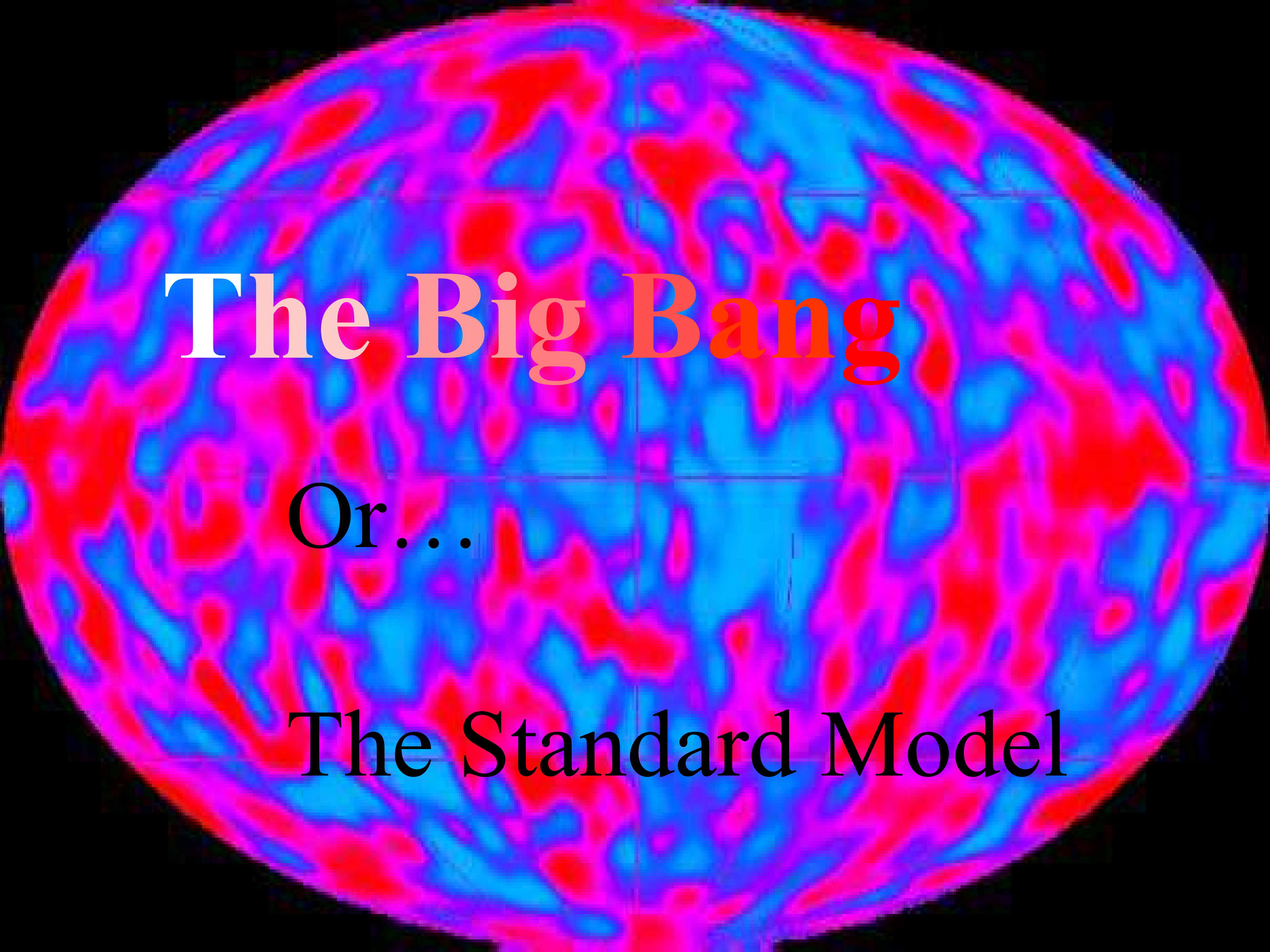


The Big Bang

Or…

The Standard Model

Precepts of the standard model

- The laws of Physics are the same throughout the Universe.
- The Universe is expanding
- The Universe is isotropic and homogeneous
- General relativity works.
- The early Universe was hotter than it is today
- The Universe is evolving.
- The cosmological principle.

A bit of history...

- 1916 Einstein's General relativity predicts that the Universe is either expanding or contracting
- 1920s Hubble discovers the expansion of the Universe.
- 1940s Gamow et al work on a Big Bang model:
- If space is expanding, then it was once small
- If it was small, it was hot. (Adiabatic expansion cools)
- If it was once hot, it should be a little warm now.

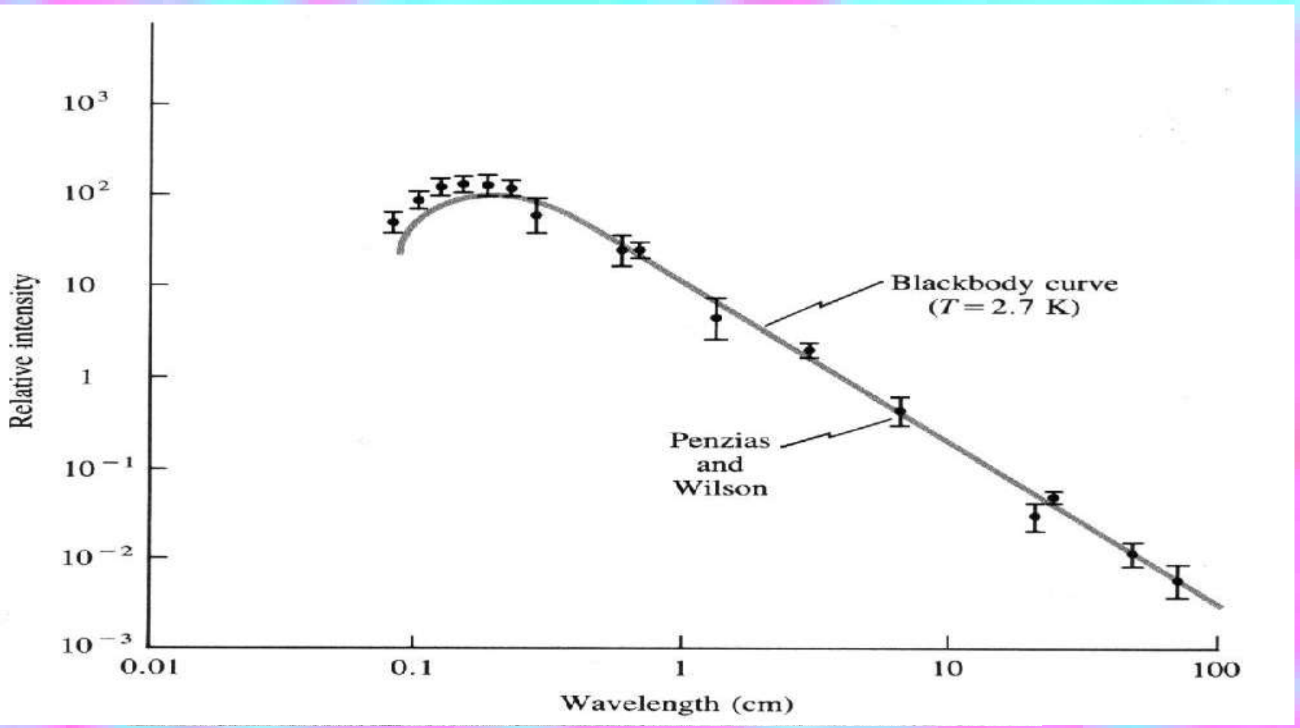
A bit of history...

- They (Gamow) predicted that we should still be able to see radiation from the young Universe. (This is known as the cosmic microwave background radiation or CMBR)
- The radiation should have a Wien temperature of about 5 K
- Display a black body curve
- Be the same in all directions

Nobody paid any attention to these predictions

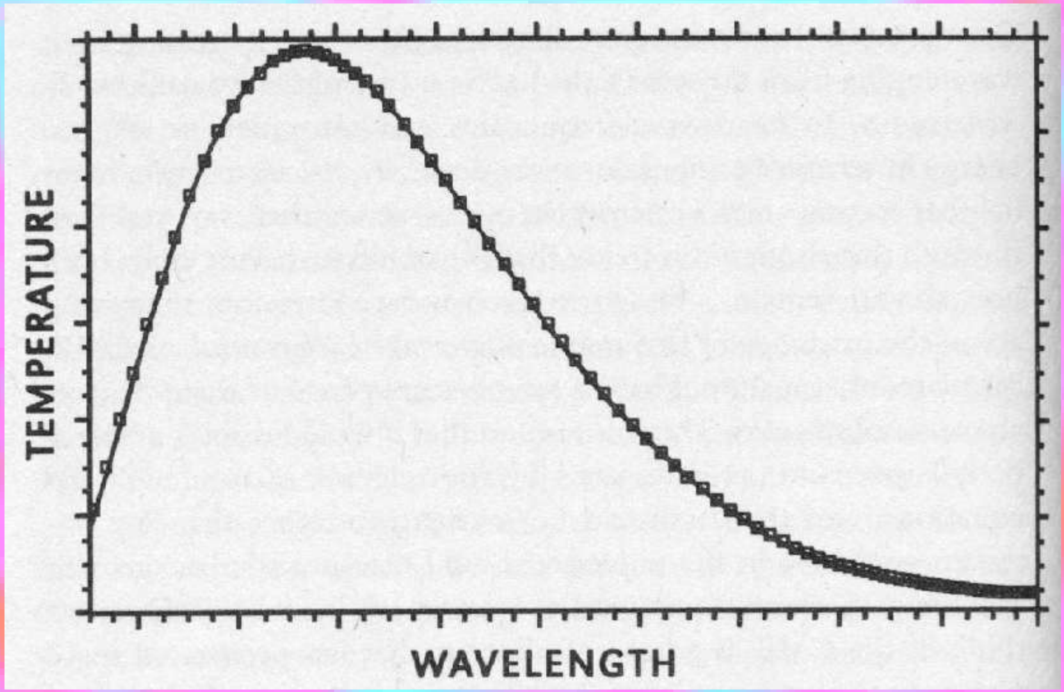
A bit of history...

- 1965 Arno Penzias and Richard Wilson are having "noise" problems with their radio telescope:
- 7.35 cm radiation is everywhere.
- At first they think it is their equipment
- But it's coming from "out there"



A bit of history...

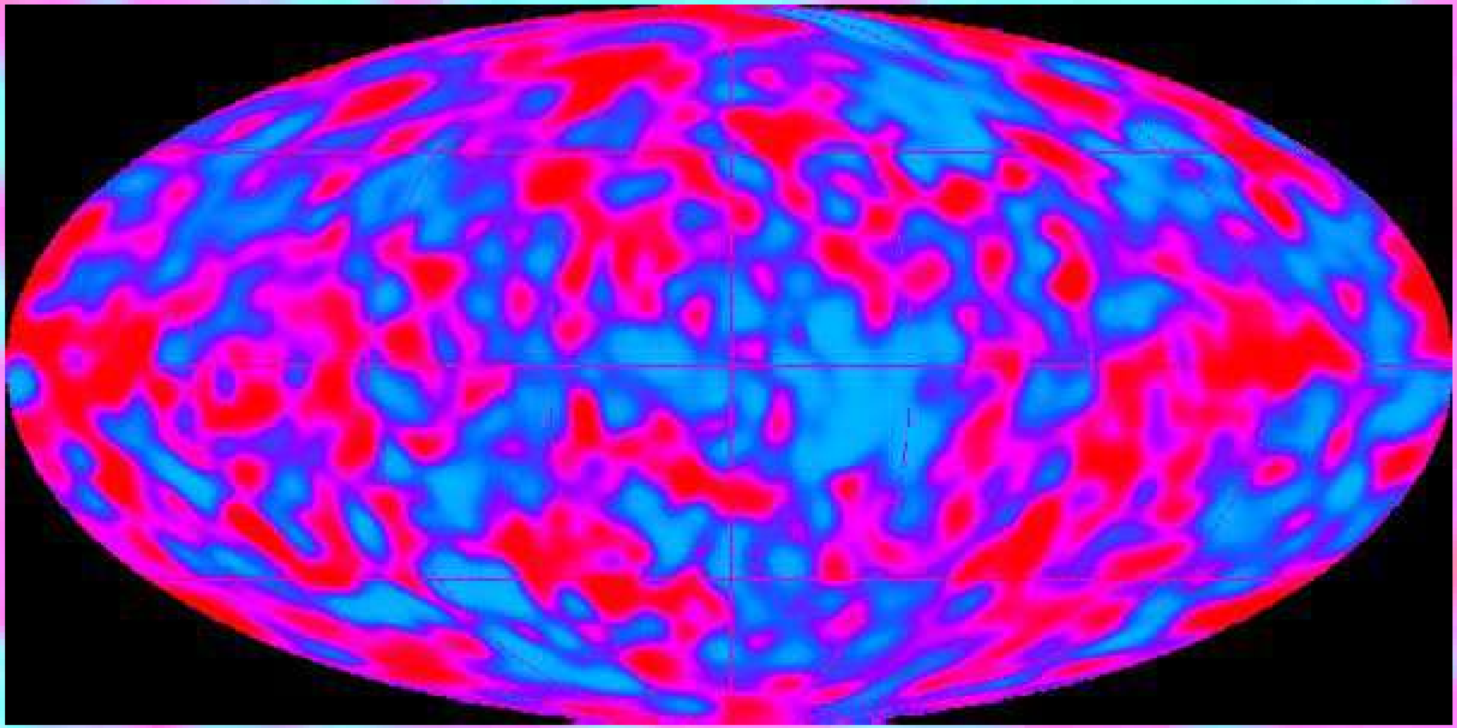
- 1989 The Cosmic Background Explorer (COBE) spacecraft measures the CMBR.
- The radiation is isotropic
- It has a Wien temperature of 2.726 K
- It is exactly black body as predicted by the big bang:



(error bars, **put λmax in notes**)

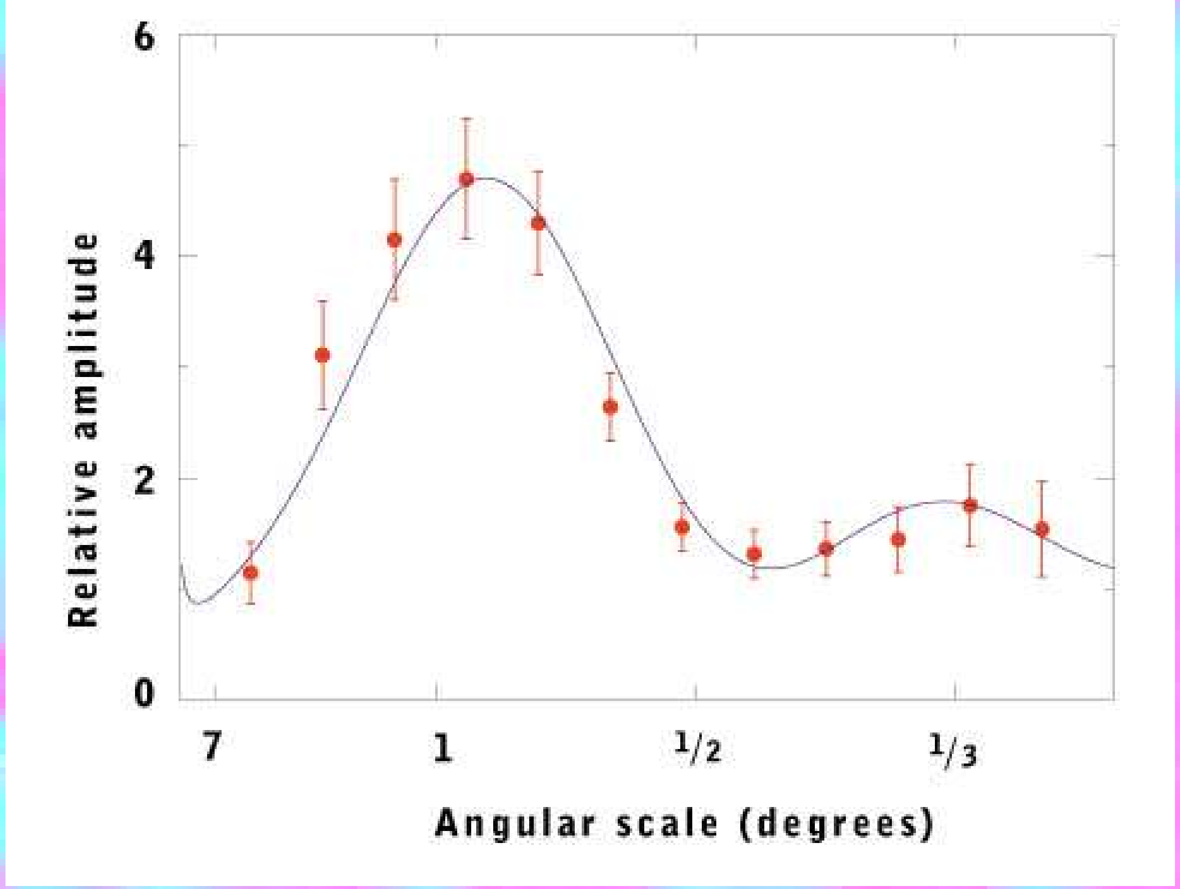
A bit of history...

- 1992 The Cosmic Background Explorer (COBE) measures miniscule fluctuations in the CMBR.
- The fluctuations are exactly what the big bang model predicts from the Heisenberg uncertainty of the early Universe:



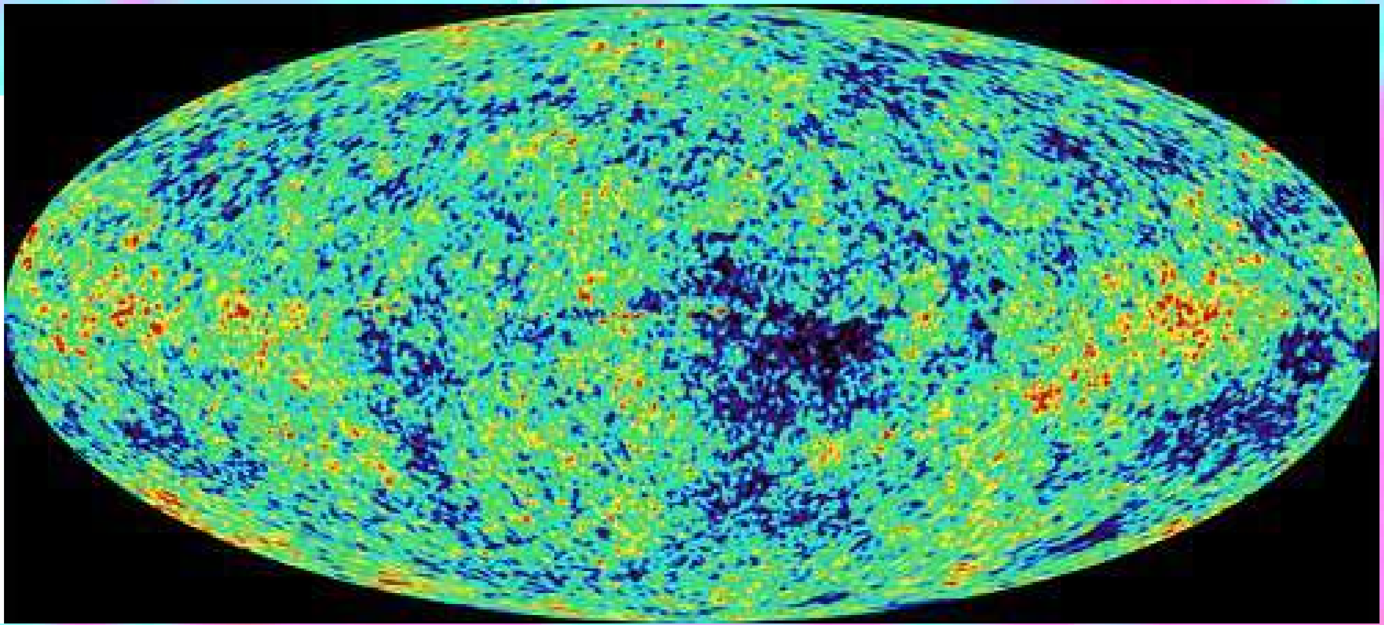
A bit of history...

- Spherical Harmonics. - the ringing of the universe
- Spring 2000, Boomerang measures primordial sound waves:



As of 2003/6 The WMAP Probe:

1) the universe was 13.7 billion years old, plus or minus about 200 million years,
2) it is composed of 4% matter, 22% dark matter, and 74% dark energy (later)
3) the Hubble Constant is 70.1(km/sec)/MPc +/- 1.3, not 50 or 100 as some researchers had suggested, and
4) the universe is flat (similar to what the BOOMERANG craft had seen).



The Standard Model

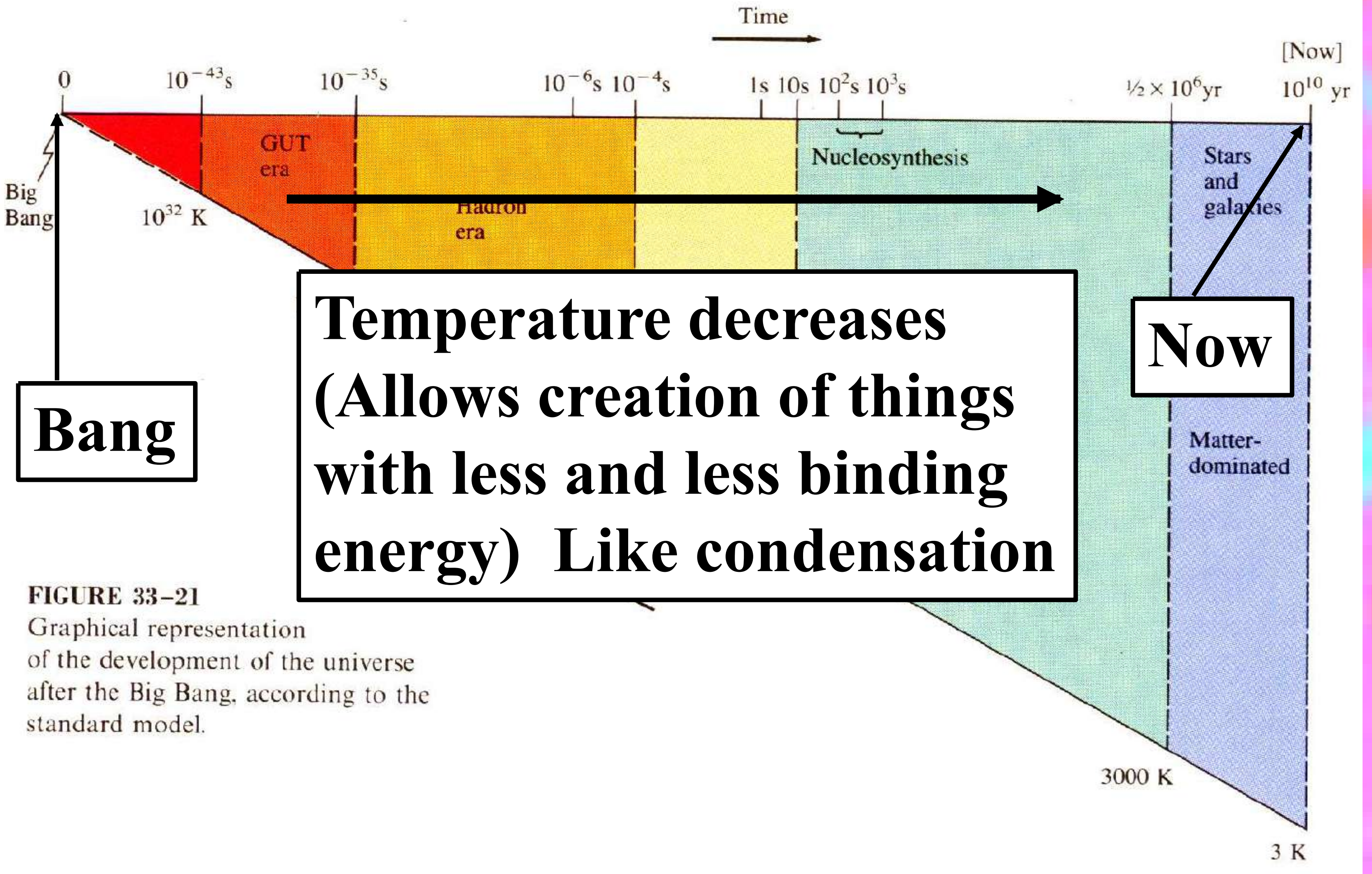


FIGURE 33–21
Graphical representation of the development of the universe after the Big Bang, according to the standard model.

The Standard Model

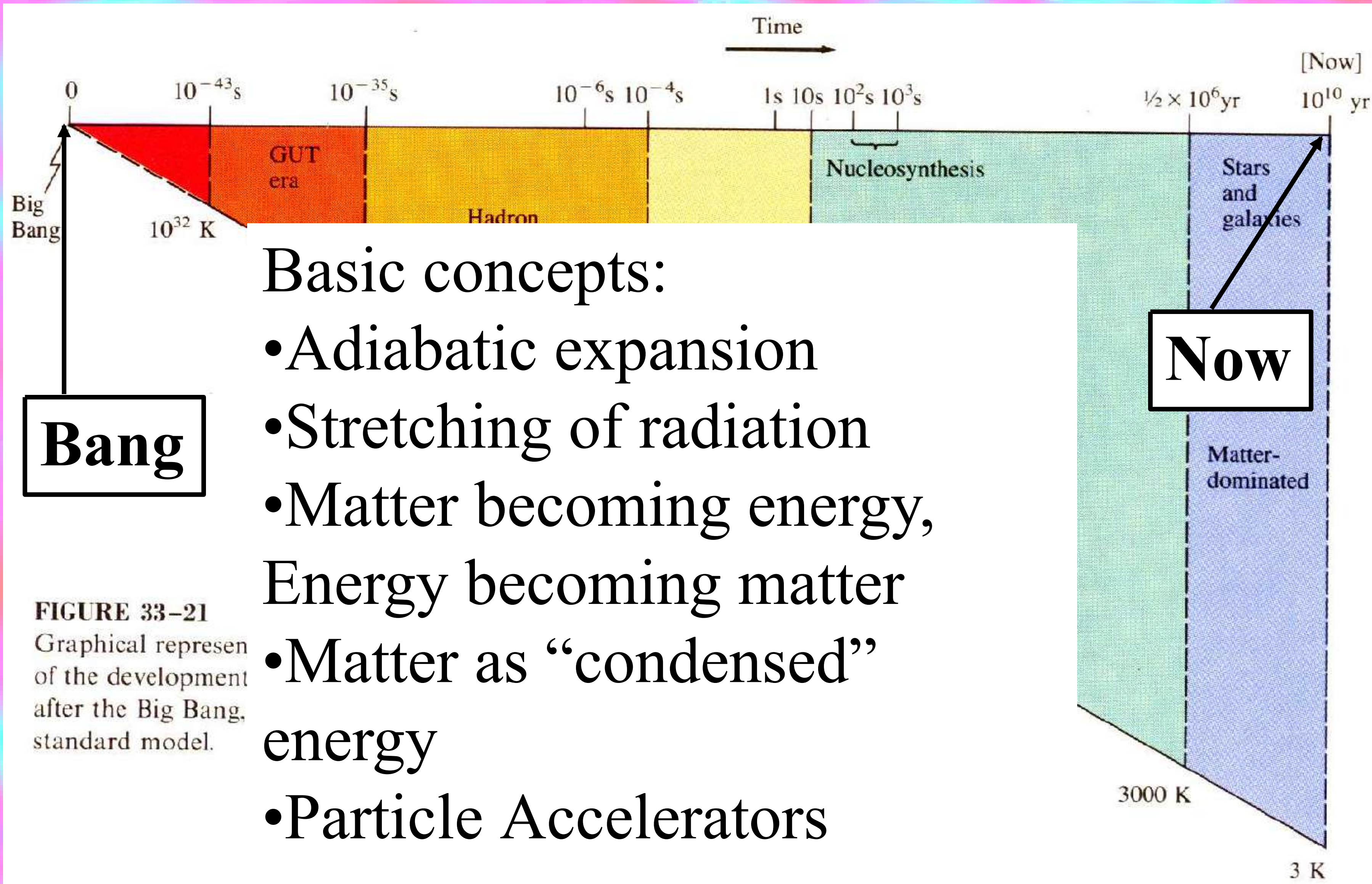


FIGURE 33–21
Graphical represen
of the development
after the Big Bang,
standard model.

Basic concepts:

- Adiabatic expansion
- Stretching of radiation
- Matter becoming energy, Energy becoming matter
- Matter as “condensed” energy
- Particle Accelerators

The Standard Model

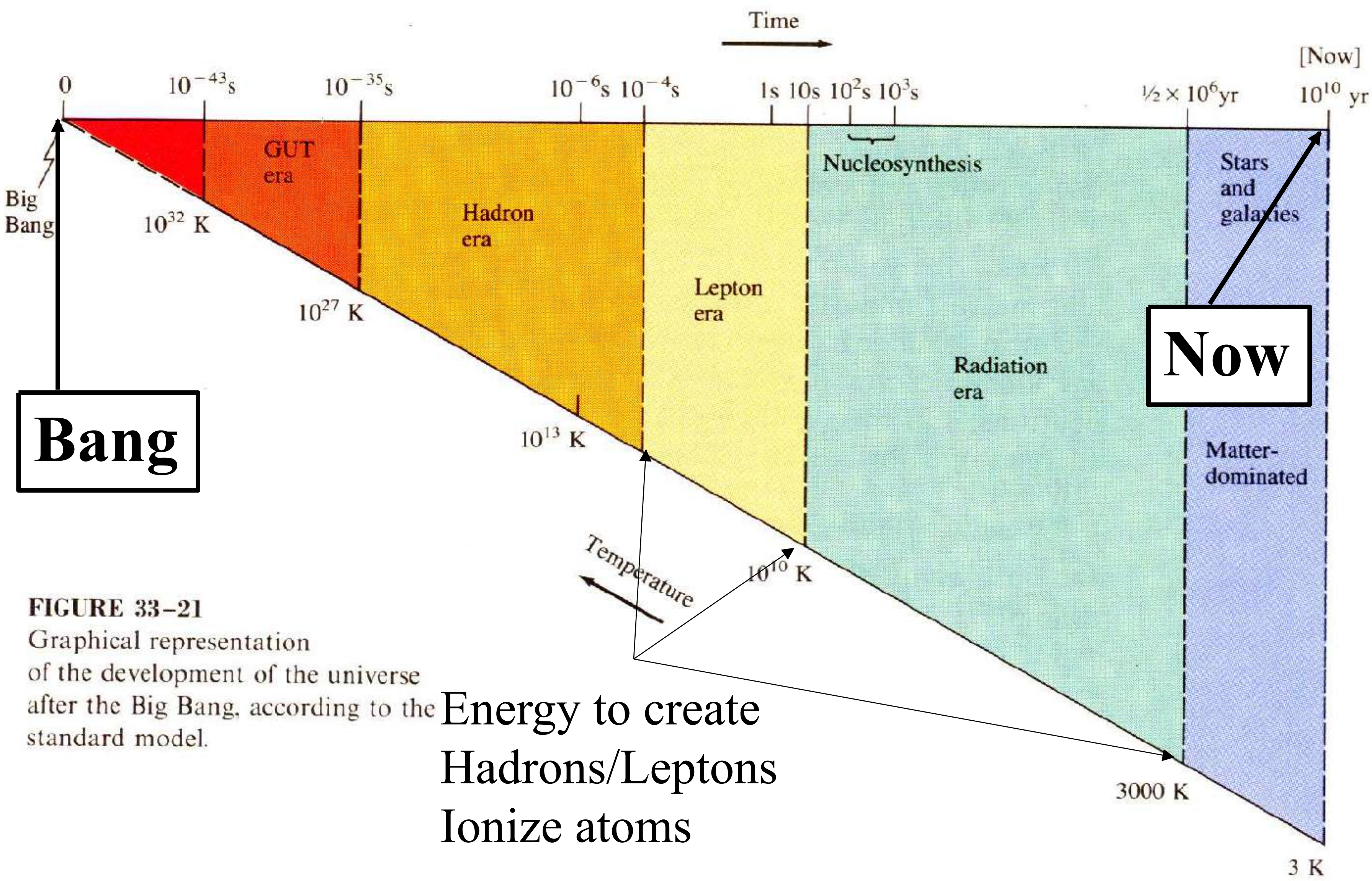
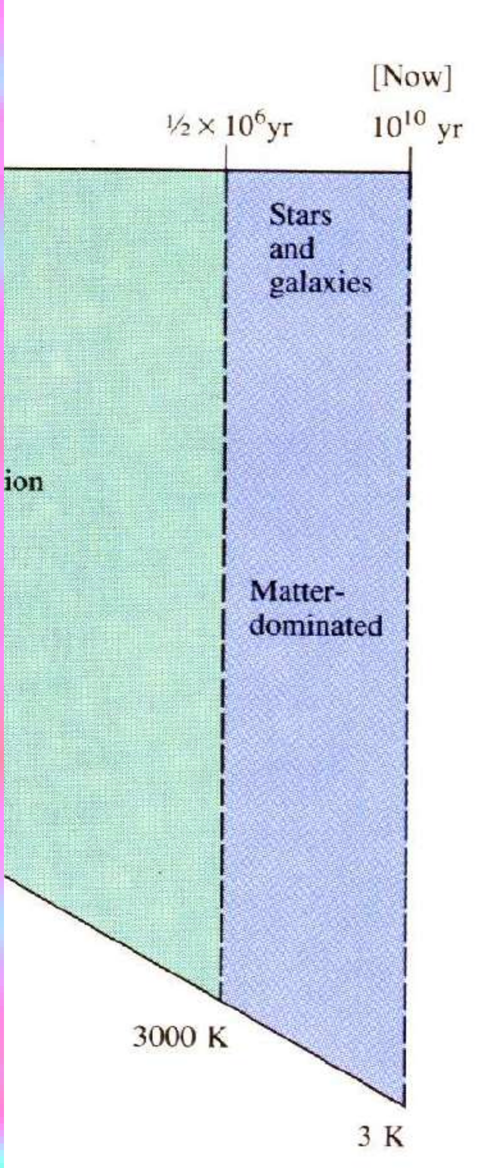


FIGURE 33–21
Graphical representation of the development of the universe after the Big Bang, according to the standard model.

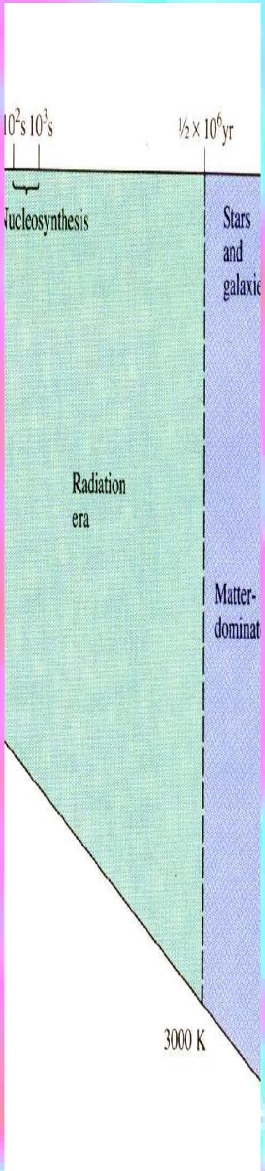
The Standard Model



.5 x 10^6 years to Present:

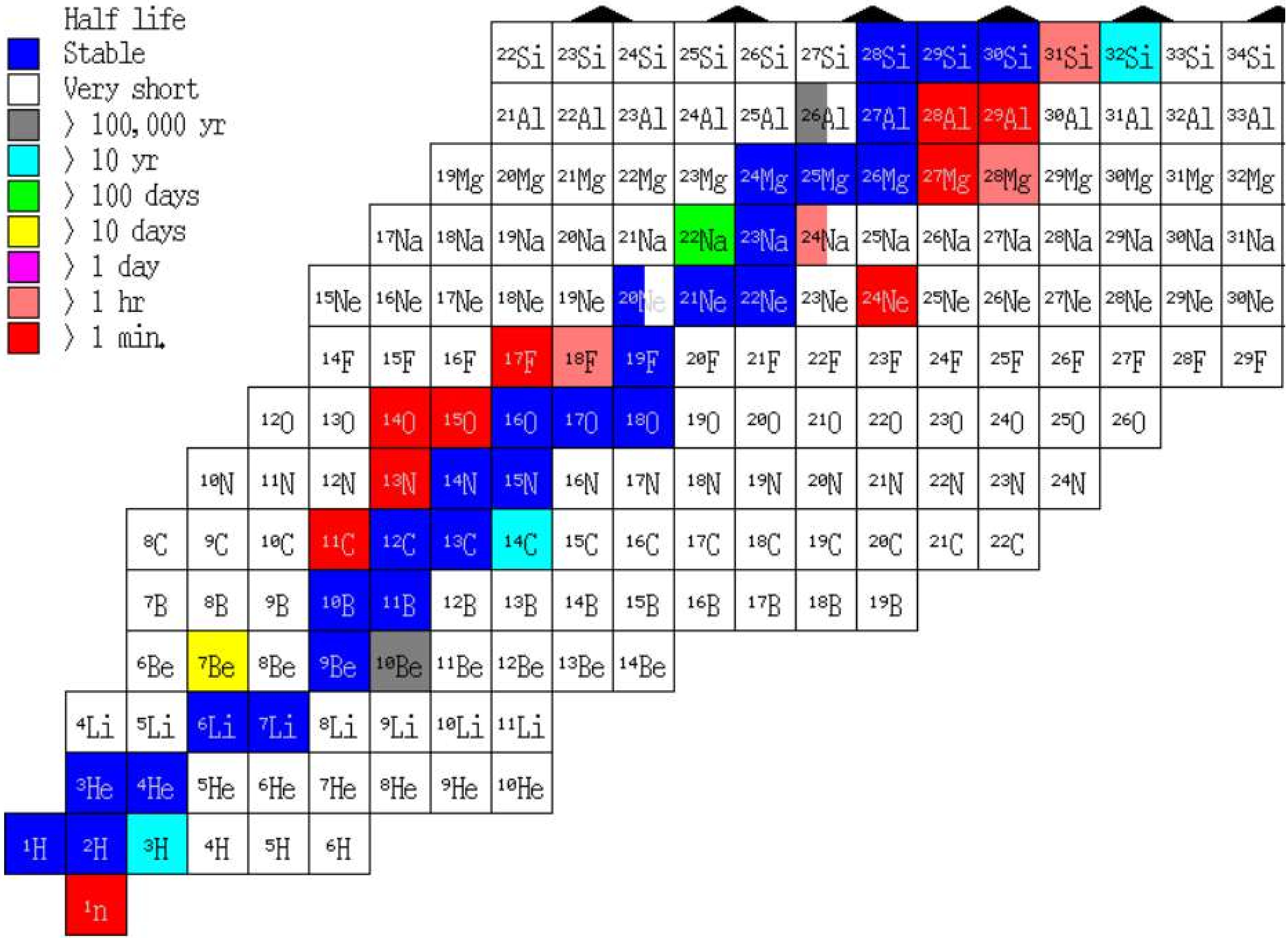
- Thermal energy drops below binding energy of atomic electrons
- Atoms are born
- Photons de-couple from matter (To become CMBR)
- Expansion of the Universe stretches out radiation
- Universe is now matter dominated.
- Soon after atoms form, stars and galaxies form as well.

The Standard Model



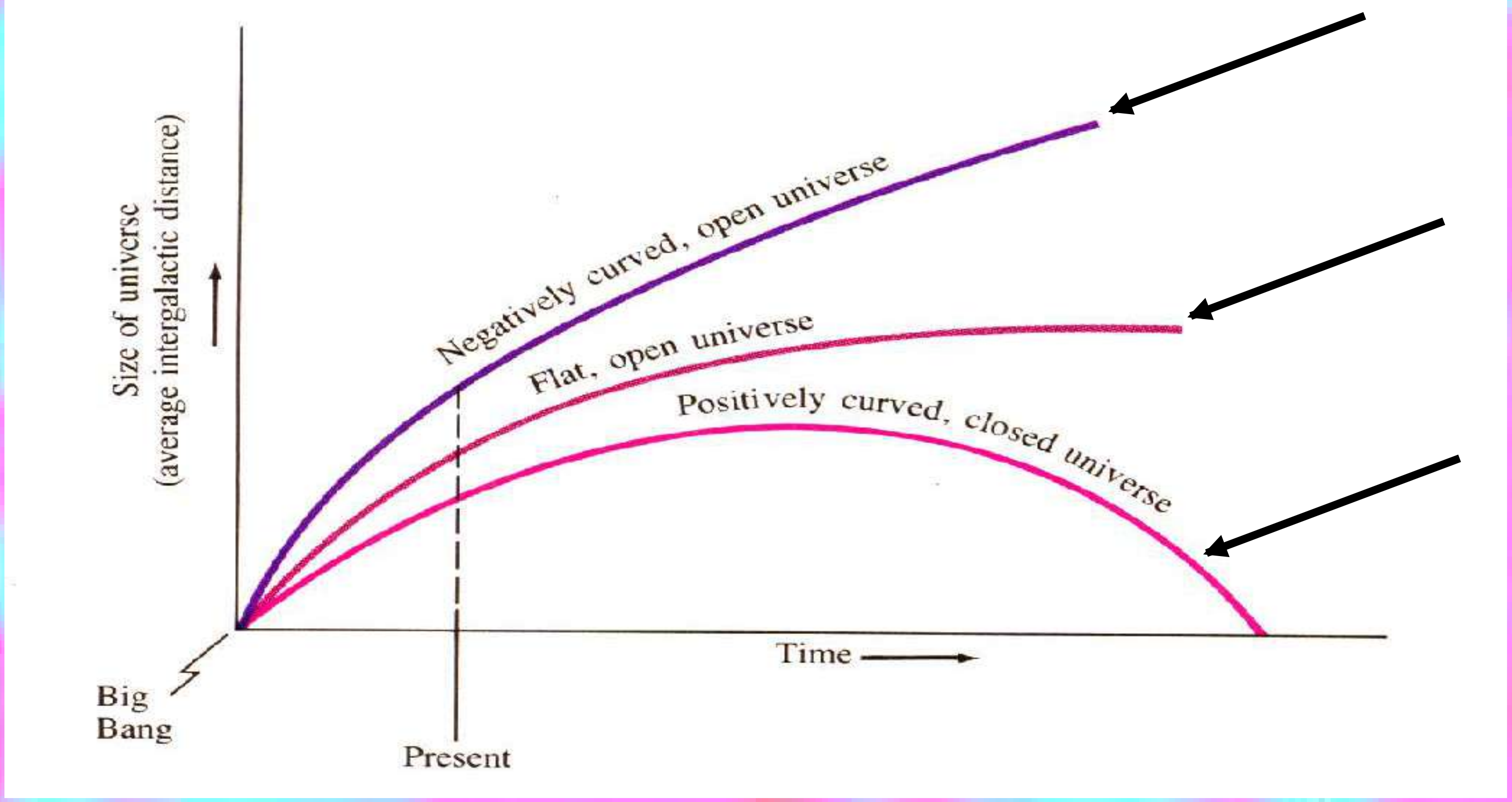
Meanwhile back at the ranch:

- About 2 or 3 minutes after the Big Bang, fusion occurs.
- ^{1}H, ^{2}H, ^{3}H, ^{4}He…maybe some Lithium…are created
- BBN theory predicts that 75% of matter be Hydrogen, and 25% Helium.
- This is what we see today.
- Stars forge heavy elements later.
- Older stars should have fewer heavy elements than new ones.
- This is what we see today.



Half life
Stable
Very short
> 100,000 yr
> 10 yr
> 100 days
> 10 days
> 1 day
> 1 hr
> 1 min.
^{22}Si ^{23}Si ^{24}Si ^{25}Si ^{26}Si ^{27}Si ^{28}Si ^{29}Si ^{30}Si ^{31}Si ^{32}Si ^{33}Si ^{34}Si
^{21}Al ^{22}Al ^{23}Al ^{24}Al ^{25}Al ^{26}Al ^{27}Al ^{28}Al ^{29}Al ^{30}Al ^{31}Al ^{32}Al ^{33}Al
^{19}Mg ^{20}Mg ^{21}Mg ^{22}Mg ^{23}Mg ^{24}Mg ^{25}Mg ^{26}Mg ^{27}Mg ^{28}Mg ^{29}Mg ^{30}Mg ^{31}Mg ^{32}Mg
^{17}Na ^{18}Na ^{19}Na ^{20}Na ^{21}Na ^{22}Na ^{23}Na ^{24}Na ^{25}Na ^{26}Na ^{27}Na ^{28}Na ^{29}Na ^{30}Na ^{31}Na
^{15}Ne ^{16}Ne ^{17}Ne ^{18}Ne ^{19}Ne ^{20}Ne ^{21}Ne ^{22}Ne ^{23}Ne ^{24}Ne ^{25}Ne ^{26}Ne ^{27}Ne ^{28}Ne ^{29}Ne ^{30}Ne
^{14}F ^{15}F ^{16}F ^{17}F ^{18}F ^{19}F ^{20}F ^{21}F ^{22}F ^{23}F ^{24}F ^{25}F ^{26}F ^{27}F ^{28}F ^{29}F
^{12}O ^{13}O ^{14}O ^{15}O ^{16}O ^{17}O ^{18}O ^{19}O ^{20}O ^{21}O ^{22}O ^{23}O ^{24}O ^{25}O ^{26}O
^{10}N ^{11}N ^{12}N ^{13}N ^{14}N ^{15}N ^{16}N ^{17}N ^{18}N ^{19}N ^{20}N ^{21}N ^{22}N ^{23}N ^{24}N
^{8}C ^{9}C ^{10}C ^{11}C ^{12}C ^{13}C ^{14}C ^{15}C ^{16}C ^{17}C ^{18}C ^{19}C ^{20}C ^{21}C ^{22}C
^{7}B ^{8}B ^{9}B ^{10}B ^{11}B ^{12}B ^{13}B ^{14}B ^{15}B ^{16}B ^{17}B ^{18}B ^{19}B
^{6}Be ^{7}Be ^{8}Be ^{9}Be ^{10}Be ^{11}Be ^{12}Be ^{13}Be ^{14}Be
^{4}Li ^{5}Li ^{6}Li ^{7}Li ^{8}Li ^{9}Li ^{10}Li ^{11}Li
^{3}He ^{4}He ^{5}He ^{6}He ^{7}He ^{8}He ^{9}He ^{10}He
^{1}H ^{2}H ^{3}H ^{4}H ^{5}H ^{6}H
^{1}n

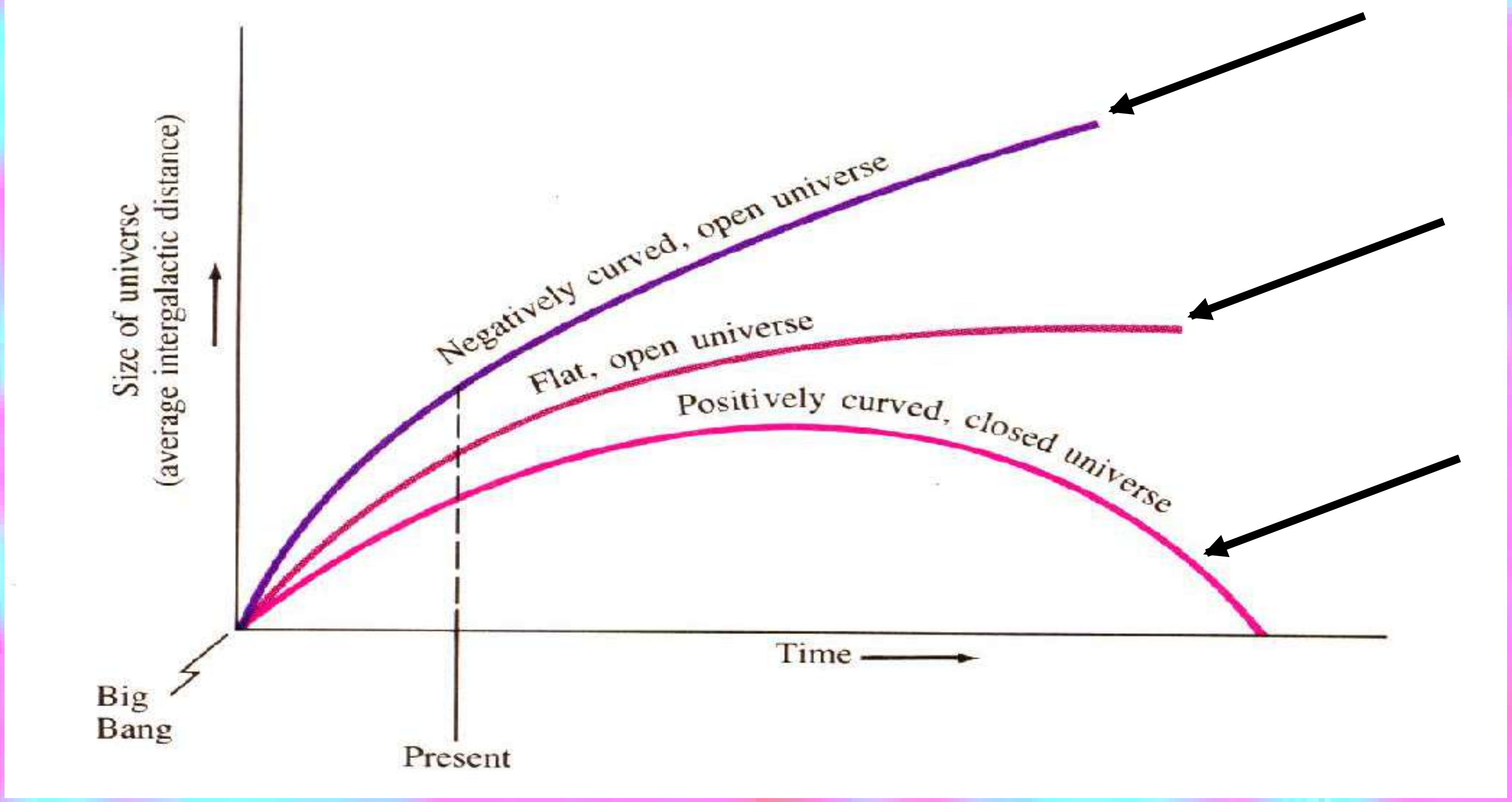
The Future of the Universe



Three possible scenarios:

- Expand forever (greater than escape velocity)
- Expand to a halt (exactly escape velocity)
- Come back together (less than escape velocity)

The Future of the Universe

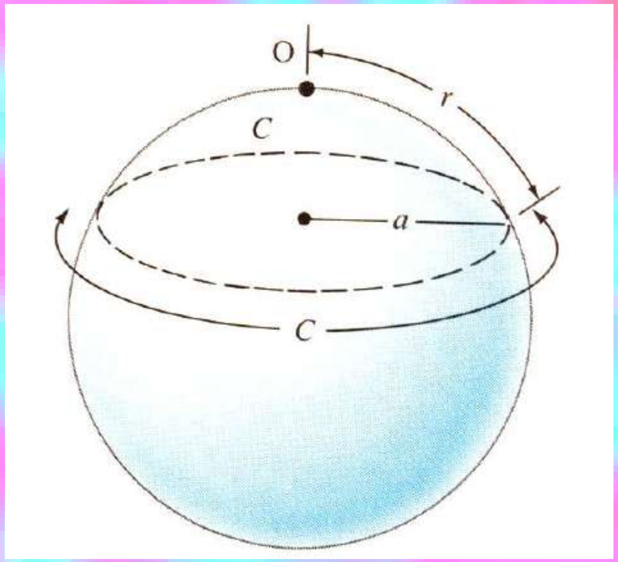


Three possible curvatures:

- Negatively curved. (Less than critical density)
- Flat (Critical Density)
- Positively curved. (More than critical density)

Curvature

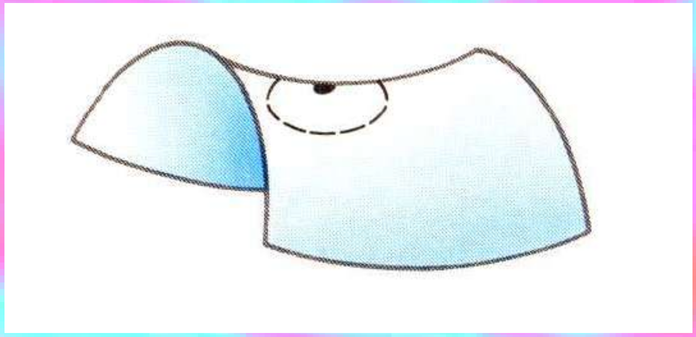
On a flat surface, C = $2\pi r$, and triangles interior angles that add up to 180^o



The Two-Dimensional surface of a sphere has positive curvature.

C is less than $2\pi r$

Triangles have more than 180^o



The saddle has negative curvature

C is more than $2\pi r$

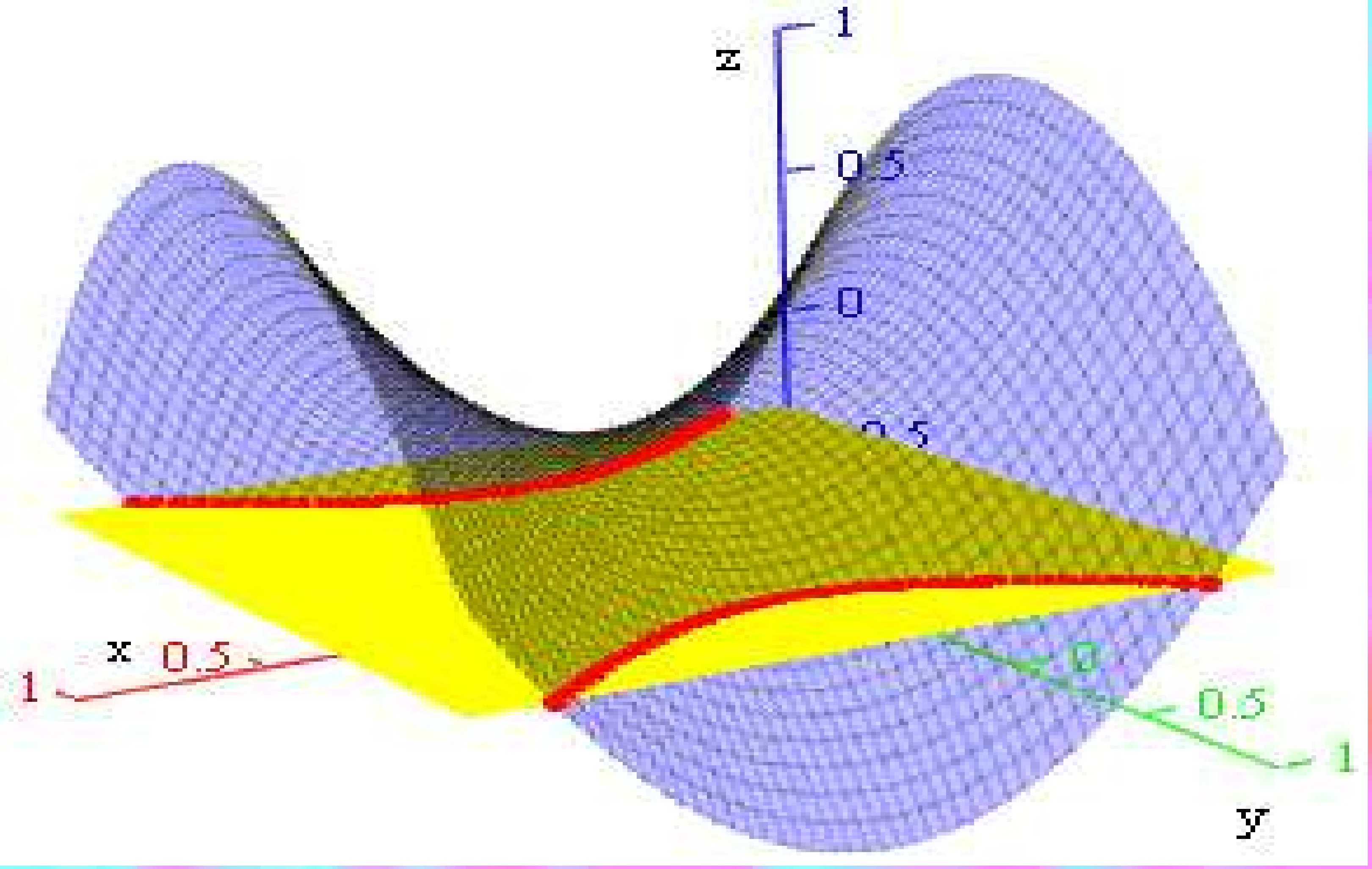
Triangles have less than 180^o

Curvature

The saddle has negative curvature

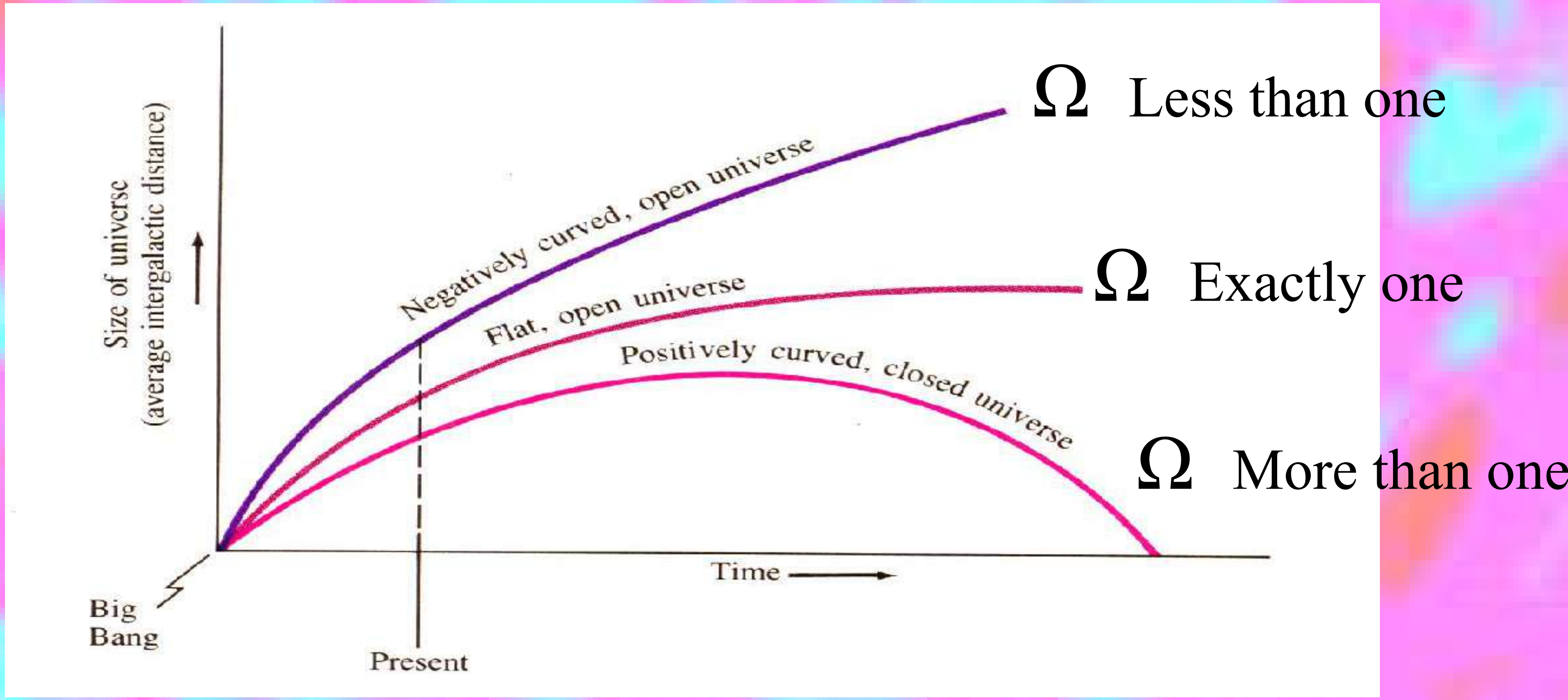
C is more than $2\pi r$

Triangles have less than 180^{o}



For convenience:

Ω - Omega - a combination of the Hubble constant and the Deceleration parameter. (related to the mass density of the Universe)



Unity of Omega

- As far as we can tell, Omega has a value of nearly one.
- Inflation – size of universe
- Relative flatness of earth

Where is all the mass? (only 4% is normal)

Two candidates for dark matter:

- MAssive Compact Halo Objects. (MACHOs) - baryonic (normal) matter
- Star cinders
- Microlensing survey
- Variable stars
- Weakly Interacting Massive Particles (WIMPs) - non baryonic
- Structure of galaxies implies WIMPS
- Neutrinos
- LSP

“Paradoxes” of the Big Bang:

- There can be no effect without a cause.
- Quantum mechanics deals with many things that have no cause.
- God apparently does play with dice
- You can’t get something from nothing.
- The net energy of the universe may be zero
- Gravitational energy is negative
- Other energies are positive
- Infinite regress: what came before before?
- May be a “bedrock” paradox
- The universe might have arisen from a quantum fluctuation. A big one.

Other Theories

Expansion of the Universe

- Tired Light theory
- E = hf
- Redshift is due to energy loss
- C-Field
- Matter is being created in all parts of the infinitely old Universe.
- How do you explain the CMB?
- Plasma model
- Pulsations - some parts expand, others contract.
- Hasn't made testable predictions.