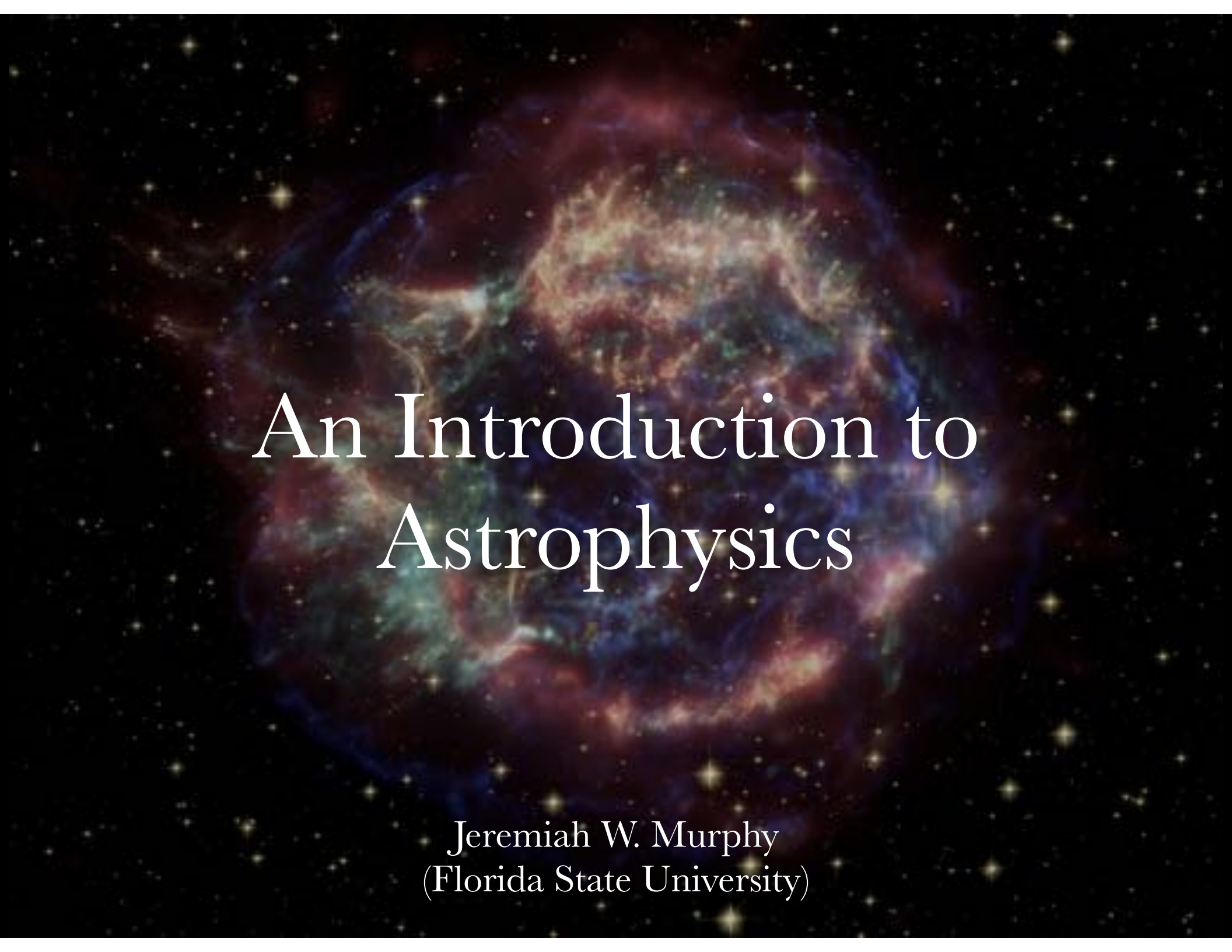

Jeremiah W. Murphy (FSU Physics)
@curiousmiah
Latest Astrophysics News, etc.



An Introduction to Astrophysics

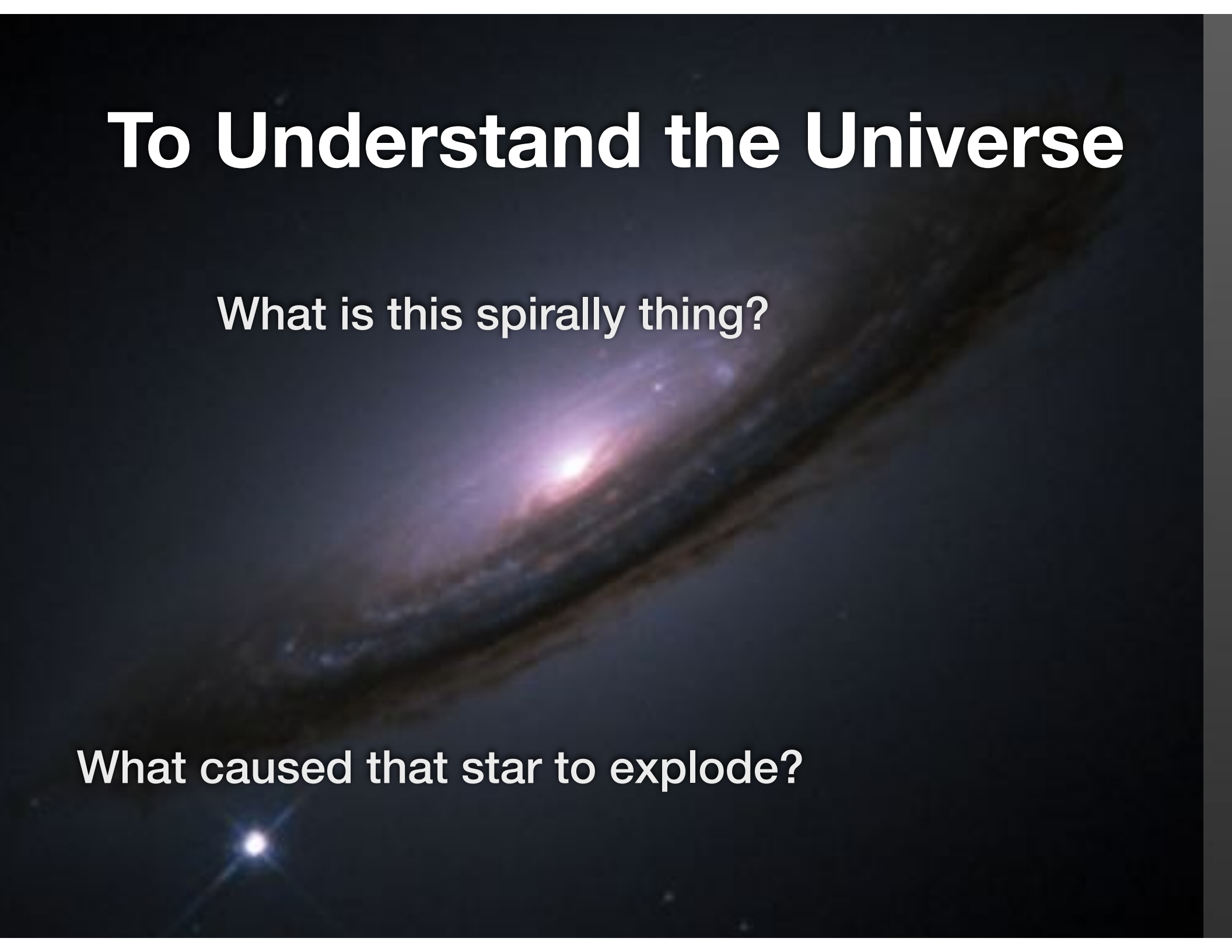
Jeremiah W. Murphy
(Florida State University)

An Introduction to the Universe…in the 60 minutes

Hold on


Why Astronomy?

Embrace your passionately curious inner child


To Understand the Universe
What is this spirally thing?
What caused that star to explode?

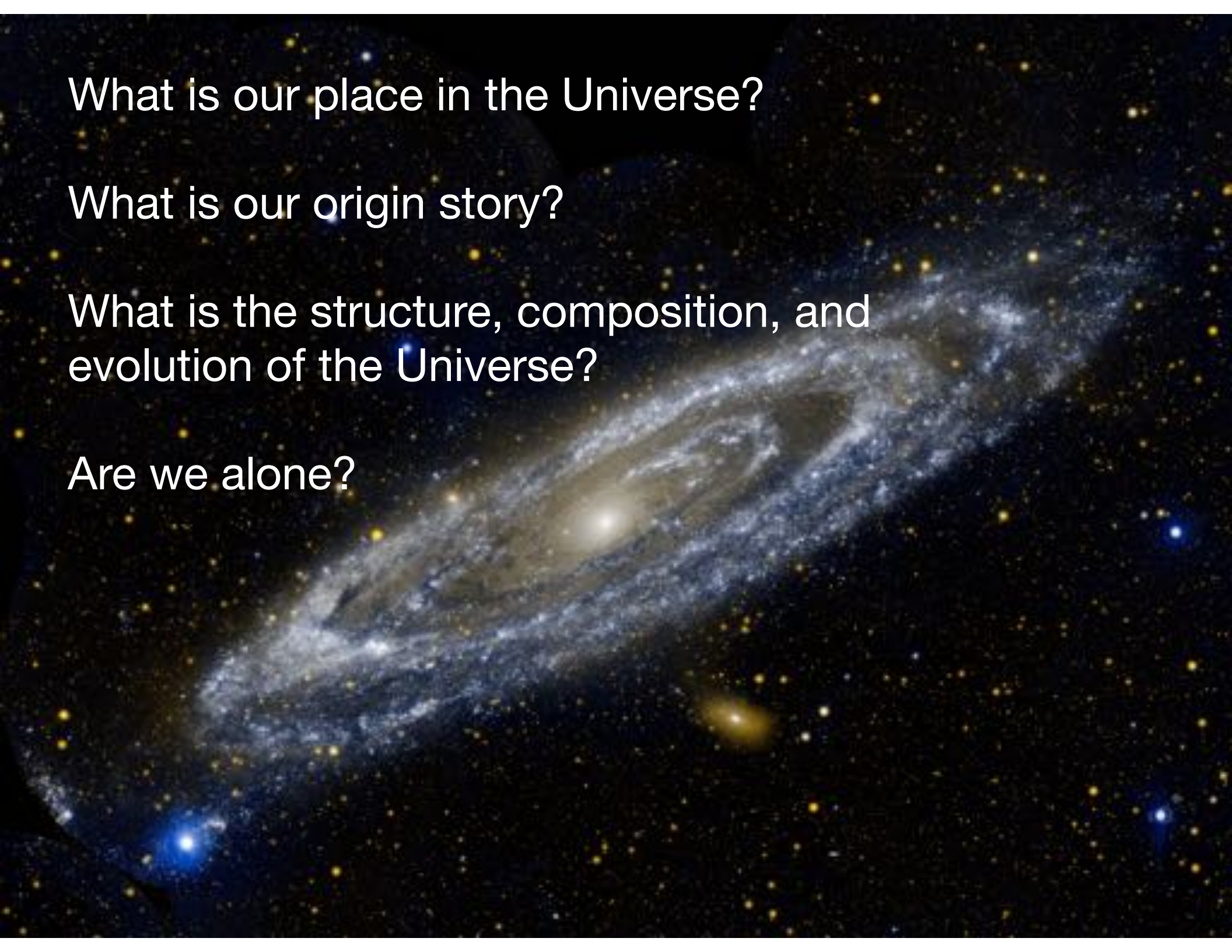
To Understand the Universe

How old is the Earth?

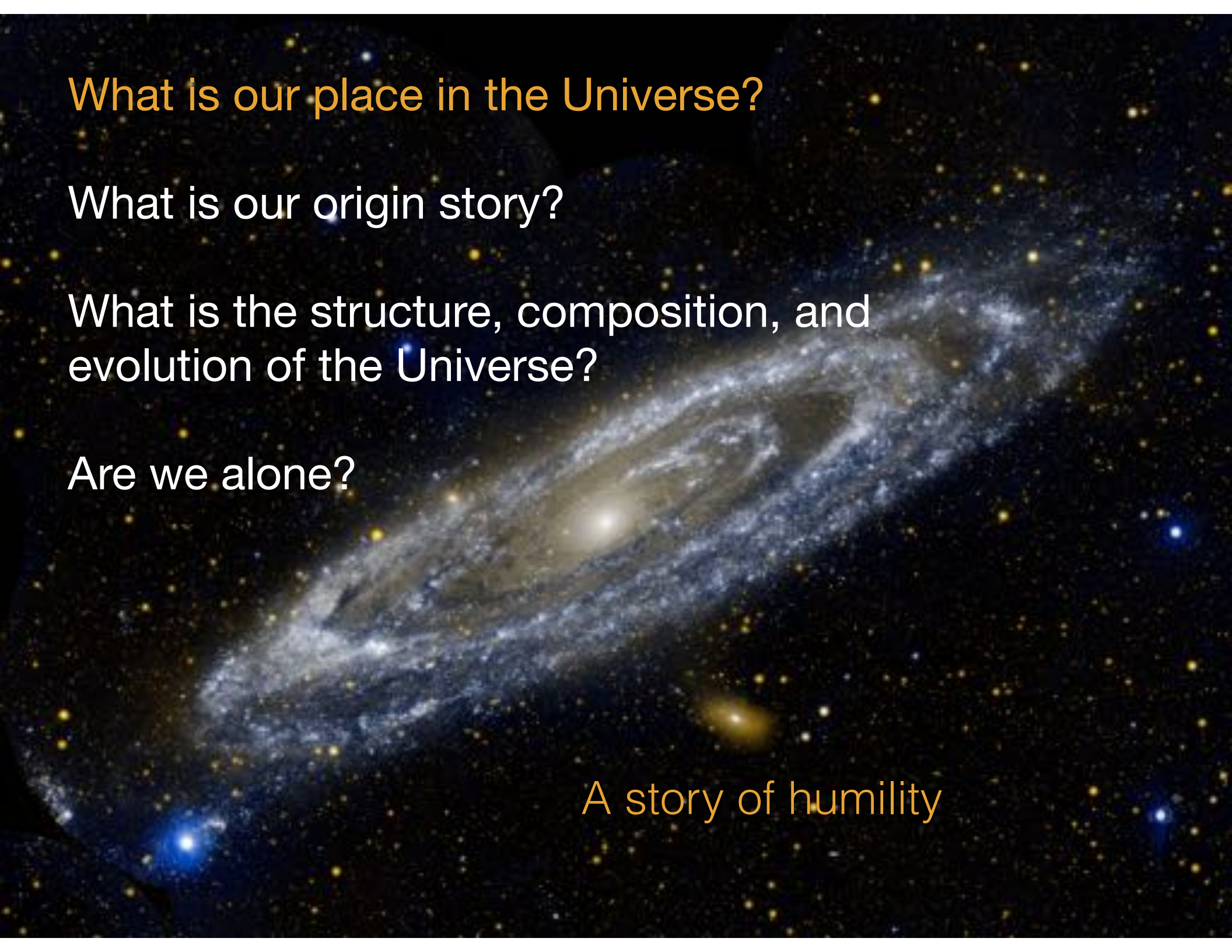
How did the Earth form?

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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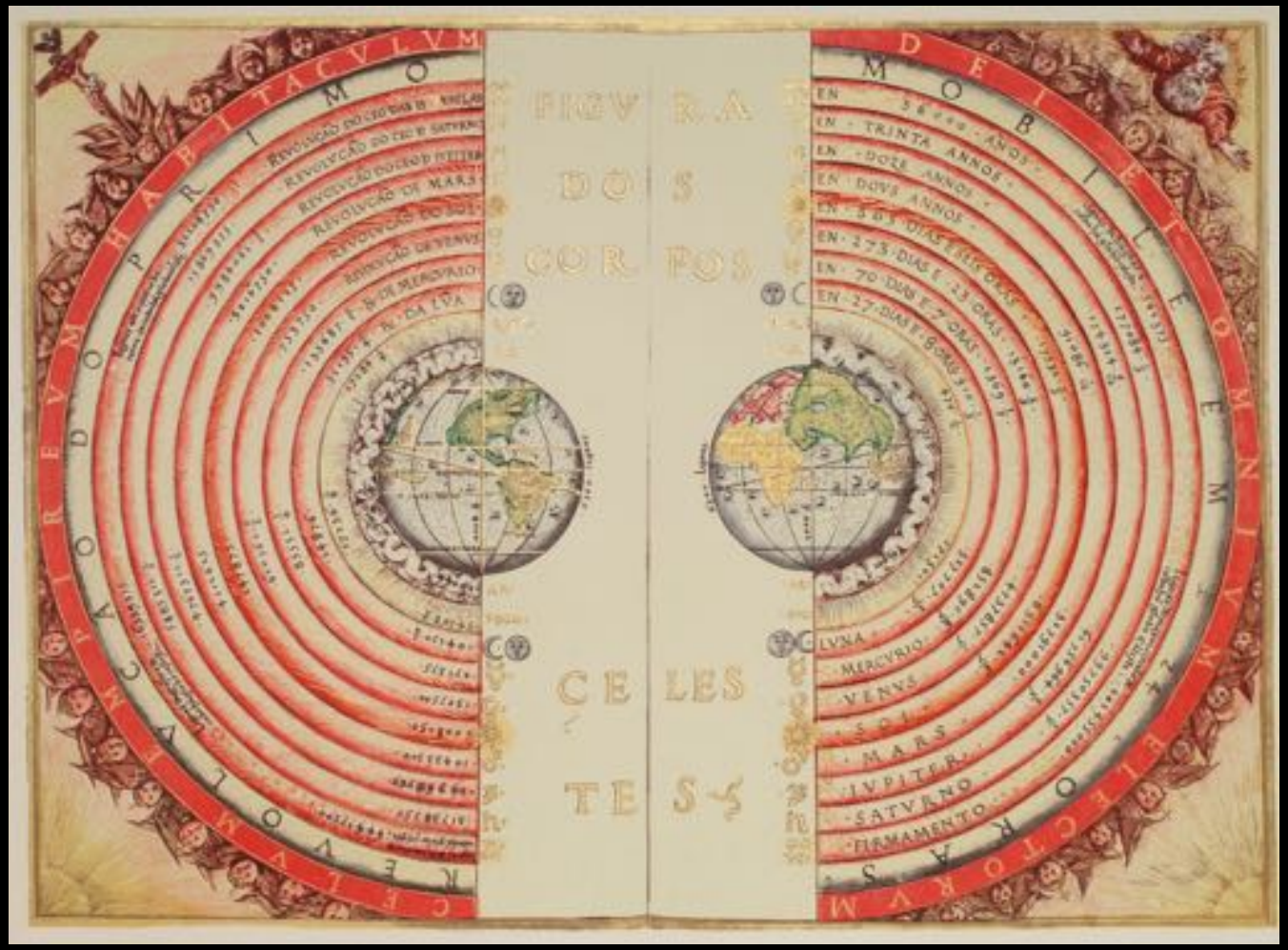
Are we alone?
A story of humility

Your Place in the Universe

Ptolemaic: Geocentric Model



Bartolomeu Velho 1568

Copernican Universe (1543)

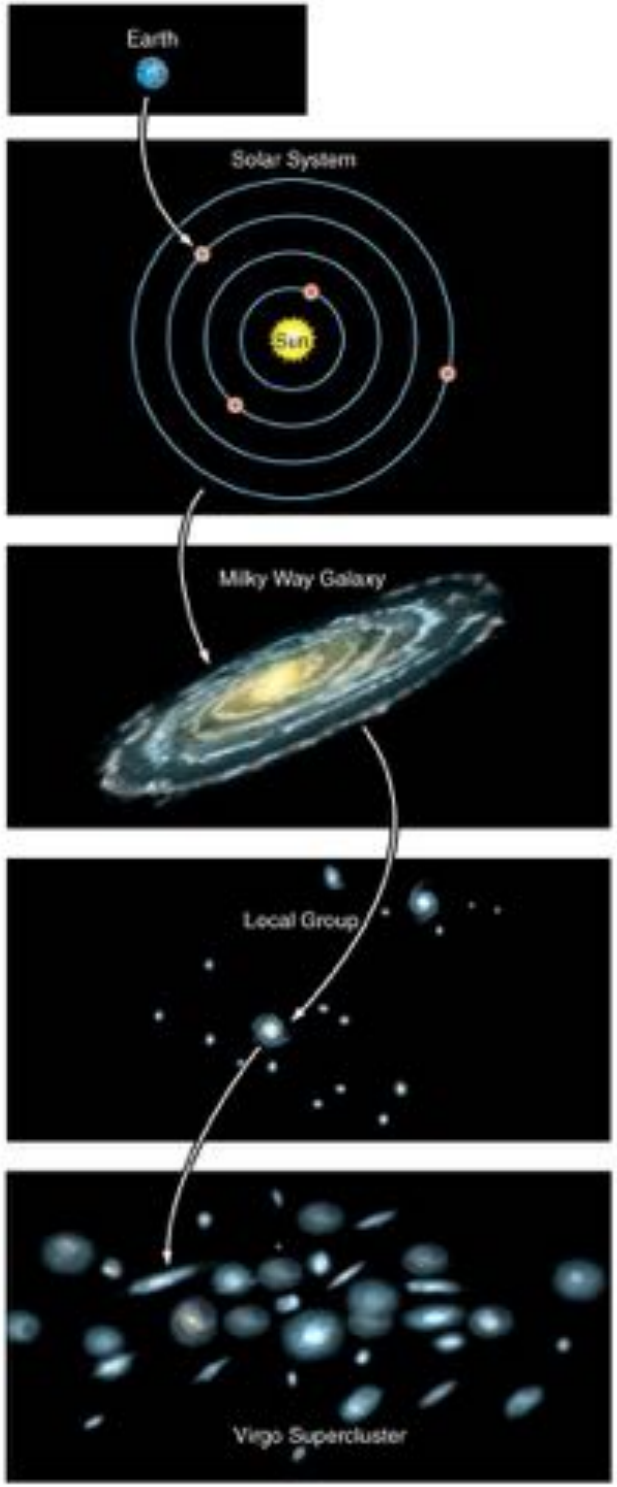
Hubble Ultra Deep Field · Infrared

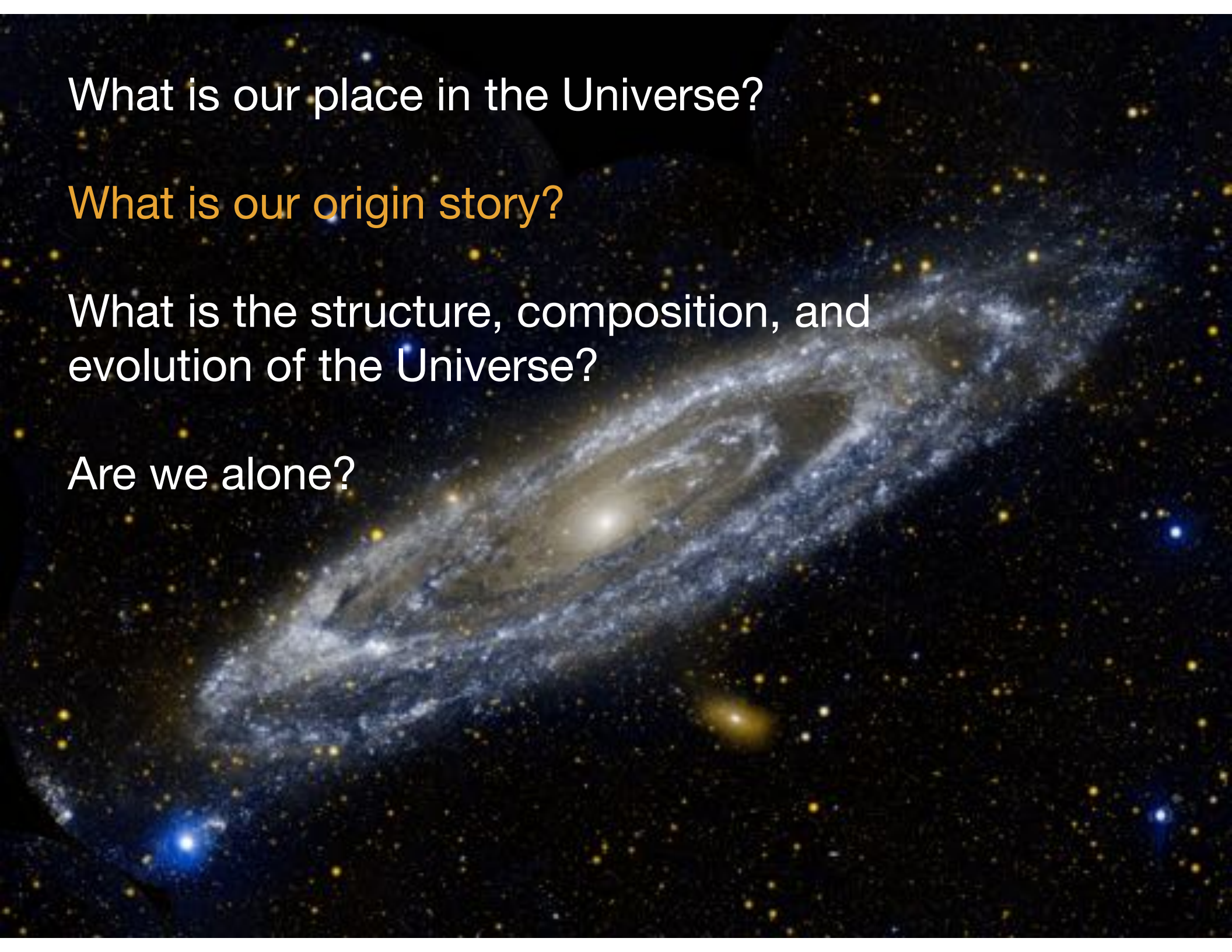
HST · WFC3/IR

NASA, ESA, G. Illingworth (UCO/Lick Observatory and University of California, Santa Cruz), and the HUDF09 Team

STScI-PRC09-31

Your Place in the Universe

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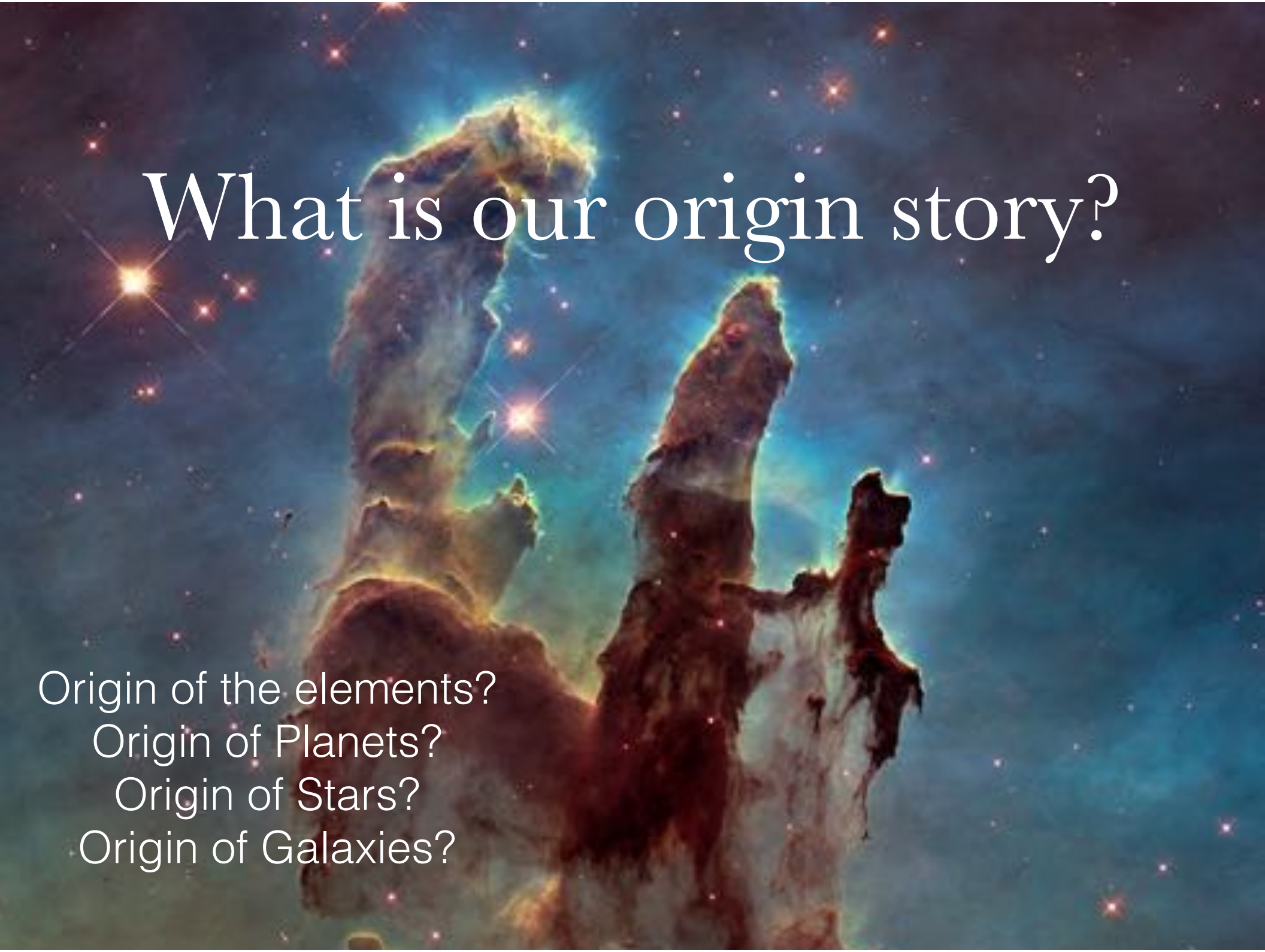
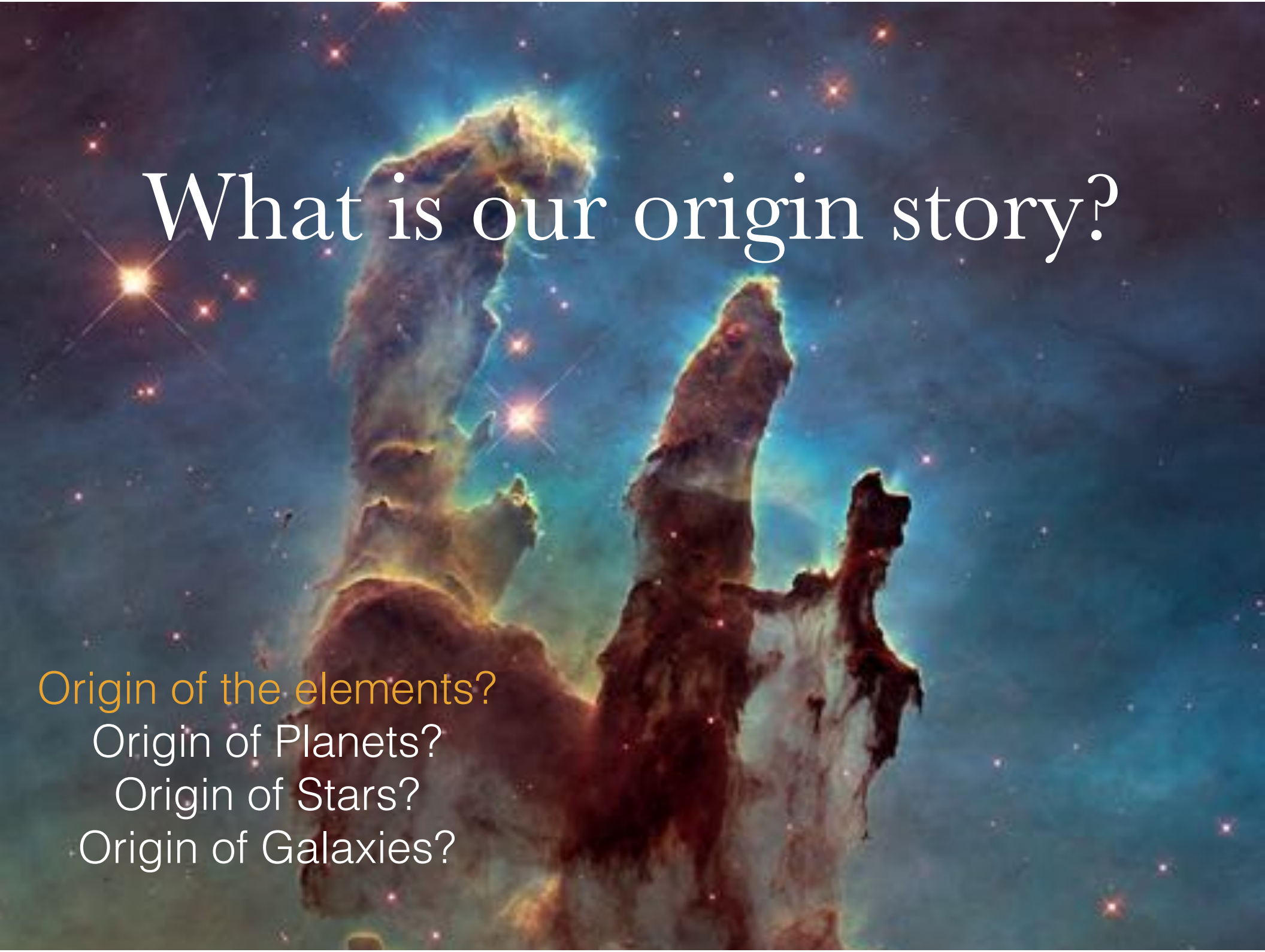

What is our origin story?
Origin of the elements?
Origin of Planets?
Origin of Stars?
Origin of Galaxies?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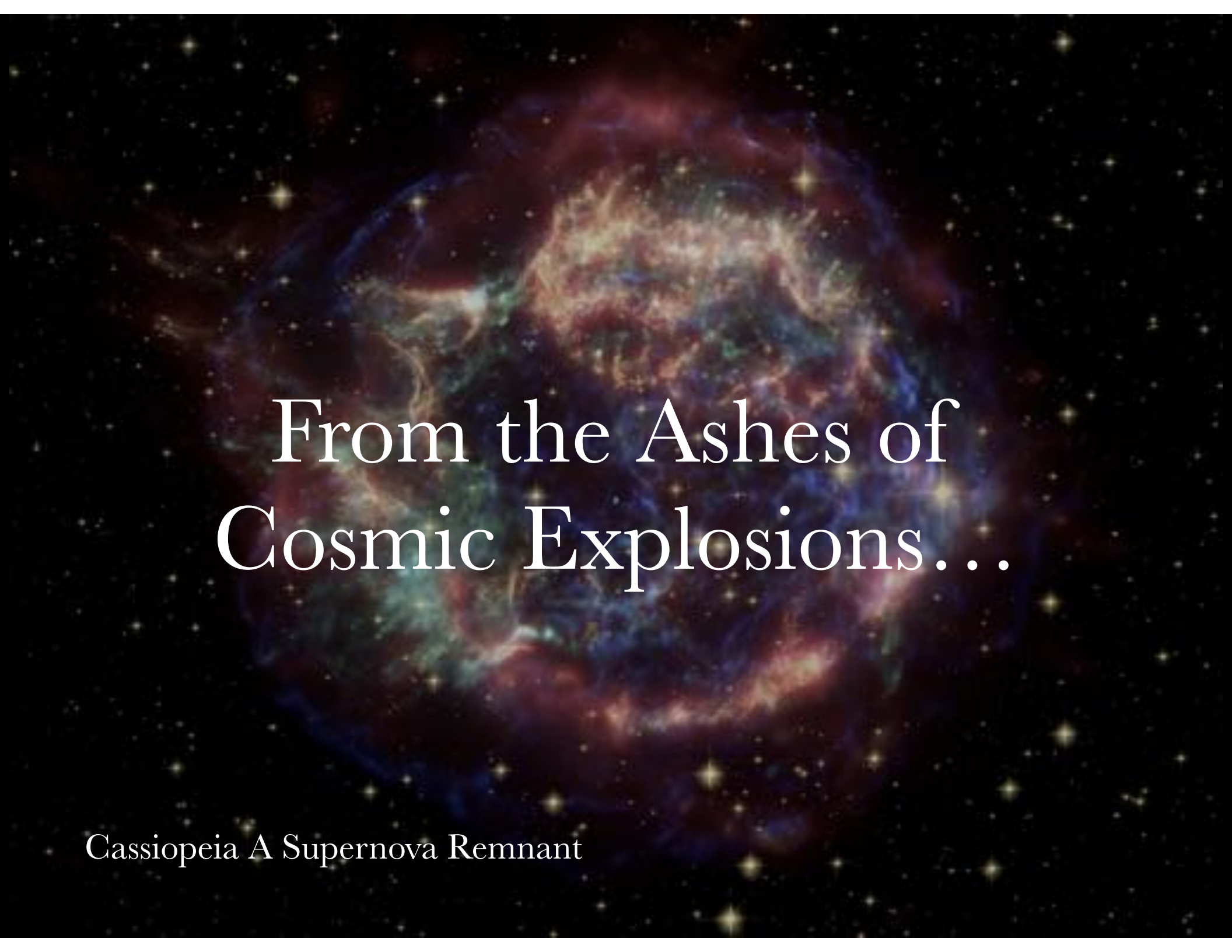
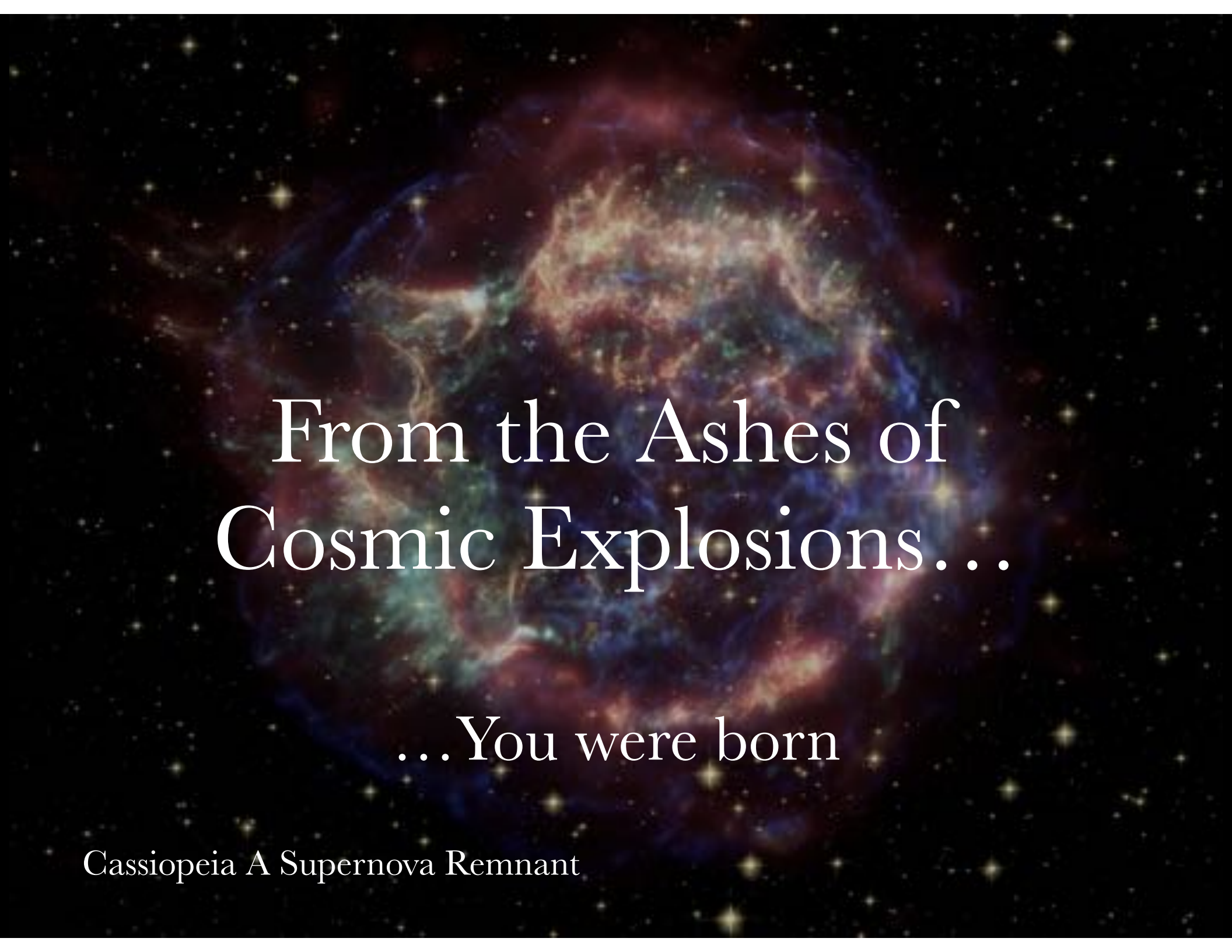


Cassiopeia A Supernova Remnant


From the Ashes of
Cosmic Explosions…
…You were born
Cassiopeia A Supernova Remnant

Luna's

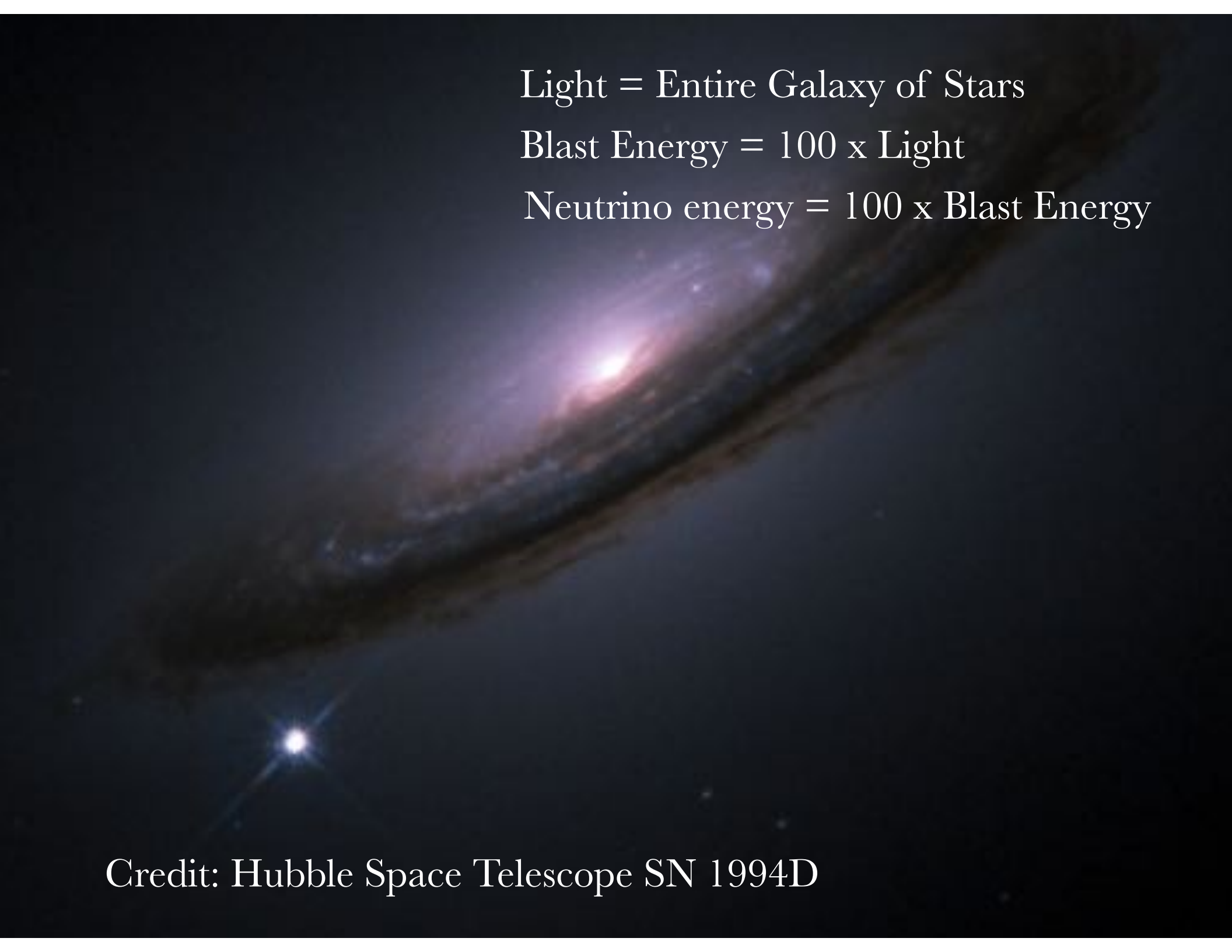
What is ~~our~~ origin story?


Supernova(e)
© Australian Astronomical Observatory

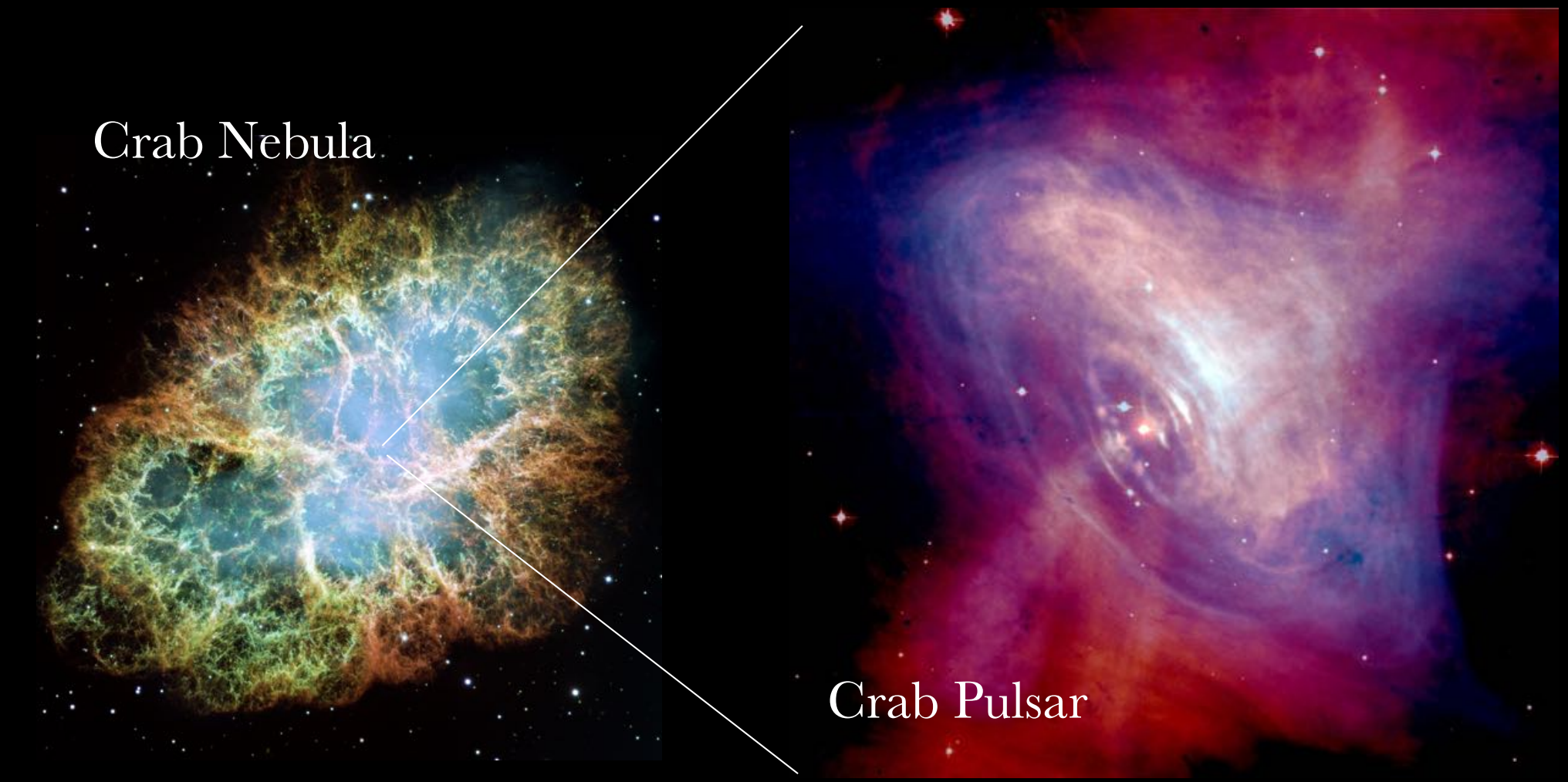

Supernova?
© Australian Astronomical Observatory

Supernovae: Stellar Explosions

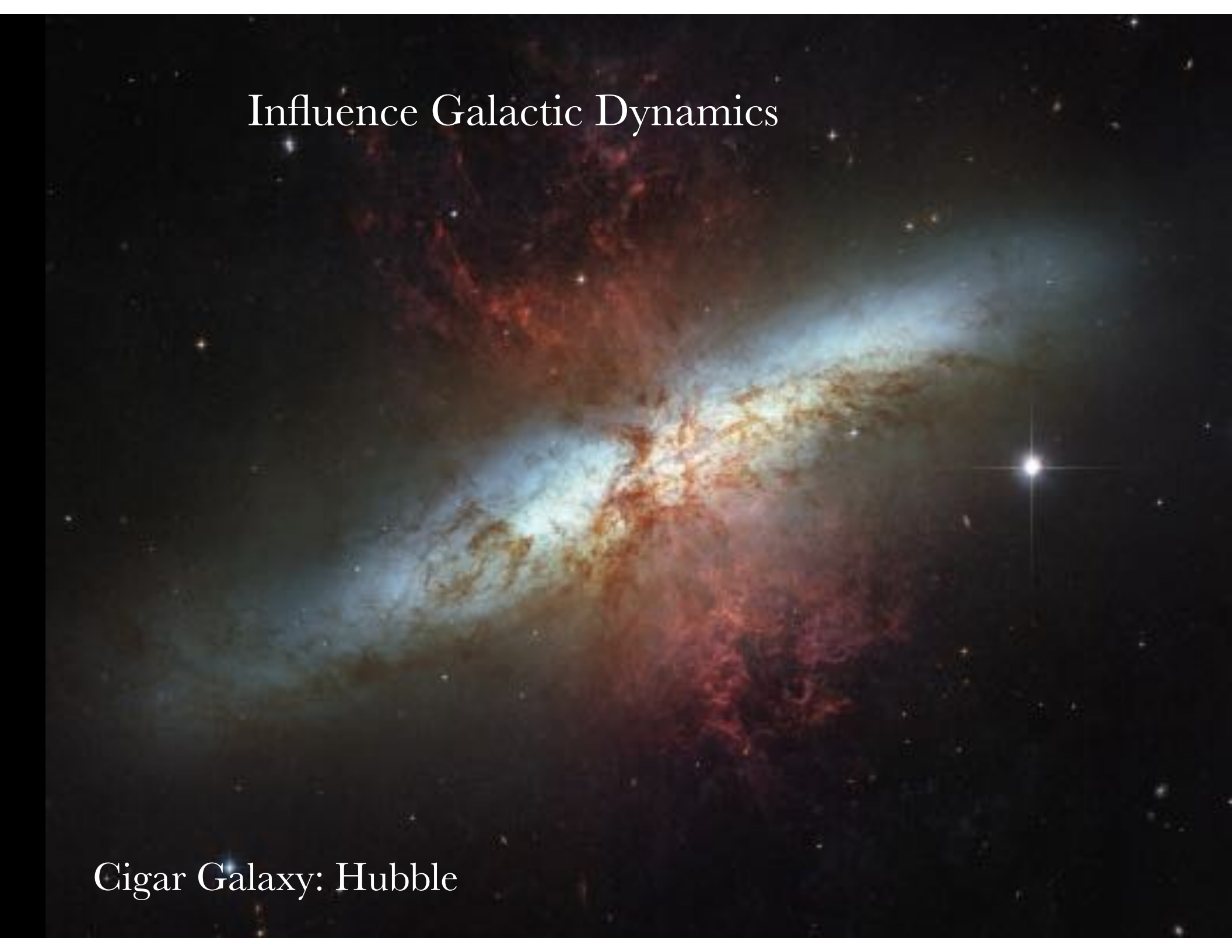
SN 1987A


Light = Entire Galaxy of Stars
Blast Energy = 100 x Light
Neutrino energy = 100 x Blast Energy
Credit: Hubble Space Telescope SN 1994D

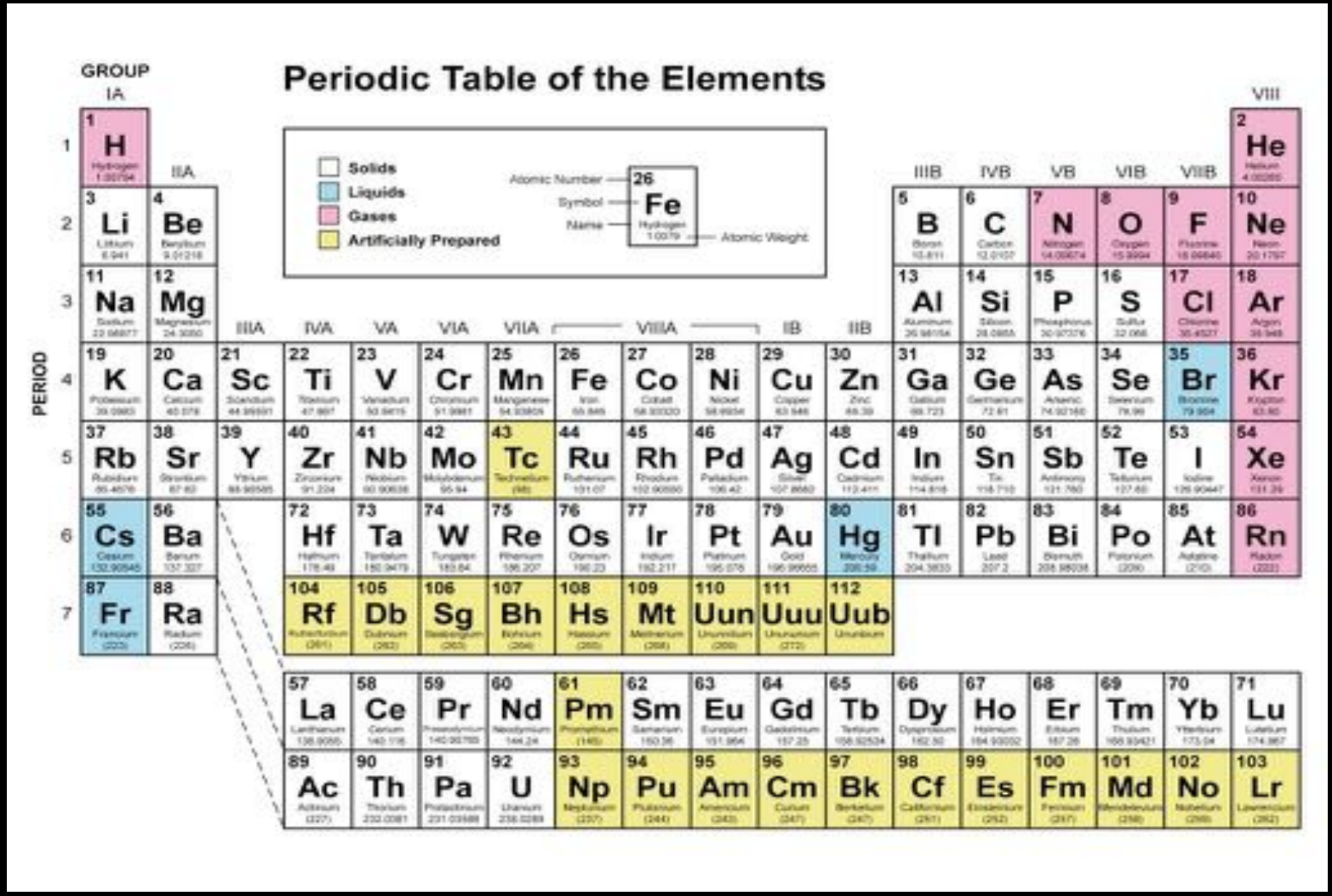
Herald the Birth of Neutron Stars & Black Holes



Trigger Further Star Formation


Influence Galactic Dynamics
Cigar Galaxy: Hubble

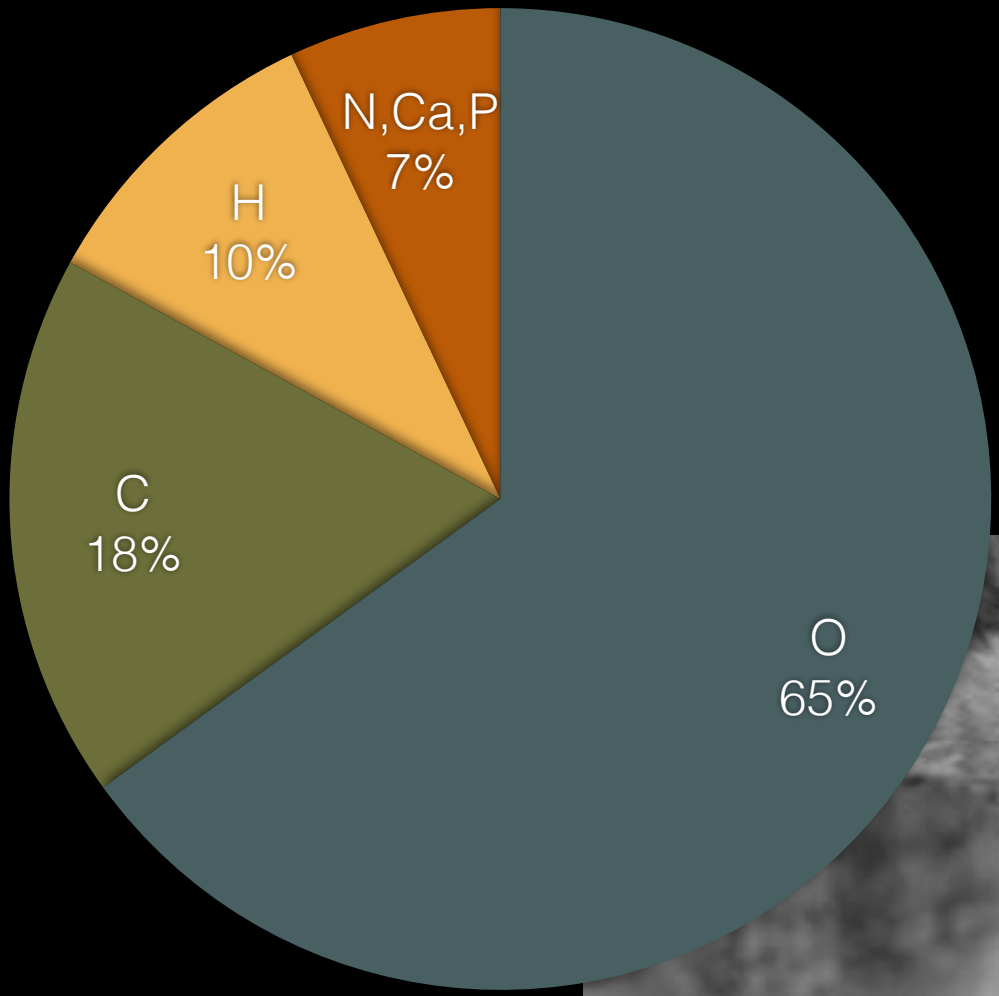
Nucleosynthesis

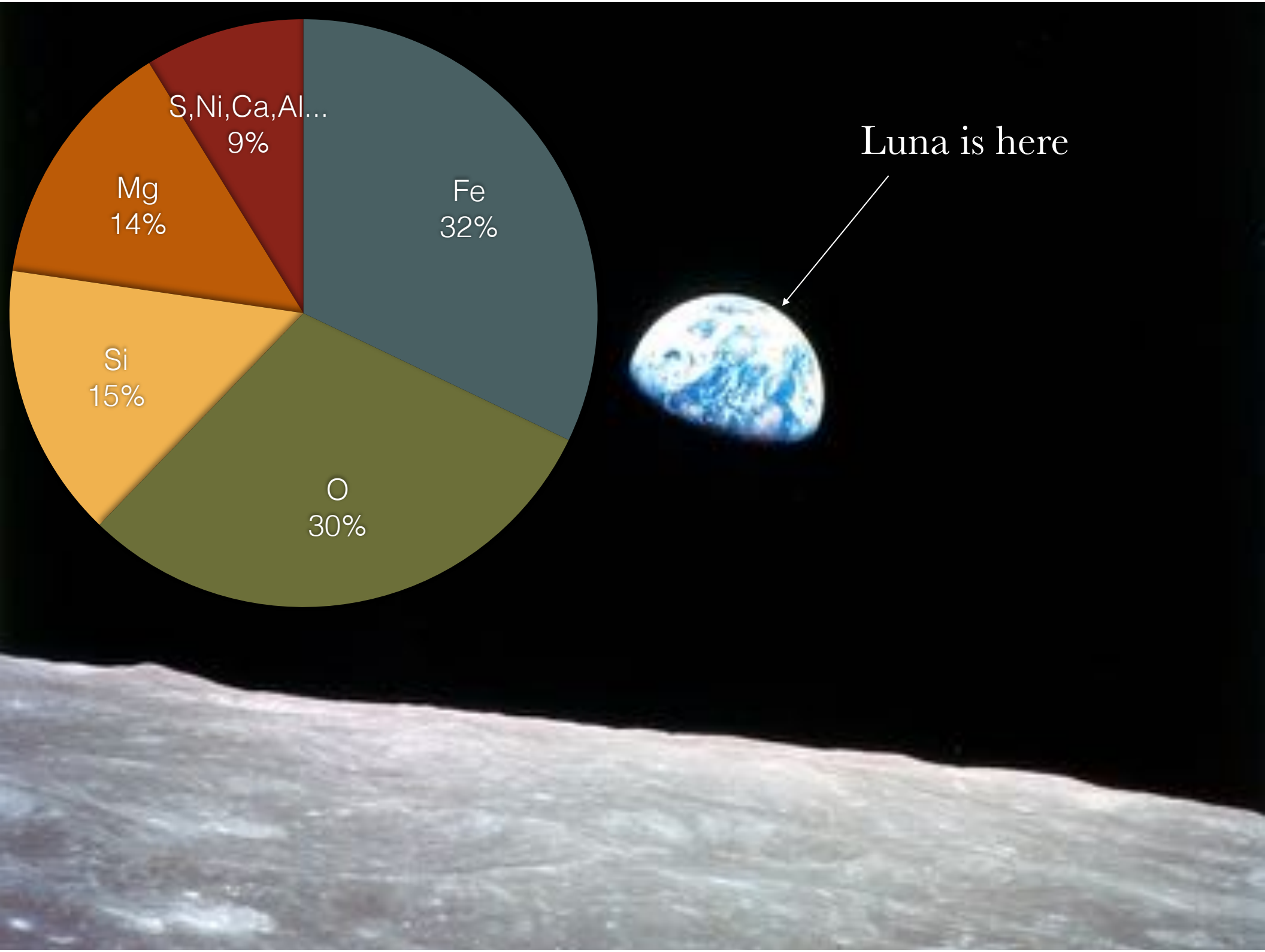


Fe and above produced in supernovae

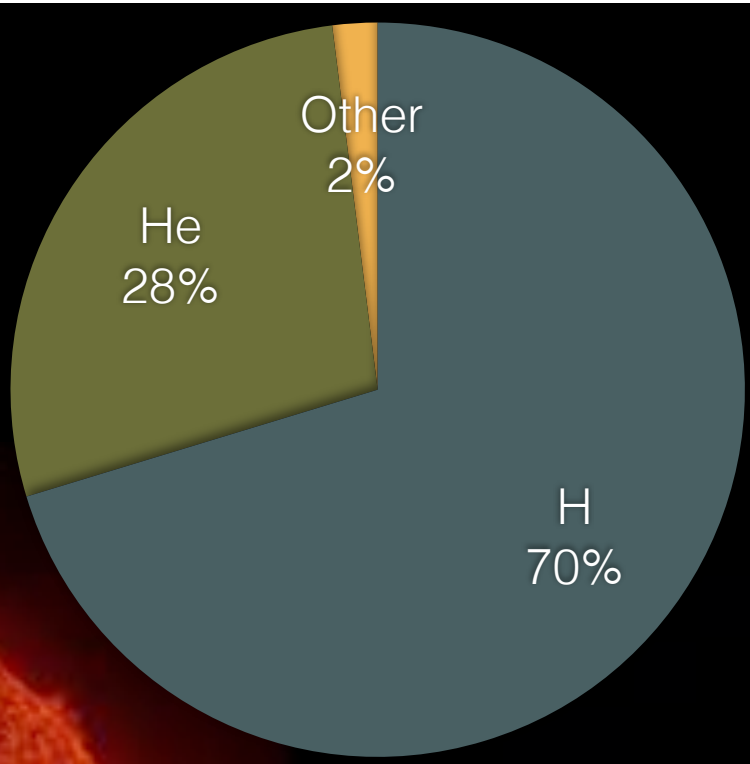
Luna's

What is ~~our~~ origin story?


N,Ca,P
7%
H
10%
C
18%
O
65%


S,Ni,Ca,Al...
9%
Mg
14%
Fe
32%
Si
15%
O
30%
Luna is here

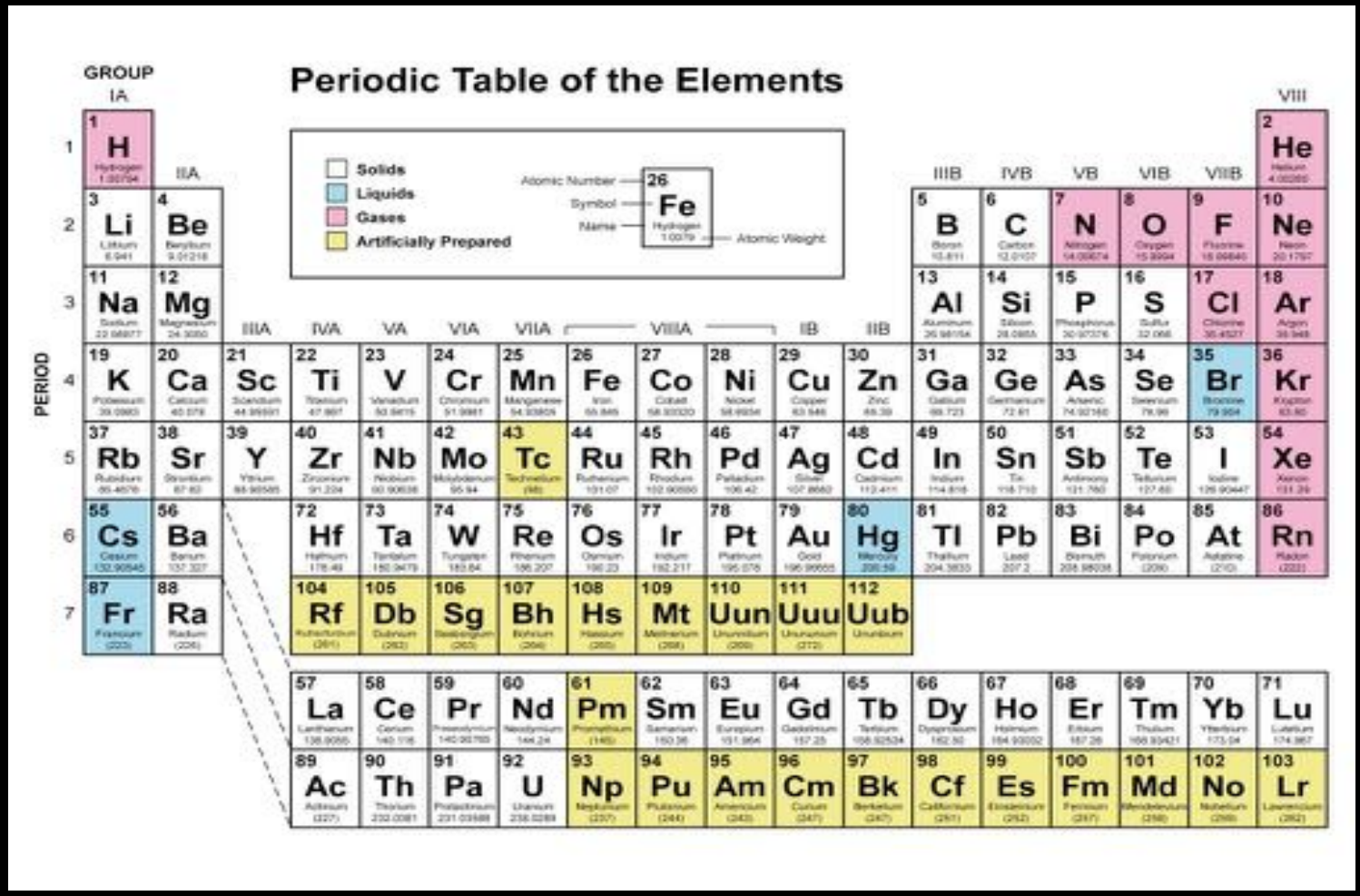
Luna orbits this star



Luna's

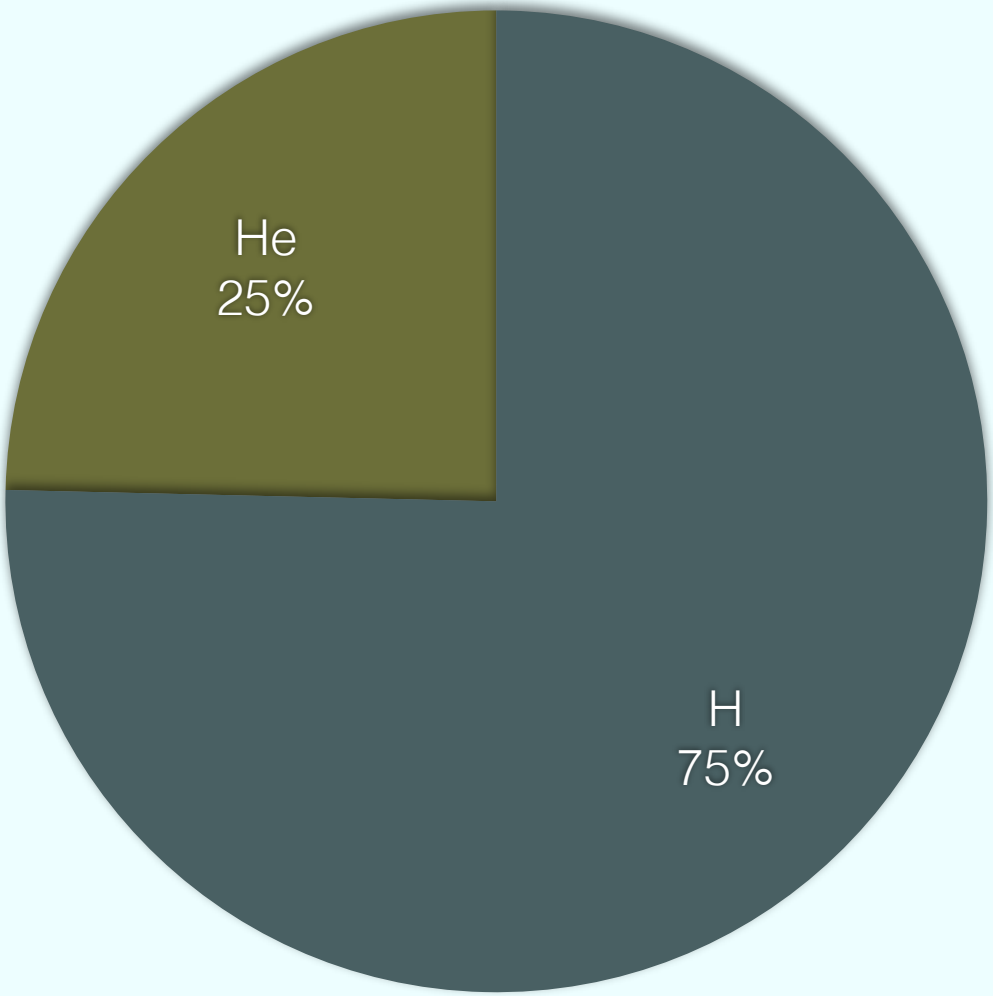
What is ~~our~~ origin story?

Origin of the elements?

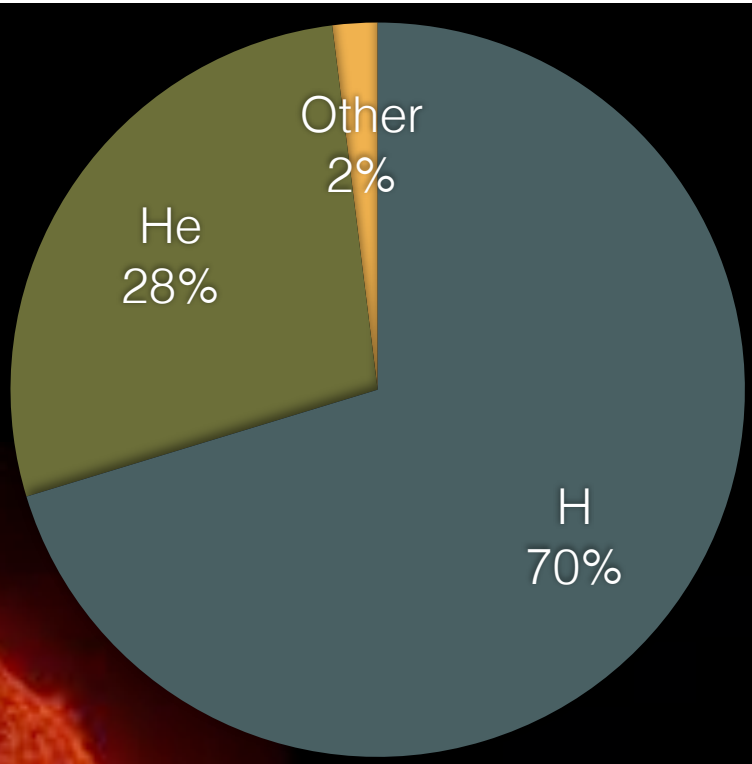


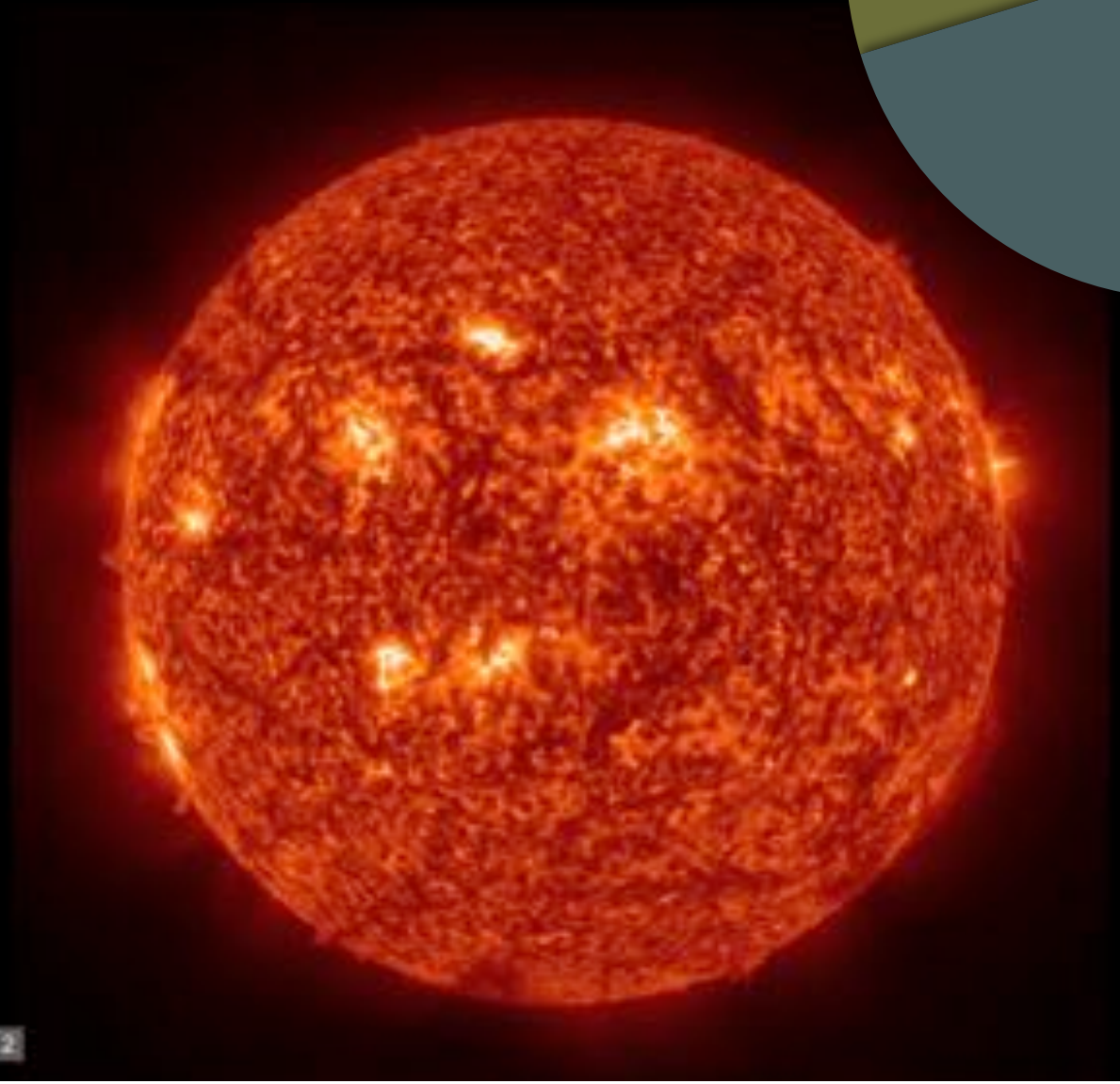
Big Bang!

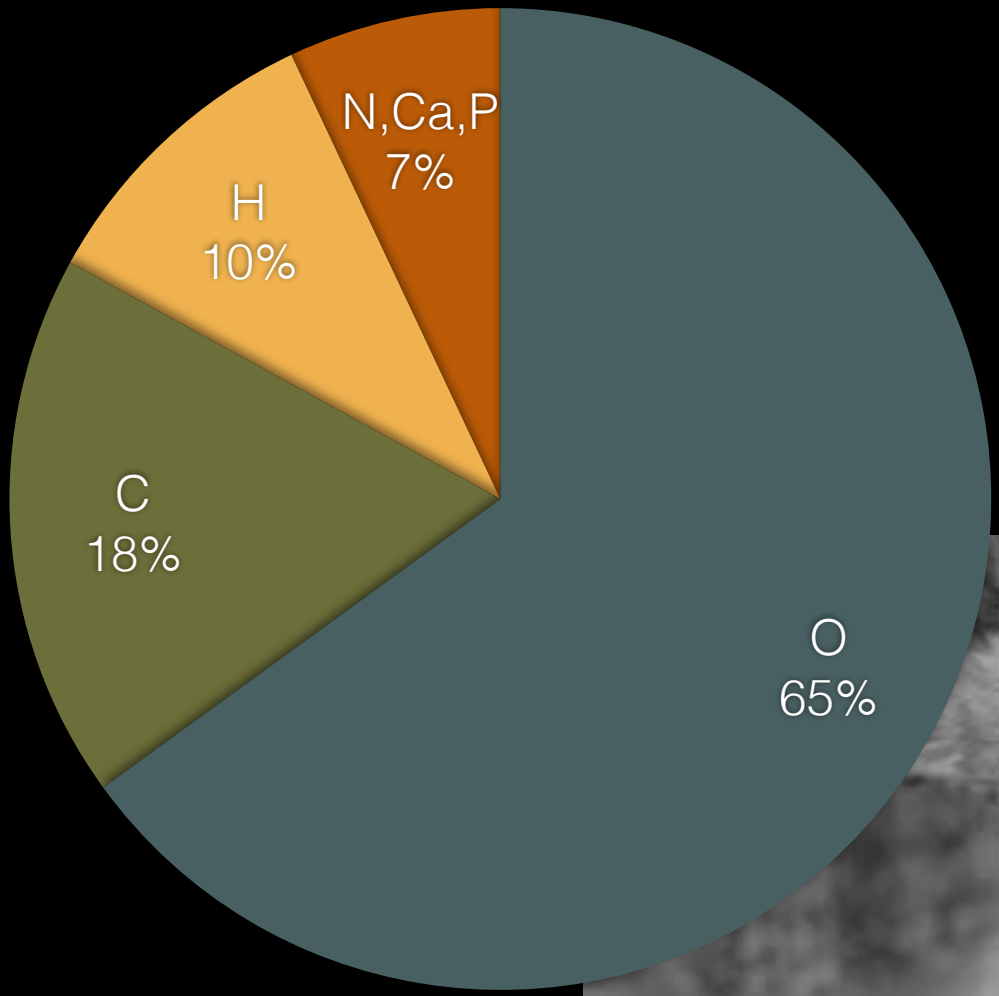
Big Bang!



Primordial Abundance

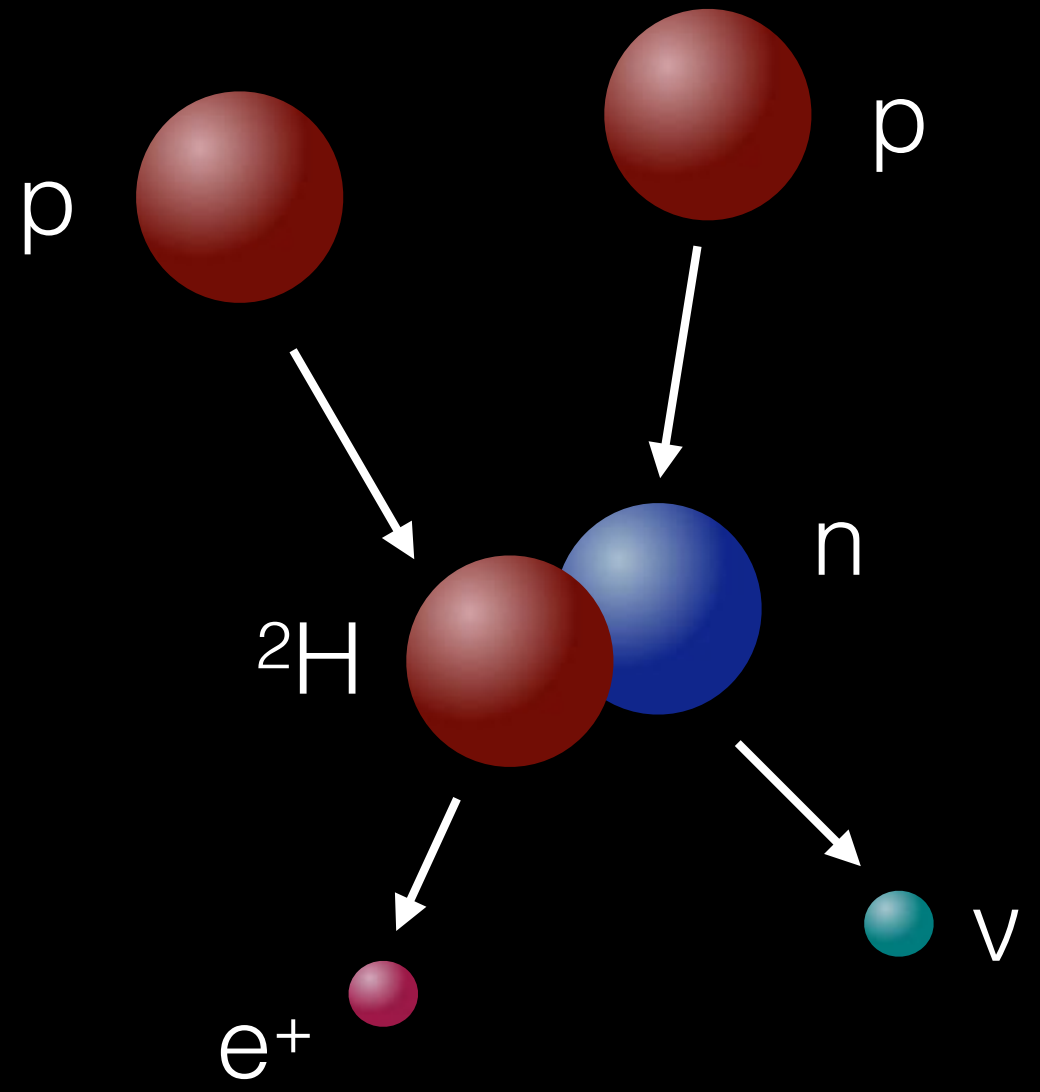




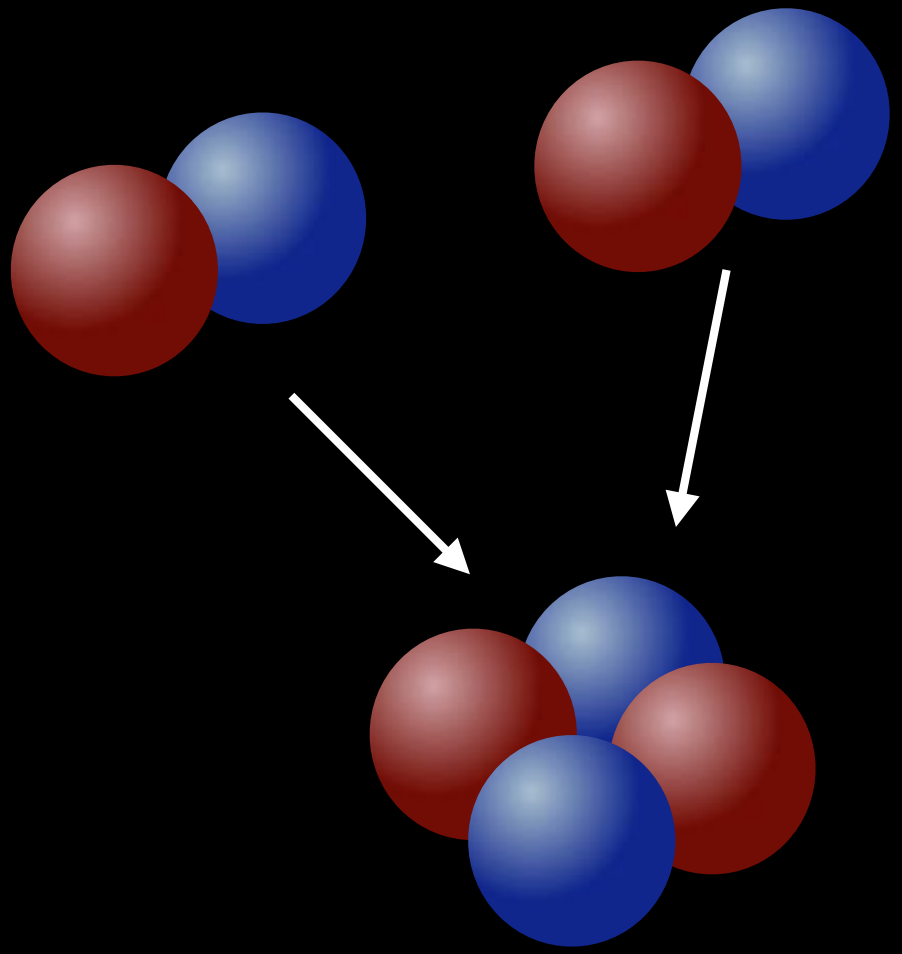


…and Luna?

Nuclear Fusion
Think Legos!

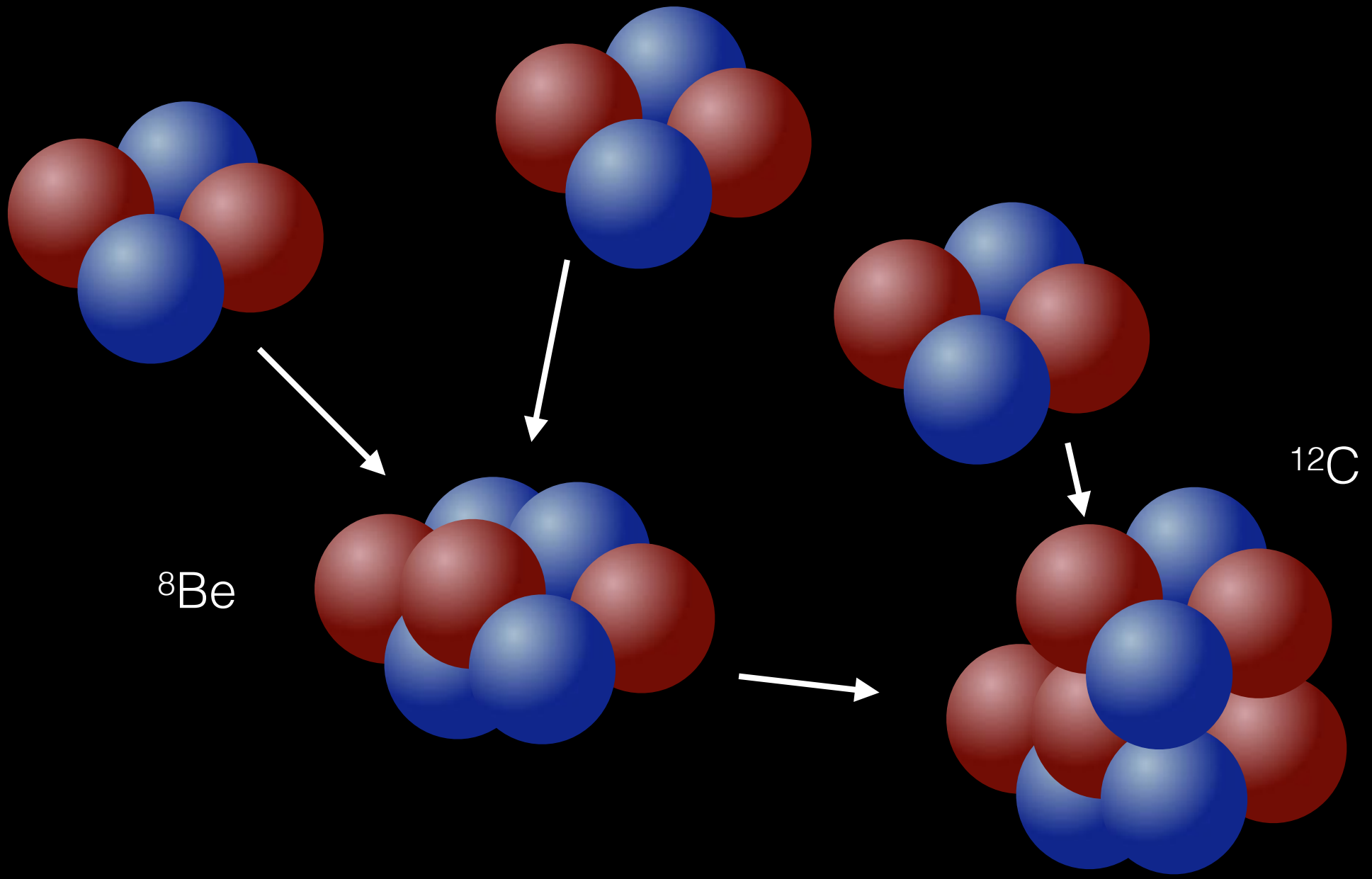


Nuclear Fusion
Think Legos!



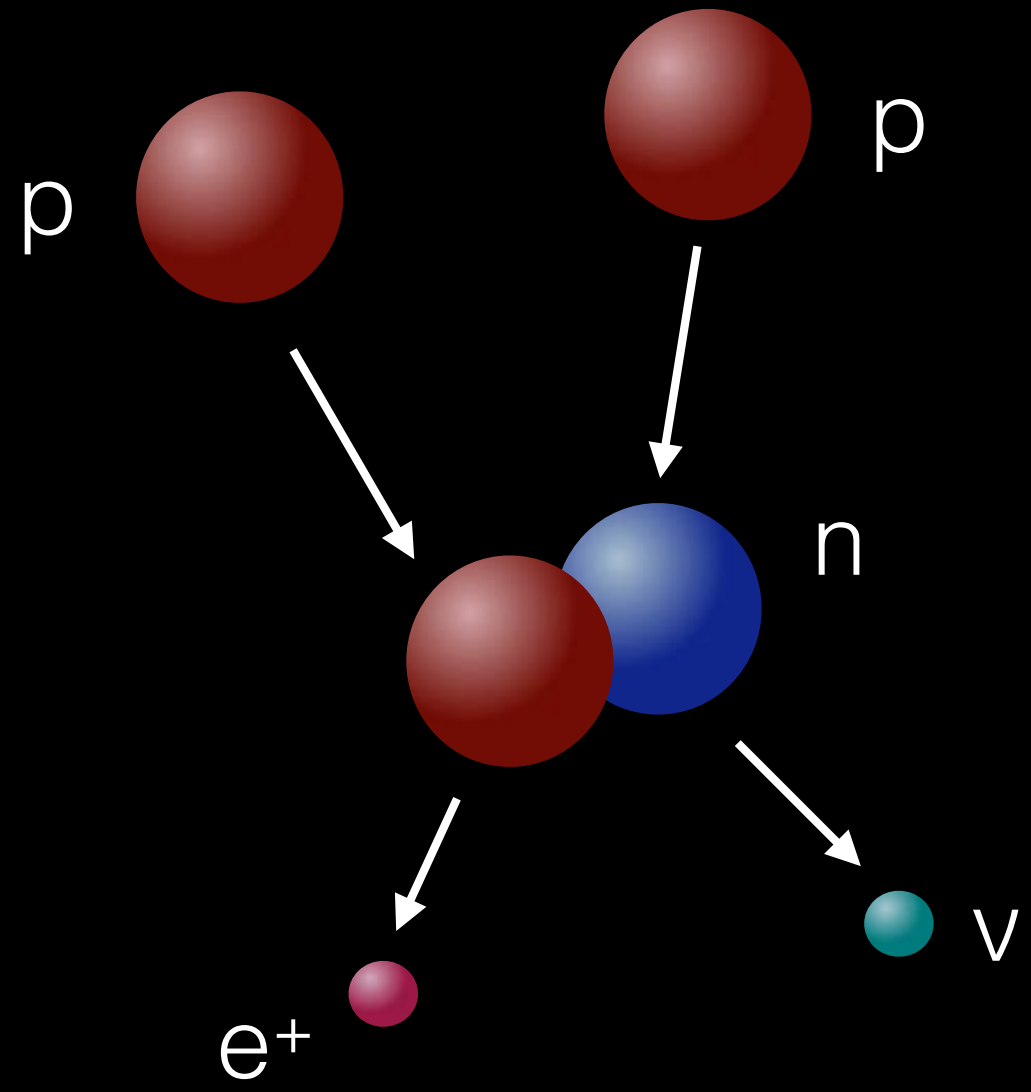
^{4}He

Nuclear Fusion
Think Legos!



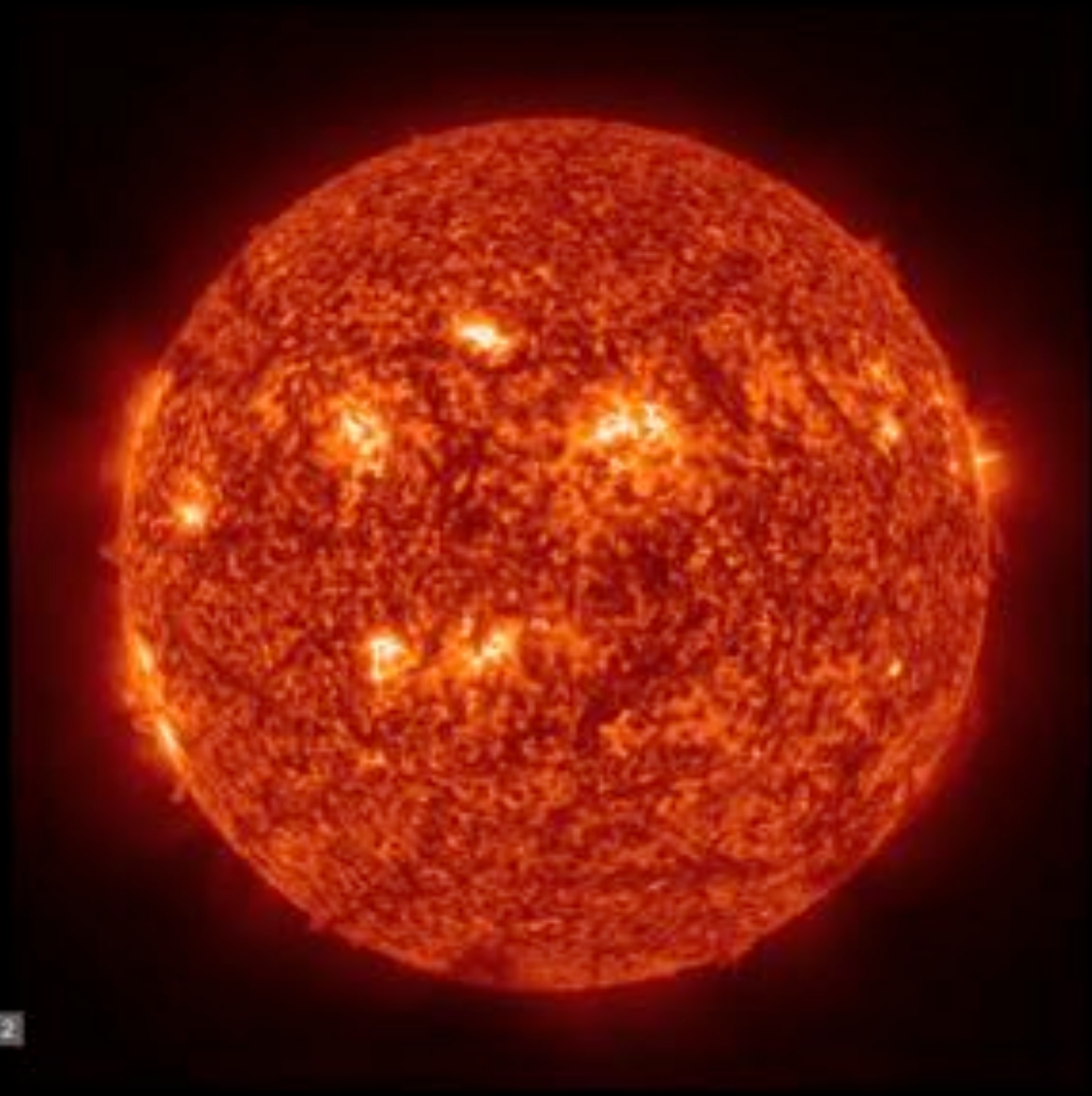
Where does fusion happen?

ElectroStatic Repulsion
Strong Force Attraction
(Really Hard)

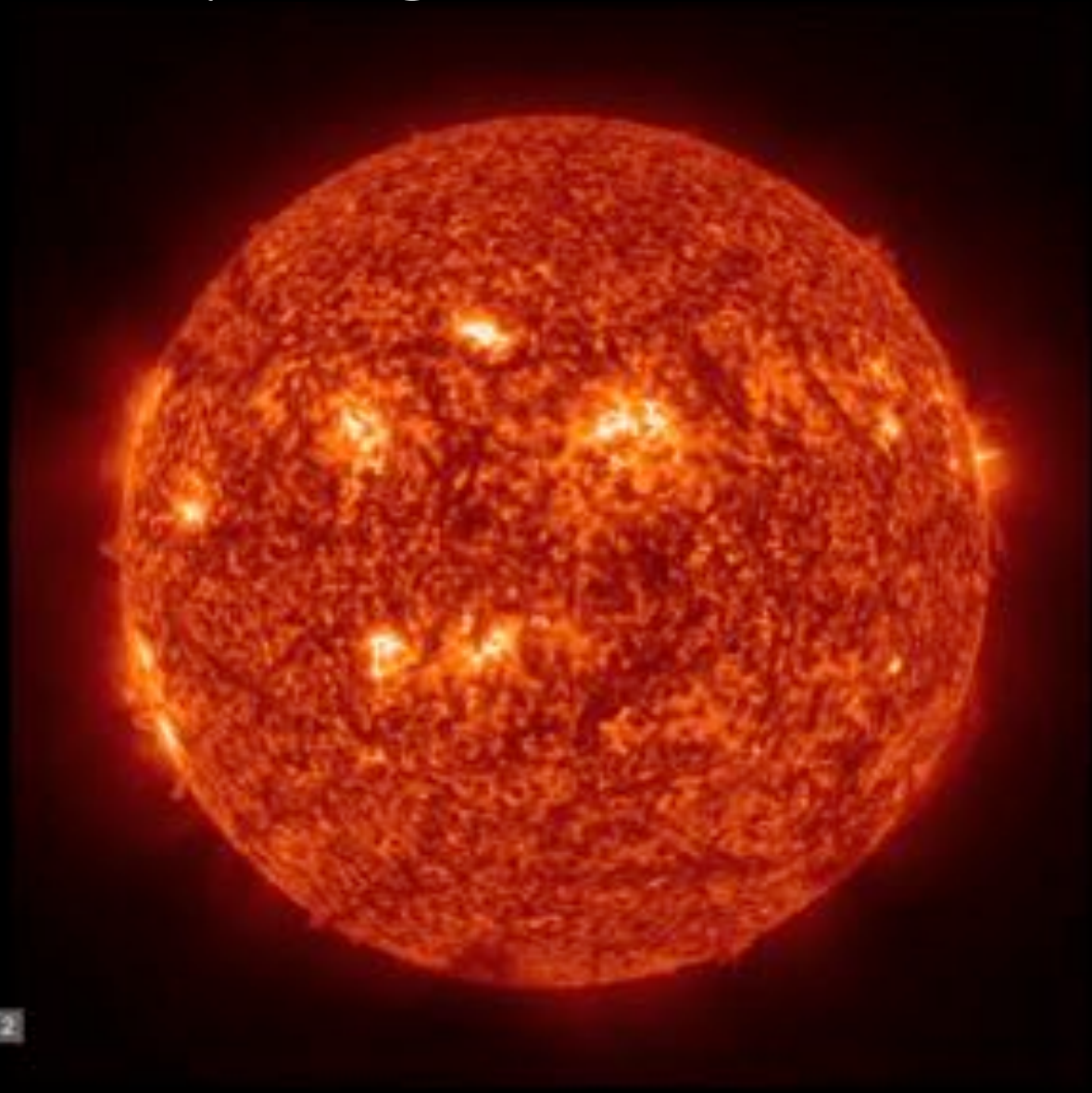


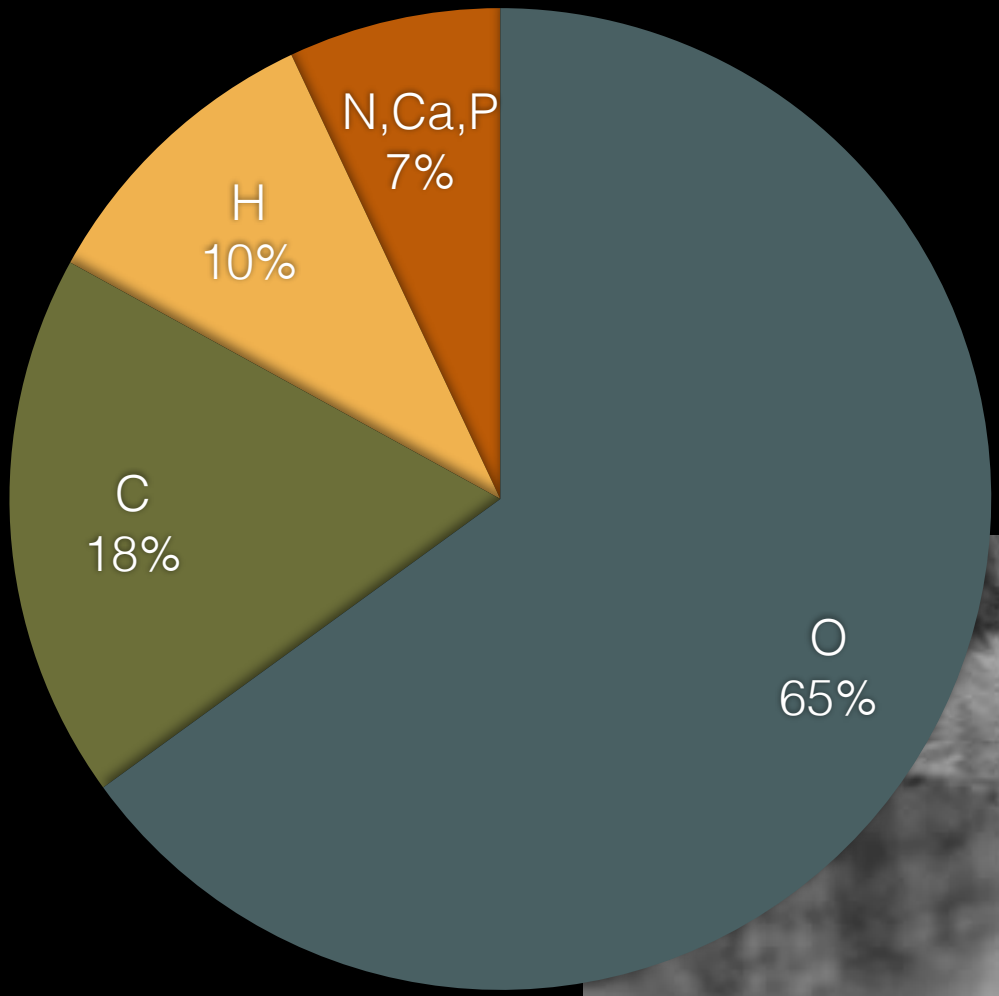
Hot & Dense
Environments

A Fusion Reactor



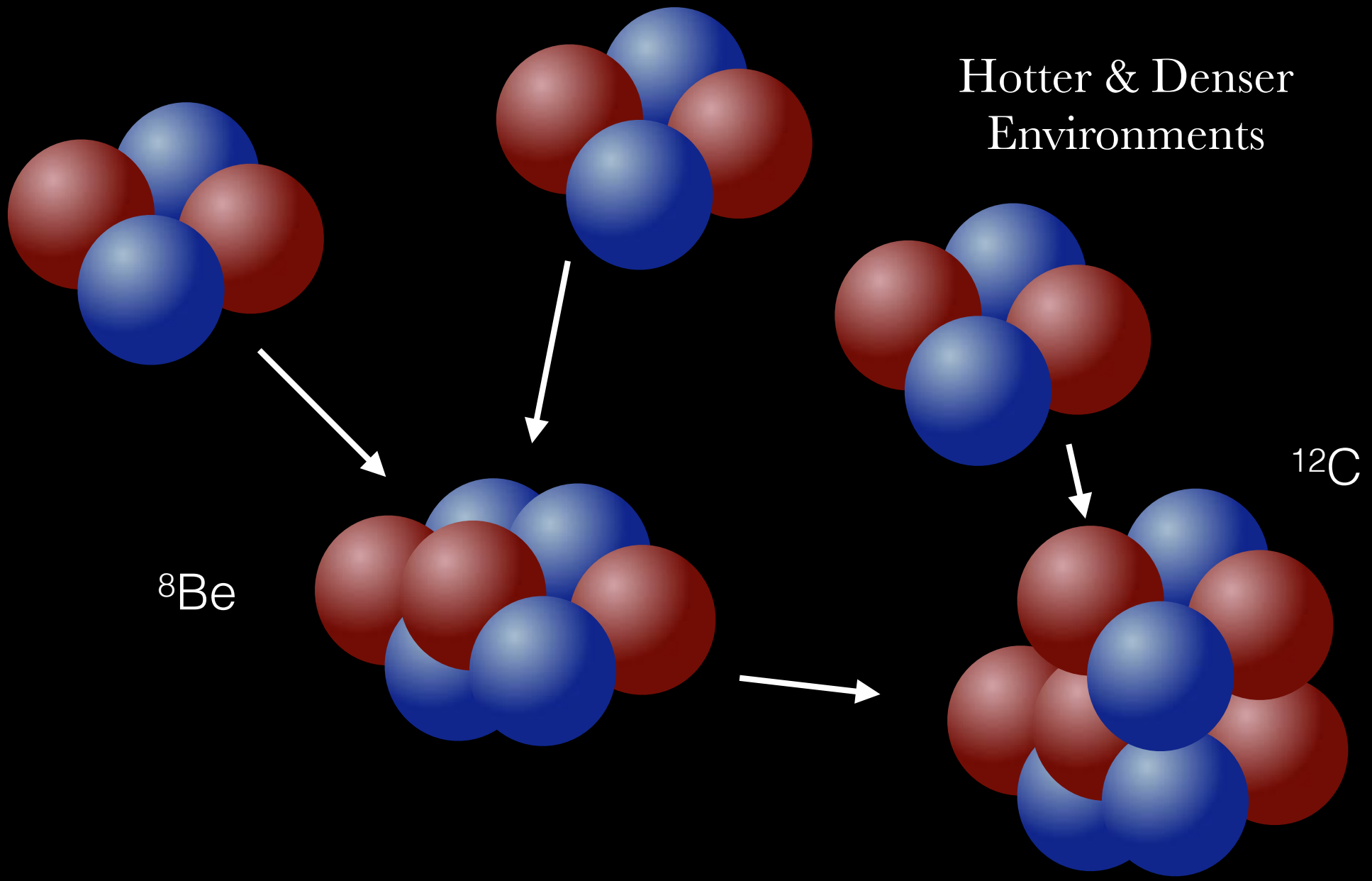
A Fusion Reactor
Hydrogen to Helium



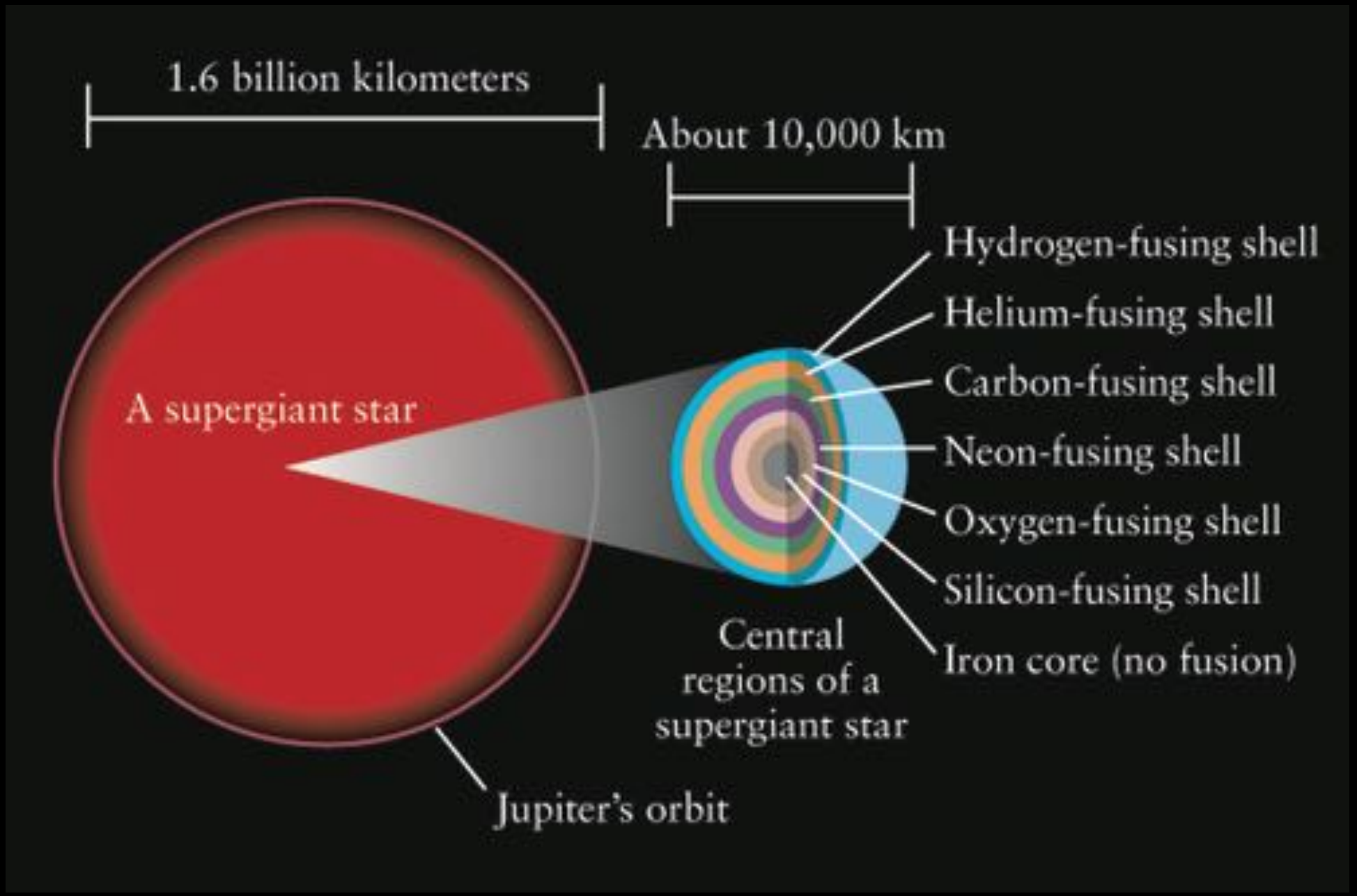


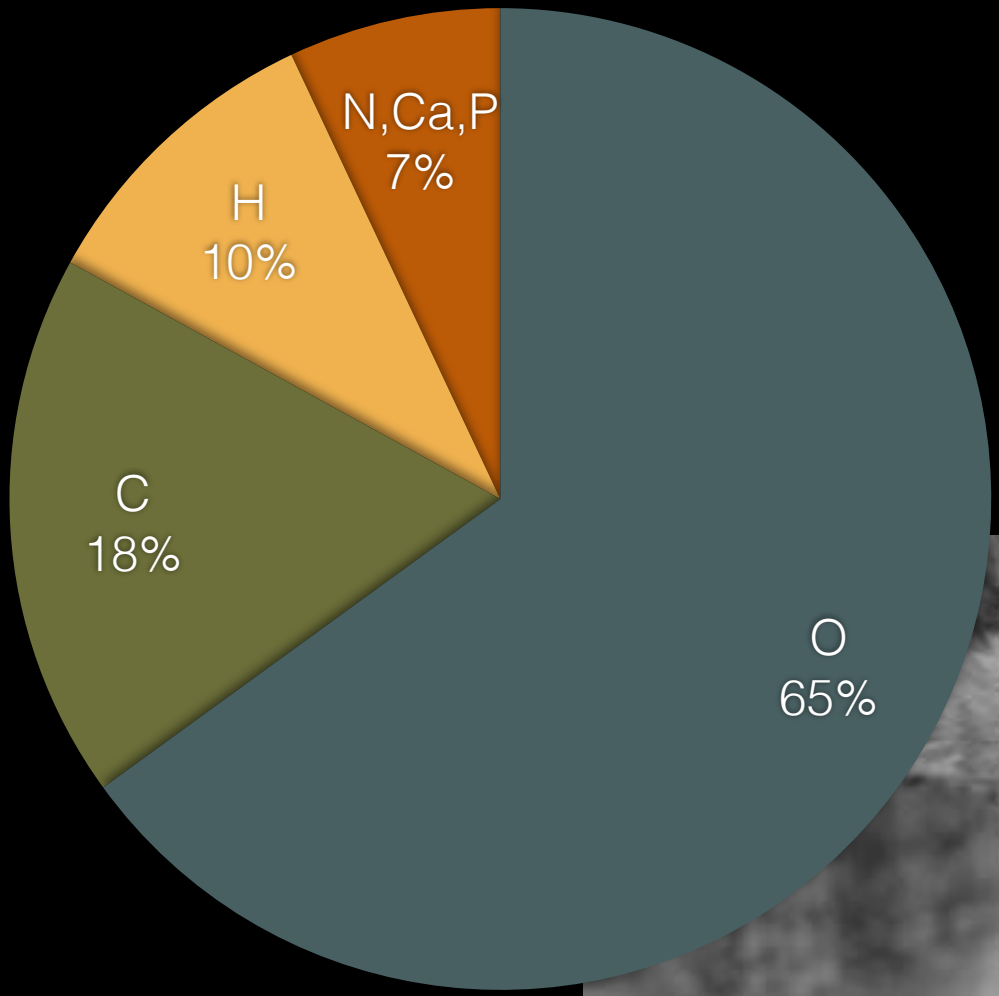
…and Luna?

Even Harder



Well…more massive stars keep going

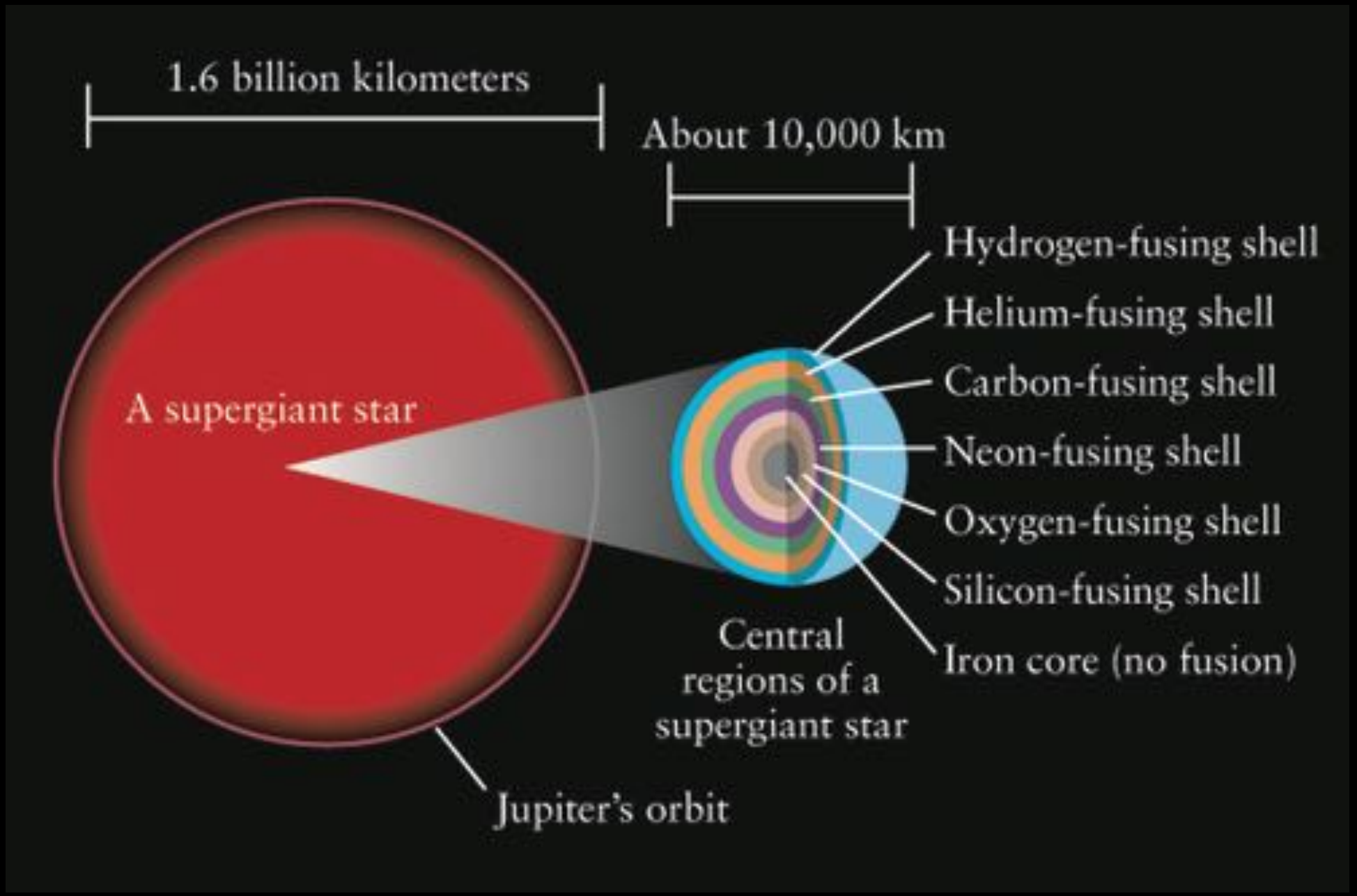

1.6 billion kilometers
About 10,000 km
A supergiant star
Hydrogen-fusing shell
Helium-fusing shell
Carbon-fusing shell
Neon-fusing shell
Oxygen-fusing shell
Silicon-fusing shell
Iron core (no fusion)
Central regions of a supergiant star
Jupiter's orbit



Elements need to come out of stars


Supernova(e)
© Australian Astronomical Observatory


What causes explosion?
© Australian Astronomical Observatory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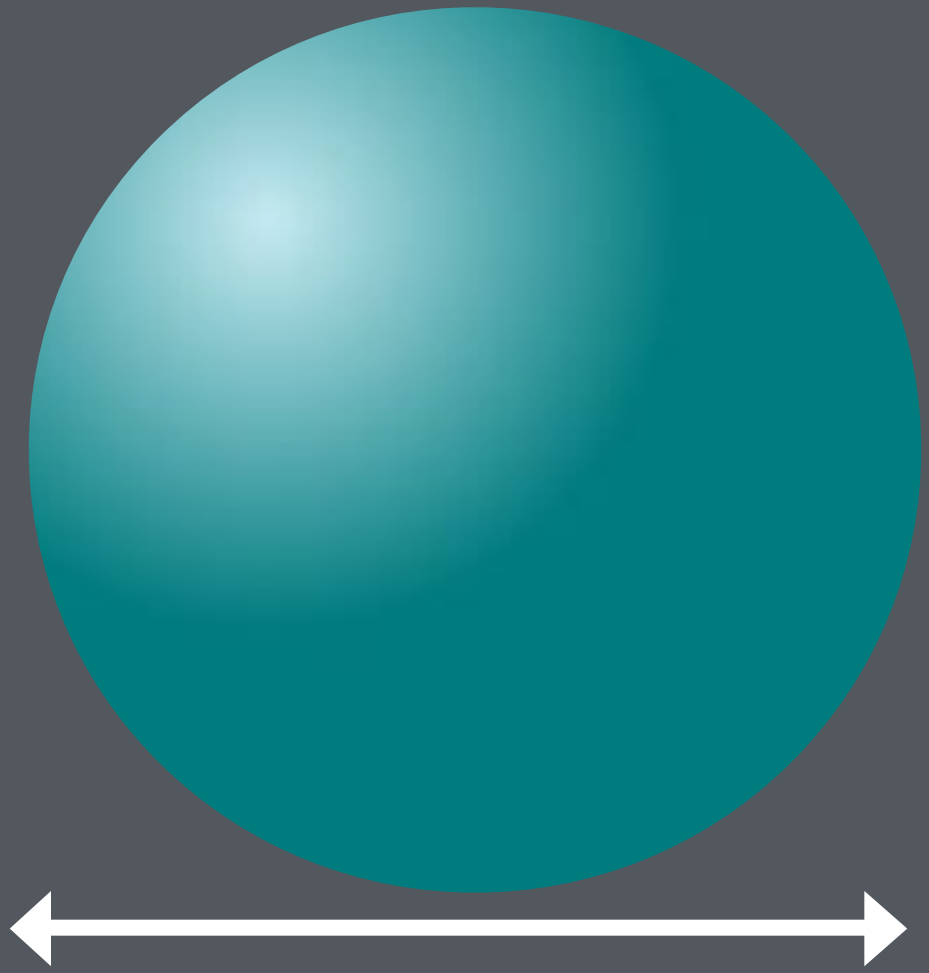
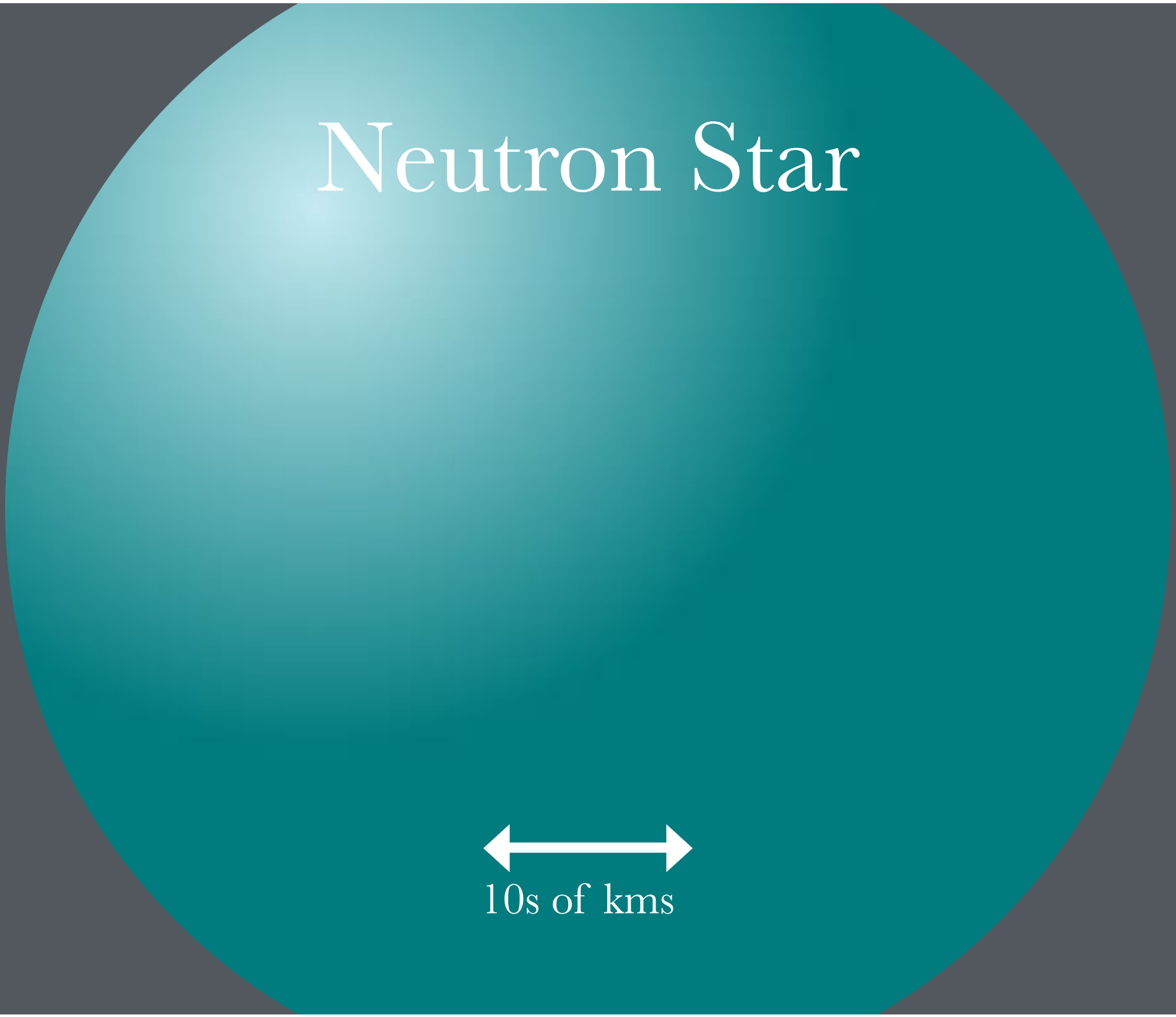
Fe Core



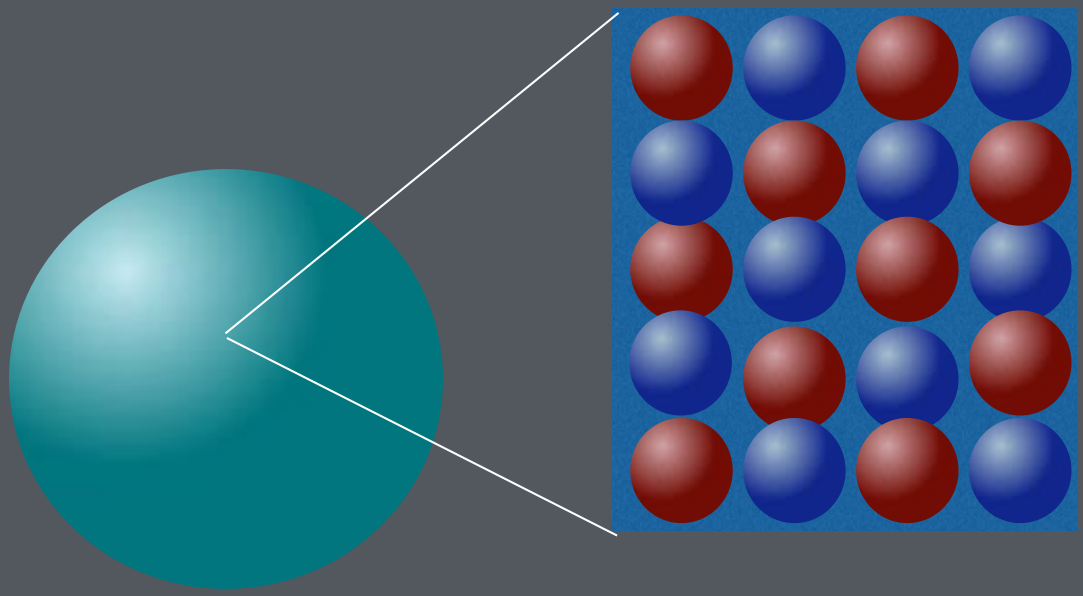
Fe Core

1.4 Mass of Sun
Collapse 0.1s

1000s of kms


Neutron Star
10s of kms

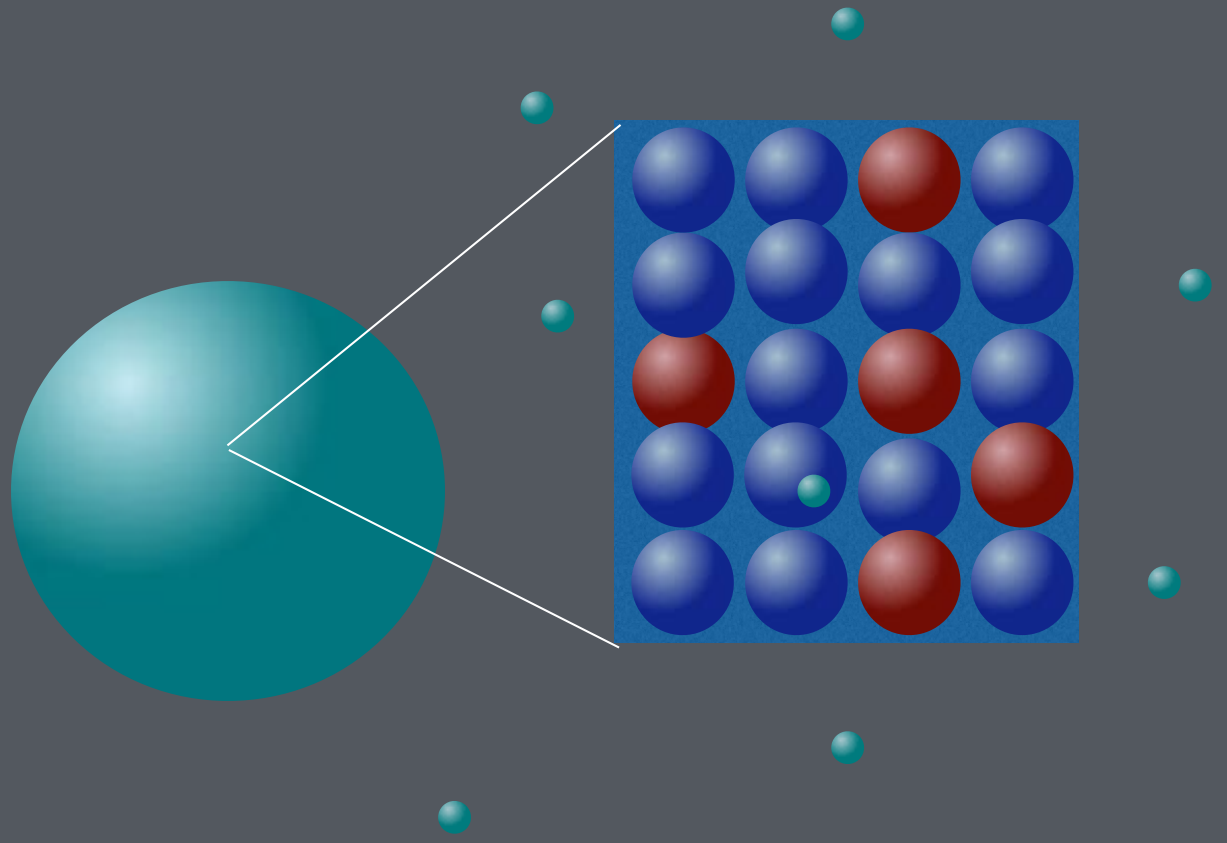
Neutron Star



Denser than the nucleus of an atom

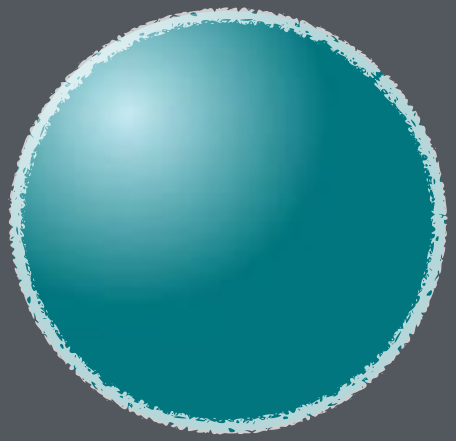
10s of kms

Neutron Star



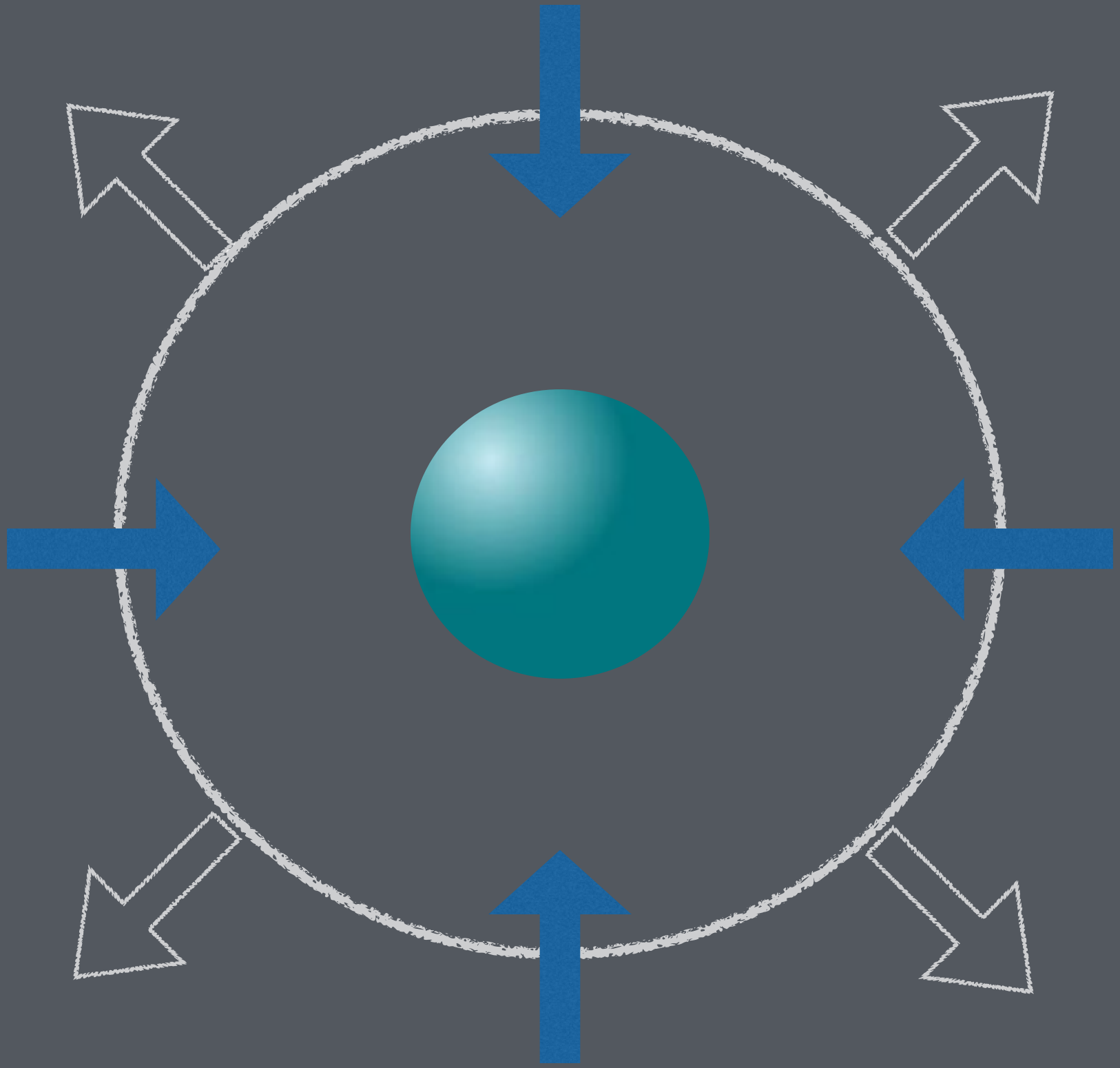
10s of kms

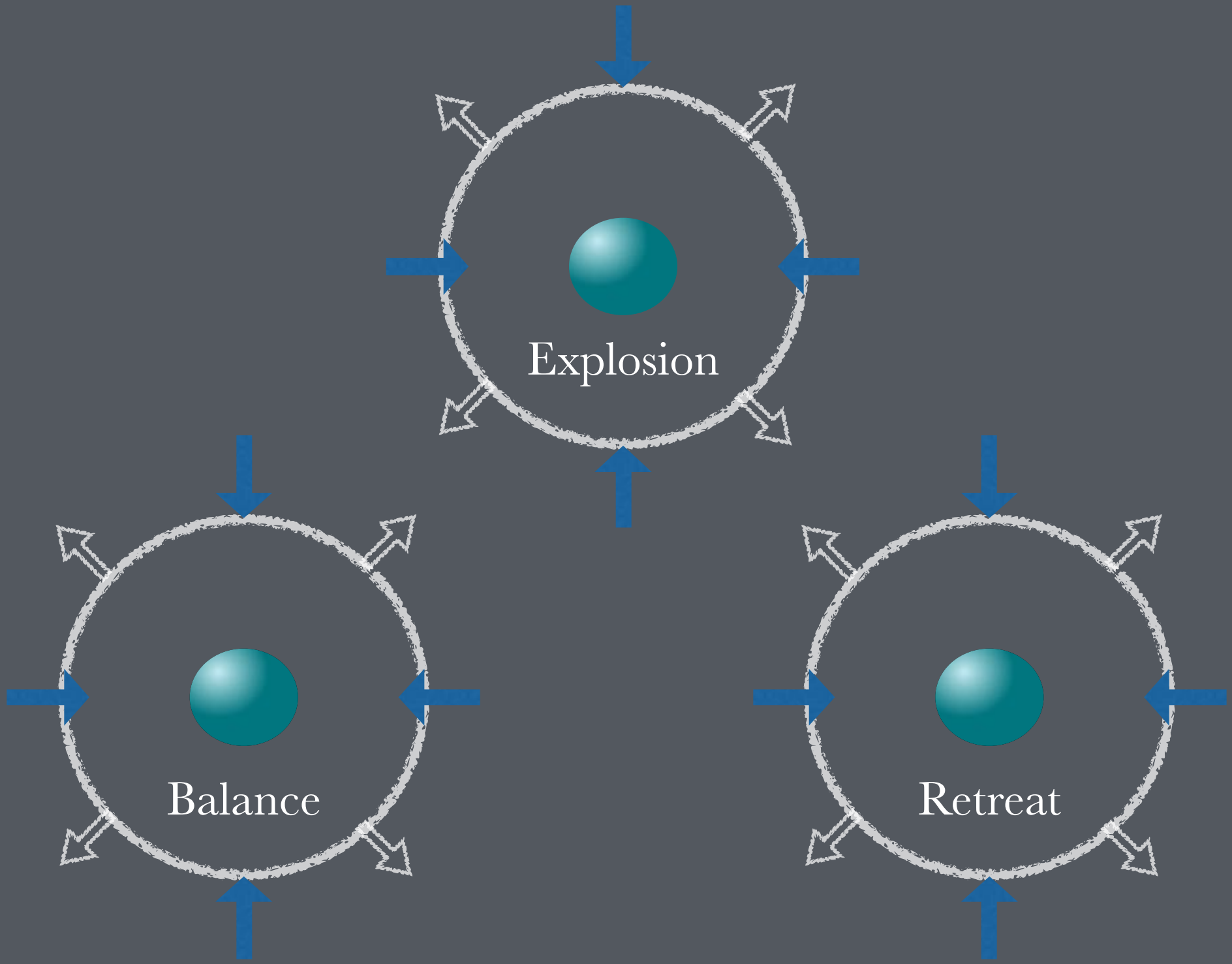
Core Stiffens Launches Blast Wave



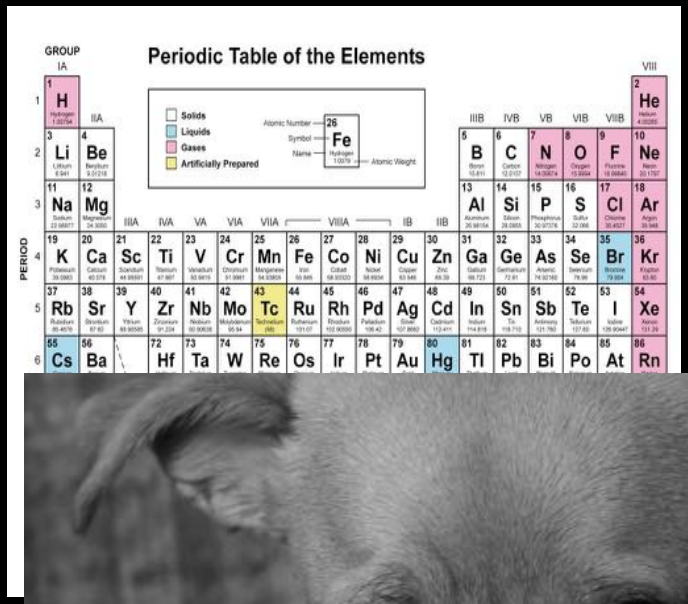
Supernova

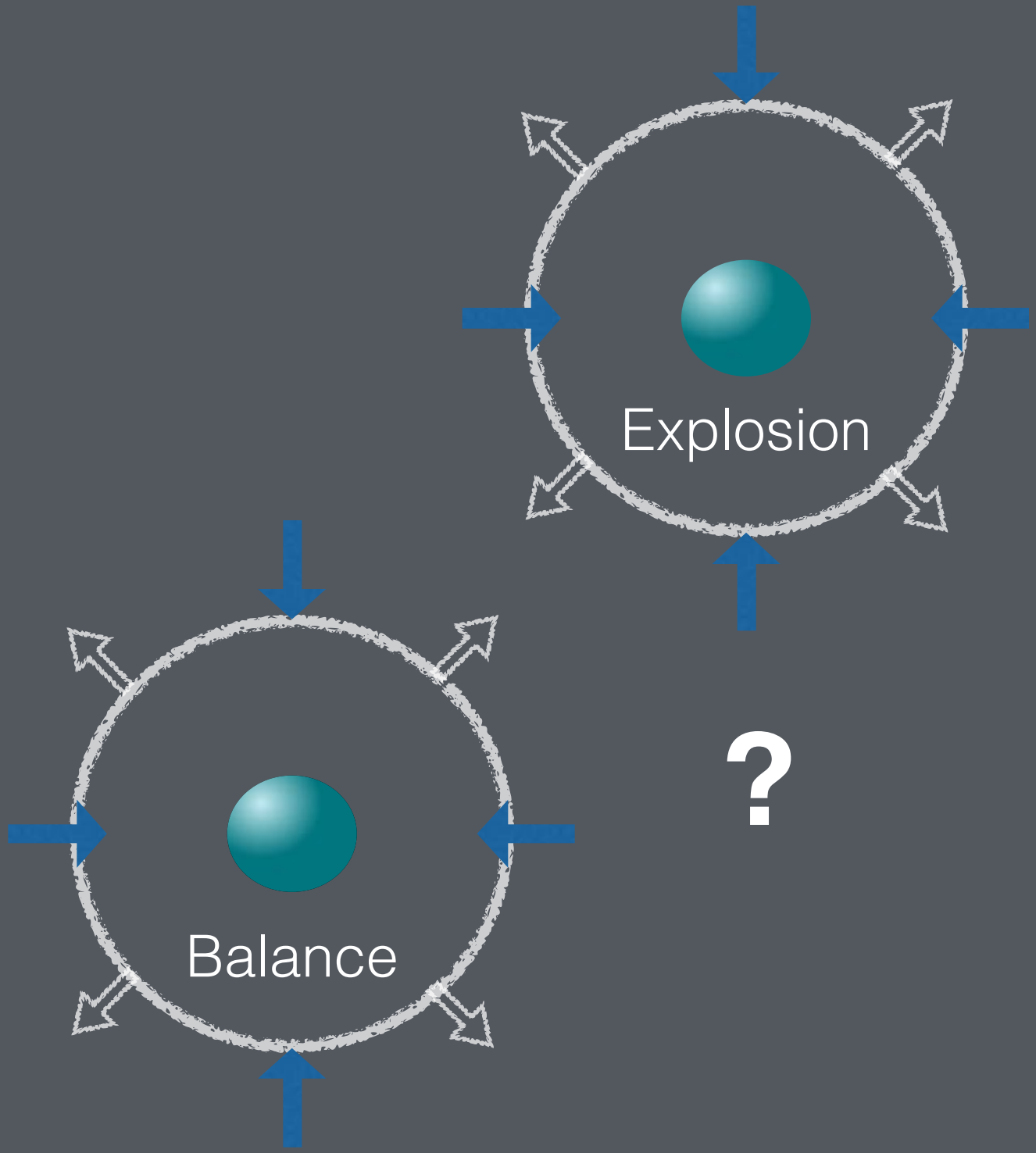
But wait!

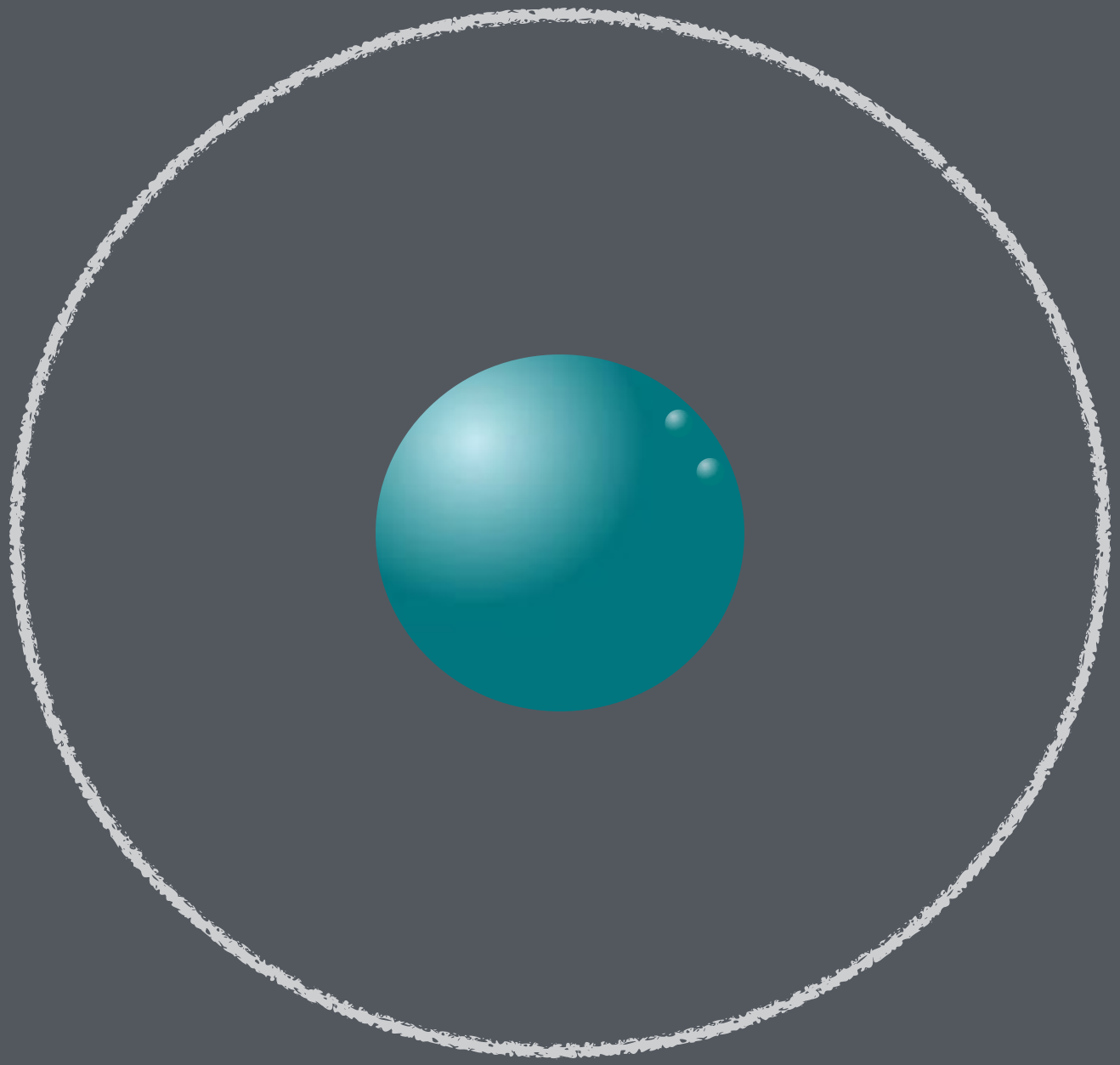


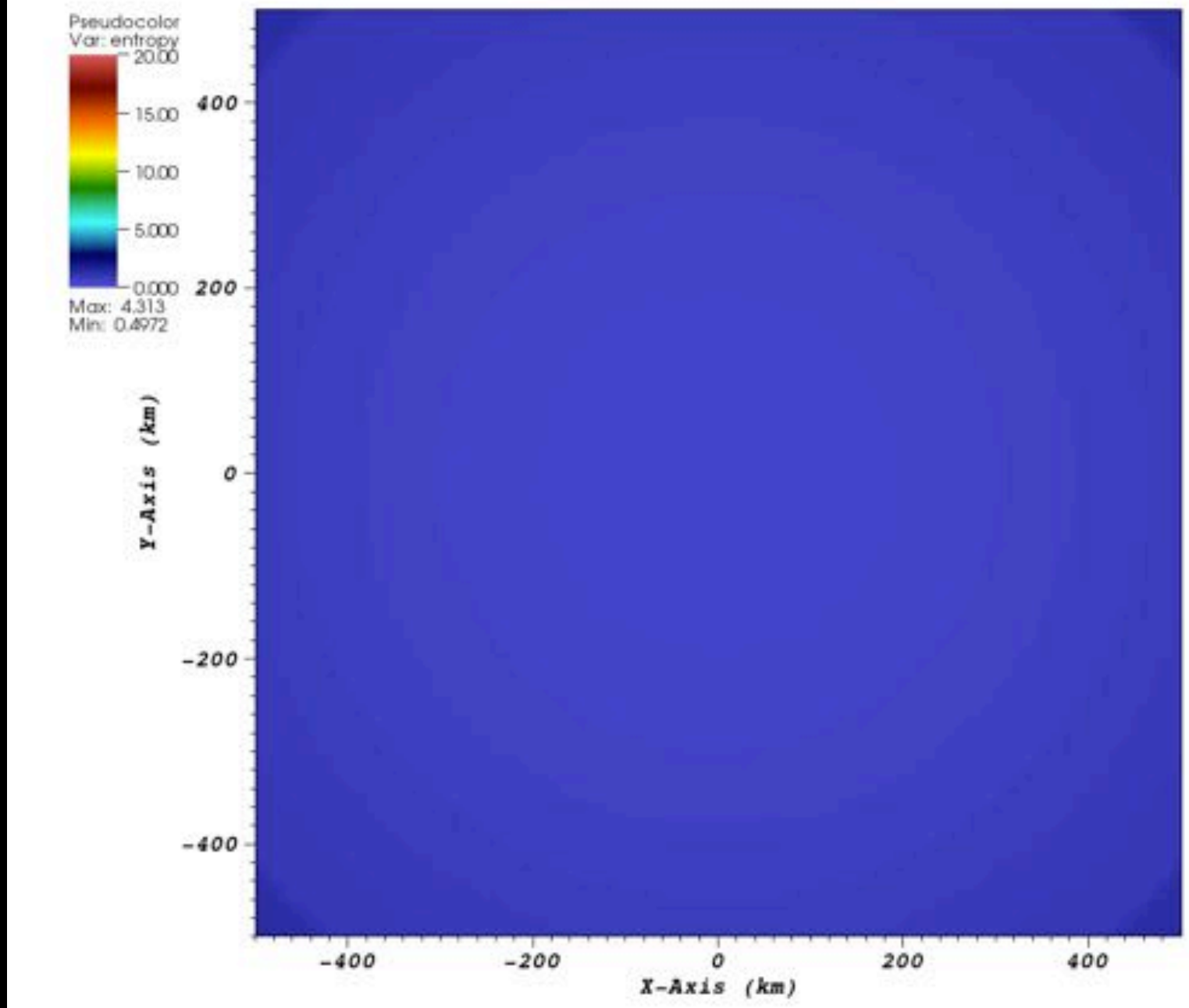

Explosion
Balance
Retreat

We know that some explode

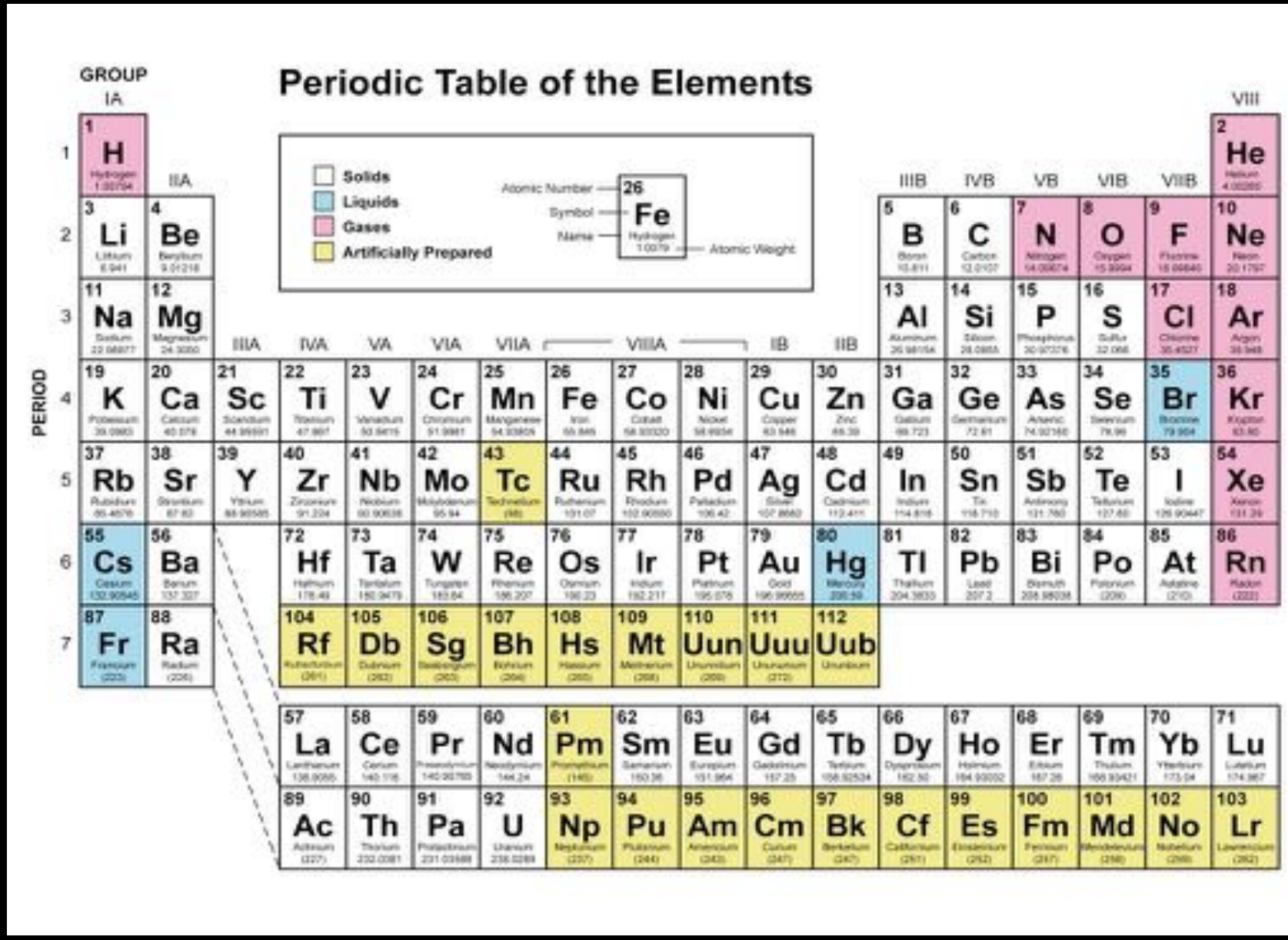



Explosion
?
Balance





Time = -0.2600 s after bounce


Periodic Table of the Elements
GROUP
PERIOD
Solids
Liquids
Gases
Artificially Prepared
Atomic Number
Symbol
Name
Atomic Weight
26
Fe
Hydrogen
1.0079
IA
IIA
IIIA
IVA
VA
VIA
VIIA
VIIIA
IB
IIB
IIIB
IVB
VB
VIB
VIIB
VIII
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
37 Rb
38 Sr
39 Y
40 Zr
41 Nb
42 Mo
43 Tc
44 Ru
45 Rh
46 Pd
47 Ag
48 Cd
49 In
50 Sn
51 Sb
52 Te
53 I
54 Xe
55 Cs
56 Ba
72 Hf
73 Ta
74 W
75 Re
76 Os
77 Ir
78 Pt
79 Au
80 Hg
81 Tl
82 Pb
83 Bi
84 Po
85 At
86 Rn
87 Fr
88 Ra
104 Rf
105 Db
106 Sg
107 Bh
108 Hs
109 Mt
110 Uun
111 Uuu
112 Uub
57 La
58 Ce
59 Pr
60 Nd
61 Pm
62 Sm
63 Eu
64 Gd
65 Tb
66 Dy
67 Ho
68 Er
69 Tm
70 Yb
71 Lu
89 Ac
90 Th
91 Pa
92 U
93 Np
94 Pu
95 Am
96 Cm
97 Bk
98 Cf
99 Es
100 Fm
101 Md
102 No
103 Lr


Credit: Davide De Martin (http://www.skyfactory.org);
ESA/ESO/NASA FITS Liberator & Digitized Sky Survey

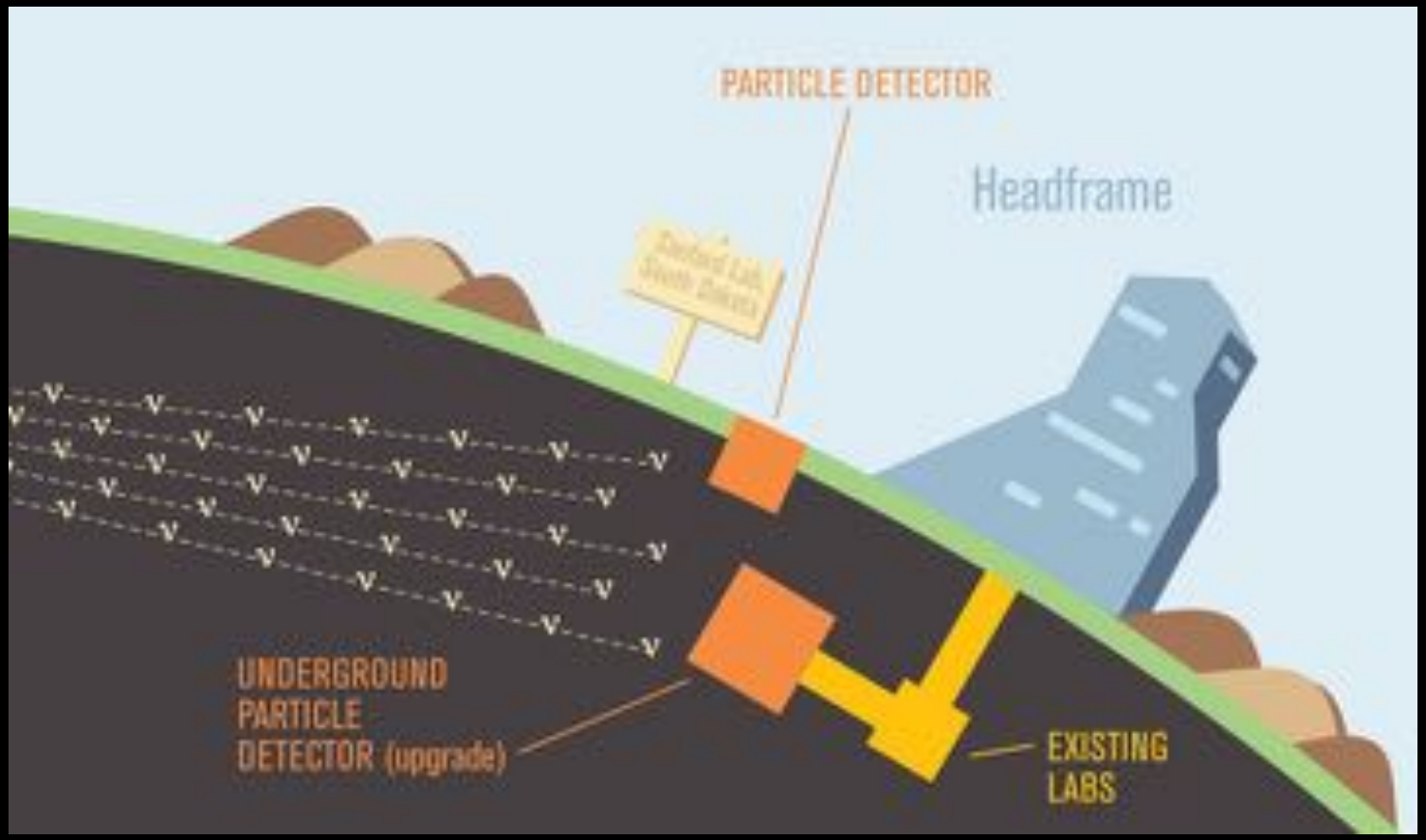
Theory

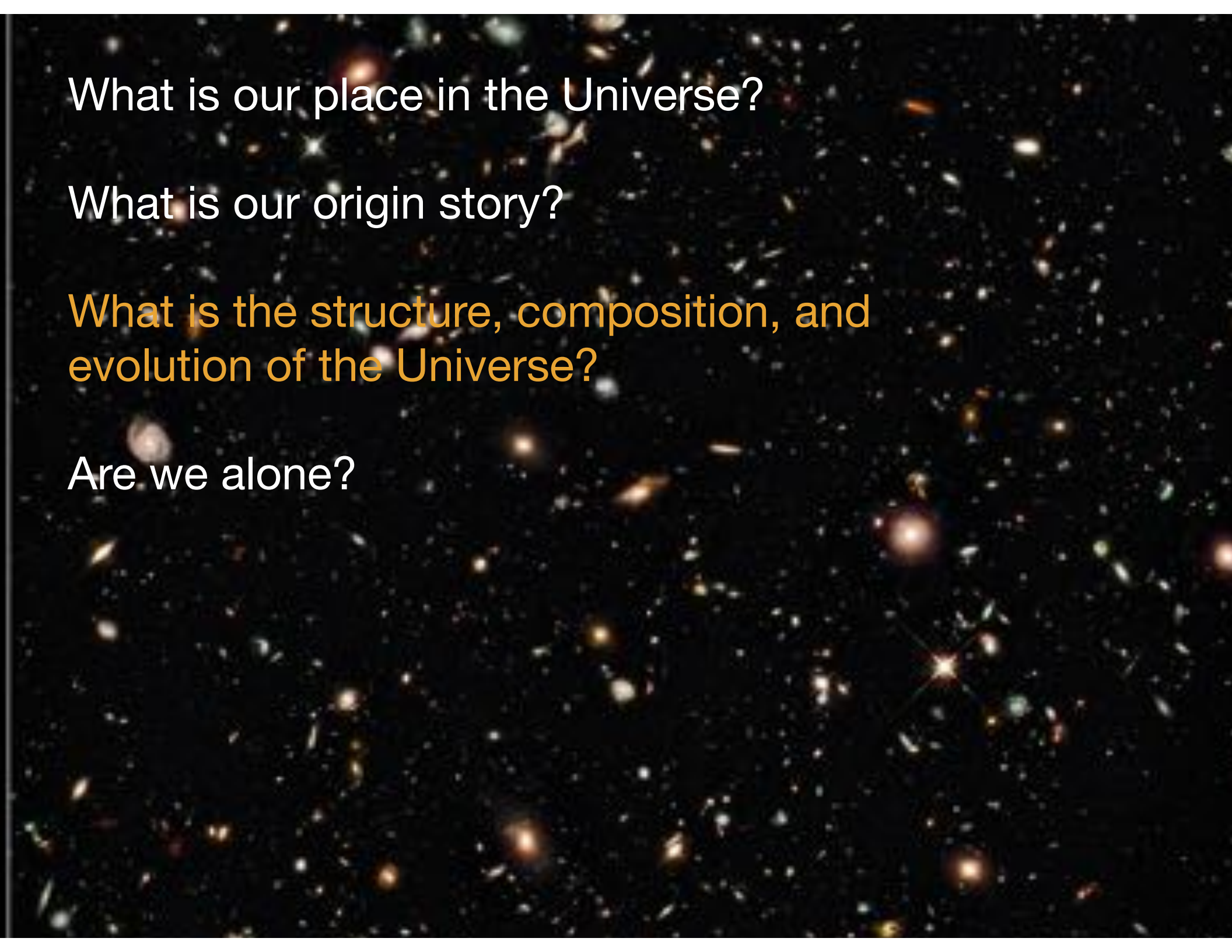
Predict

Observe

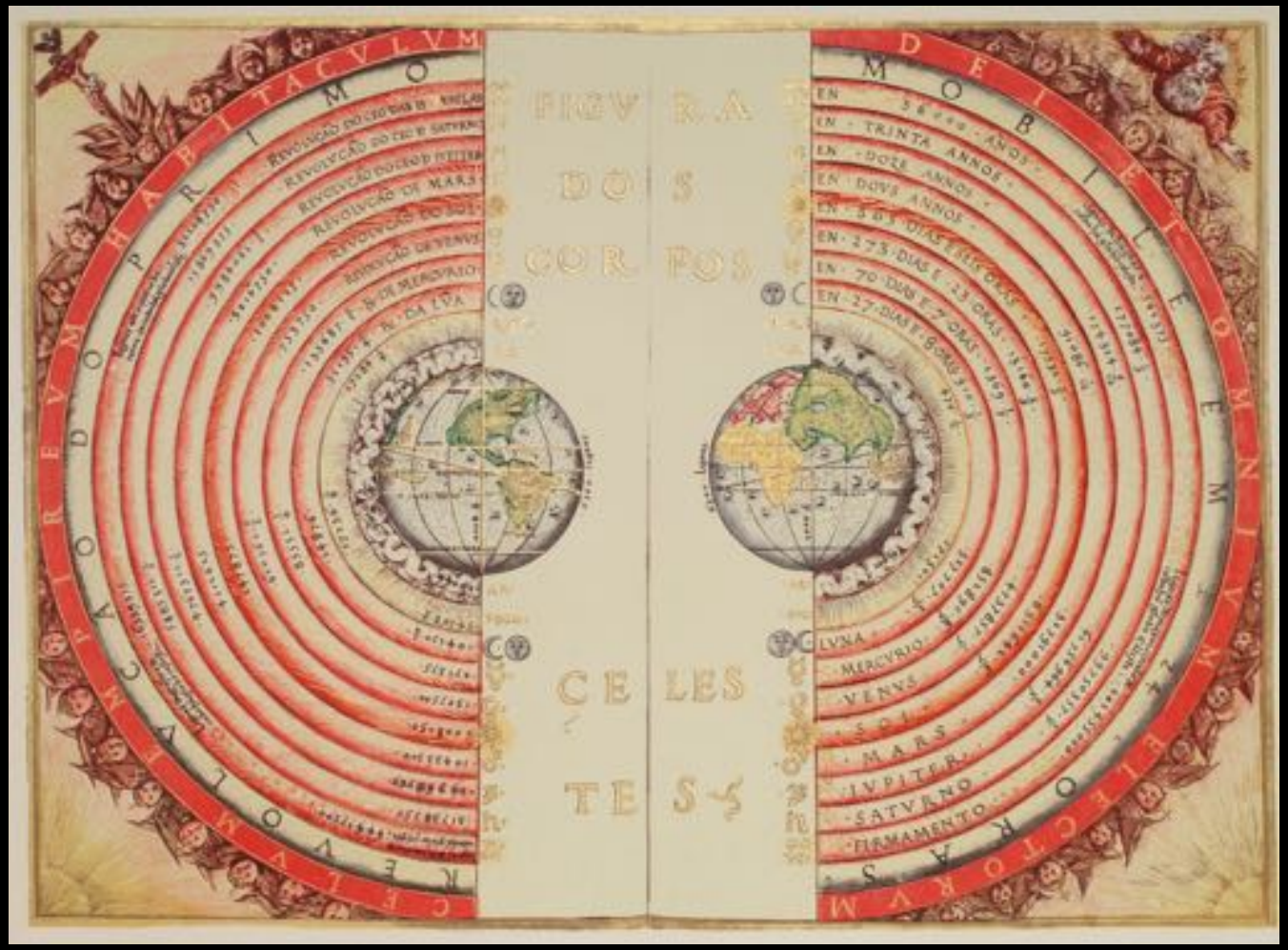

© Australian Astronomical Observatory

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?

Ptolemaic: Geocentric Model



Bartolomeu Velho 1568

Copernican Universe (1543)

Hubble Ultra Deep Field · Infrared

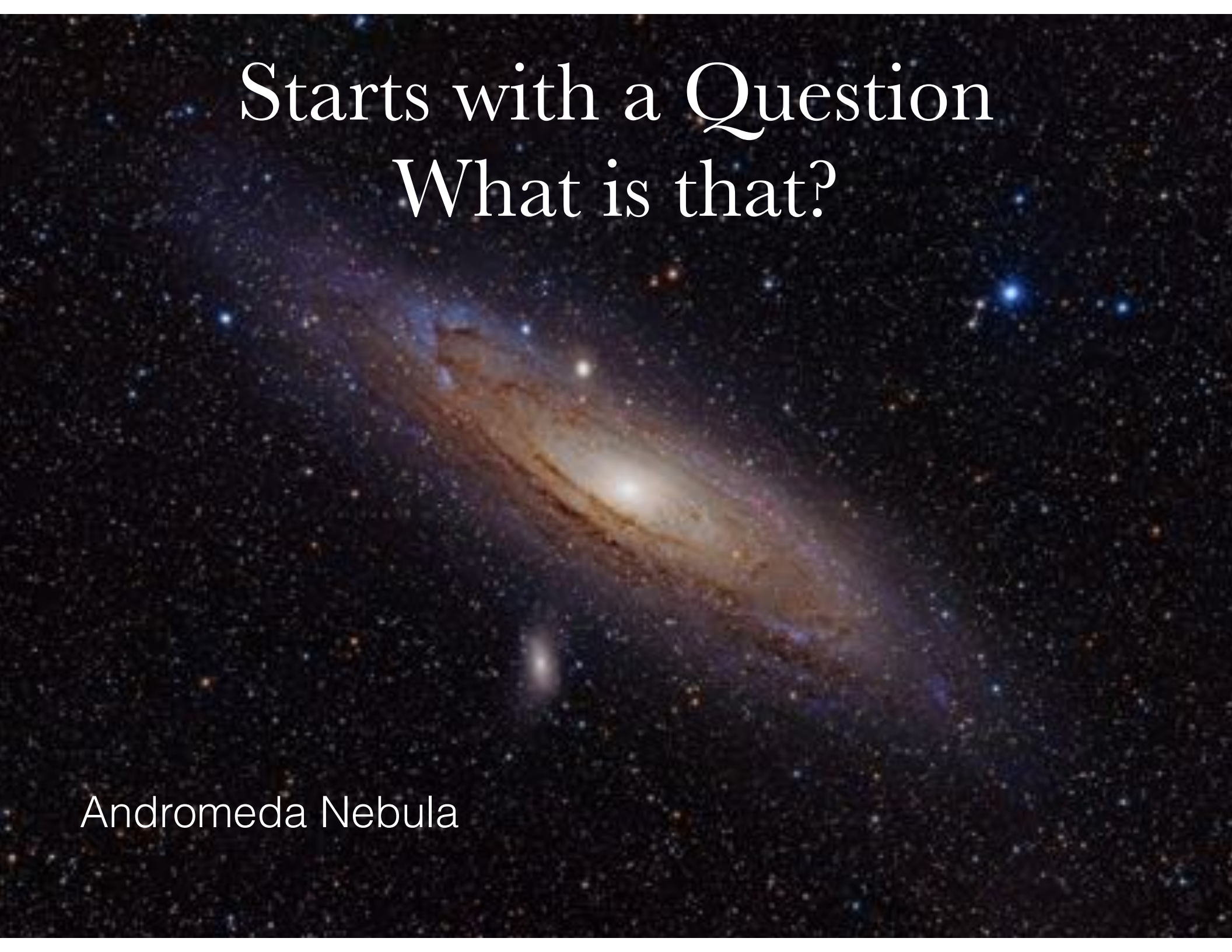
HST · WFC3/IR

NASA, ESA, G. Illingworth (UCO/Lick Observatory and University of California, Santa Cruz), and the HUDF09 Team

STScI-PRC09-31

A story of humility.
How did we get there?

Starts with a Question
What is that?



Andromeda Nebula

Look up…what do you see?

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?

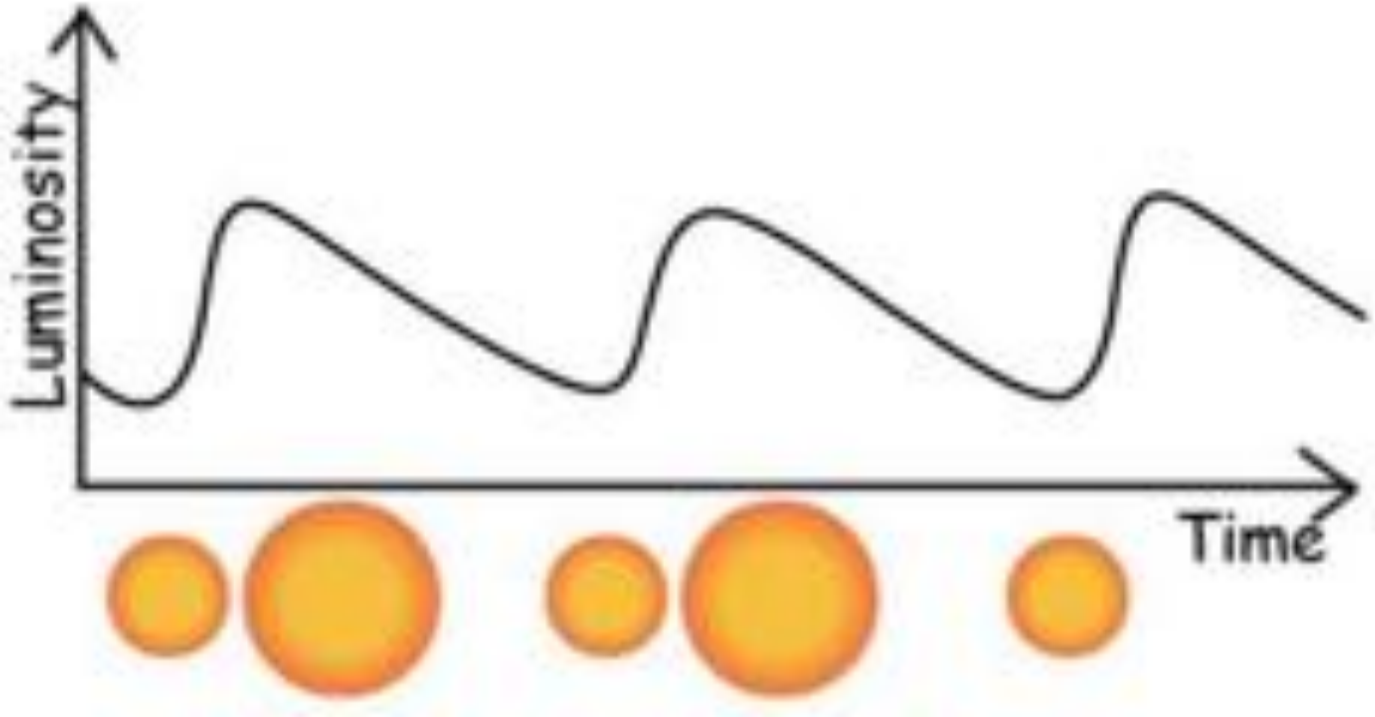
Andromeda Galaxy (Nebula)

Need a “Yard stick”

Standard Candle

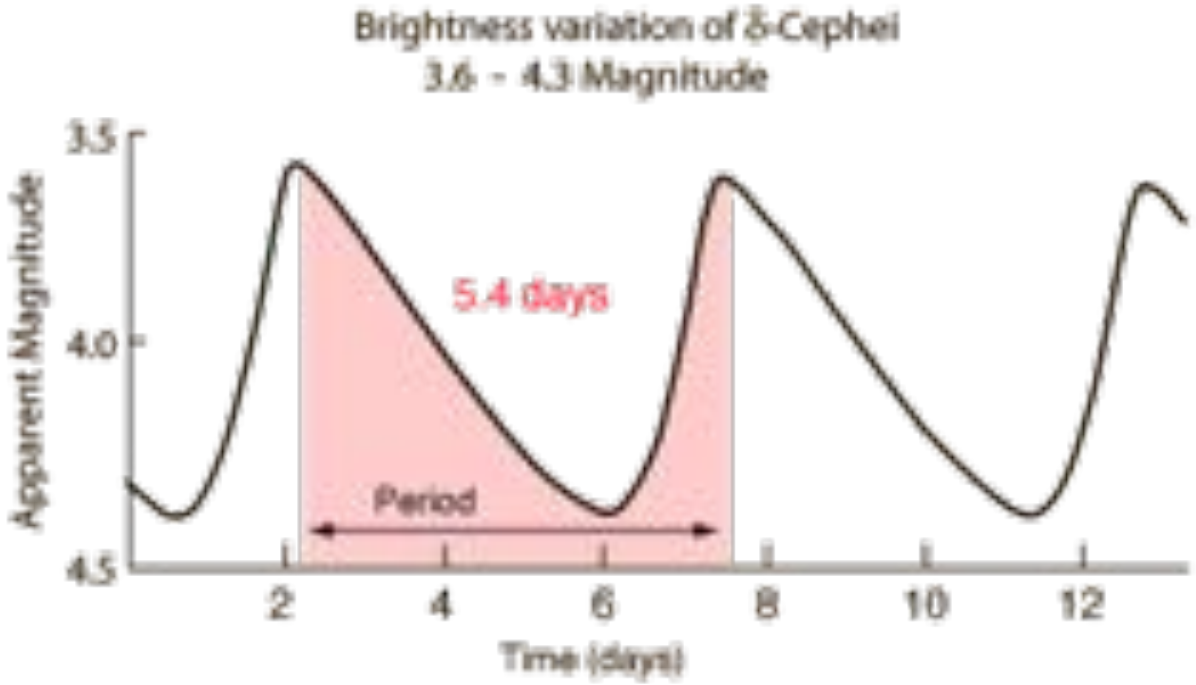
Henrietta Swan Leavitt

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
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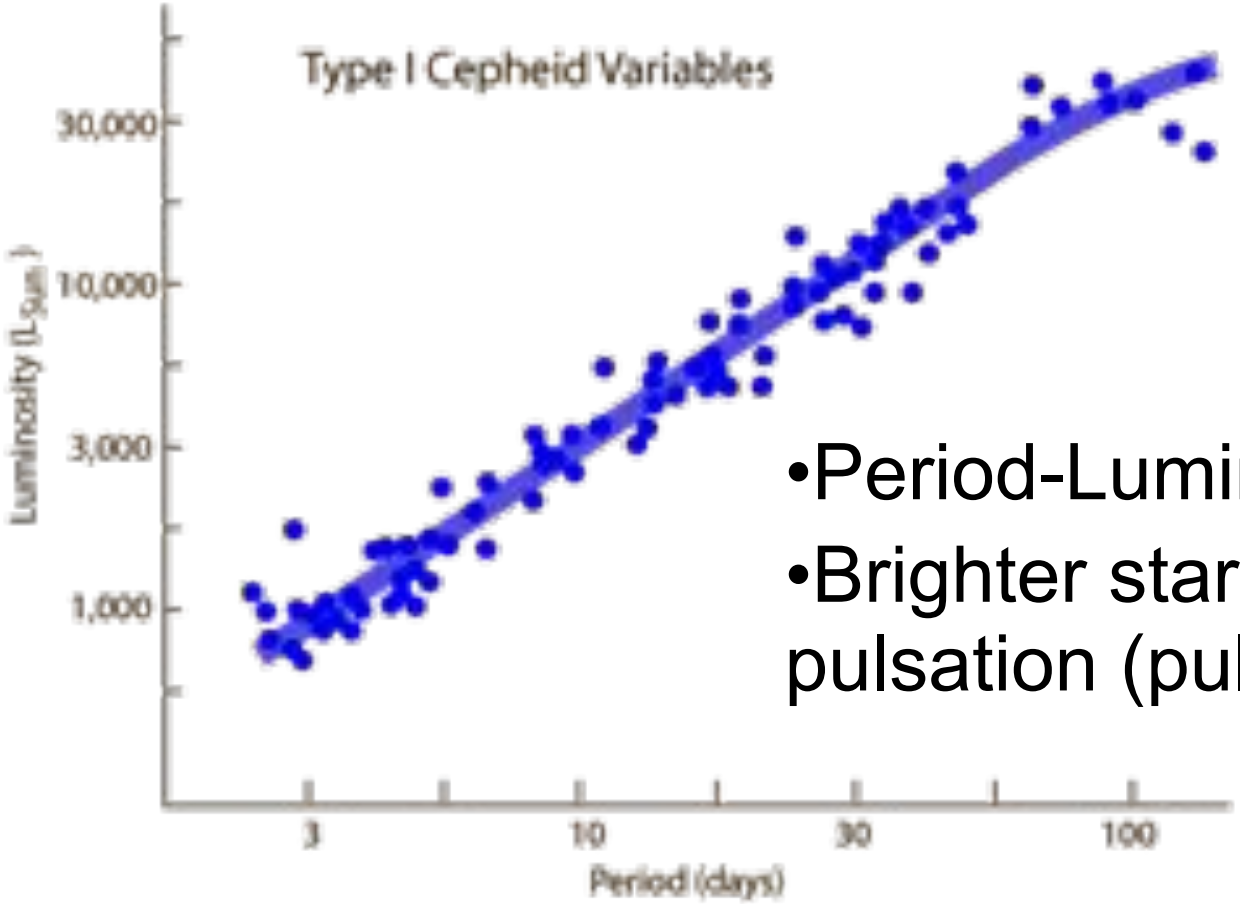
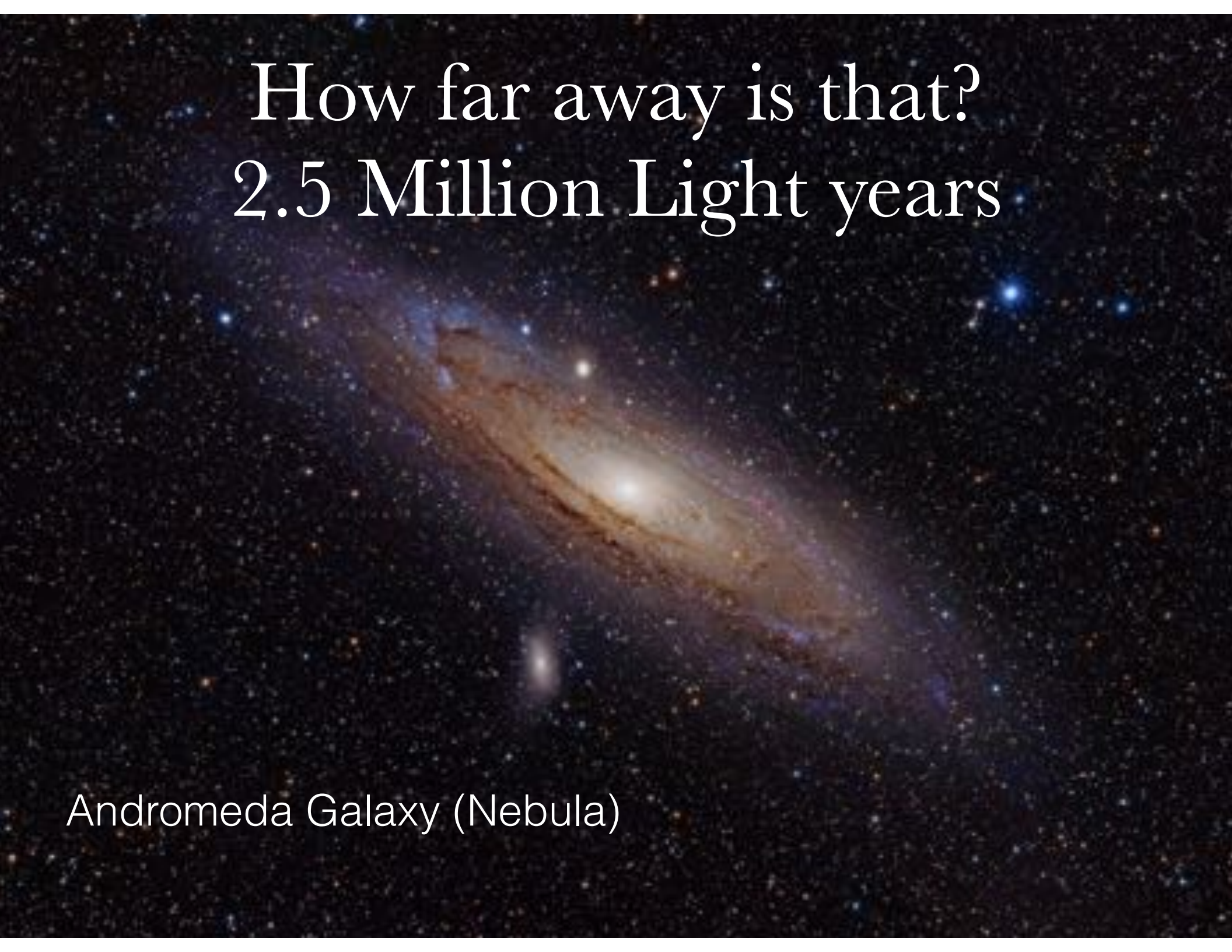
Standard Candle: Cepheid Variables



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

How far away is that?
2.5 Million Light years



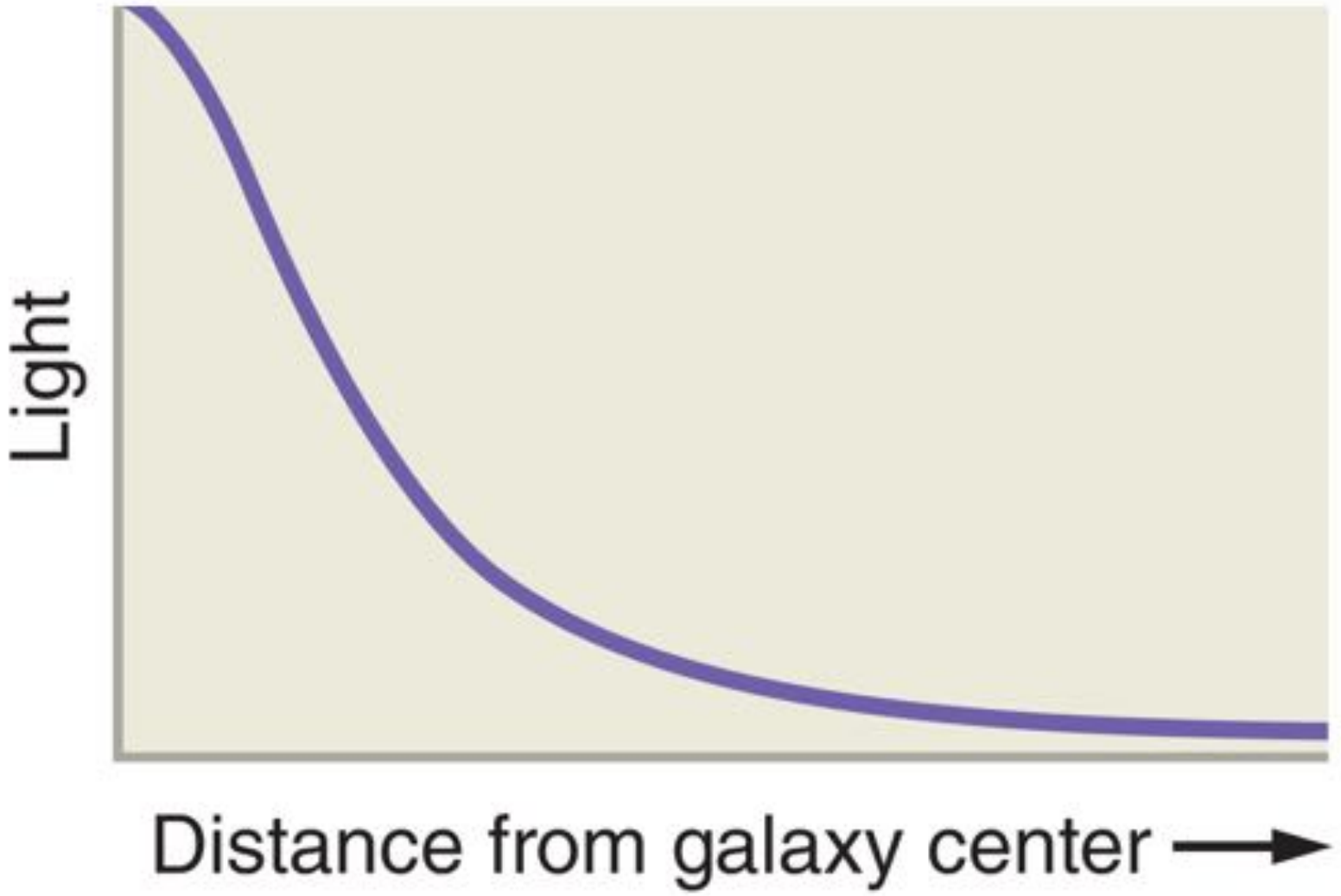
Andromeda Galaxy (Nebula)


A Galaxy of Stars
1 Trillion Stars
Andromeda Galaxy (Nebula)

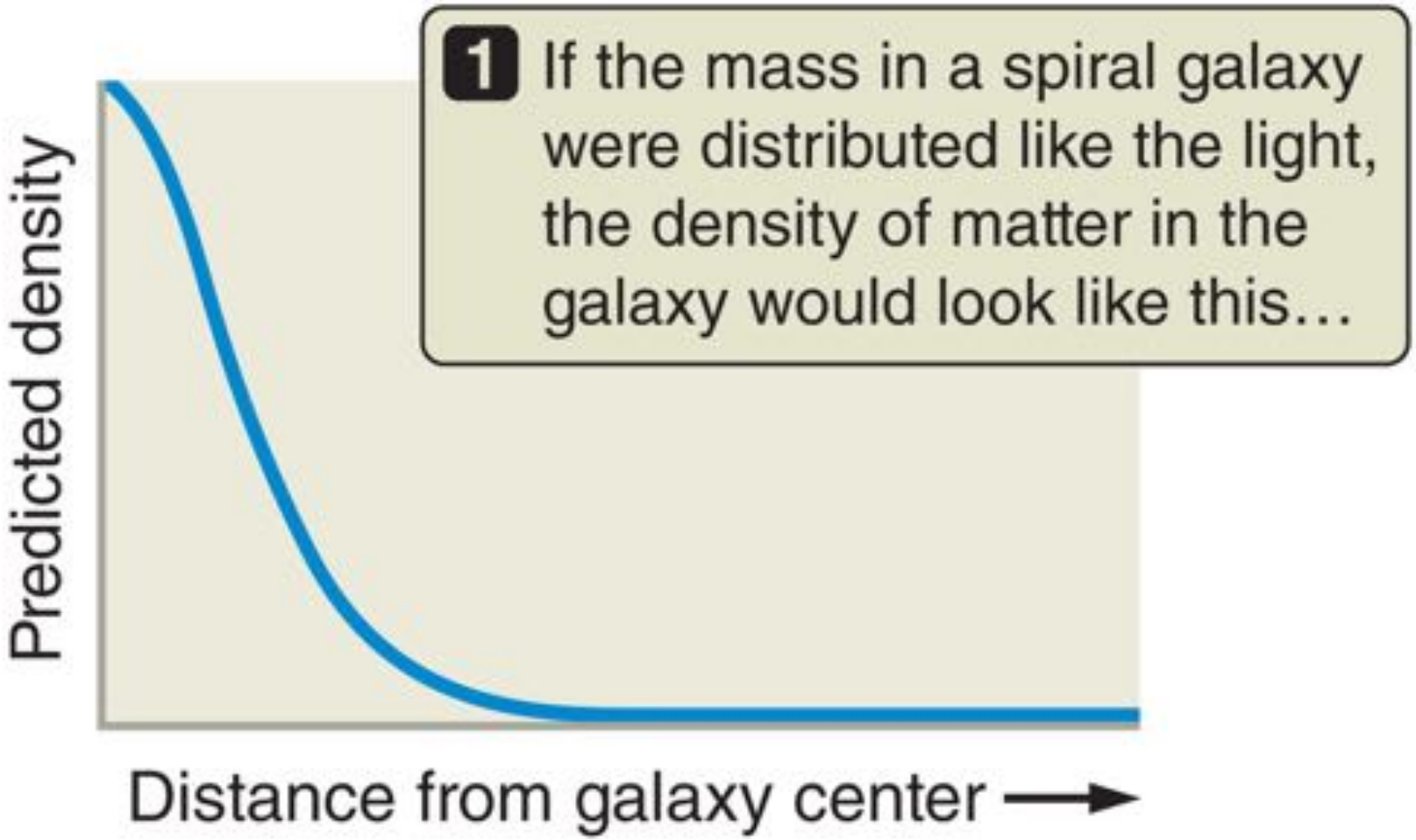
How much mass does that galaxy have?

Andromeda Galaxy (Nebula)

Measuring Mass in Galaxies

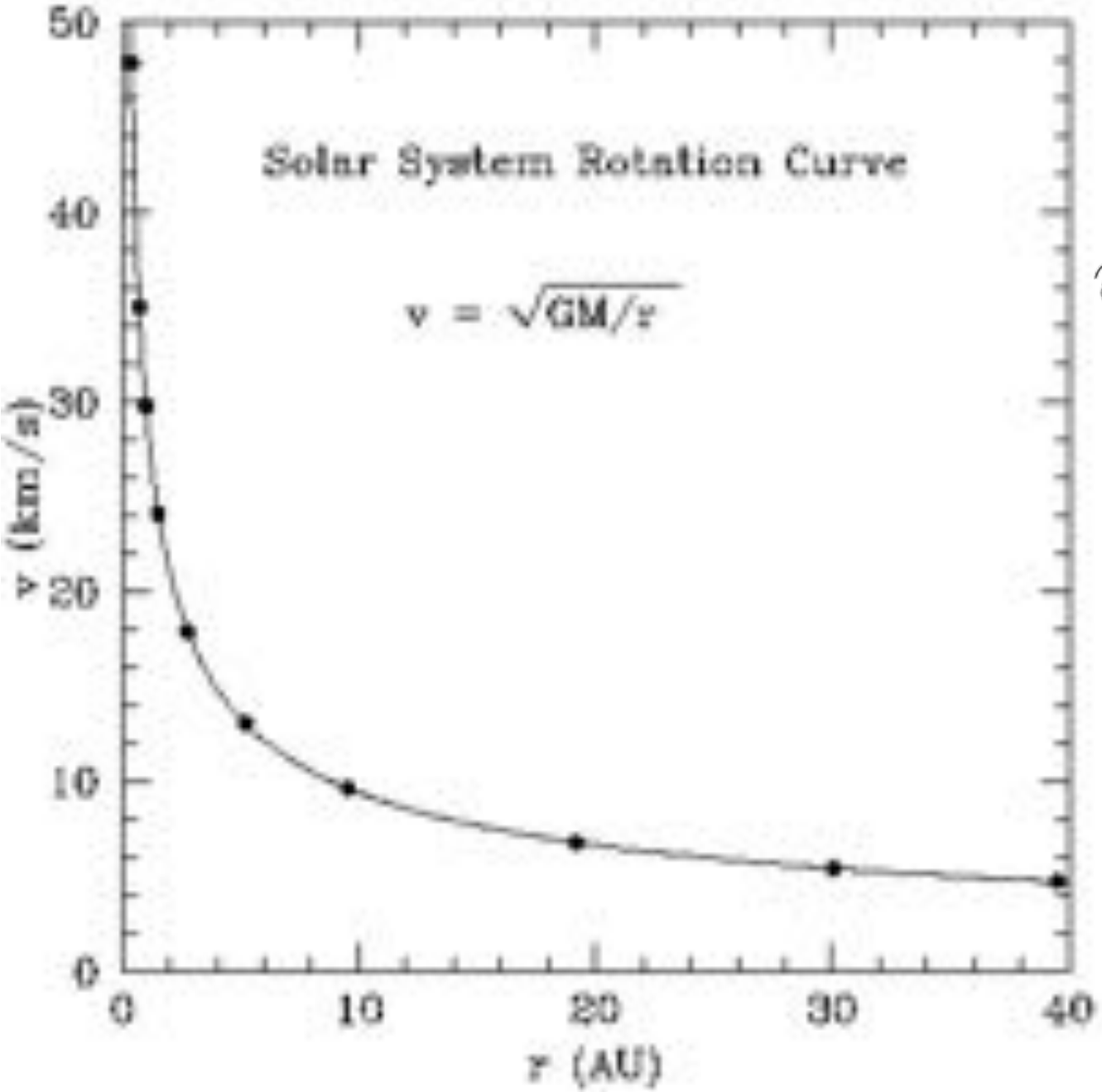


Measuring Mass in Galaxies



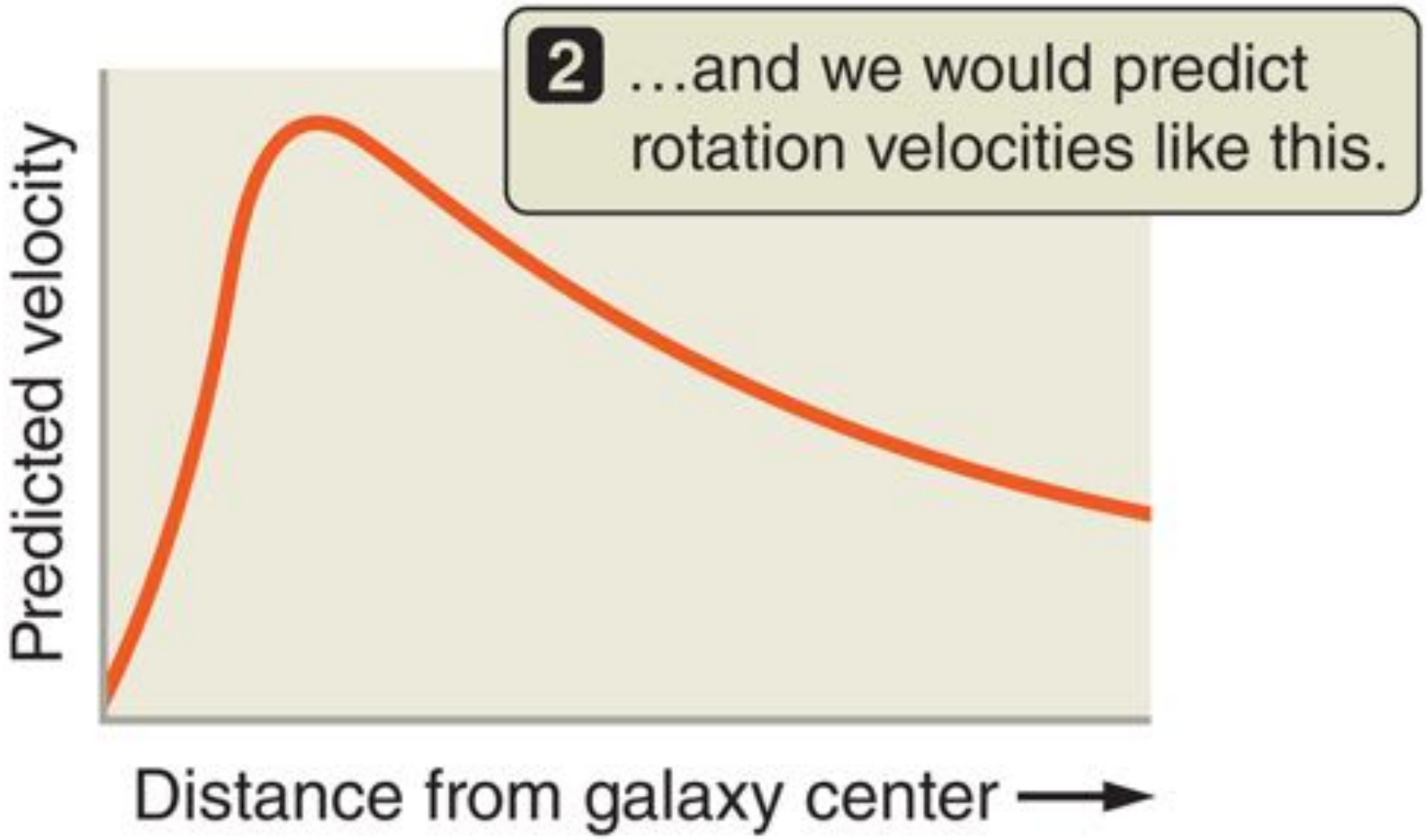
Measuring Mass in Galaxies

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

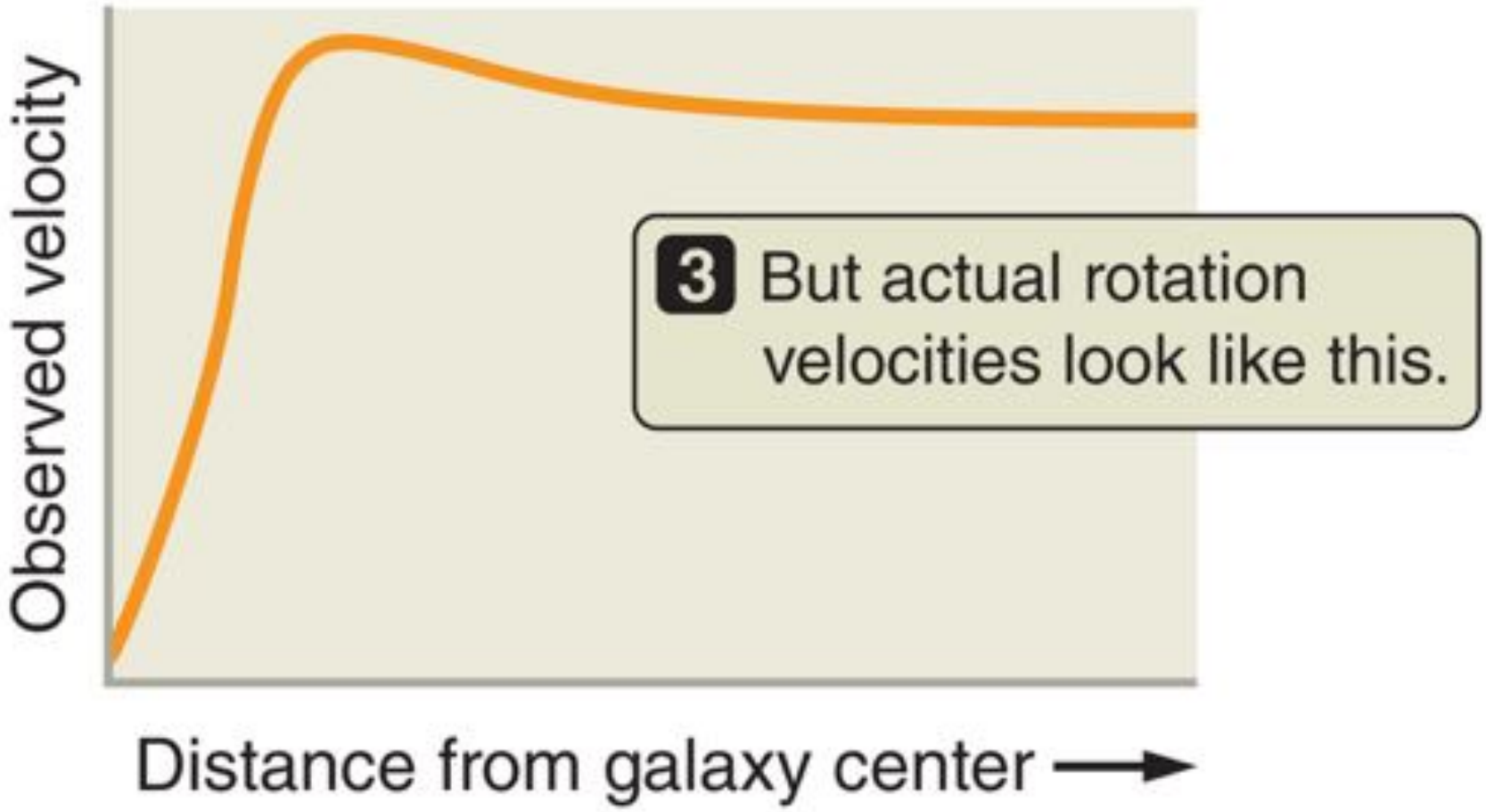


$$v_{\text{orbit}} = \sqrt{\frac{GM}{r}}$$

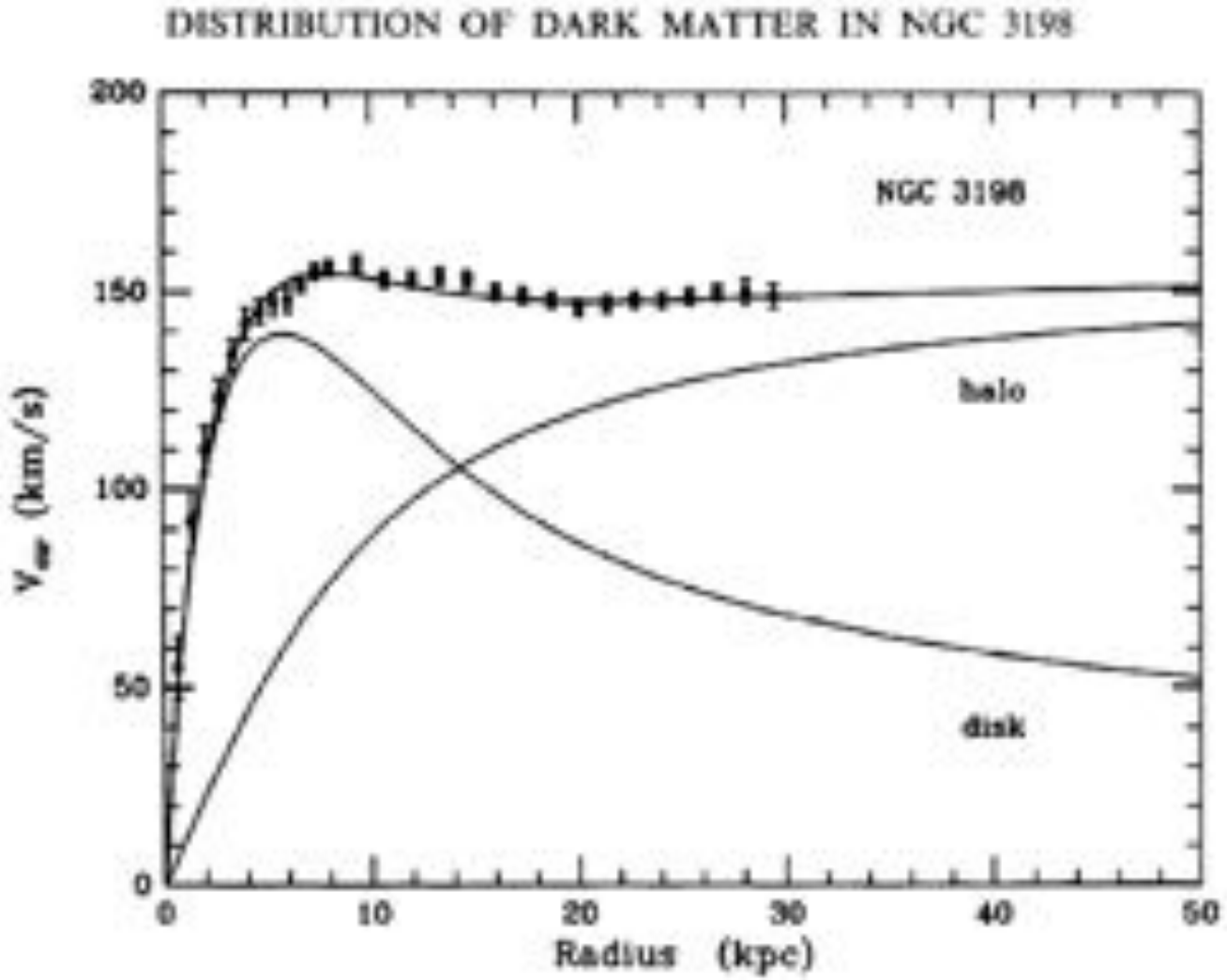
Measuring Mass in Galaxies



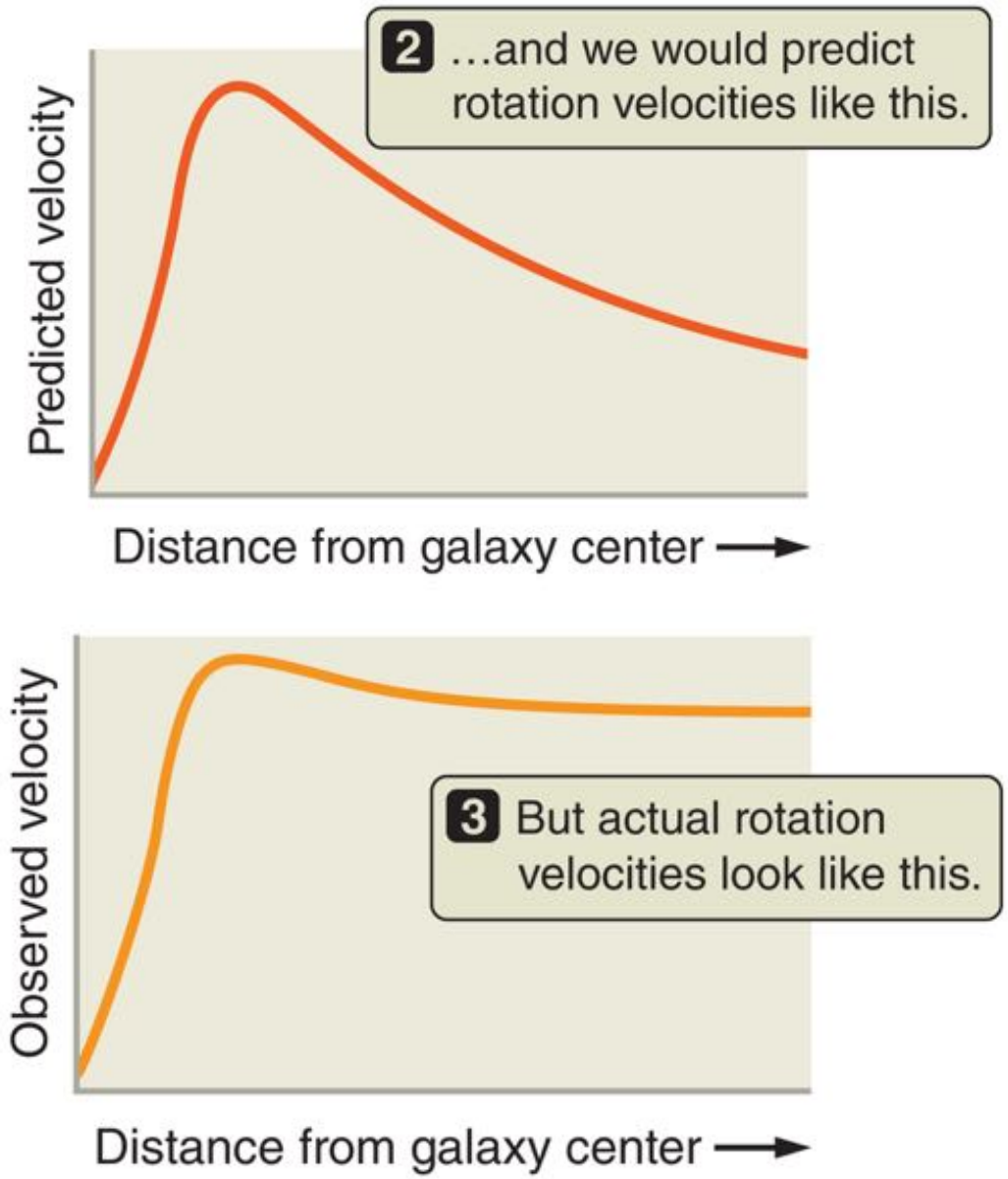
Measuring Mass in Galaxies



Measuring Mass in Galaxies



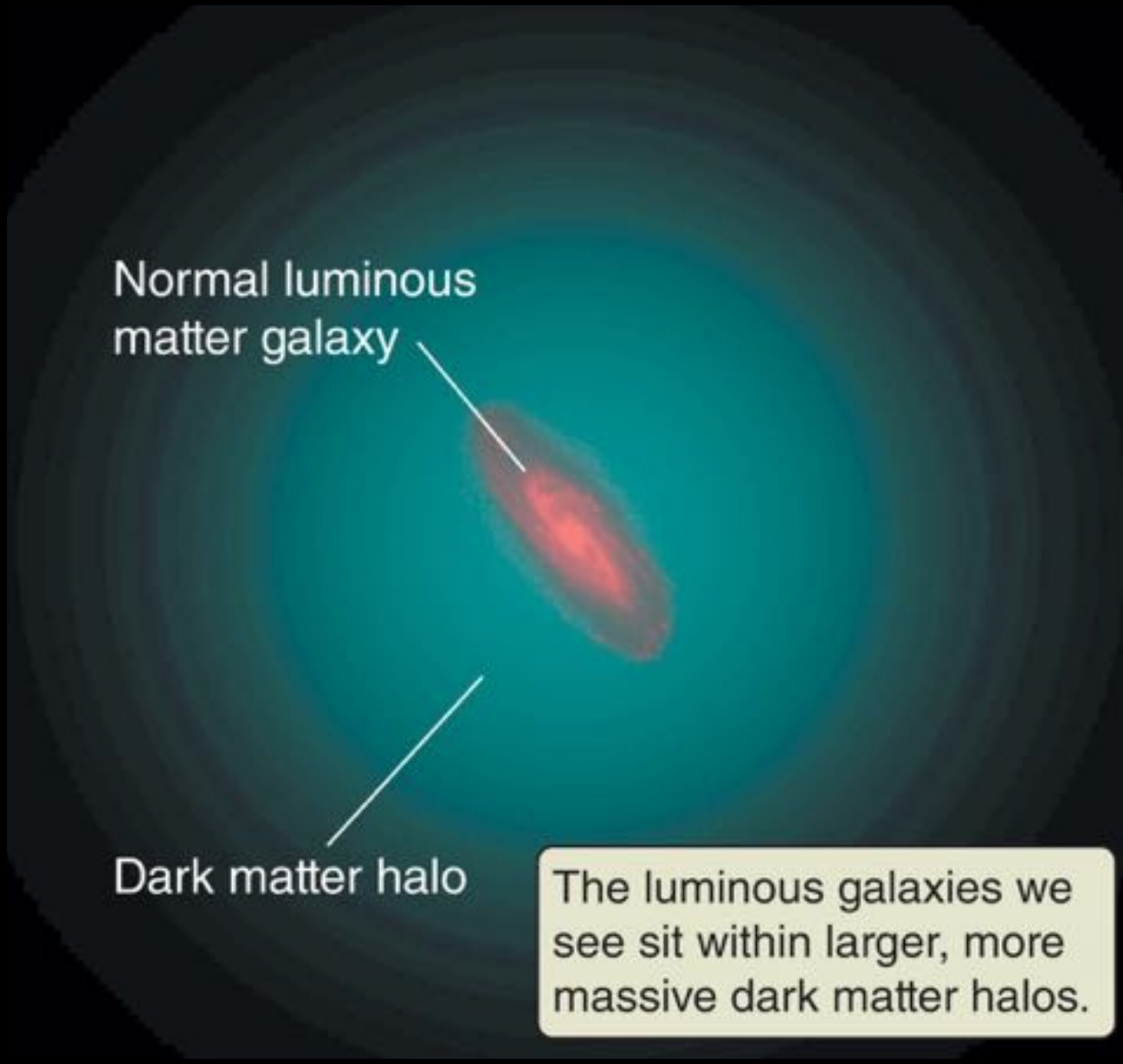
Measuring Mass in Galaxies



- 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)





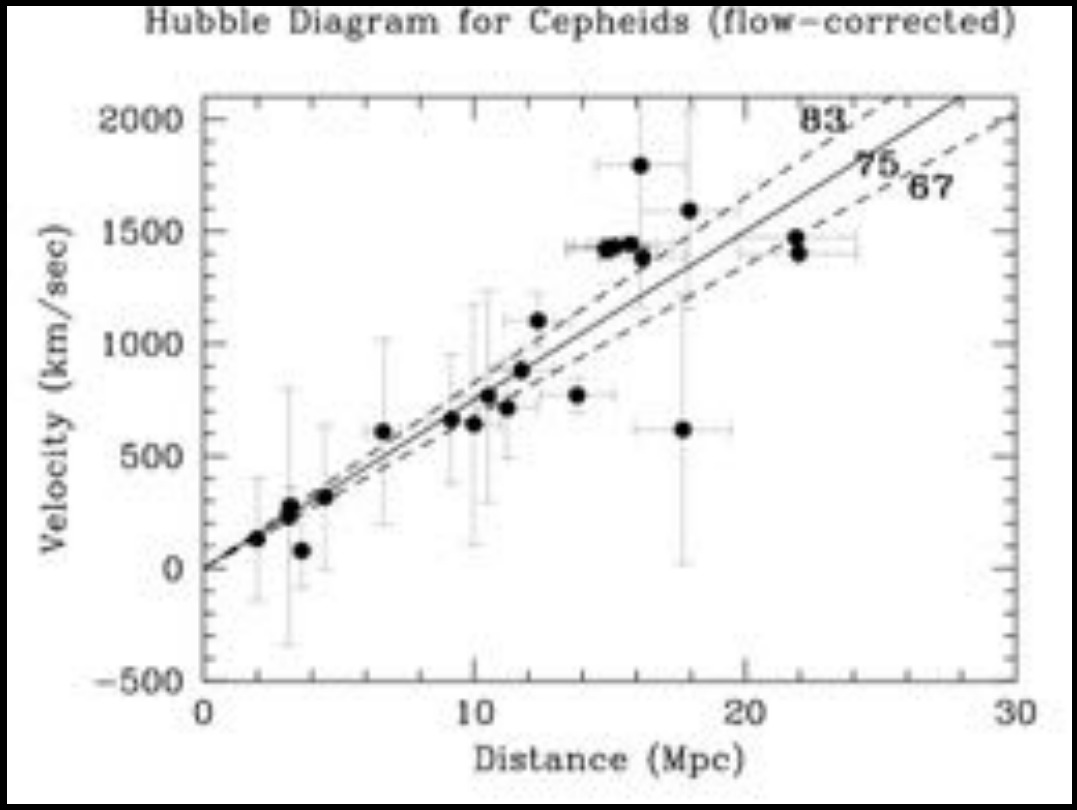

You are here




You are here

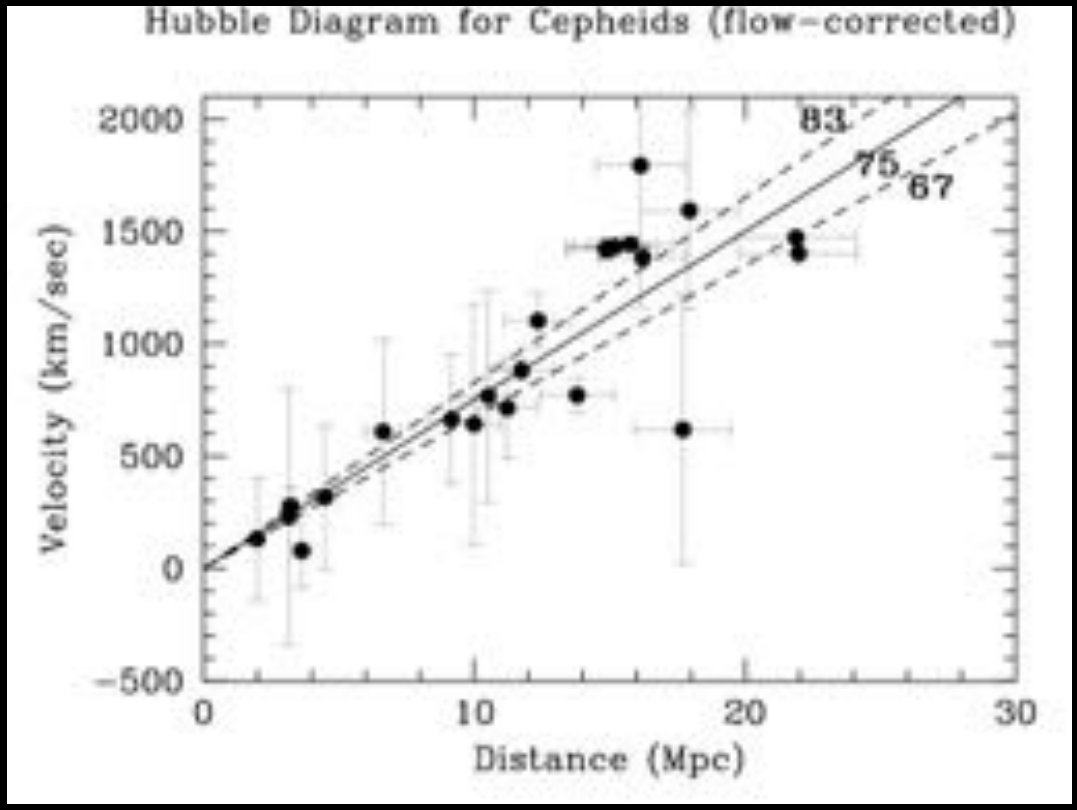
Galaxies are moving away

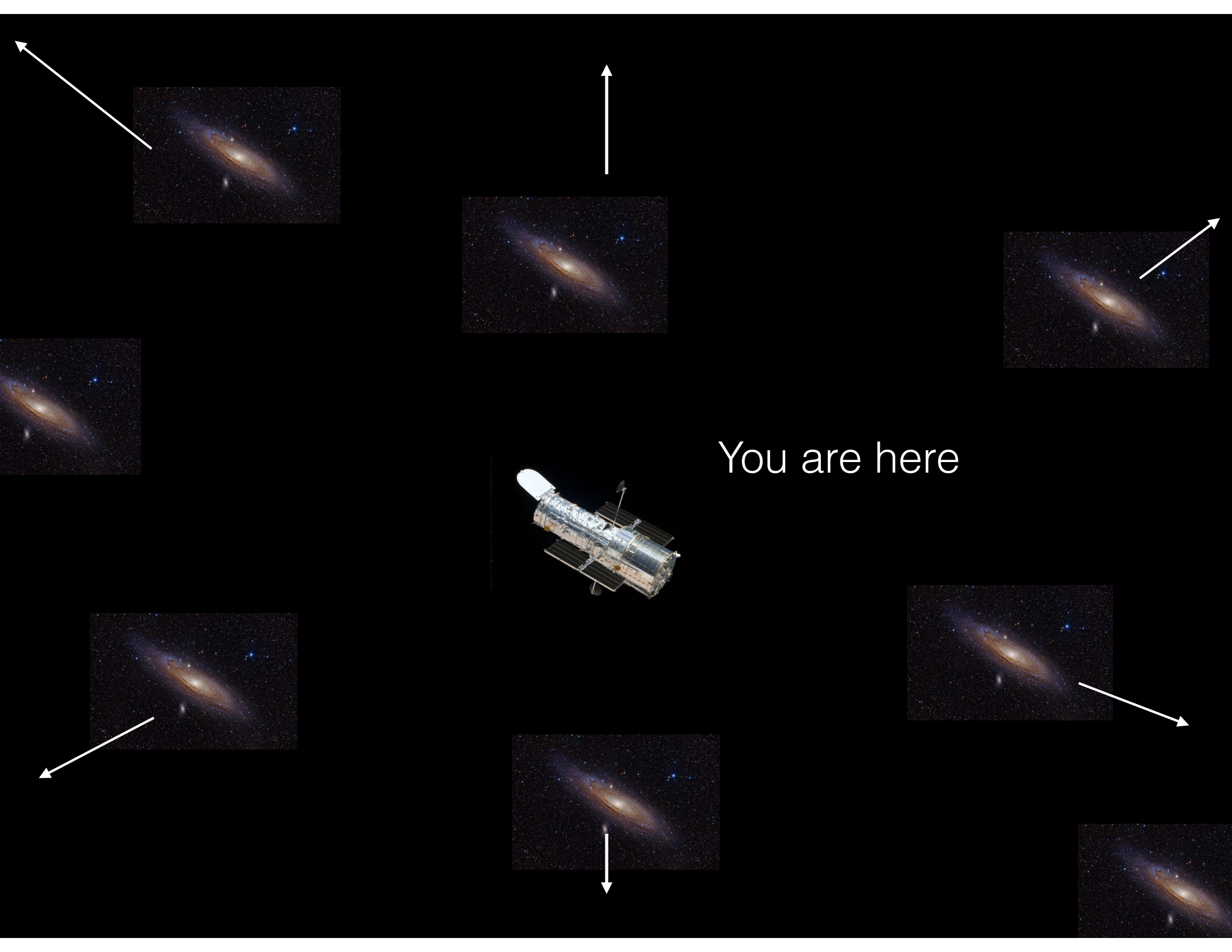
Hubble Telescope:
Key Project



What does this mean?

Hubble Telescope:
Key Project

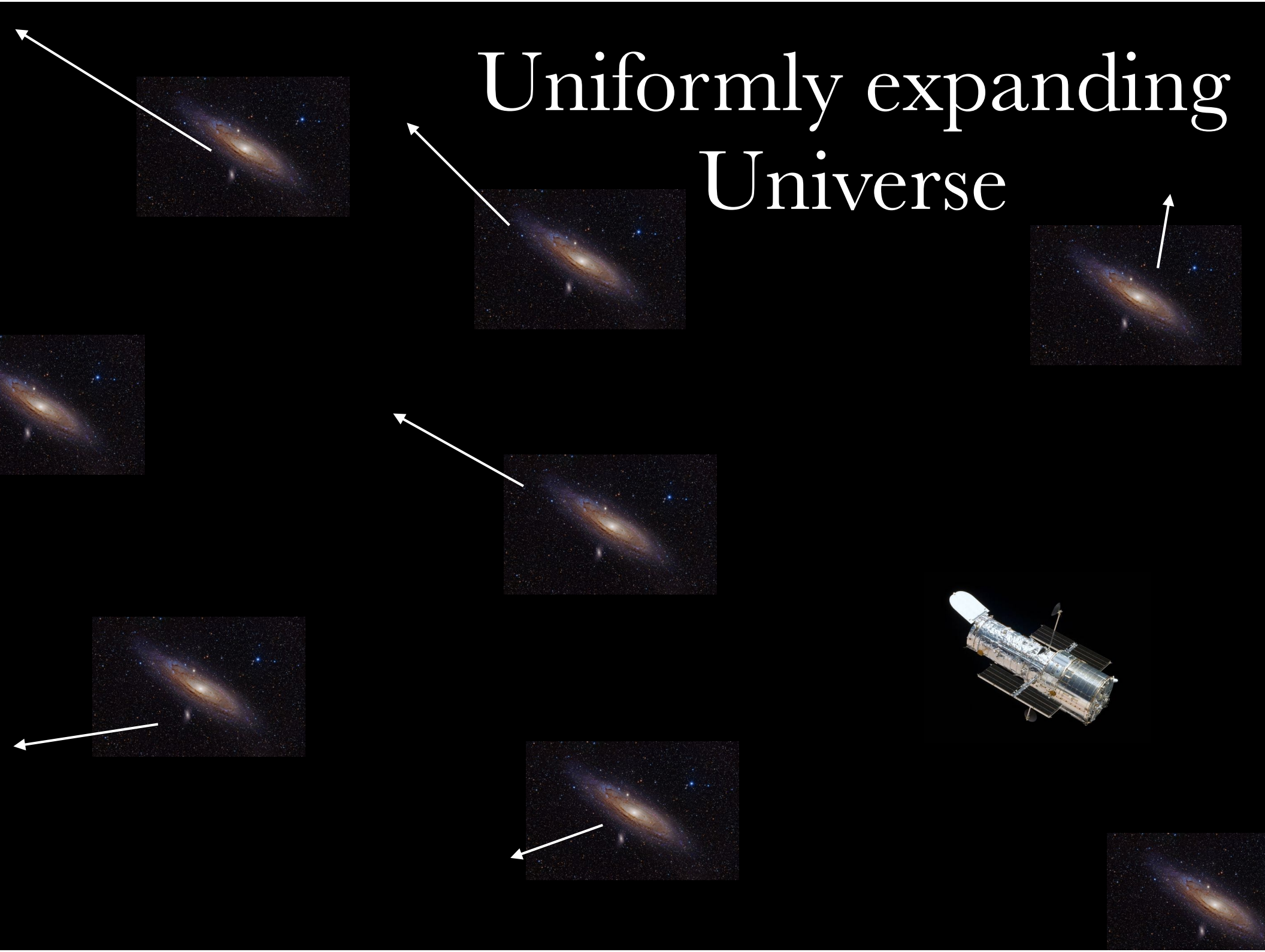



You are here

Are we at the center of the Universe?

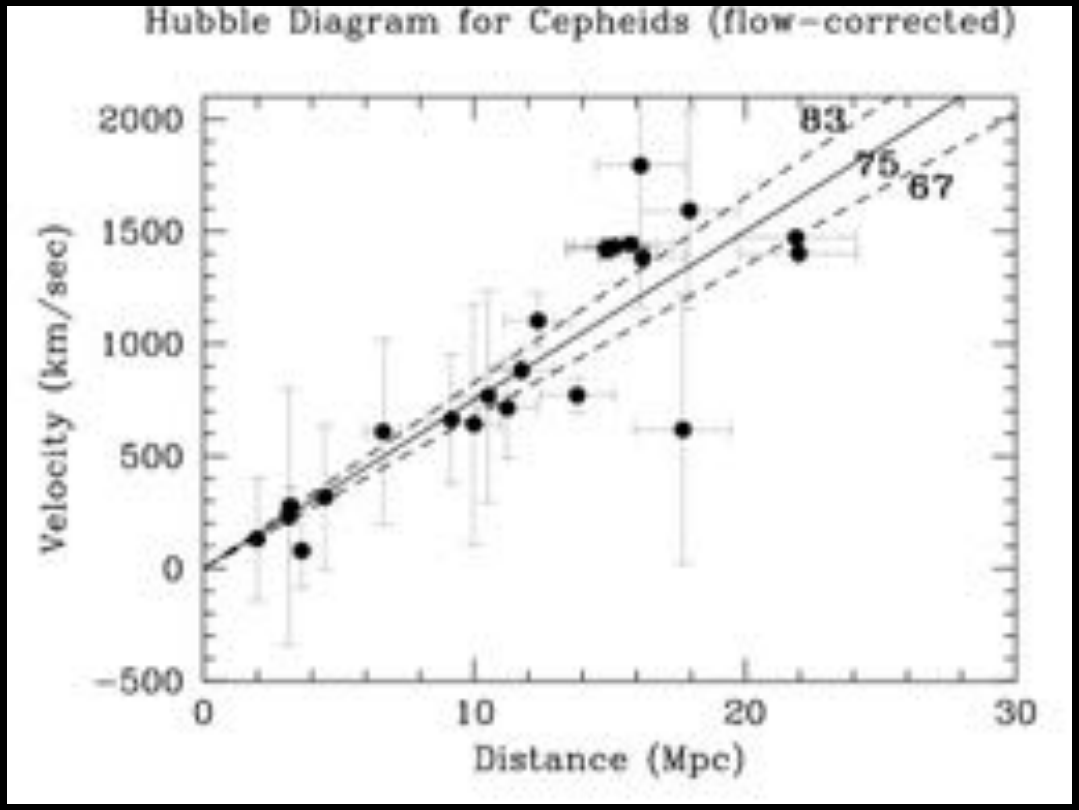
History cautions us to have humility

Uniformly expanding Universe

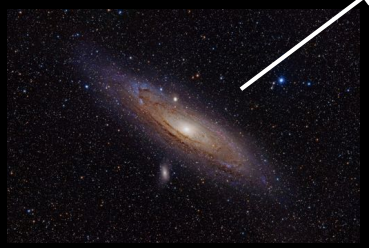


The Universe is Expanding

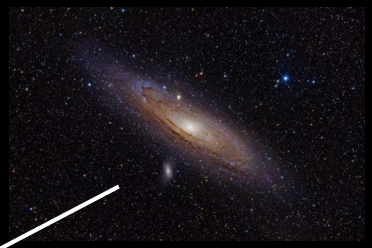
Hubble Telescope:
Key Project

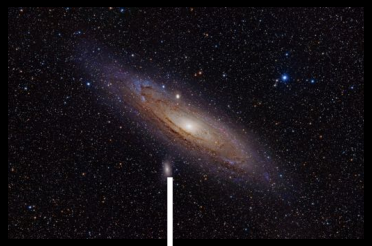


Rewind



You are here



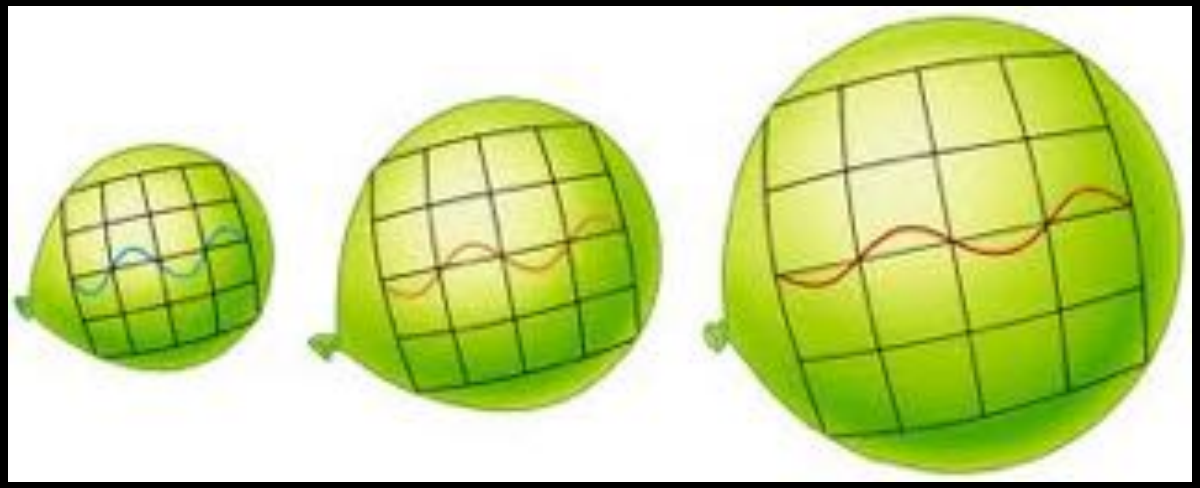


Big Bang!
Hot and Dense

Entire Universe was Glowing (13.7 billion years ago)

Where's the glow now?

General Theory of Relativity



Redshift (z)

Hot Glow

Universe Expands

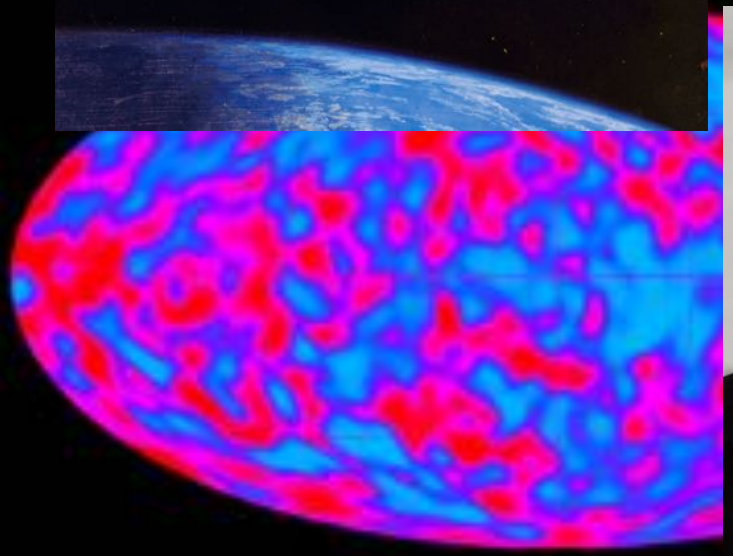
Expands 1,100

In the Microwave Today
Cosmic Microwave Background
(CMB)

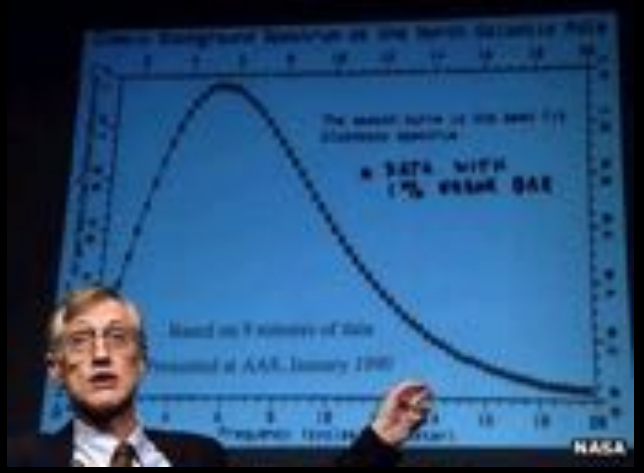
Nobel Prize #1

Penzias & Wilson

Nobel Prize #2



Smoot



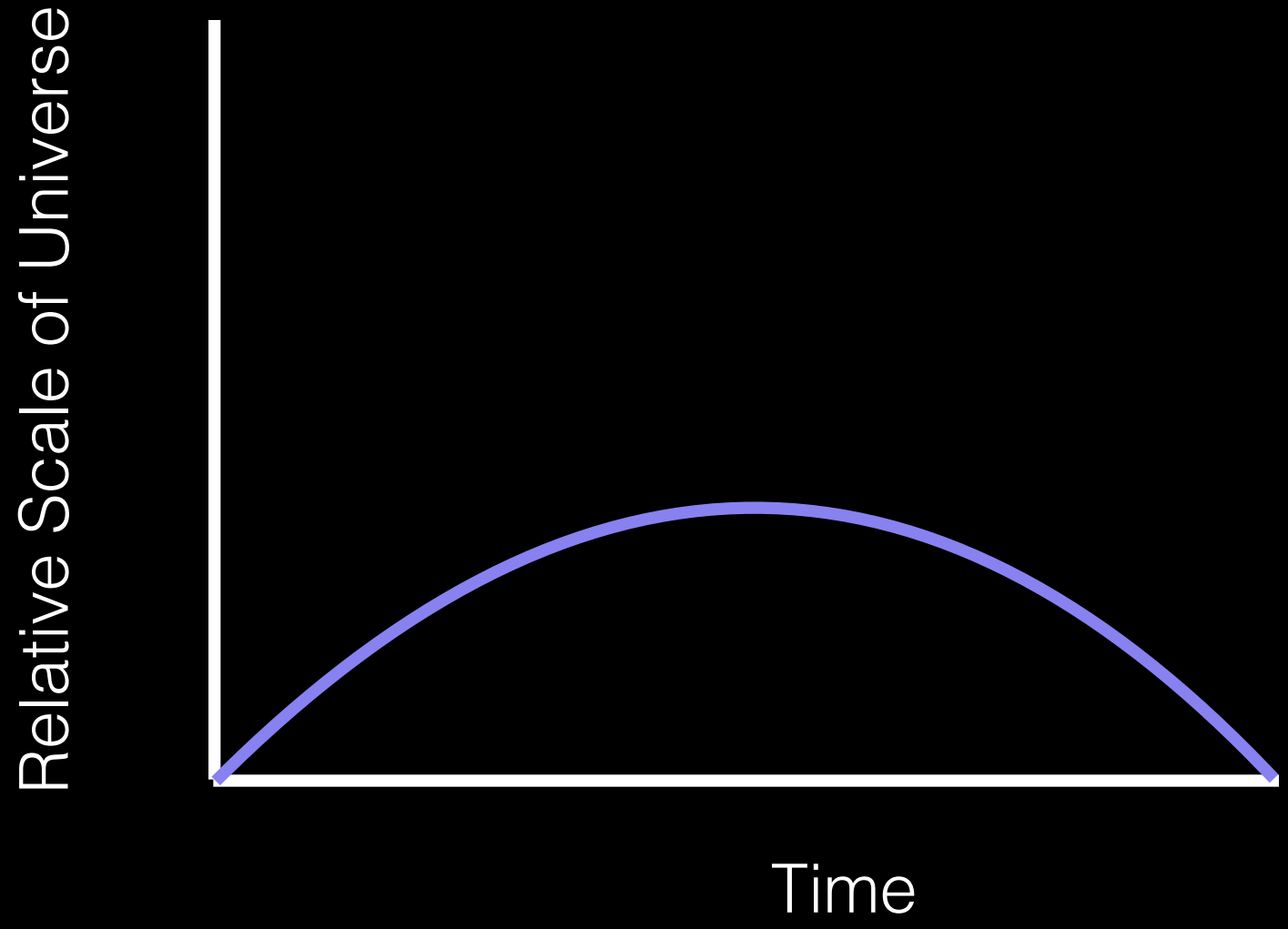
Mather

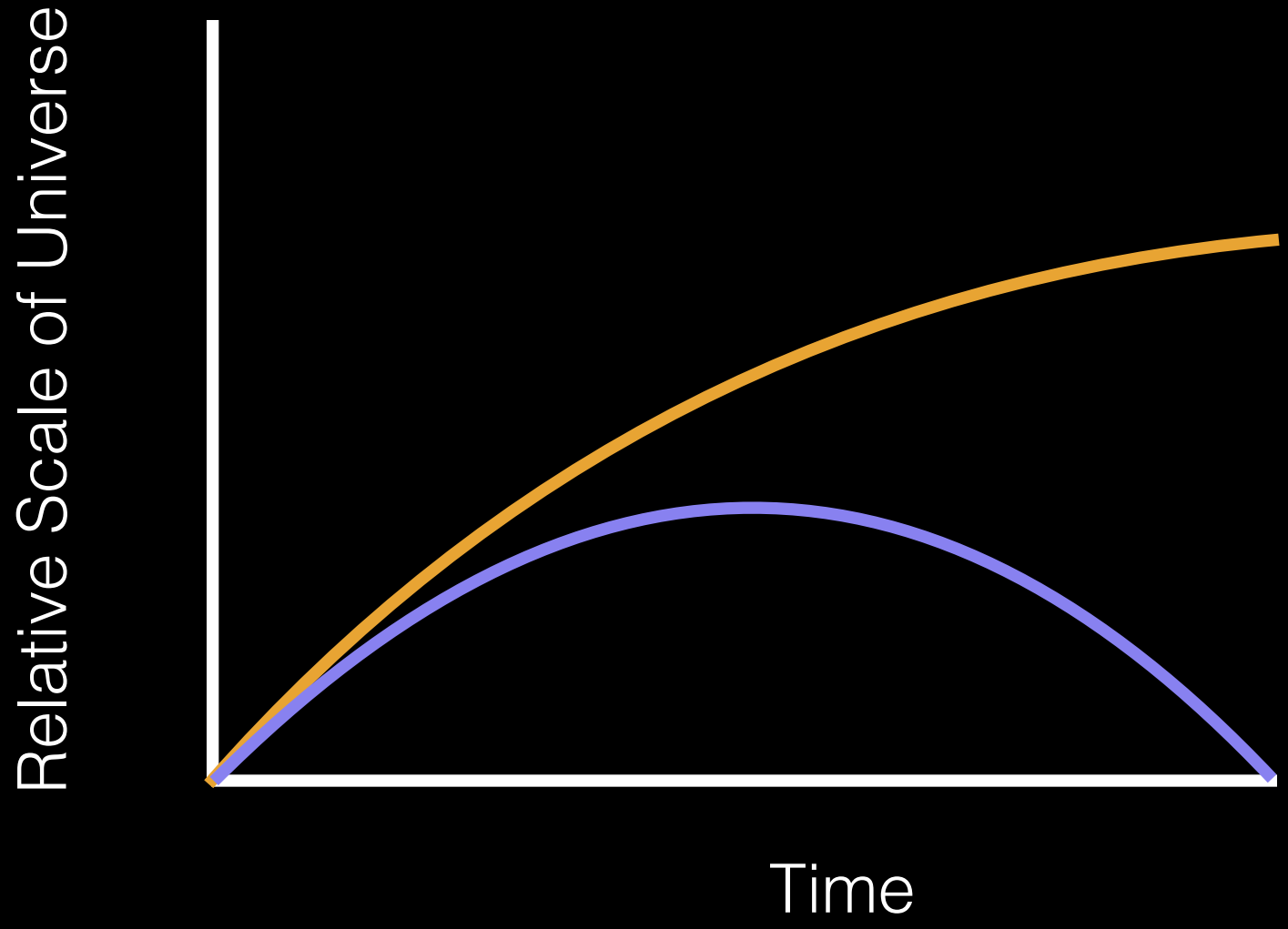
Universe is Expanding

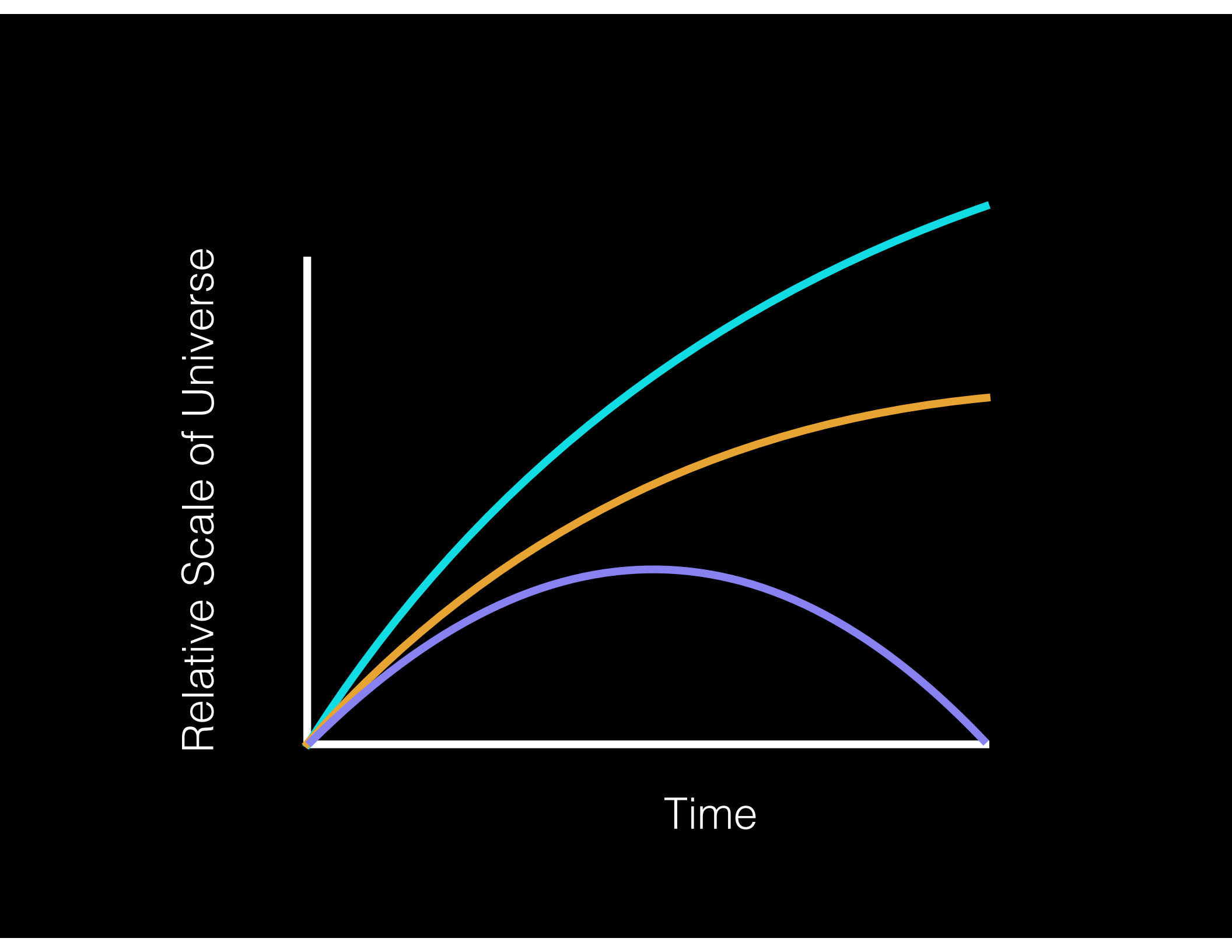
Past?

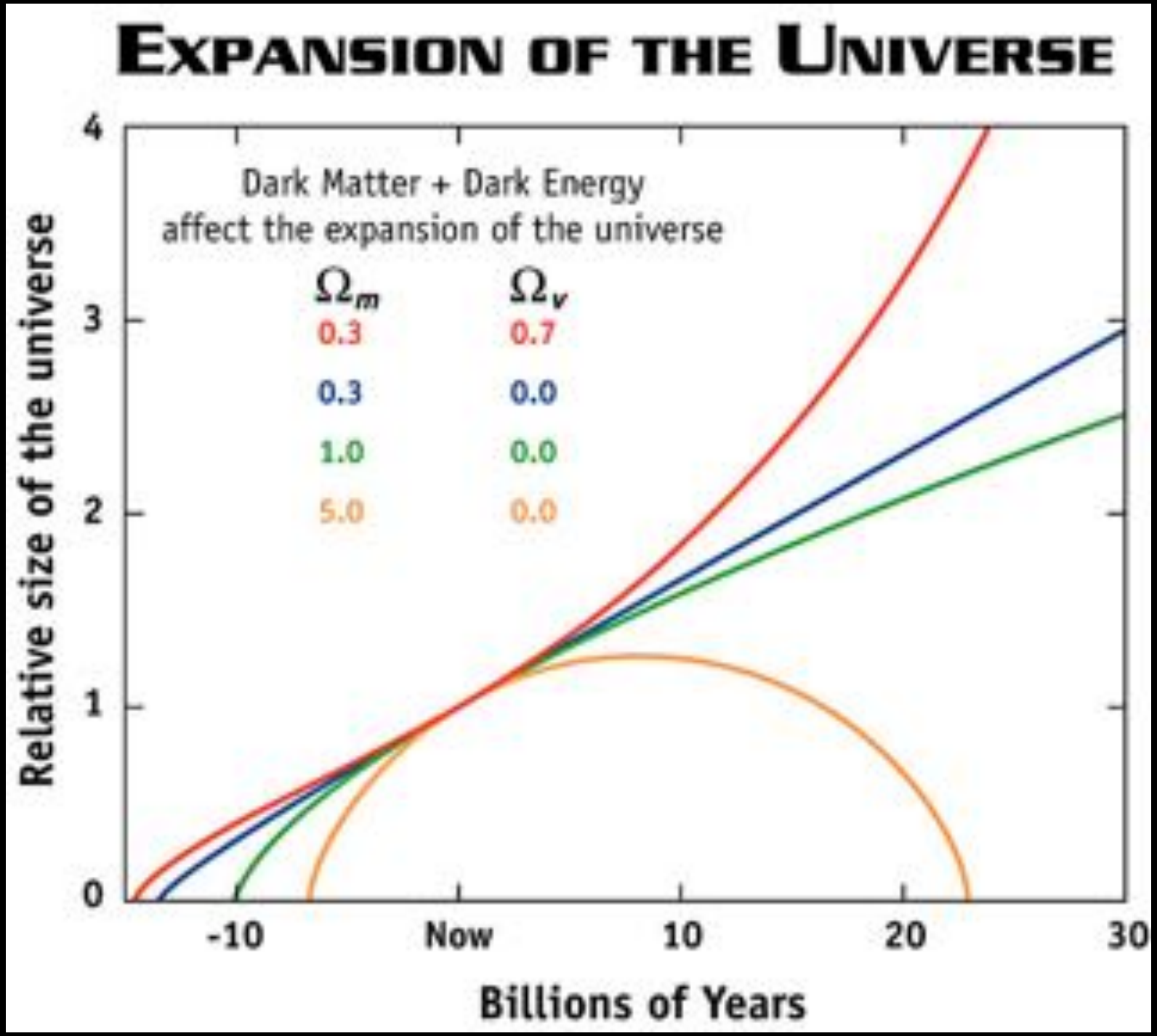
Future?


Big bang kick vs. gravity

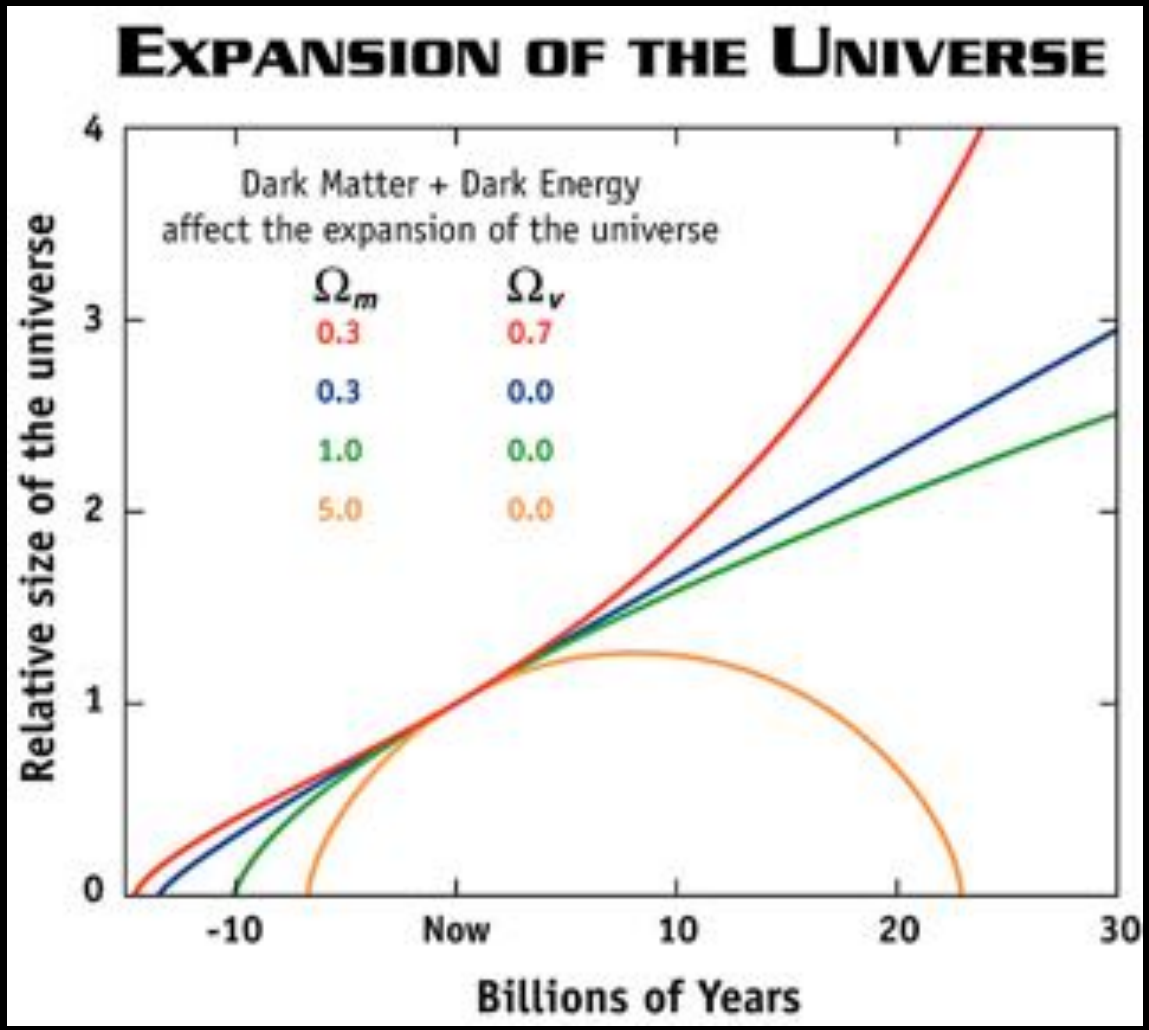

Relative Scale of Universe
Time


Relative Scale of Universe
Time


Relative Scale of Universe
Time


EXPANSION OF THE UNIVERSE
Dark Matter + Dark Energy
affect the expansion of the universe
Ω_m Ω_v
0.3 0.7
0.3 0.0
1.0 0.0
5.0 0.0
Relative size of the universe
0
1
2
3
4
-10
Now
10
20
30
Billions of Years

We need a time machine

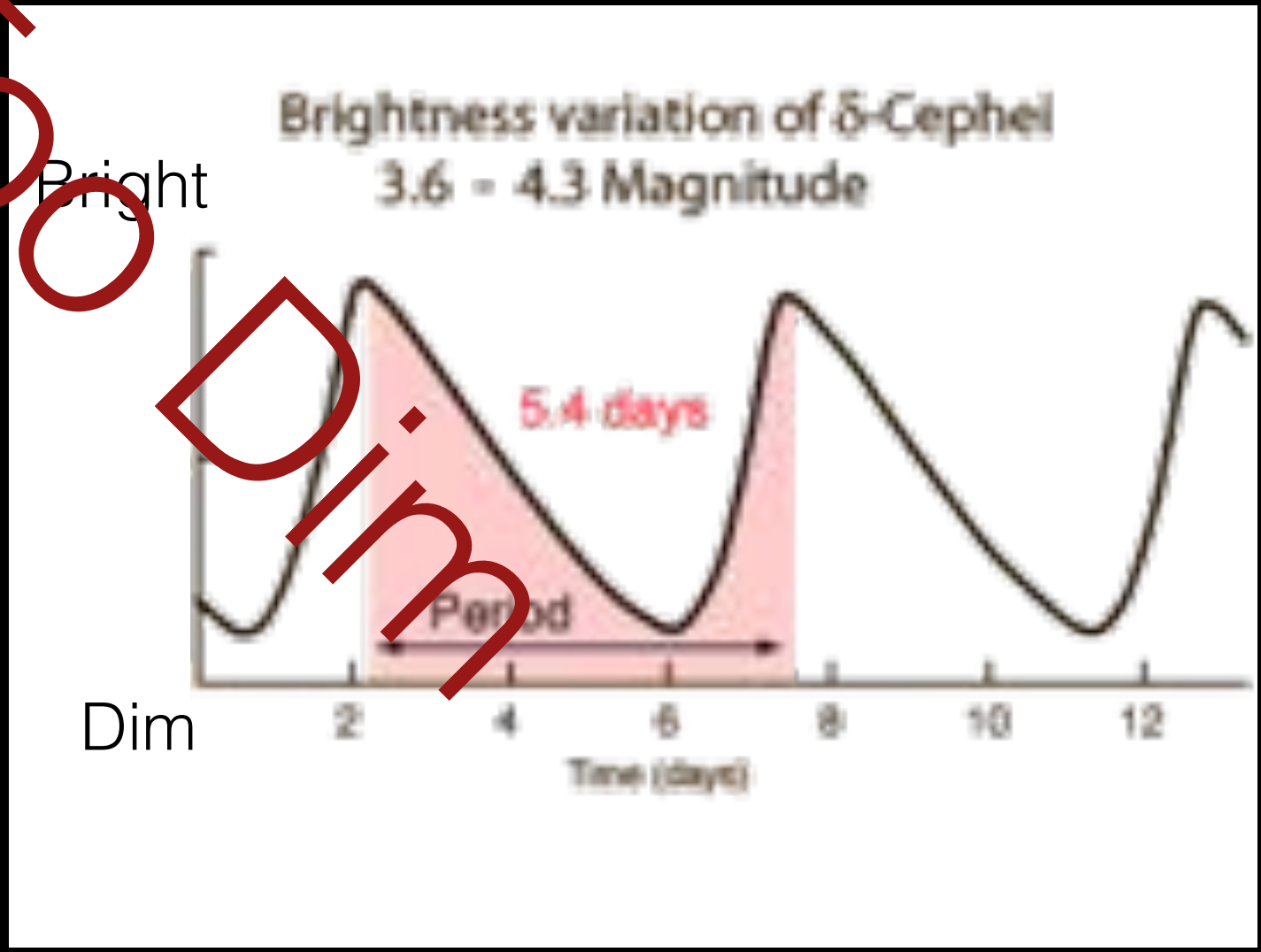


Farther away
is further back in time

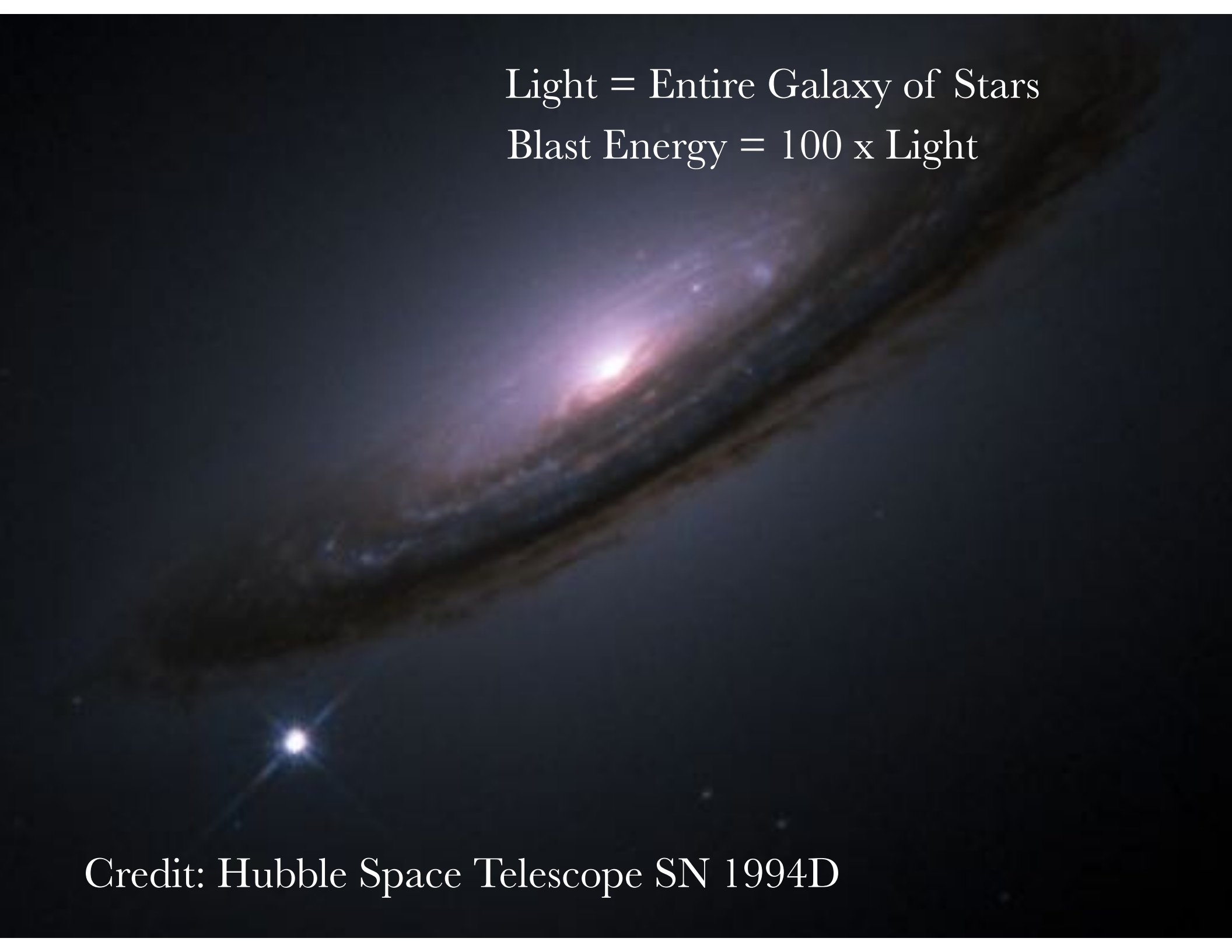
We need to look at the Hubble diagram for far away galaxies

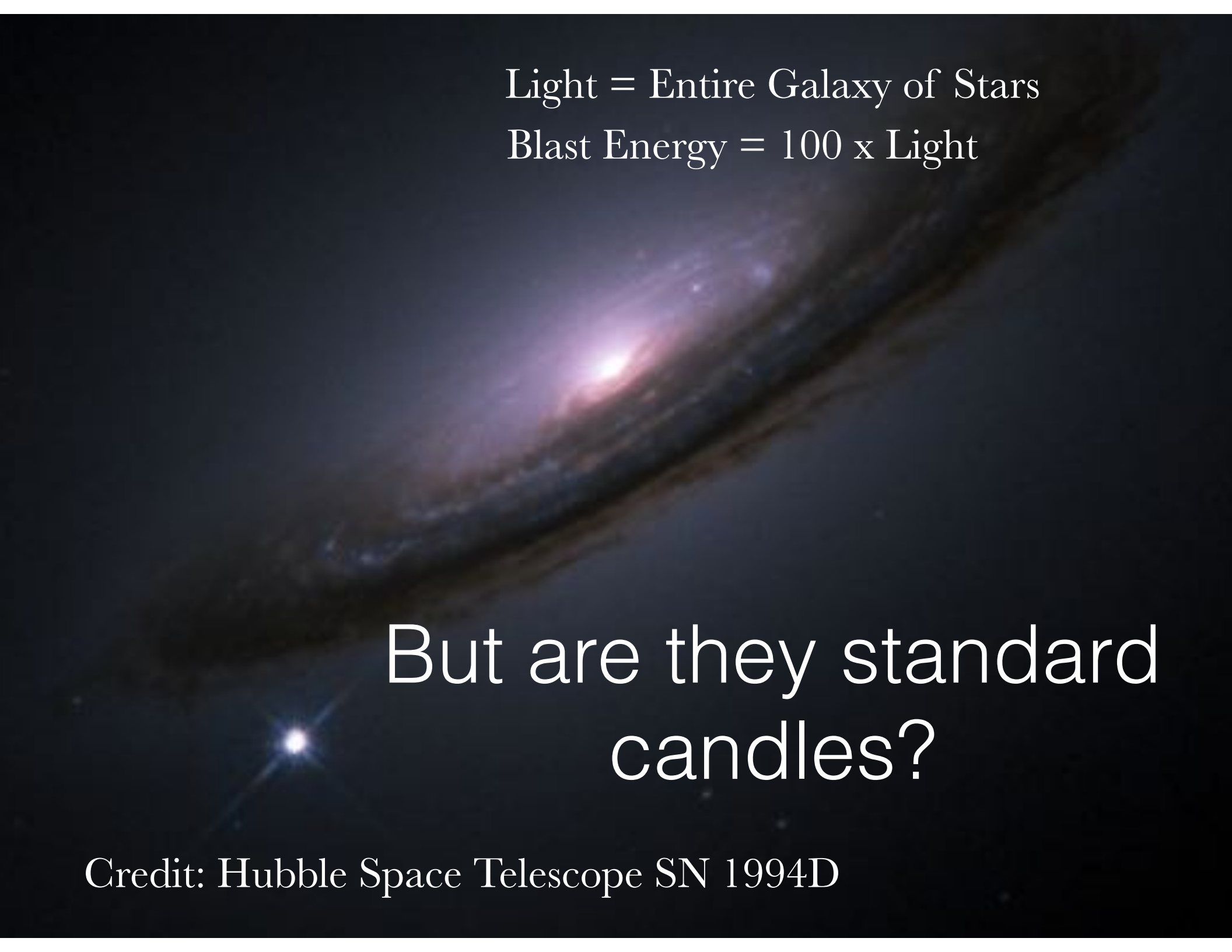
Cepheid Pulsating Stars

Too Dim

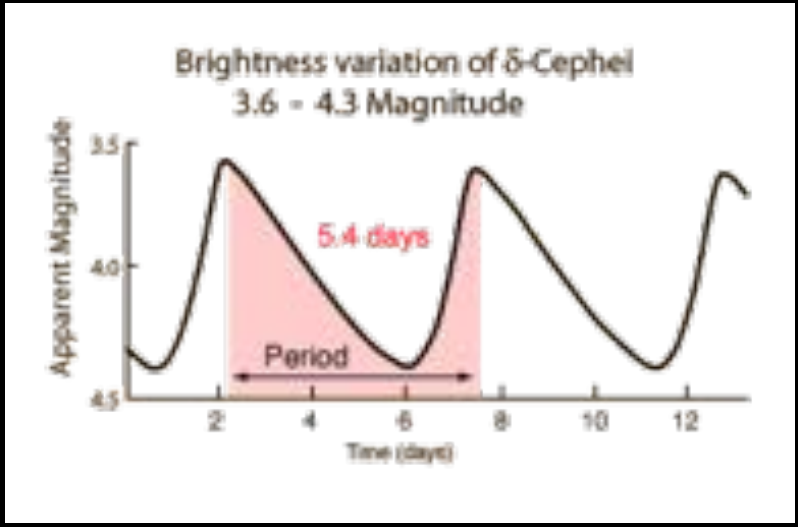


Need a much brighter standard candle

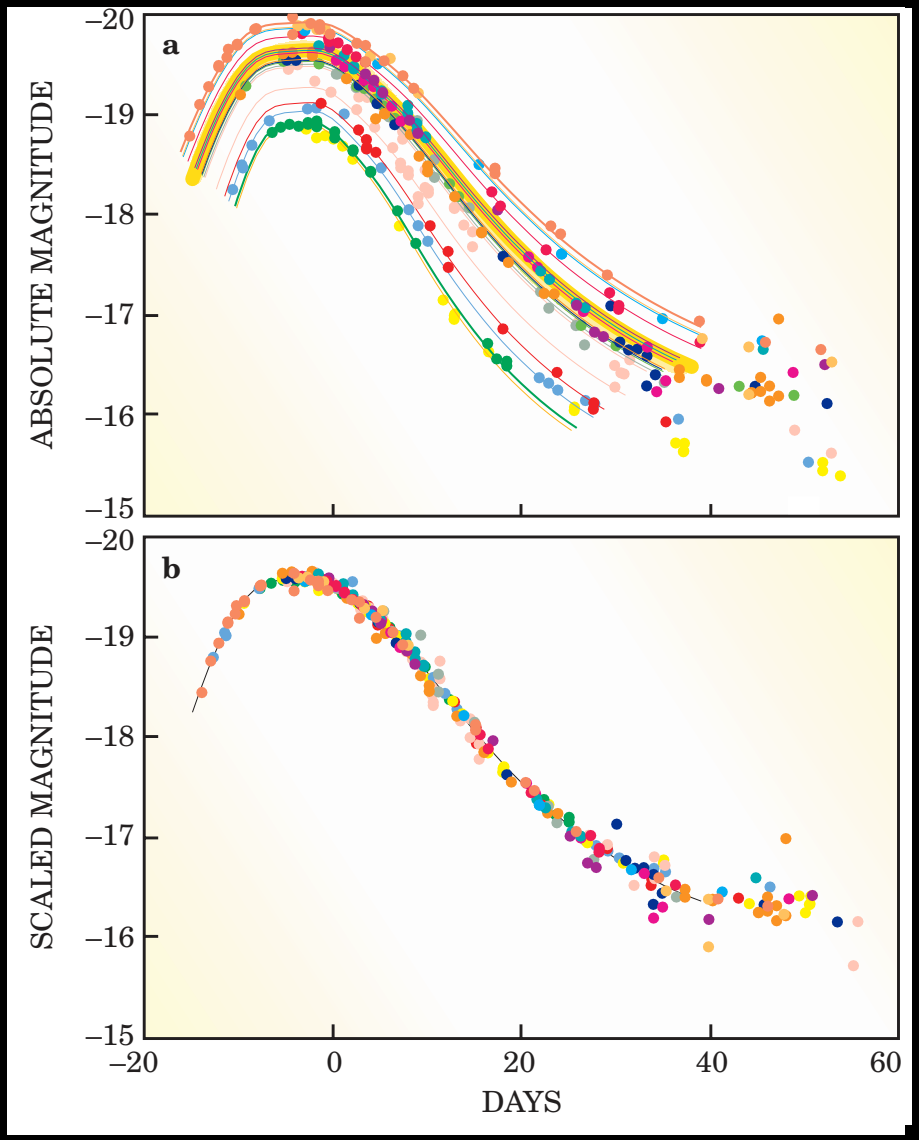

Light = Entire Galaxy of Stars
Blast Energy = 100 x Light
Credit: Hubble Space Telescope SN 1994D


Light = Entire Galaxy of Stars
Blast Energy = 100 x Light
But are they standard candles?
Credit: Hubble Space Telescope SN 1994D

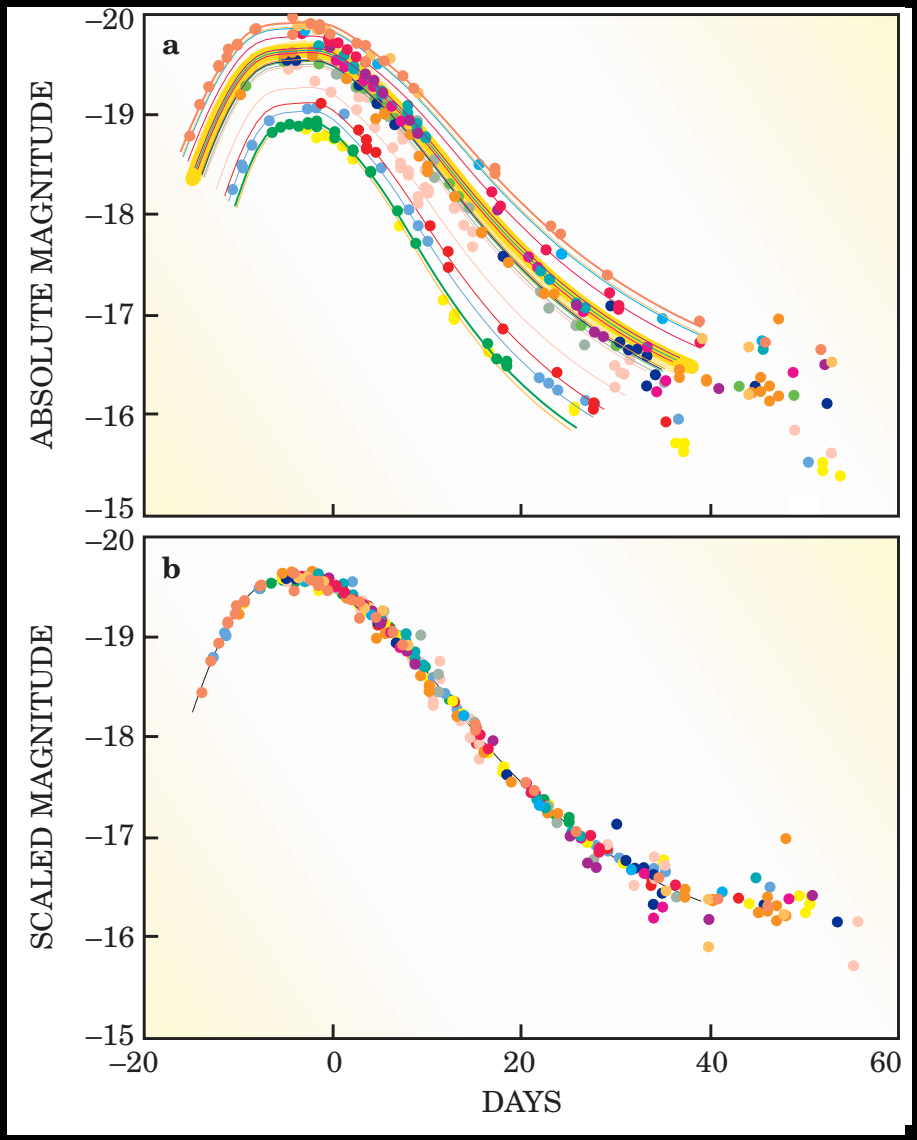
Distance Ladder



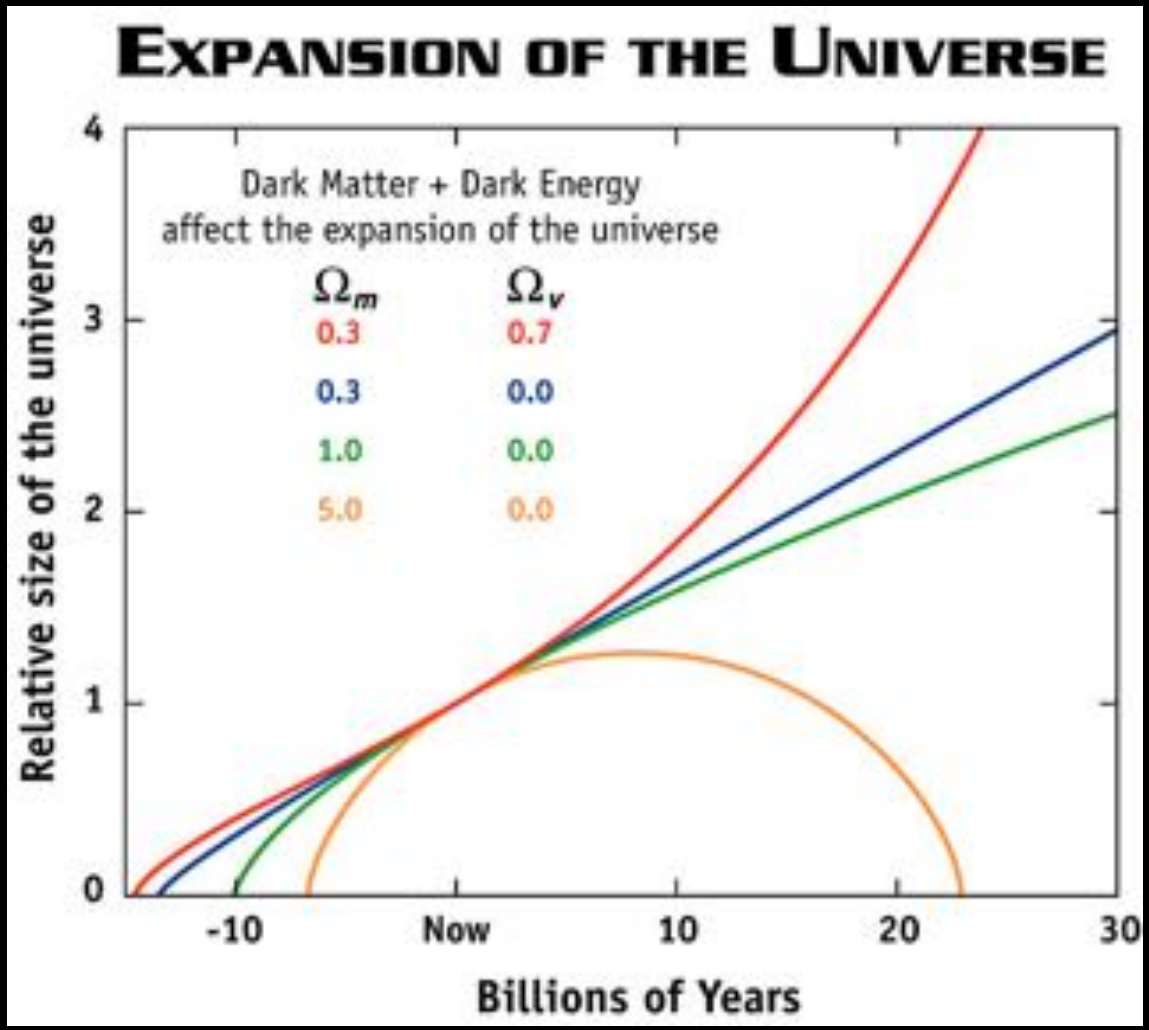
Standard Candle…sort of



Why?

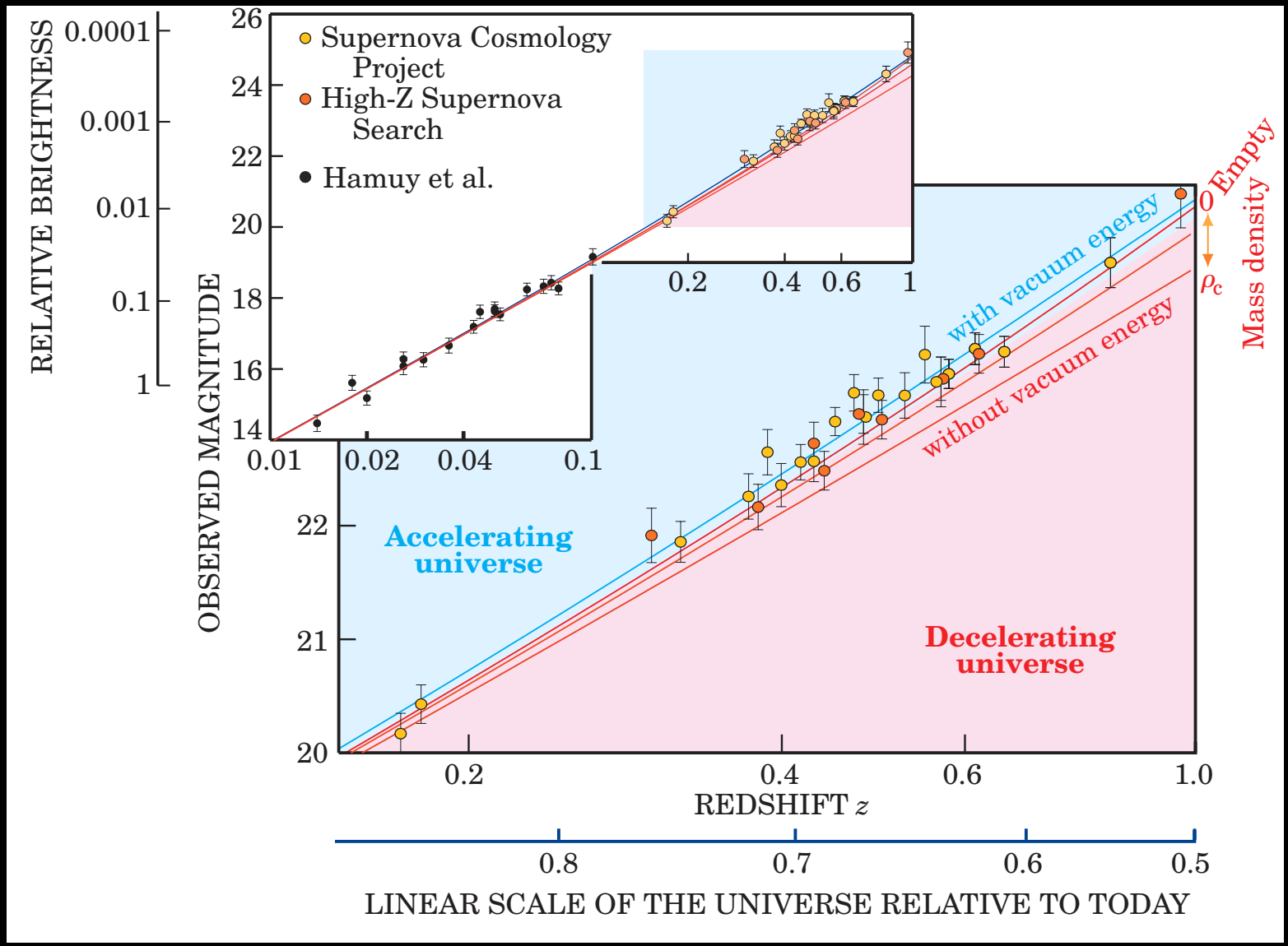

a
b
ABSOLUTE MAGNITUDE
SCALED MAGNITUDE
–20
–19
–18
–17
–16
–15
–20
0
20
40
60
DAYS

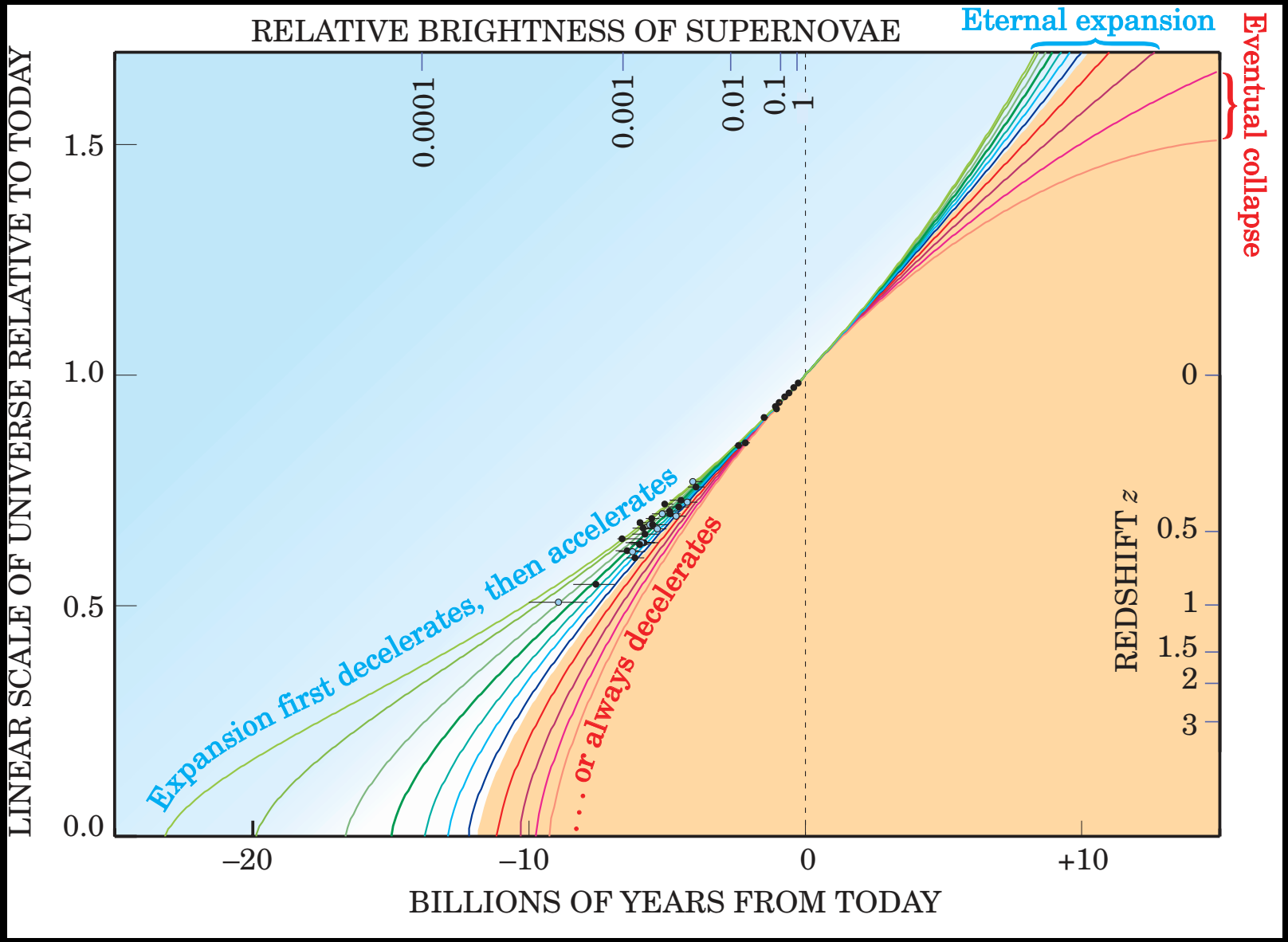
Which Evolutionary Track are we on?



Two teams

Came to an amazing answer!


RELATIVE BRIGHTNESS
0.0001
0.001
0.01
0.1
1
OBSERVED MAGNITUDE
26
24
22
20
18
16
14
Supernova Cosmology Project
High-Z Supernova Search
Hamuy et al.
0.01
0.02
0.04
0.1
0.2
0.4
0.6
1
with vacuum energy
without vacuum energy
0 Empty
ρ_c
Mass density
Accelerating universe
Decelerating universe
22
21
20
0.2
0.4
0.6
1.0
REDSHIFT z
0.8
0.7
0.6
0.5
LINEAR SCALE OF THE UNIVERSE RELATIVE TO TODAY


RELATIVE BRIGHTNESS OF SUPERNOVAE
Eternal expansion
Eventual collapse
0.0001
0.001
0.01
0.1
1
LINEAR SCALE OF UNIVERSE RELATIVE TO TODAY
1.5
1.0
0.5
0.0
Expansion first decelerates, then accelerates
. . . or always decelerates
REDSHIFT z
0
0.5
1
1.5
2
3
–20
–10
0
+10
BILLIONS OF YEARS FROM TODAY

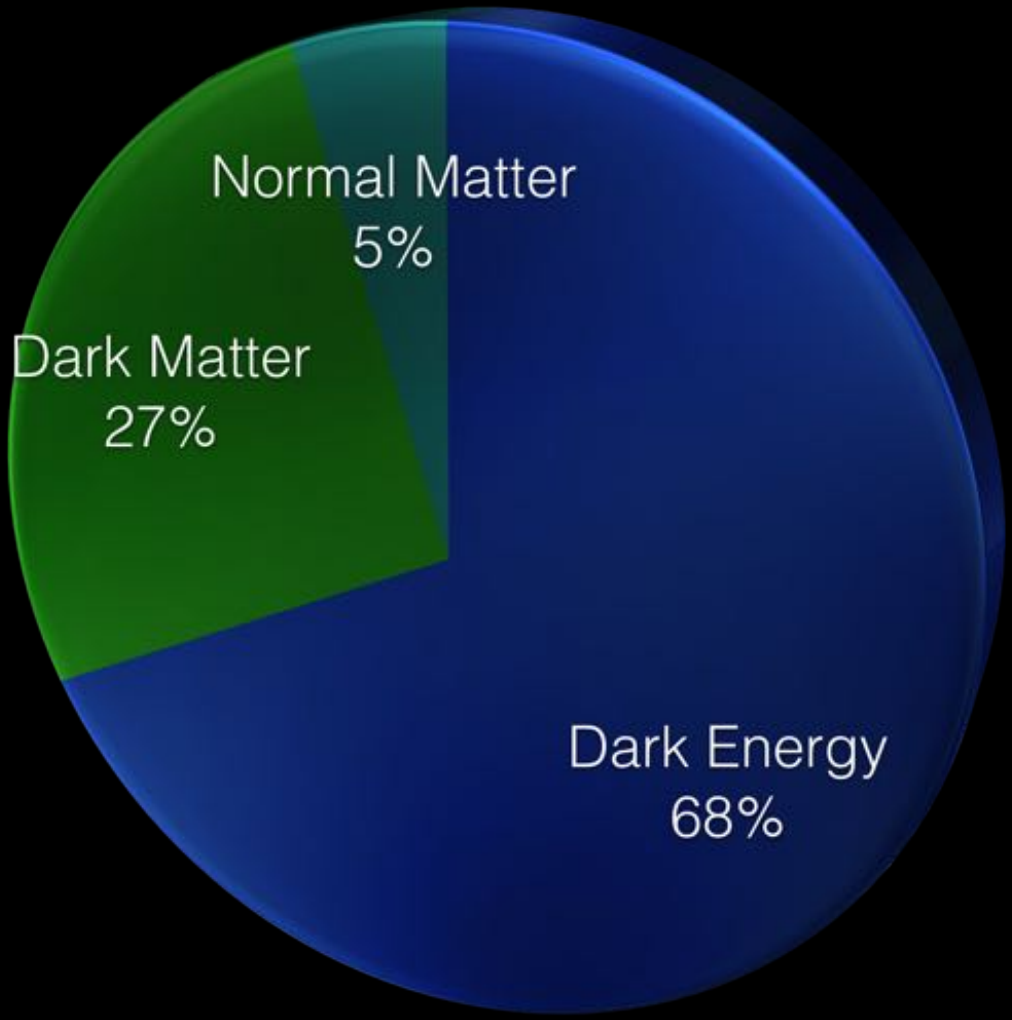
The Universe is not decelerating.
It's accelerating!

What?!!

Something is pushing the Universe apart

…Dark Energy?

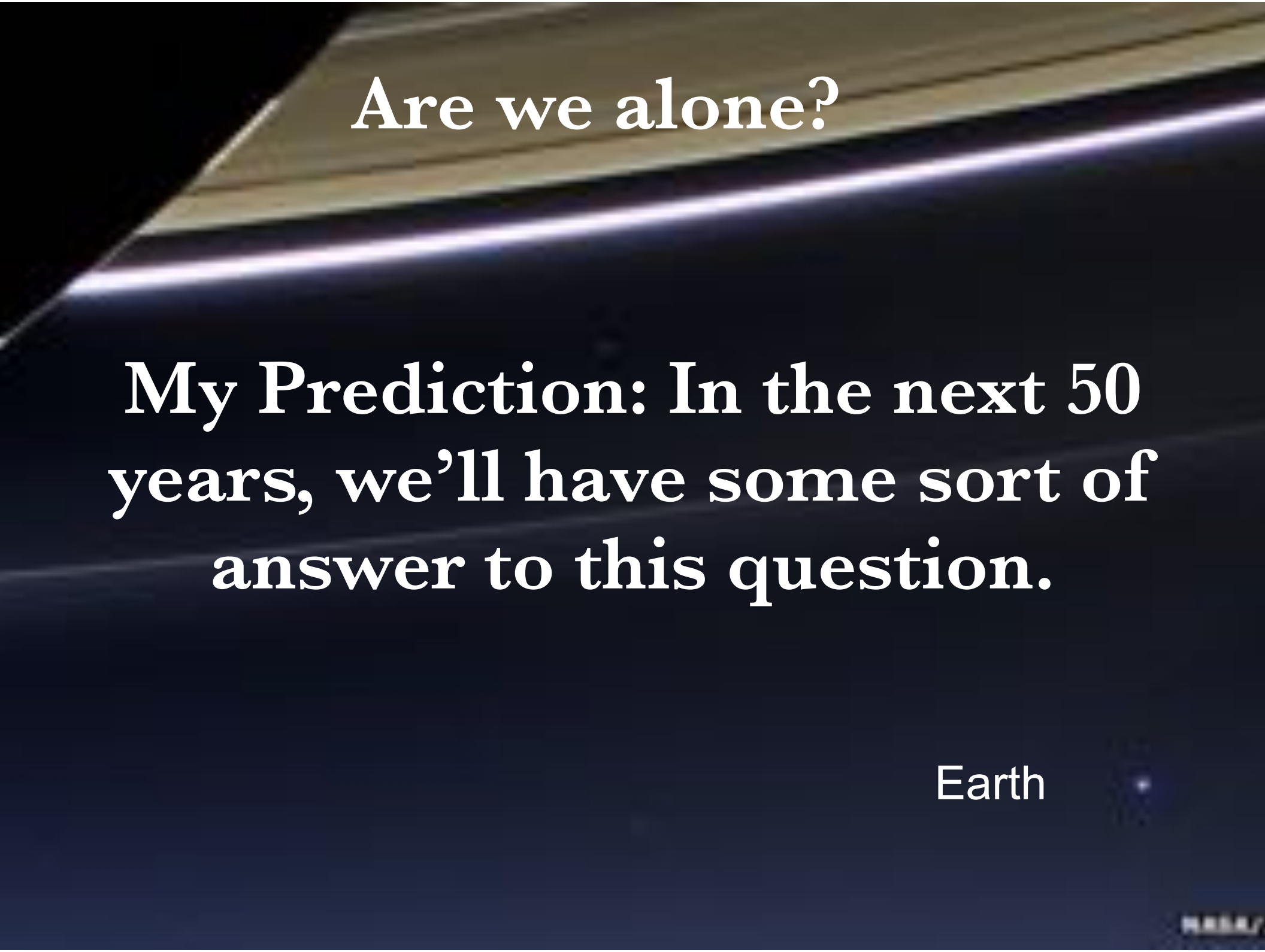
We Live in a Strange Universe



Nobel Prize #3

Are we alone?

Image by Cassini Spacecraft
from Saturn

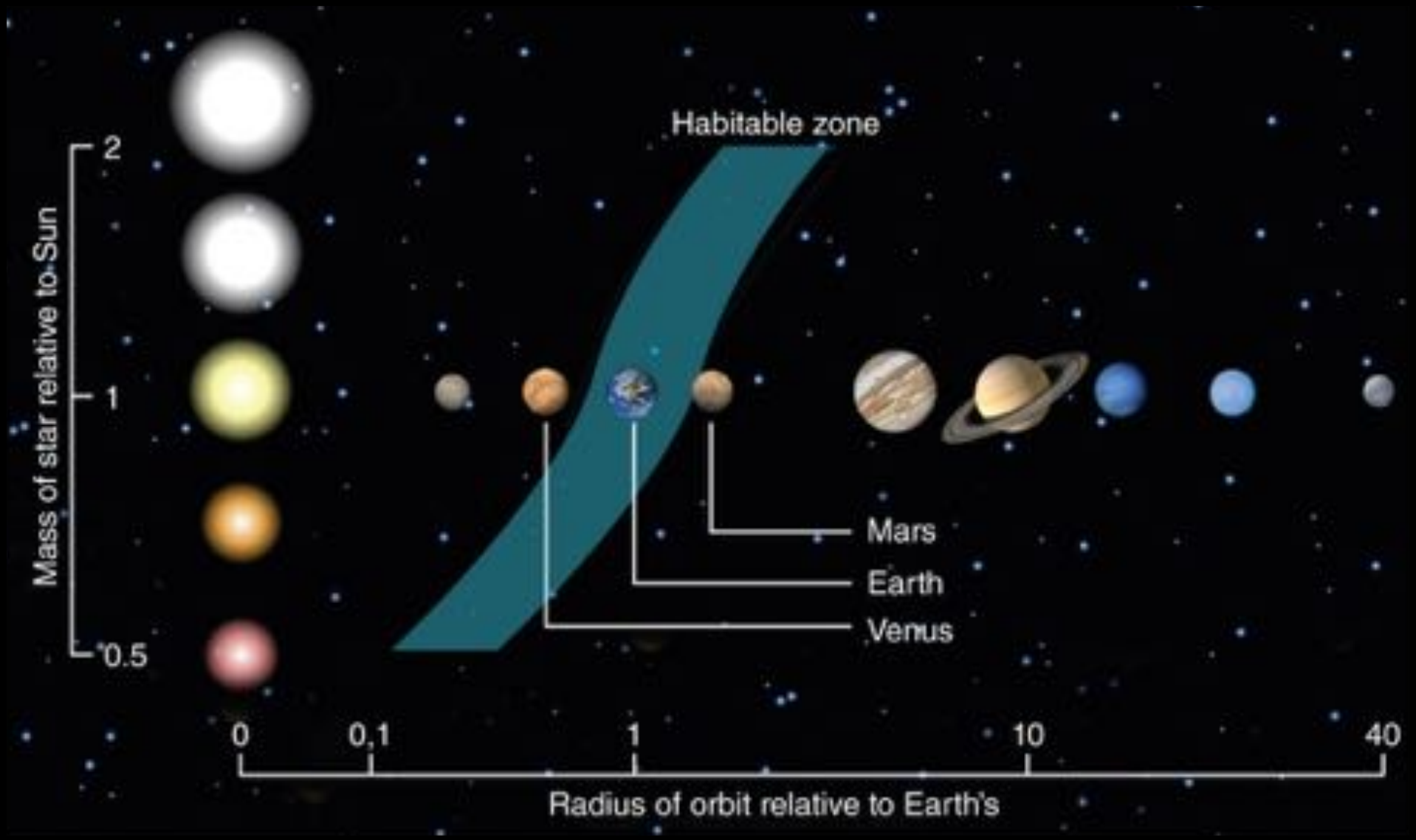

Are we alone?
My Prediction: In the next 50 years, we'll have some sort of answer to this question.
Earth


Are we alone?
Life in the Universe
Earth

The one place that we know of that has life

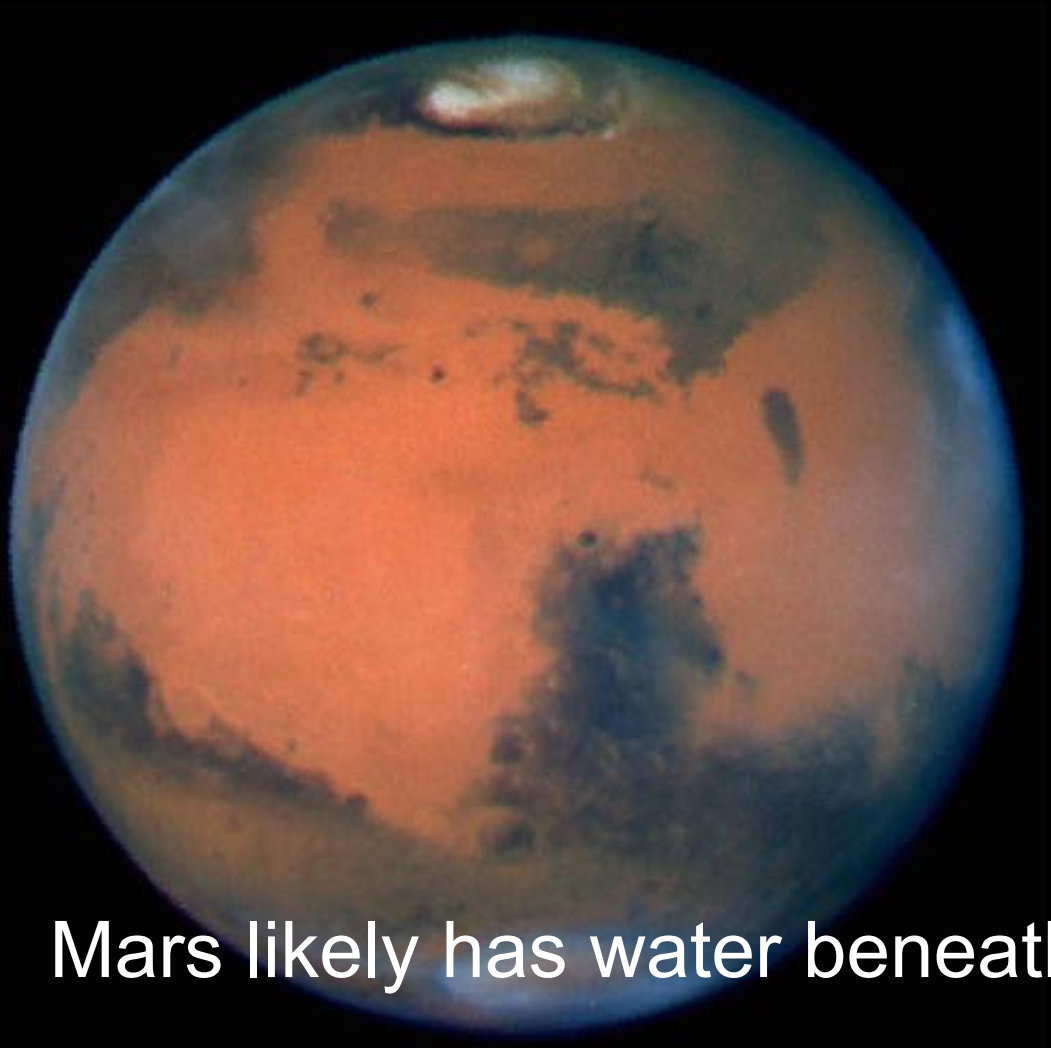
Where else might we find microbial life?

Habitable Zones



Presence of Liquid water?

Subterranean Mars

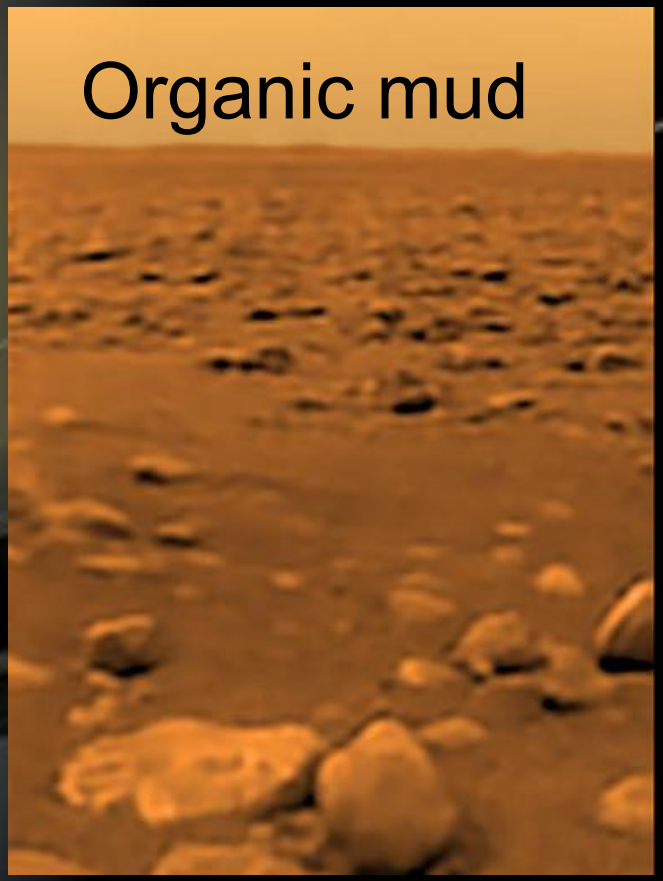


Mars likely has water beneath the surface.

Moons around Giant Planets

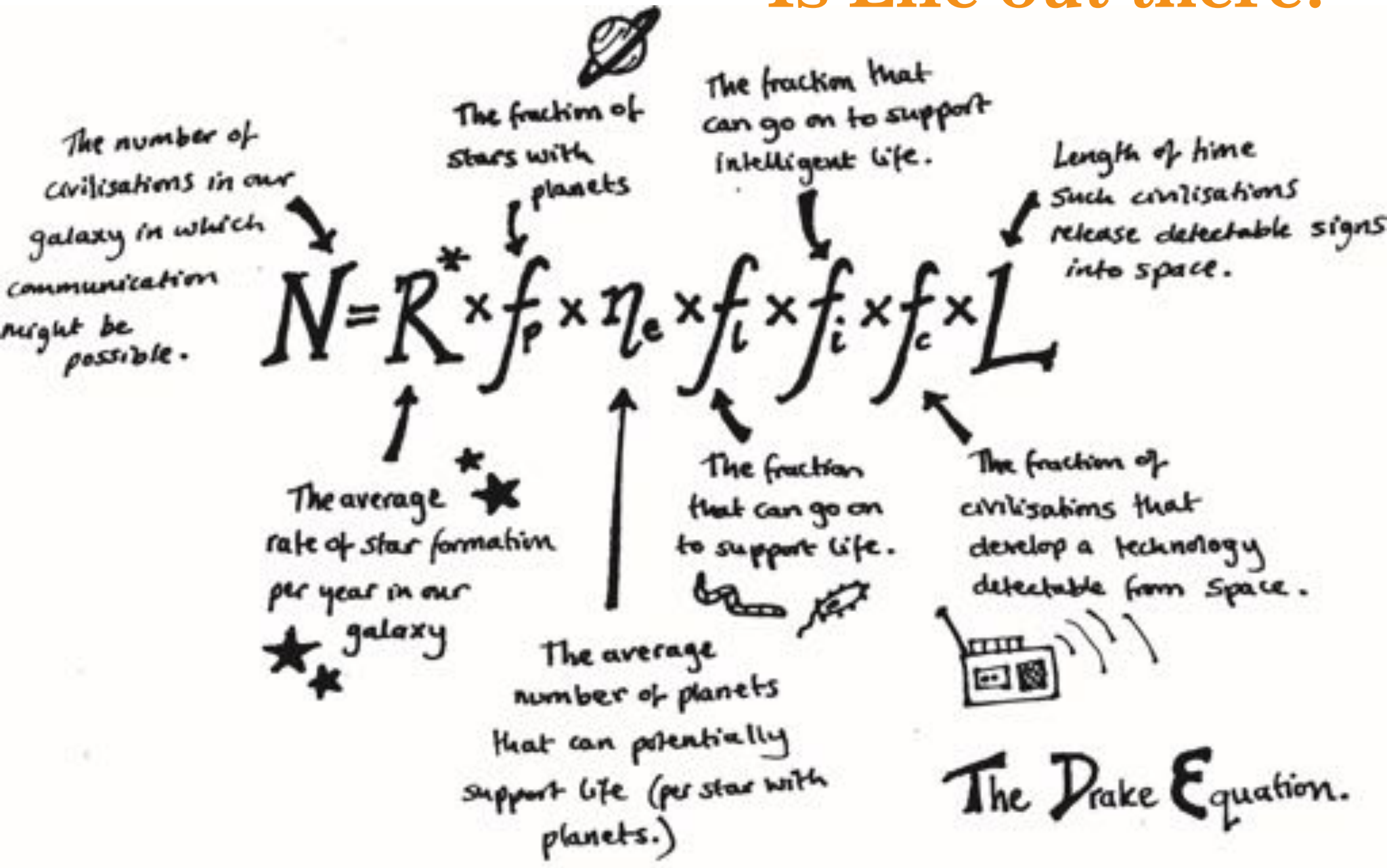
Europa likely has a liquid ocean

Moons around Giant Planets



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

Is Life out there?

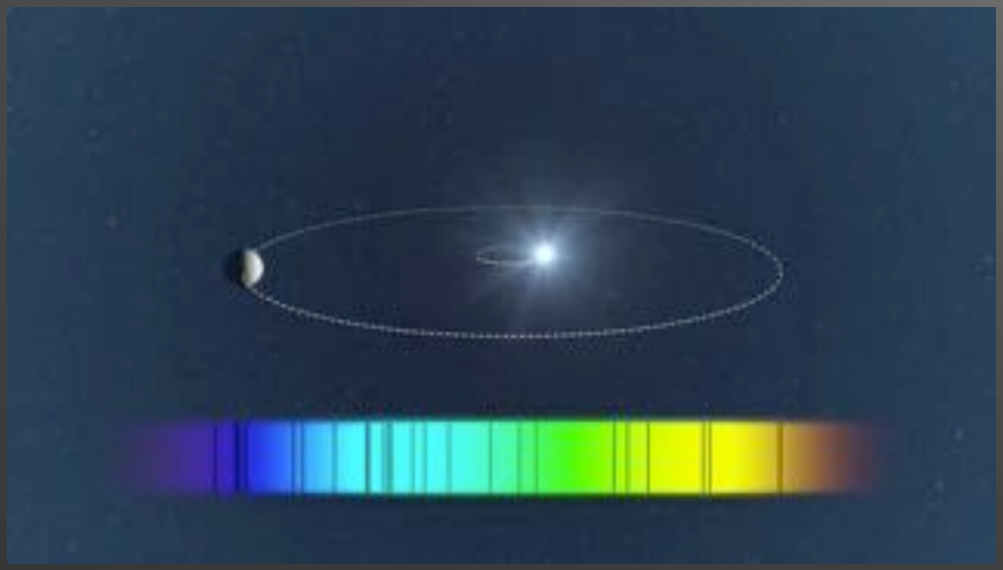


Fraction of stars with planets

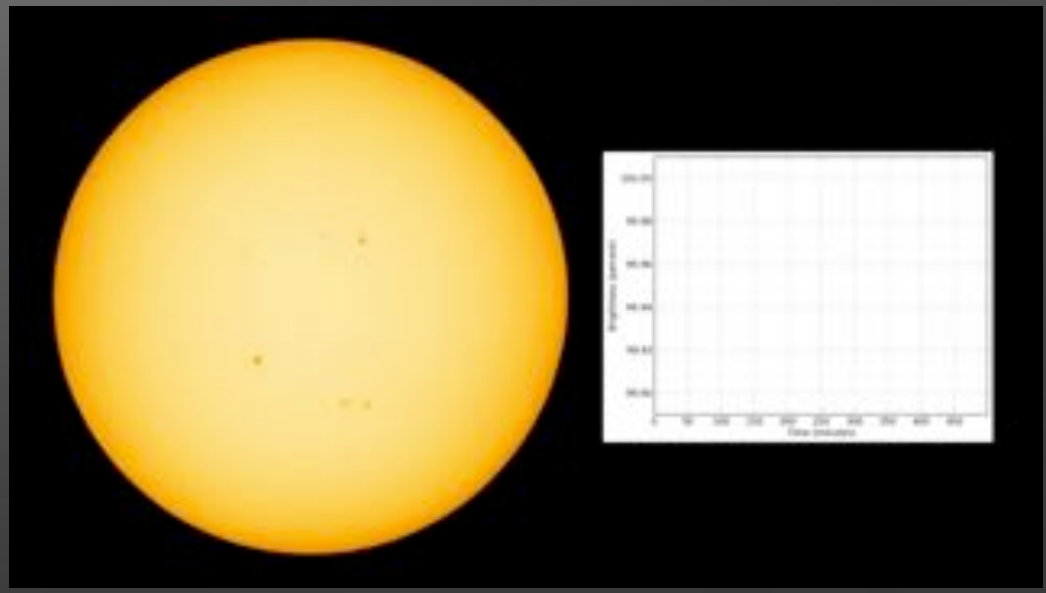
How do we find the planets around other stars?

Exoplanet Hunting

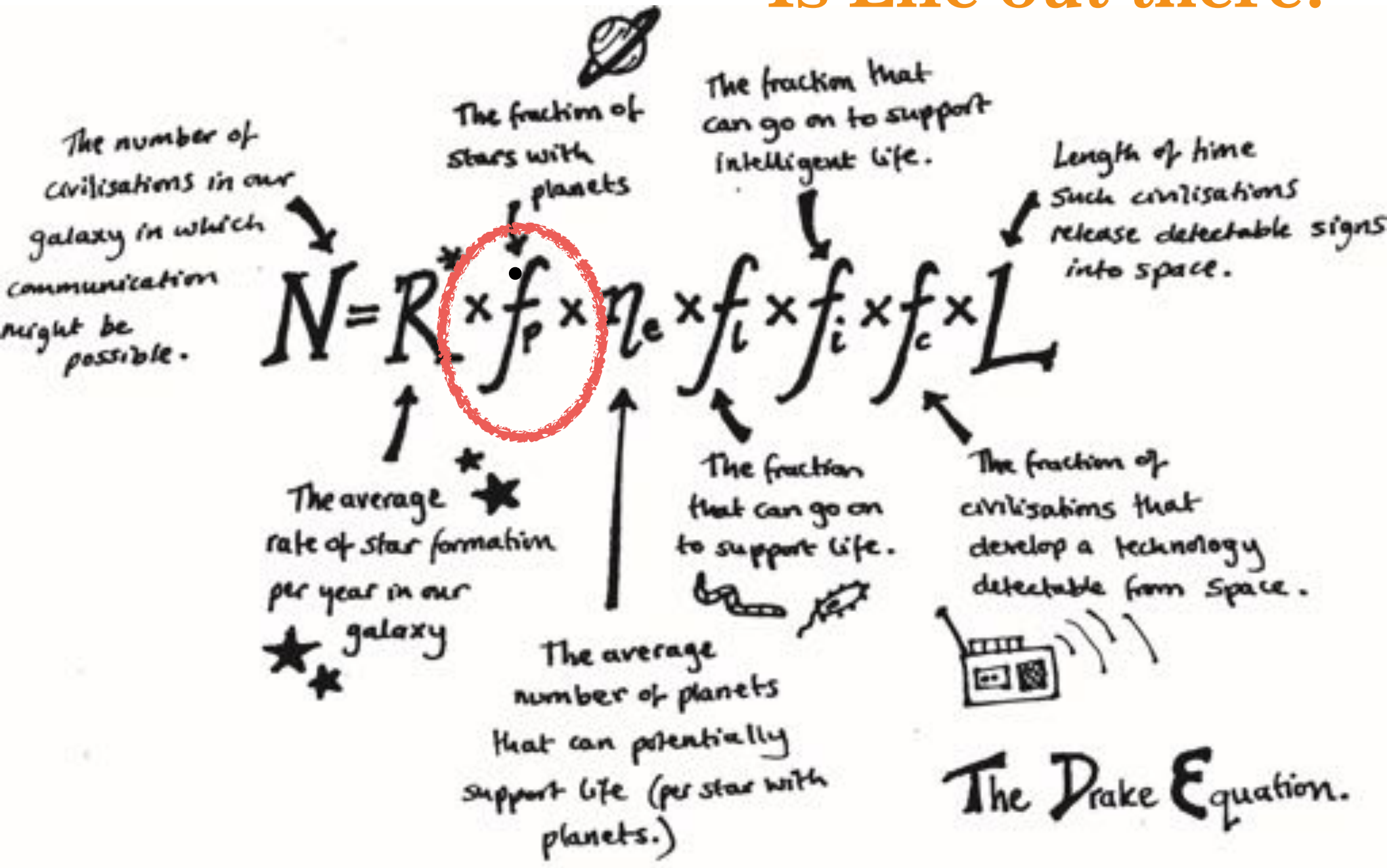
Radial Velocity or
Doppler Method



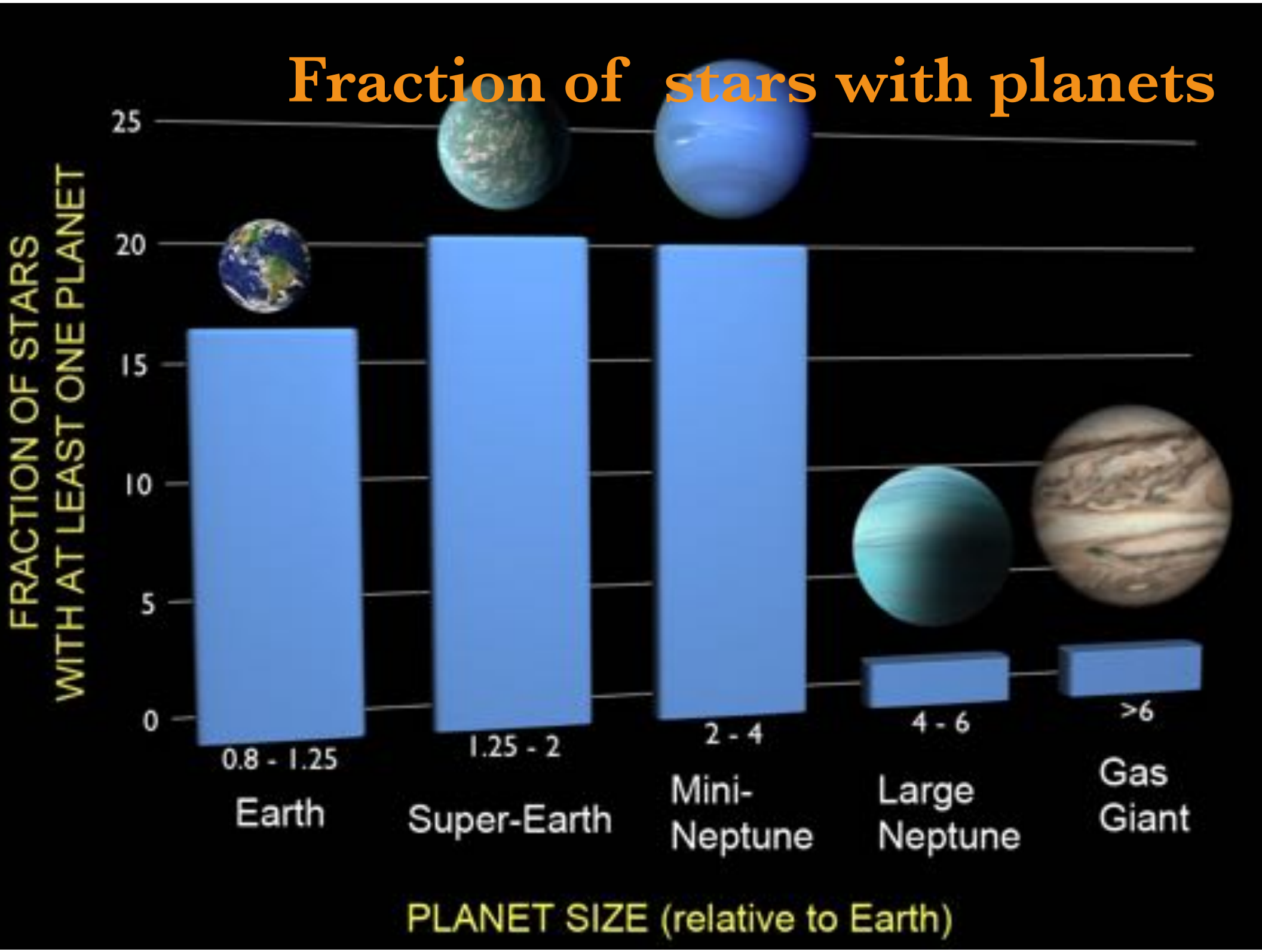
Transit Method



Is Life out there?



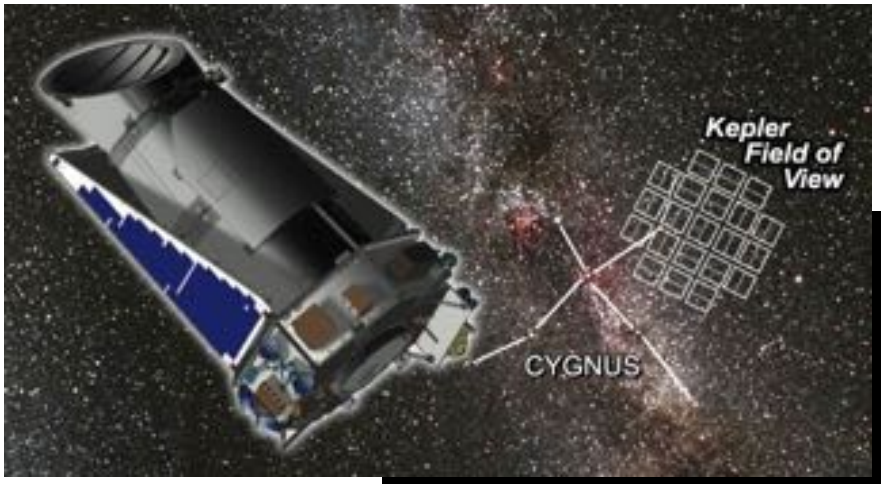
Fraction of stars with planets



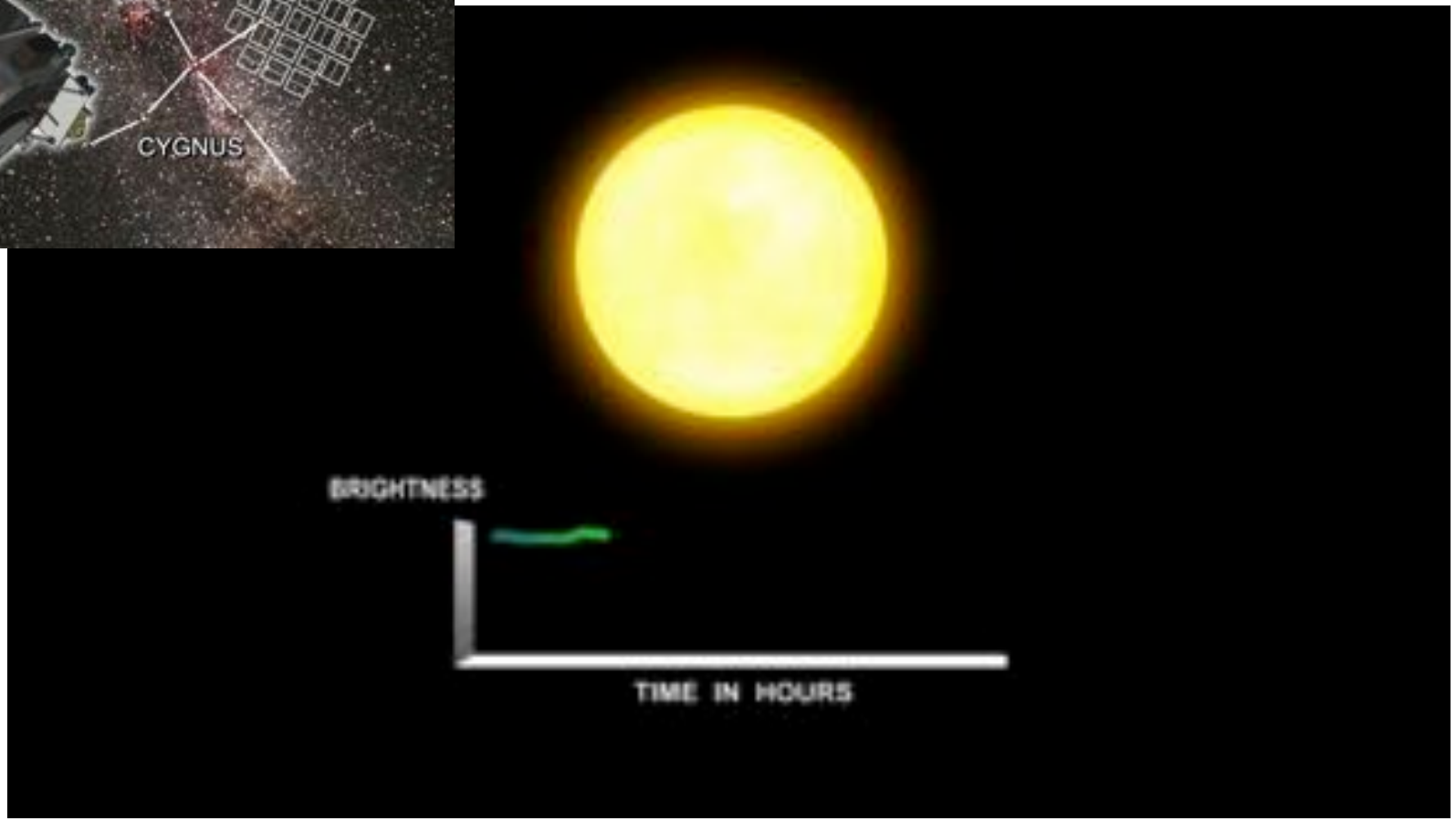
Is Life out there?

η_e = 5%, roughly

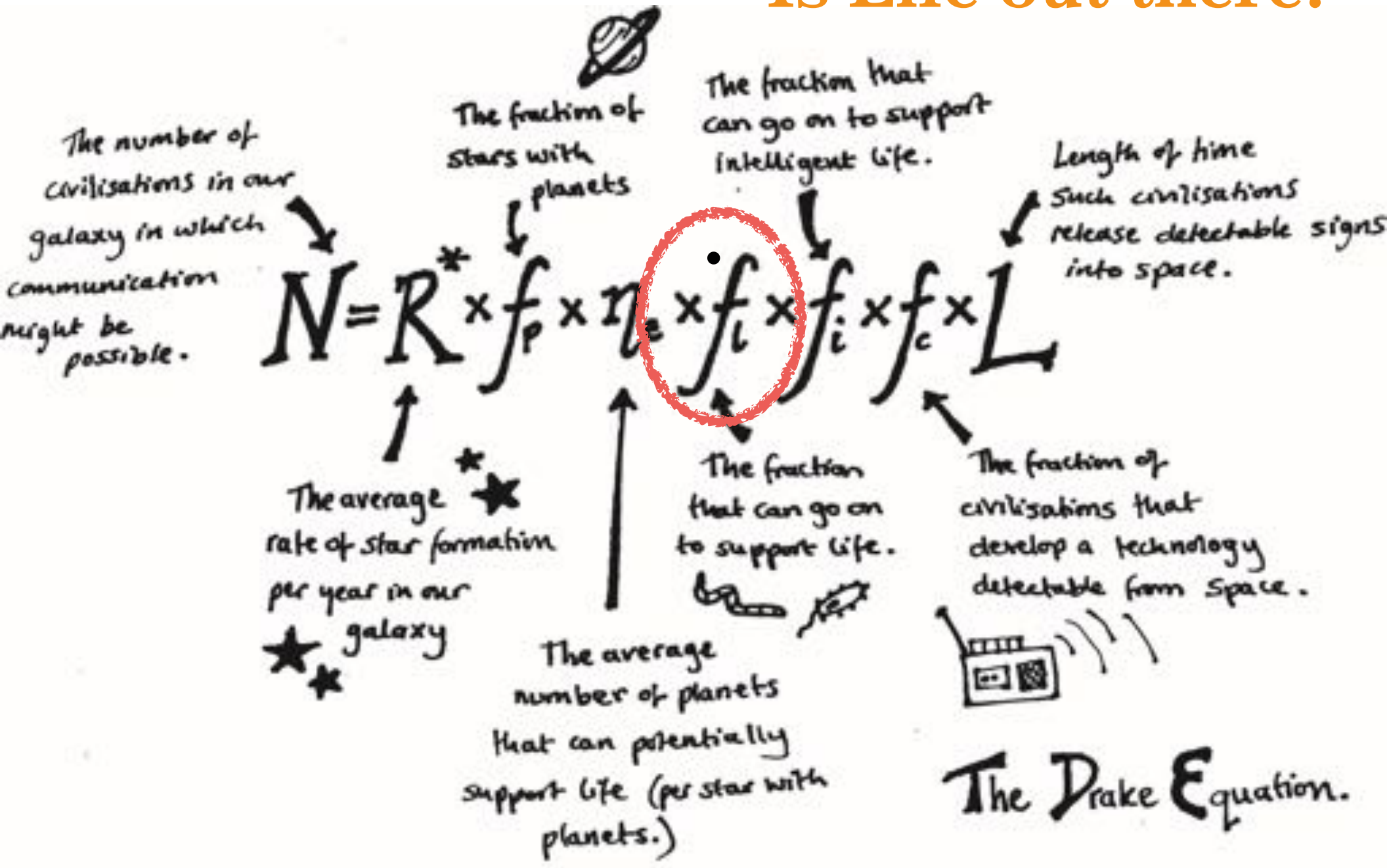
Is Life out there?



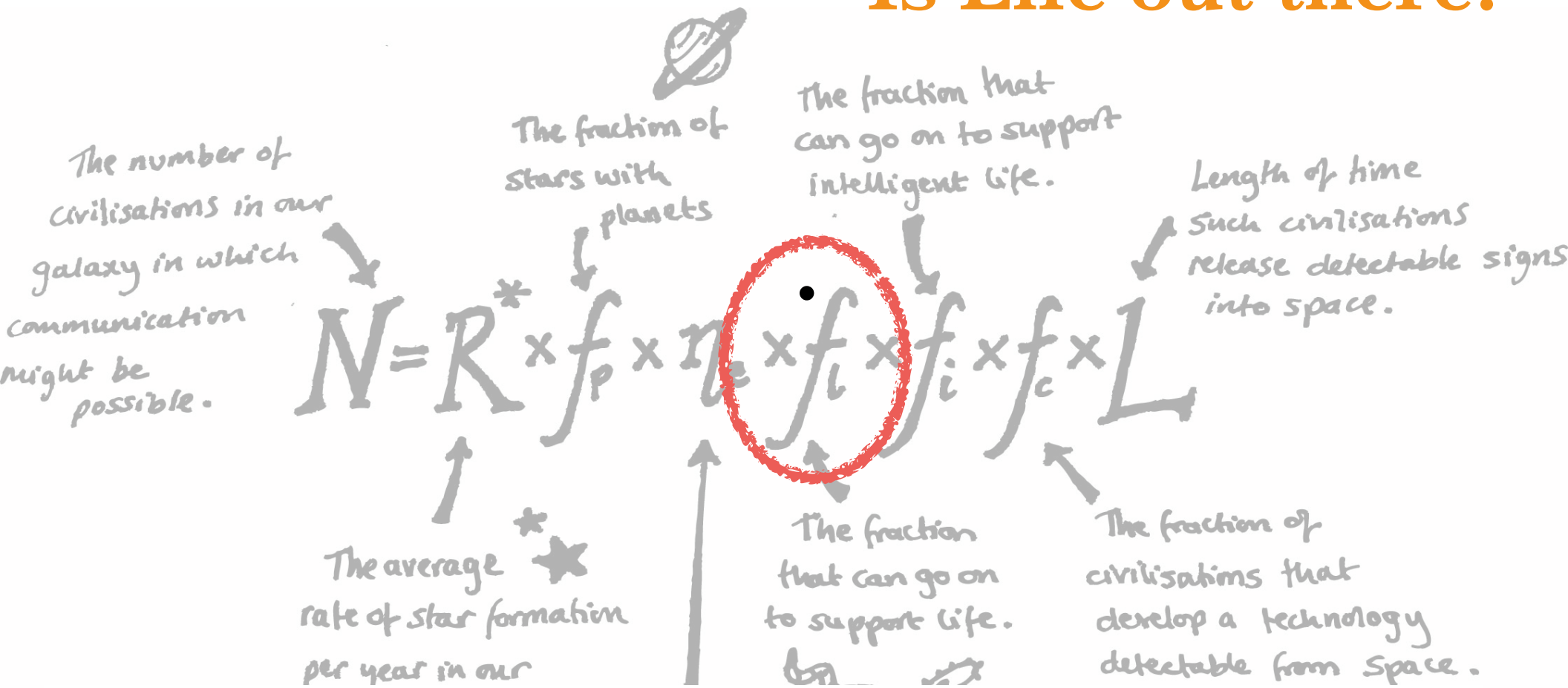
Kepler Space Craft



Is Life out there?



Is Life out there?

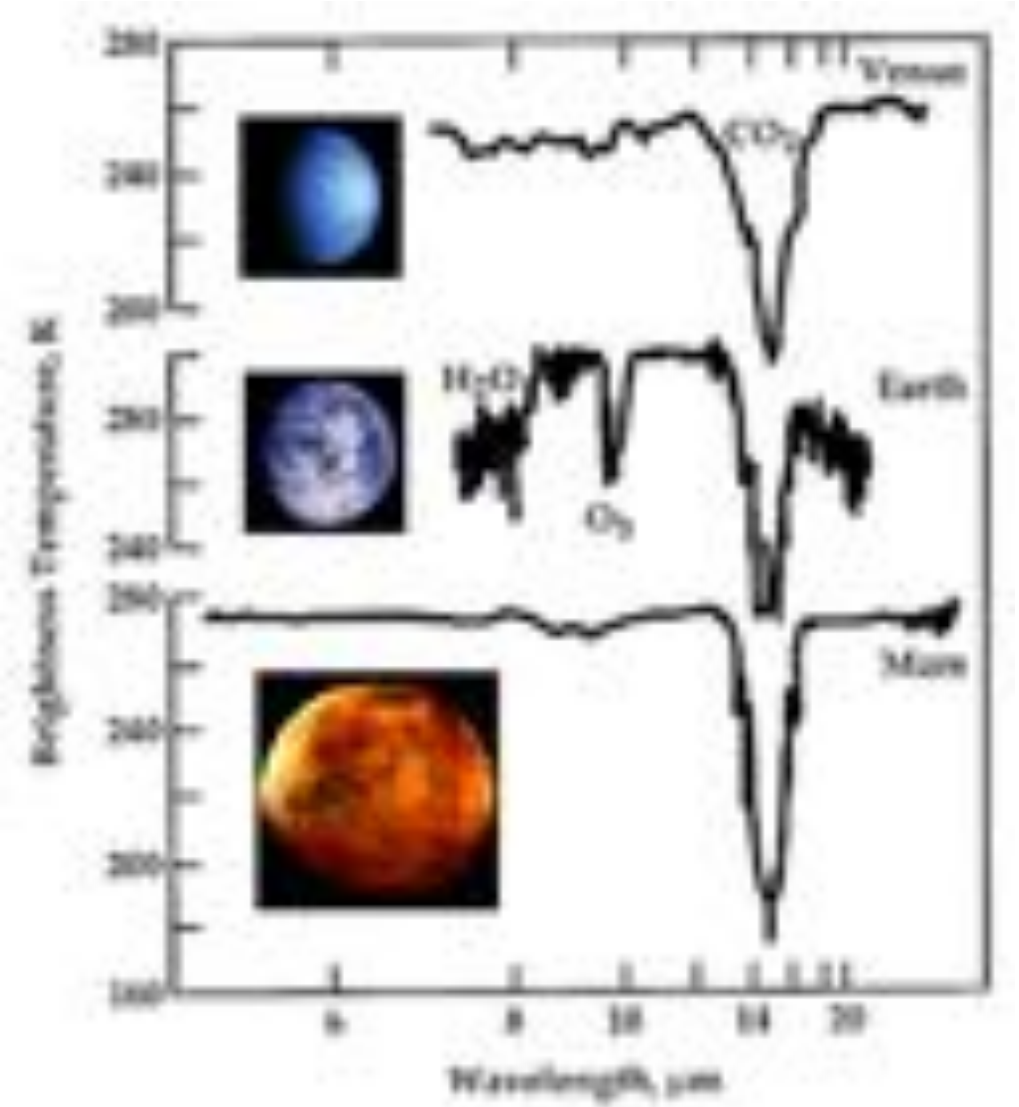


How would you measure the fraction of planets that have life?

support life (per star
planets.)

The Drake Equation.

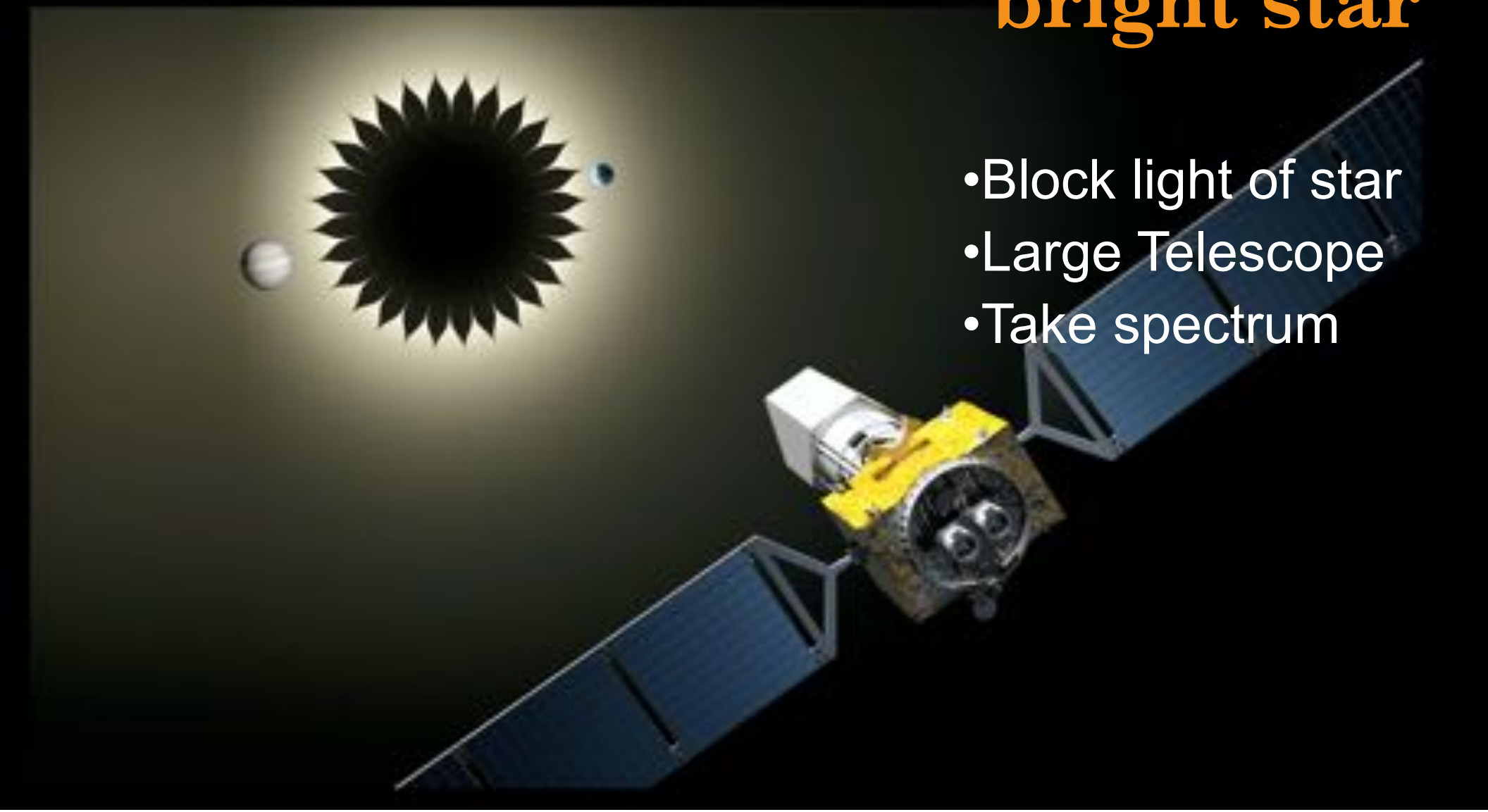
Is Life out there?



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.