Hi this is Steve Nerlich from Cheap Astronomy www.cheapastro.com and this is *Jets*.

Something we've gotten used to in astronomy without really understanding what it's all about is that if you observe an accretion disk spiraling equatorially around a central compact object - like a proto-star or a black hole – you will often find two jets of material – shooting outwards from nearby each pole of the central compact object.

It is a phenomenon that happens on many scales too. Like I said a newly forming proto-star often has these polar jets. You can also get them arising from neutron stars which might be drawing material off a binary companion – which collects in an accretion disk around the neutron star. These jets will be more energetic than a proto-star's because the whole idea of jets is that their contents (essentially superheated plasma) somehow acquires the escape velocity needed to get away from the central compact object.

So the fact that jets of material can escape from the vicinity of a neutron star’s powerful gravity - means they have gained a heck of a lot more escape velocity than jets of material arising from a run-of-the-mill proto-star.

Energetic neutron star jets radiate strongly in radio frequencies for reasons we'll get to later - but if such a jet lines up with the Earth - we will detect a pulse of radio each time the star's polar axis rotates into our line of sight. So you get a pulsar. In reality, any neutron star with an accretion disk and jets is to all intensive purposes a pulsar as well - but we only call them pulsars if the polar axis lines up with us here on Earth and we receive the *beep-beep* of radio pulses from it.

Now, taking the next step up the scale, jets arising from accretion disks around stellar-sized black holes are going to be that much more energetic because the velocity required for them the escape the vicinity of a black hole is going to be something approaching the speed of light. And black hole polar jets have been measured moving at 25% or more of the speed of light.

And not surprisingly, black hole jets radiate even more powerfully than neutron star jets. And if such a jet lines up with Earth, you get a beep-beep of radio - and also of x-rays if you happen to be looking at it with a space telescope like Chandra - remembering that x-rays of cosmic origin are normally deflected by Earth's atmosphere. And however you detect the jets, while there might be a whole bunch of black holes in the process of eating up an accretion disk and hence having two polar jets - it’s only if those jets line up with Earth that these objects get a special name, in this case micro-quasars.

And then the next step up is supermassive black holes found at the centre of active galaxies - that is galaxies that actively broadcast radiation – easily detected in the radio spectrum and sometimes in optical using ground-based equipment, and again with our space telescopes positioned outside the Earth’s atmosphere, we can measure their output across high frequencies in the electromagnetic spectrum.

One of the closest active galaxies, M87 is a giant elliptical galaxy with - and here's a lesson in being conservative with your superlatives, a giant supermassive black hole – which is over 3 billion solar masses and has an estimated diameter as big as Pluto's orbit. Yowsa. For comparison, the Milky Way's own supermassive black hole, Sagittarius A*, is just 40 million solar masses with a diameter more like the orbit of Mercury.

Jets from M87 extend out in narrow beams for at least 5,000 light years from the elliptical galaxy – or at least presumably they do. From Earth, we only really see the one jet which is pointed roughly in our direction. And it is only roughly. If it was pointed straight at us - as several active galaxy's jets are - then we'd call it a blazar - which is a compromise of pulsar and quasar and the more arcane term BL Lac object if you really want to know. These quasars and BL Lac objects are just different types of active galaxies – and in all important respects are just like blazars– except that they don't point at Earth.

Now, something interesting here is that a straight measurement of the velocity of the contents of M87's jet, gives impossible values of 4 or 5 times the speed of light. This is a kind of optical illusion caused by the fact that the jet is only a narrow angle away from the pointing straight at us. This means that although we can still see along the length of the beam - light coming to us from any point along the beam comes to us in almost the same trajectory as the beam itself.

So – remember the jet is 5,000 light years long – and obviously light should take 5,000 years to cross a distance of 5,000 light years. If we say point A is the base of the jet and point B is at the tip, 5000 light years closer to us, then even though a photon emitted by a particle of jet material at point A will really take 5,000 years to reach you, the particle of jet material that emitted that photon is moving nearly as fast as the photon.

So when it emits another photon at point B, that photon will reach your eye in much less than 5,000 years after the first one, from point A. This gives you the impression that the particle crossed 5,000 light years from A to B in much less than 5,000 years. But it is just a trick – we can determine the genuine speed of the jet through consideration of red-shift and Doppler effects – and when we do that this speed may still be around 99% of the speed of light at least near the jet's base.

But beyond this small understanding, the physics underlying the production of polar jets at any scale is not fully understood. It is likely that twisting magnetic lines of force generated within a spinning accretion disk, channel hot plasma - from the compressed centre of the accretion disk, into the narrow jets we observe.

It's as though a small amount of all the matter being squeezed in towards the centre of accretion disks finds an escape route out through a kind of magnetic firehose nozzle near each pole of the central compact object. Something like that anyway. No-one has quite managed to get a reliable mathematical model of the gravitational, magnetic and kinetic forces needed to replicate the reality of what we observe with jets - but it'll come.

In the meantime, we can at least get plenty of data about them. Radiation from polar jets is largely non-thermal – that is, not necessarily a direct result of the temperature of the jet material. All the radio wavelength emission we can see probably results from synchrotron effects - where electrons spun rapidly within a magnetic field emit radiation across the whole electromagnetic spectrum, but generally peak in radio wavelengths. On top of this, an inverse Compton effect, where a photon collision with a rapidly moving particle imparts more energy and hence a higher frequency to that photon. It's this inverse Compton effect that contributes to the higher frequency x and gamma ray radiation we can also detect from the jets.

And, at least with M87's jet, it's even possible to observe it in optical wavelengths – something that was first observed in 1918 - being noted as a 'curious straight ray', which still remains a fairly accurate description of these puzzling phenomena.

Thanks for listening. This is Steve Nerlich from Cheap Astronomy, [www.cheapastro.com](http://www.cheapastro.com). Cheap Astronomy offers an educational website where we try to explain what those funny sticky-out bits are. No ads, no profit, just good science. Bye.