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Close look at distant fireball

Black holes can now be seen in greater detail, says S.Ananthanarayanan.

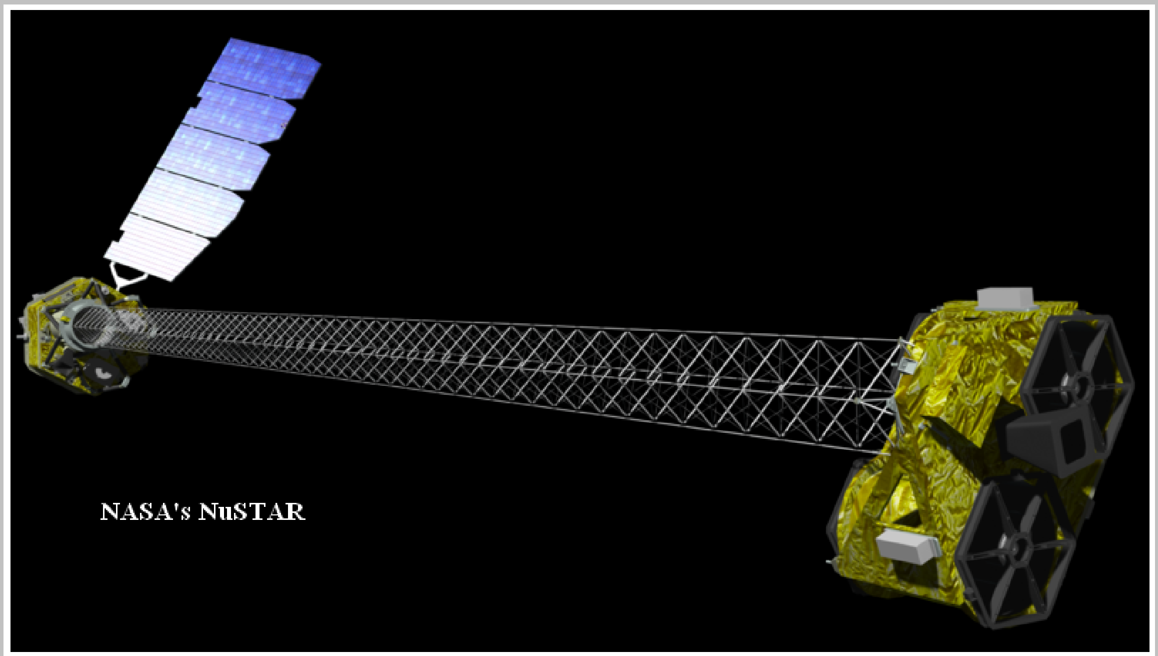
NASA's ***NuSTAR*** (***Nuclear Spectroscopic Telescope Array***) is a newest space based telescope and it forms images using high energy X Rays. It exceeds the capabilities of NASA's ***Chandra X Ray Observatory*** or the European Space Agency's ***XMM-Newton(X-Ray Multi-mirror Mission-Newton)***, the two most powerful facilities so far. NuStar has enabled views of massive black holes in the centre of a nearby galaxy and has enabled working out how fast the black hole is spinning – information that will help us understand the way black holes form.

A group of scientists from Italy, Denmark, UK and institutes in USA report in the journal, ***Nature***, the results of data collected by NuSTAR, which resolves an important question about the spin of the active core of one nearby galaxy.

X Ray telescopes

Telescopes can resolve greater detail if the light that they use is of short wavelength. Many cosmic objects are very hot and emit light in the Ultra Violet or the X Ray region. But this light is absorbed by the earth's atmosphere and the images are not visible in telescopes that are on the ground, even atop high mountains. An early solution was to raise the telescopes high into the atmosphere in gas balloons, but this method has limitations. Recent decades have seen better ways, with telescopes placed out in space, in orbit around the earth, conveying the images back to the ground by radio signals. The Chandra and the XMM-Newton (named after S Chandrashekhar and Isaac Newton) are two such, which have collected vast data in the near X Ray region.

A great difficulty in constructing X Ray telescopes is that glass lenses or simple metallic mirrors cannot be used as components. While glass lenses can focus visible light, this does not work with X Rays, which are scarcely affected by glass in their path. And as for mirrors, X Rays do not reflect off a shiny surface when they strike full on, but pass right through, and usual metallic mirrors cannot be used. The method that works is with multiple mirrors that X Rays strike at ***grazing angles*** and with these, an image of the distant object has to be managed. The Chandra and Newton telescopes had special arrangements like this and NuSTAR also has a complex, grazing angle mirror system, known as a ***Wolter Telescope***, which uses a pair of mirrors that are built in concentric shells (there are 133 shells in each mirror) which consist of multi-atom-thin-layers of materials to coax the range of X Rays into reflection, so that they form an image.



The NuSTAR optics enables detection of X Rays of about ten times the energy, or about ten times shorter wavelength than the SMM-Newton, which is a very great advance in sensitivity.

Active galactic nuclei

While stars and galaxies form when sparse matter in space comes together due to gravity, the extreme end of the process is when matter is crushed so close together that the gravity at its surface is so high that even light cannot escape. Such an object, which is the ***black hole,*** will continue to attract matter, which would be accelerated to very high speeds and despite the name, a black hole can be made out by the radiation from the matter that surrounds it. It is now believed that there is a black hole at the centre of most galaxies and in many, the black hole has become '***super-massive***' and sports a swirling disk of surrounding matter which emits radiation of millions of suns. Galaxies with this kind of core are said to have ***Active Galactic Nuclei***, or ***AGN***s. As the objects are very high energy systems, there is intense radiation in the X Ray region, indeed, even in the higher energy, gamma ray region, and the right kind of telescope can form detailed images.

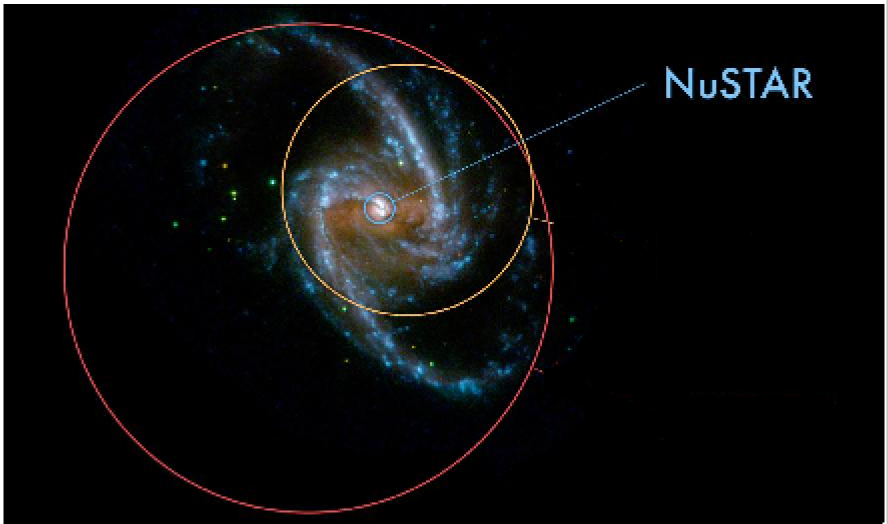
Objects that form through the accretion of matter increase not only their mass but also their rate of spin, as all the matter that comes in bring along some angular movement. This is the reason that galaxies form into disks or spirals and certain very dense objects, the neutron stars, rotate many times a second and emit pulses of radiation, as ***pulsars***. In the same way, black holes are also expected to be rotating and a measure of the speed of rotation could, ironically, '***throw light***' on how the black hole formed – is it by gobbling large objects all at once or is it gradual?. Gradual growth is likely to balance the growth of rotation and result in slower spin.

The rate of spin of black holes can be gauged using the special gravitational effects of a spinning mass. The black hole's gravity on the luminescent disk of surrounding matter would affect the quality of the light emitted and these changes can be detected, to make surmises about the rate of spin. The effect of gravity, basically, is to accelerate an object, and this would tend to stretch apart the waves of radiation emerging from the object. The wavelength of light from the object would hence grow longer, or be ***shifted to the red side***. The extent of ***red shift*** is a standard means of measuring the gravity or the speed of movement of a distant object. In the case of the light from around a black hole, it is the X Ray light from the element iron, which is of interest and the red shift which has been seen has suggested a rapid rate of spin.

But the trouble with measurements so far has been that there is an alternate, viz, other than spin, explanation for the red shift that is seen – it is possible that the X Ray emitting disk of matter is obscured by many layers of gas. These layers of gas could absorb and re-emit X rays, which would complicate the X Ray spectrum and mimic effects of spin even if there were none. The effect has '***cast a cloud'*** , says Christopher S Reynolds of the University of Maryland, who has reviewed the paper in Nature, over the effort to detect spin of super-massive black holes.

NuSTAR results

The images of ***NuSTAR***, with X Rays at frequencies about ten times higher than those of ***Chandra*** or ***Newton***, have helped resolve the uncertainty at least in the case of the AGN at the core of the nearby galaxy, ***NGC 1365***. The softer X Rays, viewed so far, had energies of ***less than 10 keV*** (kilo electron Volts) as compared to the ***79 keV*** possible with NuSTAR. The soft X Ray pictures showed variability due to movement of clouds of intervening, scattering material. With NuSTAR, it became possible to view the emission of X Rays at higher ranges of frequency, to see if there was a change in the effect of the moving clouds. The amount of radiation received in the bands of 3-5 keV and 6-10 keV, and 7-15 keV and 15-80 keV bands were studied and with statistical analyses, it was suggested that there was variability in the soft region, due to absorption of radiation.



This image of NGC 1365 is by ESA's XMM-Newton, NuSTAR could look closely at the AGN in the centre

The data was fitted to different models of black hole and accretion disc geometries. The investigation shows that the observed distortion of the emission lines of the metal iron is best explained by reflection off a fast rotating inner edge of the accretion disk. The extent of spin that is worked out leads to an estimate of the spin of the black hole itself and it is found to be 84% of the theoretical maximum spin. This is a important addition to the information about the process by which the black hole could have acquired the spin, which spurs the drive for more powerful X Ray observation tools.

Quasars and red shift

March 16th happens to be the 50th anniversary of the discovery of ***QUASARS, or Quassi Stellar Radio Sources***, by Maarten Schmidt, at Mount Palomar Observatory, in 1963. Schmidt was studying radio source 3C 273, which had the unusual feature of being a source of radio signals that was also bright, like a star. But what was more puzzling was that the spectrum of light received did not fit the emission spectrum of any known element. Till Schmidt realized that it was the spectrum of the element iron, but strongly shifted to the red side. A red shift indicates a high speed of recession or moving away of the source. It was known then that the universe was expanding and accelerating as it moved out and the speed of recession had become a measuring rod of how far away an object was. This formula, known as Hubble's law, led to 3C 273 being placed billions of light years away and therefore tremendously powerful, of the order of millions of galaxies, to be visible like a star at such a great distance. The power comes from the largest AGN at the centre of the Quasar, at the early stages of its growth. And it has been shown that the gravitation from the AGM cannot account for the Red shift – it has to be the great speed of moving away.

Maarten Schmidt

That the object was so far away implies that it belongs to a very early part of the history of the universe. Many such objects have been found since then, but they are all at similar and greater distances. The discovery was a major reason to drop the '***steady state'*** theory of the growth of the universe, as against the '***big bang'*** theory. According to the 'steady state', young galaxies should be uniformly distributed over the universe. But Maarten Schmidt showed that the youngest galaxies were found only at great distances