© 2023 IJNRD | Volume 8, Issue 6 June 2023 | ISSN: 2456-4184 | IJNRD.ORG

IJNRD.ORG ISSN : 2456-4184

INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG

An International Open Access, Peer-reviewed, Refereed Journal

Study of Stars through Optical Spectrum

Alka Nair

B.Sc. (H) Physics Semester 6
Amity Institute of Applied Sciences
Under the Guidance of Dr C. Konar

Abstract:

The field of Astronomy will always be incomplete without observation and study of light coming from the various Astronomical bodies. Light, as we know, is a combination of various wavelengths or frequencies of radiation. Hence, light is said to have a spectrum. In Astronomy, we use this knowledge about the spectrum of light to detect the light coming from various celestial bodies to get a detailed picture of the composition and working of those objects. The spectral data from stars, for example, can help us understand the composition and various processes that are occurring in the star. By recording the spectral data that is collected from the light coming from a star, we can study the physical features of the star, like the temperature of the star, the elements that are present in the star, its magnetic field strength and so on. The spectrum coming from the star is mainly of three types: continuous spectra, absorption spectra, and emission spectra. In this paper, the spectral data of a particular star from the IRTF spectral library will be used to plot a graph and to determine the various physical processes in the star and to infer its physical model.

Introduction:

Spectroscopy is the study light containing a spectrum which is obtained when electromagnetic radiation either interacts with matter or gets emitted from the matter. Through Spectroscopy we can understand the behavior of matter and electromagnetic radiation. The study of the spectrum obtained from various celestial bodies is the key to understanding them as we cannot physically travel to bodies. Also, the images that gave been captured using various Astronomical optical instruments such as telescopes solely does not provide us with adequate information about the stars. Most of the celestial bodies appear to be the same when viewed through telescopes. This is because our eyes do not have the capability to split the light into its constituent color. The images captured in photographic plates are also not capable of doing the same. Hence, we need instruments such as spectrographs that can split the light into its constituent colors. The light gathered from optical instruments like telescope is separated into its constituent spectrum with the help of instruments known as spectrographs. As we know the electromagnetic spectrum is divided into the following regions:

1. Radio waves: Frequency $3x10^{6}$-$3x10^{10}$ Hz and wavelength 10m-1cm. The energy of the radio waves that causes its production arises from the reversing of the electron or nucleus spin.

2. Microwaves: Frequency $3x10^{10}$-$3x10^{12}$ Hz and wavelength 1 cm-100μm. The energy of the microwaves that causes its production arises due to partition between molecular levels.

3. Infrared waves: Frequency $3x10^{12}$-$3x10^{14}$ Hz and wavelength 100μm-1μm. These waves have been found to be very helpful in many fields of science.

4. Visible region: Frequency $4x10^{14}$-$7.5x10^{14}$ and wavelength 400nm-700nm. We are heavily dependent on this region of electromagnetic spectrum for all the light that is visible to our eyes.

5. Ultraviolet (UV) rays: Frequency $3x10^{15}$-$3x10^{16}$ and wavelength 400nm-1nm. UV rays are the most prevalent in the radiation that Earth receives from the Sun.

6. X-rays: Frequency $3x10^{16}$-$3x10^{18}$ Hz and wavelength 10nm-100pm. The energy due to which X-rays are emitted is due to the transitions of inner shell electrons of atoms.

7. Γ-rays: Frequency $3x10^{18}$-$3x10^{20}$ Hz and wavelength 100pm-1pm. This is the most energetic region of the electromagnetic spectrum and due to its high frequency and wavelength, it has found its applications in the field of medicine as well.

Stars are the sources of light in our universe. Light coming from the stars can be studied thoroughly to understand their physical composition and their type. The spectrum obtained from the stars are mainly of three types:

1. Continuous spectrum: Continuous spectrum contains radiation of all wavelengths or frequencies. The light produced in stars is due to the energy emitted from various thermonuclear processes occurring inside the star. This light, when observed uninterrupted due to any external factors gives a continuous spectrum. The light coming from the interior of the star gives us a continuous spectrum as the interior of the star acts as a black body and emits continuous black body radiation. This type of spectrum helps us in analysing the temperature and other physical properties of the star.

2. Absorption spectrum: During the transmission from the surface of the star to space, light may pass through gas clouds and dust. When this occurs, the particles present in the gas cloud may absorb a certain amount of energy due to which the spectrum detected in such cases may show certain black lines in it. These lines indicate that this energy of that wavelength has been absorbed. Such a spectrum gives us information about the type of atoms or molecules present in the gas cloud.

3. Emission spectrum: This is one of the most important components of the spectrum that is required by Astrophysicists to understand the types of elements present in the star. Emission spectra can be seen as the exact opposite of absorption spectra. While the absorption spectra of stars show missing lines, the emission spectra show only those missing lines which correspond to the type of element present in the stars. When spectrum is obtained from star, the emission spectrum shows only some lines and the rest of the region in the spectrum is just black. This indicates the presence of certain types of elements in the Star. This also gives information about the life stage of the Star.

The spectral data obtained from the stars can be used to classify the stars based on the type of elements present in them, their age, and their physical characteristics like temperature, density, etc. This type of classification of stars based on their spectral type is known as spectral classification of stars. Spectral classification makes it easier for us to classify the stars as they can be easily obtained by either observing the spectrum of the star or by plotting certain graphs.

Stellar Spectral Classification:

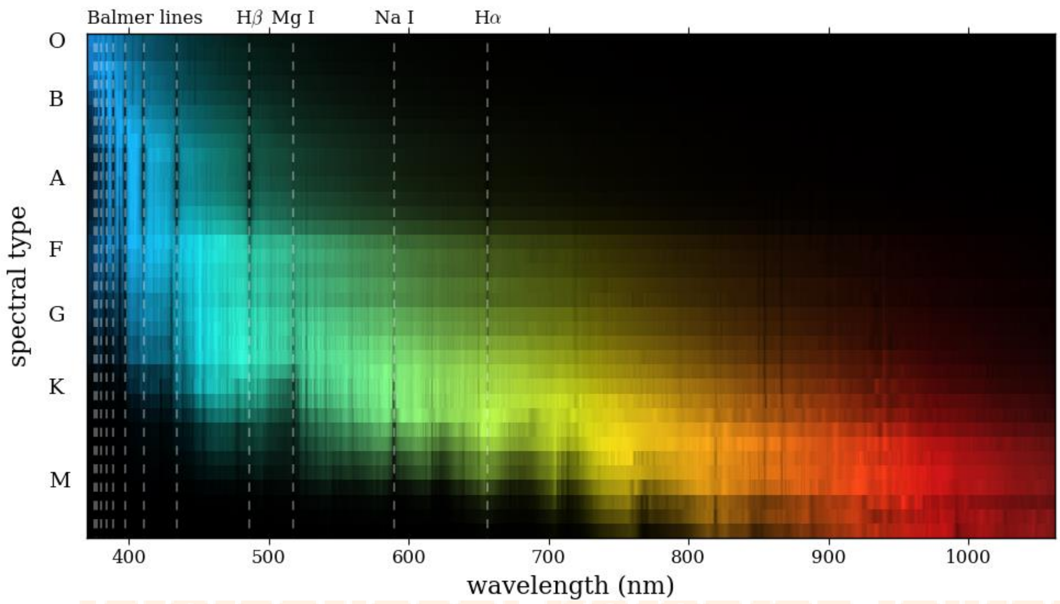
The spectral classification of stars is done based on the effective temperature of the star, the type of absorption lines observed from the spectral data of the star and its physical composition. Due to the variation of effective temperature of the stars, the stellar spectra observed for different stars observed is variable. The study of stellar spectra was started by observing the Fraunhofer lines present in the absorption spectrum of the stars.

The lines observed in the absorption spectra indicate the presence of different elements in the star. However, the thickness of the lines keeps varying even for the same element in different stars indicating the amount of that element present in a particular star. The most important factor in the spectral classification of stars is the variation of surface temperature. Mathematically, we can write.

$$\text{Spectral type of a star} = f(T_e)$$

Where T_e is the effective temperature.
From the works of Dr. M.N. Saha and a group of Astrophysicists from Harvard working under E.C. Pickering. The classification of over 400,000 stars were done. This along with the work done by many other scientists in this field was compiled in Henry Draper catalogue, named after the scientist Henry Draper.

In Henry Draper catalogue, alphabets like A, B, etc., have been used to classify the stars from hottest to the coolest. Each class has also been subdivided into ten subclasses by using numbers, such as, B0, B1……, B9. According to this catalogue, the stars can be classified into the following types: O, B, A, F, G, K, M. Later spectral class W and some branches to classes G (R and N) and K (S) were added after their discovery.



Spectral Type	Temperature	Color	Spectral Features
O5-O9	40,000K-25,000K	Blue, bluish white	Emission lines: He II and O II Absorption lines: He II, He I, O II, Si IV, N III, C III. Weak lines of H I.
B0-B9	25,000K-11,000K	Blue, bluish white	Dominant H I absorption lines. Strong lines of O II, Si III, Si II, N II, C II and Balmer lines of H I. Appearance of Fe III, Fe II, Mg II, Cr II, Ti II.
A0-A9	11,000K-7,500K	White	Strong Balmer lines of H I. Absorption lines: Mg II, Si II.

			Weak lines of Fe II, Ti II, Ca II and no He lines are present.
F0-F9	7,600K-6,000K	White, yellowish white	Weak Blamer lines of H I. Strong lines of Ca II, Fe II, Ti II. Faint Ca I and Fe I lines.
G0-G9	6,000K-5,000K	Yellowish white, yellow	Weak Balmer lines. Maximum Ca II lines. Faint lines of neutral metals and Fe I.
K0-K9	5,100K-3,500K	Dark yellow, orange, or red	Weak Balmer lines and strong lines of neutral metals. Molecular bands strong.
M0-M9	3,600K-3,000K	Red	Hydrogen lines scarce. Dominant molecular bands like TiO. Strong neutral bands.

This classification is also known as Morgan Keenan classification. The formulation of this type of classification of stars was done with reference to the works of M.N Saha. He gave an equation which establishes a relation between various ionization states of an atom in the stellar atmosphere. This equation is written as

$$\frac{N_{q+1}N_e}{N_q} = \frac{(2\pi m_e KT)^{3/2} 2u_{q+1}(T)}{h^3 u_q(T)} exp\left(-x_q / kT\right)$$

Here, N_q = number of atoms in qth ionization state.

N_{q+1} = number of atoms in (q+1)th ionization state.

X_q = energy utilized to ionize the atom from qth state to (q+1)th state.

m_e = electron's mass.

N_e = electron density.

This equation has proven to be very important in Astrophysical data analysis and spectral classification of stars as it puts forward a quantitative relation between the atoms and ions that are present in the perfect gas in the state of equilibrium.

Hertzsprung-Russel Diagram:

HR diagram is a very important tool in classifying the stars based on their spectral class. It is a plot between the temperature or the spectral type of the star with the luminosity of the star. With the help of this plot, stars can be classified based on their effective temperature and their luminosity. On close analysis of the plot, we can see that about 99% of the stars lie in a narrow band in the graph called the main sequence band. The stars lying in the main sequence band are called main sequence stars and these stars have fully evolved into stars that can ignite nuclear fusion process in their core and are in hydrostatic equilibrium. The main sequence band extends from the left corner at the top to right corner at the bottom. The top part of the band contains O and B type stars, and the bottom part of the band contains M type stars. O and B type stars are hot stars whereas M type stars are cooler, fainter red dwarfs. Some of the main sequence stars include our Sun, Sirius, Barnard's star and so on. The main sequence ranges from absolute magnitude of -7 to +15. Our Sun, which is a part of the main sequence band has an absolute magnitude of 4.8 and an effective surface temperature of 5780K.

Apart from the main sequence band, there are other smaller yet significant groups of stars that are found in the HR diagram. One such group is found at the top right corner above the main sequence band which contains the F-M class of stars. These stars are called giant stars due to their high luminosity, temperature, and mass. They have absolute magnitude of -1 to +1. Above this group lies another group of super giants that have magnitude -3 to -8. In the middle of the plot, there is another group of stars called the subgiants that have the absolute magnitude of +1 to +5 and have F to K type stars.

At the bottom left corner, we have the group of stars containing B to G type stars having absolute magnitude of +10 to +15. These are faint white dwarfs that are stellar remnants. They have masses that may be up to 1.4 M⊙ but their size is approximately that of the Earth. This makes the star extremely dense. Below the main sequence band and above the white dwarf group, there is another group of stars that are known as sub dwarfs. There is also a region in the HR diagram where there is no group of stars found and so this region is called the Hertzsprung gap.

Determination of Spectral type of a Star:

Since the various spectral classes of stars are known to Astrophysicists, with the help of the spectral data obtained from telescopes, it is now possible to create graphs and plots which help us in determining the spectral type of star. These plots are very useful in understanding the bulk properties of the stars such as their temperature, mass, density and most importantly the type of elements present in it. The spectrum obtained from the telescopes consists of information about the temperature of the star, chemical composition, and luminosity. The raw data that is obtained from the telescopes must be analyzed and segregated to get a meaningful interpretation of the data. For this, knowledge of the spectral graph is important.

The stellar spectrum consists of a series of lines. These represent both absorption and emission lines. These lines in the spectrum arise due to the various electronic transitions occurring in the atoms and molecules. As the electron makes transitions from one energy level to another, a discrete quantum of energy in the form of photons gets released which gives rise to the emission or absorption spectra depending on whether the electron has lost or gained energy. For example, in the case of hydrogen atom, a whole new spectrum can be obtained depending on the type of transition made by the electron from one level to another. The spectral series of hydrogen atom consists of Lyman series, Balmer series, Paschen series, Brackett series, Pfund series and Humphrey series. This series arises when the electron makes a transition from a higher excited state to lower excited state. A Similar trend is also exhibited by other atoms such as sodium, carbon, etc., and these elements are known to have their own spectral series. This helps scientists in identifying the type and composition of the element present in the stars. The lines present in the stellar spectrum are also useful in understanding the amount of a particular element present in the star. The width of the spectral line determines the abundance or scarcity of the element present in the spectrum of the star.

According to the Morgan Keenan classification of stars, as stated previously, the stars are classified from O to M starting from the hottest stars to the cooler ones. This classification can be made by looking at the spectrum of the star obtained. The spectral lines that are observed in the stellar spectrum depend strongly on the temperature of the star. Helium II lines are observed only in very hot O type stars as it requires a lot of energy to ionize neutral helium atoms. Also, hydrogen lines are very faint in O type stars as the surface temperature of these stars is >10,000K and due to this high temperature hydrogen atom gets ionized and since there is no electron left, it does not show any hydrogen line in the spectrum. B type stars are not hot enough to ionize He II atoms and so their characteristic spectrum only contains He I line. All other stars after B type stars do not contain, He line as they are not hot enough to even energize helium atom. In B, A, and F type stars, the surface temperature is not high enough to ionize hydrogen atoms but can energize the electrons in hydrogen atom to higher energy levels. Thus, in the spectrum of these type of stars, Blamer lines of hydrogen spectrum are present. But these lines are absent in G, K, and M type stars as their temperature is not sufficient to even energize hydrogen atoms.

Any element with atomic number more than carbon atom is a metal in Astrophysics. The metals do not require very high temperature to get ionized and hence the spectral lines of metals are also found in cooler G, K and M type of stars. The spectral lines observed for the metals are more than hydrogen and helium lines as they have more electrons. In the cool M type stars, the absorption lines turn into broad bands as there are more metals present in them and so the spectrum is more conspicuous as continuous spectrum.

The continuous spectrum of a star looks like an extended spectrum of white light coming from the star. But the spectrum that we obtain from stars also consists of some dark absorption lines. By associating these absorption lines to the wavelengths that they are observed in, we can determine the type of element present in the star that absorbs that wavelength of light. Th above mentioned information about the type of elements presenting the different spectral classes of the star is the result of such observations. Apart from the observation of the spectrum obtained from the star, we can also plot a flux density versus wavelength graph to determine the type of elements present in the star.

The flux density versus wavelength graph is a standard tool used by Astrophysicists to determine the spectral type of star and to create the physical model of the star. The data required to plot this graph is obtained from the astronomical observatories that record the light coming from a particular star over a long period of time and calculate the error in the data so obtained. This data is then uploaded into graph creating software so that we can obtain the required graph. This type of graph is called spectral energy distribution (SED) graphs. To understand this graph, it is important to have a basic understanding of the quantities that are required to plot this graph.

The first term that is plotted on the Y-axis of the graph is called the flux density. This quantity refers to the rate at which energy is converted to electromagnetic radiation by a surface per unit area per unit wavelength or per unit frequency. This term is also called, irradiance, radiant energy etc. The unit of flux density is $Wm^{-2}nm^{-1}$. The unit can be changed with respect to the unit in which the area and the wavelength is being measured. The major application of calculating the flux density is that it helps us in getting an idea about the characteristic electromagnetic radiation coming from the star. This is useful to determine the spectrum f the star. The next term that is plotted on the X-axis of the SED graph is the wavelength. It tells us about the wavelength of the light coming from the star. By taking the area under the graph we can easily calculate the flux. Flux is defined as the amount of energy that is observed in the detector. With the help of flux, we can calculate the luminosity of the star from the formula.

$$L = 4\pi\, d^2 f$$

Here d = distance of the star from the observatory.
f = flux calculated from the graph.
Apart from this, the information about the presence of the elements in the star can also be determined from the SED graph. We know that the radiation emitted from the star is not even as the star is not a perfect blackbody. So, the curve that we obtain for the stars has some dips or areas where there is rapid decrease in the flux density. These downward peaks correspond to the absorption lines as seen in the spectrum of the star. When we match the wavelengths corresponding to these dips in the curve, we can determine the type of element present in the star. The strength of the absorption lines obtained in the spectrum can be determined by looking at the how big the dip is in the curve. The stronger the strength of the line, the bigger will be the dip in the plot and the presence of that element corresponding to the absorption line will be more prominent. The weaker the line is, the smaller will be the dip and the presence of the element will be scarce. If we measure the flux density at the lower most point and at the continuum level, then we can calculate the strength of the line from the graph by using the formula.

$$\text{Strength} = 1 - \frac{f_{lin}}{f_{cont}}$$

Where f_{lin} = flux density at the lower most point in the line.
f_{cont} = flux density at the continuum level.
Thus, we can get a lot of information about the chemical composition and physical properties of the star from the SED graph.

Sources of Spectral Data:

The spectral data analysis, as mentioned above, plays a major role in deeper understanding of the celestial bodies. This also makes it important to observe and record this spectral data. The spectrum obtained from the stars is usually recorded by using photographic plates. The use of photographic plates is better than the traditional method in which the spectrum was viewed using an eyepiece and then manually drawn. Photographic plates are preferred over photographic films as films stretch over the course of time and hence alter the information which is to be derived from it. These plates can be used as records for future research purposes as the durability of these plates is also very good.

With the advancement in technology, new methods of recording spectral data are now easily available. One of these includes the use of charged coupled devices (CCDs). These are small chips that are very small in size but effective in recording the required spectral data. When light from the star falls on the chip, the electrons in the chip get excited and the spectrum thus obtained is recorded for future use. CCDs are now being widely used by scientists as they are more cost effective, and their small size provides a more efficient way to store the wide range of information.

The knowledge of spectroscopy not only helps in determining the type of elements present in the star but can also be used to study the internal processes and structure of the star. These days infrared spectroscopy, X-ray spectroscopy, γ-ray spectroscopy, etc., are being widely used to understand more about the stars. The observations obtained from spectroscopy are not only limited to stars but also these techniques are being used to understand more about interstellar gas and dust.

The Spectral Library of IRTF:

The online spectral library of IRTF consists of Stellar spectra from the observations made by the NASA Infrared telescope facility located in Mauna Kea. This spectral library consists of the spectral data for F, G, K, L, M, and C type stars. Cepheid stars are the stars with variable brightness that appear to show frequent glowing and dimming of the stars and the spectral data of these stars are also present in the spectral library of IRTF that acts as the candles in space and helps un measuring the distances to other solar systems and galaxies. This library plays a key role in understanding the atmosphere of the stars to know more about the stellar parameters like its luminosity temperature etc. Other than this, the color and spectral type of the star can also be determined using this information. The stellar data of most of the stars given in the IRTF library ranges from giants to dwarf type stars. The spectral data collected in this library is in the form of wavelengths, flux densities and the error recorded during the observation. This data is used to plot meaningful graphs which are later used to understand the mechanics of the star and to create a physical model of the star.

C-type stars:

In this case, the C type stars are being taken into consideration. C type stars are also called carbon stars. As the name suggests these stars have carbon in their outer most layer of atmosphere. These stars lie in the asymptotic giant stars line in the HR diagram. These are red giants which are stars that have reached the end of their lifetime and have more carbon in their atmosphere than hydrogen and helium. These stars have carbon compounds in their photosphere. The carbon to oxygen ratio of the C type stars C/O>1 indicating that there exists more amount of carbon and oxygen compounds in the atmosphere of the star than hydrogen and helium. It is to be noted that as C type stars are red giant stars that lie in the asymptotic giants branch of the curve, they are stars that have reached the later stages of their lifetime. These stars have already finished up with their hydrogen and helium fuel and now they have resorted to other atoms to fuse and derive energy from. The dominant spectral feature for C type stars is the C2 Swan band in their stellar spectrum.

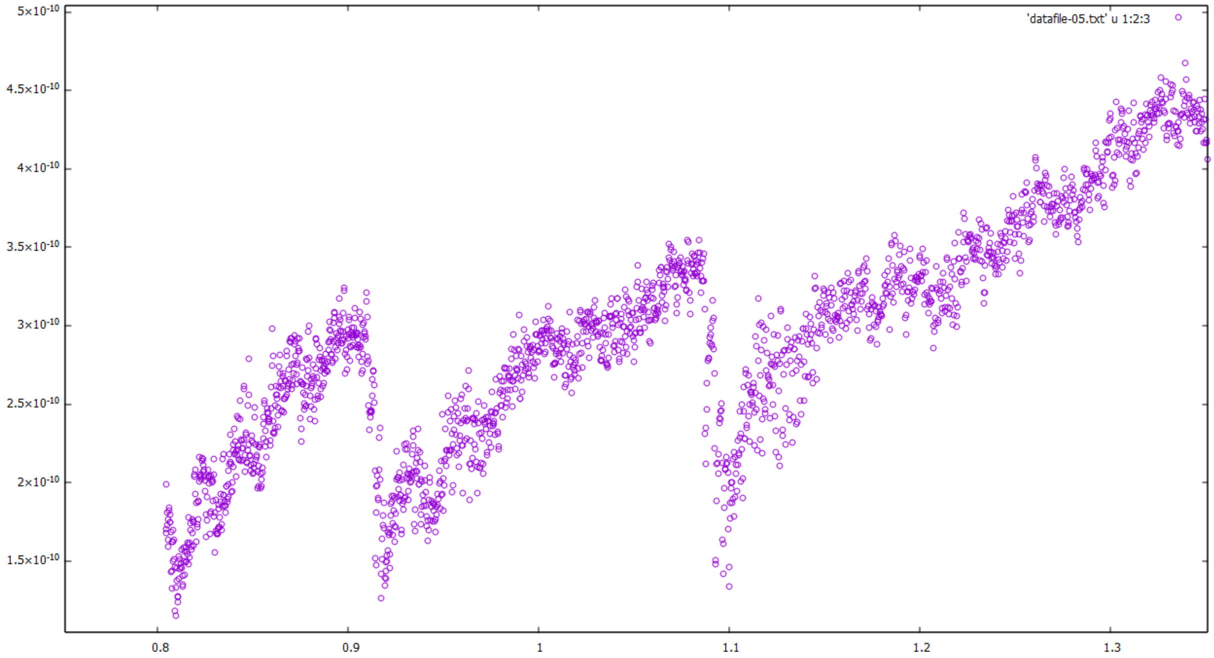
Carbon stars can be classified into two types based on the type of elements present in them and the process of fusion that they have undertaken to sustain their hydrostatic equilibrium. The first type is called the N type series. This series consists of carbon stars that have more isotopic bands of carbon, and these bands show more strength in comparison to the bands of other elements. N stars are older stars that have already undertaken the s process in their cores. S- process is the acronym for the slow neutron capture process that occurs in the stars that lie in the asymptotic giant branch. Since N type stars are carbon stars which contain the isotopes of carbon in their photosphere, the s-process results in the formations of elements that have almost half the mass of iron. During the s-process, the nucleus of an element undergoes neutron capture, and they form either stable or unstable isotopes. If the isotope formed is stable, then the mass of the newly formed element gets increased. But if the newly formed isotope in unstable then it undergoes beta decay to form a by-product of mass greater than the previous atom.

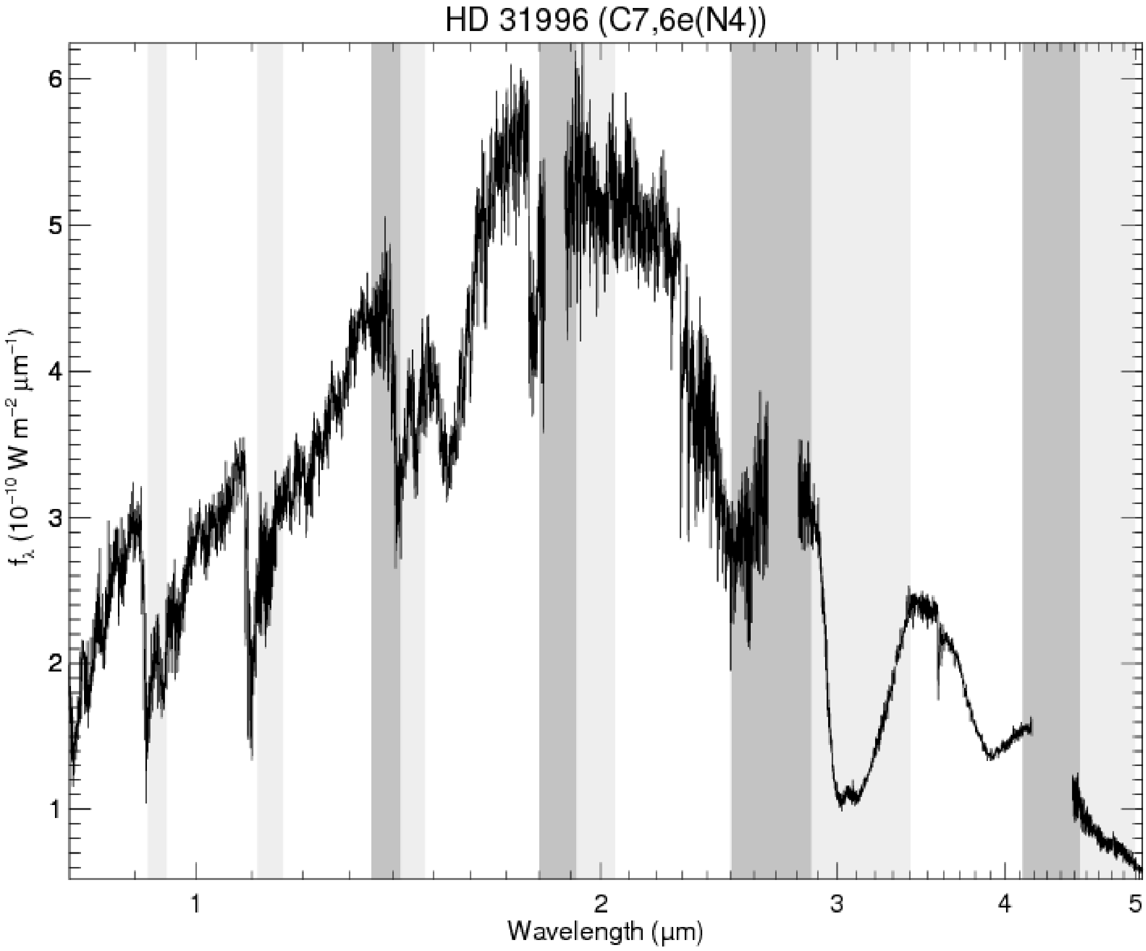
The next type of carbon stars is called the R type series. R type series is almost the same as the N type series except the absence of strong barium (Ba) lines present in the spectrum of the star. The spectrum of the star still shows the blue end of the spectrum. But in N type series, the blue end of the spectrum is almost invisible. The temperature of the R type stars ranges from 5100K to 2800K whereas for N type stars the temperature ranges from 3100K to 2600K. The temperature variation is because N type stars are older and hence cooler than the R type stars. Apart from this classification of carbon stars, N and R type series can also be classified using numbers such as C-R1, C-N1, etc., which indicates the decreasing temperature and the increasing strength of carbon band from 1 to 5.

In this paper, the N type carbon star has been taken to investigate the spectral data and to plot the SED graph for the star. The star that has been taken into consideration is a carbon N type star named C7, 6e(N4). The spectral data for this star has been taken from the IRTF spectral library and the SED graph for this star has been plotted to find the type of spectrum obtained for this star. It is a hydrogen deficient super giant. The spectral data for this star obtained from the spectral library has been given below.

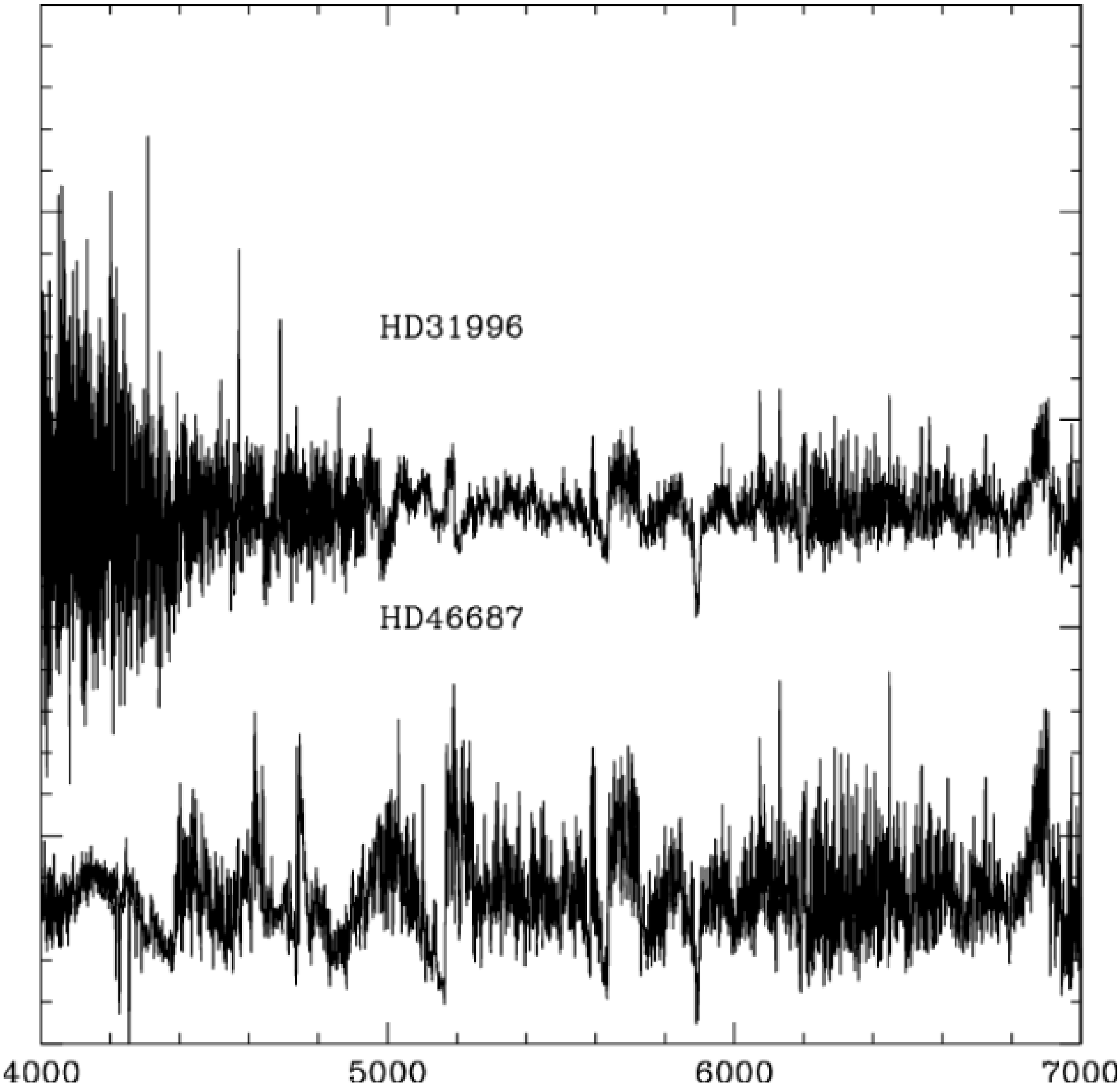
Wavelength (microns)	**Flux Density (W m^ (-2) µm^(-1))**	**Error (W m^(-2) µm^(-1))**
0.804299	1.99191e-10	9.38187e-13
0.804501	1.70085e-10	9.40262e-13
0.804703	1.67621e-10	9.94113e-13
0.804906	1.81212e-10	9.42163e-13
0.805108	1.72608e-10	9.45334e-13
0.805311	1.58961e-10	9.44479e-13
0.805513	1.63591e-10	9.39060e-13
0.805715	1.76512e-10	9.50678e-13
0.805918	1.84267e-10	9.57209e-13
0.806120	1.82189e-10	9.58713e-13
0.806322	1.74631e-10	9.56816e-13
0.806525	1.74641e-10	9.55981e-13

Using this data, a wavelength versus flux density graph can be plotted as given below.





From this graph we can infer that hydrogen and helium elements are scarcely present in this star and the peaks in the graph show that the element that corresponds to 2-3 μm is dominant in the star. Since the element that has the wavelength in this range is carbon hence, we can first confirm that this is carbon type star. Since this star has been mentioned in the Henry-Draper catalogue, the IAU designation given to this star id HD 31996. This star appears to be red in color when viewed through telescope as this is the characteristic feature of carbon stars. The blue end of the spectrum of this star. It has been determined that the star has strong carbon lines and hence the density of the peaks is the highest corresponding to the wavelength of the element carbon. The spectrum of this star has been given below.



This graph shows the comparison between another Henry Draper catalogue star HD 46697 which is a UU Aurigae star. This comparison shows us that the star that we have taken into consideration has more carbon content in it than the HD 46697 star which instead has more SiO content in it. C7, 6e(N4)) falls in the N4 category as the carbon content in it shows the presence of prominent isotopic curves in its spectra. Also, the s-process has already begun inside the star and hence heavier elements are being produced in the star.

Result:

From the graph and from the data observed from the spectral data given in the IRTF spectral library it has been observed that the wavelength of the star at maximum is about 1.262 μm. Using this information, we can calculate the temperature of the star using the prior knowledge of Wien's displacement law, which states that the wavelength of the light coming from the star is inversely proportional to the effective temperature of the star.

$$\lambda T = \text{constant}$$

$$\lambda T = 2.89\text{x}10^{-3} \text{ mK}$$

From this formula we can calculate the temperature of the star as the λ represents the wavelength of the star and the T represents its effective temperature. After calculation, the temperature of the star comes out to be 2289.8592K.

We know that the temperature of carbon stars ranges from 2000-3000K. Since the temperature we have found for HD 31996 star lies in the temperature range available for carbon type star hence, we can conclude that this star is a carbon type star.

Conclusion:

The classification of the star can be made using a lot of information that is mostly derived from the spectral data that is available to scientists in the spectral libraries. The data recorded in the spectral libraries is recorded from various instruments such as spectrographs and telescopes etc. The plot that can be made using this data is useful in determining the spectral classification of stars and about the various physical properties such as the temperature of the star and its luminosity. As the spectral type for the star HD 31996 (C7, 6e(N4)) has been determined by looking at the type of element that is prominent in the SED graph of the star, this method can also be used to determine the spectral class of other stars whose spectral data is available. Other than this many software's such as gnuplot can be used to plot SED graphs. Such an analysis of stars helps us in getting a better understanding of the types of stars present and their physical models can be made using the same. With the knowledge of spectroscopy, the analysis of stars has been made easier than before and with advancement in technology, even common masses have access to spectral data. With the help of spectroscopy, a detailed analysis of the spectrum obtained from the stars can be made and hence more knowledge about the stars can be inferred with the same. This gives us more information about the temperature, luminosity, spectral class, and types of elements present in the star. With this knowledge we can get a better understanding of our universe.

Bibliography:

The above work has been compiled through research done by the following sources.

- IRTF Extended Spectral Library: Villaume, A., Conroy, C., Johnson, B., Rayner, J., Mann, A.W. and van Dokkum, P. 2017, ApJS, 230, 23
- https://www.researchgate.net/figure/Spectrum-of-the-two-stars-HD-31996-and-HD-46687-which-have-no-known-spectral-types-Star_fig2_1777839
- https://en.wikipedia.org/wiki/Stellar_classification
- https://skyserver.sdss.org/dr1/en/proj/basic/spectraltypes/otherspectraltypes.asp

turnitin

Similarity Report ID: oid:16158:35540692

PAPER NAME	AUTHOR
20010-Alka-CK-STSM102-V2.docx	ALKA

WORD COUNT	CHARACTER COUNT
5094 Words	24809 Characters
PAGE COUNT	**FILE SIZE**
14 Pages	40.1KB
SUBMISSION DATE	**REPORT DATE**
May 16, 2023 10:28 PM GMT+5:30	May 16, 2023 10:29 PM GMT+5:30

4% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

- 4% Internet database
- 0% Publications database
- Crossref database
- Crossref Posted Content database
- 0% Submitted Works database

Excluded from Similarity Report

- Bibliographic material
- Quoted material
- Cited material
- Small Matches (Less then 14 words)

Summary

turnitin

Similarity Report ID: oid:16158:35540692

4% Overall Similarity

Top sources found in the following databases:

- 4% Internet database
- 0% Publications database
- Crossref database
- Crossref Posted Content database
- 0% Submitted Works database

TOP SOURCES

The sources with the highest number of matches within the submission. Overlapping sources will not be displayed.

1	irtfweb.ifa.hawaii.edu Internet	3%
2	posts.3cepheids.co.in Internet	<1%
3	akdtutorials.com Internet	<1%
4	K12 Incorporated on 2022-03-21 Submitted works	<1%

Sources overview