The Changing Universe

DLDK U3A
Dún Laoghaire
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Outline

• The electron was found in 1897 by J J Thomson
• Ernest Rutherford named the proton in 1920
• The fundamental constituents of the universe
• Chemical elements made in the heat of stars
• Six episodes in the evolution of the universe
• Emergence of plant and animal life on Earth
• Dark energy and the future of the universe
G. J. Stoney (1826 – 1911)

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

\[
\frac{b}{\text{wavelength}} = 1 - \frac{4}{n^2}, \quad (n = 3, 4, 5, 6)
\]

Margaret and Wm Huggins confirmed \( n = 7 \)

In 1891 Stoney coined “electron” as the "fundamental unit quantity of electricity"
Cecilia Payne (1900-1979)

Chose astronomy on hearing Eddington talk
Sun has the same composition of chemical elements as the Earth except for hydrogen
H is a million times more plentiful in the Sun when the equation of Meghnad Saha is used to adjust the spectrum for temperature effects
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 background temperature of 7 degrees Kelvin today
# Chemical Elements

![Periodic Table](image)

- **H**: Big Bang fusion
- **Li**: Dying low-mass stars
- **Be**: Exploding massive stars
- **B**: Cosmic ray fission
- **C**: Merging neutron stars
- **N**: Exploding white dwarfs

**Elements**:

- **K to Ca**: Light elements
- **Sc to Ti**: Transition metals
- **V to Mn**: Inner transition metals
- **Fe to Zn**: Transition metals
- **Ga to Hg**: Inner transition metals
- **Tl to Bi**: Heavy elements
- **Po to At**: Actinides
- **Ac to Lu**: Lanthanides

**Periods**:

- **1st Period**: Hydrogen, Helium
- **2nd Period**: Lithium to Neon
- **3rd Period**: Sodium to Argon
- **4th Period**: Krypton to Xenon
- **5th Period**: Radium to Lutetium
- **6th Period**: Actinium to Lawrencium

**Groups**:

- **1A**: Alkaline earth metals
- **2A**: Alkaline metals
- **13A to 18A**: Transition metals
- **19A to 26A**: Actinides
- **27A to 35A**: Lanthanides

**Notable Elements**:

- ** radioactive elements**: Uranium, Plutonium
- **transition elements**: Iron, Copper
- **noble gases**: Helium, Argon

**Additional Elements**:

- **Ac** (Actinium)
- **Th** (Thorium)
- **Pa** (Protactinium)
- **U** (Uranium)
- **Np** (Neptunium)
- **Pu** (Plutonium)
European laboratory for particle physics

CERN employs just over 3,000 people. Around 12,000 scientists from over 70 countries with 120 different nationalities come to Geneva & Prévessin for research.

CERN uses complex scientific instruments to study the basic constituents of matter. The particles are made to collide together to study how they interact and to provide insights into fundamental laws of nature.
The twenty two Member States of CERN

Member States (date of accession)

- Austria (1959)
- Belgium (1953)
- Bulgaria (1999)
- Czech Republic (1993)
- Denmark (1953)
- Finland (1991)
- France (1963)
- Germany (1953)
- Greece (1953)
- Hungary (1992)
- Israel (2014)
- Italy (1953)
- Netherlands (1953)
- Norway (1953)
- Poland (1991)
- Portugal (1986)
- Romania (2016)
- Slovakia (1993)
- Spain (1961-1968, 1983-)
- Sweden (1953)
- Switzerland (1953)
- United Kingdom (1953)
Englert and Higgs at CERN in 2012

Many young researchers were involved in the discovery of the Brout Englert Higgs field and its quanta, Higgs Boson (named for S N Bose)
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.
The “Standard Model” (1970s)

- Table shows the basic particles (61)
- 3 leptons and 3 quarks
- We never see free quarks
- Neutrons and protons are 3 quarks
- All particles have now been seen
- The interactions between the particles is mathematically simple but very difficult to “solve” except on big computers
- Almost complete agreement with all experiments. (0.02%)

**BUT**
- Why so many parameters? (19)
- How to combine with gravity
- Are there more particles such as WIMPS for dark matter?
- Matter/antimatter imbalance.
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
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
quarks

u s t

d c b

Higgs boson

γ

gauge bosons

W

Z

leptons

ν_e ν_μ ν_τ
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

Big Bang

Inflation

Possible Dark Matter Relics

Nucleons Form

Nuclei Form

Cosmic Microwave Background radiation is visible

Structure formation

Dark energy accelerated expansion

TODAY

High-energy cosmic rays

Accelerators

RHIC & LHC heavy ions

LHC protons

Size of visible universe

$t = \text{Time (seconds, years)}$

$E = \text{Energy of photons (units GeV) = 1.6 \times 10^{-10} joules}$

Key:

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

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

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"A universe simple enough to be understood is too simple to produce a mind capable of understanding it."

John D. Barrow