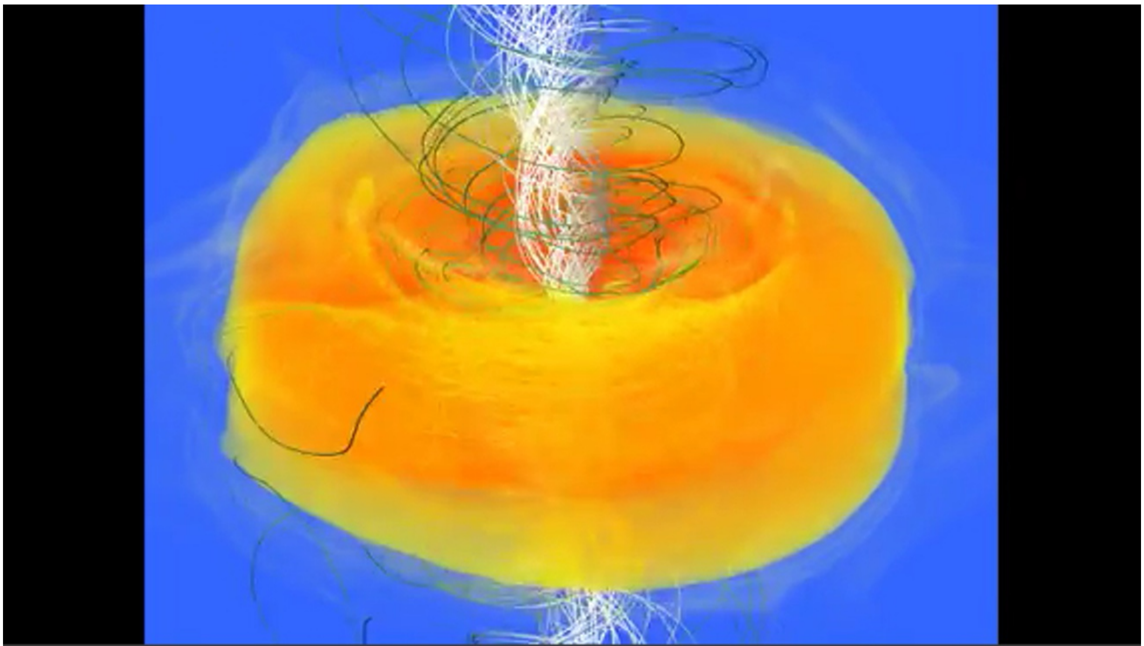
NATURE | NEWS

3D simulations of colliding black holes hailed as most realistic yet

Videos released just as a telescope survey suggests two black holes are due to collide in seven years' time.

Ron Cowen

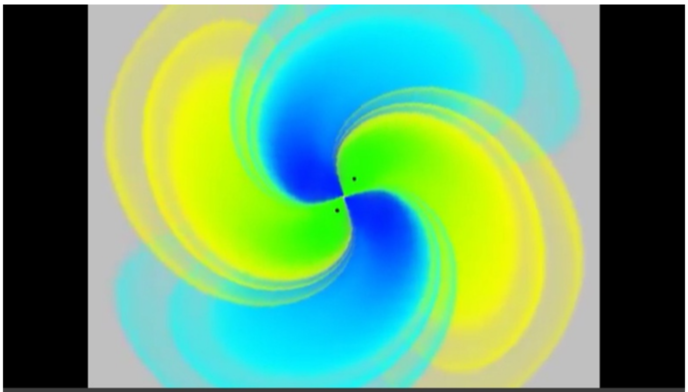
20 April 2015



In-spiral and merger of binary black holes
Simulations: S. Shapiro, R. Gold, V. Paschalidis, M. Ruiz, Z. Etienne & H. Pfeiffer. Movie: S. Shapiro, S. Connelly, A. Khan and L. Kong.

When astronomers try to simulate colliding giant black holes, they usually rely on simplified approximations to model the swirling disks of matter that surround and fuel these gravitational monsters. Researchers now report that, for the first time, they have simulated the collision of two supermassive black holes using a full-blown treatment of Einstein's general theory of relativity, allowing a 3D portrayal of these disks of magnetized matter.

The simulations more accurately describe the radiation that might be detected from such mergers. This includes electromagnetic radiation blasted into space and ripples in space-time known as gravitational waves. Stuart Shapiro of the University of Illinois at Urbana-Champaign presented movies of the simulations at a meeting of the American Physical Society in Baltimore, Maryland, on 13 April. His team had described elements of the study last November, in *Physical Review D*[1].



Gravitational waves generated by black hole merger
Simulations: S. Shapiro, R. Gold, V. Paschalidis, M. Ruiz, Z. Etienne & H. Pfeiffer. Movie: S. Shapiro, S. Connelly, A. Khan and L. Kong.

“As a technical achievement, there’s no doubt that this is a giant step forward,” says astronomer Cole Miller of the University of Maryland in College Park, who was not part of the study.

Collision course

For the simulations, Shapiro’s team developed a mathematical model to couple Einstein’s equations (which describe the gravitational field around a black hole) with equations that govern the motion of matter moving close to the speed of light in a magnetic field.

The simulations may take on added significance, says Shapiro, because recent observations hint that a black hole weighing as much as ten billion Suns might be set to collide with a similarly massive partner in a mere seven years.

Analysing data from a large telescope in Hawaii called Pan-STARRS (Panoramic Survey Telescope & Rapid Response System), Tingting Liu of the University of Maryland and her colleagues spotted what seem to be periodic variations in the radiation emitted by a quasar — a brilliant beacon of light that outshines the entire galaxy in which it resides — from which light has taken 10.4 billion years to reach Earth. The team reported its findings on 14 April in *The Astrophysical Journal Letters*[2].

Quasars are thought to be fuelled by supermassive black holes at the centres of galaxies. Liu and her colleagues interpret the apparently periodic fluctuations in the quasar light, along with information gleaned from the spectrum of that light, as a sign that the quasar’s black hole is closely orbiting another supermassive black hole in a neighbouring galaxy. If confirmed, the putative merger would be a prime candidate to examine for signs of emitted gravitational waves, says Liu.

Signal search

“This merger would be amazing, if we saw it,” says Miller. But strong evidence for an imminent collision is lacking, he adds. Random, low-frequency fluctuations in the quasar's light could partially mimic a periodic signal, he notes. And even if fluctuations in the quasar's light are truly periodic, they could be due to the properties of a single black hole and its disk, rather than to the presence of an orbiting partner, Shapiro says.

Still, he adds, it would be worth trying to spot gravitational waves from the putative merger. One way to do this would involve pulsars: compact, rapidly spinning stars that beam radio waves across the sky like lighthouse beacons. If a radio receiver on Earth could detect a correlated change to signals from an array of pulsars, that might indicate that the passage of a gravitational wave had disturbed the array. Radio receivers are not currently sensitive enough to detect a signal from Liu’s system, but future improvements could bring a detection within reach, says Shapiro.

Earlier this year, astronomers reported in *Nature* that they had found a repeating light signal that is best explained by a pair of supermassive black holes poised to spiral into each other[3]. Sadly, the collision is predicted to occur a million years from now.

Nature | doi:10.1038/nature.2015.17360

References

1. Gold, R. *et al*. *Phys. Rev. D* **90**, 104030 (2014).
2. Liu, T. *et al*. *Astrophys. J.* **803**, L16 (2015).
3. Graham, M. J. *et al*. *Nature* **518**, 74–76 (2015).