ASTROPHYSICS

Unity among black holes

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Black holes box at two weights: active galactic nuclei are in the super-heavyweight class, whereas galactic black holes are relative featherweights. But does the same physics pack both objects' punches? It seems that it does.

The existence of black holes — agglomerations of mass so concentrated that their gravitational pull allows nothing, not even light, to escape from them — is perhaps the most intriguing prediction of Einstein's general theory of relativity. Since the early 1960s, astronomers have identified two types of compact source that are probably black holes. These are galactic black holes (GBH), which have masses between 5 and 20 times that of the Sun, and active galactic nuclei (AGN), which weigh in at many millions of solar masses. On page 730 of this issue, M^cHardy *et al.*[1] present observations of X-ray emissions from these sources that indicate that, despite the huge disparity in their masses, the physical mechanisms that power these two classes of object are the same.

Evidence for AGN is to be found at the centre of most galaxies, including our own Milky Way[2]. AGN are point-like sources that radiate light equivalent to that of several billion stars — as much as their host galaxy. The maximum luminosity of GBH, on the other hand, is typically more modest, equivalent to that of a few tens of thousands of Sun-like stars. This radiation, it is important to note, does not emerge from the black hole itself. In both cases, the radiation is probably a by-product of a process known as accretion, in which matter from the host galaxy or a companion star is attracted towards the deep gravitational well of the black hole[3].

A full understanding of accretion is one of the fundamental goals of astrophysics. The process is ubiquitous in the Universe, and many astrophysical objects have undergone episodes of accretion at some point in their life. The bare bones of the process are thought to be these: owing to conservation of angular momentum, material cannot fall straight into a compact, massive object such as a black hole, but forms a disk in which angular momentum is transported outwards as the accreted material spirals inwards[4]. At the disk's inner edge, the accreted gas reaches temperatures of 10^6–10^7 K, and so emits radiation at X-ray energies. The energy thus released is between 7% and 42% of the total energy of the gas at rest, making accretion onto a compact object the most efficient energy-producing process known. (For comparison, when hydrogen atoms fuse in the centre of our Sun, the energy released is just 0.7% of their rest energy.) Thus, despite their huge luminosity, AGN need to accrete material at a rate of just 1–2 solar masses a year to fuel themselves.

Because X-rays come from the hottest parts of the accretion disk, they provide diagnostic information about physics close to the black hole itself. AGN and GBH have similar X-ray spectra, so most astronomers believe that the physics of emission is similar in both. But secondary effects, such as absorption in the material surrounding the black hole, complicate comparison of AGN and GBH spectra, and direct proof for the two sources' similarity has been lacking.

M^cHardy *et al.*[1] study the time variability of AGN and GBH. The idea is that, if the physics of AGN and GBH emission is similar, the variability in the emission should be similar too. The typical timescales of the variation should, however, scale with mass[5]. GBH are aperiodically variable on timescales from days down to around 0.01 seconds, so similar variability patterns in AGN are expected on timescales of months to years. For this reason, their variability has been studied less, as measurements routinely performed in a few hours for GBH require observational campaigns of several years for AGN. Such measurements have become available only within the past decade through satellites such as NASA's Rossi X-ray Timing Explorer (RXTE).

To measure the contribution of variations at a given frequency, f, to a source's overall variability, astronomers use a mathematical transformation of the source's light curve known as its power spectral density. With black holes, the most common feature of this function is a break[6,7] at which it turns from a shape roughly proportional to f^{-1} to one proportional to f^{-2}. Previous searches[5] had shown that this break tends to occur at a lower frequency (on a slower timescale) the greater the mass of the object. But a large scatter in the data points remained, making it difficult to extrapolate from this apparent correlation any general conclusion on the similarity of the mechanisms underlying GBH and AGN.

M^cHardy *et al.*[1] show that the reason for this scatter is that the break frequency depends strongly on luminosity. Once the authors took this into account, they could describe the observed variability of ten AGN, extending over more than three magnitudes in mass accretion rate, with one relation. Extending the sample to GBH allowed the variability properties of these sources to be explained, too. It would be hard to credit that two different physical processes should show essentially the same timing behaviour when extrapolated over such a large range of masses. Thus, these results provide a strong indication that the physics responsible for X-rays from stellar-mass and supermassive black holes is identical. The message is that for a full understanding of accretion onto compact, massive objects, objects of all sizes must be studied. At least here, the classical separation of astronomy into 'galactic', dealing with objects on the scale of GBH, and 'extragalactic', engaged with larger objects such as AGN, is artificial.

But with only ten AGN and two GBH, the number of objects in M^cHardy and colleagues' sample[1] is small. Further work is required to refine their relation by increasing the number of long-term AGN light-curves, and by adding data from more GBH-monitoring observations. Data from individual GBH should constrain the relationship between the characteristic timescale and the accretion rate: the shorter timescales of GBH mean that dramatic luminosity changes caused by changes in accretion can be observed in a single object[8]. Providing better data on AGN variability might be more challenging: understandably, it is difficult to convince the time-allocation committees of major satellites to commit themselves to such time-intensive long-term projects. RXTE is a commendable exception here.

For the next generation of satellites, dedicated, all-sky X-ray monitors are being discussed. These instruments will provide AGN light-curves without requiring repeated observations of single sources. Should these instruments come into being, together with dedicated instruments for the study of bright galactic sources, more intriguing insights should emerge from black holes. ■

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Correction

In the News & Views article "Archaeology: High tech from Ancient Greece" by François Charette (*Nature* **444**, 551–552; 2006), there was a typographical slip in reference 5. It should read: Field, J. V. & Wright, M. T. *Ann. Sci.* **42**, 87–138 (1985). Also, we were a century out in dating the re-emergence of certain elements of the Antikythera Mechanism in Byzantium. According to current scholarship, this occurred in the sixth century, not the fifth as stated.