Constraints on primordial black holes as constituents of dark matter based on OGLE observations of the LMC

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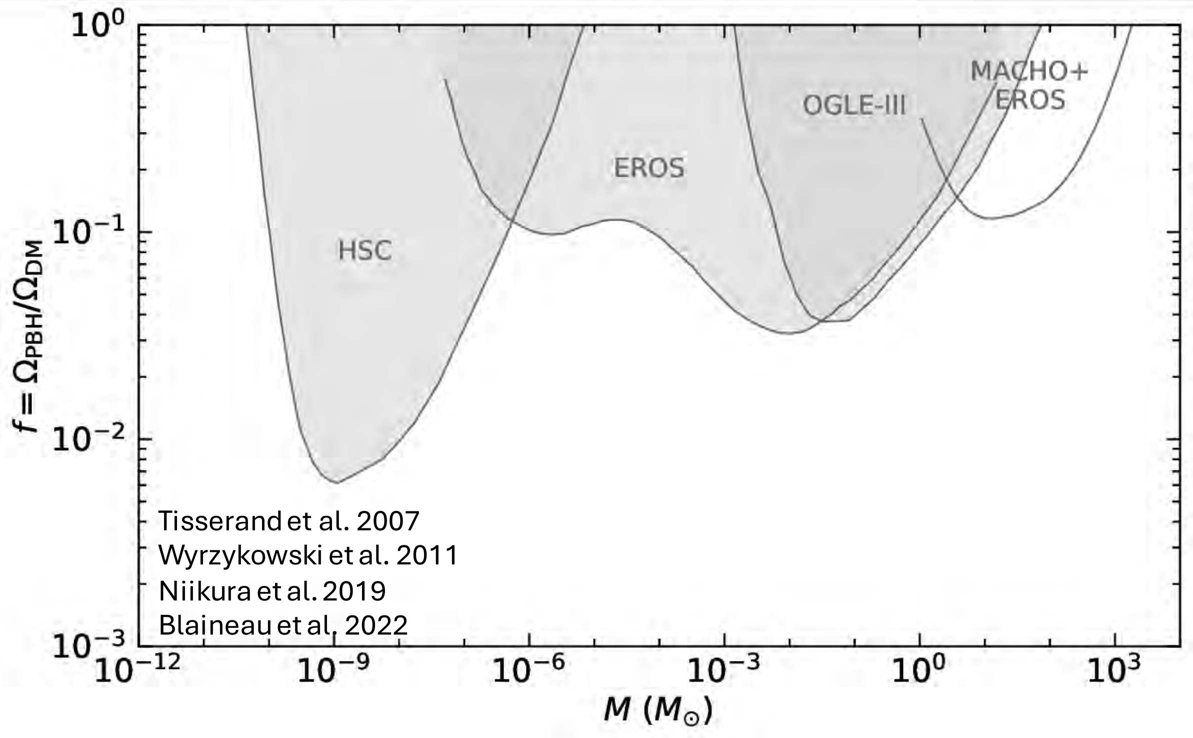
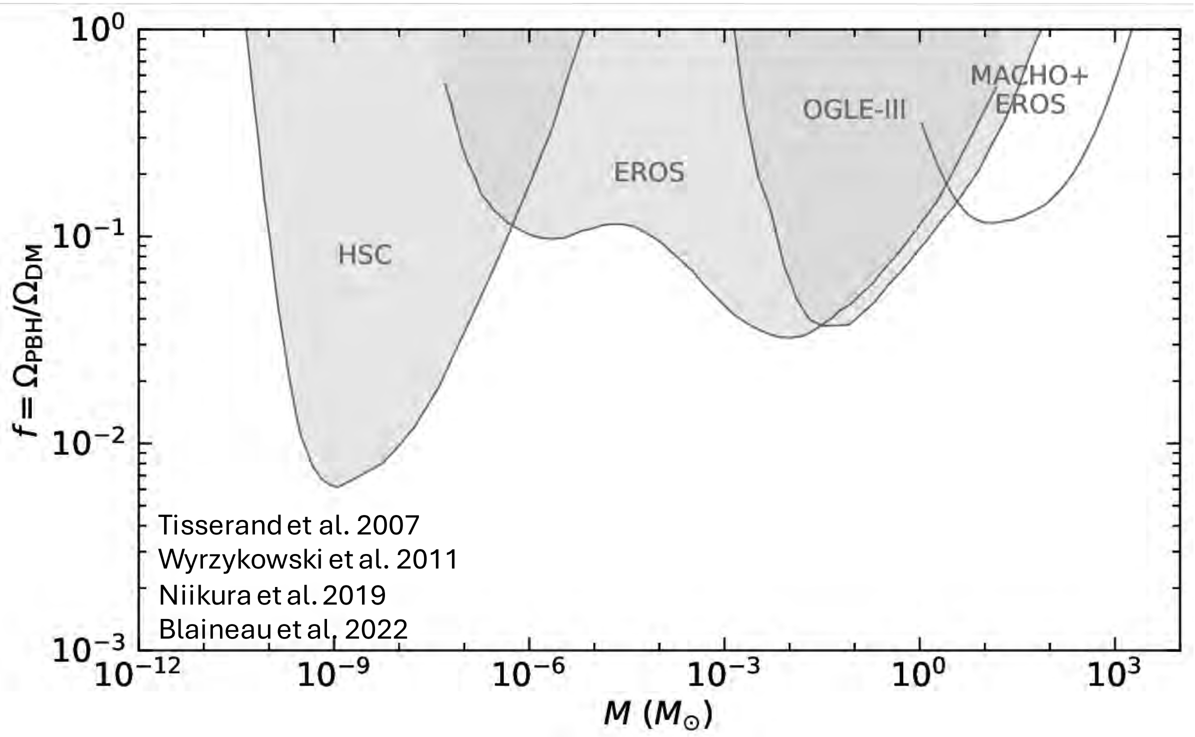
Black holes as dark matter



Microlensing experiments have ruled out compact objects (primordial black holes, MACHOs, etc) in the mass range 10^{-10} – 10 $M_\odot$ as a dominant component of dark matter

Black holes as dark matter



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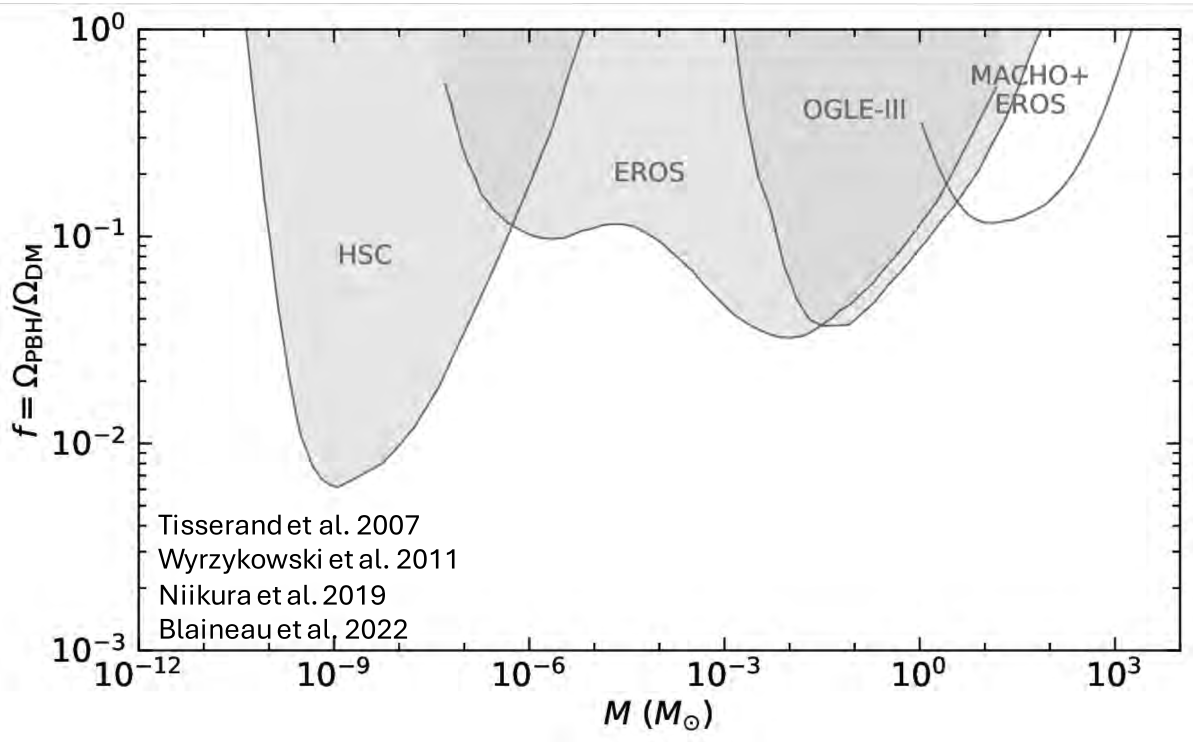
t_E = 2 yr for M = 100 $M_\odot$
t_E = 6 yr for M = 1000 $M_\odot$
t_E = 20 yr for M = 10000 $M_\odot$

Black holes as dark matter

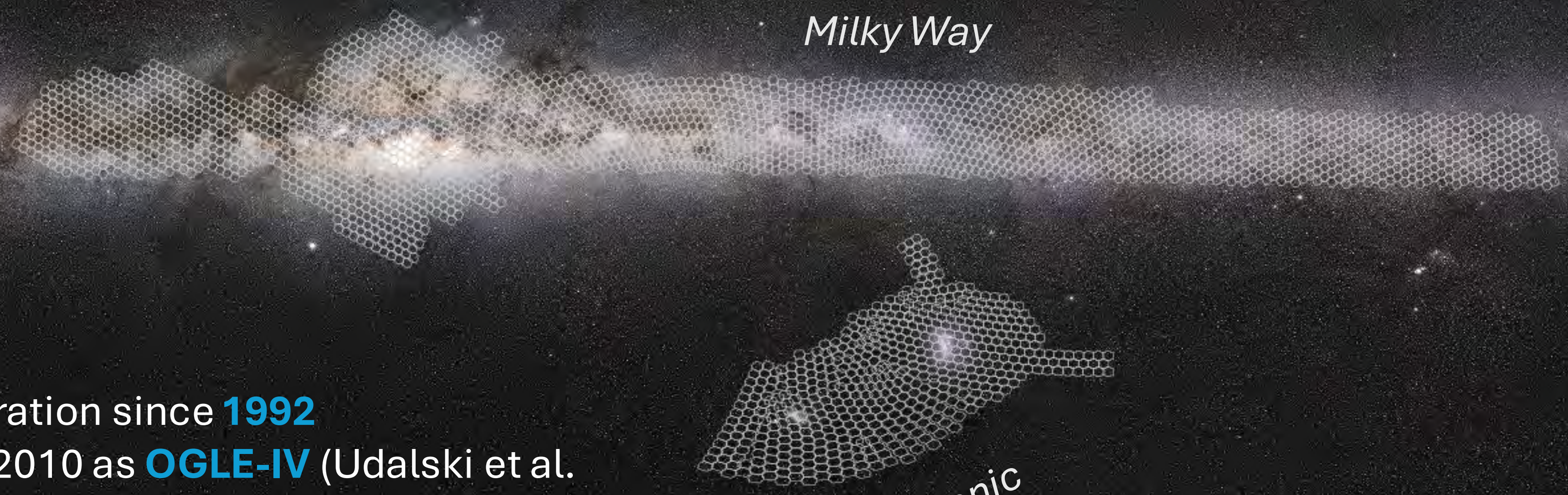


Microlensing experiments have ruled out compact objects (primordial black holes, MACHOs, etc) in the mass range 10^{-10} – 10 $M_\odot$ as a dominant component of dark matter

t_E = 2 hr   for M = 10^{-6} $M_\odot$

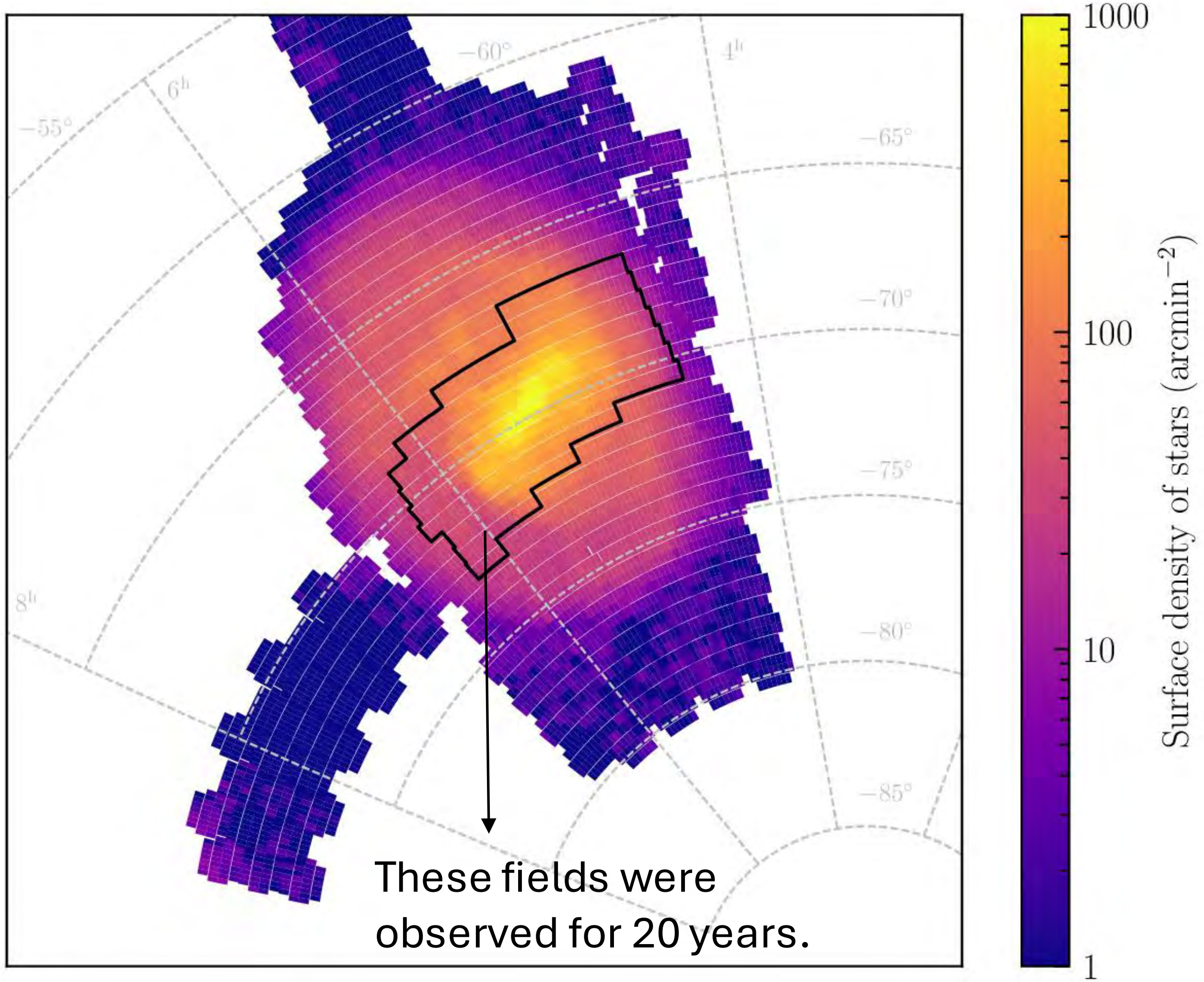
OGLE: Optical Gravitational Lensing Experiment

Warsaw 1.3-m
@ Las Campanas,
Chile



- in operation since **1992**
- since 2010 as **OGLE-IV** (Udalski et al. 2015)
- over **20,000** microlensing detections
- over **100** exoplanets discovered

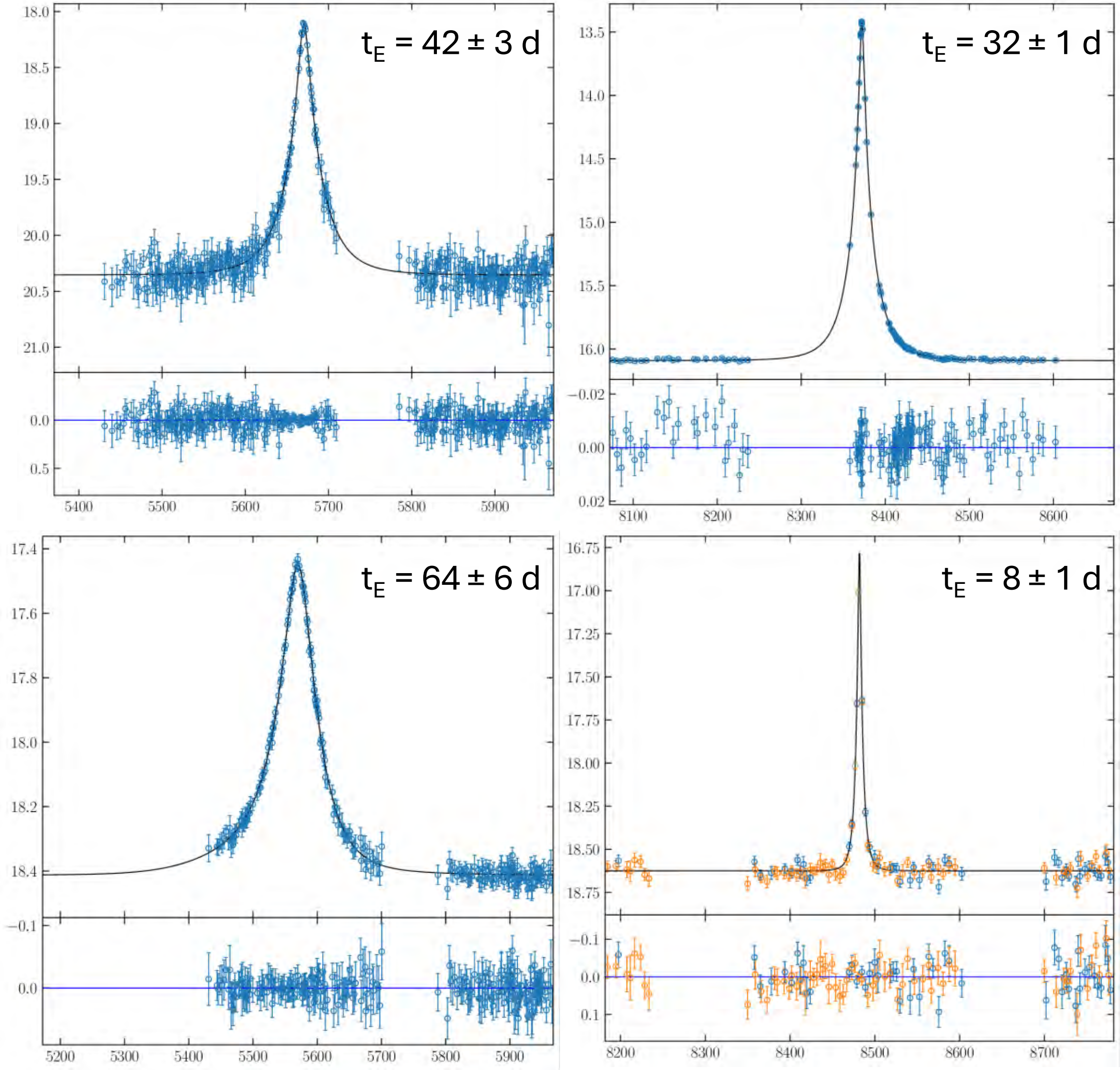
OGLE observations of the LMC



Mróz P. et al. (2024)

	Δt (yr)	Area (deg²)	# stars (million)
OGLE-III & OGLE-IV	20	42	41
OGLE-IV only	11	280	34

Searches for microlensing events



Mróz P. et al. (2024)

- 75 million objects in the OGLE database
- 500-1100 epochs per each light curve
- detected **16** short-timescale events (t_E < 200 days)
- lenses located in the LMC itself and Milky Way disk

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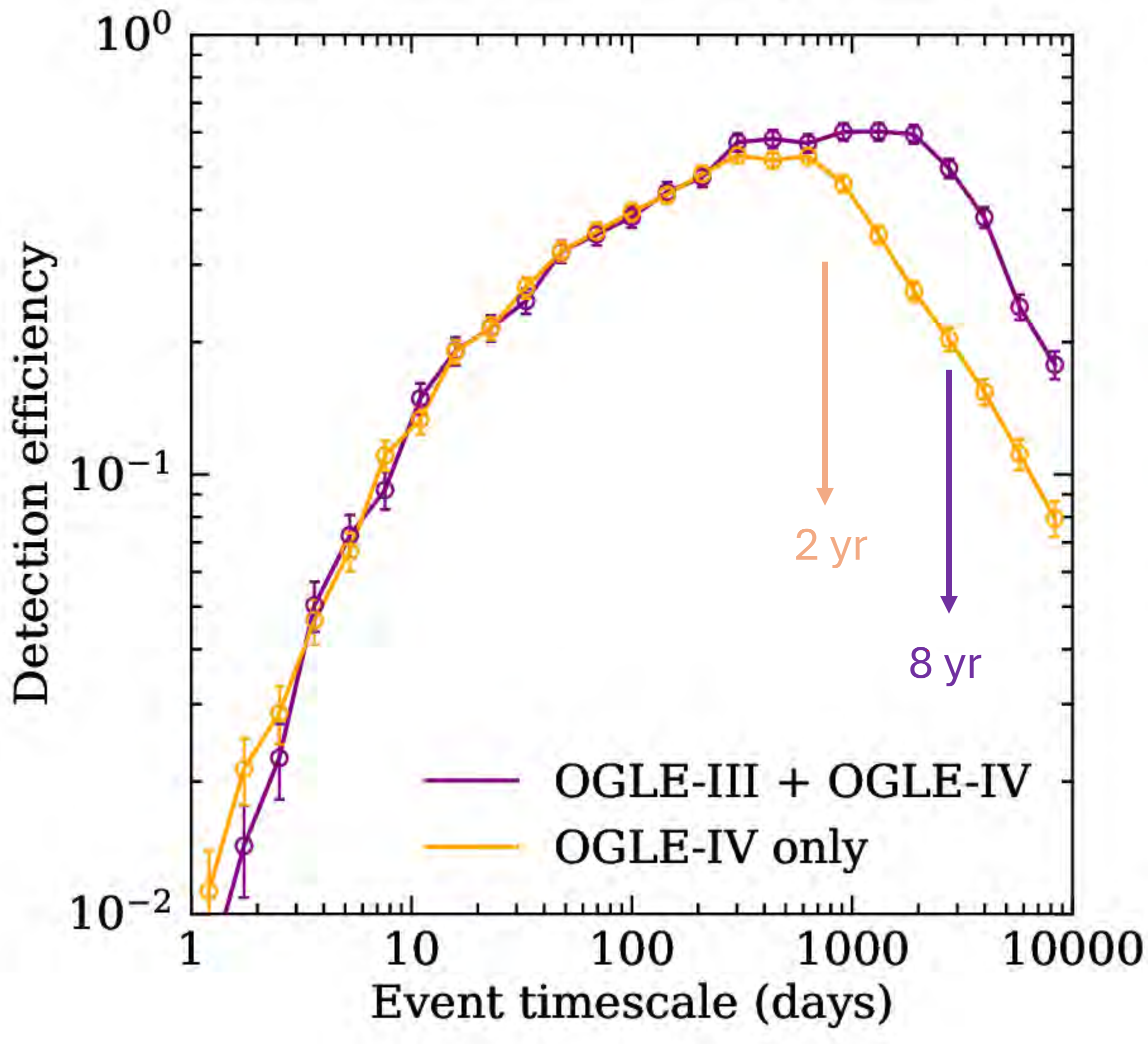

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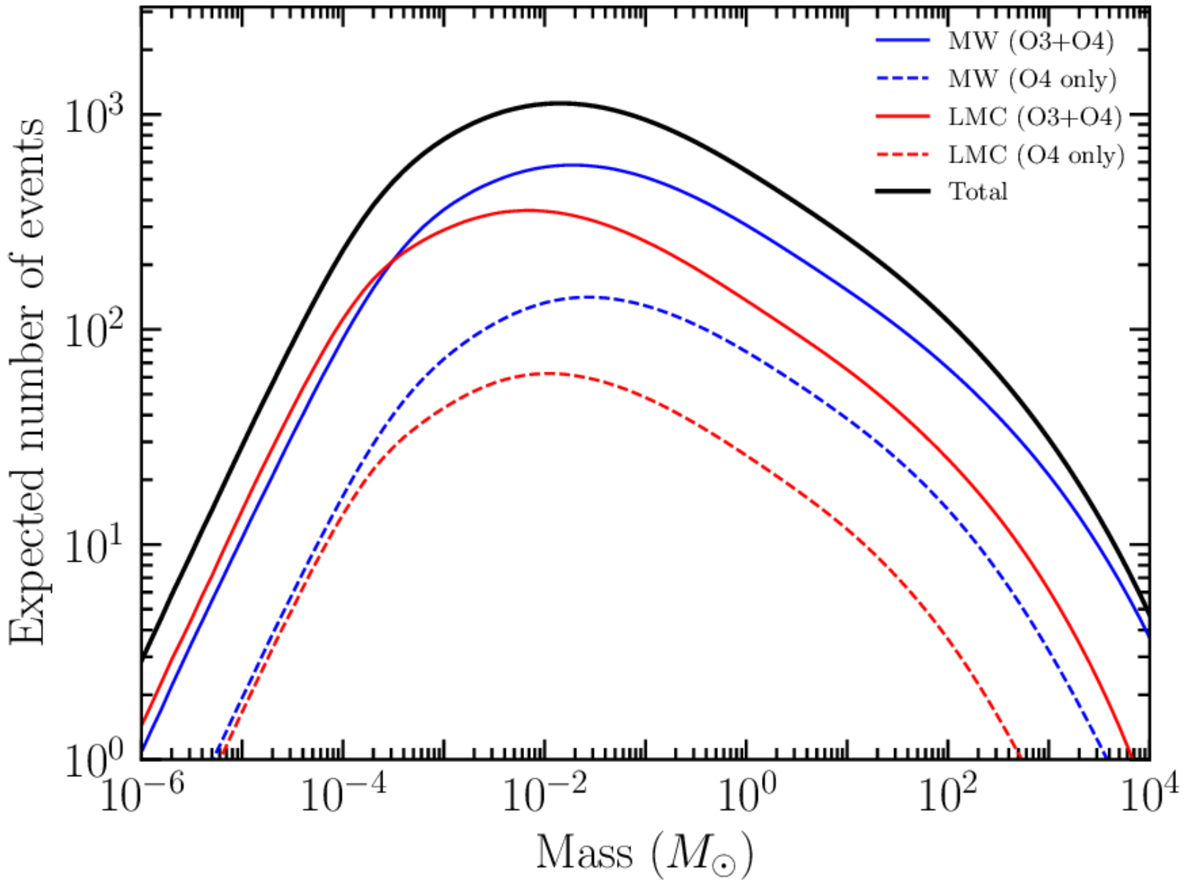
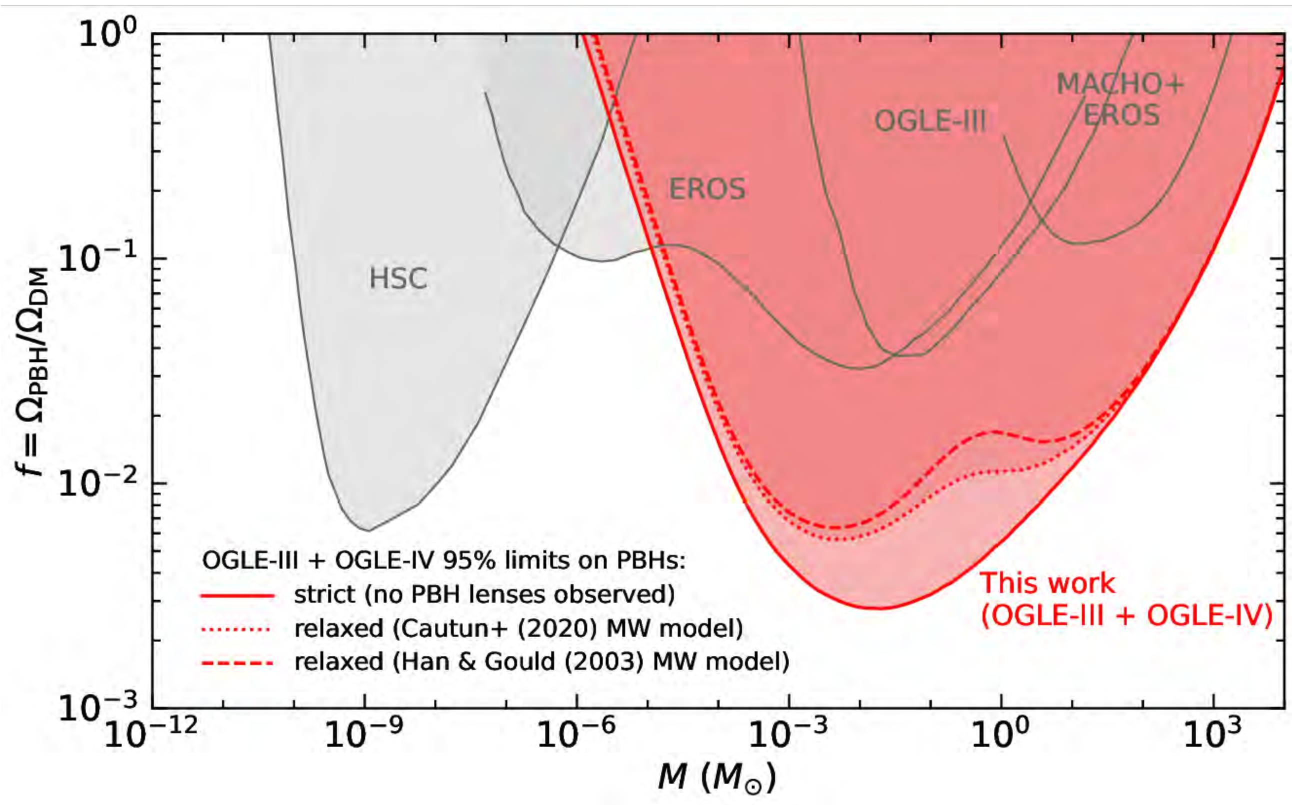
Expected number of events



Mróz P. et al. (2024)

Limits on the PBH abundance



Mróz P. et al. (2024)

Assuming a monochromatic PBH mass function:

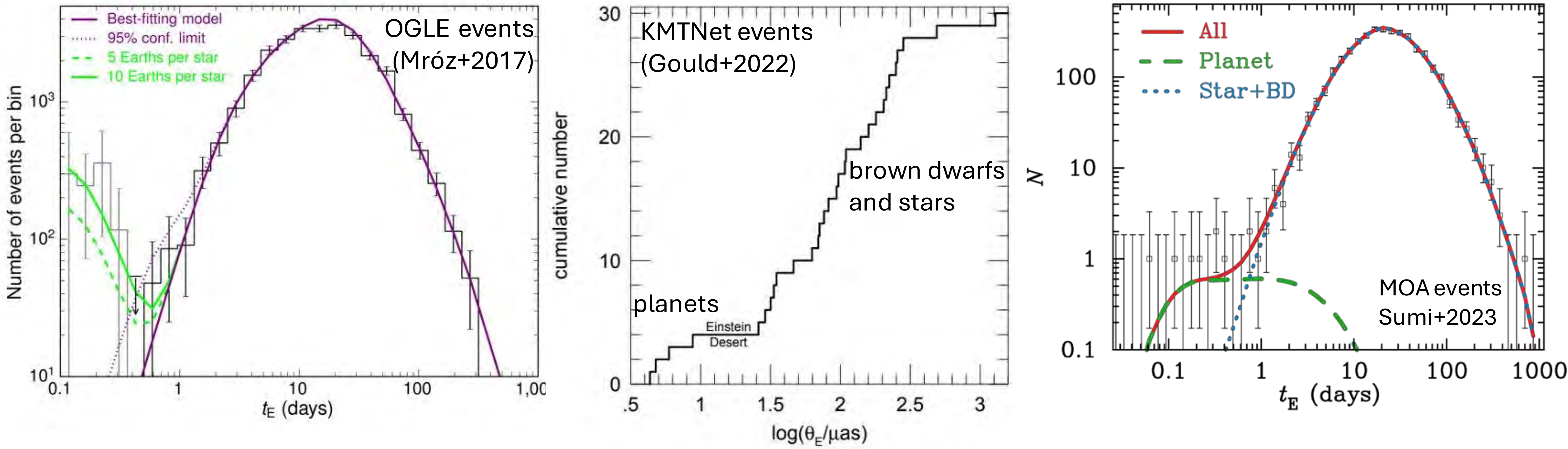
$f < 1.1\%$ for $M = 10\ M_\odot$

$f < 2.7\%$ for $M = 100\ M_\odot$

$f < 9.7\%$ for $M = 1000\ M_\odot$

(95% confidence limits)

Planetary-mass PBHs



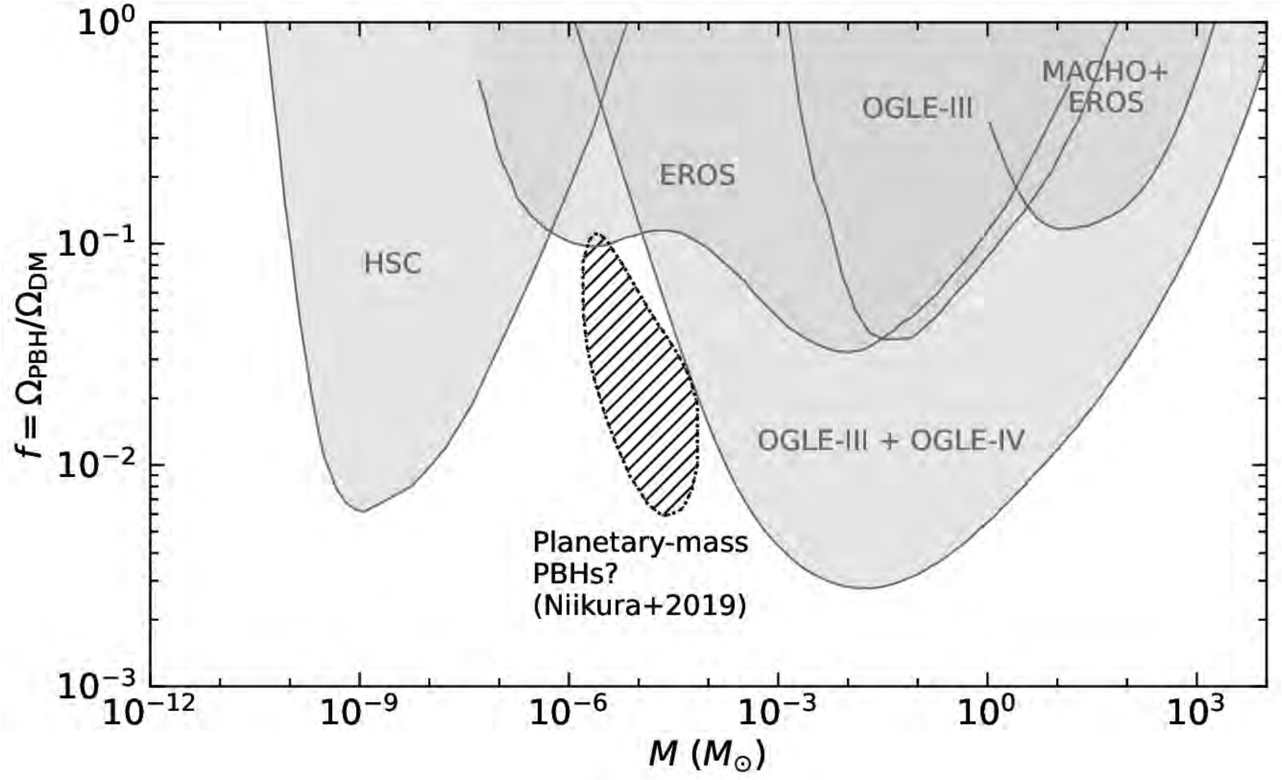
- Microlensing experiments found several very-short timescale events that may be due to free-floating or wide-orbit planets
- Implies that FFPs are common: 7^{+7}_{-5} FFPs/star (from 1 $M_{\oplus}$ to 13 M_{Jup})
- Could they be planetary-mass primordial black holes?

Planetary-mass PBHs

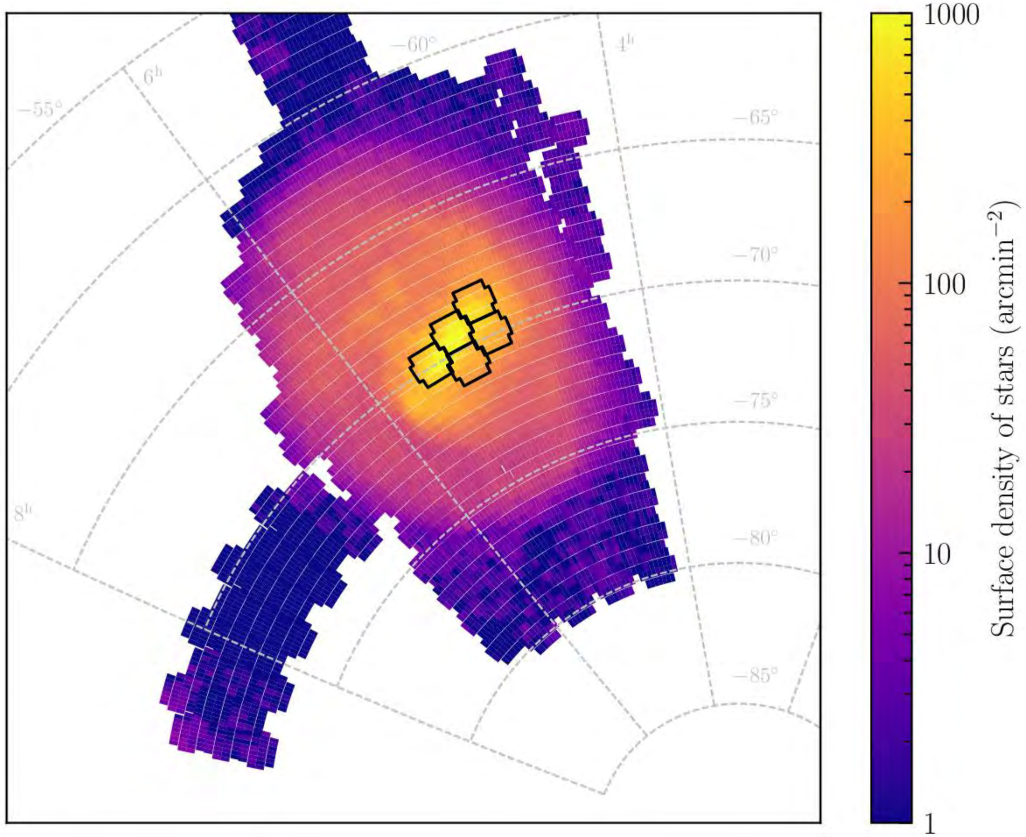
1 2019PhRvD..99h3503N 2019/04 cited: 251

Constraints on Earth-mass primordial black holes from OGLE 5-year microlensing events

Niikura, Hiroko; Takada, Masahiro; Yokoyama, Shuichiro *and 2 more*



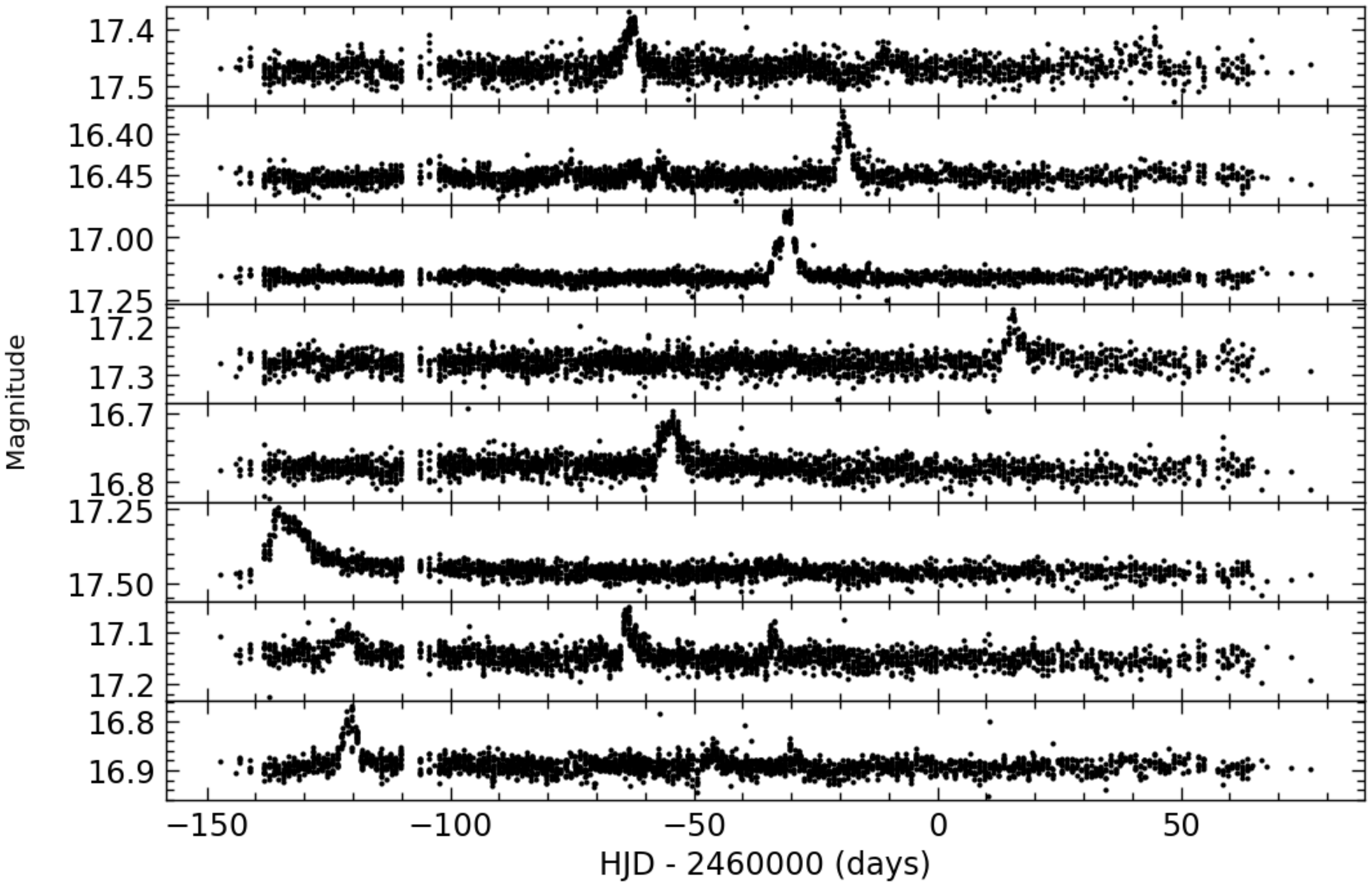
High-cadence observations of the LMC



Mróz P. et al. (in prep.)

- after the pandemic, we initiated high-cadence observations of the LMC (5 fields) and SMC (4 fields), in total 35 million stars
- cadence of 15-20 min
- observations started in the 2022/2023 season and are planned for two observing seasons (until mid-2024)
- total exposure: $E = 4 \times 10^7$ stars*year

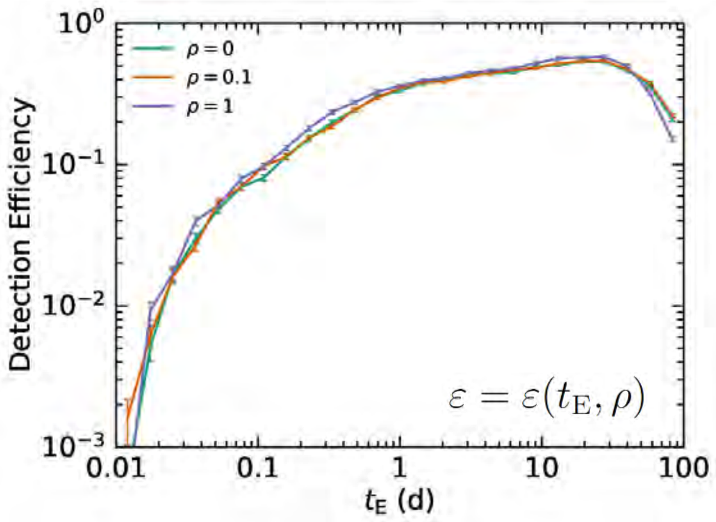
Preliminary results from the 2022/23 season

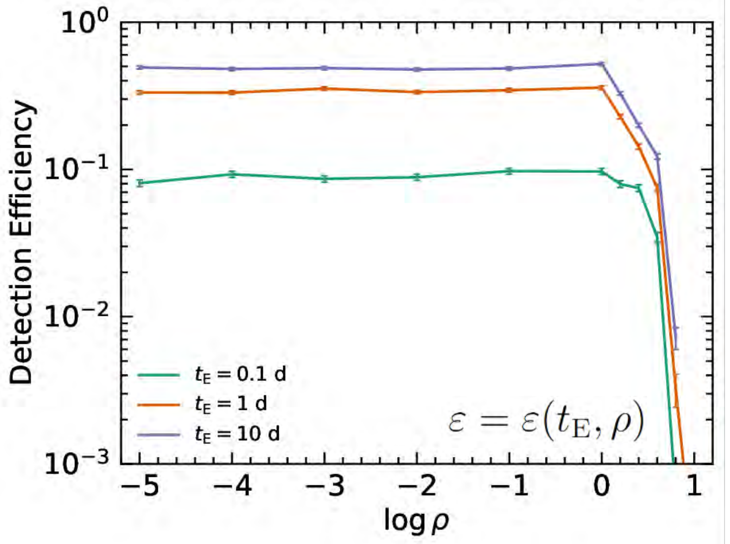


Mróz P. et al. (in prep.)

No short-timescale microlensing events in the high-cadence data!

Planetary-mass PBHs: preliminary limits





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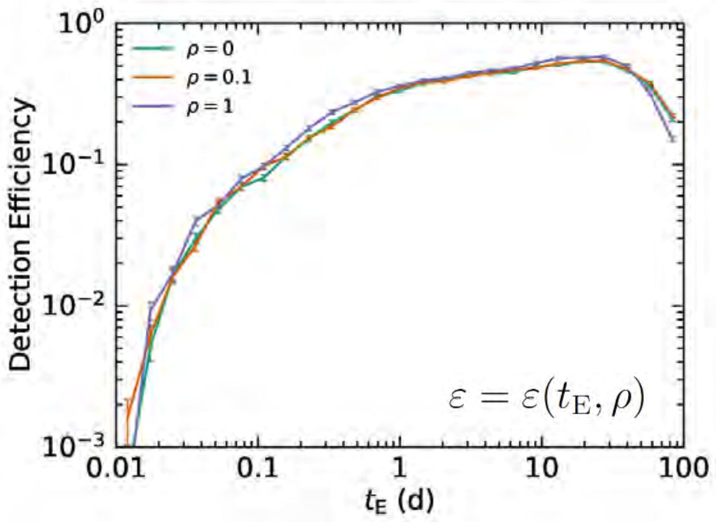

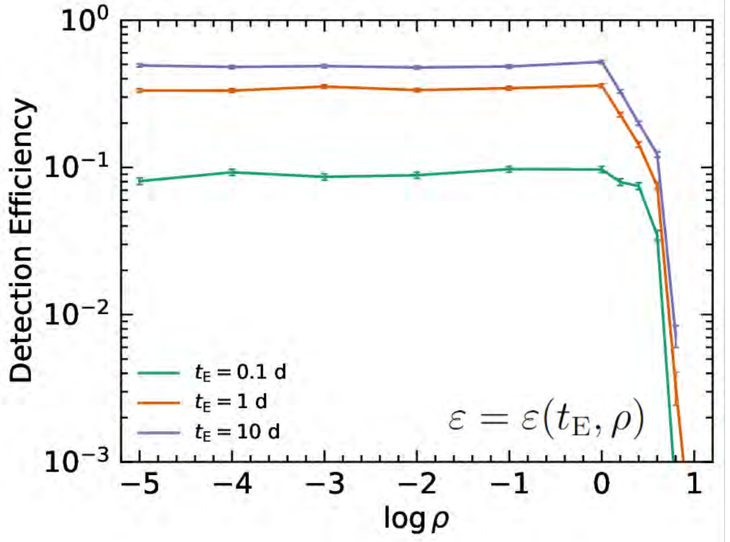

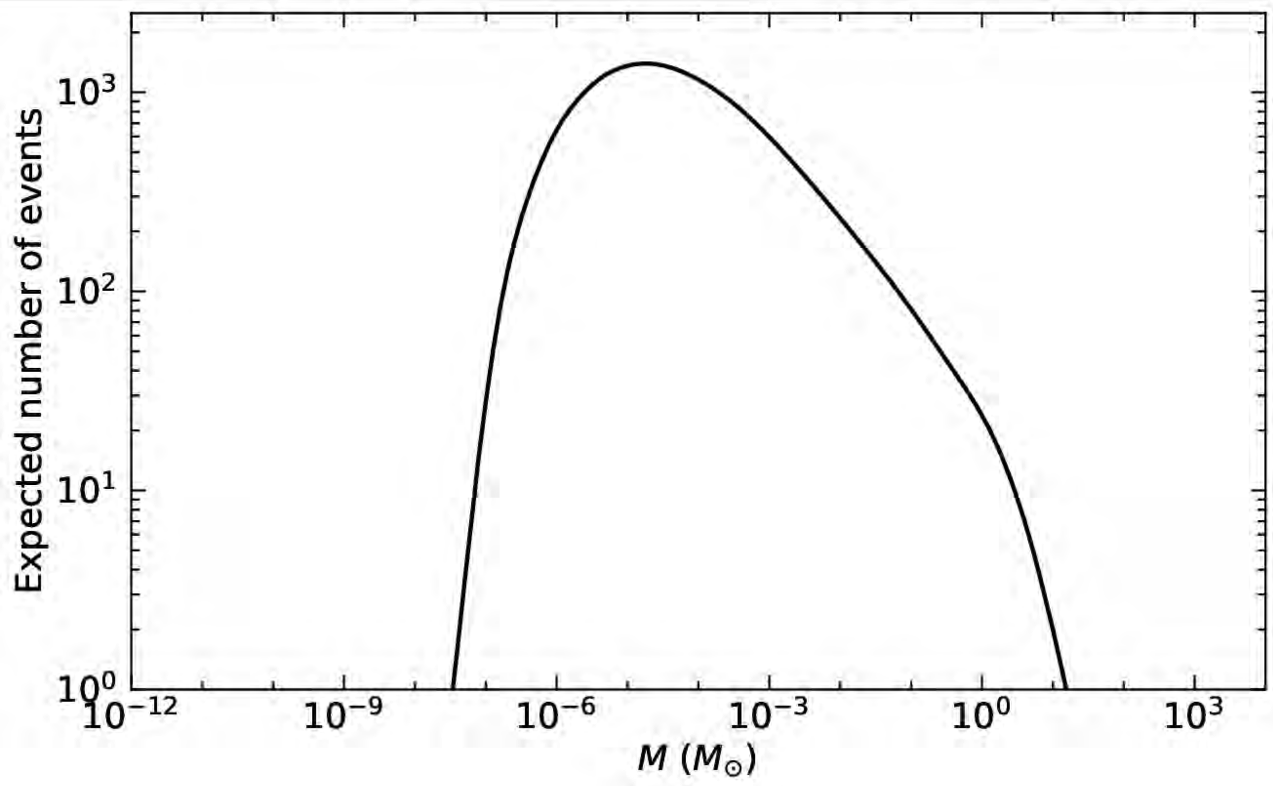

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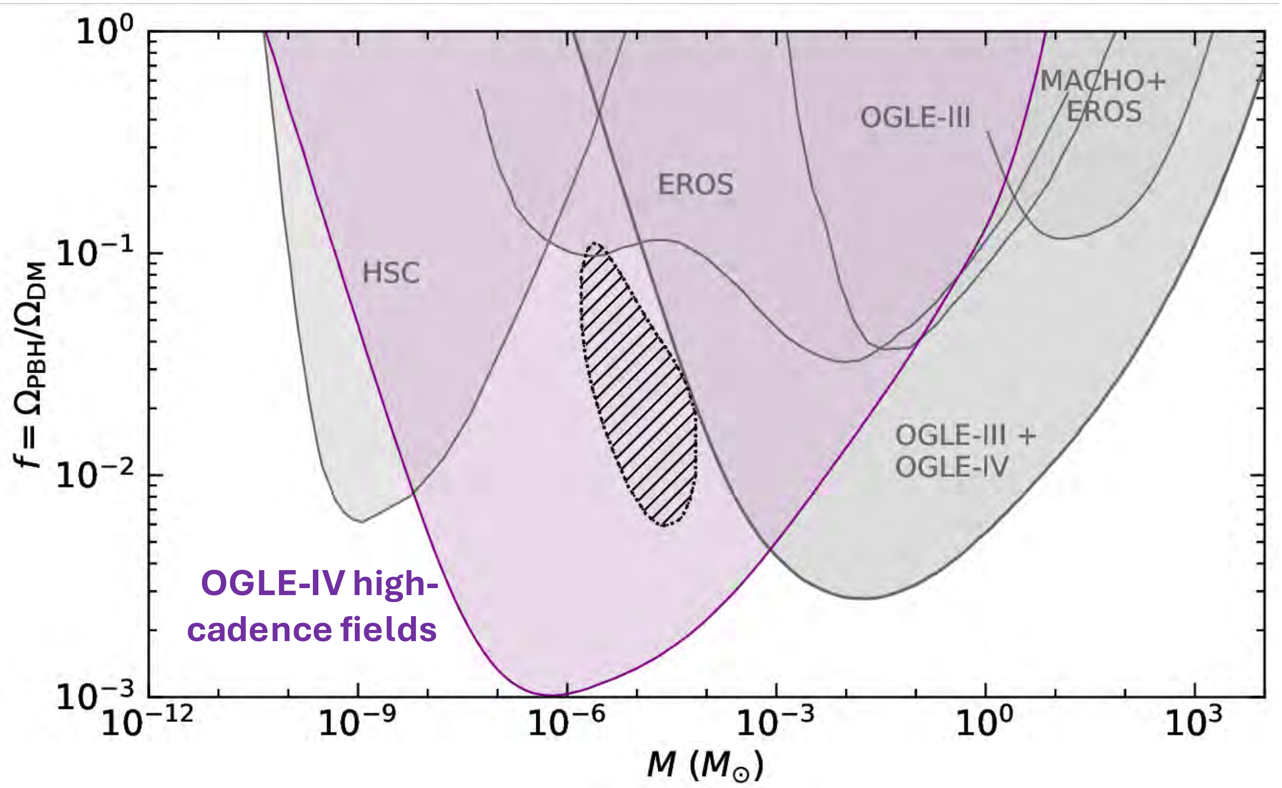

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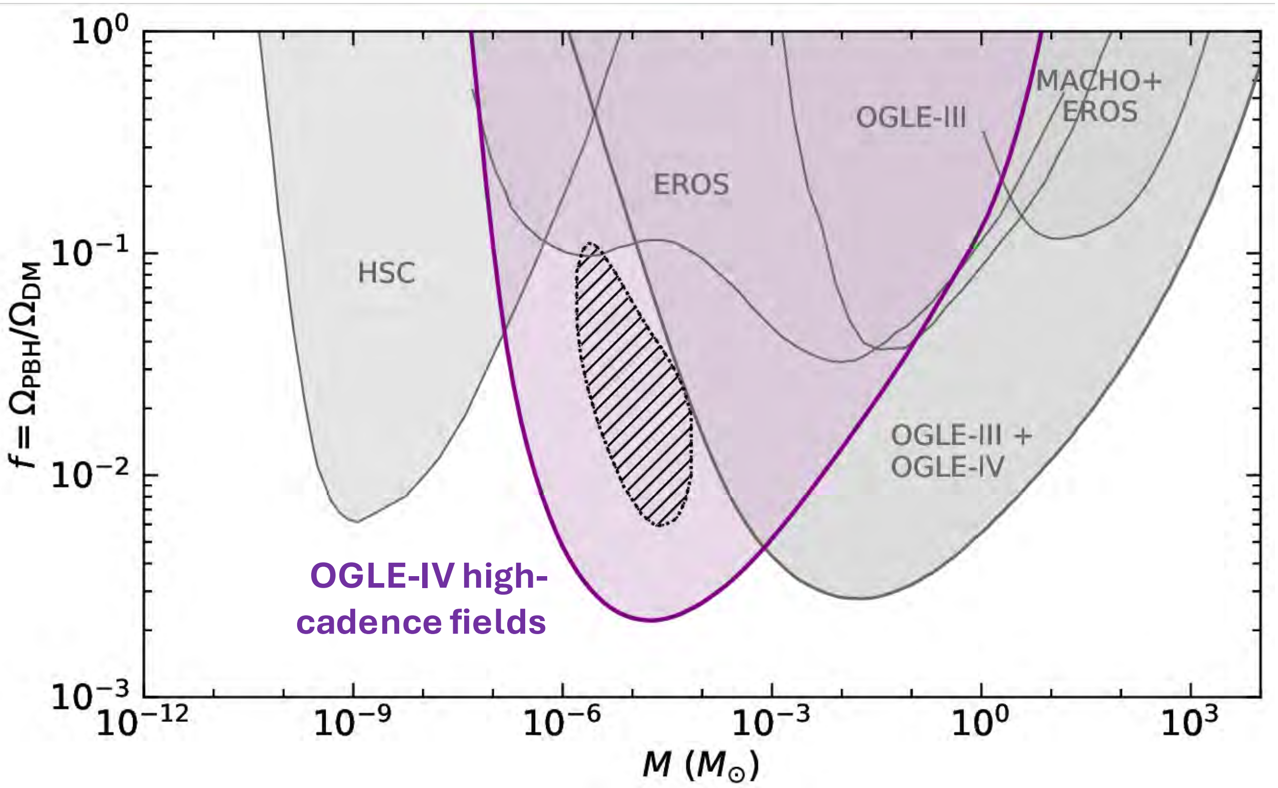
Planetary-mass PBHs: preliminary limits

Finite-source effects are important!



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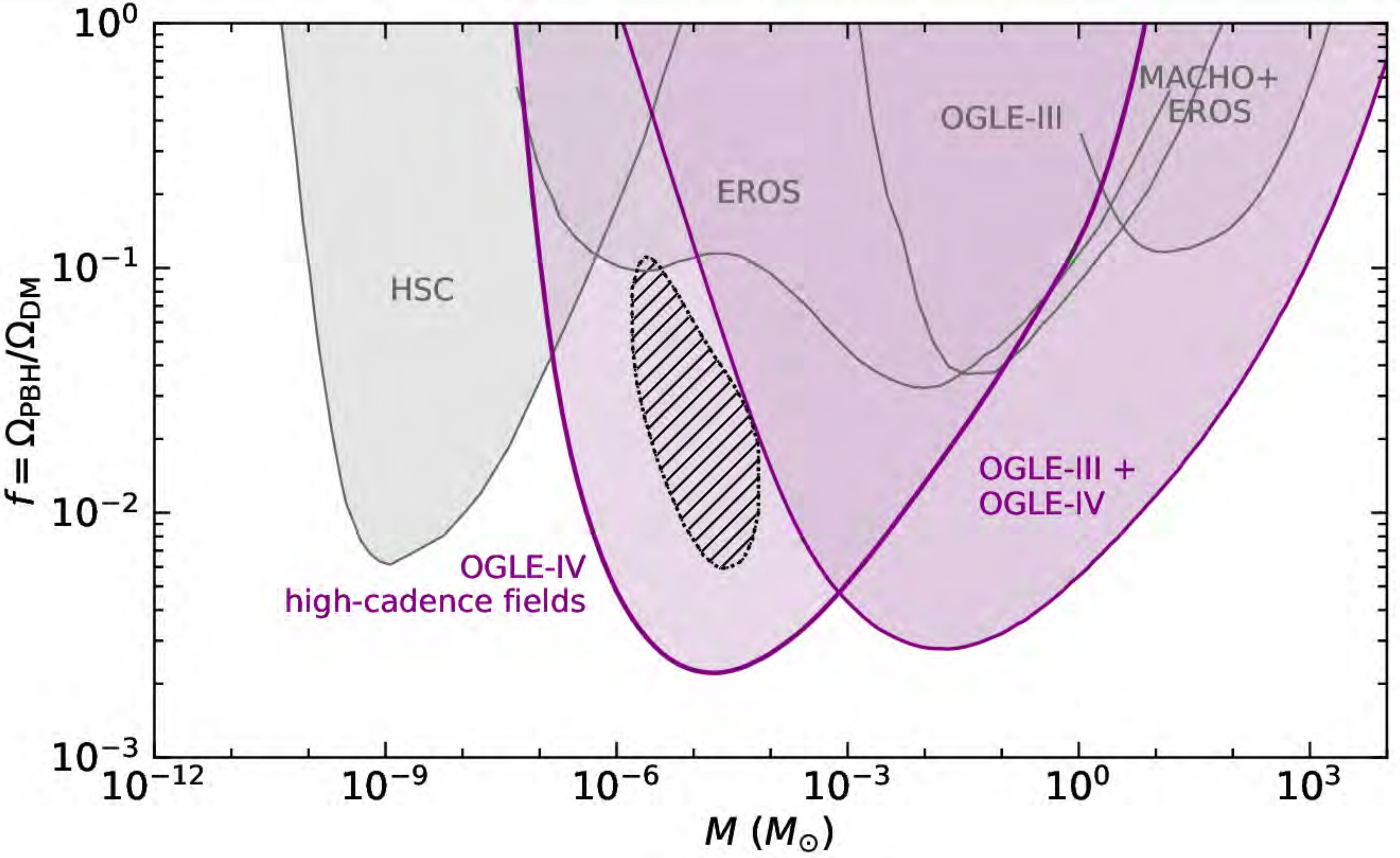
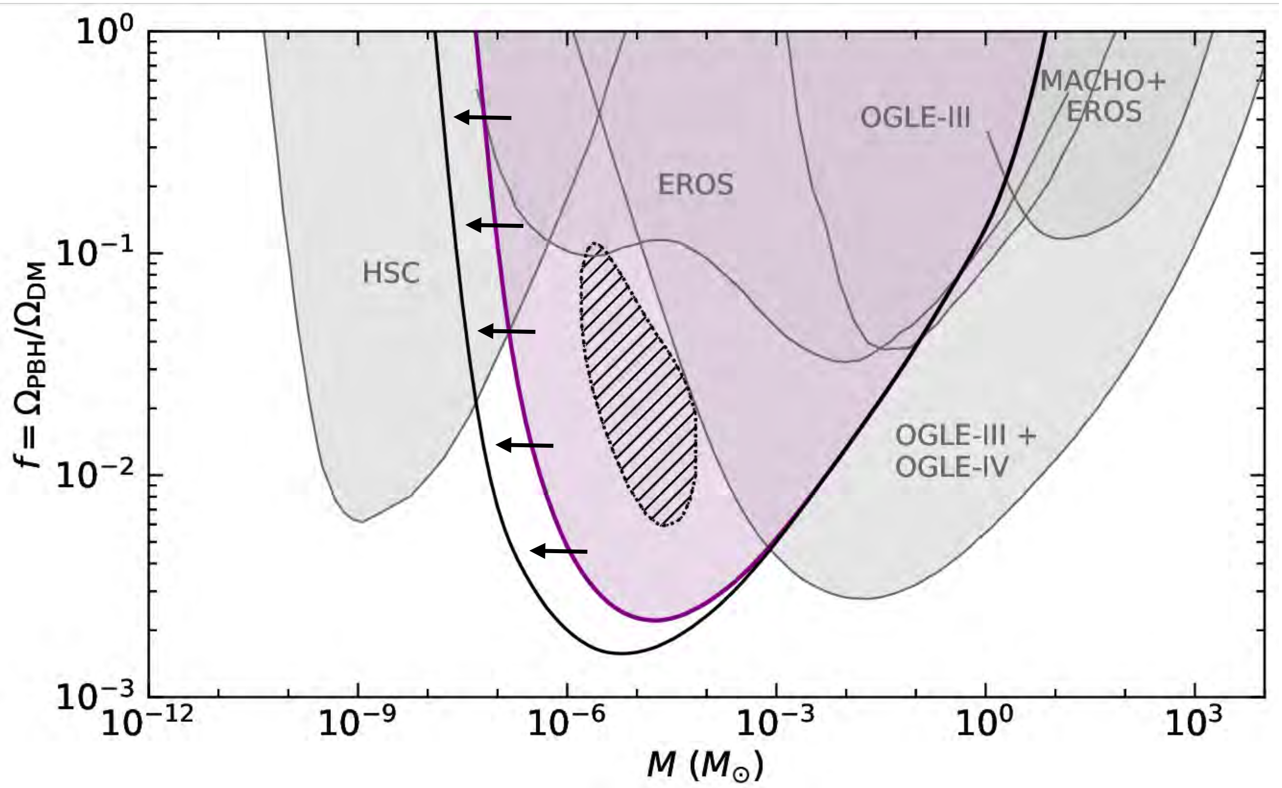
Summary



HSC
EROS
OGLE-III
MACHO+
EROS
OGLE-III +
OGLE-IV
OGLE-IV
high-cadence fields
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-12}
10^{-9}
10^{-6}
10^{-3}
10^{0}
10^{3}
$f = \Omega_{PBH}/\Omega_{DM}$
$M\ (M_\odot)$

Planetary-mass PBHs: preliminary limits

The sensitivity to low-mass PBHs would not significantly improve even if we observed fainter (smaller) sources (I < 24 mag).



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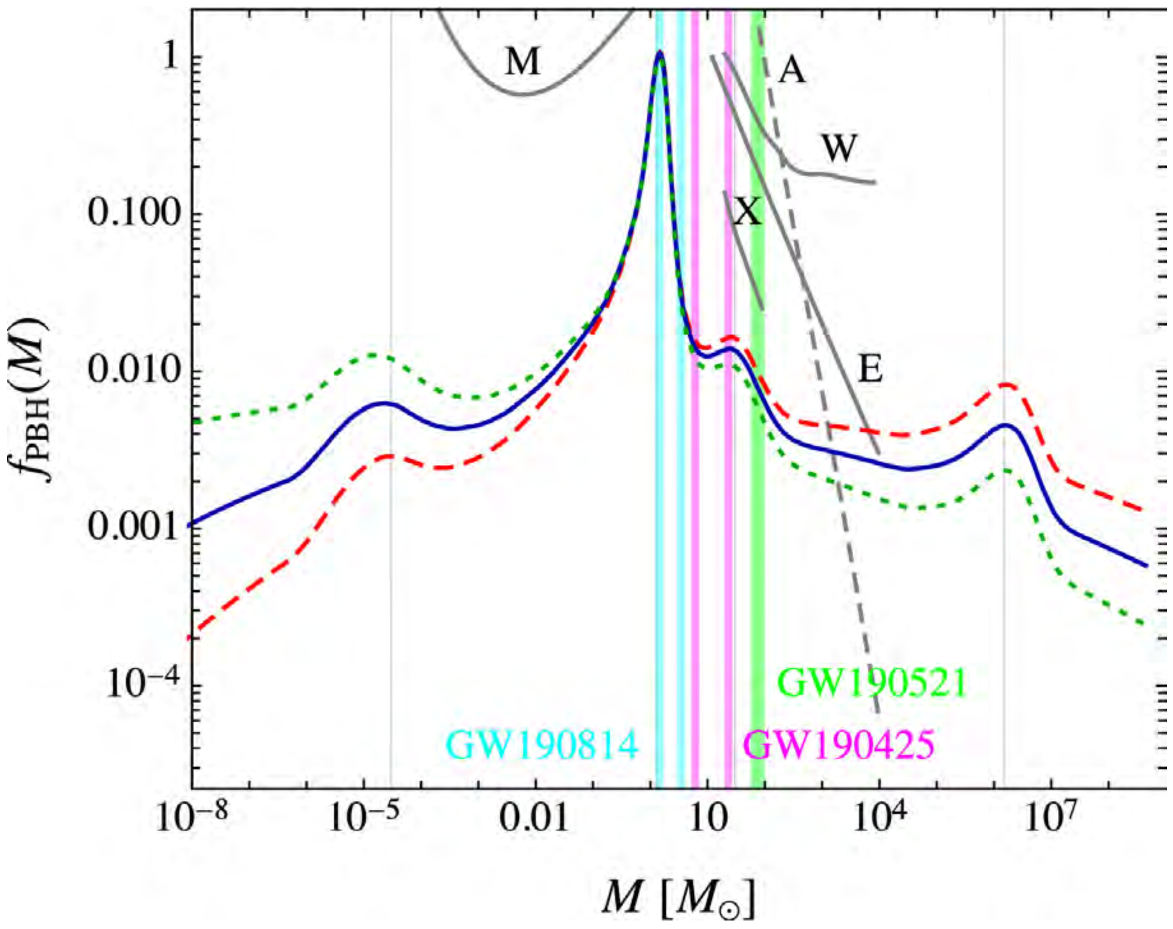
Primordial black holes



Carr et al. 2021

Black holes may have formed in the early Universe by the collapse of density perturbations.

Phase transitions in the primordial quark-gluon plasma lead to different PBH masses:
$W^\pm/Z^0$ decoupling: ~10^{-6} $M_\odot$
quark-hadron transitions: 1, 30 $M_\odot$
e^+e^- annihilation: ~10^6 $M_\odot$