Astronomy
Measuring Black Holes

Narration
Is there a theoretical model to explain these observations?

Meg Urry
The fundamental component of that structure is a massive black hole. Something like a million to a hundred million times the mass of the Sun. Around the black hole is an accretion disc which allows matter to funnel down onto the black hole, releasing a tremendous amount of energy, converting basically the gravitational potential energy into the light that we see.

Narration
Is there enough gravitational energy? To answer that we need to know the mass of the black hole.

Andrew Wilson
Measuring the actual mass of the black hole is much more difficult. The only direct way is to measure the velocity of some object or material in orbit around the black hole. Just as the velocities of the planets increase when they're closer to the Sun, the velocity of material close to the black hole orbits more quickly. So if one can observe the velocity of material orbiting around the hole, one can measure the mass of the hole. If we see that the velocities are increasing as one goes in towards the centre of the galaxy, then that's strong evidence that there's a compact, massive central object, presumably a black hole.

Meg Urry
The central part of the accretion disc is the brightest part. And it shines extremely brightly, but we think that there's an obscuring torus, or doughnut, surrounding the accretion disc. When we look face on, we can see right down into the central source, the bright continuum and the rapidly-moving illuminated gas there. But if we look edge on we don't see the central source, we see a much fainter source, and perhaps just a bit of glow above and below the doughnut. Most of the energy is absorbed by the gas and dust in the obscuring torus, and is re-radiated at longer wavelengths, say in the infra-red. The last component of this picture is outflow of extremely energetic particles.

Barrie Jones
Now this is all very well, it at least explains what we might be seeing, but it leaves completely unexplained exactly how these outflows are generated. Now we're perfectly familiar with the idea that a spinning disc will eject the material from its edges like a Catherine wheel, or a car tyre spinning on snow or in the mud, but what about material being ejected from the axis of a spinning disc – now that's really strange.

Narration
Somewhat like the strands of a rope coming together, the charged particles from the disc must follow magnetic lines of force that eventually emerge along the rotation axis. That gets them started, but how do these jets remain so narrow for such enormous distances?

Duccio Macchetto
Well there are several possible mechanisms. The first mechanism is that the electrons that are produced close to the black hole in this accretion torus carry with them a magnetic field. This magnetic field is found in the big reservoir of the torus, and these electrons carry this magnetic field with it, and it is the magnetic field that confines the jet as it bores its way through the galaxy.

Another possibility is that the external pressure exerted by the interstellar medium of the galaxy, the gas that one finds in between the stars, is producing the confinement. In this case the temperature and the density of the material should be enough to constrain the jet in the transverse direction. However, we see that the jets make it all the way from the nucleus of the galaxy to these incredible distances, boring their way through the interstellar medium of the galaxy.