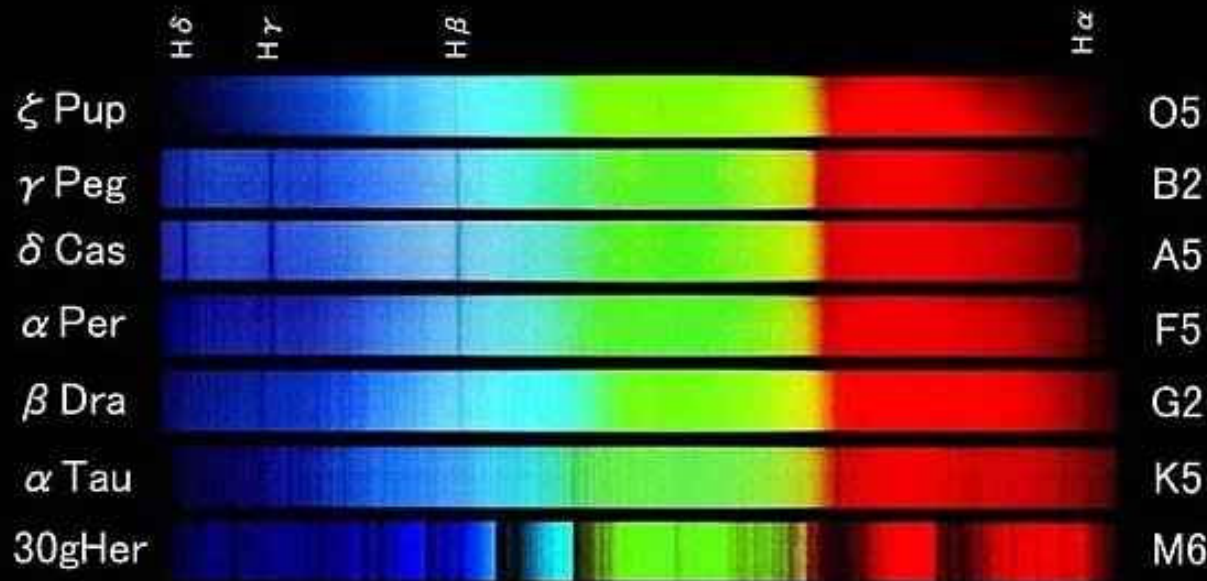


What does it all mean?

Stellar Classification Demystified



A9 lab

B3 IV

M5 Ve

PHIL CIGAN

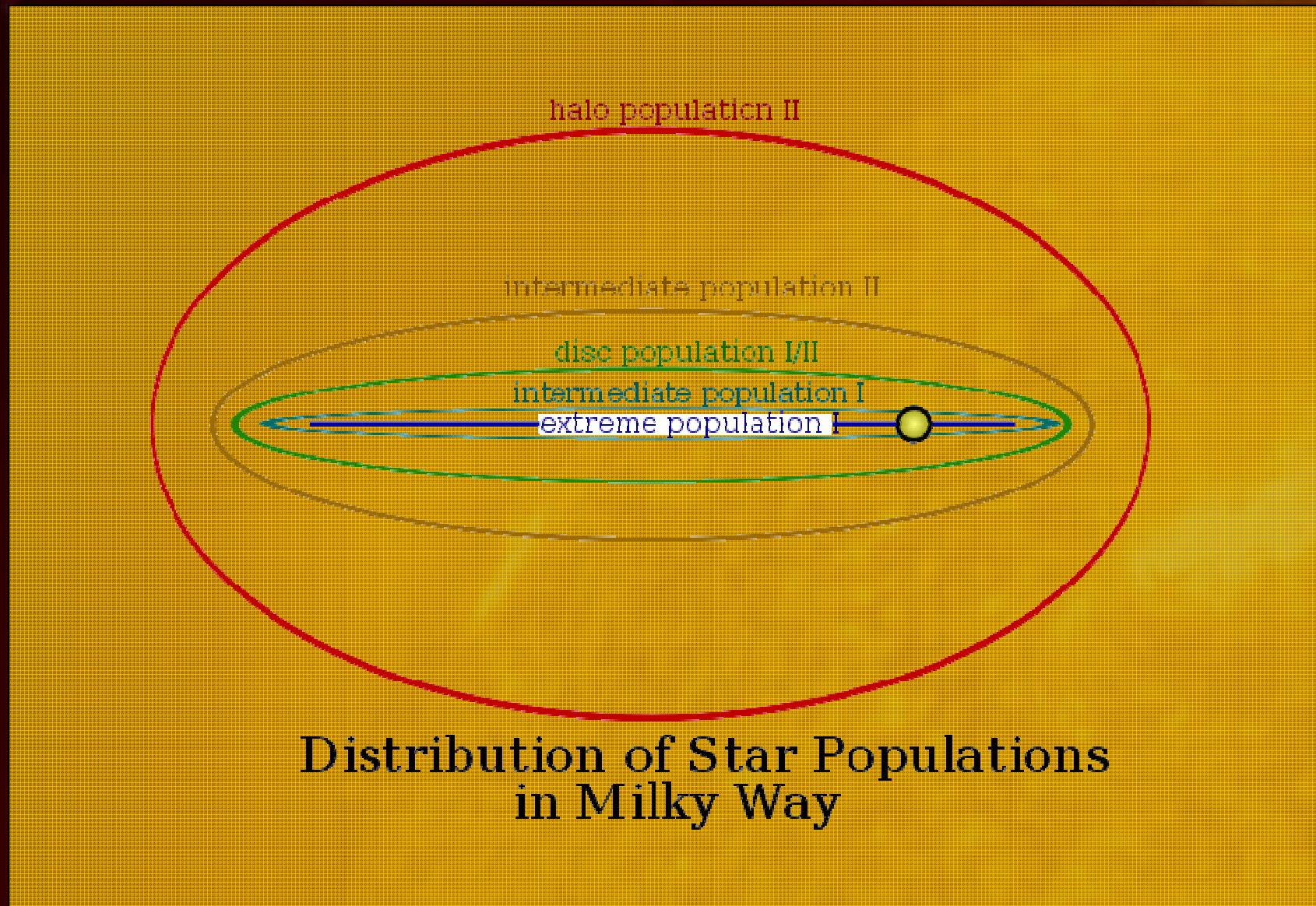
MYRIAD COMBINATIONS

- All the stars in the sky have huge variations in several distinct features, for example:
 - Composition
 - Size (mass, radius)
 - Color
 - Brightness
 - Temperature
- It's useful to have a system to describe stars based on these characteristics
- To understand the details, we need to know some... physics!

BACKGROUND – ASTROPHYSICS!

- We can classify stars by the amount of metals they have – called ‘metallicity’
- For astronomers, ‘metals’ are any element above Helium on the periodic table.
- ‘Population I’ stars are relatively young, and contain lots of metals
 - Typically found in galactic disks
- Population II stars are old, metal-poor stars
 - Typically found in globular clusters, outside of galactic planes
- Population III stars - pristine metal-free stars
 - Still hypothetical (none have been observed)

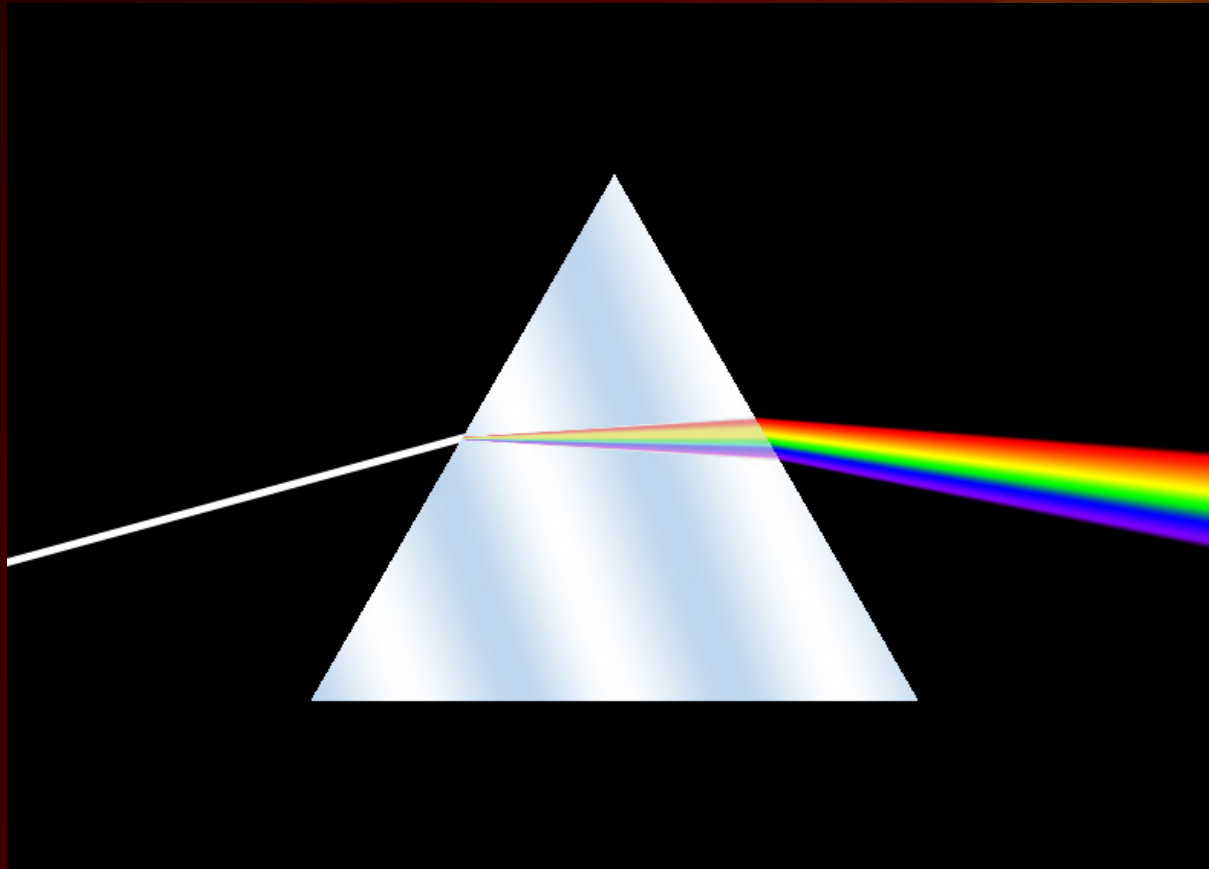
BACKGROUND – ASTROPHYSICS!



PHYSICS!

(SPECTRA)

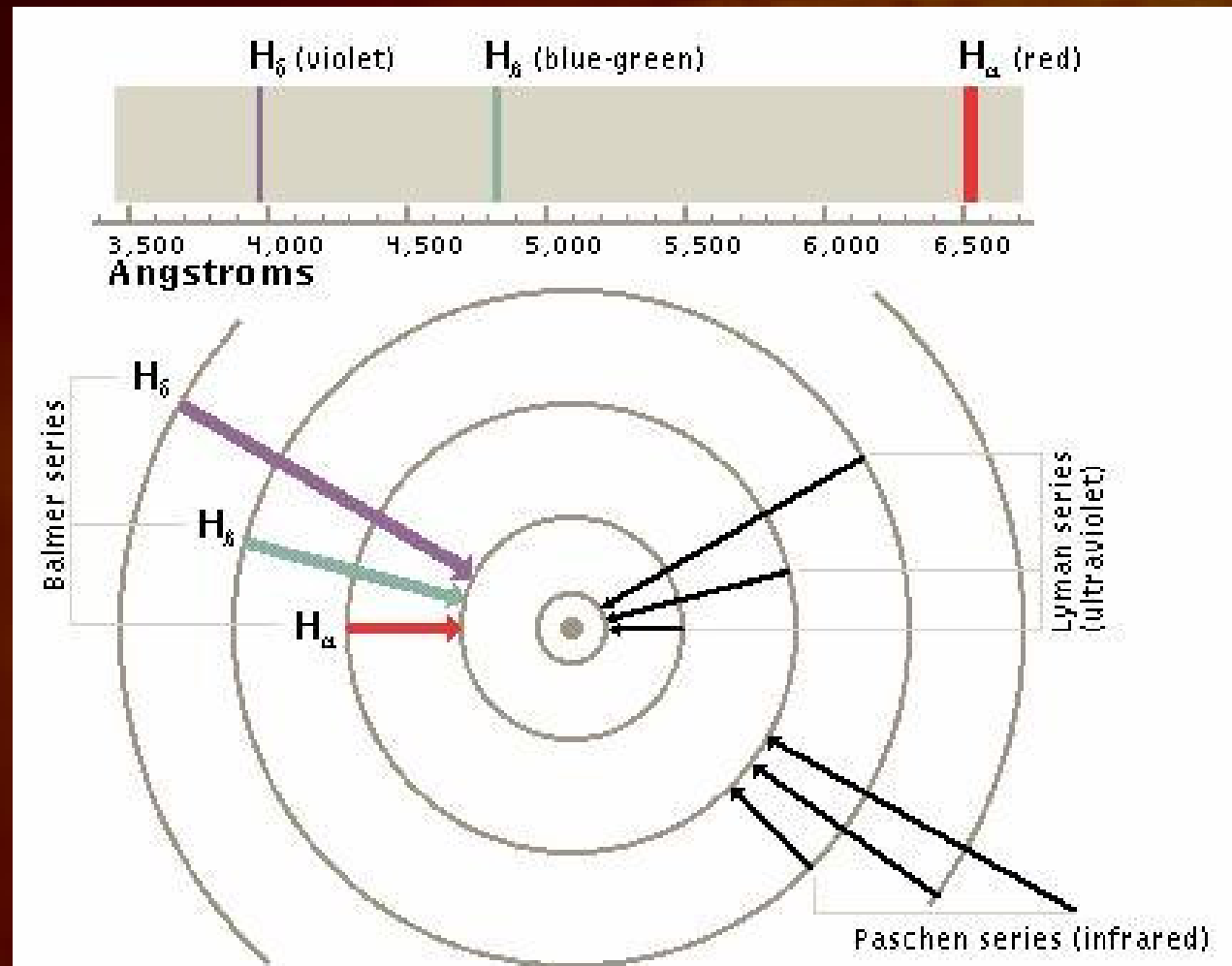
- The basic idea: a prism



- White light contains all colors (wavelengths)

PHYSICS! (SPECTRA)

- All atoms and molecules have different energy levels – distances at which their electrons can orbit



PHYSICS!

(SPECTRA)

- Sometimes, electrons can gain energy
 - (from being heated up, from collision, etc.)
- Atom wants to exist at lowest energy, so it will get rid of excess energy
- It shoots out some light!
 - A certain transition will ALWAYS result in the same color of light!

PHYSICS!

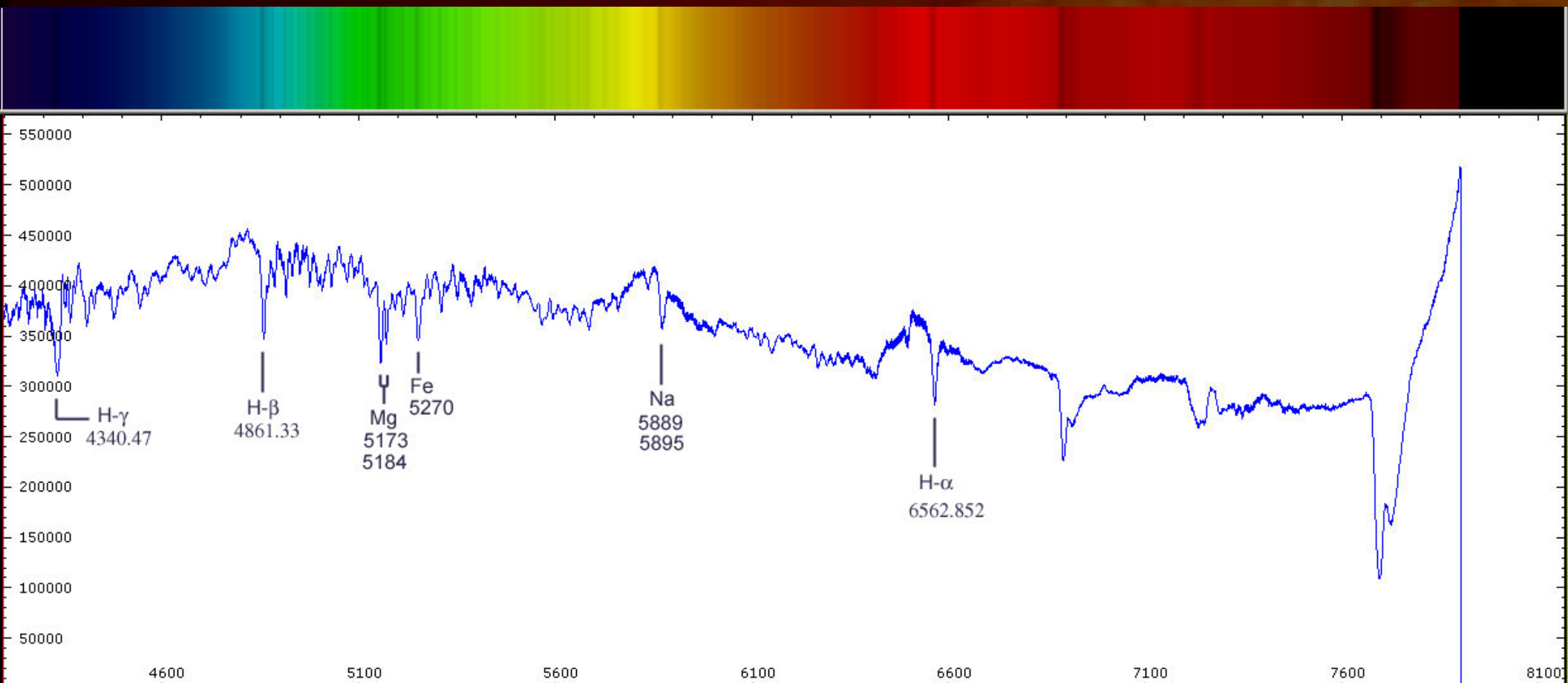
(SPECTRA)

- Stars act like 'blackbodies' – perfectly efficient emitters – which emit a continuum of light, covering all wavelengths.
- A material made up of many types of atoms and molecules will emit or absorb light that is a combination of ALL those colors
- If a spectrum is missing light in those spots, then that element is there, absorbing light
- You can tell what a material is made of by looking at its spectrum!

PHYSICS!

(SPECTRA)

Solar Spectrum



BACKGROUND-ASTROPHYSICS!

- The life of a normal 'main sequence' star is spent burning hydrogen in its core
- When normal stars stop fusing hydrogen in their cores, and instead start fusing Helium, they expand in size to become giants
- Giants that are not massive enough to fuse carbon will puff off their outer shell (to become a planetary nebula), leaving behind a white dwarf

BRIEF HISTORY

- In 1863, Father Angelo Secchi created a crude system to order stars by their spectra
- Harvard group (led by Annie Cannon) created a different spectral classification system
 - International IAU adoption in 1922
 - Called the “Harvard Scheme”
- In 1937, W.W. Morgan and P.C. Keenan at Yerkes Observatory introduced the M-K Luminosity Classification
 - Works with the Harvard Scheme, but provides important distinct subclasses

HARVARD SCHEME

- Orders stars by spectra
 - Original sample of ~400,000 stars published in the Henry Draper (HD) Catalogue
 - Order was alphabetical from A through P (and Q)
 - Originally based on strength of H-balmer absorption
 - A stars had strongest Balmer lines
- Later found that spectra also correspond to temperature
 - (from Boltzmann and Saha's equations of ionization)
 - Letter order rearranged to correspond to decreasing temperature

HARVARD SCHEME

- From hottest to coolest:

O B A F G K M

Some mnemonics:

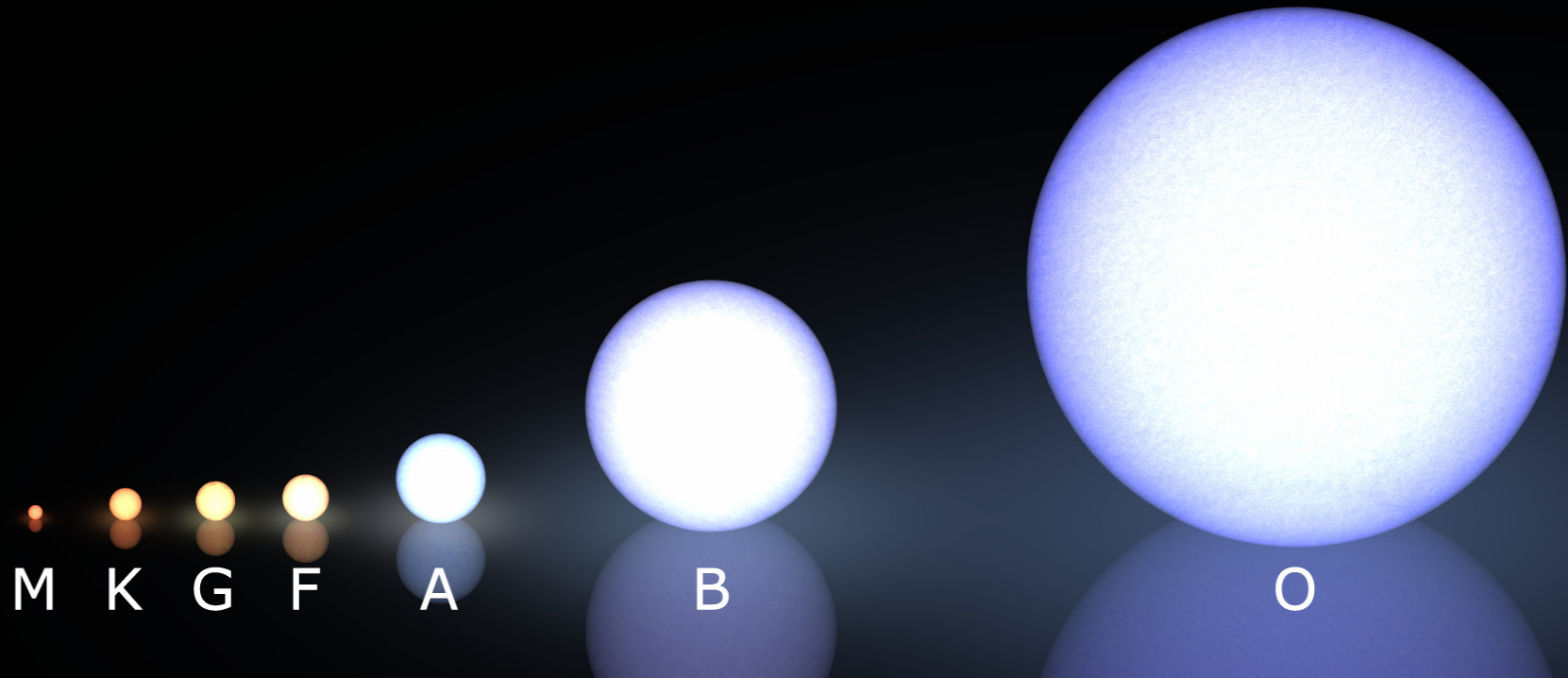
Oh, Be A Fine Girl – Kiss Me

Only Bold Astronomers Forge Great Knowledgeable Minds

Optical Binary Affairs Fundamentally Generate Keplerian Marriages

- Numbers 0-9 denote how close it is to next class.
 - 0 is hotter, 9 is cooler → F8 F9 G0 G1 G2...








HARVARD SCHEME



HARVARD SCHEME

- O – Extremely massive and luminous blue stars. Ionized He, N, O. (Ori A)
- B – Very massive, very luminous blue-white stars. Strong He lines. (Rigel)
- A – Big white stars. Strong H lines. (Sirius)
- F – Yellow-white. Weak H, strong O lines.
- G – Yellow. Weak H, many other metals. (Sol)
- K – Orange. Strong metal lines. (Arcturus)
- M – Red. Strong metals and TiO. (Betelgeuse, Antares)

Disclaimer: Many of the numbers below are incorrect, but they give a good starting reference.

<u>Main Sequence Stars</u>							
							
	O	B	A	F	G	K	M
Spectral Type:	O	B	A	F	G	K	M
Temperature:	40 000K	20 000K	8500K	6500K	5700K	4500K	3200K
Radius (Sun=1):	10	5	1.7	1.3	1.0	0.8	0.3
Mass (Sun=1):	50	10	2.0	1.5	1.0	0.7	0.2
Luminosity (Sun=1):	100 000	1000	20	4	1.0	0.2	0.01
Lifetime (million yrs):	10	100	1000	3000	10 000	50 000	200 000
Abundance:	0.00001%	0.1%	0.7%	2%	3.5%	8%	80%

<u>Giant Stars</u>	<u>White Dwarfs</u>	<u>Supergiant Stars</u>
Low mass stars near the end of their lives.	Dying remnant of an imploded star.	High mass stars near the end of their lives.
Spectral Type: Mainly G, K or M	Spectral Type: D	Spectral Type: O, B, A, F, G, K or M
Temperature: 3000 to 10 000K	Temperature: Under 80 000K	Temperature: 4000 to 40 000K
Radius (Sun=1): 10 to 50	Radius (Sun=1): Under 0.01	Radius (Sun=1): 30 to 500
Mass (Sun=1): 1 to 5	Mass (Sun=1): Under 1.4	Mass (Sun=1): 10 to 70
Luminosity (Sun=1): 50 to 1000	Luminosity (Sun=1): Under 0.01	Luminosity (Sun=1): 30 000 to 1000 000
Lifetime (million yrs): 1000	Lifetime (million yrs): -	Lifetime (million yrs): 10
Abundance: 0.4%	Abundance: 5%	Abundance: 0.0001%

r powell

NOT THE WHOLE STORY...

- Some stars with same Color-Temperature have different spectra
 - For example, a small red star on the main sequence and a red giant (more massive star nearing the end of its 'life')
- This scheme alone is not enough!

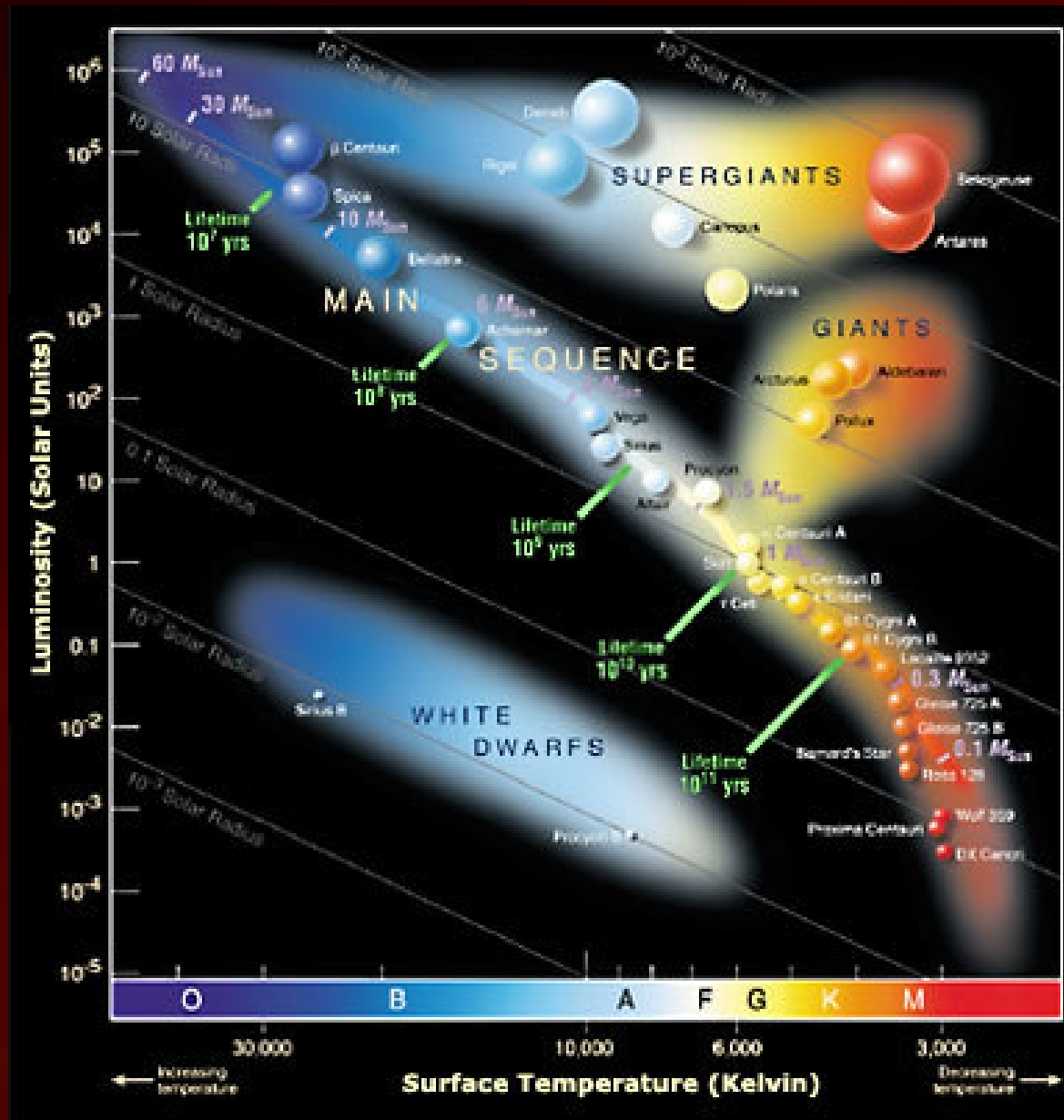
YERKES / M.K. SCHEME

- Six luminosity classes: I – VI
- There are three sub-classes: a, ab, b
 - a is hotter, ab is in-between, b is cooler
 - These are not always used
- Some use 0 or Ia+ for 'hypergiants'
- Some use VII for white dwarves

YERKES / M.K. SCHEME

- I – Supergiant
- II – Bright Giant
- III – Giant
- IV – Subgiant
- V – Dwarf (here, this means normal main-sequence stars)
- VI - Subdwarf

YERKES / M.K. SCHEME



SPECIAL/RARE CLASSES

- WR – Wolf-Rayet Stars. Thought to be massive stars whose outer layers have been ripped off. Extremely bright & hot, He dominant.
- D – white dwarf (e.g., Sirius B)
- C – Carbon Stars. Similar to G,K,M stars, but overabundant C relative to O
 - R – Carbon analogue of K stars (very rare)
 - N – Carbon analogue of M stars
- S – Similar to M stars, but with excess ZrO
 - S comes from the ‘S process’ – slow neutron capture
- L – dwarfs, 1300-2000K
- T – brown dwarfs, ~700-1300K
- P – Planetary Nebula
- Q – “other”

SPECIAL/RARE CLASSES

- Several lower-case letters can be appended
 - e – emission lines present
 - [e] – ‘forbidden’ emission lines present
 - f – NIII emission present in O stars
 - m – various metal lines present
 - n – nebulous (diffuse) lines present
 - p – peculiar lines present
 - q – red-shifted and blue-shifted lines present
 - Interpreted to indicate an expanding shell of gas or dust around the star
 - v – the spectrum is variable
 - wk – weak lines

SOME BRIGHT/FAMOUS STARS

Iota Ori A	O9 III	Alpha Centauri A	G2 V
Regulus	B7 V	Capella A	G8 III
Rigel	B8 Iab	Alpha Centauri B	K1 V
Vega	A0 V	Arcturus	K1.5 III
Deneb	A2 Ia	Aldebaran	K5 III
Canopus	F0 Ia	Proxima Centauri	M5.5 Ve
Polaris	F7 Ib-II	Barnard's Star	M4 Ve
Sol	G2 V	Betelgeuse	M2 Iab



Enjoy your new knowledge!

Any questions?