Question 1:

Dear Cheap Astronomy – What's the latest on magnetars?

Magnetars are a type of neutron star, that has a very powerful magnetic field. That magnetic field slowly decays as the magnetar releases flashes of gamma or xrays so magnetars only last briefly as magnetars, for around 10,000 years, before they drop back to being plain, old neutron stars. Indeed, there is now a suggestion now that many, if not all neutron stars may spend a small part of their lives as magnetars.

All neutron stars, including magnetars, are the remnants of a massive star that went supernova. They generally having a mass of around 1.4 times that of the Sun and a diameter of only 20 kilometres, which means they are very dense objects. As well as their hugely-powerful magnetic field, something that distinguishes magnetars from plain old neutron stars is their spin rate, where they spin once every two to ten seconds, while normal neutron stars rotate several times per second, generally one to ten times.

Another distinguishing characteristic is a magnetar's propensity to release periodic flashes of gamma rays, which is why magnetars are also traditionally called soft gamma repeaters. These flashes are not proper gamma ray bursts, which are mostly produced by core collapse supernovae explosions. However, it is now thought that magnetars may also be the at least one source of Fast Radio Bursts, FRBs. In 2020, the first FRB detected from a source in our own galaxy was tracked down to a known magnetar, SGR 1935+2154, where SGR stands for soft gamma repeater. The signal fit the specs of a FRB, although it had less intensity than other FRBs we've detected from outside our galaxy. So for now astronomers are cautiously saying that magnetars are one confirmed source of FRBs, though not necessarily the only source. If magnetars are ever confirmed to be the source of all FRBs, expect a Cheap Astronomy episode titled WTF FRBs?SGRs++.

Anyhow, the reason behind a magnetar's powerful magnetic field is also unresolved. Given that being a magnetar is a fleeting 10,000 year blip in some neutron stars' lifetimes, it may represent a brief phase of instability before a neutron star settles down into a more stable structure. If this is right, the soft gamma ray flashes and occasional fast radio bursts may arise from starquakes as the immense gravity of a neutron star reconfigures some of its outer layers into a more compact arrangement. And if all of this is true, then magnetars are more likely to be young neutron stars that are still settling down after their initial formation, which might also explain why their spin is slower, since collapsing down into a denser structure will be like an ice skater drawing his or her arms in – so a more stable compressed neutron star should spin faster than a less compressed structurally unstable magnetar We need to stress there's a lot of speculation here, but this is where current thinking seems to be trending at the moment.

Older neutron stars might also turn into magnetars if they've been disrupted in some way, perhaps by a collision. A 2017 multimessenger astronomy observation, combining gravitational wave detection by LIGO with optical observation by the Hubble space telescope, detected the merger of two neutron stars in another galaxy, the merger producing a bright kilonova and a burst of gravitational waves which left behind a hypermassive magnetar, of about 2.7 solar masses.

The mechanism underlying the intense magnetic field of magnetars is also mostly the subject of speculation. It may be a magnetohydrodynamic dynamo process, where some remnant charged protons and electrons which haven't merged into neutrons act like a fluid, which is spiraled around by the magnetar's spin and hence generates a hugely-amplified, though time-limited magnetic field – where further compression under the dead star's intense gravity eventually suppresses this process – returning that hugely-amplified magnetic field to what is considered normal for a plain, old neutron star.

Question 2:

Dear Cheap Astronomy – Is there a cosmic gravitational wave background?

Well yes there is, although all we are really saying here is that the Universe contains a lot of background noise in the form of gravitational waves because the Universe is full of moving massive bodies that interact with each other. The real interest here is whether there is some kind of background hum associated with the Big Bang, which might then confirm (or otherwise) our speculations on the events in the very first second of the Universe, including our speculation about there having been early rapid inflation, which would have been a very dramatic and dynamic process and may have left the Universe still resonating with its impact.

Any massive object that creates space-time turbulence will create gravitational waves. A perfect sphere that spins on its central axis would not create such turbulence, but add a few bumps and imperfections to that sphere and it will. A moon orbiting a planet, or a planet orbiting a star – and stars in binary orbits, as well as neutron stars and even black holes in binary orbits. These are all examples of continuous gravitational waves that are constantly radiating from multiple points across the spacetime expanse of the Universe.

The headline-grabbing gravitational wave events detected by LIGO, the laser interferometer gravitational-wave observatory were all sudden one-off events, involving two black holes in a binary system that spiralled inwards and merged, or two neutron stars that merged or a neutron star and a black hole that merged. Such events create a brief surge of gravitational waves that rise above the continuous background hum that comes from other more stable sources. So, without meaning to dismiss the grand scale, engineering sophistication and general cleverness of LIGO, for the most part it is just managing the pull out the most blaring obvious signals from what might be a vast tapestry of as-yet untapped information.

But, how of that information is really tappable remains to be seen. Given there is an ever-present background of many and varied gravitational wave sources, some continuous, others irregular and intermittent – there's a huge amount of processing required to sort all that into known sources you can filter out, allowing you to then investigate more mysterious sources.

Achieving all that involves slowly and meticulously sorting through the data already collected, a current objective of the now sixteen year old crowd-computing project Einstein@home project.

While it reasonable to assume an orbiting system of two massive bodes, like a star and a planet should produce a characteristic gravitational wave signal remember that we are a moving point in spacetime surrounded by billions of stars of different masses that have planets of different masses and different orbital periods and of course each star has different numbers of orbiting planets. So all that is an awful lot of varied signal which taken together borders on random chaos. But given what we've managed to achieve already, you wouldn't want to rule out the potential for us to sort this out in the long run.

So, if it this all works out, finding a primordial gravitational wave signal of the Big Bang may then be feasible. Nonetheless, this will be no small matter since we don't actually know what we're looking for – it's a signal arising from a hypothetical event, and we don't really know if such an event would leave behind a signal anyway. If early rapid inflation was perfectly symmetrical – like a perfect sphere growing out from a single central point, then it wouldn't leave behind any gravitational waves. There will only be a signal if there were some underlying imperfections in that early inflation process that left behind gravitational wave turbulence. So, if it exists, the cosmic microwave background will presumably appear as some kind of continuous hum that's coming at us from all directions with very attenuated waveforms of approximately the same amplitude and frequency – maybe.