Week 6 Notes
Astro 1 (Discussion Sections 101 & 102)

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Administrative Tasks

Stargazing Sign-In Sign-in was VERY popular. Too many signed up, so we'll do it again when we get closer, and we'll ask for a bit more commitment than a name.

Website Announce website, which is `www.physics.ucsb.edu/~wmwolf`. Relevant files are under the "teaching" tab.

Test Results If you still haven't gotten your test results, come and see me.

Homework My apologies for the lateness in the return of homework 3. It should be in your box now.

Midterm 2 A friendly notice that your next midterm is a week from this Friday. Thus, next week's discussion will be focused on review. Come with questions so that you get the most out of it. This test will also be open book and open notes, but it is recommended you prepare adequately beforehand, as there simply isn't enough time for you to flip through your textbook to look up every relevant topic. There will also be one free-response question in addition to the multiple choice questions. This will be graded like a homework problem by a TA.

Data Tables Note that for many questions, you need to know the radius of a planet or the distance to a moon. This data is all given in data tables at the back of the book that are at your disposal.

Questions

Concept Review

Albedo

The **Albedo** of an object is a measure of how much electromagnetic radiation it reflects. For instance, an albedo of .6 means that 60% of the radiation power is reflected away (and also that 40% is absorbed, at least temporarily).

Comprehension Questions: What do you think has a higher albedo, the moon or earth?

Answer: The Earth has a MUCH higher albedo. The moon would reflect just about as much light as it does currently if it were made out of asphalt.

Blackbody Radiation

Definition of a Blackbody A blackbody is an object that absorbs all electromagnetic radiation incident upon it.

Blackbodies also emit radiation that varies only on their temperature. The hotter an object is, the more energetic photons it will emit. The light emitted is distributed according to a blackbody curve (see Fig. 5-11). The sun is pretty close to being a blackbody. Notice that it is not at all black, despite the name. However, blackbodies at lower temperatures would appear quite black to our eyes, since their radiation would be in infrared or lower energies.

Flux and the Stefan Boltzmann Law for blackbodies In physics, we are often concerned with different types of flux, but what exactly *is* flux? For a general quantity, it can be described as:

$$\text{Flux} = \frac{\text{Quantity of interest passing through specified area in a specified time interval}}{\text{(Specified Area)(Specified Time)}}$$

As an example, consider water flowing through a tube of cross-sectional area 3 m^2. If we know that the flux of water is $F = 5\,\mathrm{kg/(m^2\,s)}$. Then we can find the total amount of water flowing past a point in the tube in a second by multiplying the flux by the total area:

$$\dot{M} = FA = 15\,\mathrm{kg/s}$$

And if we want to know the total amount of mass flowing through the tube in 2 seconds, we get

$$M = FA\Delta t = \dot{M}\Delta t = 15\,\mathrm{kg/s}(2\,\mathrm{s}) = 30\,\mathrm{kg}$$

Now, in the context of electromagnetic radiation, we usually consider the flux to be the amount of electromagnetic energy passing through an area during a given time duration. More commonly this is considered the power per unit area (energy per unit time is power). Thus, the flux is given in Watts per unit area.

This discussion is just to give you an intuition for what flux really is, in the general sense. Typically we can measure the flux of an object, determine its distance from us, and then find out the total power it is emitting through a fairly simple process. However, just knowing the flux of an object can tell us about the temperature, if it is a known blackbody. This is given through the **Stefan-Boltzmann law**:

$$F = \sigma T^4$$

where F is the electromagnetic flux at the object's surface, σ is a constant: $\sigma = 5.67 \times 10^{-8}\,\mathrm{W\ m^{-2}\,K^{-4}}$, and T is the object's surface temperature, measured in Kelvins (obviously).

Example: Surface Temperature of the Sun Suppose we know the flux from the sun (we do, it's called the solar constant and it is measured by spacecraft pretty accurately) to be $F = 1370\ \mathrm{W\ m^{-2}}$. Use this to find the surface temperature of the sun, assuming it is a perfect blackbody.

Solution: We *cannot* immediately jump to the Stefan-Boltzmann Law, because the flux we have is not from the surface of the sun. Instead, we must find the power emitted by the sun to calculate its surface flux and *then* we may apply the Stefan-Boltzmann law.

We apply the definition of flux to find the equation:

$$P = FA$$

The area the total luminosity is traveling through is the area of a sphere of radius 1 AU. This is because the sun radiates equally in all directions, and this flux was calculated near earth, at a distance of 1 AU from the sun. So,

$$P = F(4\pi(\mathrm{AU})^2$$

After converting AU to meters and plugging in the numbers, we have that

$$P = 3.90 \times 10^{26} W$$

Now we may find the surface flux. Now the area of interest is the sphere with the radius of the sun, so

$$F_{surf} = \frac{P}{4\pi R_\odot^2} = \cdots = 6.41 \times 10^7\,\mathrm{W\,m^{-2}}$$

We may now apply the Stefan-Boltzmann law to find $T_\odot$:

$$T_\odot^4 = P/\sigma = 1.13 \times 10^{15}\,\mathrm{K}^4$$

Solving for $T\odot$ yields

$$T_\odot = 5800\,\mathrm{K}$$

which is about what we'd expect.

Doppler Effect

We are all familiar with the idea of the doppler effect. The canonical example is that of a train approaching a listener, passing her, and then proceeding away. The sound of the whistle seems to increase in frequency during approach, and decrease with retreat. The same phenomenon is true of light, but changes in frequency affect “color” rather than sound’s pitch.

An equation relates the velocity of an object relative to the observer with the observed shift in wavelength from the “true” wavelength.

$$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$$

Here, $\Delta\lambda$ is the difference between the original emitted photon’s wavelength and the observed wavelength, λ_0 is the original wavelength, v is the relative radial velocity of the emitter with respect to the observer (the speed at which the distance between the two is increasing), and c is the speed of light.

Example; Blue-Shift of Vega Suppose light from vega with the telltale Hydrogen alpha line ($\lambda_0 =$ 656.285 nm arrives and is shown to have a wavelength of $\lambda = 656.255$ nm. How is Vega moving with respect to us?

We apply the above equation to solve for v.

$$v = c\frac{\Delta\lambda}{\lambda_0} = 3 \times 10^8\,\mathrm{m/s}\frac{656.255\,\mathrm{nm} - 656.285\,\mathrm{nm}}{656.285\mathrm{nm}} = -14\,\mathrm{km/s}$$

So Vega is moving 14 km/s closer to earth. However, Venus could still be moving tangentially, but we cannot detect this with the Doppler Effect. Since the wavelengths are shortened when they arrive, we say that they experience a “blue shift.” Light from objects receding from Earth will be “red-shifted.”

Questions