SPASH ASTRONOMY

CHAPTER 5: LIGHT AND THE SPECTRUM: MESSAGES FROM SPACE

1. Does light move as a particle (like a bullet or spit wad) or as a wave (like a water wave, or a sound wave)?

Light spreads out through space something like a wave in which energy is carried by tiny, particle-like photons. Consider a platypus. It has some duck-like and some beaver-like properties, but it is neither. Similarly, light has some wavelike and some particle-like properties, but it is neither a pure wave nor a pure particle.

2. What causes light to exist?

All matter is made up of atoms. All atoms have a massive nucleus with electrons swarming in discrete electron clouds (shells) orbiting the nucleus. If an electron is given enough energy (either by heating, or bombardment) the electron will take what they call a quantum leap to the higher electron cloud. The electron is unstable in this higher energy state and eventually returns to its lower energy state (or electron cloud). It is when the electron returns to the lower energy state that a photon of light is released. Light from stars is a byproduct of the fusion reaction.

3. Name the main parts of the electromagnetic spectrum: (From shortest to longest wavelength)

Cosmic rays, Gamma rays, X-rays, Ultra-violet, Visible, Infrared, Micro-waves, Radio waves, Transmission waves

4. Why do they call all types of light electro-magnetic?

Note: The answer to this question also explains how light can travel through the vacuum of space. A photon sets up an electric field in one dimension which in turn sets up a magnetic field perpendicular to the electric field in a second dimension which in turn sets up a electric field, which sets up a magnetic field, which creates a electric field, etc. and the photon moves in the third dimension, perpendicular to the electric and magnetic fields. That is why when you drive near high lines your radio signal is affected.

5. As the wavelength of a light wave decreases, what happens to its frequency (Note: A light wave's speed is always constant in a given medium)? Why is it that the bluer the light, the shorter the wavelength and the more energetic the photon?

Since speed = wavelength times frequency

And the speed stays the same number in any given medium, as the wavelength decreases the frequency must increase

The energy of a photon is directly proportional to its frequency so as the freq. increase the energy increases.

6. What is the speed of light in a vacuum in miles/sec, in m/sec, in cm/sec?

186,000 miles/sec equals 3×10^{8} m/sec equals 3×10^{10} cm/sec

7. Who is ROY G. BIV? Nobody really, this acronym just helps one remember the spectrum of visible light as one passes white light through a prism.

8. When using spectroscopy to study the light from our sun, where does sun's dominant wavelength radiation occur?
At greenish-yellow (picture page 86) (that is why our Sun is considered a medium star)

9. What is temperature and why is absolute zero Kelvin so important?
Since the average kinetic energy (motion) of the molecules of a substance determines its temperature the faster the molecules are moving the higher its temperature. They are not aware of the highest temperatures (probably the center of the largest stars) but they do know there is a point at which molecules can move no slower and this temperature is called absolute zero Kelvin or -273 degrees C or -459 degrees F. (note table 5-1 page 87)

10. What is Wien's law? The hotter an object, the bluer the radiation it emits. Now you can understand why you can't see the thermal radiation from ordinary objects or planets: They are too cold, and hence the radiation is too red; they give off infrared radiation.

11. What is the difference between emission lines and absorption lines? Emission lines are bright lines in the spectrum of light given off by electrons returning to the ground state from an excited state whereas absorption lines are dark lines in the spectrum where electrons have gained energy to go to an excited state from a ground state and thus those wavelengths are missing from the spectrum.

12. Name at least three problems our atmosphere gives Astronomers?
First, clouds block much of our view of space. One reason for putting observatories on top of mountains is to get above the clouds. Secondly, is to get above the dense, shimmer air that makes telescopic star images dance and twinkle when seen from sea level (twinkle, twinkle, little star). Thirdly many atmospheric molecules, such as water molecules, strongly absorb infrared light just beyond the reddest wavelengths we can see.

13. What are the three functions of a telescope?
First and most obvious, it magnifies the image of an object to a larger angular size than we perceive with our naked eye. The second function is resolution - the ability to discriminate fine detail. Whereas the eye can resolve angular details only a few minutes of arc across, a telescope might show details a hundred times smaller, only a second of arc across.
The telescope's third function is light-gathering power - the ability to collect light and reveal fainter details than the naked eye can see.

14. What is the difference between a refracting telescope, and reflecting telescope, and a compound telescope? A refracting telescope uses a lens to bend or refract light rays to a focus (Galileo 1609) whereas a reflector uses a curved mirror to reflect light rays to a focus (Isaac Newton 1668) and compound telescopes have combined lenses and mirrors.

15. Name at least two advantages of reflecting telescopes over refracting telescopes:
1. Since red and blue wavelengths are bent by different amounts, there is no true focal point in a refracting but a reflecting reflects all wavelengths the same thus one distinct focal point.
2. Large refractors have large and heavy lenses, which must be supported around the edge, and they may sag slightly in the middle (largest aperture 1 meter), distorting the image; reflectors use a curved mirror (largest aperture 8 meters), which can be supported across its back surface.
3. Large refractors are long and thin, so they suffer from flexure.

16. In any given telescope, the magnifying power, or power as it is usually called, is controlled by the eyepiece. What three effects limit the magnifying power that can be used?
1. Higher powers magnify air turbulence, and too high a power causes the image to shimmer hopelessly.
2. As magnification is increased, the image gets fainter and fainter because the light is spread out over a larger and larger area. Too high a power gives a hopelessly faint image.
Generally, the amount of detail that can be seen on astronomical objects depends ultimately on the stillness and clarity of the air and on the telescope aperture, since these control both the useful magnifying power and the light-gathering power.
3. Due to fundamental properties of light waves, a telescope of A-cm aperture cannot resolve details smaller than 12/A seconds of arc. Thus a 12-cm telescope can resolve about 1 second, but nothing smaller. Therefore, too high a power gives a hopelessly fuzzy image.
The maximum useful magnifying power for most Earth-based telescopes on most nights is about 20Xper cm. of aperture. Example: a 5-cm telescope might be used at 100X; a 15-cm at 300X, and a 30-cm at 600X.

17. How does one observe the Sun with a telescope?
A NORMAL TELESCOPE SHOULD NEVER, UNDER ANY CIRCUMSTANCES, BE POINTED AT THE SUN. One usually starts by putting an opaque card over the objective with a new aperture as small as 1 or 2 cm, then projecting the image onto a white card so it can be viewed.

18. Why do photographs of faint objects turn out better than with the naked eye?
Faint objects like nebulae and galaxies are usually better shown in photos, because **light can be accumulated in long exposures** whereas the eye cannot "store" light.

19. What is the most recent advancement in the field of photometry (measuring an object's brightness)?
Electronic detectors. The most important type of electronic detector is a charge-coupled device, commonly known as a CCD. CCDs are extremely light-sensitive detectors, made possible by microelectronic technology (CCDs are found in most camcorders, for example). A CCD on a large telescope can produce images of light sources that are roughly a billion 10^9 times fainter than the eye can see!

20. What is spectrophotometry?
Measure the total amount of light coming from an astronomical object is important but so is the intensity at each wavelength. Spectrophotometry is done by passing the light through a spectroscopic device that breaks the light into different colors before it enters the electronic detector. Then the detector can measure the amount in each color (that is, wavelength) range.

21. How do city lights threaten astronomy and what can be done about it besides getting rid of all the light?
The glow from these cities lights up the sky, reducing the contrast between faint stars and the dark sky background.
Many cities have acted to protect the investment in nearby observatories by adopting only streetlights that emit minimally disruptive wavelengths of light and by installing hoods that block lights from shining up into the sky.

22. What are some of the advantages and disadvantages of telescopes in space (space astronomy)?
Space astronomy offers three distinct advantages. 1). It opens up spectral regions that cannot be observed from the ground. 2). It offers an environment where the optical and infrared backgrounds are very low. 3). It allows telescopes to operate outside the blurring effects of the Earth's atmosphere.
The main disadvantage is the expense so many of these missions are joint ventures between two or more countries.

23. Name at least one major telescope in space for each group of the electromagnetic spectrum?

Radio - International VLBI Satellite (IVS) 25 meters mirror diameter.
Infrared - Stratospheric Observatory for Infrared Astronomy (SOFIA) 2.5 meters.
Visible, Ultraviolet – Hubble Space Telescope (HST) 2.4 meters.
Ultraviolet – Extreme Ultraviolet Explorer (EUVE) 0.8 meters.
X-ray – X-ray Multiple Mirror Mission (XMM)
Gamma ray – Gamma Ray Observatory (GRO) [Note Table 5-3 page 106.]

24. What is interferometry?
Interferometry involves the use of widely separated telescopes in a special arrangement to increase the resolution of fine details in astronomical objects.
Although it is now impossible to build a mile-wide telescope, it is easy to build two big telescopes and locate them a mile apart.
With the technique of interferometry, astronomers have been able to measure incredibly small angular details - 2 or 3 ten-thousandths of a second of arc - in distant stars and galaxies.
Astronomers in 1986 achieved the first space-based interferometry using a radio telescope in space linked to one on the ground, thus increasing the baseline to distances wider than the diameter of the Earth.