



DarkHistory: Modeling Early Universe Energy Injection with Dense Neural Networks

Yitian Sun

with Wenzer Qin, Gregory Ridgway,
Hongwan Liu, and Tracy Slatyer

2207.06425

■ IDM 2022 | Jul 19th

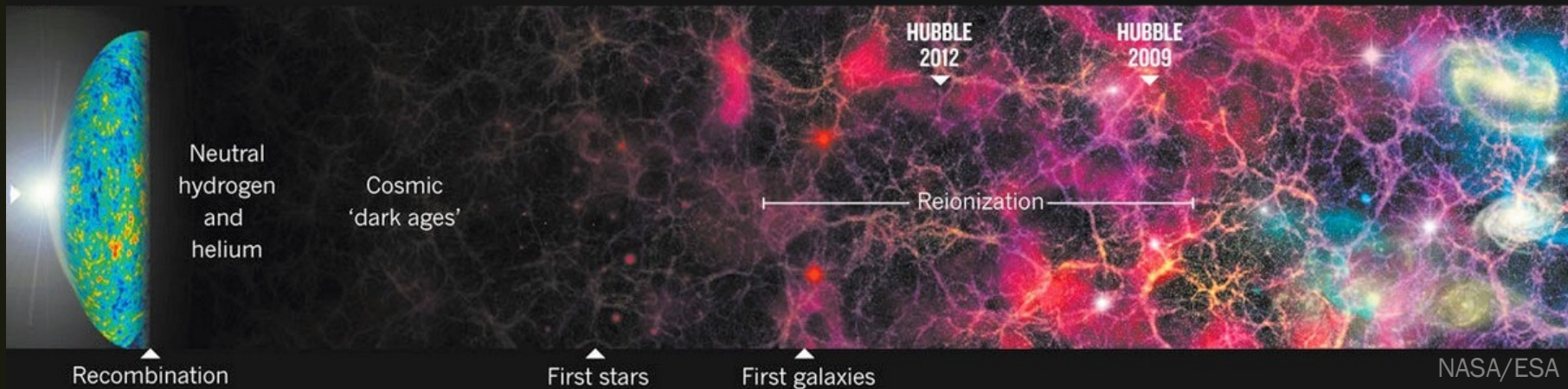
Outline

- Timeline of the early universe.
- **DarkHistory**, early universe energy injection, particle interactions and transfer functions.
- Dense Neural Networks as transfer functions.

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Timeline of the early universe

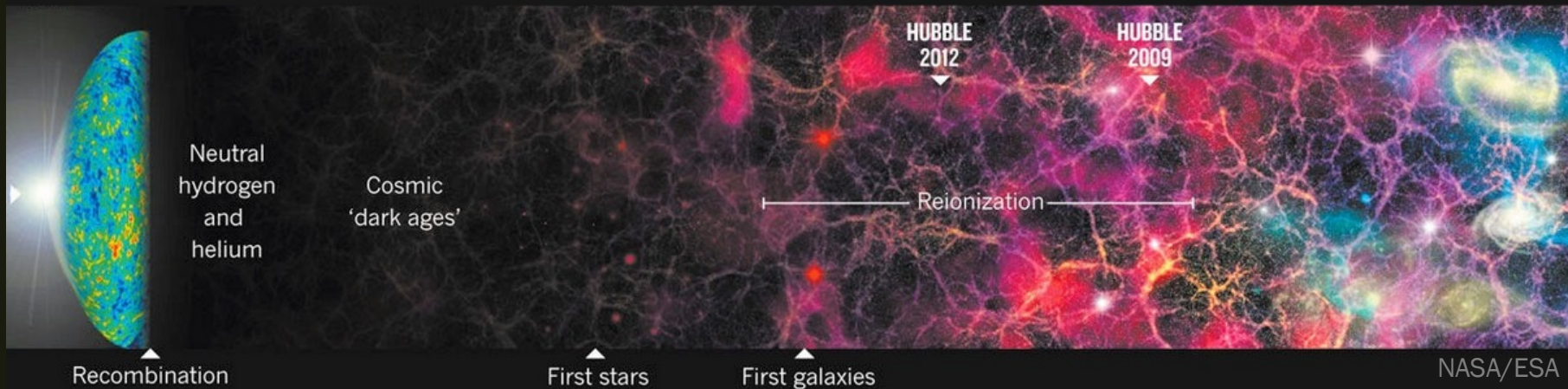


$z \sim 1100$
recombination

$z \sim 15-6$
reionization

$z \sim 0$
present day

Timeline of the early universe



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recombination

$z \sim 15-6$

reionization

$z \sim 0$

present day

Dark Matter & exotic energy injection can modify:

- gas temperature
- ionized hydrogen fraction
- ionized helium fraction (for us: singly ionized helium)

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1904.09296

python code package at
github.com/hongwanliu/DarkHistory

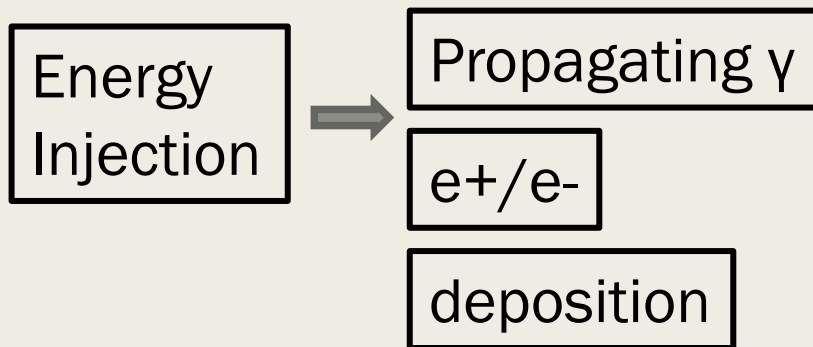
Evolves from $1+z = 3000$ to 4.

DarkHistory

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For each redshift step:

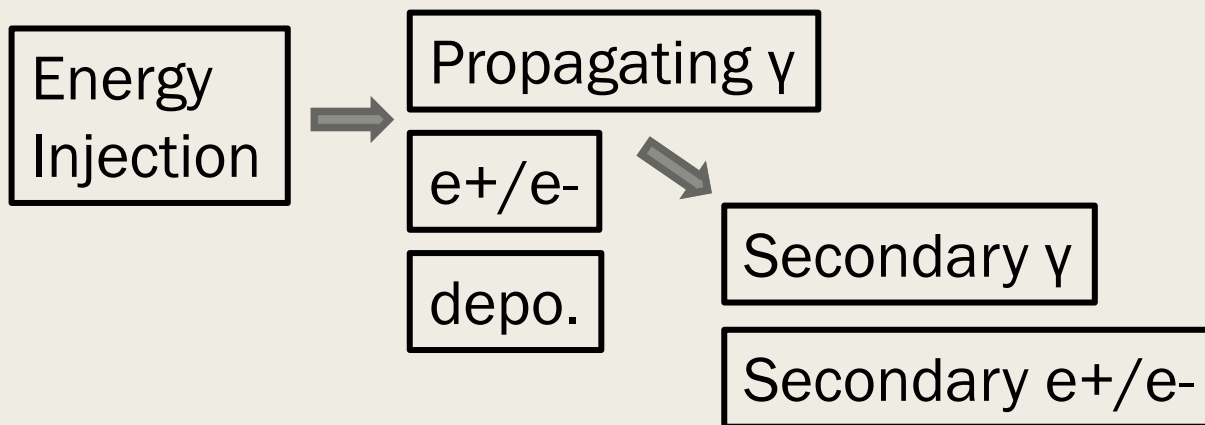


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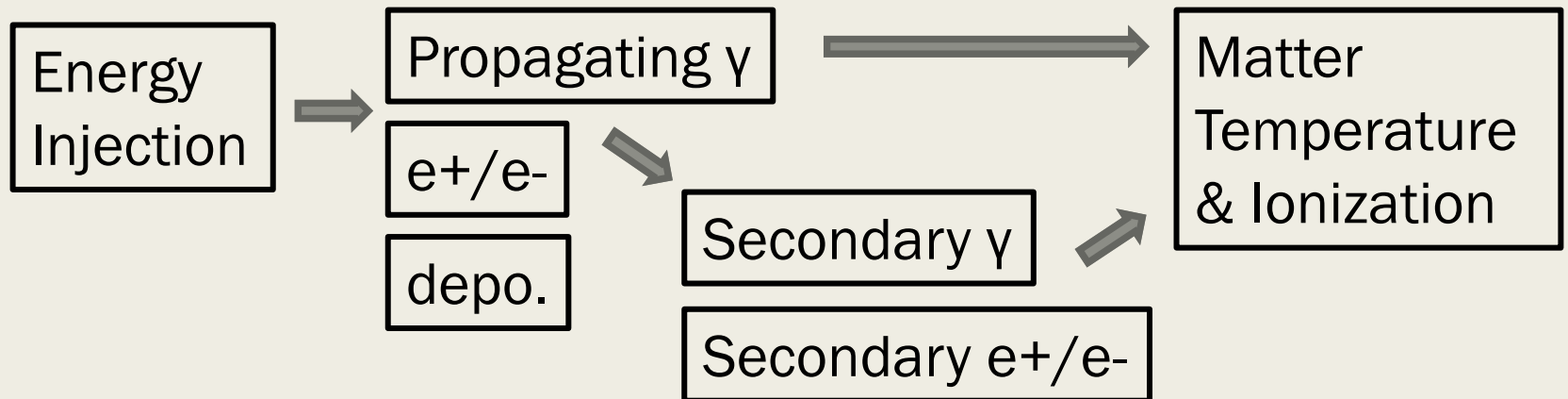
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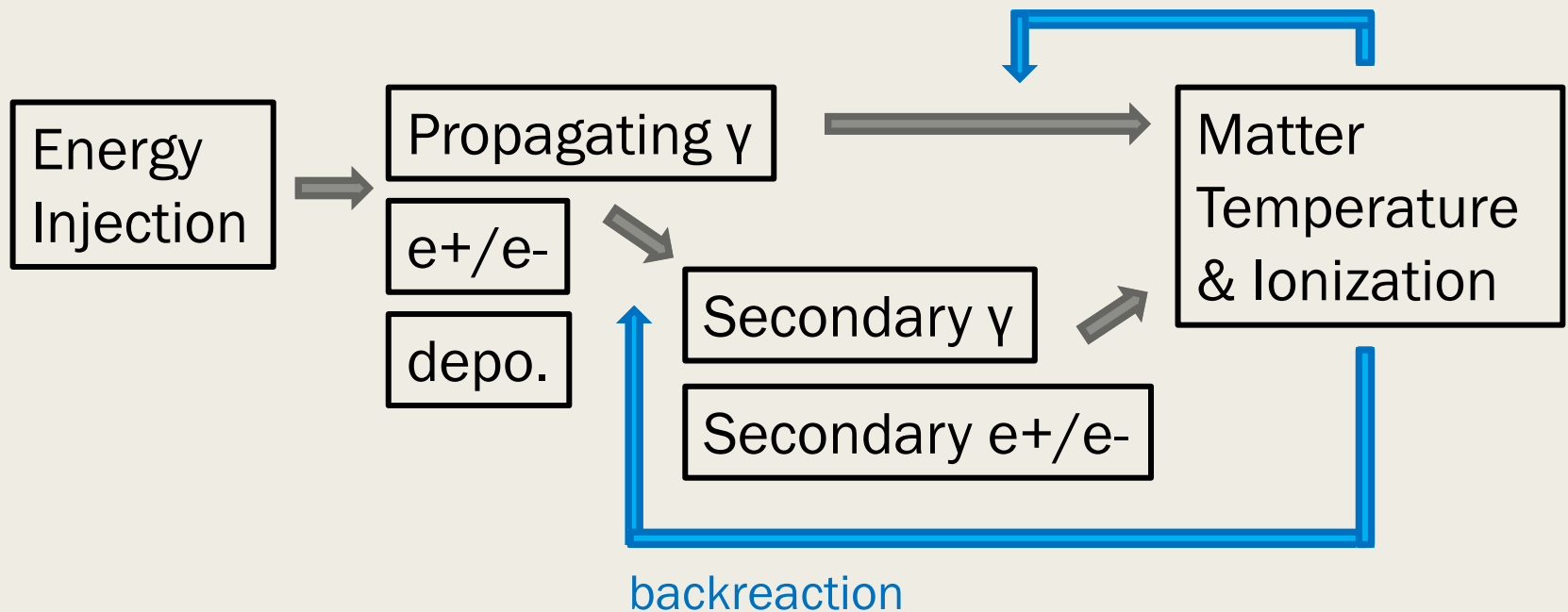


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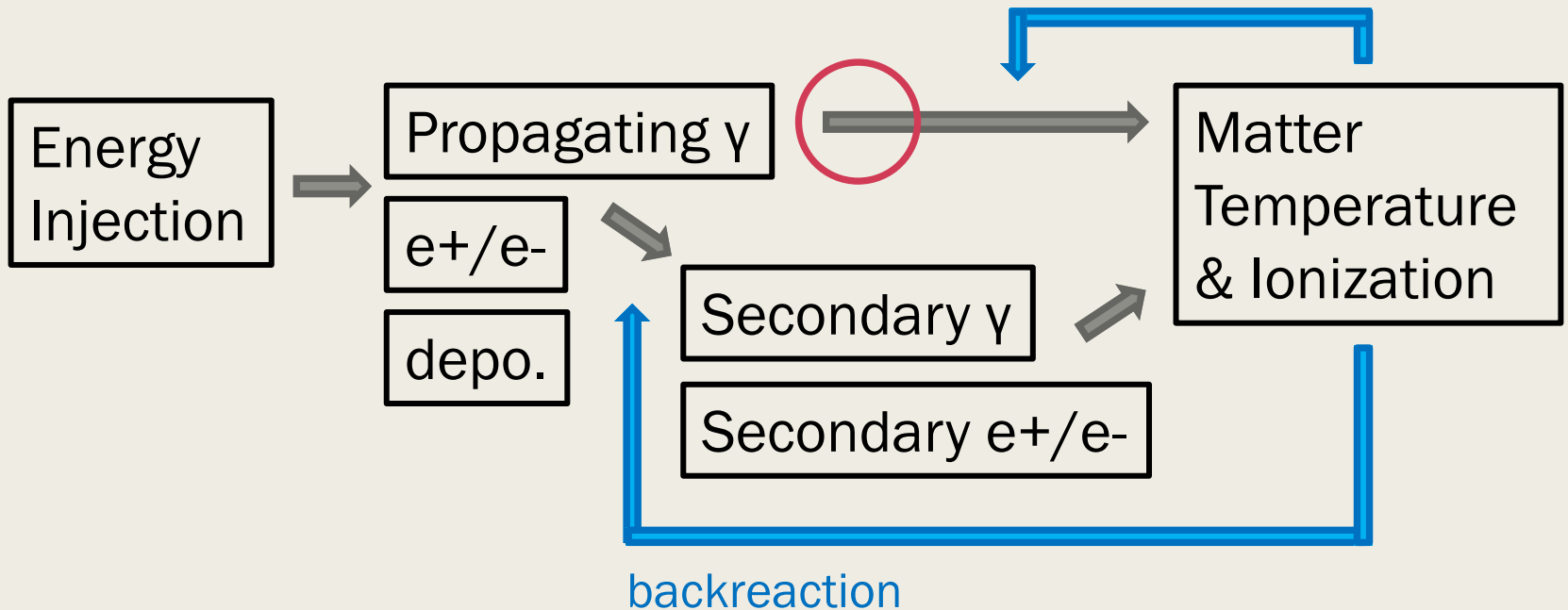


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γ : Compton scatter $\rightarrow e^+/-$
Pair produce $\rightarrow e^+/-$
Ionize & excite matter.
Do nothing (redshift) ...



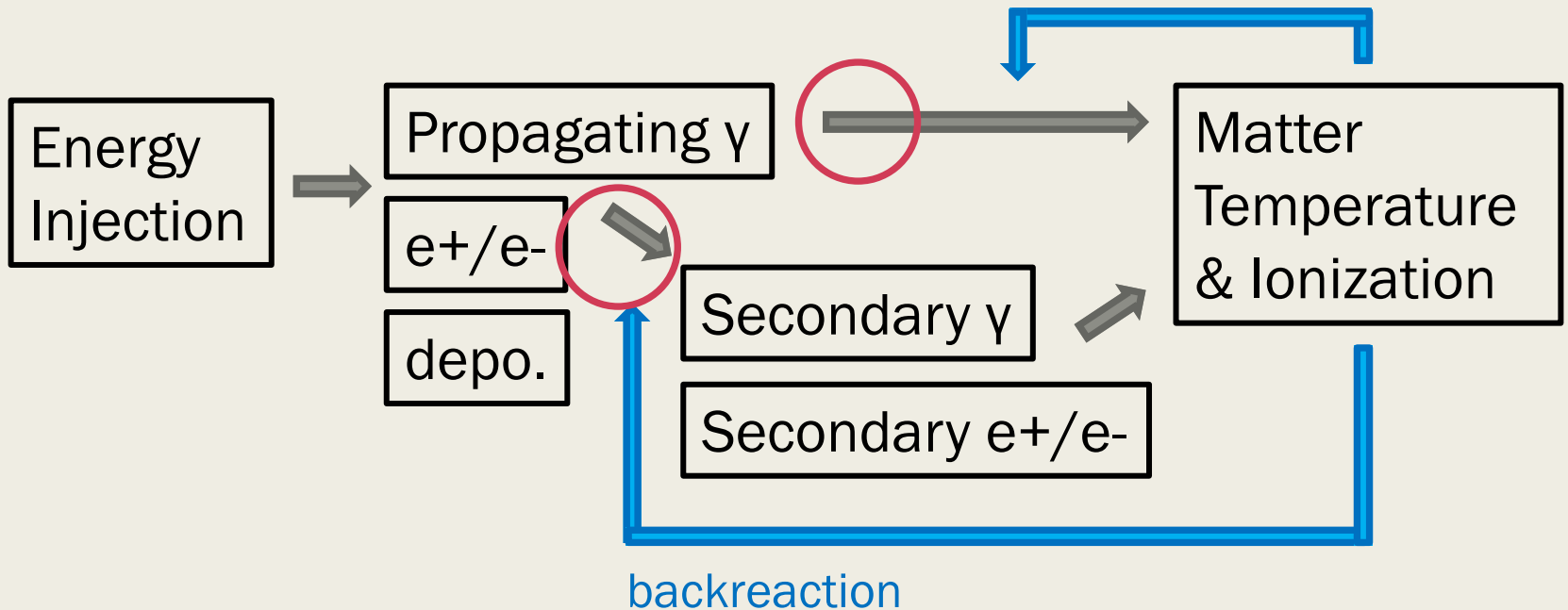
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$e^+/-$: Inverse Compton scatter \rightarrow γ
Annihilate \rightarrow γ
Heat up matter ...



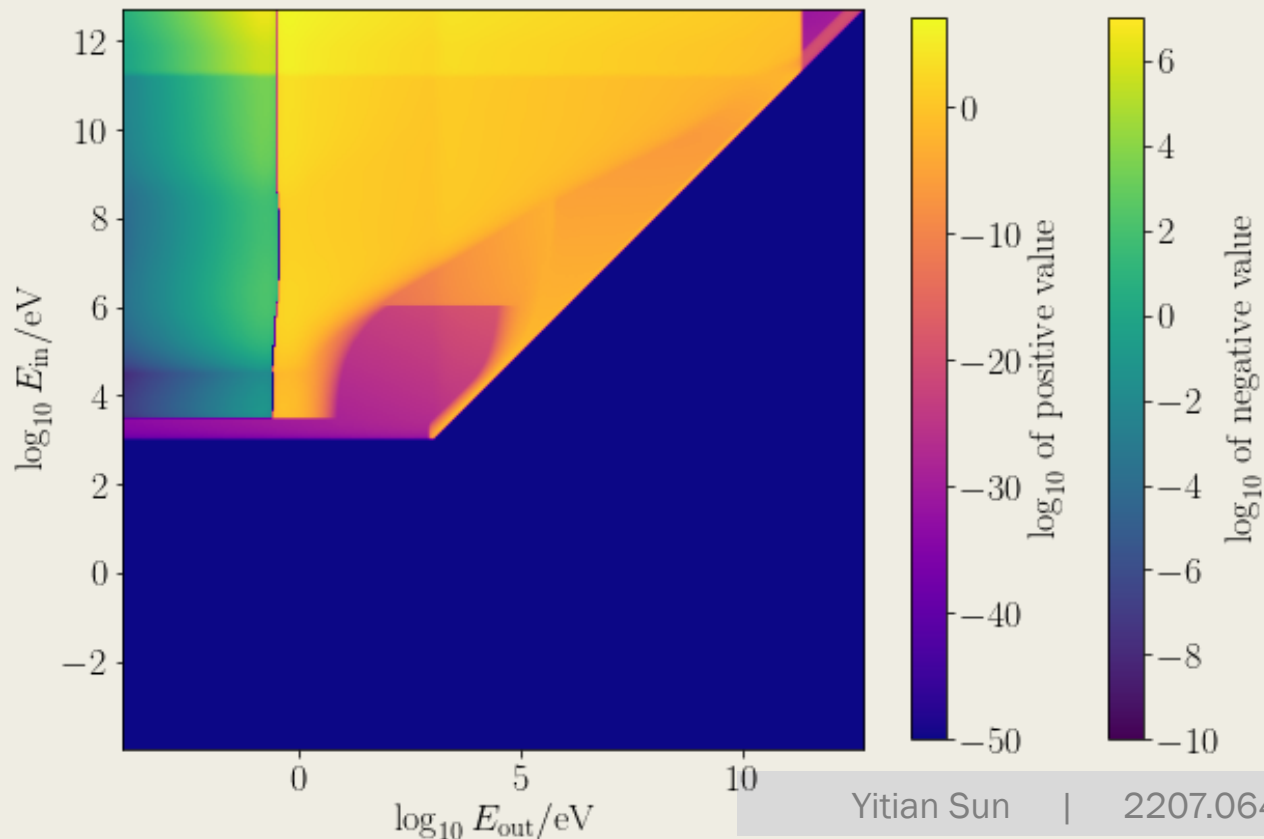
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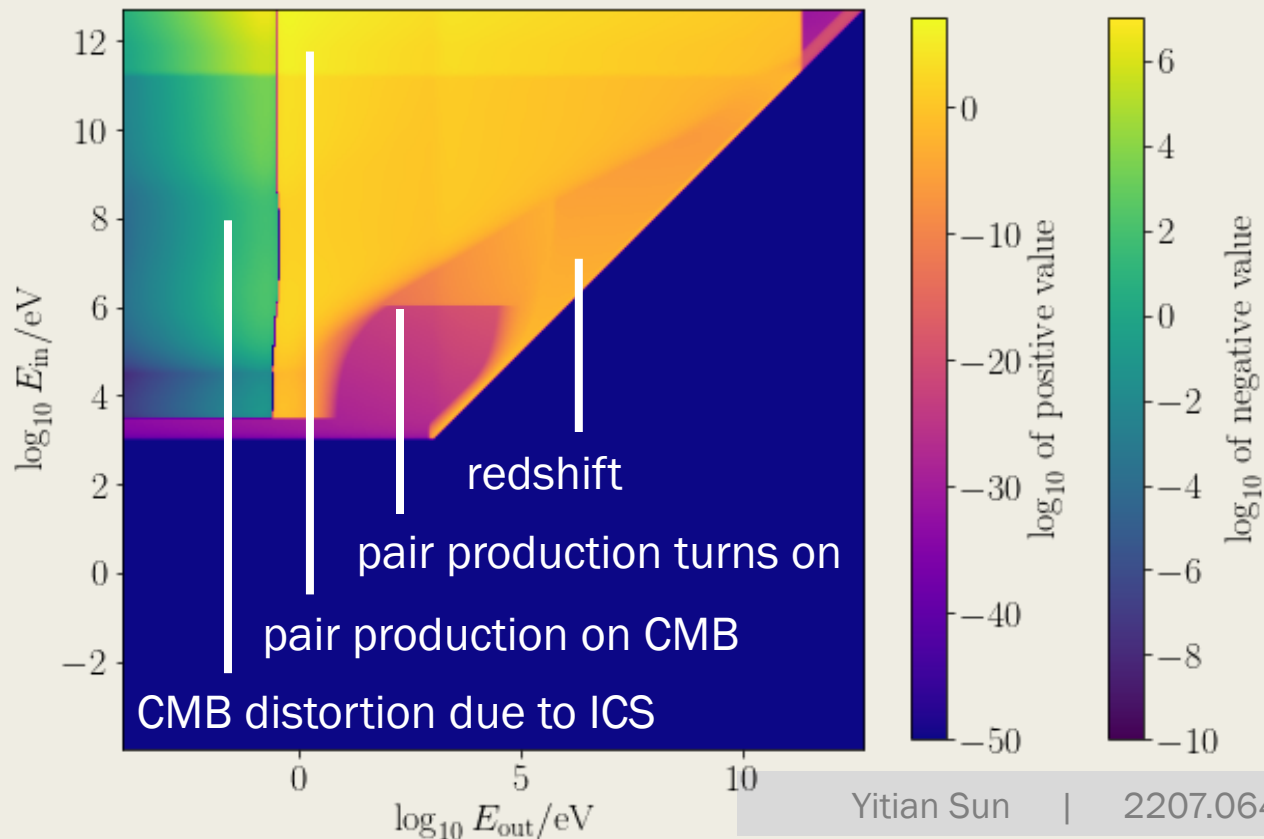
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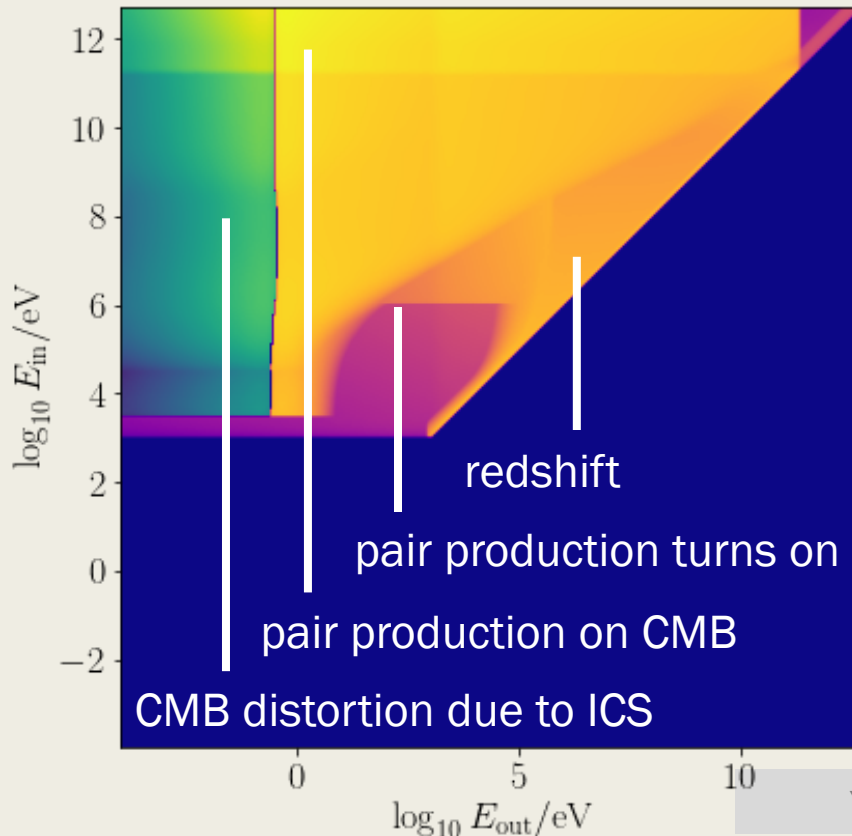
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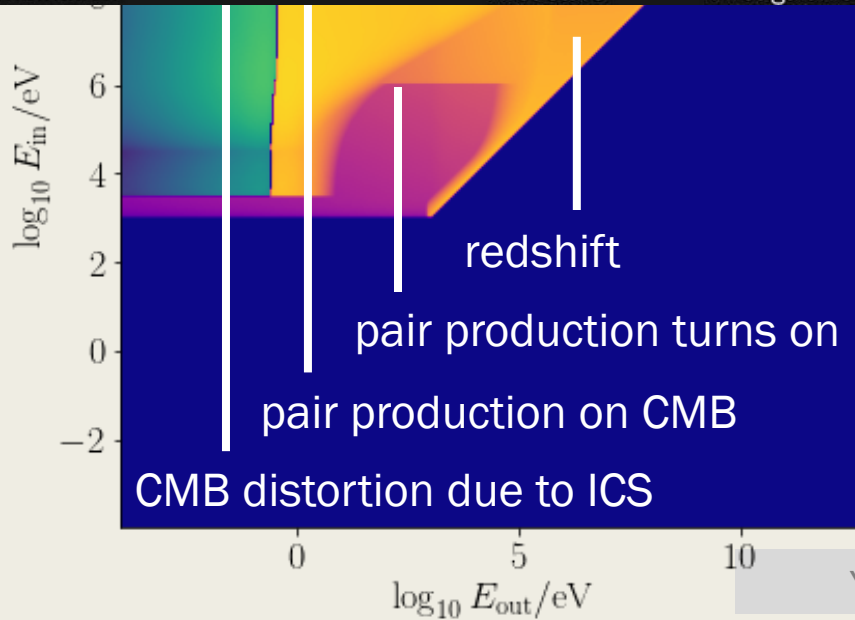
Function of

- redshift
- ionized hydrogen fraction
- (singly) ionized helium fraction
- ...?

DarkHistory

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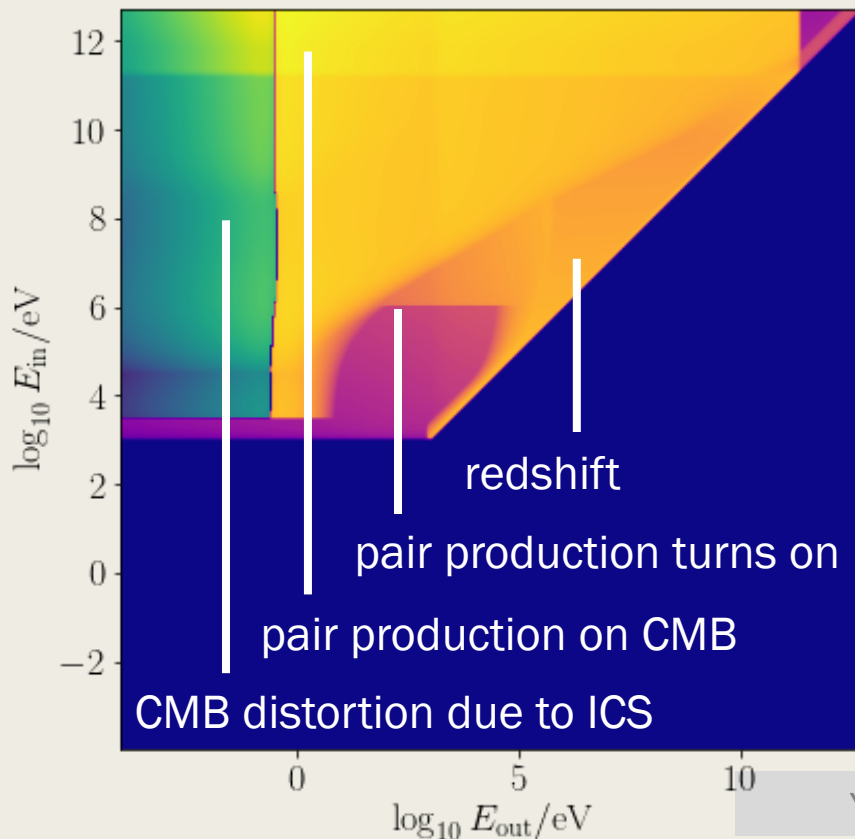
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Heat up matter ...



Function of

- redshift
- ionized hydrogen fraction
- (singly) ionized helium fraction
- gas density
- ...

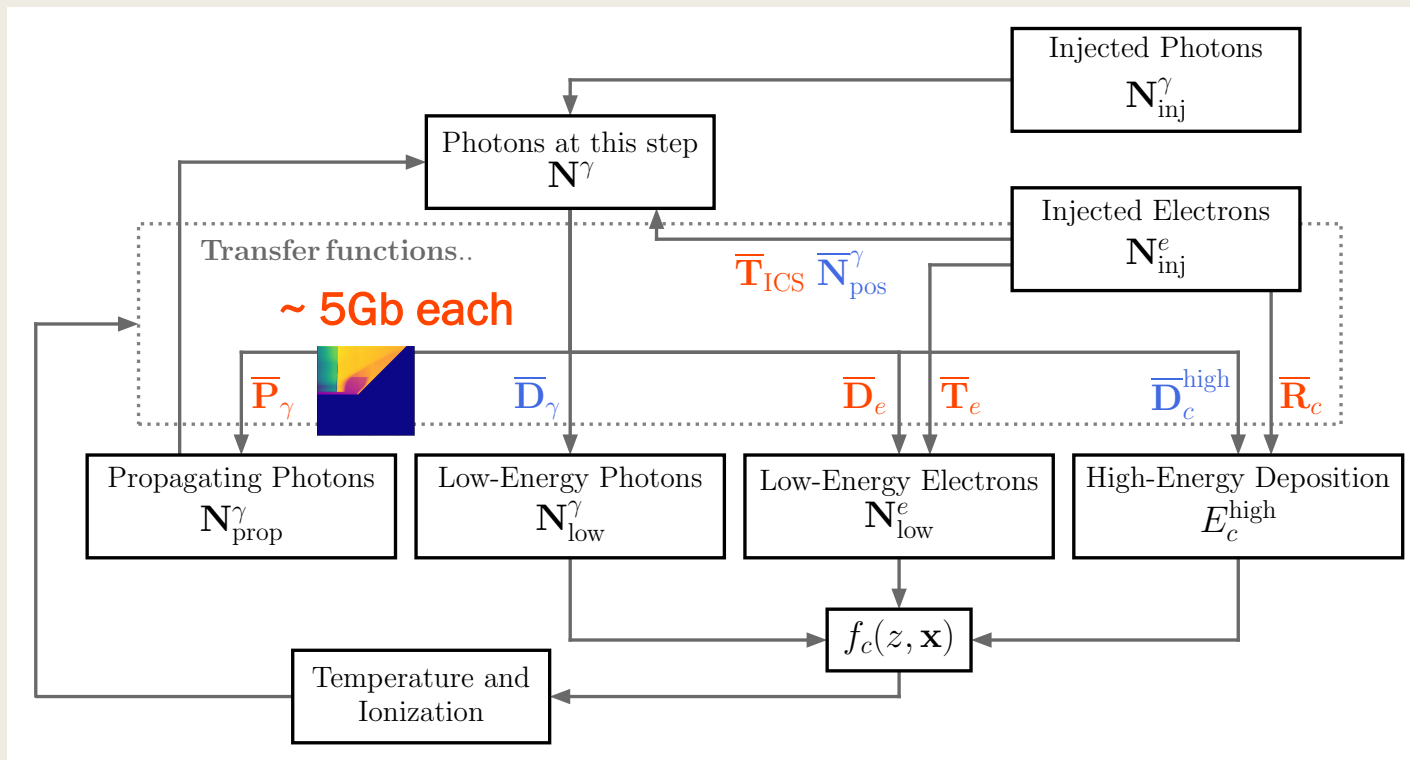
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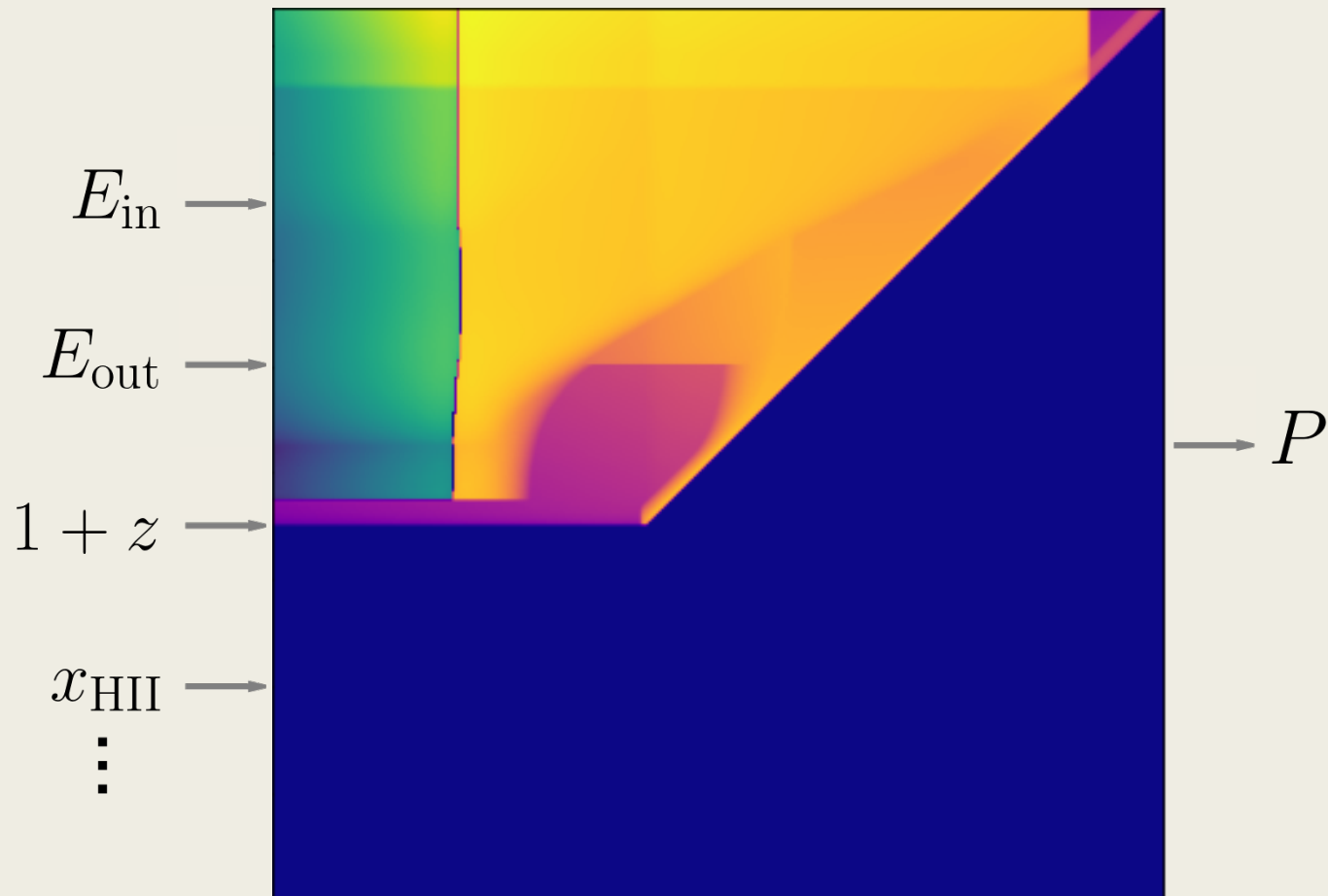
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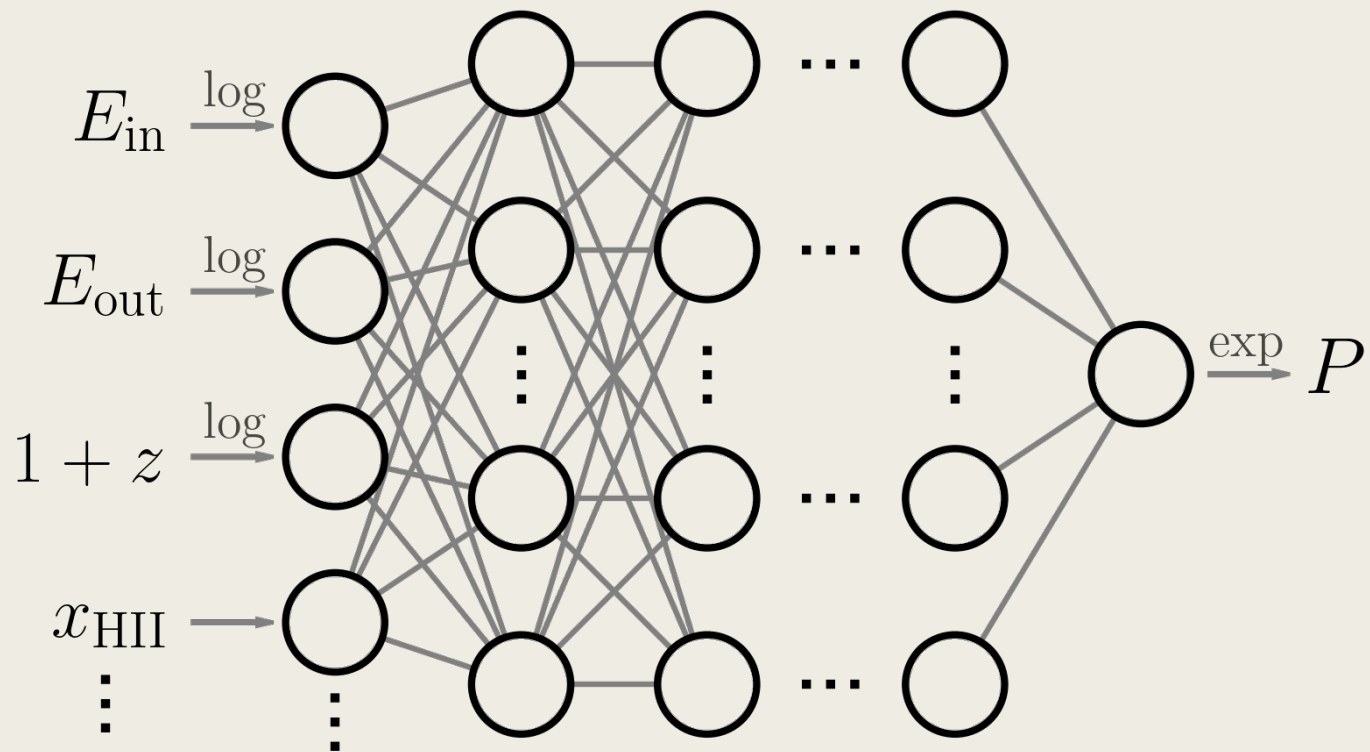
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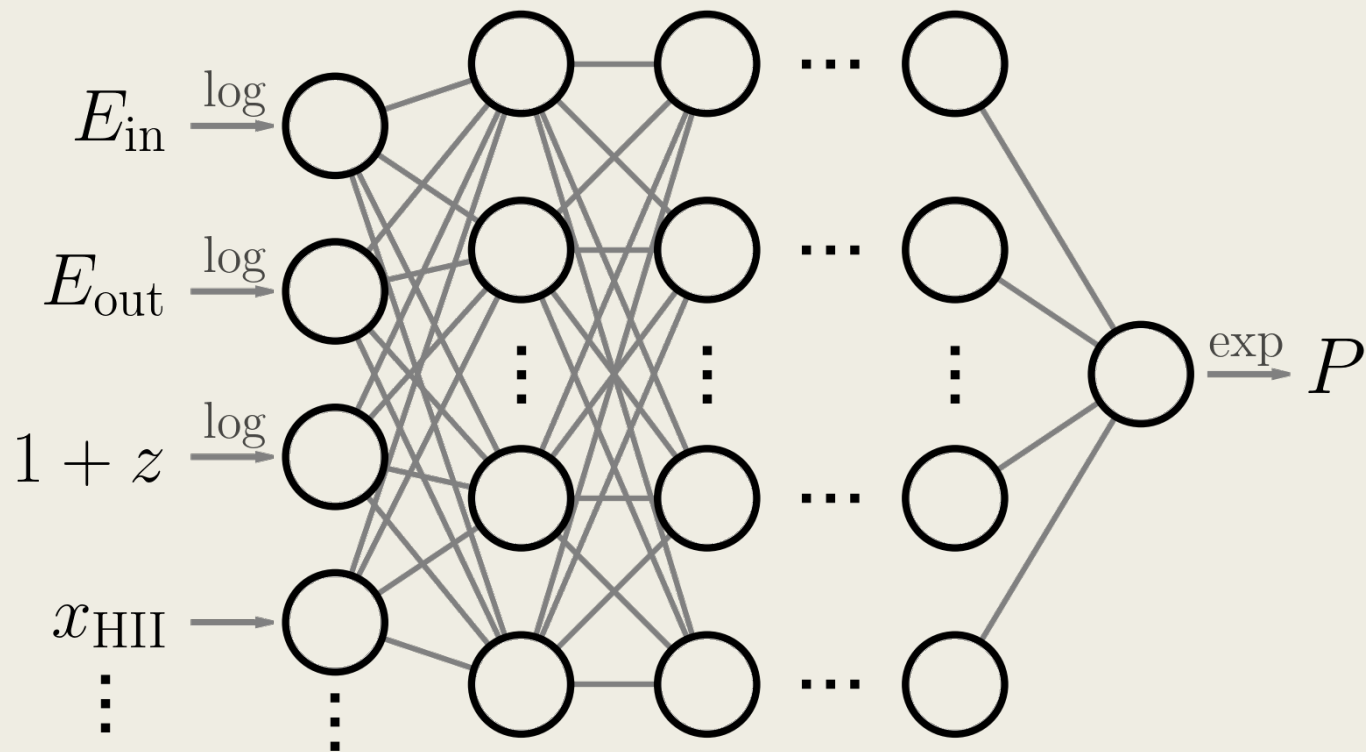
Dense Neural Networks (DNNs) as transfer functions



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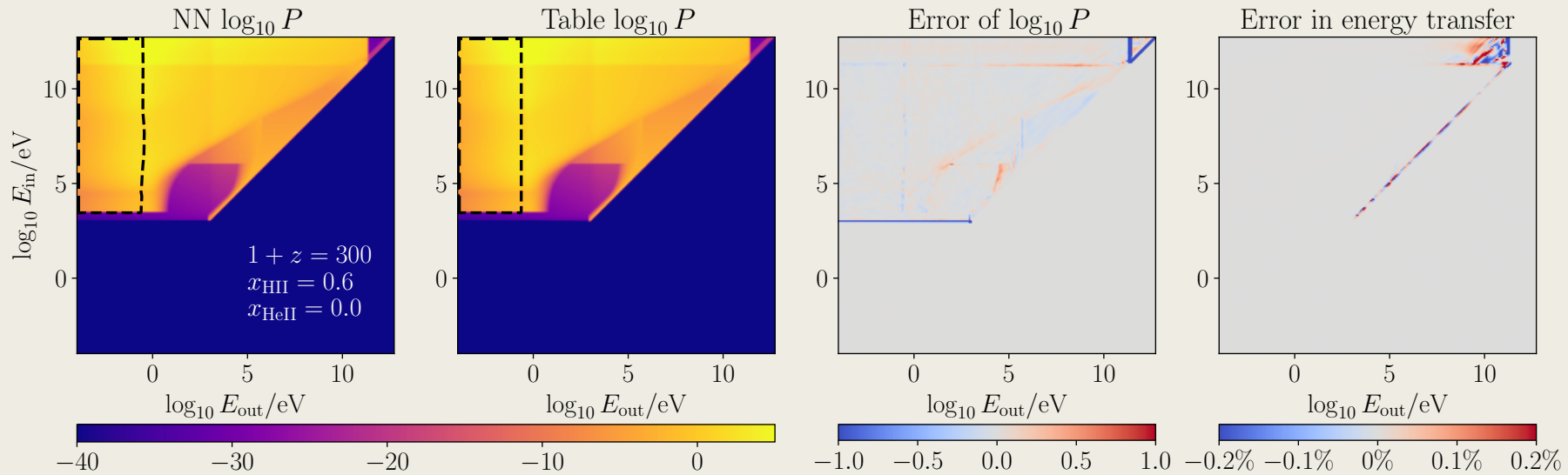
Dense Neural Networks (DNNs) as transfer functions



7 hidden layers, 400 neurons each, <1M parameters

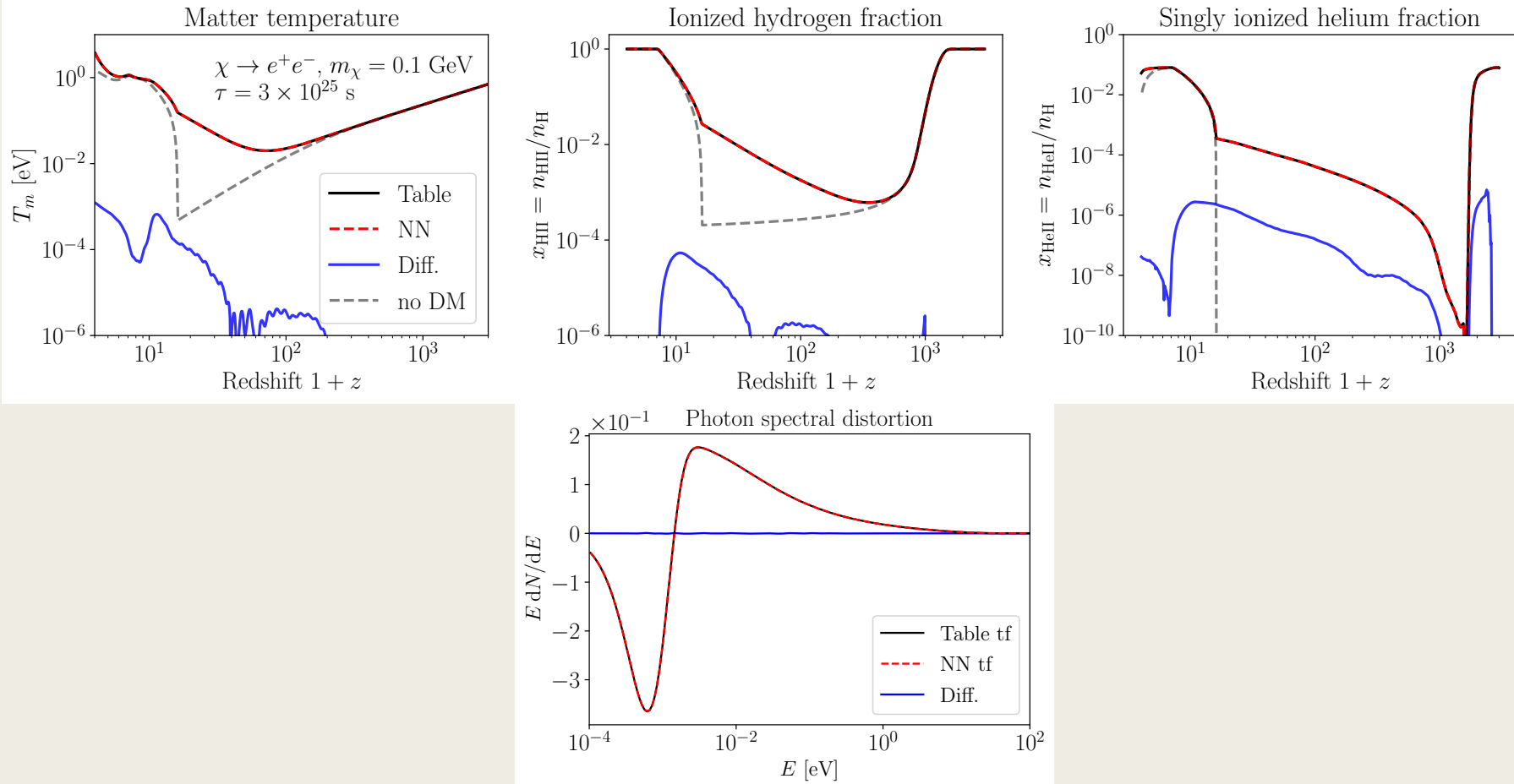
DNN vs Table transfer functions

Single transfer function prediction



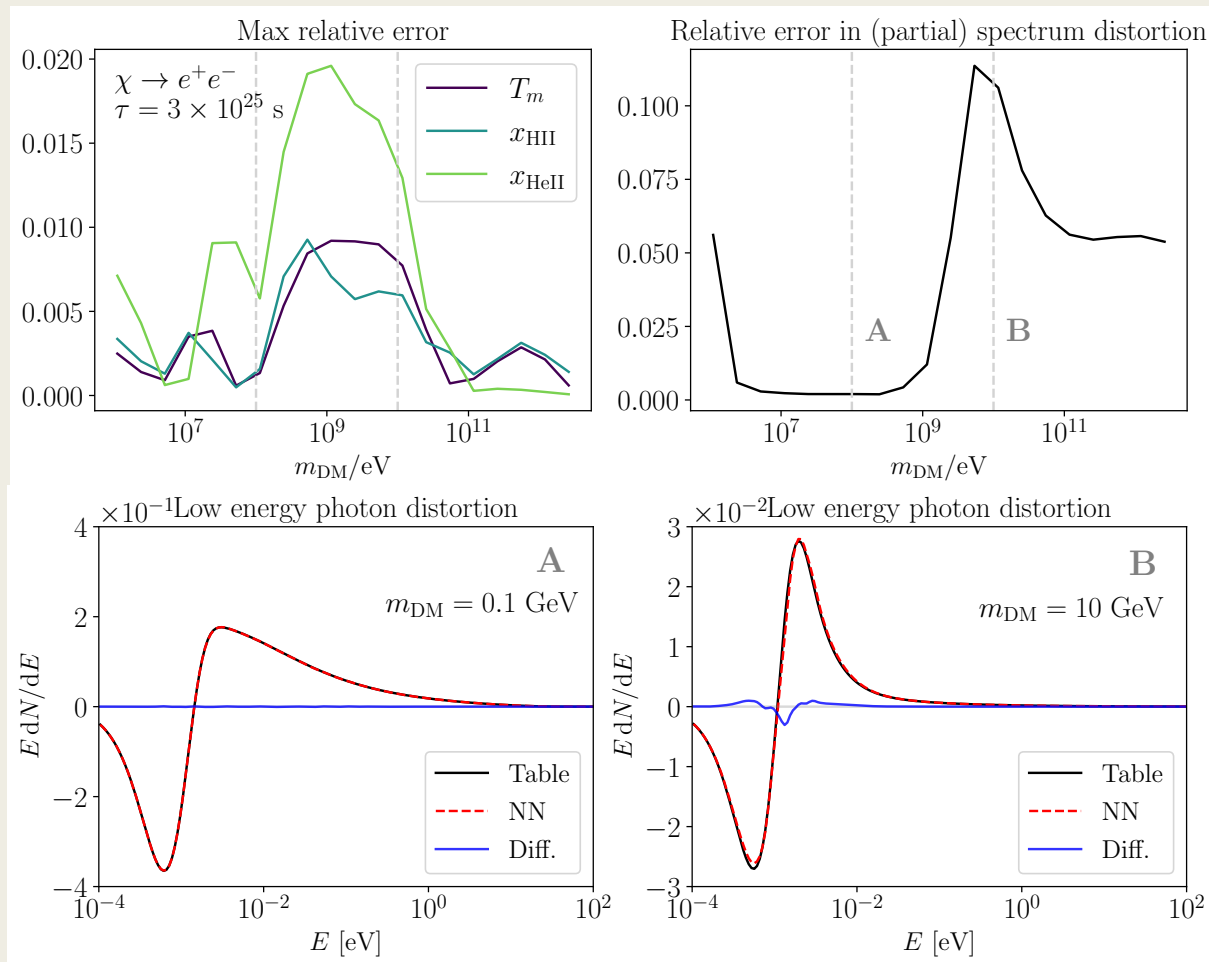
DNN vs Table transfer functions

An example simulation run



DNN vs Table transfer functions

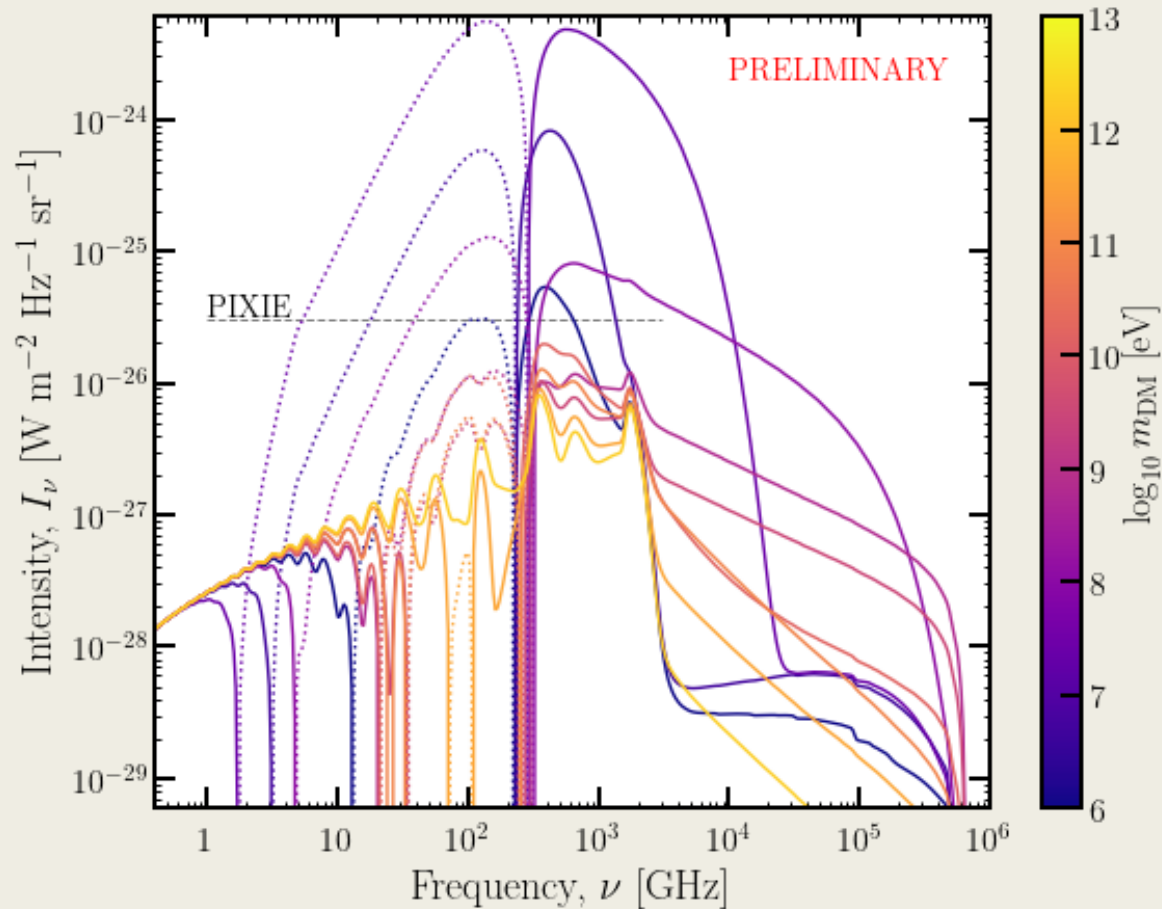
Scan over DM energy injection scenarios



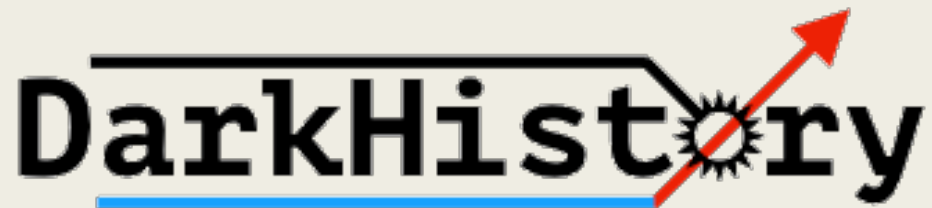
Parallel work: spectral distortions

from low energy electrons and atomic transitions.

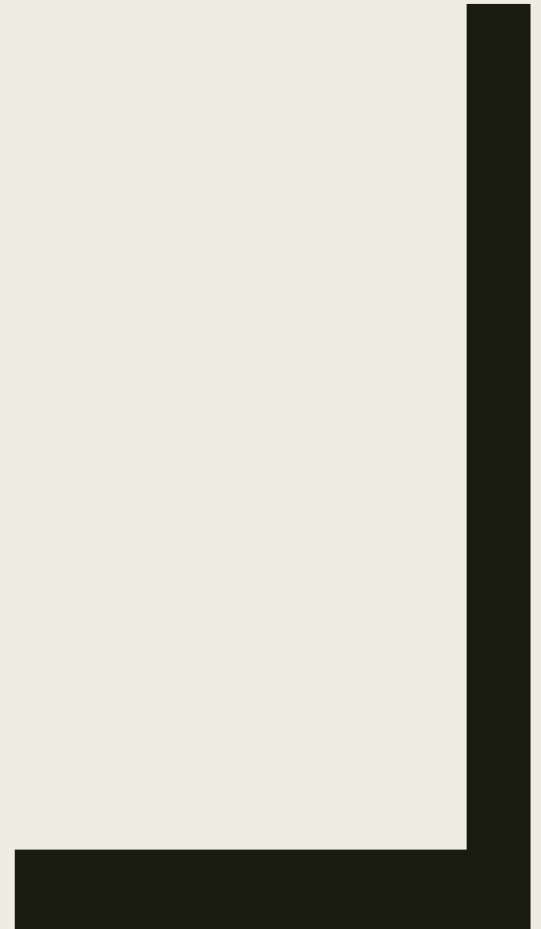
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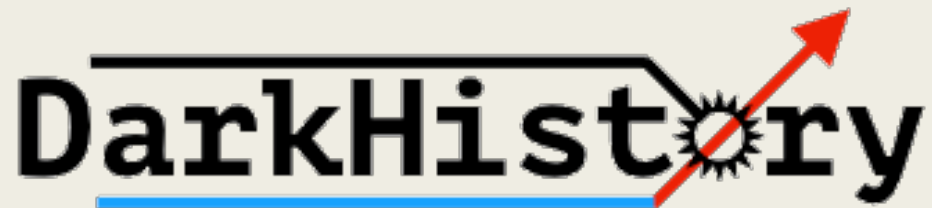


DarkHistory

The logo for 'DarkHistory' features the word in a bold, black, sans-serif font. A blue underline is positioned beneath the 'Dark' portion. A red arrow with a black outline points diagonally upwards and to the right, passing through the 'o' in 'History'. The 'o' is replaced by a black gear icon with a white center.

github.com/hongwanliu/DarkHistory
main branch (version 1.1)
paper: 2207.06425





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Thank you!