ESTIMATION OF TEMPERATURE OF STARS

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ABSTRACT

We know our sun is our source of energy and heat. Not just the sun, which is just one fish in the ocean of variety. These stars differ in temperature and we try to study the properties of these stars using various technologies in which we analyze the absorption line of various elements in the star and study the spectrum of the star. From accessing the temperature of different star according to their color, then the blue stars are hotter than the redder stars. Astronomers organized the stars according to their absorption lines in their spectra, according to which stars were classified as O, B, A, F, G, K, M that is from hottest to the coolest star respectively. In order to measure the brightness of a star by comparing the ratio of red and blue light.

The laws governing the comparison of different stellar temperature is through the Planck's law of blackbody radiation, the Stefan- Boltzmann law. Planck's law gives corrected version of the blackbody radiation curve. Here we are going to estimate the temperature of the star using the Stefan- Boltzmann law where energy emitted by the star is directly proportional to the 4^{th} power of surface temperature of the star. This relation helps in determining the surface temperature of different stars in the universe.

In this analysis paper we estimating the stellar temperature of some stars in the universe from available experimental analysis and spectral graph information.

INTRODUCTION

Ever since the existence of the mankind, we all have looked up and wondered what exactly is going on in the far ends of the infinite universe. Coming from a vague idea of how the universe was formed to immense developments in the astronomical explorations, we have come so far trying to quench our curious minds on the wonders the universe offers us as the human kind. The answers that we seek for understanding the fundamental building blocks of all the celestial objects, living beings, vegetations etc, have led us to explore the incredible celestial objects for the study of our own existence, beyond our imaginations, that now we can dive into deeper study about the secrets that the universe keeps.

Ever since the big bang and the formation of the first stars and galaxies, astronomers are trying their best to find the possible ways of how exactly the things might have turned out in the beginning and how it is proceeding in the present. There are many theories that, in general gives the idea of how life originated in the known universe. The elements created by the emergence, evolution, explosion, and recreation of celestial bodies, helped in the development of the first elements and eventually to the rise of living beings.

One of the contributing factors for sustaining life in universe is the existence of the bright shiny heavenly bodies, named stars. The heat and light received from the stars, provides the necessary needs for the sustainability of life. As it is already known that the Sun is one such star.

It a pleasure to the eye of any star gazer to see the glittering shiny objects in the night sky that evidently shows us that there exist more to be known, in this vast universe.

The study of stars helps us in understanding the processes of its formation in entirety. it would be imprudent to think that only sun like stars exist in the universe. There are billions and billions of stars that exist in different sizes and in different temperatures, starting off as a protostar to its end stages which is determined by the size and temperature of the stars.

The stars are classified into different types, depending on its temperatures. As we all know the elements present in the periodic table are in different states of matter. These matter produce bright lines which are unique to that particular element, so astronomers try and identify these bright lines found in the electromagnetic spectrum of stars through a type of study termed as spectroscopy.

The study in the spectrum of stars helps in plotting the spectral graph of any type of stars which helps in determining its temperature. Also, it helps in differentiating the types of stars present in the universe.

This research paper focuses on estimating the temperature of stars through its blackbody radiation curve or spectral curve which was obtained through the study of the spectrum of stars discussed below. This review paper also puts light on the short lived and hottest stars as well as long living and soon to be exhausted stars, in order to put insights on the classification of different kinds of stars.

STARS

The luminous celestial bodies in the night sky, which appear as tiny dots to us but are massive in size, stars are the building blocks to all the known elements in this universe. It is a sphere of hot plasma held together by its own gravity. The closest star to earth is the sun. the evolution of a galaxy, its history, dynamics, and formation could be outlined by studying the star present in that galaxy. All the heavy metals like nitrogen, carbon oxygen was all built inside the core of a star and further unite the factors for planet formation. It has been estimated that, there are around 10^{22} to 10^{24} stars present in the observable universe and that around a few thousand is visible to the naked eye.

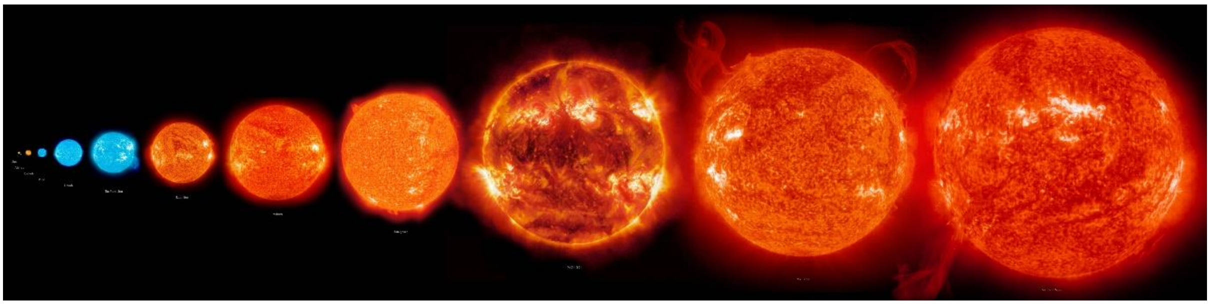


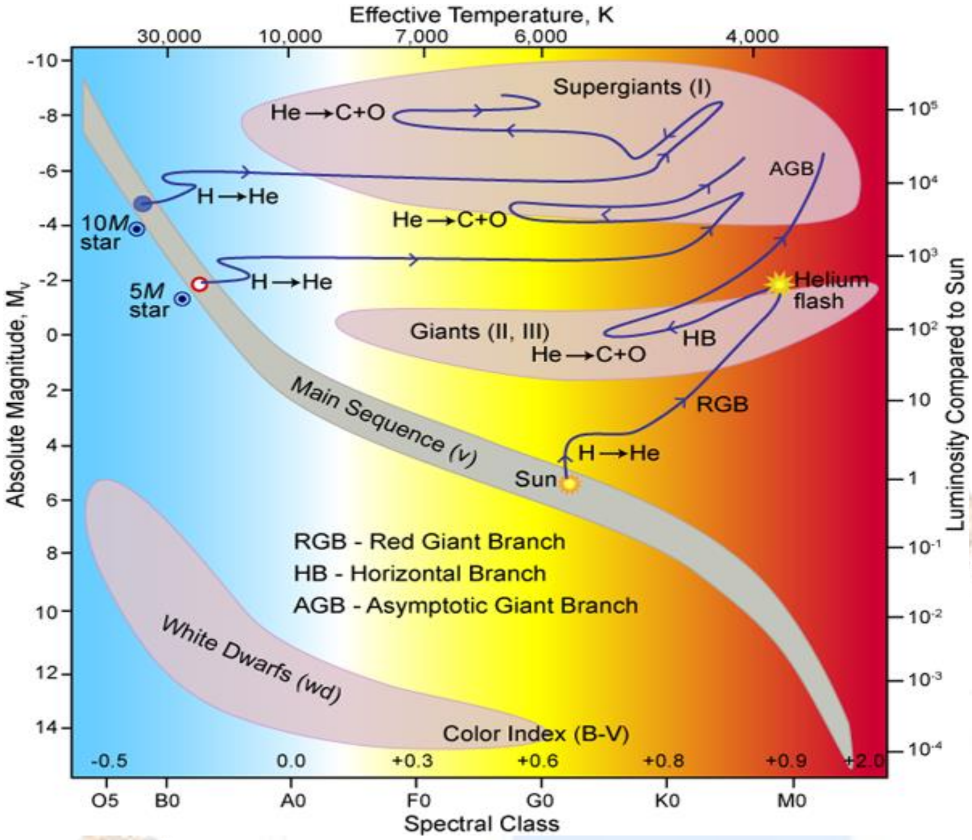
Photo courtesy internet

In most of a star's active life shines and realises immense amount of energy to the interstellar space. Very star is born out of dust and gaseous clouds present in a nebula like Orion nebula in the Orion constellation. The primary compound being hydrogen, along with helium and with traces of certain heavy elements, stars are born from the gravitational collapse of the said interstellar clouds. The total mass of the star determines its life time and eventual fate. In the active years of a star's life, it produces energy from the thermonuclear fusion of hydrogen into helium in its core. At the end of its life time, the star explodes, a phenomenon termed as supernova explosion it leaves out a stellar remnant like a white dwarf, a neutron star or if the mass is sufficiently massive it could even become a black hole. The stellar remnant so produced or the nucleosynthesis creates majority of the naturally occurring chemical elements, which returns to the interstellar medium through the supernova explosion. These elements service as the base for the formation of new stars Most of the time stars forms in groups called as clusters, which consists of hundreds and thousands of them. These massive stars illuminate a nebular gas cloud for star formation.

Star properties such as its mass, age, chemical compositions, its distance, positions, and movement throughout the space, by carrying out observations of a star's brightness, spectrum, and changes in positions in the night sky with time.

CLASSIFICATION OF STARS

When we first started observing stars with telescopes, we divided them into colour classes. White, yellow, red, dark red. The stars were then classified according to their surface temperature. From the hottest stars at about 25,000 Kelvin to the coldest at about 3,500 Kelvin, there are now O, B, A, F, G, K, and M stars, and a classification system called the Harvard system was developed by early astronomer Annie Developed by Jump. developed cannon. This temperature-based classification is based on Wiener's law of black body radiation. We analyse the light we receive from stars and associate it with specific temperatures and elements. As the star gets hotter, it strips electrons from its hydrogen and helium nuclei, forming a phase of matter known as plasma. The hottest stars, O stars, have little hydrogen because most hydrogen contains no electrons and cannot absorb or emit light. Since helium can still hold one or both electrons, we see emissions that correlate with helium. In the A star, when it cools down a bit, the hydrogen suddenly retains electrons and the spectrum changes. As it gets colder, bands appear that correspond to metals such as calcium. So this rule is derived from temperature, which is also correlated with colour and size. Hot objects such as O and B stars are blue, and cold objects such as K and M stars are red. Hotter stars also tend to burn bigger and brighter, creating extra heat by burning more fuel. All these data are related to temperature and brightness, including the information about mass and radius, can be represented on a graph termed as Hertzsprung-Russell diagram, or an H-R diagram for short form.



In this diagram, the horizontal axis shows temperature decreasing to the right, and the vertical axis shows luminosity, or the amount of energy emitted by a particular star per unit time.

We can see that most stars fall on a continuous curve, which we call main sequence stars. Ninety percent of all stars follow this trend, including our own sun, which is part of this yellow region in the above shown graph. Some stars, like red giants, are very cool yet luminous, while others, like white dwarfs, are very hot yet dim, but the majority belong to the yellow region, that is, main sequence. Even though this diagram lists only temperature and luminosity, we can infer many things about other variables. A bigger star is always brighter because it means it emits more energy. Moving from left to right, we can also clearly see the correspondence between colour and temperature. Size is also shown, with main-sequence stars decreasing in size from left to right, but this is not the case for red giants and white dwarfs. The data, collected by examining hundreds of thousands of stars in the early 20th century, reveals certain facts about stars, such as approaching small red stars. This has to do with the fact that the gravitational force pushing a star inward increases exponentially with radius, so the bigger the star, the more outward pressure it has to generate to keep it from collapsing. . You can also classify stars based on brightness instead of color. Uses Roman numerals from 1 to 5, with 1 being the brightest.

COLOUR OF THE STAR	TYPE	TEMPERATURE IN KELVIN
Blue	O	30,000 K – 60,000K
Blue- White	B	10,000 K – 30,000 K
White	A	7500 K – 10,000 K
Yellow-white	F	6000 K – 7500 K
Yellow	G	5000 K – 6000 K
Yellow – orange	K	3500 K – 5000 K
Red	M	< 3500 K

This table shows the classification with the temperature of different stars present in the universe.

So, this gives out basic information about the star classification present currently in the observable universe. Remember, for the main sequence, blue stars are big and hot and bright, up to around a hundred to two hundred solar masses, or one to two hundred times the mass of our sun. Red stars are small and cool and dim, down to around one tenth the mass of our sun. Yellow is in between, these are about the size of our sun. Then beyond main sequence stars, there are red giants, and there are white dwarfs. Those are the three main classes of stars. Most of the stars that have existed in the past, and most of the stars that exist today, fall into one of these categories. These categories are not constant, they keep changing with time.

ESTIMATION OF TEMPERATURE OF STARS

From the observations conducted by astronomers, each star shows its spectral properties which are recorded. According to the data acquired a spectral graph is traced. This graph mostly resembles to the blackbody radiation curve.

Below we will discuss and estimate the temperature of a few stars in the night sky

- THE SUN

The closest star to the earth, our sun is about 4.5 billion years old and is about 150 million kilometres away from the earth. Sun belongs to the G- type main sequence stars informally known as yellow dwarf, but the light emitted by the sun is white. Most of the matter gather in the core and the rest flattened around the fully formed star as accretion disk for the formation of solar system. sun fuses million tons of hydrogen in its core every second. Sun remains in its hydrostatic equilibrium until the hydrogen fuel is exhausted in its core and results in the increase of its density and temperature, further expanding its layers, transforming into a red giant. After a few million years sun will shed its layers and explode to a planetary nebula and then become a dense type of cooling star called as white dwarf.

The primary means of energy transfer in the sun is thermal radiation and the radiative zone is the thickest layer of the sun. in this layer the temperature is comparatively less so the radiation cannot happen through the thermal convections, which happens nearer to the core. A layer termed as tachocline separates the radiative zone from the convective zone.

The amount of radiation produced by the sun is observed in the wavelength range of about 10 angstroms to 5×10^4 angstroms. This range lies in the extreme ultraviolet through ultraviolet to the visible region and goes to the infrared region. the radiation curve produced by the sun starts rising at some wavelength in the visible region showing its thermal properties. This gives the spectral distribution the shape of the blackbody radiation curve with its peak observed to be at about 5000 angstroms, that is, in the visible region of the electromagnetic spectrum. The curve lowers at higher and lower wavelengths as the sun's radiation decreases in these regions.

The graph shown below is the spectral curve of the sun we find the energy radiated by the sun by finding the total area curved by the curve.

According to the Stephan-Boltzmann law the equation for finding the temperature from a given spectral curve is :

$$E = \sigma T^4$$

Where,

E is the energy of the radiation

σ is the Stephan-Boltzmann constant which takes the value 5.67×10^{-8} *watts/m²K⁴*

T is the temperature of the star

Spectral graph of sun is shown below

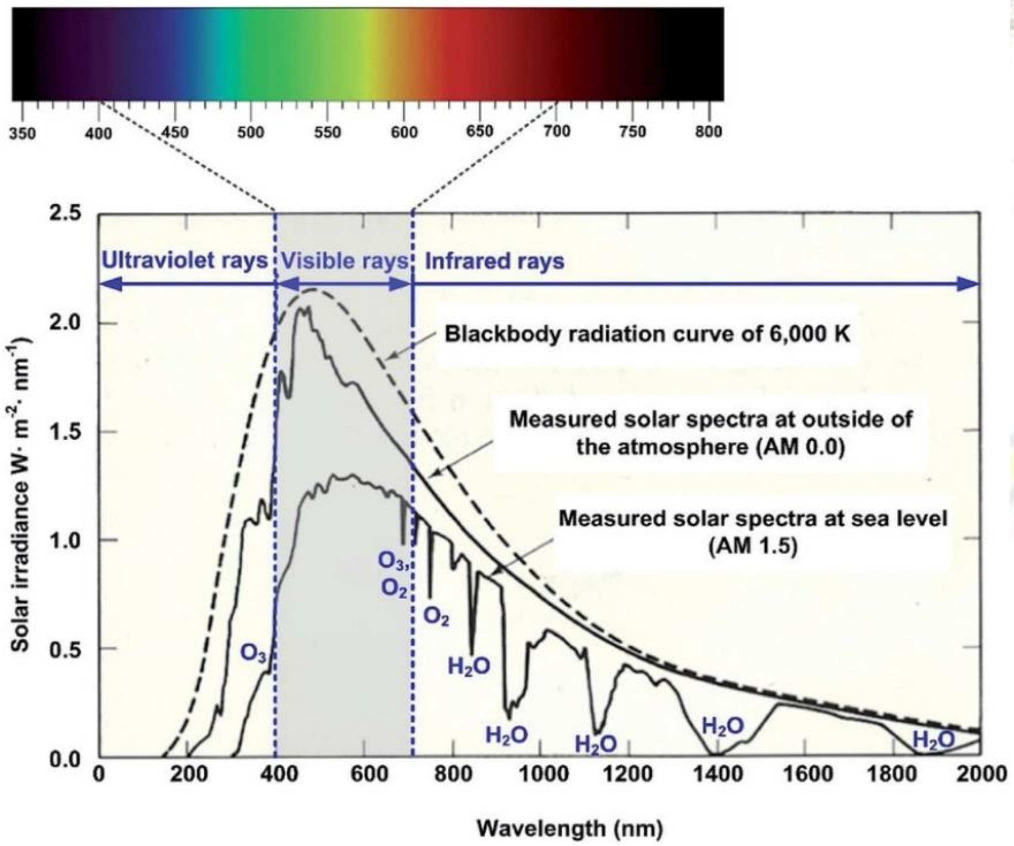


Photo courtesy internet

The area of the curve was calculated to be:

E= 3.5437500×10^7

Substituting in $E = \sigma T^4$

σ= 5.67×10^{-8}

We get T= 5000 K

Sun's surface temperature already known is 5772 K

Due to the inaccuracies in the spectral graph taken from the internet the error for the above calculation is 13.37%

- SIRIUS A

It is the brightest star in the night sky, bearing intrinsic luminosity and its proximity to our stellar system, it lies in the binary star system of Sirius. Sirius is the closest system to the earth, and its slowly moving closer to our solar system. It is seen in the constellation, Canis major, giving it a nickname a dog star. This binary system has got two white stars orbiting each other with a separation of 20 AU. The brightest among them is Sirius A and Sirius B. Sirius B has got an estimated temperature of 25,000K. it has already evolved through its main sequence and has become a white dwarf star with less luminosity.

Sirius A has got a radius higher than that of a sun and it is in its main sequence stage. Its is classified as an A type star, since the observational analysis show metallic absorption lines.

The spectral graph of Sirius A is shown below

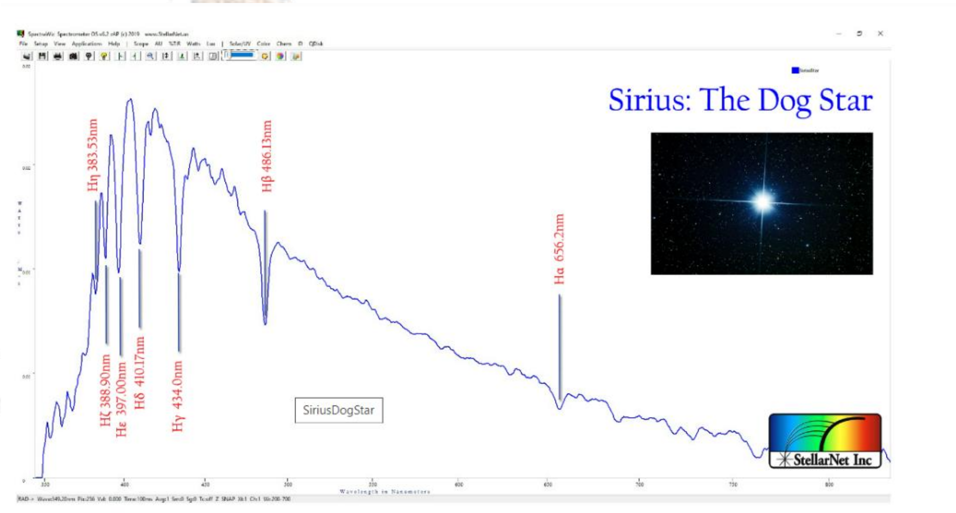


Photo courtesy internet

The area of the curve was calculated to be:

E= 3.28432167 x 10^8

Substituting in $E = \sigma T^4$

σ= 5. 67 x 10^{-8}

We get T= 8724 K

Sun's surface temperature already known is 9940 K

Due to the inaccuracies in the spectral graph taken from the internet the error for the above calculation is 12.23%

CONCLUSION

This method of estimation of temperature of stars were used before the advanced technologies took over. The spectral curve has got its inaccuracies which limits the exactness of the surface temperature. There are so many methods to find the surface temperature of a star and the analysis of the spectral graph is one of them. Here I tried to estimate the surface temperature of the sun and the Sirius A star, which came out to be T = 5000 K for the sun and T= 8724 K for Sirius A, with errors around 12%-13%.

FUTURE SCOPE

The advancing technologies, helps us to improve in the study in the field of astronomy. The analysis of the spectrum of stars helps in understanding the properties of the stars in the universe. In either way, the estimation of stellar properties is important to understand about the origin of the universe, its evolution and future. In the coming ages, the chances of achieving that milestone are highly probable.

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