CHAPTER 2

BACKGROUND THEORY

2. 1 Astronomical Spectroscopy

2.1.1 From properties of atom to spectral series

The study of the stellar spectra and the spectra of other celestial objects is called astronomical spectroscopy and it is one the most fundamental concept due to the fundamental properties of atoms. Atom has the ability to absorb and emit light and in the same time obeys the law of conservation of energy. Thus, if an atom emits some energy in the form of radiation, that energy has to come from somewhere within the atom. Niels Bohr (1912) assumes that the atom is made up of two parts; the nucleus (protons and neutrons) in the center and the electrons orbits it (Chaisson & McMillan, 1997).

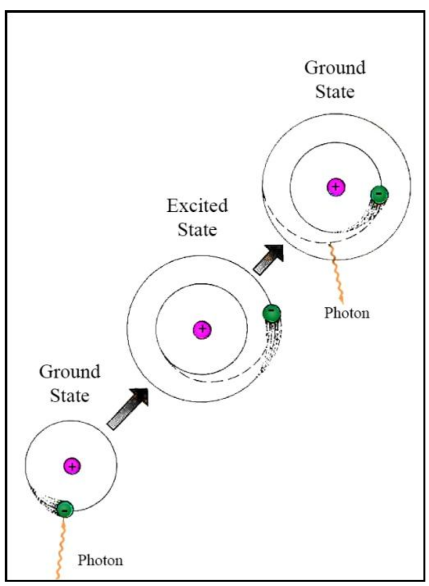

Figure 2.1: A simple illustration on how a basic atom absorbing energy and becoming excited, then releasing the energy to return to the original state.

It is the nature of an atom to absorb energy (or photon) whenever their electrons are lifted into the higher state or excited state and emits energy when they return to the ground state. The amount of energy needed to move the electron from one state to another depends on the energy difference between the orbital. In the meantime, Bohr assumed that the spinning electron is accelerated due to its motion along a circular path. However, the energy is constant. This assumption can been proved by him Newton's laws of motion.

For circular motion, the centripetal force, *F* is given by,

$$F = -\frac{mv^2}{r} \qquad \text{-------- (2.1)}$$

where
F = the centripetal force
m = the mass of electron
v = speed of electron motion
r = radius of electron orbital

and from the Coulomb's law of force,

$$F = -\frac{e \times e}{4\pi\varepsilon_o r^2} \qquad \text{-------- (2.2)}$$

where
F = force
e = electron rest mass
ε_o = electric field constant
r = orbital radius

According to Bohr's assumption, angular momentum of the electron is quantized, or in packet of,

$$L = n\frac{h}{2\pi} \qquad \text{-------- (2.3)}$$

where
$L =$ angular momentum
$n =$ energy level (positive integer)
$h =$ Planck's constant
(6.626×10^{-34} m^2 kg s^{-1})

and for a moving particle along a circular orbit around the nucleus at the *n*th energy level is,

$$L = mv_n r_n \qquad \text{-------- (2.4)}$$

where
$L =$ angular momentum
$m =$ electron's mass
$v_n =$ electron's speed at nth energy level
$r_n =$ orbital radius at nth energy level

Hence, the energy

$$E = -\frac{e^2}{8\pi\varepsilon_o} \times \frac{\pi m e^2}{\varepsilon_o h^2 n^2} \qquad \text{-------- (2.5)}$$

$$= -\frac{me^4}{8{\varepsilon_o}^2 h^2} \times \frac{1}{n^2} \qquad \text{-------- (2.6)}$$

For the ground state which is innermost orbit, n = 1, the energy value;

$$E = -\frac{me^4}{8{\varepsilon_o}^2h^2} \qquad \text{-------- (2.7)}$$

So, by putting the value for the equation above,

where e = 1.60×10^{-34} C
ε_o = 8.85×10^{-12} F m^2
m = 9.11×10^{-34} kg
h = 6.626×10^{-34} m^2 kg s^{-1}

the value of the energy for the ground state is ;

$$E = -2.179 \times 10^{-19}\,J = -13.6\,eV$$

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The using of electron volt (eV) unit is as a simplification of energy unit which has an equivalent of a quantity of energy imparted to an electron by an electron by accelerating it through an electric potential of 1 volt (Chaisson & McMillan, 1997).

Hence, the energy at the nth energy level,

$$E_n = -13.6eV \times \frac{1}{n^2} \qquad \text{-------- (2.8)}$$

where n = 1, 2, 3, etc.

Then, from the equation, energy levels of the hydrogen atom, which has one electron, can be figured as shown as Table 2.1.

Table 2.1: Energy level of hydrogen atom

n	1	2	3	4	5	…	∞
$E\ (eV)$	-13.6	-3.4	-1.5	- 0.85	0.54	…	0

Right before Bohr made the assumption; Johann Balmer (1885) found a formula in order to calculate the wavelength of the absorption or emission lines and was originally presented as follows;

$$\lambda = B\left(\frac{m^2}{m^2 - n^2}\right) \qquad \text{-------- (2.9)}$$

where
$\lambda =$ the wavelength of light
$B =$ Balmer's constant (3.635×10^{-7}m)
$n =$ 2
$m =$ positive integer larger than 2

Then, Johannes Rydberg (1888) rearranged the Balmer's formula in order to use it for any atom and any energy state and becoming:

-------- (2.10)

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where
$\lambda =$ the wavelength of light
$R =$ Rydberg constant (1.097×10^{-7} m^{-1})
$Z =$ the atomic number
$n =$ positive integer such that n_2 is larger than n_1

Thus, this formula can be used for Bohr's hypothesis about energy level of hydrogen atom by putting the atomic number hydrogen, Z, as 1. Then, by applying the relation of light frequency and Planck relation (1900):

$$f = \frac{c}{\lambda} \qquad \text{-------- (2.11)}$$

where $f =$ the frequency of light
$c =$ the speed of light (2.99×10^{8} m s^{-1})
$\lambda =$ the wavelength of light

$$E = hf \qquad \text{-------- (2.12)}$$

where $E =$ the quantized energy of light
$h =$ Planck's constant (6.626×10^{-34} m^{2} kg s^{-1})
$f =$ the frequency of light

hence, the energy for the first state is

$$E = hcR = 13.6\ eV \qquad \text{-------- (2.13)}$$

Therefore, we get

$$E_n = -\frac{13.6}{n^2} \qquad \text{-------- (2.14)}$$

This simple equation proves the relationship of Balmer's and Rydberg formula with Bohr's hypothesis. By assigning to the ground state, Bohr has found that the energy to any state could be written as follow:

$$E_n = 1.36 \times \left(1 - \frac{1}{n^2}\right) eV \qquad \text{-------- (2.15)}$$

This equation above shows the “energy levels” of the hydrogen atom. The lowest energy level is the ground states where n = 1 (E_1 = 0). Nonetheless, the atoms bash into each other, some of the energy is used to allow an electron to jump instantaneously up to the higher energy level. When this happened, it is called the “excited state” or the “excited electron”. The first excited state has an energy of E_2 = 10.2 eV, and so on. However, Bohr assumed that this excited state is just a temporary with about 10^{-8} s. After that, the electron returns back to the previous state and loses the energy by emitting the same amount of energy or photon.

In the meantime, the principle of quantum mechanics also states that an electron cannot stay "between" energy levels. The electro will lie at the same energy level until it reaches enough energy on order to be excited. However, too much energy can make the electron extremely excited so that it just jump too high until it has no longer bound to the nucleus and let the atom be ionized. As long as the electron stays within these two levels, electron can move along and between the orbital without making the atom ionized.

In our universe, celestial object such as stars emit electromagnetic radiation and it travel in the form of wave in the vacuum out space without any transmission medium. At the same time, the radiation consists of energy. In 1900, Max Planck assumed that the energy of a vibrating molecule was quantized, which has certain values. The energy would have to be proportional to the frequency of vibration, frequency multiplied by a certain constant. This constant is known as Planck's constant. As stated in equation, the frequency of the photon is proportional to the energy.

Therefore, the wavelength for the emission or absorption spectrum of hydrogen can be calculated using equation 2.11 and 2.12 Let say we are taking account on Balmer series from energy state $n = 3$ to $n - 2$.

$$E_3 - E_2 = (E_3 - E_1) - (E_2 - E_1) = 12.1 - 10.2 = 1.9\ eV$$

$$\lambda = \frac{hc}{(E_3 - E_2)} = 6563\text{Å}$$

By this value, there is a spectral line at $\lambda = 6563\text{Å}$ to be found if there is an existence of hydrogen.

2.1.2 The idea of black body radiation

There are loads of information can be gathered from a spectrum such as temperature and apparent colour if the assumption to be made that a star behaves like a black body radiation source (Kaler, 1989). This idea is made so that the overall shape of spectra and the point of the maximum can be compared based on the knowledge on the sun spectrum. Black body can be defined as an object that absorbs all radiation fall on it with no reflecting power and at the same time, a perfect emitter of radiation as well. It is also assumed that black body radiation is thermal radiation that would be emitted from a black body at particular temperature. It has a continuous distribution of wavelengths or frequencies. The plot of the graph for the energy of the radiation has a characteristic shape with one maximum value given at wavelength, λ_{max}.

At low temperature, the black body radiation is mainly in the higher region of the spectrum such as infrared. As the temperature increases, the curve maximum shifts towards the shorter region of wavelength. This trend obeys the Wien's displacement law which stated as:

$$\lambda_{\text{max}} = \frac{2.9 \times 10^{-3}\text{mK}}{T} \qquad \text{-------- (2.16)}$$

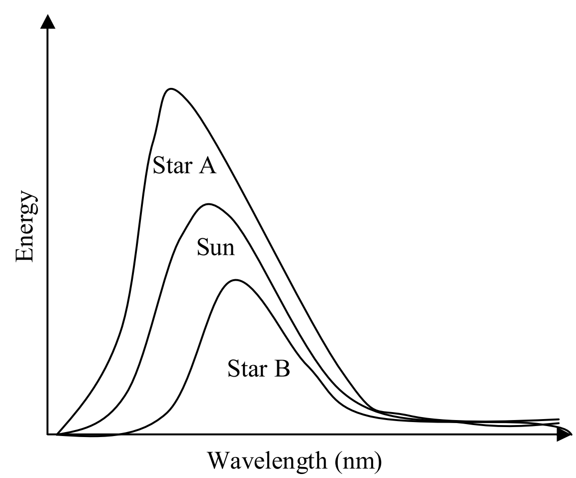
where λ_{max} = the wavelength at maximum energy
T = temperature of the black body

This law states that if an object radiates like an ideal black body, then the wavelength at which it radiates the most is related to its temperature. This means a very hot star radiates most at short wavelength and cooler star radiates most at longer wavelength. For a visible light spectrum, short wavelength means blue region while long wavelength means red region. Hence, from this idea, hot stars will be seen blue in colour while cool stars are red.

Not to be forgotten, at the same time, black bodies have to obey the Stefan-Boltzmann law as well. This law rules that any object radiates like a black body, the total energy emitted over all wavelengths per second per unit area (or the luminosity) is also related to its temperature. It is stated as

$$E = \sigma T^4 \qquad \text{-------- (2.17)}$$

where σ is a constant value 5.67×10^{8} W m^{-2} K^{-4}.



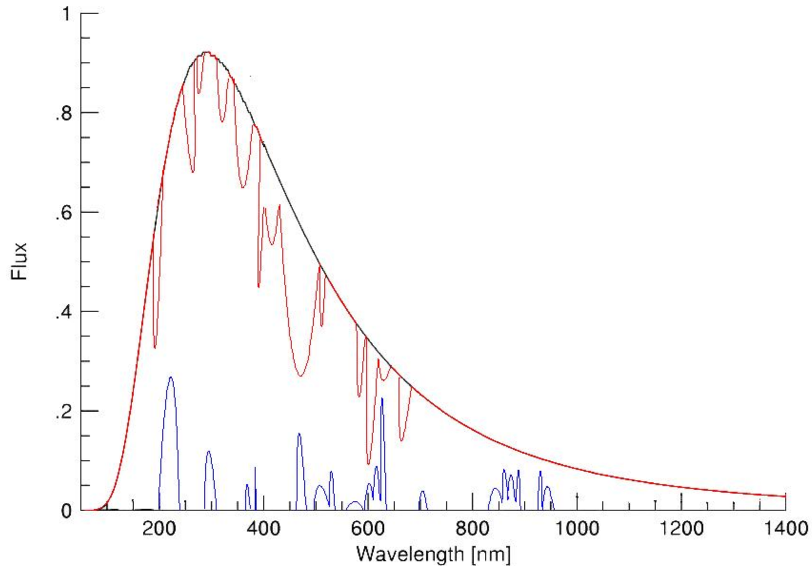
Graph 2.1: The graph of intensity of the star. Star A is hotter than the sun while star B is cooler compared to both star A and the sun. The curve peak of star A tends to the blue while star B inclines to red.

Graph 2.1 illustrates on the tendency of the curve peaks for different temperature showing that hotter stars tends to move its curve towards blue and cooler towards red. Thus, base on this concept which governing the black body radiation, the spectrum of a hot star will have a higher and sharper peak closer to the blue end of the visible spectrum while a cool star will have a lower and dampen peak towards the other end of the visible spectrum which is red.

2.1.3 Spectrum from the Stars

A spectrum is observed when light passes through a dispersing element. However, when the light comes from stars, it is called stellar spectrum. The electromagnetic wave energy can be emitted and absorbed but in lumps or packets. These packets of energy, which is so called photons or quanta, have definite size. The spectral line emitted by gaseous or other element consists of either emission or absorption lines. In astronomy, there are three types of spectra that relates with the stars. They are continuous spectrum, absorption spectrum and emission spectrum (Kaler, 1989).

On the whole, the visible light from a star would show a continuum spectrum with cuts by dark lines which are called the absorption lines. Though, there are some occasional occurrences where the continuum spectrum also has bright lines on it. These bright lines are emission lines.



Graph 2.2: Graph of three types of stellar spectrum: the continuous spectrum (black), the emission spectrum (blue) and the absorption spectrum (red).

Continuous spectrum is a spectrum consists of a continuous region of emitted or absorbed radiation with no discrete line to be determined. It is also the effect of smudging each emission line into a broad band of wavelengths. This type of spectrum comes from hot solid objet or dense matter which radiates heat via the produced light such as the continuous emission of ultraviolet, visible and infrared radiation from the inner layer of stellar photosphere. Graph 2.2 shows the flux of a black body that measured at a series of wavelength. The flux at the maximum value at certain wavelength depends on the stars. This is Kirchhoff's first law of spectroscopy.

Absorption spectrum is a continuous spectrum but with the flux of selective frequencies diminished due to the absorption process by matter. Usually, absorption spectra are produced when radiation from an incandescent source which has continuous spectrum passes through cooler matter such as atmospheres of the star. When radiation is absorbed at certain wavelengths, its intensity is weakened. Hence, a pattern of very narrow dips or wider troughs are superimposed on the continuous spectrum. This dips and troughs are absorption lines or bands. The wavelength at which absorption occurs corresponds to the energies needed causing transitions of the absorbing atoms or molecule from lower energy states to higher energy states. Each lines is formed at a different depth in the stellar atmosphere depend on the type of element produced. This phenomenon also occurs when the light from a star passes through a gas clod or interstellar medium between the star and the earth. This occurrence is also called as Kirchhoff's third law of spectroscopy.

Emission spectrum is made by a gas or a cloud emitting radiation after absorbing it from other light source. In absorption spectrum, dark lines are formed in a coloured or bright spectral band but in emission spectrum, the coloured or bright lines are visible or dominant in a black or dim coloured band. The wavelength emitted depends on the atoms contained in the gas itself. In order to create the emission lines, firstly, energy has to be supplied to the atoms or molecules. It is either by heat, by absorption of electromagnetic radiation of other matter or by impact of particles (Illingworth, 1994). As the atom or the molecules absorbing the energy, it jumps to higher energy states by absorbing an amount of energy that separate the two states. Then, the excited atoms or molecules are likely to leave the excited state spontaneously and drop to a lower level. Thus, the same amount of energy is released and giving an explicit wavelength corresponds exactly to the transition. Therefore, the spectrum consists of a dark black band with specific pattern of narrow peaks which is the emission lines. This spectrum usually occurs from a nebula that has been brightened by a nearby star. This is Kirchhoff's second law of spectroscopy.

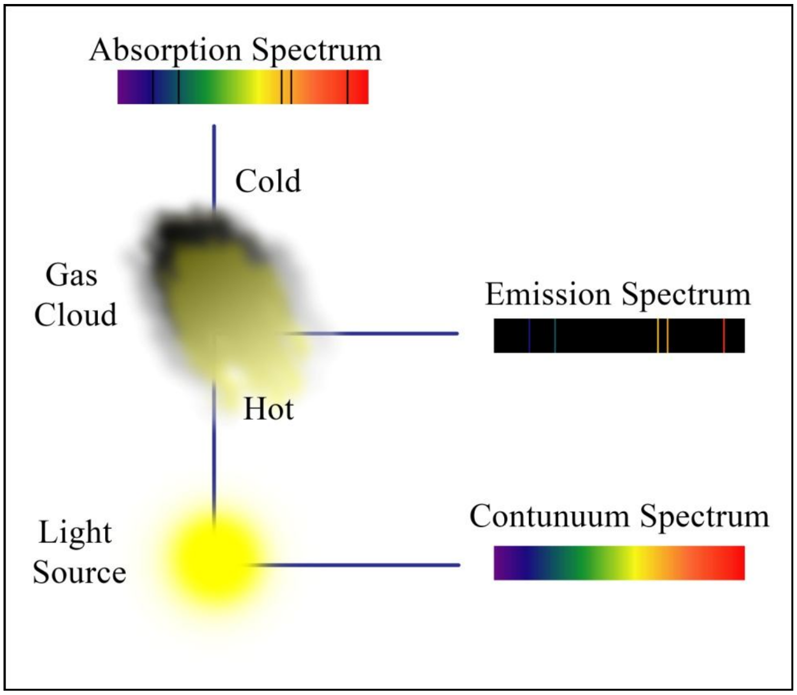


Figure 2.2: An illustration demonstrates on Kirchhoff's Law of Spectroscopy.

However, if a star surrounded by hot shell of diffuse gas such as stellar envelope, planetary nebula or quasars, the spectrum will be consists of an overlapping between continuum spectrum, absorption and emission lines. The wavelength position of the line, either absorption or emission, is matching if the source element is the same.

These lines are unique for every chemical element which is why they are also called as the "fingerprint" of gas or element. The spectral lines were indicators of the existence or abundance of a chemical composition in the source.

2. 2 Stellar Classification

Spectral classification scheme was able to be developed after the astronomers noted the changes in intensity of the spectral lines with temperatures. Hence, a star is assigned to its Spectral Type and Luminosity Class.

Before the invention of telescopes, stars were seen by naked eyes. It seems that the stars were only divided into brightness or their apparent colours. In the early 20^{th} century, Harvard Observatory has developed spectral classification system that was published in the Henry Draper Catalogue (1918 to 1924) and Henry Draper Extension (1925 to 1936). This system is based on spectral lines which are principally sensitive to stellar surface temperatures which highlight on important lines such as the hydrogen Balmer lines, lines of neutral and singly ionized helium, iron lines, the doublet of ionized calcium, the band of CH molecule, the neutral calcium line, several metal lines, and the lines of titanium oxide as shown in figure 2.5.

The spectral classification scheme used the spectral characteristics. The strength of spectral lines tells the temperature of a star. If using visible hydrogen lines only, it is not sufficient since the lines could be also produced by either a hotter or cooler star. Adding many other atoms and molecules to creates a defined system to determine stars temperature (Seeds & Backman, 2008).

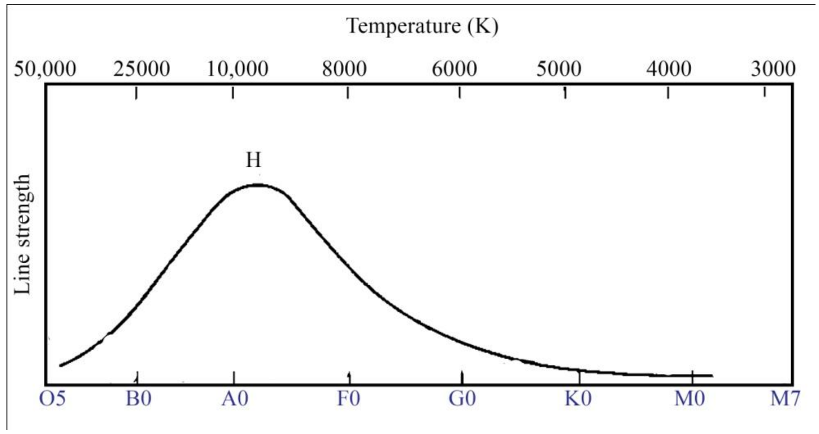


Figure 2.3: Hydrogen Balmer or Hα lines are strongest for medium-temperature stars.

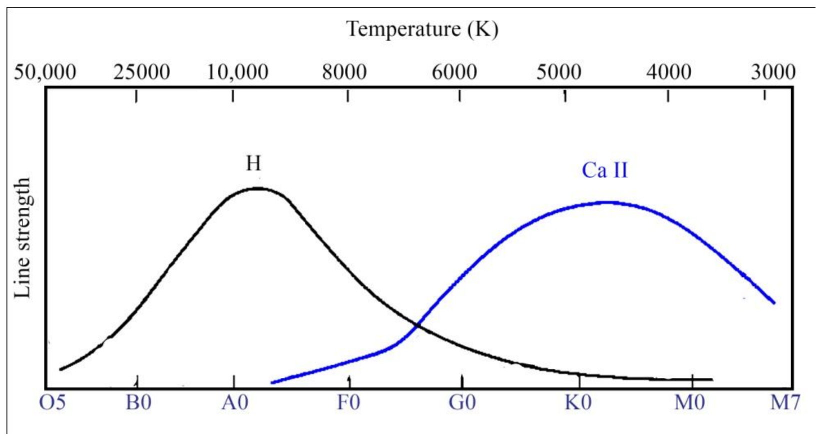


Figure 2.4: Lines of ionized calcium are strongest at lower temperatures compared to the hydrogen lines.

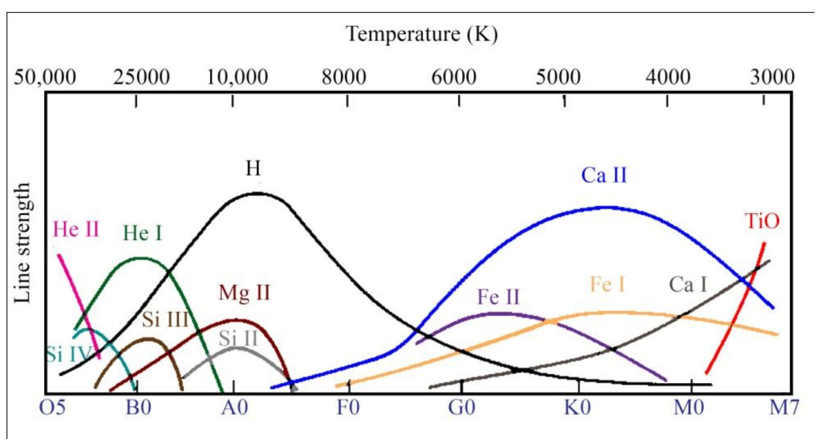


Figure 2.5: The lines of each atom or molecule are strongest at a particular temperature.

The scheme that still in used today has been invented by E.C. Pickering with the help from his assistants Annie Cannon, Antonia Maury, and William Fleming which lettered the stars according to the strengths of their hydrogen lines. However, the recent seven stellar types of O, B, A, F, G, K, and M was credited to Annie Cannon (1901).

Table 2.2 The pattern of Spectral Type and temperature.

Type	**Color**	**Surface Temperature (K)**	**Spectral Type**
O	Blue	> 25,000	Ionized He
B	Blue	11,000 - 25,000	Neutral He, H
A	Blue	7,500 - 11,000	Neutral H
F	Blue to White	6,000 - 7,500	Ca II, neutral H, metals.
G	White to Yellow	5,000 - 6,000	Ca II, Fe I.
K	Orange to Red	3,500 - 5,000	Ca, Fe, molecular bands
M	Red	< 3,500	TiO bands.

O, B, and A referred as early types, while G, K and M known as late type stars. Decimal subdivisions of the spectral classes go toward lower temperature, for example, A0 lies at the hot end of class A near a temperature of 9500 K, while A9 is at the cool end near 7200 K.

Later, a more specific classification which includes the luminosity of the star was developed. This system is called as the Yerkes classification or MKK (refers to the originators William Morgan, Philip Keenan and Edith Kellman). This scheme measures the shape and nature of certain spectral lines. For a given temperature, some stars are more luminous than others due to the larger size of the star and its weaker outer atmosphere at a lower pressure than a fainter star. The spectral lines of very luminous stars are much narrower and sharper since the effects of line broadening due to collisions are much less. These luminosity classes are denoted by roman numerals as shown in Table 2.3.

Table 2.3 The various Luminosity Classes of stars.

Class	General Features
0	Hypergiants
Ia	Extremely luminous supergiants
Ib	Luminous supergiants
II	Bright giants
III	Normal giants
IV	Subgiants
V	Main sequence stars (dwarfs)
VI/sd	Sub Dwarf
VII/d	White Dwarf

In practice some luminosity classes, particularly those of the supergiants, are subdivided into suffixes a, ab and b and a class written as III-IV means a star with characteristics in the middle between the two classes. The full spectral classification thus consists of [Spectral Type] [Number of Decimal Subdivision] [Luminosity Class] [suffix (if any)]. For example, the Vega, a hot main sequence star, is classified as A0V while Rigel, a supergiant, is classified as B8Ia.

Spectra can reveal many other things about stars. Knowledge about the classification of the star is very important as it guides to facilitate and comprehend the correct reference in the calibration process in data analysis. The presence of atoms and the chemical abundances of the star can be known by analyzing the spectrum from a star. This leads to the knowledge of how the star evolves in time.

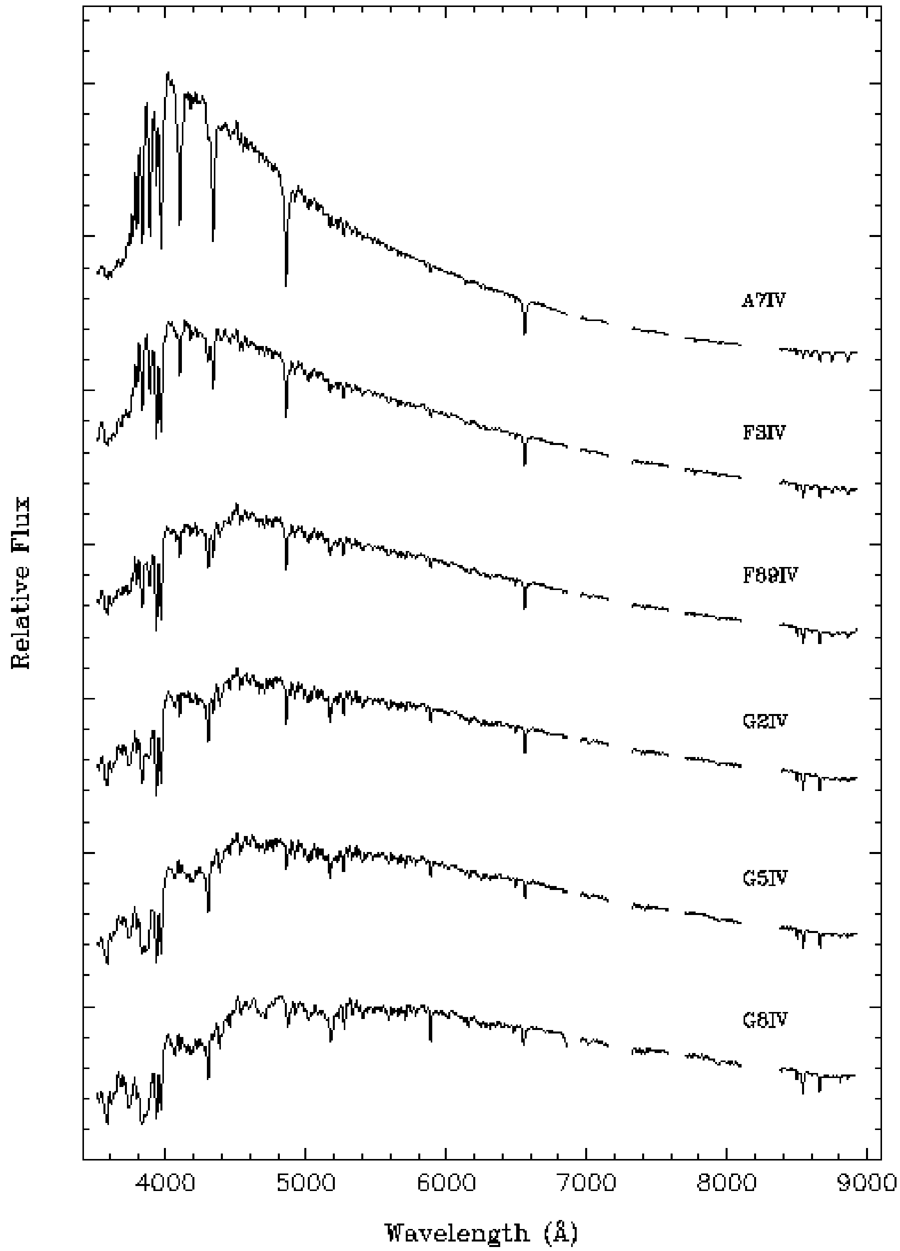


Figure 2.6: An example on spectral profile variations from F6/7V to K5V by Silva and Cornell (1992) of University of Oregon.

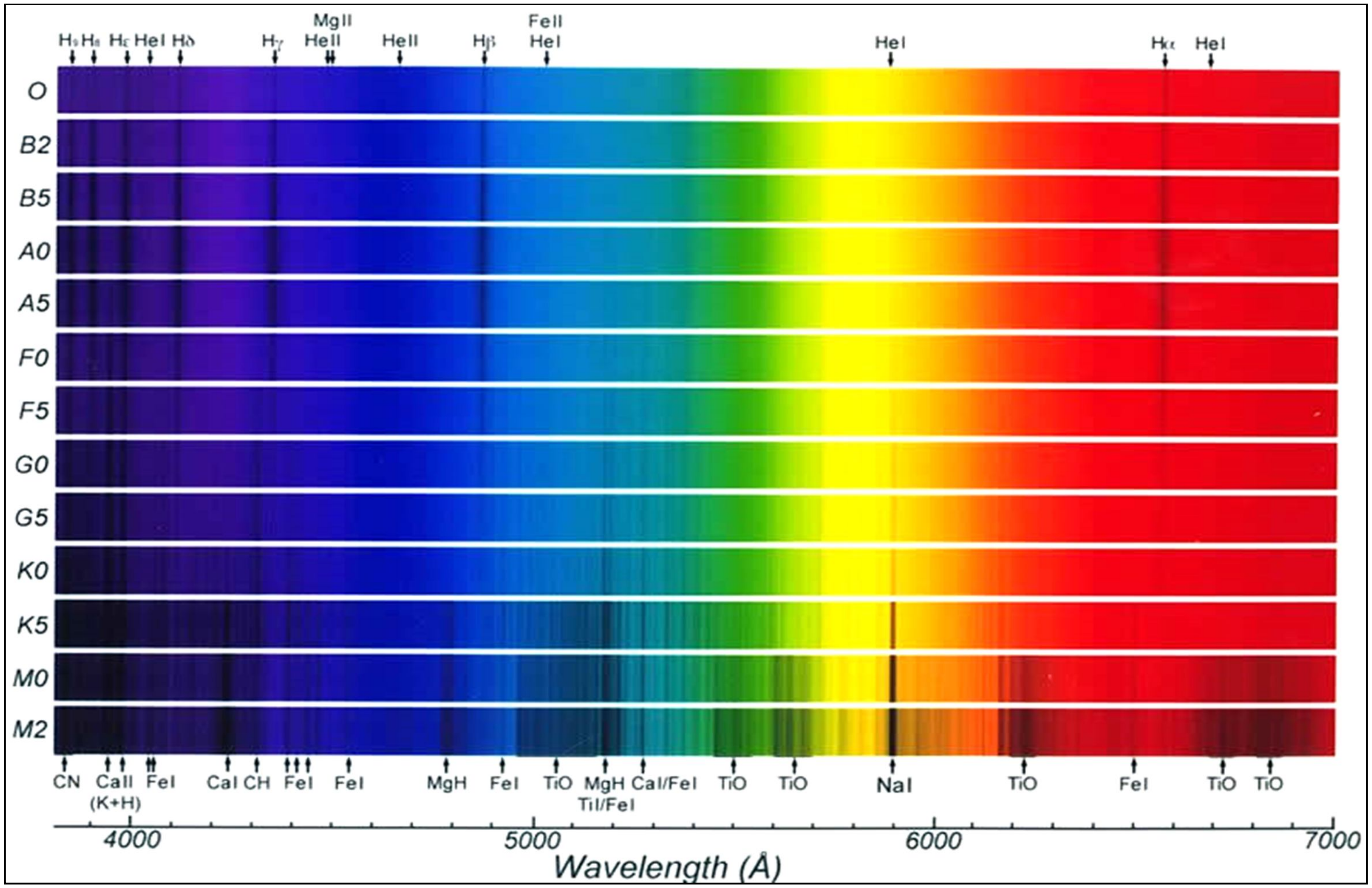


Figure 2.7: Spectral sequences according to classes with labels on elements
Source: California State Polytechnic University, Pomona

2. 3 Stellar Evolution

2.3.1 Early stage of evolution

Stellar evolution usually begins a gigantic or molecular cloud which is associated with the nickname stellar nursery. This is due to the large quantity of gasses to form a star. It begins with the gravitational collapse of a nebula with the typical size of 100 light-years across and contain up to 6 million times of solar mass. As it condenses, a giant nebula ruptures into many smaller pieces and releases gravitational potential energy as heat. The longer the collapse, more temperature and pressure are produced. As these two physical factor increases, a piece condenses into a rotating sphere of extremely hot gas known as a protostar (Prialnik, 2000). The subsequent stellar progress greatly depends on the mass of the protostar. Protostars with less than 0.08 $M_{\odot}$ will never make it to be a star since the pressure is not high enough and the temperature to start nuclear fusion of hydrogen cannot be reached. Hence, these types of protostars are known as brown dwarfs.

On the contrary, for more massive protostar, the pressure of the collapse will produce a high temperature up to 10 million Kelvin. This temperature is just right to start the nuclear fusion reaction of hydrogen and allowing it to create deuterium and helium via the proton-proton chain reaction. The starts of nuclear fusion at the core will create enormous energy so that it can balance the weight of the star. This is called as a hydrostatic equilibrium. Hence, the star begins to evolve steadily and commencing its evolution as a stable main sequence star.

2.3.2 Main Sequence Star

After a star is born, it will be placed at a point on the main sequence stretch of the Hertzsprung-Russell star diagram. The diagram consists of stars that are arranged according to the spectral type, mass and the luminosity of the star. Basically, a small low mass star or dwarf fuses hydrogen very slow due to the lack of pressure upon its core. Hence, these types of stars will stay on the main sequence for more than hundreds of billion years. On the other hand, hot massive giants and supergiants fuses faster, right from hydrogen to heavier element in a matter of a few million years only. This is due to the massive outer shell that put its pressure onto its core, thus creating extremely high pressure and temperature to fuse hydrogen and other heavier elements quicker.

After this stage, different masses determine different course of evolution. A very massive star tends to live short and the gravitational collapse on the star is so enormous that it explodes as a supernova right after it become a star (Hammer, 2003). For stars with masses about 0.25 or 0.3 times solar masses to somewhere between 4 and 6 solar masses, they have the possibility to evolve into red giant (Whitworth, 1989; Laughlin et al., 1997). While small and less massive stars will continue to be a main sequence star until it fades to become white dwarfs and has no more hydrogen to be fused since heavier elements, even helium, are impossible to be fused due to lack of temperature and pressure (Laughlin et al., 2005).

2.3.3 Late stage of evolution

Not every star is able to reach this stage as only midsize and massive star can fuse more elements in the core. A star of about 0.25 up to 4 solar masses will be able to fuse helium, and go on to further stages of evolution beyond the red giant branch (Laughlin et al., 1997). Red giants are non-main sequence stars as a result of fusion of heavier elements other than hydrogen. These types of stars are in K or M classes which stretch out along the right frame of the Hertzsprung-Russell diagram.

Red giants that evolve from medium sized stars have two different phases of post-main-sequence evolution. One is red giant branch stars with inert helium cores with hydrogen-burning shells while the other is asymptotic giant branch stars with inert carbon cores with helium-burning shells inside the hydrogen-burning shells. To be brief, asymptotic giant branch is another advance step of red giant or second red giant phase which fuses its helium core into carbon (Hansen et al., 2004).

For both cases, the rushed fusion in the hydrogen outer shell over the core causes the star to inflate and becoming a giant. The inflation of the outer layer lifts the outer shell away from the core. This event decreasing the gravitational pull on them until they expand faster than the energy produced. Hence, the expansion and the further detachment of the outer shell causes the layer cooling down and make it redder than it was during the main sequence. Sooner or later, the outer shell will leave the core completely and becoming planetary nebula. The remnant core of the star remains and becomes a white dwarf.

It is different cases for massive stars. The core of massive stars is big enough to perform a continuous fusion from hydrogen core into much heavier elements and maintaining to burn the outer hydrogen shell without any electron degeneracy pressure to be occurred. Thus, these stars are expanding everytime new heavier elements fused and the outer hydrogen shell becomes cool. Hence, it will become redder and dimmer, and yet, still more luminous than the red giants that evolved from medium and low massive star (Vanbeveren et al., 1998).

Usually, massive stars will continue to fuse until it reaches iron-56. After iron-56 is produced, no stable heavier element occurred because the fusion process no longer releases energy. Usually, for elements heavier than iron-56, they needs to break up into fragments in order to produce energy. The rationale is due to the growing positive charge of the nuclei. Individually, the electric force may seem smaller than the nuclear force, but for the case of iron and heavier elements, this case is excluded. With such bulky nuclei, overcoming the electric repulsion needs more energy than what is released by the nuclear attraction (Stern, 2009). Hence, it is hard to fuse more.

Typically, stars abruptly stop fusing the core at this point. If the core mass surpasses 1.44 time solar masses which is the Chandrasekhar limit, electron degeneracy pressure will be not capable to sustain its inward force of weight against the force of gravity. Hence, the core will collapse suddenly to form a neutron star or a black hole. However, some of the stars might have the gravitational potential energy released by this collapse then becoming a supernova.

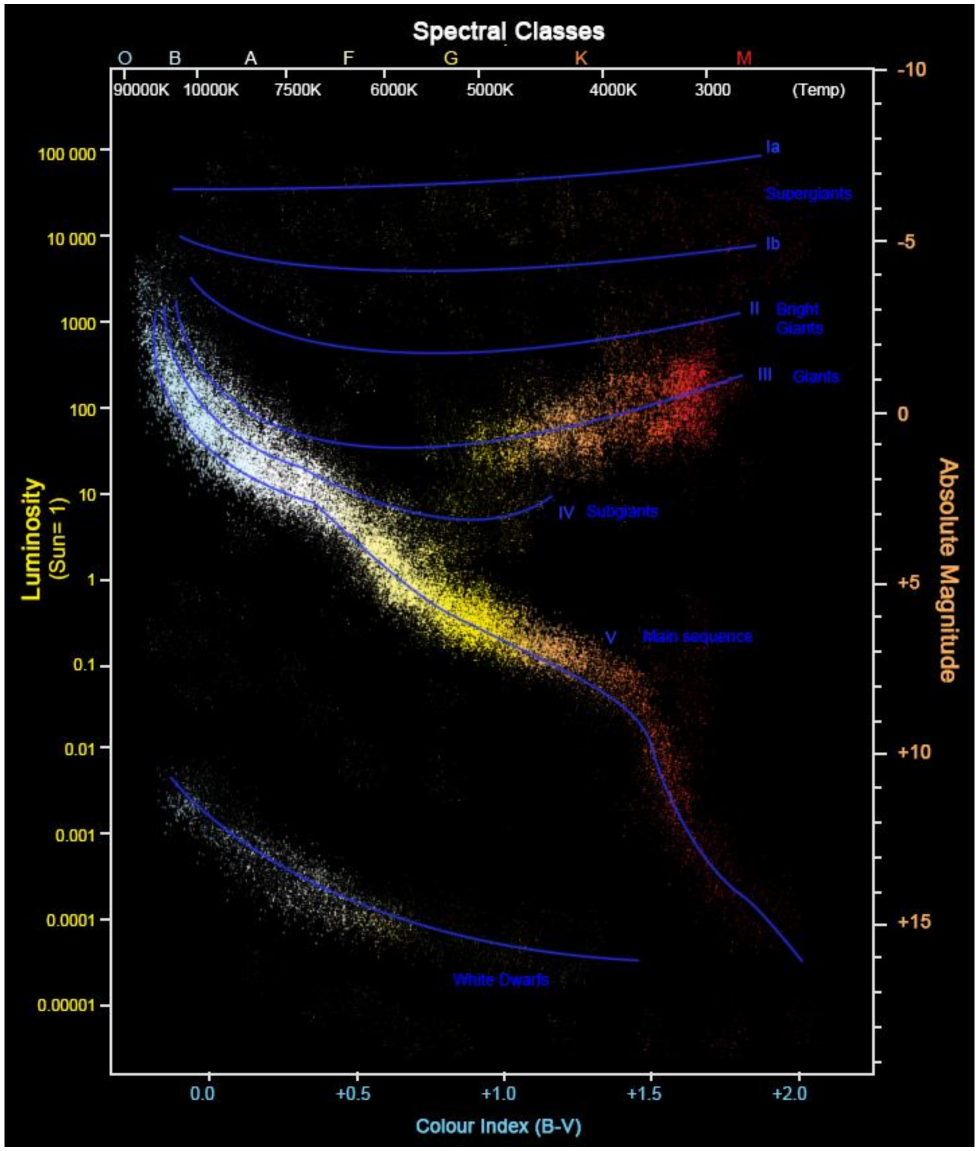


Figure 2.8: Hertzsprung-Russell diagram always used as an aid for astronomer to understand the stellar evolutionary track.

2.4 M-Type Red Giant

Cool Giants usually placed in type K and M while M is practically cooler than K even though their luminosity somewhat higher than the main sequence stars. They are virtually showing matching characteristics in their spectral features. Thus, their pattern in characteristics can be studied. Many astronomers have studied this special type. Helt and Gyldenkerne (1975) used narrowband interference filters to separate spectral region in the wavelength interval of 4000 to 5500 Å in order to develop classification parameters. In 1973, Moreno set up another classification system by using the instrumental energy distribution in M-type in the region of 3000 to 6000 Å. Beshenova and Kharitonov (1976) and Rautela and Joshi (1979) also using this type of stars with the purpose of creating special classification from spectral observation.

2.4.1 Titanium Oxide Band

One of the chemical elements that associated with M-type stars is titanium oxide. Titanium oxide is a type of an inorganic chemical molecule. The existence of titanium oxide in stars is only possible if the stars are cool enough to form it such as M-type stars. Titanium metal and titanium dioxide can be prepared at temperature of 1500°C (Holleman & Wiberg, 2001). Higher temperature will break the bond between titanium and oxygen, thus making it impossible to be produced in hot stars.

In 1947, Oliver J. Lee, Greenville D. Gore and Thomas J. Barlett presented their works on monitoring the existence of titanium oxide while observing northern stars at Dearborn Observatory. Out of 44,000 stars, almost 6.6 % belongs to M5 to M9 which contains dominant titanium oxide absorption bands. This absorption bands is so obvious at the red region of spectrum especially at 7055 Å (Howard et al., 2008).

Plentiful TiO band are already detected as part of our section in Milky Way as though as the neighbouring stars are already in the late stage which so called as TiO stage (Lee et al., 1947; Howard et al., 2008).

2.4.2 Hα Spectral Line

Hydrogen Balmer series are the spectral lines series that can be detected in visible region. It is due to the transition of electron to the second energy level from any higher states which consuming or releasing energy as the transition occurs. This energy is what giving the spectral identification for this type of element. The lowest transition is from the third level to the second level which gives out a spectral line at 6563 Å hence know as Hα. It lies in red region of visible spectrum. Hα profile line is one of the most preferred choices as parameter of study since the line is clearly separated from its associated Pickering series of helium lines (Osborn, 1974).

The discovery of the importance of Hα encouraged the studies on the line formation. Cram and Mullan (1985) had done theoretical research on the Hα absorption line formation in the chromospheres of cool stars. A number of results demonstrate that observation of this line can provide valuable information on certain properties of stellar atmosphere. They also generated model stellar chromospheres which demonstrate that Hα is an important chromospheric diagnostic in cool stars, despite the fact that it has a photoionization-dominated line source function. They also discovered that the strength of Hα especially in cool giants depends on the intensity of the line.

Hα line profiles in the M giants also been discovered that they are asymmetries through detailed observation (Boesgaard & Hagen, 1979). In 1995, Joel A. Eaton has published an extensive works on Hα measurements for cool giants which include K and M type. In his work, he found that there is little variation on the line width (FWHM ~1.44 $\pm$ 0.22 Å) or equivalent width (EW ~ 1.12 $\pm$ 0.17 Å). In the same time, the same parameters also being measured on two prominent photospheric lines which is Fe I at 6564 Å and Ca I at 6572 Å.