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A COSMIC RULER

Ken Tapping, 13th March, 2018

One of the main astronomy coffee discussion subjects at the moment is the discovery of the birth of the first stars in our universe. Even though they are too far away in space and time for us to see directly, researchers have managed to detect the changes they induced in the hydrogen clouds from which they formed. The universe began around 13.8 billion years ago – in an event referred to today as the "Big Bang". It expanded and cooled, so that eventually it was cool enough for protons and electrons to combine, forming atoms of hydrogen. This primordial hydrogen was the raw material for forming those first stars. Hydrogen is still by far the most common element in the universe today, with a constant flow of new stars being born from it. Those first stars formed about 180 million years after the Big Bang. How can we determine such a date, so far in the past? The answer comes from parallax, Cepheid variable stars and the expanding universe.

We all use parallax to measure distance, all the time. That is why we have two eyes. Each eye sees what we are looking at from a different position, so that foreground objects appear slightly displaced compared with the more distant background. Our brains use these displacements to estimate how far things are from us. Surveyors make measurements from two known points to measure the distance of a distant point by a process known as "triangulation".

The stars are immensely far away. By measuring the positions of stars against more distant background stars and doing the same thing six months later, when the Earth is on the opposite side of its orbit, we have a triangulation baseline of 300 million kilometres. We can measure star distances using this method out to about 3000 light years (one light year is about 1e13 km – 1 with 13 zeroes after it). The universe is much bigger than that. Fortunately there is a class of stars called Cepheids, which vary periodically in brightness with a cycle time that is related to the brightness of the star. So we can measure how long the star takes to cycle in brightness, calculate how bright it is, measure how bright it looks from here, and determine its distance. However, in really distant galaxies we cannot distinguish individual stars. We can reach a bit further by looking at one type of supernova explosion, the death of a star, which shines with a known brightness. After that we fall back on the expansion of the universe.

We've all noticed that the sound of a motorcycle has a higher pitch when approaching us than it does when receding. This is known as the Doppler shift. Slipher discovered that light from distant galaxies is significantly Doppler shifted: reddened, indicating they are moving away from us. Hubble found the relationship between redshift and distance. We can measure the redshift of a distant galaxy, and then estimate how far away it is. Cosmic neutral hydrogen, when excited by ultraviolet light from stars, emits radio waves with a wavelength of 21 cm. The expansion of the universe red-shifts it to longer wavelengths. We can use Hubble's relationship to determine how far away that hydrogen is. The most red-shifted (the most distant and ancient hydrogen signature we can detect) will tell us when the first stars formed. That radio signature has been stretched by the expansion of the universe to around 3 metres, putting its origin 13.62 billion light years away, only 180 million years after the Big Bang. We never thought things got started that soon.

Mercury lies very low in the sunset glow. Jupiter rises about midnight, Mars around 4am, and Saturn at 5am. The Moon will be New on the 17th. At 9:15am PST (12:15pm EST) on 20 March the Sun crosses the equator heading north, marking the beginning of spring – the Spring Equinox.

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