ASTROPHYSICS

Broad escape from the abyss

New ultra-high-resolution images of the radio galaxy M87 show the origin of a jet very close to the galaxy's black hole, revealing that jets start as broad flows before straightening into nearly cylindrical beams. SEE LETTER P.185

ALAN P. MARSCHER

Black holes are extraordinarily compact and lie at great distances from us, so telescopes generally cannot resolve phenomena that occur close to their borders. Fortunately, the giant elliptical galaxy M87, whose nucleus contains a supermassive black hole (a black hole with a mass of 6×10^9 Suns), is near enough to offer a close-up view of the high-speed jet that is launched from near the black hole. On page 185 of this issue, Hada *et al.*[1] demonstrate that radio images made with the technique of very-long-baseline interferometry directly probe the black hole–jet connection in M87. The images reveal that high-energy plasma fans out from near the black hole to form a broad jet that becomes more cylindrical farther downstream.

Black holes have a deserved reputation as the ultimate vacuum cleaners of the Universe, sucking into gravitational oblivion the cosmic litter of gas and dust that happens to enter their realm. But not all matter that falls towards these monsters becomes trapped inside the black hole's event horizon, from which nothing — not even light — can escape. In fact, many black holes are sloppy eaters: the energy contained in the 'crumbs' of matter that are left rivals that of the 'food' consumed. This phenomenon has posed a difficult challenge for astrophysicists, who have been struggling for several decades to explain how the crumbs form the jets of high-energy particles that stream out from the centres of galaxies containing supermassive black holes.

Hada *et al.*[1] observed the M87 jet with the Very Long Baseline Array (VLBA) operated by the US National Radio Astronomy Observatory. The VLBA is an interferometer consisting of ten 25-metre-diameter radio antennas, located at various sites from the Virgin Islands to Hawaii, that all point at the same object simultaneously and measure the radio signals from it as Earth rotates. This produces the data needed to create an image with angular resolution similar to that of a huge radio dish with a diameter almost equal to that of Earth. Details can be seen on scales of 0.0001 arcseconds, 400 times finer than the resolving power of the Hubble Space Telescope at visible wavelengths.

One of the main questions surrounding the launching of jets from near a black hole is the distance required for the flow to focus into a very narrow opening angle of at most a few degrees. Previous studies[2,3] found that this focusing occurs a short distance downstream of the flow's brightest feature (the core), which is seen in VLBA images obtained at a frequency of 43 gigahertz. But the data were insufficient to determine the location of the black hole in the images. Hada *et al.*[1] have now overcome this problem by obtaining data at six frequencies, ranging from 2.3 to 43 GHz, by which they could measure the change in location of the core as a function of frequency. The opacity of the jet increases towards lower frequencies, and so radio waves at these frequencies can escape only from the less dense sections of the jet farther downstream from the black hole. By measuring the shift of core location versus frequency, the authors have determined the convergence point of the jet. In doing so, they have found that the core at

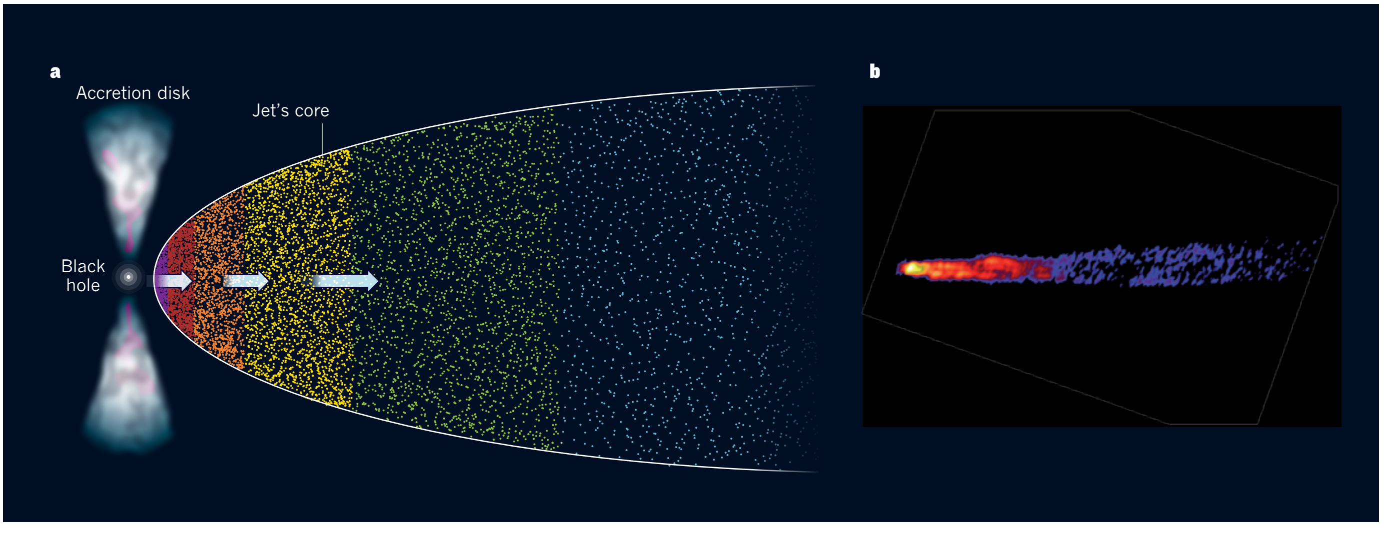

Figure 1 | Jet width and distance from the black hole in M87. a, The radio images of Hada *et al.*[1] indicate that, in the giant elliptical galaxy M87, a jet of high-energy particles (coloured dots) starts as a broad flow close to the galaxy's central black hole and accretion disk (the cross-section of which is shown as two wedges), becoming more cylindrical and faster (as indicated by arrows) with distance from the black hole. Within the jet's brightest region (core), colours correspond to jet sections that have different particle densities and that are observed at different frequencies, from about 200 GHz (purple, more dense) to 5 GHz (blue, less dense). **b**, The actual jet is seen here in an image obtained with the Very Long Baseline Array at a frequency of 15 GHz (yellow is brightest, blue is faint, black is undetected). The sketch in **a** fits into the core (yellow area) of the jet in **b**. (Image courtesy of NRAO/AUI and Y. Y. Kovalev, MPIfR and ASC Lebedev.)

43 GHz is located only 14 to 23 Schwarzschild radii from the black hole. (The Schwarzschild radius is the distance between the black hole's centre and its event horizon if the black hole does not spin, and up to twice this distance if it spins rapidly.) This value is surprisingly small, because estimates[4,5] of the black-hole-to-core distance in quasars, which are more-luminous cousins of M87, are more than 100,000 times the Schwarzschild radius.

Hada and colleagues' results[1] show that the jet flows into a broad angle between the black hole and core before becoming tightly focused farther out (Fig. 1). This agrees with predictions of some theoretical models[6,7] that explain jets as the products of magnetic fields twisted by the differential rotation of the ionized gas swirling around the black hole. In such models, the flow accelerates and narrows over hundreds to about 100,000 Schwarzschild radii, with faster jets requiring greater distances.

How are we to reconcile the short black-hole-to-core distance of M87 with the much longer distance inferred in some quasars? Perhaps jets spread out more rapidly in lower-luminosity objects because there is less hot ionized gas in the nucleus to confine the flow. Another possibility is that the jet consists of an ultra-fast (99% of the speed of light) spine surrounded by a slower (perhaps 90% of the speed of light) sheath. In quasars with bright jets, the spine points almost right at us, so we see the radiation beamed in our direction, whereas emission from the sheath is too weak to be noticed. The jet of M87 is more inclined to our line of sight, by 15–25°, so the spine is relatively dim, allowing us to see the slower sheath. The images of M87 thereby reveal slower regions of the jet that are close to the black hole, whereas in quasars the jets become bright only where the spines reach their terminal velocity at much greater distances from the black holes.

The ability to image jets on such small scales in M87 implies that very-long-baseline interferometry can explore phenomena even closer to black holes by observing at higher frequencies of 86, 230 or even 350 GHz, at which the resolution is two to eight times finer than at 43 GHz. In combination with monitoring of time variations in the radiation at infrared, visible, X-ray and γ-ray frequencies, such observations would act as an 'event-horizon telescope'[8]. ■

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NEUROSCIENCE

When lights take the circuits out

Circuit-level perturbations in the brain's electrical activity may underlie social-interaction deficits seen in people with schizophrenia and autism. A new optogenetic tool was instrumental in making this discovery. SEE ARTICLE P.171

JOÃO PEÇA & GUOPING FENG

On page 171 of this issue, Yizhar *et al.*[1] add to our understanding of the neuronal circuits that control mammalian behaviour. By tuning neuronal activity with light, they show that 'hijacking' specific brain circuits in the mouse prefrontal cortex (but not the visual cortex, for example) can selectively disrupt the normal responses to social stimuli and social interaction.

Information processing across neuronal circuits in the brain determines thoughts, shapes emotions and regulates behaviours. It will therefore come as no surprise if dysfunctions affecting synaptic communication between neurons and neuronal circuits reside at the core of several neuropsychiatric disorders. This assumption has led to considerable efforts to explore how circuit activity and information processing might differ between the healthy and the diseased brain. In recent years, one particular theory has gained substantial traction — that disorders such as autism and schizophrenia arise from imbalances in the ratio of excitatory to inhibitory synaptic inputs (E/I balance) in discrete neuronal populations[2,3].

Symptoms of various psychiatric disorders may arise from common features at cellular and circuit levels. These common features could therefore account, at least in part, for the convergence seen in the traits of broad-spectrum disorders such as autism that have a varied range of causes. Yizhar *et al.*[1] set out to directly test the hypothesis that an increase in E/I balance may underlie some of the common symptoms of neuropsychiatric diseases.

For this investigation, the authors made use of a novel optogenetic tool. Optogenetics is based on the expression of a light-sensitive ion channel in the membrane of discrete populations of neurons. Light is usually delivered through the skull to those neurons by an optical fibre, causing the channels to open. Optogenetics has allowed researchers to directly and rapidly manipulate neuronal firing, probe neuronal-circuit function and control behaviour on very fast timescales — within milliseconds. For example, in disorders in which the underlying neural-circuit dysfunction is well understood, optogenetics has been used successfully not only to mimic the expected behavioural deficiencies, but also to positively modulate symptoms in animal models of the relevant disorder[4] (Fig. 1).

Recently, Yizhar and colleagues[5] introduced step-function optogenetic channels. Tools of this new generation have been modified to remain open for longer periods of time (seconds to minutes) after light activation. This allows the induction of successive, subthreshold neuronal activation to bring cells close — although not all the way — to firing. The functional consequence of this is modulation of the properties of endogenous neuronal circuits as a whole, without 'overloading' or overriding normal neuronal firing.

For their latest study[1], the authors developed step-function optogenetic channels with improved temporal stability to prime distinct populations of neurons in the prefrontal cortex of the mouse brain so that these could more readily become active in response to native neural-network activity over long periods of time. They were thus able to manipulate neuronal E/I ratios in this brain region: when the targeted populations were excitatory neurons, the functional network output corresponded to an increase in E/I ratio; when they were inhibitory neurons, the E/I ratio decreased. On the basis of these manipulations, Yizhar *et al.* report that increased — but not reduced — E/I balance in the prefrontal cortex leads to well-defined behavioural impairments and a striking perturbation in sociability in mice.

Although these data provide strong evidence that alterations in the cortical E/I balance directly affect social behaviour in mice, we should avoid adopting a simplistic view of the implications of changes in this ratio. Recent genetic and genomic studies have identified a large number of candidate genes for autism, many of which encode proteins crucial to