POST-RECOMBINATION SPECTRAL DISTORTIONS from DARK MATTER ENERGY INJECTION

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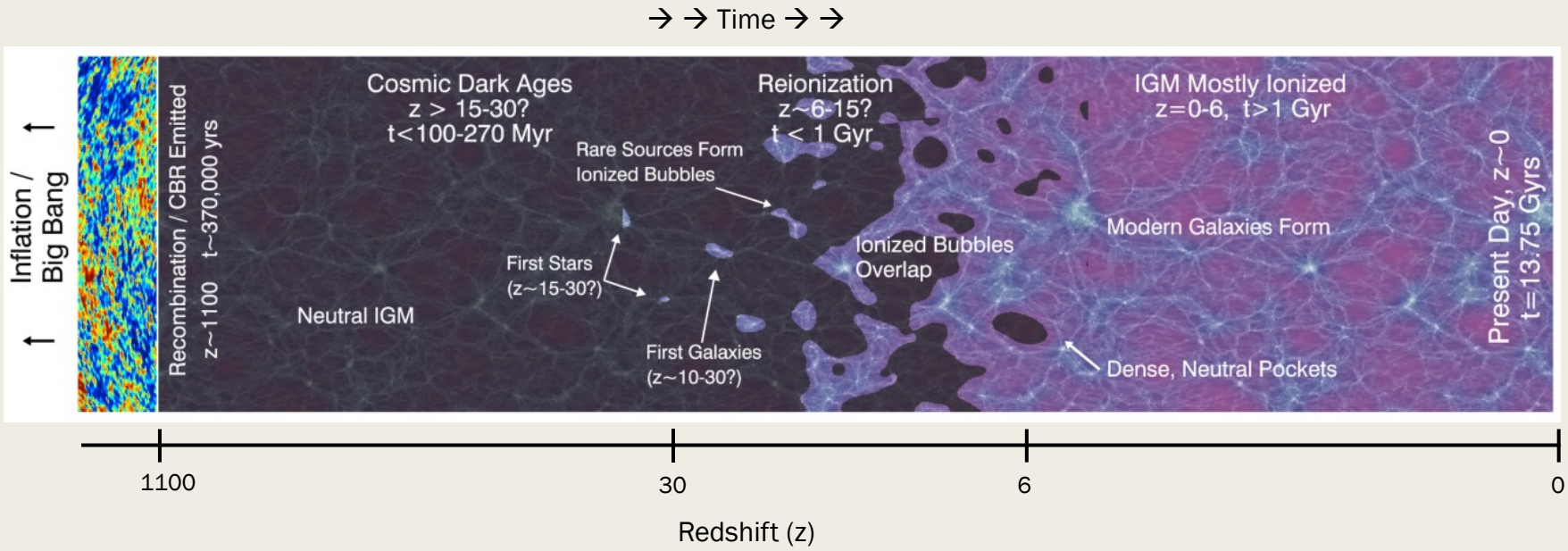
Outline

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

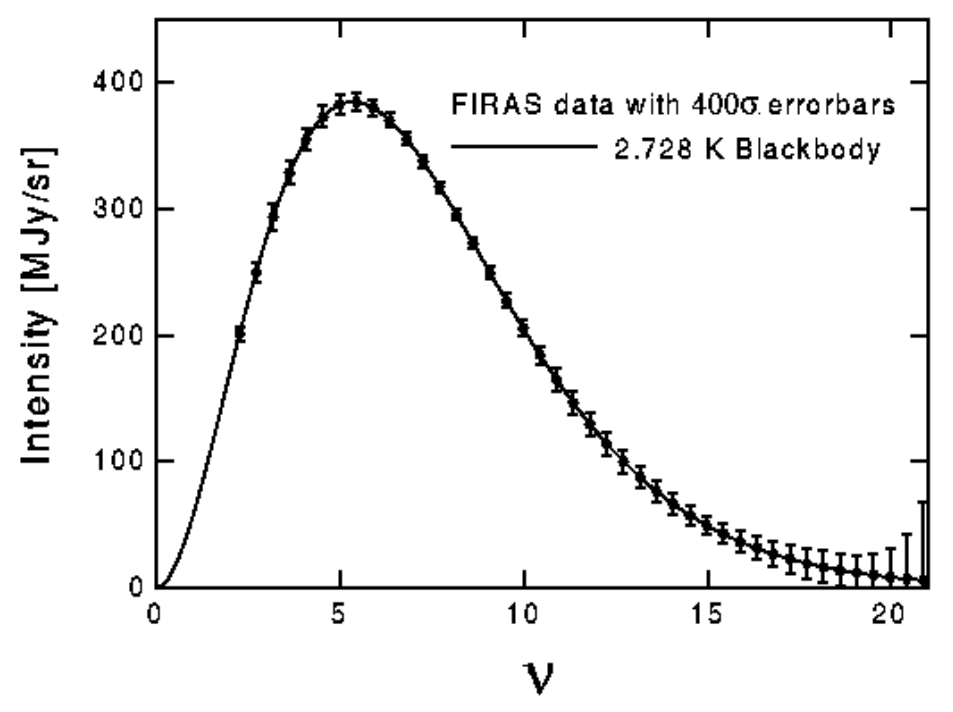
Timeline of the early universe



Robertson et al. (2010)

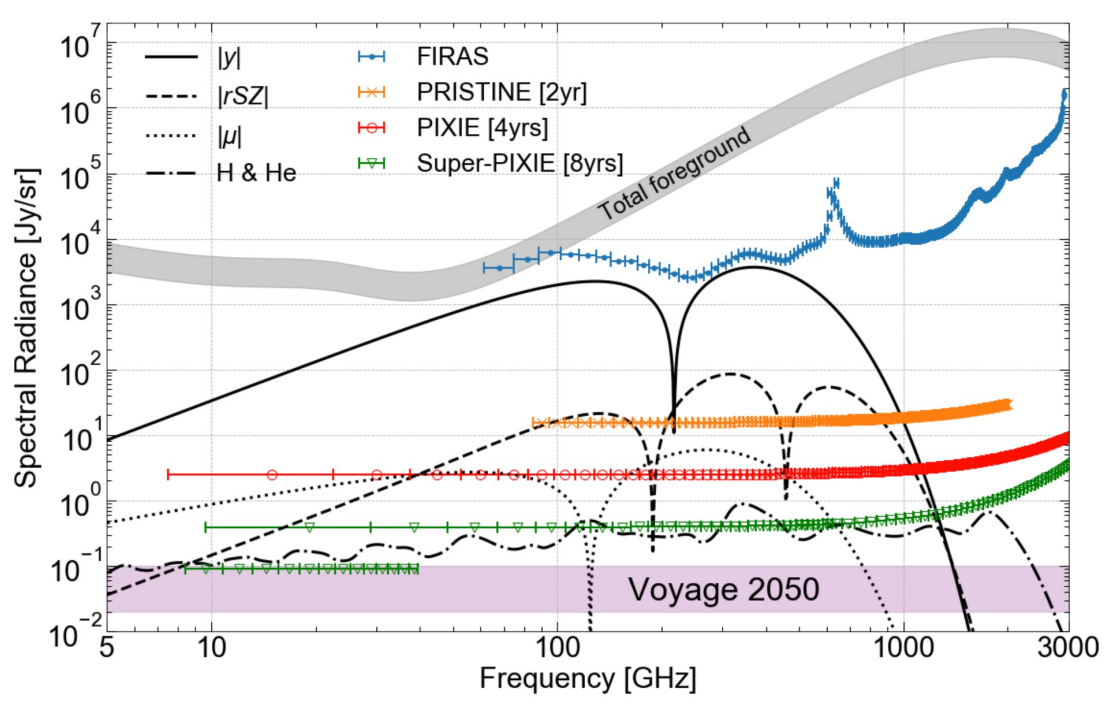
Spectral distortions

- 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*
  - *Reionization/structure formation*
  - *Thermal SZ effect*
  - *Adiabatic expansion*
  - *Dark matter*



Chluba et al. (2019)

How to form a distortion?

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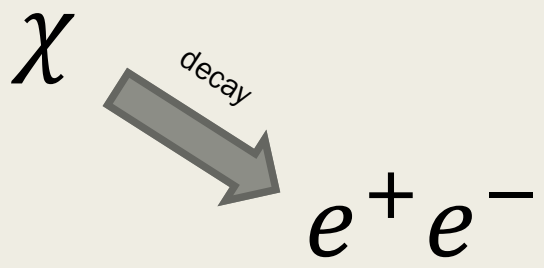

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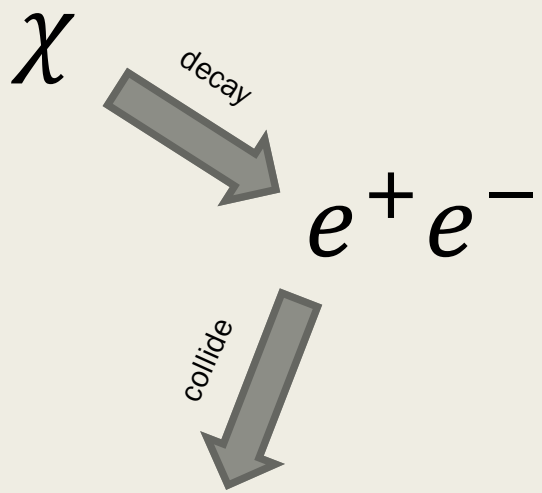
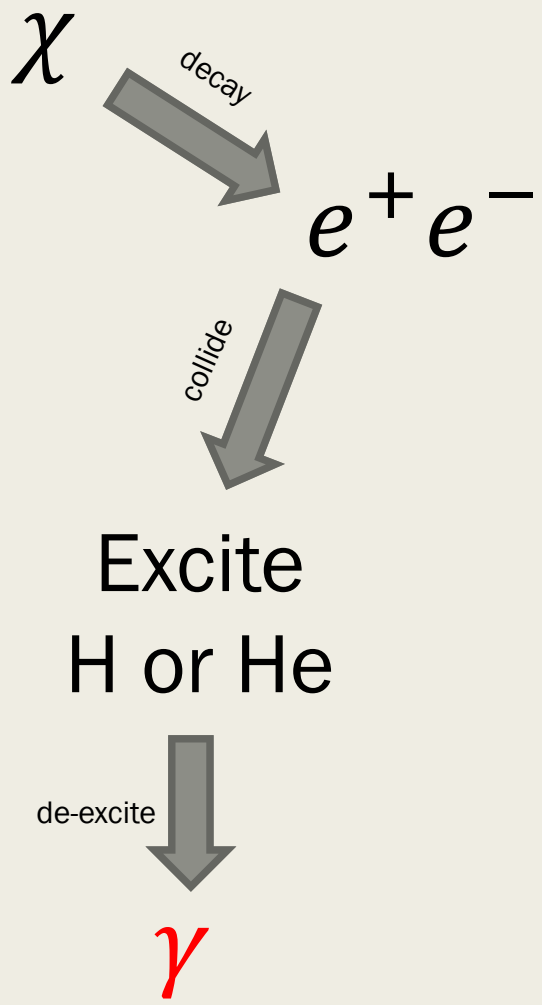


Excite
H or He

How to form a distortion?



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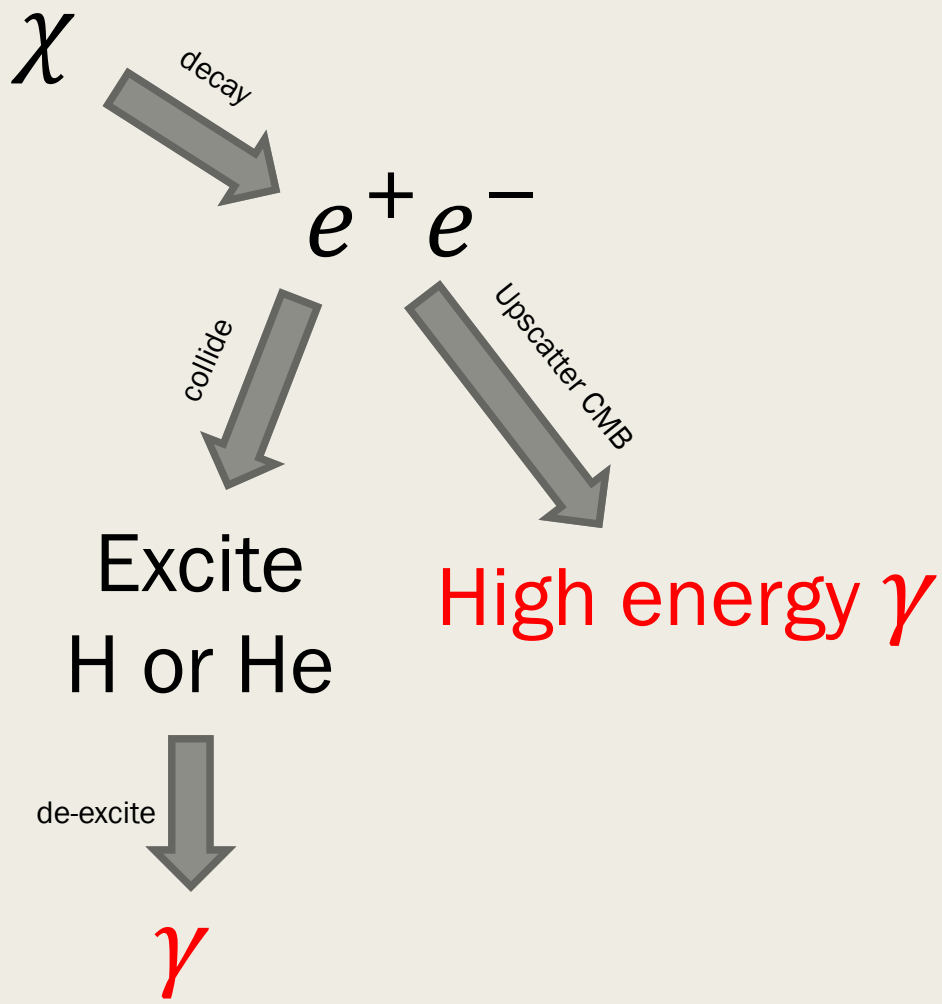

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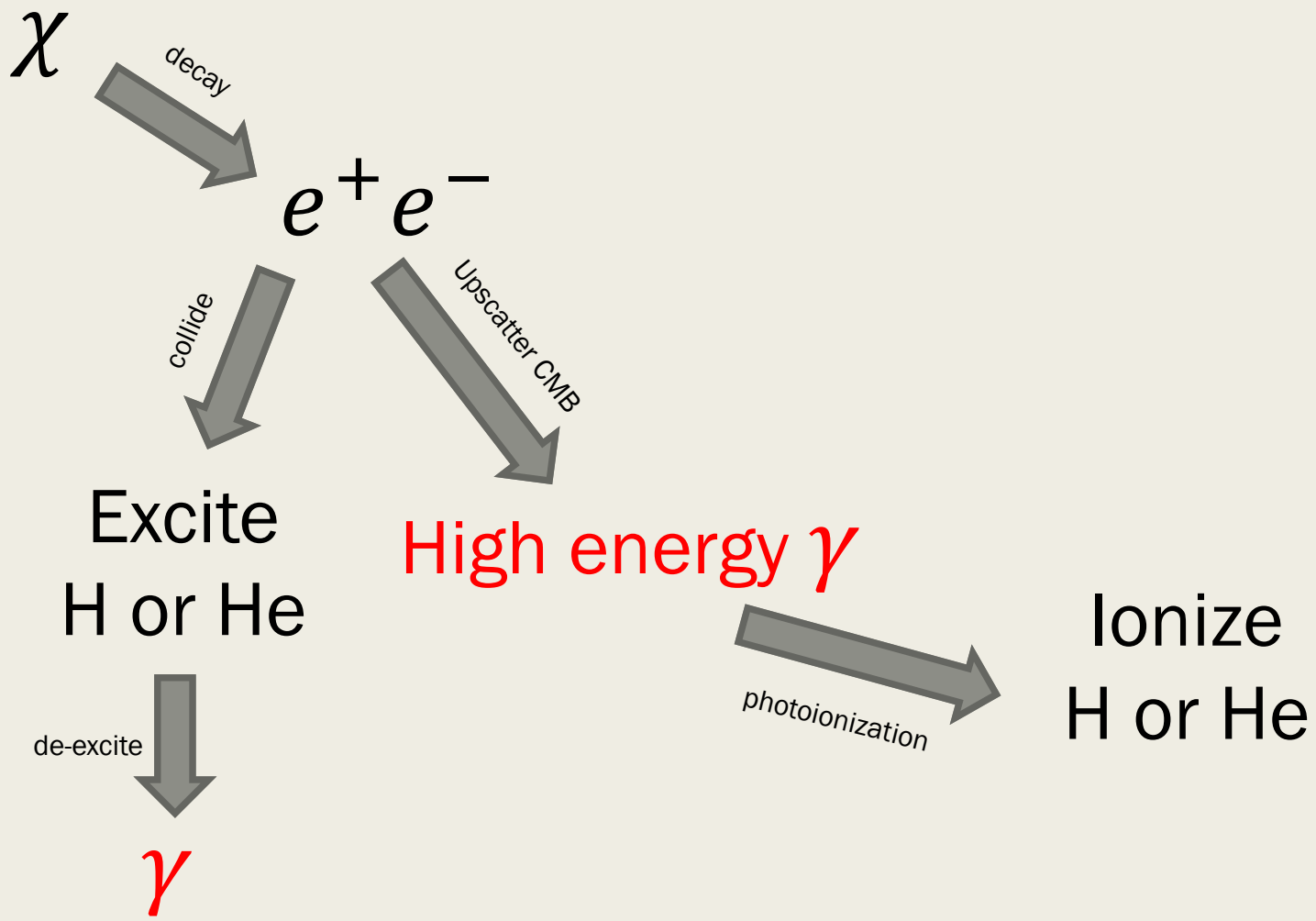

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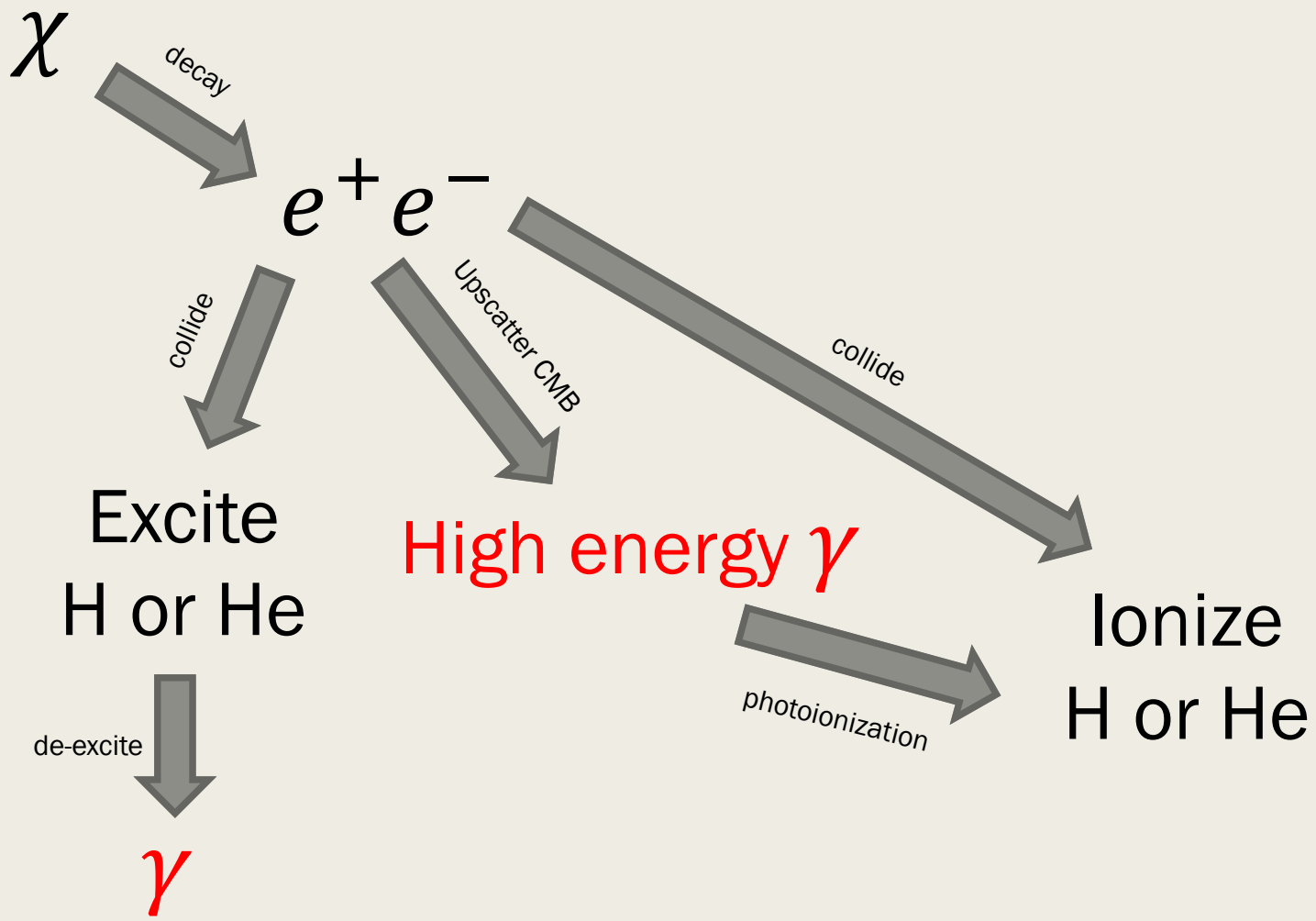

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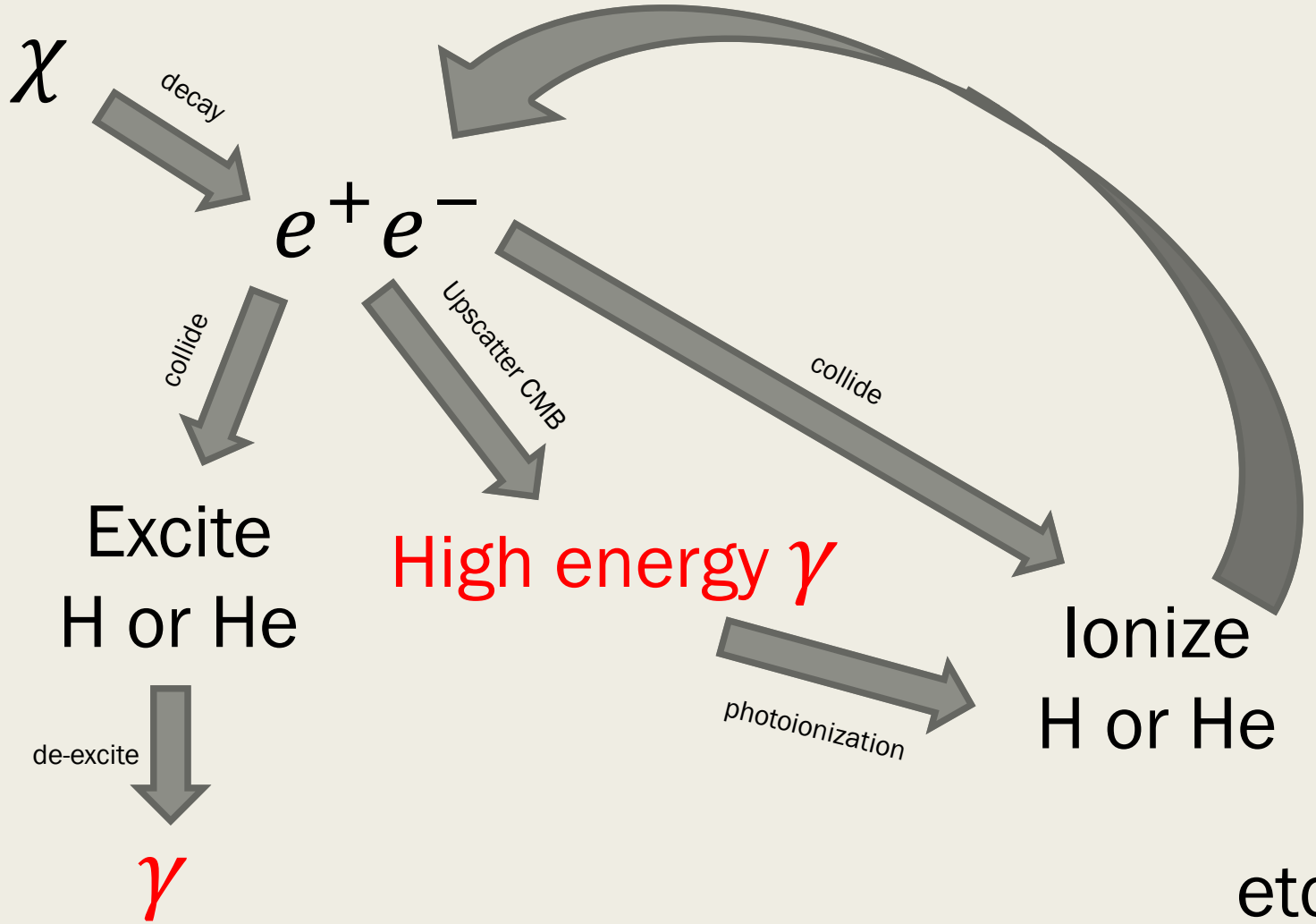
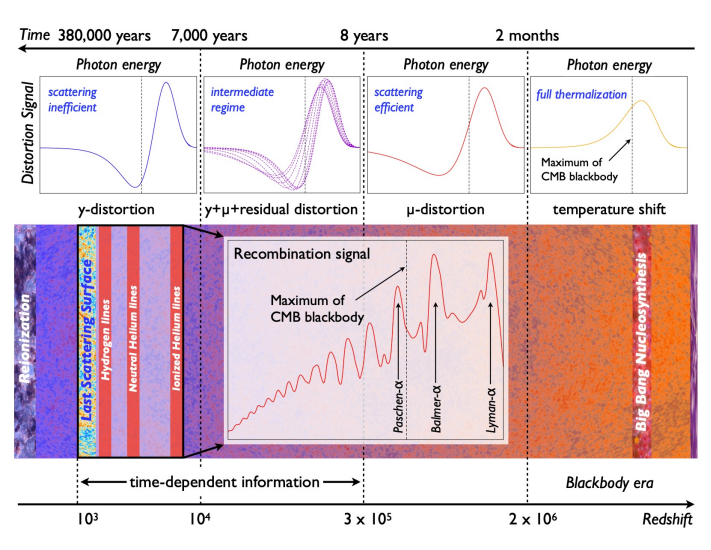


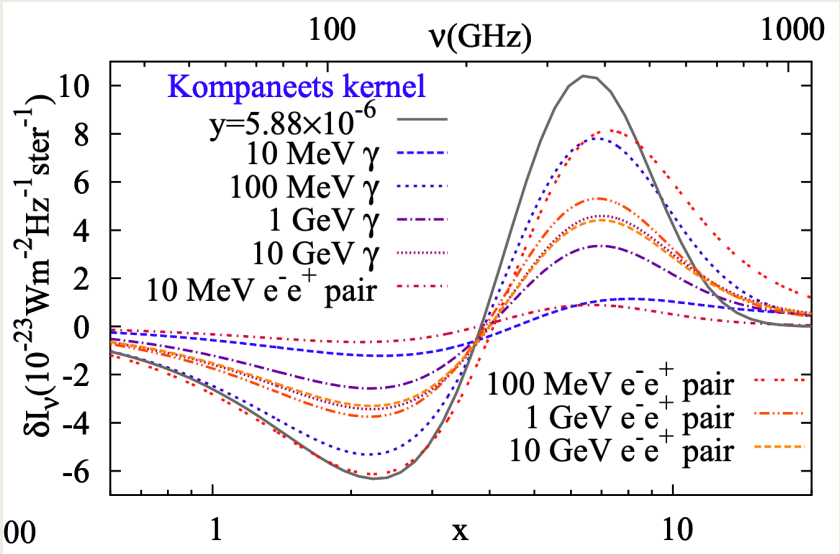
etc...

Pre-recombination

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



Chluba et al. (2019)

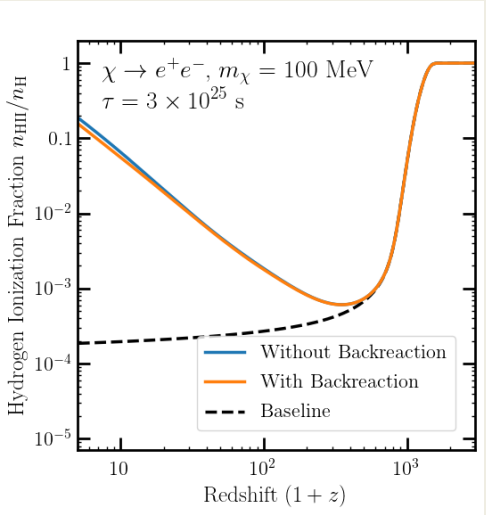


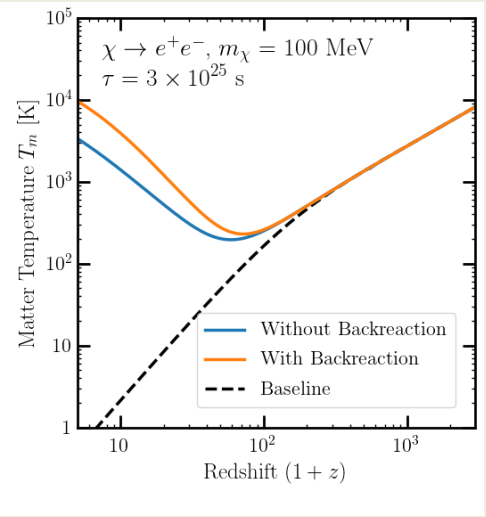
Acharya & Khatri (2019)

DarkHistory

DarkHistory

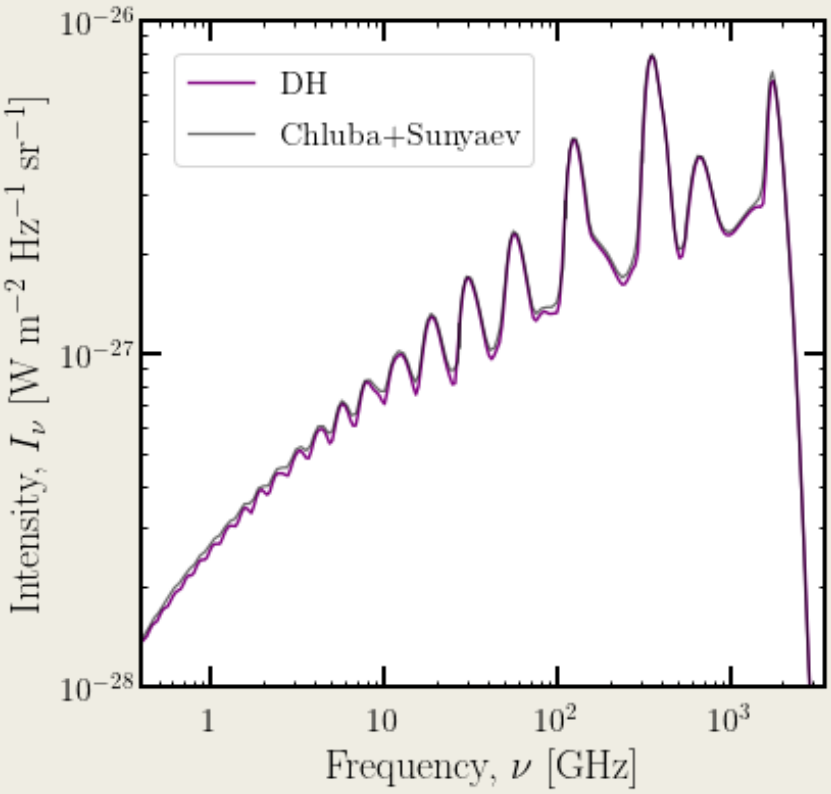
- Python code package
  - *Download at* https://github.com/hongwanliu/DarkHistory/
- Simultaneously solves for evolution of free electron fraction and gas temperature, including exotic sources of energy injection
- Accounts for ‘backreaction’, where changes in ionization/temperature modify subsequent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





Distortions with DarkHistory

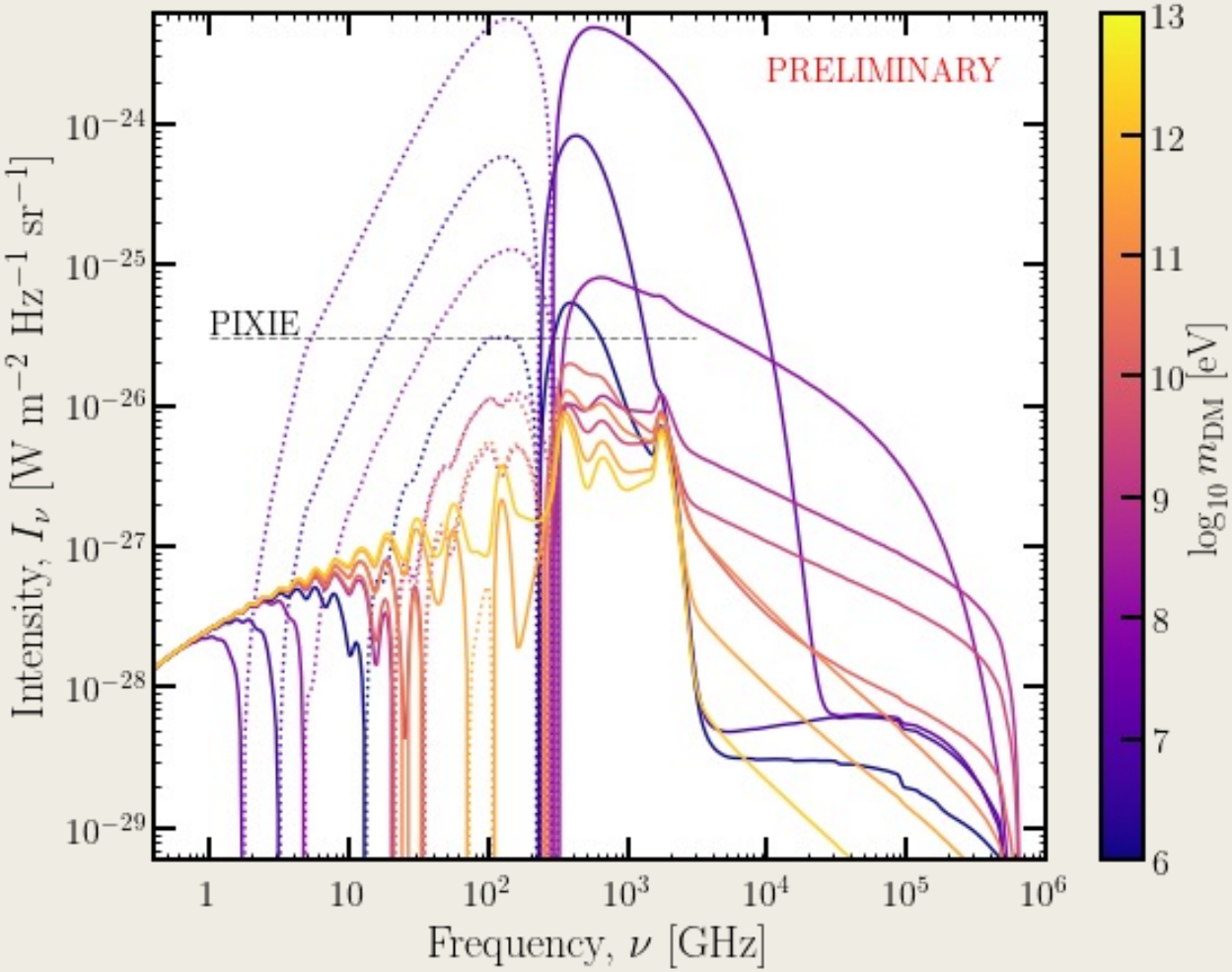
- Low energy electrons (< 3 keV)
  - *Previously resolved deposited energy as integrated energy deposited into different channels*
  - *For distortion, we need energy per bin*
- Atomic transitions
  - *Previously assumed three-level atom for hydrogen*
  - *Now keep track of arbitrary # of levels*



RESULTS

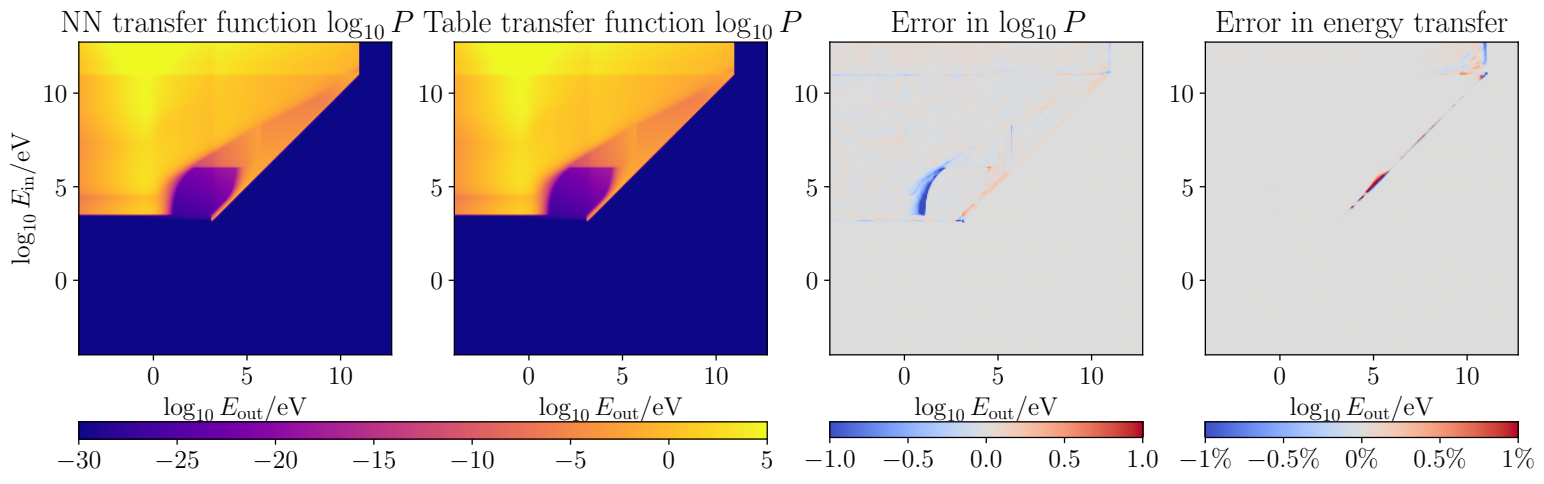
Preliminary results

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