THE STORY OF CREATION

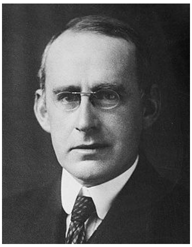
Chapter-10
THE BIGBANG MODEL

> *Science is to see what everyone else has not seen and think what no one else has thought.* (Albert Szent-Gyorgyi)

10.01. INTRODUCTION

How stars remain hot? How do they generate power for its seemingly eternal radiation? The questions are to be resolved first before we go for the story of the Creation of the Universe. The issues are intimately related.

Two fields of study, the astronomy and nuclear physics, combined to address these issues in a new field of study, *astrophysics*.



It is said that **Sir Arthur Stanley Eddington** (1882-1944), has invented the science of astrophysics. He was born in Kendal, Cumbria of England. Graduated from Manchester (1902) and then from Cambridge (1905), he became Fellow of Trinity College & Chief Assistant at the Royal Greenwich Observatory. In 1914, he became the Director of Cambridge Observatory. We already know him making experiments in 1919 to test light-bending as predicted by Einstein.

Stellar brightness is directly related to its mass. From the study of luminosity by spectroscopic method, both mass and luminosity of stars can be determined accurately. Eddington proposed in 1924 the *mass luminosity law*. Two years later, he wrote '*The Internal Constitution of Stars*'. He showed that radiation pressure played a fundamental role in maintaining stellar equilibrium. The inward gravitational pressure must be counter-balanced by outward radiation and gas pressure. Hence stellar energy would move from interior to exterior.

10.02. MAKING MATTER IN STARS

The Sun shows a composition of 70% hydrogen, 28% helium and 2% other metals. Fig:10.1 shows abundances of the elements in the

Solar system. Hydrogen and helium are most common. Next three elements (Li, Be, B) are rare as they are poorly synthesized. Two general trends can be observed. They are : (1) an alternation of abundance in elements as they have even or odd atomic numbers, and (2) a general decrease in abundance, as elements become heavier. Slight abundance of iron and nickel can be seen due to their high nuclear stability.

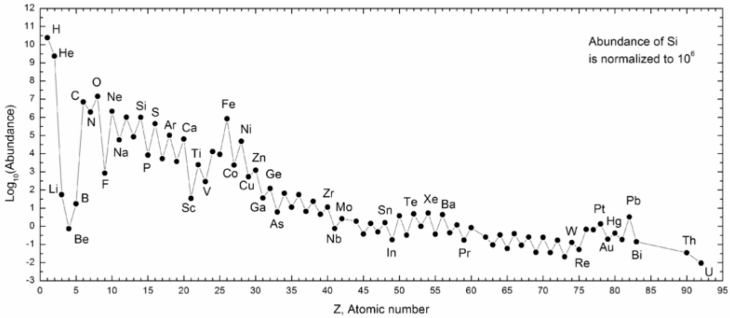


Fig:10.1.abundance of elements in the solar system

We have already seen that fission and fusion of atoms generate energy. It occurred to scientists that fusion of hydrogen into helium must be the source of energy of the Sun and other stars. A temperature of 15 million K is to be maintained in the centre to keep the visible luminosity of the surface and to hold the star against inward gravity. But this temperature is insufficient for carrying out the fusion process itself. Possibly the tunnel effect might allow fusion to occur even at 15 million K.

Well, that may be the way of burning of stars broadly. But how exactly hydrogen nuclei (protons) get converted into helium nuclei? The answer came from Hans Bethe when he explained the mechanism of energy generation in a star system.

Hans Albrecht Bethe (1906-2005) was born in Strassburg of Germany, studied at Frankfurt and Munich under Sommerfeld, and got his Ph. D. in 1928. He also worked with Rutherford at Cambridge and with Fermi at Rome in 1930-32. Bethe moved to Britain in 1933, then to USA. He was associated with the Manhattan project of USA.

The making of new matter-nucleus from some existing ones by synthesis is called *nucleosynthesis*. When it happens in a star, it is known as stellar nucleosynthesis. Bethe's paper on stellar nucleosynthesis was published in the *Physical Review* in 1939. The process involves carbon and nitrogen nuclei with hydrogen that works in a cycle. It starts and ends with making of carbon-12 in one process, converting four protons into one helium nucleus. Thereby it releases 26.72 MeV energy. The cycle is called the Carbon-Nitrogen-Oxygen cycle or **CNO cycle** (or CNO-I). In CNO-II cycle, nitrogen nuclei reacts with hydrogen to produce nitrogen again.

Table: 10.1. CNO-I & CNO-II Cycle

$C^{12} + H^1 \rightarrow N^{13} + \gamma$	or once in 1000	$N^{15} + H^1 \rightarrow O^{16} + \gamma$
$N^{13} \rightarrow C^{13} + \beta^+ + \nu_e$		$O^{16} + H^1 \rightarrow F^{17} + \gamma$
$C^{13} + H^1 \rightarrow N^{14} + \gamma$		$F^{17} \rightarrow O^{17} + \beta^+ + \nu$
$N^{14} + H^1 \rightarrow O^{15} + \gamma$		$O^{17} + H^1 \rightarrow N^{14} + He^4$
$O^{15} \rightarrow N^{15} + \beta^+ + \nu_e$		
$N^{15} + H^1 \rightarrow C^{12} + He^4$		

There emerged another process by his work with **Charles Louis Critchfield** (1910-1994) that starts with hydrogen nuclei that beta decay into a neutron via the weak interaction and builds deuterium, helium-3 and helium-4. It is called the proton-proton chain or **pp-chain**. Net effect in either way is conversion of hydrogen atom ($4H^1$) into helium atom (He^4), thereby releasing some energy.

These were brilliant breakthroughs in creating various matter out of simple elementries inside a star. So the star system is the kitchen where all pleasantries are made by the star itself. None else.

Bethe was awarded Nobel Prize in 1967 for this breakthrough. Another German scientist **Carl Friedrich von Weizsacker** (1912-2007) also discovered the same mechanism but was ignored from recognition. May be his activity on development of German nuclear weaponry during WWII went against him.

Solar energy originates mostly from pp-chain as it operates fine at 15 million K. The CNO cycle works better above 20 million K. The p-p chain operates in stars of small mass (1.5-2 M_{sun} or less). The CNO cycle is meant for massive stars. Again p-p chain would begin with hydrogen and would make helium while CNO cycle needs presence of heavier nuclei to make helium from hydrogen. Bethe's work made an impact on scientists of Kellogg Radiation Laboratory of CalTech where further works on nucleosynthesis were carried out.

Table:10.2. p-p chain

$H^1 + H^1 \rightarrow D^2 + \beta^+ + \nu_e$	or $He^3 + He^4 \rightarrow Be^7 + \gamma$	or $Be^7 + H^1 \rightarrow B^8 + \gamma$
$D^2 + H^1 \rightarrow He^3 + \gamma$	$Be^7 + e^- \rightarrow Li^7 + \gamma + \nu_e$	$B^8 \rightarrow Be^8 + \beta^+ + \nu$
$He^3 + He^3 \rightarrow He^4 + 2H^1$	$Li^7 + H^1 \rightarrow 2He^4$	$Be^8 \rightarrow 2He^4$

10.03. BIG BANG THEORY

After WWII, came the pioneering work of George Gamow dealing with the Creation of our Universe. The period was roughly 1946-50. The whole idea goes like this.

If the Universe is expanding according to Hubble's discovery, the expansion must have started somewhere in the past. If we go back, we would arrive at the time of Creation. That would be the Primeval Universe from which came the present expanding Universe.

That's a sensible argument. But how exactly the Universe was created? How it evolved into its present state? If stars can produce its energy from hydrogen and shine for million years by nuclear synthesis, what happened to the Universe at its early age? It might synthesise matter similarly by some primordial nucleosynthesis.

George Gamow (1904-1968), student of Leningrad University, studied under Alexander Freidmann. Born in Odessa, USSR, he travelled widely to Gottingen, to Institute of Theoretical Physics at Copenhagen and to Cavendish at Cambridge, during the period 1928-1931. Two years later, he left USSR for good and appeared in George Washington University to remain there for long twenty two years, from 1934 to 1956.

The baby Universe, once created, must be hot and superdense one so as to start its thermonuclear reaction – such a picture was put forward by him in 1946. Detail calculations for production of helium in the process was made two years later. A general paper was written with the help of his research assistant, **Ralph Asher Alpher** (1921-2007), for publication in the journal *Physical Review*. Interestingly, Bethe's name was included as author to fill up the gap between Greek alphabets alpha-gamma where 'alpha' stands for Alpher who passed B.Sc. from George Washington University (1943) and 'gama' for Gamow. If 'beta' for Bethe be included as author, it would complete the set of three alphabets. 'Alpha-gama paper' appeared so incomplete!

The paper was eventually published on 1st April, 1948 and became popularly known as *Alpher–Bethe–Gamow paper,* or *αβγ paper*. The detail calculations (of nuclei's capture of proton-neutron) were prepared for the Ph.D. thesis of Alpher.

How complex nuclei can be formed from simple hydrogen which is, in fact, proton?

Gamow with Alpher worked out the process of *primordial nucleosynthesis*. Their basic motive was to explain observed abundance of hydrogen and helium as a result of thermonuclear processing during early phase of the Universe. Particularly they were concerned with the issue – how the observed helium abundance could occur.

The neutron is the key element wherefrom they began. The Universe started from primordial matter of *hot neutron gas* in a *fireball of radiation*.

The beginning was described jokingly as **Big Bang** by Fred Hoyle on a BBC Radio in 1950. However the name persisted.

The superdense mass of neutron gas-cloud began to evolve and ensured supply of protons and electrons. The particles were in thermodynamic equilibrium. The temperature decreased as the Universe expanded. Free neutrons began to decay into electrons, protons and antineutrinos ($\mathbf{n^0 \rightarrow e^- + p^+ + \bar{\nu}}$).

Thus leptons (e^-) and baryons (p^+) came into existence. Alpher gave a name 'ylem' to the original mixture. The term was used by Aristotle to mean 'ultimate state of matter'. The name did not last.

At a certain stage of such cosmic evolution, nuclear fusion began. Protons and neutrons combined into heavier nuclei of deuterium, helium, lithium etc. The fusion had to depend on impact among particles in the superdense cosmic soup during first few minutes of the cosmic explosion. It was easier then for protons and neutrons to collide, overcoming their electrostatic repulsion and stick together.

The process might have worked out in the following way :

The first step was formation of deuterium (d or $^2H_1$, heavy hydrogen) nucleus, combining one proton and one neutron : ($\mathbf{n + p \leftrightarrow d}$).

Further impact would produce nucleus of unstable tritium (t or $^3H_1$) consisting of $1p^+$ and $2n^0$, or $^3He_2$ consisting of 2 protons and 1 neutron. The reactions are represented by, **d + n ↔ t** and **d + d ↔ $^3He_2$ + n**.

One neutron of tritium would soon split into proton and electron and the nucleus would evolve into helium-3 ($3He_2$) consisting of $2p^+$ and $1n^0$.

This would combine with neutron to form helium-4.

Helium-3 may also combine with neutron to form helium-1. The reaction may be represented by **$^3He_2$ + n ↔ $^3He_1$ + p**.

The helium-3 combining with another deuterium would form helium-4 consisting of $2p^+$ and $2n^0$. The equation is : **$^3He_1$ + d ↔ $^4He_2$ + n**.

Thus hydrogen would convert into helium nucleus. The conversion of helium-3 into helium-4 was not properly explained at that time. However once formed, helium could then grow into more complex elements.

In simple terms, creation (read evolution) of matter would follow the course of

neutron → proton-electron → deuterium → tritium → helium-3 → helium-4

Table:10.3. nuclear reactions in the Big Bang model.

$n^0 \longrightarrow p^+ + e^- + \bar{\nu}_e$	$p^+ + n^0 \longrightarrow {}^2_1D + \gamma$
${}^2_1D + p^+ \longrightarrow {}^3_2He + \gamma$	${}^2_1D + {}^2_1D \longrightarrow {}^3_2He + n^0$
${}^2_1D + {}^2_1D \longrightarrow {}^3_1T + p^+$	${}^3_1T + {}^2_1D \longrightarrow {}^4_2He + n^0$
${}^3_1T + {}^4_2He \longrightarrow {}^7_3Li + \gamma$	${}^3_2He + n^0 \longrightarrow {}^3_1T + p^+$
${}^3_2He + {}^2_1D \longrightarrow {}^4_2He + p^+$	${}^3_2He + {}^4_2He \longrightarrow {}^7_4Be + \gamma$
${}^7_3Li + p^+ \longrightarrow {}^4_2He + {}^4_2He$	${}^7_4Be + n^0 \longrightarrow {}^7_3Li + p^+$

Within 20 minutes, most of the nuclei had been created. When more neutrons converted into protons, they did not get enough neutrons to form higher nucleus and were left out as hydrogen. This explains overwhelming abundance of hydrogen and helium in the Universe.

It should be noted here that this theory could not go beyond the formation of helium in a significant way, though some light nuclei would be formed in the process. The Universe cooled down further. It became dominated by matter when expanded to cool down below some critical degree.

Right now our Universe contains 99% hydrogen-helium mix and only 1% other heavier elements. **Hans Eduard Sues** (1909-1993) and **Harold Clayton Urey** (1893-1981) estimated that *hydrogen abundance* in the Universe amounts to 75% by weight (1956).

Thus primordial nucleosynthesis accounts for creation of 99% of matter as hydrogen-helium. Out of this, some 33% turned into helium, rest being left as hydrogen in presence of high energy radiation. To arrive at such a state, some preconditions are there. The Universe had to start with very high temperature and high density of neutron gas. If it started with cold neutron soup, it would have transformed completely into helium. Ralph Alpher and **Robert Herman** (1914-1997) of John Hopkins Applied Physics Laboratory, calculated the possible condition of high energy radiation and found that there occurred about *a billion photon for every nuclear particle.* It meant a great fireball of radiation.

Initially radiation was opaque due to scattering of photons off electrons. After the Universe expanded and cooled below the critical temperature (3000 K), radiation separated from matter to travel on and on. The world became transparent. At our age, we should find its relic as *residual radiation.* In a paper of 1948, Alpher and Herman calculated the temperature of residual radiation to the tune of 5 K. Gamow himself in his book '*The Creation of the Universe*' published in 1952, estimated it at 50 K. Thus the figure varied between **5 K** to **50 K**.

The Universe started with proton and neutron in 50:50 ratio, instead of only neutron. Such an idea was proposed in 1950 by Chushiro Hayashi.

The Japanese scientist, **Chushiro Hayashi** (1920-2010) was born in Kyoto, Japan. After his B.Sc. in 1942 from Kyoto University, he worked in Tokyo, Kyoto and Osaka University. He pointed out that earlier than two seconds after the Big Bang (t = 0), cosmic temperature was more than 10^{10} K. At such temperature, thermal equilibrium prevailed between matter and radiation. Above that temperature, neutron would decay.

In 1953, Alpher, Herman and **J. W. Follin (Jr)** revised calculations to show how proton-neutron ratio gradually altered. It also became clear that the change of neutron-proton ratio took place largely due to collisions with electron-positron and neutrino-antineutrino, not due to radioactive decay as assumed earlier.

Gamow earlier thought of making all elements in the cosmic nucleosynthesis. It gradually dawned that heavier elements could not be made by that process. They were made in stars. Failing to understand this, Gamow's theory ran into difficulties. In 1956, he left

George Washington University for Colorado. The Big Bang team that once ventured into thinking of our Great Creation, went off with his transfer. However, the team raised two important issues. Wherefrom the initial matter would come from and what should be the residual temperature if radiation followed the course that they envisaged.

10.04. ALTERNATIVE MODELS

In the year 1948, the British astronomer Fred Hoyle and two Austrian-born astronomers **Thomas Gold** (1920-2004) and Sir **Hermann Bondi** (1919-2005) put forward another model, known as **Steady State Universe**. They discarded the idea that the Universe had a beginning and evolved from a primordial stage. According to them, the world had no beginning and remains in a steady state forever. As there is no beginning so there is no creation at all. That's a unique way to solve the issue of creation in scientific terms, appealing to divine eternity.

Sir Fred Hoyle (1915-2001) was born in Gilstead, Yorkshire. He studied at Emmanuel College in Cambridge and earned Fellowship at St. John's College (1945). He was Plumian Professor (1958) and Director of Theoretical Astronomy of Cambridge from 1967. Bondi and Gold were both born in Vienna, Austria. The approach made by Bondi and Gold was somewhat different from Hoyle but the end-result was the same.

Hoyle worked to modify Einstein's equations and explain creation of matter. Bondi-Gold modified cosmological assumptions to assume that the Universe is homogeneous and isotropic in time as per Perfect Cosmological Principle (PCP) instead of homogeneity and isotropism in space.

If the early Universe contains everything, it must also contain the same laws of physics. But in a changing Universe, this cannot be the case. Hence the Universe must remain in a steady state so that laws of physics may apply at all times. Further as PCP requires same material density as it is now or 10 million years later, so expansion must be balanced by continuous creation.

How new matter can be continuously created? It would be created from reservoir of -ve energy, known as C-field. The C-field has no mass, no charge, no spin but only appear at the time of creation. It conserves total energy. Expansion and creation are two opposite process. They are kept in balance by a steady state by creation of new matter.

In this theory, singularity-breakdown, a problem with Big Bang theory, can be avoided. As galaxies move away from each other, new galaxies are continually forming in the gaps in between, from new matter that are being constantly created. The Universe would look almost same at all points of space and at all times. Rate of creation of matter is about 1 particle/cu.km/year. The theory predicted that number of galaxies or similar objects in any given volume of space should be same wherever and whenever we look into the Universe. But the problem is, no observational evidence is available to support this theory.

A new theory of gravitation was proposed in 1964 by Fred Hoyle and J. V. Narliker. The Indian scientist **Jayant Vishnu Narliker** (b1938) is presently a Professor of Astrophysics in the Tata Institute of Fundamental Research of Bombay, India.

Hoyle-Narliker assumed an eternal steady state universe with some regions in expansion while some others in repulsion. The Universe contains isolated particles well-separated from all others, which at long range attract one another but at close range repel. Hence gravitation changes sign as it changes from attraction to repulsion at different places.

In 1971, Hoyle and Narliker proposed another theory to explain singularity. They allowed '*mass contributions to be both +ve and -ve from different regions of the Universe. This may have interesting consequences. First the possibility exists of having regions of space where particles have zero mass. As we go away from these regions the magnitude of inertia increases. These regions of zero mass region turn out to be closely related to singular epoch t=0 of a big bang Universe*.' (from *The Structure of the Universe*, by Narliker p-172) Thus when inertia is allowed to vary with time, the Universe turns out to be 'flat, non-expanding space of special relativity'. Galactic red-shifts do not occur due to cosmic expansion but due to the fact that '*the masses of atomic particles were smaller in the past than they are now*'. (Ibid)

Twenty two later, Sir Fred Hoyle, G. Burbridge and Narliker proposed a variation of steady state theory. This may be termed as **Quasi-steady state cosmology** in which authors present '*an alternative scenario*' for '*viable alternatives*'. They claim several advantages in this theory. Curiously, the idea as yet has no big takers.

Scientists are mostly working on improvement of Big Bang cosmology. Narliker wrote, '… *just as the proof of the pudding lies in the eating, the proof of a cosmological theory lies in its observational tests. It is these that will ultimately decide whether a theory stands or falls*'. (from *Elements of Cosmology* by Narliker p-86)

10.05. MAKING OF NUCLEONS

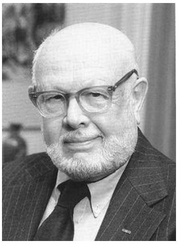
When Gamow tried to find out ways to prepare heavier elements in the early Universe, the steady state scientist Fred Hoyle looked for some processes to prepare all elements inside the star. Hoyle published two papers, in 1946 and in 1954. Some years ago, Hans Bethe had shown ways of cooking some heavier elements inside the star.

In our present Universe, stars are made up of different elements in different amounts. All these elements were perhaps cooked inside later generation stars. Our Sun is 2nd or 3rd generation star. The first generation stars got their resources from primordial cosmic matter created in the Big Bang. Apart from hydrogen and helium, traces of elements like beryllium-7 (Be^7), lithium-7 (Li^7), beryllium-8 (Be^8), and boron-8 (B^8) were there. The question remains how other heavier elements can be made? It was a major theoretical problem.

Actually scientists were busy to overcome the instability of boron-8 nucleus. Hoyle suggested that collision of boron-8 nucleus with three alpha particles might evolve into carbon-12 nucleus. That was a good possibility which Gammow could not suggest. Later, it was observed that making of carbon-12 by that way in the early Universe would not be possible since the world then must be too thin and cold to do that. However it is possible to make it inside stars where higher temperature and denser condition is available. Further, the nucleus (carbon-12) should exist in an excited state and only then sufficient carbon-12 could be made.

In 1953, Hoyle came to CalTech. He was then almost convinced that all heavier elements were made inside stars. Given simple matter like hydrogen-helium, heavier matter could be created. In other words, simple and light matter would evolve into complex and heavy matter. Meanwhile Willy Fowler, **Charles Christian Lauritsen** (1892-1968), **Thomas Lauritsen** and **Charles Cook** were successful to make excited carbon-12 from decay of boron-8. This proved Hoyle's prediction correct. In the process, some excited carbon-12 may decay into three alpha particles which would combine to form carbon-12 nucleus.

Earlier it was known that stars only burn hydrogen to make helium. Then we discovered that they also burn helium to make carbon. This helium-burning explains formation of red giant stars and supply of necessary carbon required for CNO cycle for operation in later generation stars.



William Alfred Fowler (1911-1995) in Pittsburgh and was graduated from Ohio State University (1933). His Ph.D. came in 1936 from CalTech, Pennsylvania. He was associated with Kellog Radiation Lab. The wonderful idea of stellar nuclear synthesis emerged from Hoyle's papers. In 1954-55, Fowler went to Cambridge to work with Hoyle and Burbridge couple. In 1956, **Eleanor Margaret Burbidge** (b1920) and her husband **Geoffrey Burbidge** (1925-2010), together with Fowler and Hoyle, published a short paper in *Science* on stellar nucleosynthesis. Soon they wrote another paper in long 104 pages for *Reviews of Modern Physics* next year. The paper provided answers to most of the puzzle of stellar nucleosynthesis. It showed in details how all varieties of nuclei, can be made inside stars. The four scientists are often quoted as **B^2FH**.

Assuming 70-75% hydrogen and 30-25% helium making first generation stars, all other heavy elements were made in later generation stars. Stars at first consumed hydrogen to make helium and then consumed helium to make carbon-oxygen. When old stars exploded, these heavy elements had been thrown away in the stellar cloud. This eventually enriched the raw material for later generation stars. In giant stars, **α-process** works out to cause fusion of helium nuclei into oxygen-16, then into neon-20, magnesium-24, silicon-28, sulphur-32 nuclei. The process would eventually make heavier nuclei of nickel, cobalt and iron.

In this way, varieties of elements could be created in Nature, starting from simple hydrogen-helium mixture. The Universe with such an humble beginning, evolved into complexities of higher order. None created these elements, from helium to iron. Our Grand Nature created itself by its own operating principle.

But there is one major drawback in the theory. Someone must explain wherefrom came this abundance of hydrogen and helium in the early Universe. Some explanation came later from other Big Bang scientists.

Fowler was awarded the Nobel Prize in 1983 for his brilliant work but other members of B^2FH were excluded.

Gamow's work about making hydrogen-helium during primordial nucleosynthesis was not adequately acknowledged at first. Calculations began after a long gap, around 1964, by several scientists, e.g. Yakov Boris Zeldovitch in Russia, Hoyle and R.J.Tayler in England and Peebles in USA. The calculations indicated that there should occur interesting relics of early Big Bang Universe and the relics would be in the form of helium abundance, deuterium abundance and neutrino background. The relic evidences should be observed in our present Universe. Hoyle and Tayler further pointed out that large helium abundance cannot be produced by ordinary stars. So, some 36% helium had to be produced in the early world.

Helium production in cosmos was first calculated by Jim Peebles at Princeton. It was in 1965. Willy Fowler with his student **Robert Vernon Wagoner** who switched from mechanical engineering to physics and Fred Hoyle, made these detail calculations. They established in 1967 that elements heavier than helium could not be produced by any significant amount in the Big Bang. The percentage of helium-4 should be around 25%. Some amount of deuterium, helium-3 and traces of lithium-7 would also be produced. Curiously they are available in our Sun exactly in the same ratio.

Deuterium abundance became an important pointer to the success of Big Bang theory. Wagoner calculated that if its abundance ranges in 600 parts per million, it would suggest photon/nuclear particle ratio as 10,000 million; 16 and 0.00008 parts per million abundance would indicate the ratio as 1000 and 100 million respectively. Cosmic deuterium abundance was also explored by artificial satellite Copernicus in 1973. The interstellar medium between solar system and β-Centaurus indicated an abundance by weight in the range of 20 parts per million. It means about 1100 million photons per nuclear particle. This points out that the Universe possess very small amount of matter that makes it an open Universe with continuous expansion. The critical density of nuclear particles required for a closed Universe amounts to 3000 per million litre when the observed density is only around 500.

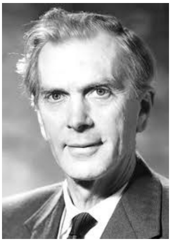
What we may conclude at this stage? The hot Big Bang Universe could not make elements heavier than helium but stellar nucleosynthesis could make everything heavier than that. In order to get the complete picture of Creation of our world, we have to combine both. Thus the Big Bang theory needed the help of stellar nucleosynthesis to come out as a successful theory of the Universe.

One consequence of Big Bang theory is that **primordial neutrinos** produced in this very early Universe, should be around us with 1000 million neutrino-antineutrino per every nuclear particle at temperature of 2K. Its detection would be another confirmation to the Big Bang model. Scientists are yet to device methods to track down those elusive particles.

10.06. RADIO TELESCOPE

The sky gives us not only light but also radiation like radio waves, infrared waves and X-rays. We see only part of these world in the visible light range. Lots remain invisible to our naked eyes. Still they are real things.

Man made radio telescopes to observe through radio waves coming from various sources in the sky. Between 1950 and 1960, a group of scientists at Cambridge, England, led by Ryle made a survey of radio sources from outer space.



Martin Ryle (1918-1984) was a graduate from Oxford (1939) and worked in Cambridge. He won the Nobel Prize with Hewish in 1974. His major contribution was organisation, construction, development and use of radio telescope at Cambridge.

First Cambridge Catalogue survey with new radio telescope was denoted by 1C. The next survey 2C was complete by 1955. Four years later 3C survey was published.

Surveying the sky, scientists located most of the radio sources lying outside our galaxy. Further there are many weak sources than strong ones. Again there are less common sources per unit volume of space for strong or nearby sources than for weak or distant sources. The findings may be explained either way. It may be that we are at centre of a great region in which sources are fewer than elsewhere. Otherwise sources were numerous in the past at the time radio waves left the source than they are now. Whatever may be the explanation, it went against the idea of immortal eternity.

The discovery of microwave radiation put the last nail in the coffin of the steady state theories. With the discovery micro-radiation, we may say that the Universe was denser in the past than its present. Hence the world cannot remain in same state forever.

These two observations, radio-galaxies and micro-radiations, became strong evidence against the steady state model of creation. Many believe that there is no more chance for any alternative scenario by steady-state-believers. Some still holds that their views with refinements might be a '*good exercise*'.

10.07. MICROWAVE RADIATION

The discovery of microwave background radiation passed through many interesting episodes. Nobody looked to it when it showed up on its own. And then it finally showed up when something else was searched for.

As early as 1940, **Walter Sidney Adams** (1876-1956), the Director of Mt. Wilson observatory, observed interstellar spectra corresponding to cyanogen (CN), a stable compound occurring in cool clouds of dust and gas. **Andrew McKeller** (1910-1960) of Canadian Dominion Astrophysical Observatory, made spectroscopic analysis of the cloud. It indicated a temperature at 2.3 K. The temperature of cloud as low as that, demands some explanations. If scientists took notice it, there would have been a possibility to interpret the observed temperature as the background radiation. But none cared to look at. Data were well known but nobody could hit upon the Prize-winning idea. Even after Gamow's team calculated the expected radiation temperature, the search for relic radiation was not conducted in right earnest. It was discovered later in a coincidence.

Robert Henry Bob Dicke (1916-1997) was born in 1916 at St. Louis of Missouri USA, was graduate from Princeton, Ph.D. from Rochester University (1941), and joined MIT before joining in Princeton in 1946. At MIT, Dick and his colleagues made an instrument to measure very short wave radiation in the microwave part of electro-magnetic spectrum. When they pointed out the instrument towards the sky, it measured very short radio micro-waves. In a paper published in 1947 in *Physical Review*, they said that background radiation should occur at a temperature below 20K. As their instrument was not sensitive below 20K, they could not collect any data. Incidentally, the paper was published in the same volume with Gamow's paper of 1946. The two papers should have intrigued anybody. But that did not happen. Dicke himself buried his observations in memory.

In early 1960s, Dicke turned towards cosmology. He was then tossing with ideas of oscillating Universe. The job of calculating temperature fluctuations of oscillating Universe was given to a young researcher named Peebles. The work was almost like investigating the Big Bang model. Peebles argued that residual heat radiation of the early Universe, could be measured only in microwave radiation. He did the same calculations Alpher and Herman made fifteen years ago. If the early Universe once glowed white-hot and dense, we may get glimpses of light of the distant past right now. But it would reach us red-shifted due to expansion of the Universe and converted into microwave radiation. Microwaves are light waves with frequency of 10,000 million waves per second. The present world would be then filled up with background radiation at temperature of 10 K or so.

The Canadian-American scientist, **Jim James Edwin Peebles** (b1935) was then with Princeton. In 1964, Dicke engaged two other research staff, P. G. Roll and D. T. Wilkinson, to look for background radiation. They set up a detector for this purpose and were preparing to fix an antenna on the roof of physics laboratory at Princeton. Meanwhile events began to roll in another way.

Arno Allan Penzias (b1933) and **Robert Woodrow Wilson** (b1936) were then working at Holmdale in Bell Telephone Laboratory in New Jersey. They were testing a sensitive microwave detector. Penzias was born in Munich but left Germany in 1939 and came to New York via England. He was graduated from City College of New York (1954) and got Ph. D. from Columbia (1962). He joined Radio Research Laboratory of Bell Labs at Crawford Hill near Holmdel, New Jersey, in 1961. Shortly he met the radio astronomer Wilson who was an American born in Houston Texas. Graduated in1957, Wilson joined CalTech and completed his Ph.D. in 1962. Next year he joined Penzias and created a history.

Apart from the Princeton group of Dicke and Peeble, several groups were preparing themselves to find out background radiation at about the same time. The English group was led by Fred Hoyle and Roger Taylor, two Soviet groups by Y.B. Zaldovich-Yu.N. Smirnov and A.G. Doroshkevich-I.D.Nobikov. But the best antenna for the job was only available at Bell Lab at Crawford Hill where Penzias and Wilson was working. It was a 20ft **horn antenna**. The antenna was originally intended to work with the Echo series of satellites for some other purpose. Engineers found the system heavily loaded with background noise that should be eliminated.

Fig:10.2. Horn Antenna.

When Penzias and Wilson tuned the antenna at high microwave frequency of 4080 megahertz (short wavelengths of 7.35 cm), the instrument picked up more noise than they had expected. So they began to track down the source to eliminate them. They cleaned up even pigeon droppings from the antenna but the radio noise did not go. Why the noise could not be eliminated? They moved the antenna and checked that it was not coming from any particular direction. Rather it showed the same amount of noise in all directions.

Rays from our horizon usually travel more through the atmosphere than overhead source. Still the noise was found the same. It did not change through day or night. So we may conclude that it was not coming from the earth. The source appeared to lie outside the atmosphere.

Again the noise was same throughout the year, thus unaffected by the position of our earth with respect to our Sun. Hence we may conclude that it was coming from source beyond our solar system. It did not originate from our galaxy because then Andromeda galaxy should have radiated the same and that could have been detected. So the source must be beyond our Galaxy. No other explanation was found to fit in except one that fixed its source at an extreme border of the Universe. The noise never varied by more than 1 in 10,000, an all directions. This confirmed Friedmann's assumption that Universe looks the same in all directions.

Penzias discussed the problem with fellow radio astronomer Bernard Burke of MIT. Burke told him about Peebles of Princeton who was talking of some left-over radiation of 10 K filling the Universe. Penzias eventually rang Dicke. All four members of Princeton team appeared at Crawford Hill. It became clear from their discussion then that Penzias and Wilson really chanced upon the **Cosmic microwave background radiation** (**CMBR**) of the Universe for which Dicke and Peebles were preparing themselves for sometime.

The duo, Penzias and Wilson, were not very much impressed at first. They moved with caution. A decision was taken that Penzias and Wilson would announce their observations in *Astrophysical Journal* and Dicke, Peebles, Roll and Wilkinson would provide its cosmological explanation in the same issue. The papers reached the Journal on 13th May 1965. Penzias and Wilson published it under a modest title '*A Measurement of Excess Antenna Temperature at 4080 Mc/s*'.

The world reacted enthusiastically. It was hailed as a great discovery. Penzias and Wilson were awarded the Nobel Prize in 1978. Human being have now touched heart of our baby Universe. It proved that the seemingly eternal Universe might have an origin. Subsequent measurements at different wavelengths established that the excess noise of background radiation have a temperature of about 3.5K (between 2.5 and 4.5 K).

10.08. MOMENTS OF CREATION

With the discovery of MBR and understanding of primordial and stellar nucleosynthesis, a model story of Creation of our Universe began to emerge. It was based upon Big Bang theory that was born in 1948 by Alpher and Gammow or more correctly by Lemaitre in 1927. The term 'Big Bang' was given by Fred Hoyle in 1950 during a BBC radio talk. It means the right moment of Creation of this World.

Adding up some refinements, Gamow's **Hot Big Bang model** has become the standard model of Creation. It is capable of explaining many observed facts. The model dealt with cosmic events when matter-density was higher than density of nuclear matter and proton-neutron occurred as separated from radiation. That happened sometime after 0.01 second after the Big Bang if the Grand Creation instant is designated by t = 0.

The Nobel-winner, Steven Weinberg, published '*The First Three Minutes*' in 1977 (revised in 1993) where he described how our early Universe evolved from 0.01 second after t= 0. We shall follow him in short.

1. At **0.01 sec** after t=0, the cosmic temperature would be **10^{11} K** and equivalent mass density **3.8-4.0 billion kg/litre** (i.e. 3.8-4.0 billion times denser than water). The Universe was dominated by radiation in a cosmic soup containing *electron-positron*, *neutrino-antineutrino* and some insignificant amount of *proton-neutron*. There would be one proton or neutron per a billion photons or electrons or neutrinos. They all remained in some thermal equilibrium. The nucleons were constantly bombarded by electron, positron and neutrino. Anti-neutrino collided with proton to produce positron and neutron : $\bar{\nu} + p^+ \leftrightarrow e^+ + n^0$

Neutrino collided with neutron to produce electron and proton :

$$\nu + n^0 \leftrightarrow e^- + p^+$$

Two reactions were reversible. Number of protons and neutrons were same till temperature dropped down to $3x10^{10}$ K. Particles were not bound into the nuclei.

Then our cosmos began to expand and cool down. The rate at which electron-positron pairs were produced on collision of neutrino particles with nucleons, had fallen below the rate at which they were annihilated. Most of the electron-positron would be annihilated to produce more photons ($e^+ + e^- \rightarrow \gamma$). There would be only few electrons left-over. The neutrinos-antineutrinos would not be annihilated that way as they would interact with themselves and with other particles very weakly. As a result, these should exist now around the present Universe. Even if they exist today, their energy would be very low so that its direct detection is quite impossible. If they have mass, we may be able to detect them indirectly. The neutrino-antineutrino may form the bulk of dark matter of our Universe.

2. Just **over 0.1 sec**, the temperature would be around **$3x10^{10}$K** and the energy density 30 million times to that of water. The cosmic expansion rate slowed down considerably. The proportion of nucleons to photons was still 1 in 1 billion. Heavy neutrons could easily turn into more light protons than proton's transformation into neutron. As a result, the proportion of proton and neutron changed into **62:38** ratio from 50:50.

3. At the end of **1.1 sec**, the temperature would come down to **10^{10} K** and total energy-density to 380,000 times to that of water. Cosmic temperature would be still twice the threshold temperature of electron-positron. At this temperature, electron-positron began to annihilate more rapidly than its creation. Neutrinos decoupled and had

no interaction with matter. It was still too hot to make atomic nuclei. Proton and neutron balance changed to **76:24** ratio.

4. At the end of **13.83 seconds**, cosmic temperature reached some **$3x10^9$ K**. Electron-positrons began to disappear rapidly. Energy released in annihilation slowed down the rate of cooling. Neutrinos were about 8% cooler than electron-positron-photons. The Universe became ready for stable nuclei production but they could not stay long. Deuterium-nuclei formed and blasted apart at high temperature of $3x10^9$ K. Neutrons still converted into proton but at a slower rate. Proton and neutron balance altered to **83:17** ratio.

5. At the end of first **3 minutes 2 seconds**, the temperature came down to **10^9 K**. The electron and positron almost disappeared and the Universe was left with photons, neutrino and antineutrino in the main. Photons attained 35% higher temperature than neutrinos, due to energy released by electron-positron annihilation. It was however cold enough to produce tritium, helium-3 and ordinary helium nuclei. Deuterium-blasting still continued. As a result, not enough number of nuclei could be formed. The collision of hadrons with leptons stopped. Decay of free neutron became significant as in each 100 sec, 10% of the remaining neutrons would decay into protons. Proton-neutron balance would be somewhere around **86:14**.

Some time after 3min 2 sec, the temperature dropped down to a point where deuterium nuclei could stay. Then heavier nuclei formed rapidly. Almost all neutrons were cooked into helium nuclei.

At **3 mins 46 seconds** after t=0, the temperature would be **$0.9x 10^9$ K**. Proton-neutron ratio would change slowly into **87:13.**

6. At the end of **34 minutes and 40.01 second**, the temperature would be **$3x10^8$ K**. Electron-positron would almost annihilate themselves. Residue may be 1 in 1 billion with small excess of electron. Energy due to annihilation raised photon temperature higher than neutrino temperature. Mass density became **9.9 gm/cc**. Energy density was equivalent with matter density. Nuclear processes stopped. Particles were mostly bound up either in helium nuclei or in hydrogen with 22-28% helium by weight.

Weinberg's account grouped into six frames ended here. The Universe continued to expand and cool down.

An hour after t=0, the temperature would have come down to **170 million K** which was still about 11.4 times higher than Sun's core temperature. Within few hours, production of helium and other elements would be stopped. The Universe continued to expand perhaps without any major events.

After **300,000-700,000 years**, temperature decreased further to a range of **4000**-**3000** degree to form atoms of hydrogen and helium. It is because electrons and nuclei then did not have sufficient energy to overcome electro-magnetic attraction between themselves. Somehow at this stage the link between matter and radiation broke up. The radiation decoupled. From then on, it began to travel on its own. We now get that radiation as cosmic microwave background radiation. The radiation is a relic of things that happened sometime around 300,000-700,000 years after the Big Bang.

The Universe continued to expand and cool down with average matter density going down. But the story was not that simple. This Grand Nature did not remain evenly spread with matter-density. There occurred some fluctuations of density, culminating in the origin of galaxies and stars. How that fluctuation originated? How fluctuation within galaxy produced stars?

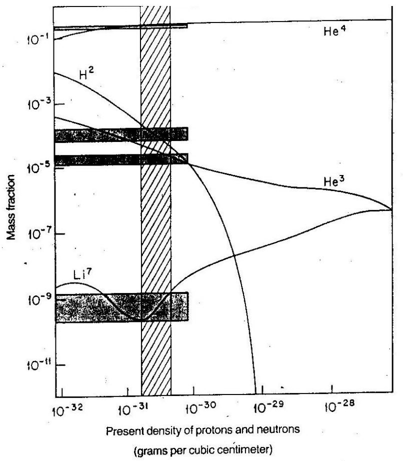


Fig.10.3. Big Bang nucleosynthesis and abundances of light chemical elements. The curves show how predicted abundances of helium-4, helium-3, deuterium (hydrohen-2) depend on the present density of proton-neutrons. Shaded horizontal bars show observed abundances. Cross-hatched region indicates a range of values for the density of proton-neutrons where each of the four calculated curves agrees with the corresponding observations. (source: Fig: 5.3/p114 Cornell, adopted from D.N.Schramm, Physics Today, April 1983)

It appears that denser regions in some parts slowed down the expansion of the region, perhaps by extra gravitational attraction of the denser region. At some stage, the expansion stopped and the process of recollapse started. As they were collapsing, the gravity pull of matter occurring outside the region, most likely started to rotate. More it collapsed, more was its rotation till, at some stage, the rotation could balance inward gravity pull. Thus rotating galaxies were formed in the region. Those that could not pick up such rotation, possibly formed into elliptical galaxies. These galaxies had no overall rotation but its individual parts had rotation around its centre.

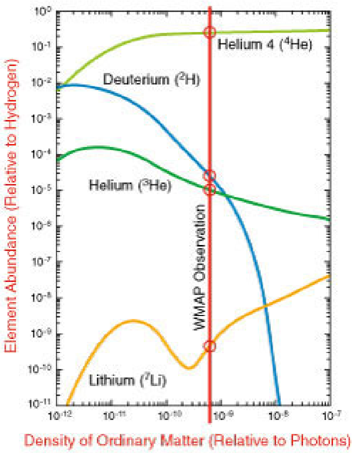


Fig.10.4. Big Bang nucleo-synthesis and abundances of light chemical elements.

Since the lightest nuclei were produced in the Big Bang, it is possible to compare calculated abundance of light nuclei by direct observations. To work out those calculations, density of proton and neutron as on today are to be known. That would not be easy to get and can only be approximated. The comparison is done for abundance of helium-4, helium-3, hydrogen-2 and lithium-7.

The predicted abundance of deuterium, helium and lithium depends on the density of ordinary matter in the early universe, as shown in the figure at left. These results indicate that the yield of helium is relatively insensitive to the abundance of ordinary matter, above a certain threshold. We generically expect about 24% of the ordinary matter in the universe to be helium produced in the Big Bang. This is in very good agreement with observations and is a triumph for the theory. However, the model can be tested further. Given a precise measurement of the abundances of ordinary matter, the predicted abundance of other light elements becomes highly constrained. The WMAP satellite is able to directly measure the ordinary matter density and finds a value of 4.6% (±0.2%), indicated by the vertical red line in the graph. This leads to predicted abundances shown by the circles in the graph, which are in good agreement with observed abundances. This is an important and detailed test of nucleosynthesis and is further evidence in support of the Big Bang theory. Had the results been in conflict, it would point to 1) errors in the data, 2) an incomplete understanding of the process of Big Bang nucleosynthesis, 3) a misunderstanding of the mechanisms that produce fluctuations in the microwave background radiation, or 4) a more fundamental problem with the Big Bang theory. (source: website, NASA, WMAP Big bang Elements Test)

Hydrogen and helium in galaxies gradually would break up into stellar clouds that would collapse under its own gravity to form stars. During its collapse, atoms would collide with one another and increase the heat of the gas. At some stage, it would become so hot as to start nuclear fusion process, converting more hydrogen into helium. Heat given off then would raise pressure of the gas-cloud and arrest further contraction. It would then burn as star for some time. When its fuel would end up, it would contract further to raise the heat. Then helium would be converted into heavier elements like carbon and oxygen. The central region would gradually become denser to form neutron star or blackhole. Outer regions may blow up as supernova, throwing some matter in space that would again form resource materials for next generation of stars.

Now we are living about 4.7×10^{17} sec after t = 0 (if we take roughly 15 billion years as the age of the Universe). The temperature of radiation has come down to 2.7 K. This is how our Universe evolved from 0.01 second after its creation. This is how matter was created in the Universe and evolved from neutron gas clouds. The whole idea has been structured as the standard model. Some predictions are found to be real facts of our present day Universe. This confirms Big Bang's success.

10.09. REMARKS

The Big Bang model of Creation of our Universe is the most popular one and by far the most acceptable one in the scientific world. It is reasonably based upon available knowledge. In no case, it should be considered final in all respect. Rather far from it, it is entangled with many more questions. In spite of that, this is the best sensible scenario with which we may carry on our scientific investigation further. Theories are always subject to revisions wherever necessary. Science keeps that option open.

This Creation model, as far as we have worked out, partially explains Creation of our Universe. Strictly speaking it does not explain the Creation proper. We see that the Universe began with neutron gas and photon. But the question remains − wherefrom neutron gas and photon had come from? How it had become in a state of hot superdense soup? How that "bang" occurred that kept on cosmic expansion even after billions of years?

Our explanation really began after the initial Creation of some primordial matter at some state. Truly speaking, this cannot be an explanation of Creation but evolution of the Universe. *Creation can only be explained if we can establish Creation out of nothing as a Natural System.* Otherwise the role of one Great Power as Creator have to be believed. Even then, the Creator had to create something out of nothing.

The Creator cannot explain everything unless it is explained how He has created, apart from the question of how He Himself was created.

Theoretically spontaneous creation out of nothing becomes the only viable explanation of Creation proper.

As yet we could not establish anything towards that end. Science continuously pushes its frontier to get truth. Till anything positive results, we remain essentially speculative. Inquisitive human being cannot even stop from speculation. Is it possible for Creation out of nothing?
