## **CLASSNOTES 11**

## HINT

There is an all too common reluctance in answering Part B Questions: (1) to cram the answer into the smallest possible available space, and (2) to give a phrase or two rather than a paragraph of enjoyable English. Few Part B questions of a homework exercise or a quiz can be tackled successfully without composing a paragraph of several complete sentences ordered in a logical sequence.

Astronomy 301

### SQUARING A QUANTITY

The light gathering power of a telescope is proportional to the AREA of the primary mirror (lens). We customarily specify a telescope's size by the DIAMETER of the primary mirror. The area A and diameter D of the mirror are related:

A proportional to  $D^2$ .

If the mirror is circular, A = $\pi D^2/4$ . Life is simpler if we think of square mirrors and then A = D<sup>2</sup>. (The area of the square is obviously larger than that of the circle of the same diameter but the difference is small:  $\pi/4 = 0.79$ .)

Newton's law of gravity states that the force decreases with increasing separation (d) between two mass *m* and *M* as  $F = Gm M/d^2$ .

Inverse-square law of brightness relates the brightness, luminosity, and distance of an astronomical object: *B* is proportional to  $L/d^2$ .

To understand the above three issues, we do need to grasp what is meant by  $d^2$ . Too many answers suggest a lacuna in your math knowledge at this point. It is not a difficult concept to grasp. I hope the following is helpful. Your comments are, as always, welcomed.

 $d^{2}$  is shorthand for d x d:  $2^{2} = 2 x 2 = 4$   $5^{2} = 5 x 5 = 25$   $10^{2} = 10 x 10 = 100$   $9^{2} = ?$  $(3d)^{2} = ?$  The answer is not  $3d^{2}$ . Suppose the diameter of the mirror is tripled from *d* to 3*d*, by how many times does the LGP increase? It increases by the ratio of  $d^2$  to  $(3d)^2$ . Here,  $(3d)^2$  means  $3d x 3d = 3 x 3 x d x d = 9 x d^2 = 9d^2$ . There is a ninefold increase — **ninefold** not **threefold**.

Introduction to Astronom

If the distance between two masses is increased 25 times from *d* to 25*d*, the force between them due to gravity decreases. How many times weaker is it at 25*d* than at *d*? The key quantity is not  $25d^2$  but  $(25d)^2$  or  $25 \times 25 \times d^2 = 625d^2$ .

#### **KEY POINTS FROM CHAPTER 8**

A few basic points about the Sun:

- It is a star, a very average star.
- Its spectral type is G2V.
- It rotates. A complete turn takes about 25 days at the solar equator. Rotation rate decreases with increasing latitude.
- The Sun is gaseous throughout: denser at the center than at the surface. The average density is about 40% higher than that of water. (Density = Mass/Volume)
- The surface temperature is about 6,000 K. Temperature increases inwards reaching about 15 million K at center. The temperature also increases outwards from the visible surface reaching 1 to 2 million K in the corona.
- The Sun feeds a wind -- the solar wind -- and we orbit in the wind.
- The chemical composition (see Seeds, Table 8-1): simply 92% H, 8% He, and 0.1% of all other elements by number of atoms.

The Sun is the star for which we have the most comprehensive set of observations. Yet, it is not a 'dead subject.' I would note four areas of great current interest:

- Solar seismology
- Solar neutrinos
- Solar corona and wind
- Sunspot cycle

Keep these in mind as you read Chapter 8. Solar neutrinos, which will be highlighted in class, are discussed in a later chapter.

Here is a brief description of the Sun as a star from "Stars and Atoms" by Stuart Clark (OUP, 1995). (I find this to be a very useful book.)

The Earth and the other eight planets orbit a star: the Sun. It is an ordinary stellar body but looks different from the stars in the night sky because it is so close to us -149.6 million kilometers away. It is more than one hundred times the diameter of the Earth, with nearly one third of a million times more mass.

Unlike the rocky Earth, however, the Sun is composed (by mass) of 73 percent hydrogen and 25 percent helium. The remaining 2 percent is made up of the heavier elements. The Sun is a population I star -- a slower-moving star found in the spiral arms of a galaxy, and believed to be relatively young.

The Sun is a fairly typical star. It has been shining for just over four and a half billion years, and will continue to do so for another four and a half billion, placing it firmly in stellar "middle age." It has an inner core (400,000 km across) in which a nuclear fusion reaction converts hydrogen into helium accompanied by the release of vast amounts of energy in the form of heat and light. Compared with other stars throughout the universe, the Sun is unremarkable in size or luminosity.

Being composed of gas, the Sun has no solid surface. What appears to an observer on Earth to be the visible surface of the Sun is actually a gaseous layer in which conditions promote the emission of electromagnetic radiation at visible wavelengths. Observing

the sun at other wavelengths -- for example X-rays, ultraviolet and so on -- allows us to see other "surfaces" to the Sun, either above or below the visible surface (known as the photosphere), depending upon the wavelength being observed. The dark atomic absorption lines in the Sun's spectrum are imposed on the Sun's light by atoms and ions in the cooler upper levels of the photosphere and in the lower part of the chromosphere, the region of gas just above it. These regions form the lowest layers of the Sun's atmosphere, above which is the more rarefied corona.

## **KEY POINTS FROM CHAPTER 9**

Stellar Distances - Why Do We 'Need' Distances?

- method of trigonometrical parallax (the Surveyor's Method)
- the parsec
- limit of the Method

### Luminosity and Brightness

- the inverse square law (no not another one!) (Be able to prove it.)
- Do not worry about absolute magnitude and distance modulus. We have already used and shall continue to use the relationship.
- L,R,T L =  $R^2T^4$

### The H-R Diagram (VERY IMPORTANT)

- nearby stars
- the brightest stars
- names of the principal regions
- spectroscopic parallax
- Stellar Luminosity Function

# **KEY POINTS FROM CHAPTER 10**

Binary Stars and Stellar Masses

- types of binaries
- mass-luminosity relation (IMPORTANT)
- Seeds says  $L = M^{3.5}$ , but  $L = M^4$  is nearer the truth and simpler to use.

### A note on parallax measurement

Figure 9-2 shows the stellar parallax to be the angle p at the star. The angle referred to as the parallax (p) is the angle at the star subtended by the radius of the Earth's orbit around the Sun. Obviously as p decreases the star's distance from us increases. Mathematically we may write d = 1/p. The unit of distance known as the parsec is the distance at which p is equal to 1 second or arc. Then, d[pc] = 1/p [sec arc].

You may wonder how from Earth we can measure this remote angle. This sketch shows how angles measured by us enable us to calculate the inaccessible angle *p*.

The three arrowed lines point to the same very distant star (hence, the lines may



be drawn as parallel). At  $E_1$ , we measure the angle between this distant star and the nearby star of interest - angle is marked  $\alpha$  on the figure. Six or so months later, we observe the same pair of stars. Now the nearby star lies to the opposite side of the distant star -- angle is marked  $\beta$ .

Since the three arrowed lines are parallel, the angles at the star are as marked,  $\alpha$  and  $\beta$  (OK?). The parallax angle is  $p = (\alpha + \beta)/2$ . Hence, p is calculable from the measurements of  $\alpha$  and  $\beta$ .