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Astronomy
The Expanding Universe

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Suppose I wanted to move one of these discs – how could I do it? And obviously that's one way of doing it – but there is another way. I've got them on a piece of stretchy rubber so the second way of doing it is simply to stretch the rubber itself which carries the disc along with it. Now this, in fact, is a very good analogy for the expansion of the Universe. These galaxies here are not so much moving through space as being carried along by an expanding space. In fact galaxies take part in both kinds of motion. If you're thinking about how the galaxy moves within its local group or cluster, you know moving around the other galaxies, and that is motion through space, the normal kind of motion. But if you're thinking about a couple of clusters of galaxies and why they are separating due to the Hubble expansion, then that movement is due to the expansion of the space between them.

If you're thinking about a very distant galaxy, or cluster of galaxies, then that kind of motion due to the expansion of space becomes the dominant motion. It's very important to get the distinction clear between the two types of motion because this sort of motion where you're thinking about motion through space, that is governed by Einstein's special theory of relativity. As you've probably heard, one of the requirements of that is that nothing can travel faster than the speed of light. But if you're thinking about the other kind of motion due to the expansion of space, then special relativity has nothing at all to say about that and therefore there's no reason why speed should not exceed the speed of light; in fact, if you're thinking about a galaxy which is so far away it's beyond the horizon of the observable universe, then sure enough they can indeed be moving faster than the speed of light.

Right now this is actually quite a good analogy in as much as not all distances here expand and as I stretch the rubber the discs themselves obviously don't change in size. And that is also the case with the galaxies; although the space is expanding, the galaxies themselves do not change in size and that's because they, like the disc, are a bound system. In that case what you've got is gravitational forces holding the stars together and that not only holds the galaxy together, but it keeps it the same size, so it's only the distances between galaxies that change. Actually, of course, it's pretty obvious that you can't have all distances changing; otherwise you wouldn't actually know that anything had happened. If you have a distance which doubles in size, but I measure that with a ruler, it also doubles in size, you get the same answer, so you can't have all distances changing. There's one way in which this is not a good analogy and that is, of course, the rubber sheet has got edges to it and as far as we know three-dimensional space does not have an edge or a boundary to it, it just carries on. Also, this sheet has got a central point which I think would be somewhere like there. Now why do I say that? Well I'm judging it as being equal distance between the two edges but, as I say, with three-dimensional space, if there's no edge then I've got no place from which to judge where the centre might be, a centre of the Universe, so any point in space is as good or as bad as at any other.

Right well, whilst we're thinking about this expanding space, how about another problem which might be bothering you and that is the cosmological red shift. Now what actually is the origin of that red shift? Take this lamp. There's a blue, at least it looks blue from here, from close up but what would it look like from a long distance away? Now suppose we were looking at it from a distant galaxy across space – well let's go and find out, shall we? Mmm, well from over here it looks as though the light is red, yet the strange thing is for someone who is actually still over there by the light source, it would still seem to be blue. So, the colours are different and that means, of course, that the wavelengths will also be different. It's shorter at emission than when we receive it. Now how does that come about? Well, whilst the wave is travelling towards us from the distant galaxy, the space between us and that galaxy expands. These humps aren't bound to each other so the distance between them, well, they will also expand, and the further it has to travel, the more it will expand. So, although the light has its normal wavelength at emission, it is red-shifted by the time we see it. The lengthening of the wavelength occurs during the journey and not at emission, which what would happen if we had a normal Doppler shift. With the normal Doppler shift, you know due to the speed of recession of the source, all the, er, lengthening occurs right at emission and what we pick up is just simply that wavelength which was stretched out at the very beginning.

Here what's happening is the lengthening occurs during the journey and the bigger the distance the light has to travel, the greater will be that lengthening. And that's very useful because it means that if we knew what the wavelength was at the beginning and we do know that from the atomic levels and the chemistry of the source, then from the red shift we can work out what the distance to the source is going to be through Hubble's Law. ne trouble is that we don't know Hubble's constant particular well but, well, we're getting there.