Local 21cm signal from Primordial Black Holes

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1. Introduction

The recent discoveries of Black Hole mergers by LIGO and VIRGO increased the interest on Primordial Black Holes (PBH) formed in the early universe as a component of the Dark Matter (DM). Despite constraints from gravitational lensing or from CMB observations restrict the maximum amount of DM as PBH, the possibility that its fraction f_{PBH} is non-negligible still remains [1].

The 21cm redshifted line, arising from spin-flip transitions between the triplet and the singlet states in neutral hydrogen, provides a powerful tool to study the evolution of the Intergalactic Medium (IGM) prior to the Epoch of Reionization. Here we compute the evolution of the signal expected from the environment around a PBH.

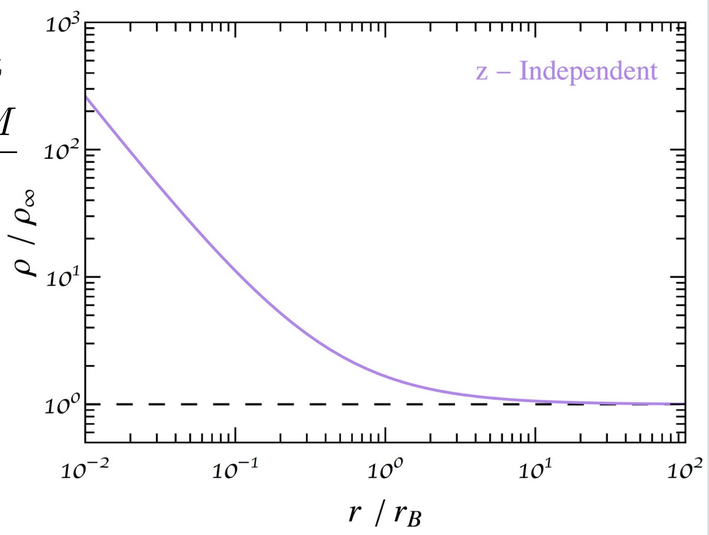
2. Accretion physics

We model the accretion of matter onto the PBH as a static spherically symmetric problem around a point, solving the continuity, Euler and ionization equations.

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

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

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



The infalling matter onto the PBH produces a energetic flux of photons capable of ionizing and excite/de-exciting medium.

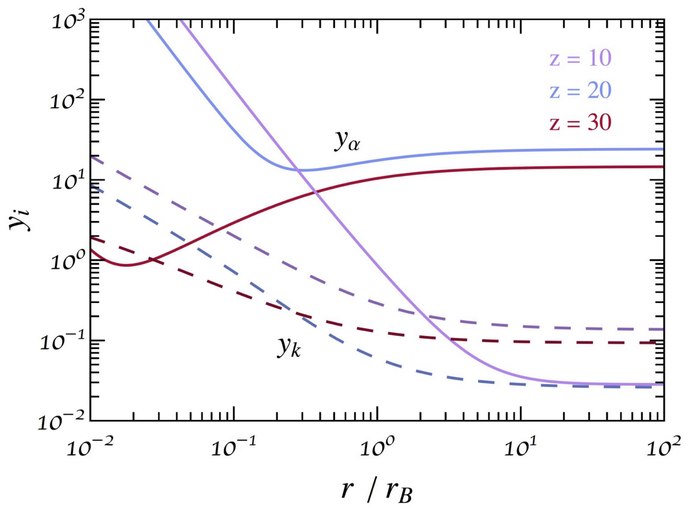
We adopt a conservative accretion framework advection-dominated **ADAF** [2,3], which radiates inefficiently, with typical luminosities $L \sim 10^{-10} L_{Edd}$.

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

$$r_{\rm B} = \frac{GM}{v_{\rm eff}^2}$$

The scale where the accretion starts to be important is the **Bondi radius** r_B, and depends on an effective velocity v_{eff} accounting for the speed of sound and the relative velocity between the PBH and the ambient medium.

3. Spin temperature



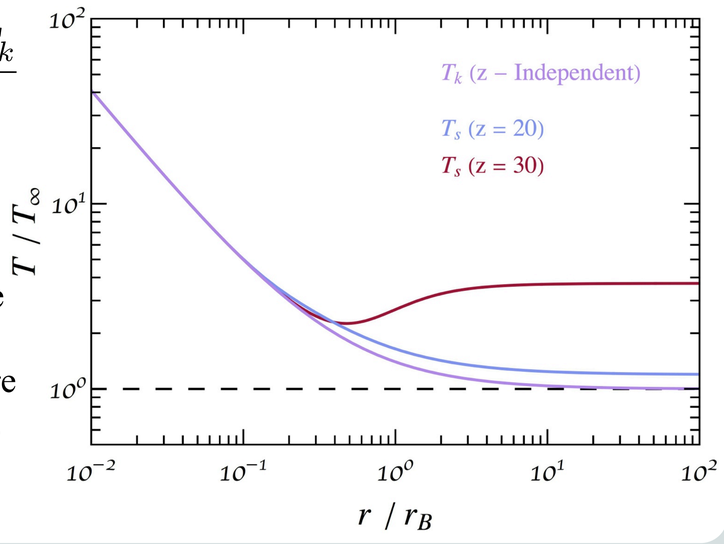
The 21 cm line depends on the **spin temperature** T_S, given by the ratio between population of the triplet and singlet hyperfine levels of the hydrogen, accordingly to:

1) Emission/absorption of CMB photons.
2) Collisions with other H atoms, protons or electrons, driven by the collisional coefficient y_k.
3) Scattering with Lyα photons, driven by the Lyα coefficient y_α.

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

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

Collisional y_k and Lyα y_α coupling coefficients are impacted by the high densities, Lyα flux and ionization near the PBH, providing a notable **coupling** of the spin temperature T_S to the kinetic temperature T_k.



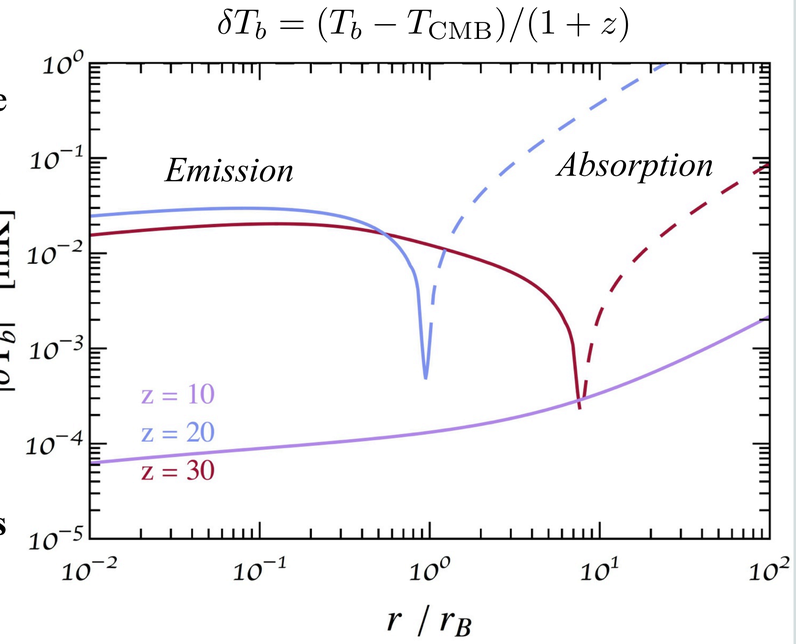
4. 21 cm line

$$\delta T_b = (T_b - T_{\rm CMB})/(1+z)$$

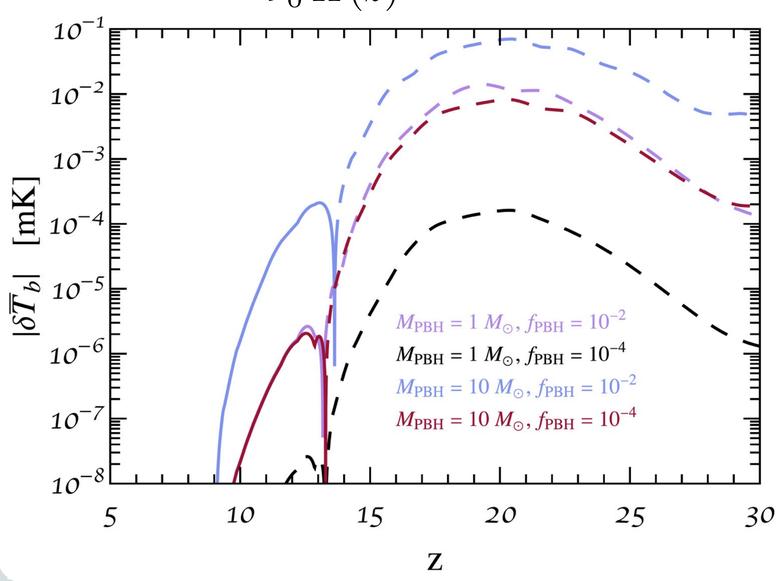
The brightness temperature T_b can be obtained via the radiative transfer equation.

$$\frac{dT_b}{dr} = -\kappa T_b + \kappa T_S$$

The upper plot depicts the radial profile relative to the CMB intensity, the **differential brightness temperature** δT_b.



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



The contribution to the global 21cm signal can be obtained by averaging over the distribution of PBHs.

For realistic scenarios, this *local* signal is **negligible** compared to the order ~1 mK signal from the IGM.

5. Conclusions

- Local 21cm signal for allowed values of parameters f_{PBH} and M_{PBH} are negligible compared to the IGM signal.
- Earlier works [4,5] overestimated this contribution taking a much larger and inappropiate luminosity, instead of the considered in the ADAF scenario.

6. References

- [1] Carr et al. Phys.Rev. D94 (2016) no.8, 083504
- [2] Poulin et al. Phys.Rev. D96 (2017) no.8, 083524
- [3] Yuan et al. Ann.Rev.Astron.Astrophys. 52 (2014) 529-588
- [4] Bernal et al. JCAP 1805 (2018) 05, 017
- [5] Tashiro et al. MNRAS 435 (2013) 3001

Acknowledgments

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