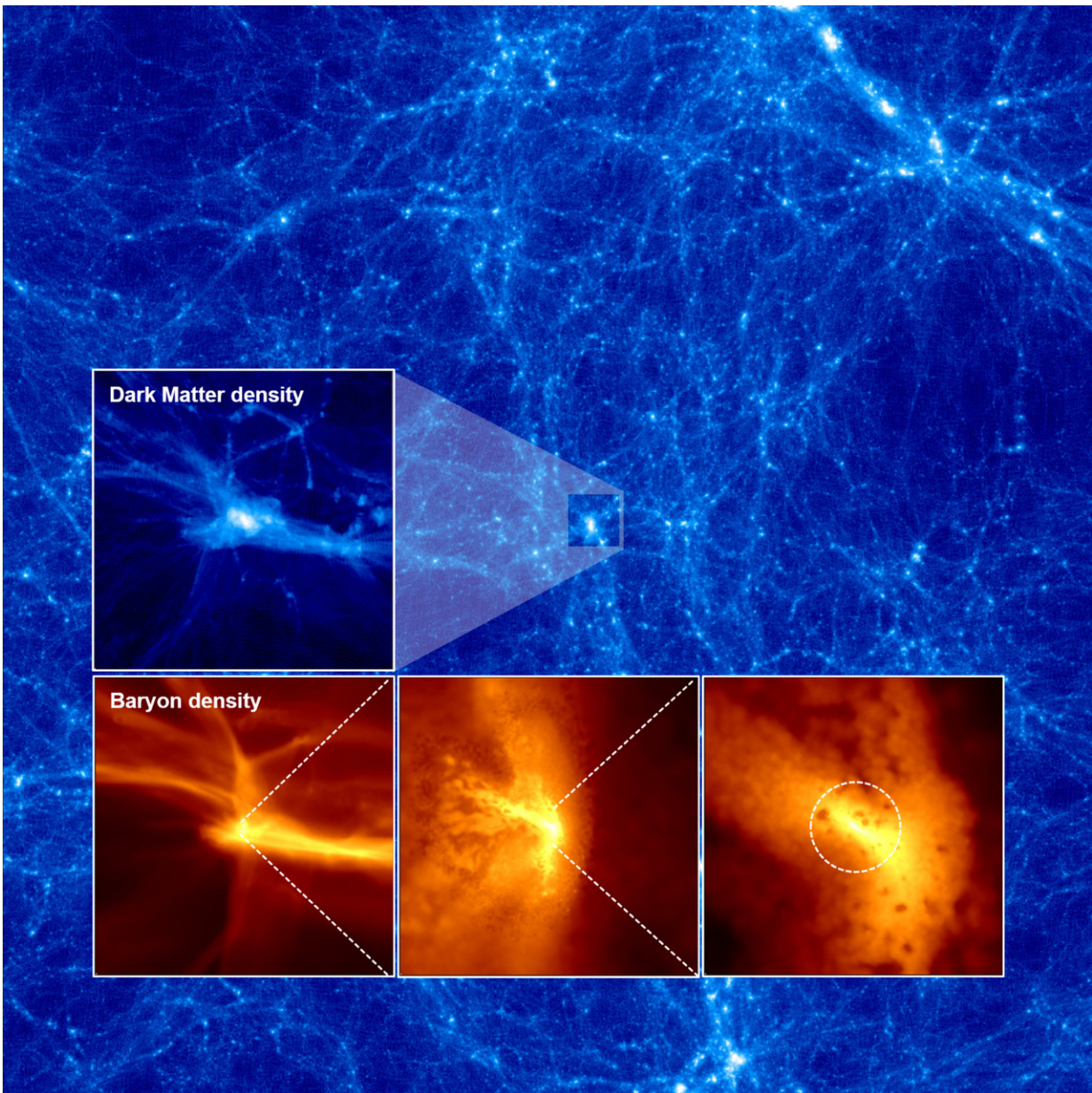


Supersonic gas streams left over from the Big Bang drive massive black hole formation

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Projected density distributions of dark matter (background and top panel) and gas (bottom three panels) components when the massive star forms. The stellar cradle is extremely assymetry as a wide wedge-shaped structure (middle panel) due to the initial supersonic gas motions left over from the Big Bang. The circle in the right panel indicates the gravitationally unstable region with mass of 26,000 solar-masses. Credit: Shingo Hirano

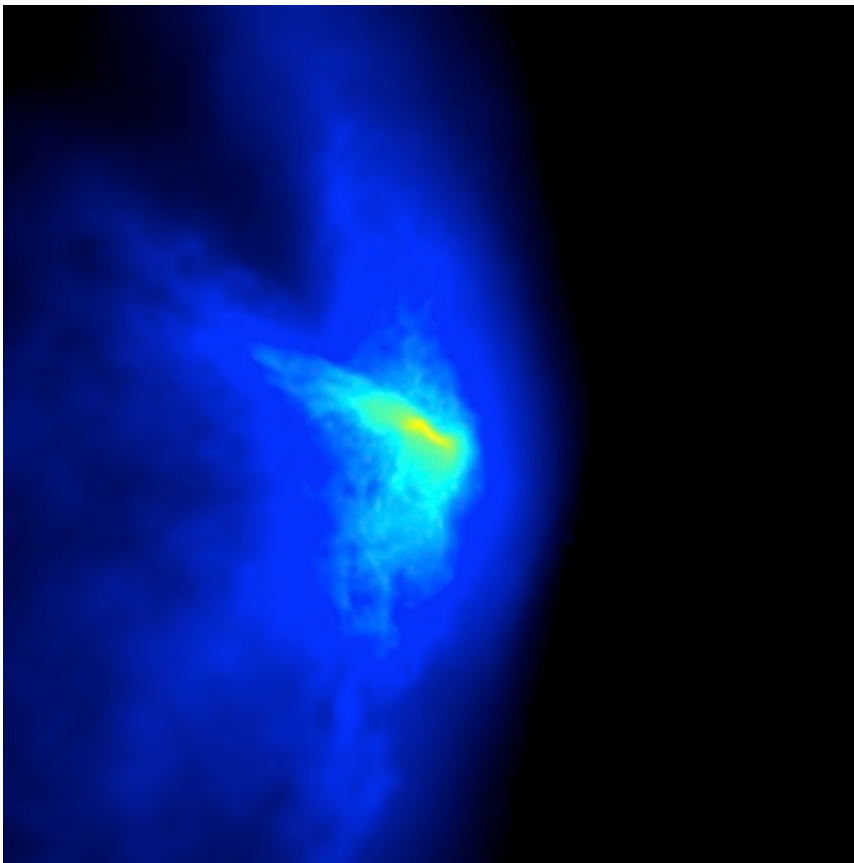
An international team of researchers has successfully used a supercomputer simulation to recreate the formation of a massive black hole from supersonic gas streams left over from the Big Bang. Their study, published in this week's *Science*, shows this black hole could be the source of the birth and development of the largest and oldest super-massive black holes recorded in our universe.

"This is significant progress. The origin of the monstrous [black holes](#) has been a long-standing mystery and now we have a solution to it," said author and Kavli Institute for the Physics and Mathematics of the universe (Kavli IPMU) principal investigator Naoki Yoshida.

Recent discoveries of these [super-massive black holes](#) located 13 billion light years away, corresponding to when the universe was just five per cent of its present age, pose a serious challenge to the theory of black hole formation and evolution. The physical mechanisms that form black holes and drive their growth are poorly understood.

Theoretical studies have suggested these black holes formed from remnants of the first generation of stars, or from a direct gravitational collapse of a massive primordial gas cloud. However, these theories either have difficulty in forming super-massive black holes fast enough, or require very particular conditions.

Yoshida and JSPS Overseas Research Fellow Shingo Hirano, currently at the University of Texas at Austin, identified a promising physical process through which a [massive black hole](#) could form fast enough. The key was incorporating the effect of supersonic gas motions with respect to dark matter. The team's supercomputer simulations showed a massive clump of dark matter had formed when the universe was 100 million years old. Supersonic gas streams generated by the Big Bang were caught by dark matter to form a dense, turbulent gas cloud. Inside, a protostar started to form, and because the surrounding gas provided more than enough material for it to feed on, the star was able to grow extremely large in a short amount of time without releasing a lot of radiation.

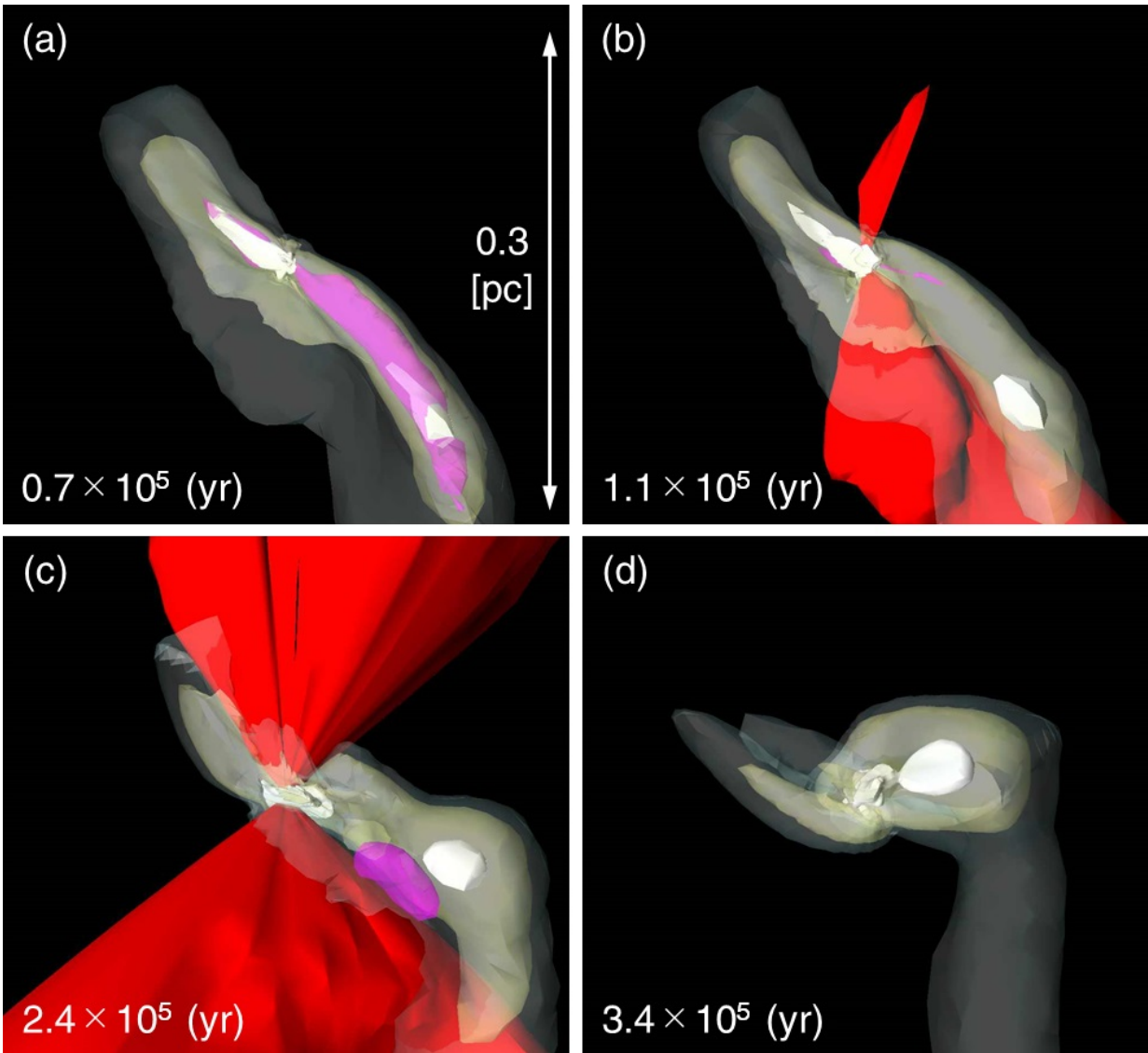


The gas density distribution around the new-born protostar. The left-to-right supersonic gas motion results in the non-spherical, compressed density structure. The collapsed inner cloud also shows the turbulent object, which can rapidly

accrete onto the central protostar and cause a fast mass growth of it. Credit: Shingo Hirano

"Once reaching the mass of 34,000 times that of our sun, the star collapsed by its own gravity, leaving a massive black hole. These massive black holes born in the early universe continued to grow and merge together to become a [supermassive black hole](#)," said Yoshida.

"The number density of massive black holes is derived to be approximately one per a volume of three billion light-years on a side—remarkably close to the observed number density of supermassive black holes," said Hirano.



The evolution of the temperature and density structure in the protostellar accretion phase after the protostar formation. The rapid accretion of dense gas cloud (white contour) constricts an expansion of the photoionized region (red) which is possible to shut off the gas accretion. Credit: Takashi Hosokawa

The result from this study will be important for future research into the growth of massive black holes. Especially with the increased number of black hole observations in the far [universe](#) that are expected to be made

when NASA's James Webb Space Telescope is launched next year.

This research was published in *Science* on September 28.

More information: S. Hirano et al., "Supersonic gas streams enhance the formation of massive black holes in the early universe," *Science* (2017). [science.sciencemag.org/cgi/doi ... 1126/science.aai9119](https://science.sciencemag.org/cgi/doi/10.1126/science.aai9119)

Provided by Kavli Institute for the Physics and Mathematics of the Universe

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