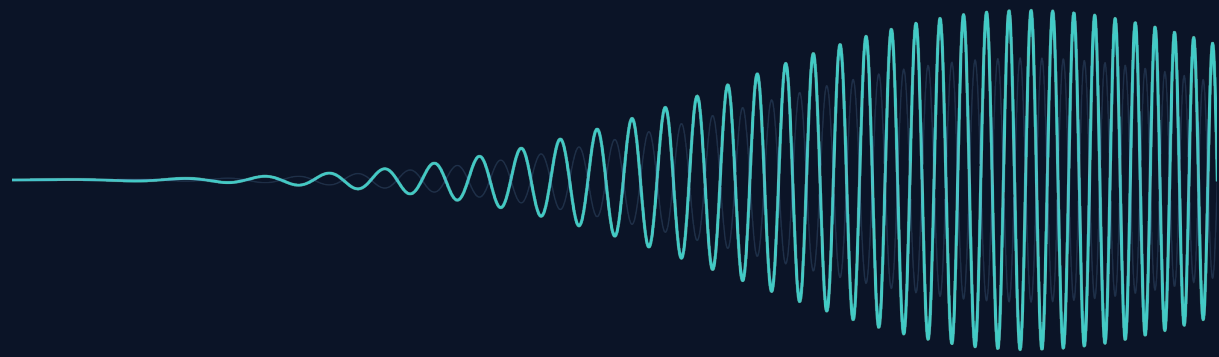
Astroparticle Symposium 2026

S251112cm: Exploring the Primordial Black Hole Origin of a Subsolar-Mass Merger Candidate



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Haque, Iocco & Visinelli, Phys.Lett.B **882** (2026) 141049

Why is a subsolar merger interesting?

A black hole below one solar mass is not expected from ordinary stellar evolution.

Conventional black holes

Stellar-collapse remnants are not expected in the subsolar-mass regime.

Subsolar compact objects

A confirmed GW signal here would require an unusual formation history or exotic object.

Primordial black holes

PBHs form from early-Universe fluctuations, independently of stars.

Key question: Could an allowed PBH population produce a detectable merger?

THE OBSERVATIONAL TRIGGER

The S251112cm candidate

12 NOV 2025
LVK public alert

~0.1–0.9 $M_\odot$
Preliminary chirp-mass range

93 ± 27 Mpc
Inferred luminosity distance

~1 IN 4 YEARS
Updated false-alarm rate

What is known and what is not

The alert favors at least one subsolar component; the final astrophysical interpretation remains open.

S251112cm occurred in O4c. Our sensitivity proxy uses released O4a MBTA results.

LVK GCN 42650 and 42690

From chirp mass to component mass

General chirp mass

$$\mathcal{M}_c = \frac{(m_1 m_2)^{3/5}}{(m_1 + m_2)^{1/5}}$$

Equal-mass binaries

$$m_1 = m_2 = m \quad \Rightarrow \quad \mathcal{M}_c = 2^{-1/5} m$$

Why choose the mass interval 0.20–1 $M_\odot$?

$$0.20\,M_\odot \leq m \leq 1.0\,M_\odot$$

Lower limit: O4a search coverage

The released O4a MBTA sensitivity reaches component masses of 0.20 $M_\odot$; we do not extrapolate below its measured range.

Upper limit: subsolar focus

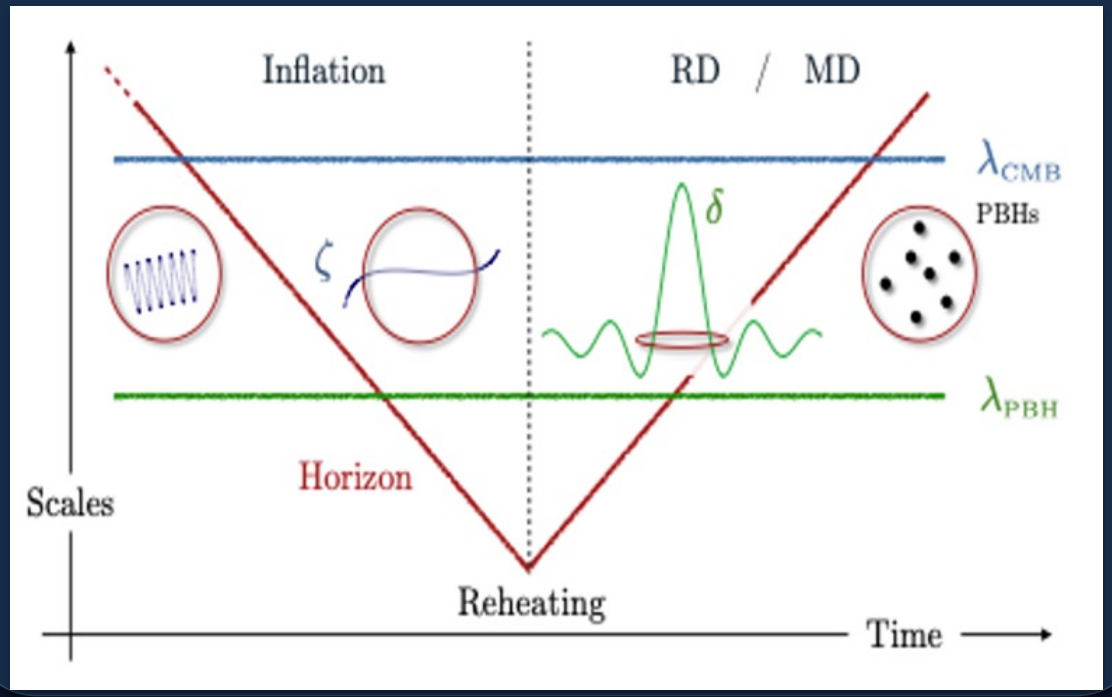
The analysis targets the subsolar-merger regime, retaining masses up to the 1 $M_\odot$ boundary.

Haque, Iocco & Visinelli, Phys. Lett. B **882** (2026) 141049, LVK, arXiv:2605.05444.

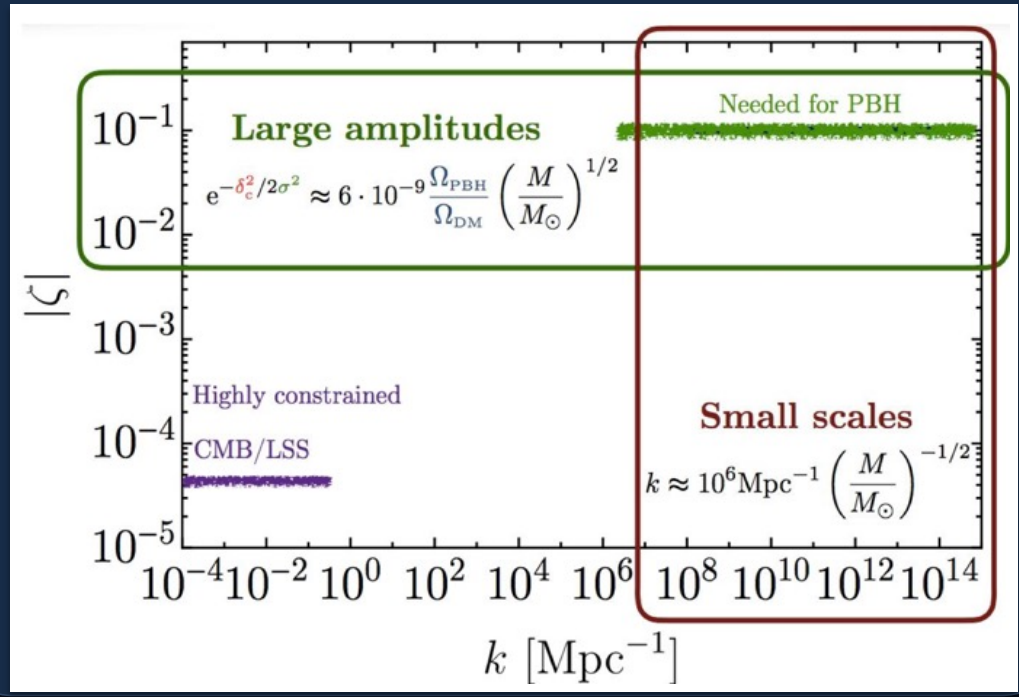
How primordial black holes form

Enhanced primordial fluctuations on small scales can collapse after horizon re-entry, independently of stellar evolution.

Horizon re-entry and gravitational collapse



Enhanced perturbations on small scales



Primordial fluctuations → horizon re-entry → gravitational collapse → PBHs

Schematic figures: G. Franciolini, arXiv:2110.06815 [astro-ph.CO].

OUR STRATEGY

Consistency test

Can an allowed PBH population yield a detectable subsolar-mass merger?

METHOD I

PBH merger-rate model

Mass distribution and merger rates

→

METHOD II

Binary suppression

Early-binary disruption effects

→

METHOD III

Microlensing limits

OGLE abundance constraints

→

METHOD IV

Detection probability

O4a sensitivity and Poisson statistics

Monochromatic benchmark vs. extended lognormal PBHs · equal-mass pairing

Haque, Iocco & Visinelli, Phys. Lett. B **882** (2026) 141049.

METHOD I

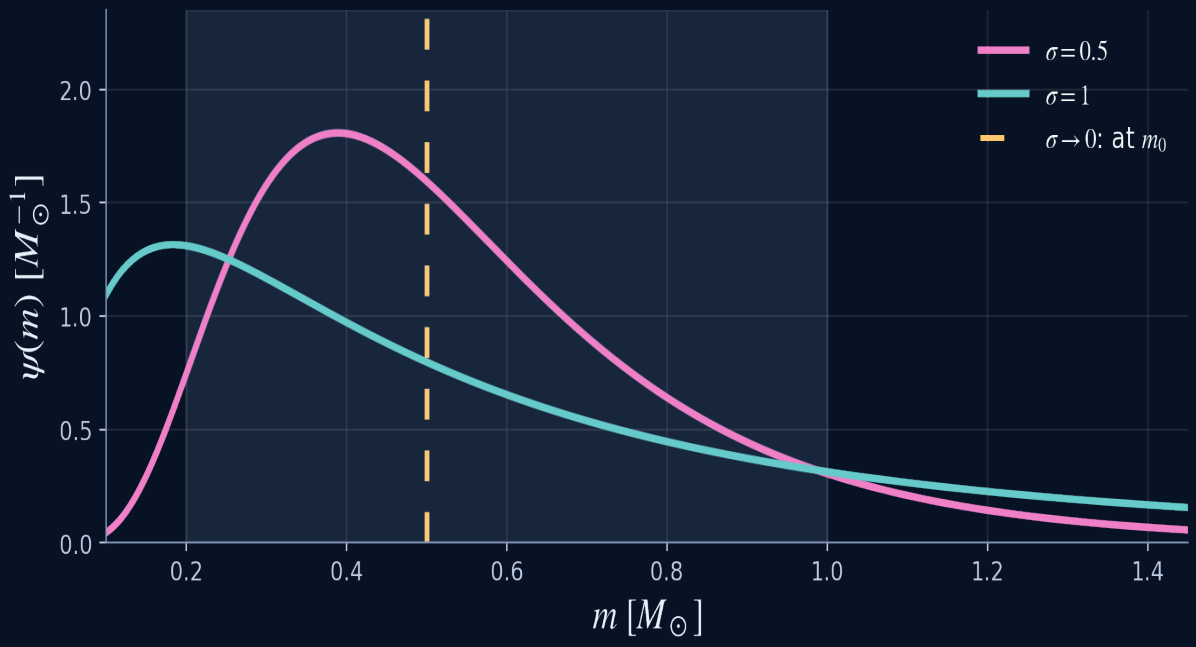
PBH merger-rate model

For an equal-mass extended PBH mass function:

$$\psi_{\rm LN}(m) = \frac{1}{\sqrt{2\pi}\,\sigma m}\exp\left[-\frac{\ln^2(m/m_0)}{2\sigma^2}\right]$$

Equal-mass pairing: $\psi_{\rm LN}(m_1)\,\delta(m_2 - m_1)$

$$\frac{dR_{\rm LN}}{dm} = 3.14\times10^6\,{\rm Gpc^{-3}\,yr^{-1}}\,f_{\rm PBH}^{53/37}\,S_{\rm LN}\left(\frac{m}{M_\odot}\right)^{-32/37}\psi_{\rm LN}(m)$$



Extended mass function

m_0: characteristic mass; σ: logarithmic width.

Illustrative MDFs at $m_0 = 0.5\ M_\odot$; blue band marks 0.2–1 $M_\odot$.

$S_{\rm LN}$ encodes binary suppression for an extended mass function.

Haque, Iocco & Visinelli, Phys. Lett. B 882 (2026) 141049.

METHOD II

Suppression factor for the extended mass function

For the lognormal PBH mass function

$$S_{\rm LN} \simeq 1.42 \left[\frac{e^{\sigma^2}}{\bar{N}+C} + \frac{\sigma_M^2}{f_{\rm PBH}^2} \right]^{-21/74} e^{-\bar{N}}$$

with $\sigma_m \simeq 0.005$

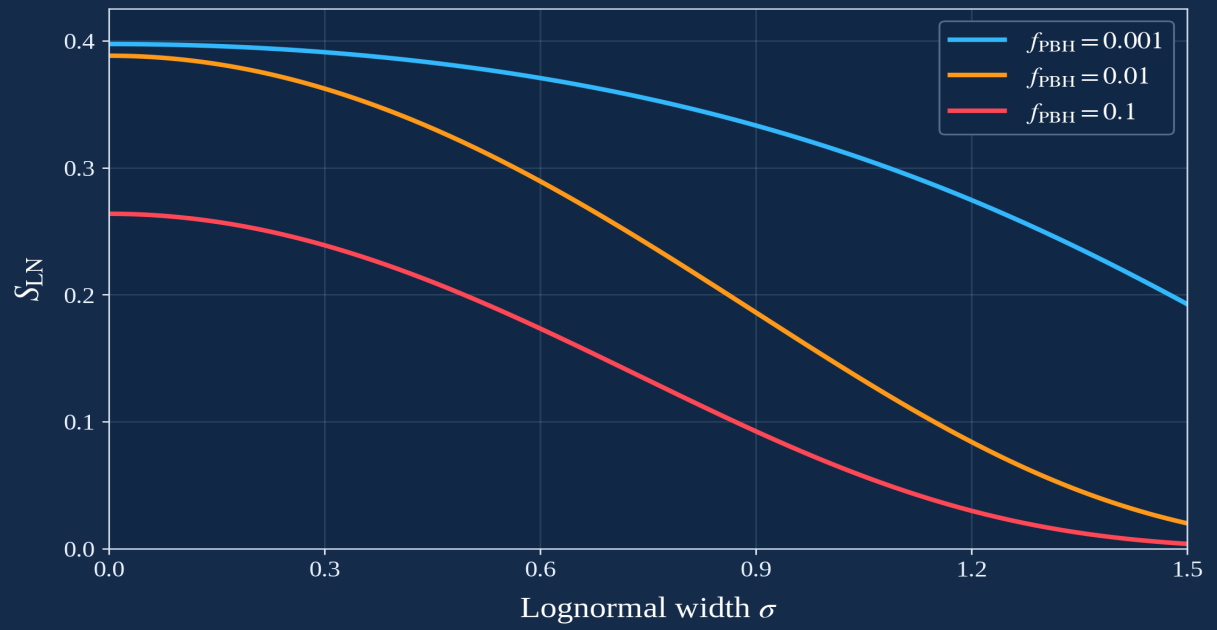
$$\bar{N} = 2\frac{m}{m_0} e^{\sigma^2/2} \frac{f_{\rm PBH}}{f_{\rm PBH}+\sigma_M}$$

$$C = \frac{f_{\rm PBH}^2}{\sigma_M^2} e^{\sigma^2} [\mathcal{U}^{-74/21} - 1]^{-1}$$

$$\mathcal{U} = \frac{\Gamma(29/37)}{\sqrt{\pi}} U\left(\frac{21}{74}, \frac{1}{2}, \frac{5 f_{\rm PBH}^2}{6\sigma_M^2}\right)$$

Suppression factor vs. lognormal width

$m = m_0$, $\sigma_m = 0.005$



Key points

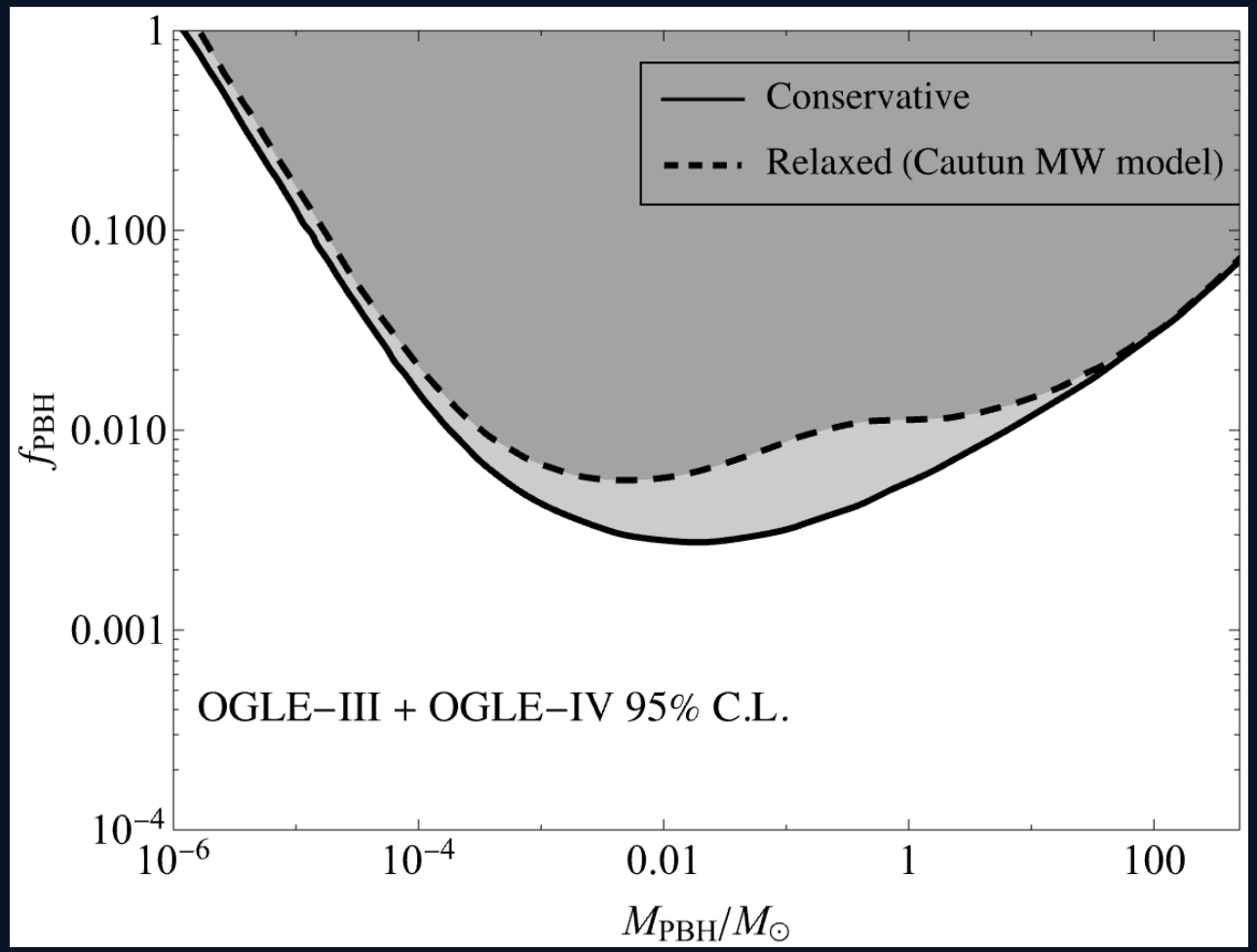
- $S_{\rm LN}$ decreases as the width σ increases.
- Broader mass functions experience stronger suppression.
- Suppression is also stronger for larger f_PBH.

$\bar{N}$: expected number of nearby perturbing PBHs; C: correction for tidal torques from surrounding matter.

Raidal et al., JCAP 02 (2019) 018; Aljaf & Cholis, Phys. Rev. D 113 (2026) 123001; Haque, Iocco & Visinelli, Phys. Lett. B 882 (2026) 141049.

METHOD III: OBSERVATIONAL CONSTRAINTS

Microlensing limits on the PBH abundance



OGLE-III + OGLE-IV · 95% C.L.

Conservative (solid)

All detected events attributed to ordinary stellar lenses.

Relaxed (dashed)

Cautun et al. (2020) Milky Way model; allows some PBH lenses.

Extended mass-function constraint

$$f^{\rm LN}_{\rm PBH,\,max} = \left[\int dm \, \frac{\psi_{\rm LN}(m)}{f^{\rm mono}_{\rm max}(m)} \right] - 1$$

Recast the monochromatic limit over the full lognormal PBH mass distribution.

OGLE data: Mróz et al., Nature 632, 749 (2024) | MW model: Cautun et al., MNRAS 494, 4291 (2020) | Recast: Carr et al., PRD 96, 023514 (2017)

From a population to an observable event

Expected detections = merger rate × sensitive spacetime volume

EXTENDED PBH MASS DISTRIBUTION

$$\mu_{\rm LN} = \int_{0.20\,M_\odot}^{1\,M_\odot} {\rm d}m \, \frac{{\rm d}R_{\rm LN}}{{\rm d}m} \, \langle VT \rangle_{\rm O4a}(m)$$

Monochromatic case: $\mu = R_0 \langle VT \rangle$

POISSON STATISTICS

$$\mathcal{P}_{\rm LN}(N \geq 1) = 1 - e^{-\mu_{\rm LN}}$$

Inputs and assumptions

Lognormal $\psi_{\rm LN}(m)$, suppression SLN, recast microlensing bounds, and O4a MBTA $\langle VT \rangle(M_{\rm PBH})$. Equal-mass pairing.

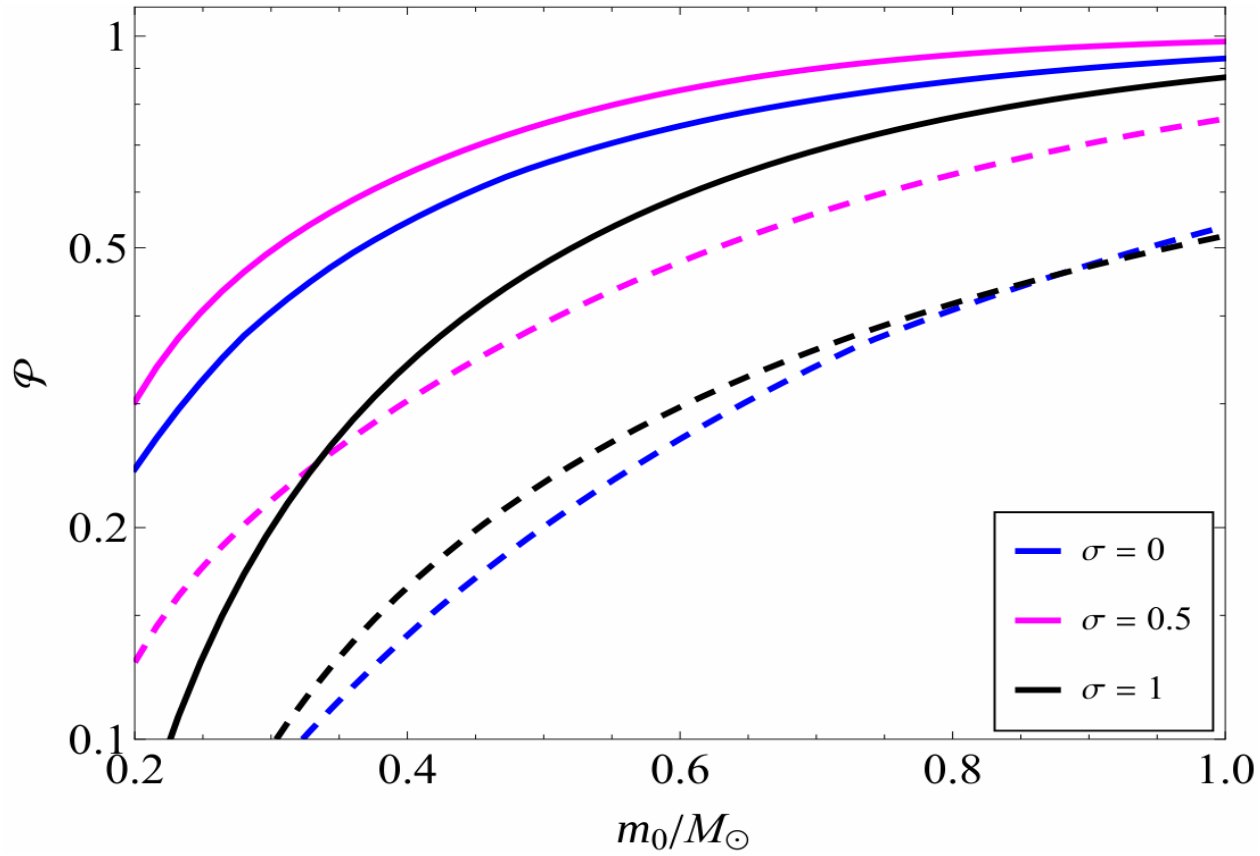
What the probability means

Chance of at least one detection for the assumed PBH population

Haque, Iocco & Visinelli, Phys. Lett. B 882 (2026) 141049, O4a MBTA sensitivity: LVK, arXiv:2605.05444.

MAIN RESULT

Result I: probability versus PBH mass



Read the curves

SOLID Relaxed microlensing limit

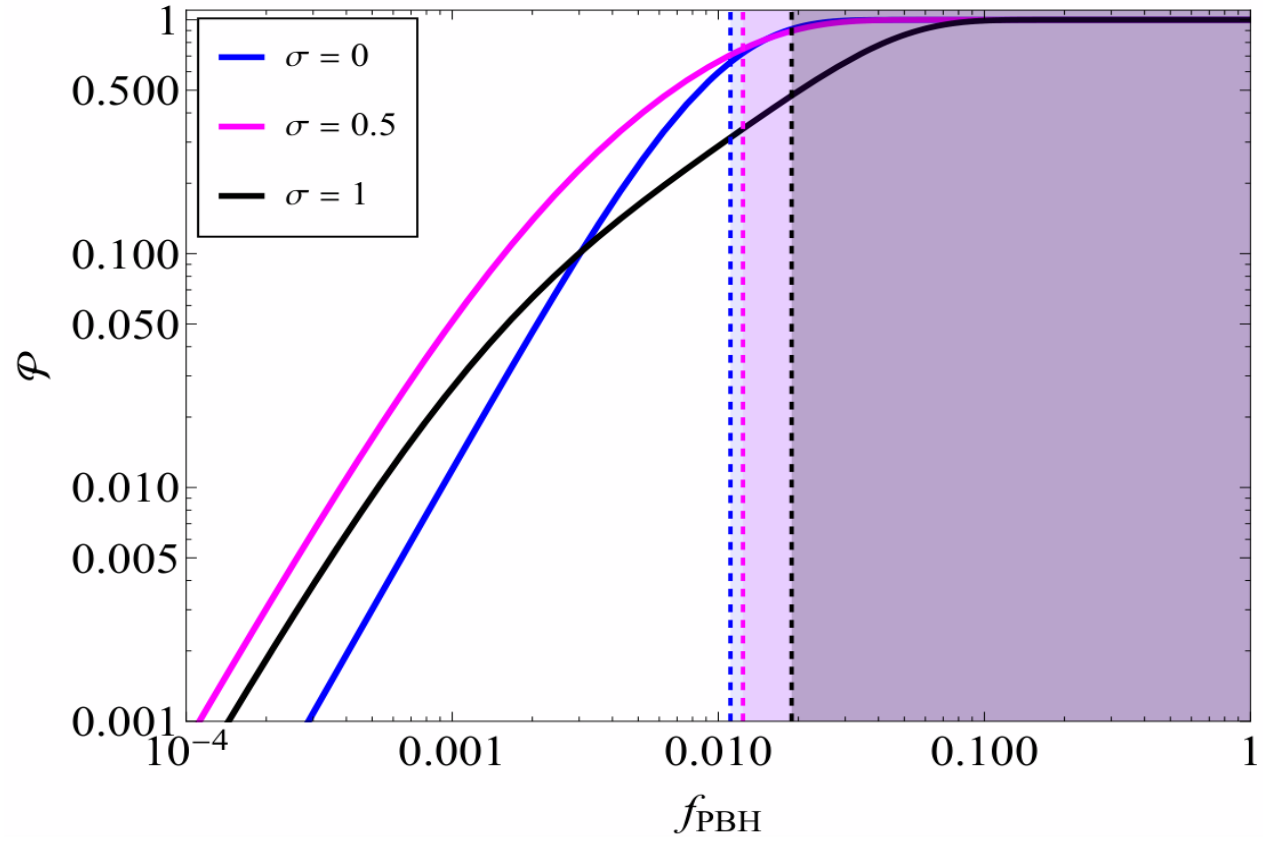
DASHED Conservative limit

σ = 0.5 can exceed σ = 0

Under relaxed bounds, P can approach unity near the upper mass end.

Haque, Iocco & Visinelli, Phys.Lett.B **882** (2026) 141049

Result II: probability versus abundance



Fixed characteristic mass

$m_0 = 0.5\ M_\odot$

P rises rapidly with f_{PBH}

Dashed vertical lines:

upper limits from relaxed microlensing constraints

Haque, Iocco & Visinelli, Phys.Lett.B **882** (2026) 141049

PHYSICAL INTERPRETATION

Why the mass-function width matters

More mass spread does not always mean more observable mergers.

$\sigma \to 0$

Monochromatic benchmark

All PBHs are concentrated at one mass. This provides the baseline merger rate and abundance constraint.

$\sigma = 0.5$

Moderately extended spectrum

Redistributing masses can improve detector-weighted sensitivity and increase the detection probability.

$\sigma = 1$

Broad mass spectrum

More mass lies outside the analyzed window, while binary suppression can offset the gain from broadening.

The net probability is determined jointly by:

Mass distribution • Binary suppression • Allowed PBH abundance • LVK sensitivity

For the O4a calculation, only mergers with 0.20–1 solar-mass components enter the detector sensitivity integral.

Haque, Iocco & Visinelli, Phys. Lett. B 882 (2026) 141049

WHAT THE RESULT DOES NOT ESTABLISH

Scope and limitations

Candidate status

S251112cm still requires confirmation and careful source classification.

Equal-mass binaries

General lognormal pairing would require a full (m_1, m_2) calculation.

O4a sensitivity proxy

We approximate O4c detectability with publicly available O4a MBTA data.

Astrophysical uncertainties

Halo/disk microlensing models and binary formation/suppression affect P.

THE NEXT OBSERVATIONS

How can the primordial hypothesis be tested?

A population, not a single alert

Repeated subsolar detections constrain the mass spectrum and rate.

Waveform information

Finite-size / tidal effects can distinguish BHs from alternative compact objects.

Improved GW sensitivity

Future LVK runs, Einstein Telescope and Cosmic Explorer expand ⟨VT⟩.

Multi-messenger constraints

Microlensing and, in some formation models, primordial induced GWs provide cross-checks.

CONCLUSIONS

Three take-home messages

01 S251112cm motivates a search for nonstellar compact objects.

02 A subdominant PBH population can be compatible with the present bounds and yield detectable mergers.

03 Mass-function width, merger suppression and microlensing limits must be modeled together.

Compatible ≠ proven · Future subsolar detections are the decisive test

Thank you

Questions & discussion

