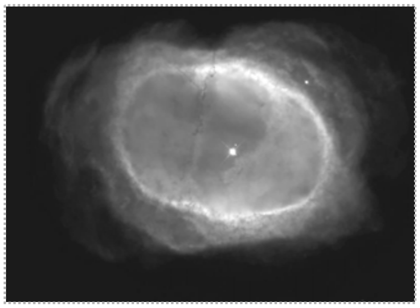
ASTR 1120: Stars & Galaxies



Planetary Nebula NGC 3132

Prof. Juri Toomre   TA: Ben Brown

Lecture 15   Mon 14 Feb 05

zeus.colorado.edu/astr1120-toomre

Topics for Today

- How do we begin to classify the stars?
- Understand why *temperature and spectral lines* are *closely linked*
- Thus why *O A B A F G K M* makes some sense – even if naming convention is from historical accident !
- *Homework Set # 4* still available, due Fri
- Expect to return graded *Exam 1* on Wed

Reading for Next Lecture

- *Complete detailed reading of Chap 16, `Properties of Stars' by Wed 16 Feb*
- *Proceed to lay the stars out on the "Hertzsprung – Russell" (or H-R) diagram*
- *Will help to sort out the life history of stars*

Reading Clicker Q   *E.*

- *The luminosity of a star is*
- *A.* apparent brightness of the star in the sky
- *B.* surface temperature of the star
- *C.* lifetime of the star
- *D.* total amount of light that the star will radiate over its entire lifetime
- *E.* total amount of light that the star radiates every second

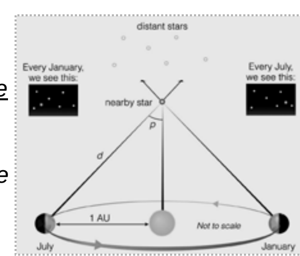
Puzzle Clicker: Stellar Parallax

- *The biggest ground-based telescopes with adaptive optics can measure a stars' position to accuracies of about 0.05 arcsec. How far away could they map the positions of stars via parallax?*
- *A.* 2 pc = 6.5 light years
- *B.* 20 pc = 65 light years
- *C.* 200 pc = 650 light years

B.

Parallax

- *B.* *maximum distance is set by the accuracy with which you can measure positions in the sky (space does better than ground)*



d (in parsecs) = 1 / p (in arcsec)

Distance (pc) =
1 / 0.05 arcsec
= 20 pc = 65 ly

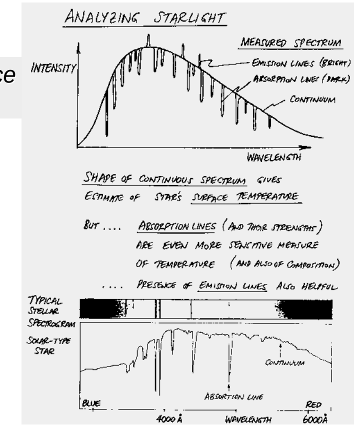
Best parallax measurer: Hipparcos satellite 1989-1993

REMINDER

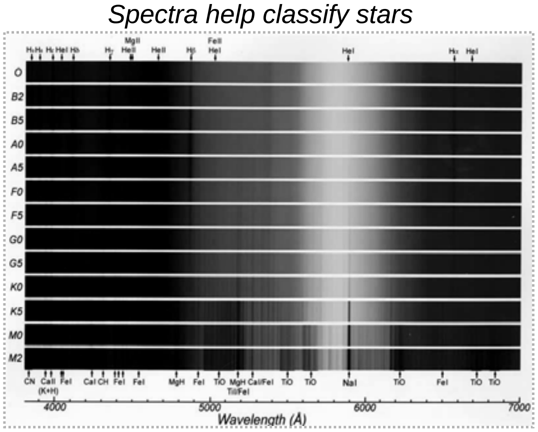
- Space measurements not affected by atmosphere
- Measurement made many times until accurate to 0.001 arcsec (→ 1000 pc or 3300 ly)
- <u>100,000 stars mapped</u>
- (2.5 million to slightly lesser accuracy)

Measuring Surface TEMPERATURE

Shape of spectrum good … but <u>spectral lines</u> much better



Spectra help classify stars



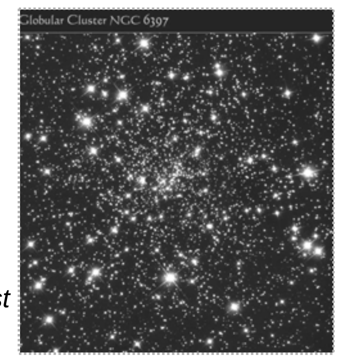
OBAFGKM ?!?

- <u>Spectral (color) classification</u>

O = bluest, hottest

G = yellow (Sun)

M = reddest, coolest



A bit of history: <u>Classifying Stars</u>

World War I, Harvard College observatory

Women were hired by Pickering as "calculators" to help with a new survey of the Milky Way

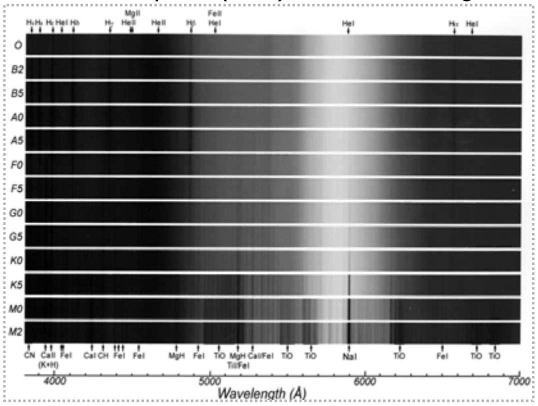
Most had studied astronomy, but were not allowed to work as scientists

Devising the strange temperature code

- <u>Original classification of spectra</u> (1890) was:
  A = strongest hydrogen feature
  B = less strong hydrogen …C, D, etc.
- Annie Jump Cannon realized that a <u>different sequence</u> made more sense (~1910)

→ O B A F G K M !!

Which absorption (dark) lines are strongest?



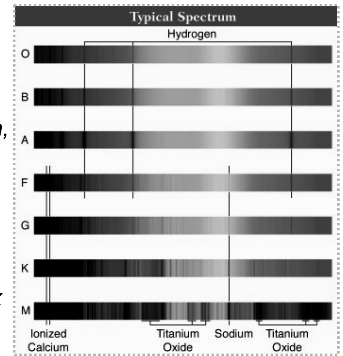
Spectral Classification: O B A F G K M

<u>Hottest stars</u>: O B
ionized helium only

<u>Hot stars</u>: A F helium, hydrogen

<u>Cooler stars</u>: G
hydrogen, heavier atoms

<u>Coolest stars</u>: M
molecules, (complex absorption bands)



Stars and their spectral classification

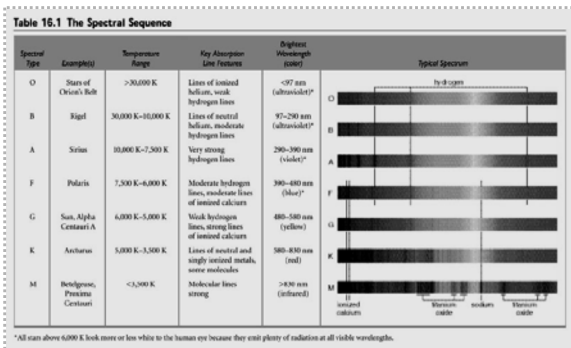


Table 16.1 The Spectral Sequence

Spectral Type	Example(s)	Temperature Range	Key Absorption Line Features	Brightest Wavelength (color)	Typical Spectrum
O	Stars of Orion's Belt	>30,000 K	Lines of ionized helium, weak hydrogen lines	<97 nm (ultraviolet)*	
B	Rigel	30,000 K–10,000 K	Lines of neutral helium, moderate hydrogen lines	97–290 nm (ultraviolet)*	
A	Sirius	10,000 K–7,500 K	Very strong hydrogen lines	290–390 nm (violet)*	
F	Polaris	7,500 K–6,000 K	Moderate hydrogen lines, moderate lines of ionized calcium	390–480 nm (blue)*	
G	Sun, Alpha Centauri A	6,000 K–5,000 K	Weak hydrogen lines, strong lines of ionized calcium	480–580 nm (yellow)	
K	Arcturus	5,000 K–3,500 K	Lines of neutral and singly ionized metals, some molecules	580–830 nm (red)	
M	Betelgeuse, Proxima Centauri	<3,500 K	Molecular lines strong	>830 nm (infrared)	

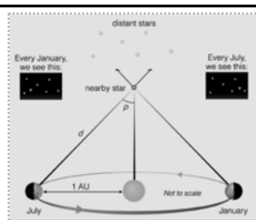
*All stars above 6,000 K look more or less white to the human eye because they emit plenty of radiation at all visible wavelengths.

Brightness / Distance Clicker Q B.

- *Leonardo and Guinevere are two stars that have the same apparent brightness. Leonardo has a larger parallax angle than Guinevere. Which star is more luminous?*

- *A.* Leonardo
- *B.* Guinevere
- *C.* Cannot determine from data given

Brightness / Distance



- *Leonardo has a <u>larger parallax angle</u> -- thus he is closer to us*
- *They both have the same APPARENT brightness, but Leo is closer*
- ***B.** <u>Guinevere</u> must be more luminous*

Cecelia figured out <u>WHY</u> stellar spectra are so different: TEMPERATURE

- *She showed that <u>SURFACE TEMPERATURE</u> is the big factor (not composition)*
- *She used the newly-devised SAHA EQUATION, estimating how many electrons remain attached to atoms as temperature is changed (or the level of ionization)*

Cecelia Payne-Gaposchkin
(Harvard PhD thesis 1925)

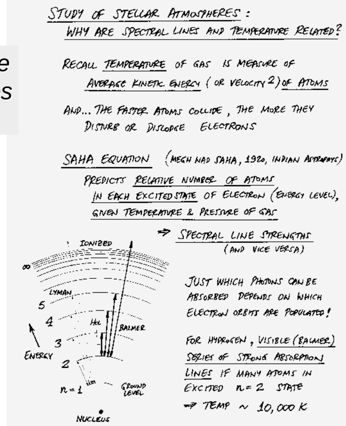
O B A F G K M → decreasing temperature

Why temperature and spectral lines are linked?

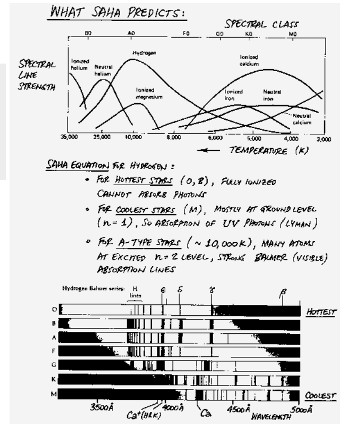
SAHA gives the answer:

can estimate "population of different energy levels" in H, He …

and ionization



SAHA predicts spectral line strengths with temperature



Spectral Classification: O B A F G K M

<u>Hottest stars</u>: ionized helium only

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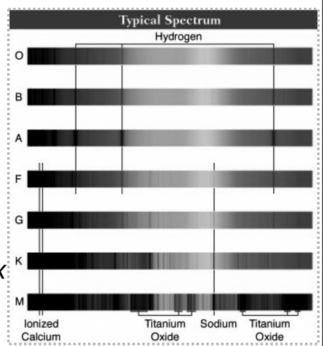
<u>Coolest stars</u>: molecules, (complex absorption bands)



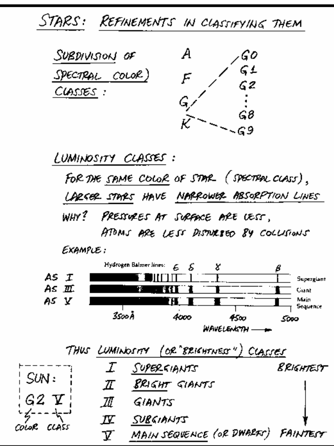
<u>Further refinements:</u>

DECIMAL SUBDIVISION

<u>LUMINOSITY CLASSES</u>

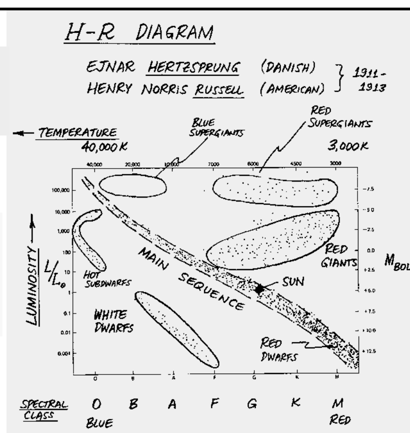
Sun is: G2 V

COLOR CLASS



Hertzsprung-Russell (H-R) Diagram

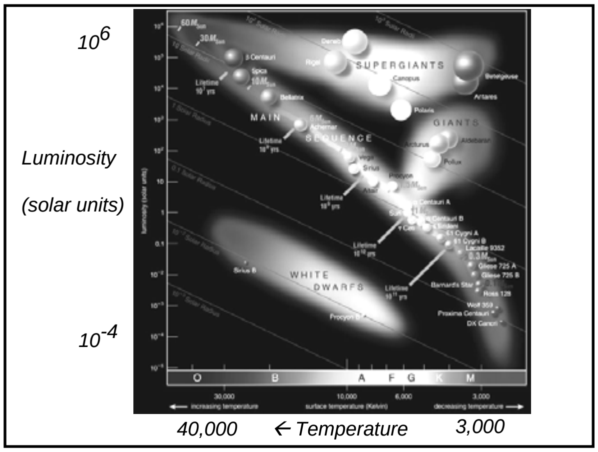
Luminosity (magnitude) vs Spectral class (temperature)



H - R Namesakes

Ejnar <u>Hertzsprung</u>

Henry Norris <u>Russell</u>


10^6
Luminosity
(solar units)
10^{-4}
SUPERGIANTS
GIANTS
MAIN
SEQUENCE
WHITE
DWARFS
40,000
← Temperature
3,000