

Question 1:

Dear Cheap Astronomy – Do gravitons exist?

Once again we're dealing with something hypothetical here – so much like virtual particle pairs that pop out of nowhere and can evaporate black holes, it's entirely possible that gravitons exist, but at this time it's probably appropriate to entertain the notion that they might not exist either. Ten years ago we would have said the same thing about the Higgs boson, but that was positively identified by the Large Hadron Collider in 2012 and hence moved from being a hypothetical to a real particle at that time.

The case for the existence gravitons is strong, where three of the four known forces – electromagnetism and the strong and weak nuclear forces – are all mediated by particles (being the photon, the gluon and w and z bosons). So it makes sense that the fourth force, gravity should also be mediated by a particle – the graviton.

Trouble is gravity is the weakest force, so presuming gravitons do exist they operate at very low energy levels, which hence makes them extremely difficult to detect. The standard line is that a detector the size of Jupiter would be unable to detect a graviton even if it was placed in the proximity of a neutron star, which in generating tremendous amounts of gravity, should also generate lots of gravitons. Freeman Dyson said that if we built a detector big enough to detect gravitons, it would collapse under its own weight and form a black hole. So, it's unlikely we are going to positively identify a graviton any time soon. The absence of evidence is not evidence of absence – but until you do have such evidence it's best to keep running with the hypothetical label.

There is something of a case for the non-existence of gravitons also. According to general relativity, gravity isn't a force at all, so rather than the Earth holding the Moon in orbit via an invisible force, the Earth's mass changes the geometry of spacetime, which results in the Moon's trajectory following a roughly circular path around the Earth. It's still feasible to envision gravitons mediating gravity by acting upon spacetime, rather than between two masses – but it means gravity works in a completely different way to any of the other forces, since those forces involve interacting particles exchanging force-mediating particles. But spacetime is not composed of particles.

The mathematics of quantum physical interactions is also difficult to apply to a gravitational context since that math assumes that such interactions happen against a fixed background of space and time. However, general relativity tells us that that there is no such fixed background, instead space and time measure differently between different frames of reference. So an external observer will observe clocks running slower and lengths contracting deep within a gravity well or on a fast moving spaceship.

This where people say the great schism of modern physics lies –general relativity works brilliantly at explaining the physics of large scale events and quantum physics works brilliantly at explaining the physics of sub-atomic events, but no-one has managed to reconcile the two. It's been proposed that the solution may be a quantum theory of gravity, sometimes referred to as a

theory of everything and the graviton would play a central role in such a reconciliation. String theory seems to be a favoured solution although String Theory remains a totally hypothetical construct, an internally consistent mathematical and conceptual model, but one which seems to have little connection with the real world or any measurable phenomenon within the real world. That is the nature of theoretical science – everyone keeps bouncing around ideas until someone figures out an experiment that effectively demonstrates that some part of that theoretical construct actually works. We aren't there yet.

Question 2:

Dear Cheap Astronomy – Is this Universe full of explosions?

Well, yes it does seem that way. There are the various classes of novae, but also bursts of various kinds, ranging from radio to gamma ray bursts. They've traditionally been classified separately although the boundaries of those classifications often blur.

The word nova means new – arising from the fact that when they happen a star may become visible due to a sudden transient brightening. A standard nova arises from binary systems in which one star is a white dwarf that gravitationally draws material off its binary companion star which is a red giant. When a clump of material falls to the surface of the white dwarf there's a nuclear explosion which temporarily enhances the brightness of the star by about a thousand times. Then you can get a kilonova, which is about a thousand times brighter than a nova – which probably arise from the merger of two compact objects like a neutron star and a black hole – or two neutron stars or even two blackholes. There is an explosion, but it's generally cut short by the merger creating a new black hole.

After that you get supernovae which are mostly massive stars detonating at the end of their hydrogen fusion main sequence period. Supernovae may be a thousand times as bright again as kilonova, although there's quite a range from bright to very bright supernova, depending on the size of the progenitor star. One notable exception are Type 1a supernovae, which can be the end result of a binary system that initially just produced nova. As more and more matter is loaded onto the white dwarf from its binary partner star, its mass may eventually exceed the Chandrasekhar limit and then kabloohey – where the resulting explosion is always the same scale, with the same intrinsic brightness – hence leading to supernovae 1a's role as standard candles for universal distance measurement.

Then there's gamma ray bursts, GRBs. GRBs are short or long, being either less or more than two seconds. Short GRBs probably arise from the merger of two high density objects – like neutron stars and black holes. So essentially they arise from kilonova – and then there's long GRBs which arise from supernova. The difference is that we are dealing with the polar jets that arise from these events rather than the general brightening of the star itself. Where you have a rapidly spinning object with powerful magnetic forces operating much of that object's energy output is channeled into beams that shot out in opposite directions from each pole. This can be the case with a massive star that goes supernova or two compact objects that spiral into a

merger – in either case much of the energy burst output is channeled into polar jets. So we may see supernova going off all over the sky but if one is aligned so that its polar jet is directed at us, we'll also record a long gamma ray burst – or a short gamma ray burst in the case of a kilonova with one polar jet pointed at us.

One of the brightest long GRBs GRB 080319B in 2008 was naked-eye visible in the night sky for a brief time, as bright as a dim star. The burst's origin was 7.5 billion light years away – although with such distances it's better to say the burst occurred 7.5 billion years ago, as its origin would have since shifted substantially further away over the subsequent 7.5 billion years due to the ongoing expansion of the Universe.

After that things get a bit more random. There are fast optical transient events, including blue and red ones that are smaller bursts of energy, still bigger than a nova, but smaller than a supernova. These are presumably some kind of stellar outburst or a perhaps the merger of two main sequence stars – but being more infrequent they are hard to nail down to a specific cause. Similarly there are fast radio burst bursts, of which there's been about 1000 detected since 2007 when they were first categorized as a thing. They could be magnetar outbursts or some kind of collision of the kilonova type, but given their variability they may arise from a variety of causes.