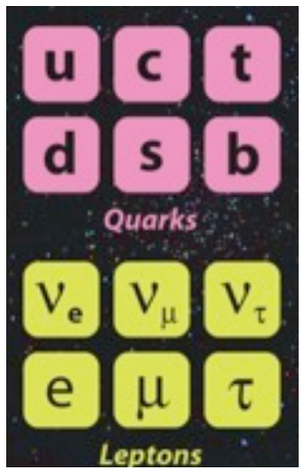
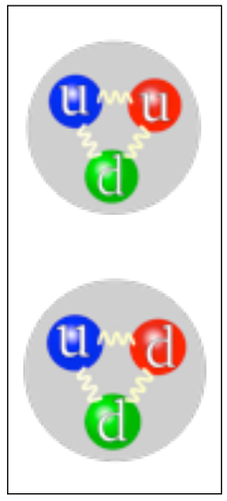
early universe

In the beginning, there is light.

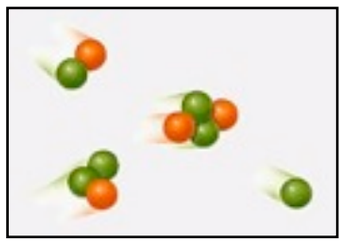
fundamental particles
~10^{-10} sec



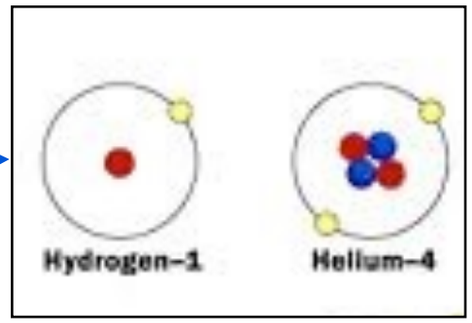
proton & neutron
0.001 sec



nuclei
3 min.



atom
300,000 yrs



era of particles **$E = h \nu \sim m c^2$**

$E > 10^{16}$ ev, no quarks

$E > 1$ G ev (10^9 ev), p, n/p, n, no stable hadron can survive

$E > 1$ Mev (10^6 ev), no stable nucleus can survive

$E > 10$ ev, no stable atom can survive

Two big events that make 'us' happen:

1) "**baryon asymmetry**"

during the particle era, particles/anti-particles continuously produced and annihilated, until the universe cools to a point.

@1 milli-second, one excess particle for every 10^9 photons.
miraculously, this explains all the matter today in the universe

exotic physics in GUT Era? inflation? other parts of universe may be anti-matter?

other examples of asymmetry: "symmetry breaking"
people 90% right-handed;
all amino acid on Earth left-handed

Nucleosynthesis

Most elements on this table are made in stars.

But H, He, Li, Be can be made in the big bang.

The Periodic Table

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
		57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

Helium in the universe

observed:

Sun:

71% H, 27% He, rest 'metal'

Jupiter:

~76% H, ~ 22% He

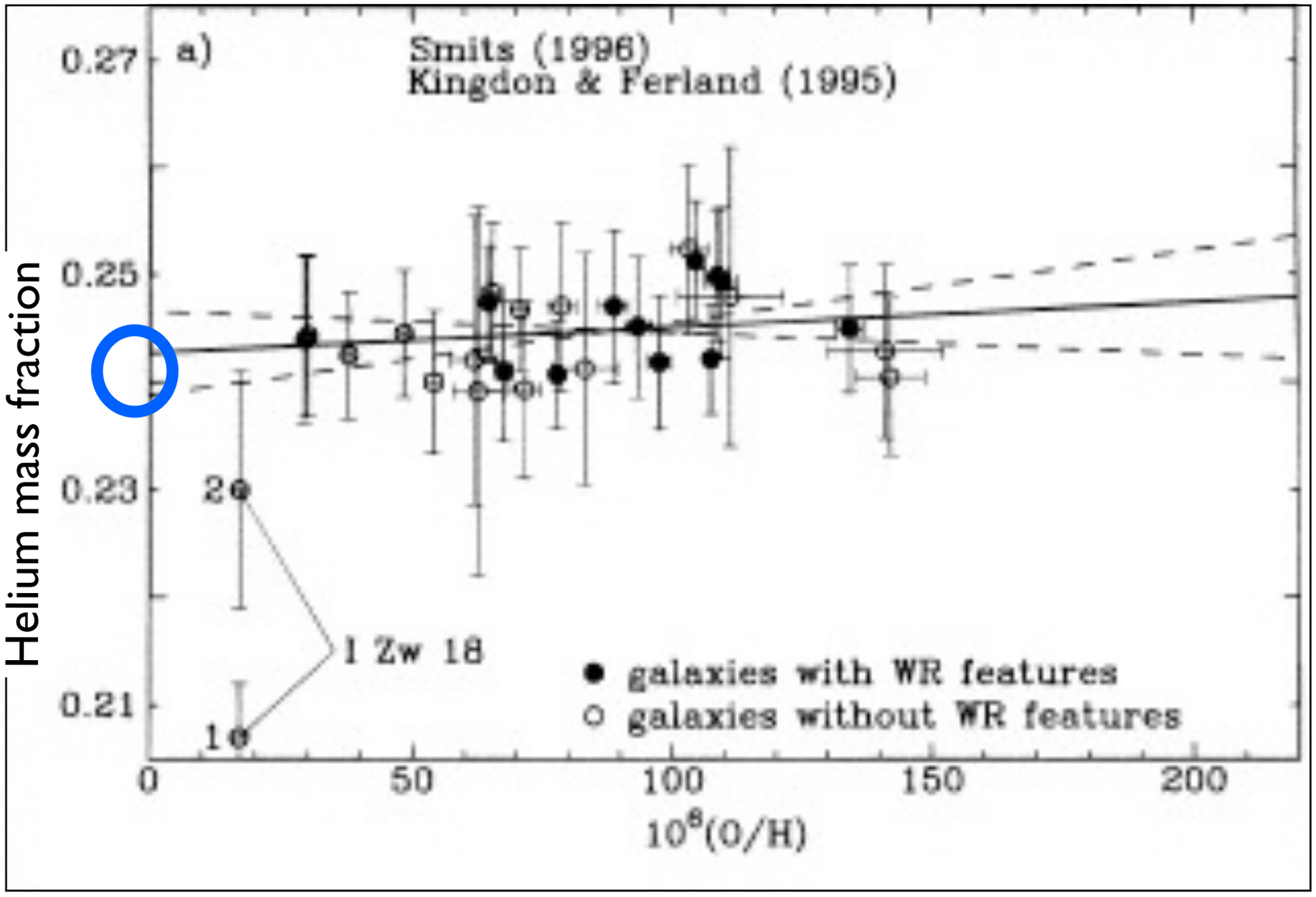
Earth:

hardly any H & He

dwarf galaxies with 'pristine' gas:

76% H, 24% He

==> a 'primordial' abundance of ~76% H, ~24% He



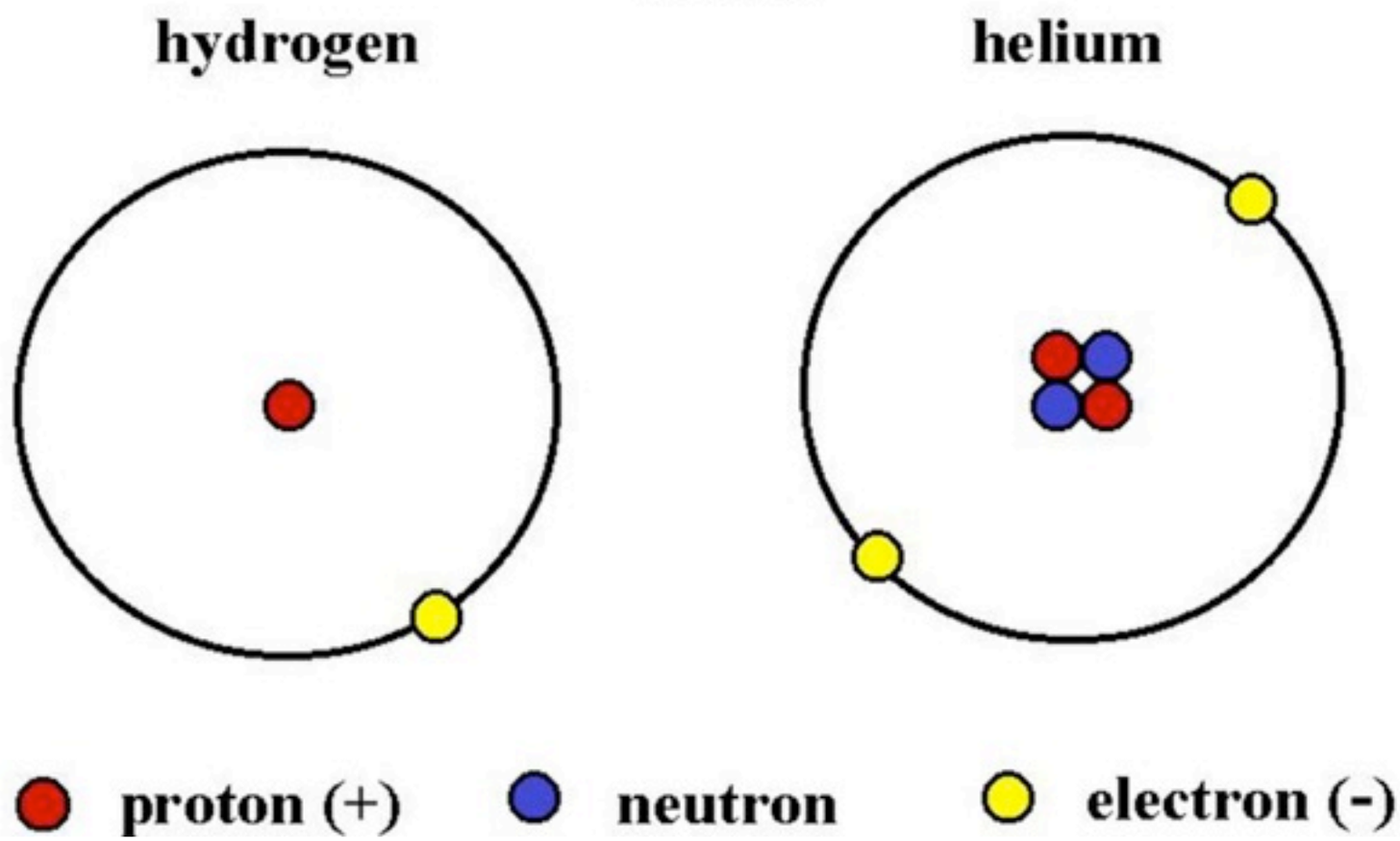
observed helium abundances in un-processed regions in the universe

- Big bang theory gave a satisfactory explanation for the primordial H/He abundances (also ^{2}H, ^{3}H, Li, Be)
- In fact, this was predicted pre-measurements (Alpher & Gamow 1940)
- It is one great success for the Hot big bang theory.

hot big bang: how much primordial helium?

During the nucleosynthesis era, the universe contains 1 neutron for every 7 protons:

1) neutrons slightly more massive
2) free neutrons decay (half life ~ 15 minutes)



Eventually all neutrons end up in helium, this determines the primordial helium abundances: ? H nuclei for every 1 He nuclei

or: ~ 76% H, 24% He by mass (as well as some light elements like Li, Be...)

The first Three Minutes

ignorance

- **PLANCK ERA**: before the Planck time. Uncertainty Principle indicates huge energy fluctuations, as well as space/time changes (space-time foam).

- **GUT ERA** (grand unified theories): GUT force combines the strong force with the electroweak force (the combination of weak and electromagnetic force). **INFLATION**

- **ELECTROWEAK ERA**: electromagnetic and weak forces were still united. Conditions achieved in particle accelerator in 1983.

- **PARTICLE ERA**: particles and anti-particles created and destroyed continuously in the hot bath, until the universe cools to a point. **Asymmetry of matter/anti-matter** 1/10^9. This slight excess explains all the matter in the universe.

- **NUCLEOSYNTHESIS ERA**: nuclei (proton + neutron) formed and broken apart continuously. The universe is one big nuclear reactor. The end of this era sets the chemical composition of the universe: 76% H + 24% He

Universe after the first 3 minutes -- in a nutshell

- **ERA of NUCLEI**: Electrons continuously bound into a nucleus or be dissociated by a photon. Foggy path for photons. As universe cools to ~ 3000K, photons no longer destroy atoms and free to travel **--CMB**. Can never look beyond CMB using photons.

- **ERA of ATOMS**: first structures getting ready to form, the "**cosmic dark ages**". Lasting from z ~ 1100 to z at least 8.4 (highest redshift galaxy known). Need infrared observations. New generations of telescopes (JWST -- Hubble Space Telescopes's successor, Herschel and ALMA) are designed to detect the first structure.

- **ERA of GALAXIES**: structures form following primordial fluctuations (imprinted on cmb). Large and small galaxies, first stars.... generations of stars burn nuclear fuels, generating the chemical elements useful for Earth and Life...

Summary of the Big Bang & CMB

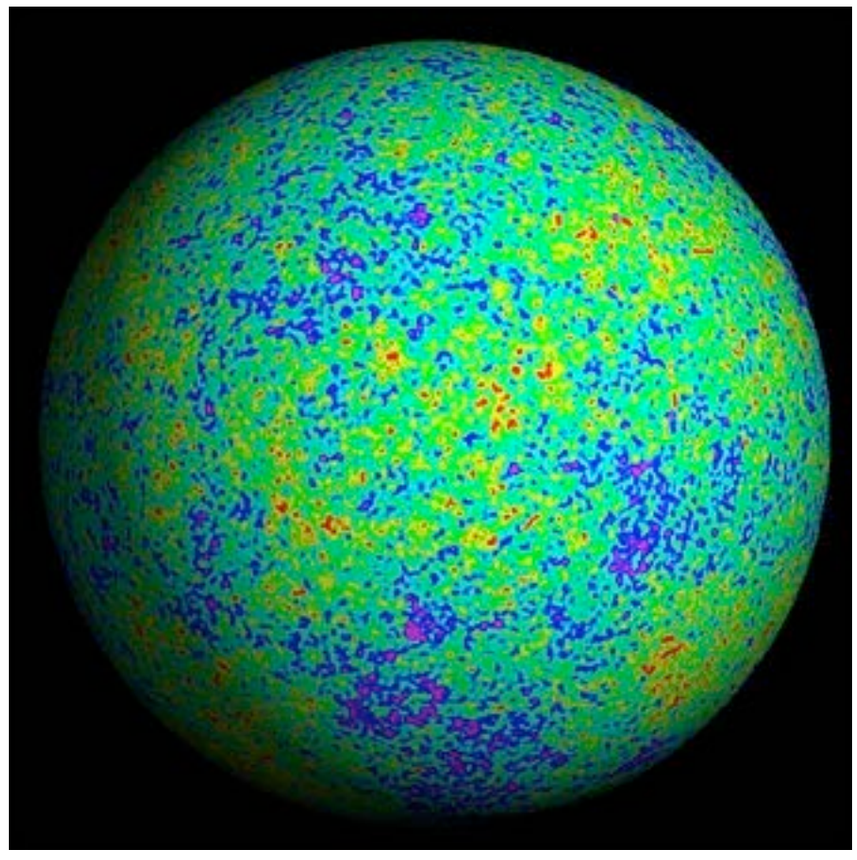
Big Bang Happened.

- No stars older than a certain age.
- Olber's paradox
- Expansion of the universe -- something set it into motion.

- CMB at T=3000K
- Observed helium (deuterium) abundances.
- early quantum fluctuations leads to 10^{-5} level density fluctuations on CMB

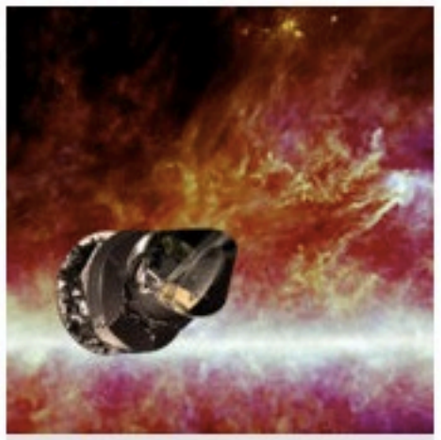
Cosmic Microwave Backgd

- currently at 3K
- universe flat: curvature ~ 0
- matter (dark matter + sprinkle baryons) ~ 0.3; dark energy ~ 0.7: $\Omega_{tot} \sim 1$
- 10^{-5} fluctuations leading to galaxies/clusters



Multimedia
- Planck images
- Planck videos
- Science@ESA vodcast

CALL FOR MEDIA: FIRST COSMOLOGY RESULTS FROM ESA'S PLANCK MISSION



Artist's impression of the Planck spacecraft

13 March 2013 Media representatives are invited to a briefing on the first cosmology data release from ESA's Planck mission. The new results include Planck's first all-sky map of the cosmic microwave background.

The media briefing is being organised by the European Space Agency at Headquarters, 8-10 rue Mario Nikis in Paris, on 21 March 2013, 10:00–12:00 CET. Doors open at 09:30 CET.

There will be an additional session in the afternoon, 14:00–15:45 CET, for the scientific community and science journalists.

Planck was launched in May 2009 and its first all-sky image, including emissions from our own Milky Way galaxy, was presented in July 2010. The first scientific dataset was released in January 2011.

After years of painstaking work, scientists have now been able to remove the bright foreground emissions that lie between us and the Universe's first light. This light was imprinted on the sky when the Universe was just 380 000 years old and seen today as the cosmic microwave background.

Planck's map of the cosmic microwave background over the whole sky is the best ever made. By analysing it in detail, scientists have made important findings about the composition and evolution of the Universe from its birth to the present day and beyond. These results will be presented at the media briefing.

Media representatives wishing to attend the event are requested to register at http://www.esa.int/media-event-planck-2013

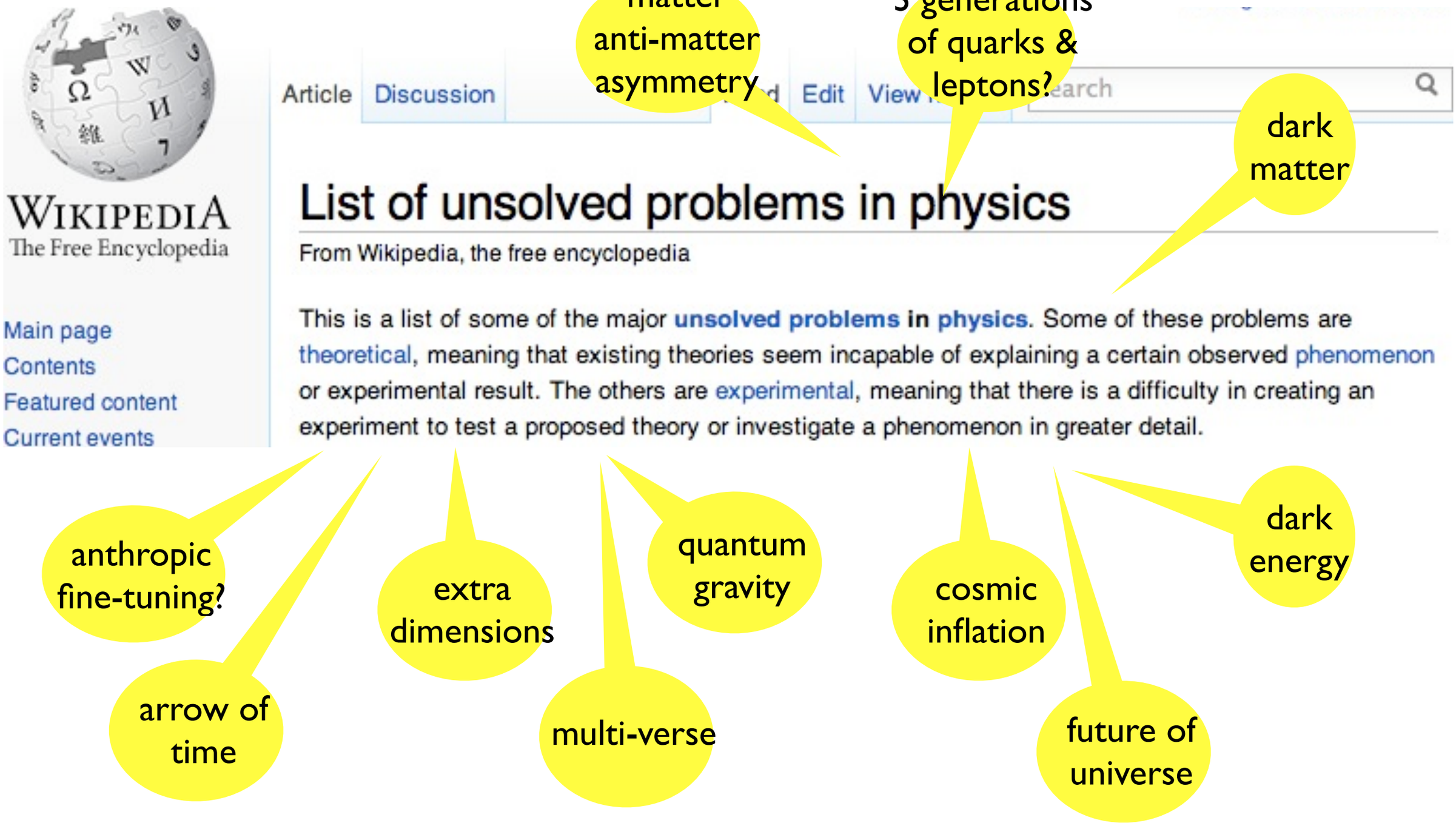
Planck: looking back at the dawn of time

In depth
- Planck in depth
- Planck Science Team

Related links
- Please register: Planck's Cosmic Microwave Background map
- Where to find us

While data from CMB, Supernova, large scale structure are in concordance with each other and establish the '**standard cosmological model**' based on inflation, dark matter, dark energy, we are in dire need of a first-principle understanding --

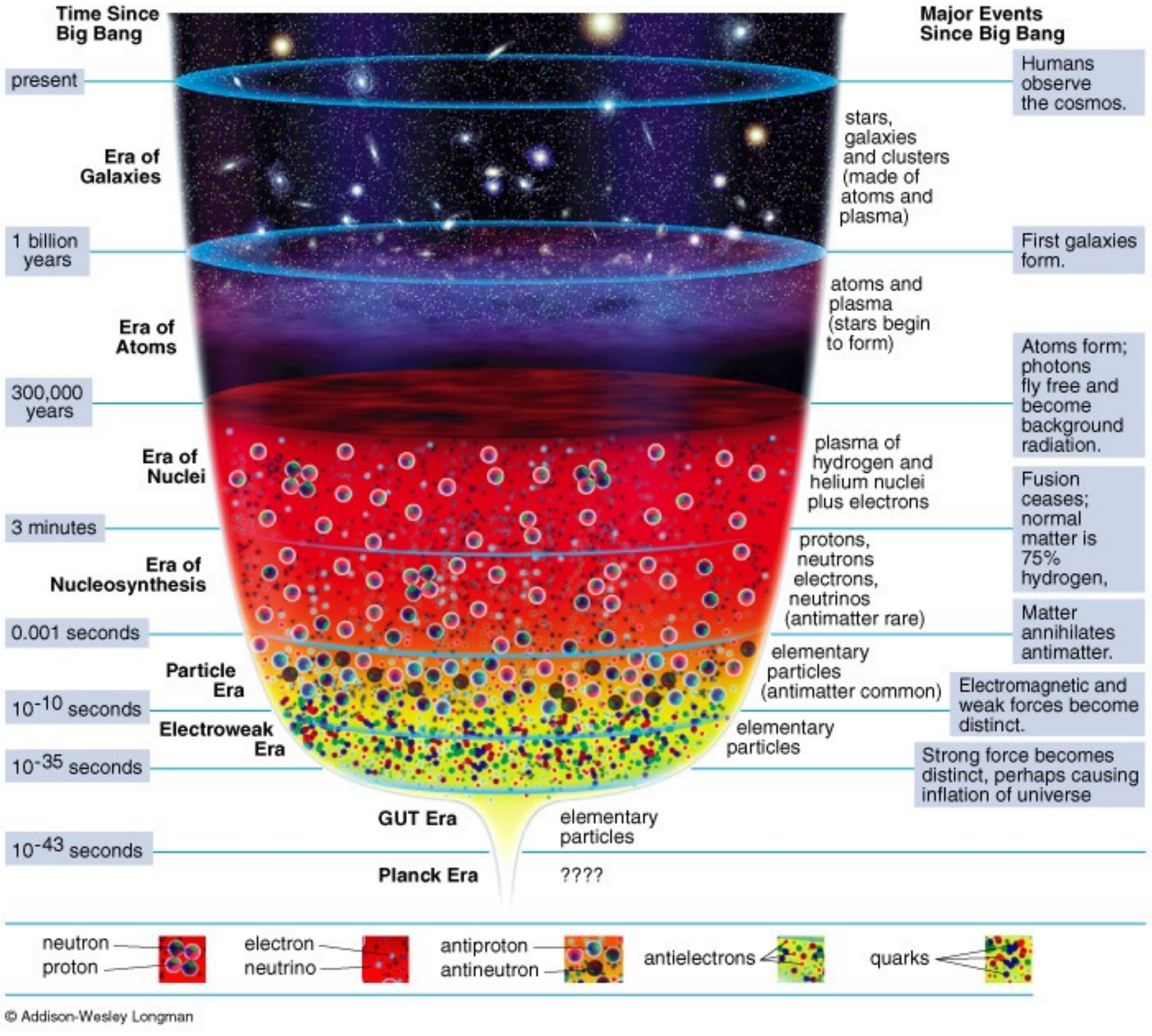
Why did the universe turn out this way?



where to seek answers?
Planck & LHC both operating now!

Safe physics

Unsafe physics



Inflation

During the GUT Era:

at least The Universe increased in size by a factor of 10^{50} in $<10^{-34}$s. A factor of 10^{50} in size is equivalent to this:

Take a proton and swell it to a size ten trillion times bigger than the present size of the entire observable universe