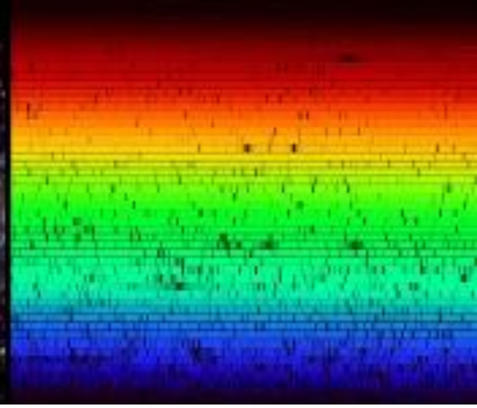
ASTR/PHYS 2500: Foundations Astronomy



Week 8: Stars Some More

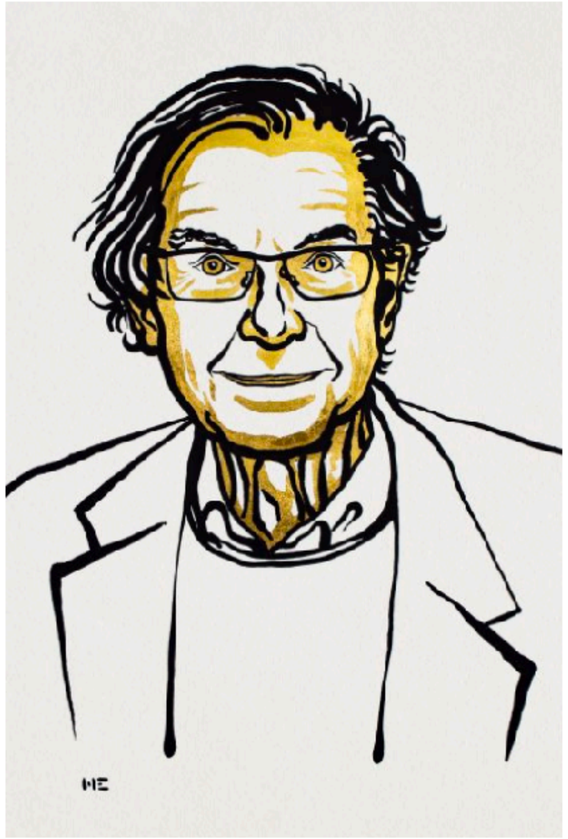
HW6 available, due Monday at 10:45am

Time to start thinking about your Communicating Science Projects!
http://www.astro.utah.edu/~wik/courses/astr2500fall2020/projects.html

Midterms not yet graded - hopefully later this week, but can't promise

2020 Physics Nobel Prize!

Proving that if GR is the correct theory of gravity, BHs are real



© Nobel Media. Ill. Niklas Elmehed.

Roger Penrose

Prize share: 1/2

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Reinhard Genzel

Prize share: 1/4

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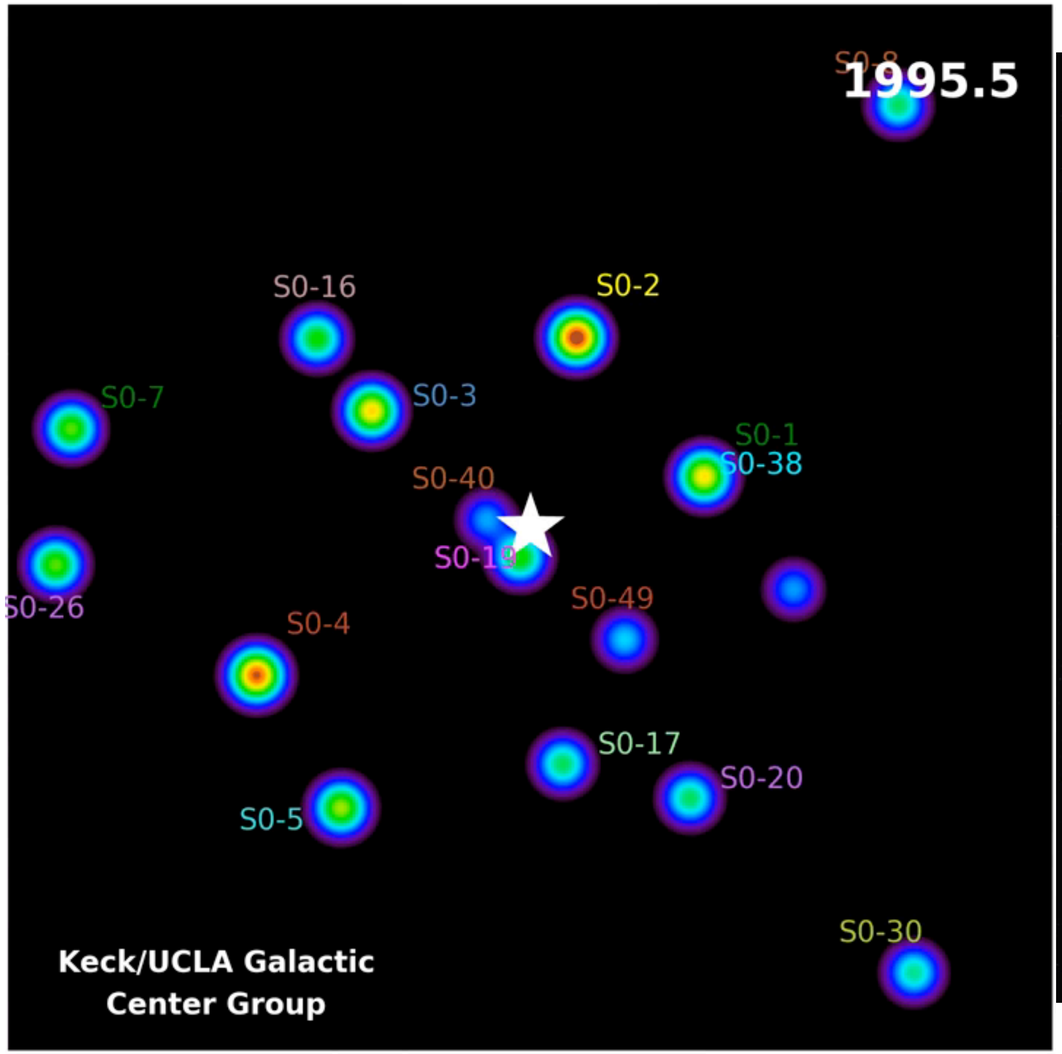
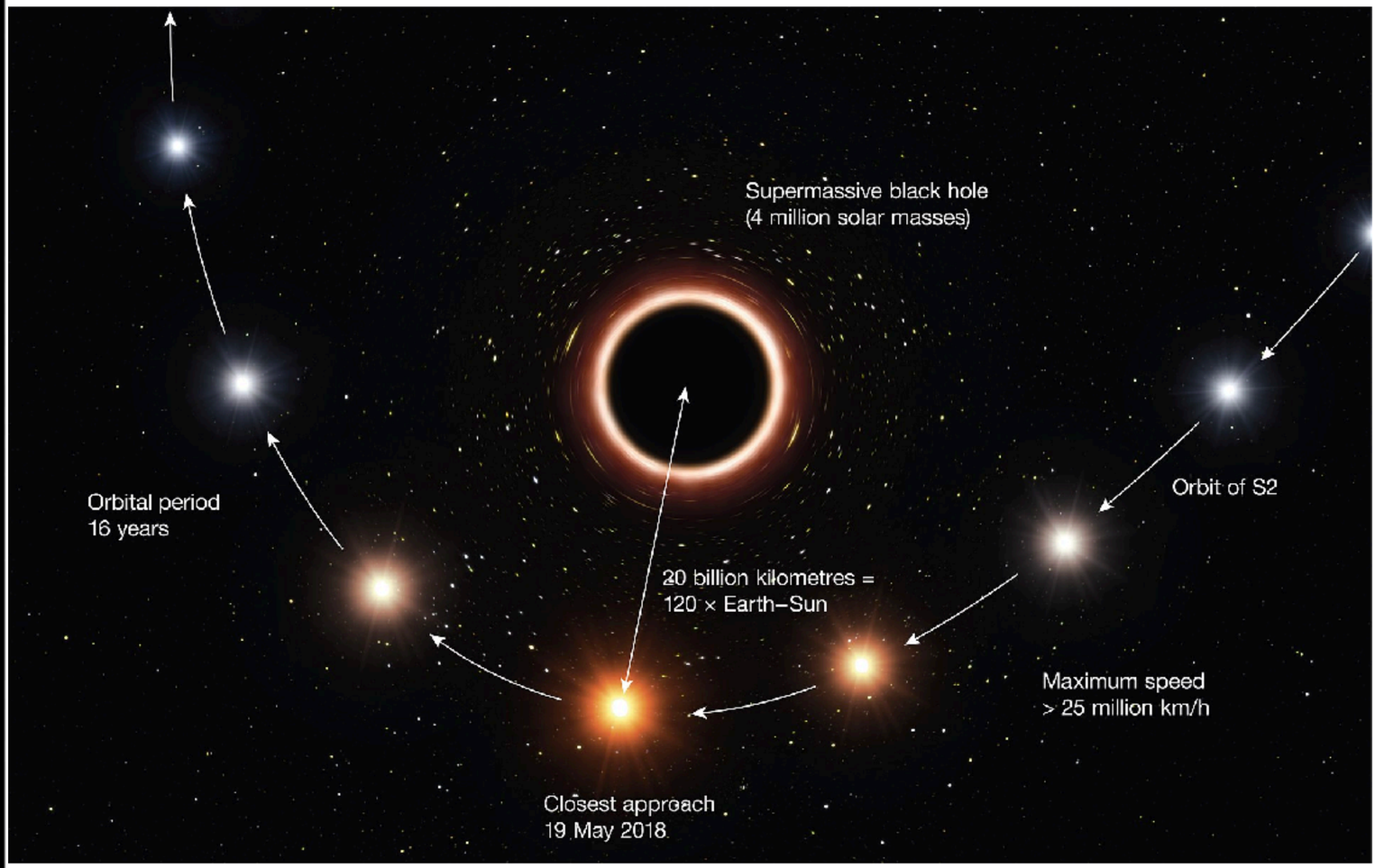
Andrea Ghez

Prize share: 1/4

Providing the best observational evidence for the existence of a BH - namely Sgr A*, the 4×10^6 M_{sun} BH in the center of the Milky Way

Stars orbiting Sgr A*!





Classifying Stars

Stars have a mass, temperature or color, radius, and luminosity.
Can they have any combination of these properties?

Nope!

$$T_{\rm eff} = \left(\frac{L}{4\pi R^2 \sigma_{\rm SB}} \right)^{1/4}$$

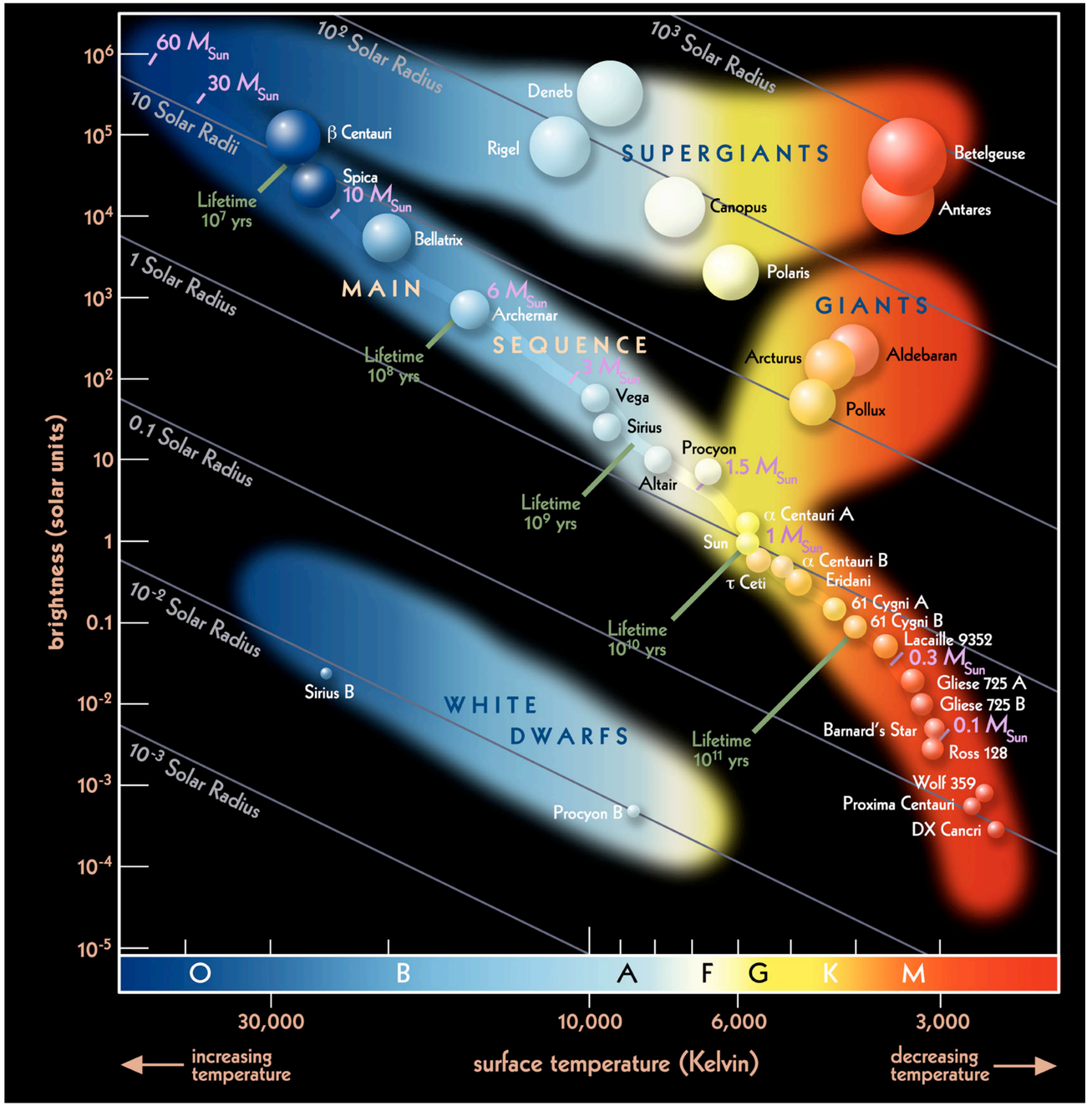
$$R/R_\odot = 1.06(M/M_\odot)^{0.945},\ M < 1.66 M_\odot$$
$$R/R_\odot = 1.33(M/M_\odot)^{0.555},\ M > 1.66 M_\odot$$

$$T \approx \frac{9000\ {\rm K}}{(B-V)+0.93}$$

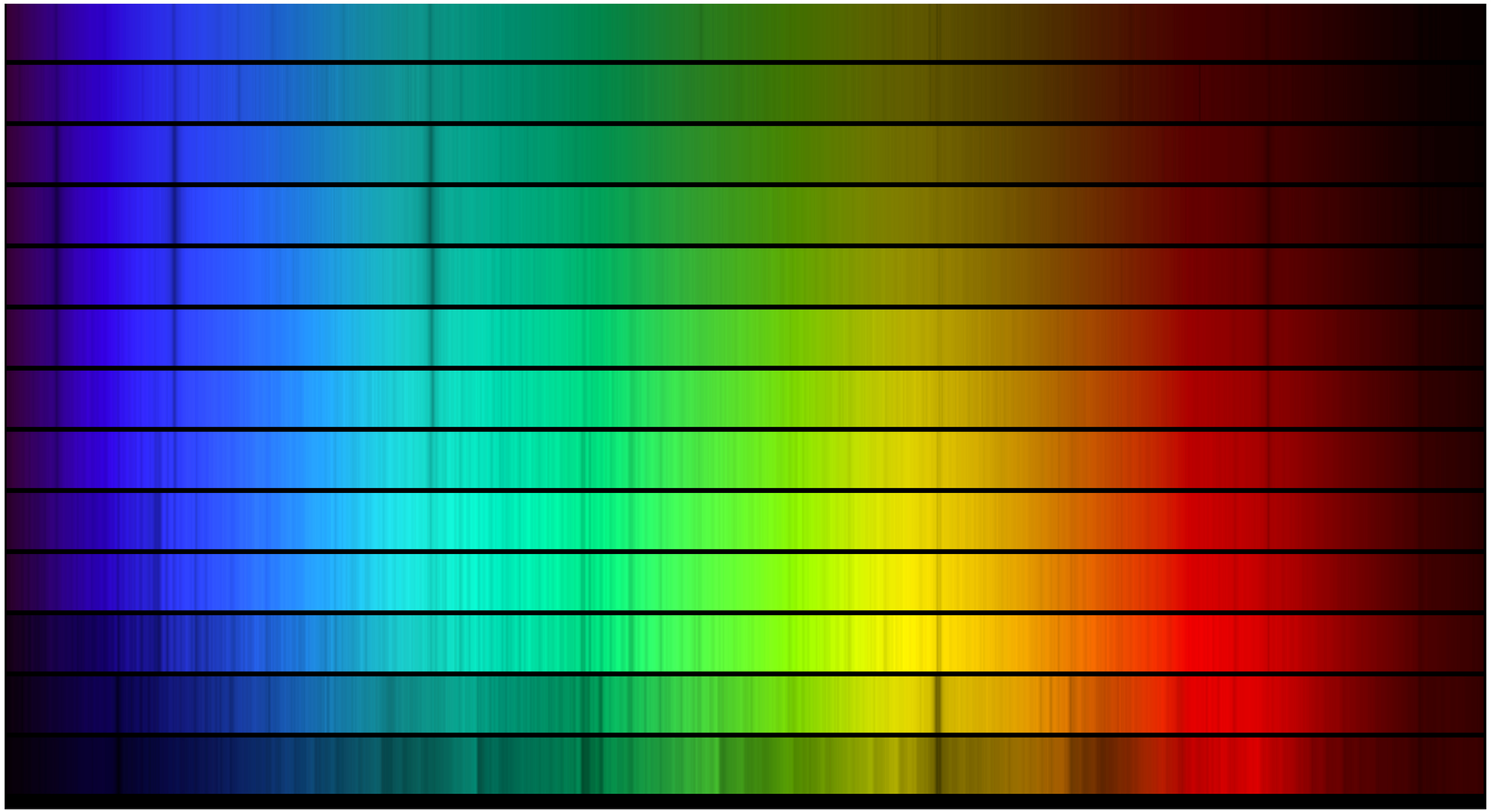
$$L/L_\odot = 0.35(M/M_\odot)^{2.62},\ M < 0.7 M_\odot$$
$$L/L_\odot = 1.02(M/M_\odot)^{3.92},\ M > 0.7 M_\odot$$

Luminosity vs Temperature

$$T_{\rm eff} = \left(\frac{L}{4\pi R^2 \sigma_{\rm SB}} \right)^{1/4}$$



But early on, no distances and no temperatures



Just spectral lines! And no quantum mechanics!!!

Harvard College Observatory

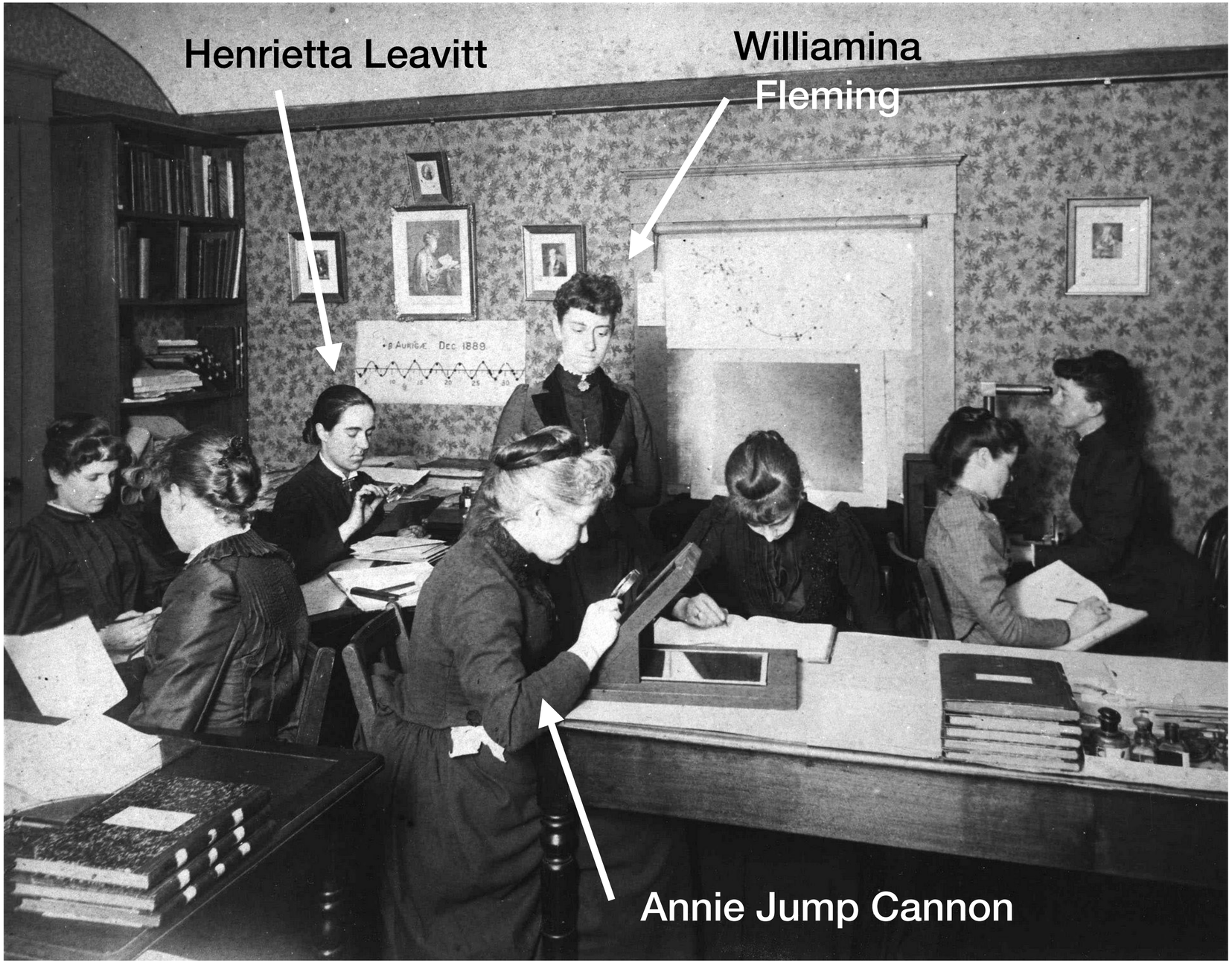
~1890

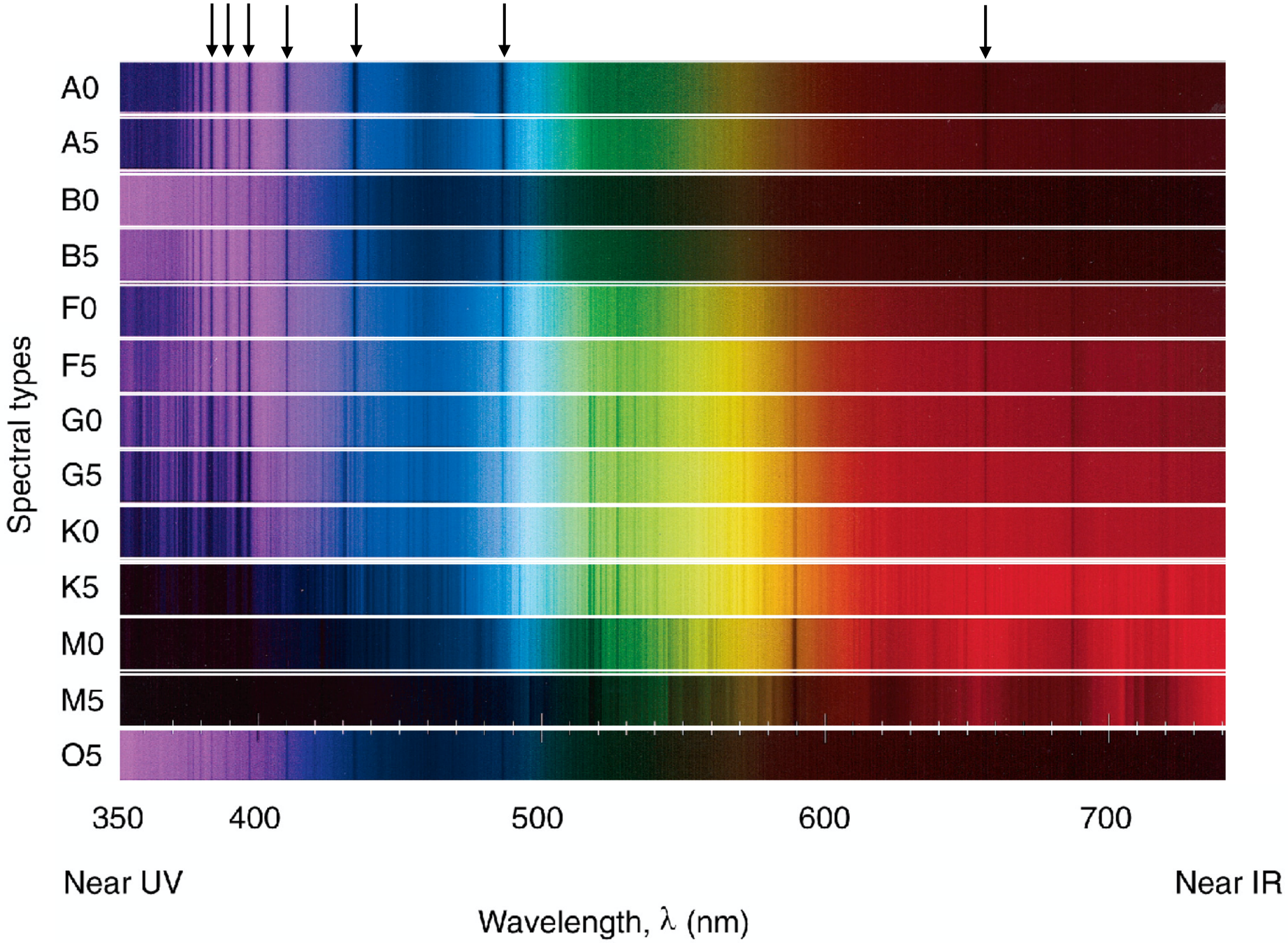
👎 “Pickering’s Harem” 👎

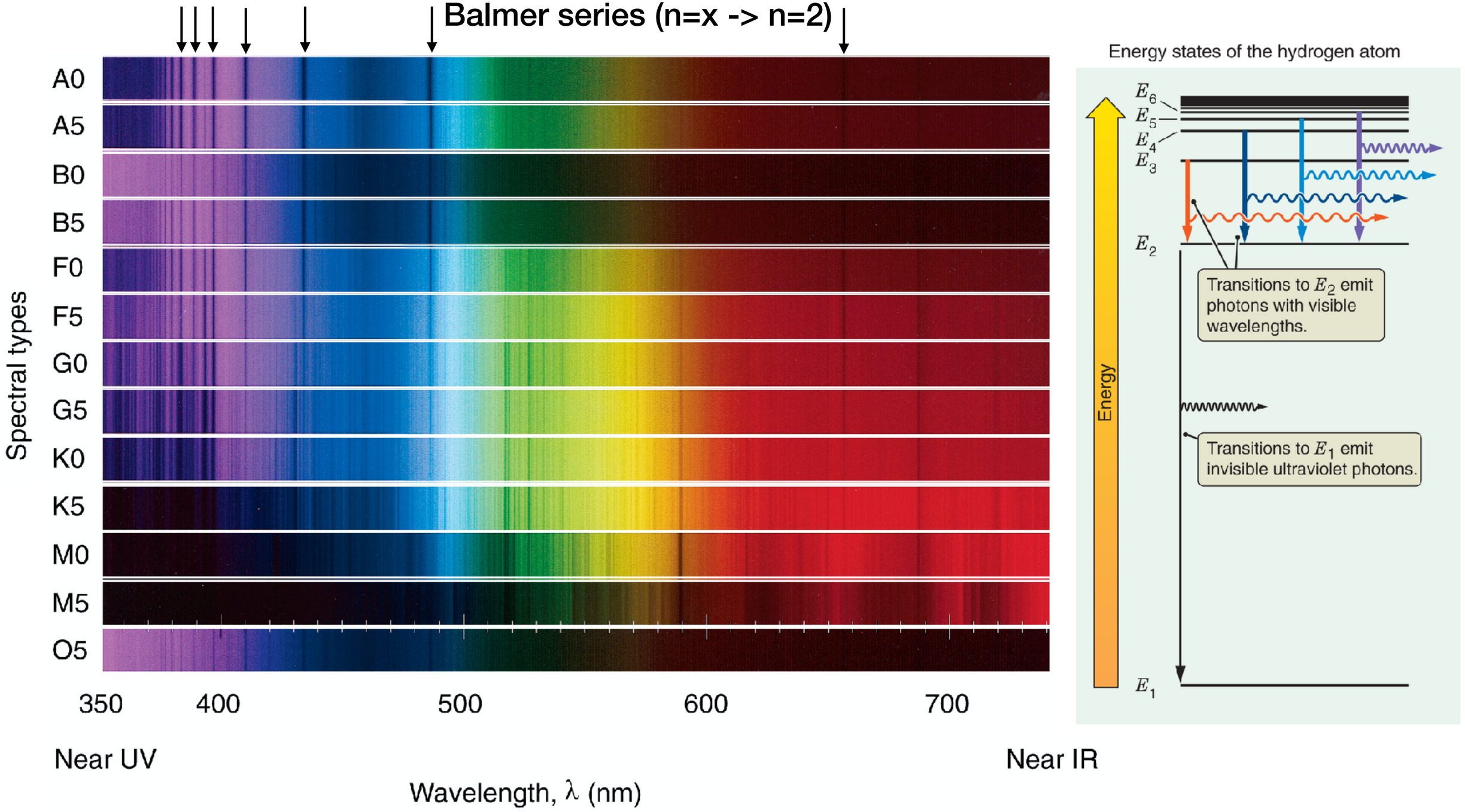
Prof Pickering did not really consider astronomy science, but the widow of Henry Draper (of the HD star catalog) donated a bunch of money.

His housekeeper, Williamina Fleming, was more competent (and cheaper) than his male assistant, so she ran the show

These female “computers” founded modern astronomy

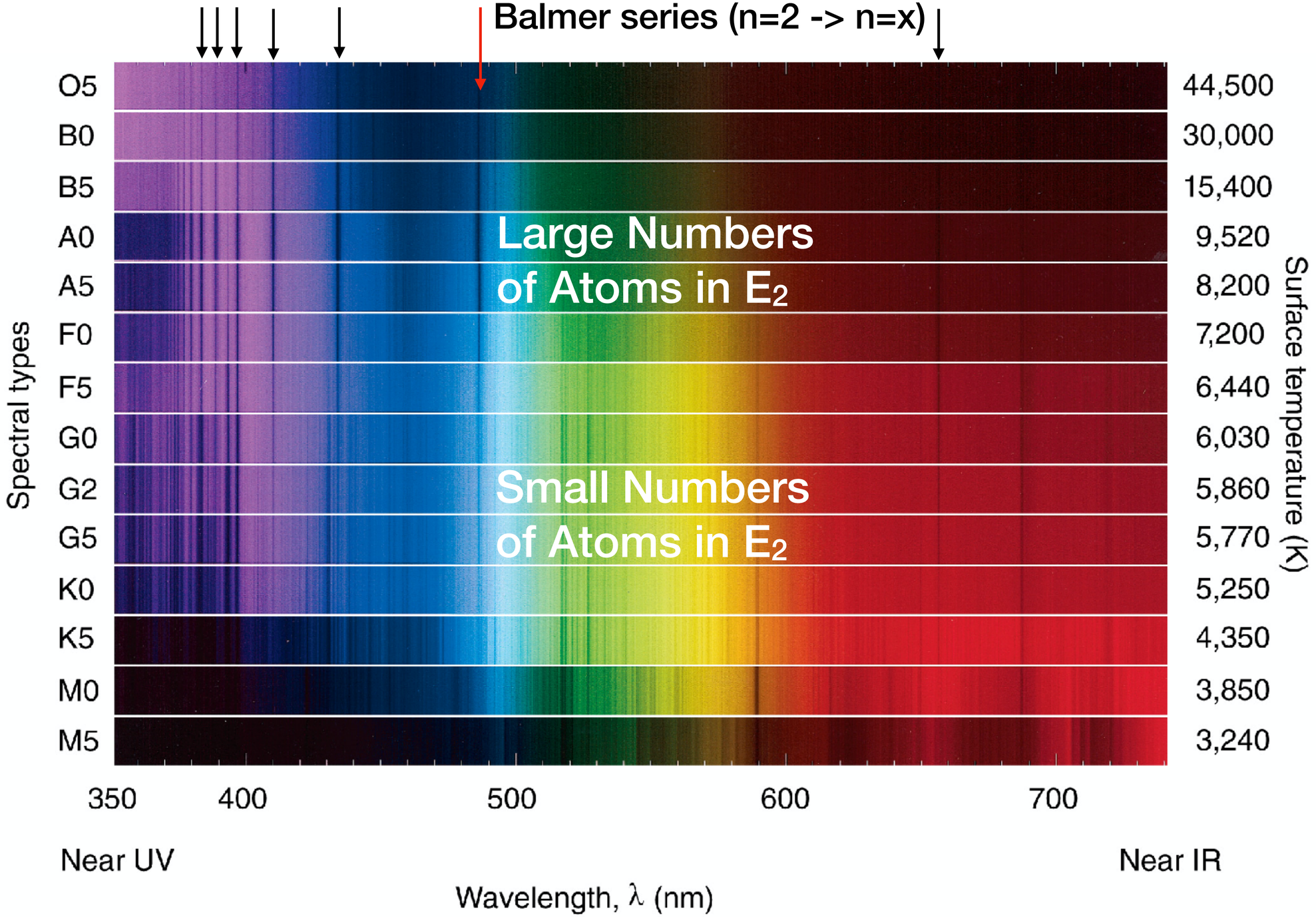



A0
A5
B0
B5
F0
F5
G0
G5
K0
K5
M0
M5
O5
Spectral types
350
400
500
600
700
Near UV
Near IR
Wavelength, λ (nm)


Balmer series (n=x -> n=2)
A0
A5
B0
B5
F0
F5
G0
G5
K0
K5
M0
M5
O5
Spectral types
350
400
500
600
700
Near UV
Near IR
Wavelength, λ (nm)
Energy states of the hydrogen atom
E_6
E_5
E_4
E_3
E_2
E_1
Energy
Transitions to E_2 emit photons with visible wavelengths.
Transitions to E_1 emit invisible ultraviolet photons.

Annie Jump Cannon Classifies the Stars

- one of “Pickering’s Harem,” a Harvard “Calculator”
- part of the effort to catalog every star in the sky down to 9th magnitude
- defined the classification scheme for stellar spectra
- manually classified over 350,000 stars
- realized stellar types correlated with temperature (but not in the original order)



More Violet Light

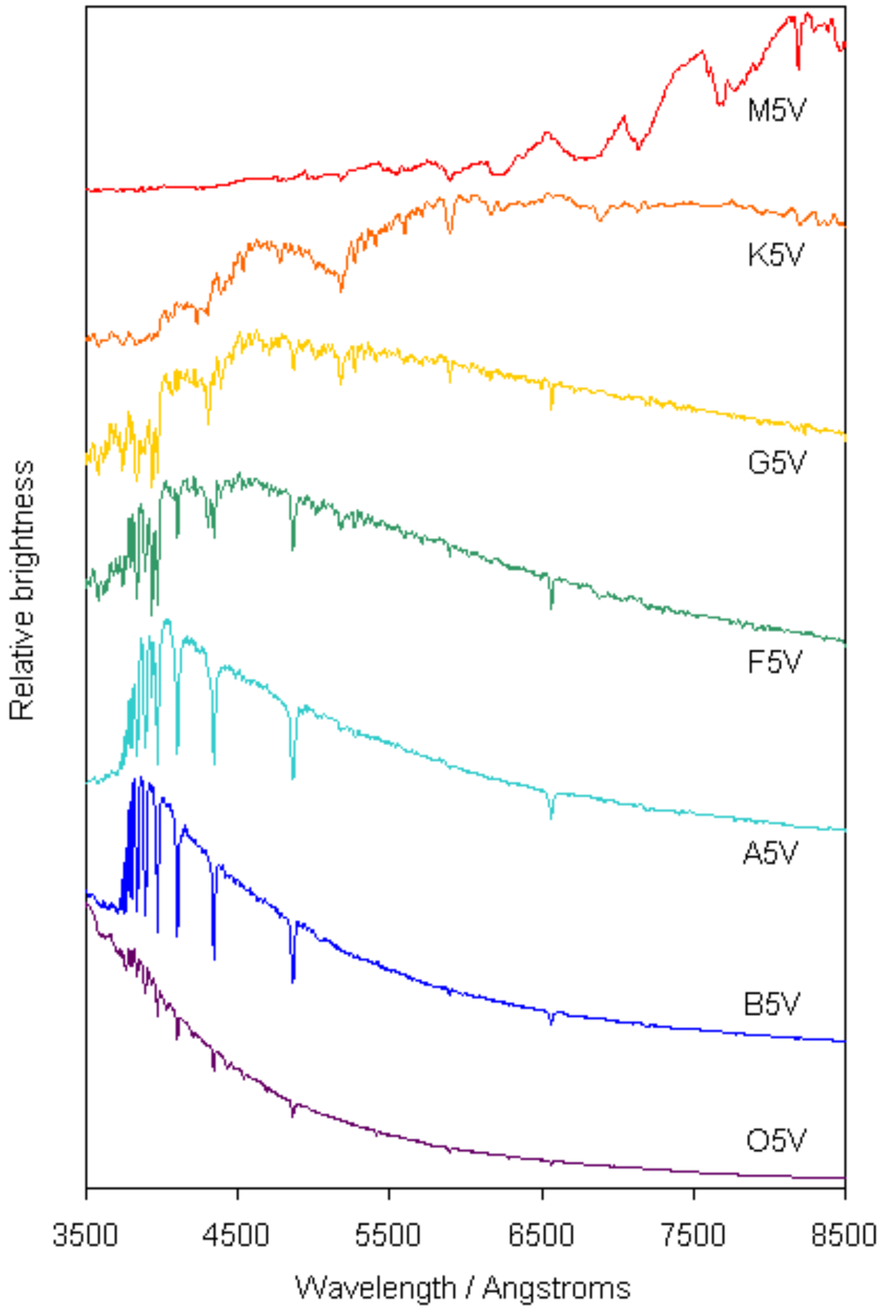
$$\langle v \rangle = \sqrt{\frac{8kT}{\pi m}}$$

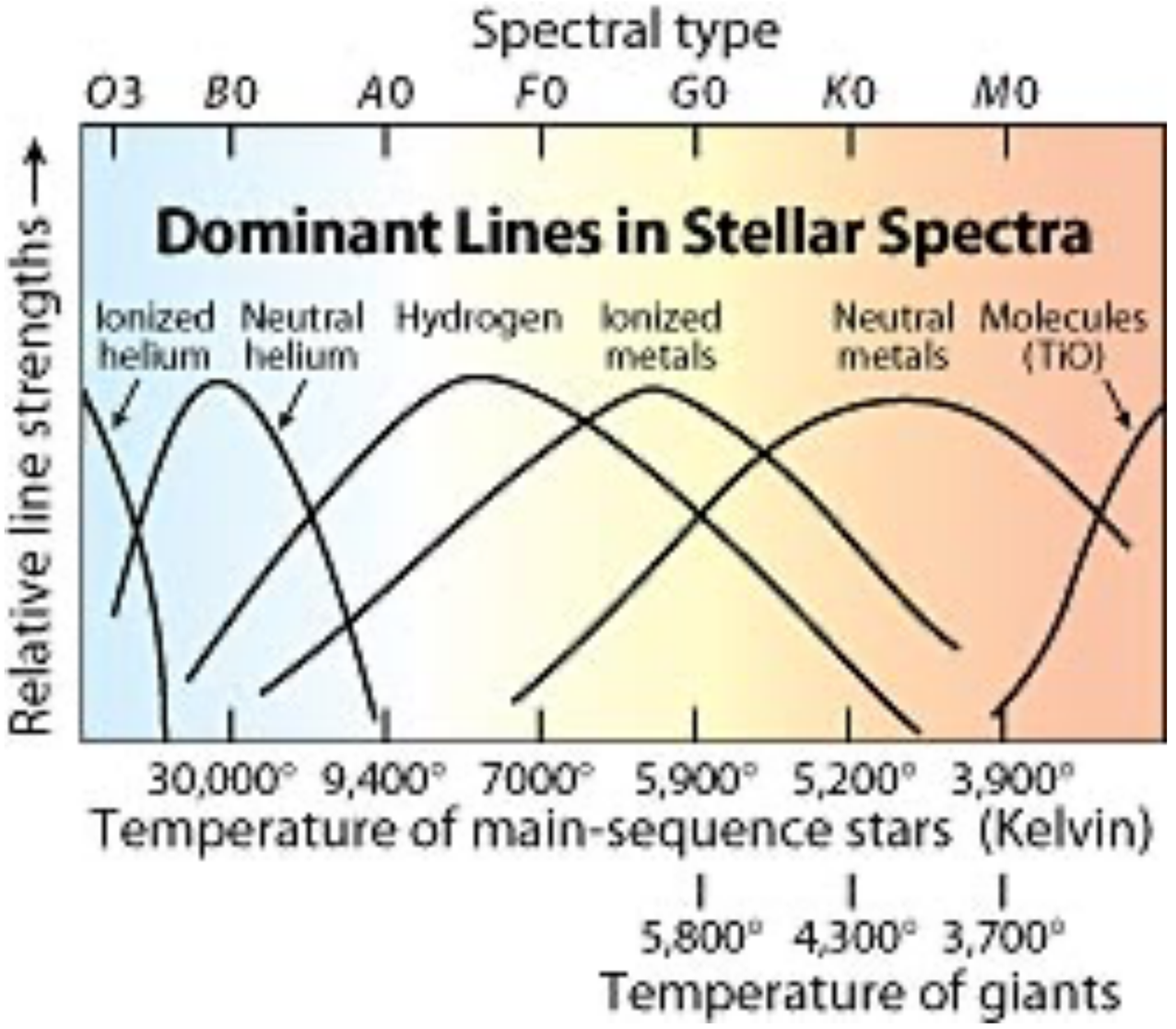
$$\langle E \rangle = \frac{3}{2} kT$$

More Red Light

<u>Brown Dwarfs</u>
L (2000 K)
T (<1300 K)

Line Strengths depend on Type





Spectral Classification

Temperature Sequence (color)

OBAFGKM
"Oh, Be A Fine Girl/Guy, Kiss Me!"
"Only Boys Accepting Feminism Get Kissed Meaningfully"
"Only Boring Astronomers Find Gratification Knowing Mnemonics!"
http://www.star.ucl.ac.uk/~pac/obafgkmrns.html

Luminosity Classes

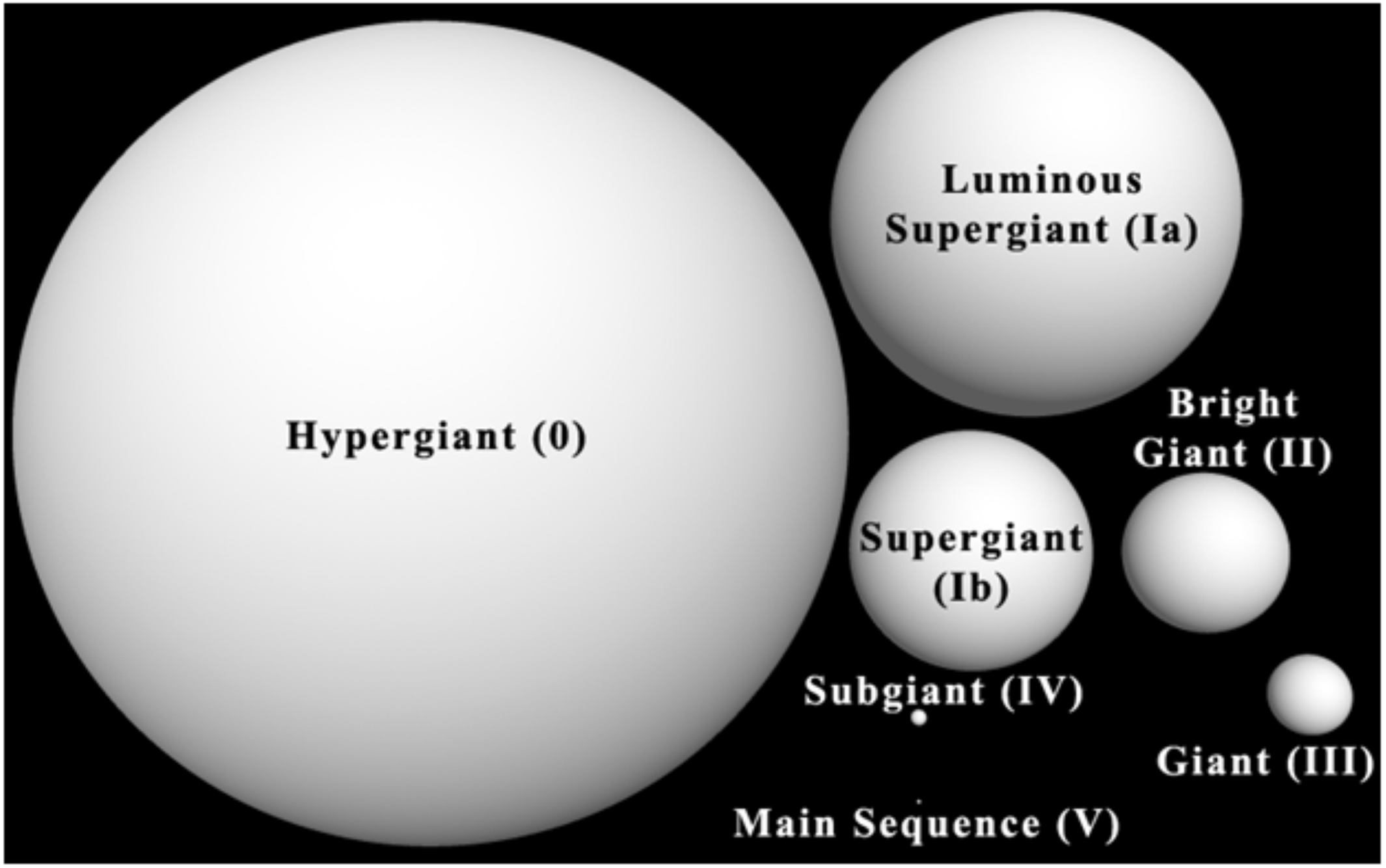
Luminosity Type corresponds to Star's Size

$$L \propto R^2 T^4$$

???

I	Supergiant
II	Bright giant
III	Giant
IV	Sub giant
V	Dwarf (main sequence)
VI	Subdwarf

Our Sun is class G2 V

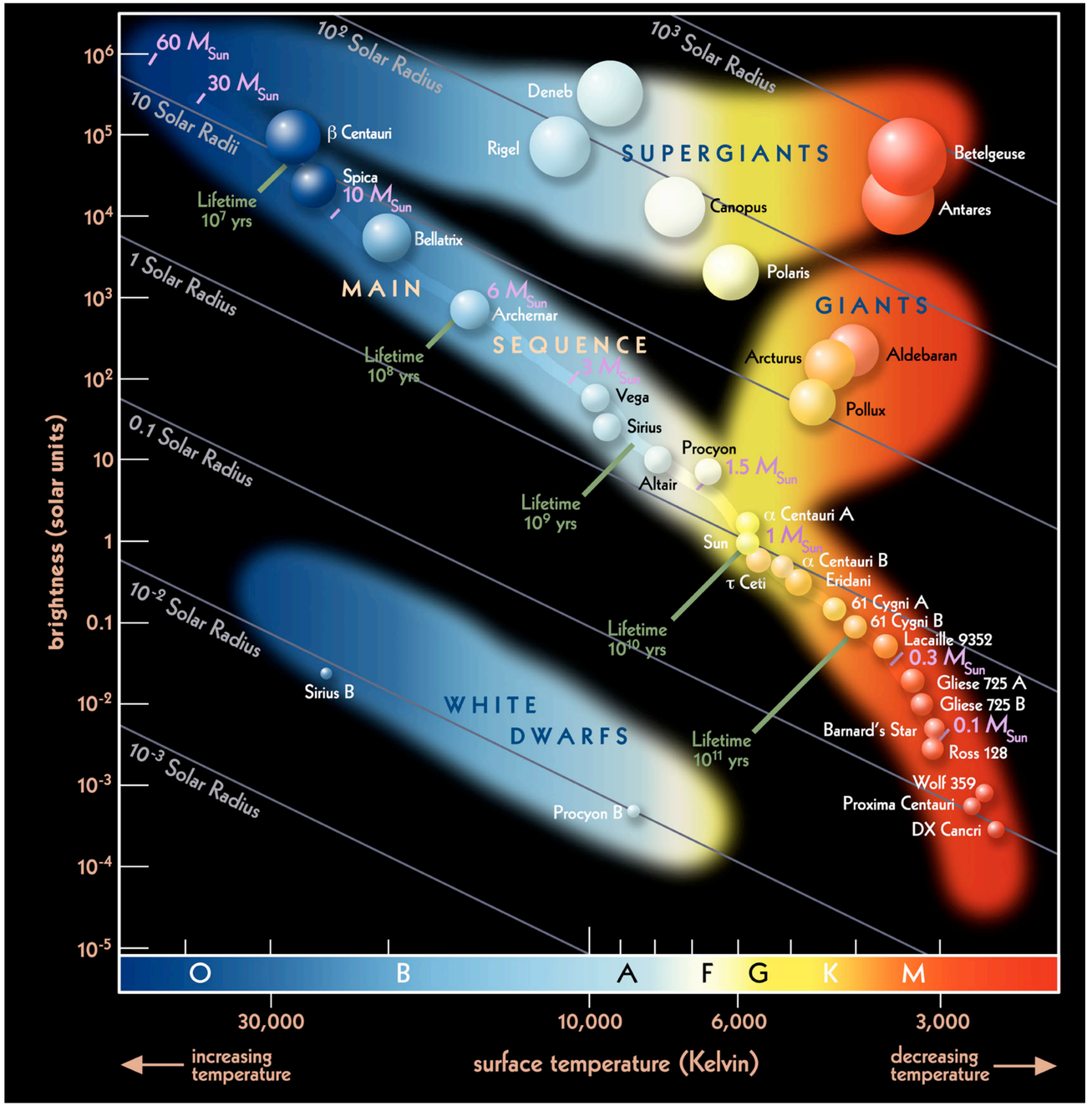

Hypergiant (0)
Luminous Supergiant (Ia)
Bright Giant (II)
Supergiant (Ib)
Subgiant (IV)
Giant (III)
Main Sequence (V)

Hertzsprung-Russell Diagram (or color-magnitude diagram: CMD)

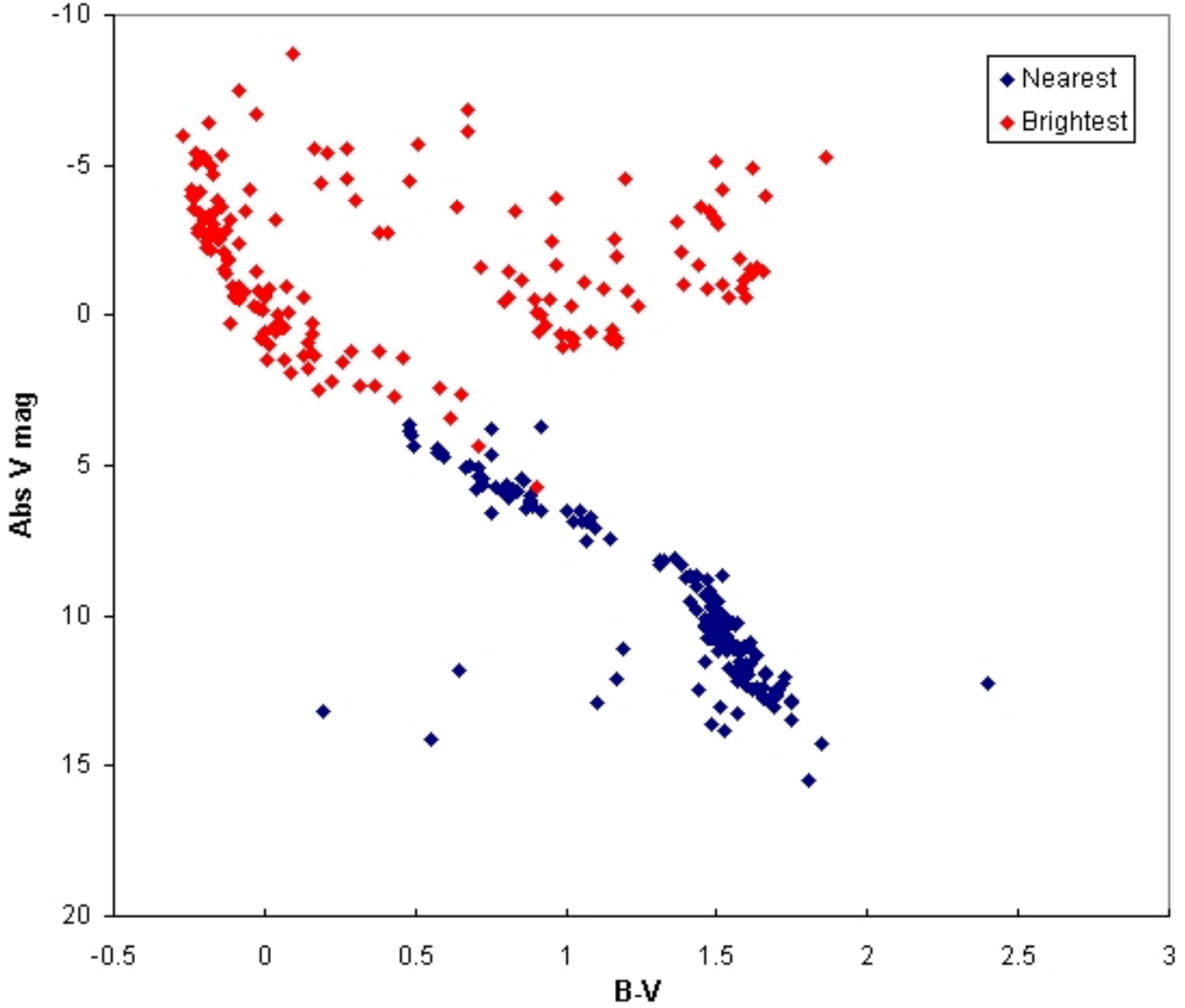
$$T_{\rm eff} = \left(\frac{L}{4\pi R^2 \sigma_{\rm SB}} \right)^{1/4}$$

$$L \propto R^2 T^4$$

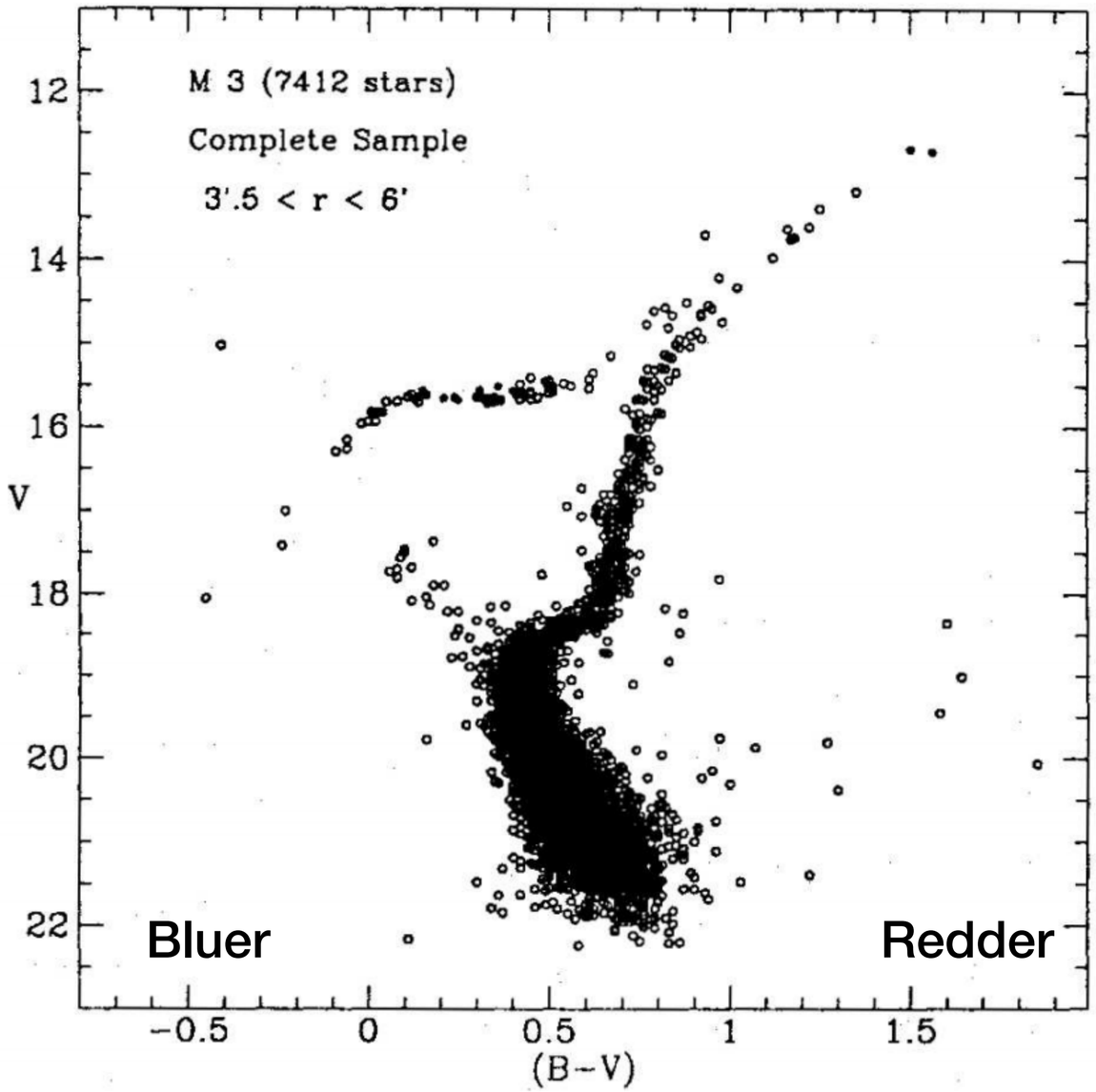
$$\log L \propto 2 \log R - 4 \log T^{-1}$$



Color (B-V) - Magnitude (V) Diagram (CMD) version



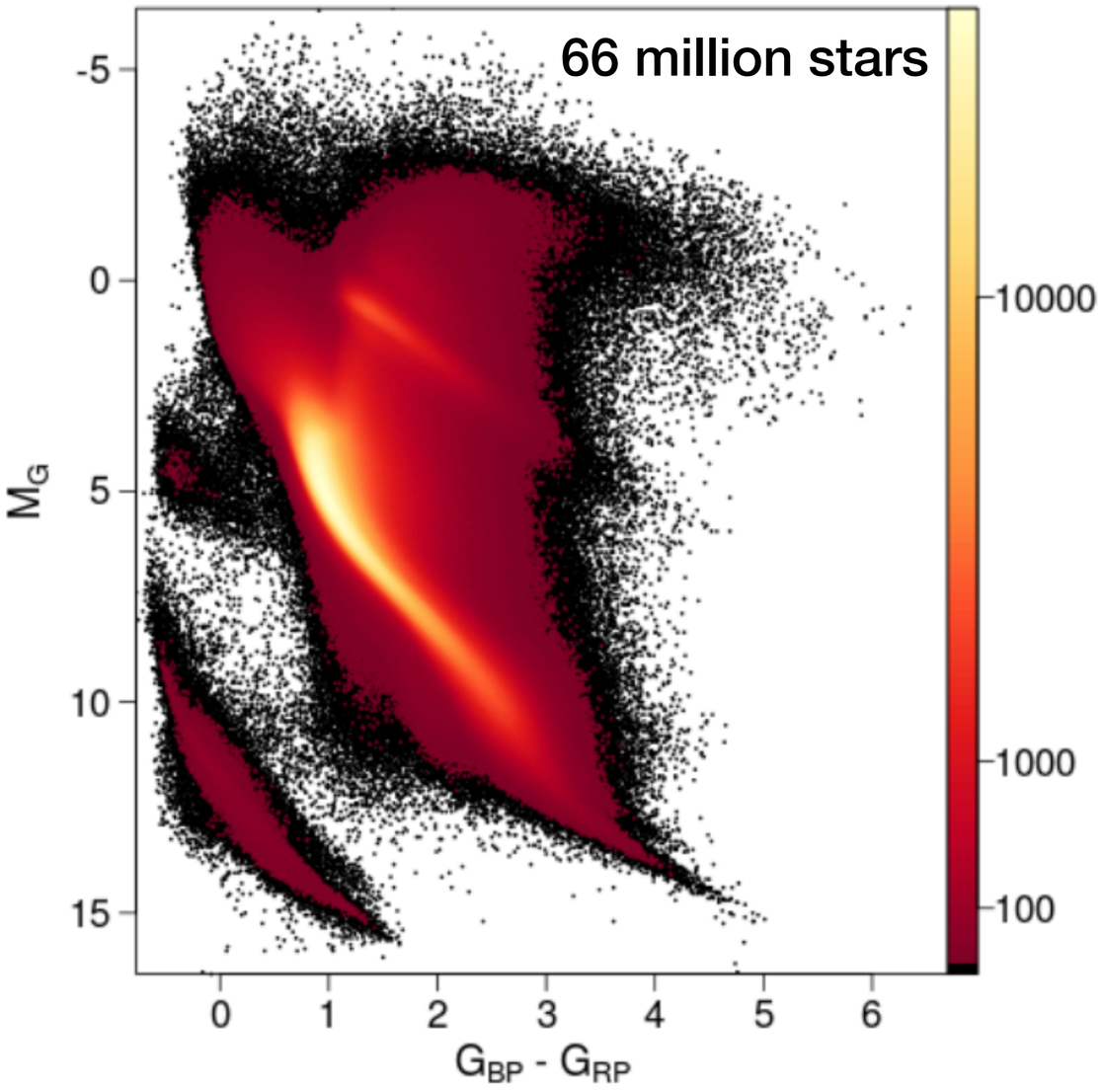
Globular Cluster Color-Magnitude Diagram

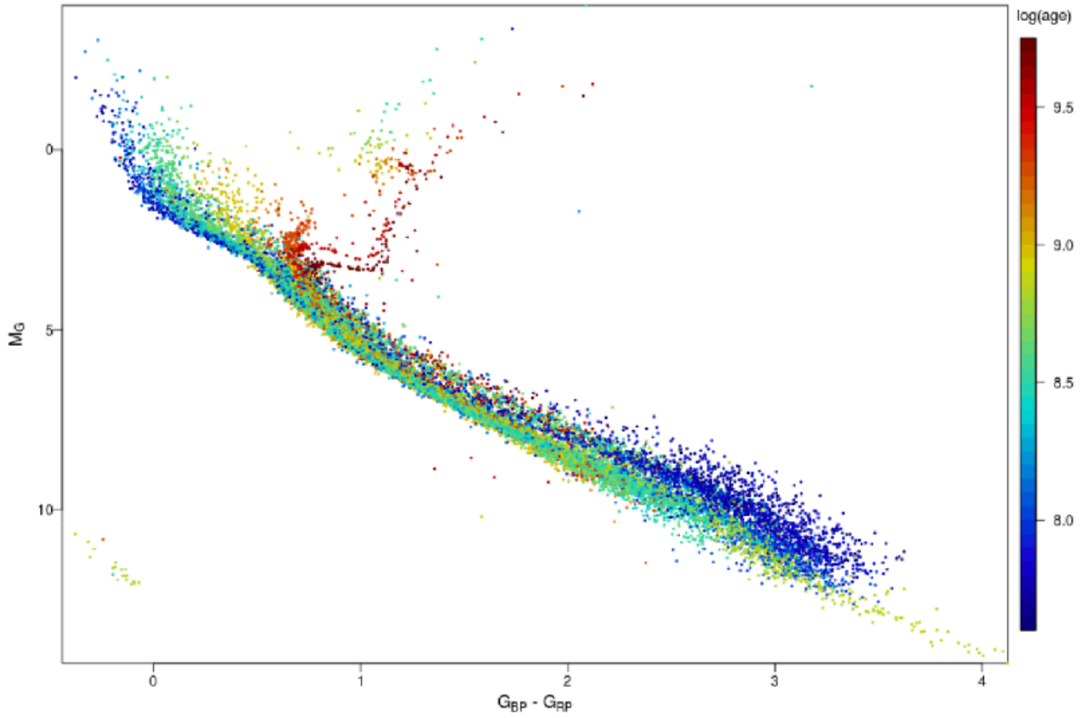


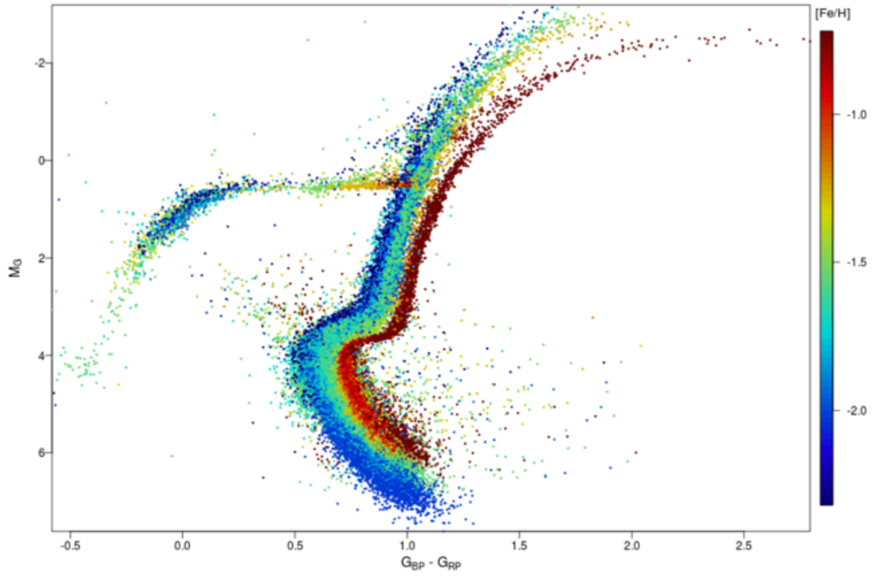
Brighter

Fainter

Gaia CMDs


66 million stars
-5
0
5
10
15
M_G
0
1
2
3
4
5
6
G_{BP} - G_{RP}
10000
1000
100


log(age)
9.5
9.0
8.5
8.0
0
5
10
M_G
0
1
2
3
4
G_{BP} - G_{RP}


[Fe/H]
-1.0
-1.5
-2.0
-2
0
2
4
6
M_G
-0.5
0.0
0.5
1.0
1.5
2.0
2.5
G_{BP} - G_{RP}

Star Atmospheres & Interiors!
To the whiteboard!