Agenda for Ast 309N, Sep. 20

- Quiz 2: light and spectra
- Card from 9/18: Doppler Effects on the Sun
- Review: fundamental forces, types of energy
- Review: some properties of stars
- Card on properties of stars
- Reading for next week:
  - Kaler, ch. 2 (pages 25 – top of page 48)
  - Wheeler, pp. 16 – 21

The Fundamental Forces

Gravity:

Works on all matter; intrinsically weak, but infinite range

Always attracts, so is cumulative: controls large bodies

Electromagnetism:

Charged matter only; stronger than gravity, infinite range

Attracts or repels, so self-cancels; special situations

Strong nuclear force:

Short-range; holds nuclei together against electric force

Weak nuclear force:

Short-range; converts particles & transmutes elements

The Fundamental Forces

CHARACTERISTICS OF THE FOUR UNIVERSAL FORCES

Force	Relative Strength	Particles Exchanged	Particles Acted Upon	Range	Example
Strong	137	Gluons	Quarks	10^{-13}cm	Binds nucleus of atom
Electromagnetic	1	Photons	Primarily electrons	Infinite $(1/d^2)$	Holds electrons to atom
Weak	1/73	Weakons	Quarks, electrons, neutrinos	$<10^{-14}$cm	Radioactive decay
Gravity	4×10^{-37}	Gravitons	All mass	Infinite $(1/d^2)$	Planetary orbits

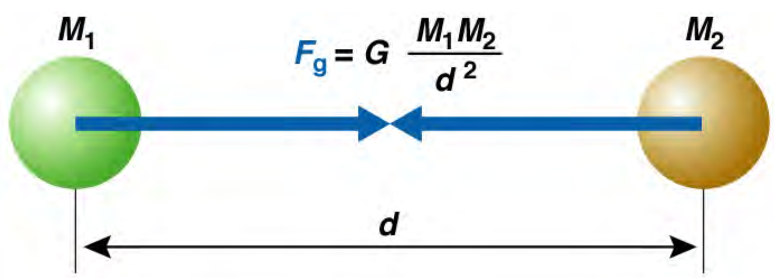
Momentum and Force

- Momentum = mass x velocity of an object
- The *rotational* or turning momentum of a spinning or orbiting object is called *angular momentum.*
- Force – an agent that can cause a change in an object's momentum
- Changing the momentum (usually) means changing the velocity, and a change in velocity is an *acceleration*.
- The amount of acceleration is related to the object's mass and the applied force, as in:

$F = m \times a$; or alternatively, $a = F / m$

How Gravity Behaves

Between every two objects there is an attractive force. Its strength is directly proportional to both of the masses, and inversely proportional to the square of the distance between the ***centers*** of the two objects.



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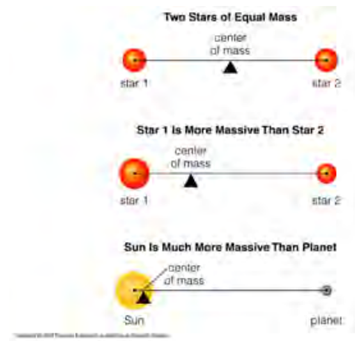
Center of Mass = Center of Gravity

- When two bodies interact by gravity, *both* experience accelerations. **Why?** Because each body feels an equal but opposite force.
- …but the more massive body experiences a smaller acceleration. **Why?** It has more mass, so it is harder to move ("inertia").



- The two bodies actually orbit around a mutual "center of mass" which lies between them but is closer to the more massive body

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Forms of Energy

- **Kinetic:** energy of motion. For $v \neq 0$, K.E. = $\frac{1}{2} m v^2$
- **Thermal:** energy of random motions of the atoms or molecules in an object (related to temperature)
- **Potential:** stored energy, related to position (e.g. height above the ground, or place in electrical field)
- **Radiation:** energy in the form of light, which is a wave of traveling electromagnetic energy
- **Mass** is in a sense the most compact form of energy: $E = m \times c^2$. One kind of energy can be converted into another, and mass can be converted into energy (also vice versa, under special circumstances).

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Conservation of Energy

1. Energy can be converted from one form to another, but the total amount (the sum of all kinds) must remain constant.

Example: A contracting protostar:

- ✧ Begins with lots of gravitational potential energy
- ✧ This is converted to kinetic energy as the cloud contracts (the outer parts falling inward)
- ✧ When the cloud becomes denser, its atoms start colliding with each other, and the kinetic infall energy is converted into thermal energy
- ✧ The protostar heats up, and radiates light energy!

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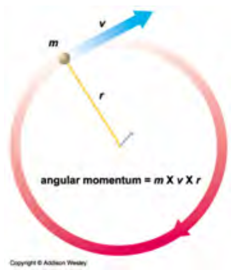
Conservation of Angular Momentum



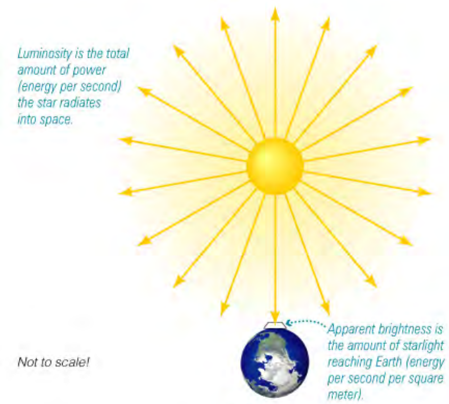
Conservation of angular momentum causes objects to rotate faster as they shrink in size (radius).

Example 1: An ice skater

Example 2: A contracting cloud forming a star

Example 3: A pulsar (spinning neutron star)

Stellar Luminosity vs. Brightness



Luminosity is the total amount of power that a star radiates in light.

Its units are energy per second = **Watts**

The intensity of the star's light that reaches us is called apparent **brightness** *b*, or more technically, **flux**, or *f*. The units are energy per unit surface area per unit time (W m^{-2} s^{-2}).

Brightness, Distance, and Luminosity

$$apparent\ brightness\ b = \frac{Luminosity}{4\pi(distance)^2}$$

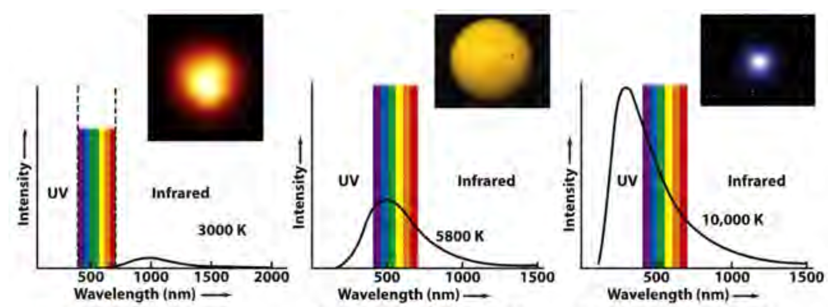
From this formula, we know that:

(1)Brightness varies *directly* with luminosity: Therefore, if *L increases*, *b increases*. If *L* decreases, *b* decreases.

(2)Brightness varies *inversely* as distance squared. If the distance <u>*increases*</u> by a factor *f*, brightness <u>*decreases*</u> by the factor $f^2 = f \times f$, and the opposite.

Temperatures from Stellar Colors

Stars of different temperatures have different relative amounts of light at different colors: more blue than red, or vice versa.



(a) A cool star with surface temperature 3000 K emits much more red light than blue light, and so appears red.

(b) A warmer star with surface temperature 5800 K (like the Sun) emits roughly equal amounts of all visible wavelengths, and so appears yellow-white.

(c) A hot star with surface temperature 10,000 K emits much more blue light than red light, and so appears blue.

Temperatures from Absorption Lines

Another method of determining a star's surface temperature is by examining the ***absorption lines*** in its spectrum. The system of **spectral types** was developed at Harvard Observatory in the 1890's by Annie Jump Cannon and her colleagues.

Figure 17-10
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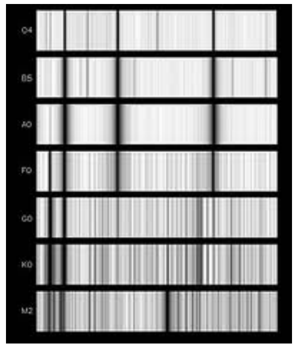

How do we Measure the Radius of a Star?

- For a few nearby stars of very large diameter, it is possible to measure the angular size with a technique called "interferometry."
- For other stars, farther away and smaller in physical (linear) extent, you're out of luck ….
- …or, are you?

Radius from Luminosity & Temperature

- The luminosity of a star is:
  Surface Area × Energy emitted per unit S.A. =
  $(4\pi R^2) \times (\sigma T^4)$ = Luminosity
- So, if you know L and T, for example, you can calculate R from this formula.
- This is, *in practice*, the way most stellar radii are estimated (indirectly, from L and T).
- A luminous star of low T must be *large;* a high-T star can only have a low luminosity if it is *very small.*

Radii from Luminosity & Temperature

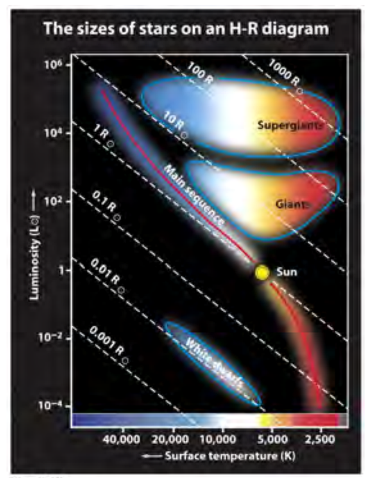

Figure 17-15b
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