The Space Telescope Looks for Black Holes

Monsters Lurk at the Centres of Many Galaxies

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Significant progress is now being made in many areas of astronomy through observations with HST (short for the Hubble Space Telescope). Orbiting above the Earth's turbulent atmosphere, it produces images nearly ten times sharper than its ground-based cousins. Such an improvement last took place at the time of Galileo!

The decade after 1965 saw the clarification and wide acceptance of the concept of black holes among gravitation theorists. Almost simultaneously, astrophysicists embraced them as an opportunity to model a whole class of objects called active galaxies in which the luminosity of more than a trillion (10^{12}) suns appeared to be emerging from a region no bigger than a few light years at the center of a galaxy. The sun emits about 4×10^{33} erg/sec, a typical galaxy 10^{43} erg/sec. But an active galaxy may easily emit 10^{46} ergs/sec, all from a small region near its centre. An early example is the object known as 3C273, which appeared like a bright star in photographs (hence the name quasi stellar radio source shortened to quasar). But analysis of its spectrum showed it was moving away at a speed nearly one sixth that of light. From Hubble's law governing the general expansion of the universe, it was clearly very distant (about a billion light years away).

It might seem paradoxical that the black hole, from within which no light can escape, can be a model for such luminous objects. The insight was that gas spiraling into a black hole picks up enormous kinetic energy from the strong gravitational field. If this energy can be converted to radiation before it enters the 'horizon', one can hope to explain objects like quasars. Though a black hole is like the dead body in the traditional detective novel – not easy to get rid of ! Even after it has done its job in powering a quasar, it must lurk somewhere in the vicinity of the centre of a galaxy. Can it be detected?

In the late 1970's, Peter Young and colleagues at the California Institute of Technology launched a programme to study the motions of stars very close to the centre of a giant galaxy called M87. This was known to radiate a large amount of energy in radio waves. The idea was that very close to any black hole, the orbits of stars would be disturbed and higher than normal velocities could be seen using the Doppler effect. Although a detailed model is complicated, think of an outsider to our solar system looking at the movements of the planets and thereby measuring the mass of the sun by the familiar formulae $GMm/r^2 = mv^2/r$, $M = v^2r/G$. This equation is basically telling us that it needs a large mass M to hold a star of high velocity v in its orbit of size r. Planets close to the sun have larger speeds.

The traditional belief however was that galaxies are more democratic than solar systems. A star orbiting at a distance r from the centre would feel the pull only from other stars inside a small volume of radius r. In this model, M would be proportional to r^3, and v would actually become *smaller* with r. On the other hand, if v became *larger* with decreasing r, ($\propto 1/\sqrt{r}$) then the same formula tells us that a dominant mass M is at the centre, controlling the dynamics as in the solar system. The early observations did show some evidence for higher velocities but were inconclusive – not surprising because even the telescope on Mount Palomar was unable to probe close enough to the centre of M87.

In the late nineteen eighties, the situation improved with more studies and better instruments. Surprisingly, disturbed velocities were found near the centres of two innocuous -looking nearby galaxies, M31 and M32. Doug Richstone of Michigan and his colleagues continue this programme with the Hubble telescope. The current situation is that strong evidence for central black holes has been found in almost every galaxy which the team could study. With the improved communication provided by internet (see the article Internet and the world wide web by Neelima Shrikhande, *Resonance*, Vol.2, No.2, 1997) one can follow the progress in this field as it unfolds . The latest announcement (Jan. 13th 1997) from HST is given in the table.

What is the picture which emerges from these new results? The tentative conclusion is that a large fraction of galaxies go through an active phase in which gas falls onto a central black hole. But the quasar (or radio galaxy) is a relatively short lived object, typically a hundred million years.

For the rest of the several billion years of its lifetime, the galaxy looks normal or quiet because the monster in its centre is not being given a rich enough diet of gas. Perhaps the early period of galaxy formation was more conducive to the activity because observations show many more quasars (per unit volume) in the past than we see today. It is remarkable that this exotic sounding picture is actually considered the conservative conventional view held by astrophysicists who try to model active galaxies.

Galaxy	Measured mass of central black hole in units of the Sun's mass
Milky way (our galaxy)	2 Million
Andromeda galaxy (our nearest large neighbour)	30 Million
Sombrero galaxy	1 Billion
M87	3 Billion

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