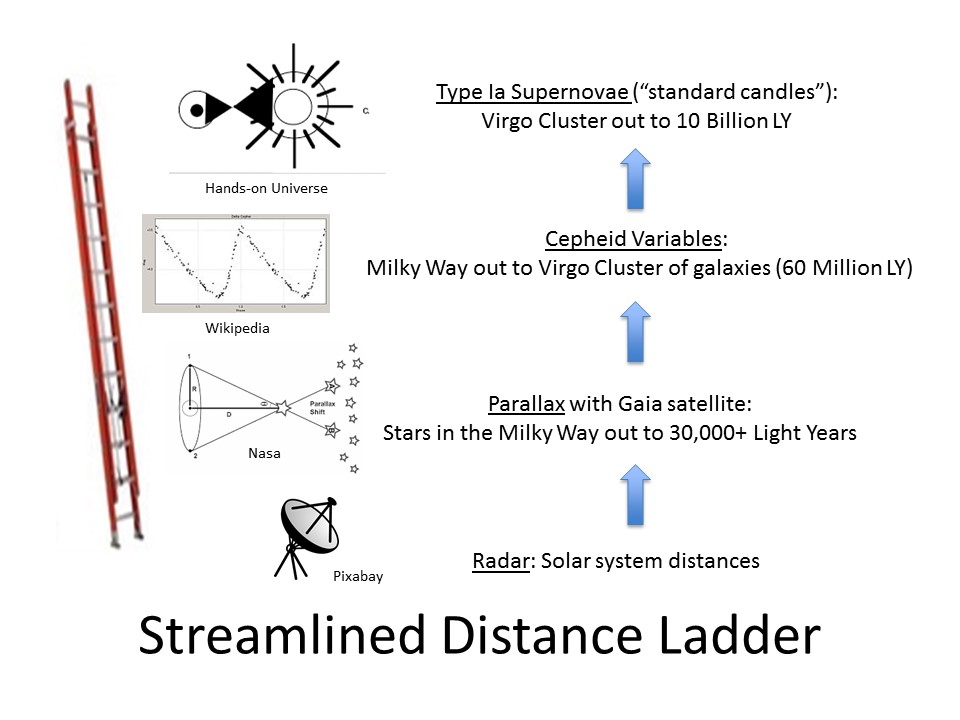
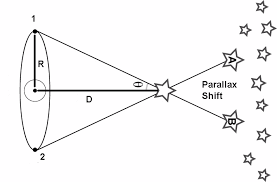
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**Unit 1: Reading 2 - The Cosmological Distance Ladder — Part 1 (Radar & Parallax)**

One of the largest and most intense on-going efforts in professional astronomy research is to understand the distances at all scales in the Universe—from the solar system to the nearby stars to further in the Milky Way and beyond. And one of the most commonly asked questions of astronomers is, “How do you know how far away things are?” The answer to that question contains many parts, but the method used depends on the distance to be measured. The different methods can be thought of as a model called the ***Cosmological Distance Ladder*** that can be diagrammed a number of ways. For one example see: <http://www.daviddarling.info/encyclopedia/C/cosmic_distance_ladder.html>

Each rung on the cosmological distance ladder is a distance-finding method that builds upon the method in the preceding rung. Rather than describing every possible distance-finding method, we will look at a **Streamlined Cosmological Distance Ladder** with only four rungs. Thanks to relatively recent breakthroughs in technology and of our understanding of Type 1a supernovae (certain types of exploding stars), we can begin to measure the scale of the Universe with just a few rungs on the ladder shown below:

**Rung #1: Radar**. The first rung of our Streamlined Cosmological Distance Ladder involves using **radar**. An electromagnetic radio wave is sent from a microwave antenna. The wave reflects off the object in question and is received back at the antenna. The time of travel is measured. Knowing the speed of the wave (speed of light), the distance is easily calculated. Radar has been used to measure precise distances to the moon, to the sun and to a few of the nearby planets. Essentially it is a method to measure distances in our solar system.

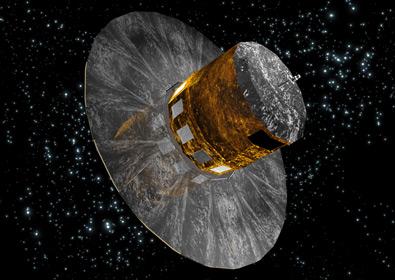
**Rung #2: Parallax**. Prior to the invention of radar, **parallax** was the first rung on the distance ladder. It was used by astronomers hundreds of years ago. We observe parallax, usually called **parallax shift**, when we view any nearby object from two different positions. The object appears to move when seen against the distant background as a reference. 

For a simple example, just view your extended thumb with one eye, then the other. As you shift from eye to eye, your thumb appears to shift position against its background. The distance of your thumb from your eyes determines how much shift you will view. The distance between the two observation points (each eye) is called the **baseline** for the parallax shift measurement.



In astronomy the parallax shift of nearby stars can be observed using the distant stars as the background. This requires a very large baseline distance. For example, two positions of Earth six months apart make a baseline equal to the diameter of Earth’s orbit.

Between 1985 and 1993 the ESA (European Space Agency) satellite, Hipparcos, measured the parallaxes of several million stars. 100,000 of them are considered very high precision measurements. Hipparcos was able to accurately measure distances out to approximately 300 light years. 

Since 2014 ESA’s newest satellite, Gaia, has used parallax to measure billions of stars with more precision than Hipparcos. These direct measurements are some of the cleanest in astrophysics and will enable improvement in the precision of further measurements on the distance ladder. Gaia is measuring distances out to approximately 1,600 light years for dim stars and up to 47,000 light years for brighter stars.



The final two rungs in our Streamlined Distance Ladder, **Cepheid Variables** and **Type 1a Supernovae**, will be addressed in Unit 4.