Dangerous Cosmology

Entry 02 by Dr Sarah Bosman (CMDR Shobah)

Elite Dangerous versus reality: Black Holes in the Milky Way

Black holes are some of the most fascinating and terrifying stellar objects in both the Elite galaxy and in real life. The first time I came across one was at The View this week. Great plans had been made to get as close as possible to study the accuracy of the light-bending, which never got put into action, as I'd vastly underestimated how *utterly terrifying* the approach would be. No matter the amount of piloting advice ("it's just modelled as a hit-box, you can get there if your cooling is good enough"). Maybe next time?



The View. Right: the puny jets of a neutron star. Top: a black hole. Bottom: my ship, the Lyman-continuum. Hazardous situation.

What makes black holes in E:D so scary is how completely dark they are: the only way to gauge the distance is through the amount of light-bending occurring in the surrounding area. The immediate question is: how could be possibly detect such a thing in real life, from many light-years away? Have such black holes even been found in our Milky Way? Well, no, they haven't – not quite.

The most successful way in which Milky Way black holes have been confirmed is through black hole **X-ray binaries**. As the name indicates, these guys emit X-ray radiation – as well as a lot of visible, infrared, and radio waves. They occur when a stellar black hole is 'eating' from a companion star, usually a binary companion. Black hole 'progenitors' are very massive stars, and therefore die first, before starting to absorb material from the left-over companion. This absorption process emits a very specific light signature – which is the only









way that stellar black have been identified in the Milky Way. That's right: the Great Annihilator, and others like it, are in fact incredibly *bright*.

Black hole X-ray binaries are very cool, though. They come in two flavours: variable ('flickering') and permanent. The variable type is the most common – we know of 18 'solidly confirmed' cases in the Milky Way, 26 'strong candidates', and 24 'dubious candidates'. This variety usually occurs when the left-over companion is a type A or later, small-ish star. Material is being 'stripped' very slowly, and falls into orbit around the stellar black hole, forming an accretion disc. As more and more material builds up, the friction causes heating, which causes increased magnetic friction – until it's too much, the disc becomes magnetically slowed, and starts to fall into the event horizon (a process that physics students might remember as the Magneto-Rotation Instability and shudder). Once enough of the disc has been eaten, the pressure is low enough again and the disc can re-build itself. These bright eating episodes can last from a month to many years.

The second variety of x-ray binaries – permanent – occurs when the companion star is type O or B and of a comparable size to the black hole. There's no time for this on-off eating business because the transfer rate is too high, typically 1/3 of Earth Mass per year (even just from the stellar wind, which is very fast in OB stars). There is only 1 confirmed case of this in the Milky Way... Cyg X-3 (V1357 Cyg) – not the Great Annihilator! There are 4 'strong candidates' (including the GA) and 2 'dubious candidates', as well as 2 confirmed cases in the Large Magellanic Cloud.

It's very hard to confirm that an X-ray binary contains a black hole, and not some other type of source. It's necessary to know exactly how far away the source is – to deduce its brightness. We also need to know how far the companion is, the shape of the orbit, and the transfer rate, to calculate how massive the 'thing' doing the accretion is. If the source is more than 3 solar masses, we can confidently slap the 'black hole' name on it since neutron stars shouldn't exist above this mass – and if it was 'just a normal star', we'd see it. One way or the other, these guys are bright and **violent**. The accretion process often powers jets much more powerful than those of a neutron star, extending up to 19 kly from the source!



Real image of the surroundings of a confirmed black-hole x-ray binary, marked with a + with arrows showing the direction of the jet. The two squares show where the jets have hit material on either side: 19,000 light-years from the central source! (Alex Tetarenko and team, 2017)





Finding these black holes in active pairs gives us an idea of how many 'inactive' or 'truly black ones' might be out there, but finding those directly is near impossible. It's simply a matter of mass and distance: the effect of these black holes on their surroundings is just too weak. While a supermassive black hole might perturb the orbits of stars on very large scales (a topic for another time), small black holes just don't have that much gravitational power.

Intermediate-mass black holes, of about 30,000 times the mass of the Sun, just about might be detected this way. Just last year, we got the first strong evidence of such a situation: an intermediate-mass black hole in the Milky Way currently forcing two gas clouds to orbit it. Even then, it's not a case of seeing the clouds move from picture to picture – it would take 46,000 and 211,000 years for the clouds to go around the black hole once – but their current speeds and shapes indicate they are indeed spinning around something heavy. There are two additional likely candidates of similar systems, all quite close to the galactic center. Thanks to the LIGO detector, we already know that black holes of these sizes exist (and collide with each other) in other galaxies.



Image of two clouds (at the bottom) and the calculated orbits they follow around a 30,000 solar masses black hole near the galactic center (Shunya Takekawa and team, 2018)

As cool as Elite's fully dark black holes are, it would definitely be fun to see some more realistic systems integrated – from ultra-bright sources which turn on and off over the course of months with jets over thousands of light-years... Even more terrifying than the current ones. The Great Annihilator being fully dark, though, is simply not accurate 😳

CMDR Shobah

(I am a cosmologist specializing in the most distant quasars – active supermassive black holes. Spend me any astrophysics questions on Discord – Shobah2200, or by email at <u>s.bosman@ucl.ac.uk</u> – I will answer them either on Distant Radio or on my stream.)

Dr Sarah Bosman got her PhD in Cambridge for her work on distant quasars. She now works as a cosmologist at University College London in the 'First Light' group, studying distant galaxies as well. <u>http://sarahbosman.co.uk</u>





