Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Stellar archaeology – the search for very old stars.*

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 even the occasional 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, you might miss it if your CCD breaks down. Stellar archaeology involves gaining data of past events from which any ephemeral information has long since passed us by.

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. Stellar metallicity is a term to describe how much stuff other than hydrogen or helium is in a star. In stellar archaeology we tend to assume that a star with low metallicity formed from a gas cloud that didn't have many metals to start with, while a high metallicity star presumably formed from a gas cloud that did have a lot of metals.

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 13.3 billion years ago.

As you may know, we refer to the very latest generation of stars - which includes the Sun - as Population I stars. These stars were formed from an 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 those Population II star deaths seeded the interstellar medium with heavy elements formed form stellar fusion, as well as from supernovae explosions. It's from this metal-enriched interstellar medium that Population I stars - like the Sun – were formed.

Of course those previous-generation Population II stars had themselves formed from an interstellar medium seeded by the death throes of an even earlier generation of stars, called Population III stars – which are thought to have been the first stars ever formed.

It's possible, although not very likely that there may still be some Population III stars still in existence, although they'd probably just be red dwarves. Red dwarves are able to persist for many billions of years, much longer than the life spans of larger stars. However, it's not likely that there ever were a lot of Population III red dwarves, since those first stars formed were probably all huge.

They were probably all huge because the early universe was a lot smaller and denser than it is now so there would have been closely packed matter to draw into star formation. As the universe has since got older, it's also got bigger – so the gas and dust available for stellar formation now is more diffuse – partly helped along by the fact that the first really big stars probably all went supernovae, hence spreading out the gas clouds that they had originally formed in.

Another reason why we are more likely to get smaller stars forming in the modern Universe is that the cohesion of large gas clouds is affected by what's called fine structure line cooling.

A compact and homogenous gas cloud can maintain thermal equilibrium since all its components are identical – so when they bounce off each other, they strike with the same energy and release the same amount of energy on impact.

However, as the first stars began to seed the interstellar medium with heavier elements, those heavier elements began to disrupt the thermal equilibrium of large gas clouds. Heavier elements have many more excitation states than hydrogen does. So when these heavier elements are mixed into mixed into a cloud of hydrogen, they can certainly be heated by hydrogen bouncing against them, but there's no guarantee that they will release the same amount of energy when they bounce against something else. Indeed, the heavier elements with many more excitation states, have much more capacity to release any energy gained as photons, which makes them cool down. So the nett result is that thermal equilibrium is not maintained, leading to areas of local cooling throughout the cloud.

Such diversity in temperature throughout the cloud, that is thermal disequilibrium, means that there are some areas where particles are bouncing off each other like crazy and other areas where they're not.

This diversity of bounciness, in a cloud with high metallicity, leads to fine structure fragmentation of the cloud – so that it is likely to break up into smaller clouds. This is another reason why later generations of stars are less likely to be as big as the first generation of stars.

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 these ancient Population III stars nearby as, being so big, they would have been short-lived. Indeed, it's thought that these stars were so big they literally blew themselves to pieces - that explosive force overcoming any gravitational force so that neither a neutron star nor a black hole was left behind for any stellar archaeologists to study later.

So, although by looking far away and hence back in time, we may see some of those early stars from a great distance, it would be too great a distance to conduct any detailed spectroscopic analysis. The current focus of stellar archaeology is to look for old low-metal stars that are in our neighbourhood, in or 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 give us a greater understanding of how stars interact and how galaxies form.

Any nearby old and low-metal stars are mostly likely to be Population II stars formed from an ancient interstellar medium which was already seeded with lots of carbon, nitrogen and oxygen – and traces of other heavier elements, either formed by stellar fusion or formed through the dynamic kinetics of dying stars, either blowing off their outer shell as they die or blowing up as a supernova.

In the halo of the Milky Way, surrounding the dense galactic bulge, we can observe stars that have may have low iron, or low carbon or low oxygen abundances. These are just the characteristics we would expect of Population II stars. And across a whole spectrum of such stars, we do find there are upper and lower extremes of iron, carbon or oxygen abundance. We think that stars at the low extremes of this scale represent the oldest and the earliest-born Population II stars.

We particularly 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 from this finding we think that our giant spiral Milky Way galaxy must have formed from the accretion of lots of smaller 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 has kept itself looking young by cannibalising other less-fortunate galaxies that didn’t get big enough, fast enough.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where, if you wish to make a podcast, you first need to make a Universe. No ads, no profit, just good science. Bye.