The Computer Deconstruction Lab Presents
What came Before the Big Bang? Answer Inflation!

A Brief Introduction and
A Walk into "Alice in Wonderland"
Mixes Physics with Philosophy

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Big Bang

- Describes what happened from
  - t ~< 1 sec to today
- But, we don't know
  - What banged
  - Why it banged
  - What happened before it banged
- Three main problems with Big Bang Theory
  - Why is Cosmic Microwave Background Radiation so uniform
  - Why is the universe flat
    - Omega Ω is the measurements of the flatness of the universe
    - (Ω ~ 1)
  - Why are there no Magnetic Monopoles
- All of these will be explained in the following slides

BBT vs. Inflation

- Before Inflation Theory Postulated
  - The only way to explain the state of the early universe is to assume that the universe (magically) came into being with
    - Cosmic Microwave Background Radiation uniform
    - Flat
    - No magnetic Monopoles
- After Inflation Theory
  - First Postulated by Guth (1979)
    - Great way to get a post-doc and tenure
  - We can explain why the above is true
  - But get new questions to ask

Background

- When physicists don't understand something, they invent new words to describe it but that does not mean they understand it.
- Examples:
  - Magnetism – "Magnetic Field"
  - Atomic Charges – "Electric Field"
  - Radio Waves - "Electromagnetic Field"
  - Gravity – "Gravitational Field"
  - Forces inside of an atom –
    "Weak Field"/"Weak Force" and "Strong Force"
- We have math to give us answers but we still do not know the answer to: What are the "Fields" ?

What is inflation?

- At some point before (?) time began postulate a "Field" * that inflates “X” ** exceeding fast
  - Called the inflaton or inflation field
  - We need a name, so X is called a “false vacuum” but we don’t really know what it is or if we can ever observe it.
- After “X” expands the "Field" "breaks***" and the rapid expansion stops and the Big Bang expansion starts (at a much slower rate)

* No clue what this field is; where it came from; why it existed; why it stopped!
** What is X? The something that is not the universe. Whatever that is!
*** The correct mathematical term is "breaks symmetry"

Inflation -2

- We do not know when the universe started
- We call time zero (t_0) the time that we calculate when we run the expansion of the universe backwards to a singularity.
- The theory of inflation has inflation starting at 10^{-37} seconds (or sooner) and ending at around 10^{-35} seconds
- In that time the universe expanded by 2^{100} times (10^{28} times) or more

Inflation - 3

- Inflation solves
  - CMB uniformity
  - Flatness
  - No magnetic monopoles
- But: Does not answer question of where universe came from, or why, or when
- Creates the idea of a multiverse
  - Multiple pocket universes with different values of Inflaton Field and therefore different initial conditions

What?

- So what supposedly happened is that:
  - Out of nothingness, a teeny-tiny bubble of space appeared and
  - Started to grow really, really, really, really, ... really, really Fast.
  - Then something (?) broke and the expansion slowed down by a lot!
  - Then what happened is that the Big Bang started
  - And this has happened multiple times to create other Universes (that we can never see)
- And they call this Physics!

Examples of Inflation

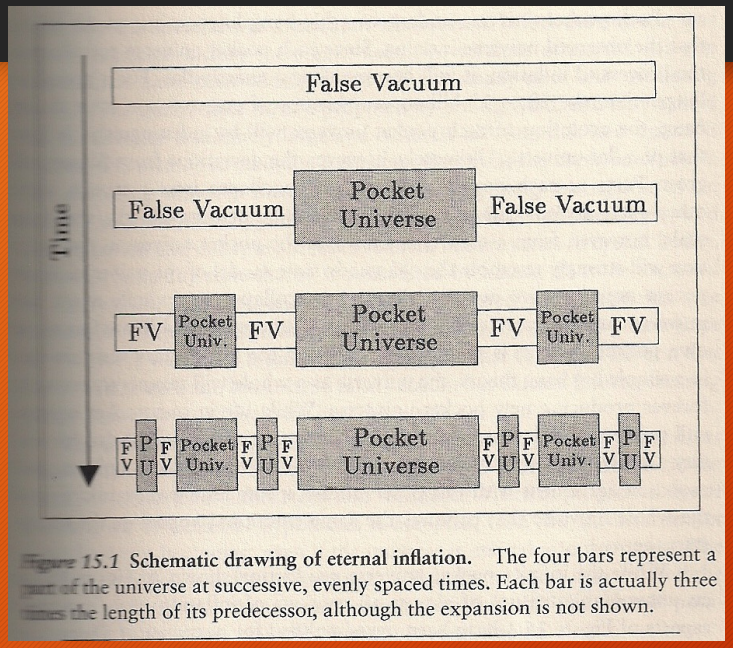


Figure 15.1 **Schematic drawing of eternal inflation.** The four bars represent a part of the universe at successive, evenly spaced times. Each bar is actually three times the length of its predecessor, although the expansion is not shown.

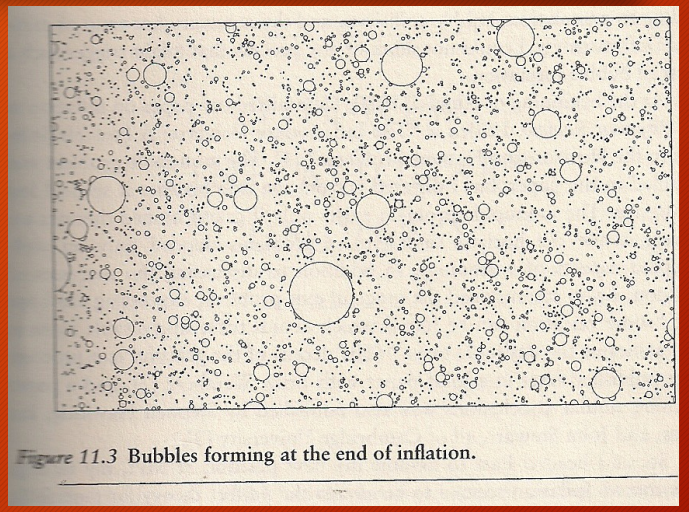
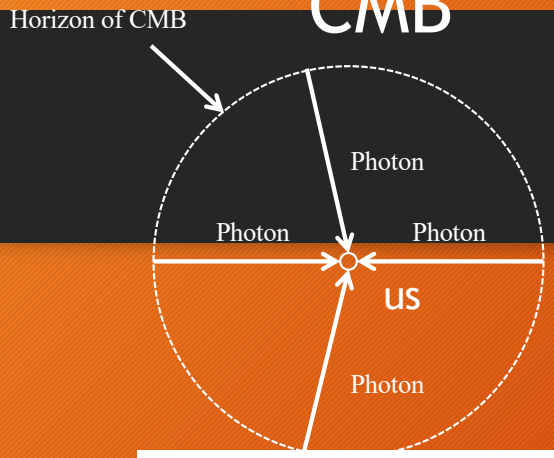


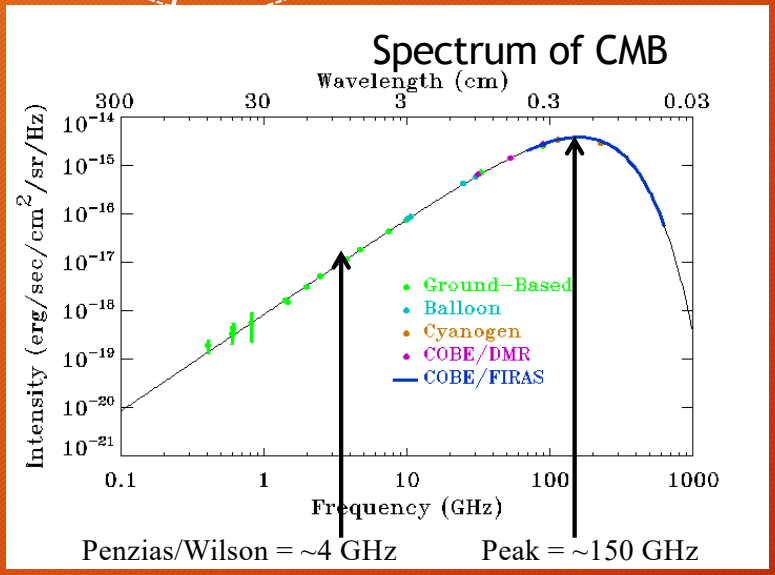
Figure 11.3 **Bubbles forming at the end of inflation.**

From Guth book

Each pocket universe expands slower than new pocket universes are created
So the theory postulates that there are an infinite number of pocket universes of which our universe is just one in a multi-verse
Remember the Science Fiction Show called "Sliders"

CMB





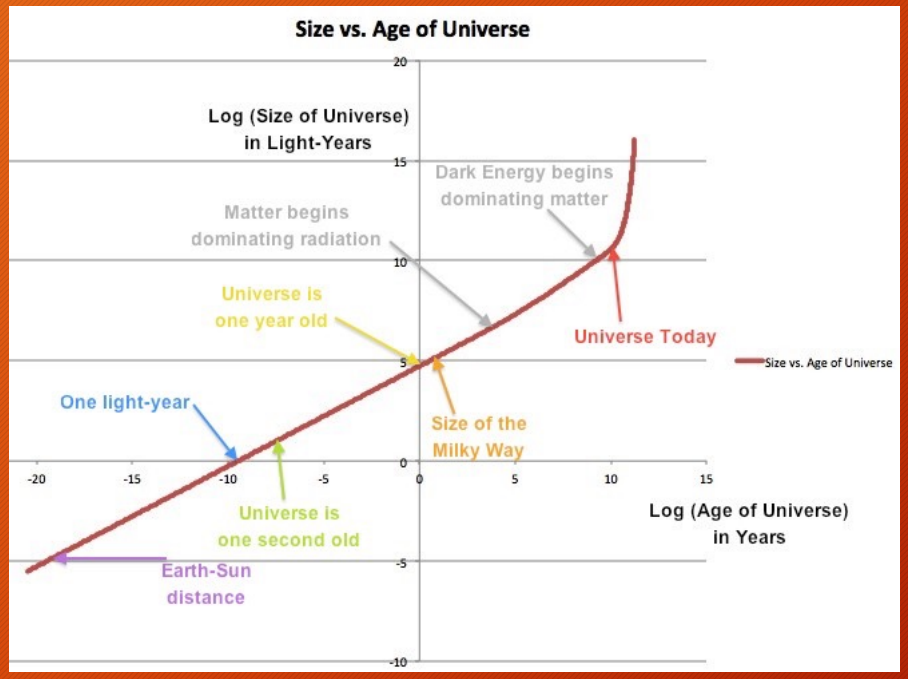
- After correcting for movement of our galaxy wrt to CMB horizon
- CMB is temperature uniform (2.725 K) to within one part in 10^{+5} with distinct ripples
- The edge or observable horizon is 42 billion light years away
- The diameter of the CMB sphere > c $t_{age\ universe}$
- CMB uniformity not explained by BBT
- No time for universe to cool to a uniform temperature

How was the CMB created

- Every object (above absolute zero) emits radiation
- This is called "Black Body Radiation"
- The physicist Plank calculated the spectrum of the radiation
- At the time the universe cooled enough so that light could propagate though the mix of particles and energy the universe was 3000 Kelvin. 380,000 years after the big bang.
- The universe has expanded by about 1000 times since then so the "light" would be at 1000 less temperature (3 degrees) and 1000 lower in frequency.
- That is how Peebles concluded that Penzias and Wilson had detected the signal from the CMB.
- see last slide for the formula for black body radiation.

event	age	diameter
inflation start	10^{-37} seconds	8×10^{-28} cm.
inflation end	10^{-35} seconds	~1-10 cm.
	1 second	~10 light years
	1 year	~100,000 light years
CMB	380,000 years	84 million light years
today	13.8 Billion years	92 Billion light years

Note inflation start and end times are assumptions

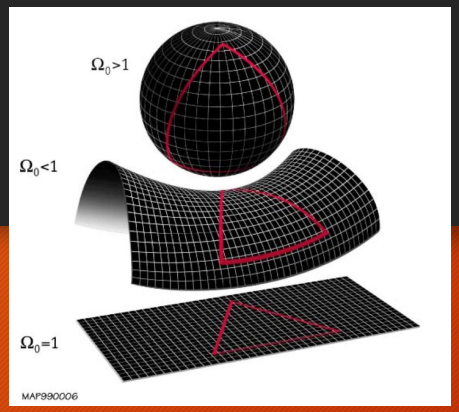


From: https://medium.com/starts-with-a-bang/how-is-the-universe-bigger-than-its-age-7a95cd59c605#.9lq0djgoe

In the standard BBT, there is no way for the universe to get into thermal equilibrium since at any point in time, the size of the universe is greater than c t_{age_univ}

When inflation starts ct=3x10-27 cm. and the universe is 4 times smaller, so thermal equilibrium is possible

The universe at creation was unbelievably flat!



shape of the universe

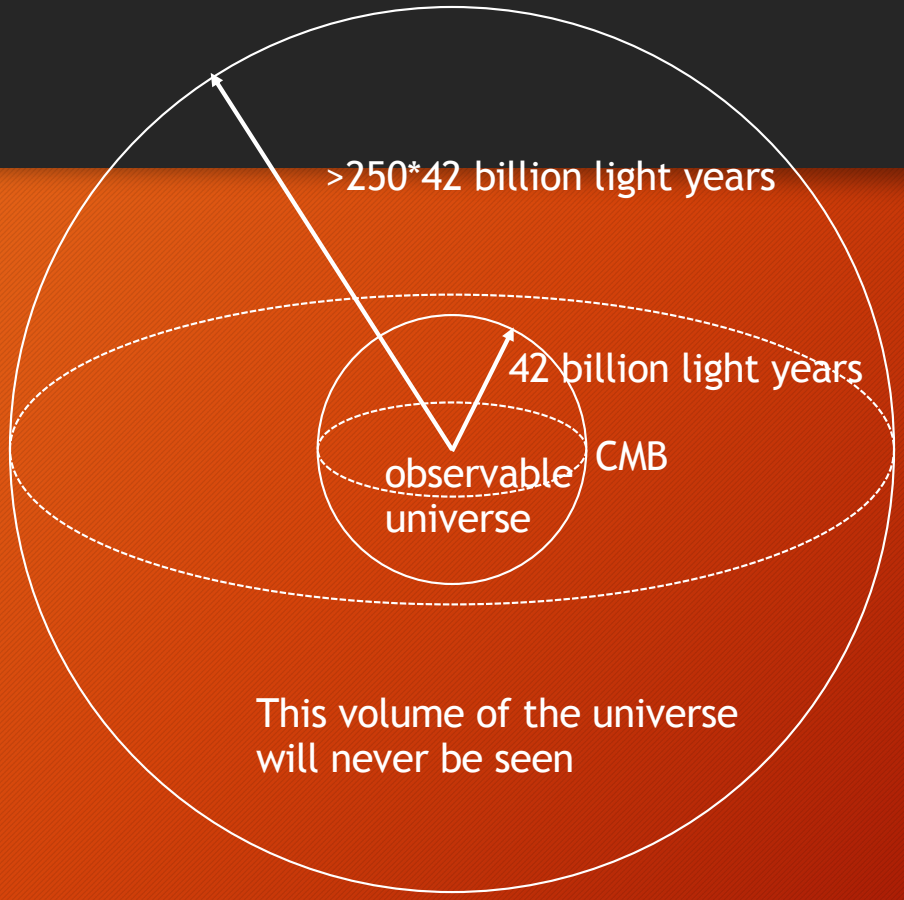
Based on latest observations: $\Omega_{today} = 1.0010 \pm 0.0065$

By calculation from today's value: $\Omega_{1\ sec.} =$ 1.00000000000000000 ±

$\Omega = \rho/\rho_c$, where: ρ is the energy density of the universe and
ρ_c is the critical energy density required for a flat universe.

The Universe

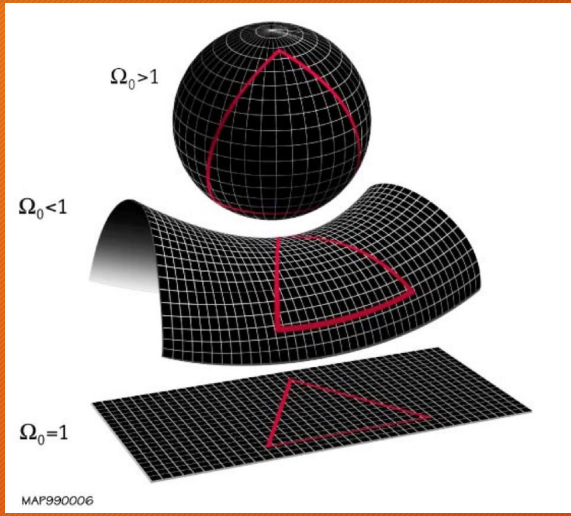
Estimated edge
If there is really
an edge



What does it mean to say the Universe is Flat?

- If the Universe is actually flat then it is infinitely big – does not have an end/edge
- Best estimates from current studies of the Cosmic Background Radiation is that the radius of the universe is about 250 times bigger than we can see but could be infinite

Why was the Early Universe so Flat?



Possible shapes of the universe

- If Ω is too far from 1,
  - the universe either: expands very rapidly, or contracts very rapidly
  - and no galaxies or stars can form
- But the universe exists so it must be flat

Flatness Problem

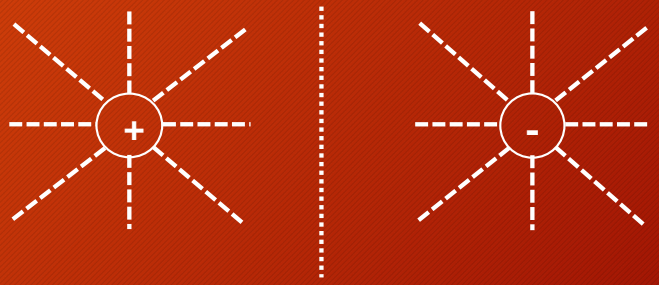
- Physicists have created equations for the expansion of the universe
- Using this equations shows some problems
- BBT Answer:
  - The Universe came into being perfectly flat.
  - Not likely to have happened
- Inflation Answer:
  - The inflation expanded everything so much so that no matter is shape at creation, it became almost perfectly flat.

What is the monopole problem

- If we project time back far enough we get:
  - Energy levels very high (10^{16} GeV)
  - At the energy level, the Weak force, the Strong force and the Electromagnetic force combine into a single force.
  - This is the realm of Grand Unified Theories (GUT) and string theory
  - As the universe expands and cools, the symmetry of the unified force is broken (creating the forces we see today) and large numbers of particles are created including magnetic monopoles
  - We have yet to find any magnetic monopoles
- Inflation explains the lack of monopole
  - During inflation, the universe expands so rapidly (and thus cools so rapidly) that we are left with one or few monopoles in the observable universe

Electric Fields

Electric fields are caused by positive and negative charges
Electrons have negative charge
Protons have positive charge



Electric Field lines of force in free space

Magnetic Fields

Magnets have a North and South Pole

There are no independent
North or South Poles
But they are predicted by Physics

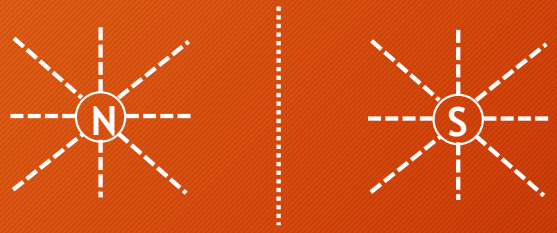
Magnetic Monopoles lines of force in free space

Either they do not exist or not found yet

Magnetic and Electric Fields

Magnets have a North and South Pole

There are no independent
North or South Poles
But they are predicted by Physics

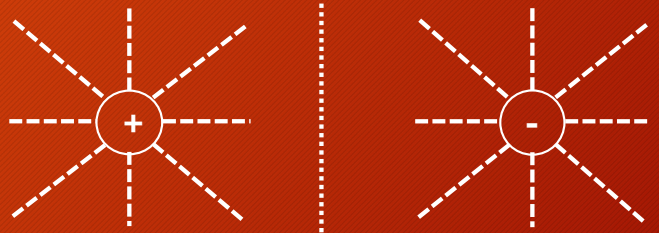


Magnetic Monopoles lines of force in free space

Either they do not exist or not found yet

Electric fields are caused by
positive and negative charges
Electrons have negative charge
Protons have positive charge

We would expect symmetry between
electric and magnetic charges
but we do not see it.



Electric Field lines of force in free space

Questions to be answered

- Did the multiverse ever have a beginning?
- Can we find other universes in the multiverse?
- What does “space” expand into or in other words what is between universes?

- Is any of this real or is it just physicists becoming philosophers instead of doing physics?

References

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- Guth Lectures from 2013
- https://ocw.mit.edu/courses/8-286-the-early-universe-fall-2013/
  - Lecture 21: Problems of the Conventional (Non-inflationary) Hot Big Bang Model
  - Lecture 22: The Higgs Field and the Cosmological Magnetic Monopole Problem
  - Lecture 23: Inflation
- https://medium.com/starts-with-a-bang/ask-ethan-the-multiverse-and-the-road-not-traveled-3086a2ca0daf#.fohqy3shp
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- http://www.forbes.com/sites/startswithabang/2016/07/30/ask-ethan-where-did-the-big-bang-happen/#6102272f7c0f
- https://en.wikipedia.org/wiki/Flatness_problem
- https://en.wikipedia.org/wiki/Symmetry_breaking
- https://en.wikipedia.org/wiki/Black-body_radiation

Black Body Radiation

Planck's law of blackbody radiation [edit]

Main article: Planck's law

Planck's law states that[34]

$$B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{h\nu/kT} - 1},$$

where

$B_\nu(T)$ is the spectral radiance (the power per unit solid angle and per unit of area normal to the propagation) density of frequency ν radiation per unit frequency at thermal equilibrium at temperature T. Units: power / [area × solid angle × frequency].
h is the Planck constant;
c is the speed of light in vacuum;
k is the Boltzmann constant;
ν is the frequency of the electromagnetic radiation;
T is the absolute temperature of the body.