Subaru telescope helps determine that dark matter is not made up of tiny primordial black holes

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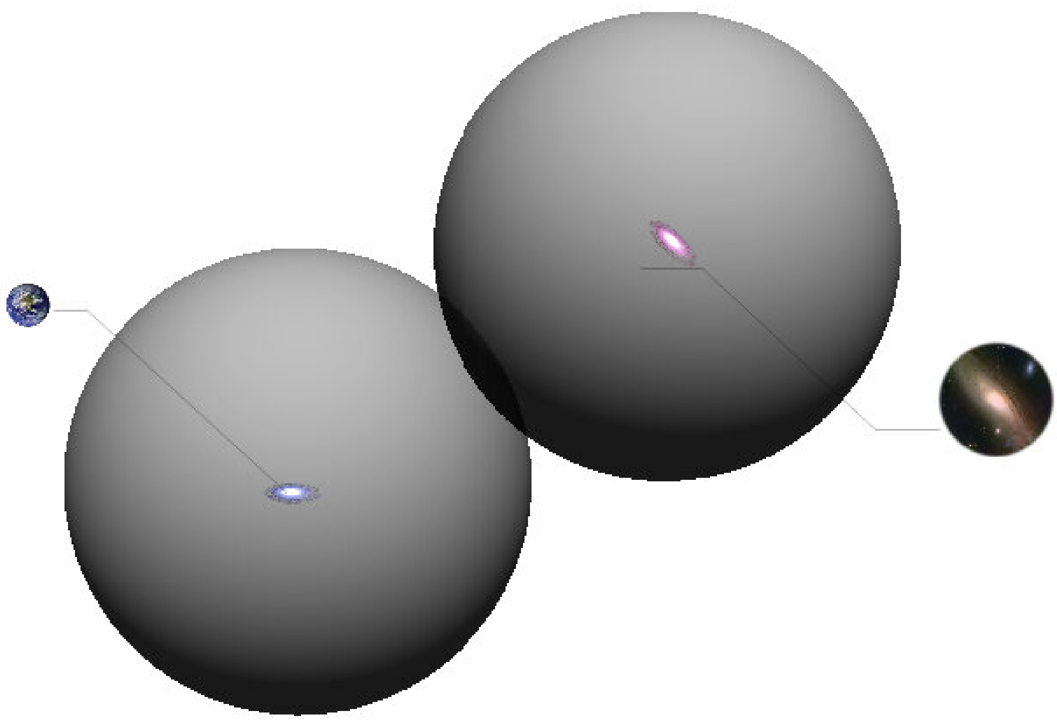

Figure 1: The Milky Way galaxy (left) and the Andromeda galaxy (right) are separated by 2.6 million light years. Compared with the areas where stars are clustered together, dark matter is believed to be distributed over a much larger volume. Credit: Kavli IPMU

An international team of researchers has put a theory speculated by the late Stephen Hawking to its most rigorous test to date, and their results based on the observations using the Subaru Telescope have ruled out the possibility that primordial black holes smaller than a tenth of a millimeter make up most of dark matter.

Scientists know that 27 per cent of the matter in the Universe is made up of dark matter. Its gravitational force prevents stars in our Milky Way from flying apart. However, attempts to detect such dark matter particles using underground experiments, or accelerator experiments including the world's largest accelerator, the Large Hadron Collider, have failed so far.

This has led scientists to consider Hawking's 1974 theory of the existence of primordial black holes, born shortly after the Big Bang, and his speculation that they could make up a large fraction of the elusive dark matter scientists are trying to discover today.

An international team of researchers, led by Kavli Institute for the Physics and Mathematics of the Universe Principal Investigator Masahiro Takada, PhD candidate student Hiroko Niikura, Professor Naoki Yasuda, and including researchers from Japan, India and the US, have used the gravitational lensing effect to look for primordial black holes between Earth and the Andromeda galaxy. Gravitational lensing, an effect first suggested by Albert Einstein, manifests itself as the bending of light rays coming from a distant object such as a star due to the gravitational effect of an intervening massive object such as a primordial black hole. In extreme cases, such light bending causes the background star to appear much brighter than it originally is.

Figure 2: As the Subaru Telescope on Earth looks at the Andromeda galaxy, a star in Andromeda will become significantly brighter if a primordial black hole passes in front of the star. As the primordial black hole continues to move out of alignment, the star will also turn dimmer (go back to its original brightness). Credit: Kavli IPMU

However, gravitational lensing effects are very rare events because it requires a star in the Andromeda galaxy, a primordial black hole acting as the gravitational lens, and an observer on Earth to be exactly in line with one another. So to maximize the chances of capturing an event, the researchers used the Hyper Suprime-Cam on the Subaru Telescope, which can capture the whole image of the Andromeda galaxy in one shot. Taking into account how fast primordial black holes are expected to move in interstellar space, the team took multiple images to be able to catch the flicker of a star as it brightens for a period of a few minutes to hours due to gravitational lensing.

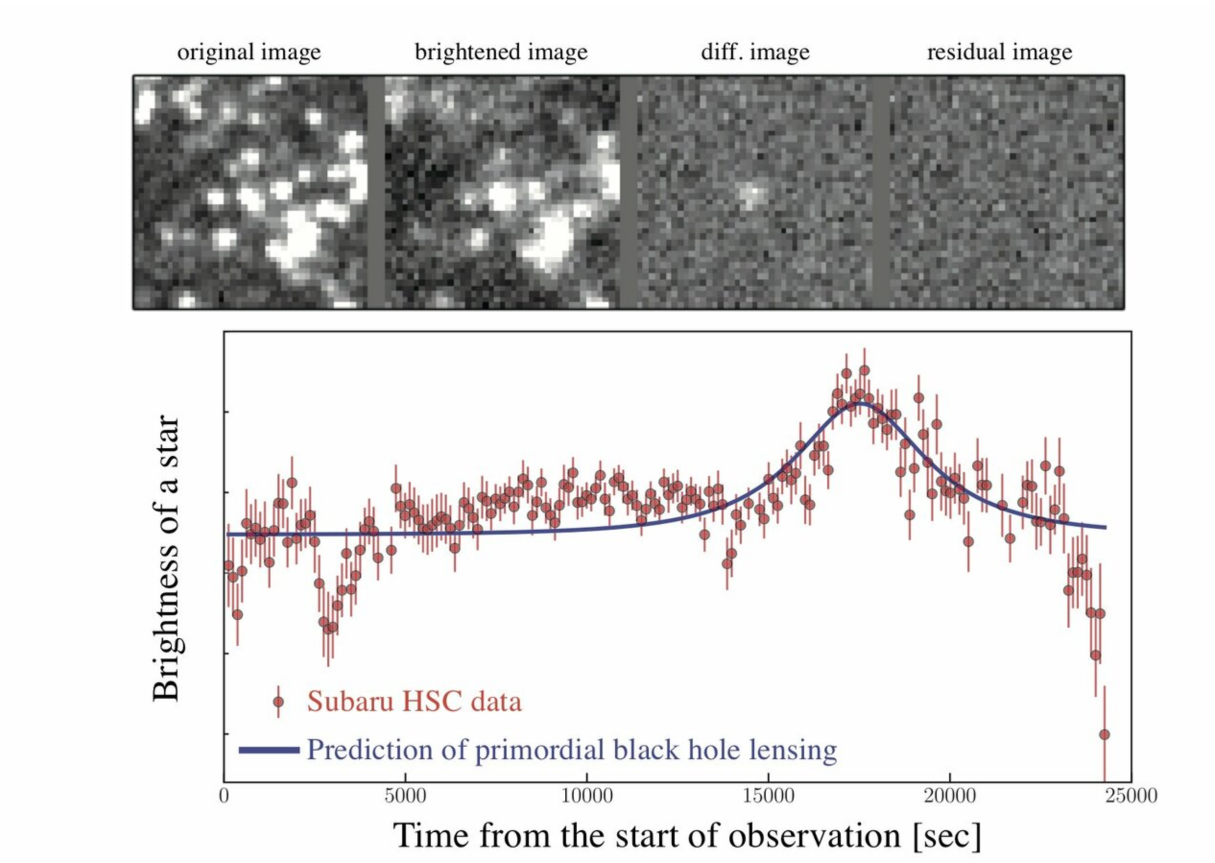

Figure 3: Data from the star which showed characteristics of being magnified by a potential gravitational lens, possibly by a primordial black hole. About 4 hours after data taking on the Subaru Telescope began, one star began to shine brighter. Less than an hour later, the star reached peak brightness before becoming dimmer. Credit: Niikura et al.

From 190 consecutive images of the Andromeda galaxy taken over seven hours during one clear night, the team scoured the data for potential gravitational lensing events. If dark matter consists of primordial black holes of a given mass, in this case masses lighter than the moon, the researchers expected to find about 1000 events. But after careful analyses, they could only identify one case. The team's results showed primordial black holes can contribute no more than 0.1 per cent of all dark matter mass. Therefore, it is unlikely the theory is true./p>

The researchers are now planning to further develop their analysis of the Andromeda galaxy. One new theory they will investigate is to find whether binary black holes discovered by gravitational wave detector LIGO are in fact primordial black holes.

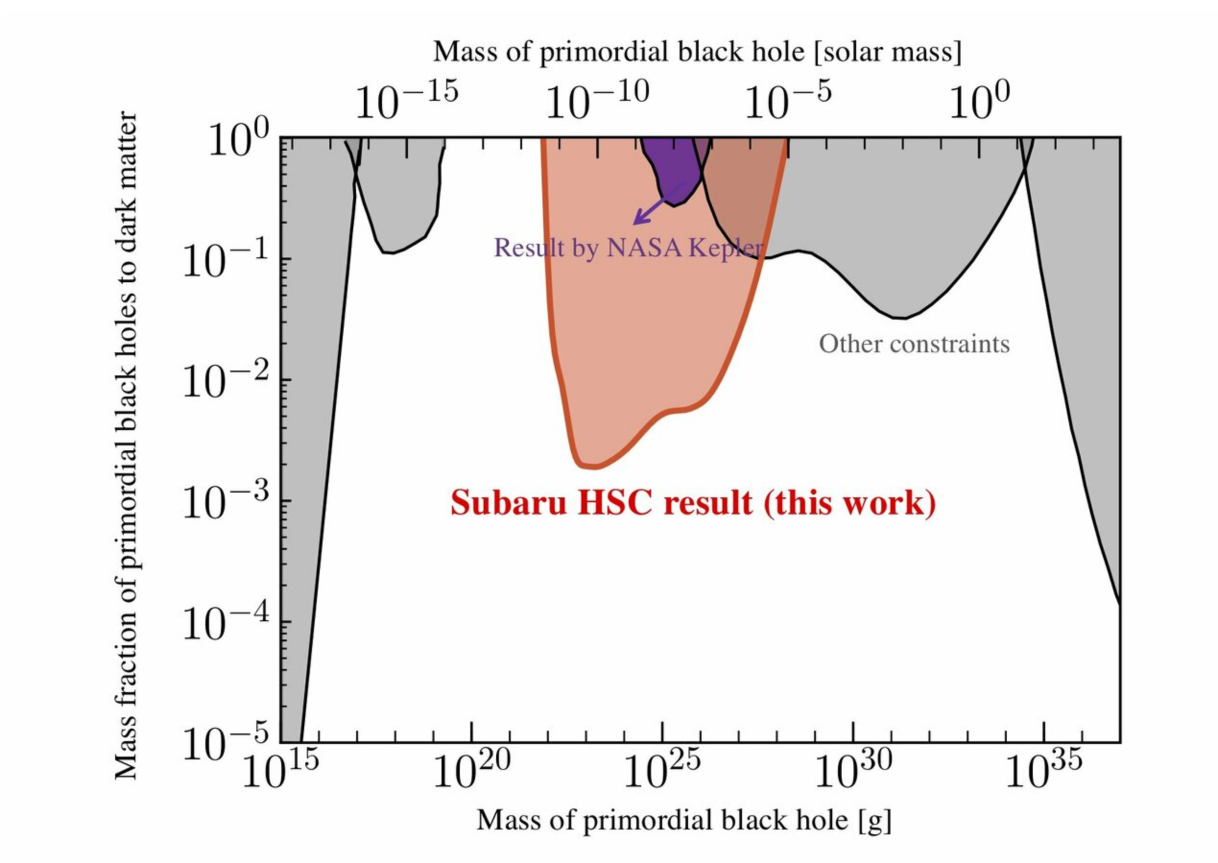

Figure 4: Constraints on the mass fraction of primordial black holes to dark matter in the Milky Way and the Andromeda galaxy as a function of primordial black hole mass. Shaded regions show excluded regions where existence of such primordial black holes are not consistent with various observation data. The red color indicates the area where this study has contributed to the study of primordial black holes. One-night HSC/Subaru gives the most stringent constraints for primordial black holes with masses lighter than moon mass, e.g. compared to the NASA Kepler 2-year data. Credit: Niikura et al.

These results were published on April 1, 2019 in *Nature Astronomy*.

More information: Hiroko Niikura et al. Microlensing constraints on primordial black holes with Subaru/HSC Andromeda observations, *Nature Astronomy* (2019). DOI: 10.1038/s41550-019-0723-1

Provided by Subaru Telescope