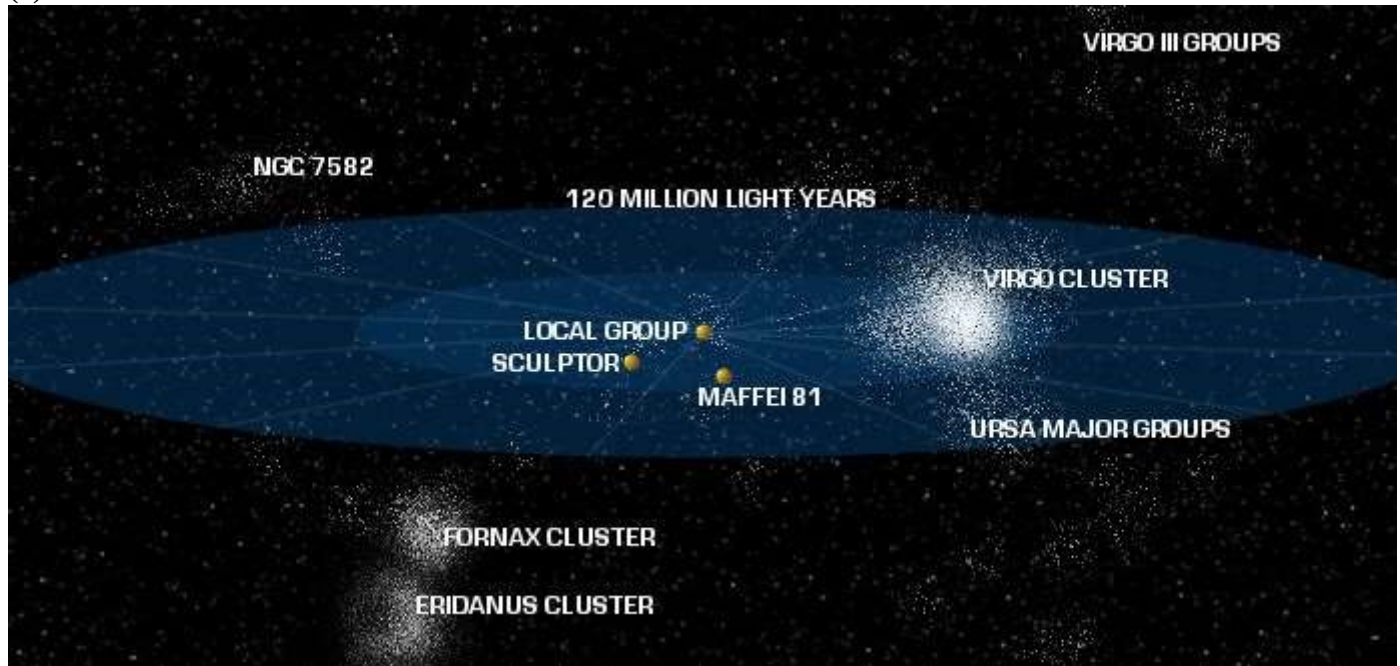


March Main Meeting - Galaxy Bimodality (Cosmic Collisions) Dr Vivienne Wild

Our Galaxy contains between 200 billion and 400 billion stars and all the stars we see in the night sky are within our Milky Way which is 100,000 light years in diameter. It is a barred spiral and it takes 26,000 years for light to reach Earth from the centre of Galaxy, so it becomes apparent that it takes a long time to get anywhere in our Galaxy and the chances of communicating with any aliens are very small. (Photo1).

(1)



Galaxy Populations

Galaxies come in different shapes and sizes – spirals, ellipticals and irregular, which include interacting galaxies, but most of the massive galaxies in the local universe come in just two types: spirals (with or without a bar) and ellipticals.

Ellipticals look like rugby balls and how elongated they are depends on how they are orientated in space from our view point. They have a smooth profile, no global rotation, a high surface brightness (lots of stars in a small place) but because they are dust and gas poor there is therefore no star birth (stars are born from gas) thus they consist mostly of old stars and appear red. On close inspection they are less regular than they appear – there can be a boxy appearance, duskiness, counterrotating cores, shells and ripples all suggesting a complex evolution. (M87 Photo 2).

(2)



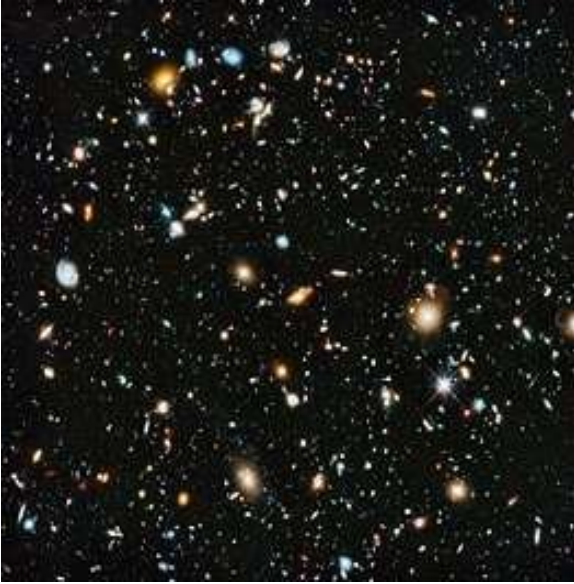
(3)



Spirals have rotating disks, a low surface brightness (stars spread out) with a lot of gas and dust (M31 Photo 3). Their spiral arms are density waves and as they plough through the gas, compressing it, star birth takes place which produces a blue disk (lots of new young stars) and a redder bulge (older stars). Spirals emit a lot of light in the ultraviolet which tells us they are very hot as there are many young, hot, massive stars.

The Hubble Space Telescope looked at a patch of sky, quarter of the size of the Moon, for 11 days. This was an area of sky that appeared empty but when the image was processed it was found to contain around 10,000 galaxies and has become known as the ultra-deep field (Photo 4) providing a view of galaxies in the early universe where the first galaxies are starting to appear. The galaxies in this image appear “messed up” – very different to the way they look today. This gives us a chance to see galaxies changing with time.

(4)

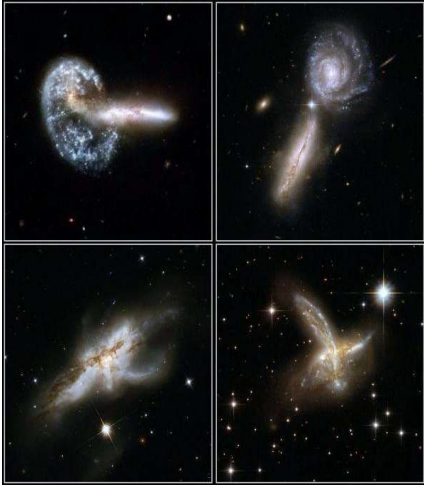


We can now ask questions in galaxy evolution about how galaxies evolve and why. We know that in the local universe we have a bimodal population of galaxies resulting in spiral and elliptical galaxies, we know that spirals are still forming stars but ellipticals are not, we know that in the early universe galaxies look “messed up” with higher star formation rates, so what happens to turn spirals into ellipticals? Why are spirals are still forming stars but ellipticals are not – this question forms the basis of Vivienne’s research. This is a hugely complex process and the answer is unlikely to be answered soon.

Galaxies in transition

One strong possibility is that cosmic collisions (Photo 5) where galaxies crash into one another may play a part. This doesn’t happen often. In the real universe, we only see snapshots in time, so hydrodynamic computer simulations of galaxies colliding can help us to understand what’s happening and to see whether they can make spirals turn into dead ellipticals. When galaxies collide there is a huge burst of star formation because dense gas is driven from the disks of the galaxy into the centre. However, although star formation rate drops they don’t stop, which is a problem as simulations cannot produce dead, red ellipticals. The only way to stop star formation is to inject a huge amount of energy from the supermassive black hole in the centre which pushes all the gas out but this isn’t seen by Observers. Nevertheless, the simulations produce something which resembles an elliptical apart from the fact they are still forming stars. So, what is going wrong with the simulations? Is the physics wrong? Simulations can help to see what a galaxy becomes and assist in answering Vivienne’s questions about how gas is driven out of the galaxy. Different researchers doing computer simulations with slightly different techniques end up with different results.

(5)

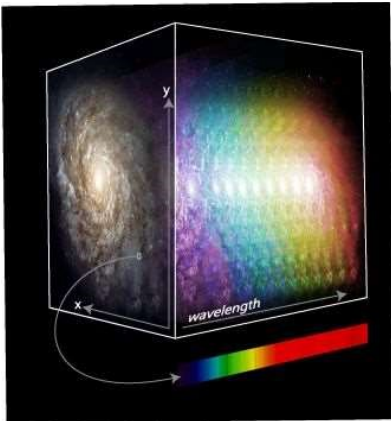


CALIFA survey

The CALIFA study is a study that Vivienne has been involved in over the last five years and entails the use of a telescope at the Calar Alto Observatory in Spain to look at 600 galaxies with imaging spectroscopy (integral field spectroscopy). Each galaxy has its spectrum split up to make a data cube showing the spectral energy distribution of the whole galaxy. In the survey it was the spectral energy distribution of the optical range. The spectral lines show the nebula emission lines which come from ionised gas – hydrogen alpha but also oxygen and nitrogen lines as well as some others – and provides lots of information of the chemical elements in these galaxies. It is spectroscopy that allows the physics to be understood.

A galaxy is “dissected” into thousands of small regions, each one having its particular spectrum analysed when using the Integral Field Spectroscopy (IFS) techniques. The result is a datacube. (Photo 6).

(6)



600 spectra for each galaxy were obtained using optical fibres placed in a grid across each part of that galaxy (this is the integral field). For the interacting galaxy called The Mice, (Photo 7) the integral field device was placed on top of the image. The brightness of the hydrogen alpha line is a function of position on the mice. The result was a huge amount of hydrogen alpha in the centre of each mouse as we would expect – this tells us that lots of star formation is taking place.

(7)



What is more exciting is that by taking a ratio of the hydrogen line and nitrogen line gives a result that tells us that high excitation gas is found either side of the disk of the northern mouse. This shows that a massive amount of gas is being driven out of the centre of the galaxy.

(8)



M82 (Photo 8) is more local and this means we can see a huge outflow of gas (red) due to supernovae outflow after lots and lots of supernovae have occurred – they then put all that energy into the gas and drive it out of the galaxy.

Outflows are one of the ways to improve the simulations – it may be a matter of getting the numbers correct and then this may solve the problem of star formation being too high at the end of the simulations done at the moment.

Vivienne carries out simulations and observations to try to understand what is happening but also research using statistical samples of mergers and post mergers to see what physical properties cause the galaxies to evolve.

Vivienne then summarised by saying that there are two types of massive galaxies in the universe, elliptical and spiral – this is what she means by galaxy bimodality. They either become one or the other but the question is why does one galaxy become an elliptical and its neighbour a spiral? We know that very distant galaxies are different to local ones suggesting they have changed over time, but what are these physical processes that cause them to evolve? Although rare, it is now thought that collisions play a major role. This is what her research is all about.