Astronomical Unit & Arc Second in Astronomy

Yao Zhang

The guy is a populace

https://zhims.github.io/

Dec 18, 2019

Astronomical Unit

The astronomical unit (AU) is the distance from the earth to the sun. It is measured from the center of the earth to the center of the sun.

Actually the distance from the earth to the sun varies about 1.7% during the year since its orbit is elliptical. Prior to 1976 the AU was defined as the semi-major axis of the earth's orbit but in 1976 the IAU redefined it to be the average distance to the sun over a year.

Its standard (1996) value is $1.495978707 \times 10^{13}$ cm.

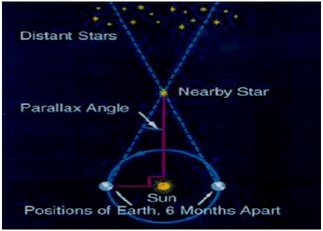
Astronomical Distance Determination

For relatively nearby sources, one can measure distances by "surveying" - by measuring the very small angles that a star's position is displaced relative to very distant objects because of the motion of the Earth around the sun. Prior knowledge of the AU is essential here.

For more distant objects one uses either "standard candles" that are calibrated from nearby sources or a theoretical model.

Obtaining Distances by Parallax

This displacement is twice the parallax angle. The displacement oscillates with a period of one year.



More complicated if the stars are actually moving with respect to the sun, but this can be adjusted for. Make many measurements over a long time span.

Remark 1

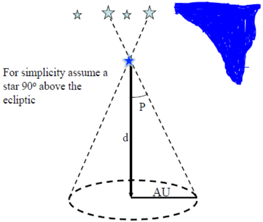
Angles are exaggerated. For "distant stars" may even use extragalactic objects

History of Parallax

- The first parallax of a star, 61 Cygni, was measured by Bessel in 1838. Measured 0.314 arc sec, today a more accurate value is 0.287 arc sec.

- Since that time, parallax has been considered the most direct and accurate way to measure the distances to nearby stars. But the farther away they are the more technically challenging the observation becomes. Must measure extremely small angles – much, much less than 1 second of arc.

Parallax



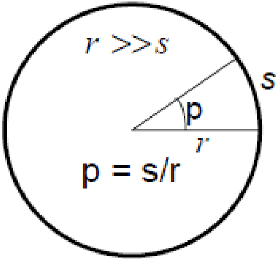
For small angles, $p \ll 1$, measured in radians.

$$\sin p \approx p, \quad \cos p \approx 1, \; \frac{AU}{d} = \tan p = \frac{\sin p}{\cos p} \approx p \tag{1}$$

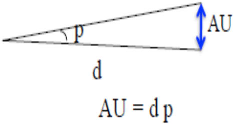
therefore

$$d = \frac{AU}{p} \quad \text{if } p \text{ measured in radians} \tag{2}$$

Parallax



(a)



(b)

$$1 \ radian \ = \frac{360}{2\pi} = 57.296\cdots^{\circ} \tag{3}$$

$$s = rp \ \ if \ \ and \ only \ \ if \ \ p \ is \ measured \ inradians. \tag{4}$$

Arc Second

But astronomers actually report the angle p in seconds of arc. 1 radian is $\frac{360^\circ}{2\pi} = 57.296\cdots^\circ$ and each degree is 3600 arc seconds. so

$$1 \; radian \; = \; 206,265 \; arc \; seconds \tag{5}$$

so

$$p \; in \; radians \; = \; \frac{1}{206,265} \; p \; in \; arc \; sec \tag{6}$$

Thus for p measured in seconds of arc (call it p''), then

$$d \; = \; \frac{AU}{p \; (in \; radians)} \tag{7}$$

then

$$d \; = \; \frac{206,265 \; AU}{p''} \tag{8}$$

1 AU seen from one parsec away would subtend an angle of 1 arc second.

Arc Second

Finally, we can get

$$d = \frac{1 \ par\,\text{sec}}{p''} \tag{9}$$

p'' = parallax angle measured in seconds of arc. This defines the parsec, a

common astronomical measure of length. It is equal to 206,265 AU's or 3.0856×10^{18} cm. It is also 3.26 light years. A little thought will show

that this also works for stars whose position is inclined at any angle to the ecliptic. What p measures then is the semi-major axis of the "parallactic ellipse" .

Last But Not Least

Thank you all of you! –Yao