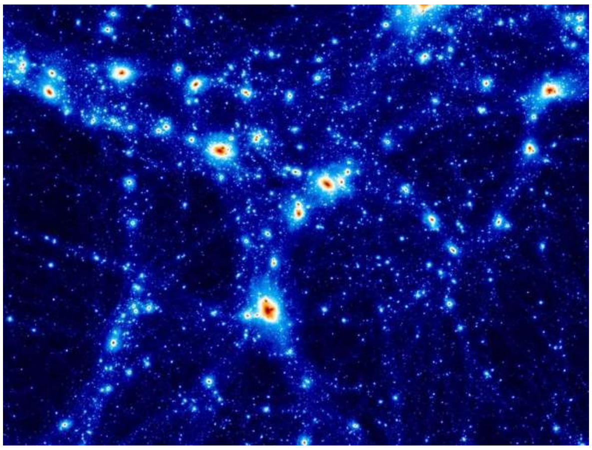
Observing the Living Galaxies by Owen Turner

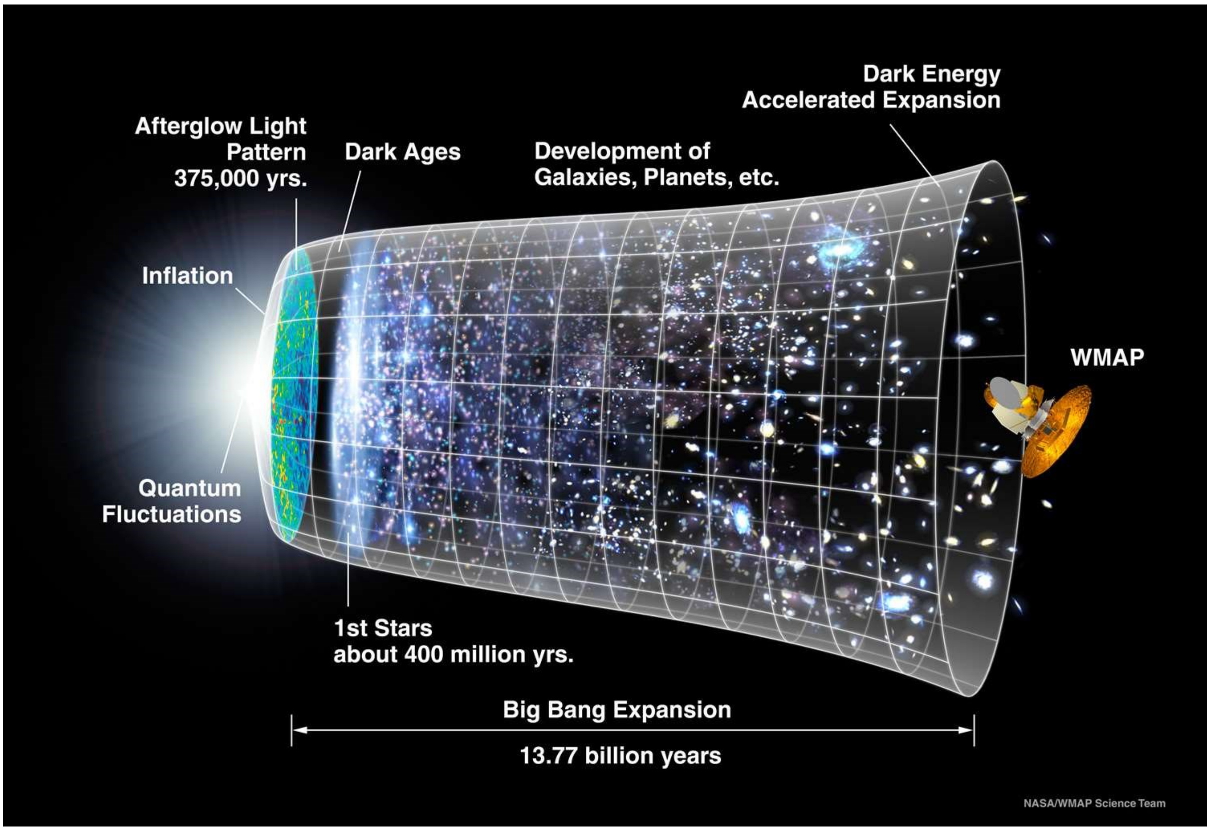
Our speaker tonight was Owen Turner, a native of Nairn, and who is currently a third year PhD student at the institute of astronomy at the Royal Observatory, Edinburgh. He is interested in the chemical and dynamical evolution of galaxies using high redshift integral field observations.

Owen's PhD is about how galaxies form and evolve. They form the building blocks of the universe so understanding their formation helps to understand how galaxies and how the universe evolves over time.



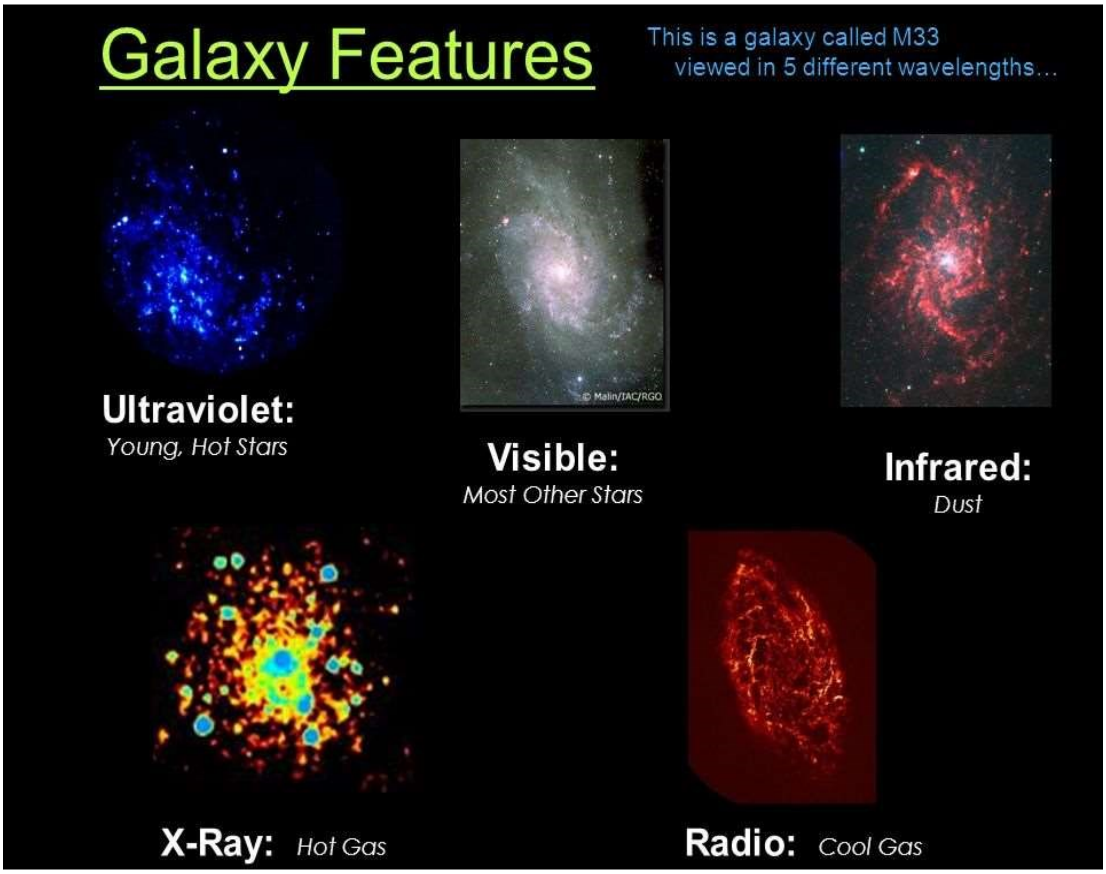
Starting with a computer simulation of galaxies forming, Owen explained that what we can see is the dark matter cosmic web which is like a backbone of the universe creating an environment into which galaxies form. It shows that galaxies do not appear randomly across the sky but instead form an ordered pattern dictated by the pattern of dark matter in the universe. The environment in which a galaxy forms, dictates how that galaxy will evolve.

Computer simulations produce realistic incarnations of the universe that match our observations and provides another tool with which to study the universe. We see the visible matter making up the galaxies but we know very little about dark matter which is an important component, so the aim is to understand what dark matter is, and how visible and dark matter are connected as this appears to be the key role in galaxy evolution at the moment.



The Big Bang occurred 13.8 billion years ago. The time immediately afterwards, along with inflation, set the initial conditions of the universe. It's thought that the first stars formed about 400 million years after the Big Bang and at the same time, we also have the formation and evolution of the galaxies. Observations of galaxies from this time to the present day show us how galaxies have changed. Another computer simulation that Owen showed us was about how the dark matter cosmic web becomes more structured from the time of the Big Bang to the present day. Supernovae begin to appear and are responsible for releasing energy and spreading 'metals' (any element heavier than helium) throughout space.

We tend to think of spiral galaxies as a typical galaxy although galaxies as a whole are diverse in form. The unifying factor is that galaxies are collections of stars, gas and dust. Spirals rotate around a central point and over time the gas settles and a disc forms, which is set at the very earliest times by the angular momentum of the gas clouds from which the galaxy forms. Star birth occurs within the disc and gives the spirals a blue appearance. The bulge contains a central supermassive black hole. The globular clusters, which rotate in random orbits around the galactic centre, formed before the rotating disc of the spiral galaxy so are very old and look red as no new stars are forming.



Spirals and ellipticals are the two main types of galaxies but we also observe irregular/peculiar galaxies.

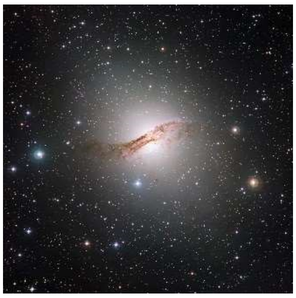
The ordered form of a spiral suggests it was formed in that way. They have intermediate stellar masses and young, blue stars in the disc with about 10% - 15% of gas to provide fuel for star birth.

Ellipticals tend to be featureless with no star birth because of very little gas, they have random stellar orbits suggesting something has upset any ordered rotation that it may have had. There is a high stellar mass but the stars are old so tend to look red.

Spiral Elliptical

Irregular galaxies (left) look peculiar in form and usually appear blue due to a lot of star formation from the large amounts of gas which may be as high as 80% but these galaxies often have a low mass.

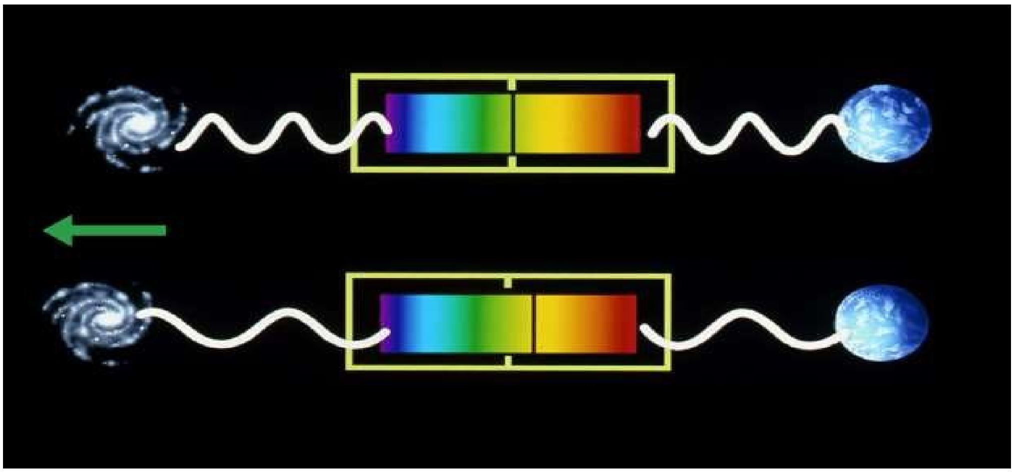
NGC 2442 (right) is often referred to as a late-type spiral or star forming galaxy 50 million light years from Earth.



Ellipticals are early-type or passive galaxies such as NGC 5128 (left) which is 12 million light years away and considered close to us. This one has dark dust lanes which are effective at absorbing light emitted by the galaxy.

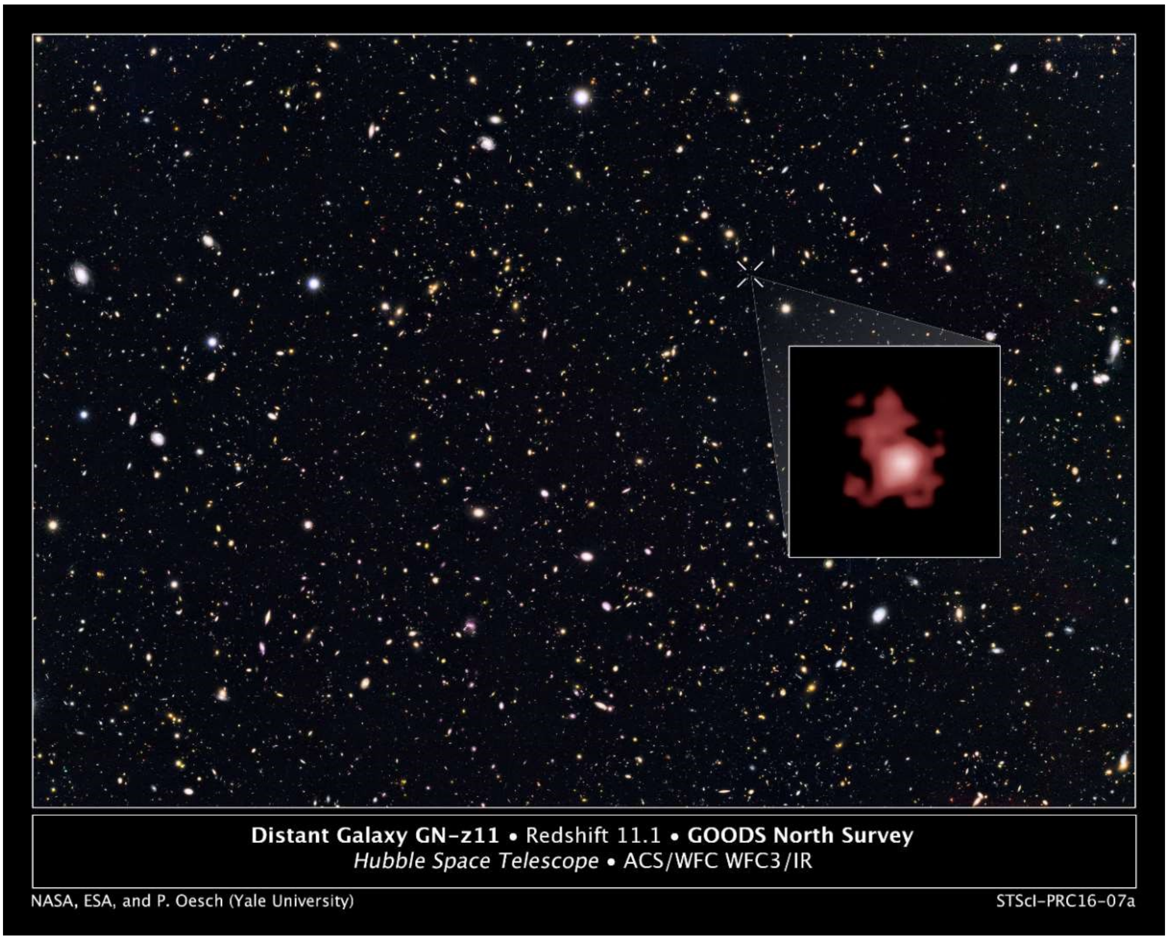
The Tinkerbell galaxy, ESO 593, is a collision of three spirals, 650 million light years away.

Hubble's' classification of galaxies (the tuning fork) suggests that spirals are turning into ellipticals as they lose their ordered appearance and use up all their gas so no more star formation takes place.



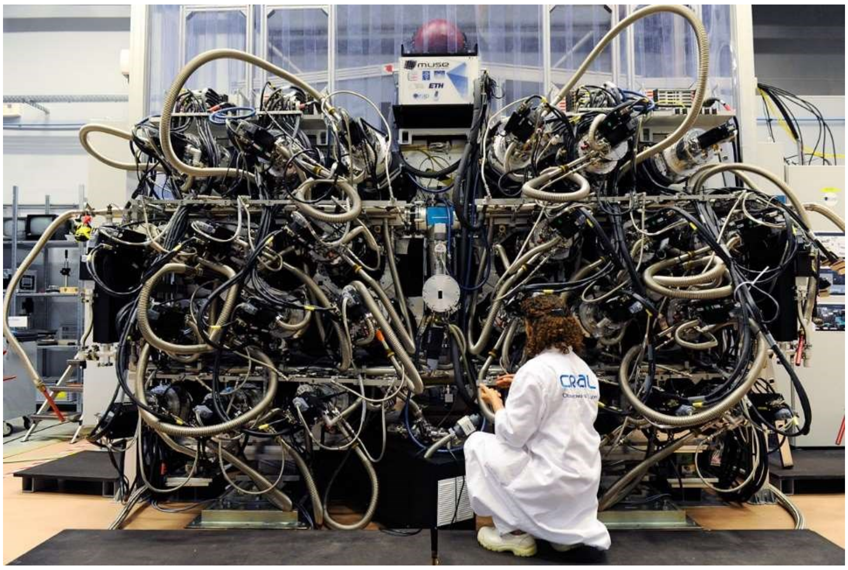
Spectra from distant stars and galaxies show a shift in their spectral lines towards the red end of the spectrum – this is known as redshift. This indicates stars and galaxies are moving away from Earth and a measure of redshift tells us how far away these stars and galaxies are.

Redshift is important because it gives us an observational measure of timescales which can be converted to distance scales in the universe.



The above animation was about finding the highest redshift galaxies and involved looking ever deeper into space, zooming in to tiny patches of sky until we are left with tiny red blobs which are so far away they appear as tiny red blobs because they cannot be resolved.

What is required is a larger telescope which will be able to resolve smaller objects in the same time as it took to see the galaxies in Hubble's deep field (four months).



To understand more about what is going on inside galaxies, we need better equipment and this is where the MUSE instrument will help. It is complicated but when working will be able to combine a detailed image of the object and its spectra but it can also look at the image in a third-dimension and get a spectrum at every single pixel. This is called integral field spectroscopy – something that Owen has been doing.

We use light to understand galaxies specifically in two ways: photometry and spectroscopy. Photometry is equivalent to photography, giving the two-dimensional pattern of the intensity of light from a certain patch of sky and we can see lots of galaxies at the same time. Spectroscopy gives us a one-dimensional view of the galaxy where light is dispersed into many smaller wavelengths and provides a very detailed view of what is happening within a galaxy. Both methods are required to understand a galaxy fully.

Whereas photometry provides the overall shape of the galaxy, spectroscopy provides information about what is happening within those galaxies. Spiral galaxy spectra have strong emission lines, due to hot young stars which heat the surrounding gas, and by absorption features due to the older, underlying stellar population.

A passive elliptical galaxy has a different spectrum to a spiral galaxy. Elliptical galaxy spectra are characterized by strong absorption lines, due to metals in the stellar atmospheres of an older star population. Few to no emission lines are present as there are essentially no young stars and no gas.

Irregular galaxy spectra have strong emission lines, again due to hot young stars.

The width and position of the emission lines can be used to infer physical properties of the gas within a galaxy, and the relative intensity of the emission lines can provide information about the chemical properties of the galaxy.

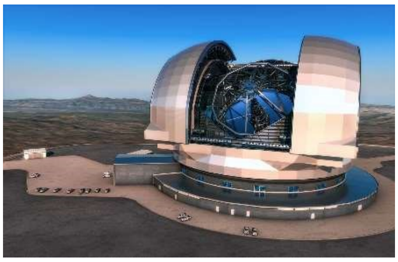
Active galactic nuclei have broad spectral lines due to gas being thrown out by black holes – this is outflowing material from the galaxy. The combined processes of supernovae and AGN ejecting energy from a galaxy is known as feedback and is very important as it heats up the gas of the galaxy preventing it from forming any more stars.

Supernovae are the end stage of massive stars, leading to neutron stars or black holes, and can outshine the rest of the galaxy. The energy they produce is very important for how galaxies evolve.

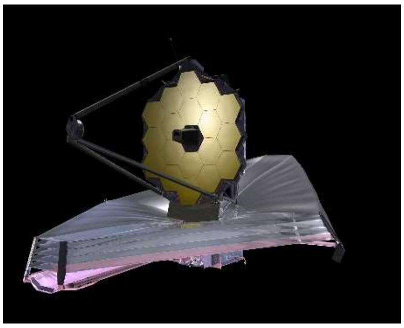
There are a number of different scenarios for galaxy evolution:

1) Slow growth pathway shows galaxies born as spirals with a large stellar mass and more metal rich stars. Eventually gas exhaustion means no more star birth resulting in a red and dead elliptical.
2) Spirals can merge resulting in irregular galaxies that eventually use up all their gas leading to elliptical galaxies. It has been shown that more irregular/interacting galaxies are present early on in the universe.
3) Spirals enter an AGN phase which expels gas, the galaxies grow by accreting other galaxies and eventually end up as some of the more massive red, dead ellipticals.
4) Small irregular galaxies form stars and exhaust their gas very quickly, may be accreted by larger galaxies but will end up as red, dead ellipticals

All of this takes billions of years.



Bigger telescopes with better resolution are required to take the investigation of the evolution of galaxies further and this is where the ELT (Extra Large Telescope), with a 40 m mirror, and the JWST (James Webb Space Telescope) will be invaluable once they come online. The JWST will be able to look at redshifts of between 15 and 20 – looking at those little red blobs.



The consensus now, is that the universe is very different today than it was perhaps 10 billion years ago when star formation was at its peak and it has been and still is evolving. The dominant form of galaxy has changed with more elliptical galaxies now than in the past, and fewer irregular galaxies because with the universe expanding, there are now far fewer mergers between galaxies than there were in the past.

The hope is to understand the properties of the whole population of galaxies using the next generation of telescopes.