Hubble sees Red!

By Colin Johnston, Science Communicator

Until the 1920s many astronomers believed that our galaxy pretty well was the entire Universe. Then Edwin Hubble, a flamboyant character of an astronomer, recognised Cepheids in the Andromeda Nebula (M31). Cepheid, stars which pulse at a rate governed by their brightness, are extremely useful 'standard candles' for astronomers, who can easily tell how far away a Cepheid is just by observing how long it takes to cycle from minimum to maximum brightness. Hubble did the maths and discovered that M31 was very distant indeed (2.2 million light years away is the accepted figure today), so far in fact that it must be a galaxy in its own right. At the time this was very controversial, but Hubble was about to create an even greater stir. However first we will need to discuss light.

"light is an electromagnetic wave"

Light travels as a wave. "A wave in what?" you may ask. "In itself" is the simplest answer, light is composed of a pair of vibrating electric and magnetic fields, they move together as an electromagnetic wave. In fact, not only is light an electromagnetic (EM) wave but so are infrared, ultraviolet, X-rays, radio and other forms of radiation. In this article we will lump these all together as 'light' Now, light has a wavelength, if you imagine waves in the ocean, their wavelength is the distance between each crest. Just for a moment think about the familiar colours of the rainbow (or spectrum). At one side we start with red which has a long wavelength, next orange with slightly shorter wavelength, moving through the colours to blue and violet the wavelengths get smaller and smaller. You may be wondering what this has to do with the size of the Universe, but be

Image Credit: NASA and STScI

Edwin Hubble (1889-1953) Like other astronomers highlighted in this series, he has a lunar crater and an asteroid (2069 Hubble) named in his honour. NASA also named a space telescope after him.

patient, we will get there eventually.

Imagine you are looking at three spaceships sitting stationary beside each other in space, each has a bright green lamp attached to it. They are steadily shining a pure green light, we are using green light in this imaginary experiment as green is in the centre of the visual spectrum. At a signal, two of the ships start moving very fast while the third ship stays where it is. One ship moves directly away from you, while the other moves straight towards you. To your amazement, the colour of the lights on the moving ships changes. The one coming towards you now looks blue; the one going away from you looks red. The stationary one remains green. What is happening? Take the ship heading towards you, the waves of green light from its light are getting squeezed into smaller wavelengths as the ship moves closer to you. Shorter wavelengths are bluer, so we say the waves are 'blue-shifted'. Meanwhile the green light waves from the ship moving away are 'stretched' into longer wavelengths which are redder, so they are 'red-shifted'.

This genuinely happens (although I have greatly simplified the details; I hope all the physicists out there will forgive me). Although it sounds unlikely, it is an absolutely real phenomena and it is called the Doppler Effect after the Austrian scientist who proposed its existence in the 1840s. If an object is coming towards you its light is blueshifted, if it is receding the light is redshifted. This effect is very useful in many aspects of astronomy. For example, by studying the light from a star we can tell if it is coming in our direction (blueshift) or moving away (redshift), or we can use the Doppler Effect to measure its speed.

"galaxies are receding as a consequence of the Universe's expansion"

Between 1912 and 1917, astronomer Vesto Slipher was using the Doppler Effect to measure the speed of 'nebulae', including M31 in Andromeda. Remember these where the days when other galaxies were still thought to be nearby objects inside our own galaxy. To his surprise, of twenty five nebulae four were blueshifted (and therefore coming towards us) and the rest were redshifted and hence moving away from us. Hubble had heard of this and was fascinated but he was not able to begin investigating immediately due to his military service in the First World War amongst other distractions. By the late 1920s Hubble was using the 100 inch Mount Wilson telescope, the largest in the world at the time, to look at distant galaxies. By 1929 he had catalogued 46 galaxies by their distance and speed (measured by the Doppler Effect).

The conclusions were unmistakeable. Firstly most galaxies are redshifted, implying that they are receding from our galaxy, confirming Slipher's results. Secondly, the degree of redshift (and therefore the galaxy's velocity) is directly proportional to its distance away. In other words, if a galaxy was twice as far away as another, it would appear to be travelling twice as fast. This

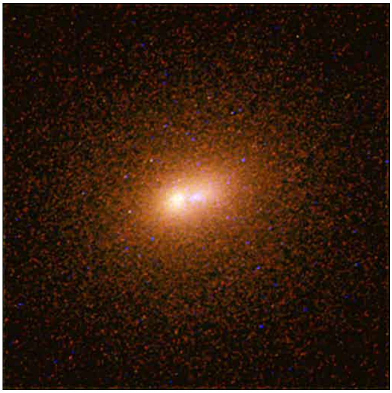

Image Credit: NASA / ESA & T. Lauer (NOAO / AURA /NSF)

M31 Andromeda Galaxy A Hubble Space Telescope view of the galaxy's core

is now called Hubble's Law, and it made his name. Soon, he was being referred to as 'the world's greatest astronomer'. His fame led him to his being invited as guest of honour to the 1937 Oscar awards ceremony where he was presented to an audience of gawping Hollywood actors. As author Simon Singh has pointed out in his excellent 'Big Bang', this meant that for once it was the stars that got to stare at an astronomer.

This article is about measuring the size of the Universe, so we will not look deeply into why this redshift is occuring. By doing this, we are following Hubble's own approach; he was a skilful observer (with a talented staff of assistants) rather than a physicist who deliberately avoided speculation on the deeper meaning of his discoveries. In brief, we know galaxies are receding from us not because they are recoiling in disgust from the Milky Way, but as a consequence of the Universe's expansion, a subject for a whole series of articles in itself. Observers in any galaxy will see every other galaxy as redshifted, so there is nothing special about the Milky Way.

However Hubble's Law opened up a new way of determining intergalactic distances. If you measure the redshift of a galaxy, you will know its velocity, and by Hubble's Law, you will automatically know its distance away.

There are a few galaxies which do not fit Hubble's Law. M31, for example, is in fact moving towards the Milky Way at 120 km/s, so it is blueshifted. Galaxies like this are said to have 'peculiar velocities', these are believed to be due to interactions between galaxies and their random motions. It is also worth noting that a handful of astronomers dispute Hubble's law, some claim to have found galaxies which are interacting, in other words touching each other, yet have wildly different redshifts. This is an impossibility by Hubble's Law, and most astronomers believe these observations are mistaken. Hubble's Law is widely accepted to be our only means to measure the distances to distant galaxies and quasars in which cepheids or other standard candles cannot be seen. I will continue this series with a look at more ways to determine the size of the Cosmos.