Question 1:

Dear Cheap Astronomy – Is there a point in a star’s life cycle where it is accumulating as much mass as it is losing through its stellar wind?

For most stars – probably not, although there are so many possible variations of star life cycles you wouldn’t want to rule any possibility out. The lifetime and evolution of a star is determined by how much mass it accumulates. As a general rule, big stars originate in dense dust clouds that have large amounts of material within gravitational reach, while small stars originate in less-dense clouds where there’s not enough material available for them to grow beyond a certain point.

A large star might still be accumulating a lot of mass when it achieves sufficient density for hydrogen fusion to ignite in its core. Once ignited a star will begin to radiate both light and stellar wind. For big, high-luminosity stars, that stellar wind is mostly driven by intense radiation pressure pushing on particles in the stars’ outer layers, while for mid-range stars like the Sun, it’s more about magnetic interactions in the outer layers accelerating particles up to high enough speeds so that they escape the star’s gravity.

The big stars ending up losing a larger proportion of their mass through stellar wind than smaller stars, at least during the main sequence part of their life cycle. But, at the end of their main sequence, when smallish stars like the Sun expand into red giants, it’s radiation pressure that’s driving that expansion and when the red giant cools most of its outer parts end up as a diffuse planetary nebula surrounding a tiny white dwarf – representing most of what’s left of the star’s original inner core. On the other hand, big stars explode at the end of their lives. The biggest stars of all blow themselves to bits as pair-instability supernovae, while less-big, although still quite-big, stars leave behind a black hole or a neutron star.

Anyhow, the question of whether a star ever reaches a point where it’s accumulating as much mass as it’s losing has to be asked in the context of all these diverse stellar life cycles. The capacity for big stars to grow any bigger is ultimately limited by their stellar wind driving away any more gas and dust than might have otherwise kept it growing. However, there are some complex dynamics underlying how and when that effect kicks in since there is a lot of variance in just how big stars can get. Those dynamical factors may include the size, density and metallicity of the gas cloud that the star arose from, as well as how fast it spins once it has compressed down and become a star.

But, the general view is that once the star ignites, any further mass accumulation ceases as a consequence of its stellar wind. So, there might be a momentary instant of balance before the in-falling mass ceases, but that about it.

And, as for the smaller Sun-like stars, there’s really no chance. Their smallish size is defined by the fact that there wasn’t ever enough material around for them to get bigger, so by the time they ignite and achieve stardom most of the in-falling mass would have already petered out.

But let’s not leave it there. Every star’s story is different – and there are just as many binary, trinary and whatevery systems out there as there are single star systems. A common scenario in a binary system is that one star goes red giant and leaves behind a white dwarf and then the other star goes red giant – and pushes a lot of its mass into the gravitation reach of its white dwarf binary companion. The sudden addition of fresh hydrogen to a dense compact white dwarf initiates fusion of that hydrogen on the white dwarf's surface turning a dim faded star into a renewed shining beacon of light – which is why such an event is called a nova.

So, somewhere in the steps towards a producing nova, the white dwarf is probably was accumulating as much mass as it's losing through its stellar wind – although that's mainly because white dwarves don't produce much stellar wind in the first place. So, there's at least one example, although it is an exception to the rule – where the rule is pretty much no.

Question 2:

Dear Cheap Astronomy – Two black holes walk into a bar...

OK, we're paraphrasing, but the question at hand why there's nothing to see when two black holes collide – all you get is gravitational waves. But when two neutron stars collide suddenly we're all talking about multi-messaging astronomy, because there's gamma rays, optical light and gravitational waves as well.

You may recall that back in October 2017 everyone got terribly excited when the fifth ever gravitational wave observation was coupled to a kilonova seen in NGC 4993 a lenticular galaxy about 130 million light years away in the constellation Hydra. The moment the distinctive gravitational chirp was picked up, the global astronomical community leapt into action. First, signs of a gamma ray burst were detected by NASA's Fermi telescope and the ESA's earlier INTEGRAL telescope – and then optical telescopes nailed down the origin to NGC 4993.

Most of the media excitement seemed to be about the observational technologies involved, rather than any new science those observations revealed. In fact, neither the gravitational waves nor the gamma ray burst provided sufficient resolution to do more than indicate a general direction in the sky. It was the subsequent optical observations that nailed it down to NGC 4993. Nonetheless, the combined observations did confirm the hypothesis that short gamma ray bursts originate from neutron star mergers, which also produce kilonovae. The term kilonova arises from the fact that neutron star mergers produce a fairly consistent energy output, including a flash of optical light, which is pretty-much one thousand times brighter than a nova. Nonetheless, even a kilonova isn't all that bright, still being one or two orders of magnitude dimmer than a supernova.

Anyhow, the question at hand is why all the earlier observations of gravitational waves, which all involved black hole mergers didn't produce an electromagnetic outburst. Well, firstly, we can't be totally sure those black hole mergers aren't accompanied by a bit of fireworks – if one or both black holes was still surrounded by accretion disk material, that interacted during the merger. Nonetheless, physics tells us that if two ideal black holes merge with nothing else in tow, then the whole event will be electromagnetically-invisible.

The reason for this is the physics that underlies a black hole event horizon. Once something crosses a black hole you will never see it ever again. The escape velocity required to get back past an event horizon is faster than the speed of light, so that’s never going to happen, and the rate of time progression that occurs within a black hole is so slow that crossing even a centimetre of distance would require the age of the Universe and beyond to complete.

A black hole event horizon is sustained by the intense spacetime curvature generated by the utterly ginormous mass-density that lies within it. So, even though gravity may be slowly drawing two black holes together, as long as there’s any kind of empty space between those two black holes, the gravitational force holding each object together will always be vastly stronger than the gravitational force that’s drawing the two objects together. So, throughout the entire merger process, nothing that’s behind the event horizon of either black hole will ever come out. So, despite there being a dramatic collision there’s no explosion and no electromagnetic outburst.

Nonetheless, the resulting gravitational shock waves then propagate throughout spacetime. They may carry the energy of several solar masses away from the merger, but there we’re talking mechanical energy not electromagnetic energy and that energy quickly dissipates over distance as the shock waves spread out, so the amplitude of those waves may only be a fraction of a proton’s diameter by the time they reach us.