
BTILLEY SanDiego Union-Tribune©
KATHERINE JOHNSON, NASA LEGEND
1918-2020

- **Please pick up your papers**

- **Next TIMESTEP meeting (March 4; PAS 218)**
  - ***Resume Building and Interview Preparation***

- **Exam #1 (March 4)**
  - **Doodle Sheet comments**
    - **open book & notes**
    - **handwritten crib sheet**

Minima for the Eclipsing Binary Algol

Computed dates (*mm/dd/yyyy*) and Universal Times of Algol minima:	Corresponding local dates (*mm/dd/yyyy*) and times of Algol minima:
02/29/2020 @ 03:55 UT	02/28/2020 @ 08:55 PM
03/03/2020 @ 00:45 UT	03/02/2020 @ 05:45 PM
03/05/2020 @ 21:34 UT	03/05/2020 @ 02:34 PM
03/08/2020 @ 18:23 UT	03/08/2020 @ 11:23 AM
03/11/2020 @ 15:13 UT	03/11/2020 @ 08:12 AM
03/14/2020 @ 12:02 UT	03/14/2020 @ 05:02 AM
03/17/2020 @ 08:51 UT	03/17/2020 @ 01:51 AM
03/20/2020 @ 05:40 UT	03/19/2020 @ 10:40 PM

Comments on Homework #16

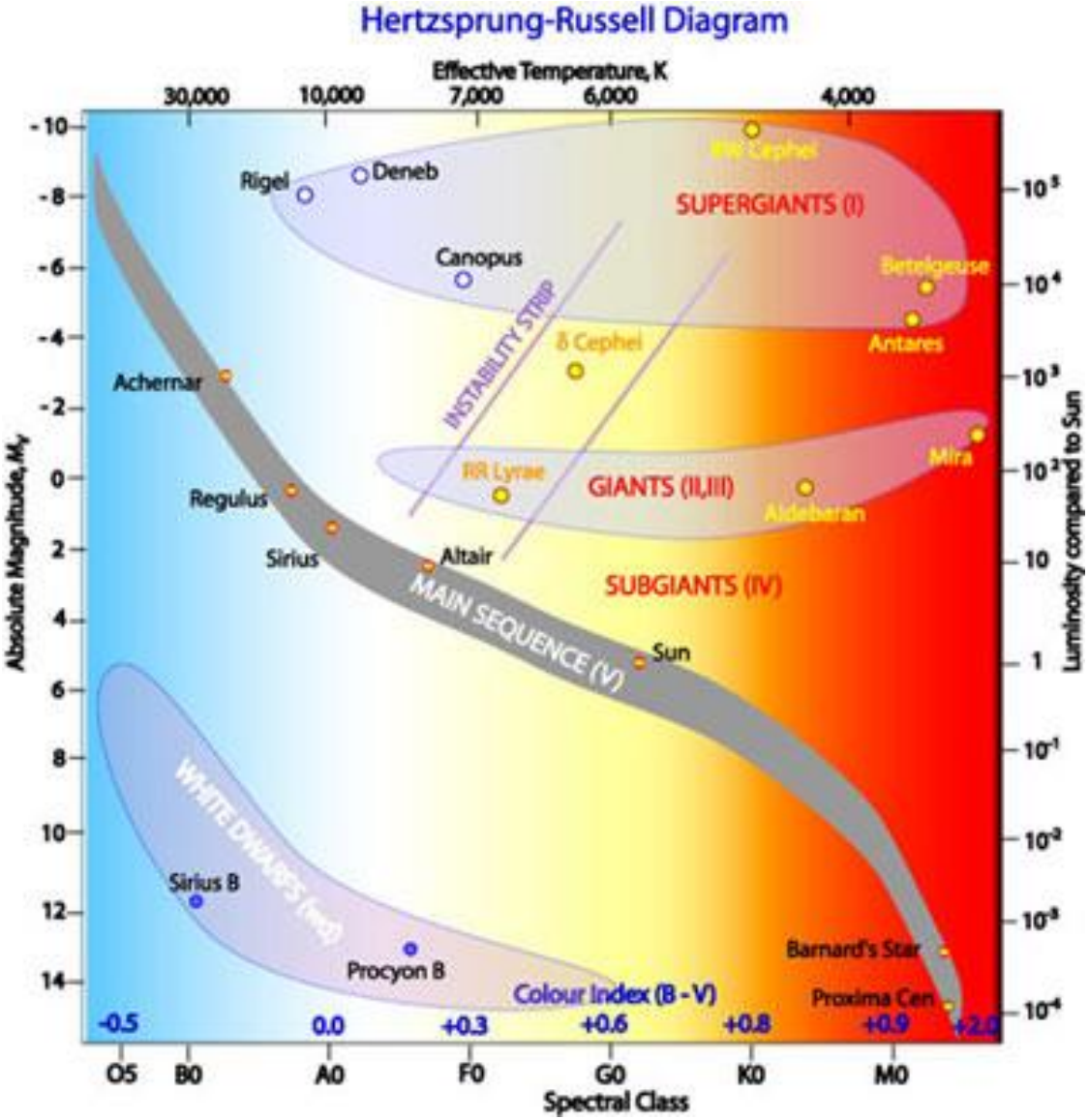
do not cancel the "sin i" – WHY?

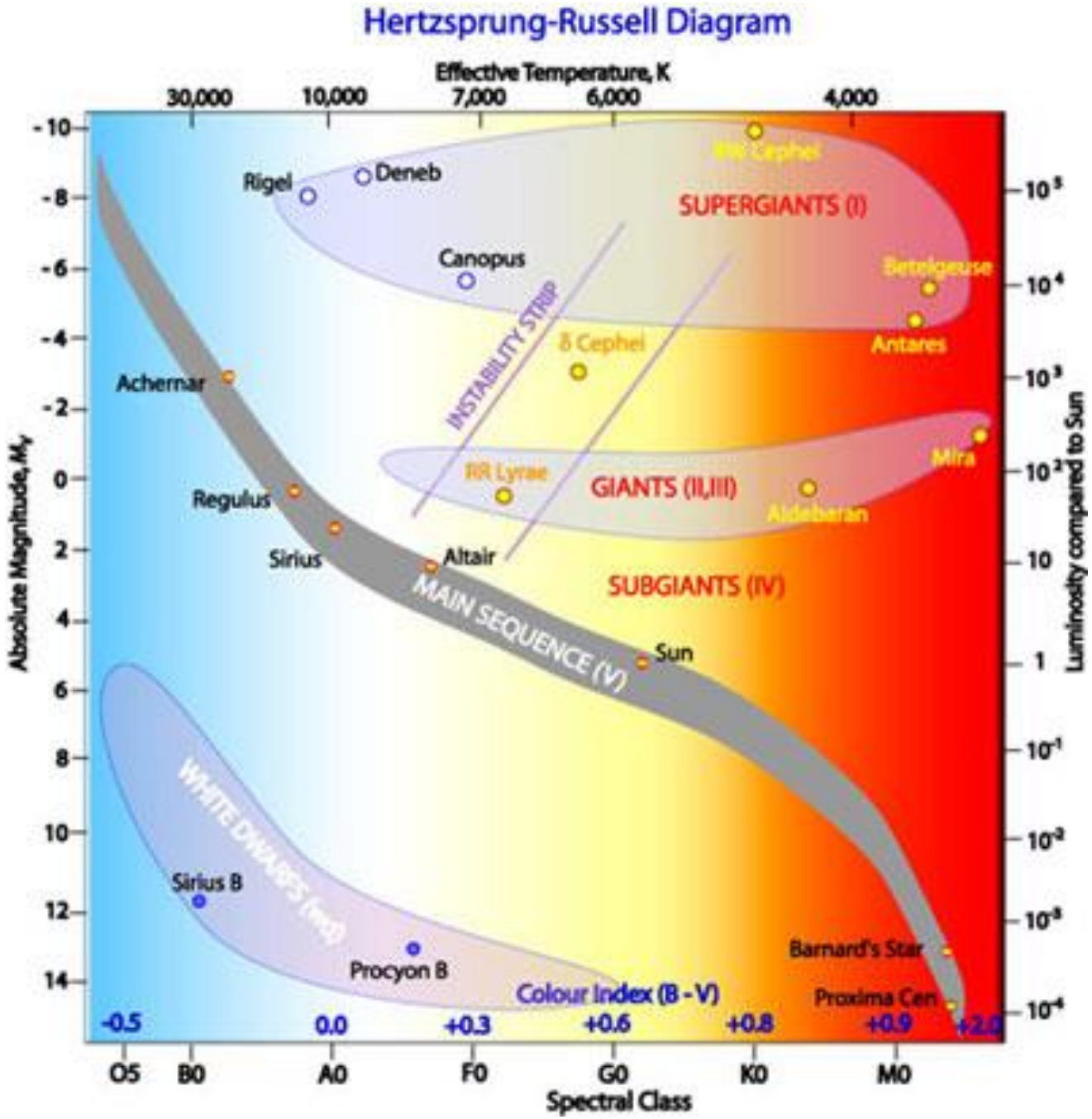
$$M_B \sin i \approx \left(\frac{M_A^2 P}{2\pi G}\right)^{1/3} v_A \sin i$$

$$\approx 11 M_\oplus \left(\frac{M_A}{1 M_\odot}\right)^{2/3} \left(\frac{P}{1\,\mathrm{yr}}\right)^{1/3} \left(\frac{v_A \sin i}{1\,\mathrm{m\,s^{-1}}}\right).$$

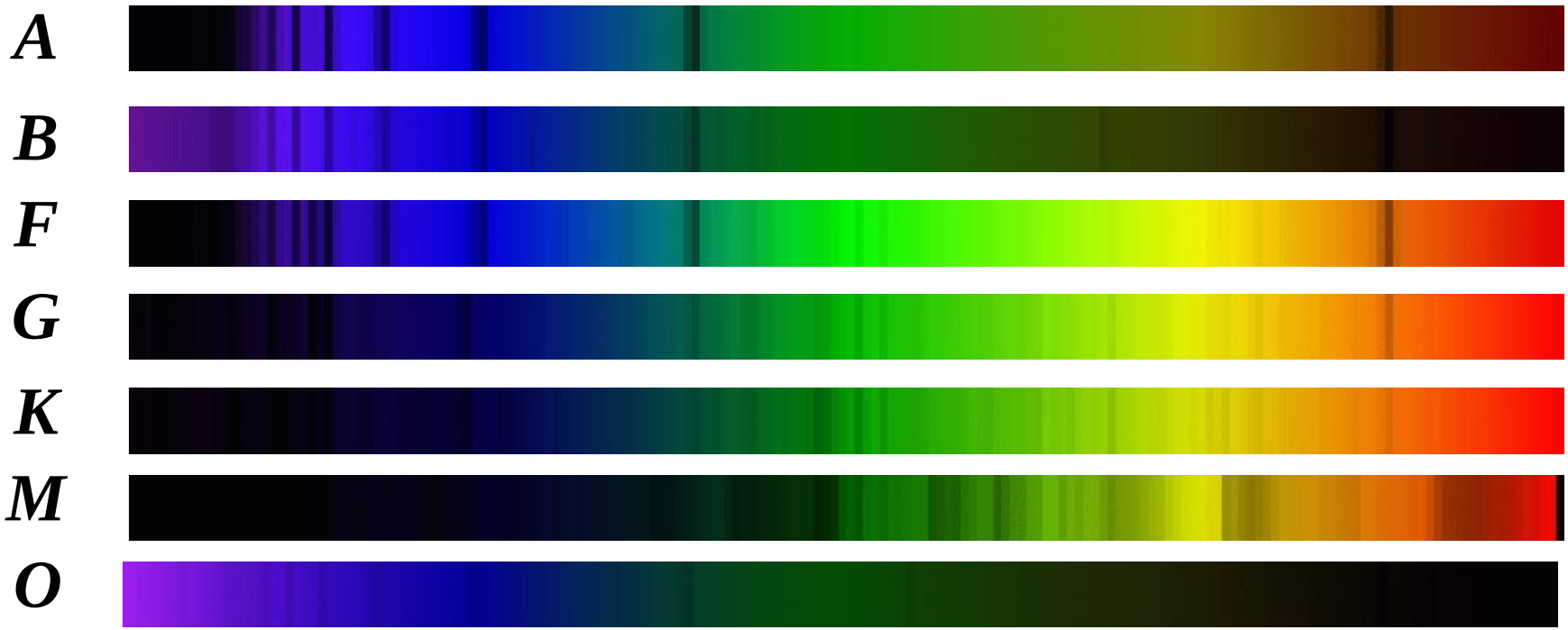
Stars

the Hertzsprung-Russell diagram

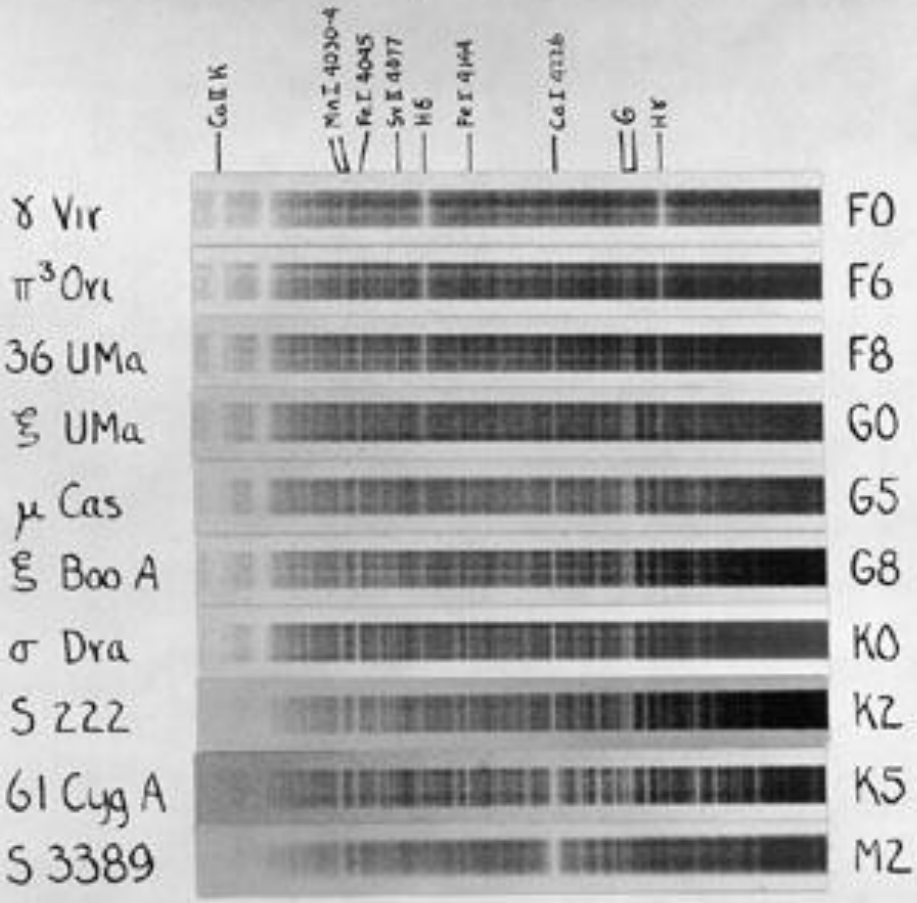



Hertzsprung-Russell Diagram
Effective Temperature, K
30,000
10,000
7,000
6,000
4,000
Absolute Magnitude, M_V
Luminosity compared to Sun
Rigel
Deneb
Canopus
SUPERGIANTS (I)
Betelgeuse
Antares
INSTABILITY STRIP
δ Cephei
Achernar
Mira
RR Lyrae
GIANTS (II,III)
Aldebaran
Regulus
Sirius
Altair
SUBGIANTS (IV)
MAIN SEQUENCE (V)
Sun
WHITE DWARFS (wd)
Sirius B
Procyon B
Barnard's Star
Proxima Cen
Colour Index (B - V)
-0.5
0.0
+0.3
+0.6
+0.8
+0.9
+2.0
O5
B0
A0
F0
G0
K0
M0
Spectral Class

Stellar "Spectral Types"
visual wavelengths (aka, "optical spectra")



Main Sequence F0 - M2



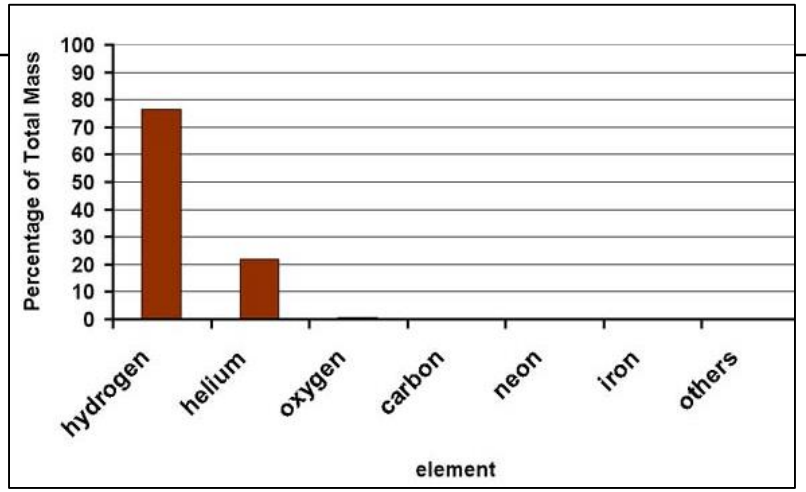
All stars illustrated are of luminosity class V
Cramer Hi-Speed Special

Cecilia Payne-Gaposchkin
1900-1979

She showed that the spectral sequence was in order of stellar temperature.

Stars are made almost entirely of hydrogen and helium even though their spectra don't always show strong lines of these elements.

<u>STARS</u>: 90% hydrogen, 9% helium, trace of heavier elements ("metals")



New discoveries in physics:

1. nuclei of atoms

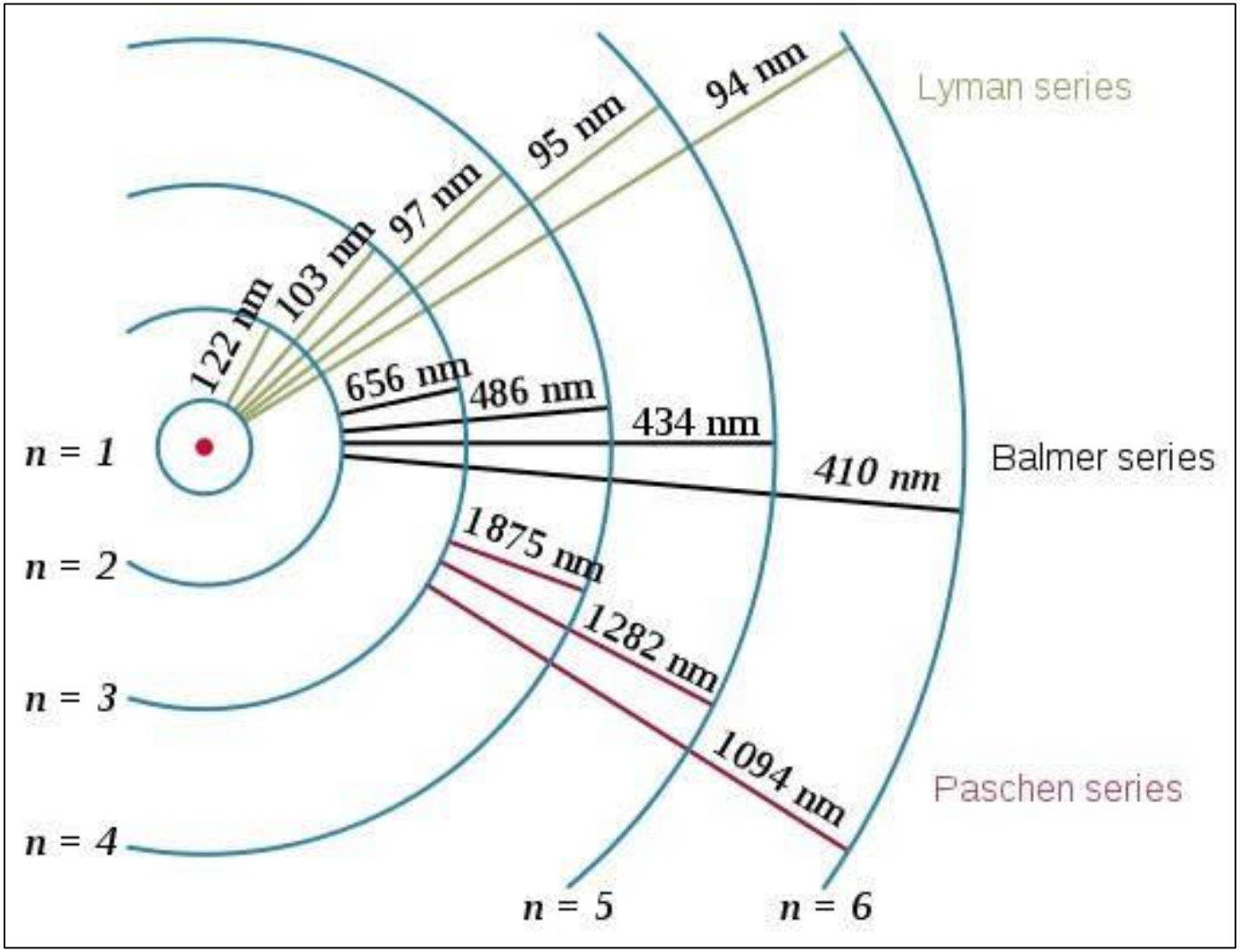
2. fixed orbits of electrons;

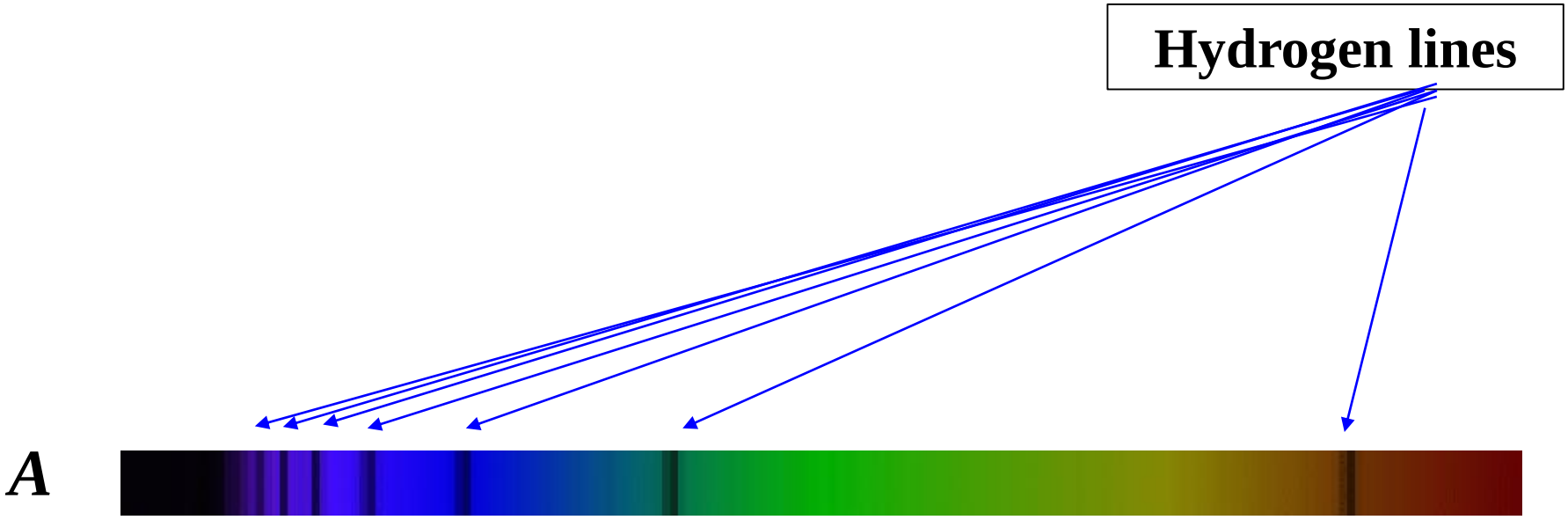
3. different number of electrons for each element;

4. temperature can affect number of spectral lines.

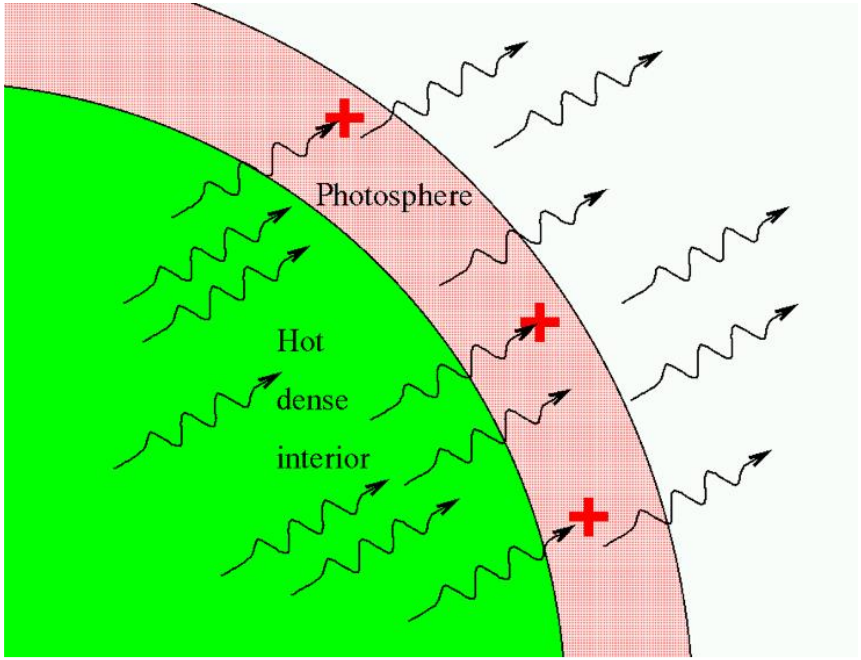
The Hydrogen Atom

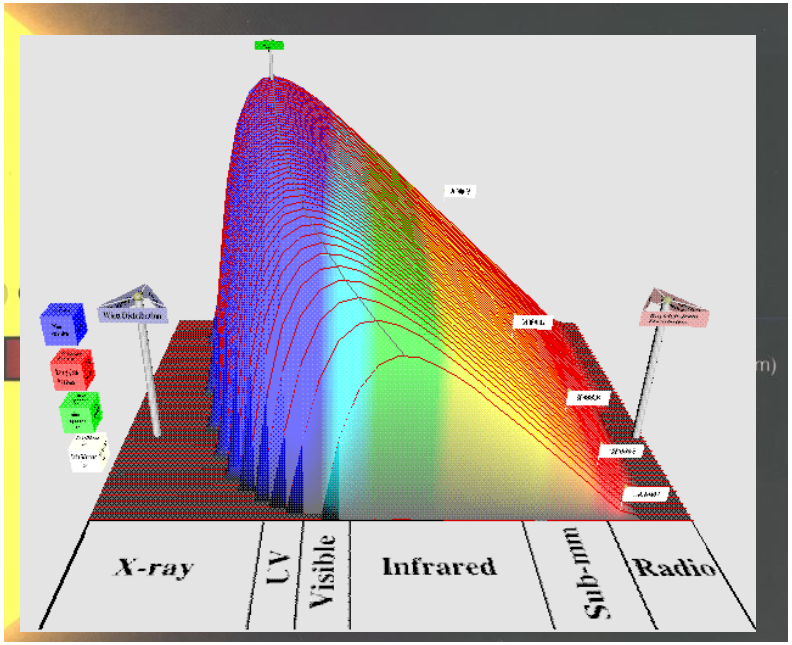
What regions of the electromagnetic spectrum?




Hydrogen lines
A

What Causes Absorption Lines?

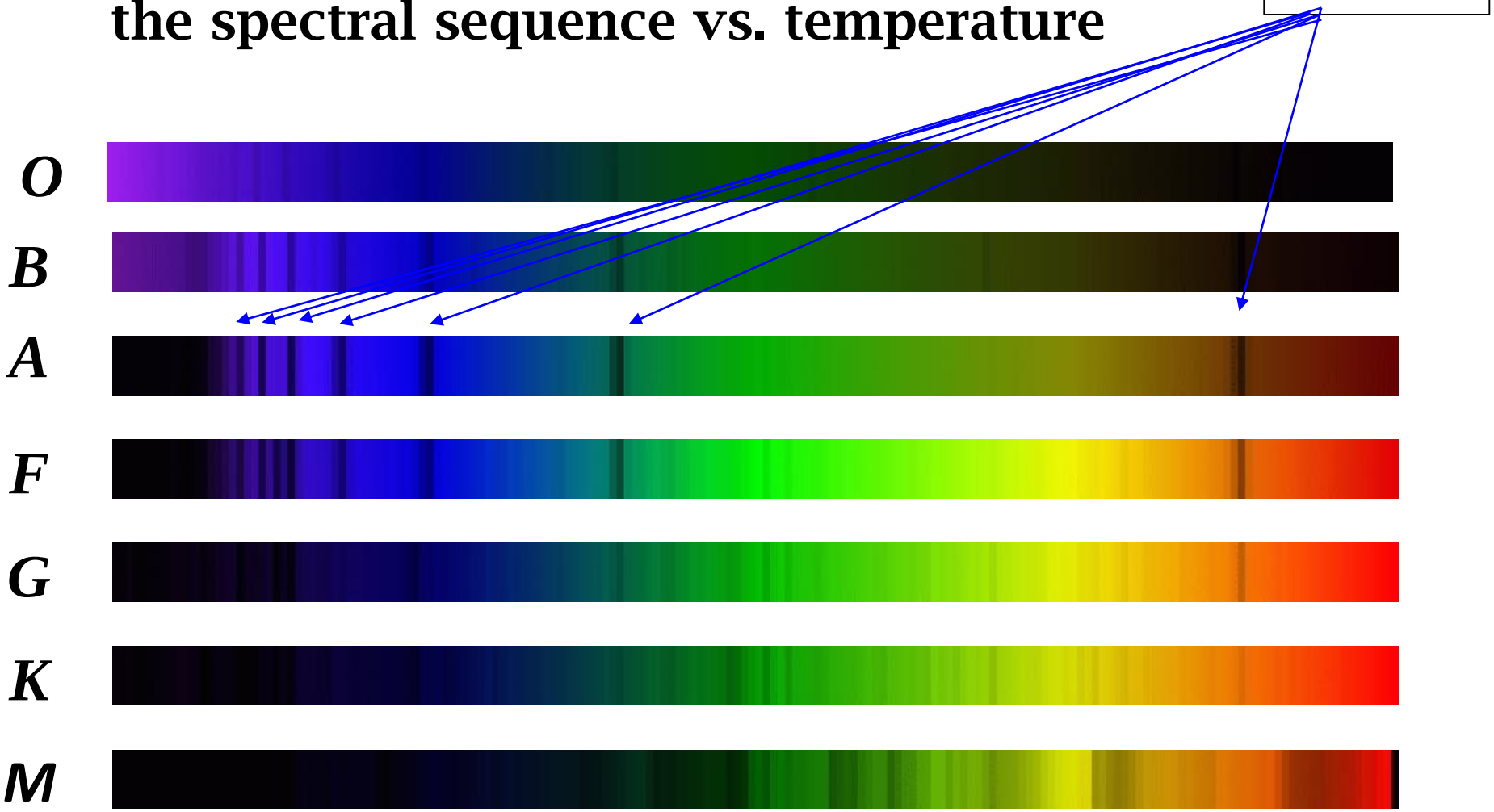




The hotter the object, the bluer its peak wavelength and the more light it emits.

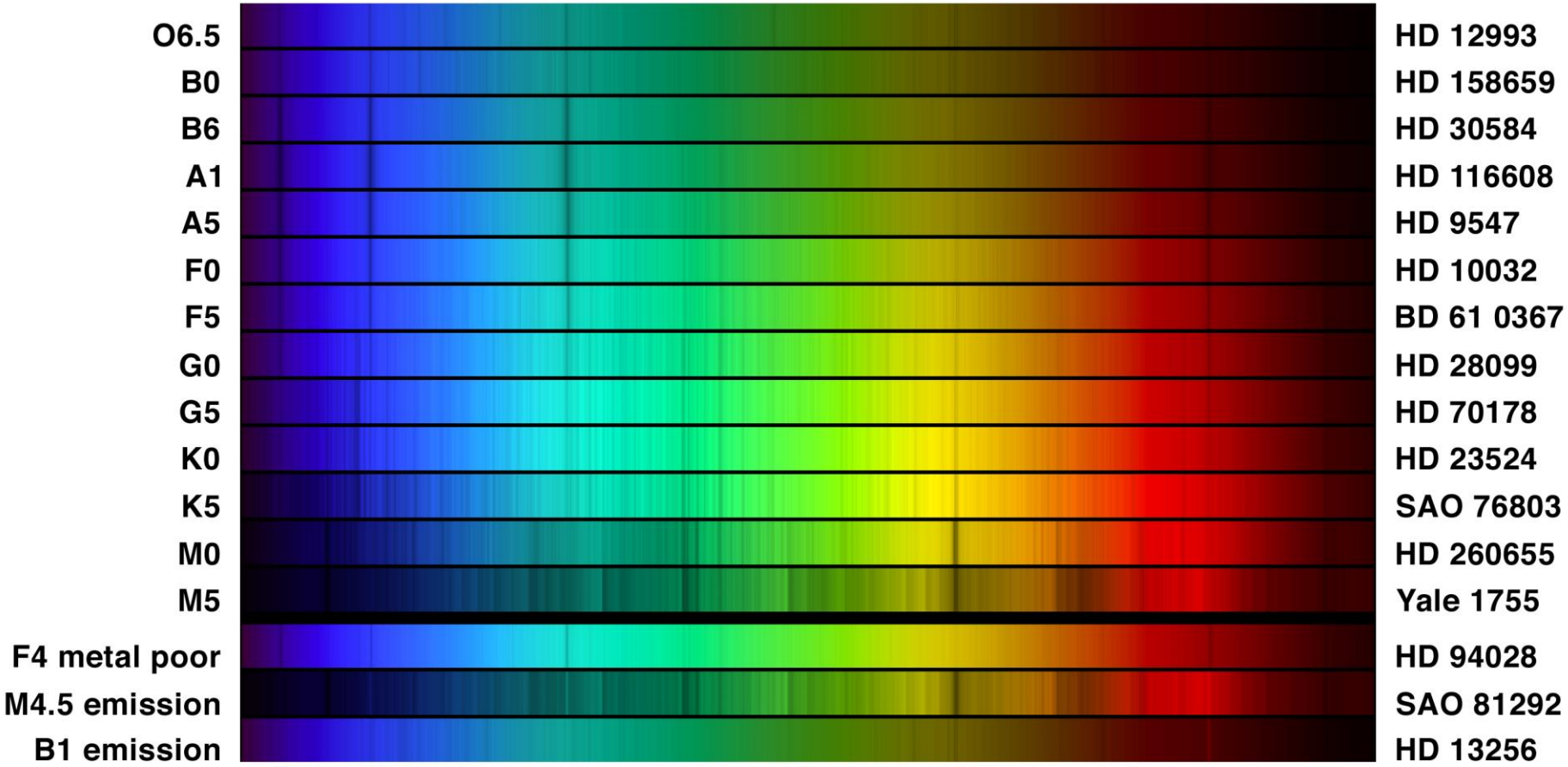
$$\lambda_{peak} = \frac{\text{constant}}{T} \quad \text{in nanometers}$$

Payne Reorganized the Alphabet
the spectral sequence vs. temperature

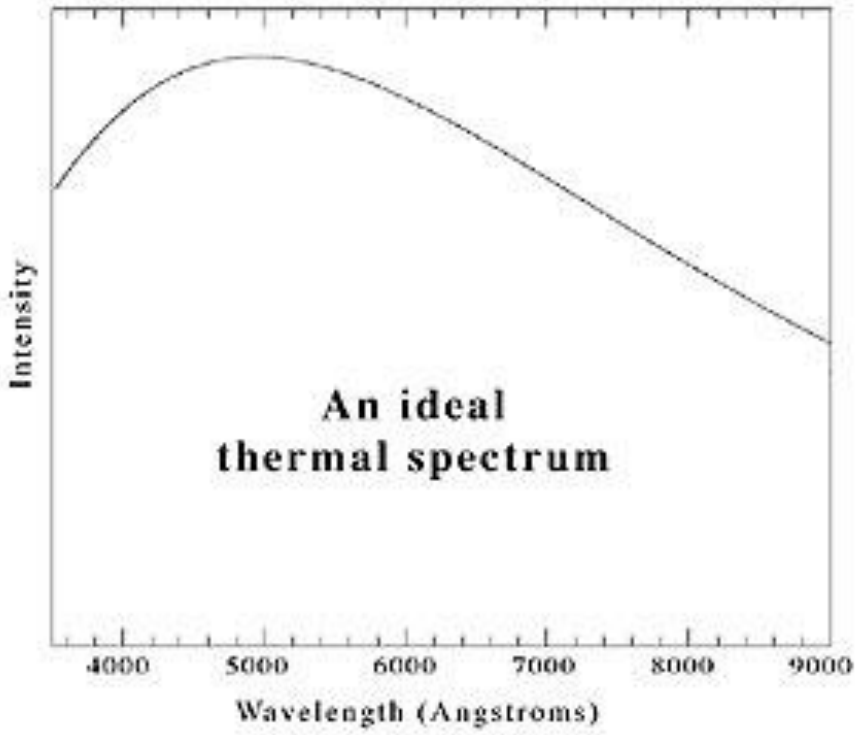


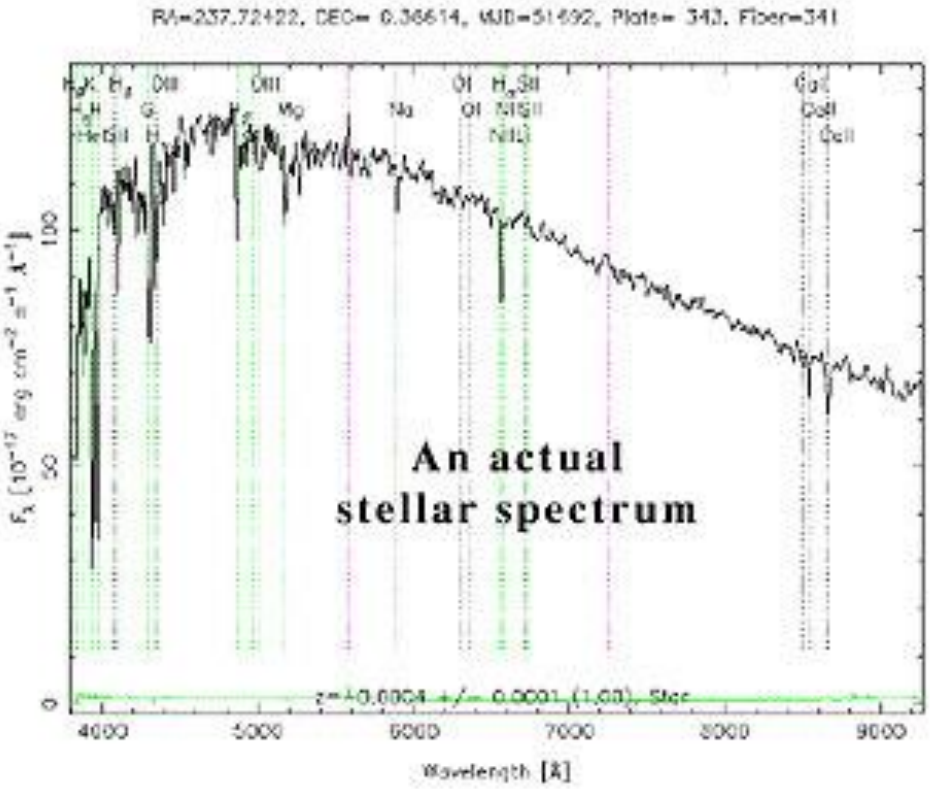
“Oh, Be A Fine Girl (or Guy) Kiss Me!”
“Only Boys Accepting Feminism Get Kissed Meaningfully.”
“One Bug Ate Five Green Killer Moths.”

The Spectral Sequence (Temperature) is continuous (i.e., very smooth)

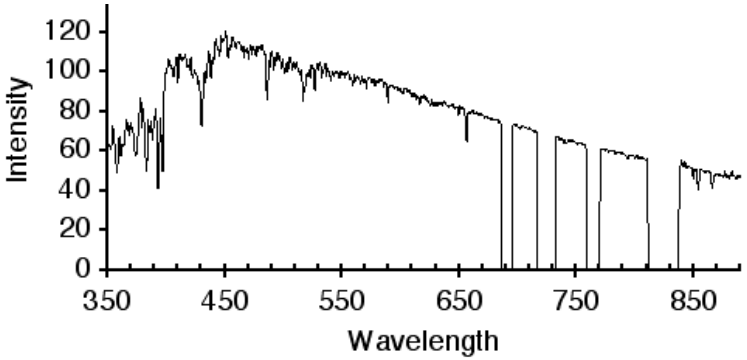


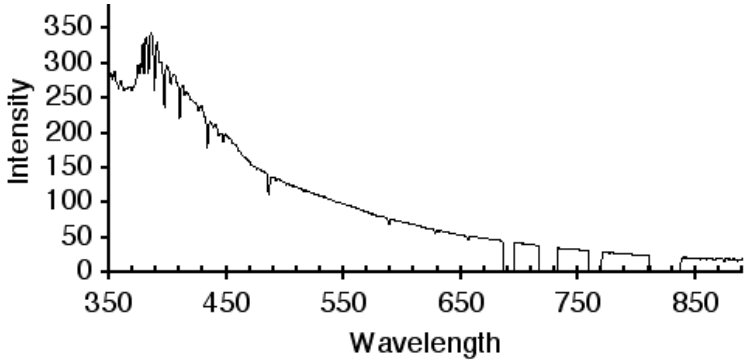
Cause of a Stellar Spectrum

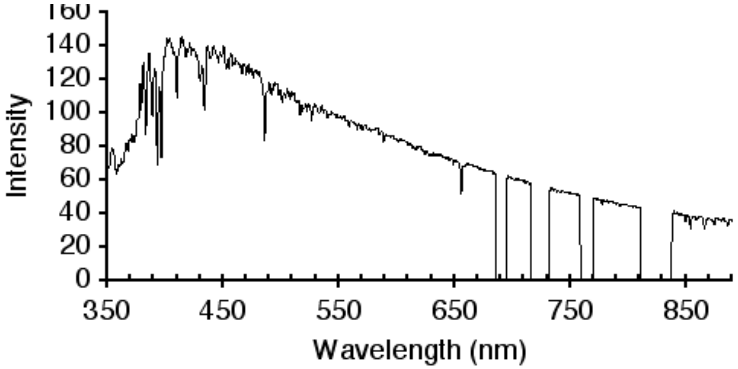




Which of these stars is hottest?

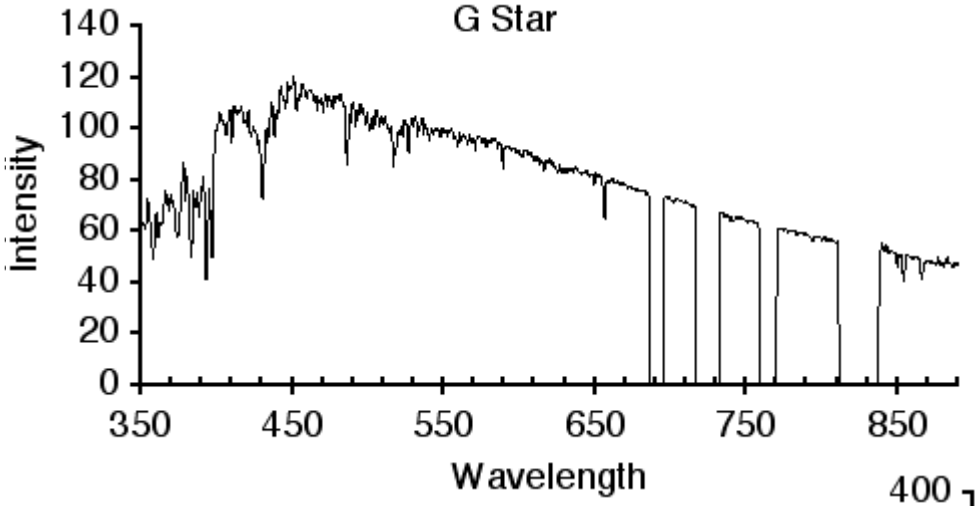


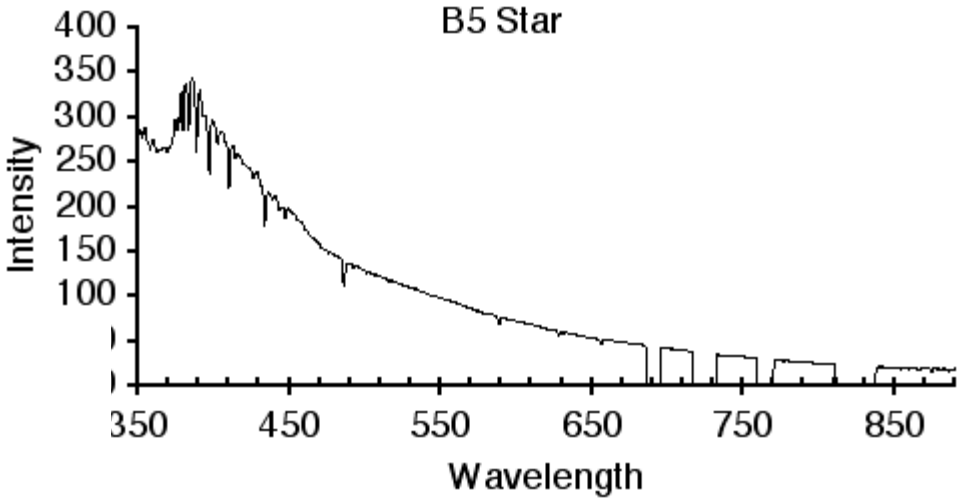


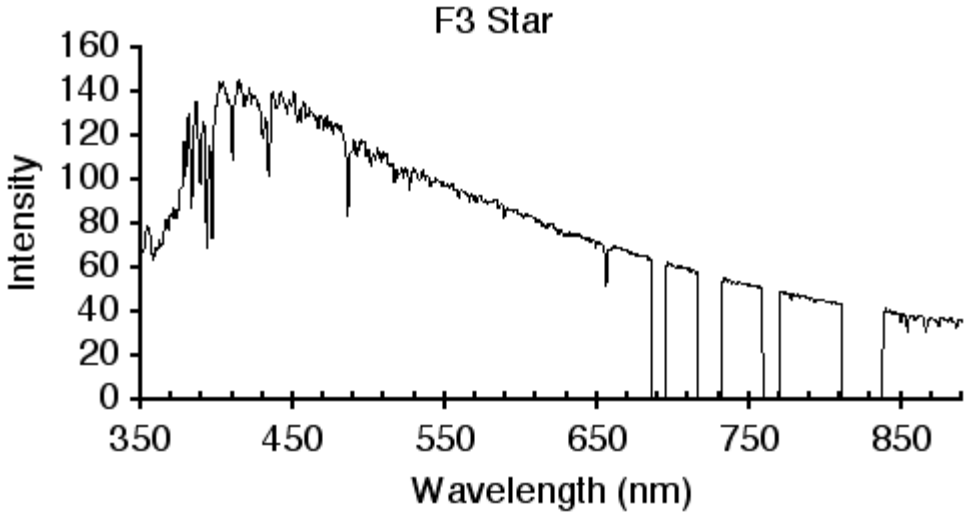


A. Top
B. Middle
C. Bottom

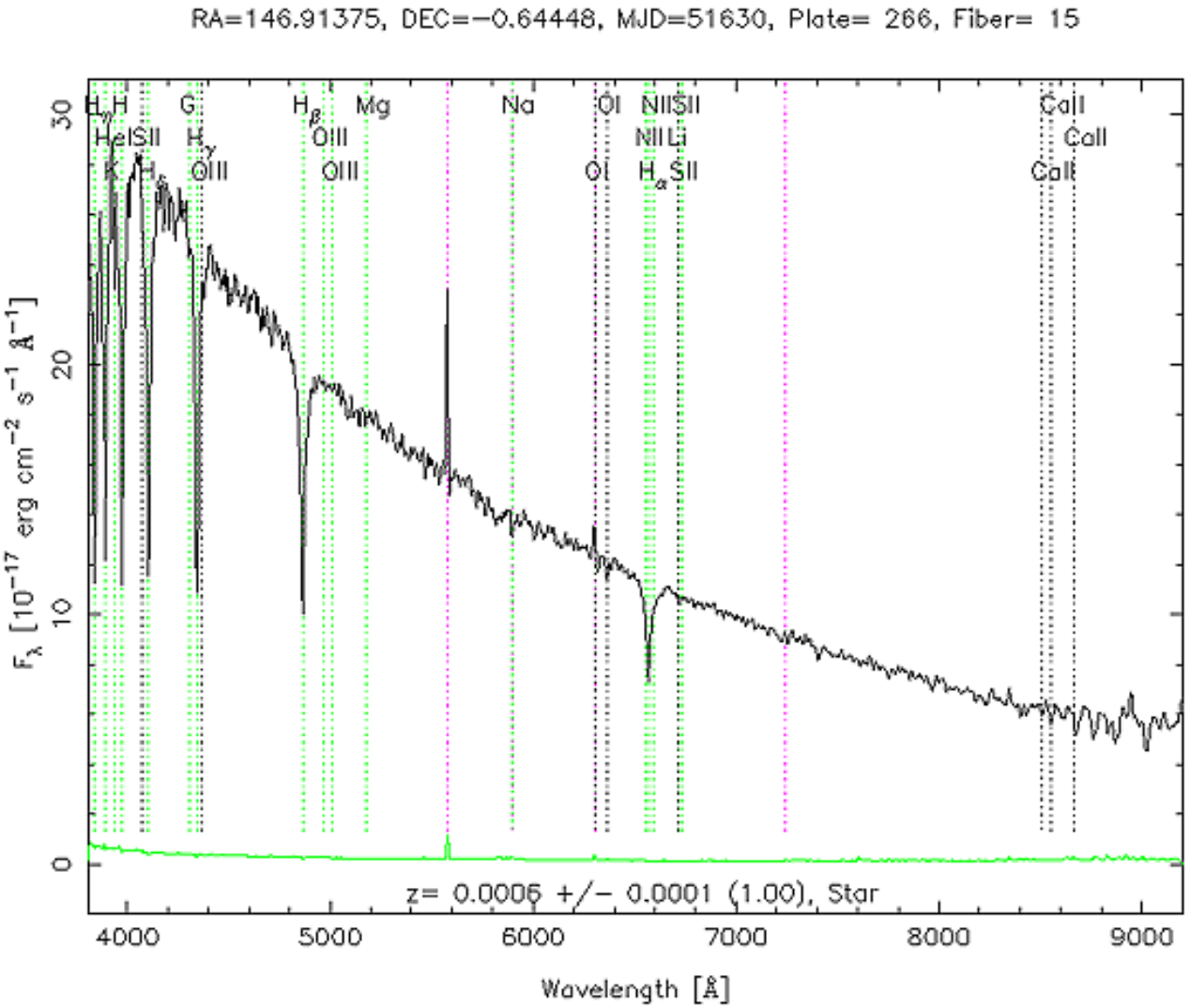
Work together!


G Star
Intensity
140
120
100
80
60
40
20
0
350
450
550
650
750
850
Wavelength

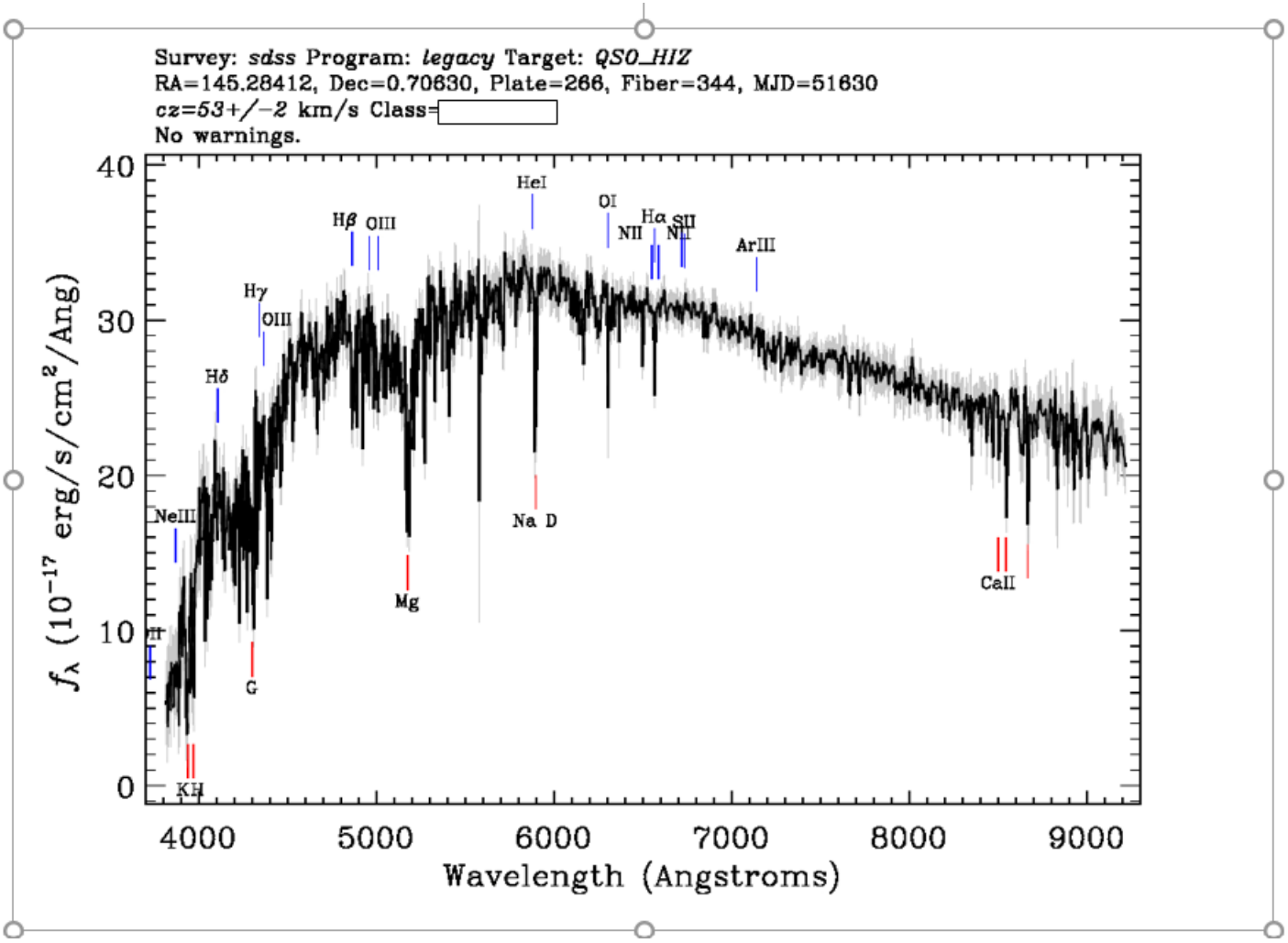

B5 Star
Intensity
400
350
300
250
200
150
100
350
450
550
650
750
850
Wavelength

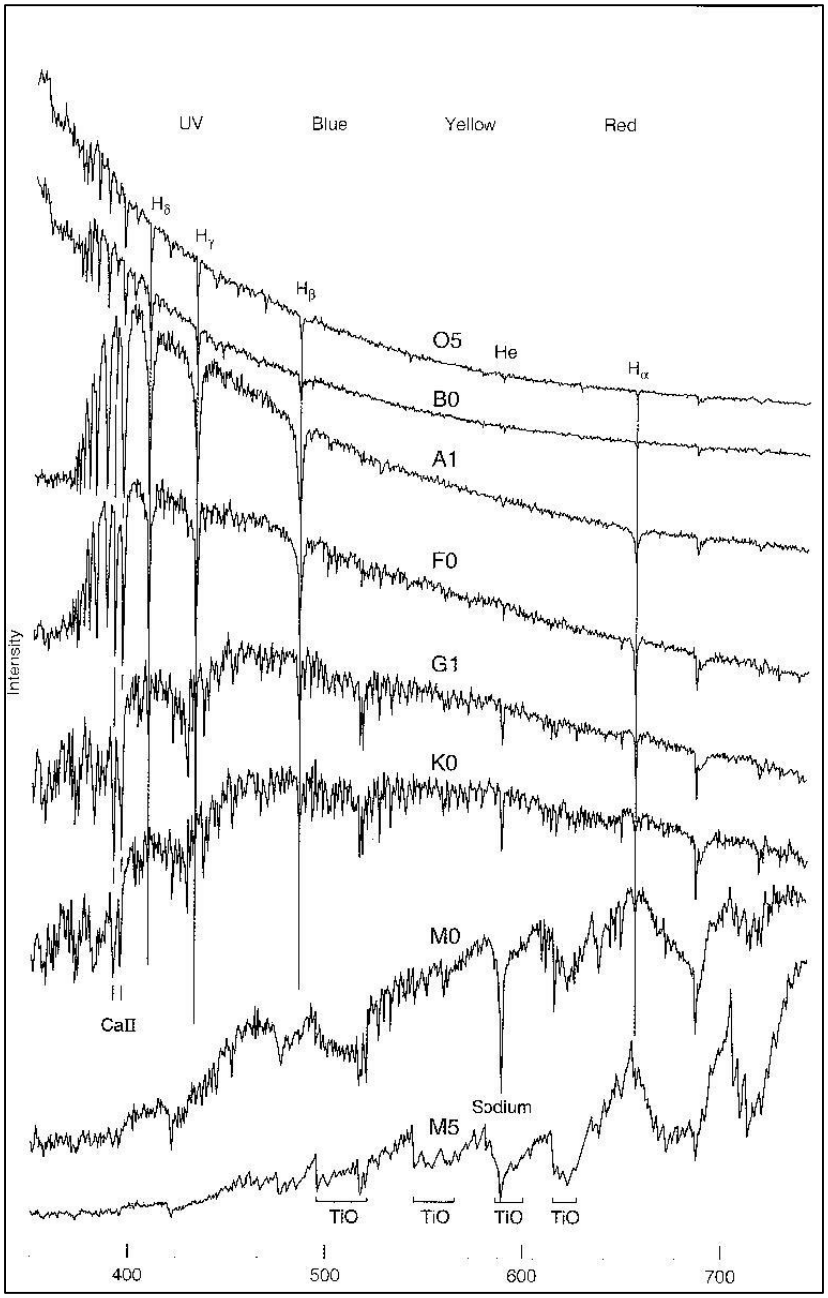

F3 Star
Intensity
160
140
120
100
80
60
40
20
0
350
450
550
650
750
850
Wavelength (nm)

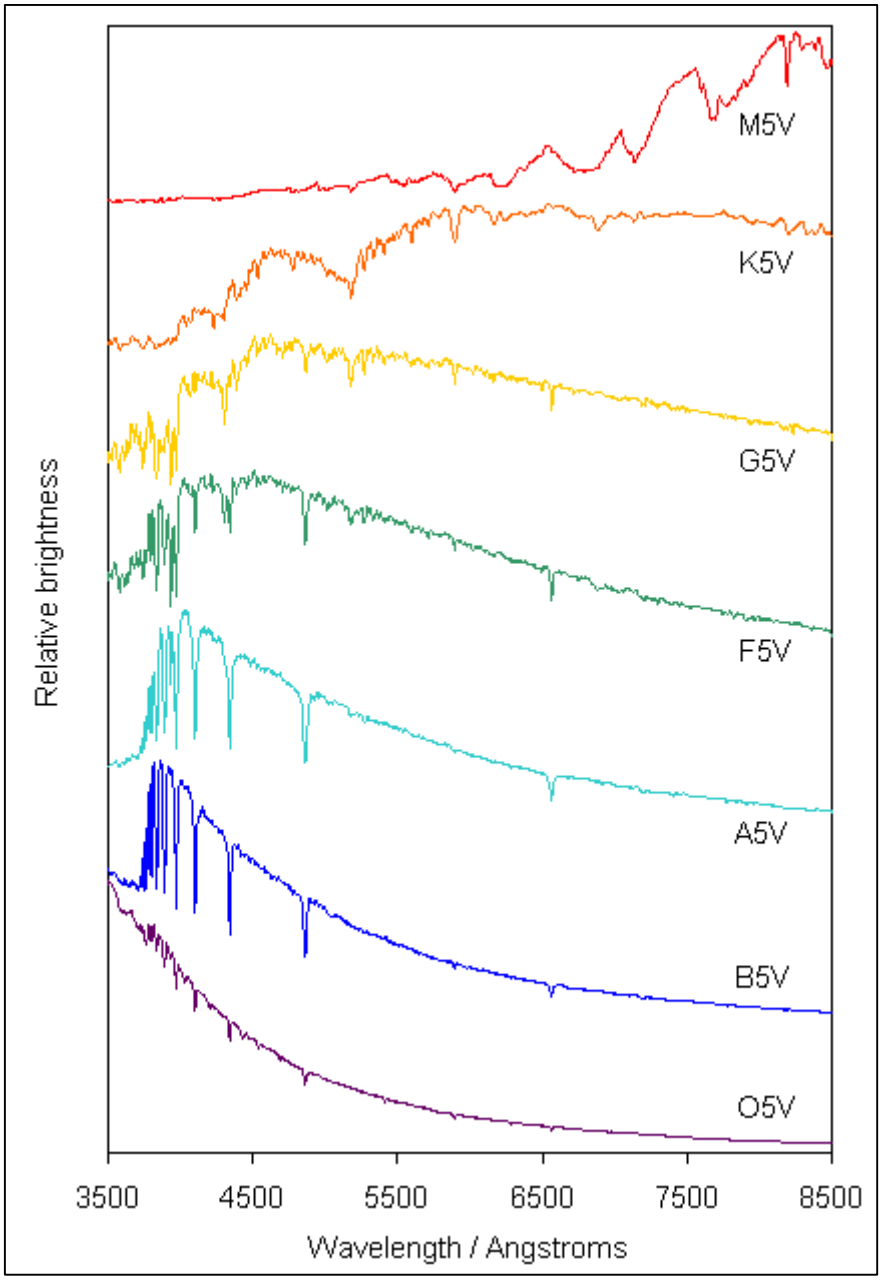
Classify this spectrum from the SDSS



Classify this spectrum from the SDSS

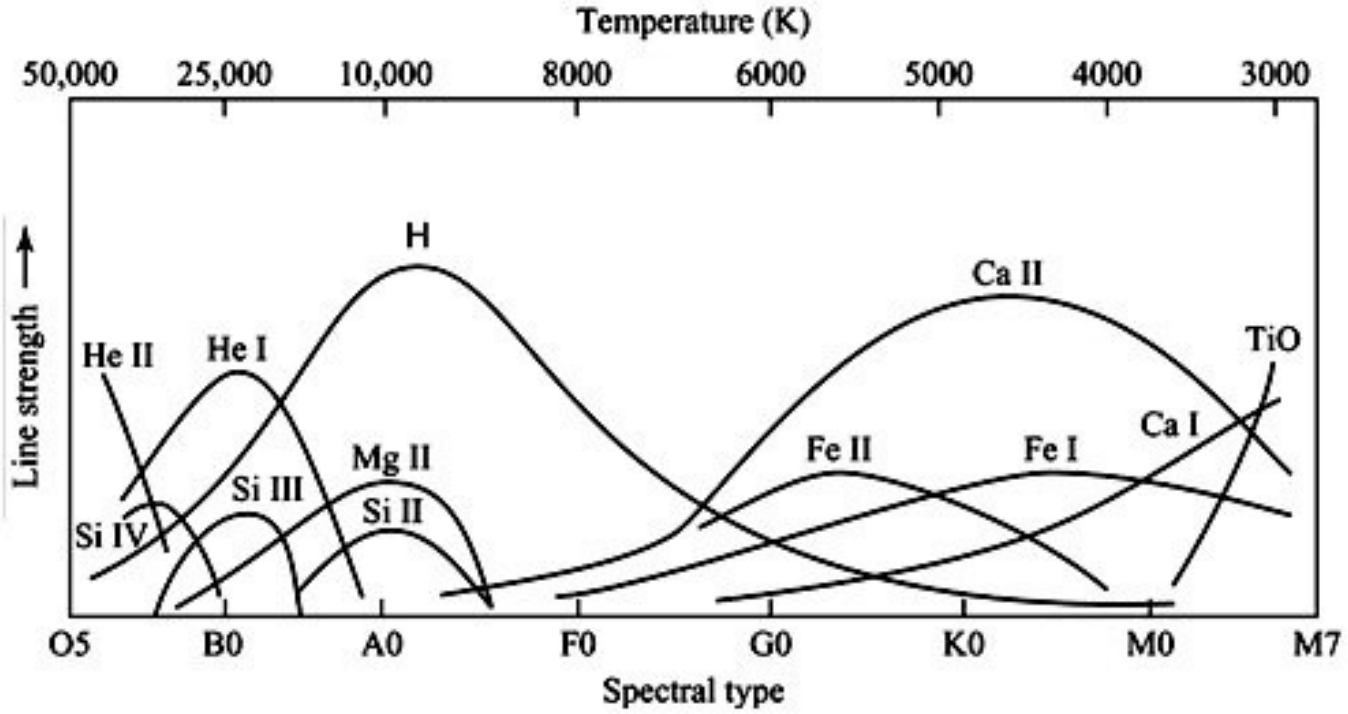



UV
Blue
Yellow
Red
H_δ
H_γ
H_β
H_α
He
O5
B0
A1
F0
G1
K0
M0
M5
CaII
Sodium
TiO
TiO
TiO
TiO
Intensity
400
500
600
700


M5V
K5V
G5V
F5V
A5V
B5V
O5V
Relative brightness
3500
4500
5500
6500
7500
8500
Wavelength / Angstroms

Line Strength

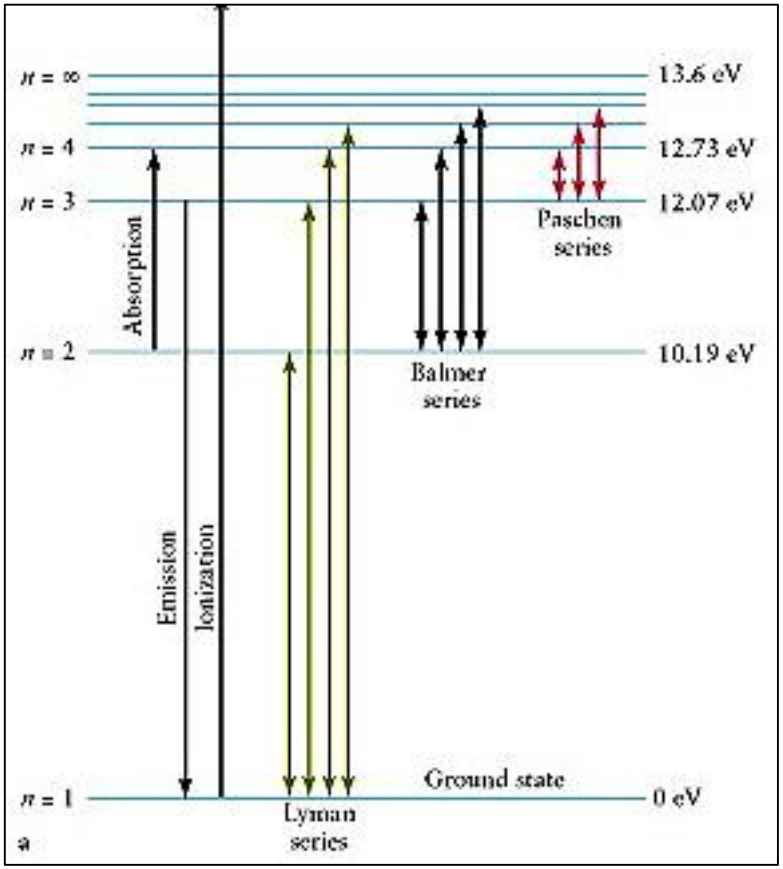
Why is temperature important?

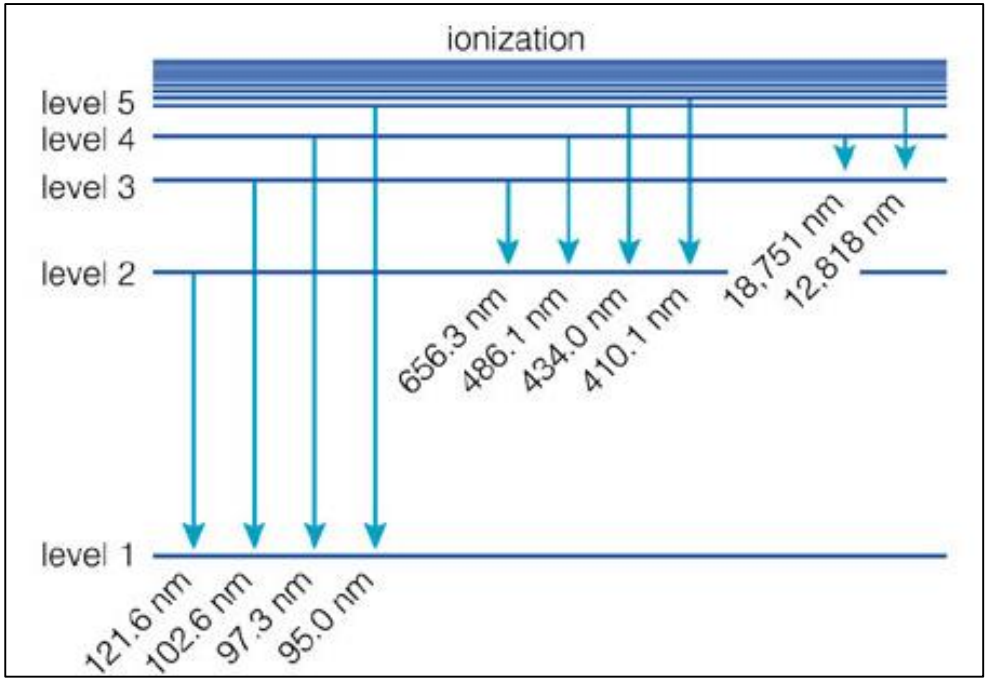


Roman "I": neutral atom

Roman "II": once ionized atom

The Hydrogen Atom
Lyman, Balmer, Paschen, … series





"Lyman limit" = 91.2 nm (912 Å; 13.6 ev)

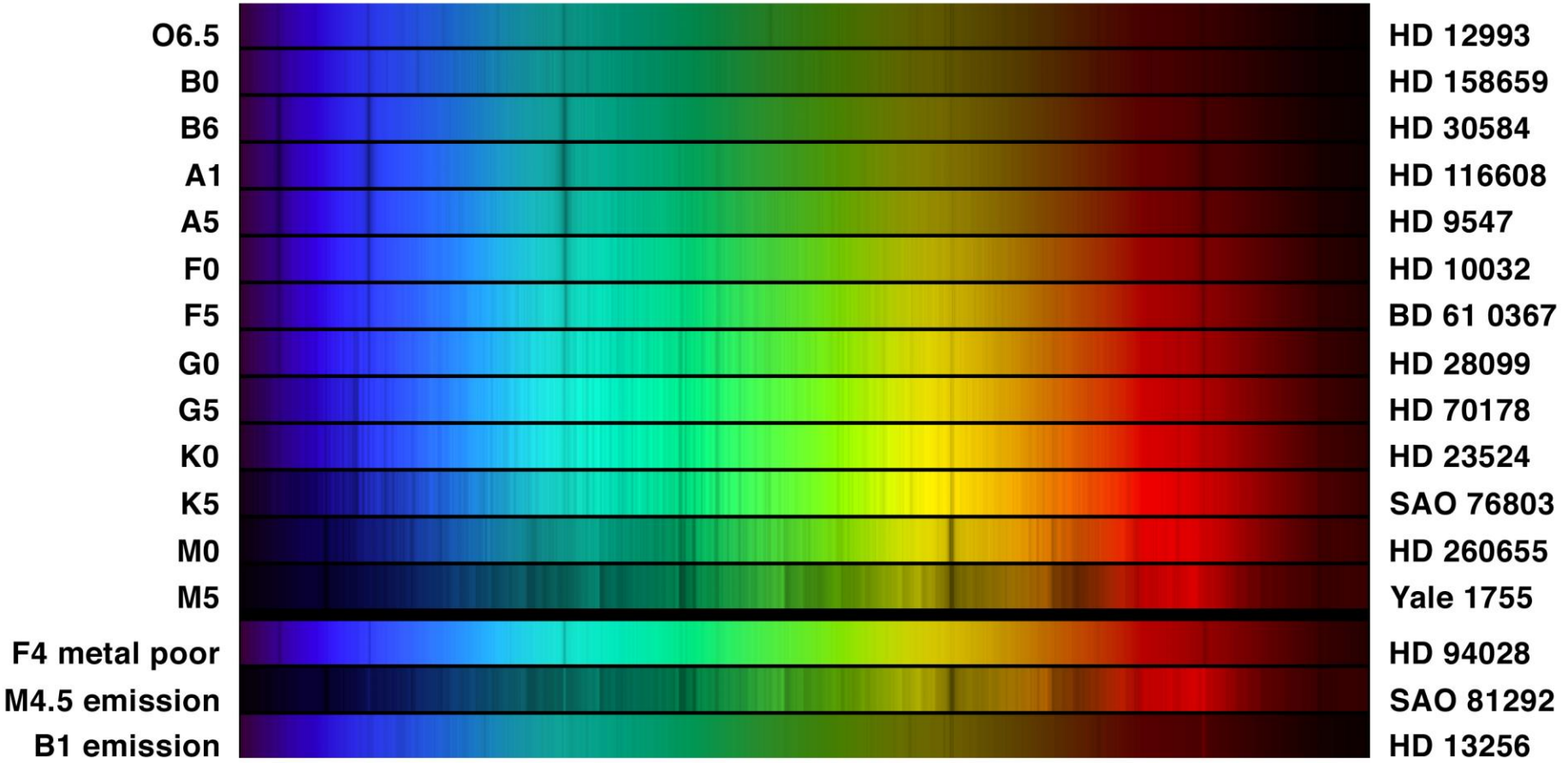
"Balmer limit" = 354 nm

Lyman-alpha (Lα): 121.6 nm (1216 Å)

Balmer-alpha (Hα): 656 nm

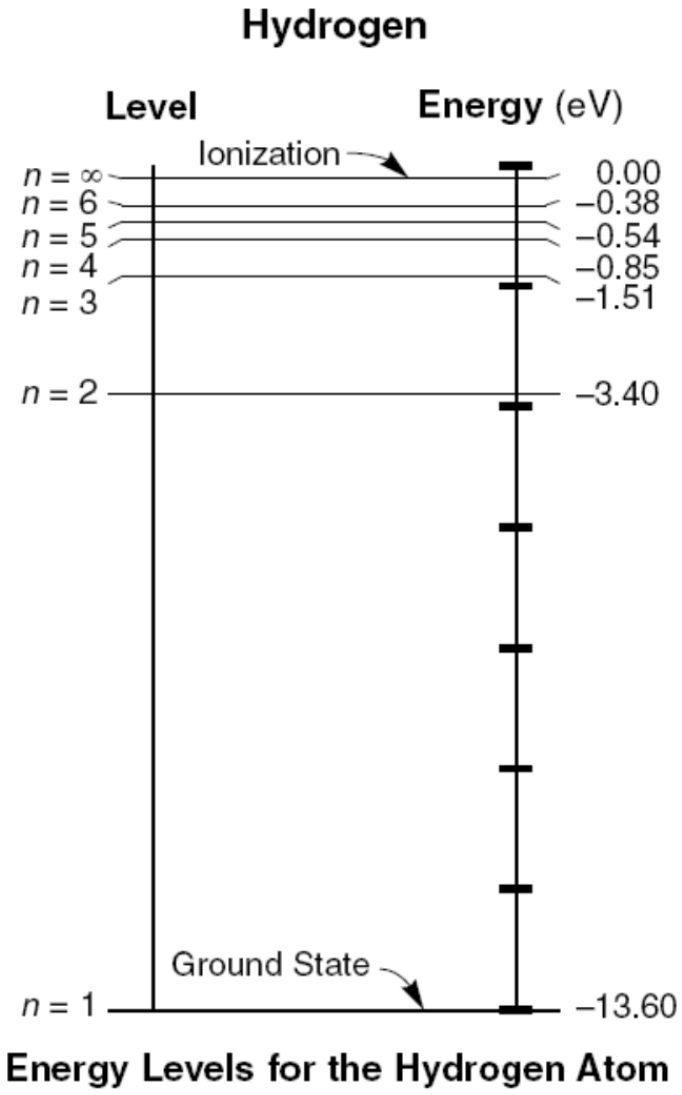
O-stars have weak hydrogen lines

Why?



Hydrogen Atom

calculate ionization (energies, λ) from n=1 and 2

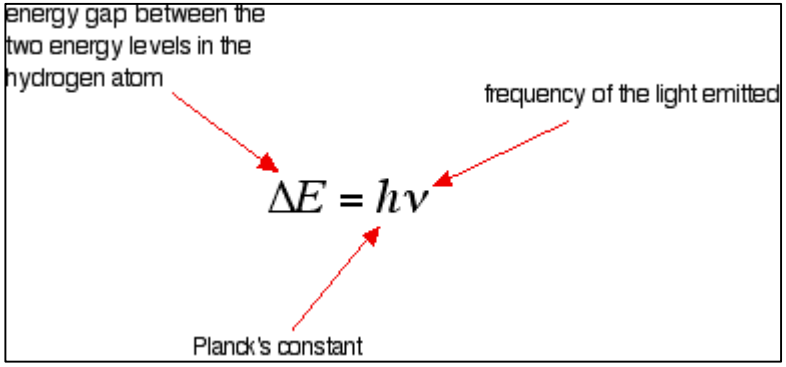


Energy Levels for the Hydrogen Atom

"ionization" energy = ?

"ionization" wavelength = ?

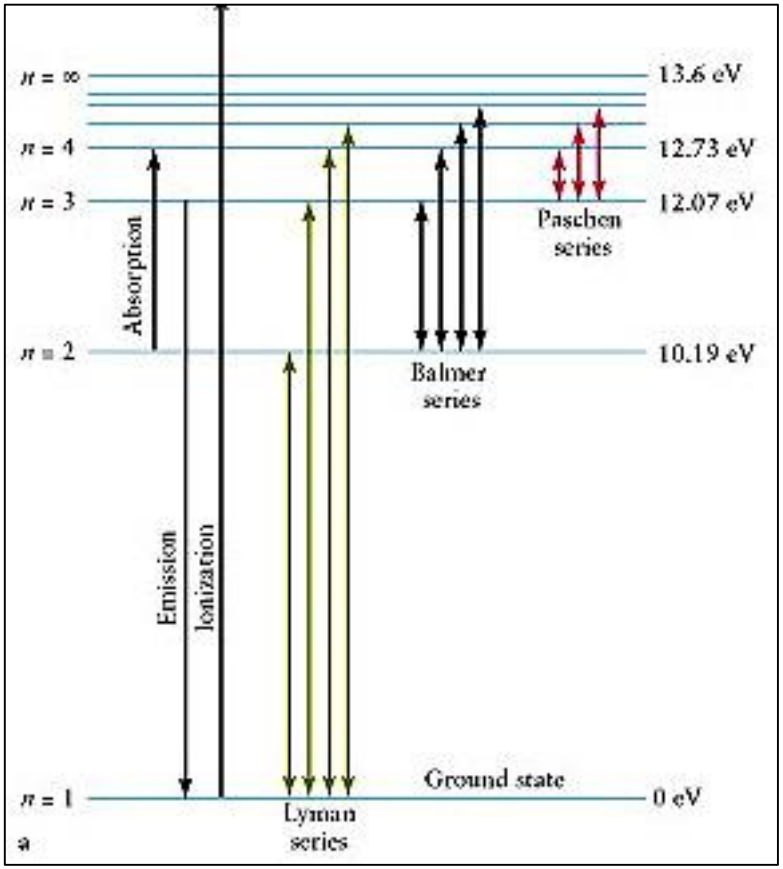
$$E_n = -13.6 \text{ eV} \frac{1}{n^2}$$

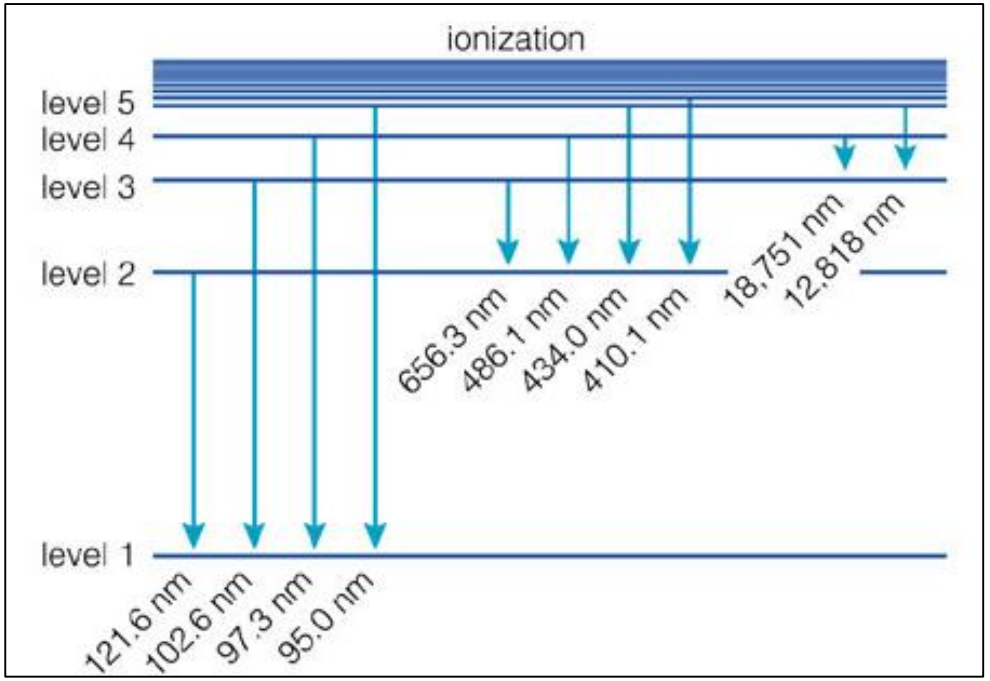


h = 6.626 x 10^{-34} m^2 kg sec^{-1}

1 ev = 1.6 x10^{-19} J

The Hydrogen Atom
Lyman, Balmer, Paschen, … series





"Lyman limit" = 91.2 nm (912 Å; 13.6 ev)

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Lyman-alpha (Lα): 121.6 nm (1216 Å)

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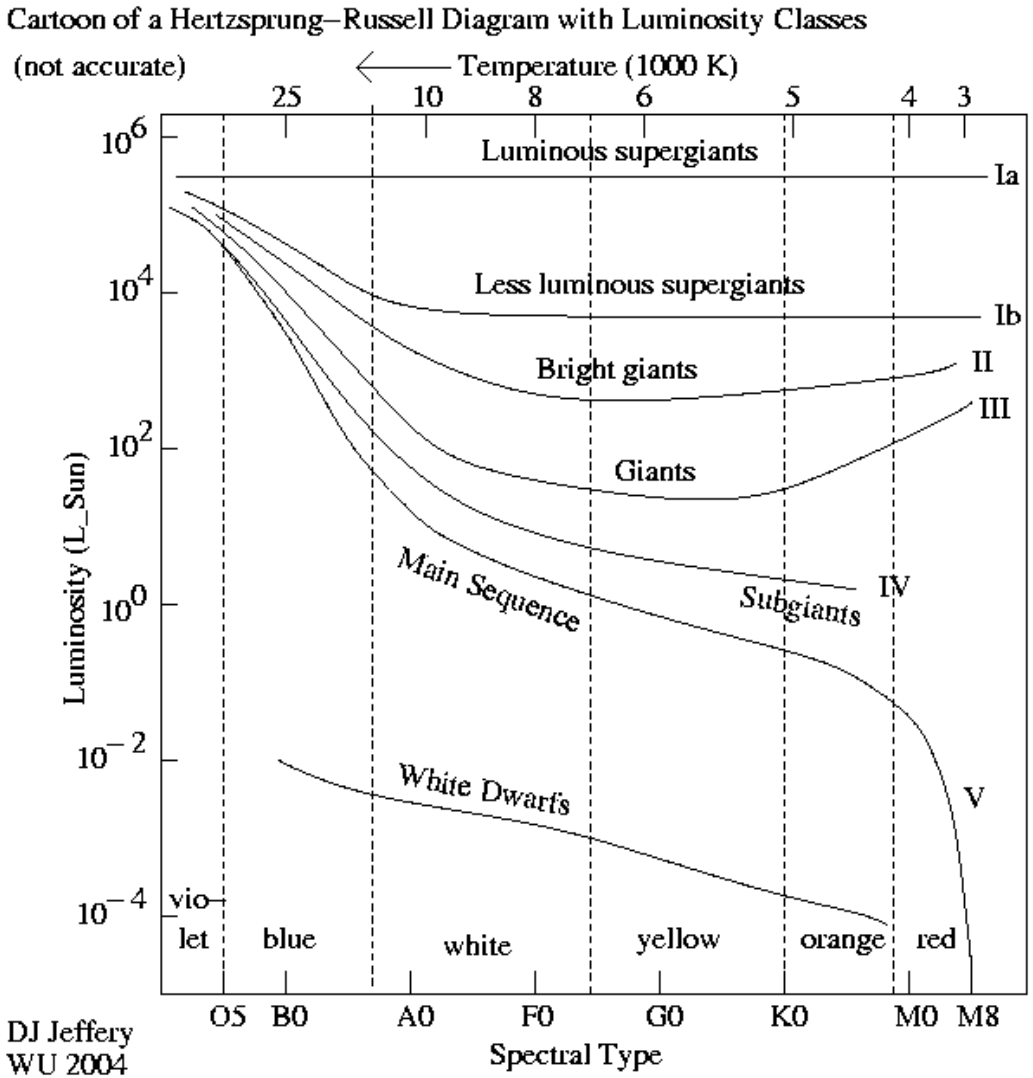
Luminosity Classes

plot these stars on the H-R Diagram

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



Sun: **G2 V**

Betelgeuse: **M2 Ia**

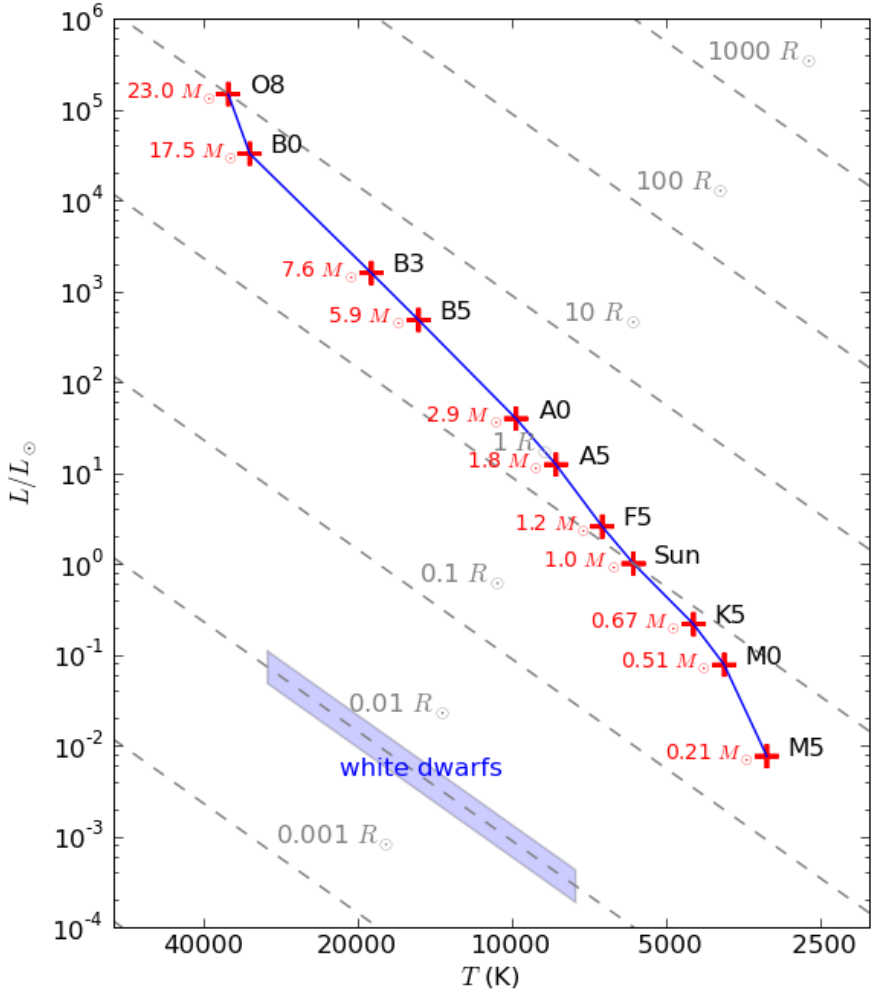
Achernar: **B6 V**

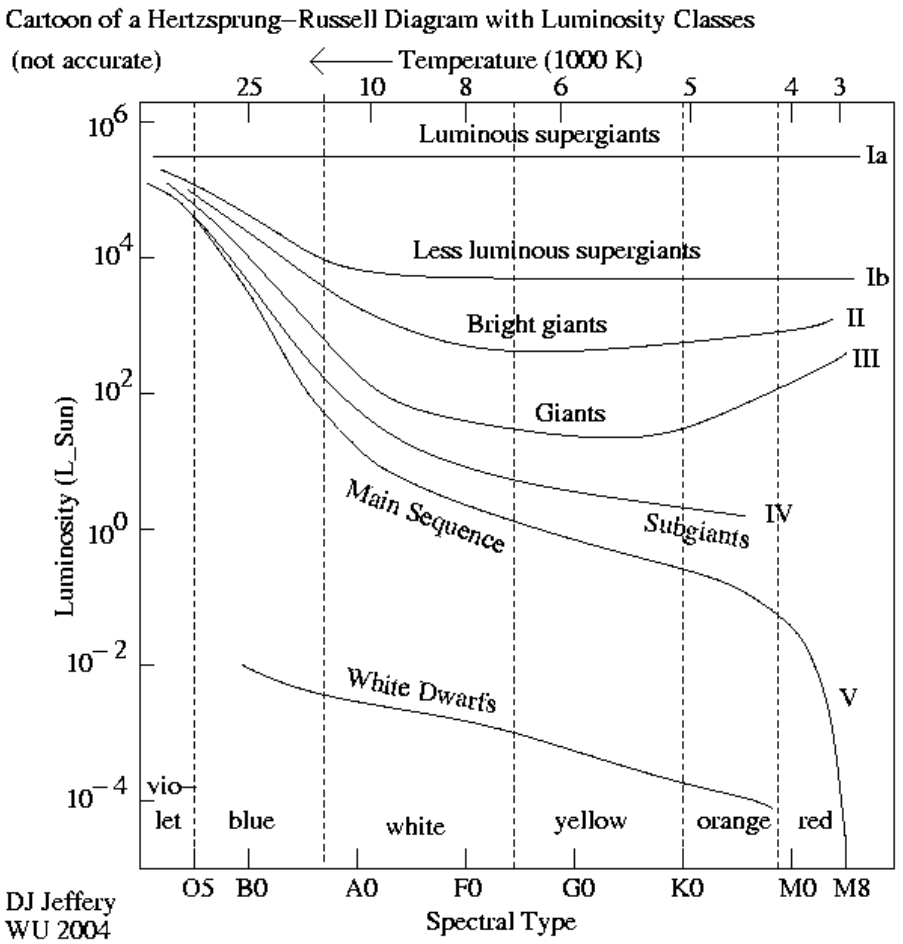
Aldebaran: **K5 III**

Vega: **A0 V**

The Hertzsprung-Russell Diagram

spectral types and luminosity classes





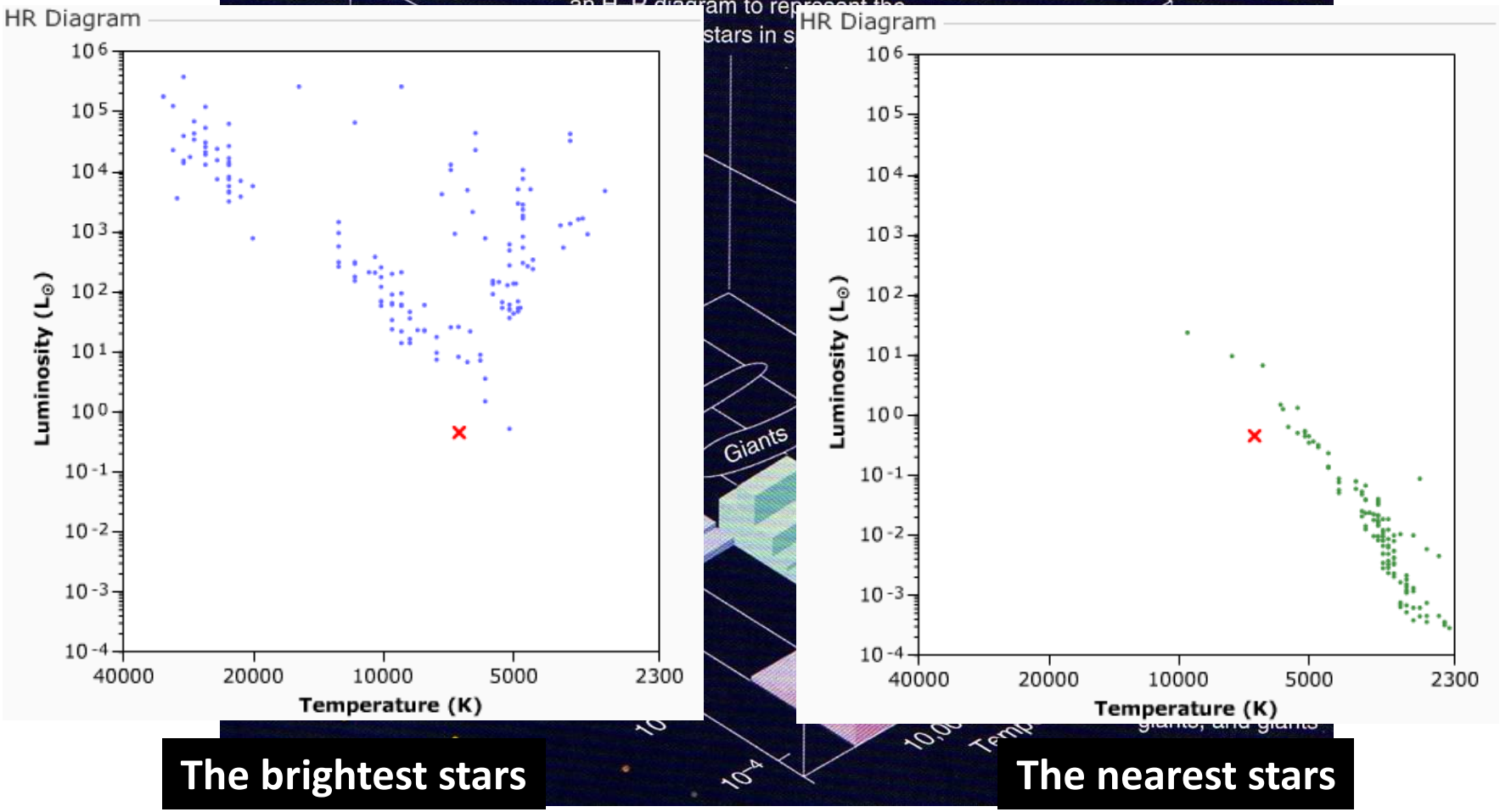
Homework #19

The H-R Diagram is usually plotted in logarithmic coordinates because the luminosity (L) and temperature (T) span such a wide range of values.

Mathematically derive the slope of a line of constant radius in a log L vs. log T version of the H-R Diagram.

Check your answer by measuring the slope of a line of constant radius in the H-R diagram below.

The Grand Illusion

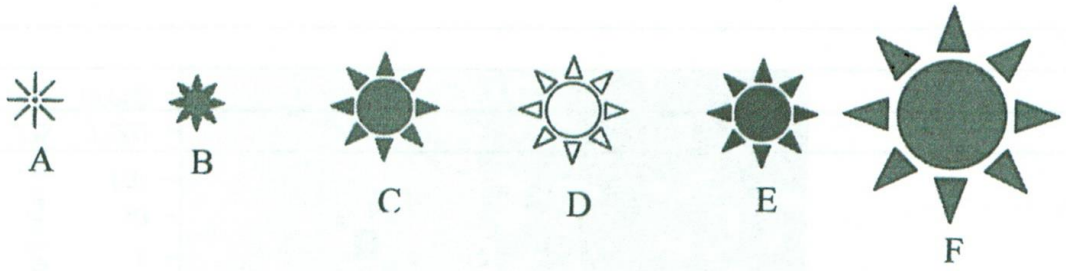


The brightest stars

The nearest stars

Rank the luminosity of the stars (A-F) from greatest to least luminous.

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



Star	A	B	C	D	E	F
Surface Area	1	1	2	2	2	4
Temperature	1000 K	2000 K	2000 K	3000 K	1000 K	2000 K

Which star has the biggest R^2T^4?

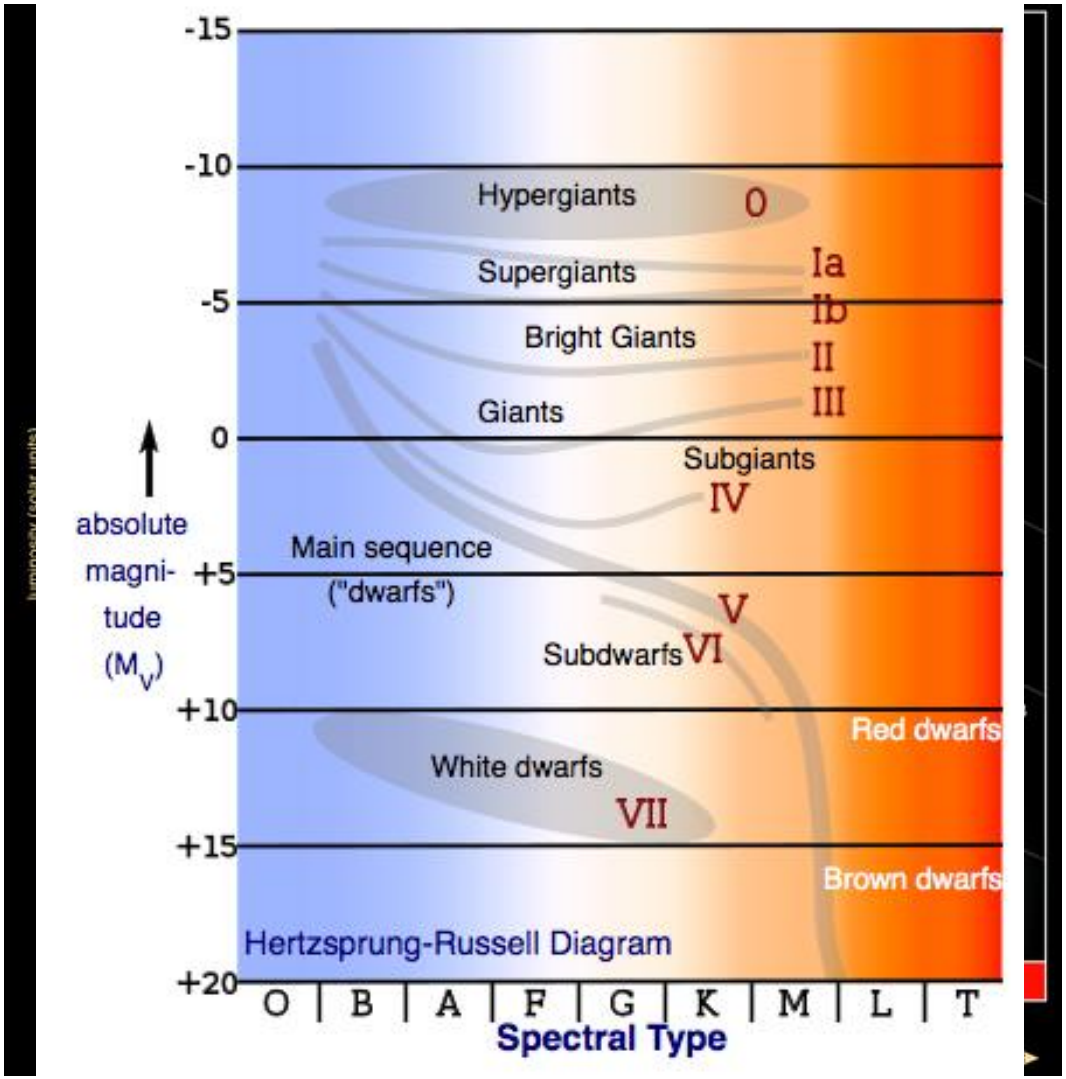
A. D,F,C,E,B,A

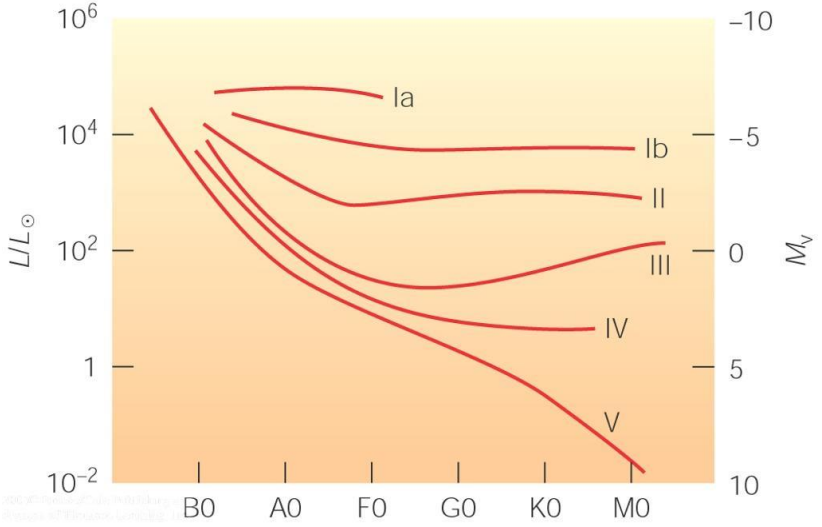
B. D,F,C,B,E,A

C. F,D,B,C,E,A

Work together!

Spectral Type ➡ temperature
Luminosity Type ➡ radius





Sun: G2 V

Betelgeuse: M2 Ia

Achernar: B6 V

Aldebaran: K5 III


Star: Betelgeuse
Spectral Type: M2 I
Parallax: 0.00763"
Distance: 131 pc
Apparent Magnitude: 0.41
Luminosity: 38,000 L☼
Star: Procyon
Spectral Type: F5 IV-V
Parallax: 0.28593"
Distance: 3.50 pc
Apparent Magnitude: 0.37
Luminosity: 7.4 L☼
Star: Sirius
Spectral Type: A1 V
Parallax: 0.37922"
Distance: 2.64 pc
Apparent Magnitude: -1.46
Luminosity: 26 L☼
Star: Rigel
Spectral Type: B8 I
Parallax: 0.00422"
Distance: 237 pc
Apparent Magnitude: 0.14
Luminosity: 70,000 L☼