

PERSON OF THE CENTURY

TIME

ALBERT
EINSTEIN

“The most beautiful thing we can experience is the mysterious. It is the source of all true art and all science. Those to whom this emotion is a stranger, who can no longer pause to wonder and stand rapt in awe, are as good as dead: their eyes are closed.”

Albert Einstein

"IT from BIT"

FATE U inflate (again)

a cold death? reheat/rebirth?

NOW 14 Gyr 1

Pythagoras formed

Galaxies Cluster
Cosmic "web" of vast filaments + membranes

Life forms on earth

9 Gyr 1.4

Carbon/oxygen/etc form

Galaxies form

2 Gyr 4

The 'Meaning' may change
But the facts will remain

Inflation fluctuations form: quantum jitter

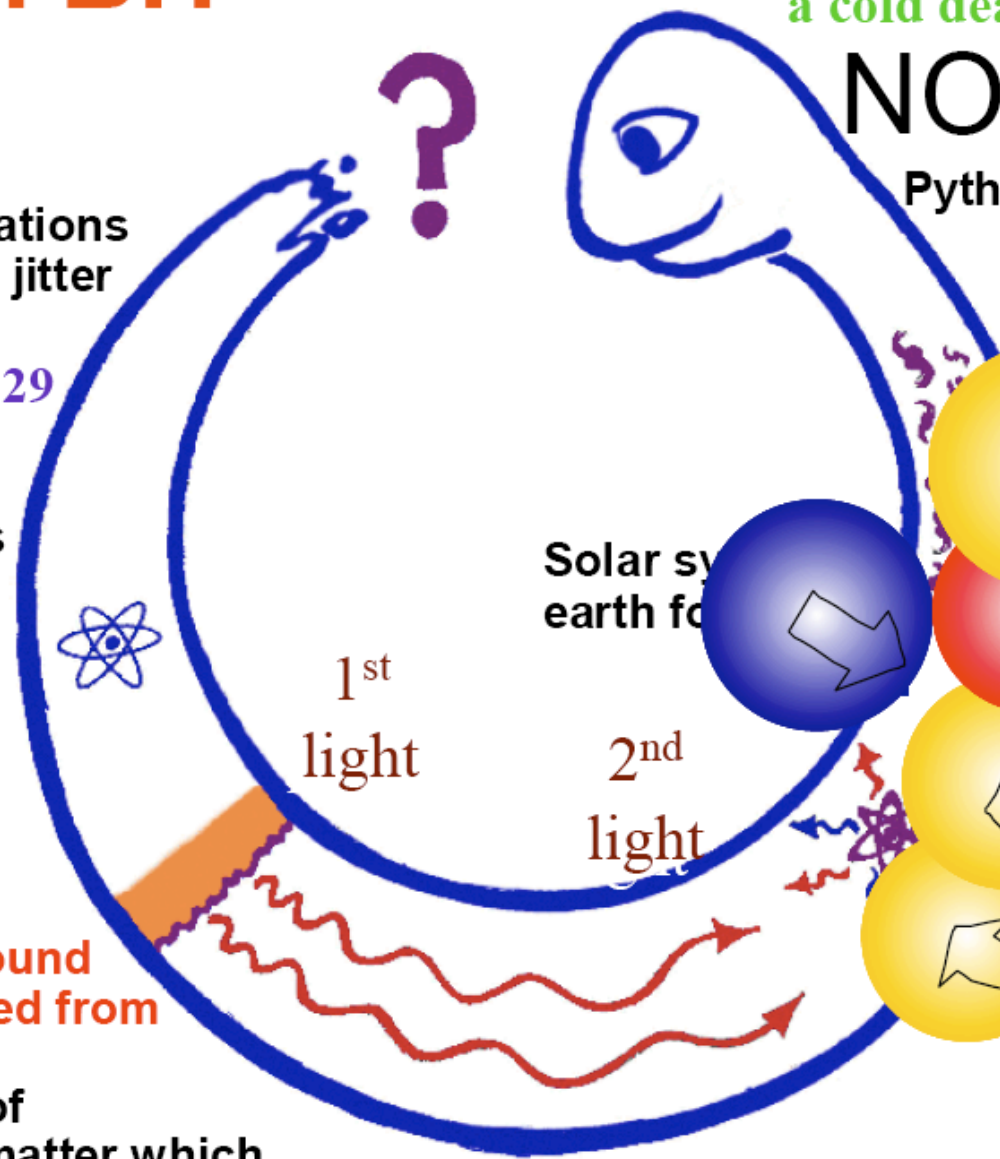
10^{-37} sec 10^{29}

Protons/Neutrons form

Helium forms
 100 sec 10^9

Cosmic background radiation released from matter carries imprint of fluctuations in matter which grow to generate galaxies etc.

0.4 Myr 1100



1st light

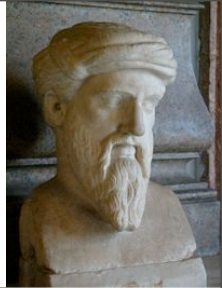
2nd light

Solar system earth forms

PYTHAGORAS ~ 550 BCE

The THEORIST

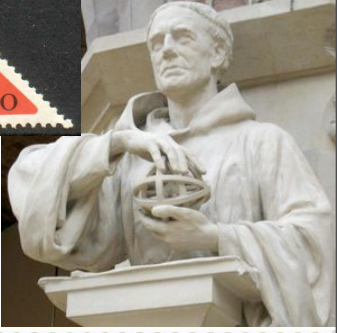
- ✓ Cosmos - The Universe as a Mathematical Entity
- ✓ Music of the Heavens – Frequency/Wavelength



ROGER BACON ~ 1260 AD

MARRIAGE: of Experiment to Theory

COPERNICUS/KEPLER/GALILEO et al. ~1600 AD



NEWTON ~ 1660 - 1690 AD

The PHYSICIST

- ✓ LAW OF GRAVITATION - Mass Attraction
- ✓ Heavenly Objects Arise via Clumping .. **Gravitational Instability**
- ✓ Thus: the Universe is Infinite



KANT ~ 1755 AD Galaxies - 'Island Universes'

YES! (Early 20s)



Milky Way 1953-55

large halo of dark matter
70s/80s relics
or remnants?

Newton's Death Mask @ROE

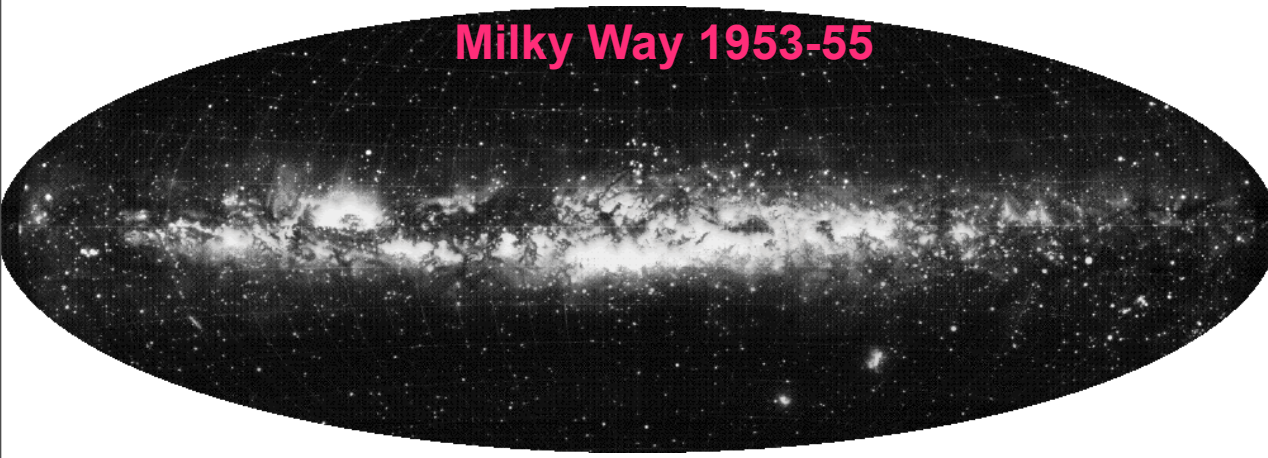
Crawford collection



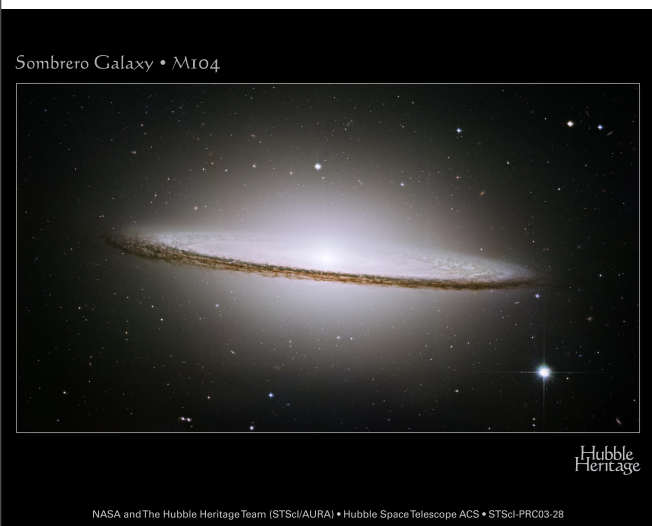
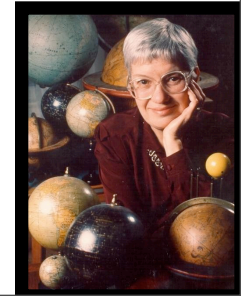
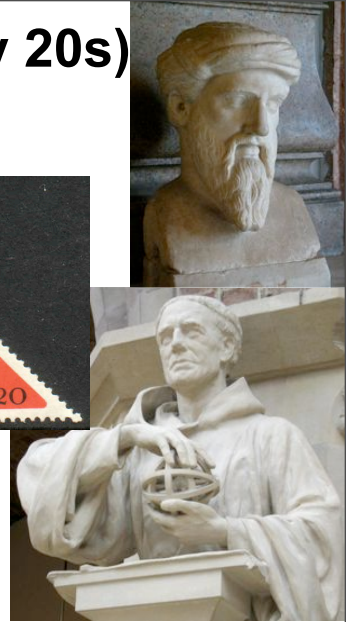
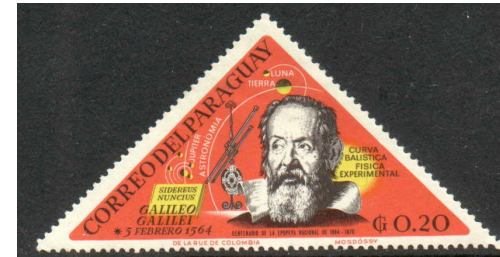
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large halo of **dark matter**
70s/80s around galaxies;
30s around clusters.
relics or remnants?



Milky Way 1953-55





Beyond Einstein

the universe is comprehensible!!!

Gravity=Geometry=Mass-Energy



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cosmological constant 1917

1998/2007+: dark energy

Ω_{Λ} (space, time)?



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Ω_{dm} = dark matter (in labs?)

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Gravitational waves – 1917

ripples in spacetime moving at the speed of

light. we will “see” it from black holes Ω_{BH}

& neutron stars ~2011, from the quantum early

Universe ~2010? Ω_{GW}

EINSTEIN: SCIENTIFIC COSMOLOGY(1917)

✓ Finite universe without a boundary

✓ “Cosmological Constant” (~ 1895) Ω_{Λ}

Make the Universe Finite via A Repulsive Force

“My greatest blunder”

FRIEDMANN (1922) Evolving (Expanding) Universe

- ✓ YES! Hubble (late 20s)
- ✓ the SINGULARITY (30s,60s),
infinite density (!!!???)

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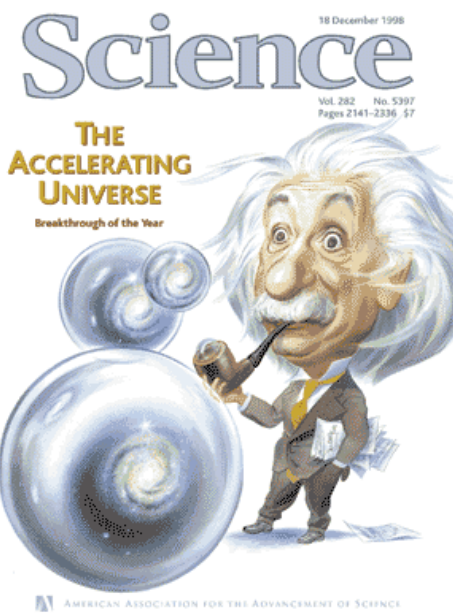
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$$\Omega_{\Lambda}$$

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$$\Omega_{\Lambda} = \text{vacuum energy}$$

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Inflation fluctuations
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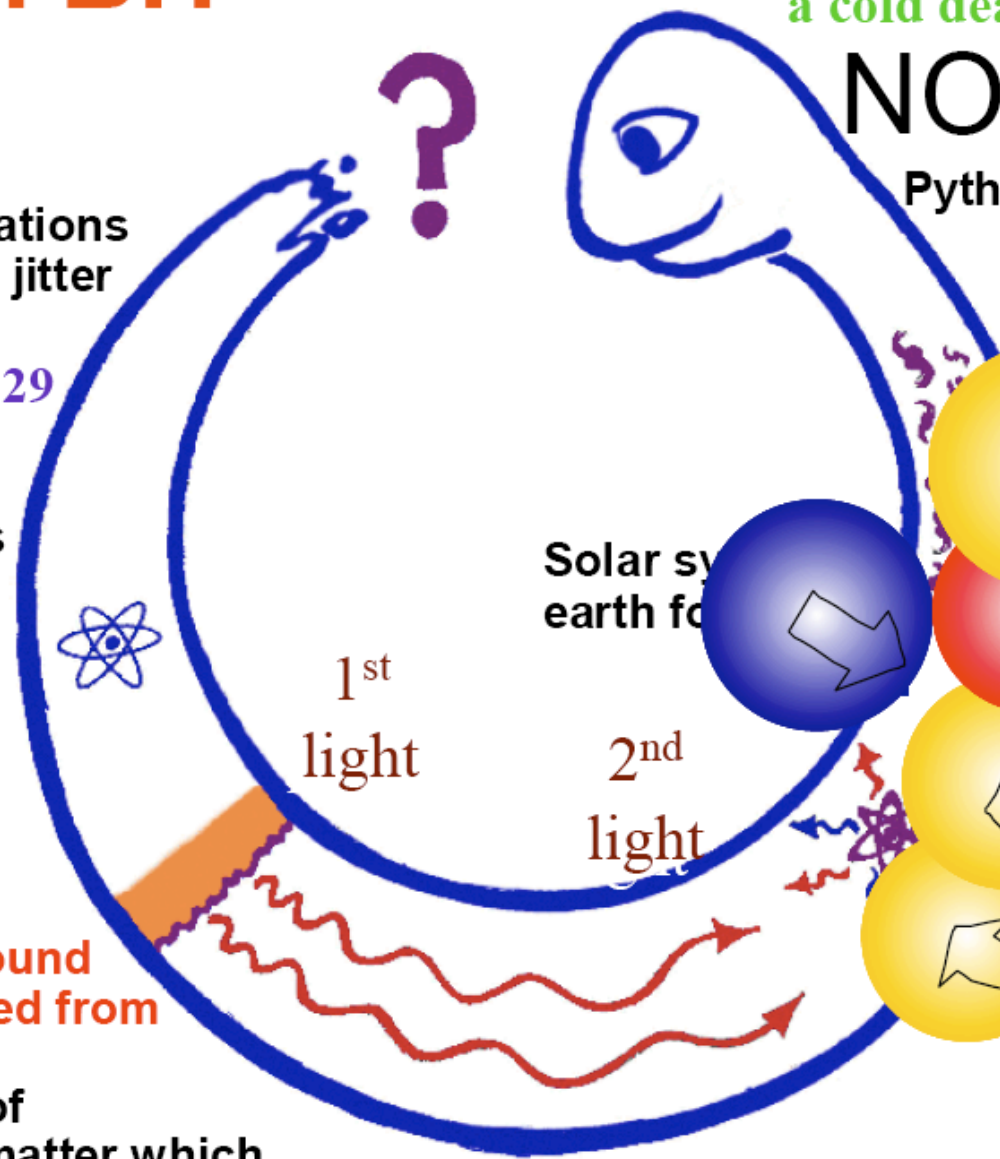
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Cosmic background
radiation released from
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0.4 Myr 1100



1st
light

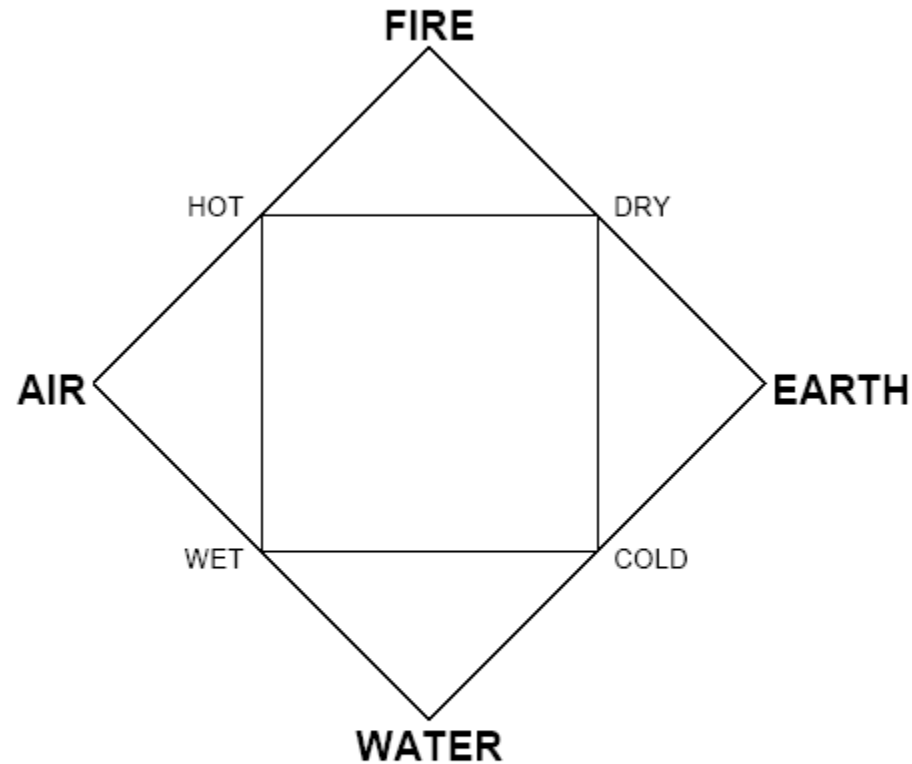
2nd
light

Solar system
earth forms



What is the Universe made of?

Chart of Plato and Aristotle (~400 BC)



Relation of the four elements and the four qualities.

A fifth element was "ETHER" or material of the heavens.



Drawing by William Perke

✓ **GAMOW (40s, early 50s) HOT BIG BANG**
 Hydrogen (75%) & Helium (25%) Deuterium/Lithium
 from the first minutes ; Carbon, Oxygen, Iron,..from
 exploding stars 40s-80s



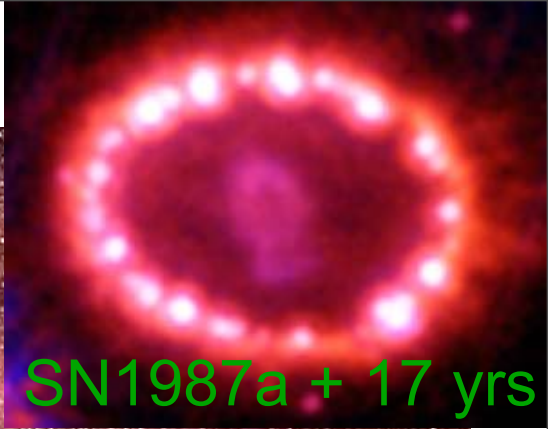
IOTA 1967, Cambridge **B²FH 57, WFH 67, sn**

Crab 1054 AD SN + pulsar
i.e. neutron star remnant

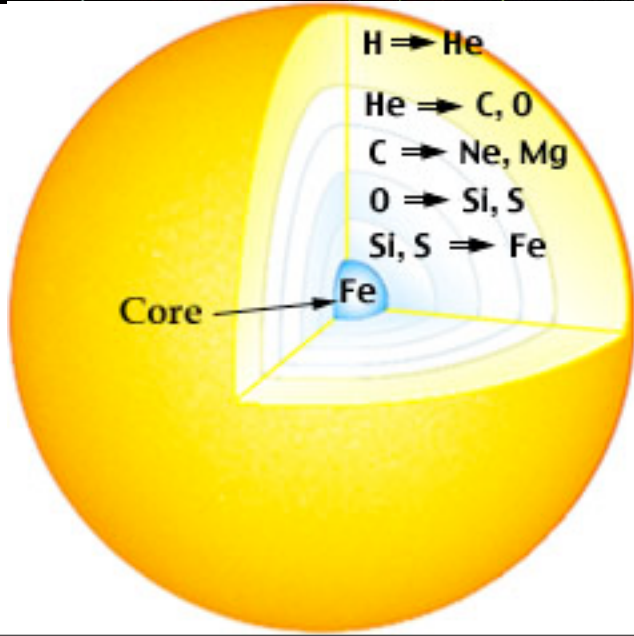


SN1987a @ LMC

collapse neutrinos,
no neutron star yet



SN1987a + 17 yrs



Nobel
Prize 84
Willy
Fowler +
Chandra-
sekhar

Periodic Table for the *Table of Isotopes** (2001)

| 1 (IA) | | | | | | | | | | 2 (IIA) | | | | | | | | | | Group | | | | | | | | | | 13 (IIIA) | | | | | | | | | | 14 (IVA) | | | | | | | | | | 15 (VA) | | | | | | | | | | 16 (VIA) | | | | | | | | | | 17 (VIIA) | | | | | | | | | | 18 (VIIIA) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|--------------------------|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|---------------------------|--|--|--|--|--|--|--|--|--|-------------------------|--|--|--|--|--|--|--|--|--|-------------------------|--|--|--|--|--|--|--|--|--|------------------------|--|--|--|--|--|--|--|--|--|------------------|--|--|--|--|--|--|--|--|--|------------------|--|--|--|--|--|--|--|--|--|------------------|--|--|--|--|--|--|--|--|--|
| Hydrogen | | | | | | | | | | Lithium | | | | | | | | | | Beryllium | | | | | | | | | | Element | | | | | | | | | | Boron | | | | | | | | | | Carbon | | | | | | | | | | Nitrogen | | | | | | | | | | Oxygen | | | | | | | | | | Fluorine | | | | | | | | | | Neon | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| H ₁ | | | | | | | | | | Li ₃ | | | | | | | | | | Be ₄ | | | | | | | | | | E _Z | | | | | | | | | | B ₅ | | | | | | | | | | C ₆ | | | | | | | | | | N ₇ | | | | | | | | | | O ₈ | | | | | | | | | | F ₉ | | | | | | | | | | Ne ₁₀ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| +1 | | | | | | | | | | +1 | | | | | | | | | | +2 | | | | | | | | | | K | | | | | | | | | | L | | | | | | | | | | M | | | | | | | | | | N | | | | | | | | | | O | | | | | | | | | | P | | | | | | | | | | Q | | | | | | | | | | R | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1.00794 | | | | | | | | | | 6.941 | | | | | | | | | | 9.012182 | | | | | | | | | | M.P. | | | | | | | | | | 4000 | | | | | | | | | | 4492 | | | | | | | | | | -210.00 | | | | | | | | | | -182.97 | | | | | | | | | | -188.12 | | | | | | | | | | -248.58 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 91.0% | | | | | | | | | | 1.86×10 ⁻⁴ % | | | | | | | | | | 2.38×10 ⁻⁴ % | | | | | | | | | | Abundance% | | | | | | | | | | 6.9×10 ⁻⁴ % | | | | | | | | | | 0.033% | | | | | | | | | | 0.102% | | | | | | | | | | 0.078% | | | | | | | | | | 2.7×10 ⁻⁶ % | | | | | | | | | | 8.9% | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sodium | | | | | | | | | | Magnesium | | | | | | | | | | 3 (IIIB) | | | | | | | | | | 4 (IVB) | | | | | | | | | | 5 (VB) | | | | | | | | | | 6 (VIB) | | | | | | | | | | 7 (VIIB) | | | | | | | | | | 8 (VIII) | | | | | | | | | | 9 (VIII) | | | | | | | | | | 10 (VIII) | | | | | | | | | | 11 (IB) | | | | | | | | | | 12 (IIB) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Na ₁₁ | | | | | | | | | | Mg ₁₂ | | | | | | | | | | K ₁₉ | | | | | | | | | | Ca ₂₀ | | | | | | | | | | Sc ₂₁ | | | | | | | | | | Ti ₂₂ | | | | | | | | | | V ₂₃ | | | | | | | | | | Cr ₂₄ | | | | | | | | | | Mn ₂₅ | | | | | | | | | | Fe ₂₆ | | | | | | | | | | Co ₂₇ | | | | | | | | | | Ni ₂₈ | | | | | | | | | | Cu ₂₉ | | | | | | | | | | Zn ₃₀ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| +1 | | | | | | | | | | +2 | | | | | | | | | | +3 | | | | | | | | | | +2+3+4 | | | | | | | | | | +2+3+4+5 | | | | | | | | | | +2+3+6 | | | | | | | | | | +2+3+4+7 | | | | | | | | | | +2+3 | | | | | | | | | | +2+3 | | | | | | | | | | +1+2 | | | | | | | | | | +2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22.989770 | | | | | | | | | | 24.3050 | | | | | | | | | | 39.0983 | | | | | | | | | | 40.078 | | | | | | | | | | 44.955910 | | | | | | | | | | 47.867 | | | | | | | | | | 50.9415 | | | | | | | | | | 51.9961 | | | | | | | | | | 54.938049 | | | | | | | | | | 55.845 | | | | | | | | | | 58.933200 | | | | | | | | | | 58.6934 | | | | | | | | | | 63.546 | | | | | | | | | | 65.39 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0.000187% | | | | | | | | | | 0.000350% | | | | | | | | | | 0.0000123% | | | | | | | | | | 0.000199% | | | | | | | | | | 1.12×10 ⁻⁴ % | | | | | | | | | | 7.8×10 ⁻⁴ % | | | | | | | | | | 9.6×10 ⁻⁴ % | | | | | | | | | | 0.000044% | | | | | | | | | | 0.000031% | | | | | | | | | | 0.000294% | | | | | | | | | | 7.3×10 ⁻⁴ % | | | | | | | | | | 0.000161% | | | | | | | | | | 1.70×10 ⁻⁴ % | | | | | | | | | | 4.11×10 ⁻⁶ % | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rubidium | | | | | | | | | | Strontium | | | | | | | | | | Yttrium | | | | | | | | | | Zirconium | | | | | | | | | | Niobium | | | | | | | | | | Molybdenum | | | | | | | | | | Technetium | | | | | | | | | | Ruthenium | | | | | | | | | | Rhodium | | | | | | | | | | Palladium | | | | | | | | | | Silver | | | | | | | | | | Cadmium | | | | | | | | | | Indium | | | | | | | | | | Tin | | | | | | | | | | Antimony | | | | | | | | | | Tellurium | | | | | | | | | | Iodine | | | | | | | | | | Xenon | | | | | | | | | |
| Rb ₃₇ | | | | | | | | | | Sr ₃₈ | | | | | | | | | | Y ₃₉ | | | | | | | | | | Zr ₄₀ | | | | | | | | | | Nb ₄₁ | | | | | | | | | | Mo ₄₂ | | | | | | | | | | Tc ₄₃ | | | | | | | | | | Ru ₄₄ | | | | | | | | | | Rh ₄₅ | | | | | | | | | | Pd ₄₆ | | | | | | | | | | Ag ₄₇ | | | | | | | | | | Cd ₄₈ | | | | | | | | | | In ₄₉ | | | | | | | | | | Sn ₅₀ | | | | | | | | | | Sb ₅₁ | | | | | | | | | | Te ₅₂ | | | | | | | | | | I ₅₃ | | | | | | | | | | Xe ₅₄ | | | | | | | | | |
| +1 | | | | | | | | | | +2 | | | | | | | | | | +3 | | | | | | | | | | +4 | | | | | | | | | | +3+5 | | | | | | | | | | +6 | | | | | | | | | | +4+6+7 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +2+4 | | | | | | | | | | +1 | | | | | | | | | | +2 | | | | | | | | | | +3 | | | | | | | | | | +2+4 | | | | | | | | | | +3+5 | | | | | | | | | | +4+6 | | | | | | | | | | +1+5+7 | | | | | | | | | | +6 | | | | | | | | | |
| 85.4678 | | | | | | | | | | 87.62 | | | | | | | | | | 88.90585 | | | | | | | | | | 91.224 | | | | | | | | | | 92.90638 | | | | | | | | | | 95.94 | | | | | | | | | | 101.07 | | | | | | | | | | 102.90550 | | | | | | | | | | 106.42 | | | | | | | | | | 107.8682 | | | | | | | | | | 112.411 | | | | | | | | | | 114.818 | | | | | | | | | | 118.710 | | | | | | | | | | 121.760 | | | | | | | | | | 127.60 | | | | | | | | | | 126.90447 | | | | | | | | | | 131.29 | | | | | | | | | | | | | | | | | | | |
| 2.31×10 ⁻⁶ % | | | | | | | | | | 7.7×10 ⁻⁶ % | | | | | | | | | | 1.51×10 ⁻⁶ % | | | | | | | | | | 3.72×10 ⁻⁶ % | | | | | | | | | | 2.28×10 ⁻⁶ % | | | | | | | | | | 8.3×10 ⁻⁶ % | | | | | | | | | | 1.12×10 ⁻⁶ % | | | | | | | | | | 4.5×10 ⁻⁶ % | | | | | | | | | | 1.58×10 ⁻⁶ % | | | | | | | | | | 5.3×10 ⁻⁶ % | | | | | | | | | | 6.0×10 ⁻⁶ % | | | | | | | | | | 1.25×10 ⁻⁶ % | | | | | | | | | | 1.01×10 ⁻⁶ % | | | | | | | | | | 1.57×10 ⁻⁶ % | | | | | | | | | | 2.9×10 ⁻⁶ % | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cesium | | | | | | | | | | Barium | | | | | | | | | | Lanthanum | | | | | | | | | | Hafnium | | | | | | | | | | Tantalum | | | | | | | | | | Tungsten | | | | | | | | | | Rhenium | | | | | | | | | | Osmium | | | | | | | | | | Iridium | | | | | | | | | | Platinum | | | | | | | | | | Gold | | | | | | | | | | Mercury | | | | | | | | | | Thallium | | | | | | | | | | Lead | | | | | | | | | | Bismuth | | | | | | | | | | Polonium | | | | | | | | | | Astatine | | | | | | | | | | Radon | | | | | | | | | |
| Cs ₅₅ | | | | | | | | | | Ba ₅₆ | | | | | | | | | | La ₅₇ | | | | | | | | | | Hf ₇₂ | | | | | | | | | | Ta ₇₃ | | | | | | | | | | W ₇₄ | | | | | | | | | | Re ₇₅ | | | | | | | | | | Os ₇₆ | | | | | | | | | | Ir ₇₇ | | | | | | | | | | Pt ₇₈ | | | | | | | | | | Au ₇₉ | | | | | | | | | | Hg ₈₀ | | | | | | | | | | Tl ₈₁ | | | | | | | | | | Pb ₈₂ | | | | | | | | | | Bi ₈₃ | | | | | | | | | | Po ₈₄ | | | | | | | | | | At ₈₅ | | | | | | | | | | Rn ₈₆ | | | | | | | | | |
| +1 | | | | | | | | | | +2 | | | | | | | | | | +3 | | | | | | | | | | +4 | | | | | | | | | | +6 | | | | | | | | | | +4+6+7 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +2+4 | | | | | | | | | | +1 | | | | | | | | | | +2 | | | | | | | | | | +3 | | | | | | | | | | +2+4 | | | | | | | | | | +3+5 | | | | | | | | | | +4+6 | | | | | | | | | | +1+5+7 | | | | | | | | | | +6 | | | | | | | | | | | | | | | | | | | |
| 132.90545 | | | | | | | | | | 137.327 | | | | | | | | | | 138.9055 | | | | | | | | | | 178.49 | | | | | | | | | | 180.9479 | | | | | | | | | | 183.84 | | | | | | | | | | 186.207 | | | | | | | | | | 190.23 | | | | | | | | | | 192.217 | | | | | | | | | | 195.078 | | | | | | | | | | 196.96655 | | | | | | | | | | 200.59 | | | | | | | | | | 204.3833 | | | | | | | | | | 207.2 | | | | | | | | | | 208.98038 | | | | | | | | | | [209] | | | | | | | | | | [210] | | | | | | | | | | [222] | | | | | | | | | |
| 1.21×10 ⁻⁴ % | | | | | | | | | | 1.46×10 ⁻⁴ % | | | | | | | | | | 1.45×10 ⁻⁶ % | | | | | | | | | | 5.02×10 ⁻¹⁰ % | | | | | | | | | | 6.75×10 ⁻¹¹ % | | | | | | | | | | 4.34×10 ⁻¹⁰ % | | | | | | | | | | 1.69×10 ⁻¹⁰ % | | | | | | | | | | 2.20×10 ⁻⁶ % | | | | | | | | | | 2.16×10 ⁻⁶ % | | | | | | | | | | 4.4×10 ⁻⁶ % | | | | | | | | | | 6.1×10 ⁻⁶ % | | | | | | | | | | 6.0×10 ⁻⁶ % | | | | | | | | | | 1.03×10 ⁻⁶ % | | | | | | | | | | 4.7×10 ⁻¹⁰ % | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Francium | | | | | | | | | | Radium | | | | | | | | | | Actinium | | | | | | | | | | Rutherfordium | | | | | | | | | | Dubnium | | | | | | | | | | Seaborgium | | | | | | | | | | Bohrium | | | | | | | | | | Hassium | | | | | | | | | | Meitnerium | | | | | | | | | | Element-110 | | | | | | | | | | Element-111 | | | | | | | | | | Element-112 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fr ₈₇ | | | | | | | | | | Ra ₈₈ | | | | | | | | | | Ac ₈₉ | | | | | | | | | | Rf ₁₀₄ | | | | | | | | | | Db ₁₀₅ | | | | | | | | | | Sg ₁₀₆ | | | | | | | | | | Bh ₁₀₇ | | | | | | | | | | Hs ₁₀₈ | | | | | | | | | | Mt ₁₀₉ | | | | | | | | | | 110 ₁₁₀ | | | | | | | | | | 111 ₁₁₁ | | | | | | | | | | 112 ₁₁₂ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| +1 | | | | | | | | | | +2 | | | | | | | | | | +3 | | | | | | | | | | +4 | | | | | | | | | | +4 | | | | | | | | | | +4 | | | | | | | | | | +4 | | | | | | | | | | +4 | | | | | | | | | | +4 | | | | | | | | | | +4 | | | | | | | | | | +4 | | | | | | | | | | +4 | | | | | | | | | | +4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| [223] | | | | | | | | | | [226] | | | | | | | | | | [227] | | | | | | | | | | [261] | | | | | | | | | | [262] | | | | | | | | | | [266] | | | | | | | | | | [264] | | | | | | | | | | [269] | | | | | | | | | | [268] | | | | | | | | | | [271] | | | | | | | | | | [272] | | | | | | | | | | [277] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| † Lanthanides | | | | | | | | | | Cerium | | | | | | | | | | Praseodymium | | | | | | | | | | Neodymium | | | | | | | | | | Promethium | | | | | | | | | | Samarium | | | | | | | | | | Europium | | | | | | | | | | Gadolinium | | | | | | | | | | Terbium | | | | | | | | | | Dysprosium | | | | | | | | | | Holmium | | | | | | | | | | Erbium | | | | | | | | | | Thulium | | | | | | | | | | Ytterbium | | | | | | | | | | Lutetium | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ce ₅₈ | | | | | | | | | | Pr ₅₉ | | | | | | | | | | Nd ₆₀ | | | | | | | | | | Pm ₆₁ | | | | | | | | | | Sm ₆₂ | | | | | | | | | | Eu ₆₃ | | | | | | | | | | Gd ₆₄ | | | | | | | | | | Tb ₆₅ | | | | | | | | | | Dy ₆₆ | | | | | | | | | | Ho ₆₇ | | | | | | | | | | Er ₆₈ | | | | | | | | | | Tm ₆₉ | | | | | | | | | | Yb ₇₀ | | | | | | | | | | Lu ₇₁ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| +3 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +2+3 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 140.116 | | | | | | | | | | 140.90765 | | | | | | | | | | 144.24 | | | | | | | | | | [145] | | | | | | | | | | 150.36 | | | | | | | | | | 151.964 | | | | | | | | | | 157.25 | | | | | | | | | | 158.92534 | | | | | | | | | | 162.50 | | | | | | | | | | 164.93032 | | | | | | | | | | 167.26 | | | | | | | | | | 168.93421 | | | | | | | | | | 173.04 | | | | | | | | | | 174.967 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3.70×10 ⁻¹⁰ % | | | | | | | | | | 5.44×10 ⁻¹⁰ % | | | | | | | | | | 2.70×10 ⁻¹⁰ % | | | | | | | | | | | | | | | | | | | | 8.42×10 ⁻¹⁰ % | | | | | | | | | | 3.17×10 ⁻¹⁰ % | | | | | | | | | | 1.076×10 ⁻⁶ % | | | | | | | | | | 1.97×10 ⁻¹⁰ % | | | | | | | | | | 1.286×10 ⁻⁶ % | | | | | | | | | | 2.90×10 ⁻¹⁰ % | | | | | | | | | | 8.18×10 ⁻¹⁰ % | | | | | | | | | | 1.197×10 ⁻¹⁰ % | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ‡ Actinides | | | | | | | | | | Thorium | | | | | | | | | | Protactinium | | | | | | | | | | Uranium | | | | | | | | | | Neptunium | | | | | | | | | | Plutonium | | | | | | | | | | Americium | | | | | | | | | | Curium | | | | | | | | | | Berkelium | | | | | | | | | | Californium | | | | | | | | | | Einsteinium | | | | | | | | | | Fermium | | | | | | | | | | Mendelevium | | | | | | | | | | Nobelium | | | | | | | | | | Lawrencium | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Th ₉₀ | | | | | | | | | | Pa ₉₁ | | | | | | | | | | U ₉₂ | | | | | | | | | | Np ₉₃ | | | | | | | | | | Pu ₉₄ | | | | | | | | | | Am ₉₅ | | | | | | | | | | Cm ₉₆ | | | | | | | | | | Bk ₉₇ | | | | | | | | | | Cf ₉₈ | | | | | | | | | | Es ₉₉ | | | | | | | | | | Fm ₁₀₀ | | | | | | | | | | Md ₁₀₁ | | | | | | | | | | No ₁₀₂ | | | | | | | | | | Lr ₁₀₃ | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| +4 | | | | | | | | | | +5+4 | | | | | | | | | | +3+4+5+6 | | | | | | | | | | +3+4+5+6 | | | | | | | | | | +3+4+5+6 | | | | | | | | | | +3+4 | | | | | | | | | | +3+4 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | +3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 232.0381 | | | | | | | | | | 231.03588 | | | | | | | | | | 238.0289 | | | | | | | | | | [237] | | | | | | | | | | [244] | | | | | | | | | | [243] | | | | | | | | | | [247] | | | | | | | | | | [247] | | | | | | | | | | [251] | | | | | | | | | | [252] | | | | | | | | | | [257] | | | | | | | | | | [258] | | | | | | | | | | [259] | | | | | | | | | | [262] | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2.09×10 ⁻¹⁶ % | | | | | | | | | | | | | | | | | | | | 2.94×10 ⁻¹⁶ % | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

cosmic baryon number $n_b = 0.261 \pm 0.005 / m^3$

from the latest data: wmap5+acbar+cbi+b03+.+WL+LSS+SNI+Lya

"IT from BIT"

FATE U inflate (again)

a cold death? reheat/rebirth?

NOW 14 Gyr 1

Pythagoras formed

Galaxies Cluster
Cosmic "web" of vast filaments + membranes

Life forms on earth

9 Gyr 1.4

Carbon/oxygen/etc form

Galaxies form

2 Gyr 4

The 'Meaning' may change
But the facts will remain

Inflation fluctuations form: quantum jitter

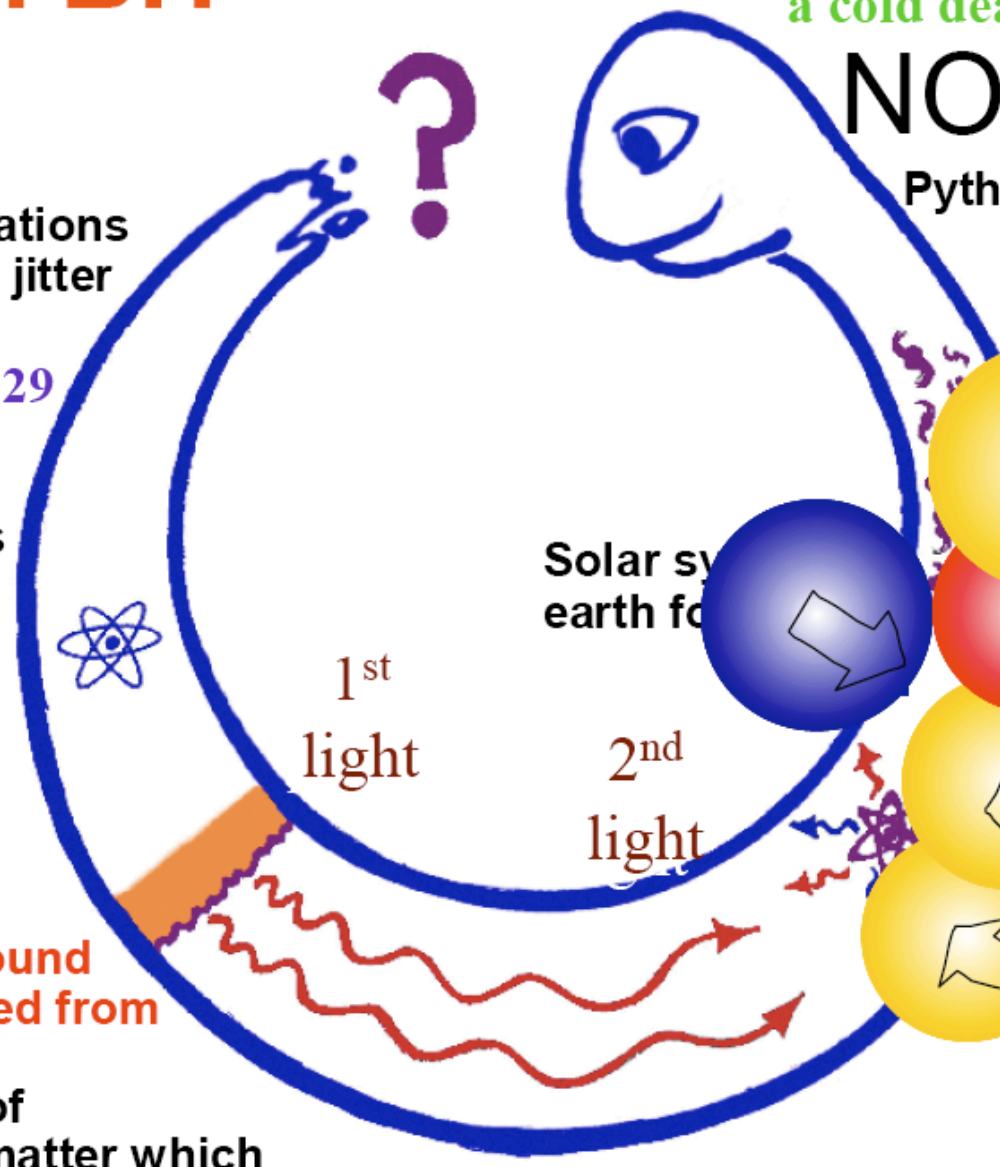
10^{-37} sec 10^{29}

Protons/Neutrons form

Helium forms
 100 sec 10^9

Cosmic background radiation released from matter carries imprint of fluctuations in matter which grow to generate galaxies etc.

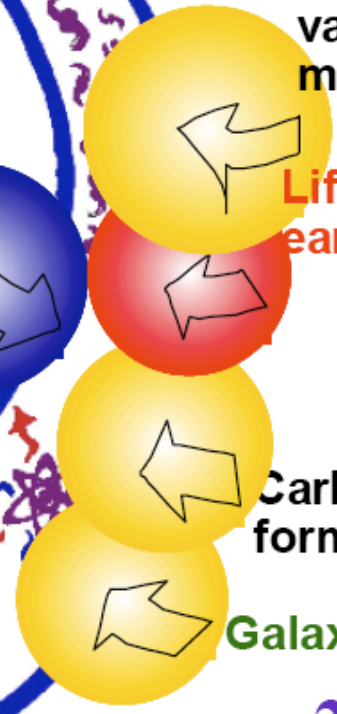
0.4 Myr 1100



1st light

2nd light

Solar system earth formed



extra-“ordinary” matter

Fermilab's

Primordial SOUP

DIRECTIONS
Heat ingredients to 3,000,000,000,000,000 degrees, stirring occasionally if you wish.

If allowed to cool for 14 billion years, this product will become the atoms that make up our known universe.

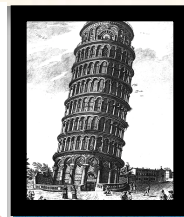
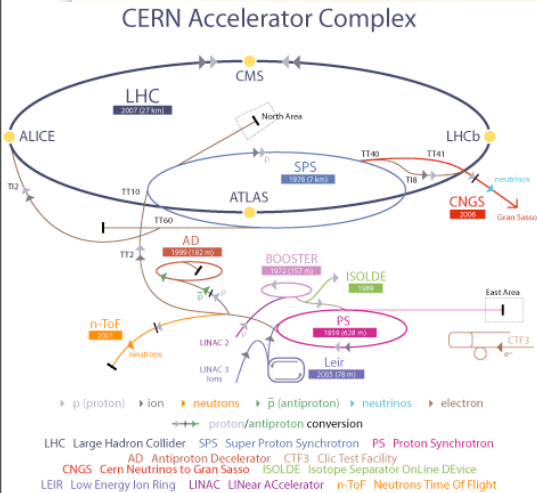
CAUTION:
Contents are extremely dense and are under enormous pressure.

INGREDIENTS

| | |
|-------------------------|-----|
| Quarks | 56% |
| Force Carriers | 29% |
| Electron-like Particles | 9% |
| Neutrinos | 5% |
| Higgs Bosons | 1% |

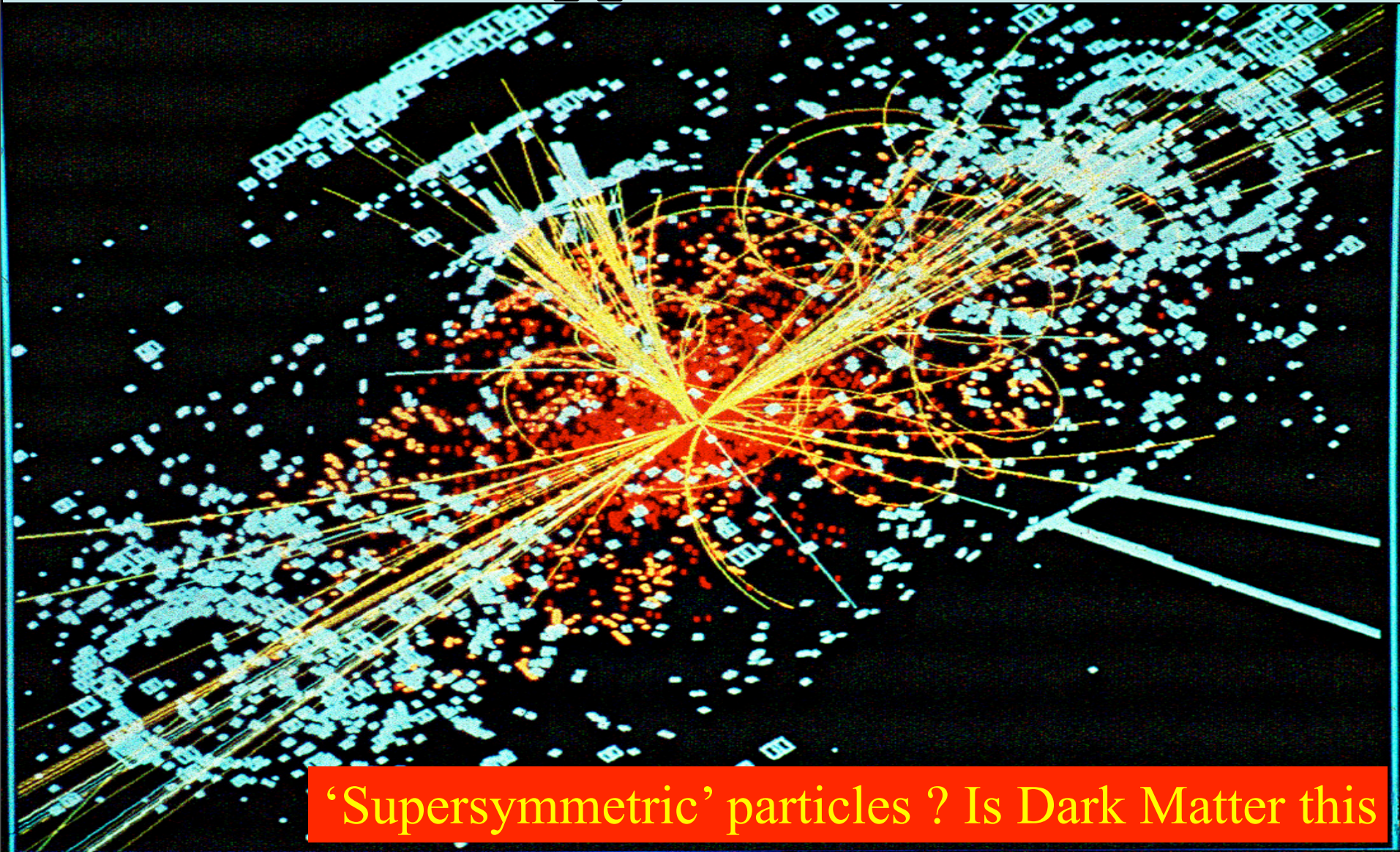
INSPECTED BY U.S. Department of Energy

Provides 100% of the minimum daily requirements for a healthy developing and expanding known universe.



what is mass?
 dark matter
 antimatter
 asymmetry
 extra dimensions

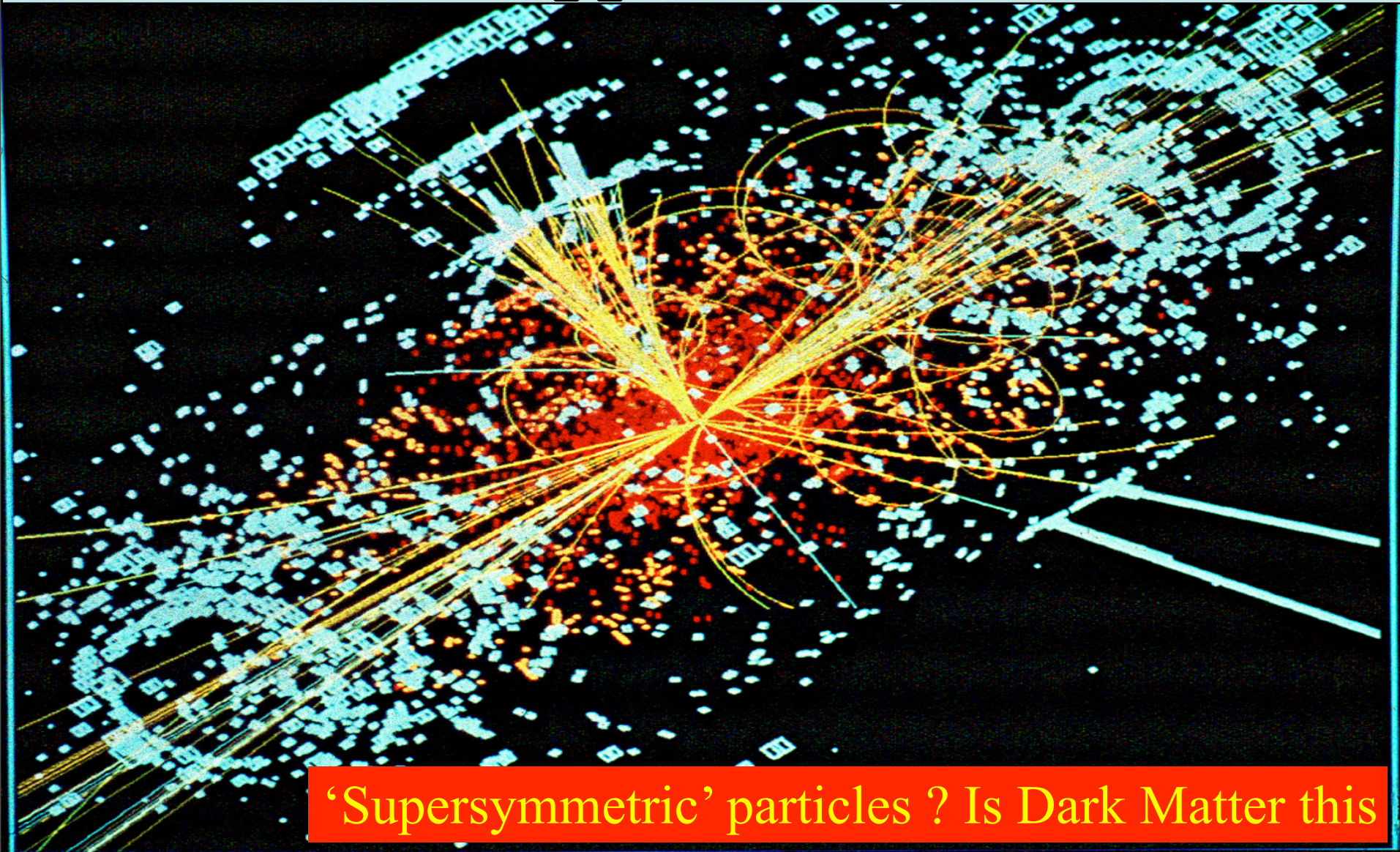
A Simulated Higgs Event in CMS: LHC



‘Supersymmetric’ particles ? Is Dark Matter this

If Dark Matter interacts with ordinary matter by more than gravity, we may “see” it at the Large Hadronic Collider 2008+ or at SNOlab 2008+ in Sudbury

A Simulated Higgs Event in CMS: LHC



‘Supersymmetric’ particles ? Is Dark Matter this

"IT from BIT"

FATE U inflate (again)

a cold death? reheat/rebirth?

NOW 14 Gyr 1

Pythagoras formed

Galaxies Cluster
Cosmic "web" of
vast filaments +
membranes

Life forms on
earth

9 Gyr 1.4

Carbon/oxygen/etc
form

Galaxies form

2 Gyr 4

The 'Meaning' may change
But the facts will remain

Inflation fluctuations
form: quantum jitter

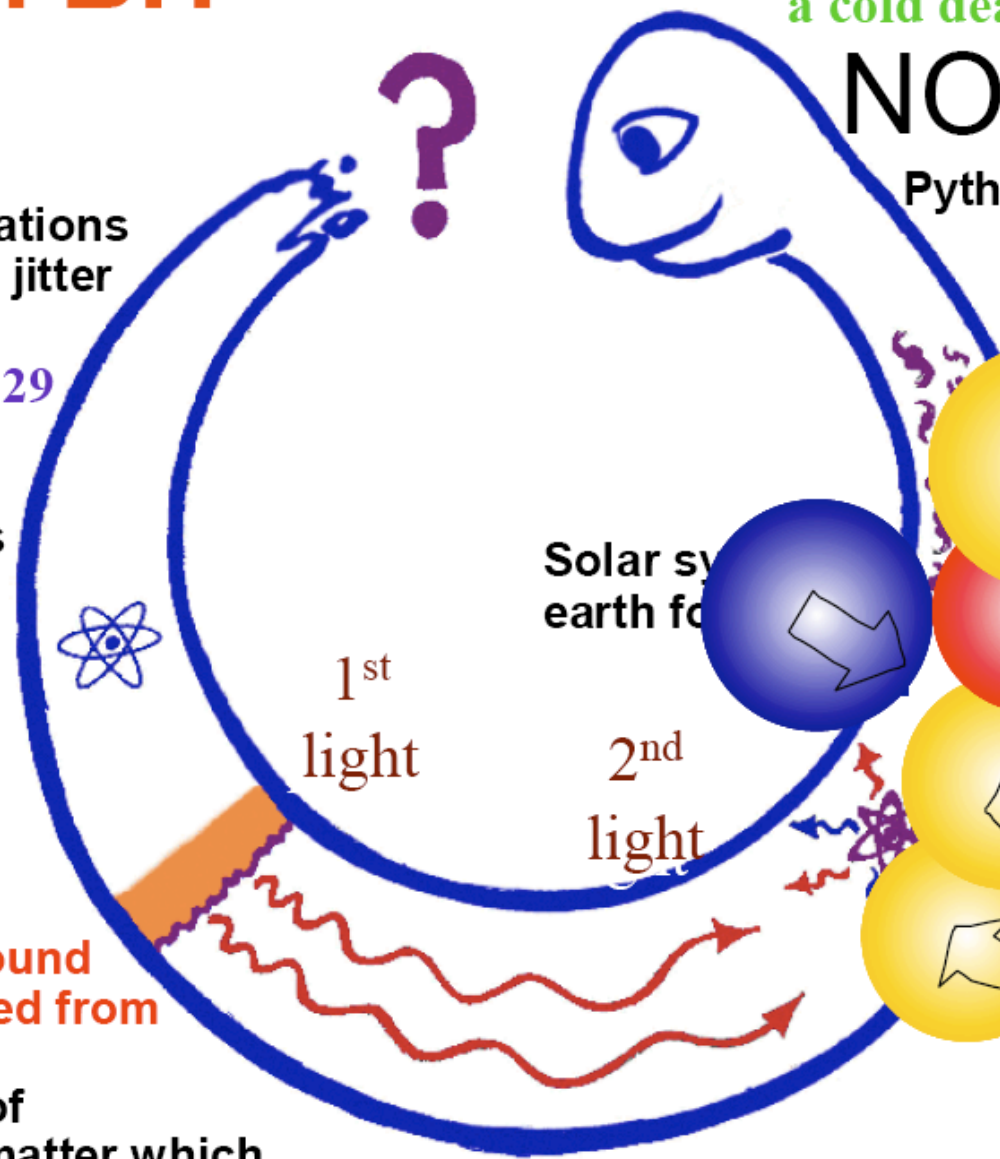
10^{-37} sec 10^{29}

Protons/Neutrons
form

Helium forms
 100 sec 10^9

Cosmic background
radiation released from
matter
carries imprint of
fluctuations in matter which
grow to generate galaxies etc.

0.4 Myr 1100



1st
light

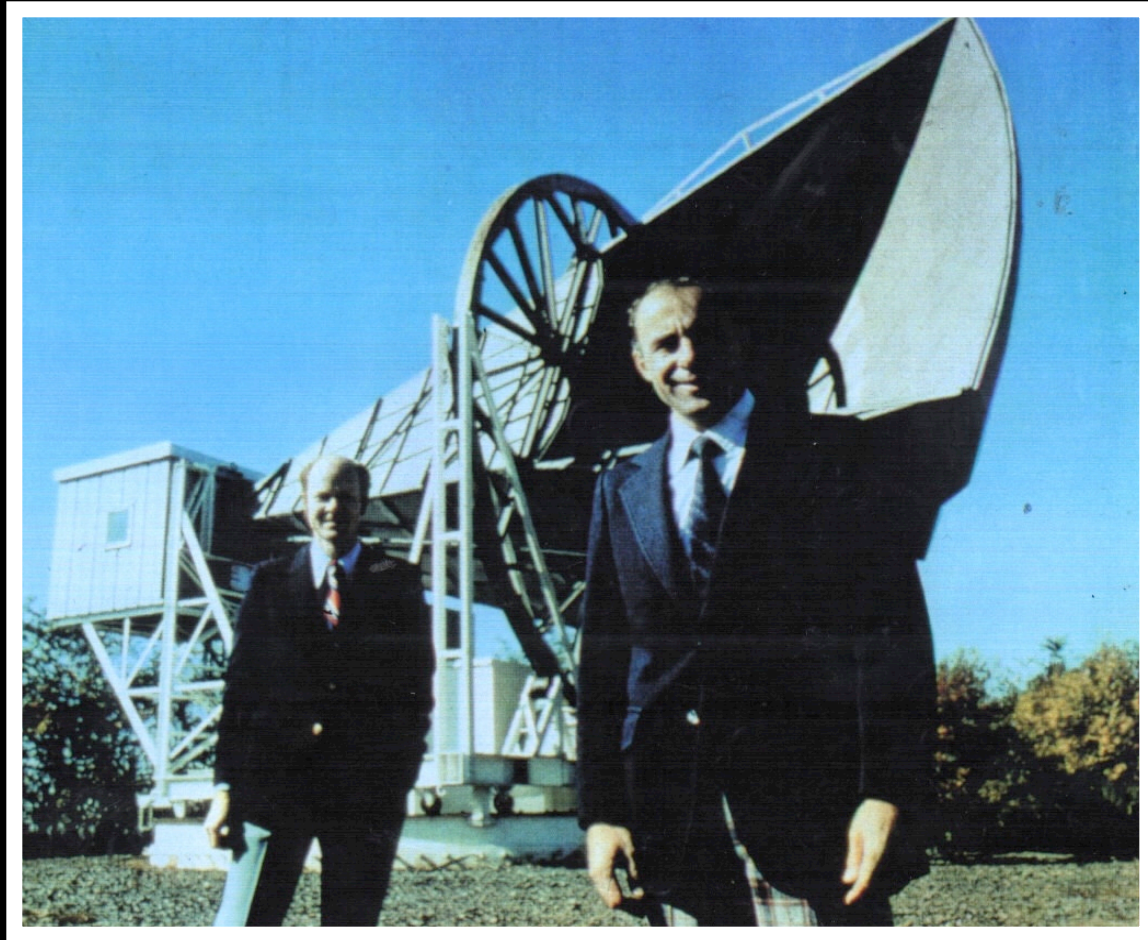
2nd
light

Solar sy
earth fo



***The
Universe
Is Radiant***

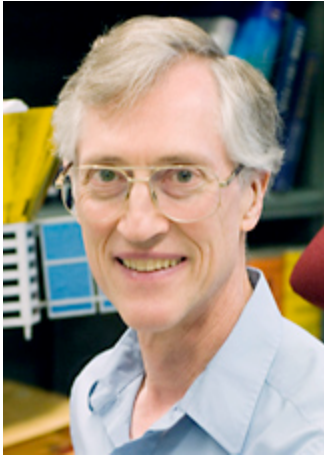
**Arno Penzias
Robert Wilson
1965**



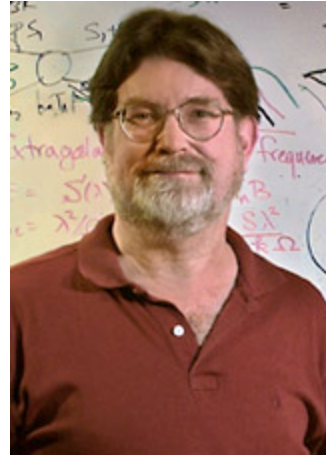
The Nobel Prize in Physics 2006

(also Gruber Prize in Cosmology 2006 for Mather + the COBE team)

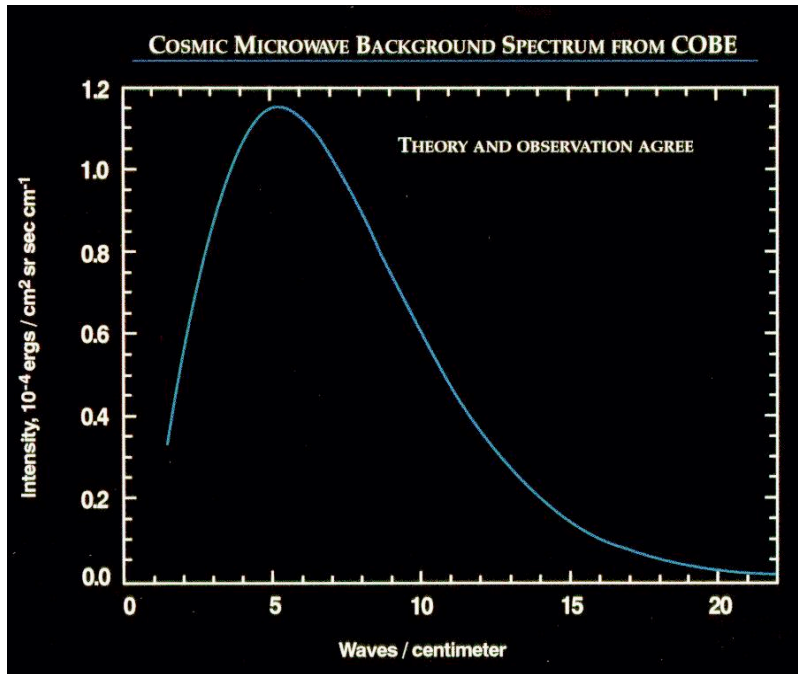
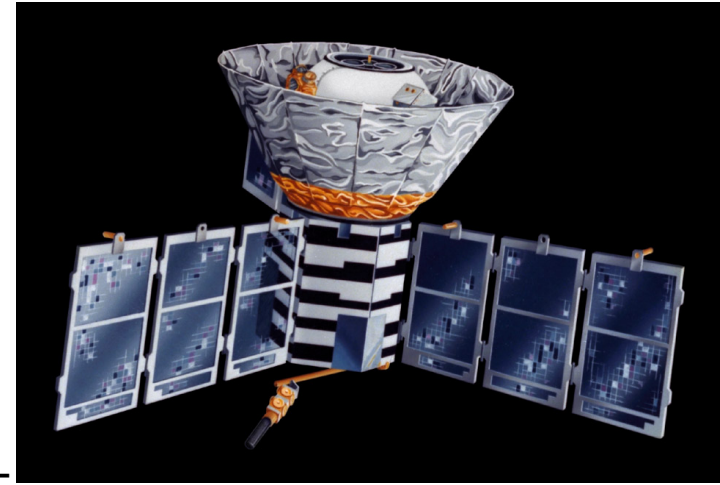
"for their discovery of the blackbody form and anisotropy of the cosmic microwave background radiation"



John C. Mather 1946-



George F. Smoot 1945-

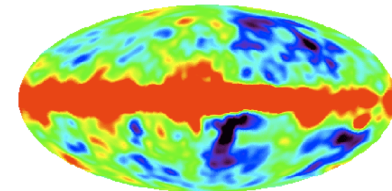
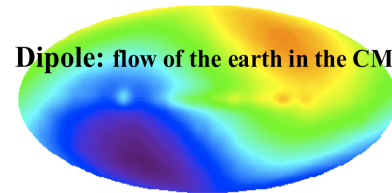


CMB

Nearly Perfect Blackbody

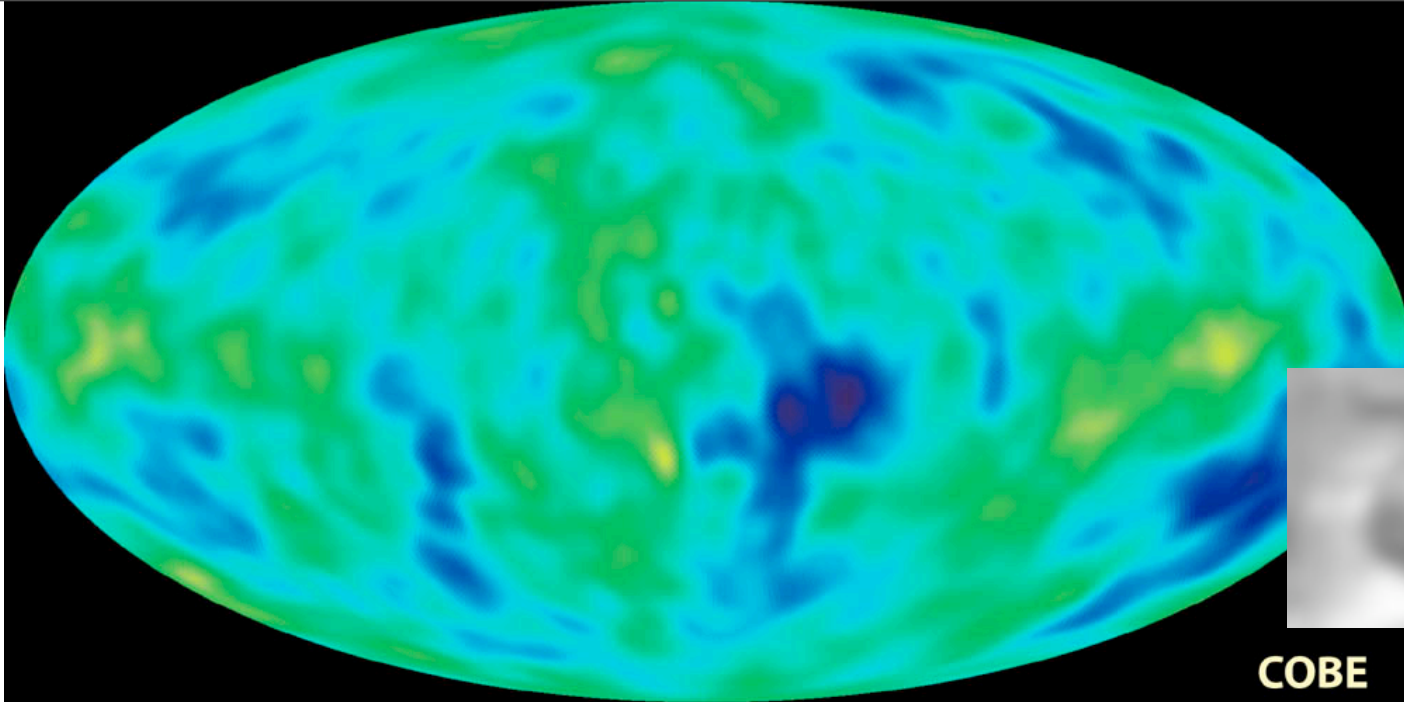
$T = 2.725 \pm 0.001$ K COBE/FIRAS

Dipole: flow of the earth in the CMB

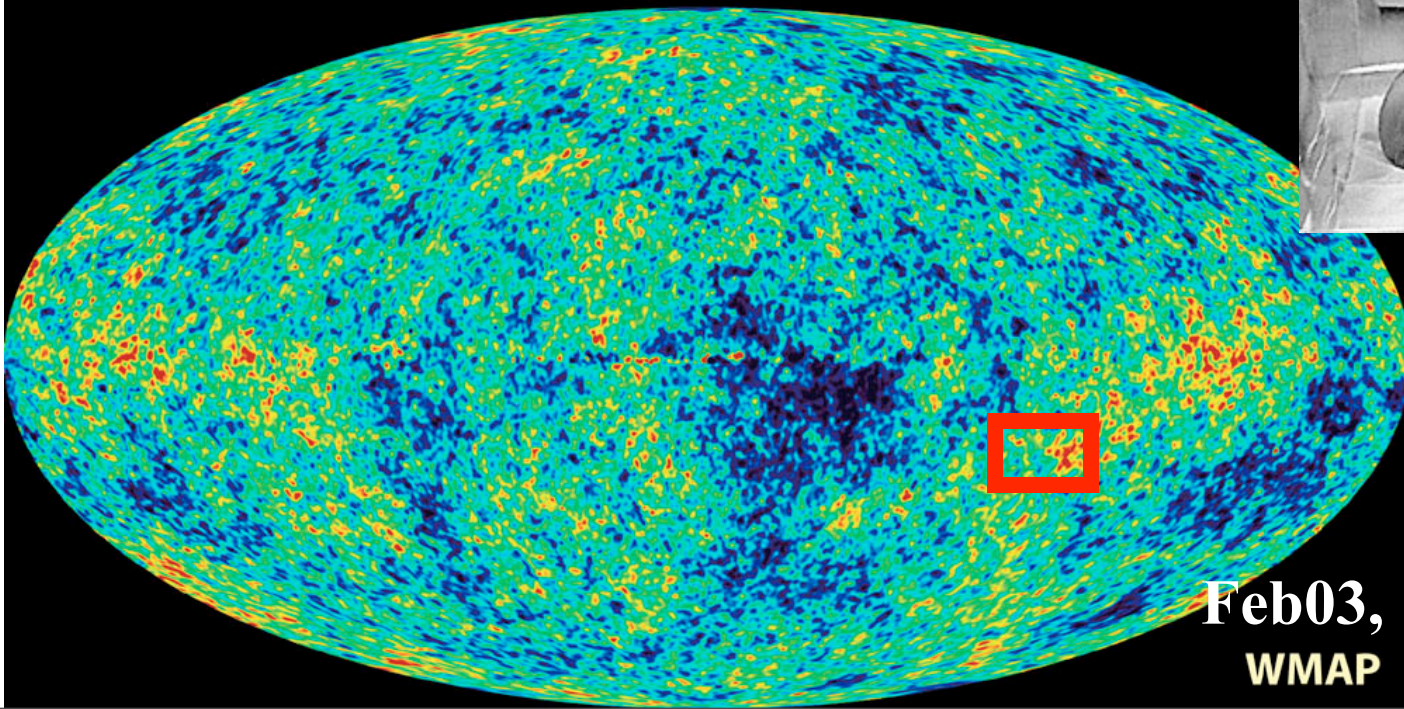


COBE/DMR:

CMB + Galactic @ 7°



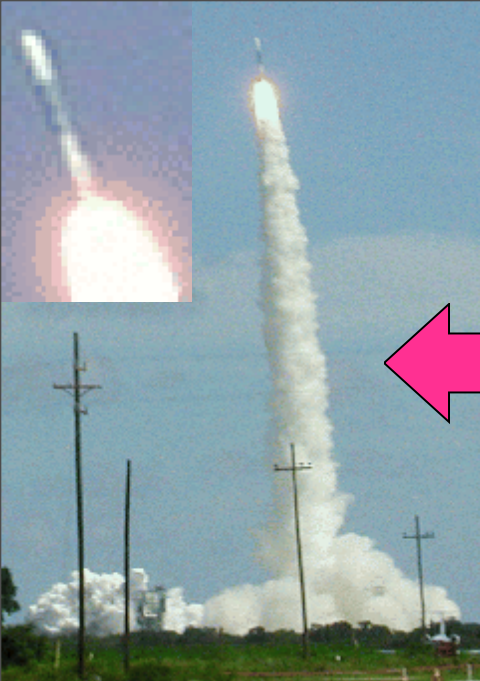
COBE



Feb03, Mar06,08

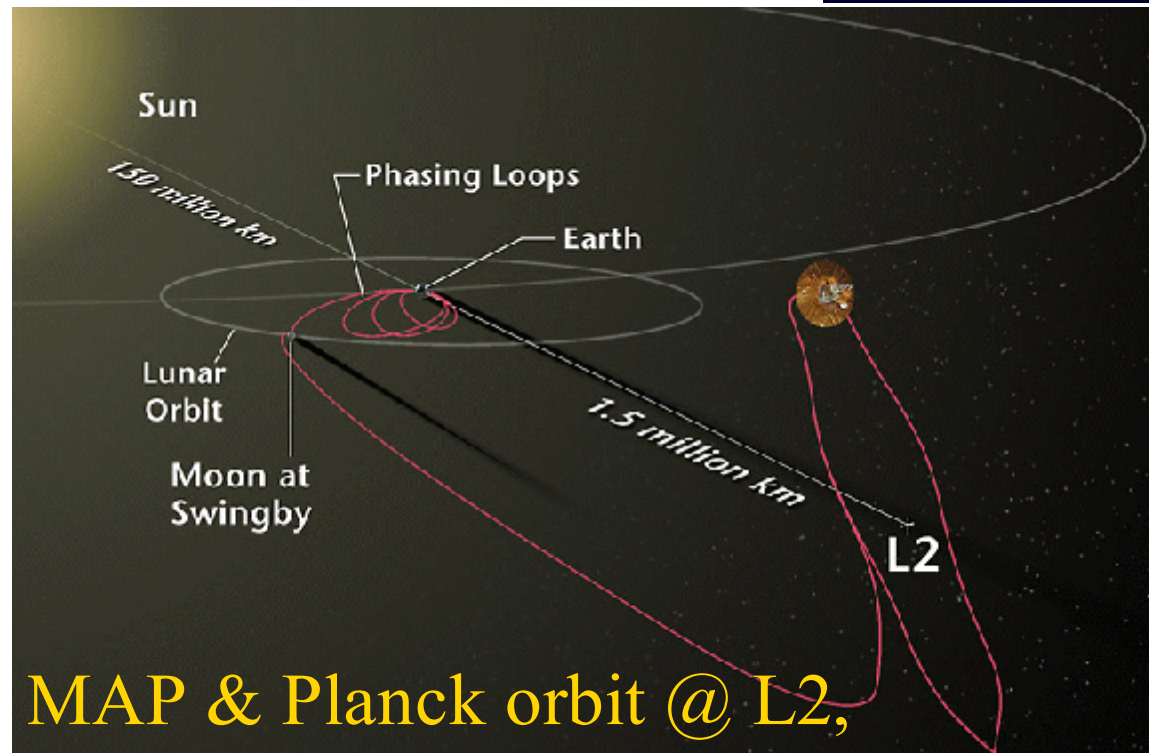
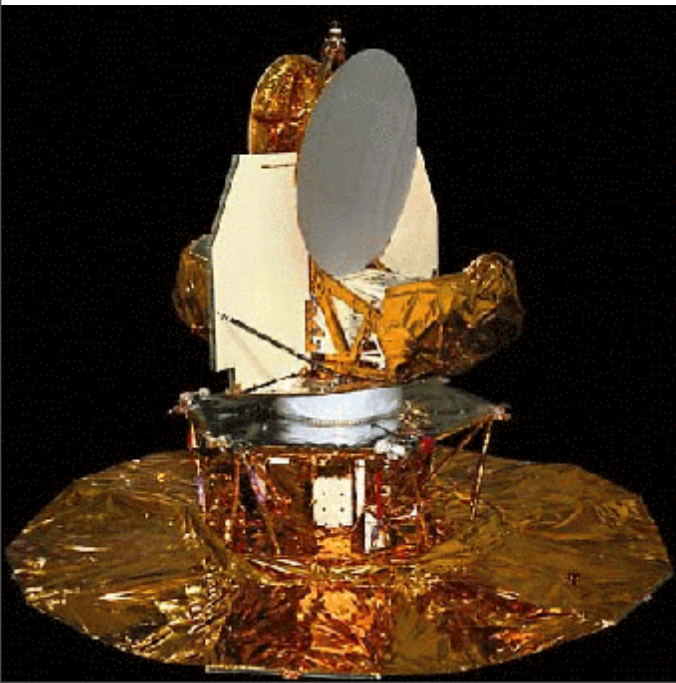
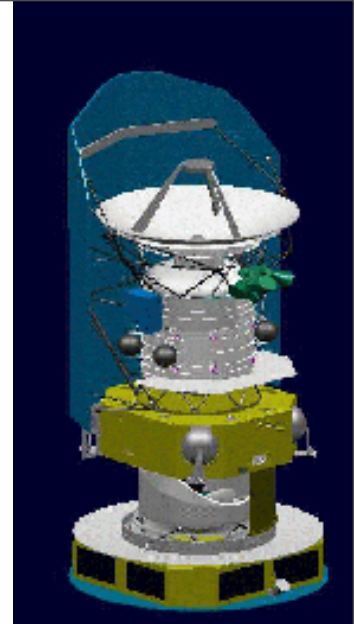
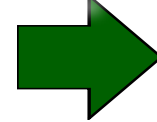
WMAP



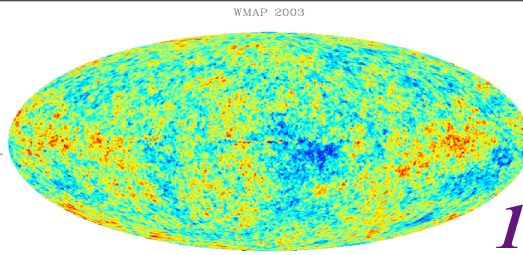


Nasa's WMAP satellite @ L2: launch 2001.5, 1yr data 2003.2, 3yr 2006.3, 5yr 2008.3, funded for 9 years

**Planck satellite @ L2: launch 2009.2
ESA+NASA+ Cdn Space Agency**

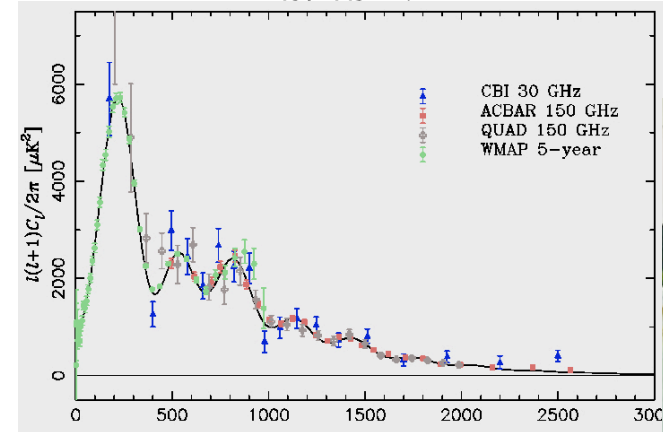
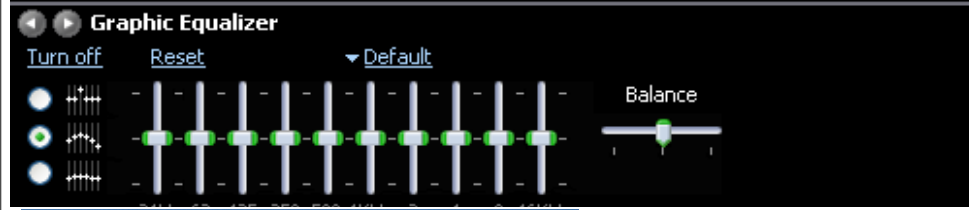
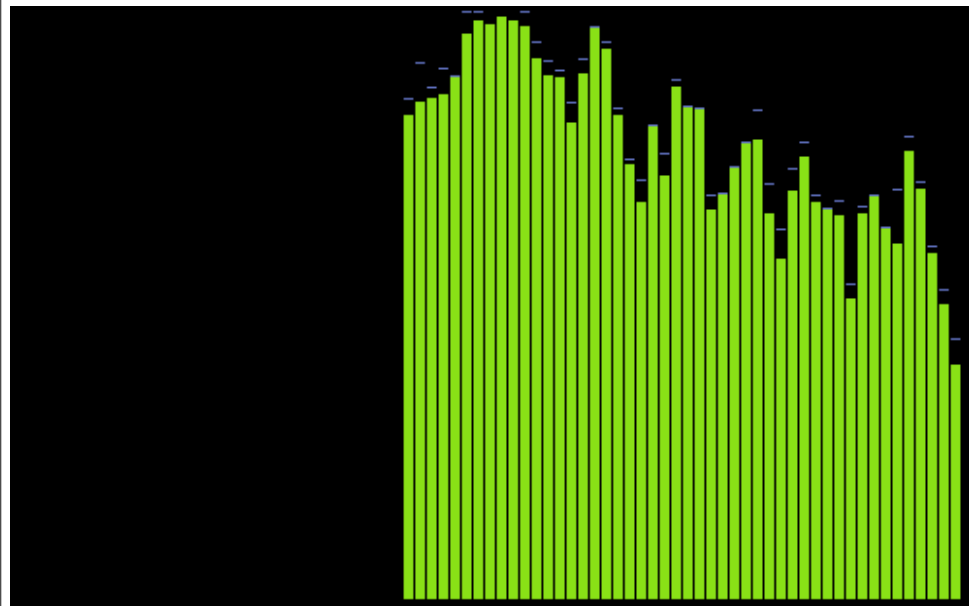
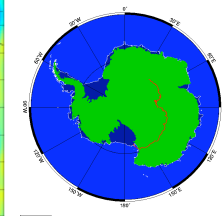
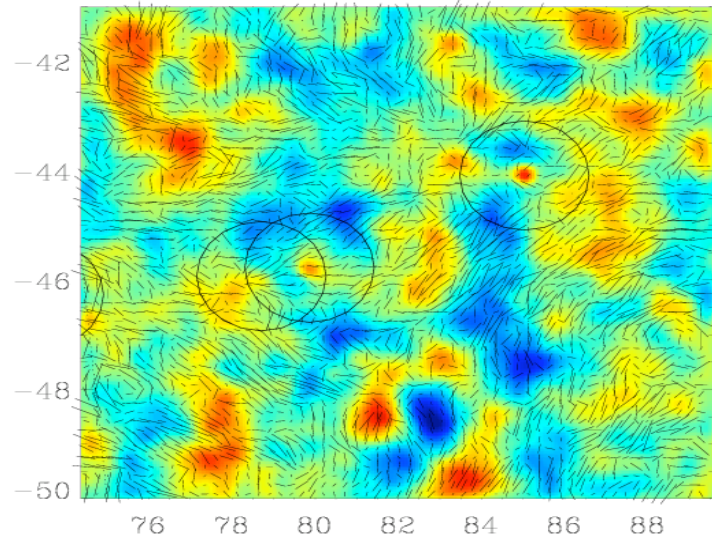


**MAP & Planck orbit @ L2,
the 2nd earth-sun Lagrange point**

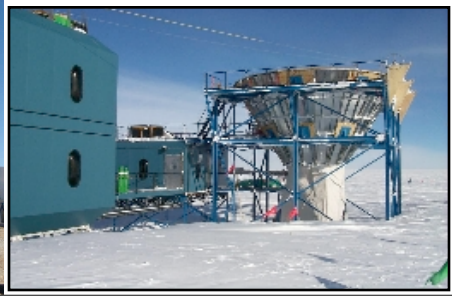
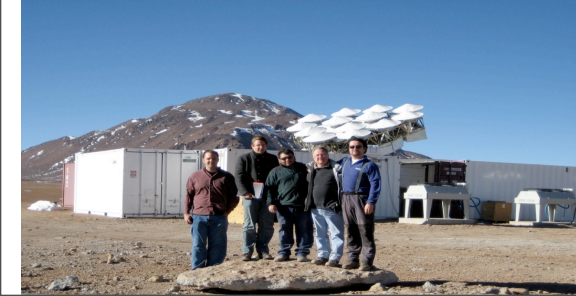
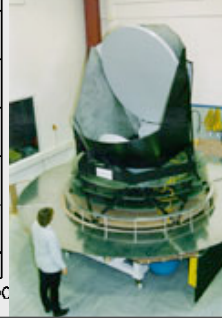


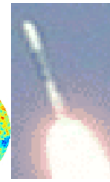
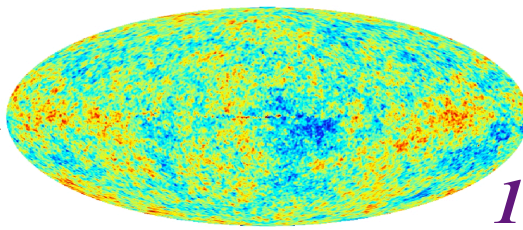
13.65 - 0.00038 billion years ago

Boom05 deep Jul05, Sept08



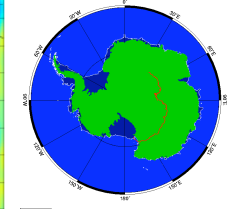
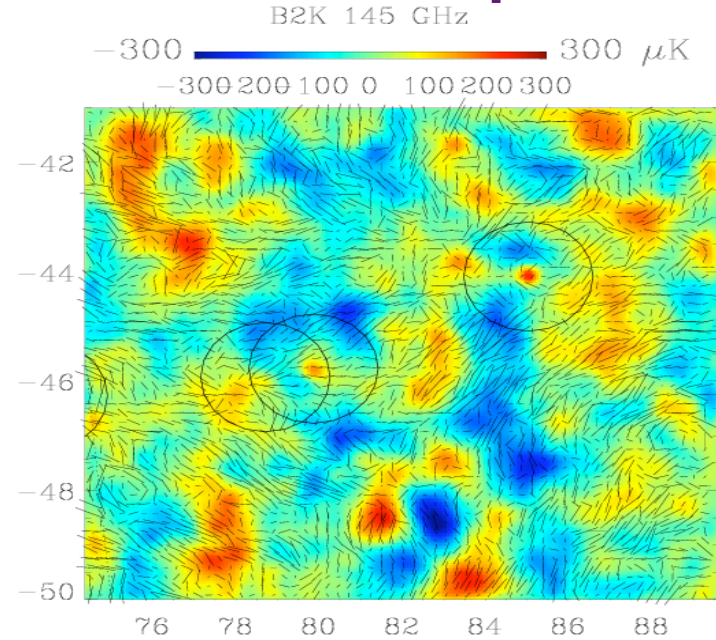
Planck09 as deep



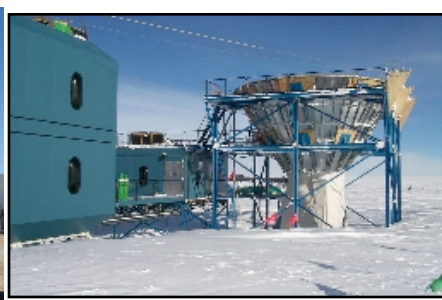
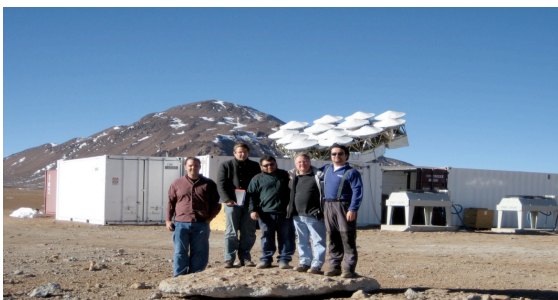
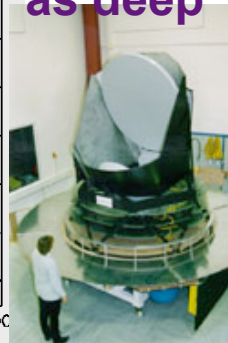
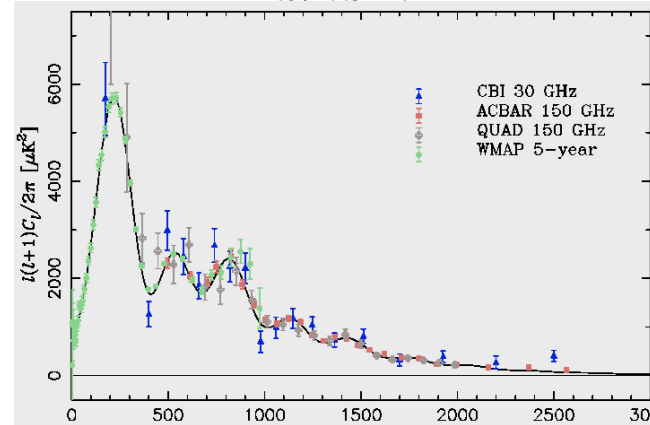


13.65 - 0.00038 billion years ago

Boom05 deep Jul05, Sept08



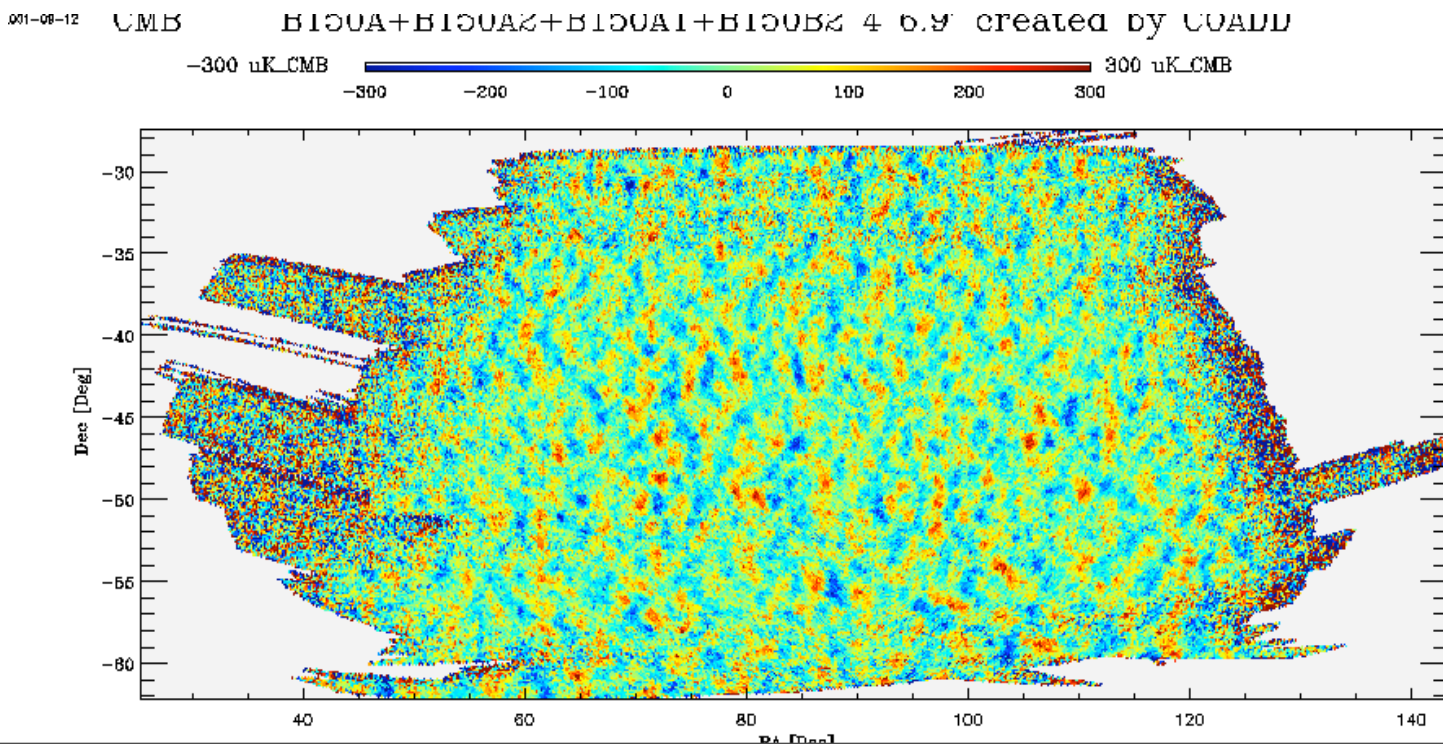
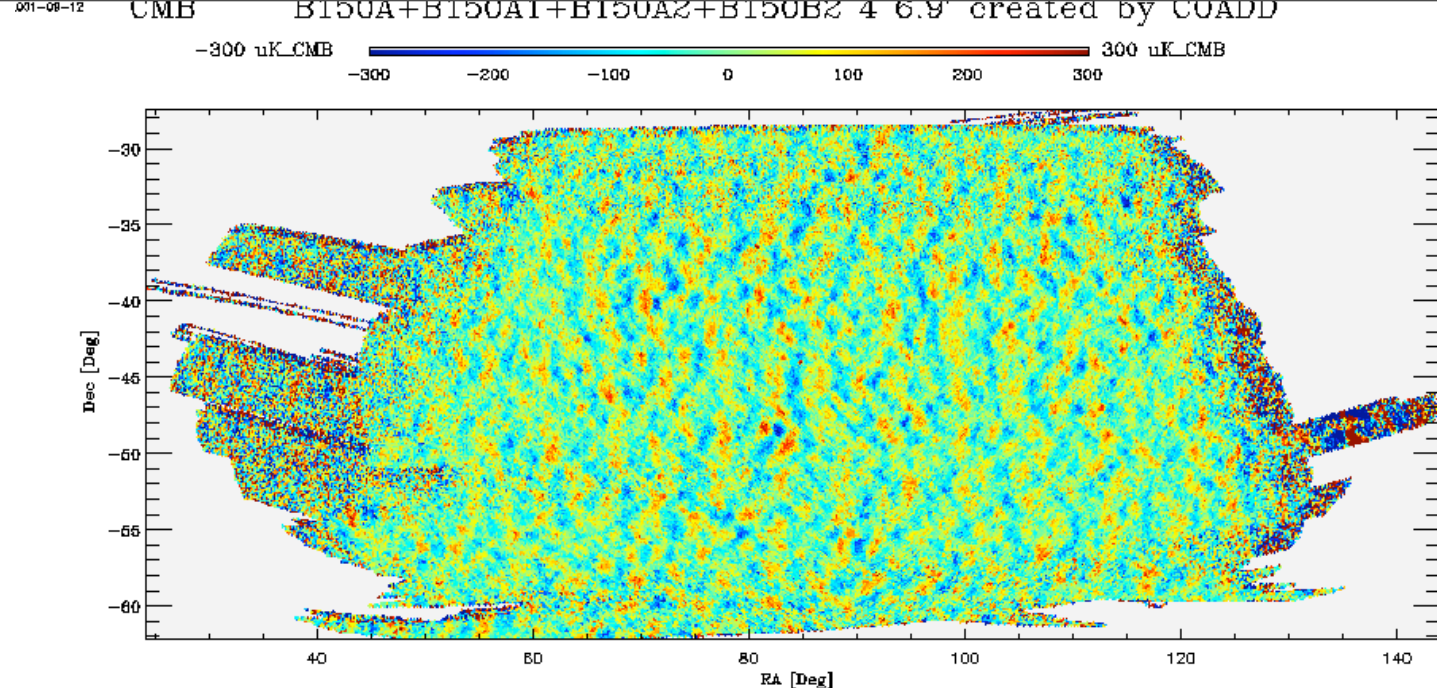
**Planck09
as deep**



Boomerang
@150GHz

Simulated
Theory
vs
Real
Data

*looks the
same*



"IT from BIT"

FATE U inflate (again)

a cold death? reheat/rebirth?

NOW 14 Gyr 1

Pythagoras formed

Galaxies Cluster
Cosmic "web" of vast filaments + membranes

Life forms on earth

9 Gyr 1.4

Carbon/oxygen/etc form

Galaxies form

2 Gyr 4

The 'Meaning' may change
But the facts will remain

Inflation fluctuations form: quantum jitter

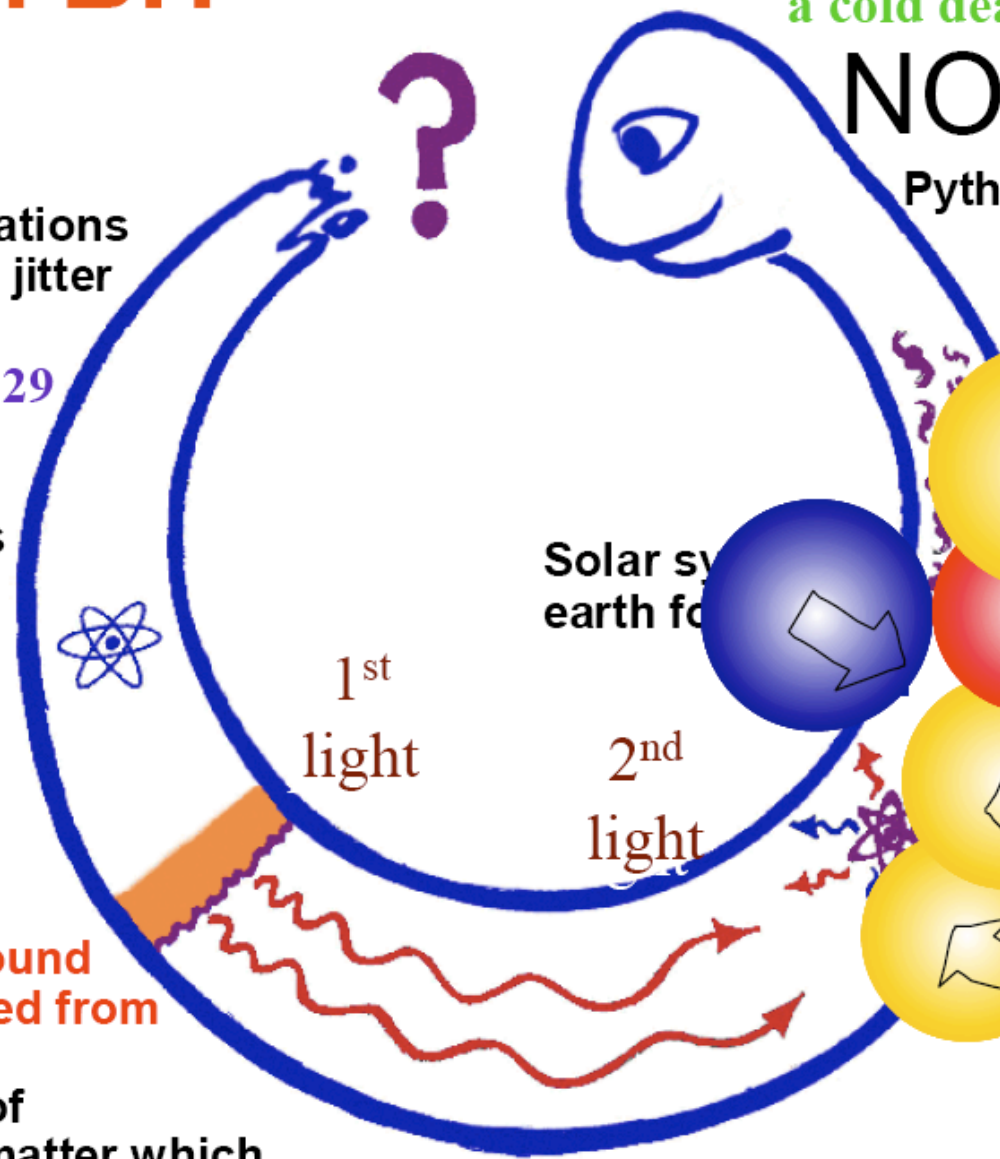
10^{-37} sec 10^{29}

Protons/Neutrons form

Helium forms
 100 sec 10^9

Cosmic background radiation released from matter carries imprint of fluctuations in matter which grow to generate galaxies etc.

0.4 Myr 1100

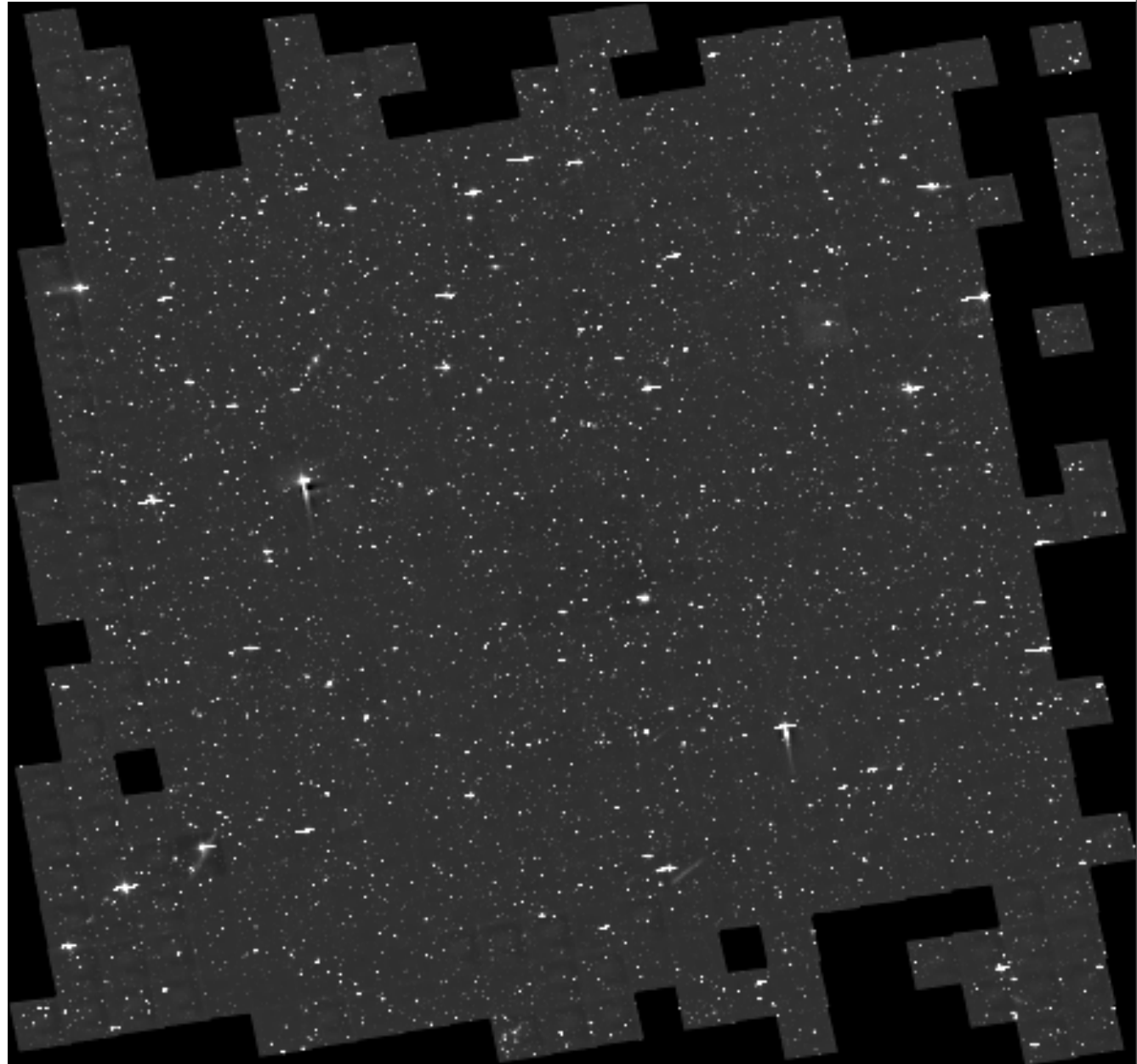


Hubble “Cosmic Evolution Survey”

- 2 deg² Hubble Space Telescope data (largest ever Hubble program)
- > 2 million faint galaxies with measurable shapes



**& Beyond
Hubble: JWST
(+TMT+)**



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- 2 deg² Hubble Space Telescope data (largest ever Hubble program)
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**& Beyond
Hubble: JWST
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EINSTEIN ... 1905 international year of physics 2005

- ✓ NEW LAW OF GRAVITATION (1916); speed of light is the ultimate speed **HORIZONS**; Space is curved by mass; Lightwaves bend, wavelengths change, under gravity

a **starless**
“**dark age**”
before the
most
distant
galaxies

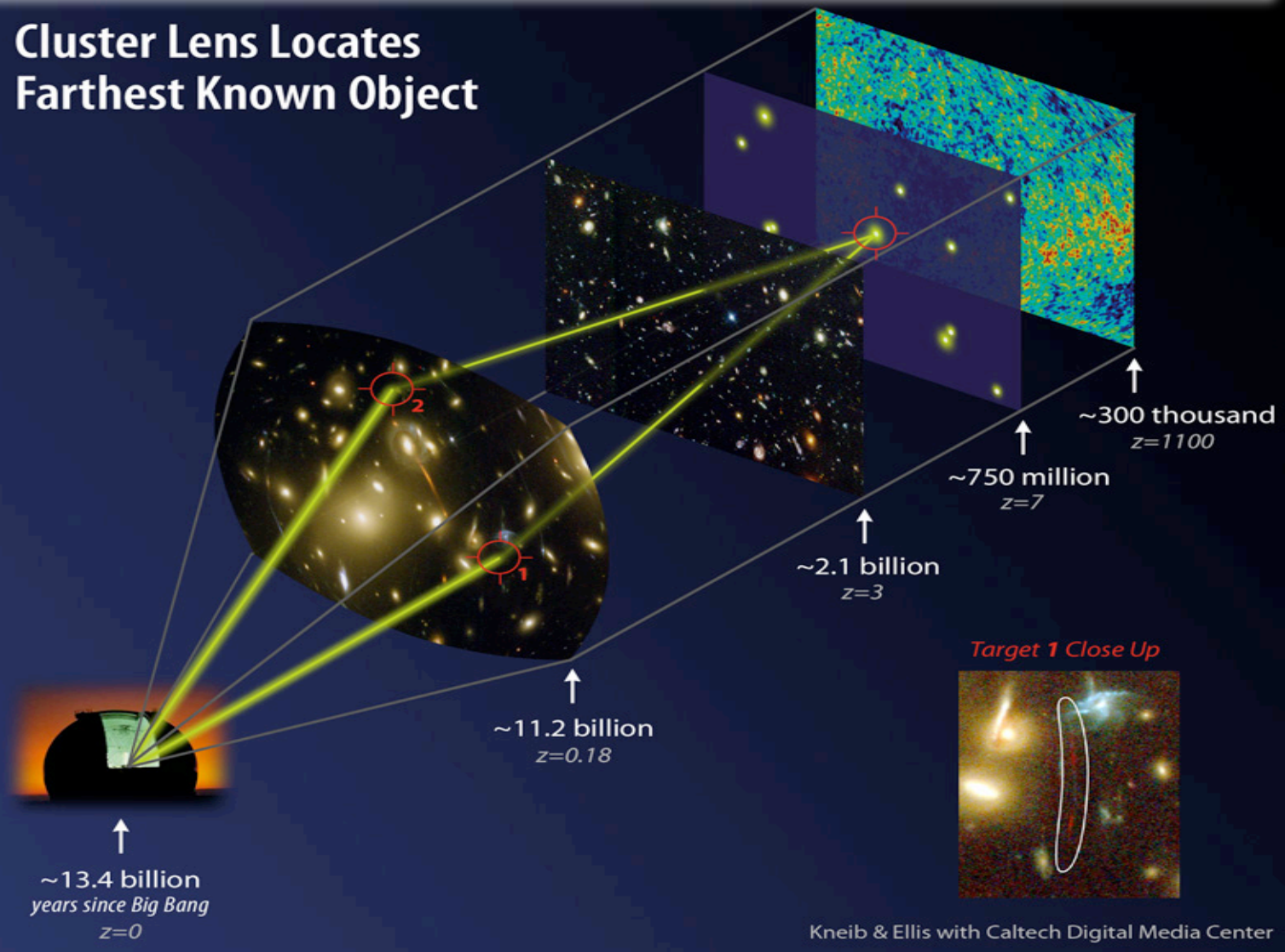
dwarflets &
the 1st stars

form at
compression 13

1st light:
Cosmic
Microwave
Background

released at
compression
1100; formed
at ~10³⁰

Cluster Lens Locates Farthest Known Object



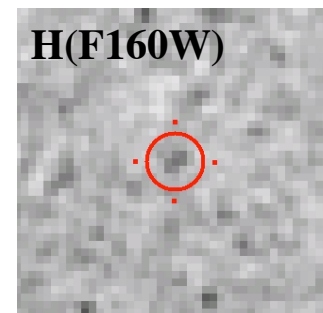
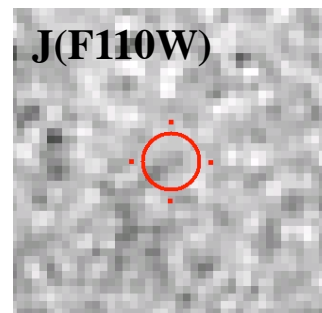
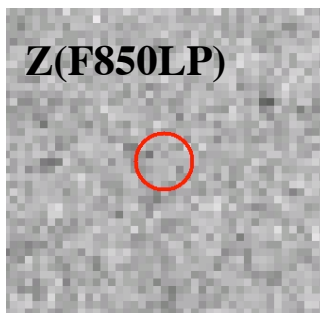
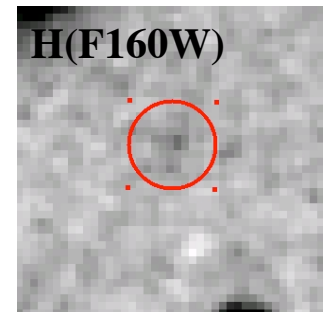
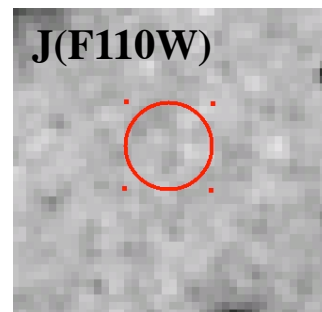
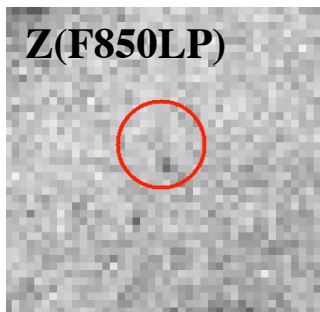


DAVE BARRY

Over the years I have been harshly critical of the scientific community for wasting time researching things nobody cares about, such as the universe. I don't know about you, but I'm tired of reading newspaper stories like this:

“Using a giant telescope, astronomers at the prestigious Crudwinkle Observatory have observed a teensy light smudge that they say is a humongous galaxy cluster 17 jillion light years away, which would make it the farthest-away thing that astronomers have discovered this week. However, astronomers at the rival Fendleman Observatory charged that what the Crudwinkle scientists discovered is actually mayonnaise on the lens. Both groups of astronomers say they plan to use these new findings to obtain even larger telescopes.”

Galaxies at compression 10



“UltraDeep” work of Richard Ellis et al. CifAR Associate

TMT: Thirty Metre Telescope

JWST: James Webb Space Telescope

SKA: Square Kilometre Array



“IT from BIT”

FATE U inflate (again)

a cold death? reheat/rebirth?

NOW 14 Gyr 1

Pythagoras formed

Galaxies Cluster
Cosmic “web” of
vast filaments +
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9 Gyr 1.4

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10^{-37} sec 10^{29}

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Helium forms

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Cosmic background
radiation released from
matter

carries imprint of
fluctuations in matter which
grow to generate galaxies etc.

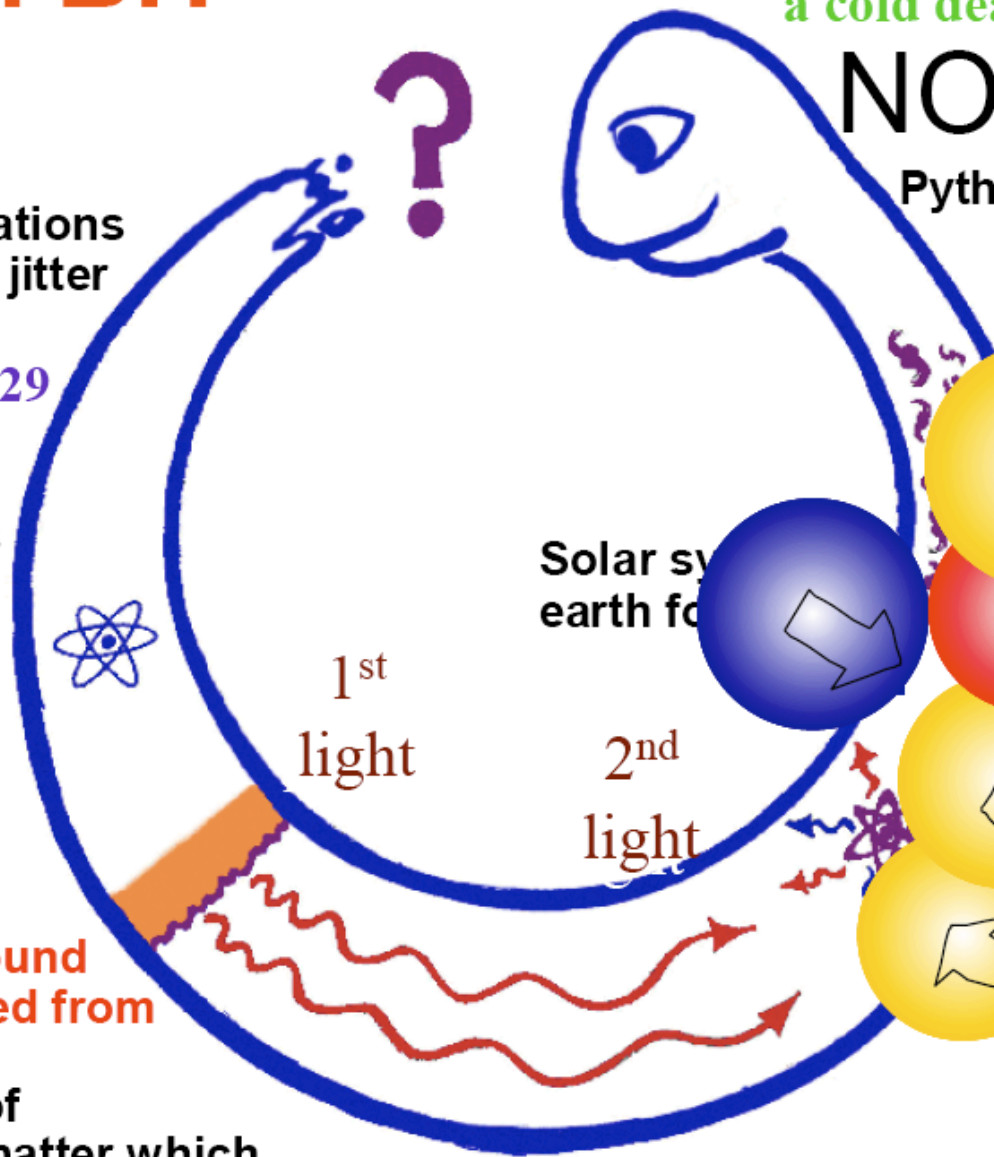
0.4 Myr 1100



1st
light

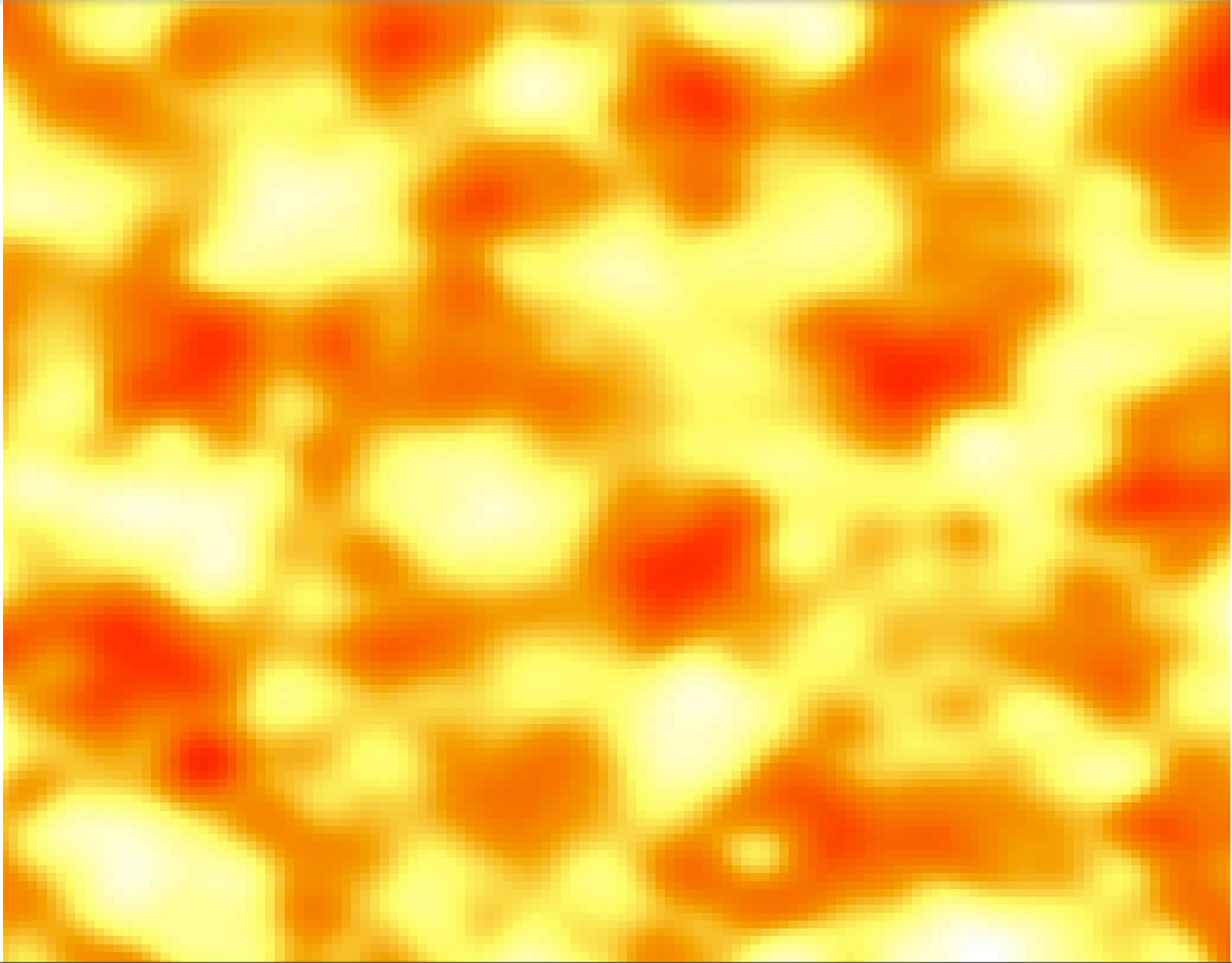
Solar system
earth form

2nd
light

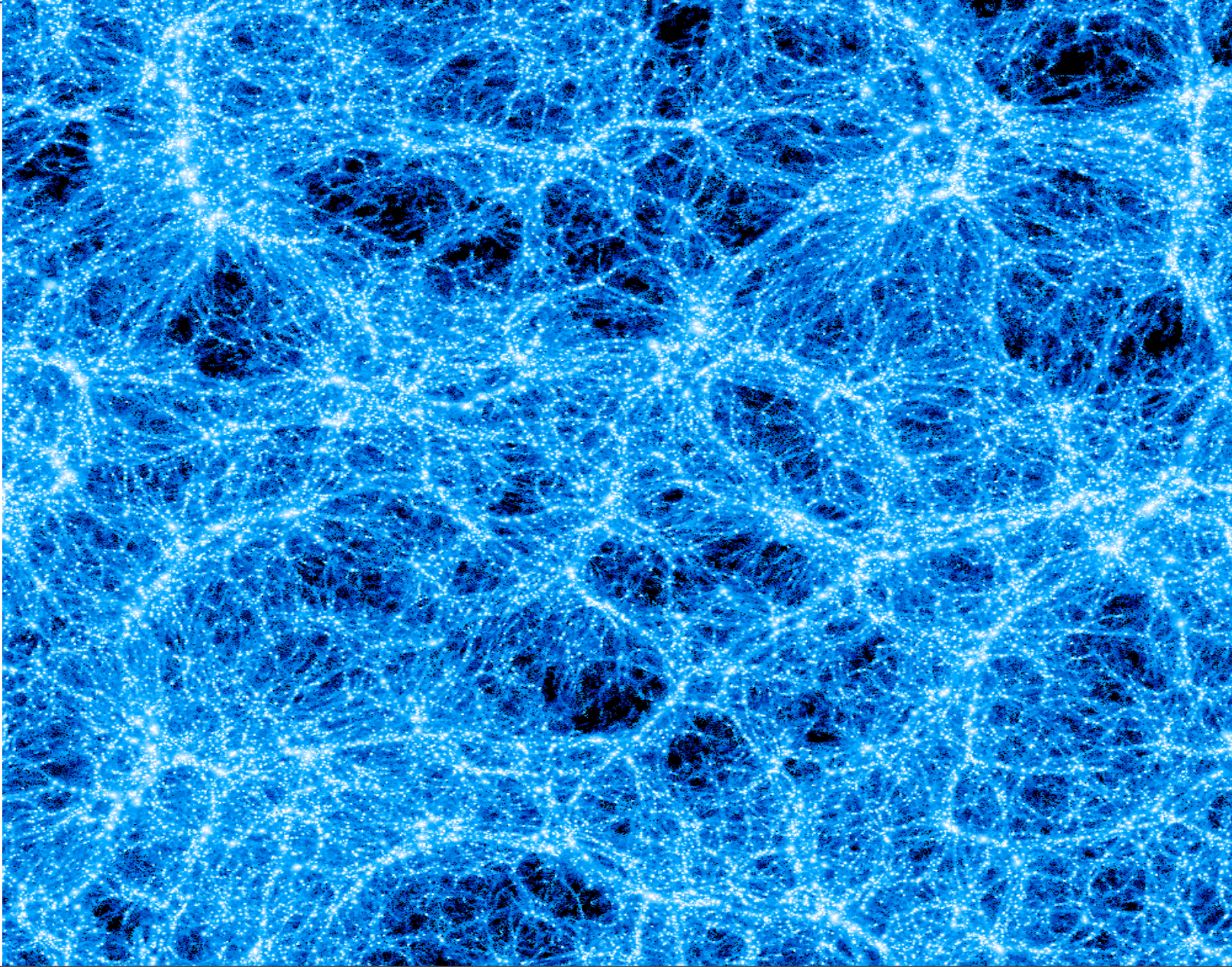


The ‘Meaning’ may change
But the facts will remain

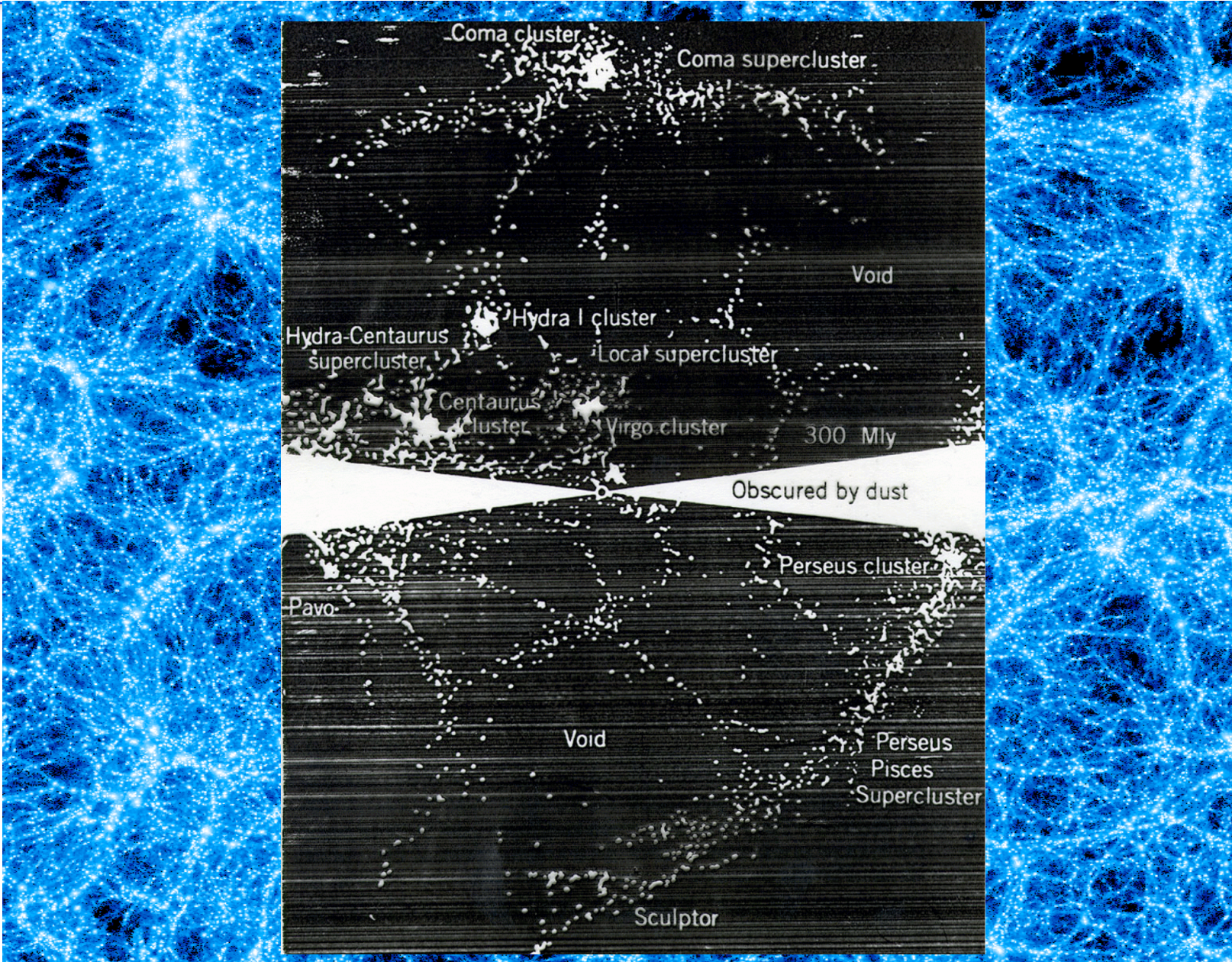
nonlinear Gas & Dark Matter Structure in the Cosmic Web the cluster/gp web “now”, the galaxy/dwarf system “then”



nonlinear Gas & Dark Matter Structure in the Cosmic Web the cluster/gp web “now”, the galaxy/dwarf system “then”



nonlinear Gas & Dark Matter Structure in the Cosmic Web the cluster/gp web “now”, the galaxy/dwarf system “then”

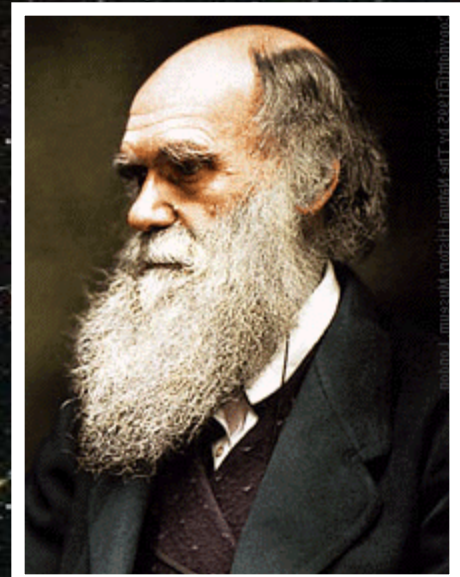


Cosmology today

- 1) Space and time: geometry shaped by mass-energy
- 2) Origin: “big bang” 13.7 aeons ago
- 3) Evolution: expanding, cooling, **accelerating**
- 4) Arrangement: galaxies in the cosmic web
- 5) Composition: **dark matter** and **dark energy & us**

There is grandeur in this view ... from so simple a beginning endless forms most beautiful and most wonderful have been, and are being, evolved.

Charles Darwin
The Origin of Species



“To me every hour of the light
and dark is a miracle. Every
cubic inch of space is a miracle.”

– Walt Whitman

In every cubic centimetre

- cosmic radiation 412 cm^{-3}

- **dark matter** $\sim \text{amu m}^{-3} \sim$

compressed in MW to $\sim 0.1 \text{ amu CM}^{-3}$ for
LHC-type DM, ~ 1 every 10 cm

- **dark energy** $\sim 4 \text{ keV cm}^{-3}$

$\sim (\text{milli-eV})^4$

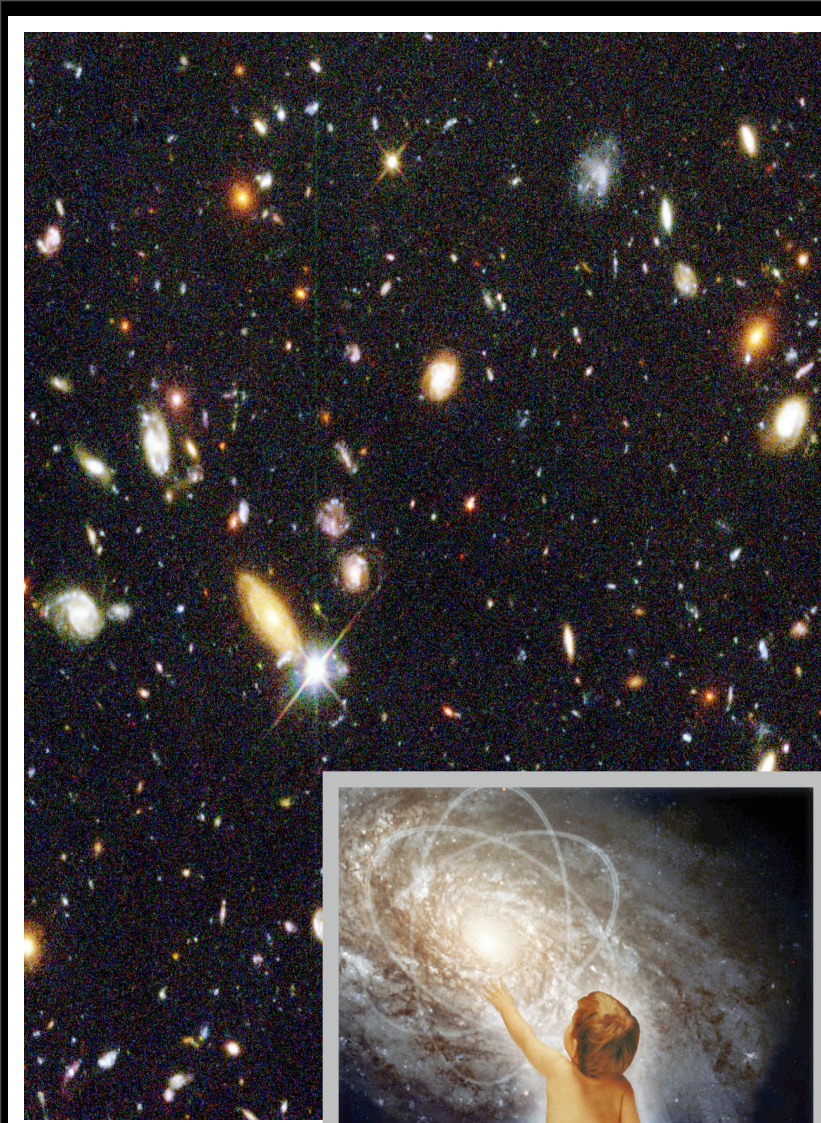
- neutrinos \sim CMB photons

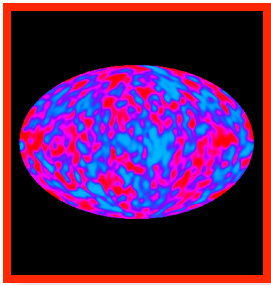
- gravity waves

- virtual particles - vacuum fluctuations

- Higgs potential - origin of mass

- **extra dimensions here, now?**

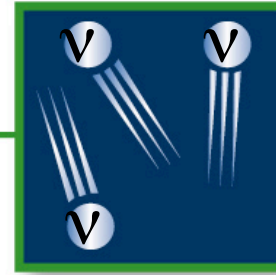




Radiation:
0.005%



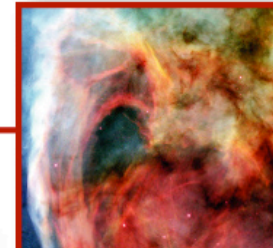
Chemical Elements:
(other than H & He) 0.025%



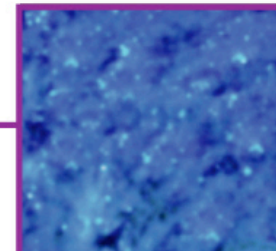
Neutrinos:
0.47%



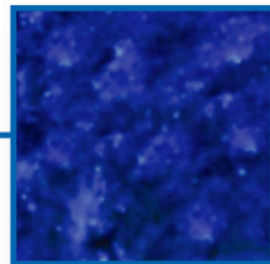
Stars:
0.5%



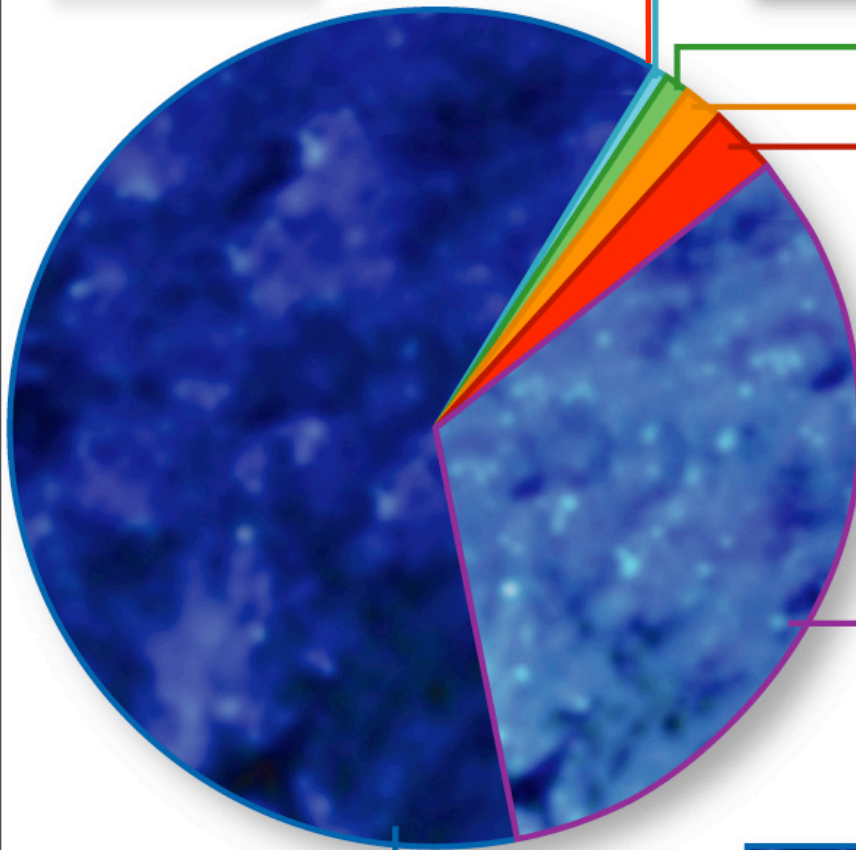
**Free
H & He:**
4.3%



Dark Matter:
 $\Omega_{\text{dm}} = 20.7 \pm 5\%$



Dark Energy:
 $\Omega_{\Lambda} = 75 \pm 3\%$



Gravity Waves
 $\Omega_{\text{GW}} \sim 10^{-14} - 10^{-10}$ LIGO
 $\Omega_{\text{BlackHoles}} \sim 10^{-7}$

detect Ω_{cdm} in lab; detect primordial Ω_{GW}

Ω_{Λ} (time, space)

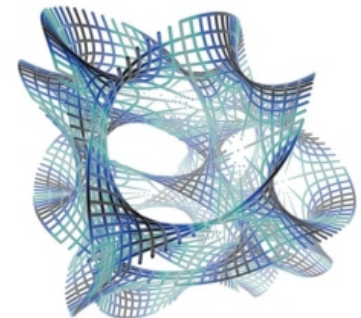
Then (10^{-37} s) inflation

Now (13.7×10^9 yr)

dark energy mystery

our CfAR future: to the
early & late Universe thru

Experiment + Theory (CMB+Lens+SN+clusters
LIGO/LISA/BBO for gravity waves + SNOlab/
CERN/ILC for dark matter)



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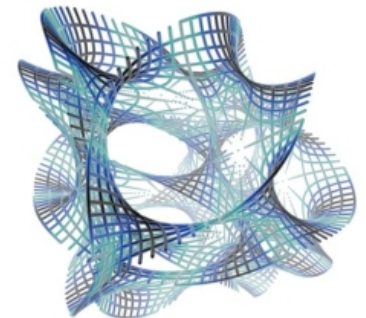
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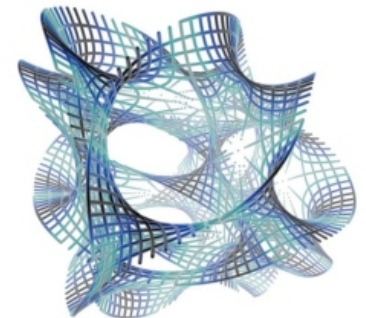
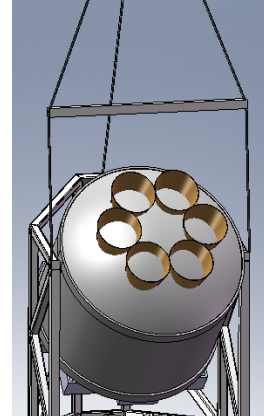
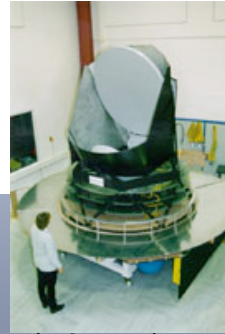
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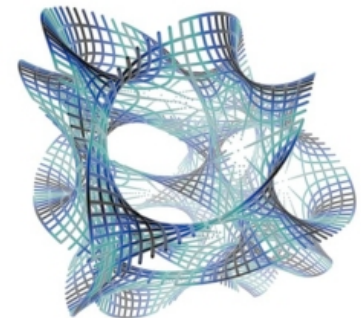
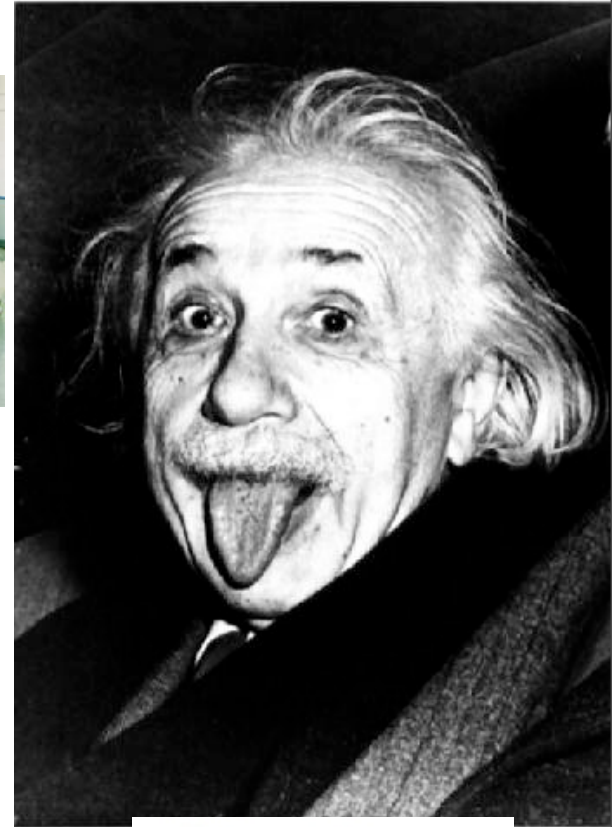
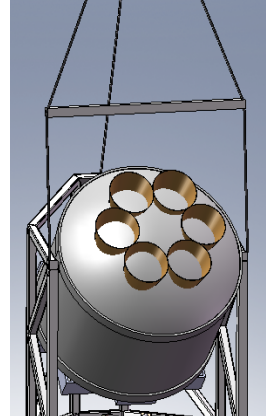
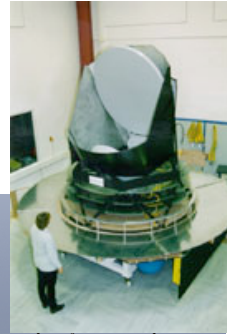
Then (10^{-37}s) inflation

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dark energy mystery

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LIGO/LISA/BBO for gravity waves + SNOlab/
CERN/ILC for dark matter)



end

**We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time.**

– T. S. Eliot

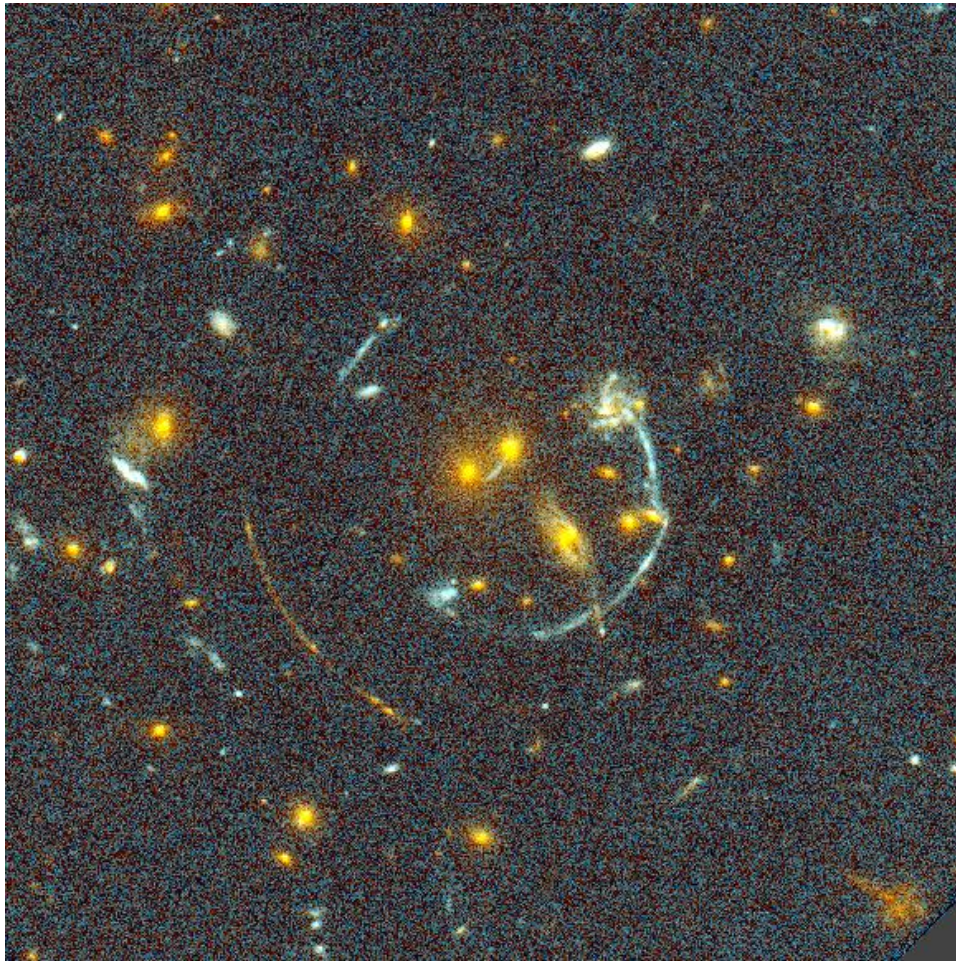
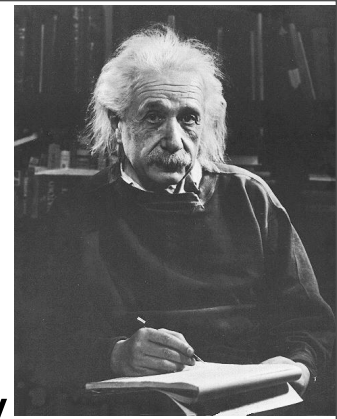


**it is primarily for
this knowing & its
inspiration to young
minds that the world
is spending tens of
billions of dollars on
the cosmic quest for
fundamental physics**

**The world wide web,
technological space
spinoffs, amazing detector
& computational advances,
are (important) asides**

EINSTEIN ... 1905 international year of physics 2005

- ✓ NEW LAW OF GRAVITATION (1916)
- ✓ speed of light is the ultimate speed (**HORIZONS**)
- ✓ Space is curved by mass
- ✓ Lightwaves bend, wavelengths change, under gravity

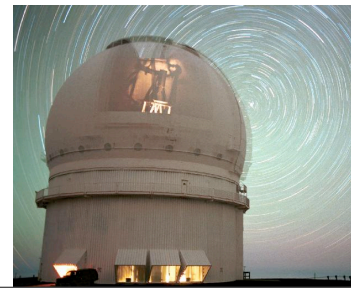


*Gravitational lensing of
deep galaxies by clusters*

Toronto RCS 2001; RCS2

 *Hoekstra, Gladders, Yee*

*Weak lensing via Canada
France Hawaii Telescope
Legacy Survey 2002-08*



*Hoekstra, van
Waerbeke*

 **CIAR**



CFHT

SN

Survey

Carlberg,
Pritchard,

et al.



3yr now
300 SN1a

5yr

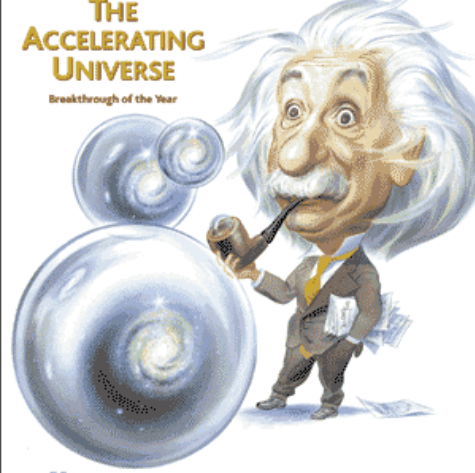
500

18 December 1998
Science

Vol. 282 No. 5397
Pages 2141-2336 57

**THE
ACCELERATING
UNIVERSE**

Breakthrough of the Year



AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE



CFHT

SN

Survey

Carlberg,
Pritchett,

et al.



3yr now
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5yr

500

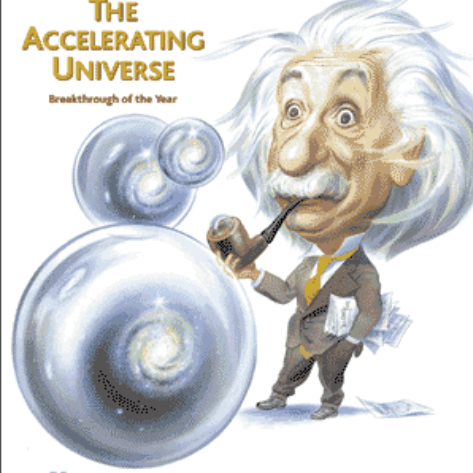
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3yr now

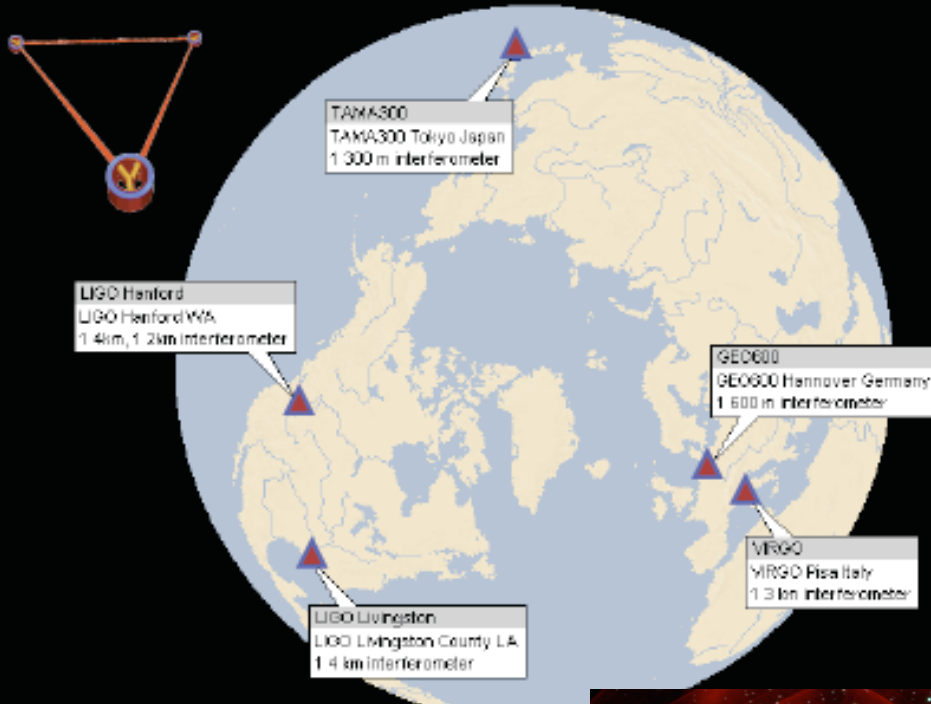
300 SN1a

5yr

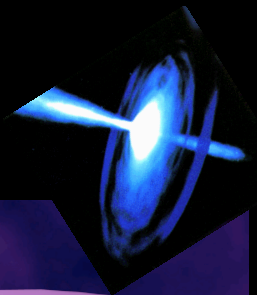
500



Worldwide Interferometer Network



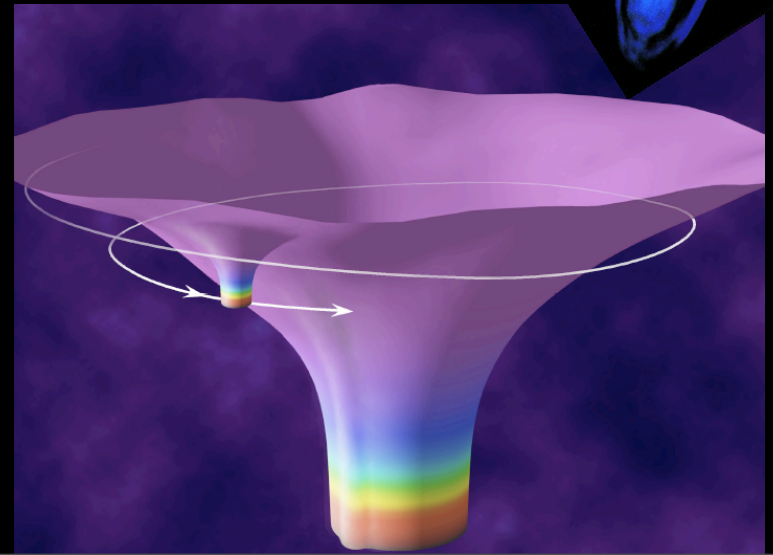
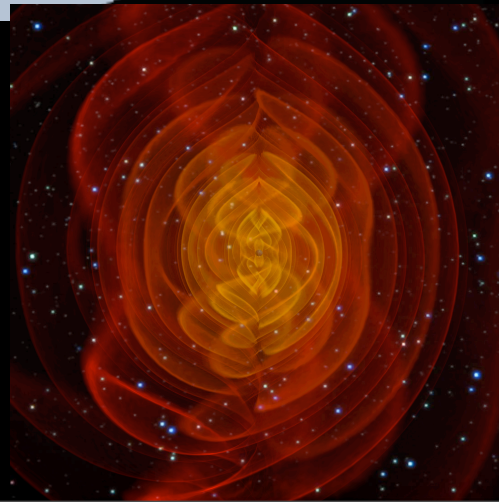
DANGER:
BLACK HOLES
MERGING



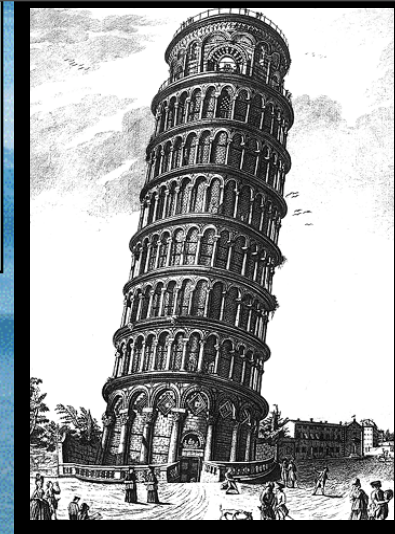
Now-2013+

~km scale

**detect .001 nuclear
radius**



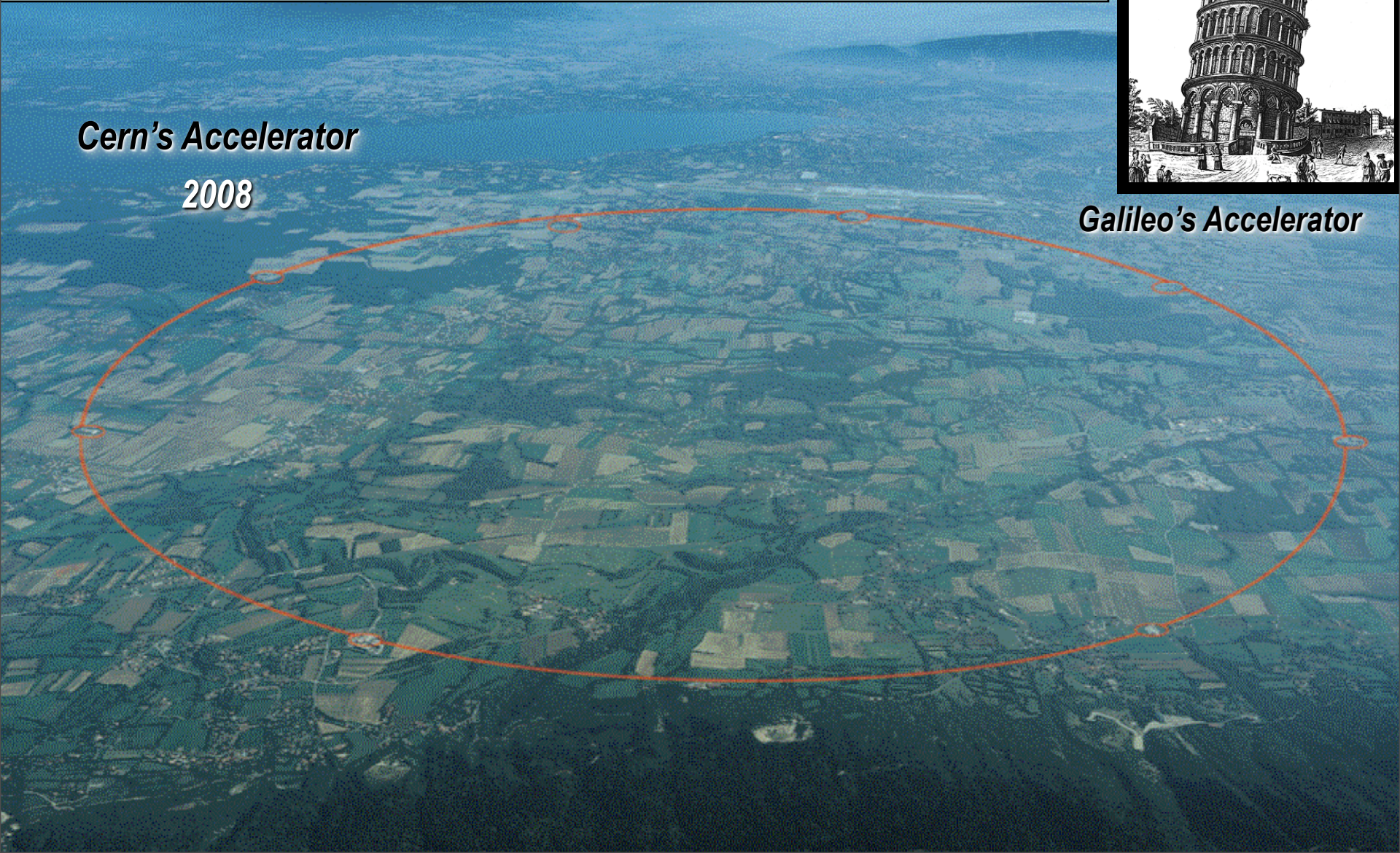
How will Accelerators cast Light on the Dark Side of the Universe?



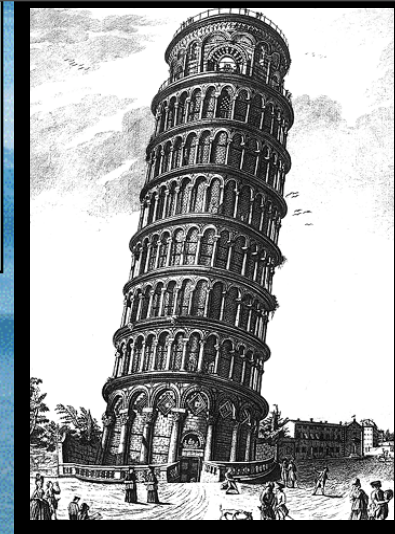
Cern's Accelerator

2008

Galileo's Accelerator



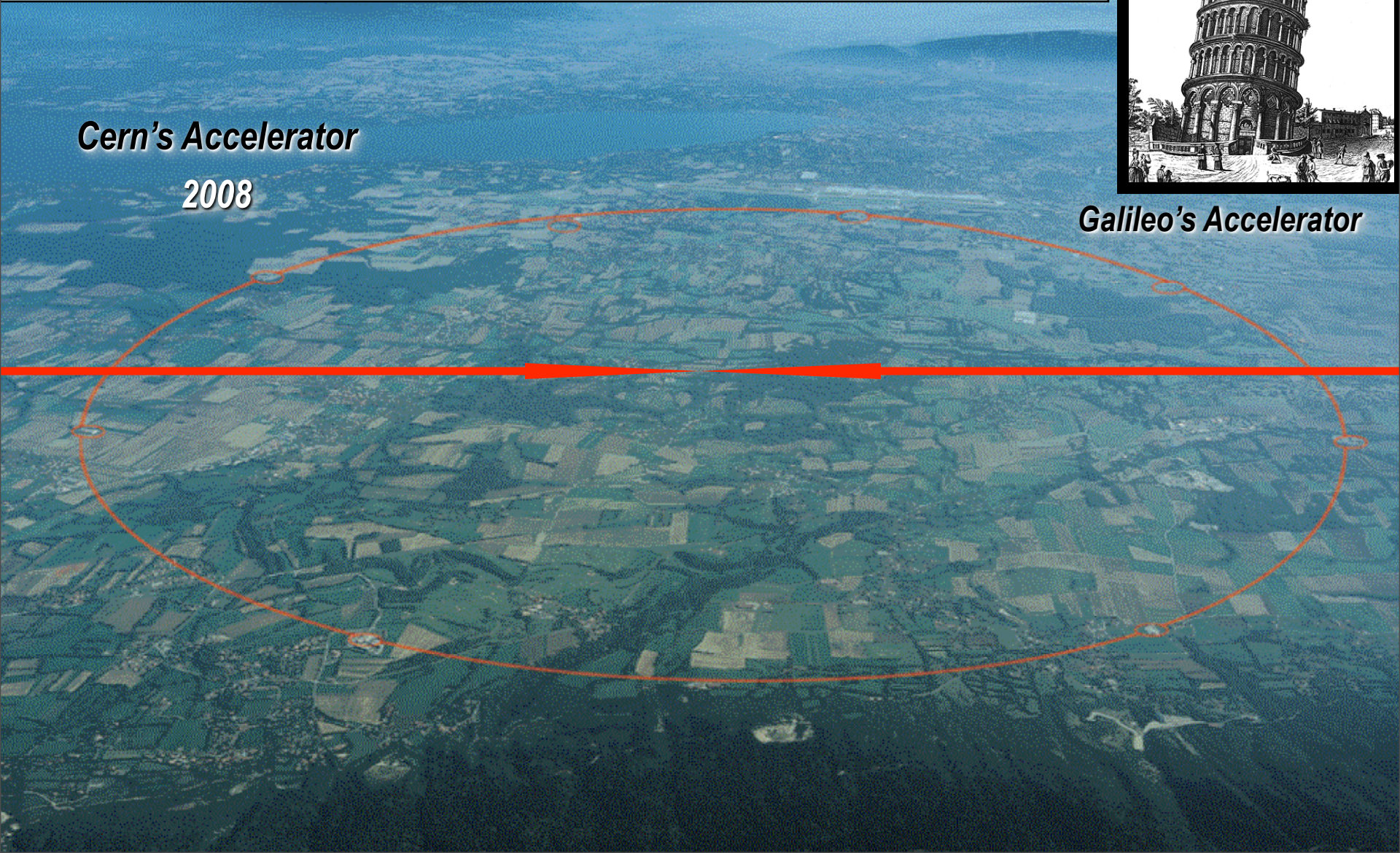
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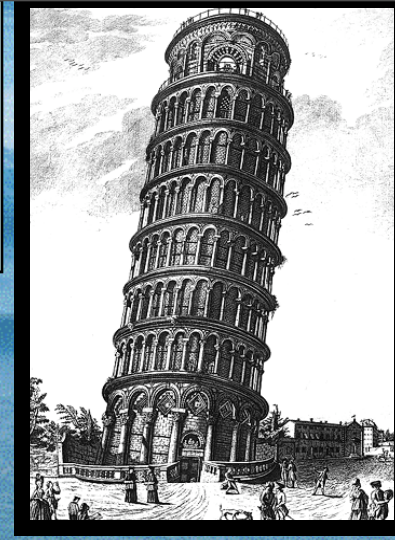
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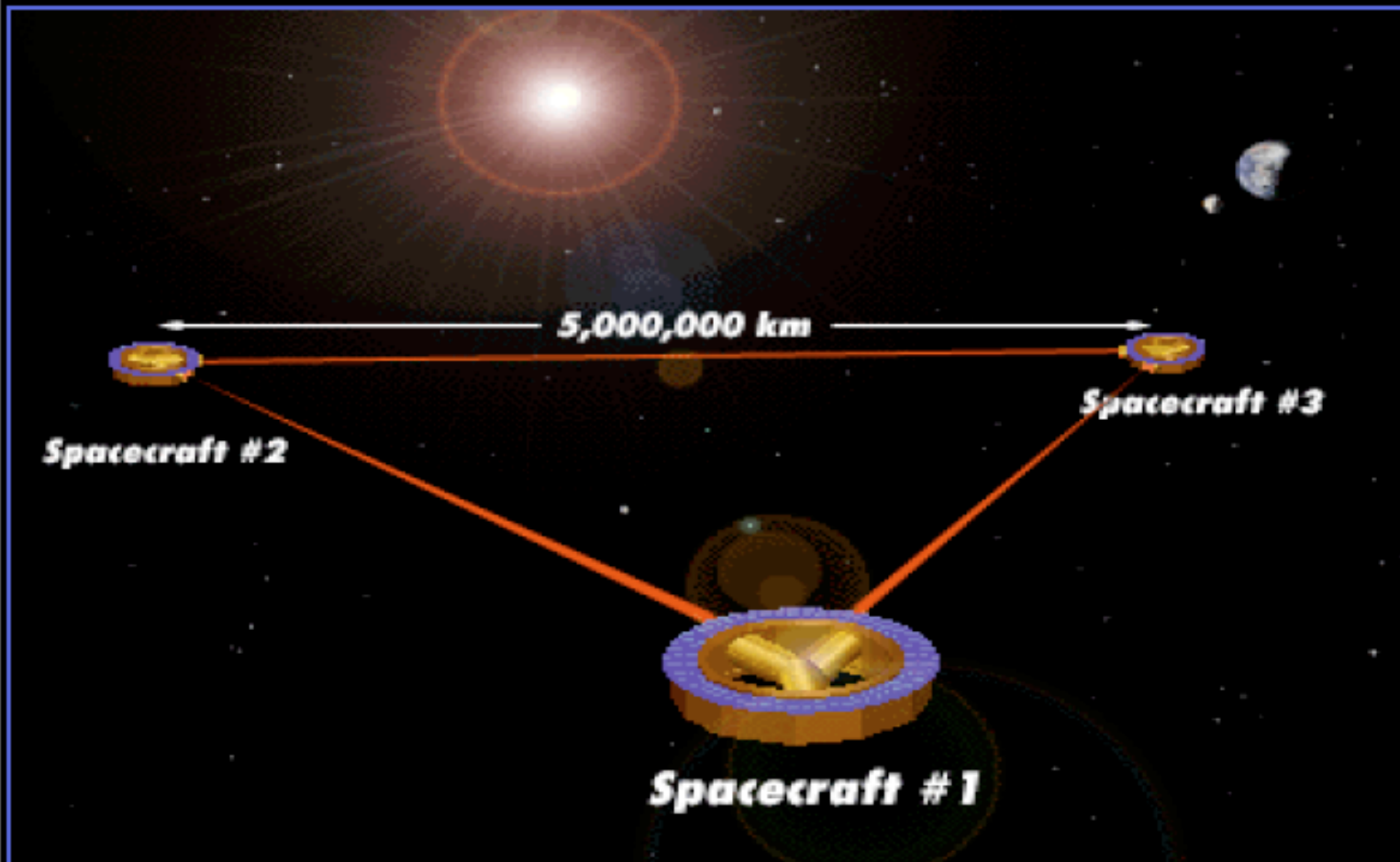
Galileo's Accelerator

Cern's Accelerator

2008

If Dark Matter interacts with ordinary matter by more than gravity, we may "see" it at the Large Hadronic Collider 2008+ or at SNOlab 2008+ in Sudbury

LISA



2017??

~5 million km scale
detect .001 atomic radius

DANGER:
SuperMassive
BLACK HOLES
MERGING

