PHYSICS 113
Assignment #3
SOLUTIONS

Chapter 4

19. How many times brighter or fainter would a star appear if it were moved to
a) twice its present distance?
b) ten times its present distance?
c) half its present distance?

Brightness (i.e., flux or luminosity of the star) varies as $1/(\text{distance})^2$.

a) If a star were moved to twice its present distance, the ratio of the brightnesses (fluxes) = $(½)^2$ = 1/4. Thus the star would appear **four times fainter**.

b) If a star were moved to ten times its present distance, the ratio of the brightnesses (fluxes) = $(1/10)^2$ = 1/100. Thus the star would appear **one hundred times fainter**.

c) If a star were moved to half its present distance, the ratio of the brightnesses (fluxes) = $(2/1)^2$ = 4. Thus the star would appear **four times brighter**.

23. Suppose that a spectral line of some element normally at 500 nm (1 nm = 0.000000001 metres), is observed in the spectrum of a star to be at 500.1 nm. How fast is the star moving toward or away from the Earth?

This is an example of the Doppler Effect. According to the formula,

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \qquad \therefore \qquad v = c\left(\frac{\Delta\lambda}{\lambda}\right)$$

where λ is the emitted wavelength (at rest) and $\Delta\lambda$ = observed wavelength - emitted wavelength. Thus λ = 500 nm and $\Delta\lambda$ = 500.1 nm - 500 nm = 0.1 nm. Since $c = 3 \times 10^8$ m/s, therefore
$v = 3 \times 10^8$ m/s (0.1 nm / 500 nm) = 3×10^8 m/s (0.1 / 500) = 3×10^8 m/s (2×10^{-4}) = **6×10^4 m/s**.
Since the wavelength is redshifted (i.e., the wavelength is increased to a larger value), it implies that **the star is moving away from the observer** (or the observer is moving away from the star). Remember that all motion is relative!

Chapter 5

5. Compare the eye, photographic film, and CCD's as detectors of light. What are the advantages and disadvantages of each?

EYE: While the eye was the first detector of starlight, it has been replaced by various detectors. Although the eye also us to “see” objects in the universe, it is very limited: (i) it has a small aperture (the pupil constrains the area of light collection to be small [few square millimetres]); (ii) the eye cannot remain perfectly stationary; (iii) the eye is inefficient -- after a certain amount of time, the brain processes all of the incoming light but does not provide any improvement in the image quality.
FILM: Advantages are: (i) long exposure (integration) times allow us to detect very faint objects; (ii) a permanent record can be maintained; (iii) can be used to do spectroscopy. Disadvantages are: (i) inefficient (only 1% of light is actually registered on the film); (ii) one plate (film) cannot be used to observe motion (e.g., eclipses).
CCD's: There are many advantages: (i) they have high efficiency and can detect 60-70% of photons (fainter objects can thus be more easily detected in shorter integration times); (ii) the data is immediately digitized and can be easily analyzed on a computer; (iii) more accurate measurements of the brightness of the object; (iv) motion can be observed in “real time” (e.g., eclipses). There are no significant disadvantages except that CCD’s cannot cover the entire spectral range of every type of plate.

7. Why do astronomers place telescopes in Earth orbit? What are the advantages for different spectral regions?

Astronomers place telescopes in Earth orbit in order **to observe radiation from those parts of the EM spectrum for which the atmosphere would normally absorb or significantly scatter that radiation**. This includes UV, X-ray, gamma ray, and some types of infrared (IR) radiation.

Thus for the UV, X-ray, gamma ray, and parts of the (IR) spectrum, it is *necessary* to place the telescopes above the Earth’s atmosphere. But there are also advantages in other spectral regions (especially the visible). For example, orbiting optical telescopes provide superior optical images because: (i) they do not have to contend with atmospheric effects (distortion/turbulence, water vapour/clouds); (ii) they can operate 24 hours a day (always pointed away from the Sun); (iii) they can be used to observe all stars on the celestial sphere; and, (iv) they experience little light pollution. A radio telescope in orbit (or on the Moon) could be used with Earth-based radio telescopes to yield a very long baseline for interferometry; thus high resolution radio images (maps) could be produced.