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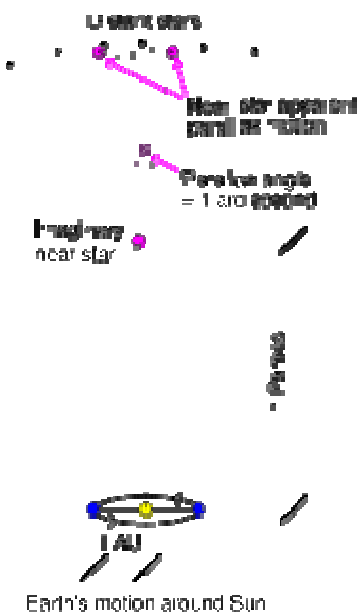
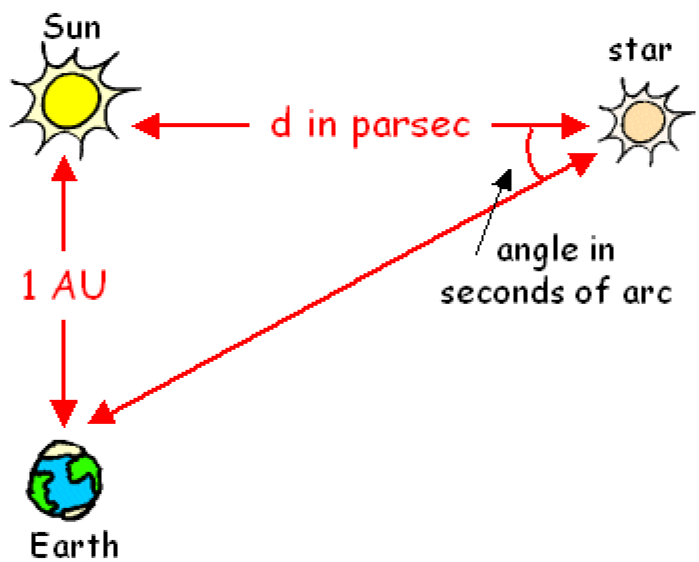
EE 106 – Planetary Exploration

Problem Set IV
Astronomical Instruments
Other Worlds

Problem 1 – The Parsec

The parsec is an astronomical unit of distance approximately equal to 3.262 light years. Short for "parallax for one arcsecond," the parsec expresses the distance of a star from Earth in terms of observable parallax, which early astronomers used as a simple (but crude) means to judge the distance of a star. Most likely, before humankind knew the exact distances of stars from Earth, the amount of motion of stars in the sky from Earth's revolution provided the most logical means of estimating their distance.





By definition, the parsec is the distance of a star at which 1 astronomical unit (AU) perpendicular to the line of sight subtends 1 arcsecond; in other words, one parsec is the distance from Earth to any star with a parallax of 1 arcsecond. As its name suggests, the parsec originated from the use of trigonometric (angular) parallax to determine the distance of a star from Earth. From the right triangle depicted above, we can ascertain the equivalence of a parsec:

$$\tan(1\text{ arcsecond}) = \frac{1\text{ astronomical unit}}{1\text{ parsec}}$$

$$1\text{ parsec} = \frac{1\text{ astronomical unit}}{\tan(1\text{ arcsecond})}$$

$$1\text{ parsec} = \frac{1\text{ AU}\left(\frac{1.496\ \times\ 10^{11}\text{ m}}{1\text{ AU}}\right)}{\tan\left(\frac{1}{3600}\text{degrees} \times \frac{\pi\text{ radians}}{180\text{ degrees}}\right)}$$

$$1\text{ parsec} = \frac{1.496\ \times\ 10^{11}\text{ m}}{\tan(4.8481368 \times 10^{-6}\text{ rad})}$$

$$1\text{ parsec} = 3.085721 \times\ 10^{16}\text{ m}\left(\frac{1\text{ light year}}{9.461 \times\ 10^{15}\text{ m}}\right)$$

$$\boxed{\mathbf{1\ parsec \approx 3.262\ light\ years}}$$

Problem 5.3 – Size of a Telescope Aperture

In the context of telescope aperture size, bigger is better because the resolving power of a telescope depends intimately on the amount of light that the telescope can gather. For example, the naked eye fails to perceive fine detail on distant stars because very little light from the star enters the small aperture of a human pupil; meanwhile, larger instruments can bring stars into focus because they can gather more light and hence accumulate a more intense, focused image. In fact, the amount of light a telescope can collect increases with the *square* of the aperture diameter, meaning that instruments with larger light-receiving openings gather quadratically more light.

Problem 5.18 – Very Long and Very Short Wavelengths

Radiation emissions of very long (radio) wavelengths could originate from electrons moving in magnetic fields; synchrotron radiation from ultra-relativistic electrons moving at extremely high speeds is a common source of long-wavelength electromagnetic radiation, as most astronomical objects are not cold enough to emit blackbody radiation at such long wavelengths. Most long-wavelength radiation in the universe is non-thermal.

On the other hand, short-wavelength light originates from a variety of astronomical objects around the universe. Hot gases, such as those witnessed in the Sun, emit x-ray wavelengths; the solar corona, too, is so hot that it, too, emits x-rays. Extremely high-energy processes also emit high-frequency radiation; explosions of volatile stars, the birth of new stars, and other comparably violent or high-energy events often yield energy transitions of such great magnitude that emitted photons constitute gamma rays at very short wavelengths.

Problem 6.4 – Craters on the Moon and Earth

As thoroughly explained on page 167, the Moon's surface contains many more craters than Earth's surface because it has been a lot longer since the Moon changed geologically. In sharp contrast, the Earth's young surface continues to morph; the motion of plate tectonics constantly renews Earth's crust, eradicating evidence of past craters. It is this constant geologic activity that cleans Earth's surface continuously, preventing craters from accumulating, whereas the Moon's surface long ago ceased activity, leaving all of the craters since the last event exposed and unchanged on the lunar surface.

Problem 6.5 – Asteroids and Comets

Asteroids comprise primarily solid rock and metal, whereas comets consist of frozen gases such as water, carbon monoxide, and methyl alcohol. While both asteroids and comets remain from the formation of the solar system, asteroid composition is mainly rock and metal, while comet composition contains ice and frozen gases. Most asteroids orbit the Sun in the space between Mars and Jupiter, whereas comets tend to orbit the Sun in much more distant, cooler regions.

Problem 6.12 – Differentiation of Planets and Asteroids

Differentiation occurs because an astronomical body was once hot enough to melt and henceforth fluidly separate into layers of varying density before cooling into place. A planet like Venus once possessed sufficient heat for melting and subsequent differentiation, but a small asteroid like Fraknoi, with no internal energy source, never heated to melting point and therefore never possessed the fluidity necessary for differentiation. Thus, asteroids retain their original composition and structure.