

# Evidence for Primordial Black Holes

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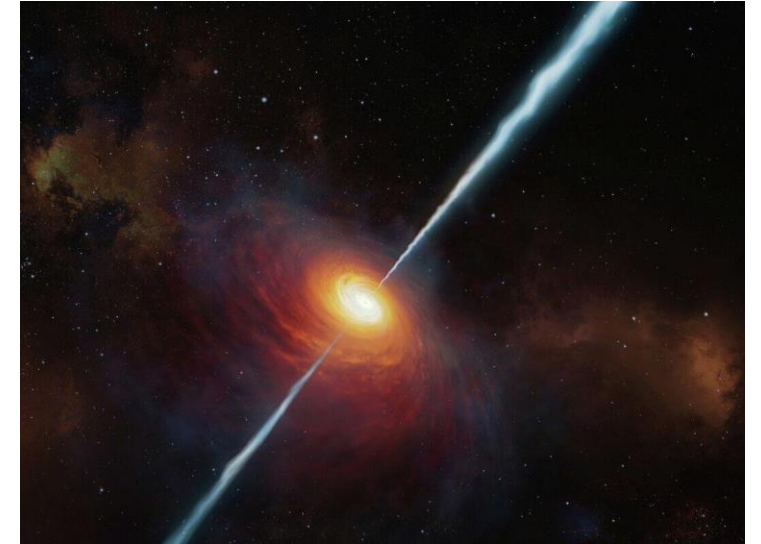


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# Lensing Evidence

- If dark matter mostly consists of compact bodies it would create a caustic network, leading to unstable changes in quasar light as it passes through a complex amplification scheme.
- ⇒ In 1993, Hawkins presented the [first evidence](#) of a cosmological distribution of PBHs based on microlensing of quasar light curves.
- In his 1985 [paper](#) Paszynski suggested searching for compact objects in the halo of the Milky Way by microlensing stars in the Magellanic Clouds.



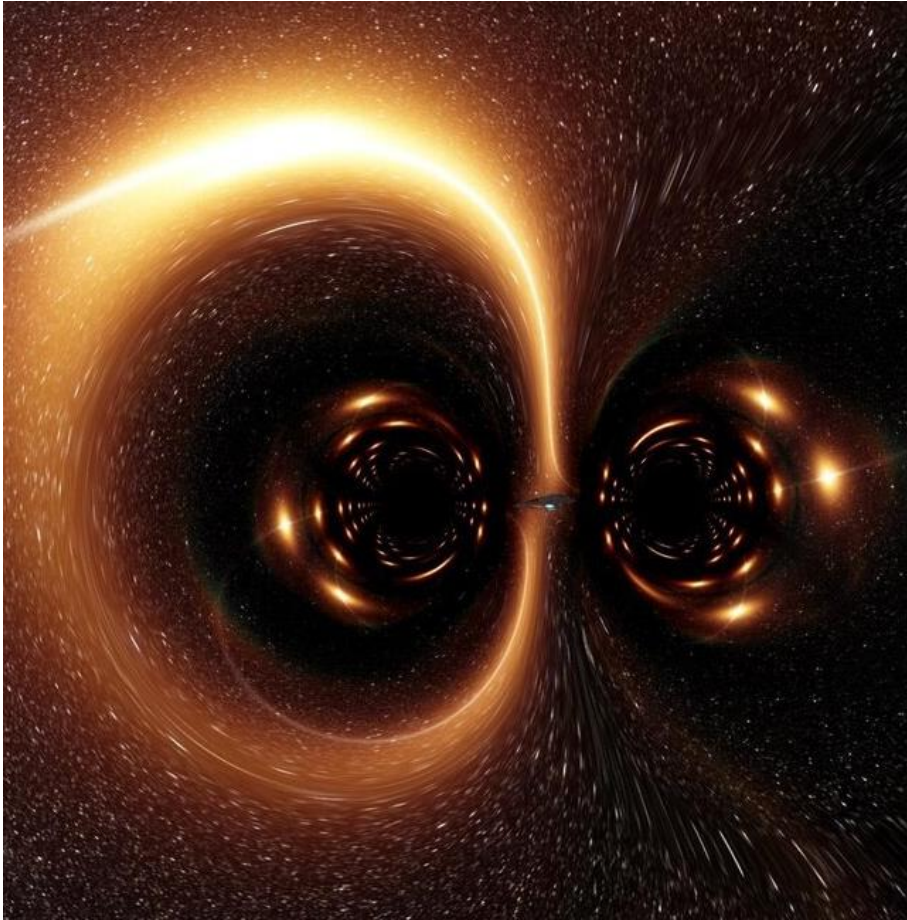
- Time of the half-intersection brightness curve depends on three quantities:  $M_D$ ,  $1/d$  and  $v$ .

$$1/d = 1/d_{OD} + 1/d_{DS}$$

$$\Delta t_{1/2} = \frac{\sqrt{4GM_D d}}{v}$$

- ⇒ Microlensing [results](#) of Paszynski and MACHO Collaboration indicate that compact objects of near-Solar masses cannot dominate in the dark matter.

# LIGO/Virgo Evidence



- Following the detection of gravitational waves (GWs), [Bird](#) and [Garcia-Bellido](#) claimed that the expected merger rates of binary PBH systems, formed in late times in compact halos, are compatible with LIGO/Virgo analysis results if they include all of dark matter.

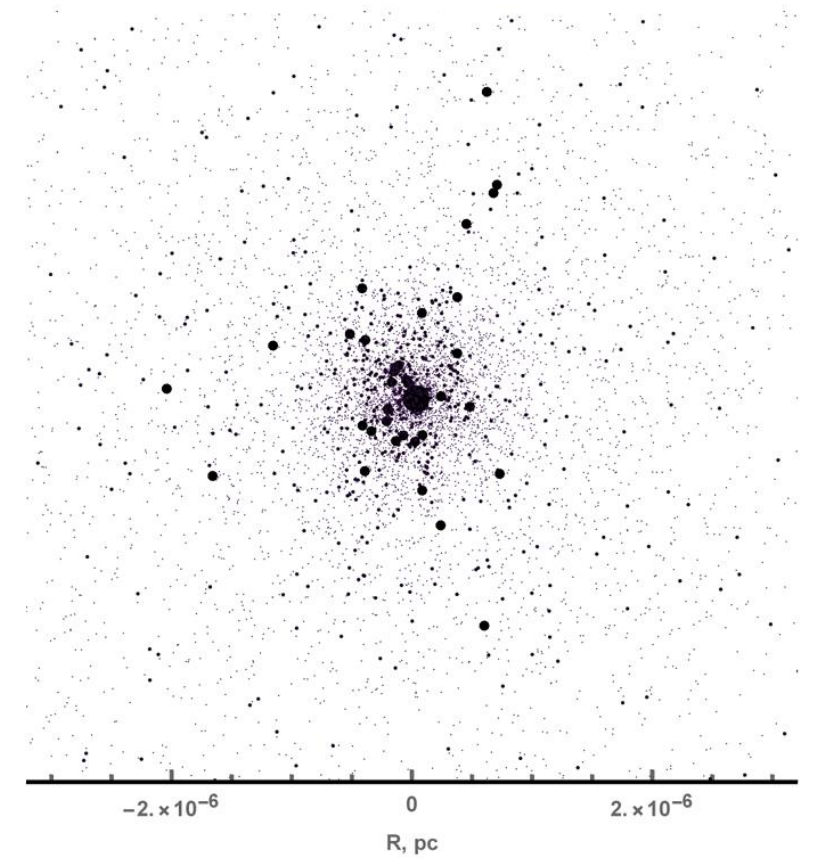
However, the results are twofold:

- ⇒ If there are few PBH, then merges occur at the rate observed by LIGO/Virgo.
- ⇒ If there are many PBH, then binary systems destroy each other and thereby the rate of merger is suppressed, thus merger rate could still be compatible with the one observed by LIGO/Virgo.

- Merger events and evolution of black holes binaries were studied in details via N-body simulations. Many researches obtained similar results independently.

# Clusters of PBHs

- The main difference between dark matter particles and black holes is an enormous mass of the latter.
  - ⇒ This leads to significant Poisson fluctuations in the spatial distribution of PBHs and ultimately results in the formation of gravitationally-bound PBH clusters.
- Some of the constraints should be reconsidered in case of clusters of PBHs, e.g.:
  1. Dynamical constraints;
  2. Gravitational-waves constraints.
- Clustering of PBHs should also affect:
  1. Formation of non-linear structures;
  2. Sizes and mass to light ratio of ultra-faint dwarf galaxies.
- Clustering of black holes might be an evidence in favor for PBHs existence.



The typical spatial black holes distribution within cluster

**Thank you for your  
attention!**