# Stars' Chamber of Secrets

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## Abstract

*Studying the spectrum of stars is the main tool for astronomers to have a deeper look at the star interior. Starting with the German physicist, Joseph Fraunhofer, who observed black lines in the sun’s spectra, the spectroscopy encountered rapid advancement and represented the building rock for astrophysics. Currently, the scientists are capable of determining different characteristics of the star using its spectra: effective temperature, radial velocity, luminosity, and mass. However, they mainly consider the main sequence stars -stars that produce energy from hydrogen fusion- as they show direct patterns, and some relations can be done between their physical properties.*

**Keywords**: Spectroscopy, Spectral Lines, Luminosity, Effective Temperature.

## I. Introduction

Scientists study the spectral lines in the star’s spectral; they’re formed when the light is scattered by atoms in the stellar atmosphere. There are two types of spectral lines, emission lines, and absorption lines, but stars mainly have absorption lines. When the photons of light coming from the star interior interact with an electron orbiting its atom, mostly hydrogen, at a specific energy level, the electron absorbs the photon and transits to a higher energy level, and the photon can’t complete its path in the star spectrum; this appears as dark lines in the star spectra. Their significance lies in the unique pattern of lines produced by each element. Since hydrogen is the main element in all main-sequence stars, the strong hydrogen lines, Balmer series, are common in the most spectrum.[1] Along with hydrogen, the presence of a specific pattern of lines indicates the presence of its element, and scientists already have patterns of most of the known elements. Therefore, the spectrum is the main guide to the star’s chemical composition. However, all main sequence stars are composed mainly of hydrogen and helium and a small portion of other elements like carbon and iron. Since all stars are mostly composed of the same elements, the main factor affecting the spectrum is the star’s temperature.

## II. Temperature

The star temperature is significant, as it is the main factor affecting the energy of the atoms or ions in the star atmosphere that enhances the spectrum. Since the stars aren’t perfect black bodies, scientists use the term effective temperature to be the temperature of a black body that would emit the same amount of radiation produced by the star. As most spectra are obtained photoelectrically, computers can easily obtain an intensity graph as shown in figure (1).

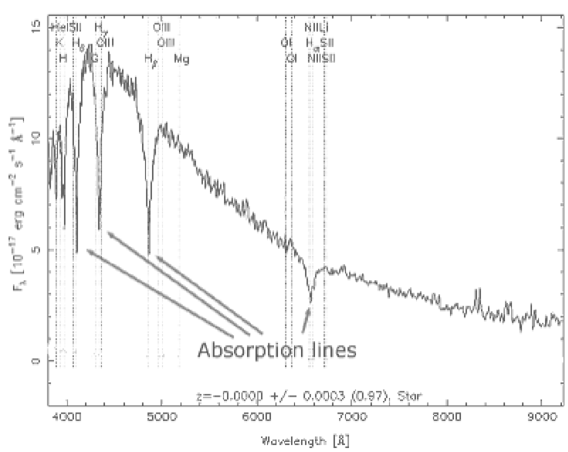



Fig (1): intensity spectrum of a star

From these graphs, the maximum wavelength intensity can be determined. Assuming the stars to be black bodies, Wein's law can be used to calculate the effective temperature of the star as following:

**λ_max=0.0029/T**, where T is in kelvin and λ in meters. [2]

Another approach can be done using UBV filters: ultraviolet, blue, and visible light. Passing the star's light through the V filter and B filter, scientists can determine the flux (F) at both wavelengths and calculate the B-V index as follows

**B-V=-2.5 log (F_B/F_V)**

Thus, the surface temperature can be calculated

**T=4600(1/(0.92(B-V)+1.7)+1/(0.92(B-V)+0.62))**

## III. Luminosity

The luminosity is the total energy emitted per second by the star at its surface. To calculate the luminosity, scientists have to determine both the apparent brightness and the distance of the star. The apparent brightness is simply the total energy per second (F) received in all wavelengths of the star spectrum; in another away, it's the power that reaches each unit area at distance d. The distance -in parsec- is calculated using the parallax method $d = \frac{1}{parallax\ angle}$ , where the parallax angle is half the maximum change in the star's angular position. Then, the luminosity can be calculated by blogging F and d in the equation [3] $F = \frac{L}{4\pi d^2}$

## IV. Radius

Since the star luminosity is defined as the total power emitted at the star surface, it can be calculated depending on the star's internal characteristics, temperature and radius in this case.

$$L = \sigma T^4 4\pi R^2$$

, where s$\sigma$ is Stephen Boltzmann's constant. As mentioned before, both the luminosity and temperature can be calculated. Therefore, the radius can be calculated by blogging the values in the equation.

## V. Mass

The mass of a star is nearly the most important property. Along its life, the star is in a continuous fight between the gravitational force and upward pressure from its produced energy, and the mass is the main factor affecting the gravitational force. So, when the luminosity of the star is known, it is easy to calculate its mass as a ration with the mass of the sun from the equation

$$\frac{L}{L_{sun}} = \left(\frac{M}{M_{sun}}\right)^{3.5}$$

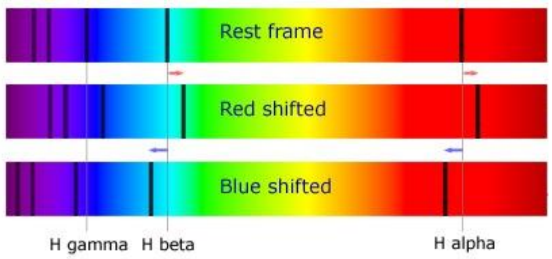
Once the mass is known, scientists can have an insight to the star's age: more massive stars produce energy rapidly consuming their hydrogen. So, massive stars have shorter lifetime, and it can be calculated from the relation

$$\frac{t}{t_{sun}} = \left(\frac{M}{M_{sun}}\right)^{-2.5}$$

, where $t_{sun}$ is estimated to be 10 billion years. [4]

## VI. Radial Velocity

Like any celestial object, the stars are in continuous motion in space. The movement in the direction parallel to our line of sight, toward us or away from us, is called radial velocity. It affects the spectrum in a phenomenon called Doppler Shift: if the star is moving away from us, the spectra are stretched increasing the wavelengths; and if it's approaching us, the spectra are compressed decreasing the




Fig(2):examples of hydrogen spectrum at rest and motion

wavelength. This shift can appear clearly as shown in figure (2).

Once the change in the wave length of specific line is determined, the radial velocity can be calculated from the equation

$$\frac{\lambda-\lambda o}{\lambda o} = \frac{v}{c}$$

, where $\lambda o$ is the wavelength of the line at rest, $\lambda$ is the measured wavelength from the star spectrum, and c is the speed of light. If $\lambda - \lambda o > 0$, this means that the spectrum is red-shifted, and the star is moving away; if $\lambda - \lambda o < 0$, the spectrum is blue-shifted, and the star is approaching us.

## VII. Conclusion

Spectroscopy played a significant role in studying the stars during the past decades. Unlike digital images, spectroscopy allowed scientists to have a deeper look at what's ongoing beneath the stars' atmosphere. The spectrum tells scientists almost everything about the star, from chemical composition to radial velocity. In addition, there are continuous advances in the tools and researches in this field. Scientists now rely on spectroscopy for studying not only stars but also galaxies, quasars, and even black holes.

## VIII. Refrences

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