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

This is the second of two podcasts on stellar archaeology.

In the first part of this series we looked at one of the major areas of stellar archaeology - which is all about finding really old stars - and then deducing the characteristics of the early Universe by studying those really old stars. But the principles of stellar archaeology, where we try to gain an understanding past events by studying what we can observe in the present can also be applied to other areas of astronomical research.

So for example – something that gives a whole new meaning to the concept of data mining is the proposal that if we dig up a few kilotons of Molybdenum ore we will gain a picture of how many supernova have gone off in the Milky Way over the last 2.6 million years. Molybdenum is sensitive to neutrino interactions – and supernovae are a very powerful source of cosmic neutrinos. Apparently, a neutrino interacting with naturally occurring Molybdenum creates the isotope Technetium 97 – and this change is retained as a reliable record over 2.6 million years. Some calibration – and a bit of statistics – can filter out solar neutrino interactions – which would be over 80% of all these interactions. The remainder would be neutrinos produced by supernovae from across the galaxy.

It's possible that this natural record, coupled with real time neutrino data being collected by human-made detectors in various coal mines and the kilometre-deep *IceCube* neutrino detector in Antarctica, might help us then gain a picture of supernova activity over the last couple of million years. Cool.

Another speculative area of stellar archaeology involves black widow pulsars. These are particular types of pulsars named after *the* black widow pulsar - or B1957 +20. You probably know that pulsars are really just neutron stars that line up with Earth, so we receive a regular pulse of radio energy as they spin.

Neutron stars are incredibly dense objects - generating a stupendously powerful gravity field due to their mass and density. What's different about a black widow pulsar is that it's a pulsar in a binary star system that's gravitationally drawing off matter from its binary companion. The result of this is that the pulsar's spin rate increases - like a spinning skater drawing his or her arms in.

So that's all very interesting, but for stellar archaeologists - what's really interesting here is what's happening to the other star. It's slowly having its outer layers stripped away by its black widow pulsar companion - so that if we keep watching, it's as though we are digging into a star's inner layers - eventually exposing its core to direct observation. A recent example of this phenomenon even made the news headlines. The companion of black widow pulsar PSR J1719-1438 was reported as a so-called diamond planet – even though it is not in fact a planet at all, but the compressed carbon core of what was once a massive star whose outer layers have been eaten away by its black widow neutron star companion.

And then, as well as stellar archaeology, there's a field of study known as interstellar archaeology – which is actually about aliens. And here we are talking about intelligent aliens

capable of building things on a massive scale that we can detect from a distance. We choose to think about this in archaeological terms because the current radio silence from 'out there', does not suggest there is anyone out there now. So we are just hoping to find relics of long-dead alien civilisations.

Interstellar archaeologists refer to the Kardashev scale of advanced civilisations. According to the scale, a civilization that has reached the Type 1 level is capable of harnessing all the power available on a single planet. A type 1 civilisation might have thoughtfully disposed of large quantities of nuclear waste in its star – which would still be observable today as A, F or G type star with an overabundance of praseodymium, neodymium or technetium.

Moving up the Kardashev scale, there's also Level 2 civilisations which can harness the entire power of a star. To find them, we might look for signs of *star-lifting*. This is a hypothesised stellar engineering project where an artificial equatorial ring of electric current creates a magnetic field sufficient to both increase and channel all the star's stellar wind into two narrow polar jets. Since such jets are normally only seen in young proto-stars, their presence in older main sequence stars might suggest alien interference.

These jets could have been used for power generation, but might also have been used to prolong the life of an aging star. Any Level 2 civilisations, orbiting a Sun-like star may be able to delay the evolution of a G-type star up to a red giant, by siphoning off stellar material using star-lifting techniques. In fact, future generations of humanity, having achieved Level 2 status, might use this approach to keep Earth's orbit as a habitable zone – which it will otherwise cease being, in a billion years or so when our Sun starts getting too hot.

Type 2 civilizations which used star-lifting techniques on very massive stars for the purpose of power generation might have employed some well-placed and appropriately-shielded nuclear bombs to stir up stellar core material in order to delay the evolution of a massive star to a core collapse supernova. It's been hypothesized that observable and mysterious giant blue straggler stars, which have not gone supernova like most stars of their type would, may have been tinkered with, by level 2 aliens, in this manner (although I am stressing the word *hypothesized*).

Type 3 civilizations on the Kardashev scale are able to harness the power of an entire galaxy. To find evidence of their past existence we might look for supermassive black holes, whose radiating accretion disks are strangely filtered, suggesting the presence of a Dyson swarm. A Dyson swarm is a plausible alternative to the implausible Dyson sphere, which would be inherently-unstable and quickly undergo gravitational collapse. A Dyson swarm is a large grouping of unconnected energy-absorbing panels, which occupy approximately the same orbit around a star, or a supermassive black hole, by floating at just the right point in space, where the outward radiation pressure matches the inward pull of gravity.

But really, it's difficult to speculate on what we should be looking for at this advanced level – who knows how our own technology might advance millions of years from now – and that's if we don't blow ourselves up, run out of energy or just kind of drown in the population versus resource availability balance.

If you are wondering, Earth is only considered to be at Level 0.73 of the Kardashev scale, since we don't yet harness our whole planet's energy sources and so can't even claim to have reached level 1 yet.

To search for another primitively-civilised planet like ourselves, we should undertake detailed spectroscopic analyses of exoplanet atmospheres where we might find free molecular oxygen - a clear indicator of life - and the presence of chlorofluorocarbons, or other industrial pollutants, which are clear indicators of industrial activity.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where you can pass the time until first contact - which we can assure you hasn't happened yet. No ads, no profit, just good science. Bye.