Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Black holes: The supermassive ones*.

This is the second of a two part series on black holes.

A long, long time ago in a smaller, denser universe, a galaxy may have started to build through the rapid aggregation of gas and dust, forming massive stars, which later collapsed into black holes – which then continued to grow rapidly in size due to the dense surrounding gas and dust that they were able to accrete. Some of them might have gotten bigger by merging together too - but in any case, being a smaller, denser universe this was an age when a black hole could get really big, really fast.

Well, really fast - but within limits. A black hole can't just suck down everything that comes near it. What happens is that an accretion disk forms around the black hole - in much the same way that water spirals down a plug hole - and this accretion disk represents a bit of a traffic jam. As material spirals in into tighter and tighter circles it is forced to occupy a steadily diminishing volume - so its density increases and it starts heating up.

This is when we start seeing black holes emitting high energy radiation. It’s not the black hole emitting radiation – because, you know, it’s a black hole – all this radiation comes from the accretion disk. For example, Sagittarius A* star, mentioned in Cheap Astronomy episode 49, was long known as a bright radio source in Sagittarius – which has since been identified as a supermassive black hole - indeed *the Blackest brother in the galaxy* – and it became visible in X-ray once we got space telescopes like Chandra above the atmosphere.

As well as the general glow of radiation from the accretion disk, you also get light year long jets of material pushed out from each pole of a supermassive black hole, due to twisting lines of magnetic force generated within the accretion disk – which were the subject of episode 93 – and a source of even more radiation.

Now there’s a concept called the Eddington limit – which is the point at which the radiation from a star achieves a dynamic balance with the gravitational compression of its mass. For very massive stars, their radiation can begin to exceed their gravity (that is exceed the Eddington limit) so that the star starts blowing off significant proportions of its mass as stellar wind. Stress on the word significant there – nearly all stars have stellar wind, like the Sun does, but only blow off a tiny proportion of their mass in this way. Massive stars, like Wolf-Rayets, can blow off huge amounts of mass just through radiation pressure – depleting much of their hydrogen content, resulting in types 1b or 1c supernovae at the end of their lives, which we covered in episode 85.

When an object is blowing off stuff in this manner – its luminosity increases dramatically – which we call Eddington luminosity. Now this Eddington – is Arthur Eddington, who like JA Wheeler in episode 98, was another great advocate of Einstein’s relativity physics (see episode 23). But Eddington was actually a black hole denier, involved in a famous stoush in the 1930s with Subramanyan Chandrasekhar – over the Chandrasekhar limit, which has it that any white dwarf with a mass greater than 1.4 solar masses will collapse and produce a type 1a supernova (also mentioned in episode 85).

Anyhow, Arthur Eddington went to his grave in 1944 in a bit of a huff – still refusing to believe that stars could collapse into nothingness, while the younger Chandrasekhar went on to win a Nobel prize in 1983 – before his death in 1995, after which a space telescope got named after him as well.

And now back to the black holes. The idea of Eddington luminosity can be applied to objects other than stars – one obvious example being accreting black holes. At a certain point, a black hole’s accretion disk is going to reach its own Eddington limit – beyond which it starts emitting Eddington luminosity which will start to blow off gas and dust – which might have otherwise have fed the black hole. This is because radiation pressure (that is, Eddington luminosity), from the supermassive black hole’s accretion disk and its polar jets, becomes so intense that it pushes large amounts of gas and dust out beyond the growing black hole’s gravitational sphere of influence.

This dispersed material could retain angular momentum, first gained from spinning around the accretion disk of the black hole – and that angular momentum would keep all that dispersed material in an orbiting halo.

When we look out at the universe, there seems to be an almost linear correlation between the mass of a central supermassive black hole – and the mass of the galactic bulge that surrounds it – so small galaxies have small supermassive black holes – and big ones have, well... big ones.

More recent findings show that this correlation only exists in larger galaxies – so the role of black holes in smaller dwarf galaxies may be more complicated. Nonetheless, it is still possible that supermassive black holes helped to form the big galaxies, like the Milky Way.

It is just a hypothesis, but maybe in the early, dense universe giant black holes were popping up all over the place, sucking down the dense gas and dust around them – but as the intensity of their feeding frenzy increased, they began to starve themselves as their Eddington luminosity dispersed the gas and dust in the accretion disks that surrounded them.

From there, those black holes could only grow in fits and starts, fed for a while as a merger with another growing galaxy brought new gas and dust to be consumed, but then trending back towards starvation again, as renewed Eddington luminosity once again pushed any remaining material out of the black hole’s reach.

And meanwhile the cloud of material pushed out beyond the black hole’s reach could grow to a stupendous size over billions of years, during which time the enormous cloud might have flattened into an enormous disk held together by lateral gravitational attractions – which, after billions of years, operated quite independently of the mass of the proportionally tiny black hole within.

So there you go. Black holes – which we normally think of as representing the end of a massive star’s life – could in a different context be the seeds from which galaxies, including our own, first grew. And it's kind of ironic that the whole business is mediated by processes named after an astronomer who refused to believe that black holes even existed.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, www.cheapastro.com. Cheap Astronomy offers an educational website where black never goes out of fashion. No ads, no profit, just good science. Bye.