

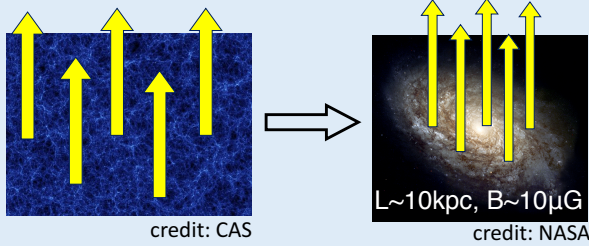
# The EDGES constraint on the primordial magnetic fields

TEPPEI MINODA, Hiroyuki Tashiro (Nagoya-U.), Tomo Takahashi (Saga-U.)  
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## 1. INTRODUCTION

What is the origin of magnetic fields with various astronomical objects?

**Magnetic fields in the early universe?**  
(=Primordial Magnetic Fields, PMFs)



Amplification by adiabatic compression  
--> The seed field  $B_{1\text{Mpc}} \sim 1 \text{ nG}$  is needed.  
PMFs with 1 nG heat up the IGM gas?

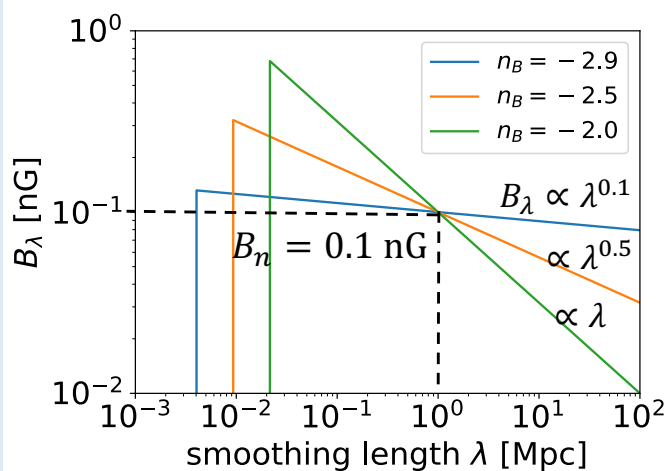
## 2. Model of PMFs

scale dependence

$$B_\lambda = B_n \left( \frac{\lambda}{1 \text{ Mpc}} \right)^{-(n_B+3)/2}$$

$B_n$  : PMF amplitude smoothed on 1Mpc

$n_B$  : spectral index of PMF strength



PMF has a cut-off scale because of the collision between baryon-photon plasma

$$\lambda_{\text{cut}}^2 = \frac{B_{\text{cut}}^2}{4\pi\rho_{\text{CMB}}\sigma_T} \int_0^{t_{\text{rec}}} \frac{c dt}{a^2 n_e}$$

## 5. Conclusion

- Calculate IGM gas temperature  $T_{\text{gas}}$  with PMFs fluctuation and dissipation
- Constrain the PMF strength from the 21-cm signal condition ( $T_{\text{gas}} < T_{\text{CMB}}$ )
- Suggestion for another amplification mechanism except for the adiabatic compression?

(References) Jedamzik+ 1998; Sethi & Subramanian 2005; Schleicher+ 2008; Marinacci & Vogelsberger 2016; Bowman+ 2018

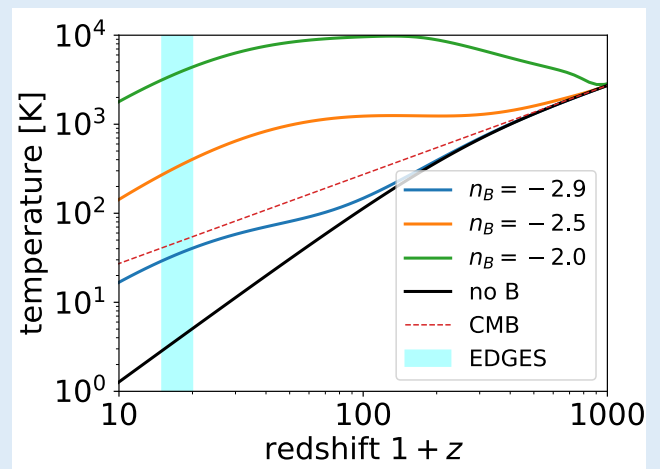
## 3. IGM thermal history

After decoupling from CMB ( $z \lesssim 200$ ),

I. Adiabatic case  $T_{\text{gas}} \propto (1+z)^2$

II. PMF heating case (this work)

- Ambipolar Diffusion (dominant)  
collision between the neutral and ionized particles
- Ohmic dissipation (sub-dominant)  
small-scale eddies from MHD turbulence

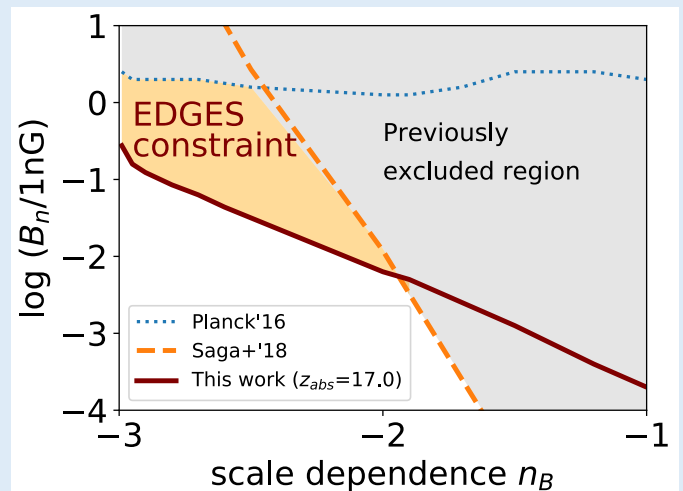


## 4. A constraint from 21-cm signal

EDGES 21-cm line observation suggests

$$T_{\text{gas}} < T_{\text{CMB}} \text{ (for } 15 < z < 20\text{)}$$

Calculate  $T_{\text{gas}}$  with various  $(B_n, n_B)$



(T. Minoda *et al.*, arXiv:1812.00730)