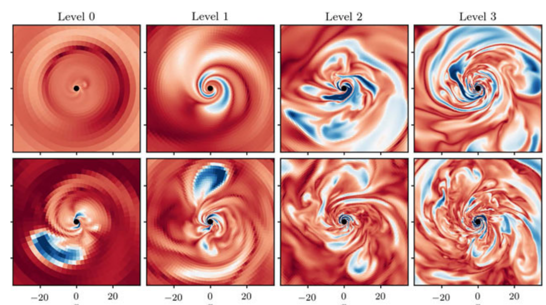
May 07, 2019 | By Kimberly Mann Bruch

Supercomputer Simulations Show Black Holes and Their Magnetic Bubbles

University of California and Princeton scientists collaborate on computational astrophysics project

When the Event Horizon Telescope team released the first picture ever taken of a black hole in mid-April, the general public became enamored by these mysterious phenomena and many questions quickly arose regarding this specific black hole, which sits in the middle of a galaxy coined Messier 87 (M87) – located approximately 55 million light years from Earth.



These Comet-enabled images depict the hot, thick disk of plasma surrounding a black hole. As resolution and reconstruction order increases, more and thinner sheets of plasma appear while highly magnetized bubbles become more numerous. Credit: Christopher White, UC Santa Barbara.

Christopher White, a computational astrophysicist at the Kavli Institute for Theoretical Physics at UC Santa Barbara, said that the powerful jets of particles surrounding the M87 black hole is a prime candidate for his research group's studies, which often rely on the *Comet* supercomputer at the San Diego Supercomputer Center (SDSC) at UC San Diego. Researchers also used *Stampede2* at the Texas Advanced Computing Center (TACC), with both systems allocated through the Extreme Science and Engineering Discovery Environment (XSEDE), which is funded by the National Science Foundation (NSF).

White and his colleagues – James Stone, chair of the Department of Astrophysical Sciences at Princeton University; and Eliot Quataert, a professor of astronomy and physics at UC Berkeley – recently published a paper explaining their *Comet*-simulated black hole visualizations, which illustrate a scenario known as a magnetically arrested disk.

The paper, called 'A Resolution Study of Magnetically Arrested Disks' and published in the April 2019 issue of *The Astrophysical Journal*, focused on the processes by which matter falls into these supermassive black holes in the centers of galaxies.

This specific scenario, which is similar to the M87 black hole, is studied by many researchers and involves a hot, thick disk of plasma and a strong magnetic field. Scientists have long believed that this magnetic field is responsible for launching the extremely powerful jets of particles and energy associated with some black holes.

In their study, White and his colleagues addressed whether the simulations of this scenario have sufficient resolution to yield trustworthy results. For most questions posed by the astrophysics community they do, though there are some results that may need higher resolutions or better numerical methods.

"We used *Comet* to run our large simulations that incorporate fluid dynamics, electromagnetism, and general relativity – showing as resolution and reconstruction order increases, more and thinner sheets of plasma appear while highly magnetized bubbles become more numerous," explained White. "These sorts of simulations are very computationally demanding and require very high resolution, which is why we used SDSC's petascale supercomputer."

The primary goal of the researchers' study was to show that as resolution increases, eventually the output of the computation stops changing because all of the relevant physical processes have been correctly modeled. Some 760,000 core-hours were used on *Comet* for the study.

"This research would not be possible without access to *Comet* and other supercomputers, as smaller university clusters would have taken years to generate our simulations," said White.

Data from Deep Space

Because black holes and their surroundings are some of the most extreme environments in the universe, they push the boundaries of our understanding of physics. Observational astronomers are now generating unprecedented data regarding these systems, allowing theorists to build better models for them. White and his colleagues now plan on continuing their work – possibly looking in much more detail at those jets surrounding the recently revealed M87.

"Figuring out how matter orbiting a black hole is ejected as a jet rather than being swallowed up is one of nature's persistent mysteries," said SDSC Director Michael Norman, who also is a Distinguished Professor of Physics at UC San Diego where he directs the Laboratory for Computational Astrophysics. "Magnetic fields have long been implicated. These sophisticated simulations bring us a step closer to solving this mystery."

This research was supported in part by XSEDE grant number TG-AST170012. This work also used resources of the Argonne Leadership Computing Facility (ALCF) via the Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program, and the *Savio* computational cluster resource provided by the Berkeley Research Computing program at the UC Berkeley. This work was also supported in part by a Simons Investigator award from the Simons Foundation and NSF grants AST 13-33612 and AST 17-15054 (EQ).

MEDIA CONTACT

Jan Zverina, 858-534-5111, jzverina@sdsc.edu
Kimberly Mann Bruch, 858-822-3622, kbruch@ucsd.edu