Hi this is Steve Nerlich (Hi this is Dr Pamela Gay and you are listening to Cheap Astronomy www.cheapastro.com) and this is *Galaxy formation.*

The very early universe is theorised to have been homogenous and isotropic – most likely because of cosmic inflation.

When Hubble demonstrated that the universe was apparently expanding in all directions, it seemed reasonable to assume that the contents of the universe must have once been all crammed together in one spot. We know from basic physics that cramming that much stuff together is going to heat it to stupendous temperatures – and we think from quantum mechanics that at such temperatures, or energy densities, the difference between what's matter and what's energy ceases to mean anything and all you have is a kind of quark-gluon soup.

But how you get from a point-like singularity to a young, flat universe – with its homogenous soupy contents spread evenly and isotropically – is one of the great puzzles of cosmology. The best suggestion is that between ten to the power of minus 35 and ten to the power of minus 32 seconds, our baby universe inflated suddenly and dramatically by a factor of 10 to the power of 26 – which is a one with 26 zeros after it. To paraphrase Douglas Adams – imagine a hundred thousand people saying 'Wop'.

But of course there were some of those pesky quantum fluctuations that always seem to pop up in these stories. It's speculated that during that the dramatic inflation phase some tiny quantum level fluctuations were hugely amplified to a macroscopic scale resulting in minor density variations across the otherwise isotropic and homogenous primordial soup of the very early universe.

The cosmic microwave background shows a 380,000 year old universe that is still very isotropic and flat, with only very minor observable structure.

The microwave background is the red-shifted remnant of a huge flash of radiation released when the universe first became transparent to photons. However, we can only observe the early distribution of visible matter, like protons and electrons, since dark matter doesn't interact with electromagnetic radiation and so doesn't show up in the microwave background snapshot.

The role of dark matter in early structure formation is more than a little speculative – but the speculation goes something like this. Whenever dark matter did freeze out within the early universe, it may have become static quite quickly – being impervious to re-heating by radiation absorption and impervious to being broken up by radiation pressure. Since it is apparently much more abundant than visible matter and apparently it only interacts with visible matter through gravity – it may have become a kind of invisible scaffolding upon which visible matter began to clump.

The first proto-galaxies were probably started as just dense clouds of hydrogen, helium and dark matter - from which the first stars then began to form.

Clumps of hydrogen and helium gas have a tendency to aggregate, partly due to local electromagnetic interactions – and once a significant centre of mass is established, gravitational influences almost inevitably lead to a rapid accretion of material and to the birth of stars.

In an earlier and more compact universe, very dense clouds of gas would tend to favour the birth of very big stars with relatively short lifespans, generally ending with a supernova blast. These supernova blasts then seeded the surrounding gas clouds with heavier elements and their shock waves also contributed to driving more gas and dust together – all leading to the rapid birth of large numbers of next generation stars.

One of the earliest observable galaxies is about 13 billion years old. This galaxy is very bright due to new star formation but relatively small in size.

As the universe expanded further, galaxies began to cluster together and great voids began appear between those clusters.

Once the early galaxies had formed and were being gravitationally attracted both to each other and to the invisible scaffolding of dark matter – the ongoing expansion of the universe led to more and more empty space appearing between the clusterings of matter that were able to hold themselves together.

One of the earliest observable galactic clusters is about 10 billion light years away – and is thought to have formed when the universe was just over 3 billion years old. Since then the ongoing expansion of the universe has opened up more voids of empty space – emphasising the very faint association between different galactic clusters – which requires us to introduce the idea of a supercluster. It's speculated that these tenuous associations between galactic clusters are facilitated by invisible filaments of dark matter that extend across hundreds of millions of light years.

But getting back to the mere galactic level…

Generally spiral galaxies have lots of interstellar gas and new star formation, while elliptical galaxies have little interstellar gas and only old stars.

In our universe things generally happen with extreme violence and cannibalism. We've talked about the earliest observable galaxy being aged at around 13 billion years ago – and we can observe it as it used to look back then. Our own Milky Way galaxy is also thought to be about 13 billion years old – but rather than being one of those small compact early galaxies – it's now a giant spiral-armed monster.

The most accepted current theory of galaxy evolution is a bottom-up one – where initially small compact galaxies began to merge, forming larger – and generally spiral – galaxies. For this reason, galaxies like the Milky Way have grown dramatically in size, but still maintained active star formation through continuing to gobble up smaller galaxies which provide an ongoing supply of free gas and dust.

Lenticular galaxies may be similar in structure to spiral galaxies – but due to an absence of ongoing star formation, their spiral arms are barely visible. Presumably they started out as bright spiral galaxies, but in the absence of a steady diet of smaller galaxies, they have exhausted most of their supplies of free gas and dust and so can't make new stars.

Irregular galaxies are most commonly the result of two large galaxies colliding – where both are unable to maintain their original shape and instead appears as a 'train-wreck'.

Finally, elliptical galaxies may be end-result of these kind of galactic collisions. Elliptical galaxies are generally large galaxies with their stars orbiting a centre of mass in quite random directions. So rather than being a flattened spiral shape, they're just kind of round and blobby. Their stars are generally older stars as any free gas and dust in the galaxy has already been used up.

As our universe ages further, these fading elliptical galaxies – as well as isolated fading lenticular galaxies – will become more and more common. Given the Milky Way's impending collision with Andromeda, in about three billion years, it's likely we will be going down the elliptical galaxy path – well, eventually.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website over at the Local Group in the Virgo Supercluster – just find the Milky Way's Orion Spur and look for that G type star broadcasting old TV shows. No ads, no profit, just good science. Bye.