Stars, Galaxies & the Universe Announcements

- **HW#4: posted Thursday; due Monday (9/20)**
- **Reading Quiz on Ch. 16.5 – Monday (9/20)**
- **Exam #1 (Next Wednesday 9/22)**
  - In class (50 minutes) – ***first 20 minutes: review***
  - 25 multiple-choice questions (each 4 pts)
  - Bring pencil; no calculators
  - No talking during exam: strict policy about cheating
  - **Review Sheet and Practice Exam – see course website:** **http://astro.physics.uiowa.edu/~clang/sgu_fall10/exams.html**

Stars, Galaxies & Universe Lecture #7 Outline

- A few more comments on parallax
- Properties of Stars: Temperature & Chemical Composition (Ch 16.5 pp 383-388)
  - Blackbody Radiation & Wien's Law (notes)
  - Spectral Lines
  - Luminosity class, Chemical Abundances, Doppler Effect on spectra (MONDAY)

Parallax: Space Observatories

- *Hipparcos (mission 1989-1993)*
  - 118,218 parallax distances determined
- *GAIA (launch 2012; 2012-2017)*
  - chart a three-dimensional map of our Galaxy
  - kinematic census of about one billion stars in our Galaxy and throughout the Local Group (1%).

Basics of Electromagnetic Radiation (or "Light")

➢ What we can learn from observing EM radiation from an astronomical object

- ***Energy* – Photoelectric effect**
- ***Temperature* – blackbody radiation, Wien's Law**
- ***Chemical composition* – atomic structure, spectral lines**
- ***Line-of-sight motion* – Doppler shift of spectral lines**

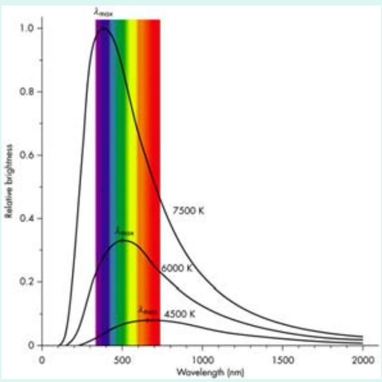
Astronomical objects as blackbodies

• Blackbodies are good absorbers and radiators

• *astronomers look at the INTENSITY of EM radiation as a function of WAVELENGTH or frequency*

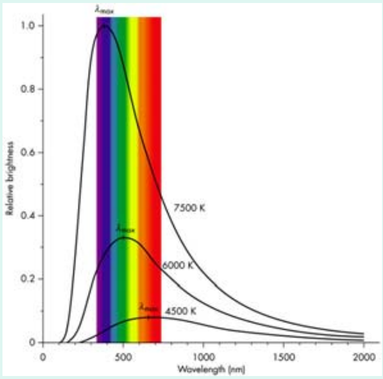
1. A BB emits something at EVERY wavelength
2. the ***temperature*** of the object determines how much radiation the blackbody will emit

HOTTER objects emit MORE intensity at all wavelengths than cooler ones



HOTTER objects have their *peak intensity* at SHORTER wavelengths than cooler ones

"bluer"



Astronomers use Kelvin or Celsius Temperatures

<u>Kelvin scale</u>

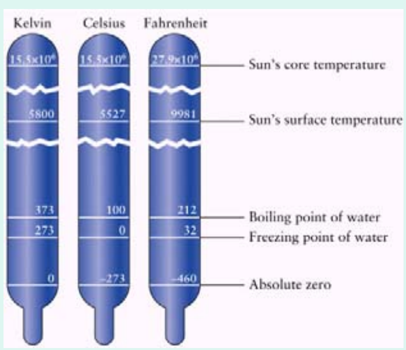
- 0 K is no atomic motion
- absolute zero

<u>0 K on Celsius scale</u>

T= –273º C

<u>0 K: Fahrenheit scale</u>

T= – 460º F



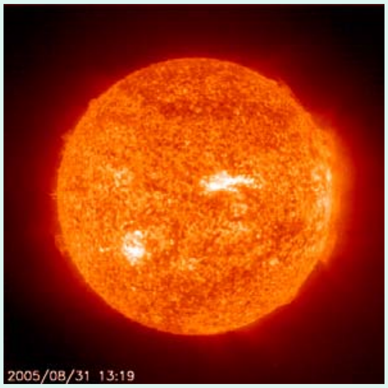
Wien's Law for blackbodies:

Relationship between
the **TEMPERATURE** of an object
the intensity of its radiation
the ***wavelength of peak intensity***

$$\lambda_{peak} = \frac{0.0029 \text{ m K}}{T}$$

HOTTER objects have peak radiation at **shorter wavelengths**

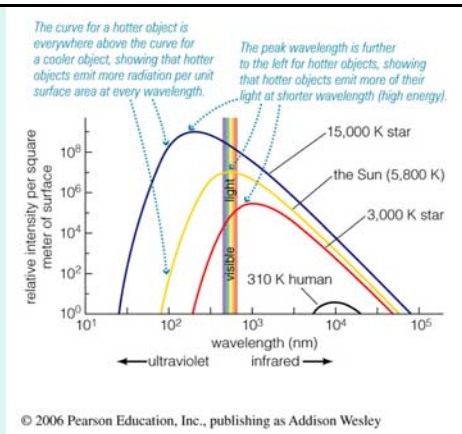
COOLER objects have peak radiation at **longer wavelengths**



The Sun is also a blackbody

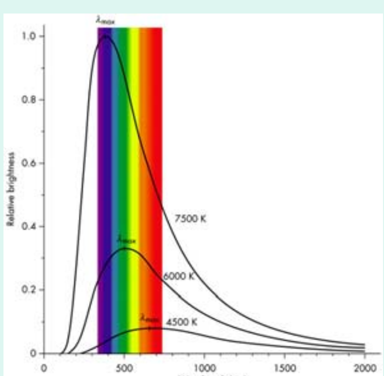
with T=5800 K

and the wavelength of peak intensity is at 500 nm



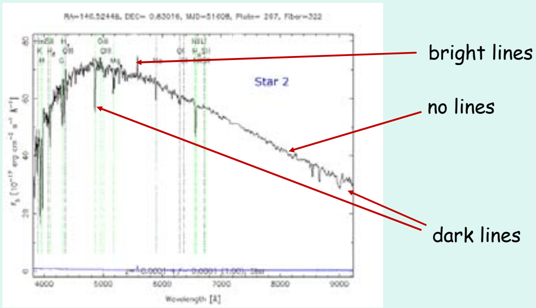
The "spectrum" of a star in the visible part of EM spectrum

A plot of **INTENSITY** vs. **WAVELENGTH**



Features of stellar spectra:

Blackbody objects (wavelength of peak intensity)
Have additional features – “spectral lines”



A detailed look at the spectrum of the Sun

Things to note in solar spectrum:

→ *brightest* intensity at green/yellow wavelengths
→ presence of many dark lines and features

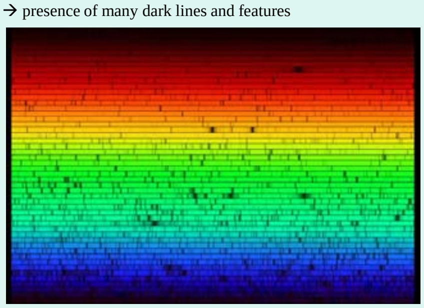
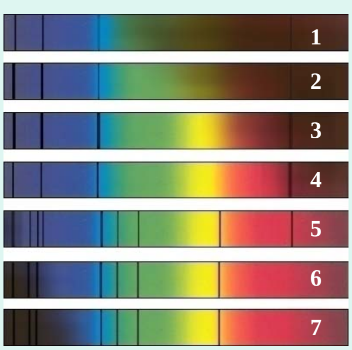


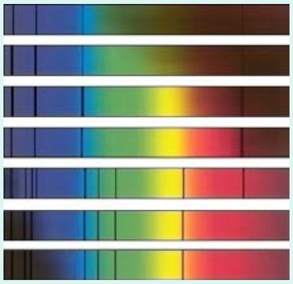
Image courtesy of the McMath-Pierce Solar Observatory

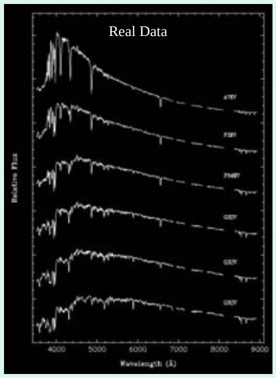
Spectra for a variety of stars



- Some stars have fewer dark lines in their spectra than the Sun and others have more dark lines than the Sun
- The dark lines are also at different positions than the Sun’s

Simulated Data



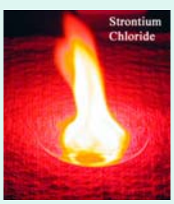


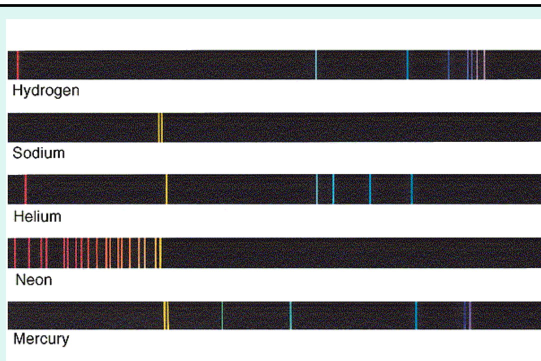
Both of these plots show wavelength vs. intensity

Experiments on Spectra of the early 1900's

Burned different elements over a bunsen burner

➔ glow different colors!!



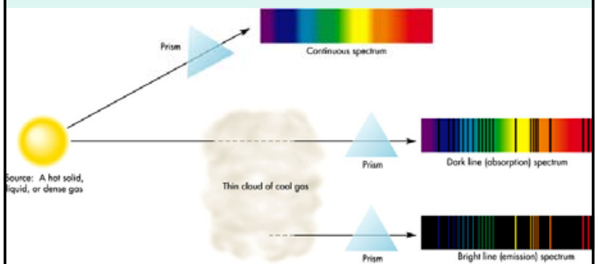


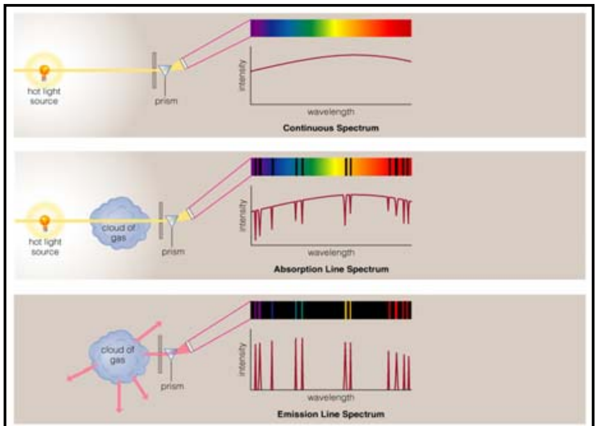
Scientists discovered that the bright lines also correspond to the dark lines

Different spectra can be explained by thinking about HOW you view the EM radiation – *either directly or through a hotter or cooler gas*

examples:

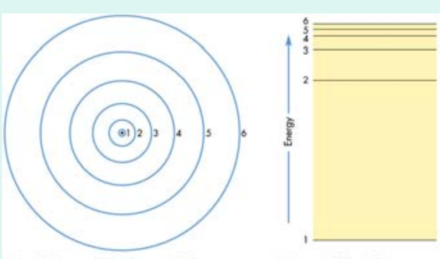
- **Earth's atmosphere**
- **Sun's layers**
- **Planet's atmosphere**





The energy levels of the Hydrogen atom:

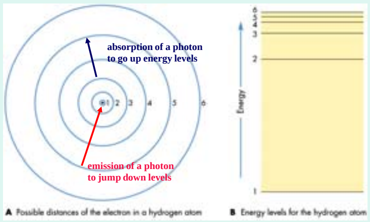
Places where the electron is located
Fixed levels by quantum mechanics
Energy levels depend on atomic make-up



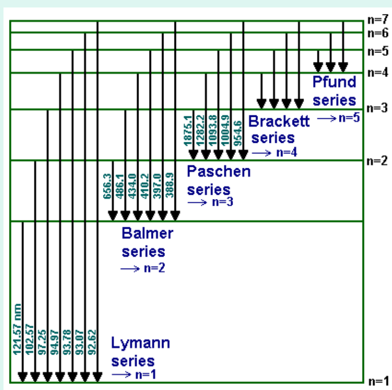
Spectral lines originate from electrons moving in atoms

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

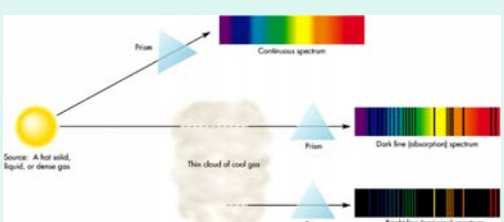
In order to go DOWN a level, electron releases energy



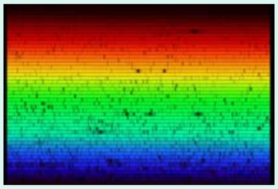
- ENERGY takes the form of EM radiation, or "photons"
- photons have wavelength which corresponds to the energy change



- **Hot solid, liquid, dense gas:** no lines, continuous spectrum
- **Hot object through cooler gas:** cooler gas ABSORBS the hotter photons (electrons go up in their energy levels)
- **Cloud of thin gas:** bright lines formed from atoms in gas colliding (excitation), electrons move down energy levels: EMISSION



Identifying the spectral lines in the Sun's spectrum

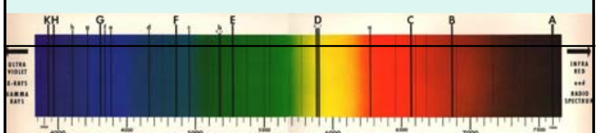


There are many dark absorption lines – what does this mean??

The Sun's cooler <u>gaseous</u> outer layers are absorbing the photons arising from the hotter inside !

Mainly ***hydrogen*** absorption lines, but over 60 different elements identified in small quantities

Identifying the spectral lines in the Sun's spectrum



O_2 at 759.4 to 726.1 nm (A)
O_2 at 686.7 to 688.4 nm (B)
O_2 at 627.6 to 628.7 nm (a)

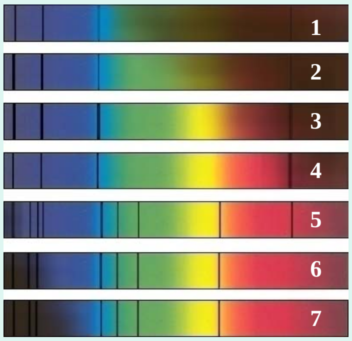
Terrestrial Oxygen – in Earth's atmosphere!

H at 656.3 nm – Hydrogen alpha line Hα (C)
→ electron moves between n=3 and n=2
H at 486.1, 434.0 and 410.2 nm (F, f, h)
Ca at 422.7, 396.8, 393.4 nm (g, H, K)
Fe at 466.8, 438.4 nm (d, e)

Identifying chemical composition of the Sun's spectrum

Element	Number %	Mass %
Hydrogen	92.0	73.4
Helium	7.8	25.0
Carbon	0.02	0.20
Nitrogen	0.008	0.09
Oxygen	0.06	0.8
Neon	0.01	0.16
Magnesium	0.003	0.06
Silicon	0.004	0.09
Sulfur	0.002	0.05
Iron	0.003	0.14

Spectra for a variety of stars



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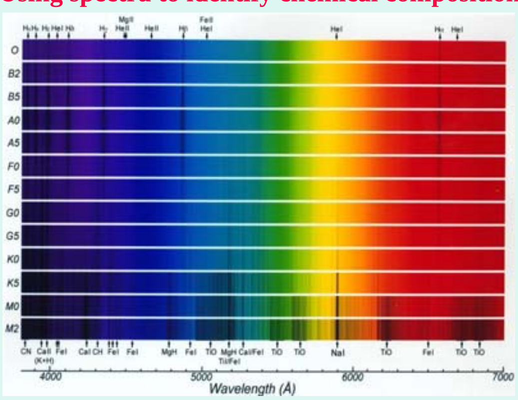
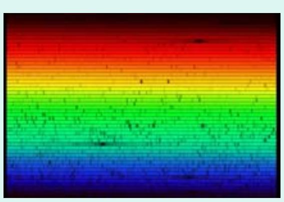
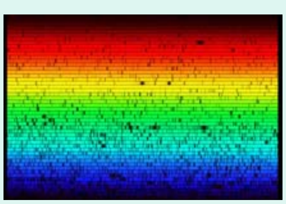
Using spectra to identify chemical compositions





Procyon (F5)



Arcturus (K1)

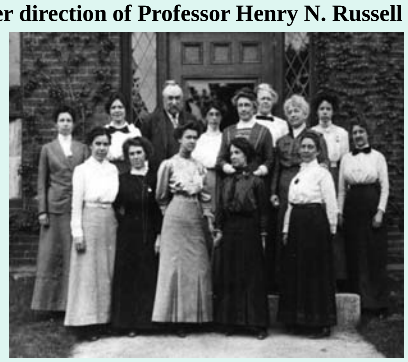
How many different kinds of spectral "signatures" are there?

What determines "signatures" of different kinds of stars?

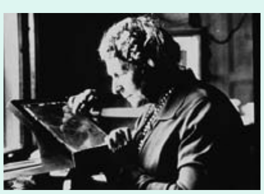
Major research effort at Harvard in the 1920's

Need to inspect many, many different stellar spectra
look for categories, patterns among them

The Harvard College Observatory: female "computers"
→ under direction of Professor Henry N. Russell



Figuring out the various types of stars



Annie Jump Cannon
(1863-1941)

1918-1924: she classified 225,000 stellar spectra!

Cecelia Payne-Gaposchkin
(1900-1979)

PhD 1925 Harvard
(first Astronomy PhD)

Figured out that different spectra were due to TEMP.

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

Differences are due to the TEMPERATURE of star

TEMPERATURE can determine:

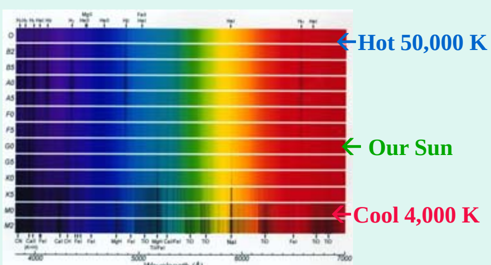
- **where the electrons are located (which energy levels)**
- **which elements have absorption, emission lines**

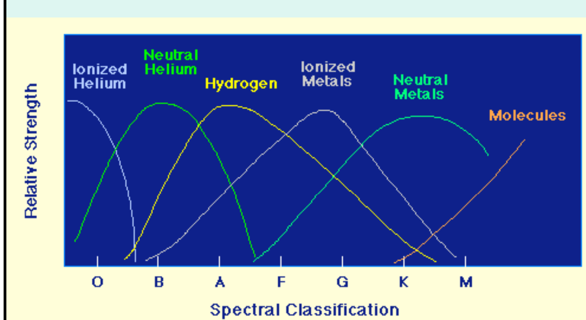
-- an O-star has a temperature of ~50,000 K

-- 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

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





Class	Color	Prominent Spectral Lines	Surface Temp. (K)
O	Blue	Ionized helium, hydrogen	> 25,000 K
B	Blue-white	Neutral helium, hydrogen	11,000 – 25,000 K
A	White	Hydrogen, ionized sodium and calcium	7,500 – 11,000 K
F	White	Hydrogen, ionized and neutral sodium and calcium	6,000 – 7,500 K
G	Yellow	Neutral sodium and calcium, ionized calcium, iron, magnesium	5,000 – 6,000 K
K	Orange	Neutral calcium, iron, magnesium	3,500 – 5,000 K
M	Red	Neutral iron, magnesium, and neutral titanium oxide	< 3,500 K