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Origins Of the Elements

8.1 The Big Bang Theory

Investigate the processes that led to the transformation of radiation into matter that followed the Big Bang.

The Big Bang theory

- **The Big Bang theory** was first proposed by Father Georges Lemaître, a Roman Catholic priest in 1927.
- The Big Bang theory proposes that the Universe began with an 'event' that produced an enormous amount of energy.
- The Big Bang event occurred about 14 billion years ago.
- The Big Bang event occurred in a position called a single position, and is also known as the singularity.
- The energy produced expanded outwards in all directions and cooled to form matter.
- The Big Bang event also signifies the beginning of time.
- *Note:* It is technically incorrect to talk about a Big Bang **explosion** because an explosion requires the existence of matter to explode – there was no matter in existence at time zero.



Father Georges Lemaître

The basic ideas in the development of the Universe from the Big Bang

- The Universe was initially compressed into zero volume and has been expanding since the 'Big Bang'.
- The Big Bang produced an enormous amount of energy.
- The temperature of the Big Bang is estimated at 10^{32} K.
- Matter as we know it cannot exist at this temperature. Only pure energy existed.
- The Universe started at intense heat and is cooling.
- As the Universe cooled, the energy started changing into matter.
- The first matter to form were the fundamental particles – leptons, neutrinos and quarks, and zero mass particles gluons and photons at time 10^{-43} s after the Big Bang.
- The energy condensed to simple particles first, then to more complex particles as its temperature fell.
- The first more complex particles were protons and neutrons at time 10^{-29} s after the Big Bang.
- As matter particles formed, the gravitational force came into existence.
- Gravity collected the newly forming particles together to form larger particles.
- These larger particles gravitated together (accreted) to form gas clouds (nebulae).
- The matter in nebulae accreted to eventually form stars.
- Millions of stars forming with large gas clouds created galaxies.



Evidence for the Big Bang theory

The spectrum shift of light from distant galaxies – Doppler effect

- This shows that the Universe is expanding, no matter in what direction we look.
- Galaxies further away from us are moving faster.

The helium-hydrogen ratio

- The Universe is composed of about 25% helium and 75% hydrogen.
- Calculations show that if the Universe began with a big bang, then hydrogen and helium would have formed in those proportions.

Cosmic background radiation

- If the Universe started with a highly energetic event, then the remnants of the energy formed should exist as a 'background radiation' of wavelength about 1 mm throughout all space.
- Two engineers, Arnold Penzias and Robert Wilson working on a new telescope at the Bell Laboratories accidentally discovered the predicted background radiation in 1964.
- In the 1980s and 1990s, following the launch of the Cosmic Background Explorer (COBE) satellite, the range of wavelengths of energy in this radiation was examined and mapped.

Not enough hot stars

- All stars (except dwarfs) fuse hydrogen to form helium.
- If the 25% helium in the Universe had been formed in this way, then most stars would be much hotter than they are because of the amount of nuclear fusion of hydrogen required.
- Calculations show that very hot stars have a very short life span and only occur in larger numbers at the edge of the Universe.
- These facts favour a big bang expansion rather than fusion inside stars.

The existence of radio galaxies

- Radio galaxies are so called because they emit radio frequency electromagnetic radiation because of the presence of the hot blue stars.
- These confirm the presence of very hot blue stars at large distances.

The presence of radio galaxies and blue stars in deep space

- If the Universe started with a Big Bang we should be able to see signs of this – light from young stars a long way away.
- Distant galaxies contain many younger, very hot, short lived blue stars.
- Light from these young stars proves their formation billions of years ago (it has taken that long for the light to reach us), thrown outwards at a huge velocity.
- This supports the idea of a Big Bang event.

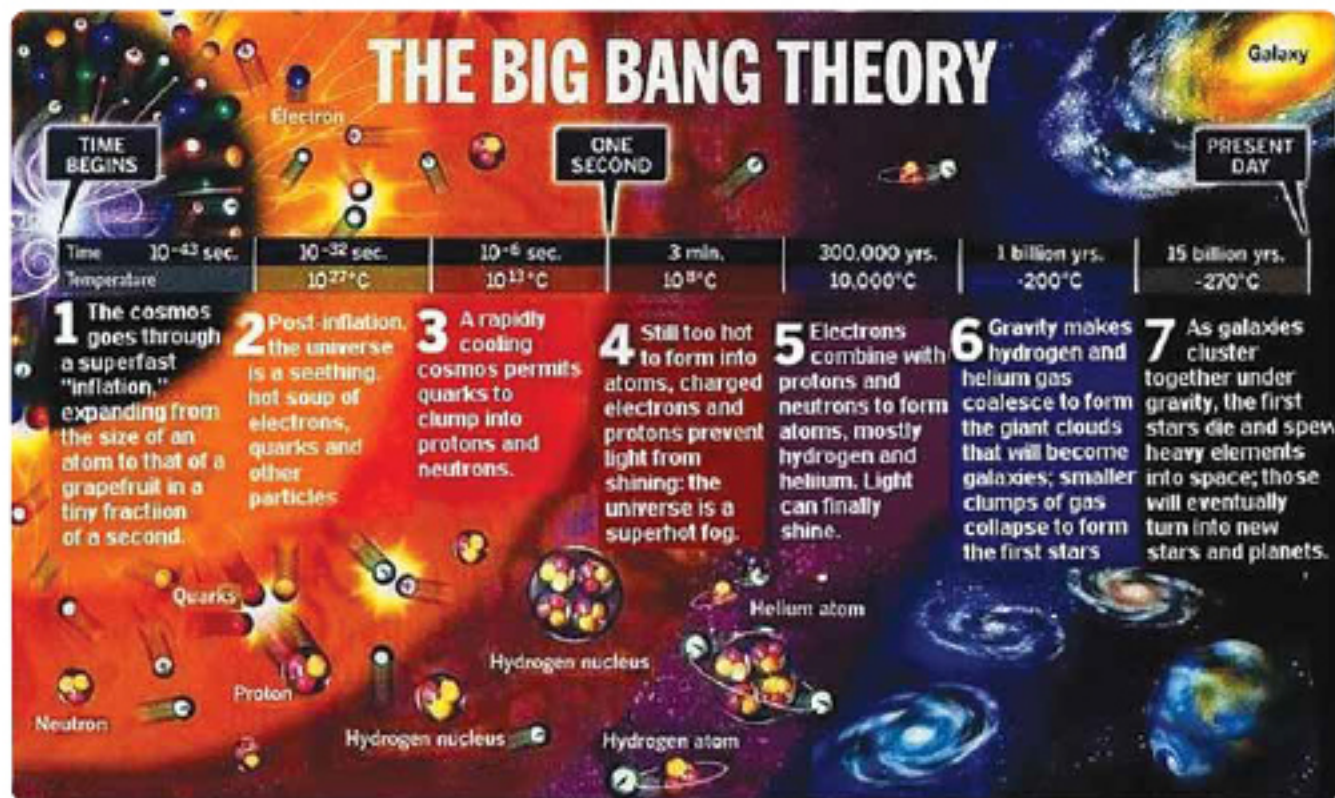
Connection between particle physics and cosmology

- Particle accelerators are producing conditions and particles that could be similar to those formed shortly after the Big Bang.
- Astronomers are hypothesising the nature of the young Universe from time zero forwards, and particle physicists are working backwards from now.
- They are both arriving at the same conclusions about an initial Big Bang event.



Sample Questions

- What is the Doppler effect?
 - Explain the term 'red shift'.
 - What two things does the red shift tell us about the Universe?
 - How does this provide us with evidence for a Big Bang event?
 - When would a blue shift occur?
- What is the measured ratio of hydrogen to helium in the Universe?
 - Why is this ratio evidence for a Big Bang event?
 - What percentage of the Universe is calculated to be composed of hydrogen and helium?
- Explain how the small number of hot stars in the known Universe provides evidence for a Big Bang event.
 - Where are most of these hot stars found?
- The discovery of radio galaxies at great distances from us provides evidence for a Big Bang event. Explain how.
 - Are there really many radio galaxies and hot blue stars at great distances from us? Explain your answer.
- Explain how the work of particle physicists is, in a way, working in the opposite direction to the events that are proposed to have occurred after the Big Bang.
 - How does this provide evidence for a Big Bang?
- What is the cosmic background Radiation?
 - How is this thought to provide evidence for a Big Bang?
- Explain how distant, very hot blue stars provide evidence for the Big Bang event.
 - Are astronomers actually seeing these stars? Explain your answer.



8.2 Ideas Leading To the Big Bang Theory

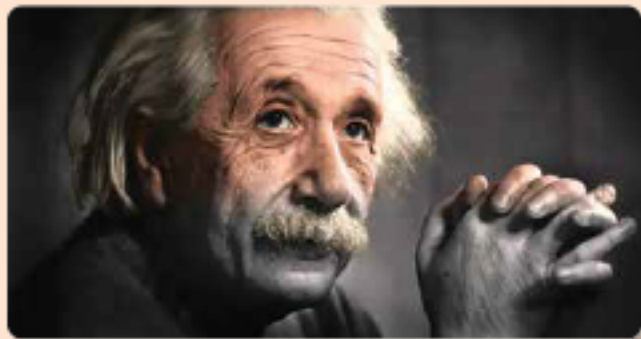
Investigate the evidence that led to the discovery of the expansion of the Universe by Hubble.

Ideas leading to the Big Bang theory

A timeline of thoughts and discovery

The information below identifies a few of the main scientists involved in the development of theories about the origins of the Universe.

- 1915 Albert Einstein
- 1912 Vestro Slipher
- 1922 Aleksandr Friedmann (1888-1925)
- 1927 Edwin Hubble
- 1927 Georges Lemaitre (1894-1966)
- 1948 George Gamow
- 1950+ Fred Hoyle
- 1955+ Martin Ryle
- 1964 Penzias and Wilson

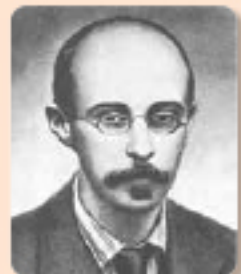


Albert Einstein (1879-1955)



Nobel Prize 1974
Sir Martin Ryle
from the presentation

• "The radio-astronomical instruments invented and developed by Martin Ryle, and utilized so successfully by him and his collaborators in their observations, have been one of the most important elements of the latest discoveries in Astrophysics."



Aleksandr Friedmann



Slipher's spectroscope



Sample Questions

1. Research the main contribution of each of the scientists mentioned above and present a two page summary of your research data.