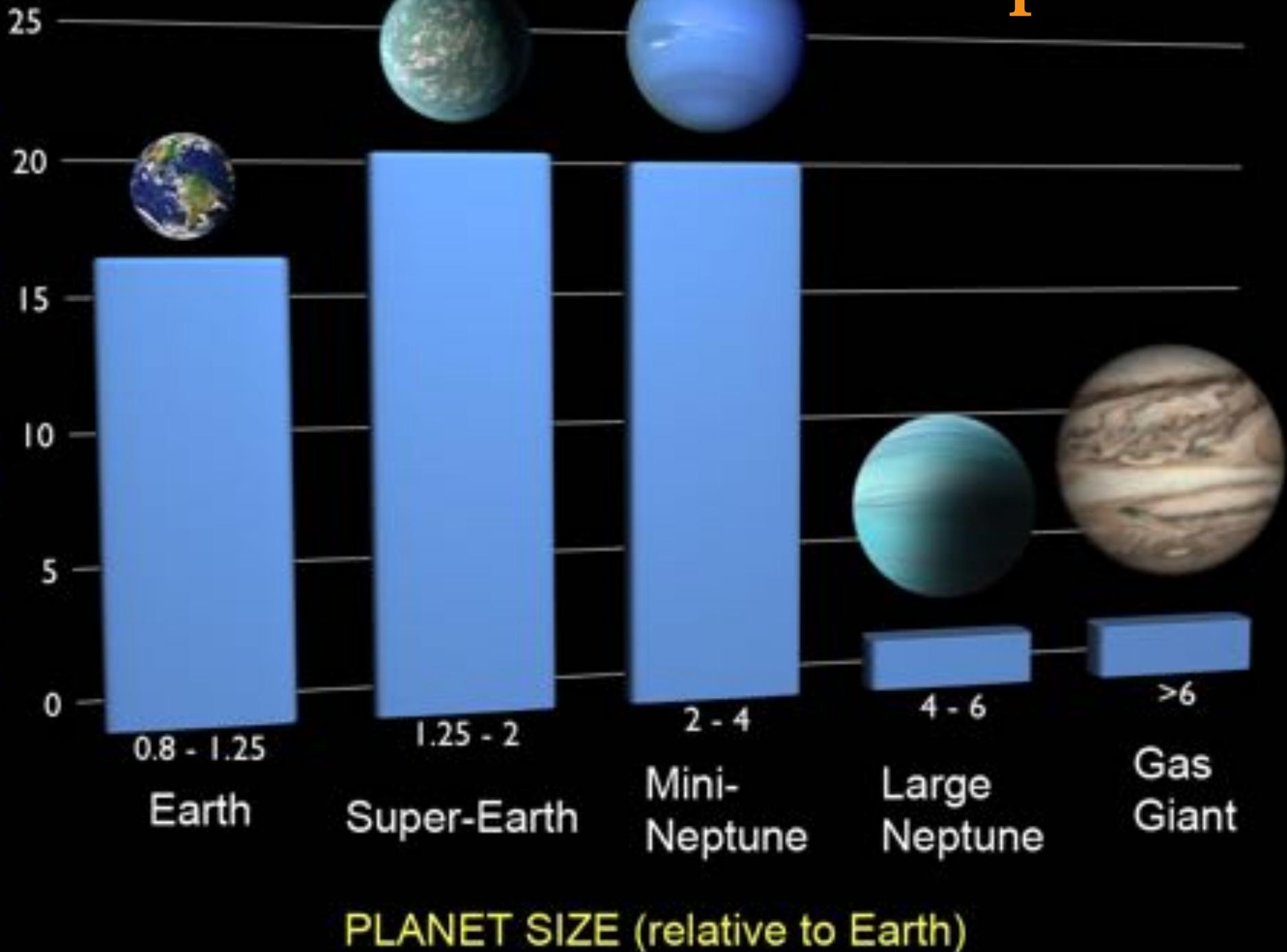


Is Life out there?



Fraction of stars with planets

FRACTION OF STARS WITH AT LEAST ONE PLANET



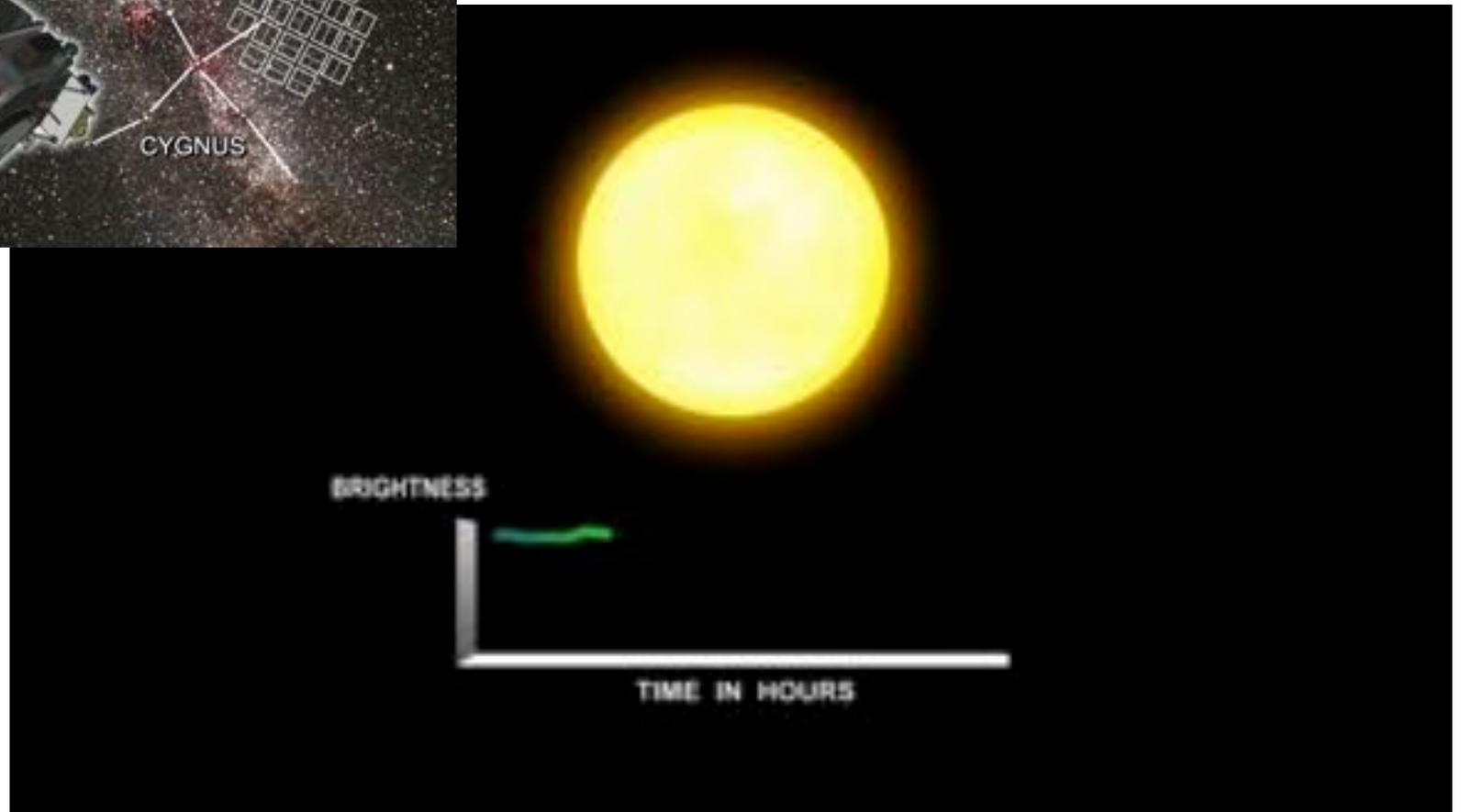
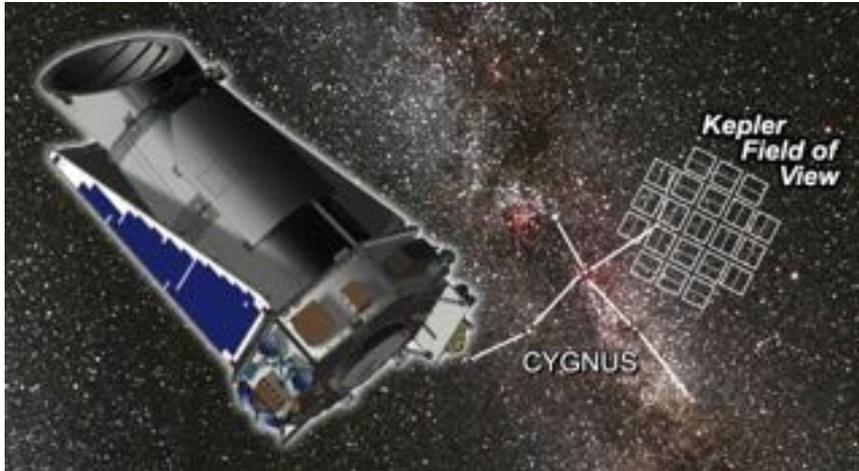
Is Life out there?



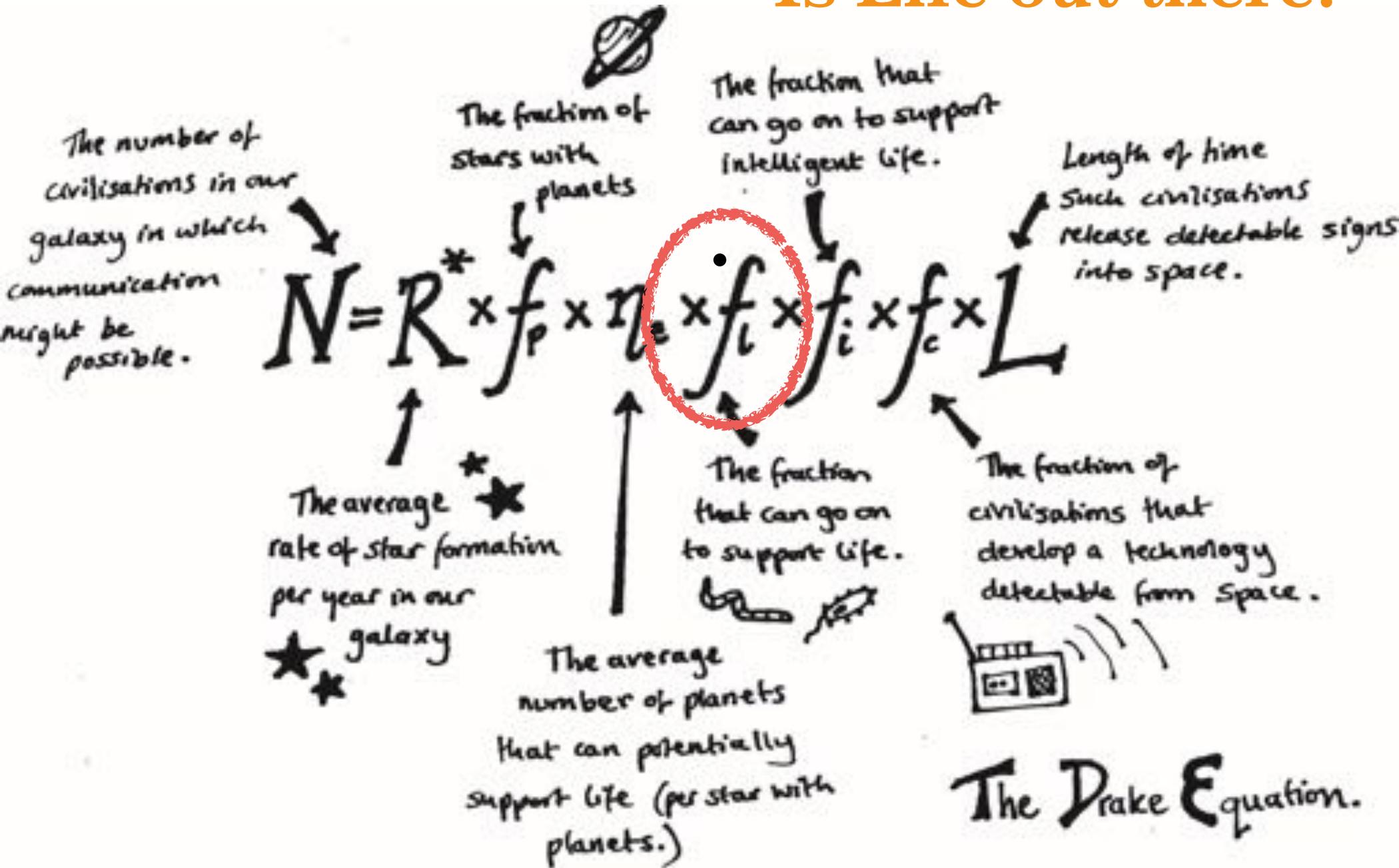
η_e = 5%, roughly

Is Life out there?

Kepler Space Craft



Is Life out there?



Is Life out there?



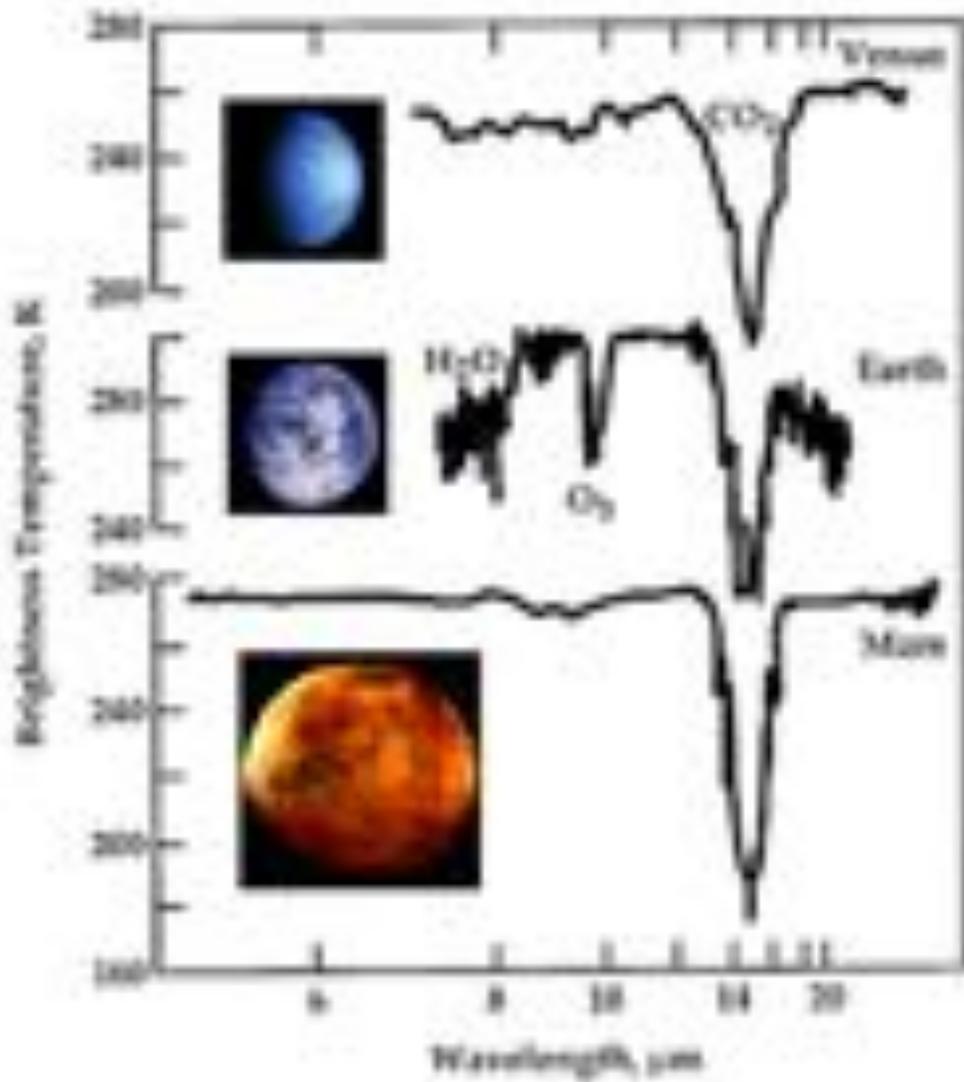
How would you measure the fraction of planets that have life?

Support life (per star with planets.)

The Drake Equation.

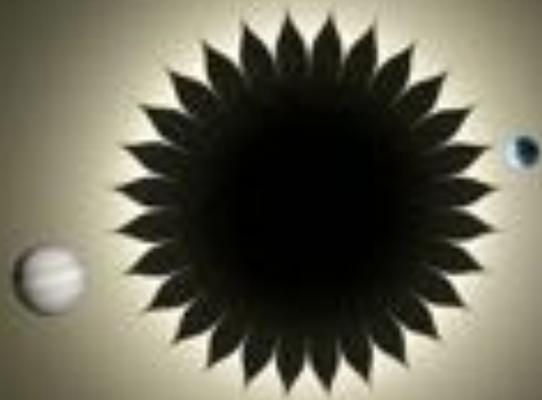
Is Life out there?

Spectrum of Earth shows Water and Oxygen



- We think water is needed for life
- Life produces oxygen in our atmosphere

Planets are dim and next to a really bright star



- Block light of star
- Large Telescope
- Take spectrum



Let's inspire the next generation to embrace their passionately curious inner child, ask profound questions, reach for the stars, and do something bold and amazing.



@curiousmiah

Latest Astrophysics News, etc.