

PRIMORDIAL BLACK HOLES

Relics from before the first star

A short overview for Meryl · May 2026



Black holes the universe *made on its own.*

Pre-stellar

Formed in the radiation era,
before any star existed.

Pre-galactic

Predates the haloes
they now haunt.

Mass-agnostic

Not bound by stellar collapse —
asteroid to supermassive.

1966

Zeldovich & Novikov

Two Soviet astrophysicists ask:
if the early universe was clumpy enough,
could bits of it have collapsed straight
into black holes?

THE CATCH

They concluded — wrongly —
that such black holes would
accrete catastrophically.

So they dismissed their own idea.

*The English translation
landed in 1967 and was
largely ignored in the West.*

Hawking and Carr rescue the idea



1971

Hawking

Gravitationally collapsed objects of very low mass.
First dedicated study.



1974

Carr & Hawking

Show no PBH grows as fast as the horizon.
Zeldovich's objection dies.



1974

Hawking radiation

Black holes evaporate.
PBHs gain an obituary — and a clock.

A PBH lighter than $\sim 10^{15}$ g should be evaporating right now.

HOW TO MAKE ONE

Pressure cooker, badly stirred.

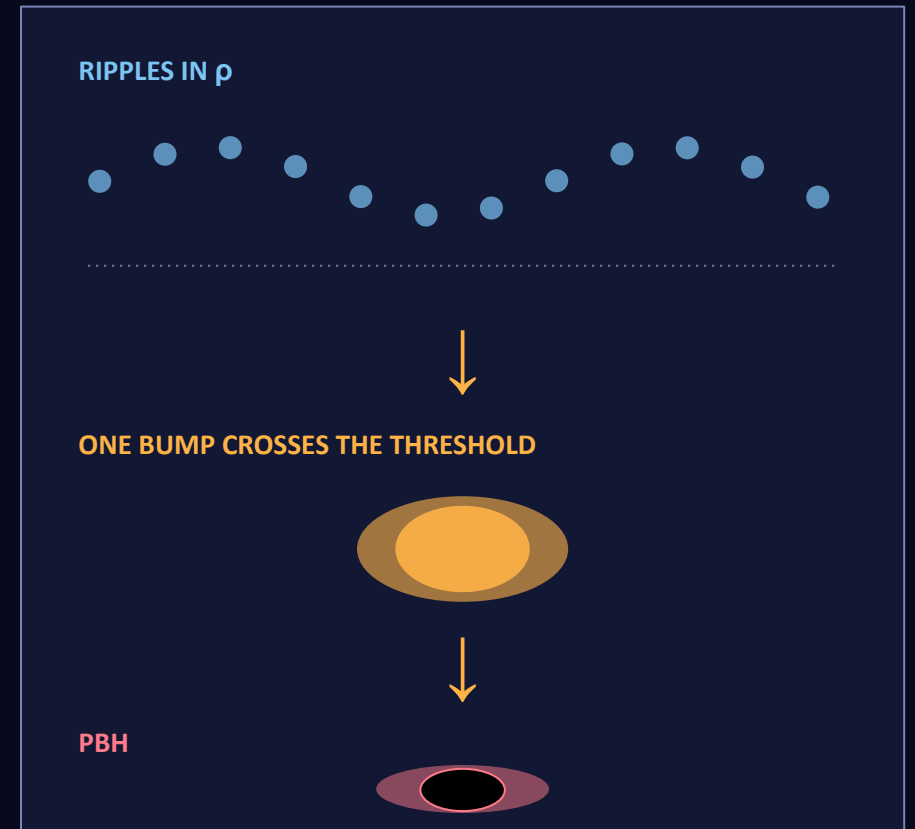
In the radiation era,
any region whose density contrast

$$\delta\rho/\rho \gtrsim 0.4$$

within one Hubble horizon

collapses straight to a black hole.

*Mass \approx horizon mass at formation.
Earlier formation \rightarrow lighter PBH.*



Twenty orders of magnitude.

Stellar collapse can't compete.



Below $\sim 10^{15} \text{ g}$: long since evaporated.

Above $\sim 10^9 M_{\odot}$: indistinguishable from quasar engines.

The asteroid-mass window

is one of the last places PBHs can still hide.

TOO LIGHT

below 10^{17} g

Would have evaporated by now — no observed gamma-ray glow.

TOO HEAVY

above 10^{23} g

Microlensing surveys (Subaru/HSC, OGLE, MACHO) would have caught them.

JUST RIGHT?

$10^{17} - 10^{23}$ g

Asteroid mass. Constraints thin. Could still be 100% of dark matter.

AND THEN JWST HAPPENED

Black holes too big, *too soon.*

$z \gtrsim 7$

where they're being found

$10^7 - 10^9$

M_{\odot}

their black-hole masses

< 700

Myr

since the Big Bang

*Standard stellar-collapse seeds can't grow this fast,
even pinned at the Eddington limit the whole way.*

Two impossibly early objects

UHZ1



$z \approx 10.3$

470 Myr after the Big Bang

Chandra X-ray + JWST joint detection (Bogdán et al., 2024).
Black hole mass roughly equal to its host's stellar mass — an absurd ratio by local standards.

Abell 2744 – QSO1



$z \approx 7$

~750 Myr after the Big Bang

JWST's flagship 'Little Red Dot'. BH/stellar mass ratio $\sim 3:1$ — roughly a thousand times the local Magorrian relation. Stunningly low metallicity too.

The host stellar masses haven't caught up — the black hole arrived first.

What if the black hole *got there before the galaxy?*

STELLAR SEED

~100 M \odot

Needs continuous Eddington-limited growth
for every Myr available.
Galaxy must already be assembling fuel.

Struggles

HEAVY PBH SEED

~10³ – 10⁵ M \odot

Starts massive. Grows in a dark-matter halo
before stars form. Galaxy assembles around it.
Reproduces A2744-QSO1's overmassive ratio.

Fits the data

Two unsolved problems, *possibly one answer.*

● The dark matter question

PBHs in the asteroid-mass window remain a viable candidate. LISA, microlensing surveys and femto-lensing of γ -ray bursts will tighten the noose.

● The seed question

JWST keeps finding more overmassive monsters. If massive PBHs explain them, we've found cosmological fossils older than the first generation of stars.

Cosmologists, as ever, are quietly thrilled to be wrong on schedule.



Further reading

Carr & Green (2024)

The History of Primordial Black Holes · [arXiv:2406.05736](https://arxiv.org/abs/2406.05736)

Bogdán et al. (2024)

UHZ1: an overmassive BH at $z \approx 10.3$ · *Nat. Astron.*

Maiolino et al. (2024)

JWST Little Red Dot population review

Zhang, Liu & Bromm (2026)

PBH seeds for overmassive JWST AGN · [arXiv:2512.14066](https://arxiv.org/abs/2512.14066)

Dayal & Maiolino (2024)

A primordial solution for early black holes · [arXiv:2407.07162](https://arxiv.org/abs/2407.07162)