

POST-RECOMBINATION SPECTRAL DISTORTIONS from DARK MATTER ENERGY INJECTION

Wenzer Qin

with Greg Ridgway, Yitian Sun,
Hongwan Liu, and Tracy Slatyer

May 10th, 2022 | Pheno 2022



Massachusetts
Institute of
Technology



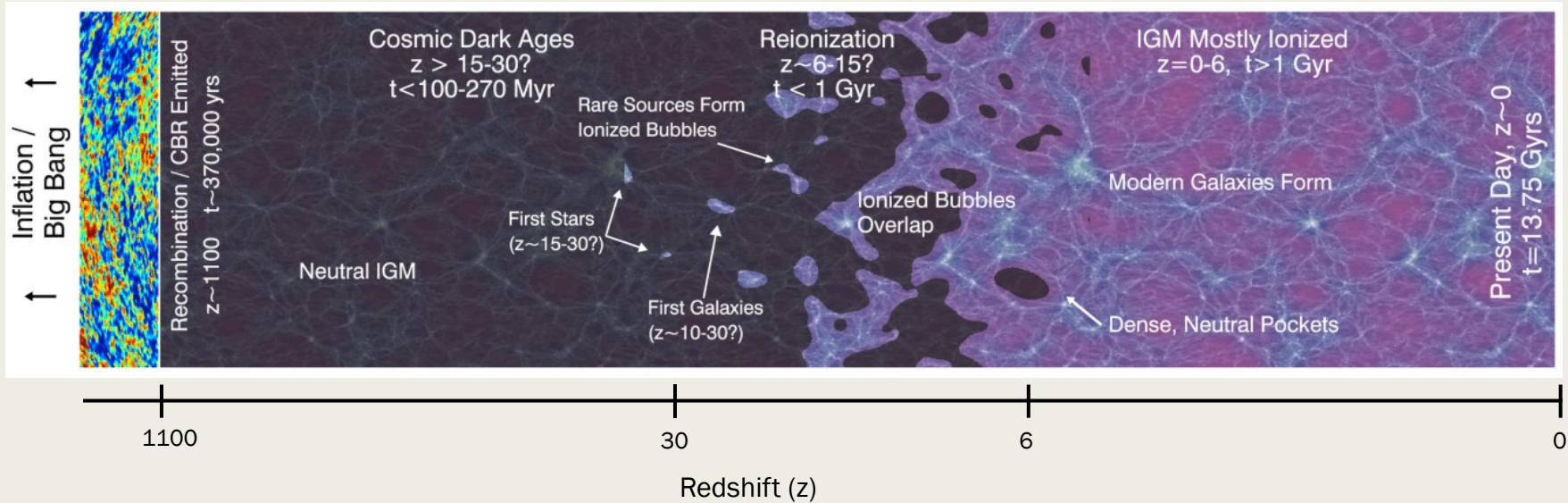
Center for
Theoretical
Physics

Outline

- Cosmic history
 - *CMB and sources of spectral distortions*
- **DarkHistory** code package
 - *Updates to low energy electron treatment*
 - *Tracking atomic transitions*
- Results
- Conclusions

Timeline of the early universe

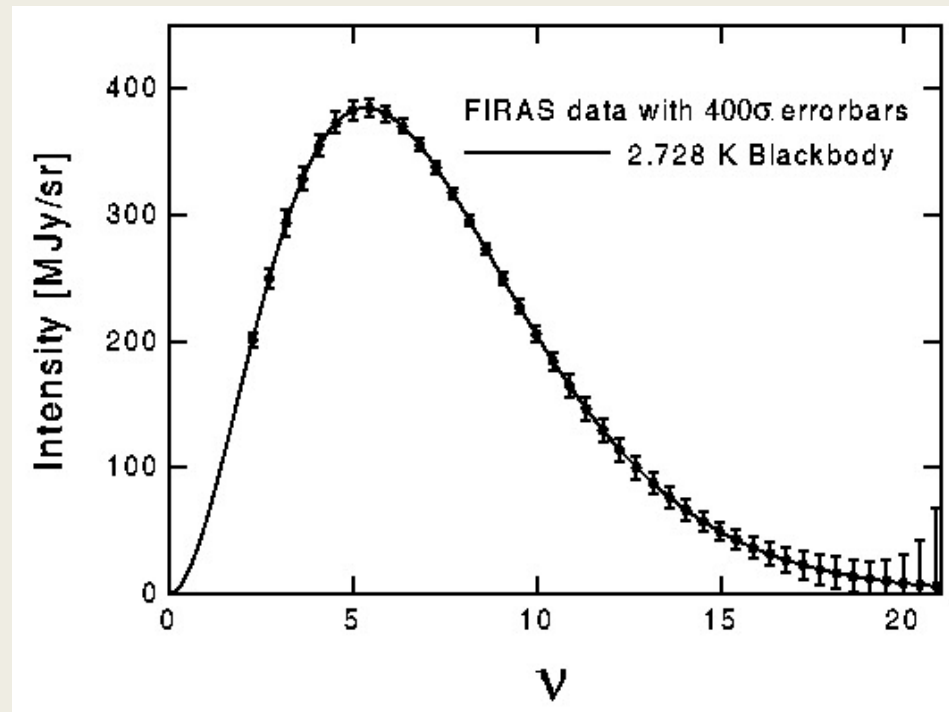
→ → Time → →



Robertson et al. (2010)

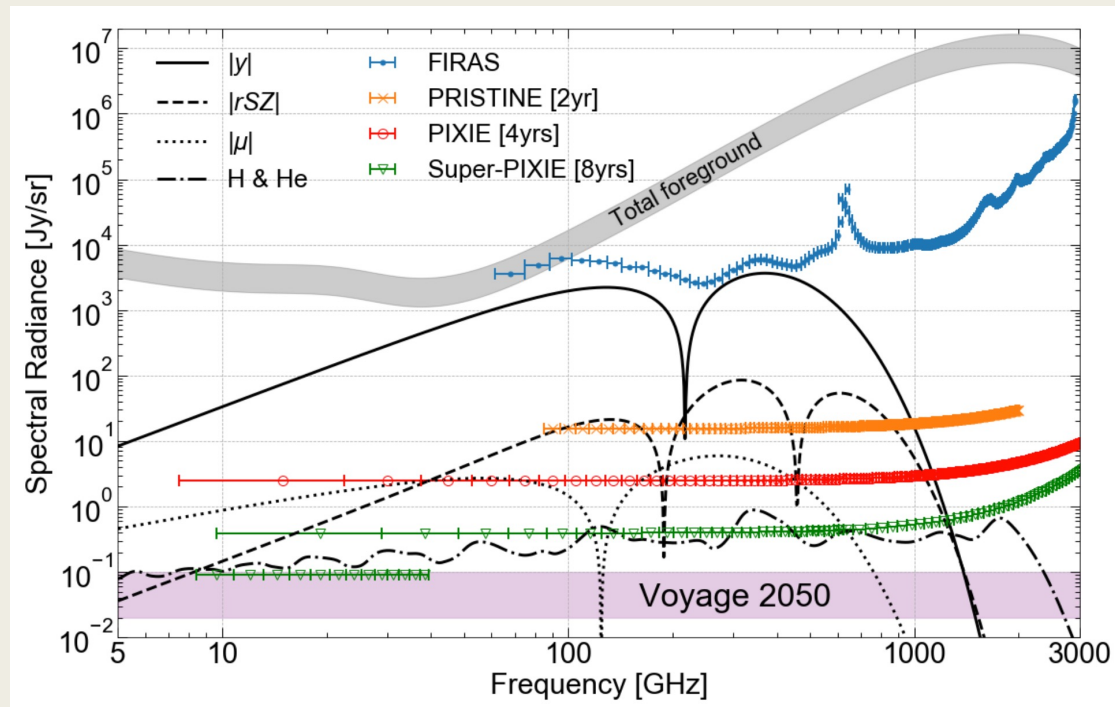
Spectral distortions

- COBE/FIRAS showed us the CMB is nearly a perfect blackbody
- If addition (or subtraction) of energy from photons **cannot fully thermalize**, the CMB spectrum will **no longer be blackbody**
- Distortions are known to be very small, $\Delta I/I < 10^{-4}$



Spectral distortions

- Many possible sources of distortions
 - *Recombination/atomic transitions of H and He*
 - *Thermal SZ effect*
 - *Reionization/structure formation*
 - *Adiabatic expansion*
 - *Dark matter*

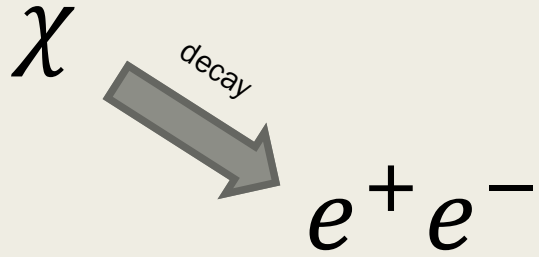


How to form a **distortion**?

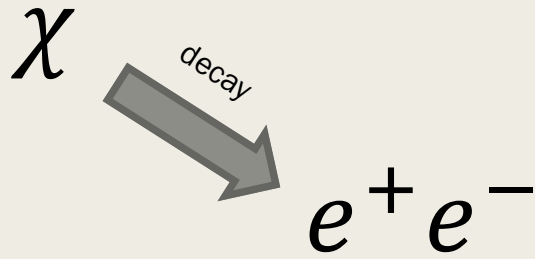
How to form a **distortion**?

χ

How to form a **distortion**?

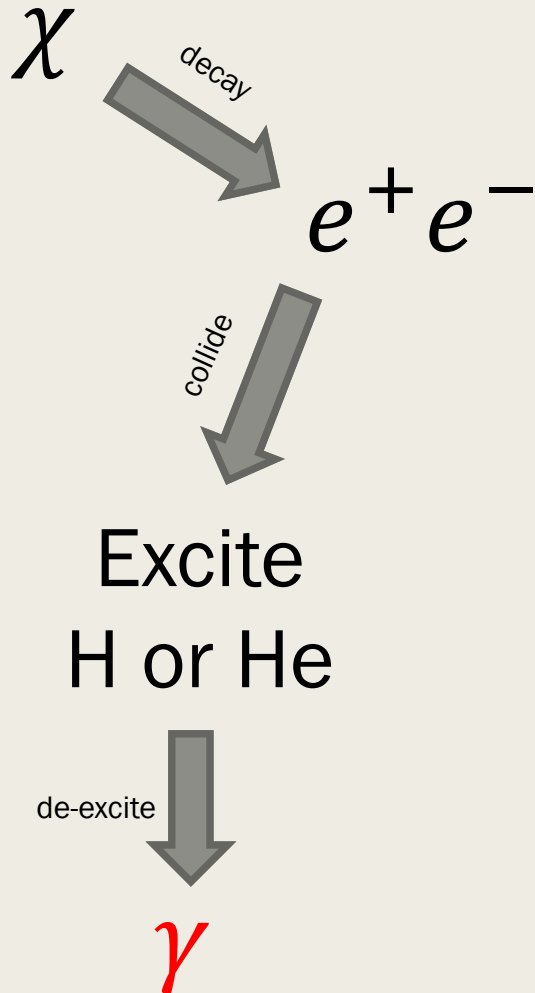


How to form a **distortion**?

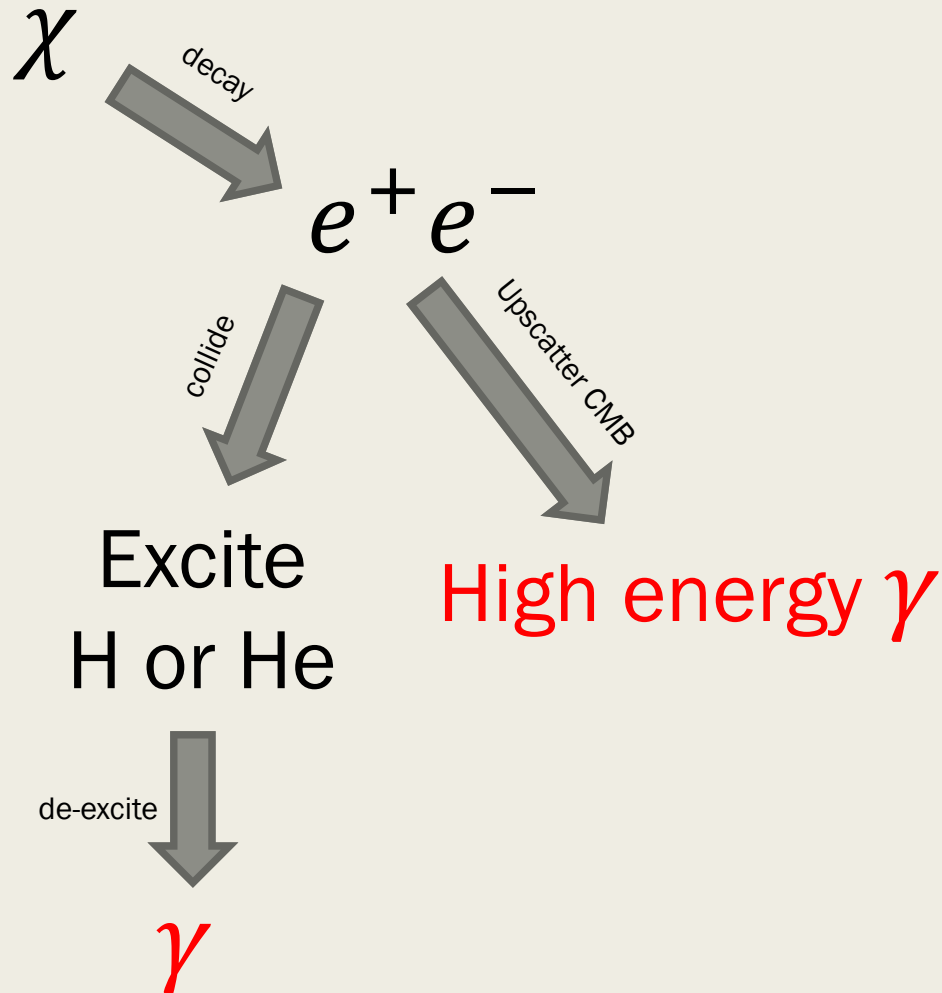


Excite
H or He

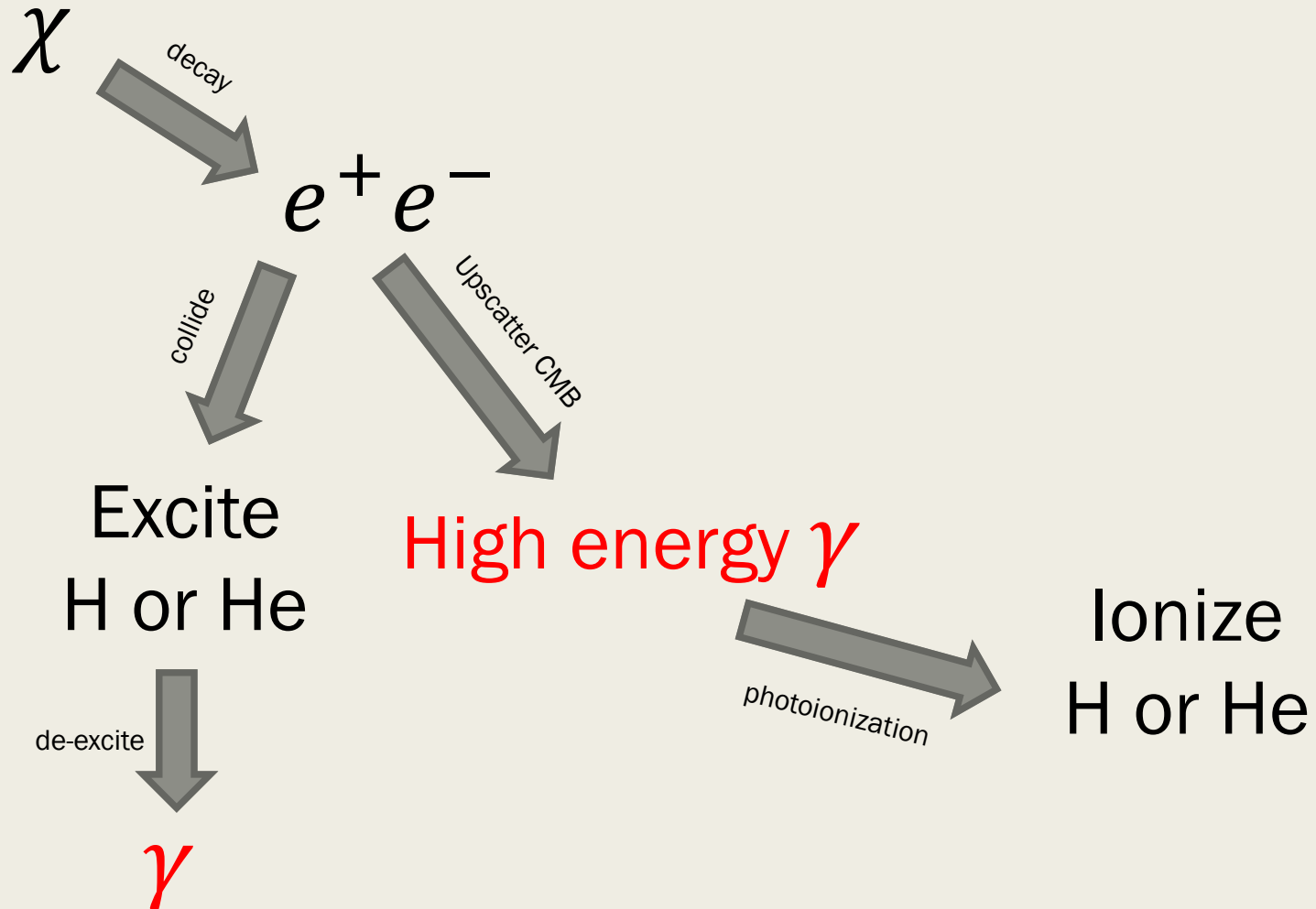
How to form a **distortion**?



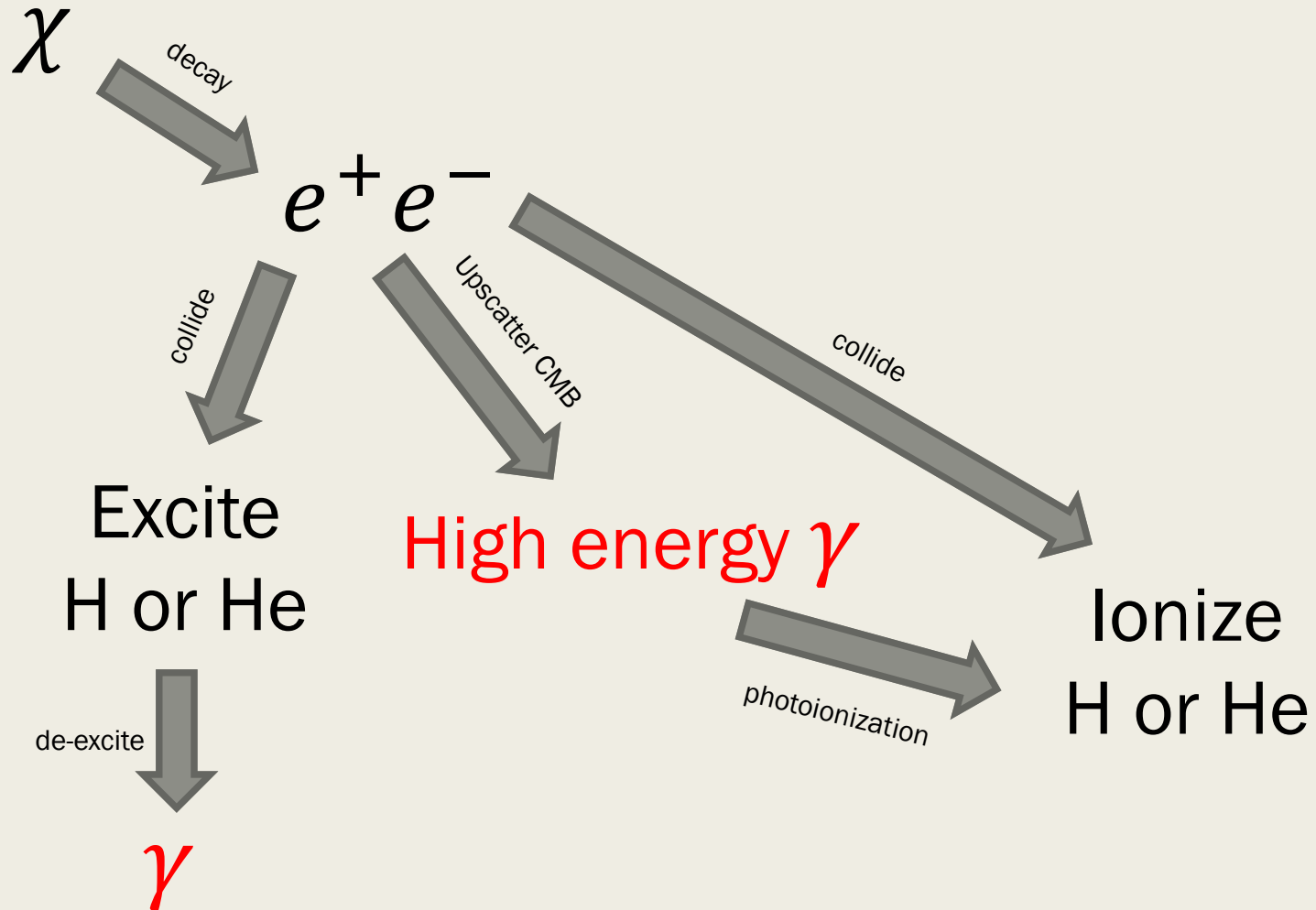
How to form a distortion?



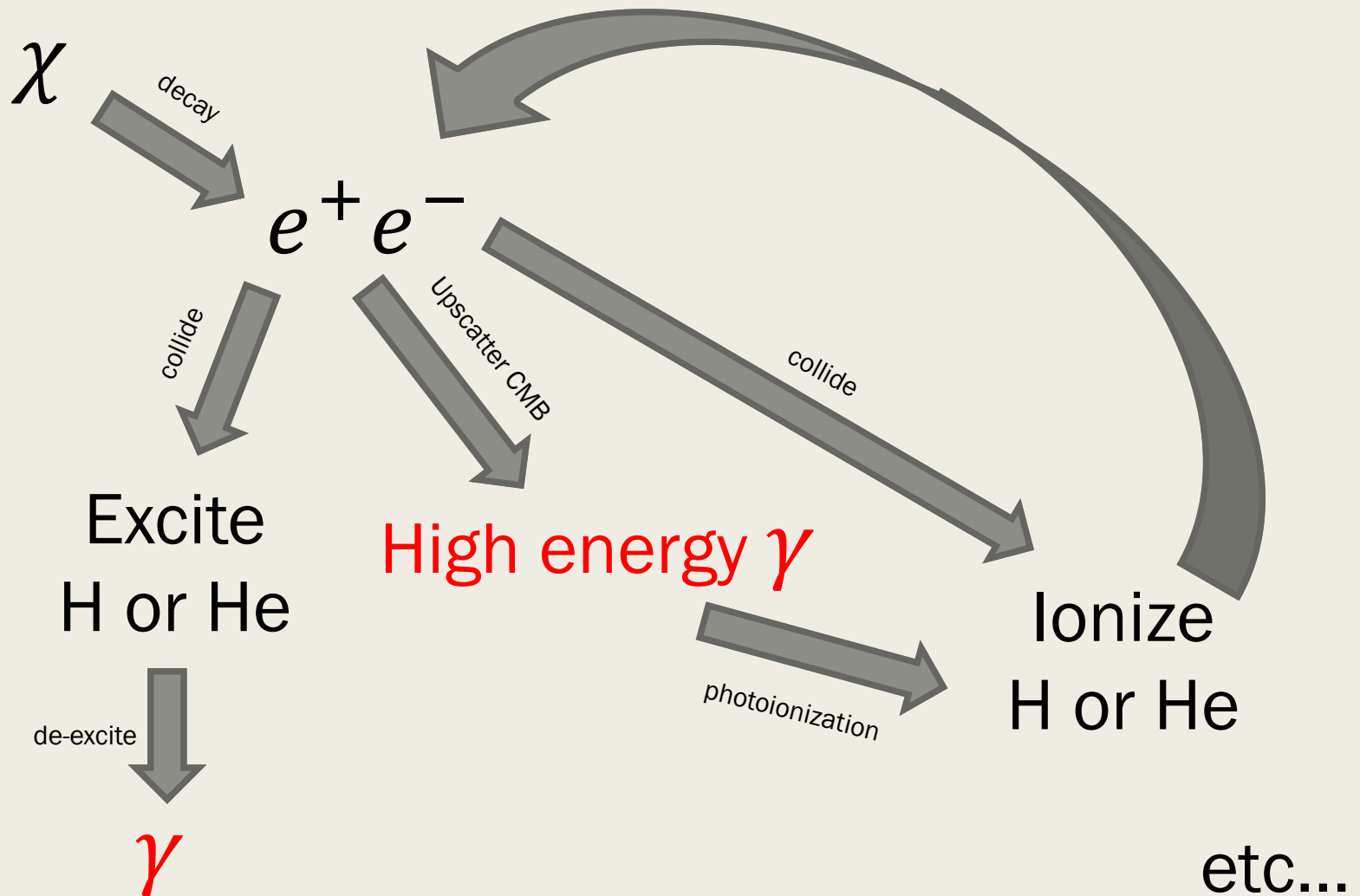
How to form a **distortion**?



How to form a **distortion**?

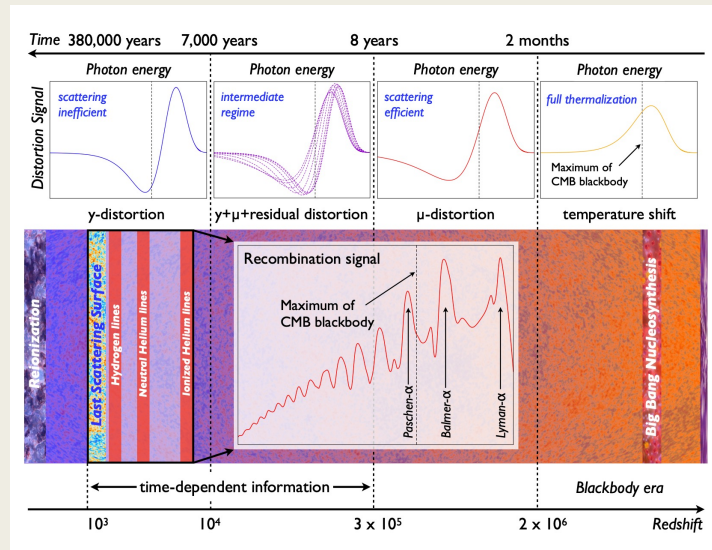


How to form a **distortion**?

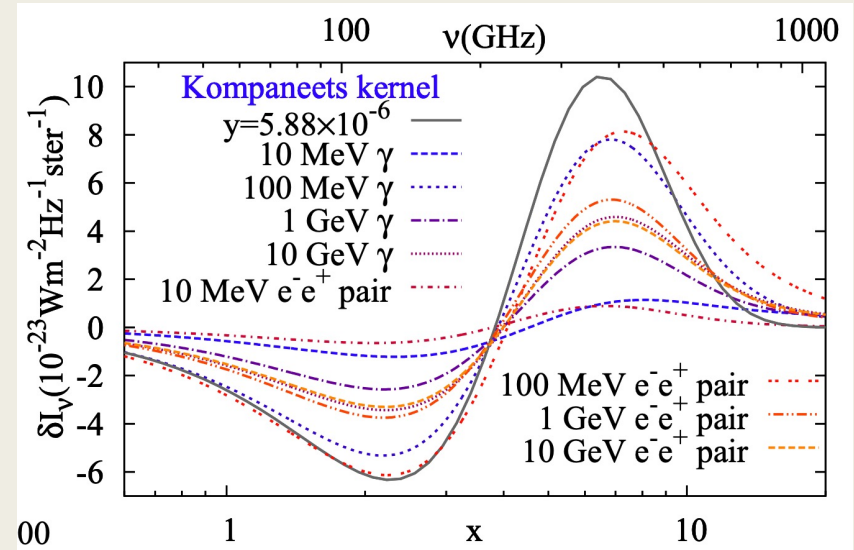


Pre-recombination

- Detailed studies of energy injection prior to recombination have been done



Chluba et al. (2019)



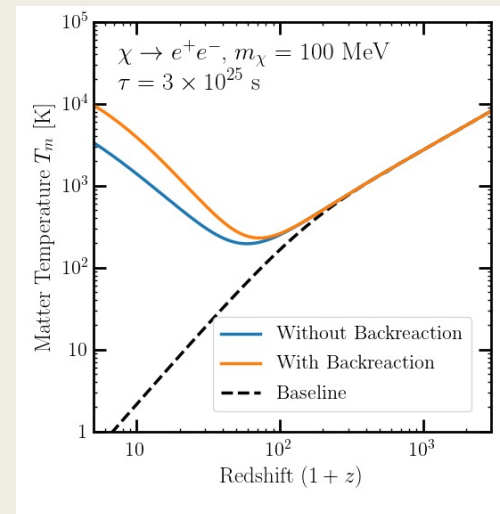
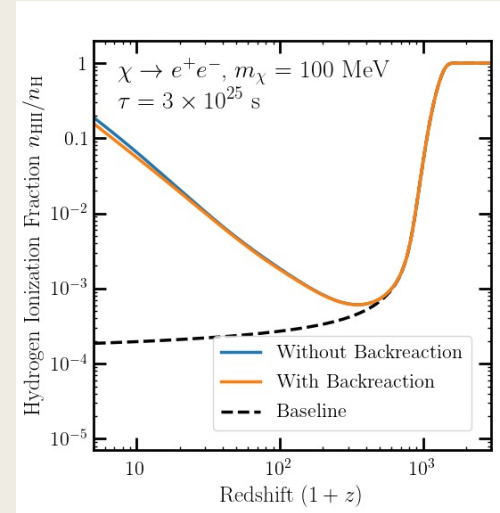
Acharya & Khatri (2019)

DarkHistory



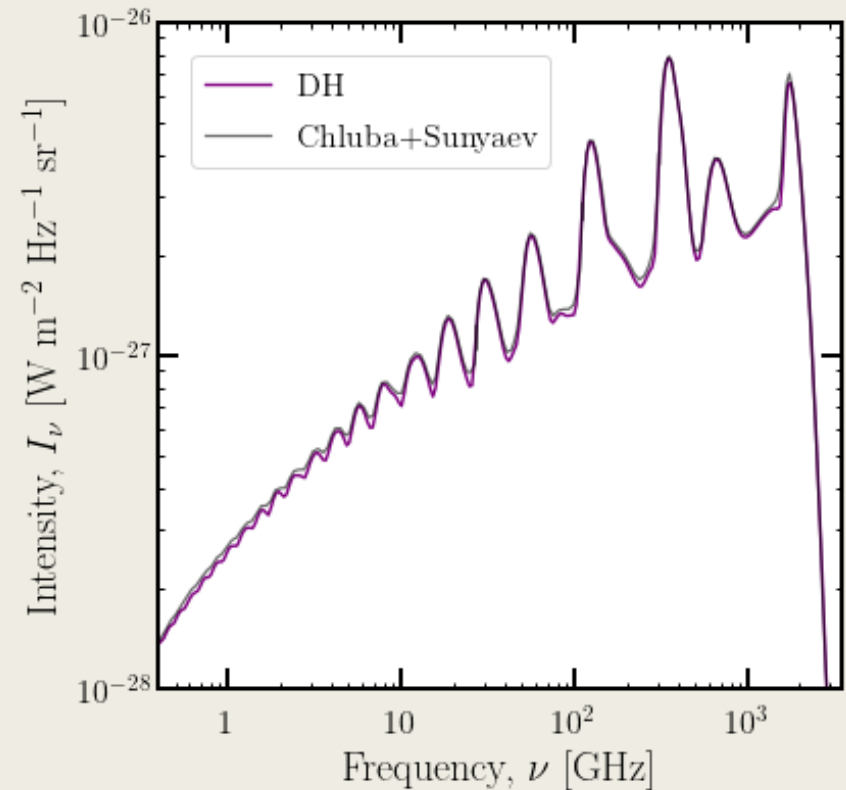
DarkHistory

- Python code package
 - Download at <https://github.com/hongwanliu/DarkHistory/>
- Simultaneously solves for evolution of free electron fraction and gas temperature, including exotic sources of energy injection
- Accounts for ‘backreaction’, where changes in ionization/temperature modify subsequent energy-loss processes



Distortions with **DarkHistory**

- Low energy electrons (< 3 keV)
 - *Previously resolved deposited energy as integrated energy deposited into different channels*
 - *For distortion, we need energy per bin*
- Atomic transitions
 - *Previously assumed three-level atom for hydrogen*
 - *Now keep track of arbitrary # of levels*

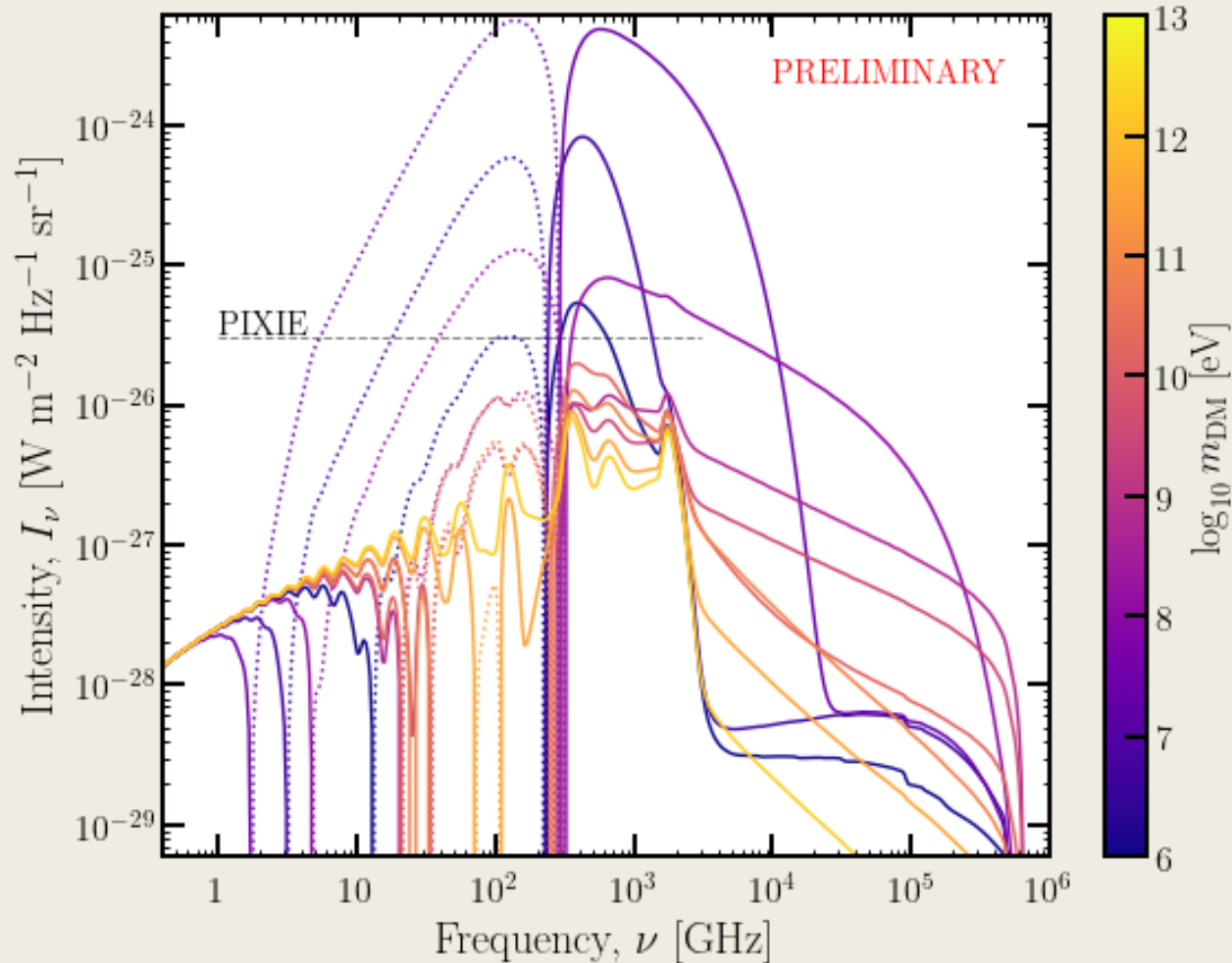


RESULTS



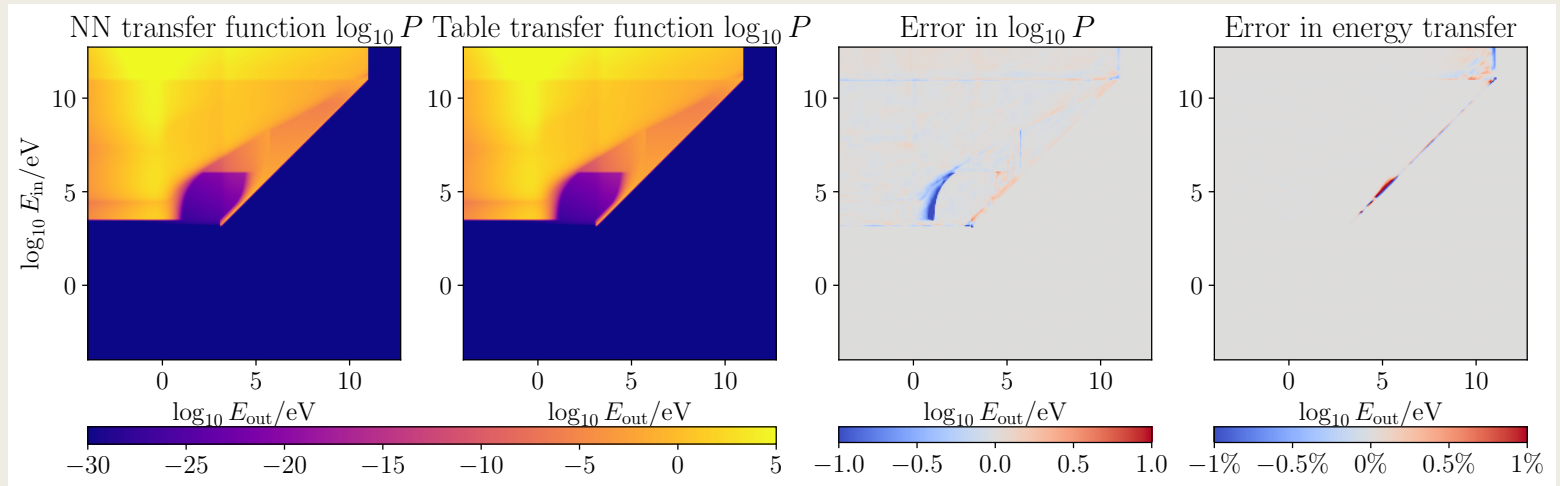
Preliminary results

Decay to e⁺e⁻ pairs



Future work

- Non-thermal distortions are a necessary ingredient to studying dark matter effects on **star formation** and **21cm cosmology**
- Compact version of the **DarkHistory** code with **machine learning** (Yitian Sun)



Summary

- Dark matter interactions with Standard Model can deposit energy into photon bath → CMB spectral distortions
- We've updated the **DarkHistory** code to study the contribution to this effect from after recombination
- This is a useful step for future studies of dark matter effects on star formation and 21 cm cosmology