Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *The centre of a black hole*.

Hey, remember how we used to do ten minute Cheap Astronomy episodes? Nowadays we just do five minutes answers to Dear Cheap Astronomy questions and ten minute ISS episodes and of course you have to spend equal time listening to me bang on about my PhD – which has been going on nearly 4 four years now. I mean, come on.

But, just now and again, we do try and surprise you by throwing in a real 10 minute long, just like the old days, Cheap Astronomy episode – with the intro and the outro and a whole bunch of stuff in the middle. This one actually arises from a Dear Cheap Astronomy question, a question from Kent, where I read it and went hey, what, um, huh and then oh...

So, firstly there's an old physics thought experiment that says that if you drill a hole all the way through the diameter of the Earth – and we pretend there's no air resistance and it's not all hot and molteny inside – then you will fall through that hole, accelerated by the gravity of the planet, right through to the other side – and be decelerated before you reach the other side, at which point you fall back again. And the whole process repeats over and over in an endless fall. Allegedly, the whole passage from one side to the other always takes 42 minutes, but that calculation assumes the Earth is uniformly-dense, which of course it isn't. A fall through a properly-modelled Earth, with a diffuse crust and a dense core, has a fall-through time of several minutes less than 42 – and is hence not equivalent to half an orbit (a calculation which only works if we pretend the Earth is uniformly-dense).

But putting most of that aside, what's important for this podcast is that if you fell down that hole in the Earth with a jetpack and used it to slow yourself to a halt right at the centre of the Earth, then you would just float there weightless. There would be equal mass spread equidistantly around you, so the nett gravitational effect upon you would be zero.

Of course what makes gravity work the way that it does is that mass bends space-time and the degree of space-time bending at any point is dependent upon the amount of mass that you are adjacent to. So, at the centre of the Earth space-time is equally bent from all directions – and the nett effect is that it flattens out.

While mass does warp space-time, we should also qualify the effect of density, because the extent of local space-time warpage does also depend upon mass density. For example, if you compress the Earth down to half its diameter you will increase its density by a factor of 8 and the gravitational force you will feel standing up on its surface will quadruple from nearly 10 metres per second to nearly 40 metres per second per second, even though it's the same 1 Earth mass beneath your feet. So on the surface of the compressed Earth your clock would run slower than a clock on the surface of a normal-density Earth.

But density only matters up to a point. If you climbed a very tall ladder up from the surface that compressed mini-Earth, when you reached an altitude that was at the distance from the centre that the original Earth's surface used to be, then you would a gravitational force of 1g and your clock would be running at normal Earth sea-level rate. Even if you compressed the Earth down to such an extreme density that light could not escape from it – that is, a black hole – from a point that was one Earth radius distance from the centre of that black hole, you would still experience a 1G of gravity and an Earth sea-level clock rate.

So, pulling all that together now, gravity is really just space-time curvature, because the presence of mass curves space-time. However, the degree of local space-time torsion – that is, the degree of gravity that you experience when you are near a mass – depends not only on the mass of that mass, but also on its density. To put it another way, the gravitational force that you experience near a massive object is always determined by your distance from its centre, but it's also determined by just how much mass may be tightly-packed between where you are and where its centre is.

But of course, if your distance from that centre of mass is zero, that is you *are* at the centre, then there is no nett gravitational force acting upon you, because there is equally-dense mass in all directions around you, so space-time flattens out.

So, now to Kent's question – which, as you may have guessed already, is whether there is zero-G at the centre of a black hole. From a pure Einsteinian view, the answer is no since all the mass in a black hole is supposedly compressed to a point of infinite density and zero volume. If there's no volume then there is no point further within where you could find mass equal distributed around you. All the mass is simply at one single point.

This idea may seem extraordinary, but it is also irrefutable, since the nature of the mass distribution inside a black hole is unknowable, because the whole thing lies behind an event horizon. So in the absence of observational data all we have to go by is the mathematics of Einstein.

But let's also remember what the eminent gentleman who presented this math to the world had to say about math: *As far as the laws of mathematics refer to reality, they are not certain, and as far as they are certain, they do not refer to reality.*

As we have previously discussed in other Cheap Astronomy episodes, it is puzzling that we now have observational evidence of supermassive black holes and also stellar-sized black holes.

Should we assume then that the mass within the supermassive black holes has a really-big infinite density compressed into zero volume, while a stellar black hole has just a middling kind of infinite density compressed into zero volume? One should always be a bit sceptical when your math starts producing infinites – and perhaps a bit more sceptical when it starts telling you about different-sized infinites.

If it isn't the case that all mass shrinks down to a single point within a black hole – but instead perhaps compresses down into some unimaginably-dense state of degenerate matter, which actually has a quantifiable volume and hence both an outer surface and a centre – then it does start sounding plausible that at the central point of that extraordinary object, there might be point of zero G since that point would be surrounded by equidistant amounts of mass with utterly-humungous, but equal, densities.

But while there might be a tiny point of zero G at the very centre, it’s still a point that’s way down at the bottom of a deep, dense black hole. To fall all the way down to the centre of a black hole, firstly you would die, but you would also have to fall through regions where relative time slows to almost nothing. So, just because you’re at zero G does doesn’t mean your clock will start running at the same rate it might out in interstellar space.

And of course there is no way we could ever verify this claim, since you have fallen past an event horizon, which means you can’t transmit a signal out – nor are you ever going to get back out again yourself, to tell anyone about the rate of your clock or the length of your ruler.

Nonetheless, zero-G at the centre of a black hole, although utterly-unverifiable as a hypothesis, does seem almost plausible – well, a bit… maybe.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy www.cheapastro.com. Cheap Astronomy offers an educational website full of answers to unknowable questions, since no-one can ever prove us wrong. No ads, no profit, just good science. Bye.