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COSMIC DISTANCES

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For thousands of years people have used triangulation for surveying and measuring the distances of things. We can also use it for cosmic objects too. However, triangulation breaks down for distances more than about 1600 light years. A light year is the distance light travels in a year, which is a little less than 10,000,000,000,000 km. We can measure the distances to the nearest stars, but that is only our cosmic backyard. Most of our galaxy lies beyond that distance, and the other galaxies are much further away. Fortunately there is another method, which is usable out to the maximum distance telescopes can discern stars.

Many stars vary in brightness. One such star is Delta Cephei, in the constellation of Cepheus. This star was noticed to be variable by John Goodricke, an 18th Century English amateur astronomer. Delta Cephei doubles in brightness over a cycle of just over five days. The variation is due to a structural instability in the star. More stars like this one were discovered, and were classified as “Cepheid Variables”, or just “Cepheids”.

In 1908 astronomer Henrietta Leavitt was studying at Cepheids in the Magellanic Clouds, small galaxies close to ours. Since those galaxies are very small compared with their distance from us, she could assume that all those Cepheids are at more or less the same distance from us. This led to her finding something really odd; the average brightness of Cepheids is related to the time it takes for them to cycle in brightness. We can measure that time, and from that establish how bright the star really is – its luminosity, and then measure how bright that star looks to us here on Earth. From that it is easy to calculate its distance.

This was a revelation. If we can distinguish individual stars in a star cluster or distant galaxy, we can look for cepheids, measure their cycle times and apparent brightnesses, and determine the distance to that star cluster galaxy. Henrietta Leavitt had given us a ruler that extends nearly to the edge of the observable universe, and our improving telescopes are making it possible to identify more and more distant cepheids. So far it has been possible to use Cepheid variable stars to measure distances out to about 7.5 billion light years; that is over halfway back to the Big Bang.

Cepheids played a key role in establishing that our universe is expanding. Astronomers analyzing the light from distant galaxies found they are receding from us. Using cepheids to determine the distance, they found that the further away a galaxy is, the faster it is receding from us. We call this “cosmic redshift”. That does not mean everything in the universe has taken an aversion to us personally. Imagine the raisins in a rising cake as it bakes in the oven. No matter what raisin you are sitting on, you will see the same thing, all the other raisins are moving away, and the further they are, the faster that is happening. Of course, once the relationship between the distance and the rate of expansion was determined, it was an obvious move to determine if everything tracked back to the same point in space and time, and if so, when that was. Everything indeed started from the same place, just under 14 billion years ago.

At distances beyond where we can identify Cepheids we have to resort to other, rather less precise methods. We can use particular types of exploding stars and some types of galaxy. We can also use the relationship between distance and cosmic redshift, obtained by comparing Cepheid distances with redshift measurements. If we measure the cosmic redshift, we can estimate the distance. Using this method we calculate that the most distant galaxies, with redshifts of up to 11.1, lie about 13 billion light years away, that is, they existed only 400 million years after the Big Bang.

Mars and Saturn lie very low in the southwest after dark. Mars is on the left and Saturn on the right. The Moon will reach First Quarter on the 8th.

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