

Candles in the Dark

By Colin Johnston, Science Communicator

Since the mid-nineteenth century astronomers have used the principle of parallax to measure the distance to other stars. However this technique gets harder to use for more distant stars and is in fact useless for measuring distances of more than about 1600 light years. How then can we tell, for example, that M31, the galaxy in Andromeda, is 2.2 million light years away?

It would be straight-forward to tell how far away a star was if it was exactly the same brightness as our own Sun. We know how bright the Sun is and we know how the apparent brightness of a celestial body decreases with distance. It gets dimmer according to the Inverse Square Law, so

“M31 and other nebulae were galaxies of many billions of stars”

we could use how much dimmer a star appears than the Sun to calculate how far away it is. In fact, the great William Herschel tried to use this idea to give a relative scale to the galaxy a couple of decades before parallax was successfully used in 1838 by Bessel. Rather than using the Sun as his standard star, Herschel used Sirius, but the idea was the same. Of course Herschel himself knew that it was unlikely that every star was exactly as bright as Sirius but it was the best anyone could do at the time.

Now bear with me as I'm going to appear to change the subject but this is still part of the same story. Our Sun emits a steady stream of light and other radiation. In fact, and lucky for us, this stream is very steady; it has varied by only about 0.1% over the past couple of dec-



Image Credit: Wikipedia.org

Henrietta Swan Leavitt (1868-1921) She has a lunar crater and asteroid 5383 Leavitt named in her honour. Her death prevented her nomination for a Nobel Prize.

ades. Not all stars are as constant as this, and astronomers know of thousands of variable stars which get brighter then dimmer, then brighter again. Some vary irregularly but many follow regular patterns, flickering in seconds or pulsing over years to a steady beat. Why this happens can be explained by the physics going on inside the star, but the details aren't important here.

There is a type of giant yellow variable star called a Cepheid. Delta Cephei was the first to be identified, but there are many others, in fact familiar Polaris is a cepheid. In 1912 an American astronomer called Henrietta Leavitt realized something very special about cepheids. We had accurate distances to some cepheids, so we knew exactly how bright they were. We also knew how long it took the same cepheids to go through a cycle of getting dimmer then bright again. Leavitt's great discovery was to recognise that the brighter the cepheid, the longer it took to vary. Polaris, which varies in about four days, is about 2200 times as bright as the Sun, while a thirty-day cepheid is about 10 000 times as bright as the Sun. The variation is by a strict mathematical relationship, so how long it takes a cepheid of given brightness to fluctuate is completely predictable. It

works the other way around too. If you found a cepheid anywhere in the Universe, you could watch how long it took its brightness to go up and down, and this would tell you how bright it was. Comparing this with how bright it looks would give you how far away it was. Suddenly we had a new way of measuring the size of the Universe!

An early and important usage of this was when Edwin Hubble recognised a cepheid in what was then called the Andromeda Nebula (M31). Back in the 1920s, most astronomers believed that the Milky Way was the whole Universe, so M31 was presumably a relatively small and nearby object. Hubble calculated from the variation of his Andromeda Cepheid how far away it was and came up with the answer of more than 900 000 light years (better modern measurements give the accepted figure of 2.2 million light years). There was no possibility that M31 was inside the Milky Way. Not only

that, but it also meant that M31 and other 'spiral nebulae' were themselves galaxies of many billions of stars. In rather the same way as Bessel's discovery that 61 Cygni was 10 light years away had shocked astronomers a century before, astronomers abruptly had to accept that the scale of space was much, much bigger than they had previously thought.

Cepheids are still used today as 'standard candles' by astronomers. As they tend to be very bright, cepheid stars can be seen when they are very distant. The Hubble Space Telescope has been used to identify some cepheids in the Virgo cluster of galaxies showing them to be about 50-60 million light years away. However, some galaxies are much further away than this. We will examine how we measure the scale of the greater universe in the next article in this series.