Question 1:

Dear Cheap Astronomy – How hot do black hole accretion disks get?

This question follows on from a previous DCA on the temperature of black holes, but there are all sorts of accretion disks out there. Accretion disks can form around any dense centre of mass with sufficient gravity to draw in surrounding matter. As matter falls inwards it is constrained within a smaller volume creating collisions and frictional interactions. All that creates heat and the congestion of in-falling material forces that material into an in-spiralling orbit – hence creating the appearance of a disk. Nonetheless, that material is falling inwards occupying progressively lower orbits as its angular momentum is lost in the form of heat due to all the collisions and the friction. An average protoplanetary disk does heat up and most of it eventually spirals into its star, with any planets formed representing the scant remains that were left behind when the disk has lost too much density for angular momentum to be further lost in collisions and heating. So, since that remaining material couldn't unload its angular momentum, it just stayed in the same orbit around the star.

But moving beyond simple stellar systems, if you keep upping the scale – so that you make a black hole the centre of mass and you also scale up the amount of raw material that's available to fall towards it, then you will start getting much more dramatic effects. Most of the black holes that we know about, we know about because they radiate x-rays from their accretion disks. Of course there may be many more black holes out there that don't have accretion disks and hence don't radiate anything.

We think the hottest accretion disks of all are found around quasars, which are supermassive black holes that are consuming large proportions of the galaxies they reside in. Quasars are mostly found in very distant parts of the Universe, which is another way of saying they are mostly found in very early parts of the Universe. It may be that a younger, more compact and denser Universe has a greater propensity to make really big – and really hot – accretion disks. Nonetheless, the closest quasar to us, Markarian 231 is only 600 million light years away, so it isn't really all that old.

But just how hot are these quasars? We can only estimate their temperature from the radiation we receive on Earth, adjusted for any red shift that may be imposed upon very distant objects. So, for example, we routinely pick up quasars with radio telescopes since much of their original energy output has been red-shifted to radio frequencies. Nonetheless, we can readily estimate that their peak emissions were in x-ray range when emitted. The general principle of heat and light, where red is hot but blue is hotter –applies across the whole electromagnetic spectrum, where the hotter something is the shorter is the wavelength of its peak emission. So, if something does have peak emission wavelengths in x-rays you can be sure those things are going to be pretty darned hot – anywhere in the range of 300,000 Kelvin to 300 million Kelvin.

For your average quasar, we think that the temperature of the innermost parts of their accretion disks probably approach 80 million Kelvin. So, yep, that is pretty darned hot. But just like how we've previously reported that the coldest place in the Universe is probably the Cold Atom Lab aboard the International Space Station, the hottest place in the Universe is probably in the Large Hadron Collider, where we can generate temperatures similar to those prevalent a few micro-moments after the Big Bang when the Universe was full of quark gluon soup. Of course those sort of temperatures only last for a moment and only occur within a very tiny volume.

So, if you are looking for a very large volume of stuff that remains very hot over a very long time period, then you can't go past quasar accretion disks.

Question 2:

Dear Cheap Astronomy – How will the Parker solar probe work?

The Parker solar probe will launch in August 2018, Since, it's already in orbit around the Sun, it will get closer by modifying its solar orbit with the help of gravity assist, using Venus as a pivot point.

Coming from Earth naturally gives you a solar orbital velocity of 30 kilometres a second and a 365 and a quarter day orbital period. Kepler's 3rd law is all that stuff about the square of the orbital period and the cube of the semi-major axis – but basically says that you have to move a lot faster to maintain a close orbit than you do to maintain a distant orbit. The Parker probe needs to shift from a 365 day solar orbit to a faster 88 day solar orbit, but to achieve that the Parker probe has to decelerate to decay its Earth-equivalent orbit. Rather than burning lots of fuel, the Parker probe will fly the wrong way past Venus so that Venus' gravitational drag slows it down.

The Parker probe's first Venus fly-by is planned for October 2018 and its first perihelion, where it passes close to the Sun, is planned for November 2018. There will be 24 solar orbits in all, that include seven more Venus flybys, with each of those fly-bys modifying the Parker's probe's orbit a little more so that its perihelion gets closer and closer to the Sun each time. Perihelions 22, 23 and 24, coming after the 7th Venus flyby will be the really close-in ones. It's unclear what the plan is after perihelion 24 which takes place in June 2025. What happens from there will depend on the condition of the ship and its fuel reserves. And really, giving the perilous nature of the mission, we're not totally confident the spacecraft will survive to perihelion 25, although everyone is optimistic.

On the closest passes planned, the spacecraft will fly through the Sun's corona to within 6.2 million kilometers of the photosphere of the Sun, which is essentially its surface. The Parker probe will have to face 520 times the incident solar intensity that we experience in Earth orbit – which will mean it experiences temperatures of about 1,400 degrees Celsius, which is hot enough to melt steel.

Of course, the Parker probe will have a heat shield. It's not made of vibranium, but the next best (and real) thing – reinforced carbon-carbon. Reinforced carbon-carbon is carbon fibre, reinforced with graphite – which is, you know, carbon, hence the name. Without the shield, all the delicate parts of the spacecraft and its scientific instruments would last for about a tenth of a second when it's close to the Sun. But carbon is not only lightweight but in pure form is also the most refractory material known – which means it can maintain its structural integrity up to very high temperatures, indeed up to about 4,000 degrees Celsius. And carbon also has quite low thermal conductivity – so when it's surface is exposed to high temperature, that heat will spread very slowly through its structure.

Nonetheless, matter is matter and any material exposed to unrelenting heat is eventually going to equilibrate to that same temperature. And even if that temperature is not hot enough to destroy the heat shield, that heat will eventually be conducted through to the rest of the spacecraft. But remember that the Parker probe's mission orbits are highly elliptical – coming in close to the Sun at perihelion, but then swinging way out back to Venus at aphelion. So, at each perihelion the Parker probe will be moving at its maximal orbital speed of around 200 kilometres a second, before it pulls away adopting a more leisurely pace back to Venus, giving it plenty of time to cool down again before the next perihelion.

This is why it's being touted as the fastest machine ever built, way faster than New Horizons' rocket-assisted 23 kilometers a second and way faster than Juno's 74 kilometre a second plunge into Jupiter's gravity well. Although again, ironically, in order to achieve this record-breaking feat, the Parker probe will have to decelerate first. You've got to love astrophysics.