Black hole at the galactic centre

The latest accurate measurements of the size of the galactic core at centimetre radio-wavelengths leave no reasonable escape from the conclusion that there is a black hole at the centre.

WE HAD best learn to live with the idea that there is a black hole at the centre of our Galaxy. That is the implication of the article by K.Y. Lo *et al.* on p.124 of this issue. Perceptive readers will think the paper, which is the culmination of eight years of observation of the galactic centre with coordinated radiotelescopes separated by great distances, is over-modest. Others may think it over-cautious. The phrase "black hole" appears only once, and then as a quotation from an article by Lynden-Bell and Rees, who first floated the idea.

The new development is essentially nothing but a more accurate measurement of the diameter of the radio source known, for the past decade and more, to be located at the galactic centre. The result is startling. At the shorter of the two radio-wavelengths (1.35 cm) at which measurements have been made, the angular diameter of the source is merely 0.002 second of arc (2.1 milli-arc seconds), which at the distance of the galactic centre corresponds to a physical diameter of about 20 astronomical units, the size of the Solar System within the orbit of Saturn. At the longer wavelength (3.6 cm), the source at the centre of the Galaxy appears to be shaped like an ellipsoid with a long axis lying only 8 degrees away from the rotational axis of the Galaxy as a whole.

The case for supposing that there is a black hole at the centre rests almost entirely on the difficulty of accounting for such a prolific source of radio emission in any other way. Lo *et al.* argue that the supposition that the galactic centre might be the site of a rapid burst of star formation, tenable when the limits on the size of the central source were more than a hundred times greater than they have now become, plainly cannot be accommodated within a region no bigger than the orbit of Saturn. A stellar system which is a powerful source of radio emission might fill the bill, but only artificially; such systems are short-lived compared with the lifetime of the Galaxy. Black holes, on the other hand, endure (unless they are very small compared with the masses of typical stars) and even grow more massive with the passage of time. By default, the presence of a black hole at the galactic centre emerges as the simplest explanation of the new observation.

But is it not disconcerting that such an important and interesting conclusion should rest on such a negative argument? That is a natural but not a particularly pointed question. Black holes as such are by their nature invisible, although that does not apply to whatever matter may be dragged by gravitation into such an entity. Captured material, whatever its chemical composition, will be unspecifically ionized and will yield synchrotron radiation if there are magnetic fields to play with. Visible radiation will however be absorbed (or converted into low-frequency radiation) by the molecular and dust clouds lying around the galactic centre. Infrared observations are also limited in this way, as well as by the mismatch between the resolution of the telescopes for the time being available and the angular diameter of the source. This is why long-baseline radio-interferometry is, for the time being, the best hope for an unambiguous description of the object at the galactic centre.

In the circumstances, the temperature of the source estimated by Lo *et al.* means very little, for the radiation distribution is clearly very different from that of a black body. But the temperature (100 million K) is an accurate measure of the intensity of the radio-emission from the central object and its surroundings. The variation of the apparent angular size of the object with the wavelength of observation is surprisingly tidy — a simple proportionality to the square of the wavelength. The interaction of radiation with electrons is implicated in some way, but just what form this takes will depend, Lo *et al.* say, on the construction of a brightness map for the source.

There is little that can at present be said about the mass of the black hole at the centre of the Galaxy, and indeed a mere measurement of the geometrical size of the region from which radiation is emitted can be neither here nor there. But measurements such as have been attempted in the past few years of the motion of objects, stars and clouds in the neighbourhood of the centre should eventually help to define the mass of the object. As things are, systematic studies of the velocity distribution of nearby objects are inconclusive and open to conflicting interpretations. But presumably it is a matter of time spent on observations before something can be said about the variation with distance of angular velocities of nearby objects about the centre of the Galaxy, from which it should be possible to infer what mass there is at the centre.

Meanwhile, studies of this kind are for some time likely to be more profitable when applied to other galaxies than this. So much should be clear from the account two weeks ago by C.M. Gaskell (*Nature* **314**, 672; 1985) of the recent demonstration by J.L. Tonry that there is a black hole at the centre of the dwarf galaxy M32, a satellite of M31 (Andromeda). The technique is to determine the non-radial velocity of central objects as a function of radial distance from the centre, which should be a measure of the mass lying within that distance. Gaskell explained some of the pitfalls in this process, and in particular the failure by these means to demonstrate the presence of a black hole in M87.

The implications of these developments for the present understanding of galactic evolution are clearly important. Any galaxy, if left alone, should eventually collapse under its own weight after several repetitions of the cycle of stellar nuclear synthesis. So there should be no surprise that the end point of galactic evolution should often be a black hole, one whose mass is not very different from that of the original galaxy. That black holes begin forming (at least in M32 and in this Galaxy) is not surprising either, but it is helpful that at least two cases of this phenomenon are now known. To generalize from two cases, one an elliptical galaxy (M32) and one a spiral (this), may seem rash, but it would be no great upset for the applecart if most galaxies turn out to have a black hole at the centre.

As is now generally understood, this seems to be the case for active galaxies, quasars spectacularly but other active galaxies such as Seyfert galaxies as well. But it remains to be told whether the difference between such a galaxy and this, where the central black hole is only a modest source of radiation, lies simply in the amount of material accessible to the central attracting source or whether there is something extra special about quasars and similar galaxies. The importance of answering that question is that it will decide whether quasars are exceptional galaxies rather than ordinary galaxies in a particular (and brief) stage in their evolution.

Meanwhile, this development has no immediate bearing on the grander cosmological question of whether there is enough hidden mass to close the Universe, or eventually bring the present expansion to a halt. The mass of the black hole in M32 is estimated at 5 million solar masses, a tiny fraction of the whole. The black hole at the centre of this Galaxy, whatever its mass, is unlikely to be much bigger. So the missing mass that matters must still be sought elsewhere.

John Maddox