Question 1:

Dear Cheap Astronomy – What's your favourite citizen science project?

This is a tough one – because they're all good. There's still a few citizen science projects out there where you can devote your own computer to crunching through data. SETI@home is still going strong after eighteen years – and it's still not finding alien signals in radio telescope data. Mind you only about 2 per cent of the sky has been properly surveyed so far, so we shouldn't give up just yet. And Einstein@home is still going strong after twelve years of sifting through gravitational wave data, collected by the now famous LIGO, the Laser Inferometer Gravitational-Wave Observatory, involving those 4 kilometer-long detectors at Hanford and Livingston in the USA.

We only recently observed gravitational waves in 2016 and Einstein@home didn't have a direct role in that discovery, but along the way it has helped to refine lots of search algorithms that are used to analyse LIGO data and Einstein@home has also been analysing radio wave data from Arecibo and Parkes radio telescopes, looking for close binary pulsars that might be sources of continuous gravitational waves. In this area, Einstein@home has been very successful in identifying over 50 pulsars, although that is just from the radio data – no luck so far in finding any pulsar-originated gravitational waves.

Of course, citizens can contribute far more than just passively-sharing their computer resources. You can send in cell phone videos of shooting stars (Fireballs in the Sky), sort galaxy types from a sky survey database (Galaxy Zoo), characterise moon craters from lunar reconnaissance images (Moon Zoo), spot solar storms in STEREO spacecraft data (Solar Storm Watch), explore the surface of Mars (Be a Martian) and find exoplanets (Planet Hunters).

And, if you're a fan of the fabulous podcast, I think it's called Science on the ISS, you can play with space seeds in the Tomatosphere project, which is targeted at schools, where a class can get to grow and monitor one sample of tomato seeds which have only ever been on Earth and another sample of seeds flown for about 6 weeks aboard the ISS in 2016. It's a blind test, so the students don't know which sample is which – they just grow the plants and then send the results in – but that means it's totally science and with a bit of space mixed in. No conclusive results from this one yet, apart from a lot of tomatoes.

If you want to move beyond being a weekend hobbyist and have a few geek skills at your disposal you can do some pretty-serious science through the Internet. Various space agencies publicly release data and imagery, allowing citizen nerds to do some nifty visualisation work – like changes in Rosetta's images of the surface of comet 62P before and after perihelion, or perhaps tack together other spacecraft imagery to make a virtual video – like those recent Juno fly-by motion pictures of Jupiter, or you can just photoshop the heck out of some stacked astrophotography and then Twitter the outcome to engage casual readers in the wonders of astronomy.

In fact, there's some pretty high-level science citizens out there. Many have seriously-expensive telescopes in their backyards – maybe built under observing domes or maybe just built under a roll-back garage roof. These folks get their astrophotography published in glossy astronomy magazines and some of them get research grants and mentions in scientific papers and all that.

And there are even some that are out there tracking near-Earth objects, collecting data to more accurately estimate the orbits of those near-Earth objects. These folks are saving the world, in their own potential and vicarious fashion, since we been lucky to not yet discover any mass-extinction inducing objects heading right for us.

And hopefully, by the time one does swings around, we'll have the technology to avert impact. That technology may still be 100 years away, so let us be grateful for those unnamed few who keep looking and not-finding that our doom is nigh.

Question 2:

Dear Cheap Astronomy – How many black holes are in our galaxy?

The trouble with black holes is that they're black and hence hard to see, so we don't absolutely know how many are in our galaxy. A reasonable presumption is that there are about 100 million, since we know that stars more than five times as massive as the Sun will end their lives as a supernova and leave a black hole behind. Well, that's excepting a very small number of humungously big stars that are likely to destroy themselves as pair-instability supernovae and leave nothing at all behind.

So, there's your answer, there should be about 100 million black holes in our galaxy since we know our galaxy is at least 13 billion years old and has hosted well over a hundred billion stars in that period, although we can't positively verify the 100 million black holes estimate, since they are mostly invisible. We have positively identified around 20, either in our galaxy or in our neighbouring dwarf galaxies, because those black holes are in a binary orbit with something that is visible, like a red giant or a white dwarf. And we also know about the supermassive black holes at the centre of ours and other galaxies, as they have a substantial mass and a substantial gravitational influence on the things that are in orbit around them.

So, we could just end the episode there, but that's not how we do things here at Cheap Astronomy. So far, we've mentioned supermassive black holes and stellar-remnant black holes. Up until 2016, the biggest stellar-remnant black hole we'd ever detected was about 15 solar masses. But then something interesting happened. LIGO, the Laser Interferometer Gravitational-Wave Observatory, in the first-ever direct observation of gravitational waves, found two black holes, each of around 30 solar masses in the process of merging into one black hole of around 60 solar masses. It may have been lost in all the hoo ha about the first gravitational wave observation, but this was also the first observation of any non-supermassive black holes outside of our local galactic neighbourhood. Indeed, all three black hole mergers that have now been observed by LIGO were all way out of our neighbourhood – somewhere between 1 and 3 billion light years away.

So, it is interesting that we are now finding what are apparently stellar-remnant black holes that are way bigger than any we know about in or around our galaxy, even though our galaxy is pretty big and pretty old and pretty-much your stock-standard galaxy – and we are finding these unusually-big black holes in the process of merging to become even bigger black holes. It may seem somewhat startling that we've found 3 such unusual merger events in less than two years of searching. But, remember these three events were collected from a sphere of observation of a least 3 billion light years in radius – so three events in two years across such a massive area should not be taken to suggest that such events are especially commonplace. Also, since these things happened 1 to 3 billion light years away, they also happened 1 to 3 billion years ago – so who knows what might be going on out there right now.

But anyway, we might reasonably deduce from the LIGO findings that amongst the 100 million black holes that we think are in our galaxy, there could be some right-whoppers – not anything in the supermassive range, but black holes that are still way bigger than any stellar-remnant black holes we've detected so far.

Indeed, some have taken this thinking further, to revive the notion of MACHOs, massive astrophysical compact halo objects, as the possible source of all the dark matter in the Universe. If the upper limit to stellar black holes is higher than we've been assuming then the 100 million undetected stellar-remnant black holes that we think are in our galaxy could represent a lot more mas than we've been assuming. And perhaps the population of undetected black holes is a lot bigger than we've been assuming, due to the inclusion of black holes that aren't of stellar origin at all, but might be left-overs from the early stages of matter clumping when our Universe was forming and everything was much smaller and denser.

But of course, when you're talking the science of invisible and undetectable things, you can't really do much more than speculate. So, how many black holes are in our galaxy? Well, we know there's around fifteen, but there's probably 100 million based on what we know about stellar evolution, and some say there could be orders of magnitude more based on a whole bunch of speculative modelling. Presumably, the truth lies somewhere in the middle of all that.