Looking for blue in the dark

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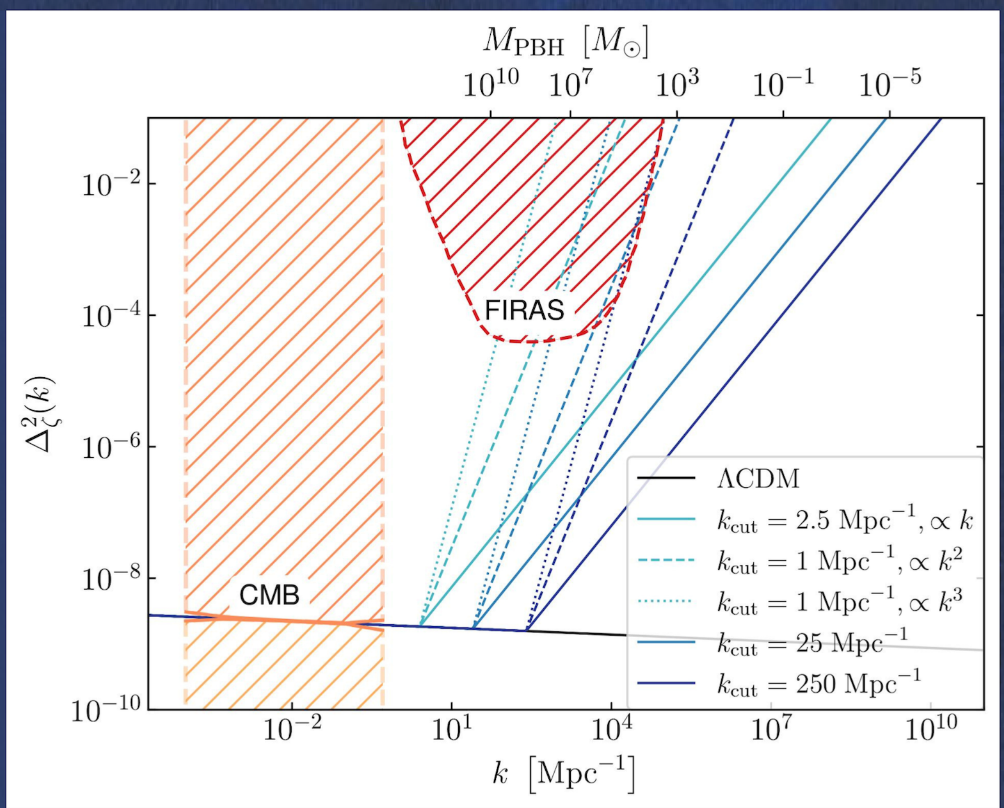
We investigate how the **primordial power spectrum on small scales** could be constrained using **21cm line intensity mapping (LIM) in the dark ages** ($30 \leq z \leq 200$), focusing on models that imprint an **increase of the matter spectrum at large angular multipoles**. We study an agnostic parameterization and look at several specific models, including primordial black holes (PBH), vector dark matter and quantum decoherence during inflation. We present **forecasts for measurments with SKA** and a few possible future instruments, both Earth (**aSKAO**) and Moon (**LRAI/II**) based.

Agnostic parameterization

Our agnostic model, which **satisfies CMB constraints on large scales** and then, **at a given cut-off scale, starts increasing with a certain slope**:

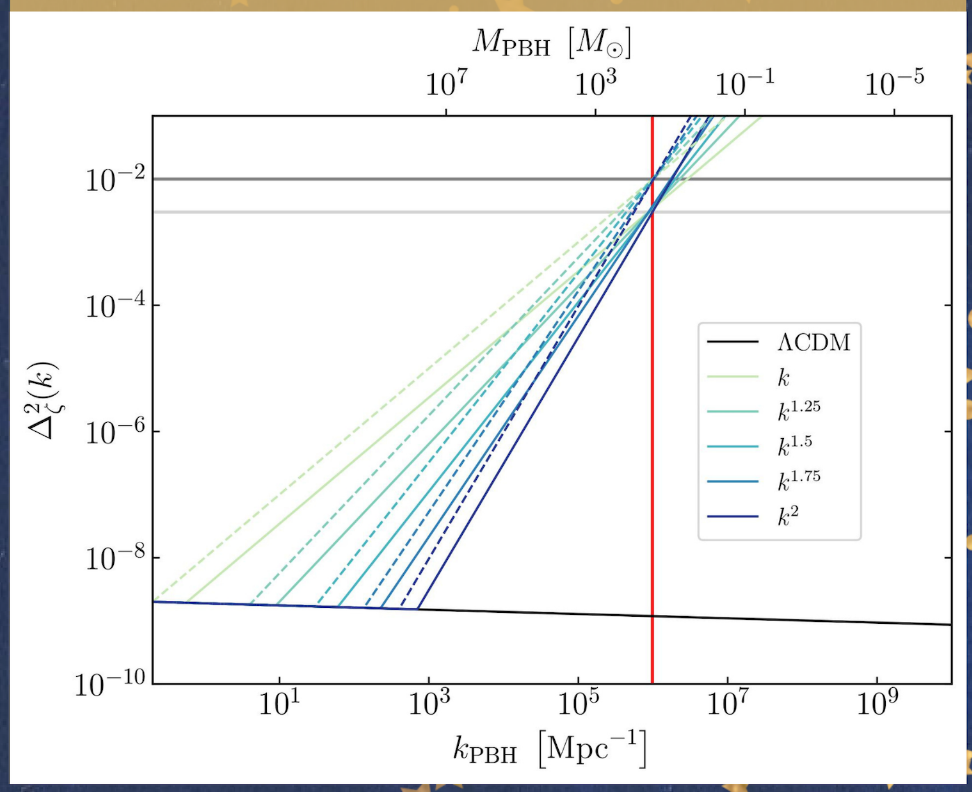
$$\Delta^2_\zeta(k) = \begin{cases} A_s \left(\frac{k}{k_0}\right)^{n_s-1} & k < k_{\rm cut} \\ A_b \left(\frac{k}{k_{\rm cut}}\right)^{n_b-1} & k > k_{\rm cut} \end{cases}$$

with $A_b = A_s \left(\frac{k_{\rm cut}}{k_0}\right)^{n_s-1}$



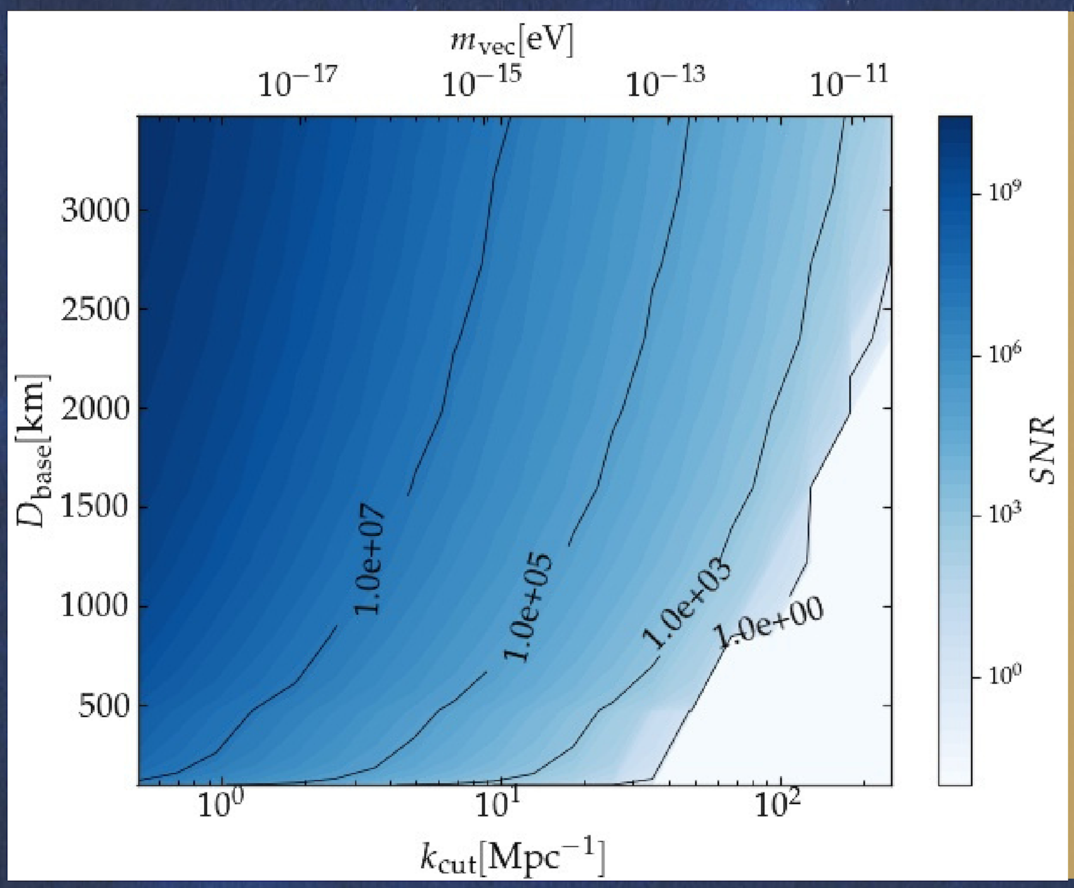
Primordial black holes

could have formed in the early universe from the collapse of patches of the universe [1] . The power spectrum of curvature perturbations must reach an **amplitude of at least 0.003** (light grey line) **to form any PBH, and 0.01** (dark grey line) **to form all of the dark matter** [2]. The **maximum allowed slope is k⁴** but more shallow slopes are also allowed. The mass of the PBH is determined by the scale of the collapsing region, therefore probing the blue-tilted power spectrum allows us to indicate the mass of the PBHs, with a degeneracy with the fraction formed. For $M_{\rm PBH} = 30 M_\odot$:



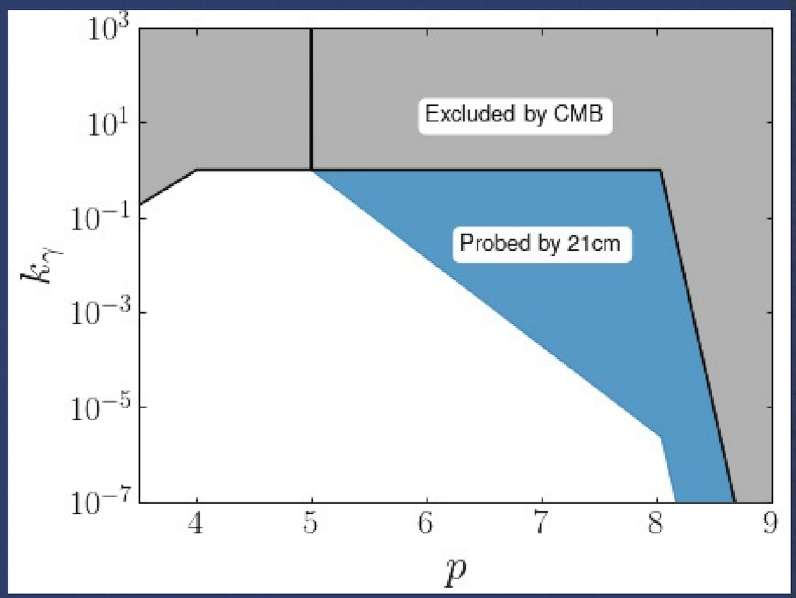
Vector dark matter

Dark matter (DM) could be an ultralight vector boson, without significant self-interaction[3]. This leads to a power spectrum which starts to **increase as k³** until a peak of order 1, on a scale which is linked to the vector mass. Using 21cm LIM we can **indicate the possible mass of vector DM**. Here we show the signal-to-noise ratio from a **lunar array with different baselines**, shown for different cut-off scales corresponding to different vector masses.



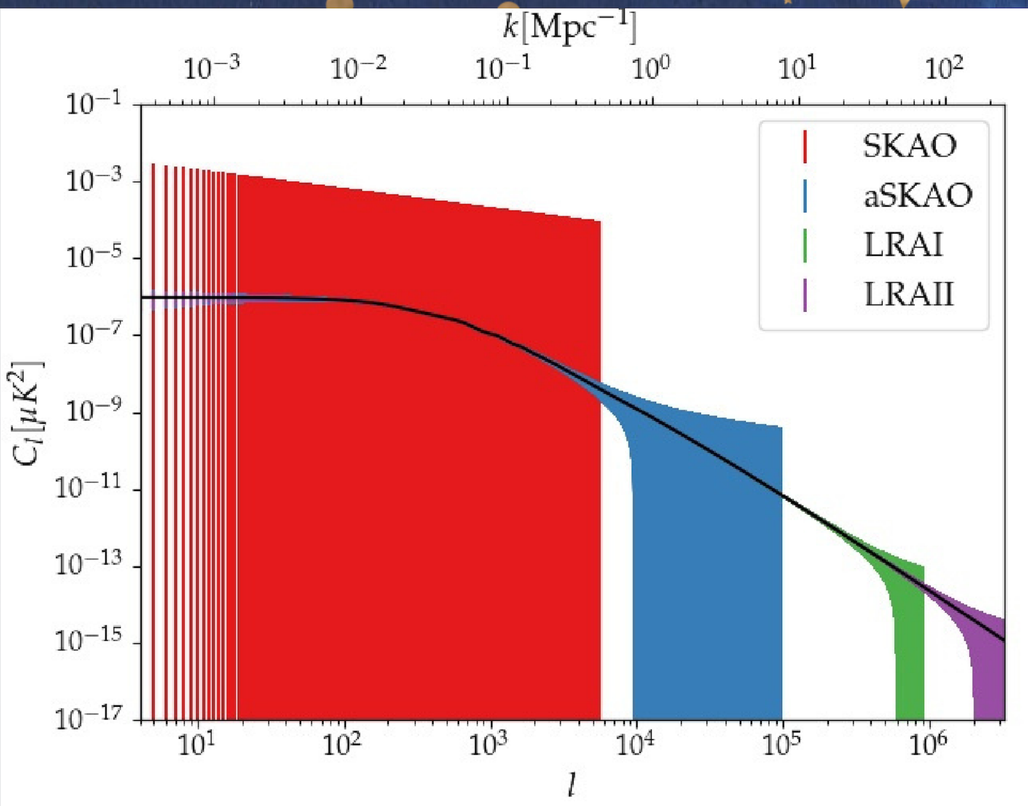
Quantum decoherence

Scalar quantum fluctuations during inflation should be treated as an **open quantum system interacting with an environment**. Leading to the quantum decoherence of the system, and corrections to the power spectrum, depending on the **interaction strength** k_γ and the time dependence of the interaction p [4]. **The current parameter constraints can be improved** as:



Conclusions

21cm LIM is a very useful probe of the power spectrum on small scales. Using **earth based instruments** we can look at **scales up to ~10 Mpc⁻¹**, while using a **lunar array** we can probe scales as small as **~250 Mpc⁻¹**. This allows us to constrain the **mass of PBH and vector DM**, the **interaction strength of quantum decoherence**, and more blue-tilted models.



References

[1] Carr, B. and Kühnel, F., ARNPS 70 (2020); [2] Kalaja, A. et al., JCAP 10 (2019), 031; [3] Graham, P. et al., PhysRevD 93 (2016); [4] Martin, J. and Vennin, V., JCAP 05 (2018)