II. Stellar Luminosity

Note: Luminosity is an absolute quantity. In order to measure luminosity you must understand the difference between apparent and absolute quantities. In order to determine the luminosity of a star you must first measure its apparent brightness and its distance.

1. Apparent vs. Absolute quantities (e.g. brightness vs. luminosity)
   The most important concept to understand is the distinction between
   - apparent quantities (e.g. brightness)
   - absolute quantities (e.g. luminosity)
   In simple terms, absolute quantities measure how the star really is while apparent quantities measure how a star appears to be. Apparent quantities are what are measured at the telescope. What is then needed to calculate the corresponding absolute quantity is the distance between you, the observer, and the star.

2. Measuring stellar distances – the concept of parallax
   In astronomy, the key to determining distances to astronomical objects is the concept of parallax. Parallax refers to the angular movement of an object, with reference to a more distant and fixed background, when observed from two different viewing locations. By knowing the distance between the two observing points and the parallax angle (p), you can determine the distance (d) to the object using a right triangle.

   **Example:** hold your thumb at arms length and view it alternately with the right eye (left eye closed) and then the left eye (right eye closed) and then note how your thumb appears to jump back and forth when compared to a distant background. The angular movement of your thumb is approximately 6 degrees, and the parallax is defined to be half that, or 3 degrees. The distance between your nose and either the right or left eye is typically 1.5 inches. The distance of your thumb from your nose is given by the formula \( d(\text{in}) = \frac{1.5\text{in}}{\tan(3\text{deg})} = \frac{1.5\text{in}}{.0524} = 28.6\text{in}. \)

   The above example is an interesting way to determine the length of your arm, and it can also be applied to the nearby stars. In the case of the stars, we simply substitute for your right and left eye, two positions of the Earth separated by 1/2 Earth year, which will then correspond to a change in viewing distance of 2 AU. If a nearby star, viewed at these two times, appears to move by 2 arcseconds with respect to the background of much more distant stars, then its distance - computed just as in the above example - turns out to be 1 parsec! This is actually the definition of a parsec. To a very close approximation (i.e. for such small angles as an arcsec) the parallax angle (p) when measured in arcsec is related to the distance (d) measured in parsecs, by

   \[ d(\text{parsecs}) = \frac{1}{p \text{ (arcsec)}} \]

3. Inverse square law -- To calculate absolute quantities from apparent quantities you use the inverse square law which says that an object's brightness varies as the inverse square of its distance from the observer.

4. Luminosity
   When we use the term luminosity, we are referring to the absolute brightness of a star. A star’s apparent brightness (i.e. measured in units of watts per square centimeter at the telescope) is related to the star’s absolute brightness or luminosity (by the inverse square law) by multiplying the apparent brightness by \( 4\pi D^2 \).

   **Magnitudes** -- Your book discusses the measurement of stellar brightness in terms of the historic astronomical term “magnitudes”, but we will not make much use of this term in this course.