Stellar Classification Systems - MK, Harvard, Hertzsprung–Russell

Wikipedia - "In astronomy, stellar classification is the classification of stars based on their **spectral characteristics**. Electromagnetic radiation from the star is analyzed by splitting it with a prism or diffraction grating into a spectrum exhibiting the rainbow of colors interspersed with spectral lines. Each line indicates a particular chemical element or molecule, with the line strength indicating the abundance of that element. The strengths of the different spectral lines vary mainly due to the temperature of the photosphere, although in some cases there are true abundance differences. The spectral class of a star is a short code primarily summarizing the ionization state, giving an objective measure of the photosphere's temperature.

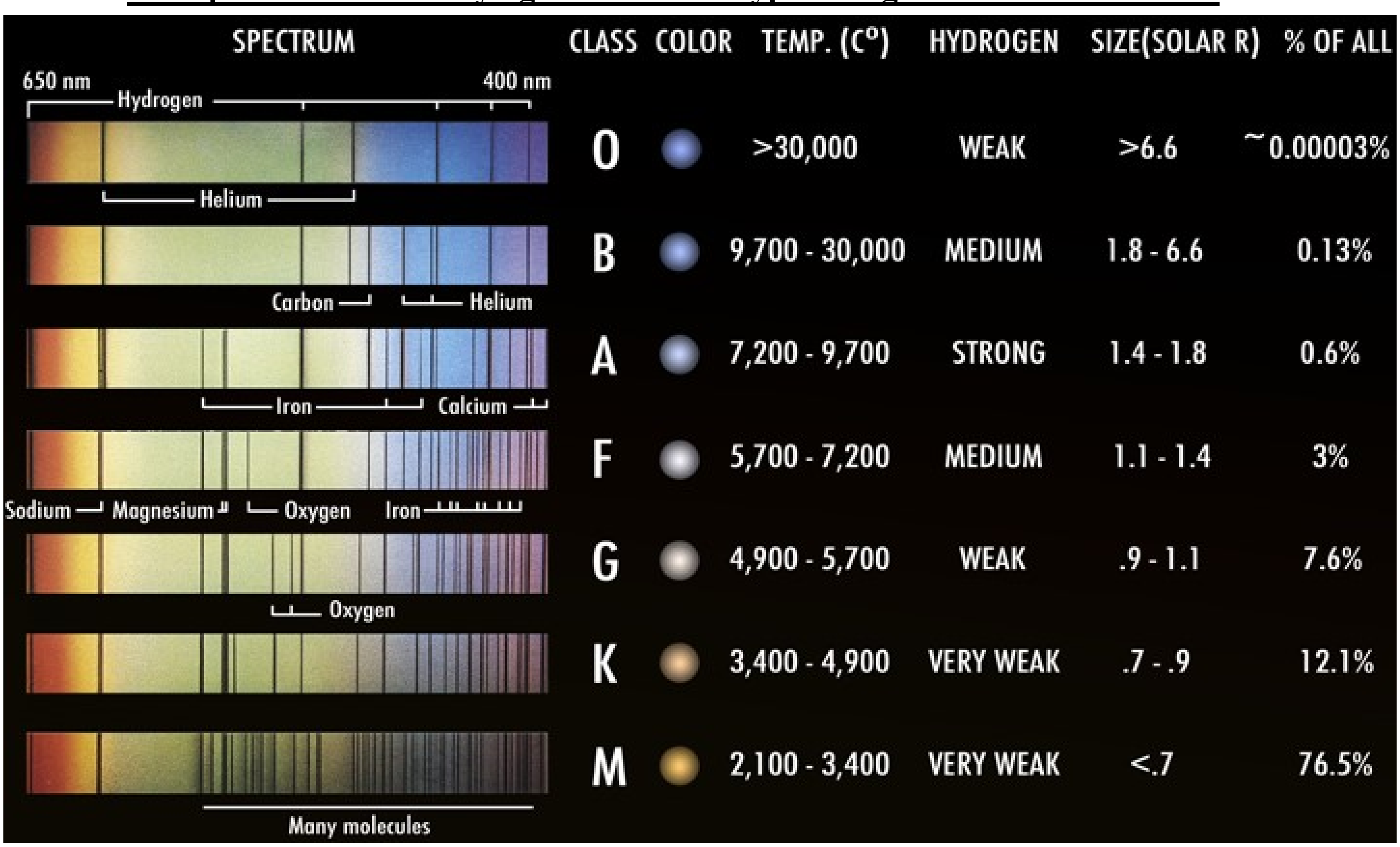
Most stars are currently classified under the Morgan–Keenan (MK) system using the letters O, B, A, F, G, K, and M, a sequence from the hottest (O type) to the coolest (M type). Each letter class is then subdivided using a numeric digit with 0 being hottest and 9 being coolest (e.g., A8, A9, F0, and F1 form a sequence from hotter to cooler). The sequence has been expanded with classes for other stars and star-like objects that do not fit in the classical system, such as class D for white dwarfs and classes S and C for carbon stars.

In the MK system, a luminosity class is added to the spectral class using Roman numerals. This is based on the width of certain absorption lines in the star's spectrum, which vary with the density of the atmosphere and so distinguish giant stars from dwarfs. Luminosity class 0 or Ia+ is used for hypergiants, class I for supergiants, class II for bright giants, class III for regular giants, class IV for subgiants, class V for main-sequence stars, class sd (or VI) for subdwarfs, and class D (or VII) for white dwarfs. The full spectral class for the Sun is then G2V, indicating a main-sequence star with a surface temperature around 5,800 K.

Harvard spectral classification

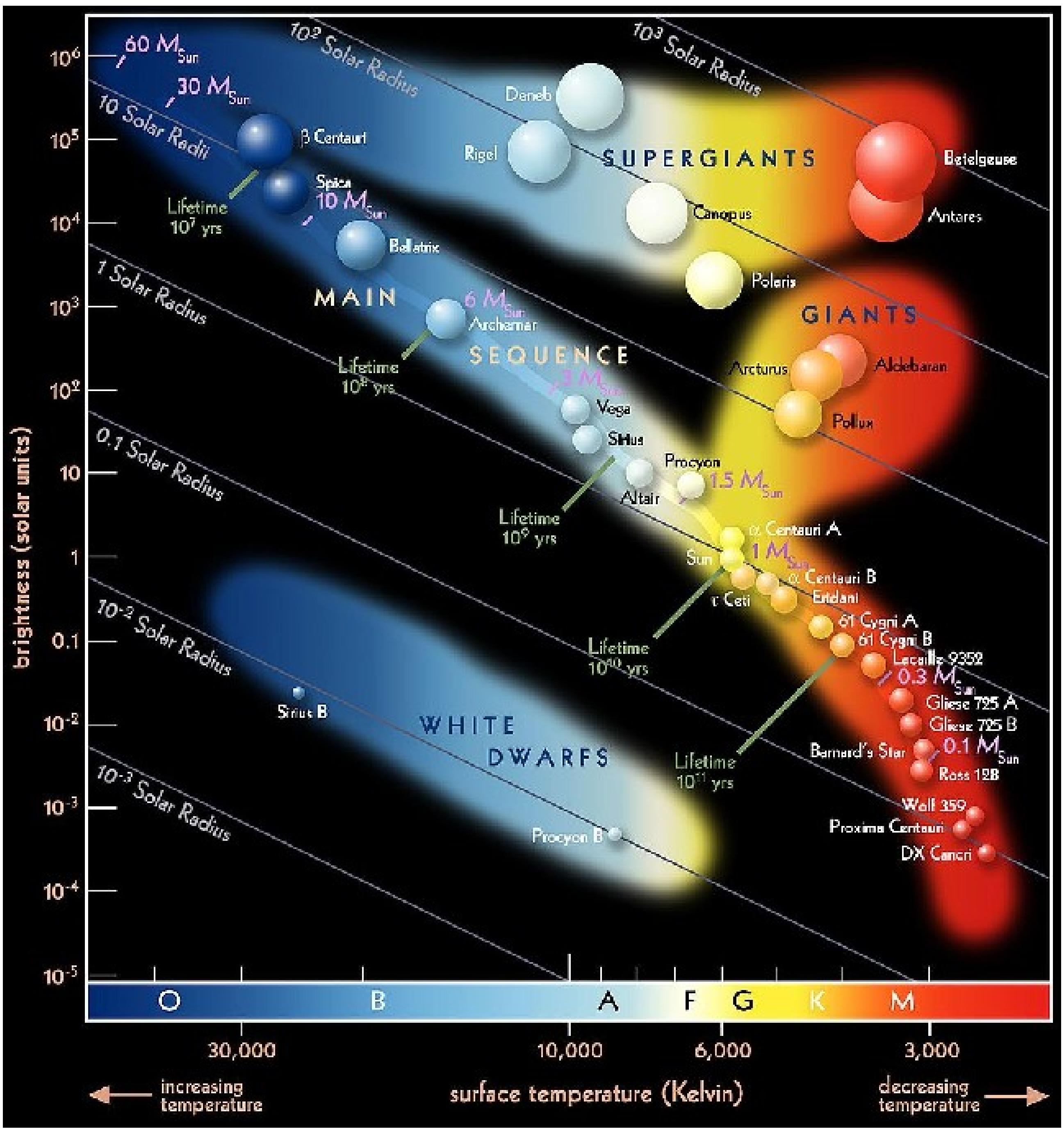
The Harvard system is a one-dimensional classification scheme by astronomer Annie Jump Cannon, who re-ordered and simplified the prior alphabetical system by Draper (see History). Stars are grouped according to their spectral characteristics by single letters of the alphabet, optionally with numeric subdivisions. Main-sequence stars vary in surface temperature from approximately 2,000 to 50,000 K, whereas more-evolved stars can have temperatures above 100,000 K[citation needed]. Physically, the classes indicate the temperature of the star's atmosphere and are normally listed from hottest to coldest."

A simple chart for classifying the main star types using Harvard classification



The Hertzsprung–Russell (H-R) diagram: Absolute Magnitude vs. Classification

Is a **scatter plot** of stars showing the relationship between the stars' **absolute magnitudes** or **luminosities versus their stellar classifications or effective temperatures**. The diagram was created in 1911 and represented a major step towards an understanding of stellar evolution. The H-R diagram is quite easy to understand if you can interpret what each axis means. The horizontal axis measures the surface temperature of the star in Kelvin. Stars on the right of the horizontal axis are cooler and redder in colour than the stars on the left, with temperatures of around 3000 Kelvin as opposed to 25,000 Kelvin upwards. The vertical axis on the left measures **luminosity using the Sun as our comparison**. So, a luminosity of one is equal to one Sun. The vertical axis on the right measure's absolute magnitude, or brightness, crucially considering a star's distance. The bottom axis identifies spectral type, or, spectral class of a star, which is another way to describe the colour and temperature. **Plotting Cepheids, RR Lyrae, Mira and Semiregular pulsating variable stars** on the H-R diagram is **not a single plot** like non-pulsating stars. During their evolution through the instability strips they are pulsationally **unstable – expanding and brightening,** then **contracting and become dimmer**. The instability strips for Miras and Cepheids are especially elongated because of these expansions and contractions. Some pulsating variable stars change in temperature by two spectral classes during one cycle from max to min. To show the entire cycle of change for individual variable stars, it is necessary to plot them twice on the H-R diagram – both at max and min absolute magnitude.



Spectral Analysis of Different Types of Stars

Dwarf Stars: Main Sequence stars of low class V **Luminosity.** Dwarf stars are fainter than giant stars. **Blue** (Types O and B), **Yellow** (mass like sun - Type G), **Orange** (K-type), **Red** (cooler - low mass K to M). **White** (remains of a dead star, electron degenerate, **not massive enough** to be Neutron Star), **Black** a **White** dwarf cooled so no longer emits visible light. Universe not old enought for Black dwarfs. **Brown** dwarf: substellar object not massive enough to fuse hydrogen to helium.

Main Sequence Star Types by Temperature

Our Bright Astronomers Frequently Generate Killer Mnemonics!

Type	Absorption lines	Temperature	Example
O	(H I, He I,) He II, N III , O III, Si IV	> 30000	
B	H I, He I, O II,Si III	> 10000	Orion's Belt
A	**H I**, Mg II,Si II, (Fe II, Ti II, Ca II)	> 7000	Sirius
F	H I, Ca II, Fe I, Ti I, Fe II, Ti II	> 6000	Procyon
G	(H I,) **Ca II**, Fe I, Ti I, etc., CH	> 5300	Sun
K	Ca II, **Ca I**, etc., TiO	> 4000	Arcturus
M	Ca I, TiO, etc.	> 2000	Betelgeuse

Get Star Data From PV Light House Spectral Irradiance Measurement Library

https://www2.pvlighthouse.com.au/resources/optics/spectrum%20library/spectrum%20library.aspx

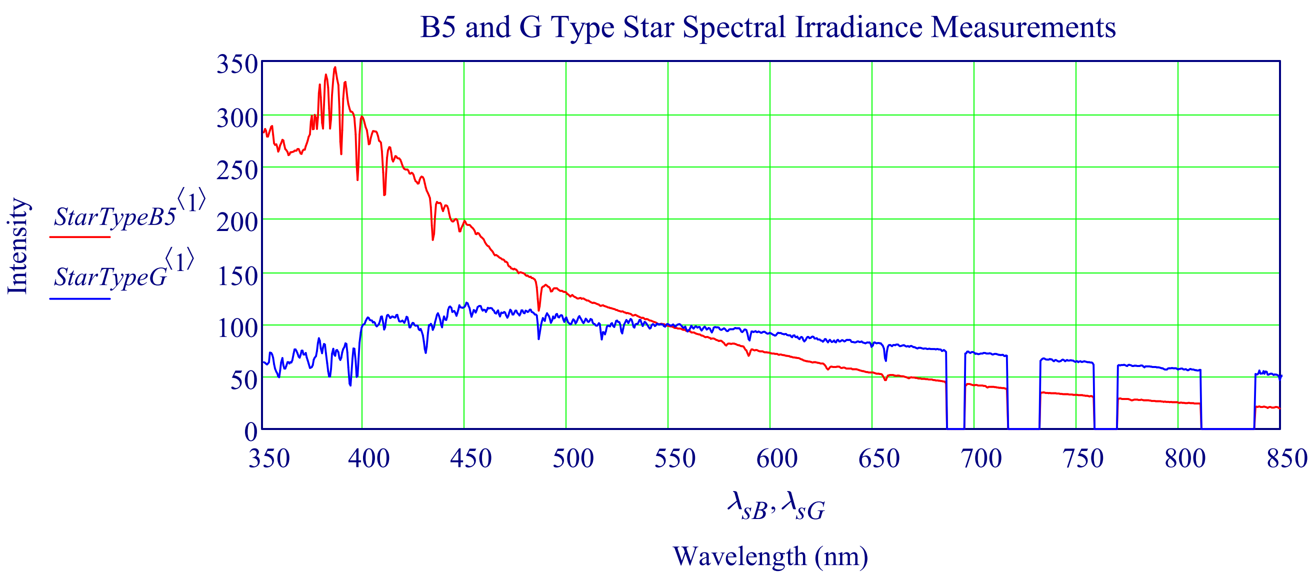
B Type Star Spectral Irradiance Measurements

$StarTypeB5 := READPRN(\text{"B5 Star Spectrum.txt"})$ $\lambda_{sB} := StarTypeB5^{\langle 0 \rangle}$

G Type Star Spectral Irradiance Measurement

$StarTypeG := READPRN(\text{"G Star Spectrum3.txt"})$ $\lambda_{sG} := StarTypeG^{\langle 0 \rangle}$

Note: For these particular Type B and G stars, the peaks are consistent with Type, but shapes are different.



G Type Star (Sun) Spectral Irradiance Data - Sun AM0 & AM1.5

Get Star Spectral Irradiance Data From Spectrum Library

https://www2.pvlighthouse.com.au/resources/optics/spectrum%20library/spectrum%20library.aspx

AM0 and AM1.5 Correspond to the Sunlight at the Top of Atmosphere and at Sea Level, Respectively.

$SolarSpec_0 := READPRN("Solar AM0 Spectrum 280 -2500 2nm.txt")$ $\quad SS_0 := SolarSpec_0$

$SolarSpec_{1.5} := READPRN("Solar AM1-5g Spectrum 280 -2500 2nm.txt")$ $\quad SS_{1.5} := SolarSpec_{1.5}$

Planck's Spectral Radiation Law, B(λ,T)

$h := 6.6260693 \cdot 10^{-34} \cdot joule \cdot sec$ $\quad k_b := 1.3806505 \cdot 10^{-23} \cdot \frac{joule}{K}$ $\quad \lambda_s := SolarSpec_0^{\langle 0 \rangle}$

$$B(\lambda, T) := \frac{2h \cdot c^2}{(nm \cdot \lambda)^5} \cdot \frac{1}{e^{\frac{h \cdot c}{nm \cdot \lambda \cdot k_b \cdot T}} - 1}$$

$T_{sun} := 5777K$

Normalize Units B(λ,T): $Units := 2 \cdot B(500, T_{sun})^{-1}$ $\quad B_N(\lambda) := B(\lambda, T_{sun}) \cdot Units$

Find Peak Wavelength for the AM0 Sun from its Blackbody Spectrum

$max\left(SolarSpec_0^{\langle 1 \rangle}\right) = 2.075$ $\quad match\left(max\left(SolarSpec_0^{\langle 1 \rangle}\right), SolarSpec_0^{\langle 1 \rangle}\right) = (91)$

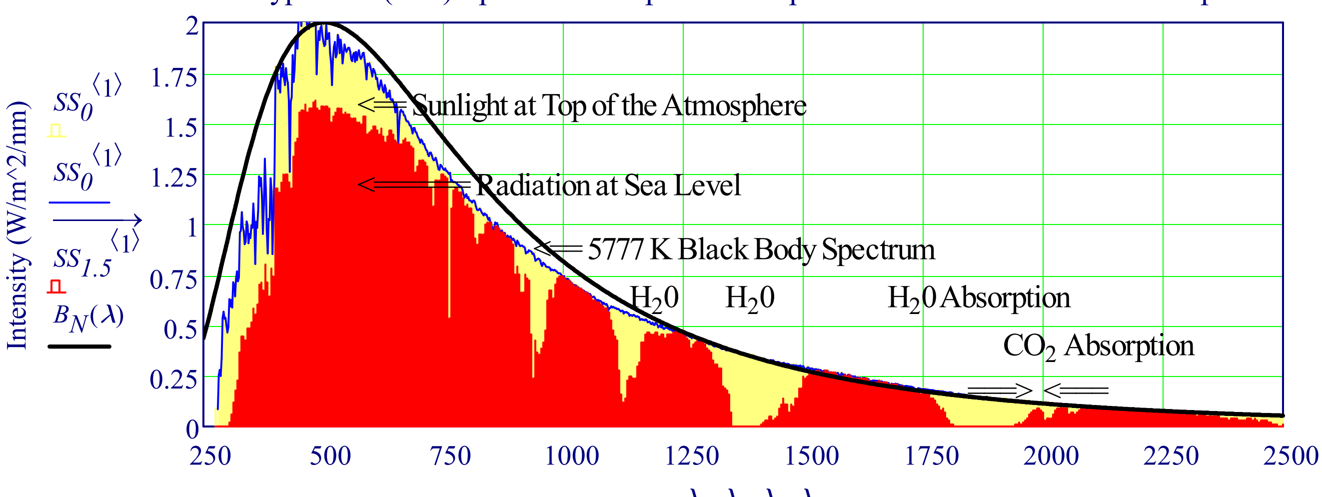
$\left(SolarSpec_0^{\langle 0 \rangle}\right)_{91} = 462$ $\quad \lambda_{peak} := 462$ $\quad B_N(462) = 1.967$

The Sun's peak wavelength is between 483-504 nm (Green)

Wien's Displacement Law: Peak Wavelength Law

$\lambda_{max}(T) := \frac{0.2898 cm \cdot K}{T}$ $\quad \lambda_{max}(T_{sun}) = 501.644 \cdot nm$

G Type Star (Sun) Spectrum - Top of Atmosphere & Sea Level - H2O Absorption



$\lambda_{peak} = 501$ nm