Local 21 cm signal from Primordial Black Holes

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Based on:
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Introduction

- Primordial Black Holes (PBH) formed in the early universe could account for part of the Dark Matter (DM).
- The 21 cm redshifted line from spin-flip transitions in the Hydrogen provides a powerful tool to study the evolution of the universe prior to Reionization.
- Here we compute the evolution of the 21 cm signal expected from the local environment around a PBH.
- More details on the IGM signal in Sam Witte's talk!

Accretion physics

- PBHs inject energy into their environment via accretion.
- Accretion onto PBHs of $M_{\rm PBH} \gtrsim M_\odot$ at high redshifts could be properly described by the advection-dominated accretion flow (ADAF) framework (Poulin et al. 2017).

$$L = \epsilon(\dot{M})\dot{M}c^2$$

- For the ADAF scenario and masses $M \sim M_\odot$, PBHs radiate inefficiently, $L \sim 10^{-10} L_{\rm Edd}$.

Accretion physics

We model the accretion of matter onto the PBH as a static spherically symmetric problem.

- Continuity:

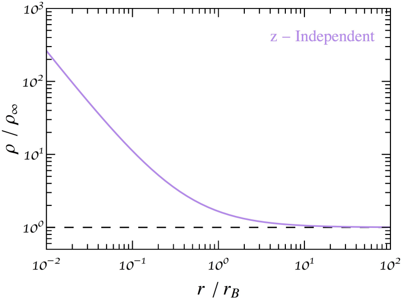
$$4\pi r^2 \rho |v| = \dot{M} = \mathrm{constant}$$

- Moment conservation:

$$v \frac{dv}{dr} = -\frac{1}{\rho}\frac{dP}{dr} - \frac{GM}{r^2}$$

- Ionization:

$$\Lambda_{\mathrm{ion}}(1 - x_e) = \alpha_{\mathrm{B}}\, n_{\mathrm{H}}\, x_e^2$$



Accretion scale given by the Bondi radius: $r_{\mathrm{B}} = \frac{GM}{v_{\mathrm{eff}}^2}$

Spin temperature

The spin temperature T_S, given by the ratio between population of the triplet and singlet hyperfine levels of the hydrogen, accordingly to:

$$\frac{n_1}{n_0} = 3\, e^{-h\nu_0/T_S}$$

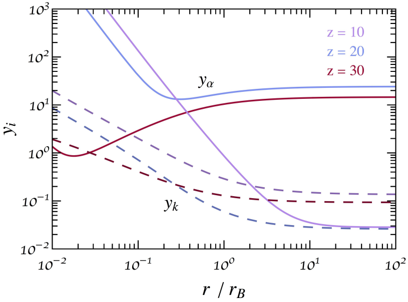
1. Emission/absorption of CMB photons.
2. Collisions with other H atoms, protons or electrons.
3. Scattering with Lyα photons.

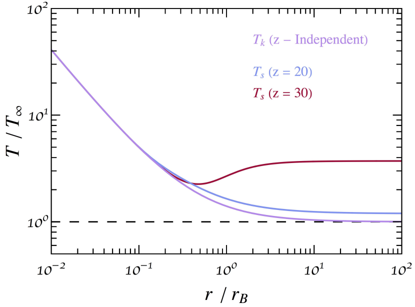
$$T_S = \frac{T_{\rm CMB} + (y_k + y_\alpha)\, T_k}{1 + y_k + y_\alpha}$$

T_k: kinetic temperature

Spin temperature

Coupling of T_S to T_k at low radii due to high density, ionization and Lyα flux.





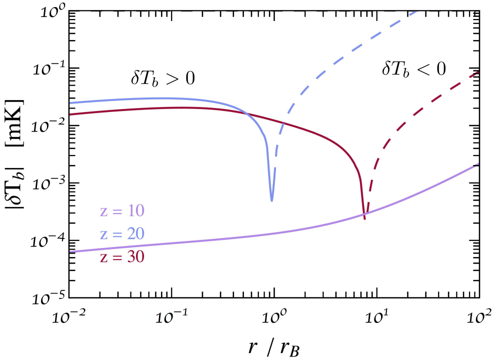
$$T_S = \frac{T_{\mathrm{CMB}} + (y_k + y_\alpha)\, T_k}{1 + y_k + y_\alpha}$$

Radiative transfer

- The brightness temperature T_b can be obtained solving the radiative transfer equation:

$$\frac{dT_b}{dr} = -\kappa \left[T_b - T_S \right]$$

- Differential brightness temperature:

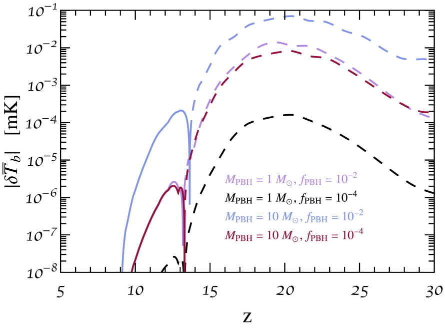


$$\delta T_b = \frac{T_b - T_{\rm CMB}}{1+z} = \int_0^r dr' \, \kappa(r') \, \frac{T_S(r') - T_{\rm CMB}}{1+z} \, e^{-\tau_\nu(r',r)}$$

Averaged 21 cm line & Conclusions

- The global 21 cm signal can be obtained by averaging over the distribution of PBHs.
- For realistic scenarios, negligible compared to the order of ~ 1 mK signal from the IGM.
- Earlier works (Tashiro et al. 2013, Bernal et al. 2018) overestimated this contribution taking a larger luminosity.

$$\delta \overline{T}_b = \frac{c\,(1+z)^4}{\nu_0\, H(z)}\, n_{\rm PBH}\, \langle \Delta\nu_{\rm eff}\, \delta T_b \rangle\, A$$



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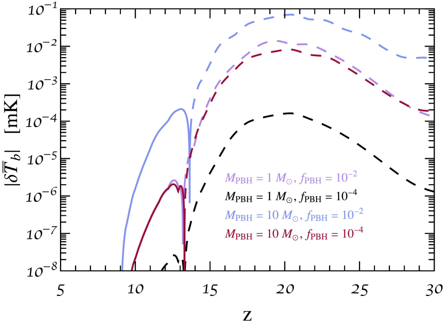

Thanks for your attention!