



Cosmology, Meaning, and Human Destiny

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NCCC Radio Club
July 25, 2020

A fly-through toward Orion, through the Galaxy, and into intergalactic space



Courtesy Brent Tully, Institute for Astronomy, University of Hawaii

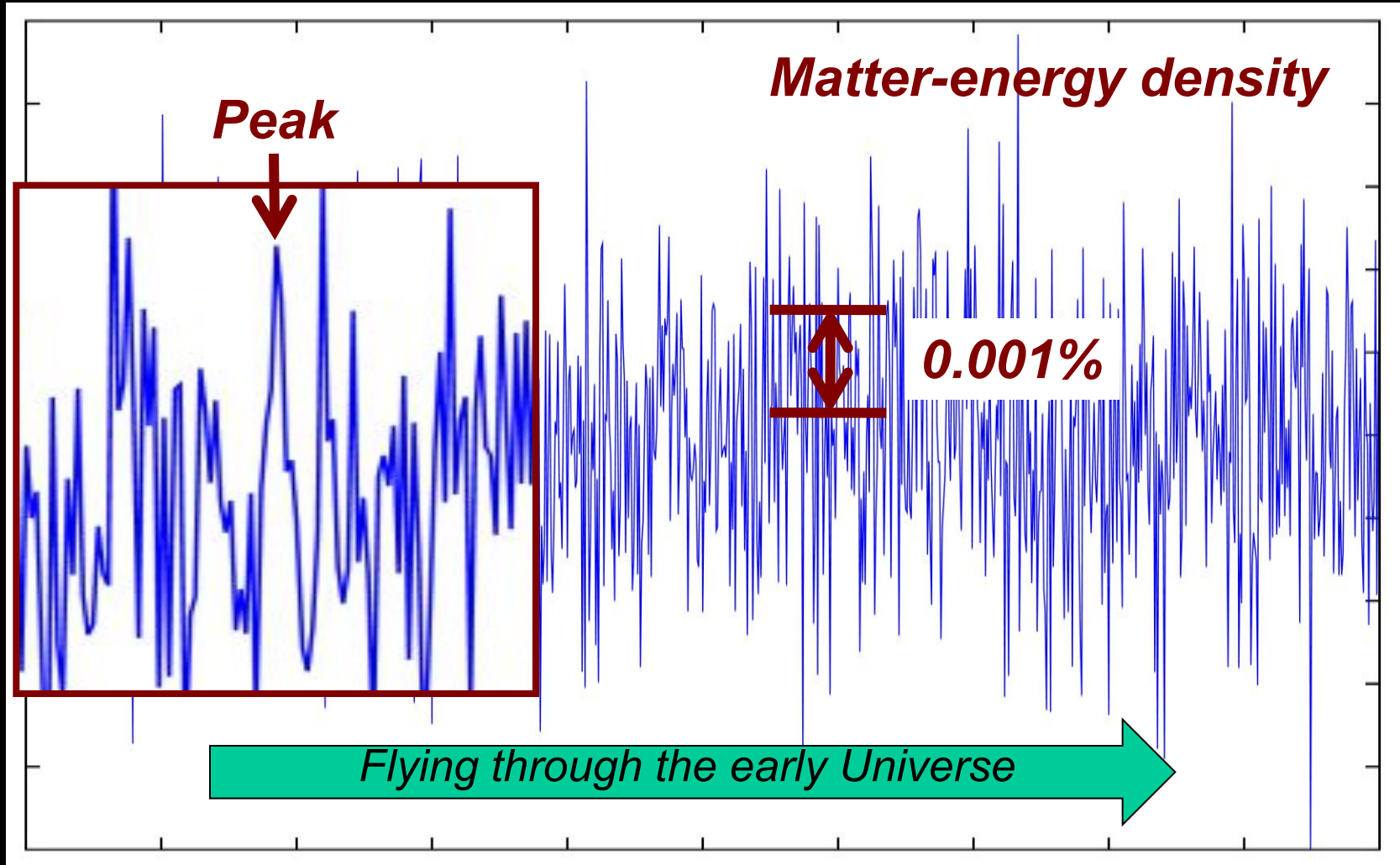
14 Billion Years Ago

The Early \wedge Universe: Almost smooth but with density fluctuations at about 1 part in 100,000

Time = 10^{-35} sec

Temp = 10^{27} degrees

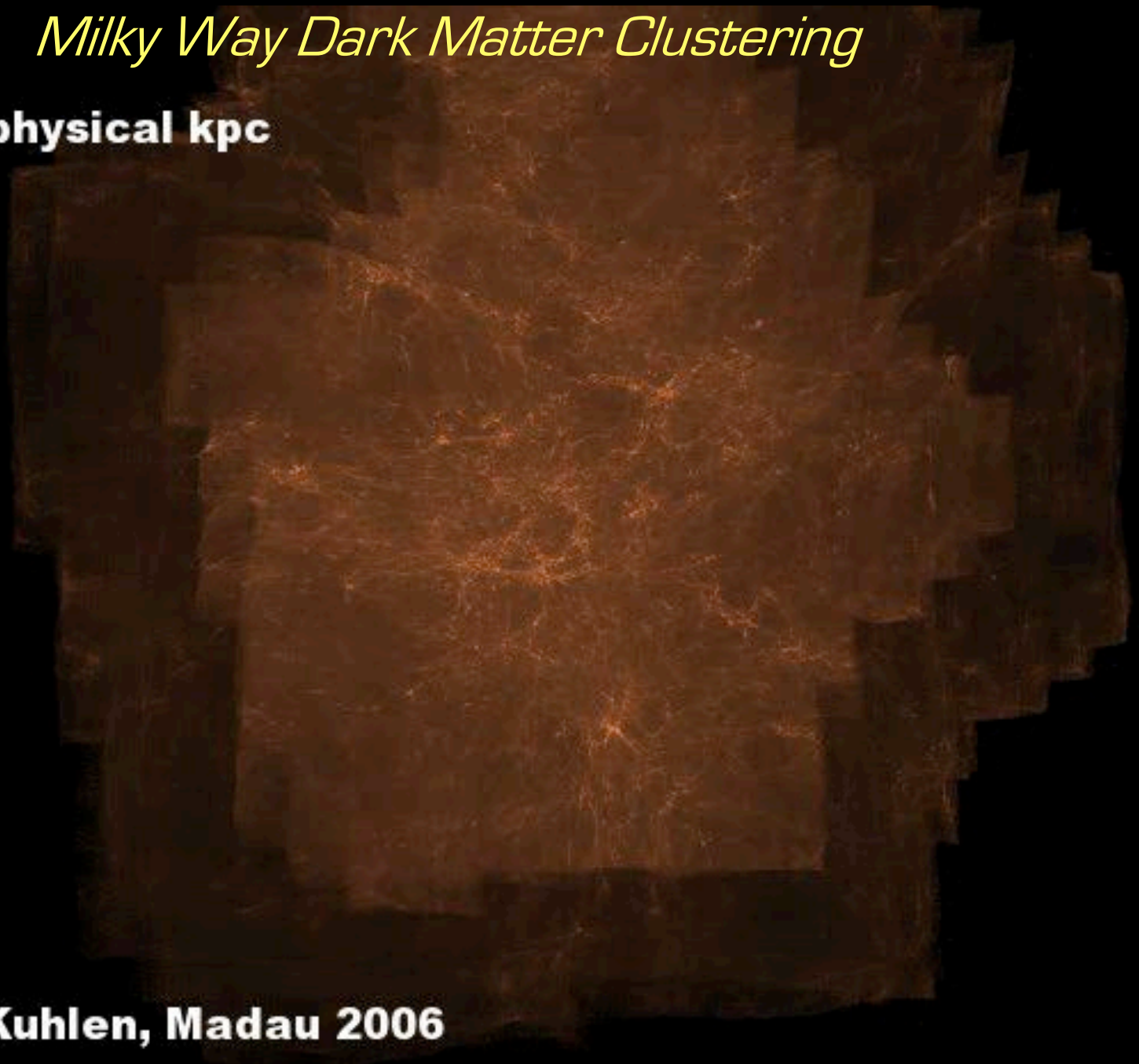
Density Fluctuations in the Early Universe



$z=11.9$

Milky Way Dark Matter Clustering

800 x 600 physical kpc



Diemand, Kuhlen, Madau 2006

How do we know that this picture is right?

Three tests:

- *The properties of galaxies today*
- *The cosmic microwave background radiation*
- *Looking back along the “arrow of time” in the Hubble Ultradeep Field*

Galaxies exhibit both disks and spheroids, like the models

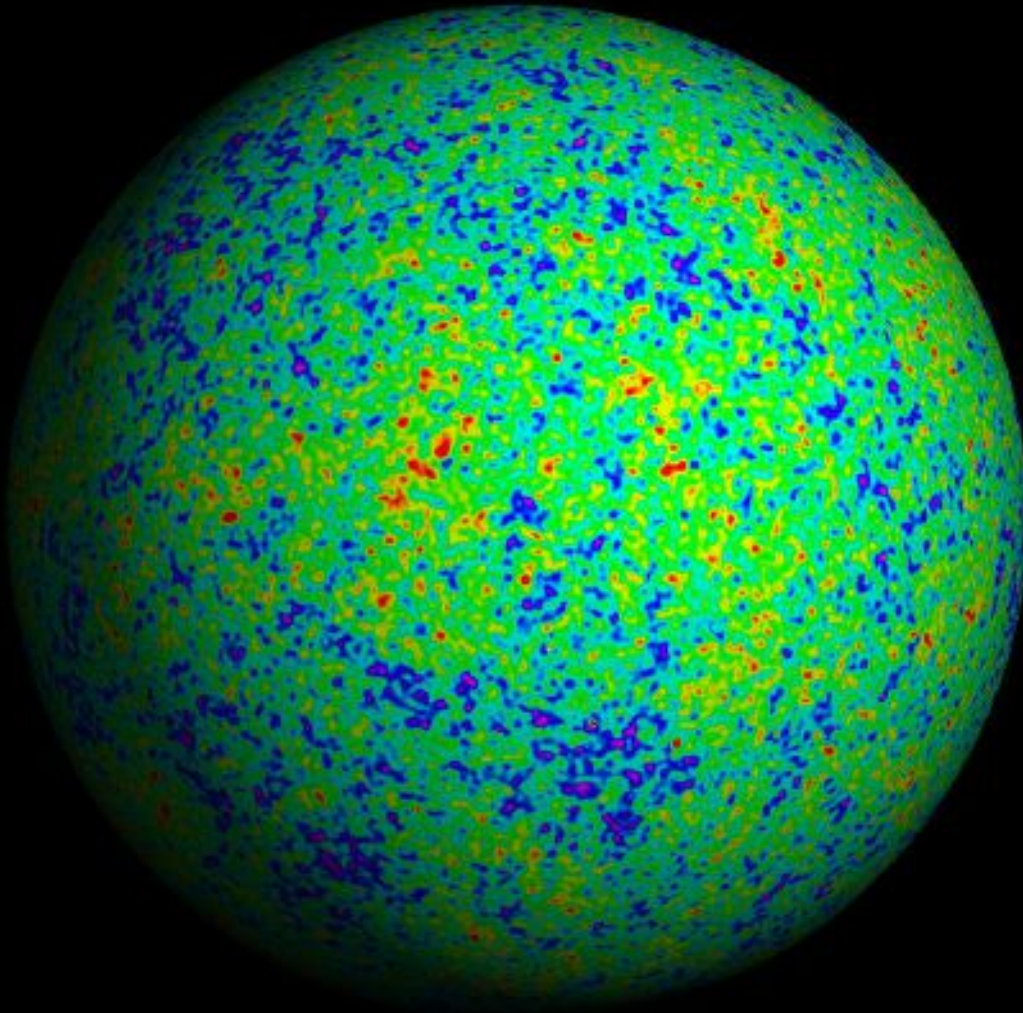
MOSTLY DISK...

MOSTLY SPHEROID...





COSMIC MICROWAVE BACKGROUND FROM THE BIG BANG

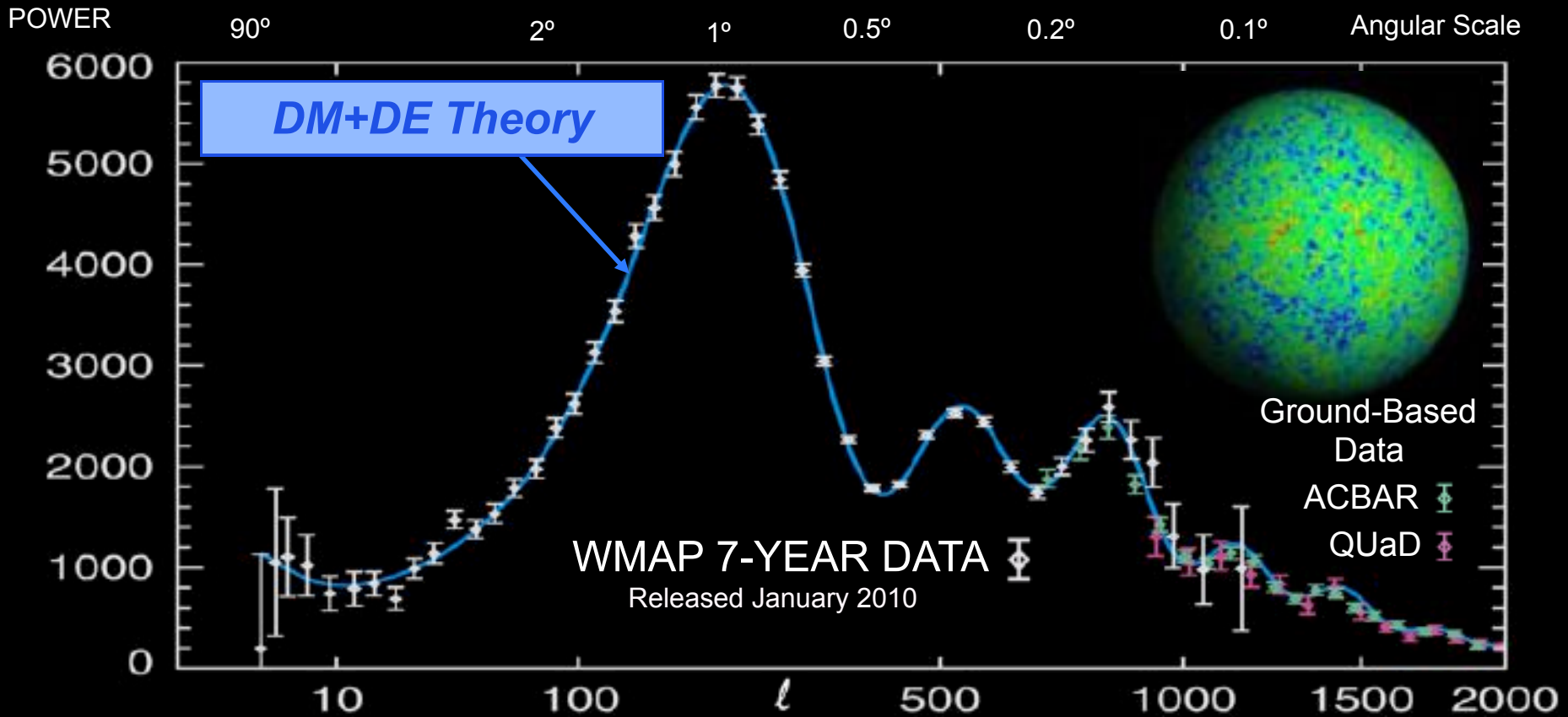


Ripples in the CMB intensity on the celestial sphere

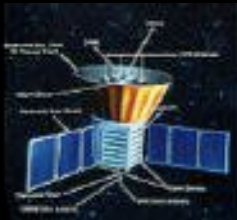
The celestial sphere as mapped by the WMAP satellite, portrayed from the outside.

The Milky Way is at the center of this sphere.

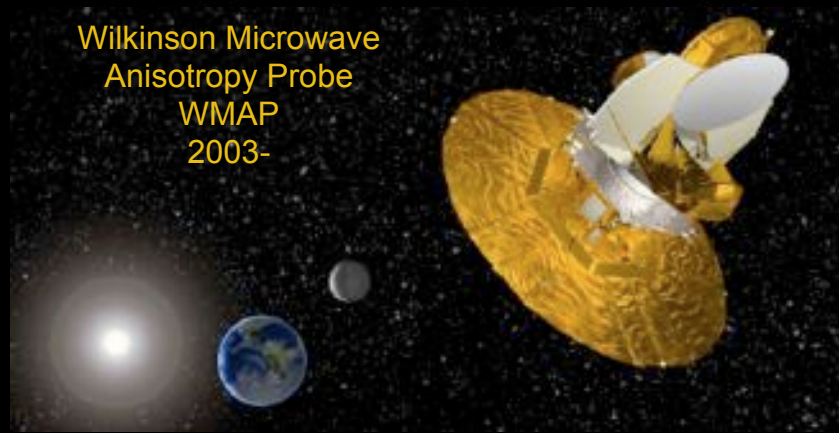
CMB CONFIRMS INFLATION + DARK MATTER + DARK ENERGY



Cosmic
Background
Explorer
COBE
1992



Wilkinson Microwave
Anisotropy Probe
WMAP
2003-



ACBAR

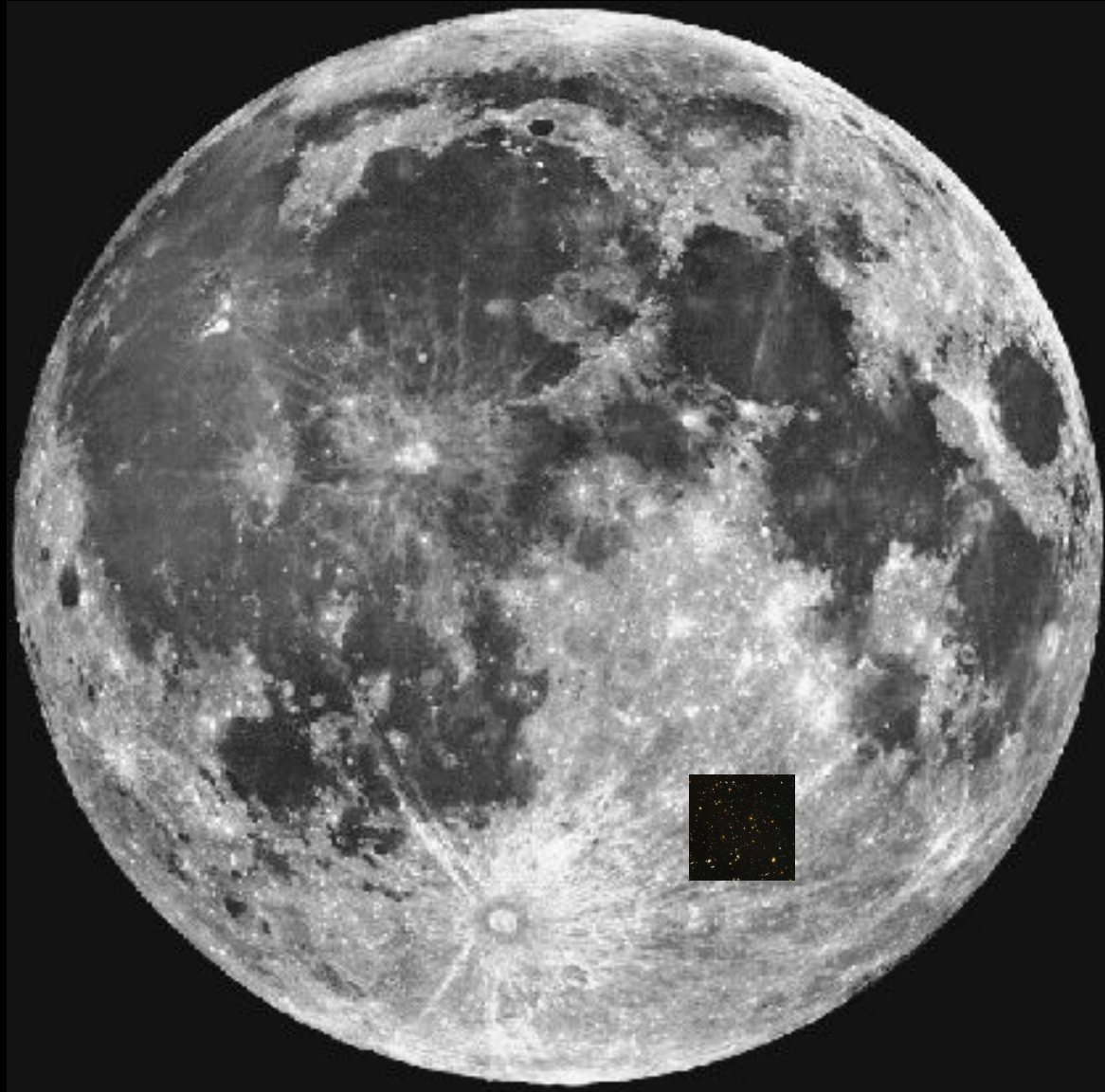


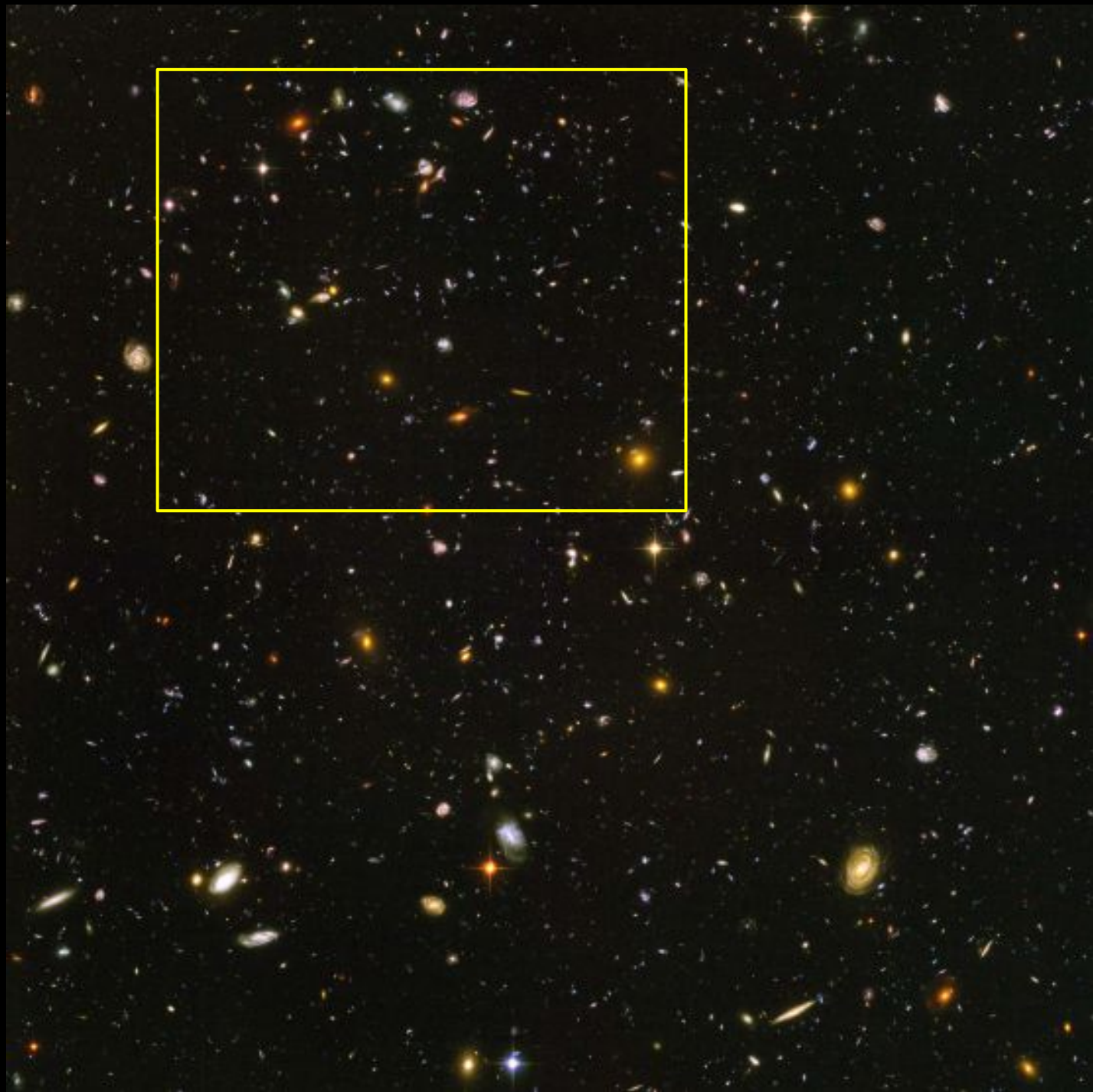
QUaD

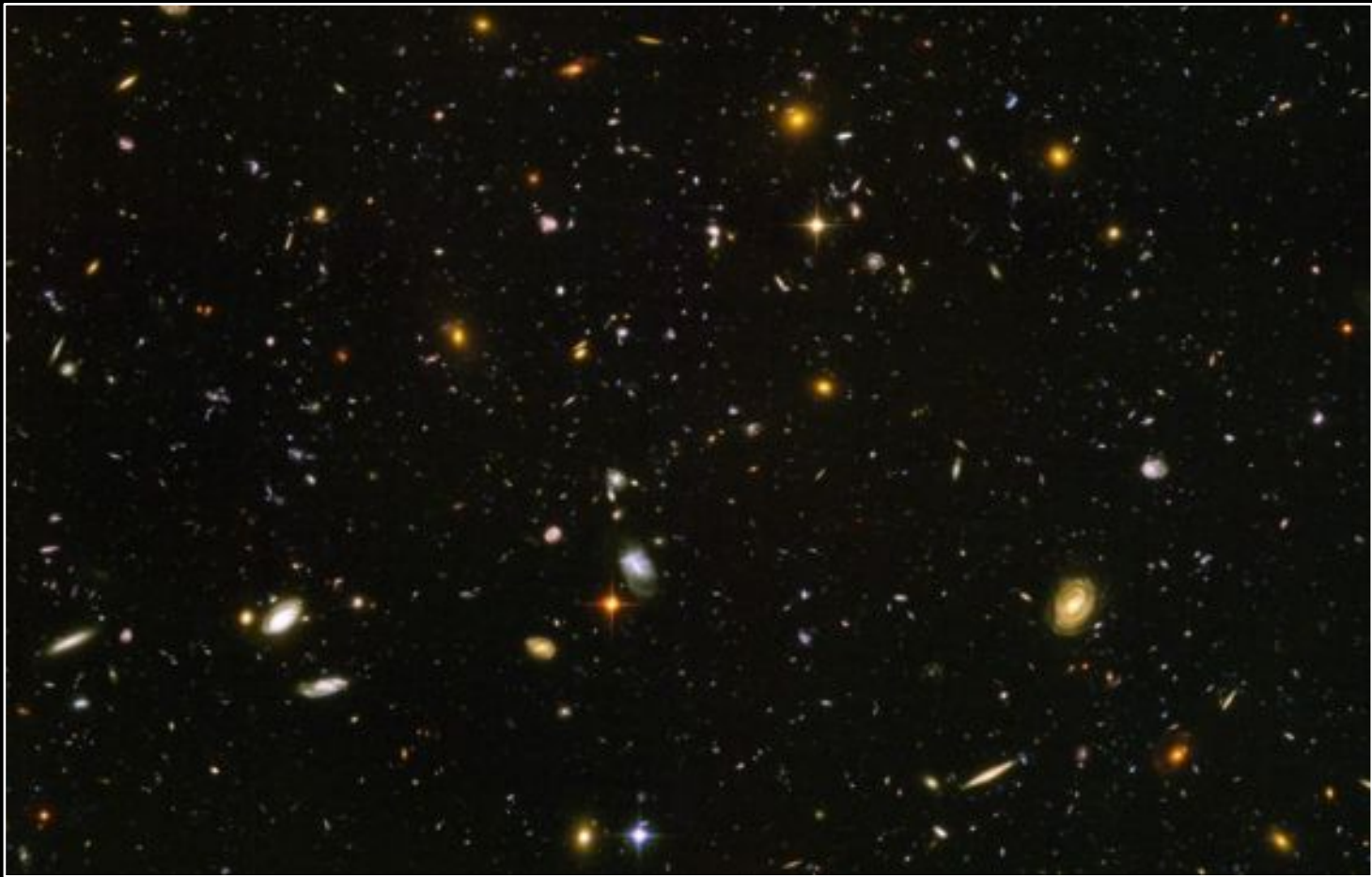


Joel
Primack

The Hubble Ultradeep Field to Scale



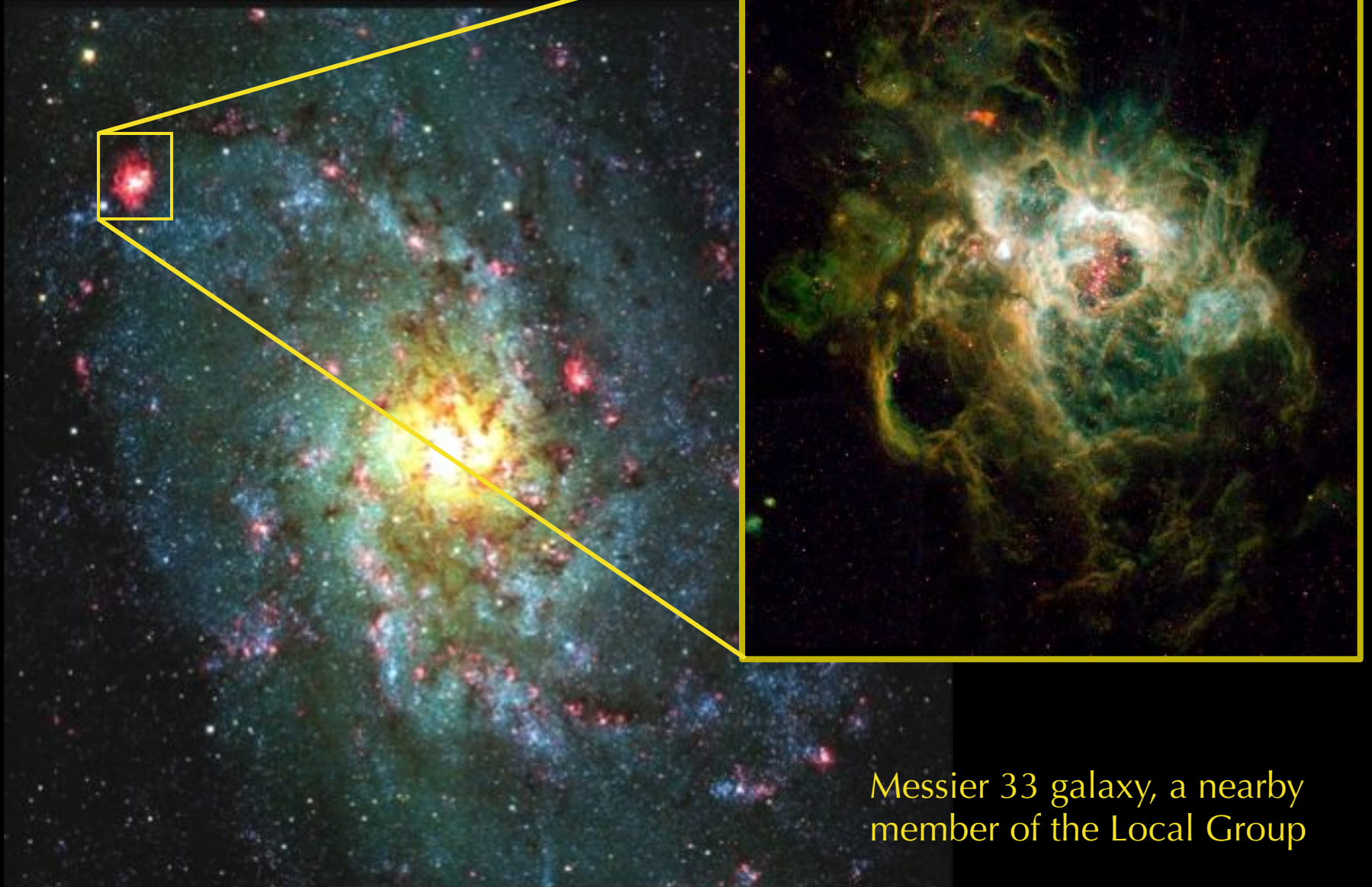




COSMOLOGY

FINDING OUT YOU REALLY JUST DON'T MATTER

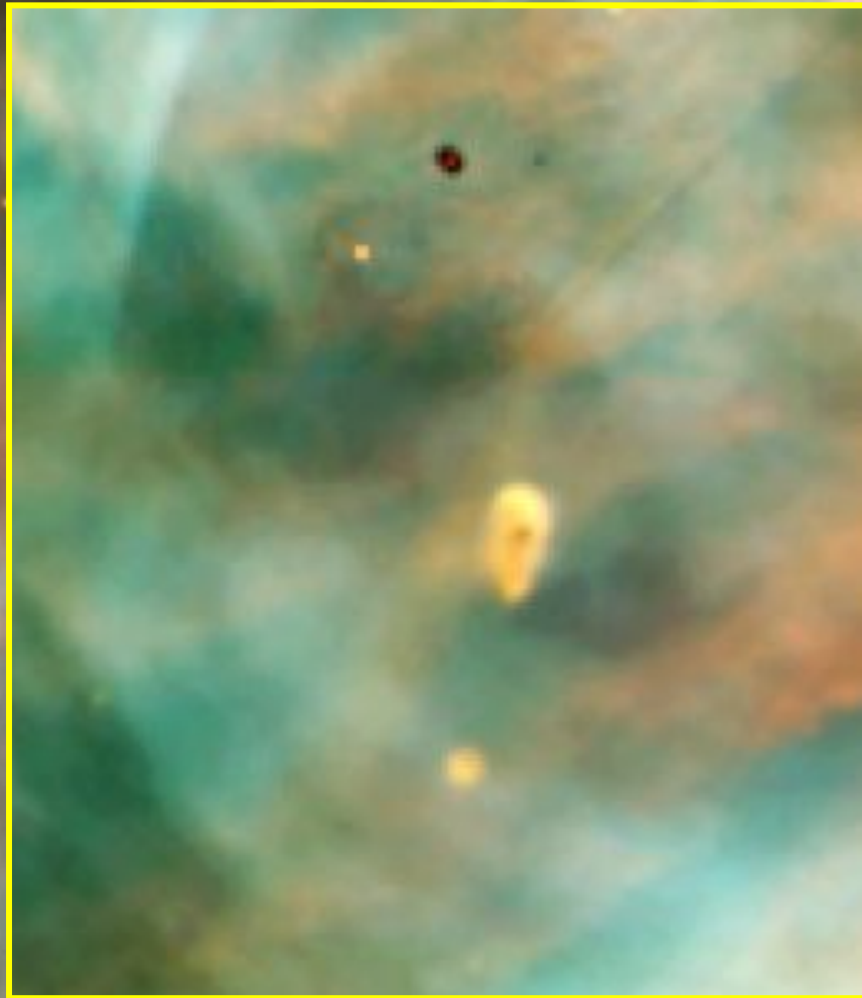
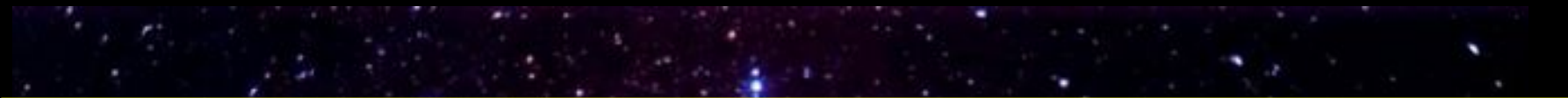
Stars form from dense clouds of gas

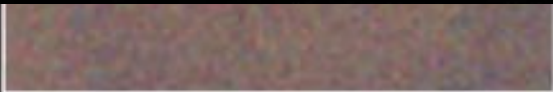
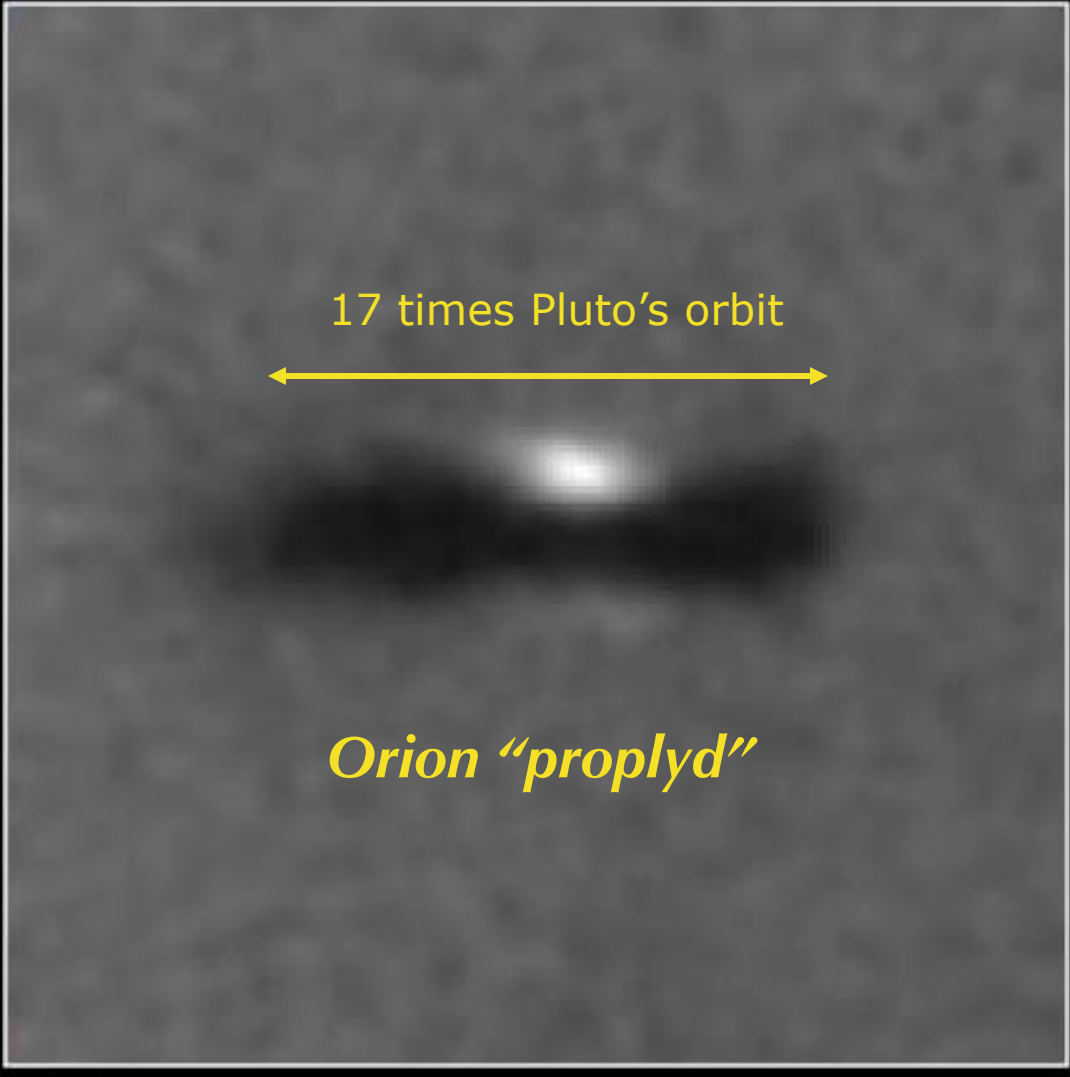
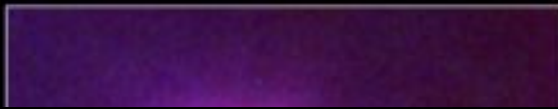
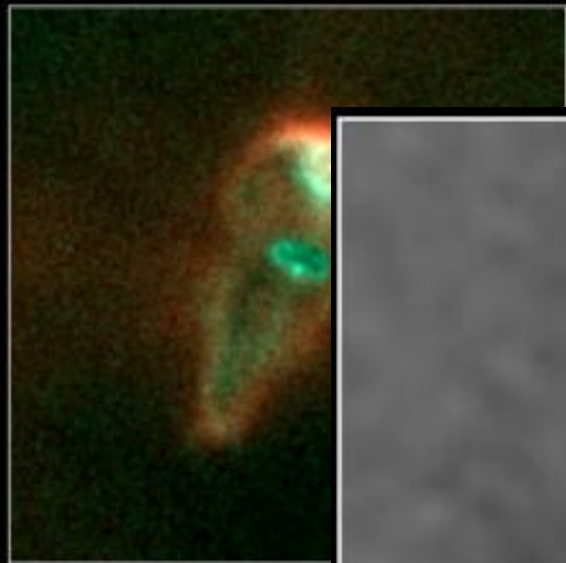


Messier 33 galaxy, a nearby member of the Local Group

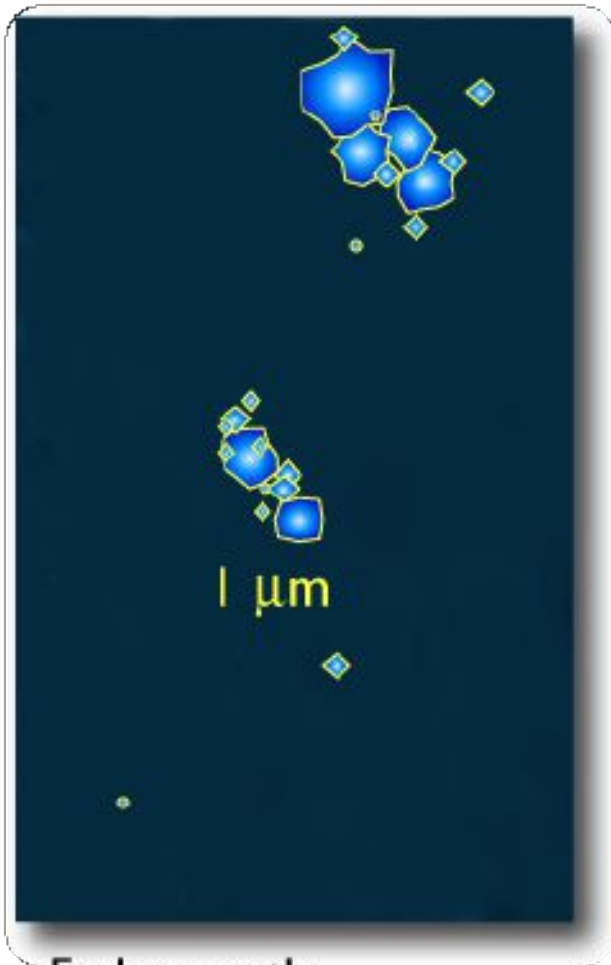




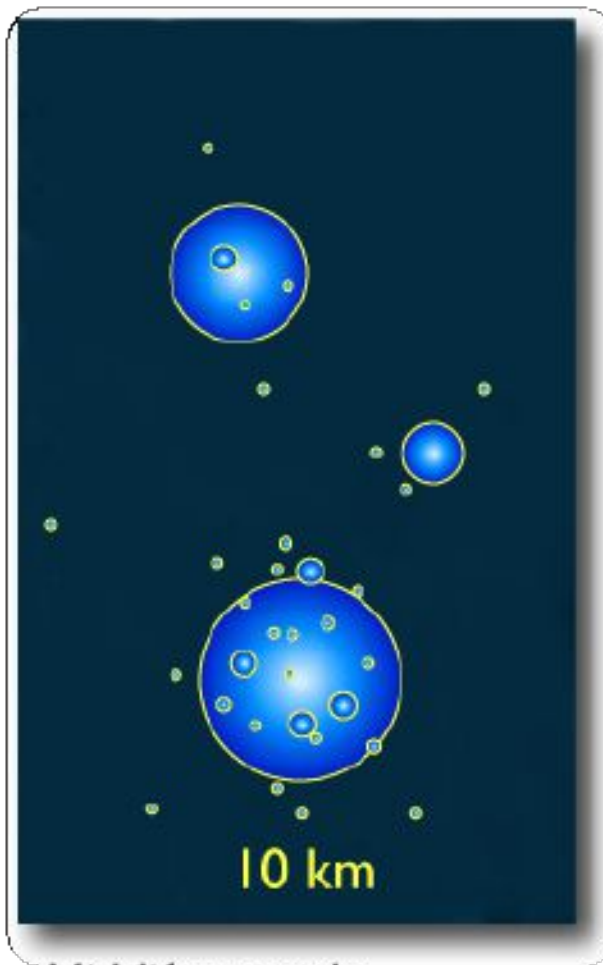




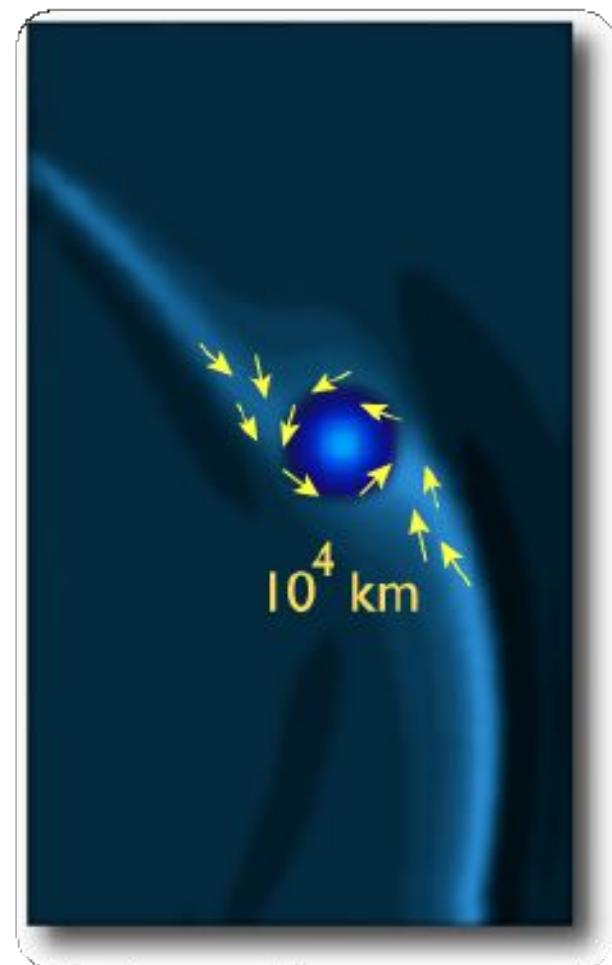
Interstellar dust grains stick together to make rocky planets



**Early growth:
Sticking and Coagulation**

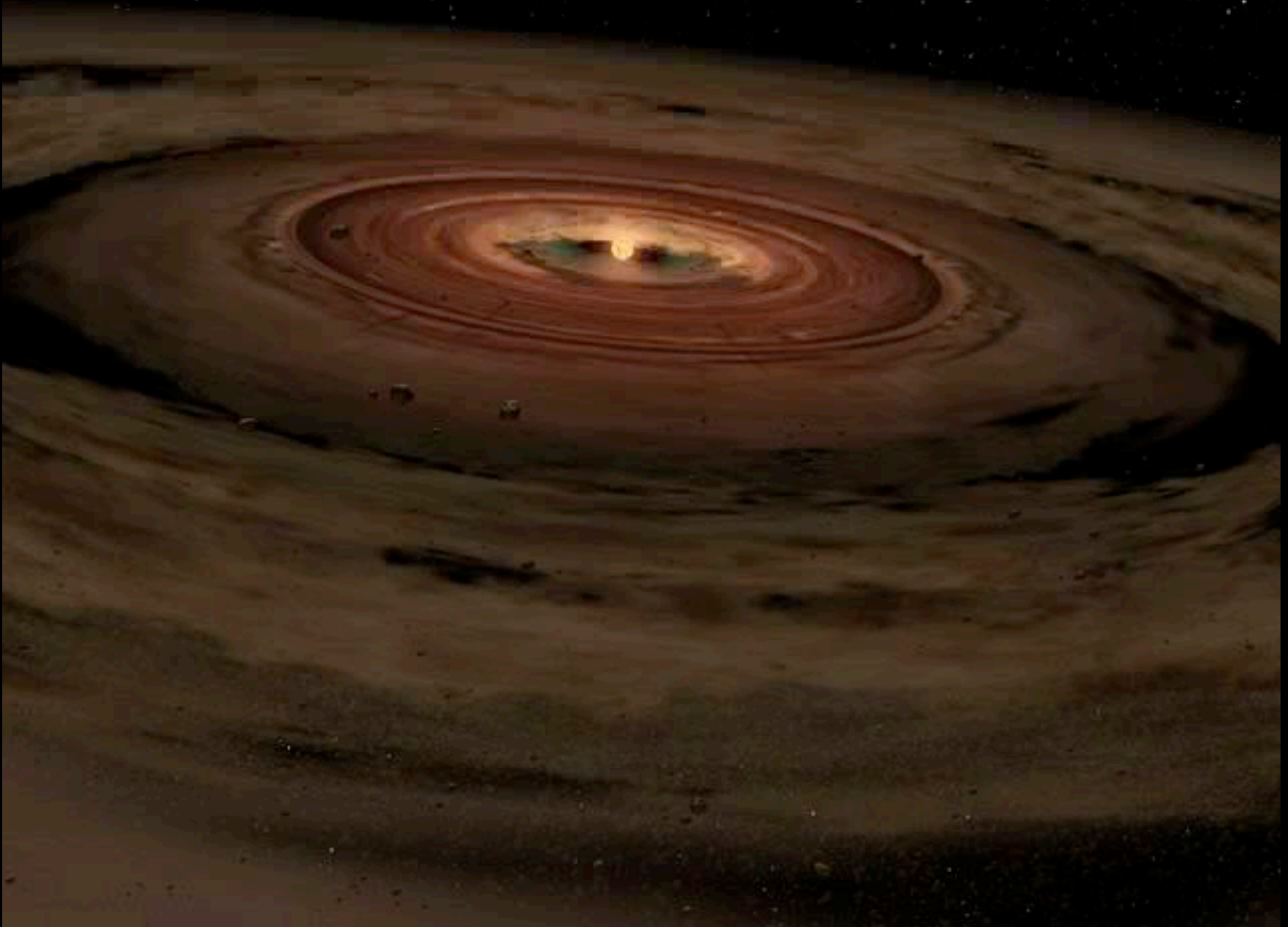


**Mid-life growth:
Gravitational Attraction**



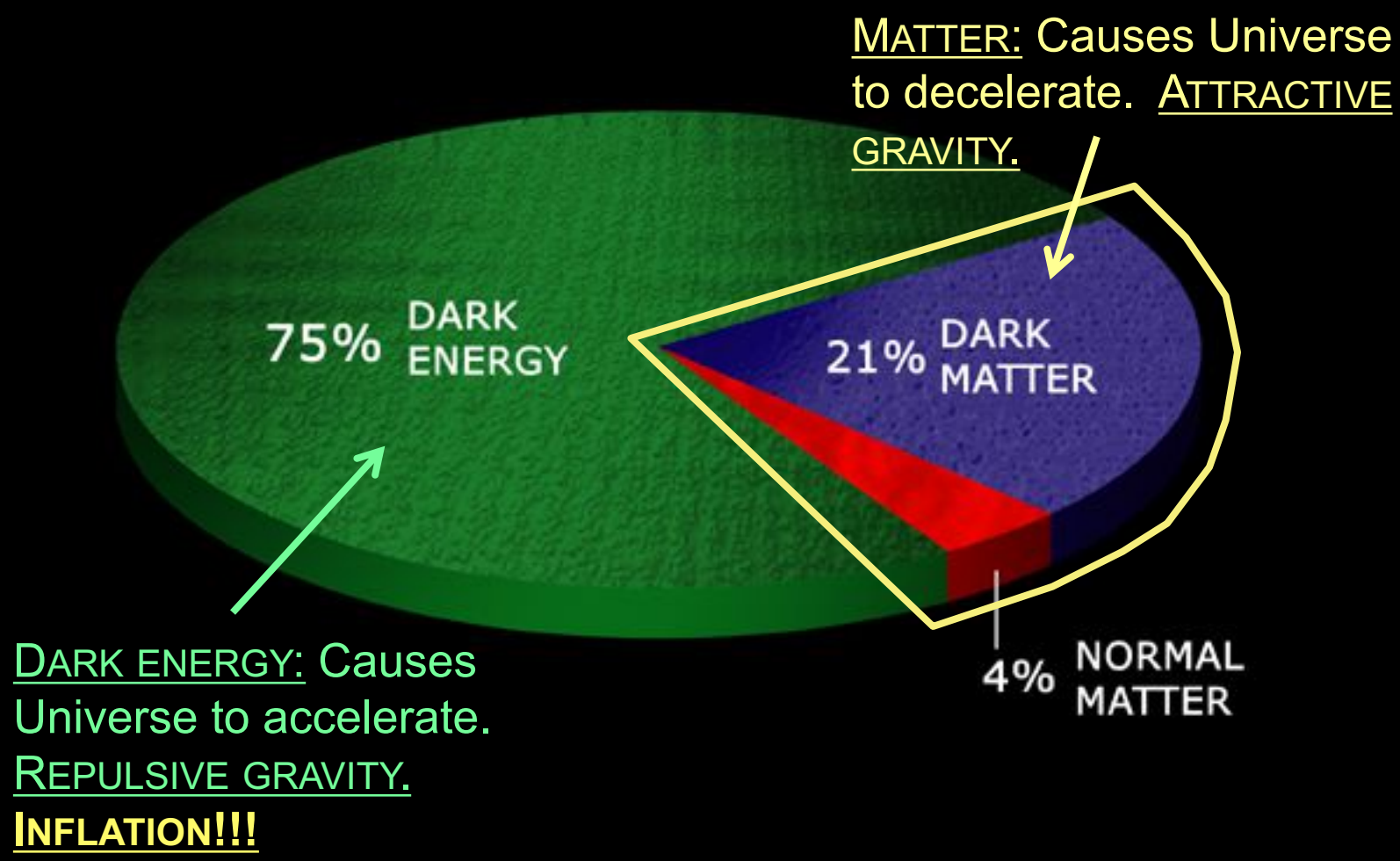
**Late growth:
Gas Sweeping**

A rotating proto-solar nebula

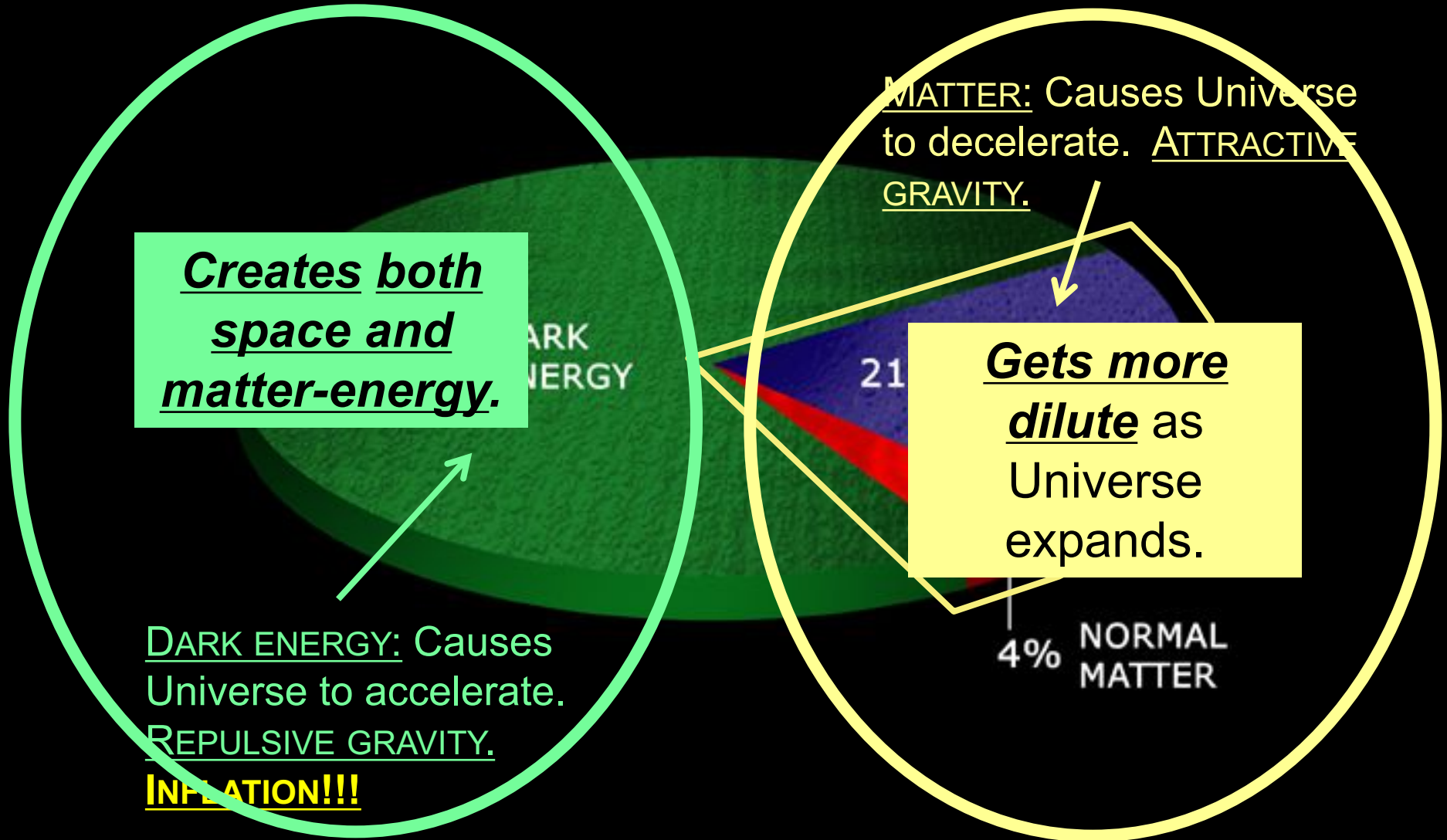




Matter-Energy Budget of the Universe Today



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Creates both space and matter-energy.

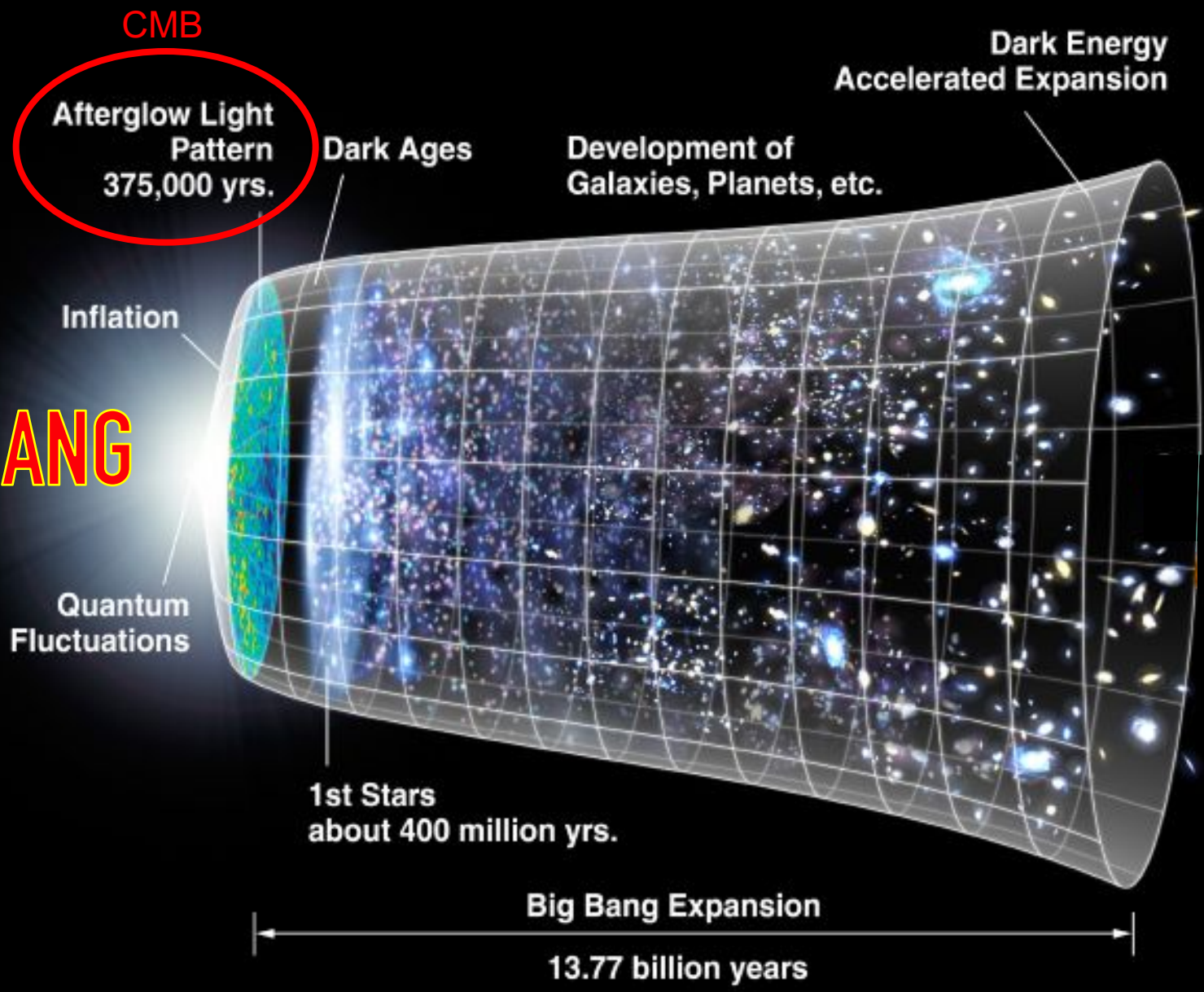
DARK ENERGY: Causes Universe to accelerate. **REPULSIVE GRAVITY.**
INFLATION!!!

MATTER: Causes Universe to decelerate. **ATTRACTIVE GRAVITY.**

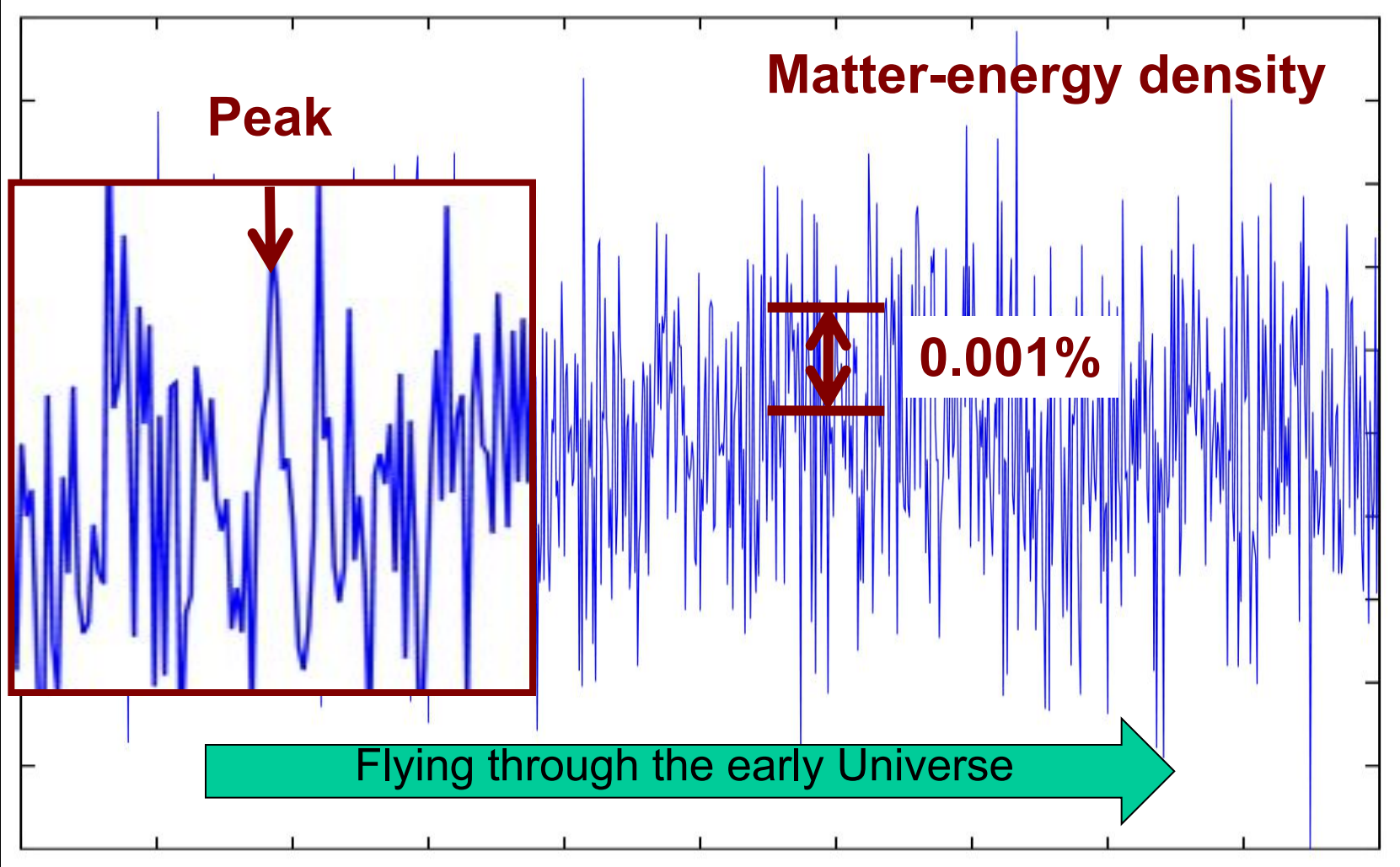
Gets more dilute as Universe expands.

4% **NORMAL MATTER**

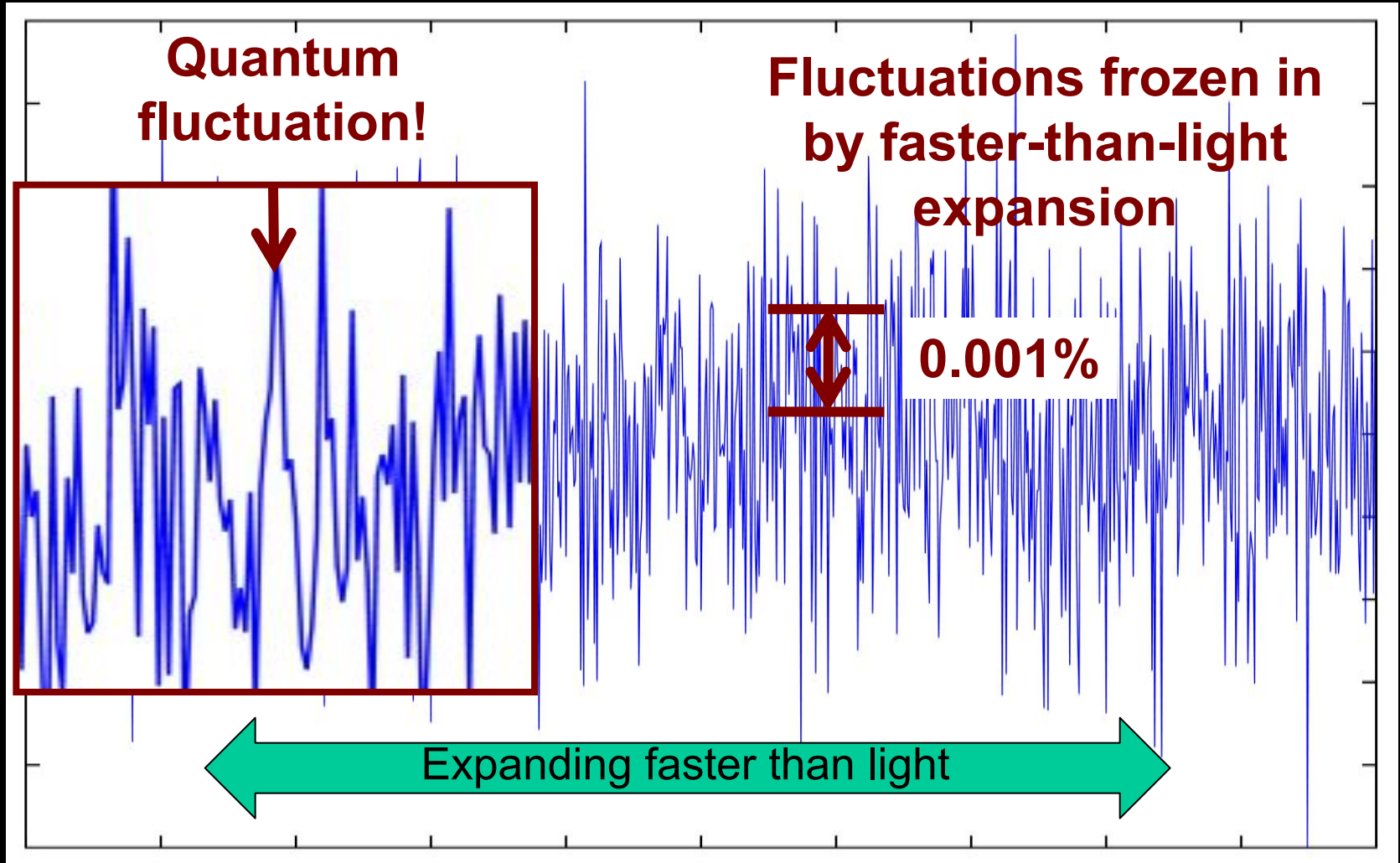
BIG BANG



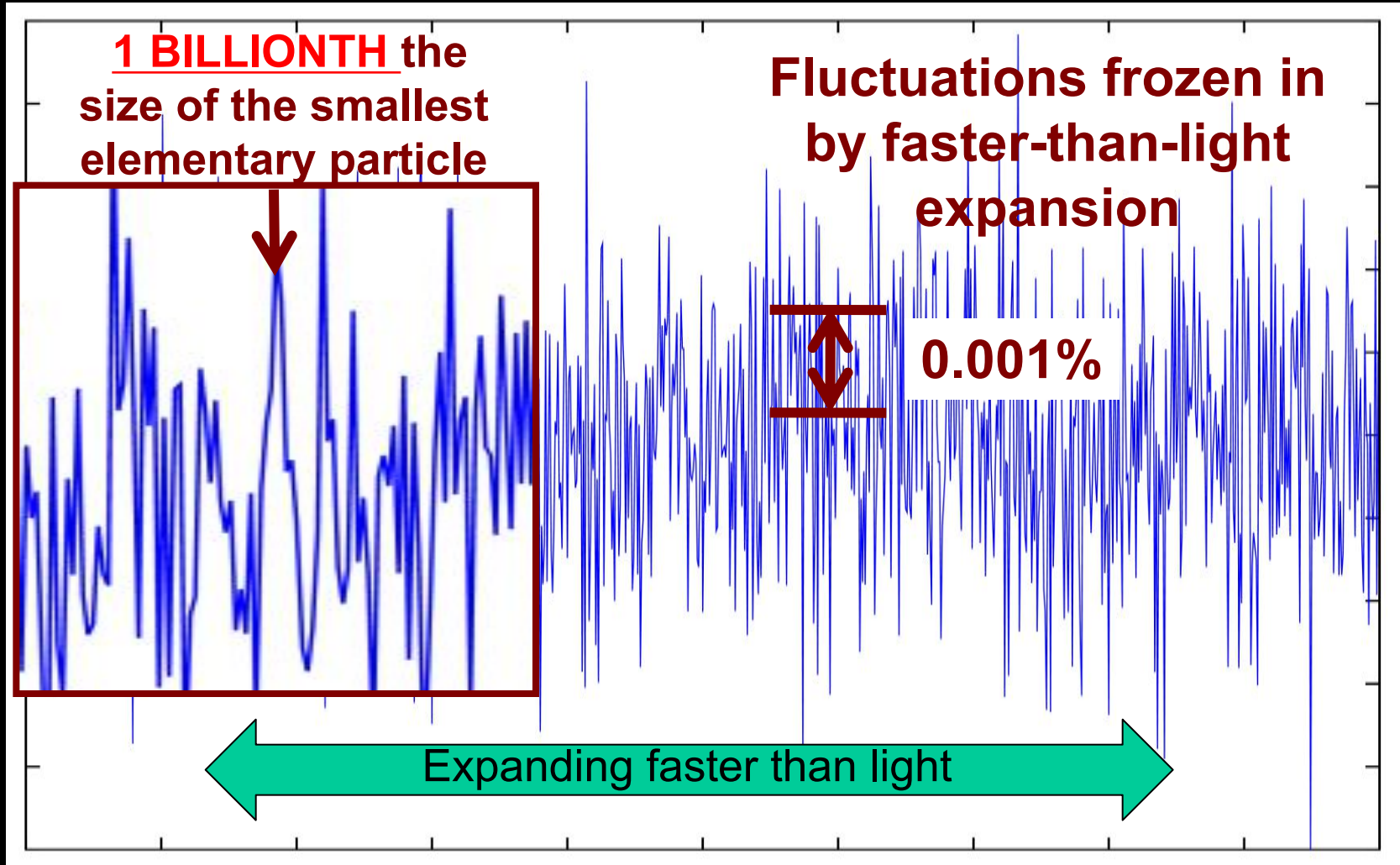
The Density Fluctuations Were Generated by Inflation



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The Density Fluctuations Were Generated by Inflation



Extraordinary Consequences of First Inflation

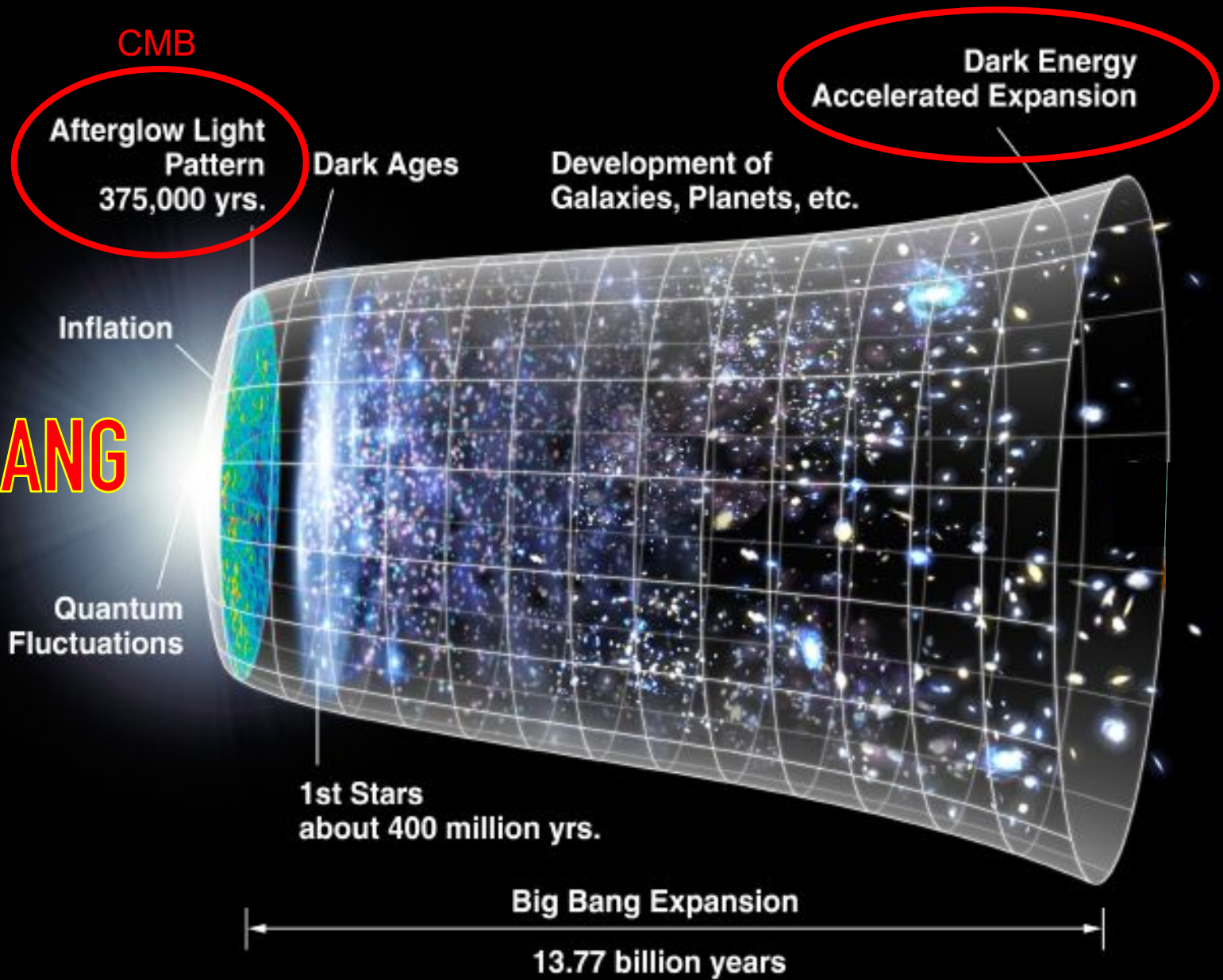
- INFLATION CREATES MATTER-ENERGY: We now have more space with the SAME density of dark energy!
- INFLATION CREATES DENSITY FLUCTUATIONS, which lead to galaxies via standard gravity.



Quantum noise!

*INFLATION PLUS QUANTUM NOISE ARE THE
CREATIVE DUO OF OUR UNIVERSE.*

BIG BANG



Extraordinary Consequences of Second Inflation

WE ARE NOW ENTERING THE ERA OF A **SECOND INFLATION!!!**

If Dark Energy stays constant, size of Universe will **double** every 11 Byr.

Consider a galaxy moving away from us now at 10,000 km/s:

Now →	14 Byr	10,000 km/s	
	25 Byr	20,000 km/s	
	36 Byr	40,000 km/s	
	47 Byr	80,000 km/s	
	58 Byr	160,000 km/s	
	69 Byr	320,000 km/s	> speed of light!

- All galaxies expanding away from us now will **redshift out of sight**. We, the Andromeda galaxy, and the other small members of the Local Group will be **all alone in the cosmos**.

Differences Between Second and First Inflation

- 2nd inflation occurs at much lower energy density
- 2nd inflation started recently (only ~1 doubling so far, 1st had >100)
- 1st inflation was temporary – the scale factor grew faster than matter and photons and inflation stopped. We don't know what happened next.
- Future of 2nd inflation is unknown because it's so recent. Will dark energy decay or be forever constant? We don't know.
- **2nd inflation: no known physical explanation.** Why is Λ so small? Most natural value for a constant Λ is “Planck density”, which is 10^{120} times bigger than seen.

Cosmological
Constant, Λ

*The Fine-Tuning
Problem*

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Cosmological
Constant, Λ

*Cosmic Evidence
for God!*



An Alternative to God: The Multiverse

What if...there is a “cosmic machine” out there that is churning out universes in huge numbers and they are all different. Our Universe is the way it is because it is one of the few whose parameters are in the range to support our kind of life.

Example: Why is the radius of the Earth approx. 4,000 miles?

Answer: Because human bodies are adapted to a rocky planet of roughly that size. We can only be on a planet like Earth.

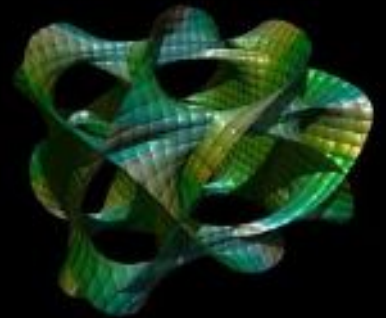
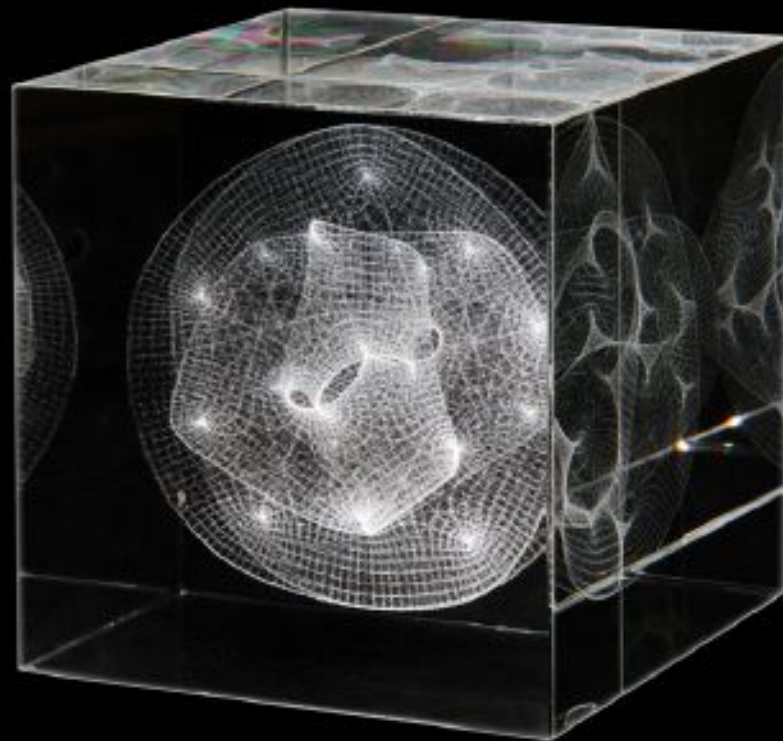
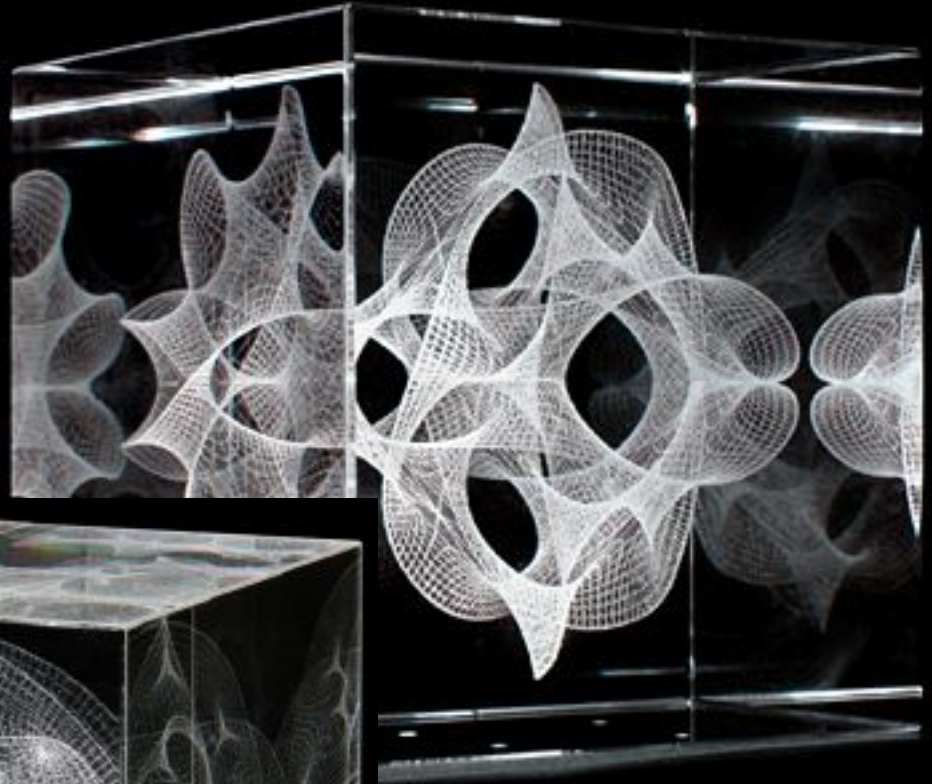
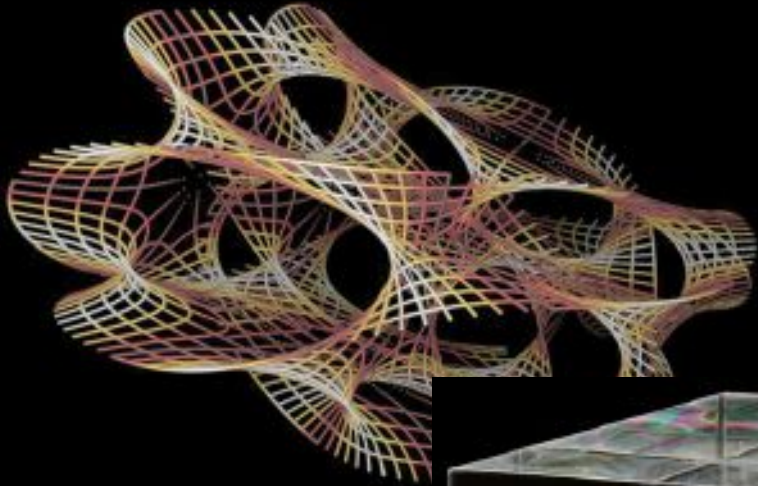
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This logic is called **Anthropic Reasoning**: our existence picks Earth’s properties out of a much larger ensemble of planets with varied properties.

Same reasoning explains our Sun, Solar System, and Milky Way galaxy. **Can it explain the Universe?**

Supersymmetric String Theory



Supersymmetric String Theory

Solves several key problems in cosmology:

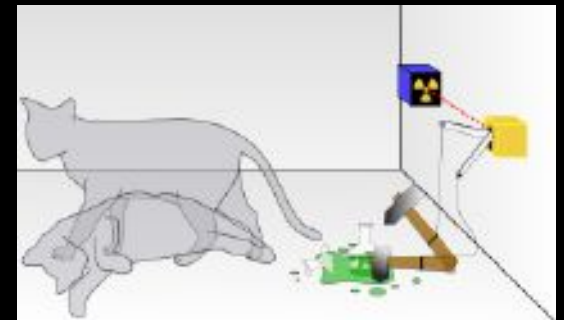
- Has a natural candidate particle to be the **Dark Matter**.
- Can produce a **small Cosmological Constant** (though rarely).
- Has an infinitude (10^{500}) of possible solutions, each one of which could be a universe **with different physical laws**.
- Can generate these universes in an endless stream by a process called “**eternal inflation**”. Universes erupt out of a “**substrate of dark energy**” that is infinite in extent and endlessly inflating.

“Ridiculous” Notions

- We can actually talk meaningfully about processes at 10^{-35} sec and 10^{27} ° K.
- An empty vacuum can actually have an **intense energy density**.
- A universe can **expand faster than light**...
...and matter-energy **spontaneously appears** when this happens.
- **A quantum fluctuation** smaller than the smallest elementary particle can grow to become a galaxy 100,000 light years across.
- The **Milky Way is like Schrödinger's Cat**, and all the famous puzzles about the meaning of quantum mechanics apply -- to it and to US!



SCHRÖDINGER'S CAT IS
A L E A V I E

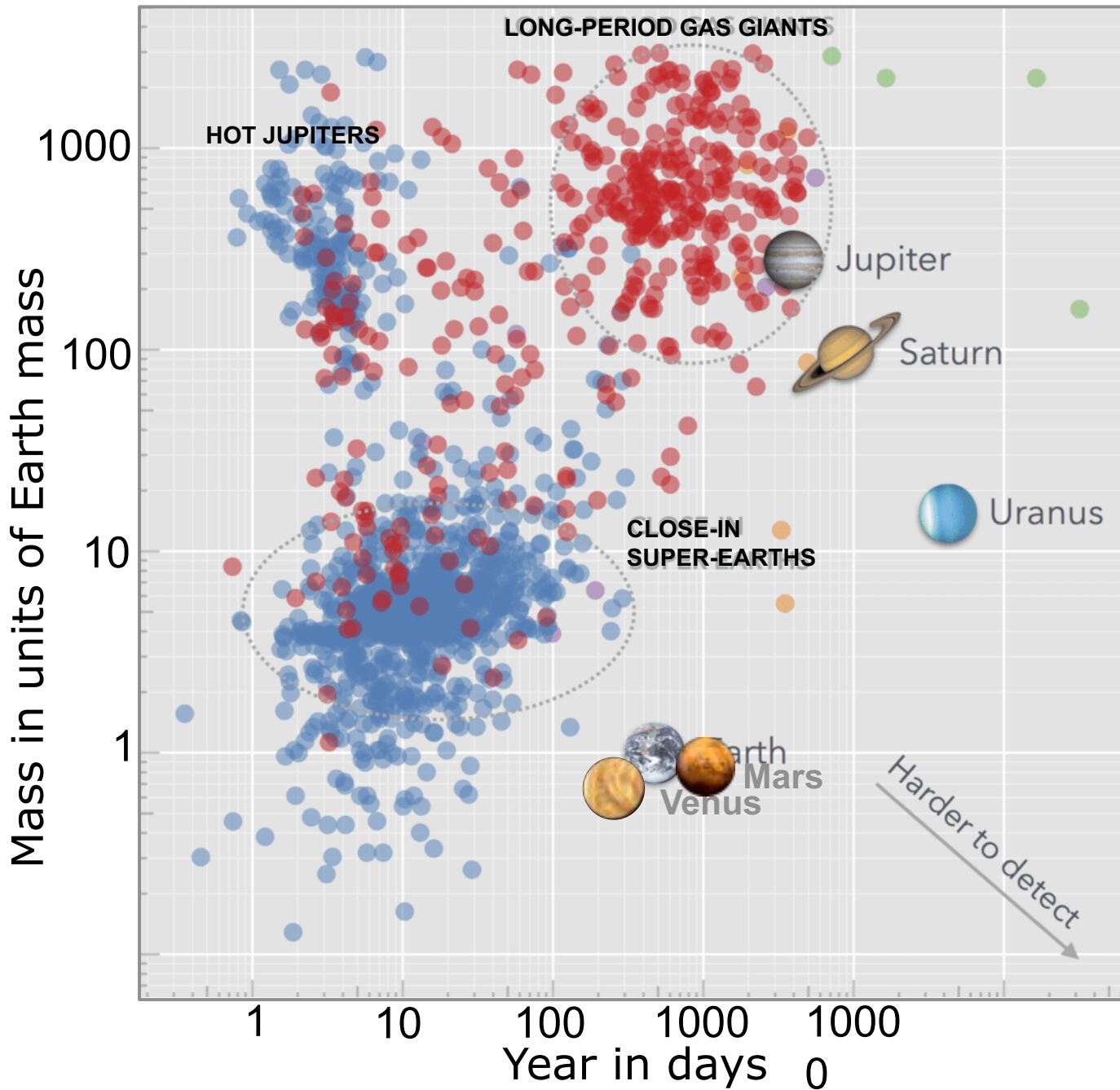


Implications of Inflation

- For anthropic reasoning to make sense, we have to assume that the **Multiverse really exists** even though we have not yet seen it.
- Is anthropic reasoning “scientific”? Yes! It has consistently been the **most fruitful concept** in cosmology. It explains the properties of Earth, Solar System, Galaxy....explaining the Universe is the next logical step.

INFLATION is generic and is responsible for both the Multiverse and for everything in our Universe. It is the “Creator”. It is why we are here.

Inflation is the closest thing that Physics has to God.



Courtesy:
Stefano Meschiari

IS EARTH RARE?

- We don't know how many Earth-mass planets are in the habitable zone. Probably many.
- But not all planets in the habitable zone are habitable: e.g., Venus, Mars.
- But more features of Earth are essential: dynamically stable Solar System, Earth mass, magnetic field, plate tectonics, right abundance of water, right atmosphere mass, even a big Moon. **Much more fine-tuning!**

It's OK for Earth to be rare if the planetary ensemble it is drawn from is large enough.

THE RARE EARTH EQUATION

Peter D. Ward and Donald Brownlee, Rare Earth: Why Complex Life is Uncommon in the Universe

Number of Earth-like planets in the Galaxy having complex life forms

$$N = N_* f_p f_{pm} n_e n_g f_l f_i f_c f_m f_j f_{me}$$

Moon ↙

IMHO: Earth as it precisely is extremely rare.

EARTH'S COSMIC FUTURE

- Major cosmic threats to intelligent life: Nearby supernova, Sun aging and warming, asteroid impact, failure of the dynamo, ice ages.....

VOLCANOES!

High probability: we have at least a few hundred million good years to play with.

LESSONS FROM COSMOLOGY

LESSON #1

- We got here according to the **laws of physics**.
- We are subject to those laws and must live within them.

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**THERE WERE NO MIRACLES IN OUR PAST
AND THERE WILL BE NONE IN FUTURE.**

LESSON #2

- Earth will provide a livable home for at least **100 million years**, perhaps longer.
- We have been given the **precious gift of cosmic time.**

WILL WE USE WELL, OR WILL WE SQUANDER?

We are the first generation of human beings to face this challenge.

The “miracle” of compound interest... on cosmic time

3.5% growth every year for 100 million years...

WHAT HAPPENS?

$$10^{1,500,000}$$

That's "10" with **1.5 million zeros** after it.

**“Sustainable growth” on cosmic
time means **NO GROWTH****

NO net increase in resource use. Waste reduced to levels that can be **completely naturally recycled.**

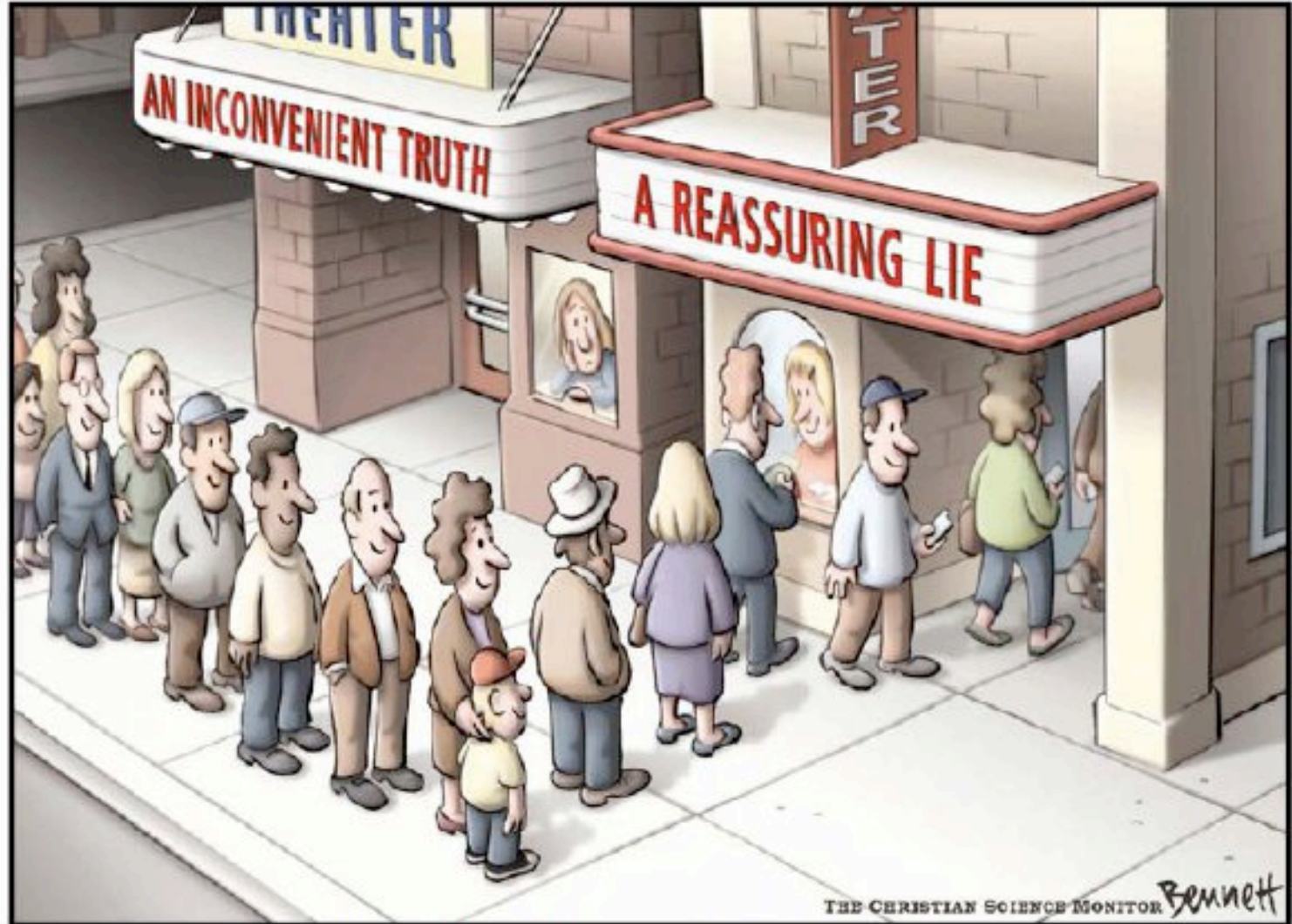


Fig. 56 "Now Playing – A Reassuring Lie"



Fig. 56 "Now Playing – An Inconvenient Truth"

NEW MORAL ISSUES

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- Will the human moral code adjust to deal with these new questions? If religion-based? If genetics-based?

Announcing:

The Earth Futures Institute at UC Santa Cruz

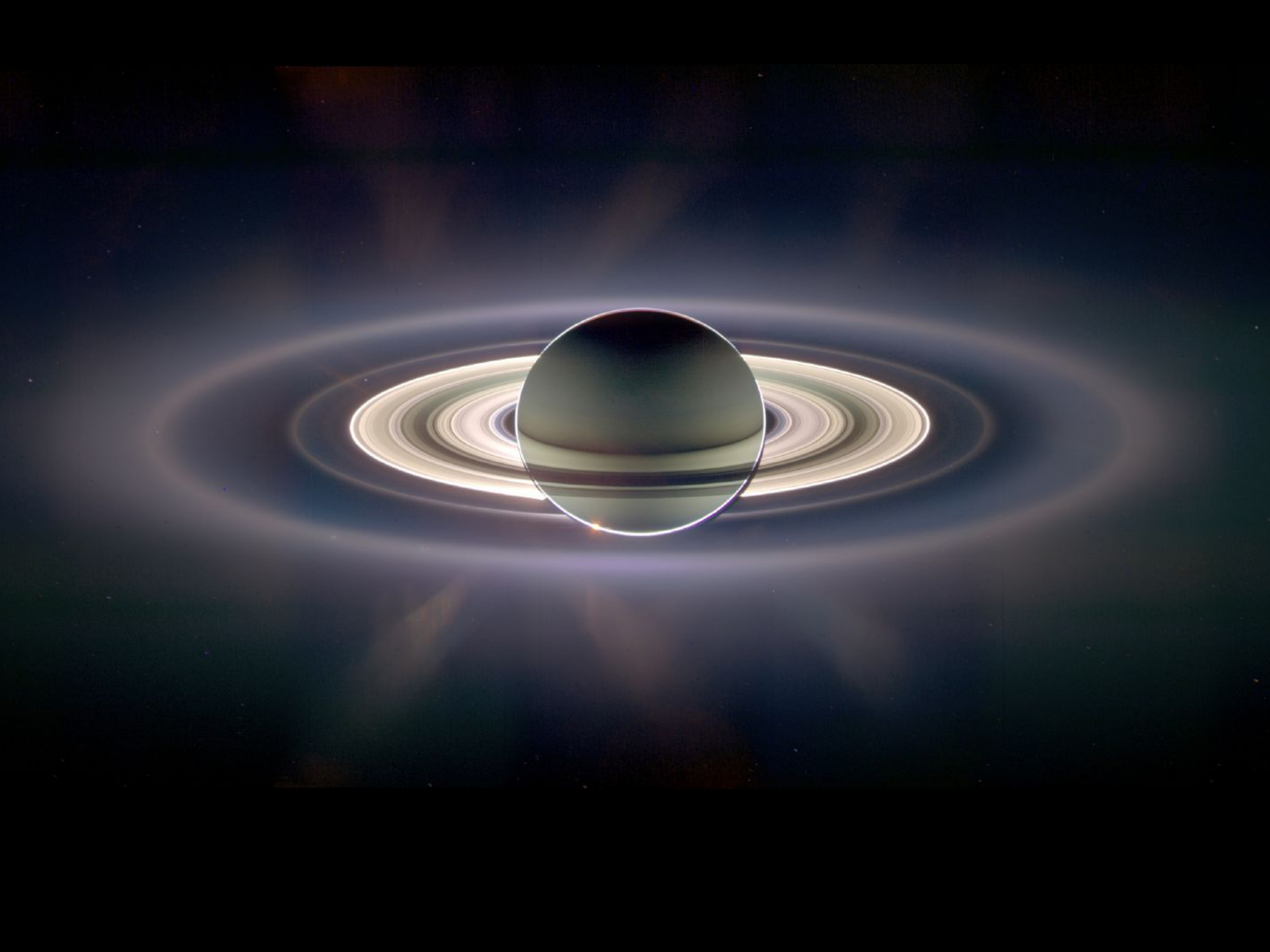
The only institute of its kind in the world

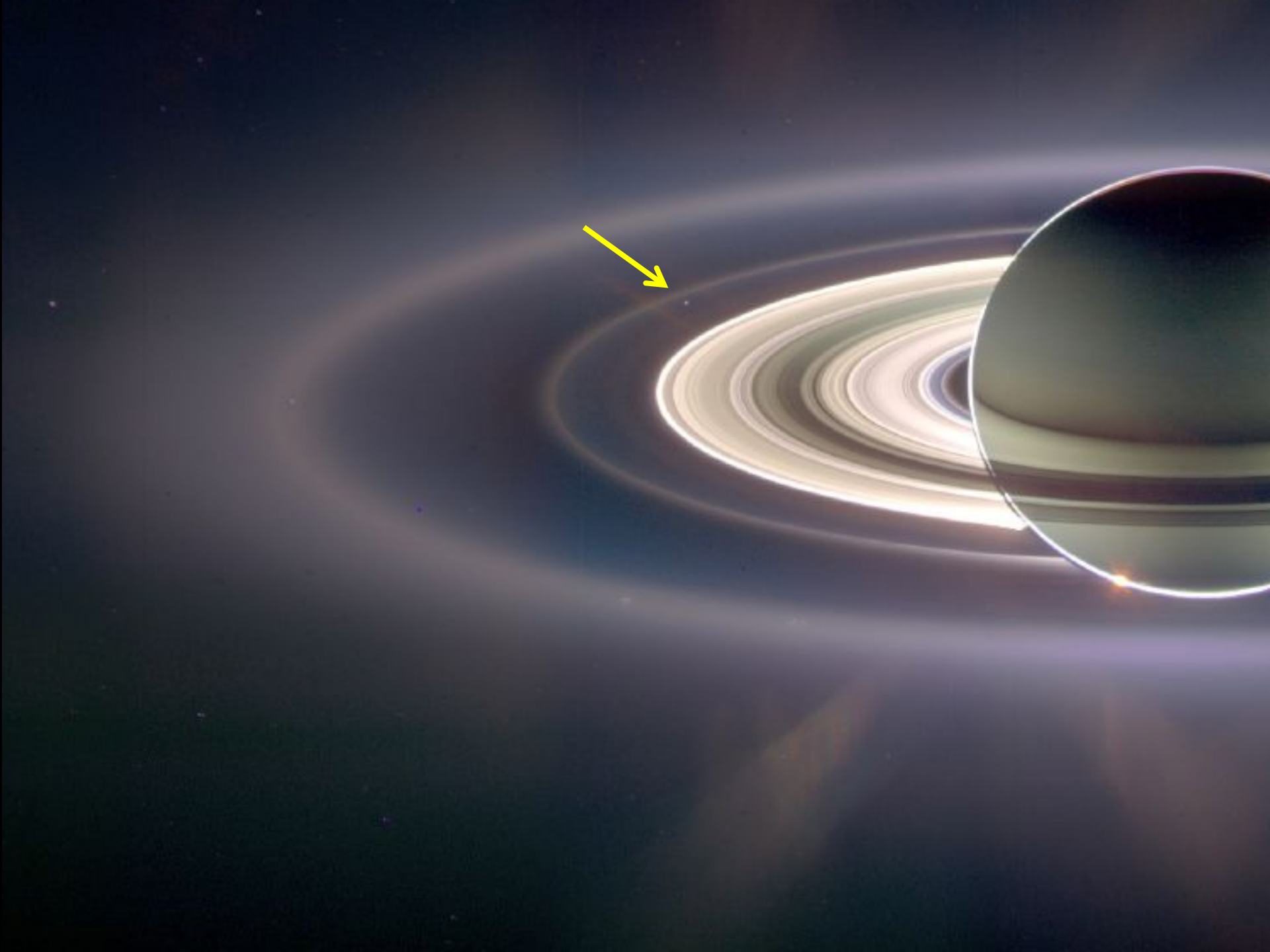
Why unique?



*A focus on cosmic time:
1000 yr to 100 million years*

*▮ **Ethics of the Future** ▮*







COSMOLOGY

FINDING OUT YOU REALLY JUST DON'T MATTER



COSMOLOGY

INSPIRING US TO SAVE THE EARTH