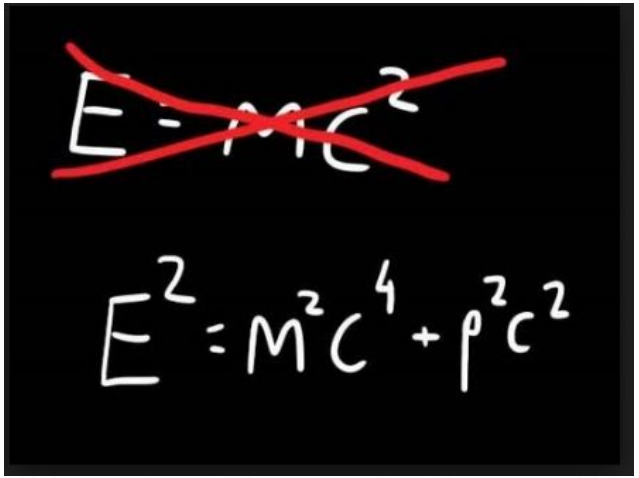
How the Universe Created What We Observe

A Modern View of History

Clip 1: Big Bang

Create Some Particles from Energy



Event/Epoch	Redshift z	Time	Temp, K
Big bang	∞	0	∞
TOE/Planck time	$\cdots$	10^{-43} sec	10^{32}
GUT/Strong force separates from Weak/EM	$\cdots$	10^{-36} sec	10^{28}
Inflation starts	$\cdots$	10^{-36} sec	10^{28}
Inflation ends	$\cdots$	10^{-34} sec	10^{28}
Weak force separates from EM	$\cdots$	10^{-12} sec	10^{16}
Radiation-nucleon soup	$\cdots$	10^{-1} sec	$3 \cdot 10^{10}$

Frame 2: Big Bang Nucleosynthesis

Combine Particles into Matter

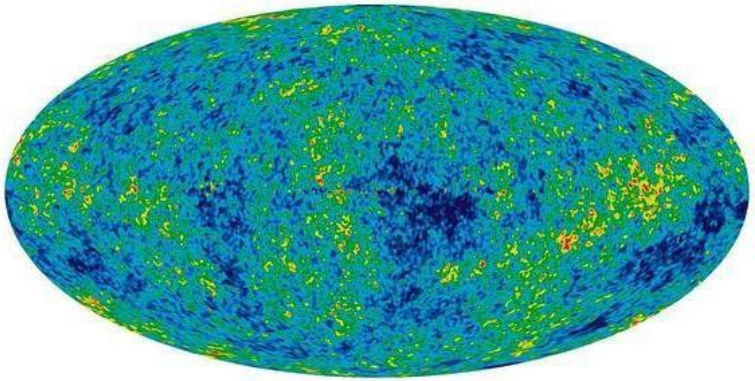
$$n + e^+ \rightleftharpoons \bar{\nu}_e + p$$
$$n + \nu e \rightleftharpoons p + e^-$$

$$p + n \longrightarrow {}^2H + \gamma$$
$$p + {}^2H \longrightarrow {}^3He + \gamma$$
$${}^2H + {}^2H \longrightarrow {}^3He + n$$
$${}^2H + {}^2H \longrightarrow {}^3H + p$$
$${}^3He + {}^2H \longrightarrow {}^4He + p$$
$${}^3H + {}^2H \longrightarrow {}^4He + n$$

Event/Epoch	Redshift z	Time	Temp, K
Neutrinos decouple from nucleons	$\cdots$	1 sec	$3 \cdot 10^9$
Big bang Nucleosynthesis begins	$\cdots$	200 sec	$8 \cdot 10^8$
BBN ends = H, He, Li nuclei	$\cdots$	15 min	$3 \cdot 10^8$

Frame 3: Cosmic Microwave Background

Cool Remaining Radiation



Event/Epoch	Redshift z	Time	Temp, K
Radiation-matter energy density equality	3570	50,000 yrs	9,390
Recombination (ionized plasma to neutral atoms)	1380	250,000 yrs	9,390
Photon decoupling (from electrons = CMB)	1070	370,000 yrs	2,970

Frame 4: 14 Gyrs

Gravity works locally

Event/Epoch	Redshift z	Time	Temp, K
First Stars	50	50 Myrs	$\cdots$
Reionization: H, He	8	650 Myrs	$\cdots$
Matter-Lambda energy density equality	0.4	10.2 Gyrs	$\cdots$
Today	0	13.8 Gyrs	2.73

Frame 5: Future State - A Sequel

Expansion Continues to Accelerate

Backup Slides

1. Summary Timeline

1 Timeline

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Table 1: Evolution of the Expanding Universe (flat, ΛCDM)