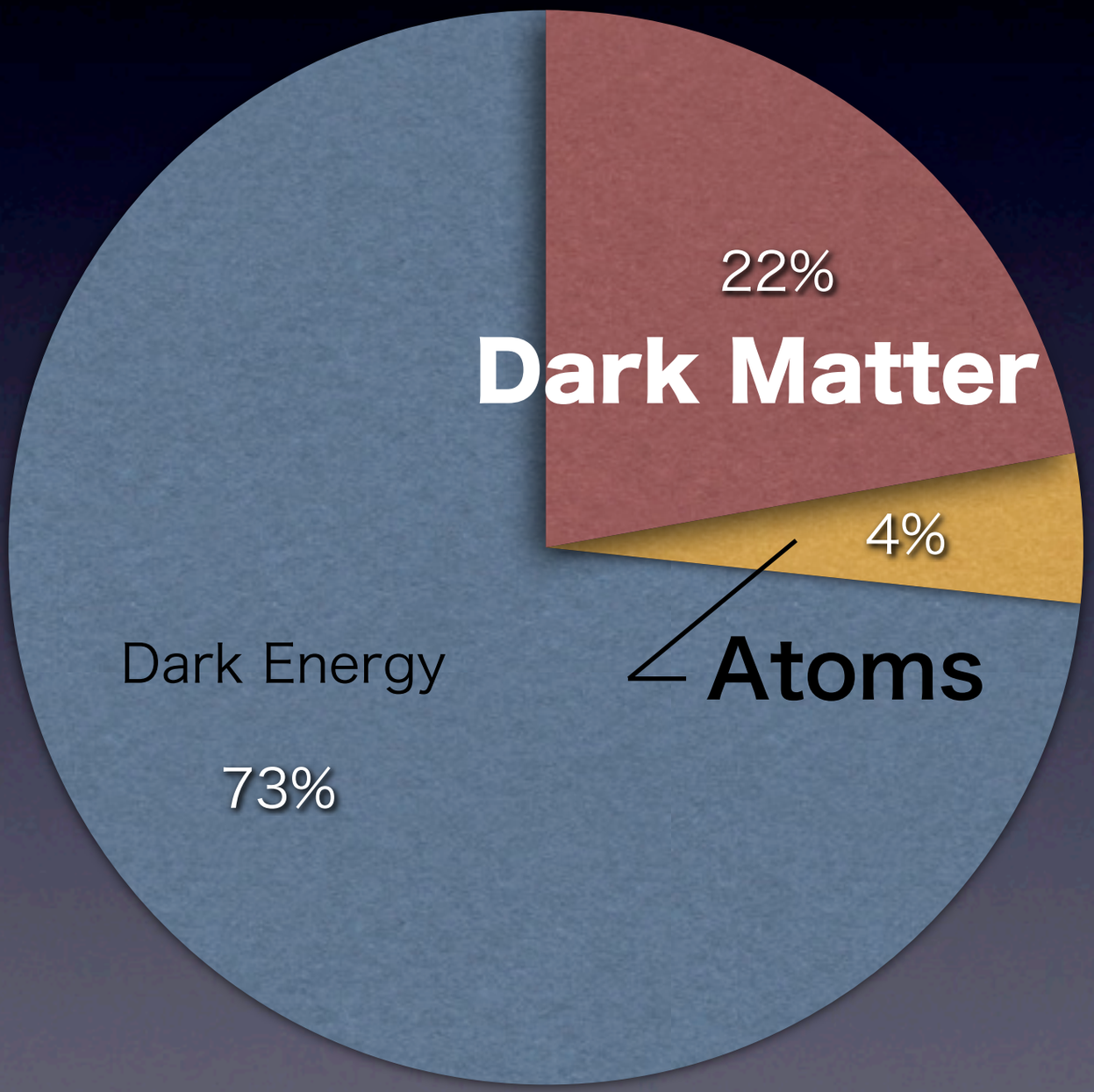
Lunch meeting 9th Nov. 2011

BLACK HOLE DARK MATTER

RYO SAITO

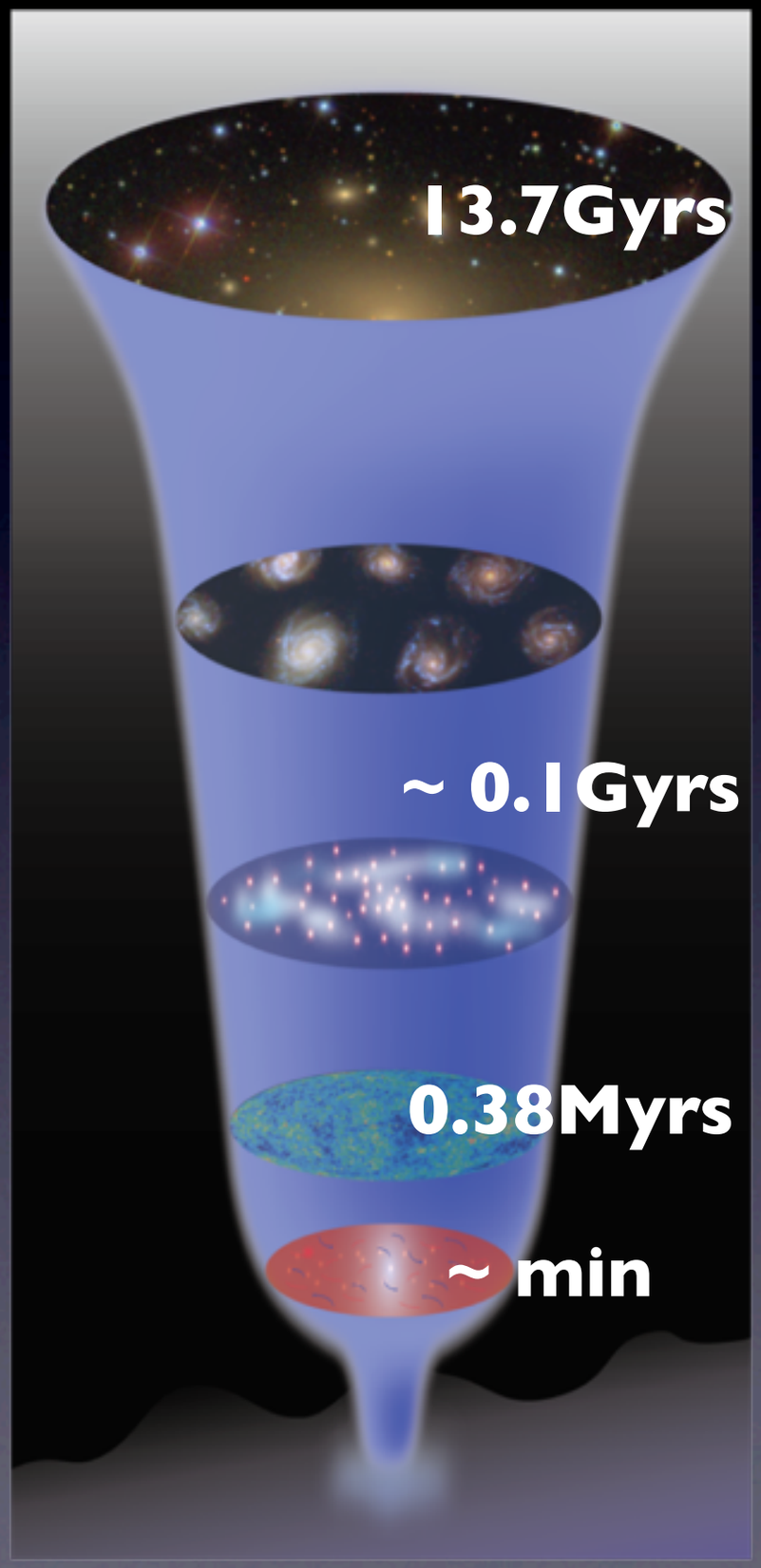
RS & J. Yokoyama PRL102 (2009)
RS & J. Yokoyama PTP123 (2010)
RS & S. Shirai PLB697 (2011)
WIP with S. Matsumoto, S. Shirai, & T. Yanagida

Non-relativistic Matter in the Universe is almost non-baryonic (not atoms), and non-luminous (dark).



Why necessary?
What is it made of?

Evidences



- Many evidences on different scales and at different epochs.

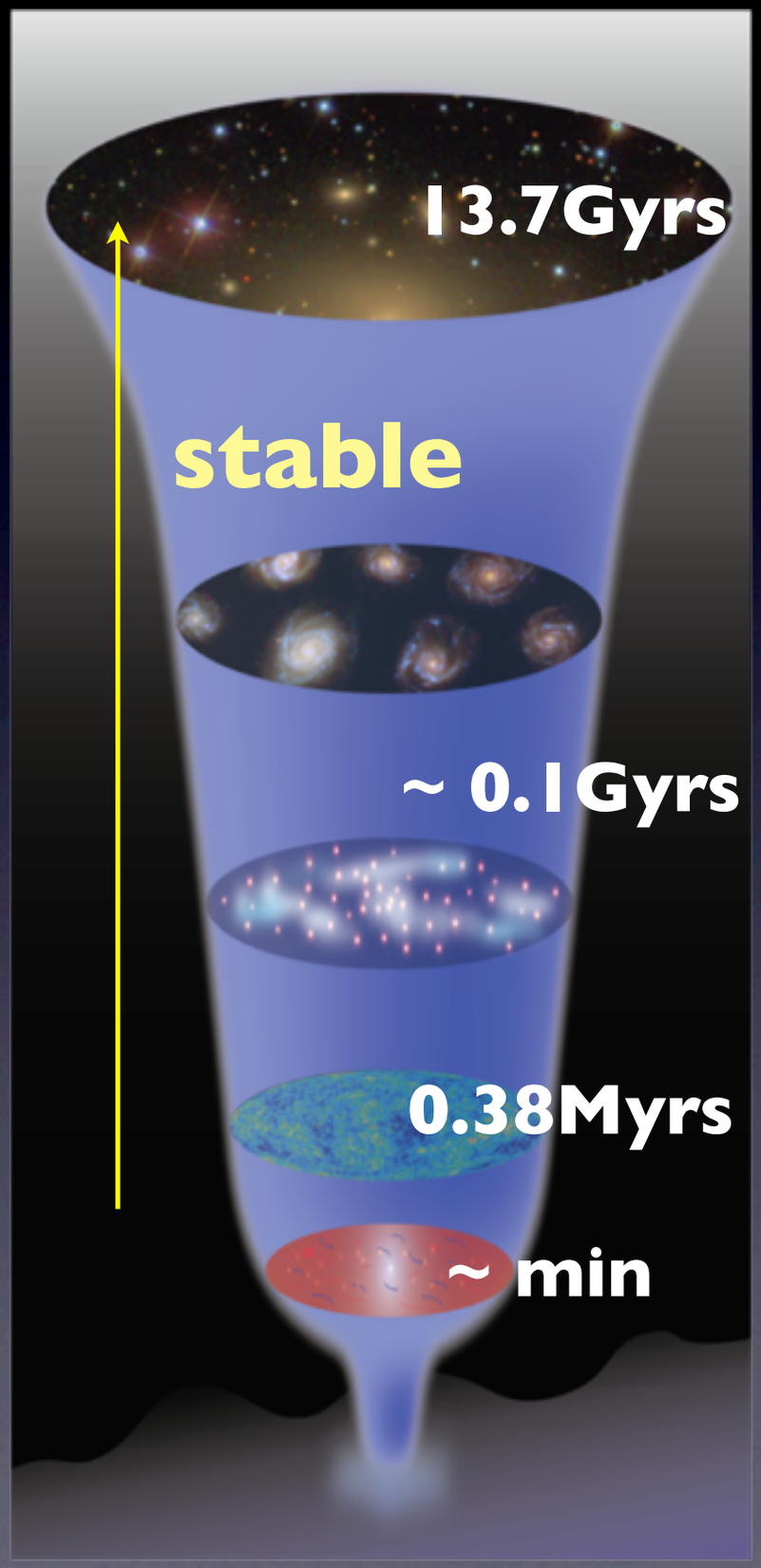
Rotation Curves of Galaxies

Formation of Large Scale Structures
(galaxy clusters, galaxies, stars,...)

Cosmic Microwave Background (CMB)

Big Bang Nucleosynthesis (BBN)
(Synthesis of light elements)

Evidences → Properties



- Many evidences on different scales and at different epochs.

Rotation Curves of Galaxies
→ **neutral**

Formation of Large Scale Structures
(galaxy clusters, galaxies, stars,...)
→ **cold (low velocity)**

Cosmic Microwave Background (CMB)

Big Bang Nucleosynthesis (BBN)
(Synthesis of light elements)
→ **non-baryonic**

Candidates of Dark Matter

Properties

neutral (non-luminous),
non-baryonic (not atoms),
stable (produced in the early Universe),
cold (low velocity)

New particle like WIMPs (Neutralino,...), Gravitino, Axion?, or ...

Candidates of Dark Matter

Properties

neutral (non-luminous),
non-baryonic (not atoms),
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New particle like WIMPs (Neutralino,...), Gravitino, Axion?, or ...

astronomical objects like

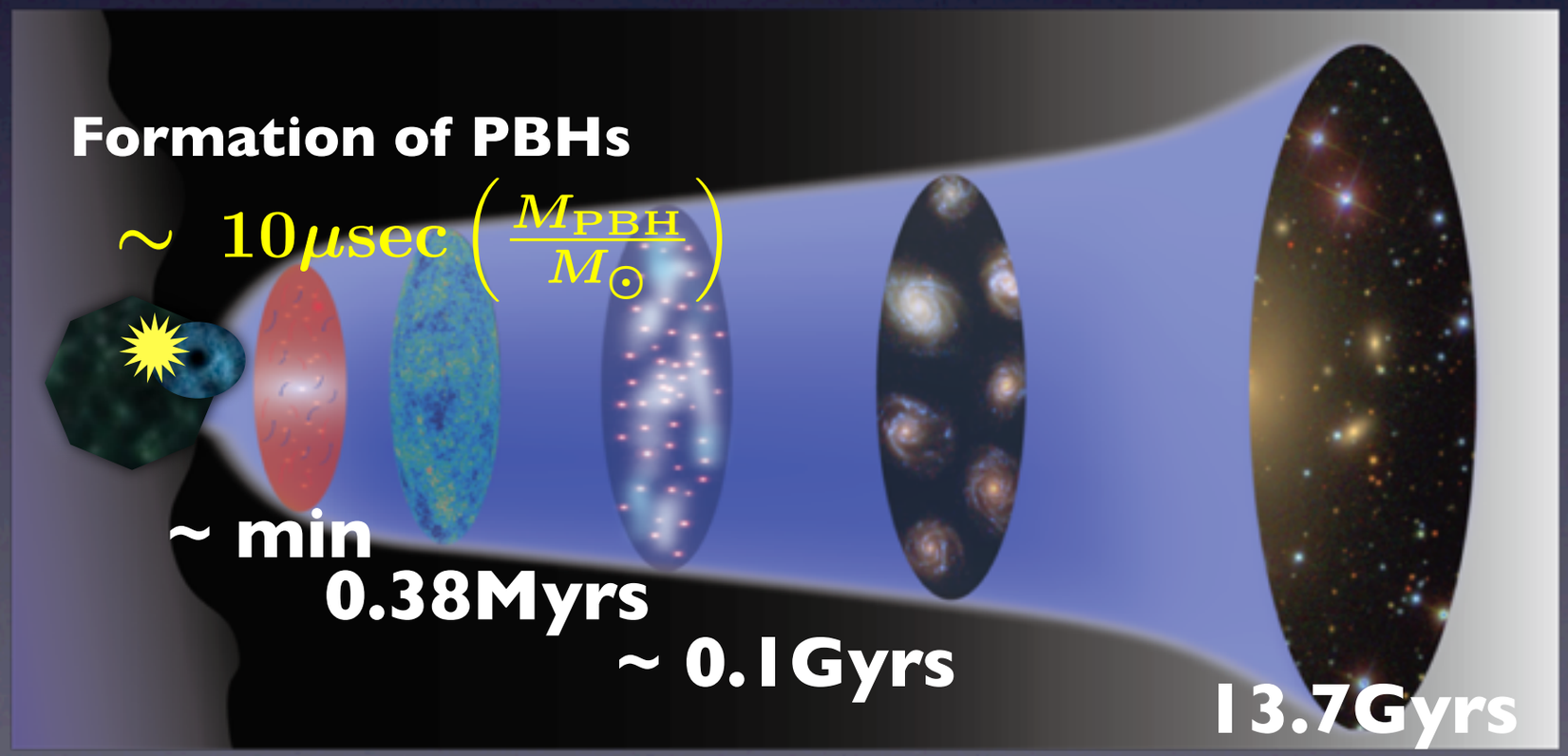
"Primordial" Black Holes?

Primordial Black Holes

Primordial Black Holes (PBHs)

Black holes produced in the early Universe through phase transitions or gravitational collapse of large primordial density fluctuations.

(Zel'dovich & Novikov '66, Hawking '71)



Primordial Black Holes

Mass

determined by scales of the seed density fluctuations.

A wide range of masses is possible

from the Planck mass to masses much larger than the solar mass.

Light PBHs $(M_{PBH} < 10^{15}\mathrm{g})$

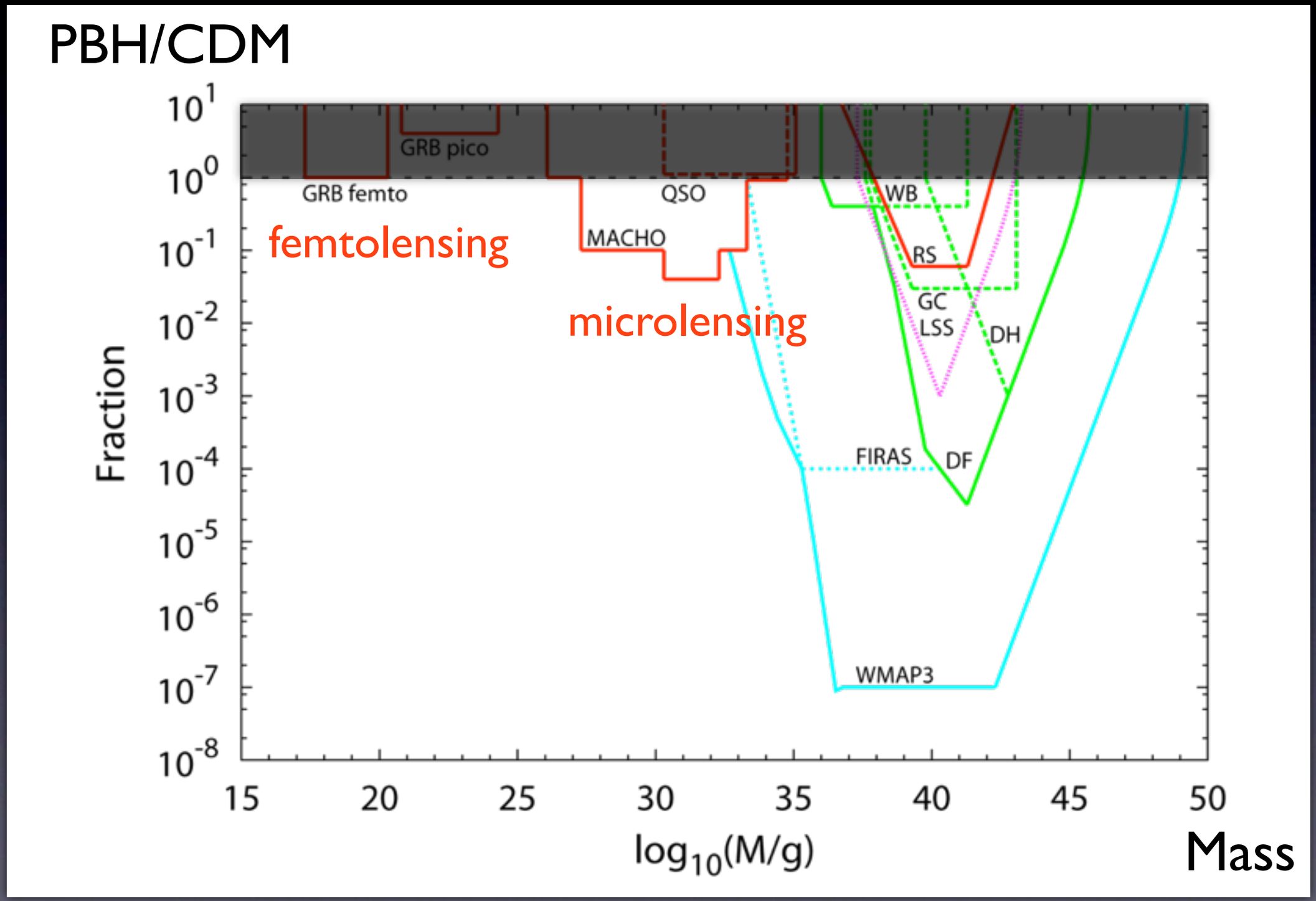
evaporated by now due to the Hawking radiation.

Heavy PBHs $(M_{PBH} > 10^{15}\mathrm{g})$

remain until now. → a candidate of dark matter

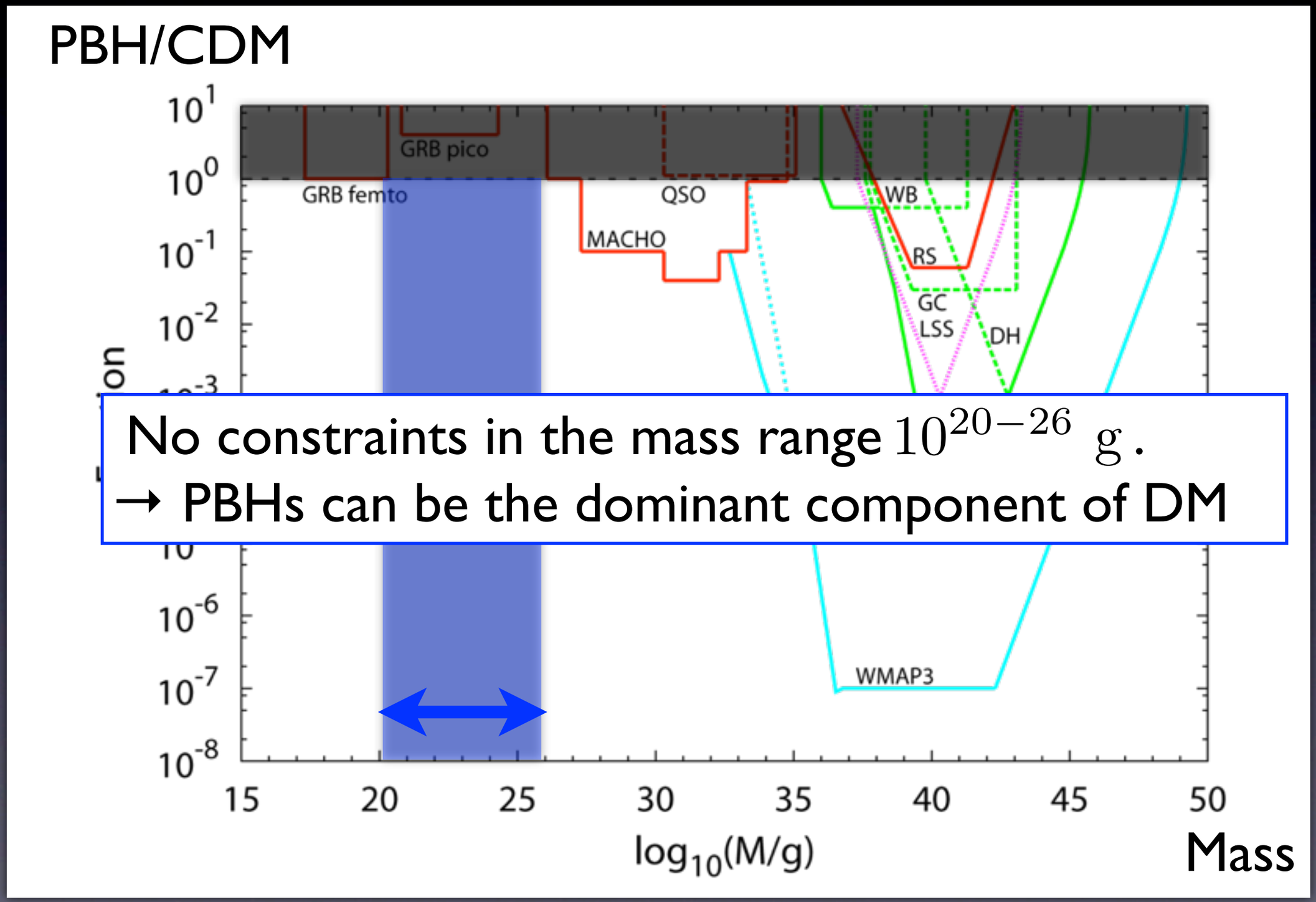
Constraints on the PBH abundance

Carr, Kohri, Sendouda, & Yokoyama '09



Constraints on the PBH abundance

Carr, Kohri, Sendouda, & Yokoyama '09



Gravitational Waves

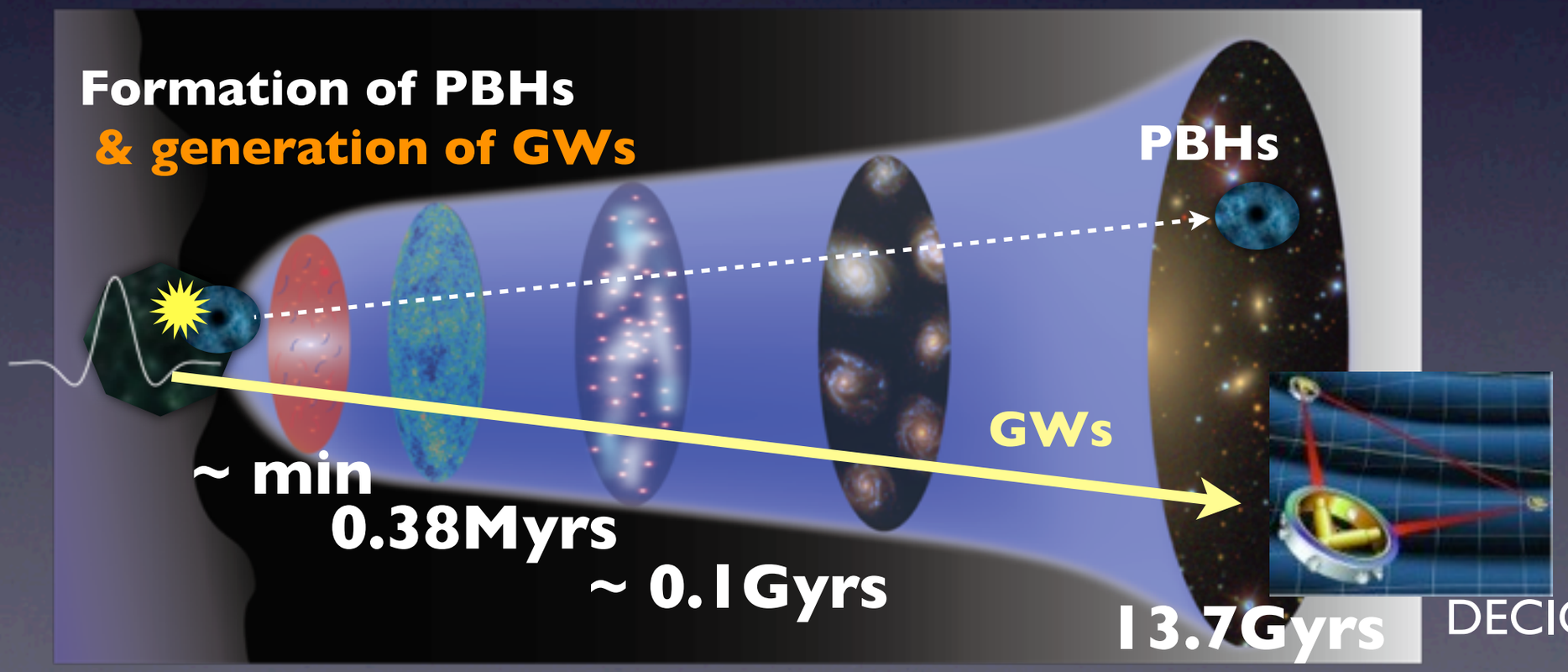
RS & J. Yokoyama '09
RS & J. Yokoyama '10

The large density fluctuations that produce PBHs inevitably produce gravitational waves (GWs).

PBHs ⟷ **GWs**

Mass (DM) ⟷ Frequency (space-based interferometers)

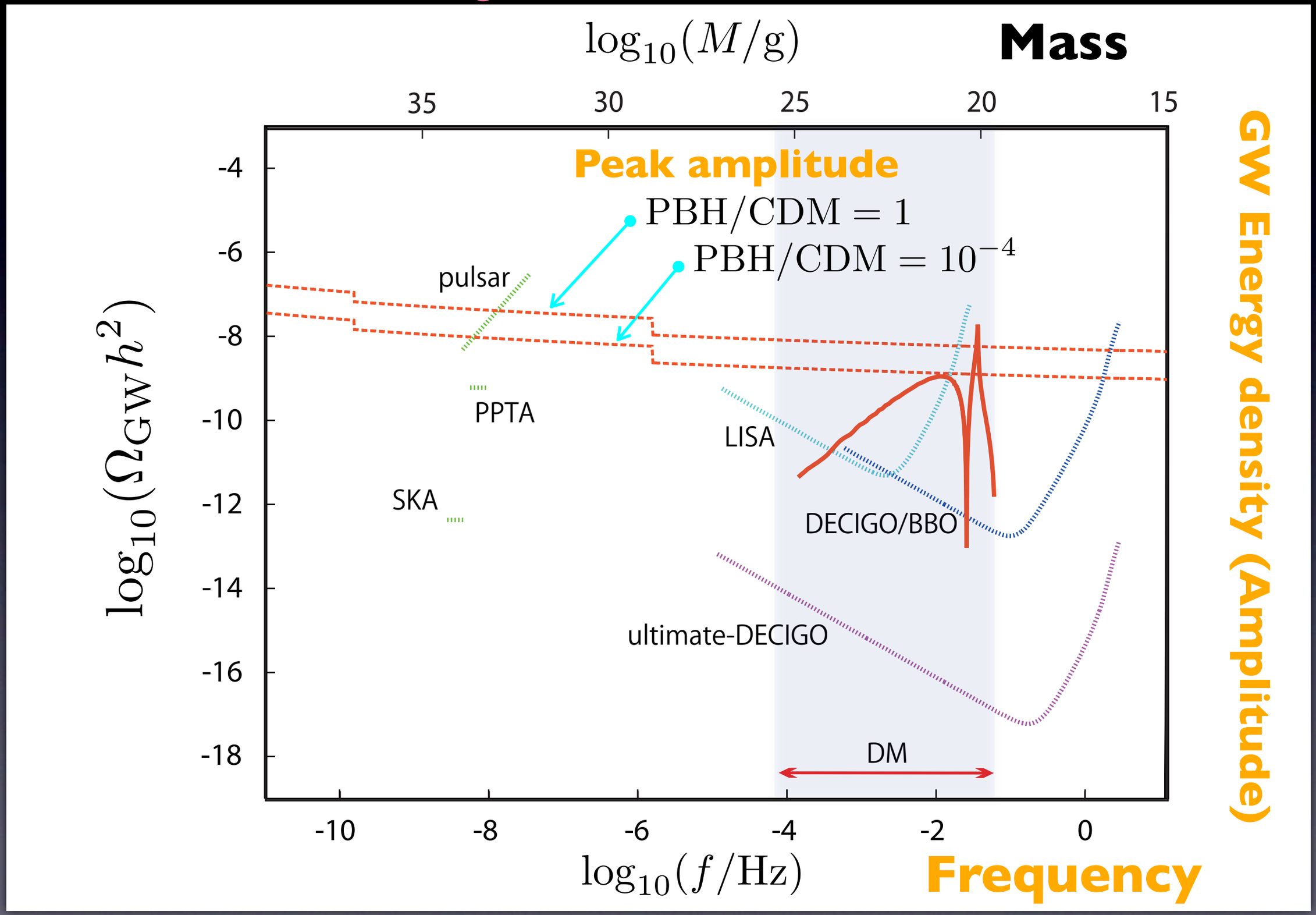
Abundance ⟷ Amplitude



DECIGO, LISA, ...

Gravitational Waves - results

Detector sensitivities & Signals



Cosmic Rays

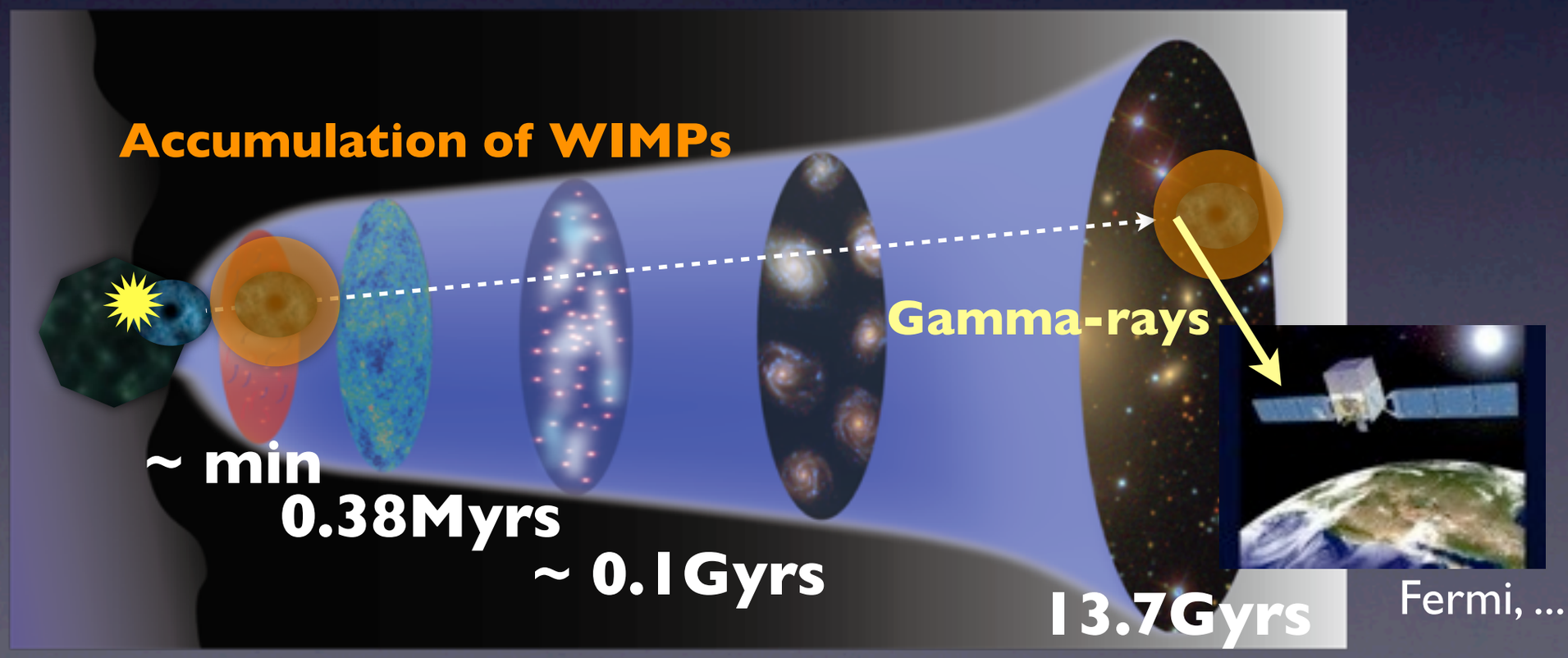
Lacki & Beacom '10
WIP with S. Matsumoto, S.Shirai, T.Yanagida

If DM is made of PBHs **and** WIMPs, "cloud" of WIMPs forms around PBHs and becomes gamma-ray sources.

PBHs
Mass, Abundance

WIMPs
Mass, Abundance, Cross sections

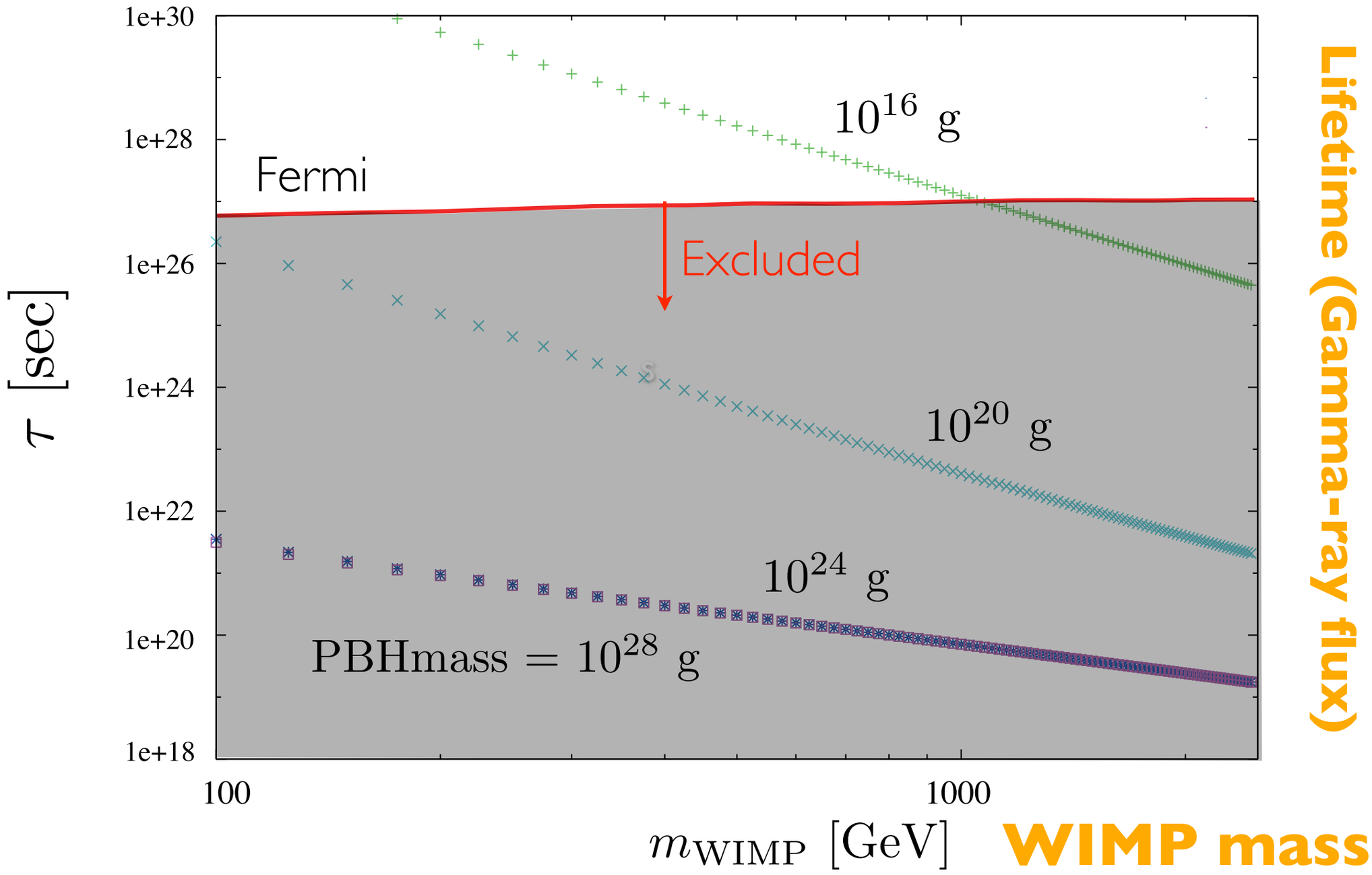
⟷ **γ-ray spectrum**



Cosmic Rays - (preliminary) results

Constraints from the Fermi telescope & Gamma-ray flux

Assumption: CDM = PBH + Neutralino (Wino like)



Summary

- Black holes produced in the early Universe (Primordial black holes, PBHs) are a candidate of dark matter.

- There are no means to observe/constrain PBHs in the mass range

$$10^{20}\ \mathrm{g} - 10^{26}\ \mathrm{g}$$

- Two new probes:

Gravitational waves

Secondary GWs from the seed density fluctuations. The planned space-based interferometers can detect/exclude the PBH-DM.

Cosmic rays

Gamma rays emitted from WIMP halos around PBHs. The PBH-DM is tightly constrained provided WIMP data.
(Inversely, WIMP models are constrained if PBHs are detected.)