

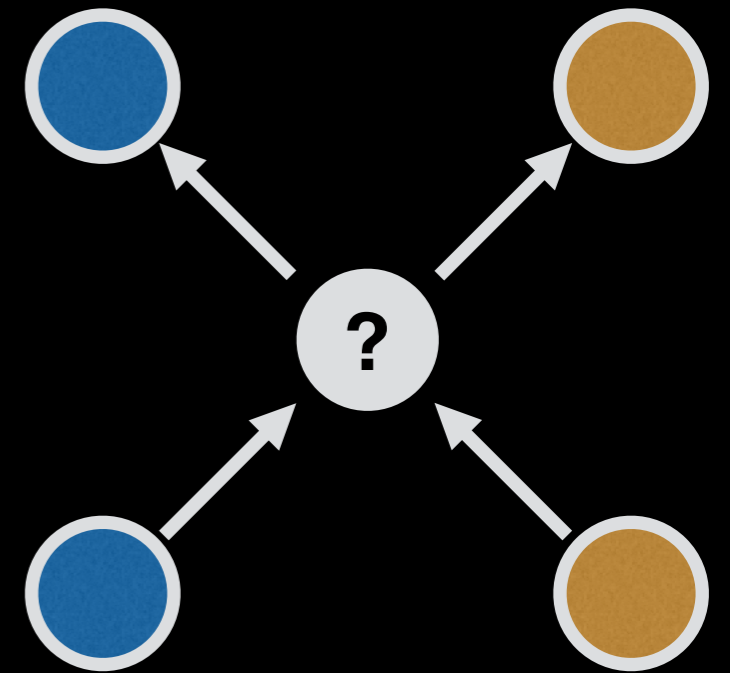
Dark Matter, First Light

Katie Mack

North Carolina State University

Annihilating WIMPS

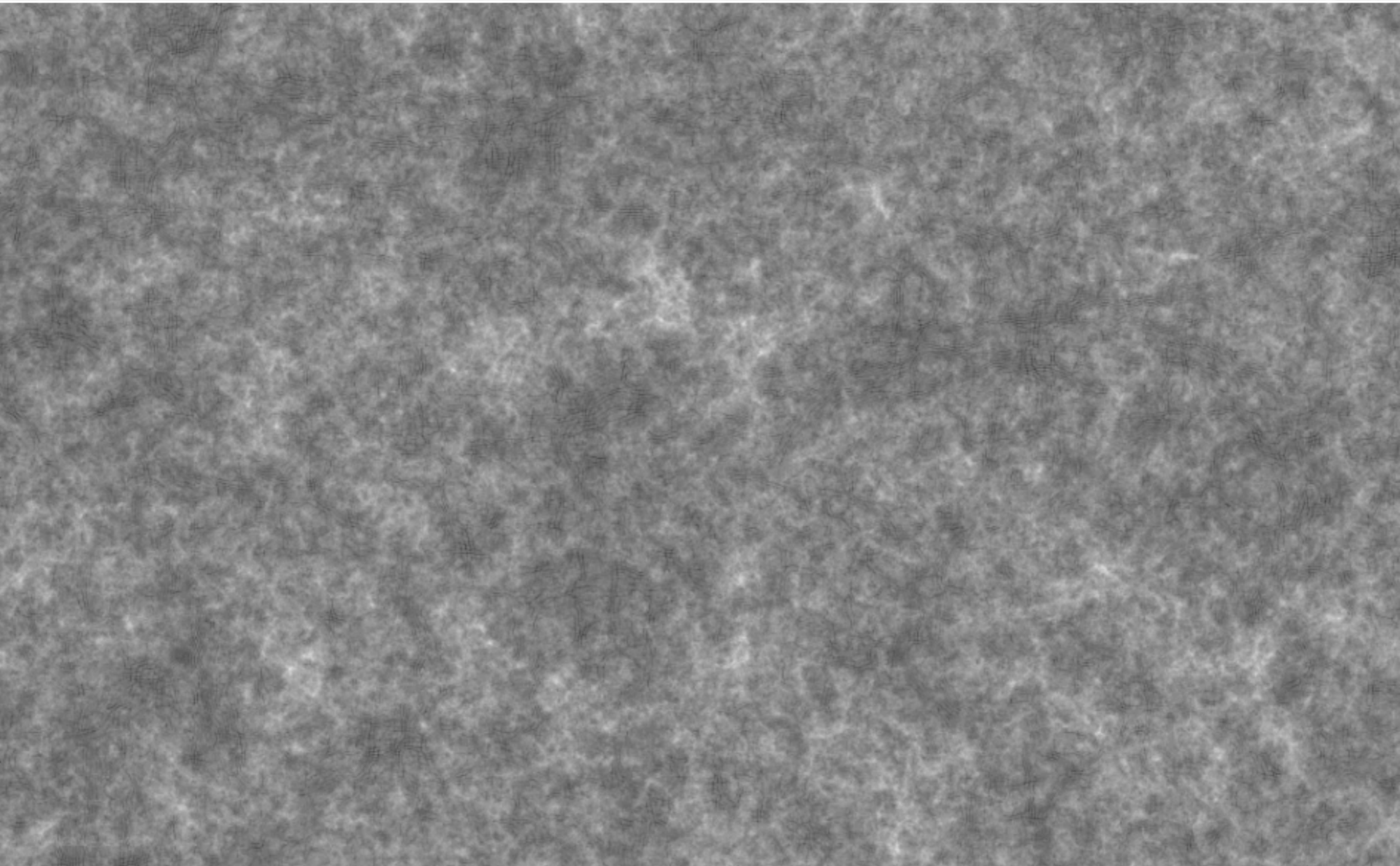
Key detection signature:
WIMP annihilation



Why **annihilating** dark matter?

- ▶ Good candidates in *supersymmetry* (e.g. neutralino), *Kaluza-Klein theory* (e.g. B^1)
- ▶ Early thermal equilibrium and freeze-out gives natural production mechanism

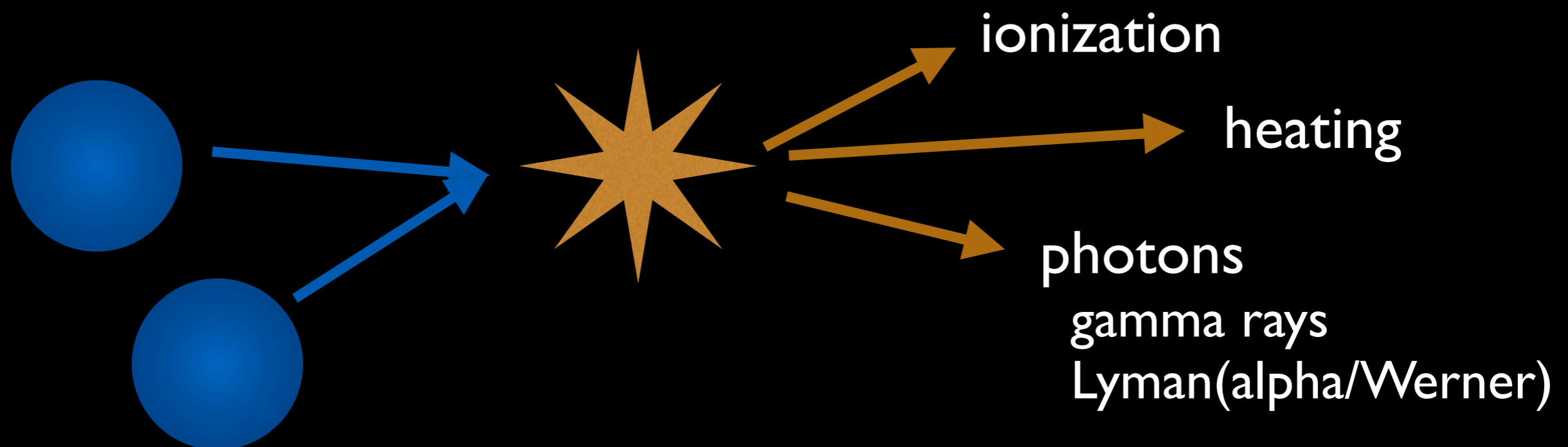
Dark Matter: Cosmology



Impact of Dark Matter Annihilation

Major unanswered question:

If dark matter **annihilates** across all of cosmic time, **how does it affect the first stars and galaxies?**



Annihilation Over Cosmic Time

First question to ask:
When is annihilation
power **strongest**?

Balance:
density of universe
(decreasing with time)

vs

growth of structure
(increasing with time)

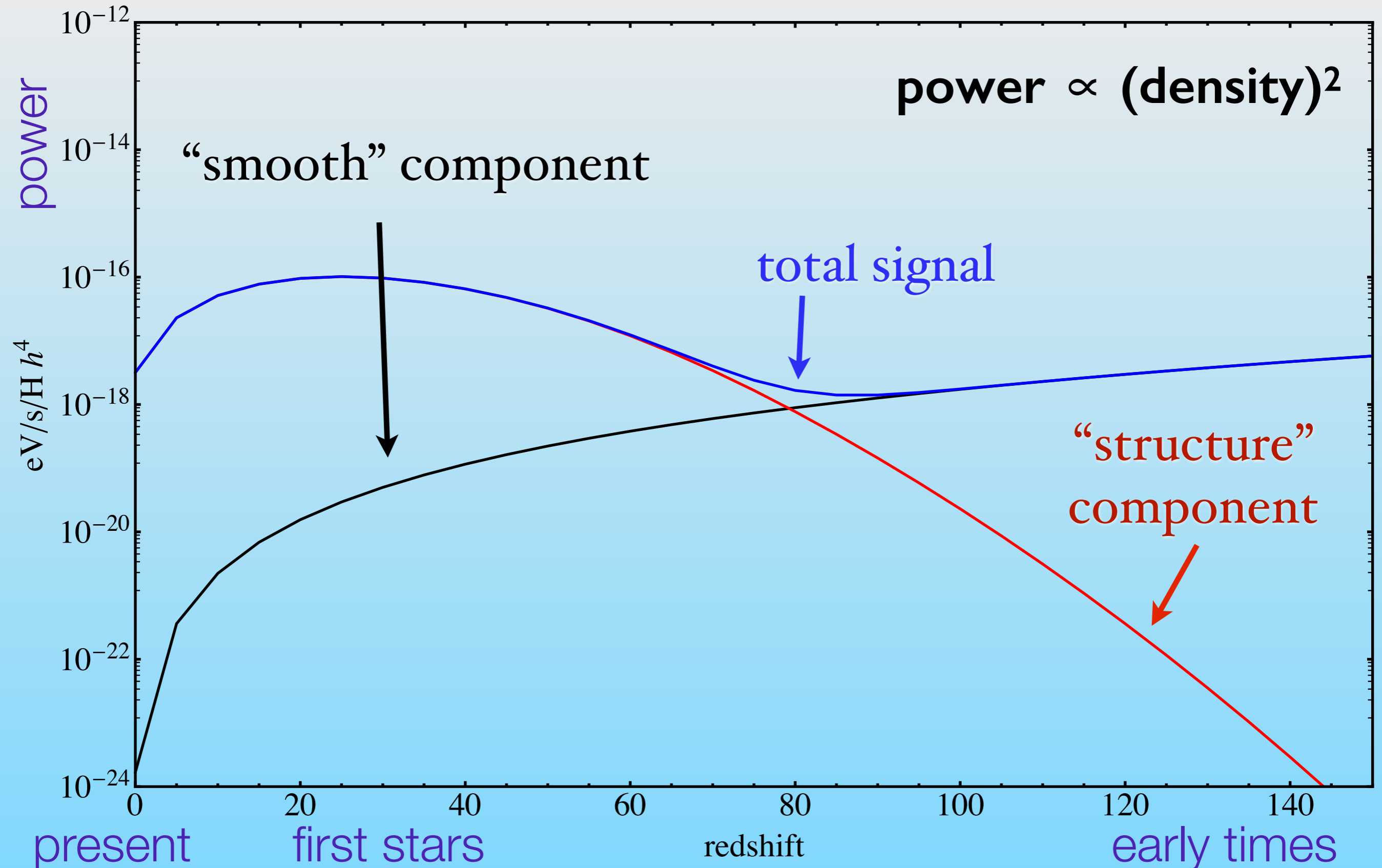
$$\frac{\text{power}}{\text{volume}} = \frac{\langle \sigma v \rangle \rho_{\chi}^2}{m_{\chi}}$$

$\langle \sigma v \rangle$ velocity-averaged self-annihilation rate

ρ_{χ} dark matter density

m_{χ} dark matter particle mass

Annihilation Over Cosmic Time



Complications

- Dark matter halo **density profile** (NFW? Einasto? Other?)
- Mass-**concentration** relation $c(M,z)$
- Lower mass cutoff in **power spectrum**
- Alterations in **density profile** due to:
 - **Baryonic effects** (feedback)
 - Halo **formation histories** (low masses / high redshift)

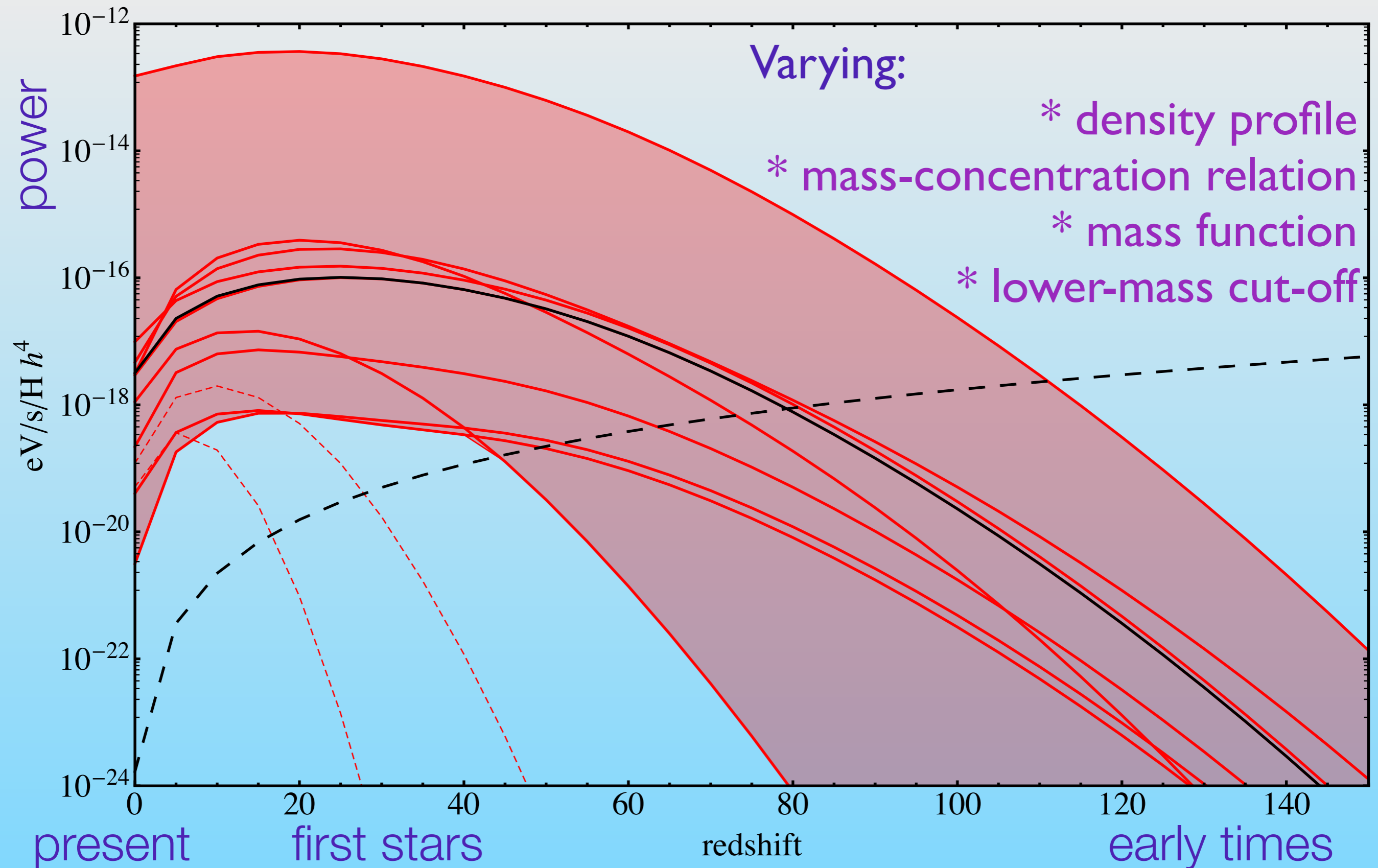


NOAO/AURA/NSF/WIYN

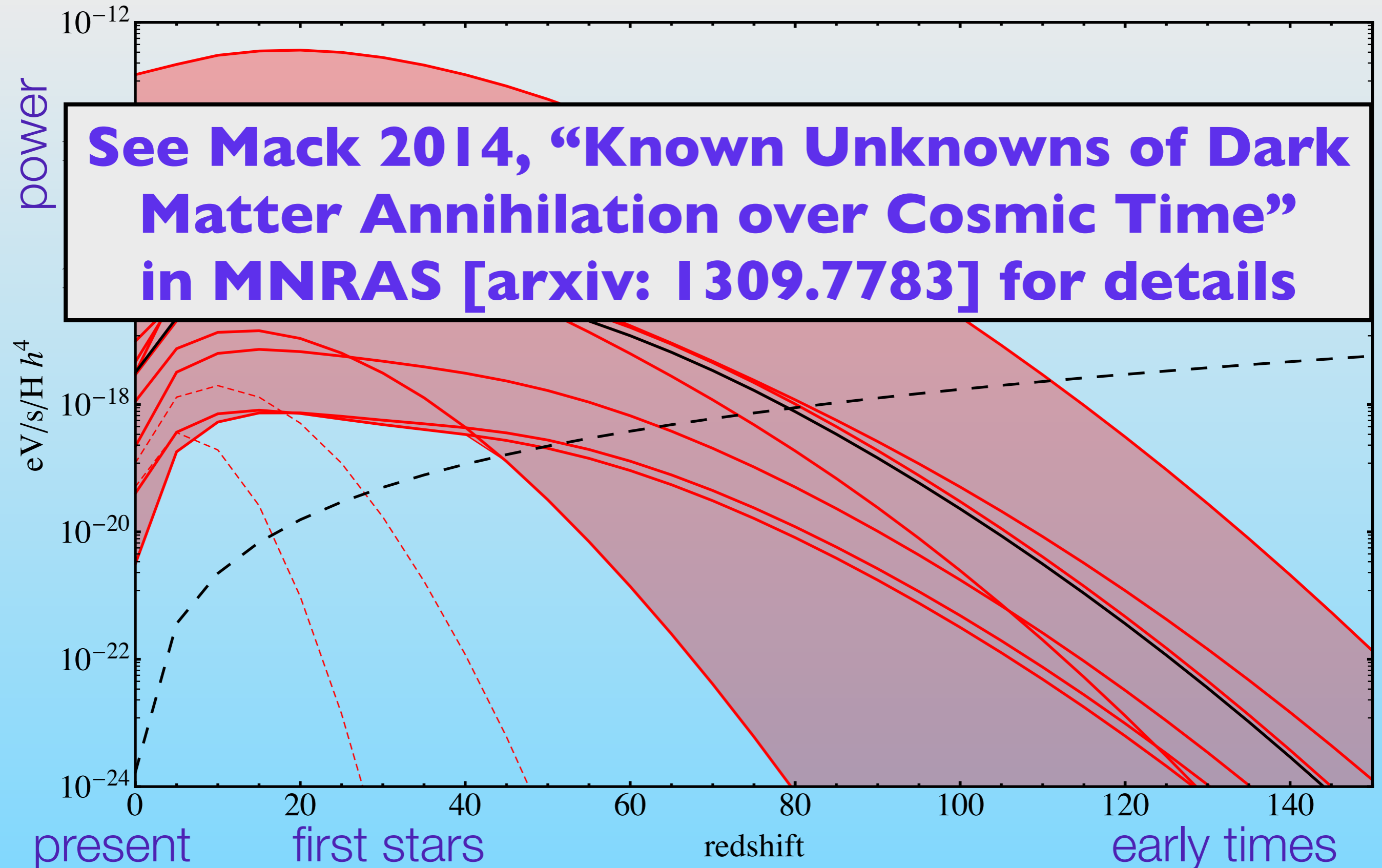
R Jay Gabany (Blackbird Observatory)



Annihilation Over Cosmic Time



Annihilation Over Cosmic Time



Annihilation in the Intergalactic Medium



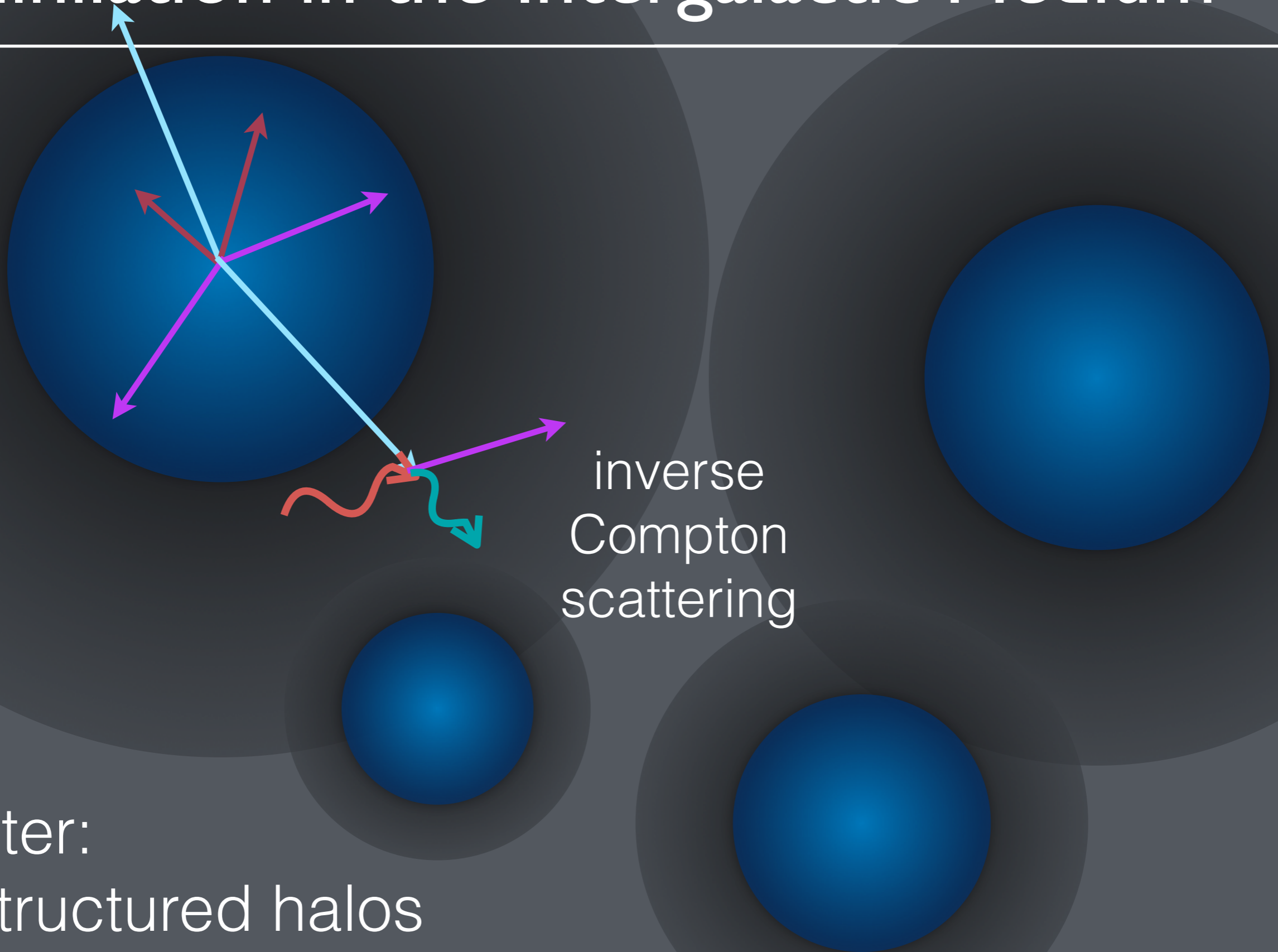
Annihilation in the Intergalactic Medium



Usual treatment:

- monolithic halos
- immediate uniform energy deposition

Annihilation in the Intergalactic Medium

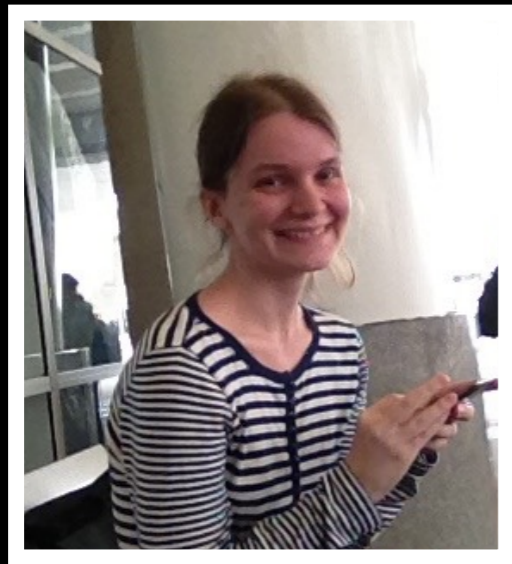


Better:

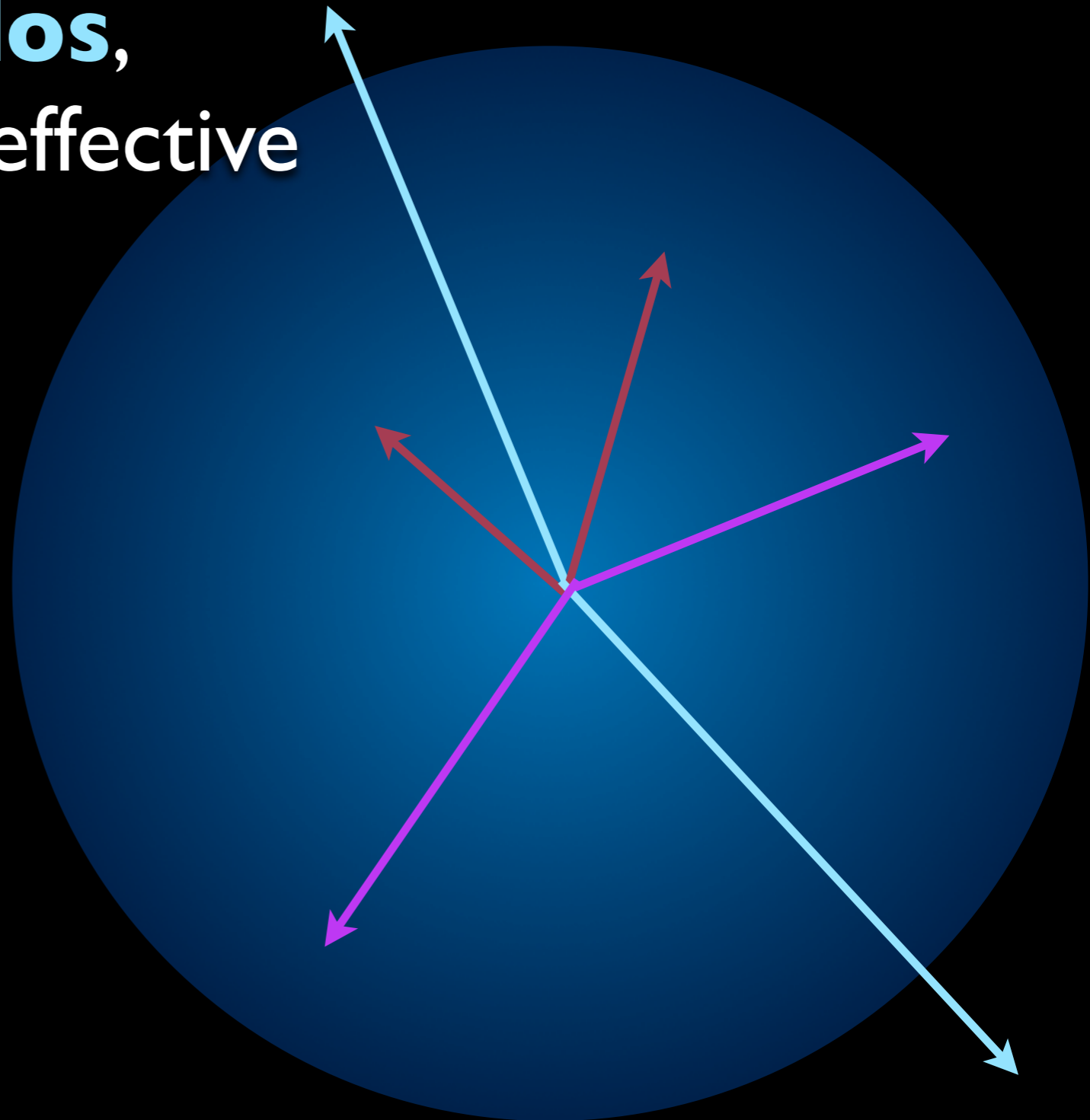
- structured halos
- delayed energy deposition

Annihilation Feedback on Halo Gas

If dark matter is annihilating **within baryonic halos**, does this constitute an effective **“feedback”** process?



Sarah Schon,
Queens U, Canada



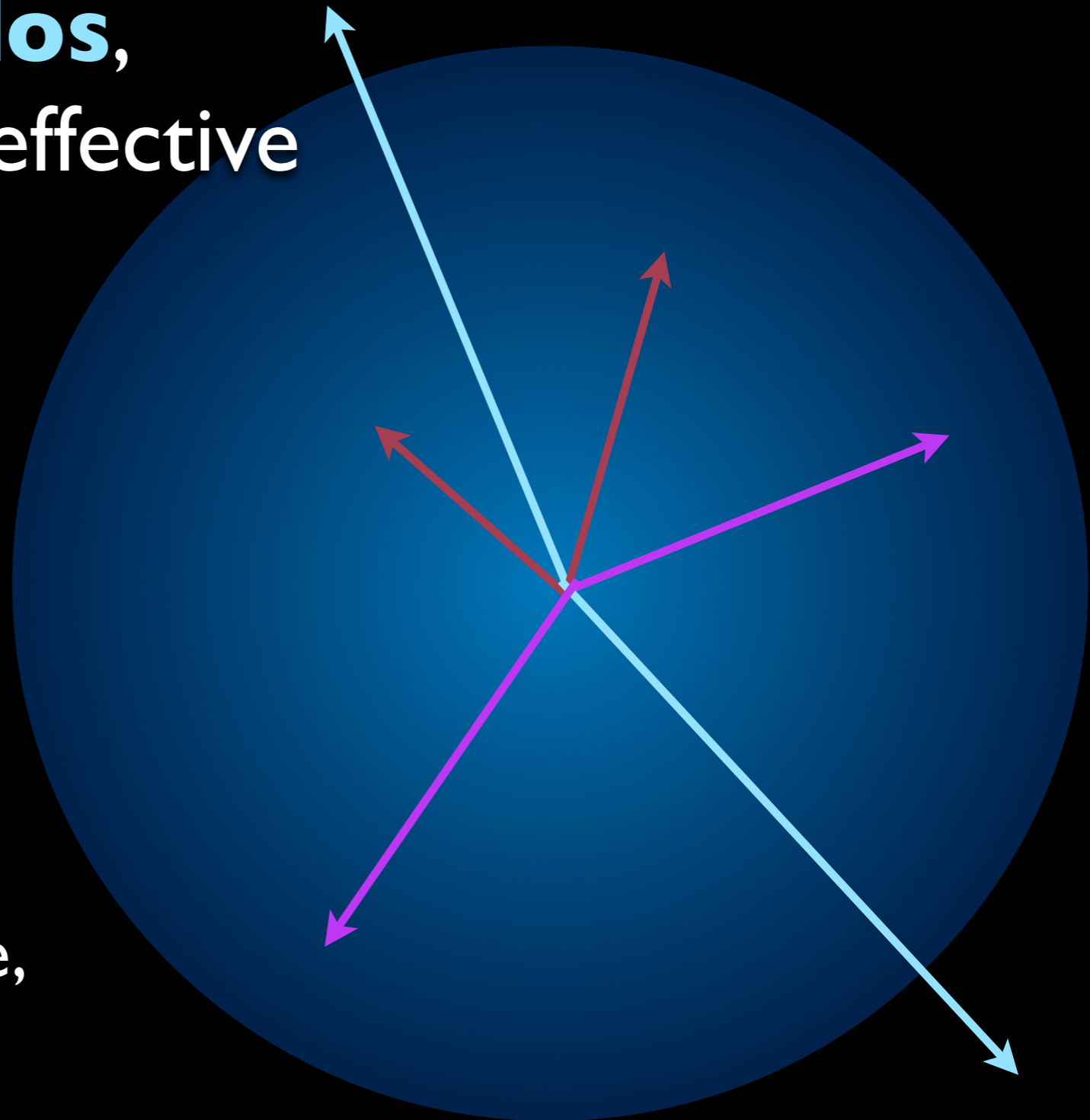
Annihilation Feedback on Halo Gas

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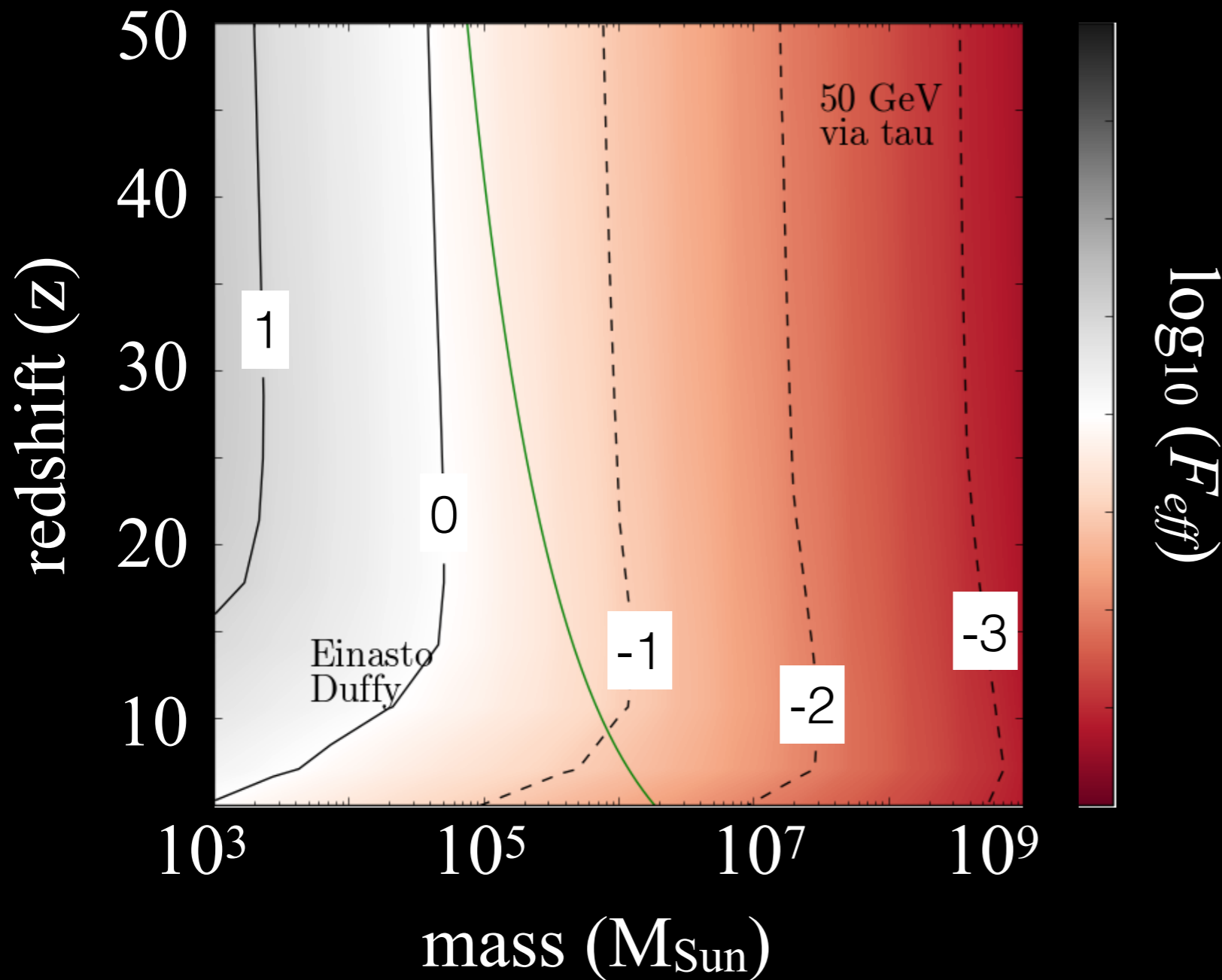
PYTHIA code: dark matter annihilation events

MEDEA2 code: energy transfer to baryons

Halo models: density profile, mass-concentration



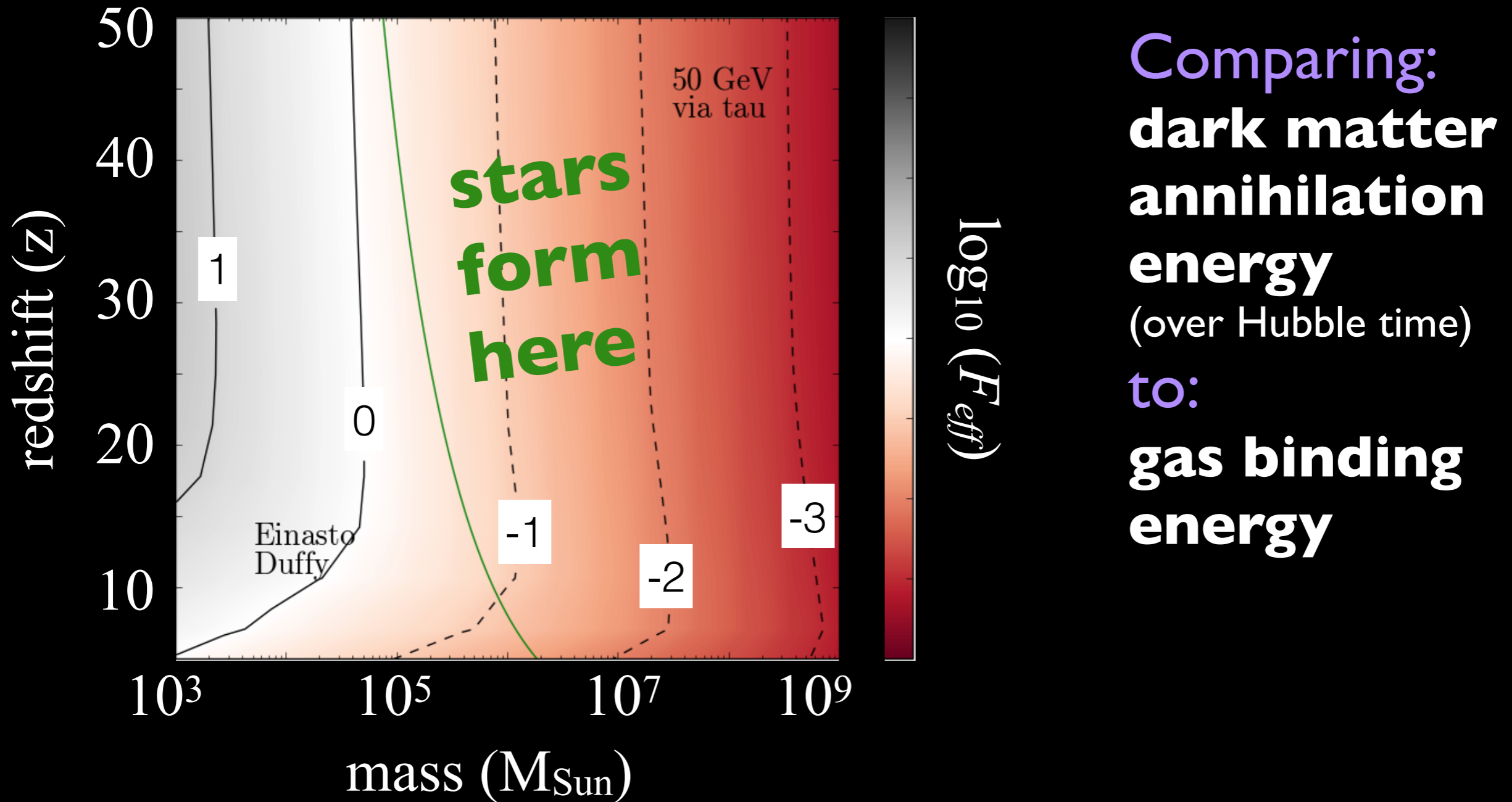
Annihilation Feedback on Halo Gas



Comparing:
dark matter annihilation energy
(over Hubble time)
to:
gas binding energy

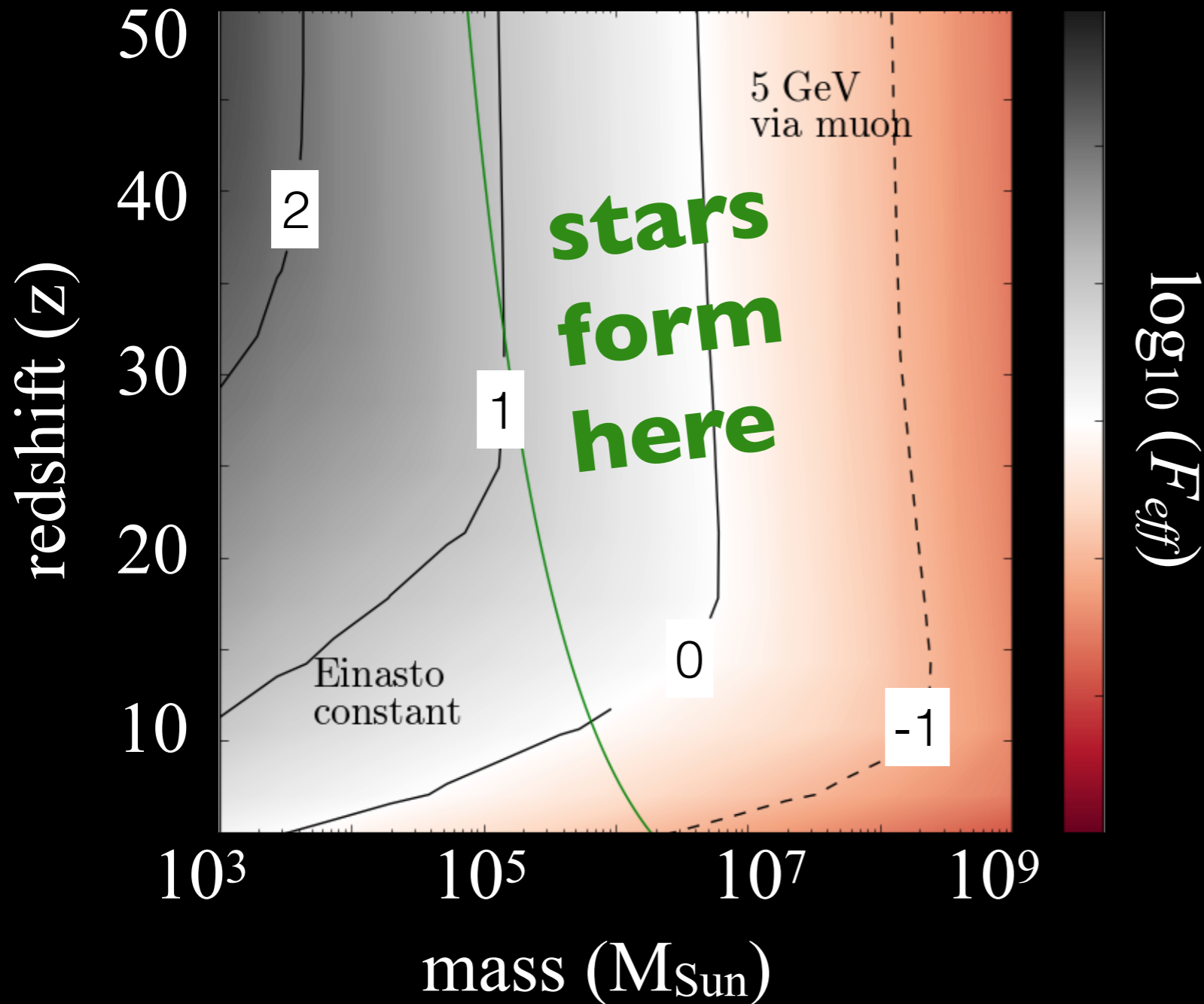
Schon, Mack+ 2015, MNRAS [arxiv: 1411.3783]

Annihilation Feedback on Halo Gas



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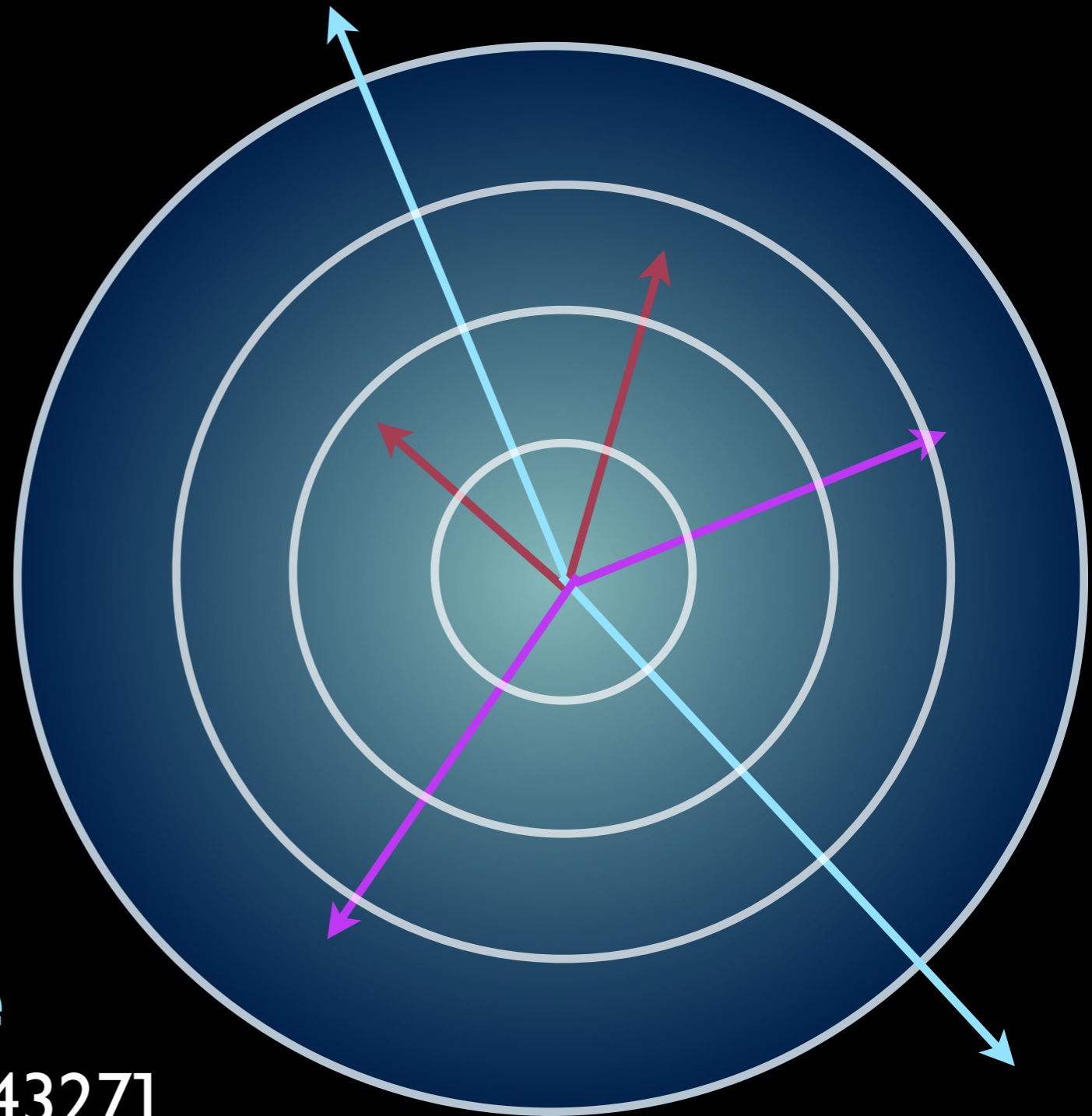
Halo Structure and Environment

Improved code: tracks full particle cascades & deposition within halos

Main questions:

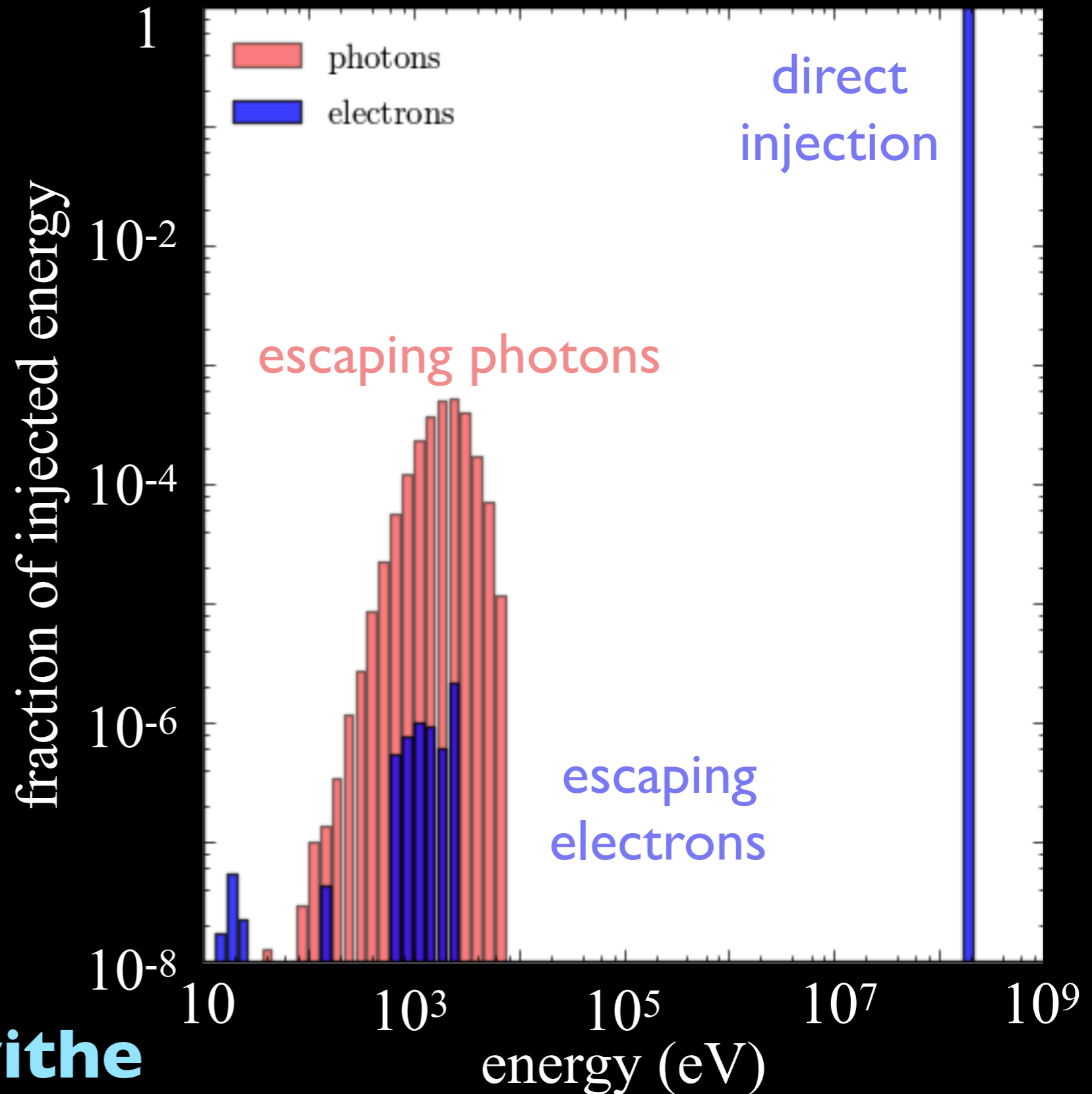
- ▶ Where is the energy deposited?
- ▶ What is the effect on the halo environment?

Schon, Mack & Wyithe
2018, MNRAS [arxiv:1706.04327]

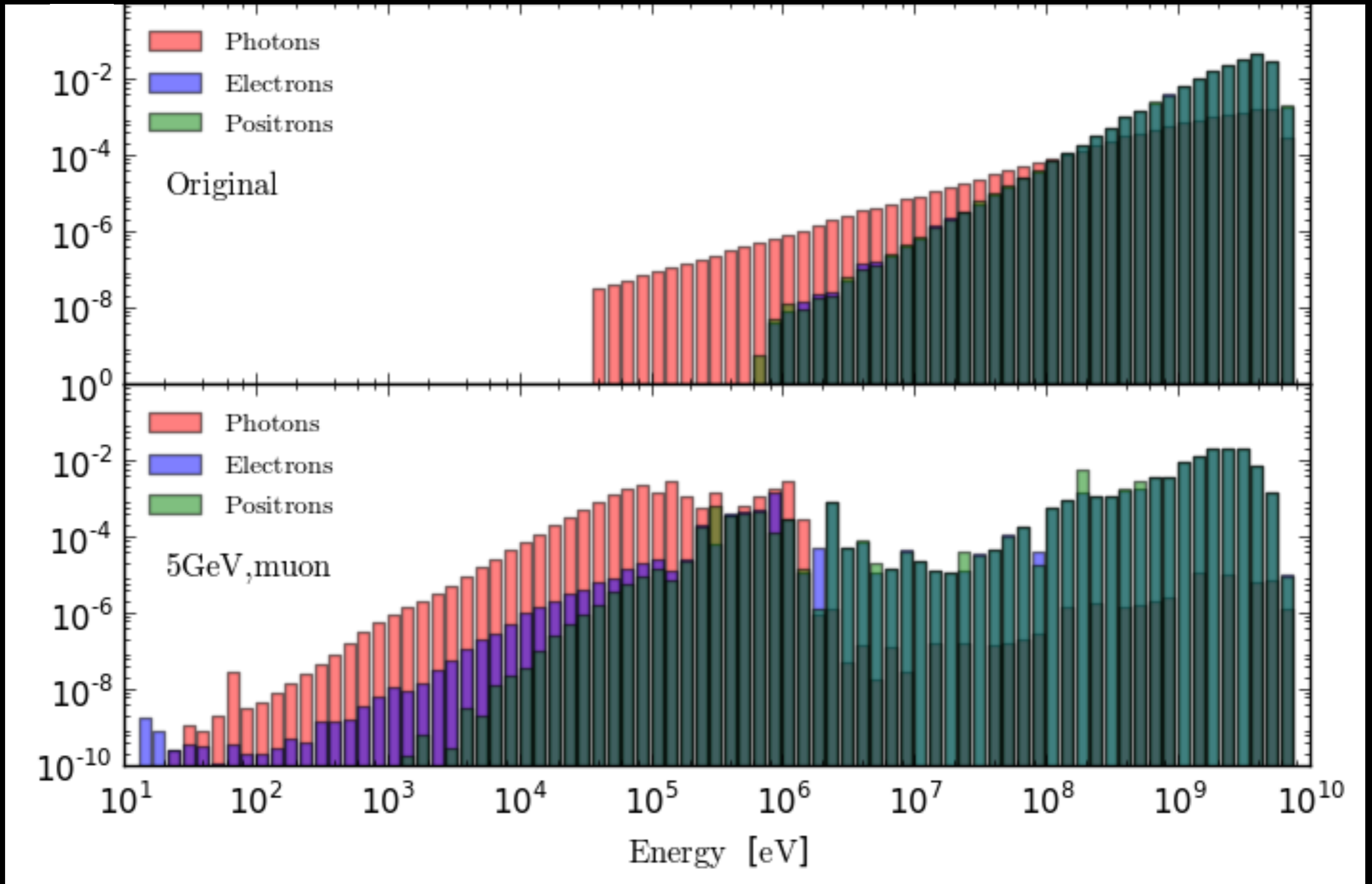


Halo Structure and Environment

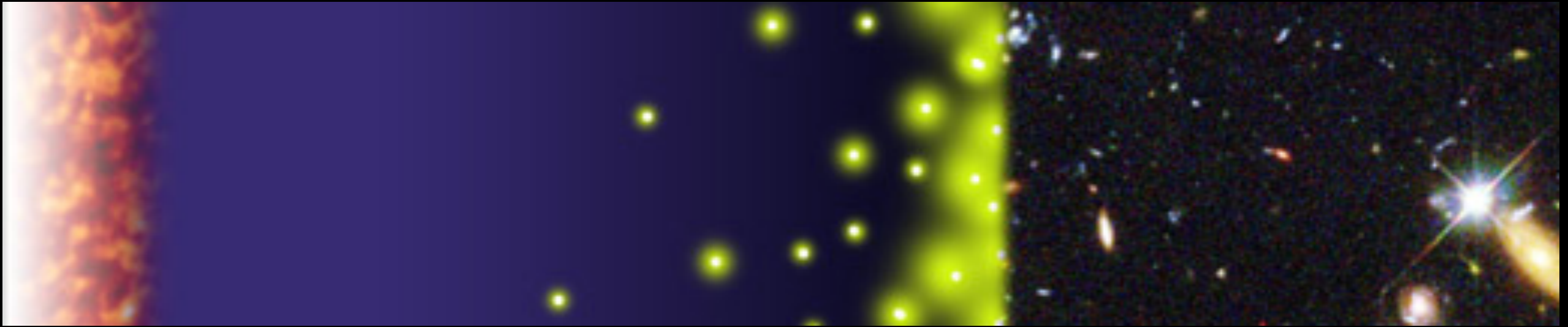
Annihilation products
filtered
through halo
baryons



Halo Structure and Environment



Probing Cosmic Dawn



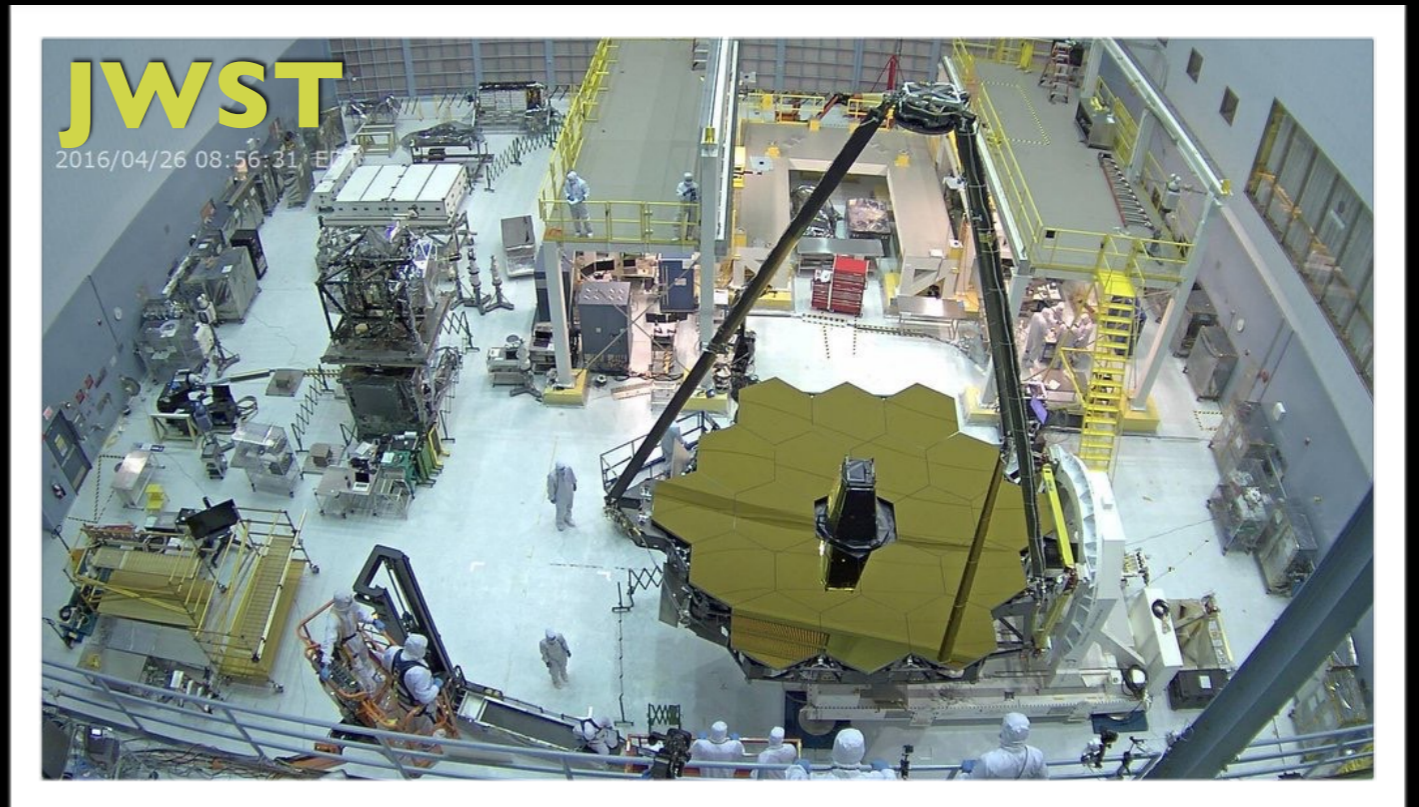
Djorgovski et al., Caltech

← current instruments

← next decade



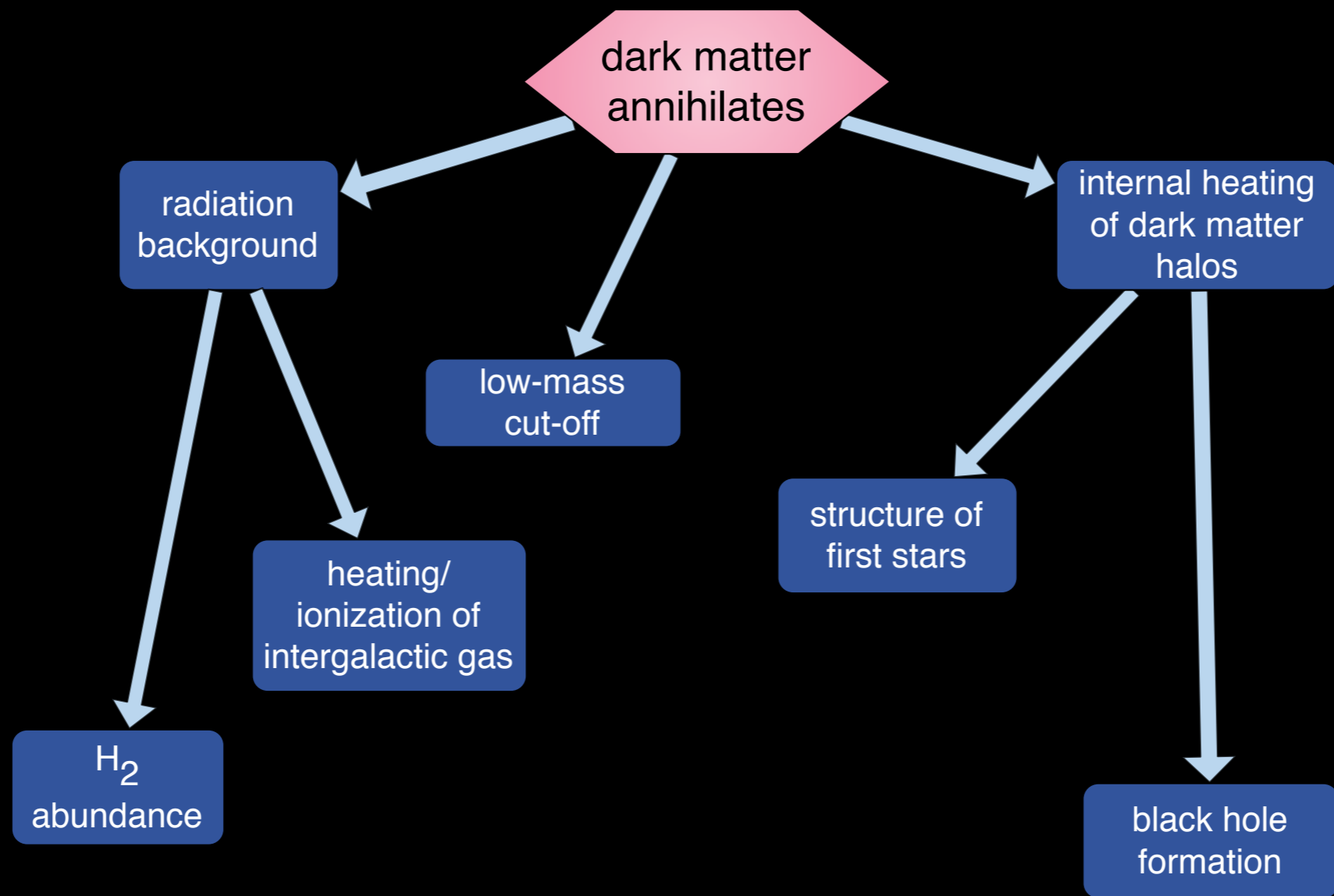
SKA

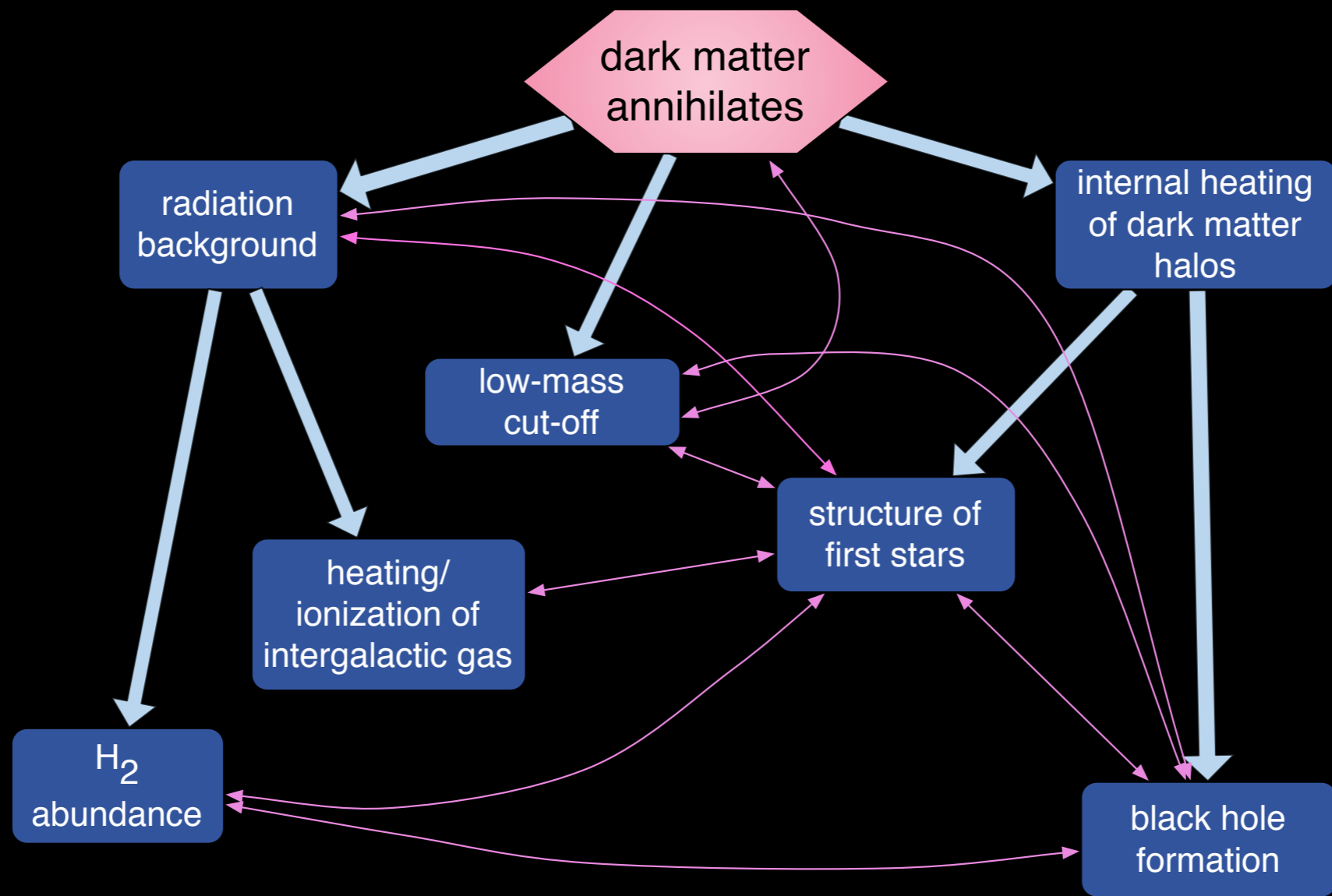


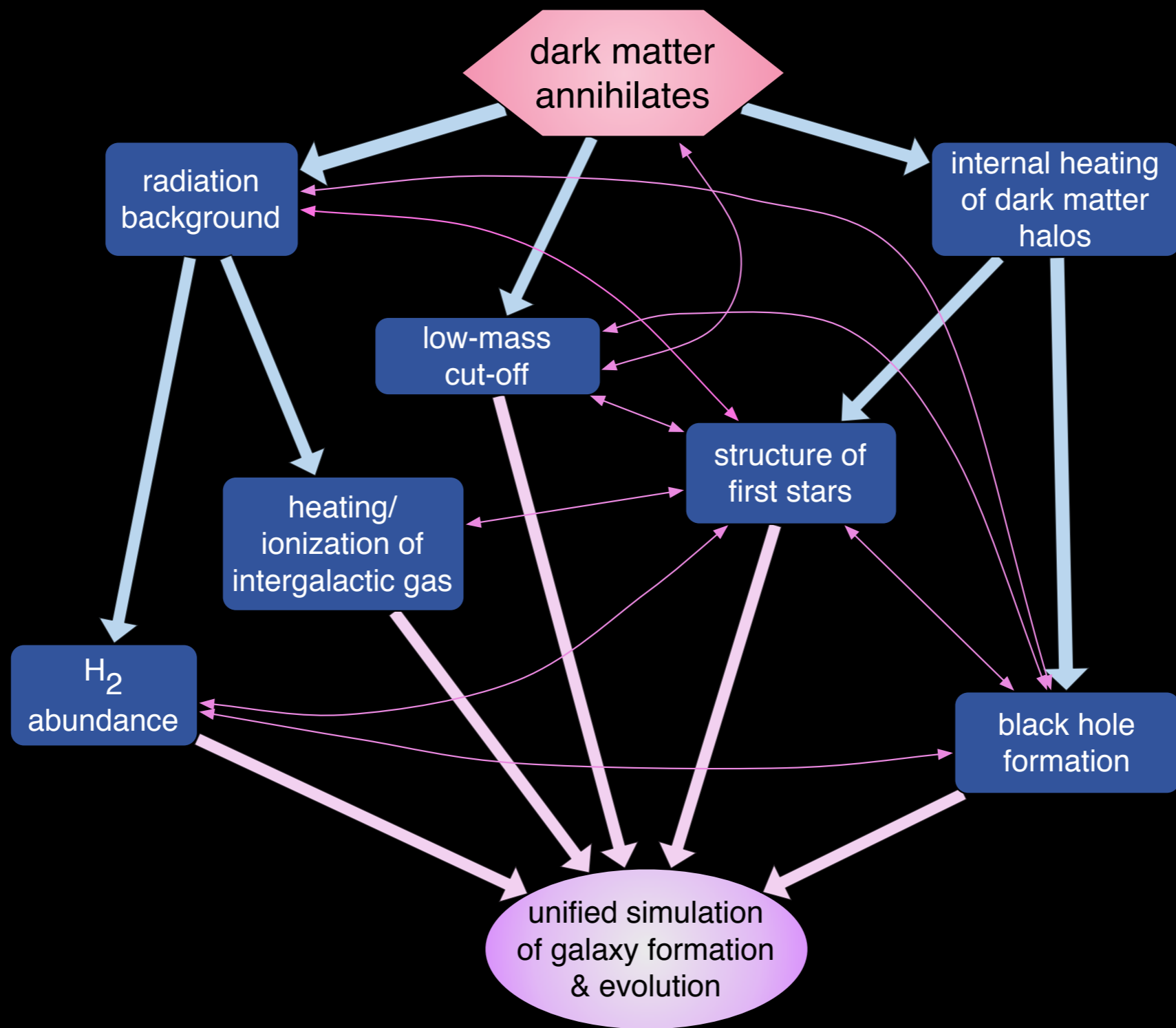
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dark matter
annihilates









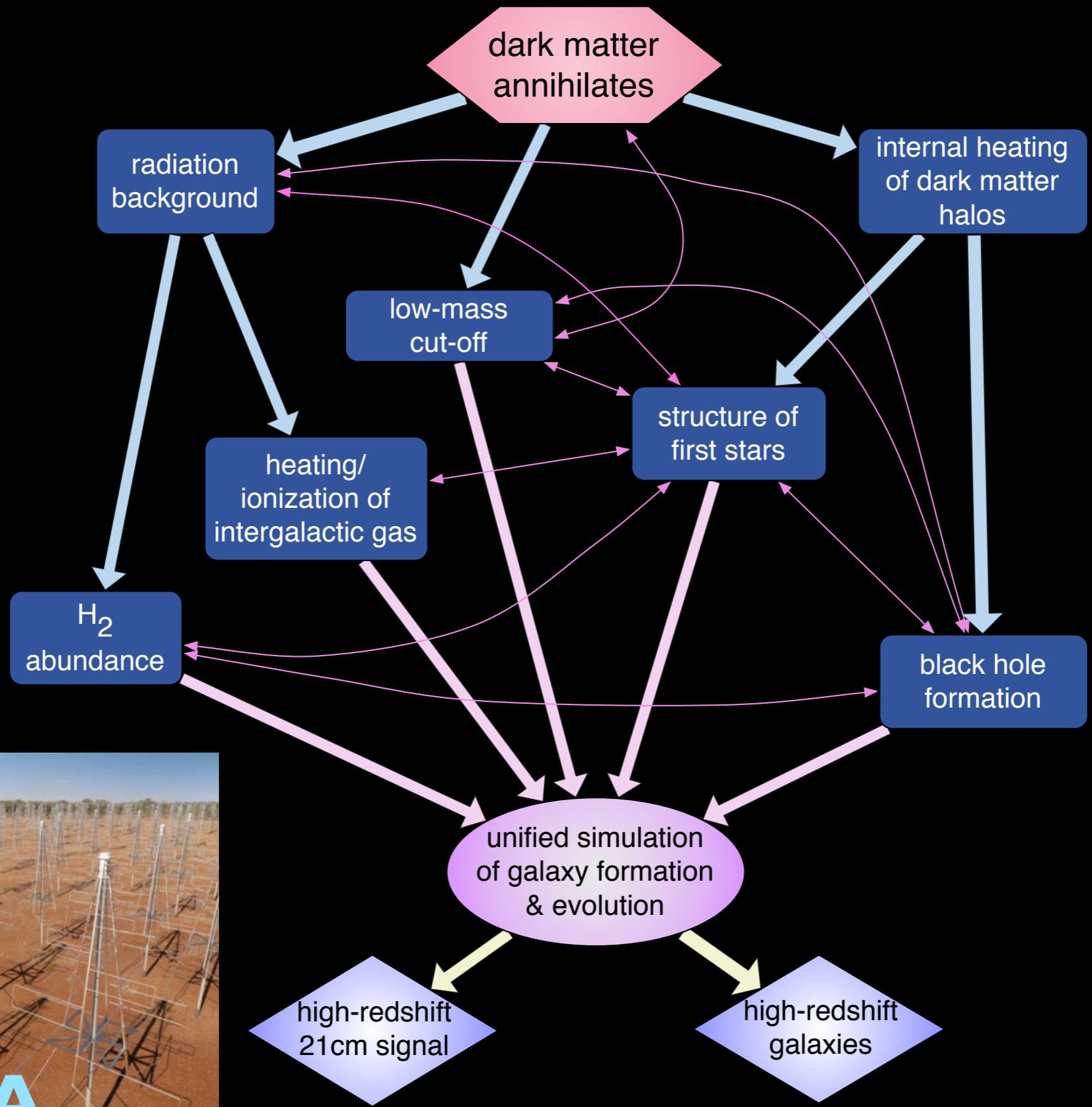


Image credit: Swinburne/
ICRAR/Cambridge/ASTRON



SKA

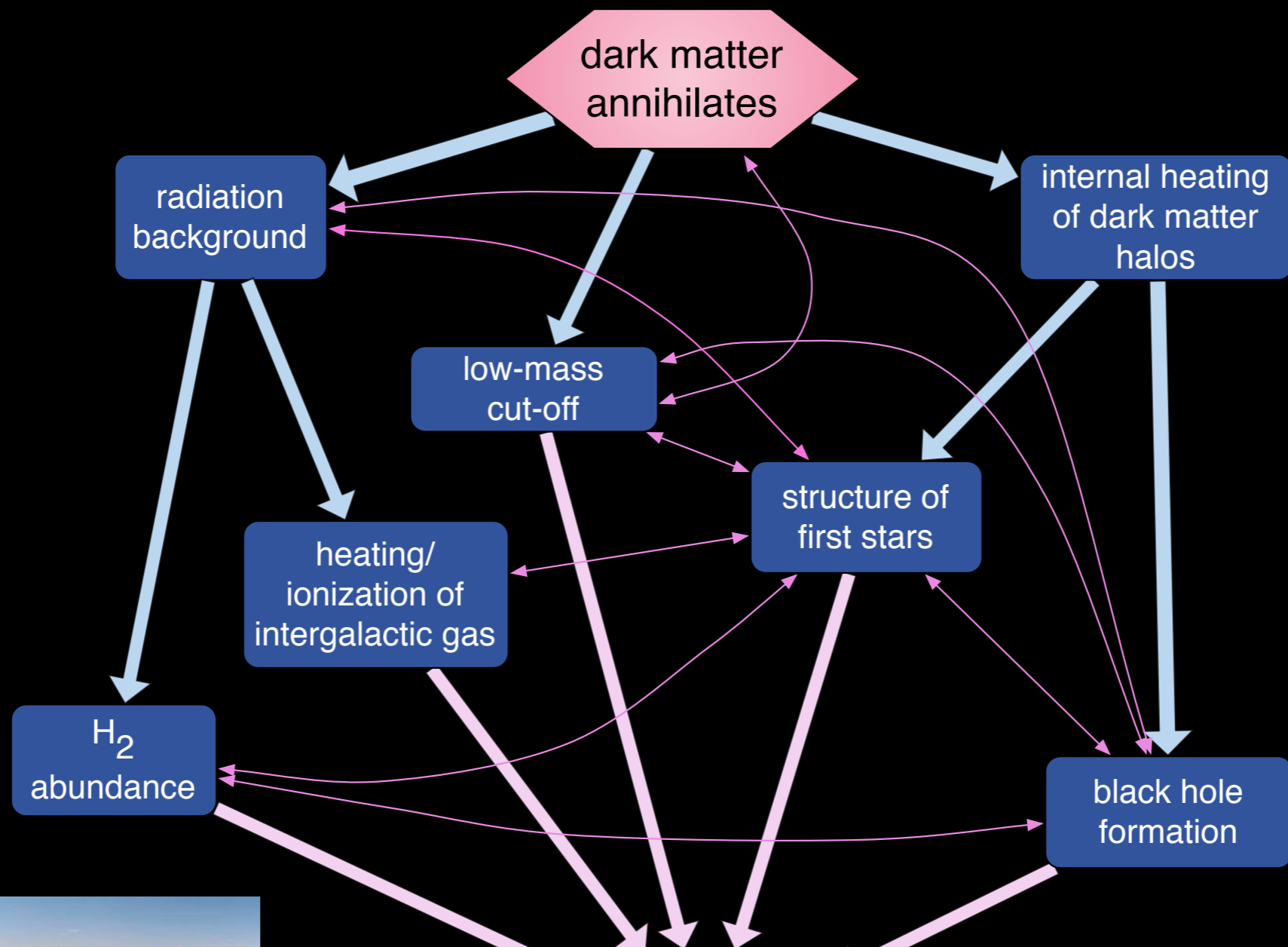


Image credit: Swinburne/ICRAR/Cambridge/ASTRON



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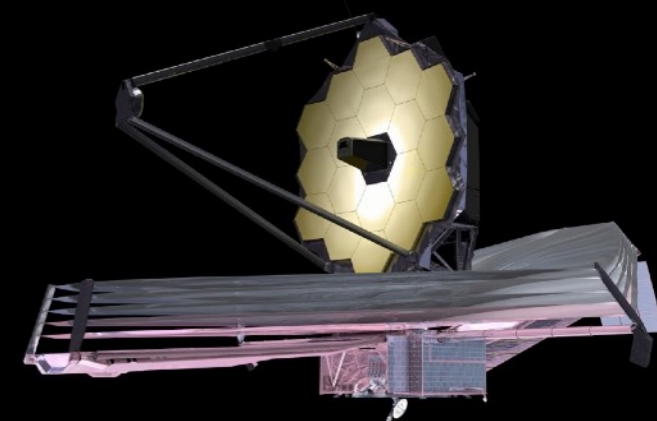


Image credit: NASA

high-redshift
21cm signal

high-redshift
galaxies

Take-Home Messages

- ✦ Future surveys can probe the **particle physics of dark matter** and produce a more consistent picture of cosmology
- ✦ To determine dark matter's impact on high-redshift astrophysics, we need to understand **small halos** and their evolution