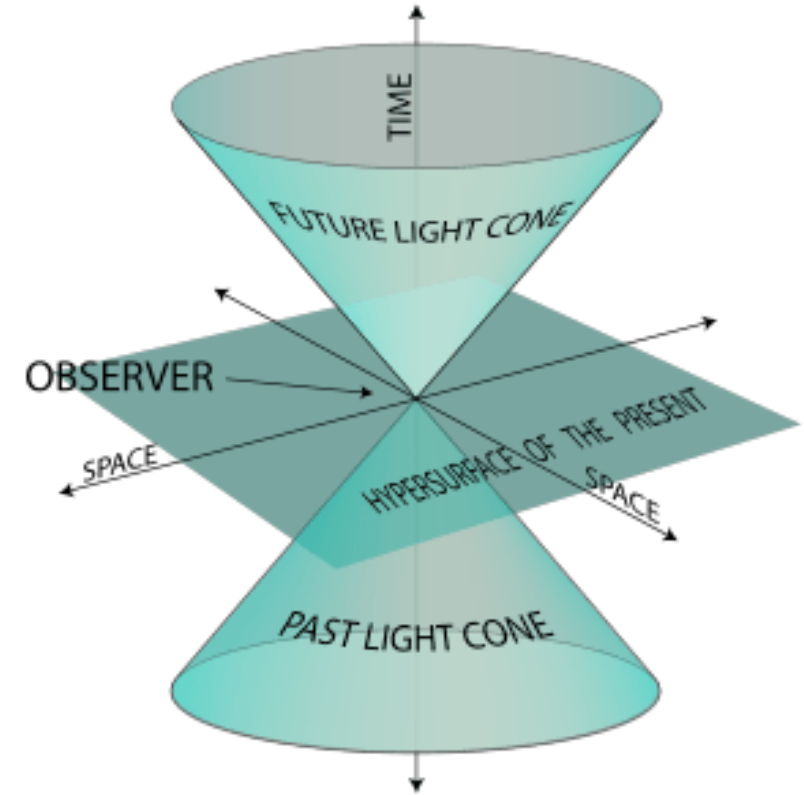


Literature Review

Observable Universe: Fate



Swapnil Bhatta

The University of Southern Mississippi

May 8, 2020



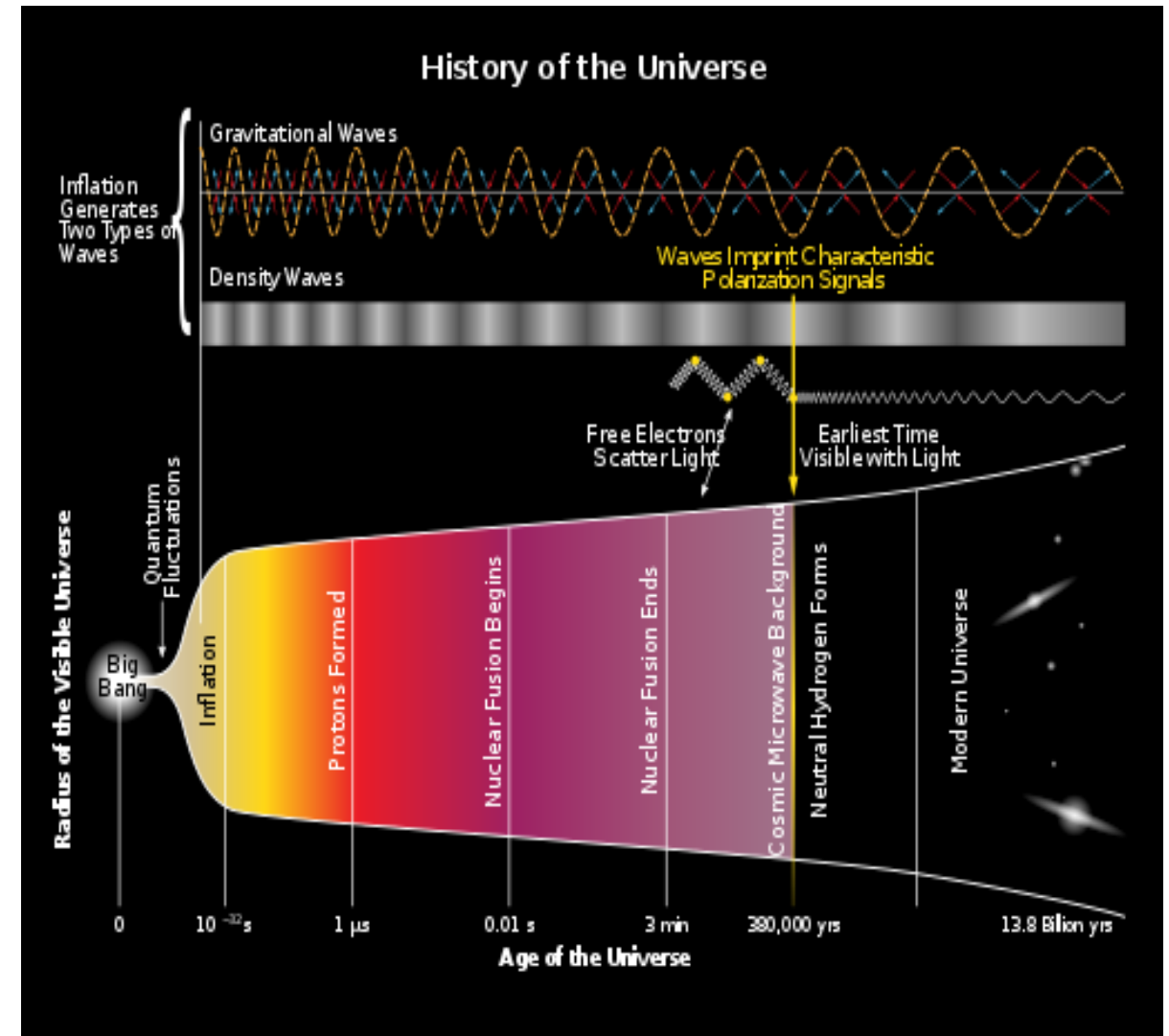
Summary of topics:

- Introduction
 - Rationale
 - History
- Theory
 - Big Bang
 - Cosmological principle
 - General Theory of Relativity
 - Shape of the Universe
 - Density Parameter
 - Heat Death
 - The Big Rip
 - The Big Crunch
 - The Big Bounce
 - The Big Slurp
- Conclusions
- Questions



Introduction : Rationale

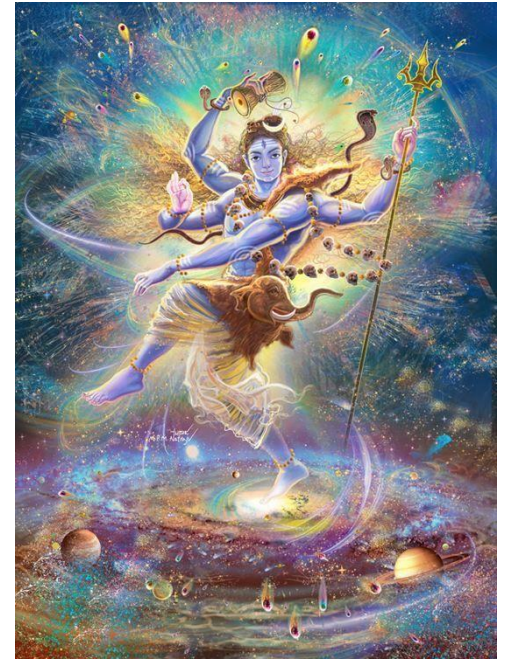
- Observable universe has existed for around 13.8 billion years.
- We have a good idea of what happened, but the future remains unsure.
- Even though it might take place billions of years from now, research into this will yield results for other branches of physics and cosmology.



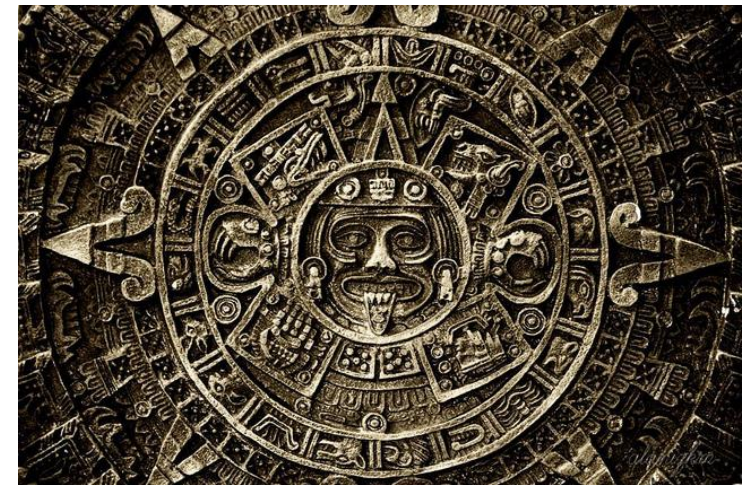


Introduction : History

- Religious scripture and artefacts have mentions of the possible end of creation, we have been curious about the universes fate.
 - Hinduism: Cyclic Universe that gets destroyed and recreated.
 - Mayan Calendar: An end date for our planet and our existence.
- Greeks like Plato believed in a beginning for the universe but did not expect it to end.



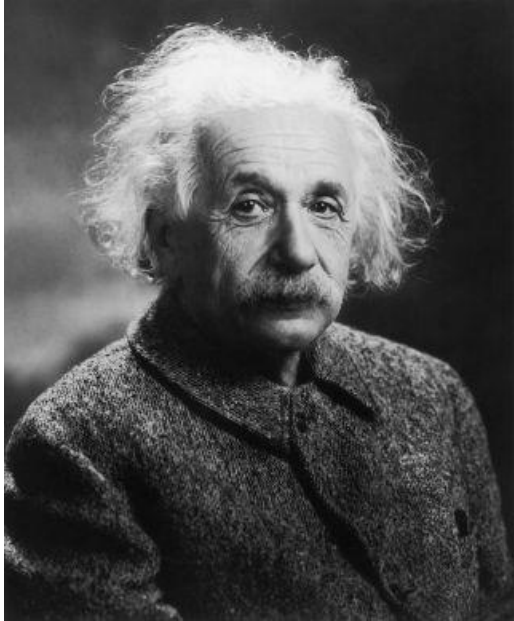
[2]



[3]



Introduction : History



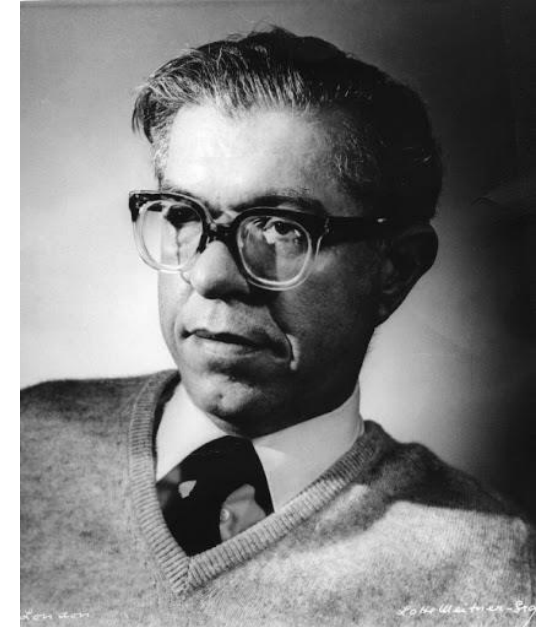
Albert Einstein



Edwin Hubble



George Gamow



Fred Hoyle

[4]

At the turn of the twentieth century modern theories entered the fray; Special Relativity, Expansion of the Universe, General Relativity, Cosmic Microwave Background Radiation and the Big Bang theory.



Theory: The Big Bang

- Theory which states that the universe initially was a hot and dense singularity, which started inflating, expanding and cooling off after an event known as the Big Bang.
- Took place 13.7×10^9 years ago.
- Supported by:
 1. Co-moving space density of distant radio galaxies.
 2. Present abundance of Helium in the universe.
 3. Cosmic microwave background radiation



Theory: General Relativity

General Theory of Relativity:

Geometric theory of gravitation.

$$R_{\mu\nu} - \frac{1}{2}R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$$

Cosmological Principle:

The universe is homogeneous and isotropic in space and time. If viewed on a sufficiently large scale, the properties of the universe are the same for all observers.

Cosmological Constant:

Incorporated in the EFE to show a static universe. Has since been used as an explanation for dark energy.



Theory: Shape of the Universe

Geometric form of the universe that can be either local or global, determined by the curvature. Assuming the Cosmological principle is true, it can exist in three types of curvatures.

a) A positive curvature.

The surface of a sphere and finite in extent.

b) A negative curvature.

The surface of a saddle and infinite in extent.

c) Flat.

The surface of a plane, still infinite in extent.



Theory: Shape of the Universe

Average density of matter in the universe determines its geometry. Matter itself is present in various forms.

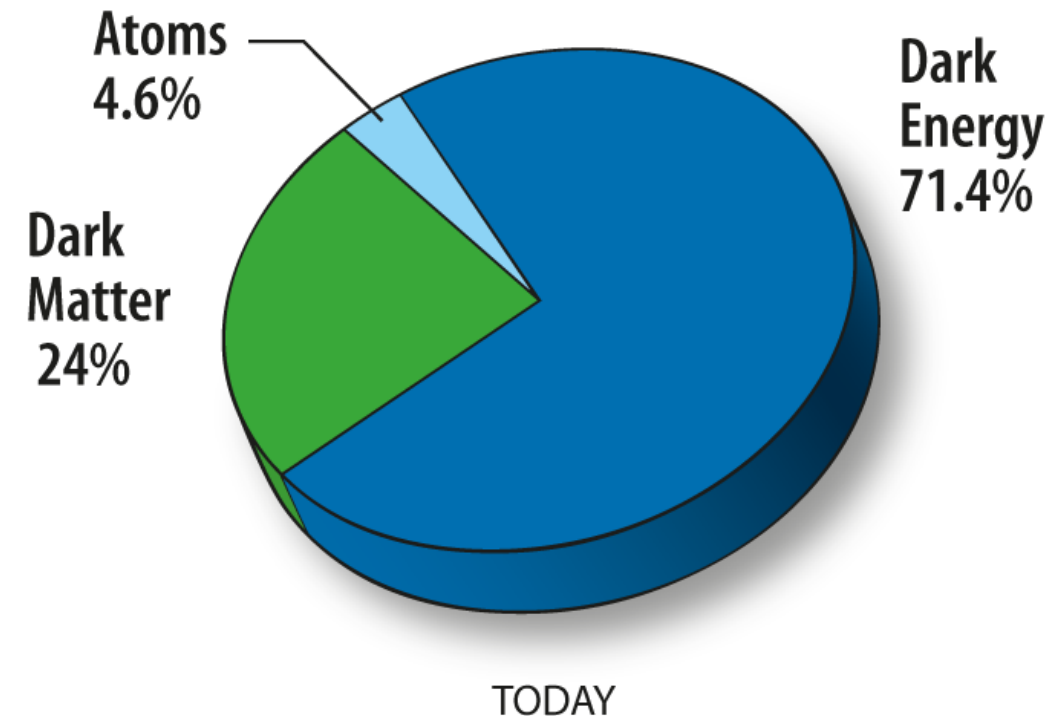
a) Dark Energy.

A theoretical force that counteracts gravity and thus aids with the expansion of the universe.

b) Dark Matter.

Matter composed of subatomic particles that do not interact with ordinary matter or electromagnetic radiation.

c) Atoms and relativistic particles.





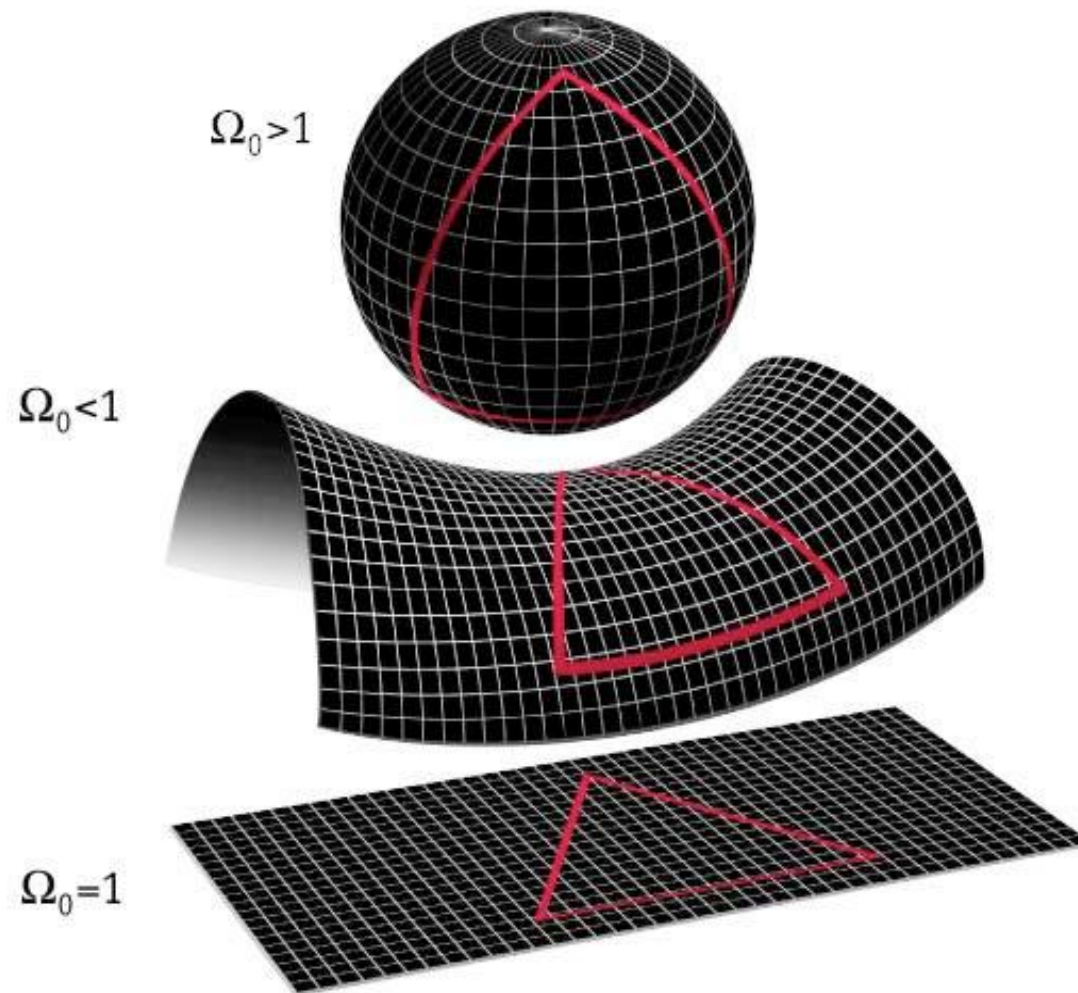
Theory: Shape of the Universe

Density Parameter:

Dividing the average density by the critical energy density gives the density parameter Ω . It gives the curvature of the geometry for the universe.

$$\Omega_t = \Omega_m + \Omega_r + \Omega_\Lambda$$

Ω_t is the total density parameter, Ω_m is the mass density of ordinary mass, which includes dark matter and baryonic mass, Ω_r is the effective mass density of relativistic particles and Ω_Λ is the effective mass density of dark energy.



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Theory: Shape of the Universe

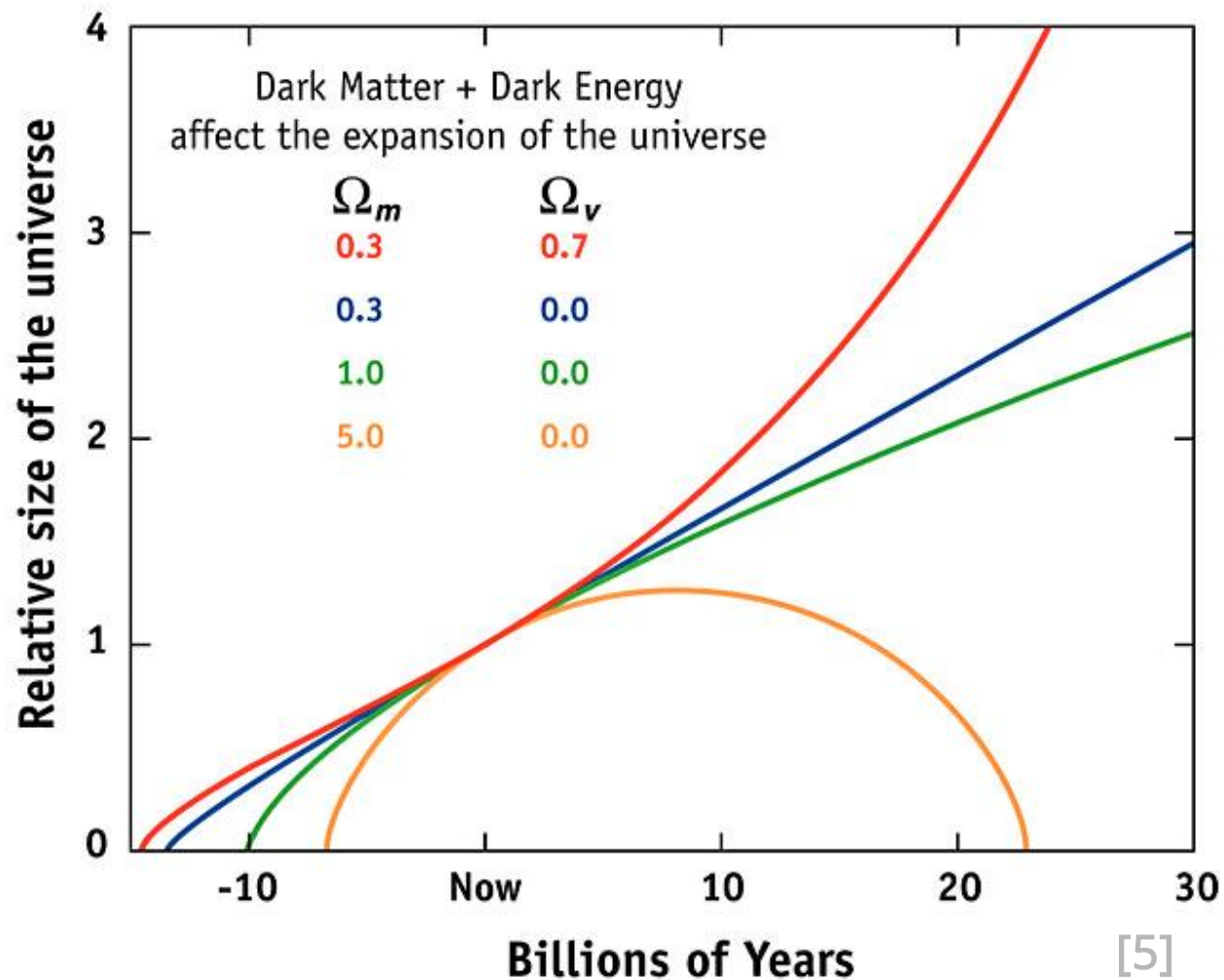
Density Parameter:

Given matter is in different forms the total density parameter is a combination of individual measurements.

$$\Omega_t = \Omega_m + \Omega_r + \Omega_\Lambda$$

Ω_t is the total density parameter, Ω_m is the mass density of ordinary mass, which includes dark matter and baryonic mass, Ω_r is the effective mass density of relativistic particles and Ω_Λ is the effective mass density of dark energy.

EXPANSION OF THE UNIVERSE





Theory: Shape of the Universe

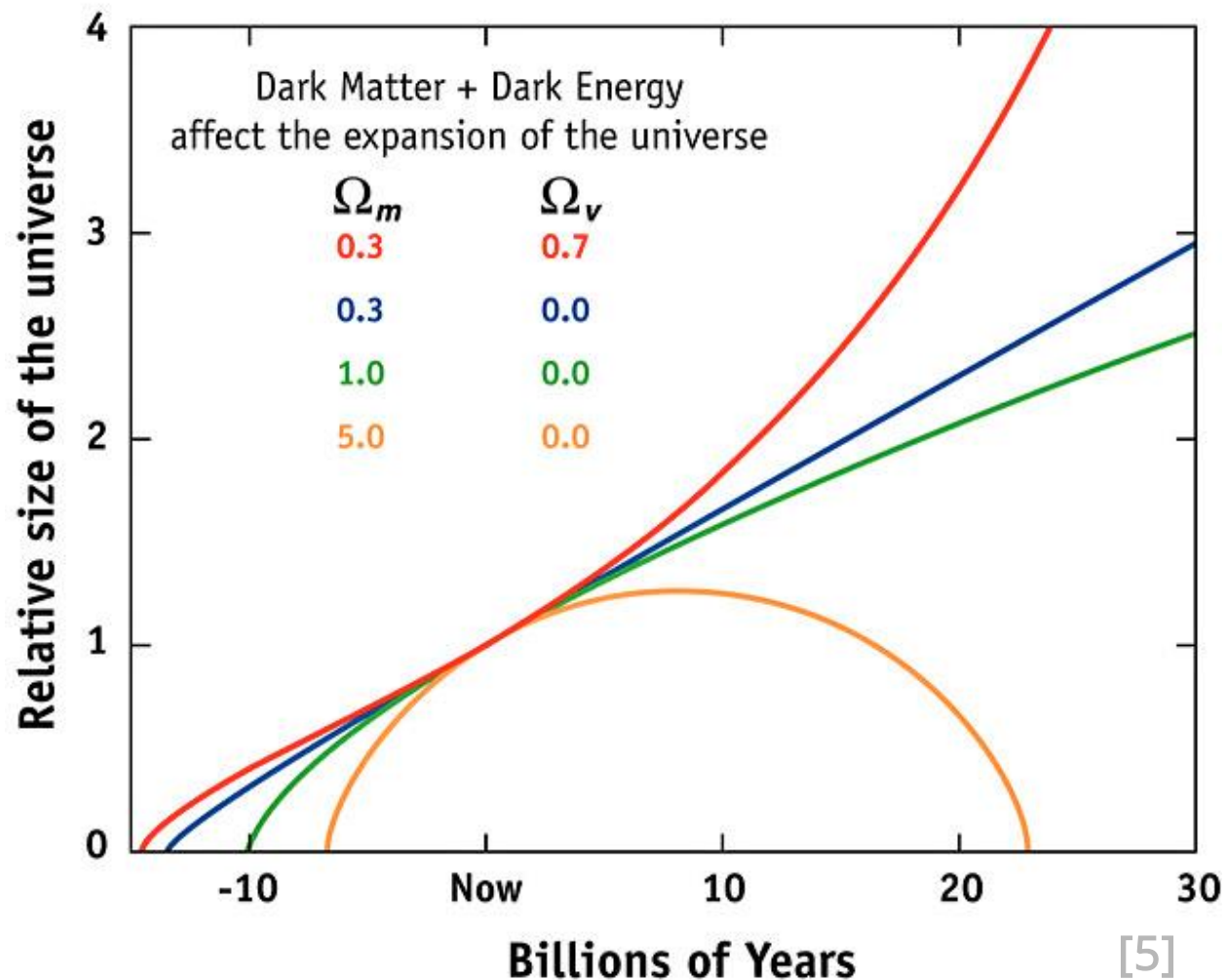
Density Parameter:

Based on observations by the Wilkinson Microwave Anisotropy Probe (WMAP) as well as the Planck spacecraft.

- $\Omega_m = 0.315 \pm 0.018$
- $\Omega_r = 9.24 \times 10^{-5}$
- $\Omega_\Lambda = 0.6817 \pm 0.0018$
- Which gives Ω_t as 1.00 ± 0.02

[6]

EXPANSION OF THE UNIVERSE





Theory: Heat Death (The Big Freeze)

- Speculated by Lord Kelvin in 1852 based on the second law of thermodynamics.
- A conjecture in which the universe will cool off to lead to a universe void of thermodynamic free energy.
- Net temperature will not be zero, but a positive constant.
- Also known as the Big Chill or the Big Freeze.
- Requires the universe to be open, infinite and expanding.
- Unlikely if energy can be generated from dark energy.



Theory: The Big Rip

- The expansion of the universe will continue at an unprecedented rate and rip all matter, ranging from stars to molecules into their sub-atomic constituents.
- Assumes the ratio between dark energy pressure and its energy density, known as phantom energy will continue increasing and grow so dominant overtime that other forces of nature such as the strong nuclear force can no longer hold atoms together.

$$t_{\text{rip}} - t_0 \approx \frac{2}{3|1 + w|H_0 \sqrt{1 - \Omega_m}} \quad [7]$$

- Where $t_{\text{rip}} - t_0$ is the time to the Big Rip, w is the phantom energy, H_0 is the Hubble constant and Ω_m the density of all matter.
- Requires the universe to be open, infinite and expanding.



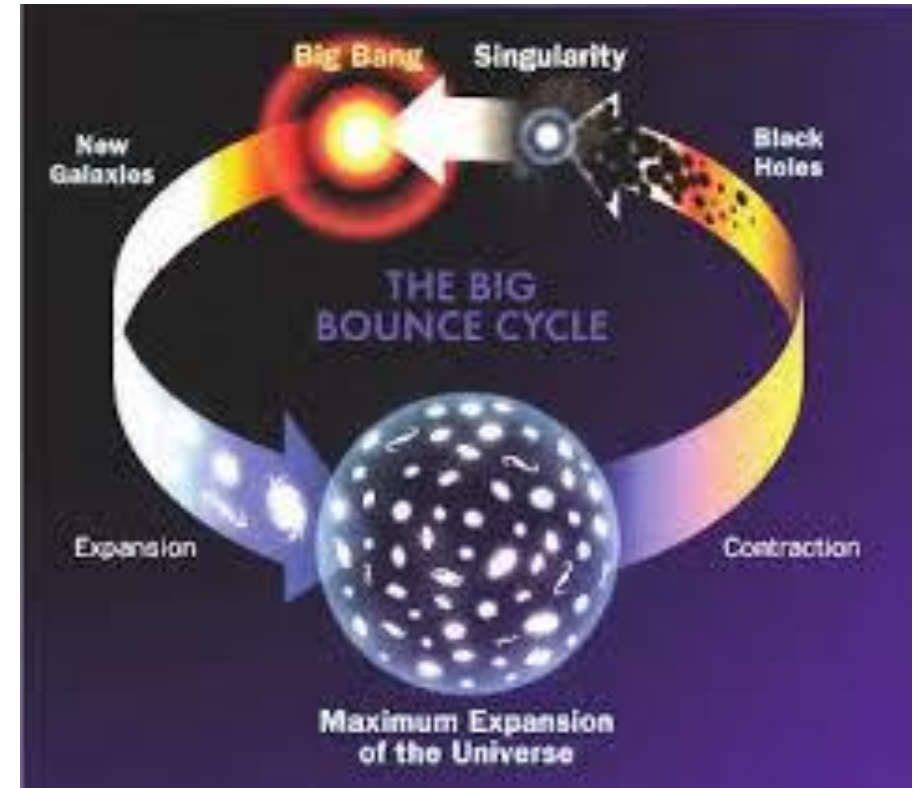
Theory: The Big Crunch

- The Big Crunch is a theory on the future of the universe in which the current expansion of the universe stops and after a certain time, the expansion reverse and the universe collapses onto itself.
- Underlying assumption is that the density parameter is lower than one, so the universe is closed and finite.
- The WMAP data shows the density parameter being equal to, or slightly higher than one and thus suggesting that our universe is shown to be spatially flat and not closed.



Theory: The Big Bounce

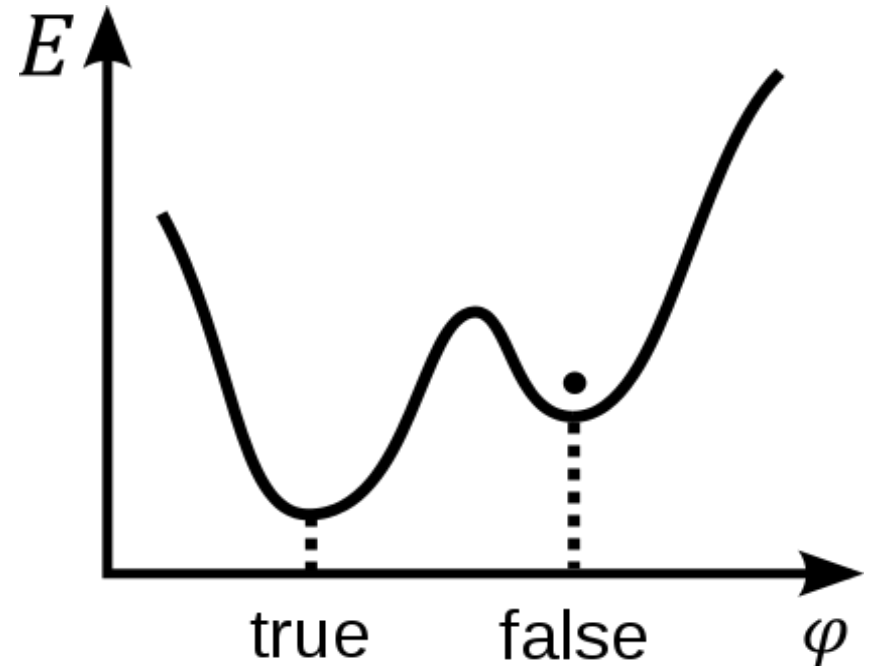
- Encompasses the Big Bang and the Big Crunch, hypothesizing that the evolution of the universe is a cyclic process.
- A culminating process of an eternal universe, which is in a cyclic process of expansions and contractions.
- Recent developments in loop quantum cosmology support it.
- Same issues as with the Big Crunch.





Theory: The Big Slurp

- The Big Slurp is a theory based on the existence of false vacuum, a state in quantum field theory that is pseudo stable.
- Assumed there exists a state with higher stability known as true vacuum.
- The theory suggests the universe can instantaneously move to a true vacuum by tunneling through a barrier as proven in quantum tunneling of electrons.





Conclusion

- Given the observations by WMAP, the Planck satellite, and the existing standard model of cosmology, the most likely fate of the universe seems to be either a heat death, or a Big Rip.
- There is still a 3% uncertainty on the data recorded by the explorations, more data is needed.
- We know very little about the physics of dark matter given its lack of interaction with electromagnetic waves and also not a lot about dark energy.



Citations

- [1] History of the Universe. Wikimedia commons.
https://commons.wikimedia.org/wiki/File:History_of_the_Universe.svg
- [2] Image – Hinduism <https://za.pinterest.com/pin/598978819165473528/>
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Thank you.

Questions?