Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Stellar archaeology.*

This is the first of two podcasts on stellar archaeology.

Astronomy is mostly about collecting whatever celestial information happens to come our way - most often in the form of photons - but also in the form of subatomic particles like cosmic rays or neutrinos and occasionally the odd meteor might fall out of the sky.

Apart from the meteors though, most of this information is ephemeral - meaning that if you blink you might miss it - or, here in the 21st century, if your CCD breaks down you might miss it. Stellar archaeology is all about gaining data of past events from which any ephemeral information has long since flashed past - and it's mostly, but not solely, about looking for very old stars.

And why do we say stellar archaeology, which is the science of interpreting ancient remains of human culture rather than stellar palaeontology, which is the more generic science of interpreting the form, that is the ontology, of early - and hence generally ancient - stuff. Maybe it’s just because Indiana Jones is better known that Alan Grant (who was Sam Neill's character in Jurassic Park).

Anyhow, a good place to start with this study of ancient celestial remains of the early universe is with the search for metal poor stars. Astronomers, never big ones for being pedantic about naming things - refer to any stellar elements with more protons than helium as metals – including elements like carbon, oxygen and nitrogen. Although that's a bit strange, stellar metallicity – which means how much stuff other than hydrogen or helium is in a star – is often measured as a star’s iron-to-hydrogen ratio, which does make some kind of sense.

The key assumption of stellar archaeology is that the composition of stars should reflect the state of the interstellar medium as it was at the time those stars were formed.

We know there have been sequential generations of stars going all the way back to the first stars – which appeared less than half a billion years after the Big Bang – that is, more than 13.2 billion years ago.

As you may already know, we refer to the latest generation of stars - which includes the Sun - as Population I stars. These stars were formed from a interstellar medium that had been seeded by the previous generation of stars, called Population II stars. Population II stars would have included average sized stars which blew off a planetary nebula at the end of their lives – or bigger stars which blew up as supernovae. All these death throes of Population II stars seeded the interstellar medium from which metal-rich Population I stars - like the Sun – were formed. And those Population II stars had formed from an interstellar medium seeded by the death throes of Population III stars – which are thought to have been the first stars ever formed.

To try and make more sense of this – when we talk about these Populations we are mainly talking about the more common low mass stars which have life spans in the order of billions of years and some of them might still be observable today. Potentially there could have been many more than three generations of really big stars that only survive a few million years – but these are probably just a minority of all the stars that have ever been.

This is because, as the universe gets older, its gets bigger – so the gas and dust available for stellar formation becomes more diffuse – particularly when you have big star supernovae exploding and spreading out the gas clouds that they themselves formed in.

Also the cohesion of large gas clouds is affected by what's called fine structure line cooling. While a compact and homogenous gas cloud might maintain thermal equilibrium by all the protons in it just bouncing back and forth off each other, the introduction of heavier elements can lead to localised cooling because these more complex elements have more excitation states - so that when they are raised to a higher energy state by being bounced against – they have more opportunities to drop back to a lower energy state by the release of a photon of energy. This means they have much more capacity to cool down – meaning they become less excited and less bouncy.

This diversity of bounciness leads to fine structure fragmentation of a gas cloud – so that it breaks up and later generations of stars are hence not as likely to become as big.

Current thinking is that the first stars in the universe were probably hypergiants, of at least 100 solar masses. No-one is expecting to find any Population III stars nearby as they would have been big and short-lived. Indeed, it's thought that these stars were so big they literally blew themselves to pieces - the explosive force overcoming any gravitational force so that neither a neutron star or a black hole was left behind.

Anyway, the current focus of stellar archaeology is to look for old low metal stars in local areas around the Milky Way. Their proximity should allow detailed measurement of their composition – and where we find them in and around the Milky Way should tell us a lot about galaxy formation.

These old low metal stars are likely to be all Population II stars formed from an ancient interstellar medium which was seeded with lots of carbon, nitrogen and oxygen – and traces of other elements all the way up to iron – all of which were produced by exploded Population III stars.

In the Milky Way's halo, surrounding the dense galactic bulge, we can observe stars that have both low iron-hydrogen ratios – and low carbon and/or oxygen abundances. These are exactly the characteristics we would expect of Population II stars. And across a whole collection of such stars it's possible to measure a steady decrease in carbon or oxygen abundance – combined with a steady decrease in iron-to-hydrogen ratio. We think that stars at the low extremes of this scale represent the oldest and the earliest Population II stars.

And given that we find these very old Population II type stars in the fainter dwarf galaxies that cluster about the Milky Way and well as in the Milky Way's halo – it's hypothesised that our giant spiral Milky Way galaxy formed from the accretion of lots of smaller units - presumably smaller units of dwarf galaxies.

So although our galaxy seems full of stellar nurseries and young stars - really the Milky Way is an ancient thirteen billion year old structure - it's just been able to maintain a regular diet of dwarf galaxies to keep itself looking young. It's a sort of Dorian Grey thing - except not really. It's actually not a very good analogy at all Steve.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where it takes a universe to raise a podcast. No ads, no profit, just good science. Bye.