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Background of radio photons from primordial black holes

Shikhar Mittal

Tata Institute of Fundamental Research, India

with Girish Kulkarni

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TIFR

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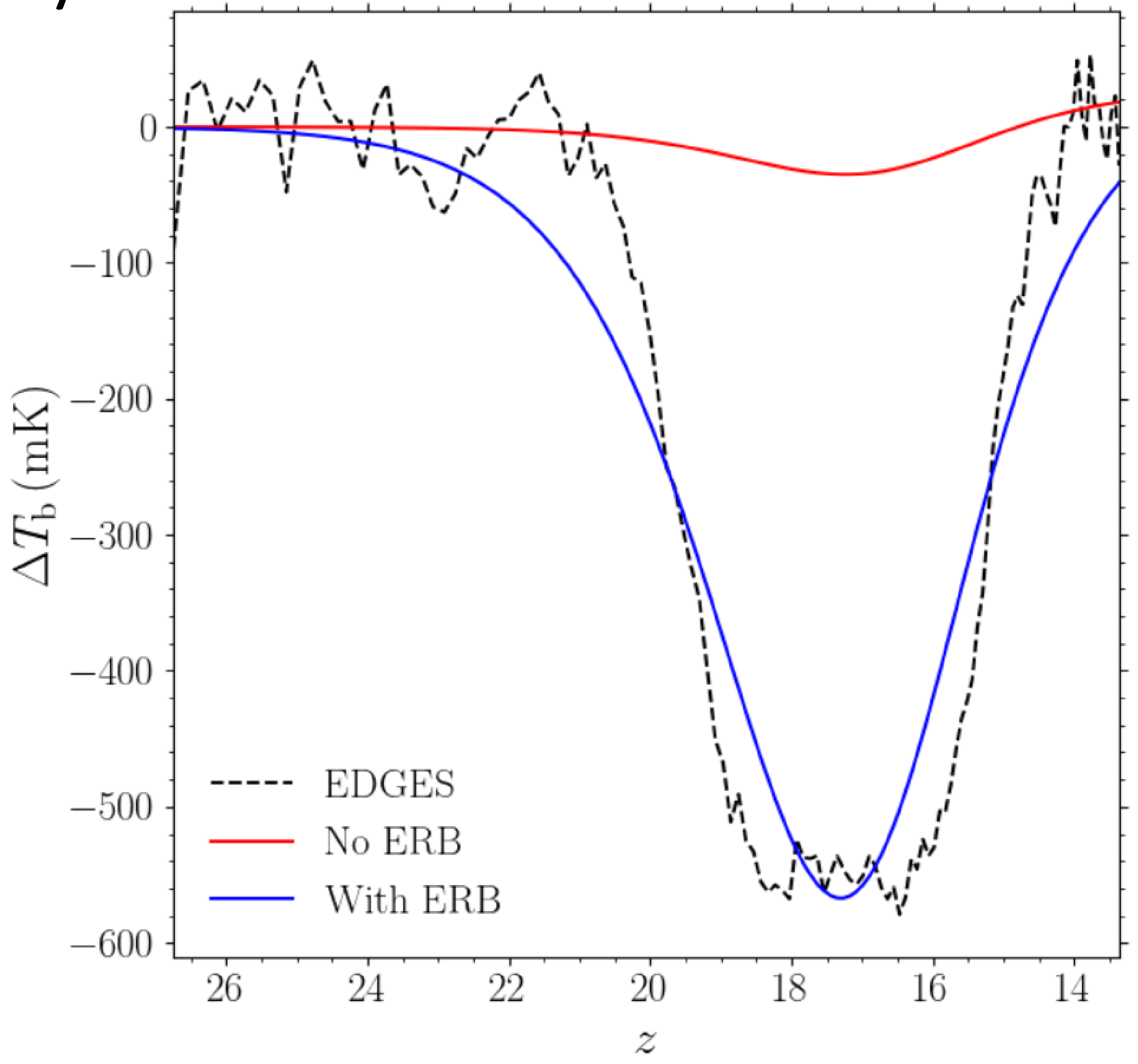
A strong absorption feature in the 21-cm signal detected by EDGES

- $\Delta T_{\mathrm{b}} \propto x_{\mathrm{HI}} \left(1 - \frac{T_{\mathrm{r}}}{T_{\mathrm{k}}}\right)$
- 21-cm signal encodes the information about the state of H & thermal history of IGM
- *Excess radio background* is a potential explanation of the EDGES signal



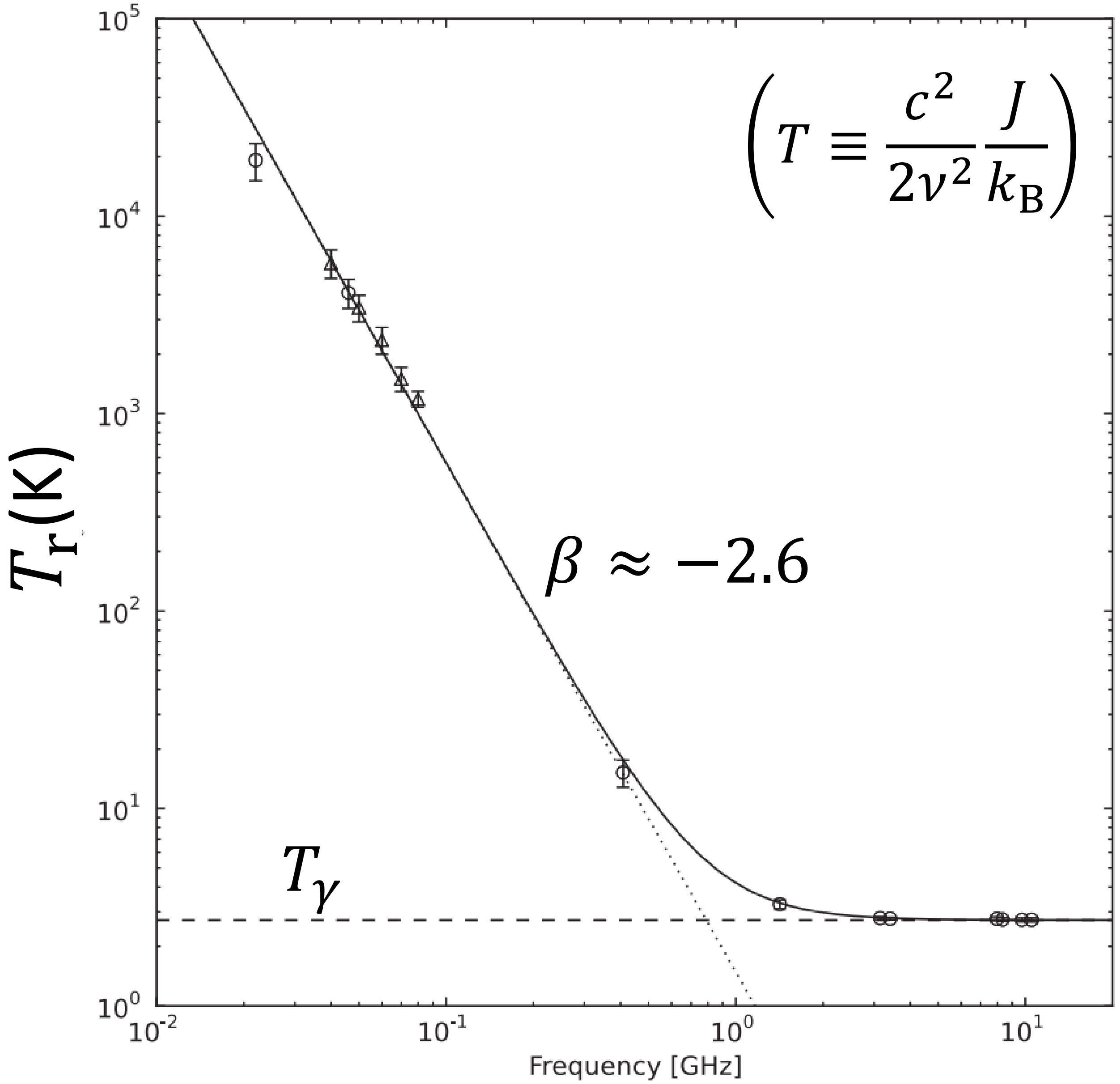
EDGES: **E**xperiment to **D**etect the **G**lobal **E**poch of reionization **S**ignal (Bowman et al. 2018)

ARCADE2/LWA1: radio background

- The origin of this radio background is unknown
- About 5% of this excess explains the EDGES signal

$$T_{\mathrm{ERB}} = T_0 \left(\frac{\nu}{\nu_0}\right)^{\beta}, \quad \boldsymbol{\beta = -2.6}$$

$$T_{\mathrm{r}} = T_\gamma + T_{\mathrm{ERB}}$$



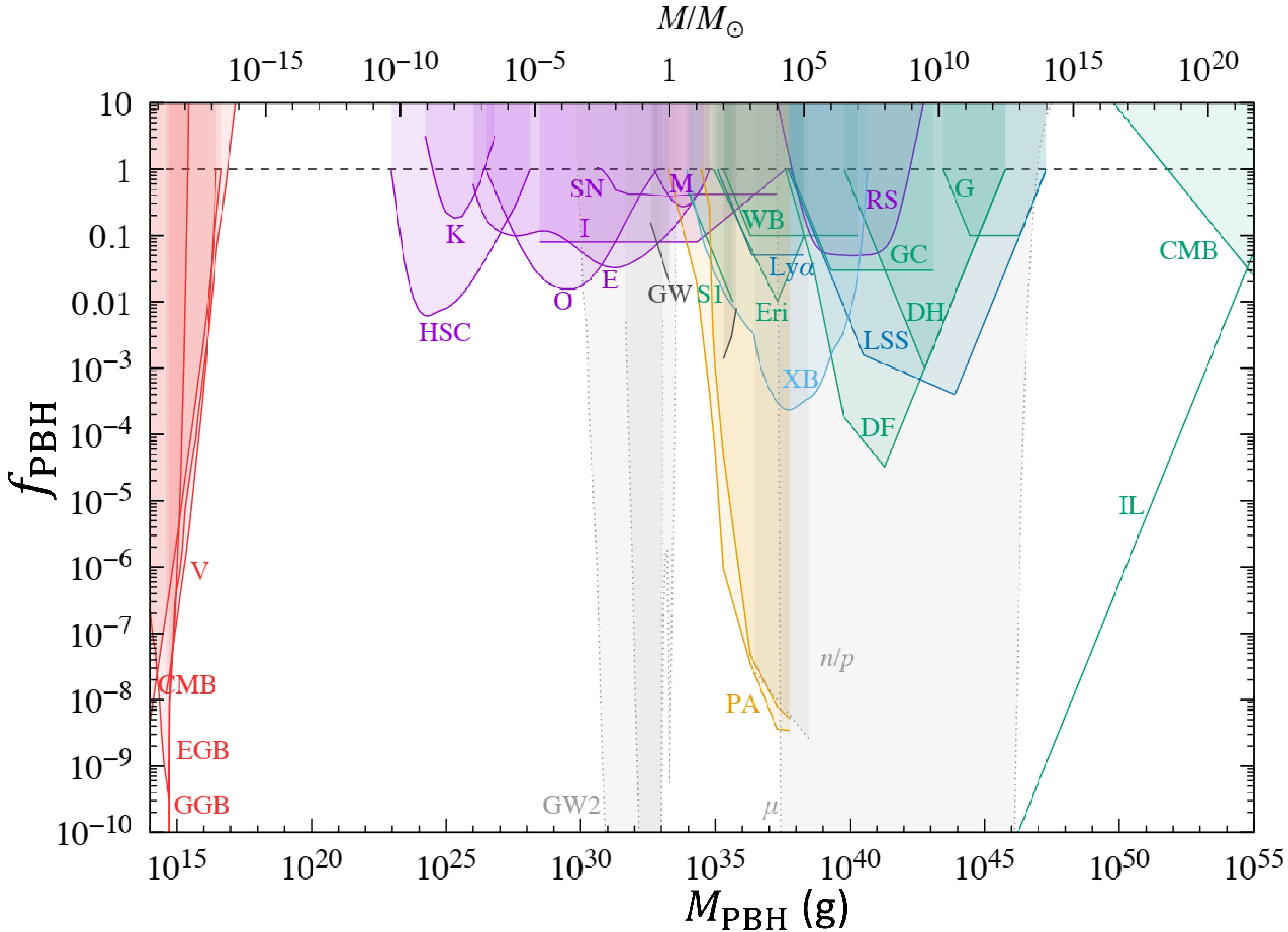
Fixsen et al (2011), Dowell & Taylor (2018)

Mechanisms that try to explain such an ERB

- Annihilating axion-like dark matter particles (Fraser et al. 2018)
- Dark photons (Pospelov et al. 2018)
- Super-conducting cosmic strings (Brandenberger et al. 2019)
- Radiative decay of relic to sterile neutrinos (Chianese et al. 2019)
- Accreting astrophysical black holes (Ewall-Wice et al. 2018, 2020)

Primordial black holes are interesting dark matter candidates

$$f_{\text{PBH}} = \frac{\rho_{\text{PBH}}}{\rho_{\text{DM}}}$$



Carr et al. (2021) [2002.12778]

Background due to accreting PBHs

$$J_{\mathrm{acc}} = \frac{c}{4\pi}\int_{t_{\mathrm{free}}}^{t_0} \epsilon_{\mathrm{acc}} \mathrm{d}t'$$

(Energy per unit time per unit area per unit energy per unit solid angle)

$$\epsilon_{\mathrm{acc}}(E) = n_{\mathrm{pbh}} l_{\mathrm{R}}(E)$$

Background due to accreting PBHs

$$J_{\rm acc} = \frac{c}{4\pi}\int_{t_{\rm free}}^{t_0} \epsilon_{\rm acc}\,{\rm d}t'$$

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$$\epsilon_{\rm acc}(E) = n_{\rm pbh}\, l_{\rm R}(E)$$

Fundamental plane of black hole activity:

$$\log_{10}\left(\frac{\nu l_{\rm R}}{L_{\rm E}}\right) = 0.86\,\log_{10}\left(\frac{L_{\rm X}}{L_{\rm E}}\right) - 5.08$$

$L_{\rm E}$ is the Eddington luminosity,
$\nu \approx 1.4$ GHz

Wang et al. (2006), Ishibashi & Courvoisier (2011), Hasinger (2020)

Background due to accreting PBHs

$$J_{\rm acc} = \frac{c}{4\pi}\int_{t_{\rm free}}^{t_0} \epsilon_{\rm acc}\,\mathrm{d}t'$$

(Energy per unit time per unit area per unit energy per unit solid angle)

$$\epsilon_{\rm acc}(E) = n_{\rm pbh} l_{\rm R}(E)$$

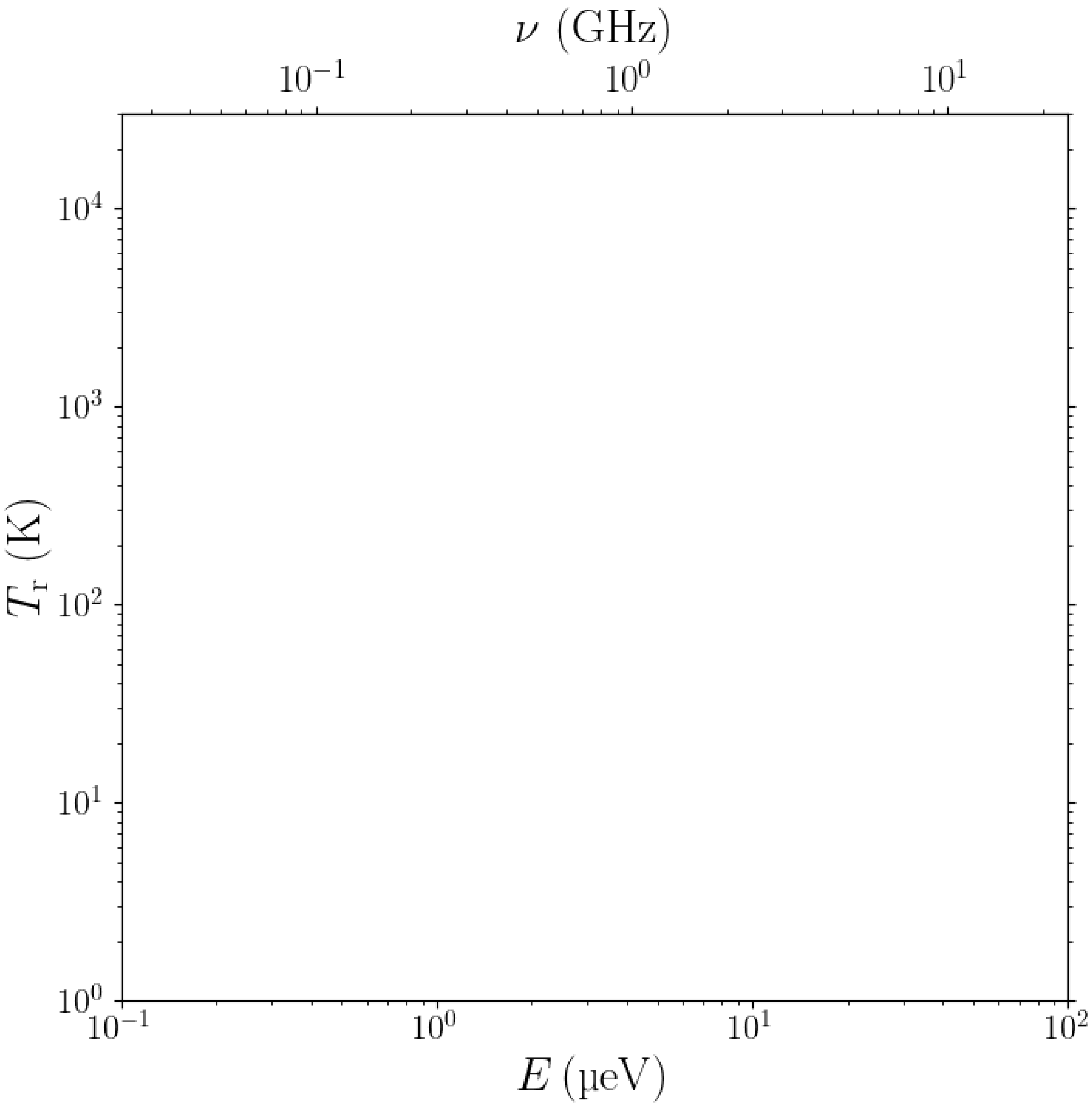
For synchrotron emission by relativistic jets,

$$l_{\rm R}(E) \propto (f_{\rm duty}\lambda^{0.86}) E^{-0.6}$$

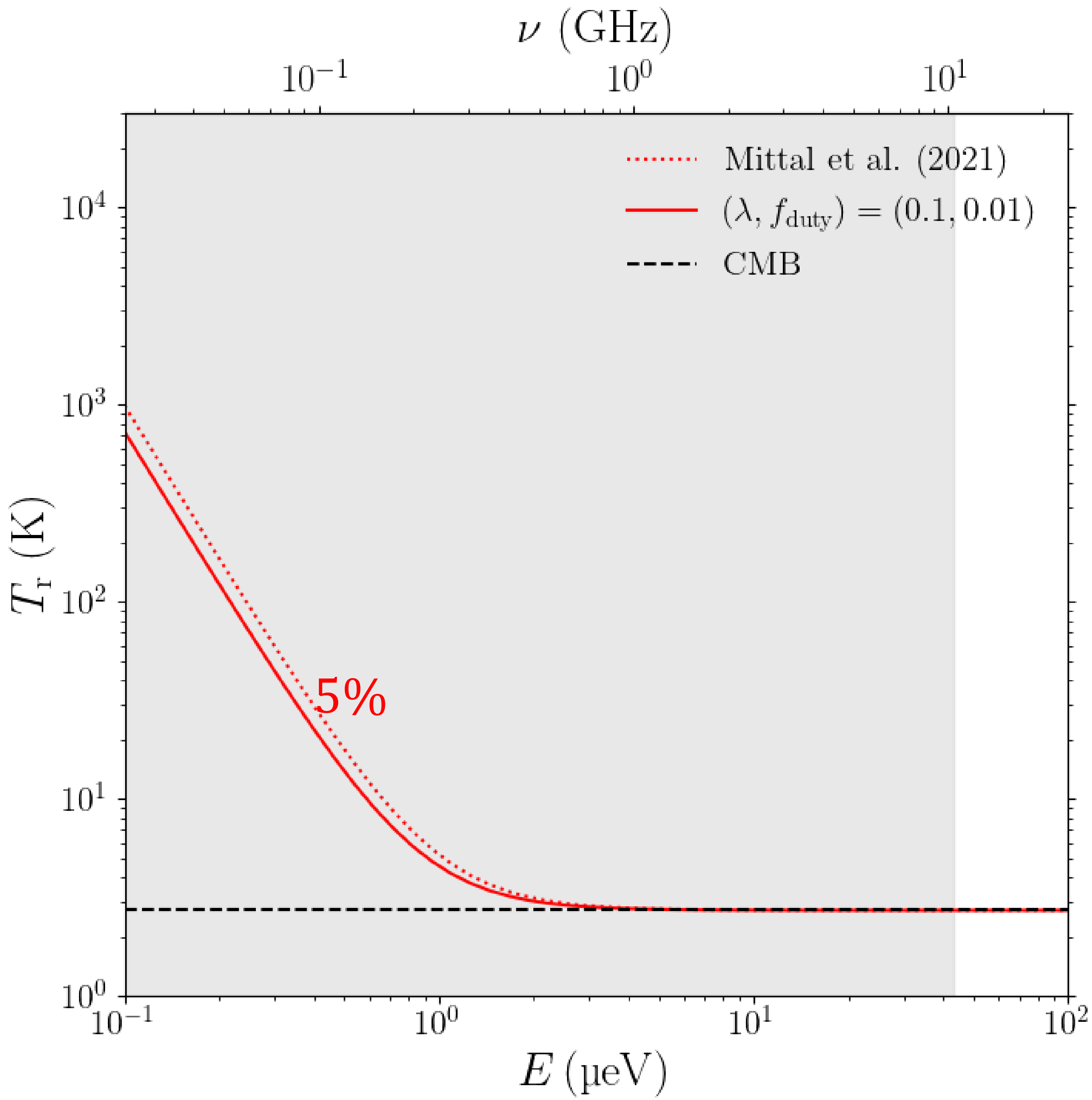
This is also expected from first-order Fermi acceleration in shocks.

$f_{\rm duty}$ = duty cycle — the probability that a black hole is active at a particular time
λ = Eddington ratio – ratio of bolometric to Eddington luminosity

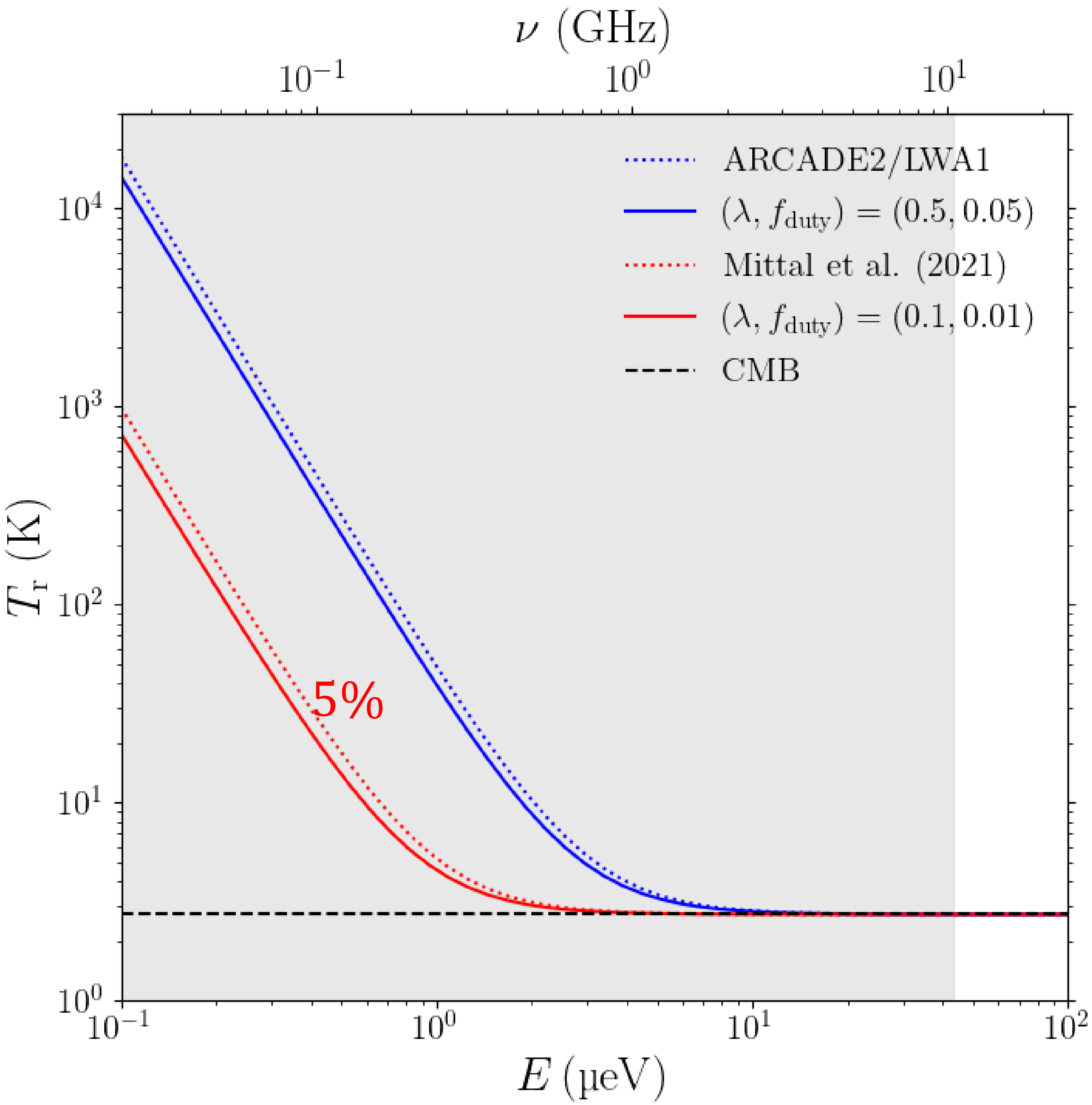
Wang et al. (2006), Ishibashi & Courvoisier (2011), Hasinger (2020)



ν (GHz)
10^−1
10^0
10^1
T_r (K)
10^4
10^3
10^2
10^1
10^0
10^−1
10^0
10^1
10^2
E (µeV)



ν (GHz)
10^−1
10^0
10^1
Mittal et al. (2021)
(λ, f_duty) = (0.1, 0.01)
CMB
T_r (K)
10^4
10^3
10^2
10^1
10^0
5%
10^−1
10^0
10^1
10^2
E (μeV)



ν (GHz)
10^{-1}
10^{0}
10^{1}
ARCADE2/LWA1
$(\lambda, f_{\rm duty}) = (0.5, 0.05)$
Mittal et al. (2021)
$(\lambda, f_{\rm duty}) = (0.1, 0.01)$
CMB
5%
$T_{\rm r}$ (K)
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{-1}
10^{0}
10^{1}
10^{2}
E (μeV)

Conclusions

- Accreting PBHs not only explain the magnitude observed by ARCADE2/LWA1, but also the slope -2.6
- This excess radio background can alleviate the tension between standard 21-cm model and EDGES observation