STANDARD BIG BANG MODEL

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B.Sc. (Hons.) Physics

PY1480 Seminar Presentation

Submitted to Dr. Anupam Sharma

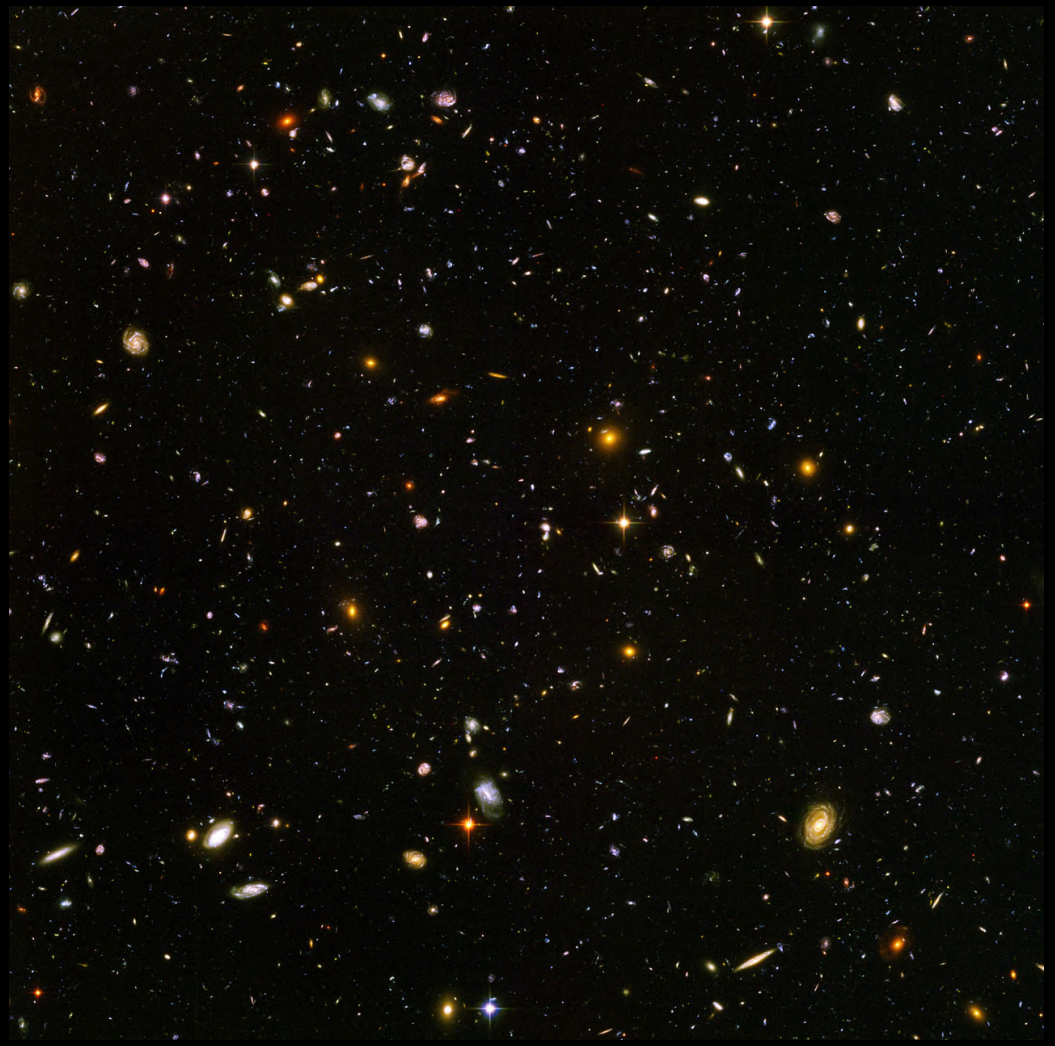
CONTENTS

- Standard Big Bang Model (an overview)
- Mass Distribution in the Universe and Stability
- Kinematics of Universe according to Standard Big bang
- Friedmann Equations and Solutions
- CMB
- Cosmological Horizon

What is it ?

- Theory that the Universe as we know it began $13 - 14$ billion years ago.
  (Latest estimate 13.799 ± 0.021 billion years)

- Initial state was a hot, dense, uniform soup of particles that filled space uniformly, and was expanding rapidly.



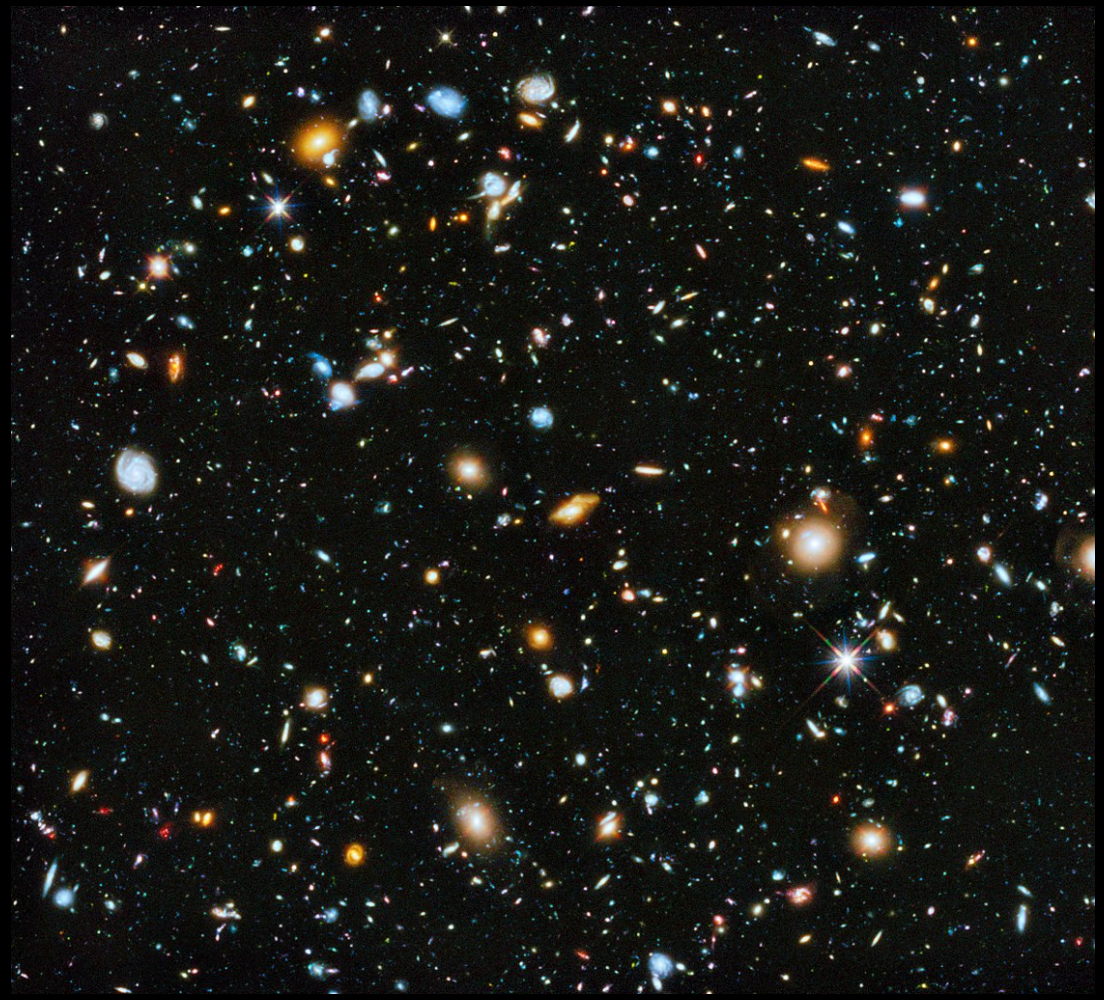
HUBBLE ULTRA DEEP FIELD

What it describes ?

- How the early Universe expanded and cooled. How the Universe evolved over time.

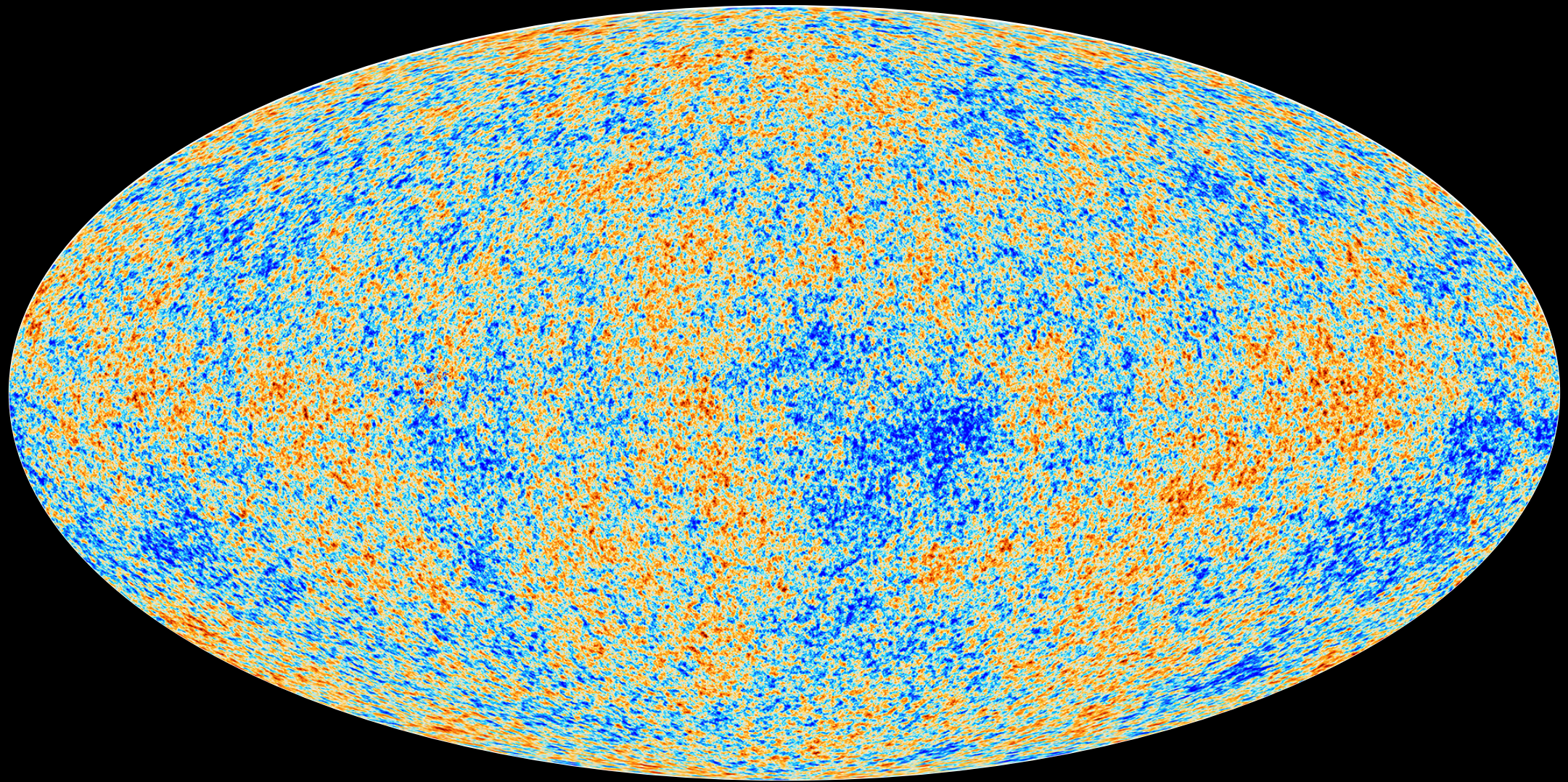
- How the matter congealed to form stars, galaxies and clusters of galaxies.

- How the light chemical elements formed.



Hubble Extreme Deep Field published 2014

ISOTROPY

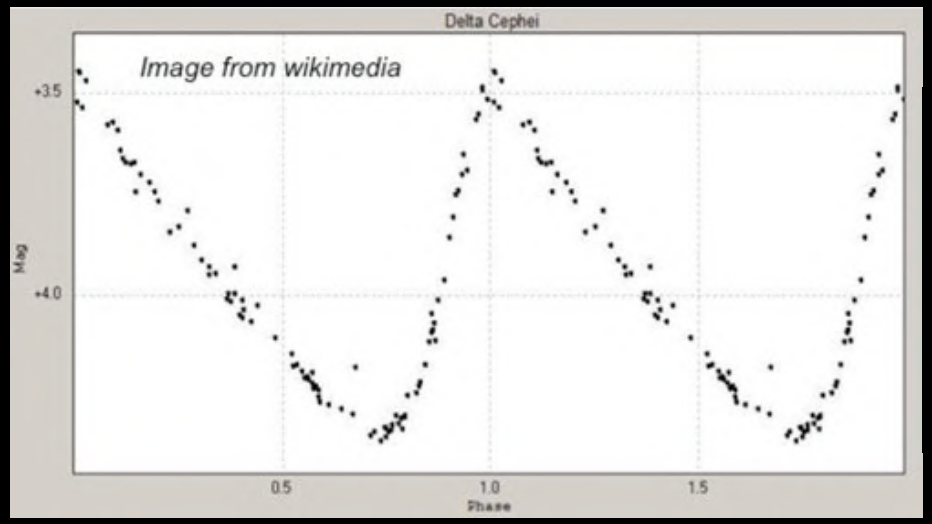


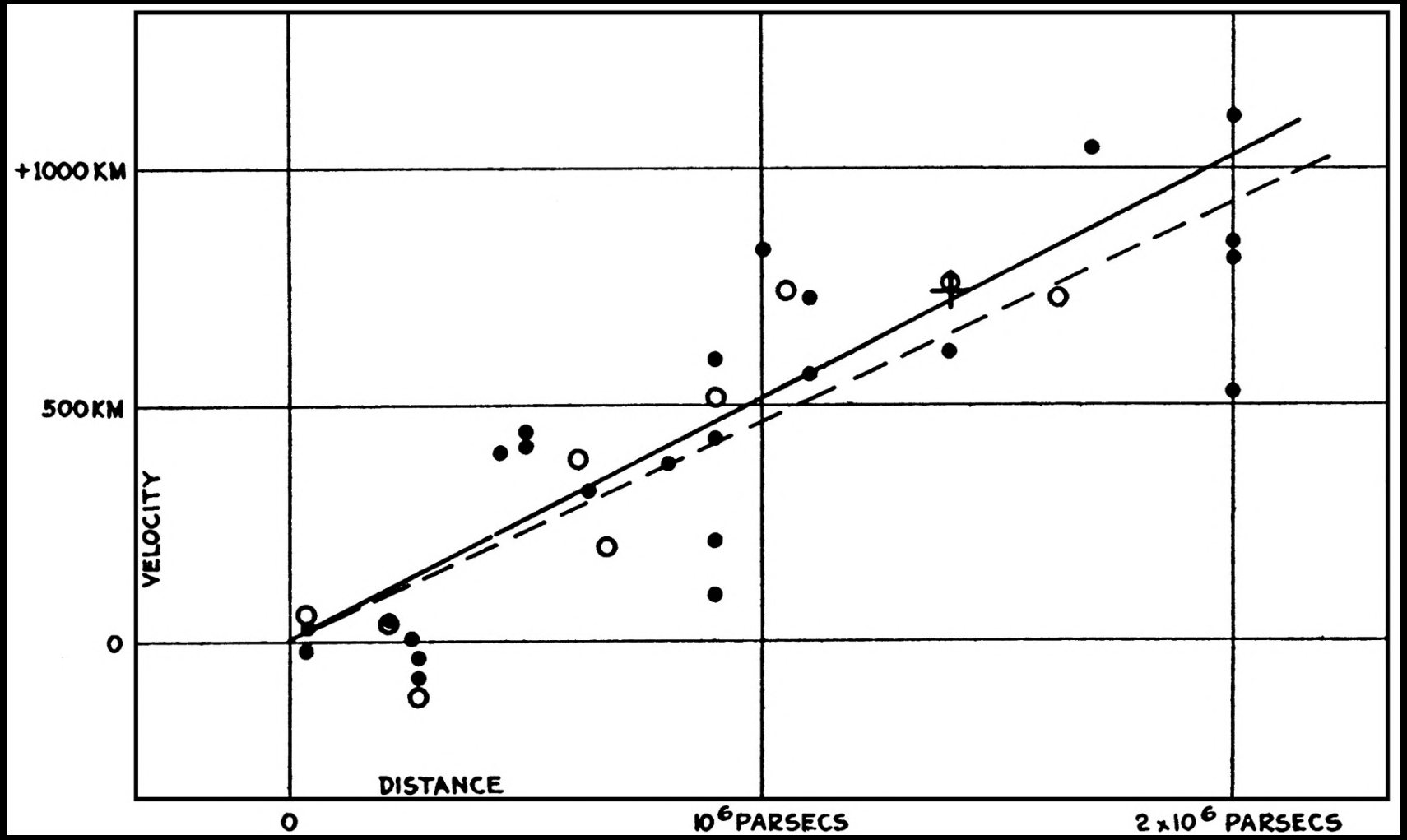
CMB PLANCK MISSION

HOMOGENIETY (No Absolute Centre)

Edwin Hubble stands by the 48-inch telescope at Palomar Observatory

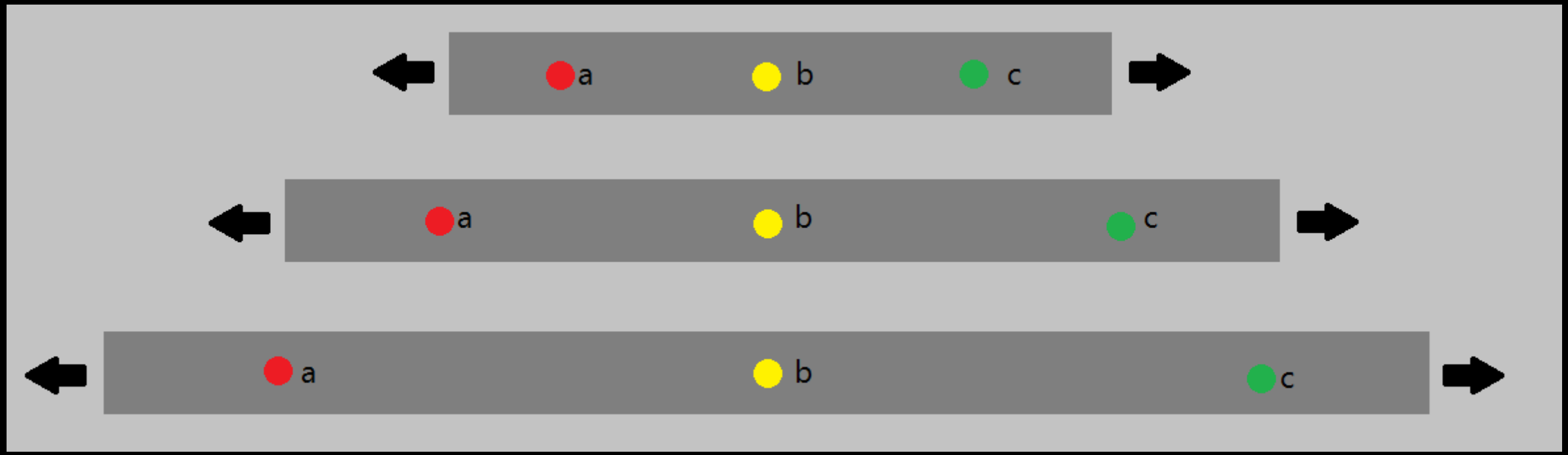
- Cepheid Variables (For distance estimation)
- Redshifts from spectrum (For recessional velocities)





Velocity-Distance Plot from Hubble's data (1924)

$$v = Hr$$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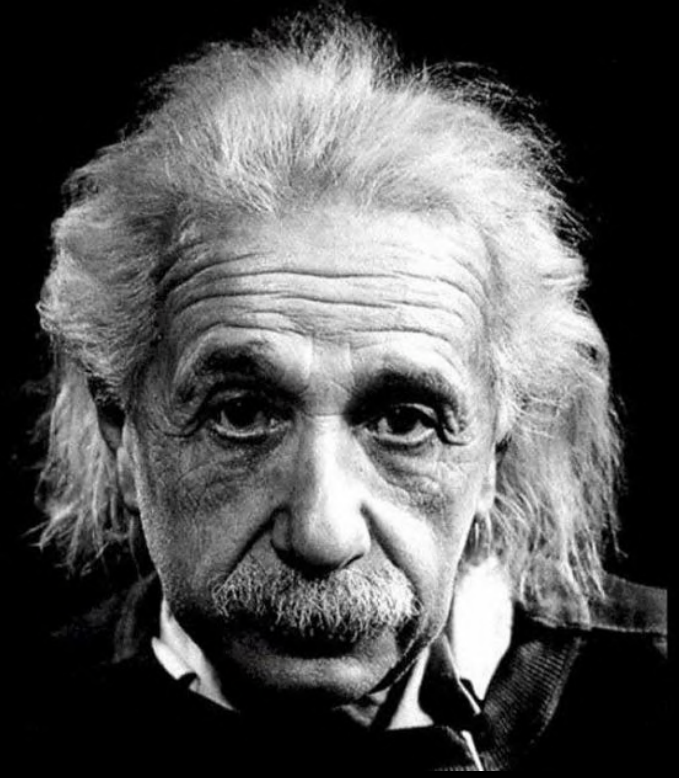
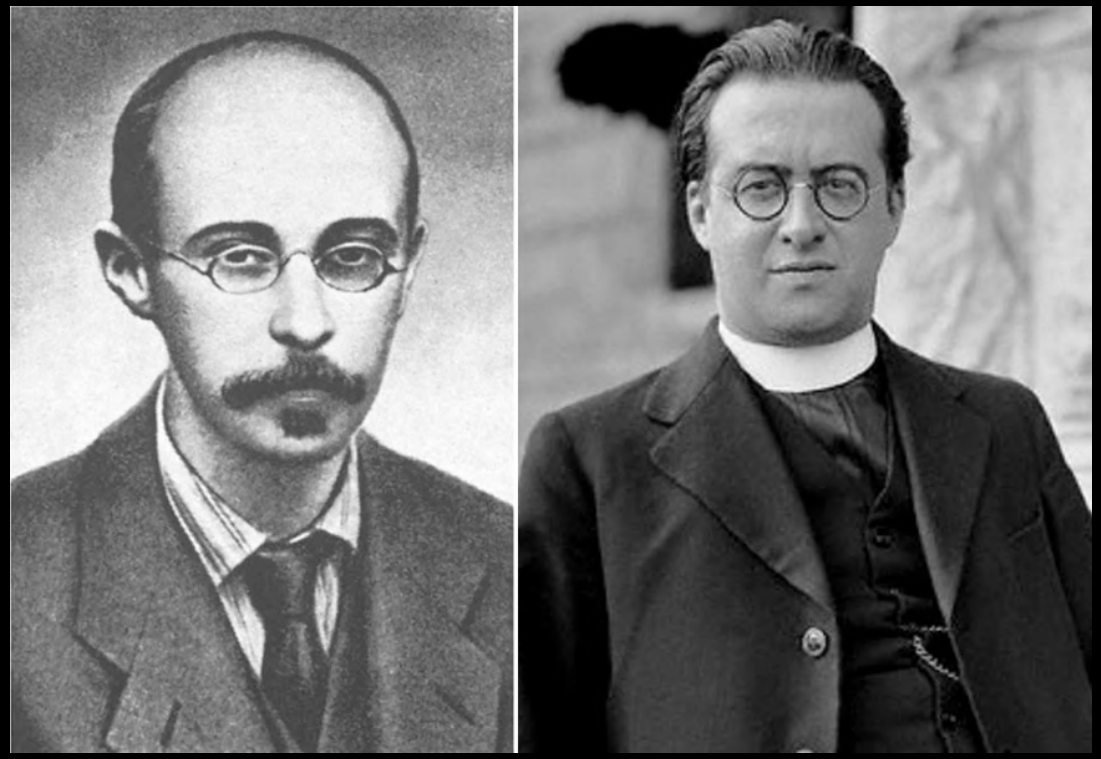


GENERAL THEORY OF RELATIVITY (1915)

Einstein’s Field Equations

- Alexander Friedmann in 1922 introduced the idea of an expanding universe that contained moving matter, governed by a set of equations he developed now known as the Friedmann Equations.
- Belgian astronomer Georges Lemaître later independently reach the same conclusion in 1927.



Alexander Friedmann and Georges Lemaître

Isaac Newton to Richard Bentley, Letter 1
Newton on the Infinite Universe

As to your first query, it seems to me that if the matter of our sun and planets and all the matter of the universe were evenly scattered throughout all the heavens, and every particle had an innate gravity toward all the rest, and the whole space throughout which this matter was scattered was but finite, the matter on the outside of this space would, by its gravity, tend toward all the matter on the inside and, by consequence, fall down into the middle of the whole space and there compose one great spherical mass. But if the matter was evenly disposed throughout an infinite space, it could never convene into one mass; but some of it would convene into one mass and some into another, so as to make an infinite number of great masses, scattered at great distances from one to another throughout all that infinite space. And thus might the sun and fixed stars be formed, supposing the matter were of a lucid nature.

— December 10, 1692

But how the matter should divide itself into two sorts, and that part of it which is to compose a shining body should fall down into one mass and make a sun and the rest which is fit to compose an opaque body should coalesce, not into one great body, like the shining matter, but into many little ones; or if the sun at first were an opaque body like the planets or the planets lucid bodies like the sun, how he alone should be changed into a shining body whilst all they continue opaque, or all they be changed into opaque ones whilst he remains unchanged, I do not think explicable by mere natural causes, but am forced to ascribe it to the counsel and contrivance of a voluntary Agent.

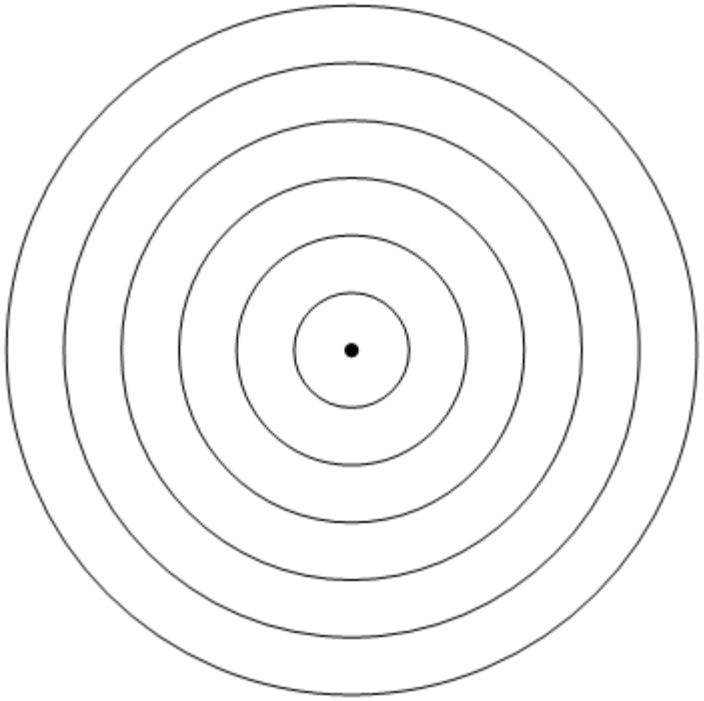
— December 10, 1692

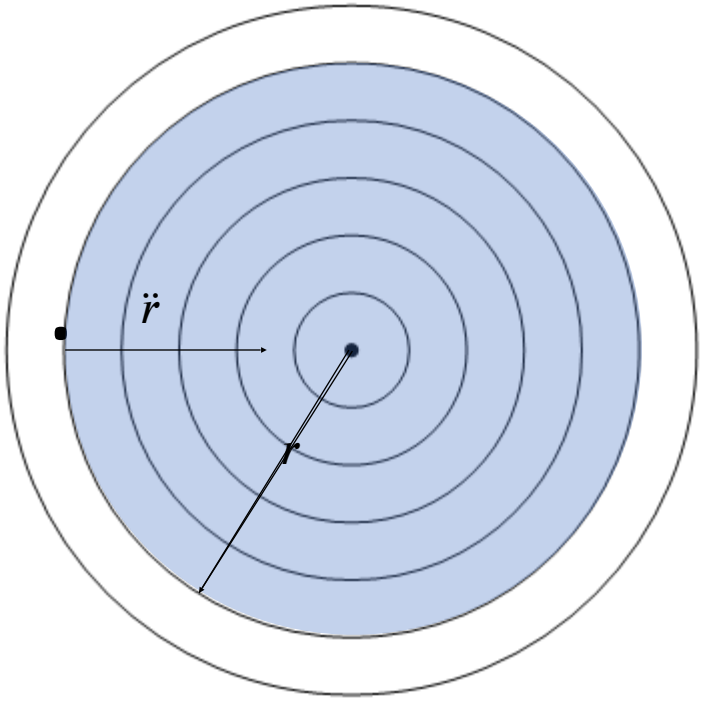
Web references: http://www.newtonproject.sussex.ac.uk/view/texts/normalized/THEM00254
http://books.google.com/books?id=8DkCAAAAQAAJ&pg=PA201

Isaac Newton to Richard Bentley, Letter 2
Newton on Infinities

But you argue, in the next paragraph of your letter, that every particle of matter in an infinite space has an infinite quantity of matter on all sides, and, by consequence, an infinite attraction every way, and therefore must rest in equilibrio, because all infinites are equal. Yet you suspect a paralogism in this argument; and I conceive the paralogism lies in the position, that all infinites are equal. The generality of mankind consider infinites no other ways than indefinitely; and in this sense they say all infinites are equal; though they would speak more truly if they should say, they are neither equal nor unequal, nor have any certain difference or proportion one to another. In this sense, therefore, no conclusions can be drawn from them about the equality, proportions, or differences of things; and they that attempt to do it usually fall into paralogisms.

— January 17, 1693





- Uniform mass distribution ρ_i at t_i
- Isotropy

- Introducing a scale factor $a = \dfrac{r}{r_i}$

$$\therefore \ \ddot{r} = \ddot{a} r_i$$

$$\ddot{r} = \frac{-G(\frac{4\pi r_i^3}{3})\rho_i}{r^2}$$

$$\ddot{a} r_i = \frac{-G(\frac{4\pi r_i^3}{3})\rho_i}{r^2}$$

$$\ddot{a} = \frac{-G(\frac{4\pi r_i^2}{3})\rho_i}{r^2} = \frac{-G(\frac{4\pi}{3})\rho_i}{a^2}$$

Thus all observers measure same $\ddot{a}$ independent of their r_i

Thus for any particle,

$$E_m = \frac{m(\dot{a}r_i)^2}{2} - \frac{Gm(\frac{4\pi r_i^2}{3})\rho_i}{a}$$

We define E such that

$$E = \frac{E_m}{mr_i^2} = \frac{\dot{a}^2}{2} - \frac{G\left(\frac{4\pi}{3}\right)\rho_i}{a} \qquad - \quad \rho_t = \frac{\rho_i}{a^2}$$

$$\frac{2E}{a^2} = \frac{\dot{a}^2}{a^2} - \frac{8\pi G\rho_t}{3}$$

To make it look like Friedmann equation

$$\frac{-2E}{c^2} = k$$

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho_t}{3} - \frac{kc^2}{a^2} \qquad - \quad H = \frac{\dot{r}}{r} = \frac{\dot{a}}{a}$$

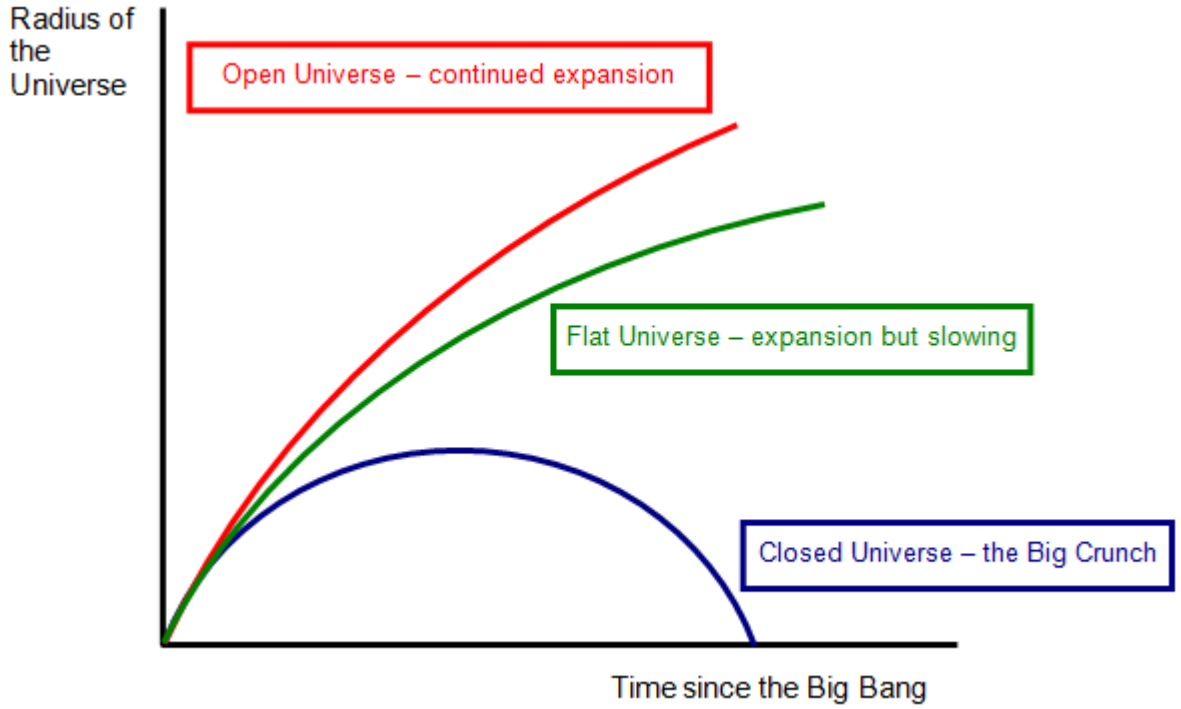
$$H^2 = \frac{8\pi G\rho_t}{3} - \frac{kc^2}{a^2}$$

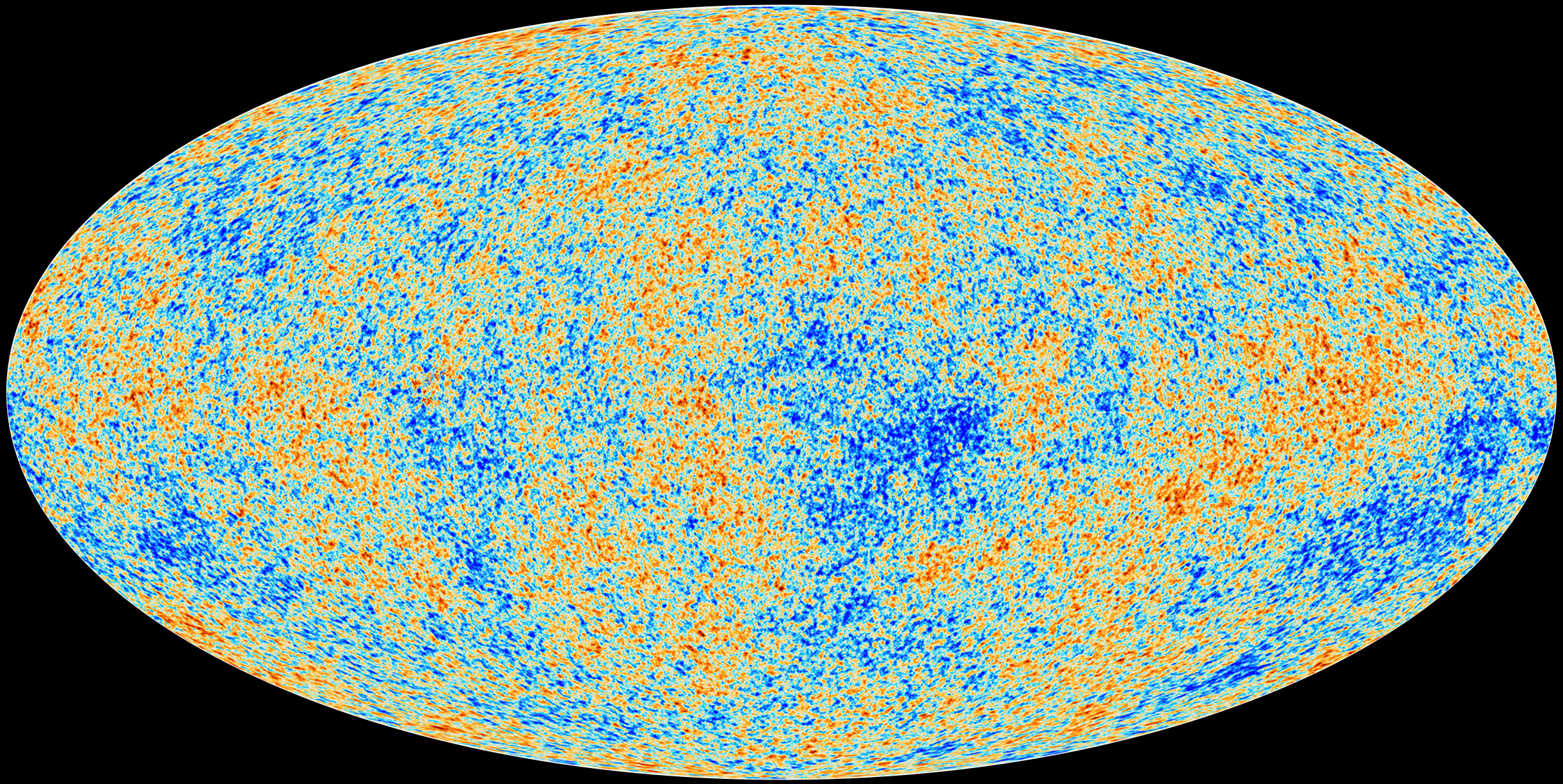
$$H^2 = \frac{8\pi G\rho_t}{3} - \frac{kc^2}{a^2} \qquad \frac{2E}{a^2} = \frac{\dot{a}^2}{a^2} - \frac{8\pi G\rho_t}{3}$$

- If $E > 0$ or $k < 0$
  OPEN UNIVERSE a increases forever, Universe expands forever

- If $E < 0$ or $k > 0$
  CLOSED UNIVERSE a reaches a maximum value and decreases later, Universe reaches a maximum size and collapses later

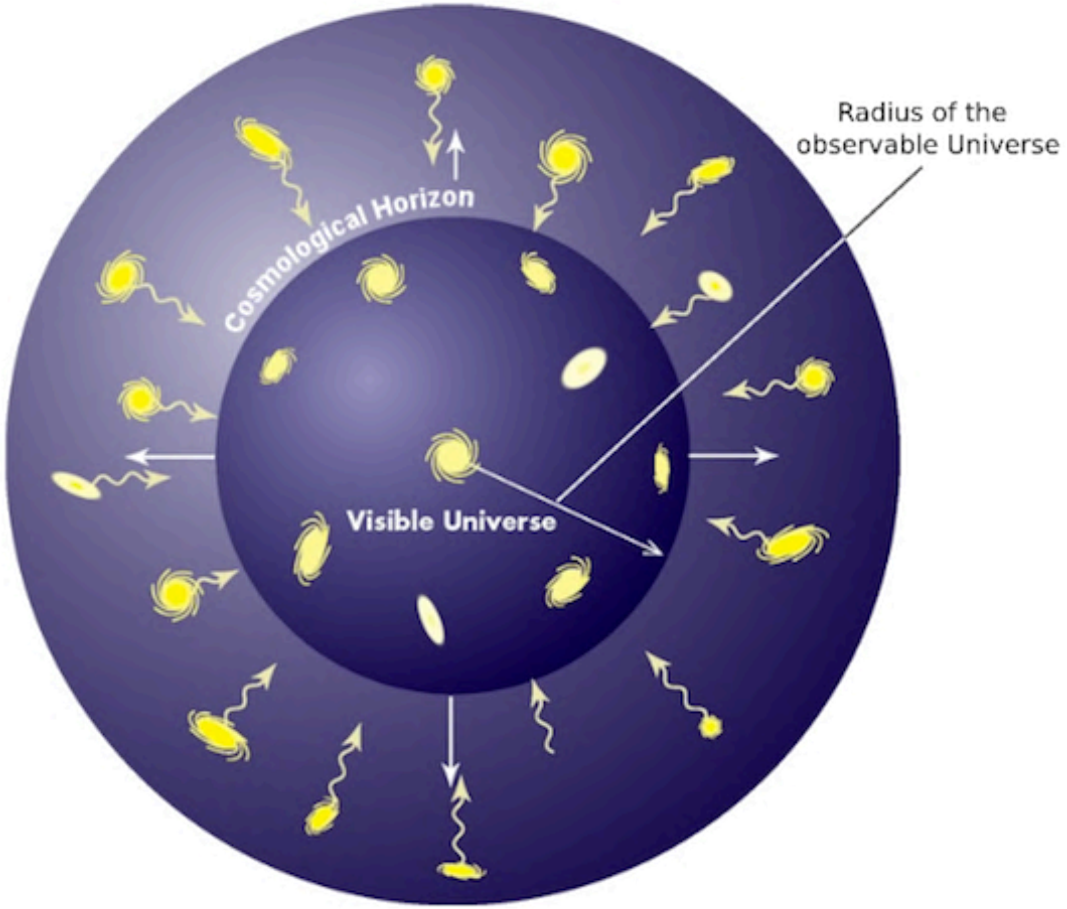
- If $E = 0$ or $k = 0$
  FLAT UNIVERSE





CMB PLANCK MISSION

Cosmological HORIZON



What it doesn’t describe ?

- What caused the expansion? (The big bang theory describes only the aftermath of the bang.)
- Where did the matter come from? (The theory assumes that all matter existed from the very beginning.)

“INFLATION”

Accelerated Expansion

Dark Energy

Dark matter

THANK YOU