HOW BIG IS THE UNIVERSE?

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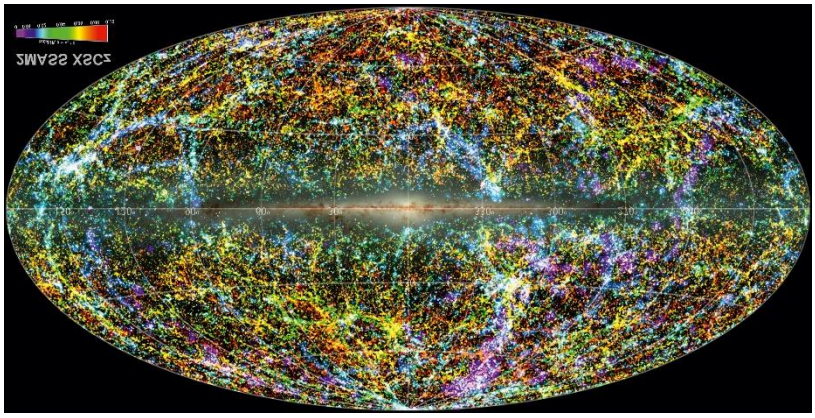
Ken Tapping, 11th June 2024

At this point, we don't know how big the universe is. However, a question we can address is how big is the chunk of universe that we can see. That is basically a measurement problem; it is not an easy one, but one we have been making good progress with over the last century or so. It comes down to two sets of measurements: distances and speeds.



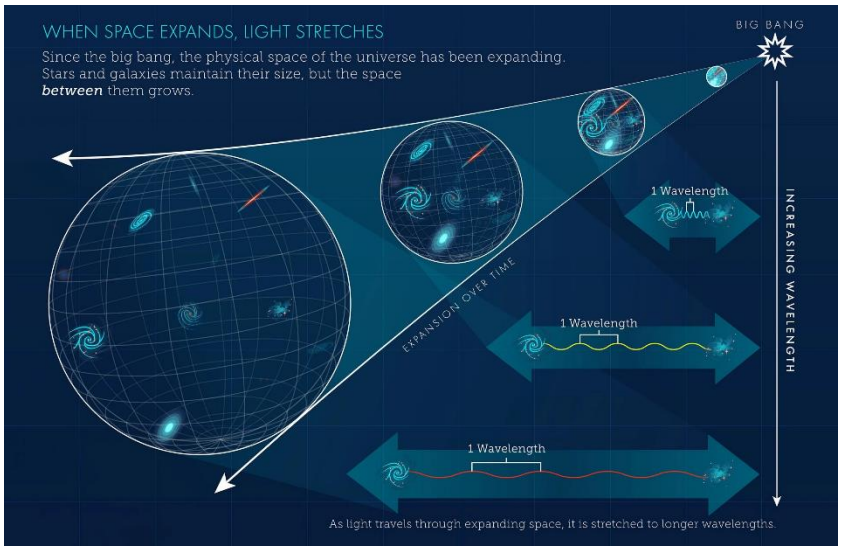
This image shows the universe stretching out for about a billion light years, which is only a small fraction of its total size. Each of the 50,000 dots represents an entire galaxy

For nearby stars in our galaxy, we can determine how far away they are by using the classical method of triangulation, as used by surveyors for centuries if not longer. Unfortunately, for anything lying outside our galaxy that method is useless.

Luckily there are variable stars (such as cepheids), where measuring the timescale of the variability enables us to calculate how bright the star would look at a standard distance. Then, comparing this with how bright the star looks enables us to determine how far away that star is. Spotting these stars in distant galaxies enables us to estimate how far away they are.

Then there is a type of supernova explosion, which always liberates more or less the same amount of light. These are produced by two stars orbiting closely around one another. One ages first and becomes a white dwarf. This then snacks on material from the other star. When a critical mass of this is captured and accumulates on the white dwarf's surface, it explodes, producing a "standard flash". If we spot these in distant galaxies and measure how bright they look, we can calculate the distance. Even further away, there are galaxies that have more-or-less standard brightnesses, extending our "cosmic ruler" out to even greater distances.

Measuring the speed with which distant galaxies are being carried away from us by the expansion of the universe is comparatively easy. The elements making up stars and other structures in the universe have specific light signatures.



If the source of the light is receding from us, then the colours compared with the light emitted by those elements in the laboratory are reddened by an amount dependent on the speed the source is receding from us. So, we can look at distant galaxies and get their distances and the speeds with which they are being carried away by the expansion of the universe. These data indicate that at some point in the past everything in the universe was together in one dense lump. From the speeds and distances, we can estimate when that lump started to expand, in an event now known as the Big Bang. It happened about 13.8 billion years ago.

Since cosmic distances can be huge, light from distant objects can take up to billions of years to get to us. We see a galaxy a billion light years away as it was when the light, we are seeing set out on its journey to us, that is, a billion years ago. Over the time the light was travelling to us, that galaxy has been moving further and further away, carried by the expansion of the universe.

The James Webb Space Telescope has detected galaxies that existed 300 million years after the Big Bang. That means, the light just observed is some 13.5 billion years old, from a distance of 13.5 billion light years. Since then, those galaxies have continued to recede from us. So how far away are they now? This depends on the rate of expansion of the universe and how that expansion changes with time. The best estimate is that today, due to its expansion over the last 13.8 billion years, the edge of the observable universe now lies some 46.5 billion light years away. That 46.5 billion light years distance refers to the Observable Universe, where the most distant things we can see in the sky lie today. We have no way of knowing what, if anything, lies further away than that. Of course, to see what the most distant galaxies look like today, in 2024, we are going to have to wait a long time for their light to reach us.

Just before dawn, look for Mars low in the dawn glow, and Saturn a bit higher and further west. The Moon will reach First Quarter on the 13th.

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