The cosmic weighing scale

Watching the weight of black holes can suggest how galaxies evolved, says s ananthanarayanan


Michele Cappellari


Combined Array for Research in Millimetre-wave Astronomy.

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 black holes and evolution of the galaxies are interconnected. Getting a fix on the mass of black holes in galaxies could, thus, indicate the history of galaxies and help understand how they form.

Timothy A Davis, Martin Bureau, Michele Cappellari, Marc Sarzi and Leo Blitz of the European Southern Observatory in Germany, the Universities of Oxford, Hertforshire and California, respectively, report in the journal *Nature* that they have improved measuring the mass of one so-called *Supermassive Black Hole* (SMB) 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, its 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 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 of times the mass of the sun. And practically all galaxies, the *Milky Way* included, have a Supermassive Black Hole 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. While 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 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 Supermassive Black Holes, 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 Supermassive Black Holes 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 the Supermassive Black Holes. As a result, there are not many of these whose mass is known and we are not able to really examine how the evolution of galaxies and their Supermassive Black Holes 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 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, millimetre 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 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 kilometres 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 was 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.

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 modelling 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.

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

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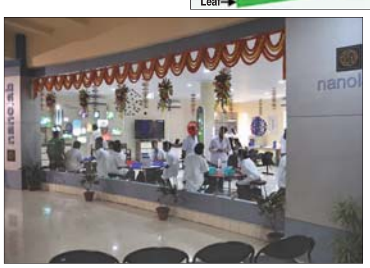
Cutting edge technology

Kolkatans will soon enough have the opportunity to peek into the expanding frontiers of science and plumb depths that has, till now, been the privilege of top scientists, writes debameeta bhattacharya

IMAGINE scientists exploring matter on a scale that is 80,000 times smaller than a human hair. Where all this is possible is a gigantic global laboratory where scientists from all disciplines will converge and dedicate themselves to observing and manipulating the smallest particles in the natural world. Thirty years ago, new microscopes opened the doors to this new dimension and allowed for the movement of individual atoms and molecules. This science of the miniscule has since opened up a new world of possibilities and Kolkatans will soon enough have the opportunity to peek into the expanding frontiers of science and plumb depths that has, till now, been the privilege of top scientists.



A high-tech laboratory that can rival some of the best facilities in top-draw scientific institutes will be opened to the general public at Science City within a month. To be housed in the DynaMotion Hall next to the dome theatre, this Rs 45-lakh lab will be equipped with a microscope so powerful it can enlarge an image 1,000 million times.

If that is difficult to perceive, here's what the scanning tunneling microscope can do. Viewed through it, a metal ball 1.27 millimetres diameter can be magnified to the size of earth, which has a diameter of 12,700 km. This is the first such laboratory being set up by the National Council of Science Museums, the worlds largest network of science museums under a single umbrella. Indeed, this Nano lab will encourage an understanding of science's new horizons and will cater to schools, colleges and engineering institutes so that students get hands-on experience of what they are taught in the classroom.

The Swiss-made microscope, priced at Rs 24 lakh, is capable of imaging surfaces at the atomic level. Its resolution will allow imaging and manipulation of individual atoms within materials.

Also under way at Science City is a Rs 19-crore Science Exploration Hall that will house three major exhibitions — Evolution of Life, Evolution of Man and ancient civilisations and India's Science and Technology Heritage as well as tomorrow's cutting edge technology.

The Lotus Effect

Nanotechnology has been called "the next technological revolution" given that it provides groundbreaking solutions to the most serious problems that threaten our future – it promises faster computers, improved security, longer, healthier lives and a cleaner earth. Science describes lotus leaves as super hydrophobic, or highly water-repellent. For the lotus, it means more sunlight and less bacteria — for us, it's inspiration.

The lotus effect refers to the superhydrophobicity exhibited by the leaves of the lotus flower (*Nelumbo*). Dirt particles are picked up by water droplets because of a complex micro and nanoscopic architecture of the surface, which minimises adhesion. This effect can easily be demonstrated in many other plants, for example *Tropaeolum* (nasturtium), *Opuntia* (prickly pear), *Alchemilla*, cane and on the wings of certain insects. RH Dettre and RE Johnson first studied the phenomenon in 1964 using rough hydrophobic surfaces. Their work developed a theoretical model based on experiments with glass beads coated with paraffin or PTFE telomer.

The self-cleaning property of superhydrophobic micro-nanostructured surfaces was studied by W Barthlott and N Ehler in 1977 and in 1986 SS Brown developed materials for handling chemical and biological fluids. Other biotechnical applications have since emerged.

Earth's environment faces some great challenges and it doesn't take much to realise there's no time to waste. Scientists assume that nanotechnology may be the key to overcoming the biosphere's environmental problems, for example the arsenic in contaminated groundwater. A nano solar cell has proven to make power cheaper and more efficient by capturing the sun's infrared rays. Adding cerium oxide in nano form to diesel can make it both more efficient and clean up emissions, and the technology can also contribute to treating contaminated soil.

But will we create pollutants than the ones we already have? What happens when nano-structured materials decay? Scientists are investigating the possible environmental impact of silver nanoparticles being used as anti-bacterials in consumer products. One can only hope that the technology will pave the way to a cleaner, safer future.

Nuclear envelope

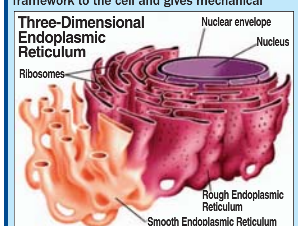
tapan kumar maitra **explains the origin and functions of endoplasmic reticulum**

THE cytoplasmic matrix is traversed by a complex network of inter-connecting membrane-bound vacuoles or cavities. These vacuoles or cavities often remain concentrated in the endoplasmic portion of the cytoplasm and are, therefore, known as Endoplasmic Reticulum, which was first reported by Keith R Porter in 1945.

The exact process of the origin of ER is still unknown. But because its membranes resemble nuclear membrane and plasma membrane and also the telophase, ER membranes are found to form the nuclear envelope. Therefore, it is normally assumed that the ER originated from the evagination of nuclear membranes. P Seikevitz and G Palade (1996) reported that the granular type of ER originated first and later it synthesised into the agranular or smooth type Endoplasmic Reticulum. The likes of Leskes, Eytan and Ohad have suggested that one cell receives a full set of membranes from its ancestor cell and as there is no *de novo* synthesis of membranes they grow by expansion of pre-existing membranes.

The Endoplasmic Reticulum acts as a secretory, storage, circulatory and nervous system for the cell. It performs the following important functions:

- The ER provides an ultrastructural skeletal framework to the cell and gives mechanical support to the colloidal cytoplasmic matrix;



- The exchange of molecules by the process of osmosis, diffusion and active transport occurs through ER membranes. Like the plasma membrane, the ER membrane has permeases and carriers;
- The endoplasmic membranes contain many enzymes that perform various synthetic and metabolic activities. Further, the ER provides increased surface for various enzymatic reactions;
- The ER acts as a circulatory or transporting system. Various secretory products of granular endoplasmic reticulum are transported to various organelles as follows: Granular ER-Golgi membrane – lysosomes or secreiary granules;
- The ER membranes are found to conduct intra-cellular impulses. For example, the sacroplasmic reticulum transmits impulses from the surface membrane into the deep region of the muscle fibres, and ER membranes from the new nuclear envelop after each nuclear division;
- The ER membranes protect the cell by the toxic effects of various substances through a process of detoxification. Jones and Fawcett (1966) reported that when a toxicant known as phenobarbitol was injected in the animal cell, ER enzymes such as NADPH2 became active and and hypertrophy of Endoplasmic Reticulum took place.

The granular endoplasmic reticulum possesses attached ribosomes with its membranes. The ribosomes synthesise new proteins according to the direction of the nuclear DNA either for intra-cellular organelles or for extra-cellular use. For instance, the ribosomes of certain cells sometimes synthesise proteins such as haemoglobin and fibrous proteins, which are usually stored in the cytoplasmic matrix. The Endoplasmic Reticulum has no concern with such secretory proteins. But sometimes the ribosomes synthesise the proteins as trophocollagen serum proteins, enzymatic proteins for extra-cellular export. These proteins are transported by the ER to the exterior of the cell via the Golgi complex and secretory granules.

The agranular or smooth type of Endosplamic Reticulum synthesises and stores various substances, namely:

- Synthesis of lipids: The cells in which active lipid metabolism takes place are found to contain a large amount of the smooth type of Endoplasmic Reticulum. According to Christensen (1961) and Claude (1968), the smooth type of ER is related with the synthesis and metabolism of the lipids and lipoproteins;
- Glucogenolysis: The synthesis of glycogen is accomplished in the cytoplasmic matrix, but the smooth ER is involved in the glucogenolysis (digestion of glucose) through the action of glucose-6-phosphatase.
- Other synthetic functions: The smooth type of ER also synthesises steroid compounds like cholesterol glycerides, hormones, testosterone and progesterone. Further, the smooth ER of the pigmented epithelial cells of the retina synthesises certain visual pigments from vitamin A. In plant cells, the smooth ER develops along the surface where the cellulose walls are being formed (Porter and Machado, 1960).

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