

New Physics Explanations of PTA signal are incompatible with WIMPs Dark Matter

Yann Gouttenoire

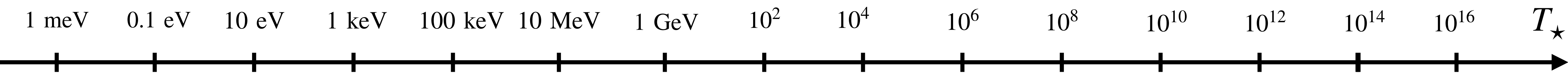
24th March 2026



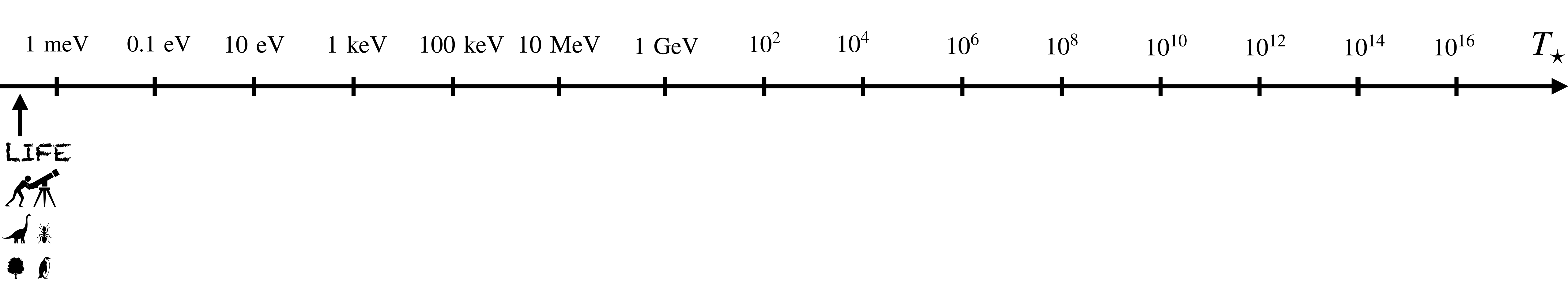
Workshop: Dark Matter Beyond the Weak Scale IV

Institute of Astrophysics in Paris

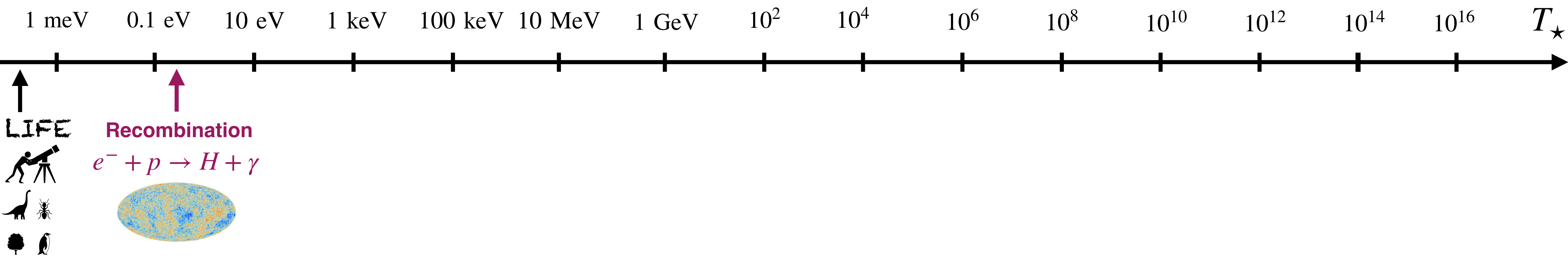




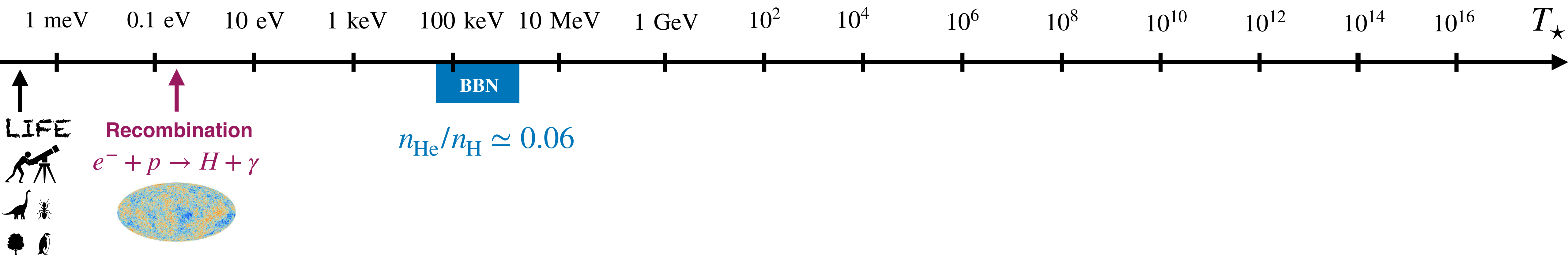
What we do know about the
History of our Universe



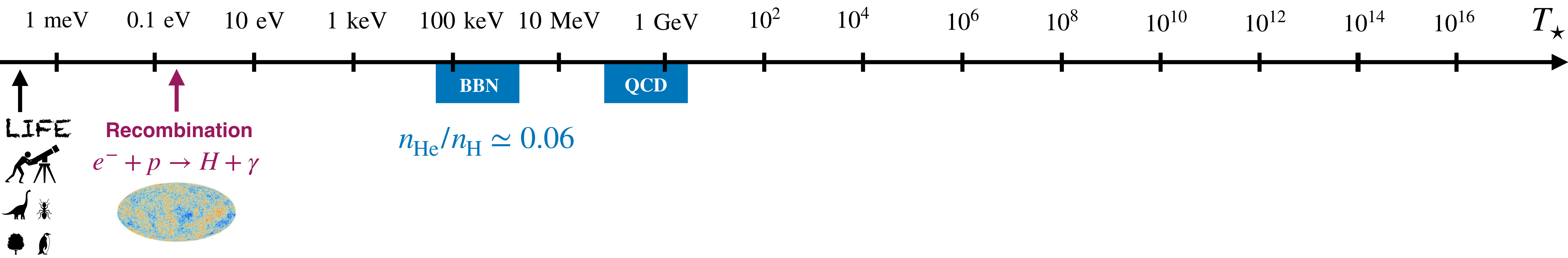
What we do know about the
 History of our Universe



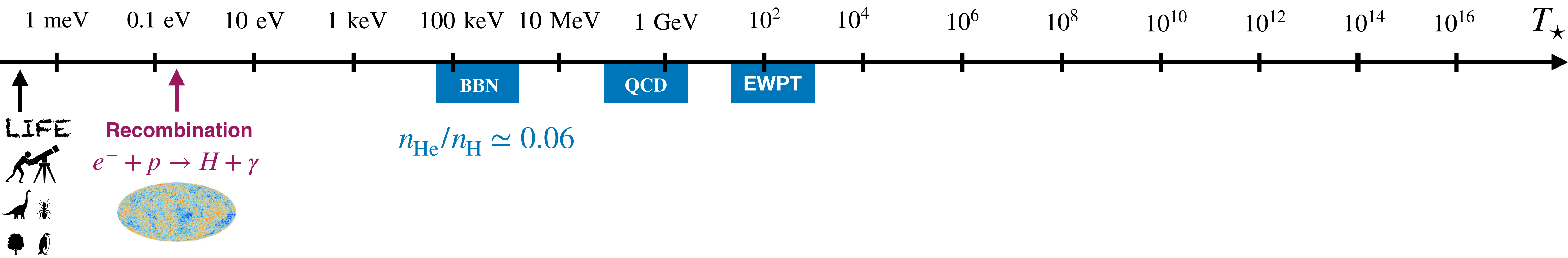
What we do know about the
 History of our Universe



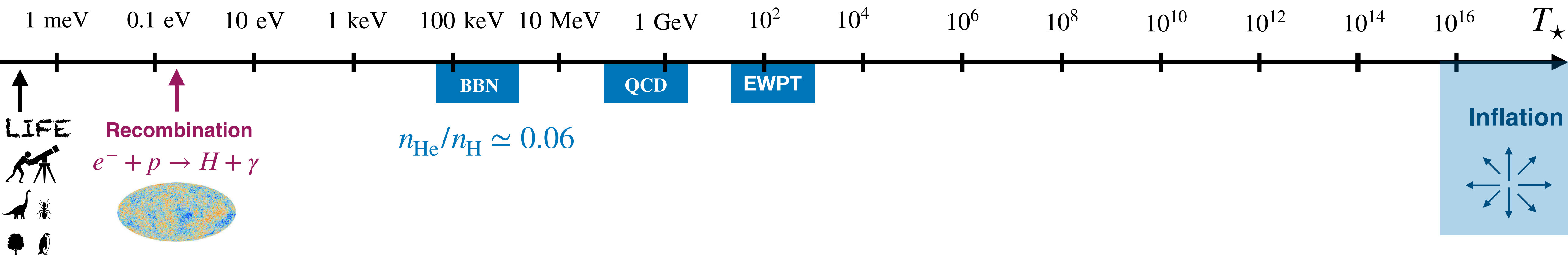
What we do know about the
 History of our Universe



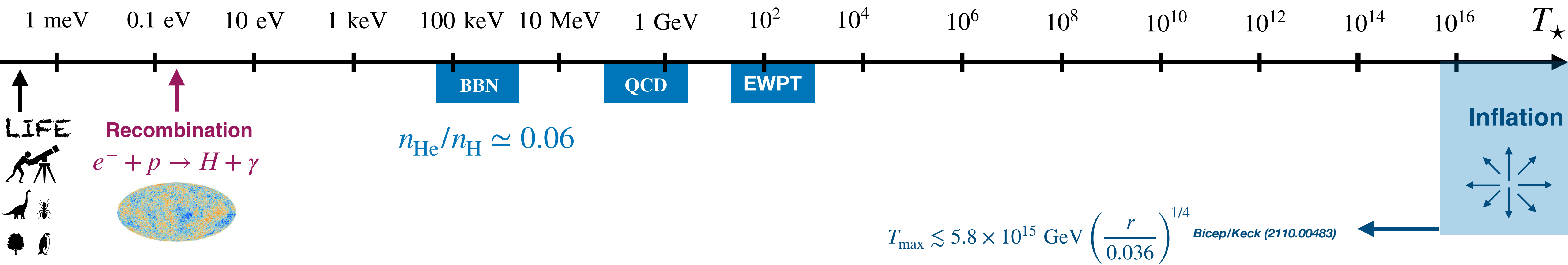
What we do know about the
 History of our Universe



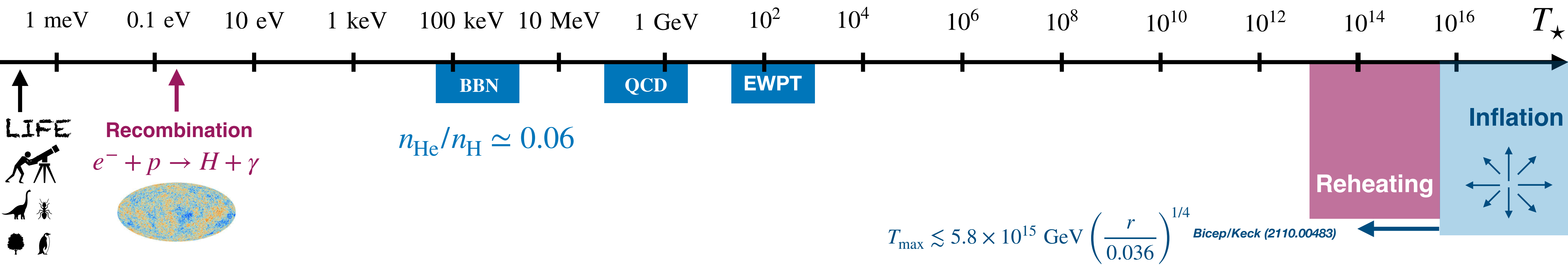
What we do know about the
 History of our Universe



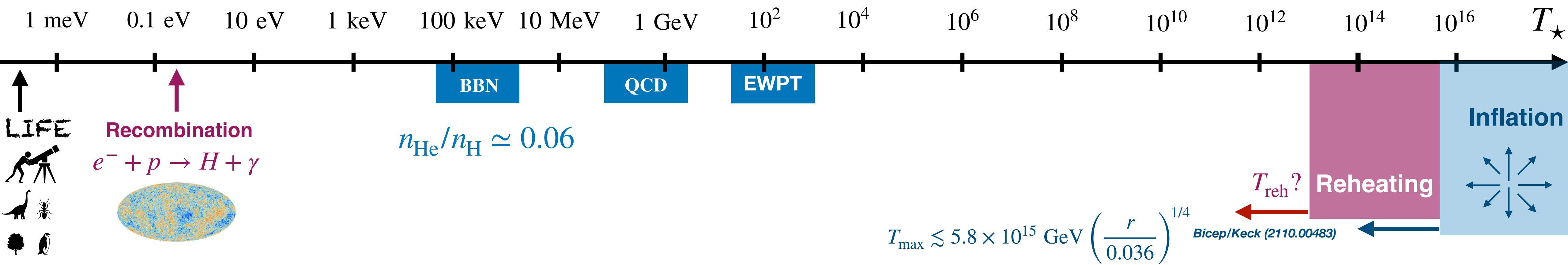
What we do know about the
 History of our Universe



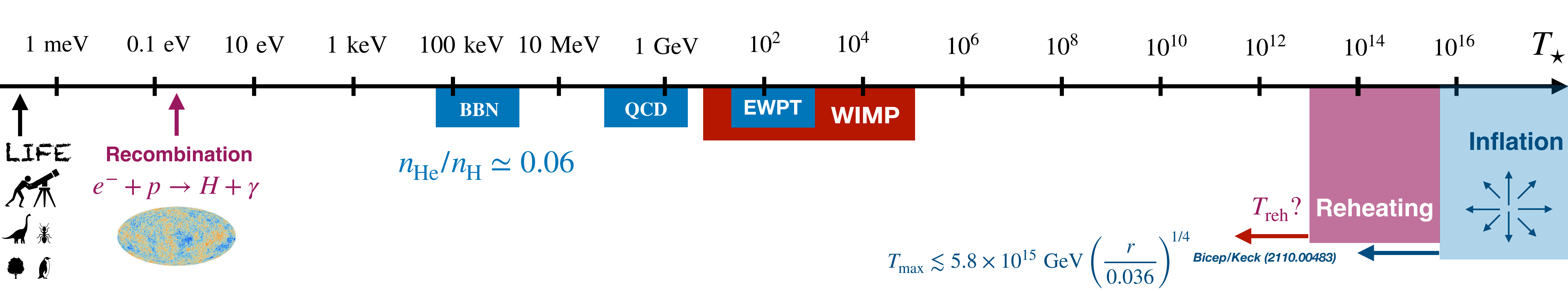
What we do know about the History of our Universe



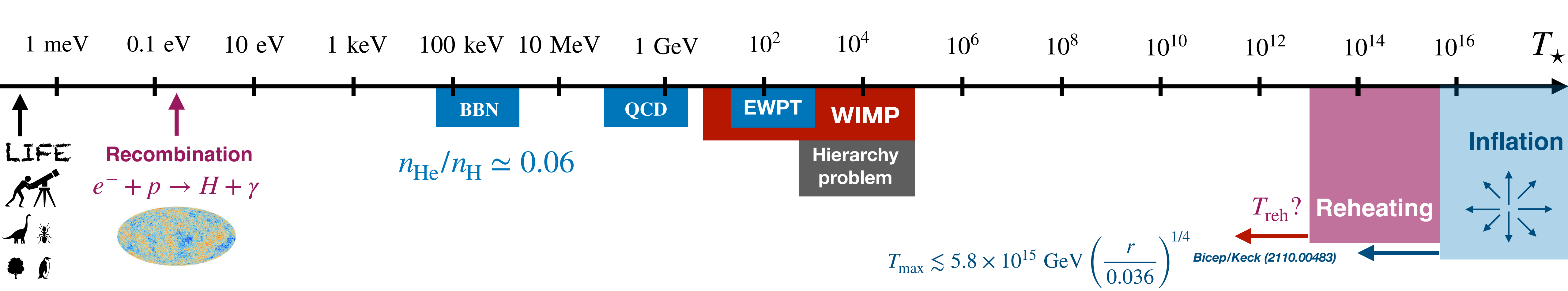
What we do know about the
History of our Universe



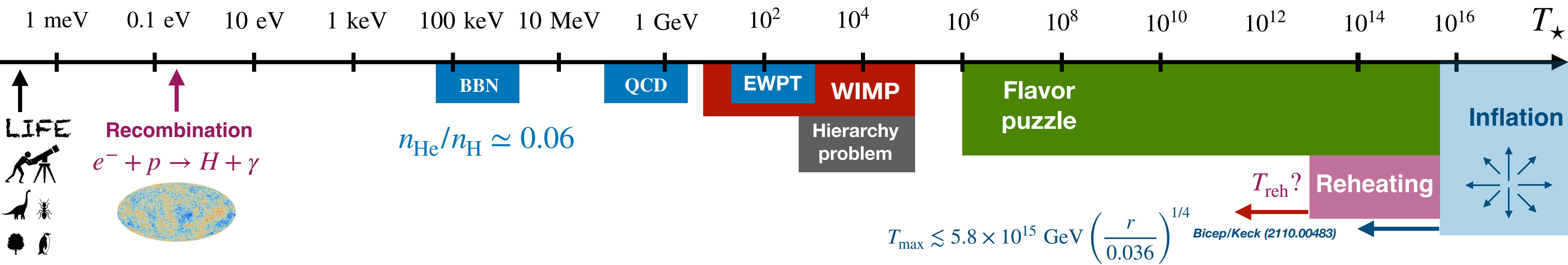
What we **don't** know about the
 History of our Universe



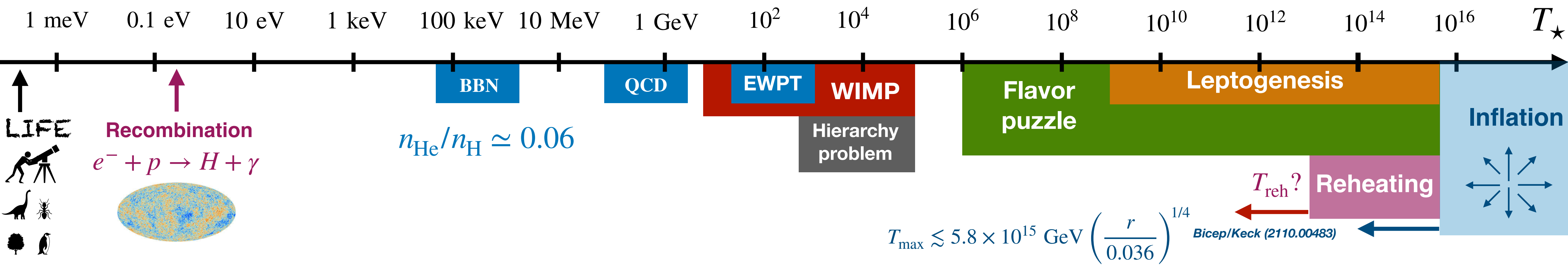
What we **don't** know about the
 History of our Universe



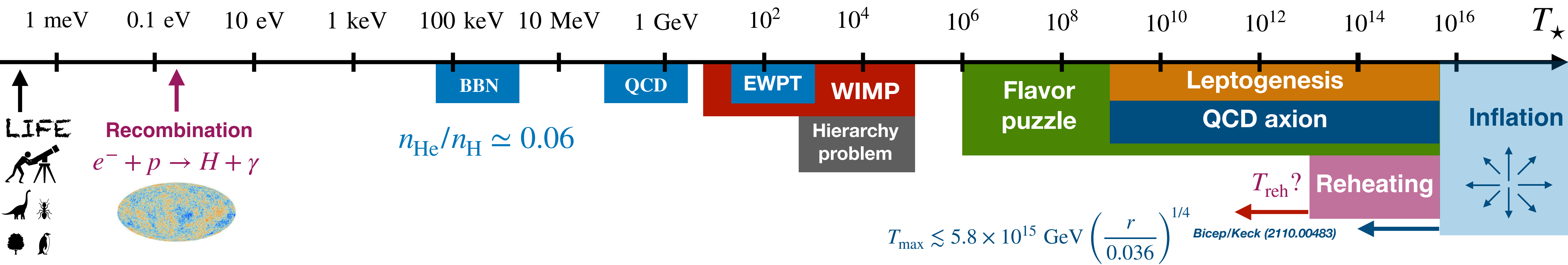
What we **don't** know about the History of our Universe



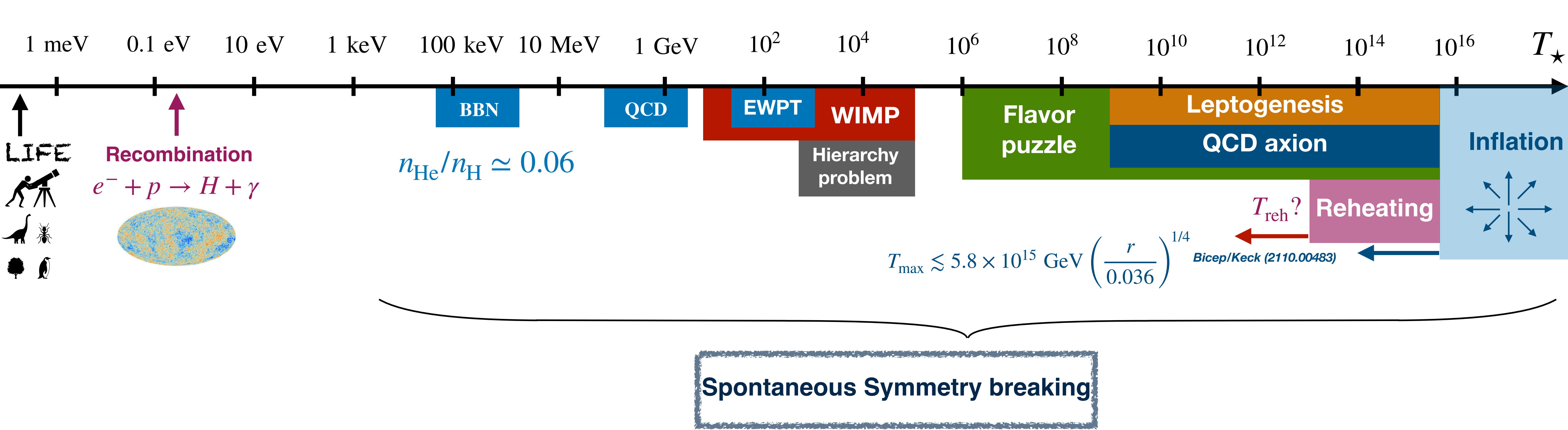
What we **don't** know about the
 History of our Universe

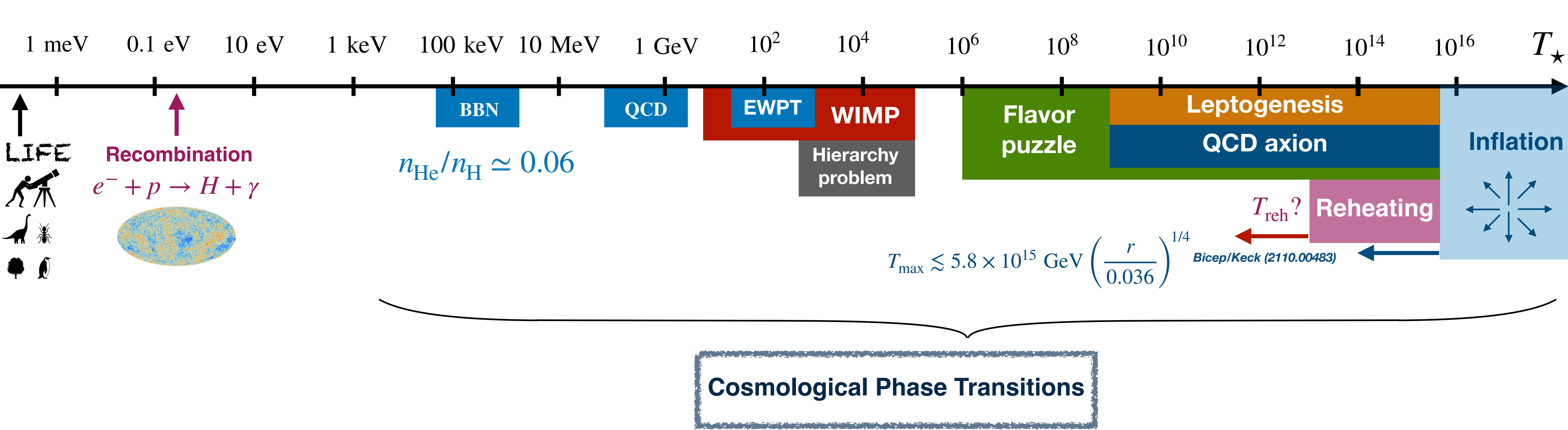


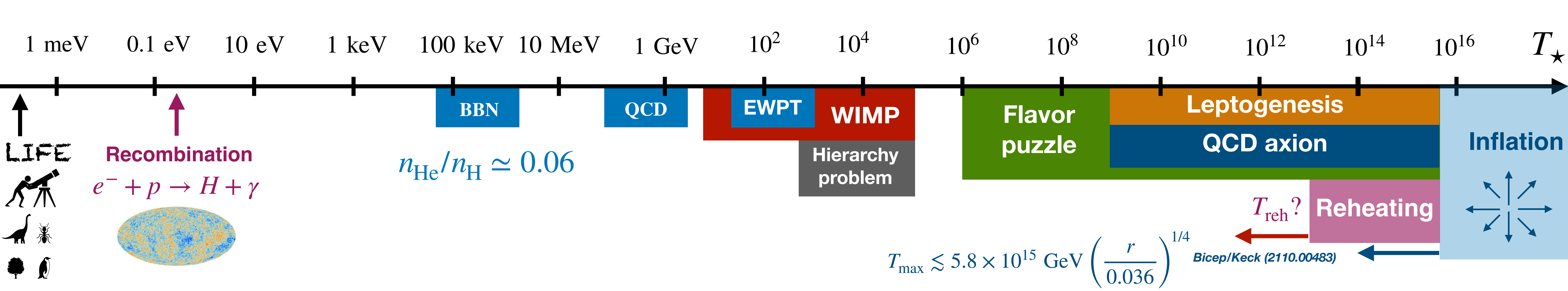
What we **don't** know about the
 History of our Universe



What we **don't** know about the History of our Universe



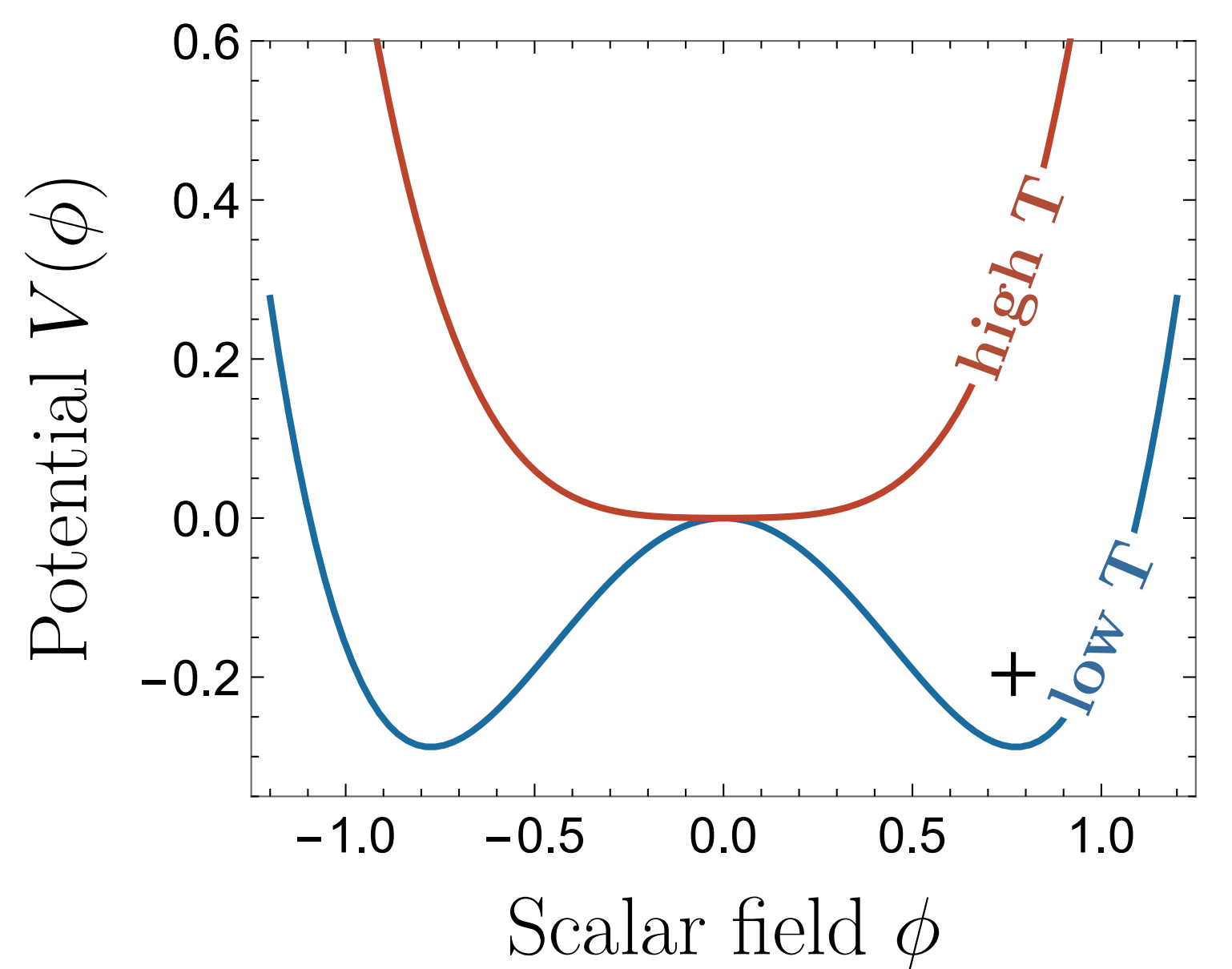


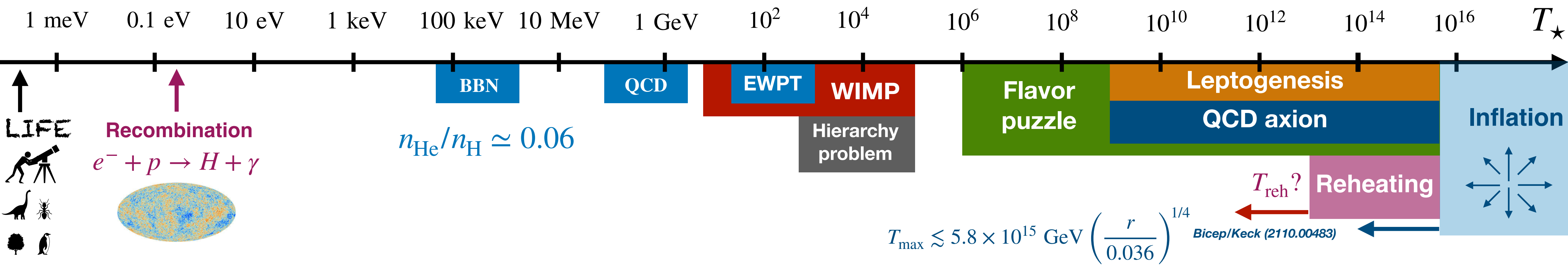


$$T_{\text{max}} \lesssim 5.8 \times 10^{15} \text{ GeV} \left(\frac{r}{0.036} \right)^{1/4}$$

Bicep/Keck (2110.00483)

Cosmological Phase Transitions

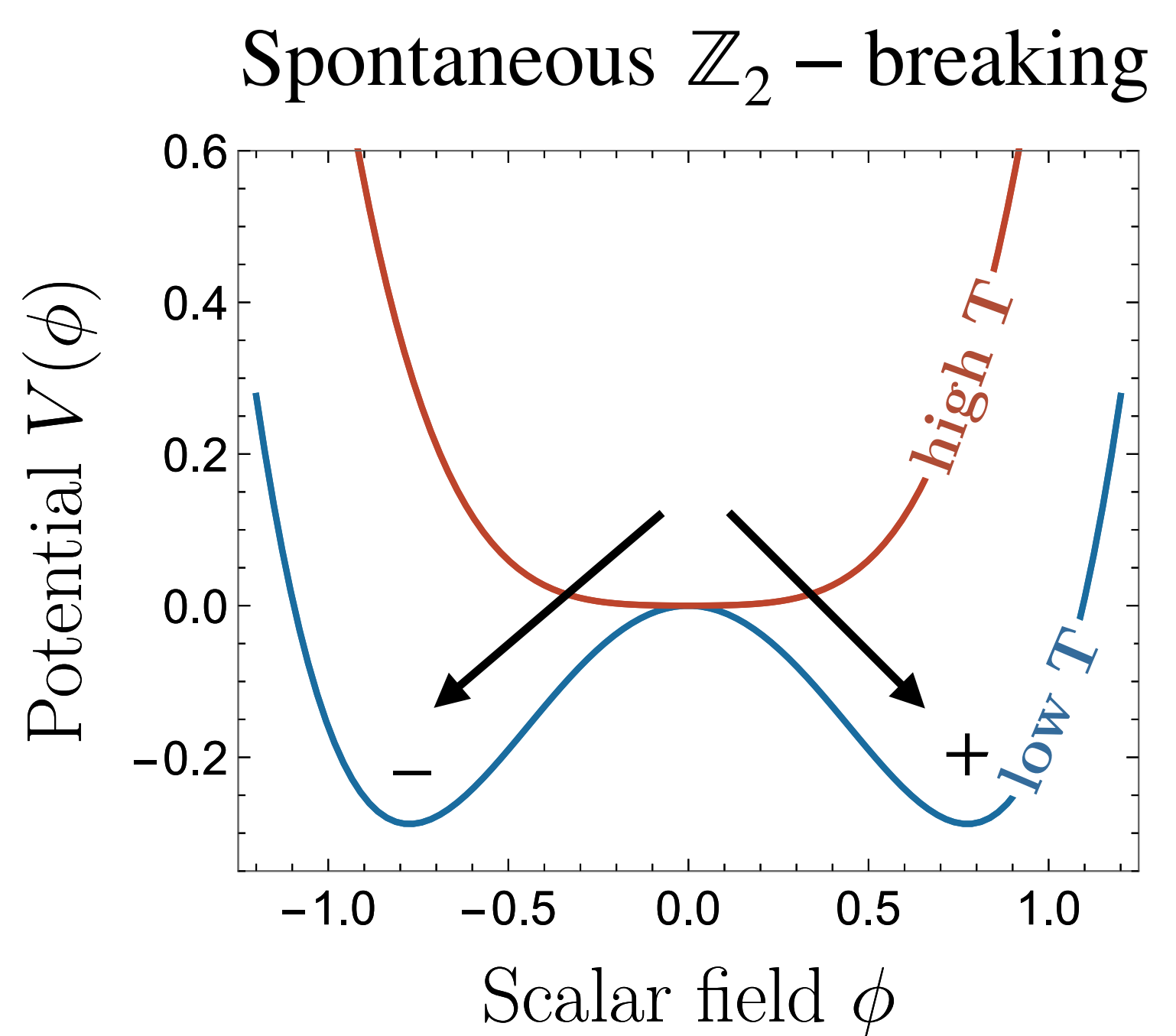
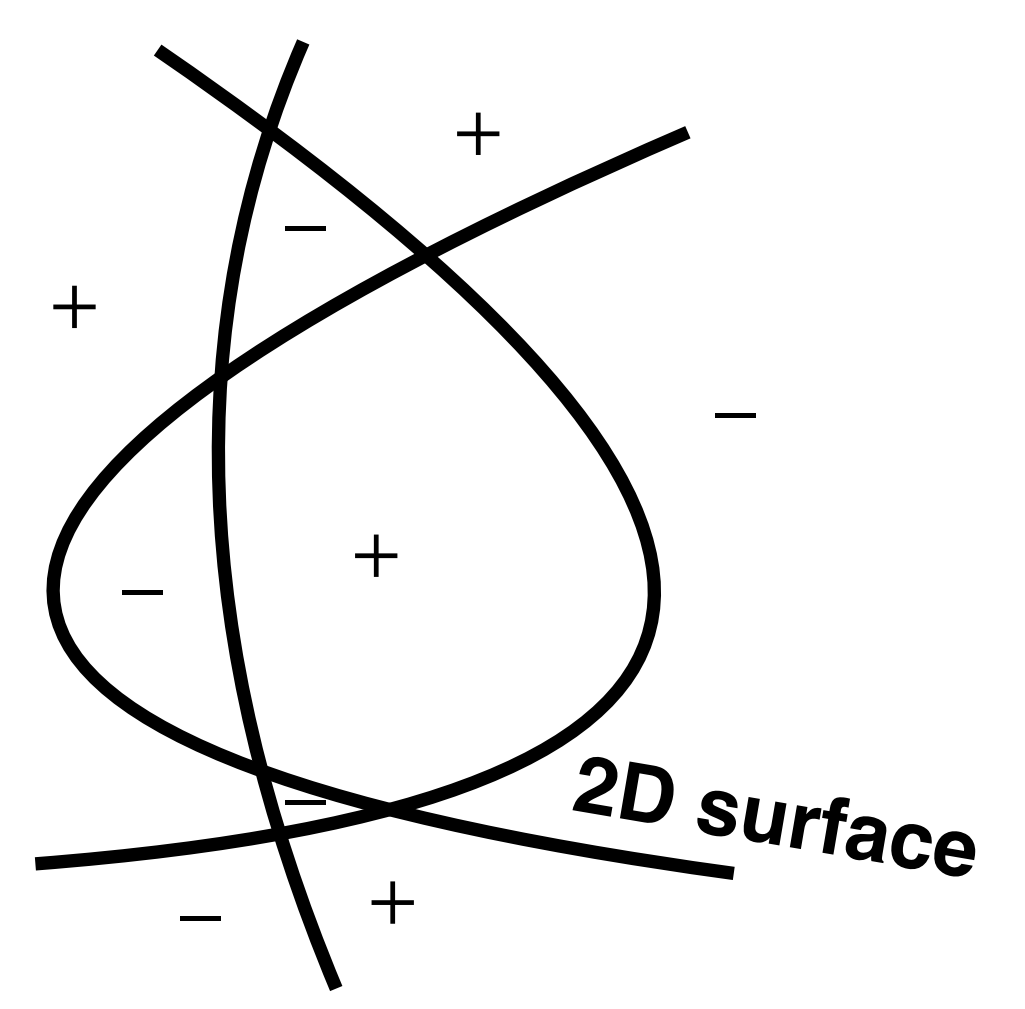


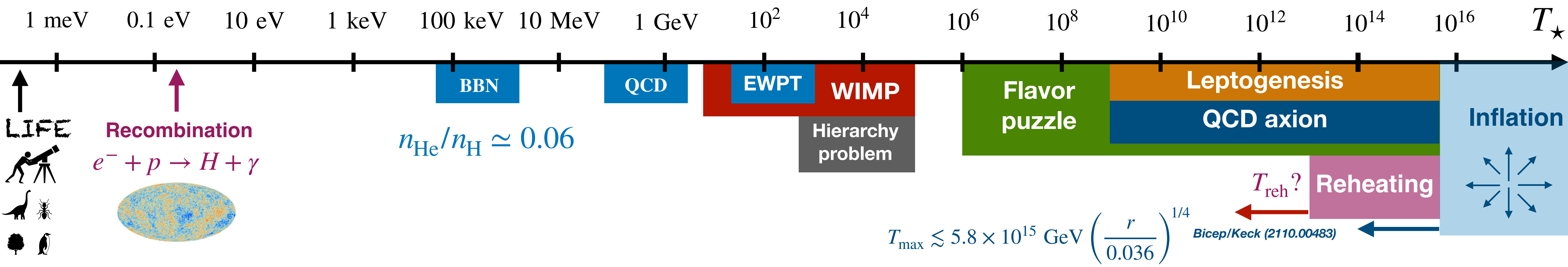


$$T_{\text{max}} \lesssim 5.8 \times 10^{15} \text{ GeV} \left(\frac{r}{0.036} \right)^{1/4}$$

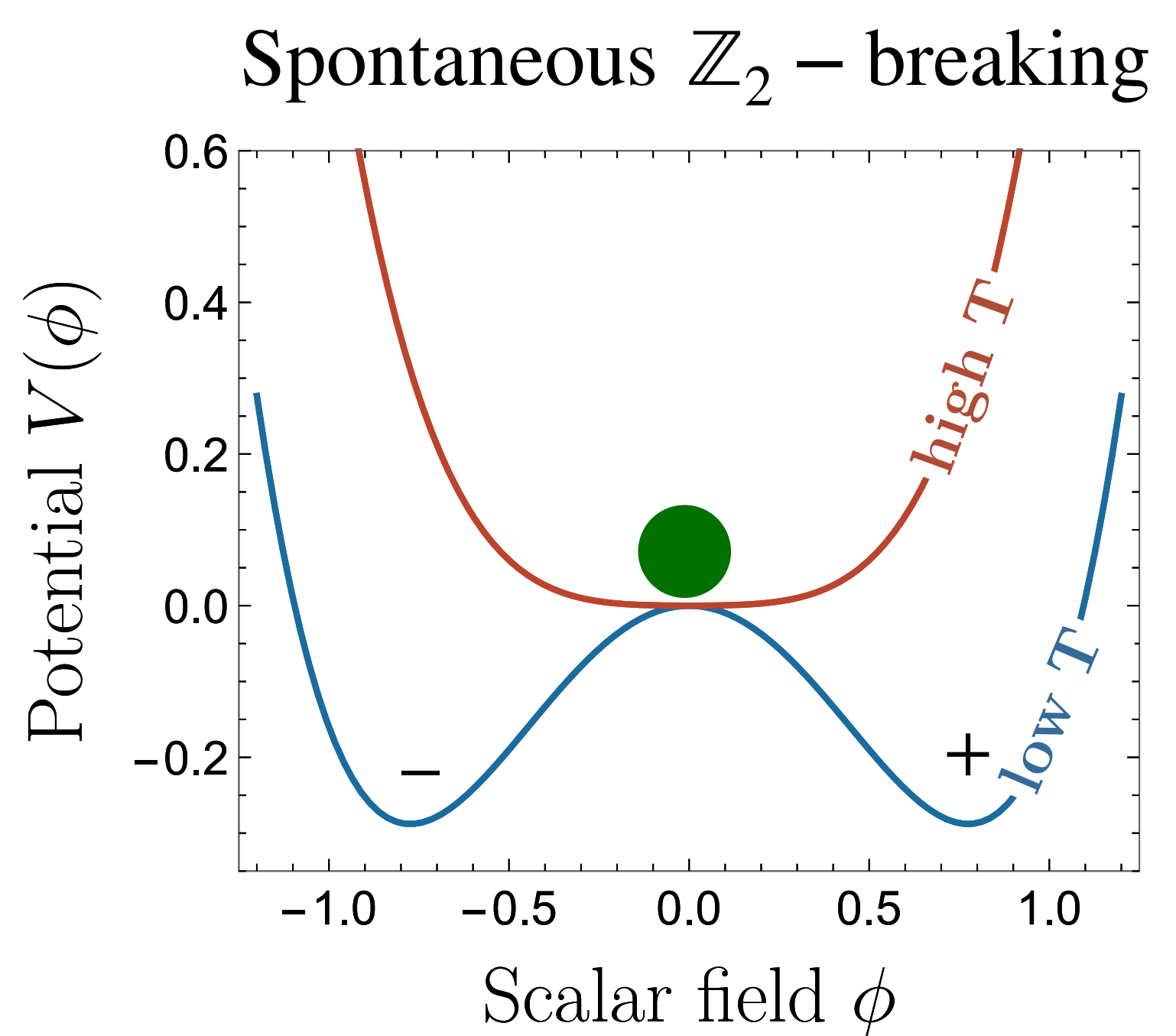
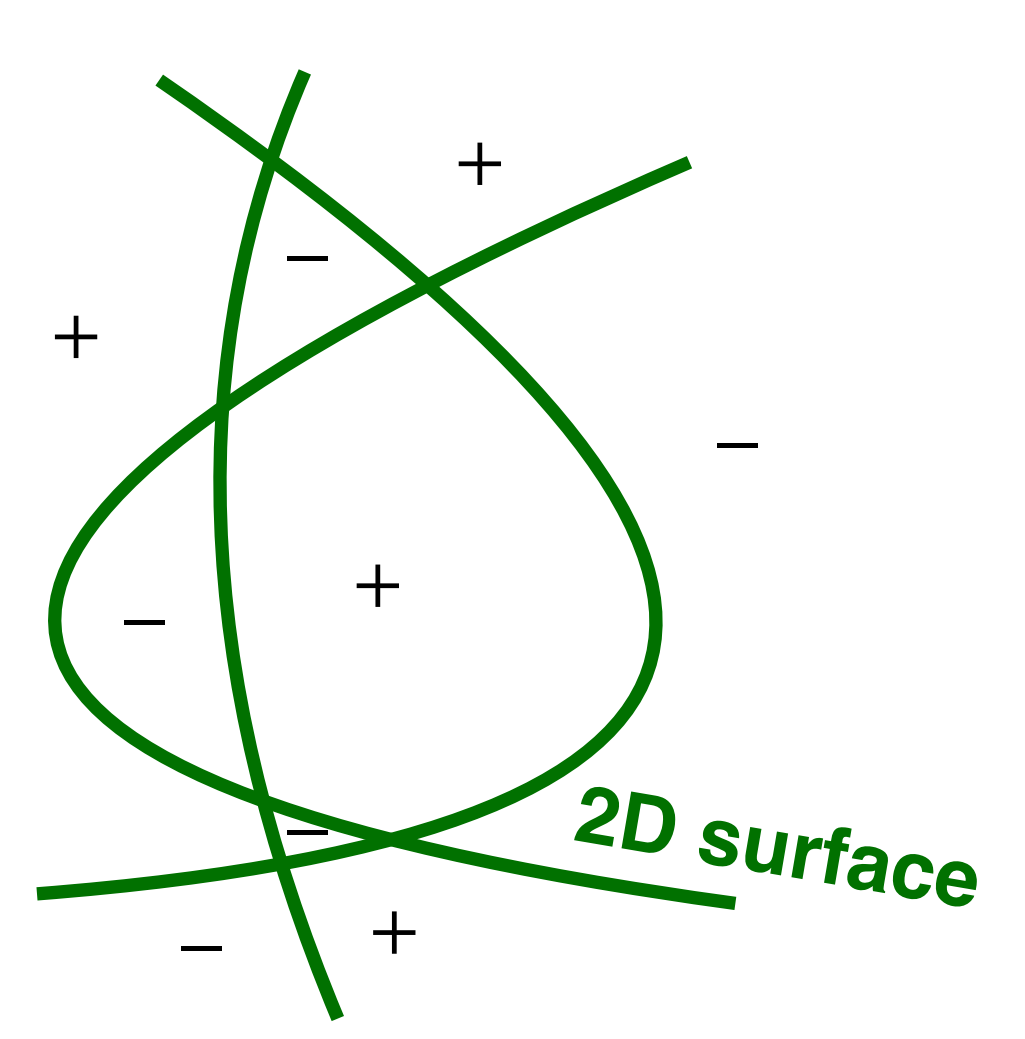
Bicep/Keck (2110.00483)

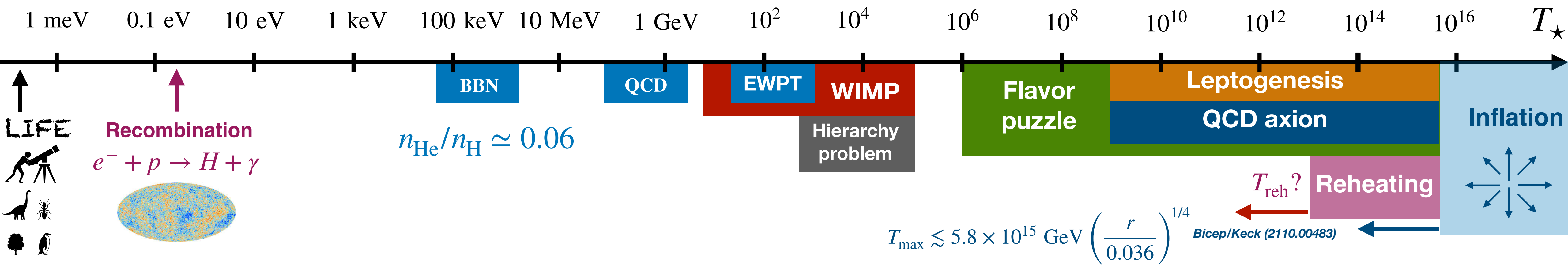
Cosmological Phase Transitions



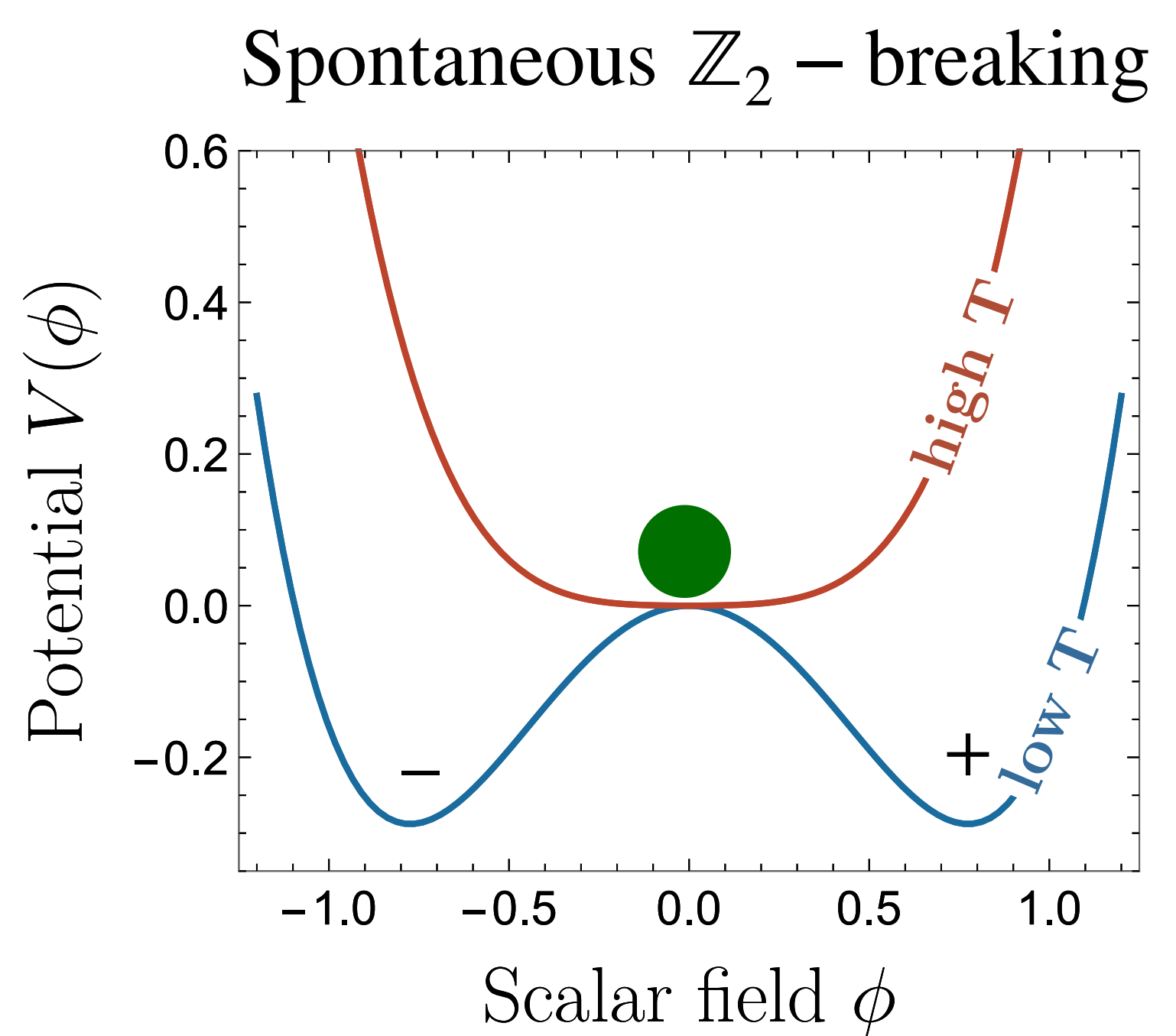
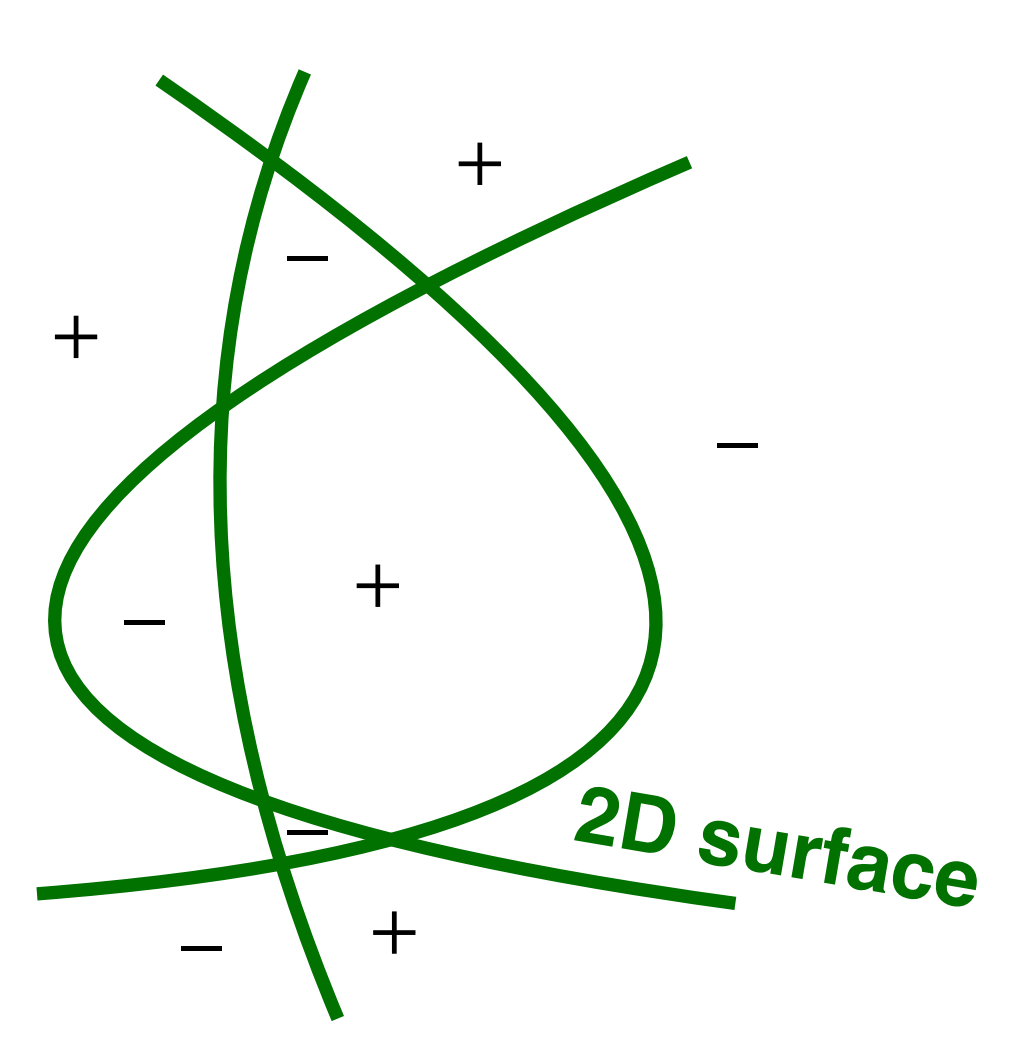


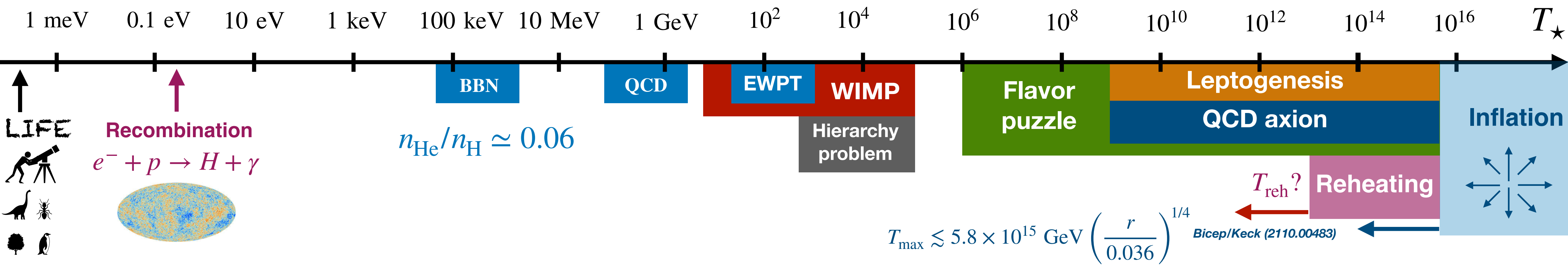
Cosmological Phase Transitions



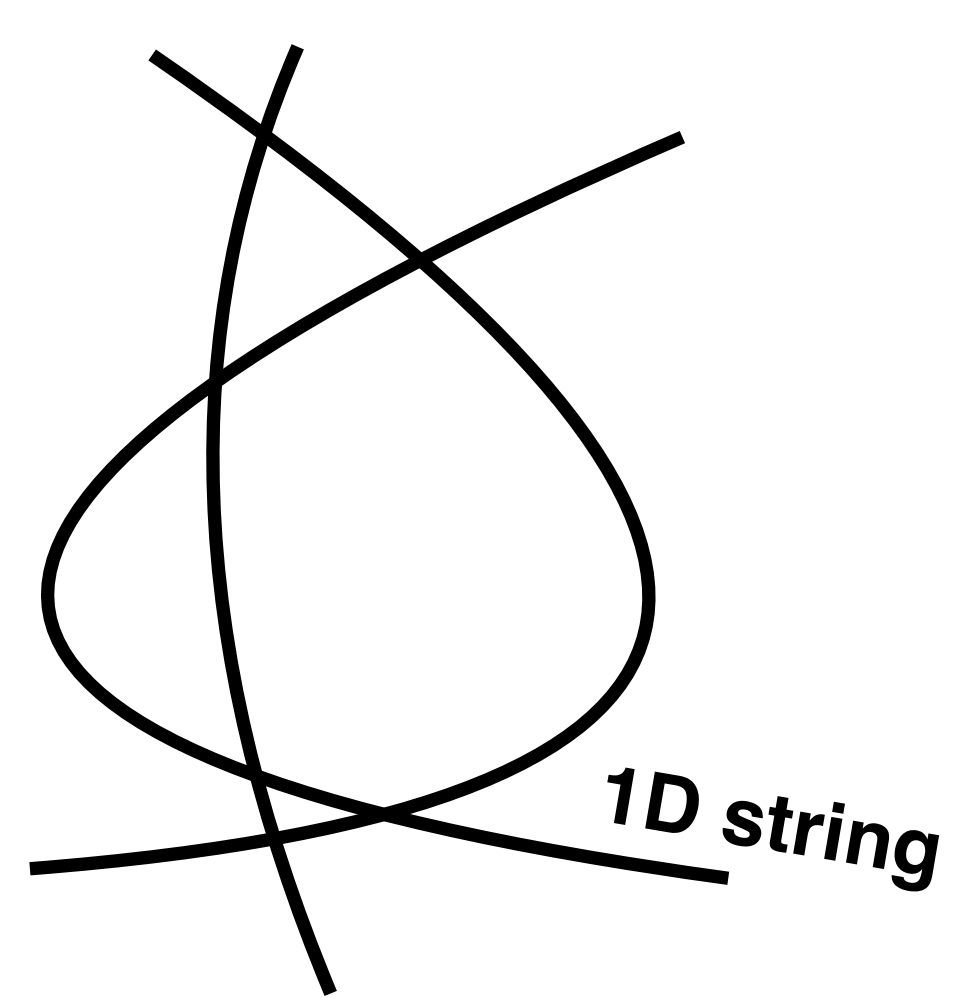


Cosmological Phase Transitions

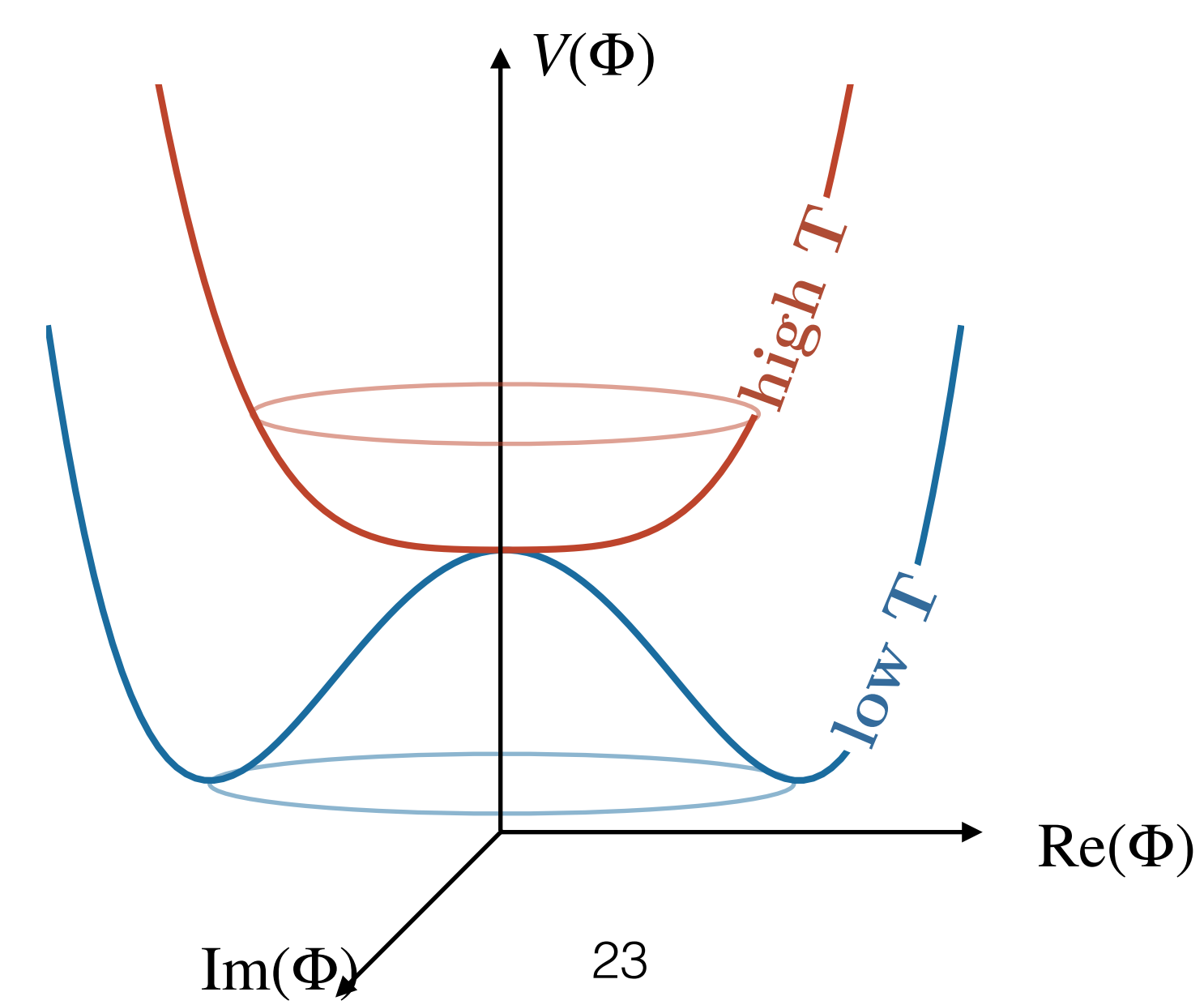


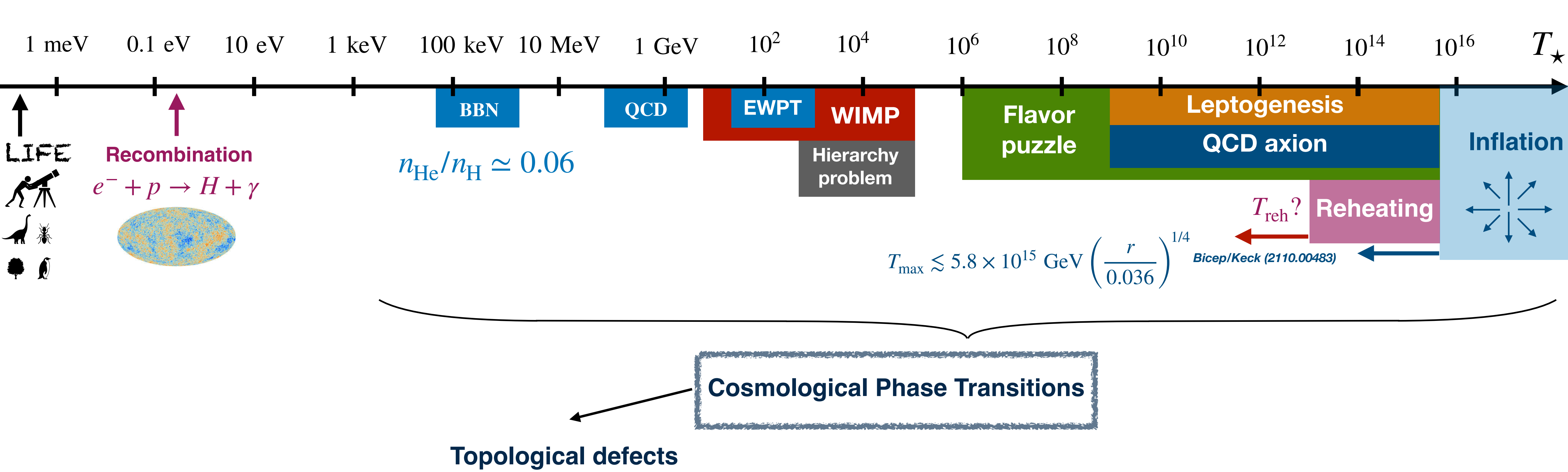


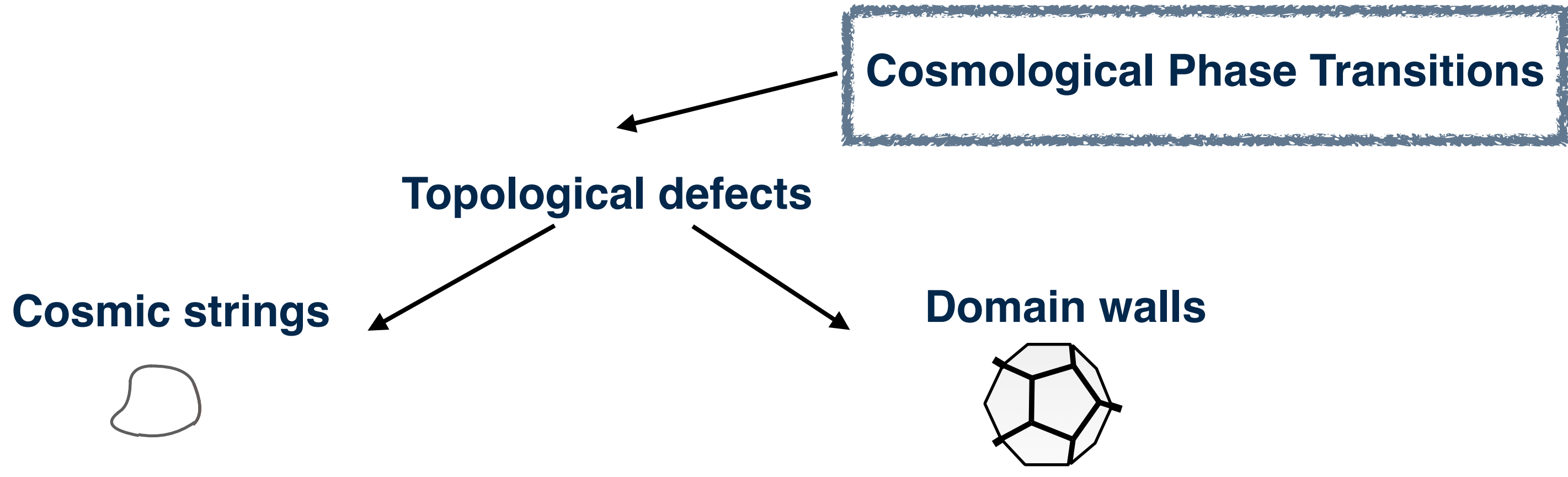
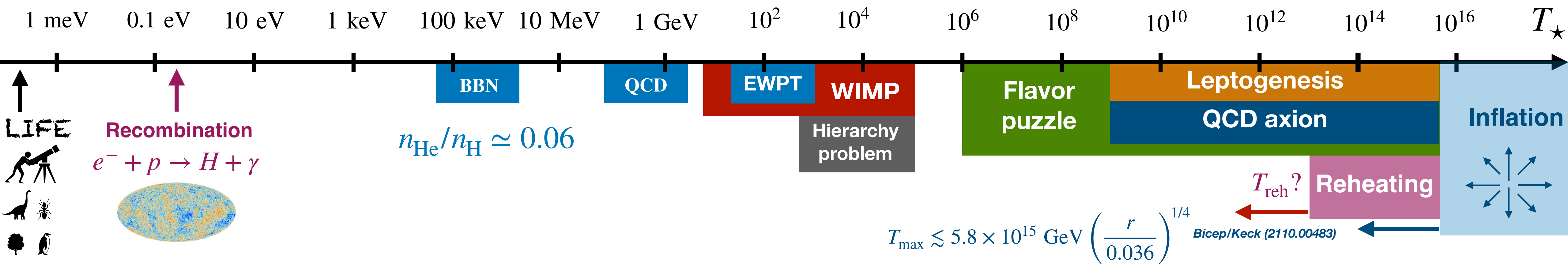
Cosmological Phase Transitions

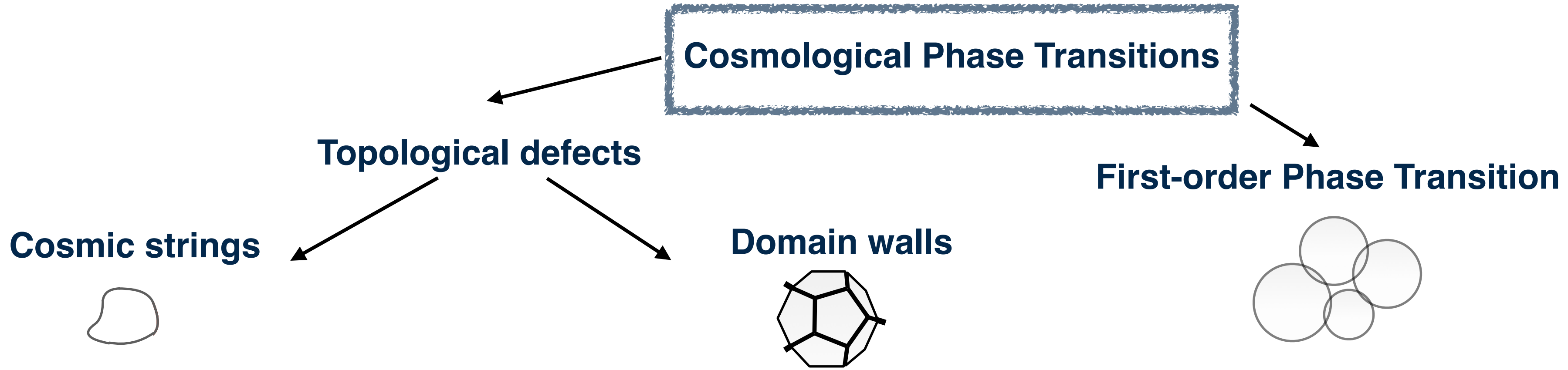
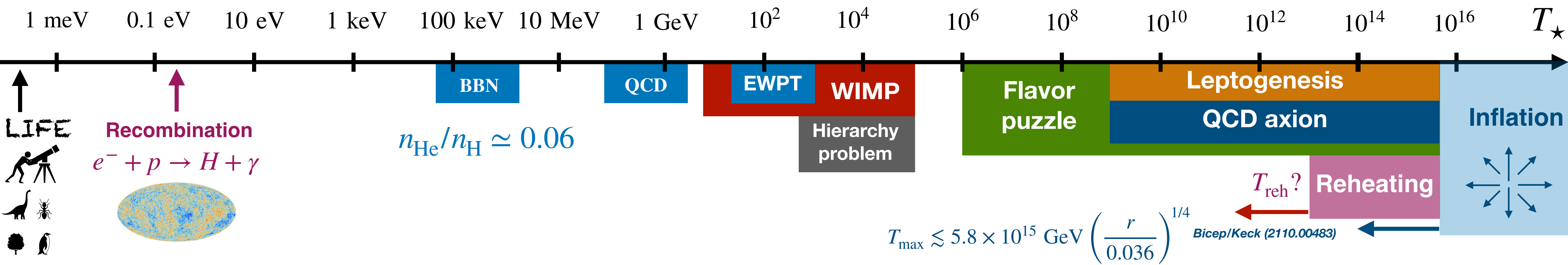


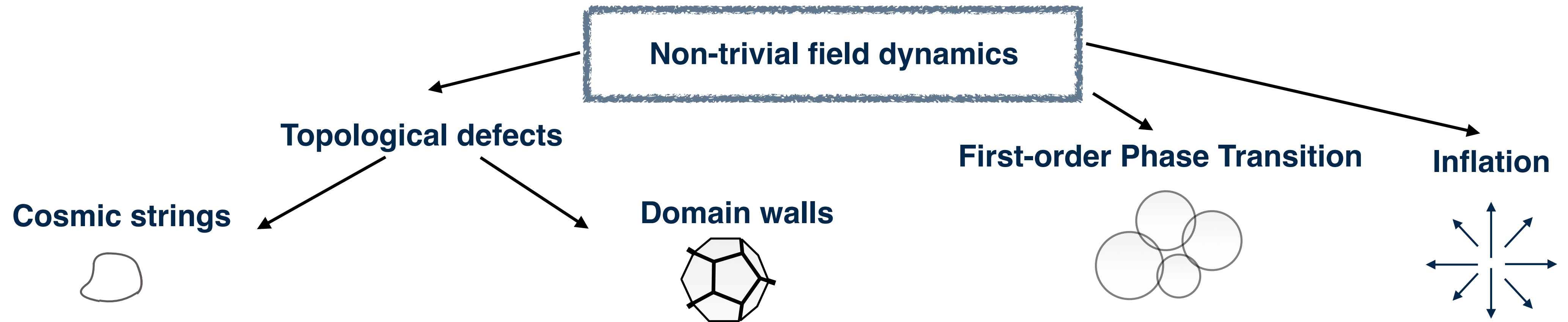
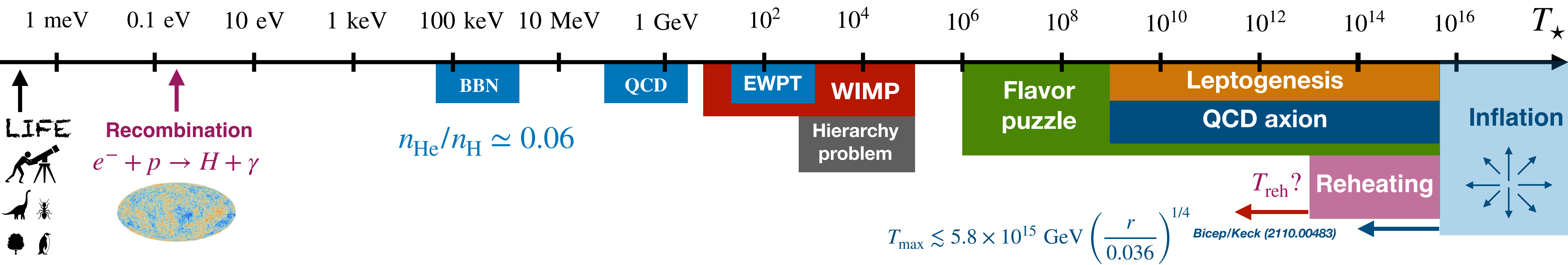
Spontaneous U(1) – breaking

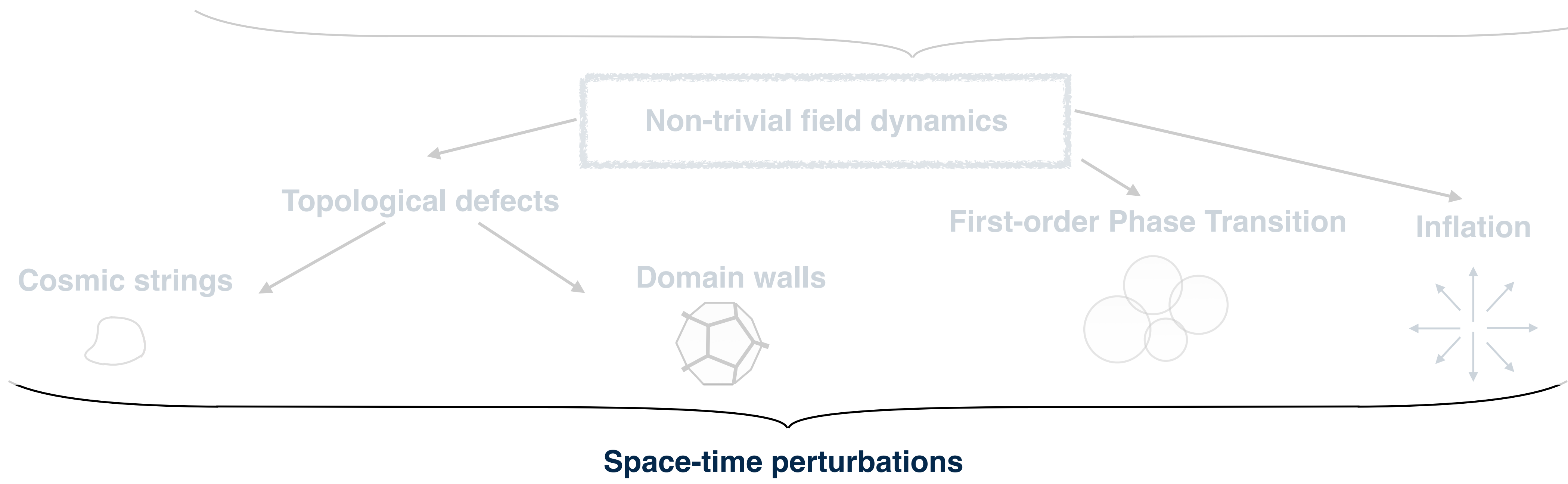
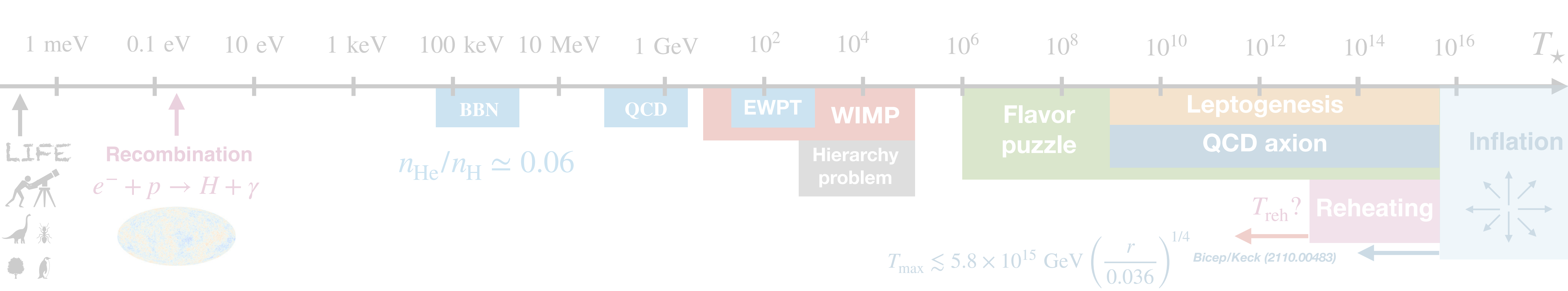


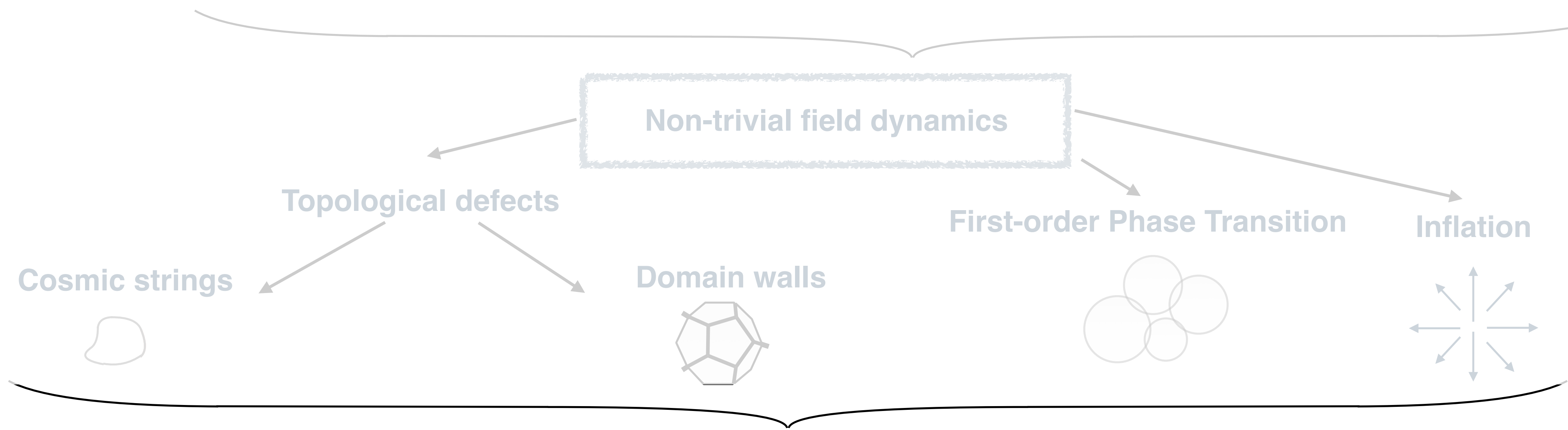
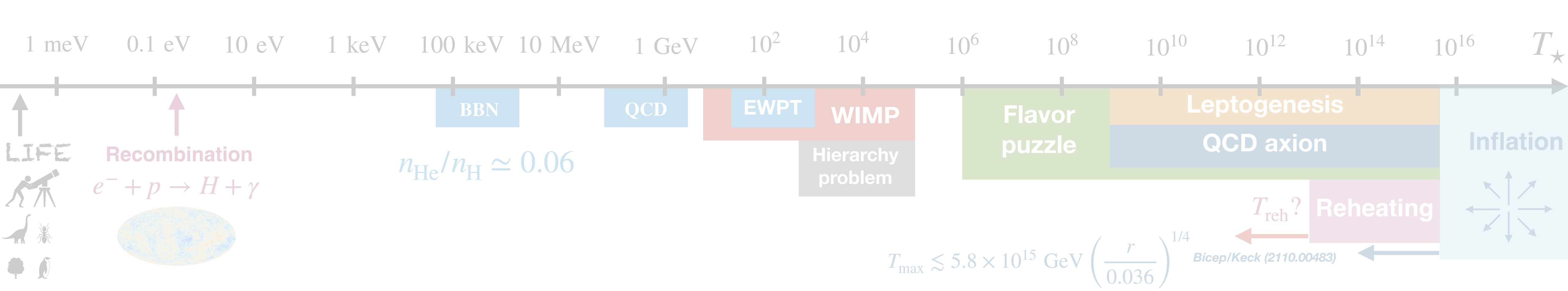








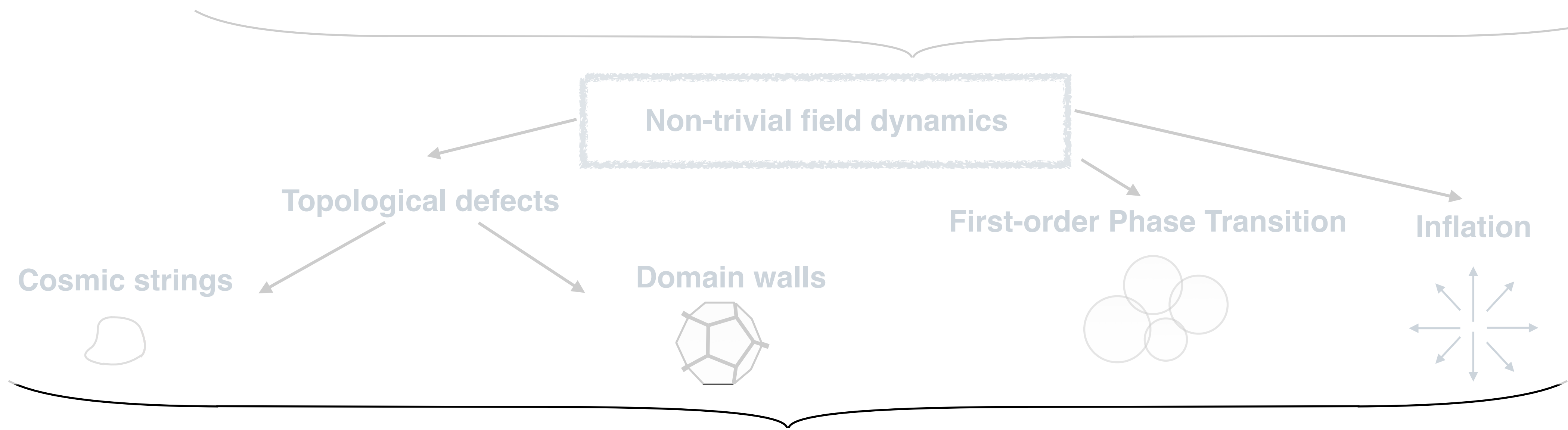
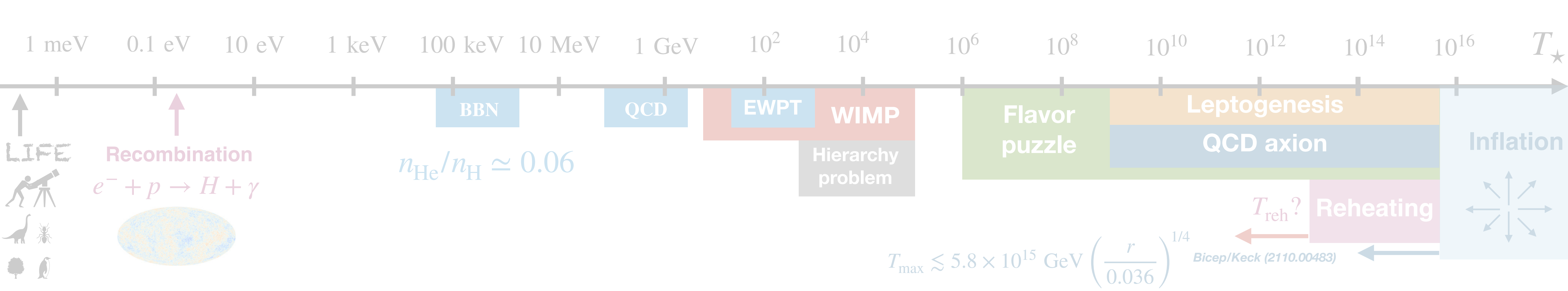




Space-time perturbations

Gravitational Waves (GWs)

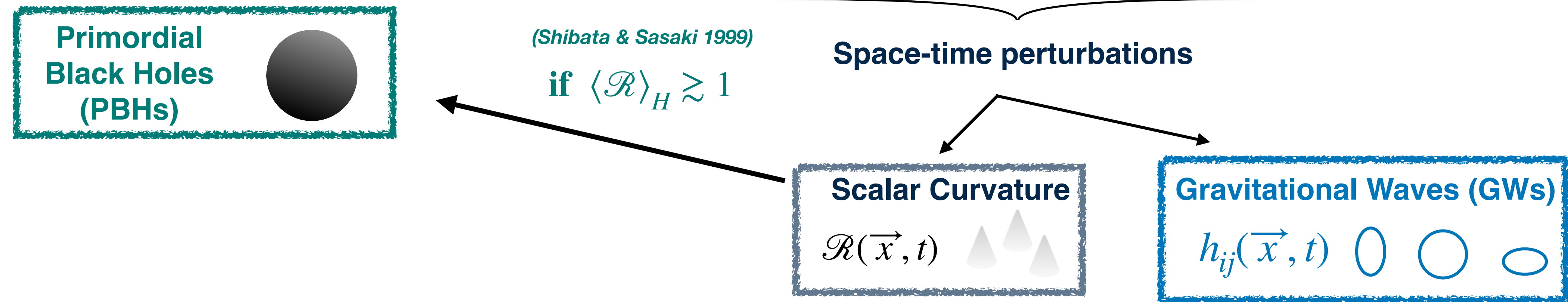
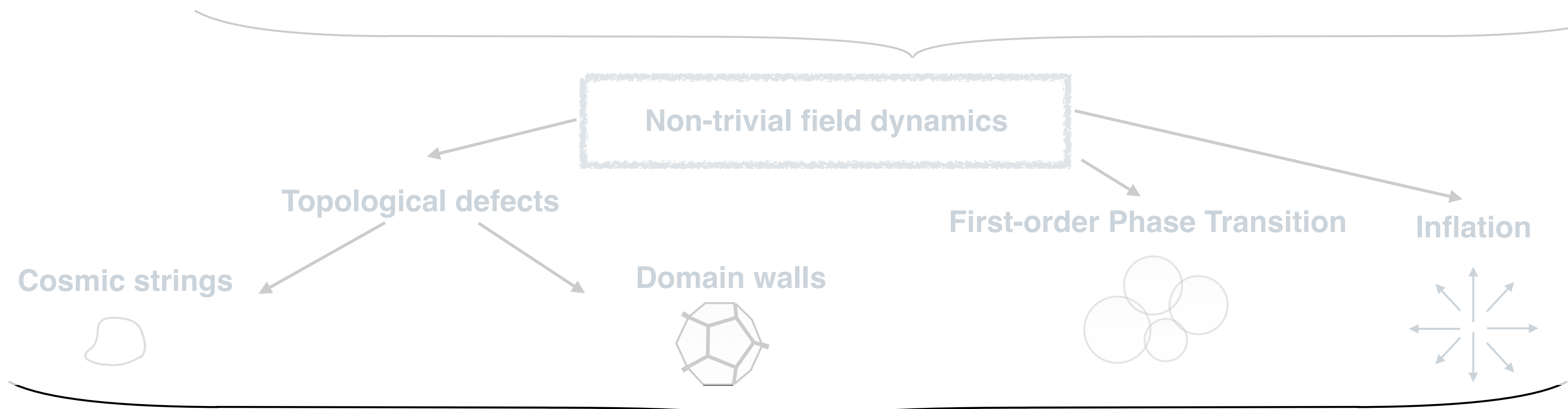
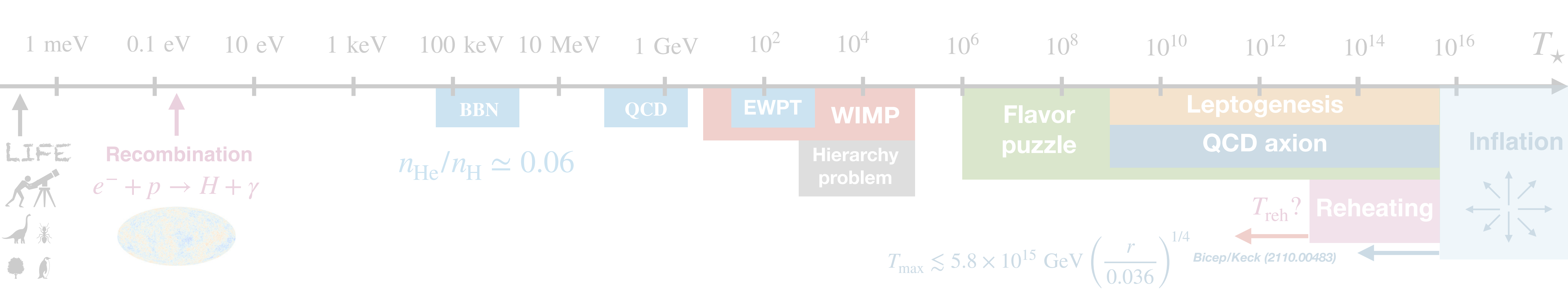
$$h_{ij}(\vec{x}, t) \quad \text{O} \quad \text{O} \quad \text{O}$$

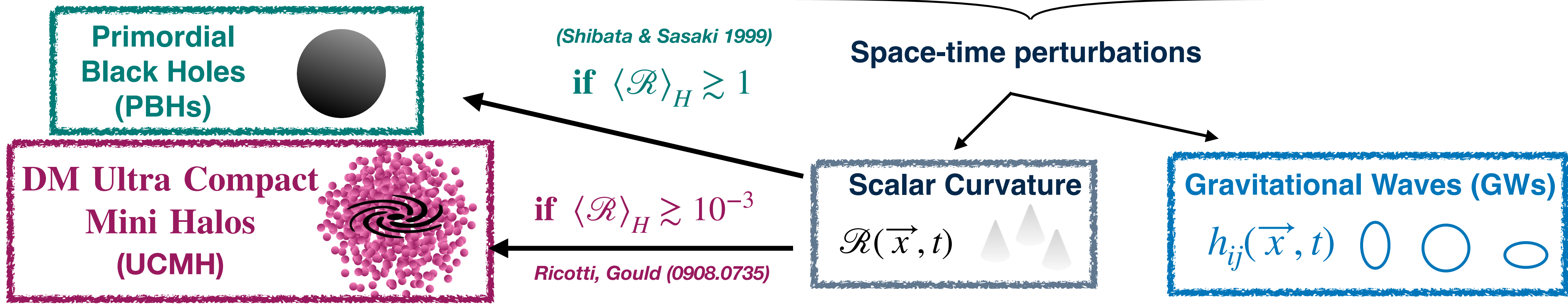
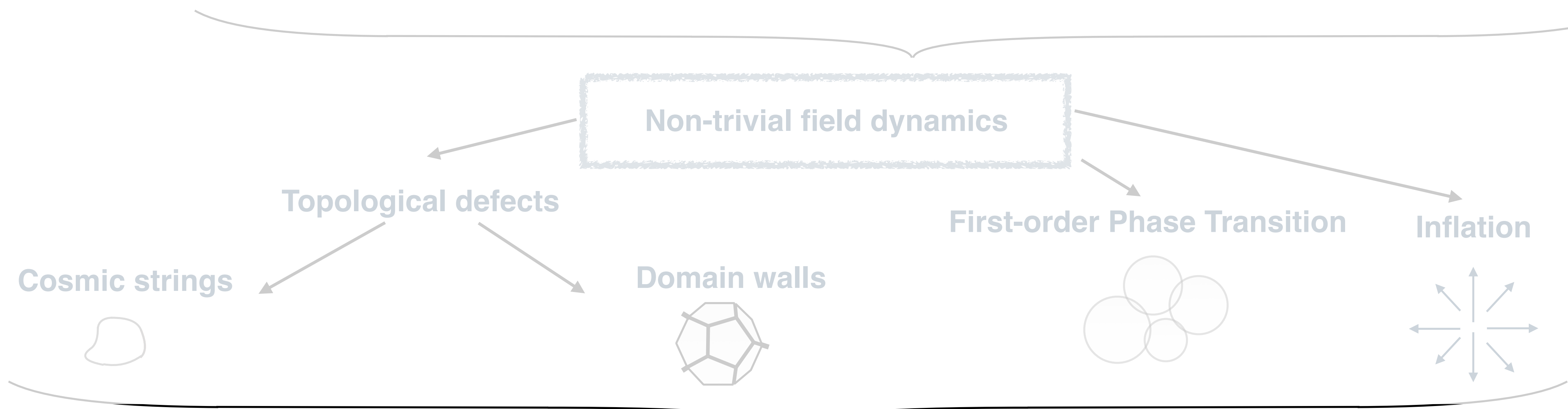
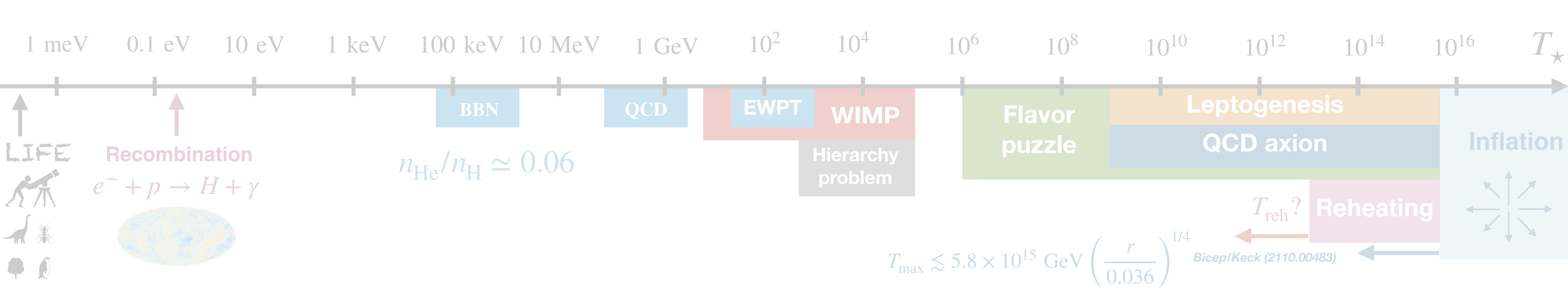


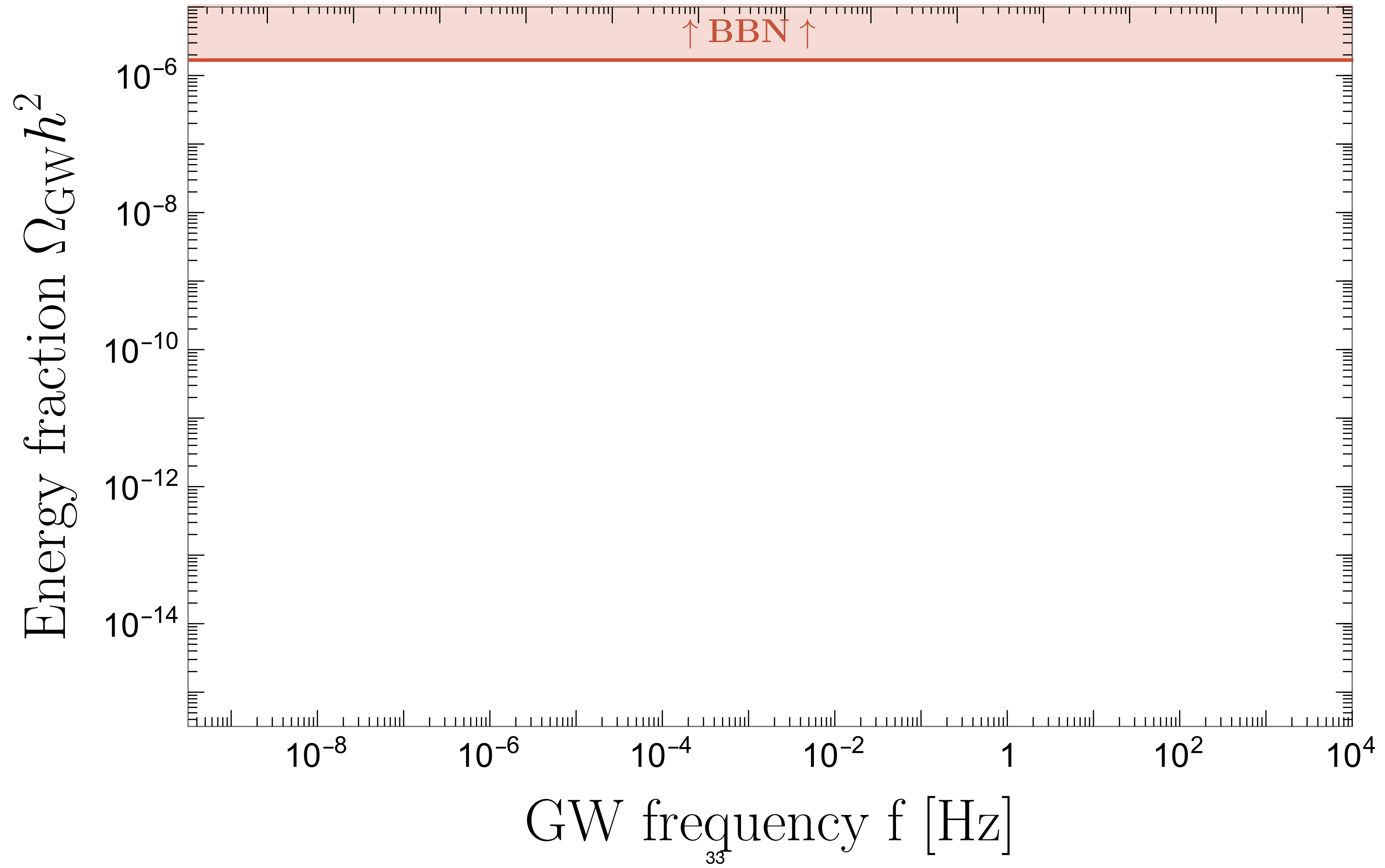
Space-time perturbations

Scalar Curvature
 $\mathcal{R}(\vec{x}, t)$

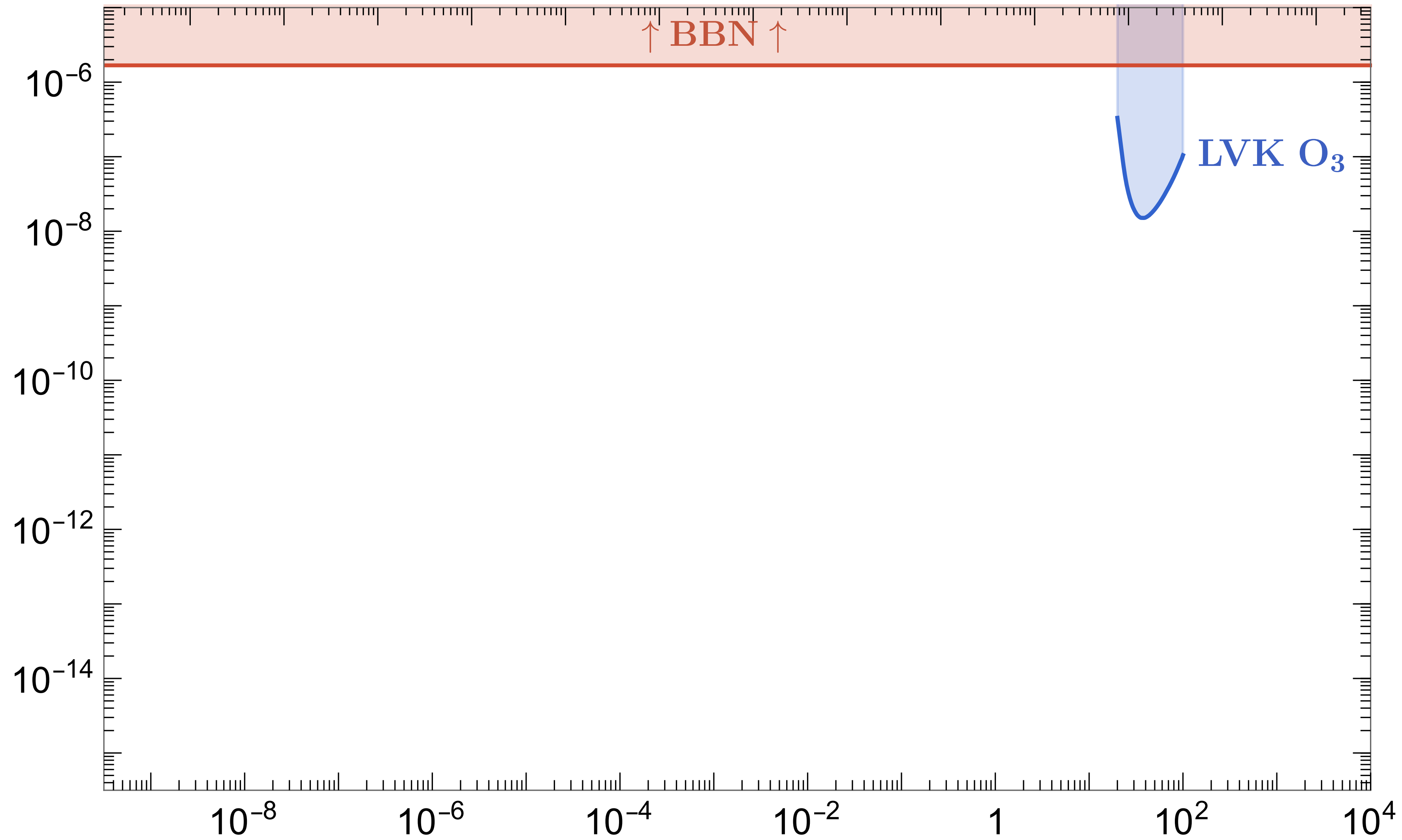
Gravitational Waves (GWs)
 $h_{ij}(\vec{x}, t)$





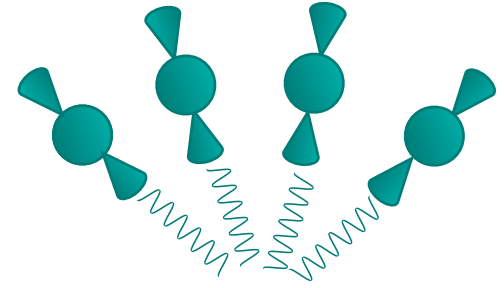


Energy fraction $\Omega_{\text{GW}} h^2$

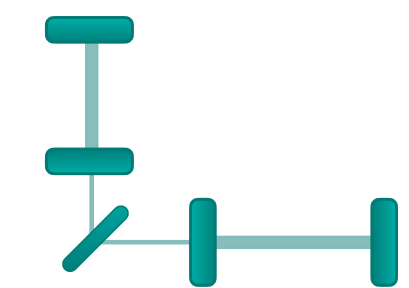


Laser interferometers (Earth-based)

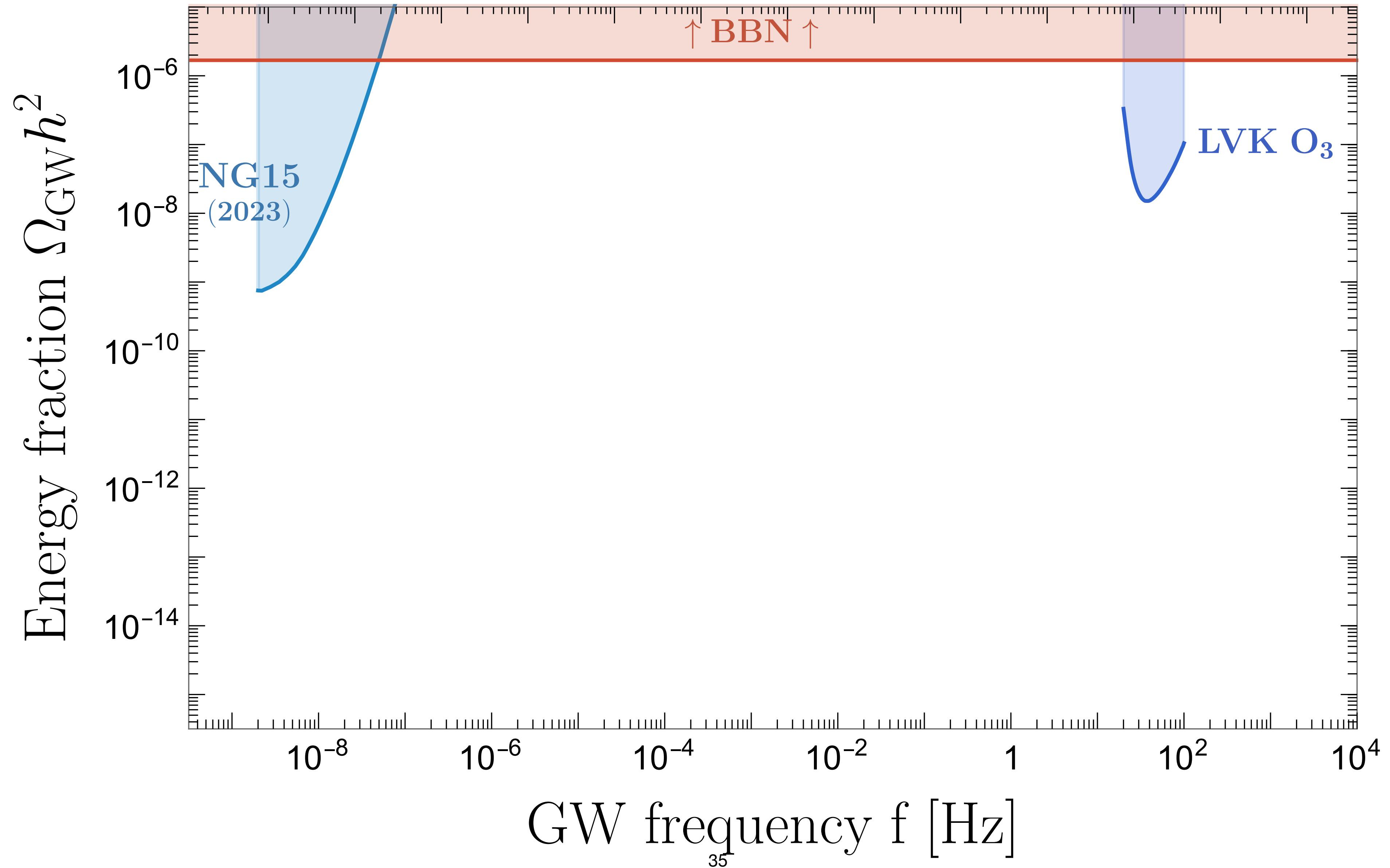
GW frequency f [Hz]

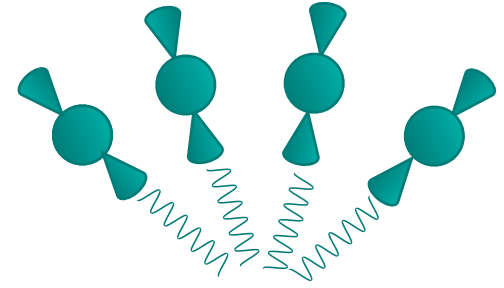


Pulsar Timing Arrays

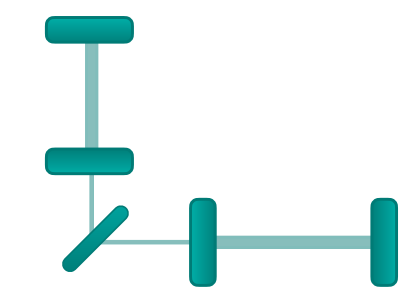


Laser interferometers (Earth-based)

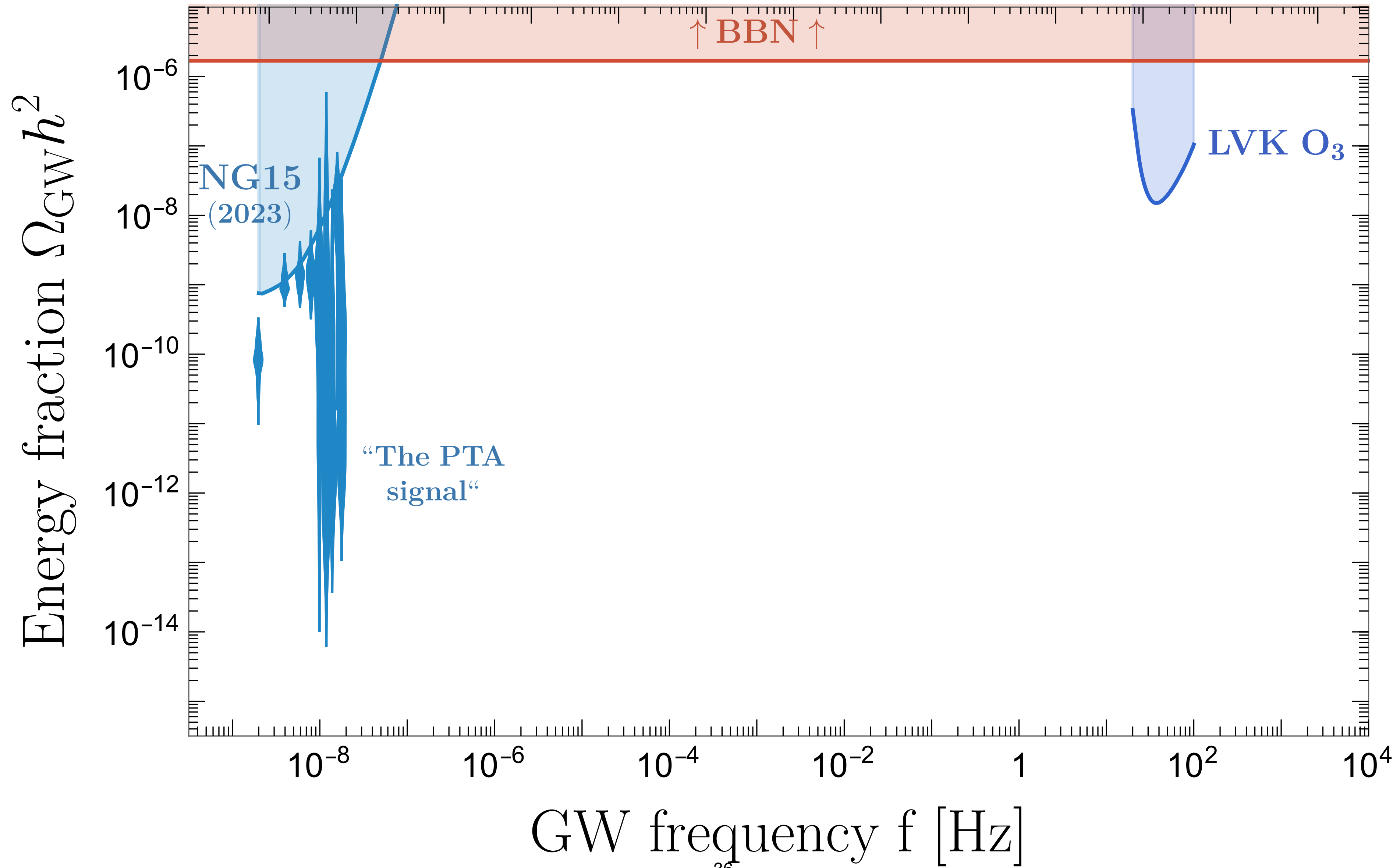


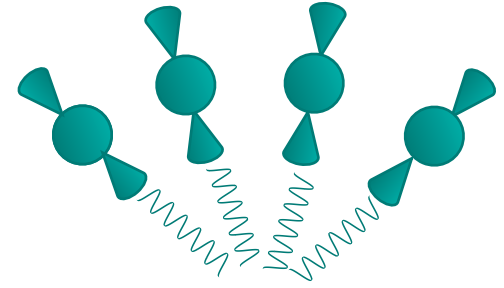


Pulsar Timing Arrays

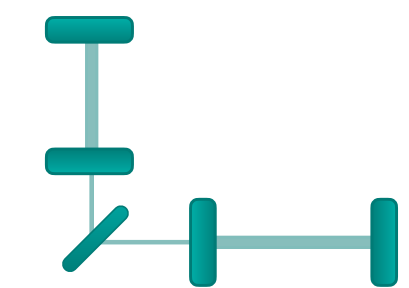


Laser interferometers (Earth-based)

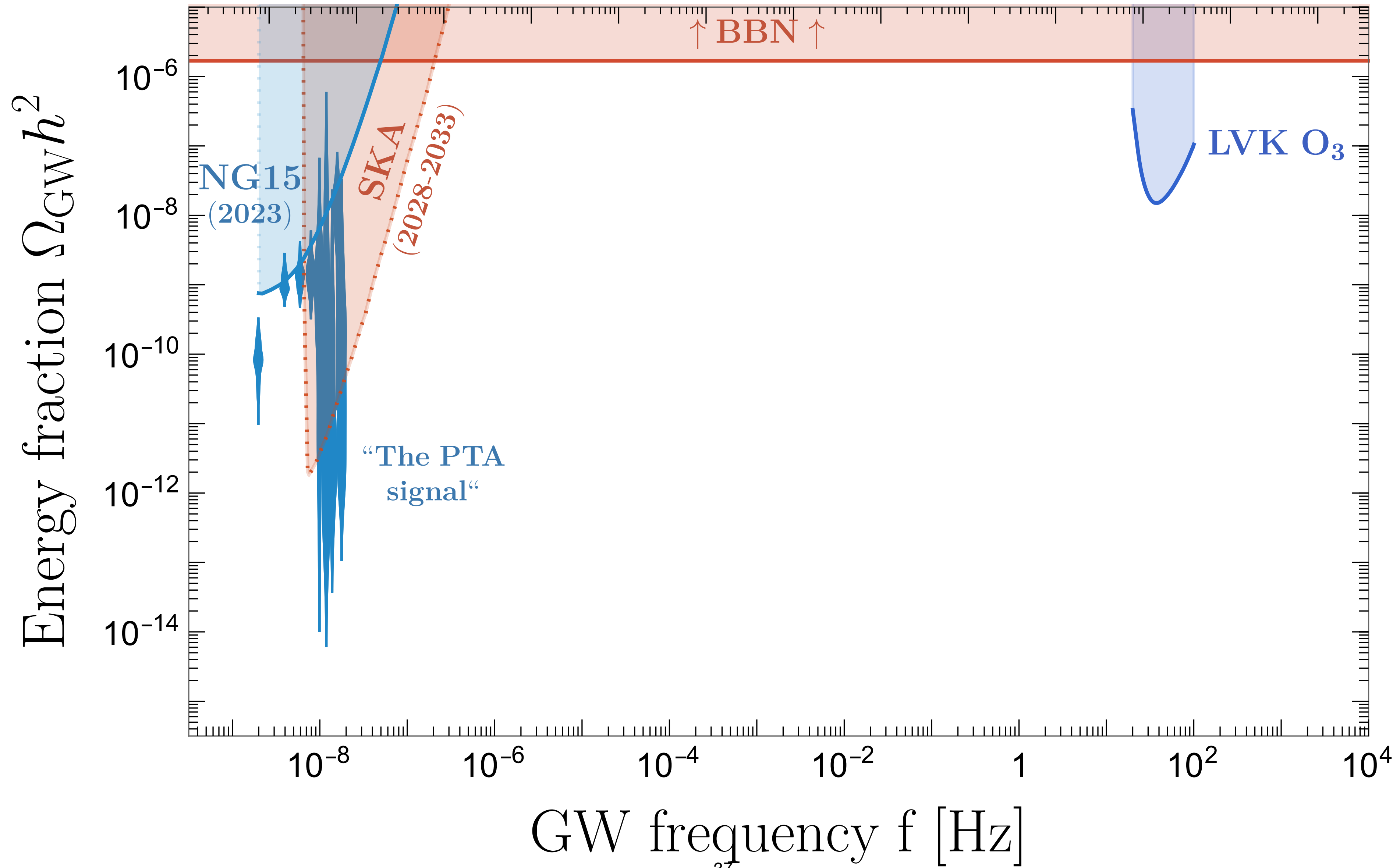


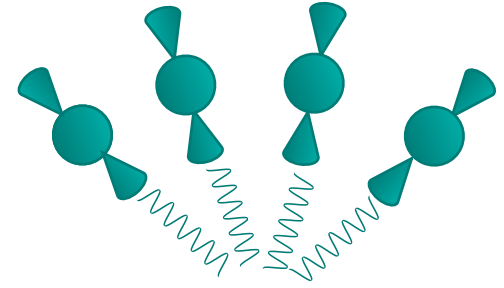


Pulsar Timing Arrays

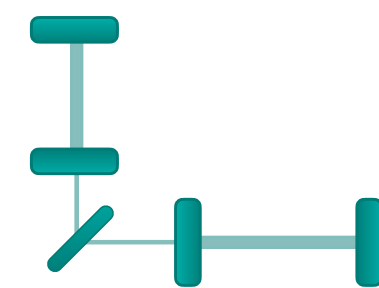


Laser interferometers (Earth-based)

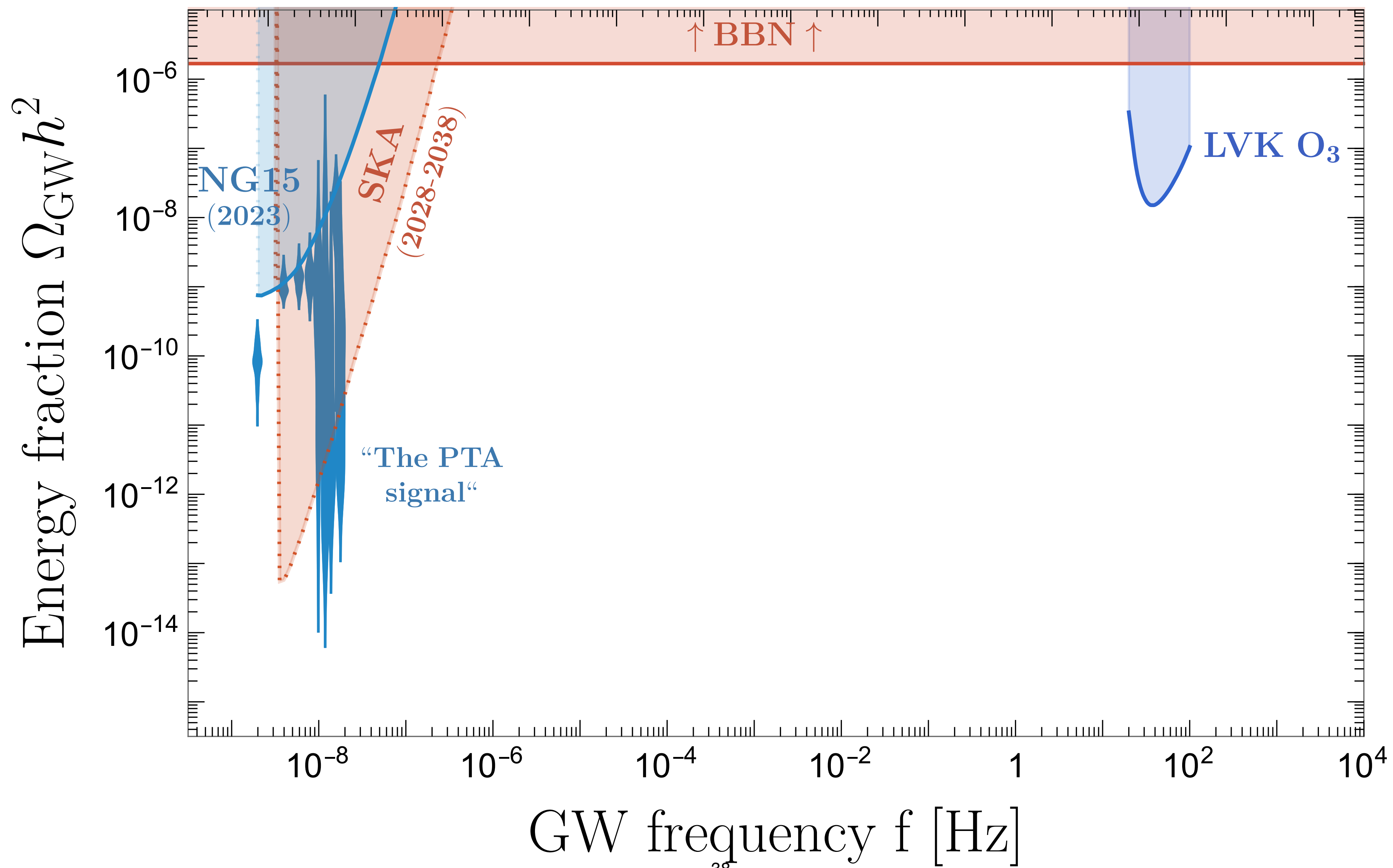


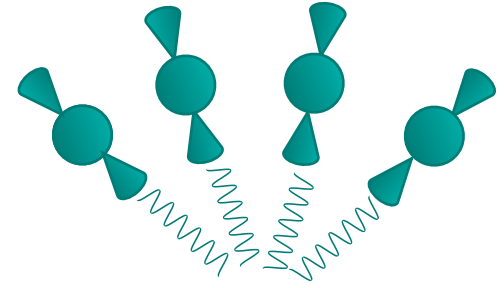


Pulsar Timing Arrays

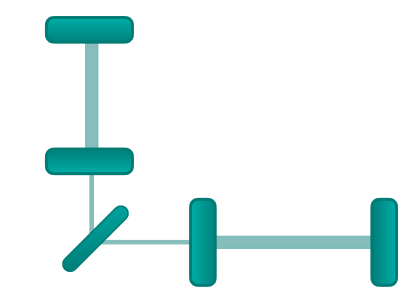


Laser interferometers (Earth-based)

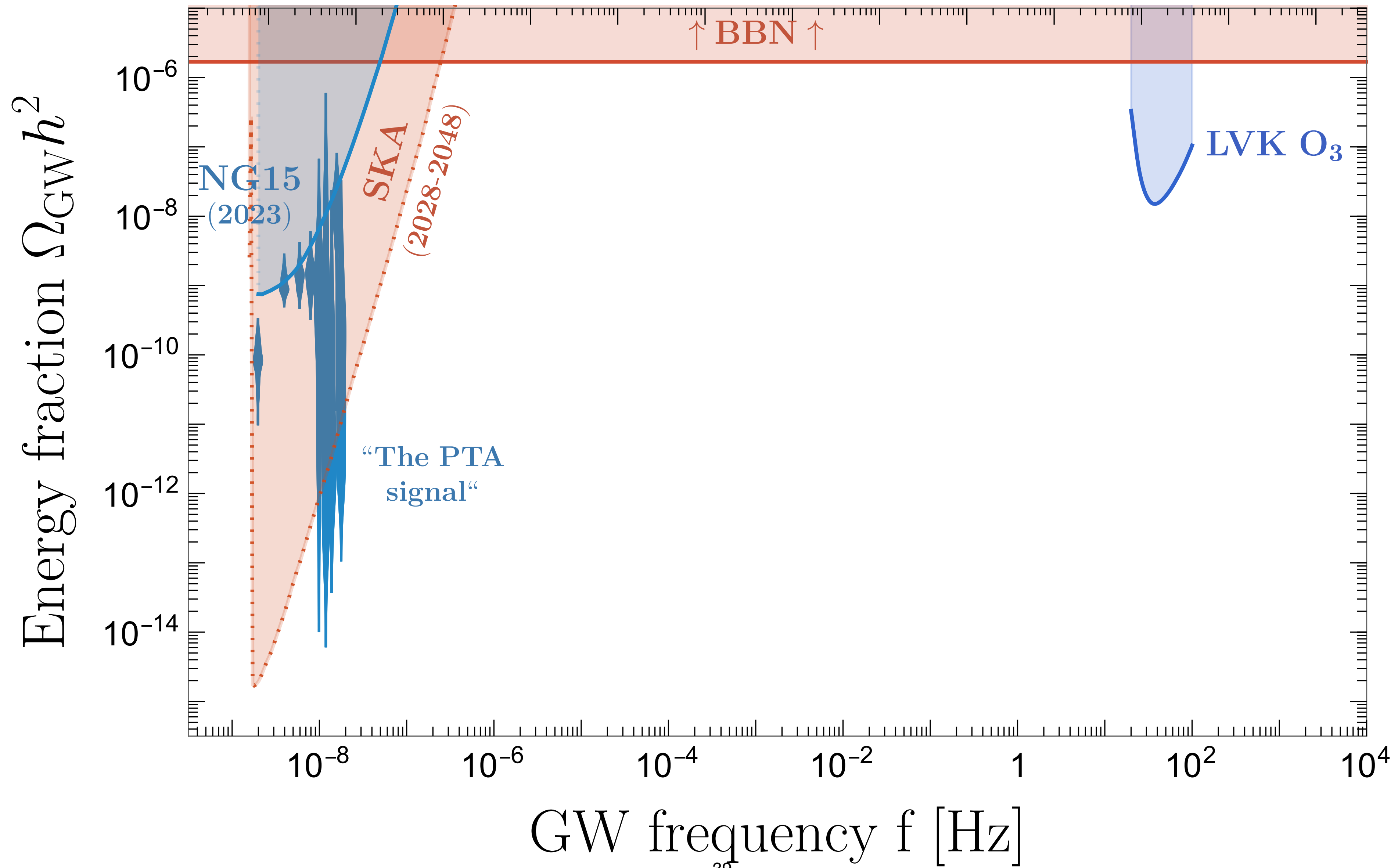


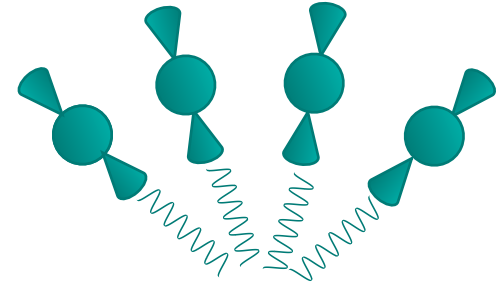


Pulsar Timing Arrays

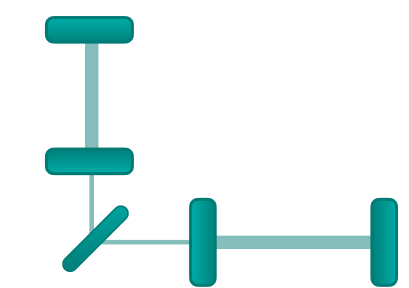


Laser interferometers (Earth-based)

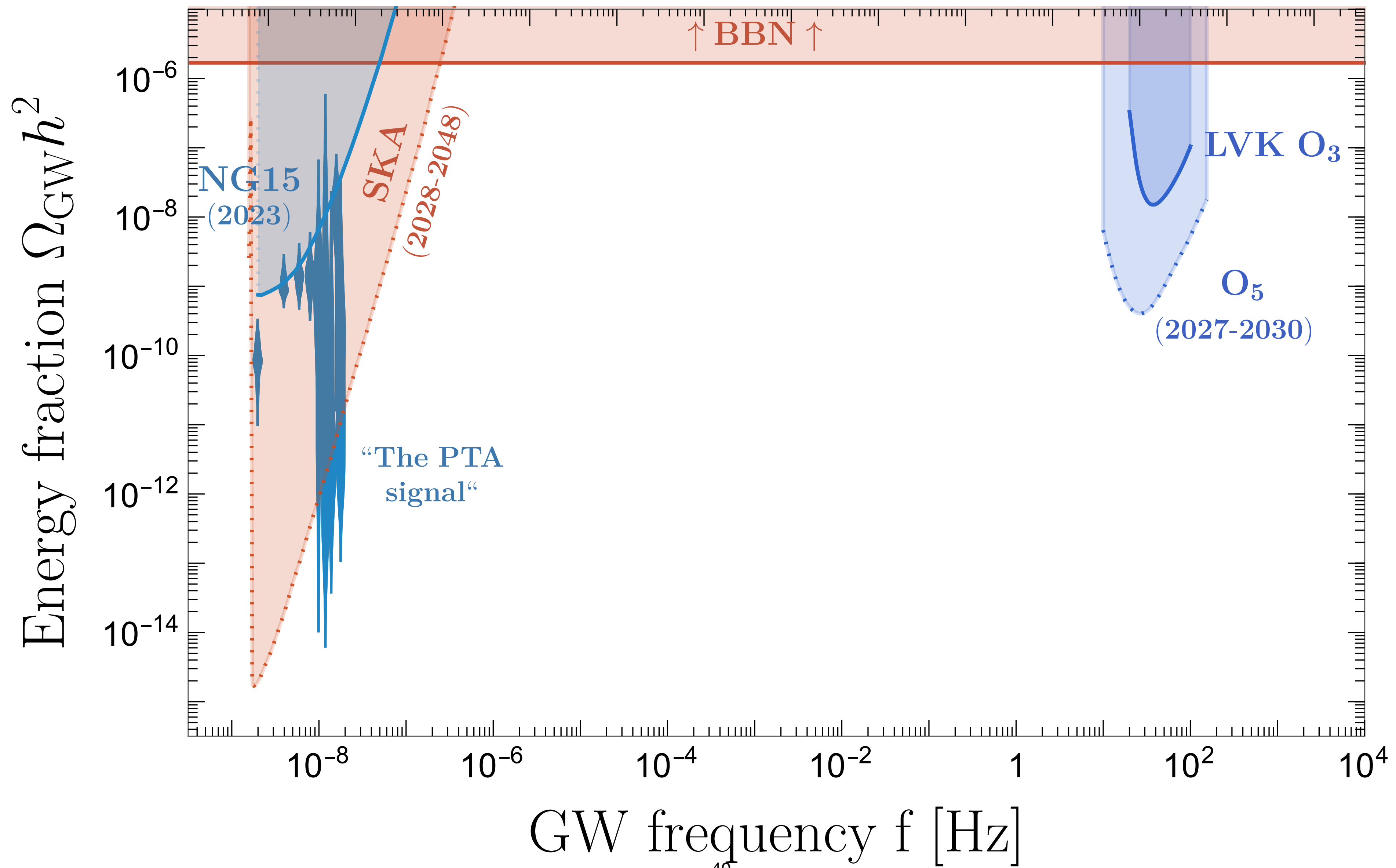


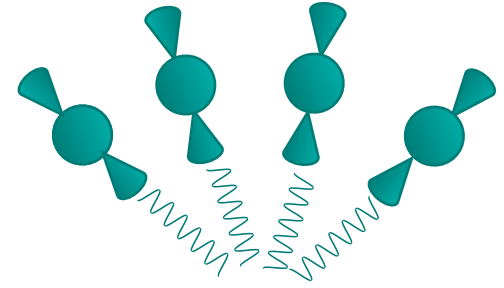


Pulsar Timing Arrays

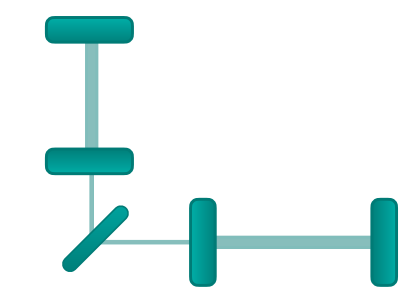


Laser interferometers (Earth-based)

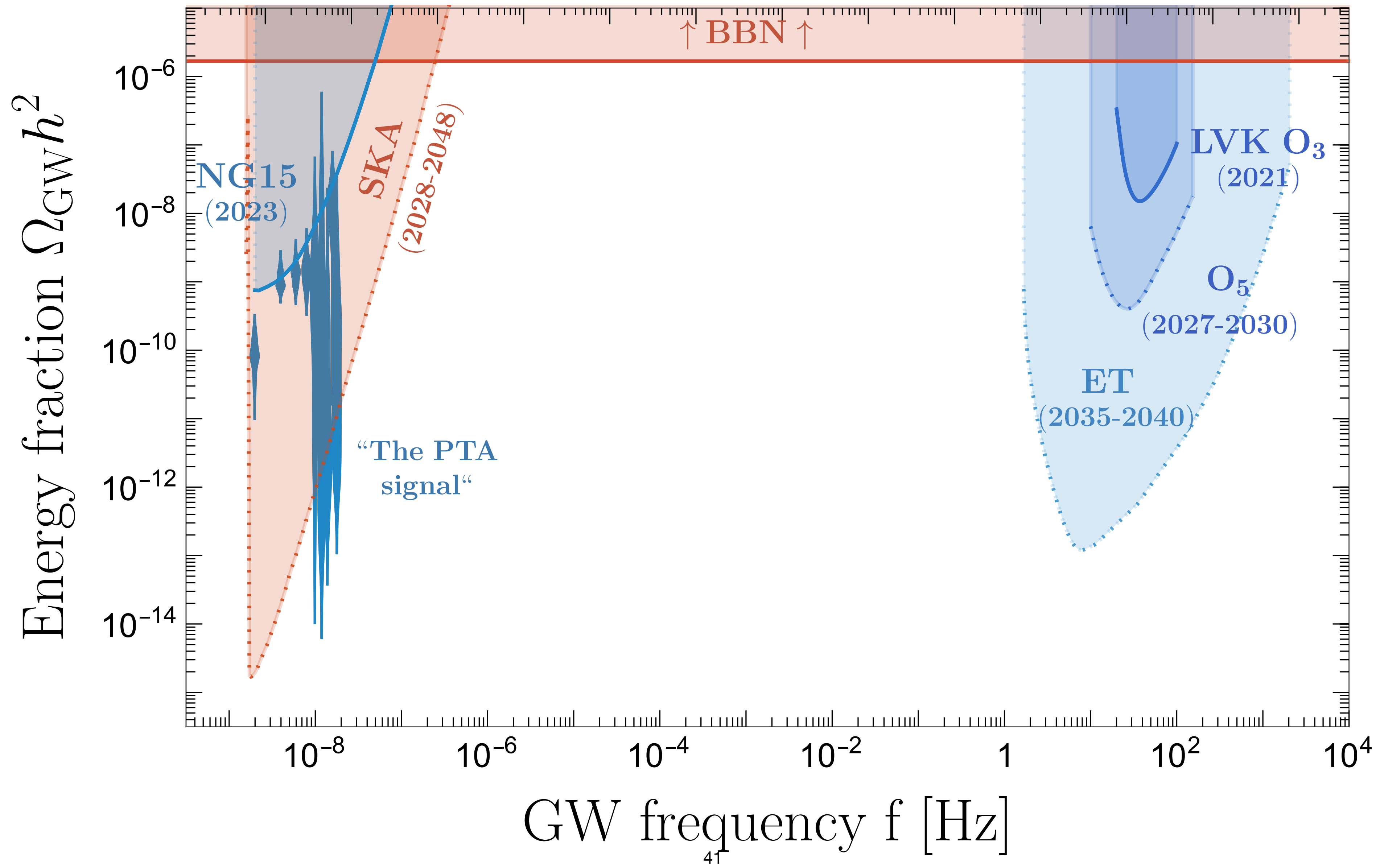


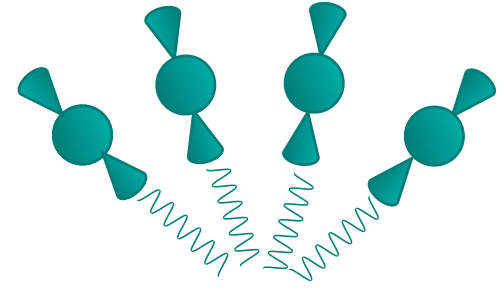


Pulsar Timing Arrays

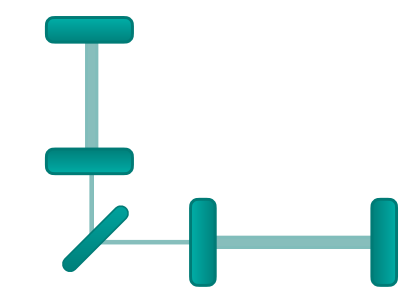


Laser interferometers (Earth-based)

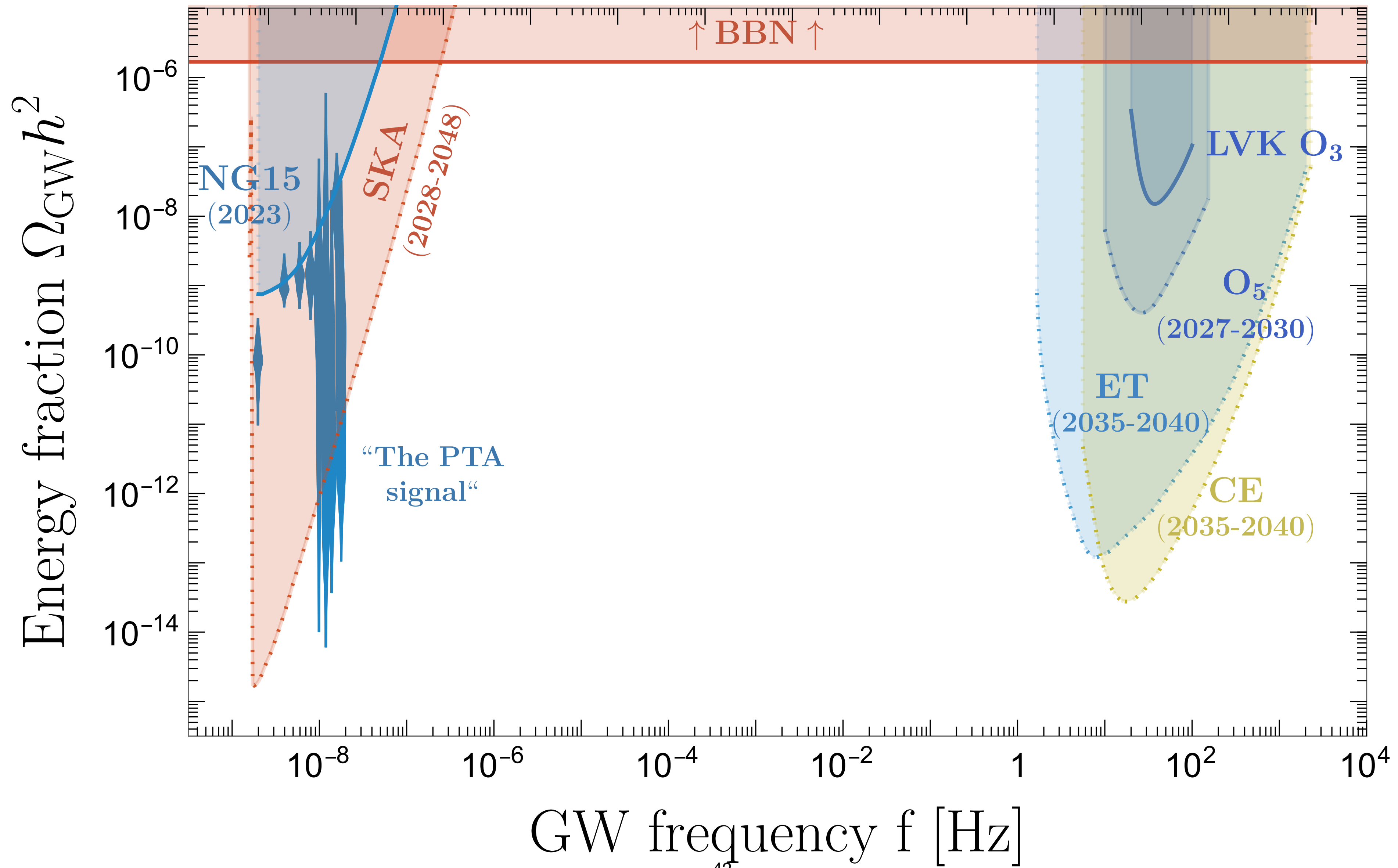


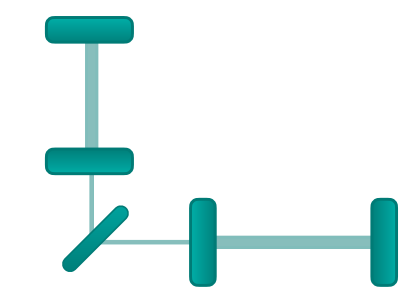
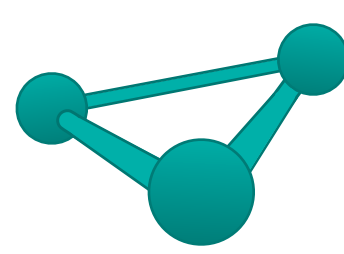
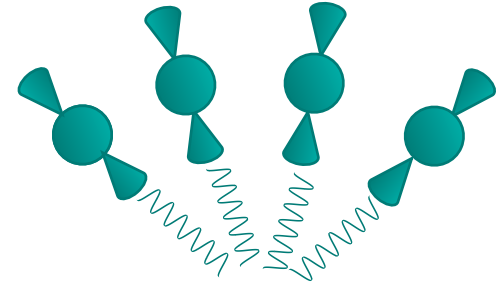


Pulsar Timing Arrays



Laser interferometers (Earth-based)

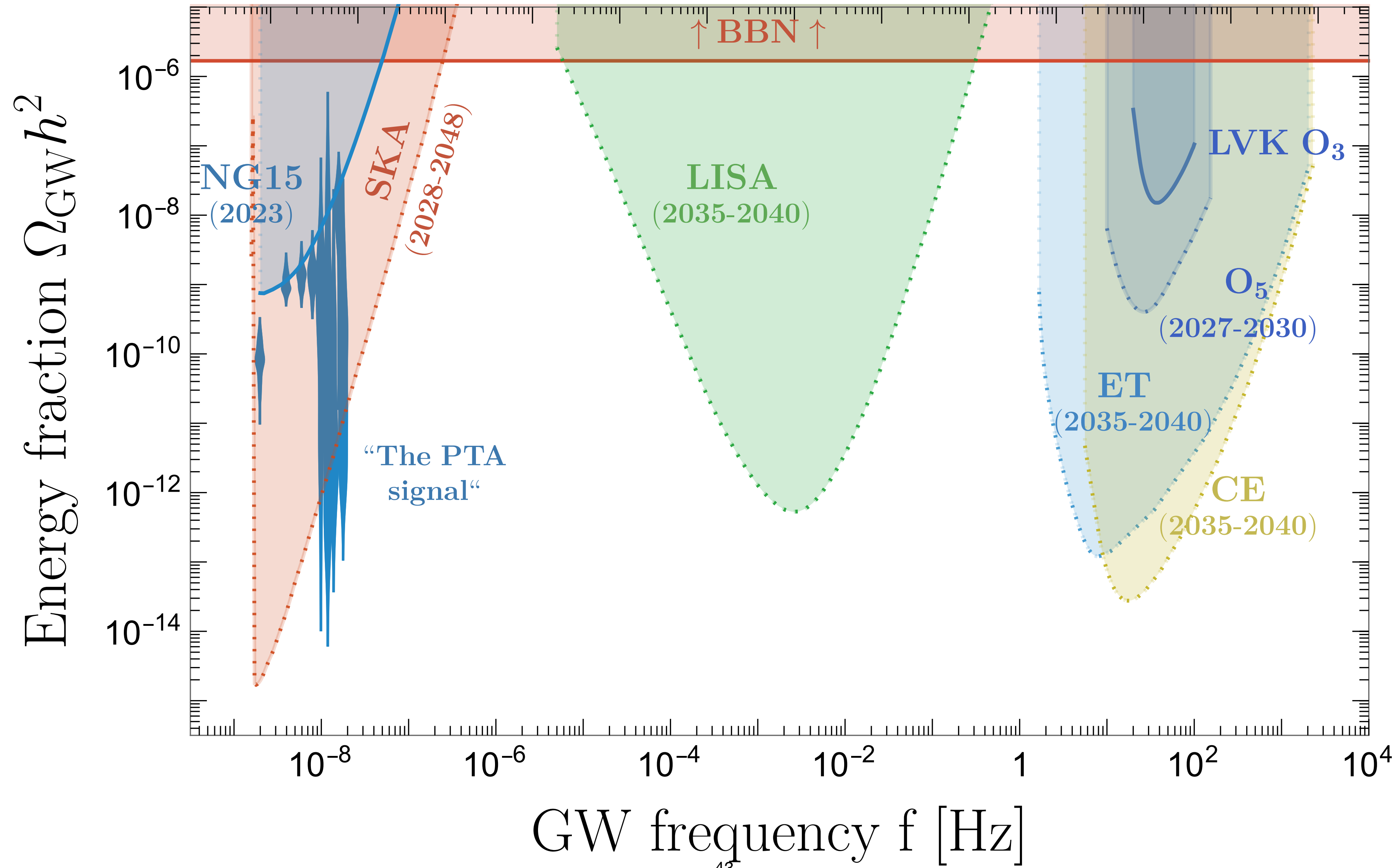


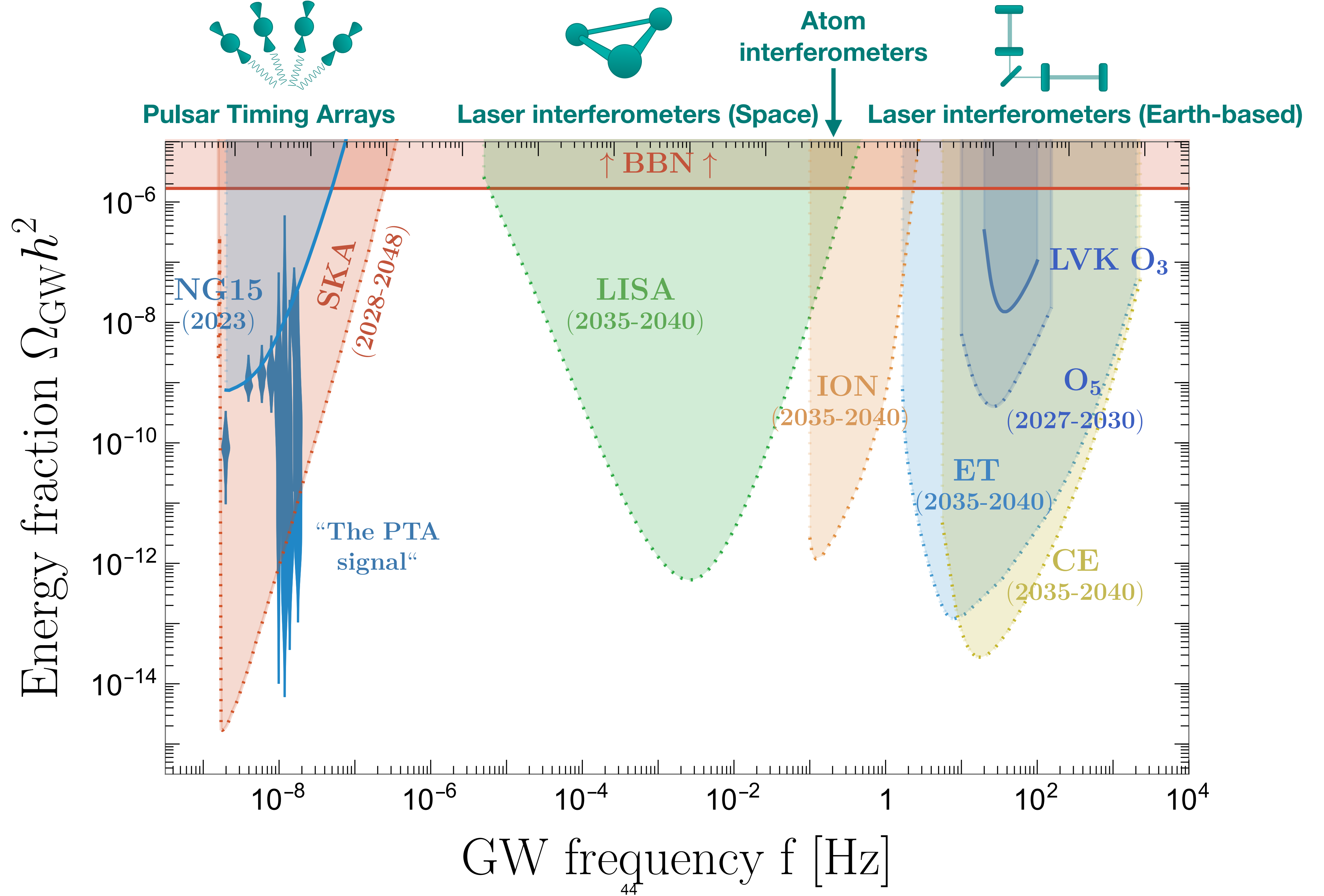


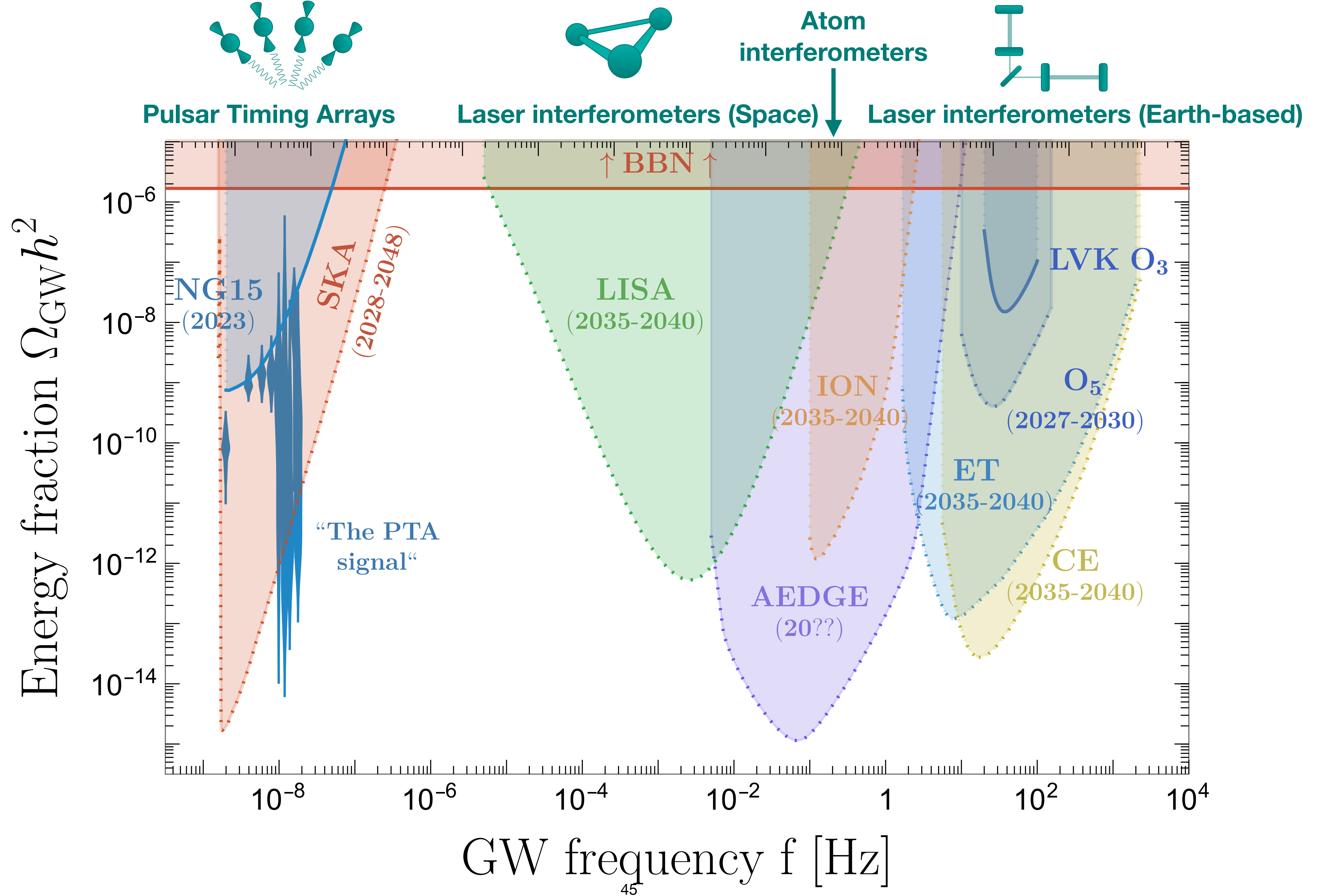
Pulsar Timing Arrays

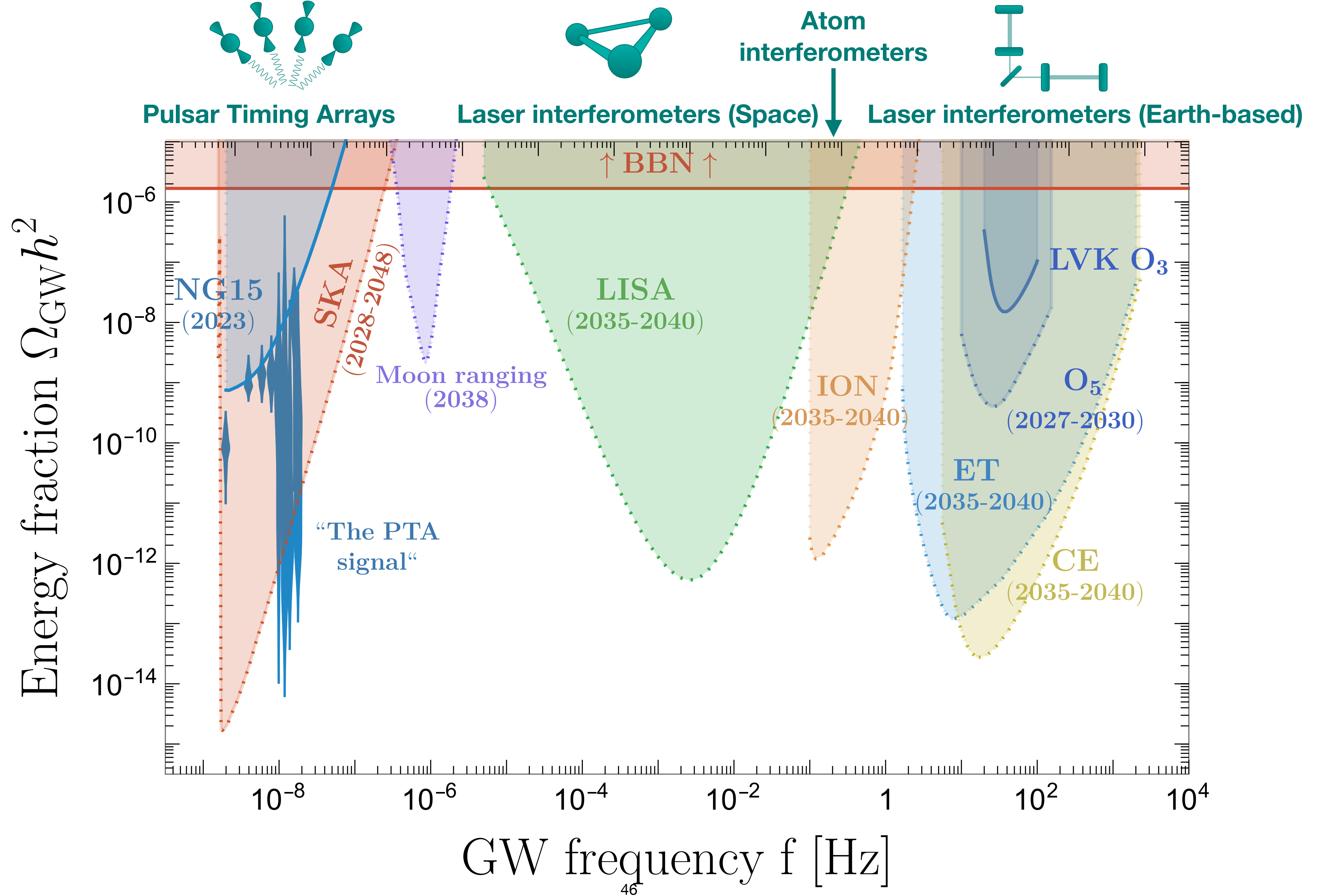
Laser interferometers (Space)

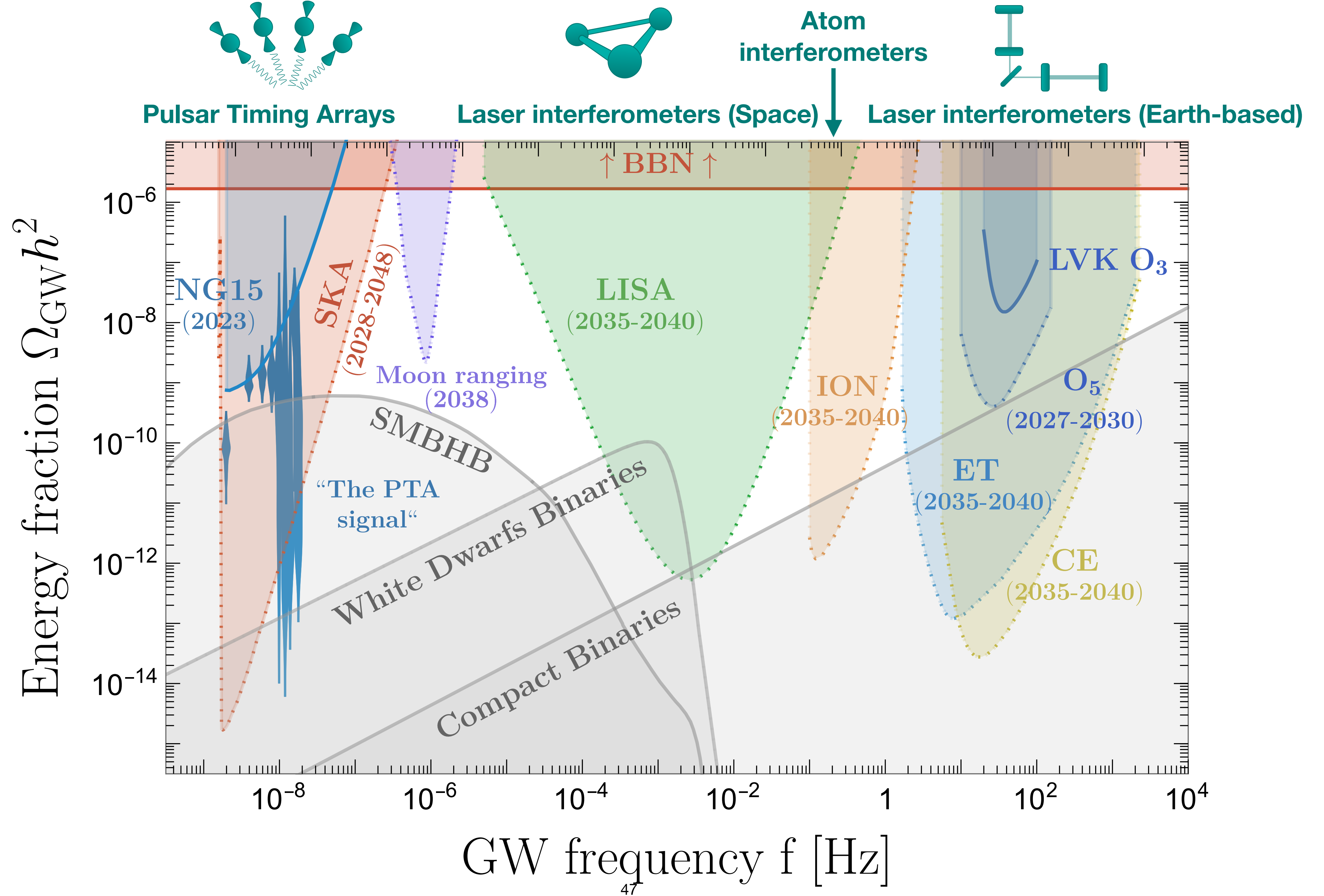
Laser interferometers (Earth-based)





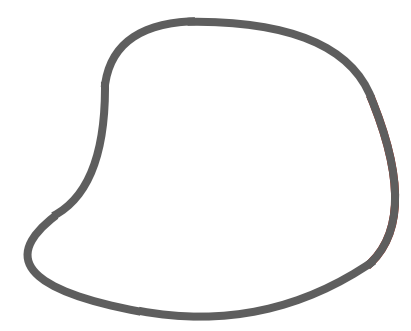




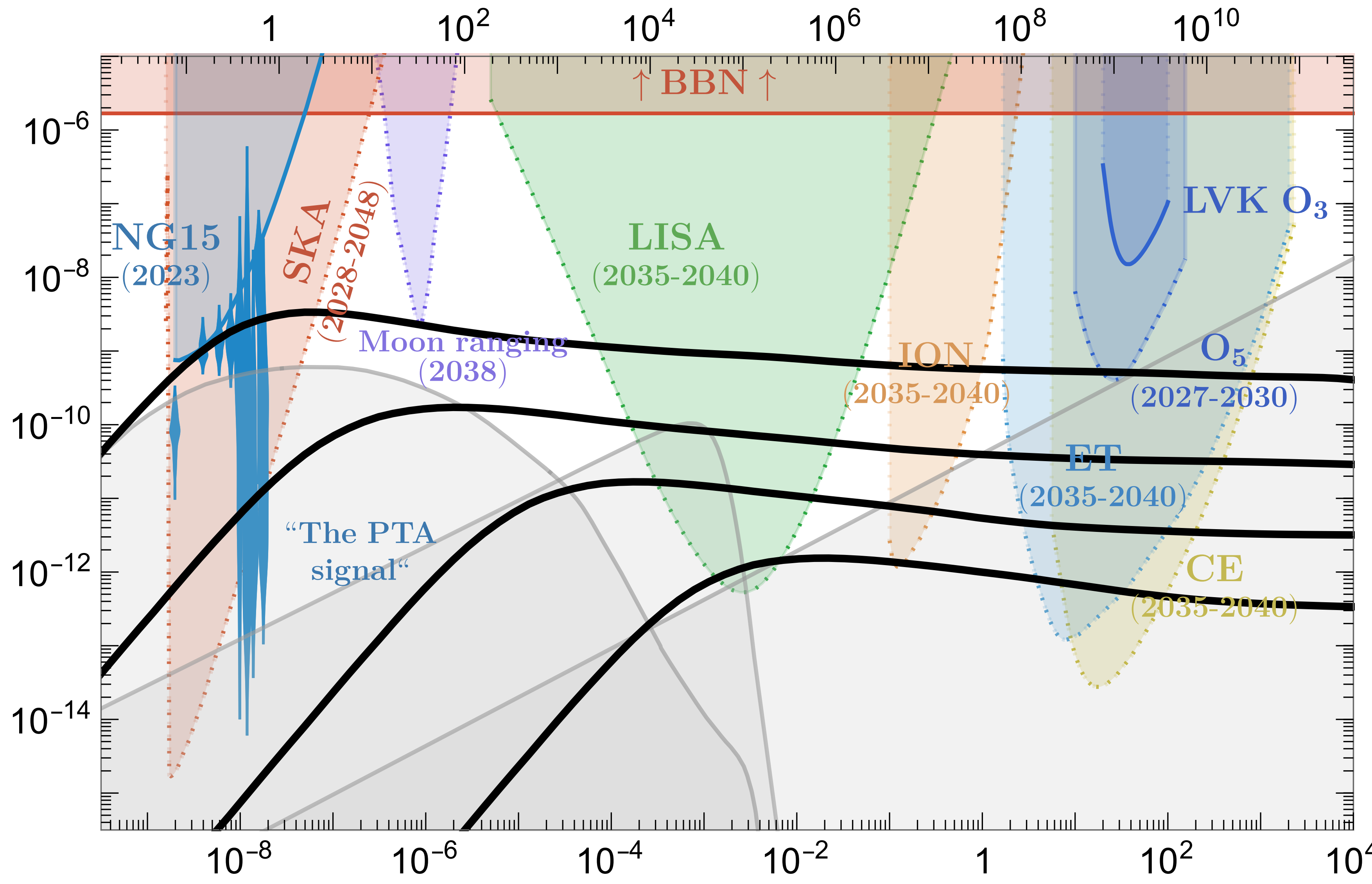


Universe temperature T [GeV]

Cosmic strings



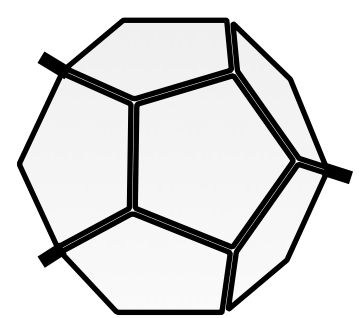
Energy fraction $\Omega_{\text{GW}} h^2$



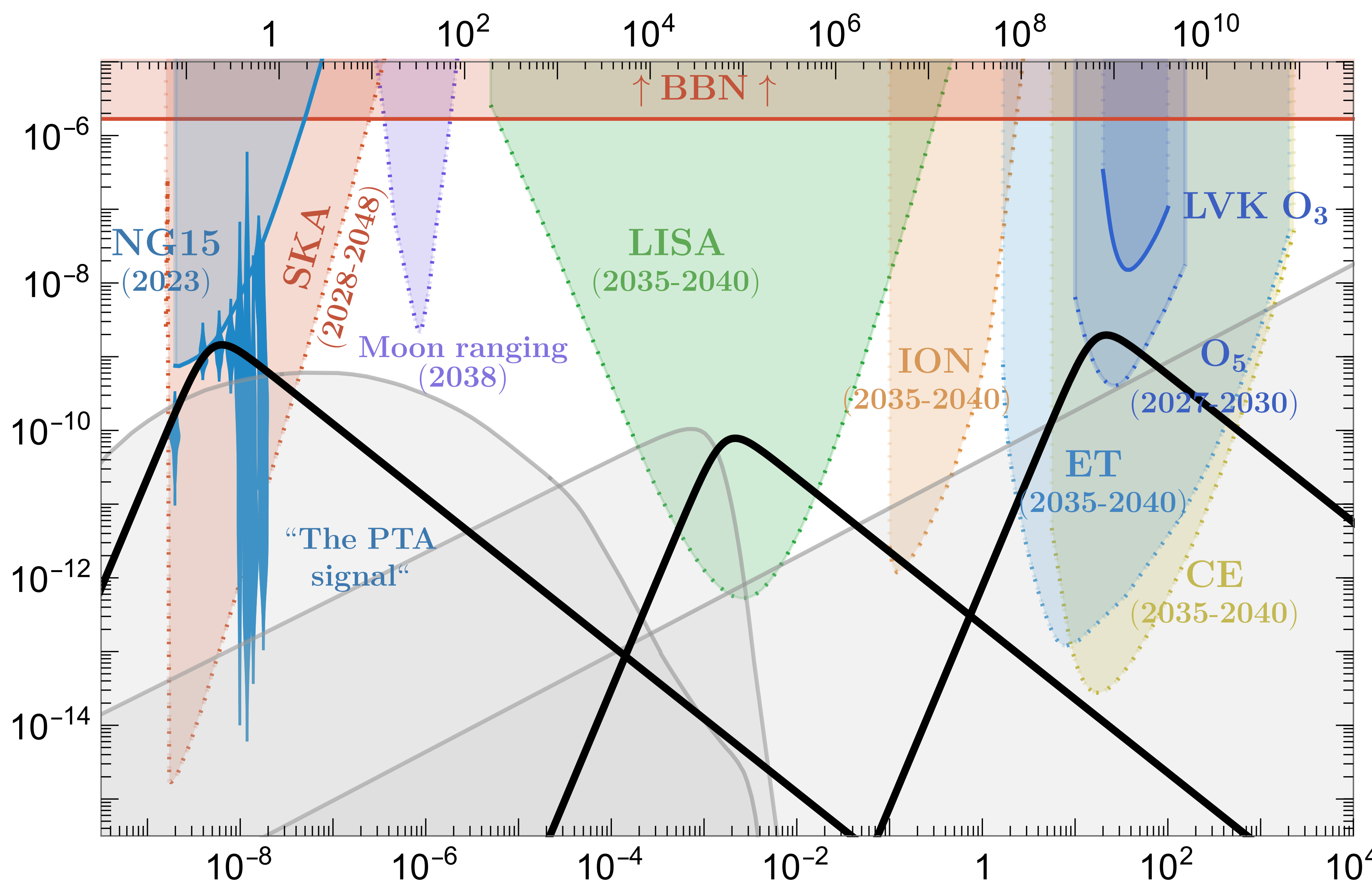
GW frequency f [Hz]

Universe temperature T [GeV]

Domain walls



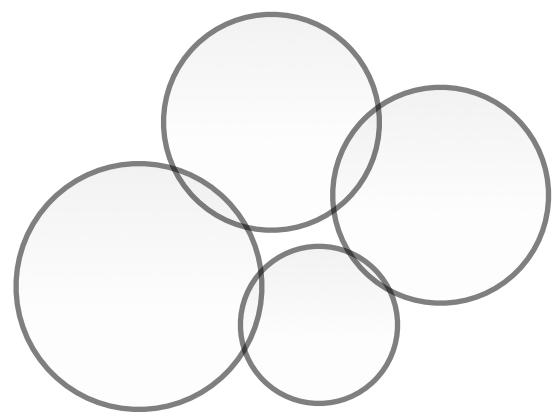
Energy fraction $\Omega_{\text{GW}} h^2$



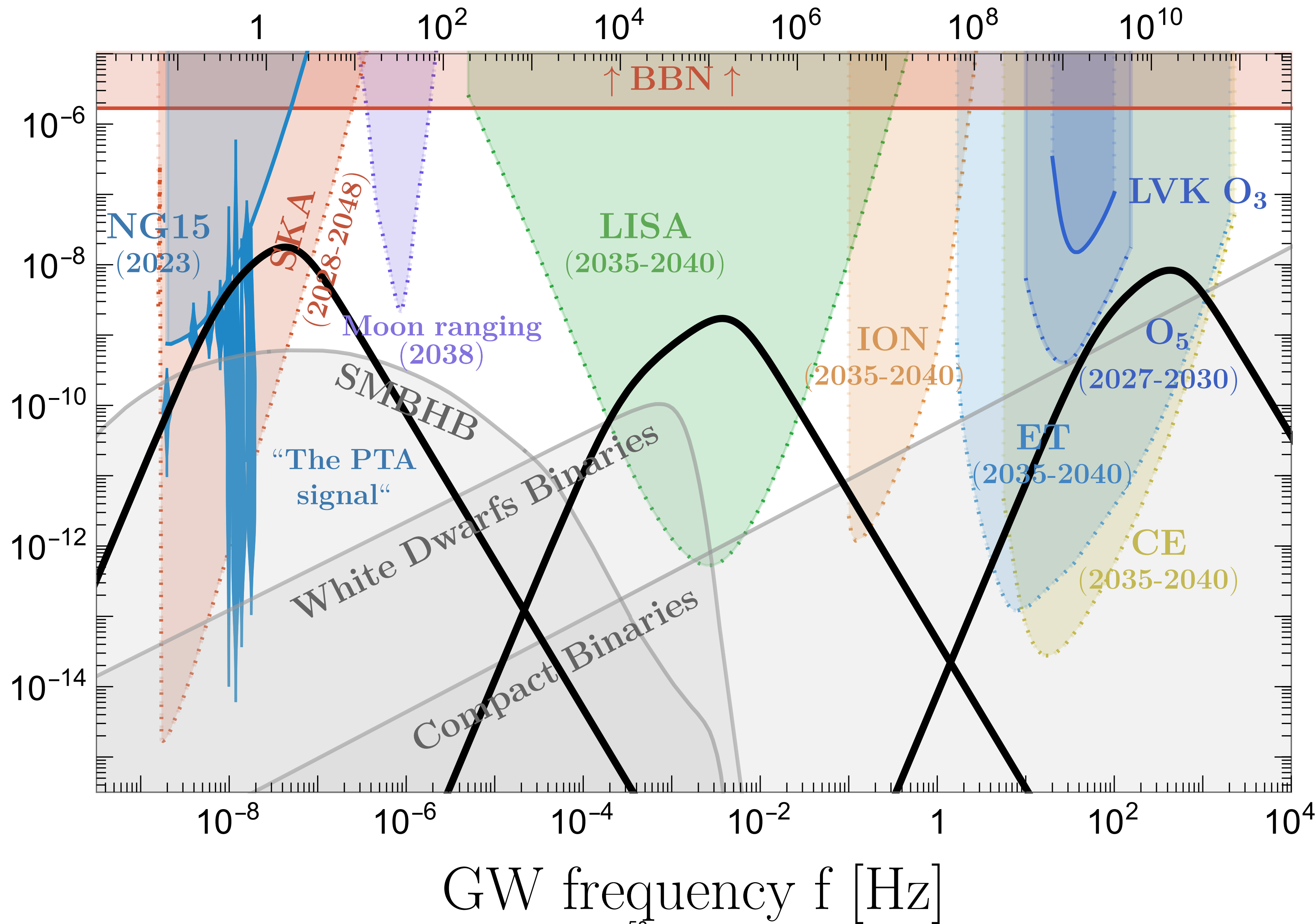
GW frequency f [Hz]

Universe temperature T [GeV]

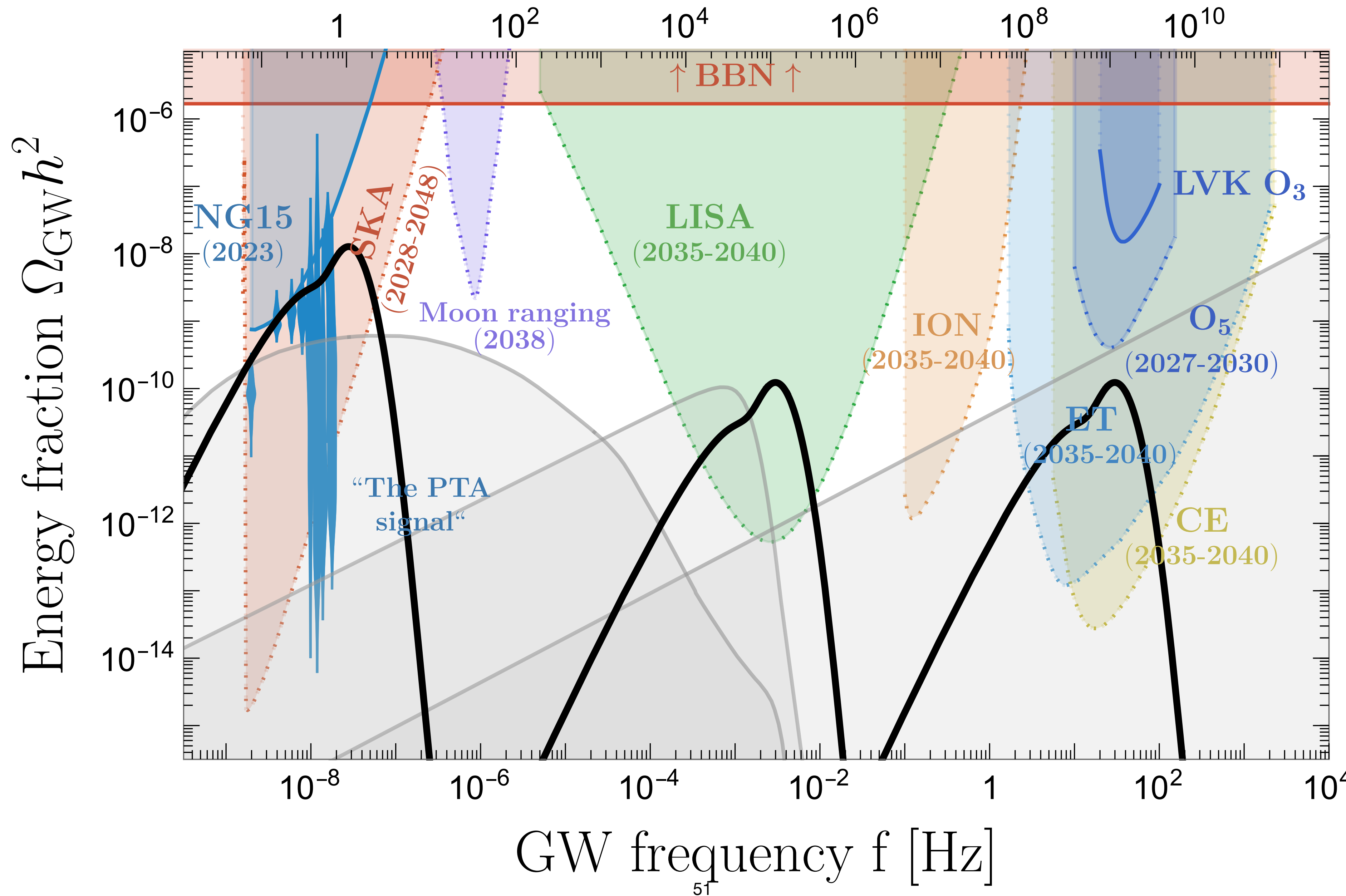
**First-order
phase transition**



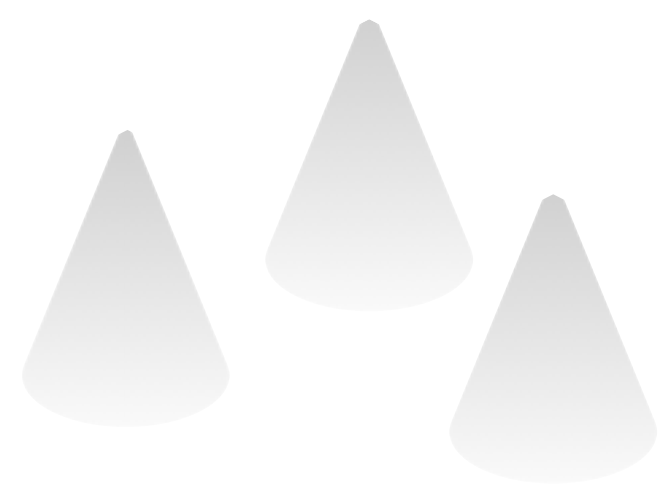
Energy fraction $\Omega_{\text{GW}} h^2$



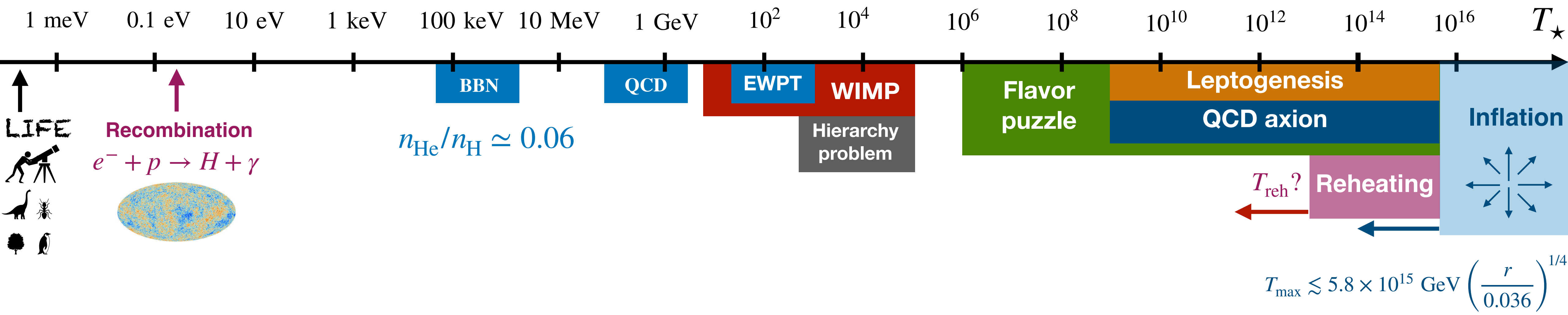
Universe temperature T [GeV]



Curvature peaks

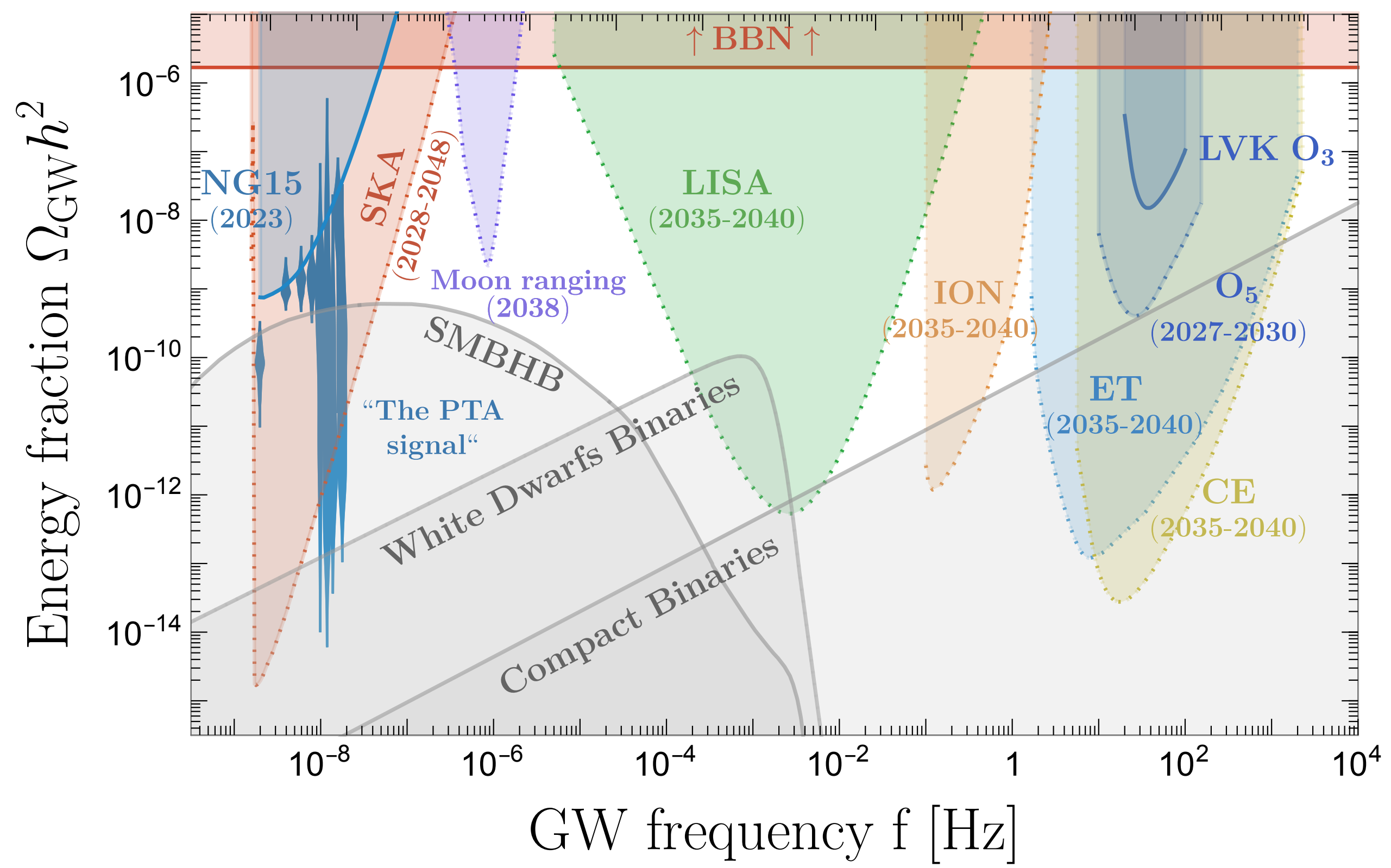


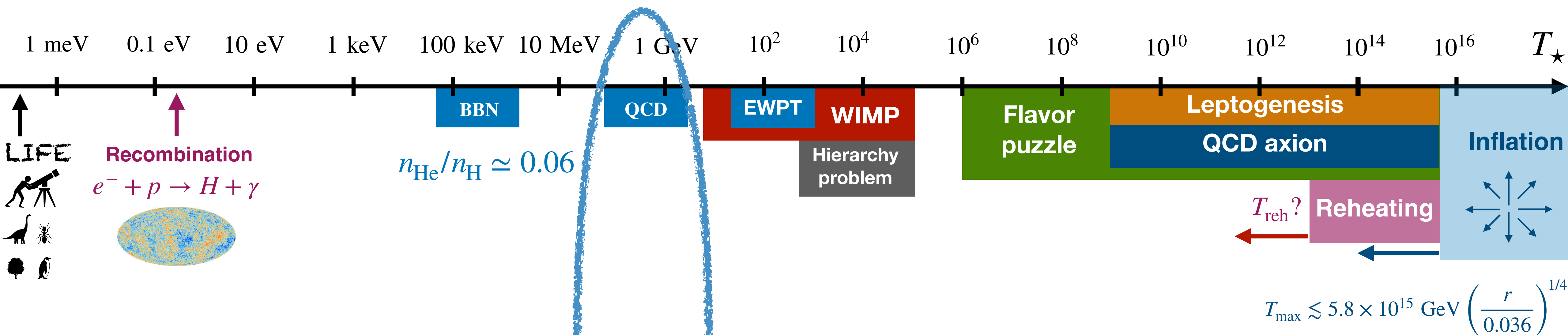
Produce GW at 2nd order in perturbation theory



$$T_{\text{max}} \lesssim 5.8 \times 10^{15} \text{ GeV} \left(\frac{r}{0.036} \right)^{1/4}$$

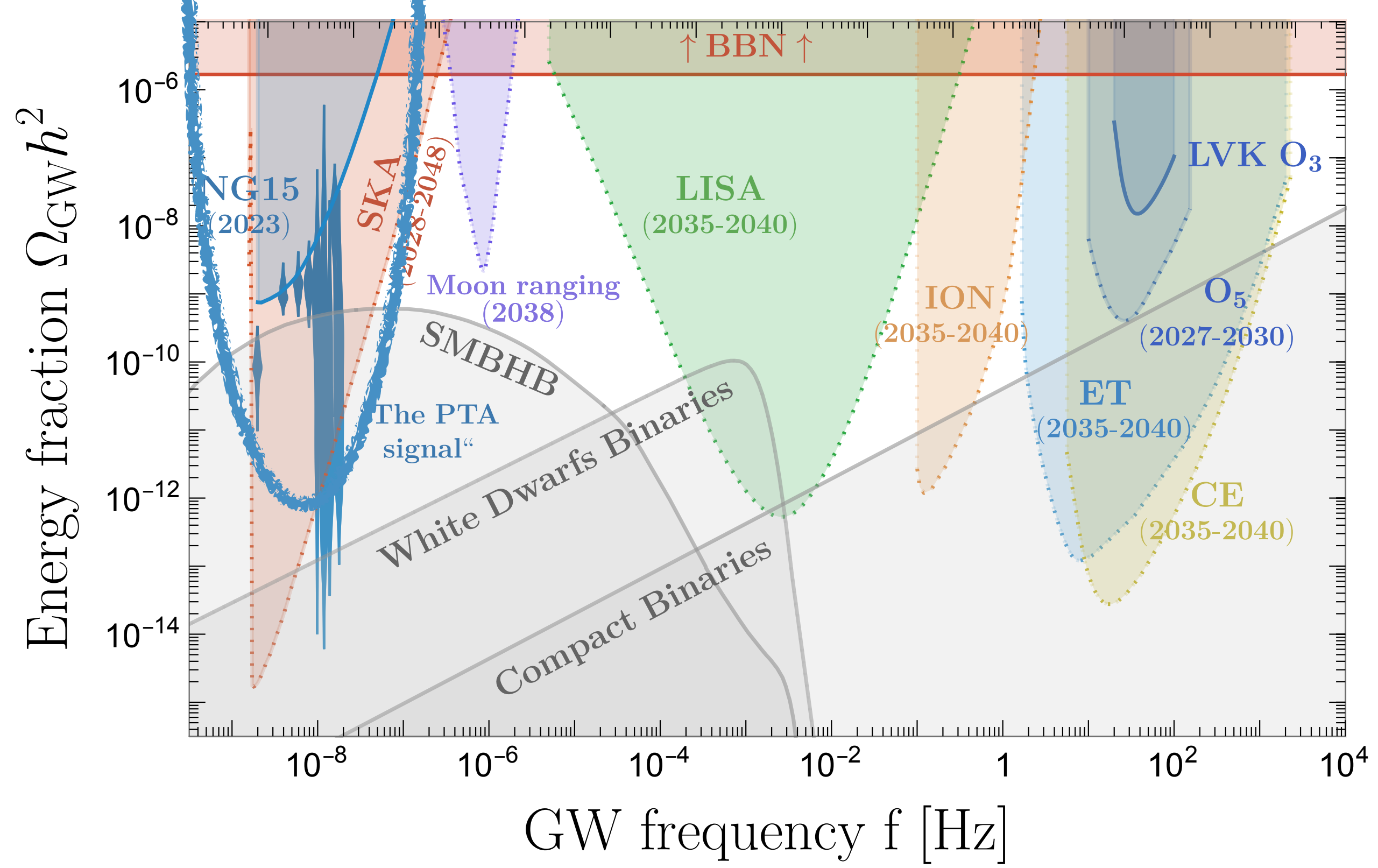
Bicep/Keck (2110.00483)

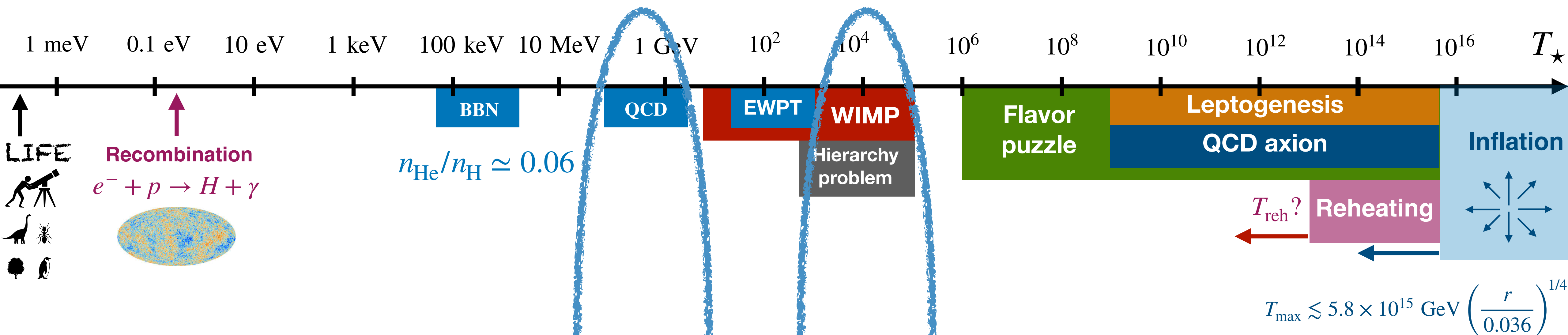




$$T_{\text{max}} \lesssim 5.8 \times 10^{15} \text{ GeV} \left(\frac{r}{0.036} \right)^{1/4}$$

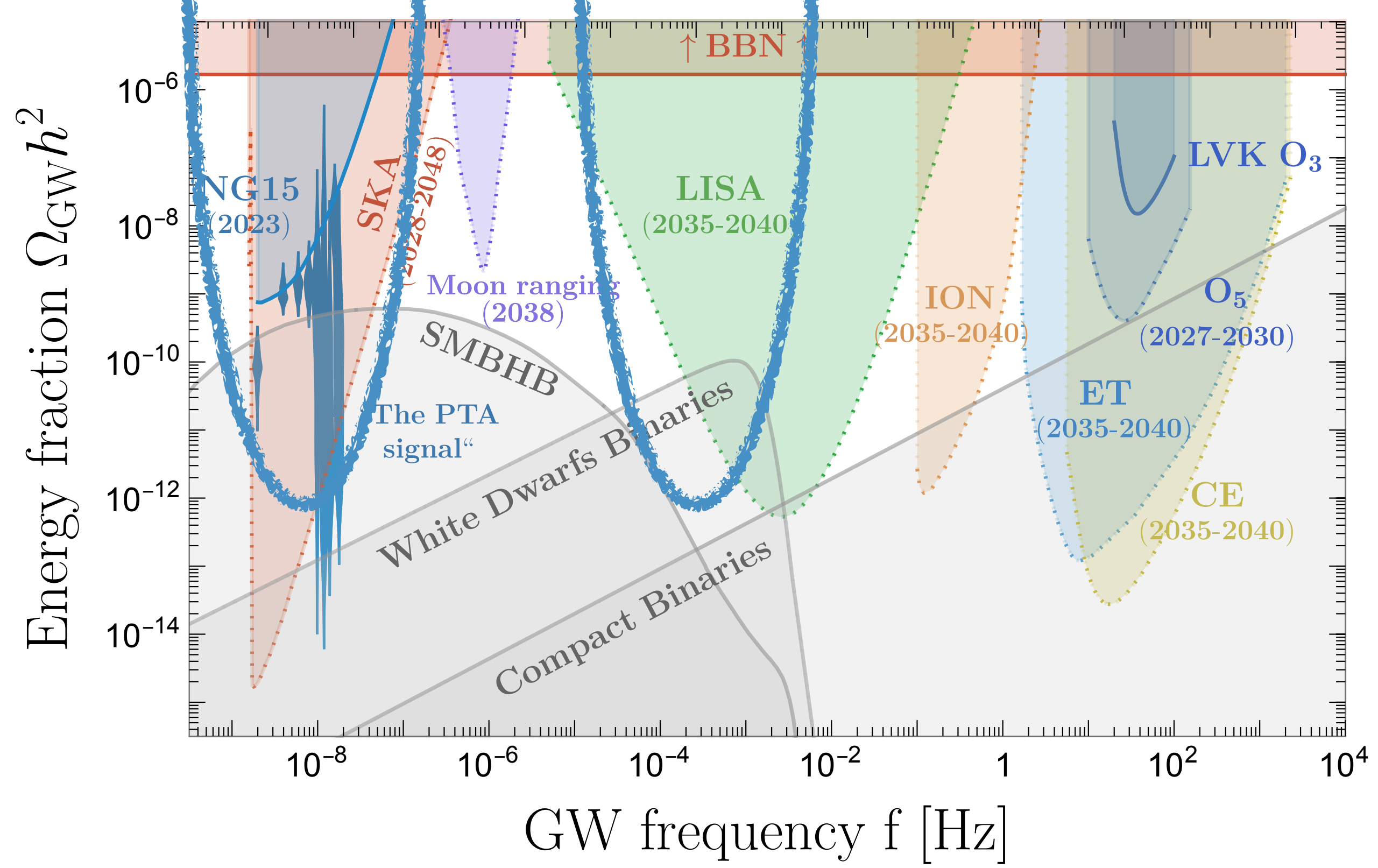
Bicep/Keck (2110.00483)

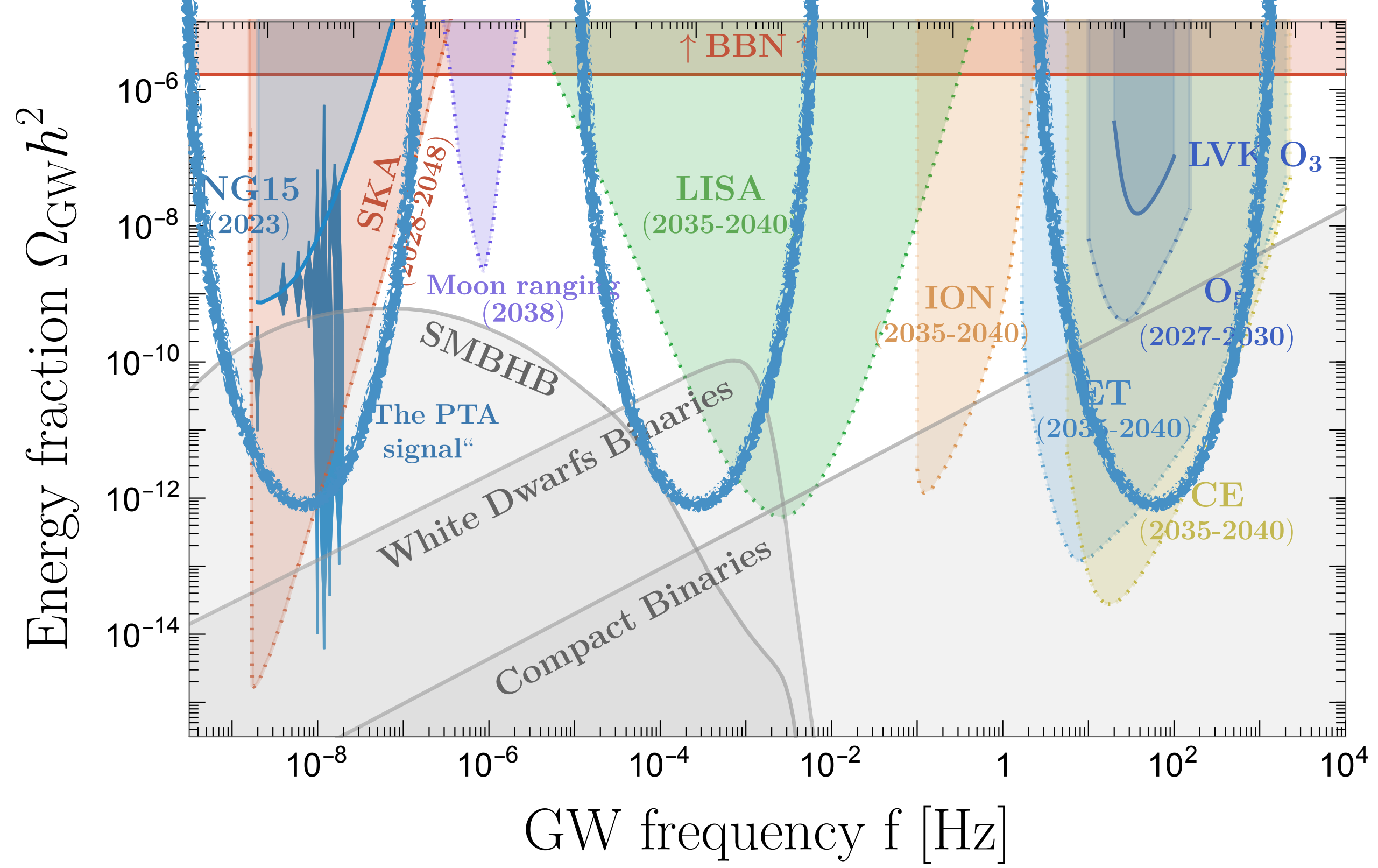
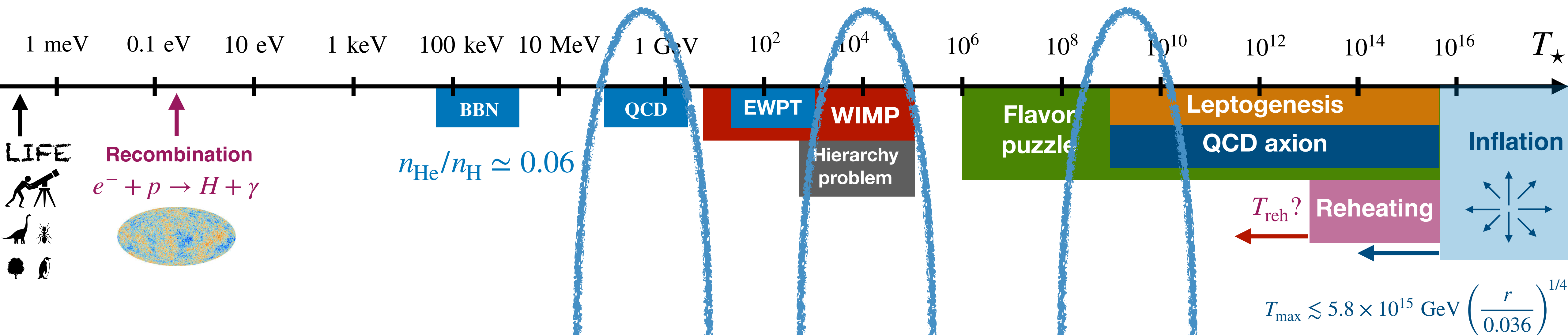


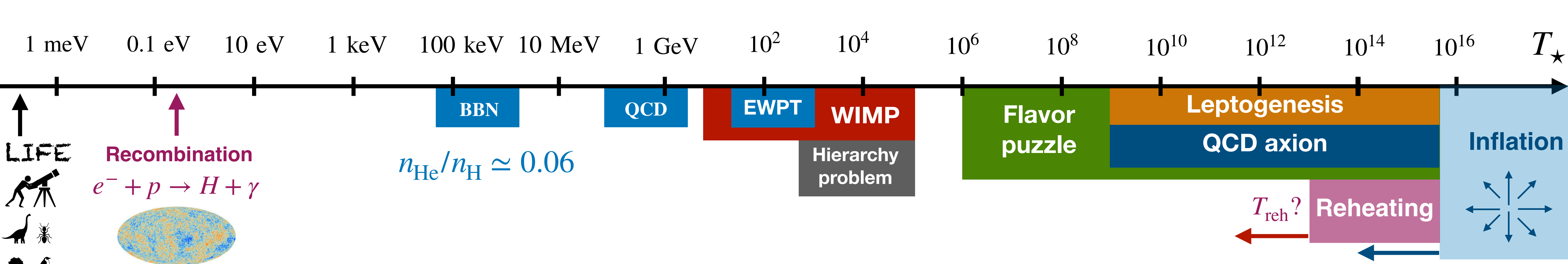


$$T_{\text{max}} \lesssim 5.8 \times 10^{15} \text{ GeV} \left(\frac{r}{0.036} \right)^{1/4}$$

Bicep/Keck (2110.00483)

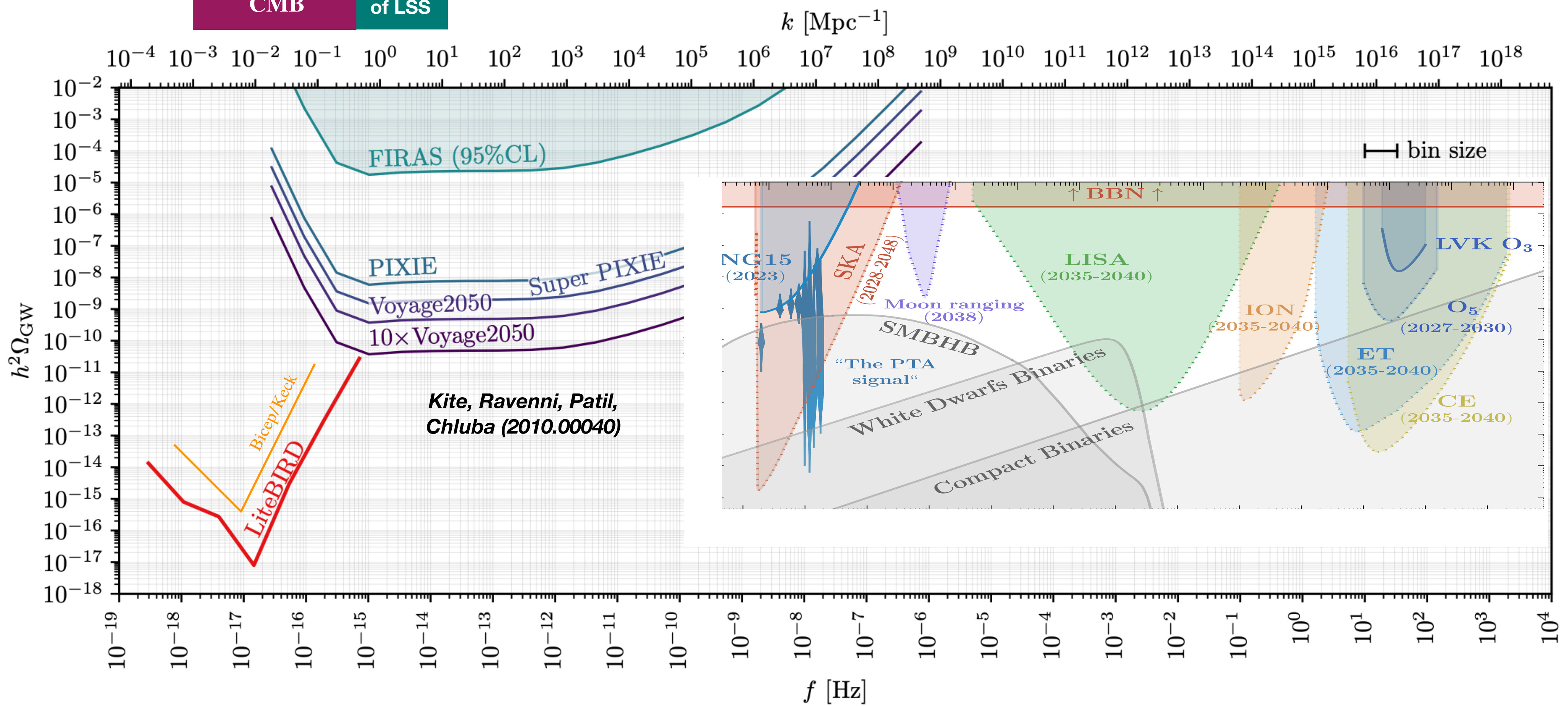


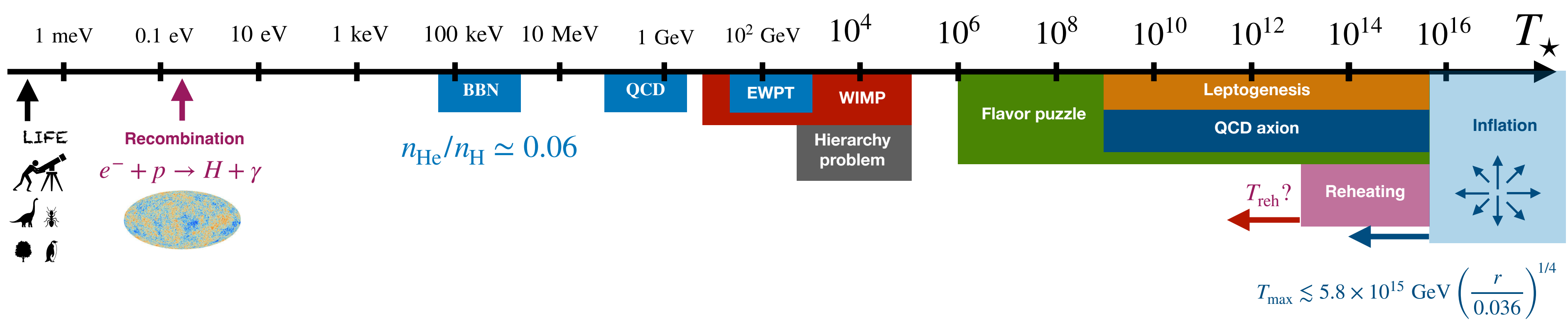




$$T_{\text{max}} \lesssim 5.8 \times 10^{15} \text{ GeV} \left(\frac{r}{0.036} \right)^{1/4}$$

Bicep/Keck (2110.00483)

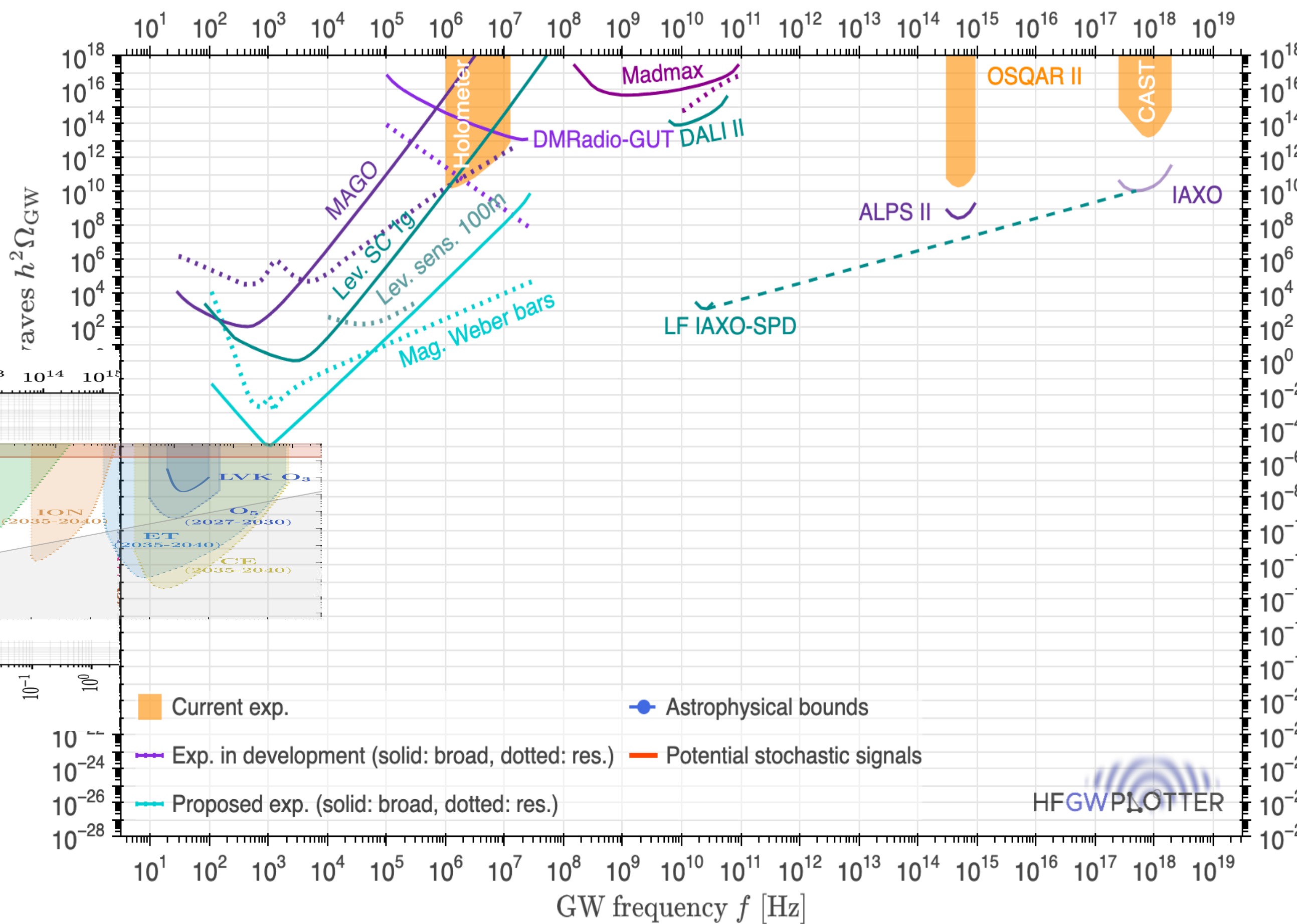
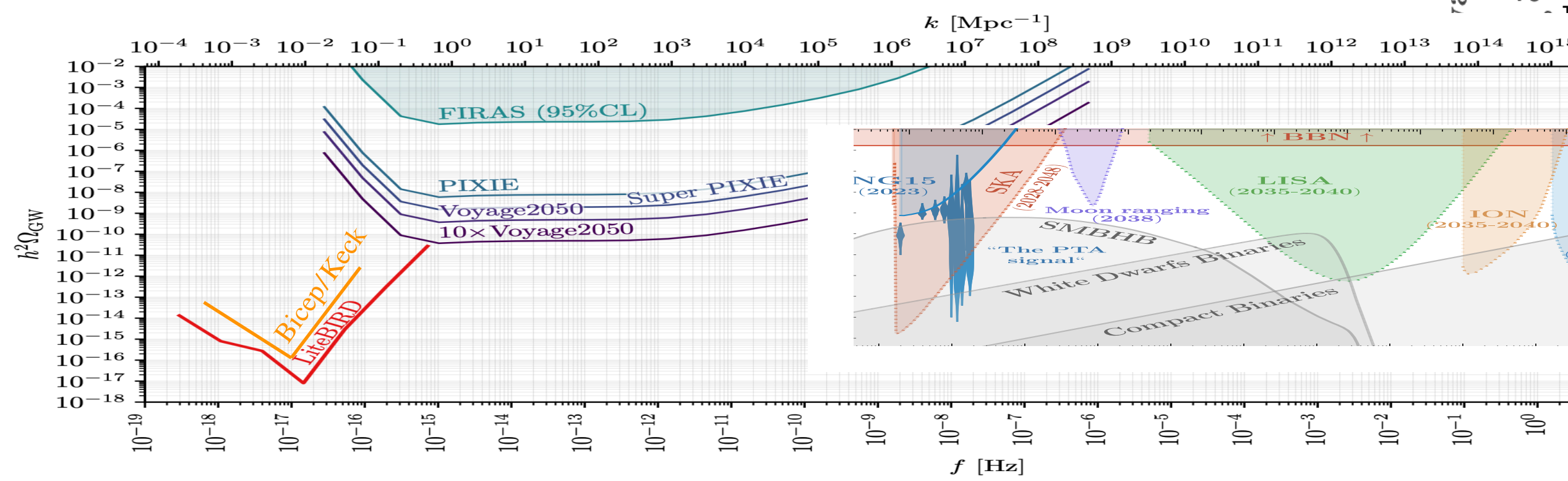




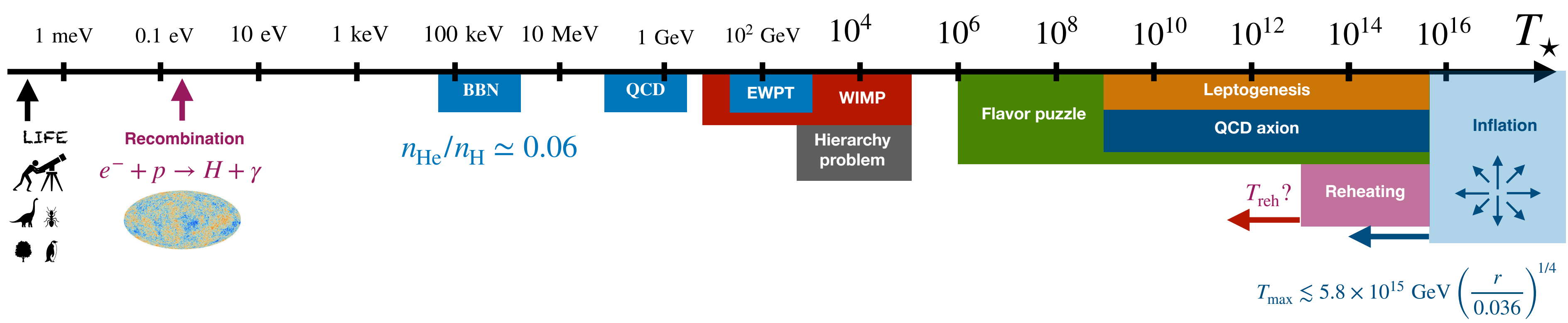
Bicep/Keck (2110.00483)

GWPlotter: Muia, Ringwald, Tamarit (2501.11723)

Kite, Ravenni, Patil, Chluba (2010.00040)



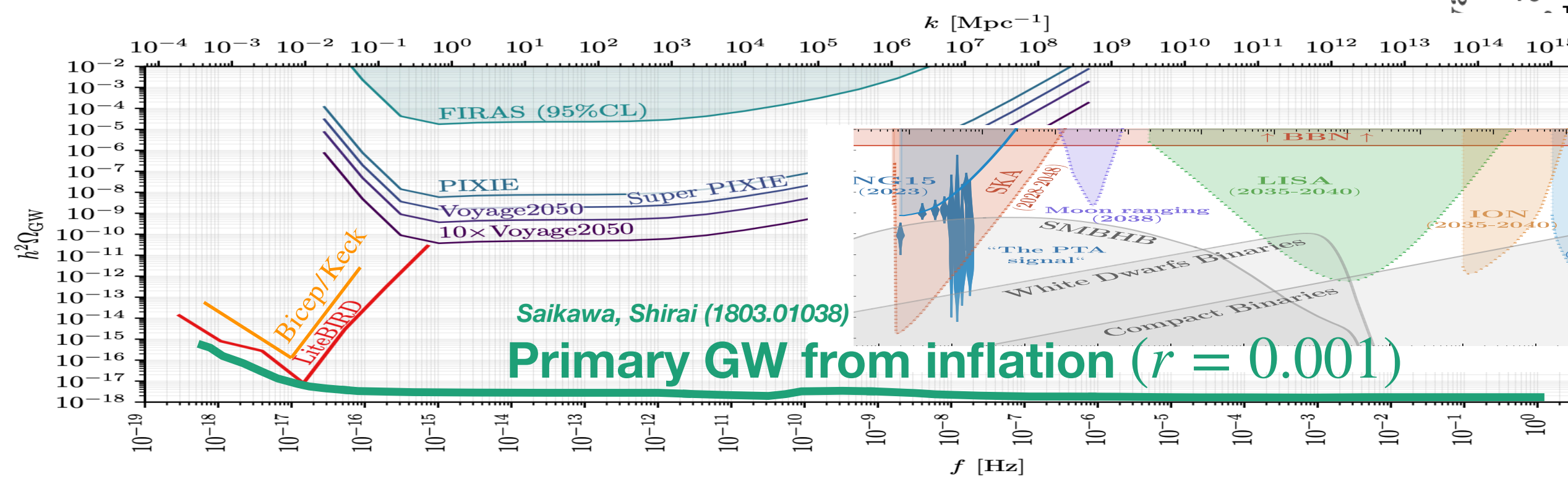
HFGW PLOTTER



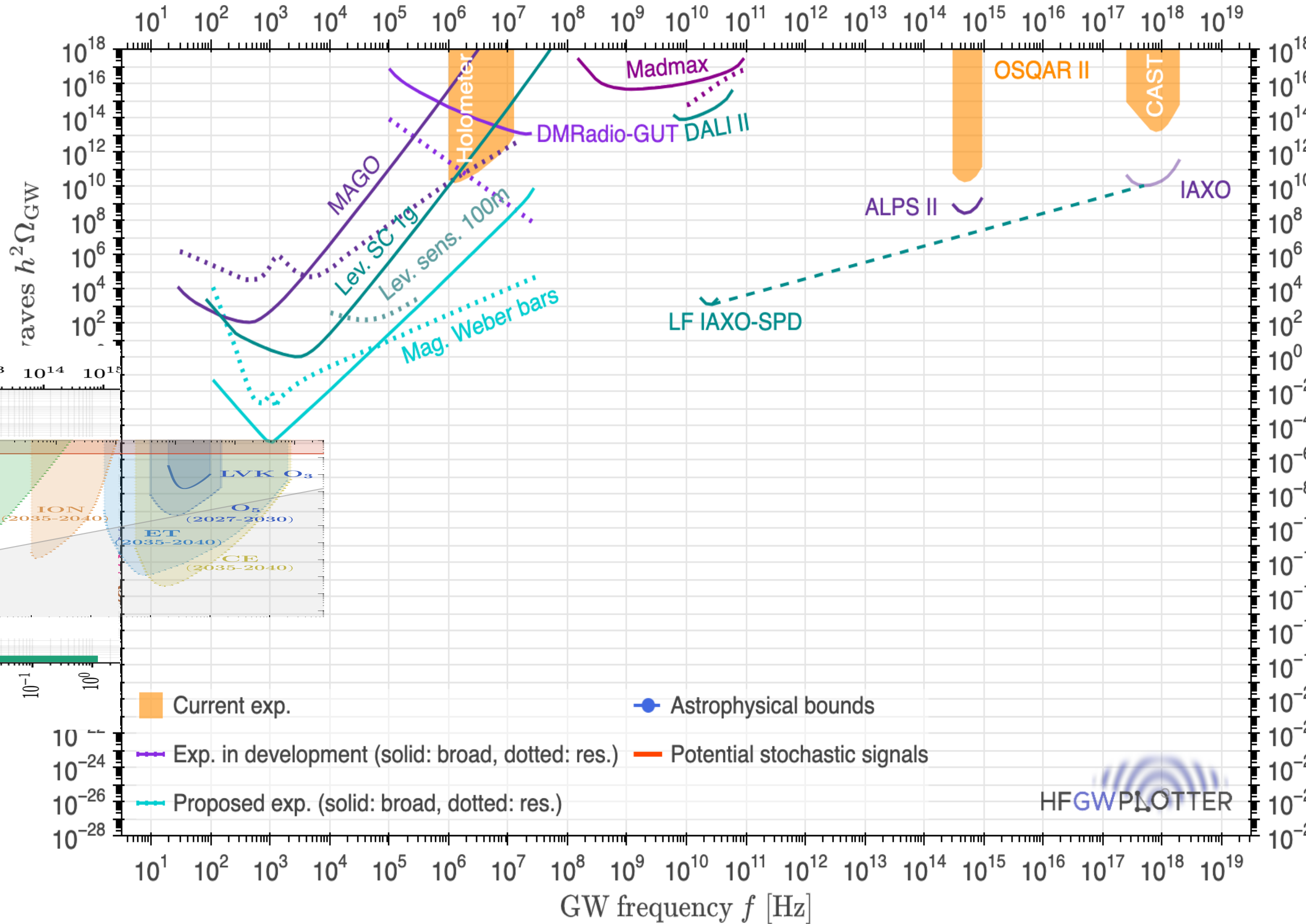
Bicep/Keck (2110.00483)

GWPlotter: Muia, Ringwald, Tamarit (2501.11723)

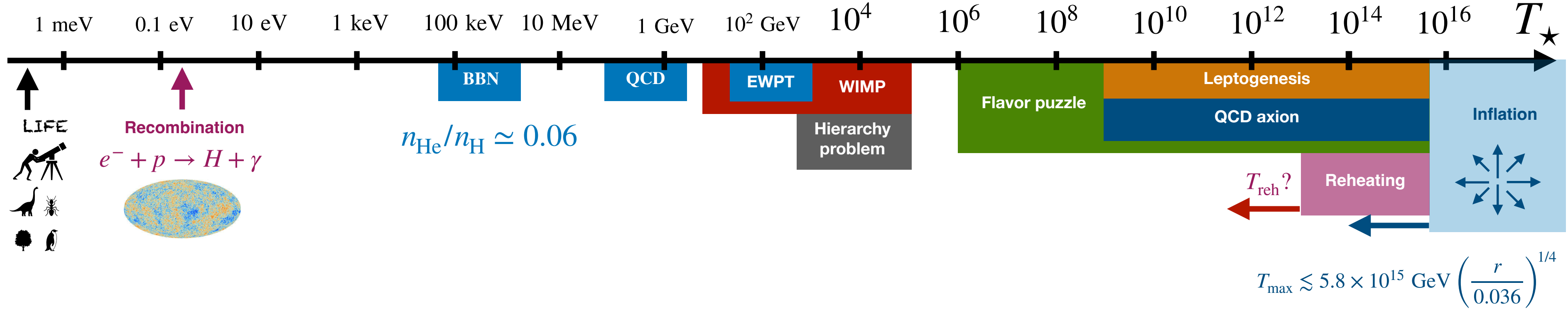
Kite, Ravenni, Patil, Chluba (2010.00040)



Saikawa, Shirai (1803.01038)
Primary GW from inflation ($r = 0.001$)

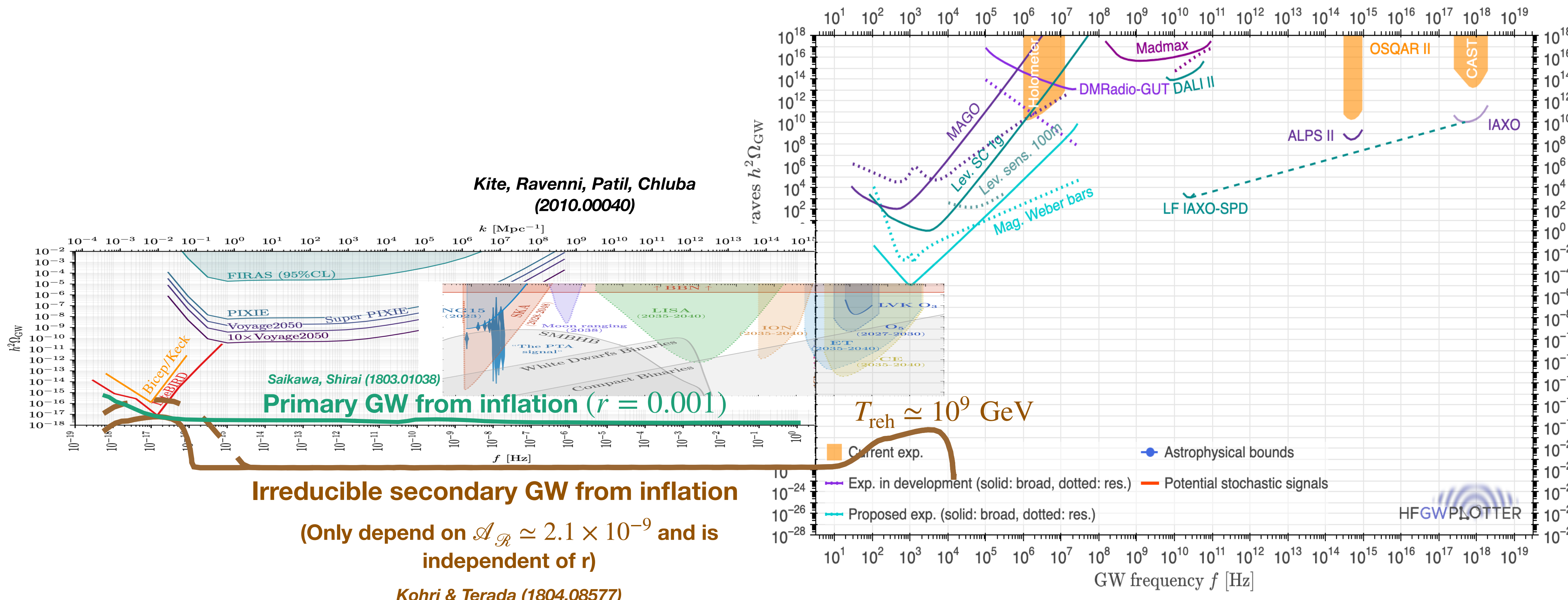


HFGWPLOTTER



Bicep/Keck (2110.00483)

GWPlotter: Muia, Ringwald, Tamarit (2501.11723)



Kite, Ravenni, Patil, Chluba (2010.00040)

Saikawa, Shirai (1803.01038)
Primary GW from inflation ($r = 0.001$)

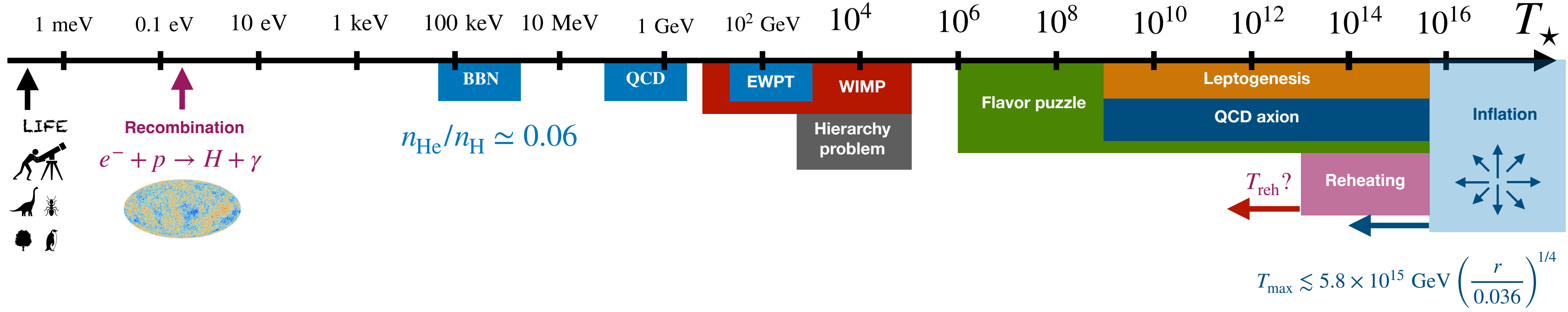
Irreducible secondary GW from inflation
(Only depend on $\mathcal{A}_{\mathcal{R}} \approx 2.1 \times 10^{-9}$ and is independent of r)

Kohri & Terada (1804.08577)

$T_{\text{reh}} \approx 10^9 \text{ GeV}$

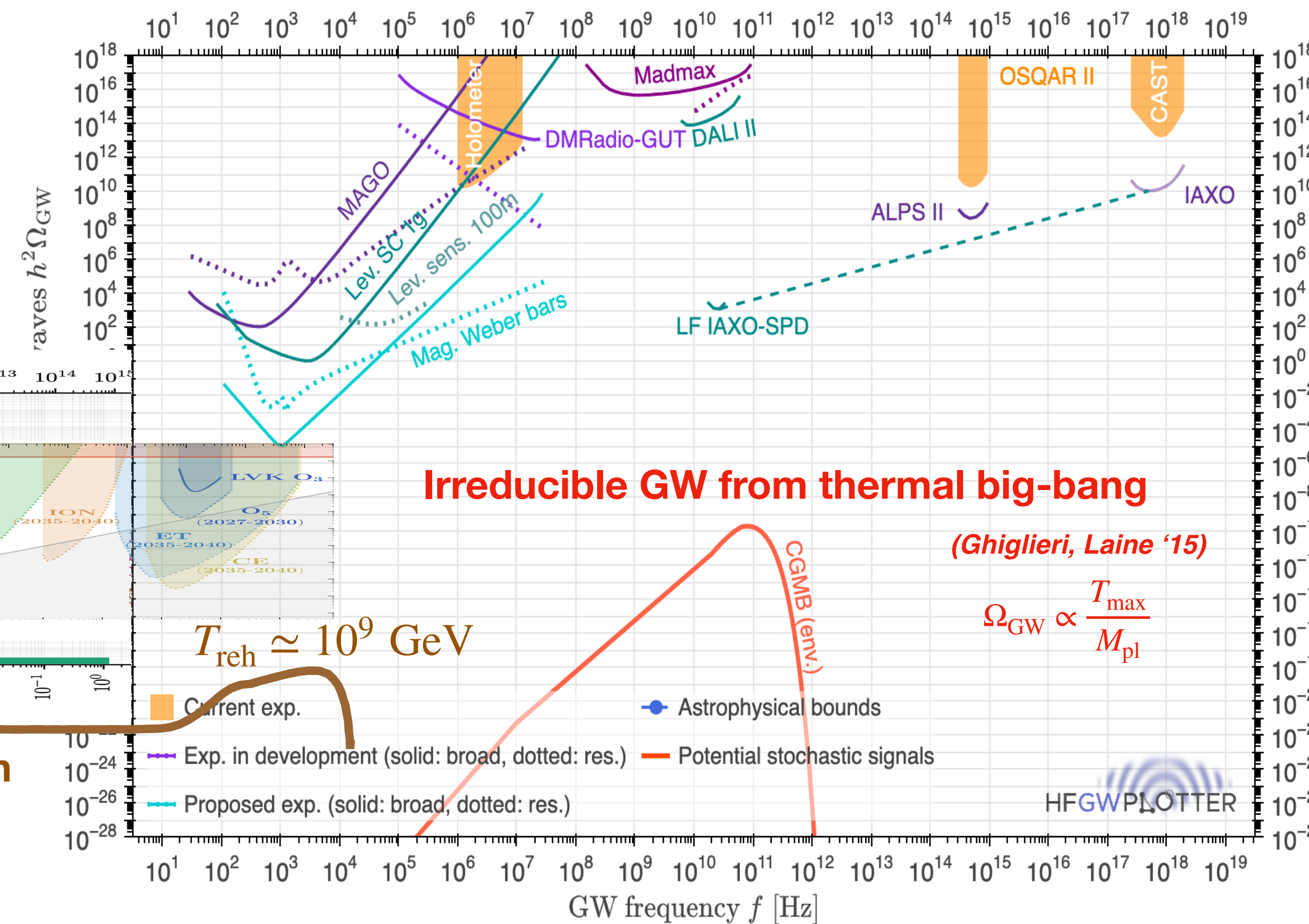
Legend:
 - Current exp. (orange box)
 - Exp. in development (solid: broad, dotted: res.) (purple line)
 - Proposed exp. (solid: broad, dotted: res.) (cyan line)
 - Astrophysical bounds (blue circle)
 - Potential stochastic signals (orange line)

HFGWPLOTTER

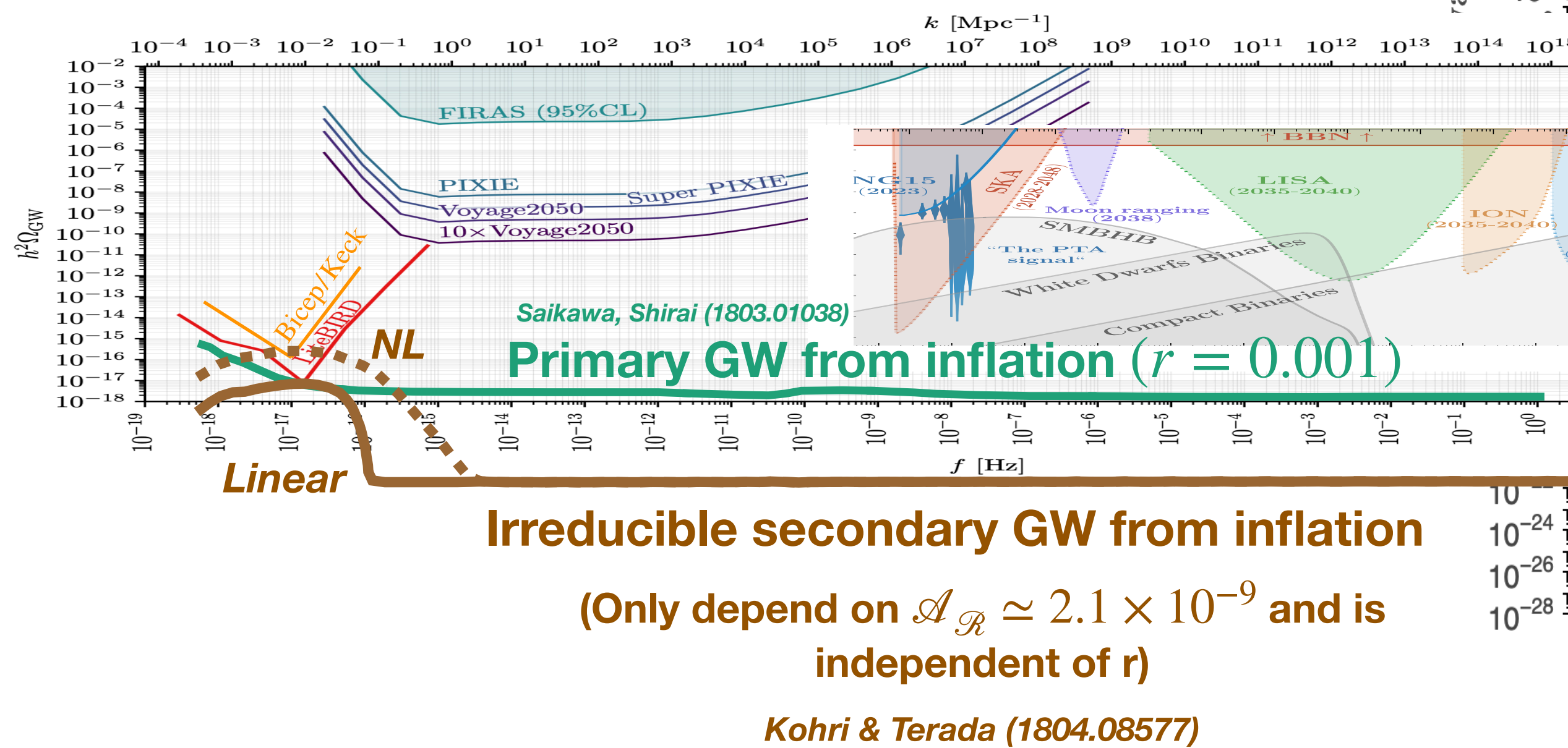


Bicep/Keck (2110.00483)

GWPlotter: Muia, Ringwald, Tamarit (2501.11723)



Kite, Ravenni, Patil, Chluba (2010.00040)



Irreducible secondary GW from inflation (Only depend on $\mathcal{A}_{\mathcal{R}} \simeq 2.1 \times 10^{-9}$ and is independent of r)

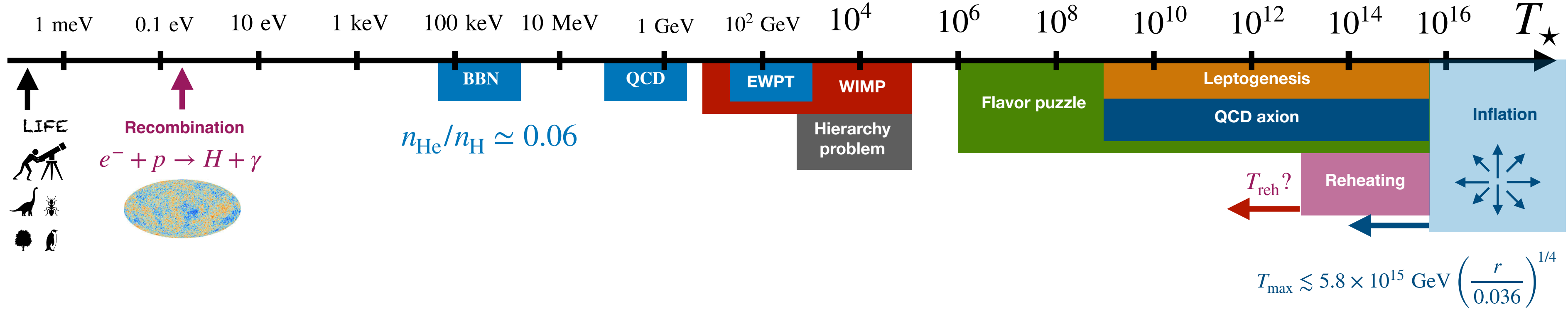
Kohri & Terada (1804.08577)

Irreducible GW from thermal big-bang

(Ghiglieri, Laine '15)

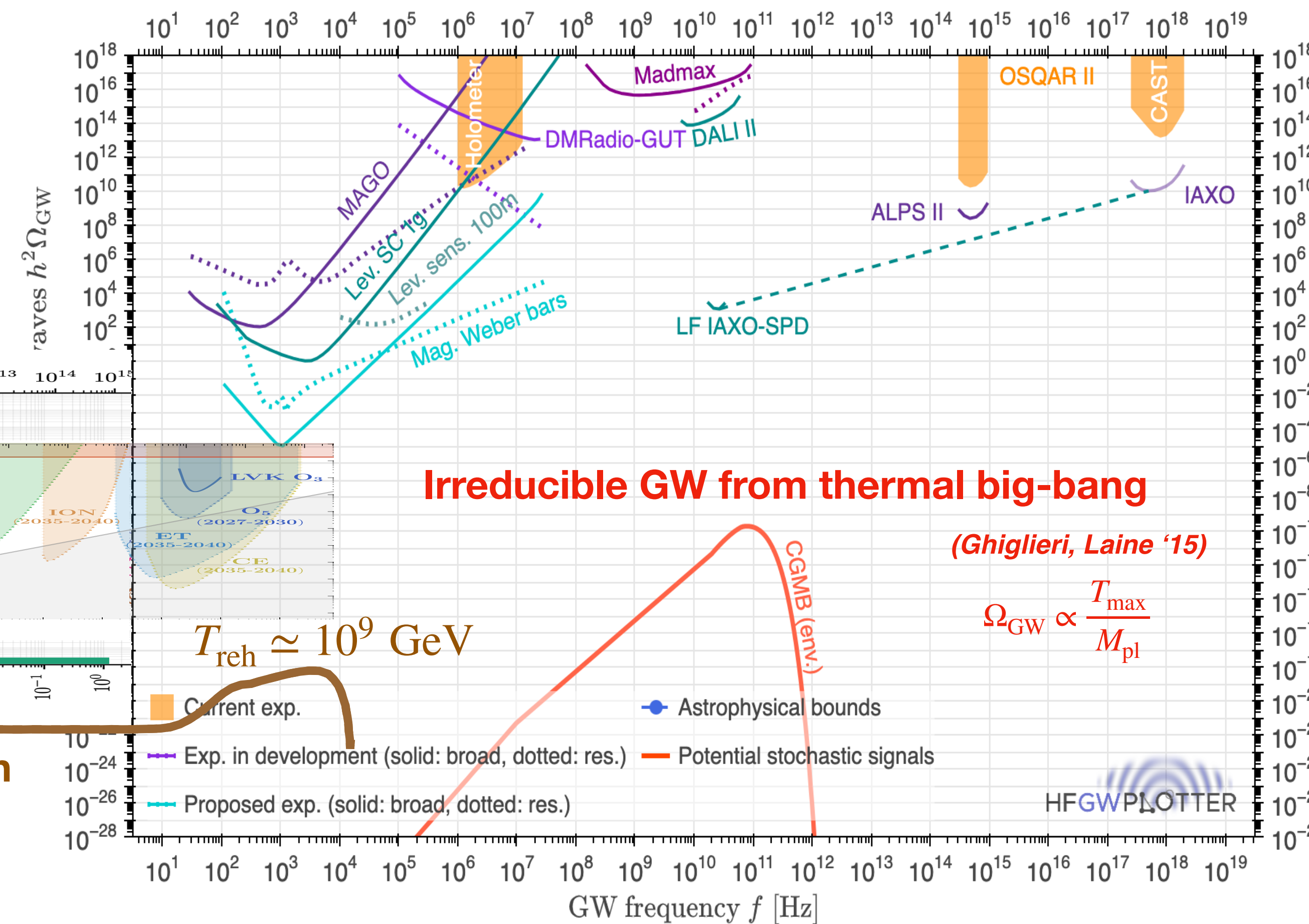
$$\Omega_{\text{GW}} \propto \frac{T_{\text{max}}}{M_{\text{pl}}}$$

HFGW PLOTTER

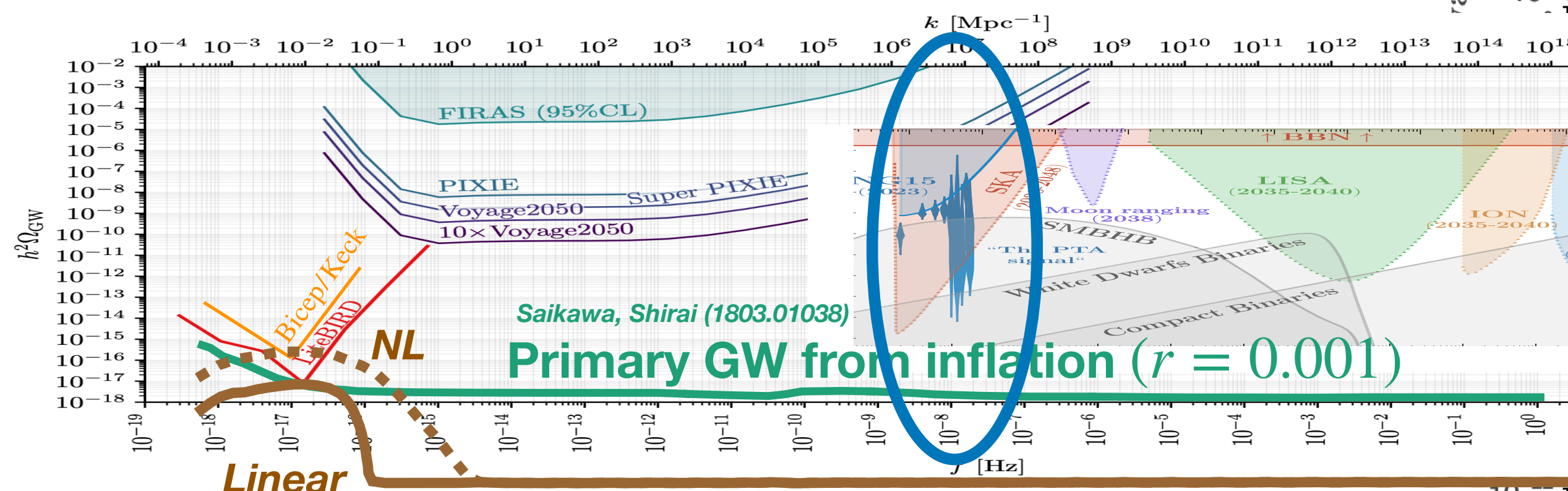


Bicep/Keck (2110.00483)

GWPlotter: Muia, Ringwald, Tamarit (2501.11723)



Pulsar Timing Arrays



Irreducible secondary GW from inflation (Only depend on $\mathcal{A}_{\mathcal{R}} \approx 2.1 \times 10^{-9}$ and is independent of r)

Kohri & Terada (1804.08577)

Irreducible GW from thermal big-bang

(Ghiglieri, Laine '15)

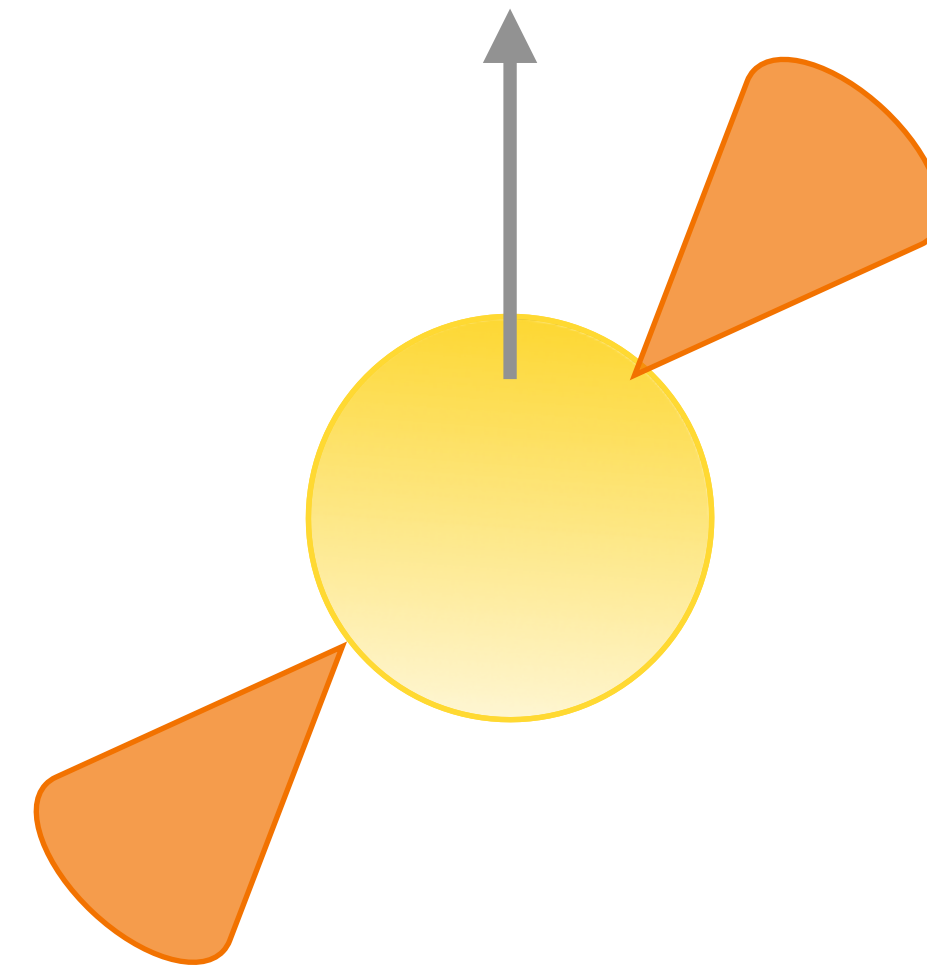
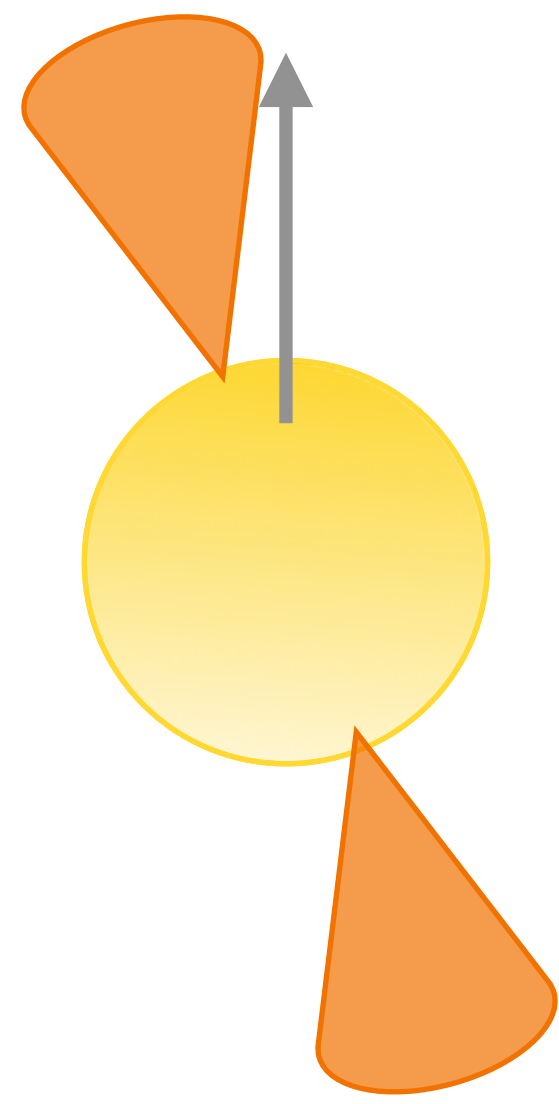
$$\Omega_{\text{GW}} \propto \frac{T_{\text{max}}}{M_{\text{pl}}}$$

$T_{\text{reh}} \approx 10^9 \text{ GeV}$

- Current exp.
- Exp. in development (solid: broad, dotted: res.)
- Proposed exp. (solid: broad, dotted: res.)
- Astrophysical bounds
- Potential stochastic signals

HFGW PLOTTER

Pulsar Timing Arrays (PTA)



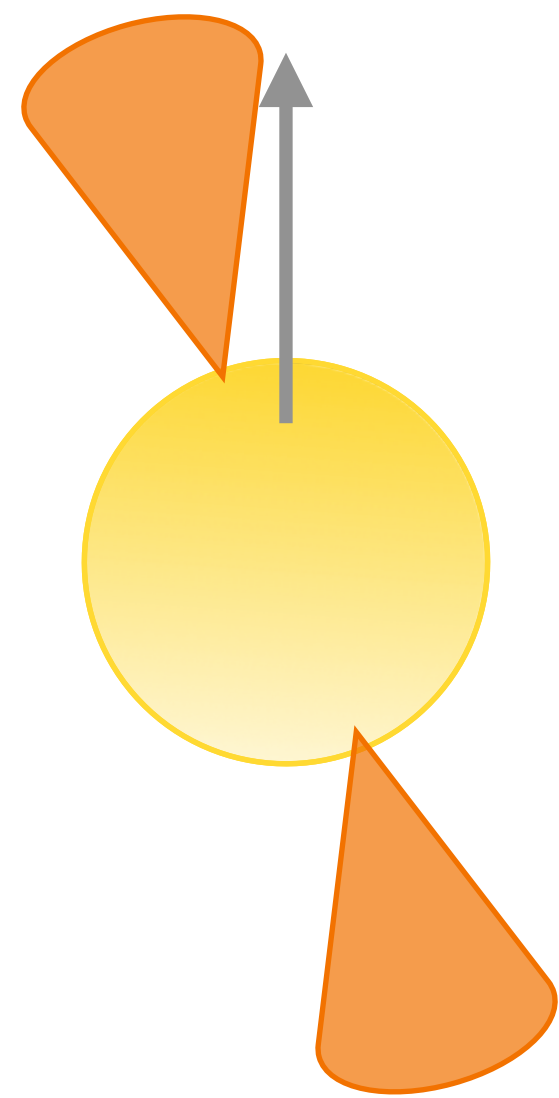
The New York Times

© 2023 The New York Times Company

NEW YORK, THURSDAY, JUNE 29, 2023

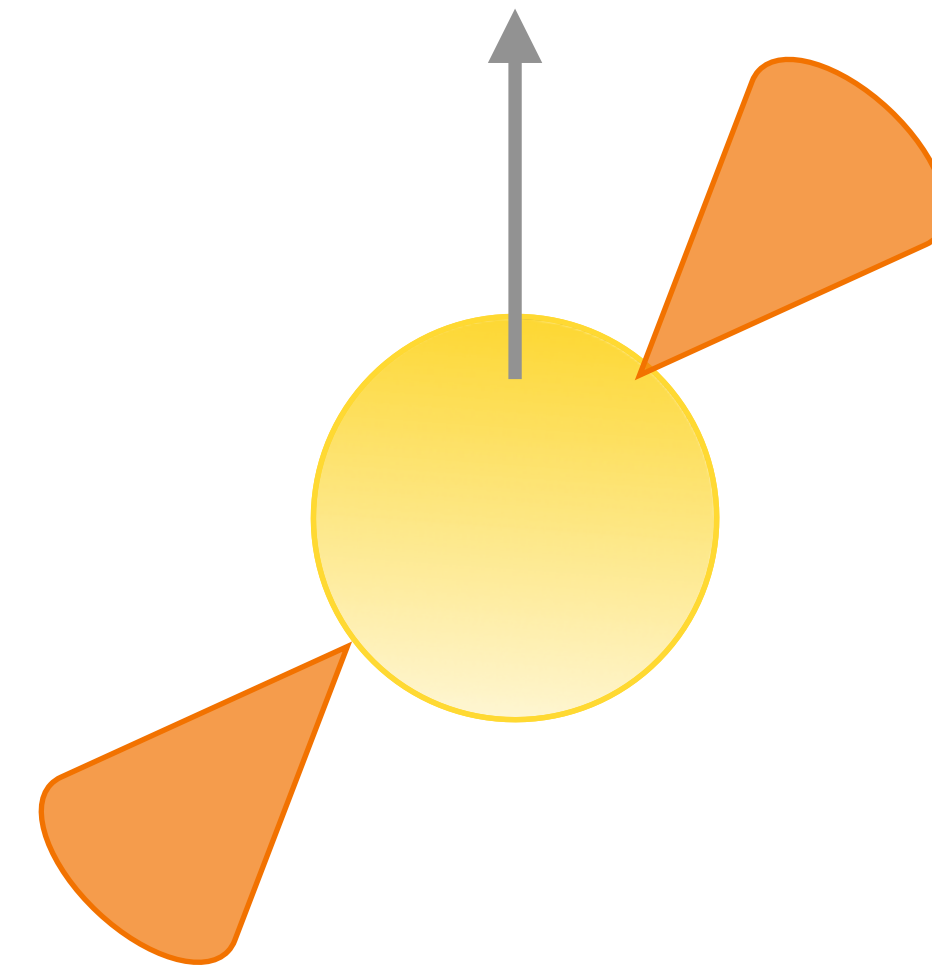
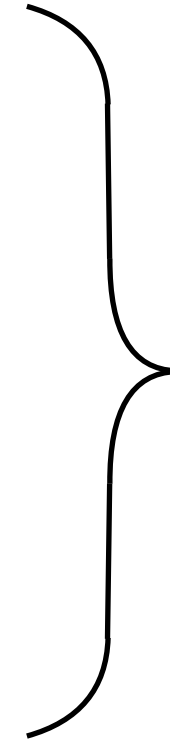
The Cosmos Is Thrumming With Gravitational Waves, Astronomers Find





Pulsar Timing Arrays (PTA)

1 M_{\odot}



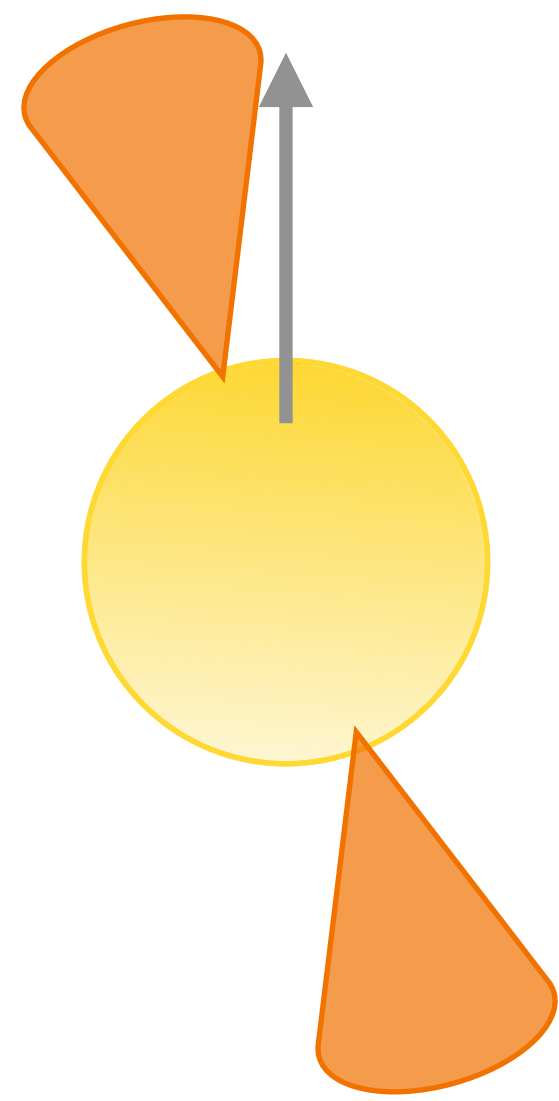
The New York Times

© 2023 The New York Times Company

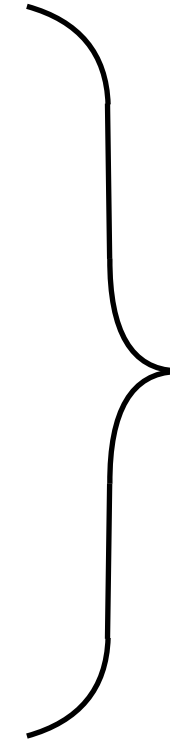
NEW YORK, THURSDAY, JUNE 29, 2023

The Cosmos Is Thrumming With Gravitational Waves, Astronomers Find



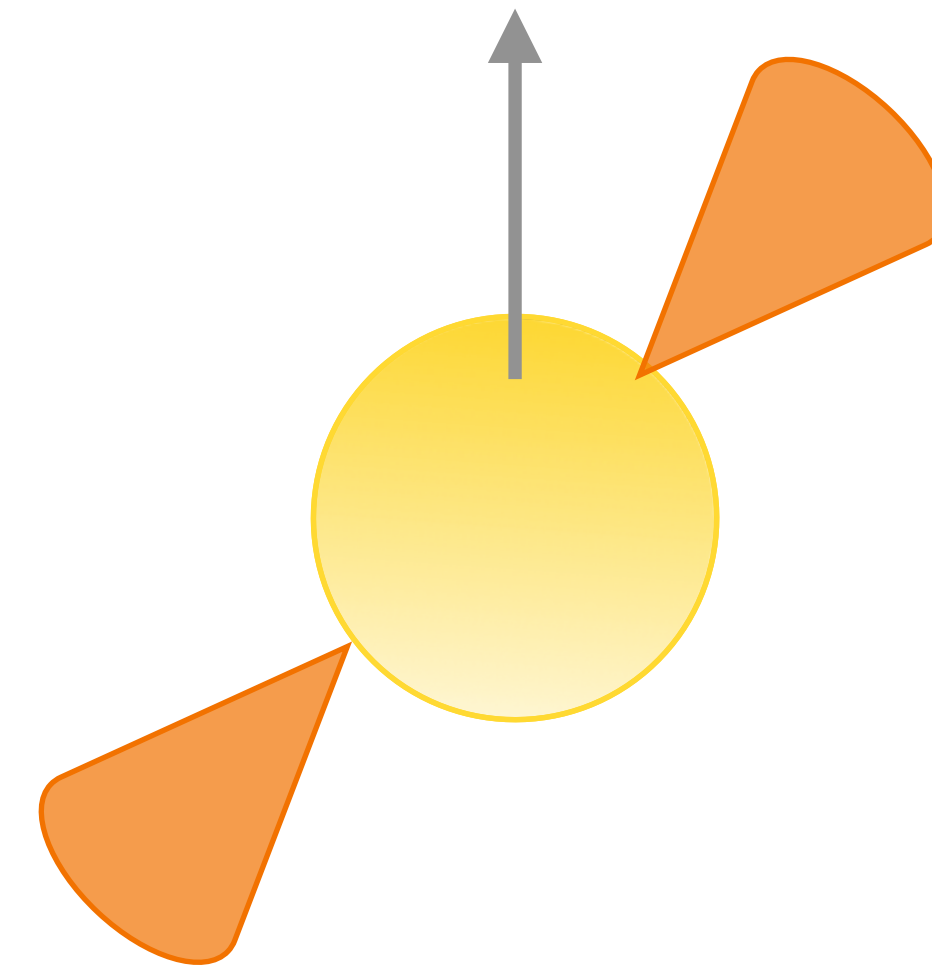


Pulsar Timing Arrays (PTA)



1 M_{\odot}

10 km



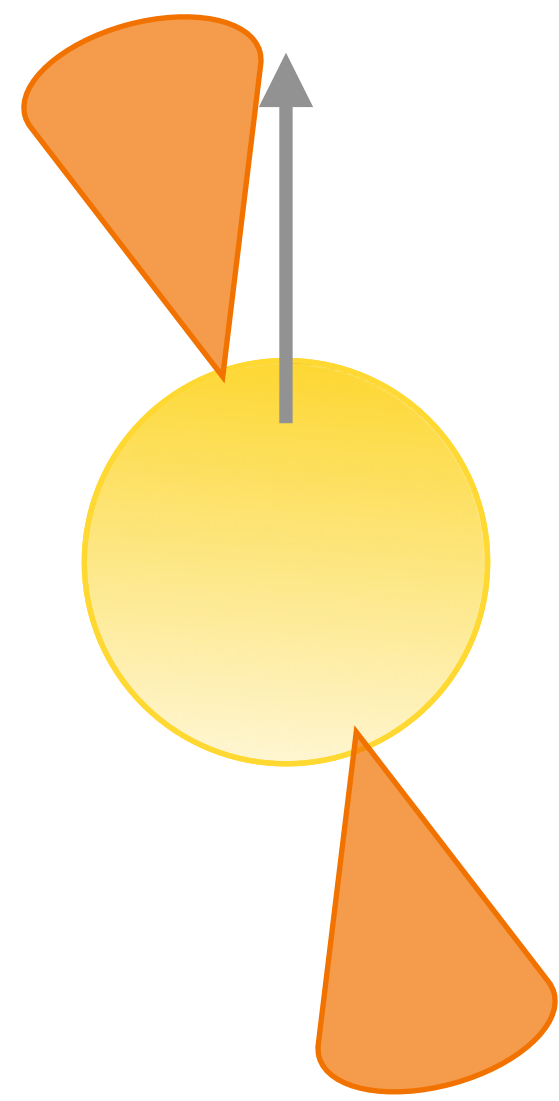
The New York Times

© 2023 The New York Times Company

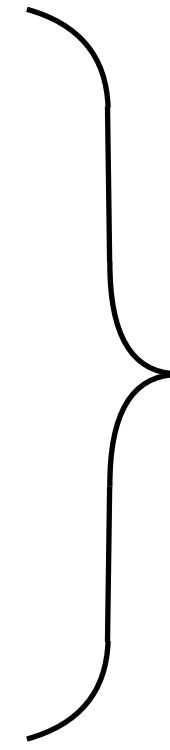
NEW YORK, THURSDAY, JUNE 29, 2023

The Cosmos Is Thrumming With Gravitational Waves, Astronomers Find





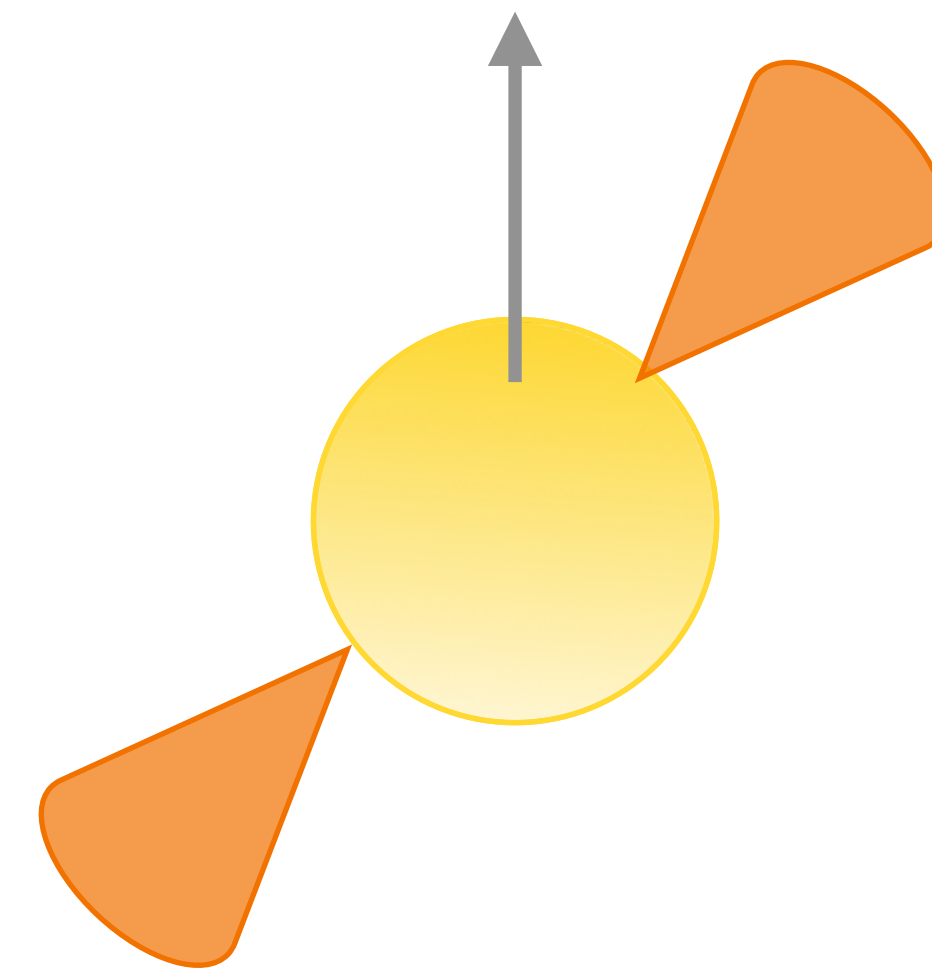
Pulsar Timing Arrays (PTA)



1 M_{\odot}

10 km

500 rotations/s



The New York Times

© 2023 The New York Times Company

NEW YORK, THURSDAY, JUNE 29, 2023

The Cosmos Is Thrumming With Gravitational Waves, Astronomers Find

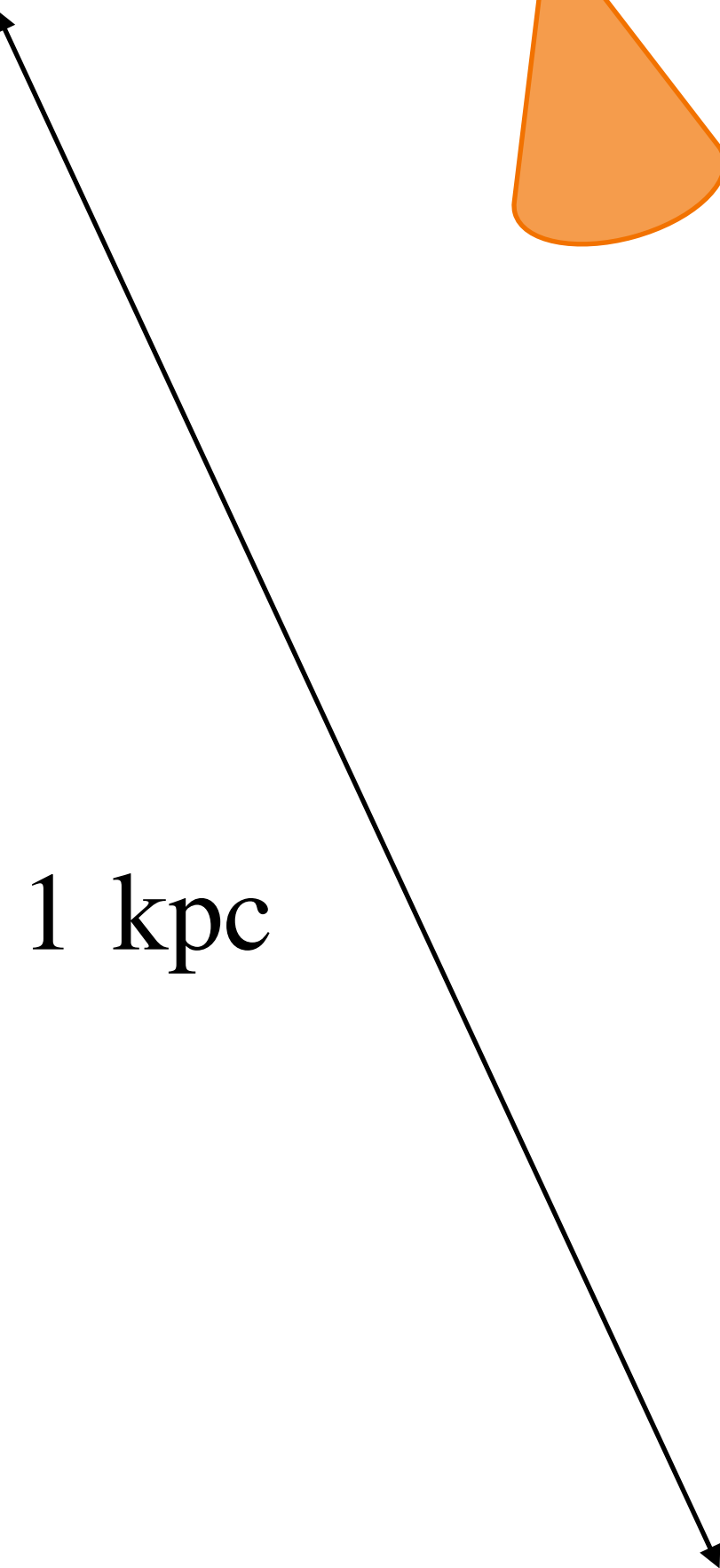
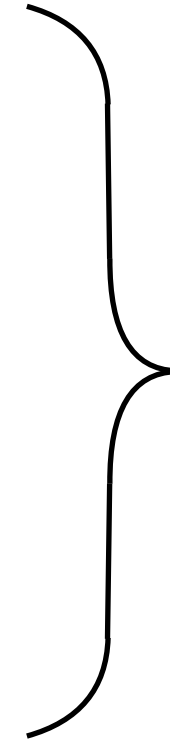
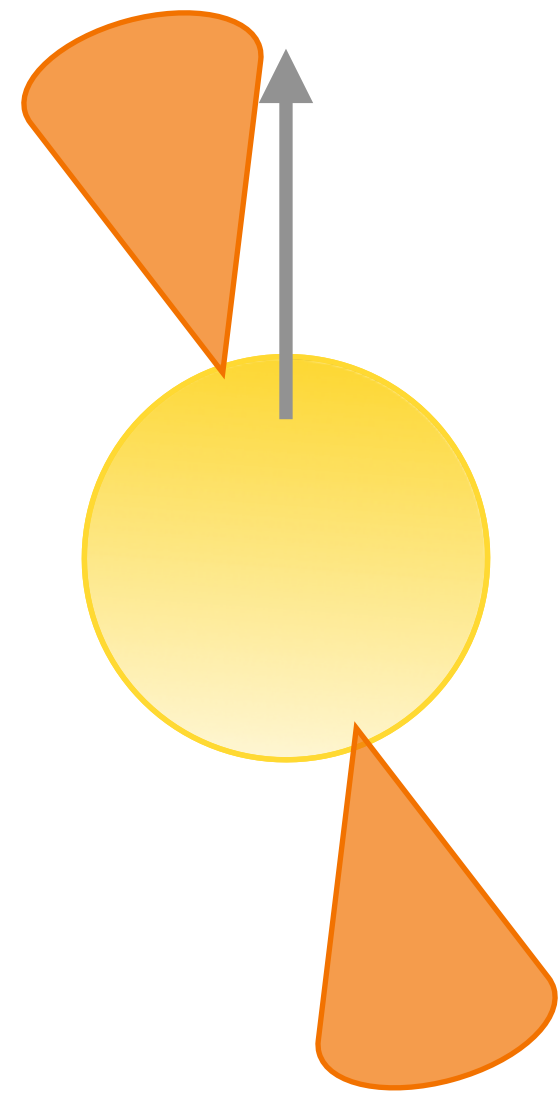


Pulsar Timing Arrays (PTA)

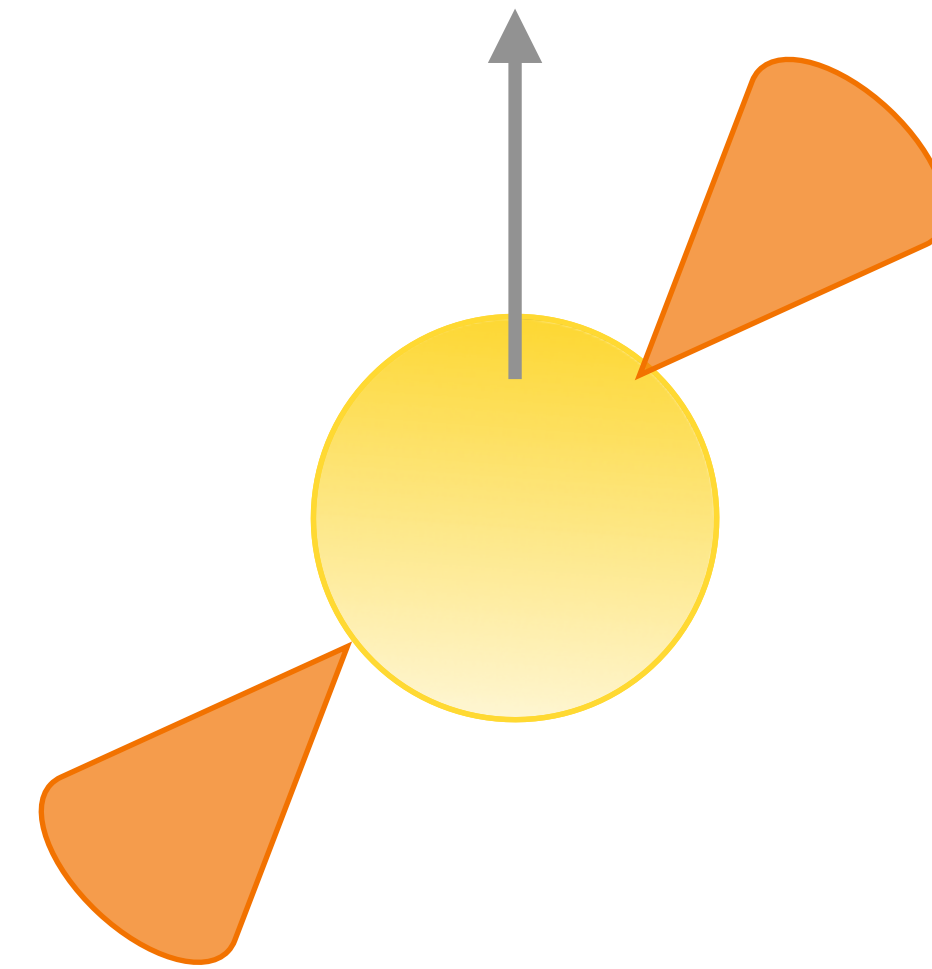
1 M_{\odot}

10 km

500 rotations/s



1 kpc



The New York Times

© 2023 The New York Times Company

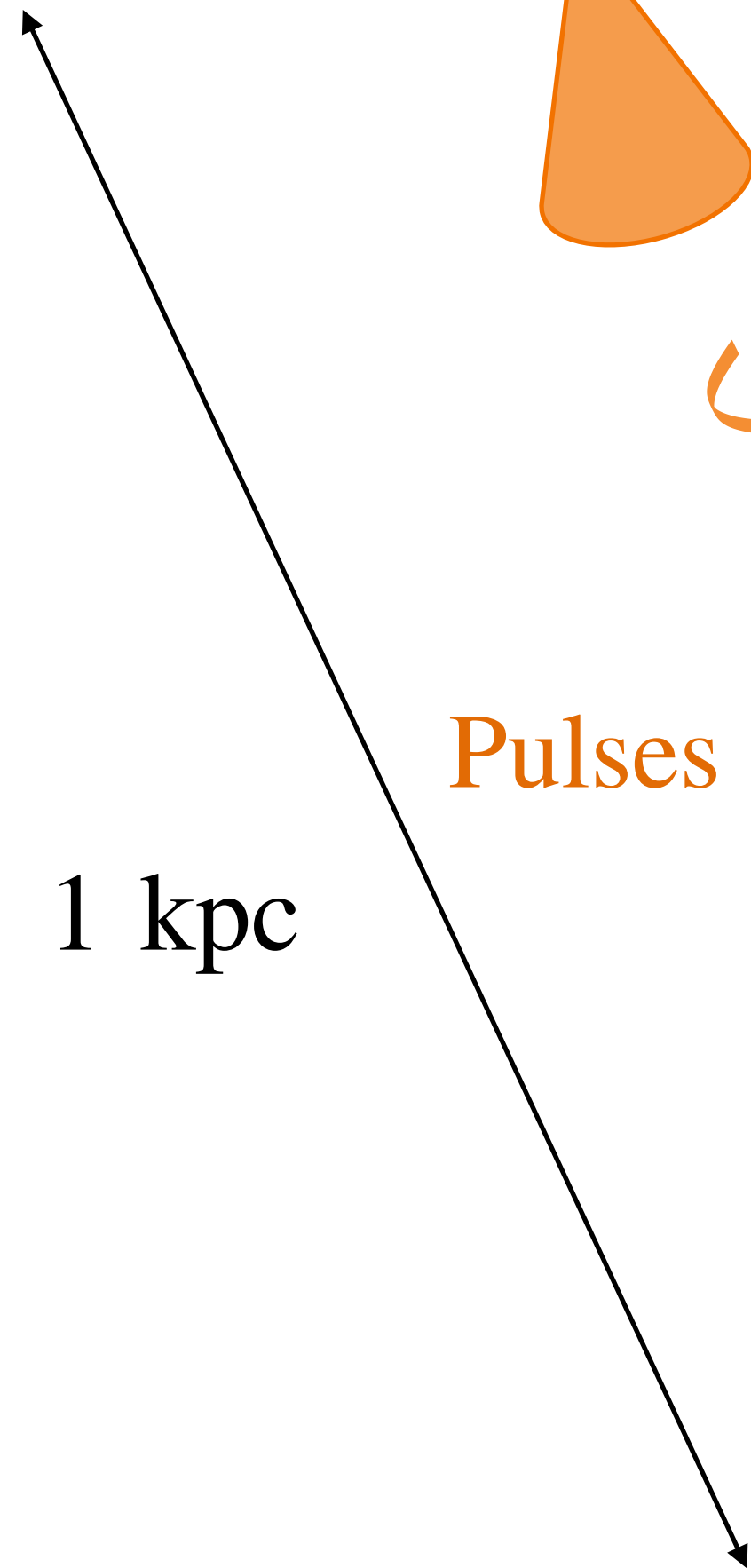
NEW YORK, THURSDAY, JUNE 29, 2023

The Cosmos Is Thrumming With Gravitational Waves, Astronomers Find



Pulsar Timing Arrays (PTA)

1 M_{\odot}
10 km
500 rotations/s



Pulses

Pulses

The New York Times

© 2023 The New York Times Company

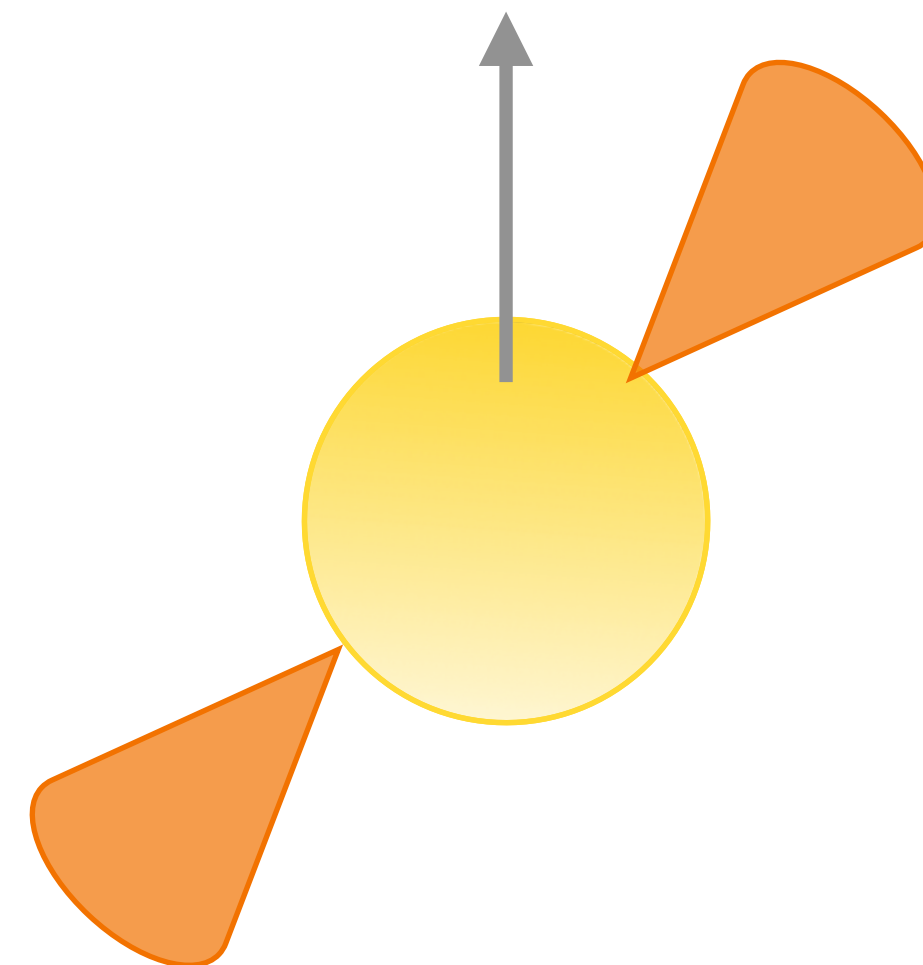
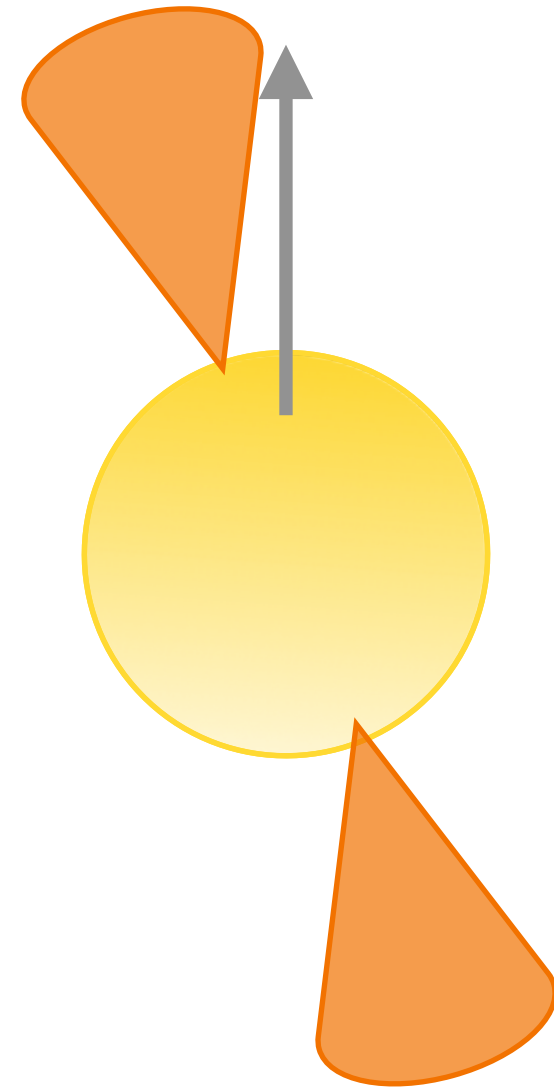
NEW YORK, THURSDAY, JUNE 29, 2023

The Cosmos Is Thrumming With Gravitational Waves, Astronomers Find



Pulsar Timing Arrays (PTA)

1 M_{\odot}
10 km
500 rotations/s



Pulses

Pulses

Gravitational
Waves

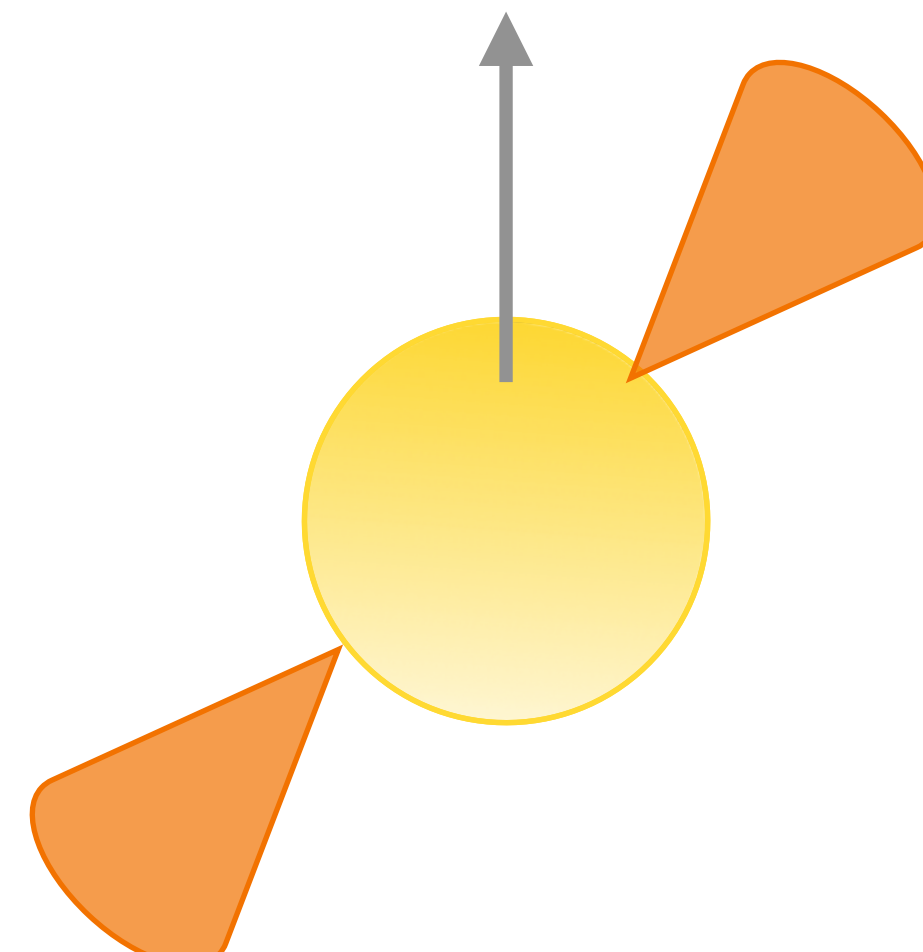
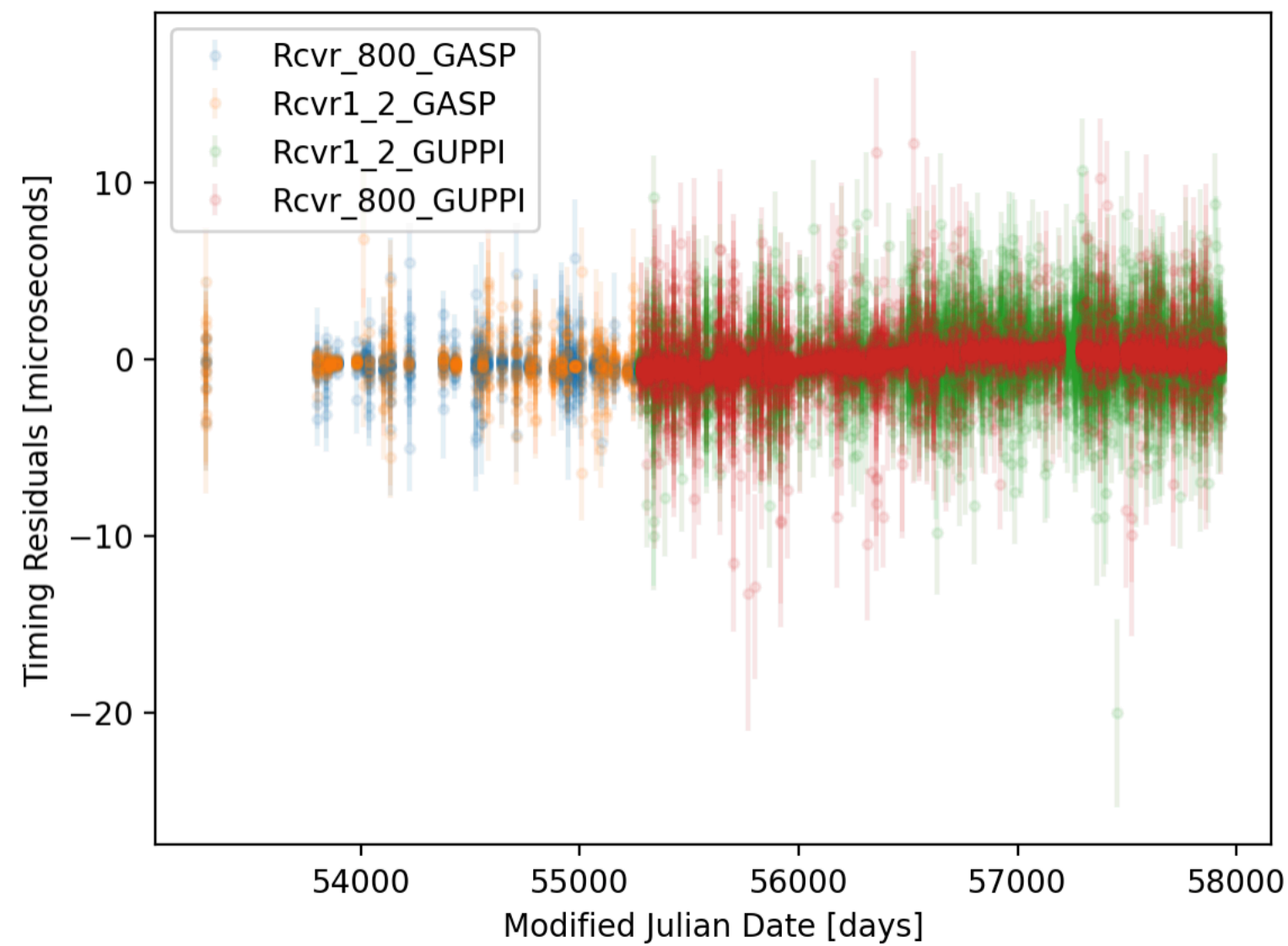
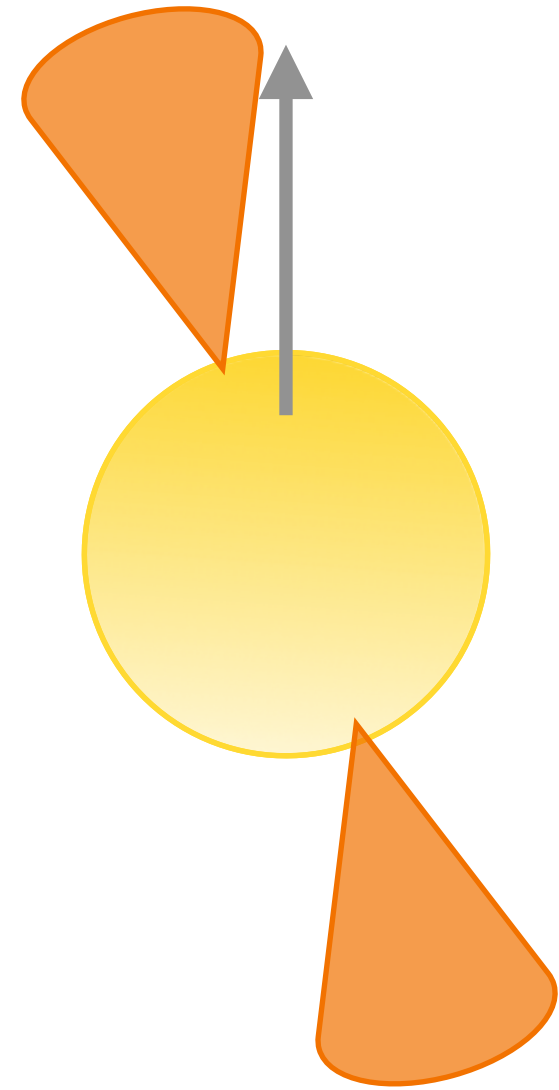


The New York Times

© 2023 The New York Times Company NEW YORK, THURSDAY, JUNE 29, 2023

The Cosmos Is Thrumming With Gravitational Waves, Astronomers Find





Pulses

Pulses

Gravitational
Waves

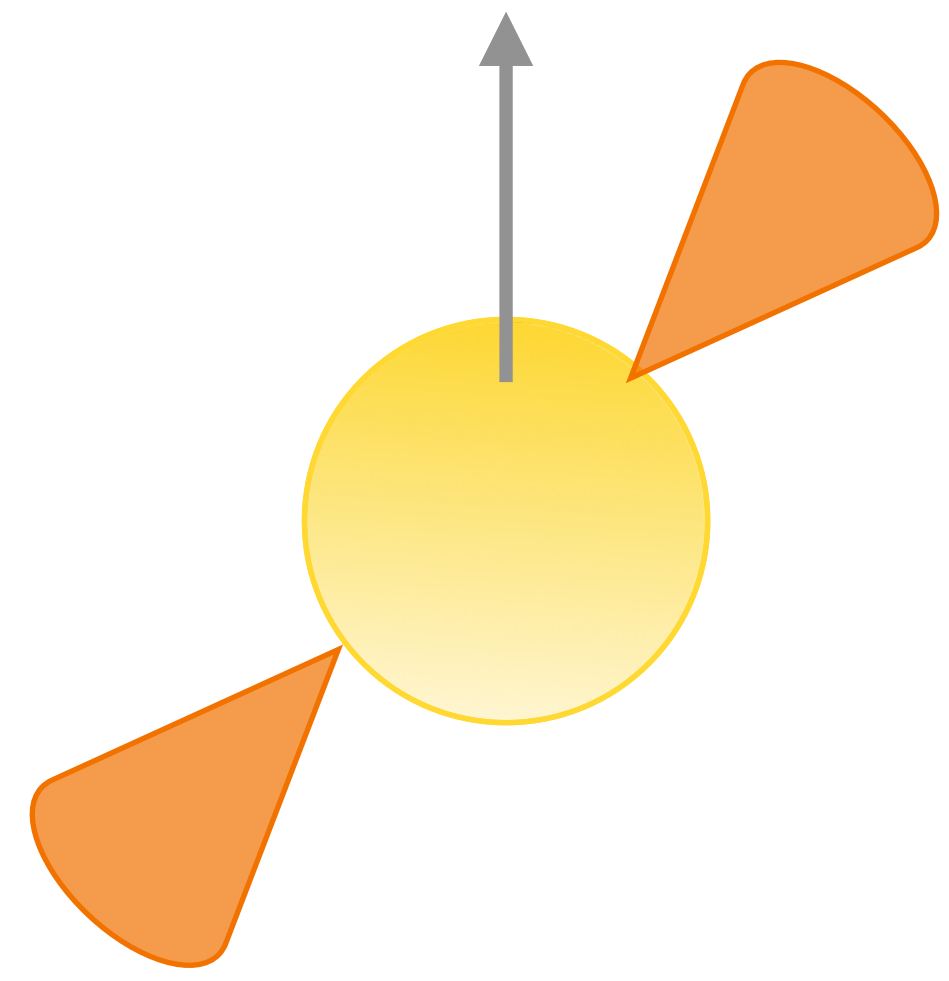
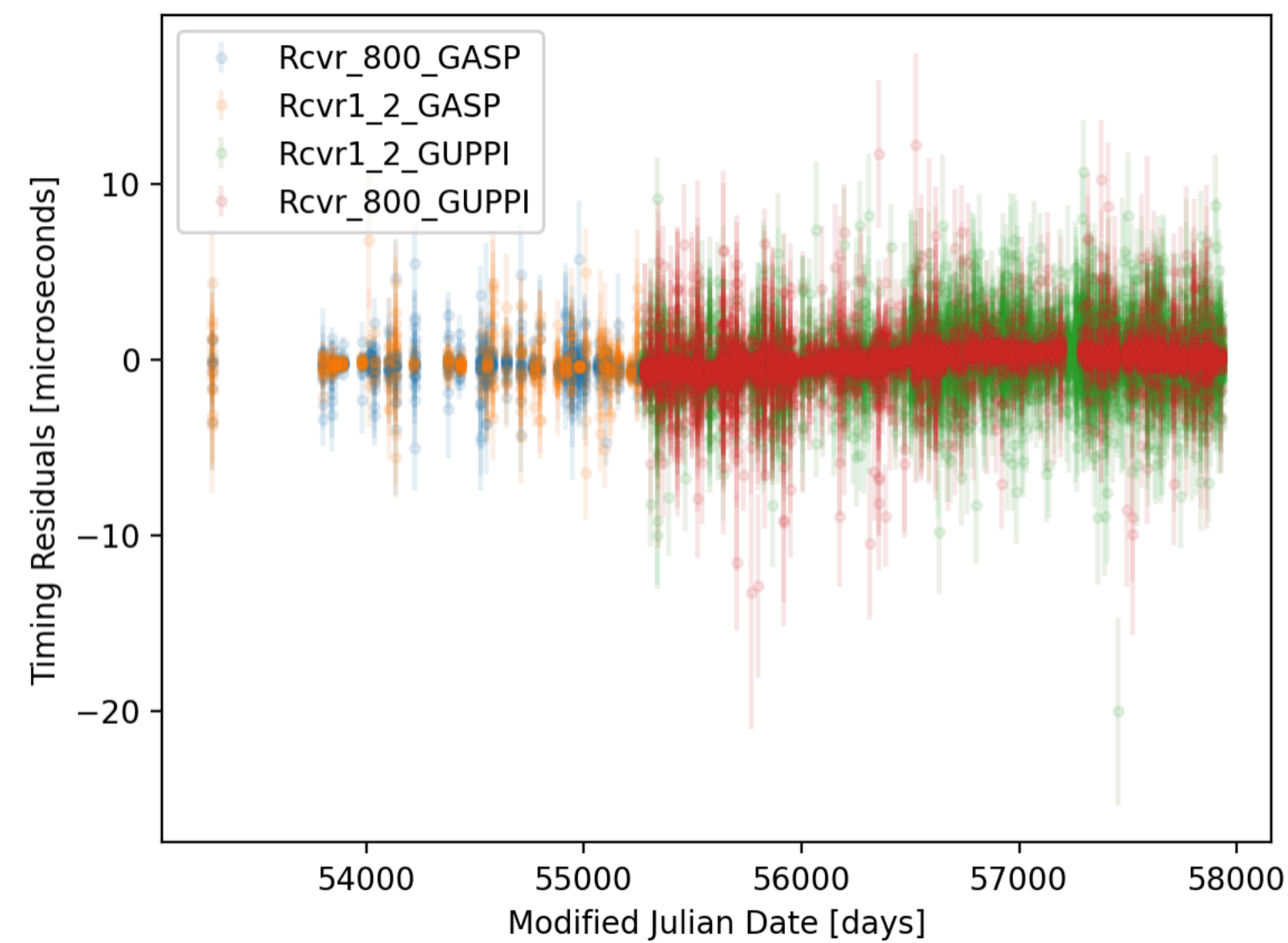
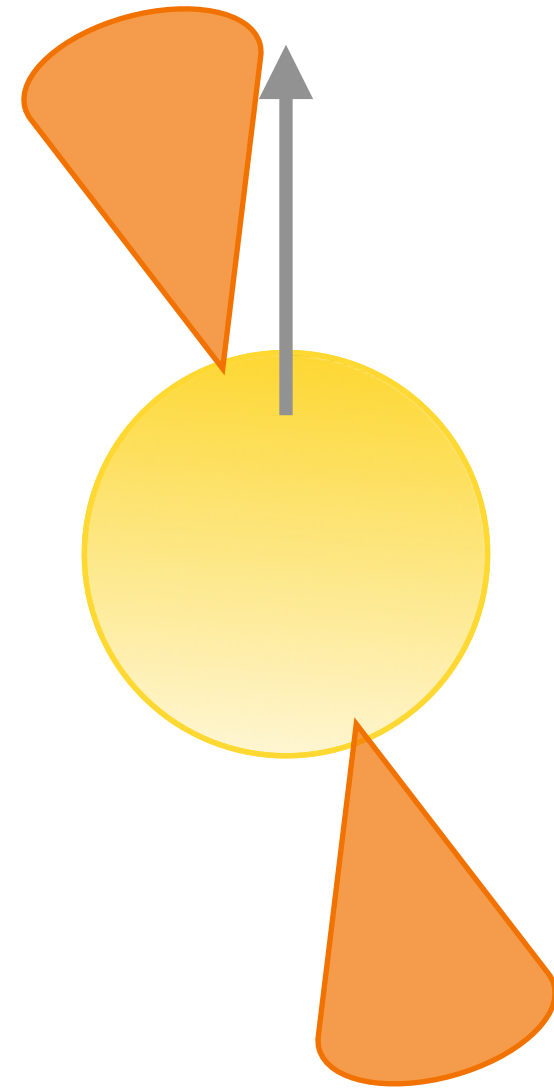


The New York Times

© 2023 The New York Times Company NEW YORK, THURSDAY, JUNE 29, 2023

The Cosmos Is Thrumming With Gravitational Waves, Astronomers Find

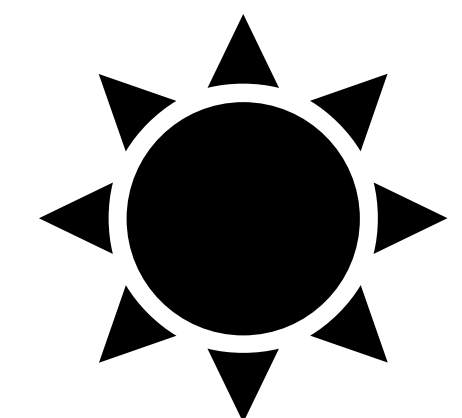
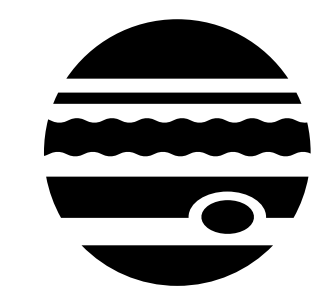
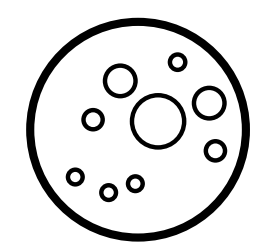




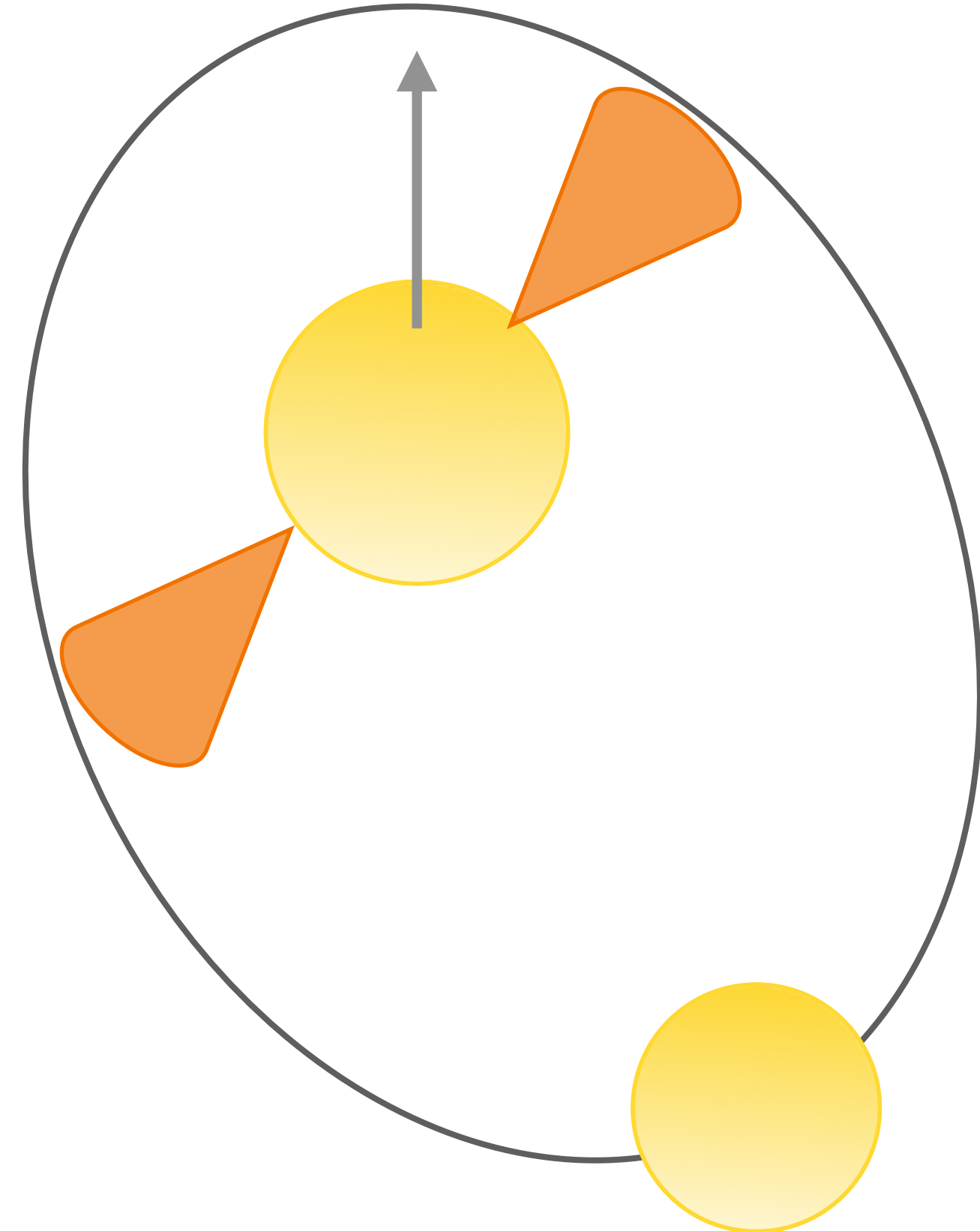
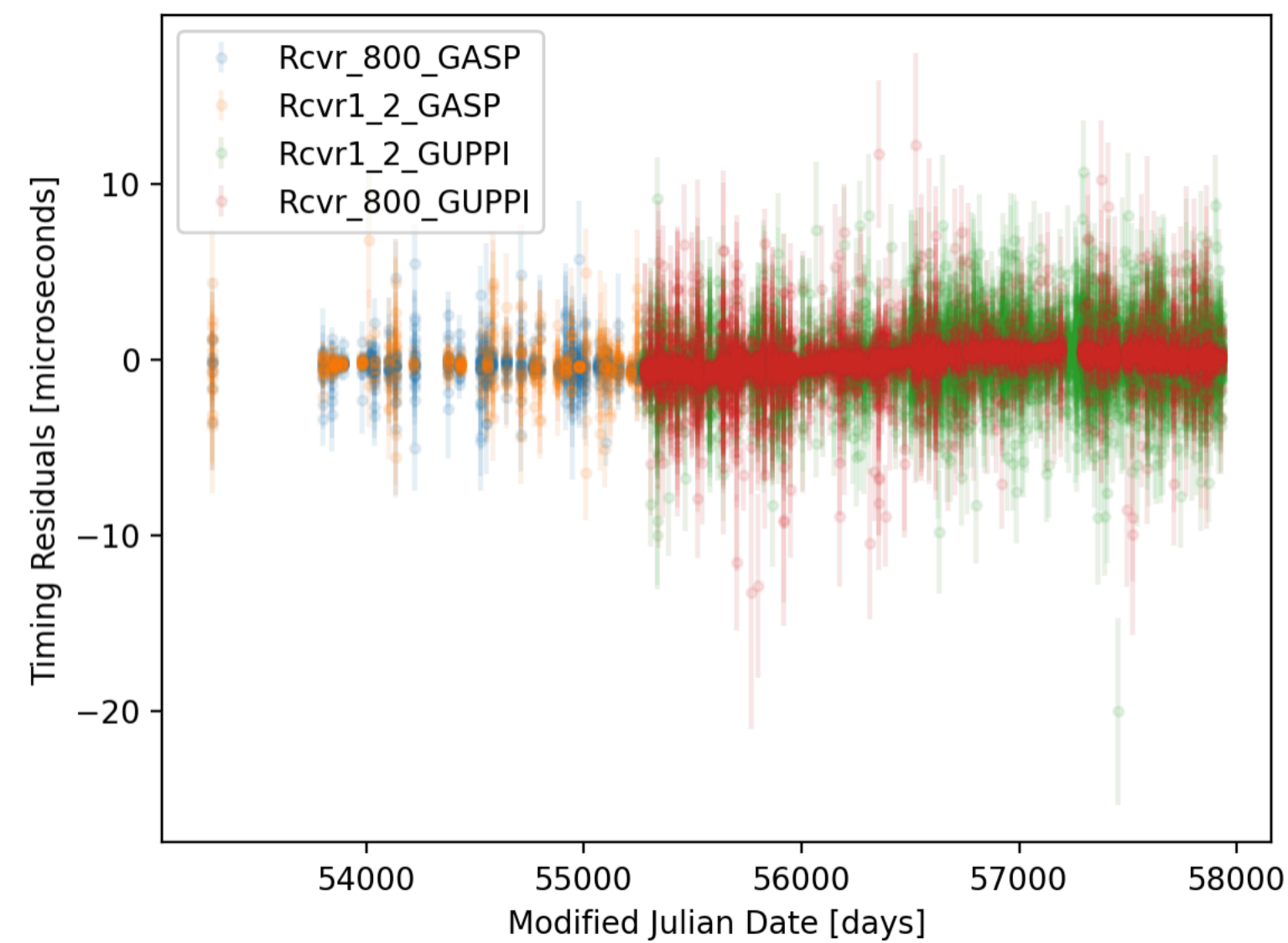
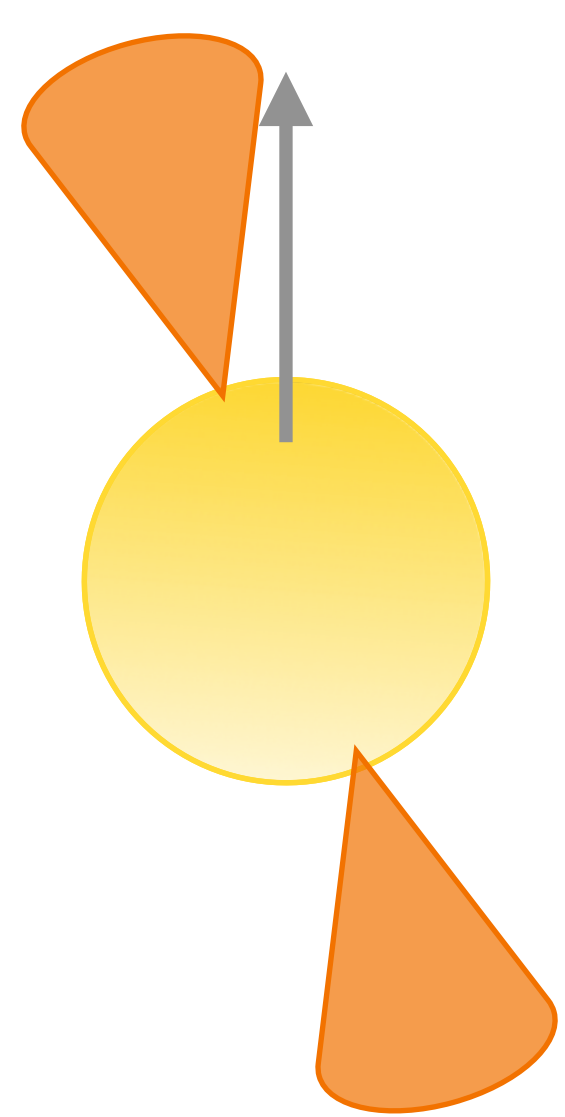
Pulses

Pulses

Gravitational
Waves



Solar system systematics

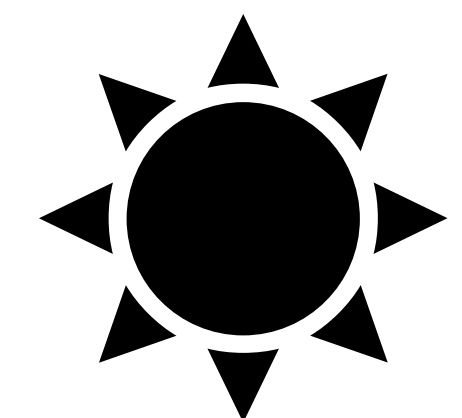
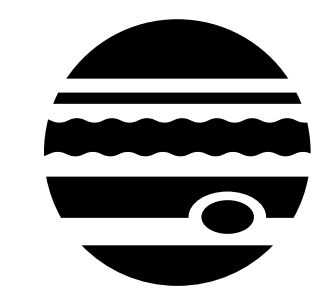
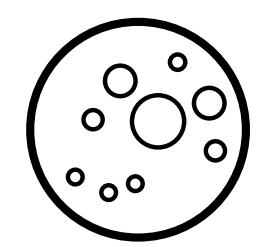


Pulses

Pulses

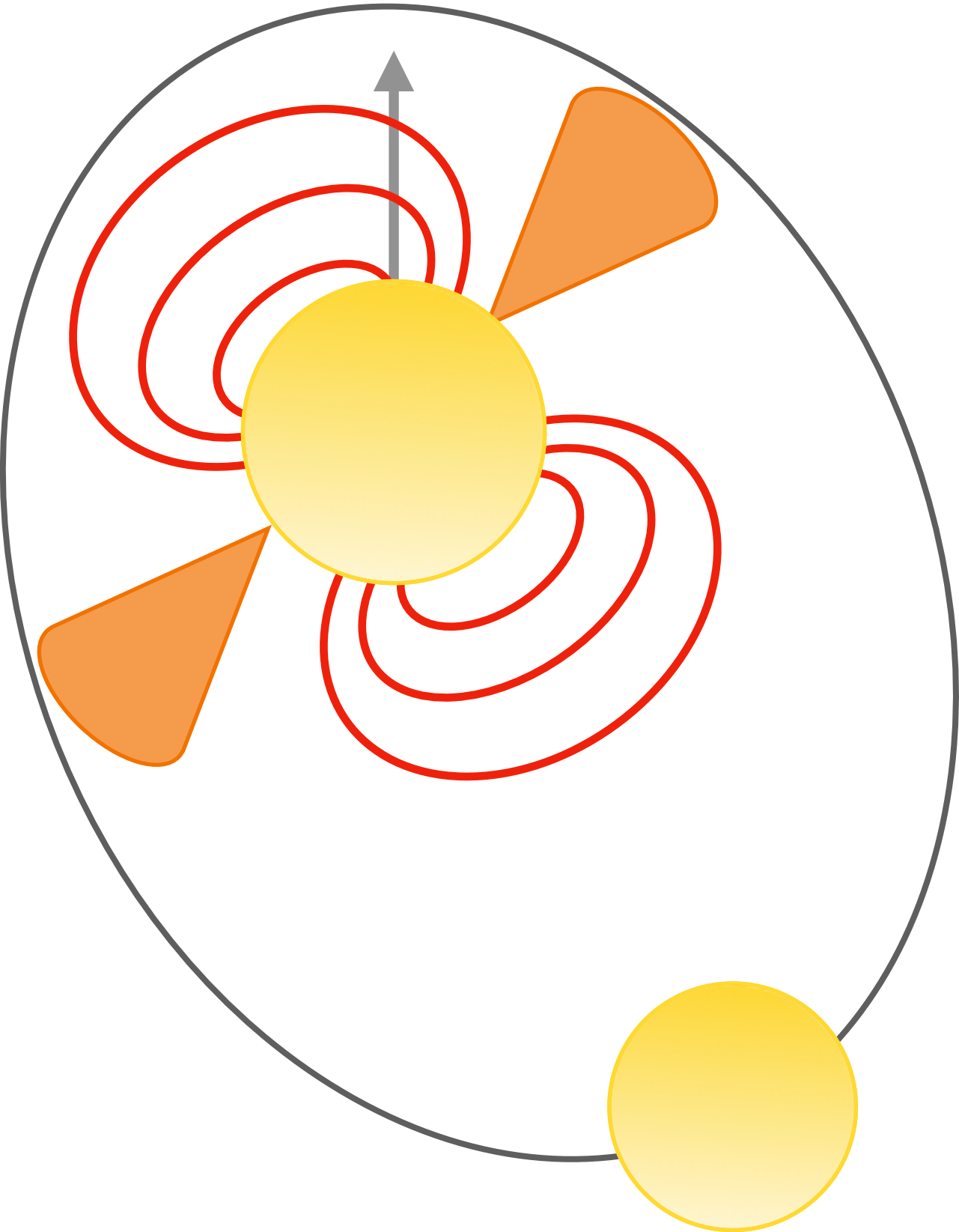
Pulsar companion systematics

Gravitational Waves



Solar system systematics

Pulsar red noise
(e.g. magnetosphere fluctuation)

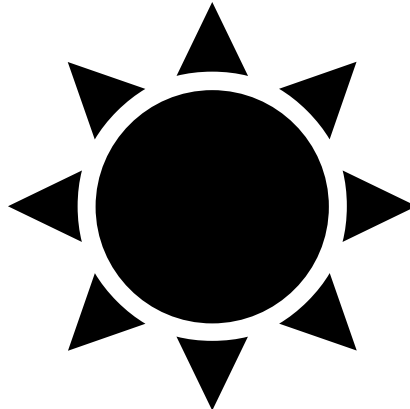
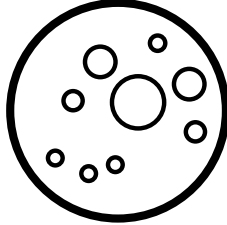


Pulsar companion systematics

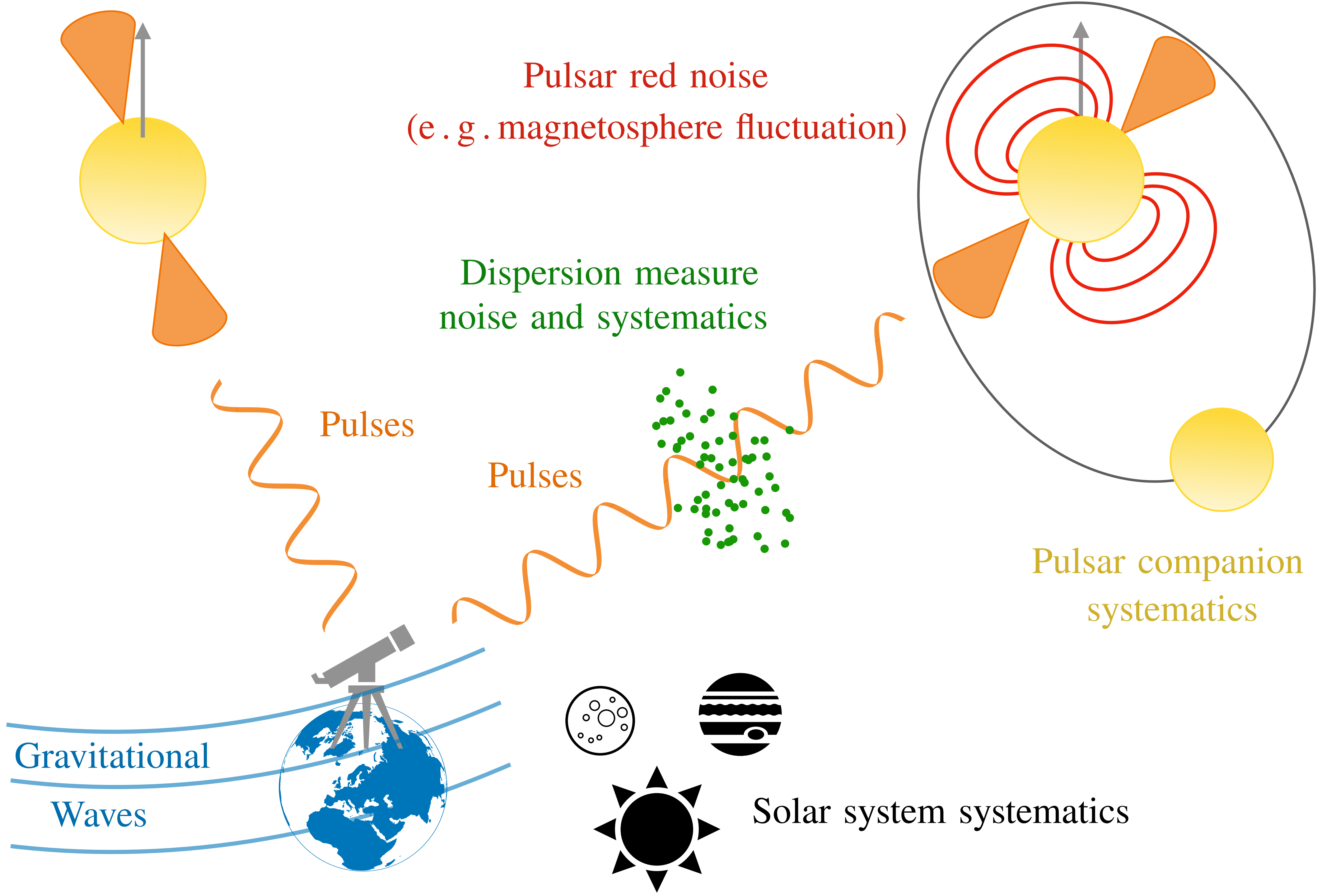
Pulses

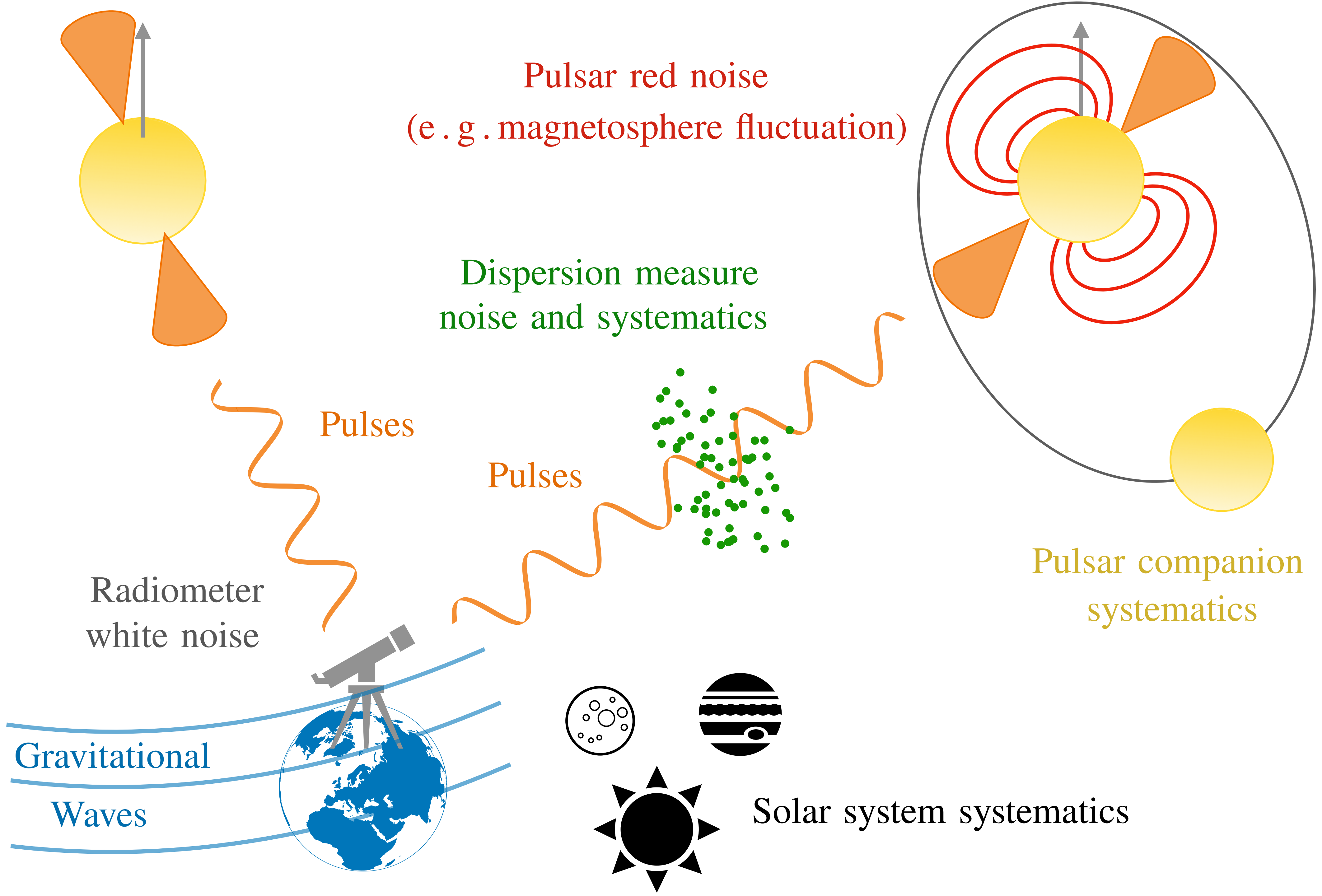
Pulses

Gravitational Waves

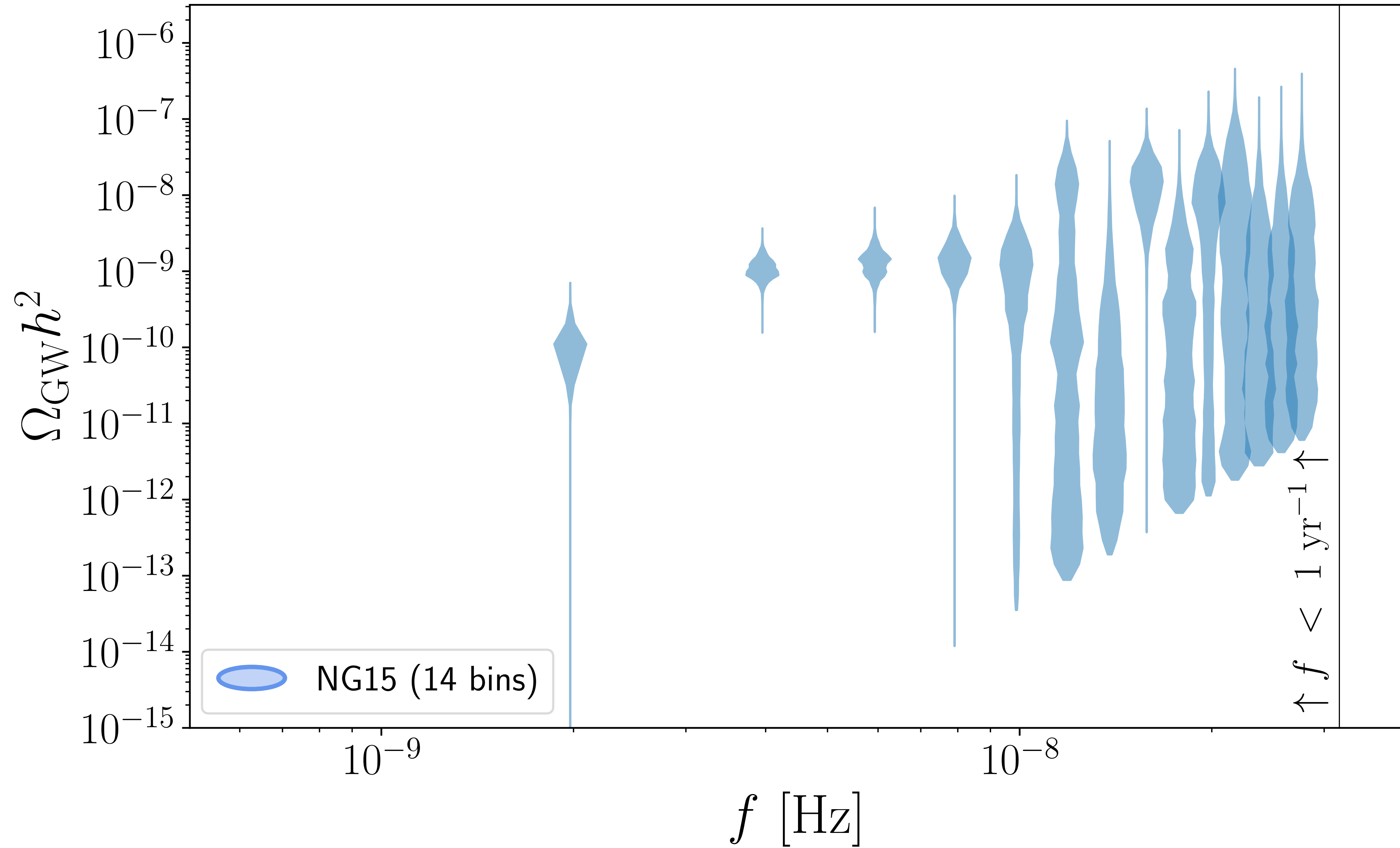


Solar system systematics

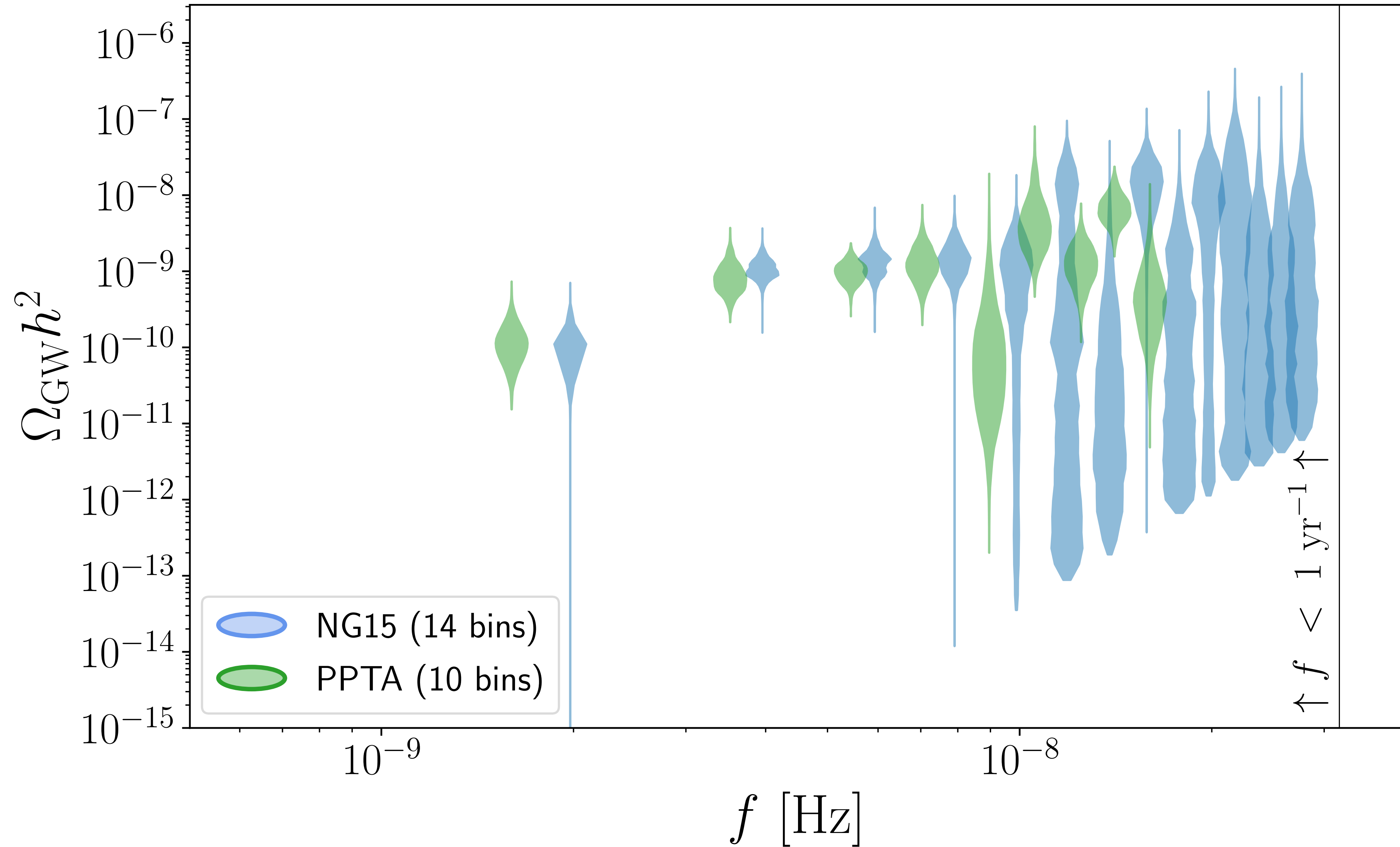




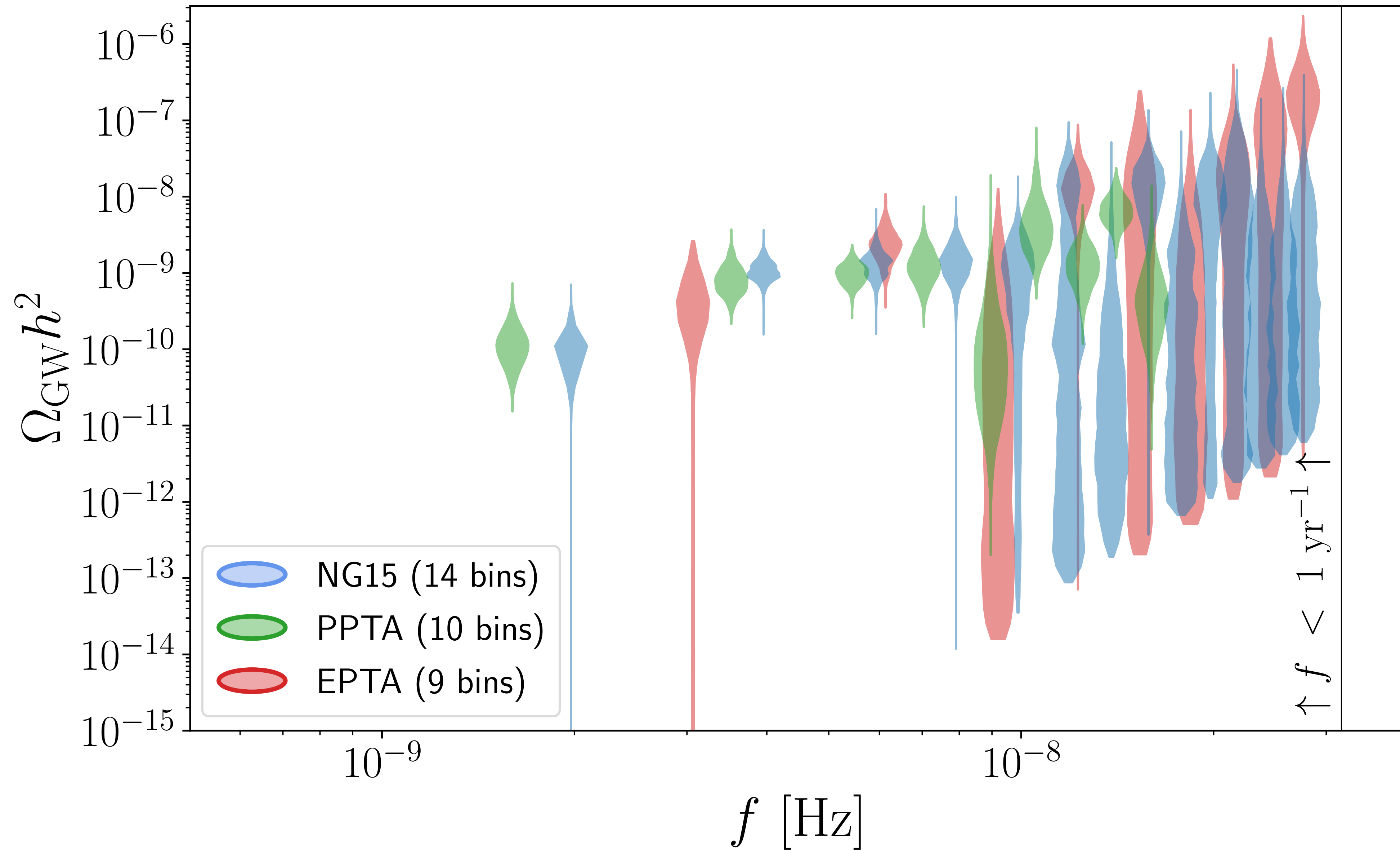
Discovery of the first stochastic GW background by Pulsar Timing Arrays (PTA)



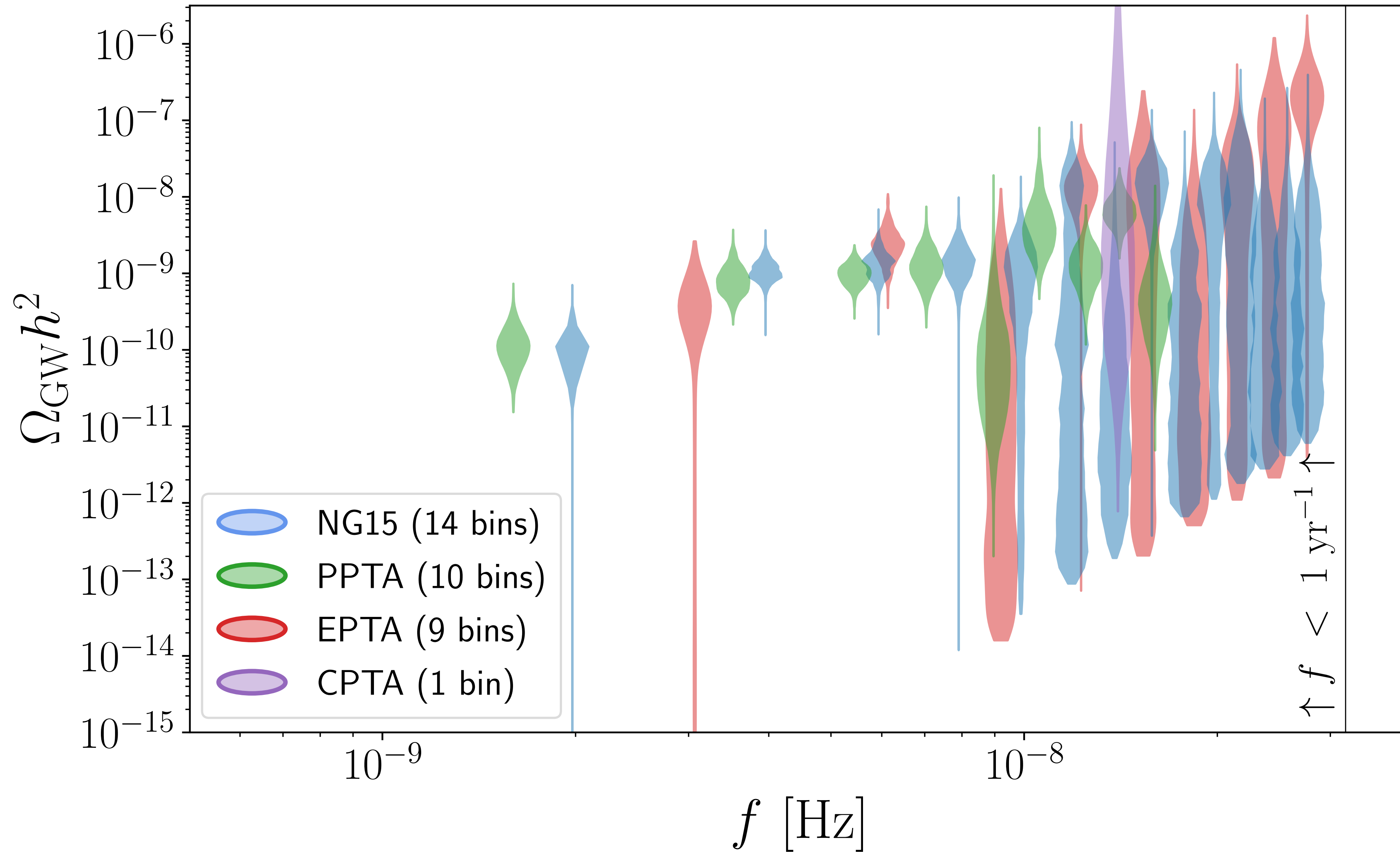
Discovery of the first stochastic GW background by Pulsar Timing Arrays (PTA)



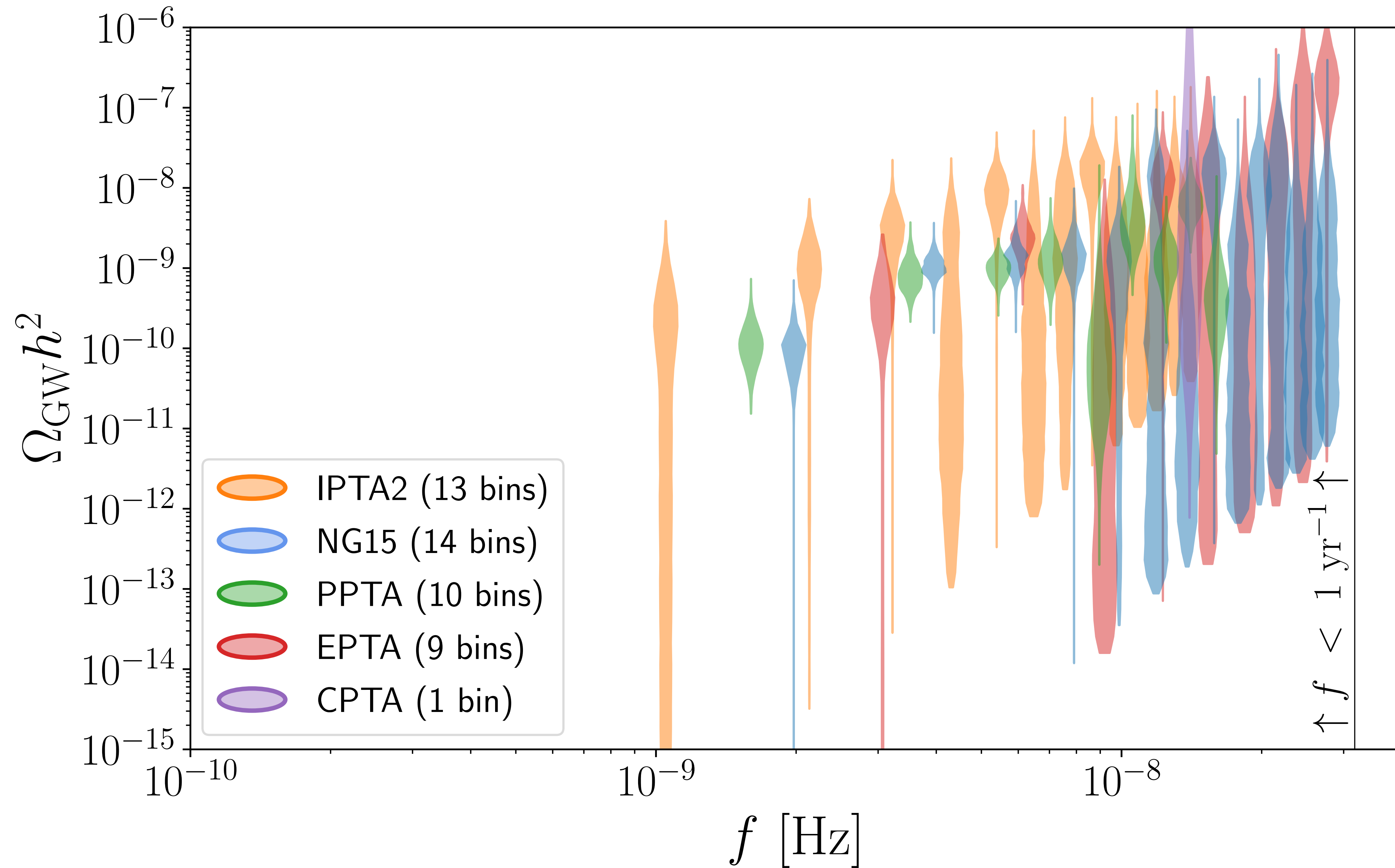
Discovery of the first stochastic GW background by Pulsar Timing Arrays (PTA)



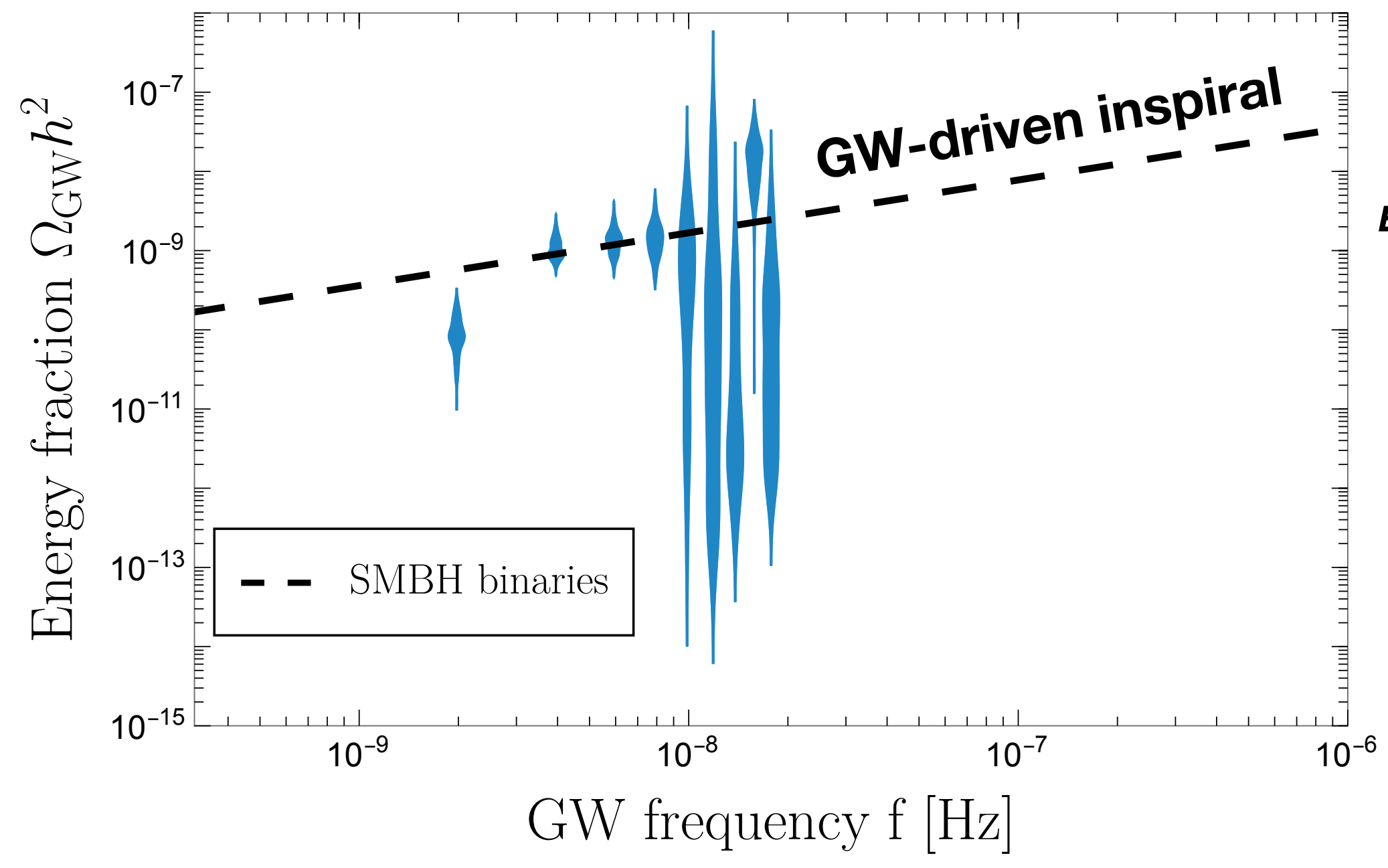
Discovery of the first stochastic GW background by Pulsar Timing Arrays (PTA)



Discovery of the first stochastic GW background by Pulsar Timing Arrays (PTA)

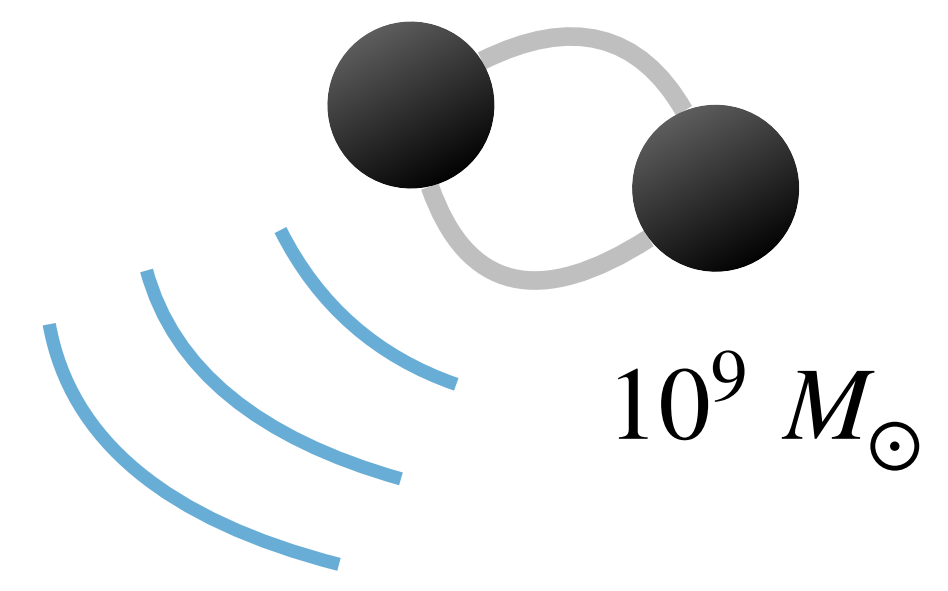


Pulsar Timing Arrays (PTA)



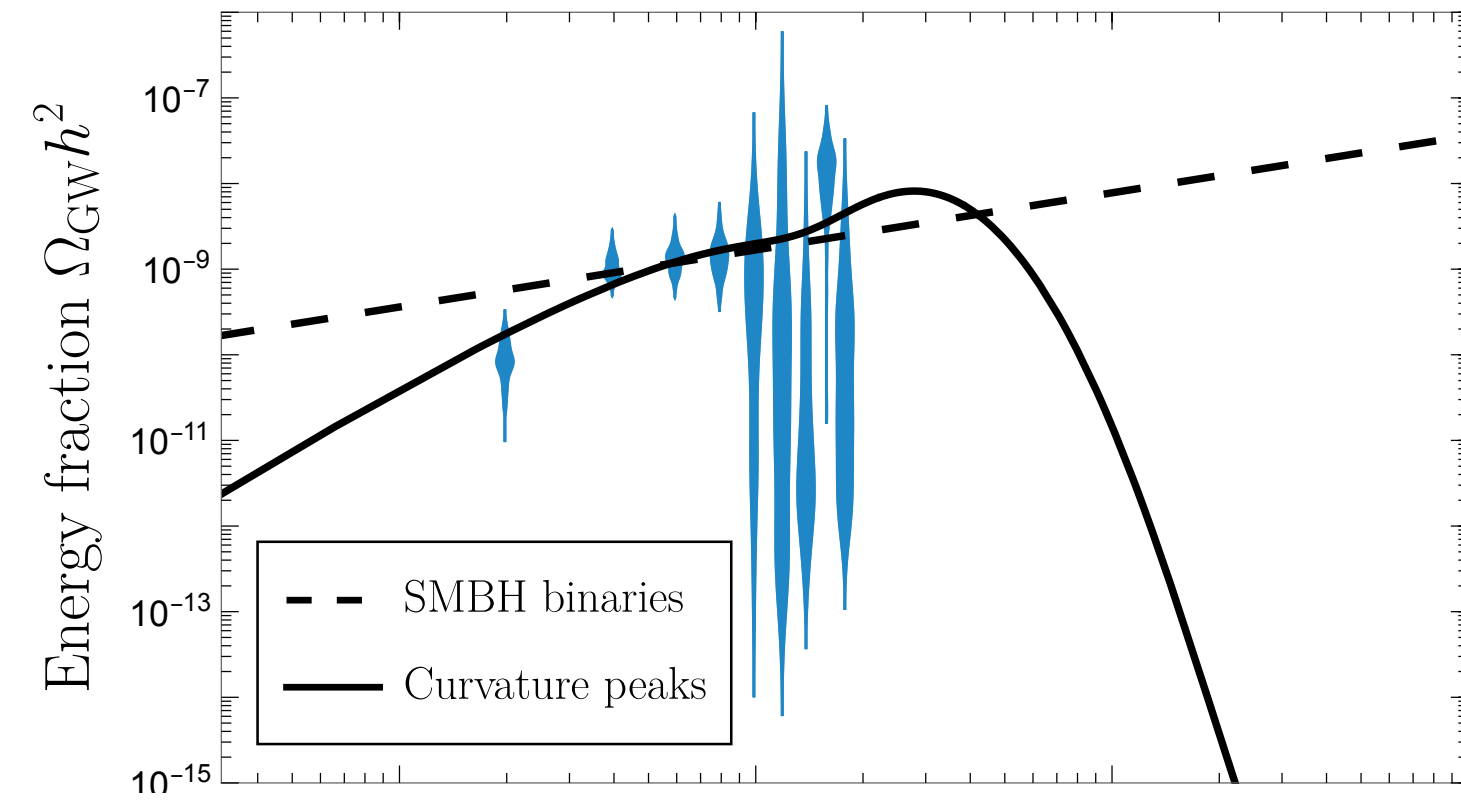
*Ellis, Fairbairn, Hutsi, Raidal, Urrutia,
Vaskonen, Veermäe (23', 24')*

Supermassive
black holes binaries



Gravitational Waves

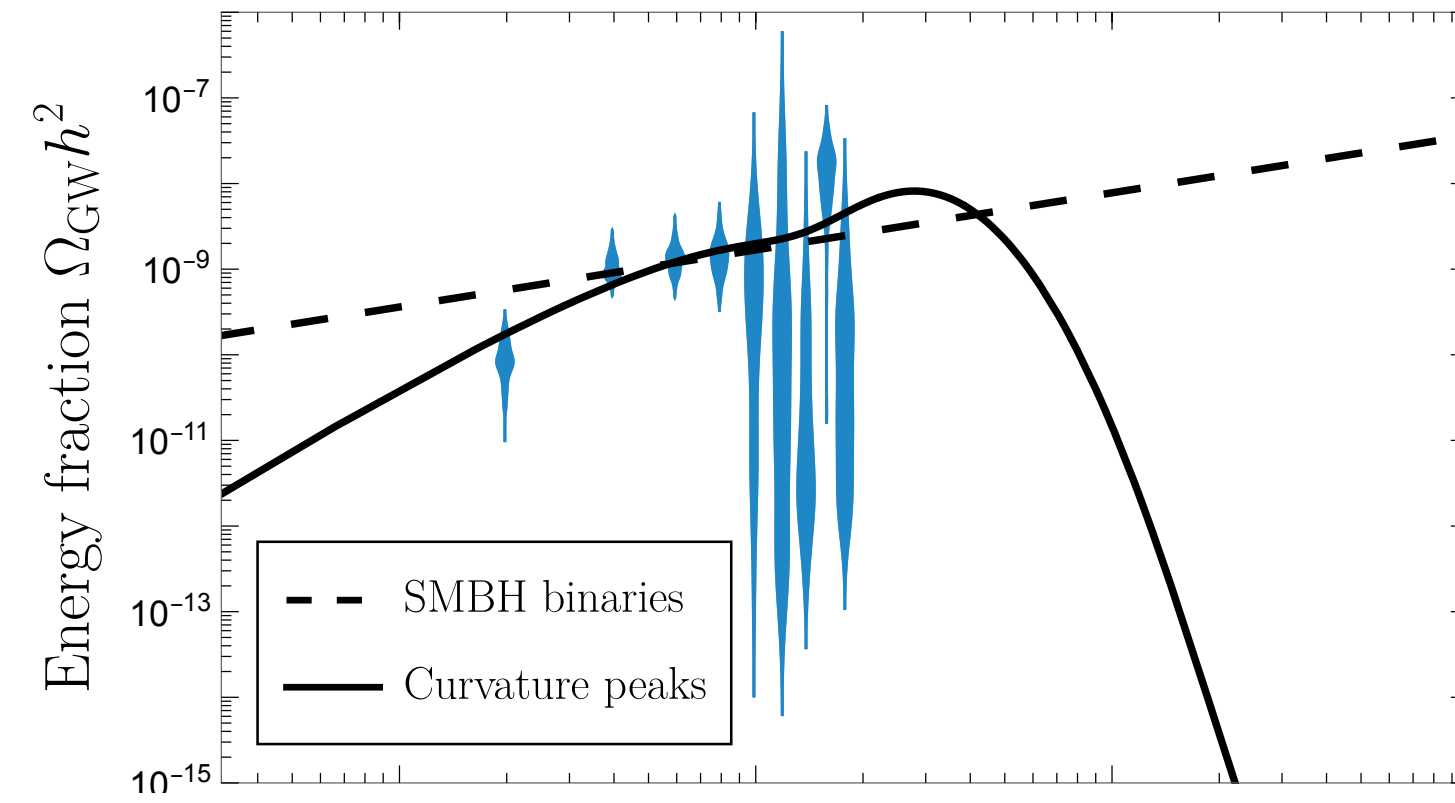




Curvature peaks

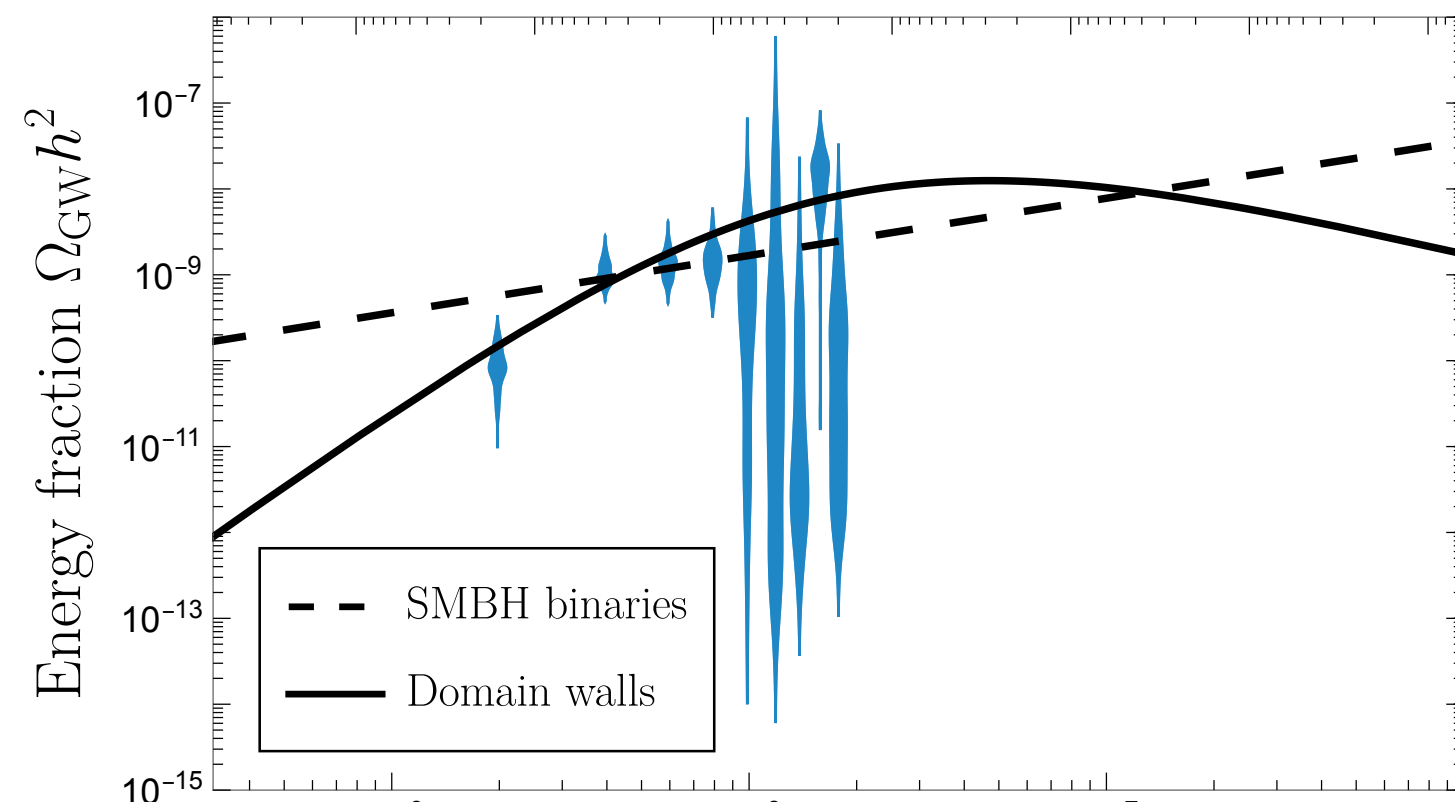
Kohri, Terada (2009.11853)
Vaskonen, Veermae (2009.07832),
Franciolini, Iovino, Vaskonen, Vermae (2306.17143)
Cecchini, Franciolini, Pieroni (2503.10805)
...





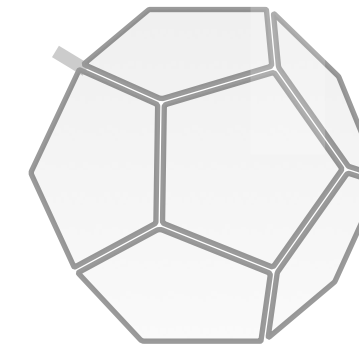
Curvature peaks

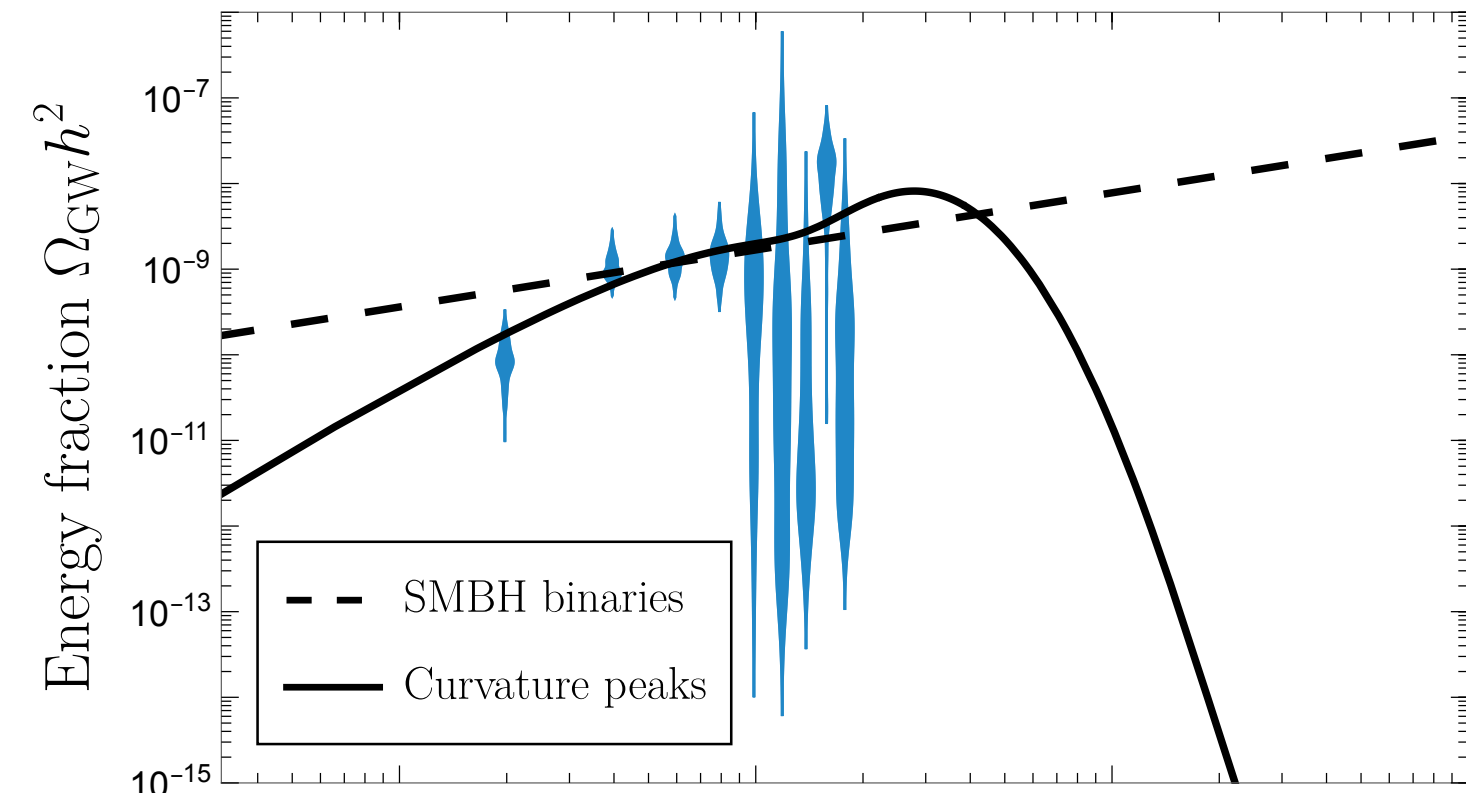
Kohri, Terada (2009.11853)
Vaskonen, Veermae (2009.07832),
Franciolini, Iovino, Vaskonen, Vermae (2306.17143)
Cecchini, Franciolini, Pieroni (2503.10805)
...



Domain wall networks

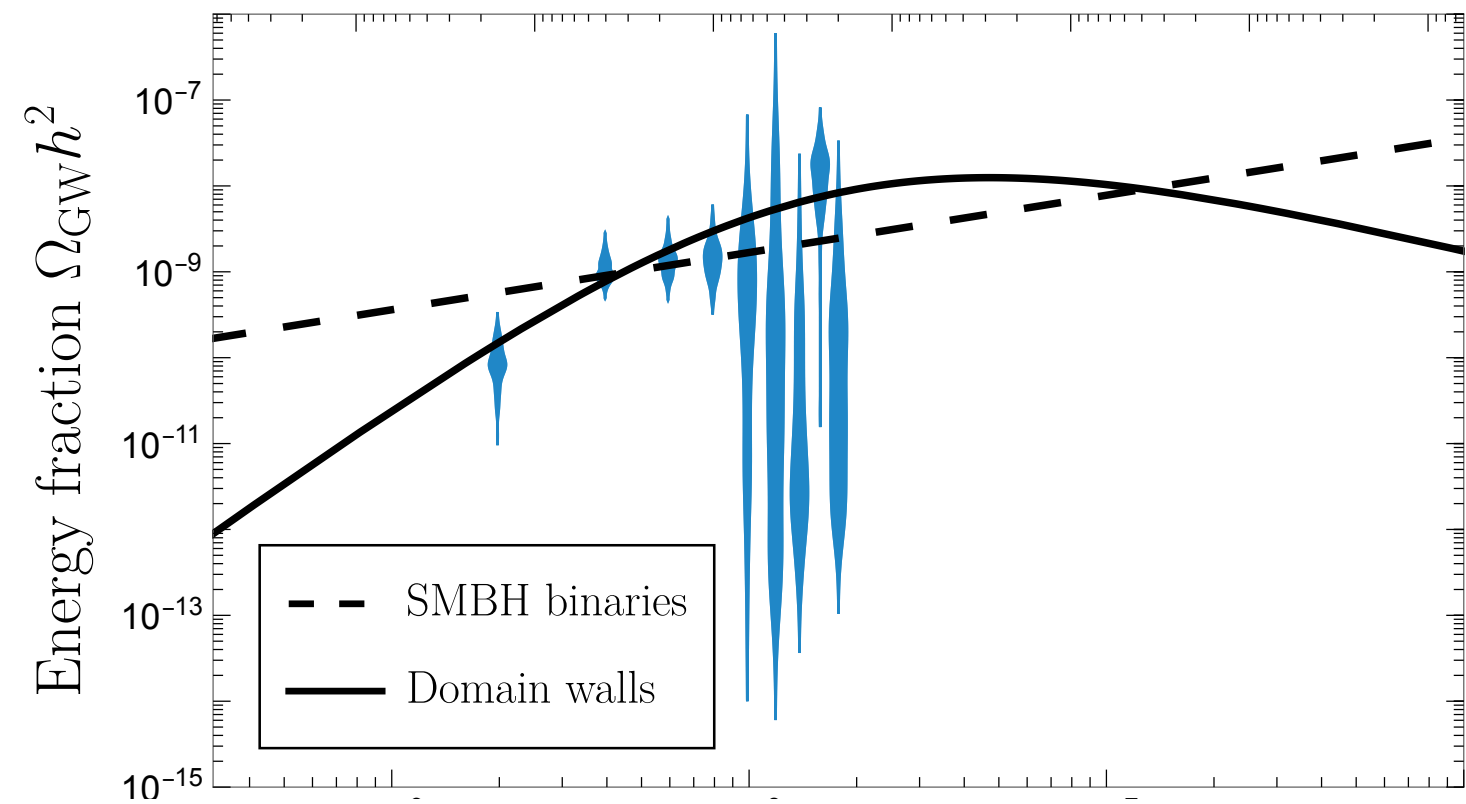
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
...





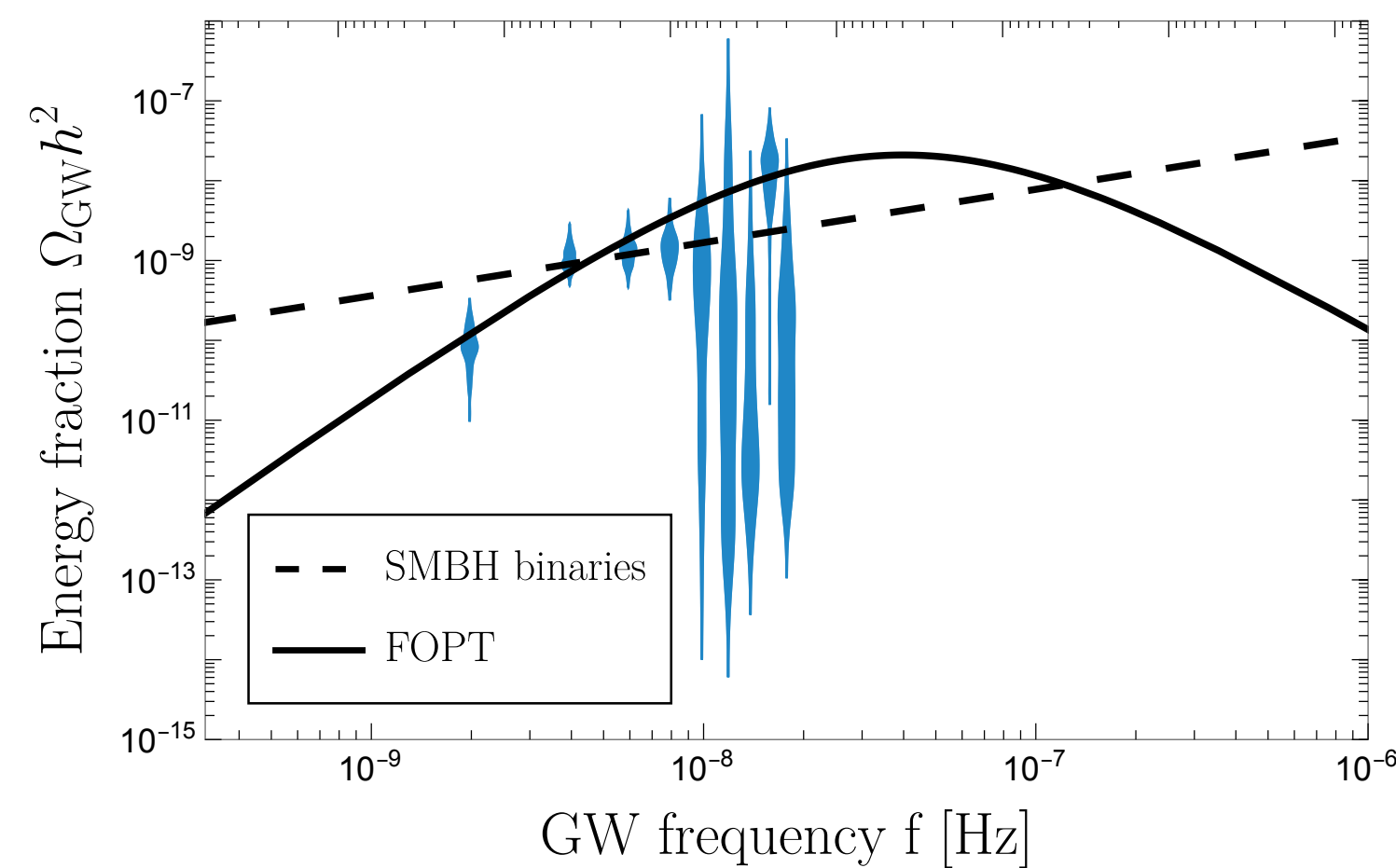
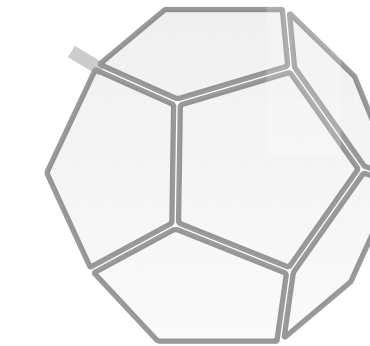
Curvature peaks

Kohri, Terada (2009.11853)
Vaskonen, Veermae (2009.07832),
Franciolini, Iovino, Vaskonen, Vermae (2306.17143)
Cecchini, Franciolini, Pieroni (2503.10805)
 ...



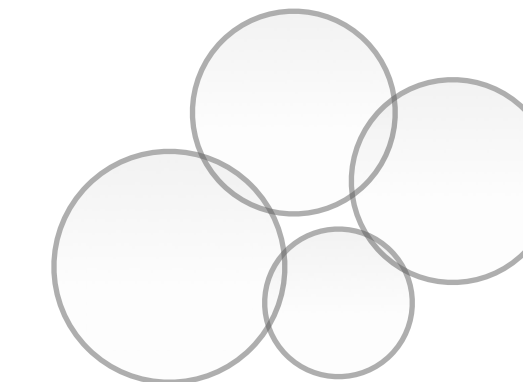
Domain wall networks

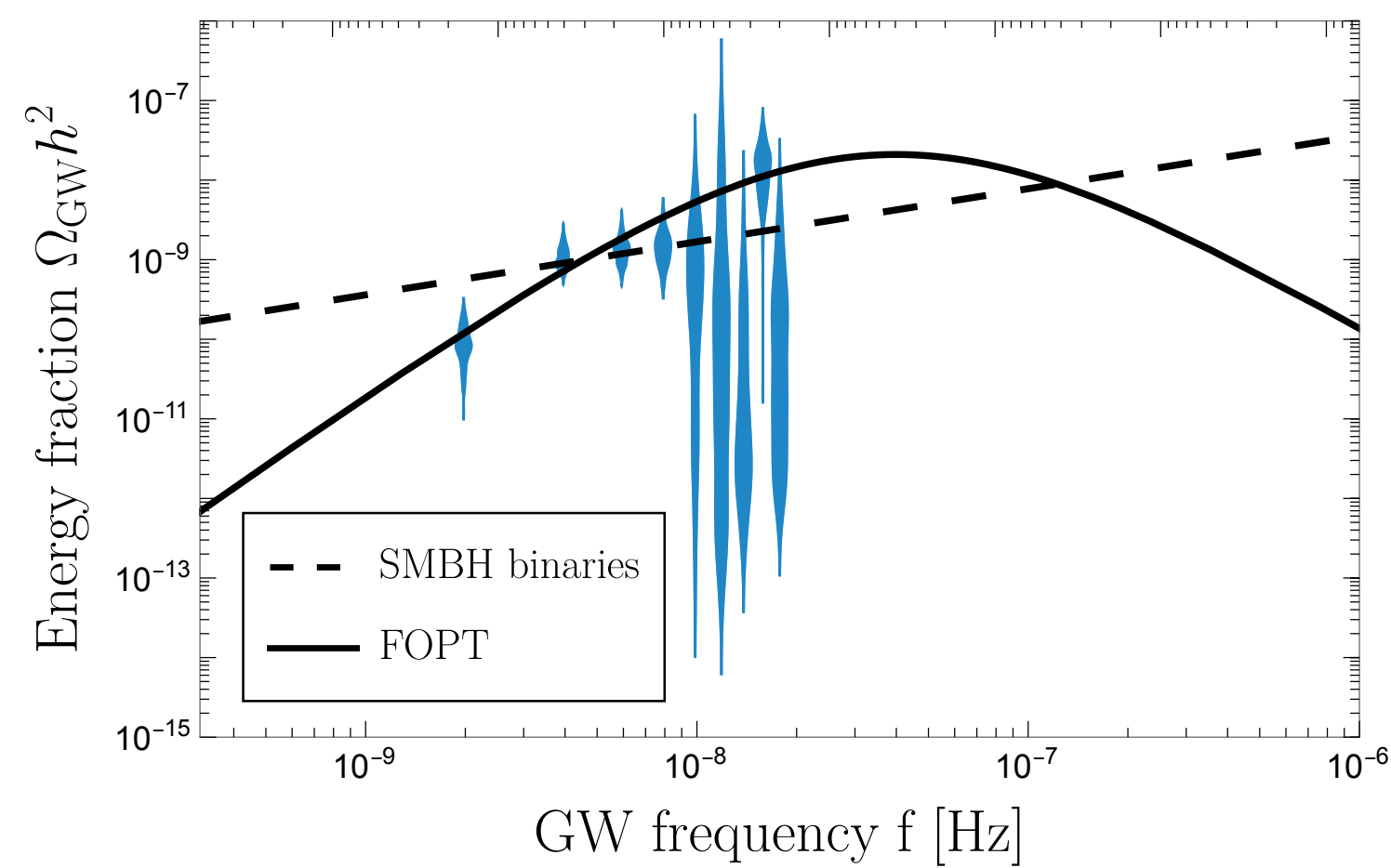
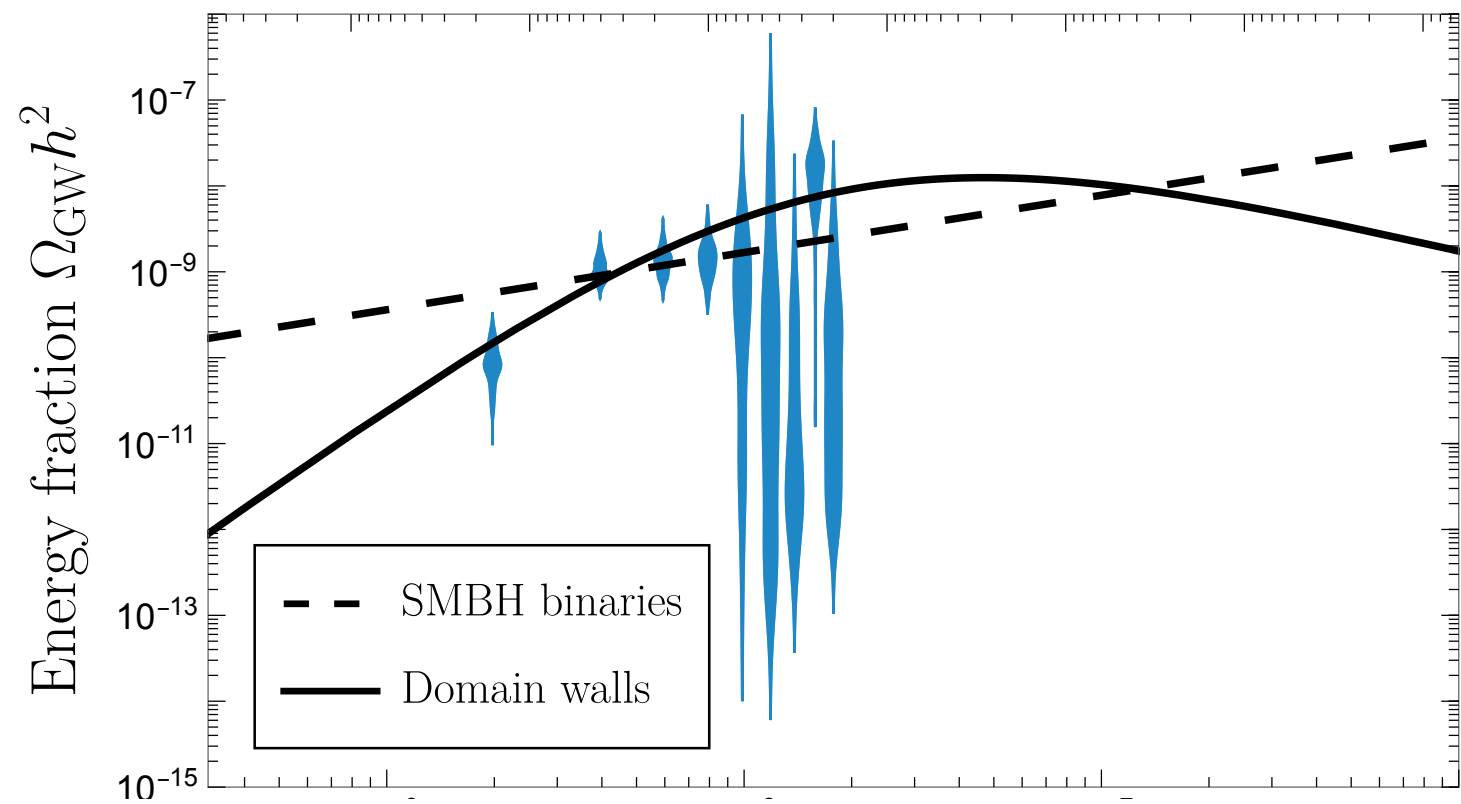
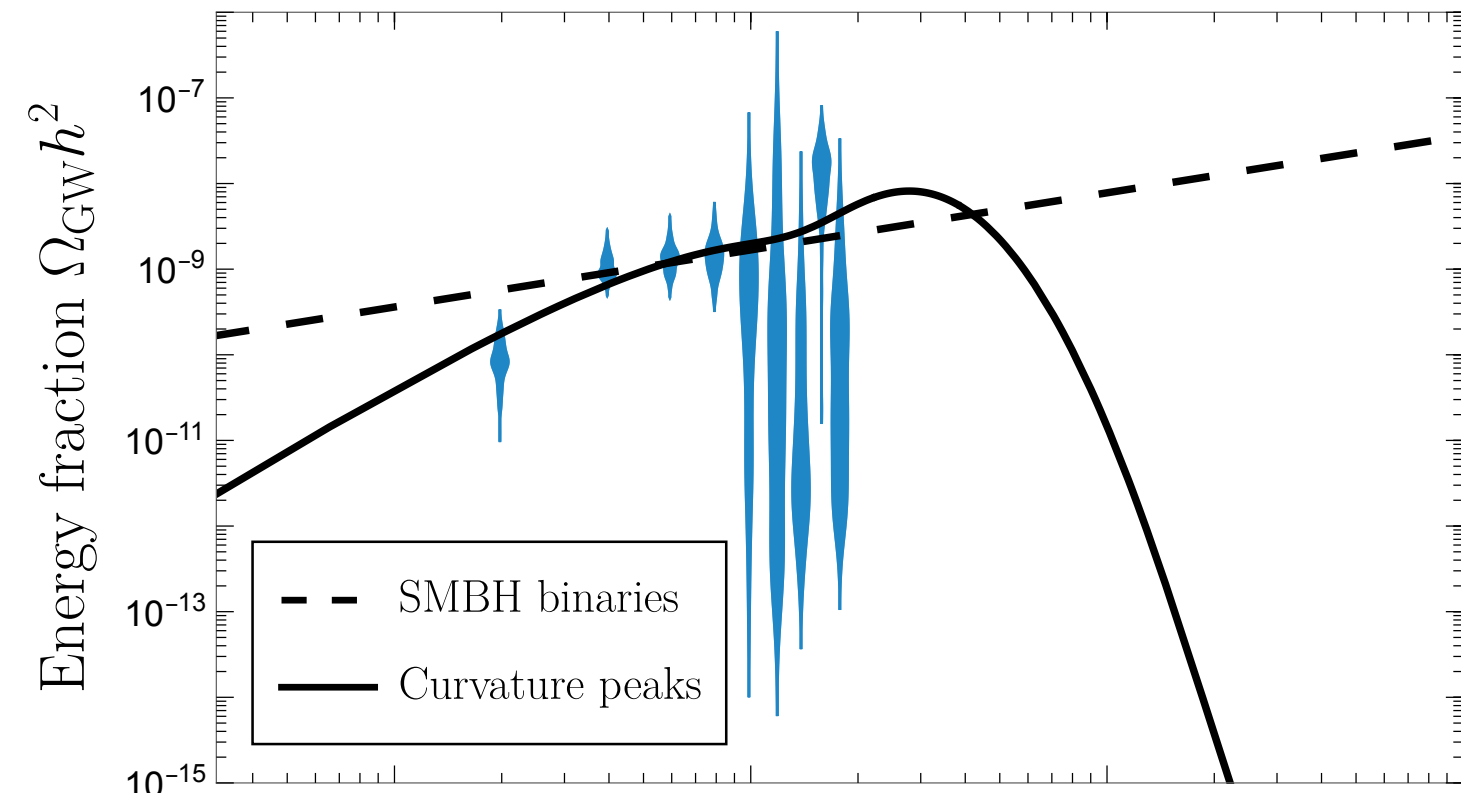
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...



First-order phase transitions

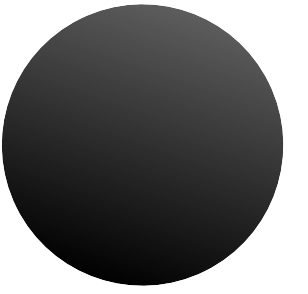
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...





Curvature peaks

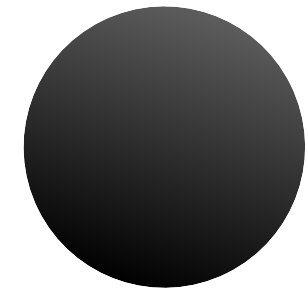
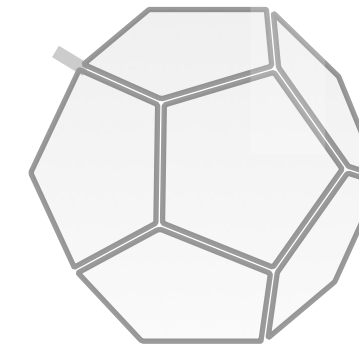
Kohri, Terada (2009.11853)
Vaskonen, Veermae (2009.07832),
Franciolini, Iovino, Vaskonen, Vermae (2306.17143)
Cecchini, Franciolini, Pieroni (2503.10805)
 ...



PBH

Domain wall networks

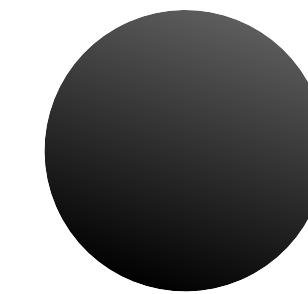
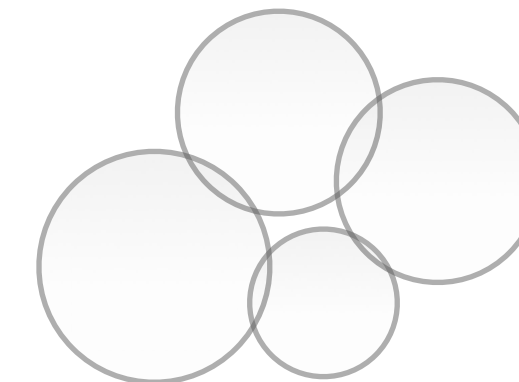
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...



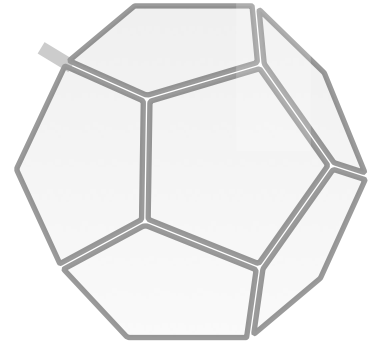
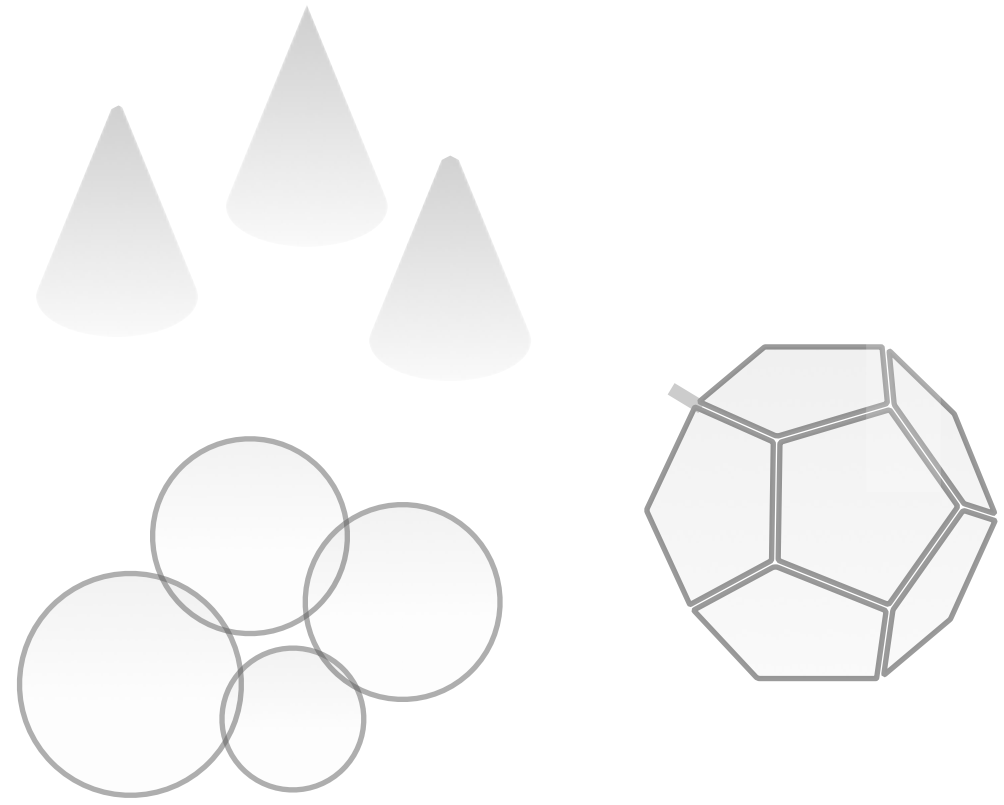
PBH

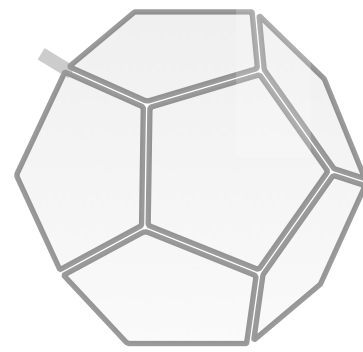
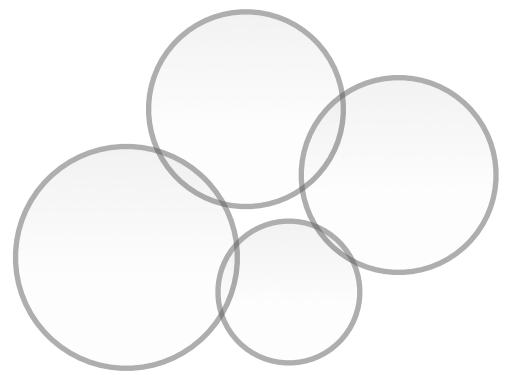
First-order phase transitions

Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...



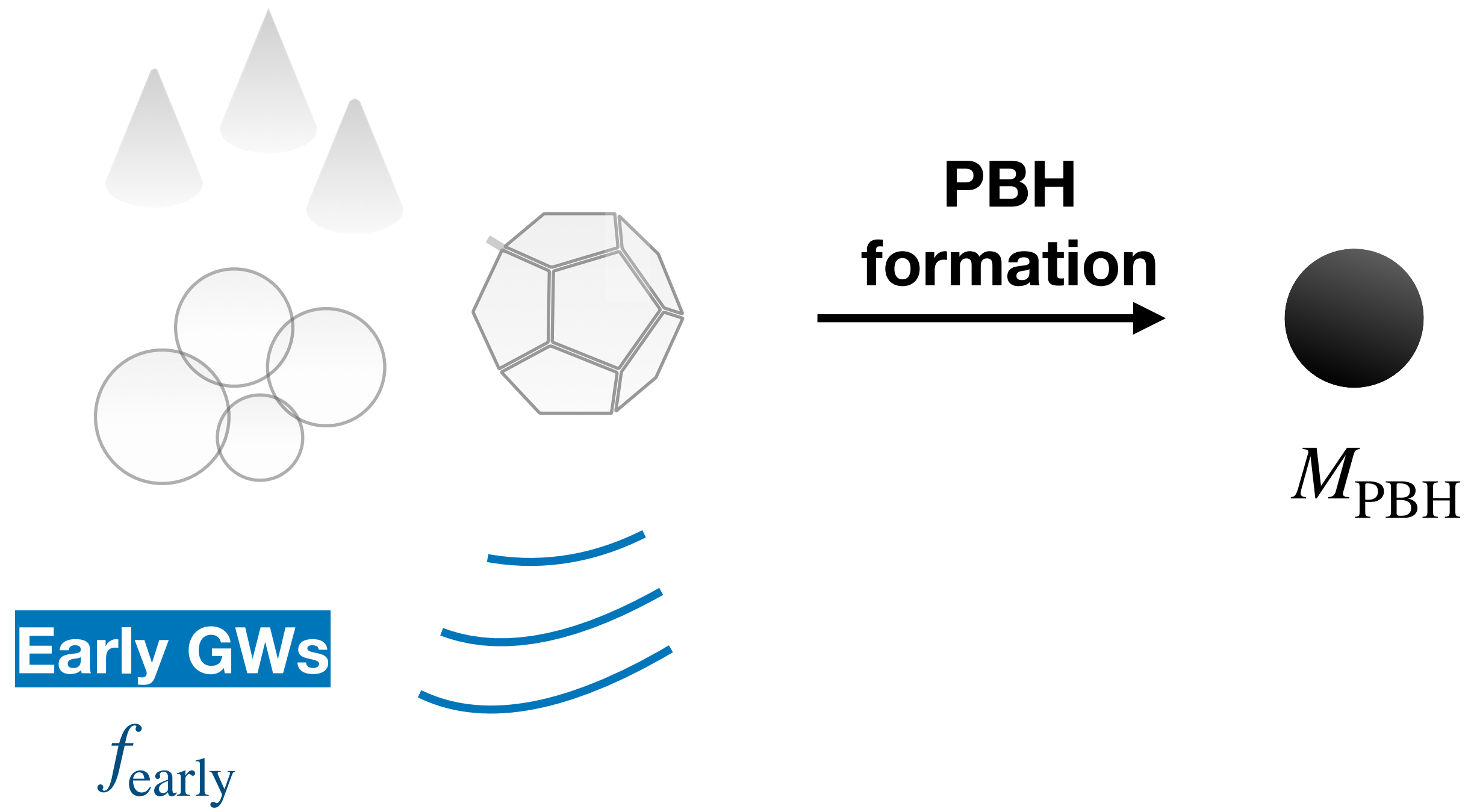
PBH

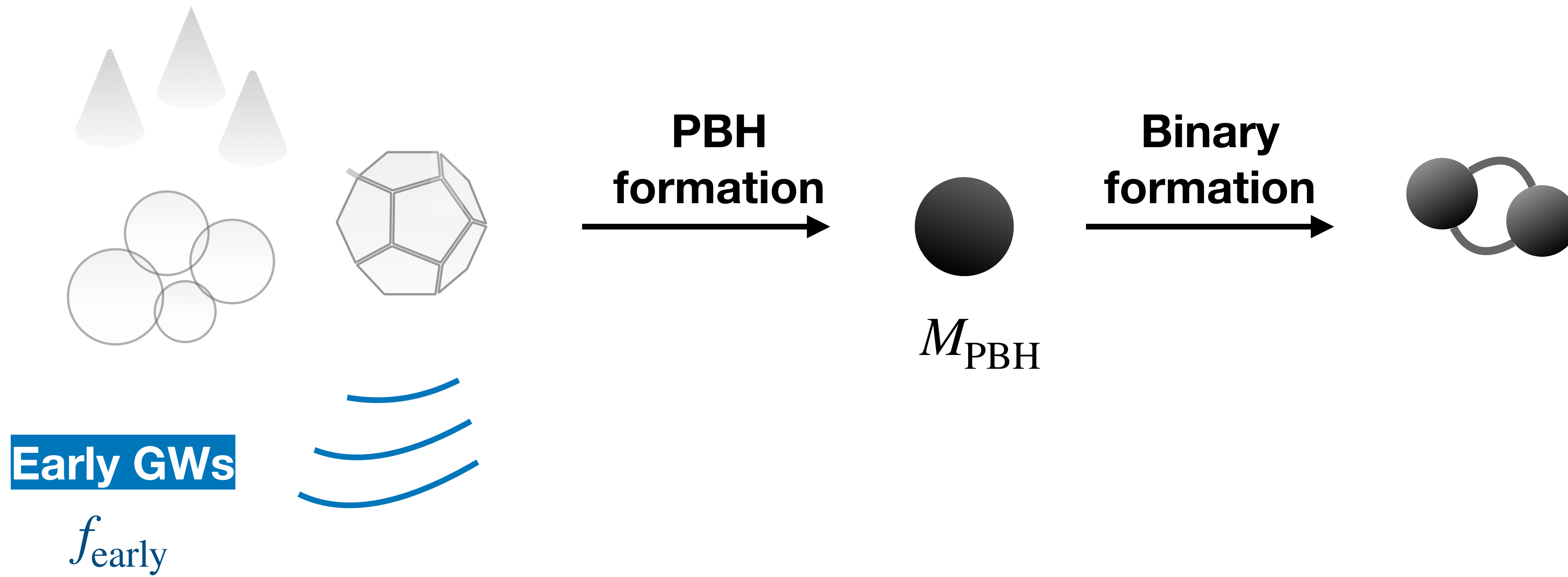


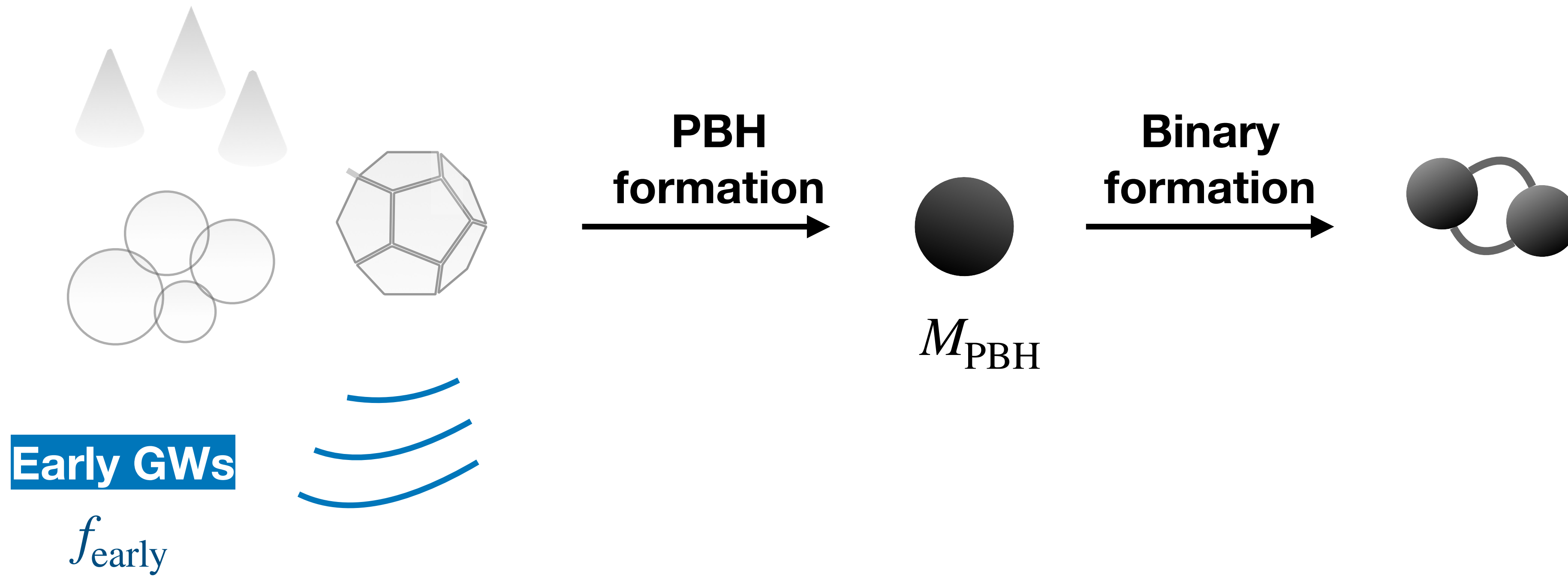


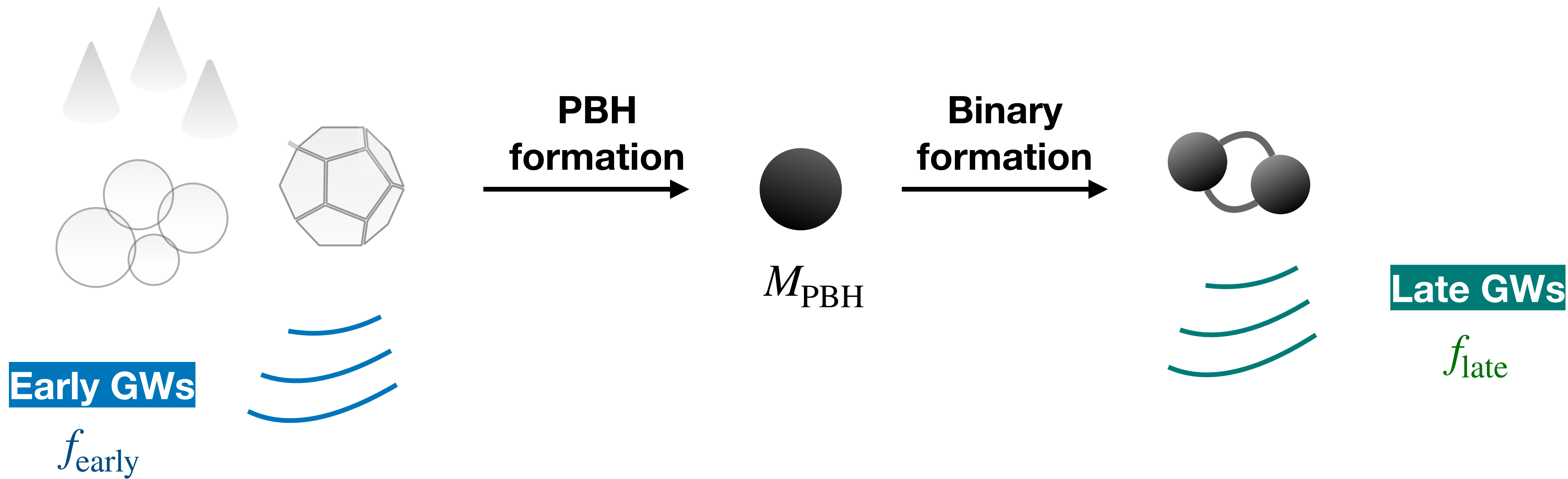
Early GWs

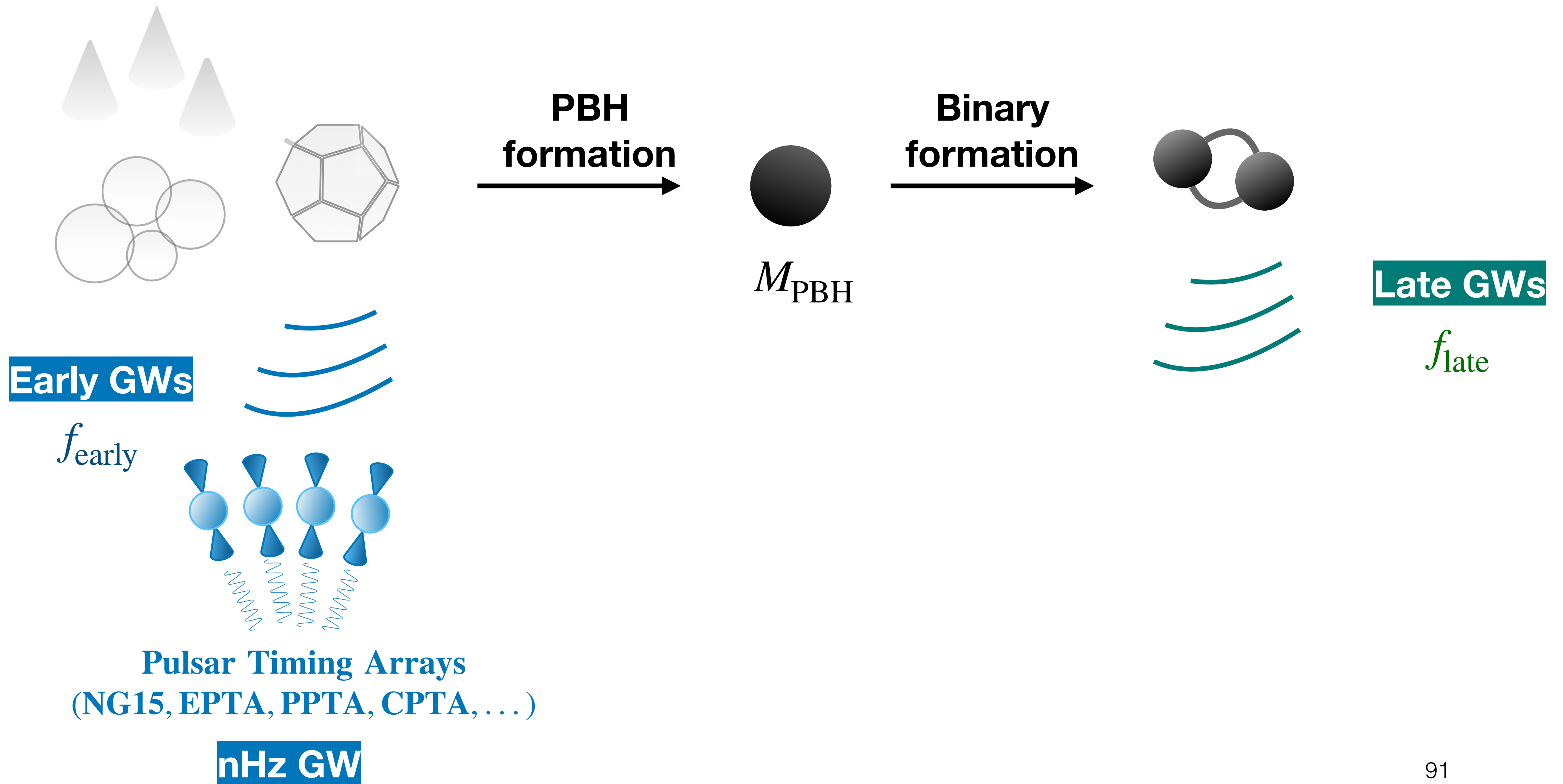
f_{early}

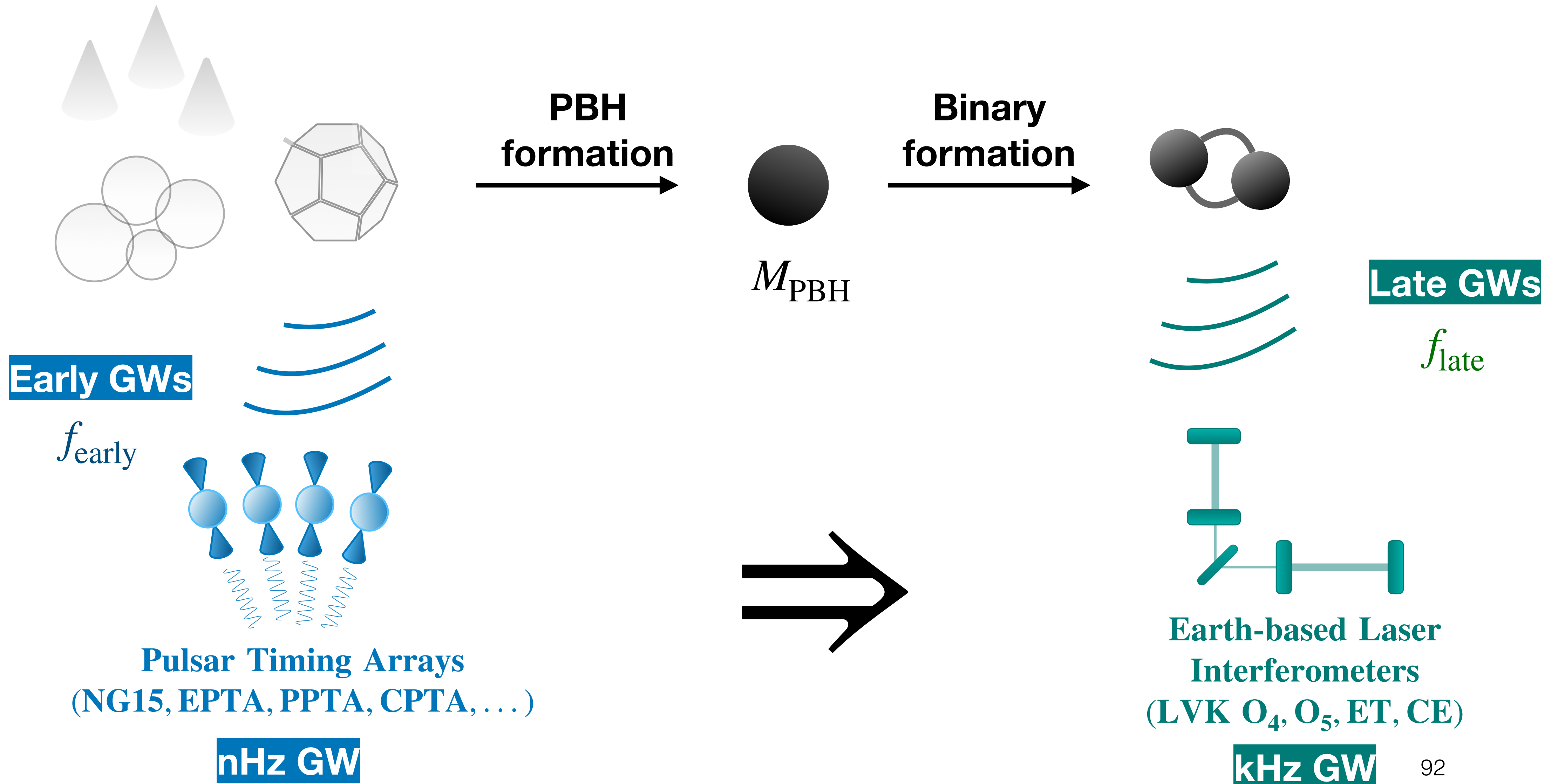


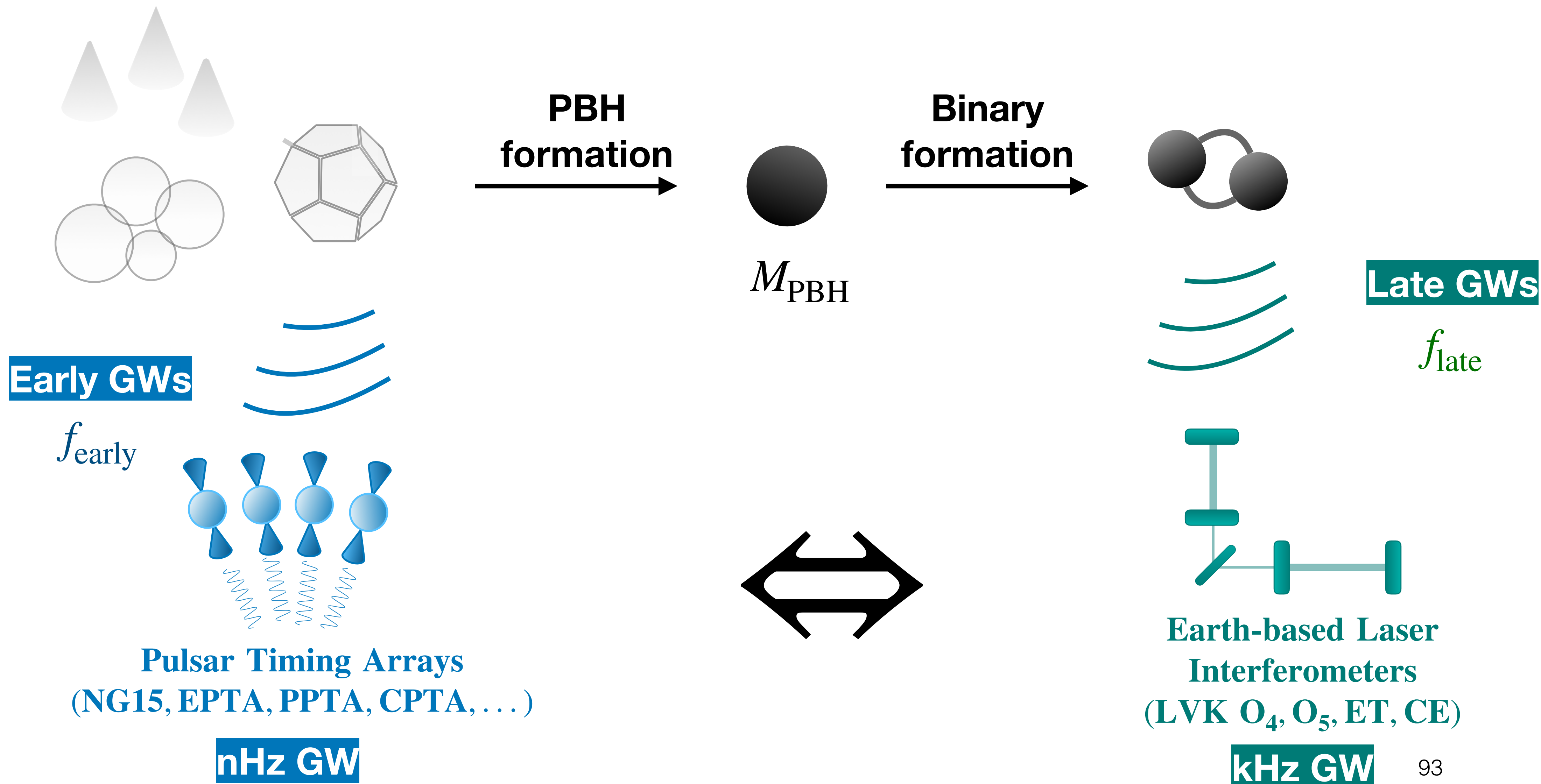










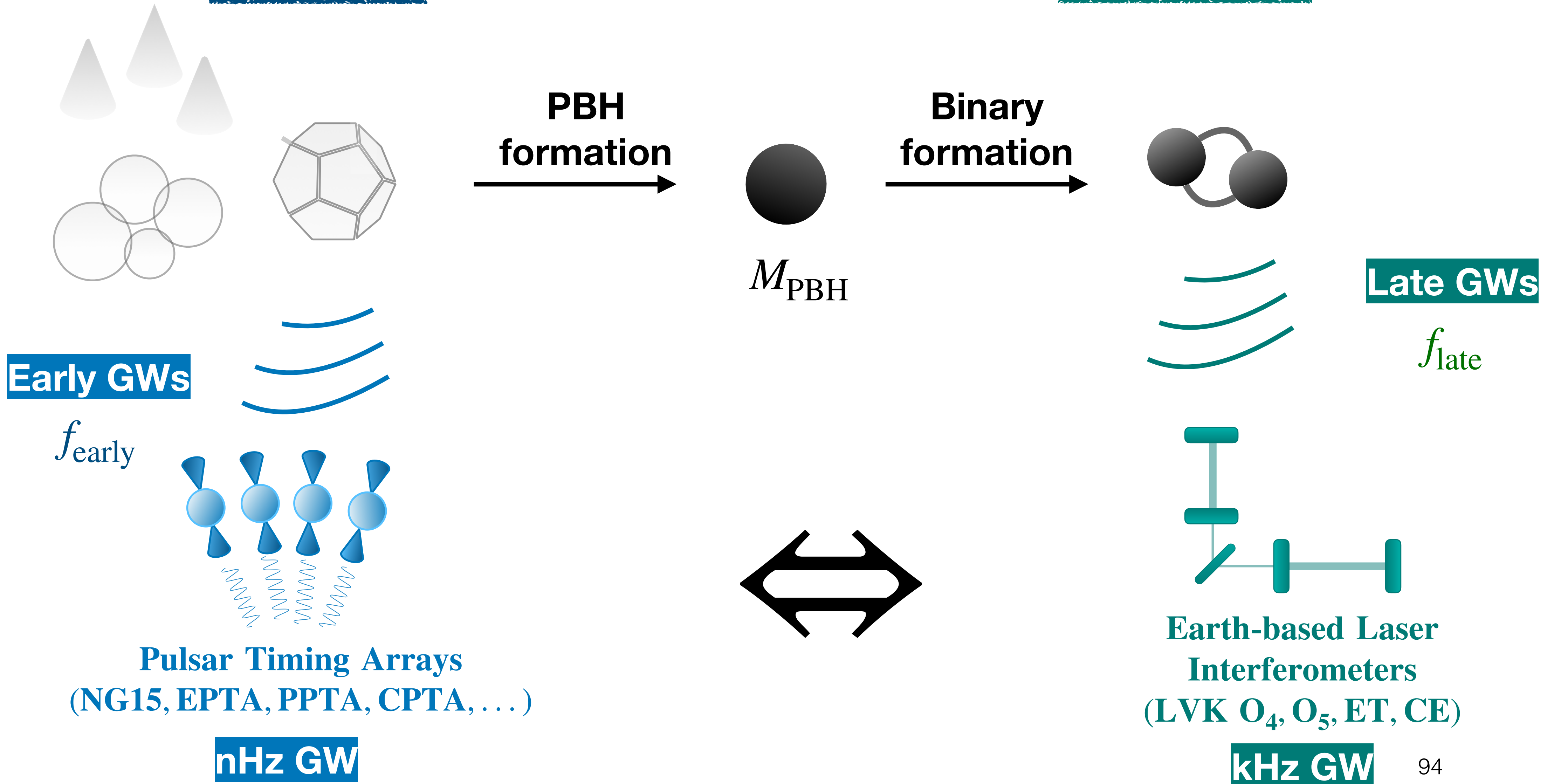


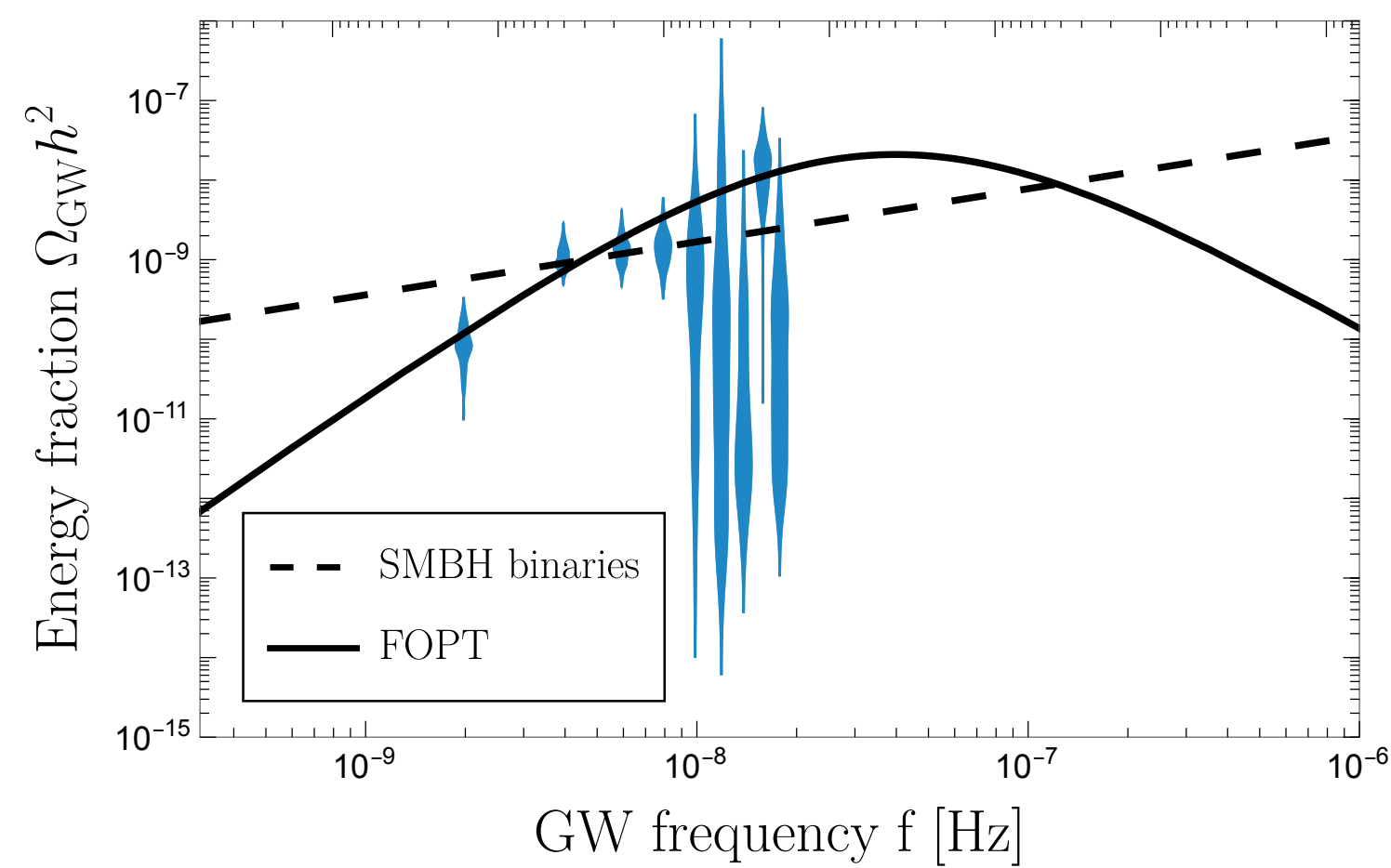
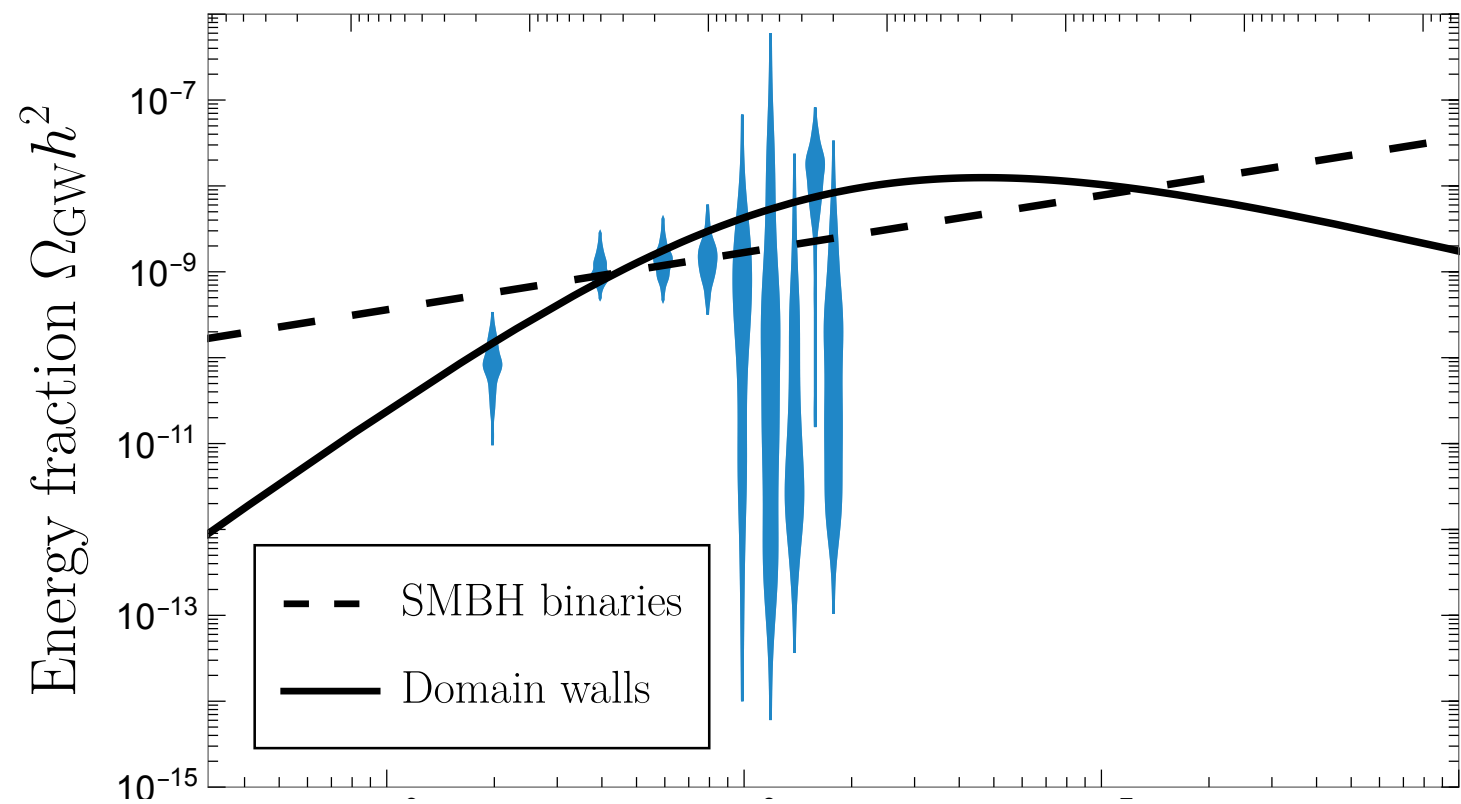
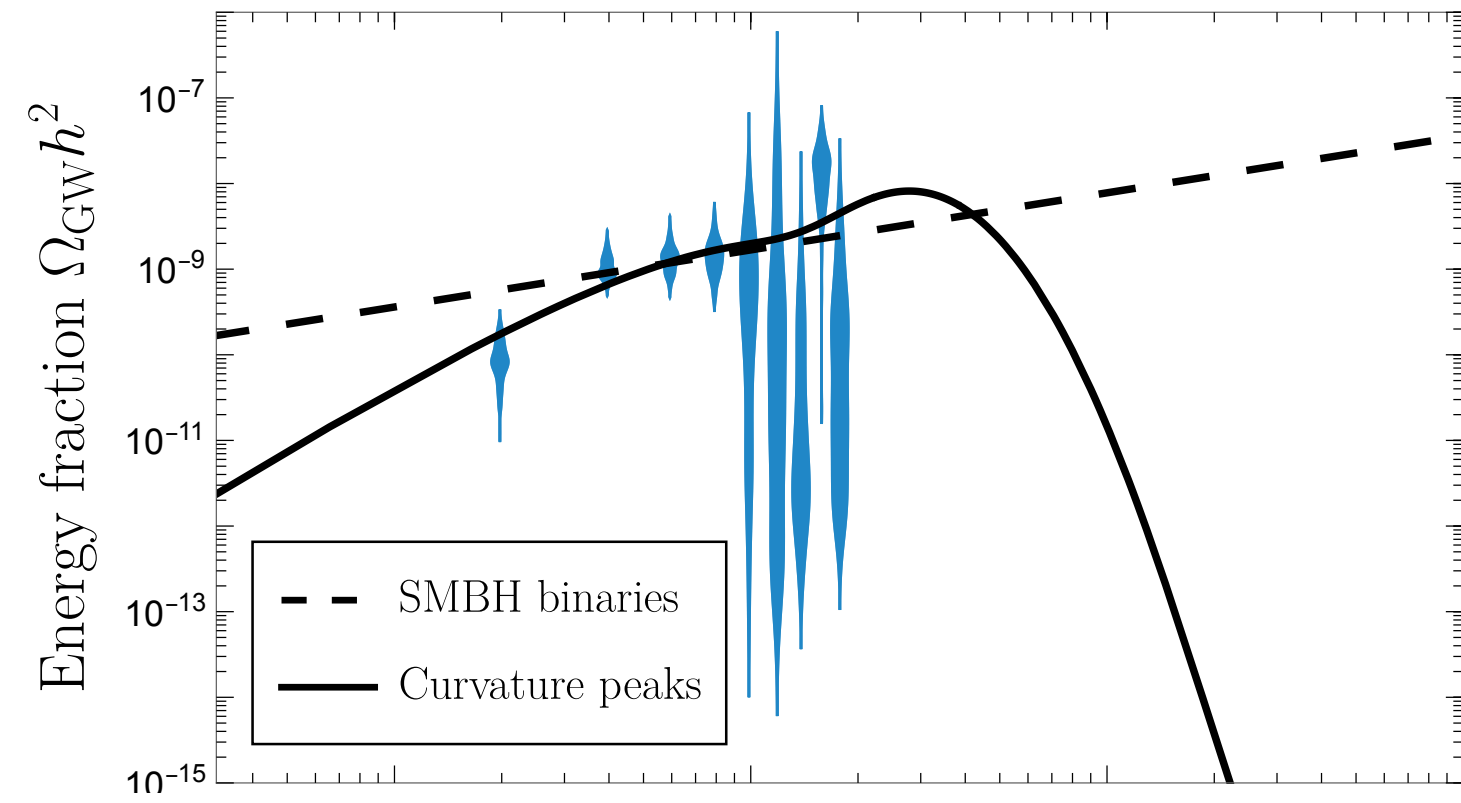
$$\left(\frac{f_{\text{early}}}{3 \text{ nHz}} \right)$$

$$\approx \epsilon_{\star} \left(\frac{4 M_{\odot}}{M_{\text{PBH}}} \right)^{1/2}$$

$$\approx \epsilon_{\star} \left(\frac{f_{\text{late}}}{1 \text{ kHz}} \right)^{1/2}$$

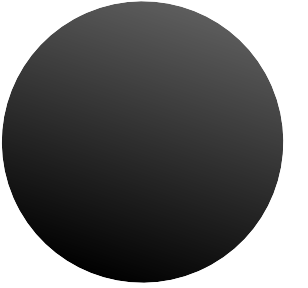
$$\left(\epsilon_{\star} \equiv \frac{k_{\star}}{\mathcal{H}_{\star}} \right)$$





Curvature peaks

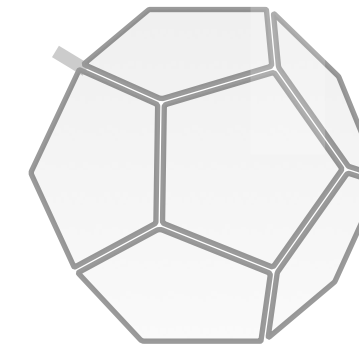
*Kohri, Terada (2009.11853)
 Vaskonen, Veermae (2009.07832),
 Franciolini, Iovino, Vaskonen, Vermae (2306.17143)
 Cecchini, Franciolini, Pieroni (2503.10805)
 ...*



PBH

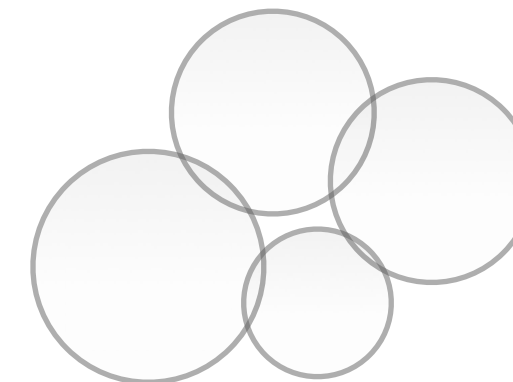
Domain wall networks

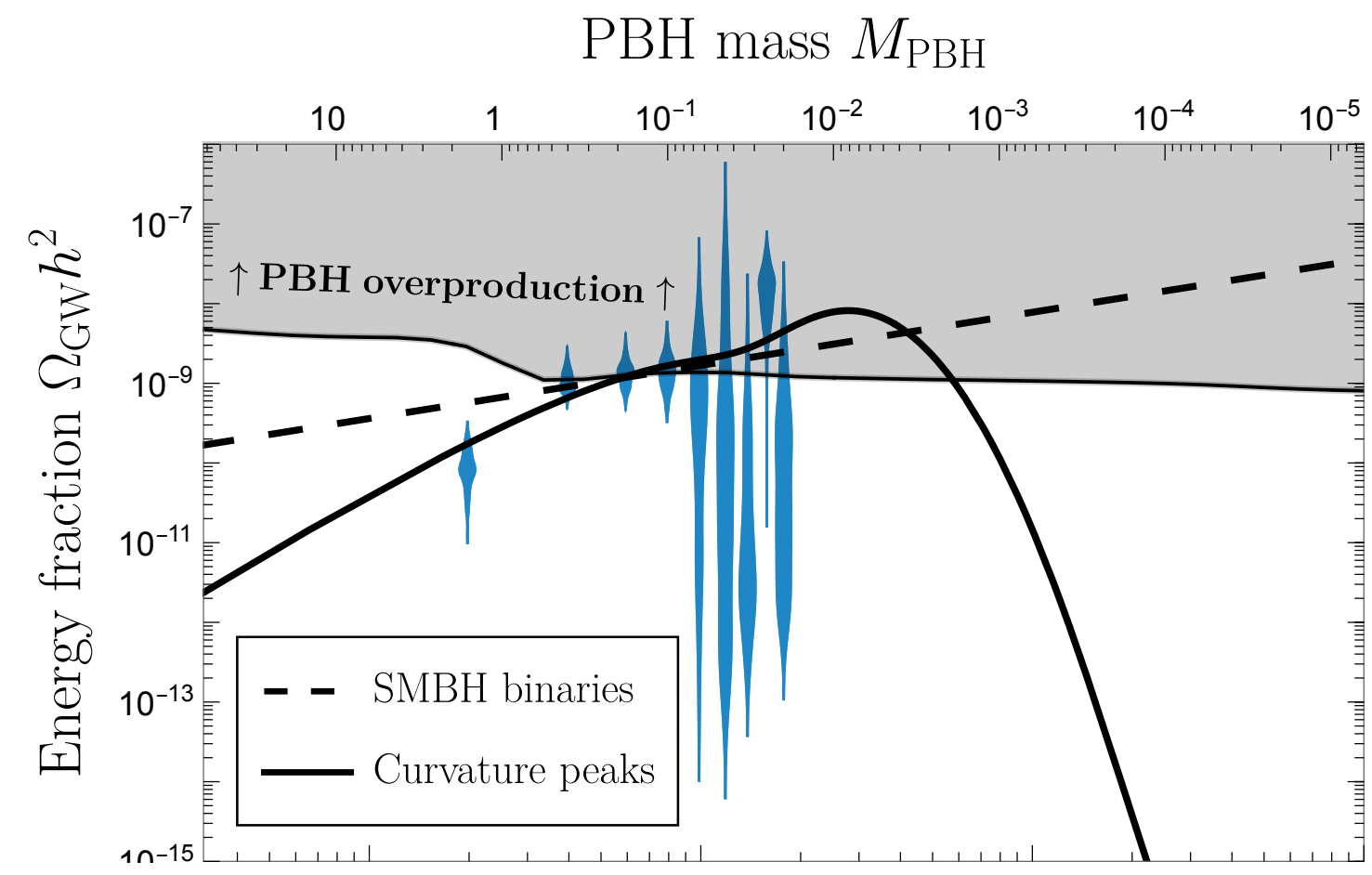
*Ferreira, Notari, Pujolas, Rompineve (2204.04228)
 Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...*



First-order phase transitions

*Roper Pol et al. (2201.05630)
 Ghoshal, White et al. (2307.02259)
 YG (2307.04239)
 Lewicki, Toczek, Vaskonen (2402.04158)
 Hoefken Zink et al. (2501.15649)
 ...*

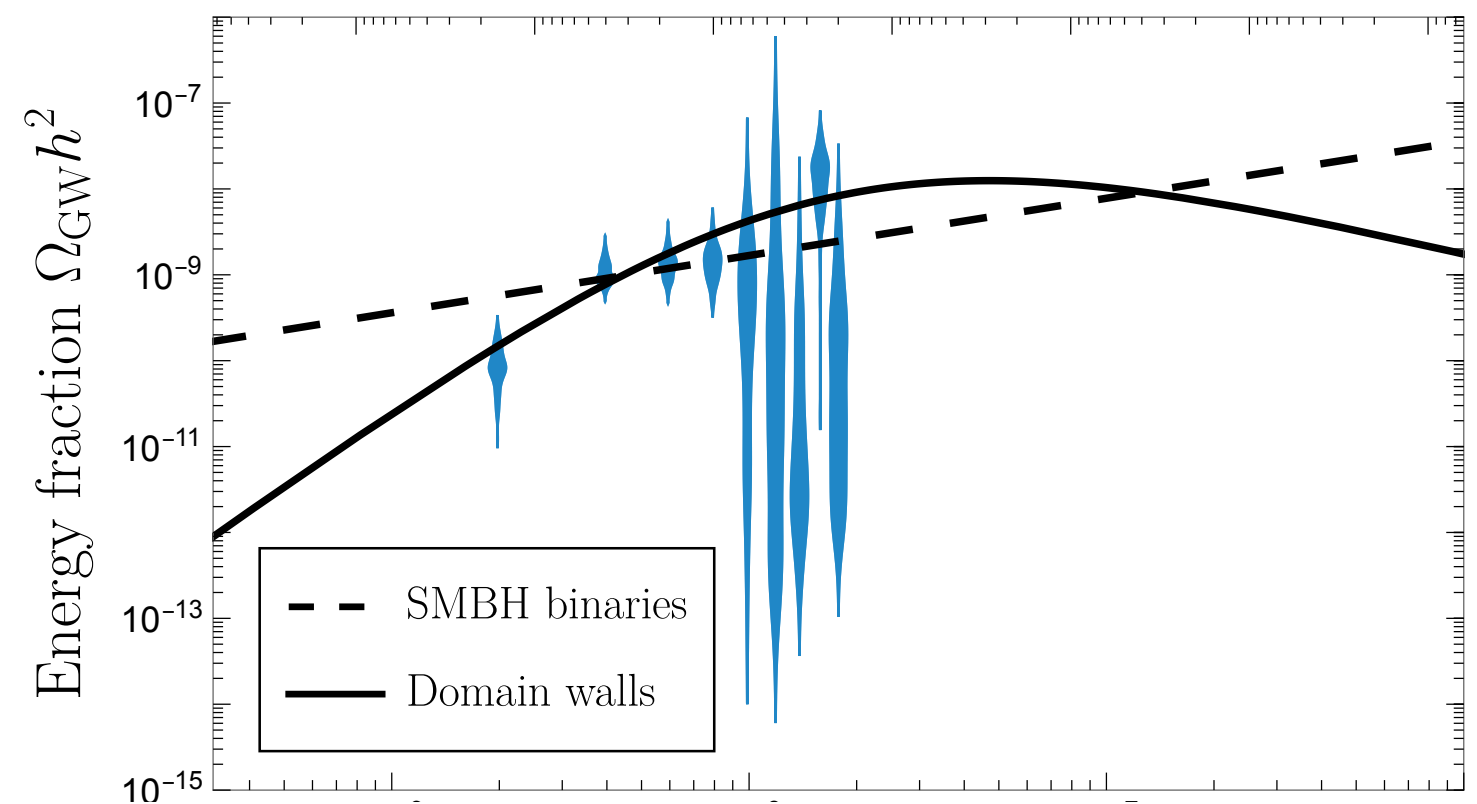
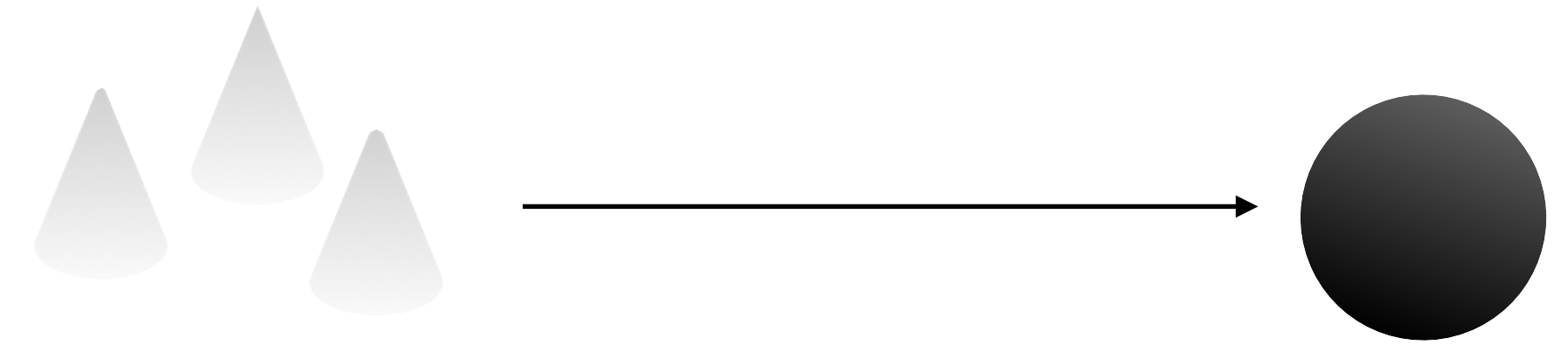




Curvature peaks

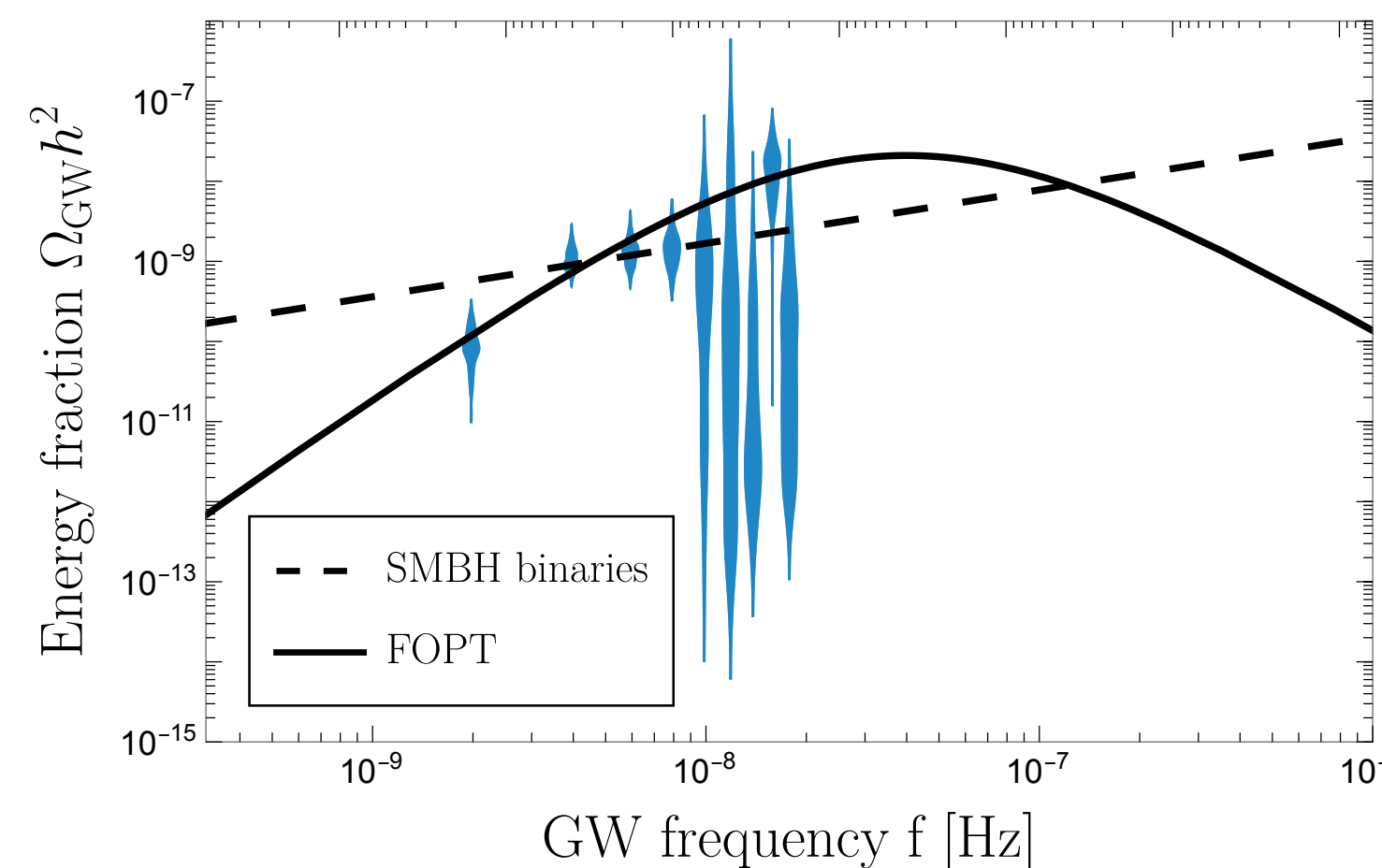
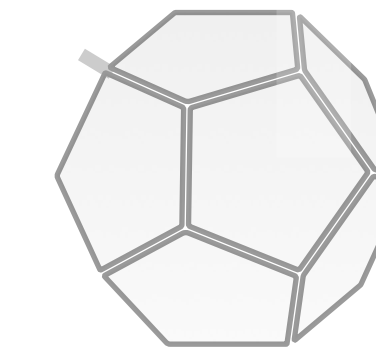
Overproduce PBH

Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Clesse, Dandoy, Verma (2412.15989)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)



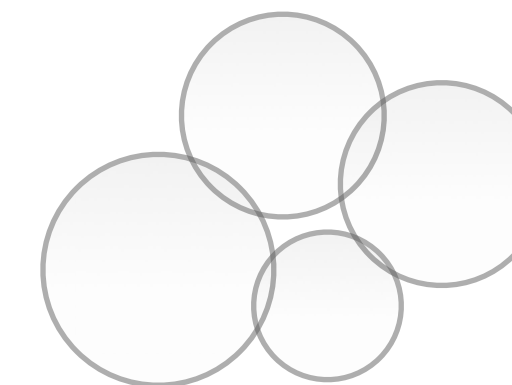
Domain wall networks

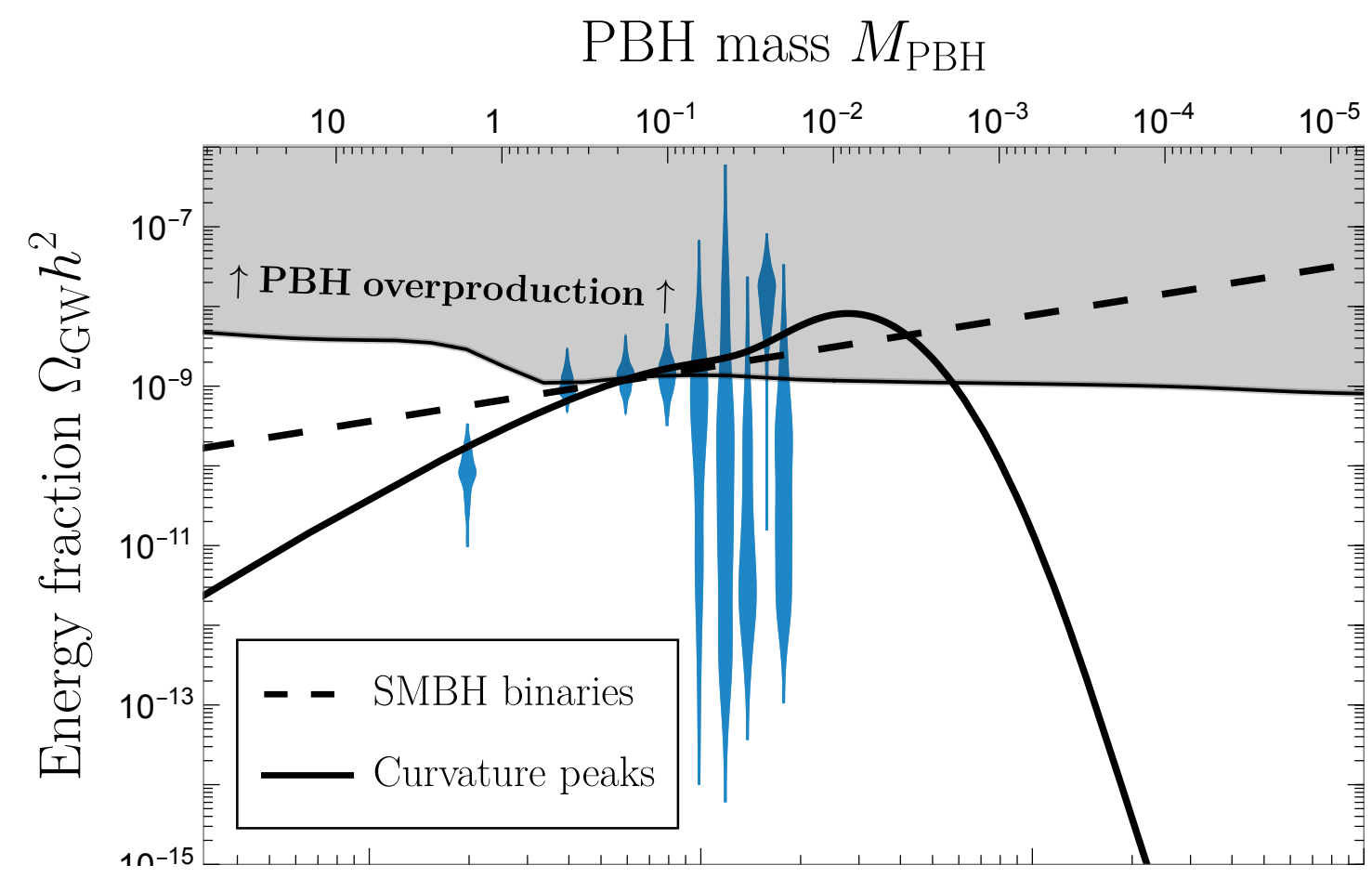
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...



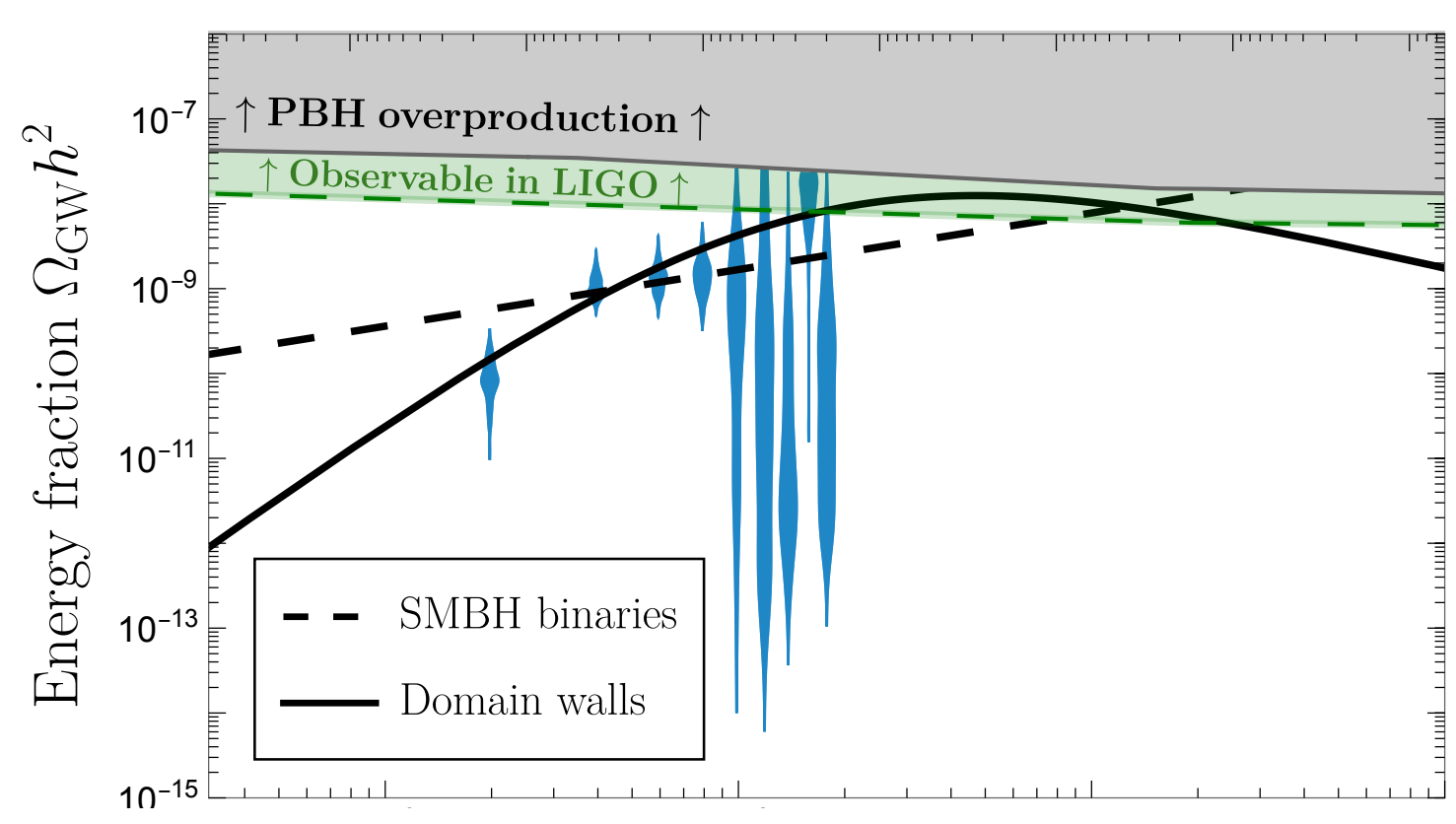
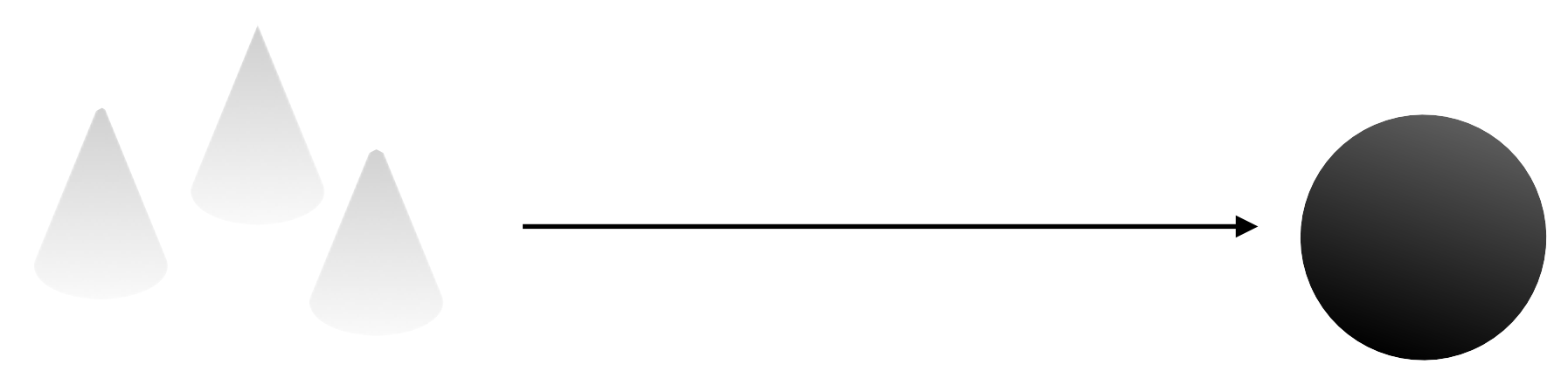
First-order phase transitions

Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...

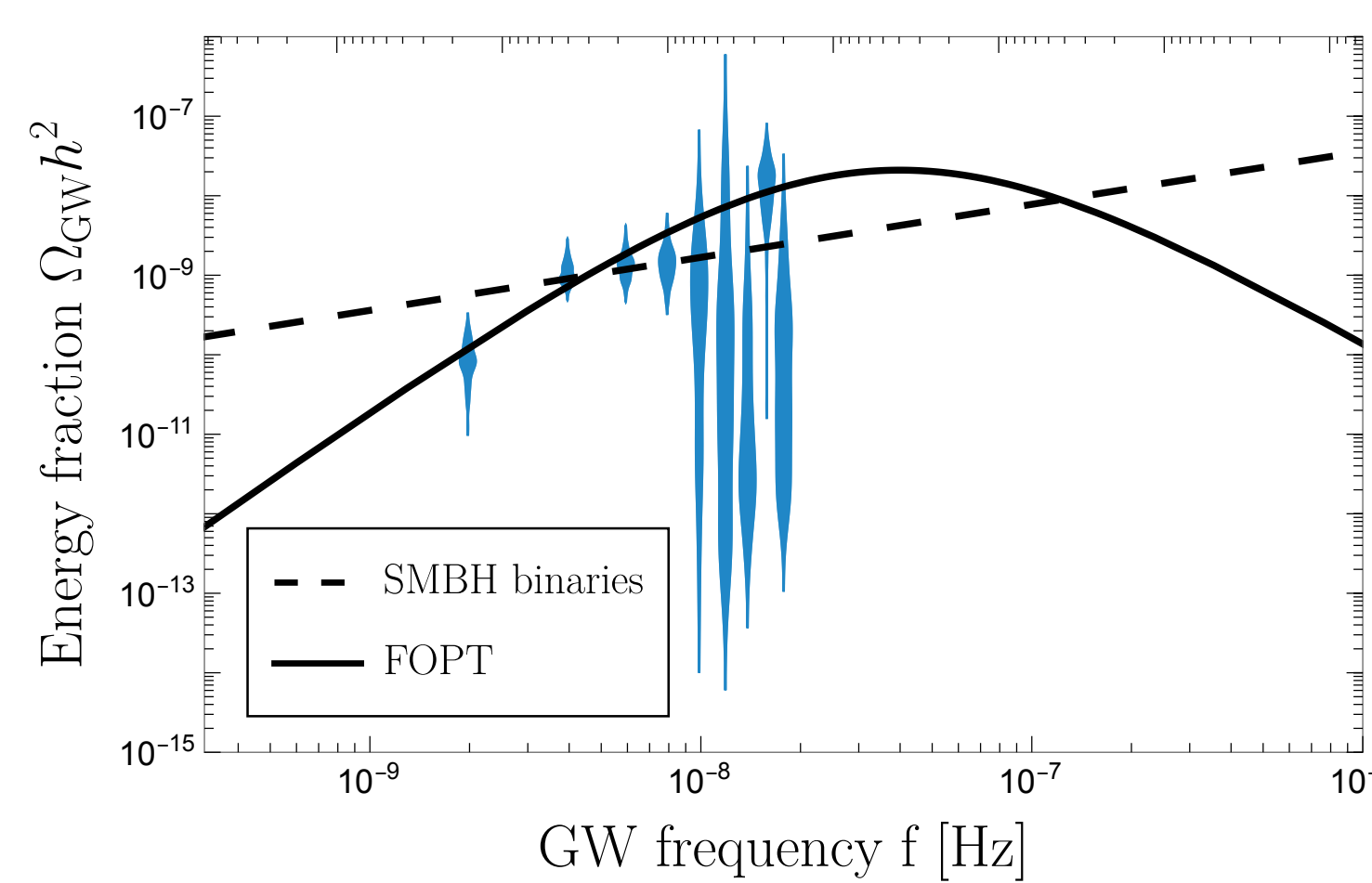
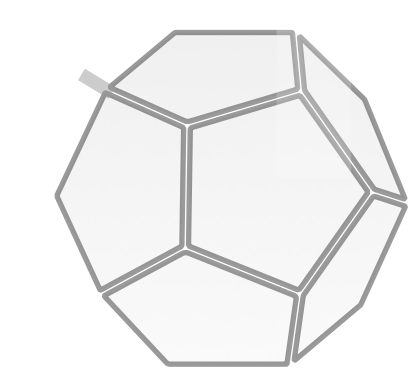




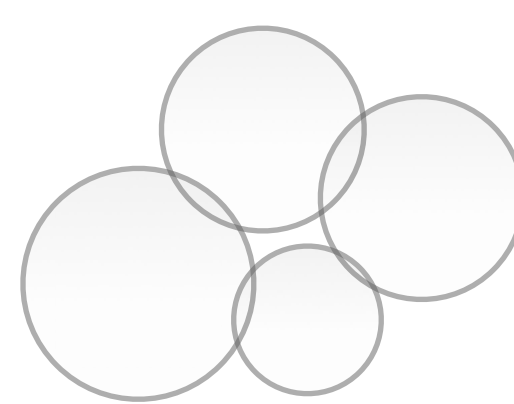
Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Clesse, Dandoy, Verma (2412.15989)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)

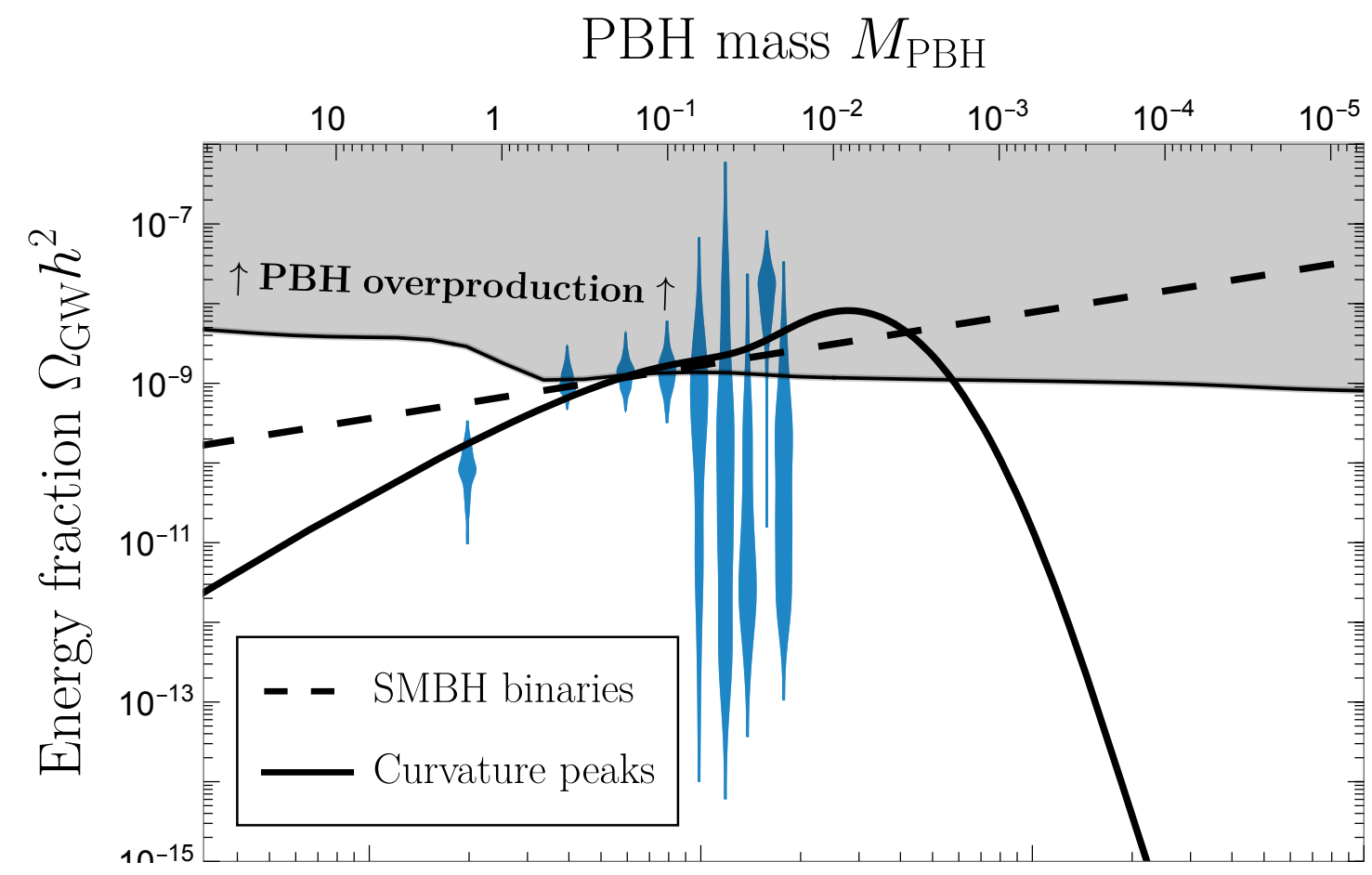


Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841

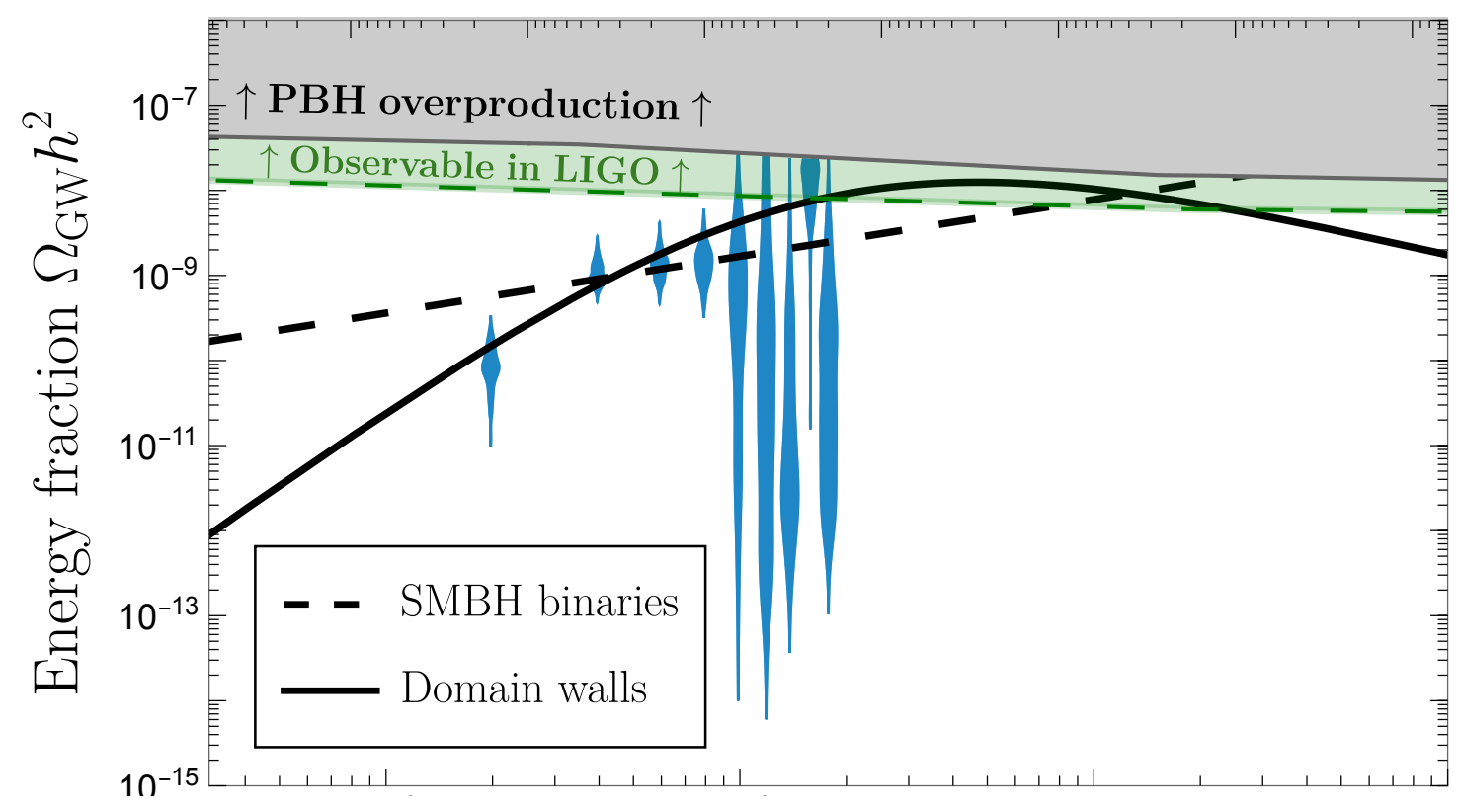
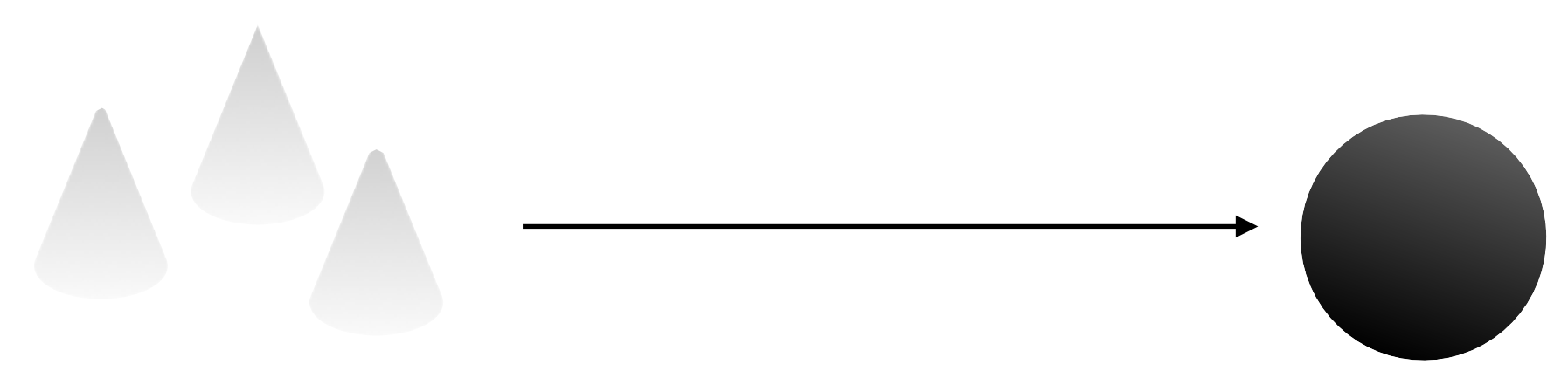


First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...

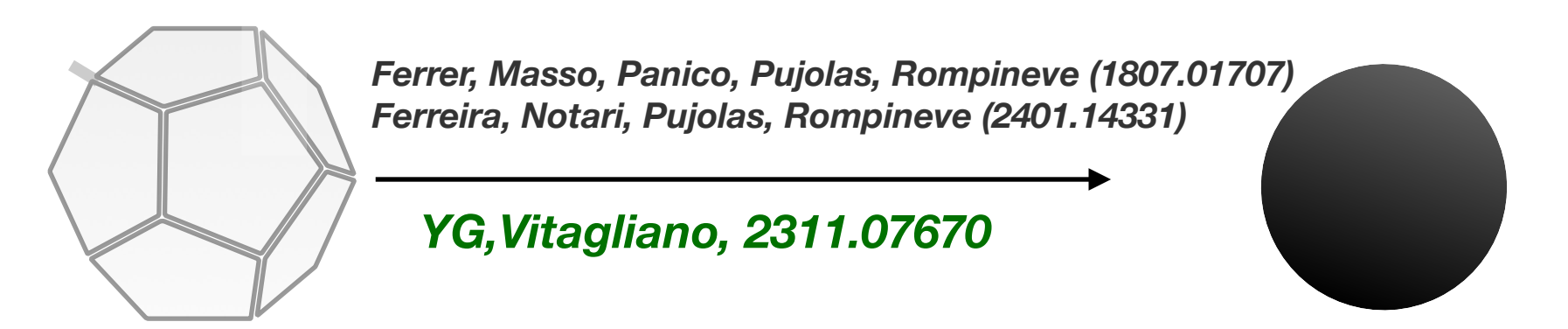




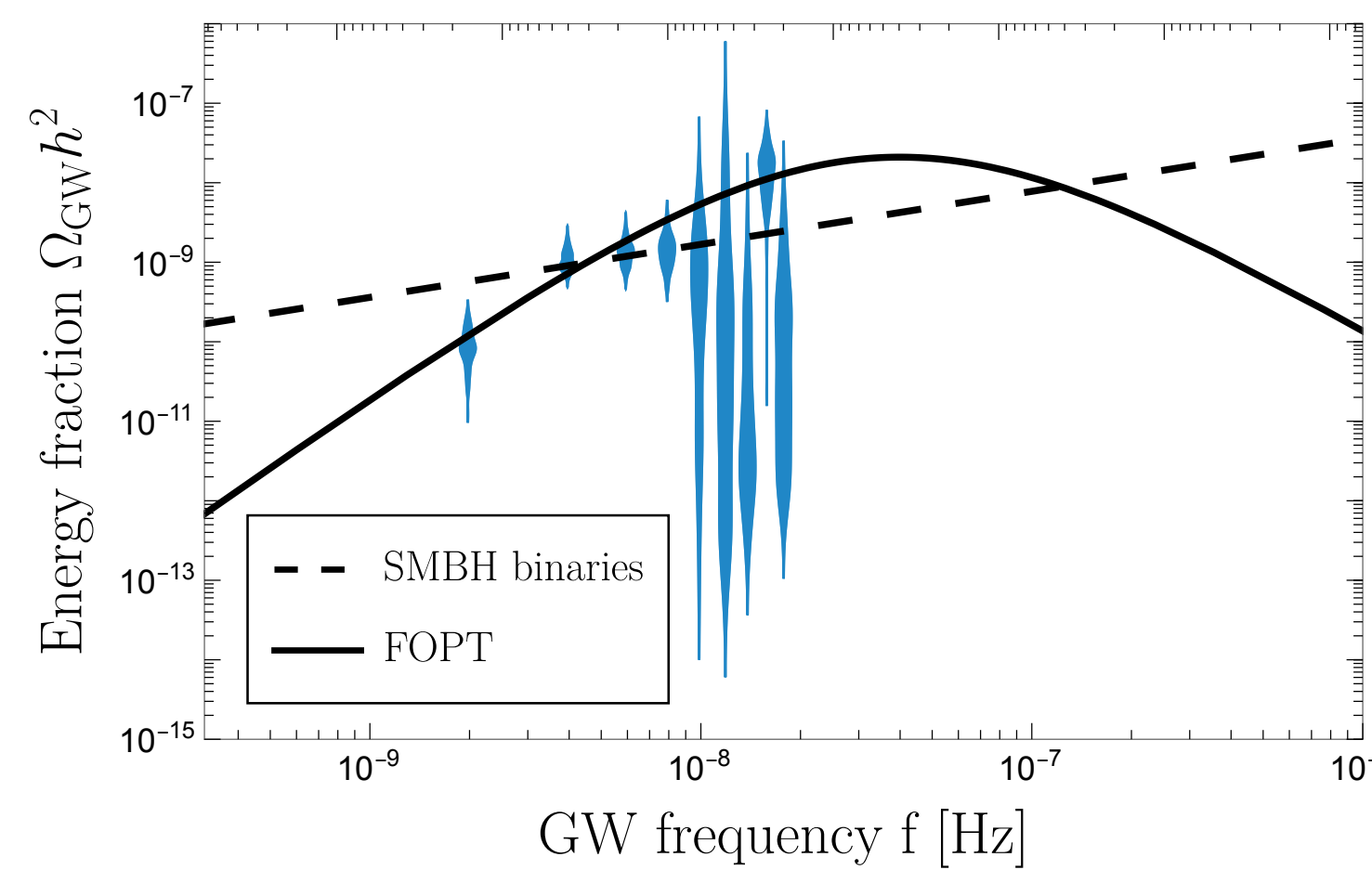
Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Clesse, Dandoy, Verma (2412.15989)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)



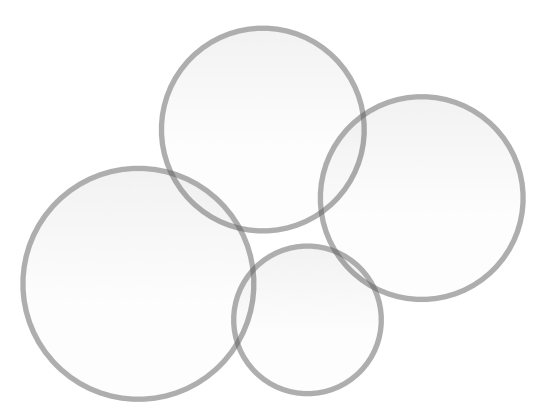
Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841

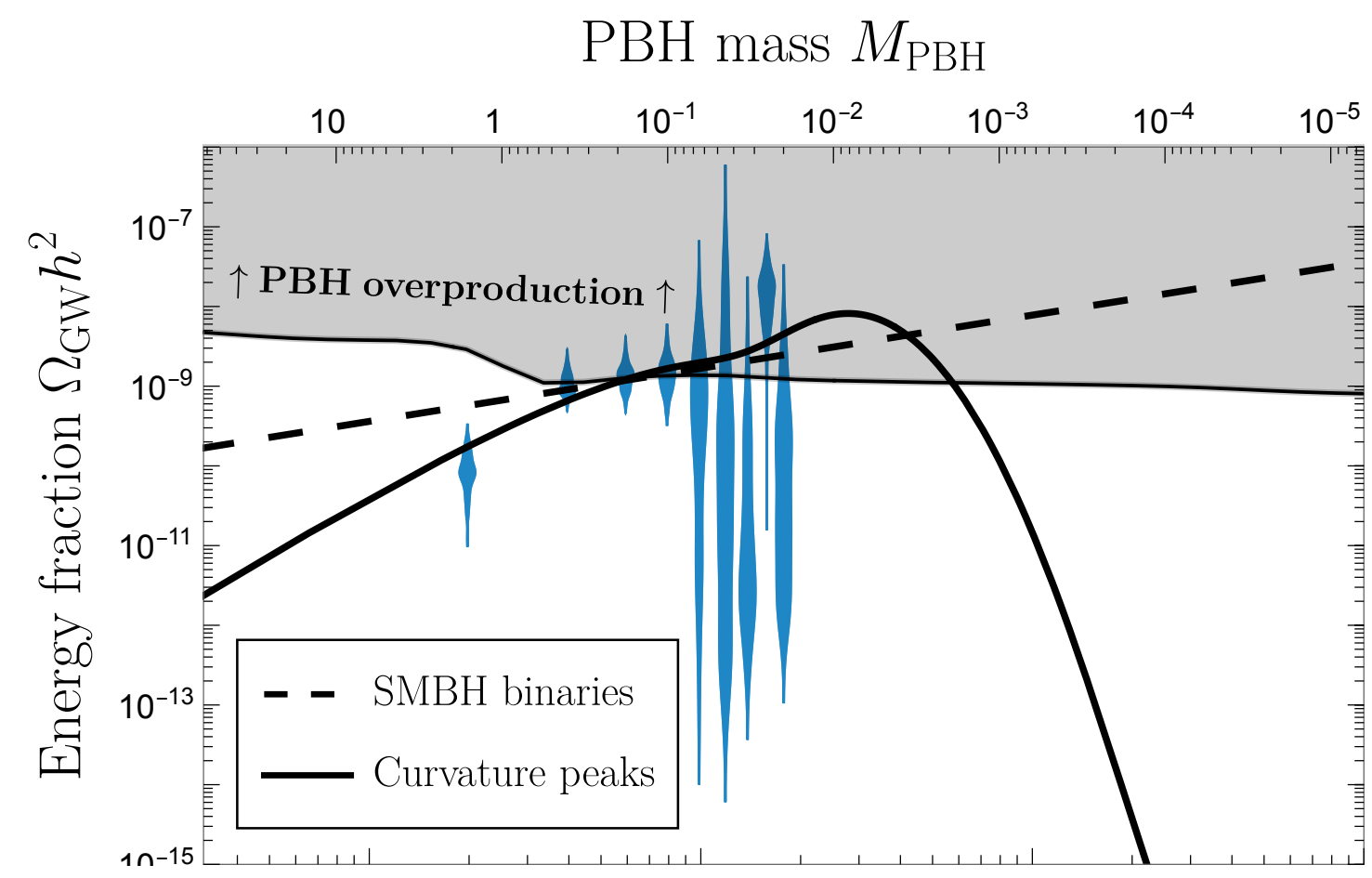


PBH

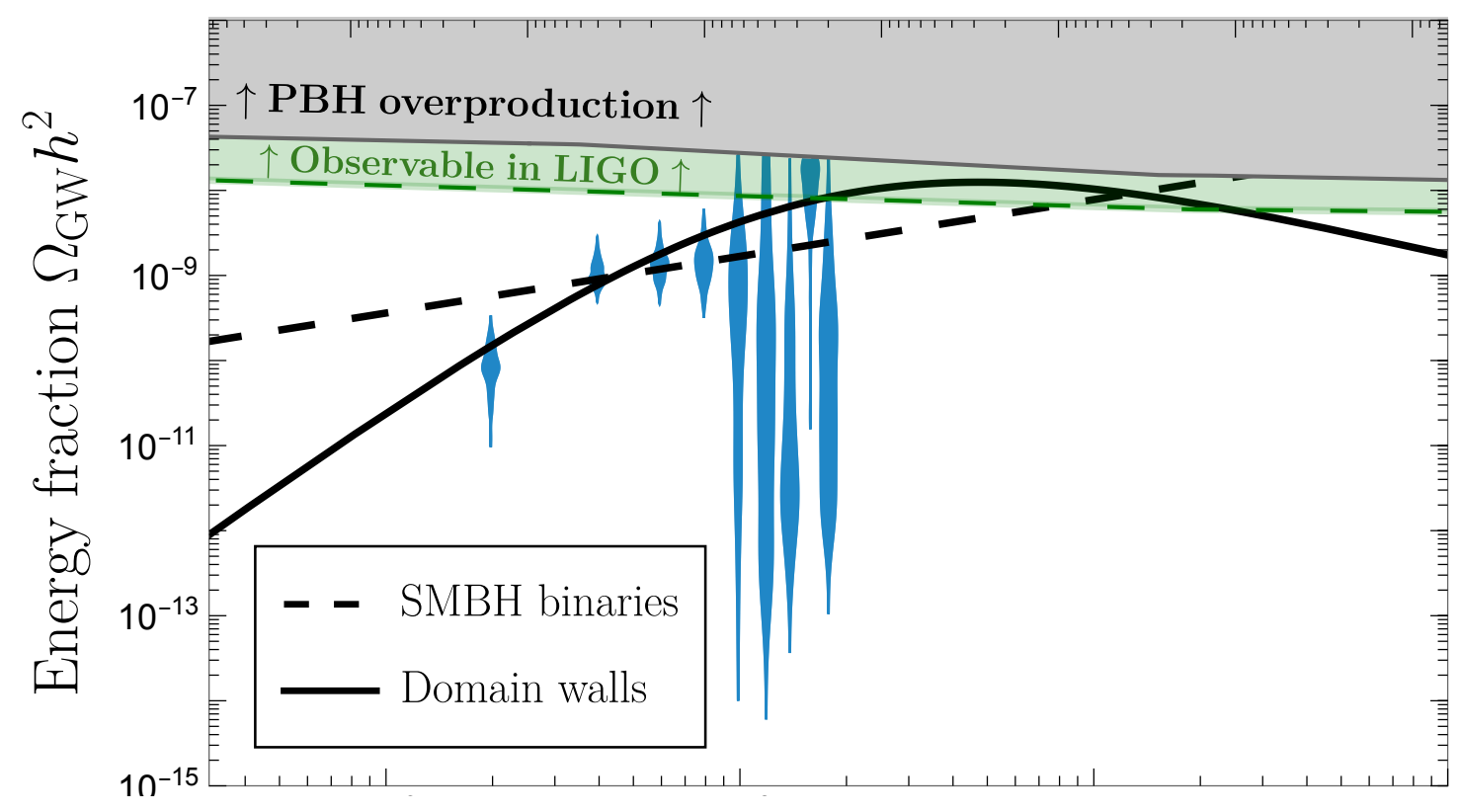
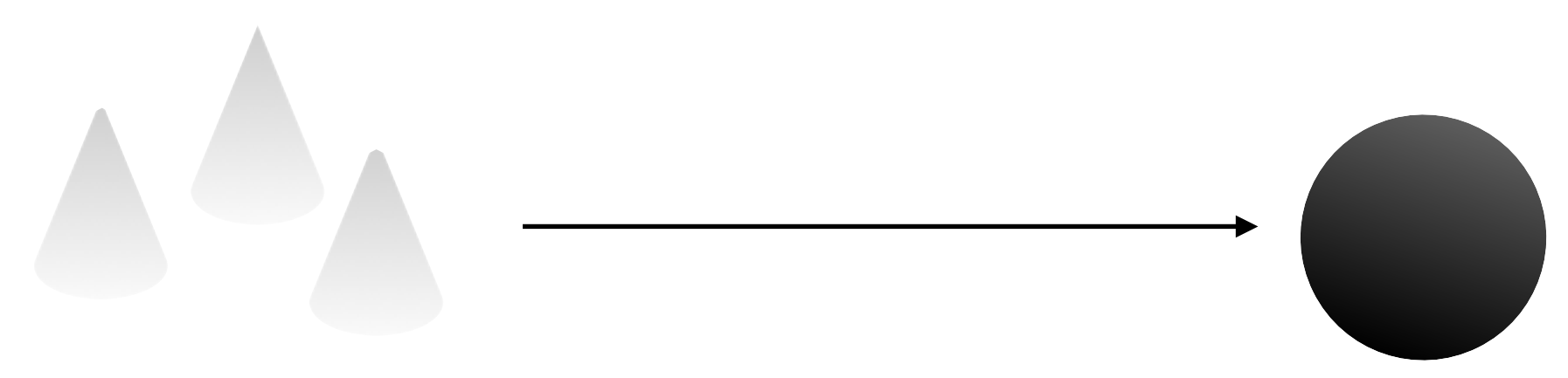


First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...

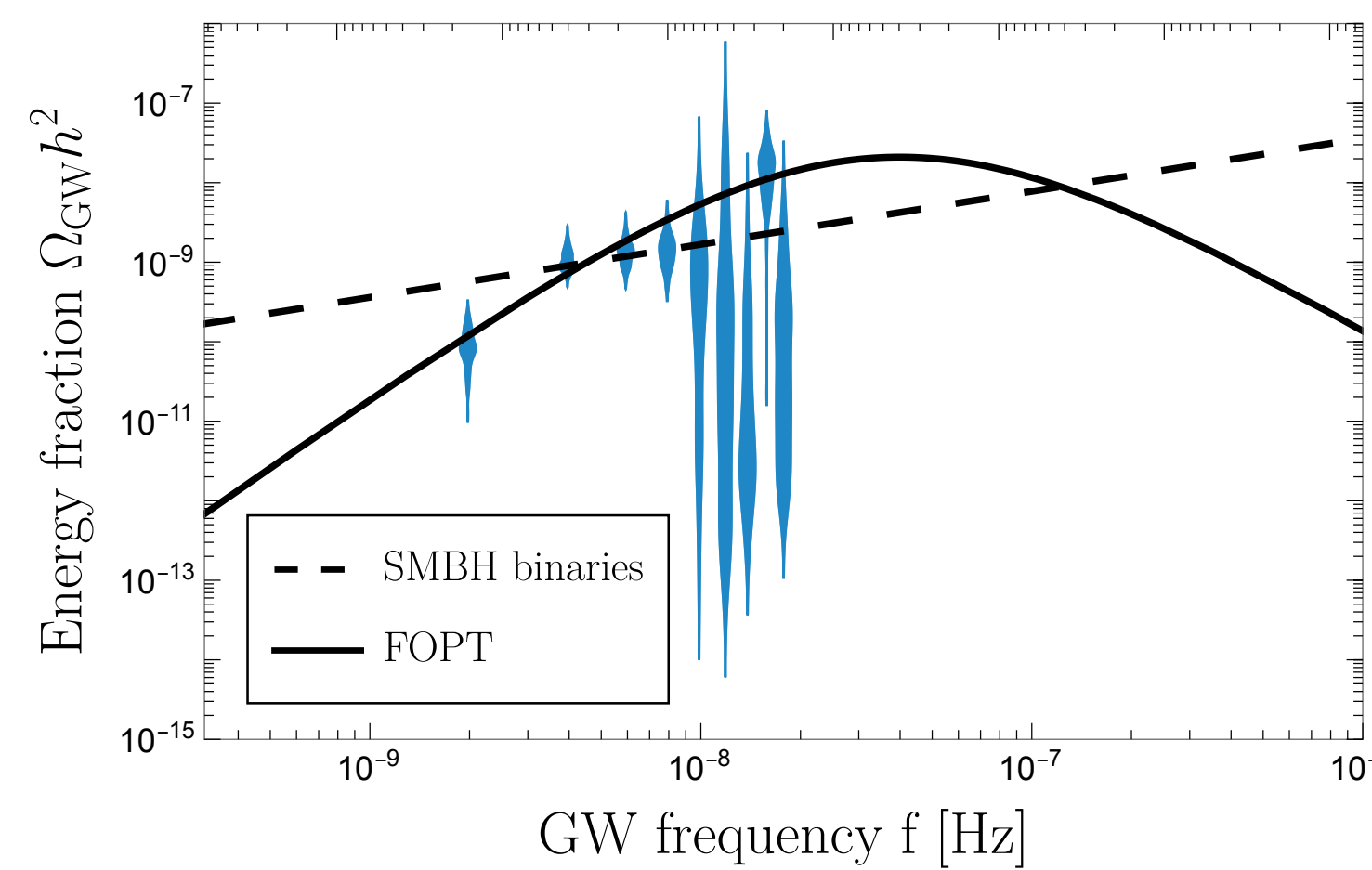
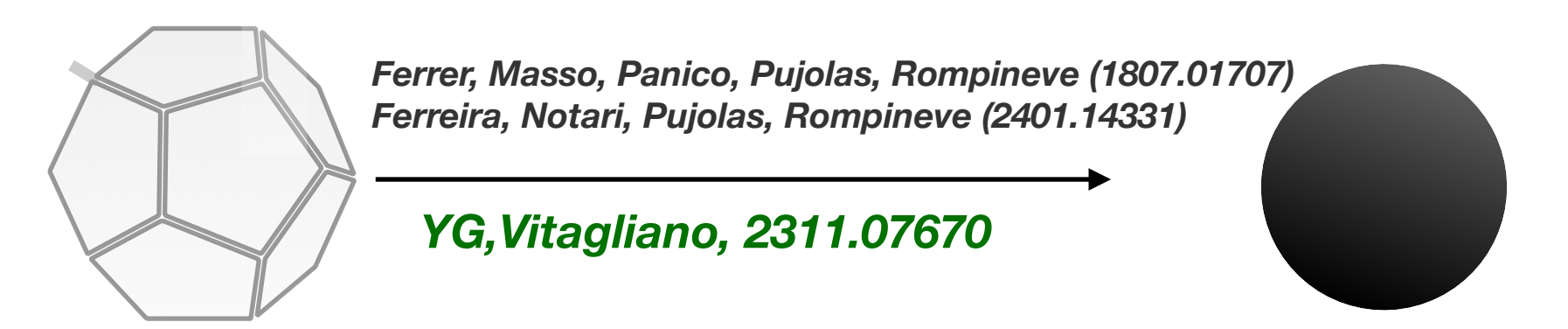




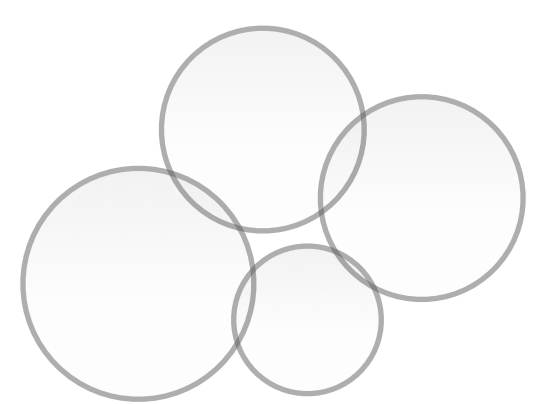
Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Clesse, Dandoy, Verma (2412.15989)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)



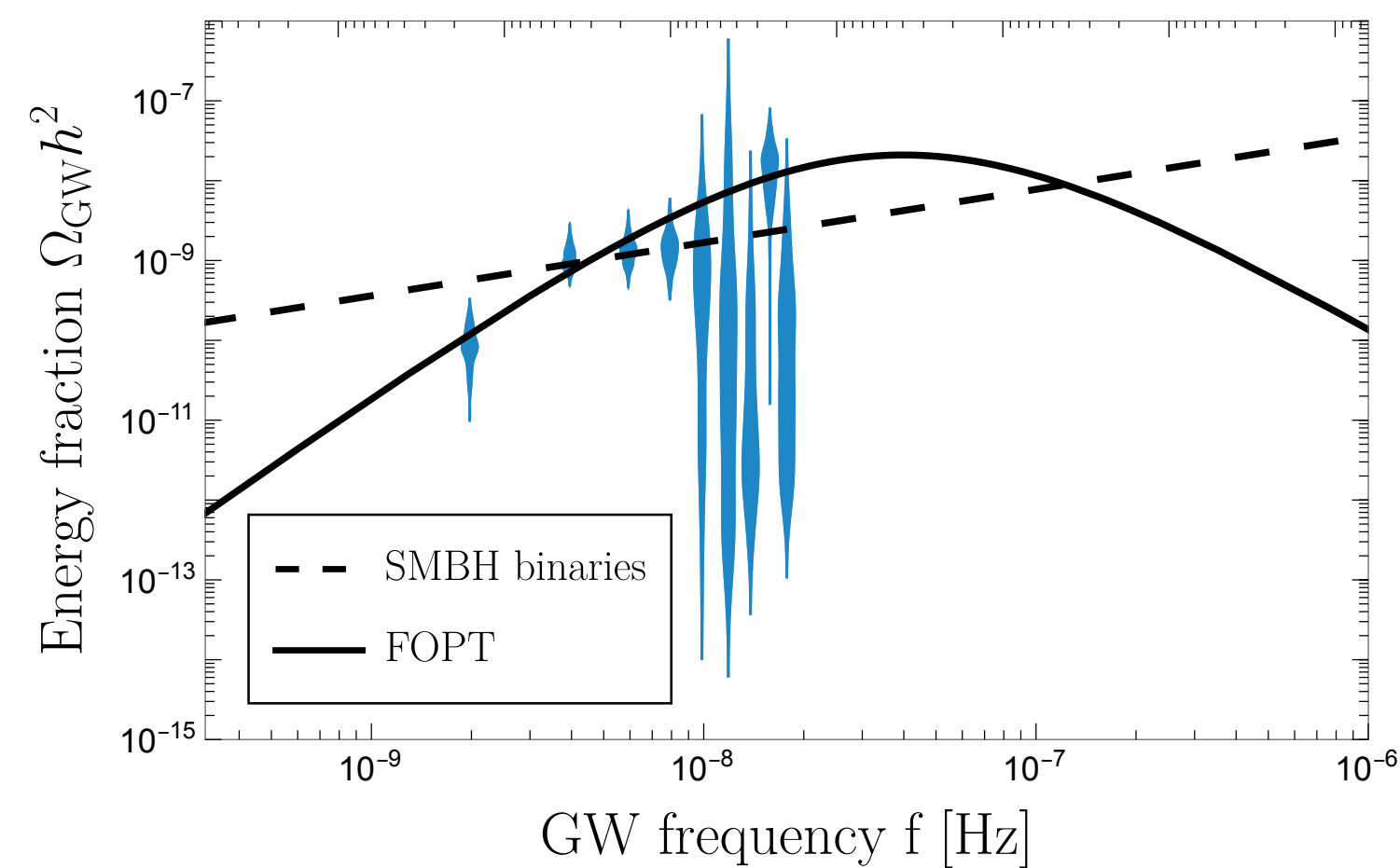
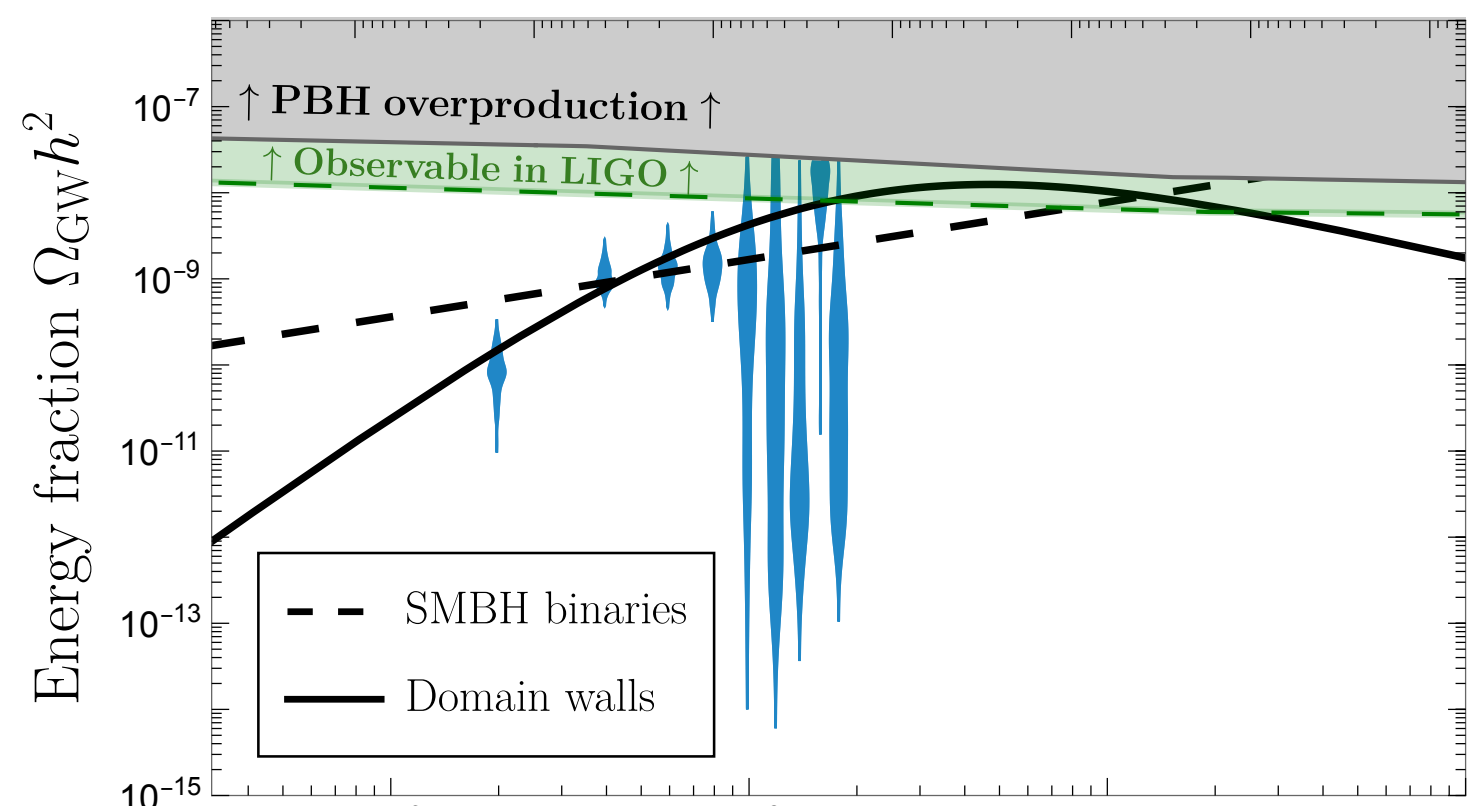
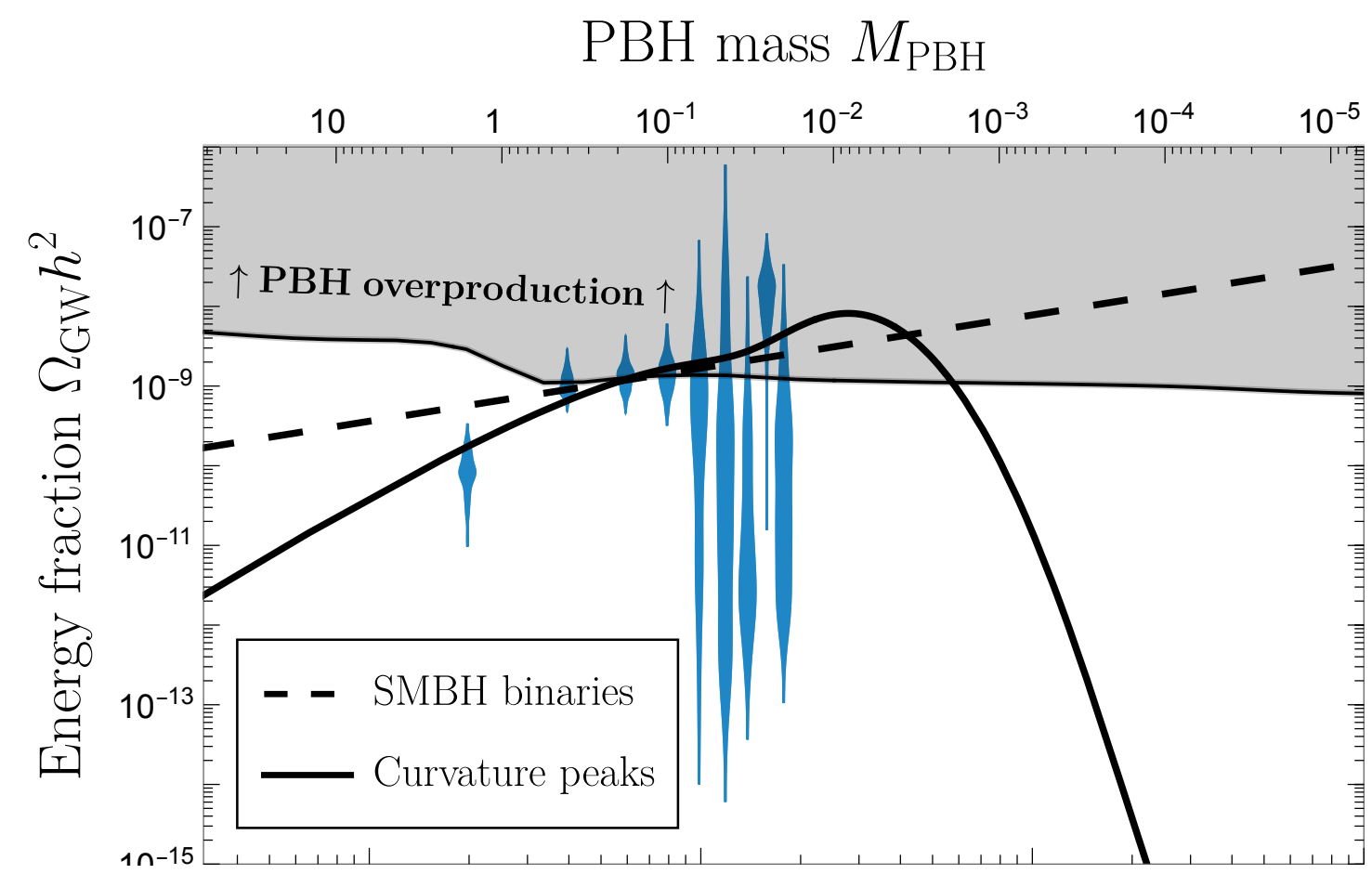
Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841



First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...



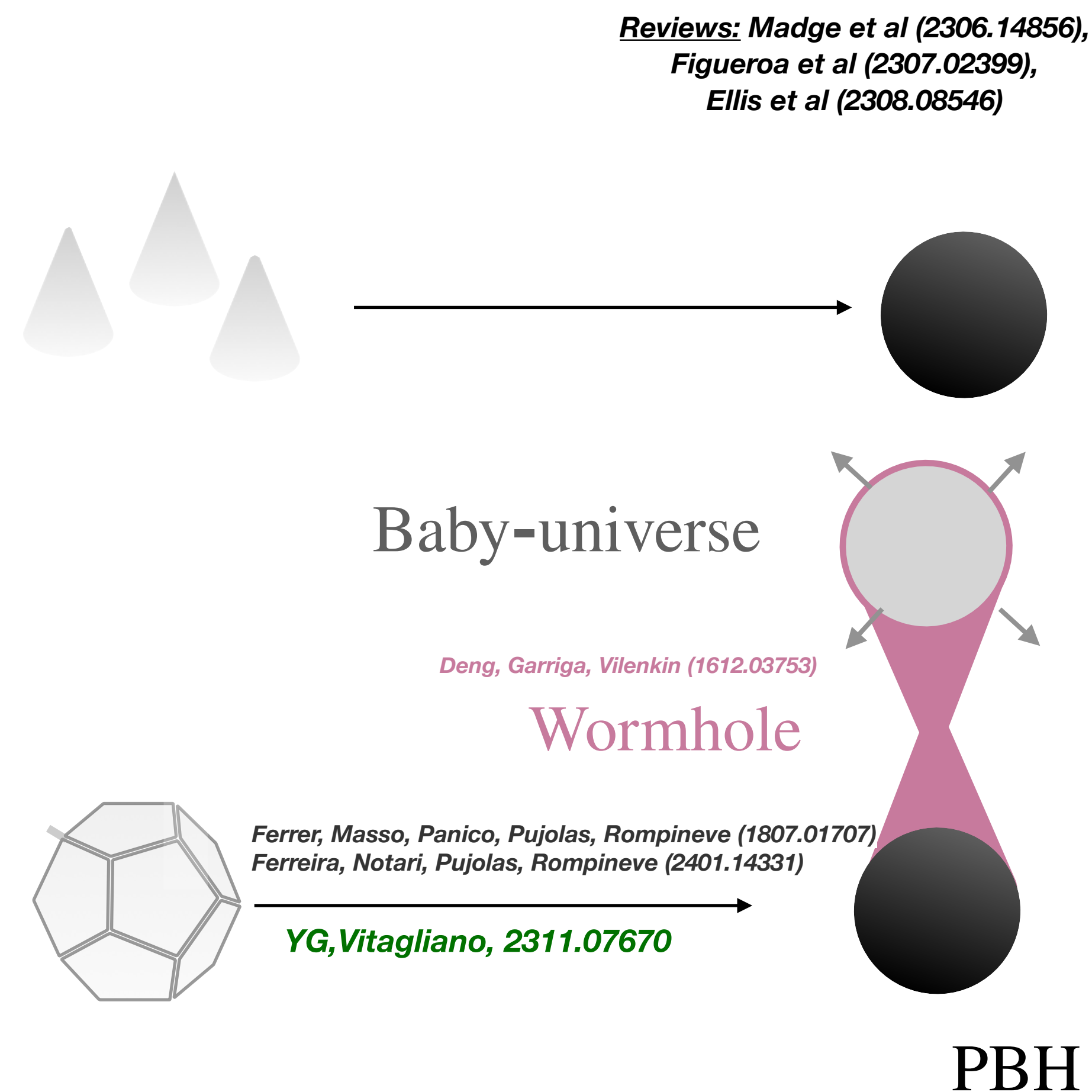
PBH

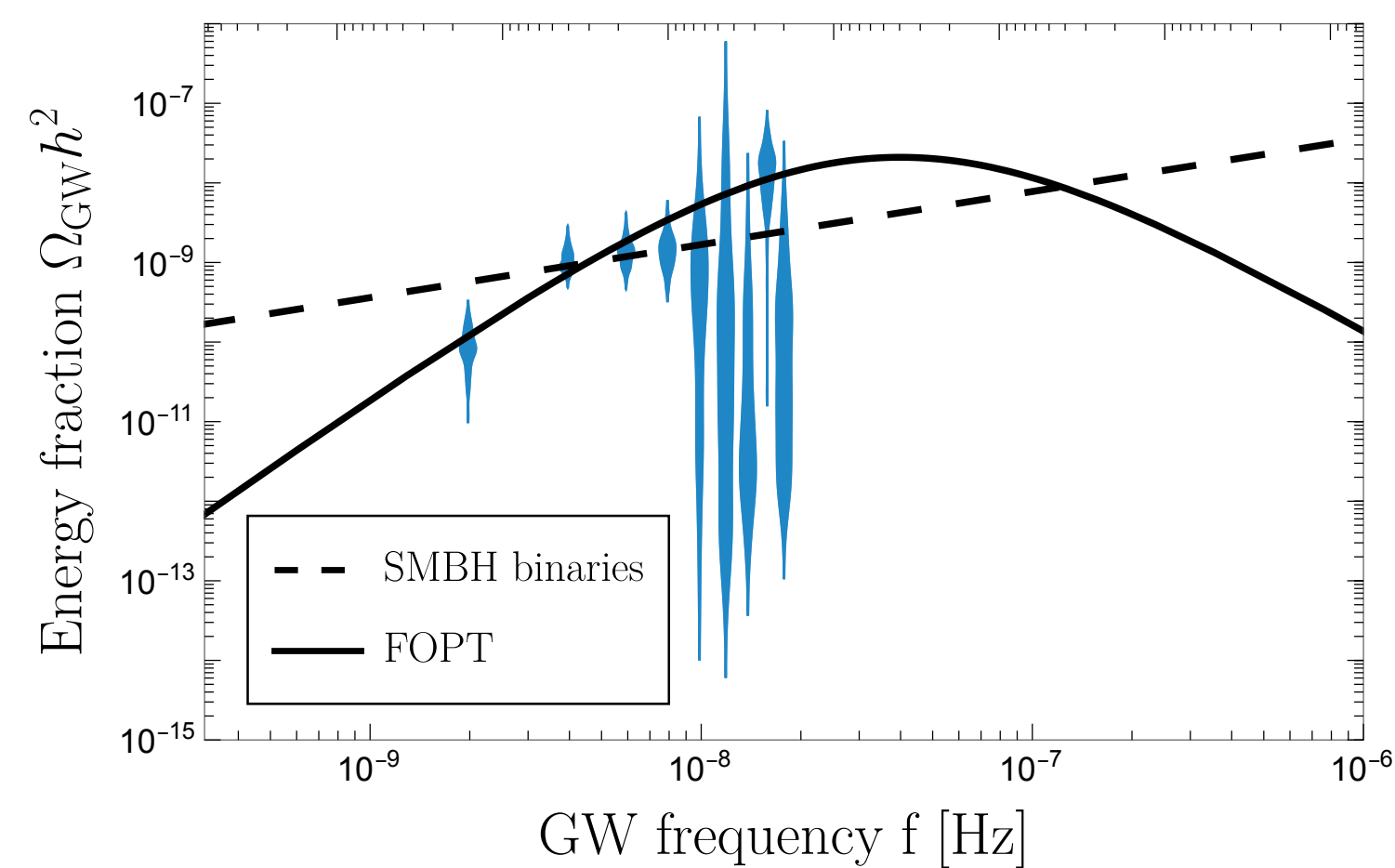
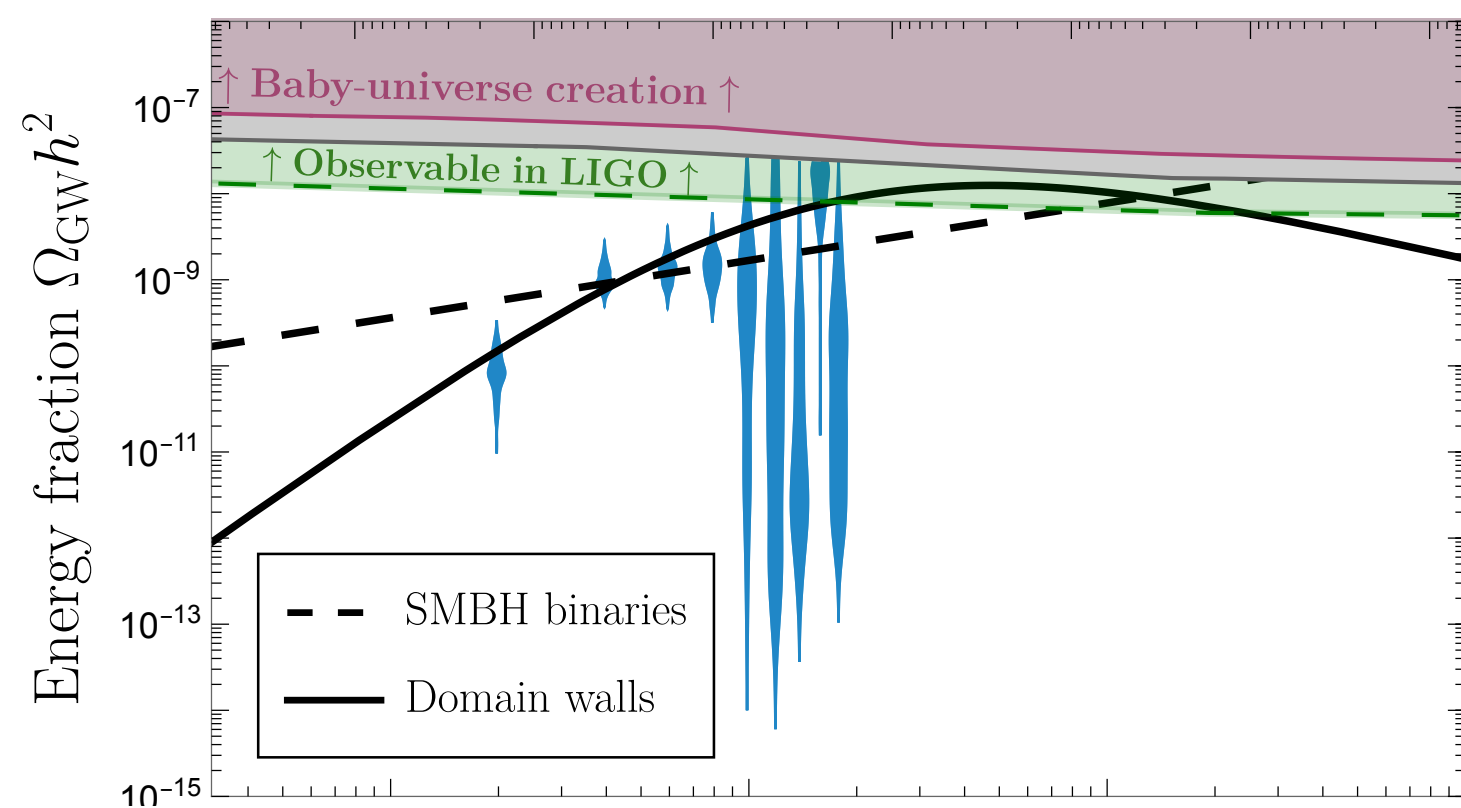
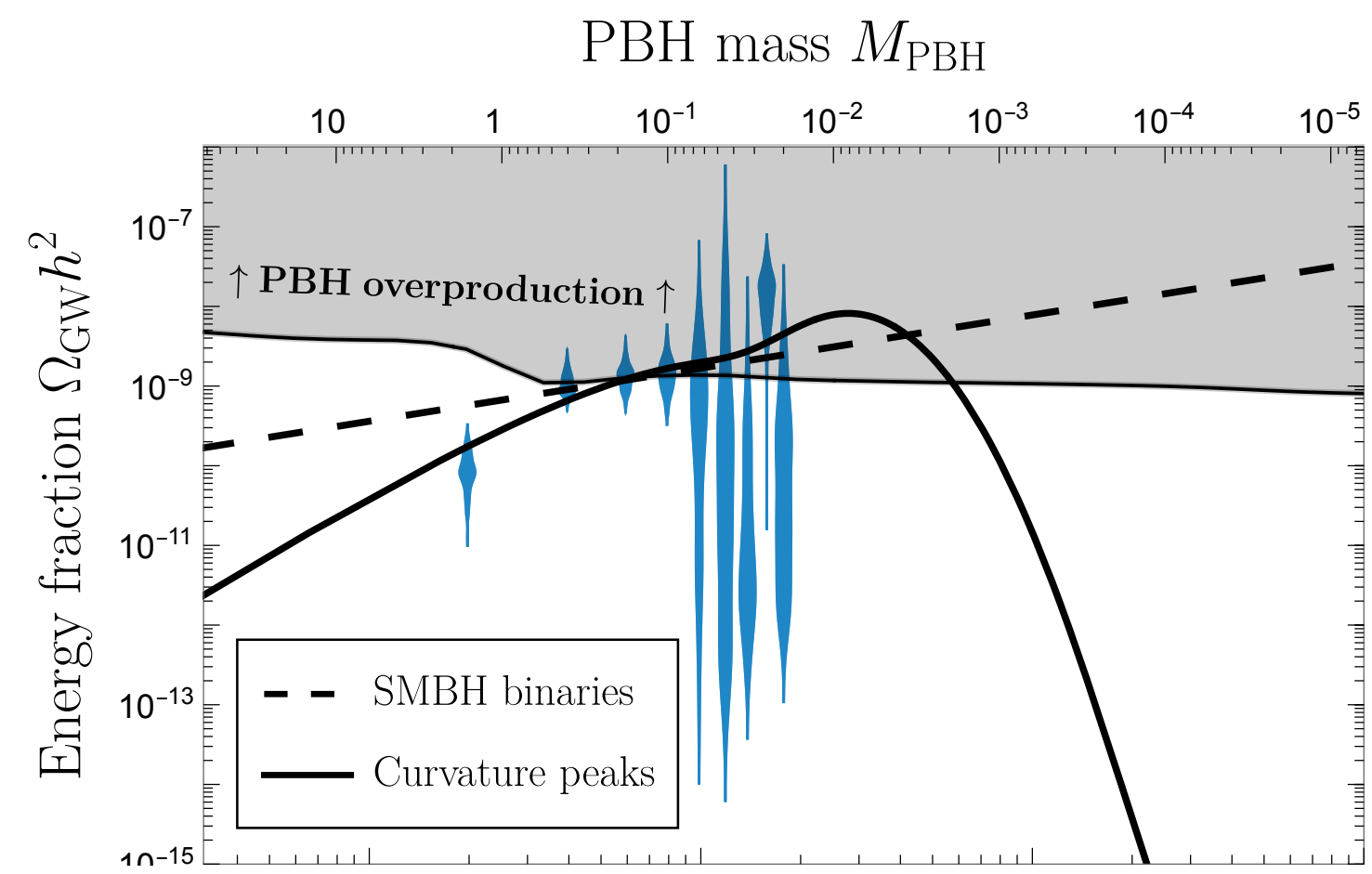


Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Clesse, Dandoy, Verma (2412.15989)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)

Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841

First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...





Curvature peaks

Overproduce PBH

Chen, Yuan, Huang (1910.12239)

Kohri, Terada (2009.11853)

Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)

Vaskonen, Veermae (2009.07832),

De Luca, Franciolini, Riotto (2009.08268)

Clesse, Dandoy, Verma (2412.15989)

Except if negative non-Gaussianities

Franciolini, Iovino, Vaskonen, Veermae (2306.17143)

YG, Trifinopoulos, Vanvlasselaer (2508.19328)

Domain wall networks

Ferreira, Notari, Pujolas, Rompineve (2204.04228)

Blasi, Mariotti, Rase, Sevrin (2306.17830)

...

Produce solar-mass PBH

YG, Vitagliano 2306.17841

First-order phase transitions

Roper Pol et al. (2201.05630)

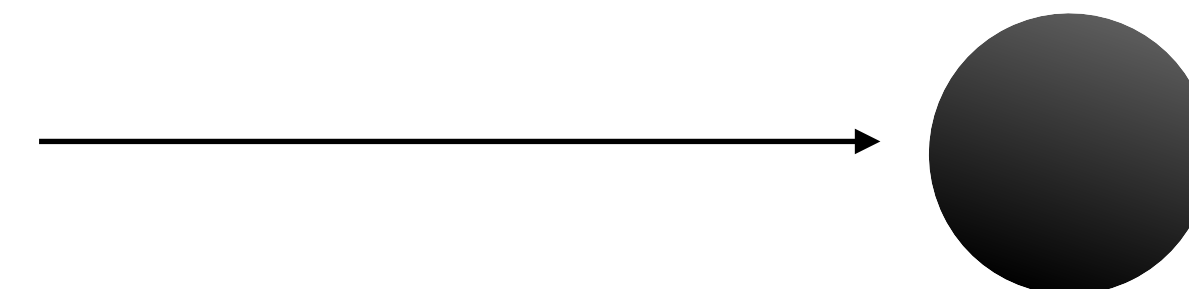
Ghoshal, White et al. (2307.02259)

YG (2307.04239)

Lewicki, Toczek, Vaskonen (2402.04158)

Hoefken Zink et al. (2501.15649)

...



Baby-universe

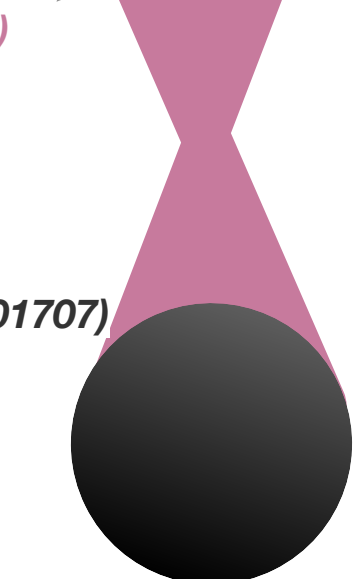
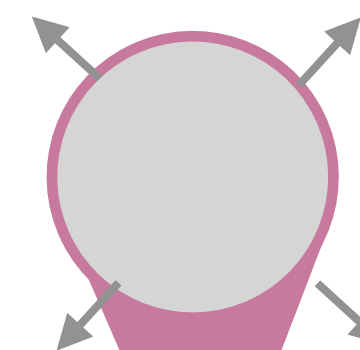
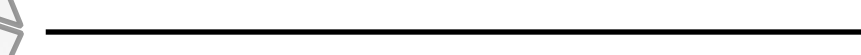
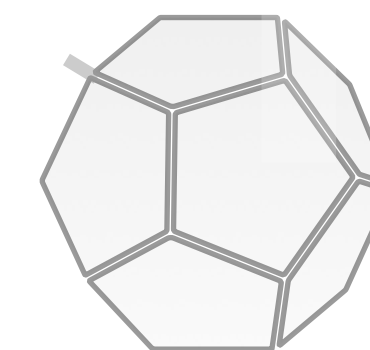
Deng, Garriga, Vilenkin (1612.03753)

Wormhole

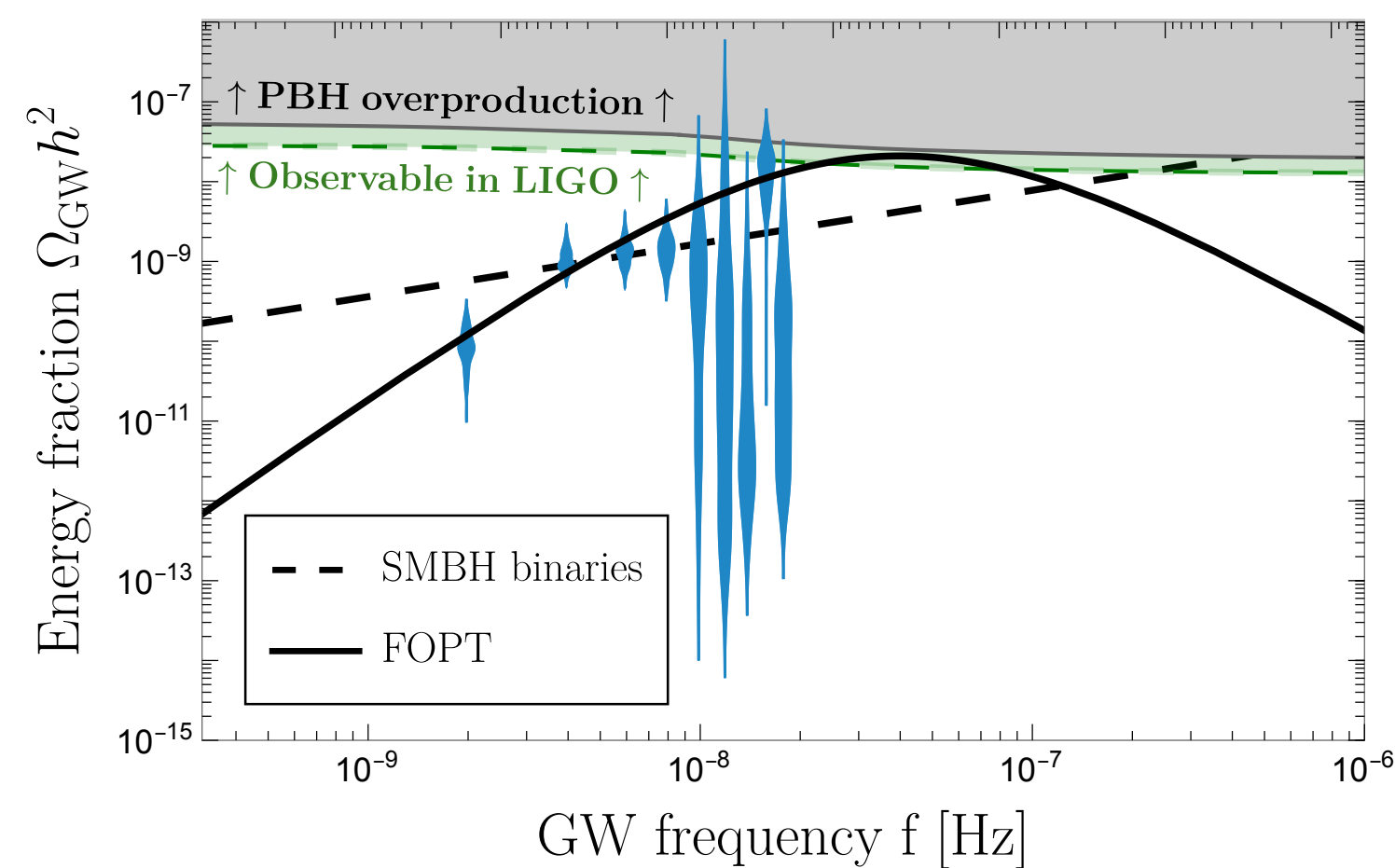
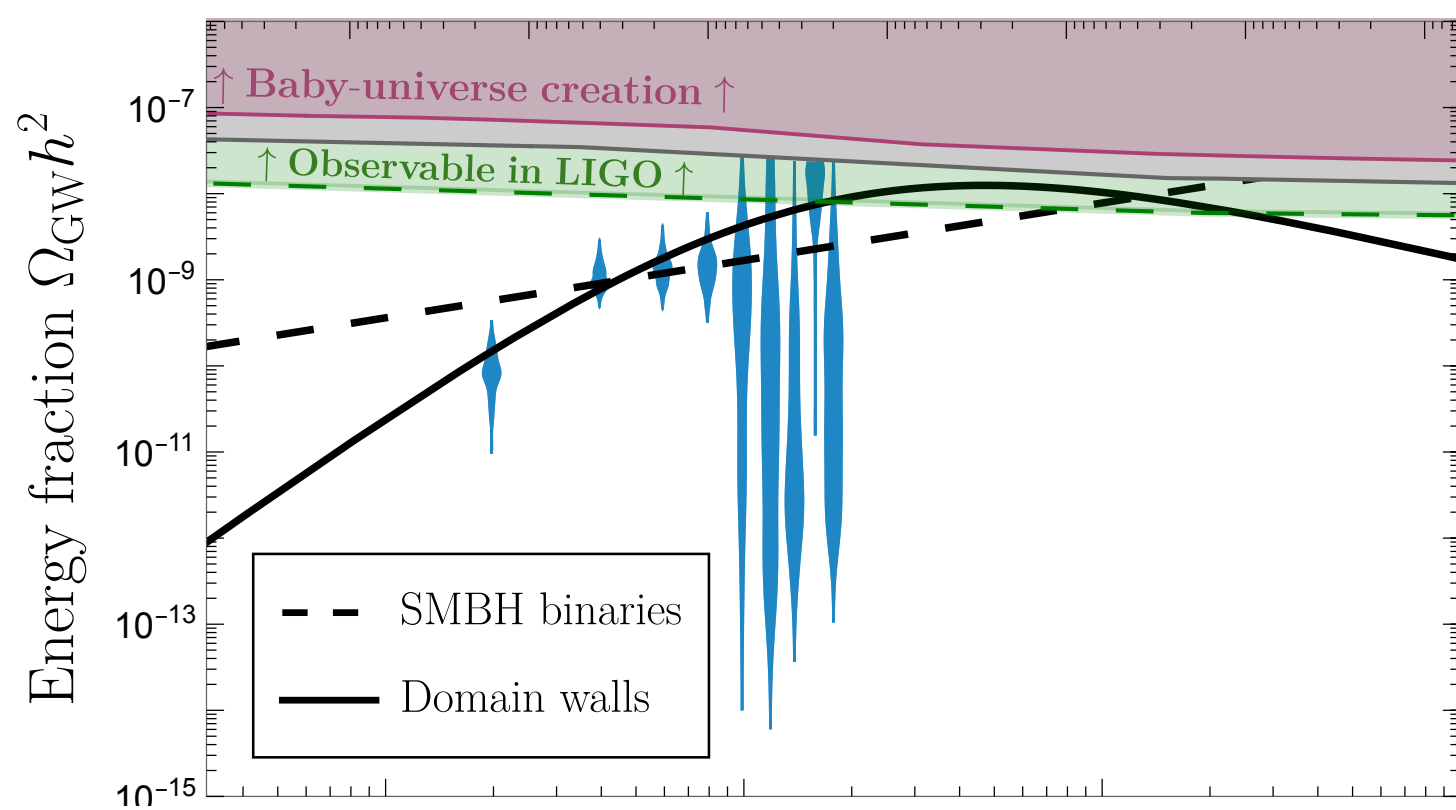
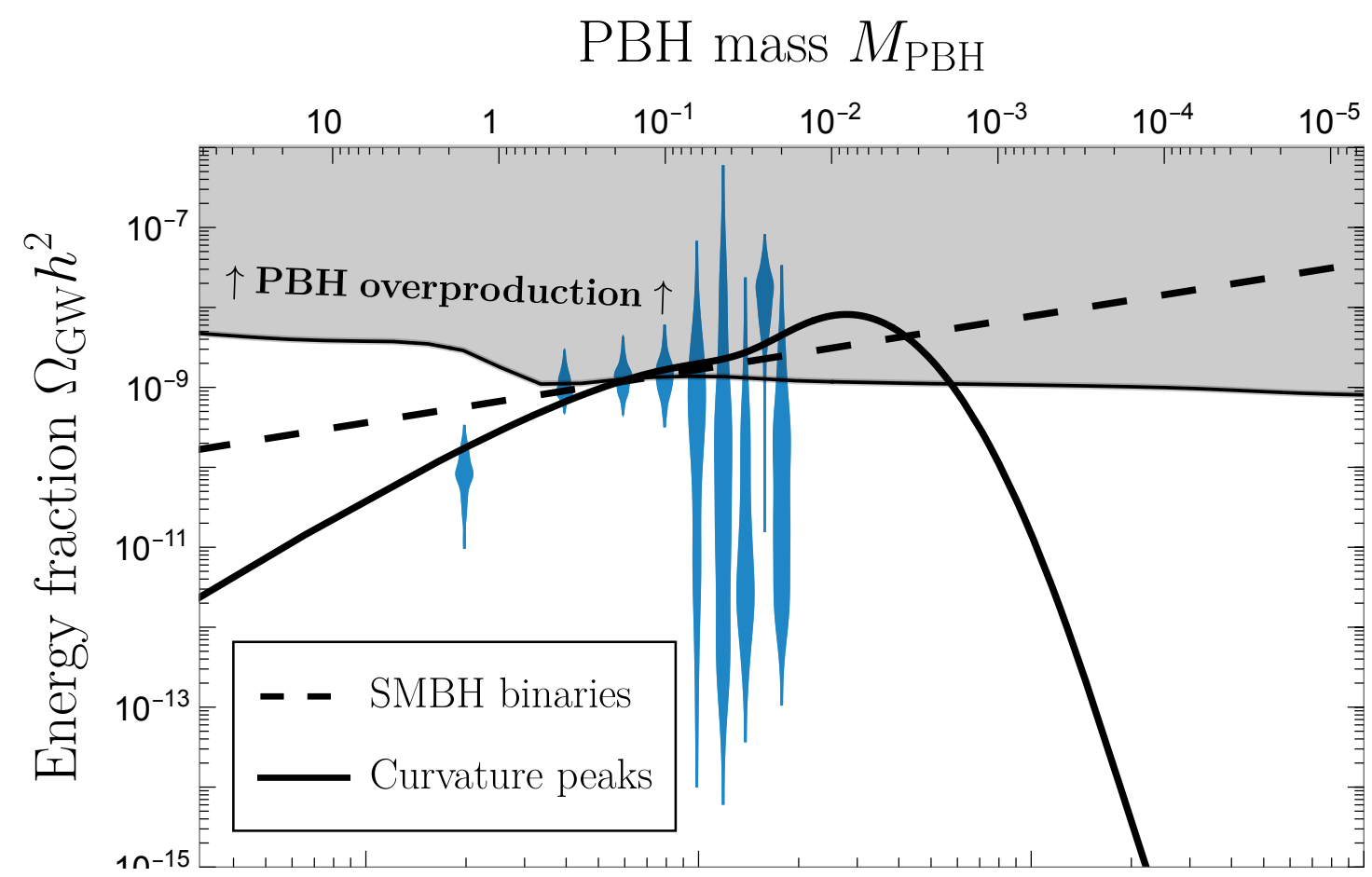
Ferrer, Masso, Panico, Pujolas, Rompineve (1807.01707)

Ferreira, Notari, Pujolas, Rompineve (2401.14331)

YG, Vitagliano, 2311.07670



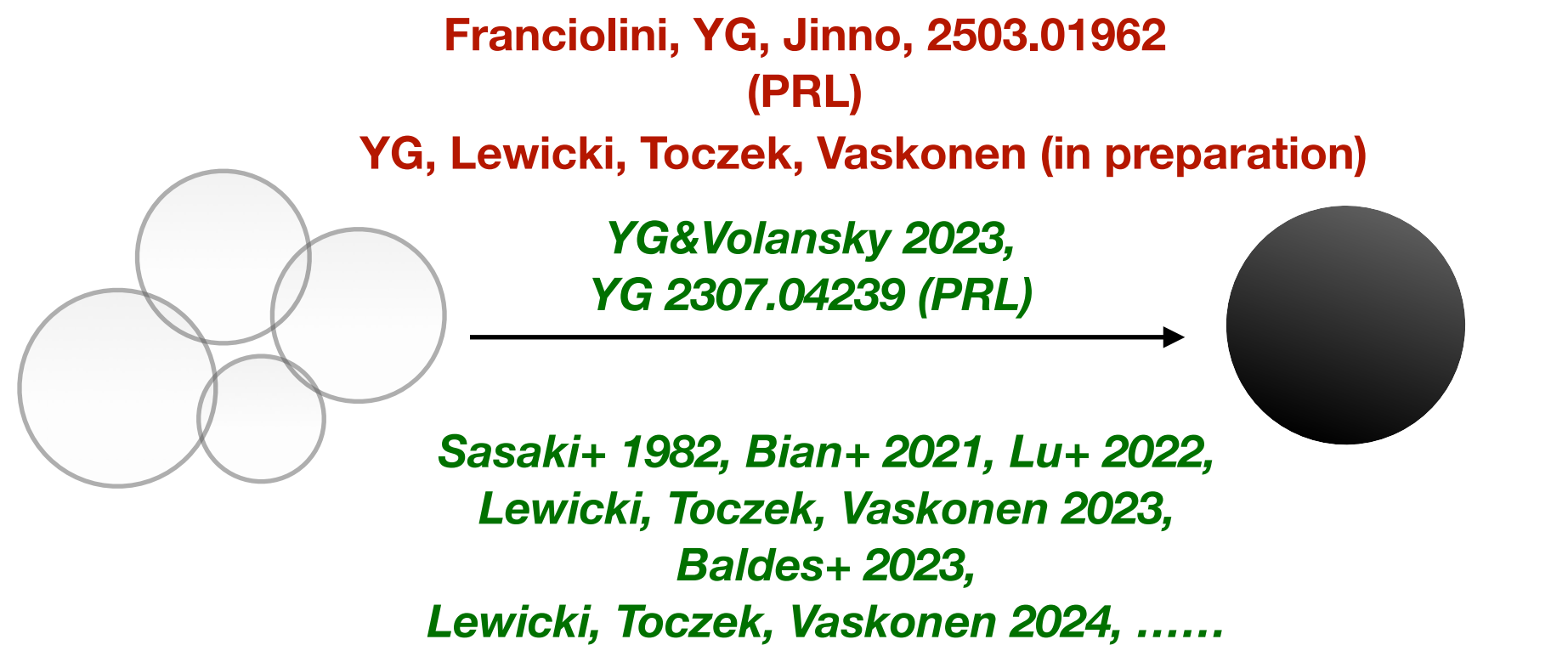
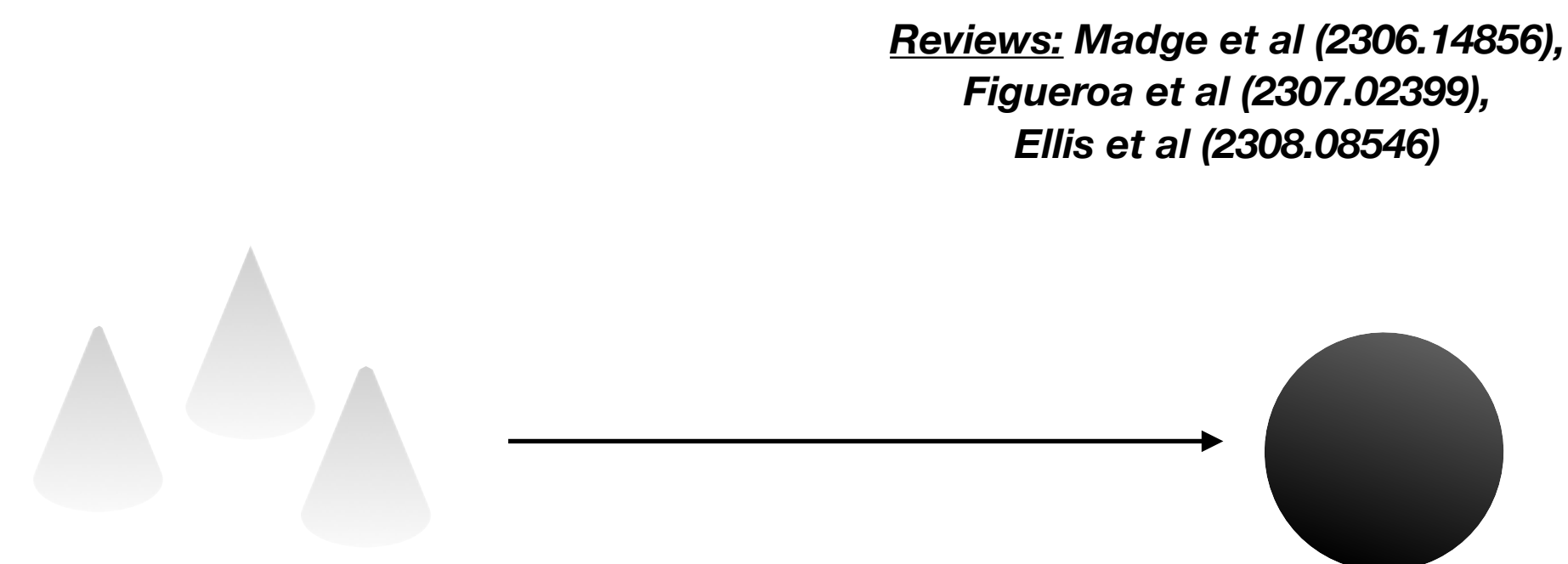
PBH



Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Clesse, Dandoy, Verma (2412.15989)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)

Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841

First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczec, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...



*Reviews: Madge et al (2306.14856),
 Figueroa et al (2307.02399),
 Ellis et al (2308.08546)*

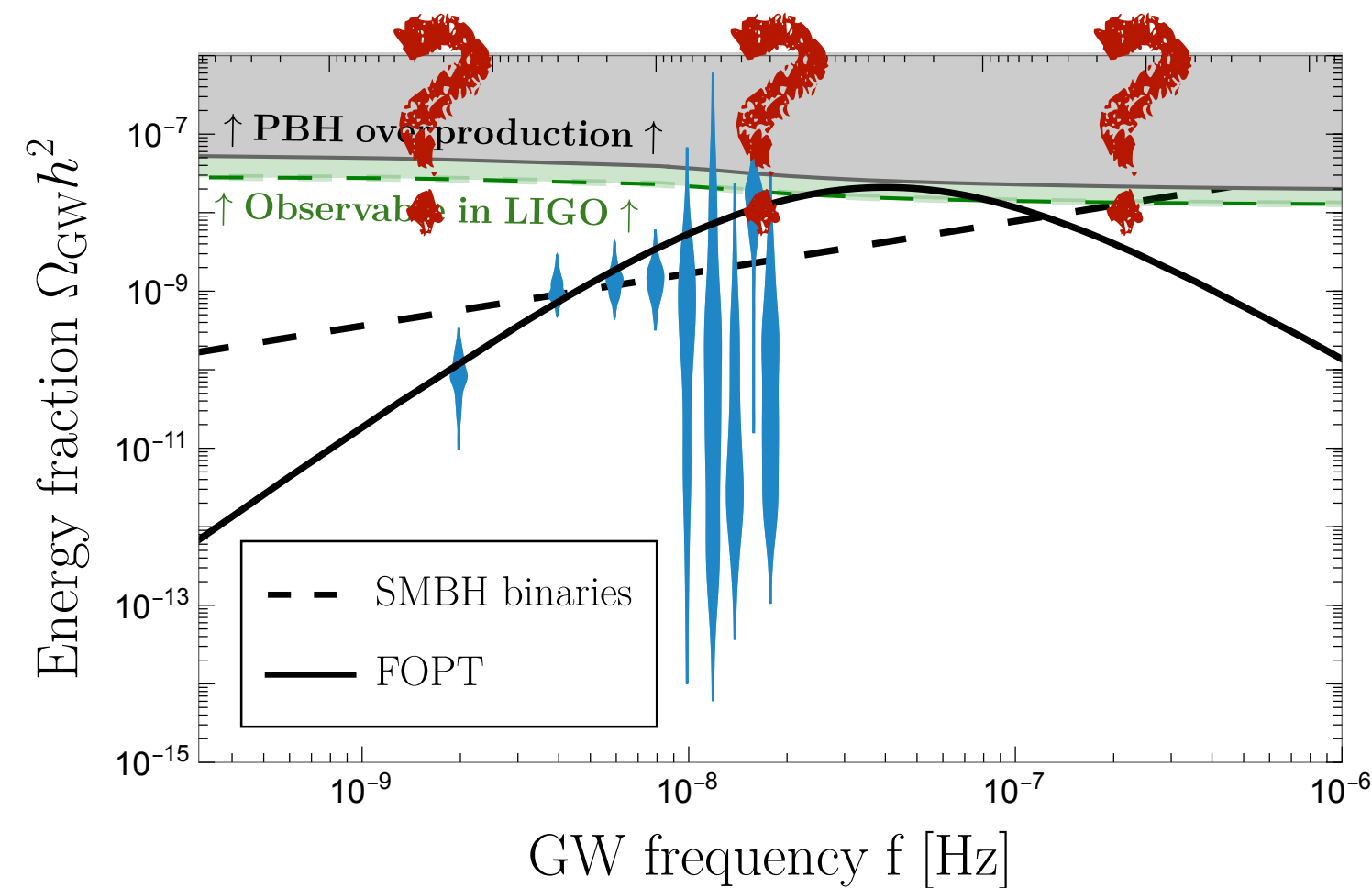
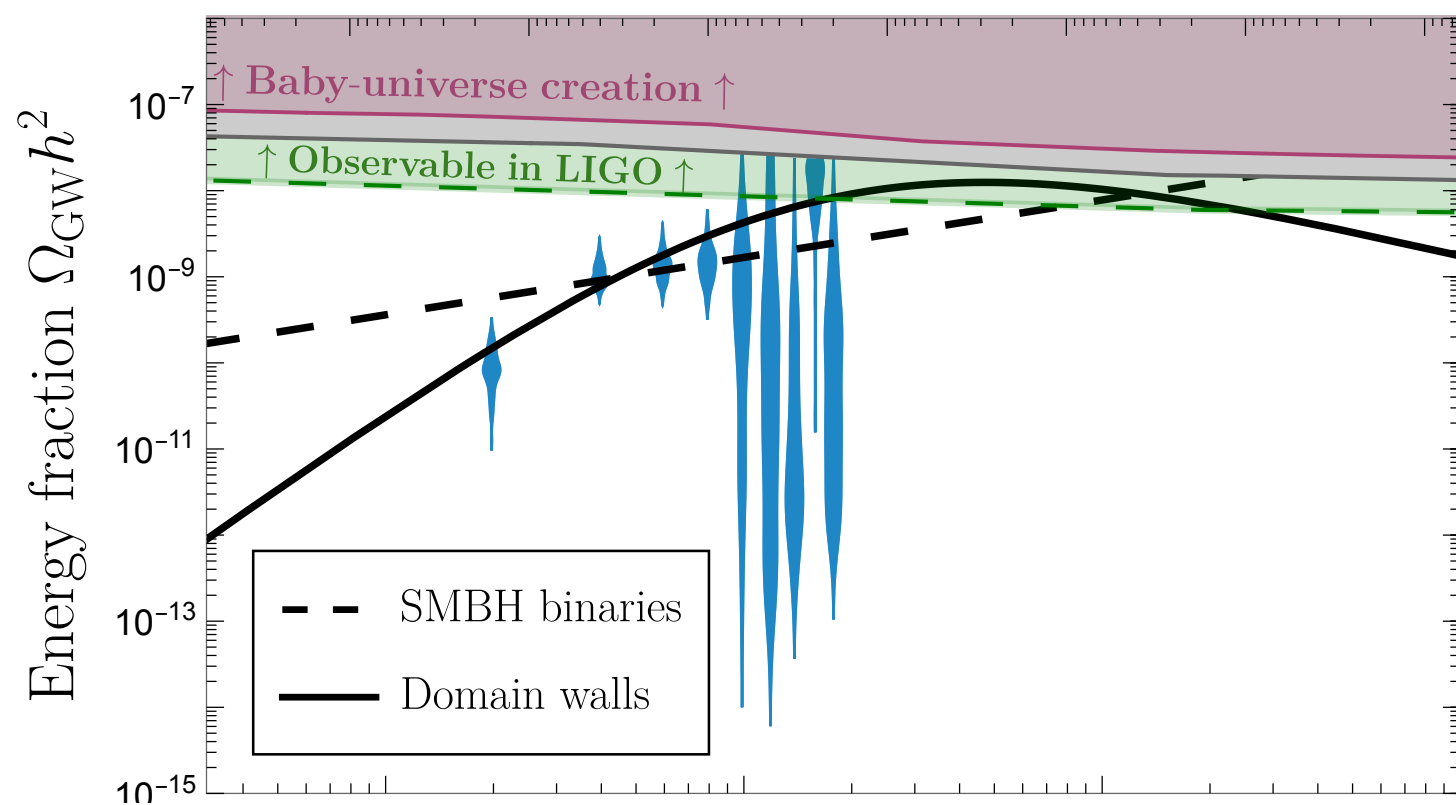
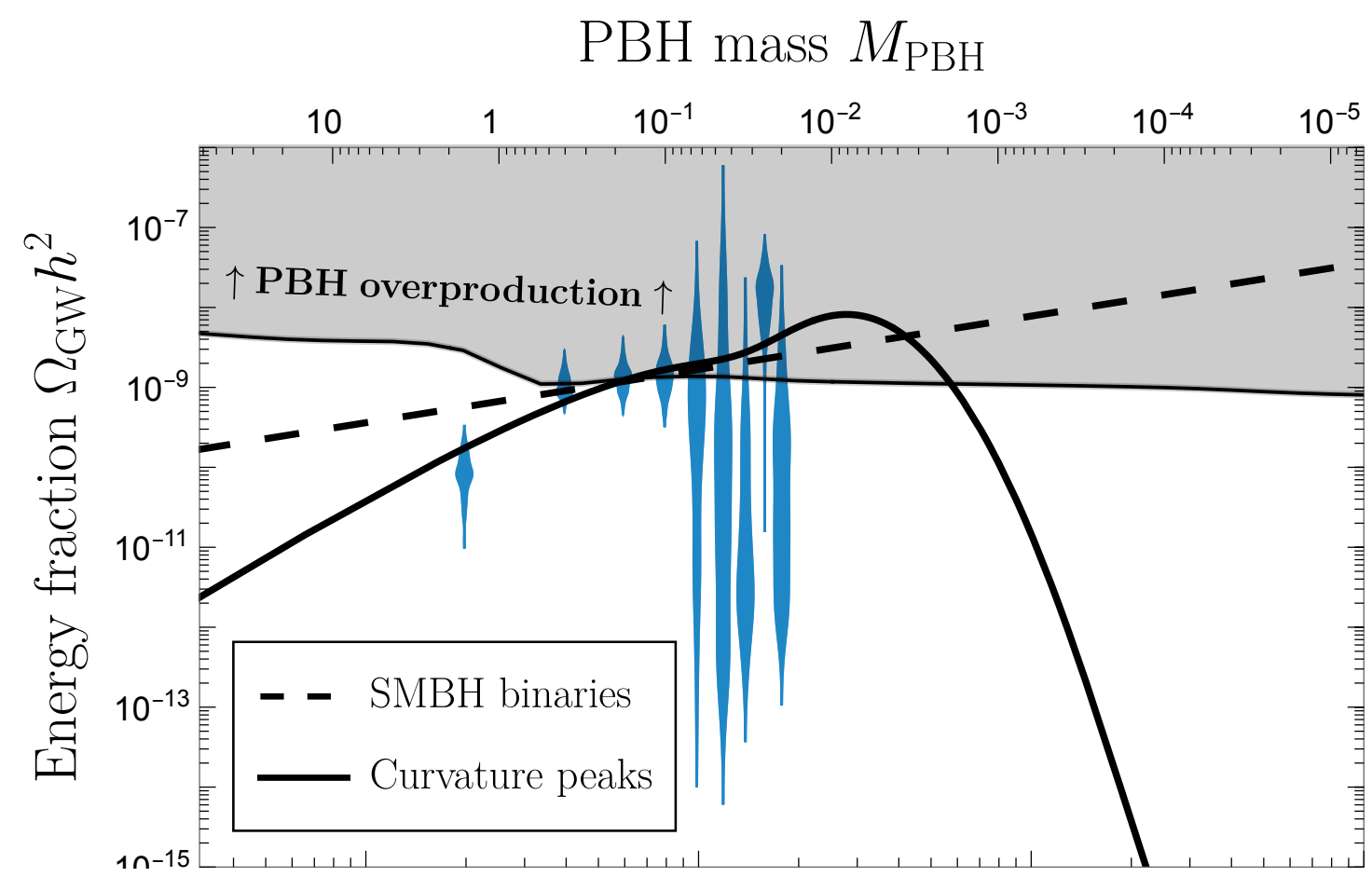
Deng, Garriga, Vilenkin (1612.03753)

Ferrer, Masso, Panico, Pujolas, Rompineve (1807.01707)
Ferreira, Notari, Pujolas, Rompineve (2401.14331)

Franciolini, YG, Jinno, 2503.01962 (PRL)
YG, Lewicki, Toczec, Vaskonen (in preparation)

YG&Volansky 2023,
YG 2307.04239 (PRL)

Sasaki+ 1982, Bian+ 2021, Lu+ 2022,
Lewicki, Toczec, Vaskonen 2023,
Baldes+ 2023,
Lewicki, Toczec, Vaskonen 2024,



Curvature peaks

Overproduce PBH

Chen, Yuan, Huang (1910.12239)

Kohri, Terada (2009.11853)

Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)

Vaskonen, Veermae (2009.07832),

De Luca, Franciolini, Riotto (2009.08268)

Clesse, Dandoy, Verma (2412.15989)

Except if negative non-Gaussianities

Franciolini, Iovino, Vaskonen, Veermae (2306.17143)

YG, Trifinopoulos, Vanvlasselaer (2508.19328)

Domain wall networks

Ferreira, Notari, Pujolas, Rompineve (2204.04228)

Blasi, Mariotti, Rase, Sevrin (2306.17830)

...

Produce solar-mass PBH

YG, Vitagliano 2306.17841

First-order phase transitions

Roper Pol et al. (2201.05630)

Ghoshal, White et al. (2307.02259)

YG (2307.04239)

Lewicki, Toczec, Vaskonen (2402.04158)

Hoefken Zink et al. (2501.15649)

...



Baby-universe

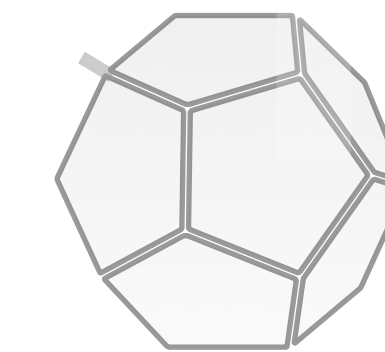
Deng, Garriga, Vilenkin (1612.03753)

Wormhole

Ferrer, Masso, Panico, Pujolas, Rompineve (1807.01707)

Ferreira, Notari, Pujolas, Rompineve (2401.14331)

YG, Vitagliano, 2311.07670



PBH

Franciolini, YG, Jinno, 2503.01962

(PRL)

YG, Lewicki, Toczec, Vaskonen (in preparation)

YG&Volansky 2023,

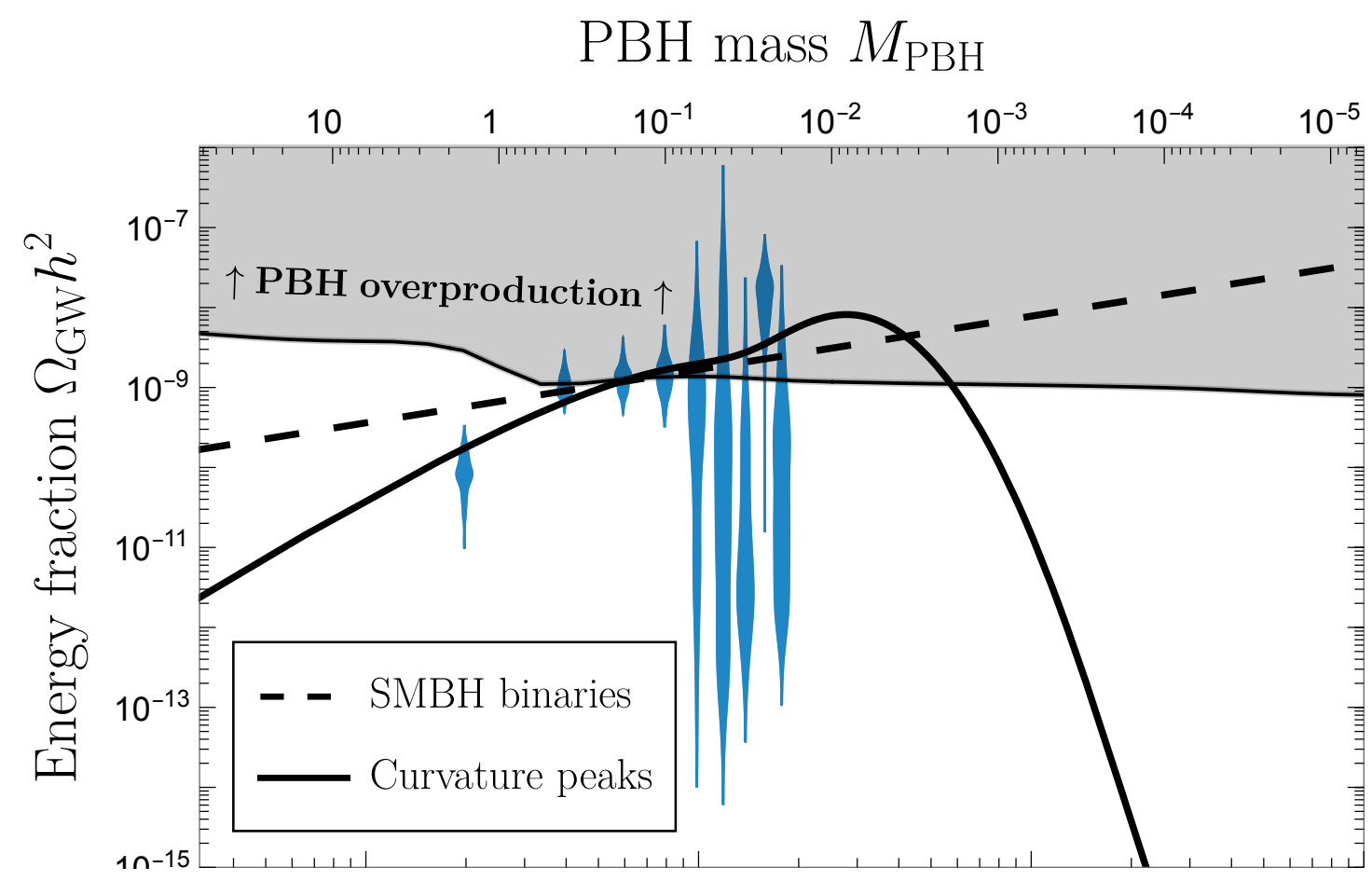
YG 2307.04239 (PRL)

Sasaki+ 1982, Bian+ 2021, Lu+ 2022,

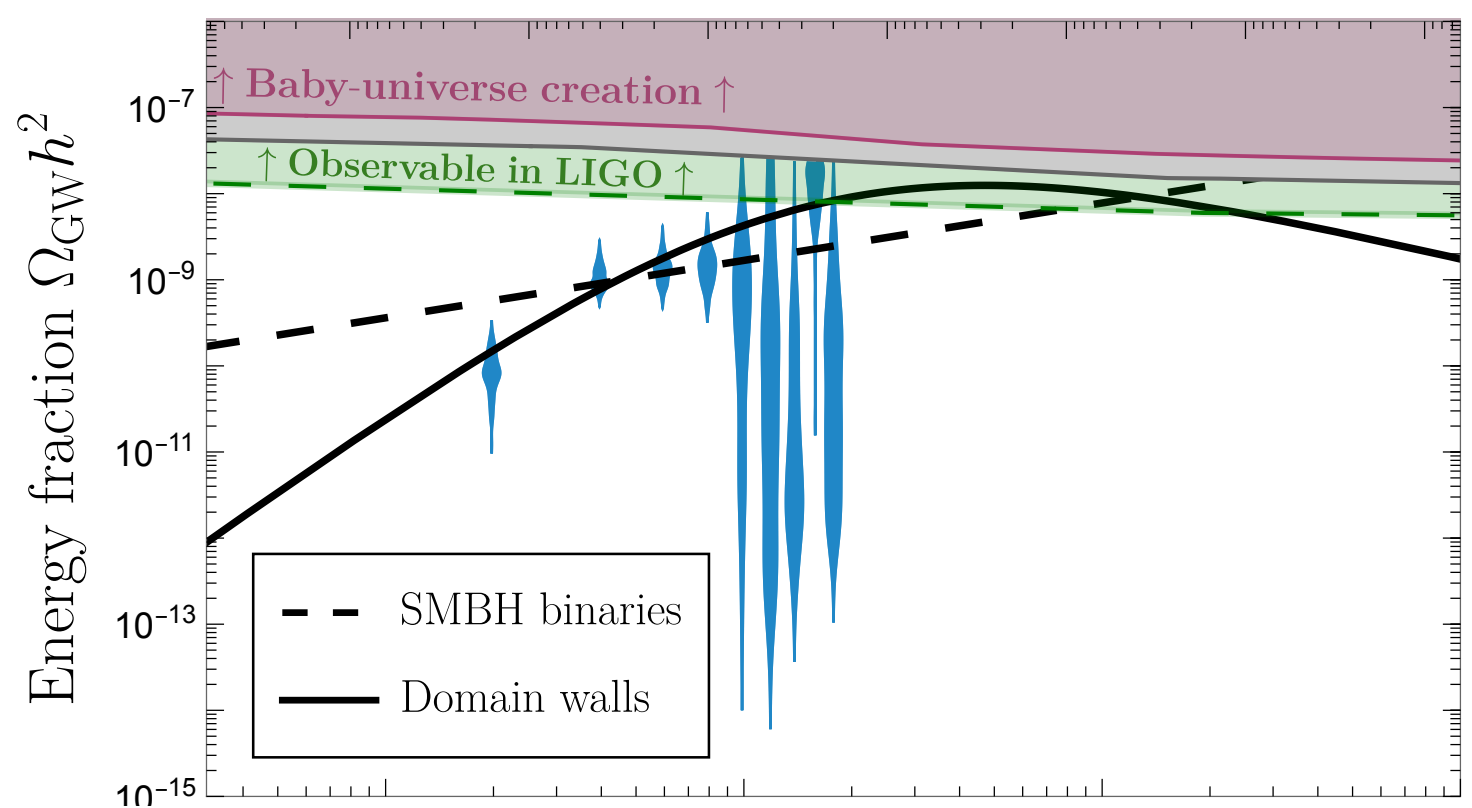
Lewicki, Toczec, Vaskonen 2023,

Baldes+ 2023,

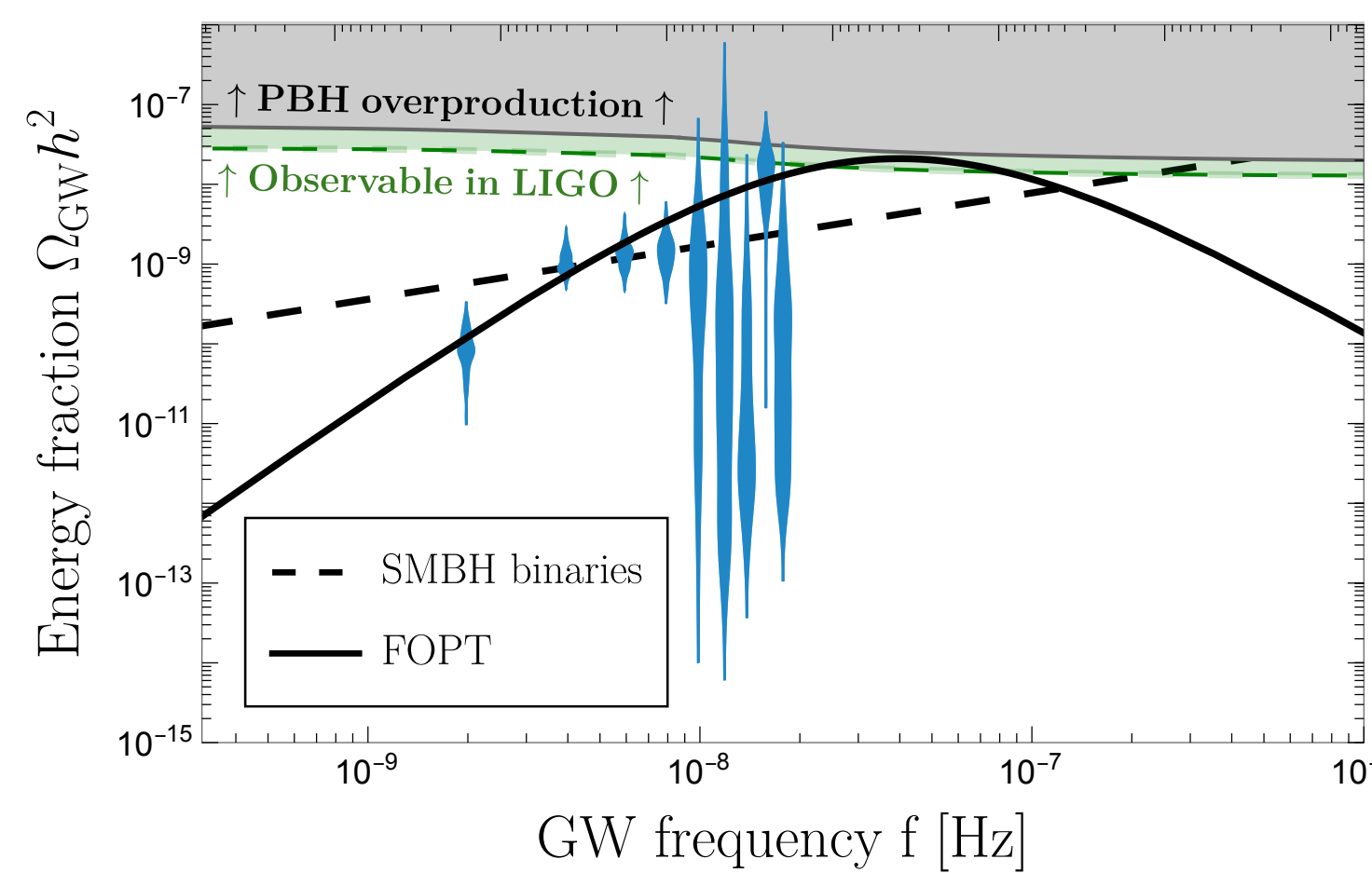
Lewicki, Toczec, Vaskonen 2024,



Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Clesse, Dandoy, Verma (2412.15989)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)



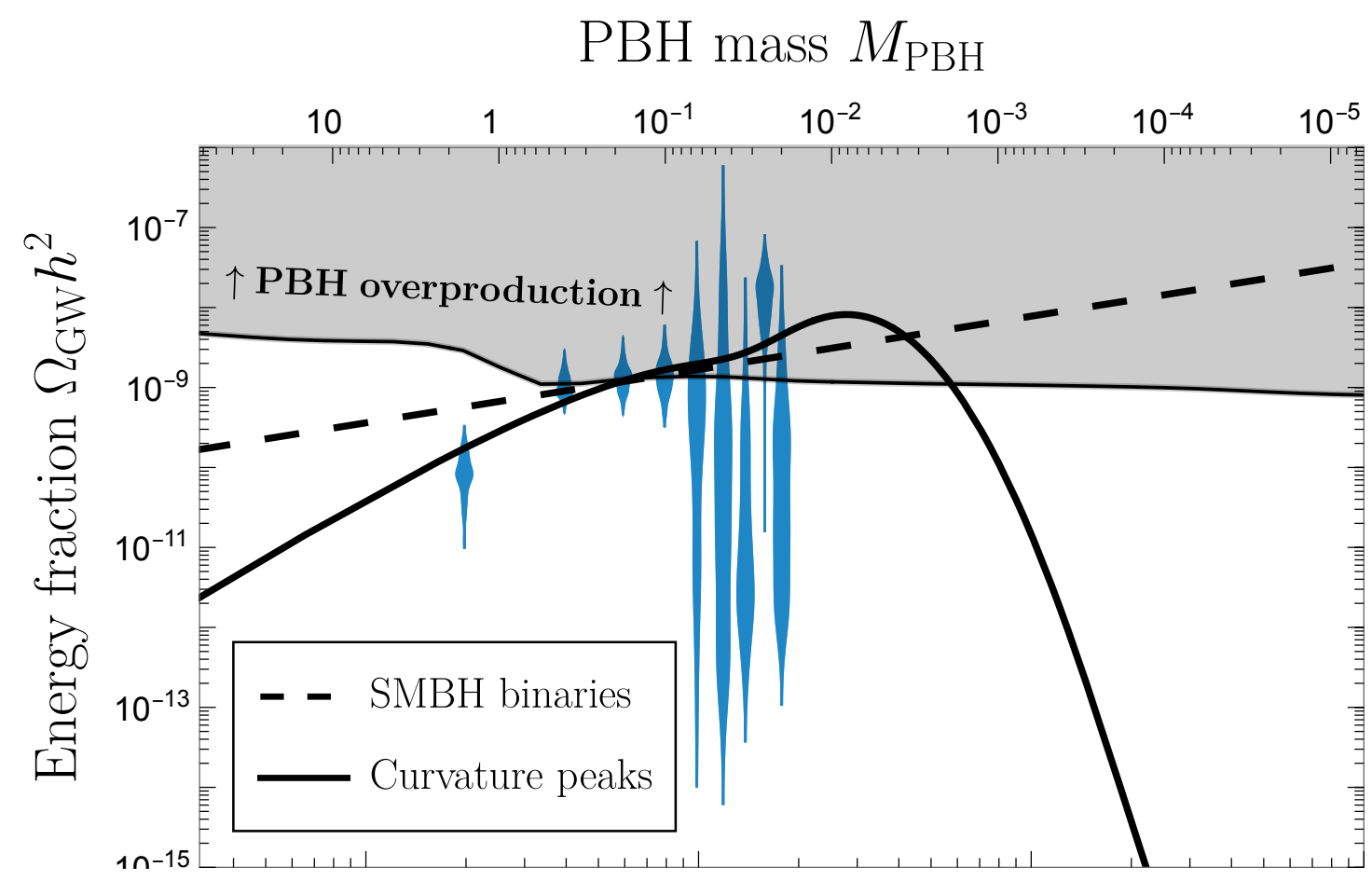
Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841



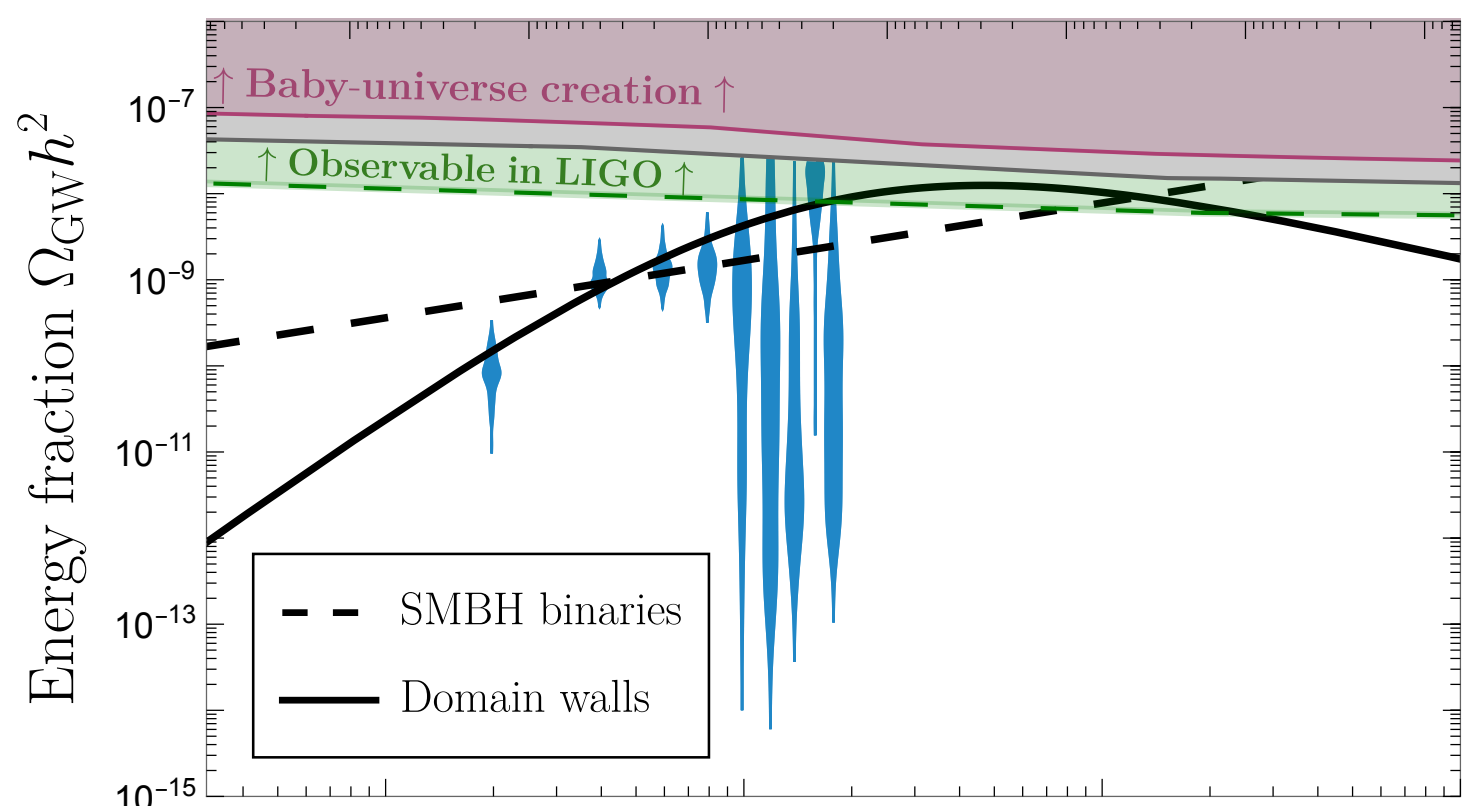
First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...

Scalar Curvature
 $\mathcal{R}(\vec{x}, t)$

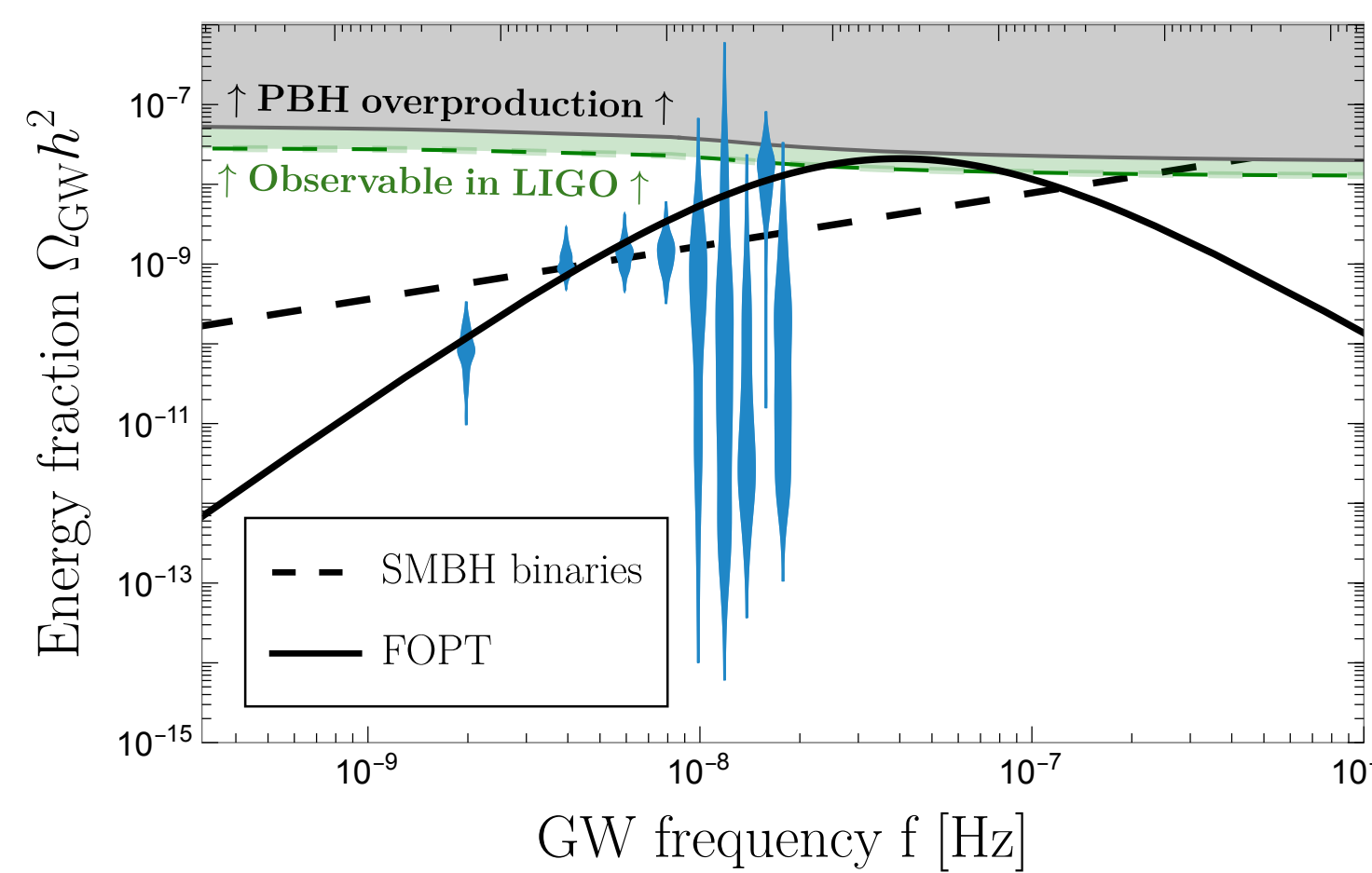
YG 2503.03857
Franciolini, YG, Jinno,
2503.01962 (PRL)



Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Clesse, Dandoy, Verma (2412.15989)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)

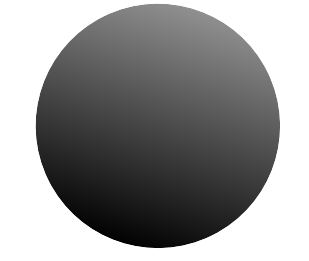


Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841



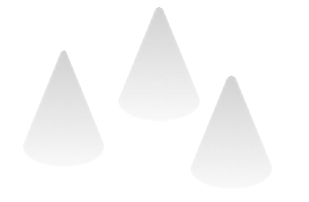
First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...

Primordial Black Holes (PBHs)

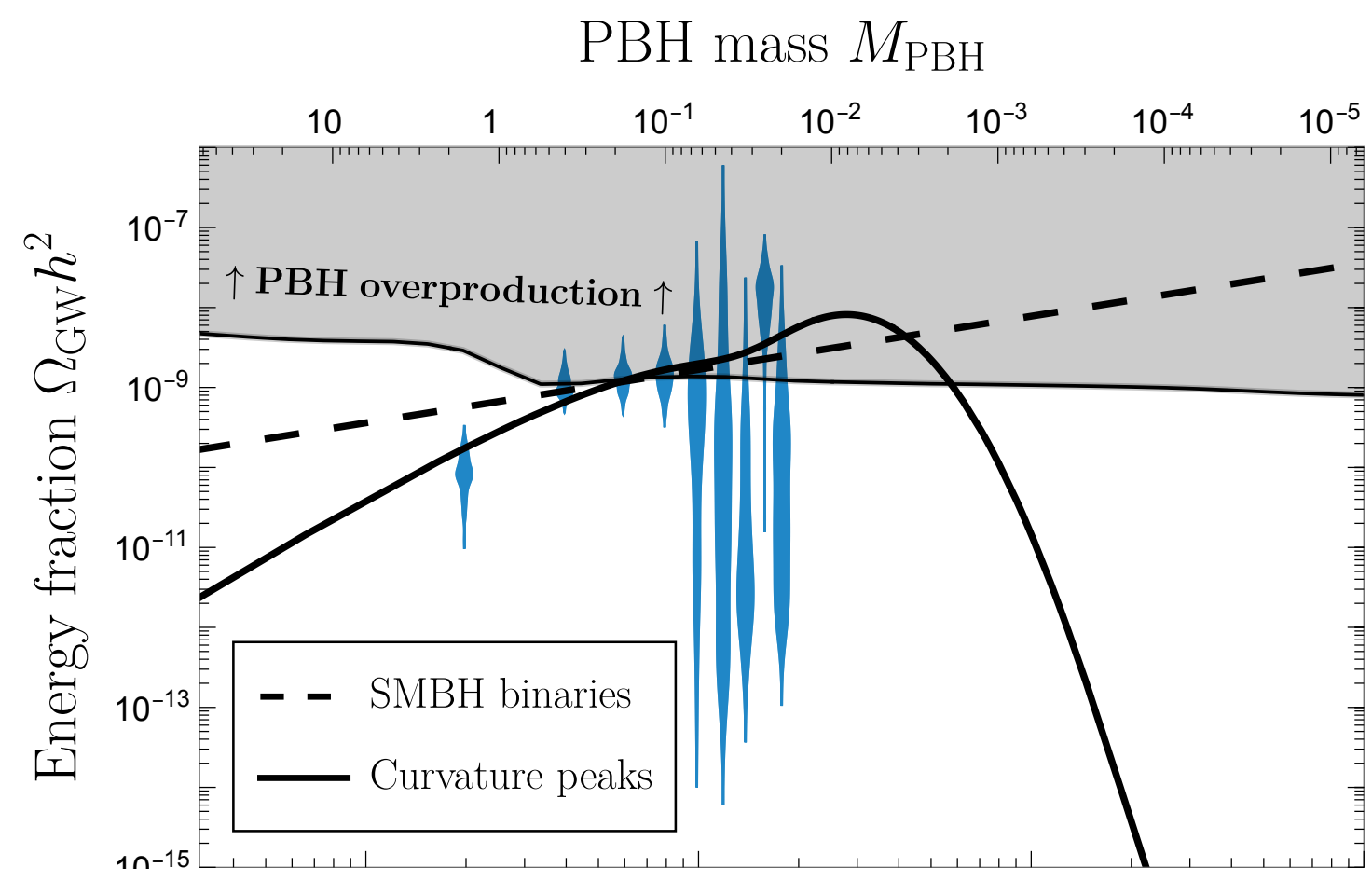


if $\langle \mathcal{R} \rangle_H \gtrsim 0.1$
(Shibata & Sasaki 1999)

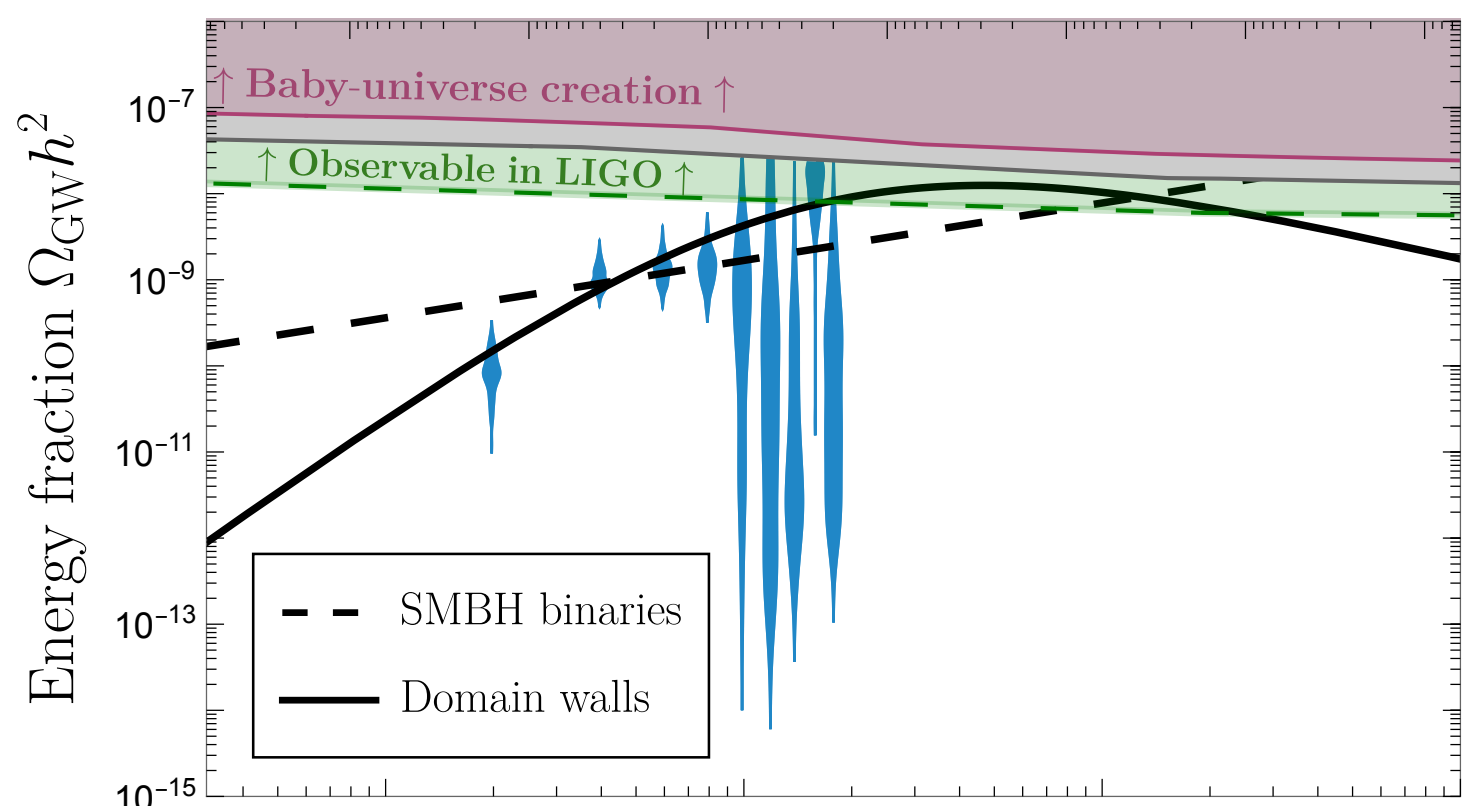
Scalar Curvature
 $\mathcal{R}(\vec{x}, t)$



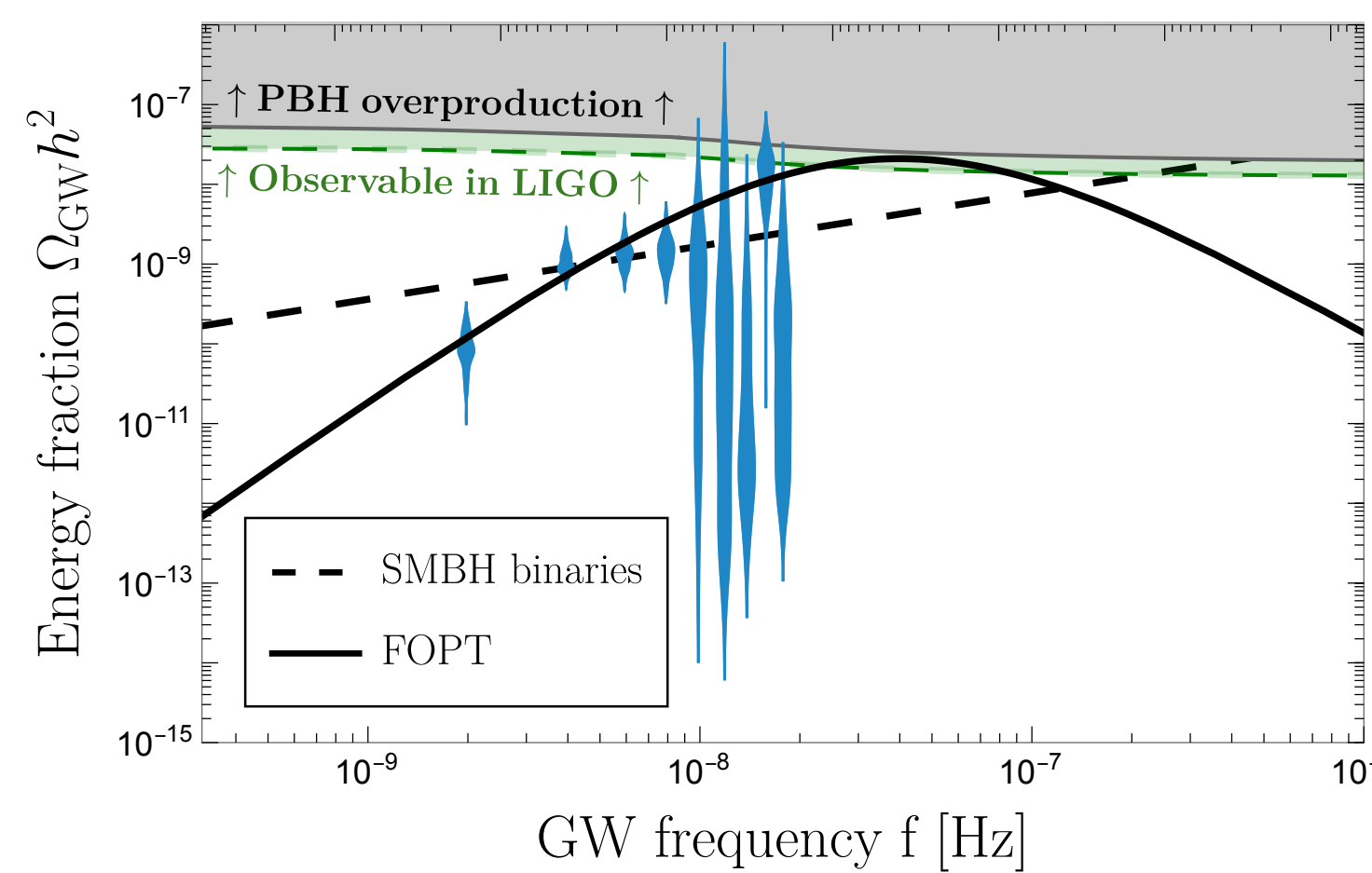
YG 2503.03857
Franciolini, YG, Jinno, 2503.01962 (PRL)



Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Clesse, Dandoy, Verma (2412.15989)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)

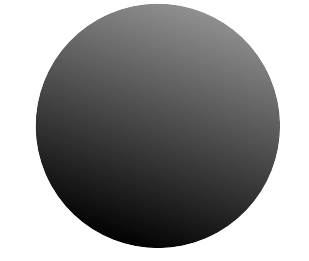


Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841



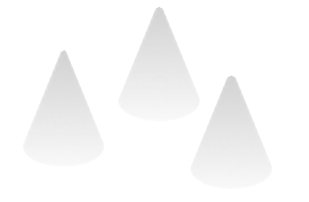
First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...

Primordial Black Holes (PBHs)



if $\langle \mathcal{R} \rangle_H \gtrsim 0.1$
(Shibata & Sasaki 1999)

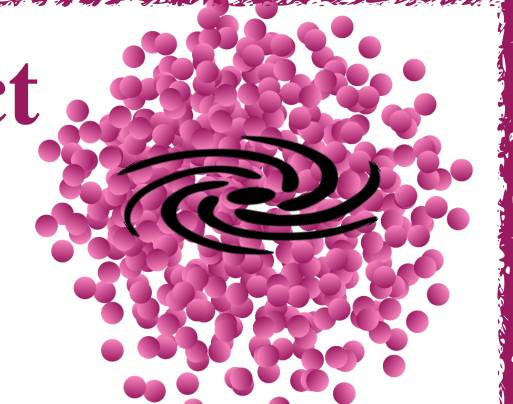
Scalar Curvature
 $\mathcal{R}(\vec{x}, t)$

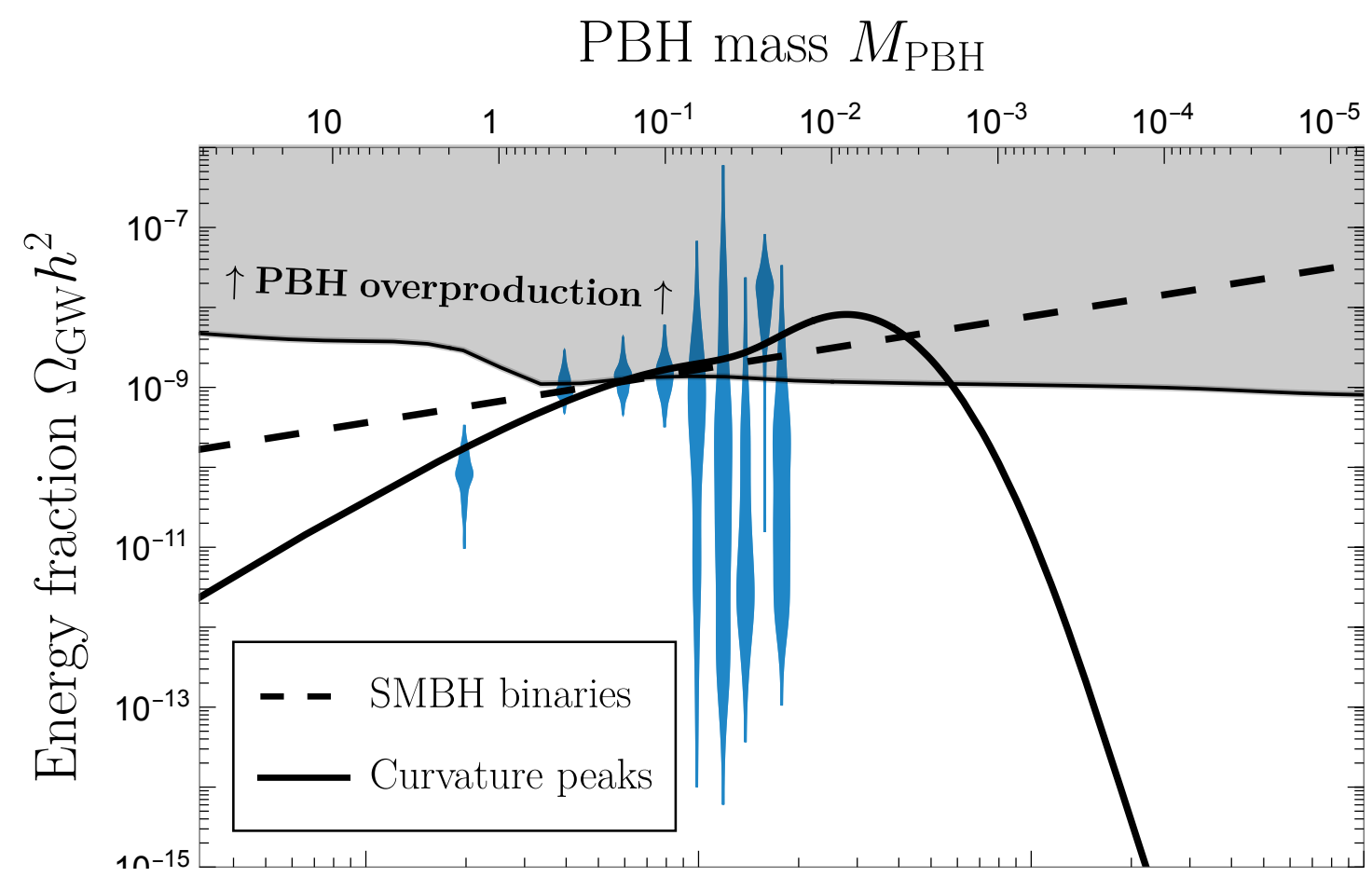


YG 2503.03857
Franciolini, YG, Jinno, 2503.01962 (PRL)

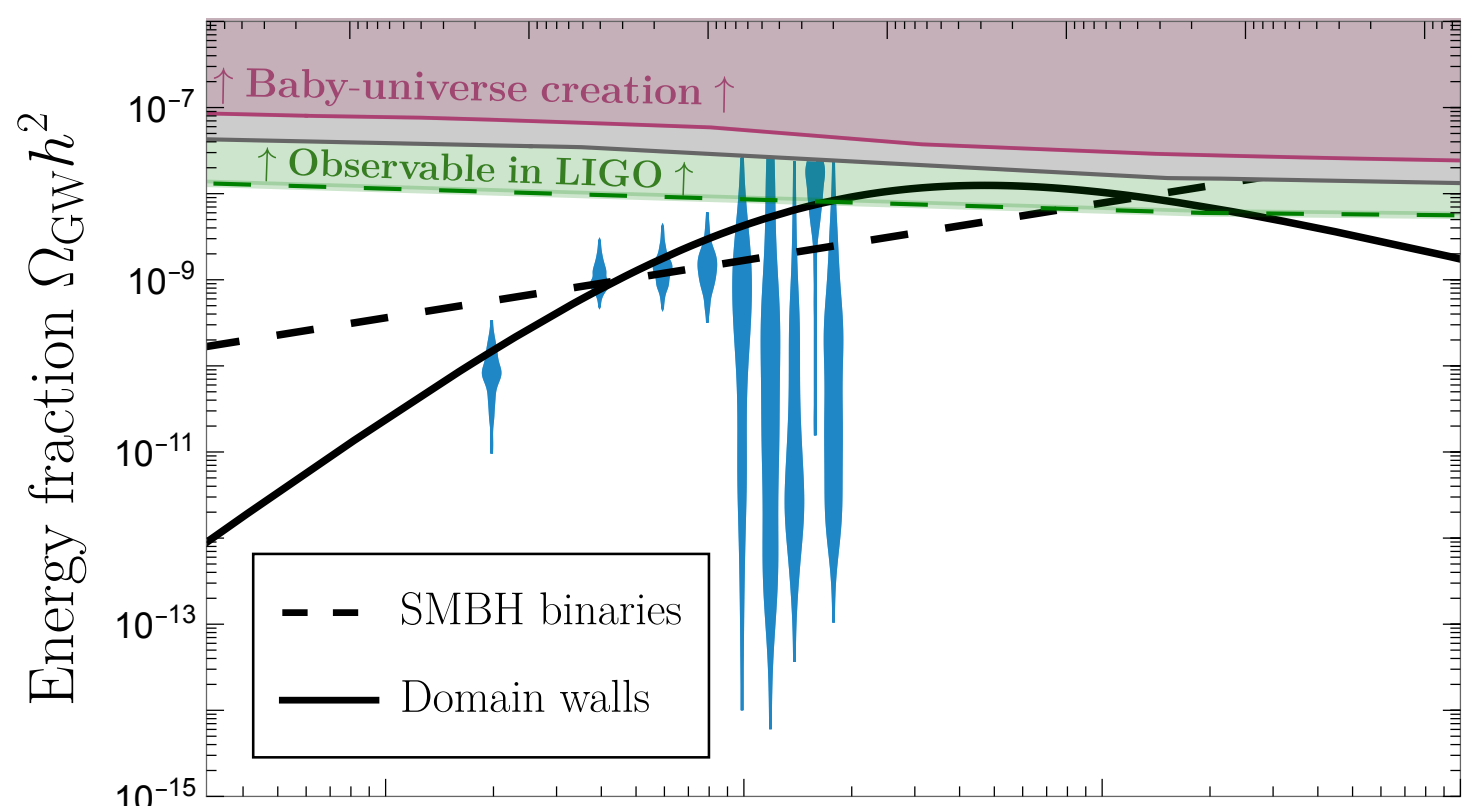
if $\langle \mathcal{R} \rangle_H \gtrsim 10^{-3}$
Ricotti, Gould (0908.0735)

DM Ultra Compact Mini Halos (UCMH)

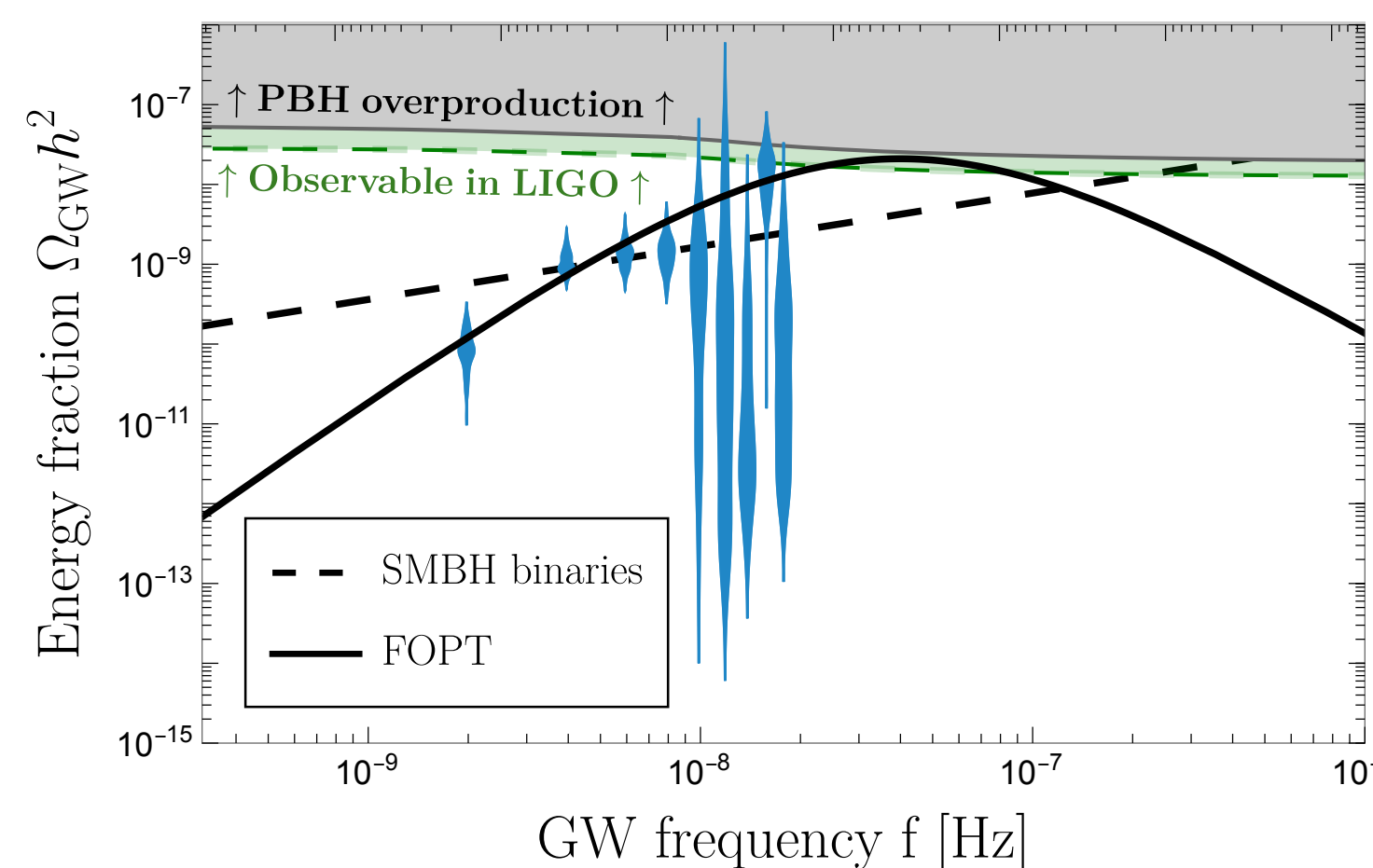




Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)



Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841

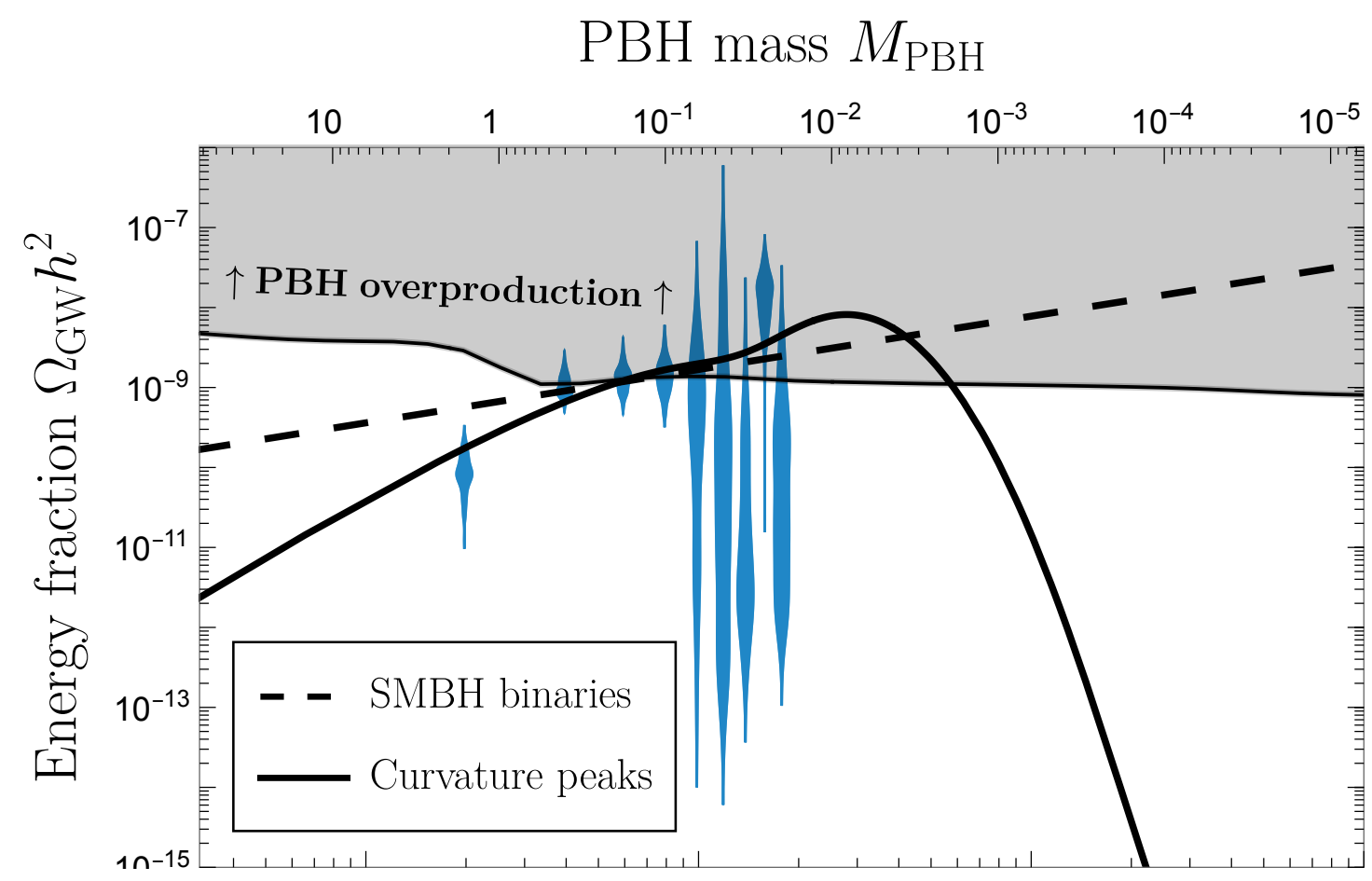


First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...

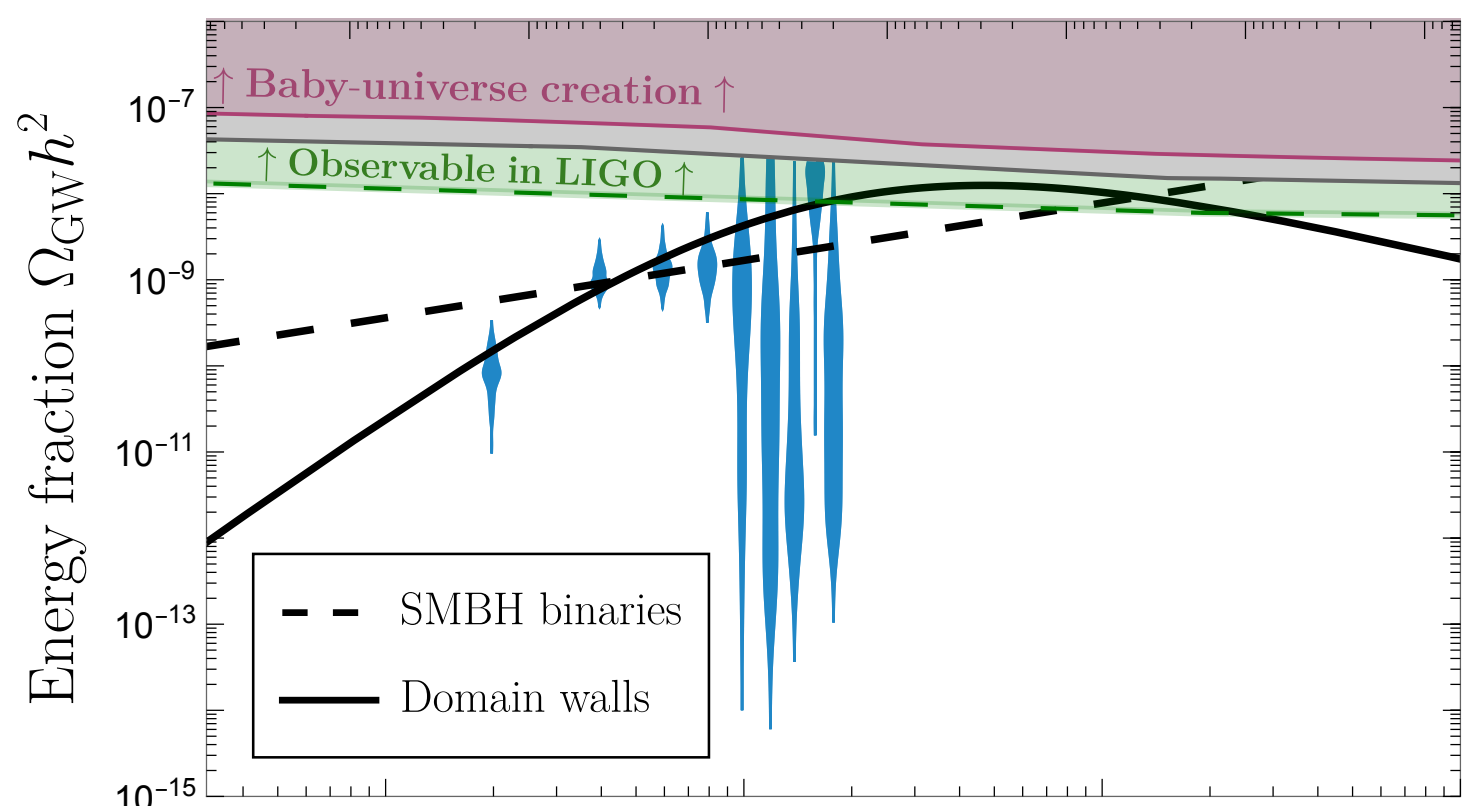
DM Ultra Compact Mini Halos

$$R_{\text{UCMH}} \sim 200 \text{ AU} \left(\frac{1000}{z_{\text{collapse}}} \right)$$

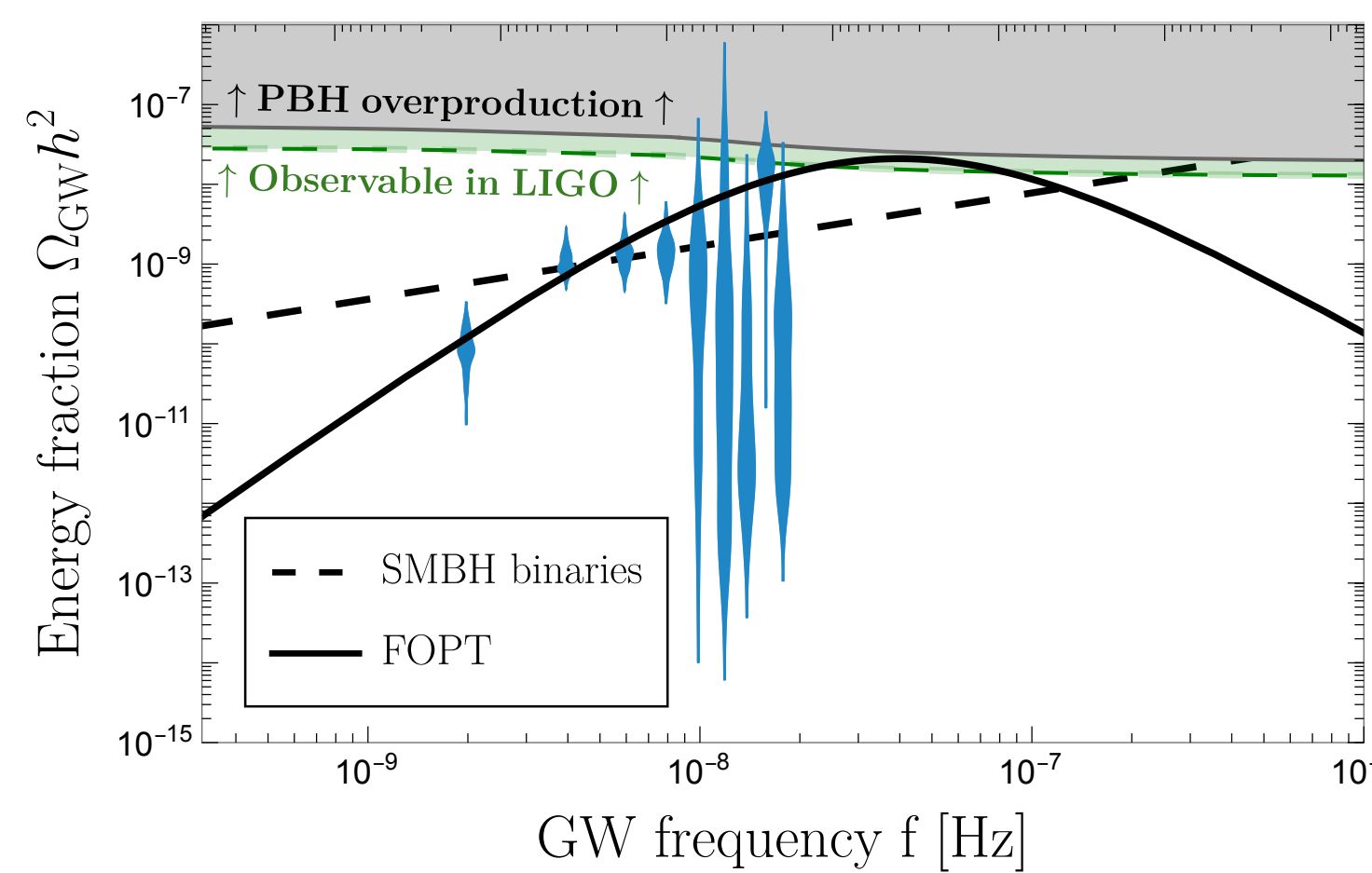
$$M_{\text{UCMH}} \sim 10^{-7} M_{\odot}$$



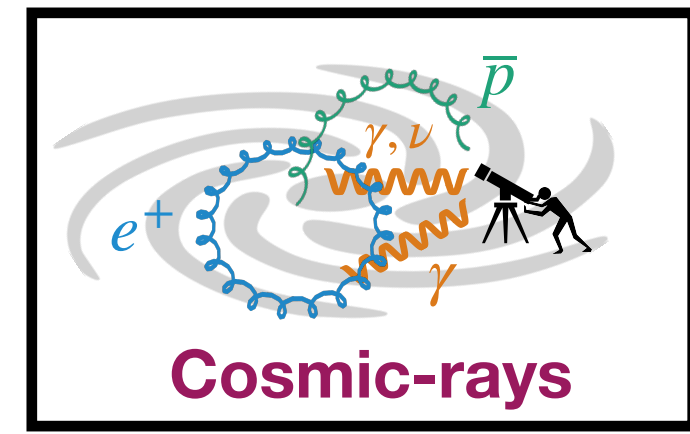
Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)



Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841



First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...

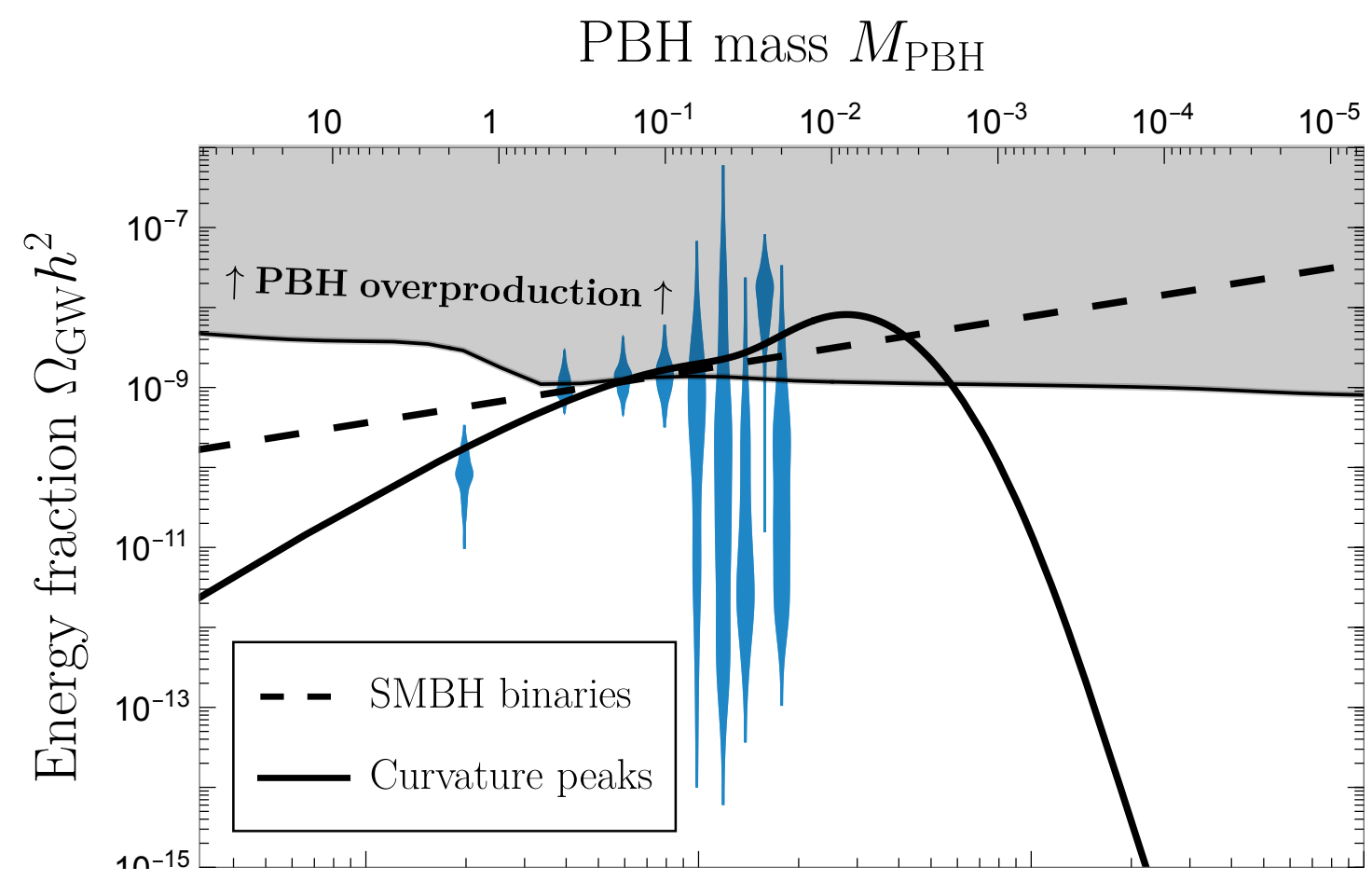


if DM=WIMPs
 YG 2503.03857

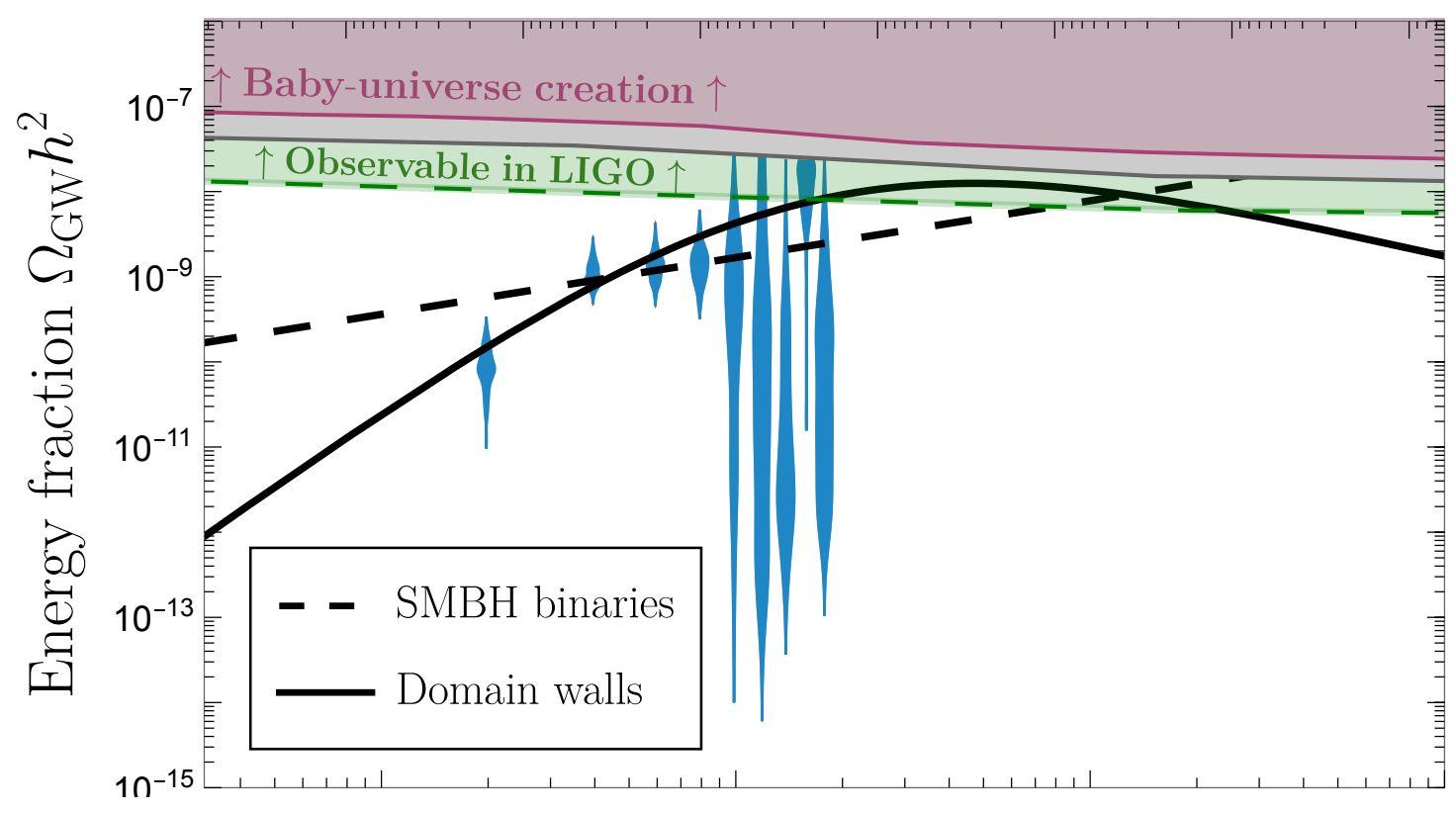
DM Ultra Compact Mini Halos

$R_{\text{UCMH}} \sim 200 \text{ AU} \left(\frac{1000}{z_{\text{collapse}}} \right)$

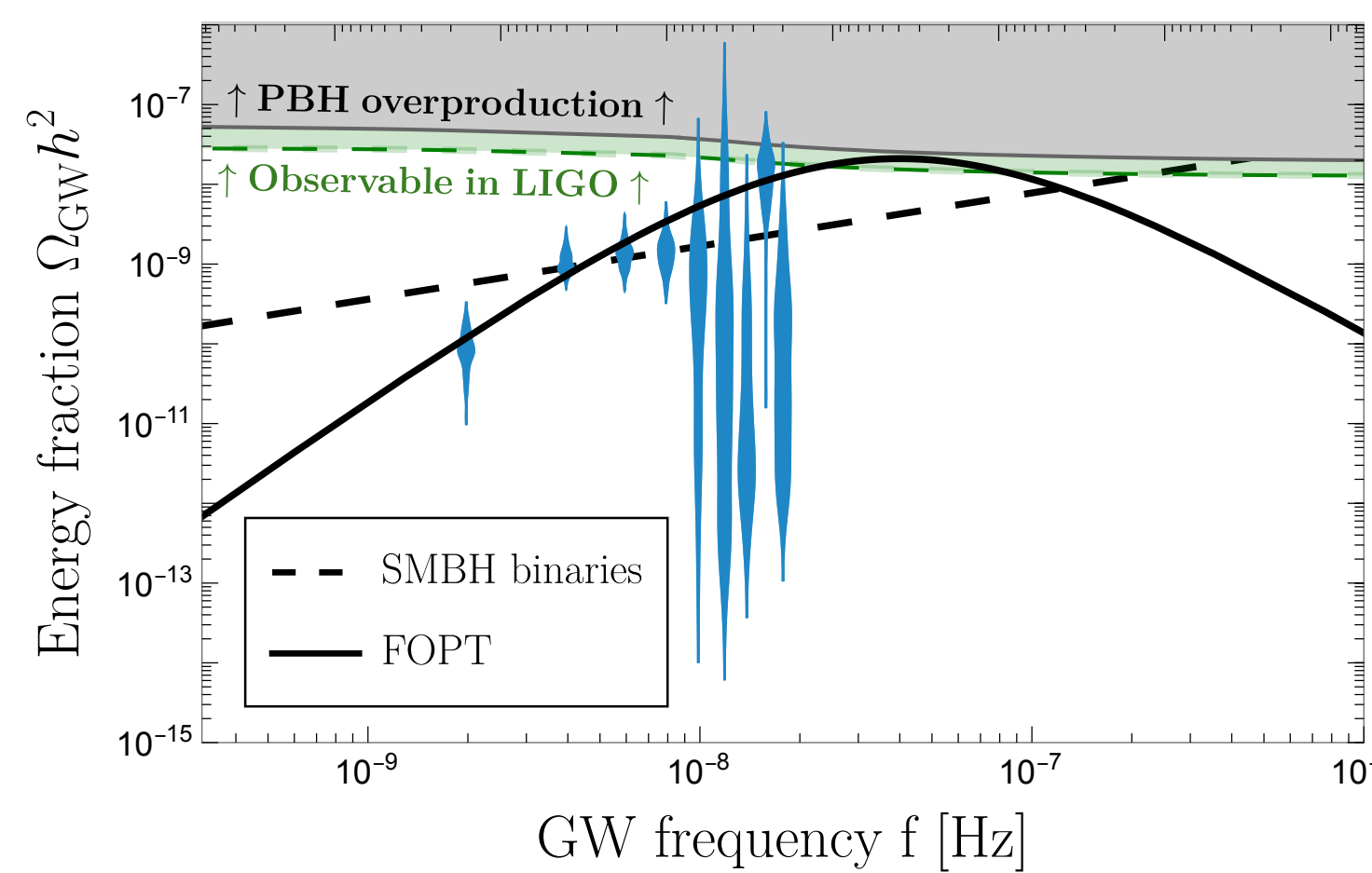
$M_{\text{UCMH}} \sim 10^{-7} M_{\odot}$



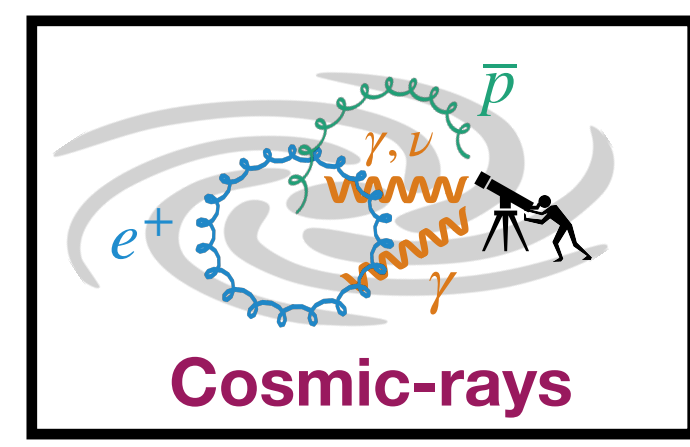
Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)



Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841



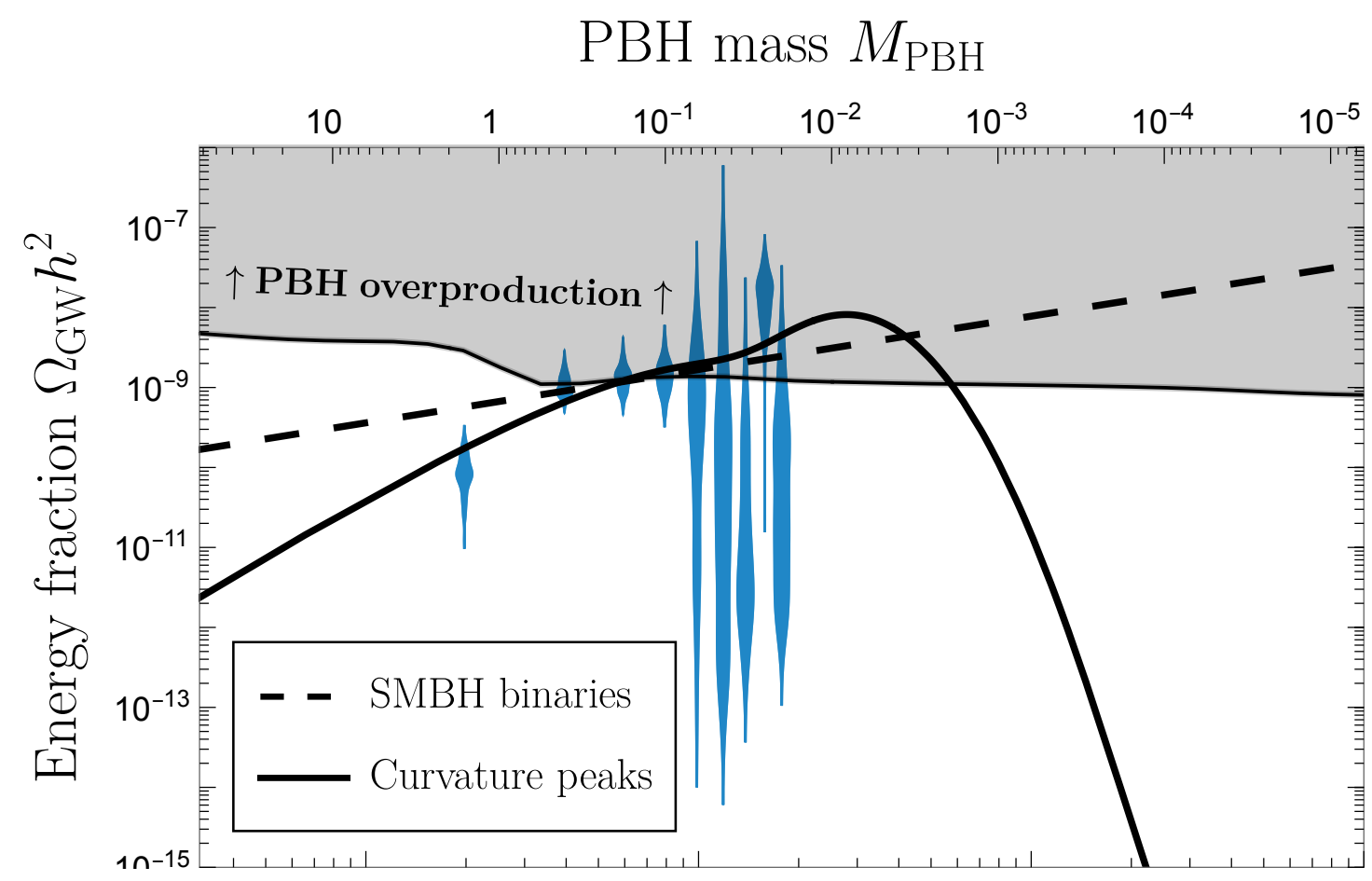
First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...



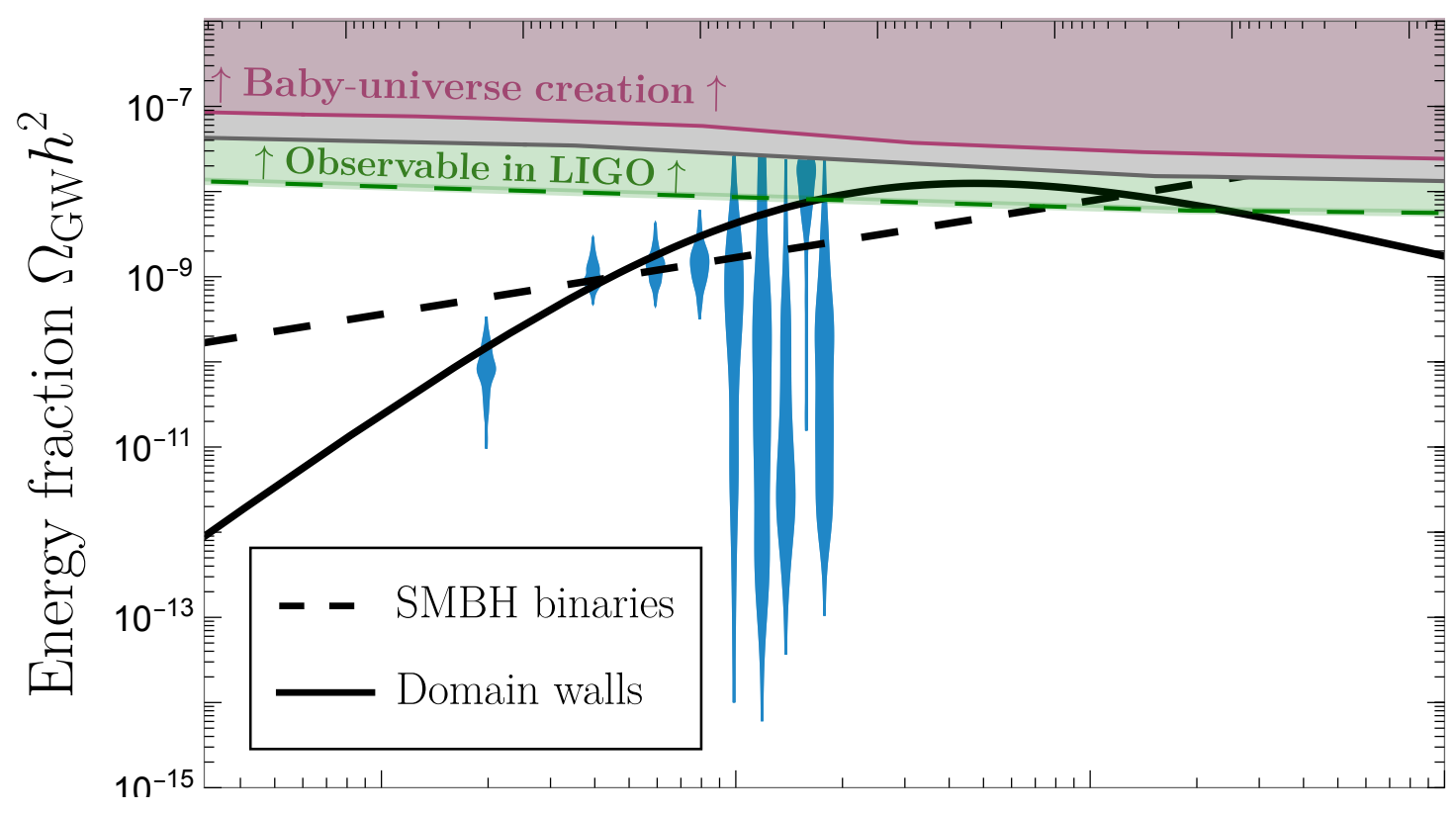
if DM=WIMPs
 YG 2503.03857



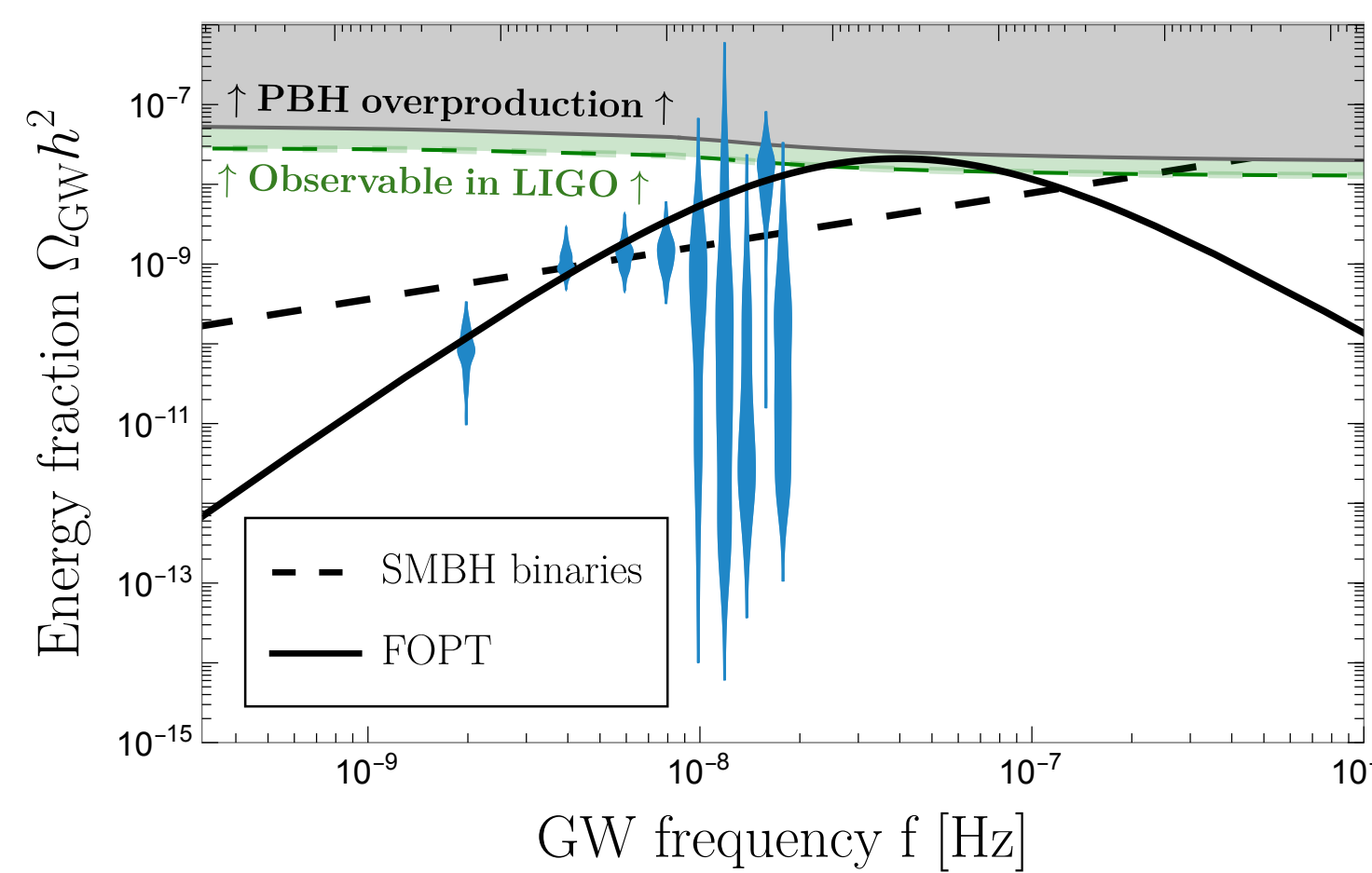
For any DMs



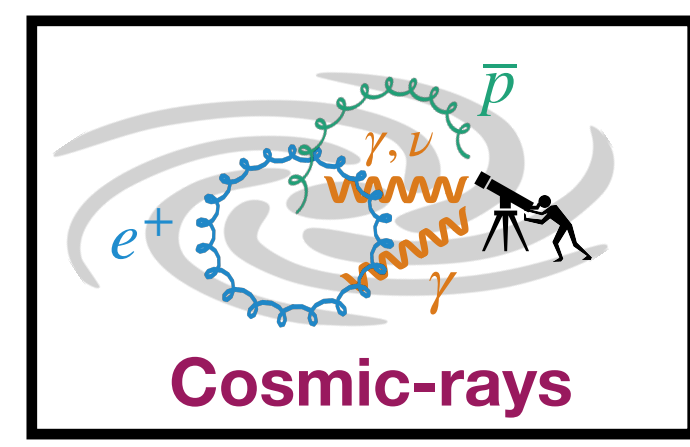
Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)



Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841



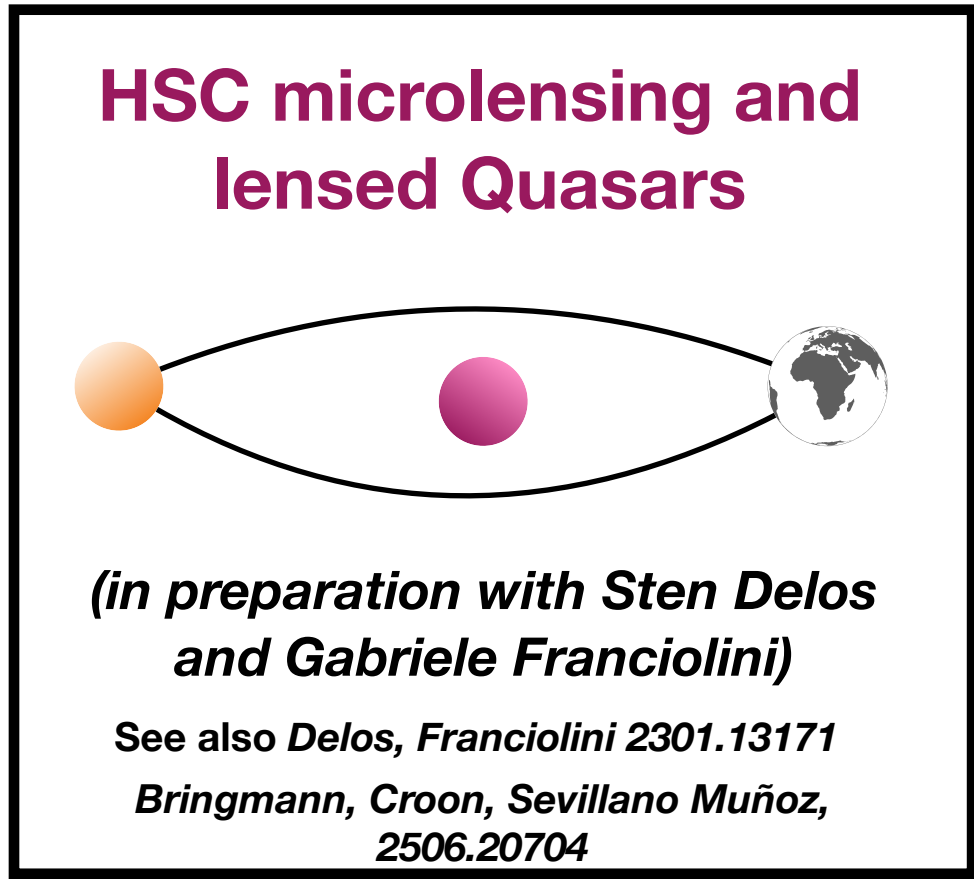
First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...

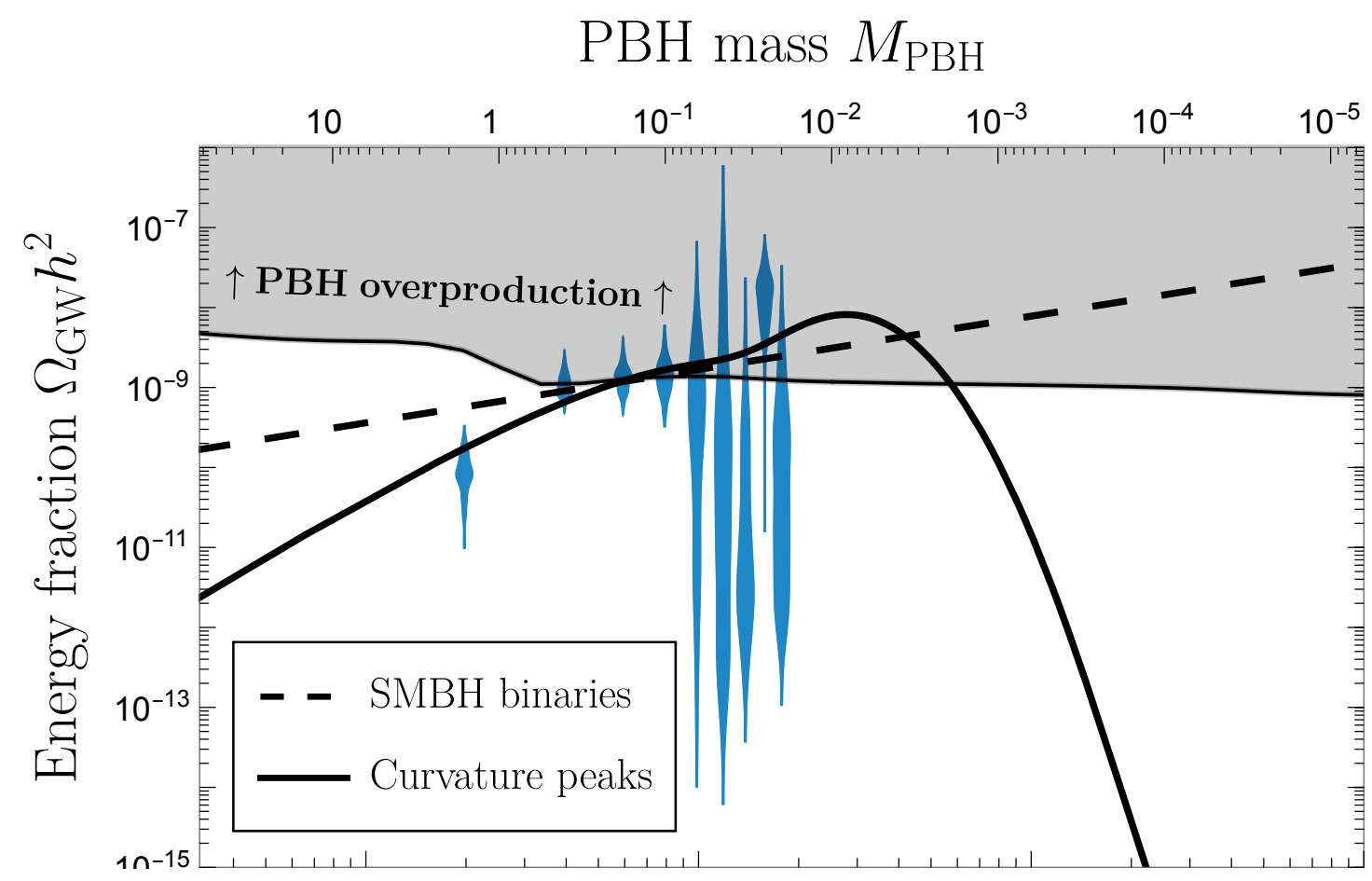


if DM=WIMPs
YG 2503.03857

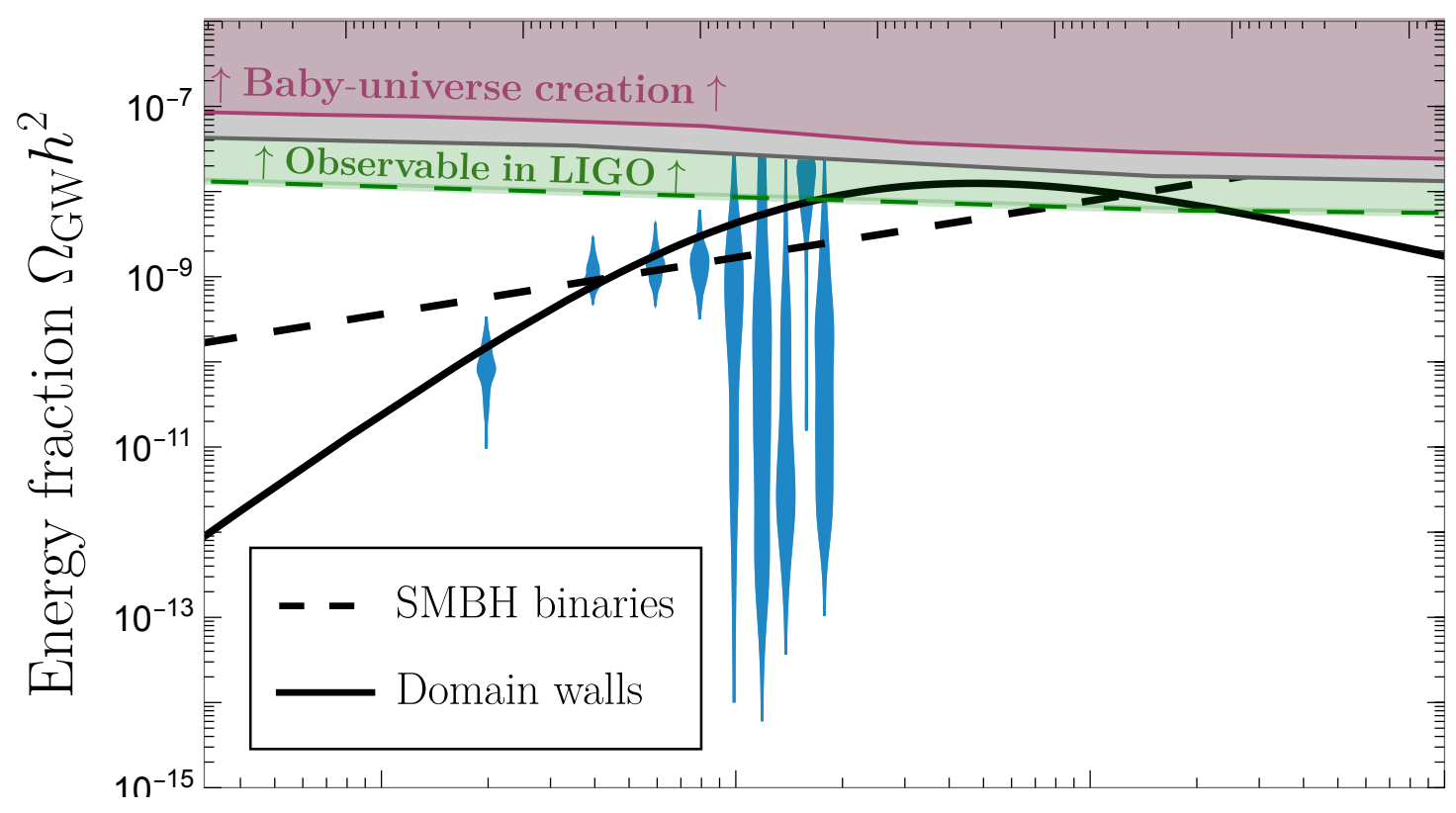


For any DMs

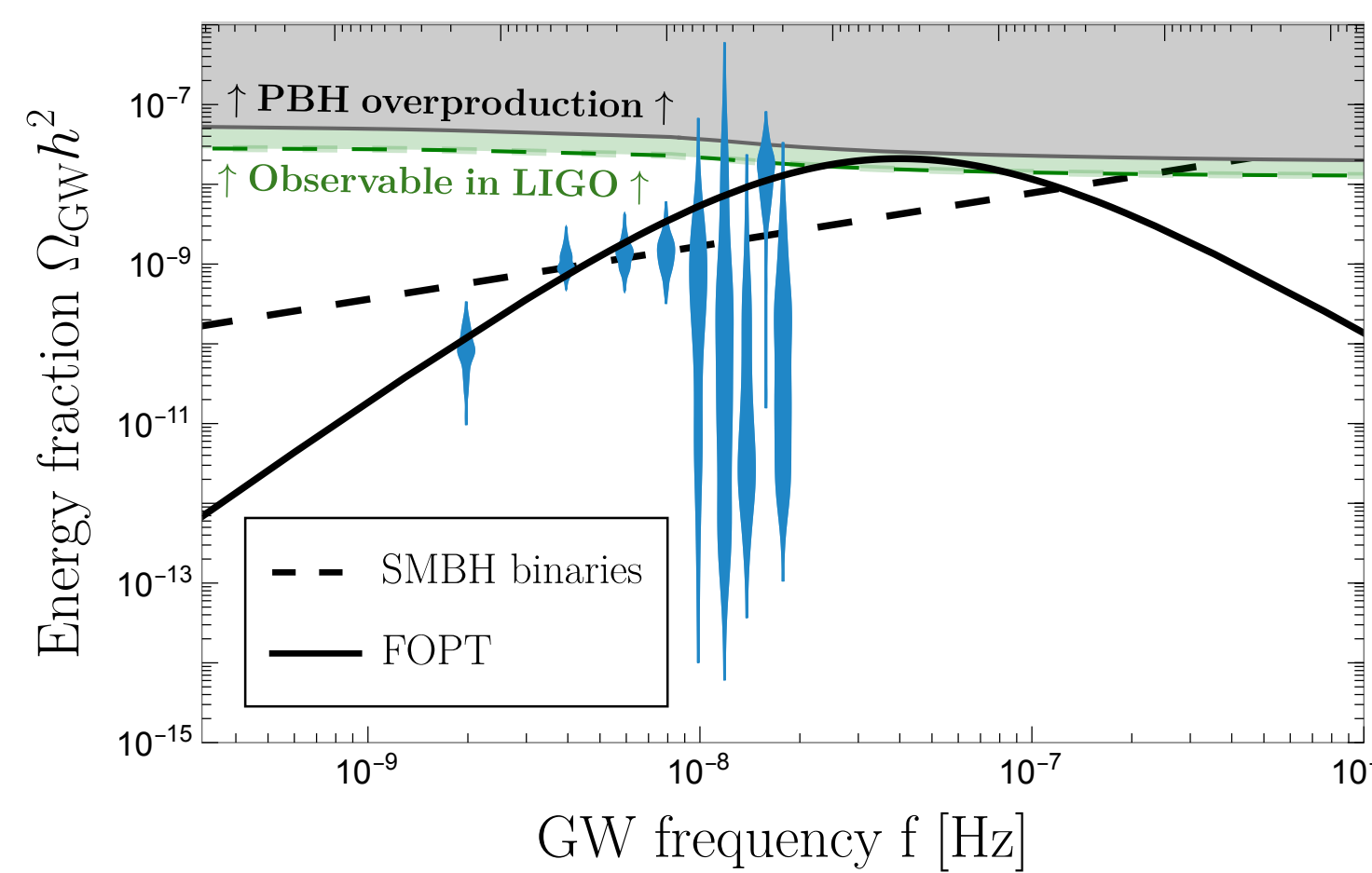




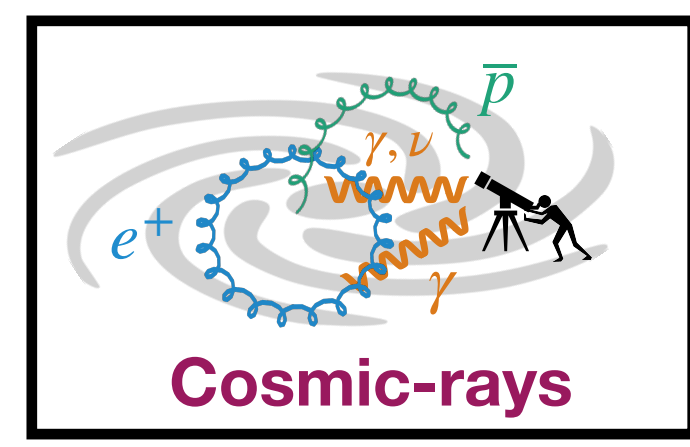
Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)



Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841



First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...



if DM=WIMPs
 YG 2503.03857

DM Ultra Compact Mini Halos

$R_{\text{UCMH}} \sim 200 \text{ AU} \left(\frac{1000}{z_{\text{collapse}}} \right)$

$M_{\text{UCMH}} \sim 10^{-7} M_{\odot}$

For any DMs

HSC microlensing and lensed Quasars

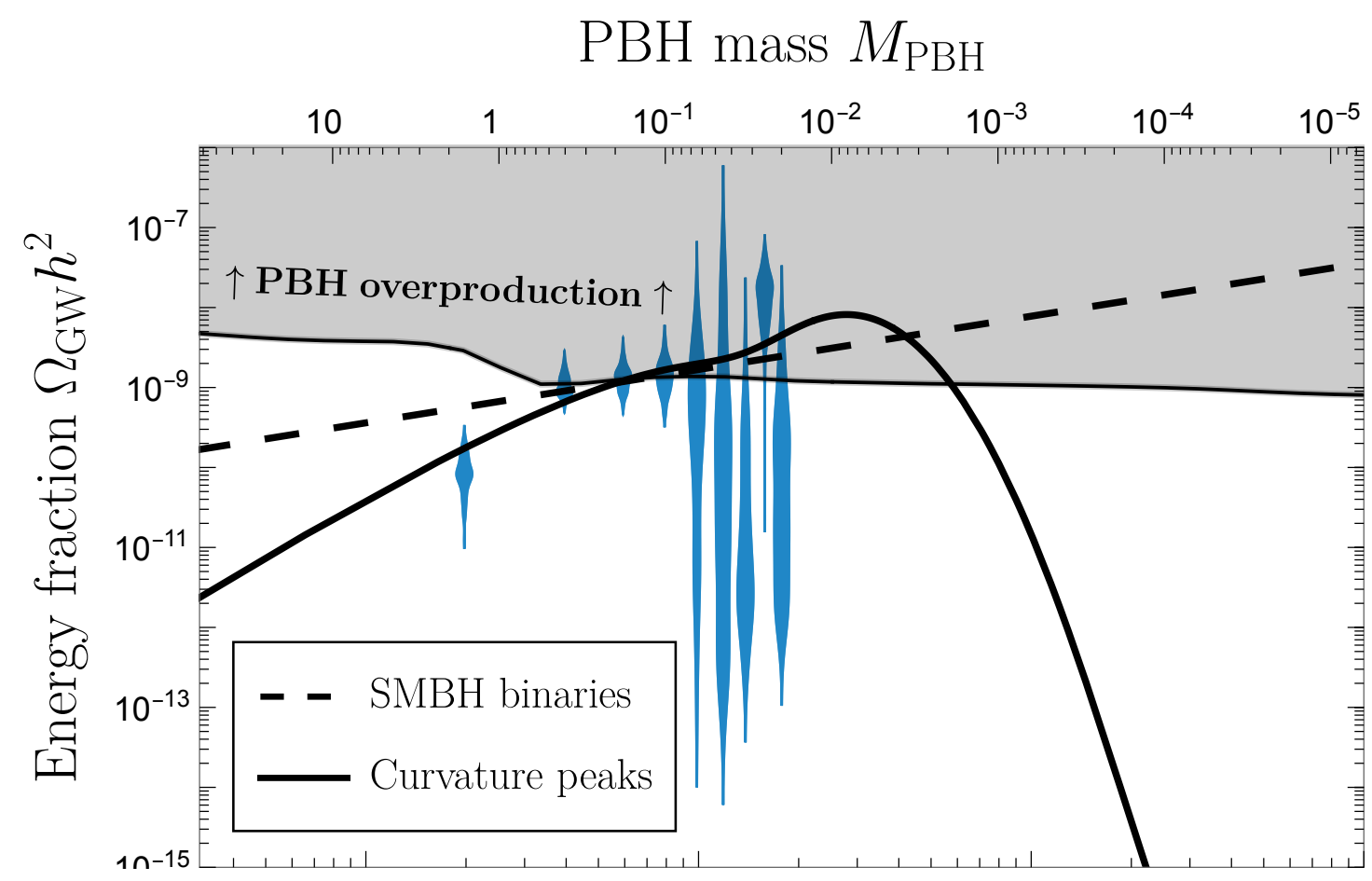
(in preparation with Sten Delos and Gabriele Franciolini)

See also Delos, Franciolini 2301.13171
 Bringmann, Croon, Sevillano Muñoz, 2506.20704

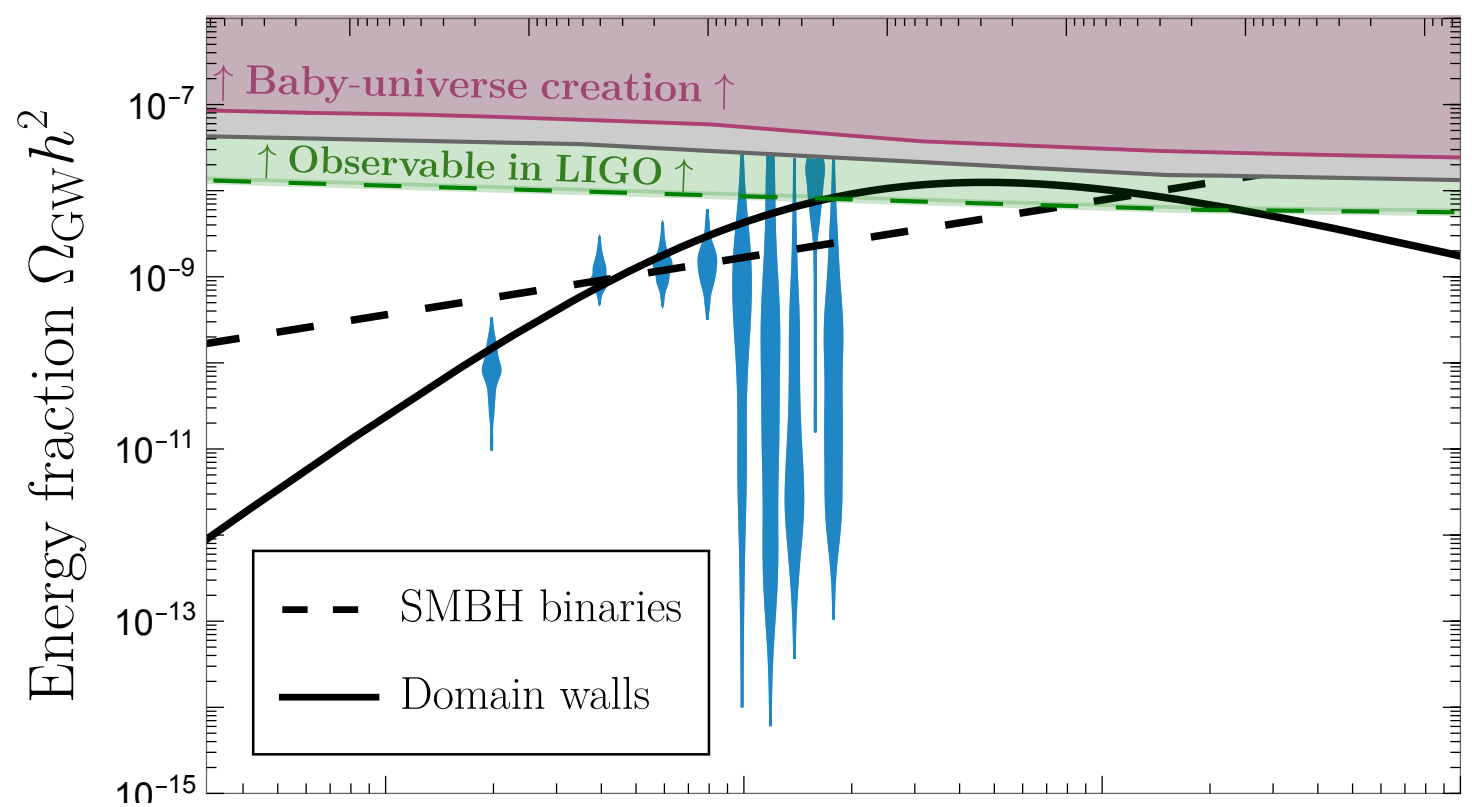
Pulsar Timing Arrays

1) Doppler drift
 2) Shapiro shift

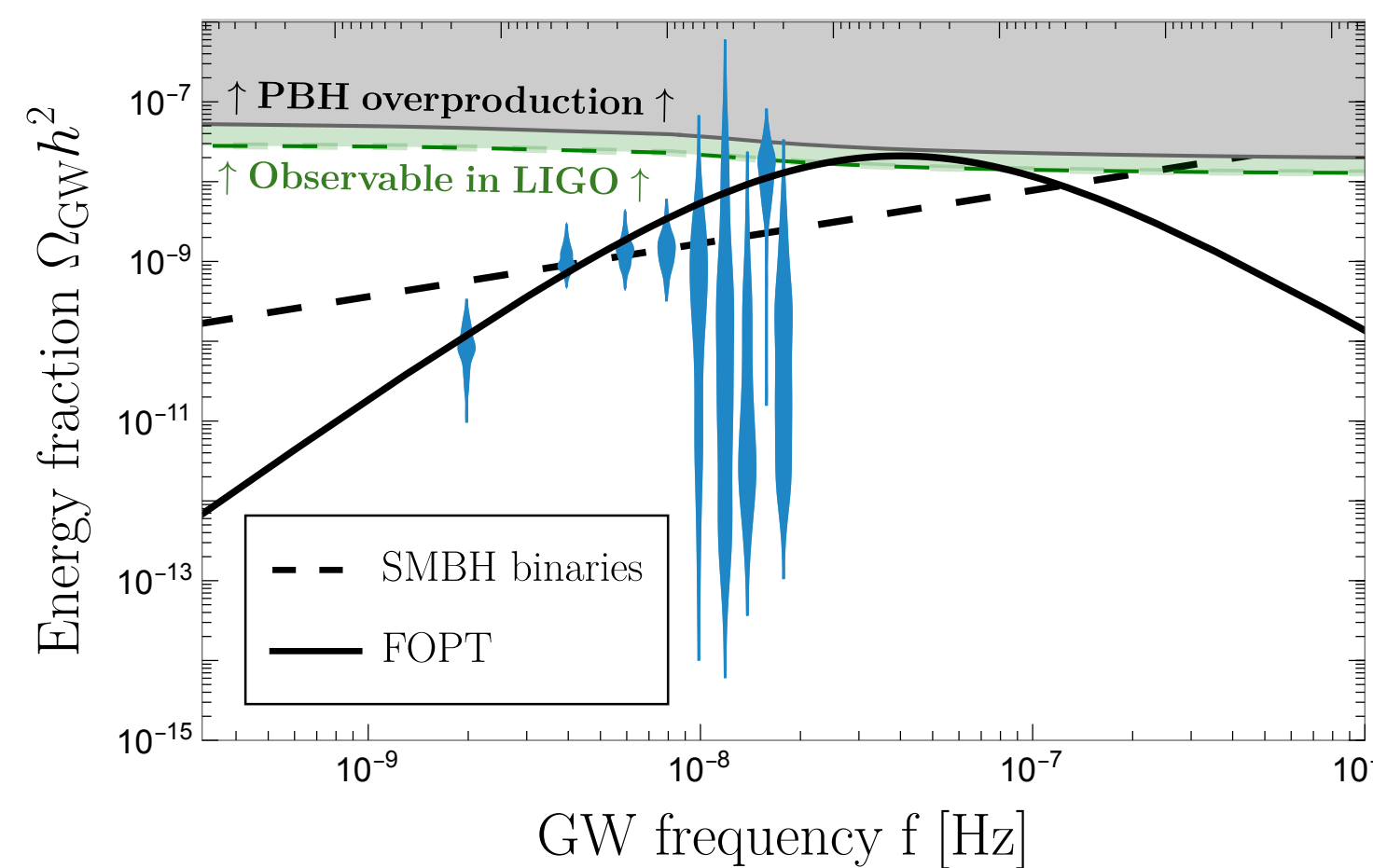
NANOGrav, New Physics 2306.16219
 Lee, Mitridate, Trickle, Zurek 2012.09857



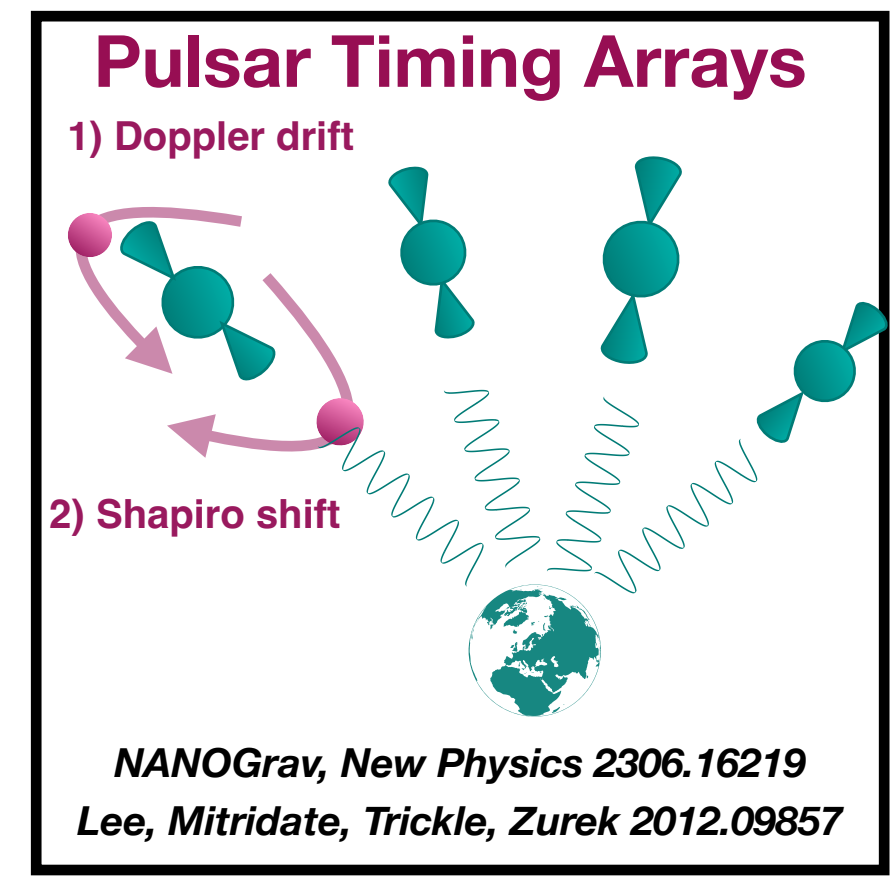
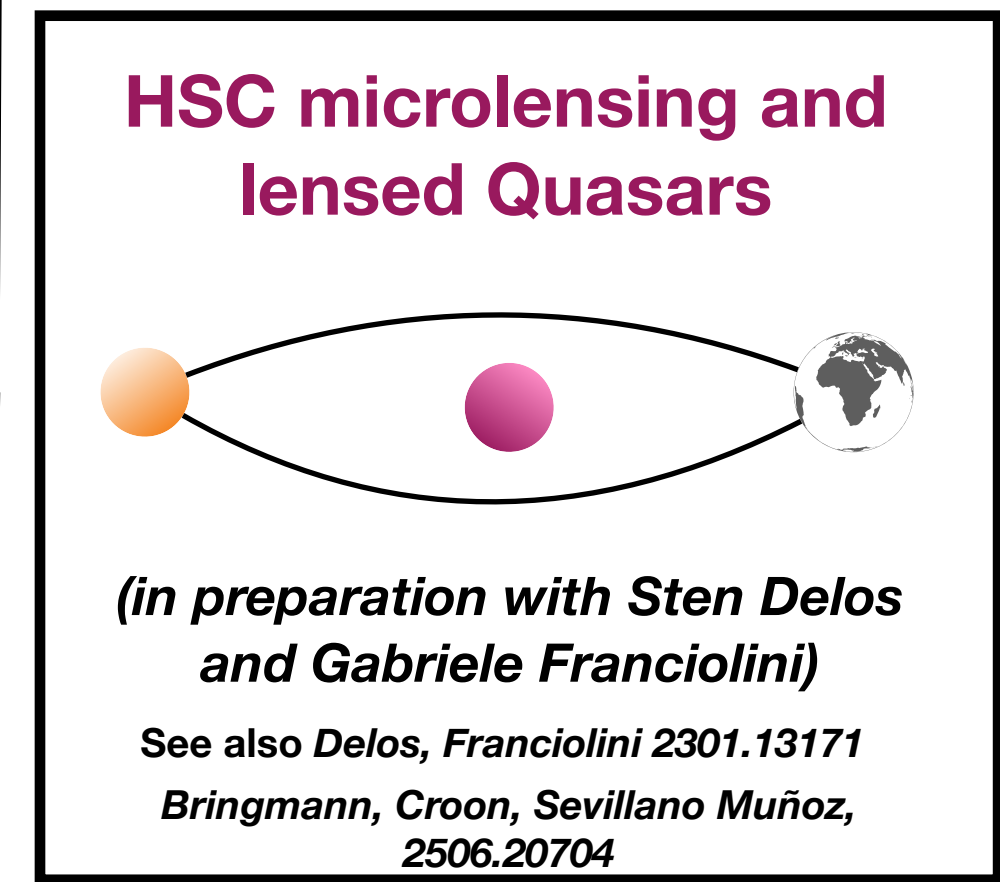
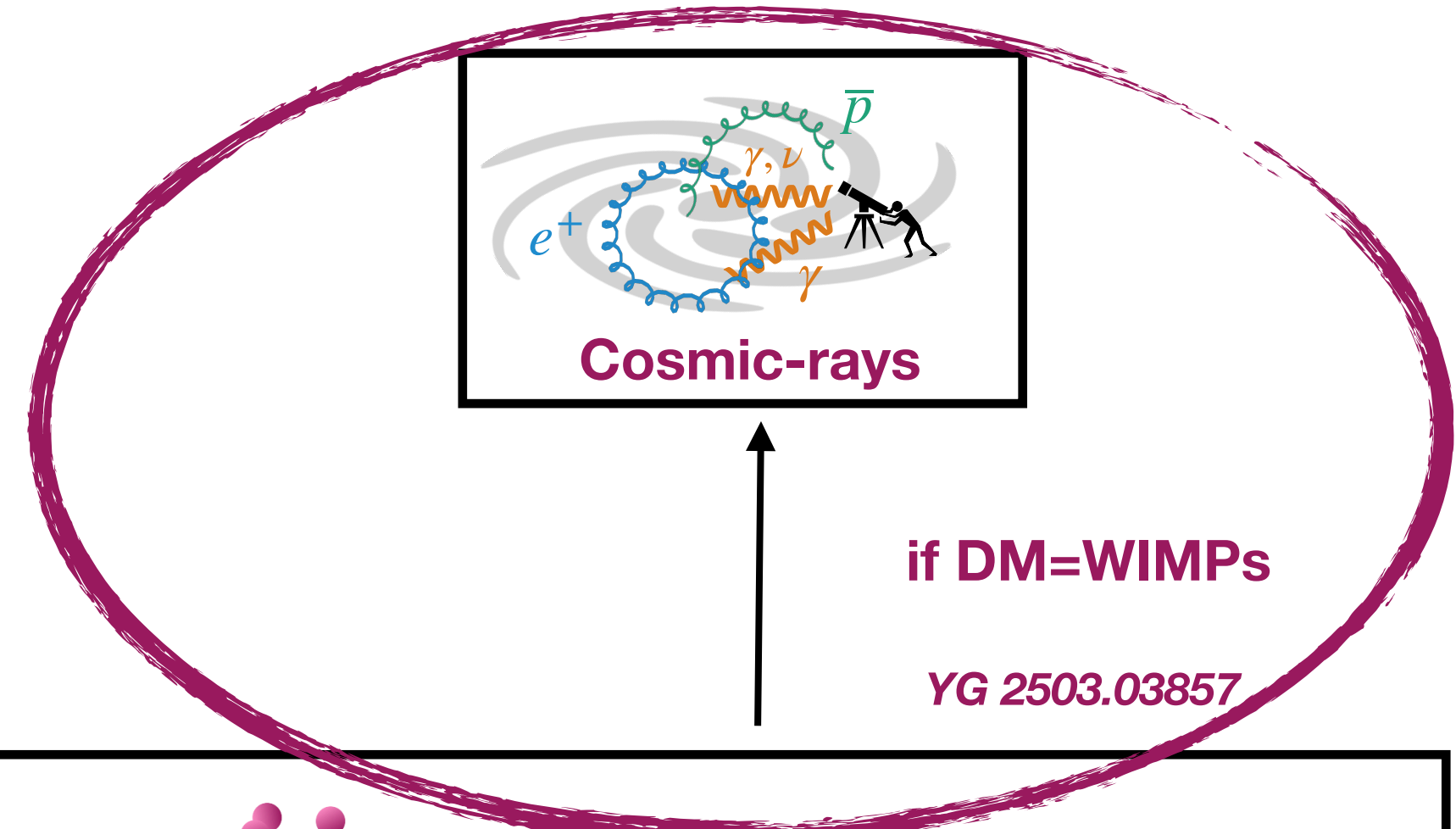
Curvature peaks
Overproduce PBH
Chen, Yuan, Huang (1910.12239)
Kohri, Terada (2009.11853)
Inomata, Kawasaki, Mukaida, Yanagida (2011.01270)
Vaskonen, Veermae (2009.07832),
De Luca, Franciolini, Riotto (2009.08268)
Except if negative non-Gaussianities
Franciolini, Iovino, Vaskonen, Veermae (2306.17143)
YG, Trifinopoulos, Vanvlasselaer (2508.19328)

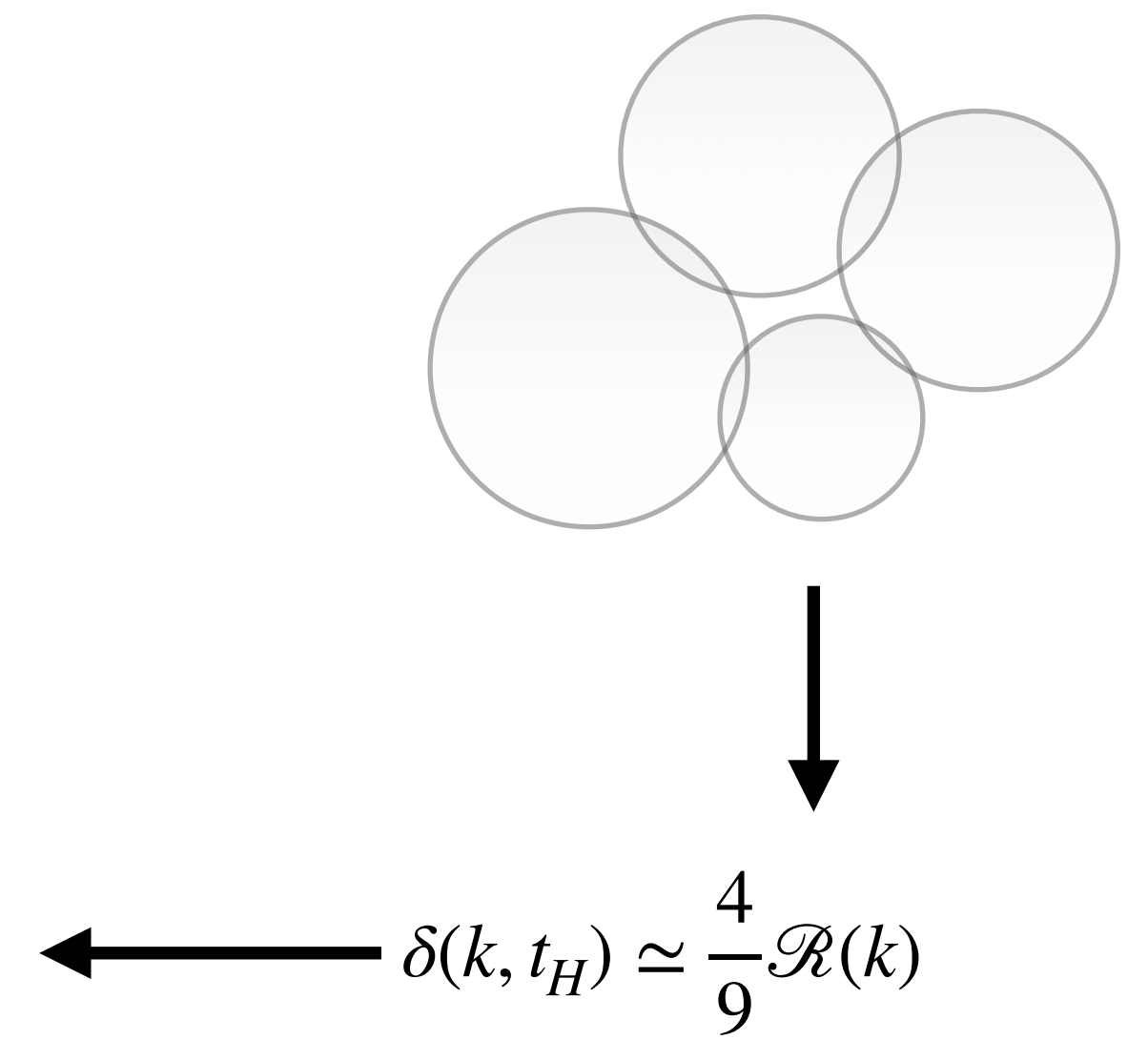
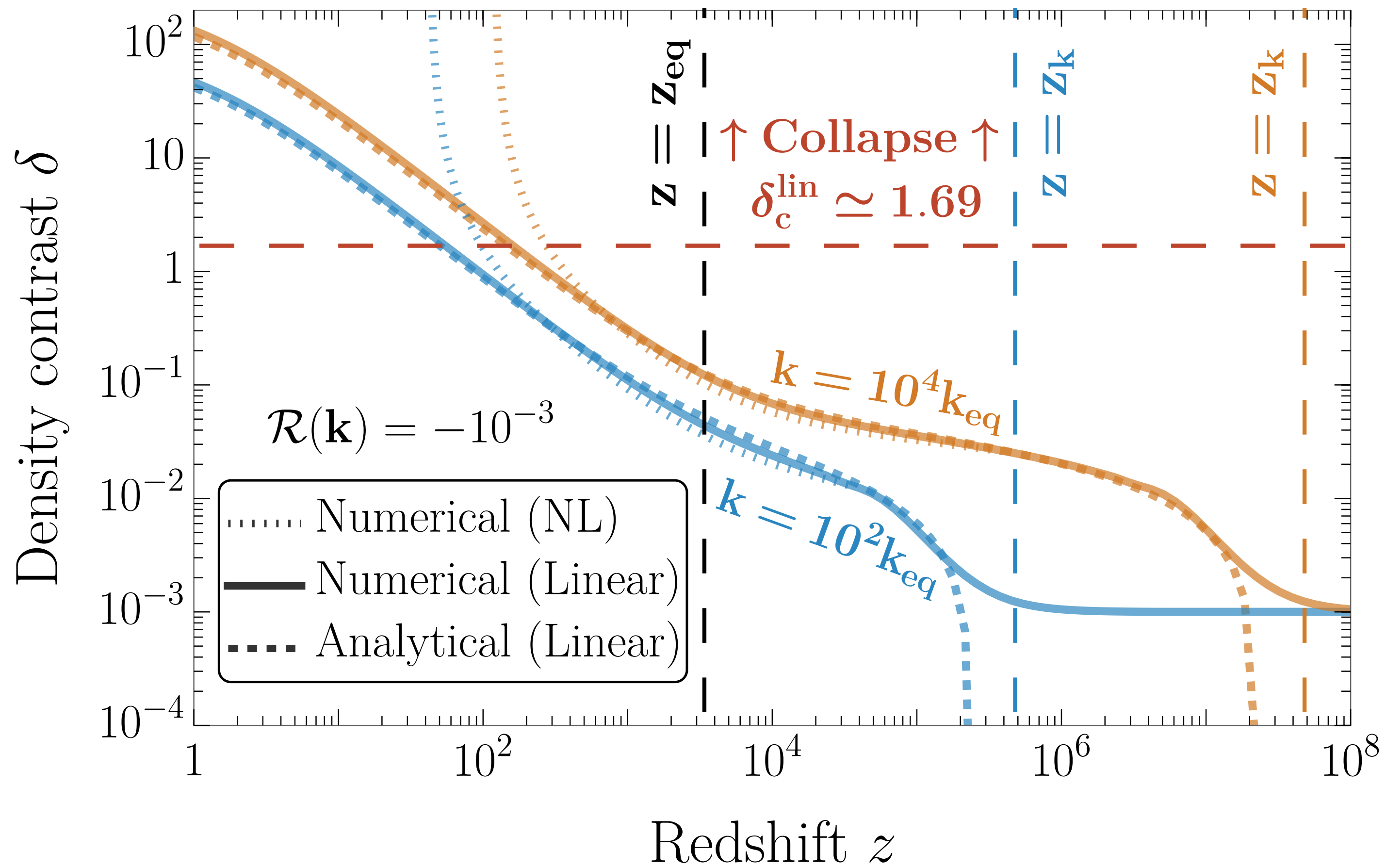


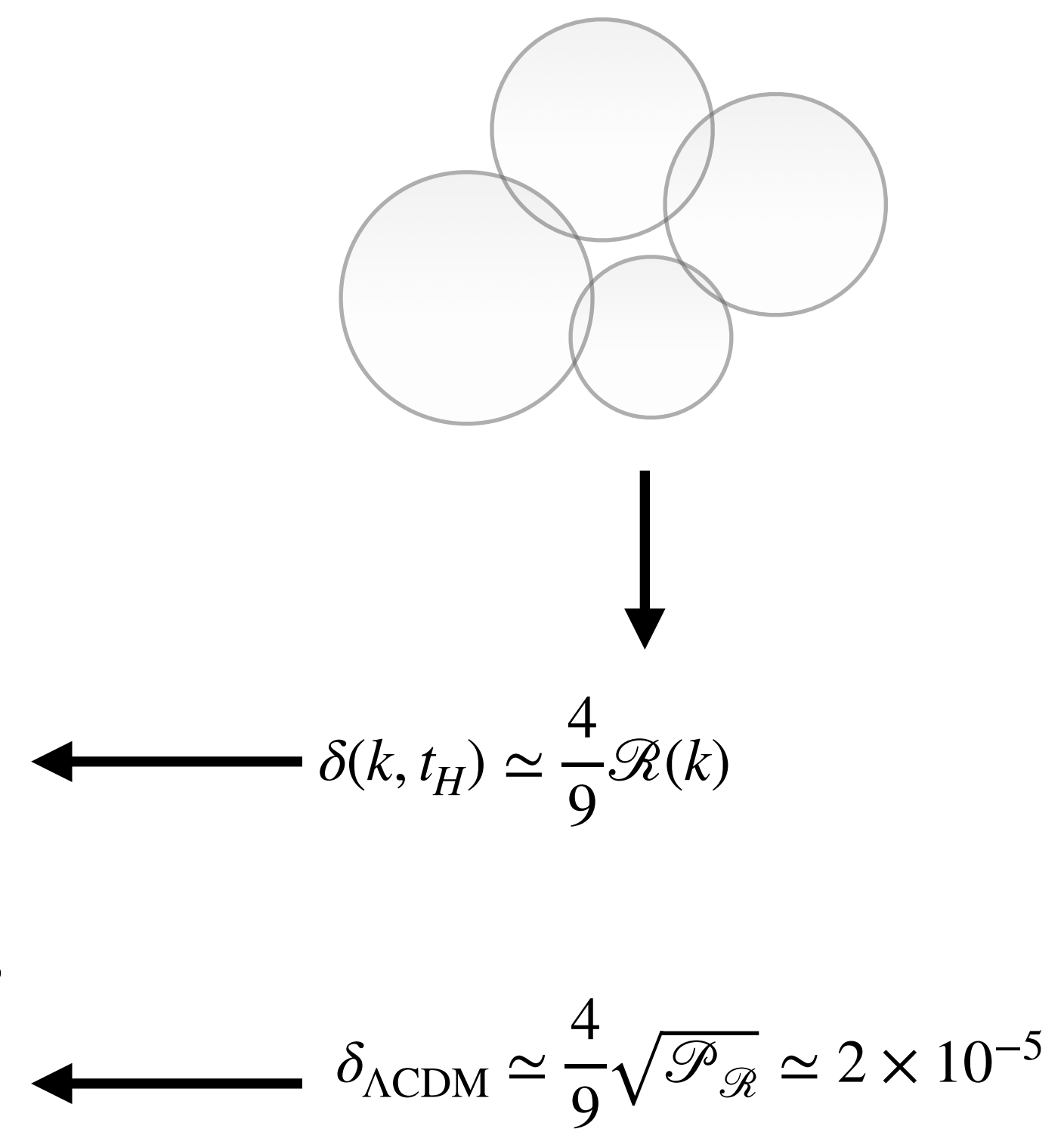
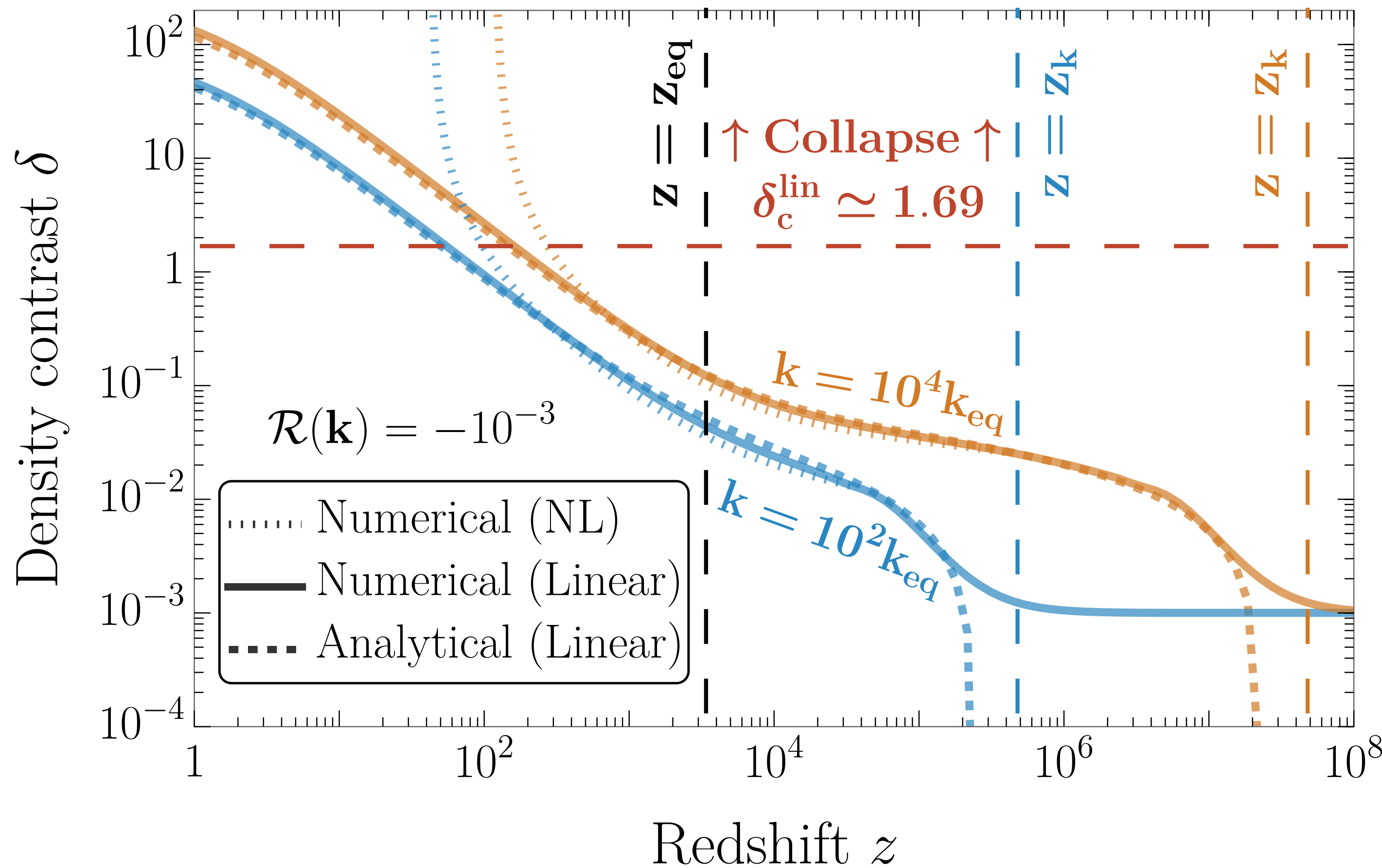
Domain wall networks
Ferreira, Notari, Pujolas, Rompineve (2204.04228)
Blasi, Mariotti, Rase, Sevrin (2306.17830)
 ...
Produce solar-mass PBH
YG, Vitagliano 2306.17841

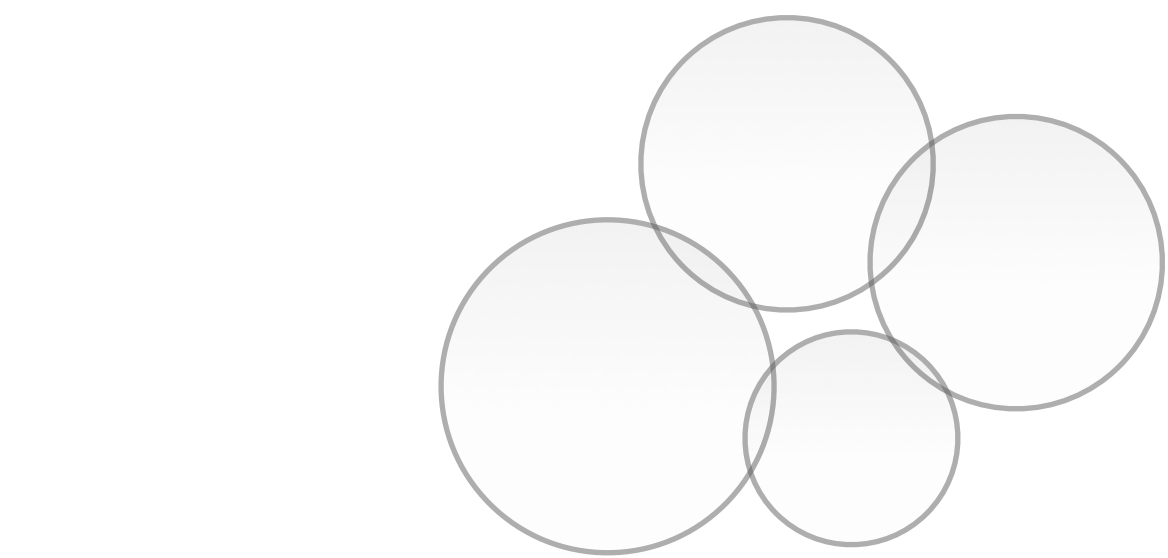
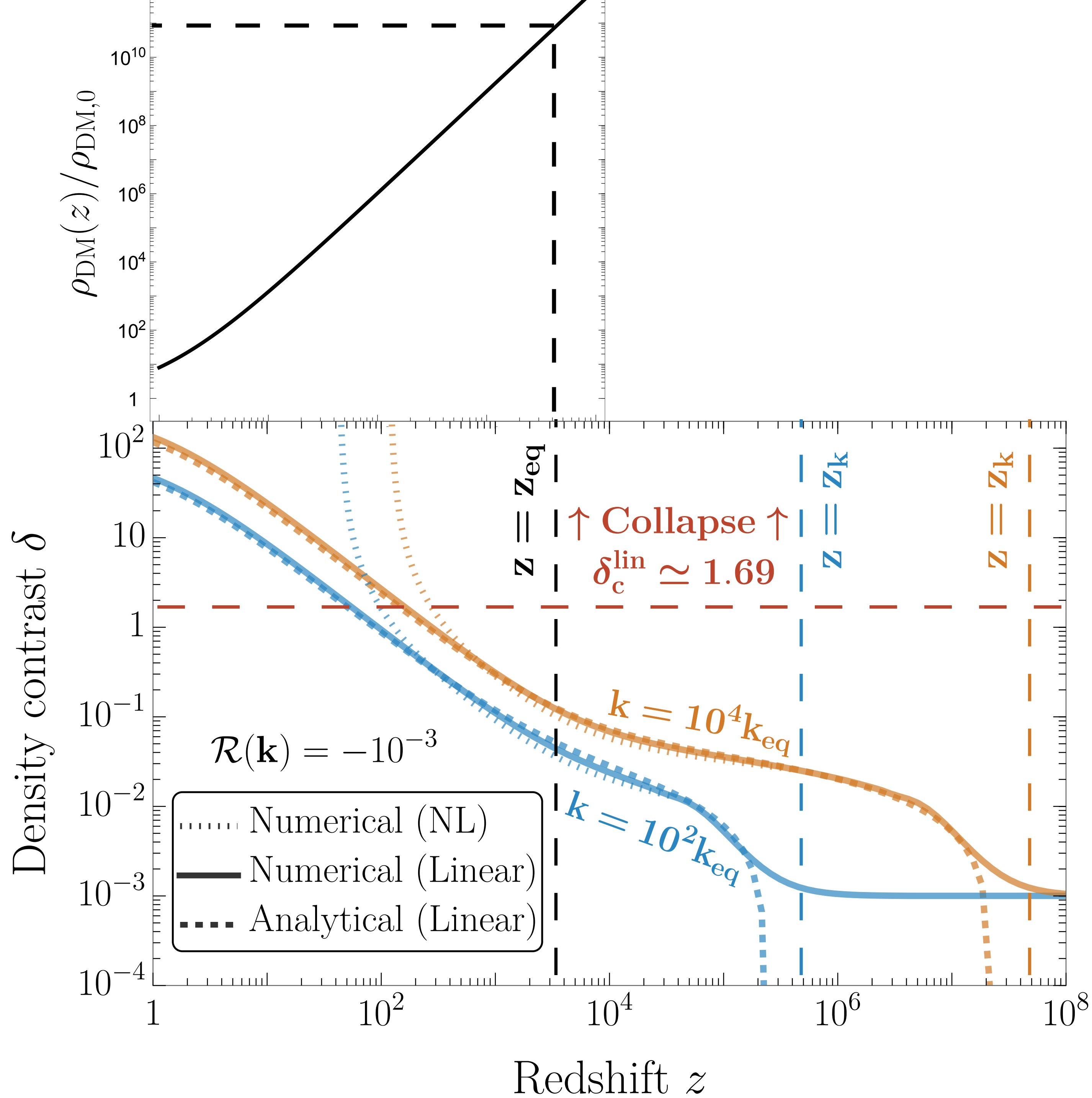


First-order phase transitions
Roper Pol et al. (2201.05630)
Ghoshal, White et al. (2307.02259)
YG (2307.04239)
Lewicki, Toczek, Vaskonen (2402.04158)
Hoefken Zink et al. (2501.15649)
 ...





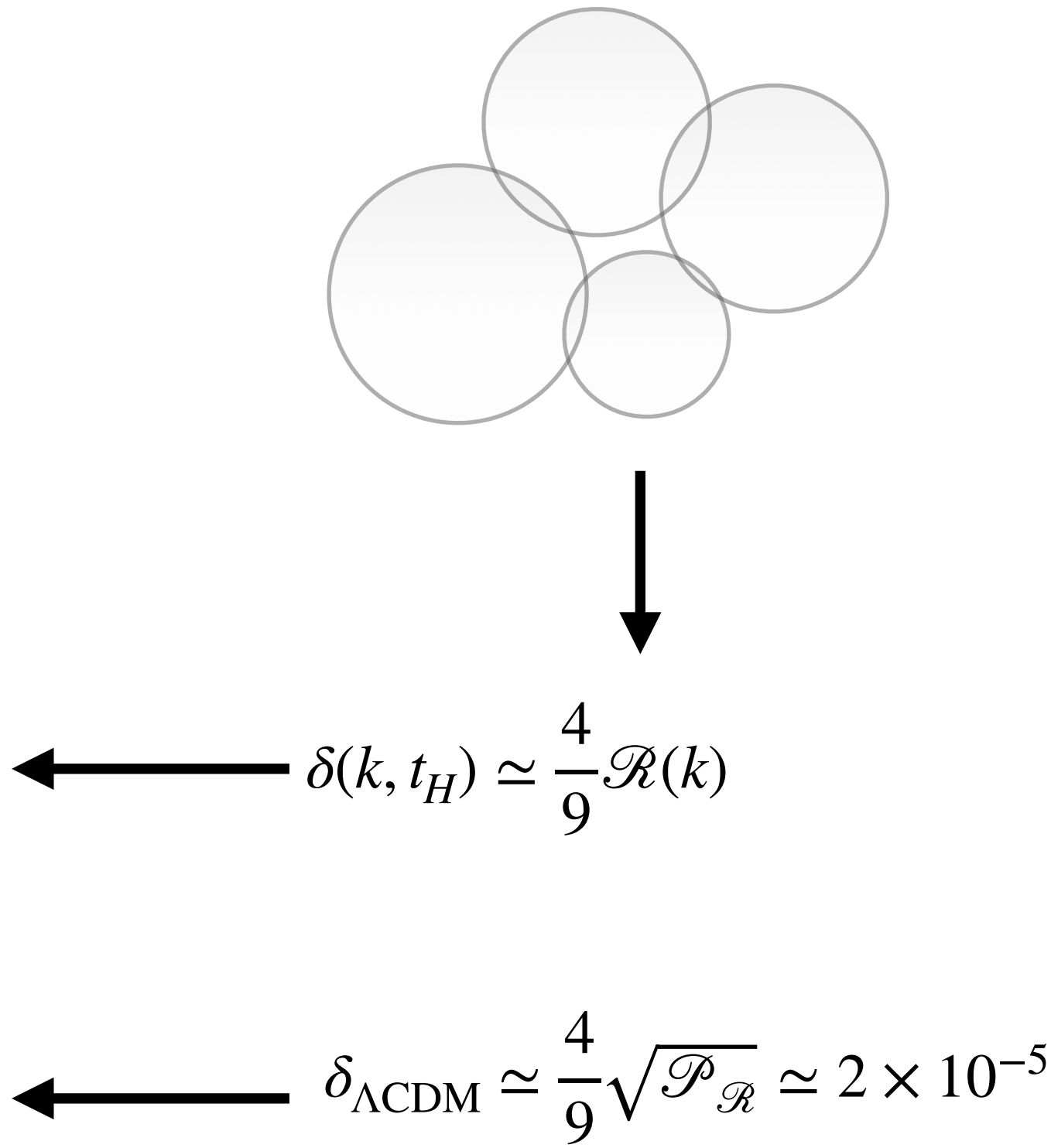
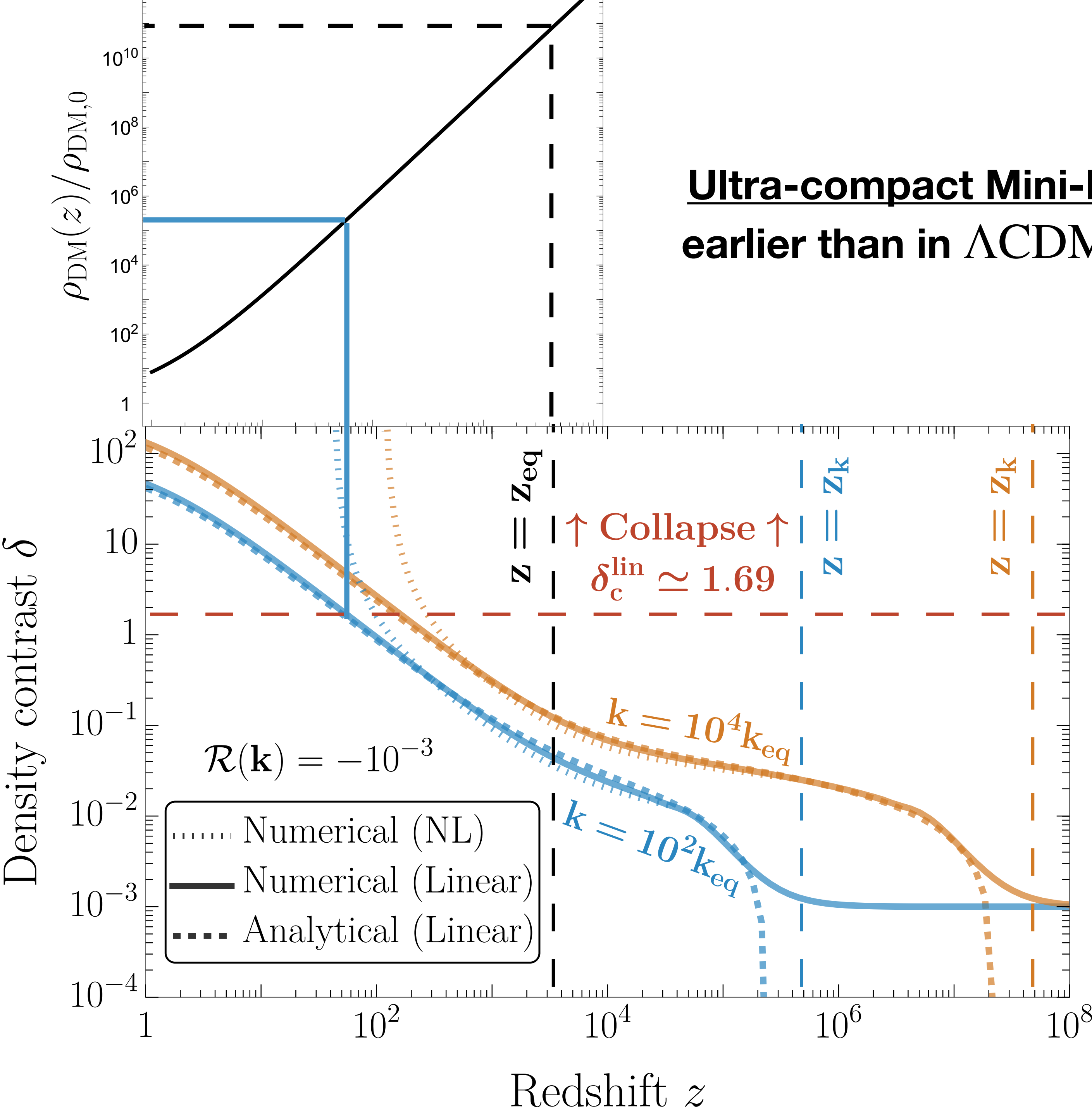


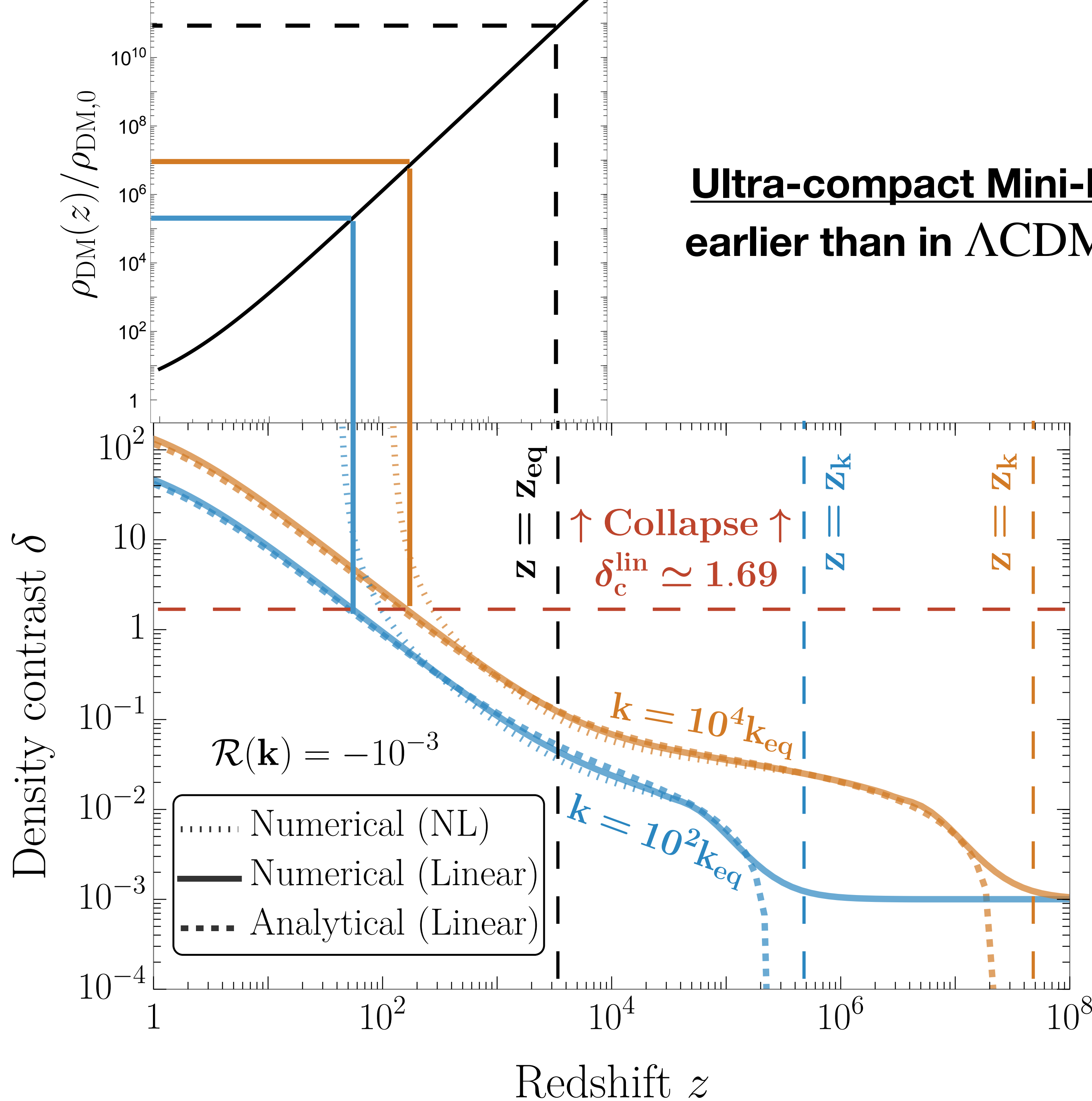


$\delta(k, t_H) \simeq \frac{4}{9} \mathcal{R}(k)$

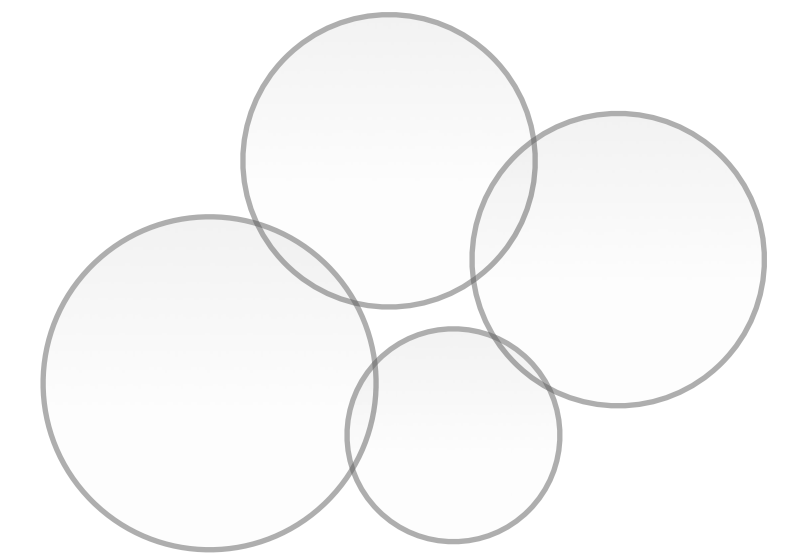
$\delta_{\Lambda\text{CDM}} \simeq \frac{4}{9} \sqrt{\mathcal{P}_{\mathcal{R}}} \simeq 2 \times 10^{-5}$

Ultra-compact Mini-Halo: DM halo that formed earlier than in Λ CDM and therefore are denser





Ultra-compact Mini-Halo: DM halo that formed earlier than in Λ CDM and therefore are denser

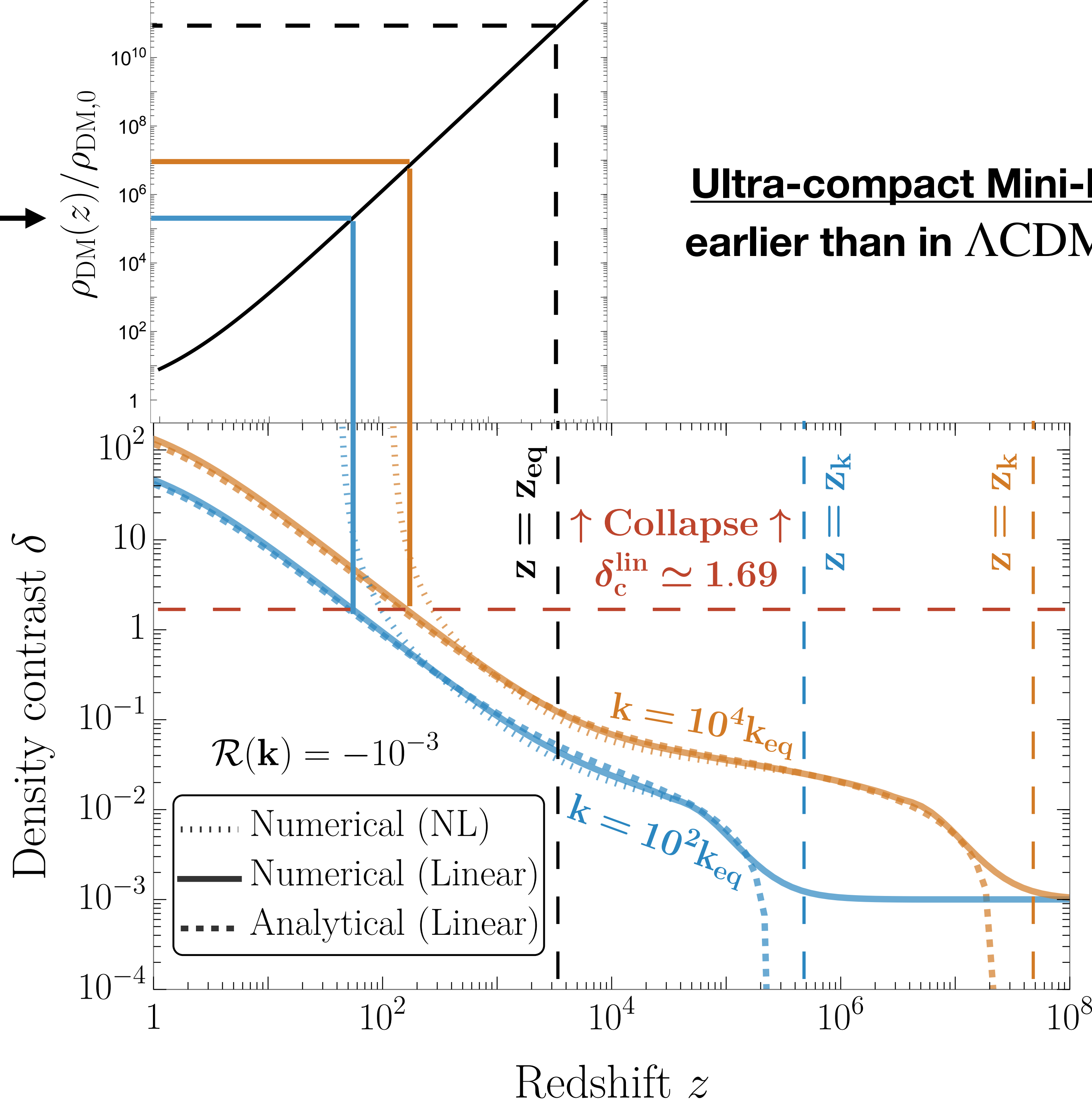


$\delta(k, t_H) \simeq \frac{4}{9} \mathcal{R}(k)$

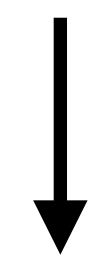
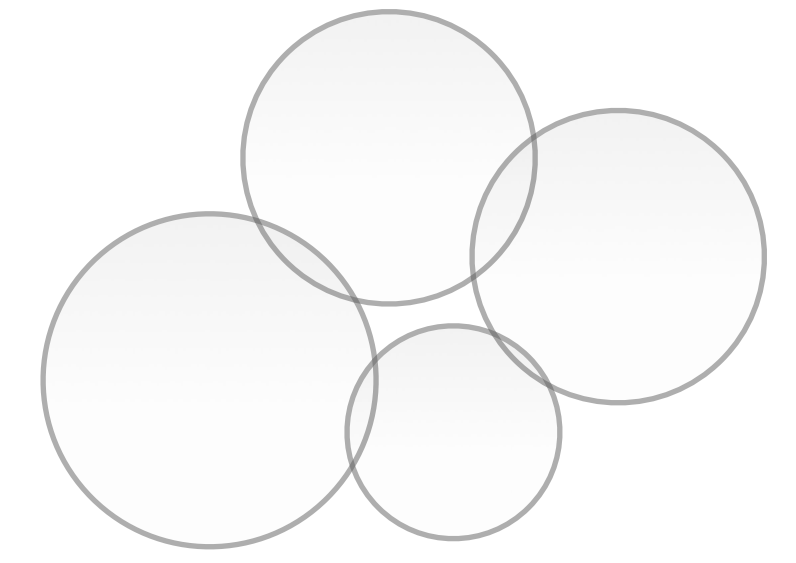
$\delta_{\Lambda\text{CDM}} \simeq \frac{4}{9} \sqrt{\mathcal{P}_{\mathcal{R}}} \simeq 2 \times 10^{-5}$

$$\rho_{\odot} \simeq 0.3 \text{ GeV/cm}^3$$

$$\simeq 2 \times 10^5 \rho_{\text{DM},0}$$



Ultra-compact Mini-Halo: DM halo that formed earlier than in Λ CDM and therefore are denser

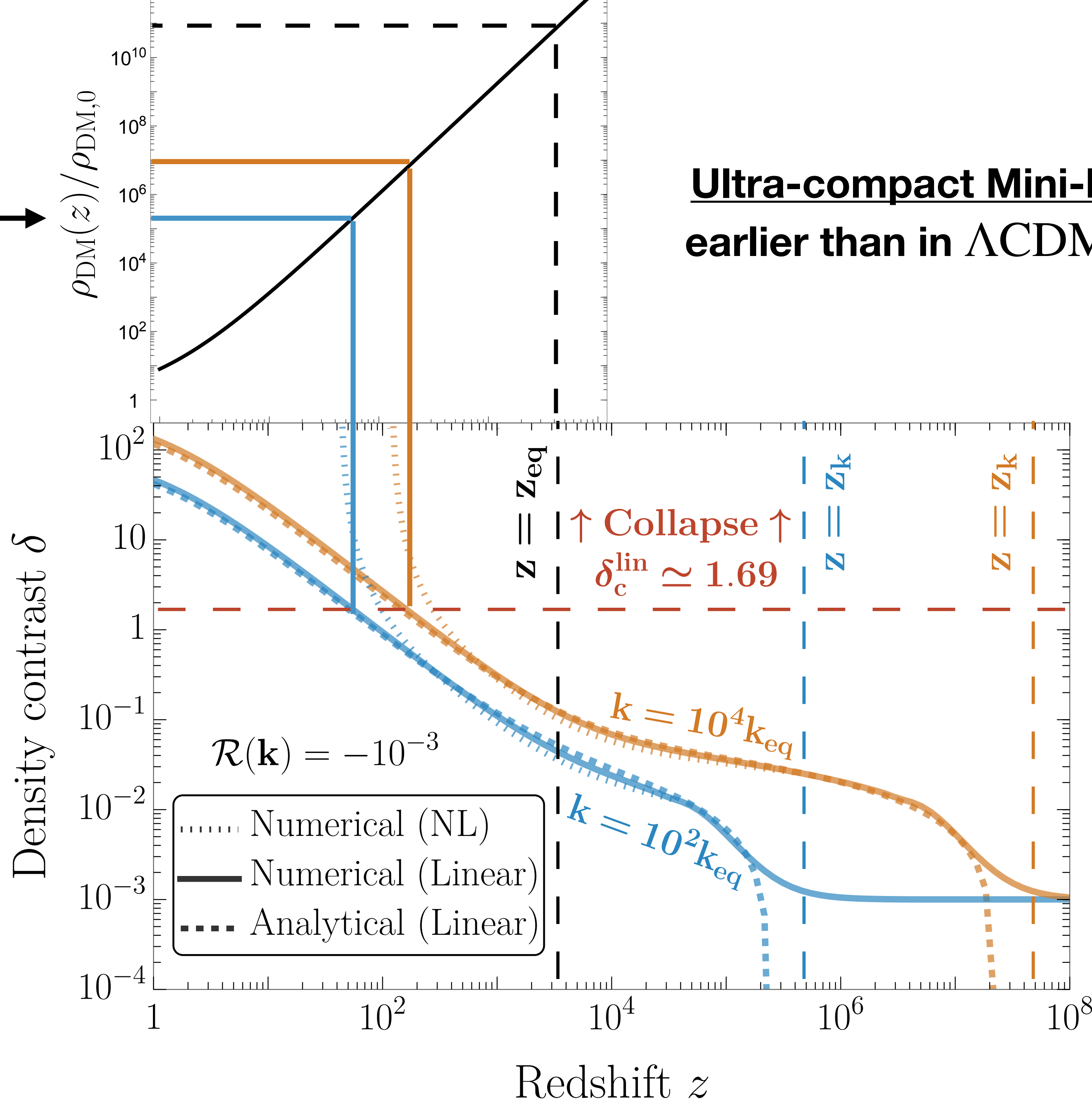


$$\delta(k, t_H) \simeq \frac{4}{9} \mathcal{R}(k)$$

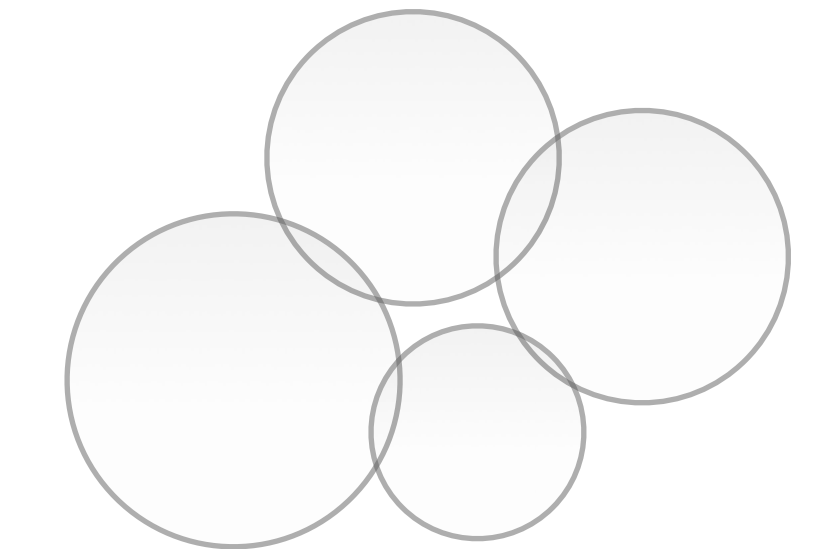
$$\delta_{\Lambda\text{CDM}} \simeq \frac{4}{9} \sqrt{\mathcal{P}_{\mathcal{R}}} \simeq 2 \times 10^{-5}$$

$$\rho_{\odot} \simeq 0.3 \text{ GeV/cm}^3$$

$$\simeq 2 \times 10^5 \rho_{\text{DM},0}$$



Ultra-compact Mini-Halo: DM halo that formed earlier than in Λ CDM and therefore are denser



$\delta(k, t_H) \simeq \frac{4}{9} \mathcal{R}(k)$

$\delta_{\Lambda\text{CDM}} \simeq \frac{4}{9} \sqrt{\mathcal{P}_{\mathcal{R}}} \simeq 2 \times 10^{-5}$

Gamma-rays from Ultra-Compact Mini-Halo

YG 2503.03857

“Number of DM pairs”

$$d\vec{r}^3 \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(\vec{r})}{m_{\text{DM}}} \right)^2$$

“Number of annihilation per second”

$$d\vec{r}^3 \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(\vec{r})}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle$$

“Number of photon produced per second”

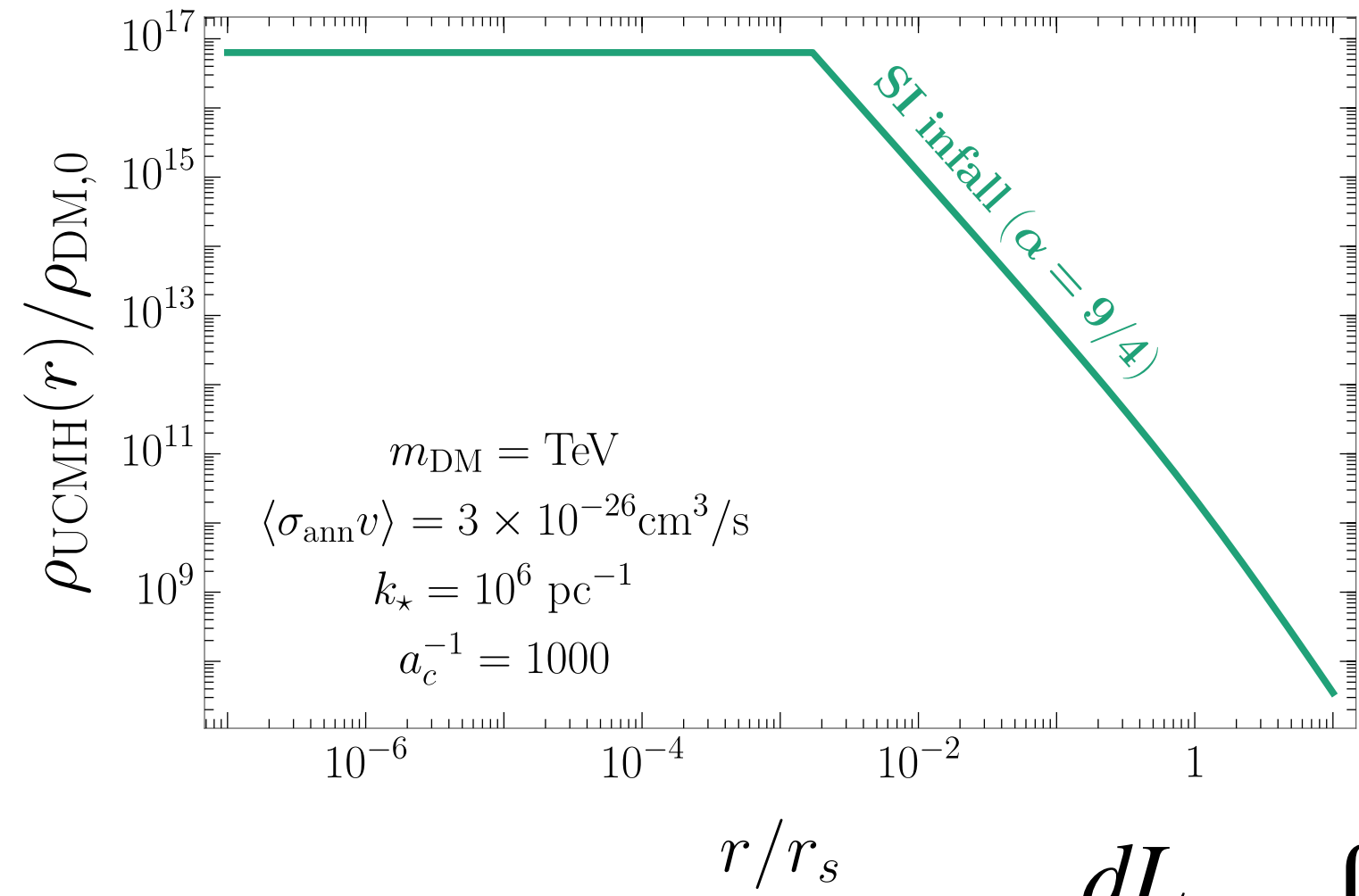
$$d\vec{r}^3 \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(\vec{r})}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

“Number of photon produced per second per halo”

$$\frac{dL}{dE} = \int_0^R d\vec{r}^3 \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(\vec{r})}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

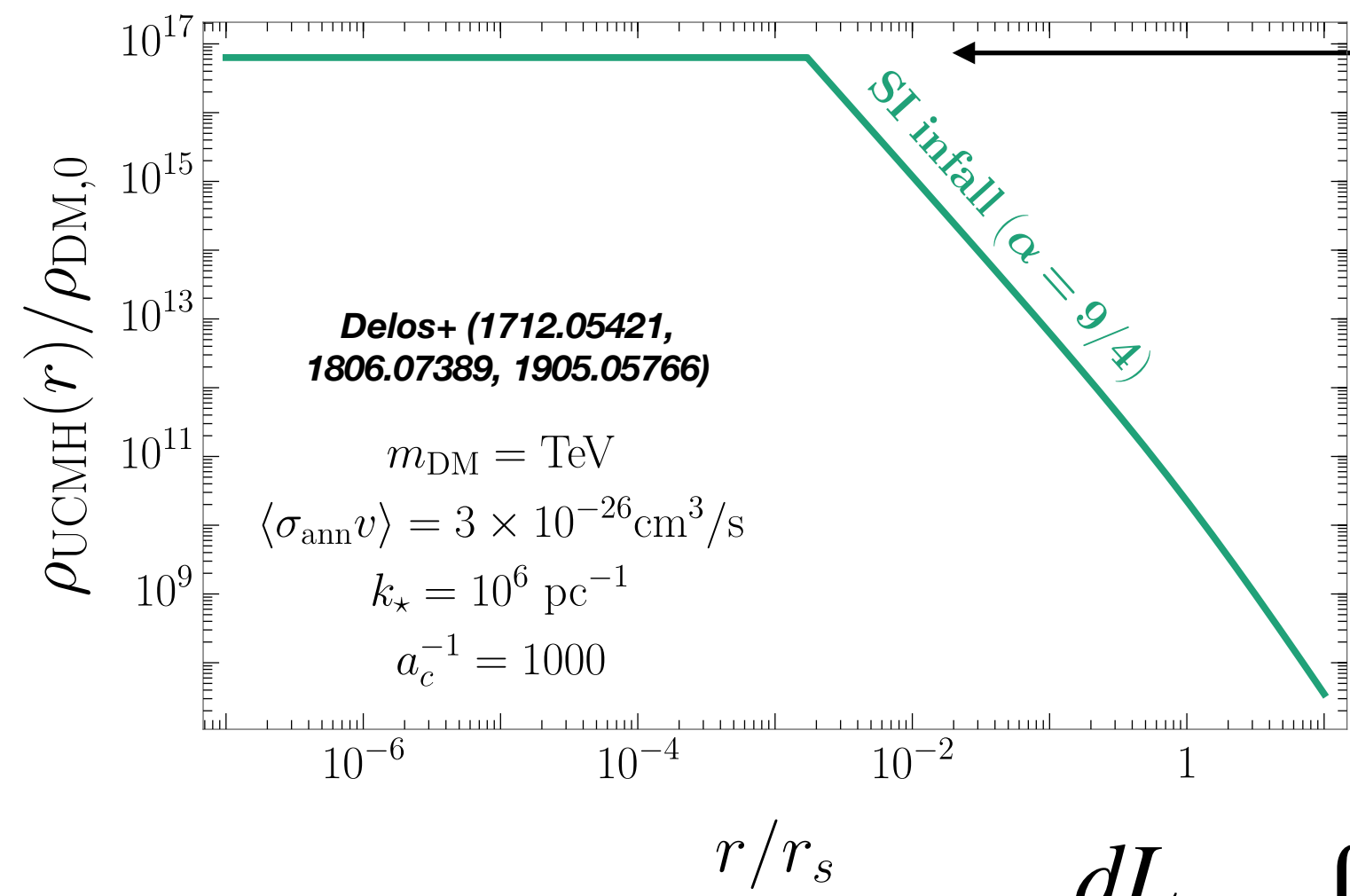
“Halo luminosity”

$$\frac{dL}{dE} = \int_0^R d\vec{r}^3 \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(\vec{r})}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$



$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

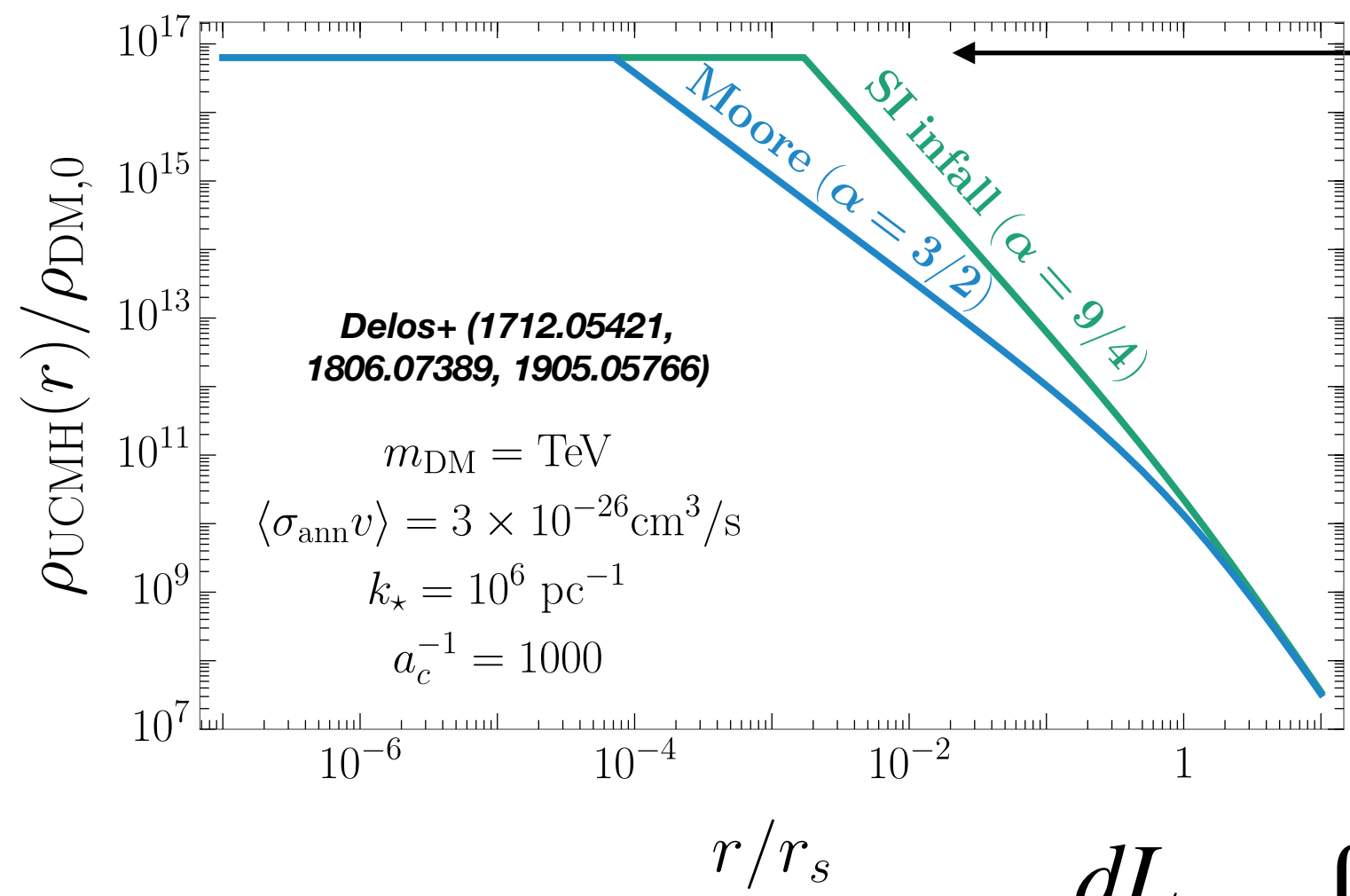
“Halo luminosity”



$$\rho_{\max} = \frac{m_{\text{DM}}}{\langle \sigma_{\text{ann}} v \rangle \times 13.8 \text{ Gyrs}}$$

$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

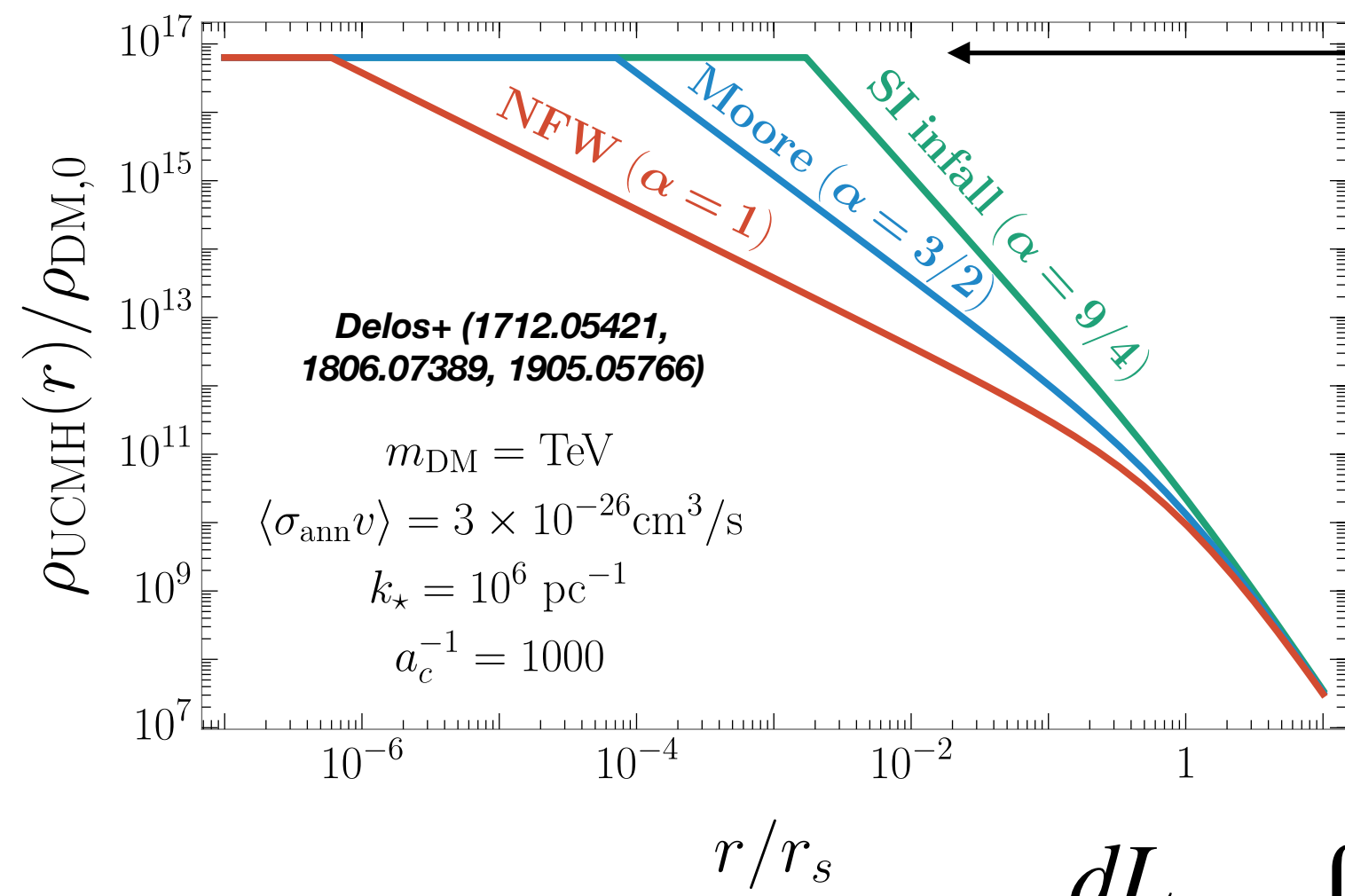
“Halo luminosity”



$$\rho_{\text{max}} = \frac{m_{\text{DM}}}{\langle\sigma_{\text{ann}}v\rangle \times 13.8 \text{ Gyrs}}$$

$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle\sigma_f v\rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

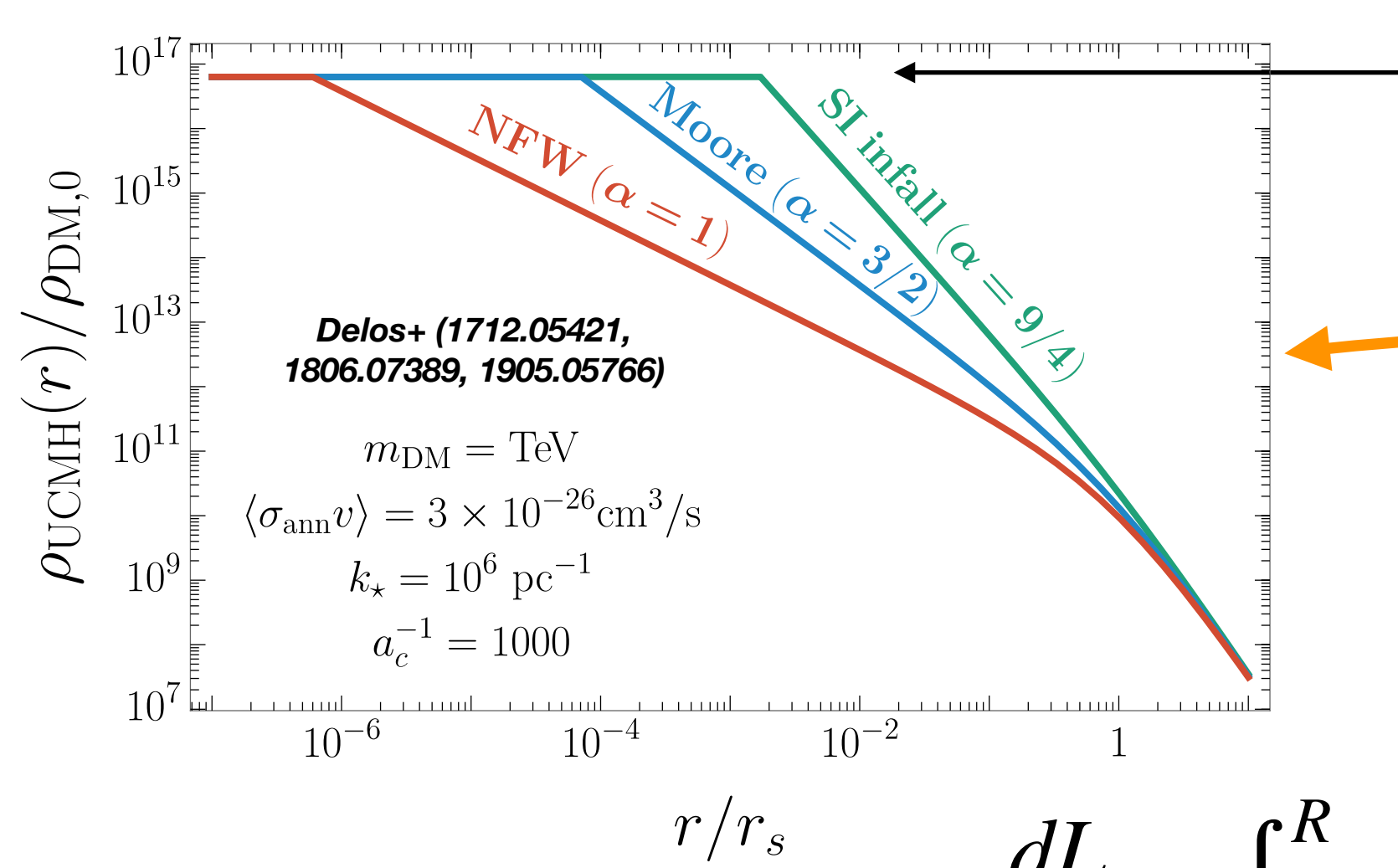
“Halo luminosity”



$$\rho_{\text{max}} = \frac{m_{\text{DM}}}{\langle \sigma_{\text{ann}} v \rangle \times 13.8 \text{ Gyrs}}$$

$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

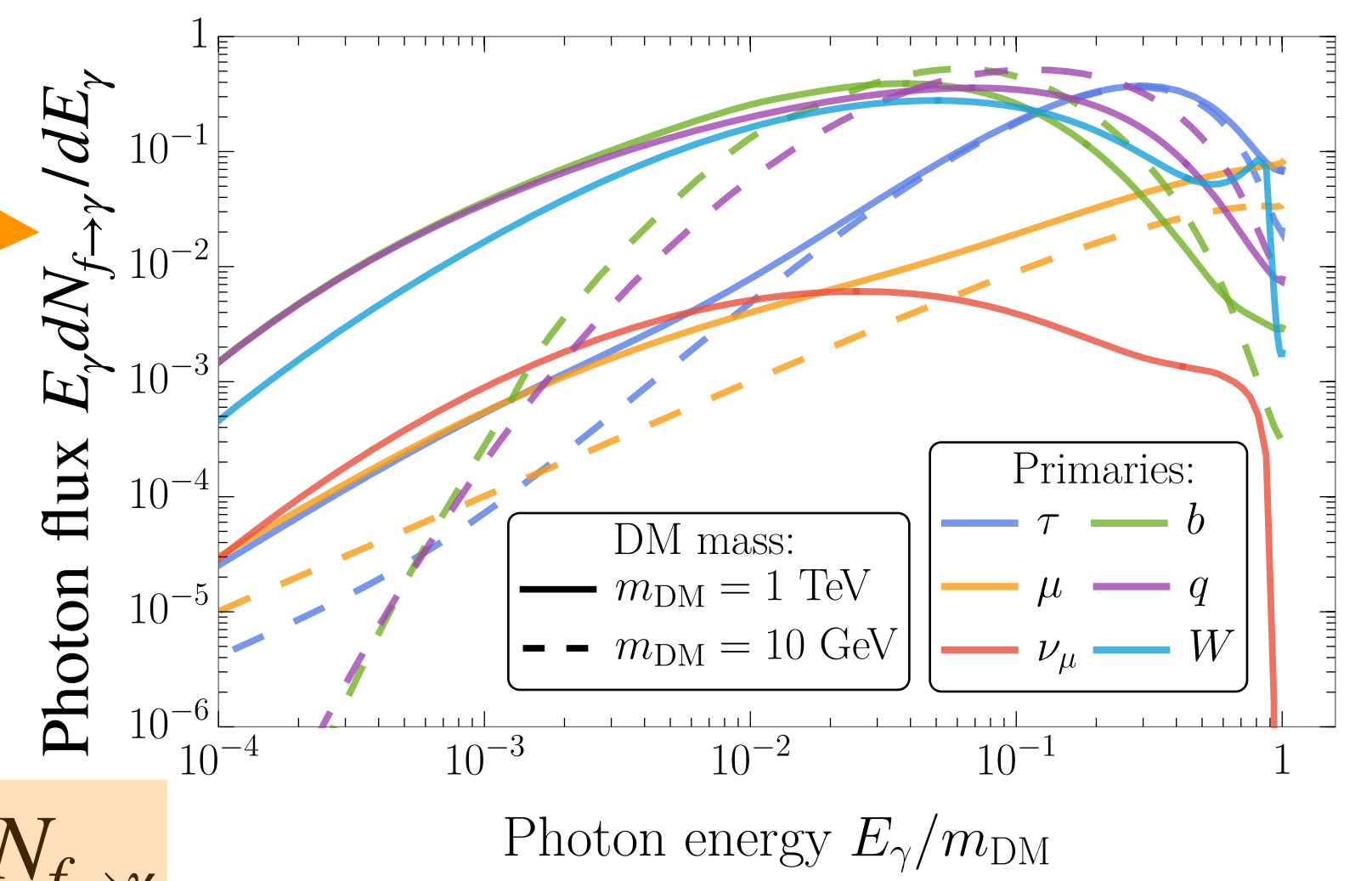
“Halo luminosity”



$$\rho_{\text{max}} = \frac{m_{\text{DM}}}{\langle\sigma_{\text{ann}}v\rangle \times 13.8 \text{ Gyrs}}$$

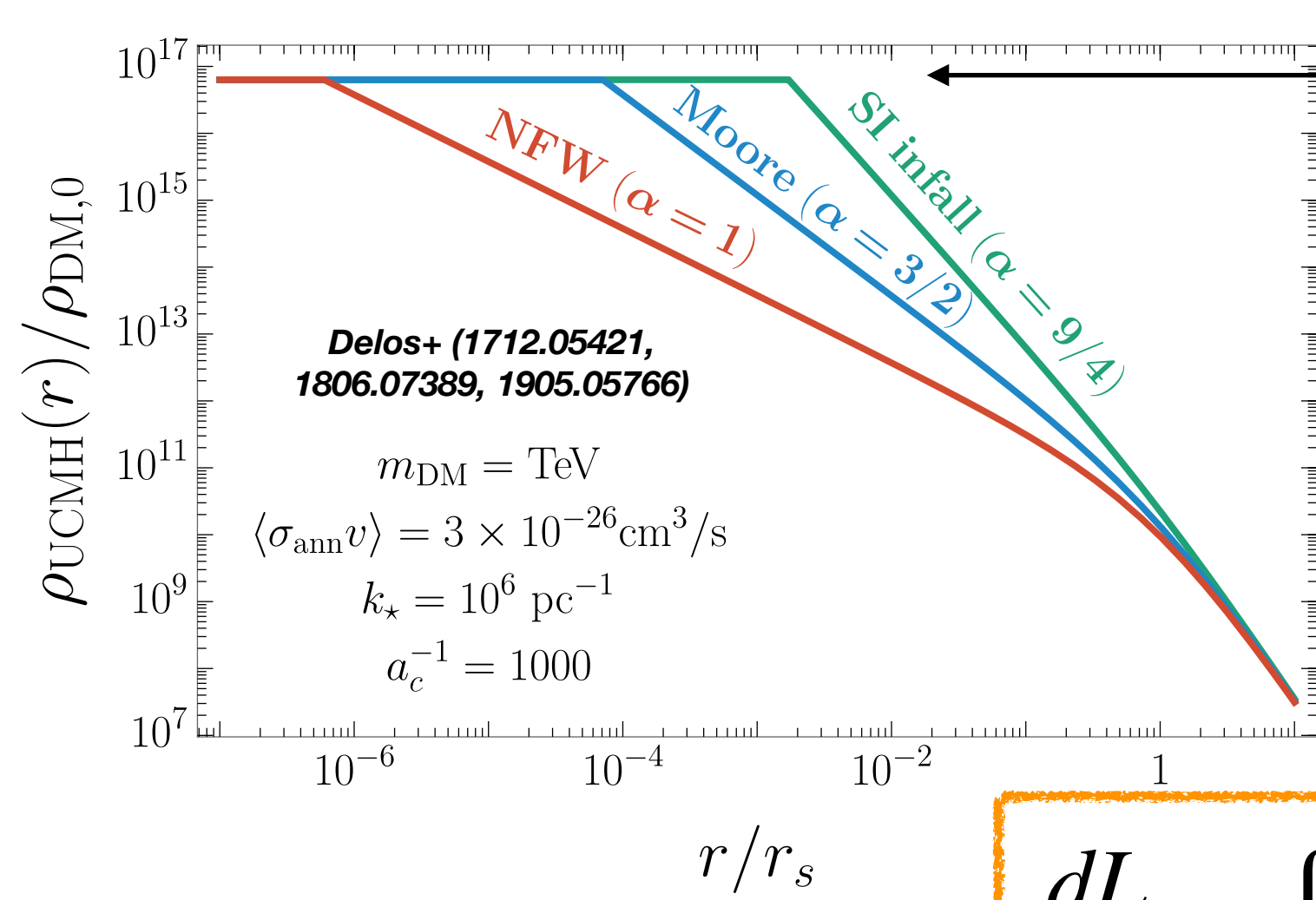
PPPC 4 DM ID
1012.4515 (Sala+)

$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle\sigma_f v\rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

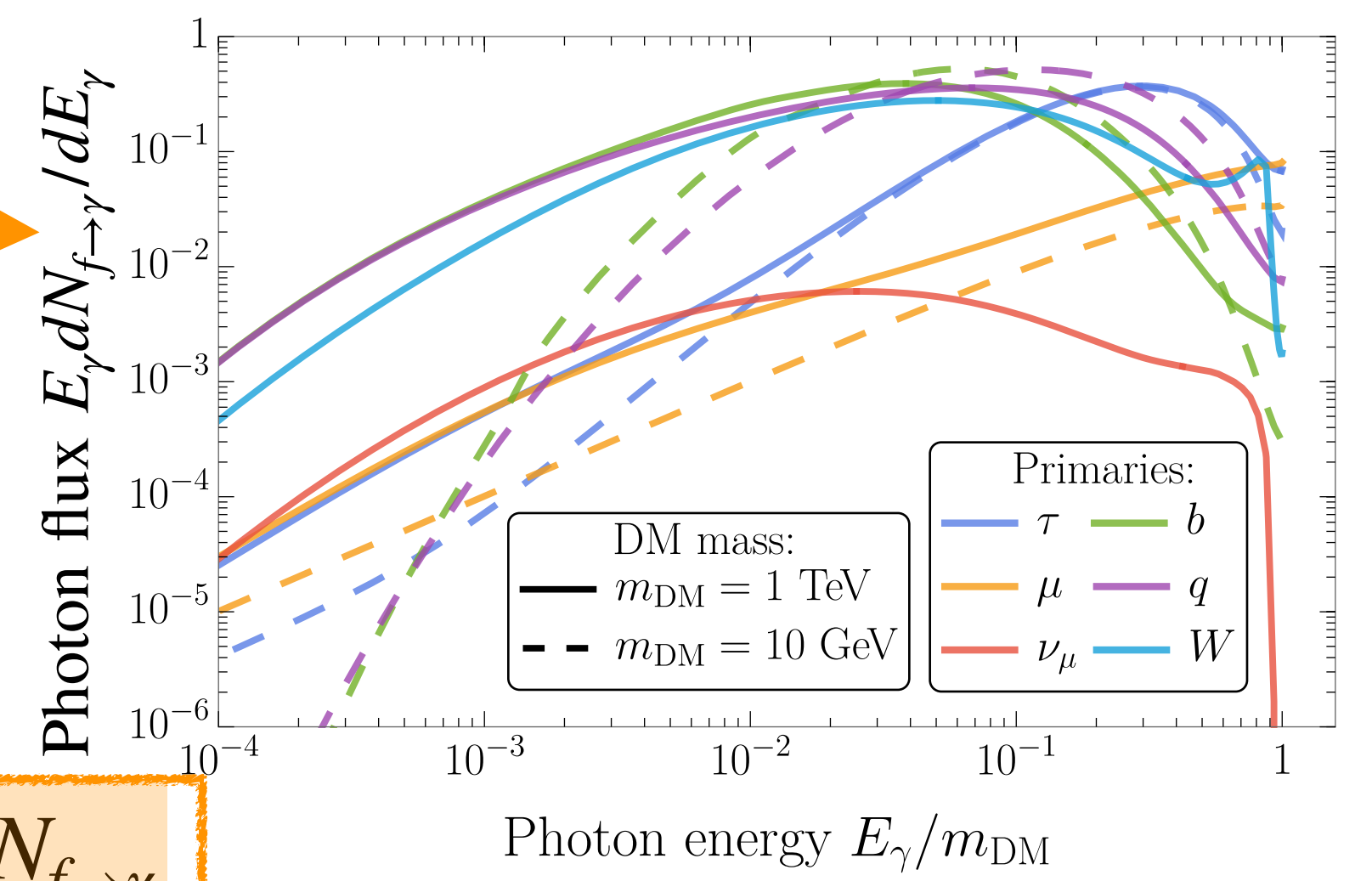


YG 2503.03857

“Halo luminosity”



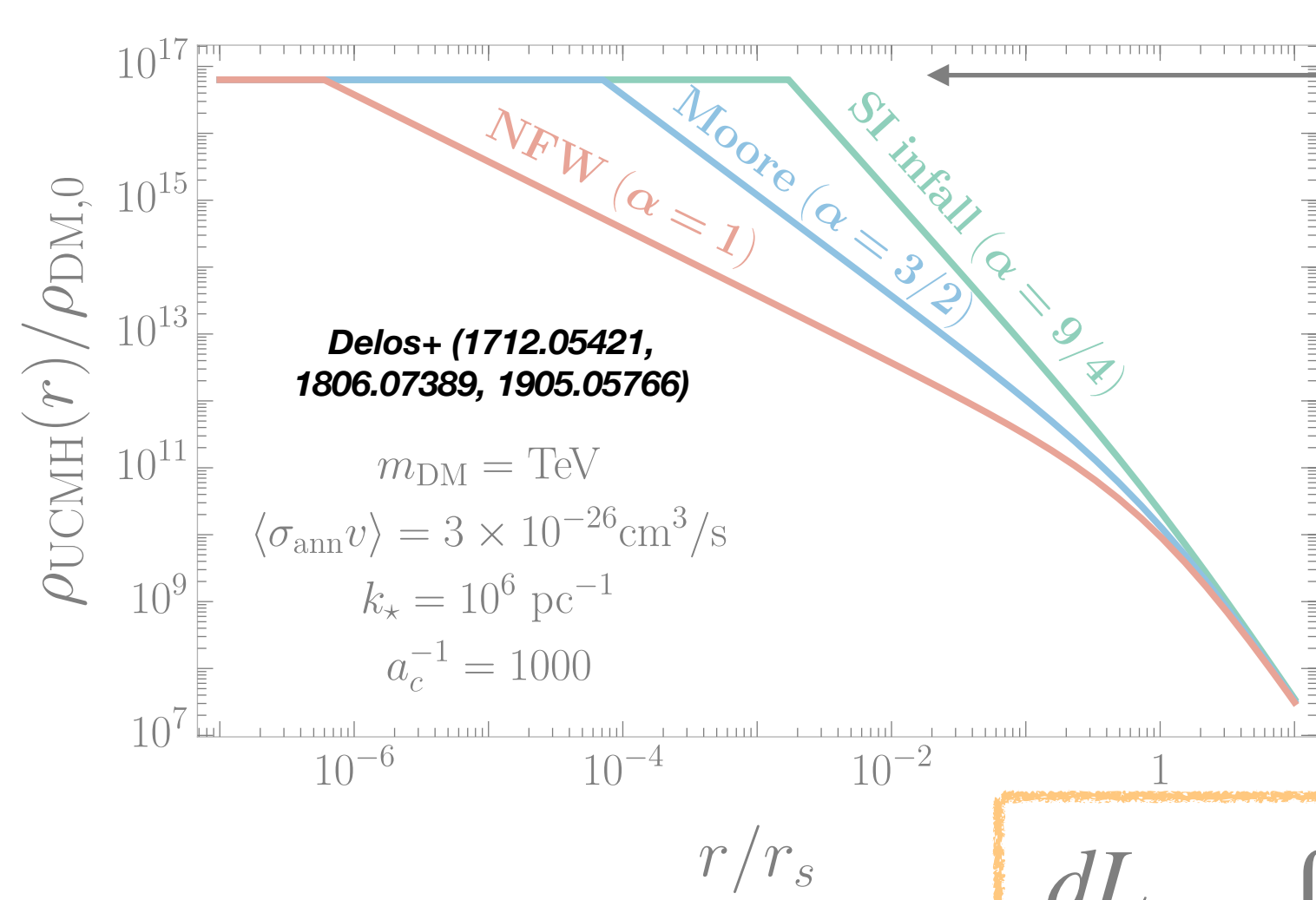
$$\rho_{\text{max}} = \frac{m_{\text{DM}}}{\langle\sigma_{\text{ann}}v\rangle \times 13.8 \text{ Gyrs}}$$



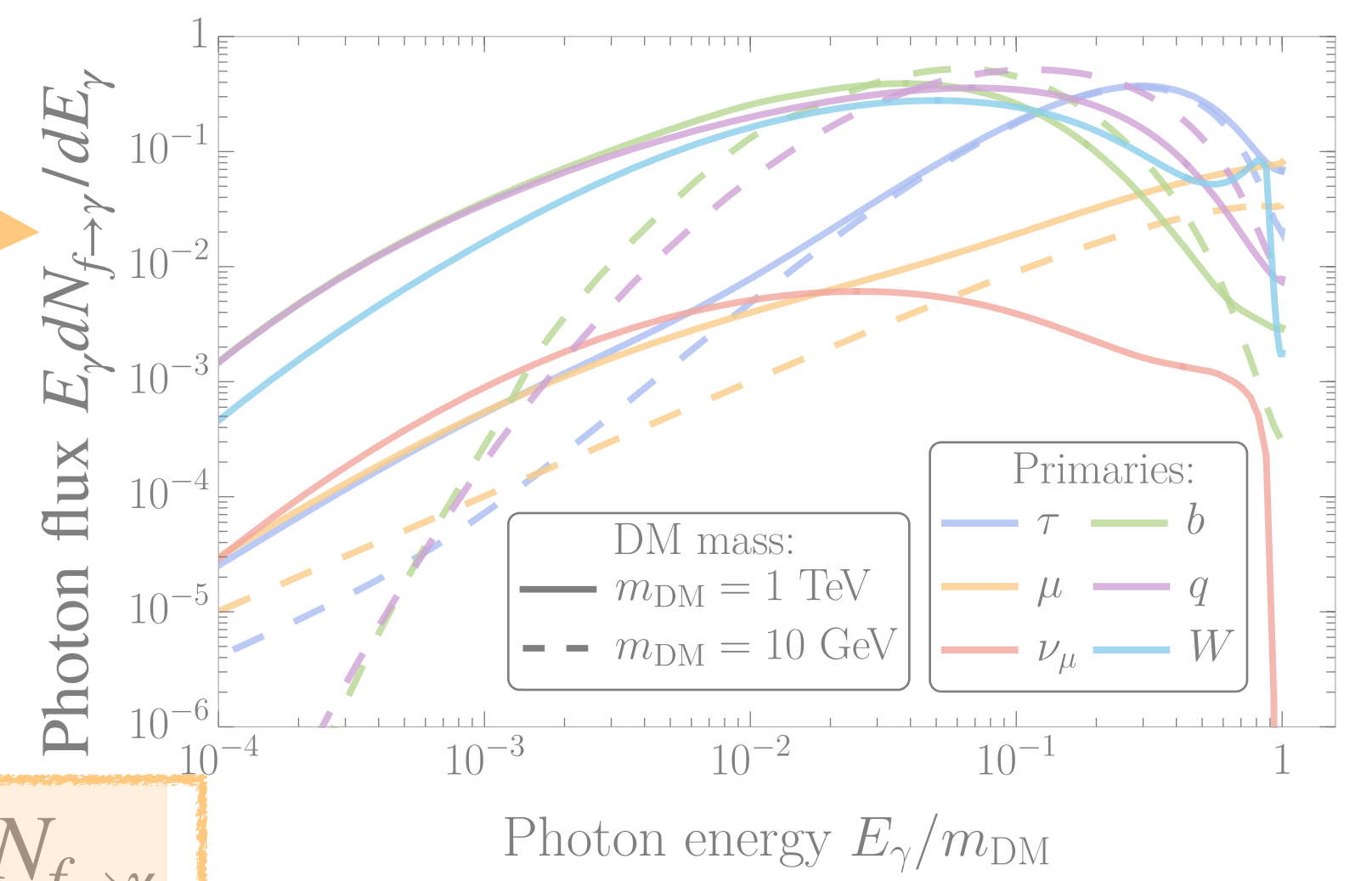
$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle\sigma_f v\rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

YG 2503.03857

$$\frac{d^2 \mathcal{F}_\gamma(\theta)}{d\Omega dE} = \int_0^\infty \frac{ds}{4\pi} \frac{\rho_{\text{DM}}(s, \theta)}{\bar{\rho}_{\text{DM},0}} \times \int_0^\infty da_c \int_0^\infty \frac{dR}{R} \frac{dn}{da_c} \times \frac{dL[E, a_c, R]}{dE}$$



$$\rho_{\text{max}} = \frac{m_{\text{DM}}}{\langle \sigma_{\text{ann}} v \rangle \times 13.8 \text{ Gyrs}}$$

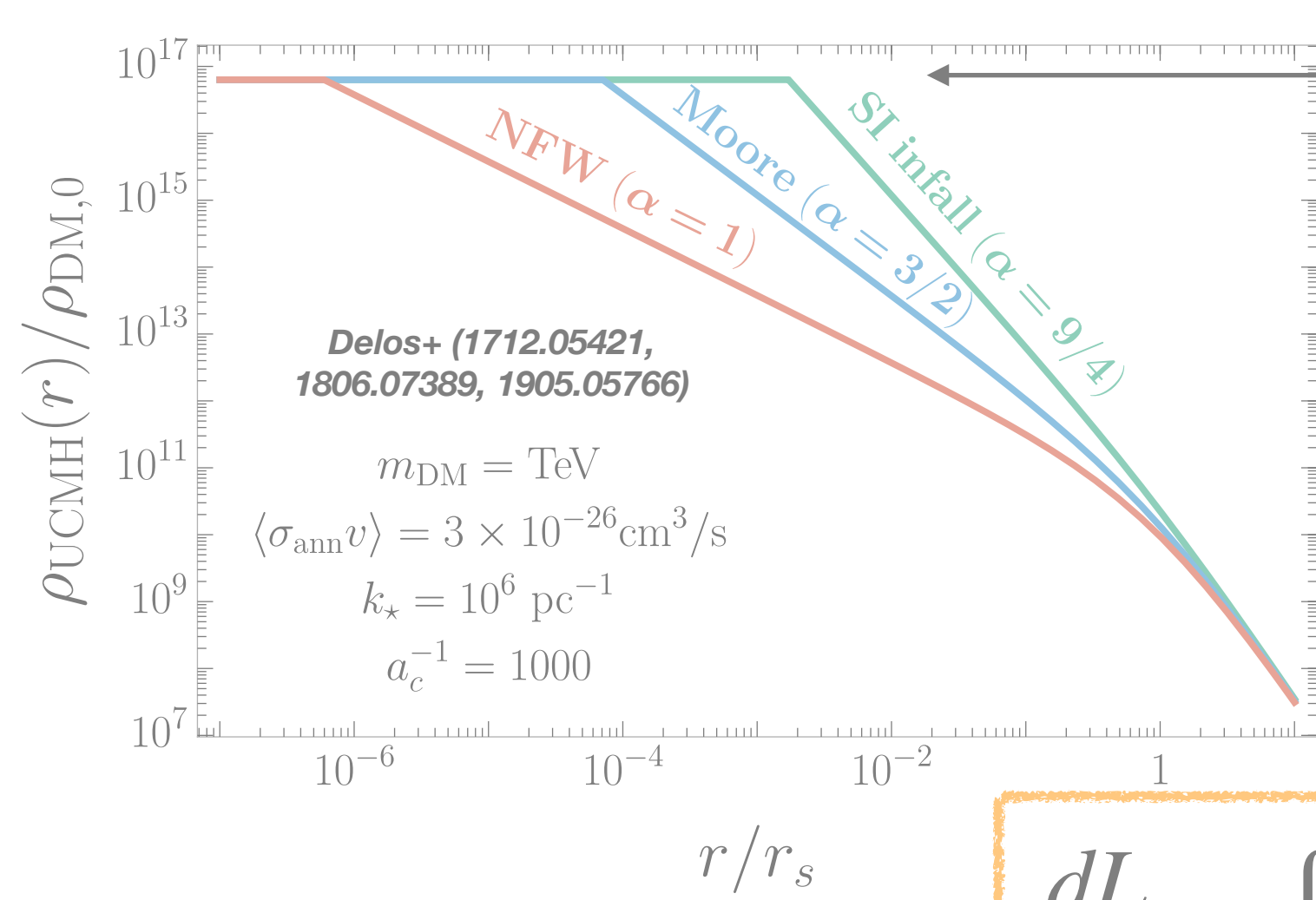


$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

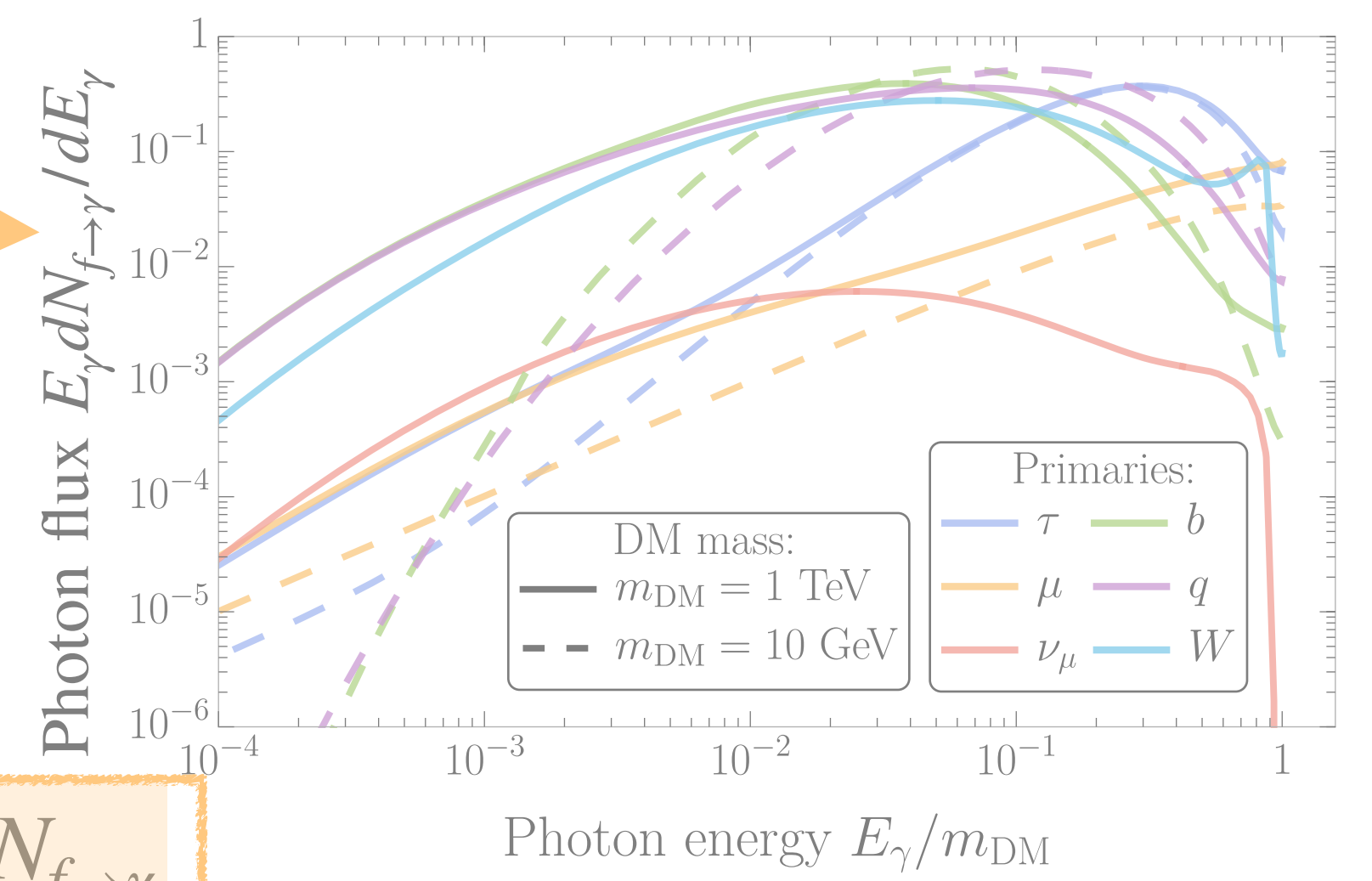
YG 2503.03857

$$\frac{d^2 \mathcal{F}_\gamma(\theta)}{d\Omega dE} = \int_0^\infty \frac{ds}{4\pi} \frac{\rho_{\text{DM}}(s, \theta)}{\bar{\rho}_{\text{DM},0}} \times \int_0^\infty da_c \int_0^\infty \frac{dR}{R} \frac{dn}{da_c} \times \frac{dL[E, a_c, R]}{dE}$$

$$\rho_{\text{DM}}(s, \theta) = \rho_{\text{MW}} \left[\sqrt{s^2 + r_\odot^2 - 2r_\odot s \cos \theta} \right]$$



$$\rho_{\max} = \frac{m_{\text{DM}}}{\langle \sigma_{\text{ann}} v \rangle \times 13.8 \text{ Gyrs}}$$

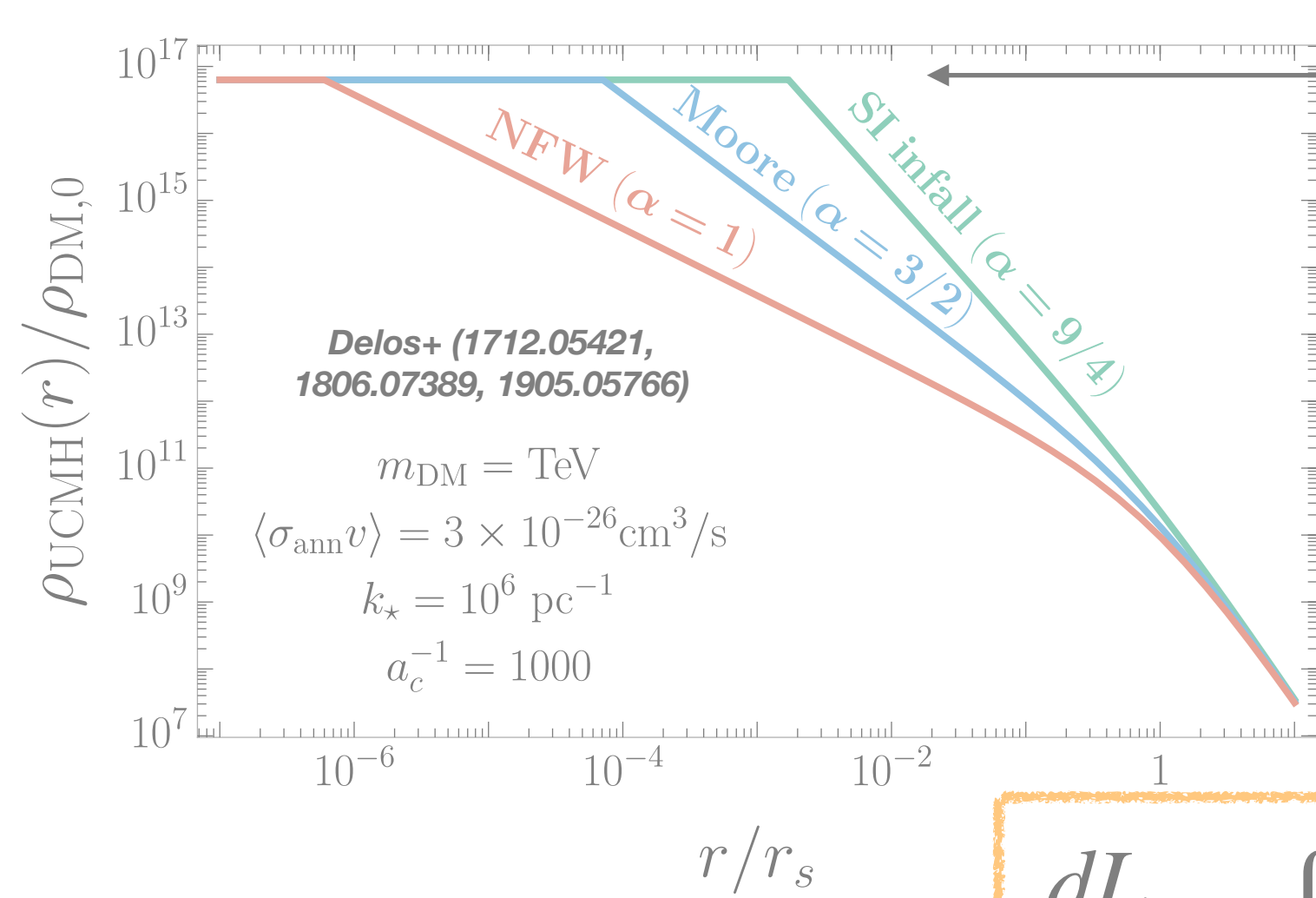


$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

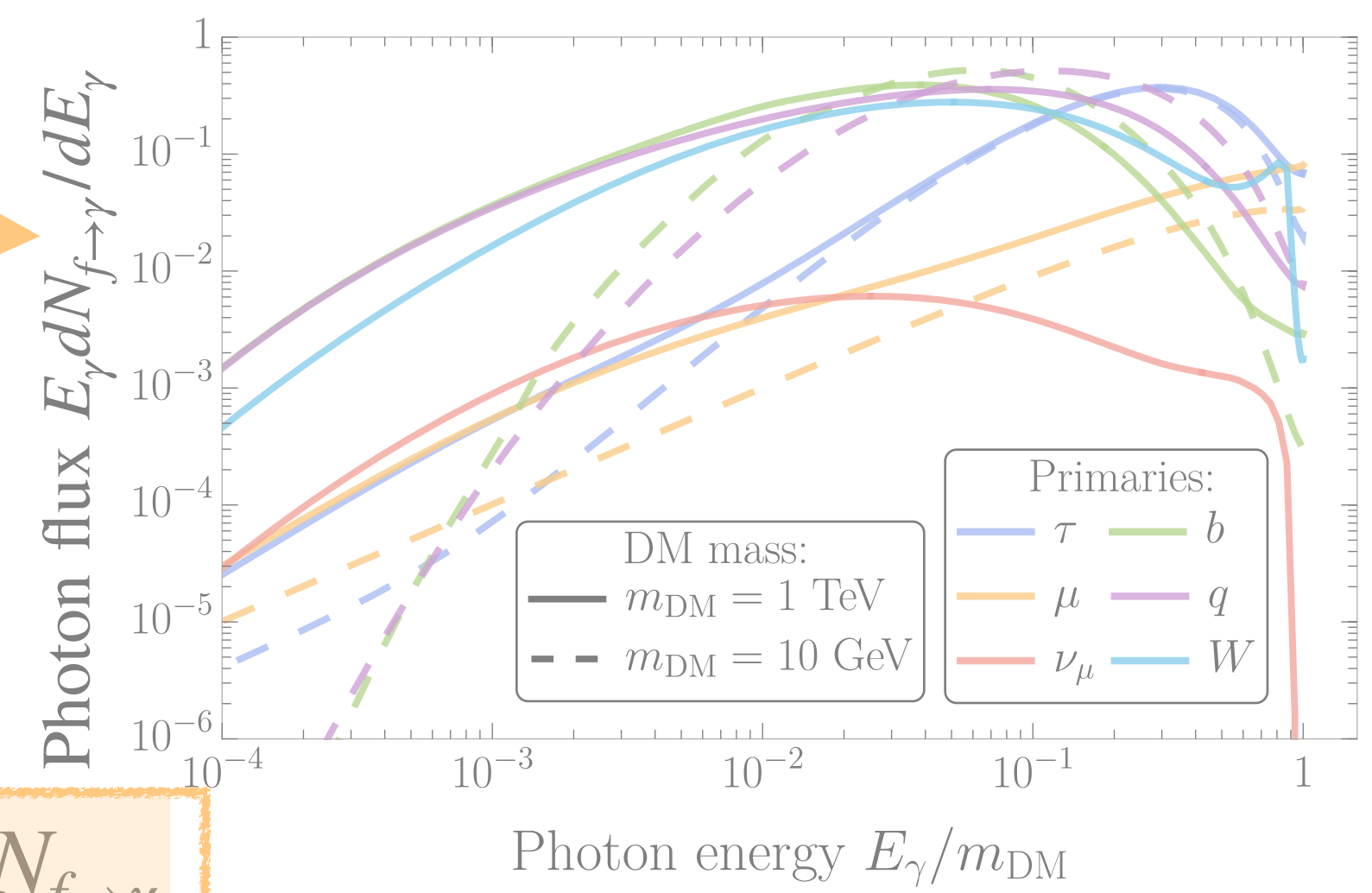
YG 2503.03857

$$\frac{d^2 \mathcal{F}_\gamma(\theta)}{d\Omega dE} = \int_0^\infty \frac{ds}{4\pi} \frac{\rho_{\text{DM}}(s, \theta)}{\bar{\rho}_{\text{DM},0}} \times \int_0^\infty da_c \int_0^\infty \frac{dR}{R} \frac{dn}{da_c} \times \frac{dL[(1+z_e)E, a_c, R]}{dE}$$

$$\rho_{\text{DM}}(s, \theta) = \rho_{\text{MW}} \left[\sqrt{s^2 + r_\odot^2 - 2r_\odot s \cos \theta} \right] + \frac{e^{-\tau(E, z_e)}}{(1+z_e)^3} \bar{\rho}_{\text{DM},0}$$



$$\rho_{\max} = \frac{m_{\text{DM}}}{\langle \sigma_{\text{ann}} v \rangle \times 13.8 \text{ Gyrs}}$$



$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

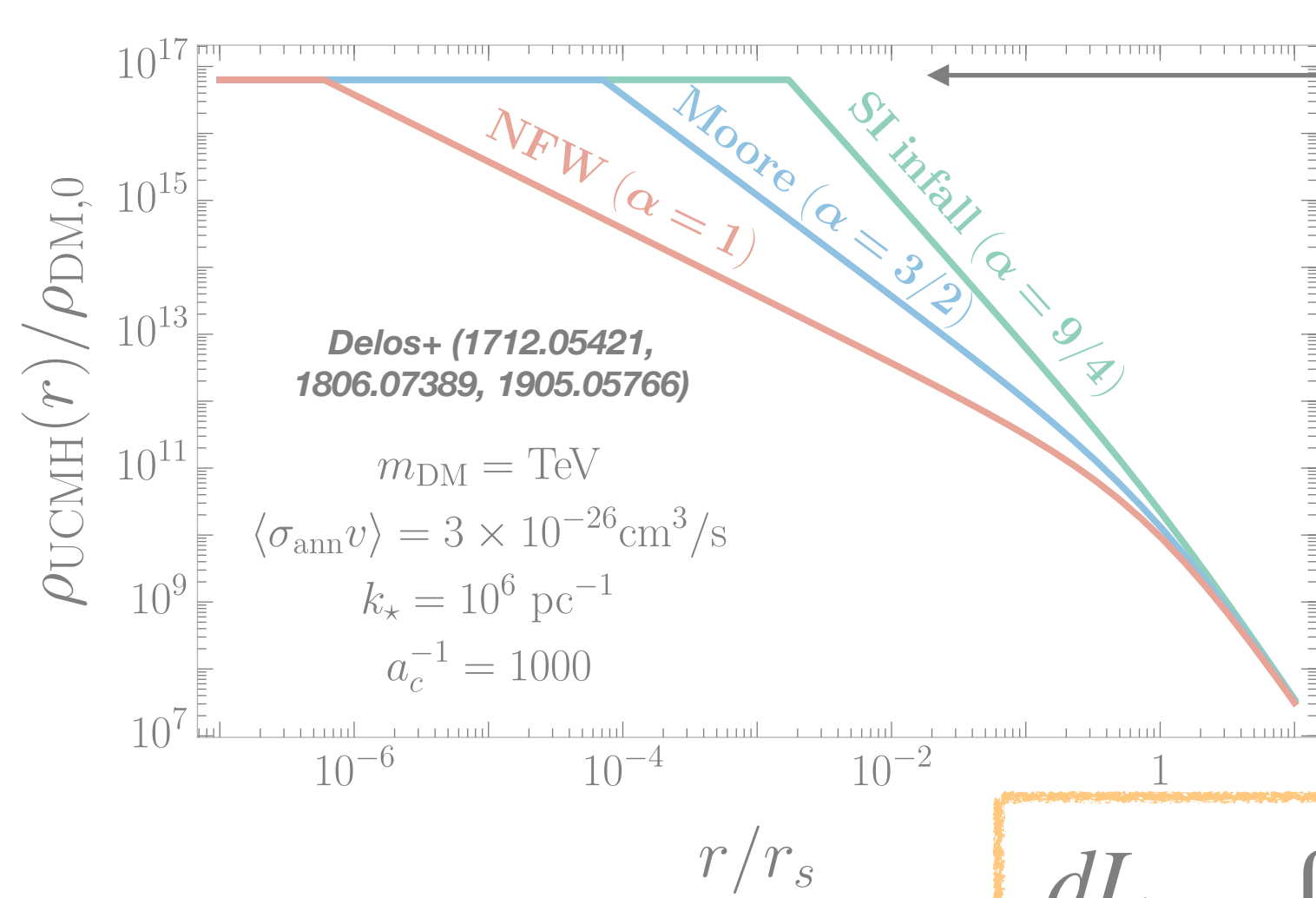
YG 2503.03857

$$\frac{d^2 \mathcal{F}_\gamma(\theta)}{d\Omega dE} = \int_0^\infty \frac{ds}{4\pi} \frac{\rho_{\text{DM}}(s, \theta)}{\bar{\rho}_{\text{DM},0}} \times \int_0^\infty da_c \int_0^\infty \frac{dR}{R} \frac{dn}{da_c} \times \frac{dL[(1+z_e)E, a_c, R]}{dE}$$

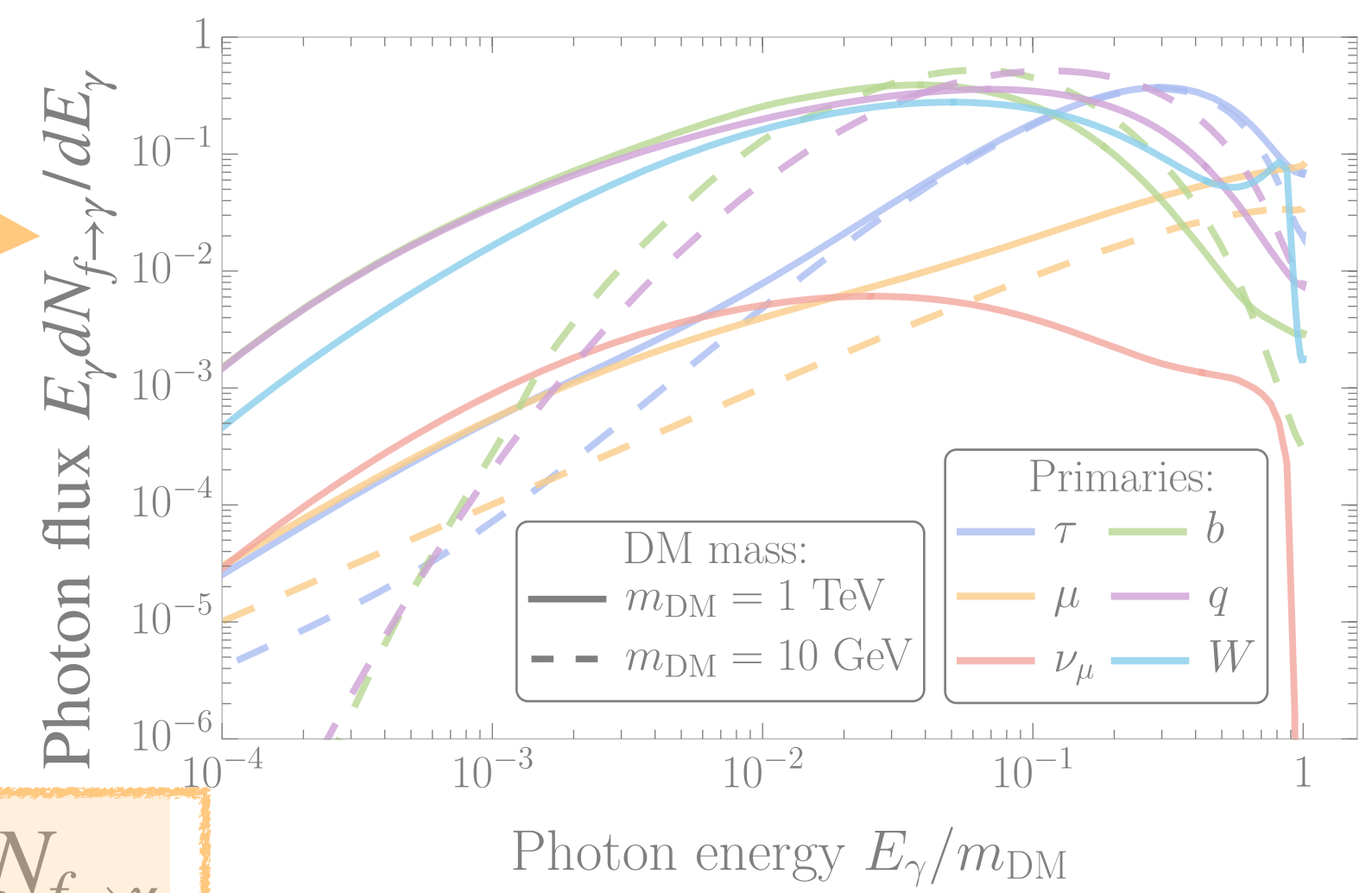
Press – Schechter theory

$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{v_c}{a_c} \exp\left(-\frac{v_c^2}{2}\right)$$

$$\rho_{\text{DM}}(s, \theta) = \rho_{\text{MW}} \left[\sqrt{s^2 + r_\odot^2 - 2r_\odot s \cos \theta} \right] + \frac{e^{-\tau(E, z_e)}}{(1+z_e)^3} \bar{\rho}_{\text{DM},0}$$



$$\rho_{\max} = \frac{m_{\text{DM}}}{\langle \sigma_{\text{ann}} v \rangle \times 13.8 \text{ Gyrs}}$$



$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

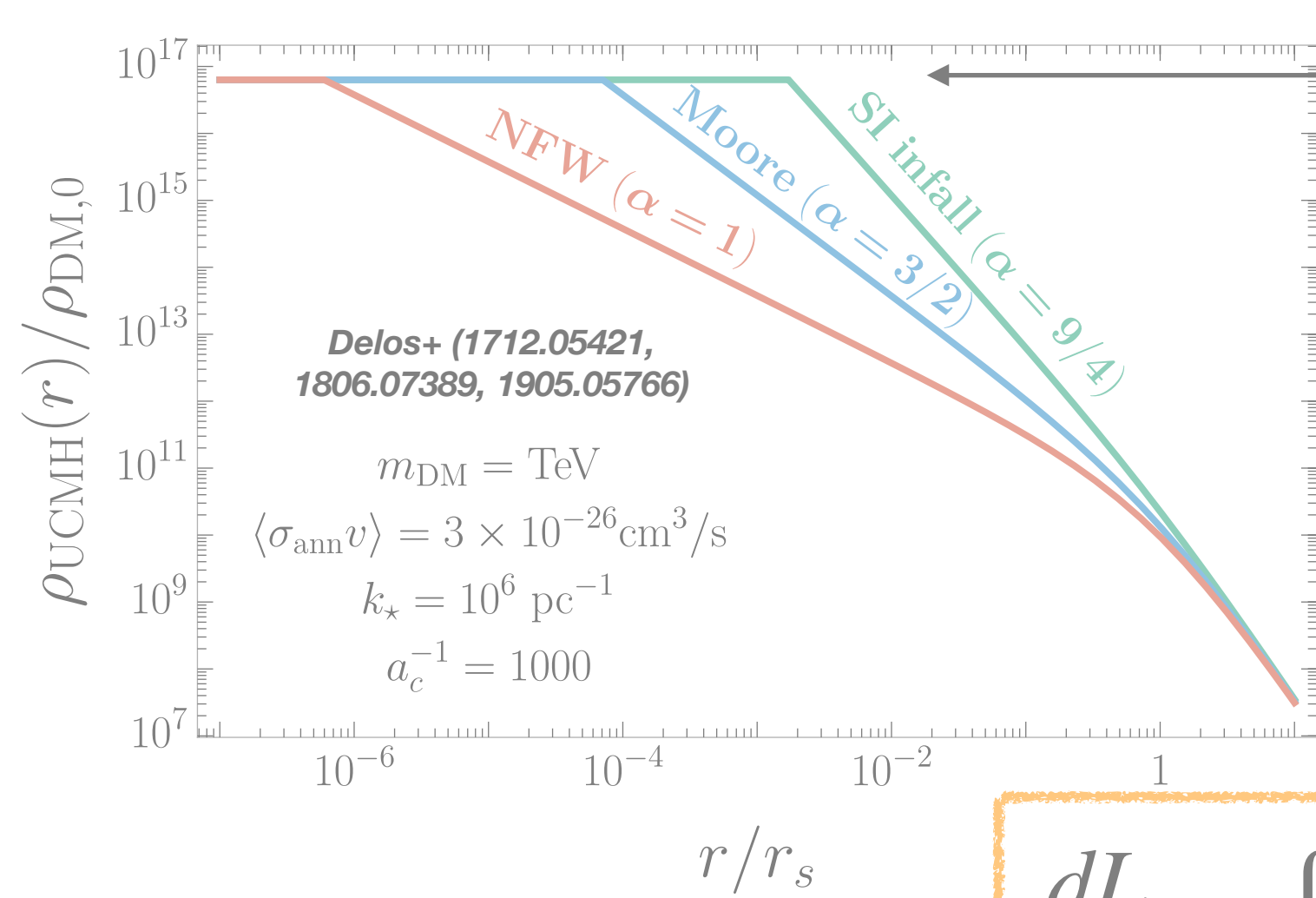
YG 2503.03857

$$\frac{d^2 \mathcal{F}_\gamma(\theta)}{d\Omega dE} = \int_0^\infty \frac{ds}{4\pi} \frac{\rho_{\text{DM}}(s, \theta)}{\bar{\rho}_{\text{DM},0}} \times \int_0^\infty da_c \int_0^\infty \frac{dR}{R} \frac{dn}{da_c} \times \frac{dL[(1+z_e)E, a_c, R]}{dE}$$

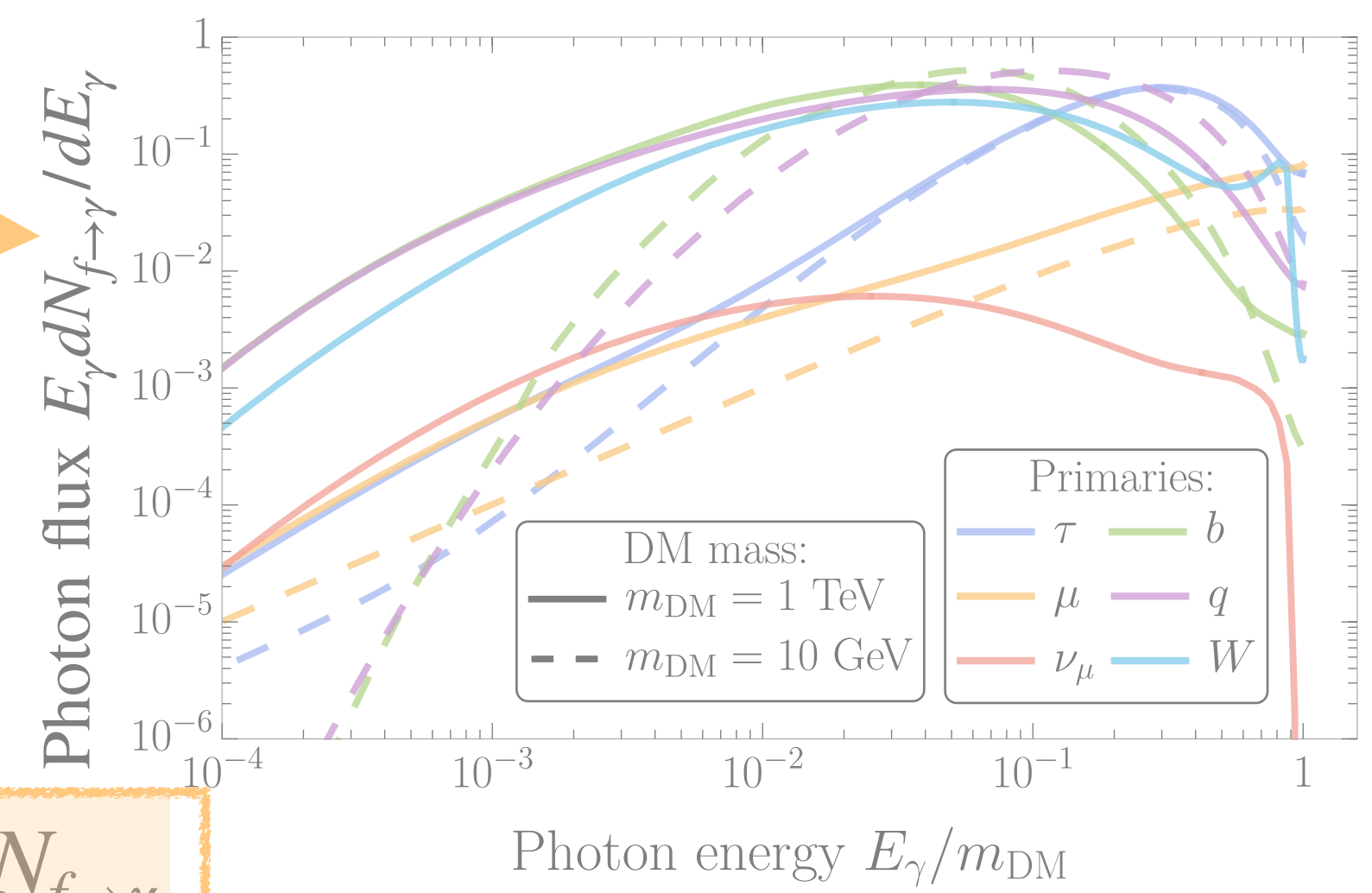
Press – Schechter theory

$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{\nu_c}{a_c} \exp\left(-\frac{\nu_c^2}{2}\right) \quad \nu_c \equiv \frac{\delta_{\min}(a_c)}{\sigma_0(R)}$$

$$\rho_{\text{DM}}(s, \theta) = \rho_{\text{MW}} \left[\sqrt{s^2 + r_\odot^2 - 2r_\odot s \cos \theta} \right] + \frac{e^{-\tau(E, z_e)}}{(1+z_e)^3} \bar{\rho}_{\text{DM},0}$$



$$\rho_{\text{max}} = \frac{m_{\text{DM}}}{\langle\sigma_{\text{ann}}v\rangle \times 13.8 \text{ Gyrs}}$$



$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle\sigma_f v\rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

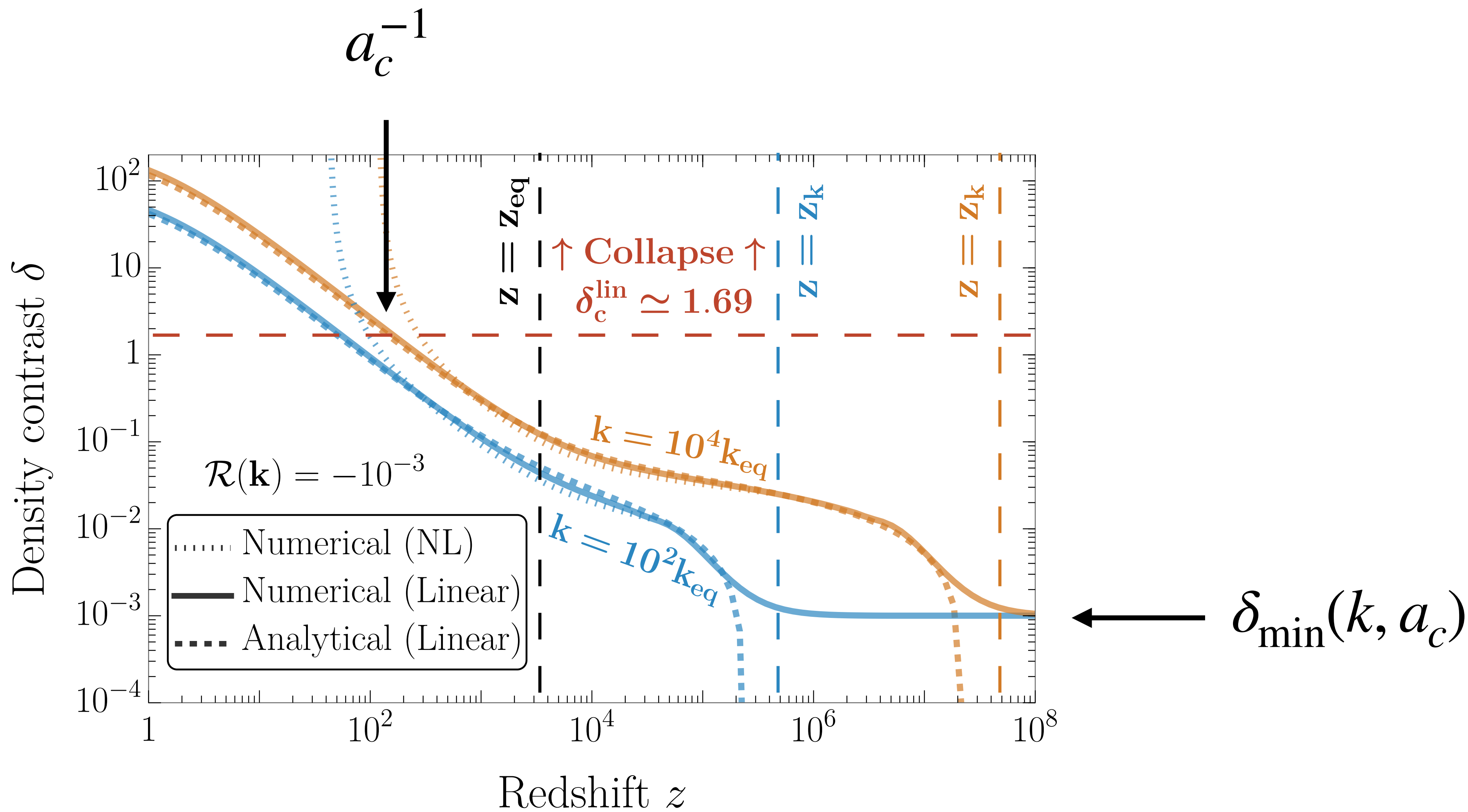
YG 2503.03857

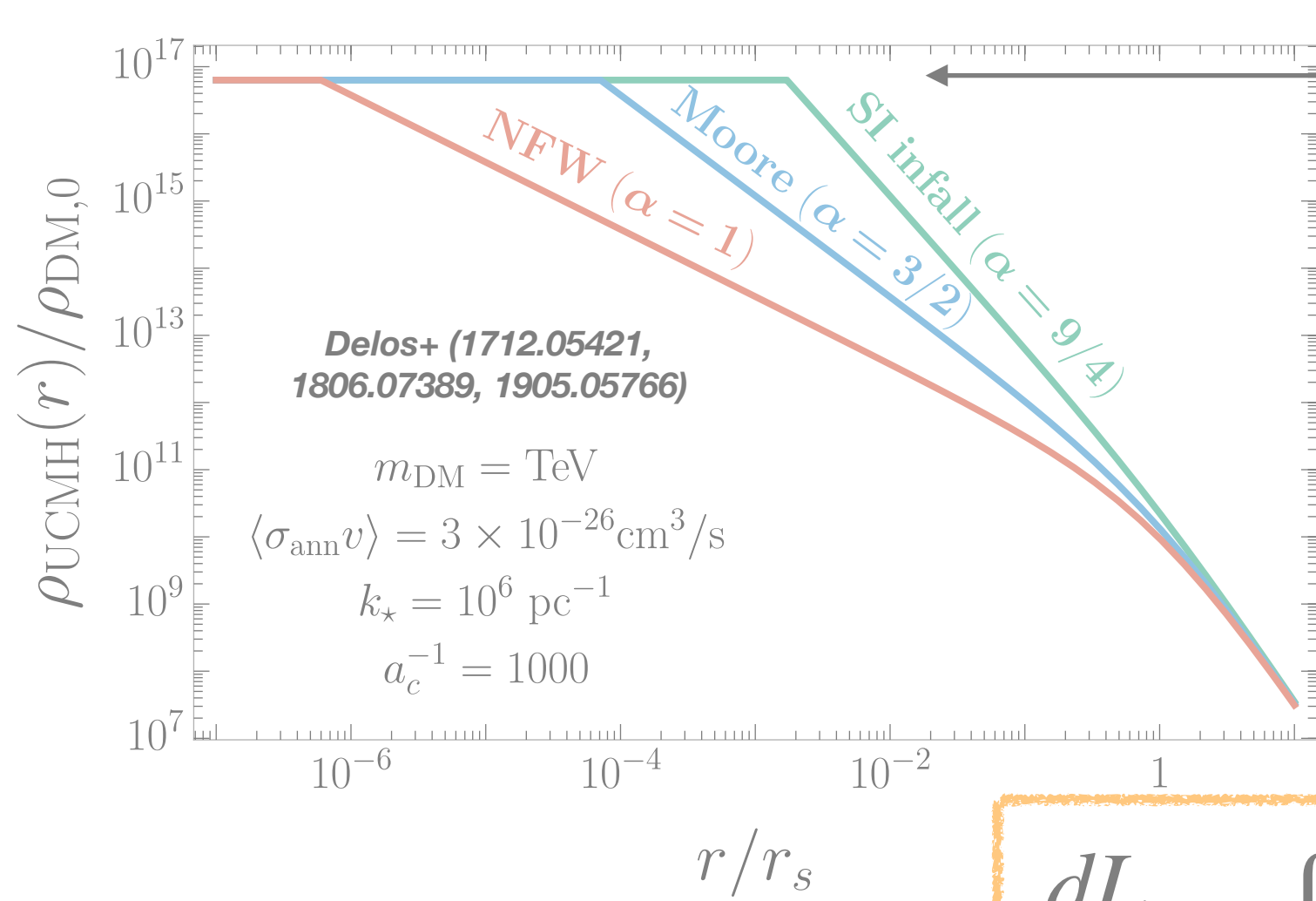
$$\frac{d^2 \mathcal{F}_\gamma(\theta)}{d\Omega dE} = \int_0^\infty \frac{ds}{4\pi} \frac{\rho_{\text{DM}}(s, \theta)}{\bar{\rho}_{\text{DM},0}} \times \int_0^\infty da_c \int_0^\infty \frac{dR}{R} \frac{dn}{da_c} \times \frac{dL[(1+z_e)E, a_c, R]}{dE}$$

Press – Schechter theory

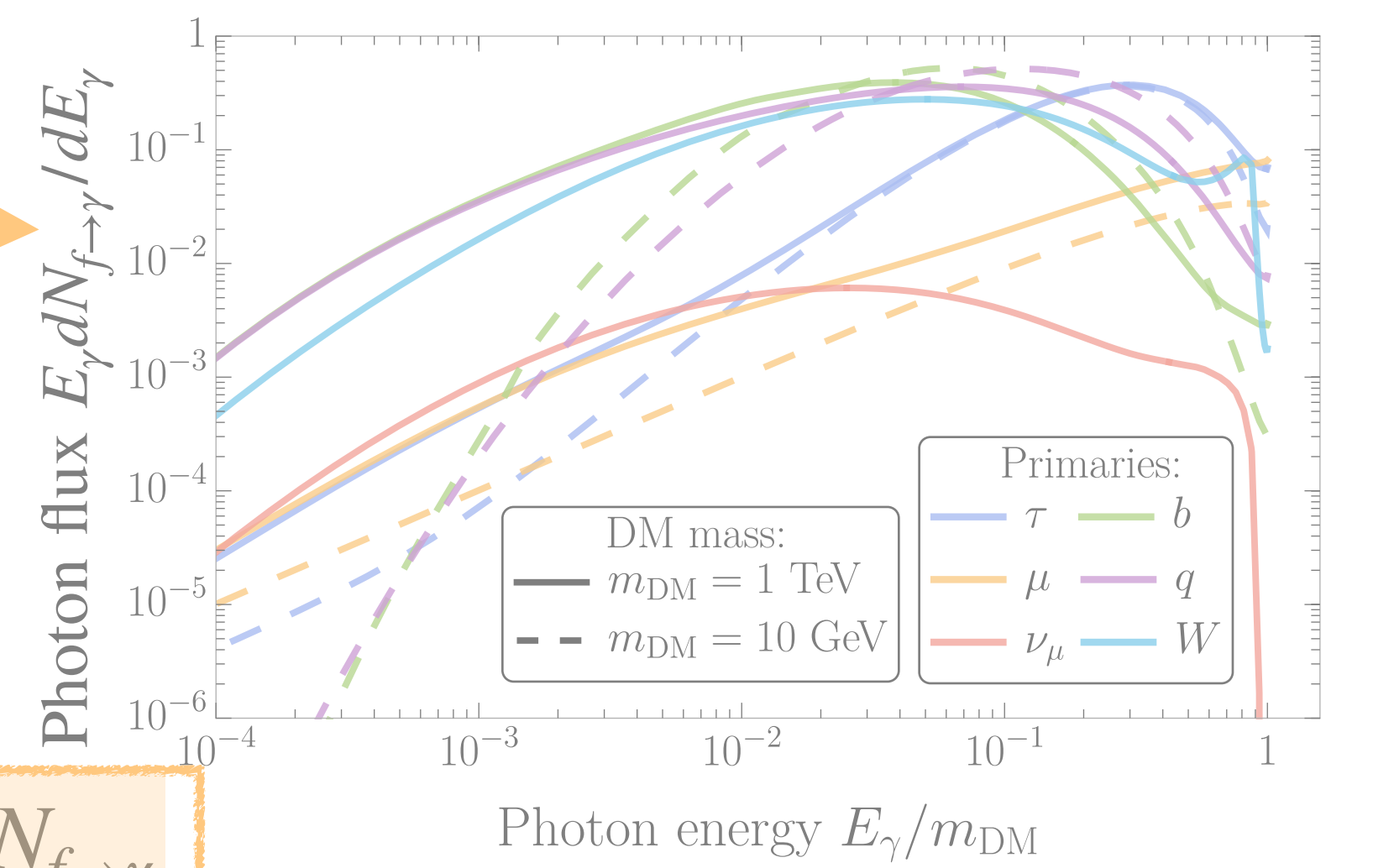
$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{v_c}{a_c} \exp\left(-\frac{v_c^2}{2}\right) \quad v_c \equiv \frac{\delta_{\text{min}}(a_c)}{\sigma_0(R)} \quad \delta_{\text{min}} \simeq 10^{-4} \frac{a_c^{-1}}{100}$$

$$\rho_{\text{DM}}(s, \theta) = \rho_{\text{MW}} \left[\sqrt{s^2 + r_\odot^2 - 2r_\odot s \cos \theta} \right] + \frac{e^{-\tau(E, z_e)}}{(1+z_e)^3} \bar{\rho}_{\text{DM},0}$$





$$\rho_{\text{max}} = \frac{m_{\text{DM}}}{\langle\sigma_{\text{ann}}v\rangle \times 13.8 \text{ Gyrs}}$$



$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle\sigma_f v\rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

YG 2503.03857

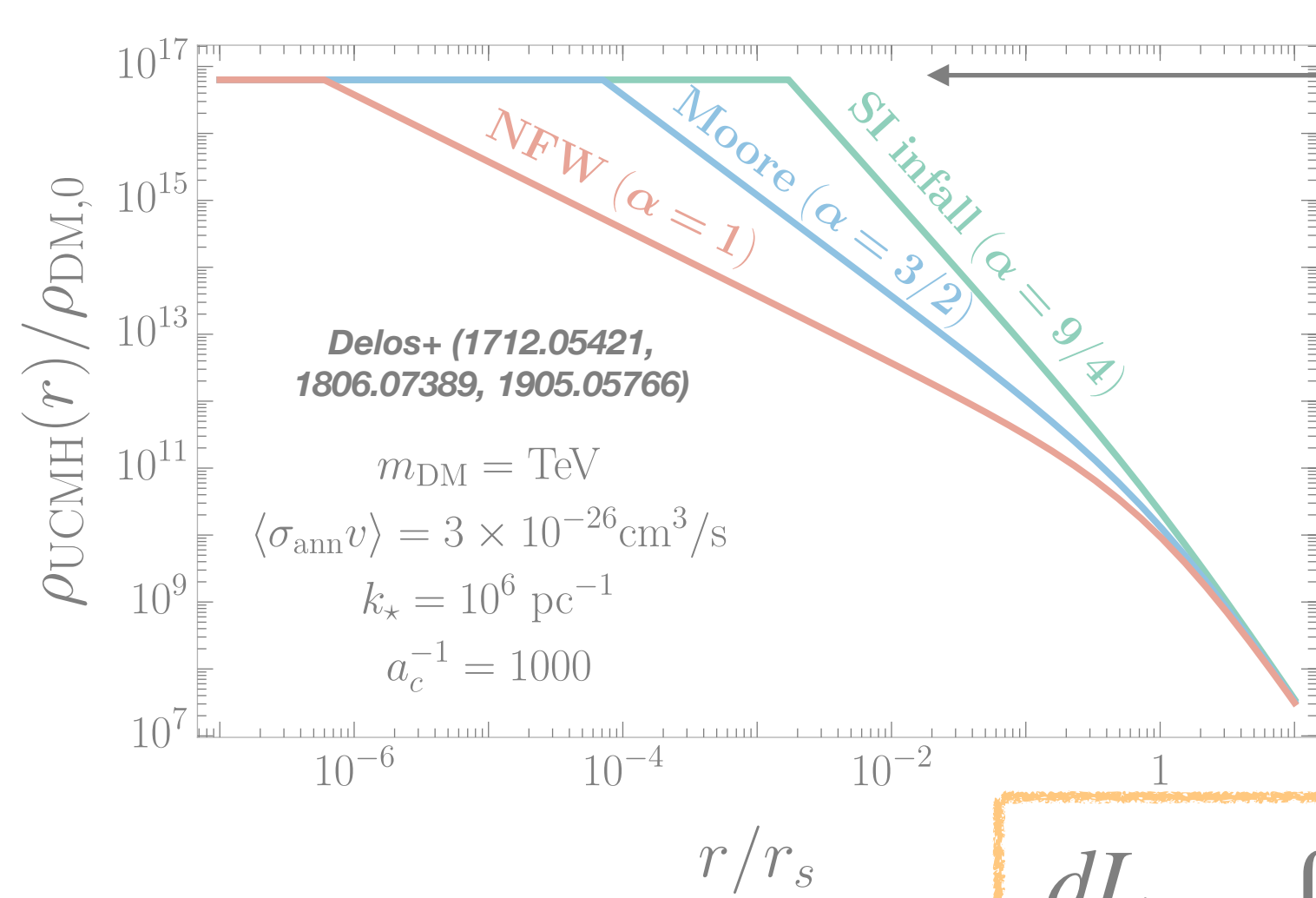
$$\frac{d^2 \mathcal{F}_\gamma(\theta)}{d\Omega dE} = \int_0^\infty \frac{ds}{4\pi} \frac{\rho_{\text{DM}}(s, \theta)}{\bar{\rho}_{\text{DM},0}} \times \int_0^\infty da_c \int_0^\infty \frac{dR}{R} \frac{dn}{da_c} \times \frac{dL[(1+z_e)E, a_c, R]}{dE}$$

Press – Schechter theory

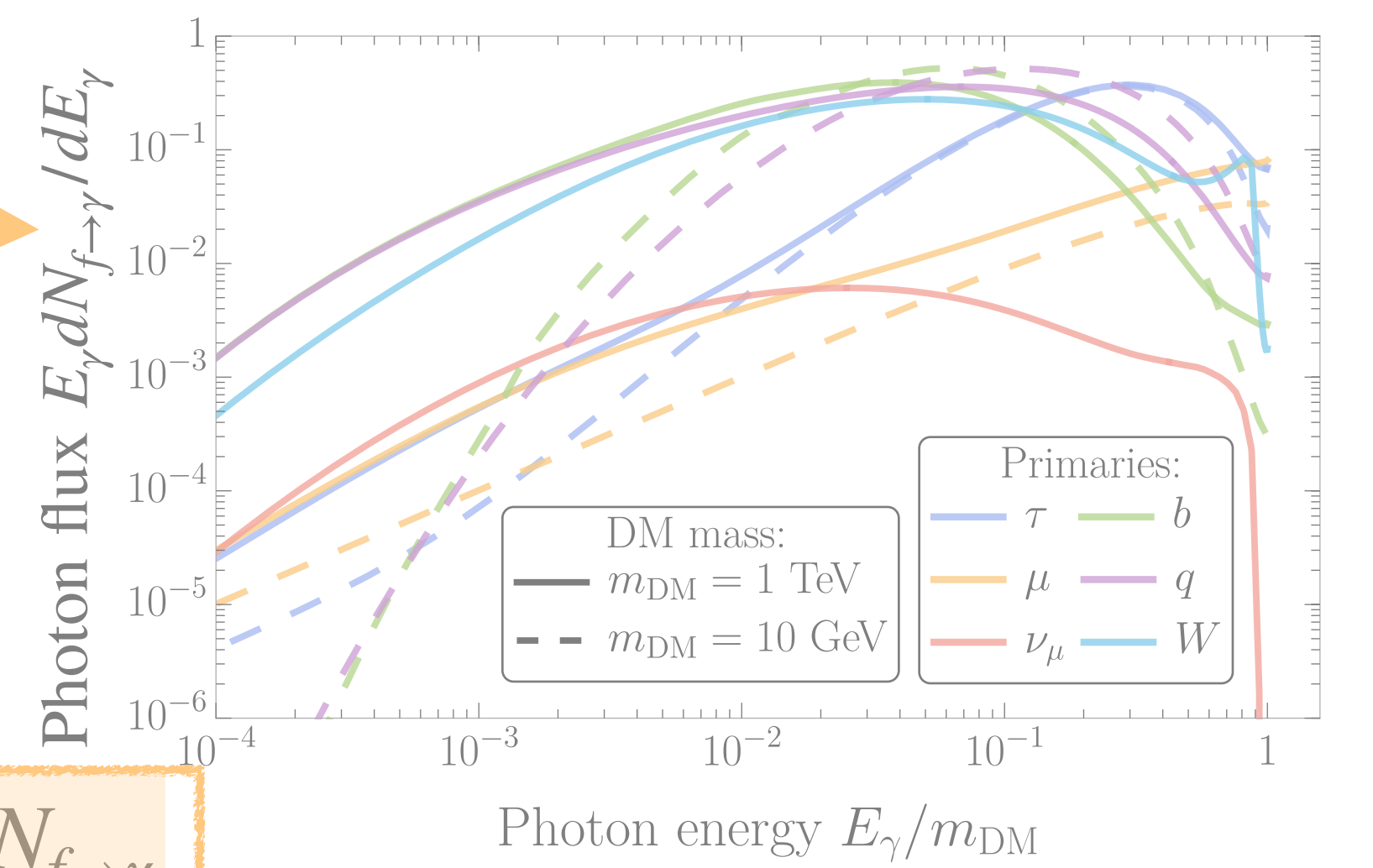
$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{\nu_c}{a_c} \exp\left(-\frac{\nu_c^2}{2}\right) \quad \nu_c \equiv \frac{\delta_{\text{min}}(a_c)}{\sigma_0(R)} \quad \delta_{\text{min}} \simeq 10^{-4} \frac{a_c^{-1}}{100}$$

$$\sigma_0^2(R) = \frac{16}{81} \int_0^\infty \frac{dk}{k} \tilde{W}(k, R)^2 (kR)^4 T(k, R)^2 \mathcal{P}_{\mathcal{R}}(k, t_H)$$

$$\rho_{\text{DM}}(s, \theta) = \rho_{\text{MW}} \left[\sqrt{s^2 + r_\odot^2 - 2r_\odot s \cos \theta} \right] + \frac{e^{-\tau(E, z_e)}}{(1+z_e)^3} \bar{\rho}_{\text{DM},0}$$



$$\rho_{\max} = \frac{m_{\text{DM}}}{\langle \sigma_{\text{ann}} v \rangle \times 13.8 \text{ Gyrs}}$$



$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle \sigma_f v \rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

YG 2503.03857

$$\frac{d^2 \mathcal{F}_\gamma(\theta)}{d\Omega dE} = \int_0^\infty \frac{ds}{4\pi} \frac{\rho_{\text{DM}}(s, \theta)}{\bar{\rho}_{\text{DM},0}} \times \int_0^\infty da_c \int_0^\infty \frac{dR}{R} \frac{dn}{da_c} \times \frac{dL[(1+z_e)E, a_c, R]}{dE}$$

Press – Schechter theory

$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{\nu_c}{a_c} \exp\left(-\frac{\nu_c^2}{2}\right) \quad \nu_c \equiv \frac{\delta_{\min}(a_c)}{\sigma_0(R)} \quad \delta_{\min} \simeq 10^{-4} \frac{a_c^{-1}}{100}$$

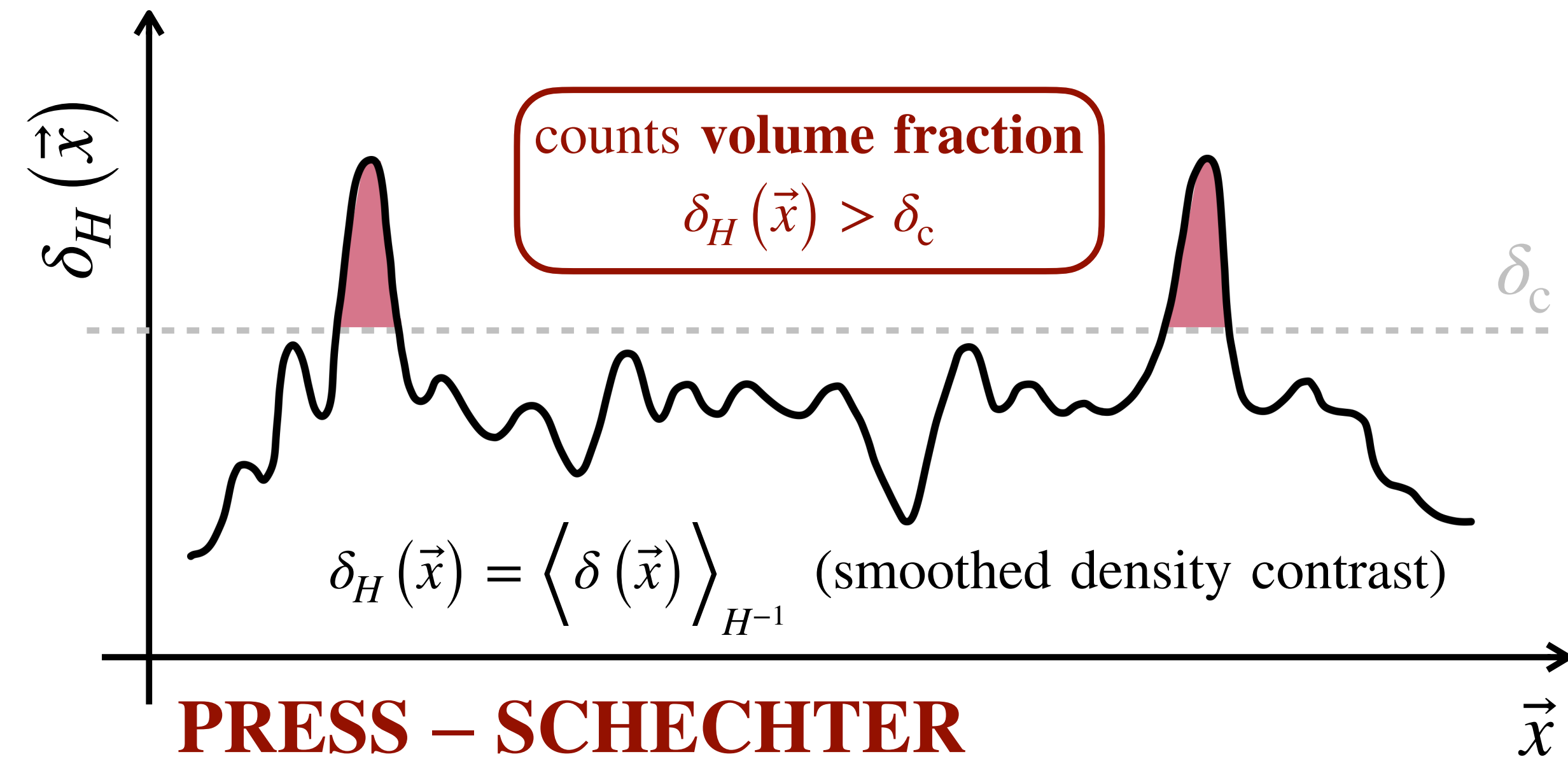
$$\sigma_0^2(R) = \frac{16}{81} \int_0^\infty \frac{dk}{k} \tilde{W}(k, R)^2 (kR)^4 T(k, R)^2 \mathcal{P}_{\mathcal{R}}(k, t_H)$$

$$\rho_{\text{DM}}(s, \theta) = \rho_{\text{MW}} \left[\sqrt{s^2 + r_\odot^2 - 2r_\odot s \cos \theta} \right] + \frac{e^{-\tau(E, z_e)}}{(1+z_e)^3} \bar{\rho}_{\text{DM},0}$$

Press – Schechter theory

$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{\nu_c}{a_c} \exp\left(-\frac{\nu_c^2}{2}\right) \quad \nu_c \equiv \frac{\delta_{\min}(a_c)}{\sigma_0(R)} \quad \delta_{\min} \simeq 10^{-4} \frac{a_c^{-1}}{100}$$

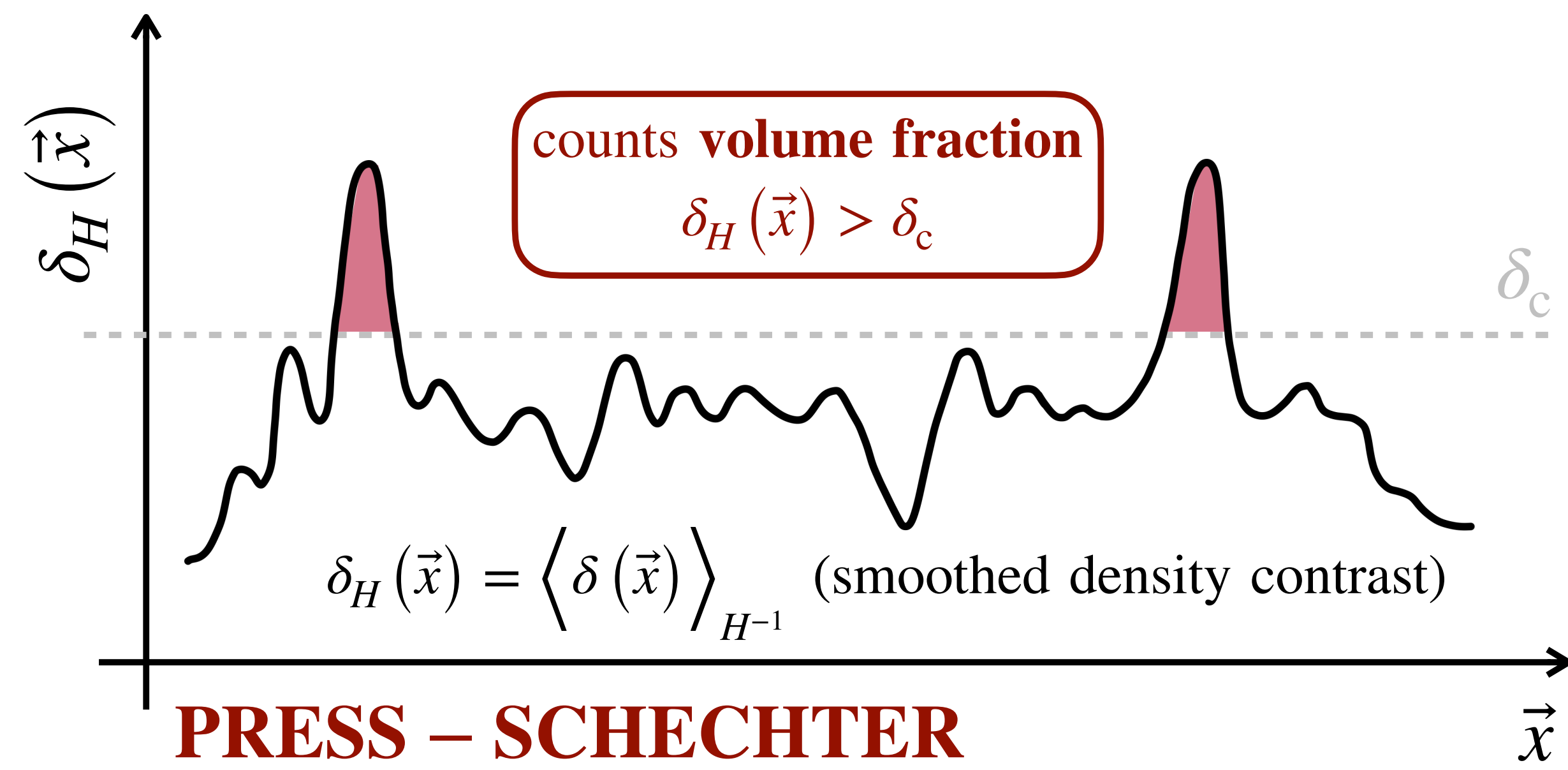
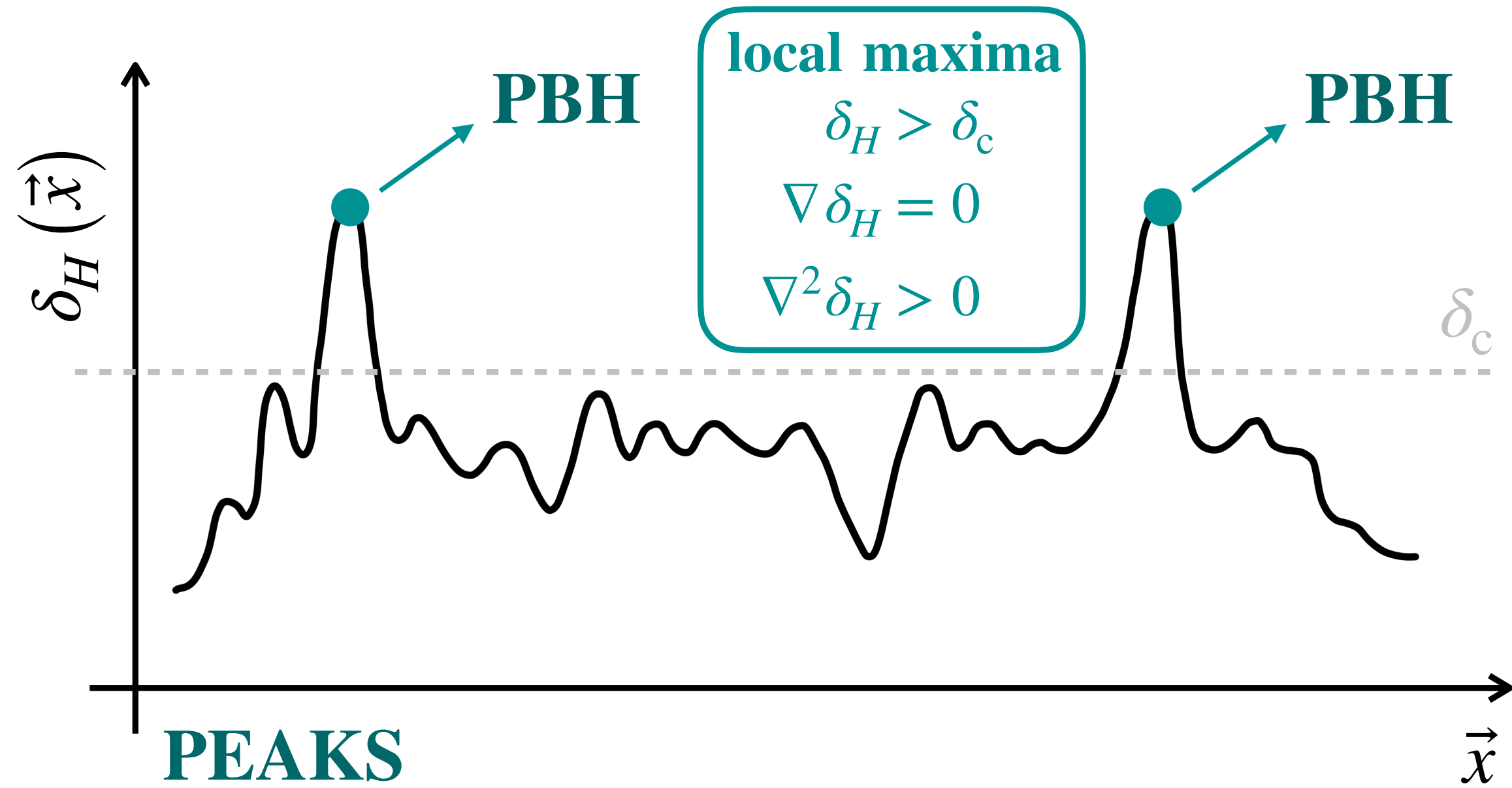
$$\sigma_0^2(R) = \frac{16}{81} \int_0^\infty \frac{dk}{k} \tilde{W}(k, R)^2 (kR)^4 T(k, R)^2 \mathcal{P}_{\mathcal{R}}(k, t_H)$$



Press – Schechter theory

$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{\nu_c}{a_c} \exp\left(-\frac{\nu_c^2}{2}\right) \quad \nu_c \equiv \frac{\delta_{\min}(a_c)}{\sigma_0(R)} \quad \delta_{\min} \simeq 10^{-4} \frac{a_c^{-1}}{100}$$

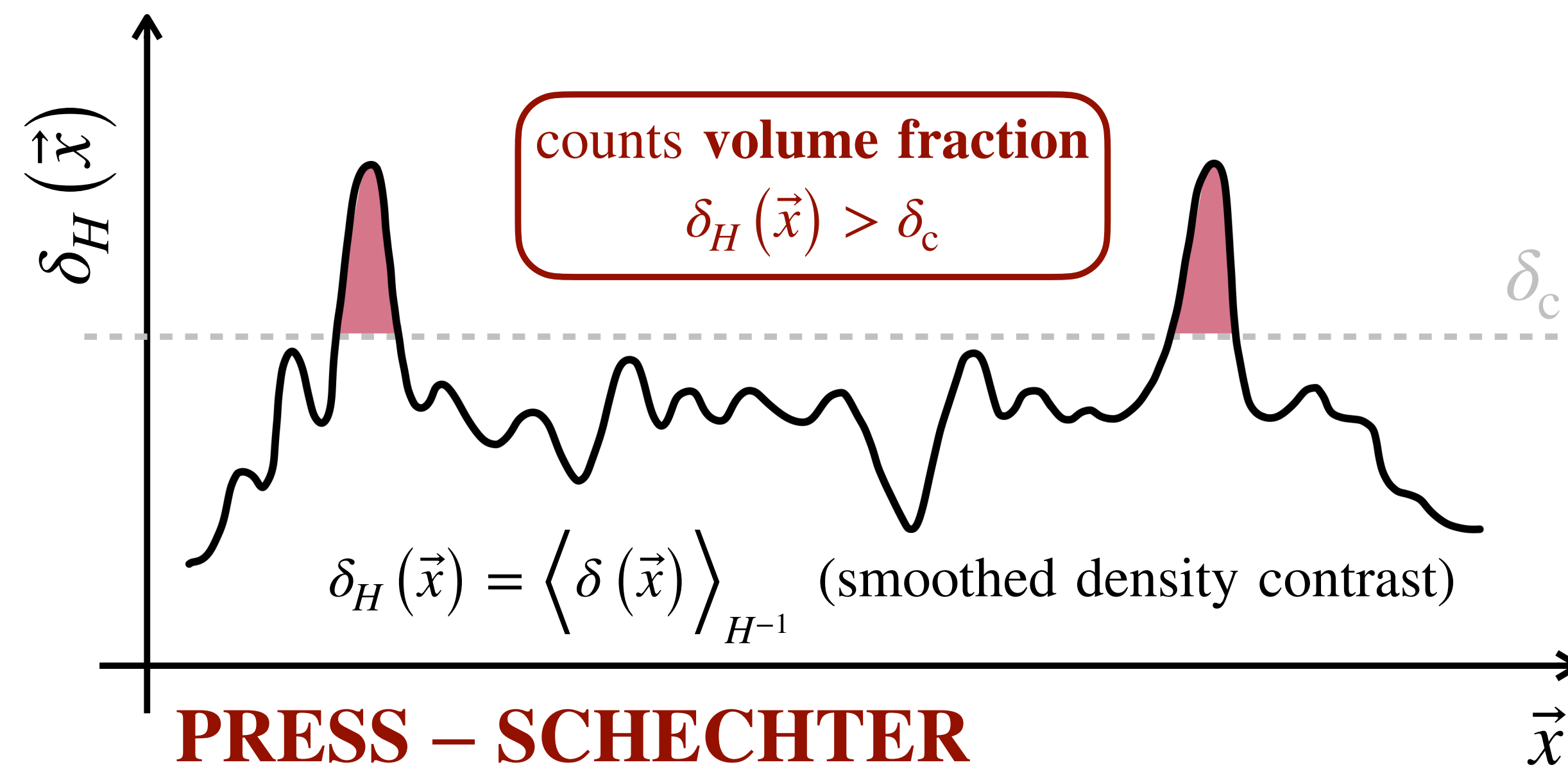
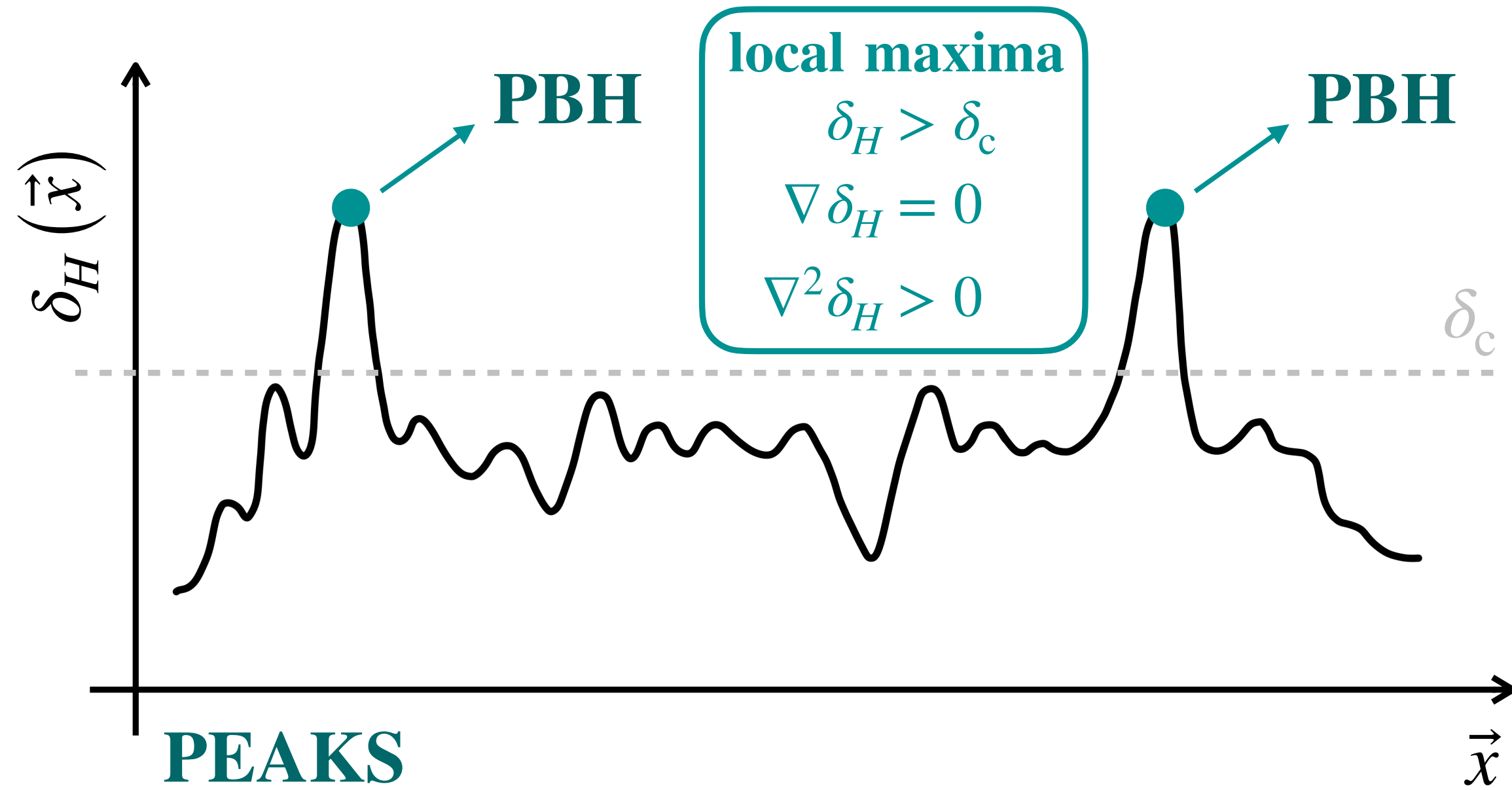
$$\sigma_0^2(R) = \frac{16}{81} \int_0^\infty \frac{dk}{k} \tilde{W}(k, R)^2 (kR)^4 T(k, R)^2 \mathcal{P}_{\mathcal{R}}(k, t_H)$$



Press – Schechter theory

$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{\nu_c}{a_c} \exp\left(-\frac{\nu_c^2}{2}\right) \quad \nu_c \equiv \frac{\delta_{\min}(a_c)}{\sigma_0(R)} \quad \delta_{\min} \simeq 10^{-4} \frac{a_c^{-1}}{100}$$

$$\sigma_0^2(R) = \frac{16}{81} \int_0^\infty \frac{dk}{k} \tilde{W}(k, R)^2 (kR)^4 T(k, R)^2 \mathcal{P}_{\mathcal{R}}(k, t_H)$$



Peak theory

PBHs collapse around peaks:

1. Peak height

$$\delta_{\text{th}}, \sigma_0$$

2. Peak shape

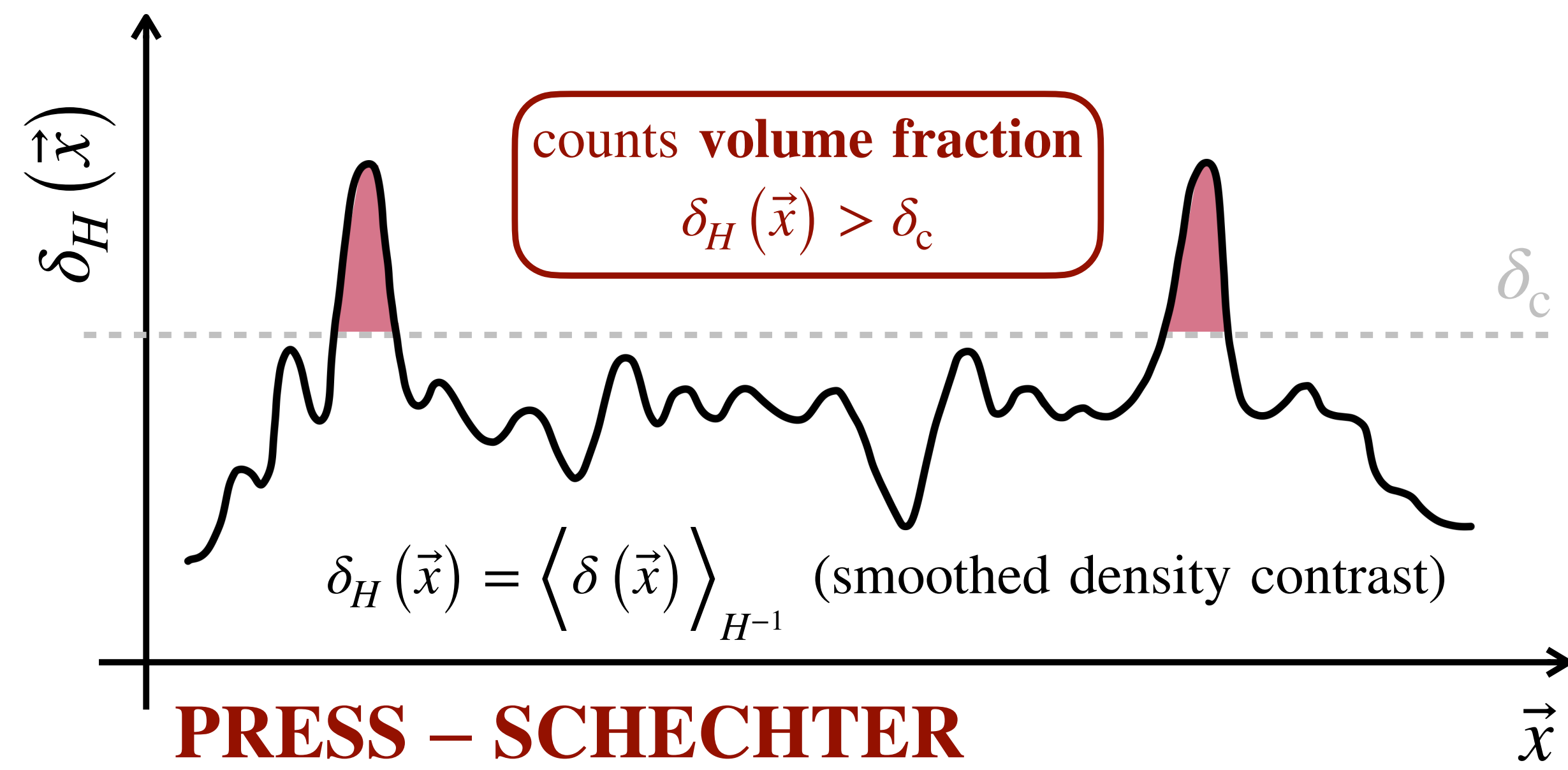
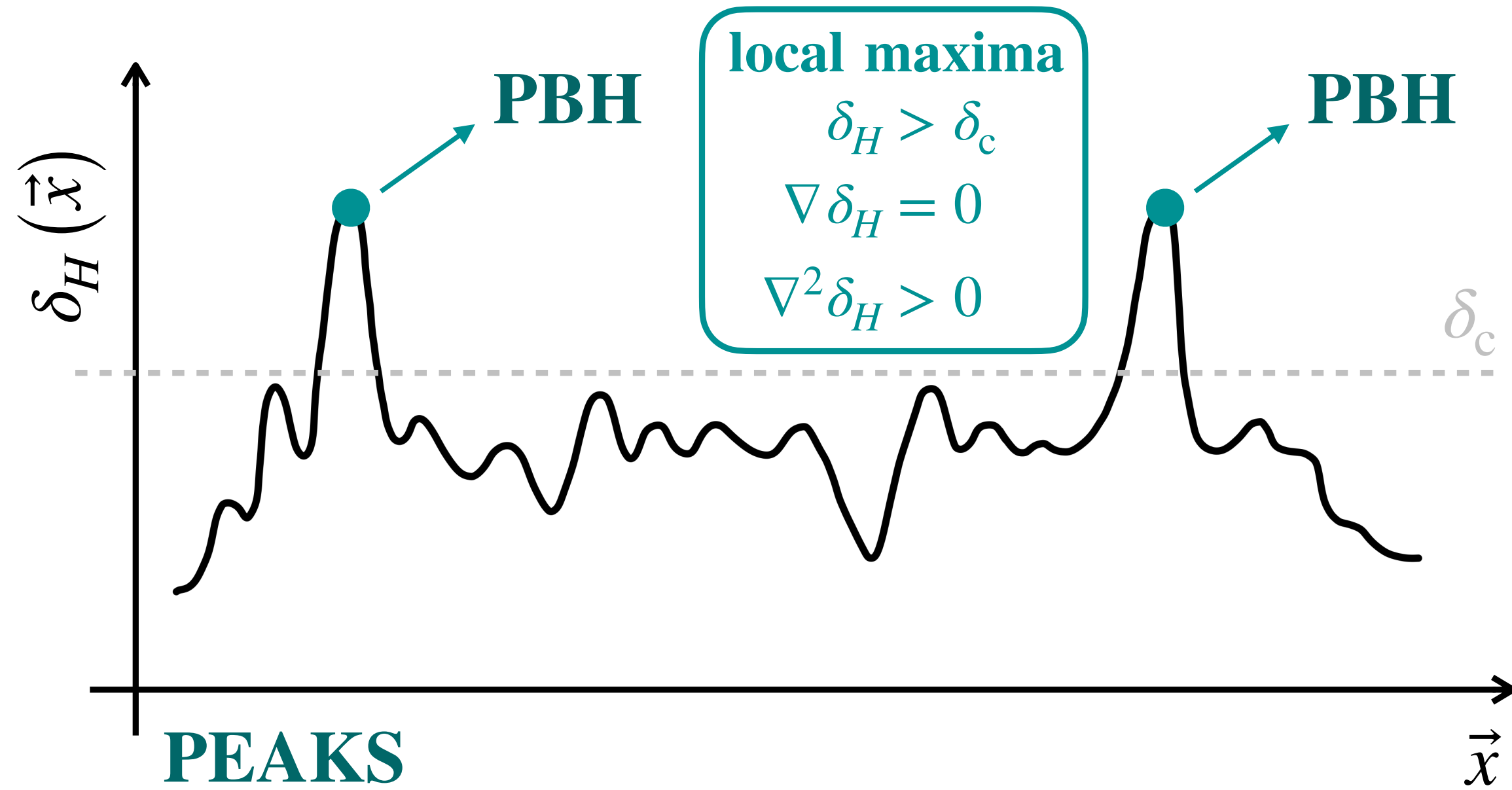
$$\sigma_j \sim \langle k^{2j} \delta^2(k) \rangle$$

Press – Schechter theory

$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{\nu_c}{a_c} \exp\left(-\frac{\nu_c^2}{2}\right)$$

$$\nu_c \equiv \frac{\delta_{\text{min}}(a_c)}{\sigma_0(R)} \quad \delta_{\text{min}} \simeq 10^{-4} \frac{a_c^{-1}}{100}$$

$$\sigma_0^2(R) = \frac{16}{81} \int_0^\infty \frac{dk}{k} \tilde{W}(k, R)^2 (kR)^4 T(k, R)^2 \mathcal{P}_{\mathcal{R}}(k, t_H)$$



Peak theory

Press - Schechter theory

PBHs collapse around peaks:

1. Peak height

2. Peak shape

$$\delta_{\text{th}}, \sigma_0$$

$$\sigma_j \sim \langle k^{2j} \delta^2(k) \rangle$$

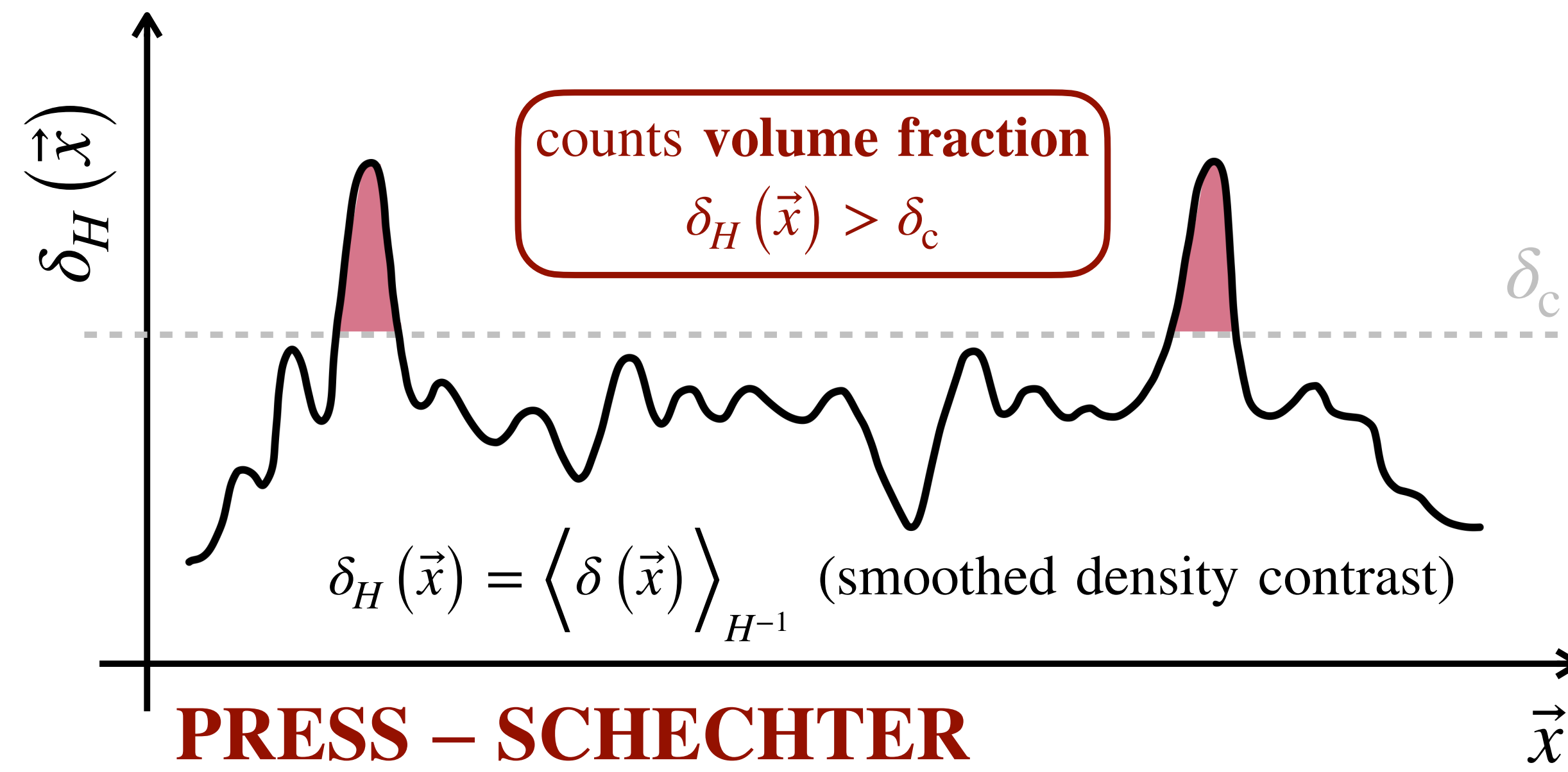
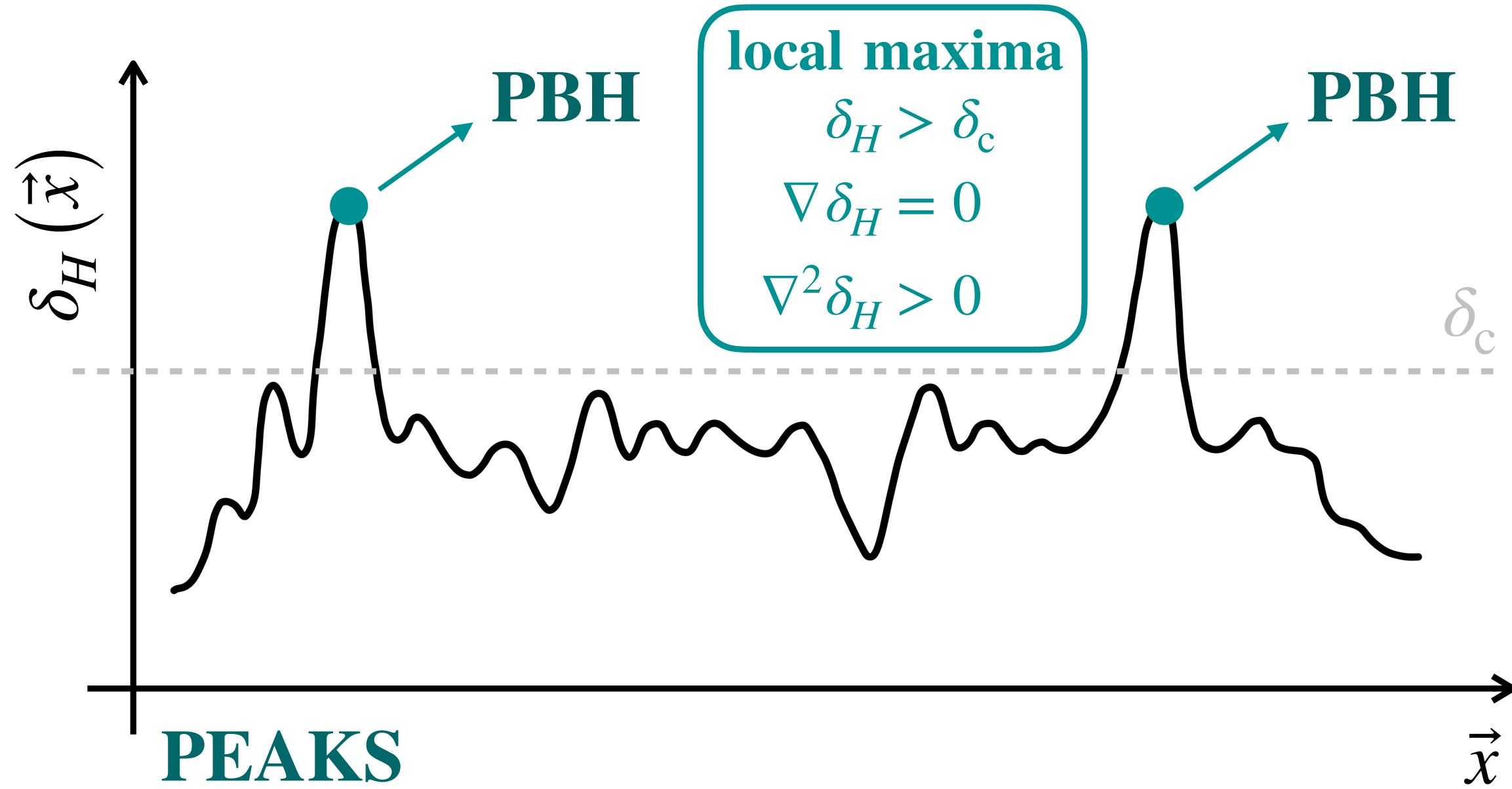
High peak limit:

$$\frac{dn(R, a_c)}{da_c} \simeq \frac{R^{-3}}{3\pi} \left(\frac{\sigma_1}{\sqrt{3}\sigma_0} \right)^3 \nu_c^3 \exp\left(-\frac{\nu_c^2}{2}\right)$$

$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{\nu_c}{a_c} \exp\left(-\frac{\nu_c^2}{2}\right)$$

$$\nu_c \equiv \frac{\delta_{\text{min}}(a_c)}{\sigma_0(R)} \quad \delta_{\text{min}} \simeq 10^{-4} \frac{a_c^{-1}}{100}$$

$$\sigma_0^2(R) = \frac{16}{81} \int_0^\infty \frac{dk}{k} \tilde{W}(k, R)^2 (kR)^4 T(k, R)^2 \mathcal{P}_{\mathcal{R}}(k, t_H)$$



Peak theory

Press – Schechter theory

PBHs collapse around peaks:

1. Peak high

2. Peak shape

$$\delta_{\text{th}}, \sigma_0$$

$$\sigma_j \sim \langle k^{2j} \delta^2(k) \rangle$$

High peak limit:

$$\frac{dn(R, a_c)}{da_c} \simeq \frac{R^{-3}}{3\pi} \left(\frac{\sigma_1}{\sqrt{3}\sigma_0} \right)^3 \nu_c^3 \exp\left(-\frac{\nu_c^2}{2}\right)$$

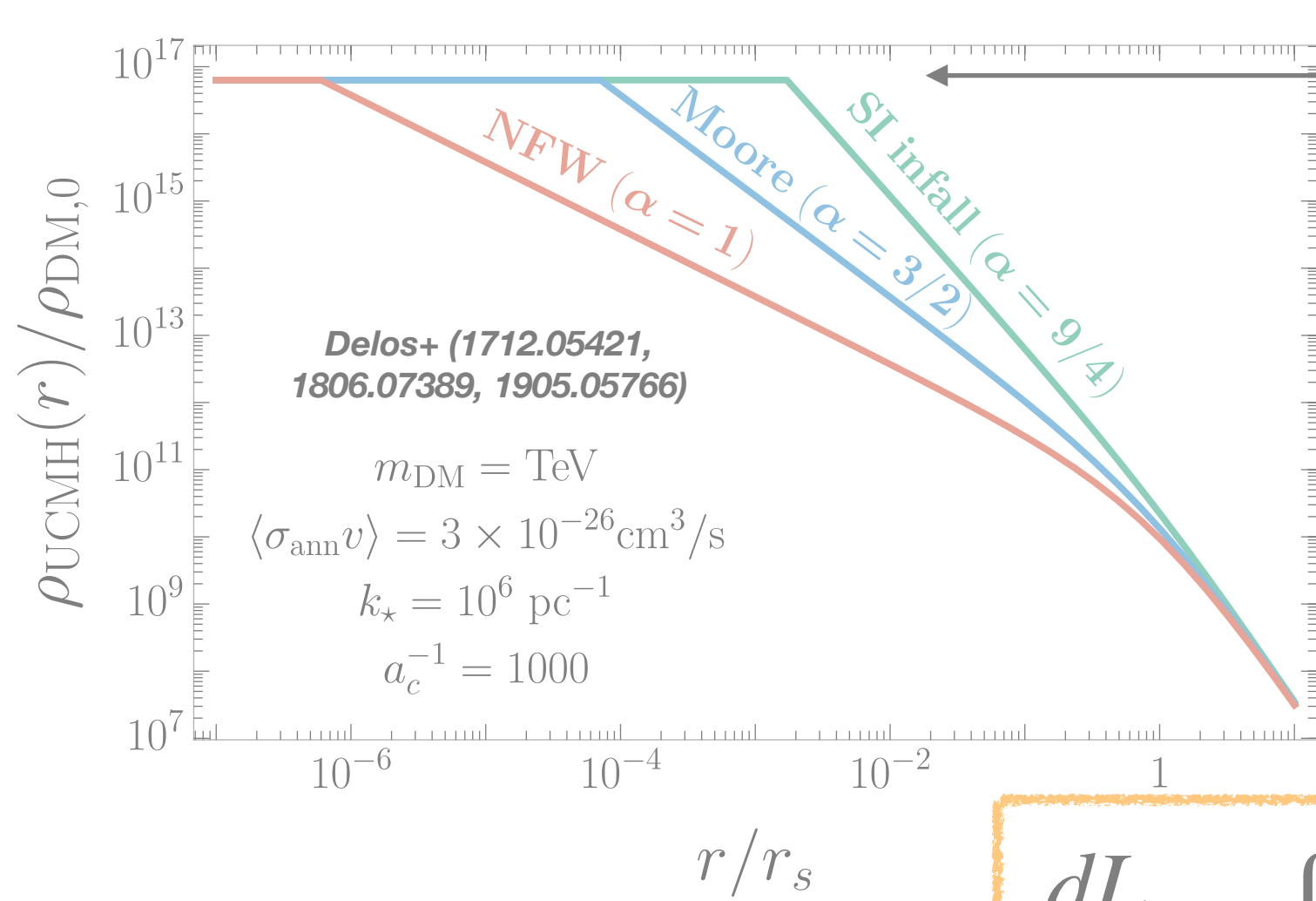
$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{\nu_c}{a_c} \exp\left(-\frac{\nu_c^2}{2}\right)$$

$$\nu_c \equiv \frac{\delta_{\text{min}}(a_c)}{\sigma_0(R)} \quad \delta_{\text{min}} \simeq 10^{-4} \frac{a_c^{-1}}{100}$$

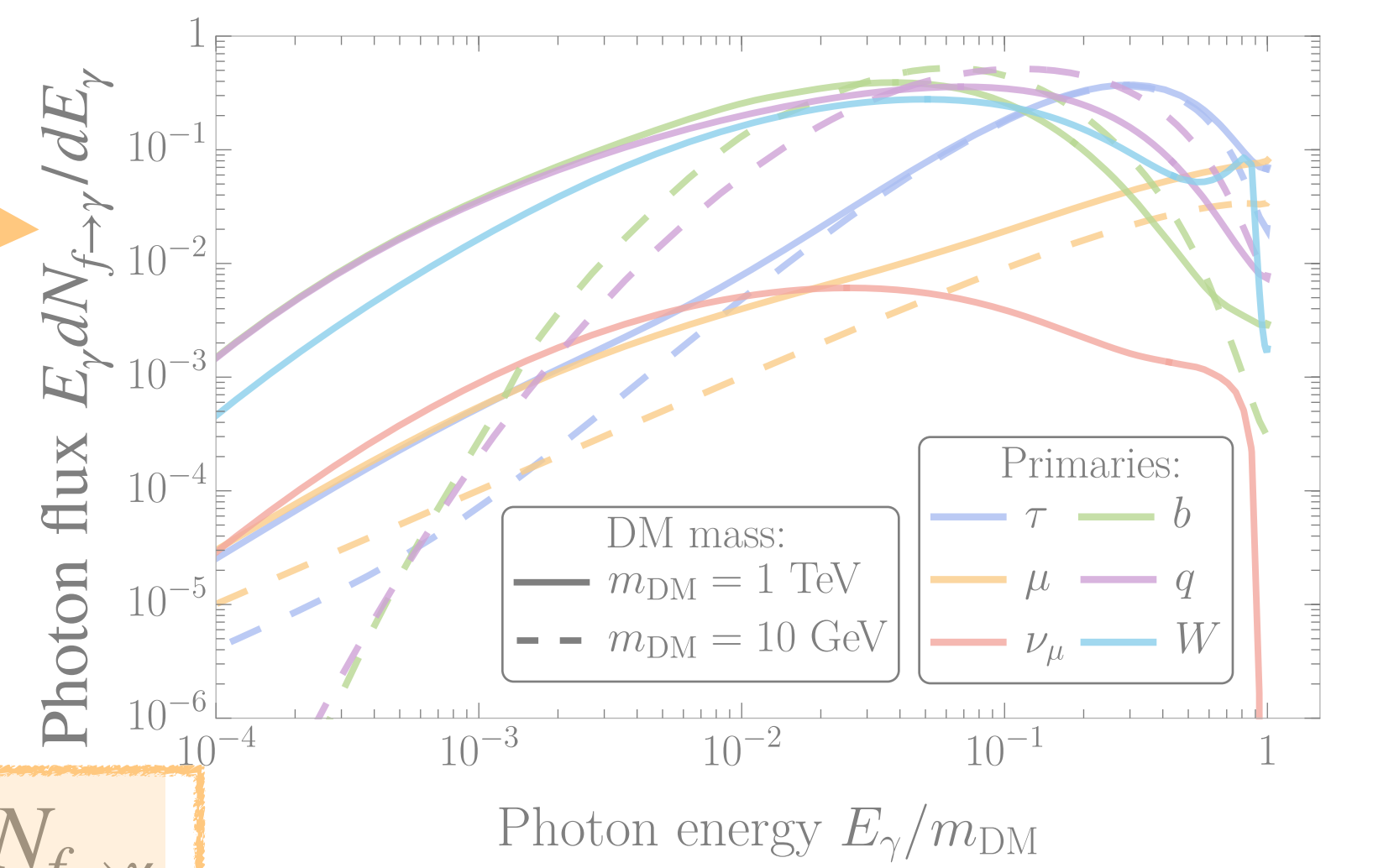
$$\sigma_0^2(R) = \frac{16}{81} \int_0^\infty \frac{dk}{k} \tilde{W}(k, R)^2 (kR)^4 T(k, R)^2 \mathcal{P}_{\mathcal{R}}(k, t_H)$$

$$T(k, R) \rightarrow T(k, R) \times \exp\left[-\frac{1}{2} \left(\frac{k}{k_D}\right)^2\right]$$

$$k_D \simeq \frac{1.7 \times 10^8}{\text{Mpc}} \left(\frac{m_{\text{DM}}}{1 \text{ TeV}}\right)^{1/2} \left(\frac{T_{\text{KD}}}{30 \text{ MeV}}\right)^{1/2}$$



$$\rho_{\text{max}} = \frac{m_{\text{DM}}}{\langle\sigma_{\text{ann}}v\rangle \times 13.8 \text{ Gyrs}}$$



$$\frac{dL}{dE} = \int_0^R 4\pi r^2 dr \frac{1}{2} \left(\frac{\rho_{\text{UCMH}}(r, a_c)}{m_{\text{DM}}} \right)^2 \sum_f \langle\sigma_f v\rangle \frac{dN_{f \rightarrow \gamma}}{dE}$$

YG 2503.03857

$$\frac{d^2 \mathcal{F}_\gamma(\theta)}{d\Omega dE} = \int_0^\infty \frac{ds}{4\pi} \frac{\rho_{\text{DM}}(s, \theta)}{\bar{\rho}_{\text{DM},0}} \times \int_0^\infty da_c \int_0^\infty \frac{dR}{R} \frac{dn}{da_c} \times \frac{dL[(1+z_e)E, a_c, R]}{dE}$$

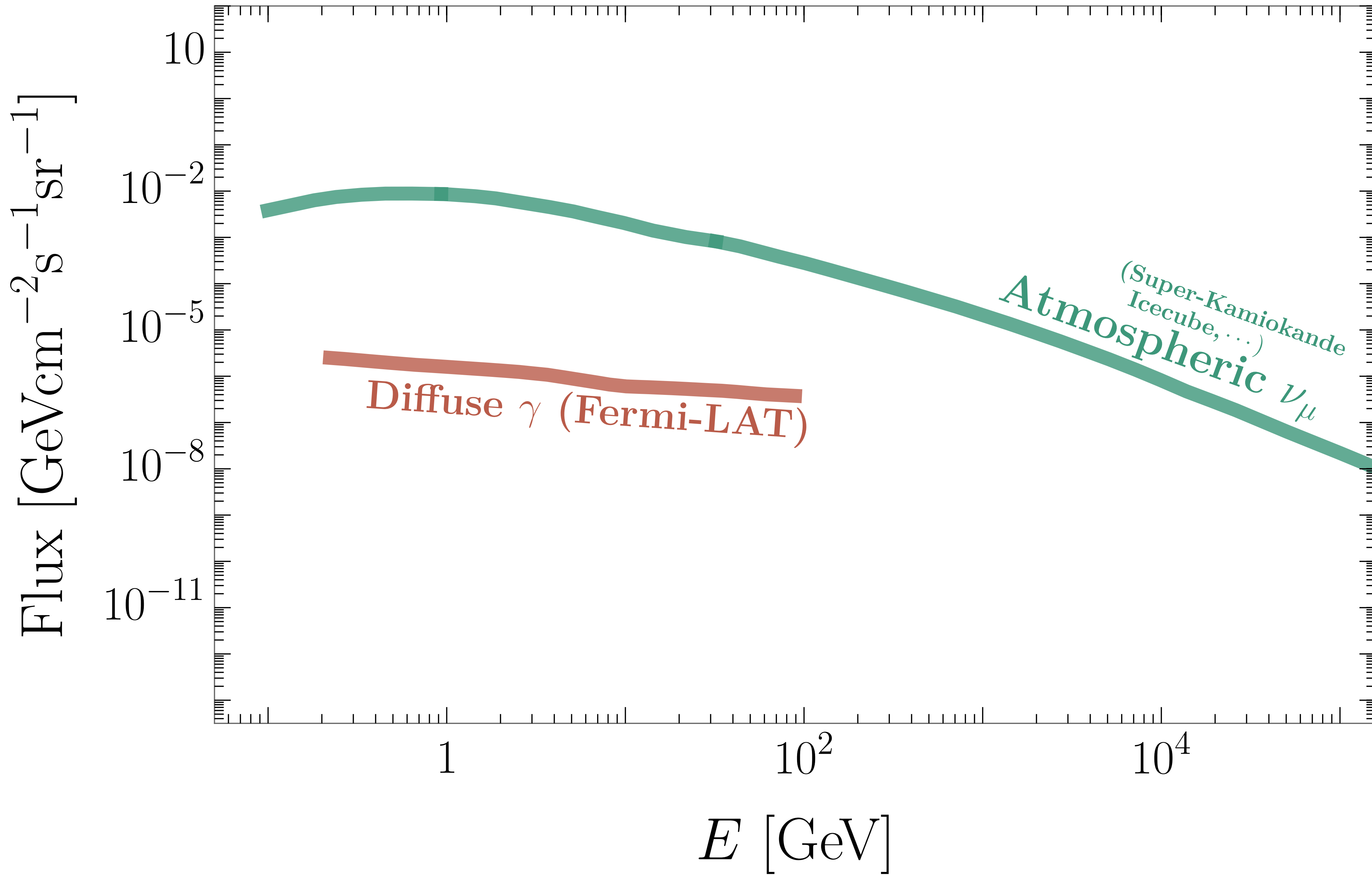
Press – Schechter theory

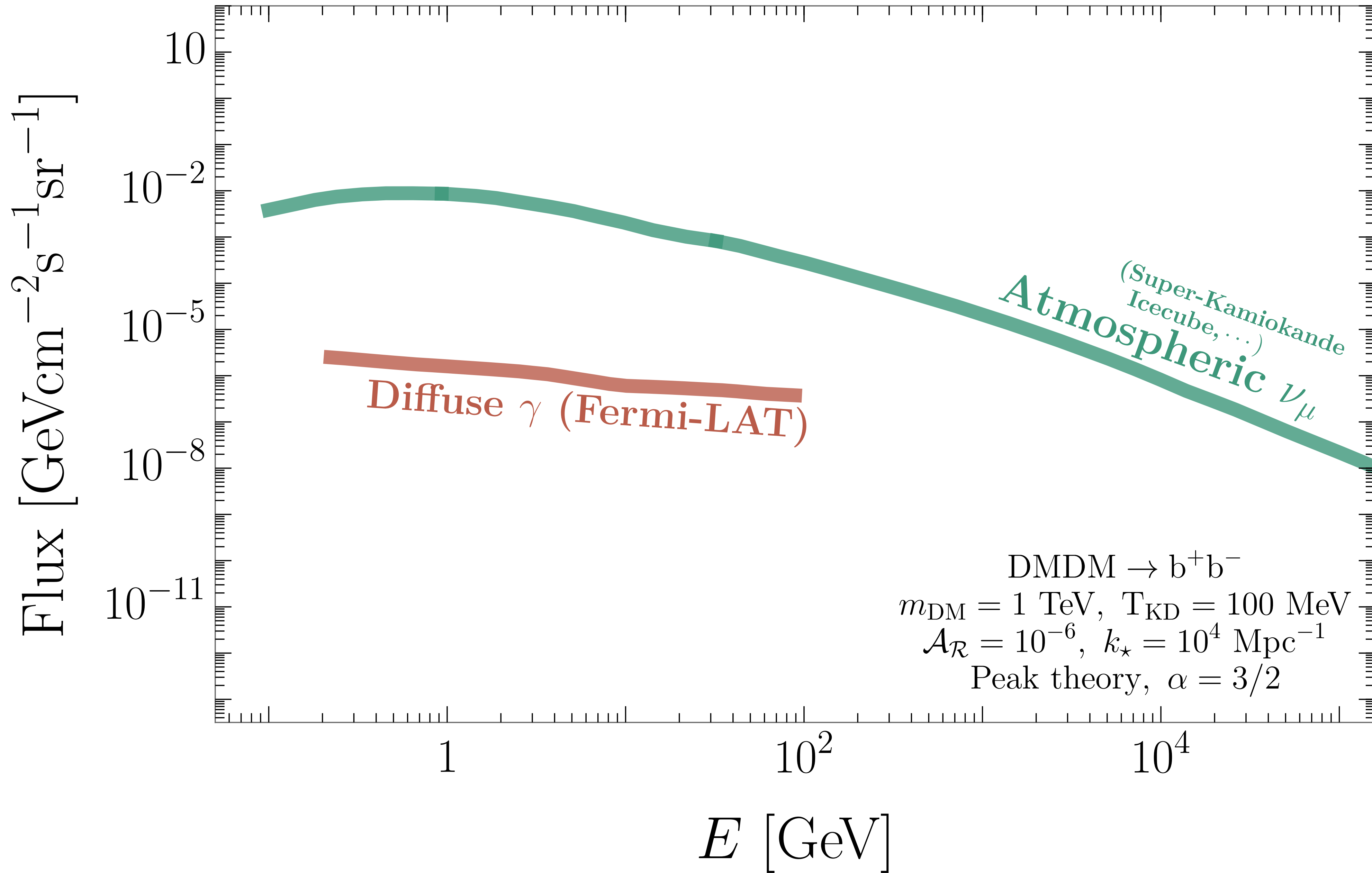
$$\frac{dn(R, a_c)}{da_c} \simeq R^{-3} \sqrt{\frac{2}{\pi}} \frac{\nu_c}{a_c} \exp\left(-\frac{\nu_c^2}{2}\right) \quad \nu_c \equiv \frac{\delta_{\text{min}}(a_c)}{\sigma_0(R)} \quad \delta_{\text{min}} \simeq 10^{-4} \frac{a_c^{-1}}{100}$$

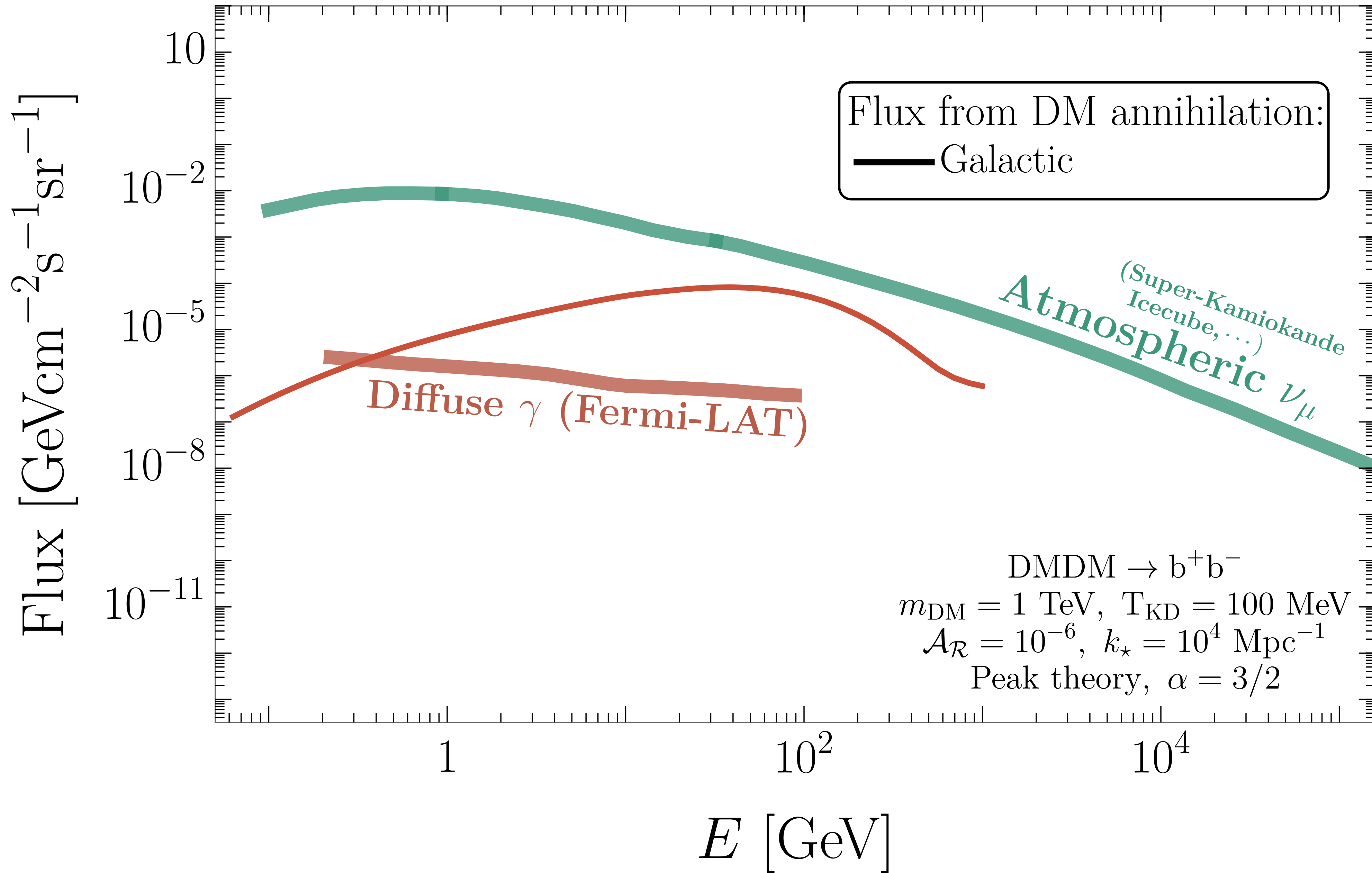
$$\sigma_0^2(R) = \frac{16}{81} \int_0^\infty \frac{dk}{k} \tilde{W}(k, R)^2 (kR)^4 T(k, R)^2 \mathcal{P}_{\mathcal{R}}(k, t_H)$$

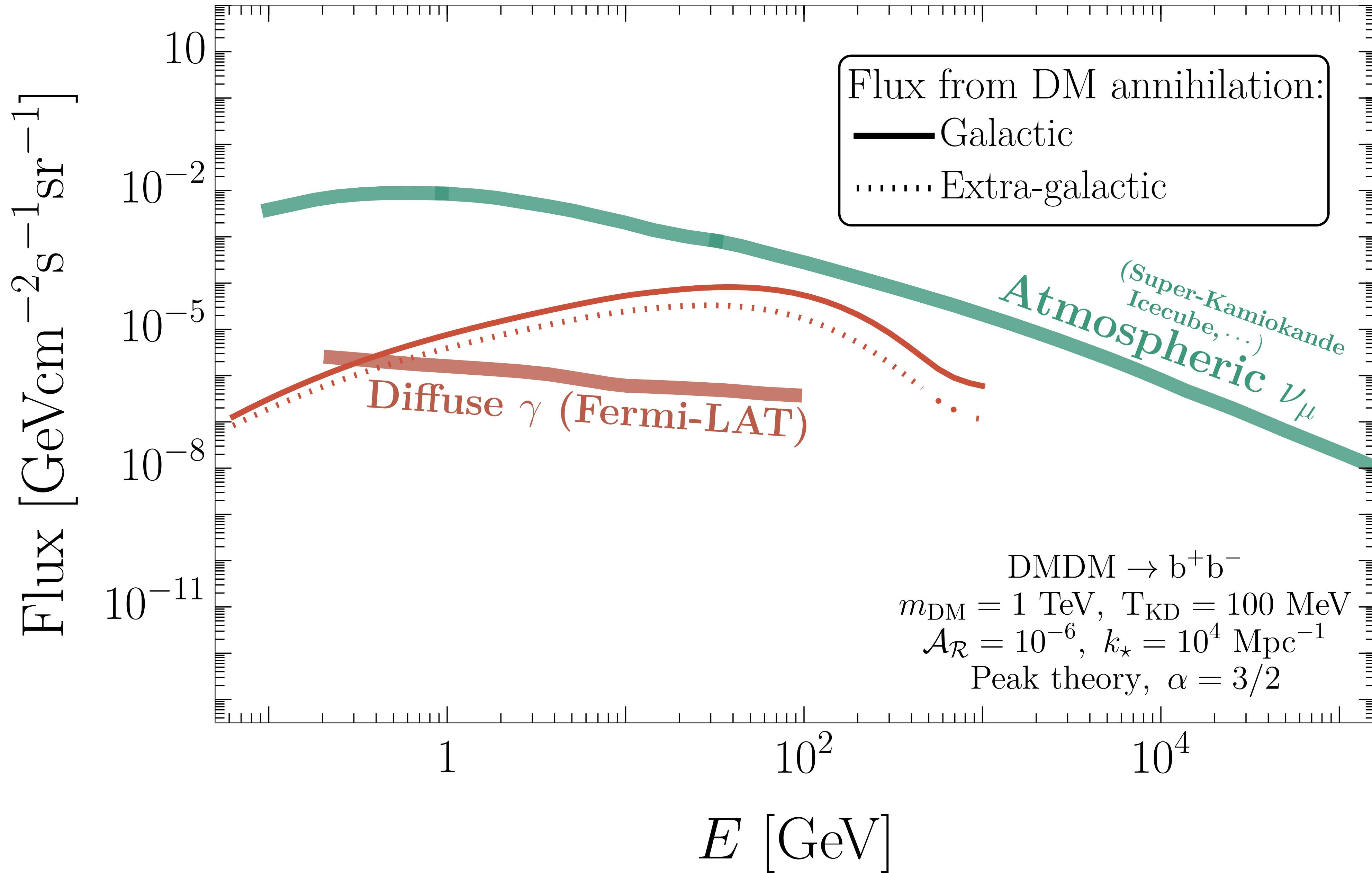
$$T(k, R) \rightarrow T(k, R) \times \exp\left[-\frac{1}{2} \left(\frac{k}{k_D}\right)^2\right] \quad k_D \simeq \frac{1.7 \times 10^8}{\text{Mpc}} \left(\frac{m_{\text{DM}}}{1 \text{ TeV}}\right)^{1/2} \left(\frac{T_{\text{KD}}}{30 \text{ MeV}}\right)^{1/2}$$

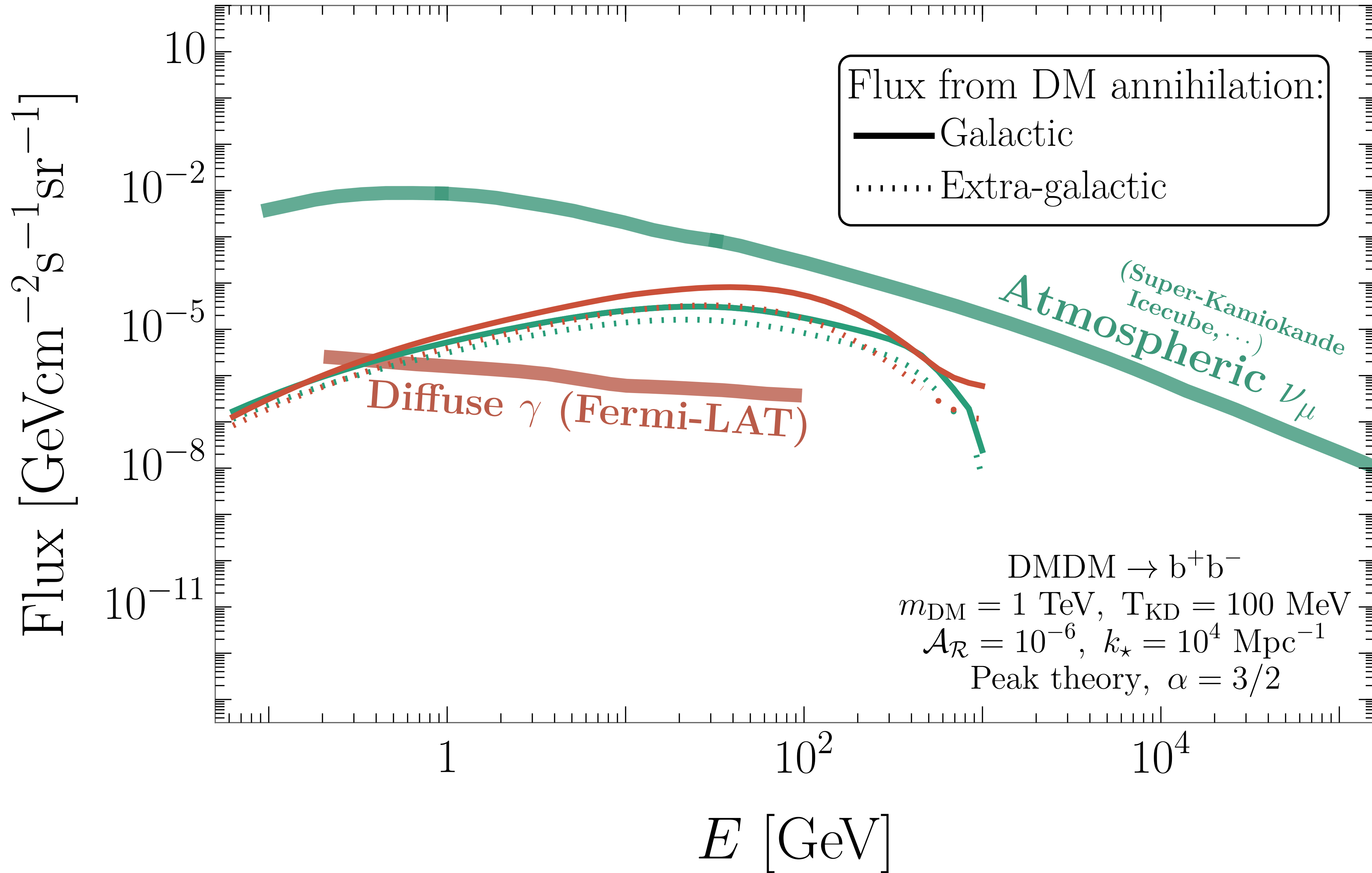
$$\rho_{\text{DM}}(s, \theta) = \rho_{\text{MW}} \left[\sqrt{s^2 + r_\odot^2 - 2r_\odot s \cos \theta} \right] + \frac{e^{-\tau(E, z_e)}}{(1+z_e)^3} \bar{\rho}_{\text{DM},0}$$











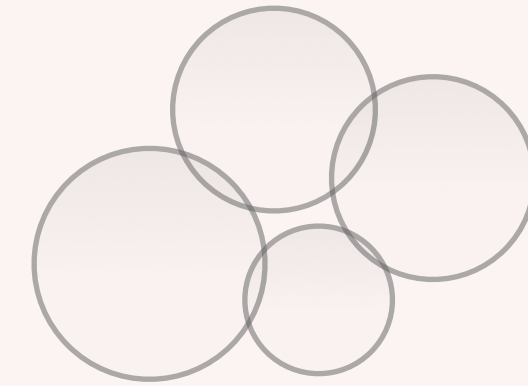
YG 2503.03857

**“New Physics Explanations of PTA
signal are incompatible with WIMPs
Dark Matter”**

First-order Phase Transition

YG 2503.03857

**“New Physics Explanations of PTA
signal are incompatible with WIMPs
Dark Matter”**

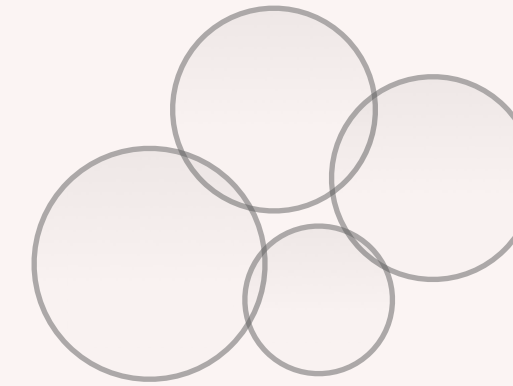


First-order Phase Transition

$$\mathcal{P}_{\mathcal{R}}(k) = \left(\frac{\alpha_{\star}}{1 + \alpha_{\star}} \right)^2 \left(\frac{H_{\star}}{\beta} \right)^2 \frac{a_1 (k_p / \beta)^3}{\left(a_2 + (k_p / \beta)^2 \right)^3}$$

Franciolini, YG, Jinno
(PRL)
2503.01962

Elor, Jinno, Kumar,
McGehee, Tsai,
2311.16222 (PRL)

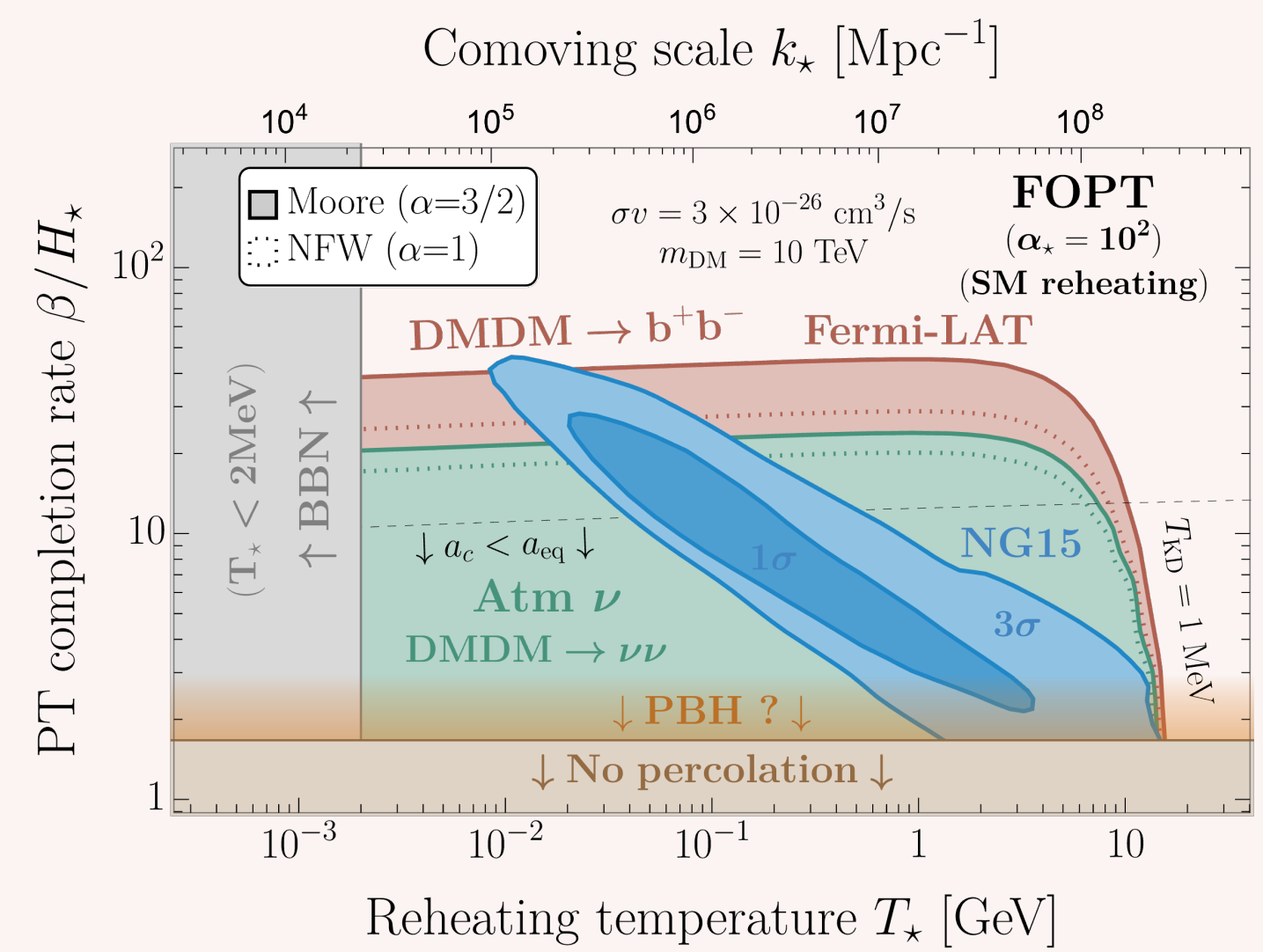


$$k_p = k_{\star} / a_{\star}$$

YG 2503.03857

**“New Physics Explanations of PTA
signal are incompatible with WIMPs
Dark Matter”**

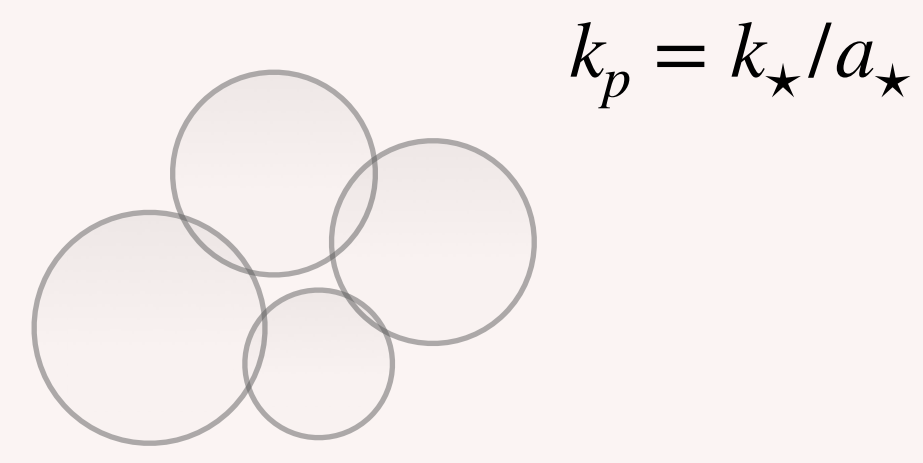
First-order Phase Transition



$$\mathcal{P}_{\mathcal{R}}(k) = \left(\frac{\alpha_*}{1 + \alpha_*} \right)^2 \left(\frac{H_*}{\beta} \right)^2 \frac{a_1 (k_p/\beta)^3}{\left(a_2 + (k_p/\beta)^2 \right)^3}$$

Franciolini, YG, Jinno (PRL) 2503.01962

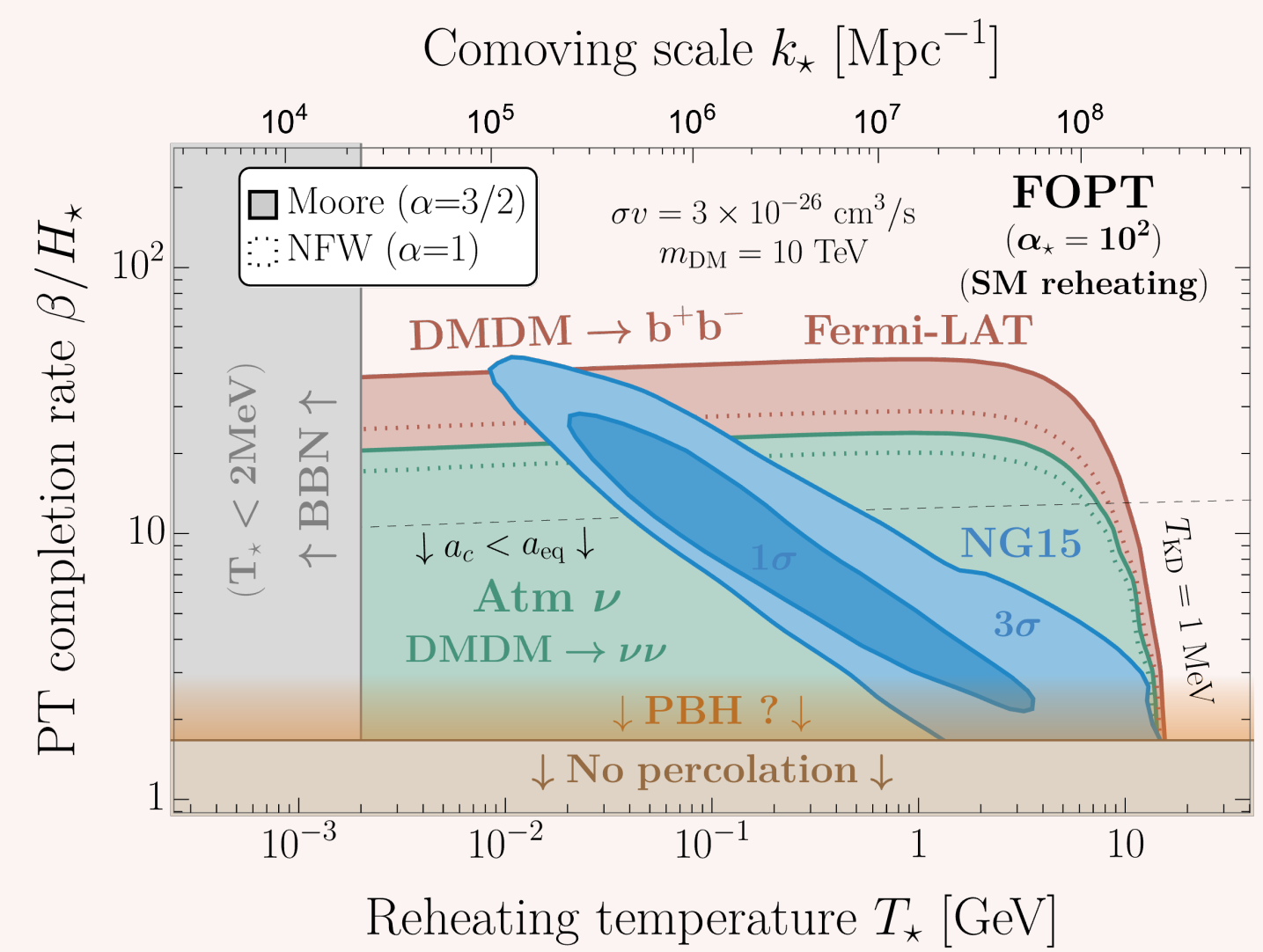
Elor, Jinno, Kumar, McGehee, Tsai, 2311.16222 (PRL)



YG 2503.03857

“New Physics Explanations of PTA signal are incompatible with WIMPs Dark Matter”

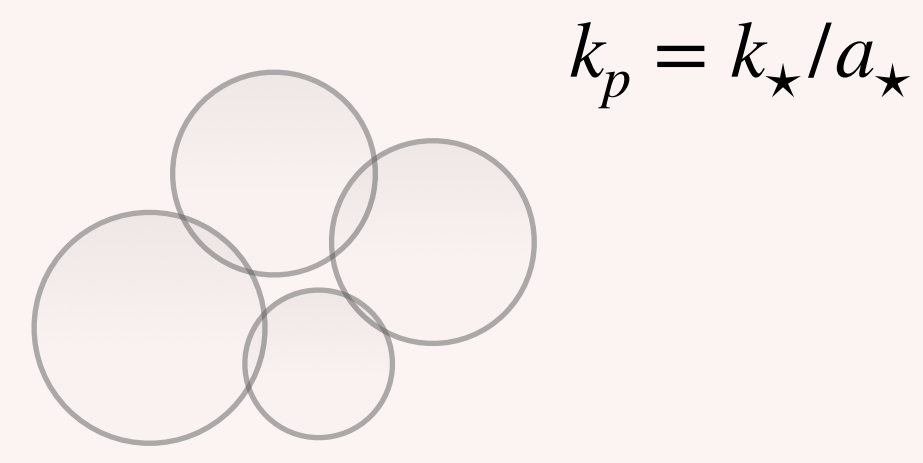
First-order Phase Transition



$$\mathcal{P}_{\mathcal{R}}(k) = \left(\frac{\alpha_{\star}}{1 + \alpha_{\star}} \right)^2 \left(\frac{H_{\star}}{\beta} \right)^2 \frac{a_1 (k_p / \beta)^3}{\left(a_2 + (k_p / \beta)^2 \right)^3}$$

Franciolini, YG, Jinno (PRL) 2503.01962

Elor, Jinno, Kumar, McGehee, Tsai, 2311.16222 (PRL)



YG 2503.03857

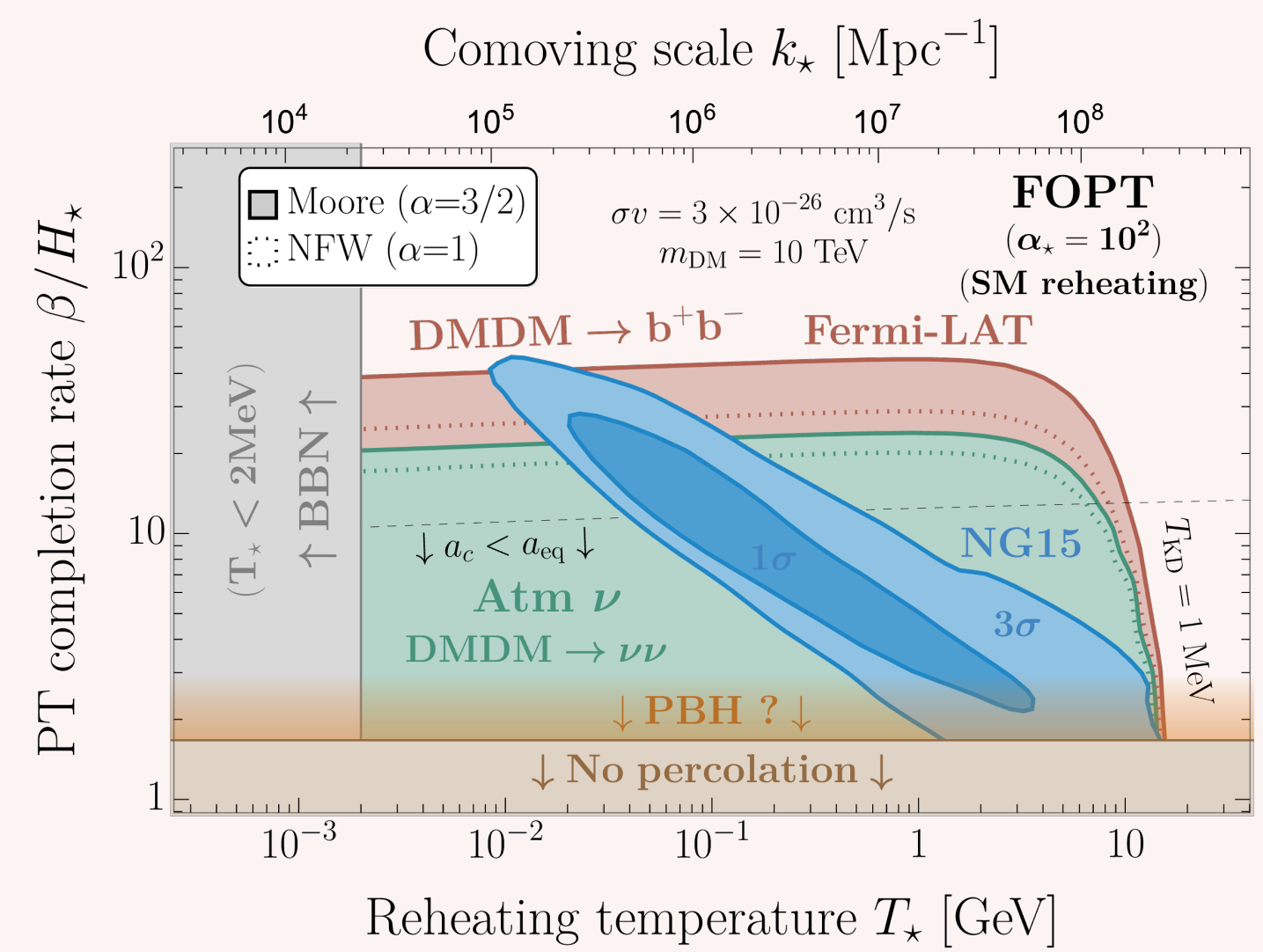
“New Physics Explanations of PTA signal are incompatible with WIMPs Dark Matter”

Gaussian curvature peaks

$$\mathcal{P}_{\mathcal{R}}(k) = \frac{\mathcal{A}_{\mathcal{R}}}{\sqrt{2\pi\Delta}} \exp \left[-\frac{\log^2(k/k_{\star})}{2\Delta^2} \right]$$



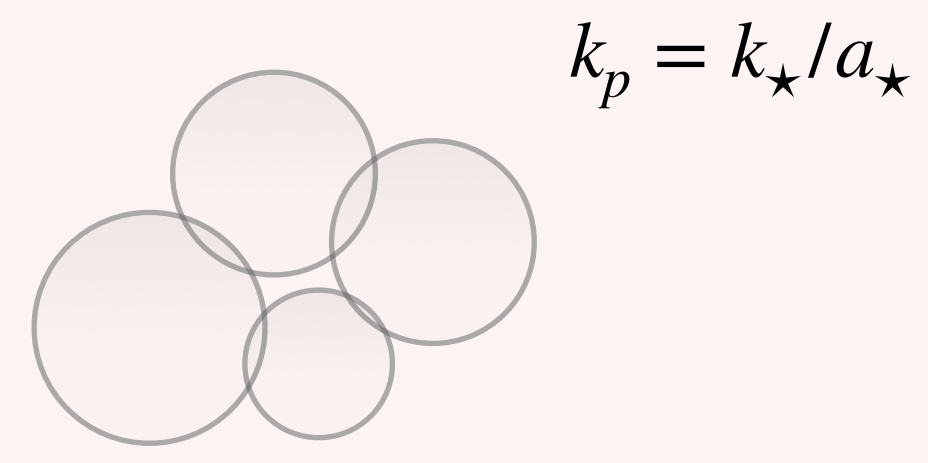
First-order Phase Transition



$$\mathcal{P}_{\mathcal{R}}(k) = \left(\frac{\alpha_*}{1 + \alpha_*} \right)^2 \left(\frac{H_*}{\beta} \right)^2 \frac{a_1 (k_p/\beta)^3}{\left(a_2 + (k_p/\beta)^2 \right)^3}$$

Franciolini, YG, Jinno (PRL) 2503.01962

Elor, Jinno, Kumar, McGehee, Tsai, 2311.16222 (PRL)

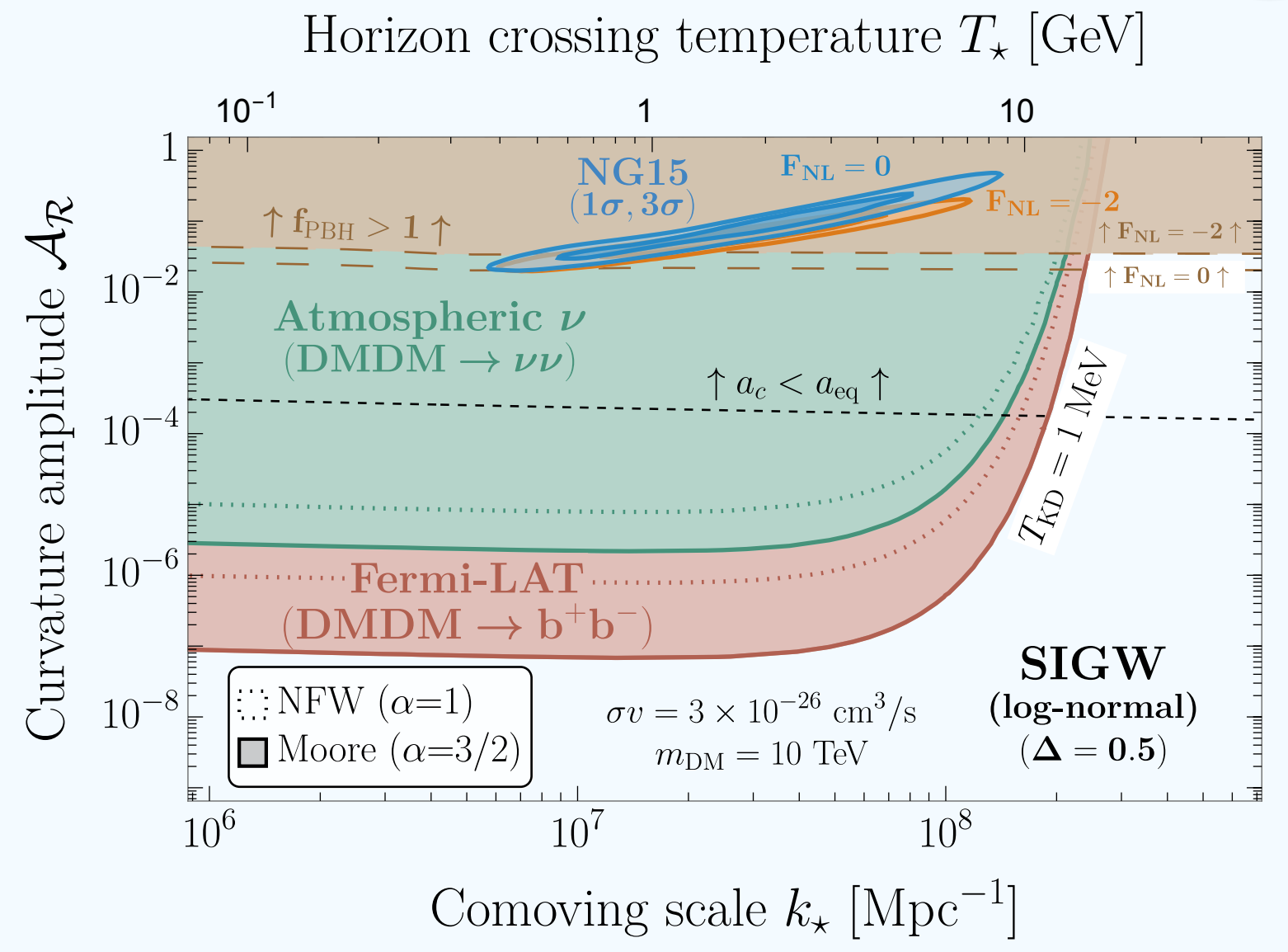


YG 2503.03857

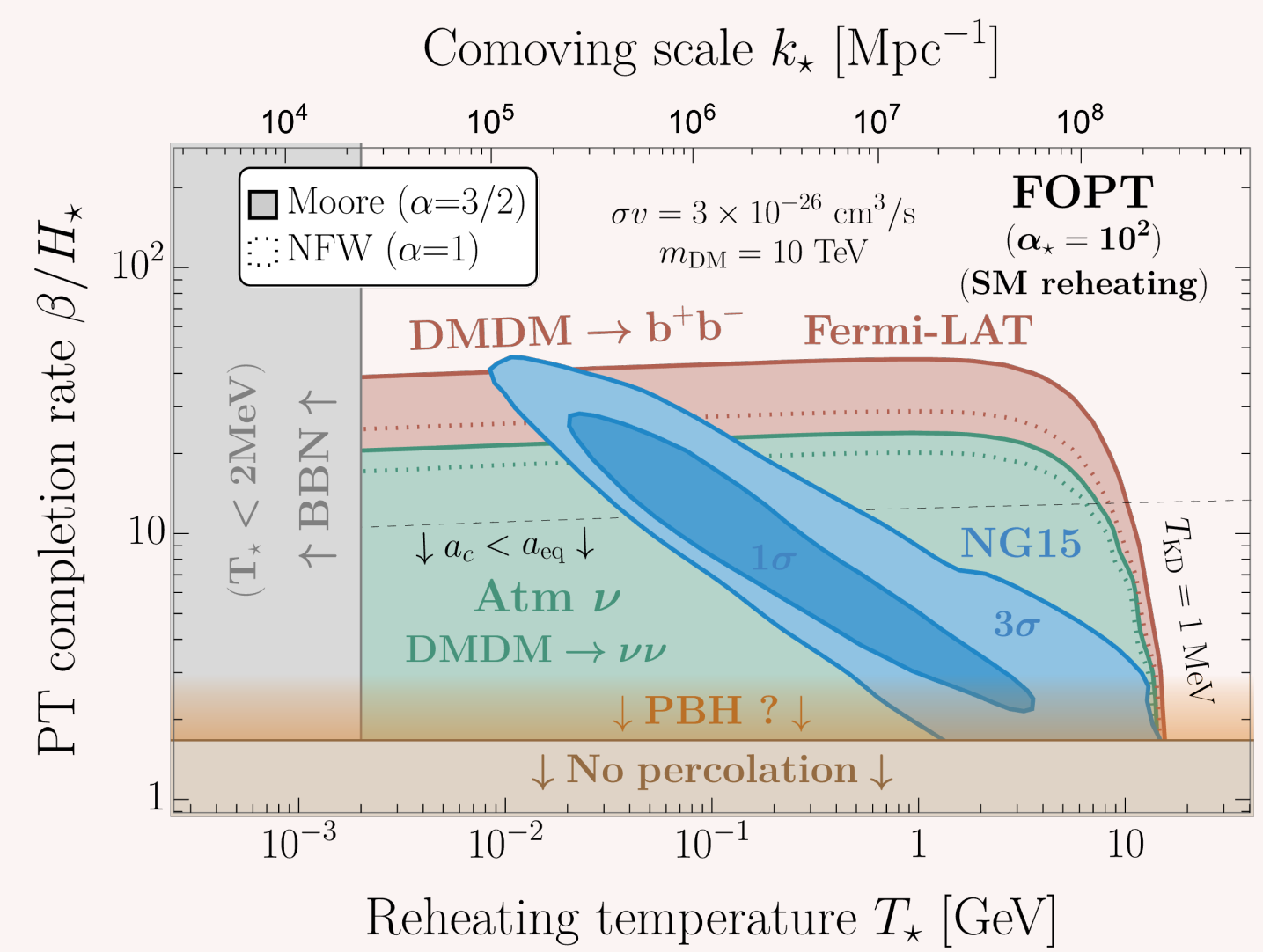
“New Physics Explanations of PTA signal are incompatible with WIMPs Dark Matter”

Gaussian curvature peaks

$$\mathcal{P}_{\mathcal{R}}(k) = \frac{\mathcal{A}_{\mathcal{R}}}{\sqrt{2\pi}\Delta} \exp \left[-\frac{\log^2(k/k_*)}{2\Delta^2} \right]$$



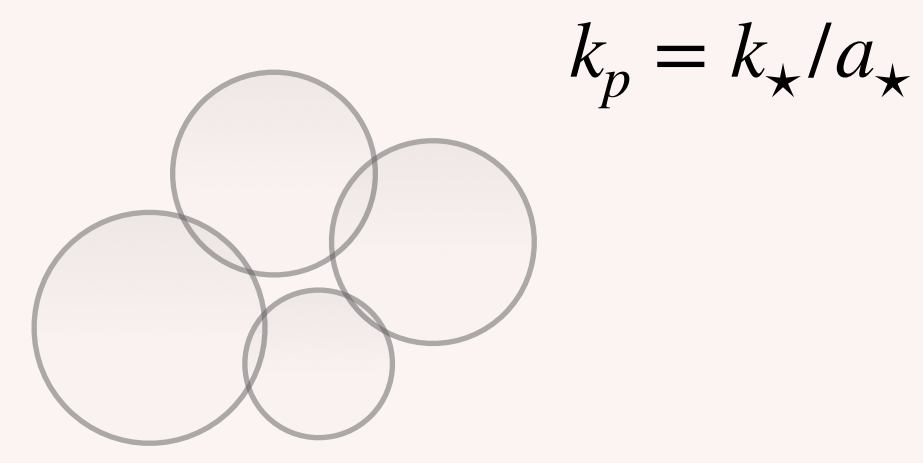
First-order Phase Transition



$$\mathcal{P}_{\mathcal{R}}(k) = \left(\frac{\alpha_{\star}}{1 + \alpha_{\star}} \right)^2 \left(\frac{H_{\star}}{\beta} \right)^2 \frac{a_1 (k_p/\beta)^3}{\left(a_2 + (k_p/\beta)^2 \right)^3}$$

Franciolini, YG, Jinno (PRL) 2503.01962

Elor, Jinno, Kumar, McGehee, Tsai, 2311.16222 (PRL)

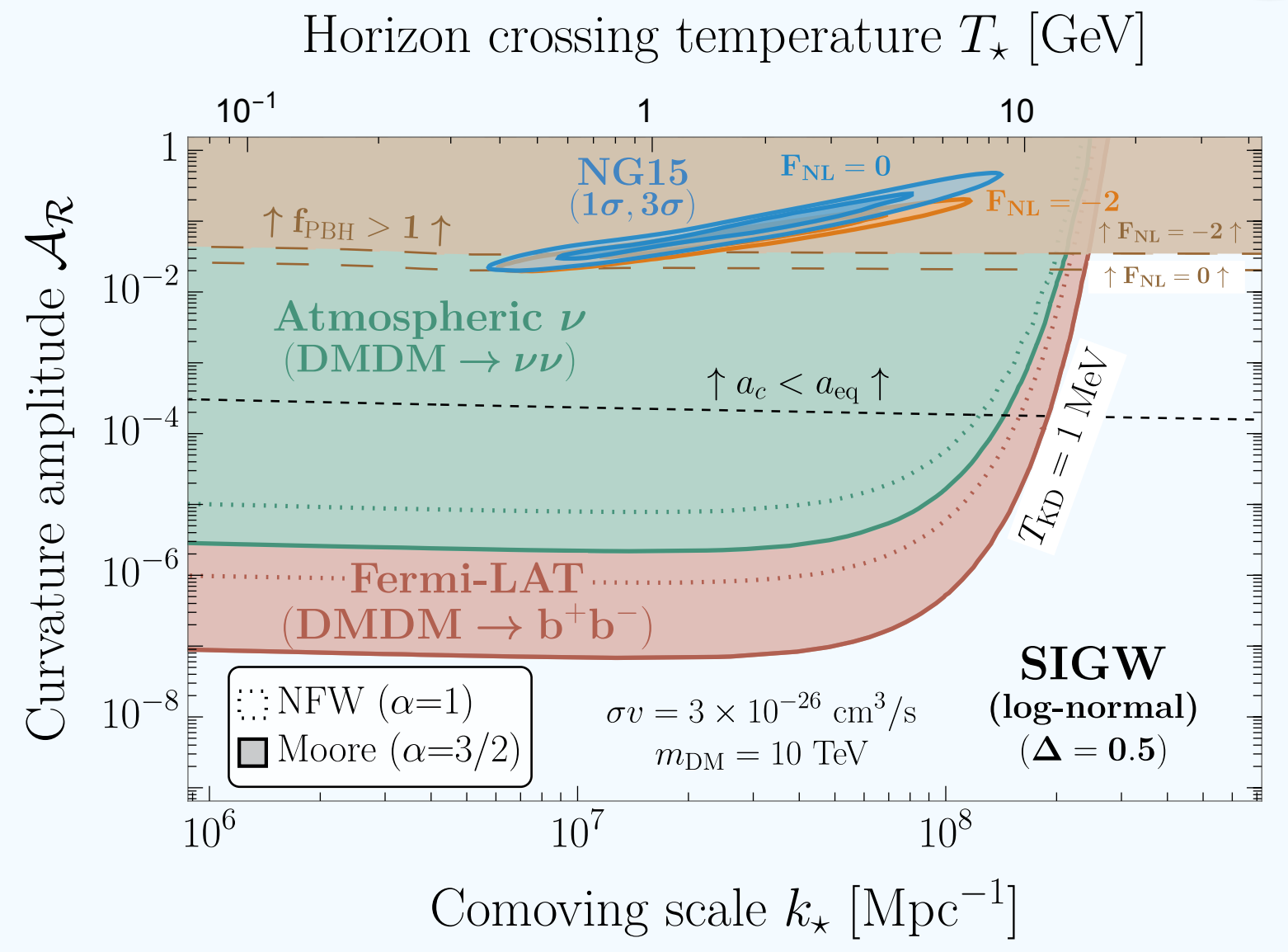


YG 2503.03857

“New Physics Explanations of PTA signal are incompatible with WIMPs Dark Matter”

Gaussian curvature peaks

$$\mathcal{P}_{\mathcal{R}}(k) = \frac{\mathcal{A}_{\mathcal{R}}}{\sqrt{2\pi}\Delta} \exp \left[-\frac{\log^2(k/k_{\star})}{2\Delta^2} \right]$$

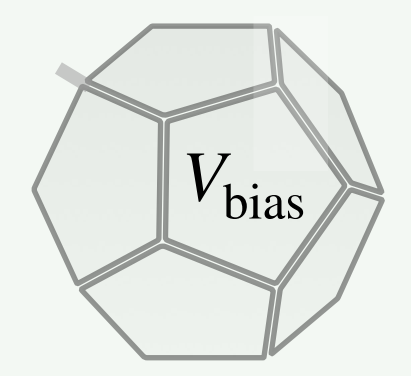


YG 2503.03857

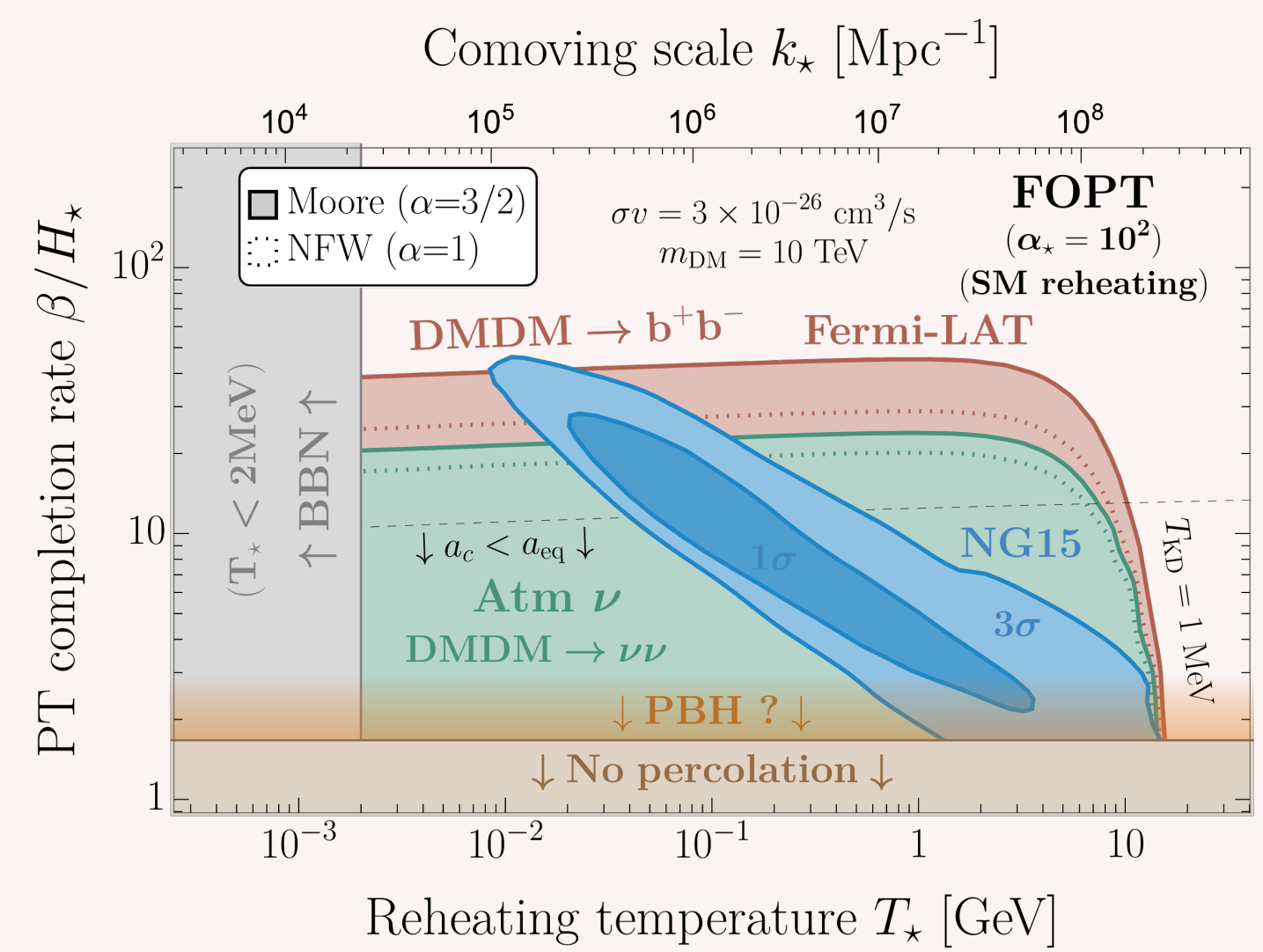
Domain Wall Networks

$$\mathcal{P}_{\mathcal{R}}(k) = \frac{\alpha_V^2}{2\pi} \frac{(k_p L_{\text{ann}})^3}{\left[4 + (k_p L_{\text{ann}})^2 \right]^2}$$

$$\alpha_V = V_{\text{bias}} / \rho_{\text{rad}} \Big|_{t=t_{\text{ann}}} \quad L_{\text{ann}} \sim t_{\text{ann}}$$



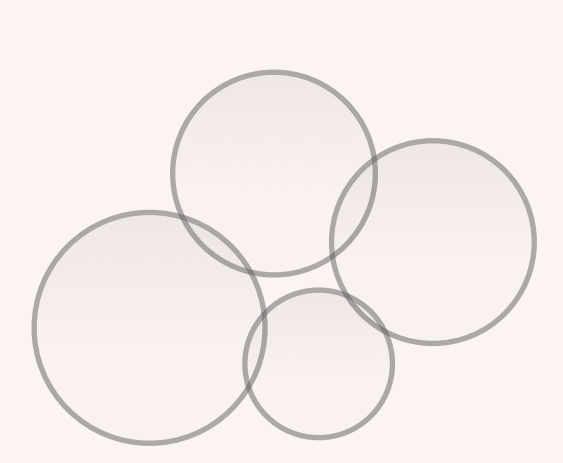
First-order Phase Transition



$$\mathcal{P}_{\mathcal{R}}(k) = \left(\frac{\alpha_{\star}}{1 + \alpha_{\star}} \right)^2 \left(\frac{H_{\star}}{\beta} \right)^2 \frac{a_1 (k_p/\beta)^3}{\left(a_2 + (k_p/\beta)^2 \right)^3}$$

Franciolini, YG, Jinno (PRL) 2503.01962

Elor, Jinno, Kumar, McGehee, Tsai, 2311.16222 (PRL)



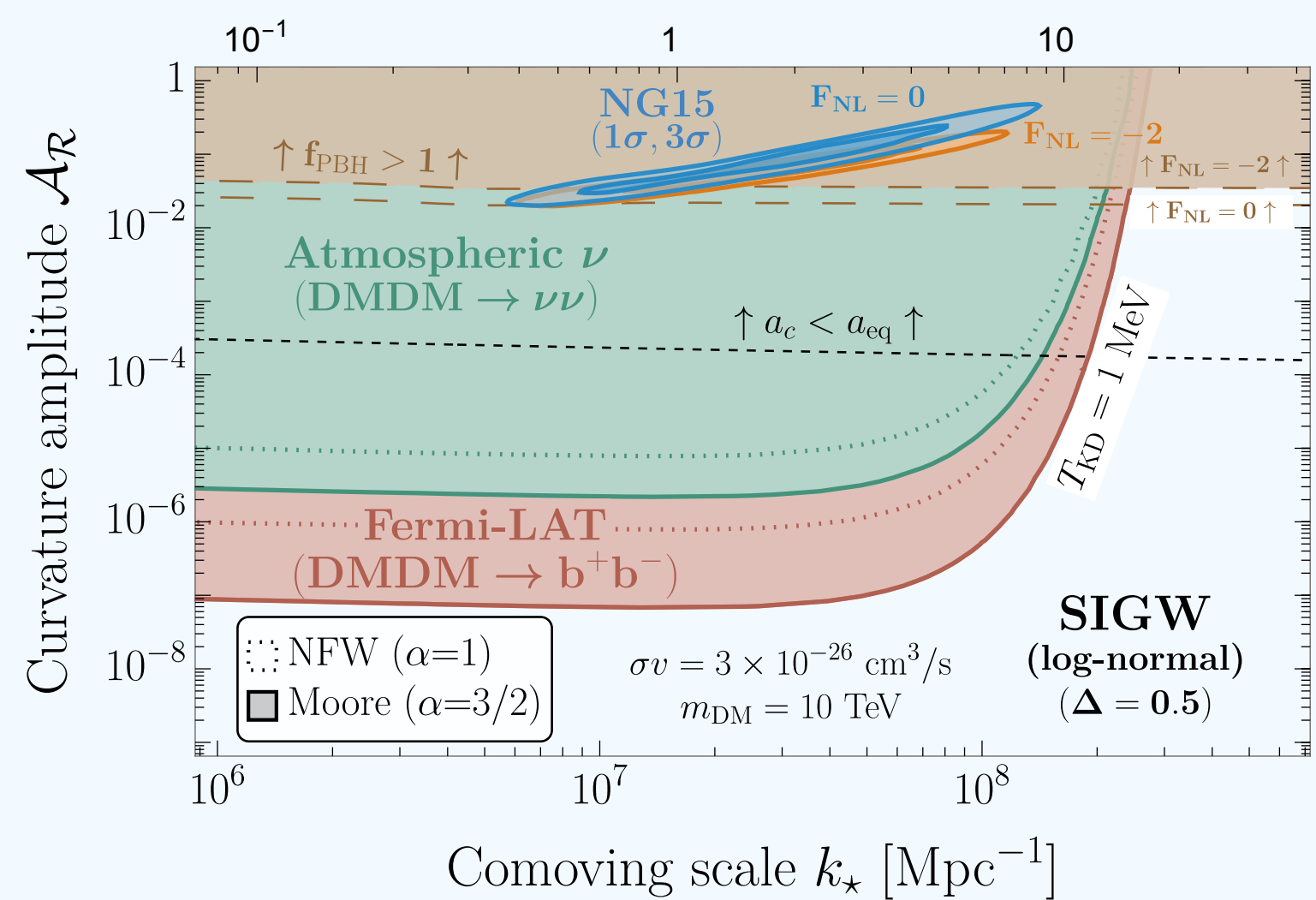
$$k_p = k_{\star}/a_{\star}$$

YG 2503.03857

“New Physics Explanations of PTA signal are incompatible with WIMPs Dark Matter”

Gaussian curvature peaks

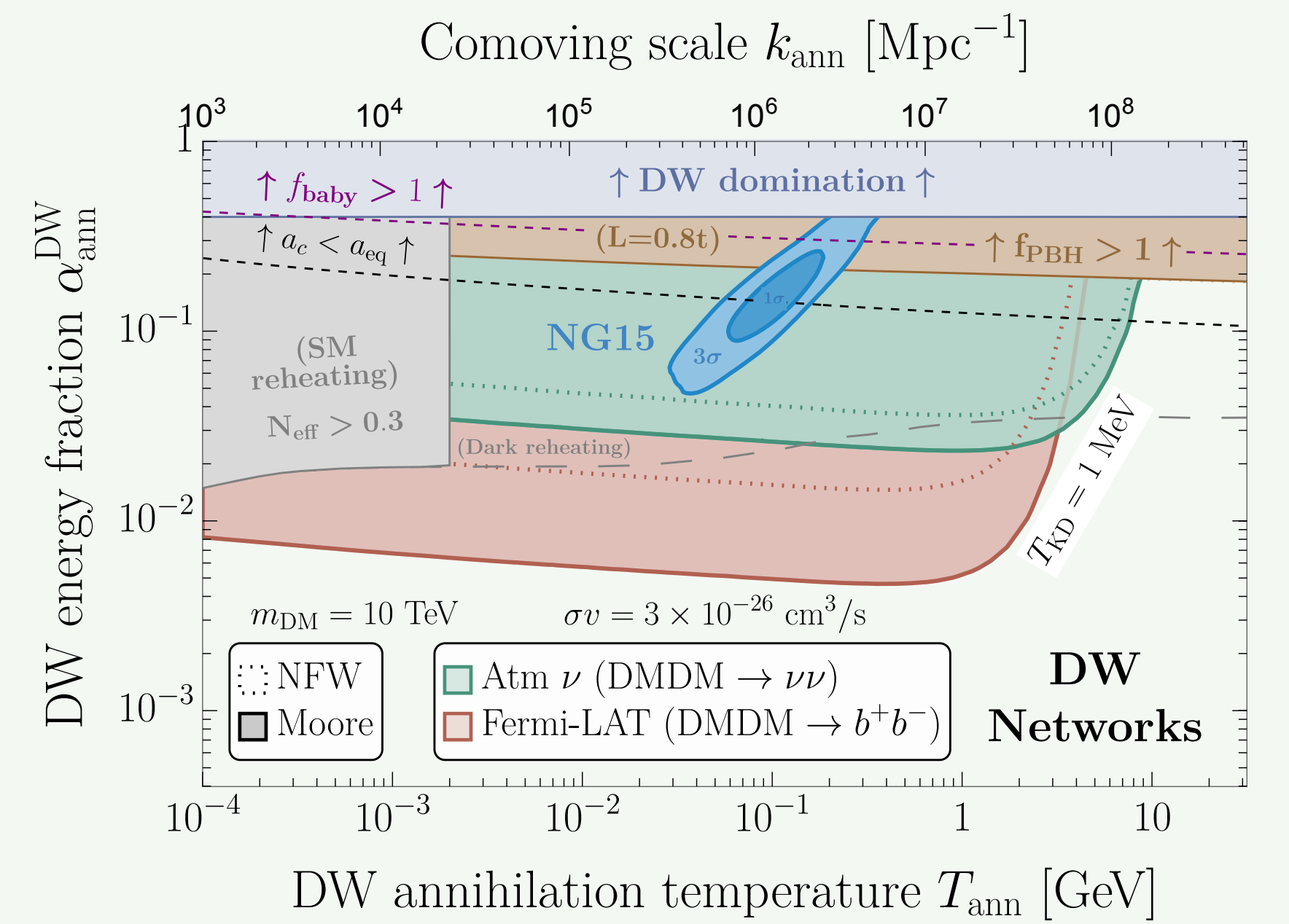
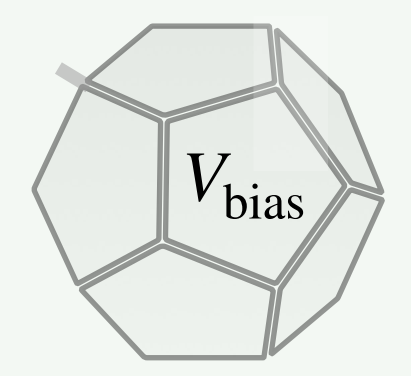
$$\mathcal{P}_{\mathcal{R}}(k) = \frac{\mathcal{A}_{\mathcal{R}}}{\sqrt{2\pi}\Delta} \exp \left[-\frac{\log^2(k/k_{\star})}{2\Delta^2} \right]$$



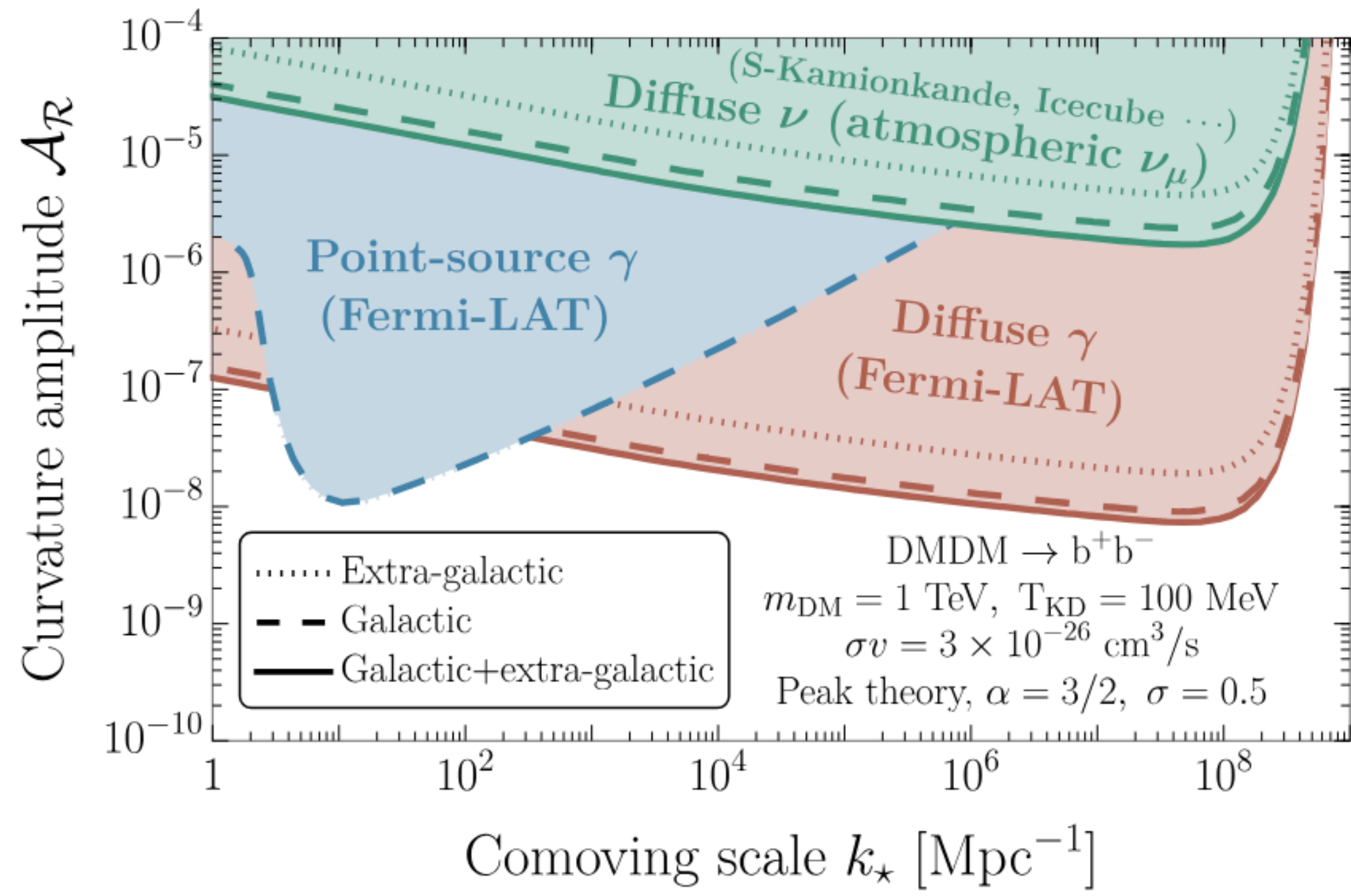
Domain Wall Networks

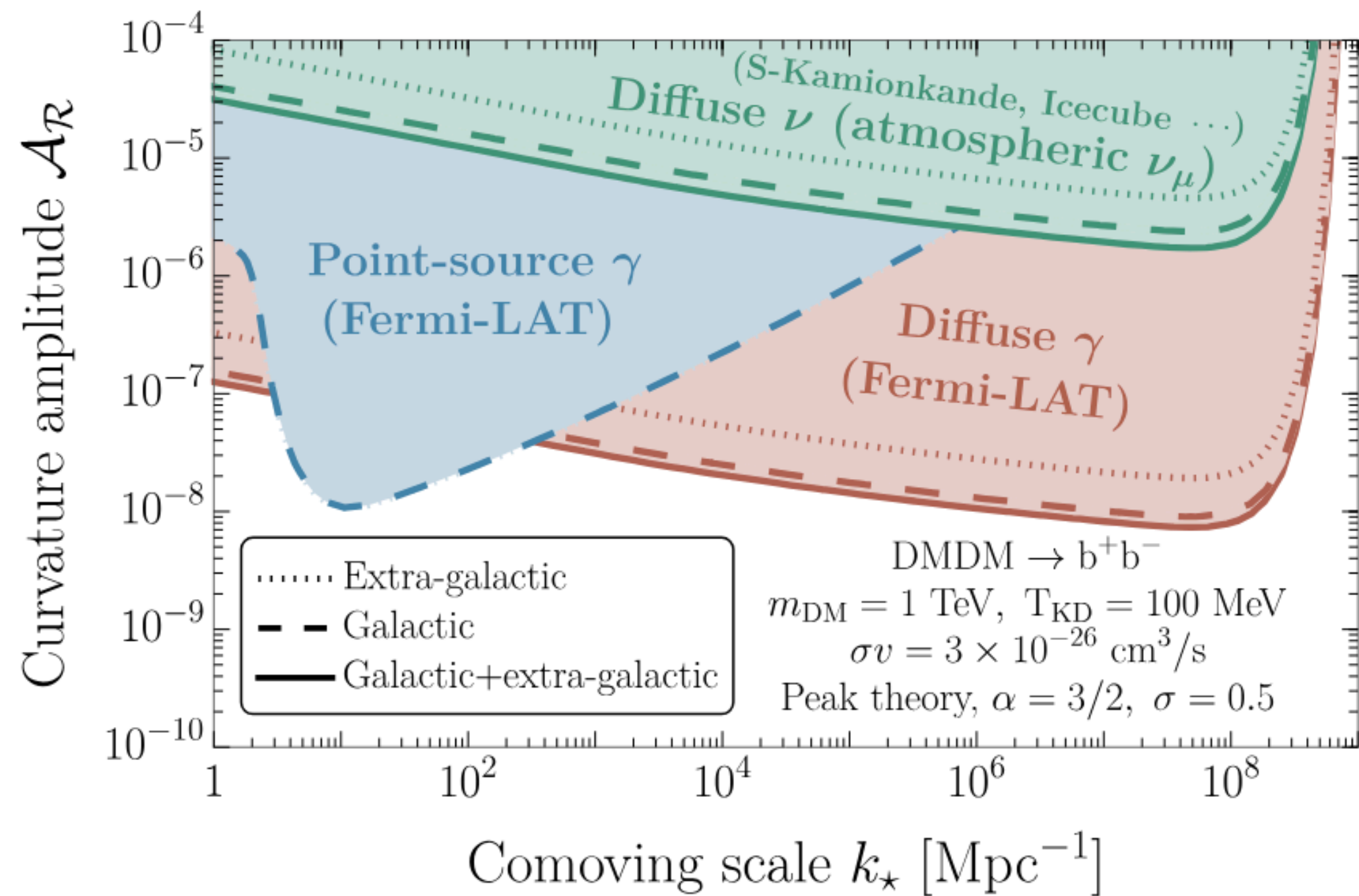
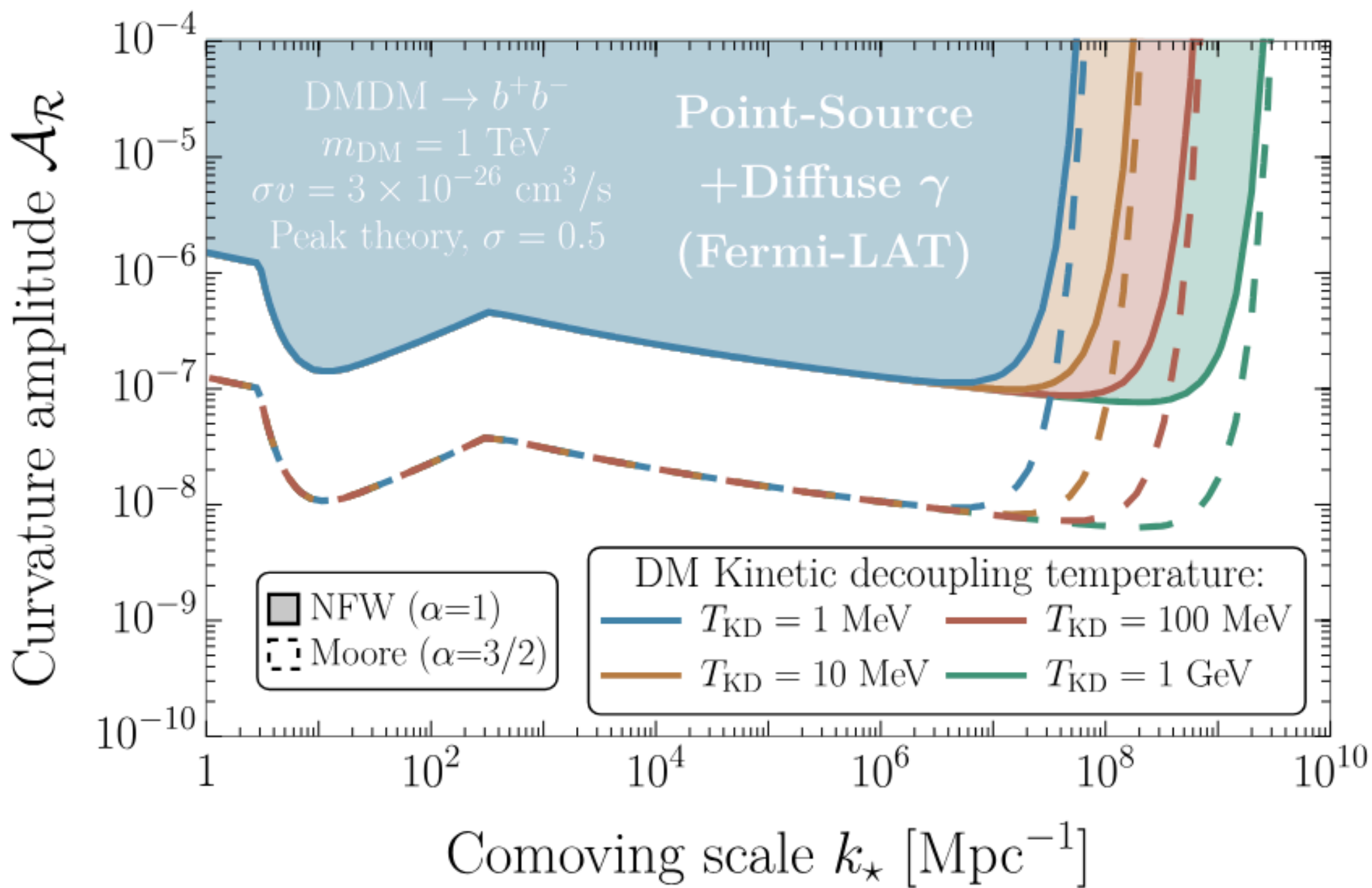
$$\mathcal{P}_{\mathcal{R}}(k) = \frac{\alpha_V^2}{2\pi} \frac{(k_p L_{\text{ann}})^3}{\left[4 + (k_p L_{\text{ann}})^2 \right]^2}$$

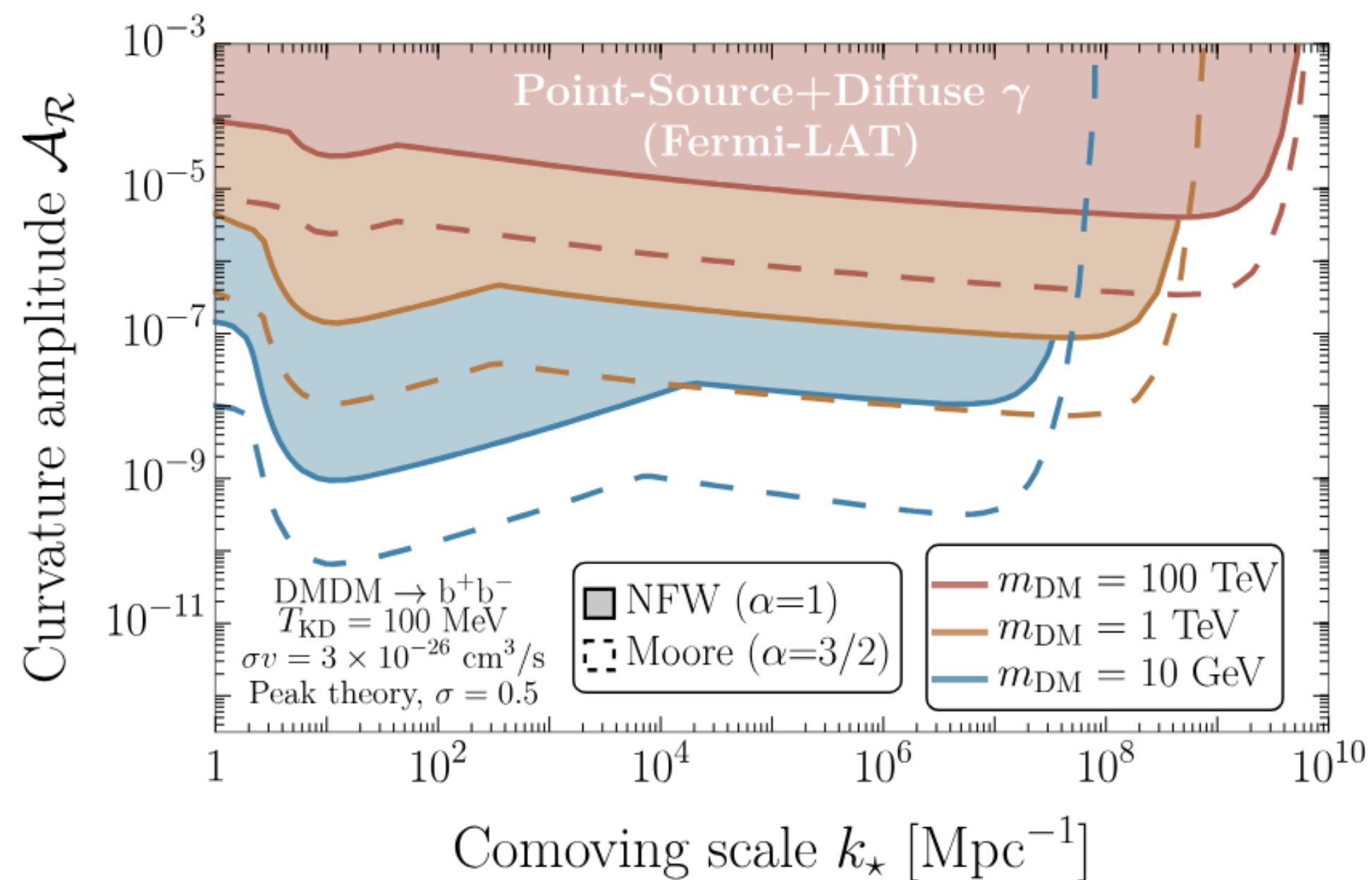
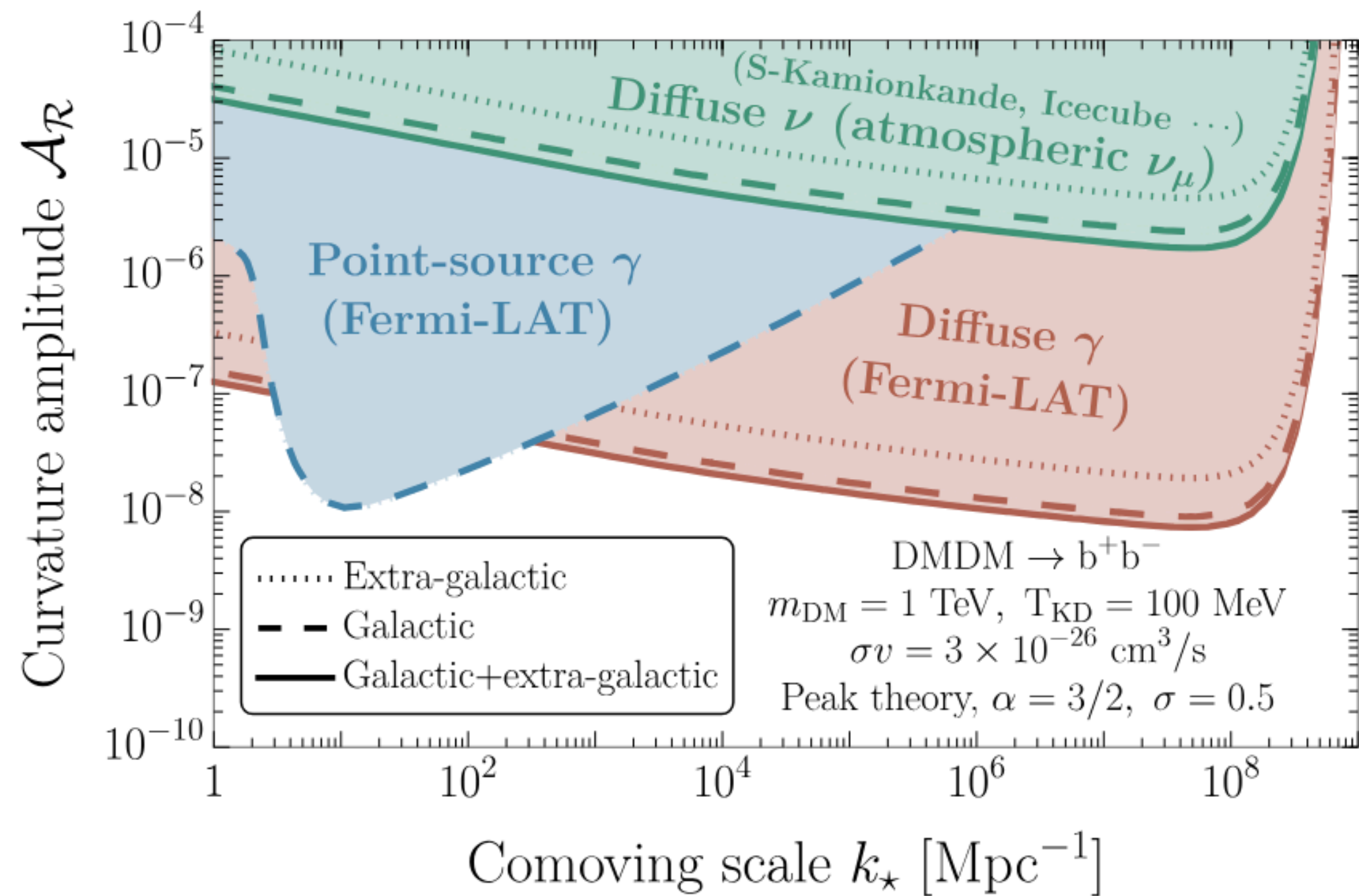
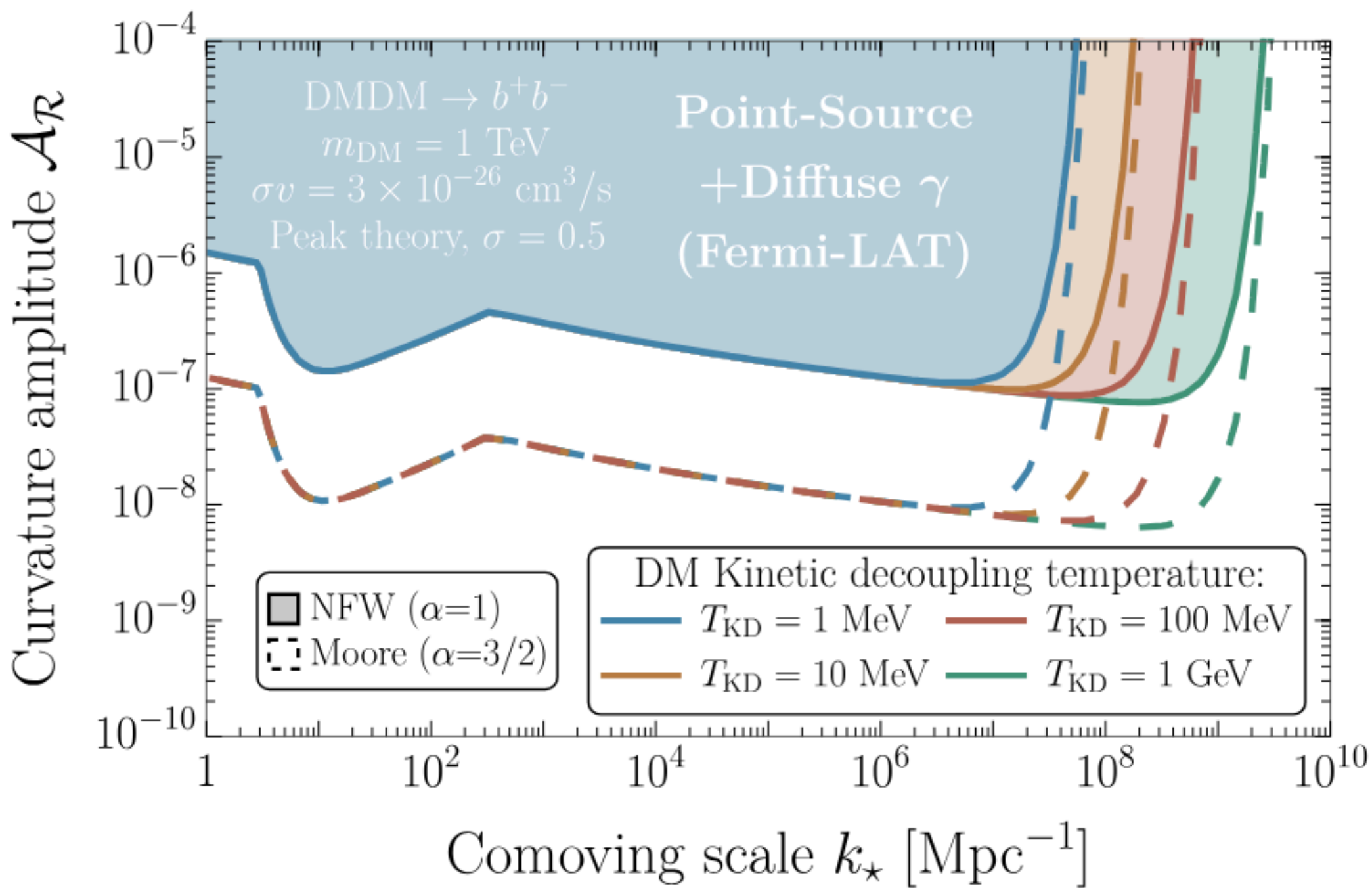
$$\alpha_V = V_{\text{bias}}/\rho_{\text{rad}} \Big|_{t=t_{\text{ann}}} \quad L_{\text{ann}} \sim t_{\text{ann}}$$

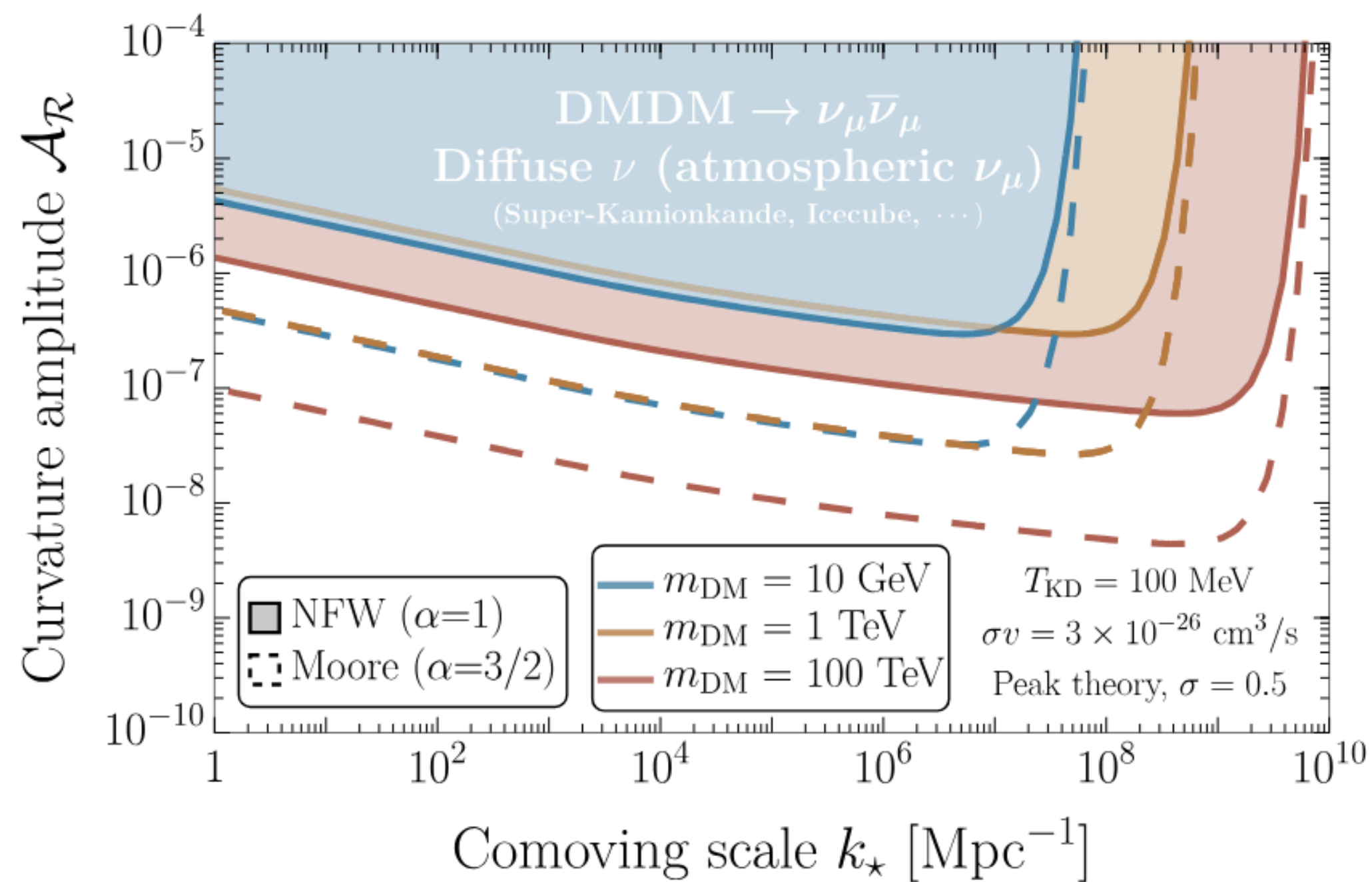
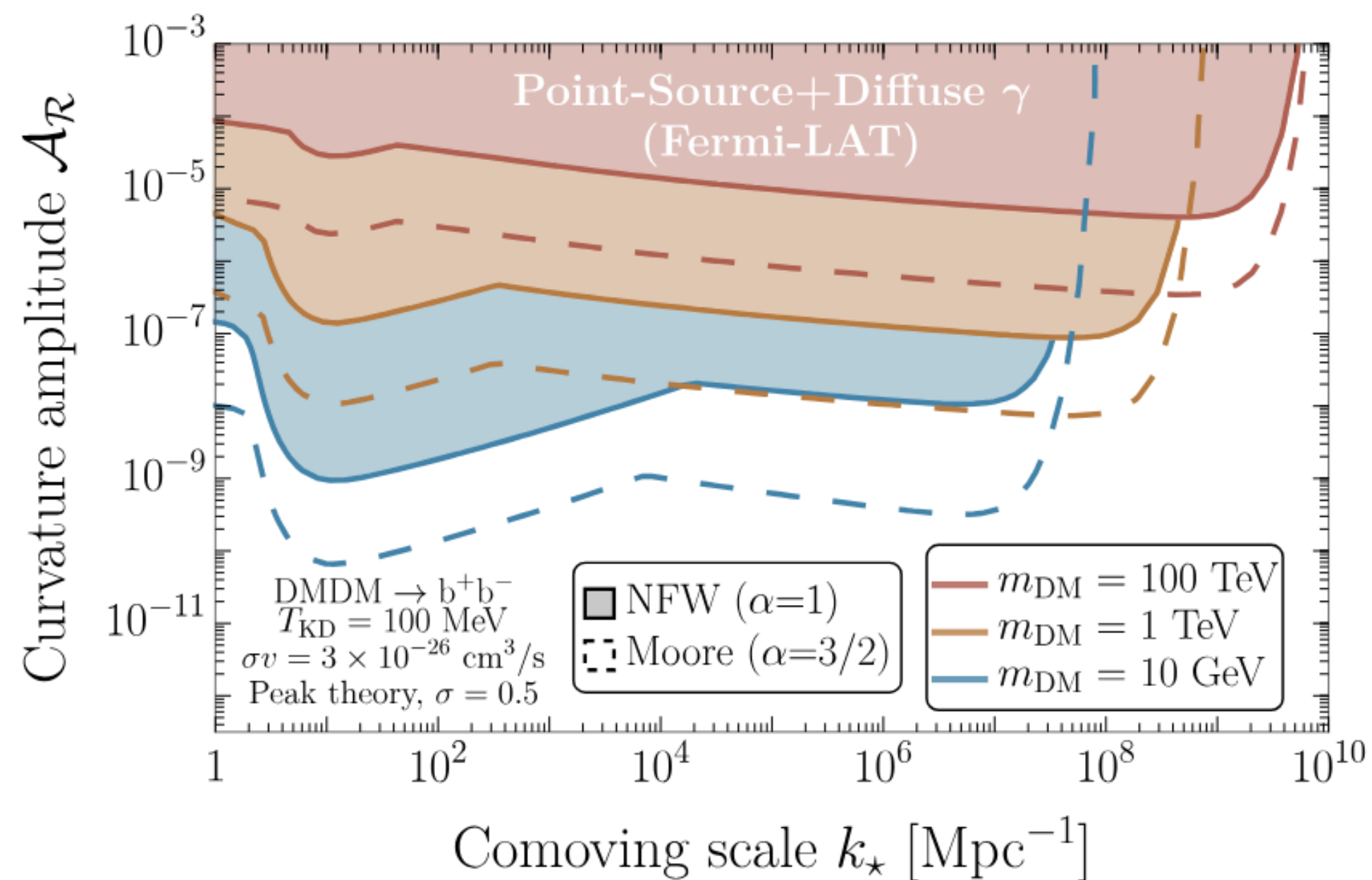
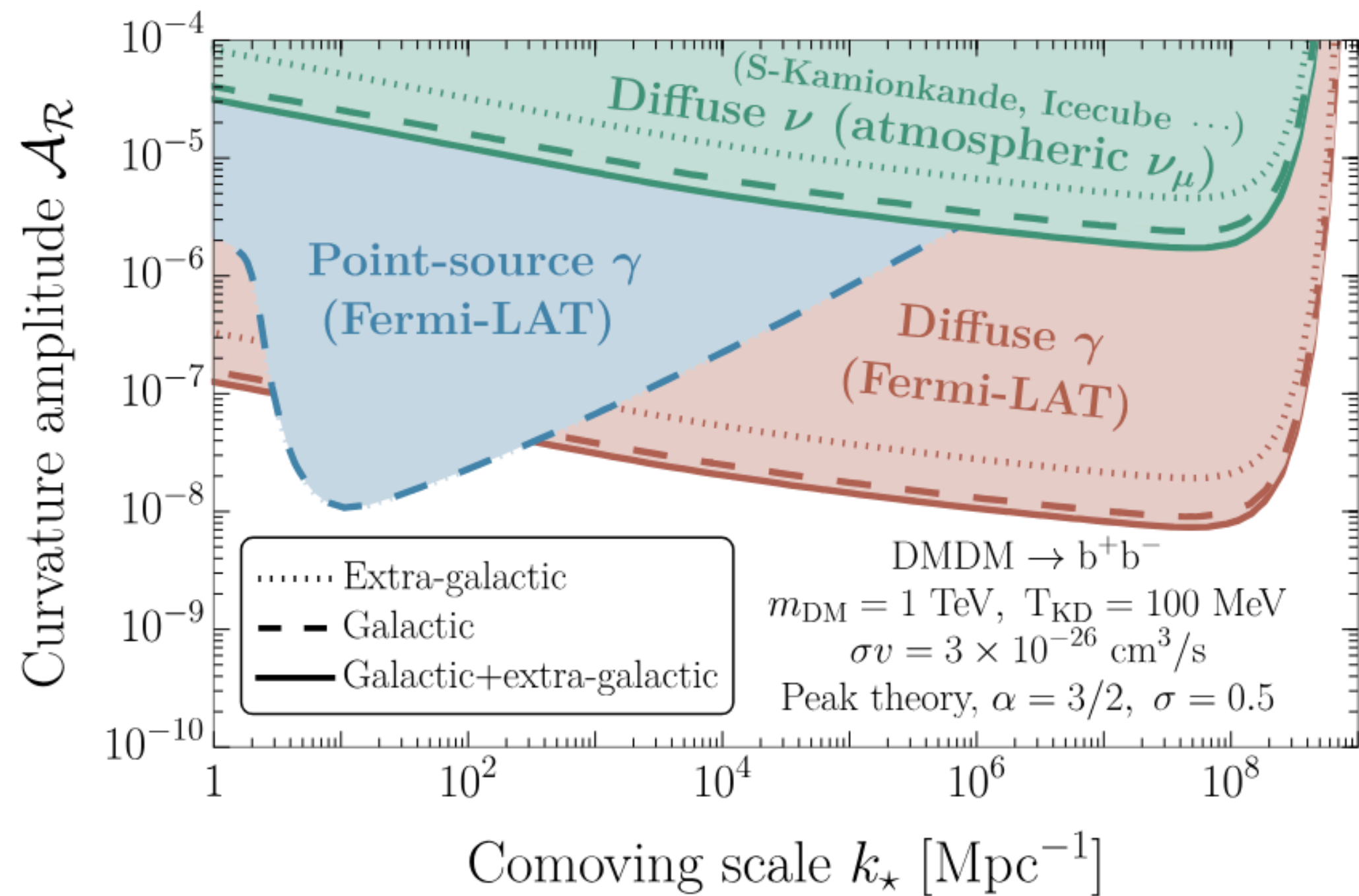
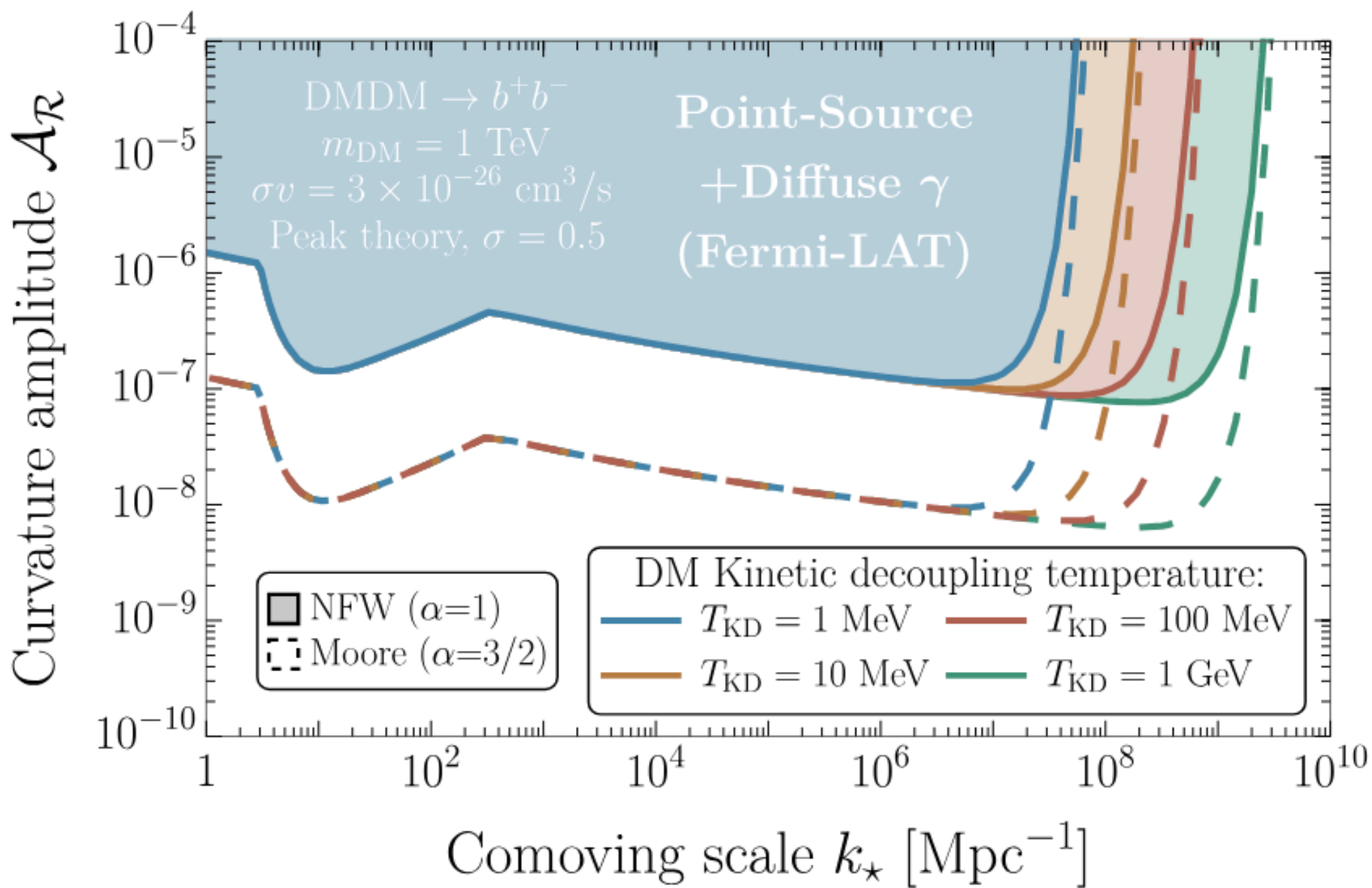


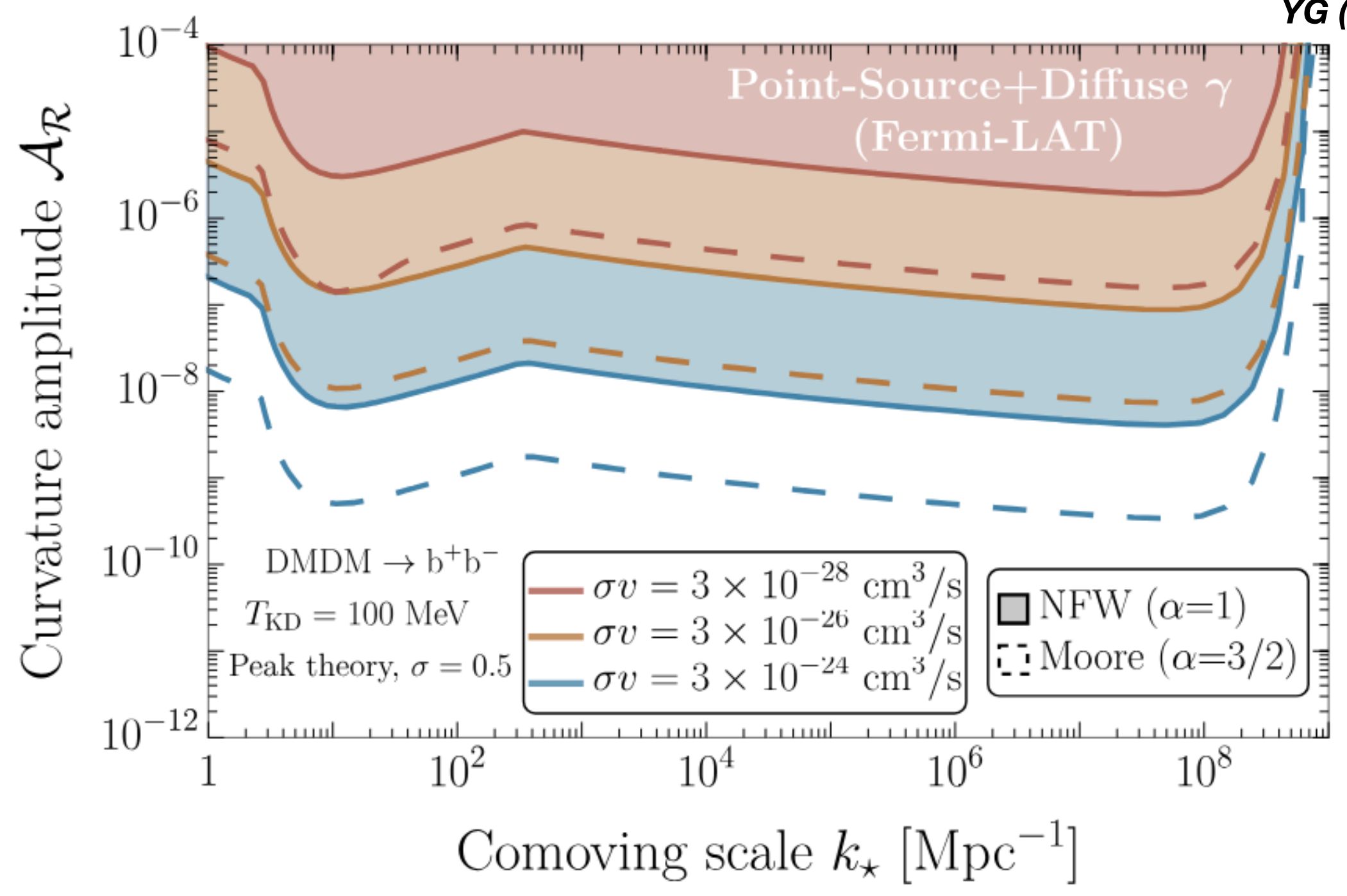
YG 2503.03857

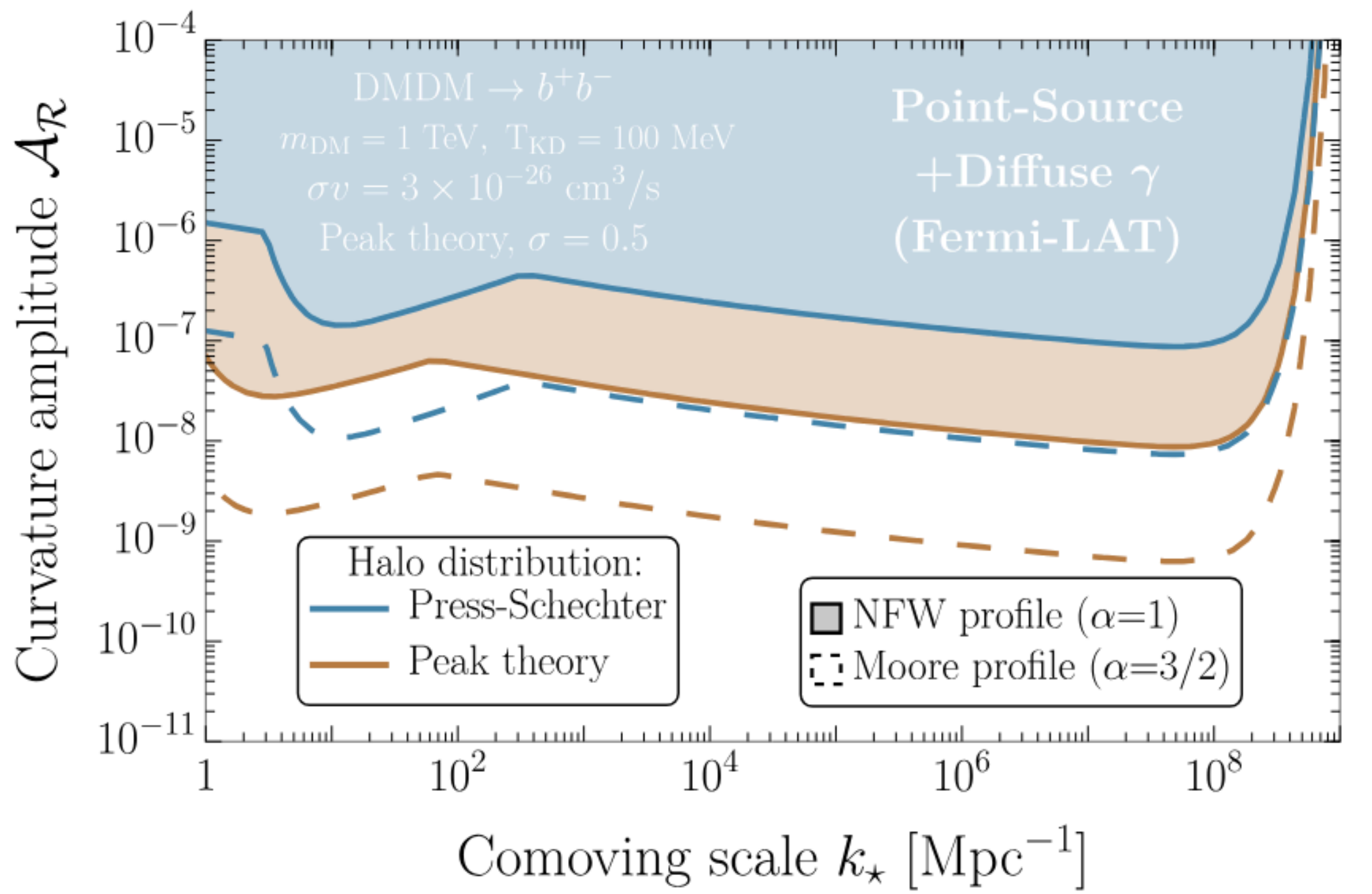
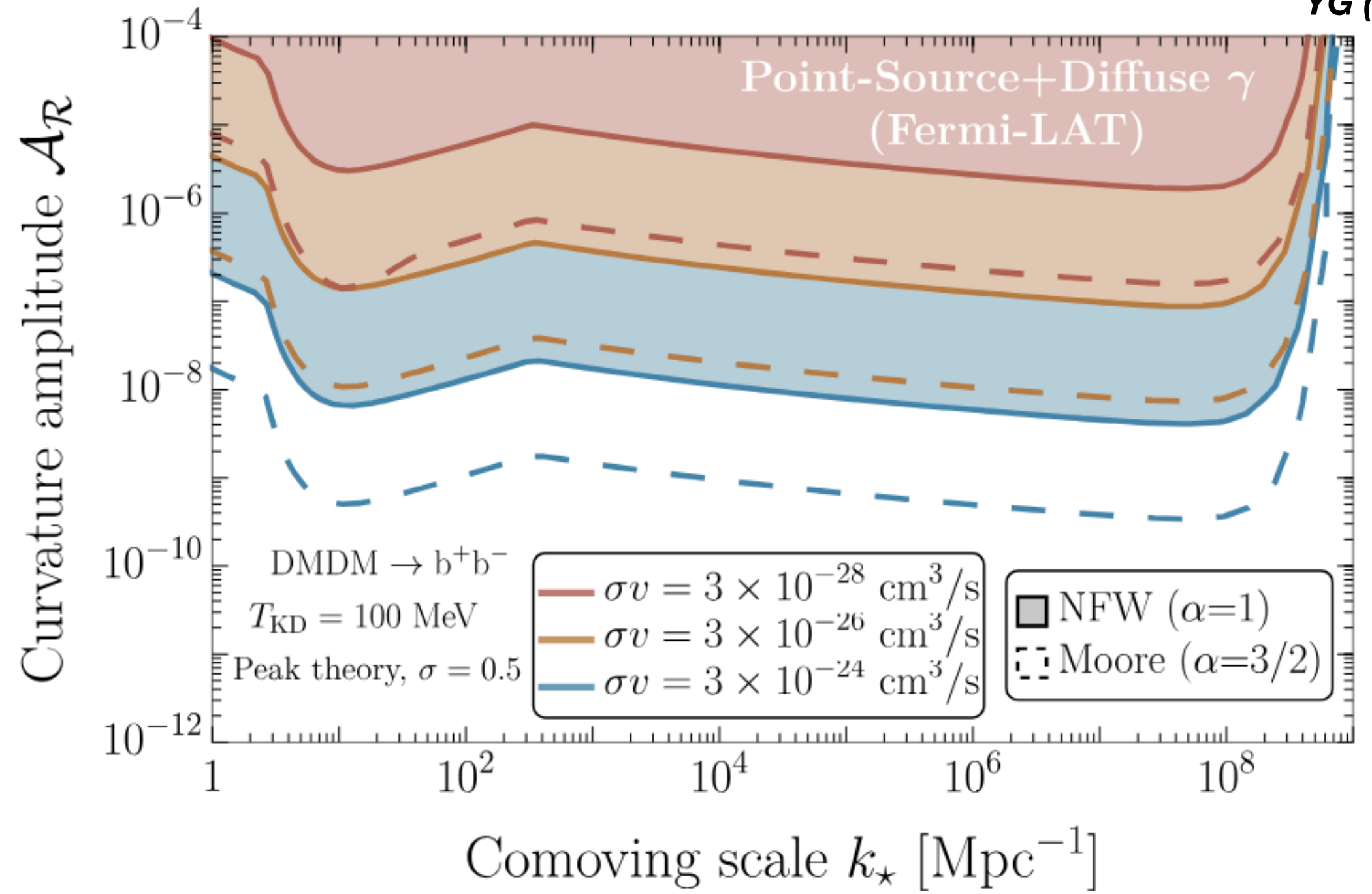


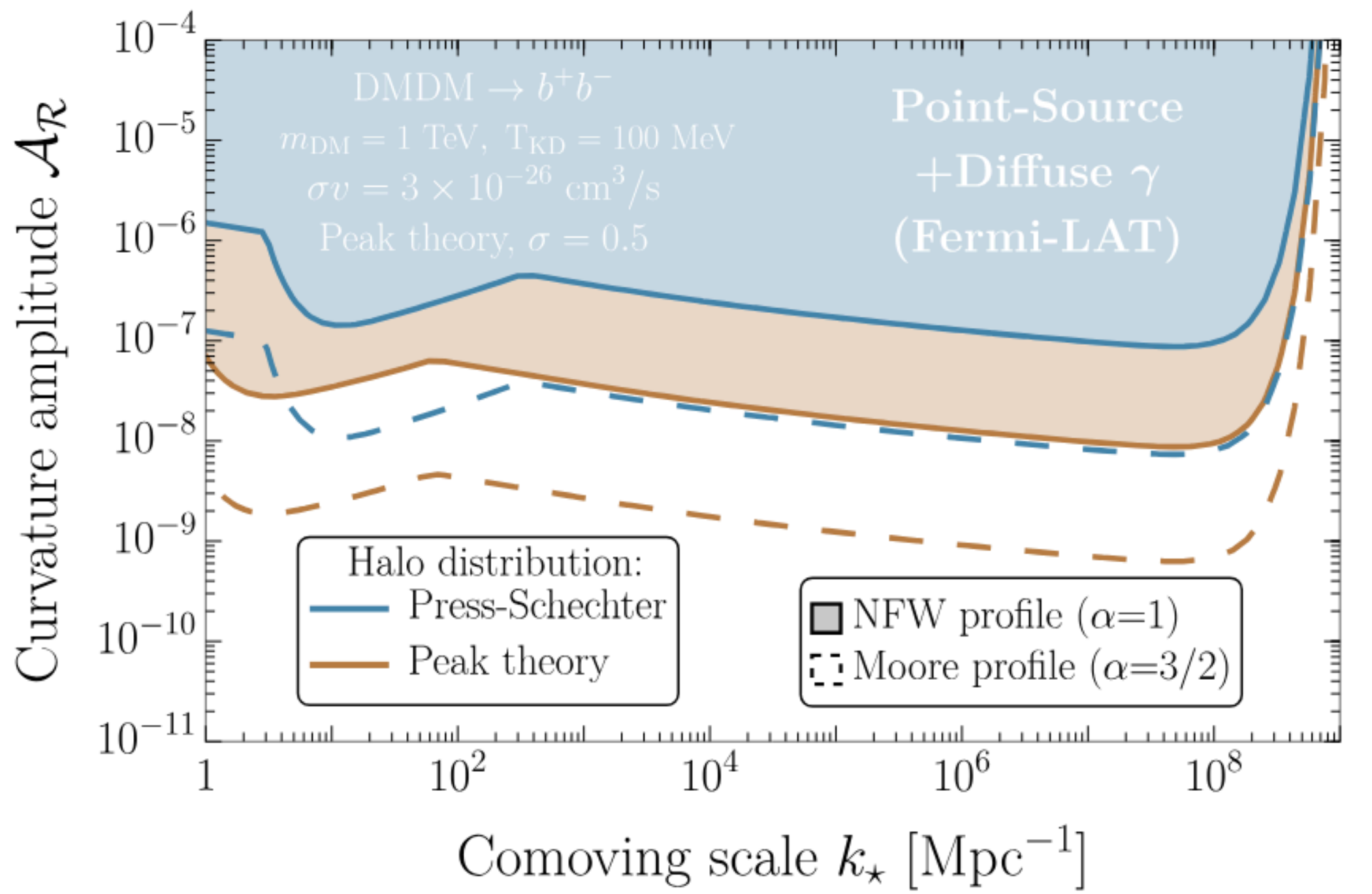
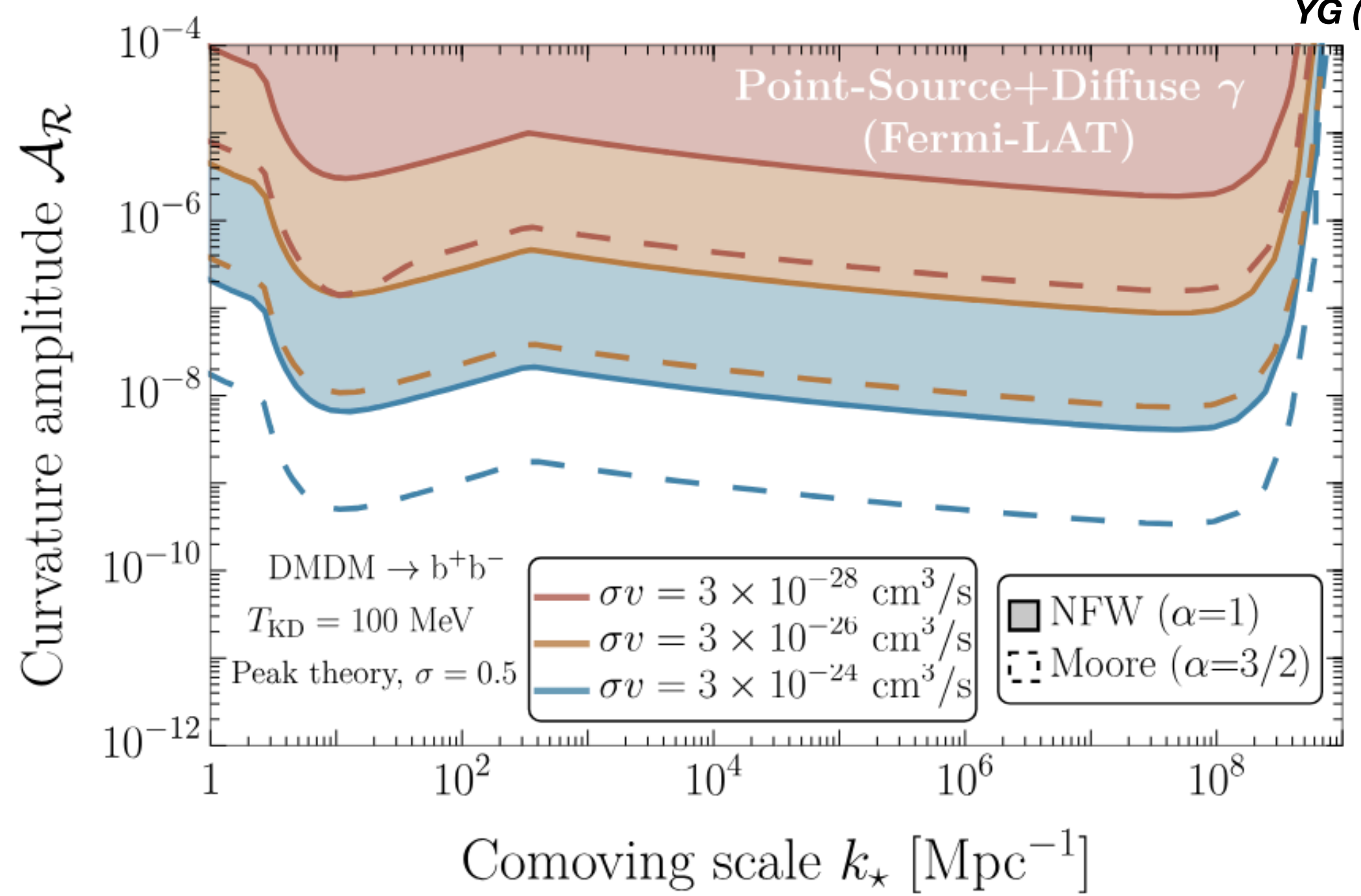
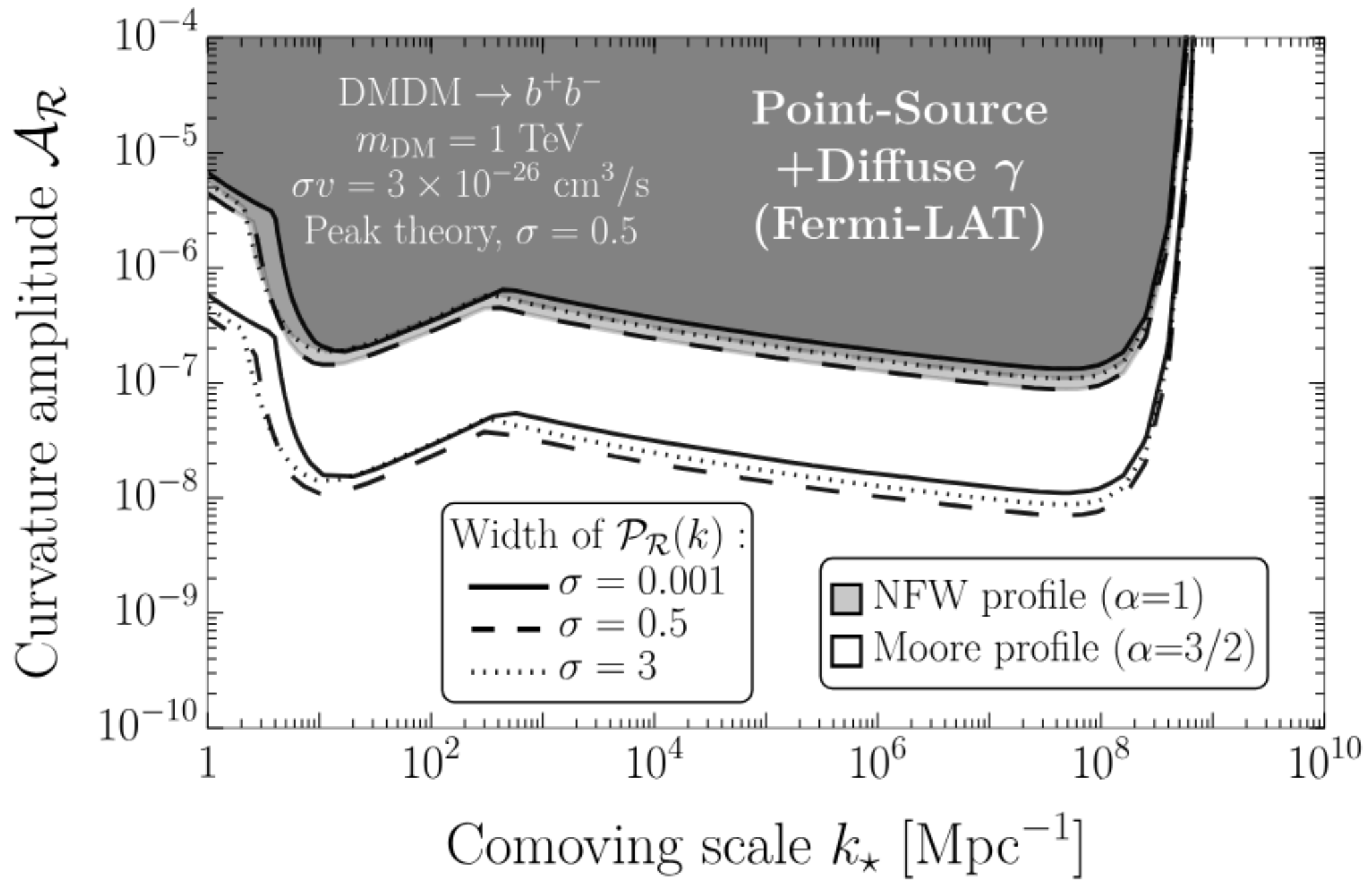


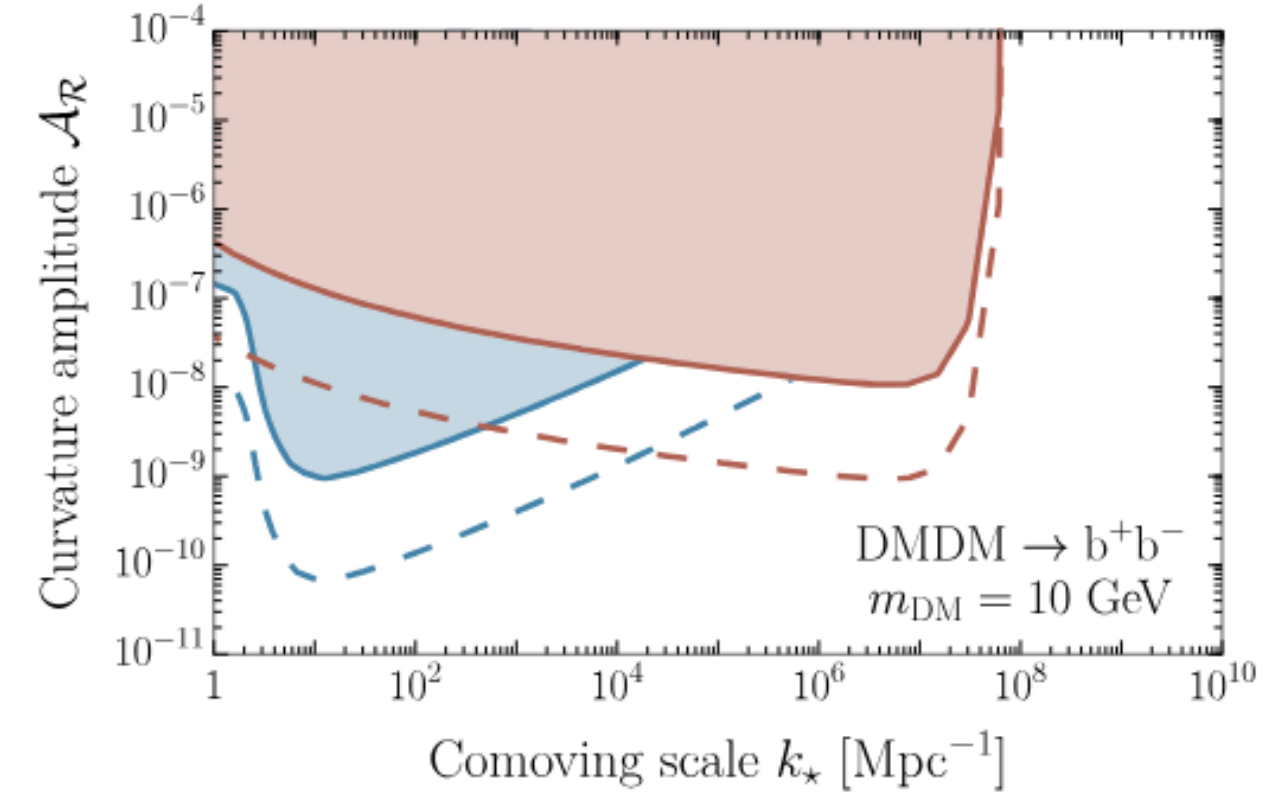


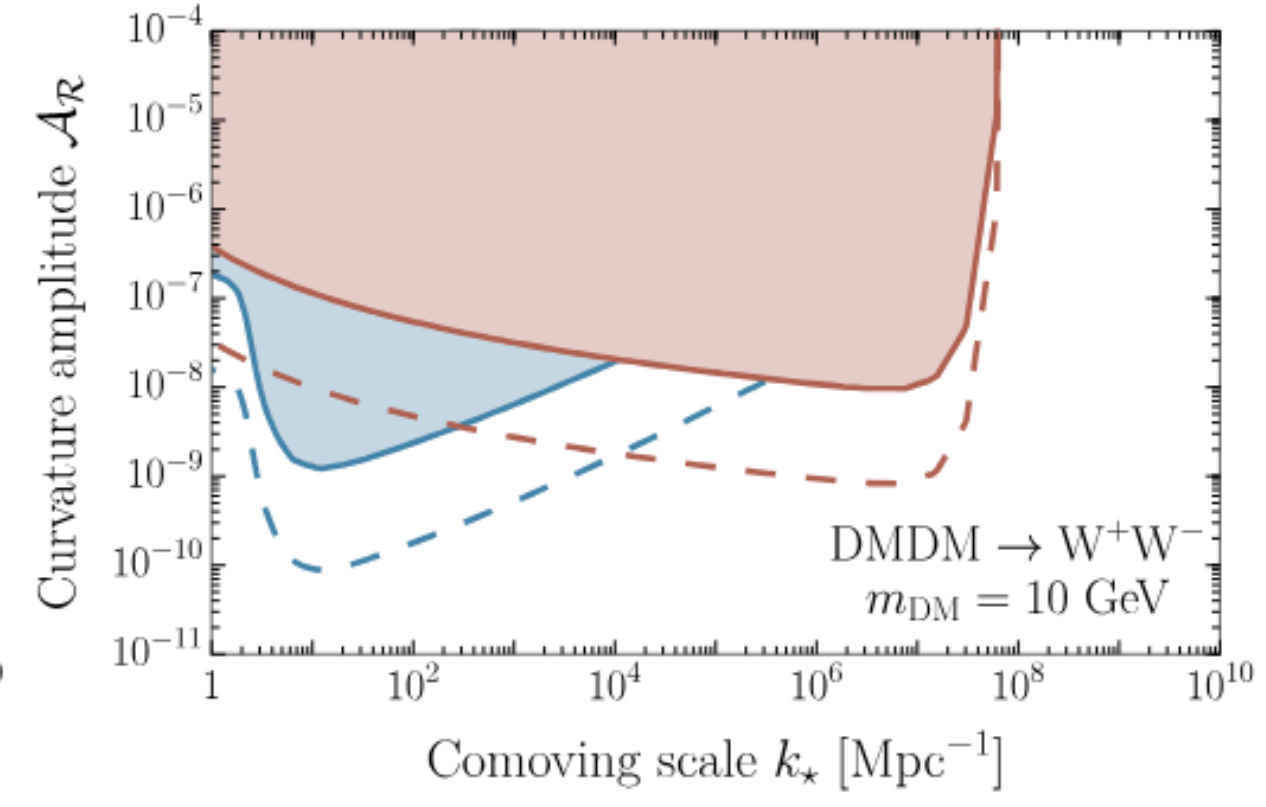
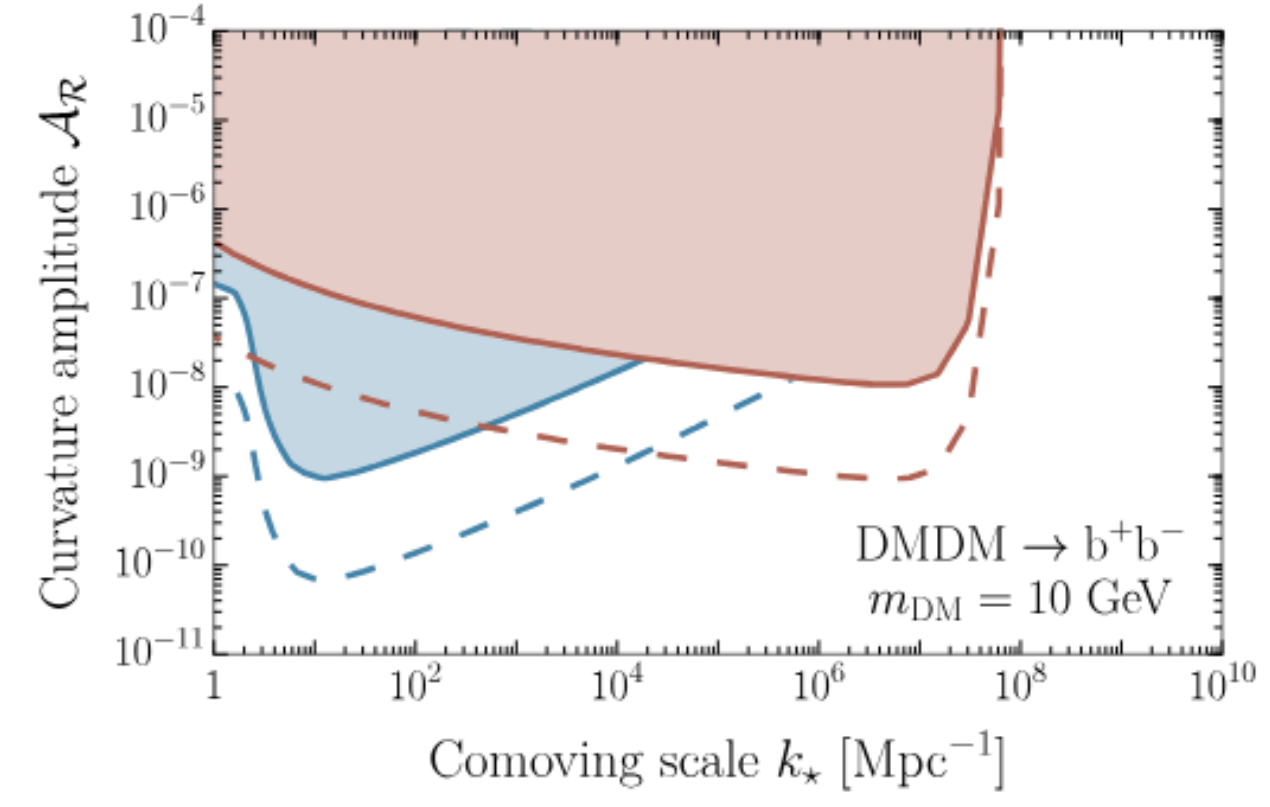


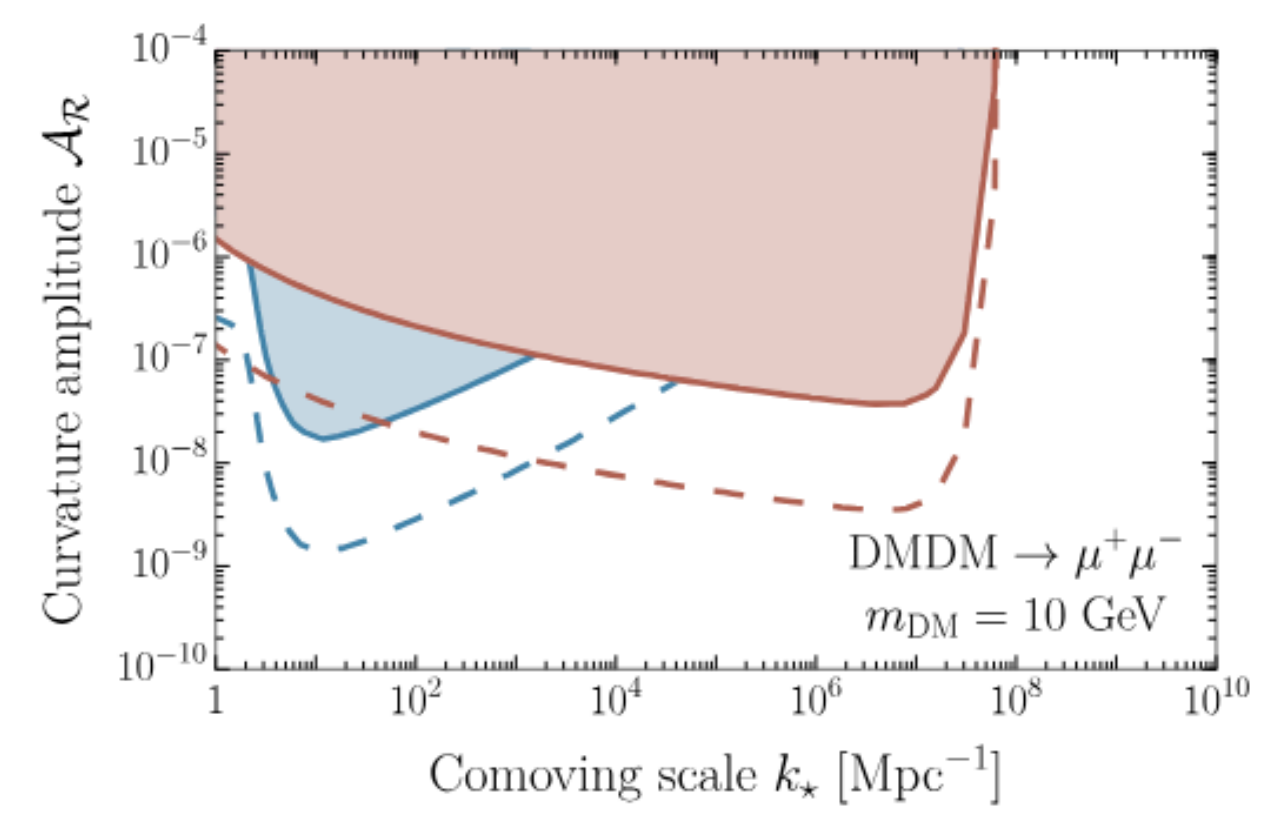
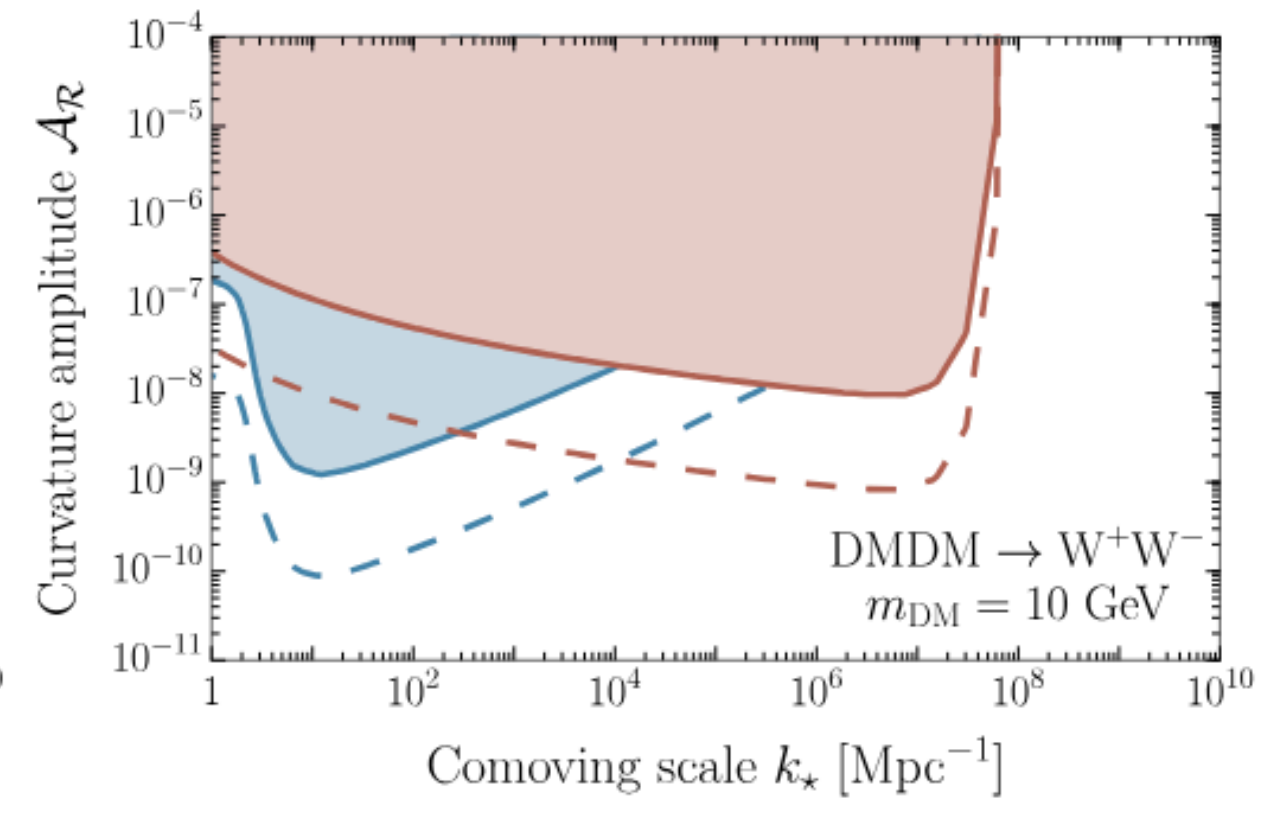
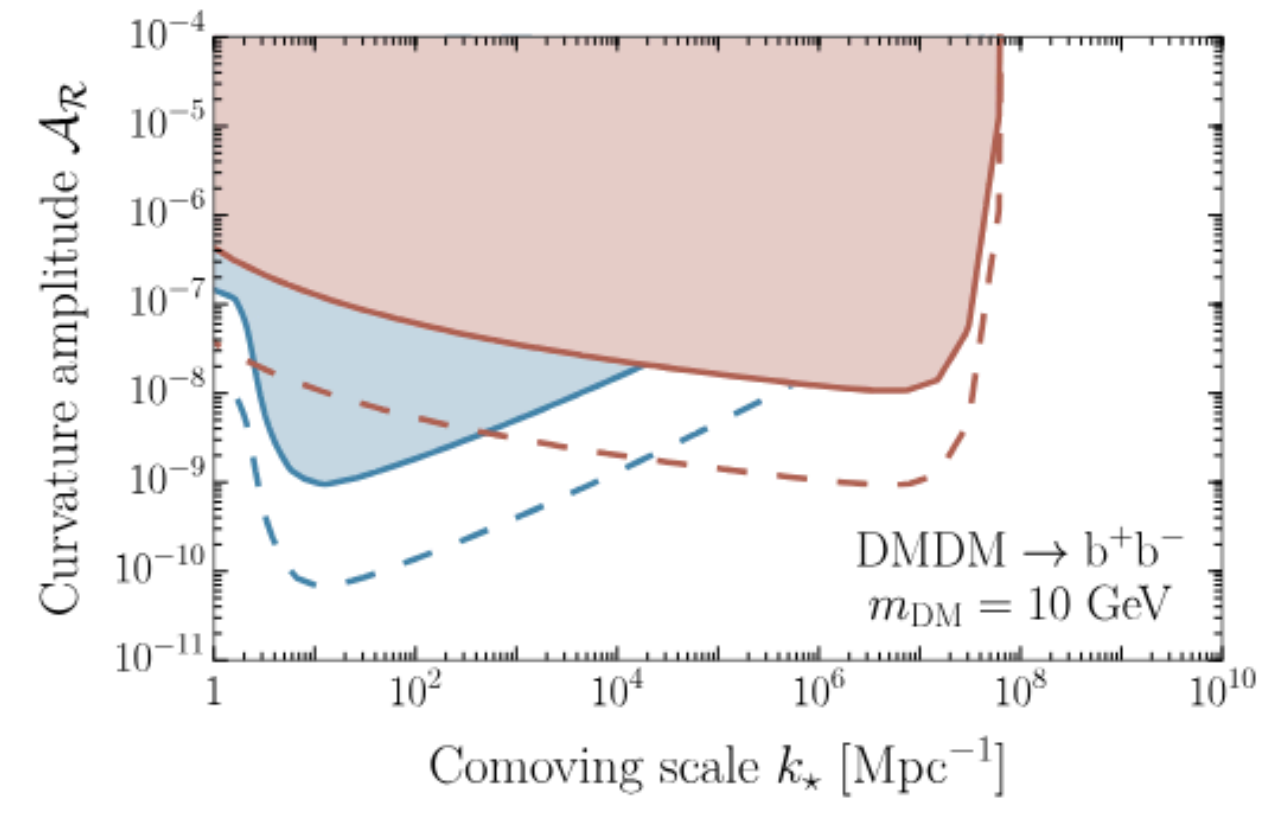


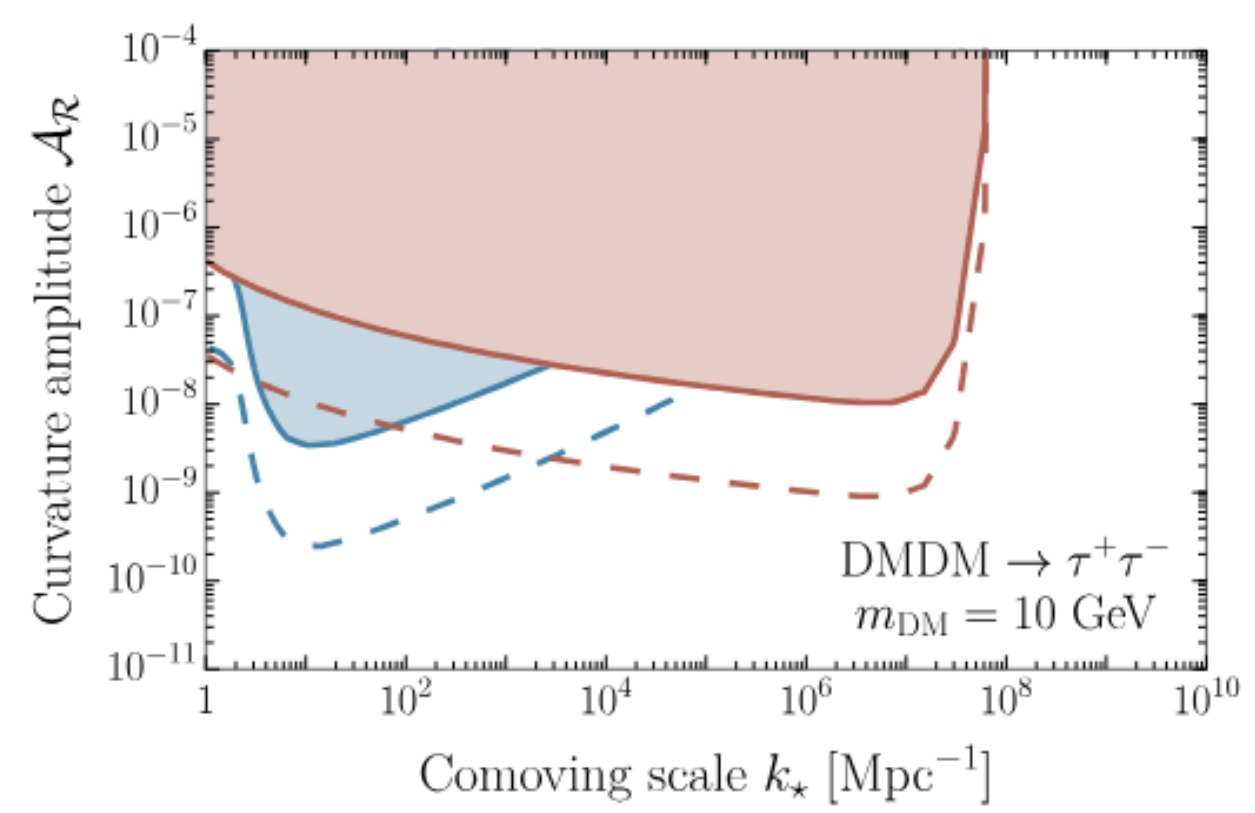
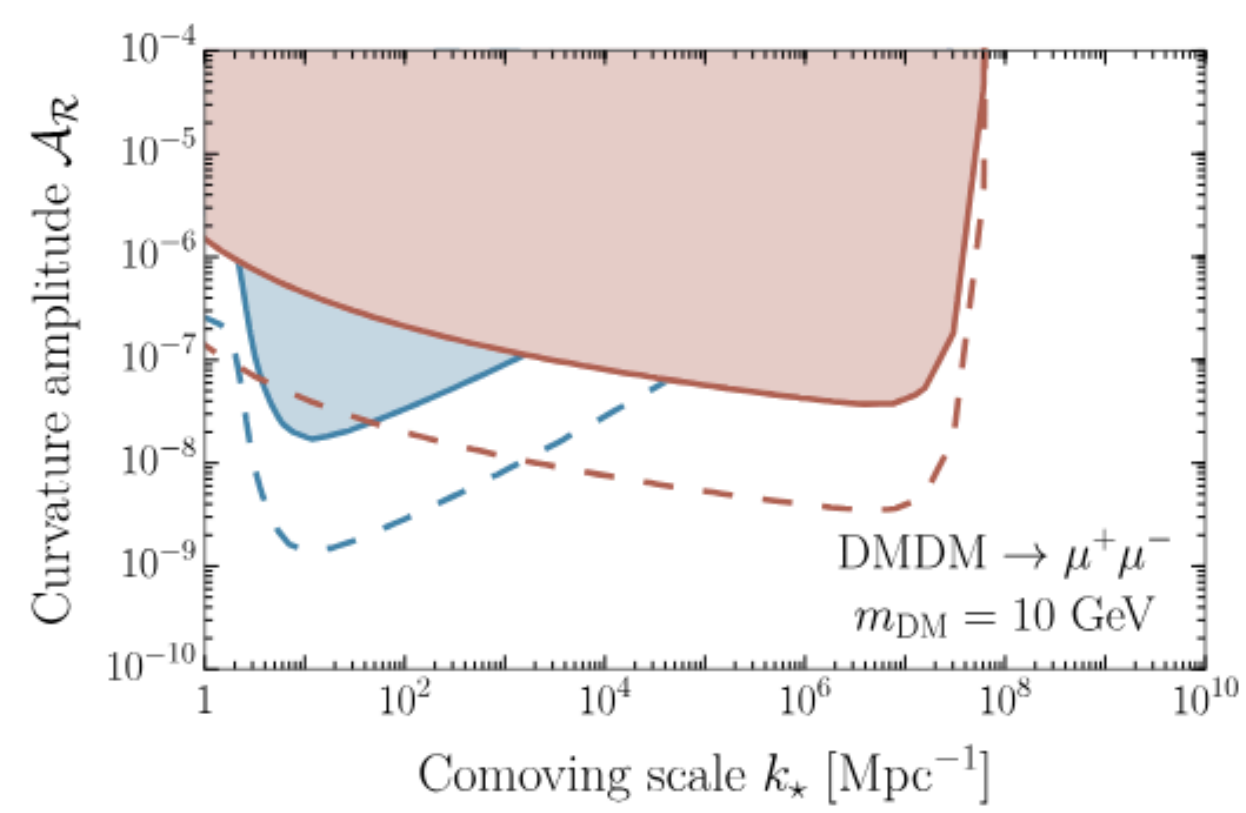
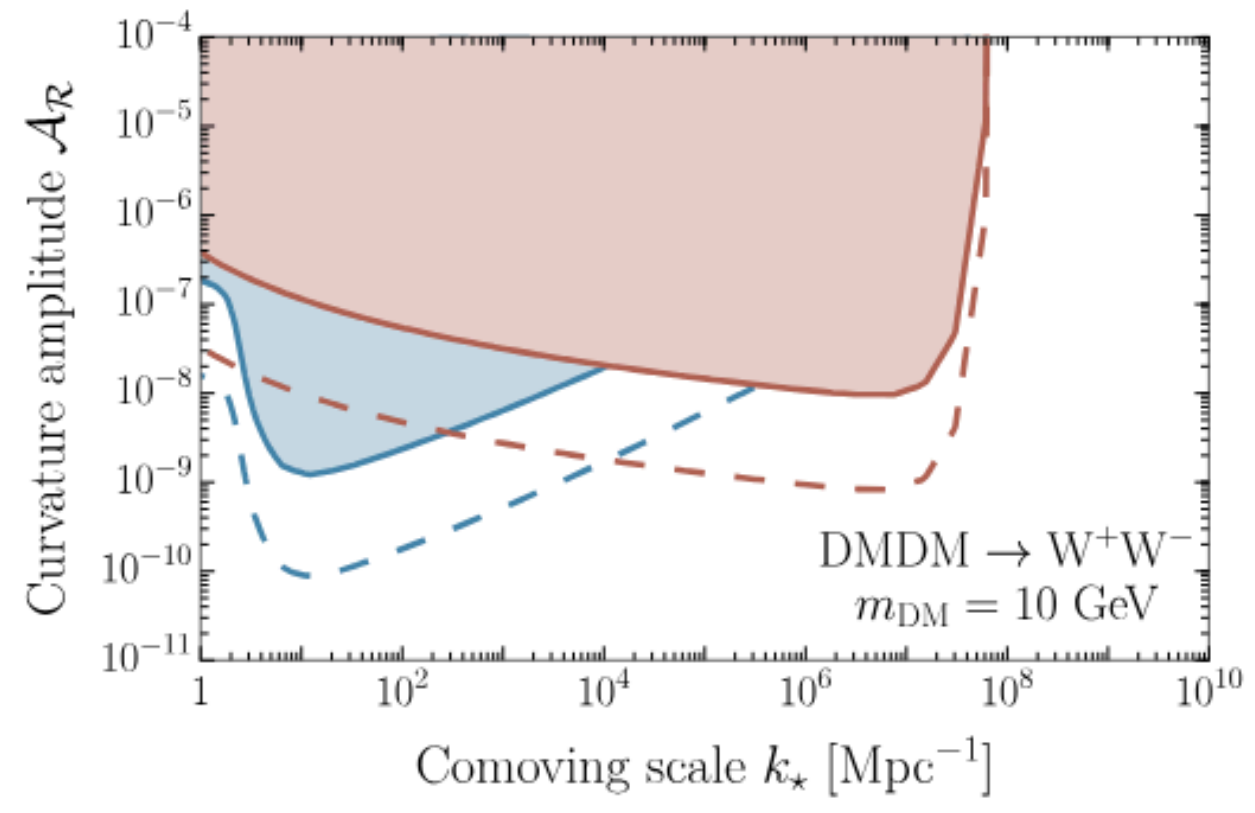
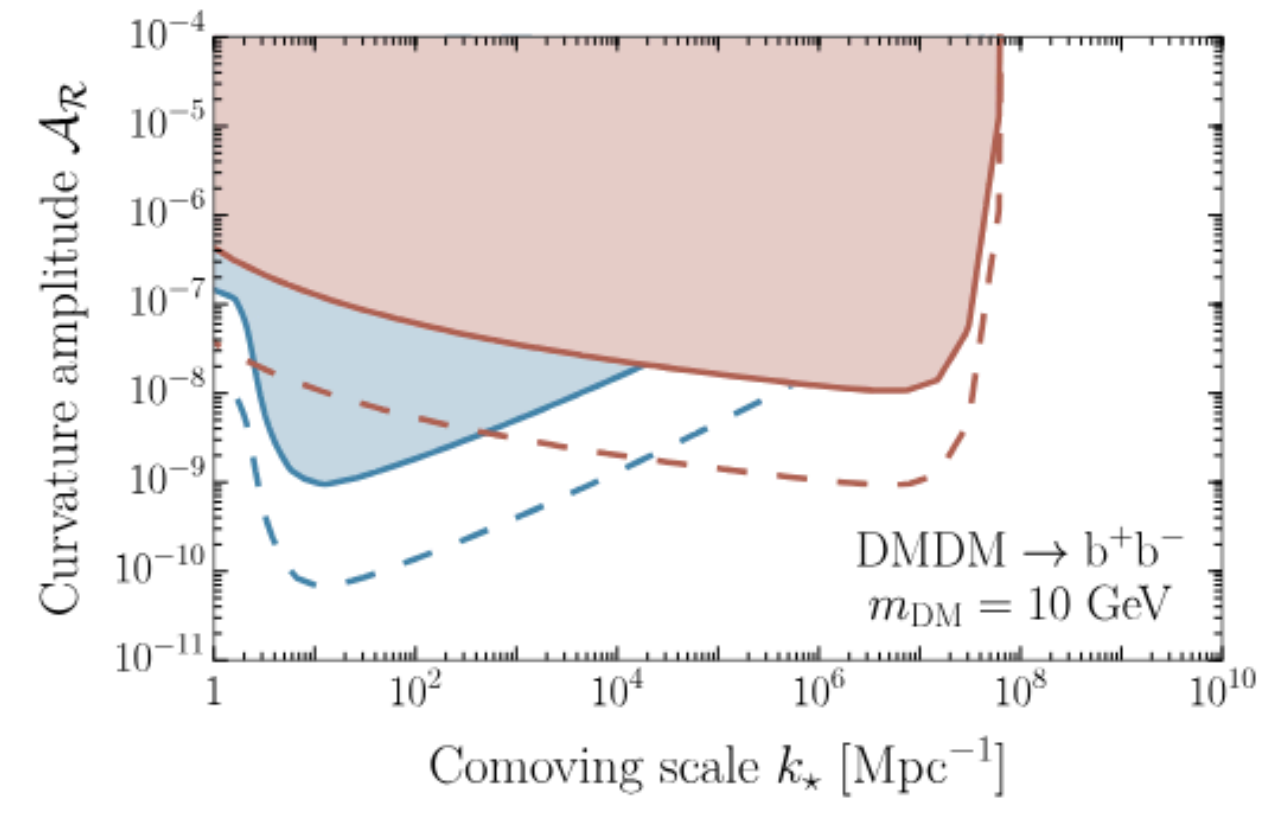


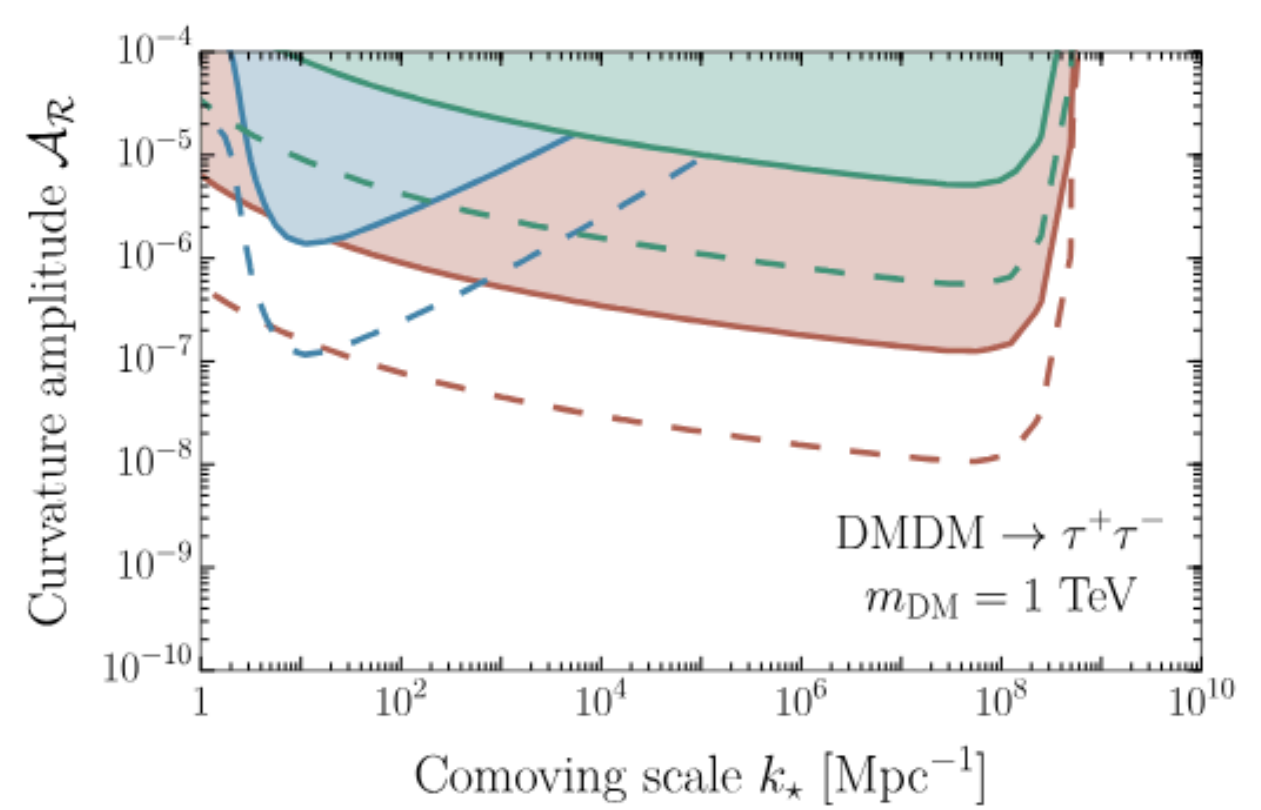
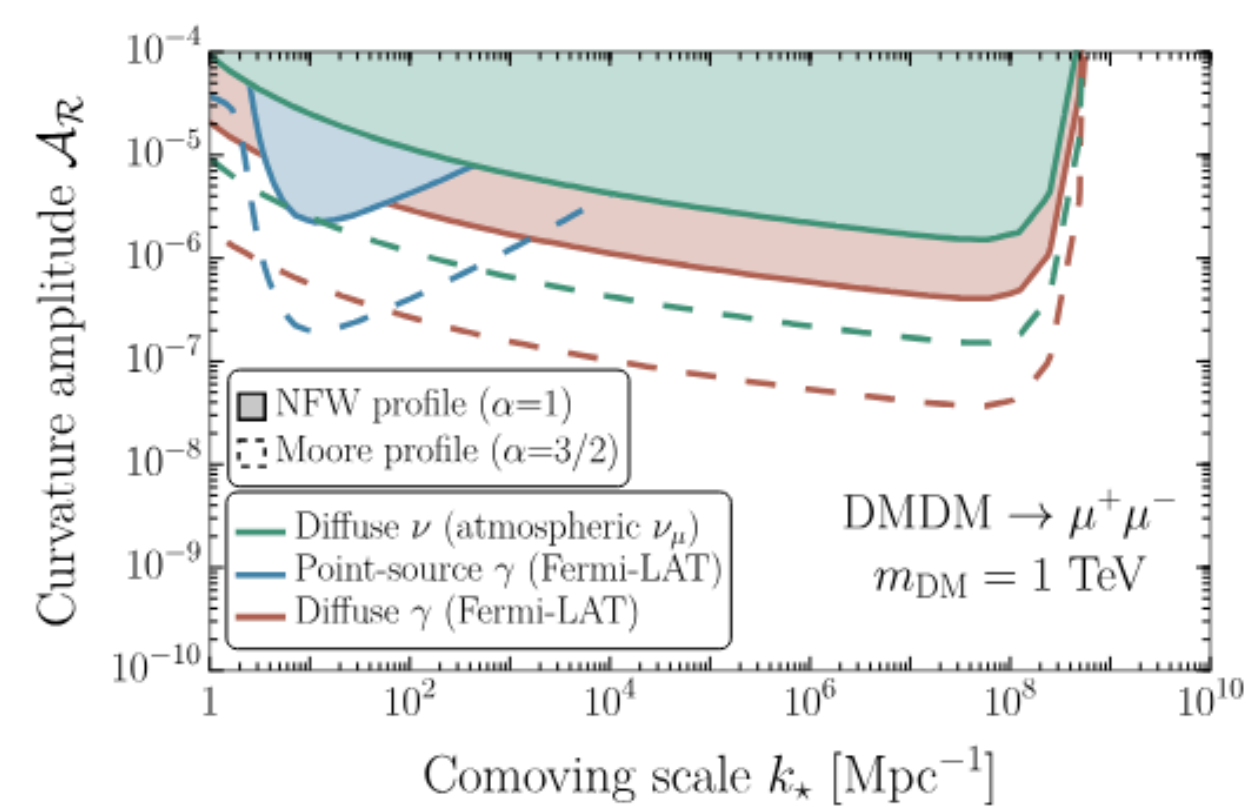
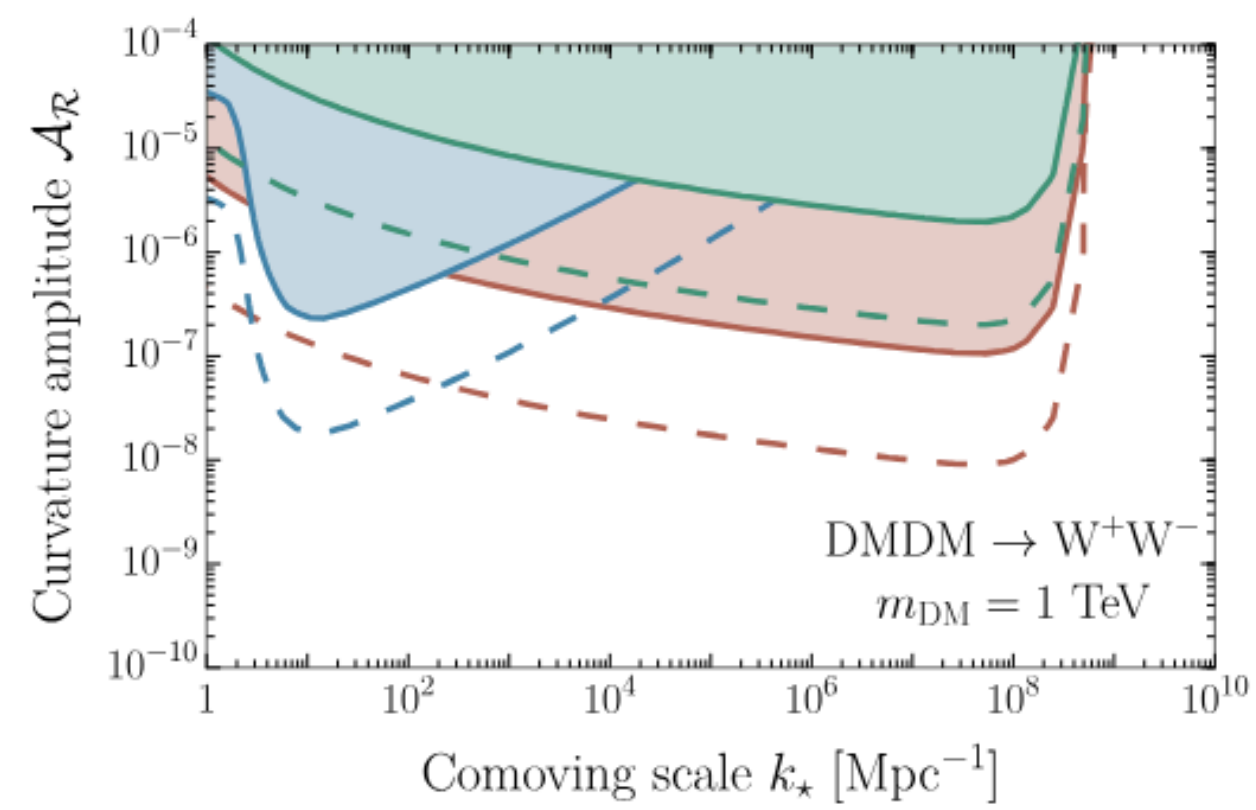
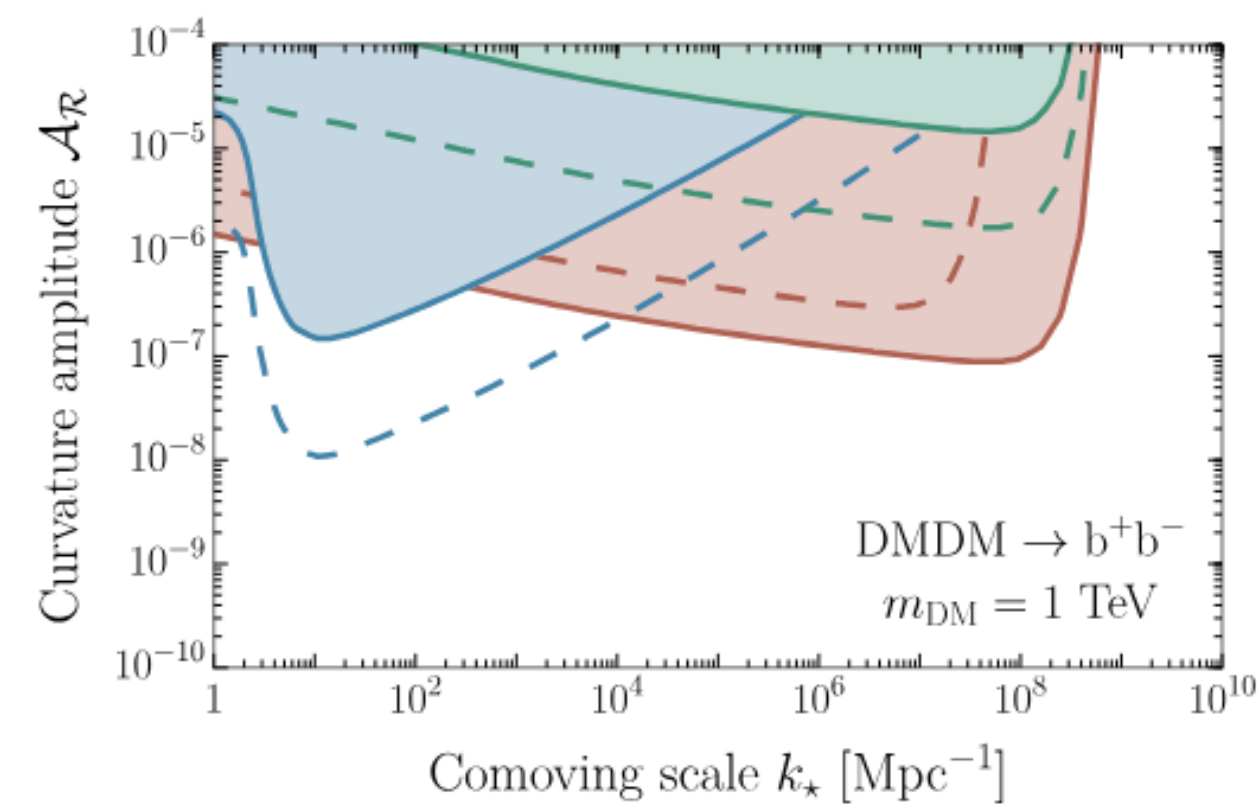
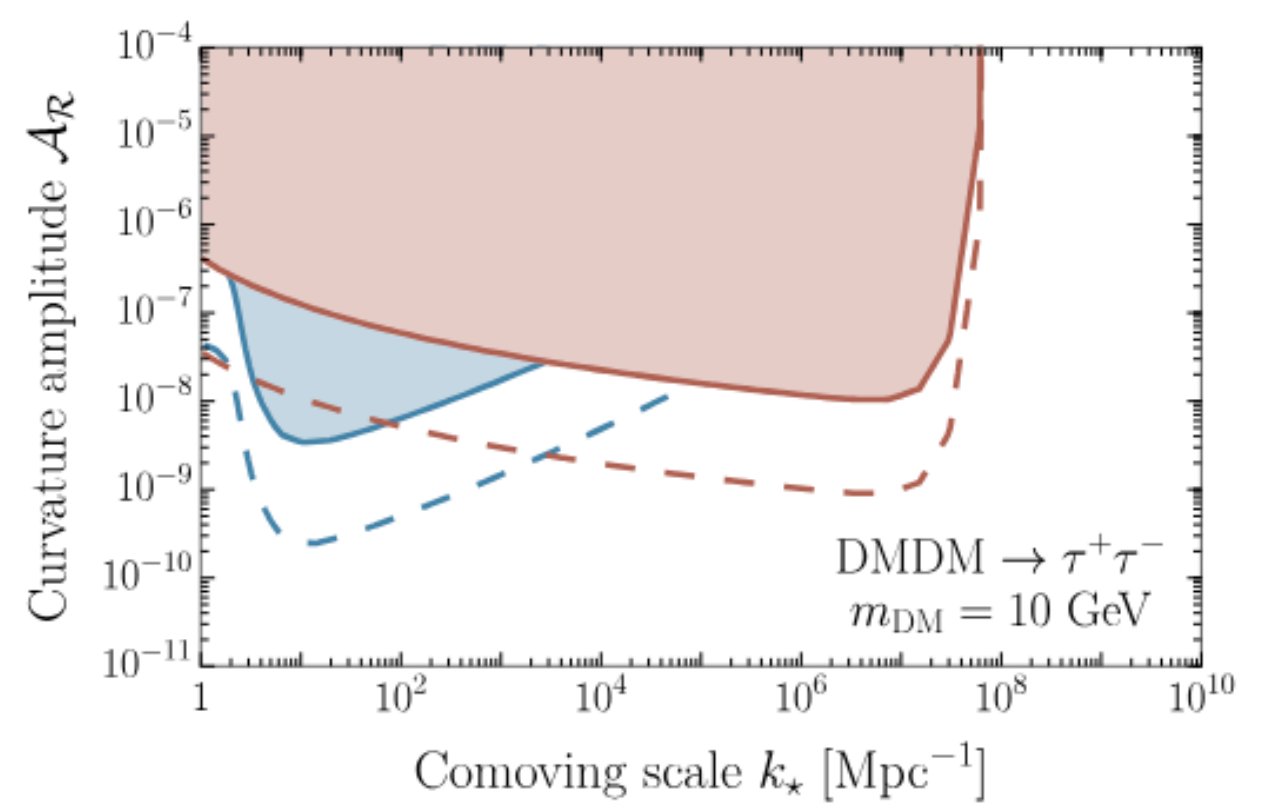
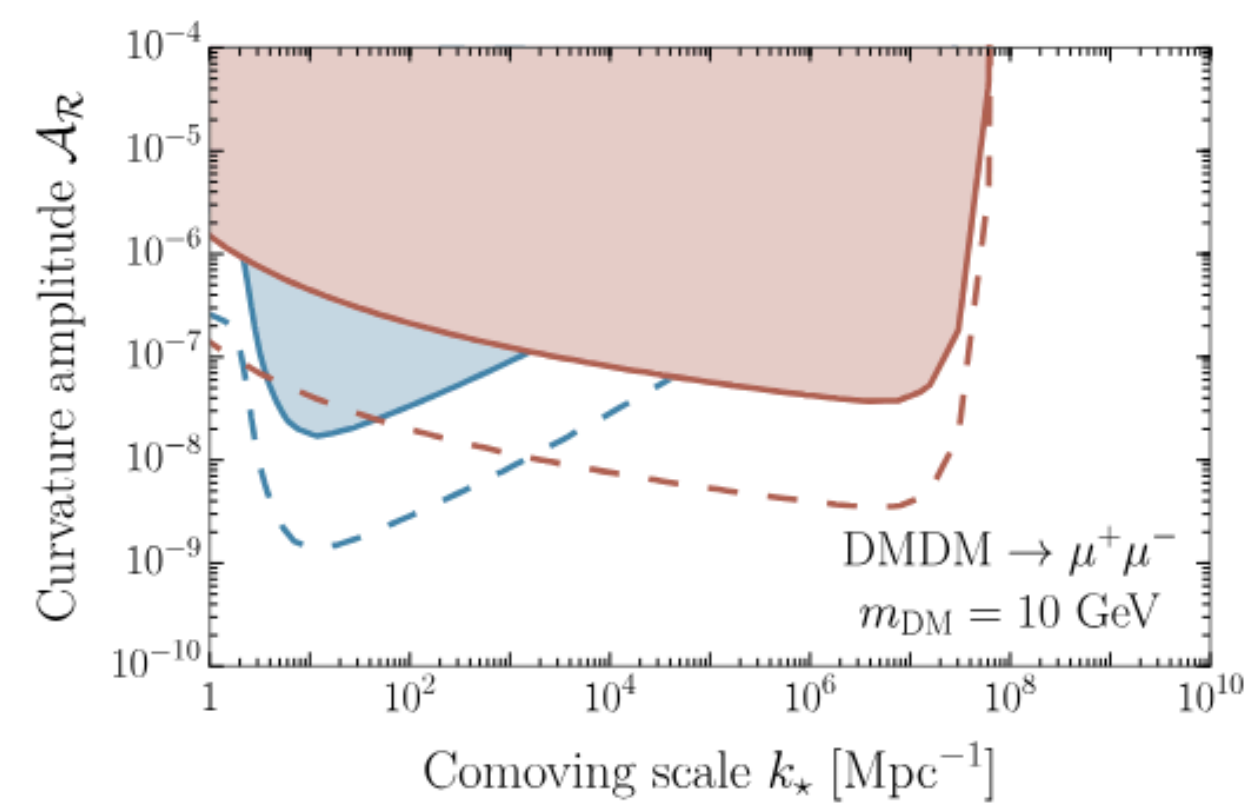
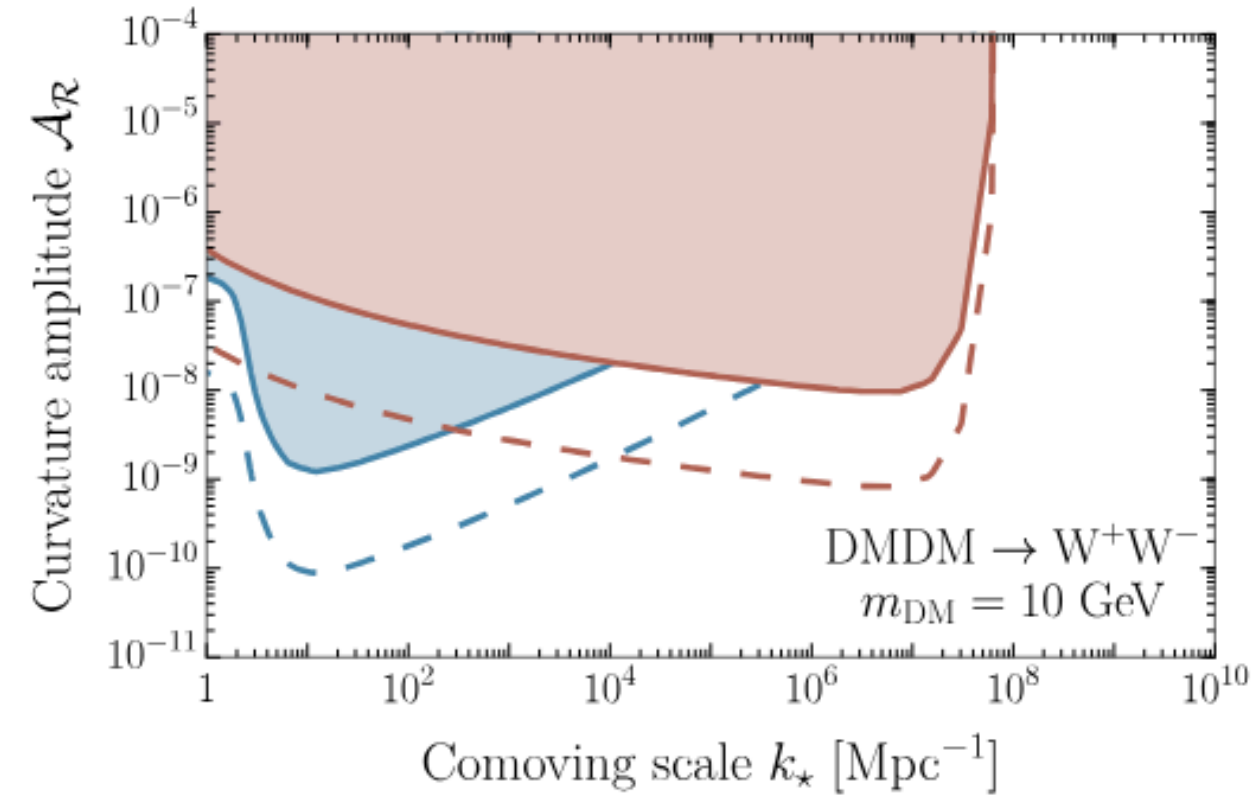
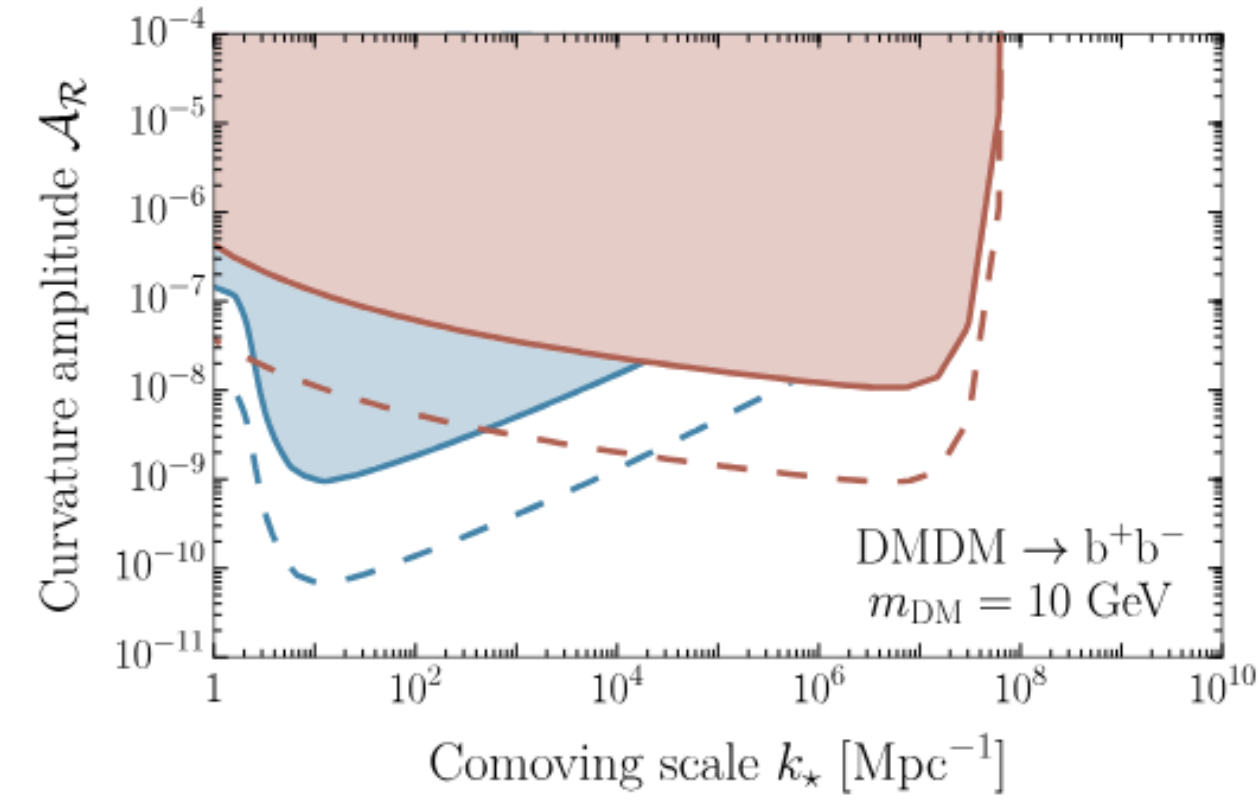


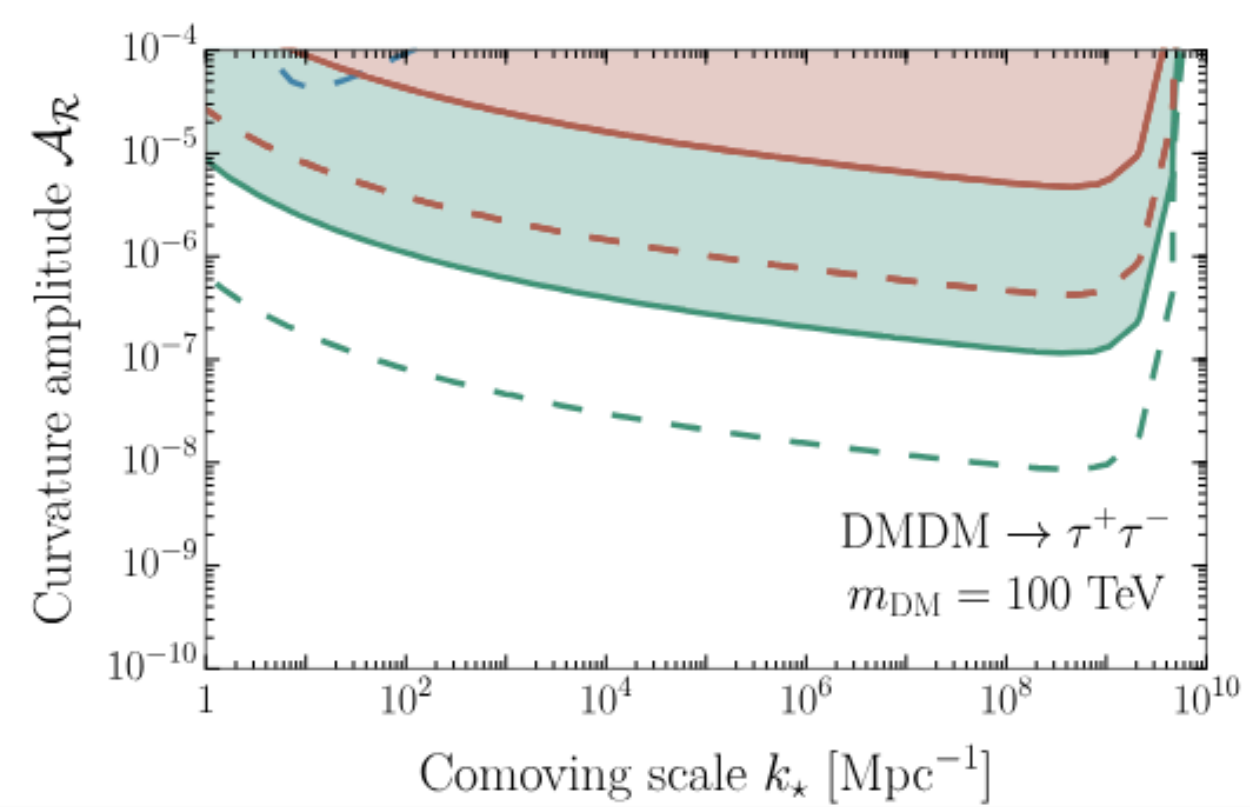
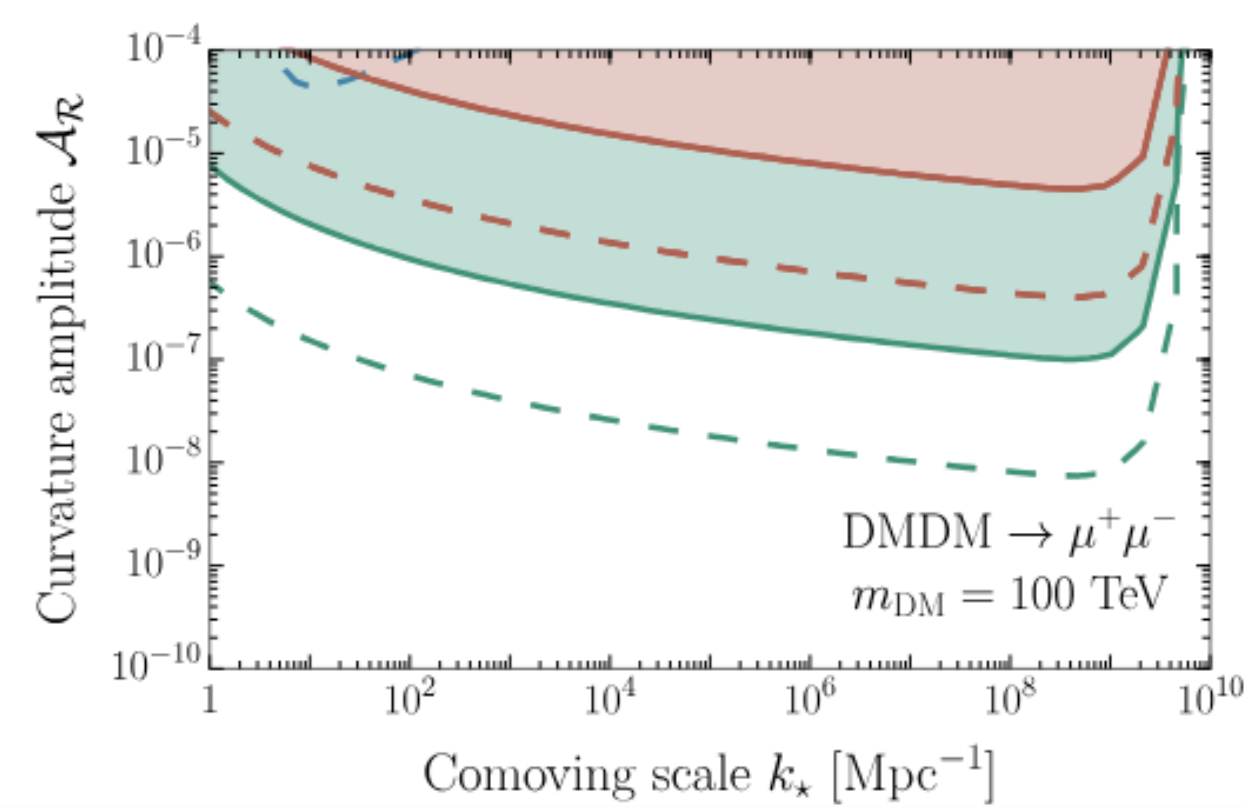
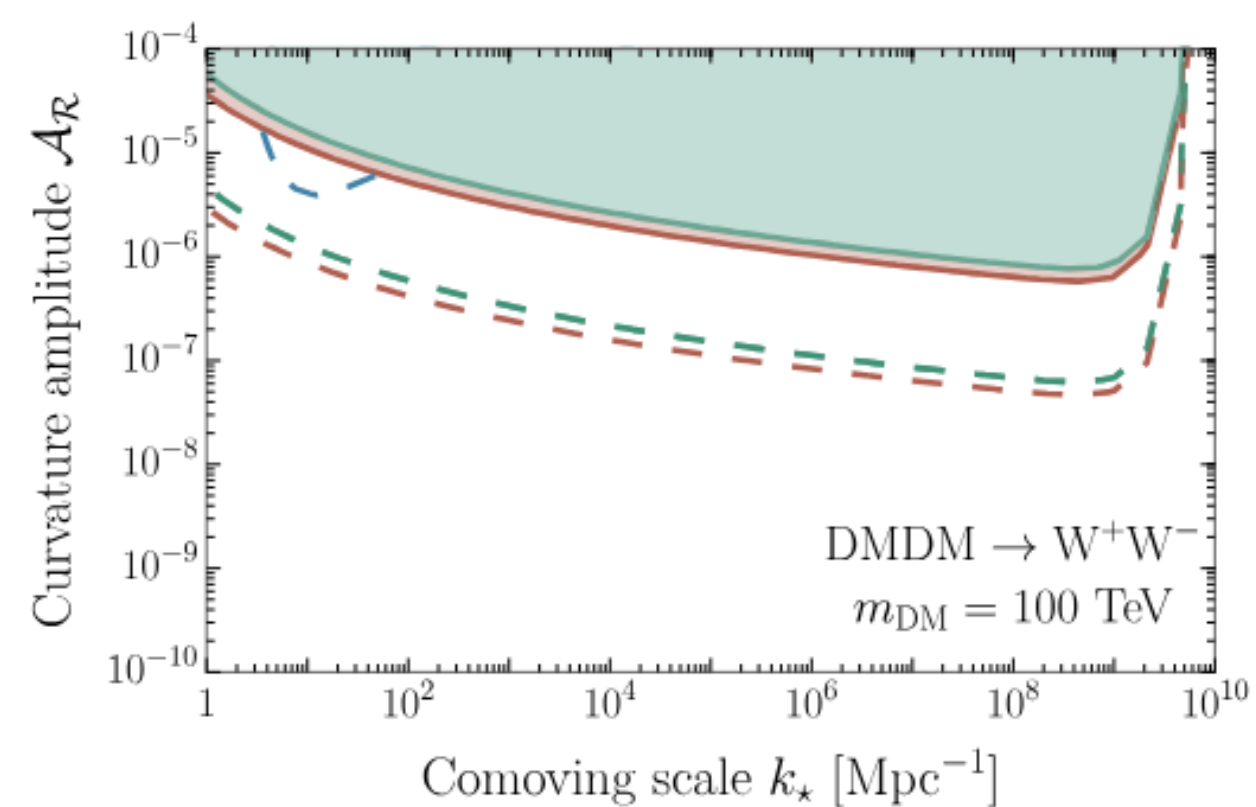
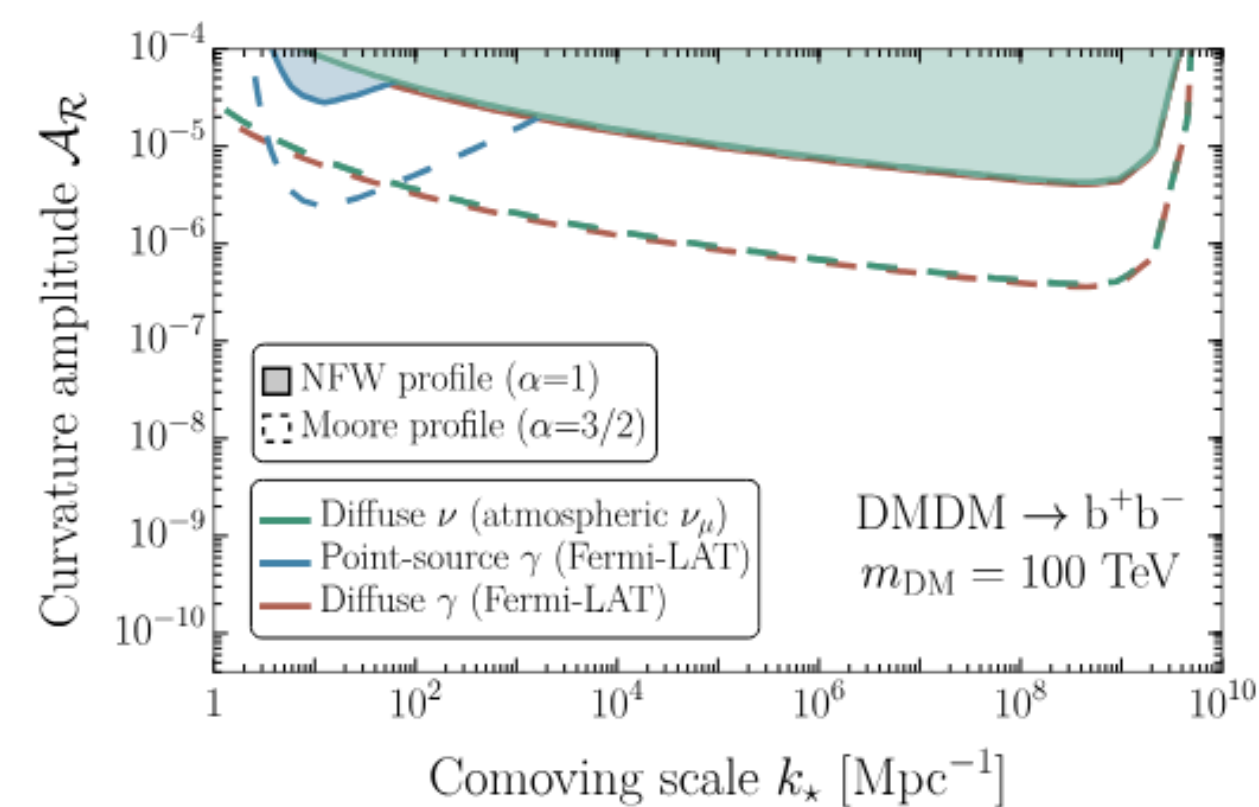
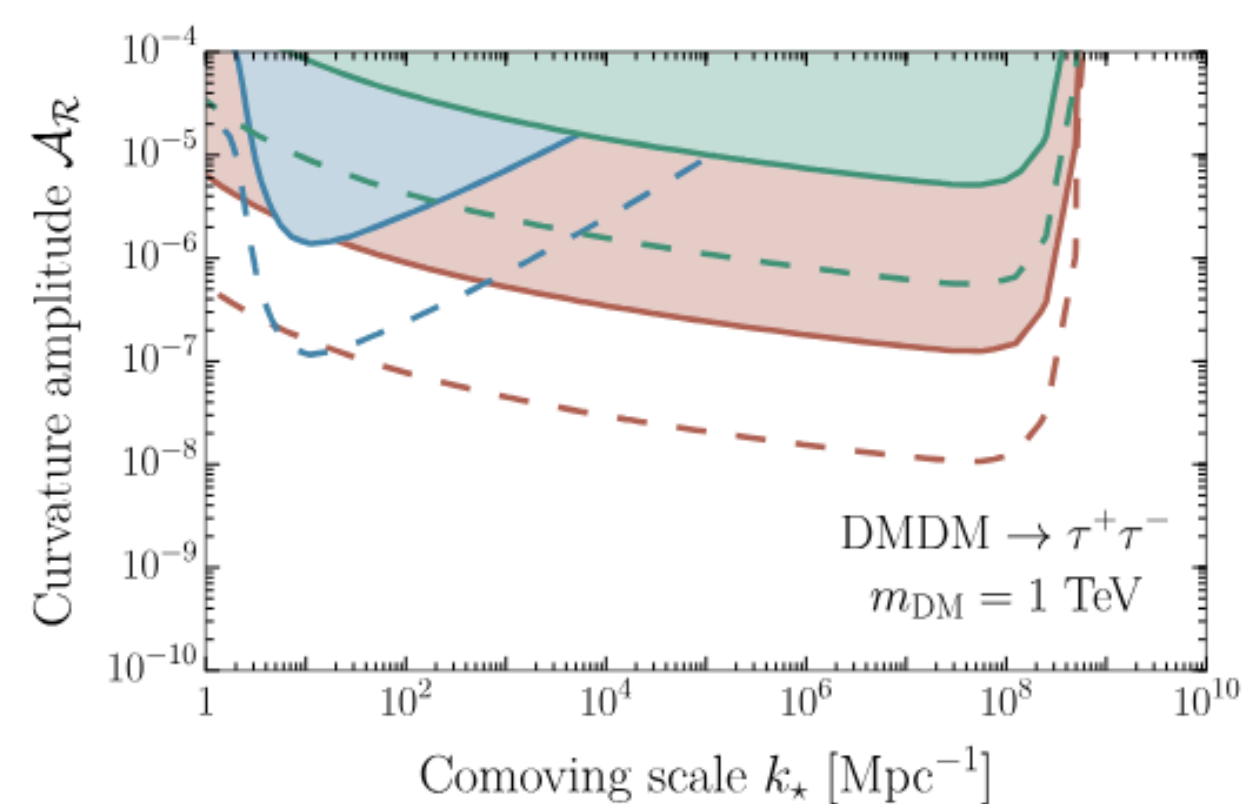
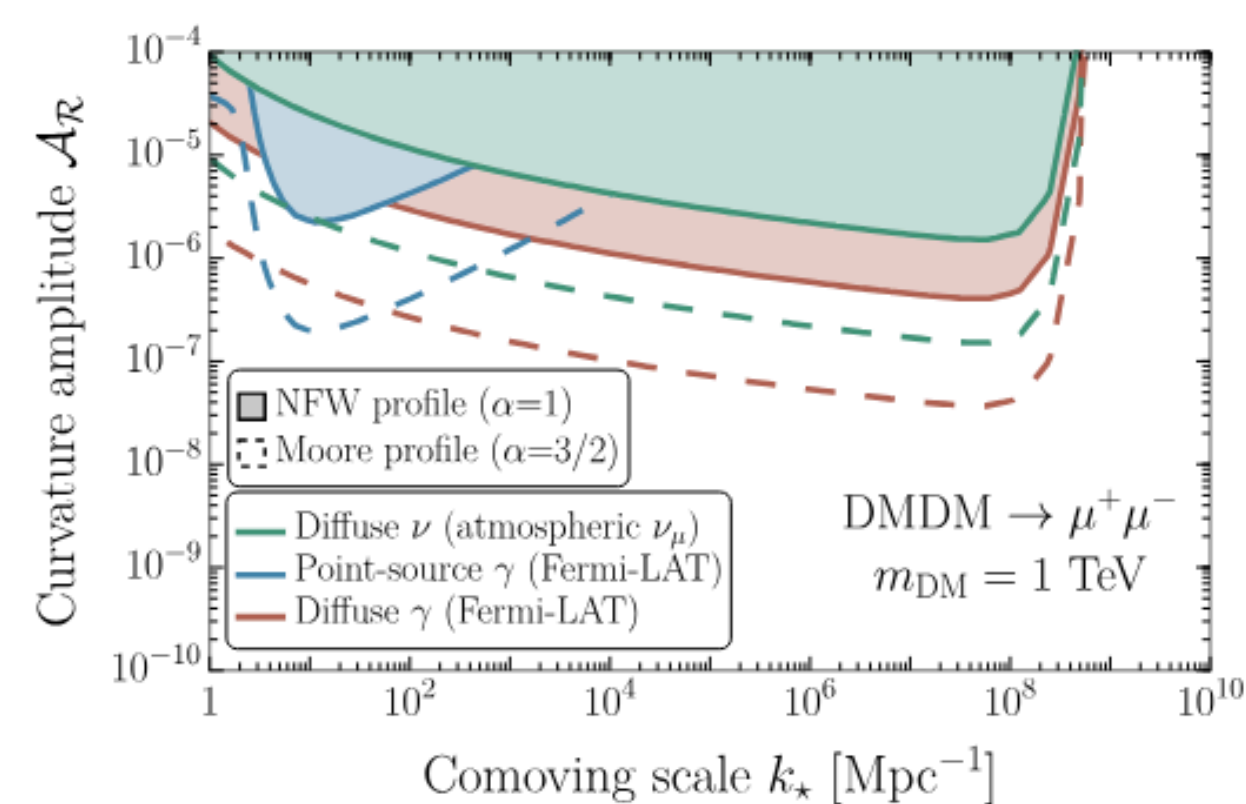
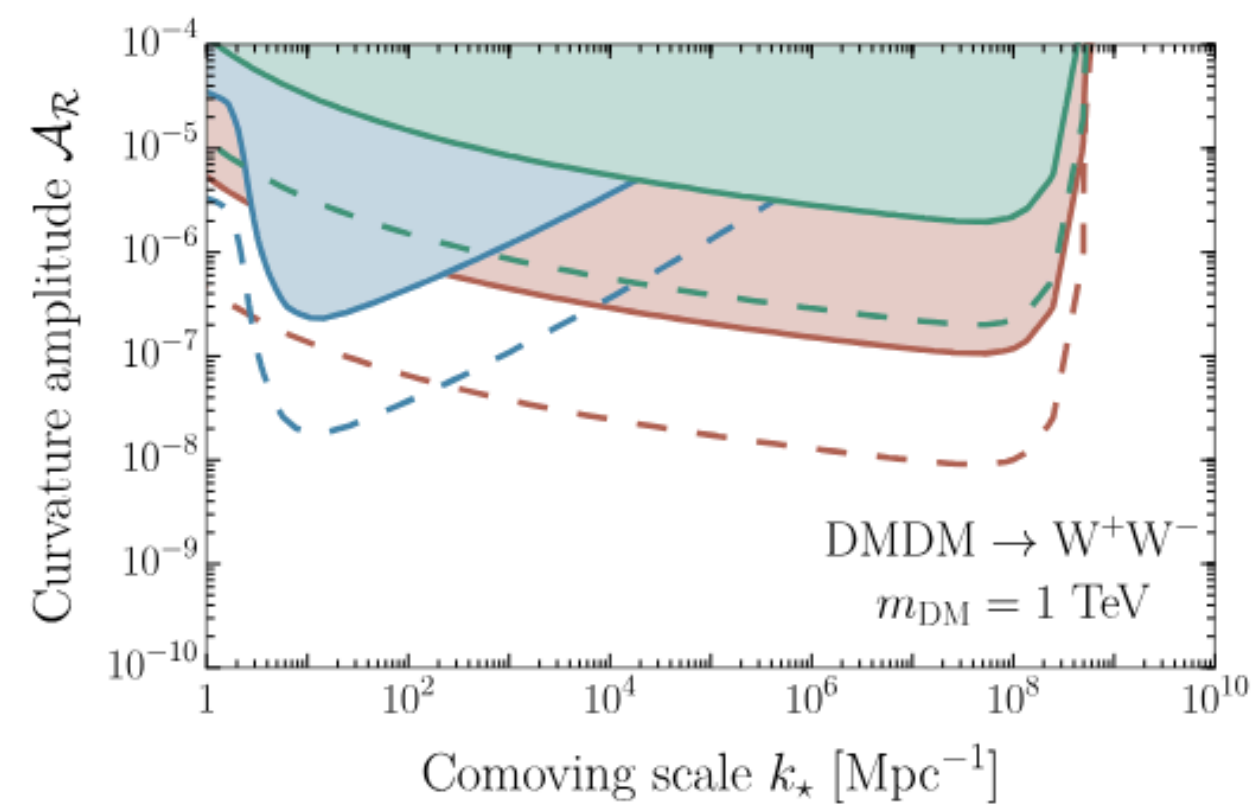
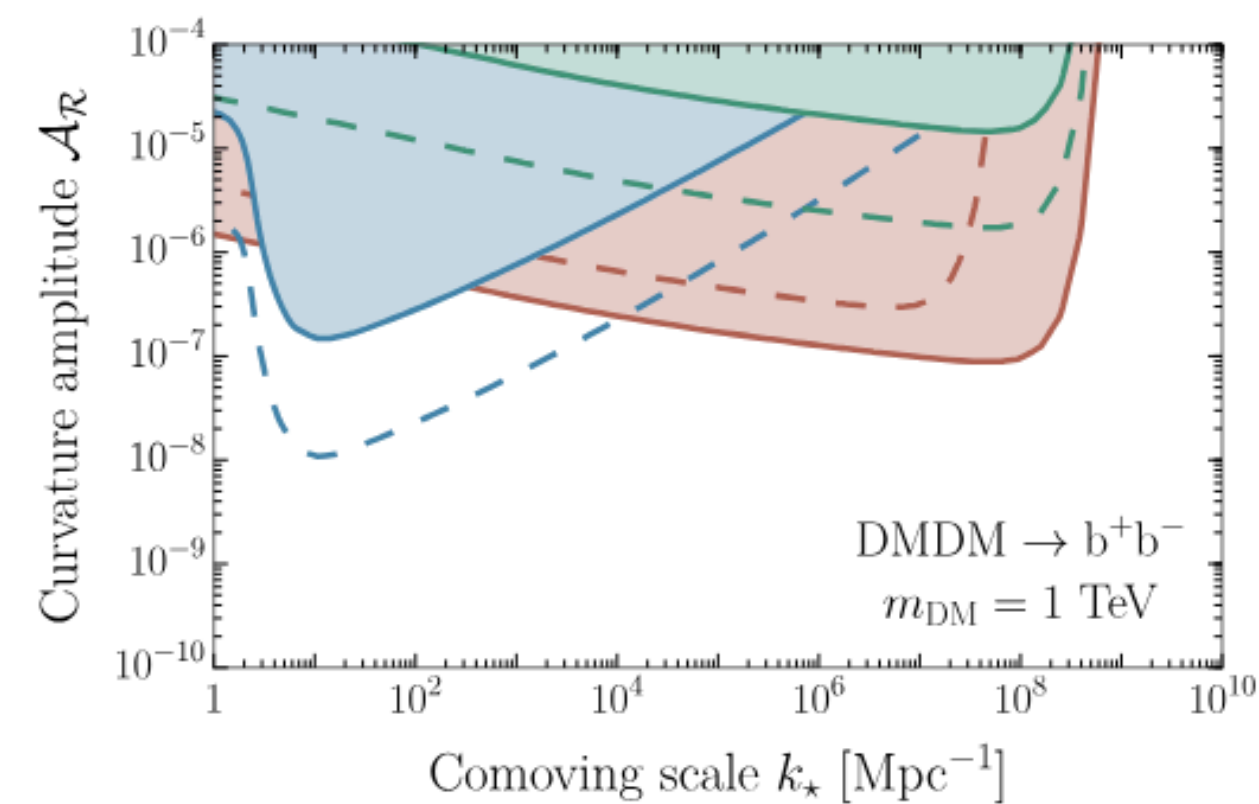
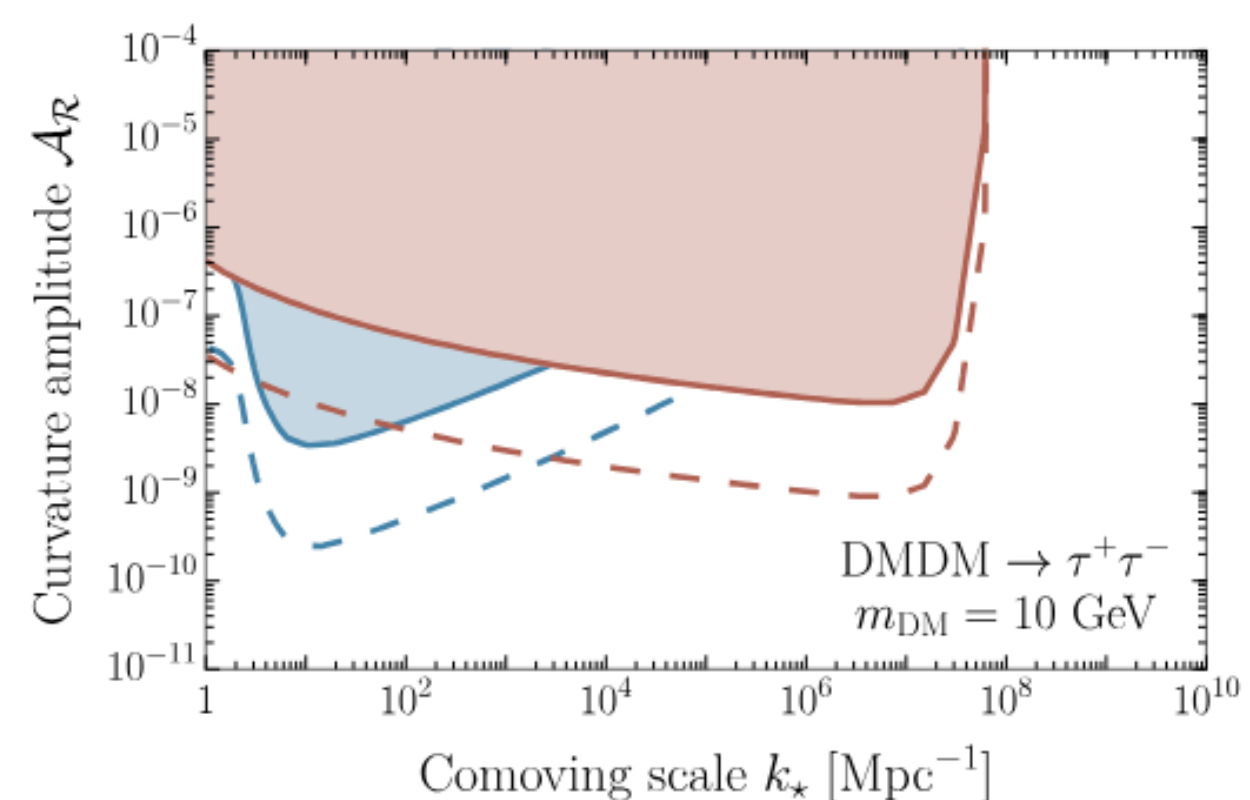
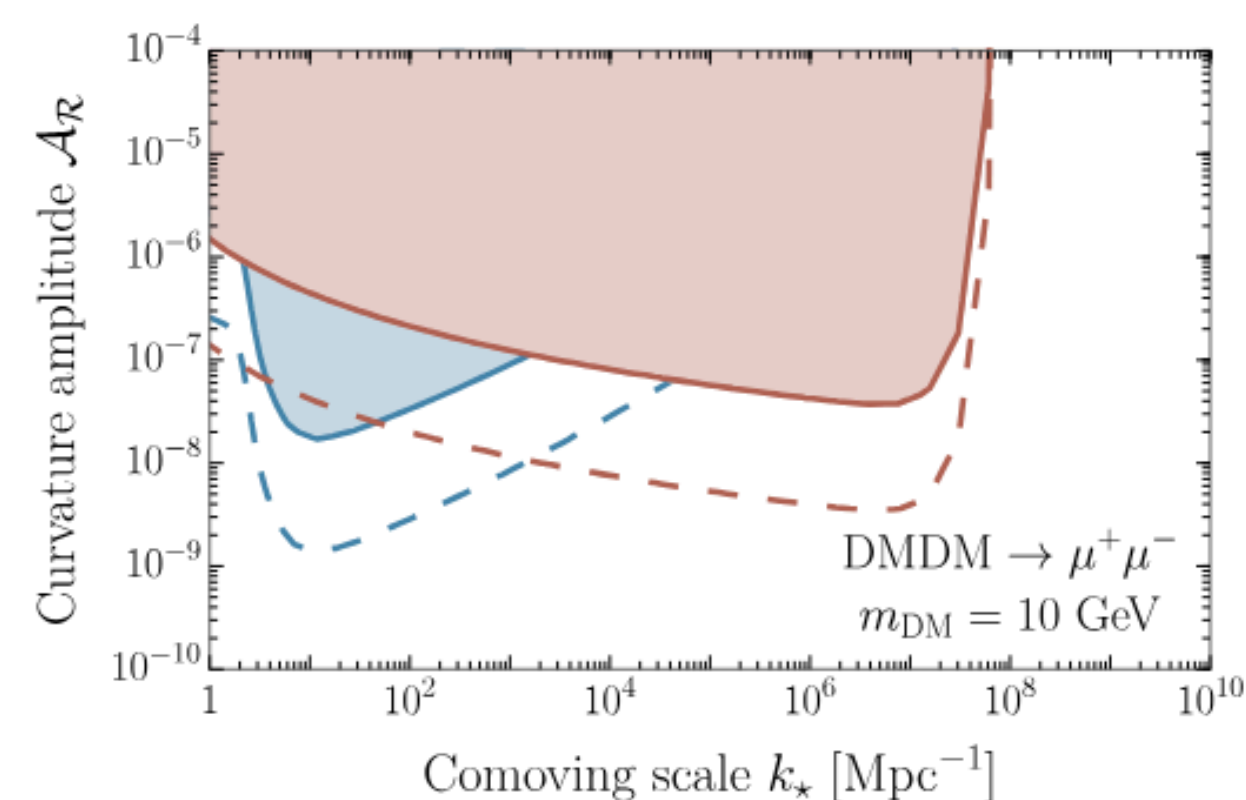
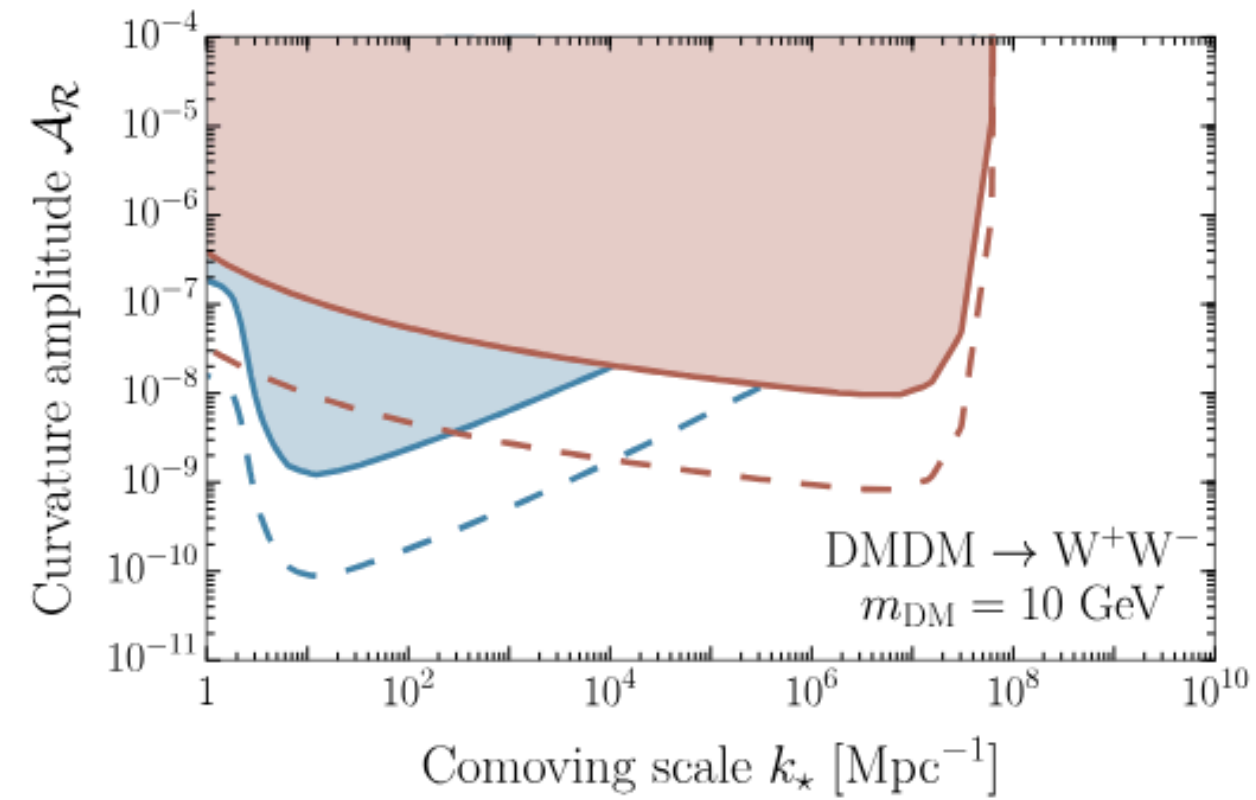
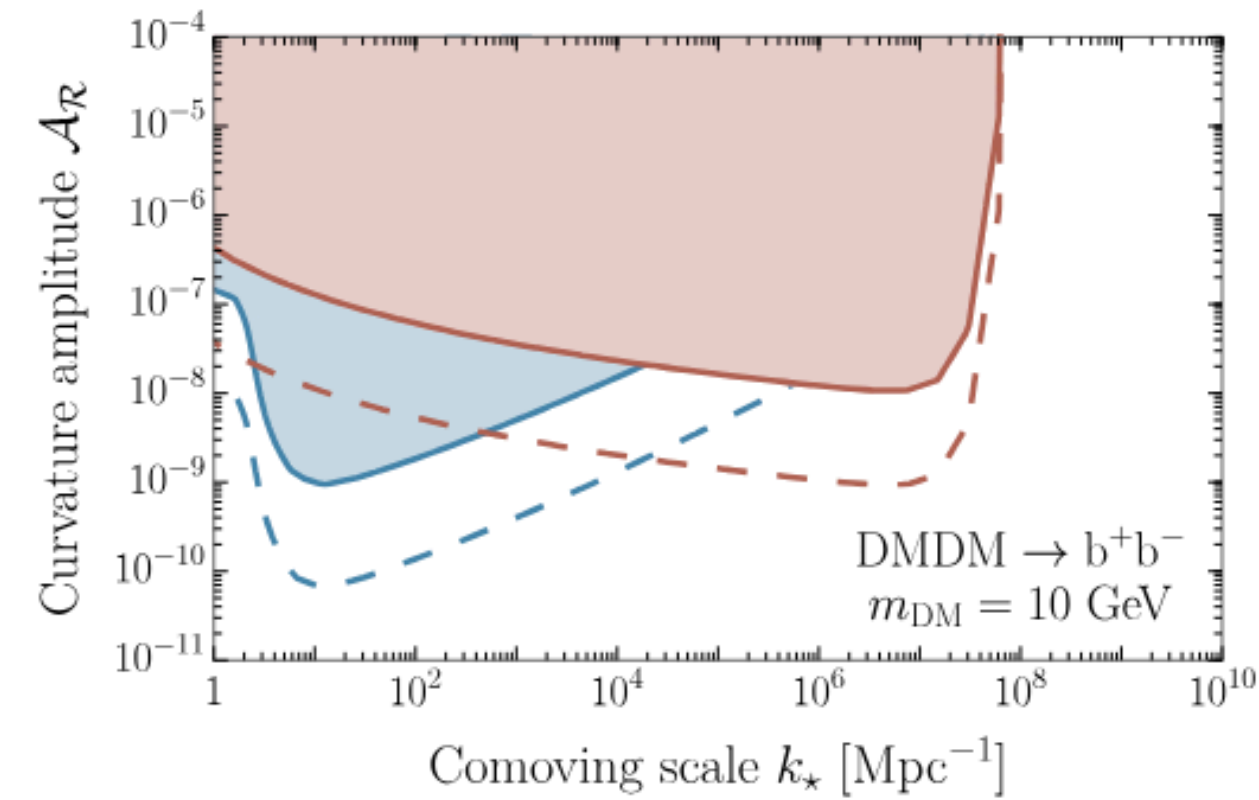








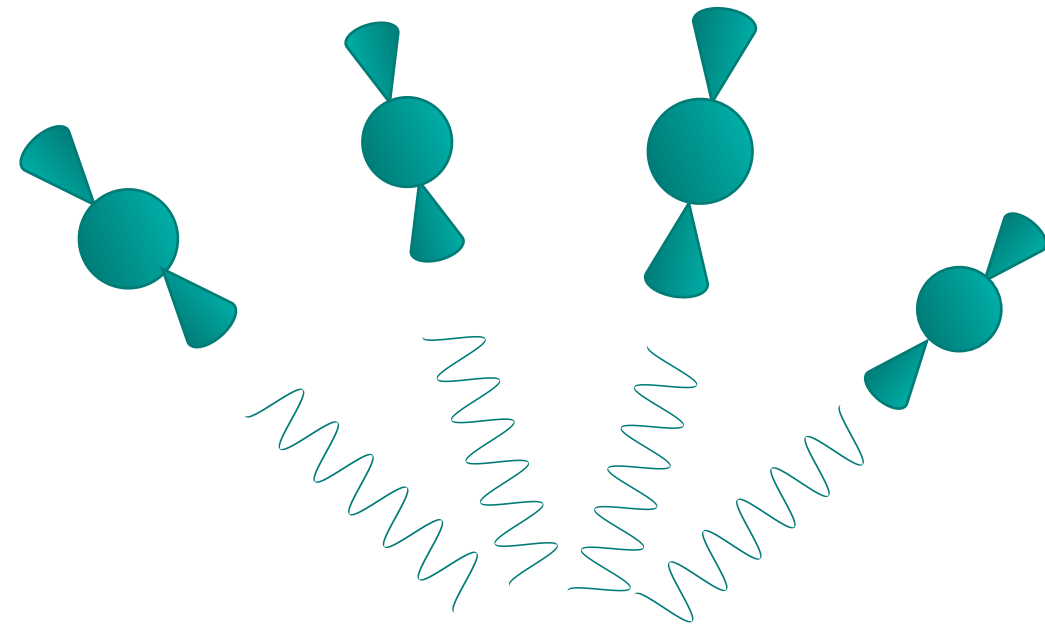




Conclusion

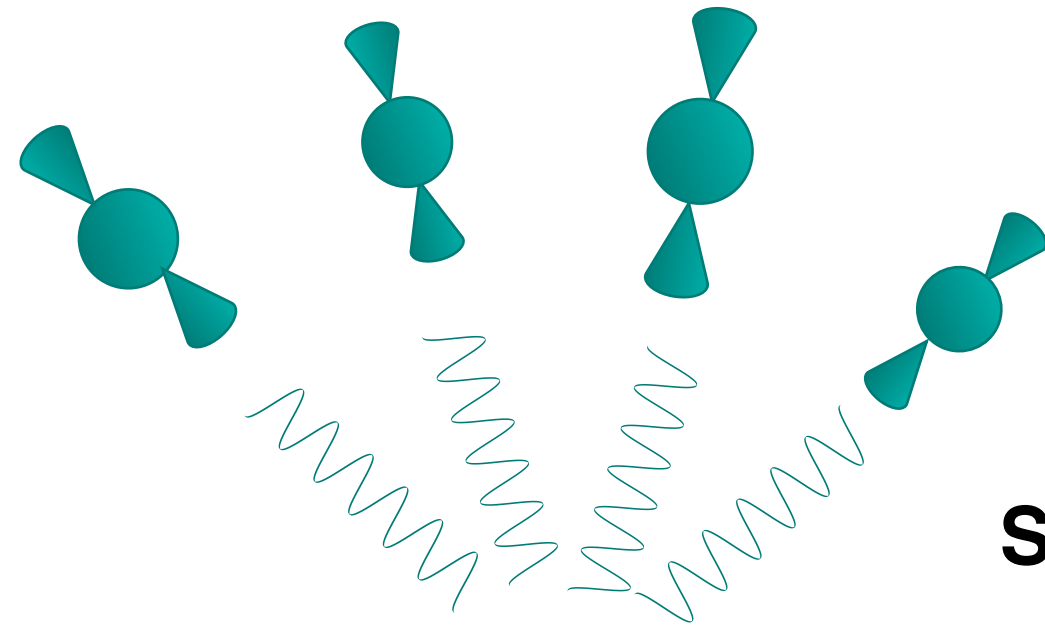
Conclusion

What is the PTA signal?

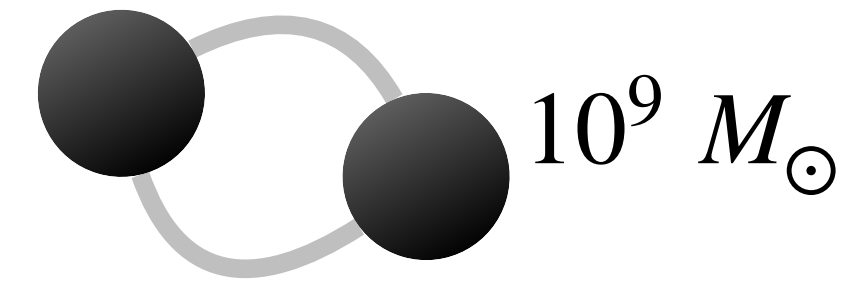


Conclusion

What is the PTA signal?



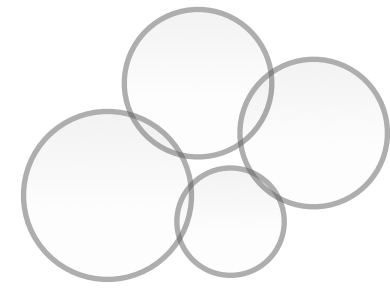
Supermassive Black Holes



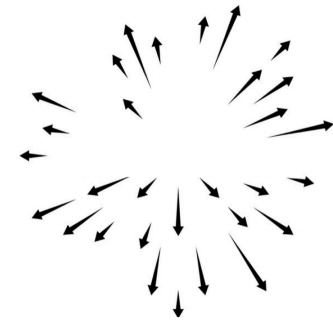
Conclusion

What is the PTA signal?

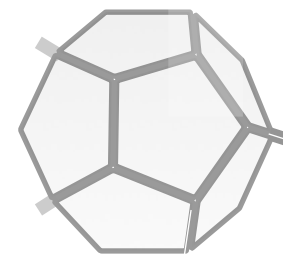
First-order
Phase Transition



Inflation



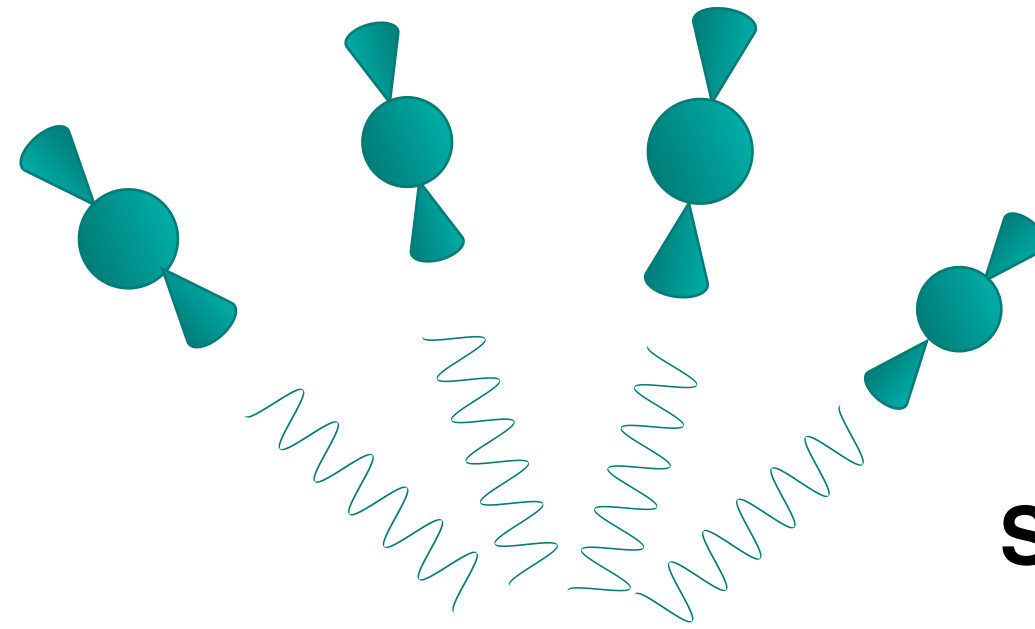
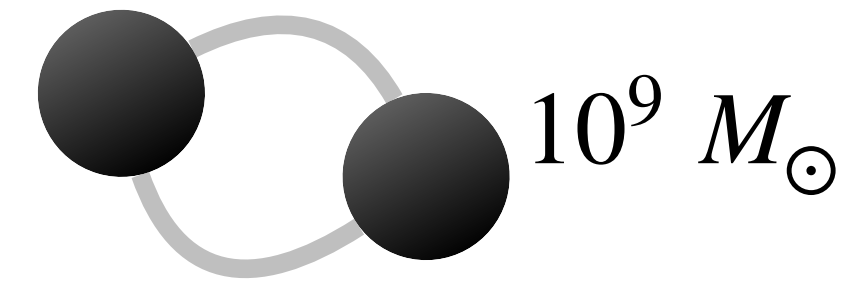
Domain walls



Cosmic strings

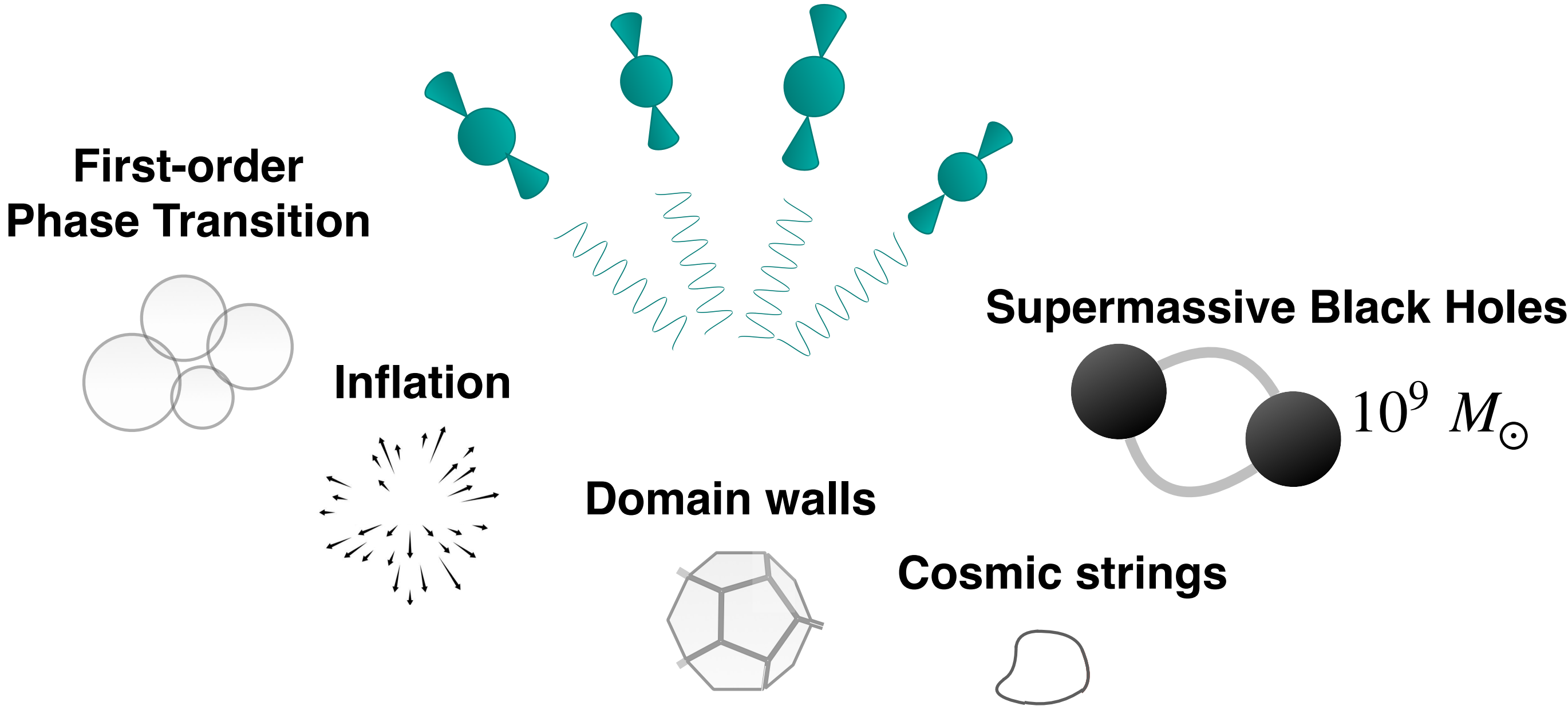


Supermassive Black Holes



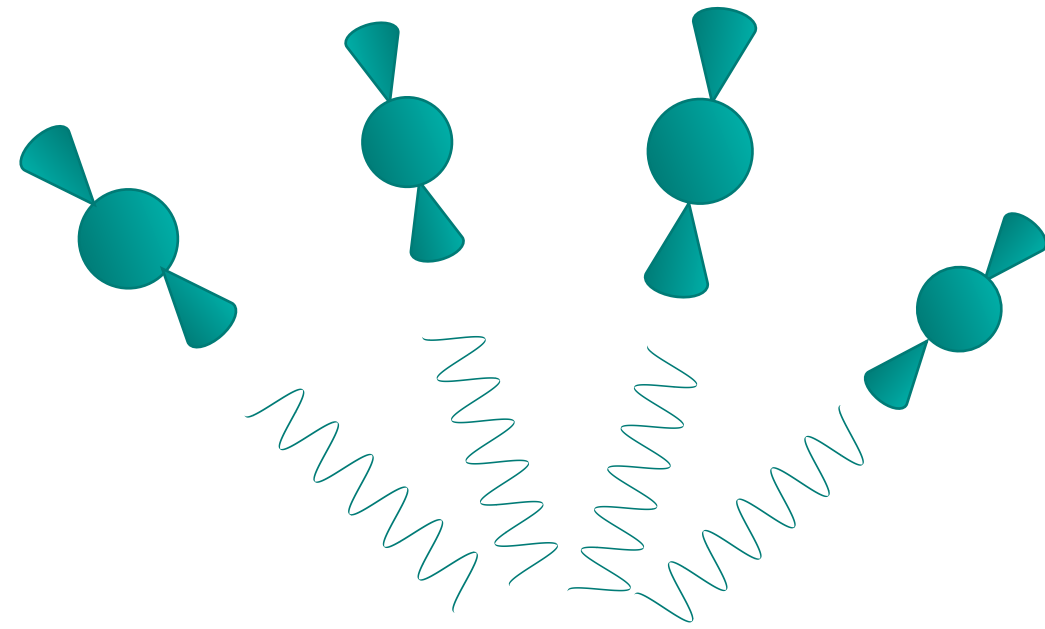
Conclusion

Search for new observables of primordial sources of PTA signal



Conclusion

Search for new observables of
primordial sources of PTA signal



Conclusion

Primordial Black Holes (PBHs)

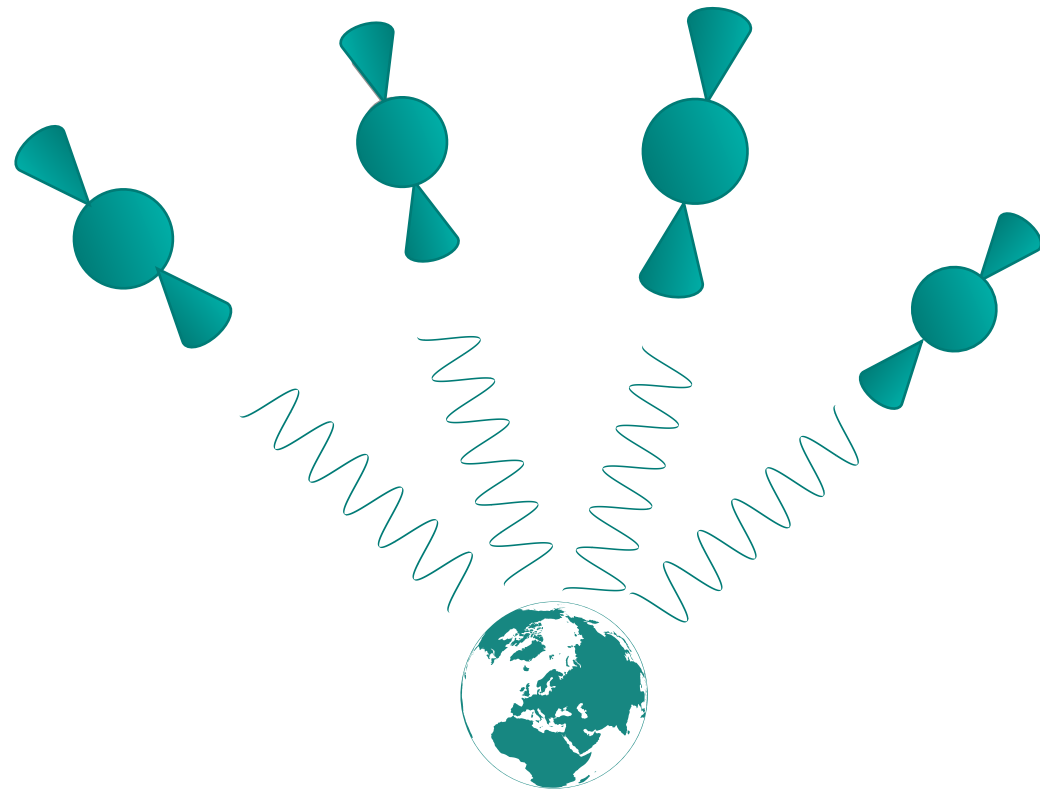
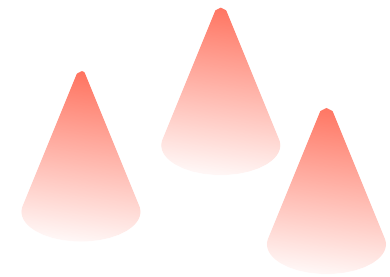
Search for new observables of
primordial sources of PTA signal

YG, Trifinopoulos, Vanvlasselaer (2508.19328)
YG 2307.042039 PRL
YG, Vitagliano 2306.1784

Scalar curvature

Gravitational Waves (GWs)

“Space-time
perturbation Triangle”



Conclusion

Primordial Black Holes (PBHs)

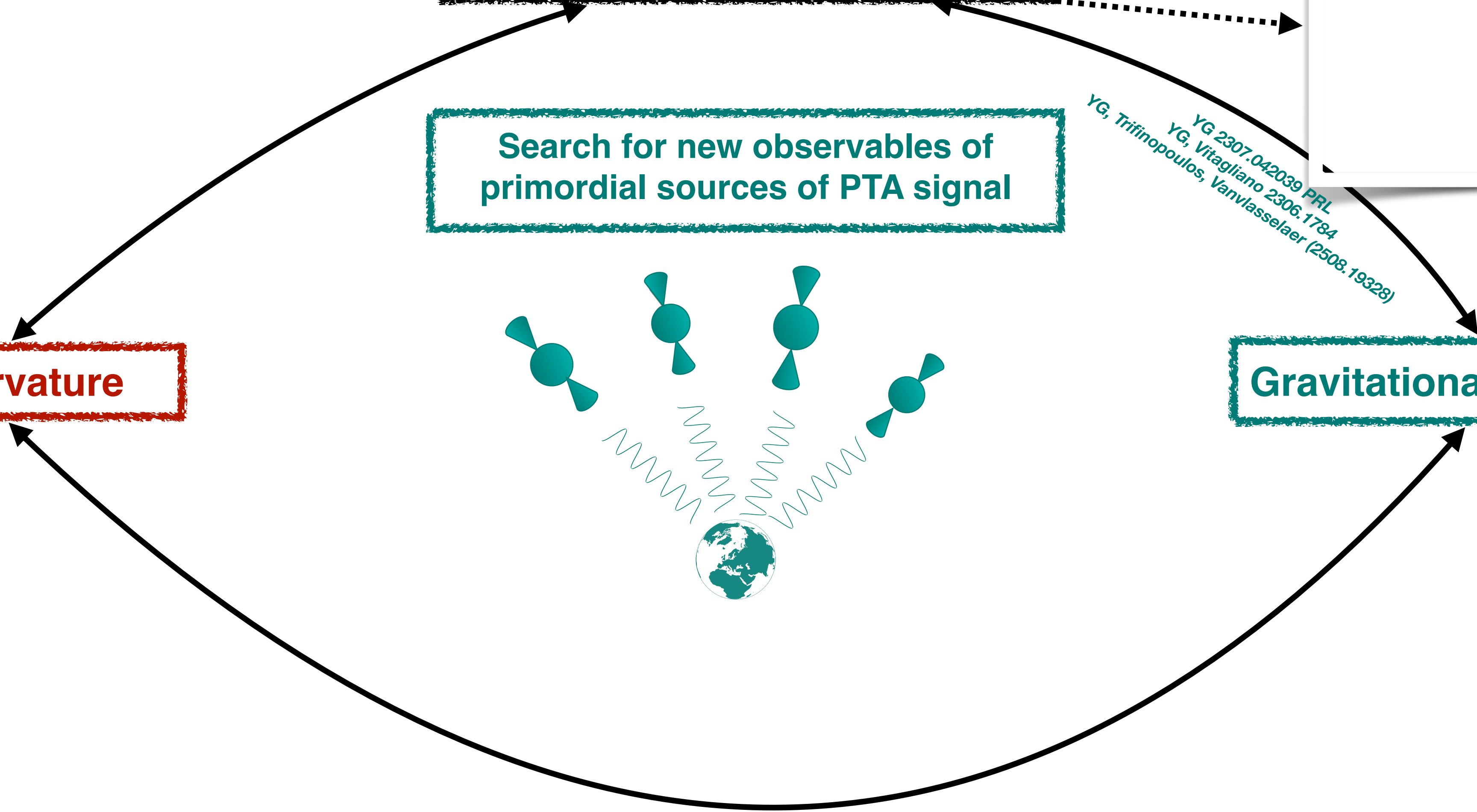
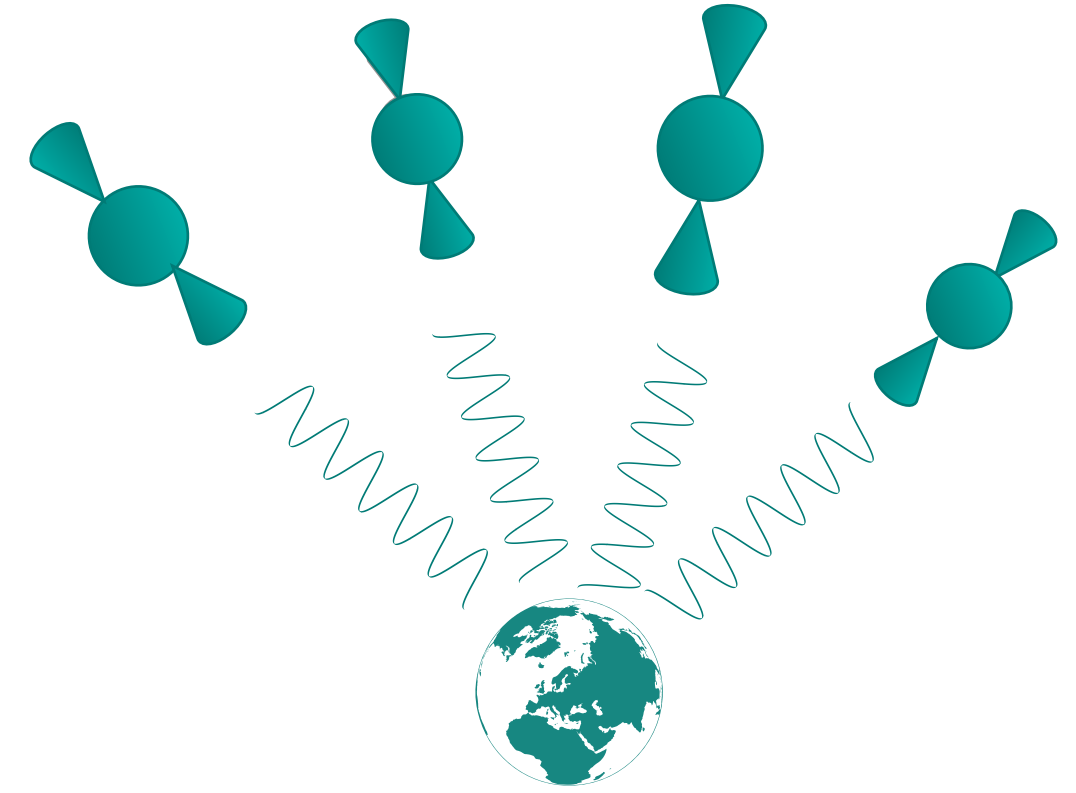
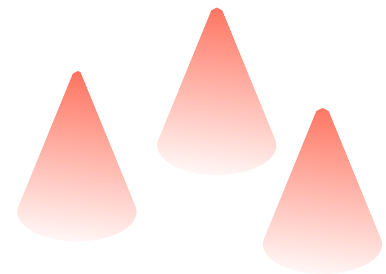
Motivate search in LIGO data

Search for new observables of primordial sources of PTA signal

YG, Trifinopoulos, Vanvlasselaer (2508.19328)
YG 2307.042039 PRL
YG, Vitagliano 2306.1784

Scalar curvature

Gravitational Waves (GWs)



Conclusion

Primordial Black Holes (PBHs)

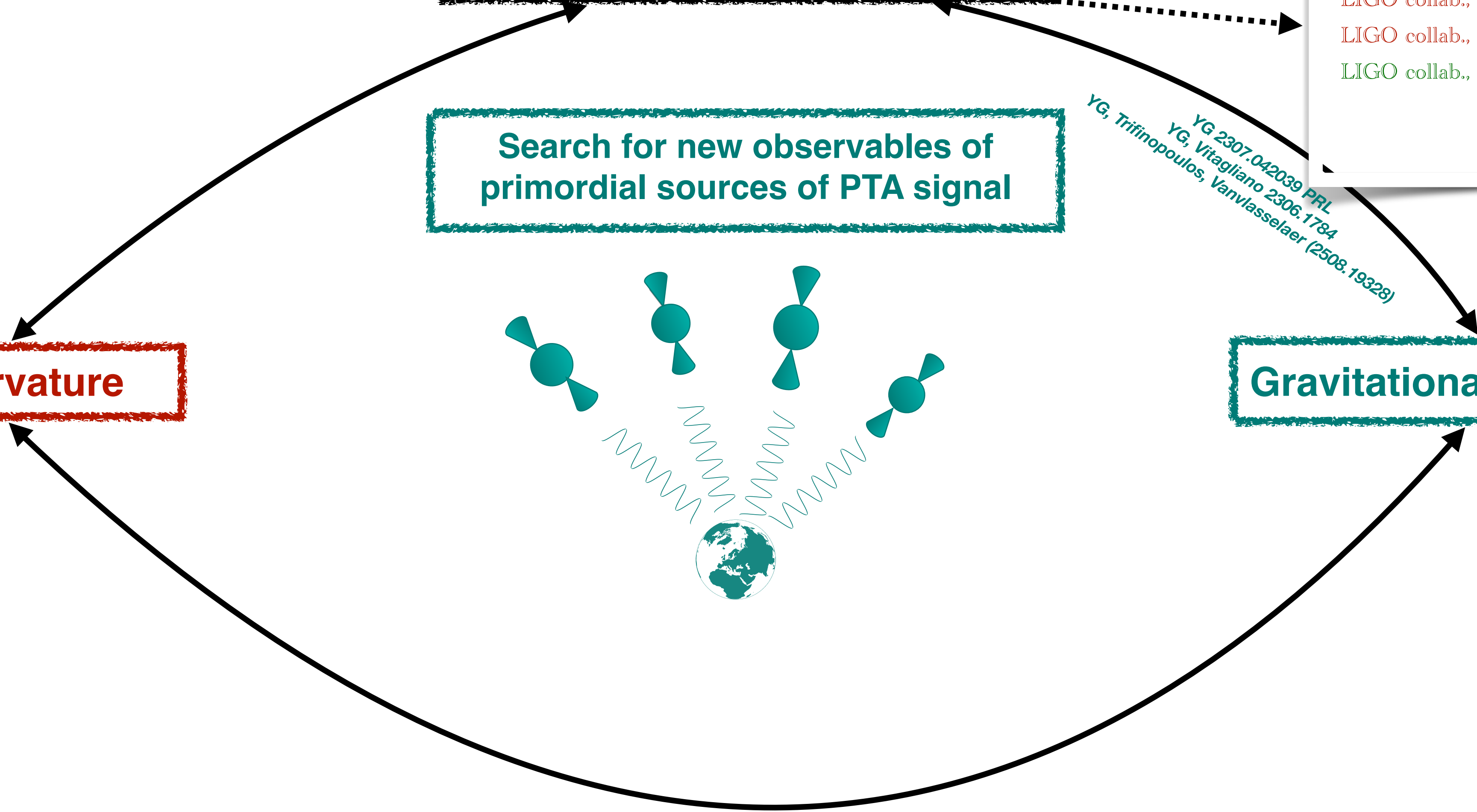
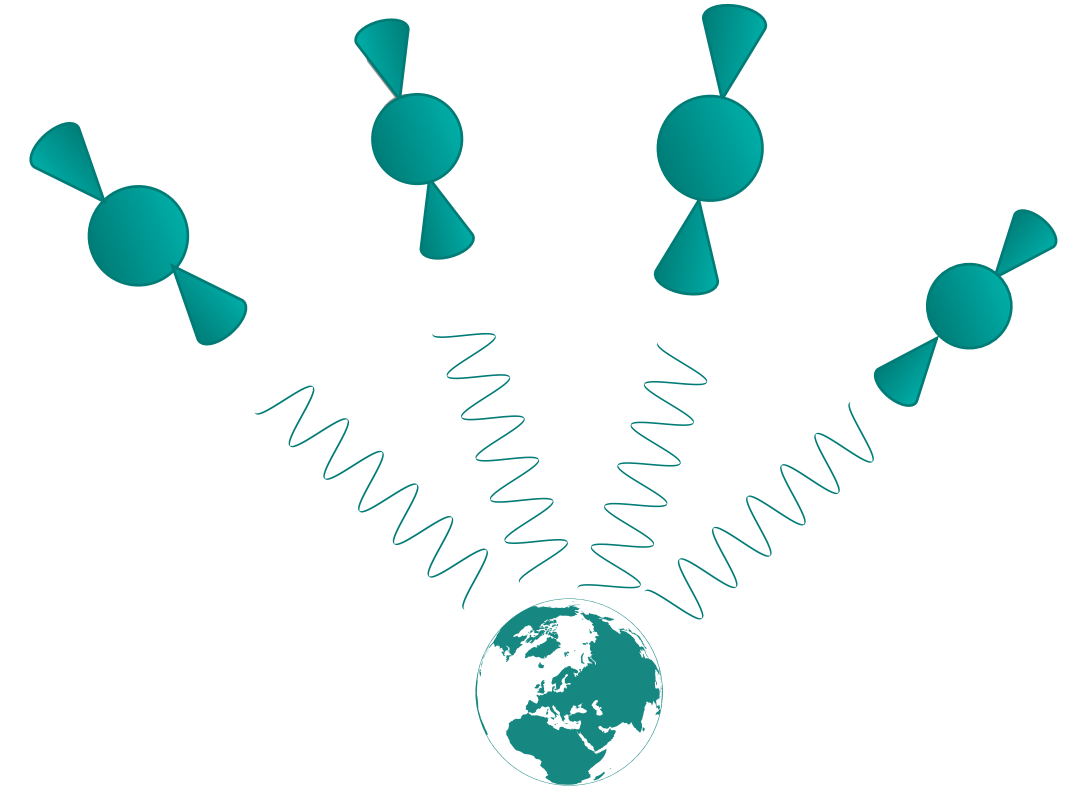
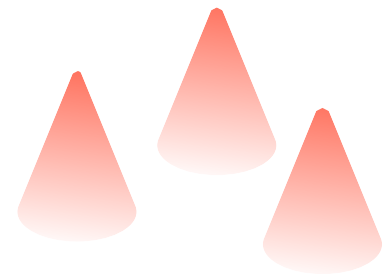
Search for new observables of primordial sources of PTA signal

Gravitational Waves (GWs)

Scalar curvature

Motivate search in LIGO data
LIGO collab., "Sub-solar search", PRL 2018
LIGO collab., "Sub-solar search", PRL 2019
LIGO collab., "Sub-solar search", PRL 2022

YG, Trifinopoulos, Vanvlasselaer (2508.19328)
YG 2307.042039 PRL
YG, Vitagliano 2306.1784



Conclusion

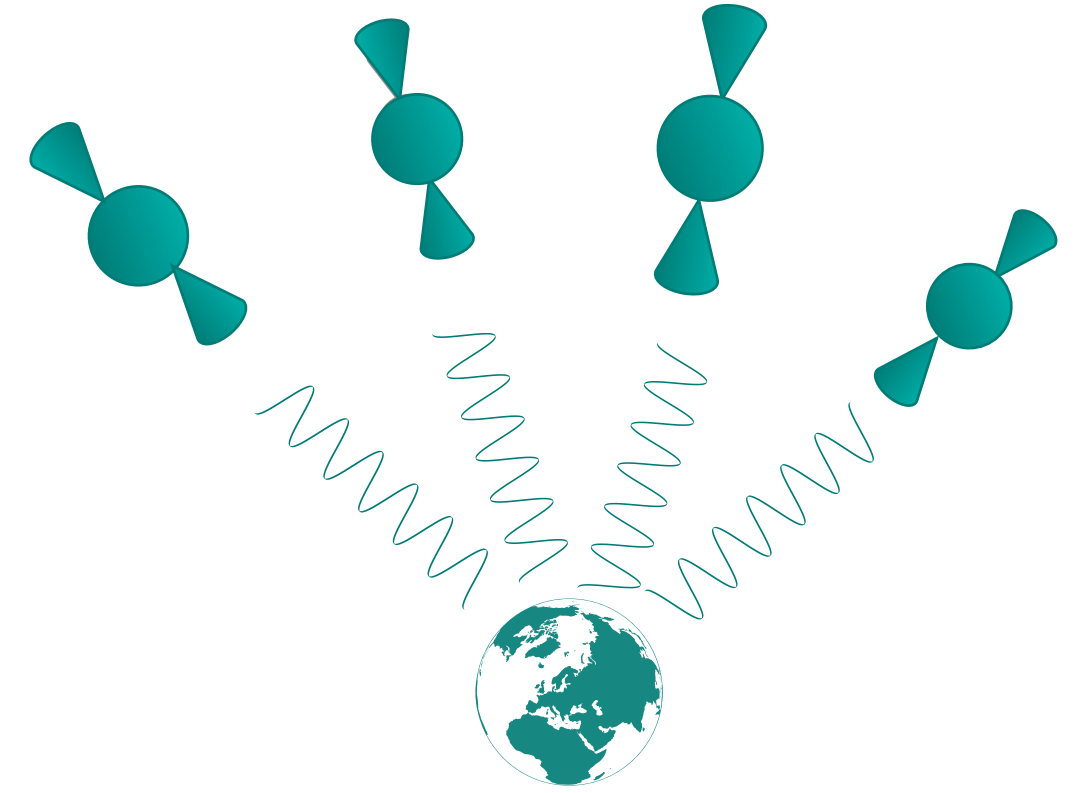
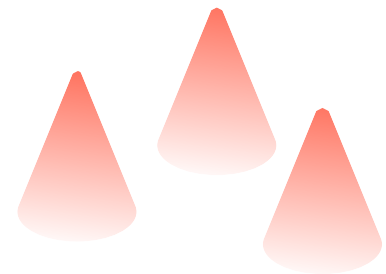
Primordial Black Holes (PBHs)

Search for new observables of primordial sources of PTA signal

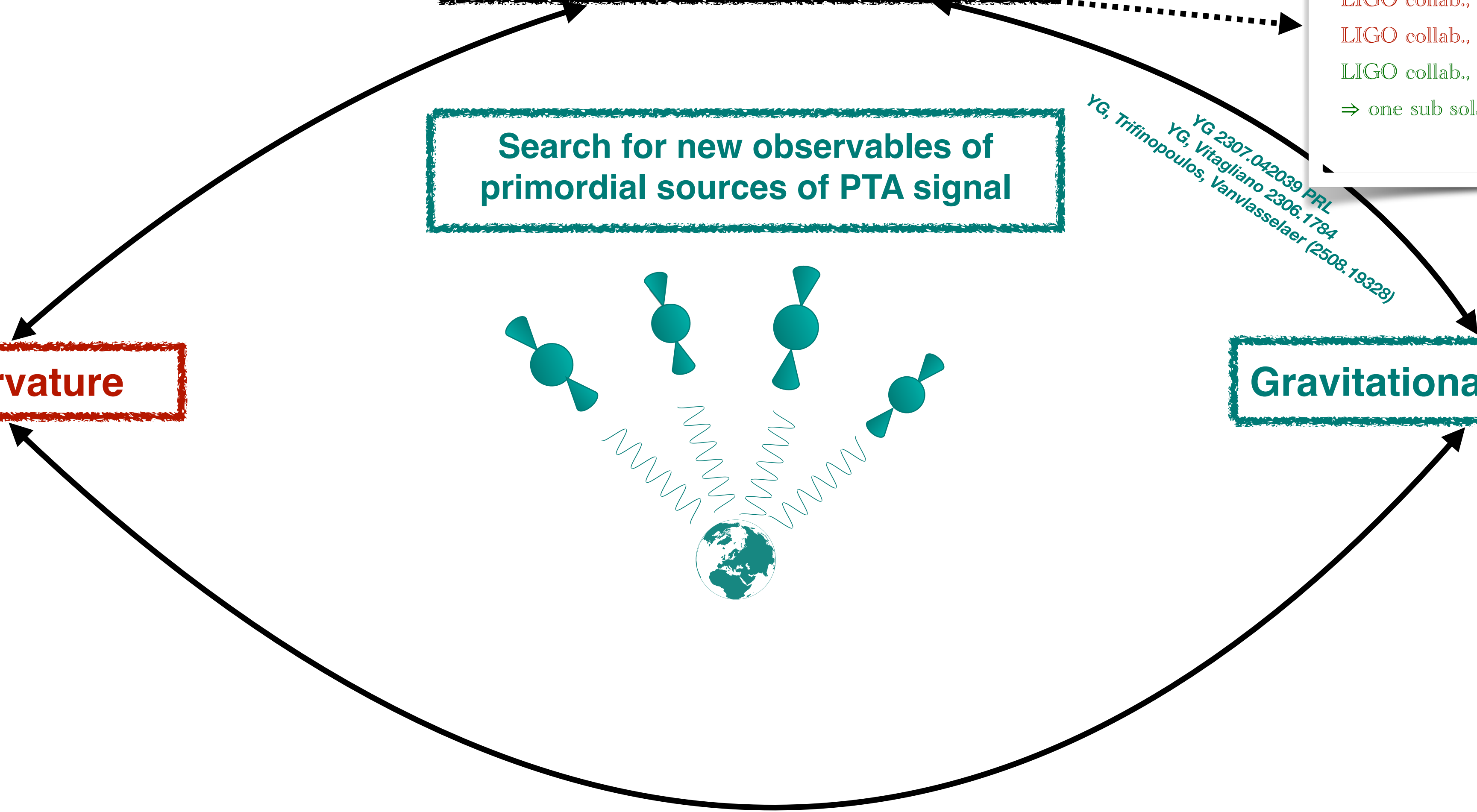
Gravitational Waves (GWs)

Scalar curvature

Motivate search in LIGO data
LIGO collab., "Sub-solar search", PRL 2018
LIGO collab., "Sub-solar search", PRL 2019
LIGO collab., "Sub-solar search", PRL 2022
⇒ one sub-solar candidate at 3.7σ : $m = 0.27^{+0.12}_{-0.10}$



YG, Trifinopoulos, Vanvlasselaer (2508.19328)
YG 2307.042039 PRL
YG, Vitagliano 2306.1784



Conclusion

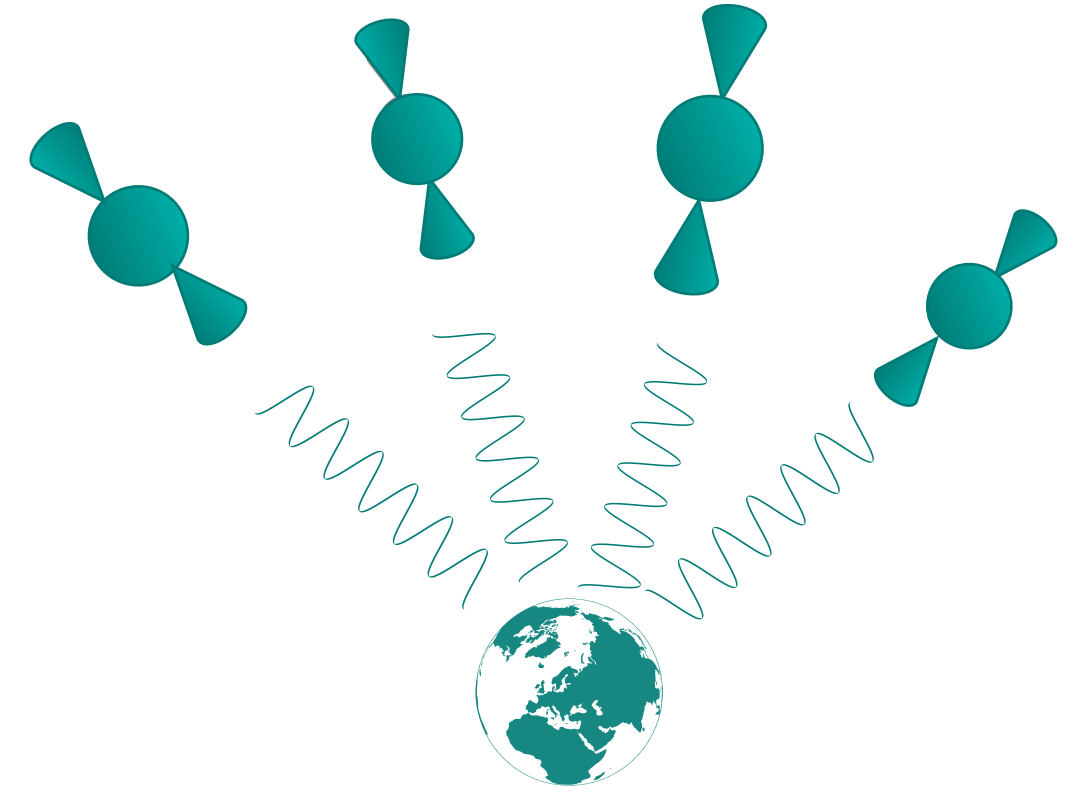
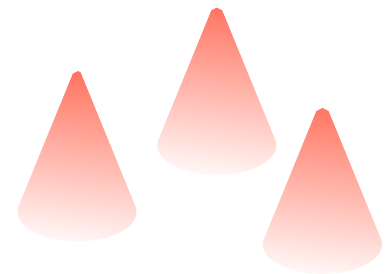
Primordial Black Holes (PBHs)

Search for new observables of primordial sources of PTA signal

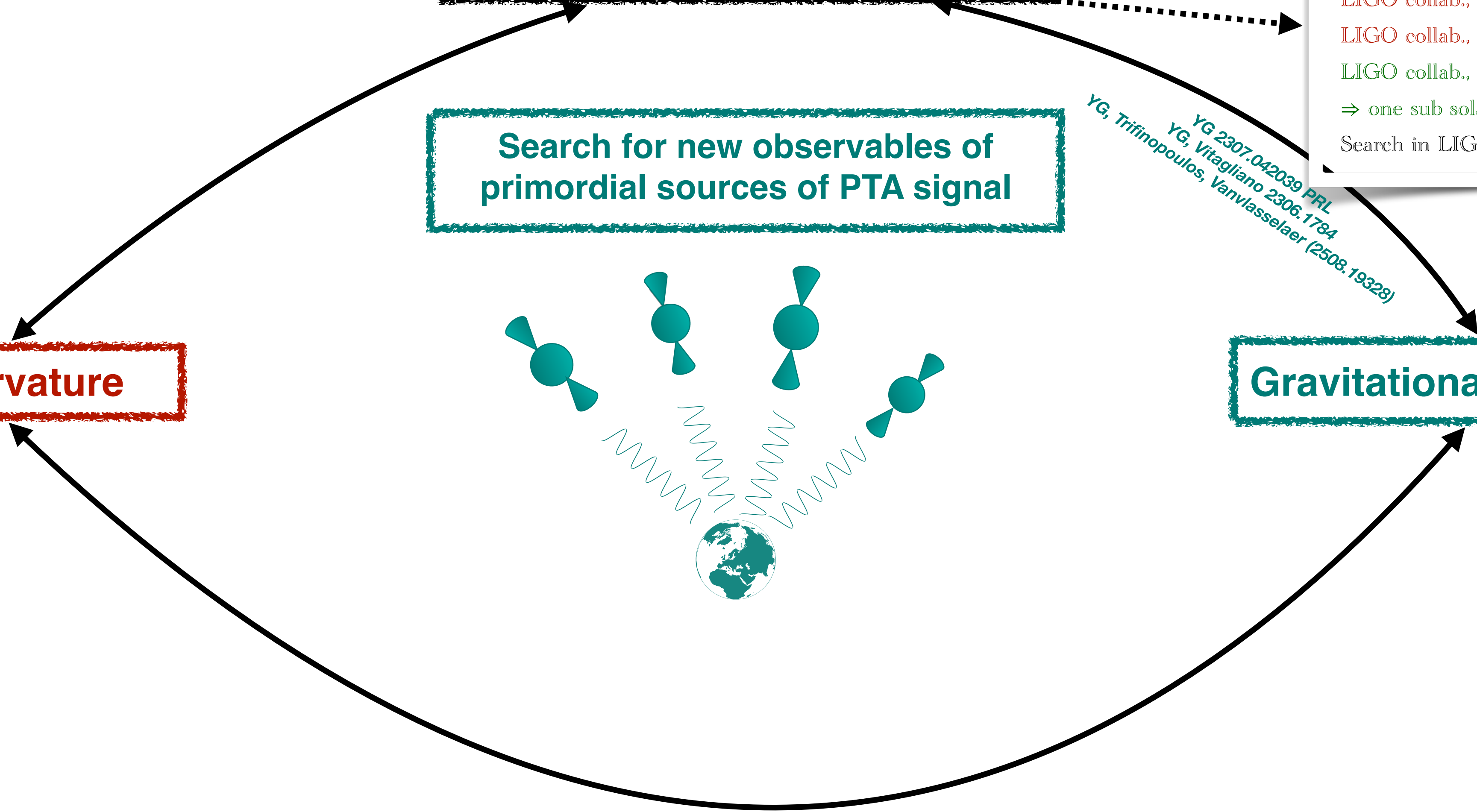
Gravitational Waves (GWs)

Scalar curvature

Motivate search in LIGO data
LIGO collab., "Sub-solar search", PRL 2018
LIGO collab., "Sub-solar search", PRL 2019
LIGO collab., "Sub-solar search", PRL 2022
⇒ one sub-solar candidate at 3.7σ : $m = 0.27^{+0.12}_{-0.10}$
Search in LIGO O4 on-going



YG, Trifinopoulos, Vanvlasselaer (2508.19328)
YG 2307.042039 PRL
YG, Vitagliano 2306.1784



Conclusion

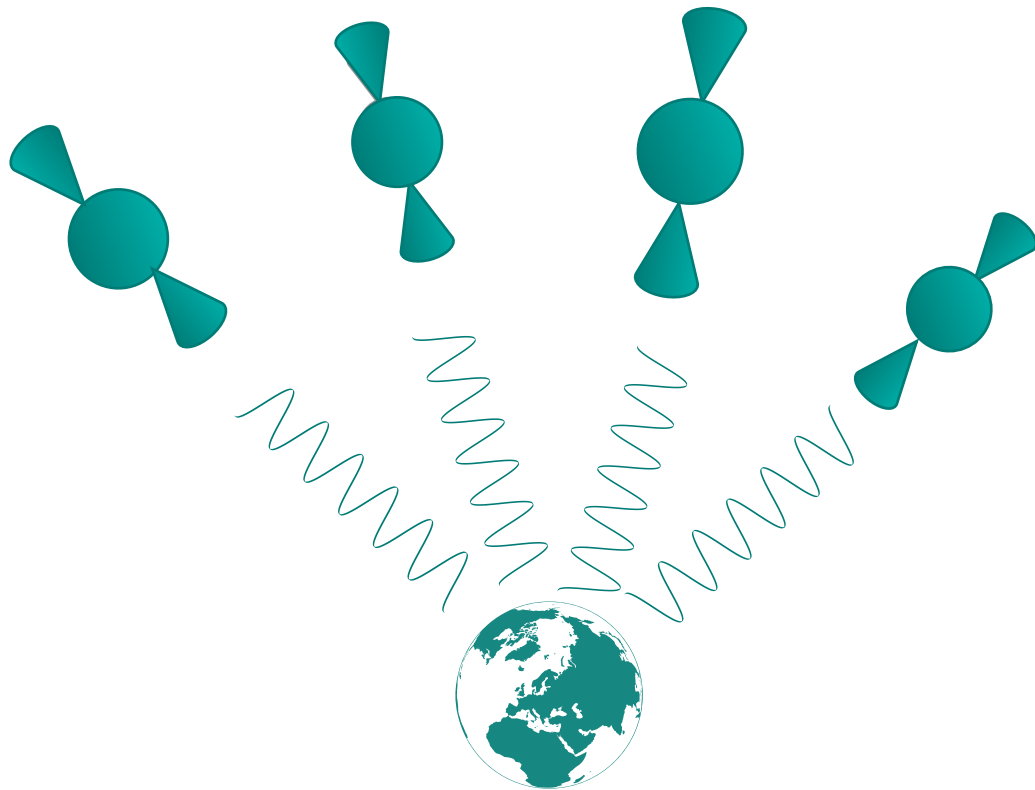
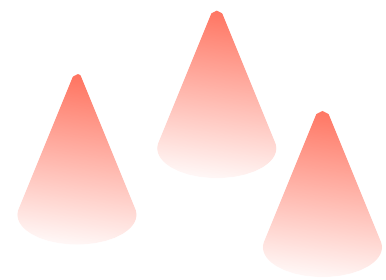
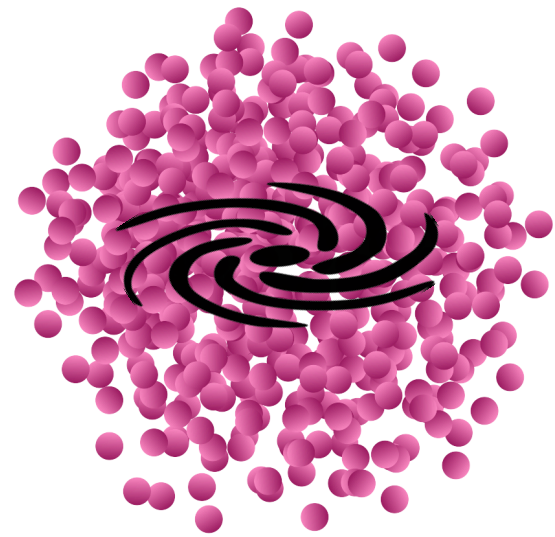
Primordial Black Holes (PBHs)

Search for new observables of primordial sources of PTA signal

Gravitational Waves (GWs)

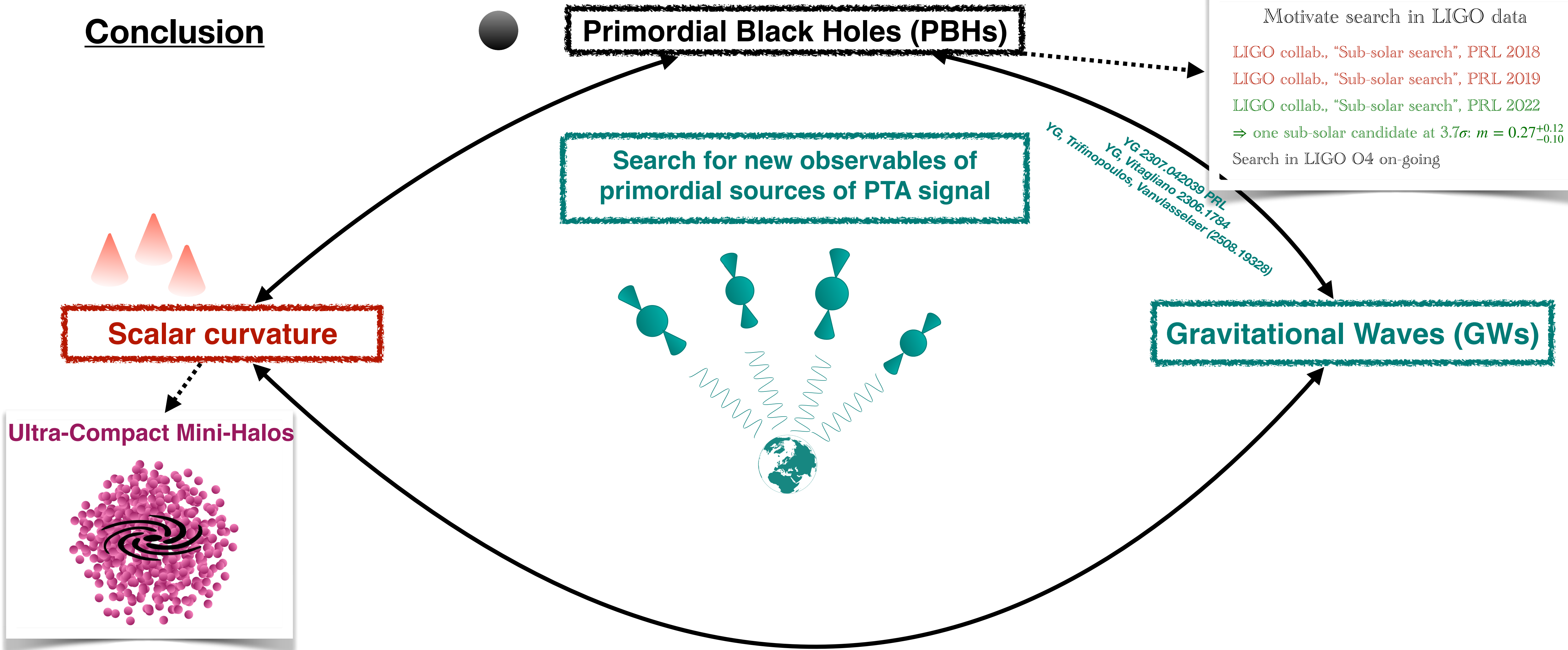
Scalar curvature

Ultra-Compact Mini-Halos



Motivate search in LIGO data
LIGO collab., "Sub-solar search", PRL 2018
LIGO collab., "Sub-solar search", PRL 2019
LIGO collab., "Sub-solar search", PRL 2022
⇒ one sub-solar candidate at 3.7σ : $m = 0.27^{+0.12}_{-0.10}$
Search in LIGO O4 on-going

YG, Trifinopoulos, Vanvlasselaer (2508.19328)
YG 2307.042039 PRL
YG, Vitagliano 2306.1784



Conclusion

Primordial Black Holes (PBHs)

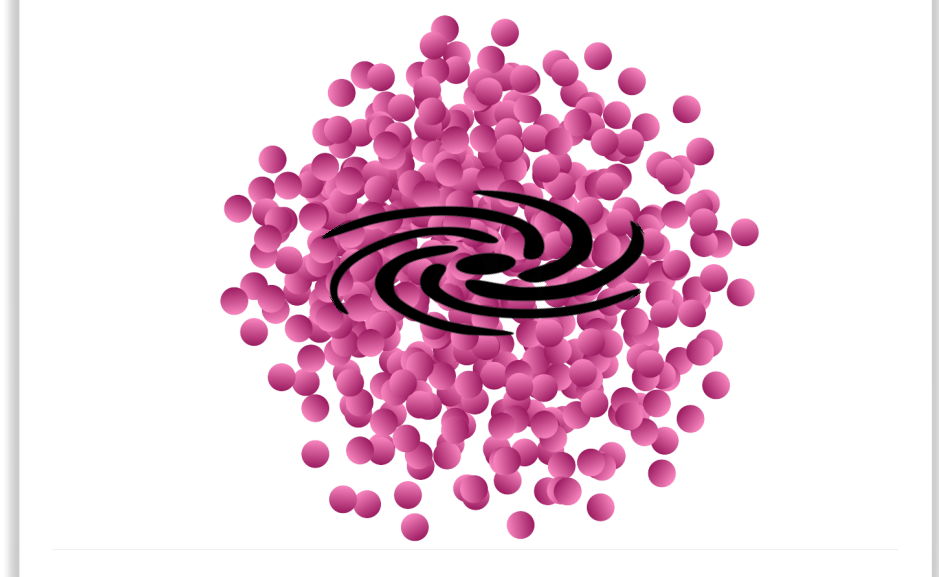
Search for new observables of primordial sources of PTA signal

Gravitational Waves (GWs)

Scalar curvature

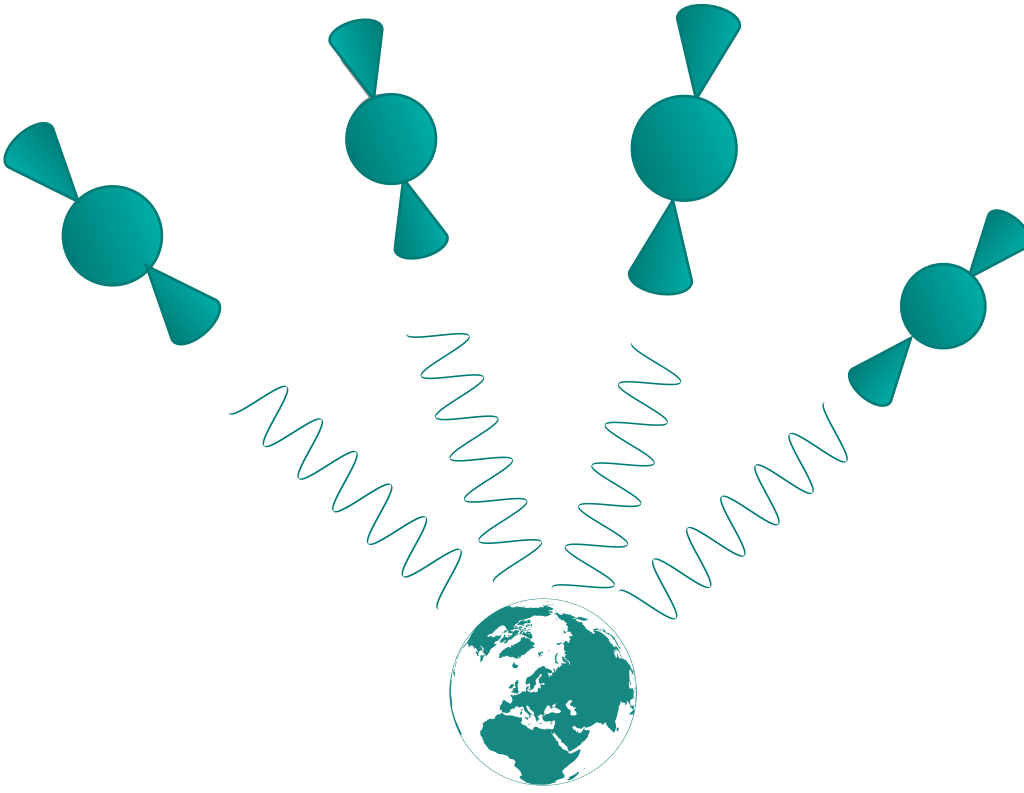
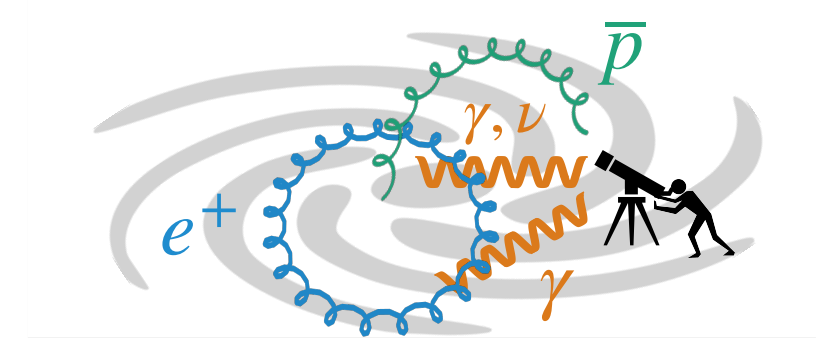
Motivate search in LIGO data
LIGO collab., "Sub-solar search", PRL 2018
LIGO collab., "Sub-solar search", PRL 2019
LIGO collab., "Sub-solar search", PRL 2022
⇒ one sub-solar candidate at 3.7σ : $m = 0.27^{+0.12}_{-0.10}$
Search in LIGO O4 on-going

Ultra-Compact Mini-Halos



If DM=WIMPs
YG 2503.03857

Cosmic rays ($\gamma, \nu, \bar{p}, e^+$)



YG, Trifinopoulos, Vanvlasselaer (2508.19328)
YG 2307.042039 PRL
YG, Vitagliano 2306.1784

Conclusion

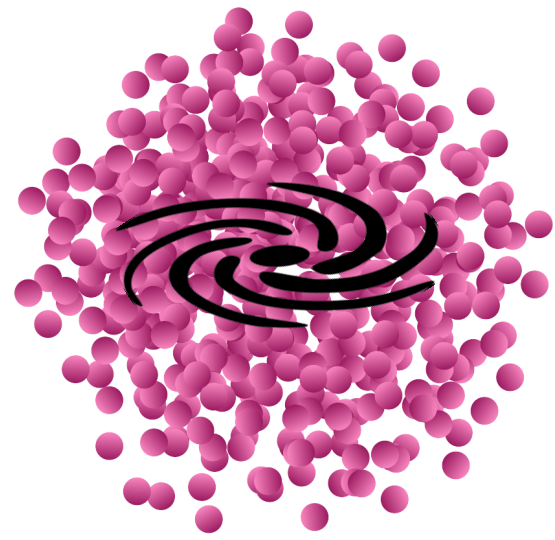
Primordial Black Holes (PBHs)

Search for new observables of primordial sources of PTA signal

Gravitational Waves (GWs)

Scalar curvature

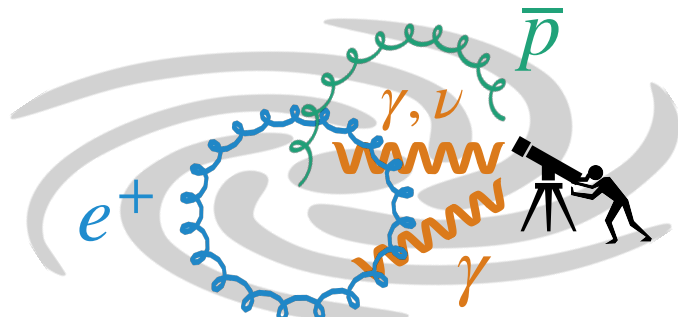
Ultra-Compact Mini-Halos



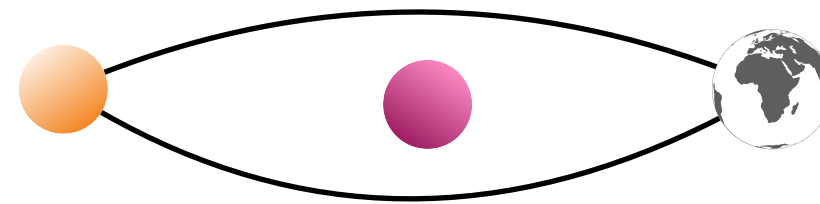
If DM=WIMPs
YG 2503.03857

On-going

Cosmic rays ($\gamma, \nu, \bar{p}, e^+$)



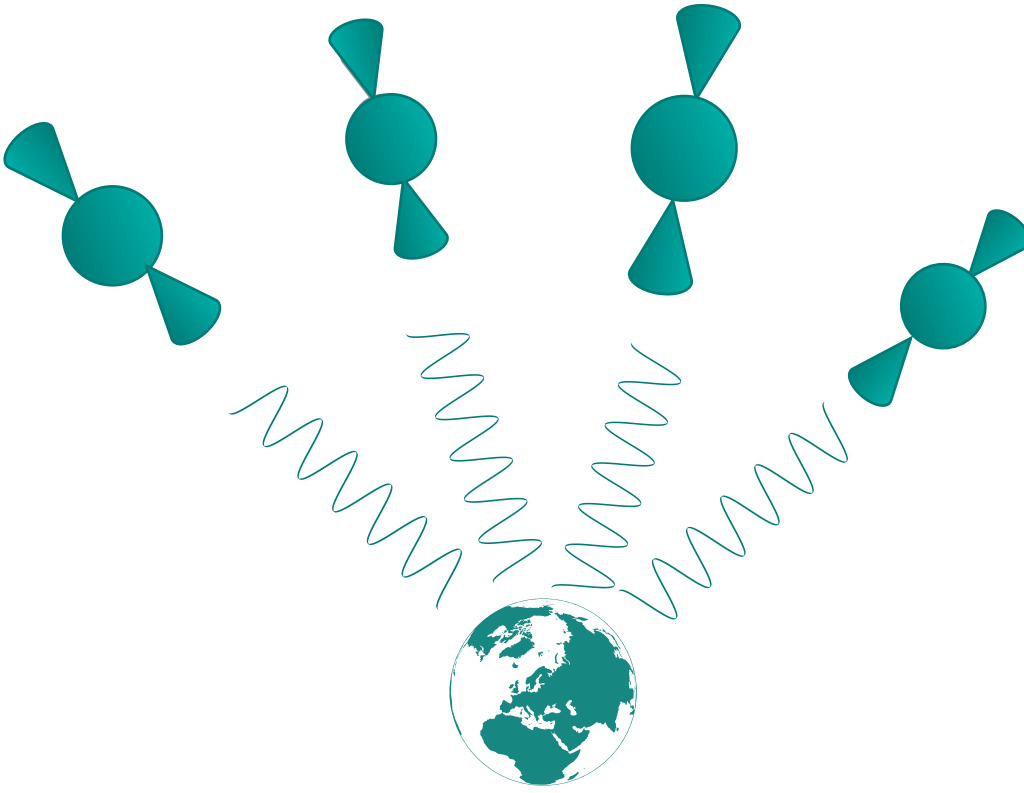
HSC microlensing and lensed Quasars



(in preparation with Sten Delos and Gabriele Franciolini)
See also Delos, Franciolini 2301.13171
Bringmann, Croon, Sevillano Muñoz, 2506.20704

Motivate search in LIGO data
LIGO collab., "Sub-solar search", PRL 2018
LIGO collab., "Sub-solar search", PRL 2019
LIGO collab., "Sub-solar search", PRL 2022
⇒ one sub-solar candidate at 3.7σ : $m = 0.27^{+0.12}_{-0.10}$
Search in LIGO O4 on-going

YG, Trifinopoulos, Vanvlasselaer (2508.19328)
YG 2307.042039 PRL
YG, Vitagliano 2306.1784



Conclusion

Primordial Black Holes (PBHs)

Search for new observables of primordial sources of PTA signal

Gravitational Waves (GWs)

Scalar curvature

Motivate search in LIGO data
LIGO collab., "Sub-solar search", PRL 2018
LIGO collab., "Sub-solar search", PRL 2019
LIGO collab., "Sub-solar search", PRL 2022
⇒ one sub-solar candidate at 3.7σ : $m = 0.27^{+0.12}_{-0.10}$
Search in LIGO O4 on-going

Ultra-Compact Mini-Halos

If DM=WIMPs
YG 2503.03857

Cosmic rays ($\gamma, \nu, \bar{p}, e^+$)

On-going

HSC microlensing and lensed Quasars

(in preparation with Sten Delos and Gabriele Franciolini)
See also Delos, Franciolini 2301.13171
Bringmann, Croon, Sevillano Muñoz, 2506.20704

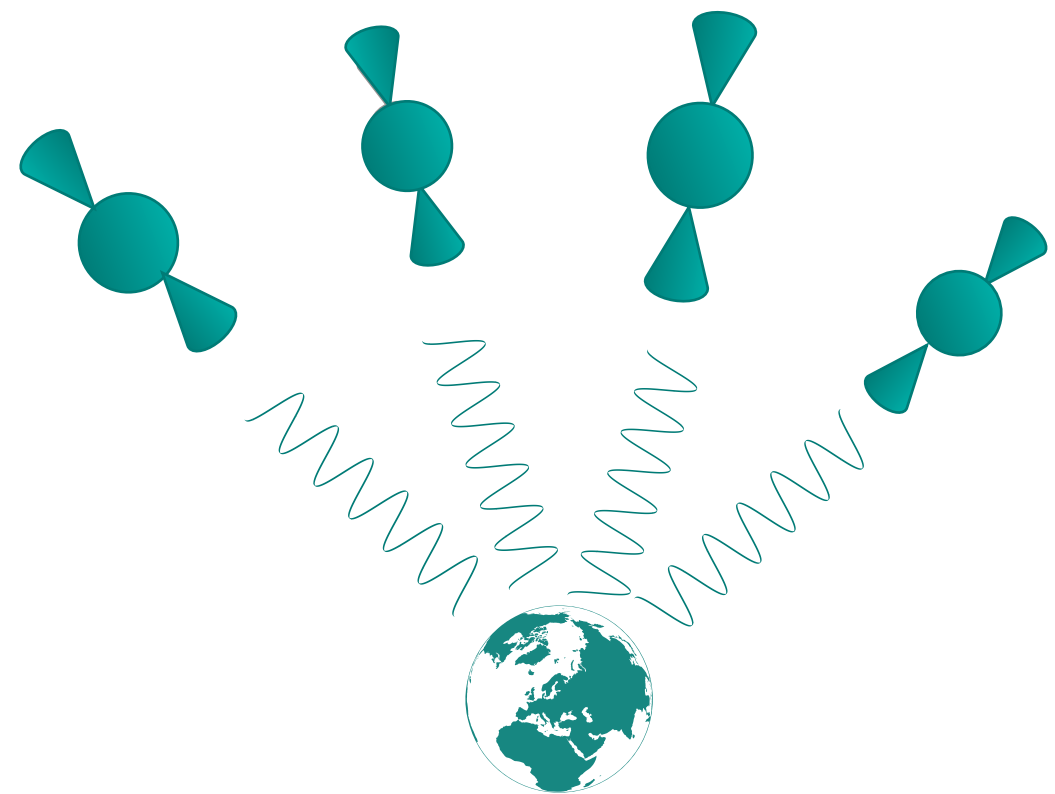
Future

Pulsar Timing Arrays

- 1) Doppler drift
- 2) Shapiro shift

NANOGrav, New Physics 2306.16219
Lee, Mitridate, Trickle, Zurek 2012.09857

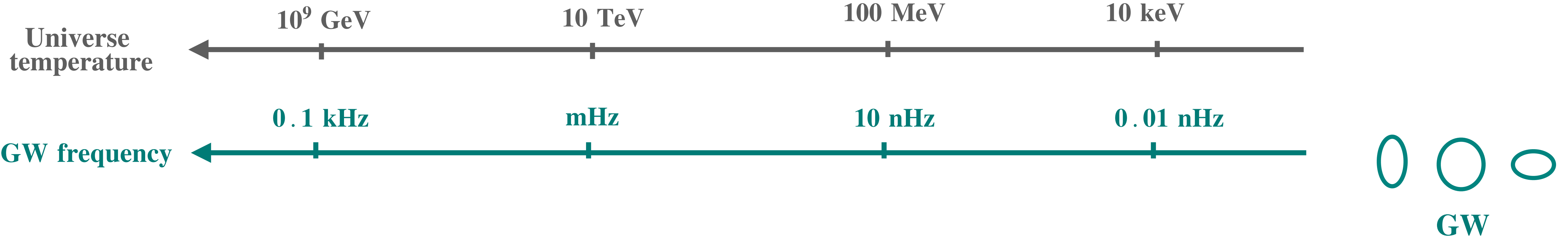
YG, Trifinopoulos, Vanvlasselaer (2508.19328)
YG 2307.042039 PRL
YG, Vitagliano 2306.1784



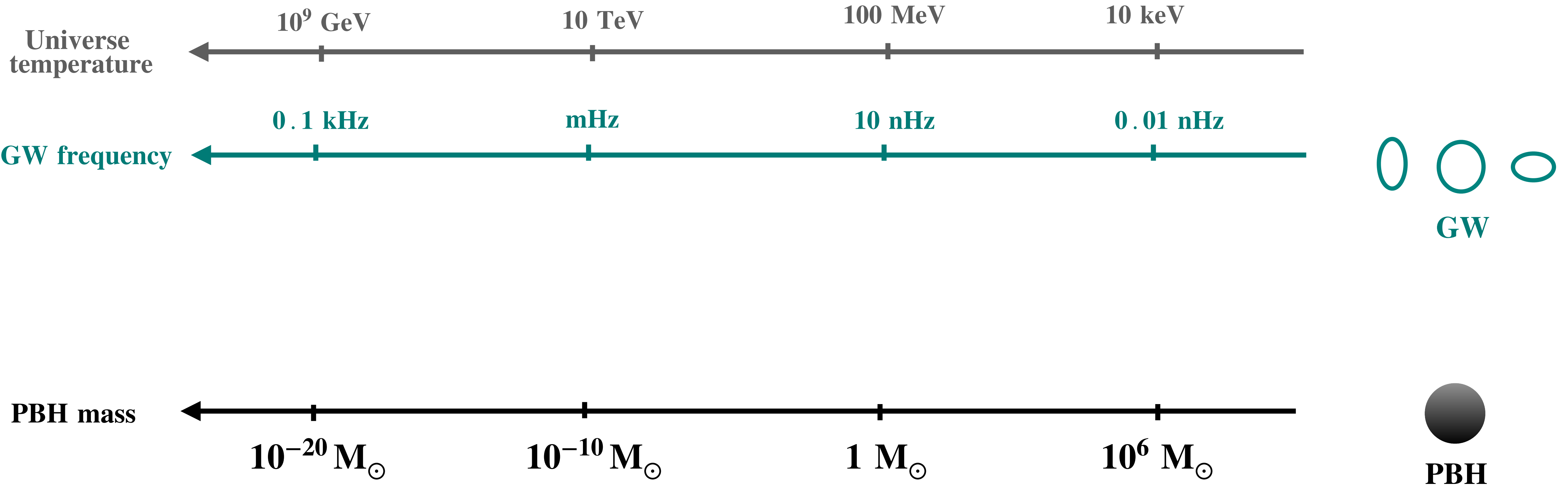
**Universe
temperature**



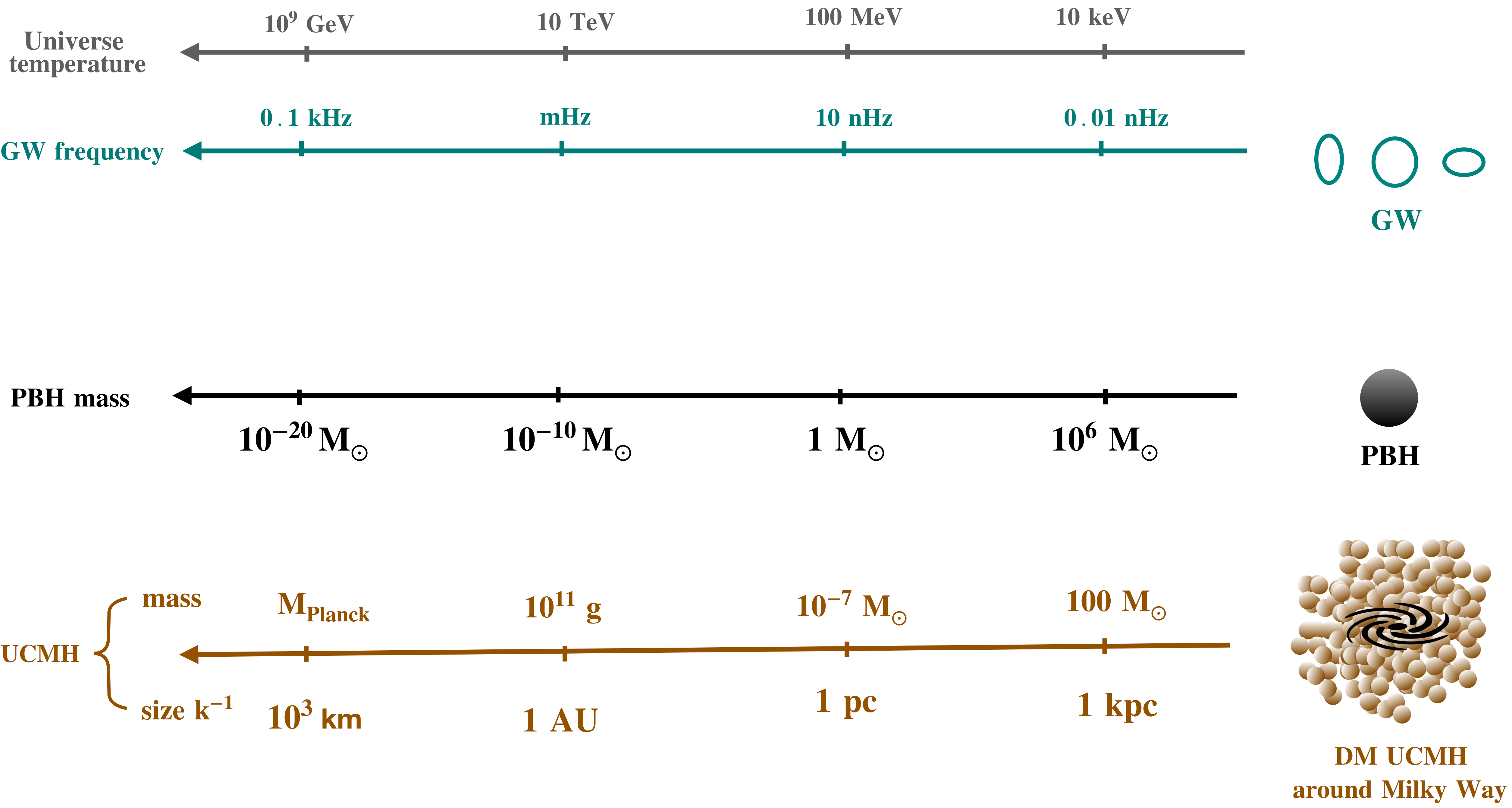
What we do know about the
History of our Universe

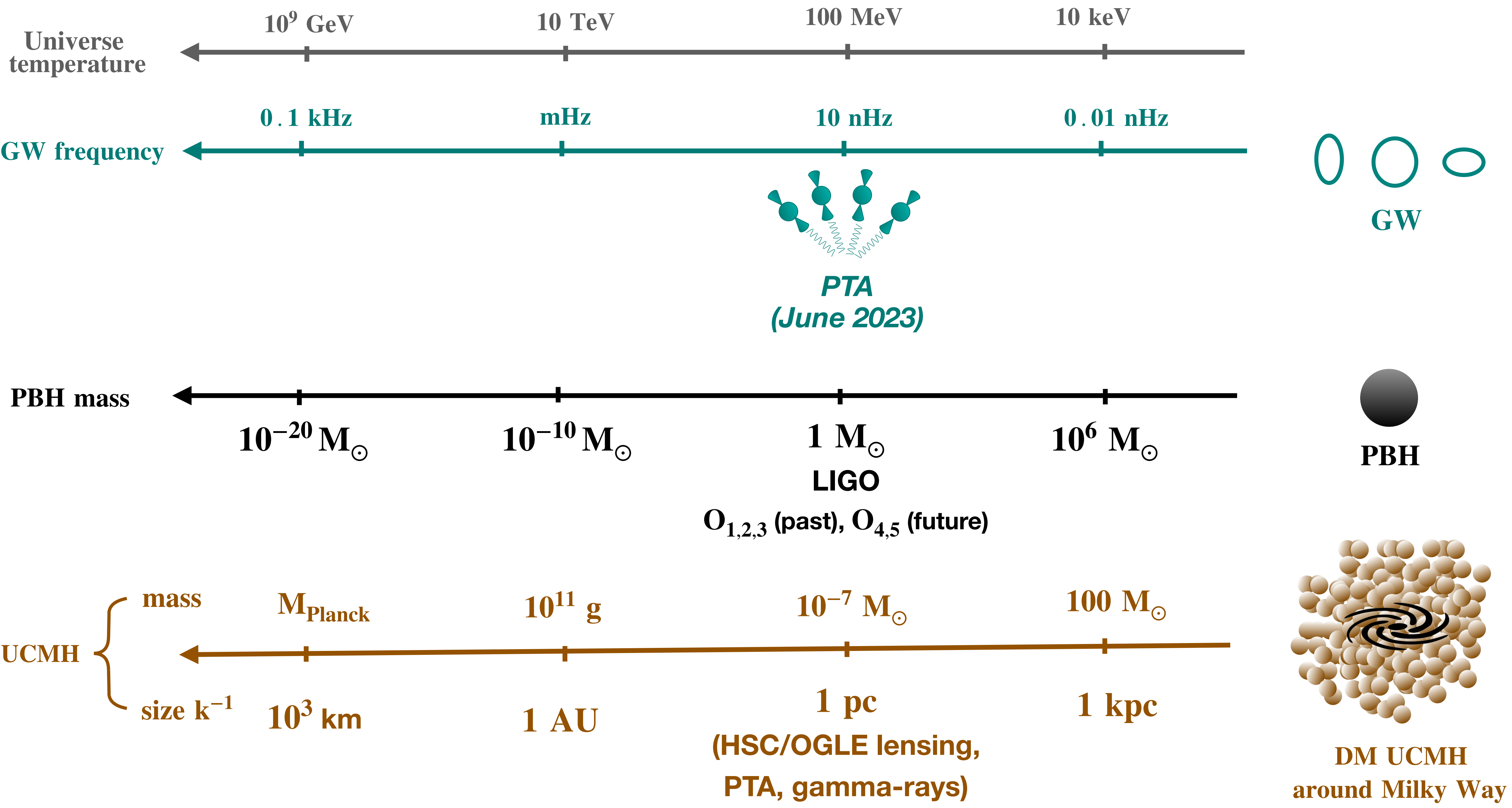


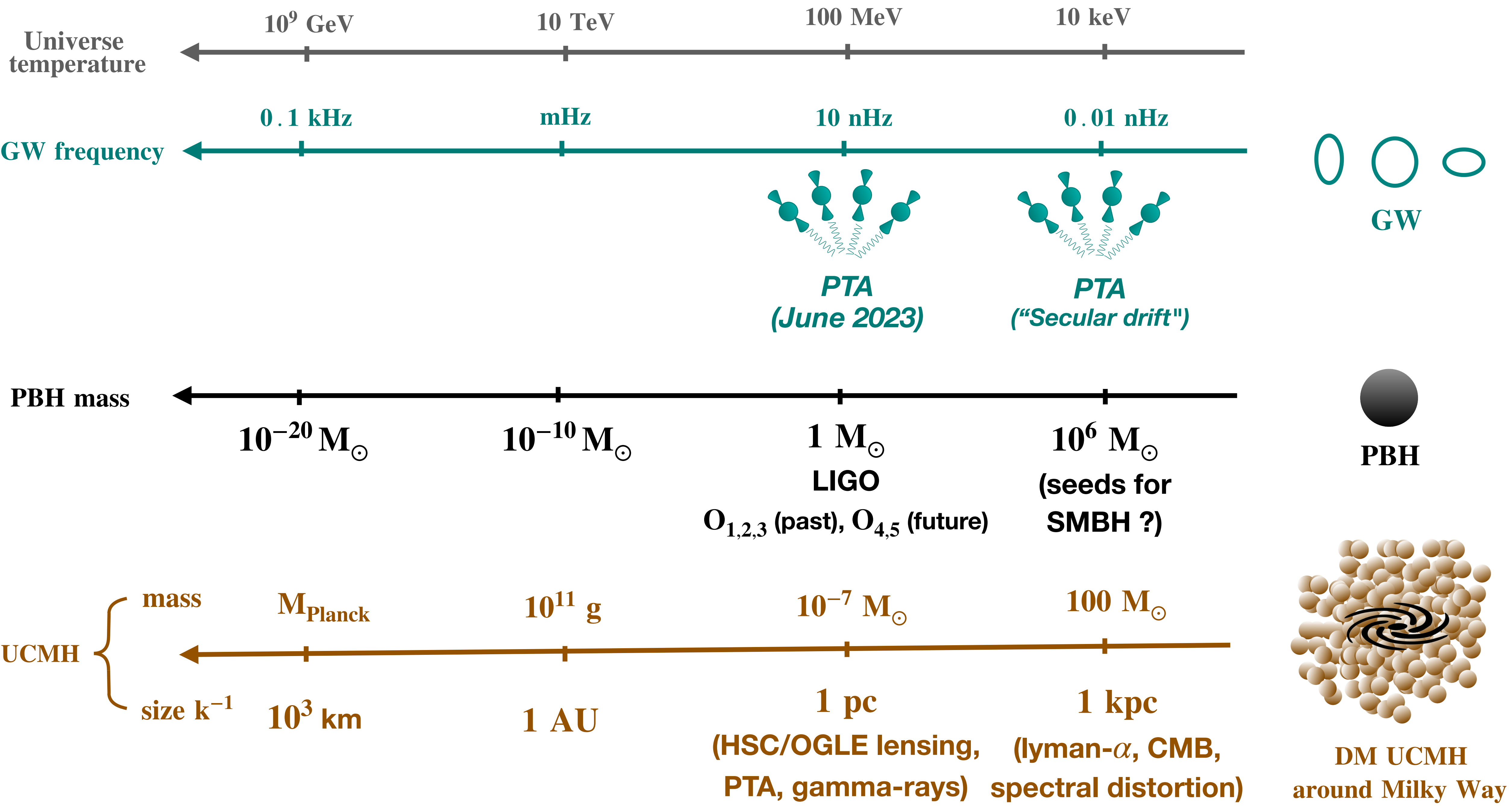
What we do know about the
History of our Universe

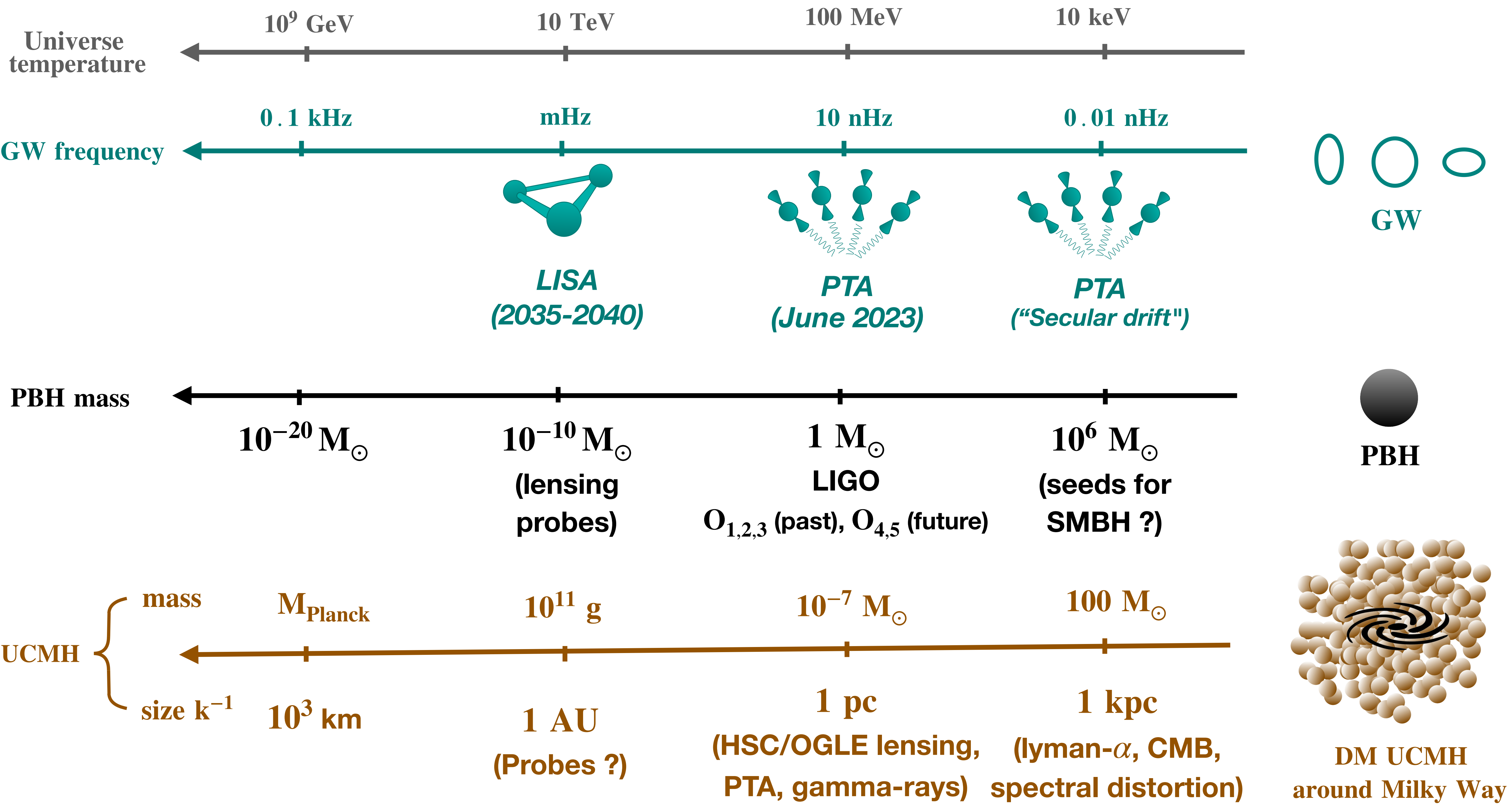


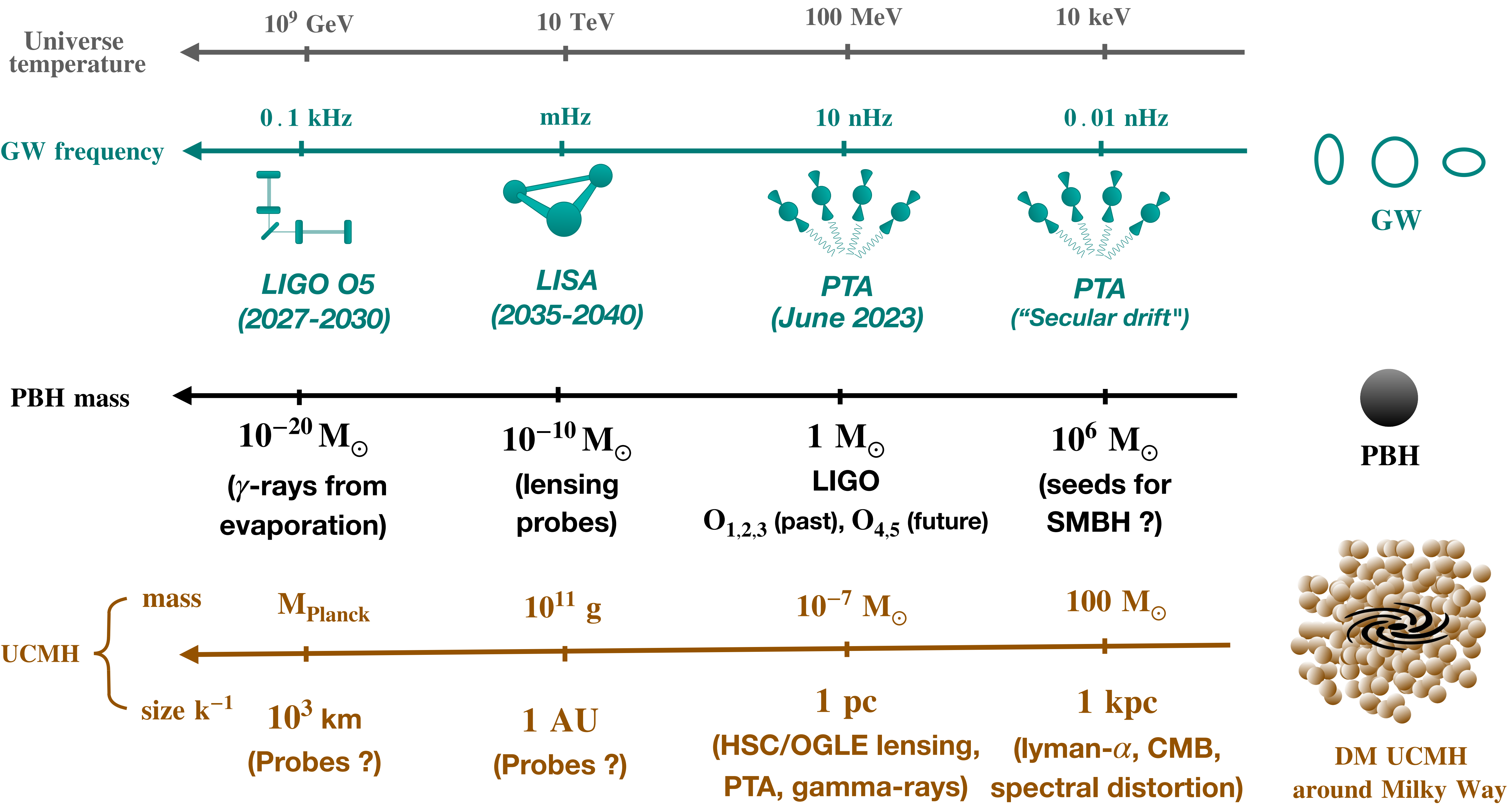
What we do know about the
History of our Universe



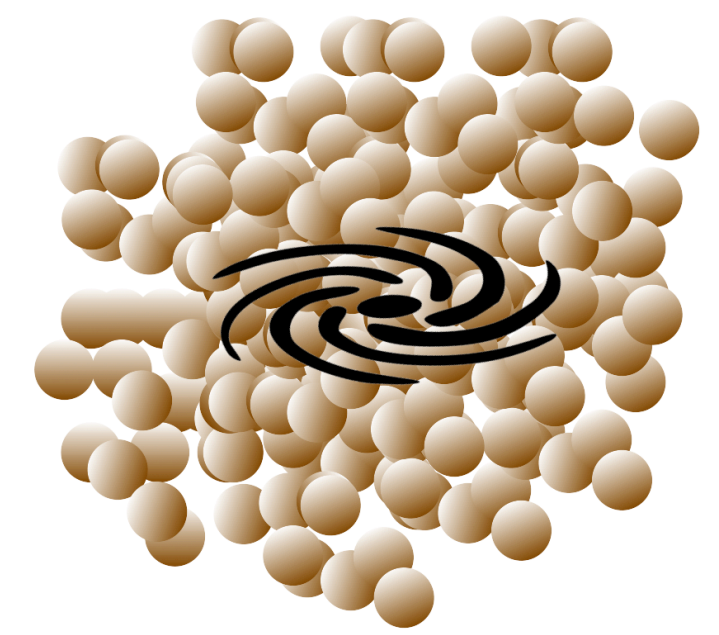
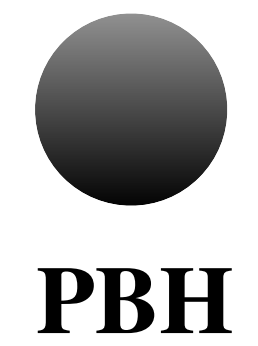




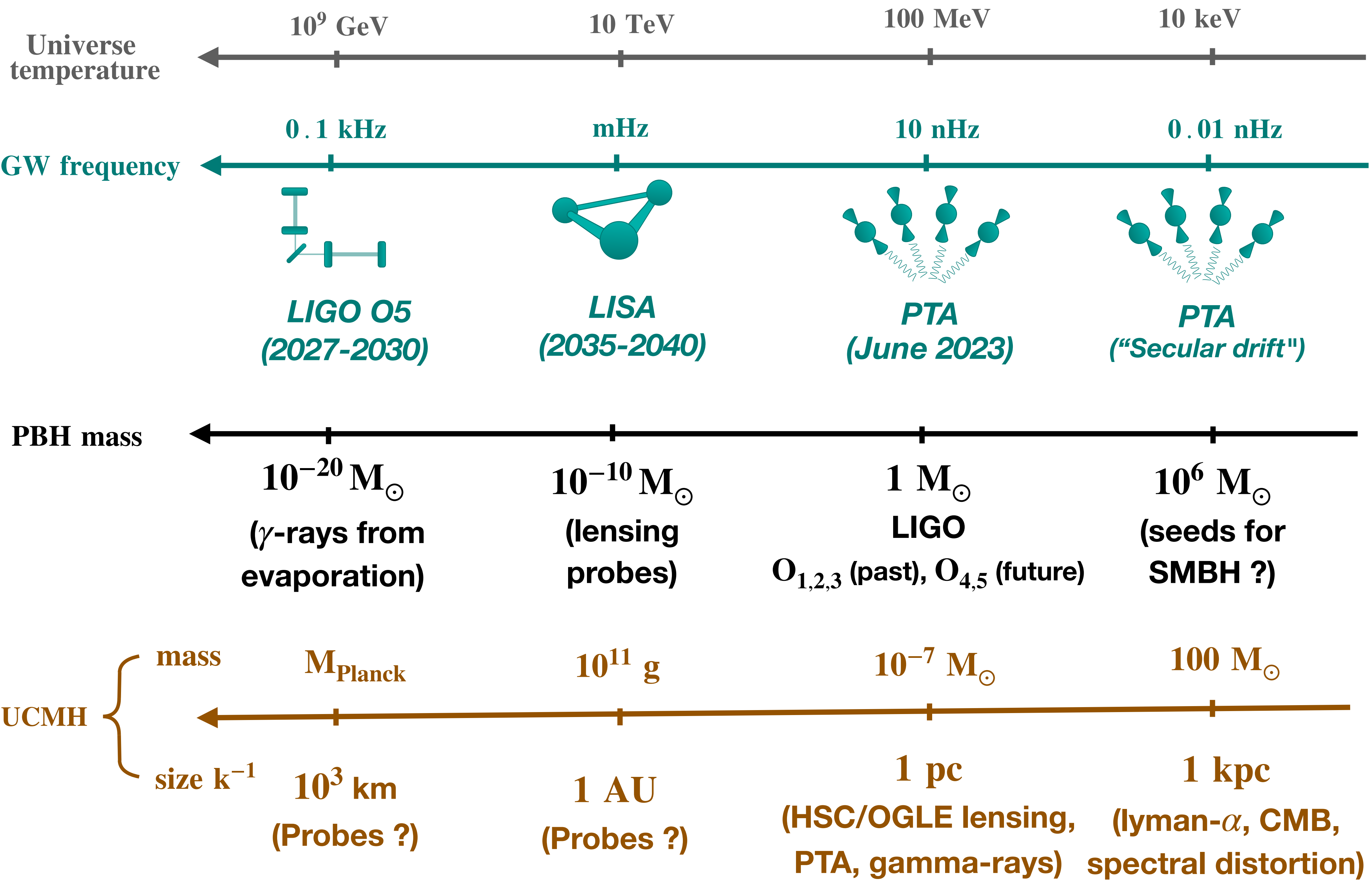




Thank
you



DM UCMH
around Milky Way



Universe temperature

GW frequency

PBH mass

UCMH

LIGO O5
(2027-2030)

LISA
(2035-2040)

PTA
(June 2023)

PTA
("Secular drift")

$10^{-20} M_{\odot}$
(γ -rays from evaporation)

$10^{-10} M_{\odot}$
(lensing probes)

$1 M_{\odot}$
LIGO
 $O_{1,2,3}$ (past), $O_{4,5}$ (future)

$10^6 M_{\odot}$
(seeds for SMBH ?)

mass
 M_{Planck}

size k^{-1}
 10^3 km
(Probes ?)

10^{11} g

1 AU
(Probes ?)

$10^{-7} M_{\odot}$

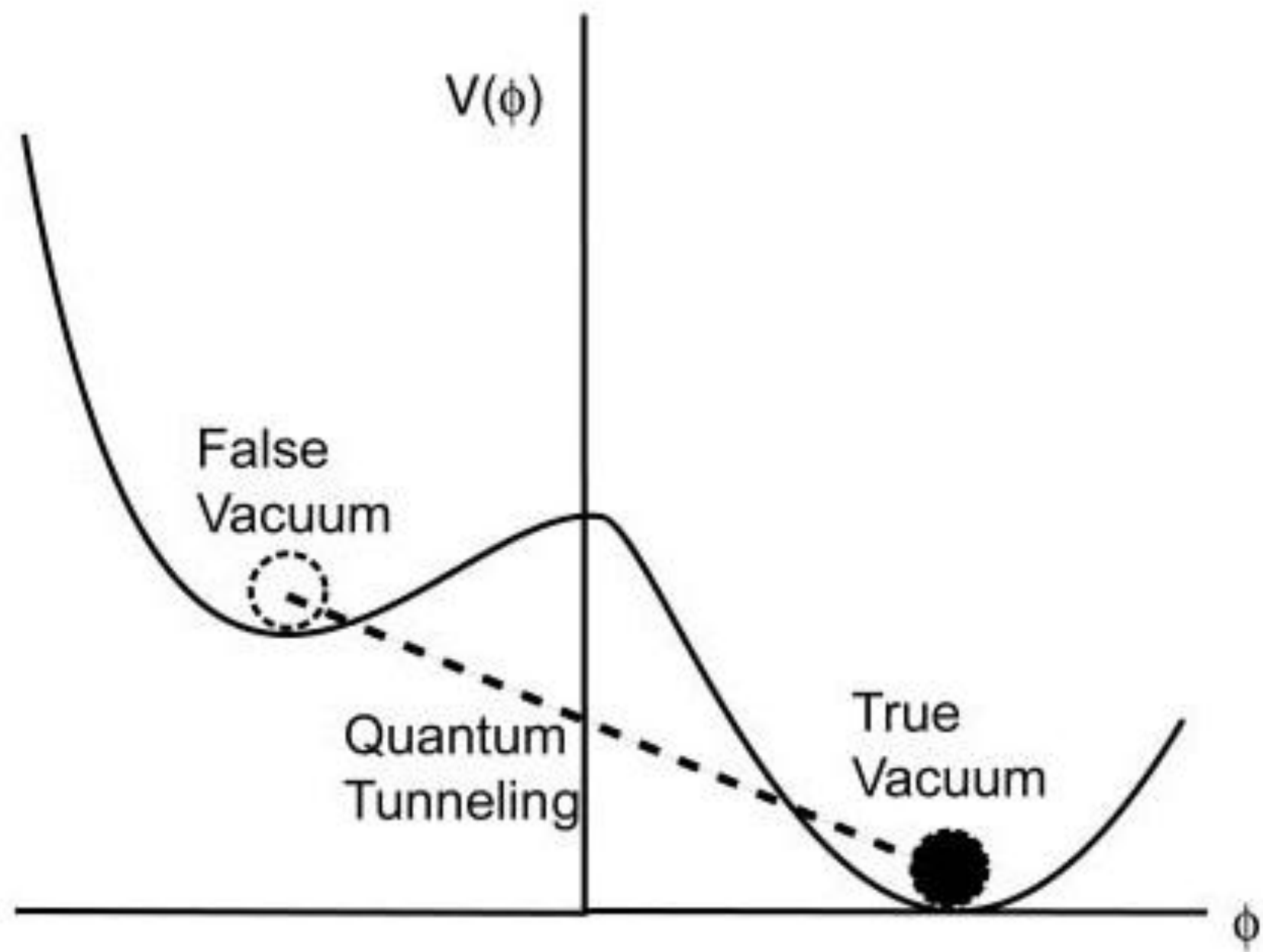
1 pc
(HSC/OGLE lensing, PTA, gamma-rays)

100 M_{\odot}

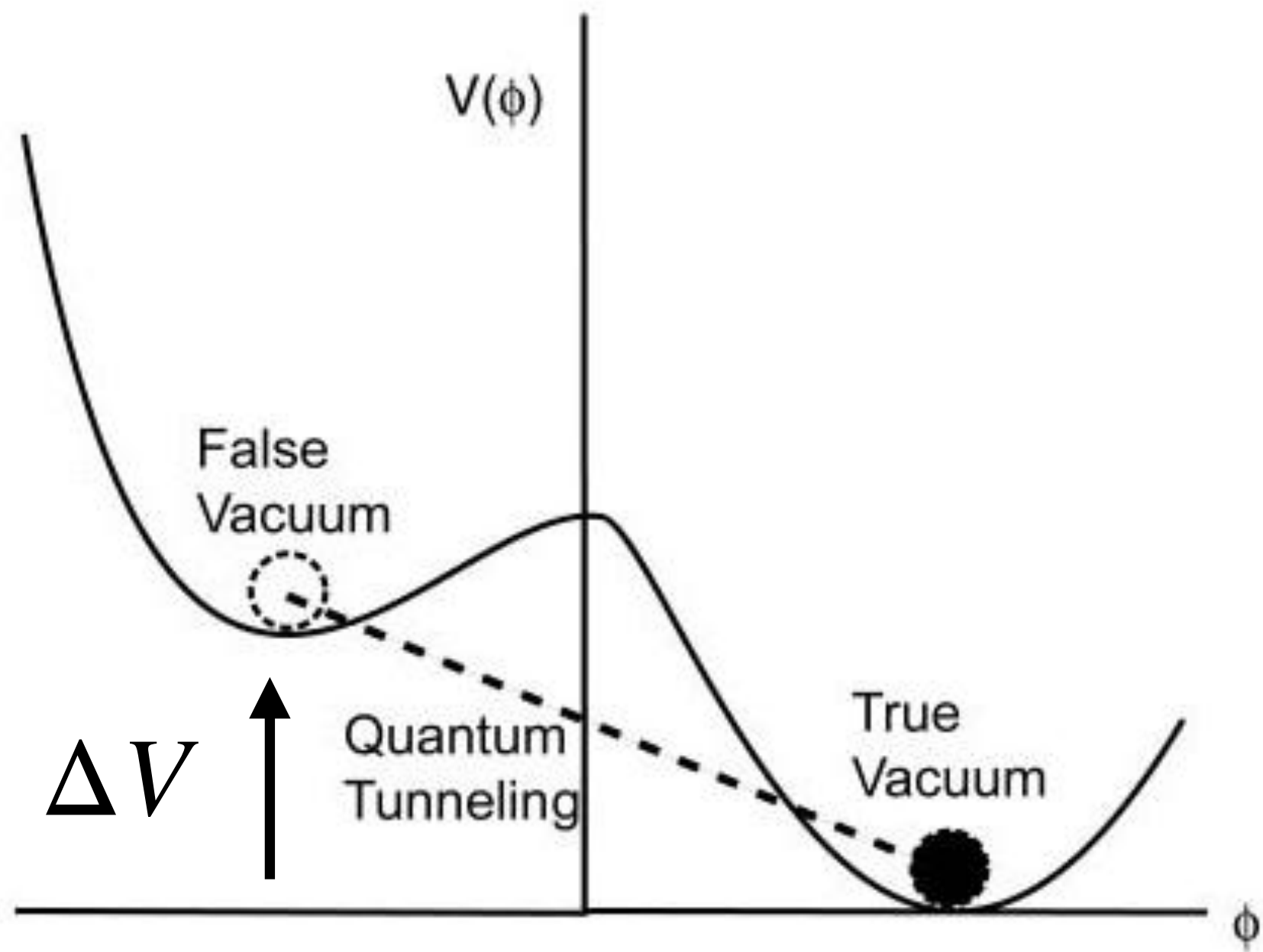
1 kpc
(lyman- α , CMB, spectral distortion)

PBHs from 1stOPT

YG, Volansky 2305:04942

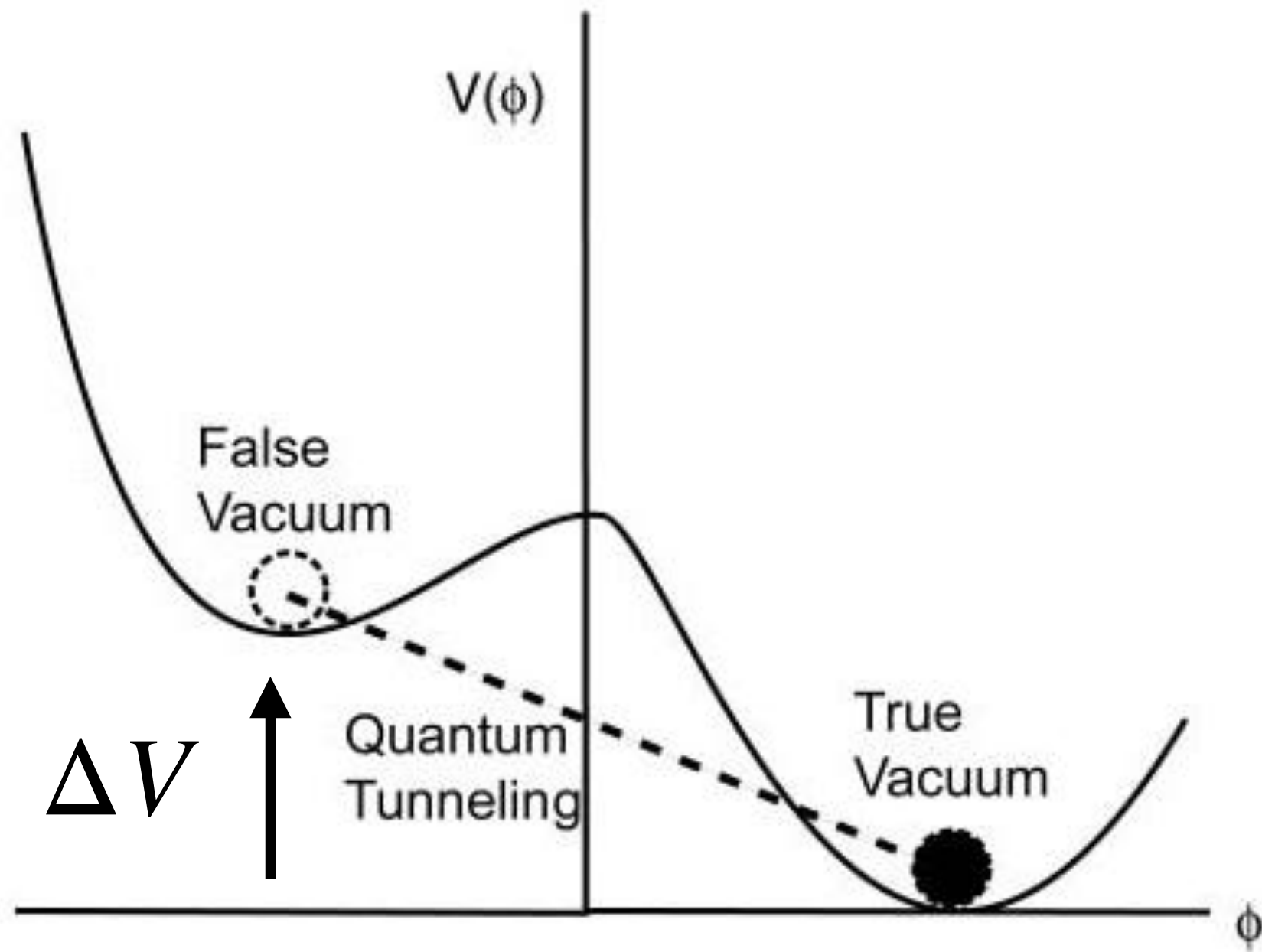


PBHs from 1stOPT

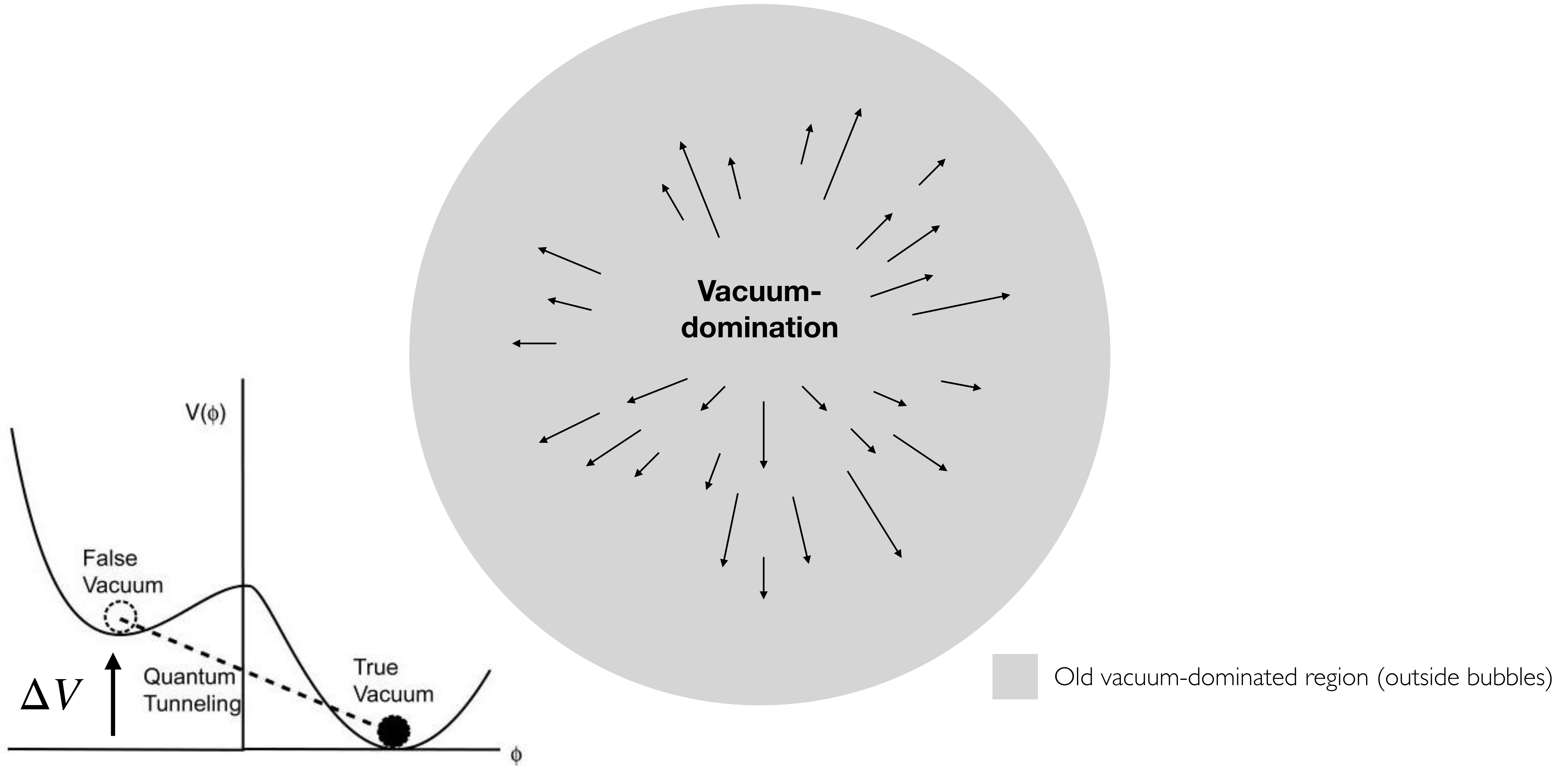


Strong 1st order PT:

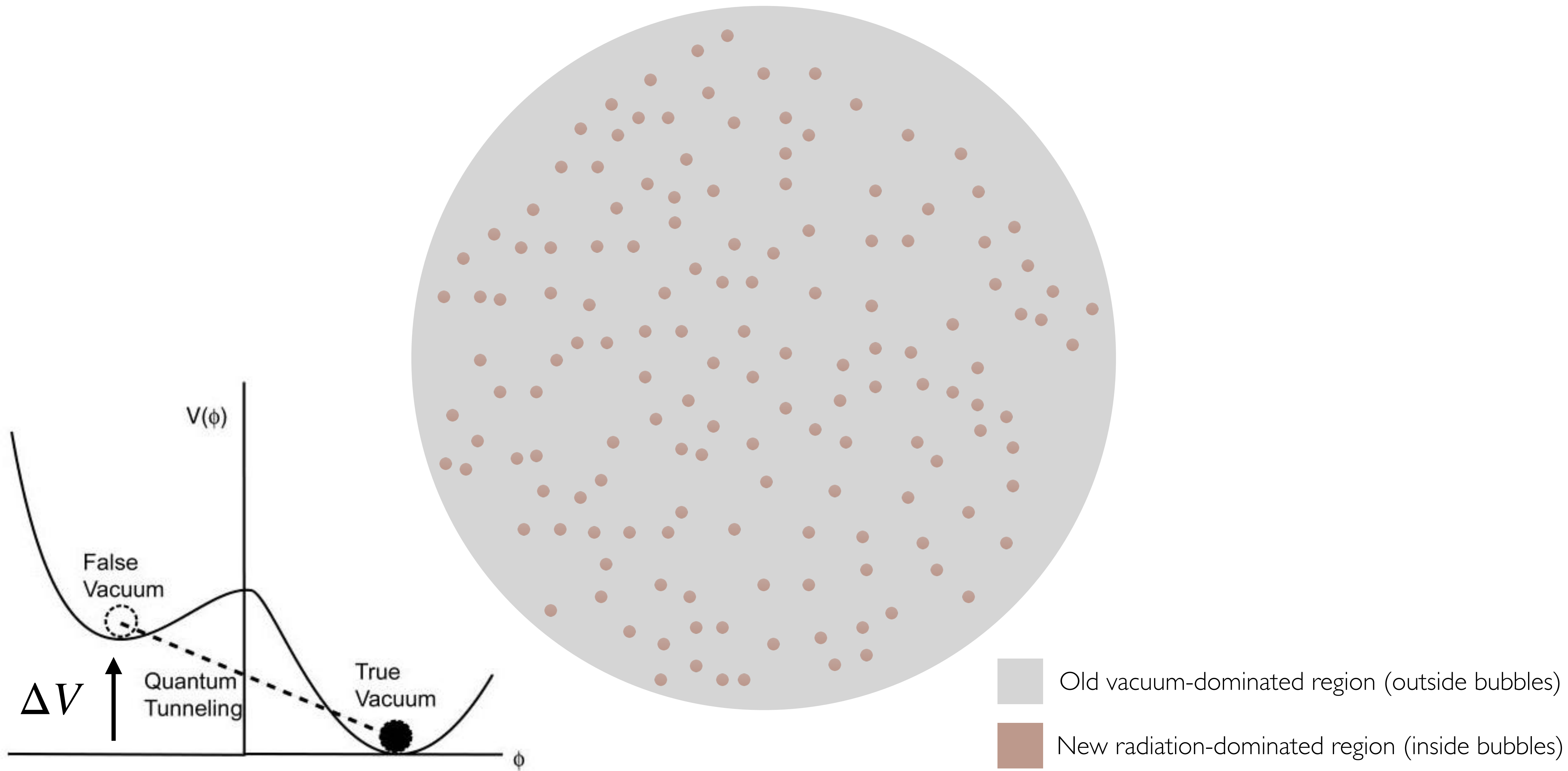
$$\Delta V \gg \rho_{\text{rad}}$$



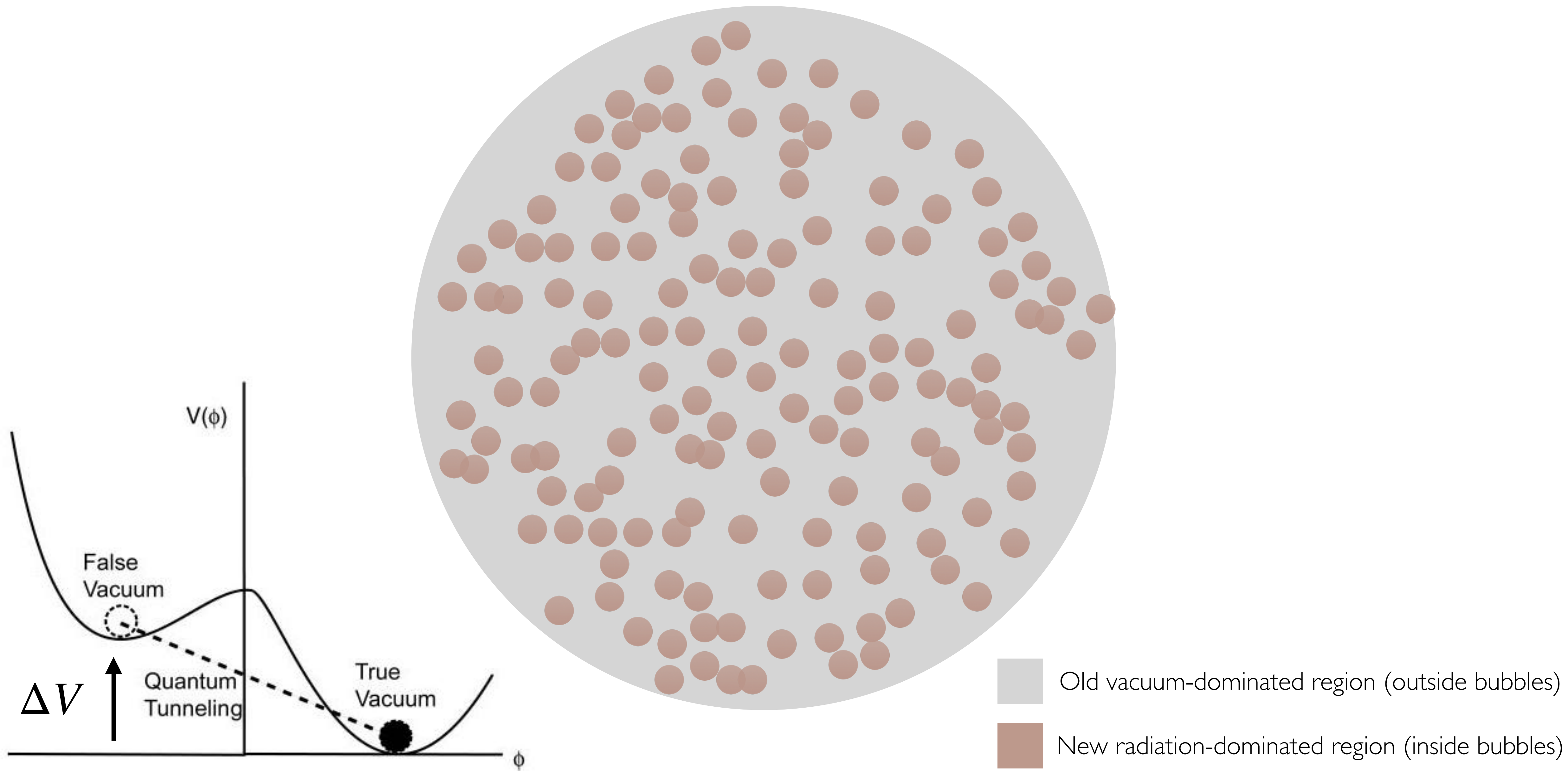
PBHs from 1stOPT



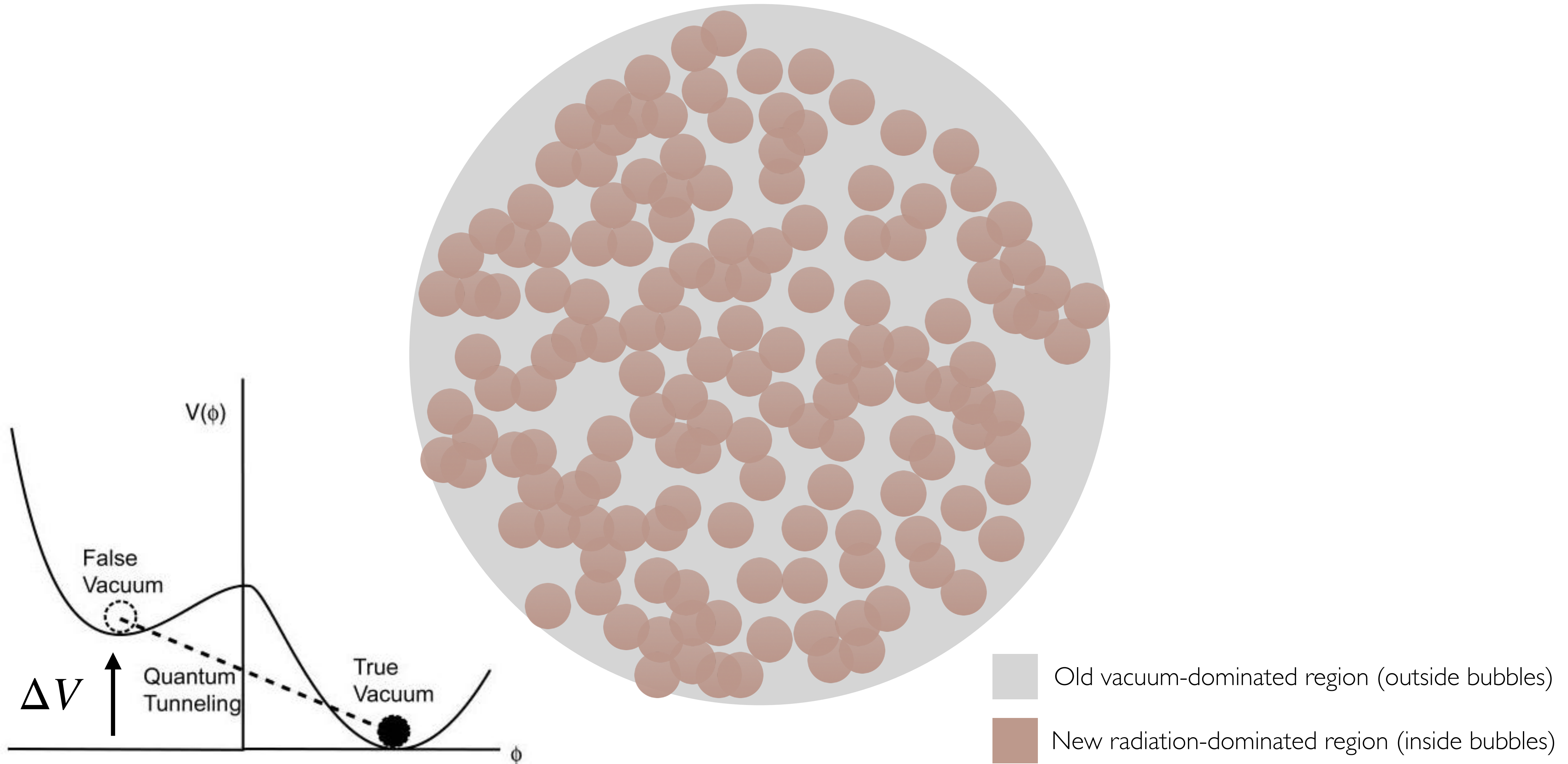
PBHs from 1stOPT



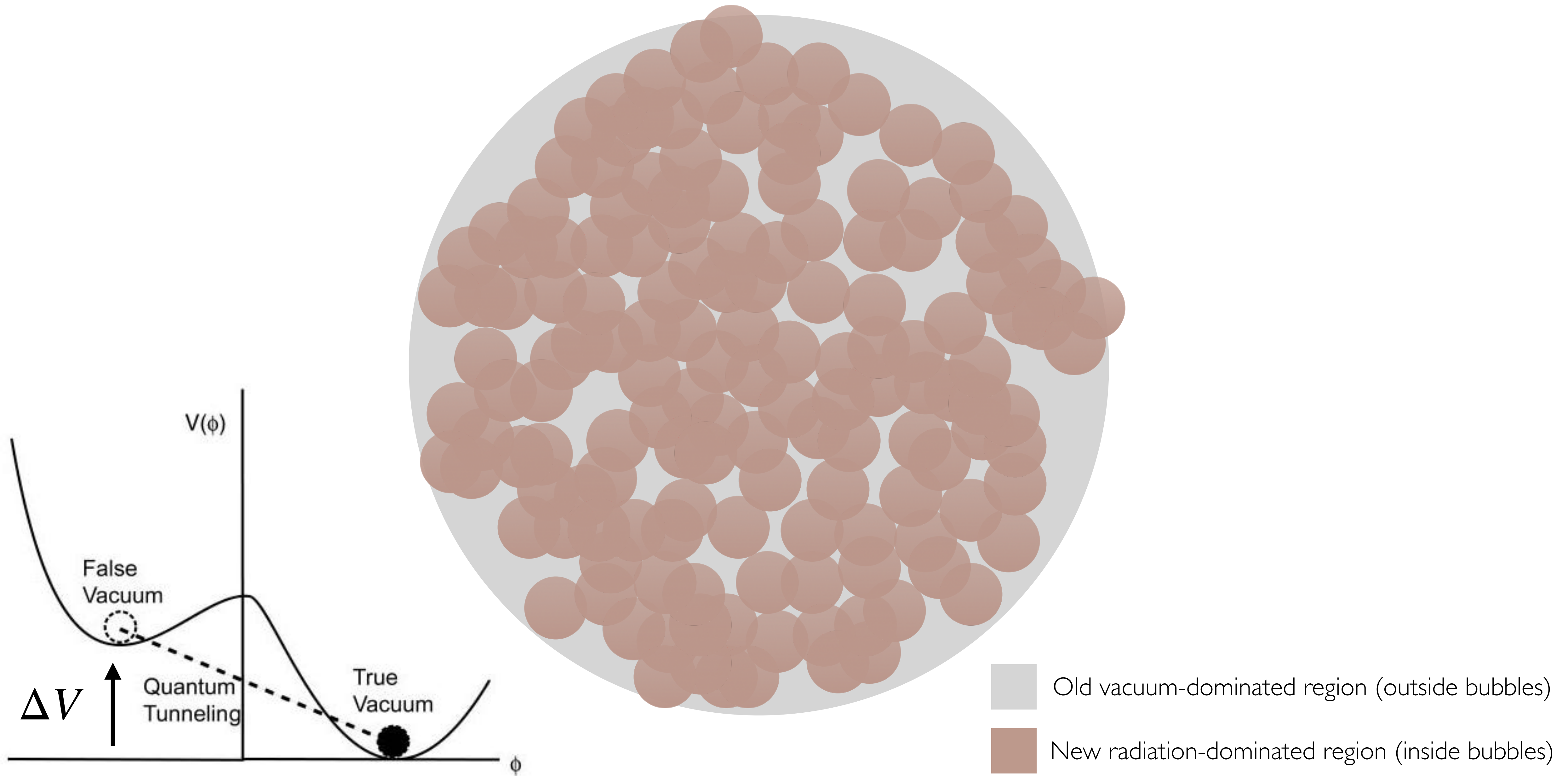
PBHs from 1stOPT



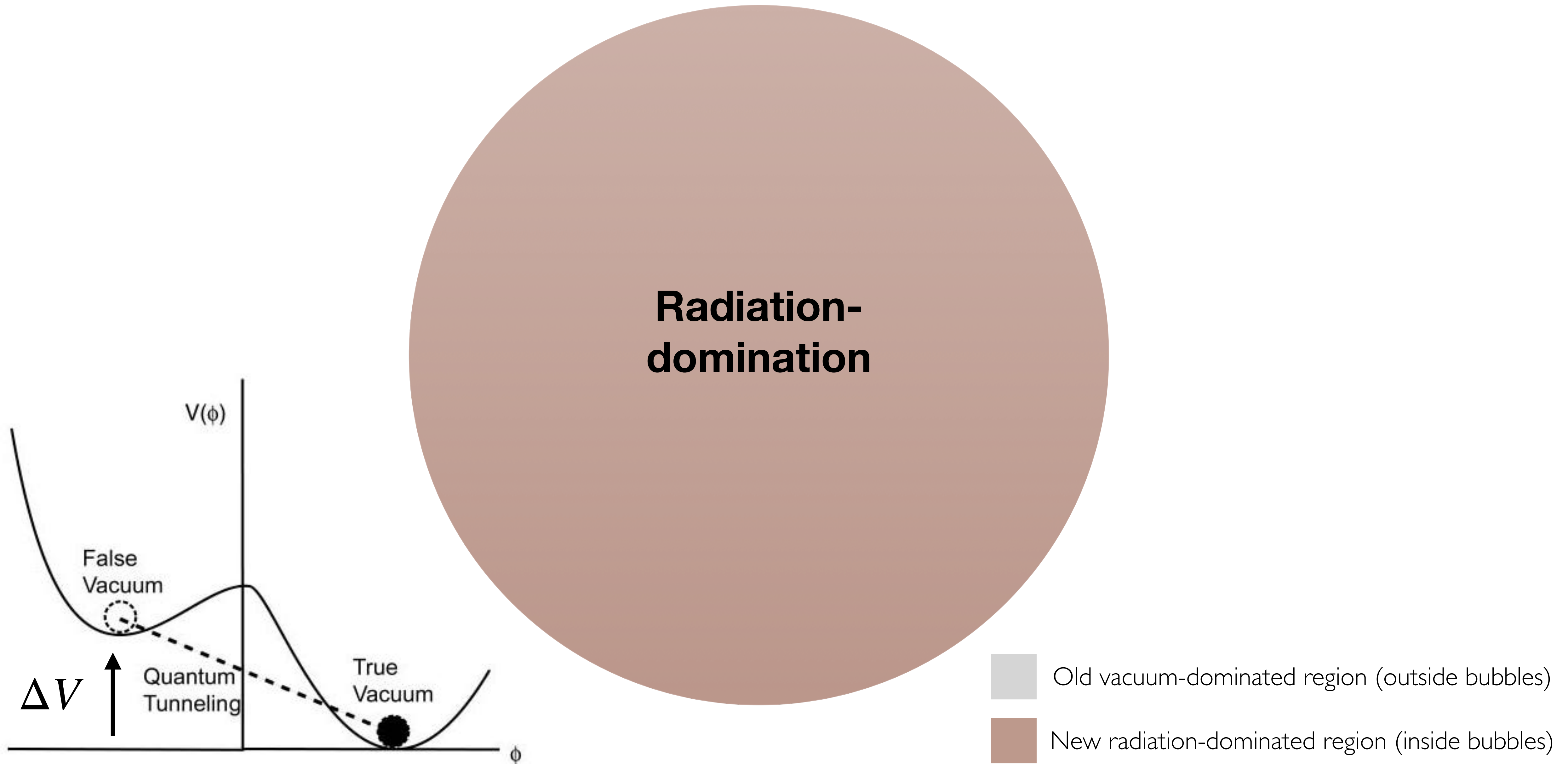
PBHs from 1stOPT



PBHs from 1stOPT

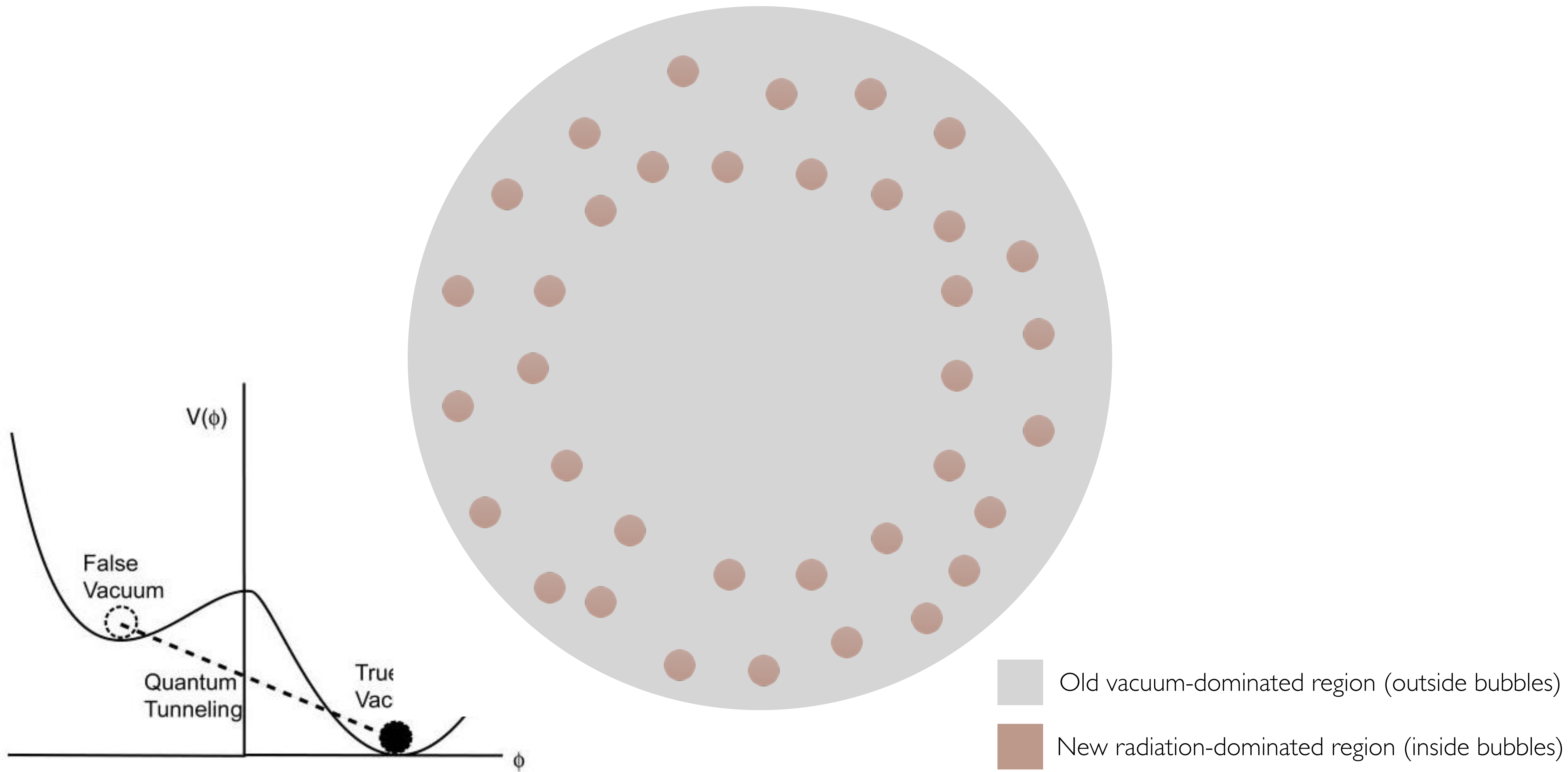


PBHs from 1stOPT

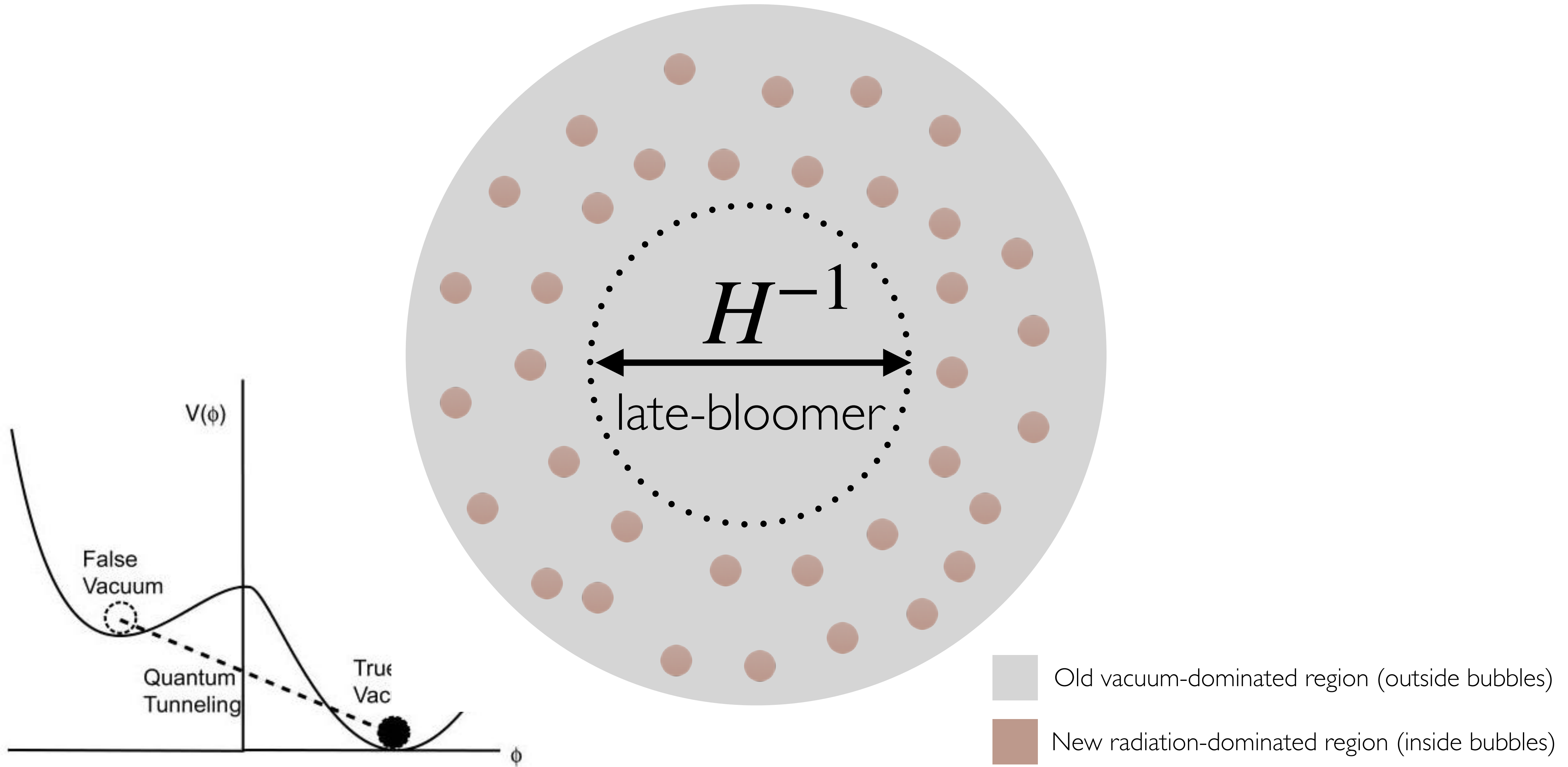


PBHs from 1stOPT

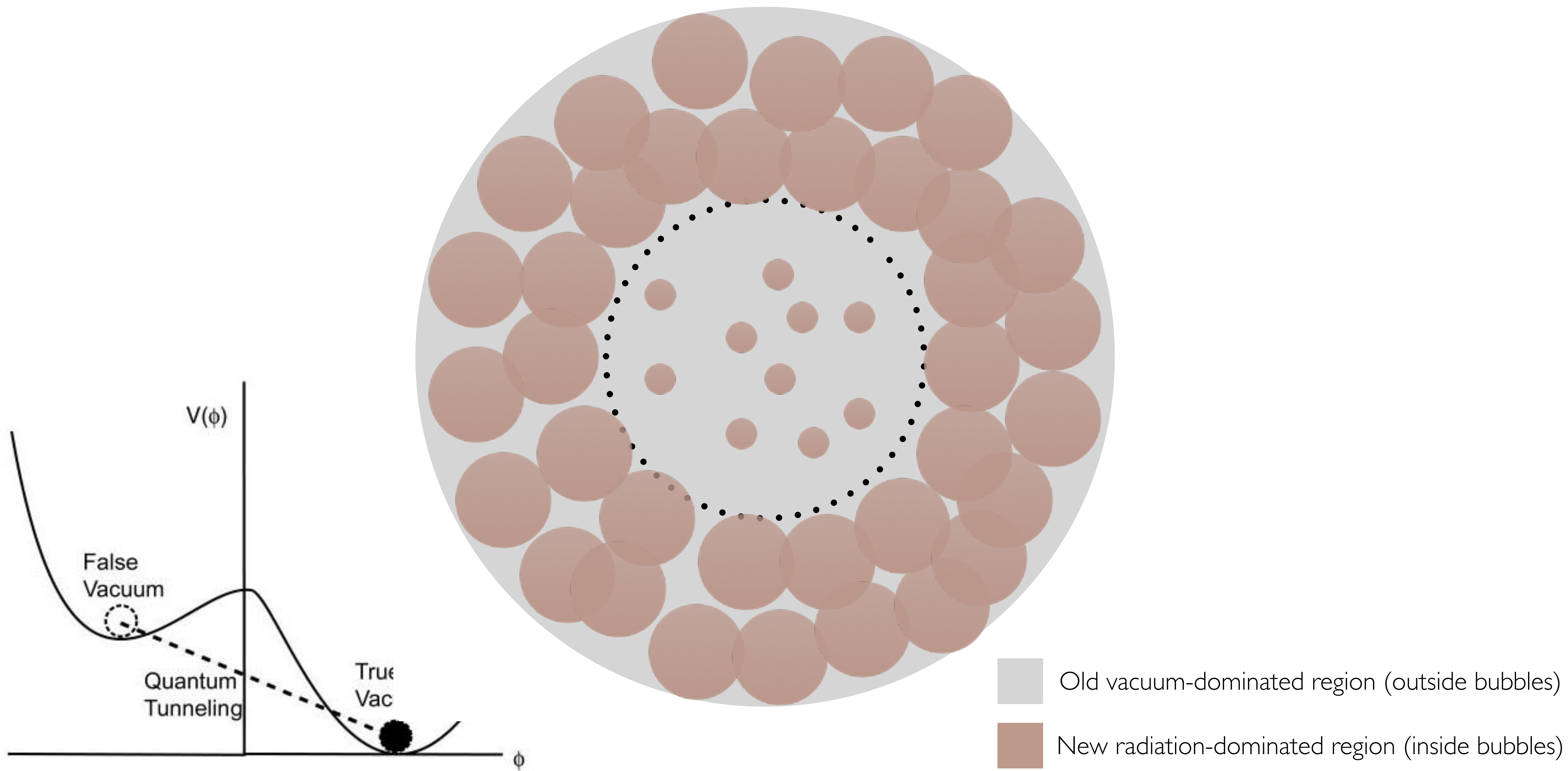
YG, Volansky 2305:04942



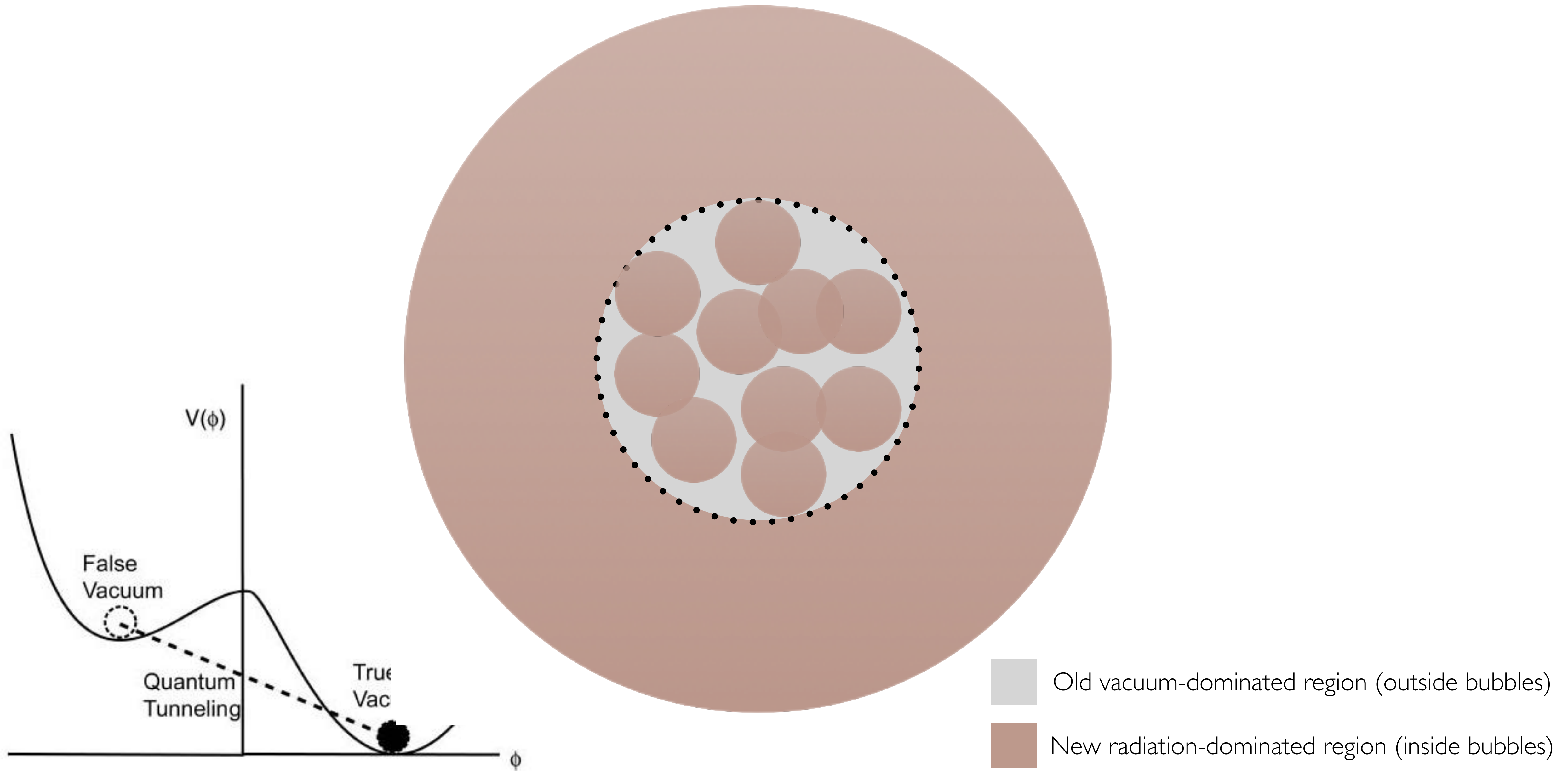
PBHs from 1stOPT



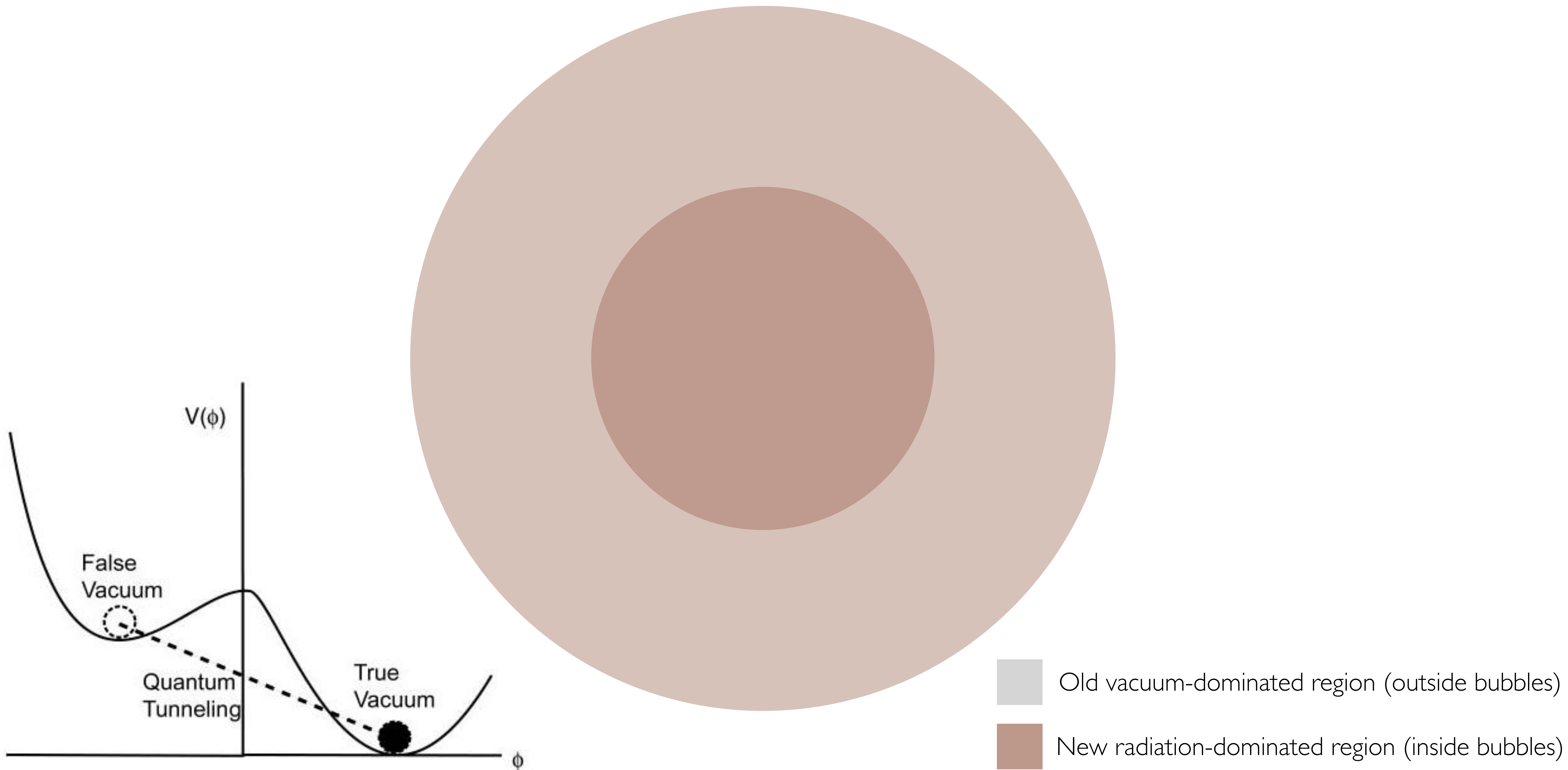
PBHs from 1stOPT



PBHs from 1stOPT



PBHs from 1stOPT

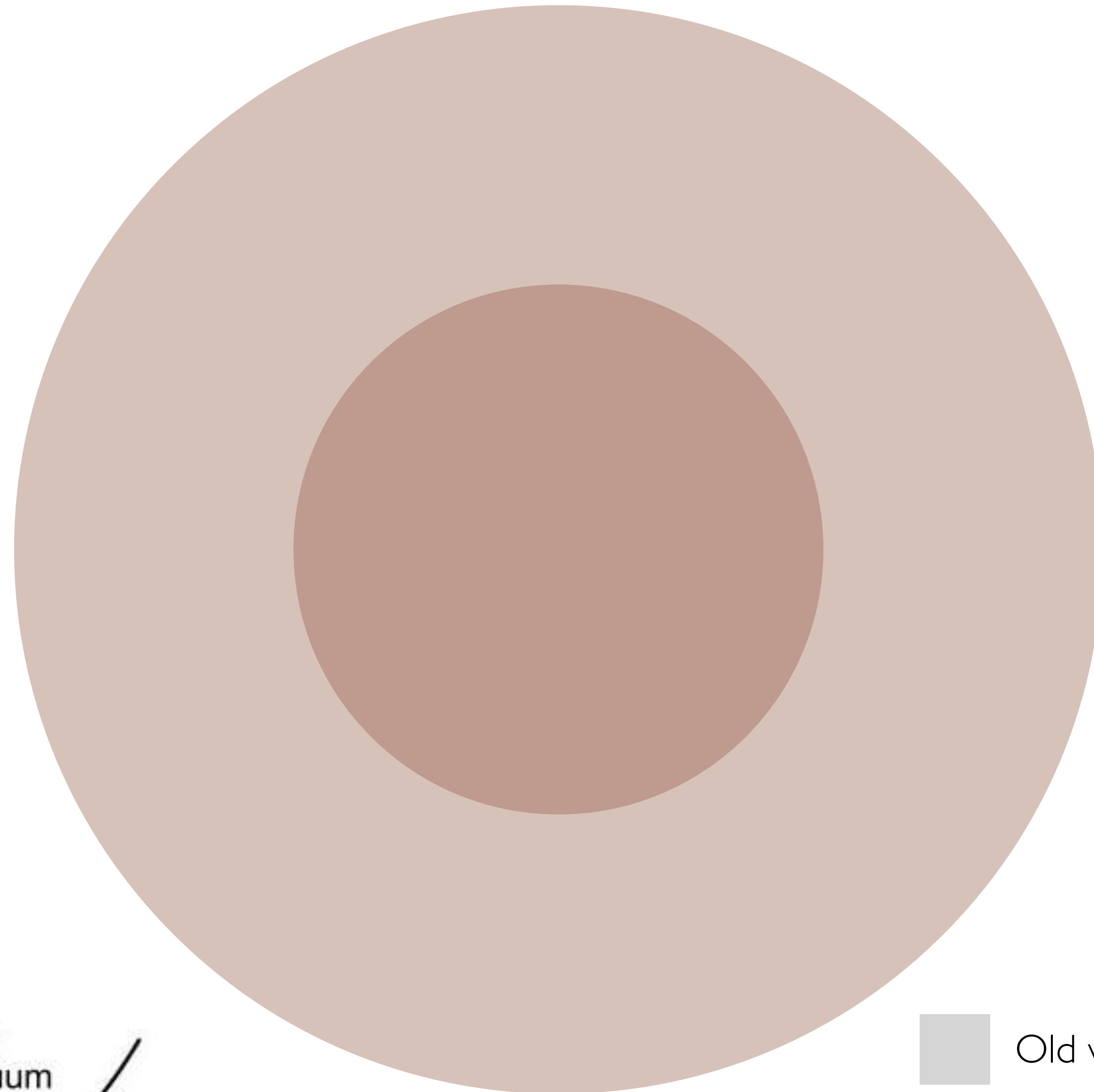
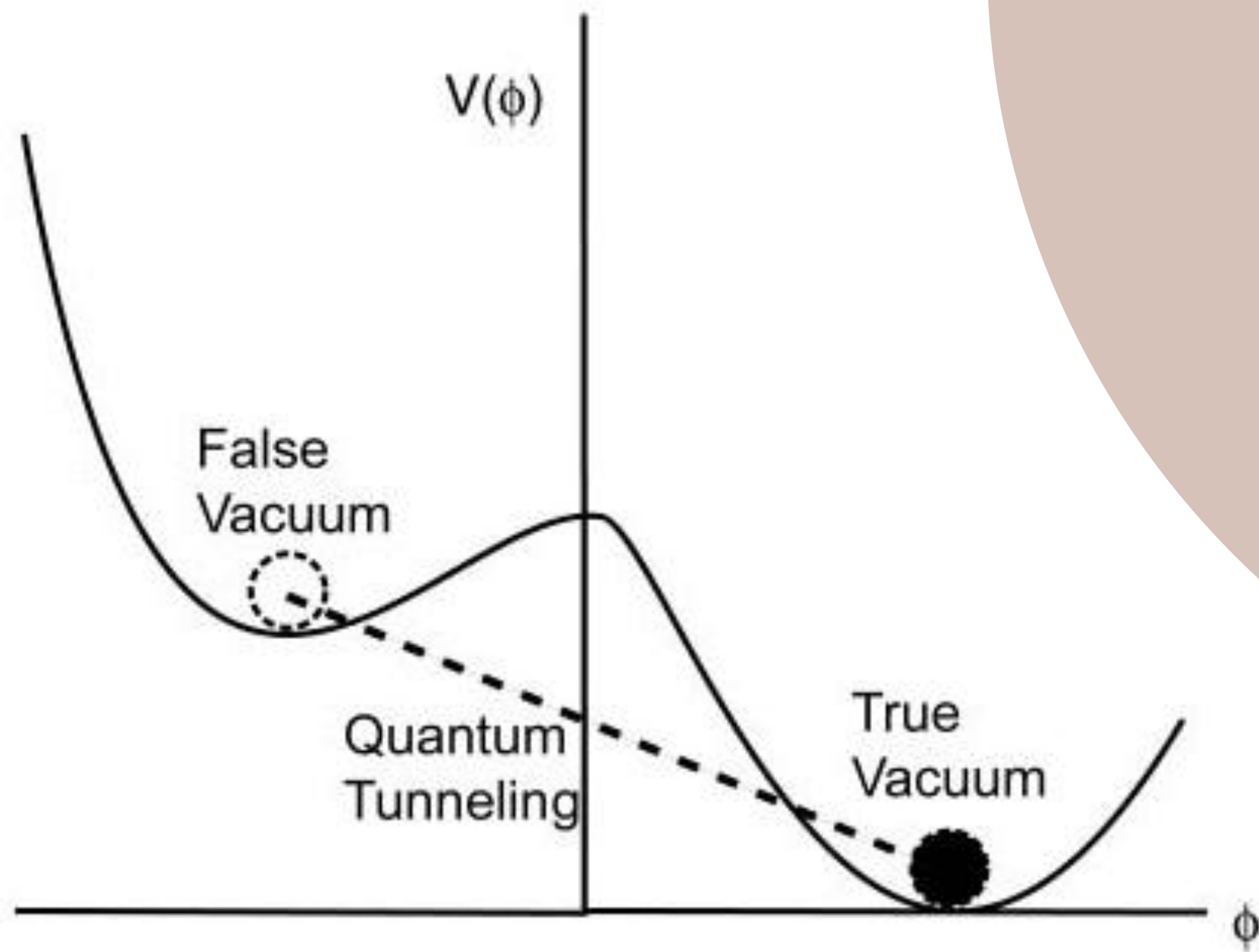


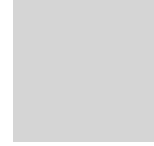

PBHs from 1stOPT

YG, Volansky 2305:04942

if

$$\delta\rho/\rho \gtrsim 0.50.$$



-  Old vacuum-dominated region (outside bubbles)
-  New radiation-dominated region (inside bubbles)

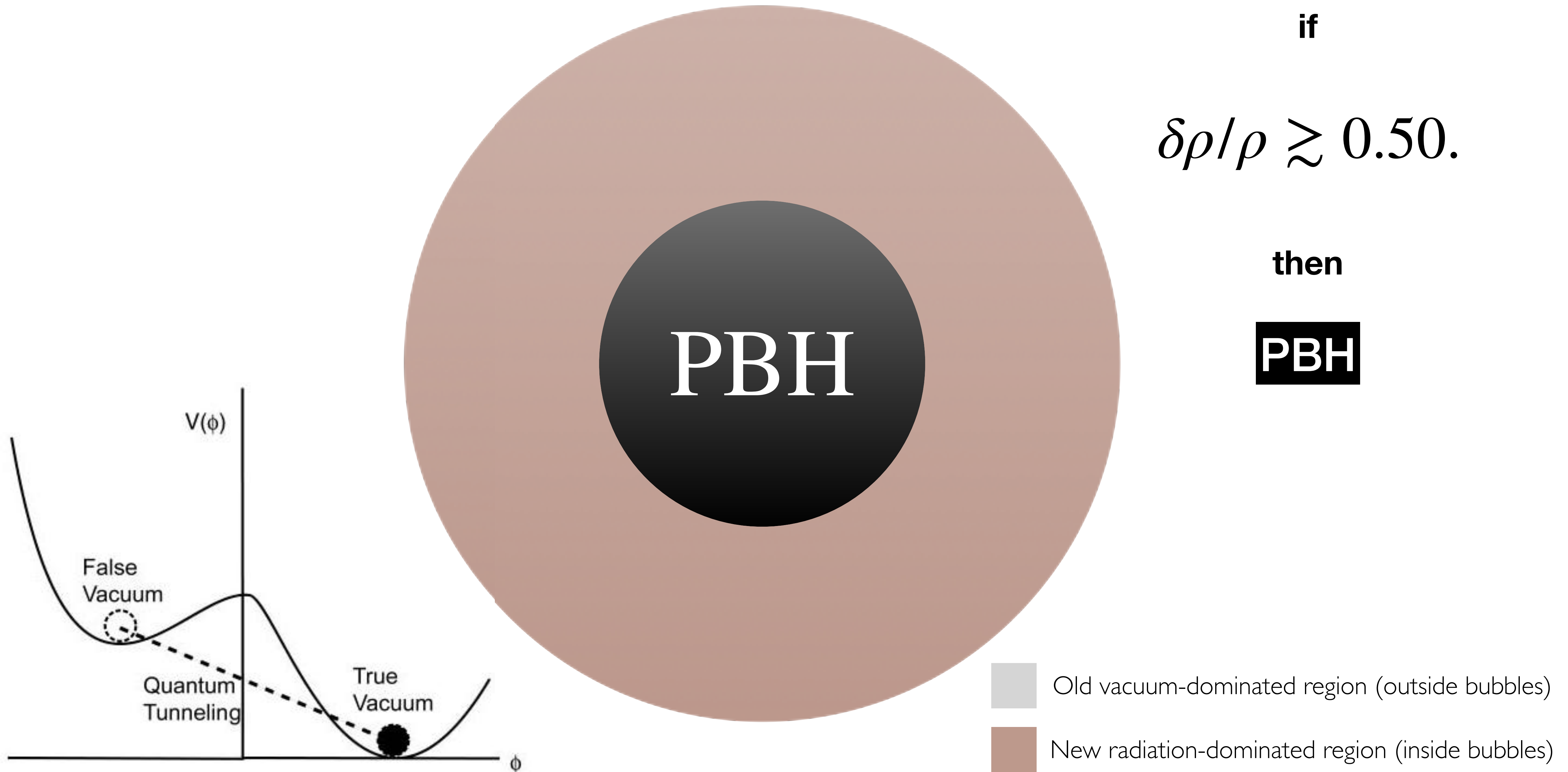
PBHs from 1stOPT

if

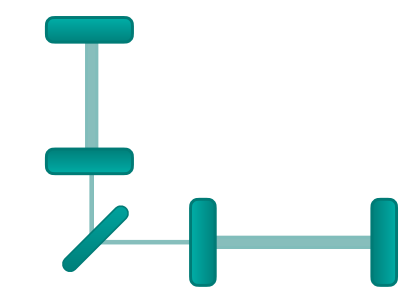
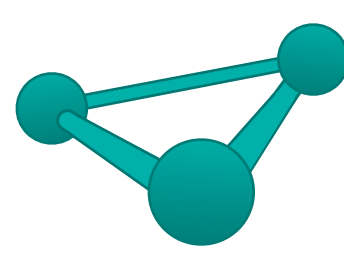
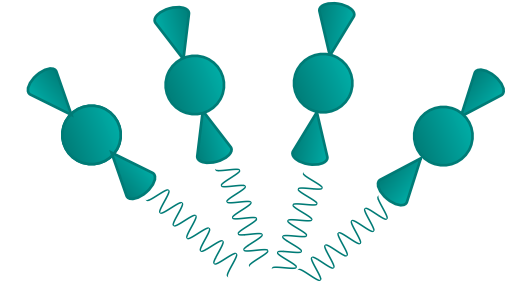
$$\delta\rho/\rho \gtrsim 0.50.$$

then

PBH



“The GW Era”



Pulsar Timing Arrays

Laser interferometers (Space)

Atom interferometers

Laser interferometers (Earth-based)

