The cosmic weighing scale

Watching the weight of black holes can suggest how galaxies evolved, says S.Ananthanarayanan.

Observation has shown that the masses of very massive black holes that lie at the centre of galaxies are related to many other features of the galaxies. This strongly suggests that the growth of the black holes and the evolution of the galaxies are interconnected. Getting a fix on the mass of the black holes in the galaxies could thus indicate the history of galaxies and help understand how they form. ***Timothy A. Davis, Martin Bureau, Michele Cappellari, Marc Sarzi & Leo Blitz***, of the European Southern Observatory in Germany, in the UK and of the Universities of Oxford, Hertforshire and California report in the journal, ***Nature*** that they have improved the measuring the mass of one so-called ***Supermassive Black Hole*** in one of oldest galaxies.

Black holes are the way larger stars, when they die, end up as a result of their own gravity. At the end of a star's active lifetime, when its nuclear fuel is used up, there is nothing to prevent its collapse by gravity and it compresses into a core of exceedingly high density. Now, when the star gets denser and smaller, the star's surface is nearer the centre and the force of gravity becomes greater. If the star is more than some 1.4 times the mass of the sun, it is found that the force of gravity at the surface can grow so high that that even light is not able escape. As no light can come from such a star, it is called ***black***. And as objects in its vicinity would be drawn to crash into the massive star and disappear, it is called a ***hole***. But it is a good thing that objects are drawn in like this, as it is by the radiation emitted by this matter that crashes in that a black hole is actually detected. Through such accretion, a black hole grows in size and many are thousands to billions times the mass of the sun. And practically all galaxies, the ***Milky Way*** included, have a ***supermassive black hole*** (***SMB***) at their centre.

The high gravity at the surface of black holes drives surrounding matter to fantastic velocities and the vicinity of a black hole can be brightly lit by high frequency radiation. One of the methods of estimating the size of black holes, in fact, is by timing x-ray bursts that come from their surroundings. The duration of the burst suggests the distance between the points involved and the dimensions of the black hole are estimated to be about 1/100 of this distance. White it is stars of more that 1.4 times the mass of the sun that collapse by themselves to become black holes, any sphere, in principle, can be squeezed till its density is so high enough that light is cannot escape at its surface. This limit of squeezing, which depends on the mass of the sphere, is called the ***Schwarzchild radius*** for the sphere. An estimate of the dimensions of a black hole thus allows its mass to be calculated.

In the case of SMBs, the large mass gives rise to a large Schwarzchild radius, which in turn, in spite of the great mass of the star, keeps the density quite low. The conditions at the extremities of SMB are thus materially different from what they are near a normal black hole and the usual ways of estimating the size do not work with SMBs. As a result, there are not many SMBs whose mass is known and we are not able to really examine how the evolution of galaxies and their SMBs are related.

Spotting SMBs

As there is no high gravity at the extremities of SMBs, the flashes of light or X Rays are from deep within and do not yield reliable estimates of dimensions. SMBs are also typically at great distances and even the images at such visible or higher frequency light, as detected by telescopes, which are placed in orbit around the earth, are of poor resolution. A better marker of SMBs would be low frequency emissions, typically from molecular gases surrounding SMBs. Light at low frequency is less scattered in its long passage through space and is perhaps the only set of signals we receive from the most distant and most ancient parts of the universe. Emission at these low frequencies, unlike the higher frequency emission from electron transitions in atoms, arises from vibration or rotation transitions of molecules of gases. These transitions are extremely low energy and the emissions are long, millimeter waves, as opposed even to microwave radiation, which has wavelength in microns.

While X Ray and visible light can be detected and focused using lenses or mirrors, long waves, like radio waves, need devices with very large aperture sizes. Fortunately, long waves survive passage through the earth's atmosphere and can be detected by ground based arrangements. The radio telescope is then an array of detectors that is spread over several kilometers and the signals detected by the array, over hours or days, can be combined in computers to generate well resolved images of the sources of the signals. The arrangement that Timothy A Davis and others made use of is ***CARMA***, the ***Combined Array for Research in Millimeter-wave Astronomy***, an array of 23 specialised radio telescopes placed atop a plateau called ***Cedar Flat*** in the ***Inyo Mountains*** in eastern California.

Combined Array for Research in Millimeter-wave Astronomy

The group trained the array to sight the galaxy ***NGC 4526*** and observed the activity of carbon monoxide gas that surrounds the SMB at its centre. This galaxy has the features that indicate an SMB in its centre and although the SMB has not been measured using any method, it was estimated to have mass of about 200 million times that of the sun, with a ***sphere of influence*** of almost one light year. Observation by the ***Hubble telescope*** had indicated the presence of a molecular gas envelope, whose activity could reflect the nature of the SMB.

The group used data of the emissions from the carbon monoxide gas within the galaxy and constructed a picture of the movement and activity of the gas. They then tried out possible models of the central SMB to see which one would fit the observed activity of molecular gas. The result of the simulations was a ***best fit*** with a size of 450 million solar masses, which is not far off the estimate. Observations showed that the gas in this galaxy did not show turbulence, which could have affected conclusions about the SMB. The modeling method also took care of the effect of dust that could affect conclusions and the group says future attempts to use this technique to estimate SMB mass should select targets after considering such effects. "The use of molecular gas as a kinematic tracer should thus allow one to estimate black-hole masses in hundreds of galaxies in the local Universe, many more than are accessible with current techniques.," the authors say in their paper.

The authors are looking forward to the next generation of millimeter wave detectors which would enable mass estimates like the present one with SMBs five times further away, within just 5 hours of observation time, in place of over 100 hours that it took this time..

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