appeared in 2002

Surveying in the cosmos – astronomical distances

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How high is the sky? How far away are the stars? How large is the universe? How do we go about measuring astronomical distances?

Astronomers first borrowed a method of sailors and surveyors - you measure the angle to an object from one spot, and then from another spot, and you can work out the distance to the object with the help of the distance between the two places and the change in the angle. Astronomers use the same method, by sighting a star now and six months later, when the earth at the other side of the sun. But this works only with nearer stars, and the best they have done is up to about 300 light years, while our own galaxy is 10,000 light years across!

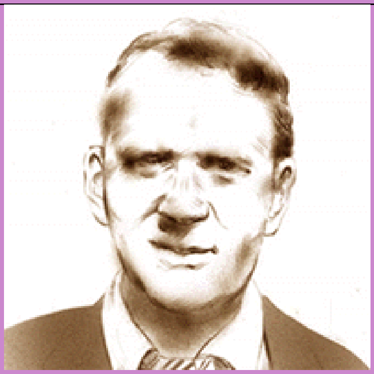
Using 'brightness'

Bright stars get dimmer as we move further away. Hence, if we know how 'intrinsically' bright a star is, then a measure of its 'apparent' brightness could help work out its distance. In the beginning of the 20th century, a method was found to estimate the intrinsic brightness of a star.

Henrietta Swan Leavitt (1868-1921)

This was by Henrietta Swan Leavitt, who studied stars called '***Cepheid variables'***, which have 'cycles of brightness'. Leavitt found that the 'cycles' were slowest with the brightest stars. And then, by observing the periodicity of the 'cycle' of Cepheids of known brightness, a link was found between periodicity and 'intrinsic' luminosity.
When dealing with a new Cepheid, its periodicity thus gave a measure of the 'real' brightness. And the 'apparent' brightness then helped work out how far away the star was!

Hubble and the Red Shift



Edwin Powell Hubble (1889-1953)

In the 1920s Edwin Hubble discovered another remarkable thing about distant stars. First, that they were receding, or moving away, and then, that the further away they were, the faster they were receding! During observation of distant stars, their distances were found by the period-luminosity relationship, while the speed at which the stars were moving came from observing the a change in the frequency of known colours of light that the star emitted, known as the 'red shift'.

We have all noticed that the whistle from an approaching train is shrill, but the pitch falls as the train passes us and begins to move 'away'. This is because when the train is coming towards us, the sound waves get ‘pressed’ together and the sound is shrill. But when the train is moving away, the waves are ‘stretched out’.

In the same way, the light from a fast approaching star would change colour, towards the violet side, and the light from a star moving away would change towards the red side. The speed with which a star is moving towards or away from us can thus be made out by measuring the observed frequency of emissions from the star of known elements.

Now Hubble analysed the light from stars at all kinds of distances and he found that the well-known spectral lines of elements, like hydrogen, sodium, iron, were all shifted to the red side. This suggested that the stars were moving away. And what was more, the further away the star the greater the red shift. Or, the further away a star, the faster it was moving away!

Looking at this the other way around, if we find how fast the star is moving away, we could tell how far away it was. The speed is readily measured by checking the spectrum for the red shift. And from there, we get the distance!