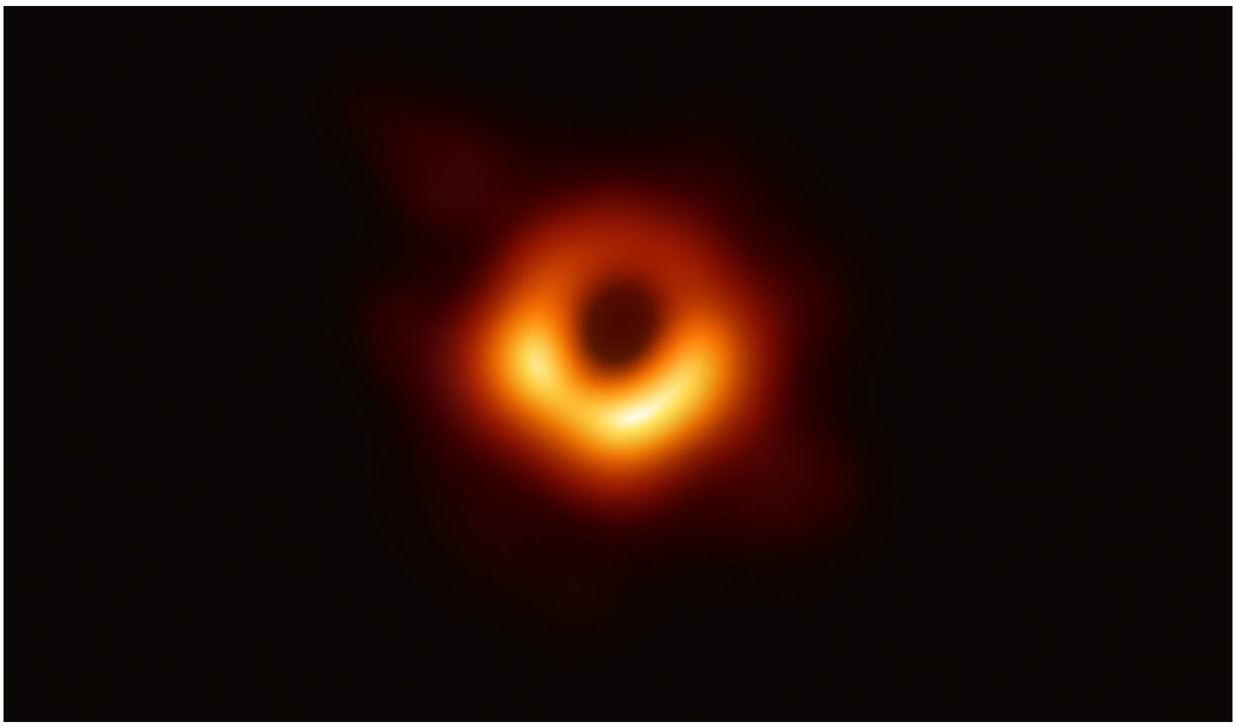
How did supermassive black holes grow so fast?

December 9 2019, by Jonathan O'callaghan, From Horizon Magazine



Astronomers are trying to determine how supermassive black holes, such as the one at the heart of the galaxy M87, grew so quickly. Credit: EHT Collaboration

Black holes in the early universe pose a bit of a problem. Based on observations from telescopes on Earth and in space, we know that some black holes grew to be a billion times the mass of the sun just one billion years after the Big Bang. Our current models of black hole growth, however, can't explain this speed of growth. So how did these supermassive black holes come about?

This is a problem that has long plagued astronomers. Our current understanding suggests that in this time frame, only so-called intermediate mass black holes up to 100,000 times the mass of our Sun should have been able to grow. And while several theories for this rapid early black hole growth have been proposed, the answer remains elusive.

"That is still a huge problem in astrophysics," said Dr. John Regan, an astrophysicist from Dublin City University, Ireland.

Black holes form after a massive star runs out of fuel, sometimes resulting from a supernova and other times without a supernova, which is called the direct collapse scenario. Once a star has no fuel left to burn, it can no longer support its mass and collapses. If the mass of the star was large enough, it will collapse into an object with an immense gravitational pull from which nothing, not even light, can escape—a black hole.

As the black hole gradually draws in more and more nearby dust and gas it can grow in size, eventually reaching the gigantic proportions of a supermassive black hole, such as the first one ever imaged in April 2019. Scientists are now investigating whether supermassive black holes could have formed from supermassive stars which collapsed to form large 'seed' black holes, giving them a head start in their growth.

Dr. Regan coordinated a project called SmartStars, which used one of the most powerful supercomputers in Ireland, ICHEC, to model how supergiant stars might provide the seeds for supermassive black holes. The team wanted to see if these stars could account for the rapid growth of supermassive black holes, which we see at the centre of nearly every galaxy today.

250,000

They found such stars could grow up to 250,000 times the mass of the sun within 200 million years of the Big Bang—a tantalising result. However, even supercomputers have their limitations. The researchers were only able to model the future of such stars for a million years, but the modelling needs to cover 800 million years to see if these stars really could be the seeds of supermassive black holes.

"It's a really excellent starting point," said Dr. Regan. "Over the next generation of supercomputers we'll be able to bring those simulations further and further along."

Other theories for how these black holes grew so quickly are that a tiny fraction of black holes grew at incredible rates, or that smaller black holes merged together to grow into a supermassive black hole.

Dr. Muhammad Latif, an astrophysicist at United Arab Emirates University in Abu Dhabi, agrees with Dr. Regan that the supermassive star model remains our best theory at the moment. Dr. Latif was the principal investigator for the FIRSTBHs project which, like SmartStars, investigated the plausibility of the supermassive star model, using simulations on a supercomputer in France.

His project, which was carried out at CNRS in France, showed that supermassive stars could produce seed black holes hundreds of thousands of times the mass of our sun. "We found this method is basically feasible," said Dr. Latif, explaining that these initial seed black holes are large enough to account for the growth of supermassive black holes of a billion solar masses in a small time frame.

However, it requires conditions in the early universe to have been just right for these black holes to form. Large amounts of material made of hydrogen and helium would be needed to form enough massive seed black holes to produce supermassive black holes, which appears to have been possible.

But other unexplained factors mean this is still an open question. The seed black holes would need to draw in matter at a rate of at least 0.1 solar masses per year, for example, and at the moment it is not clear if this is possible.

Observatories

Several observatories are already enabling us to probe black holes in the early universe with great detail. In October 2019, astronomers announced that they had used the Atacama Large Millimetre/submillimetre Array (ALMA) in Chile to find a thick ring of dust and gas around a supermassive black hole inside a distant galaxy. With two gas streams rotating in opposite directions, it's thought this ring could have fed the supermassive black hole with enough material to cause it to grow rapidly.

Previously, in August 2019, NASA's Chandra X-ray Observatory managed to spot a so-called 'cloaked' black hole growing rapidly when the universe was just 6% of its current age. A thick cloud of gas hides the black hole and its resulting quasar, a bright region of superheated material that surrounds it, but Chandra was able to spot it by seeing X-rays emerge from the cloud.

However, future telescopes will likely be needed to study the rapid growth of supermassive black holes in even more detail. For example, while we can predict the existence of seed black holes, we can't yet see them. NASA's upcoming James Webb Space Telescope (JWST), due to launch in 2021, may be capable of spotting some of the undiscovered seed black holes.

The European Space Agency's Advanced Telescope for High Energy Astrophysics (ATHENA), meanwhile, set to launch in 2031, should give us an even better understanding of how supermassive black holes arise.

"People are quite hopeful that we will get a rather better picture with the ATHENA mission," said Dr. Latif. And maybe soon, we'll finally know how these huge objects grew so big in such a short space of time.

"It's like going to kindergarten and finding a seven-feet tall baby," added Dr. Latif.

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