Primordial black holes can only explain a fraction of dark matter: LIGO-Virgo-KAGRA

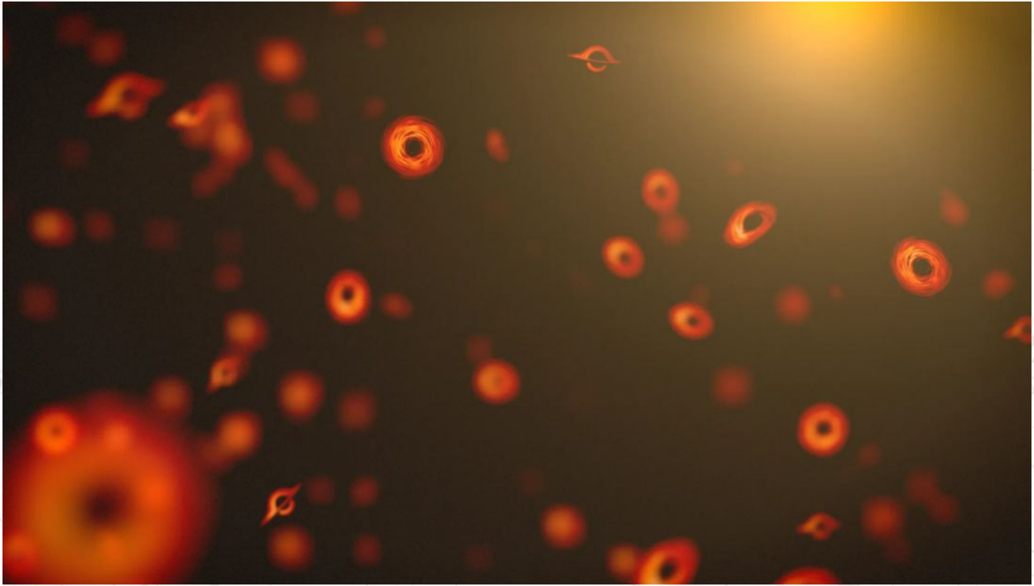
Chitta Ranjan Das

Bogoliubov Laboratory of Theoretical Physics (BLTP), The Joint Institute for Nuclear Research (JINR)

Monday 8 July 2024 at 11:00 A.M.

arXiv: 2405.05732

Astrophysics - Cosmology and Nongalactic Astrophysics



This artist's rendering depicts the possible appearance of primordial black holes. As depicted, the black holes would actually have difficulty forming accretion disks.

- Primordial black holes, which were formed in the early universe without a collapsing star as a progenitor, are one hypothesised component of dark matter.
- One missing mass problem is the dark matter problem. It is not expected that galaxies will remain intact based only on their detectable mass. The components of their observable mass are stars, gas, dust, and a few planets.
- Primordial black holes (PBHs) are a prominent dark matter candidate. Dense pockets of subatomic matter might have developed spontaneously in the early universe. They might have fallen straight into black holes if they had become sufficiently thick. They had no star progenitors, in contrast to their astrophysical equivalents.
- LIGO/Virgo data and recent JWST findings lend credence to the theory that PBHs constitute dark matter. Some scientists even go so far as to claim that this data lends credence to the theory that dark matter is composed entirely of PBHs and has no other constituents.

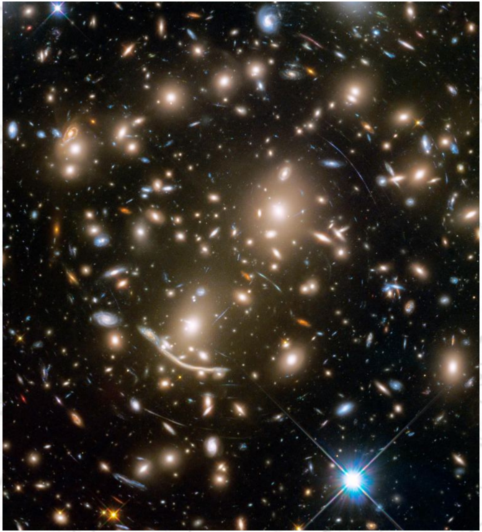
- According to a recent study, LIGO/Virgo can detect the gravitational waves produced by mergers, and some early PBHs may fuse.
- The thorough computations show that black holes with a mass of 10 solar masses could make up no more than 1.2% of dark matter, those with a mass of 100 solar masses, 3.0% of dark matter, and those with a mass of 1,000 solar masses, 11% of dark matter.

No massive black holes in the Milky Way halo, Przemek Mróz et al, Nature (2024)

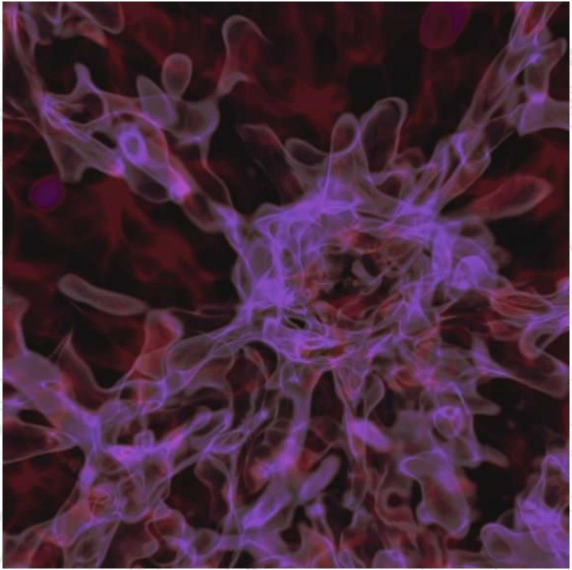
Microlensing Optical Depth and Event Rate toward the Large Magellanic Cloud Based on 20 yr of OGLE Observations, Przemek Mróz et al, The Astrophysical Journal Supplement Series (2024)

- The PBHs can contribute no more than fPBH $\lesssim 10^{-3}$ of dark matter in the mass range of 1 to 200 $M_{\odot}$.

Constraints on primordial black holes from LIGO-Virgo-KAGRA O3 events, M. Andrés-Carcasona et al, arXiv: 2405.05732

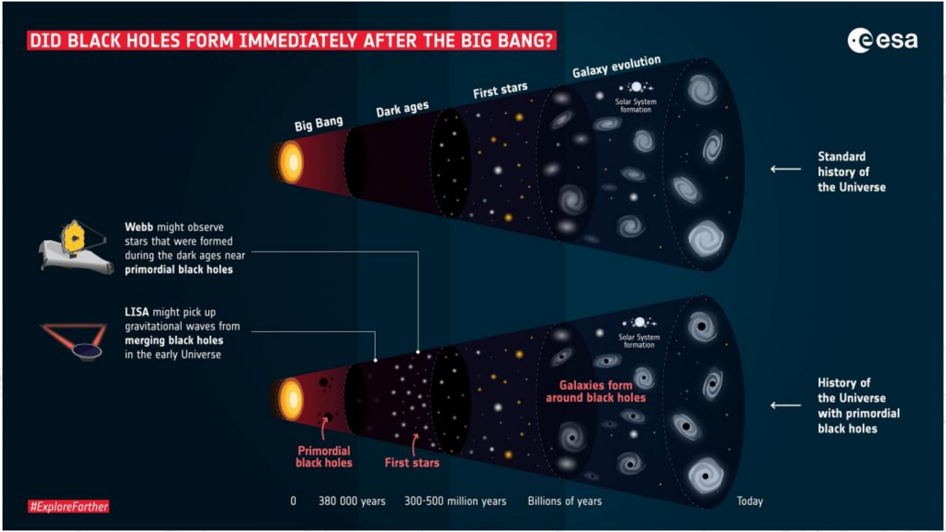


This Hubble Space Telescope mosaic displays a section of the vast 300 million light-year-distance Coma galaxy cluster, which is home to over 1,000 galaxies. The first indication that dark matter existed came from the speed at which its galaxies moved.



An image based on a supercomputer simulation of the cosmological environment where primordial gas undergoes the direct collapse into a black hole.

- The first black hole merger was discovered by LIGO (Laser Interferometer Gravitational-Wave Observatory) in 2015. Researchers hailed this fresh glimpse into the universe at the time. Up until then, electromagnetic radiation was the basis for astronomical measurements; LIGO/Virgo changed that.
- The worldwide partnership known as LIGO/Virgo/Karga (LVK) has now included Japan with its Karga gravitational wave observatory. The three observatories work together to collect gravitational wave data.
- The use of GW data to uncover direct or indirect evidence of PBHs has been investigated in earlier studies. Thus far, there has been no success in conducting focused searches for subsolar mass compact objects (SMCs), which could yield conclusive evidence of PBH existence.
- Certain component masses are found in areas that are not predicted by astrophysical theories, which may indicate the presence of a PBH population. The development of PBHs is largely influenced by their mass function. Here is an update to the mass limitations on PBHs in GW data.

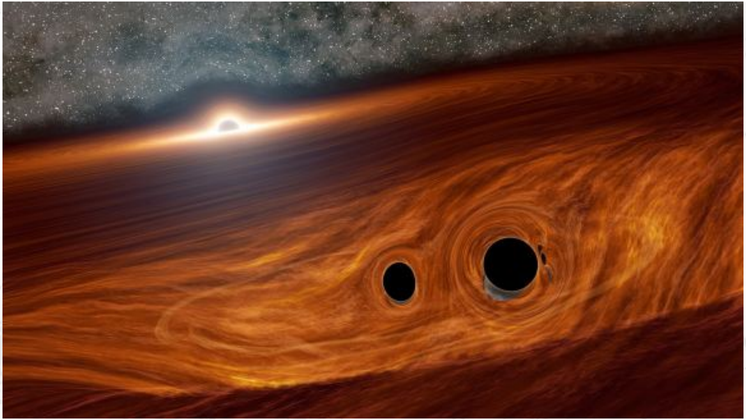


How to use JWST and LISA, the Laser Interferometer Space Antenna, to find primordial black holes and contribute to the solution of the dark matter enigma. Regretfully, LISA won't launch for at least ten years.

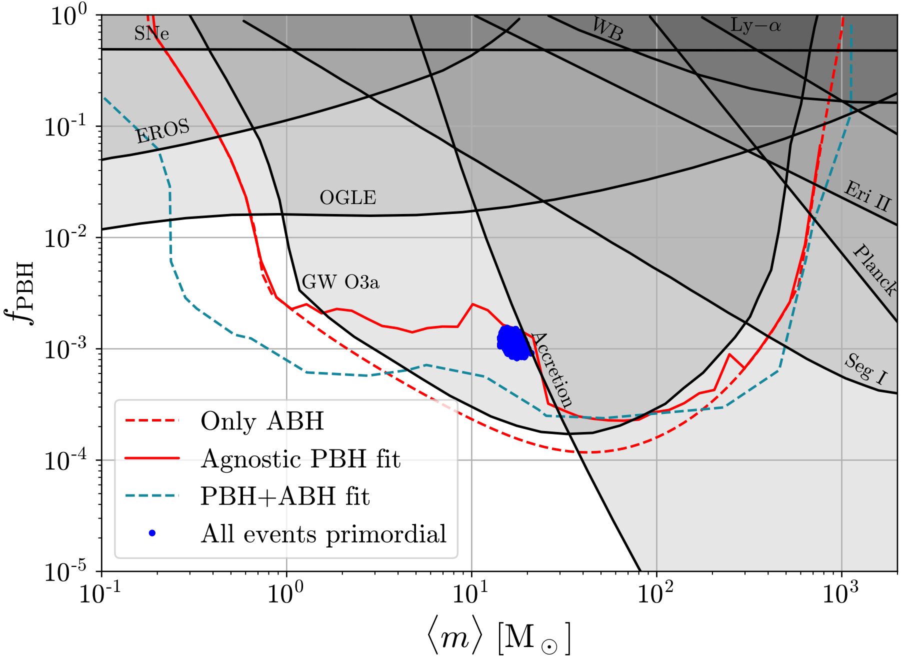
- They identify two fundamental formation scenarios: the astrophysical and the primordial. PBHs can originate in a variety of ways within the primordial category, and these formation processes are all intertwined with mass function. If PBHs fall between 10^{-16} and 10^{-12} solar masses, they might account for all of dark matter.
- Lighter PBHs can only make up a minor fraction of the DM and would be disappearing right now.
- Astrophysical black holes have the ability to fuse into binaries and release gravitational waves. Gravitational waves would also be emitted by merging PBHs. Some GW data found by LIGO/Virgo/Karga during its third observational run may be the result of these mergers. The results are presented by the authors as both an optimistic and a pessimistic situation. While the optimistic hypothesis argues that some GW sightings are from PBH mergers, the pessimistic scenario claims that all GW observations are from Astrophysical Black Hole (ABH) mergers.
- PBHs in the mass range of 1-200 solar masses can contribute no more than fPBH less than or equal to 10^{-3} of dark matter in all cases.

Our interpretation:

The solar mass range should be sufficient to explain why PBHs can only account for a very small portion of dark matter.



Small black holes are depicted in the accretion disk of a supermassive black hole in this artist's illustration. Researchers discovered evidence of a tiny black hole inside the supermassive black hole's accretion disk early in 2024. If the tiny BH is real, its mass ranges from 100 to 10,000 solar masses. It has the same mass as a PBH at the bottom of that range. Although it isn't believed to be primordial, it shows how much more there is to understand about black holes.



SNe
EROS
OGLE
GW O3a
Accretion
WB
Ly−α
Eri II
Planck
Seg I
f_{PBH}
$\langle m \rangle$ [$M_\odot$]
Only ABH
Agnostic PBH fit
PBH+ABH fit
All events primordial