Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Why we need neutrino telescopes*.

Rule Number 7 of the 365 Days of Astronomy Podcast states *The subject matter need not be appropriate for all listeners… A podcast about the magnitude scale is encouraged, as is one on neutrinos in the early universe*. Since Chris Marr from Western Australia did a such a sterling job on the magnitude scale on March 29, Cheap Astronomy will have a go at neutrinos in early universe.

I mean, how hard can it be?

So to start with, let's look at neutrinos. They are in a class of subatomic particles, called leptons, which include electrons. But unlike electrons, they are electrically neutral and almost massless and they hardly interact at all with other matter.

Neutrinos are produced in great abundance by the Sun, during the fusion of hydrogen to helium which produces large amounts of energy carried by photons, but also produces neutrinos. As soon as these neutrinos are produced they shoot straight out of the Sun at close to the speed of light, passing by and through the Earth a few minutes later. Trillions of neutrinos are passing through your body as we speak.

It's very different story for the photons produced by fusion within the Sun. Because photons interact strongly with matter and there's a heck of a lot of matter within the dense plasma of the Sun, new photons produced from fusion reactions are almost constantly being absorbed and then re-emitted – over and over again.

For this reason, it may be hundreds of thousands, even millions of years, before a unit of energy produced by fusion in the Sun's core is released from the Sun's surface in the form of a photon, which flies off at the speed of light.

And what's all this got to do with the early universe? Well, conditions within the Sun are roughly analogous how the universe was from around 300,000 years after the Big Bang. That is – a dense hot plasma of hydrogen, helium and some trace elements.

It's probably worth mentioning here that plasma is the fourth state of matter – where a gas has been heated so much that positively charged electrons disassociate from atoms and begin to move freely from their negatively charged nuclei – which in a plasma state are called ionized.

Anyway, in the 300,000 year old universe, photons were caught up in constant interaction with the surrounding plasma, similar to the way they get caught up in the middle of the Sun. But when the universe was 380,000 years old, it had expanded to a point where its temperature was no longer hot enough to keep its contents in a plasma state. Electrons began to associate with ionized nuclei forming the first atoms, in an event called recombination. At this point, the universe became for the first time, transparent to radiation.

A burst of radiation, carrying a temperature of just under 3,000 Kelvin and an imprint conditions at that time, filled the universe and continues to fill it today, except that filling a steadily expanding universe means that the wavelength of this radiation burst has now been stretched into the microwave spectrum over the intervening 13.3 billion years – and consequently it carries a temperature of just 2.7 Kelvin.

So in the unlikely event that you've never heard of the cosmic microwave background radiation – well that's what it is. But even if you have heard all this before, it's worth reiterating the story behind it, because now I want to take you back to an even earlier time when the universe was so dense and so hot, that even neutrinos were caught up, forced into interacting with everything else in the universe, rather than enjoying the calm, detached existence they have today.

Just after the end of the first second after the big bang, its thought the universe was cool enough that quarks and gluons were present, but it was still too hot for the gluons to glue the quarks together into protons and neutrons – being that stuff we think of today as matter (well, at least non-dark matter).

But after the first second, as the universe continued to cool, things started 'freezing out' and neutrinos were the first particles to do so – freezing out as a mixed population of neutrinos and anti-neutrinos most of which annihilated each other, but a residue of neutrinos remained which then fled the scene and from thereon had little more to do with the rest of the universe.

And these very first neutrinos, often called relic neutrinos, that now fill the universe, even though they are barely detectable – yes, they are collectively called the cosmic neutrino background!

This neutrino background has experienced the same expansion and cooling as the microwave background – in fact it is predicted to carry a temperature today of only 1.95 Kelvin.

So, isn't it time we stopped to reflect that here we are getting all excited about having mapped a cosmic microwave background that shows the universe at 380,000 years of age, while all the while there's this cosmic neutrino background just sitting there that will show us the universe when it was one to two seconds old.

So come on – let's just build a neutrino telescope and take a look, There's way too much quitter talk out there about how the neutrino background 'might never be observed directly' and the usual issues of how it takes would take a light year of lead to stop a neutrino in its tracks, so how could you possibly build a detector – yada, yada.

Well, already there are some neutrino telescopes out there which are able to detect, well the Sun and, uh, a supernova… once.

But hey, early days, there's some smart people in the world and they can build cool stuff. For example, there's AMANDA, or the *Antarctic Muon and Neutrino Detector*

Array which used glacial ice from Antarctica as its neutrino detector – and the next upgrade appropriately called Ice-Cube will use a detector array made of one cubic kilometre of Antarctic ice.

No-one is expecting Ice-Cube will be picking up the neutrino background anytime soon, but it’s not like Galileo was able to observe gamma ray bursts either. Everything in science has its beginnings.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where the universe is more than you bargained for. No ads, no profit, just good science. Bye.