GR and H. Liu, in progress

p-wave annihilating DM and the EDGES 21-cm Signal

Gregory Ridgway

Hongwan Liu and **GR**, in preparation

Massachusetts Institute of Technology

p-wave Annihilation

- Working definition: $\langle \sigma v \rangle \propto v^2$
- Fairly common amongst DM models
- One of the models used to explain the EDGES signal
- Sensitive to late-time constraints, i.e. a natural target for 21-cm measurements

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What Did EDGES Measure?

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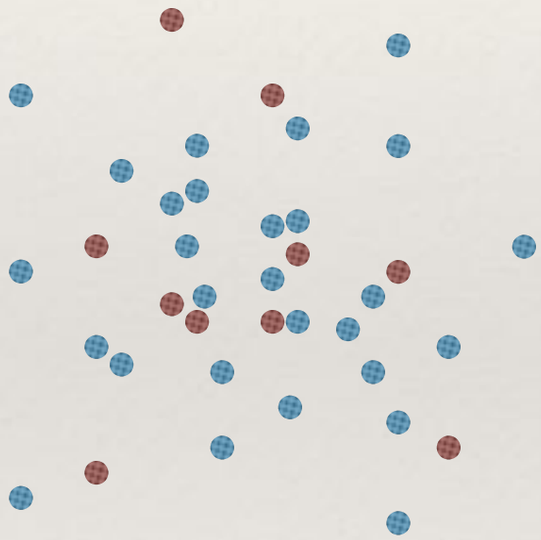
The Global 21-cm Signal



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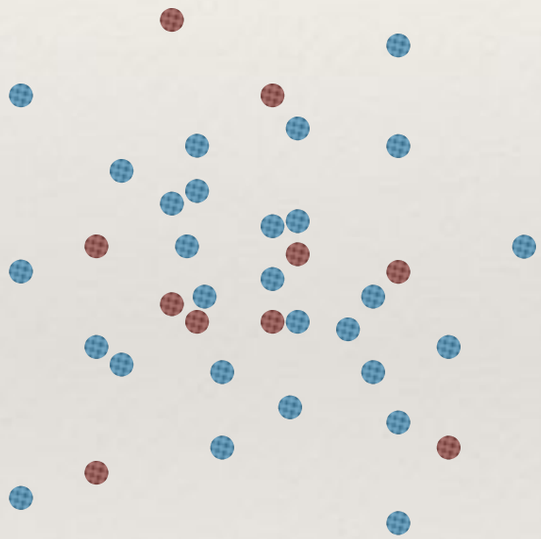
The Global 21-cm Signal

Main Characters

21-cm radiation



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The Global 21-cm Signal

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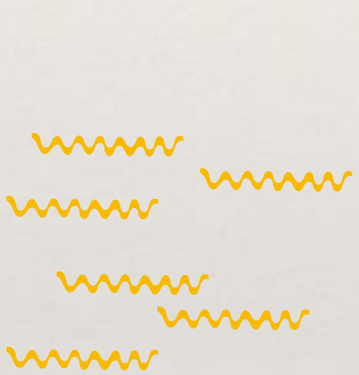
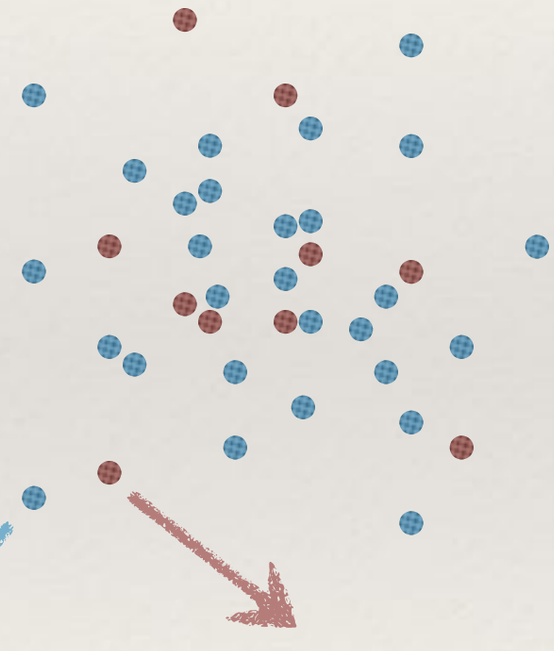


Hydrogen Cloud



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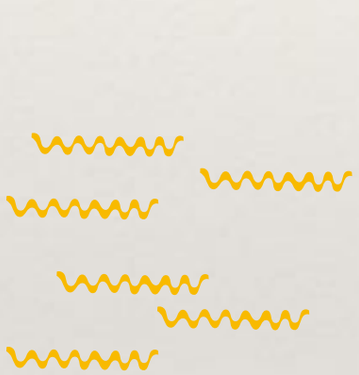

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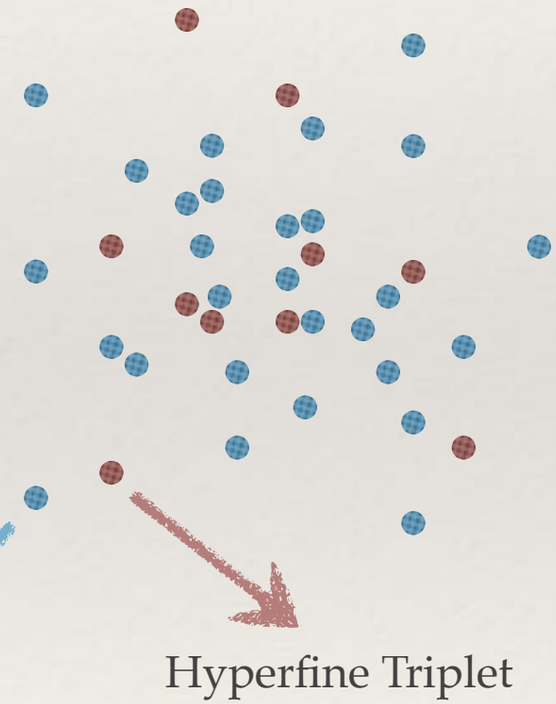


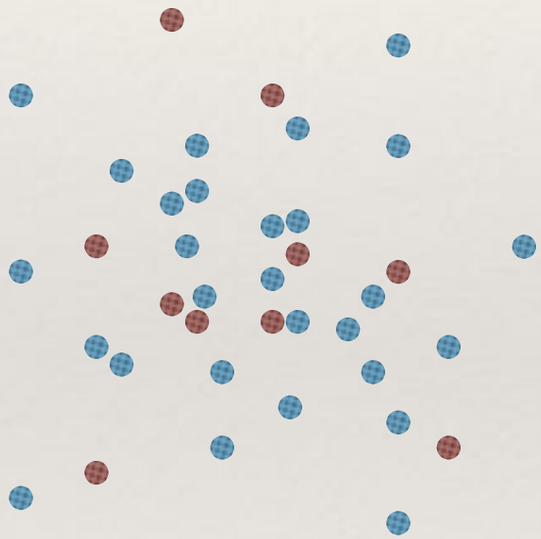
Observer

ΔT_{21}

differential brightness temperature of the 21cm line

The Global 21-cm Signal

Example 1: absorption



ΔT_{21}

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The Global 21-cm Signal

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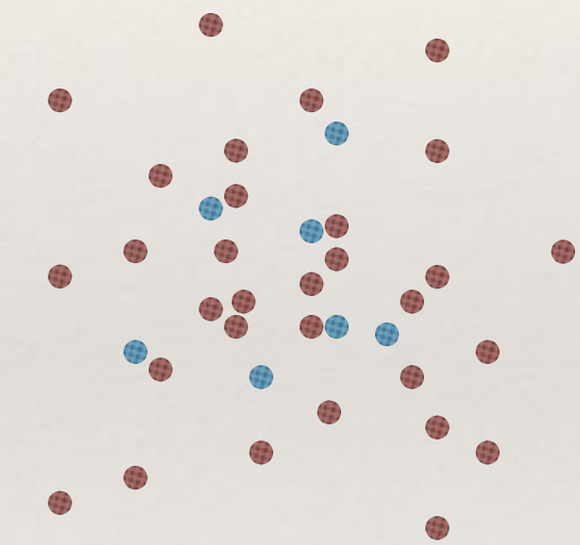

$$\Delta T_{21} < 0$$

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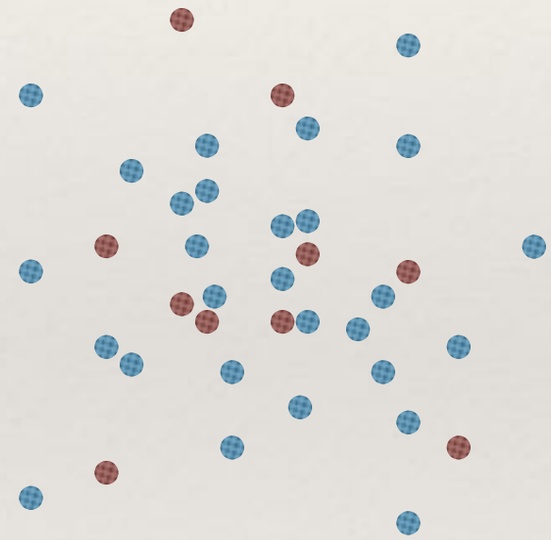
The Global 21-cm Signal

Example 2: emission



ΔT_{21}

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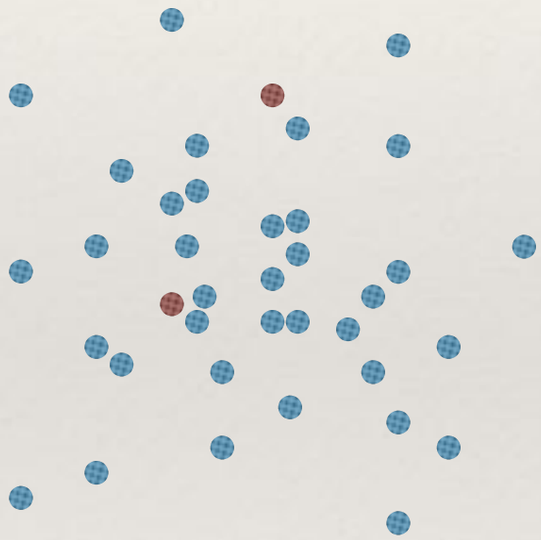
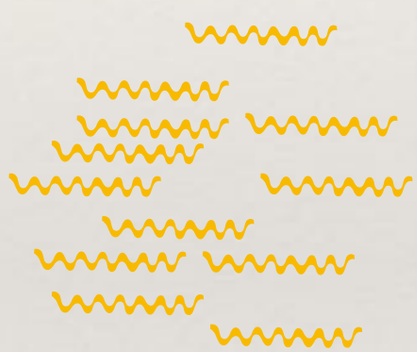
The Global 21-cm Signal

Example 2: emission





$$\Delta T_{21} > 0$$

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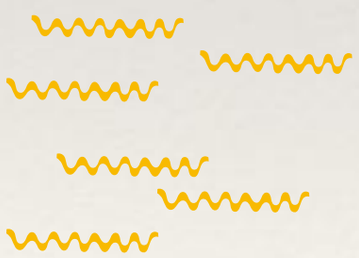
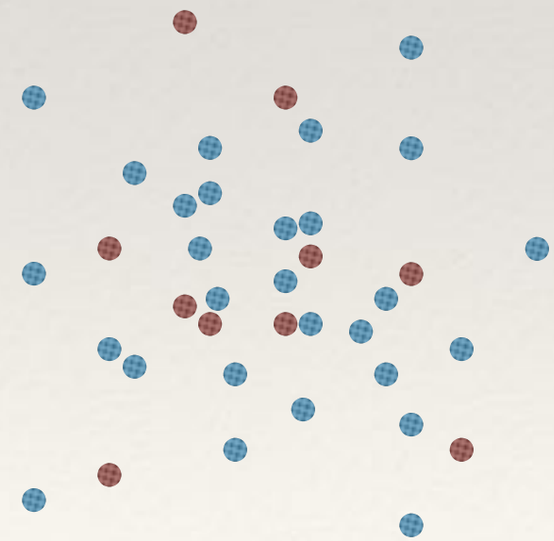
The Global 21-cm Signal

Important points:

- Sky-averaged signal (i.e. Global signal)
- **Redshift information** contained in ~~~~
- ΔT_{21} depends on radiation temperature, T_R, and visible matter temperature, T_m.





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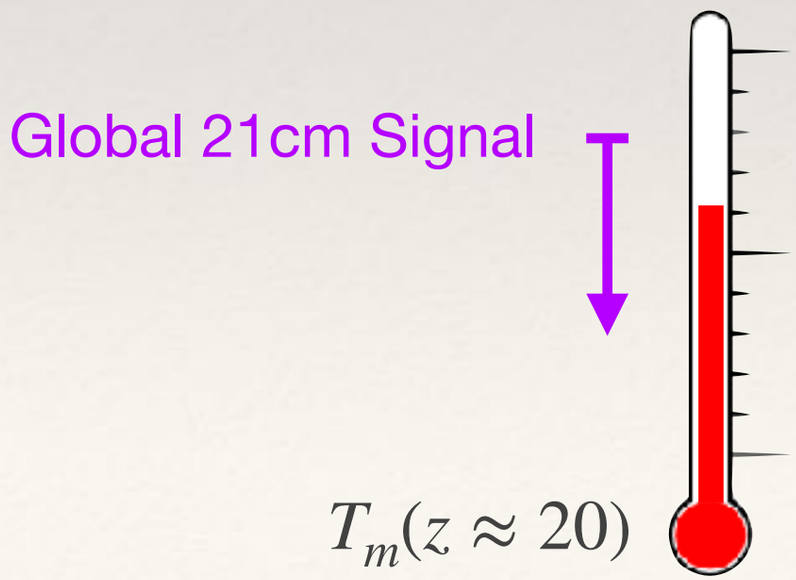

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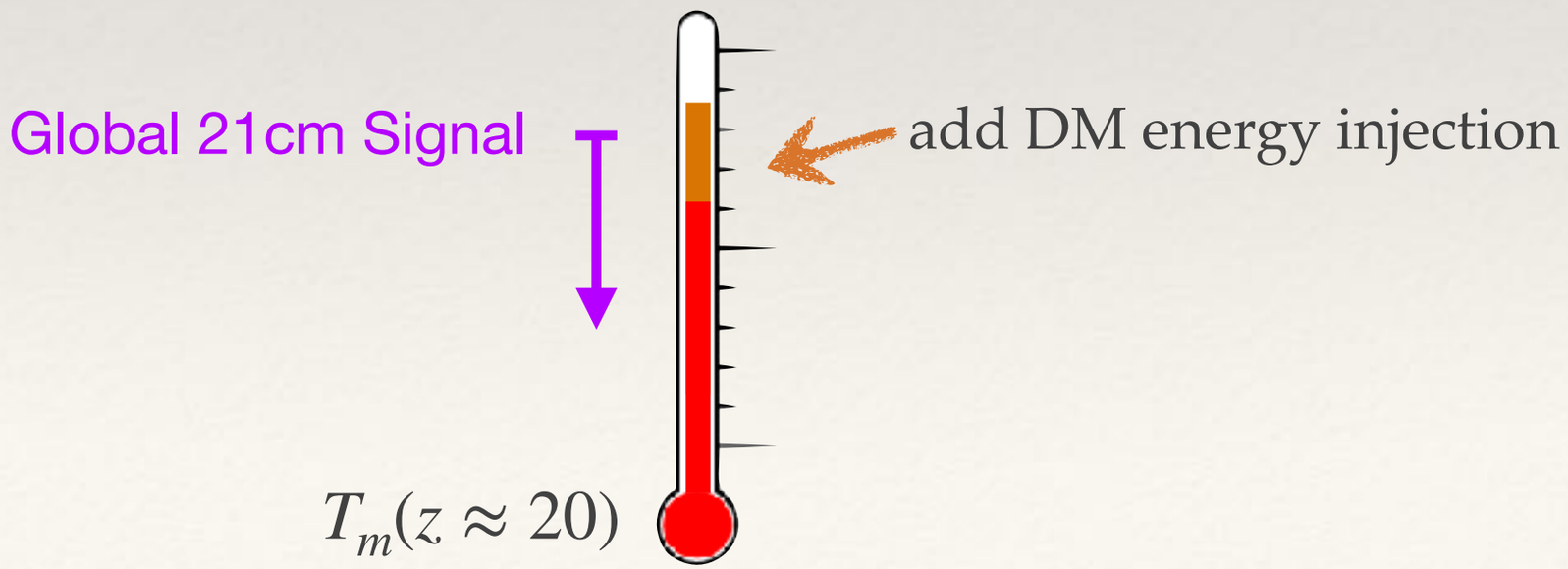

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Global 21cm Signal

DM energy injection

Derive Constraints

$T_m(z \approx 20)$

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How Do We Calculate $T_m(z)$ in the presence of p-wave annihilating DM?

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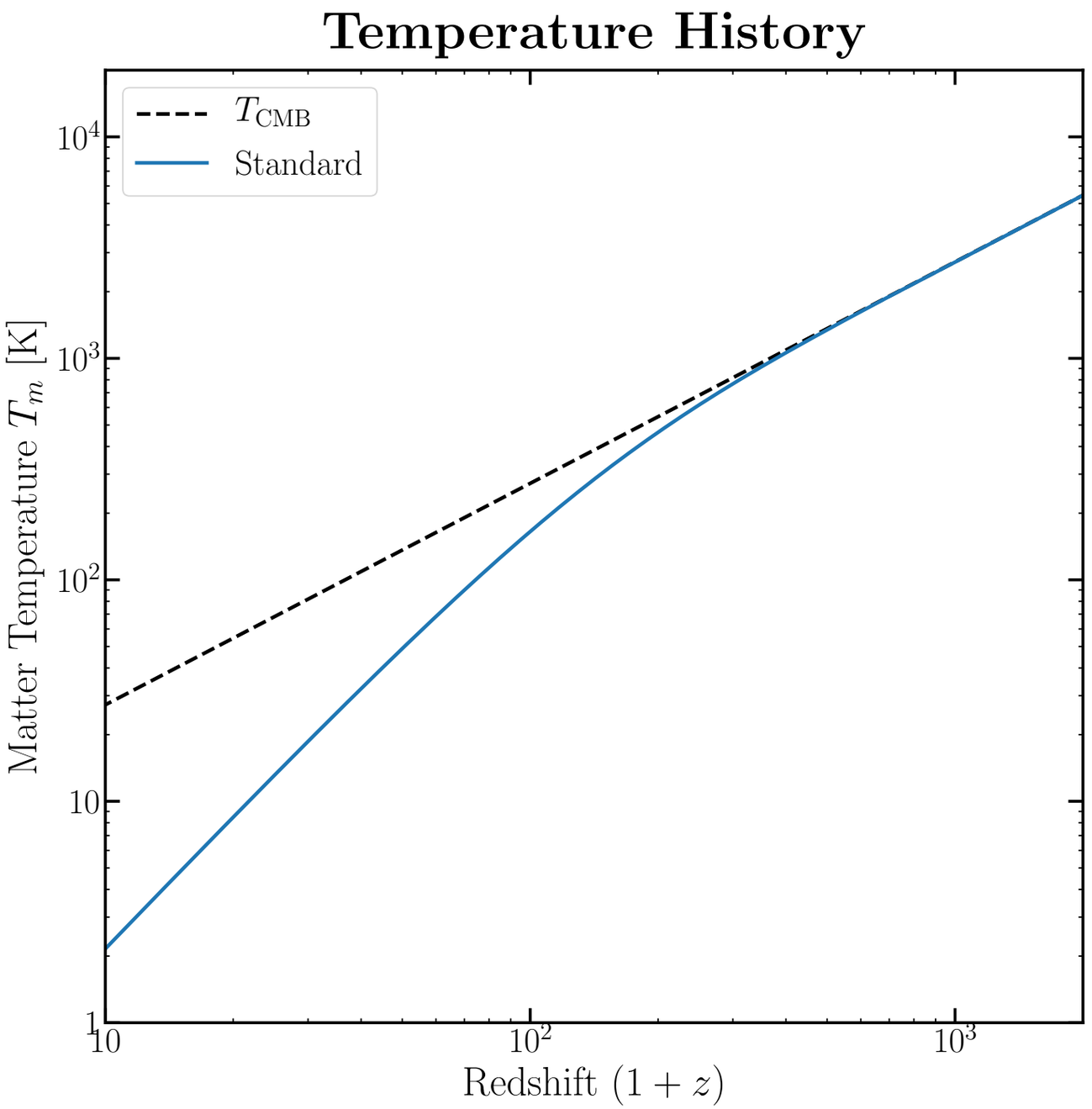
Temperature Histories



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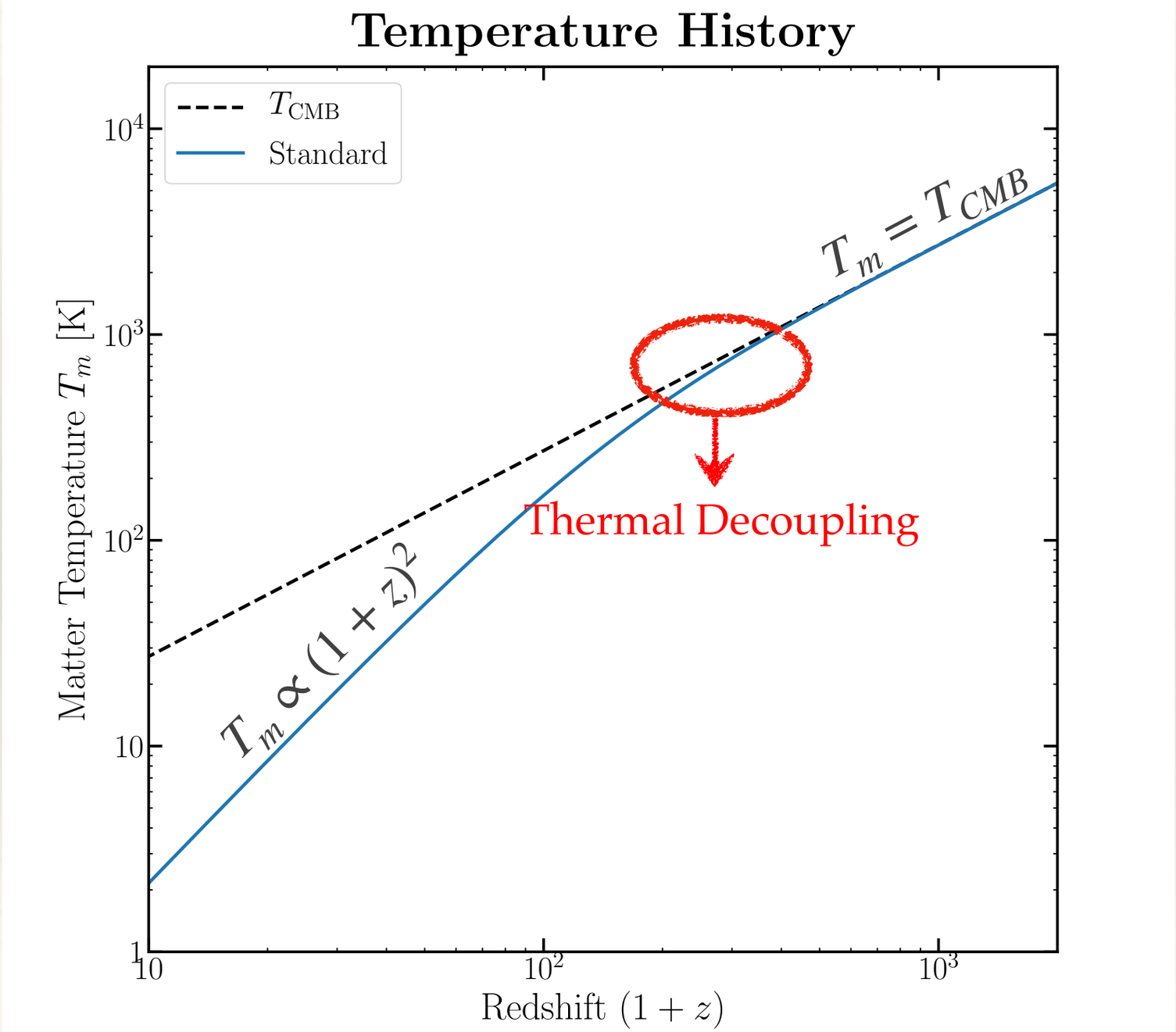

GR and H. Liu, in progress

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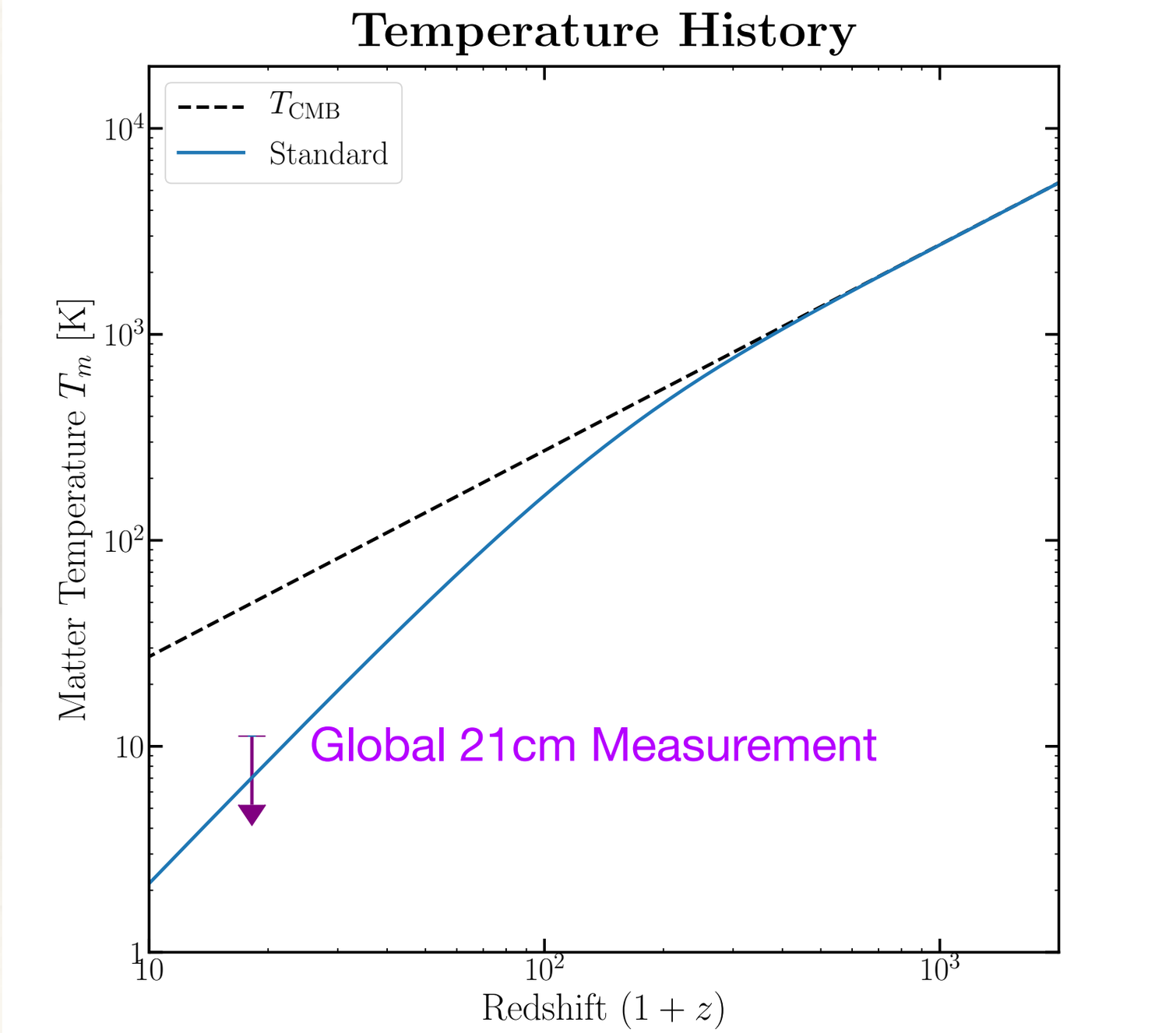

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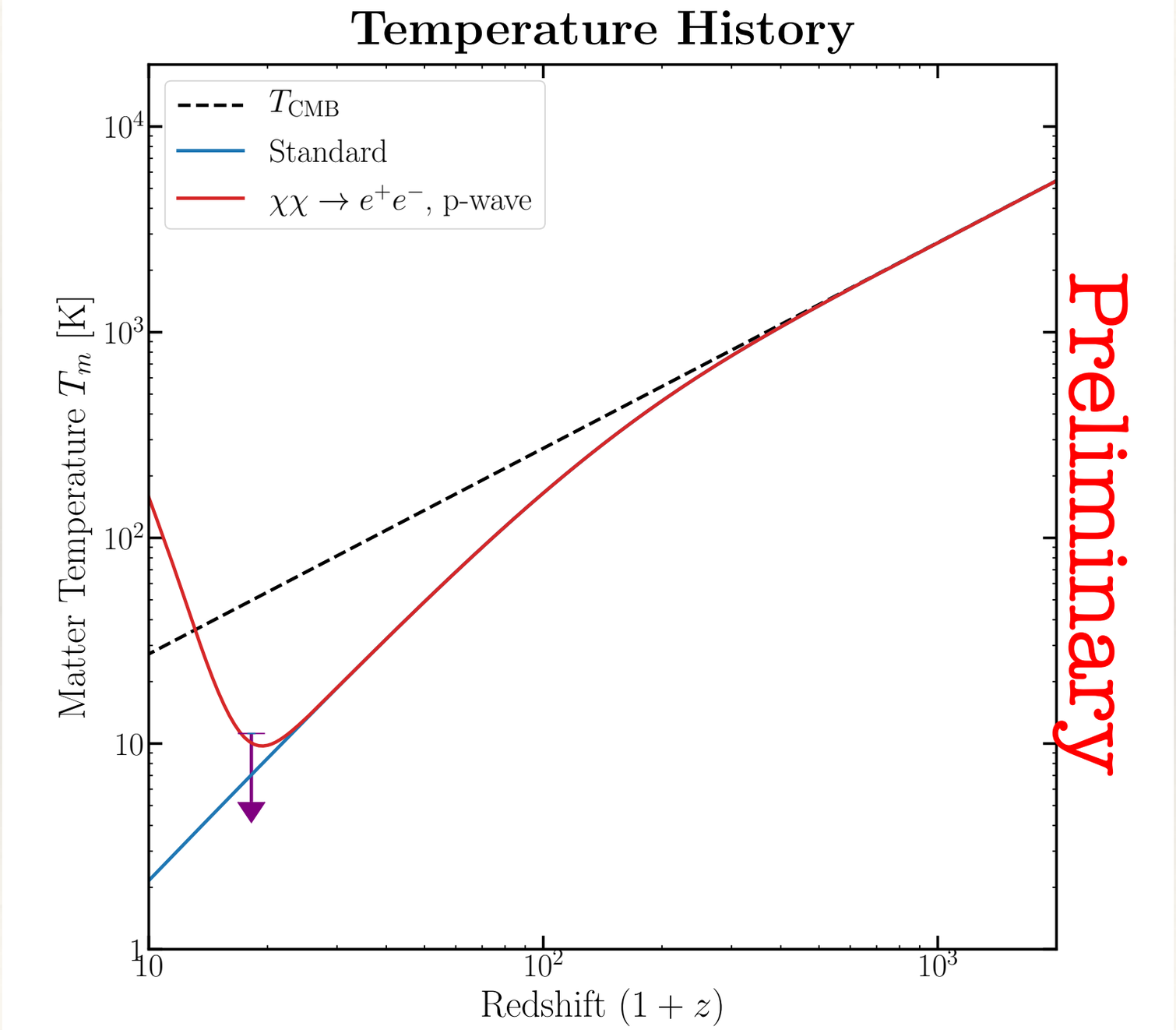
Temperature Histories with DM

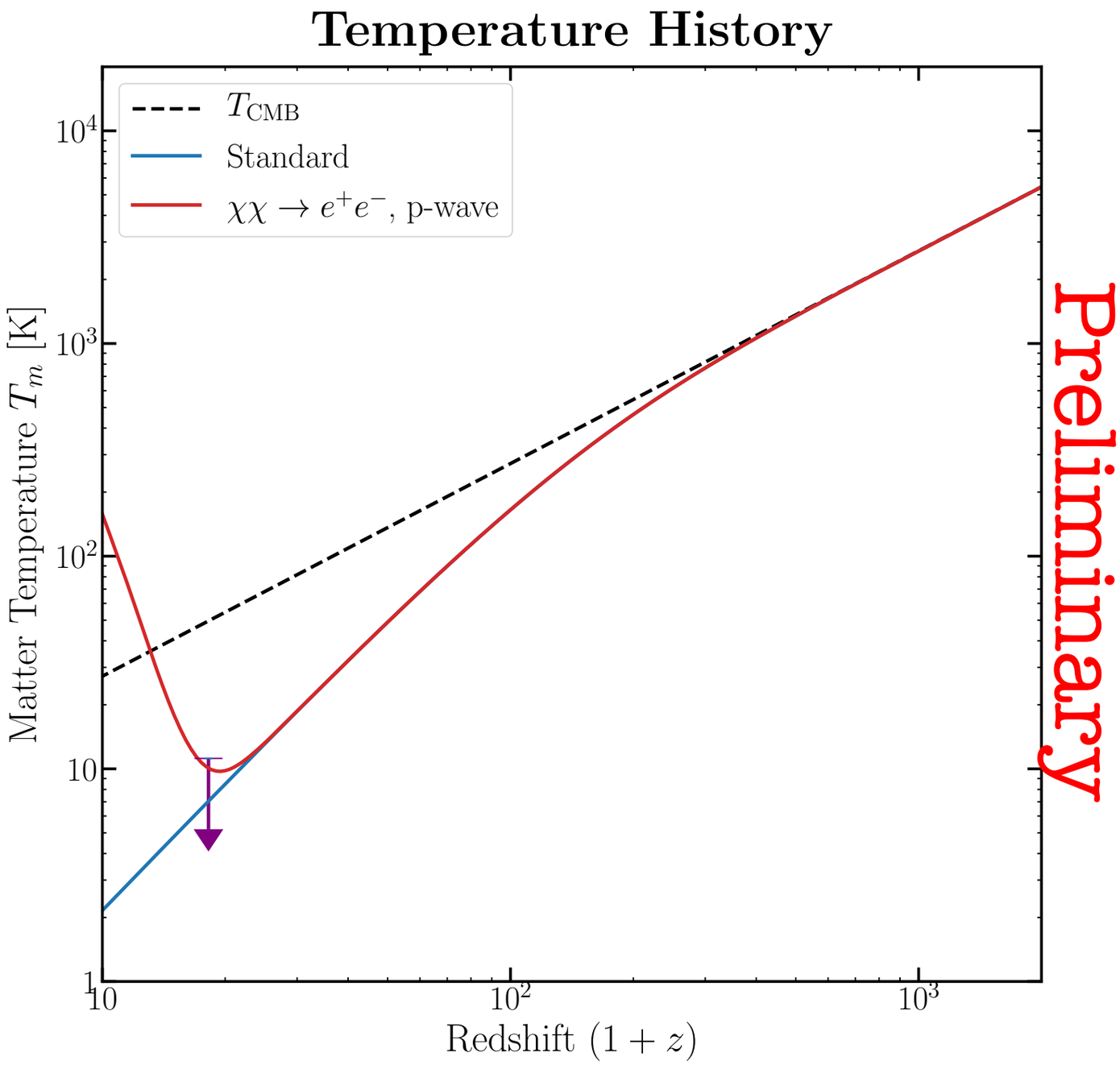


Temperature Histories with DM

$$\langle \sigma v \rangle \propto v^2$$

energy injection rate:

$$\left(\frac{dE}{dVdt}\right)_{\text{inj}} \propto \rho^2 v^2$$



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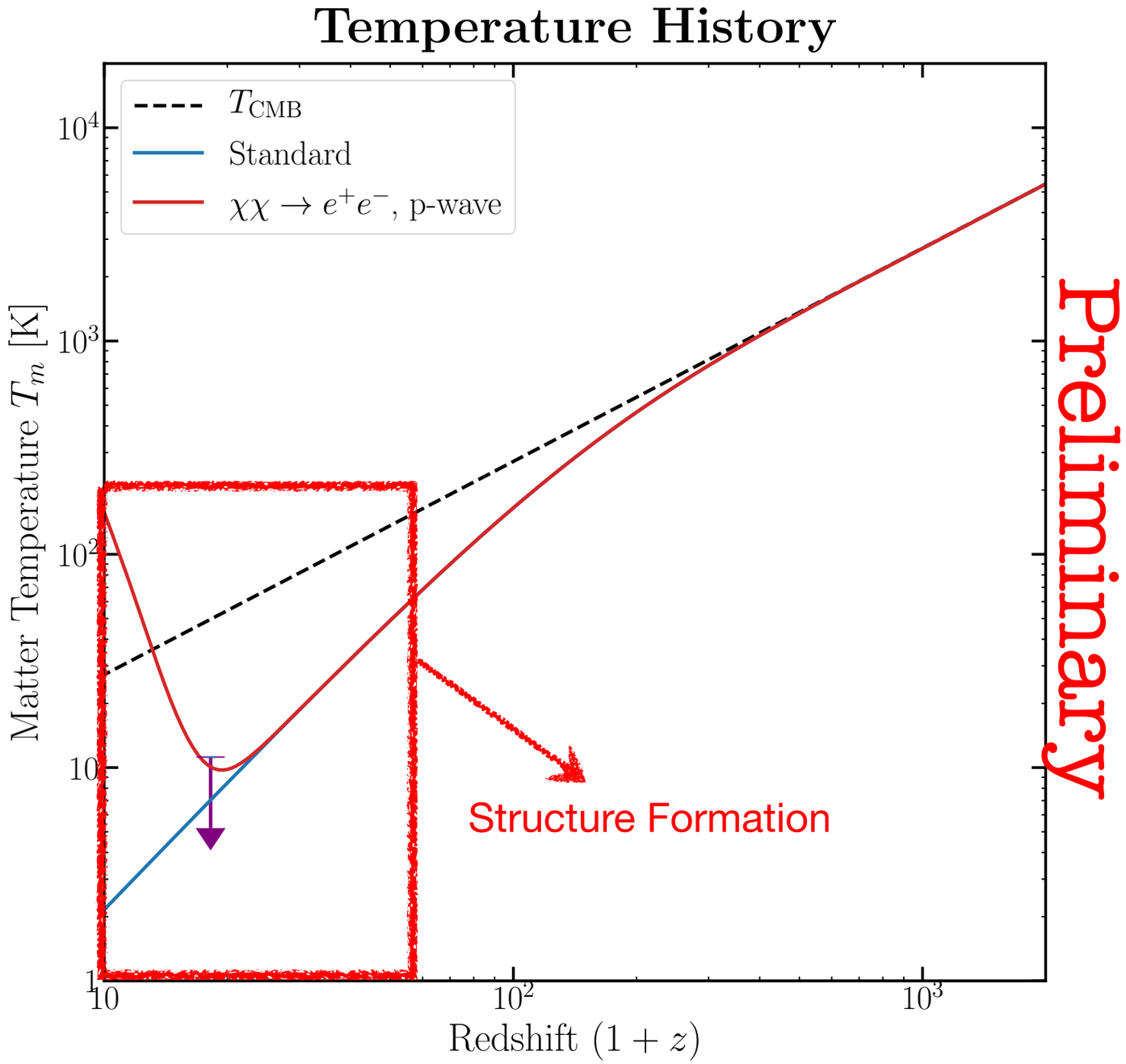

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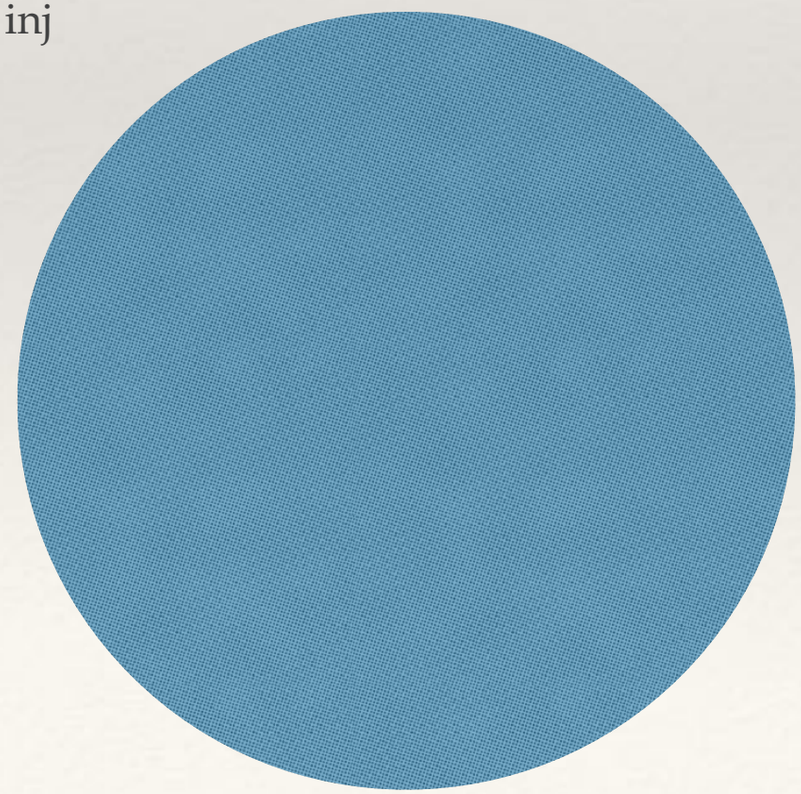
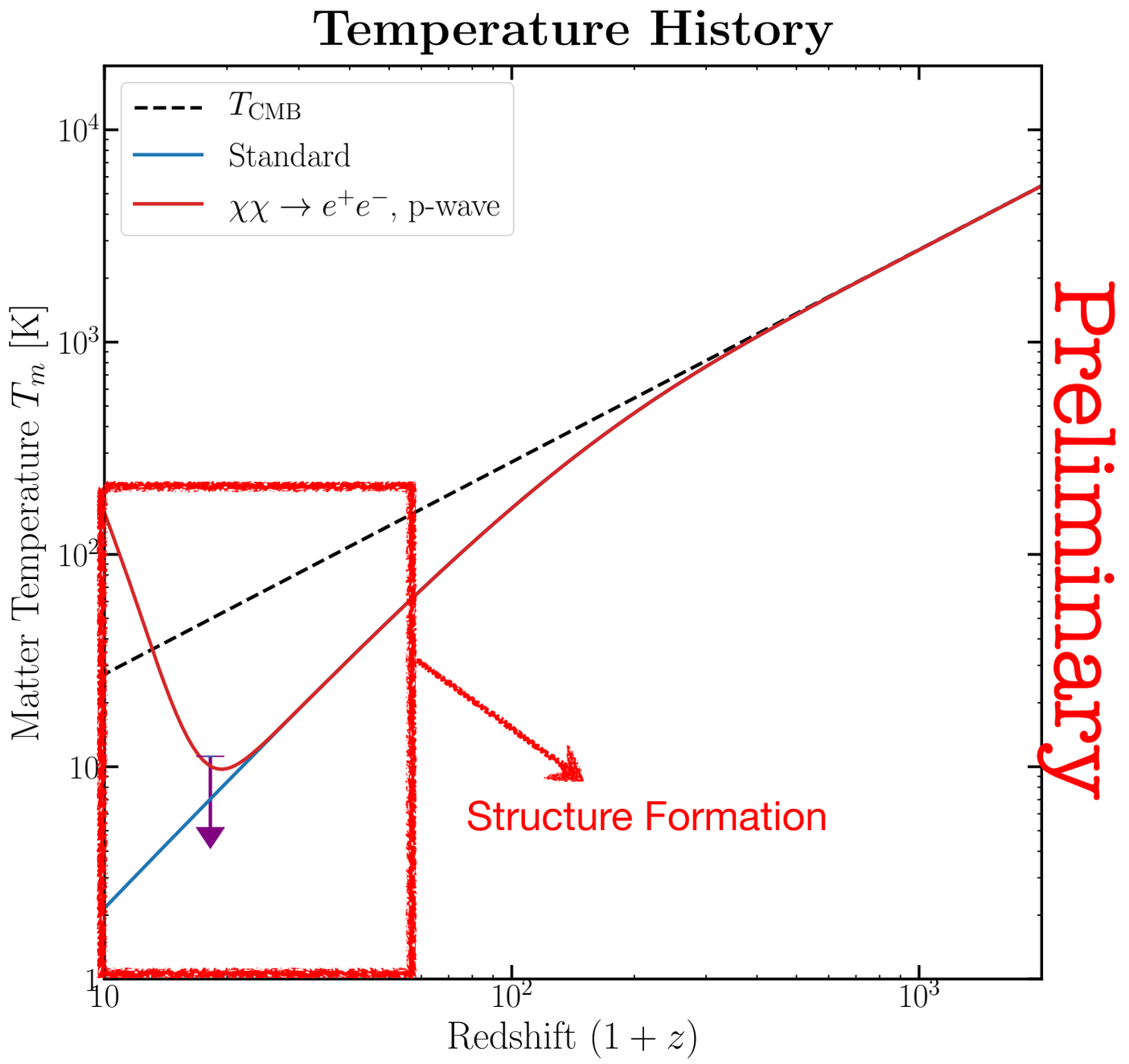
Halo





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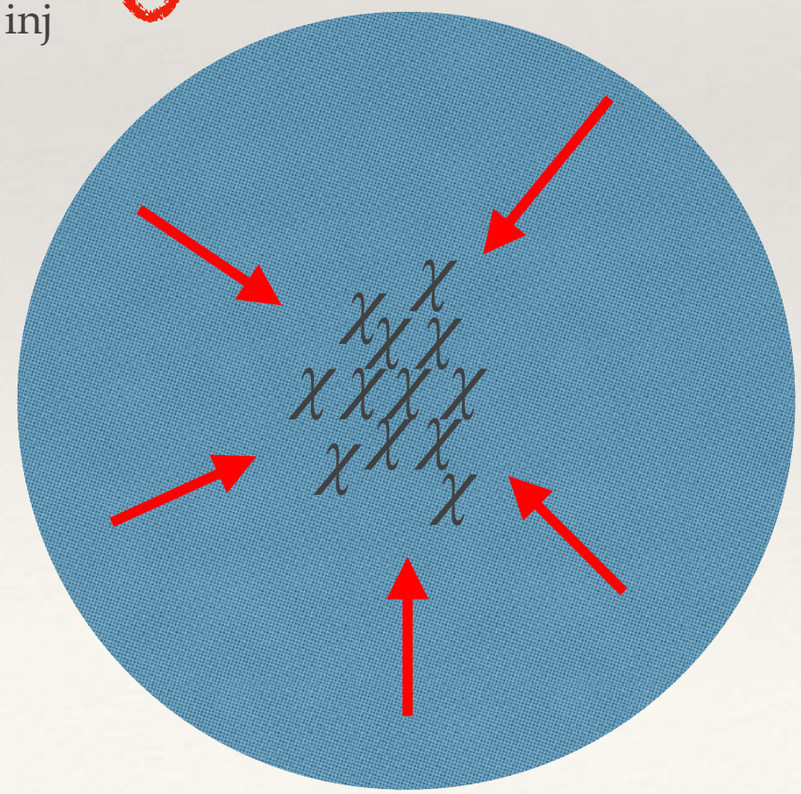

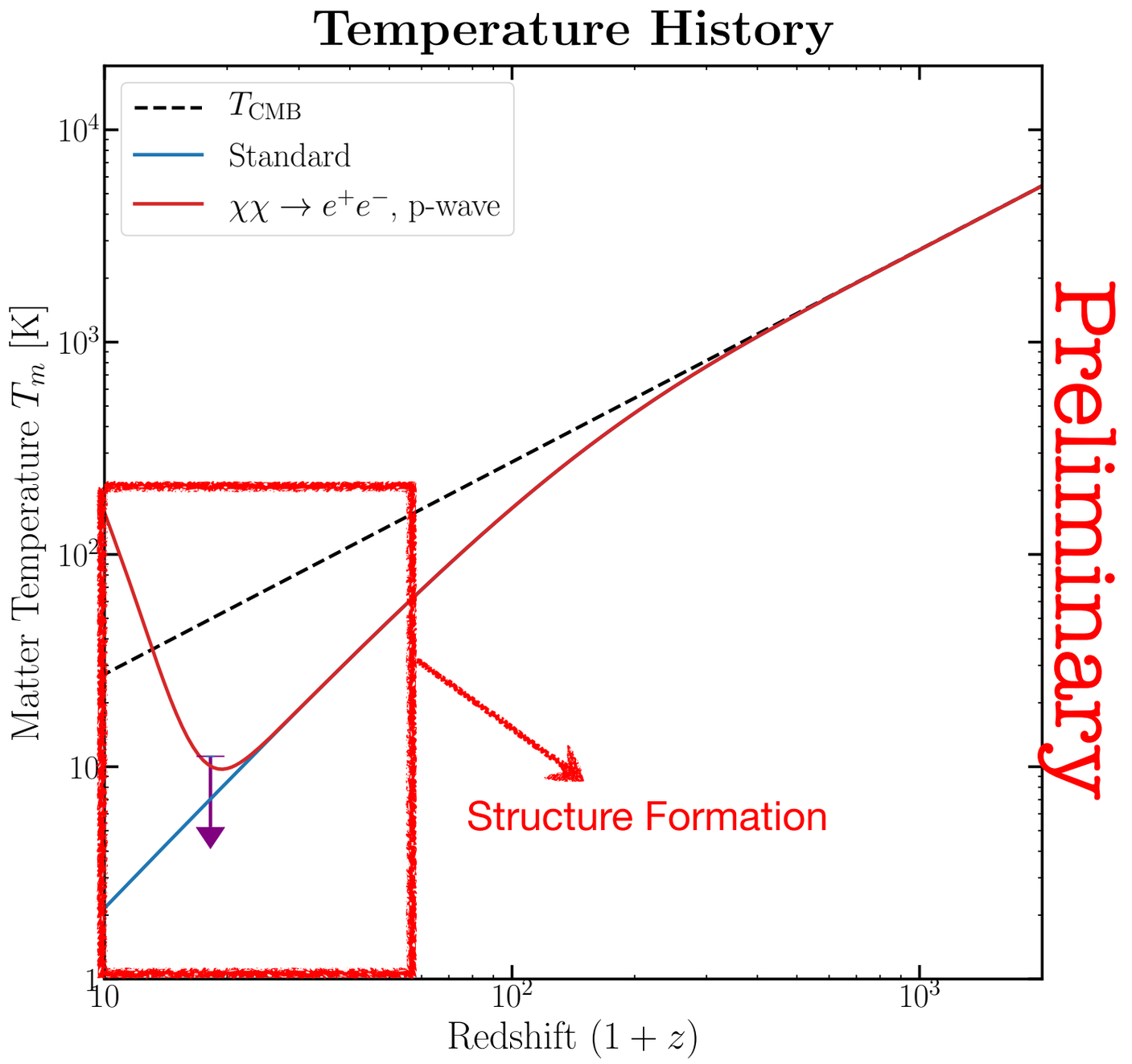

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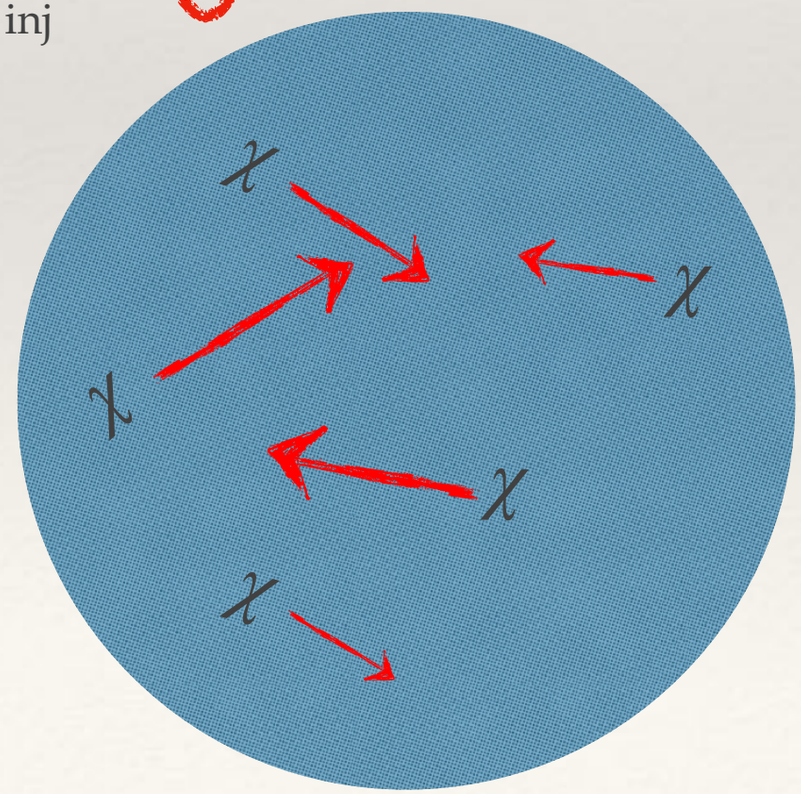

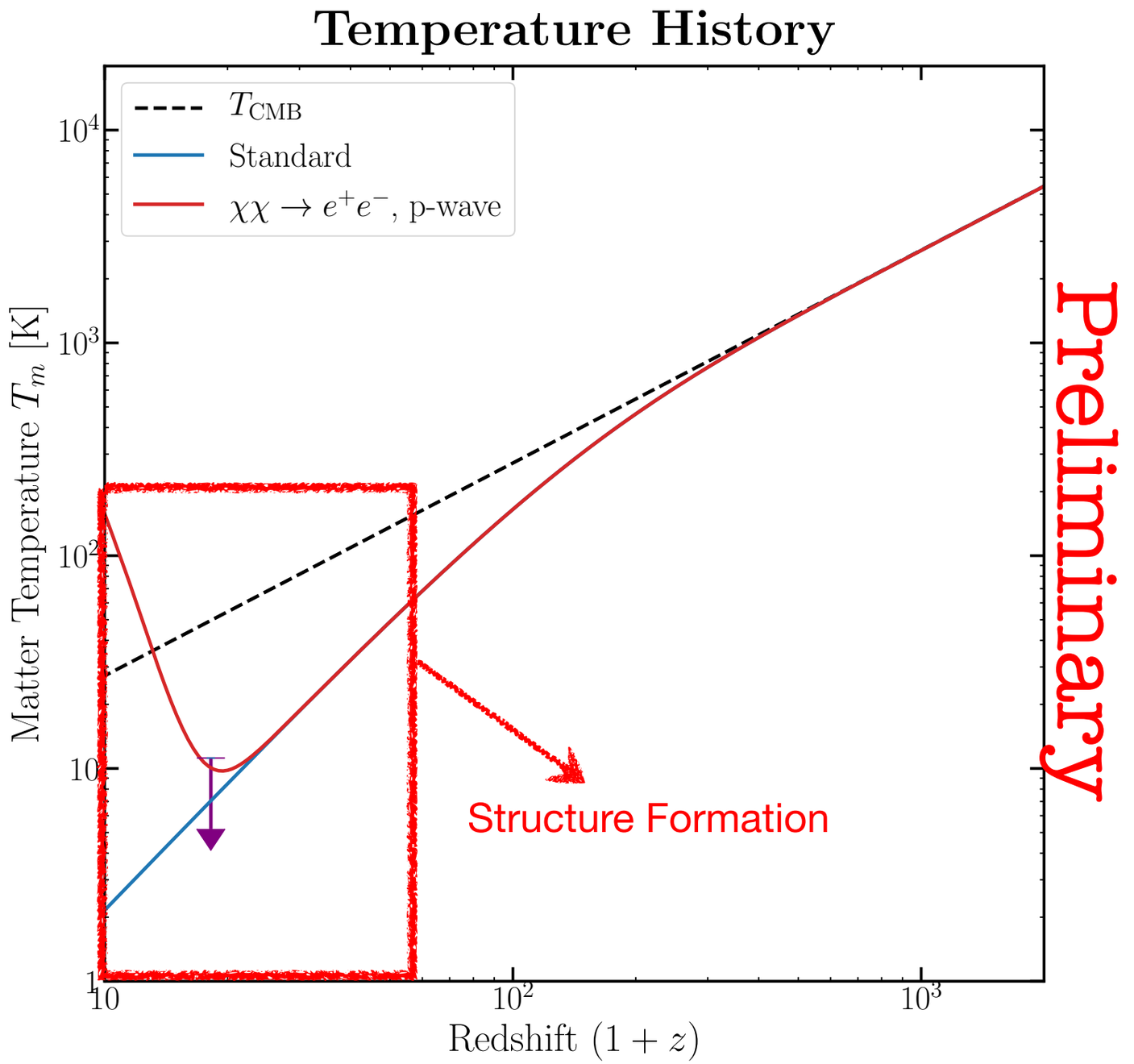

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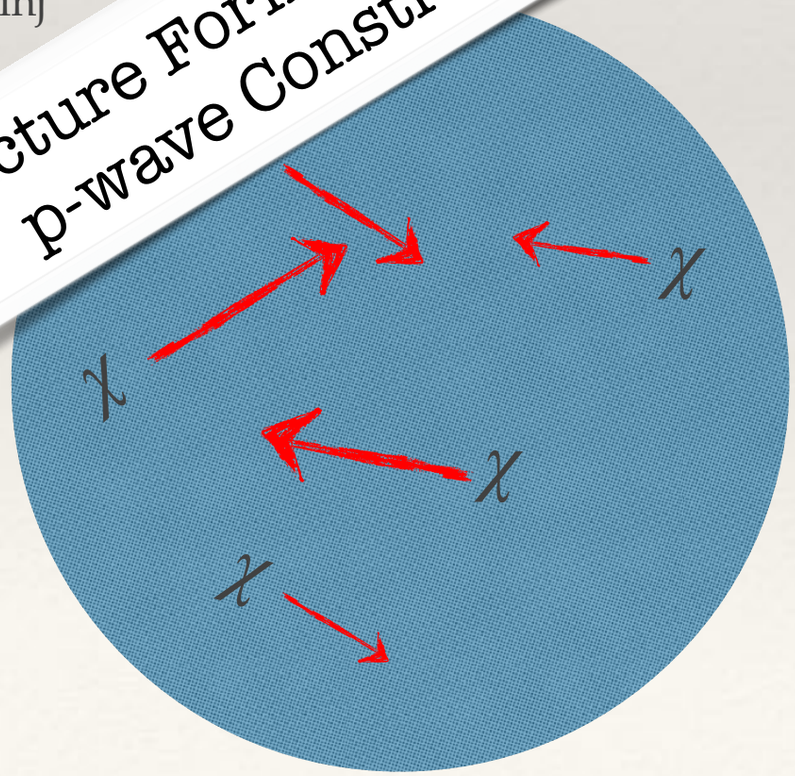
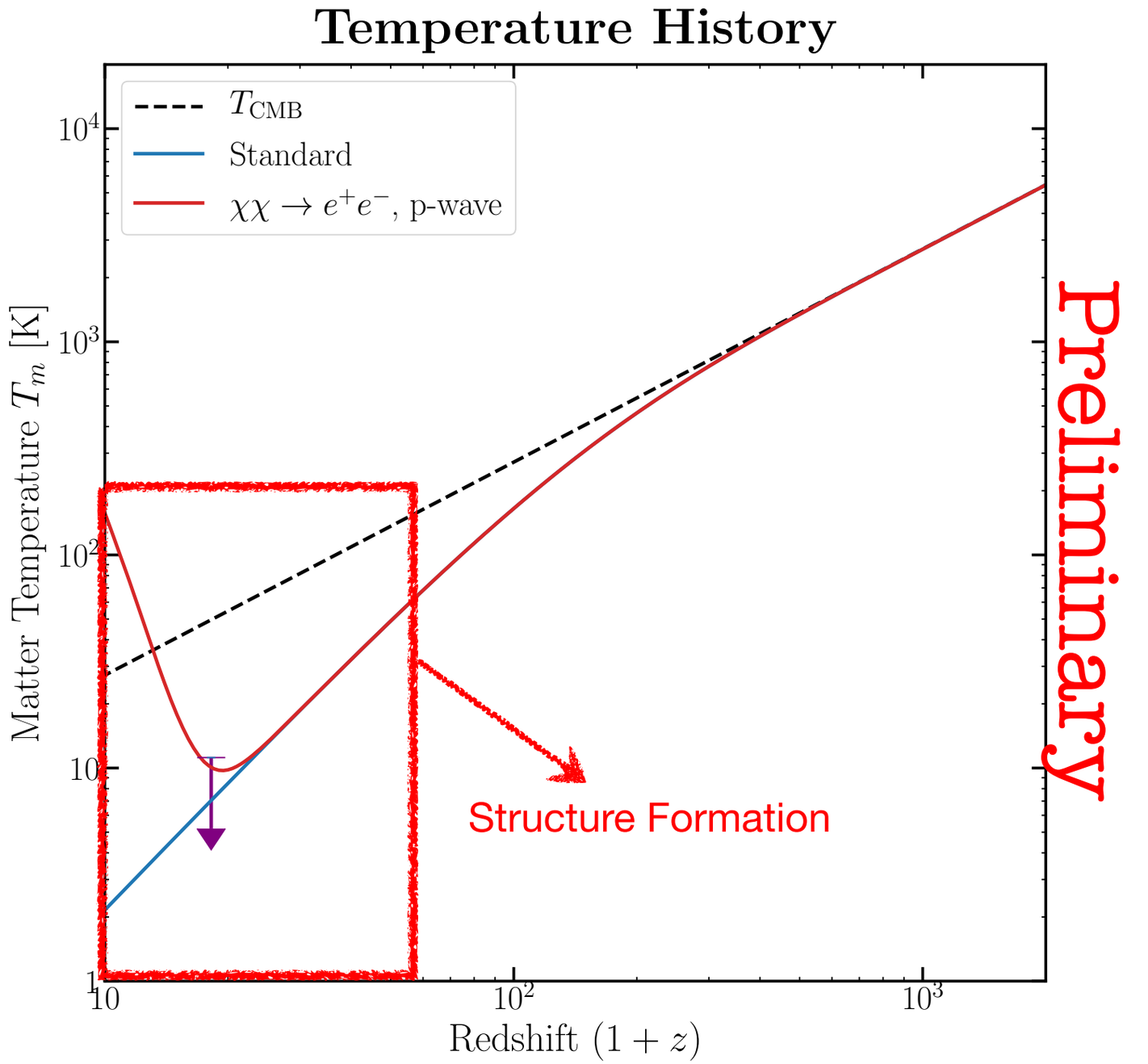
Structure Formation Drives p-wave Constraints





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How sensitive is a 21-cm constraint compared to other constraints?

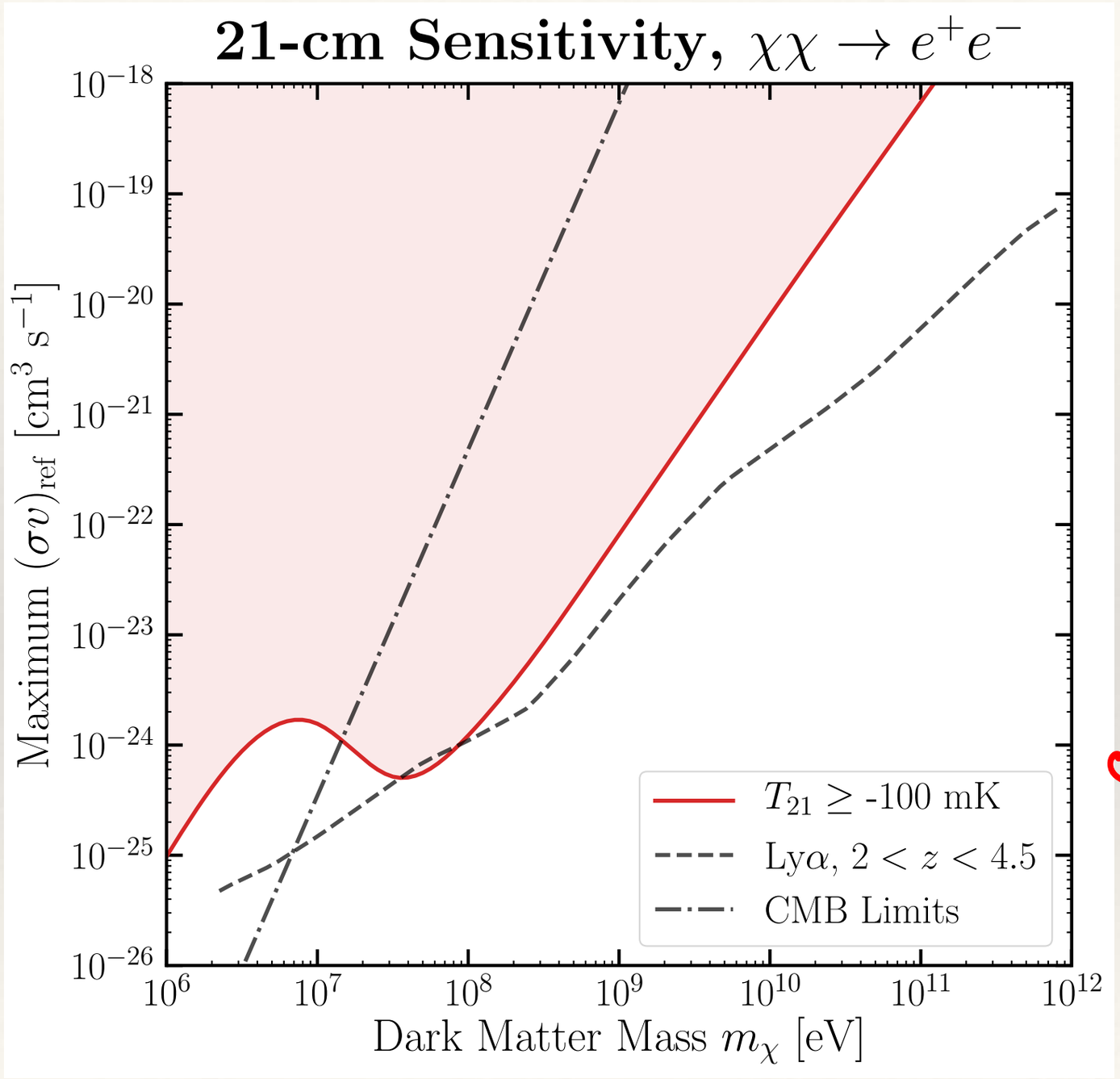
21-cm Sensitivity

Standard Assumptions

$$T_R = T_{\rm CMB}$$

$$\Delta T_{21} \approx -100\text{mK}$$

(Ignore EDGES)



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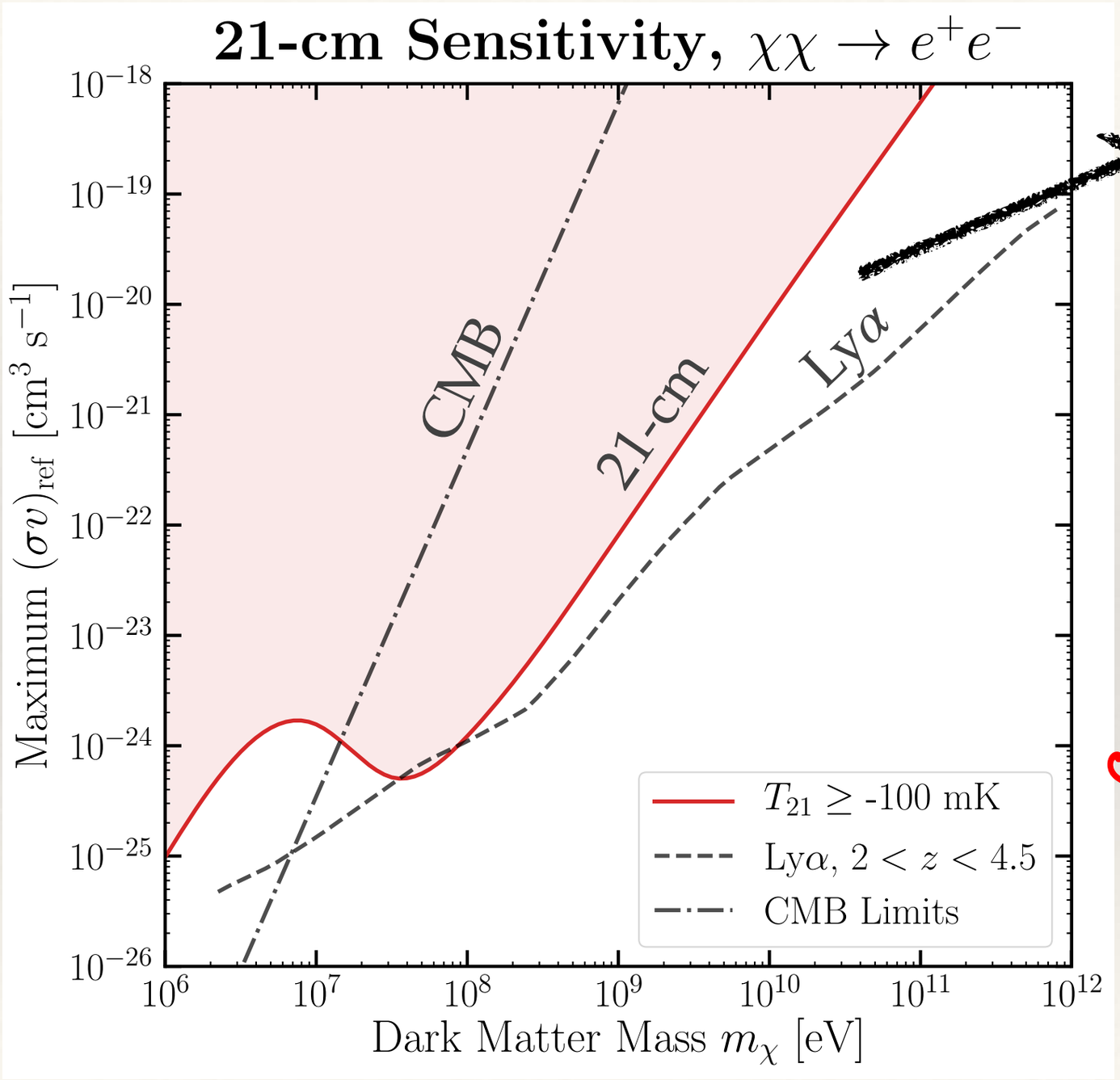

Complementary constraints probing different eras

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How can we use the EDGES result?

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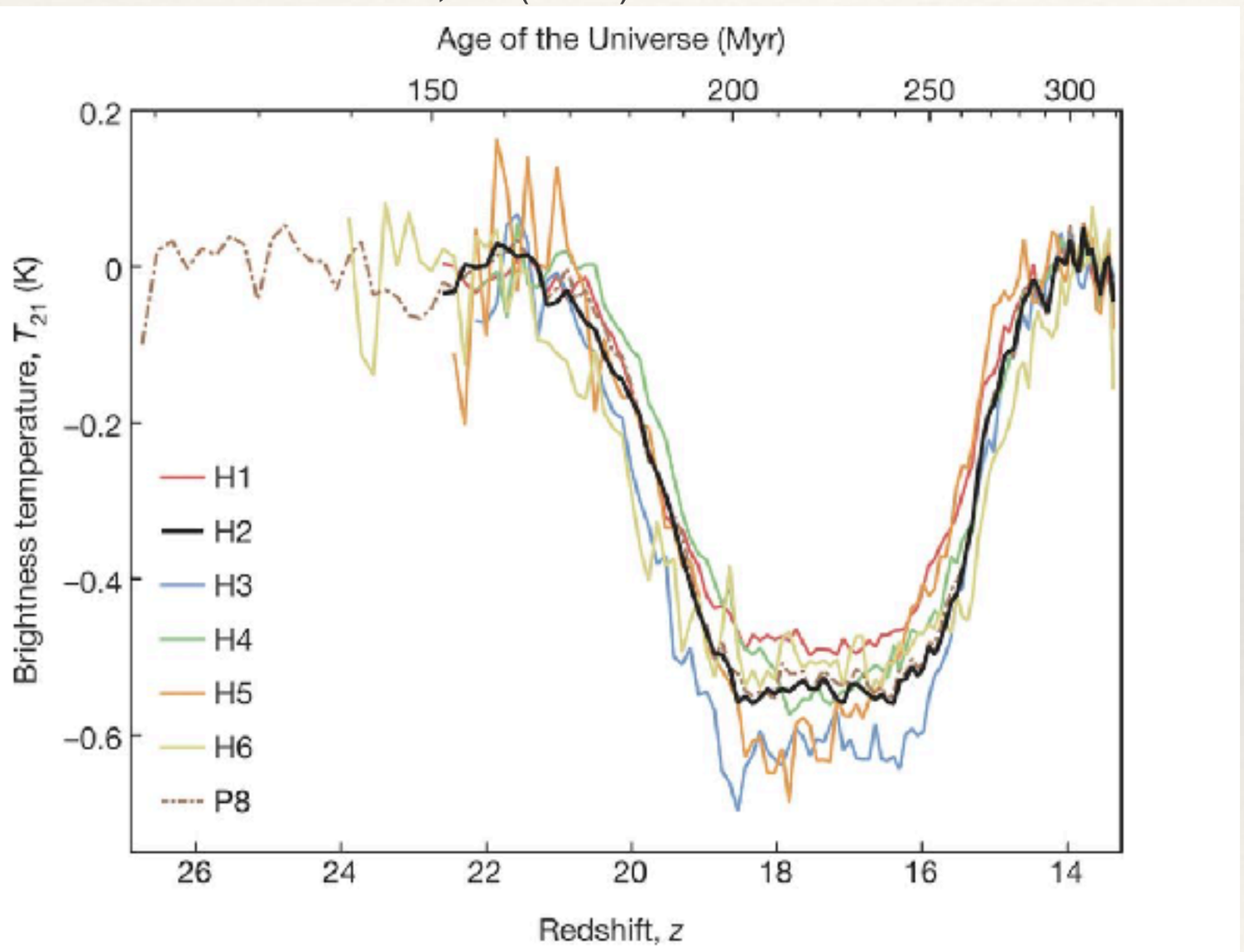
The EDGES signal

Bowman et. al: Nature 555, 67 (2018)



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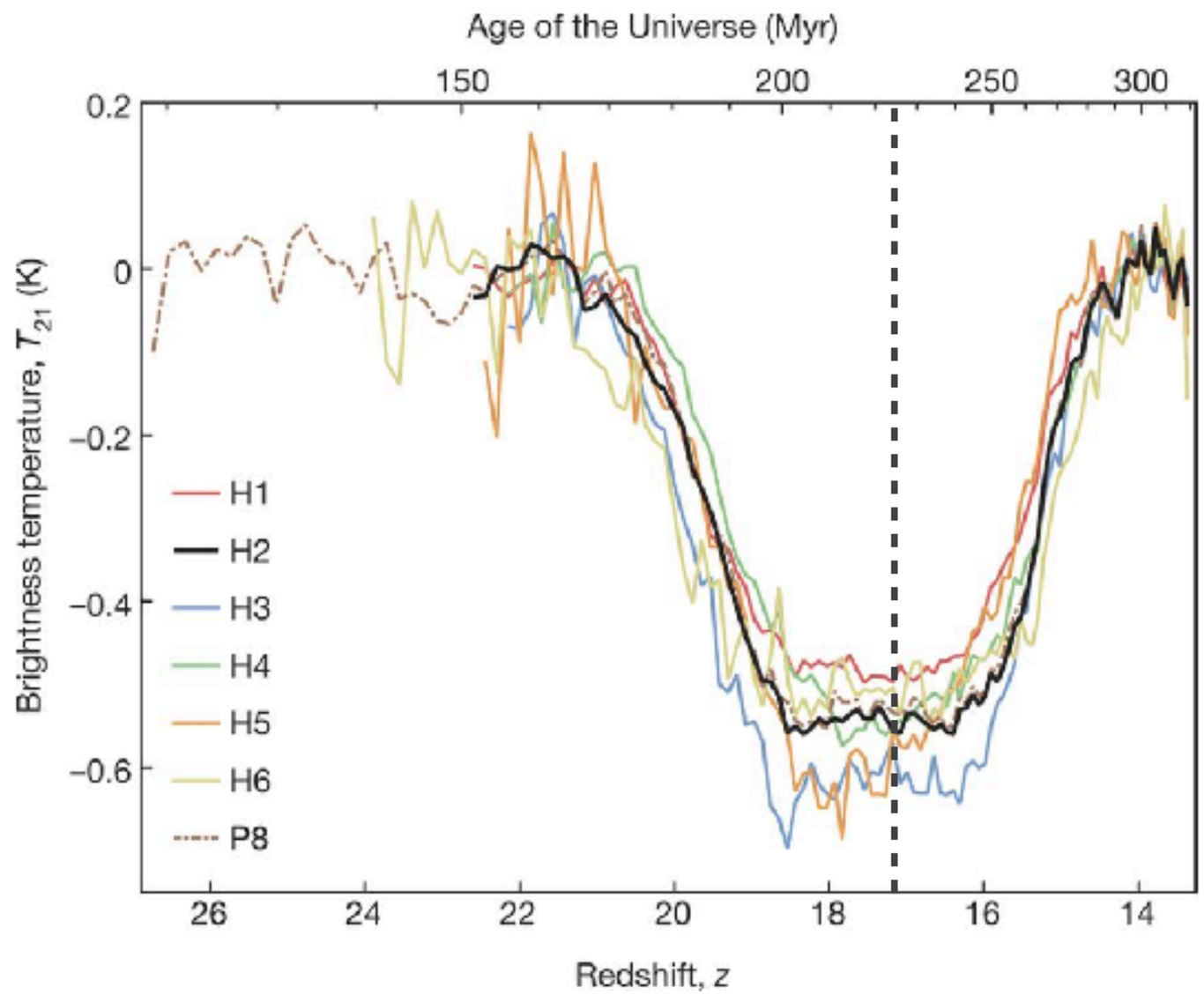

$$\frac{T_m}{T_R}(z = 17.2) \leq 0.105$$

at 99% CL

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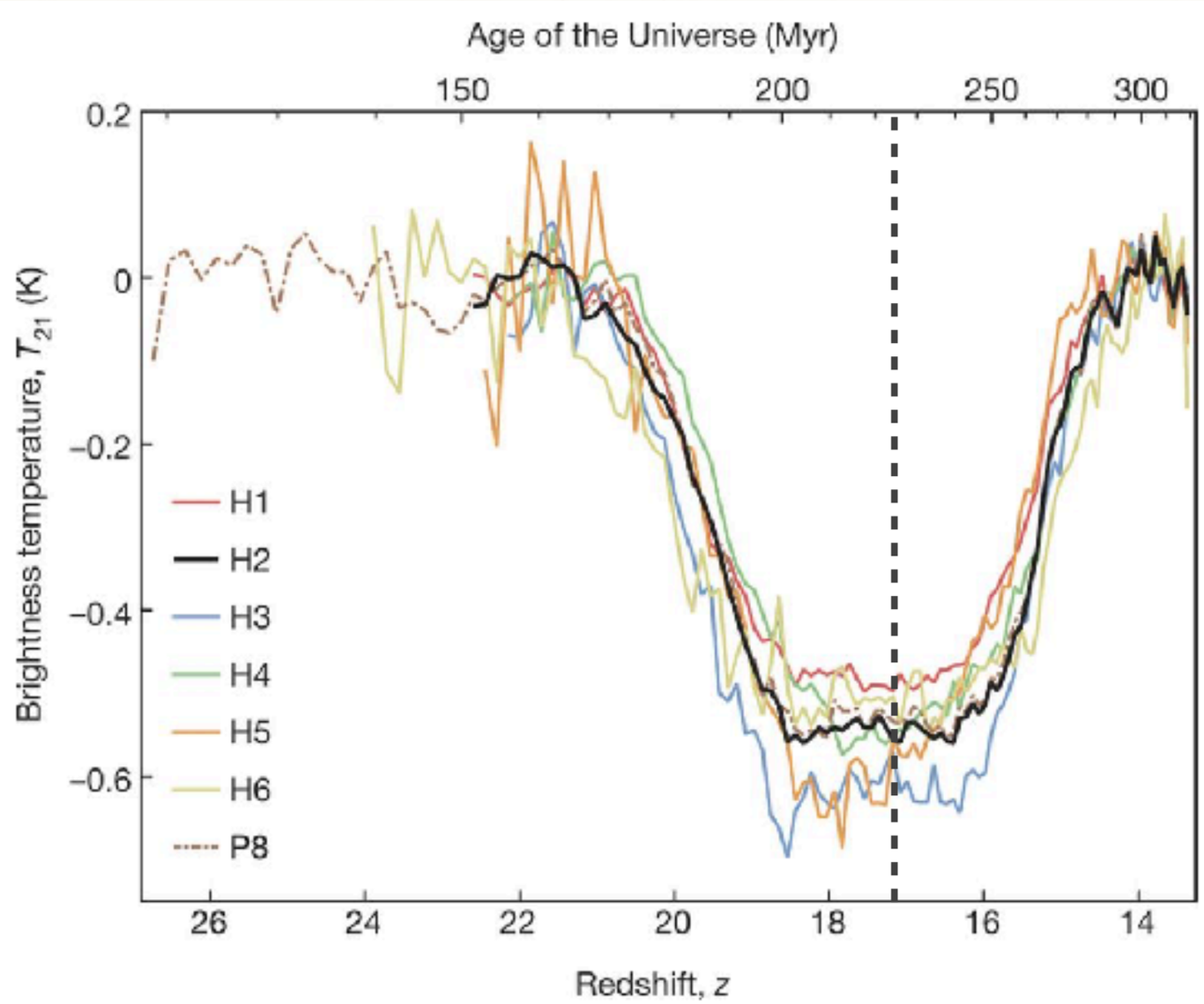
The EDGES signal

Bowman et. al: Nature 555, 67 (2018)



$$\frac{T_m}{T_R}(z = 17.2) \leq 0.105$$

Cannot be satisfied by

$T_R = T_{CMB}$

and

standard T_m

The EDGES signal

So either make

- T_R hotter

$$\frac{T_m}{T_R}(z = 17.2) \leq 0.105$$

The EDGES signal

So either make

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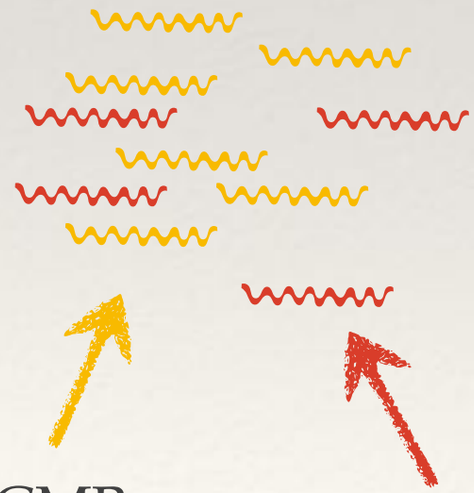
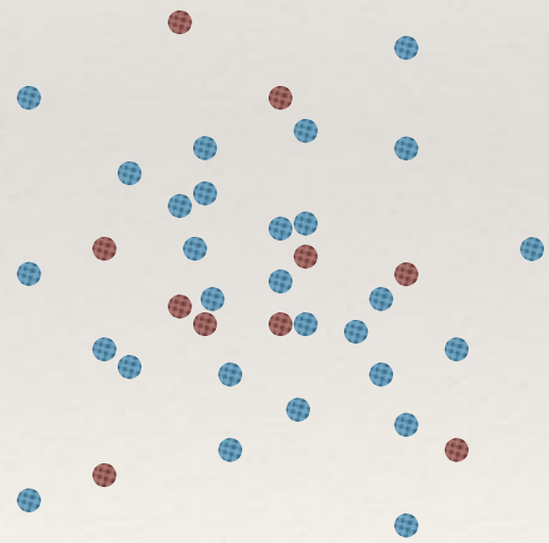
$$\frac{T_m}{T_R}(z = 17.2) \leq 0.105$$

1. There was an additional source(s) of 21cm radiation





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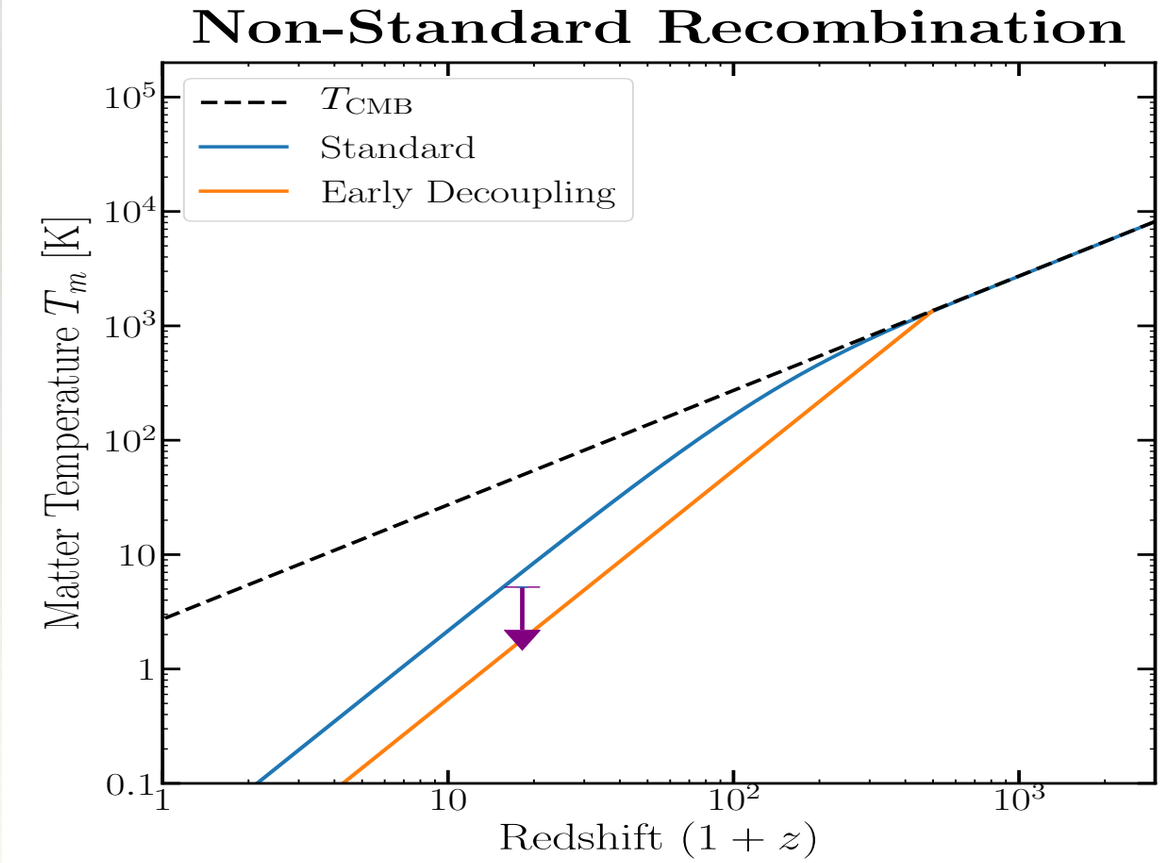
The EDGES signal

So either make

- T_R hotter or
- T_m colder

$$\frac{T_m}{T_R}(z = 17.2) \leq 0.105$$

1. There was an additional source(s) of 21cm radiation
2. T_m decoupled from T_{CMB} earlier than is typically assumed



The EDGES signal

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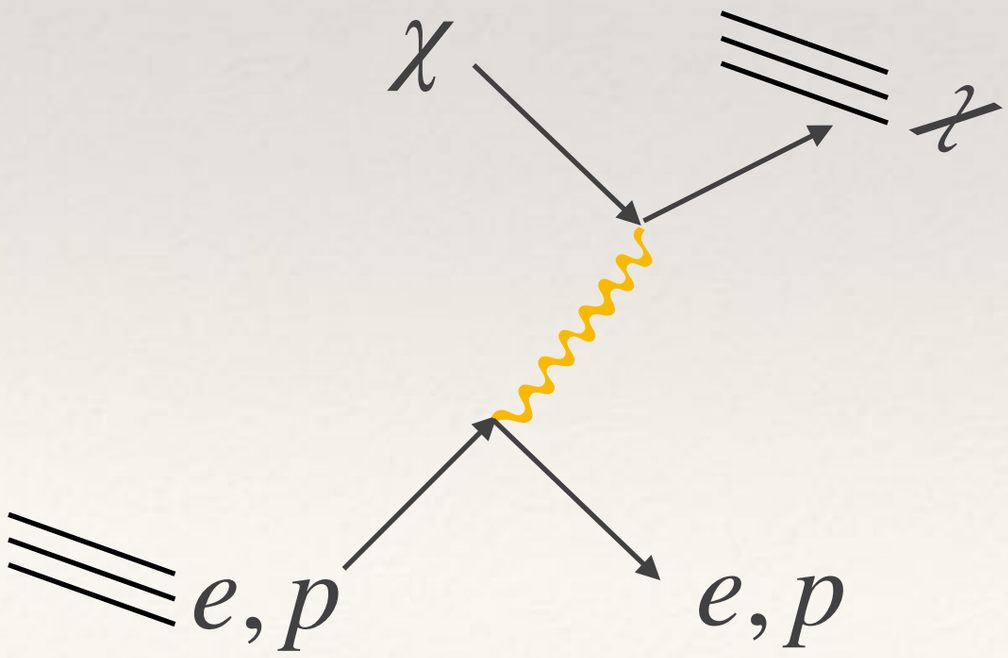
3. There is a DM component that cools T_m through its interactions

Focus for remainder of talk



The EDGES signal

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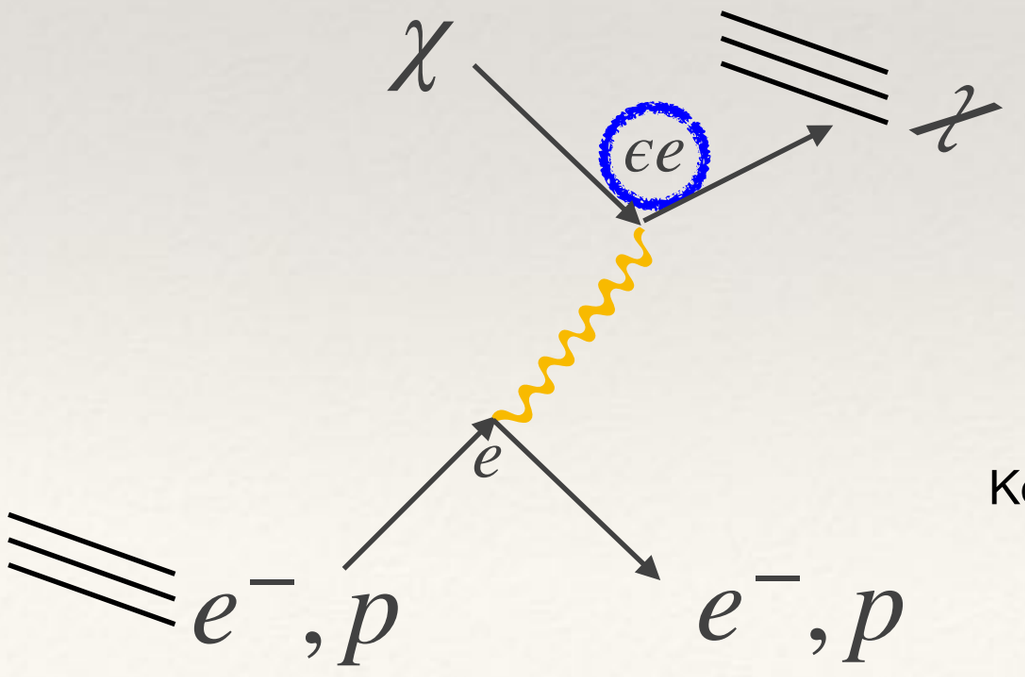
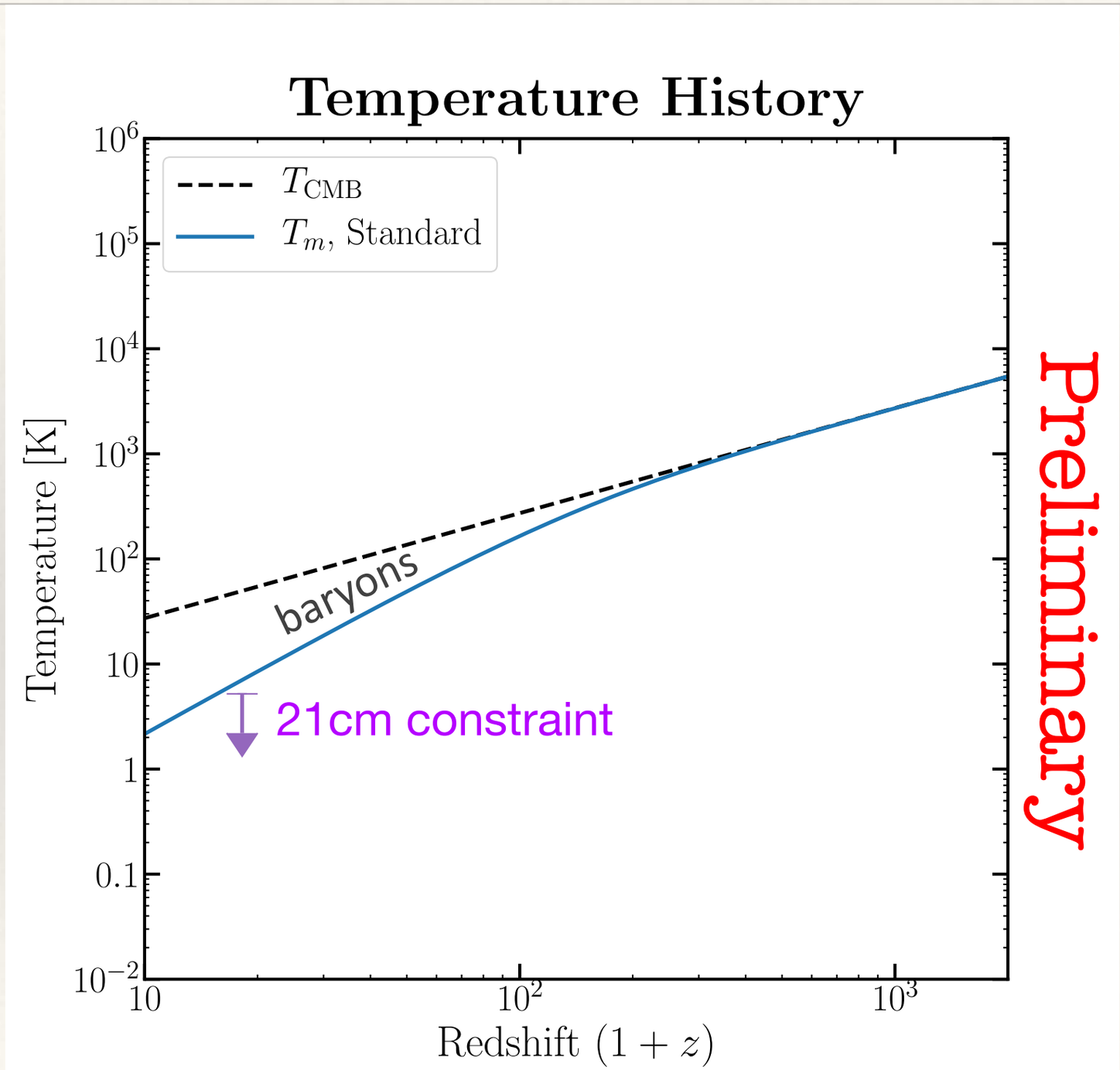


We will consider scalar (p-wave) milli-charged model:

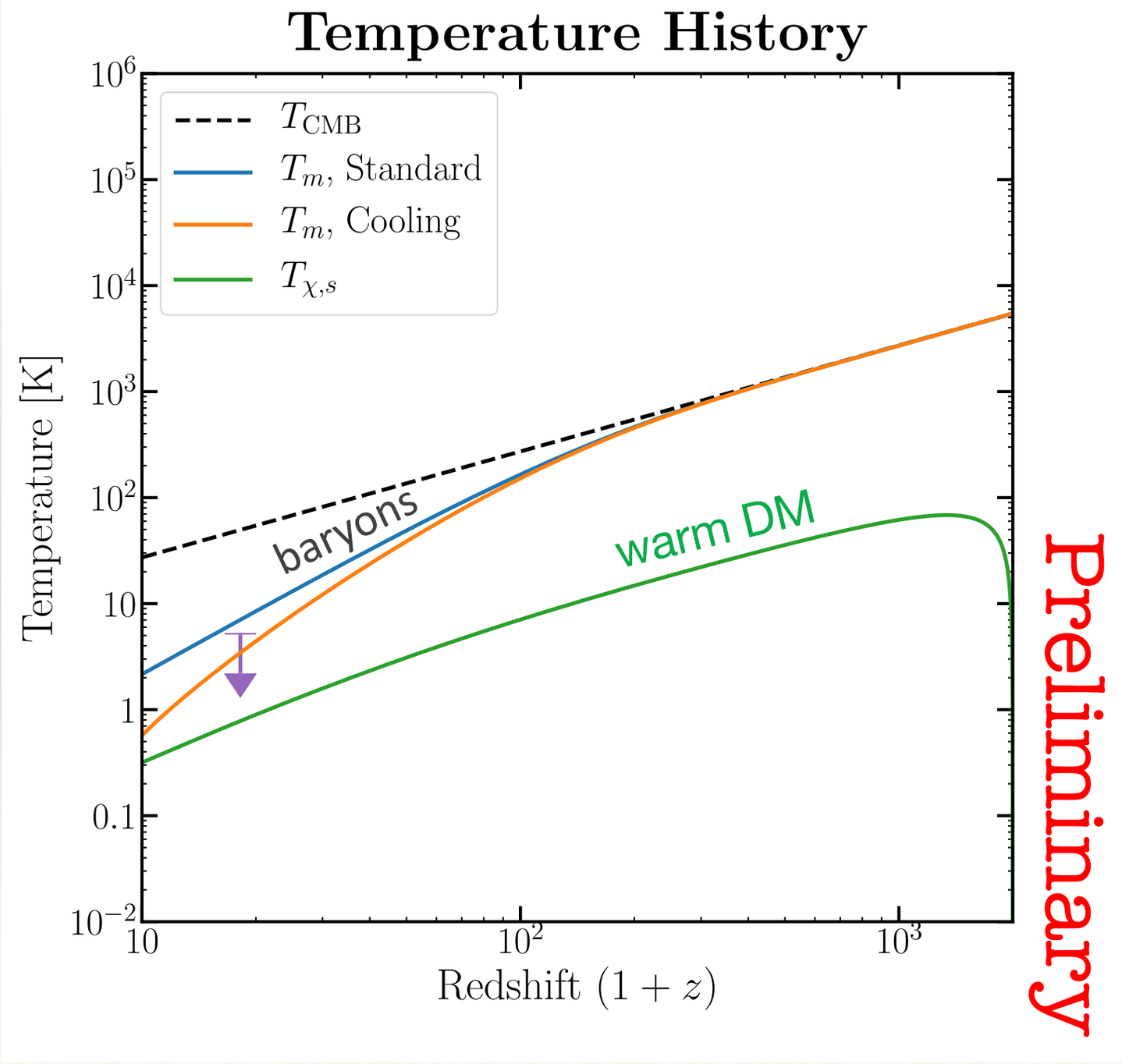
Muñoz and Loeb 1802.10094
Muñoz, Dvorkin and Loeb 1804.01092
Berlin, Hooper, Krnjaic, McDermott, 1803.02804
Kovetz, Poulin, Gluscevic, Boddy, Barkana, Kamionkowski, 1807.11482

Constraints



GR and H. Liu, in progress

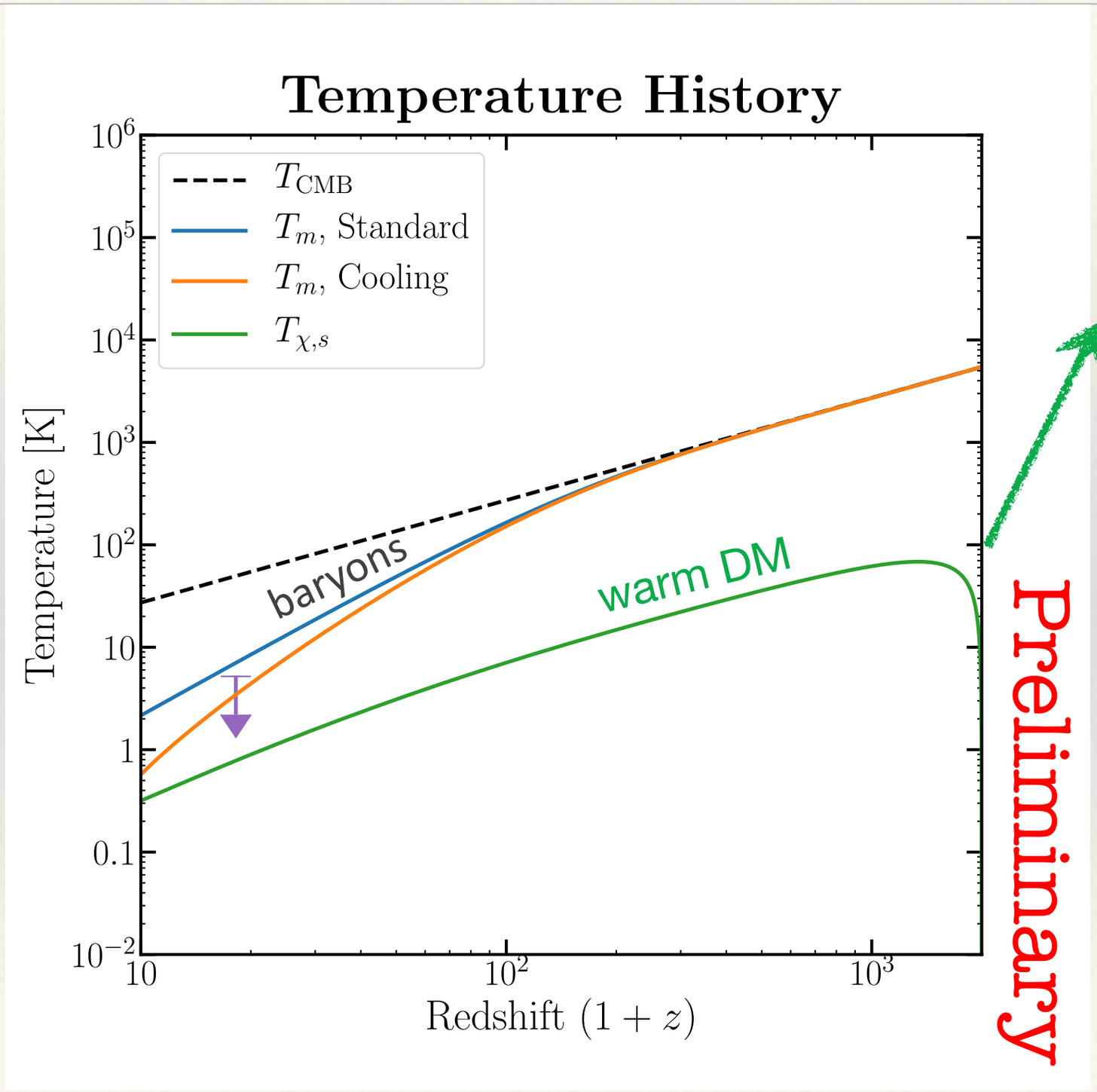
Constraints



H. Liu and **GR, in progress**

GR and H. Liu, in progress

Constraints



$\chi\chi \to e^+e^-$

DM has a much larger velocity than before

Preliminary

H. Liu and **GR, in progress**

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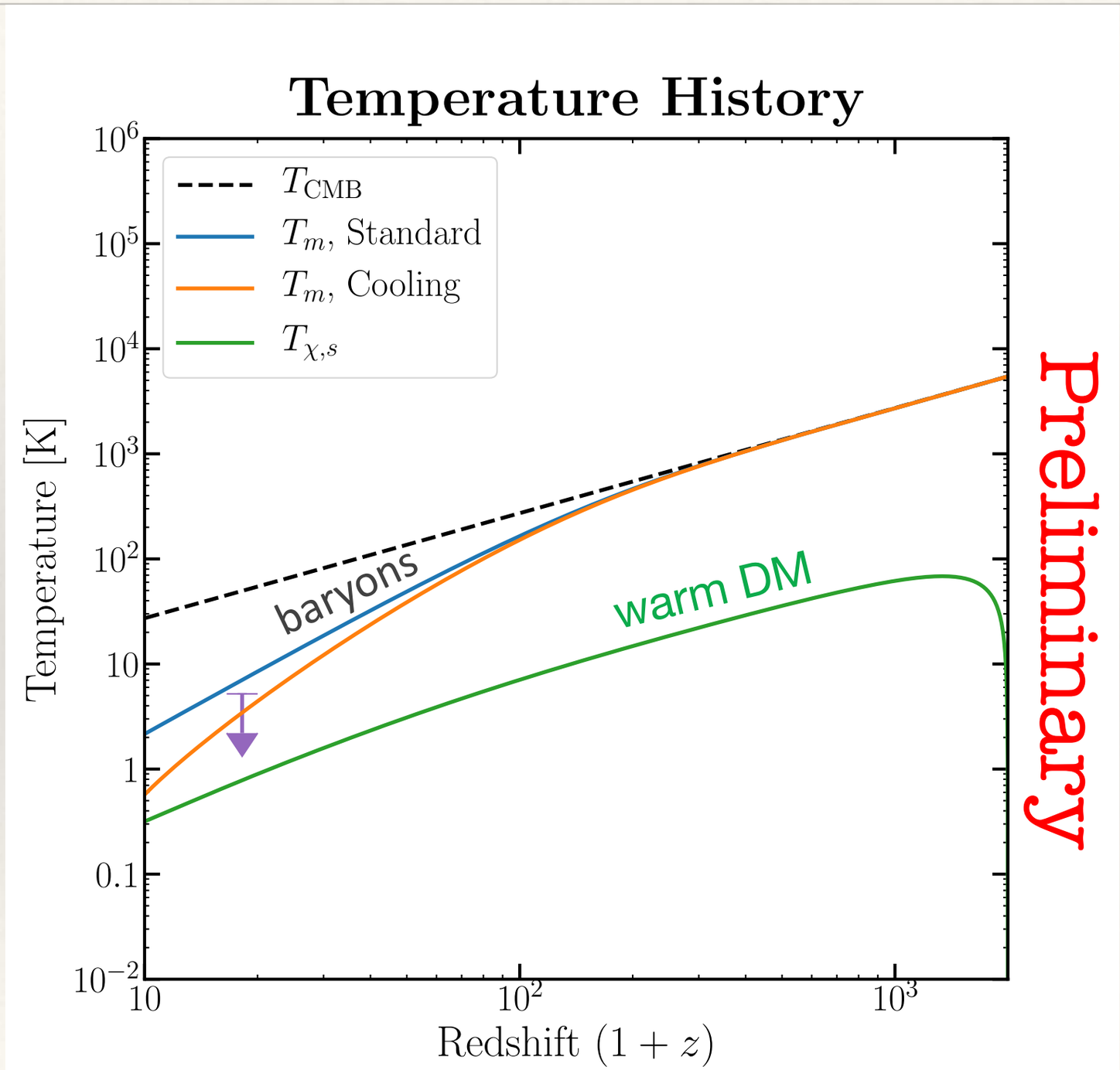
Constraints



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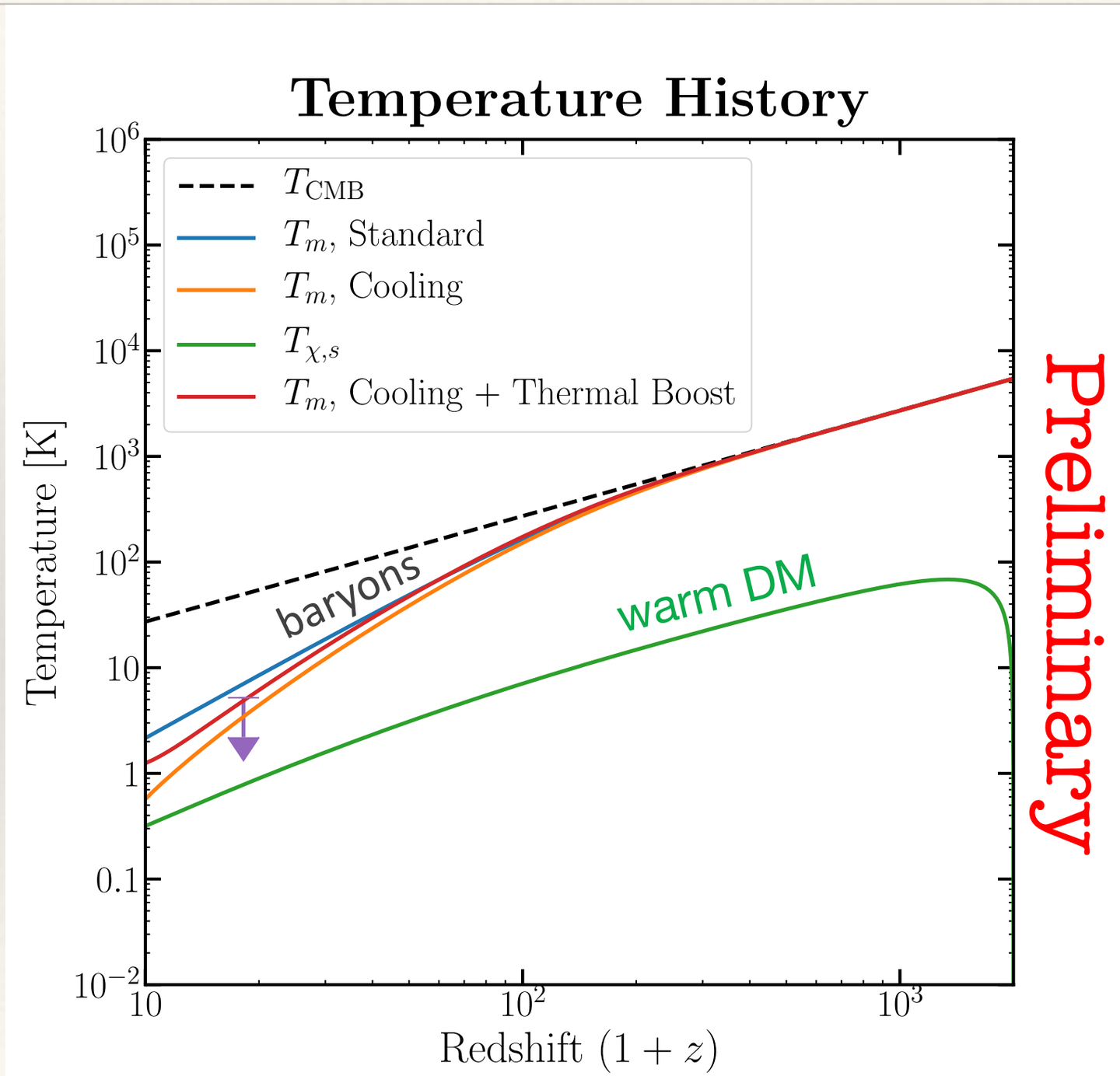
$\chi\chi \to e^+e^-$

DM has a much larger velocity than before

$\langle \sigma v \rangle \propto v^2$

Yet another **energy injection boost**

Constraints



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$\chi\chi \to e^+e^-$

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$\langle \sigma v \rangle \propto v^2$

Yet another **energy injection boost**

Primary source of constraints

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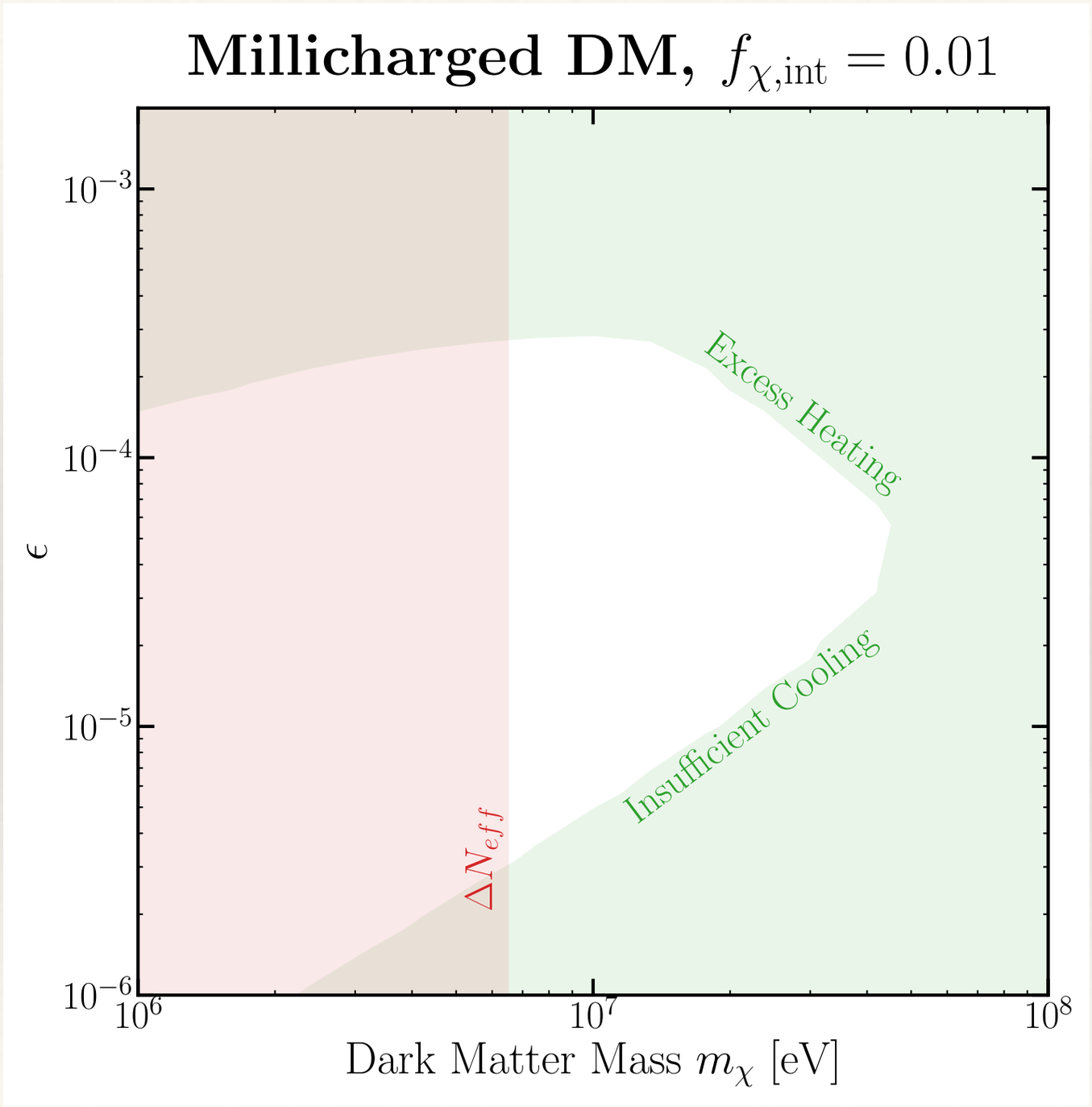
Constraints



Recap

- The **21-cm signal** is a powerful tool for studying DM models, particularly p-wave annihilating models. It puts an upper bound on T_m at $z \sim 17.2$.

- **Structure formation** is an essential ingredient in p-wave analyses

- The EDGES signal forces us to consider exotic temperature histories or sources of 21-cm radiation.

- The **non-zero thermal velocity** in the **milli-charged scalar model** is an important constraint of that model.

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Thank You