



DarkHistory: Modeling Early Universe Energy Injection with Dense Neural Networks

Yitian Sun

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



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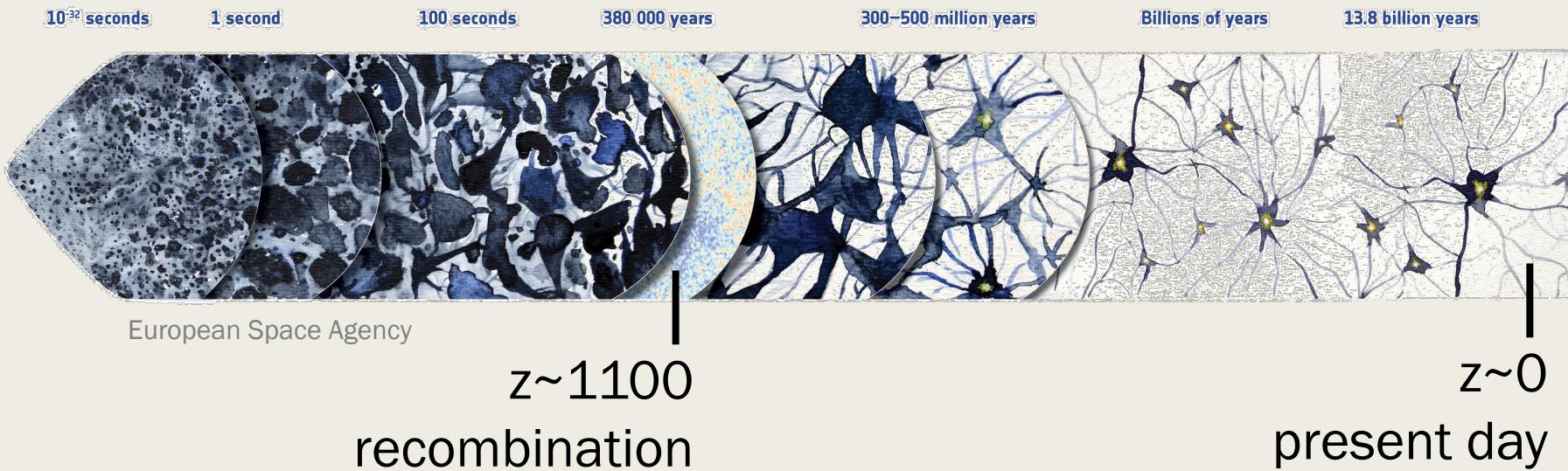
Outline

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

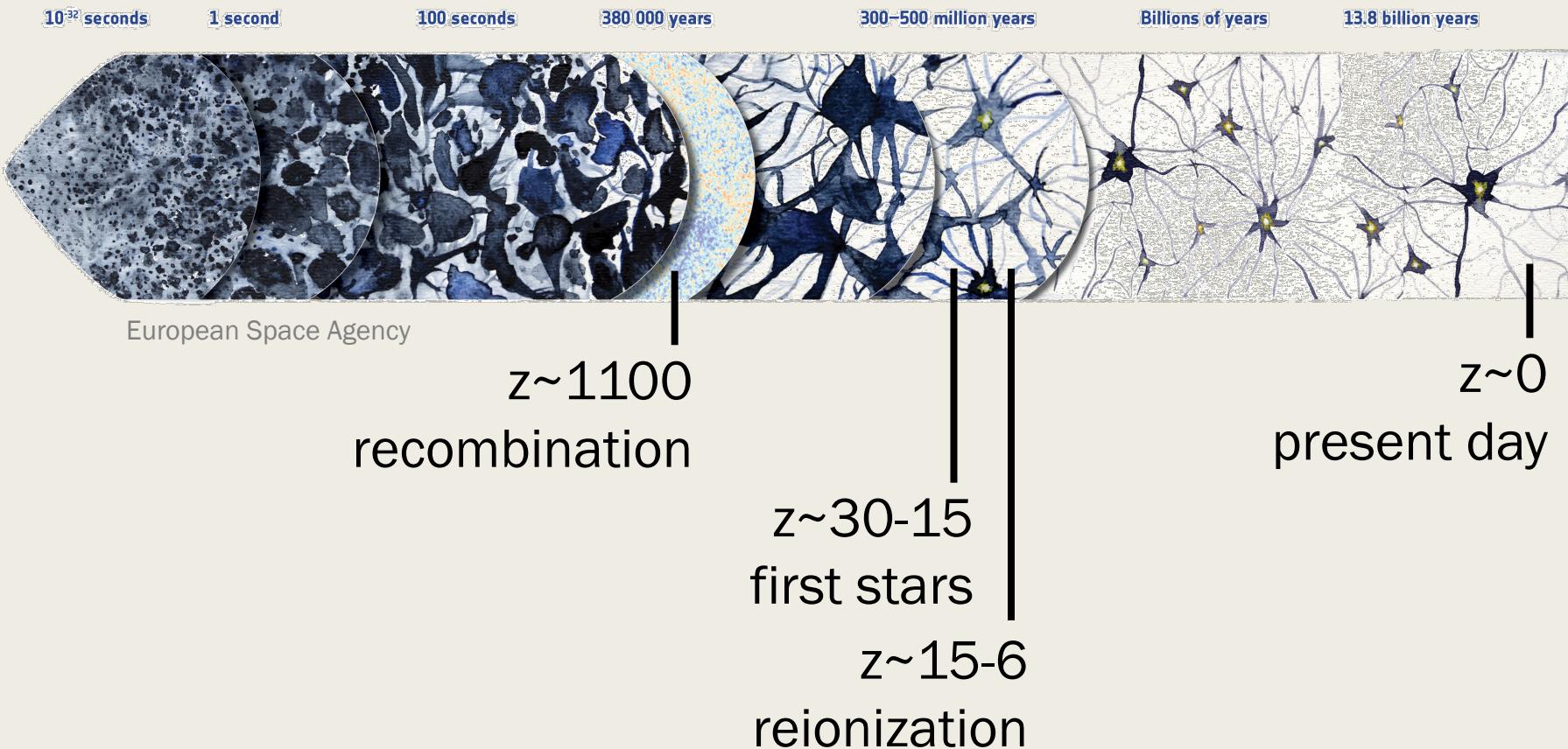
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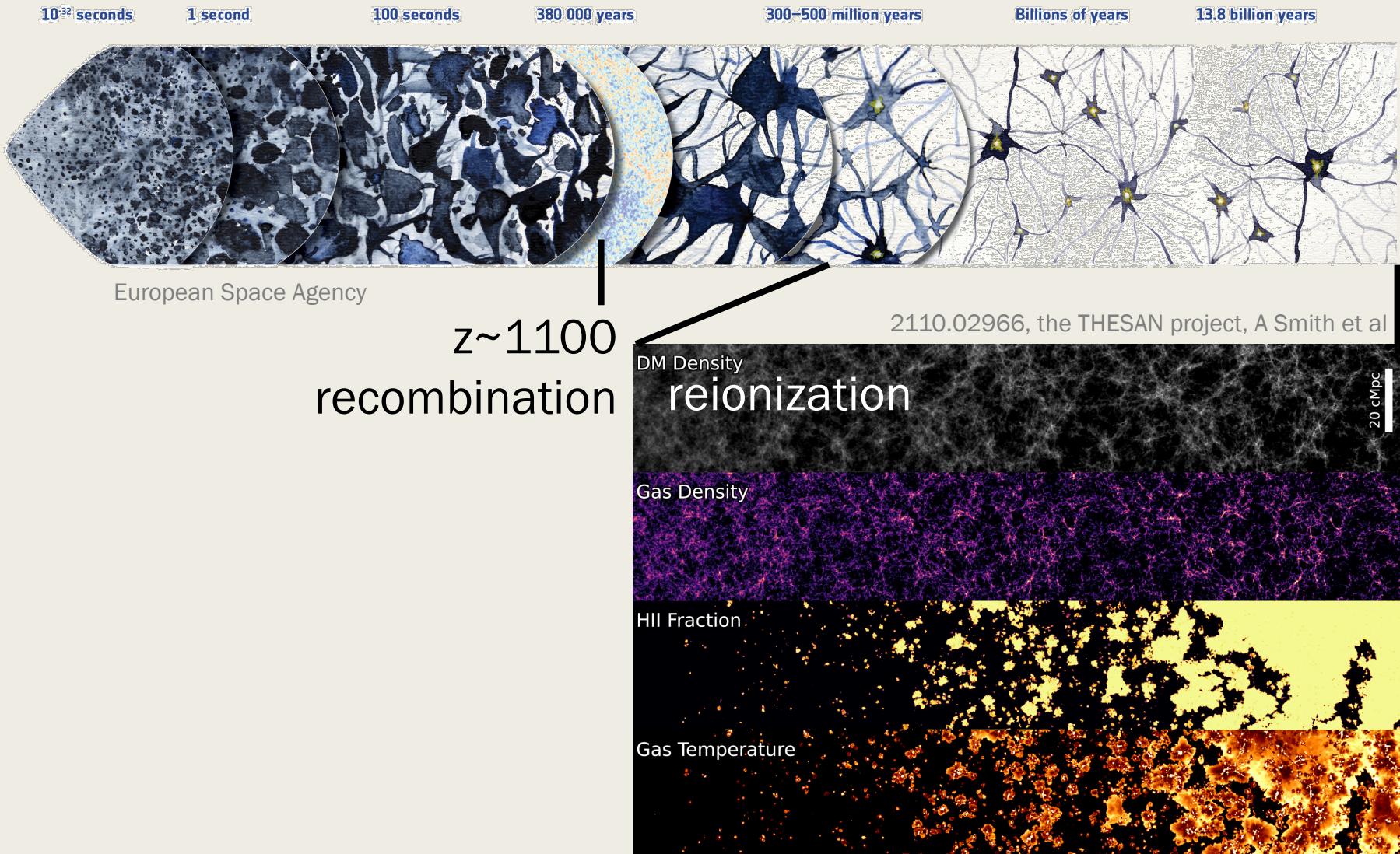
Timeline of the early universe



Timeline of the early universe



Timeline of the early universe



Timeline of the early universe



European Space Agency

$z \sim 1100$
recombination

2110.02966, the THESAN project, A Smith et al

Dark Matter & exotic
energy injection modifies:

- gas temperature
- ionized hydrogen fraction
- (singly) ionized helium fraction



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DarkHistory



10^{-32} seconds

1 second

100 seconds

380 000 years

300–500 million years

Billions of years

13.8 billion years



European Space Agency

$z=3000$ ————— $z=4$

1904.09296

python code package at

github.com/hongwanliu/DarkHistory

DarkHistory

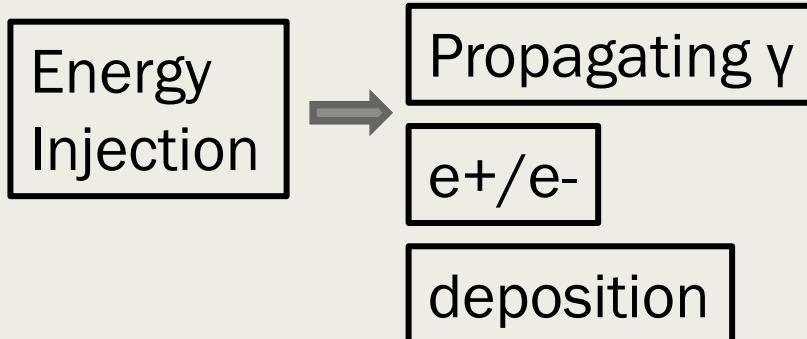


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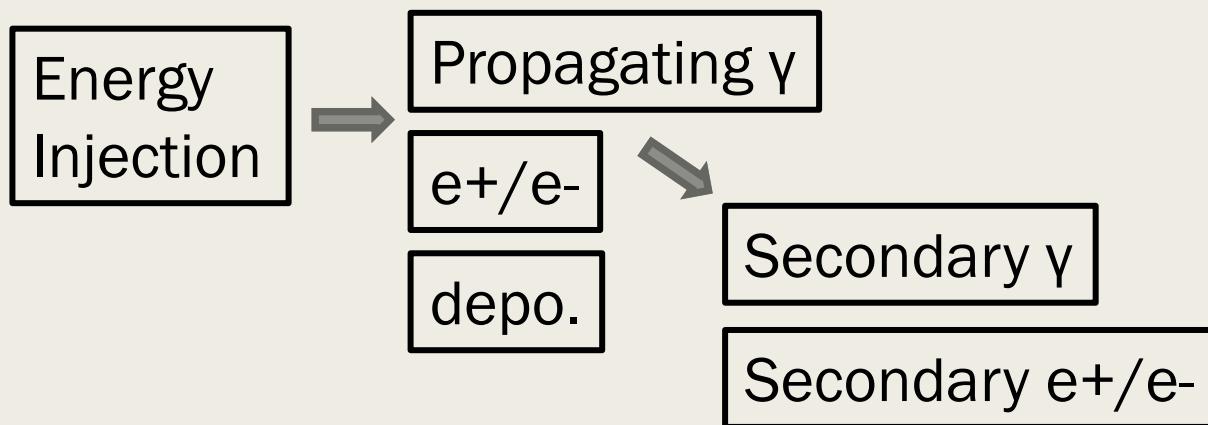
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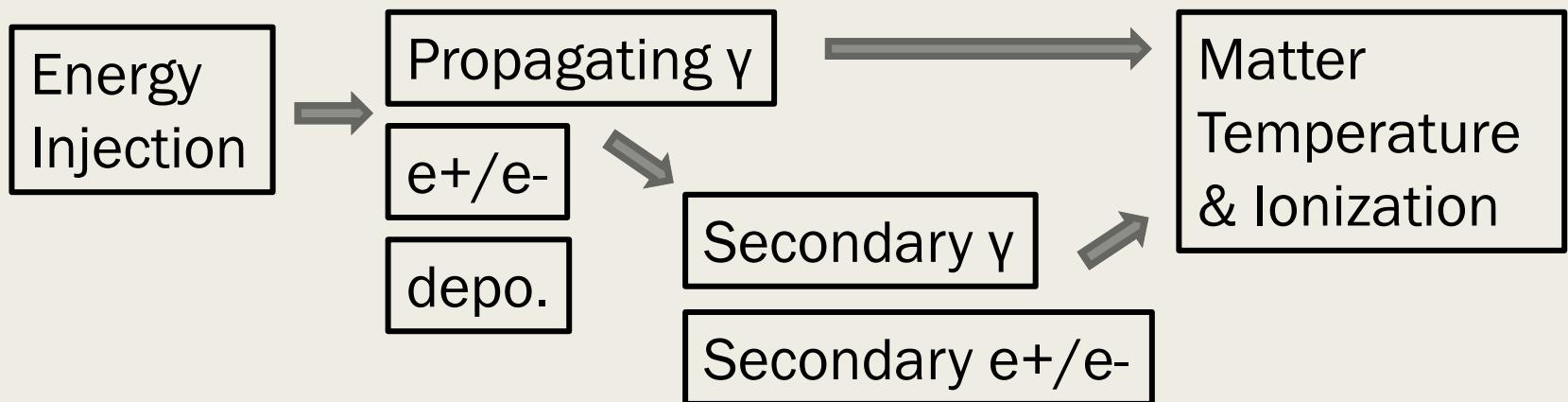
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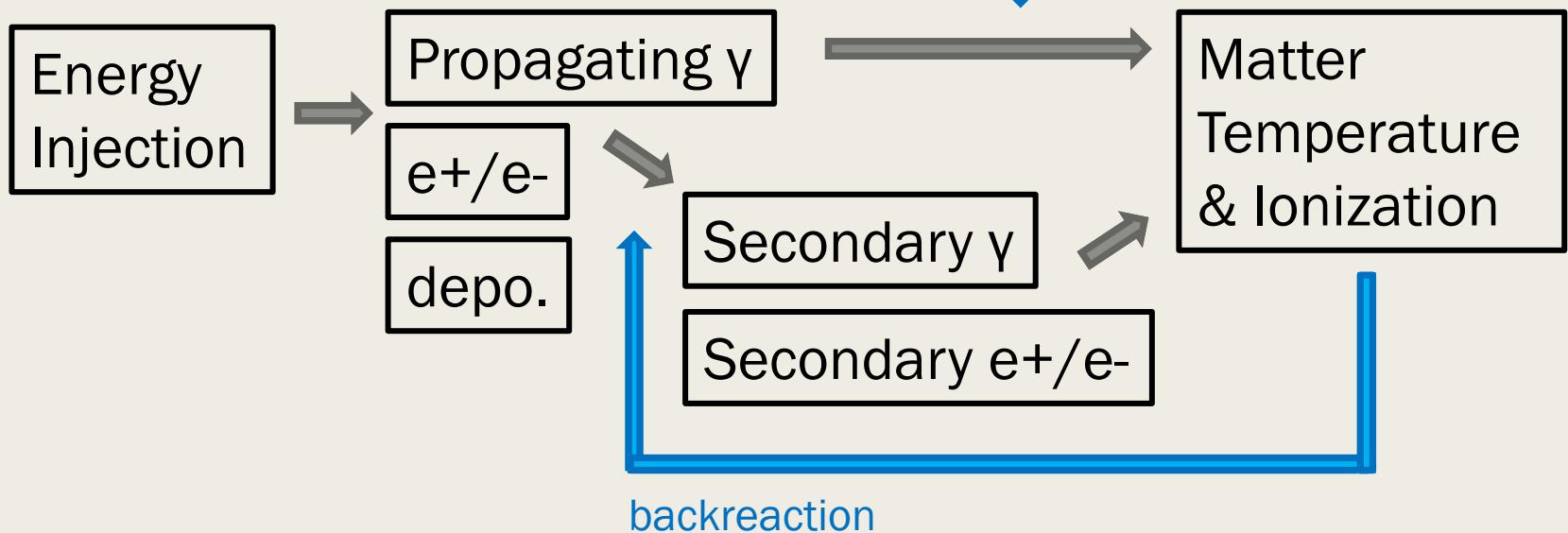
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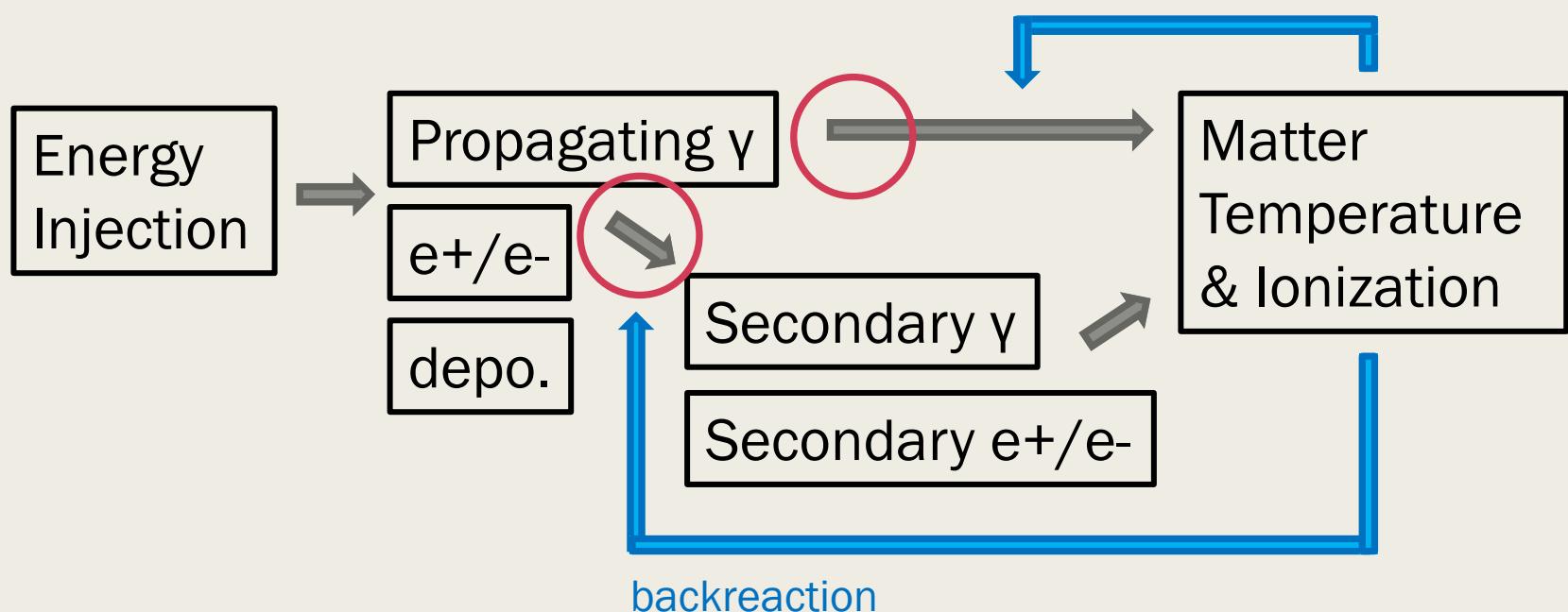


~~DarkHistory~~

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

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



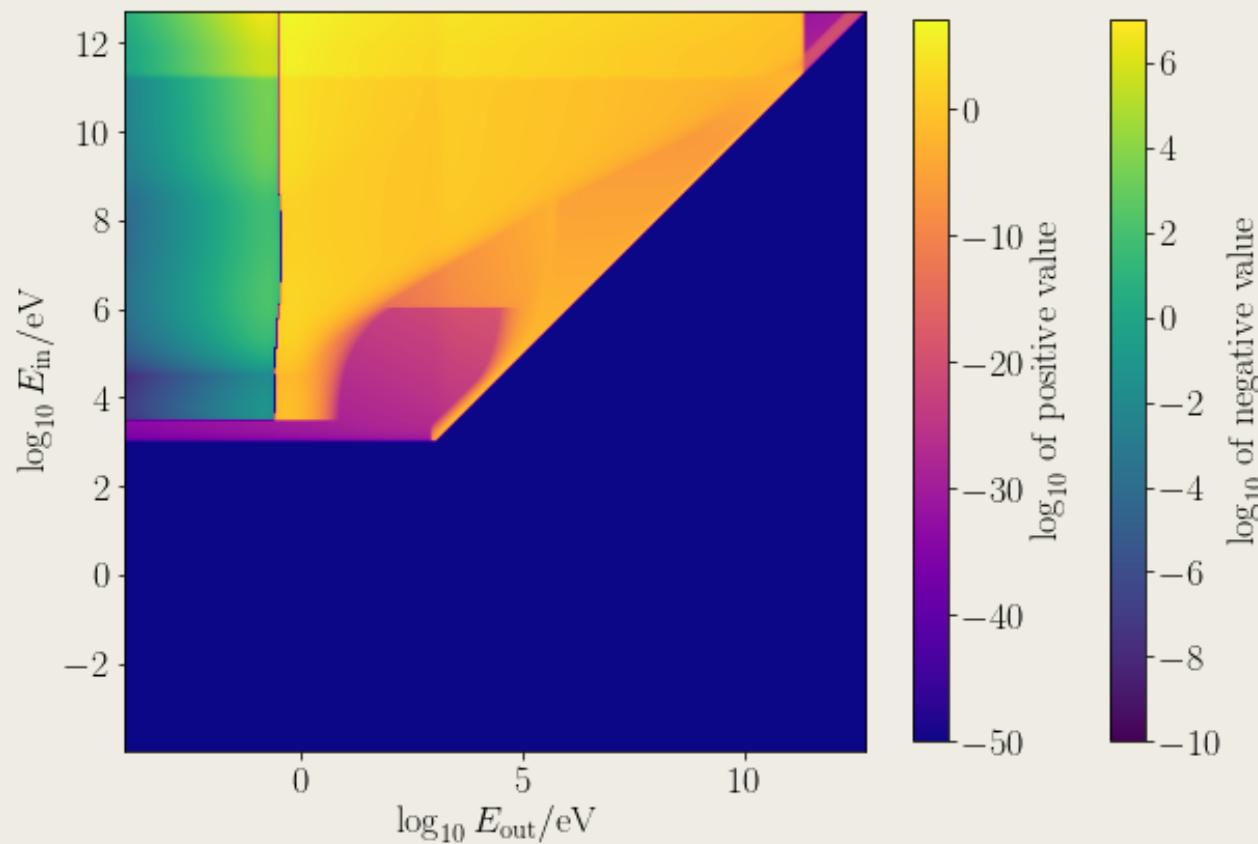
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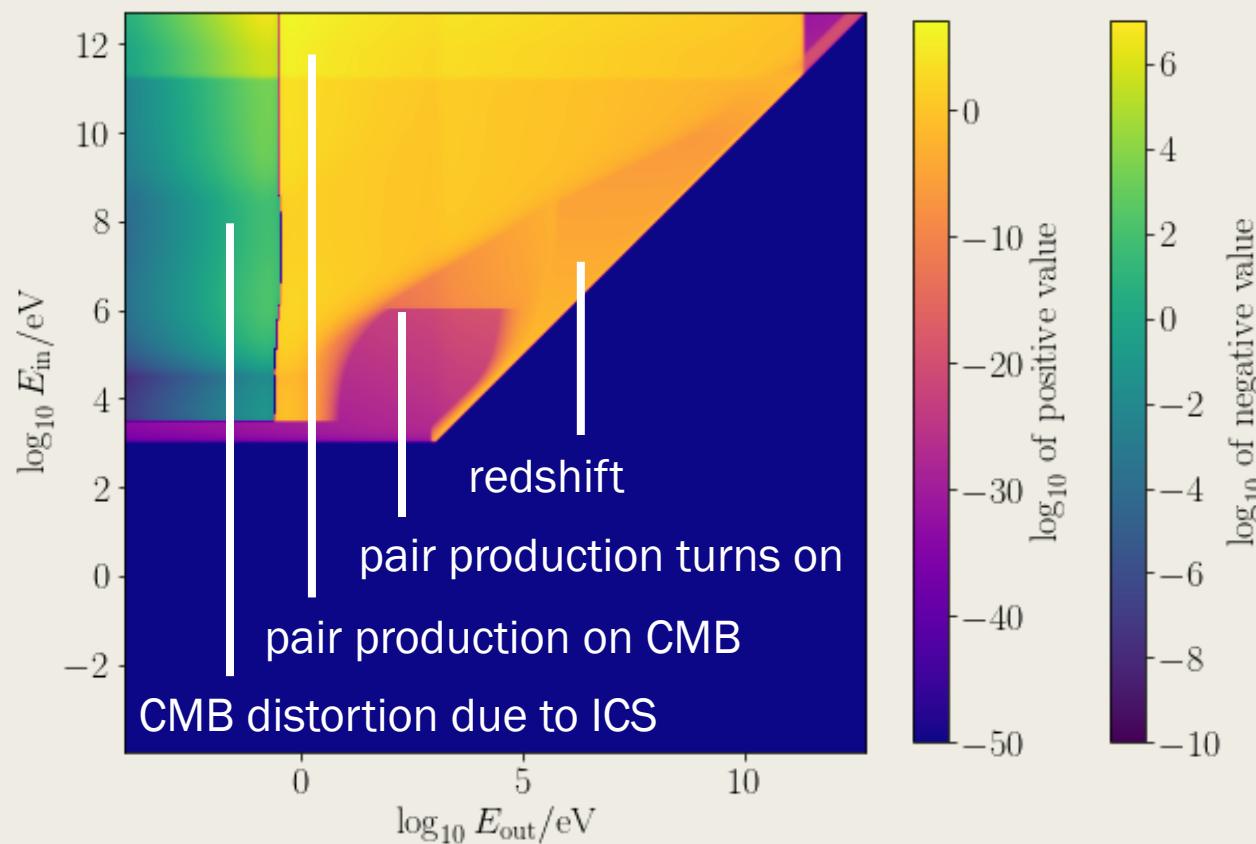
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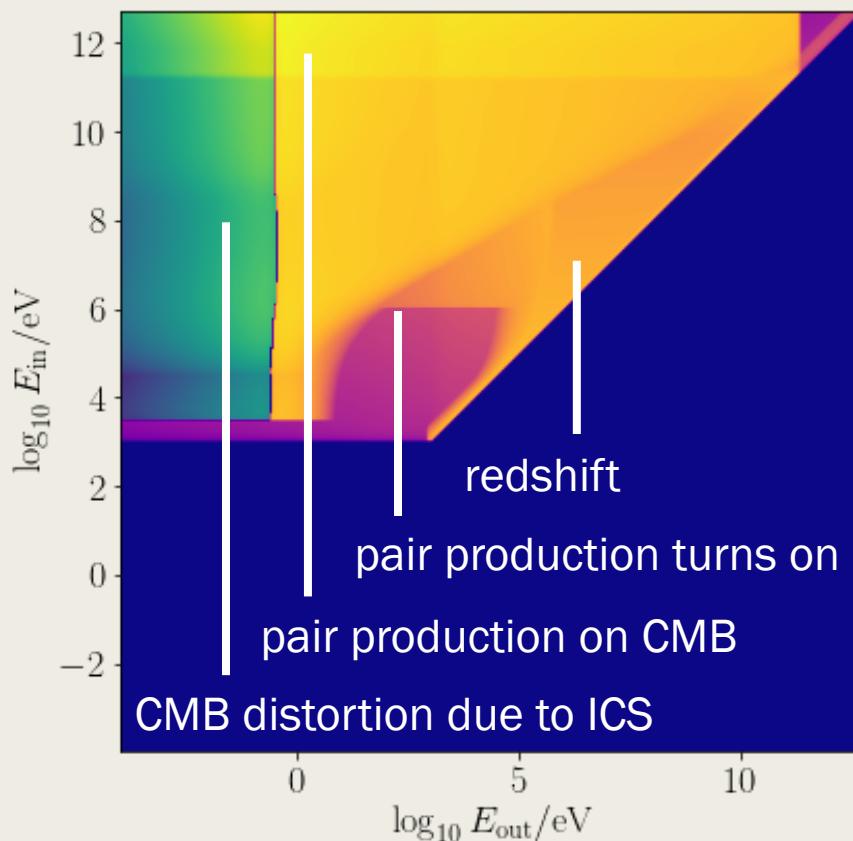
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Function of

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



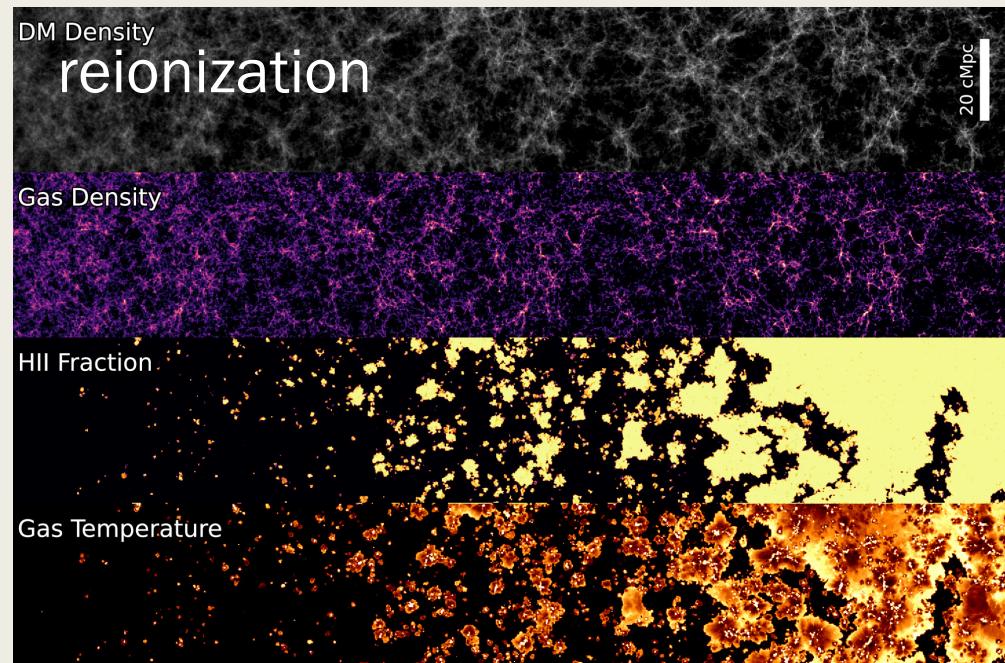
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2110.02966, the THESAN project, A Smith et al



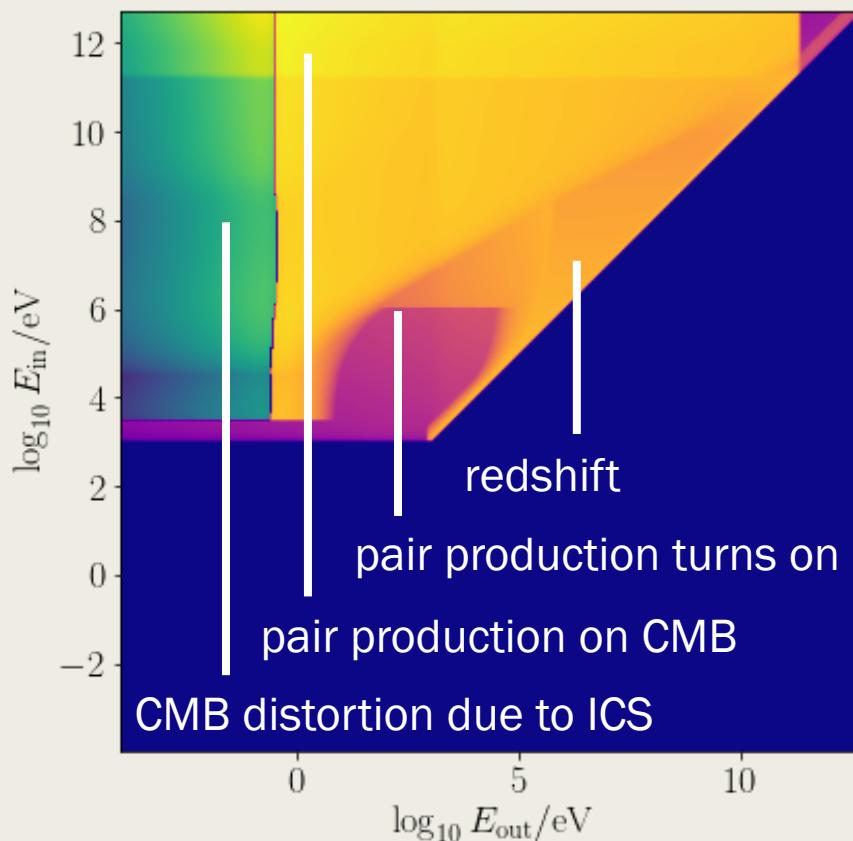
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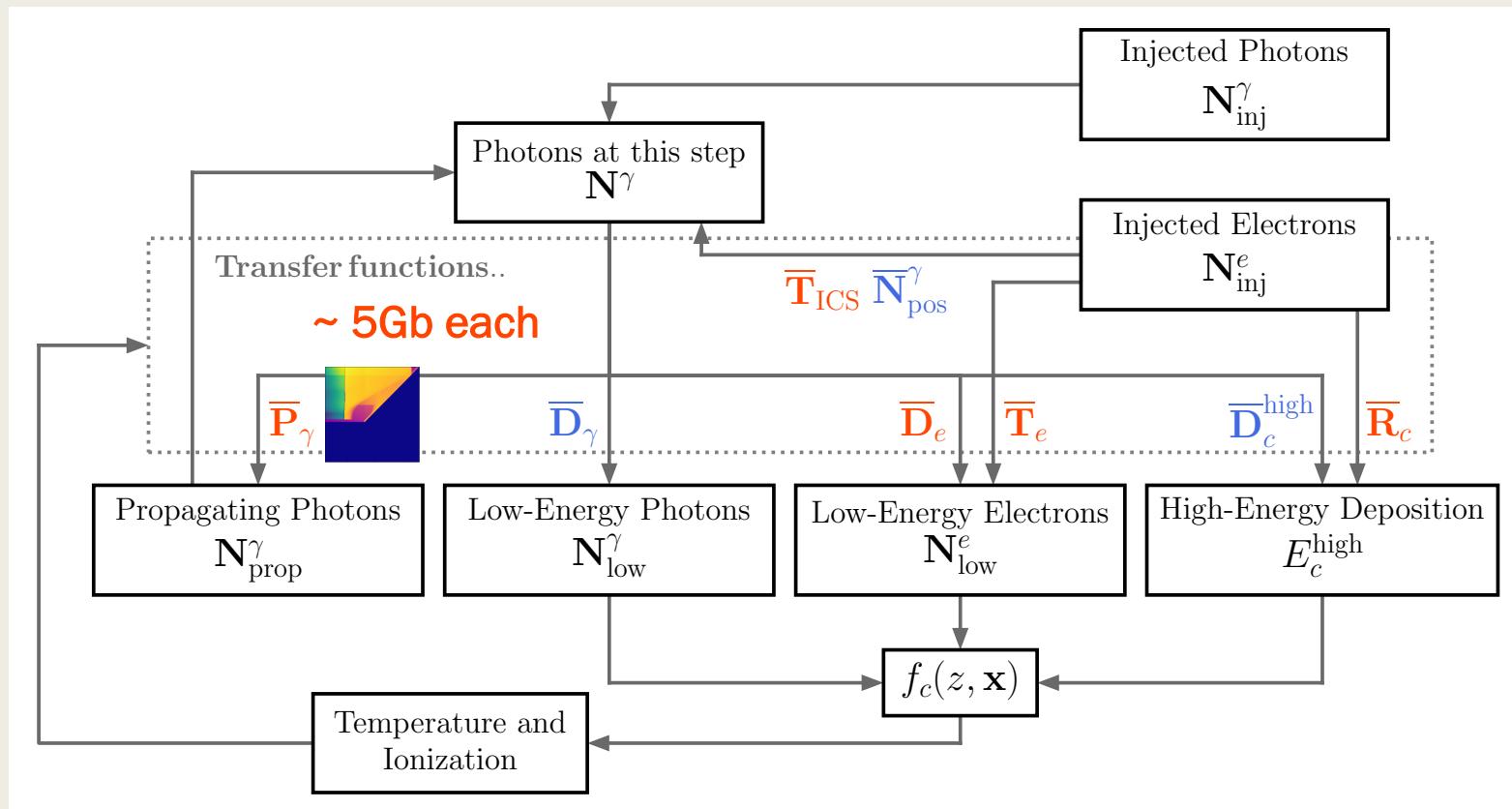
- redshift
- ionized hydrogen fraction
- singly ionized helium fraction
- (future) gas density

DarkHistory

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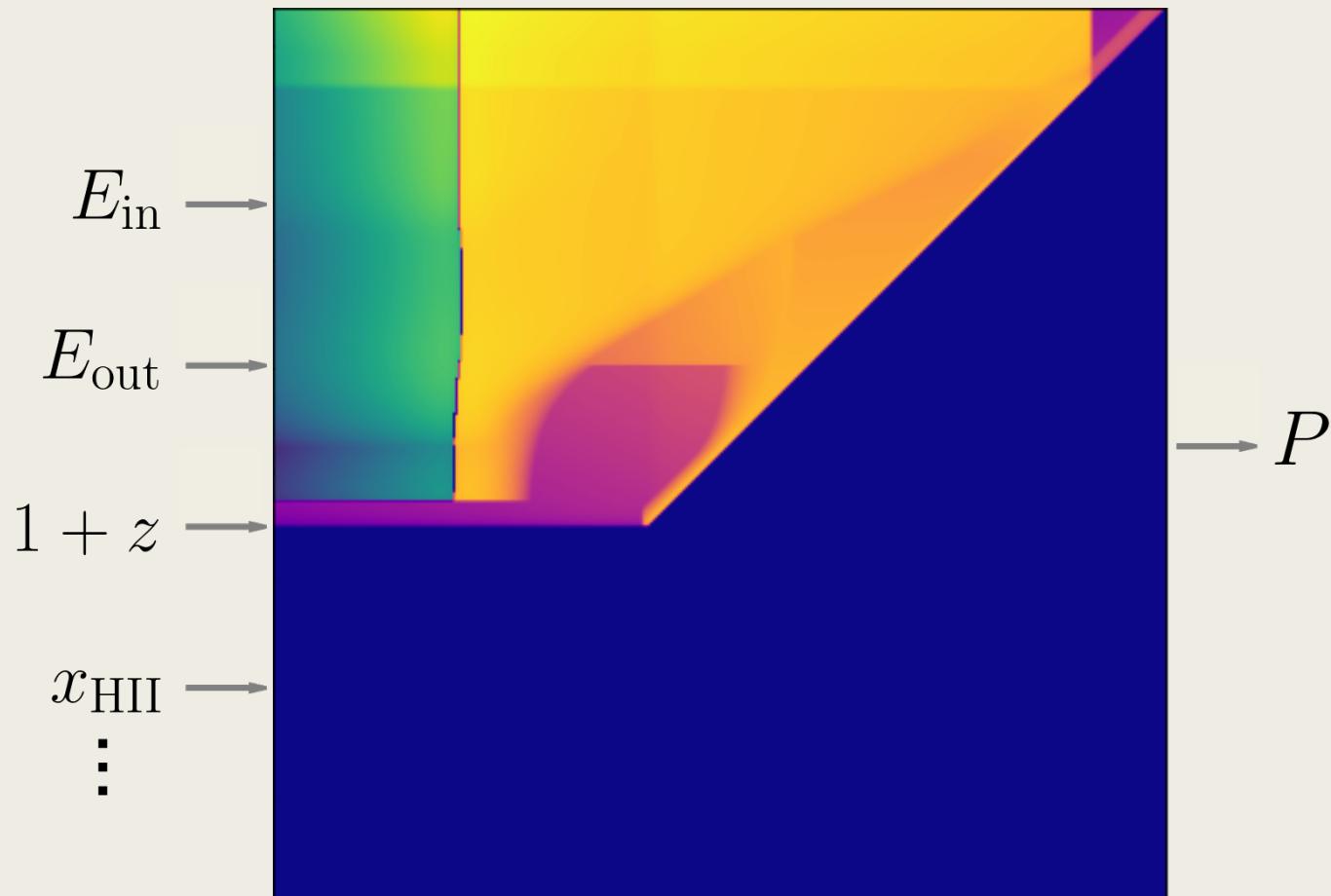
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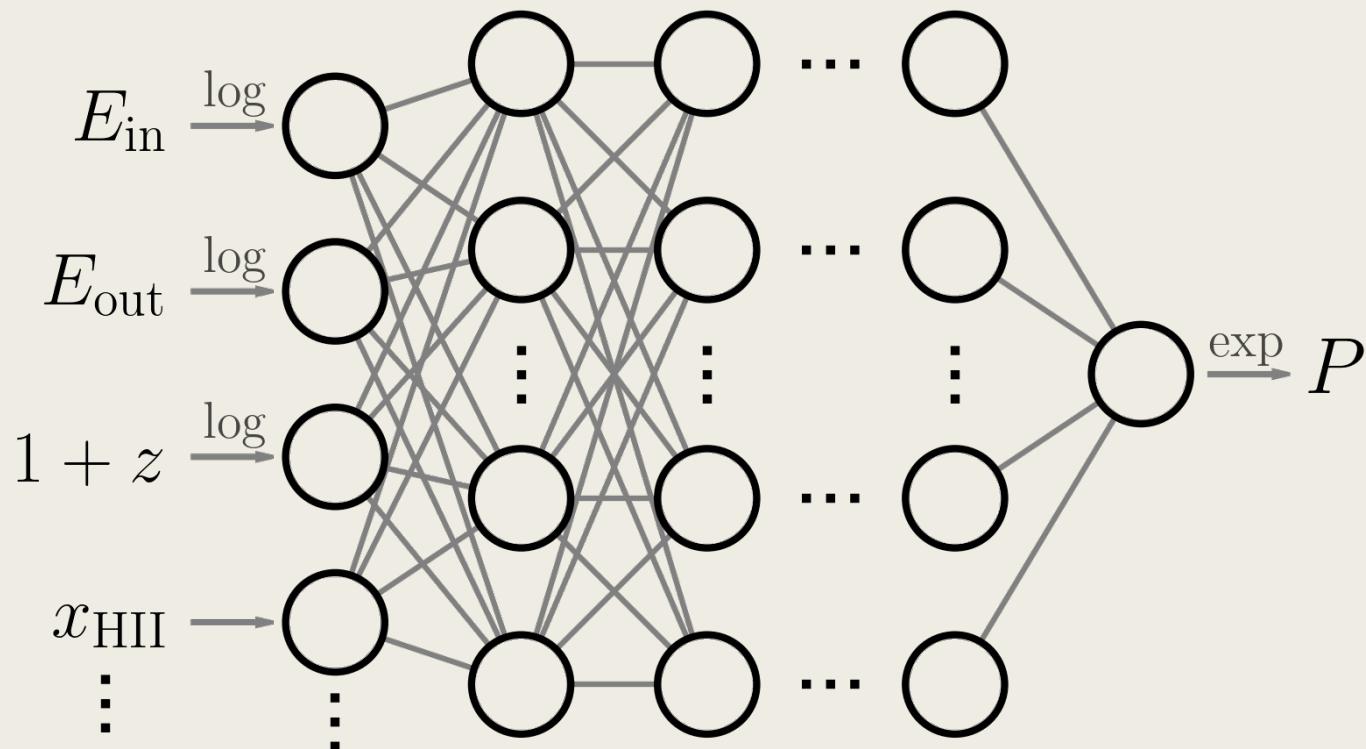
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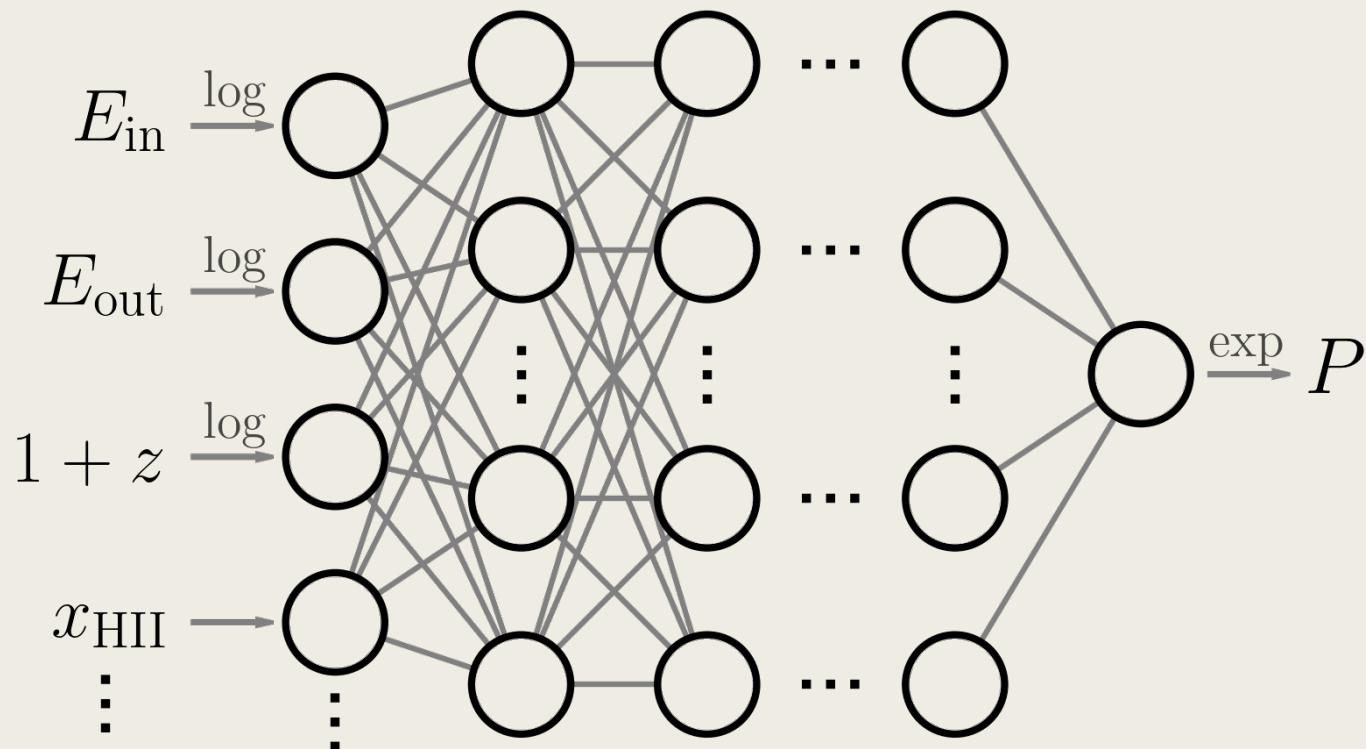
Dense Neural Networks (DNNs) as transfer functions



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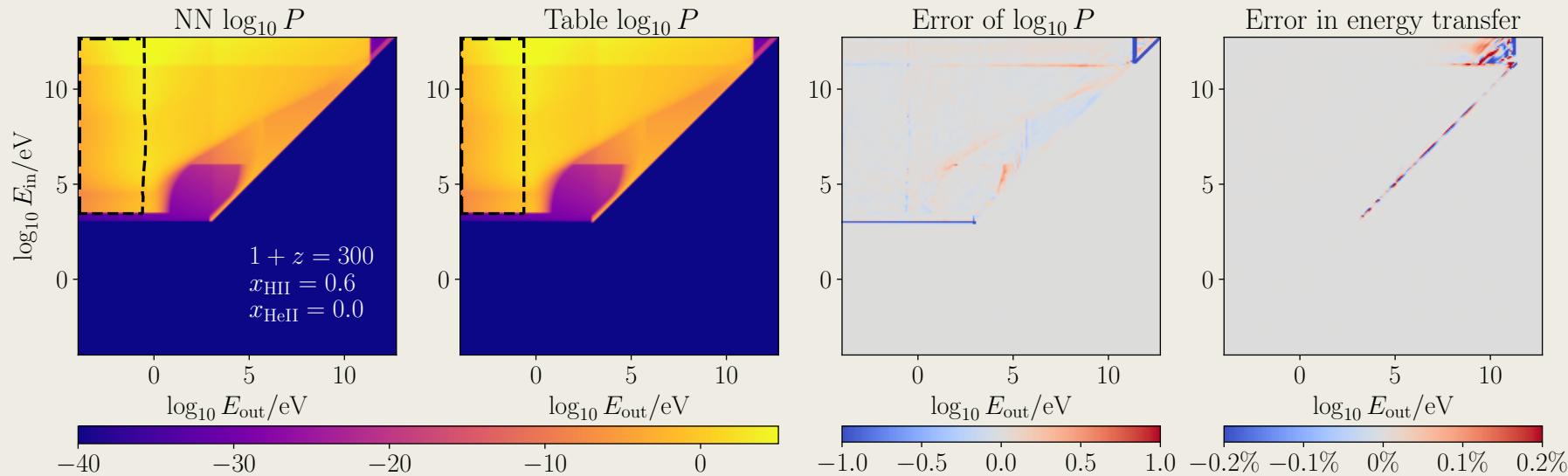
Dense Neural Networks (DNNs) as transfer functions



6 hidden layers, 400 neurons each, ~800k parameters

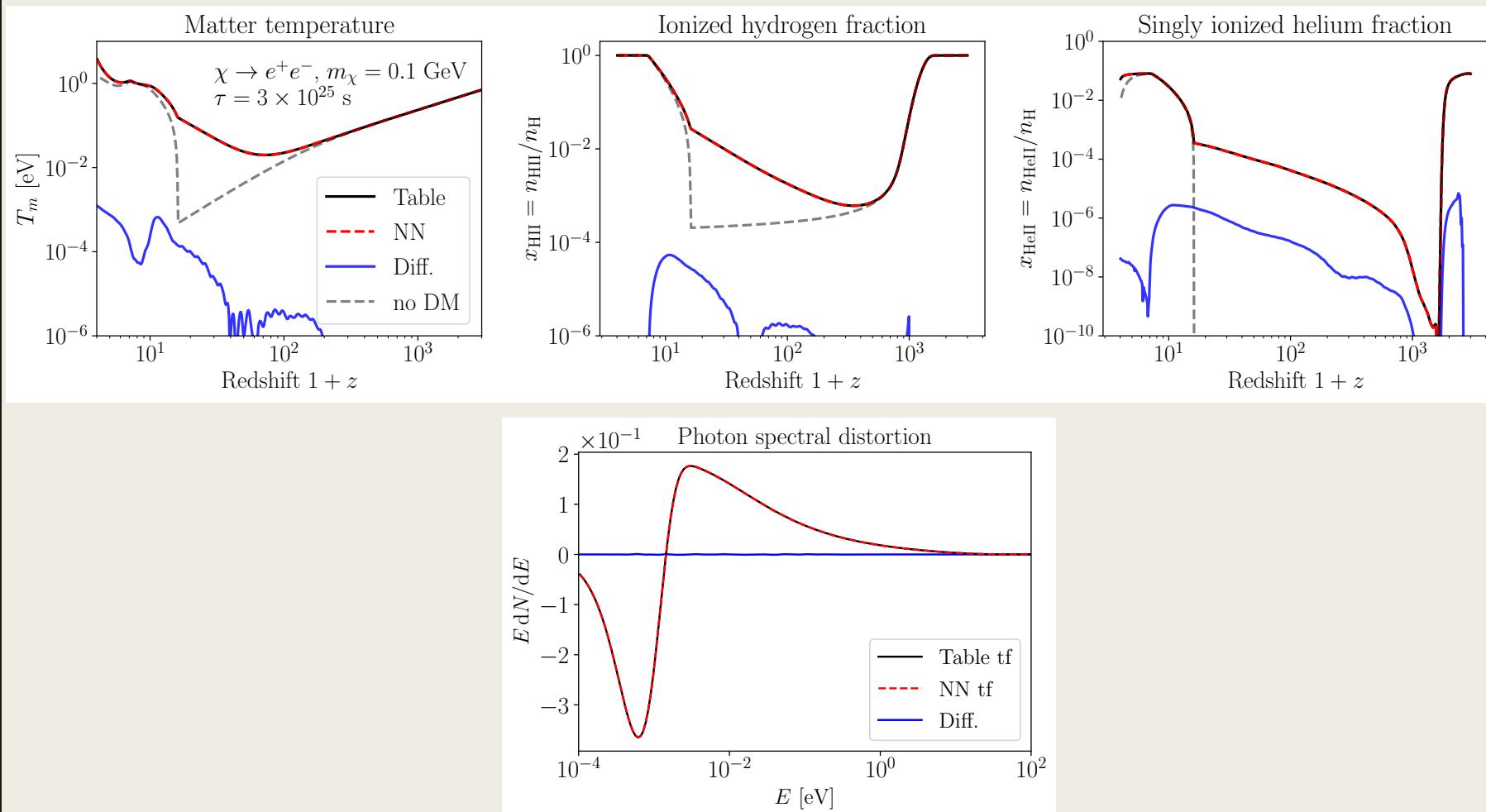
DNN vs Table transfer functions

Single transfer function prediction



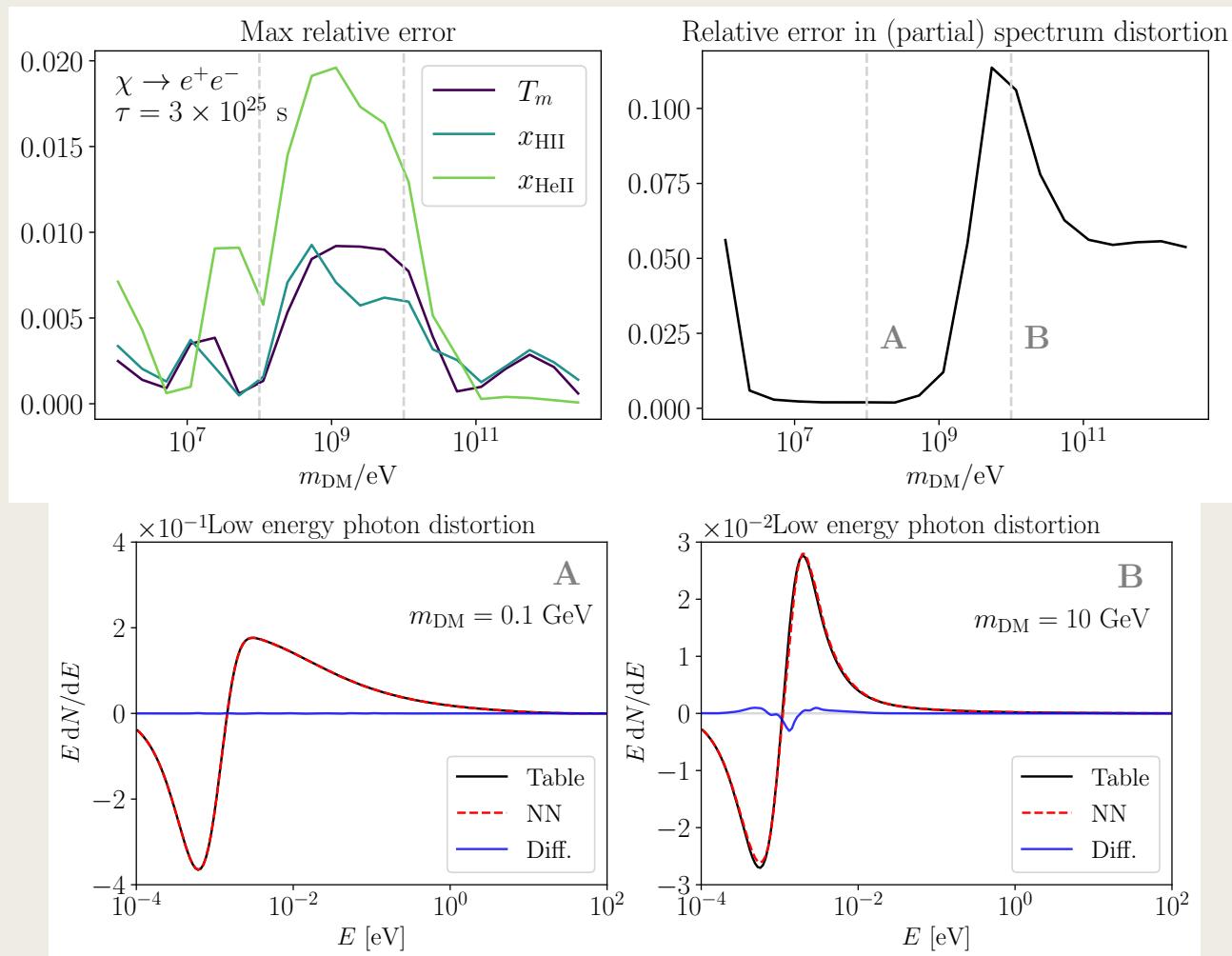
DNN vs Table transfer functions

An example simulation run



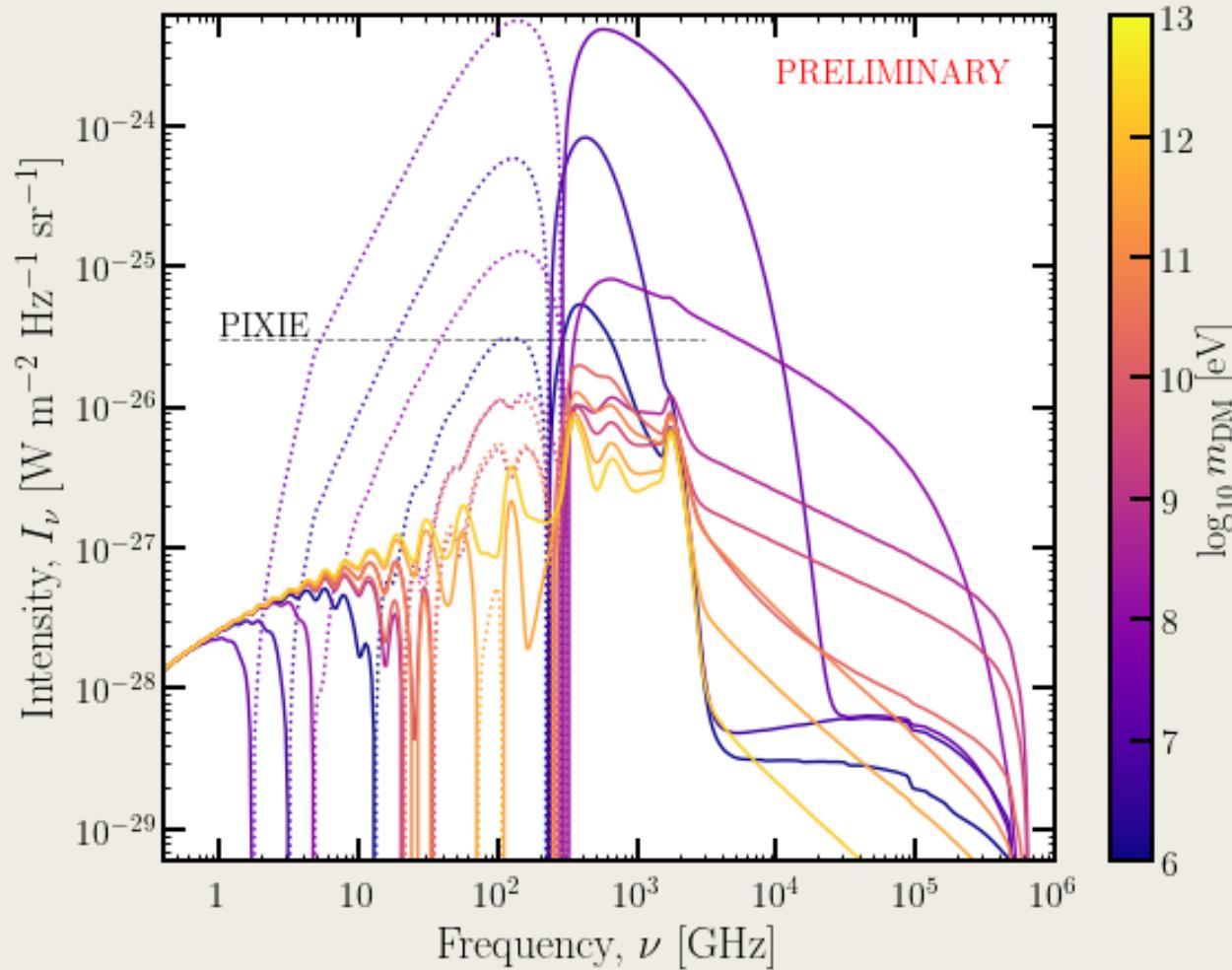
DNN vs Table transfer functions

Scan over DM energy injection scenarios



Parallel work: spectral distortions

from low energy electrons and atomic transitions.
Wenzer Qin et al





github.com/hongwanliu/DarkHistory
Look for version 1.1 release.
2207.xxxx out soon.



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Thank you!