International Research Journal of Natural and Applied Sciences
ISSN: (2349-4077)
Impact Factor 7.032 Volume 9, Issue 12, December 2022
Website- www.aarf.asia, Email : editor@aarf.asia , editoraarf@gmail.com

Some wonderful information about our star: The Sun

Bhagvat K. Kumthekar
Head, Department of Physics, Nutan Mahavidyalaya, Sailu, Dist Parbhani - 431503 (MS), India
Email: bkumthekar@gmail.com

Abstract: In the present paper, I would like to discuss about some wonderful information about the Sun. It generates energy continuous in the form of electromagnetic radiation by using nuclear fusion reaction. When radiation travels from core to photosphere, it will take 10 million years due to opacity of the Sun. There is solar neutrino puzzle. It is now considered a solved problem.

Introduction:

Universe is made up of billions of galaxies. There are four types ofgalaxies such as Elliptical, Spiral, Lenticular and Irregular. Each galaxycontains about a billions (10^9) to a trillions (10^{12}) stars. We live in aspiral galaxy situated in the Virgo Cluster. This galaxy is known asthe Milky Way. The Indian name of the galaxy is the Akashganga. Our galaxy contains two hundred billion (2×10^{11}) stars which rangein mass from about one-tenth to a hundred times the mass of the Sun[1].

The Milky Way is convex shaped and its about 10^5 light year (ly) in diameter. One light year means light travels a distance in one year. The speed of light is 3 x 10^8 m/s and in one year there are 365.25 x 24 x60 x 60 seconds. Therefore one light year means 9.45 x 10^{15} m [2].The thickness of the Milky Way at the center is about 5000 ly. From the center of the galaxy at a distance of 30,000 ly, there is a system consists of one star and eight planets, known as the solar system. This star is nothing but our Sun and the other eight planetsare Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus Neptune. Except Mercury and Venus, these planets have their satellites revolving around them. The Earth and other planets are revolving around theSun in their elliptical orbits.

The formation and evolution of the solar system is estimated to havebegun about 4.6 billion years ago with the gravitational collapse of asmall part of a giant molecular cloud. This is a one of the theoriesaccepted by a large section of scientists. Most of the collapsing mass collected in the centre, forming the Sun, while the rest flattened into a proto planetary disc out of which the planets, satellites, asteroids, andother small bodies are formed. This model is known as the nebularhypothesis. The nebular hypothesis was first proposed in 1734 by Emanuel Swedenborg [3] and later on elaborated and expanded by Immanuel Kant in 1755. A similar theory was independently formulated by Pierre- Simon Laplace in 1796 [4].

The Sun

Our star, Sun is situated at the center of the solar system. The Sunis a ball of hot gas held together by gravity. It consists mostly of hydrogenand helium which are in the ionized state, because of very hightemperature in the Sun. In addition to these, there are other elements like carbon, nitrogen, oxygen, neon, etc. in very small quantities [5].The average mass of the Sun is 1.99×10^{30} kg and average radius 6.96×10^5 km [6]. Its spectral type is G2V with visual magnitude − 26.74and absolute magnitude 4.8. Here, G2 stands for the spectral classificationof stars having the surface temperature between 4500 –6000K. V stands for luminosity classification of the star. Some physicalproperties of the Sun are given in Table 1.

Sr. no.	Name of the parameter	Numerical value
1	Age	4.5×10^9 years
2	Mass (solar mass)	1.99×10^{30} kg
3	Radius (solar Radius)	6.96×10^5 km
4	Mean Density	1.4×10^3 kg m^{-3}
5	Mean Distance from the Earth	1.50×10^8 km
6	Escape velocity	618 km s^{-1}
7	Luminosity	3.86×10^{26} W
8	Equatorial rotation period	26 days
9	Polar rotation period	31 days
10	Mass loss rate	10^9 kg s^{-1}
11	Hydrogen	92.1 %
12	Helium	7.8 %

Table1. Physical properties of the Sun

Mainly, the Sun is divided into two parts i) solar interior and ii) solar outer. The interior part is completely opaque and we cannot lookinto it. There are no direct observations about the interior part. Thetheoretical models suggested that the three major regions in the solarinterior are the core, the radiative zone and the convective zone.A schematic view of the general structure of the Sun is shown in Figure 1. The outer part again it consist of 3 regions i.e photosphere, chromosphere and corona.

Solar spectrum consists of a continuum on which numerous dark lines, called Fraunhoffer Lines. Some of the strongest lines belong toCa I,Ca II, H I, Fe I, Fe II, Mg I, Na I. From the spectra, more than 60 elements are identified in the sun's atmosphere. There are many lines are yet unidentified. It is believed that all known elements are present in the sun.

The Sun is a magnetically active star. It supports a strong, changingmagnetic field that varies year-to-year and reverses its direction everytime in about eleven years.The Sun's magnetic field gives rise to manyeffects that are collectively called the solar activities, including sunspotson the surface of the Sun, Solar flares, and variations in solar wind thatcarry material through the Solar System.Since electron density in theionosphere around the earth varies with the solar activity, the radiocommunication depends on the solar activity. If two light nuclei combine to form a single larger nucleus, a process is called the nuclear fusion. For such reaction requires large temperature.

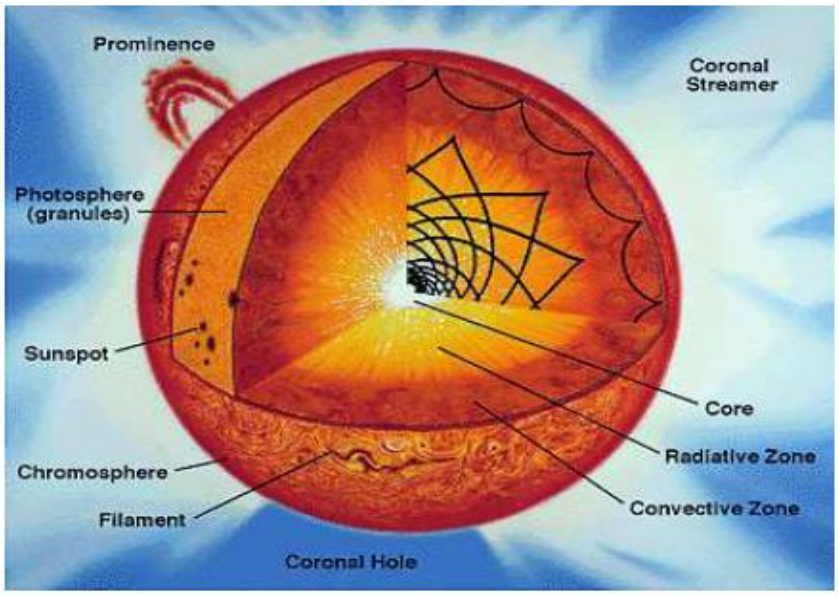

Figure1. General structure of the Sun.

If the fusion reaction is to be take place, it must involve protons whoseenergies are far above the average energy. The central temperature anddensity are so high that nuclear fusion reaction in which hydrogen isburned into helium, hydrogen being the 'fuel' and helium is the 'ashes'.This reaction is known as p-p chain reaction. It is represented by thefollowing set of reactions:

$${}_1^1H + {}_1^1H \rightarrow {}_1^2H + e^+ + v + 0.42 \text{ MeV} \qquad \text{(i)}$$

$$e^+ + e^- \rightarrow \gamma + \gamma + 1.02 \text{ Me V} \quad \text{(ii)}$$

$${}_1^2H + {}_1^1H \rightarrow {}_2^3He + \gamma + 5.49 \text{ MeV} \qquad \text{(iii)}$$

$${}_2^3He + {}_2^3He \rightarrow {}_2^4He + {}_1^1H + {}_1^1H + 12.86 \text{ MeV(iv)}$$

For occurring the fourth reaction, the first three reaction must be occurstwice time, in which case two light helium nuclei unite to form ordinaryhelium nucleus. If we consider the combination 2 (i) + 2 (ii) + 2(iii) + (iv), the net effect is

$$4\ {}_1^1H + 2e^- + {}_2^4He + 2v + 6\gamma + 26.7 \text{ MeV}$$

Thus, four hydrogen atoms combine to form a ${}_2^4He$atom with a releaseof 26.7 MeV of energy. There is a another one possible reaction has putforth by scientists which is known as CNO cycle.

$${}_6^{12}C + {}_1^1H \rightarrow {}_7^{13}N + \gamma + 1.93 \text{ MeV}$$
$${}_7^{13}N \rightarrow {}_6^{13}C + e^+ v + 1.20 \text{ MeV}$$
$${}_6^{13}C + {}_1^1H \rightarrow {}_7^{14}N + \gamma + 7.6 \text{ MeV}$$
$${}_7^{14}N + {}_1^1H \rightarrow {}_8^{15}O + \gamma + 7.39 \text{ MeV}$$
$${}_8^{15}O \rightarrow {}_7^{15}N + e^+ + v + 1.71 \text{ MeV}$$
$${}_7^{15}N + {}_1^1H \rightarrow {}_6^{12}C + {}_2^4He + 4.99 \text{ MeV}$$
$$4\ {}_1^1H + {}_6^{12}C \rightarrow {}_2^4He + 2\ e^+ + 2v + 3\gamma + 24.8 \text{ MeV}$$

It also gives the same thing i.e. four hydrogen atoms comes together and form a helium atom and gives 24.8 MeV [7].

The escape of radiation from the core is not completely blocked.Photons progress from one collision to the next, diffusing outwardsin a manner that resembles a random walk. A temperature gradientis established between the hot core and the cool outer layers which promotes the outward flow of heat. The mean energy of the photonsdecreases as the temperature drops. The electromagnetic radiation leaks out slowly, but the interior isvery opaque, like a thick fog, so that it undergoes under many reflections.If it had come straight out it would have taken two seconds only,but there are so many reflections that it takes 10 million years to reach the surface of the Sun from the core.

Solar neutrino problem

Neutrinos are released by the fusion reactions in the core, but unlikephotons they rarely interact with matter, so almost all are able toescape the Sun immediately. Several neutrino observatories were builtin the 1980s to measure the solar neutrino flux as accurately as possible,including the Sudbury Neutrino Observatory and Kamiokande [8].For many years the number of solar electron neutrinos detected onEarth was one third to one half of the number predicted by the standardsolar model. This anomalous result was termed the solar neutrino problem.Theories proposed to resolve the problem either tried to reducethe temperature of the Sun's interior to explain the lower neutrino flux, or posited that electron neutrinos could oscillate-that is, change intoundetectable tau (τ) and muon (μ) neutrinos as they traveled betweenthe Sun and the Earth.

Results from these observatories eventuallyled to the discovery that neutrinos have a very small rest mass and doindeed oscillate. Moreover, in 2001 the Sudbury Neutrino Observatorywas able to detect all three types of neutrinos directly, and found thatthe Sun's total neutrino emission rate agreed with the Standard SolarModel, although depending on the neutrino energy as few as one-thirdof the neutrinos seen at Earth are of the electron type. This proportion agrees with that predicted by the Mikheyev-Smirnov-Wolfenstein effect. This effect is also known as the matter effect whichstates that neutrinos in matter have a different effective mass thanneutrinos in vacuum, and since neutrino oscillations depend upon thesquared mass difference of the neutrinos, therefore, the neutrino oscillationsmay be different in matter than they are in vacuum. Theeffect is important at the very large electron densities of the Sun whereelectron neutrinos are produced. Finally this effect describes neutrinooscillation in matter, and it is now considered a solved problem.

Conclusions:

It is seen that Sun rotates from west to east and its equator makes an angle of about 7^o with the ecliptic and also observed that Sun does not rotate like a solid body. It rotates with different speeds. The Speed of rotation is maximum at rotational period of about 25 days near the equator and minimum at rotational period of about 35 days near the poles.If a photon comes out straight from the coreto the photosphereit takes 2 sec, but it undergoes many reflections and takes time of $\sim 10^6$ years. Now, photon takes 500 sec (8 minutes and 20 second) to travel from photosphere to the Earth surface. From the spectral observations it is found that more than 60 elements are identified in the Sun's atmosphere.

Acknowledgement:

I am heartily thankful to Prof. Suresh Chandra for his valuable guidance. Also thankful to Dr. Uttam C. Rathod, Principal, Nutan Mahavidyalaya, Selu, Dist Parbhani for providing me necessary facilities for my research work and his kind cooperation.

References

[1] B. Basu and T. Chattopadhyay, An Introduction to Astrophysics, second edition 2010 PHI learning Pvt. Ltd
[2] Zirin Harold, Astrophysics of the Sun, 1988, Cambridge university press.
[3] Swedenborg, Emanuel. 1734, (Principia) Latin: Opera PhilosophicaetMineralia (English: Philosophical and MineralogicalWorks),(Principia, Volume 1)

[4] T. J. J. (1909). Proceedings of the American Philosophical Society48: 119.

[5] Das A. C., Space Plasma Physics, An Introduction, Narosa Publishing House, New Delhi, India (2004)

[6] Priest ER. Solar Magnetohydrodynamics, Dordrecht, Holland: D.Reidel Publishing Company;1982.

[7] Irving Keplan, NuclearPhysics, 1962, Narosa Publishing House, New Delhi.

[8] MacDonald, A.B. (2004) "Solar neutrinos". New Journal of Physics6 : 121.