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

So look everyone makes mistake. And as it happens, some of the best science podcasts out there make occasional slip-ups – I mean, big deal right? It would be both petty and a bit pathetic really for some cheap podcast to go into *CapsLock* on rant mode and start criticising such trivial errors. And that is pretty much the plan for today's Cheap Astronomy episode.

Now with this first one, I wrote in to their Contact us email months ago to explain the problem – and I'm not upset that I didn't get an answer, I mean hey these are busy people. And look, I love the podcast, I've bought the t-shirt, the coffee mug and the extended version releases – I do try to be a good listener.

But anyway here's the problem – and no prizes for guessing which podcast this is.

The Hubble Space telescope has identified the furthest galaxy protocluster ever discovered about thirteen billion light years away...

And just in case you actually don't actually know, that was the Skeptics Guide to the Universe, episode 339, about 59 minutes in.

And if you are not immediately seeing the problem – well, you can observe something the way that it looked 13 billion years ago – but no way is that something 13 billion light years away – because light years is a measurement of distance. We live in an expanding universe – which means that our location and a distant object's location would have been much closer together 13 billion years ago when the light that we are now seeing first left the object. In fact today, the object (if it even still exists) will have moved much further away than 13 billion light years anyway – indeed our location has also moved way out in the opposite direction. I mean (engage CapsLock) – COME ON.

Anyway, inspired by all this corrective thinking, I've asked Barry Haworth to read a short piece on cosmic event horizons – so take it away Barry (noting of course that any mistakes made in this are all mine).

Event horizons - read by Barry Haworth

The universe has two event horizons. First, there is what Wikipedia calls the particle horizon - which is the largest distance from which a photon of light could *ever* reach you - even though the object that emitted that photon over 13 billion years ago would have since been moved by the ongoing expansion of the universe far beyond our current observable limit.

So the particle horizon represents the fullest extent of what we call the observable universe - which we estimate to be 46 billion light years from us - meaning that the full diameter of the observable universe is 92 billion light years. There is no particular reason to think that the universe isn't a lot bigger than this but we do not expect that we will ever be able to observe whether it is... or not.

The other event horizon is called the cosmic event horizon - which is the largest distance from which a photon could be emitted right now, like today now - and still reach an observer at your location in the far future. The cosmic event horizon is estimated to be 16 billion light years away - which means that an observer at your

location will be able to see that photon, which was emitted today, when it finally arrives at your location years in the future.

This also means that if an object that is, say, 17 billion light years away emitted a photon today that photon will *never* reach your location. The ongoing expansion of the universe will add so much distance between your location and it, that the photon could travel at the speed of light for the whole remaining lifetime of the universe without it ever reaching your location.

So to summarise - we can potentially see photons emitted from objects that may *today* be 46 billion light years away. And we will be able to see photons that are emitted *today* from 16 billion light year distant objects - but that's all we are ever going to see, or know about, because information can only move through the universe as fast as the speed of light in a vacuum.

Still that does leave an awful lot of stuff out there for us to look at - we probably shouldn't complain.

And thanks Barry. And next, well now I really am just nitpicking. This is awesome Naked Scientists Dr Chris Smith ad-libbing on Radio 4's Up All Night program. So the guy has got to think on hiis feet and it's all a bit unreasonable to start calling him out on this off-the-cuff statement. But for the sake of educational pedantry, let's consider what's wrong with this.

Einstein might be right after all - light is the fastest thing...

So it's OK to say that light can moves at the fastest speed that anything can move, but the speed limit of the universe is really determined by the nature of space-time. Light being an energetic, self-propagating wave-particle thingey with no mass ends up moving as fast as anything can move in our universe. But it's not *the* fastest thing, it's just one of the fastest things that can move at this absolute speed. At least one other thing that can do this is the effect of gravity - or if you like, the speed at which a massive object produces space-time curvature at a distance.

And now, here’s one more correction to fill out today's episode, which is something I recorded for the kick ass Australian podcast Smart Enough To Know Better – which they actually asked me to do although they didn't specifically ask for the sound effects.

To actually put it out, Hawking radiation would require the background universe to be quite cold, so you don't have to worry about Hawking radiation until way off into the future..

Ahem... now, here's the real story. According to quantum physics, the universe is full of quantum fluctuations. Two virtual particles - let's say an electron and a positron - appear out of nowhere and then this matter and anti-matter pair collide, annihilate and wink out of existence again - which means there's a nett energy production of zero and the whole thing happens within a tiny space of time - called a Planck time, so no-one is going to notice it happened anyway..

But, if you have a quantum fluctuation near a black hole and one of the particle-antiparticle pair goes into the black hole. Then:

a) the one that goes into the BH annihilates with its opposite in there; and

b) the one left over joins the outside universe without being annihilated - and it's this remaining particle that represents Hawking radiation. So, it's not really electromagnetic radiation, but something like electrons or positrons.

Anyhow, the nett result is that the black hole decreases in mass since one particle that was already in there is annihilated - and the universe outside the black hole gains one particle.

This process is supposedly how black holes will eventually evaporate although it will take them a googol years or more to do so. That's googol, -ol, not google, le. A googol years is 1 times ten to the power of one hundred years - or a one with a hundred zeros after it.

After this aired, someone pointed out that the annihilation of a particle within a black hole shouldn't reduce its mass, since the annihilation produces a photon - which still represents mass in a mass-energy equivalence sort of way. Apparently you need negative energy for the black hole evaporation idea to work. So yep, I get things wrong too - and yep I don't really understand Hawking radiation either.

Anyway, there you go. Podcast mistakes can occur across the US, the UK and Australia. Next week, Canada (just kidding).

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an edutational weeblight where we never get nothing wrong. No ads, no profit, just good science. Bye (and sorry).