Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Why the LHC won't kill you.*

Concerns about a 'big science machine' that could destroy the Earth have been around since the steam engine. And surprisingly, rumors still persist in some corners of the Internet that the Large Hadron Collider (the LHC) is going to destroy the Earth – even though nearly three years have passed since it was first turned on.

This may be because it is yet to be ramped up to full power in 2014 – although it seems more likely that this is just a case of moving the goal posts, since the same doomsayers were initially adamant that the Earth would be destroyed the moment that the LHC was switched on, in September 2008.

But perhaps one should not be too harsh as there may be a degree of genuine concern out there – however, there's probably also an equal degree of conspiracy-theory-mediated-website-traffic-for-profit out there too – so sometimes it's hard to know where to park one's sympathies.

In any case, for the record I think death-by-LHC is a load of old bollocks and I acknowledge there's a certain irony in doing podcasts already on that one in a million chance of a mass extinction asteroid striking the Earth – while dealing with the supposedly equivalent risk of death-by-LHC with a fair degree of disdain. The fundamental difference is that there is tangible evidence and a plausible mechanism for the former and there is really neither for the latter.

The story goes that the very high energy collisions engineered by the LHC could jam colliding particles together with such force that their mass would be compressed into a volume of less than the Schwarzschild radius corresponding to their combined mass. In other words, a microscopic black hole would form and then grow in size as it sucked in more matter, until it eventually consumed the Earth.

Now, coventional physics says this can't happen, but it such an 'out there' idea, that conventional physics doesn't spend a lot of time explaining why it can't happen. Mathematically, anything that has a quantity of mass has a calculable Schwarzschild radius, but that does not mean you can necessarily turn any mass you like into a black hole.

For example, while a teaspoon of neutron star material might weigh several million tons, if you extract a teaspoon of neutron star material from a neutron star it will immediately blow out into the volume you might expect several million tons of mass to normally occupy. Without the surrounding stellar scale mass pressing in on it, there's nothing that can hold it together.

Applying this same logic to small scale black holes is tricky, since you can't physically extract a teaspoon of black hole material since nothing is able to escape from a black hole – so we are better off looking at the various reasons why you could never plausibly form a small-scale black hole in the first place.

The problem becomes apparent when you look at the fundamental principles of quantum mechanics. Gravity is the weakest force – weaker than the electromagnetic force – which is weaker than the weak nuclear force, which is weaker than the strong nuclear force. And that's all you've got to work with – the four forces. The hypothetical physics that might allow for the creation of microscopic black holes (a theory called large extra dimensions) proposes that gravity gains more strength in sub-Planck scale dimensions. However, there is no evidence to support this theory –

indeed there is a growing level of disconfirming evidence arising from various sources, including the LHC.

Anyhow in a nutshell, you can't make a small number of protons stick together – since they don't have the self-gravity to overcome the repulsive electromagnetic force they generate when they come into close proximity. Of course, the momentum of a particle collider collision carries sufficient kinetic energy to overcome that repulsion – but the result is consistently found to be that the collision results in everything being blown apart into bits of sub-atomic shrapnel.

But let's now go back to the point that just because there is math that says you can take a mass, compress it into its Schwarzschild radius density and you get a black hole. Compressed mass within a neutron star, is a result of gravity overcoming the electromagnetic force and pushing the electrons and protons together to form neutrons. We're not really sure what happens when neutrons are compressed down to form black holes – but perhaps the strong nuclear force is overcome and you get an even denser quark matter.

In any case, since we have never created anything remotely like stable (or even unstable) neutron star material in our current colliders - nor have we seen even the most basic step of a fusion of hydrogen nuclei into helium nuclei - there's no grounds to think we can ever create black holes in the LHC.

After all, the whole point of particle accelerators is to attempt to mimic conditions in the early universe just after the Big Bang – not the conditions found inside the core of a massive star. Mimicking the conditions within the core of a massive star is more the job of fusion reactors, but it seems no-one is complaining about those putting the Earth at risk - and nor am I - I'm just saying that complaining about those might make very slightly more sense than worrying about the LHC.

So, hoping that I have convinced you that we can't make microscopic black holes in the first place, there's also some basic physics which can explain why a hypothetical microscopic black hole – couldn't a) grow in size, or b) consume the Earth.

Although whatever goes on inside the event horizon of a black hole is all a bit mysterious and unknowable – physics still operates in a conventional fashion outside a black hole. The gravitational influence exerted by the mass of a black hole falls away by the inverse square of the distance from it, just like it does for any other celestial body.

The gravitational influence exerted by a microscopic black hole composed of, let's say 1000 hyper-compressed neutrons, would be laughably small at a distance of more than its own Schwarzschild radius (which is theoretically about 10^{-18} metres) – that is, about 1,000 times smaller than an uncompressed hydrogen nucleus.

So, this means that a microscopic black hole would have no hope of consuming a nucleus in one go - so the only way it could consume any more matter and grow in size - is if it could overcome the forces that hold a nucleus together and kind of cut a little bit of it out. Now, this seems an unlikely scenario since gravity is the weakest force and the physical nature of a nucleus having a bit cut out of it, is not an object that is familiar to science. And perhaps not surprisingly, this is not the level of detail that your average conspiracy theorist ever gets down to.

And then there's the issue that matter at the sub-atomic scale is mostly empty space. It's been estimated that if the Earth had the density of solid iron, a hypothetical microscopic black hole in linear motion would be unlikely to encounter an atomic nucleus more than once every 200 kilometres – and the microscopic black hole might have only 100 such encounters before its momentum carried it all the way through the Earth and out the other side.

The transverse momentum imparted to LHC collision fragments after a head-on collision of two particles travelling at around 300,000 kilometres a second easily gives them an escape velocity from the Earth (being just 11.2 kilometres a second, at sea-level).

And then there's the issue that some people refer to the concept of Hawking radiation – since such a hypothetical black hole would evaporate shortly after it formed. Indeed, we may expect some discussion about whether or not microscopic black holes have formed in the LHC for a Planck time before evaporating.

And lastly of course, there's the issue of cosmic rays. The Earth's upper atmosphere is regularly bombarded with cosmic ray particles travelling at more than 99% of the speed of light. And these cosmic ray collisions with the atmosphere have been measured as having 50 times the energy that will ever be generated by LHC collisions.

So folks, it's well past time to wake up and smell the coffee about climate change and even the faint risk of asteroid impact – but I suggest to you that there really is no need to lose any sleep over death-by-LHC.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where heat makes gravitationally unbound objects expand - not contract. No ads, no profit, just good science. Bye.