The History of The Cosmos

[From The Big-Bang to The Present-Epoch]

Improving The **S**tandard **M**odel **o**f **C**osmology **(SMoC)**

What are we going to cover ?

→ 1. Present-Epoch Parameters [CMBR-Constrained vs. CMBR-UnConstrained]

→ 2. The Big Picture [CMBR-Constrained vs. CMBR-UnConstrained]

→ 3. The Primordial Universe → The first 10^{-21} (s)

→ 4. Cosmological Inflation & Accelerated Expansion → The Cosmic Envelope

→ 5. The Cosmic Acceleration Problem → PDG, US-DoE, FermiLab

→ 6. The Flatness Problem → What Problem ?

→ 7. Presentation Closeout & Appendices [*if we have time*]

Let's begin with a brief Overview of The Present-Epoch

NATIONAL GEOGRAPHIC

As far as we can see with our ever improving telescopes, there are at least a hundred billion galaxies arrayed throughout the universe. Each, like the Milky Way, is an "island universe" containing billions of stars. Nearly all galaxies are members of groups or clusters, which are part of even larger structures called superclusters. All of these large concentrations are connected by filaments or sheets of galaxies, which enclose huge, bubble-like volumes of empty space, the cosmic voids.

The great unifier of the cosmos is gravity. It holds the stars of a galaxy, and the galaxies of a cluster, together. But clusters, groups, and isolated individual galaxies are all flying away from each other, a continuing aftermath of the big bang, an explosion of space itself that astronomers believe formed the universe 11 to 15 billion years ago.

EVOLUTION OF THE UNIVERSE

Combining evidence from microwave observations of deep space with supercomputer models, scientists have theorized about the structure of the universe from the big bang to the present (above). From the time that radiation and matter separated—300,000 years or so after the big bang—gravity began drawing matter first into clumps, then into stars. Perhaps a billion years later the first galaxies formed. As clusters of matter accumulated, the filament-and-void structure of today's universe unfolded.

Timeline (top band)

| Smooth space: energy and matter nearly uniform | Universe transparent to radiation — Differences in temperature and density emerge | Stars form in protogalactic clumps — First stars emit high thermonuclear fusion of hydrogen and helium into heavy elements | Most distant galaxy discovered (December 1998) | Galaxies and quasars emerge from clouds of gas and dust | Gravity enhances filament-like formations of galaxies | Galaxies coalesce in filaments — Deep voids develop |

Big bang | 300,000 years after big bang | 50 million years after big bang | | One billion years after big bang | Five billion years after big bang | Ten billion years after big bang | Present

Redshift—a measure of how far light, traveling along galaxies has been stretched to longer, or redder, wavelengths—marks cosmic distances.

1 SIZE OF THE UNIVERSE

So vast is space that just to find our solar system we must make five leaps of scale. In the background image on this sheet we see a mere sliver of the sky—roughly one percent of the diameter of the observable universe—yet even the smallest dots represent not stars or galaxies but great congregations of galaxies. Scattered clumps of dark matter and galaxies appear as bright colors in the image, which is based on a supercomputer simulation. Within this sliver lies our supercluster (right), mapped using the actual positions of its celestial elements.

2 OUR SUPERCLUSTER

Some 150 million light-years across, our supercluster is a great aggregation of clusters of galaxies. The supercluster is centered on the Virgo cluster, which itself contains thousands of galaxies. Among them is M87, which astronomers now know surround a gigantic black hole. Virgo's gravity affects the movement of its neighbors, including the Local Group.

Virgo, the Ursa Major cluster, and other clusters float in our supercluster, last outposts before a space traveler would enter a nearly galaxy-free region called a cosmic void. Not that the region within our supercluster is teeming with galaxies: Although the supercluster has a mass equaling some thousand trillion suns, virtually all its volume is empty. Empty, that is, except for a certain density of dark matter, the hidden mass of the universe that helps hold galaxies and clusters together.

Recent observations reveal that early in the universe's history galaxies collided and merged more often than they do now. That indicates that they were more numerous in the past and that many have grown larger over billions of years.

3 THE LOCAL GROUP

Galaxies stretch in every direction beyond the Milky Way, but gravity keeps a family of some 30 galaxies, including our own, loosely bound.

This Local Group of galaxies extends some four million light-years across. Most galaxies in the group are considered dwarfs, but the two largest—our own Milky Way and the Andromeda galaxy—are giant spirals. Andromeda is at the center of a small subgroup, which includes two elliptical galaxies, M32 and NGC 205, where star formation has ceased. Even though it is more than two million light-years away from Earth, the Andromeda galaxy can be seen readily with the naked eye. With even a small telescope, its bright bulge is unmistakable.

It is possible that astronomers have not found some of our group's smaller galaxies, which may be hidden behind dust clouds in the Milky Way.

All three main types of galaxies are represented in the Local Group: spirals, ellipticals, and irregulars. Nevertheless, the group has relatively few members, a hundredth that of some large galaxy clusters.

The galaxies of the Local Group are traveling together through space. Measurements show that the Milky Way is falling toward Andromeda. No collision is expected, however: Like race cars on opposite straightaways, the two are most likely at opposite ends of a highly elongated orbit around the group's center of mass.

4 OUR GALACTIC REALM

Until the early 20th century the best guess of astronomers was that the Milky Way galaxy was the entire universe. We now know that ours is only one of at least a hundred billion galaxies.

The Milky Way is a spiral galaxy, and our solar system is located in what is called the spiral's Orion arm, about 25,000 light-years from the center. Our sun orbits the galactic center about once every 225 million years and has made the circuit about 20 times. In the spiral arms, new stars form as clouds of gas and dust condense. The stars' energy ionizes nearby parts of the clouds, causing them to glow.

The central bulge of the galaxy glows with the light of older, redder stars. More ancient stars, orbiting the galaxy in a diffuse halo, formed more than ten billion years ago. Several satellite galaxies cluster around the Milky Way. Two of them, the Large and the Small Magellanic Clouds, are visible on Earth only from the Southern Hemisphere. The closest galaxy is a small spheroid called the Sagittarius Dwarf.

5 OUR SUN'S NEIGHBORHOOD

The stars reaching 20 light-years in all directions from our sun make up the solar neighborhood. Each light-year measures 5.9 trillion miles, yet the neighborhood is a tiny part of the Milky Way. Most of the stars shown here are too dim to be seen with the naked eye, but a few, such as Sirius and Procyon—greatly exaggerated here and each actually two stars—are beacons in the sky.

In cosmic terms the sun is an ordinary yellow star, average in size and temperature. The hottest stars glow blue, the coolest shine red.

Many stars are binary or multiple. Our nearest neighbor is the Alpha Centauri triple system, 4.3 light-years away. Closest of the three is Proxima Centauri (Alpha Centauri C), a red dwarf with 1/10 the mass and 1/17,000 the brightness of the sun.

In recent years astronomers have discovered evidence of planets, similar to Jupiter in mass, orbiting stars. The closest example is Gl 876.

6 OUR SOLAR SYSTEM

A tiny dot on the scale of the universe, the solar system—our home in the galaxy—measures some 4.6 billion miles from the sun to the farthest extent of Pluto's orbit. Sunlight reaches Earth in about 8 minutes and Jupiter in 43 minutes, but it takes nearly 7 hours to pass the orbit of Pluto.

Beyond Neptune are icy bodies smaller than planets. These are Kuiper belt objects, over a hundred of which have been observed by telescope. Some scientists suggest that Pluto is a Kuiper belt object, rather than a planet. Spread in a great sphere around the entire solar system is the Oort cloud, trillions of comets, a few of which make spectacular visits to the sun.

Labels (galaxies / clusters)

NGC 5907, NGC 5248, NGC 6946, NGC 5457, NGC 5194, NGC 5055, NGC 5236, NGC 4826, NGC 4594, NGC 4565, NGC 4571, M87, M100, NGC 5128, IC 342, NGC 3031, NGC 628, NGC 891, NGC 3623, NGC 3627, NGC 3628, NGC 3593, NGC 4038/4039, NGC 253, NGC 2903, NGC 1569

Virgo, Ursa Major, Virgo W, Local Group (Milky Way), Solar System

Leo II, Leo I, Draco, Ursa Minor, Sextans, Sagittarius, Large Magellanic Cloud, Small Magellanic Cloud, Sculptor, Fornax, IC 10, And VII, NGC 185, And V, And VI, M110 (NGC 205), M32, And II, And I, And III, Andromeda (M31), Triangulum (M33), Phoenix, LGS 3, Pegasus, IC 1613, DDO 210, Sagittarius Dwarf, Ursa Minor, Milky Way, Large Magellanic Cloud, Small Magellanic Cloud, Sculptor

Solar neighborhood stars

Lalande 21251, WX Ursae Majoris, Groombridge 1618, AD Leonis, Wolf 424 A, B, Gl 687, Ross 128, Wolf 359, Lalande 21185, Kruger 60 A, B, Gl 570 A, B, C, Gl 1245 A, B, C, Gl 628, Barnard's Star, Gl 702 A, B, Gl 664, Eta Cassiopeia A, B, Procyon A, B, Solar System, Proxima Centauri, 61 Cygni A, B, Altair, Luyten's Star, Groombridge 34 A, B, Alpha Centauri B, Alpha Centauri A, Ross 154, Gl 674, Sirius A, B, LHS 288, Gl 440, Ross 614 A, B, Epsilon Eridani, UV Ceti, EV Aquarii A, B, C, Kapteyn's Star, AX Microscopii, Gl 166 A, B, C, Lacaille 9352, Gl 783 A, B, Tau Ceti, VZ Ceti, Gl 1002, LP 944-20 A, Gl 876 and planet, Epsilon Indi, Delta Pavonis

Solar system

PLUTO, NEPTUNE, URANUS, MERCURY, VENUS, SUN, MARS, JUPITER, EARTH, SATURN, Asteroid belt, Kuiper belt

Planetary alignment, January 1, 2000

2 million light-years, 1 million, 250,000 light-years, 200,000, 150,000, 100,000, 50,000, 1 million, 75 million light-years, 50 million, 25 million, 20 light-years, 10, 15, 5

Text by Stephen P. Moran. Art by Kenneth Eward

Universe consultants: Edward Bertschinger, Massachusetts Institute of Technology; Avishai E. Dekel, Mario L. Mateo, University of Michigan; Todd J. Henry, Harvard-Smithsonian Center for Astrophysics; Jeff Hester, Arizona State University; Chris D. Impey, University of Arizona; Marc Postman, Space Telescope Science Institute; Donald P. Schneider, Pennsylvania State University; Francois Schweizer, Carnegie Institution of Washington; R. Brent Tully, University of Hawaii; Wil van Breugel, Lawrence Livermore National Laboratory

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Present-Epoch Parameters

The History of The Cosmos

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Improving The **S**tandard **M**odel **O**f **C**osmology **(SMoC)**

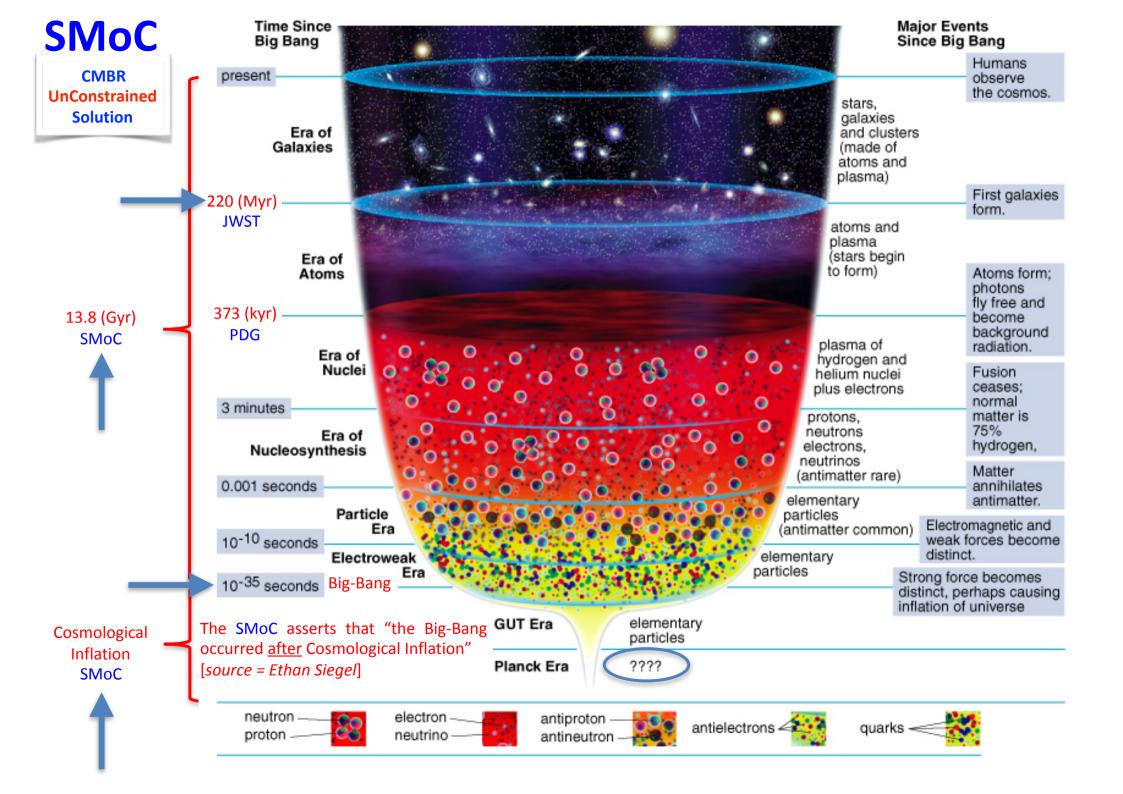[Our CMBR-Constrained Methodology] vs [The CMBR-Unconstrained SMoC]
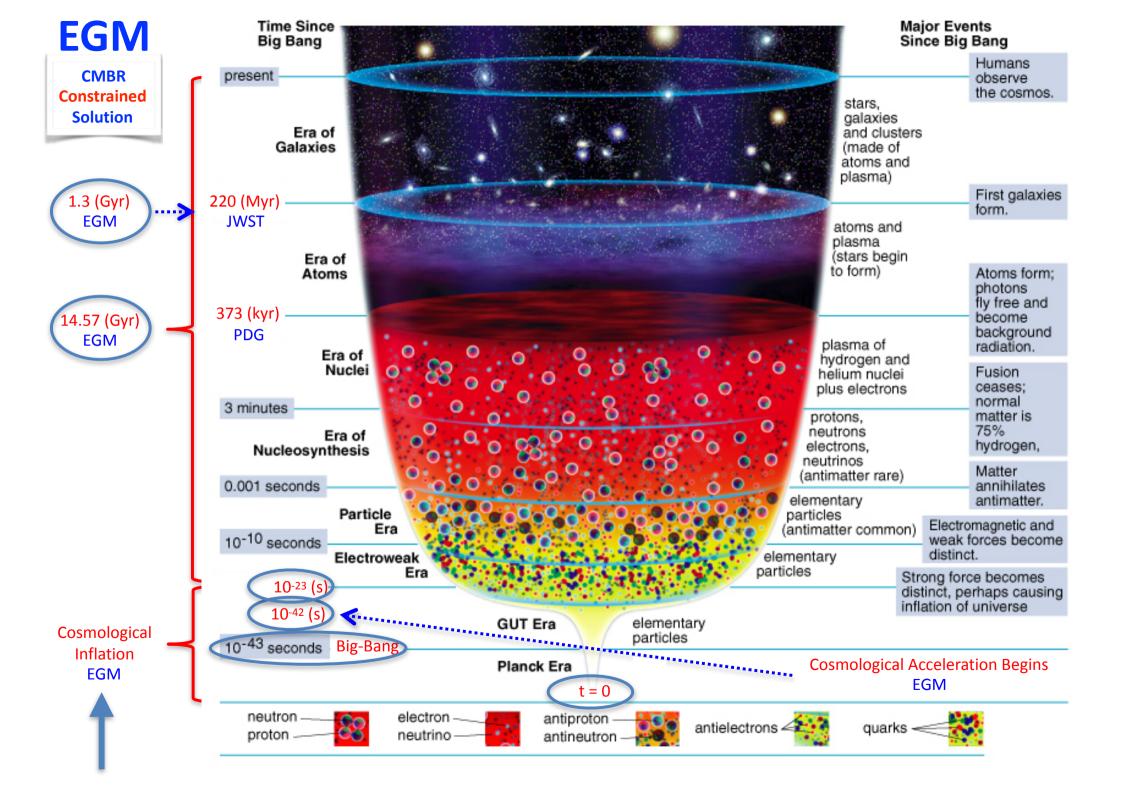
Comparative Overview of The Present-Epoch

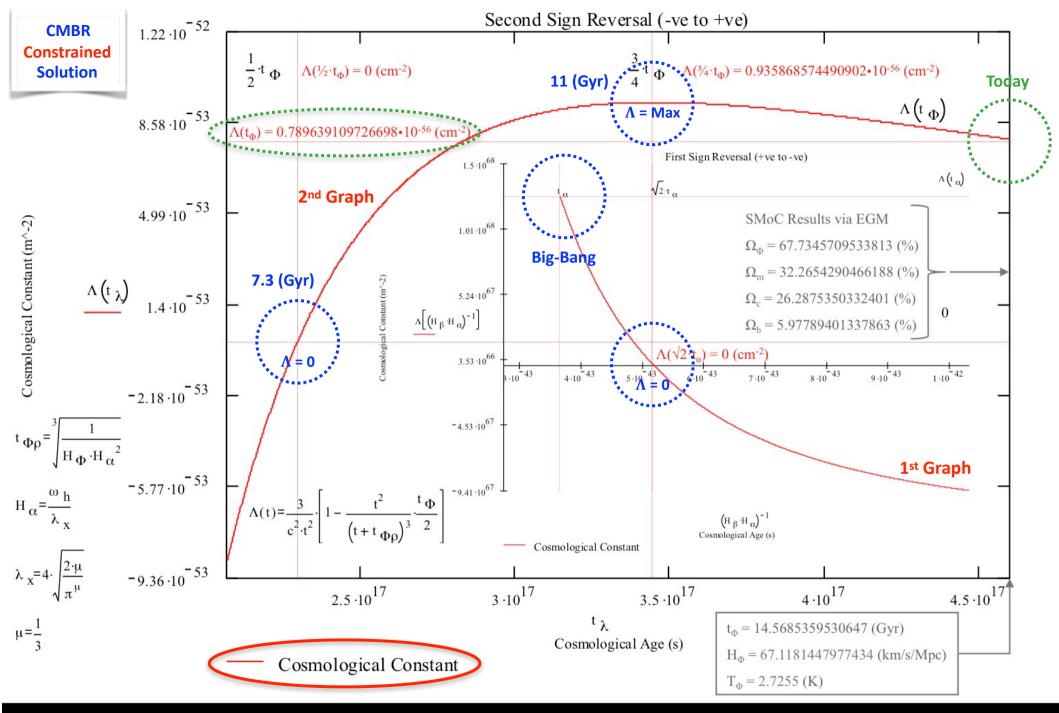Electro-Gravi-Magnetics (EGM) vs. Standard Model of Cosmology (SMoC)

	EGM	PDG-2022
1	$H_\Phi = 67.1181447977434$ (km/s/Mpc)	$H_0 = 67.4$ (km/s/Mpc)
2	$t_\Phi = 14.5685359530647$ (Gyr)	$t_0 = 13.797$ (Gyr)
3	$\Omega_\Phi = 0.677345709533812$	$\Omega_\Lambda = 0.685$
4	$\Omega_m = 0.322654290466188$	$\Omega_m = 0.315$
5	$\Omega_c = 0.262875350332401$	$\Omega_c = 0.265$
6	$\Omega_b = 0.059778940133786$	$\Omega_b = 0.0493$
7	$\Omega_K = 0.000654290466188$	$\Omega_K = 0.0007$
8	$\rho_\Phi = 8.46163851959276 \cdot 10^{-27}$ (kg/m^3)	$\rho_{crit} = 8.53286 \cdot 10^{-27}$ (kg/m^3)
9	$\rho_\Lambda = 5.73145454687219 \cdot 10^{-30}$ (gm/cm^3)	$\rho_\Lambda = 5.83 \cdot 10^{-30}$ (gm/cm^3)
10	$n_\gamma = 410.726847902135$ (cm^{-3})	$n_\gamma = 410.73$ (cm^{-3})
11	$\rho_\gamma = 0.260570578238883$ (eV/cm^3)	$\rho_\gamma = 0.260$ (eV/cm^3)
12	$\eta = 7.35787809937048 \cdot 10^{-10}$	$\eta = 6.14 \cdot 10^{-10}$
13	$n_b = 3.02207807900259 \cdot 10^{-7}$ (cm^{-3})	$n_b = 2.515 \cdot 10^{-7}$ (cm^{-3})
14	$\Omega_\gamma = 5.48958983118303 \cdot 10^{-5}$	$\Omega_\gamma = 5.38 \cdot 10^{-5}$
15	$R_\Phi = 14.5685359530647$ (GLyr)	$c/H_0 = 14.502$ (GLyr)
16	$\Lambda_S = 6.33200653109817 \cdot 10^{51}$ (m^2)	$\Lambda_S = 6.28 \cdot 10^{51}$ (m^2)
17	$\Lambda_\Phi = 0.789639109726698 \cdot 10^{-56}$ (cm^{-2})	$\Lambda = 1.088 \cdot 10^{-56}$ (cm^{-2})

CMBR Constrained

CMBR UnConstrained

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The Big Picture

Evolution timeline (top banner)

Smooth space: energy and matter nearly uniform — Big bang

Universe transparent to radiation — 300,000 years after big bang

Differences in temperature and density emerge

Redshift—a measure of how far light/microwaves from distant galaxies has been stretched to longer, or redder, wavelengths—marks cosmic distances.

Stars form in protogalactic clumps — First stars emit light; thermonuclear fusion of hydrogen and helium into heavy elements — 50 million years after big bang

Most distant galaxy (discovered December 1998)

Universe cools

Galaxies and quasars emerge from clouds of gas and dust — One billion years after big bang

Gravity enhances filament-like formations of galaxies — Five billion years after big bang

Galaxies coalesce in filaments — Deep voids develop — Ten billion years after big bang

Present

Labels (galaxy/star maps)

NGC 5907, NGC 5248, NGC 6946, NGC 5457, NGC 5055, NGC 5194, NGC 5236, NGC 4826, NGC 4594, NGC 5128, IC 342, NGC 3031, NGC 253, NGC 891, Virgo, M87, M100, Ursa Major, Virgo W, NGC 4571, NGC 4565, NGC 4631, NGC 4656, Local Group (Milky Way), NGC 3623, 3627, 3628, NGC 3593, NGC 4038/4039, NGC 628, NGC 2903, NGC 1566, Fornax

Leo II, Leo I, Draco, Ursa Minor, Sextans, Milky Way, Large Magellanic Cloud, Small Magellanic Cloud, Sagittarius, Carina, Sculptor, NGC 6822, IC 10, And VII, NGC 185, NGC 147, And V, M110 (NGC 205), M32, Andromeda (M31), And II, And I, And III, And VI, Triangulum (M33), Phoenix, Pegasus, LGS 3, IC 1613, DDO 210, Fornax

2 million light-years, 1 million, 250,000 light-years, 200,000, 150,000, 100,000, 50,000, 1 million, 2 million light-years

Sagittarius Dwarf, Small Magellanic Cloud, Large Magellanic Cloud, Milky Way, Ursa Minor, Sculptor

Eta Cassiopeia A, B; Procyon A, B; Luyten's Star; Ross 614 A, B; Sirius A, B; Epsilon Eridani; Kapteyn's Star; Solar System; Proxima Centauri; Alpha Centauri A; Alpha Centauri B; Alpha Centauri C; Barnard's Star; Altair; Ross 154; Gl 876 and planet; Delta Pavonis; Tau Ceti; Wolf 359; Lalande 21185; Ross 128; Groombridge 34 A, B; Wolf 629; Gl 166 A, B, C

20 light-years, 10, 15, 50 million, 75 million light-years, 25 million

SUN, MERCURY, VENUS, EARTH, MARS, JUPITER, SATURN, URANUS, NEPTUNE, PLUTO, Asteroid belt, Kuiper belt

Planetary alignment, January 1, 2000

SMoC

Time Since Big Bang

Major Events Since Big Bang

present — Humans observe the cosmos.

Era of Galaxies

stars, galaxies and clusters (made of atoms and plasma)

220 (Myr)
JWST

First galaxies form.

Era of Atoms

atoms and plasma (stars begin to form)

13.8 (Gyr)
SMoC

373 (kyr)
PDG

Atoms form; photons fly free and become background radiation.

Era of Nuclei

plasma of hydrogen and helium nuclei plus electrons

3 minutes

Fusion ceases; normal matter is 75% hydrogen,

Era of Nucleosynthesis

protons, neutrons electrons, neutrinos (antimatter rare)

0.001 seconds

Matter annihilates antimatter.

Particle Era

elementary particles (antimatter common)

10^{-10} seconds

Electromagnetic and weak forces become distinct.

Electroweak Era

elementary particles

10^{-35} seconds   Big-Bang

Strong force becomes distinct, perhaps causing inflation of universe

Cosmological Inflation SMoC

The SMoC asserts that "the Big-Bang occurred <u>after</u> Cosmological Inflation" [*source = Ethan Siegel*]

GUT Era   elementary particles

Planck Era   ????

neutron — proton   electron — neutrino   antiproton — antineutron   antielectrons   quarks

EGM

CMBR Constrained Solution

1.3 (Gyr) EGM

14.57 (Gyr) EGM

Cosmological Inflation EGM

Time Since Big Bang

present

Era of Galaxies

220 (Myr) JWST

Era of Atoms

373 (kyr) PDG

Era of Nuclei

3 minutes

Era of Nucleosynthesis

0.001 seconds

Particle Era

10^{-10} seconds

Electroweak Era

10^{-23} (s)

10^{-42} (s)

10^{-43} seconds   Big-Bang

GUT Era

Planck Era

t = 0

Major Events Since Big Bang

Humans observe the cosmos.

stars, galaxies and clusters (made of atoms and plasma)

First galaxies form.

atoms and plasma (stars begin to form)

Atoms form; photons fly free and become background radiation.

plasma of hydrogen and helium nuclei plus electrons

Fusion ceases; normal matter is 75% hydrogen,

protons, neutrons electrons, neutrinos (antimatter rare)

Matter annihilates antimatter.

elementary particles (antimatter common)

Electromagnetic and weak forces become distinct.

elementary particles

Strong force becomes distinct, perhaps causing inflation of universe

elementary particles

Cosmological Acceleration Begins EGM

neutron
proton
electron
neutrino
antiproton
antineutron
antielectrons
quarks

Second Sign Reversal (-ve to +ve)

CMBR Constrained Solution

$\frac{1}{2} \cdot t_\Phi$ $\Lambda(\frac{1}{2} \cdot t_\Phi) = 0$ (cm^{-2})

11 (Gyr) $\frac{3}{4} \cdot t_\Phi$ $\Lambda(\frac{3}{4} \cdot t_\Phi) = 0.935868574490902 \cdot 10^{-56}$ (cm^{-2})

Today

$\Lambda = $ Max

$\Lambda(t_\Phi) = 0.789639109726698 \cdot 10^{-56}$ (cm^{-2})

$\Lambda(t_\Phi)$

First Sign Reversal (+ve to -ve)

2nd Graph

$\Lambda(t_\alpha)$

$\Lambda(t_\lambda)$

Big-Bang

SMoC Results via EGM

$\Omega_\Phi = 67.7345709533813$ (%)

7.3 (Gyr)

$\Omega_m = 32.2654290466188$ (%)

$\Omega_c = 26.2875350332401$ (%)

$\Lambda = 0$

$\Omega_b = 5.97789401337863$ (%)

$\Lambda[(H_\beta \cdot H_\alpha)^{-1}]$

$\Lambda(\sqrt{2} \cdot t_\alpha) = 0$ (cm^{-2})

$\Lambda = 0$

$t_{\Phi\rho} = \sqrt[3]{\frac{1}{H_\Phi \cdot H_\alpha^2}}$

$H_\alpha = \frac{\omega_h}{\lambda_x}$

1st Graph

$\Lambda(t) = \frac{3}{c^2 \cdot t^2} \cdot \left[1 - \frac{t^2}{(t + t_{\Phi\rho})^3} \cdot \frac{t_\Phi}{2}\right]$

$\lambda_x = 4 \cdot \sqrt{\frac{2 \cdot \mu}{\pi^\mu}}$

$(H_\beta \cdot H_\alpha)^{-1}$
Cosmological Age (s)

Cosmological Constant

$\mu = \frac{1}{3}$

Cosmological Constant

t_λ
Cosmological Age (s)

$t_\Phi = 14.5685359530647$ (Gyr)

$H_\Phi = 67.1181447977434$ (km/s/Mpc)

$T_\Phi = 2.7255$ (K)

- $t_\alpha = 3.64699500847915 \cdot 10^{-43}$ (s); T = 0 (K); H = $8.46087689814736 \cdot 10^{61}$ (km/s/Mpc); $\Lambda = 1.25481446197314 \cdot 10^{64}$ (cm^{-2})
- $\sqrt{2} \cdot t_\alpha = 5.1576298028982 \cdot 10^{-43}$ (s); T = $1.37954687987071 \cdot 10^{31}$ (K); H = $5.80641973431186 \cdot 10^{61}$ (km/s/Mpc); $\Lambda = 0$ (cm^{-2})
- $\frac{1}{2} \cdot t_\Phi = 7.28426797653236$ (Gyr); T = 3.98569741894682 (K); H = 134.220589740631 (km/s/Mpc); $\Lambda = 0$ (cm^{-2})
- $\frac{3}{4} \cdot t_\Phi = 10.9264019647985$ (Gyr); T = 3.19119125008962 (K); H = 89.4865230672685 (km/s/Mpc); $\Lambda = 0.935868574490902 \cdot 10^{-56}$ (cm^{-2})

Planck Frequency
$\omega_h = 7.3998153159224 \cdot 10^{42}$ (Hz)

THE UNIVERSE

NATIONAL GEOGRAPHIC

(3)

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| Differences in temperature and density emerge | | | First stars emit light; thermonuclear fusion of hydrogen and helium into heavy elements | Most distant galaxy discovered December 1998 | | | |

Redshift 1,000   Redshift 30   U n i v e r s e   c o o l s

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The Primordial Universe

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Text by Stephen P. Moran,
Art by Kenneth Eward

Planetary alignment, January 1, 2000

PLUTO
NEPTUNE
URANUS   MERCURY   VENUS
SUN
JUPITER   MARS   Asteroid belt
EARTH
SATURN

K u i p e r   b e l t

Galaxy and structure labels:
NGC 5907, NGC 5248, NGC 6946, NGC 5457, NGC 5055, NGC 5194, NGC 5236, NGC 4826, NGC 4594, NGC 4565, NGC 4631, NGC 4656, NGC 4571, M87, M100, NGC 5128, IC 342, NGC 3031, NGC 253, NGC 628, NGC 891, NGC 3623, NGC 3627, NGC 3628, NGC 3593, NGC 4038/4039, NGC 2903, NGC 1566, Virgo, Ursa Major, Virgo W, Local Group (Milky Way)

Leo II, Leo I, Draco, Ursa Minor, Sextans, Milky Way, Large Magellanic Cloud, Small Magellanic Cloud, NGC 6822, Carina, Sculptor, IC 10, And VII, NGC 185, And V, NGC 147, Andromeda (M31), M110 (NGC 205), M32, And II, And III, And I, Triangulum (M33), And VI, Phoenix, LGS 3, Pegasus, IC 1613, Fornax, DDO 210

Sagittarius Dwarf, Small Magellanic Cloud, Large Magellanic Cloud, Sculptor, Milky Way, Ursa Minor

Solar neighborhood labels:
WX Ursae Majoris, Groombridge 1618, AD Leonis, Lalande 21185, Ross 128, Wolf 359, Kruger 60 A, B, Eta Cassiopeia A, B, Procyon A, B, Luyten's Star, Groombridge 34 A, B, Solar System, Proxima Centauri, Barnard's Star, Alpha Centauri B, Alpha Centauri A, Altair, Ross 614 A, B, Ross 154, Sirius A, B, LHS 288, 61 Cygni A, B, EZ Aquarii A, B, C, AX Microscopii, Epsilon Eridani, UV Cet, GI 65 A, Epsilon Indi, Kapteyn's Star, Tau Ceti, GI 166 A, B, GI 1002, GI 876 and planet, GI 783 A, B, Delta Pavonis, Wolf 629 A, B, GI 687, GI 1245 A, B, GI 628, GI 570 A, B, C, GI 702 A, B, GI 663 A, B, GI 674, Lalande 21258

2 million light-years, 1 million, 250,000 light-years, 200,000, 150,000, 100,000, 50,000, 75 million light-years, 50 million, 25 million, 20 light-years

Magnitude of Hubble Con. vs. Cosm. Age

$$H_{\alpha t} = \sqrt{\left| dH_{dt}(H_\gamma) \right|}$$

$$H_\gamma = \left(\frac{t_\alpha}{t}\right)^\eta, \quad \eta = 1$$

$$t_\alpha = \frac{1}{H_\alpha}$$

$$t = \frac{1}{H_\beta \cdot H_\alpha}$$

$$H_\alpha = \frac{\omega_h}{\lambda_x}$$

$$\lambda_x = 4 \cdot \sqrt{\frac{2\cdot\mu}{\pi^\mu}} \quad \mu = \frac{1}{3}$$

|H| — Magnitude of Hubble Constant (Hz)

dH/dt — 1st Derivative of the Hubble Constant

Region of positive Hubble gradient
• Accelerated Cosmological Expansion: $> t_1$

Region of negative Hubble gradient
• Decelerating Cosmological Expansion: $< t_1$

$$dH_{\alpha dt}(H_\gamma) = H_\alpha^2 \cdot H_\gamma^{14\mu^2} \cdot \left(5\cdot\mu^2 \cdot \ln\left(\frac{1}{H_\gamma}\right) - 1\right)$$

$t_\Phi \approx 14.568536$ (Gyr) [Constrained by T_0]

$H_\Phi \approx 67.118145$ (km/s/Mpc) [Constrained by T_0]

$T_\Phi = 2.7255$ (K)

Max. Cosm. Temp. Line: 3.2x10^31 (K)

Big-Bang: 0(K) $\omega_h = 7.3998153159224\cdot10^{42}$ (Hz)

Phase	Region	Start	End
Planck Inflation	A	0	t_α
Thermal Inflation	B	t_α	t_1
Hubble Inflation	C	t_1	t_2
Hubble Expansion	D	t_2	t_Φ
Cosmological Inflation	E	0	$2\cdot t_{\Phi\rho}$
Cosmological Expansion	F	t_α	t_Φ

Time	T (K)	dH/dt (km/s/Mpc)^2	H (km/s/Mpc)
0	$-\infty$	$-\infty$	$+\infty$
$t_\alpha \approx 3.646995\cdot10^{-43}$(s)	0	$\approx -7.158644\cdot10^{123}$	$\approx 8.460877\cdot10^{61}$
$t_1 \approx 2.206303\cdot10^{-42}$(s)	$\approx 3.195497\cdot10^{31}$	0	0
$t_2 \approx 4.196184\cdot10^{-42}$(s)	$\approx 3.034302\cdot10^{31}$	$\approx 5.719442\cdot10^{121}$	$\approx 7.5627\cdot10^{60}$
$2\cdot t_{\Phi\rho} \approx 7.879348\cdot10^{-23}$(s)	$\approx 1.140344\cdot10^{22}$	$\approx 1.455322\cdot10^{83}$	$\approx 3.814868\cdot10^{41}$

Inflation/Expansion

Cosmological Inflation

Cosmological Expansion

$$\Omega_\Sigma(t) = \frac{t^2}{(t+t_{\Phi\rho})^3}\cdot t_\Phi$$

$$\Omega_q(t) = 1 - \Omega_\Sigma(t)$$

$$t_{\Phi\rho} = \sqrt[3]{\frac{1}{H_\Phi \cdot H_\alpha^2}}$$

— EGM Total Density Parameter
— EGM Deceleration Parameter

Cosmological Evolution of The Primordial Universe
• Decelerating Cosmological Expansion [dH/dt = negative]: $0 \leq t < t_1$
• Accelerated Cosmological Expansion [dH/dt = positive]: $> t_1$
• Cosmological Inflation ceases at $2\cdot t_{\Phi\rho}$

Av. Cosmological Temperature vs. Age

t_α t_1 $T_{U3}(t_1)$

Max. Cosm. Temp: 3.2×10^{31} (K)

CMBR

$T_{U3}\left[\left(H_\beta \cdot H_\alpha\right)^{-1}\right]$

$t = \dfrac{1}{H_\beta \cdot H_\alpha}$

Av. Cosmological Temperature (K)

$3 \cdot 10^{31}$

$2 \cdot 10^{31}$

$1 \cdot 10^{31}$

0

1st Derivative of Av. Cosmological Temp.

$\dfrac{dT}{dt}(t) = -K_W \cdot St_T \cdot \left(\dfrac{5 \cdot \ln(H_\alpha \cdot t) \cdot \mu^2 - 1}{t^{5 \cdot \mu^2} \cdot t}\right)$

1st Deriv.

$T_{U3}(t) = K_W \cdot St_T \cdot \ln(H_\alpha \cdot t) \cdot \left(\dfrac{1}{t}\right)^{5 \cdot \mu^2}$

$\left(H_\beta \cdot H_\alpha\right)^{-1}$
Cosmological Age (s)

Big-Bang: 0(K)

$1 \cdot 10^{-43}$ $1 \cdot 10^{-42}$ $1 \cdot 10^{-41}$ $1 \cdot 10^{-40}$ $1 \cdot 10^{-39}$ $1 \cdot 10^{-38}$ $1 \cdot 10^{-37}$ $1 \cdot 10^{-36}$

Primordial Evolution of Cosmic Microwave Background Radiation (CMBR)

2nd Derivative of Av. Cosmological Temp.

$H_\alpha = \dfrac{\omega_h}{\lambda_x}$

Max. Post-Big-Bang Hubble Constant Line: 7.6×10^{60} (km/s/Mpc)

$t_\alpha = \dfrac{1}{H_\alpha}$

t_2 t_3 $\dfrac{dT2}{dt2}(t_3)$

2nd Deriv.

$\dfrac{dT2}{dt2}(t) = K_W \cdot St_T \cdot \left[\dfrac{5 \cdot \mu^2 \cdot \left[\ln(H_\alpha \cdot t) \cdot \left(5 \cdot \mu^2 + 1\right) - 2\right] - 1}{t^{5 \cdot \mu^2} \cdot t^2}\right]$

$K_W = 2.897771955$ (mm·K)

$1 \cdot 10^{113}$

$5 \cdot 10^{112}$

0

$-5 \cdot 10^{112}$

$-1 \cdot 10^{113}$

$-1.5 \cdot 10^{113}$

$-2 \cdot 10^{113}$

$\dfrac{dT2}{dt2}\left[\left(H_\beta \cdot H_\alpha\right)^{-1}\right]$

(K/s^2)

3rd Derivative of Av. Cosmological Temp.

t_3 t_4

$\dfrac{dT3}{dt3}(t) = -K_W \cdot St_T \cdot \left[\dfrac{5 \cdot \mu^2 \cdot \ln(H_\alpha \cdot t) \cdot \left[5 \cdot \mu^2 \cdot \left(5 \cdot \mu^2 + 3\right) + 2\right] - 15 \cdot \mu^2 \cdot \left(5 \cdot \mu^2 + 2\right) - 2}{t^{5 \cdot \mu^2} \cdot t^3}\right]$

3rd Deriv.

$\dfrac{dT3}{dt3}\left[\left(H_\beta \cdot H_\alpha\right)^{-1}\right]$

(K/s^3)

$\omega_h = 7.3998153159224 \cdot 10^{42}$ (Hz)

$\lambda_x = 4 \cdot \sqrt{\dfrac{2 \cdot \mu}{\pi^\mu}} \qquad \mu = \dfrac{1}{3}$

$St_T = \dfrac{4 \cdot \mu}{(4 \cdot \mu)^\mu \cdot c} \cdot \left(\dfrac{\lambda_x \cdot \omega_h^2}{\pi}\right)^{2 \cdot \mu^2}$

$3 \cdot 10^{-42}$ $4 \cdot 10^{-42}$ $5 \cdot 10^{-42}$ $6 \cdot 10^{-42}$ $7 \cdot 10^{-42}$ $8 \cdot 10^{-42}$ $9 \cdot 10^{-42}$ $1 \cdot 10^{-41}$ $1.1 \cdot 10^{-41}$ $1.2 \cdot 10^{-41}$ $1.3 \cdot 10^{-41}$ $1.4 \cdot 10^{-41}$ $1.5 \cdot 10^{-41}$

$\left(H_\beta \cdot H_\alpha\right)^{-1}$
Cosmological Age (s)

THE UNIVERSE

(4)

Cosmological Inflation
&
Accelerated Expansion

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Combining evidence from microwave observations of deep space with supercomputer models, scientists have theorized about the structure of the universe from the big bang to the present (above). From the time that radiation and matter separated—300,000 years or so after the big bang—gravity began drawing matter first into clumps, then into stars. Perhaps a billion years later the first galaxies formed. As clusters of matter accumulated, the filament-and-void structure of today's universe unfolded.

Evolution timeline (top)

Smooth space: energy and matter nearly uniform | Universe transparent to radiation — Differences in temperature and density emerge | Stars form in protogalactic clumps — First stars emit light; thermonuclear fusion of hydrogen and helium into heavy elements | Most distant galaxy (discovered December 1998) | Galaxies and quasars emerge from clouds of gas and dust | Gravity enhances filament-like formations of galaxies | Galaxies coalesce in filaments — Deep voids develop

Big bang · 300,000 years after big bang · 50 million years after big bang · One billion years after big bang · Five billion years after big bang · Ten billion years after big bang · Present

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Cosmological Inflation & Accelerated Expansion

History of Cosmological Inflation →

[Start] Inflation $t = 0$

$\sqrt{2} \cdot t_\alpha$ $\Lambda = 0$ $\Omega_\Lambda = 0$

[Start] Acceleration $T_{Max} \mid H = 0$ t_1

H_{Max} t_2

[End] Inflation $2 \cdot t_{\Phi\rho}$

$t_\alpha \mid H_\alpha$ $T = 0$ [Start] Expansion

$t_{\Lambda\Lambda}$ $z_\Lambda = 0$

t_M $\Omega_M = q$

PDG — $\frac{1}{2} \cdot t_\Phi$ $\Lambda = 0$ $\Omega_\Lambda = 0$

US-DoE — t_Λ $\Omega_\Lambda = q$

FermiLab — t_q $q = 0$

$\frac{3}{4} \cdot t_\Phi$ Λ_{Max}

$t_{\Lambda M}$ $\Omega_\Lambda = \Omega_M$

Today t_Φ H_Φ

Big Bang

History of The Cosmos

1st Event : $t_\alpha = 1/H_\alpha = 3.64699500847915 \cdot 10^{-43}$ (s) ; $H_\alpha = 1/t_\alpha = 8.46087689814736 \cdot 10^{61}$ (km/s/Mpc) ; $T = 0$

2nd Event : $\sqrt{2} \cdot t_\alpha = 5.1576298028982 \cdot 10^{-43}$ (s) ; $\Lambda = 0, \Omega_\Lambda = 0$

3rd Event : $t_1 = 2.20630341057726 \cdot 10^{-42}$ (s) ; $T_{Max} = 3.19549736932411 \cdot 10^{31}$ (K) ; $H = 0$; [Start] Acceleration

4th Event : $t_2 = 4.19618421889086 \cdot 10^{-42}$ (s) ; $H_{Max} = 7.56269951315196 \cdot 10^{60}$ (km/s/Mpc)

5th Event : $2 \cdot t_{\Phi\rho} = 7.8793484858429 \cdot 10^{-23}$ (s) ; [End] Inflation

6th Event : $t_{\Lambda\Lambda} = 4.70060063106724$ (Gyr) ; $z_\Lambda = 0$

7th Event : $t_M = 4.93396766099874$ (Gyr) ; $\Omega_M = q$

8th Event : $\frac{1}{2} \cdot t_\Phi = 7.28426797653236$ (Gyr) ; $\Lambda = 0, \Omega_\Lambda = 0$ ← PDG ⎫

9th Event : $t_\Lambda = 8.45941813429917$ (Gyr) ; $\Omega_\Lambda = q$ ← US-DoE ⎬ Cosmic Acceleration Problem

10th Event : $t_q = 9.63456829206598$ (Gyr) ; $q = 0$ ← FermiLab ⎭

11th Event : $\frac{3}{4} \cdot t_\Phi = 10.9264019647985$ (Gyr) ; $\Lambda_{Max} = 0.935868574490902 \cdot 10^{-56}$ (cm^{-2})

12th Event : $t_{\Lambda M} = 11.9848686075996$ (Gyr) ; $\Omega_\Lambda = \Omega_M$

13th Event : $t_\Phi = 1/H_\Phi = 14.5685359530647$ (Gyr) ; $H_\Phi = 1/t_\Phi = 67.1181447977434$ (km/s/Mpc) ; Present-Epoch

14th Event : $T_L = 4.10165382157836 \cdot 10^{13}$ (Gyr) ; Distant Future

Cosmological Parameters vs. Cos. Age

$$\Omega_{\Sigma}(t) = \frac{t^2}{(t + t_{\Phi\rho})^3} \cdot t_{\Phi}$$

$$t_{\Phi\rho} = \sqrt[3]{\frac{1}{H_{\Phi} \cdot H_{\alpha}^2}}$$

$$H_{\alpha} = \frac{\omega_h}{\lambda_x}$$

$$\lambda_x = 4 \cdot \sqrt{\frac{2 \cdot \mu}{\pi^{\mu}}}$$

$$\mu = \frac{1}{3}$$

$$\Lambda(t) = \frac{3}{c^2 \cdot t^2} \cdot \left[1 - \frac{t^2}{(t + t_{\Phi\rho})^3} \cdot \frac{t_{\Phi}}{2} \right]$$

SMoC Results via EGM

$\Omega_{\Phi} = 67.7345709533813$ (%)

$\Omega_m = 32.2654290466188$ (%)

$\Omega_c = 26.2875350332401$ (%)

$\Omega_b = 5.97789401337863$ (%)

$H_{\Phi} = 67.1181447977434$ (km/s/Mpc)

$\Lambda_{\Phi} = 0.789639109726698 \cdot 10^{-56}$ (cm^{-2})

$T_{\Phi} = 2.7255$ (K)

$$\Omega_M(t) = \Omega_m \cdot \frac{t^2}{(t + t_{\Phi\rho})^3} \cdot t_{\Phi}$$

Cosmic Acceleration Problem

PDG 7.3 (Gyr)

US-DoE 8.5 (Gyr)

FermiLab 9.6 (Gyr)

$$\Omega_{\Lambda}(t) = 1 - \frac{t^2}{(t + t_{\Phi\rho})^3} \cdot \frac{t_{\Phi}}{2}$$

$$q(t) = \frac{t^2}{(t + t_{\Phi\rho})^3} \cdot \frac{t_{\Phi}}{2} \cdot (\Omega_m + 1) - 1$$

$$\Omega_q(t) = 1 - \Omega_{\Sigma}(t)$$

t_{Ψ} [$\Omega_q = q$]

$\frac{1}{4} \cdot t_{\Phi}$

t_M [$\Omega_M = q$]

$\frac{1}{2} \cdot t_{\Phi}$ [$\Omega_{\Lambda} = 0, \Lambda = 0$]

t_{Λ} [$\Omega_{\Lambda} = q$]

t_q [$q = 0$]

$\frac{3}{4} \cdot t_{\Phi}$

$t_{\Lambda M}$ [$\Omega_M = \Omega_{\Lambda}$]

t_{Θ} [2nd Tangent]

t_{Φ}

t_{λ} Cosmological Age (s)

$\Lambda_{EGM} = 0.935868574490902 \cdot 10^{-56}$ (cm^{-2})

$\Lambda_{PDG} = 1.088 \cdot 10^{-56}$ (cm^{-2})

Legend:
- SMoC Dark Energy Density Parameter
- SMoC Matter Density Parameter
- SMoC Deceleration Parameter
- EGM Total Density Parameter
- EGM Deceleration Parameter
- 1st Tangent to EGM Deceleration Parameter
- 2nd Tangent to EGM Deceleration Parameter

t_M: $\Omega_M = q = 0.952701953890743$

t_{Λ}: $\Omega_{\Lambda} = q = 0.138916192474527$

$t_{\Lambda M}$: $\Omega_M = \Omega_{\Lambda} = 0.39221127781798$

t_{Ψ}: $\Omega_q = q = -0.203856811548931$

$\frac{1}{4} \cdot t_{\Phi} = 3.64213398826618$ (Gyr)

$t_q = 9.63456829206598$ (Gyr)

$t_{\Theta} = 13.6580024559982$ (Gyr)

$t_M = 4.93396766099874$ (Gyr)

$\frac{3}{4} \cdot t_{\Phi} = 10.9264019647985$ (Gyr)

$t_{\Phi} = 14.5685359530647$ (Gyr)

$\frac{1}{2} \cdot t_{\Phi} = 7.28426797653236$ (Gyr)

$t_{\Lambda M} = 11.9848686075996$ (Gyr)

$\omega_h = 7.3998153159224 \cdot 10^{42}$ (Hz)

$t_{\Lambda} = 8.45941813429917$ (Gyr)

$t_{\Psi} = 12.1015521225654$ (Gyr)

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Planetary alignment, January 1, 2000

The Cosmic Acceleration Problem

NGC 5907 — NGC 5248 — NGC 6946 — NGC 5457 — NGC 5055 — NGC 5194 — NGC 4571 — M87 — M100 — Ursa Major — Virgo W — NGC 5236 — NGC 4826 — NGC 4594 — NGC 4565 — NGC 4631 — NGC 4656 — Virgo — NGC 5128 — IC 342 — NGC 3031 — Local Group (Milky Way) — NGC 253 — NGC 891 — NGC 3623 3627, 3628 — NGC 3593 — NGC 4038/4039 — NGC 628 — NGC 2903

2 million light-years — 1 million — 25 million — 50 million — 75 million light-years — 75 million light-years — 50 million — 25 million

Leo II — Leo I — Draco — Ursa Minor — Sextans — Sculptor — Carina — Sagittarius — Small Magellanic Cloud — Large Magellanic Cloud — Milky Way — IC 10 — And VII — And V — And VI — And II — And I — And III — M110 (NGC 205) — M32 — Andromeda (M31) — NGC 147 — Triangulum (M33) — Phoenix — LGS 3 — Pegasus — IC 1613 — Fornax — NGC 1566 — DDO 210 — And VI

250,000 light-years — 200,000 — 150,000 — 100,000 — 50,000 — 1 million — 2 million light-years

Sagittarius Dwarf — Small Magellanic Cloud — Large Magellanic Cloud — Milky Way — Ursa Minor — Sculptor — Magellanic Bridge

Lalande 21258 — WX Ursae Majoris — Groombridge 1618 — AD Leonis — Lalande 21185 — Wolf 359 — Ross 128 — Wolf 424 A, B — Gl 687 — Kruger 60 A, B — Gl 1245 A, B — Barnard's Star — Gl 570 A, B, C — Gl 625 — Gl 702 A, B — Gl 663 A, B — Gl 664 — Eta Cassiopeia A, B — Procyon A, B — Luyten's Star — Solar System — 61 Cygni A, B — Altair — Groombridge 34 A, B — Proxima Centauri — Alpha Centauri A — Ross 154 — Gl 674 — Sirius A, B — Alpha Centauri B — LHS 288 — Gl 440 — EF Aquarii A, B, C — AX Microscopii — Gl 783 A, B — Epsilon Eridani — UV Cet / Gl 65 A — Kapteyn's Star — Gl 908 — VZ Ceti — Gl 876 and planet — Ross 614 A, B — Tau Ceti — Gl 1002 — Delta Pavonis — Gl 166 A, B, C — LP 944-20 A

5 million — 10 — 15 — 20 light-years — 20 light-years

NEPTUNE — URANUS — MERCURY — VENUS — SUN — JUPITER — MARS — EARTH — SATURN — PLUTO — Asteroid belt — Kuiper belt

The Cosmic Acceleration Problem

When did it start ?

- **3rd Event** (Maximum Cosmological Temperature)
  - $H = 0$ (km/s/Mpc)
  - $\Lambda = -1.18624205780952 \cdot 10^{64}$ (cm^{-2})
  - $t_1 = 2.20630341057726 \cdot 10^{-42}$ (s)
  - $T_{Max} = 3.19549736932411 \cdot 10^{31}$ (K)
  - Actual Cosmological Acceleration Commences

Storti

Solution

CMBR Constrained Solution

- **8th Event** ($\Lambda = 0$)
  - $\frac{1}{2} \cdot t_\Phi = 7.28426797653236$ (Gyr)
  - $T = 3.98569741894682$ (K)

Particle **D**ata **G**roup (PDG) ~ 7.7 (Gyr)

- **9th Event** (*Dark Energy Density Parameter = Deceleration Parameter*)
  - $\Lambda = 0.650672352266949 \cdot 10^{-56}$ (cm^{-2})
  - $t_\Lambda = 8.45941813429917$ (Gyr)
  - $T = 3.67189222792196$ (K)

US **D**epartment **o**f **E**nergy (US-DoE) ~ 9 (Gyr)

- **10th Event** ($q = 0$)
  - $\Lambda = 0.880880602181968 \cdot 10^{-56}$ (cm^{-2})
  - $t_q = 9.63456829206598$ (Gyr)
  - $T = 3.41912708997334$ (K)

Frieman et. al. [FermiLab] ~ 10 (Gyr)

Problem

CMBR UnConstrained Solutions

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Text by Stephen P. Moran,
Art by Kenneth Eward

For information regarding available maps call 1-800-962-1643 or write to National Geographic Maps, PO Box 4357, Evergreen, CO 80437-4357. You can find us on the Internet at nationalgeographic.com/Maps.

The Flatness Problem

The Flatness Problem

Does <u>Not</u> Exist ! → We show that The Universe is 'Barely Open' !

'Barely Open' → $\Omega_\Phi = -2.59792187762287 \cdot 10^{-14}$

https://encyclopediaofmath.org/wiki/Negative_curvature,_surface_of

CMBR UnConstrained Solution

CMBR Constrained Solution

Flat: $\Omega_\Phi = 0$ Closed: $\Omega_\Phi > 0$ Open: $\Omega_\Phi < 0$

ZERO CURVATURE   POSITIVE CURVATURE   NEGATIVE CURVATURE

https://starchild.gsfc.nasa.gov/docs/StarChild/questions/question35.html

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Text by Stephen P. Maran,
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Universe consultants:
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Labels on supercluster diagram: NGC 5907, NGC 5248, NGC 6946, NGC 5457, NGC 5055, NGC 5194, NGC 5236, NGC 4826, NGC 4594, NGC 4565, Virgo, NGC 4571, M87, M100, Ursa Major, Virgo W, NGC 4631, NGC 4656, Local Group (Milky Way), NGC 5128, IC 342, NGC 3031, NGC 253, NGC 628, NGC 891, NGC 3623, NGC 3627, 3626, NGC 3593, NGC 4038/4039, NGC 2903

Labels on Local Group diagram: Leo II, Leo I, Drace, Ursa Minor, Sextans, Milky Way, Large Magellanic Cloud, Small Magellanic Cloud, Sagittarius, Carina, Sculptor, Fornax, IC 10, And VII, And V, NGC 185, NGC 147, M110 (NGC 205), M32, And II, And I, And III, Andromeda (M31), And VI, Triangulum (M33), LGS 3, Phoenix, Pegasus, IC 1613, DDO 210, Sextans

Galactic realm labels: Milky Way, Sagittarius Dwarf, Small Magellanic Cloud, Large Magellanic Cloud, Sculptor, Ursa Minor

Sun's neighborhood labels: Solar System, Alpha Centauri A, B, C, Proxima Centauri, Sirius A, B, Procyon A, B, Eta Cassiopeia A, B, Barnard's Star, Altair, Ross 154, Epsilon Eridani, Delta Pavonis, GI 876 and planet, Tau Ceti

Solar system labels: Kuiper belt, PLUTO, NEPTUNE, URANUS, MERCURY, VENUS, SUN, MARS, EARTH, JUPITER, SATURN, Asteroid belt

Planetary alignment, January 1, 2000

Presentation Closeout

The History of The Cosmos

[From The Big-Bang to The Present-Epoch]

Improving The **S**tandard **M**odel **O**f **C**osmology **(SMoC)**

What CMBR-Constrained Interpretation of the SMoC have we established so far ?

1. Cosmological Inflation [Start]: $t = 0$

2. Cold Big-Bang [T = 0]: $t = 10^{-43}$ (s)

3. Maximum Cosmological Temperature [T_{Max}]: $t = 10^{-42}$ (s)

4. Cosmological Acceleration [Start]: $t = 10^{-42}$ (s)

5. Maximum Hubble Constant [H_{Max}]: $t = 10^{-42}$ (s)

Events encapsulated by Cosmological Inflation

6. Cosmological Inflation [End]: $t = 10^{-23}$ (s)

7. Cosmological Acceleration Problem = Resolved

8. Flatness Problem = Does Not Exist [The Universe is Open]

Significant Conclusions

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Governing Equations

$$\Lambda(t) = \frac{3}{c^2 t^2}\left(1 - \frac{1}{2}\Omega_\Sigma(t)\right) \qquad \text{Cosmological Constant} \qquad (1)$$

$$\Omega_\Lambda(t) = 1 - \frac{1}{2}\Omega_\Sigma(t) \qquad \text{Dark Energy Density Parameter} \qquad (2)$$

$$\Omega_M(t) = \Omega_m \Omega_\Sigma(t) \qquad \text{Pressureless Matter Parameter} \qquad (3)$$

$$q(t) = \frac{1}{2}\Omega_\Sigma(t)(\Omega_m + 1) - 1 \qquad \text{Deceleration Parameter} \qquad (4)$$

$$\Omega_\Sigma(t) = \frac{t^2}{(t+t_{\Phi\rho})^3}\, t_\Phi \qquad \text{EGM Total Density Parameter} \qquad (5)$$

$$\rho_m(t) = \frac{3M_\Phi}{4\pi c^3 (t+t_{\Phi\rho})^3} \qquad \text{Cosmological Mass Density} \qquad (6)$$

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Supporting Equations

- Cosmological Mass (*Total*) [14]: [pg. 7]

$$M_\Phi = \frac{c^3}{2GH_\Phi} \qquad M_\Phi = 4.66692747982406 \cdot 10^{22} \ (M_\odot)$$

Mathematical Constants

- 1st EGM Constant (*assigned value*)

$$\mu = \tfrac{1}{3}$$

- 2nd EGM Constant [15]: [pg. 327-328]

$$\lambda_x = 4\sqrt{\frac{2\mu}{\pi^\mu}} \qquad \lambda_x = 2.69870895208366$$

Physical Constants

- Big-Bang Hubble Constant [15]: [pg. 343-344]

$$H_\alpha = \frac{\omega_h}{\lambda_x} = \frac{1}{t_\alpha} \qquad H_\alpha = 8.46087689814736 \cdot 10^{61} \ (km/s/Mpc)$$

- Cosmological Time Constant [14]: [pg. 58]

$$t_{\Phi\rho} = \sqrt[3]{\frac{1}{H_\Phi H_\alpha{}^2}} \qquad t_{\Phi\rho} = 3.93967424292145 \cdot 10^{-23} \ (s)$$

The History of The Cosmos

[From The Big-Bang to The Present-Epoch]

Improving The **S**tandard **M**odel **o**f **C**osmology **(SMoC)**

Thanks for watching this presentation !

This Research Article:
- https://www.researchgate.net/publication/363860392_The_History_of_The_Cosmos_From_The_Big-Bang_to_The_Present-Epoch

Solution Algorithm (*Calculations & Mathematical Model for this Research Article*):
- https://www.researchgate.net/publication/345236498_Quinta_Essentia_Part_52_History_of_The_Cosmos_Solution_Algorithm

Literature Supporting This Research Article (*Cosmological Age*):
- https://www.hindawi.com/journals/aa/2020/2436965/

Smooth space: energy and matter nearly uniform
Differences in temperature and density emerge

Most distant galaxy discovered (December 1998)

First stars emit light; thermonuclear fusion of hydrogen and helium into heavy elements

Big bang 300,000 years after big bang 50 million years after big bang One billion years after big bang Five billion years after big bang Ten billion years after big bang Present

Redshift 1,000   Redshift 30

Redshift—a measure of how far light, traveling through galaxies, has been stretched to longer, or redder, wavelengths—marks cosmic distances.

THE UNIVERSE

NATIONAL GEOGRAPHIC

A far as we can see with our ever improving telescopes, there are at least a hundred billion galaxies arrayed throughout the universe. Each, like the Milky Way, is an "island universe" containing billions of stars. Nearly all galaxies are members of groups or clusters, which are part of even larger structures called superclusters. All of these large concentrations are connected by filaments or sheets of galaxies, which enclose huge, bubble-like volumes of empty space, the cosmic voids.

The great unifier of the cosmos is gravity. It holds the stars of a galaxy, and the galaxies of a cluster, together. But clusters, groups, and isolated individual galaxies are all flying away from each other, a continuing aftermath of the big bang, an explosion of space itself that astronomers believe formed the universe 11 to 15 billion years ago.

EVOLUTION OF THE UNIVERSE

Combining evidence from microwave observations of deep space with supercomputer models, scientists have theorized about the structure of the universe from the big bang to the present (above). From the time that radiation and matter separated—300,000 years or so after the big bang—gravity began drawing matter, first into clumps, then into stars. Perhaps a billion years later the first galaxies formed. As clusters of matter accumulated, the filament-and-void structure of today's universe unfolded.

1 SIZE OF THE UNIVERSE

So vast is space that just to find our solar system we must make five leaps of scale. In the background image on this sheet we see a mere sliver of the sky—roughly one percent of the diameter of the observable universe—yet even the smallest dots represent not stars or galaxies but great congregations of galaxies. Scattered clumps of dark matter and galaxies appear as bright colors in the image, which is based on a supercomputer simulation. Within this sliver lies our supercluster (right), mapped using the actual positions of its celestial elements.

2 OUR SUPERCLUSTER

Some 150 million light-years across, our supercluster is a great aggregation of clusters of galaxies. The supercluster is centered on the Virgo cluster, which itself contains thousands of galaxies. Among them is M87, which astronomers now know surrounds a gigantic black hole. Virgo's gravity affects the movement of its neighbors, including the Local Group.

Virgo, the Ursa Major cluster, and other clusters float in our supercluster, last outposts before a space traveler would enter a nearly galaxy-free region called a cosmic void. Not that the region within our supercluster is teeming with galaxies: Although the supercluster has a mass equaling some thousand trillion suns, virtually all its volume is empty. Empty, that is, except for a certain density of dark matter, the hidden mass of the universe that helps hold galaxies and clusters together.

Recent observations reveal that early in the universe's history galaxies collided and merged more often than they do now. That indicates that they were more numerous in the past and that many have grown larger over billions of years.

The End

Local Group (Milky Way)

Virgo   M87 M100   Ursa Major   Virgo W

NGC 5907 · NGC 5248 · NGC 6946 · NGC 5457 · NGC 5055 · NGC 5194 · NGC 4571 · NGC 4565 · NGC 5236 · NGC 4826 · NGC 4594 · NGC 4631 · NGC 4656 · NGC 5128 · IC 342 · NGC 3031 · NGC 253 · NGC 891 · NGC 3623 3627, 3628 · NGC 3593 · NGC 4038/4039 · NGC 628 · NGC 2903 · NGC 1566 · Fornax

3 THE LOCAL GROUP

Galaxies stretch in every direction beyond the Milky Way, but gravity keeps a family of some 30 galaxies, including our own, loosely bound.

This Local Group of galaxies extends some four million light-years across. Most galaxies in the group are considered dwarfs, but the two largest—our own Milky Way and the Andromeda galaxy—are giant spirals. Andromeda is at the center of a small subgroup, which includes two elliptical galaxies, M32 and NGC 205, where star formation has ceased. Even though it is more than two million light-years away from Earth, the Andromeda galaxy can be seen readily with the naked eye. With even a small telescope, its bright bulge is unmistakable.

It is possible that astronomers have not found some of our group's smaller galaxies, which may be hidden behind dust clouds in the Milky Way.

All three main types of galaxies are represented in the Local Group: spirals, ellipticals, and irregulars. Nevertheless, the group has relatively few members, a hundredth that of some large galaxy clusters.

The galaxies of the Local Group are traveling together through space. Measurements show that the Milky Way is falling toward Andromeda. No collision is expected, however: Like race cars on opposite straightaways, the two are most likely at opposite ends of a highly elongated orbit around the group's center of mass.

Leo II · Leo I · Draco · Ursa Minor · Sextans · Sagittarius · IC 10 · Milky Way · Large Magellanic Cloud · Small Magellanic Cloud · Carina · Sculptor · NGC 6822 · Fornax · NGC 185 · NGC 147 · And VII · And V · M110 (NGC 205) · M32 · Andromeda (M31) · And II · And I · And III · Triangulum (M33) · And VI · Phoenix · LGS 3 · Pegasus · IC 1613 · DDO 210 · And VI

2 million light-years · 1 million · 250,000 light-years · 200,000 · 150,000 · 100,000 · 50,000 · 1 million · 2 million light-years

4 OUR GALACTIC REALM

Until the early 20th century the best guess of astronomers was that the Milky Way galaxy was the entire universe. We now know that ours is only one of at least a hundred billion galaxies.

The Milky Way is a spiral galaxy, and our solar system is located in what is called the spiral's Orion arm, about 25,000 light-years from the center. Our sun orbits the galactic center about once every 225 million years and has made the circuit about 20 times. In the spiral arms, new stars form as clouds of gas and dust condense. The stars' energy ionizes nearby parts of the clouds, causing them to glow.

The central bulge of the galaxy glows with the light of older, redder stars. More ancient stars, orbiting the galaxy in a diffuse halo, formed more than ten billion years ago. Several satellite galaxies cluster around the Milky Way. Two of them, the Large and the Small Magellanic Clouds, are visible on Earth only from the Southern Hemisphere. The closest galaxy is a small spheroid called the Sagittarius Dwarf.

Sagittarius Dwarf · Small Magellanic Cloud · Large Magellanic Cloud · Milky Way · Ursa Minor · Sculptor

5 OUR SUN'S NEIGHBORHOOD

The stars reaching 20 light-years in all directions from our sun make up the solar neighborhood. Each light-year measures 5.9 trillion miles, yet the neighborhood is a tiny part of the Milky Way. Most of the stars shown here are too dim to be seen with the naked eye, but a few, such as Sirius and Procyon—greatly exaggerated here and each actually two stars—are beacons in the sky.

In cosmic terms the sun is an ordinary yellow star, average in size and temperature. The hottest stars glow blue, the coolest shine red.

Many stars are binary or multiple. Our nearest neighbor is the Alpha Centauri triple system, 4.3 light-years away. Closest of the three is Proxima Centauri (Alpha Centauri C), a red dwarf with 1/10 the mass and 1/17,000 the brightness of the sun.

In recent years astronomers have discovered evidence of planets, similar to Jupiter in mass, orbiting stars. The closest example is Gl 876.

Solar System · Proxima Centauri · Alpha Centauri A · Alpha Centauri B · Eta Cassiopeia A, B · Procyon A, B · Luyten's Star · Barnard's Star · Altair · Sirius A, B · LHS 288 · Ross 154 · Epsilon Eridani · Kapteyn's Star · Tau Ceti · Gl 876 and planet · Delta Pavonis · Wolf 359 · Ross 128 · Lalande 21185 · Groombridge 34 A, B · Gl 166 A, B, C

6 OUR SOLAR SYSTEM

A tiny dot on the scale of the universe, the solar system—our home in the galaxy—measures some 4.6 billion miles from the sun to the farthest extent of Pluto's orbit. Sunlight reaches Earth in about 8 minutes and Jupiter in 43 minutes, but it takes nearly 7 hours to pass the orbit of Pluto.

Beyond Neptune are icy bodies smaller than planets. These are Kuiper belt objects, over a hundred of which have been observed by telescope. Some scientists suggest that Pluto is a Kuiper belt object, rather than a planet. Spread in a great sphere around the entire solar system is the Oort cloud, trillions of comets, a few of which make spectacular visits to the sun.

Kuiper belt · PLUTO · NEPTUNE · URANUS · SATURN · JUPITER · MARS · EARTH · VENUS · MERCURY · SUN · Asteroid belt

Planetary alignment, January 1, 2000