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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/23000713
Skygazing: Astronomy through the seasons, 2016-08-30

HOW FAR IS THAT STAR?

Ken Tapping, 30th August, 2016

How far away is that star? How did we determine that galaxy is a billion light years away? This process has taken us thousands of years and involves several different methods. However, they all depend upon one basic foundation – parallax.

If you close one eye while looking at a scene, then close that eye and open the other, you will notice that foreground objects move against the background of more distant objects. This phenomenon is called parallax, and is how our brains assess distance. In surveying, this process is called triangulation, where we observe distant objects from two ends of a carefully surveyed line. So the first step in measuring the Cosmos is to measure the Earth. That will give us our initial surveyed base from which we can push outwards.

The first accurate determination of the size of the Earth was made around 200 BCE by the Greek philosopher Eratosthenes. He noticed that on the summer solstice, the Sun shone straight down a well at Syene, now called Aswan, in Egypt, meaning the Sun passed overhead. In Alexandria, where he worked, he knew this was not the case. The Sun never got within a few degrees of the zenith. Greek scientists already believed the Earth was spherical, and this led to Eratosthenes proposing that the relationship between that angle of a few degrees and a circle would be the same as that between the distance between Syene and Alexandria and the circumference of the Earth. The angle was a 1/50 of a circle, so the distance between Alexandria and Syene was 1/50 of the circumference of the Earth. However, how far was Syene from Alexandria? Many accounts suggest he paced out the distance himself. However, since he was a senior philosopher, it is more likely he paid or cajoled someone else to do it, perhaps one of his students. He then calculated the circumference of the Earth, and got the right value.

Once we could establish the precise relative positions of two well-separated places on Earth, we could measure the distance and size of the Moon. At as close to the same time as possible, we observe at both locations the Moon's position against the distant background stars. From this we can estimate the Moon's parallax and determine its distance. Knowing how far away it is and measuring how big it looks in the sky, we can then find how big it is. This method also works for the Sun. However, beyond that it gets difficult.

If space is filled with stars, some of them will be much nearer to us than others. However, measurements made from different places on Earth showed no stars having different positions against the other stars. The parallax was too small to measure, indicating the stars are very far away. However, it is possible to have a triangulation baseline bigger than the Earth. The Earth orbits the Sun at a measured distance of about 150 million kilometres, and takes a year to do so. If we take pictures of the sky six months apart, we are taking them from opposite ends of a 300 million kilometre baseline. It worked. Some stars showed small parallaxes. However, even those stars turned out to be enormously far away – so far that expressing those distances in kilometres was not really practical, the light year is a better unit (a light year is almost 10,000,000,000,000 km).

Thanks to improvements in our instruments, we have used parallax measurements to determine star distances out to about 1600 light years. However, the Universe extends way beyond that. We had to find other methods for measuring distance, but without parallax they could never have been developed. Moreover I think we would not have much trouble explaining them to Eratosthenes, or the unknown person who paced out the distance between Syene and Alexandria.

Mars and Saturn lie low in the southwest after dark. Saturn is above Mars, fainter and to the right. The Moon will be New on the 1st.

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