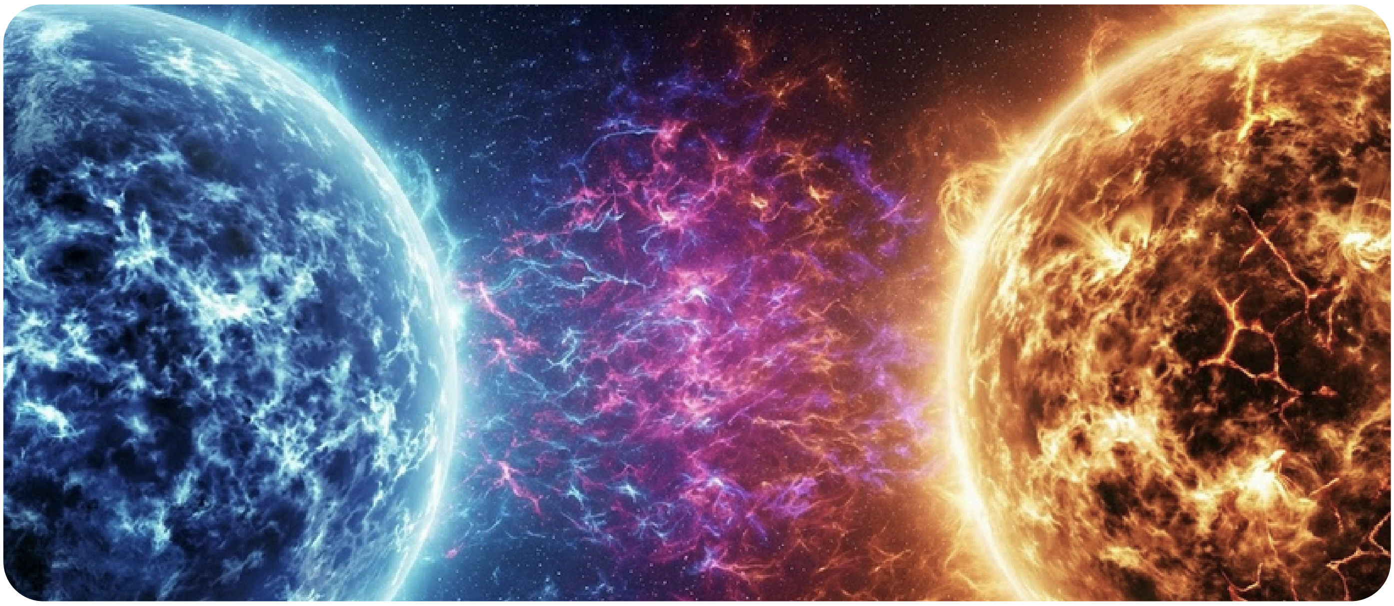
Wien’s Constant: How We Determine the Temperature of Stars



Ever wondered when scientists announce the temperature of the Sun, how they actually measure it? Do they use some kind of thermometer? The temperature of the surface of Sun is 5,772 K, a temperature at which any metal would instantly melt.
In reality, measuring the temperature of stars is very different from what we do in our day to day life. Surprisingly, it is quite easy too. Anyone who understands a bit of maths, the color of light, and **Wien’s constant** can estimate the temperature of a star just by looking at it!
Sounds interesting? Let’s learn how to do it.

Stars as Blackbody Radiators

Every star emits light. This light is not random. It carries detailed information about the star, including its temperature. In fact, just by studying the color of the light coming from a star, we can estimate how hot it is.

Stars behave almost like blackbodies, which means they absorb energy and re-emit it in a predictable way. The light they emit spreads over many wavelengths, forming a continuous spectrum. However, there is always one wavelength at which the emission is strongest which we see as colour of a star.

That peak wavelength depends only on the **star’s temperature**.

Wien’s Displacement Law

This is where Wien’s displacement law comes in. It tells us that the wavelength of maximum intensity is inversely proportional to the temperature of the star.

Mathematically, it is written as:

$$\lambda_{max} T = b$$

Here,

- λ_{max} is the wavelength at which the star emits the most light,
- T is the surface temperature of the star in kelvin,
- b is Wien’s constant, and its value is

b = 2.9 x 10^{-3} mK

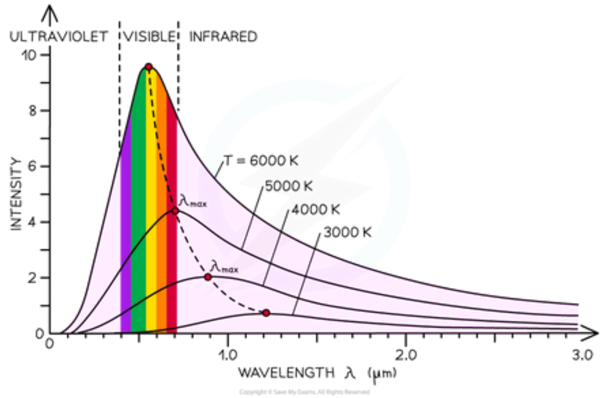
Once we know the peak wavelength, we can easily calculate the temperature of stars also.

Measuring the Temperature of a Star

Astronomers use telescopes fitted with spectrometers to split the star's light into its spectrum. From this spectrum, they identify the wavelength where the intensity is maximum.
Then they simply rearrange Wien's law:

$$T = \frac{b}{\lambda_{max}}$$

That's it. No direct contact, just light and mathematics. Isn't it interesting?
Like how much the light of the star tells us about the star.



Wien's Displacement Law

Color and Temperature

This also explains why stars have different colors.
Hot stars emit more light at shorter wavelengths, so they appear **blue or bluish-white**. **Cooler stars** emit more light at longer wavelengths and appear **red**.

For example:

- **Blue stars** can have temperatures above **20,000 K**.
- **White stars** have moderate temperatures.
- **Yellow stars** like our Sun have a surface temperature of about **5800 K**.
- **Red stars** are cooler, often around **3000 K**.

So from now on even you can tell the approx temperature of any star just by looking at it.

Why This Method Is So Powerful?

The most amazing part is that this method works even for stars that are millions of lightyears away. Just by analyzing their light, astronomers can:

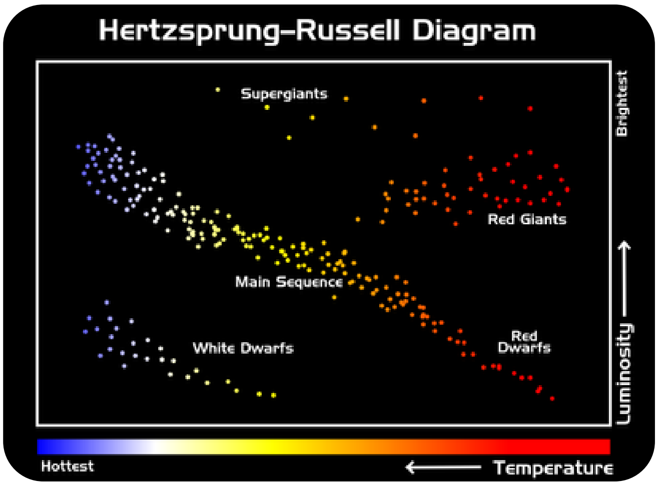
- Measure stellar temperatures,
- Classify stars into different types,
- Study how stars evolve over time,
- Understand the physics of galaxies and the universe.

Temperature, Color, and the H–R Diagram

Once astronomers know the temperature of a star using Wien's law, they can place it on one of the most important tools in stellar astronomy: the Hertzsprung–Russell (H–R) diagram.

The H–R diagram is a graph that shows the relationship between a star's surface temperature and its luminosity (how much energy it emits). Temperature is usually plotted on the horizontal axis, decreasing from left to right.

By this we can categorise the type of the star depending on its position in the diagram.



Hertzsprung–Russell (H-R) Diagram

> *“We learn more about the stars by studying their light than by any other means.”*
>
> *- Arthur Eddington*

The Main Sequence

Most stars, including our Sun, fall on a diagonal band called the main sequence. Stars on the main sequence are in a stable phase of their life, where they generate energy by fusing hydrogen into helium in their cores.

A star’s position on the main sequence is strongly connected to its temperature:

- Hotter main sequence stars are brighter and more massive.
- Cooler main sequence stars are dimmer and less massive.

So by measuring a star’s temperature from its light, we already know a lot about its mass, brightness, and life stage.

Giants, Supergiants, and White Dwarfs

Not all stars lie on the main sequence.

- Red giants and supergiants appear on the upper-right part of the H–R diagram. They are cool on the surface but extremely luminous because of their enormous size.
- White dwarfs are found in the lower-left region. They are very hot but faint, since they are small in size.

Even though a red giant and a white dwarf may have similar colors to other stars, their positions on the H–R diagram reveal their true nature.

Conclusion

Measuring the temperature of stars may sound impossible at first, but nature makes it way too simple. Light acts as a messenger, carrying all the information. With a basic understanding of light, color, Wien’s constant and most importantly observation and curiosity, we can determine the temperature of a star without ever going near it.

After using the powerful tool like H-R diagram with Wien’s constant we can get many info about a star. Light by which we are familiar from birth can give us this much info about star, isn’t it mindblowing??

That’s the beauty of astronomy, that’s the beauty of nature: sometimes, just looking carefully is enough.