Black Hole in the Nucleus of Active Galaxies

While the energy sources of the most active systems in the sky (e.g. quasars, radio-galaxies and active galactic nuclei) are still far from understood, many models invoke a gravitational source of energy and in particular, a massive black hole. If a supermassive object such as a black hole lies at the centre of an active system, the surrounding matter will fall in towards the centre and a part of the kinetic energy of the infalling gas will be radiated. If all the gravitational energy were transformed into radiation, the energy output would correspond to 10^8 solar masses (1 solar mass = 1 $M_\odot$ = 2×10^{33} g).

The presence of a massive core would have observable effects on the nucleus. The large concentration of stars bound to it will create a central bump in the luminosity profile, which can be observed using photometric techniques, and the large gravitational potential will increase the velocity dispersion of the surrounding stars, which can be measured from the broadening of the absorption line spectra.

The peculiar elliptic galaxy M 87 which lies in the centre of the Virgo cluster of galaxies appeared to be a particularly promising candidate for sheltering a supermassive core. It is relatively close (15 MPc = 4.5×10^{20} m), it is known to be an active radio source with a compact component (1.3 arc ms), and there is optical evidence of ejection of mass from the nucleus in the form of a jet. The total anomalous radiation output from the galaxy is 2×10^{42} erg s^{-1} which places it among the weakest of the radio sources associated with supergiant elliptical galaxies.

The search for a supermassive object was undertaken by two teams of astronomers *, most of whom came from the California Institute of Technology. One made photometric studies with the 200 in and 60 in telescopes in Palomar, the second made spectrometric measurements with the 4 m telescope at Kitt Peak National Observatory in Arizona.

For the photometric studies two different electronic imaging systems were used: an SIT (silicon intensified target) television-camera tube, and a CCD (charge coupled device) camera which is particulary suitable for two dimensional photometry of faint objects since it has a wide dynamic range and no image distortion. It has, moreover, a high spatial resolution: 0.25" at the 200 in prime focus. The accurate luminosity map shows the presence of a tiny bright spot which lies within 0.02 arc s of the centre of the galaxy, and a luminosity excess, compared to the luminosity profile of normal elliptical galaxies, which extends up to 20 arc s from the centre. The luminosity profile could be explained by assuming that the centre of the galaxy had an excess of massive stars, but this kind of model fails to explain the observed velocity dispersion, predicting instead a constant velocity dispersion across the core.

The velocity study was done using a two dimensional photon counting system designed by A. Boksenberg of University College, London. Spectra taken at different distances from the centre along the main axis of the galaxy, showed that the dispersion increases sharply from 230 km/s in the external part to 290 km/s at 10 arc s, and 350 km/s at 1.5 arc s from the centre. For comparison, a similar measurement made on the normal elliptical galaxy NCC 3379 shows only a very moderate increase (190 km/s in the external part to 220 km/s in the central part). The velocity dispersion data are consistent with a very compact object which appears as a point source to its surroundings.

Combining their results, the teams concluded that within 1.5 arc s (110 Pc) of its centre, M 87 has an excess mass of 5×10^9 $M_\odot$. Moreover this mass is very dim since the luminosity increase is 10 times smaller than it would be if the mass were in the form of normal stars.

This all points to the existence of a massive black hole in the centre of M 87. It should be emphasized that it is not the only way in which the data can be explained, but in many respects it is the most attractive. Whatever the actual nature of this supermassive heart of M 87, its discovery will have important consequences for our understanding of very active objects in the sky. Unfortunately, present observations are at the limit of what is possible from ground-based observations and significant improvements in the data on M 87 or other similar galaxies will not be achieved until the launching of the Space Telescope.

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Nominal D-T Ignition Temperature Exceeded

The 7th International Conference on Plasma Physics and Controlled Nuclear Fusion, organized by the International Atomic Energy Agency, was held at Innsbruck from 23 to 30 August, 1978. It was attended by about 500 scientists from all over the world, two thirds of whom were European.

The most important single result reported at the Conference was in the field of magnetic plasma confinement which continues to receive most attention. This was the attainment of an ion temperature of 5.5 keV in the Princeton Large Tokamak by injecting neutral particle beams carrying 2 MW for 100 ms. Such a temperature is higher than that required to make fusion-α-particle self-heating of a deuterium-tritium plasma larger than its bremsstrahlung loss: in other words the nominal ignition temperature of a DT plasma has been exceeded, and the range of thermonuclear fusion ion temperatures entered. Even more important is that no deleterious effects on plasma confinement were observed, in contrast to theoretical expectations which forecast new types of instabilities as collision effects in the plasma decreased in strength.

The ion heating experiment was done at relatively low plasma densities (about 10^{13} particles/cm^3) which implies that the electron temperature of 2 keV, reached by ohmic heating, was increased by only 50 % to about 3 keV, and the overall energy confinement time, determined by electron heat losses, was relatively short, namely 30 ms. Consequently the product of density and confinement time is more than two orders of magnitude below that necessary for a DT plasma to be self-sustained by fusion heating. The maximum value of this product attained in tokamaks has been reported to have reached 3×10^{13} cm^{-3} s in ALCATOR at MIT in discharges