The H-R Diagram:

Represents one of the great observational syntheses in astrophysics

Ejnar Hertzsprung (1911) & Henry Norris Russell (1913)

Absolute magnitude plotted verses Spectral type: the two most observable intrinsic properties of stars

Absolute magnitude (**M_V**)
(original-traditional)

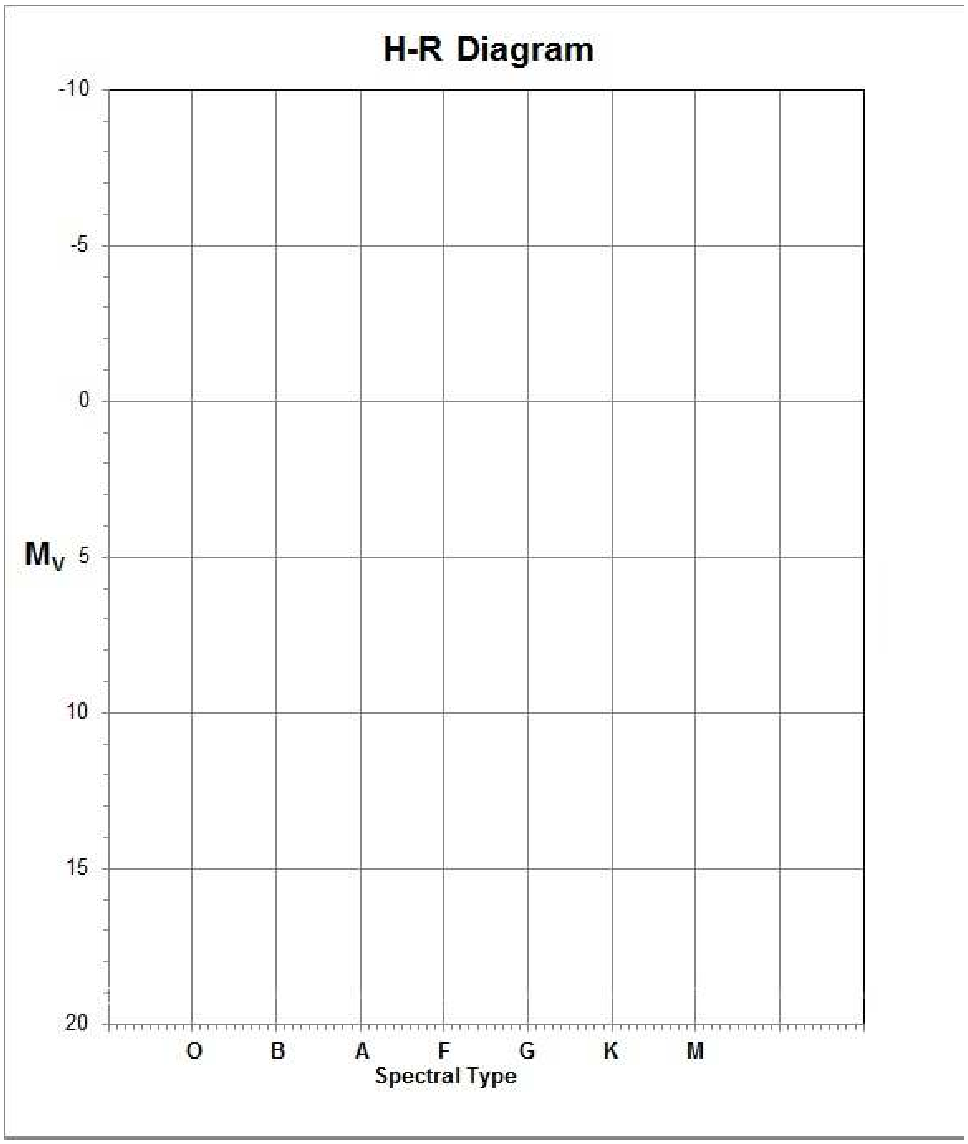
Luminosity (**$\log[L/L_\odot]$**)
(theoretical)

Apparent magnitude (**V**)
(observational color-magnitude diagram; all plotted stars at the same distance)

Spectral type
(original-traditional)

Surface Temp. (**$\log[T/T_\odot]$**)
(theoretical)

Color-index
(observational color-magnitude diagram; all plotted stars at the same distance)



$\log[L/L_\odot]$ **$\log[T/T_\odot]$**

Absolute magnitude:

First diagram used stars with classified spectral type, measured apparent mags, and parallaxes.

Example:

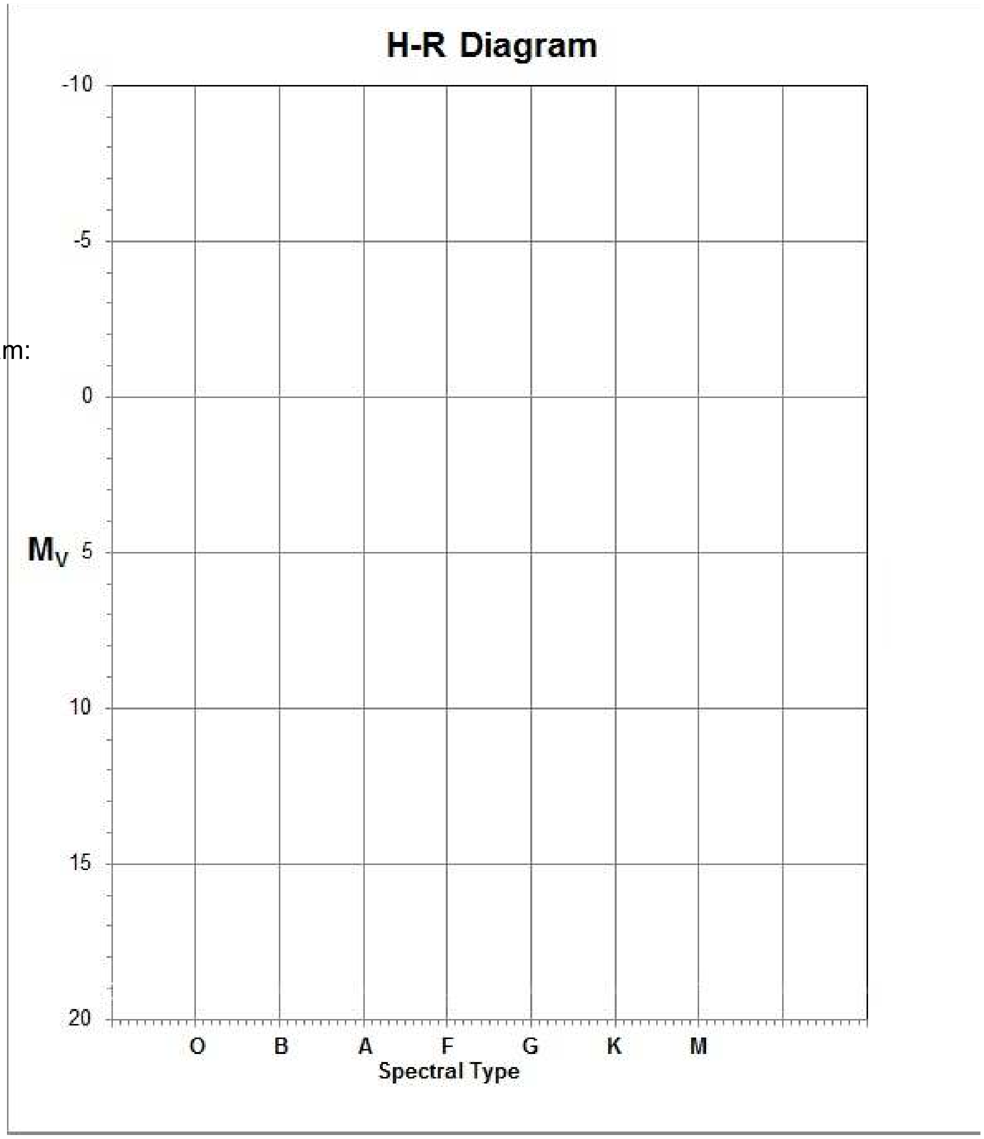
Plot Sirius A & B on diagram:

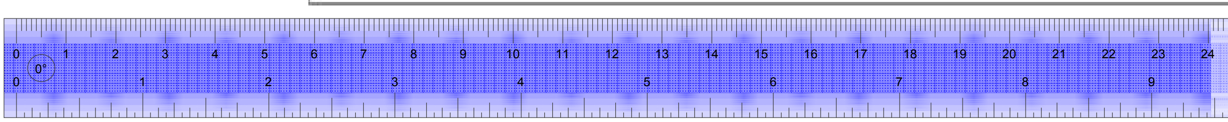
Sirius A: $m_V = -1.44$
$r = 2.63$ pc
Sp = A1

Sirius B: $m_V = 8.44$
$r = 2.63$ pc
Sp = A2

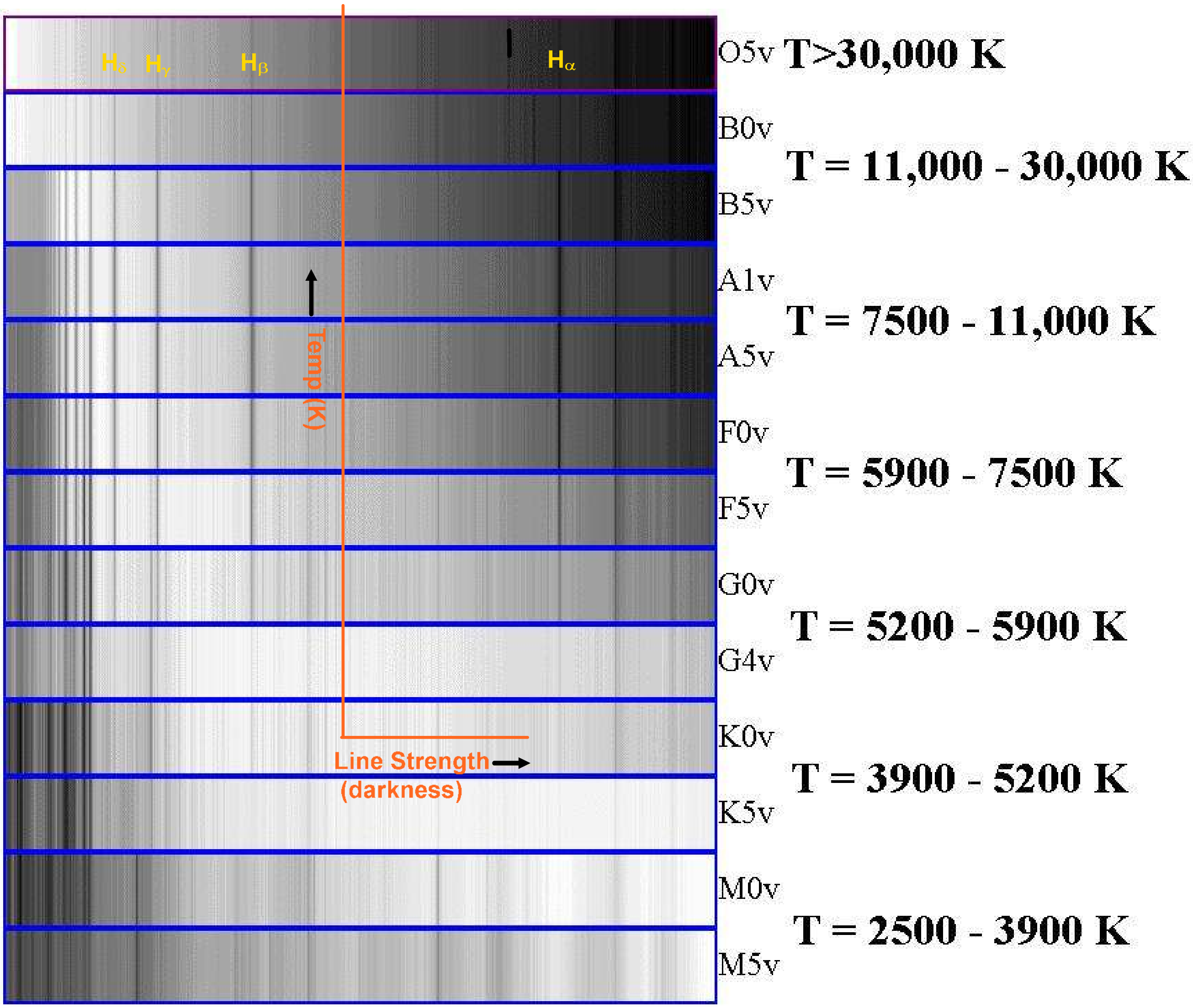
Determine the abs. mags using the dist. modulus - distance relation:

$M = m + 5 - 5\log(r)$

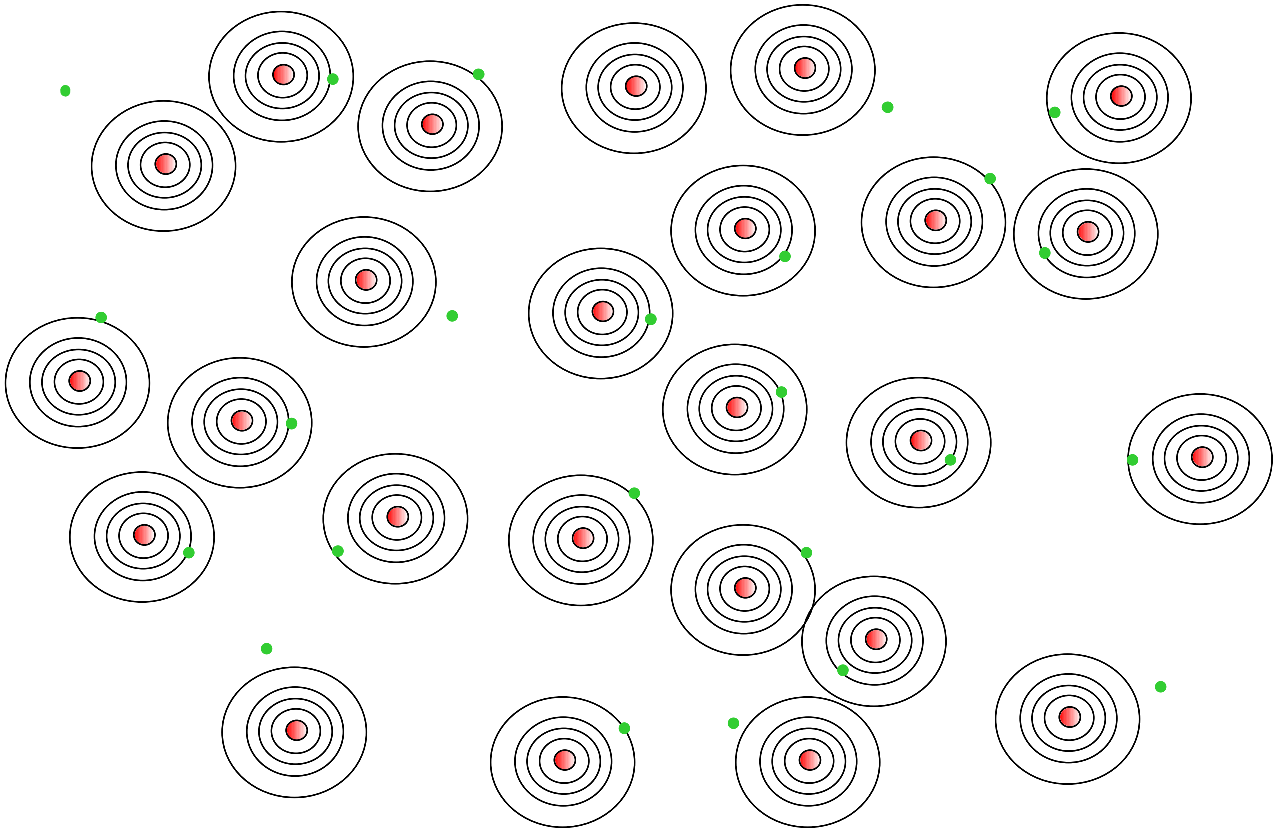


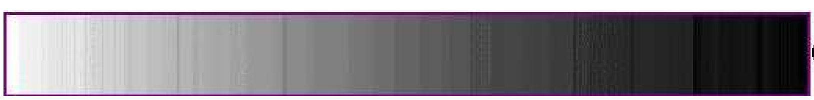


Spectral type and Color index:

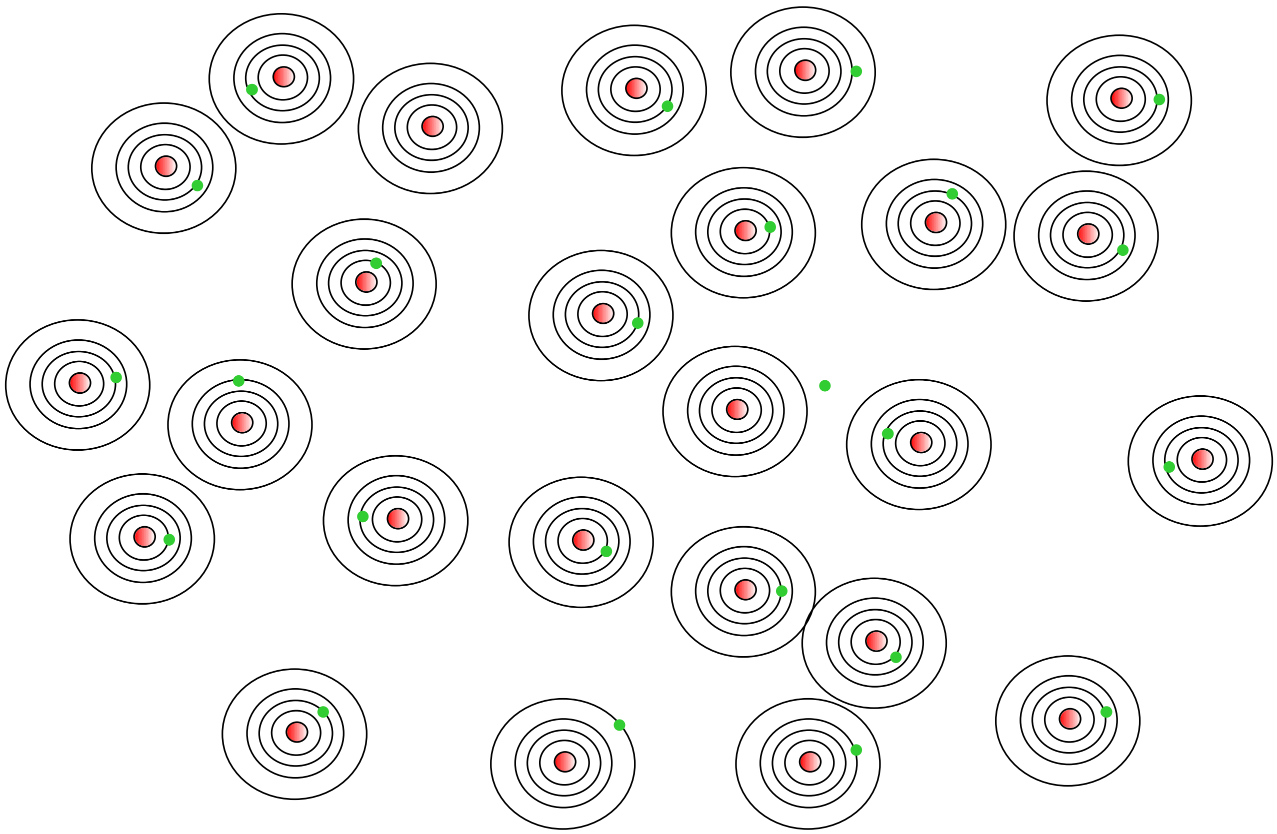


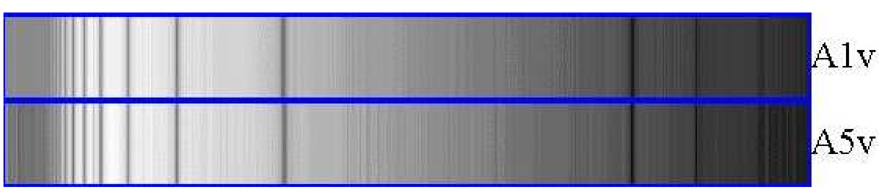
(See exercise 6)



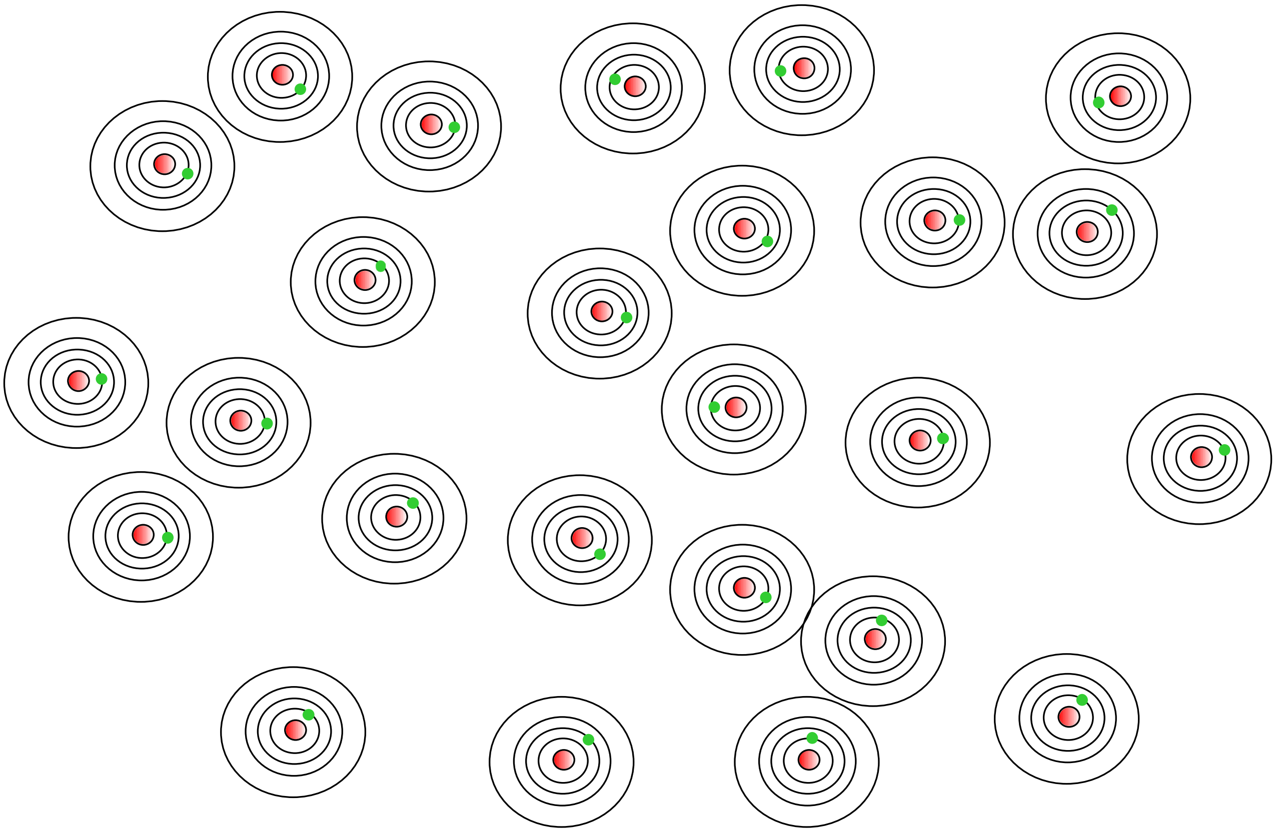


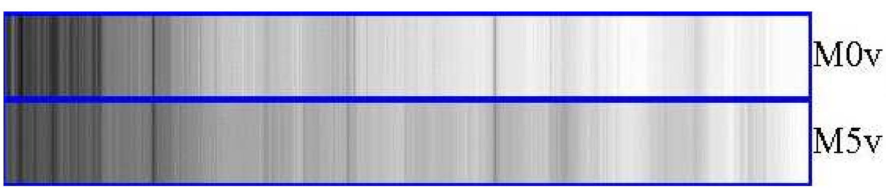
O5v T>30,000 K





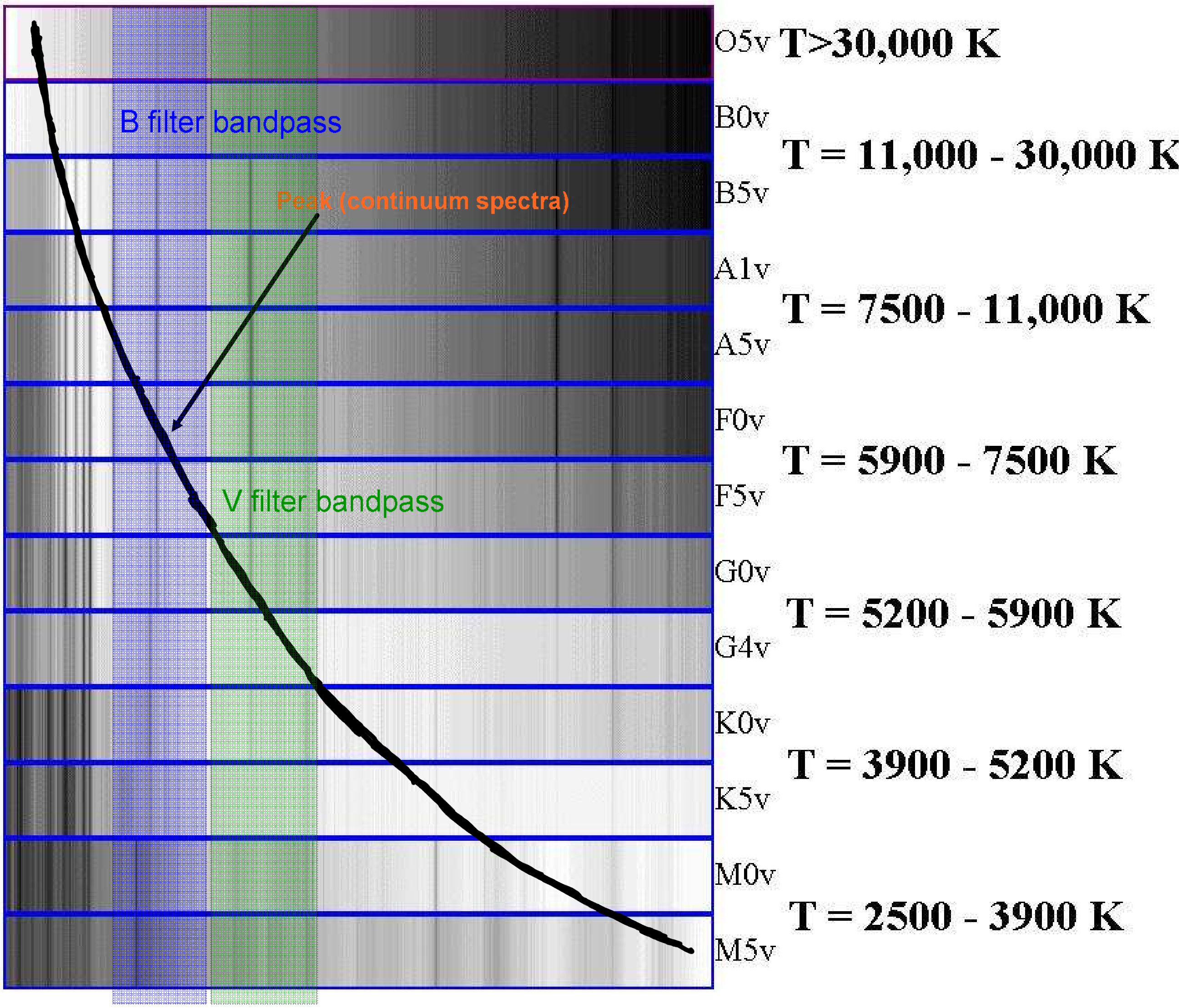
T = 7500 - 11,000 K

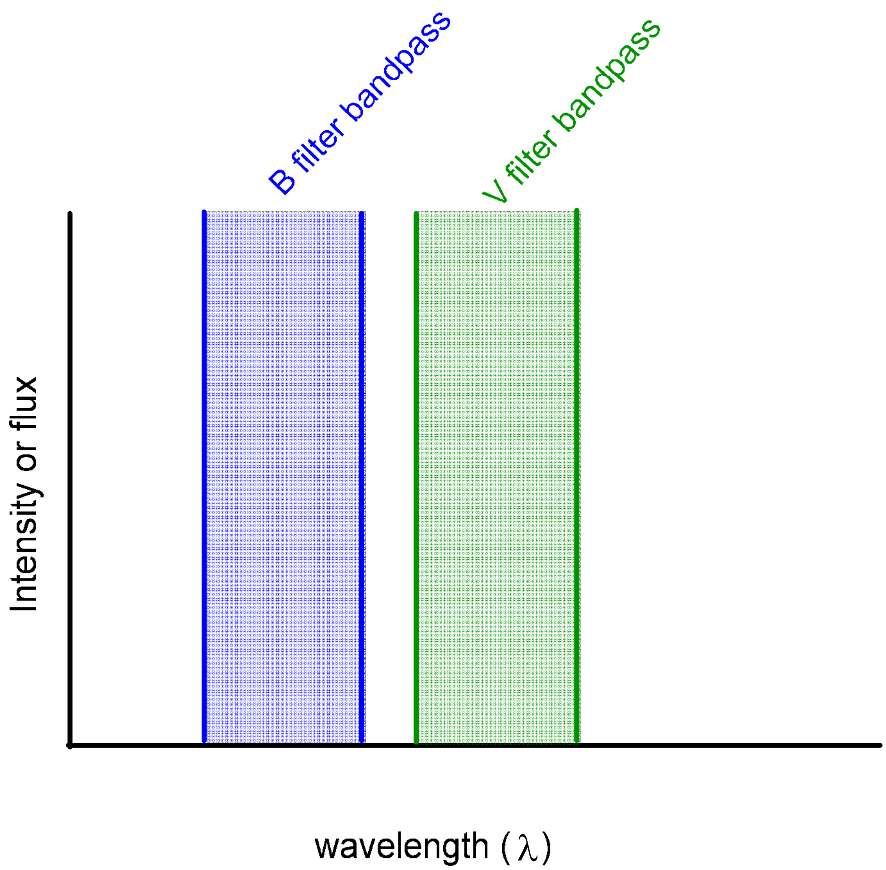




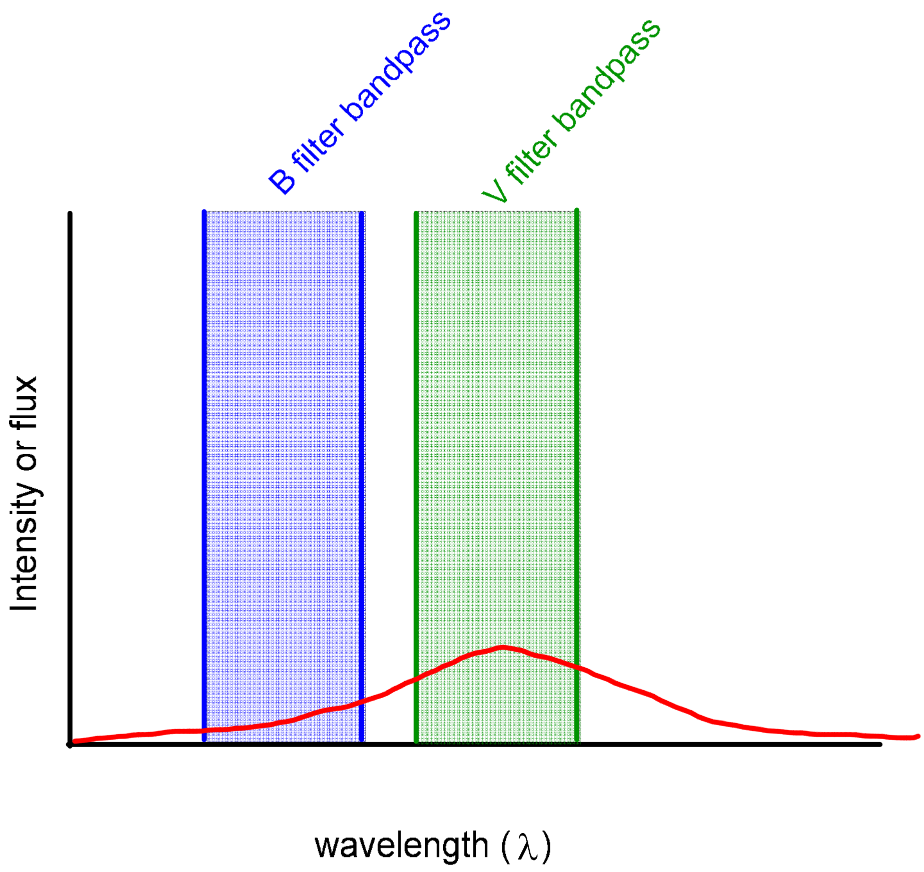
T = 2500 - 3900 K

Color index:


B filter bandpass
Peak (continuum spectra)
V filter bandpass
O5v
B0v
B5v
A1v
A5v
F0v
F5v
G0v
G4v
K0v
K5v
M0v
M5v
T>30,000 K
T = 11,000 - 30,000 K
T = 7500 - 11,000 K
T = 5900 - 7500 K
T = 5200 - 5900 K
T = 3900 - 5200 K
T = 2500 - 3900 K



Note: V = "visual" filter = green bandpass



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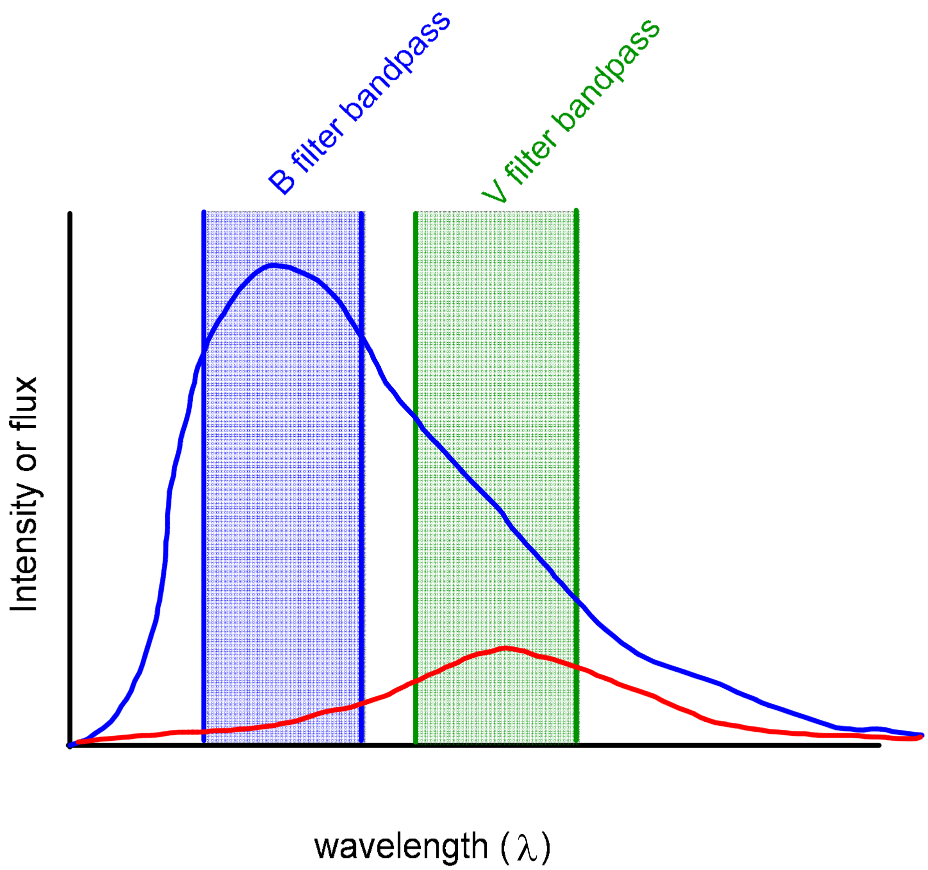

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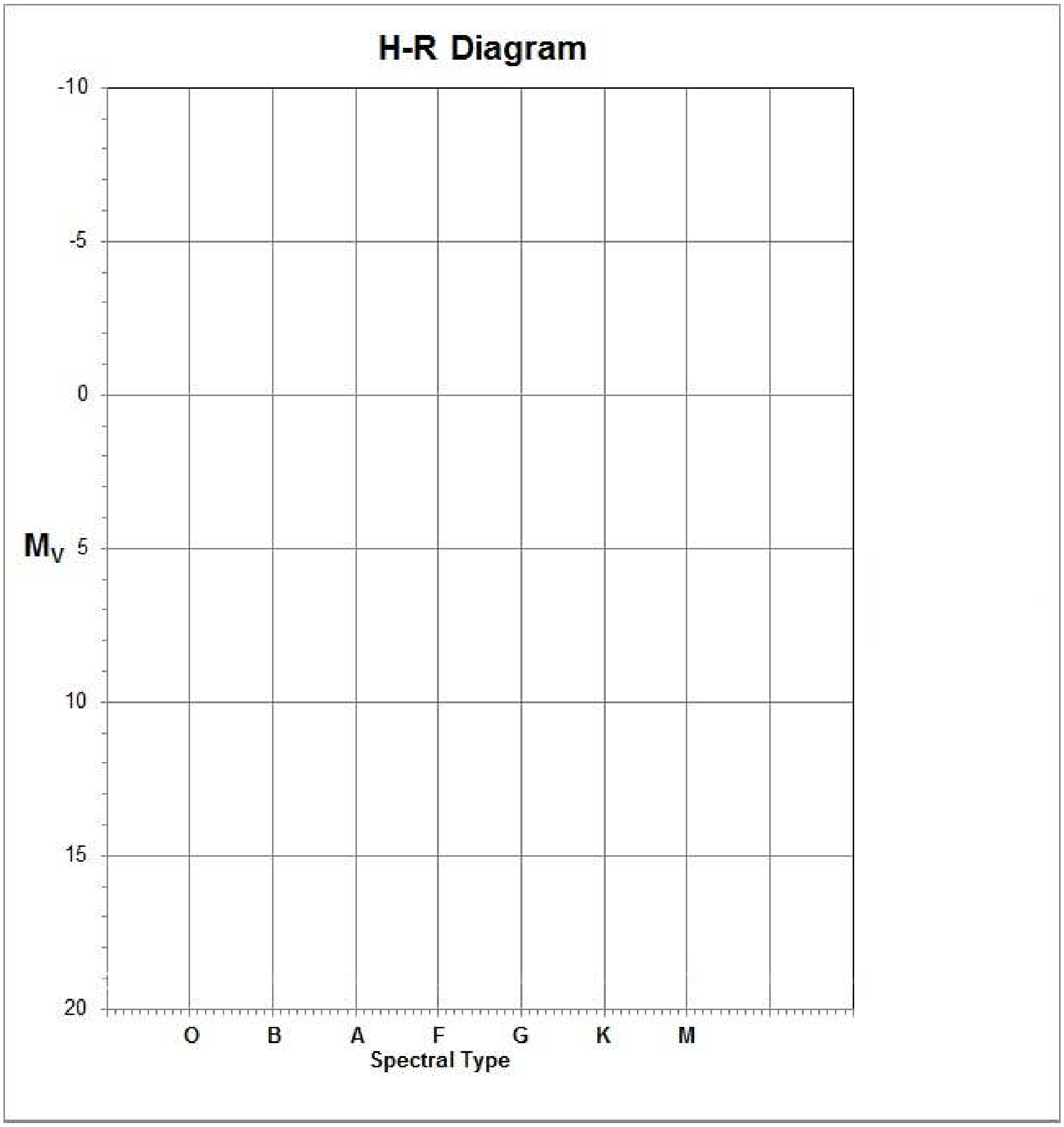
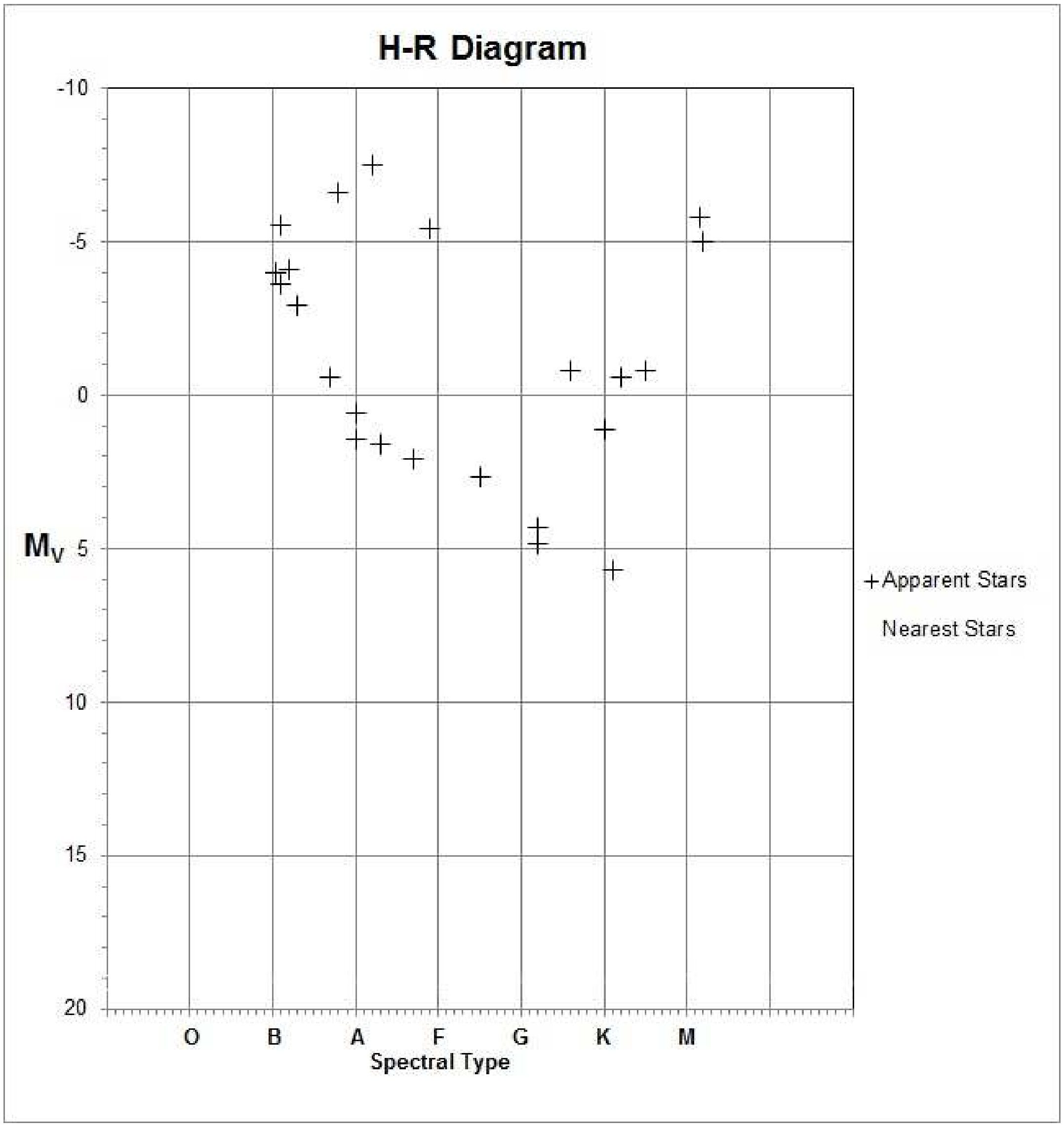
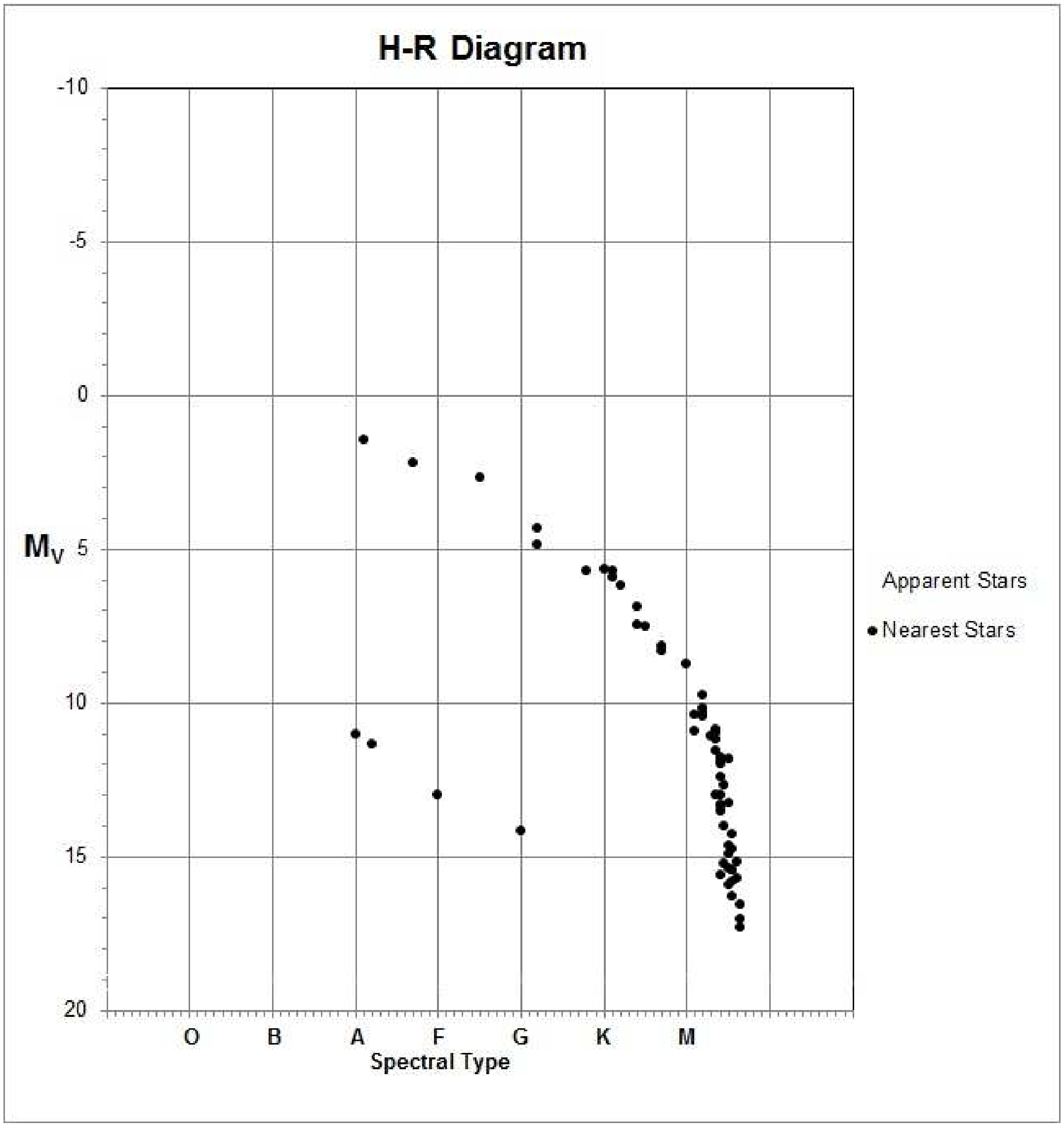
H-R Diagram; relative no.s of types of stars; sequences of stars on the diagram



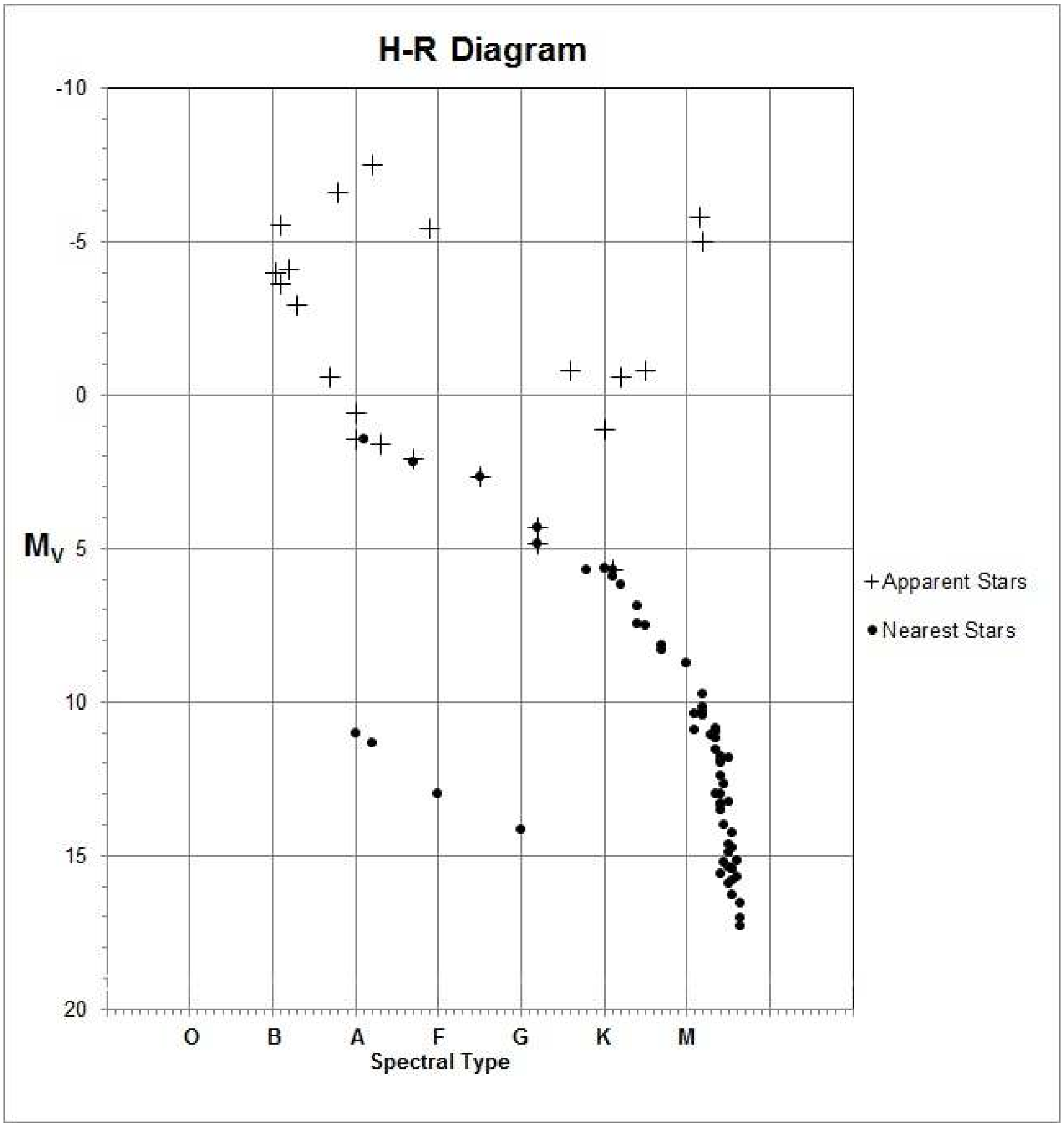
H-R Diagram; Types of stars



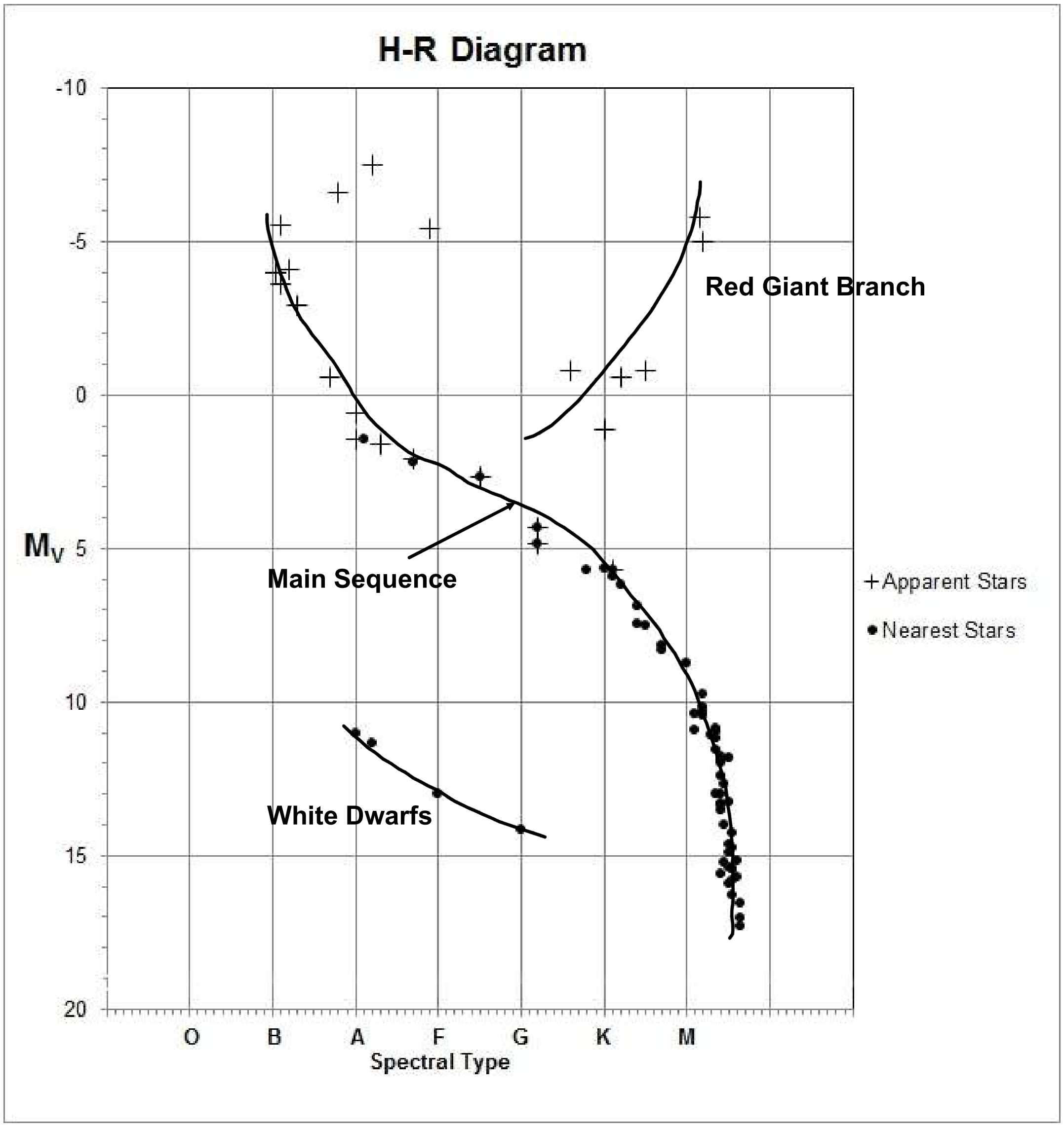
H-R Diagram; Types of stars



H-R Diagram; Sequences of stars

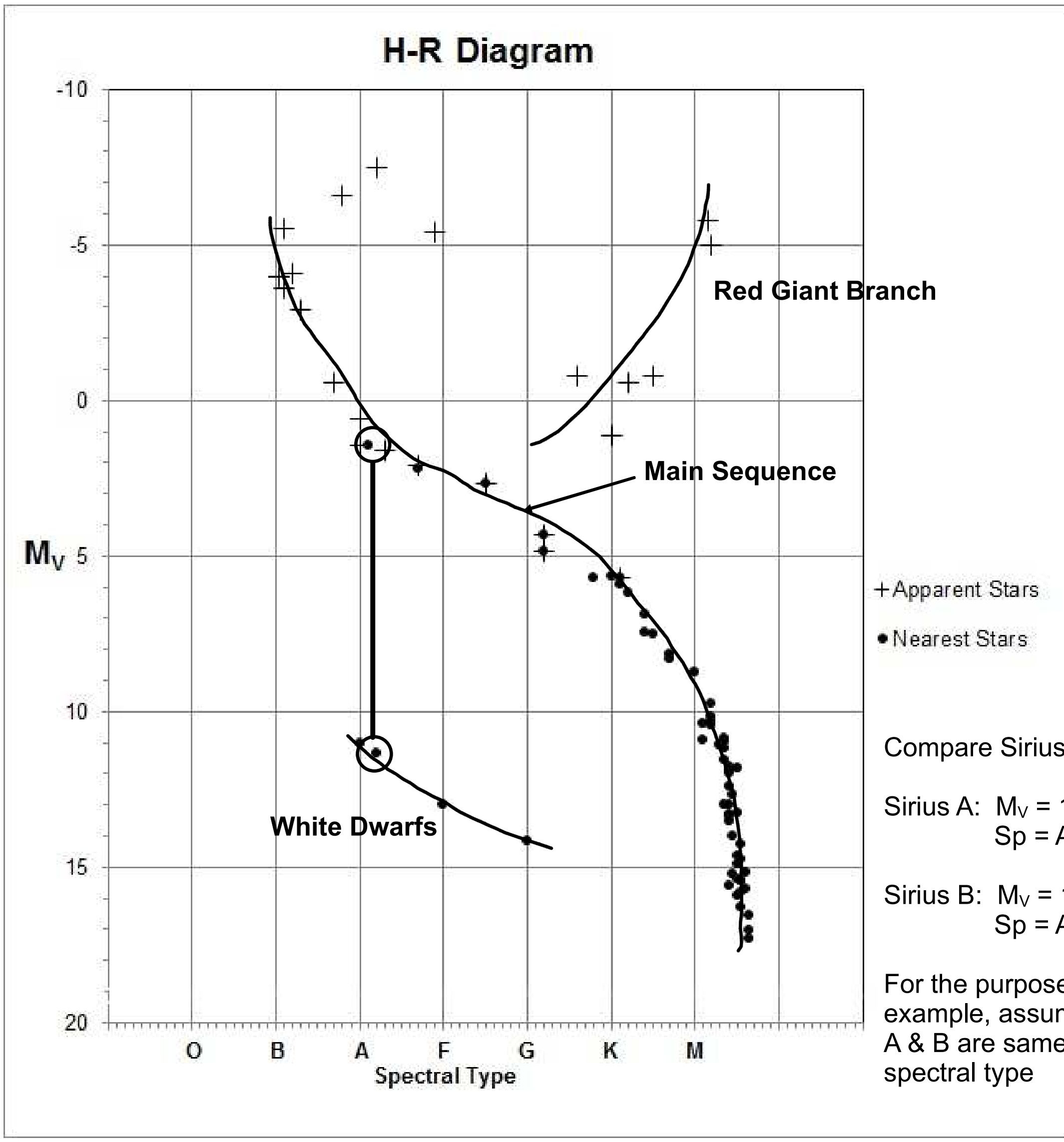


H-R Diagram; Sequences of stars



Note: mass measurements from binary stars shows that the MS is a "mass sequence".
i.e.: the cool, low luminosity stars are low mass stars and as we go up the MS to greater surface temperatures and higher luminosity stars, the mass of MS stars increases.

H-R Diagram: How come "Giant" or "Dwarf"? (radii of stars)



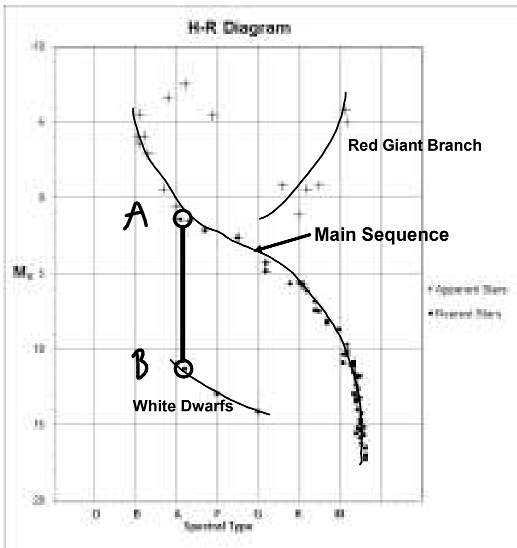
Compare Sirius A & B:

Sirius A: M_V = 1.47
Sp = A1

Sirius B: M_V = 11.34
Sp = A2

For the purpose of the example, assume both A & B are same spectral type

H-R Diagram: How come "Giant" or "Dwarf"? (radii of stars)



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$Sp_A = Sp_B \quad T_A = T_B = T$

From S-B law:

$$\left(\frac{P}{A}\right)_A = \left(\frac{P}{A}\right)_B = \sigma T^4$$

note: $L \equiv P$

A is much brighter (more luminous) than B: $L_A > L_B$ or $P_A > P_B$

$$\frac{P_A}{A_A} = \frac{P_B}{A_B} \qquad \frac{A_A}{A_B} = \frac{P_A}{P_B}$$

$$A_A > A_B$$

A is much larger in radius than B: $R_A > R_B$

H-R Diagram: How come "Giant" or "Dwarf"? (radii of stars)

From S-B law:

Note: total radiative power of star is its luminosity

$$\frac{P}{A} = \sigma T^4 \qquad P \equiv L$$

$$L = \sigma T^4 A \qquad A = CR^2 \qquad C = 4\pi$$

$$L = CR^2 \sigma T^4 \qquad \text{Sun: } L_\odot = CR_\odot^2 \sigma T_\odot^4$$

$$\frac{L}{L_\odot} = \frac{R^2}{R_\odot^2}\frac{T^4}{T_\odot^4} = \left(\frac{R}{R_\odot}\right)^2 \left(\frac{T}{T_\odot}\right)^4$$

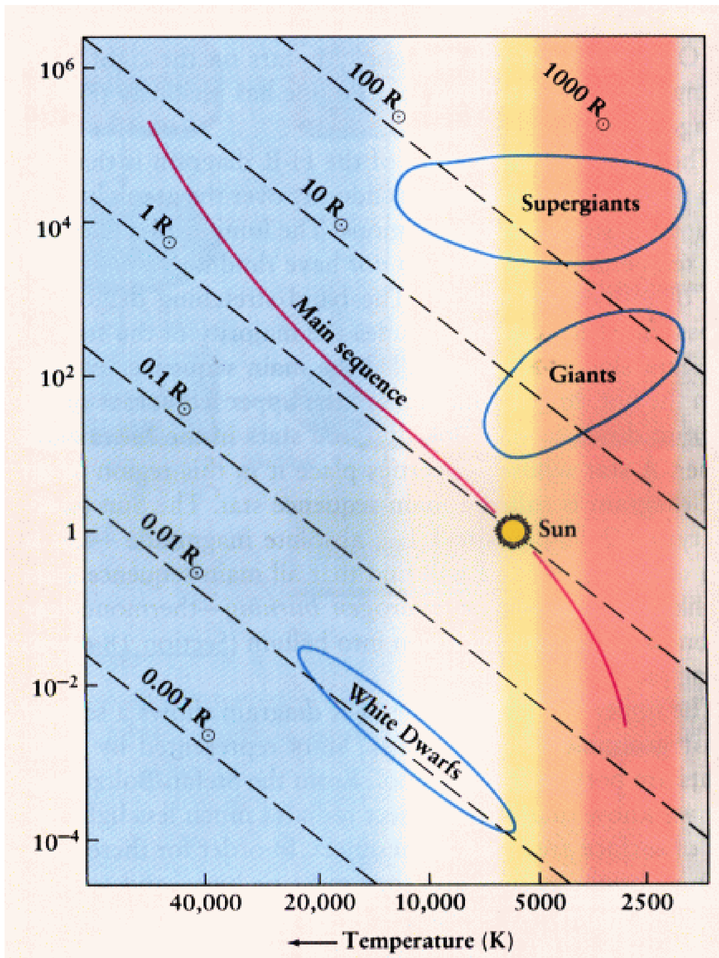
$$\log(L/L_\odot) = \log\left[(R/R_\odot)^2 (T/T_\odot)^4\right] = 2\log(R/R_\odot) + 4\log(T/T_\odot)$$

$$\boxed{\log(L/L_\odot) = 4\log(T/T_\odot) + 2\log(R/R_\odot)}$$

Above result shows that lines of constant radius would be straight lines with a slope of 4 as plotted on a theoretical H-R Diagram.

(See next page.)

log[L/L⊙]


10^6
10^4
10^2
1
10^{-2}
10^{-4}
100 R⊙
1000 R⊙
10 R⊙
1 R⊙
0.1 R⊙
0.01 R⊙
0.001 R⊙
Supergiants
Giants
Main sequence
Sun
White Dwarfs
40,000
20,000
10,000
5000
2500
← Temperature (K)

log[T/T⊙]