Light in a Dark Universe

Dalkey Island Probus

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Outline

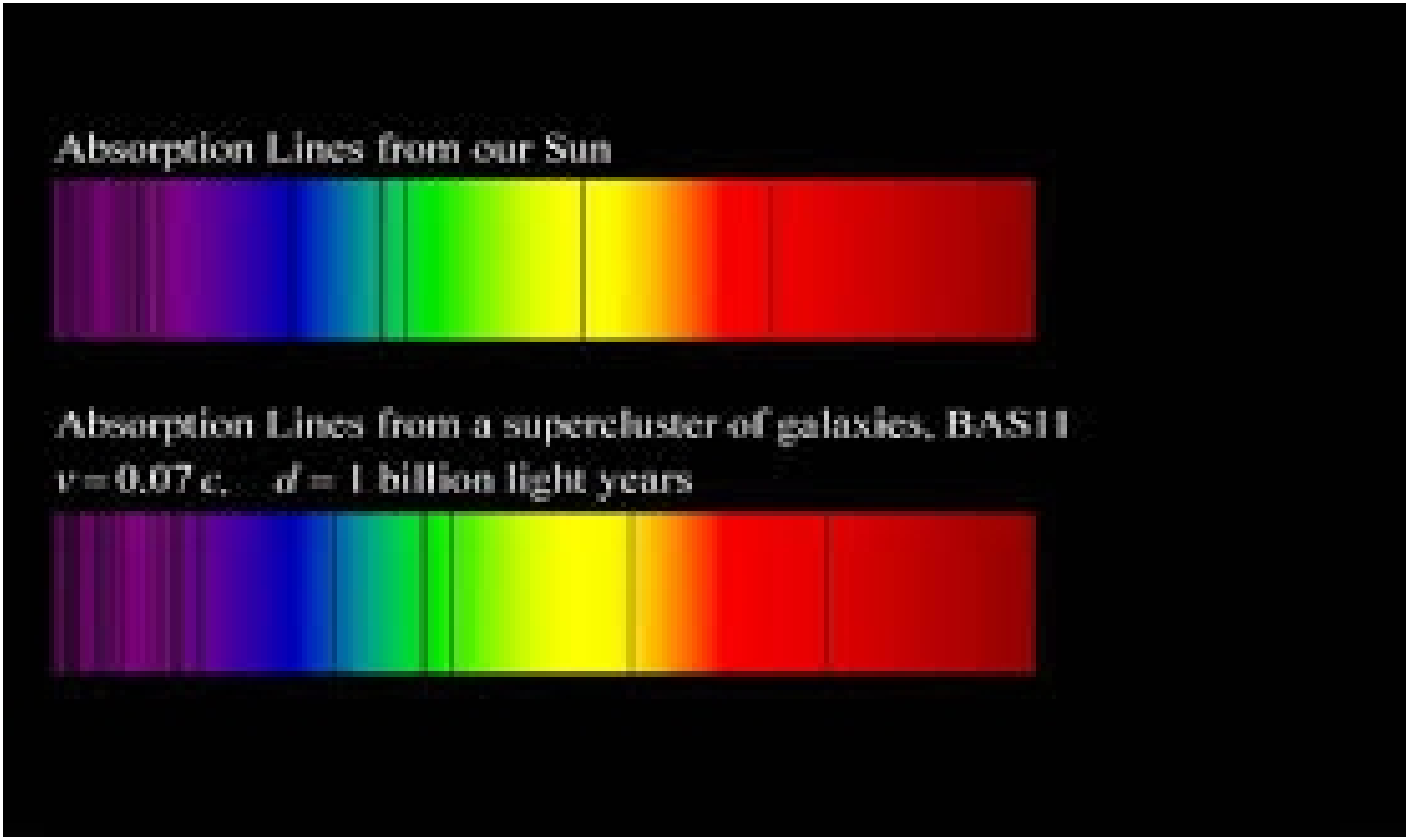
- Colour and distance from earth of the stars
- Gravity theory of 1915 applied to Universe
- Universe may contract - or expand forever
- Chemical elements are forged in the stars
- Emergence of plant and animal life on Earth
- Six episodes in the evolution of the universe

Christian Doppler (1803-1853)

1842 The colour of a star alters when the star changes its velocity; e.g., in a binary star one star approaches - the other receeds

1953 Echocardiograms and ultrasonographs routinely use the Doppler Effect today to measure blood flow and fluid flow.

Solar dark lines and the redshift of dark lines for a receding galaxy



G. J. Stoney (1826 – 1911)

looked for a formula for the hydrogen lines
which was found by Johann Balmer in 1885

$b / wavelength = 1 - 4 / n^2, \ (n = 3, 4, 5, 6)$

Margaret and Wm Huggins confirmed $n = 7$

In 1891 Stoney coined “electron” as the
"fundamental unit quantity of electricity"

Henrietta Leavitt (1869-1921)

1900 Studied 1777 stars of variable brightness from Harvard's photographic plates of the Magellanic Clouds seen by telescope

1912 She found that, the brighter the variable star she measured, the longer was the time period of its peak to peak variation

Maximum and Minimum Brightness

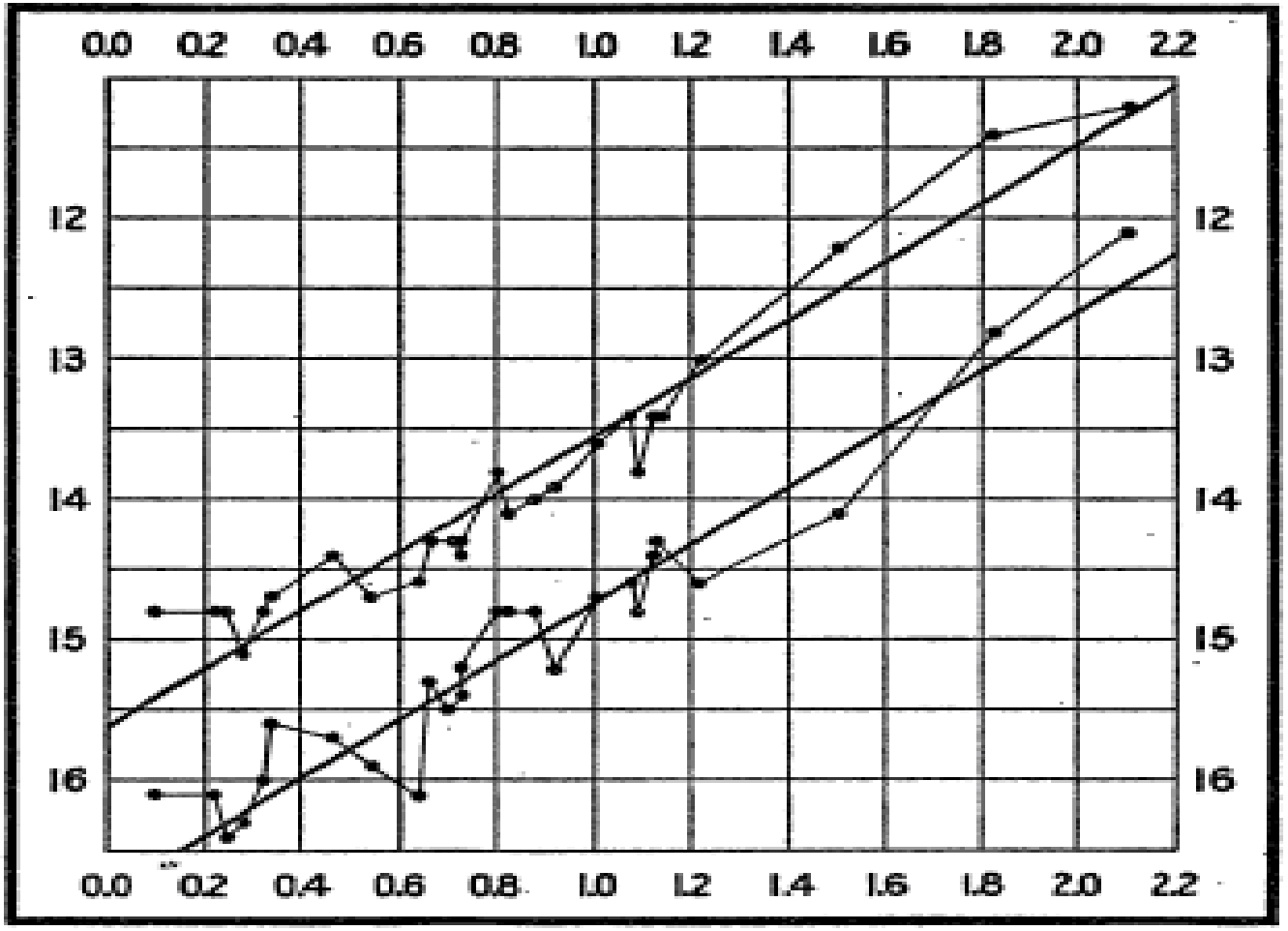
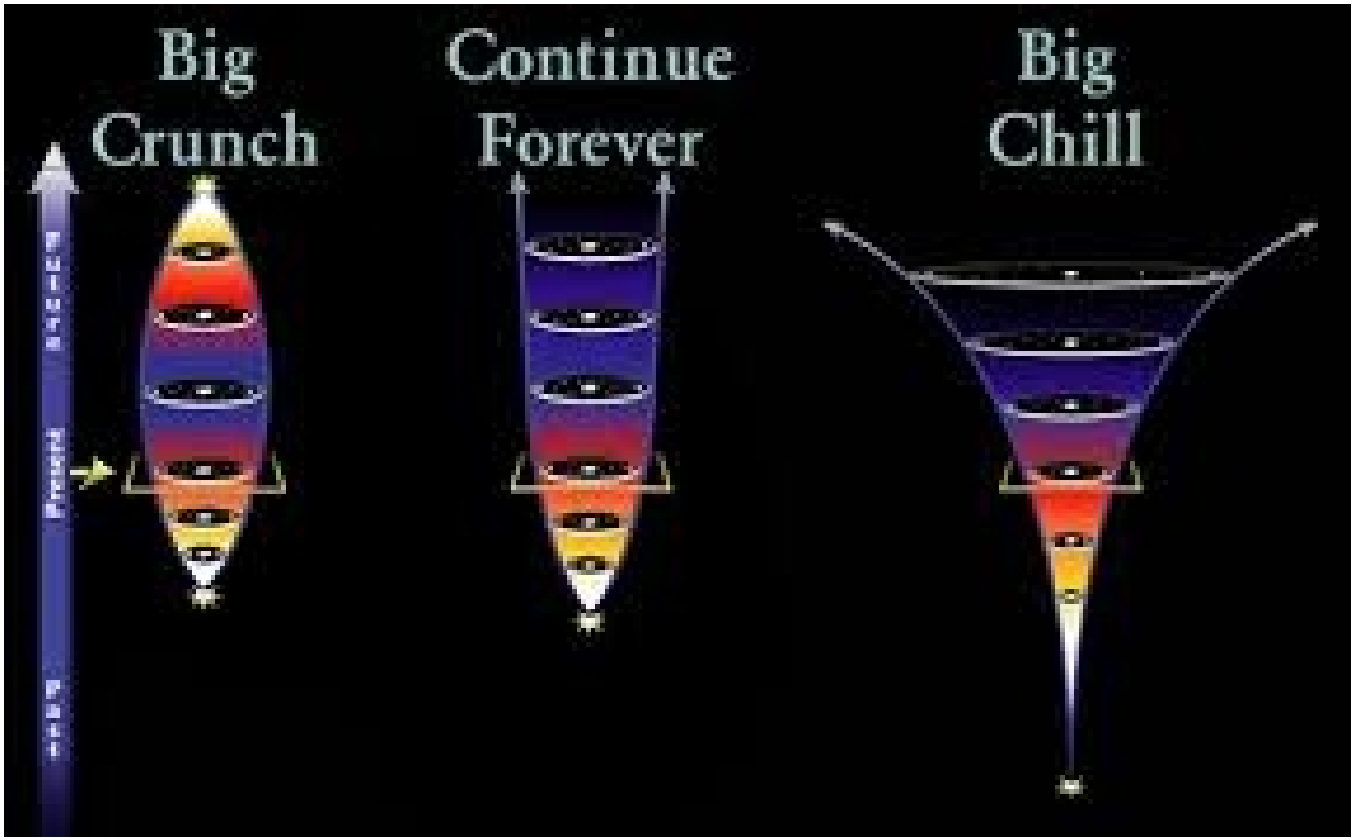


FIG. 2.

Figure from (Leavitt 1912)

1922 Alexander Friedmann (1888-1925)

1927 Georges Lemaître (1894-1966)



Edwin Hubble (1889-1953)

1924 Used variable stars to show that there were galaxies beyond the Milky Way

1929 Found a relation between distance and the velocity of many receding galaxies

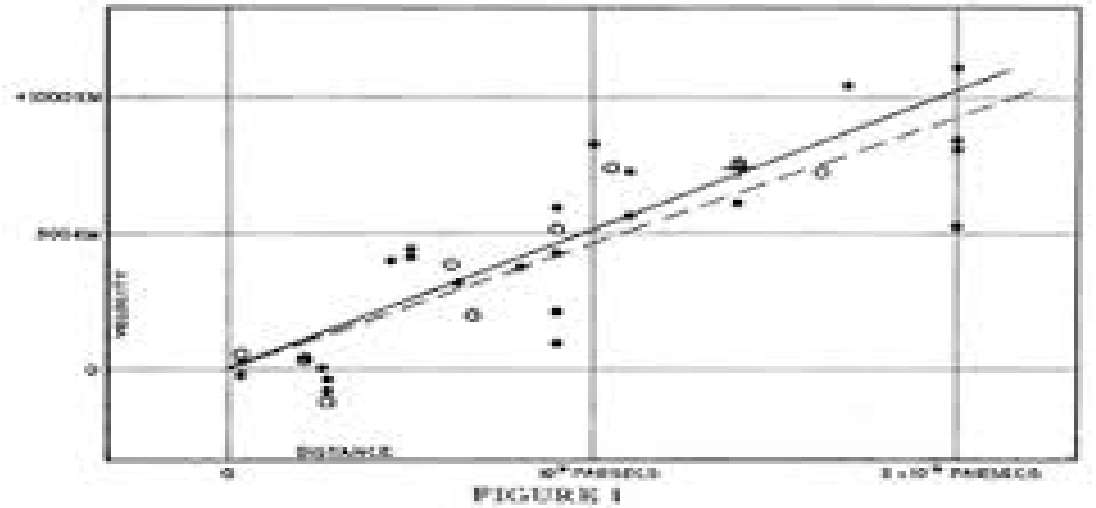


FIGURE 1

Velocity-Distance Relation among Extra-Galactic Nebulae.

Figure from (Hubble 1929)

John Wheeler (1911-2008)

expressed the gravity equation of general relativity:

“spacetime tells matter how to move;

matter tells spacetime how to curve”

$c^2 \times \text{Curvature} = 8 \times \pi \times G \times \text{Energy} / c^2$

The top of Lugnaquilla ages faster than its base by about 20 mins over its 420 million year existence.

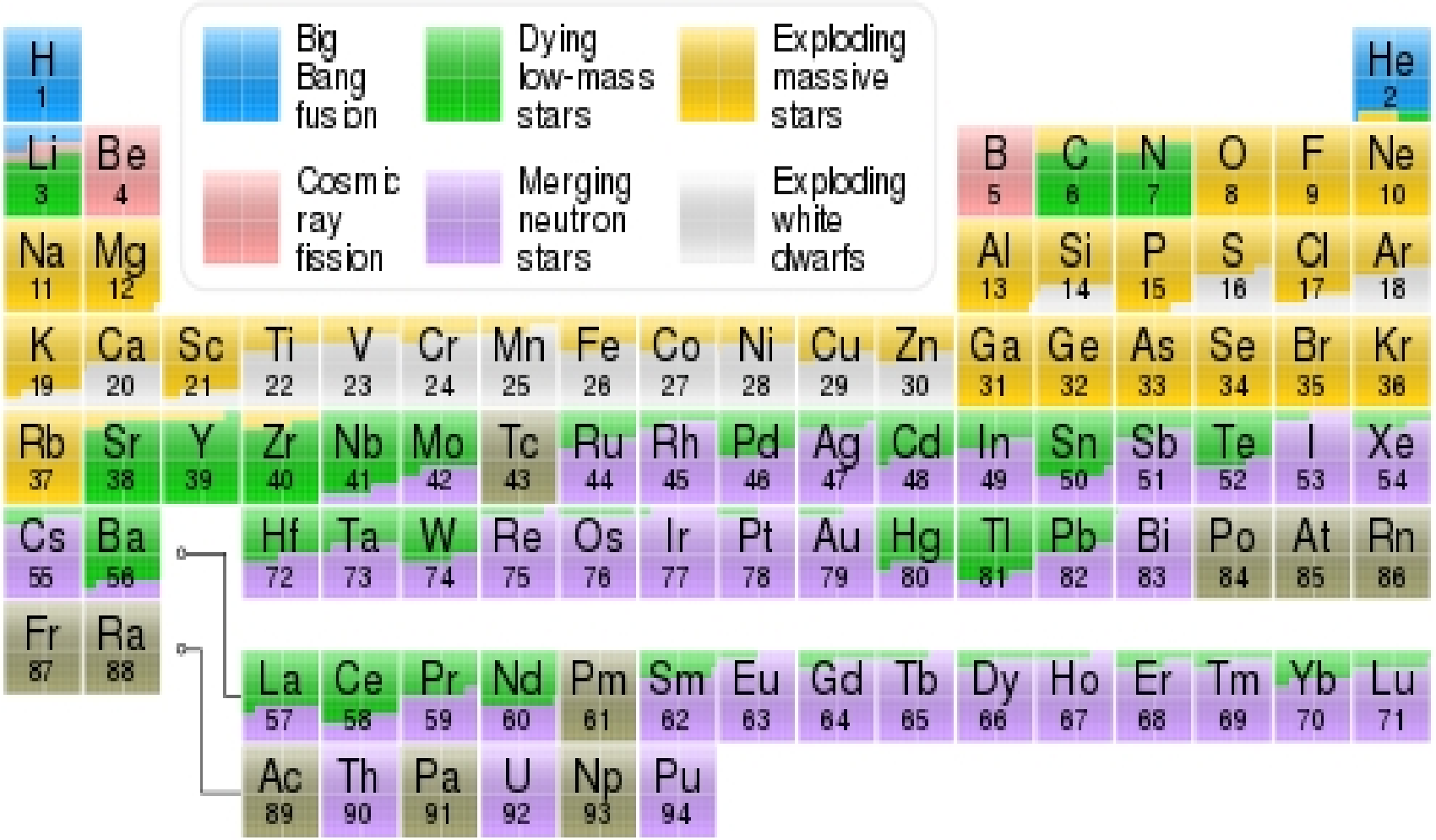
“Time is Nature's way to keep everything from happening all at once”

George Gamov (1904 – 1968)

- explained the alpha decay of a nucleus in 1928 using the quantum theory of 1926 and talked to Cockcroft and Walton about proton beams
- employed the Friedmann solution of gravity and assumed the early universe was mostly radiation to predict, in 1953, a cosmic back-ground temperature of 7 degrees Kelvin today

WALTON, RUTHERFORD, AND COCKCROFT

Chemical Elements



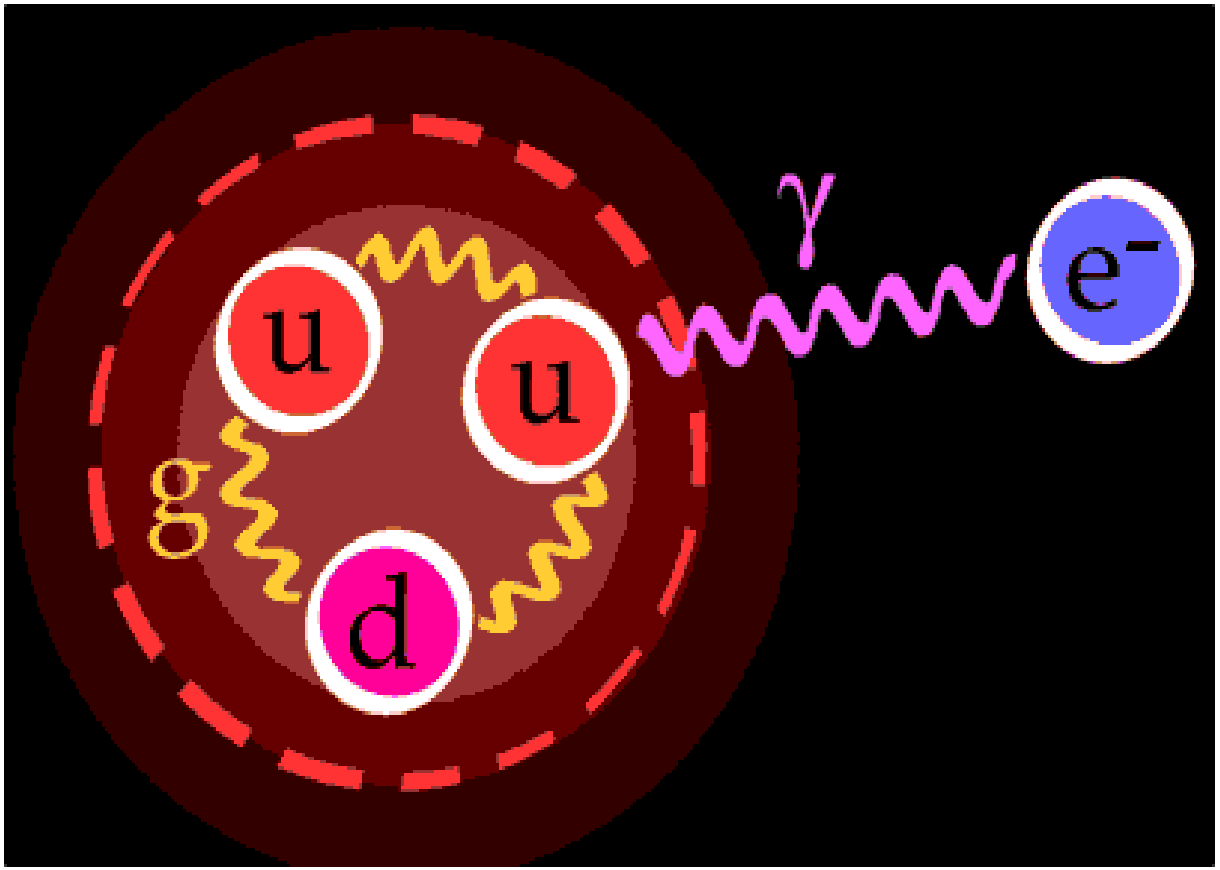
Progress in the Sixties

1963 Murray Gell-Mann introduces 'quark' as "Three quarks for Muster Mark" appears in Finnegans Wake 1939 by James Joyce

1964 Brout & Englert, Higgs, . . . , publish a mechanism for imparting mass to many fundamental particles; Higgs predicts the existence of a Boson of unknown mass

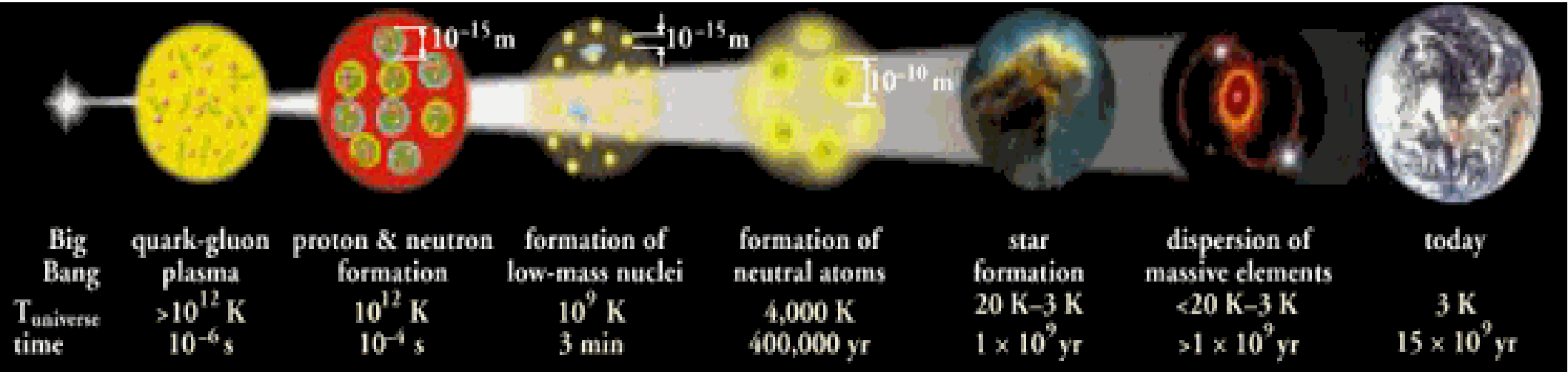
1965 Penzias and Wilson accidentally discover the cosmic microwave background (CMR)

Hydrogen atom: a proton (uud) emits a photon (γ) that is absorbed by an electron (e^-) giving rise to an attractive force between the opposite charges



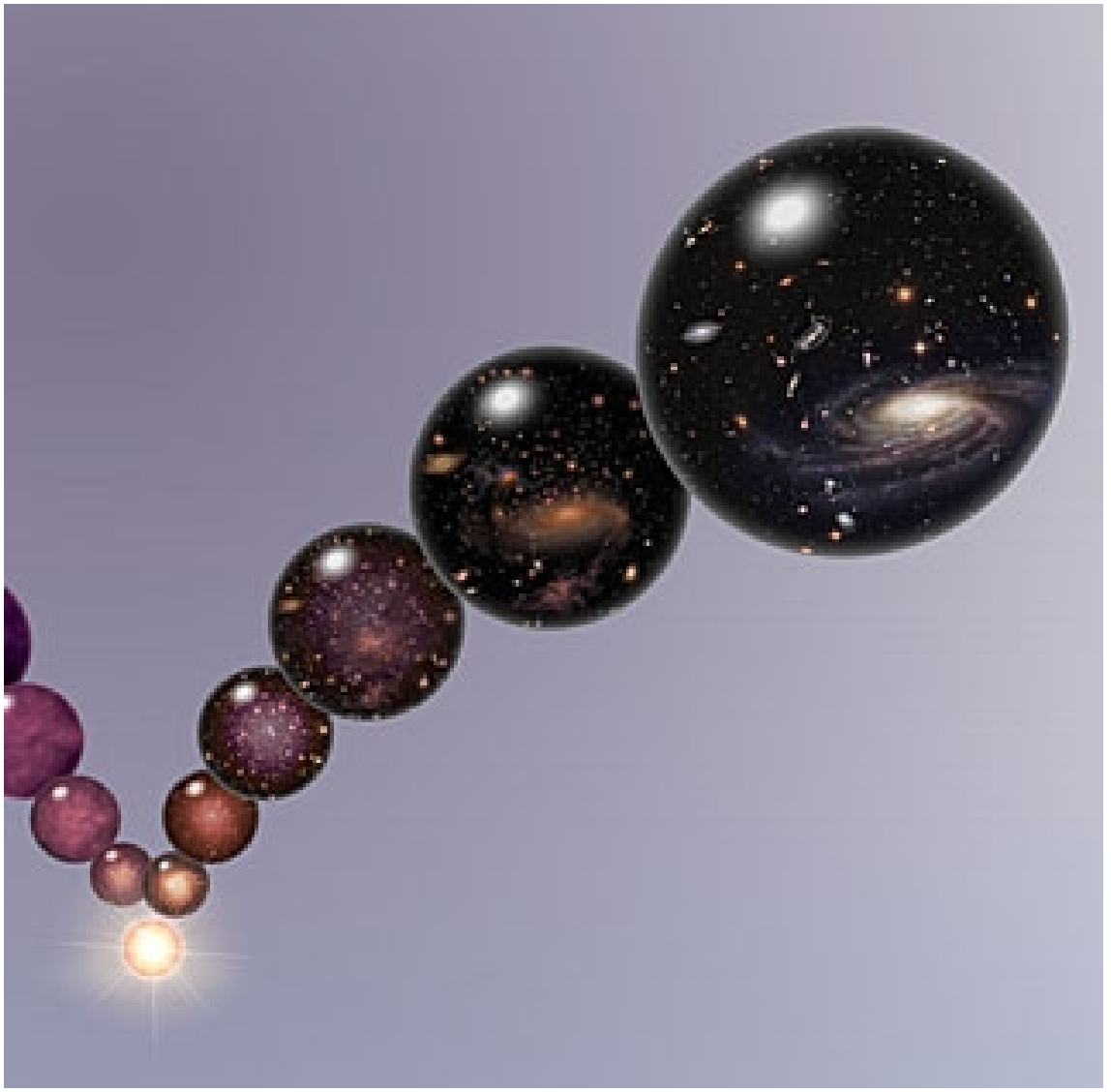
Evolution of the Universe

1 P°C	1 ps	Higgs imparts mass to fermions & weak bosons
1 T°C	9 µs	quarks coalesce to form protons and neutrons
1 G°C	3 min	neutrons and some protons form helium nuclei
4 kK	0.4 My	hydrogen and helium nuclei attract electrons
30 K	90 My	atoms condense to initiate stars and galaxies
10 K	9 Gy	sun and earth form out of clouds of star-dust



Life in the Universe

9 Gyr	Sun's fire ignites; earth & water appear
10	Life begins with the emergence of DNA
11	Cells and sunlight make oxygen in the air
12	Animals differentiate from static plants
13	Life advances from the sea to the land
13.8	Humankind studies its past and future

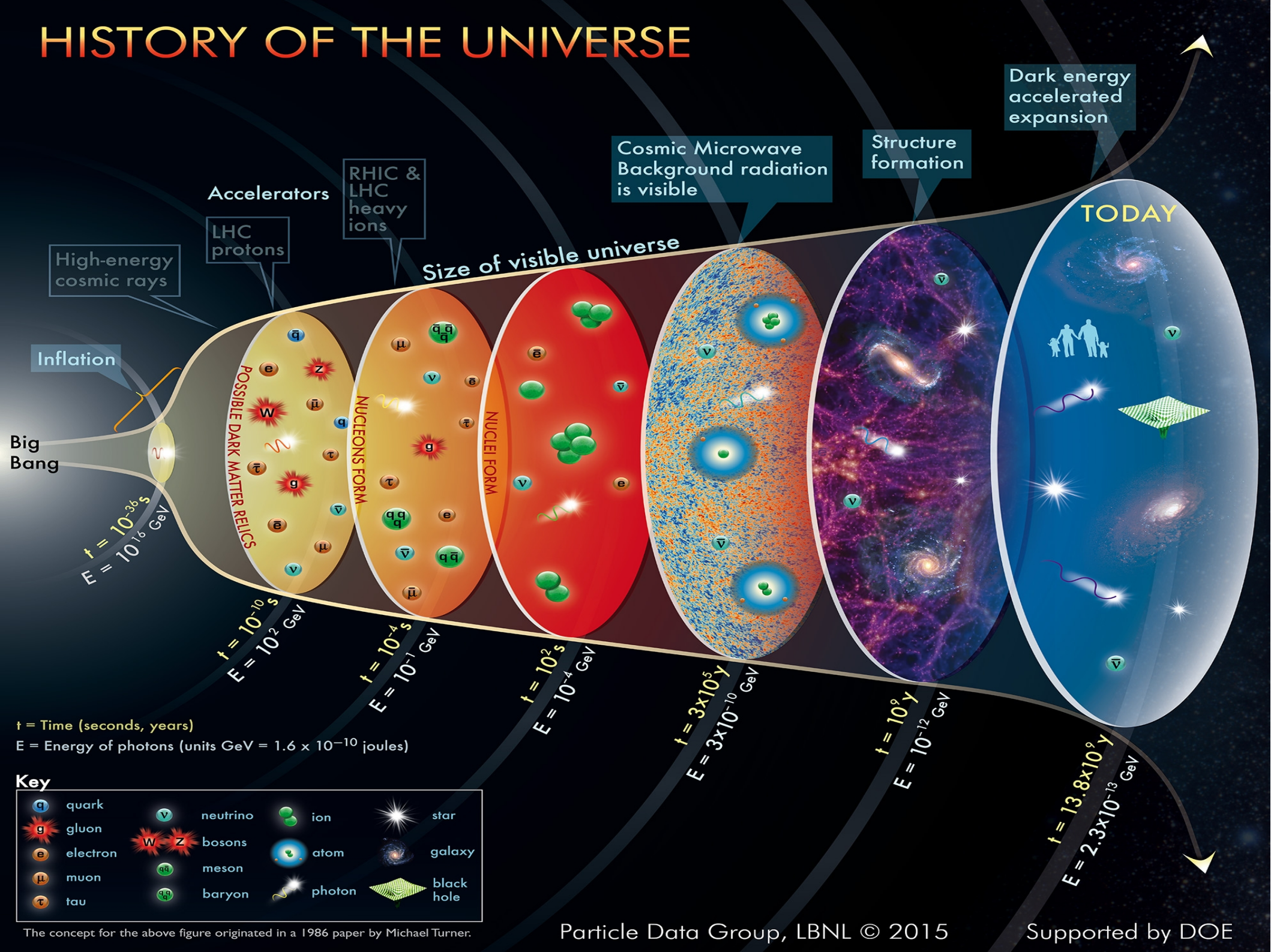


Fine-tuned Universe

If gravity were too strong compared with the expansion, the universe would have collapsed before life could have evolved.

If gravity were too weak, no stars would have formed to generate the heavier chemical elements necessary for life.

HISTORY OF THE UNIVERSE



t = Time (seconds, years)

E = Energy of photons (units GeV = 1.6 x 10^{-10} joules)

Key

- quark
- gluon
- electron
- muon
- tau
- neutrino
- bosons
- meson
- baryon
- ion
- atom
- photon
- star
- galaxy
- black hole

The concept for the above figure originated in a 1986 paper by Michael Turner.

Supported by DOE

Dark Energy (1998)

- The expansion of the universe is found to be accelerating (from a study of supernovae)
- An accelerated expansion term in the equations for gravity has been called 'dark energy' in 1998
- The Hubble space telescope indicates that dark energy has been present for over 9 billion years
- Its source is unknown – the universe comprises 68% dark energy, 27% dark & 5% visible matter