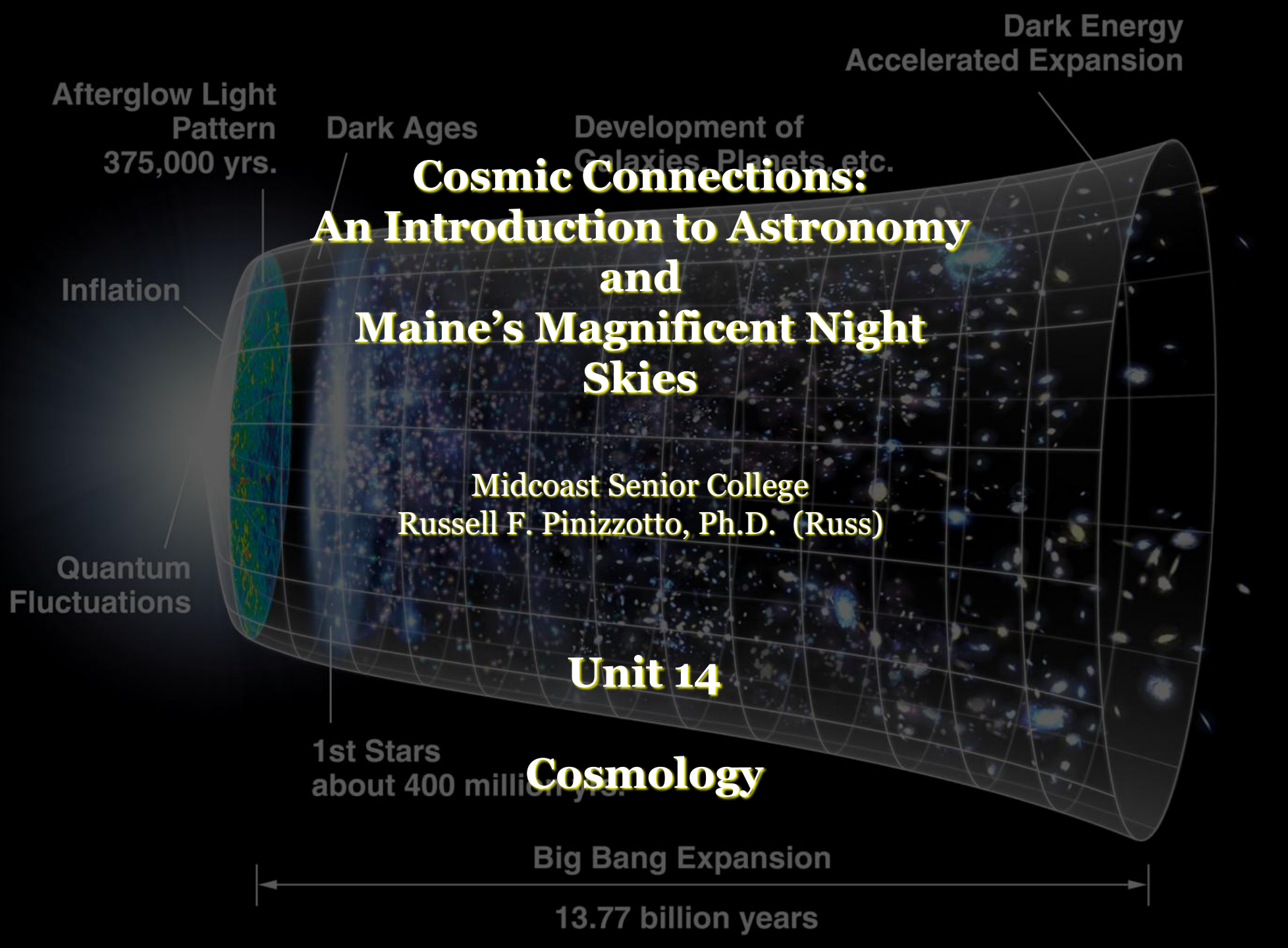


Cosmic Connections: An Introduction to Astronomy and Maine's Magnificent Night Skies

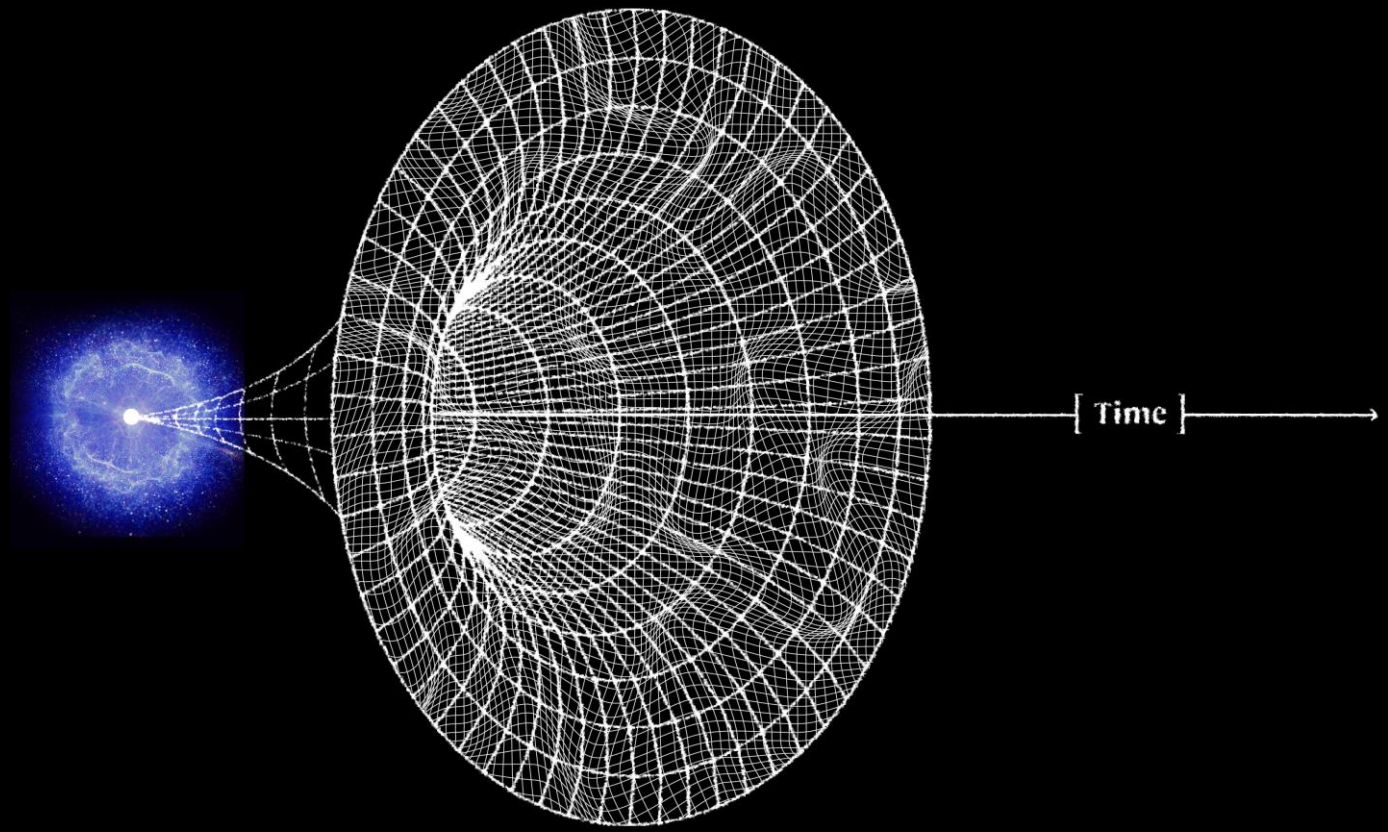
Midcoast Senior College
Russell F. Pinizzotto, Ph.D. (Russ)

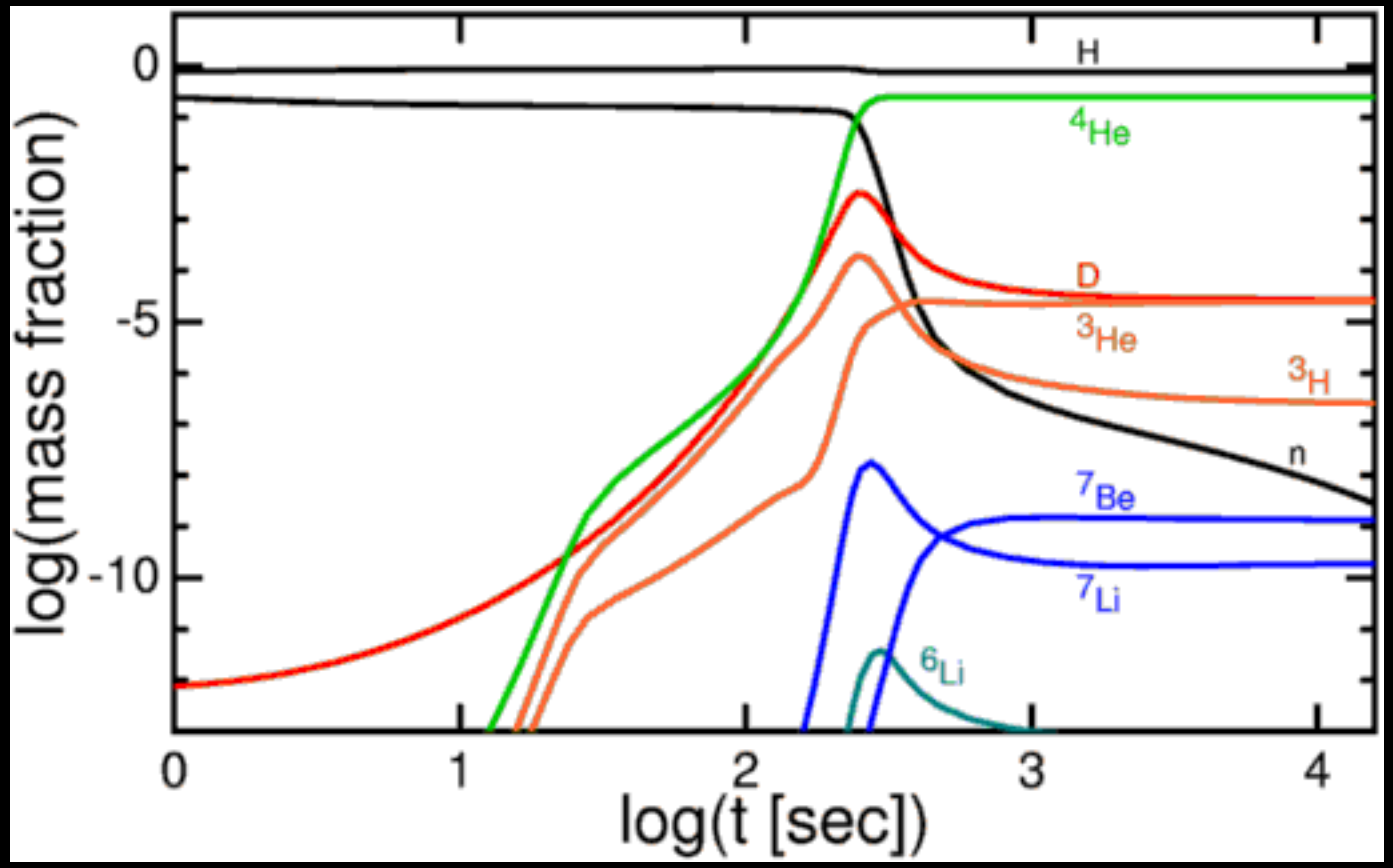
Unit 14

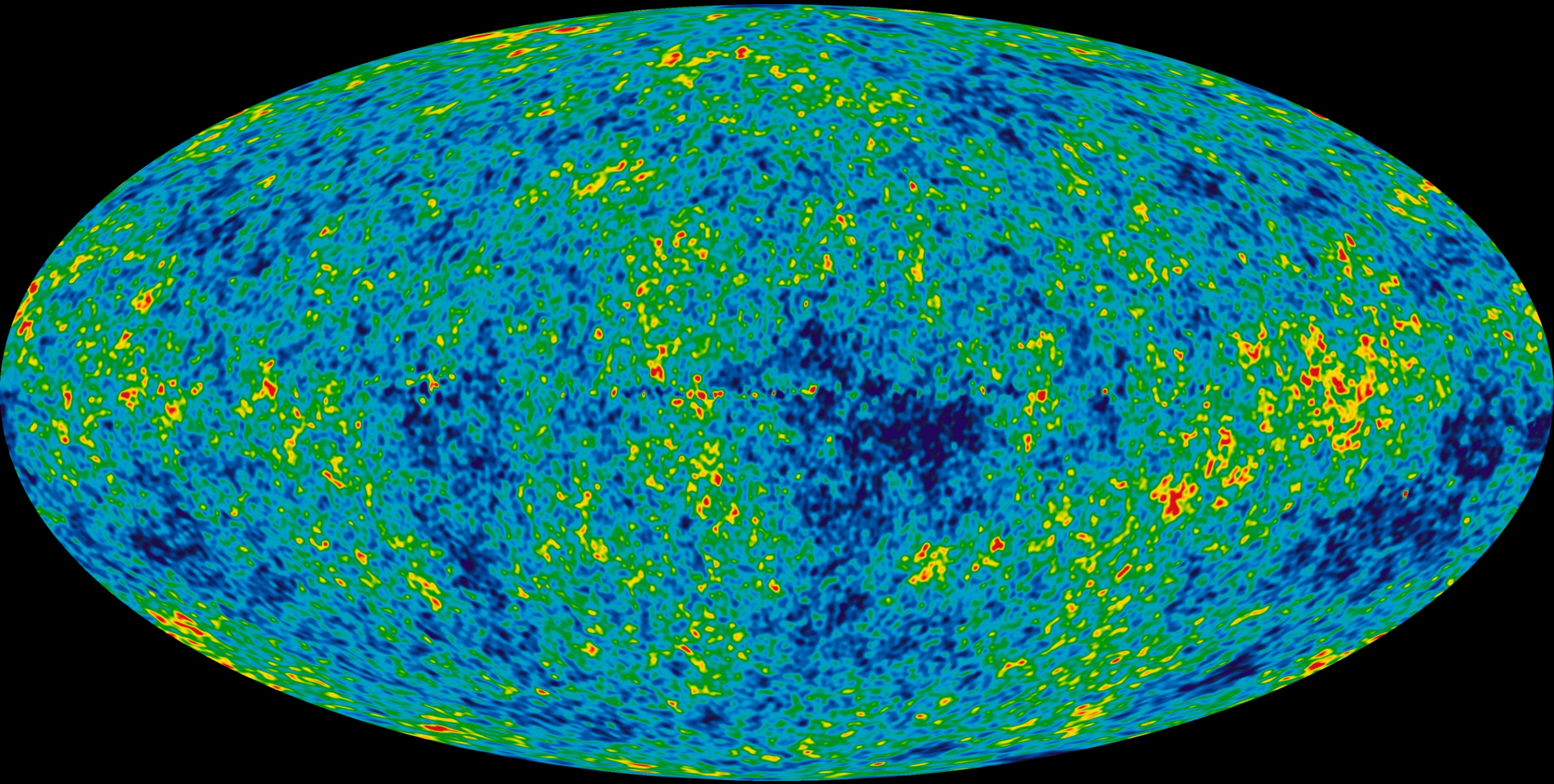
Cosmology

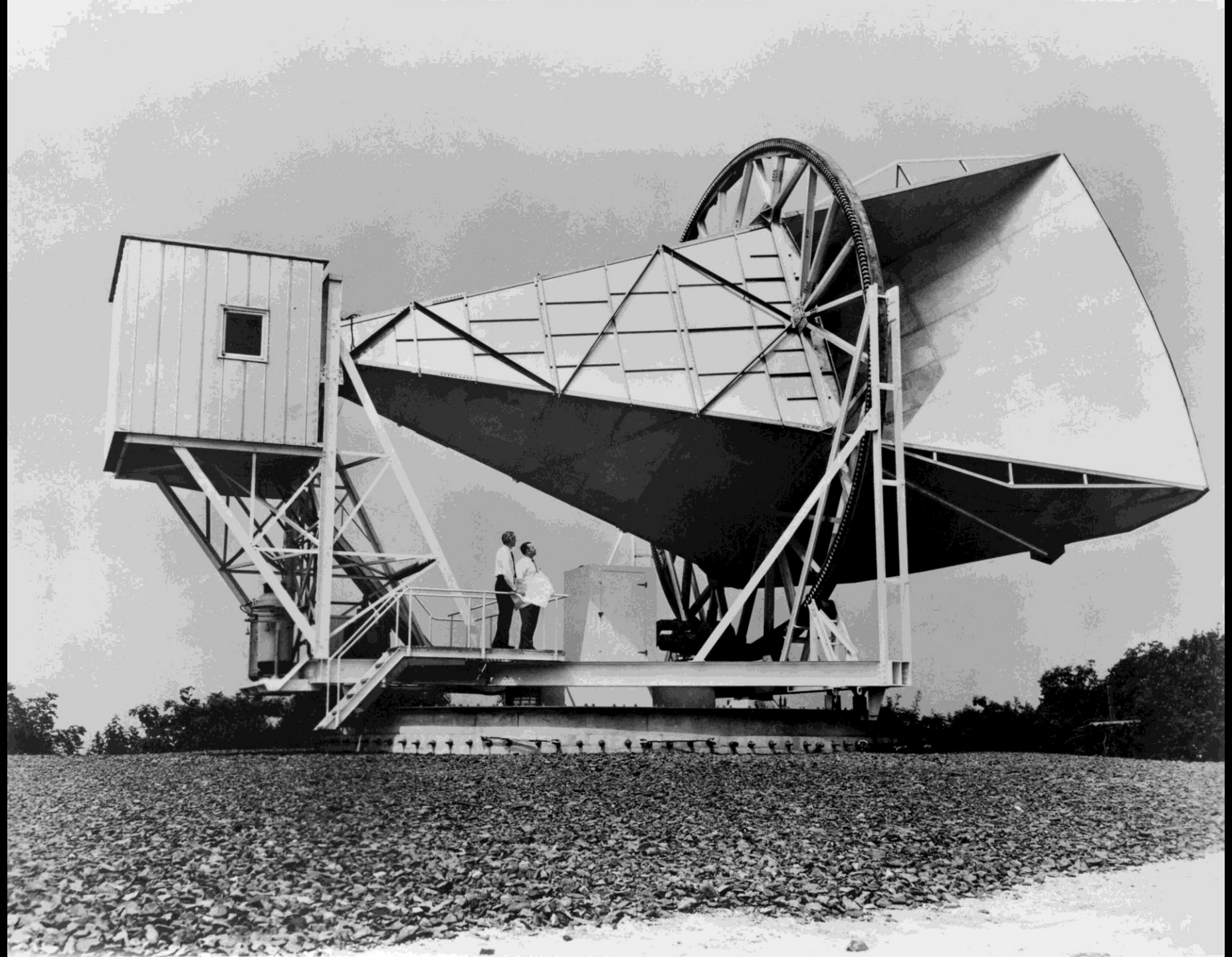
The Big Bang!

Cosmic Inflation – 10^{-32} sec

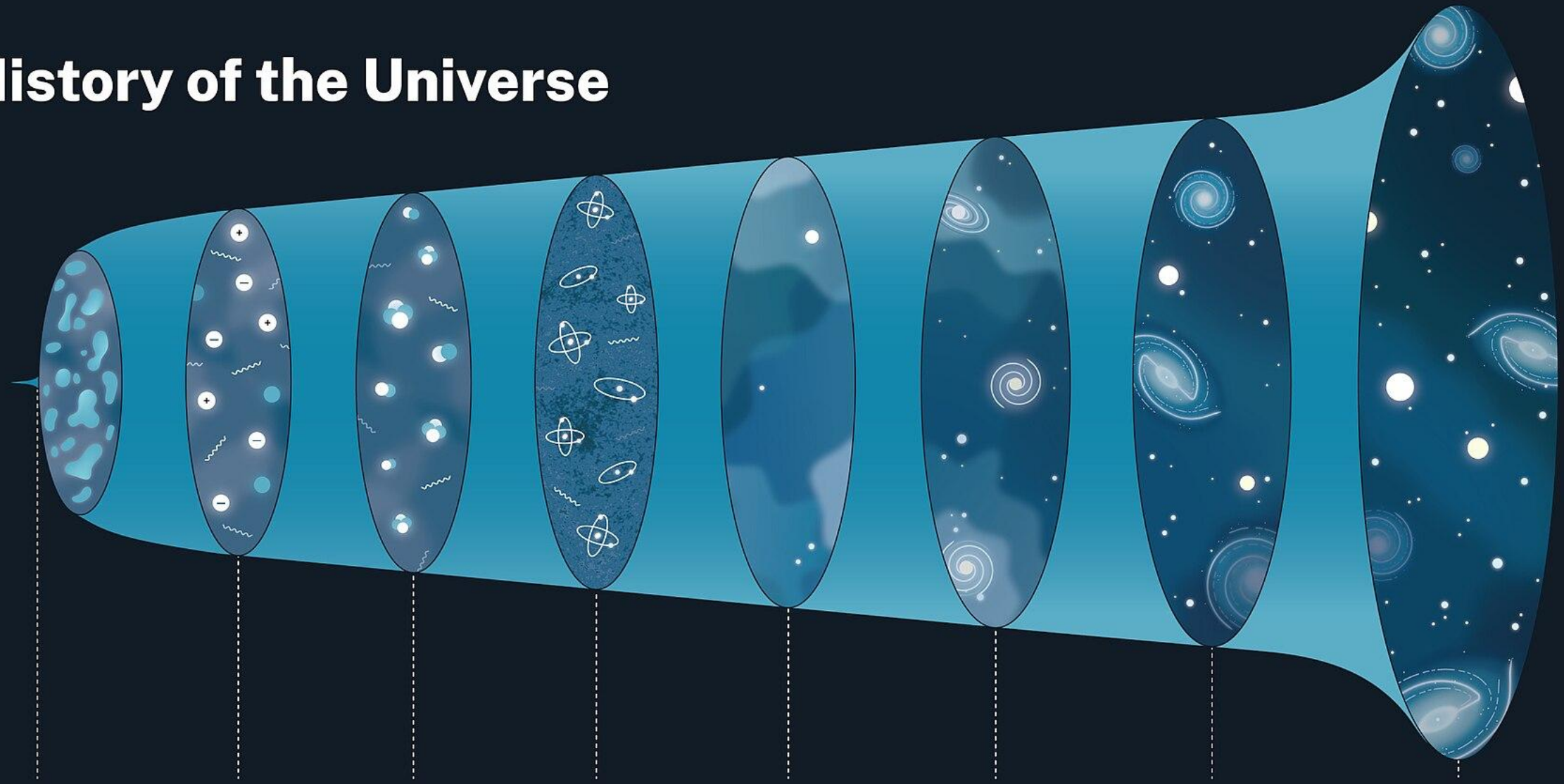



0
-5
-10
log(mass fraction)
0
1
2
3
4
log(t [sec])
H
4He
D
3He
3H
n
7Be
7Li
6Li

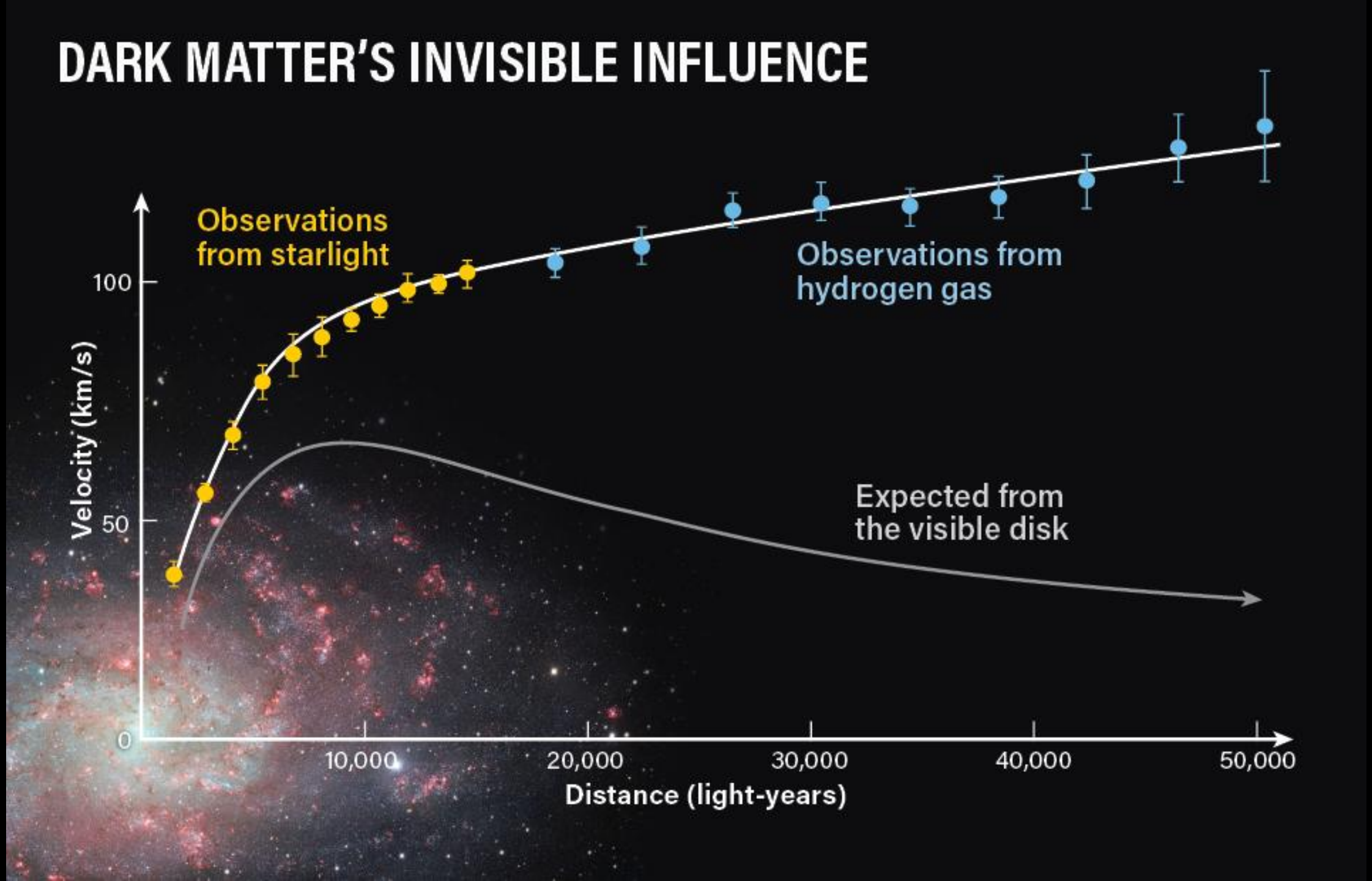


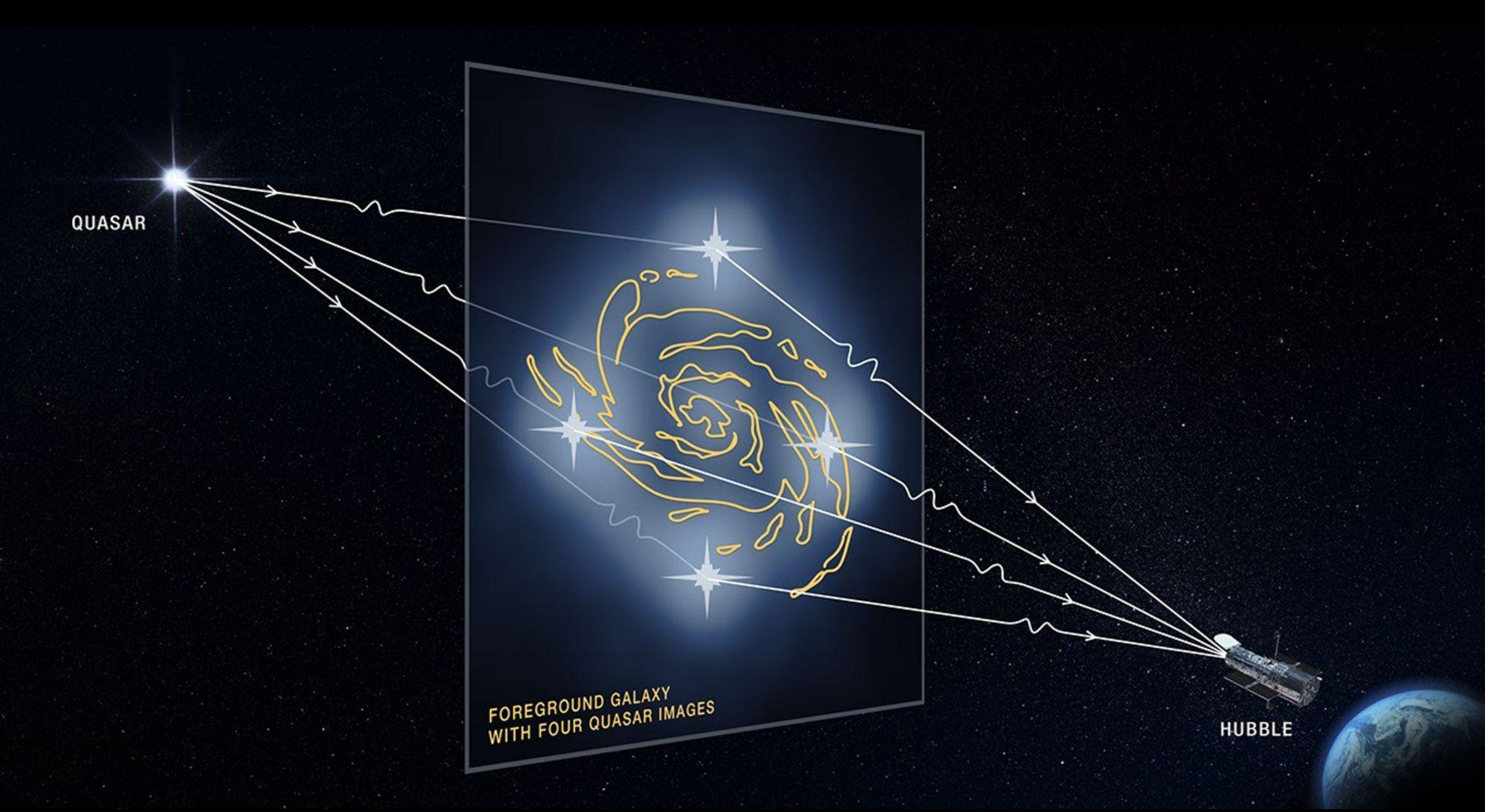


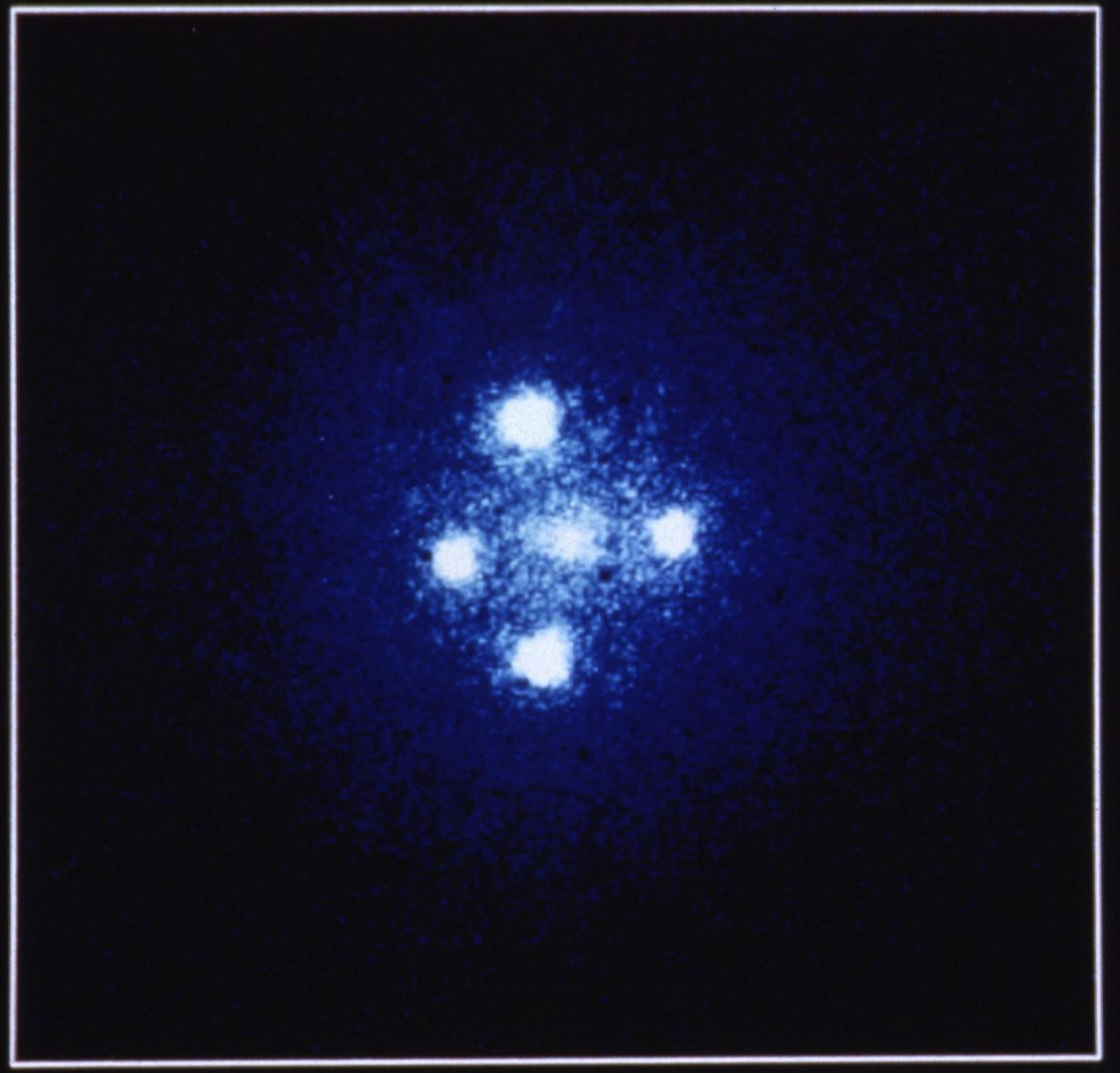
History of the Universe



10^{-32} seconds	1 microsecond	3 minutes	380,000 years	200 million years	400 million years	10 billion years	13.8 billion years
Inflation	**First Particles**	**First Nuclei**	**First Light**	**First Stars**	**Galaxies & Dark Matter**	**Dark Energy**	**Today**
Initial expansion	Neutrons, protons, and electrons form	Helium and hydrogen form	The first atoms form	Gas and dust condense into stars	Galaxies form in dark matter cradles	Expansion accelerates	Humans observe the universe


DARK MATTER'S INVISIBLE INFLUENCE
Observations from starlight
Observations from hydrogen gas
Expected from the visible disk
Velocity (km/s)
100
50
0
10,000
20,000
30,000
40,000
50,000
Distance (light-years)


QUASAR
FOREGROUND GALAXY
WITH FOUR QUASAR IMAGES
HUBBLE



Gravitational Lens G2237+0305

At high acceleration:

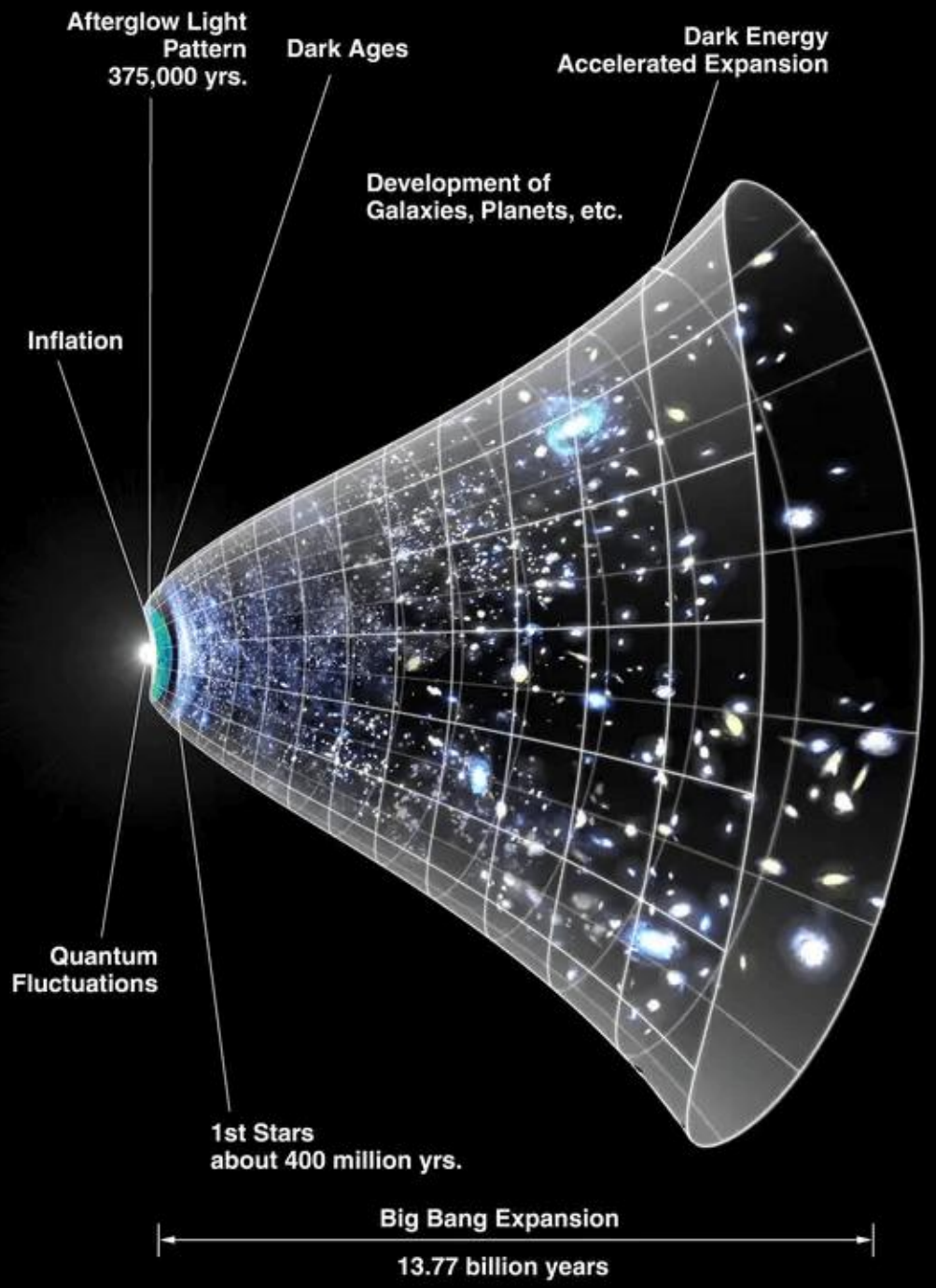
$$F = G\frac{m_1 m_2}{r^2},$$

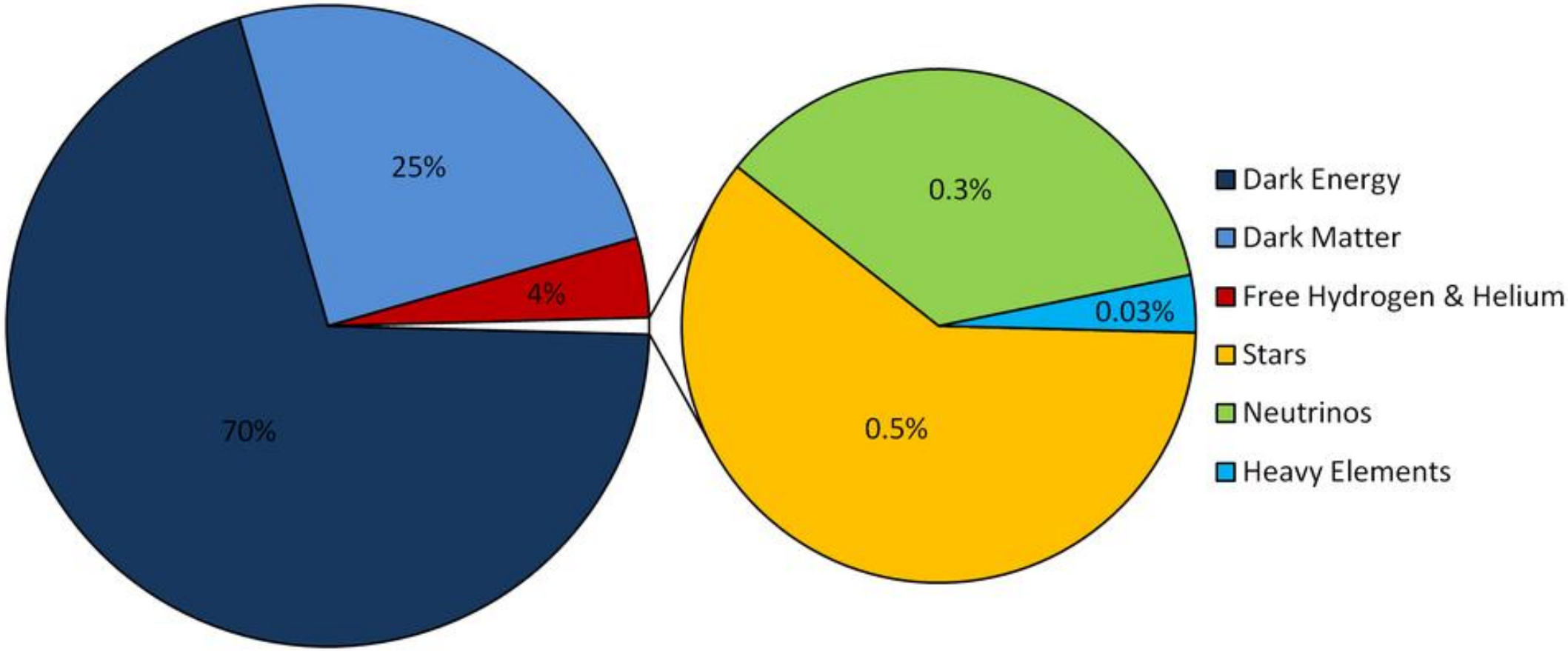
At low acceleration:

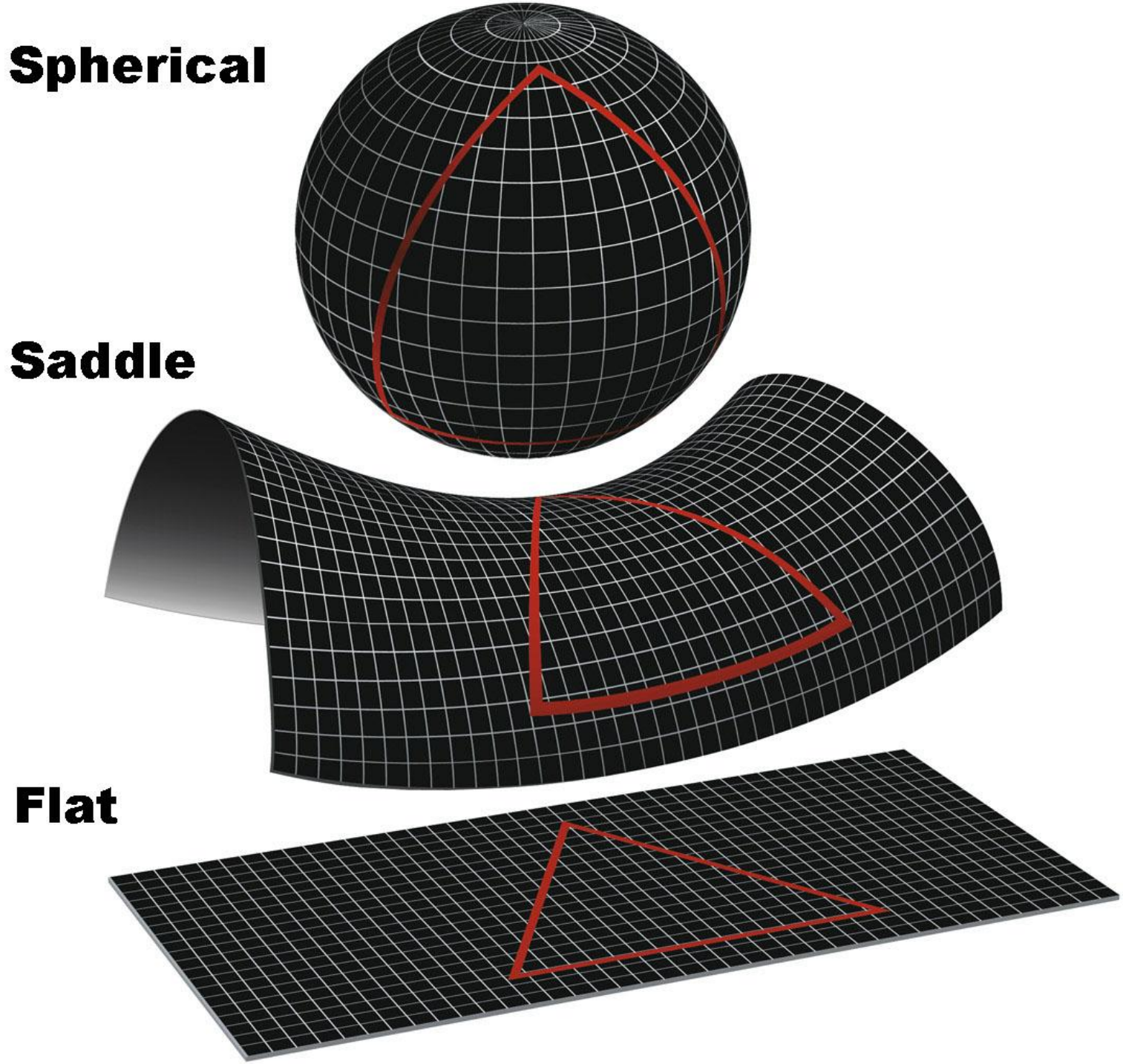
$$F = \frac{GMm}{\mu\left(\frac{a}{a_0}\right) r^2}$$

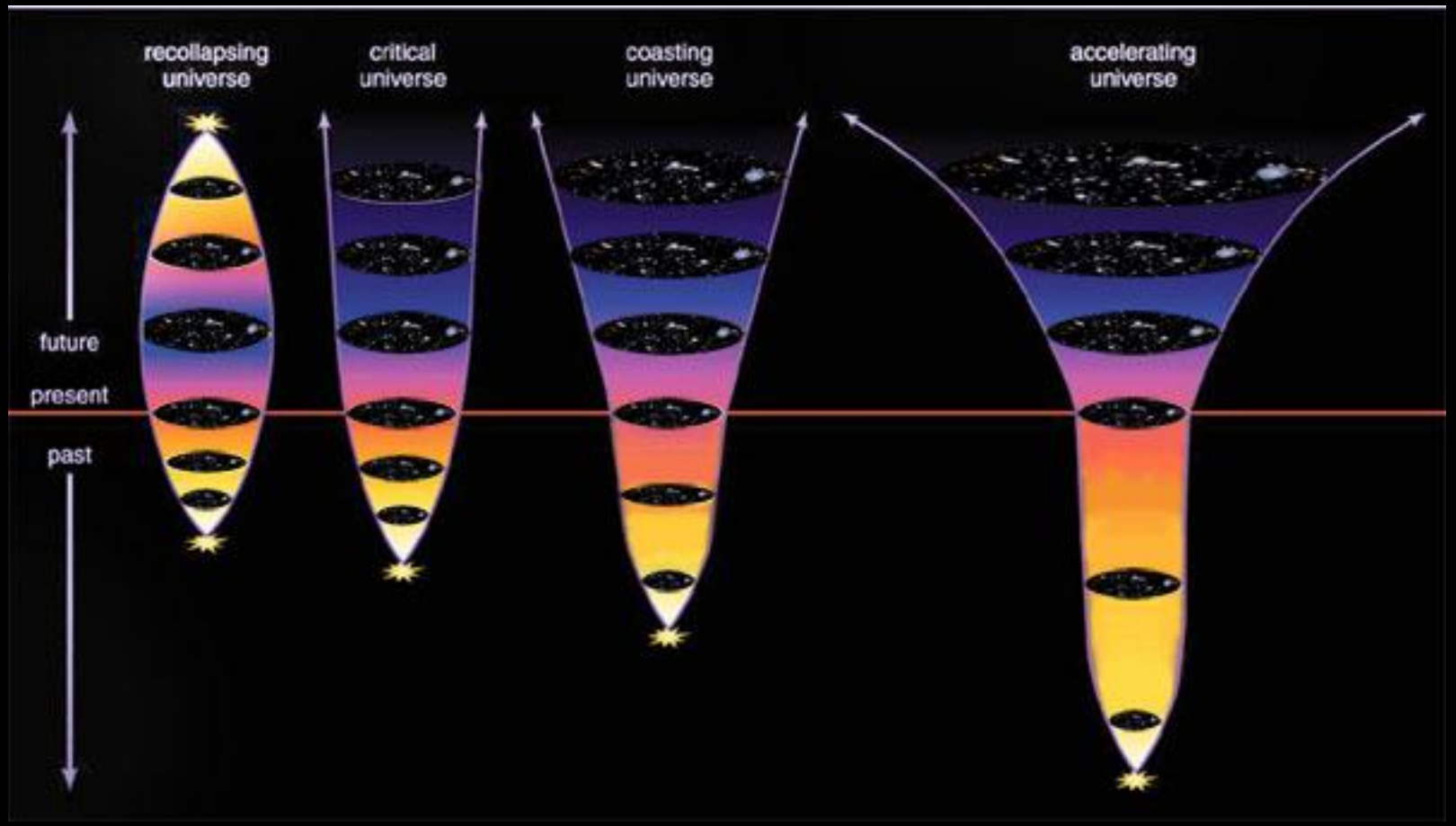
interpolating function

new fundamental constant


Afterglow Light Pattern 375,000 yrs.
Dark Ages
Dark Energy Accelerated Expansion
Development of Galaxies, Planets, etc.
Inflation
Quantum Fluctuations
1st Stars about 400 million yrs.
Big Bang Expansion
13.77 billion years


25%
4%
70%
0.3%
0.03%
0.5%
Dark Energy
Dark Matter
Free Hydrogen & Helium
Stars
Neutrinos
Heavy Elements


Spherical
Saddle
Flat


recollapsing universe
critical universe
coasting universe
accelerating universe
future
present
past

The evolution of the world may be compared to a display of fireworks that has just ended: some few red wisps, ashes, and smoke. Standing on a cooled cinder, we see the slow fading of the suns, and we try to recall the vanished brilliance of the origin of the worlds.

Georges Lemaître
(cosmologist and Jesuit priest)

Nine gaps in our understanding of cosmic history

- What triggered or preceded cosmic inflation?
- What “flavor” of inflation occurred?
- How did baryogenesis occur?
- What is the nature of dark matter?
- How and when did the first stars appear?
- How “alone” are we in the Universe?
- How did life on Earth begin?
- What is dark energy’s nature?
- What’s our ultimate cosmic fate?