the Stars

I. Position and Motion
Parallax, Proper Motion, Redshift

II. Size
Dwarfs, Giants, Stefan-Boltzman

III. Brightness
Magnitude, flux, distance

IV. Color & Temperature
***B*-*V* index, Spectral Type**

V. H-R diagrams
Luminosity Classes

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	The student will be able to:	HW:
1	Define and apply stellar parallax and the unit of the parsec.	1 – 3
2	Relate parallax and the parsec to skinny triangles and other units such as meters and light years.	
3	Define and describe proper motion.	4 – 6
4	Describe and apply methods by which the velocity of a star through space may be determined by including both radial and transverse velocity.	
5	Describe direct and indirect methods used to determine the size of a star and classify stars as giants, supergiants, or dwarfs.	7 – 8
6	State and apply the relation between luminosity, radius, and temperature.	
7	State and apply the relation between luminosity, distance, and energy flux.	9 – 16
8	Define and contrast the concepts: absolute magnitude, intrinsic brightness, luminosity, and apparent magnitude, apparent brightness, energy flux.	
9	Explain and apply the magnitude scale of brightness.	
10	Describe and apply the relation between a stars color and its temperature.	17
11	Define, describe, and apply color index and explain its application in photometry and its relationship to blackbody radiation and Wein's Law.	
12	State in order of temperature the stellar spectral classes and list characteristics and examples of each.	18
13	Describe and define the Hertzsprung-Russell diagram in terms of each axis.	19 – 23
14	Plot a star's coordinates on the H-R diagram.	
15	Explain and illustrate how the H-R diagram is used to help classify and understand different types of stars such as main sequence stars, red giants, blue giants, supergiants, red dwarfs, and white dwarfs.	
16	Define, describe, and give examples of the stellar luminosity classes.	24 – 25
17	Describe and apply the method of spectroscopic parallax and explain the importance of luminosity class to this method.	
18	Describe and explain methods for determining a star's mass and relate to the different types of binary-star systems: visual binary, spectroscopic binary, and eclipsing binary.	26
19	Describe and explain the significance of a star's mass in determining its location on the H-R diagram and in determining the lifetime of the star.	27
20	Describe properties and significance of open clusters and globular clusters.	

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Stellar Color and Temperature

Color Index and Spectral Class

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Stellar Color and Temperature

- Recall that according to Wein's Law, as the temperature of a blackbody radiator increases, the wavelength of the peak intensity decreases.
- Or, put another way, as the temperature increases the peak frequency increases.
- As temperature increases, the color of a star goes from red to orange to yellow to white to blue . . .

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B–V Index

- In order to get a simple and reliable means of establishing relative color (and also temperature), astronomers measure the brightness through different filters.
- A B filter allows light with wavelengths from 380 to 480 nm. (B = "blue")
- A V filter allows light with wavelengths from 490 to 590 nm. (V = "visual")
- Measuring brightness of stars with and without filters is called "photometry".

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B–V Index

- The magnitudes of the star when viewed through the two filters are subtracted to find the difference: $m_B - m_V$
- This difference is called the B–V color index.
- Let’s try it . . .

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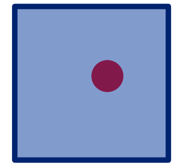
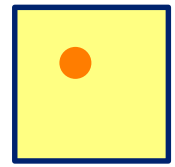
a “red” star: 

viewed through B filter:  appears much dimmer, magnitude 3

viewed through V filter:  appears some dimmer, magnitude 1

$$m_B = 3$$

$$m_V = 1$$

$$m_B - m_V = 2$$

$$B\text{-}V \text{ index} = 2$$

This red star has a color index of 2 based on the observations through the filters.

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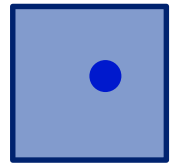
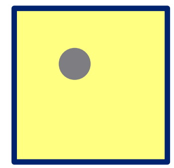
a “blue” star: 

viewed through B filter: 

appears some dimmer,
magnitude 1

viewed through V filter: 

appears much dimmer,
magnitude 3

$$m_B = 1$$

$$m_V = 3$$

$$m_B - m_V = -2$$

$$B\text{-}V \text{ index} = -2$$

This blue star has a color index of −2 based on the observations through the filters.

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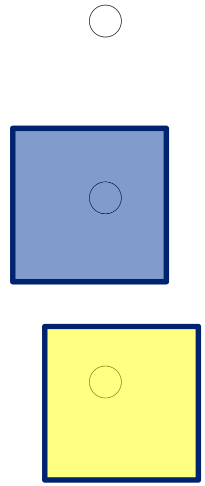
a "white" star:

viewed through B filter:

viewed through V filter:



appears some dimmer,
magnitude 1

appears some dimmer,
magnitude 1

$m_{\mathrm{B}} = 1$

$m_{\mathrm{V}} = 1$

$m_{\mathrm{B}} - m_{\mathrm{V}} = 0$

$B\text{-}V$ index = 0

This white star has a color index of 0 based on the observations through the filters.

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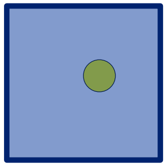
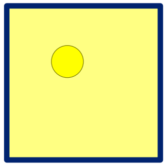
a “yellow” star: 

viewed through B filter:  appears dimmer, magnitude 1.5

viewed through V filter:  appears some dimmer, magnitude 1

$m_B = 1.5$

$m_V = 1$

$m_B - m_V = 0.5$

$B\text{-}V$ index = 0.5

This yellow star has a color index of 0.5 based on the observations through the filters.

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B–V Index

- The greater the B–V index, the less blue (and the more red) the star.
- A difference of zero is basically a white star. (Why does this make sense?)
- A negative difference indicates a bluish star.
- A positive difference indicates a yellow, orange, or reddish star.
- The *order* of subtraction is important!

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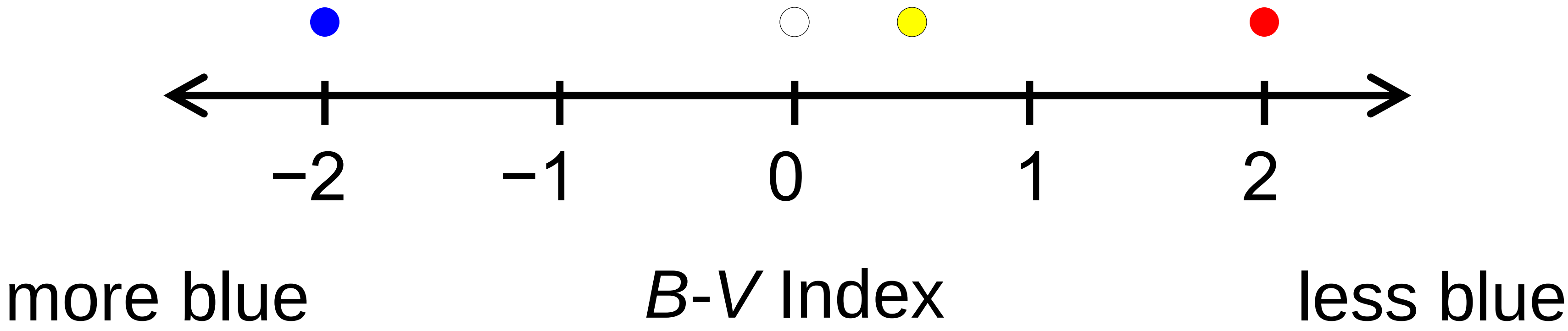

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Connection w/ Temperature

- The temperature of a star affects the relative intensity of the various wavelengths of radiation that it emits.
- Therefore the B–V color index is also an indirect measurement of temperature.

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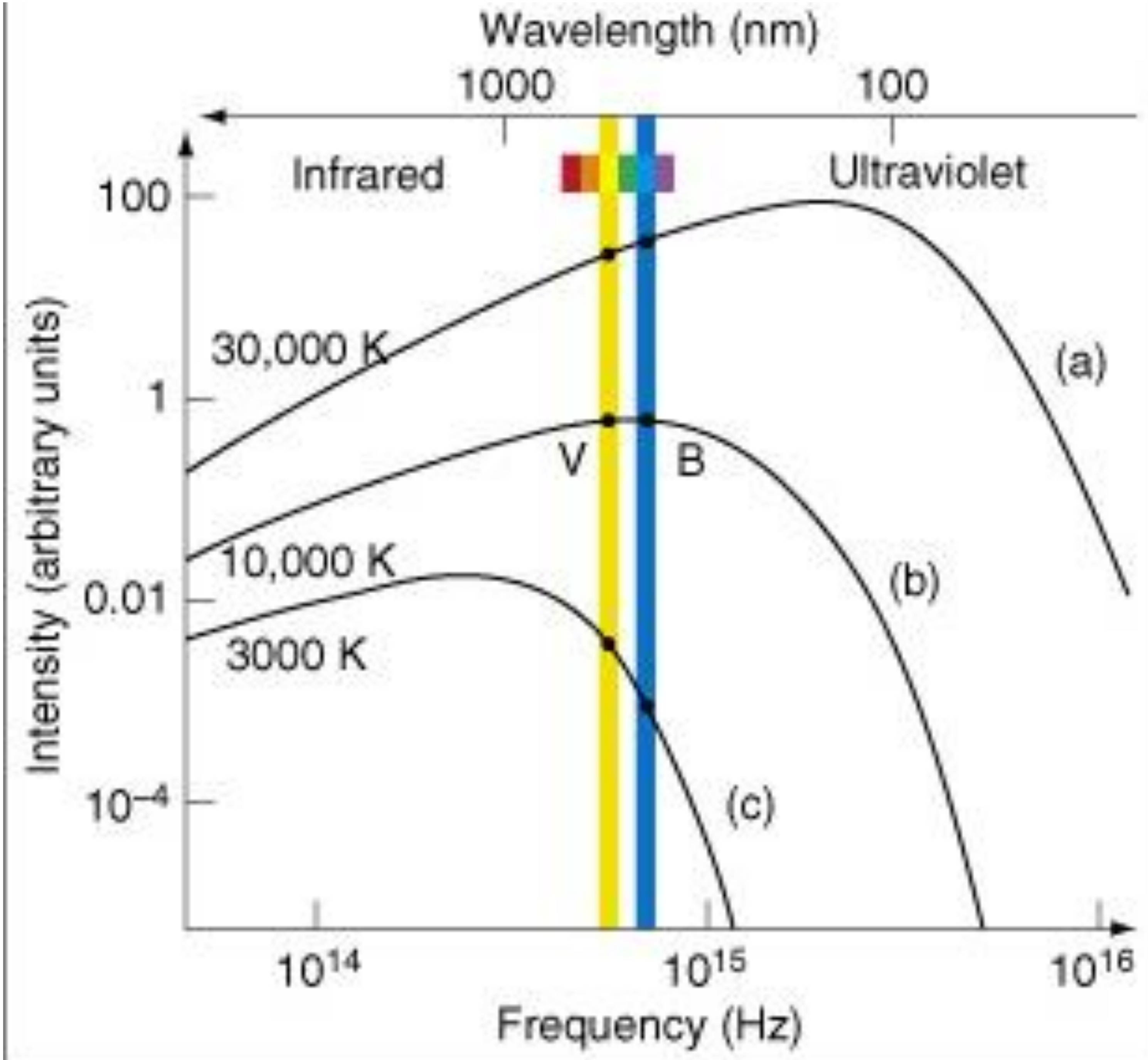

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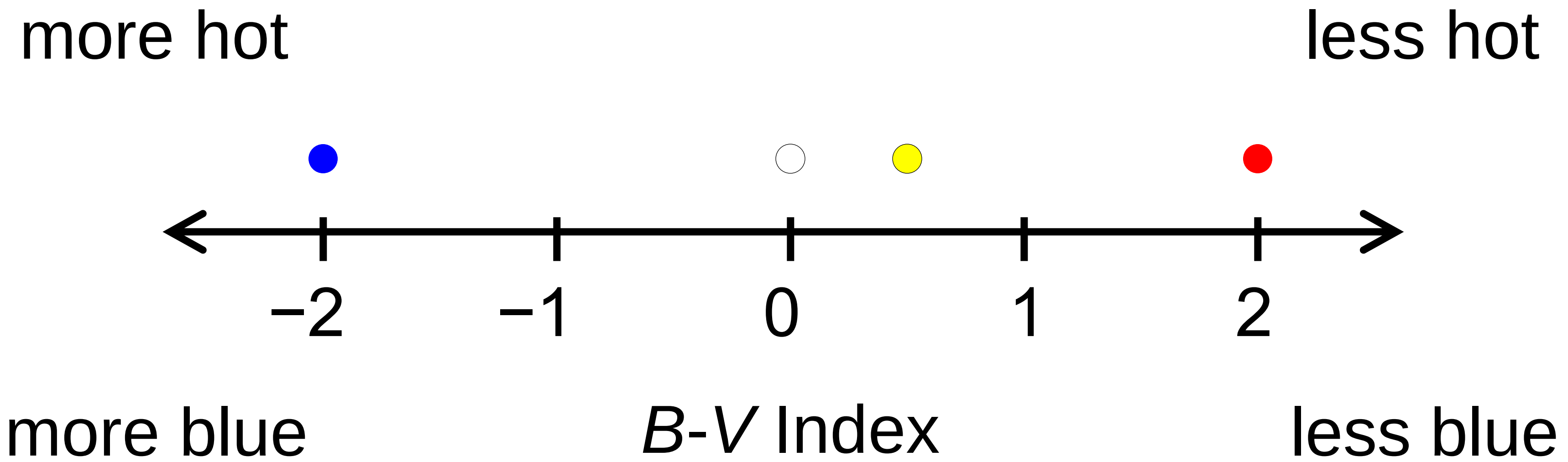

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Stellar Colors and Temperatures			
B–V	Color	Temp. (K)	examples
– 0.31	blue-violet	30000	Mintaka
– 0.24	blue	20000	Rigel
0.00	white	10000	Vega, Sirius
0.35	yellow-white	7000	Canopus
0.65	yellow	6000	Sun, α-Cent
1.2	orange	4000	Arcturus
1.7	red	3000	Betelgeuse

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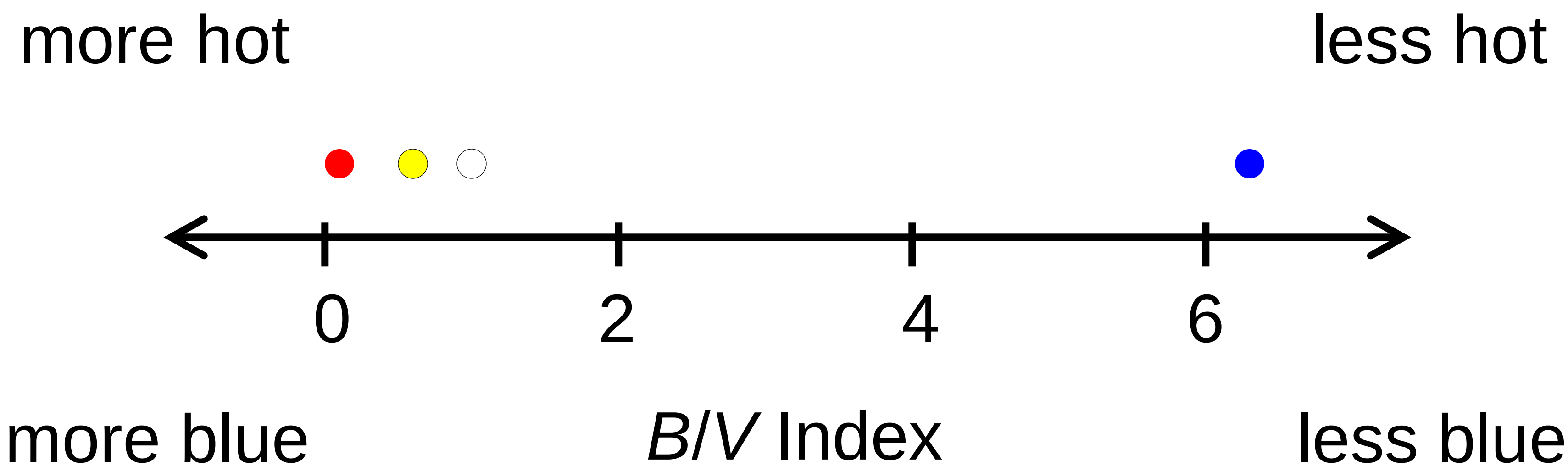
B/V Index



Some prefer *B*/*V* index – the ***ratio*** B of V *fluxes*:

$$2.512^{3-1} = 6.31$$

$$2.512^{1-1} = 1.00$$

$$2.512^{1-1.5} = 0.63$$

$$2.512^{1-3} = 0.16$$

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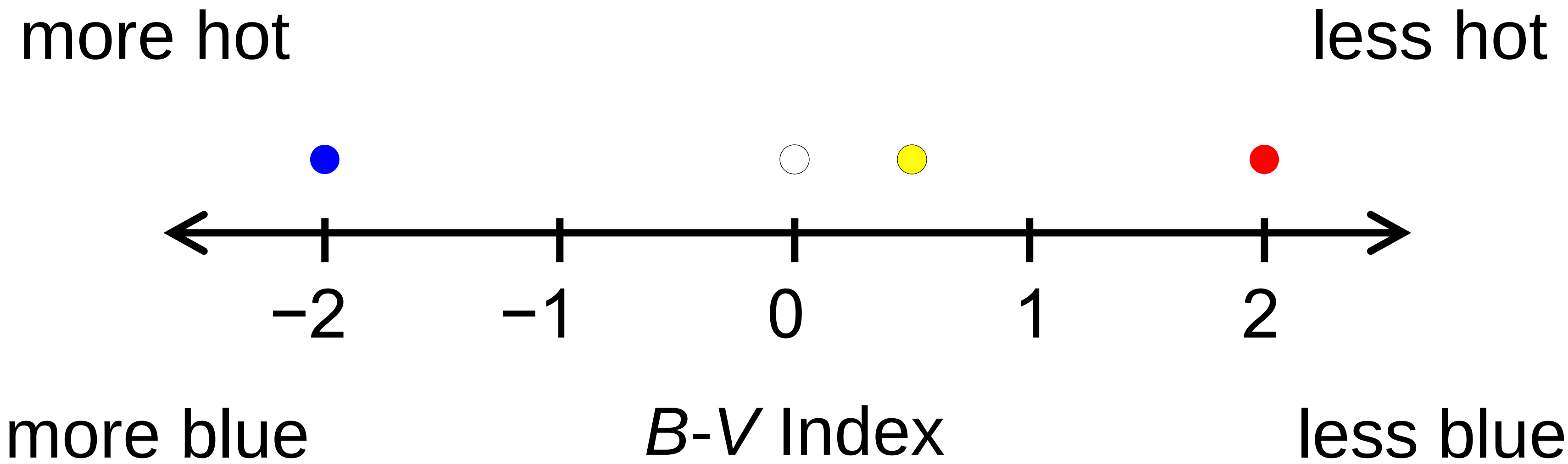
B-V Index



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$$\text{B–V index} = m_B - m_V$$

Stellar Colors and Temperatures			
B–V	Color	Temp. (K)	examples
– 0.31	blue-violet	30000	Mintaka
– 0.24	blue	20000	Rigel
0.00	white	10000	Vega, Sirius
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0.65	yellow	6000	Sun, α-Cent
1.2	orange	4000	Arcturus
1.7	red	3000	Betelgeuse

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$$\text{B/V index} = 2.512^{(m_V - m_B)}$$

Stellar Colors and Temperatures			
B/V	Color	Temp. (K)	examples
1.33	blue-violet	30000	Mintaka
1.25	blue	20000	Rigel
1.00	white	10000	Vega, Sirius
0.72	yellow-white	7000	Canopus
0.55	yellow	6000	Sun, α-Cent
0.33	orange	4000	Arcturus
0.21	red	3000	Betelgeuse

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Spectral Class

- A different method for determining color and temperature involves analysis of relative strengths of the lines in a star's spectrum.
- Originally these spectra were graded on the strength of the hydrogen lines and put in order A, B, C, D . . . etc.
- Later it was determined that the relative strength of the lines had more to do with temperature than with the amount of hydrogen.

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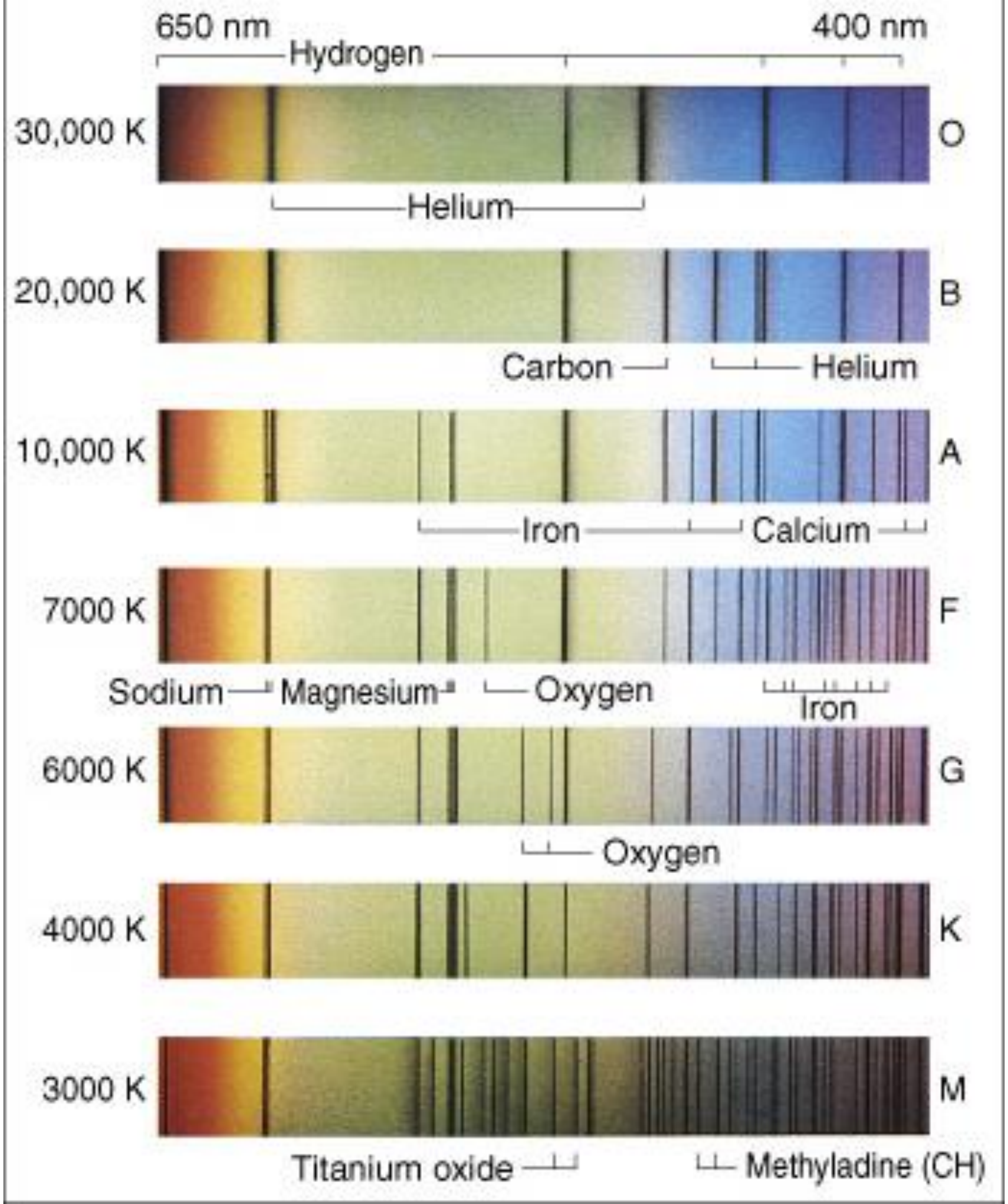
650 nm
400 nm
Hydrogen
30,000 K
O
Helium
20,000 K
B
Carbon
Helium
10,000 K
A
Iron
Calcium
7000 K
F
Sodium
Magnesium
Oxygen
Iron
6000 K
G
Oxygen
4000 K
K
3000 K
M
Titanium oxide
Methyladine (CH)

Stellar Colors and Temperatures			
Spectral Class	Color	Temp. (K)	examples
O	blue-violet	30000	Mintaka
B	blue	20000	Rigel
A	white	10000	Vega, Sirius
F	yellow-white	7000	Canopus
G	yellow	6000	Sun, α-Cent
K	orange	4000	Arcturus
M	red	3000	Betelgeuse

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Class	Absorption Spectrum Features
O	ionized helium strong; multiply ionized heavy elements
B	neutral helium moderate; singly ionized heavy elements; hydrogen moderate
A	neutral helium very faint; singly ionized heavy elements; hydrogen strong
F	singly ionized heavy elements; neutral metals, hydrogen moderate
G	singly ionized heavy elements; neutral metals, hydrogen faint
K	singly ionized heavy elements; neutral metals strong; hydrogen faint
M	neutral atoms strong; molecules moderate; hydrogen very faint

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Spectral Class Subdivisions

- Each letter class is further subdivided into ten categories 0 through 9…
- …(in order of *decreasing* temperature).
- (of course)
- A star's spectral classification is then given with a letter and a number such as G2 for the Sun, A0 for Vega, M2 for Betelgeuse, and so on.

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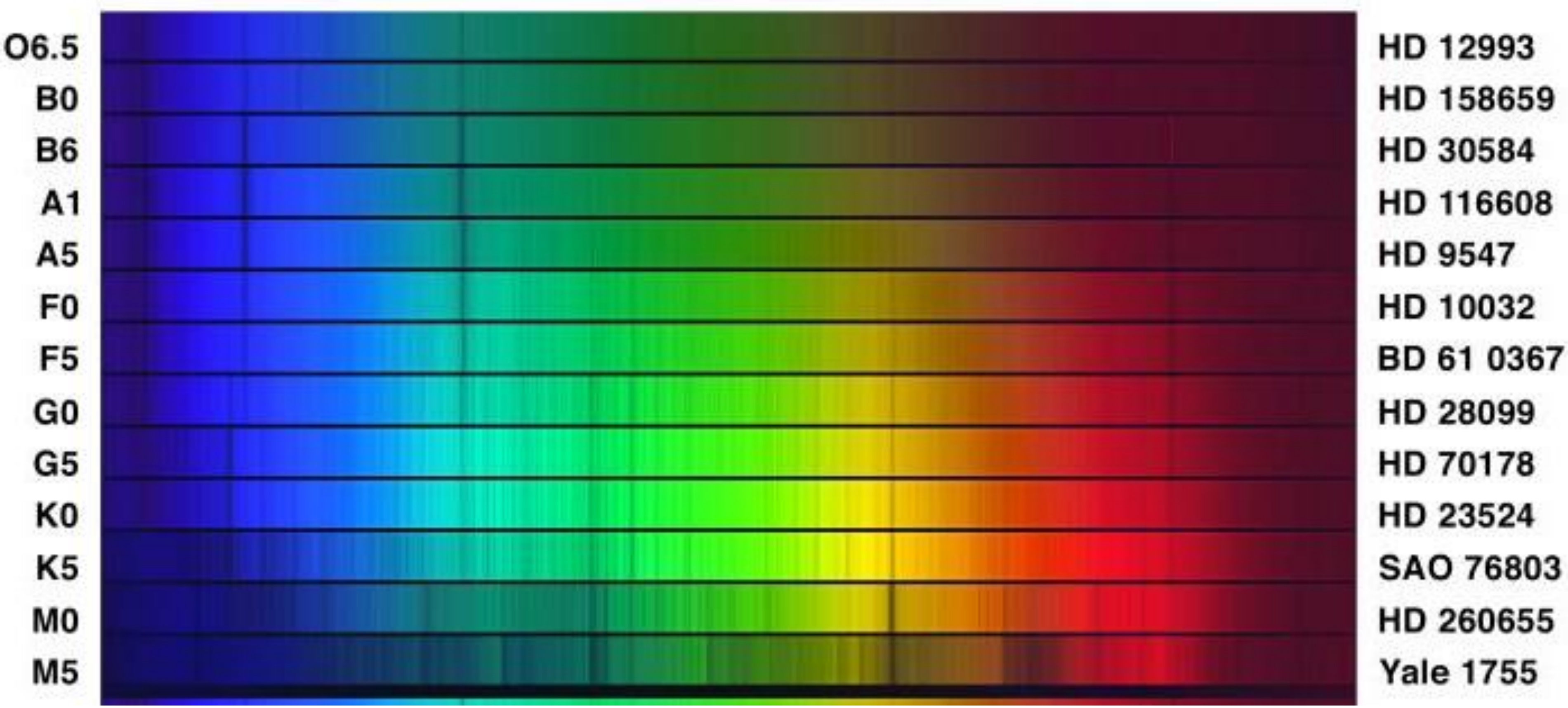
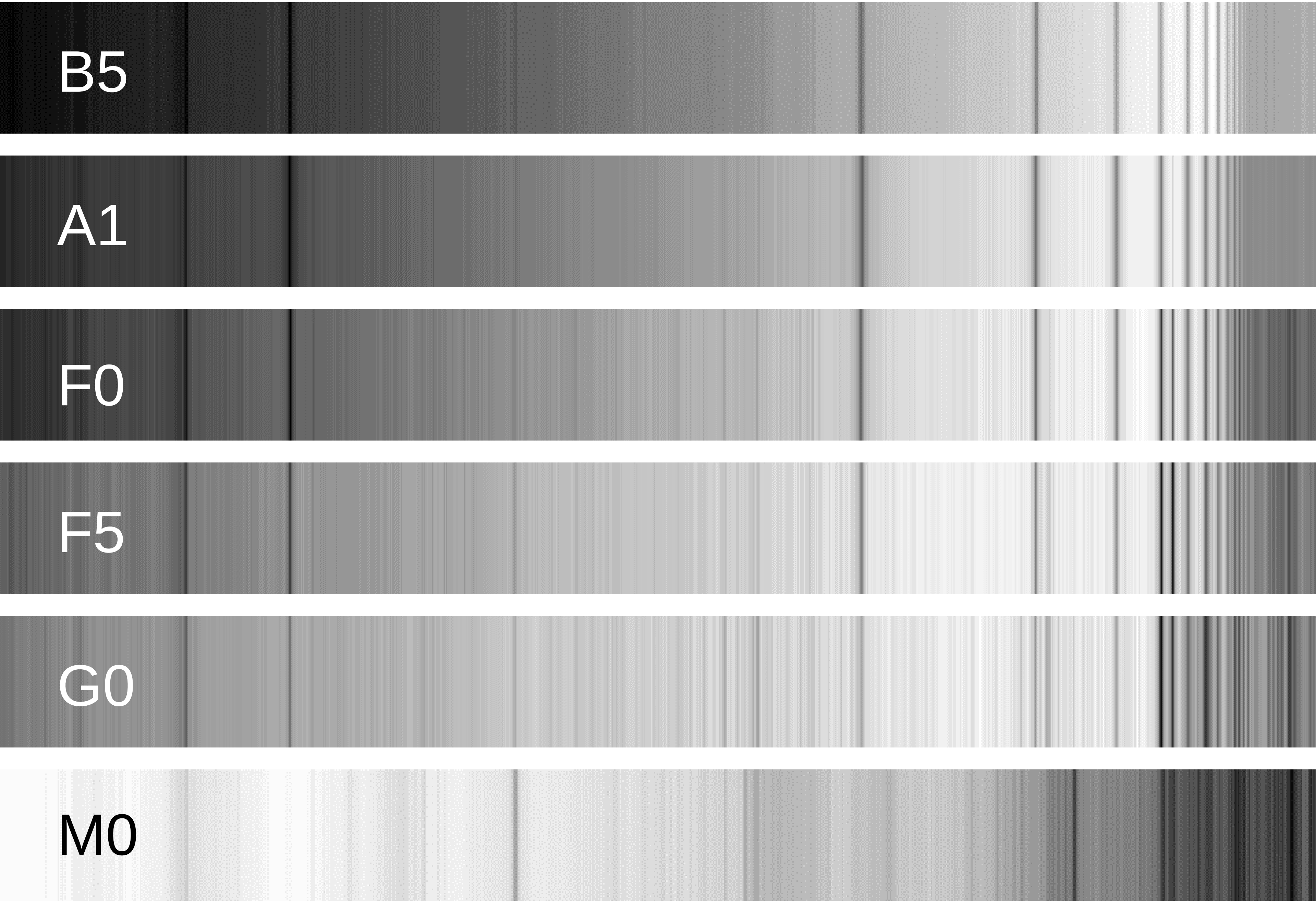
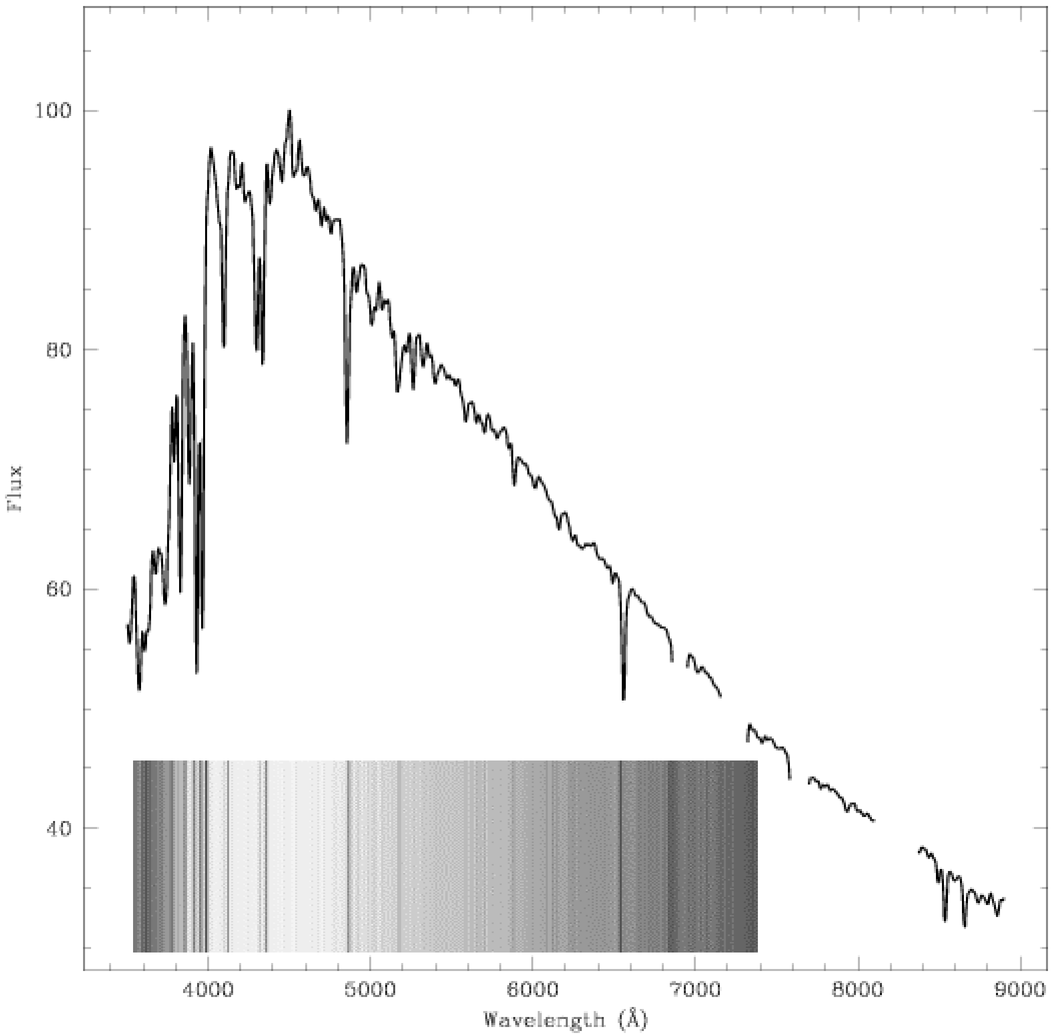
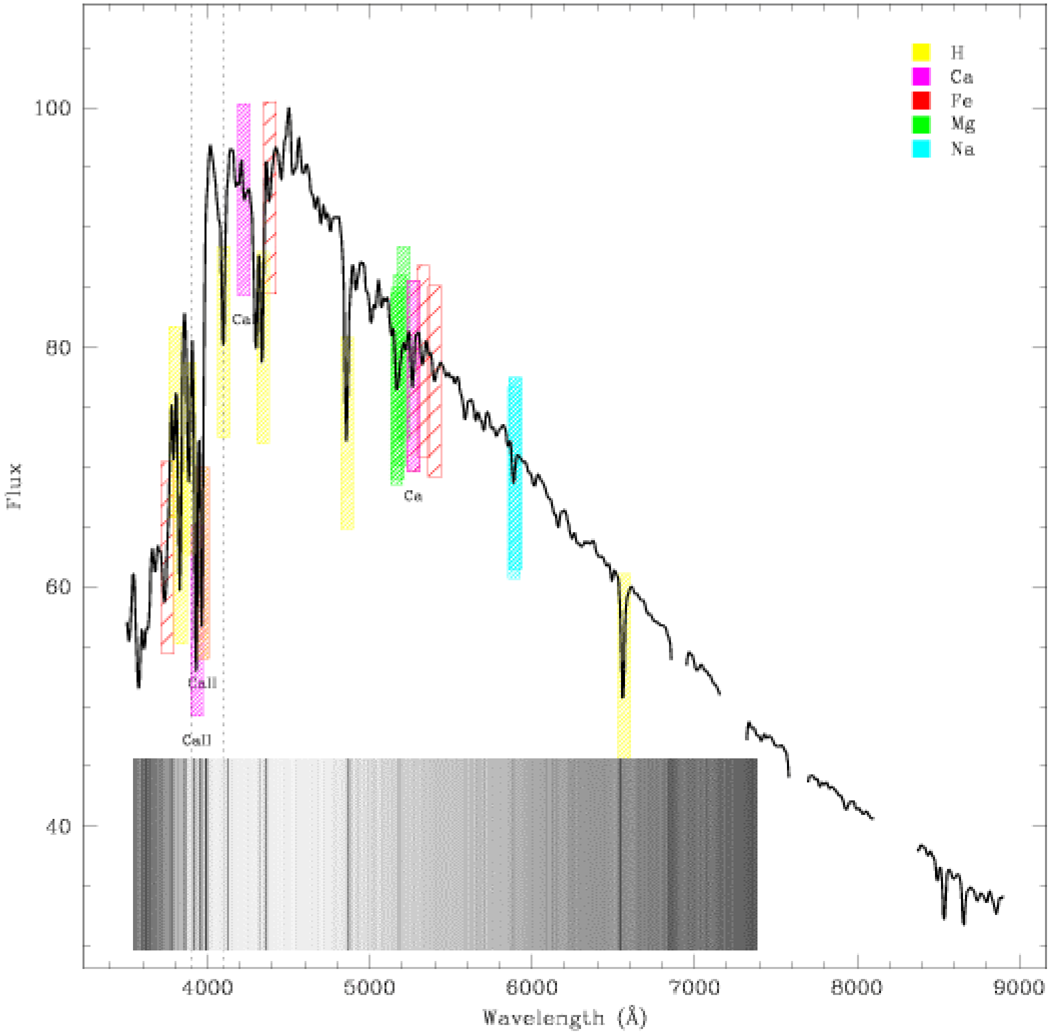


image credit: KPNO, 0.9m Telescope, AURA, NOAO, NSF


B5
A1
F0
F5
G0
M0



100
80
60
40
Flux
4000
5000
6000
7000
8000
9000
Wavelength (Å)



H
Ca
Fe
Mg
Na
100
80
60
40
Flux
CaII
CaII
Ca
Ca
4000
5000
6000
7000
8000
9000
Wavelength (Å)