Stars, Galaxies & the Universe
Announcements

- **Lab Observing Trip**
  - **Next week: Tues (9/28) & Thurs (9/30)**
  - **let me know ASAP if you have an official conflict (class, work)**
  - **website: http://astro.physics.uiowa.edu/~clang/sgu_fall10/observing_trip.html**
- **Tutorial Hours: MWF 11:30-12:30 pm VAN 666 or 665**
- **Office Hours: MW 1:30-2:30 pm VAN 703 or email**
- **First Exam**
  - **in class on Wednesday (see website for more info)**
  - **review for 15 minutes; exam is ~50 minutes**

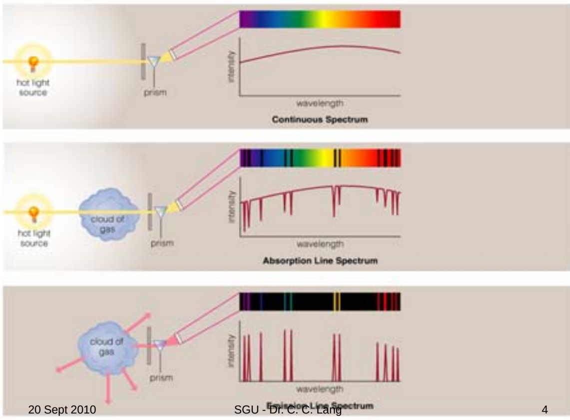
Stars, Galaxies & the Universe
Observing Highlights

Autumnal Equinox

Wed. 22nd September: Autumn begins in the Northern Hemisphere, and spring in the Southern Hemisphere, at 11:09 p.m. EDT. This equinox marks when the Sun crosses the equator heading south for the year. Day and night (if you include twilight as night) are about equally long.

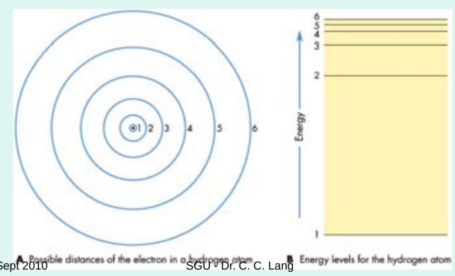
Stars, Galaxies & the Universe
Lecture Outline

- Stellar Spectra: a few last details
  - Spectrum tubes and the bright line spectrum
  - Doppler Effect
- H-R Diagram for the Variety of Stars
  - How big is that star?
  - Range of stellar masses
- (Some of this material we will revisit!)
- *Quiz #4 – Reading Quiz*
- Preview: Our Star-The Sun



The energy levels of the Hydrogen atom:

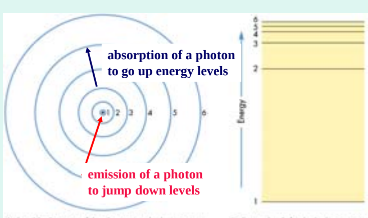
Places where the electron is located
Fixed levels by quantum mechanics
Energy levels depend on atomic make-up



Spectral lines originate from electrons moving in atoms

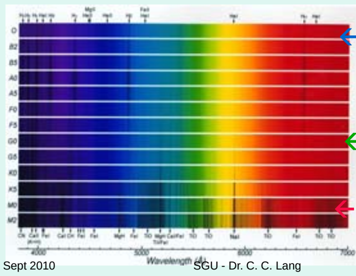
In order to go UP a level, electron must absorb energy

In order to go DOWN a level, electron releases energy



- ENERGY takes the form of EM radiation, or "photons"
- photons have wavelength which corresponds to the energy change

• Different stars have different spectral “signatures”
• All stars fall into several categories: O-B-A-F-G-K-M



←Hot 50,000 K

← Our Sun

←Cool 4,000 K

The categories of stars: O B A F G K M

Differences are due to the TEMPERATURE of star

TEMPERATURE can determine:

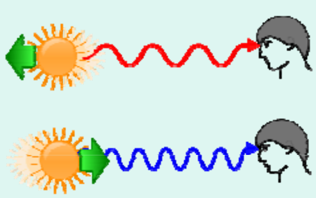
- **where the electrons are located (which energy levels)**
- **which elements have absorption, emission lines**

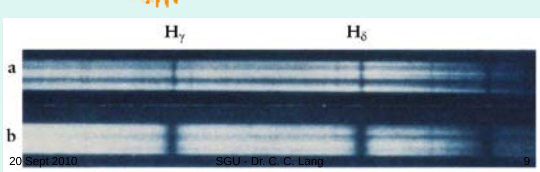
-- an O-star has a temperature of ~50,000 K

-- an A-star has a temp of ~10,000 K, enough for hydrogen to be ionized (spectral lines in the UV)

-- a G-star (like our Sun) has a temperature of ~6,000 K

Doppler Shifts can be used to detect stars’ rotation



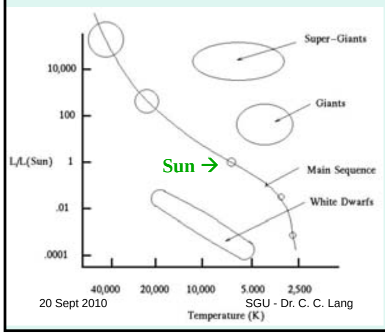


Stellar Evolution **is the study of**

- how stars are born
- how stars live their "lives"
- how stars end their lives

The Hertzsprung-Russell Diagram (H-R Diagram)

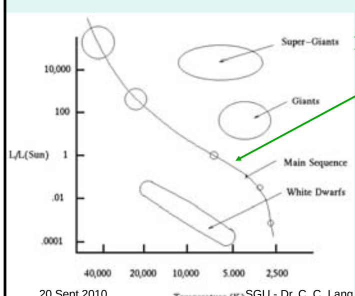
Plots the relationship between TEMPERATURE (x) and LUMINOSITY (y) of different stars



- **not a star chart (positions)!**
- **shows that a star's T is related to its Luminosity in a certain way**

The Hertzsprung-Russell Diagram (H-R Diagram)

Plots the relationship between TEMPERATURE (x) and LUMINOSITY (y) of different stars



For the MAIN SEQUENCE

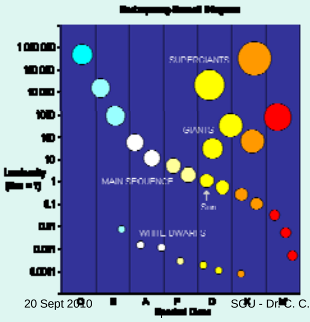
Most stars fall along this line

The MORE LUMINOUS the star, the HOTTER it is

The LESS LUMINOUS the star, the COOLER it is

The Hertzsprung-Russell Diagram (H-R Diagram)

Plots the relationship between TEMPERATURE (x) and LUMINOSITY (y) of different stars

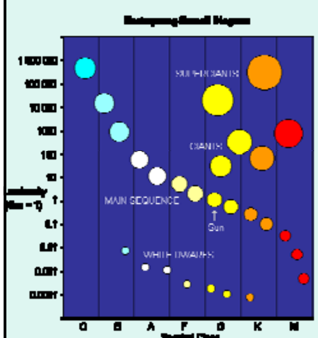


color illustrates the main sequence (MS)

BLUE MS stars are LUMINOUS, HOT

RED MS stars are DIM, COOL

The Hertzsprung-Russell Diagram (H-R Diagram)



Two other categories of where stars are:

SUPERGIANTS – COOL but very very LUMINOUS

WHITE DWARFS – HOT but very very DIM

Stars come in a variety of sizes

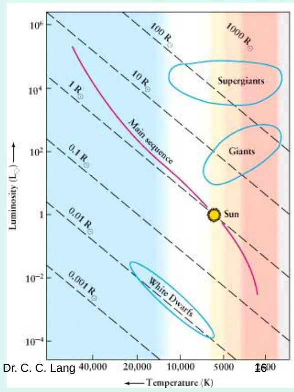
The Stefan-Boltzmann law relates luminosity, temperature, and size for stars:

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

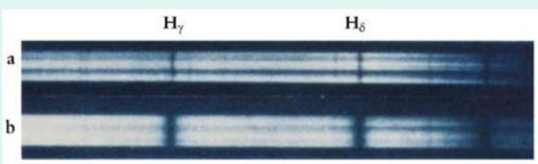
- Small stars will have low luminosities unless they are very hot → red dwarfs
- Stars with low surface temperatures must be very large in order to have large luminosities → red super giants

Determining the Sizes of Stars from an HR Diagram

- Main sequence stars are found in a band from the upper left to the lower right.
- Giant and supergiant stars are found in the upper right corner.
- Tiny white dwarf stars are found in the lower left corner of the HR diagram.

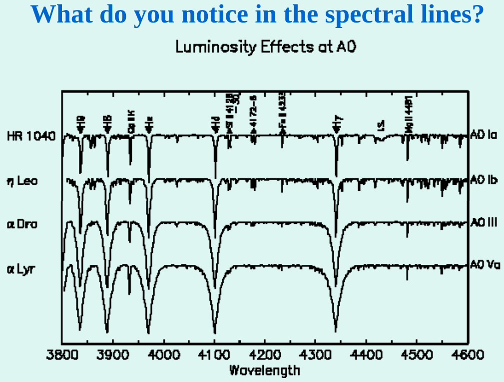


Details of a star's spectrum reveal whether it is a giant, a white dwarf, or a main-sequence star.



Both of these stars are spectral class B8. However, *star a* is a luminous super giant and *star b* is a typical main-sequence star. Notice how the hydrogen absorption lines for the more luminous stars are narrower.

What do you notice in the spectral lines?



Broad lines – physically what causes this?

The basic idea is that the photospheres of some stars have much lower pressures and densities than others, even though the temperatures are the same

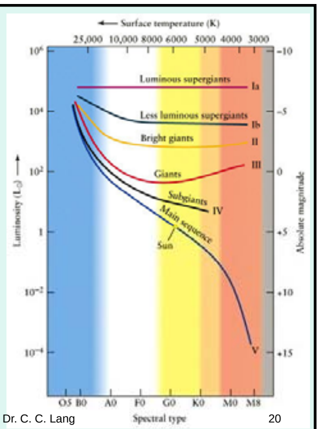
higher pressures lead to more collisions and <u>broader lines</u>

lower pressures lead to fewer collisions and <u>narrower lines</u>

Details of a star's spectrum reveal whether it is a giant, a white dwarf, or a main-sequence star.

Luminosity classes

- Class I includes all the supergiants.
- Class V includes the main sequence stars.
- e.g., the Sun is a G2 V



Stellar Luminosity Classes

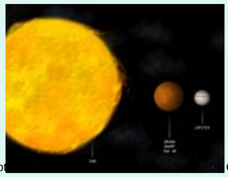
Table 15.2 Stellar Luminosity Classes

Class	Description
I	Supergiants
II	Bright giants
III	Giants
IV	Subgiants
V	Main-sequence stars

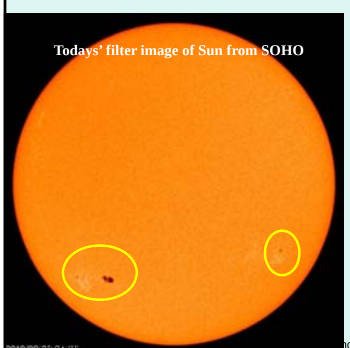
The range of stellar masses

We will use binary stars to find mass but for now you should know that the typical masses of stars are between

0.08 solar masses - 80 solar masses

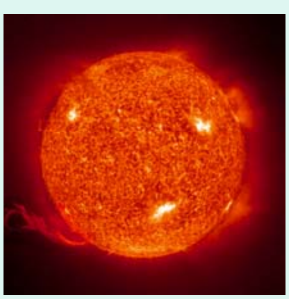


Measurable Properties of our Sun



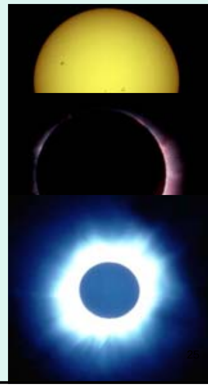
- Nearest star!!
- Distance ~ 1 AU
- Radius ~ 7 x 10^8 m
  - 100x earth radius
  - from distance, angular size
- Mass ~ 2 x 10^{30} kg
  - 333, 000x Earth mass
  - from orbits of planets
- Temperature ~ 5800 K
  - from peak of intensity at wavelength of 500 nm

Composition of Sun



- Sun is gaseous
  - -violent, bubbling up close
  - -too hot to be solid, liquid
- Sun's layers
  - - more dense inside
  - - less dense near surface
- Chemical composition
  - - 71% Hydrogen
  - - 27% Helium, 2% other (surface)
- Physical State
  - - The Sun is a "plasma"
  - - made of charged particles e^- (usually electrons who have gained enough energy to leave nucleus)
  - - plasmas are often magnetic
  - - plasma attaches itself to fields

Exterior Layers of the Sun:



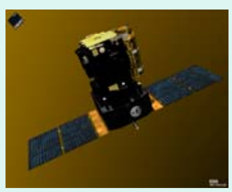
Photosphere:
- ‘visible surface’ of Sun
- T = 5800 K
- sunspots, surface features present

Chromosphere:
- just outside of photosphere
- hot gas, magnetic features
- T = 10,000 K

Corona:
- Very hot (few million degrees)
- visible during eclipse, coronagraph

How do we observe the Sun?

- from both ground and from space
- radio, optical EM waves from ground
- X-rays, UV waves from space



PHOTOSPHERE: visible surface of the Sun

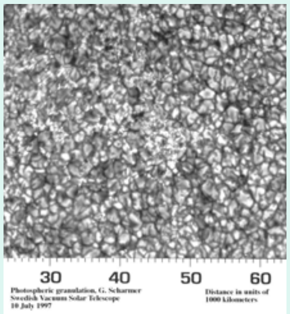
Two features:

• sharp edge “limb”

• brighter in center than along the limb

“limb darkening”
limb less dense
less light emitted

Solar Surface: Granulation



- on the solar surface
- 1000's miles across
- dark = cooler gas
- light = hotter gas
- speed of motion up & down measured by DOPPLER EFFECT!