Explainer: Light-years and units for the stars

August 21 2013, by Michael J. I. Brown

The nearest stars to Earth – apart from the sun – are more than $4x10^{13}$ kilometres away. Credit: Stinger_Y_Y

"Space is Big. Really Big." The Hitchhiker's Guide to the Galaxy pretty much nailed space with those five words. And space is so really big that our earthly measures of distance struggle.

The distance to the sun? Just under 150 million kilometres.

The distance to the nearest stars? They are more than $4x10^{13}$ kilometres away. And if you aren't familiar with scientific notation, that's 40,000,000,000,000 kilometres, or 40 trillion kilometres.

Almost everyone struggles with numbers so unbelievably big, including astronomers. Could you memorise that the Large Magellanic Cloud is 1.5×10^{18} kilometres away? I start losing track somewhere around the 14^{th} nought.

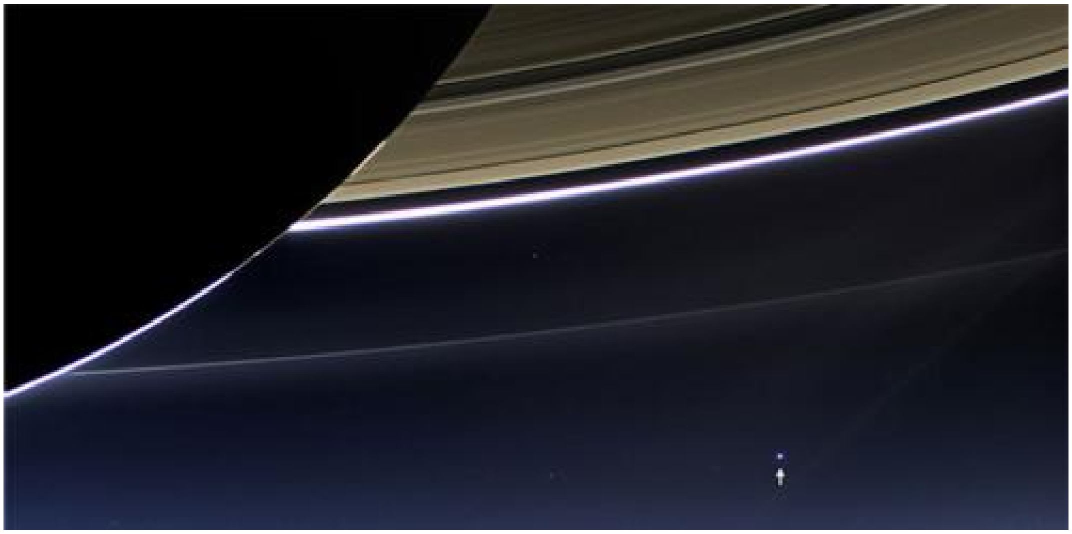
So, to cope with the overwhelming bigness of space, astronomers have devised a series of really big units.

Starting small?

The starting point is the Astronomical Unit, often abbreviated to AU. It corresponds to the (almost) comprehensible distance of 149.6 million kilometres. By construction, that's almost the exact distance from Earth to the sun.

Our solar system fits snugly within tens of Astronomical Units, with Neptune being roughly 30 AU away. The planet Venus, which is now the brightest "star" in the early evening sky, can be a mere 0.28 AU from Earth.

Saturn, the most distant planet we can easily see, is at a distance of 10 AU. Ten is a reassuringly small number, but remember 10 AU is 1.5 billion kilometres. Last month, the Cassini spacecraft took a photo of Earth from Saturn, and our home was reduced to a mere dot:



Earth (above the arrow), as viewed from a distance of 10 AU by the Cassini spacecraft, which is currently orbiting Saturn. Earth is so far away and its angular size so reduced, that it appears as a mere dot. Credit: NASA/JPL-Caltech/Space Science Institute

Truly astronomical distances

How do astronomers measure distances across the universe? With parsecs and light-years.

The parsec is the unit astronomers use professionally, and is celebrating its 100th birthday this year. The light-year has long been used by astronomers when they are trying to communicate to a broad audience, perhaps with mixed success.

A parsec is 206,265 AU and is roughly the distance to the nearest stars. If we were to view a giant star with a diameter of 1 AU at a distance of one parsec, it would appear to be just $1/3600^{th}$ of a degree in angular size. For comparison, the sun and moon are both half a degree in angular size when viewed from Earth.

The parsec is what astronomers use every day but, being 206,265 AU and ending in "sec", it isn't the most easily understood unit of distance. Perhaps this is why Han Solo talks about parsecs as if they are units of time, not distance. And why Star Wars nerds have spent countless hours trying to explain away this broken piece of techno-babble dialogue.

The light-year is a more comprehensible measure of distance than the parsec – the catch being (and it is a big one) that you need to accept the finite speed of light and time machines.

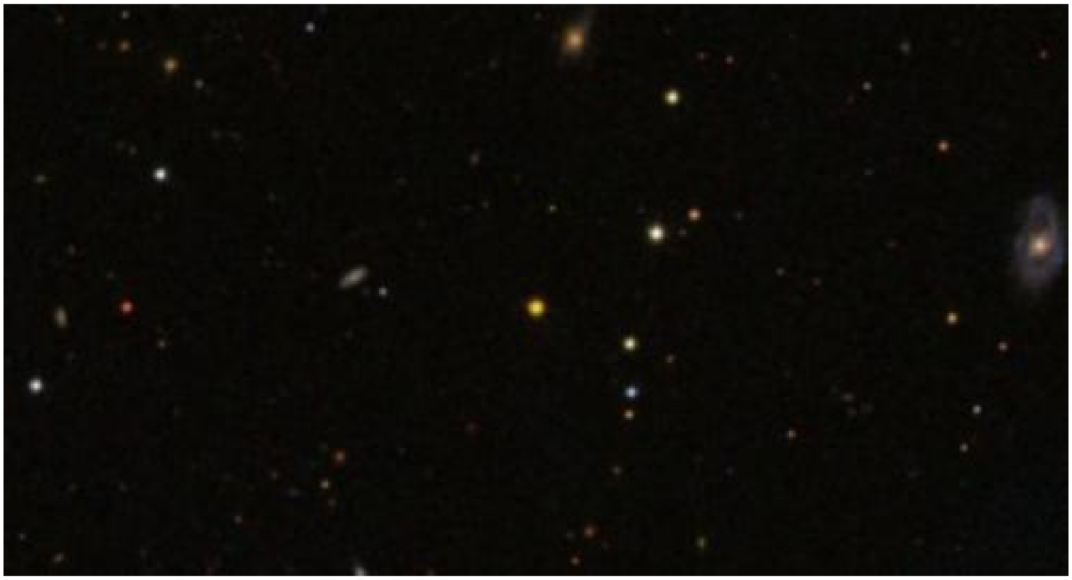
We are comfortable with the finite speed of sound. There is a flash of lightning and some seconds later we hear the roll of thunder. The speed of sound is roughly 340 metres every second, or 1,200 kilometres an hour.

Light travels almost a million times faster than sound, a little under 300,000 kilometres every second, or just over a billion kilometres an hour.

That means the further we look, the further we look back in time. Our eyes and telescopes are time machines for looking into the past. When we look at the moon, we are seeing it as it was a second ago, because the light takes a second to travel from the moon to us.

The light-year is the distance light travels in a year in the emptiness of space, and is just shy of 10 trillion kilometres (or 10^{13} kilometres).

Despite a light-year being a vast distance, even the nearest stars are several light-years away. Alpha Centauri, the brightest of "The Pointers" near the Southern Cross, is over four light-years away. That means we are viewing Alpha Centauri as it was four years ago.



Quasar APM 08279+5255, the yellow dot at the centre of this image, is 12 billion light-years from Earth. Credit: Sloan Digital Sky Survey

Across the universe

Even nearby galaxies are at vast distances compared to the stars we see at night. The Large Magellanic Cloud, which can be seen on very dark nights, is 160,000 light-years away!

Astronomers regularly observe galaxies that are billions of light-years away, and I have even seen such distant objects with my own eyes.

One evening, at Mount Lemmon Observatory in Arizona, I used an eyepiece and 1.5-m telescope to peer across the universe. Barely detectable to the human eye was the faint glow of the quasar APM 08279+5255. This quasar is more than 12 billion light-years from Earth.

The light from APM 08279+5255 took 12 billion years to reach Earth and started its journey when the universe was just a tenth of its current age. Billions of years before there were people, billions of years before there were dinosaurs, and even billions of years before Earth itself was formed.

Even to astronomers, the distance to APM 08279+5255 is truly "astronomical".

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