6.2: Standard Ruler

Learning Objectives

- You will know the standard ruler principle and when it applies
- You will be able to interpret examples from everyday life and from astronomy
- You will be able to perform calculations and understand conceptually the small-angle formula: which relates distance and angular size

What Do You Think: Standard Ruler

A common way to estimate distances, one we use all the time without even thinking about it, is the essence of the standard ruler technique in astronomy. If you see a friend in the distance, you have a sense of how far away she is because you see her apparent size and compare that to your knowledge of how big she would look if she were right next to you. To do this, your brain is automatically drawing on the principle of perspective: objects appear smaller the farther away they are from you.

Mathematically, this can be expressed as:

$$d = \frac{S}{\theta}$$

where d is the distance, S is the size of the object, and θ is the apparent angular size of the object. You might recognize this as the small-angle approximation. This is also the parallax relationship turned around, because both use the same principle of geometry: given the length of one side of a right triangle and an angle, you can find the length of the other side.

In the standard ruler method, we must compare the observed angular size of an object to its known intrinsic size to calculate its distance. This can be used for everything from figuring out the length of your arm to measuring the distances to galaxies.

Distance to Your Thumb

Worked Example:

1. As an example, hold your thumb out at arm's length. The width of your thumbnail spans about 1 degree. If you know that your thumbnail is 1 cm across, you can figure out how far away it is using the small-angle approximation.

We will assume that a thumb subtends an angle of about 1 degree when held at arm's length and use that to estimate the length of an arm. We will also assume the true width of a thumb is about 1 cm. Then we can use the small angle relationship.

$$\theta = \frac{S}{d}$$

As previously, S is the size (width) of a thumb and d is the distance to it (the length of an arm). We can now solve this for d.

$$d = \frac{S}{\theta}$$
$$= \left(\frac{1\,\text{cm}}{1\,\text{deg}}\right)\left(\frac{180\,\text{deg}}{\pi\,\text{radians}}\right)$$
$$= 57\,\text{cm}$$

Notice that we had to convert from degrees to radians to use the small-angle approximation. The degrees cancel and radians are not really a unit (being the ratio of two distances), so we are left with cm for the answer.

Questions

Of course, your thumb and your arm might be slightly different from these measurements. The angle subtended by your thumb also might not be exactly a degree, but this illustrates the method of the standard ruler for measuring distances to objects.

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The same principle that you just used in the activity can be used in astronomy. If we know, for example, how big a galaxy really is, and if we measure its apparent size on the sky, then we can measure the distance to it. The trick is to find objects whose inherent size we know to serve as standard rulers. In astronomy, we can use the small-angle approximation because astronomical objects are typically so far away that they subtend very small angles. Even 1 degree is small enough for this, and most astronomical objects are even smaller; the full moon is only half a degree across, to give a concrete example.

Standard Ruler: Using Your Hands to Measure Angles

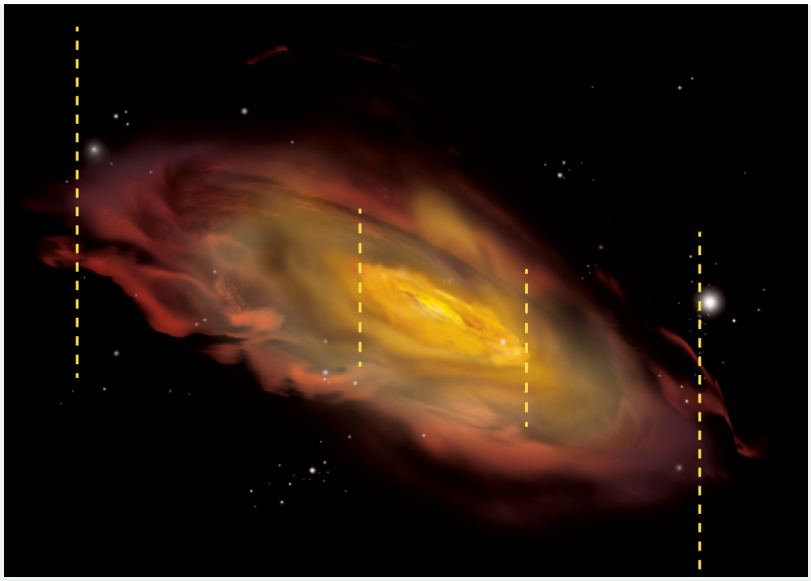

Figure A.6.2: Artist's conception of a galaxy. Credit: NASA/SSU/Aurore Simonnet

A. Measurements.

To see how the standard ruler technique works quantitatively in everyday life, you will be investigating the relationship between size, distance, and apparent angular size. You will need a ruler or a tape measure to do this activity.

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4. Now use the graphing tool to plot your data from the summary table on a graph, so that distance from the screen is on the x-axis, and angular size in degrees is on the y-axis. Use the default color to plot the data for the disk. When you have plotted the three points for the disk, click the box with the plus underneath the Data Set Control panel to add a second data set and choose a different color for the points for the core. Now add the data points for the core to the graph using this new color.

B. Discussion

1.

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Standard Ruler in Astronomy

In this activity, you will see four different spiral galaxies. In the standard ruler method, all of these galaxies are assumed to have the same intrinsic size. Therefore, the relative sizes of the galaxies will provide information about their relative distances. To do the activity:

- Hover over each galaxy to reveal its apparent size.
- Rank the galaxies in order of increasing distance using the selection boxes below the images.
- Click “submit” to check your answer.
- Click “reset” to reshuffle the galaxies, and try again, if desired.

Play Activity

Several types of astronomical objects have been studied in the hope of using them as standard rulers, for example, the diameters of galaxies or the largest ionized gas clouds in a galaxy. Unfortunately, many have not turned out to be very “standard” in size, but instead, have too much variation in their intrinsic size to be useful rulers.
