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 the main thrust of stellar archaeology - which is all about finding really old stars - and then kind of digging up information about the early universe from them. But despite the fact that archaeology is the wrong term for all this activity anyway, it's kind of caught on and is being used in the context of other astronomical investigations as well. So this podcast will try and cover some of that other stuff.

So for starters – 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 galactic 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 a reliable record over 2.6 million years. A bit of statistics and calibration work can filter out solar neutrino interactions – which would be over 80% of all these interactions.

It's possible this natural record, coupled with real time 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 of million year periods. Cool.

And then there's an arcane little field sometimes called interstellar archaeology – which is really about aliens. And here we are talking about intelligent aliens capable of building stuff, which may be visible or otherwise detectable. The term archaeology is used where the current apparent radio silence from 'out there', suggests no-one's actually active at the moment (or at least the light that's reaching us at the moment contains no evidence of activity). Arguably this might just be because they, like us, are becoming increasingly radio-quiet by finding more efficient ways to broadcast information. But in any case maybe we have to look for relics of past civilisations - or other incidental signs that *someone is out there*.

Now, in this area we can geek out a bit and consider 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. On this basis, it might be a civilisation that inadvertently signals its presence after thoughtfully disposing of large quantities of nuclear waste in its star. Apparently, we should be scanning A and F type stars for spectral signatures of (funnily enough) technetium – or perhaps an overabundance of praseodymium and neodymium.

If you are wondering, Earth is for various arcane reasons considered to be at Level 0.73, since we don't yet harness our whole planet's power sources – which will hopefully be more about renewable energy sources – well, hopefully.

To search for some primitively civilised planet like ourselves, we should probably undertake detailed spectroscopic analyses of exoplanet atmospheres where (using Earth as an example) we might find free molecular oxygen - a clear indicator of life - and the presence of chlorofluorocarbons is a clear indicator of industrial activity.

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.

These jets could be used for power generation, but might also represent a way to prolong the life of an aging star. In fact future generations of humanity, having achieved Level 2 status, might use this approach to keep Earth's orbit as a habitable zone. It's thought that, in less than a billion years, Earth's oceans will evaporate due to the Sun's steadily increasing luminosity, but some carefully managed star lifting to modify the Sun's luminosity by modifying its mass could extend this time limit significantly.

Type 2 civilizations in orbit around bigger stars might employ some well placed and appropriately shielded nuclear bombs to stir up stellar material that would delay a big star's shift to core collapse. Core collapse happens when there's not enough hydrogen available in or near the core to maintain the fusion burning that maintains the outward radiation pressure that stops a massive star from collapsing in on itself due to its own self-gravity.

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 here I am stressing the word *hypothesized* there).

As for detecting Type 3 civilizations which are by definition able to harness the power of an entire galaxy, well maybe we'll find evidence of Dyson nets around supermassive black holes. But really, at this level, it's difficult to speculate on what we should be looking for - since all we have to go on is how our own technology might advance millions of years from now - if we don't blow ourselves up, run out of energy or just kind of drown in the population versus resource availability balance.

But anyway - that's aliens and interstellar archaeology. Another speculative area of stellar archaeology involves black widow pulsars. These are types of pulsars named after THE black widow pulsar - or B1957 +20.

So, you probably know how normally a big star goes supernova and it might leave behind a remanent neutron star - which might maintain the angular momentum of its progenitor star so that it spins quite fast and every time one of its polar jets lines up with Earth it delivers a regular beep of radio energy - and really it is just a standard neutron star at a particular orientation to Earth. Neutron stars are incredibly dense objects - kind of half way towards a black hole and 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 sucking off matter from its binary companion. The result of this is that the

pulsar spins faster - becoming what's known as a millisecond pulsar. Isolated pulsars normally blow off stellar wind and hence mass - which makes them slow down (following that standard analogy of spinning skaters who open out their arms). But a black widow pulsar, by continually gaining mass from its stellar companion, speeds up, like spinning skaters drawing their 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 - although it will be a core that is not subject to the normally intense gravitational compression that stellar cores are normally exposed to. Still - it'll be interesting and it'll be data.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where you can find the whole universe in a periodic table. No ads, no profit, just good science. Bye.