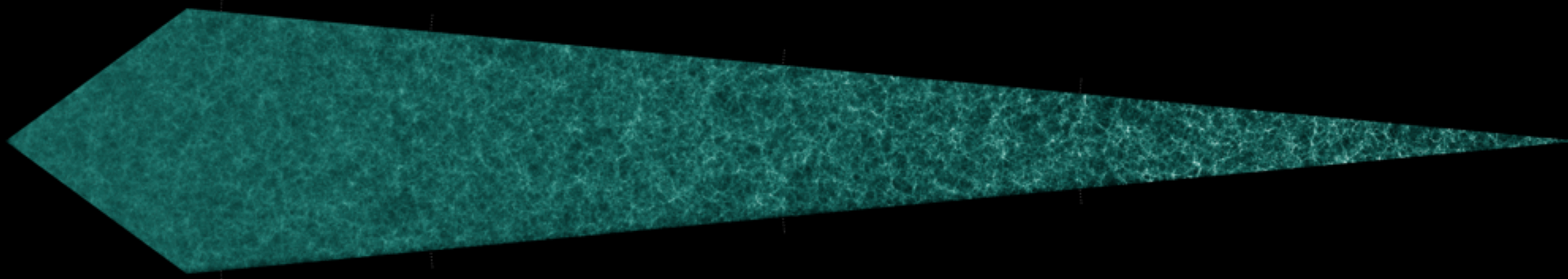
Dark Matter Halos and Cosmic Evolution



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: @AstroKatie

what we know

dark matter is:

massive (gravitationally attractive & clustering)

cold (slow-moving)

non- (or weakly-) interacting
(no confirmed non-gravitational interactions)

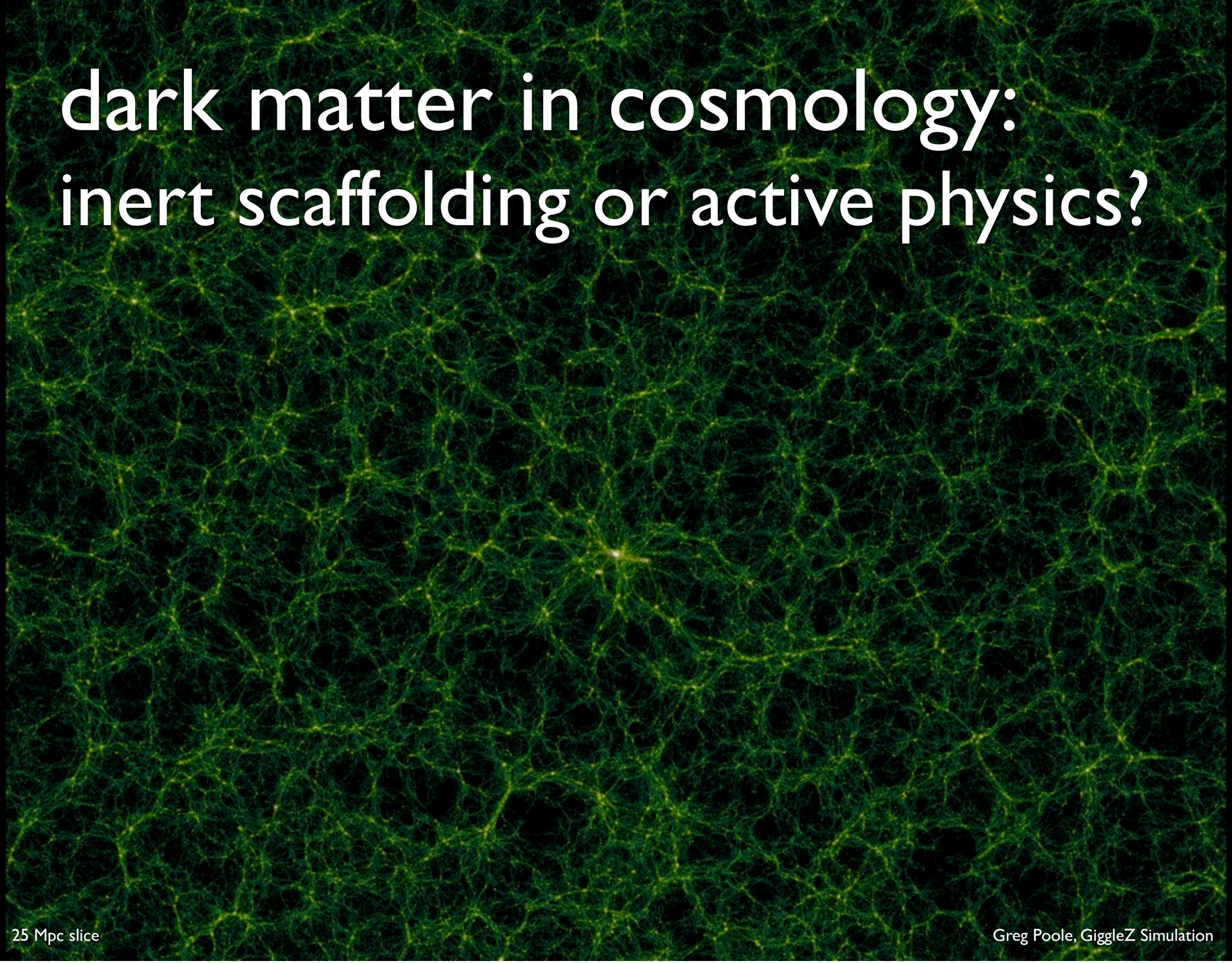
collisionless (passes through itself and other matter)

invisible (does not emit or absorb light)

lines of evidence

- Rotation curves/galactic dynamics (missing mass)
- Cluster dynamics (missing mass)
- Strong & weak gravitational lensing (missing mass / halo shapes / substructure)
- Gravitational microlensing (mass distribution)
- CMB acoustic peaks (DM/baryon ratio)
- Matter power spectrum & structure formation (DM/baryon ratio)
- Cluster collisions (missing mass / collisionless matter)

dark matter in cosmology:
inert scaffolding or active physics?



dark matter particle physics in cosmology

Key question:

If dark matter is annihilating when the first stars and galaxies are forming, where does all that energy go?

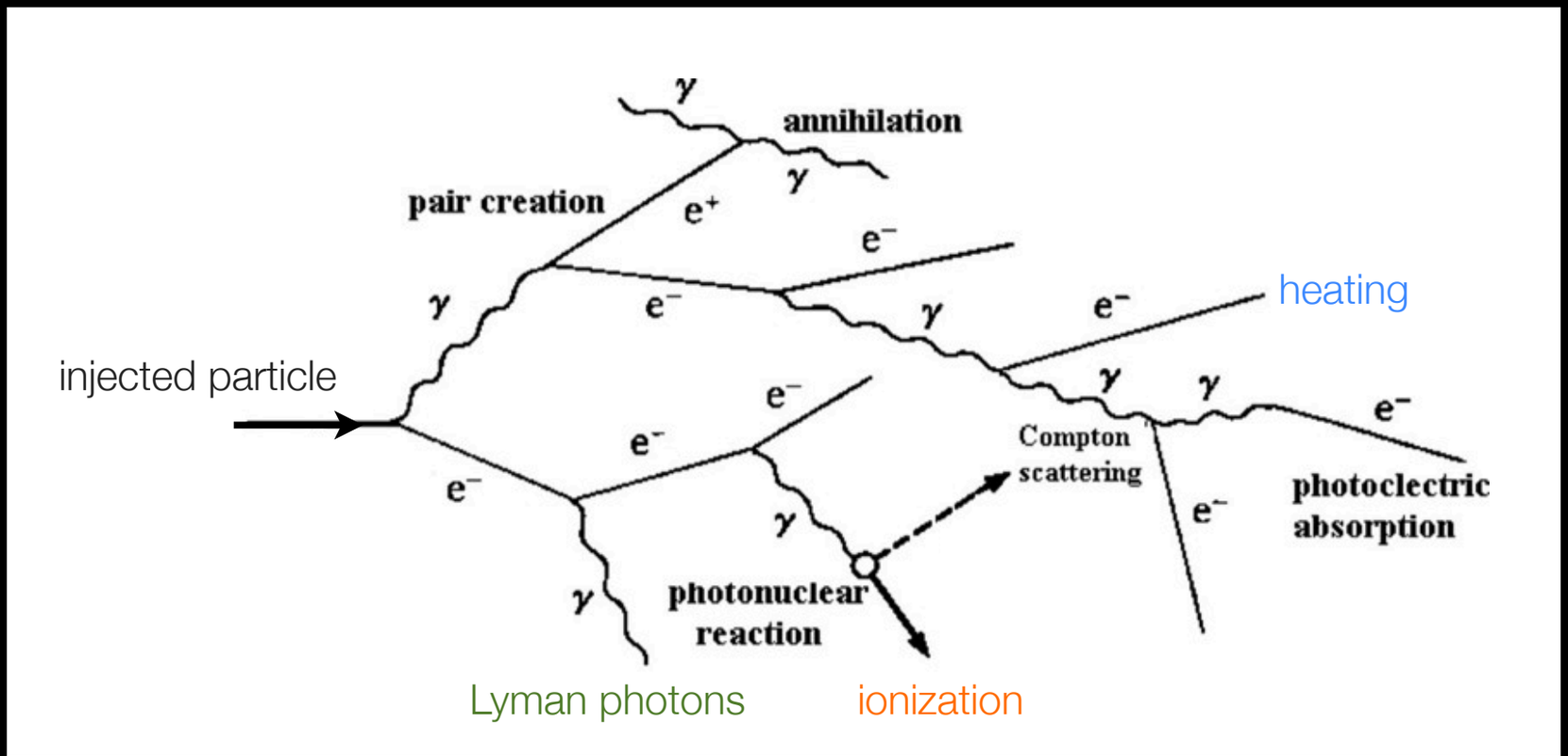
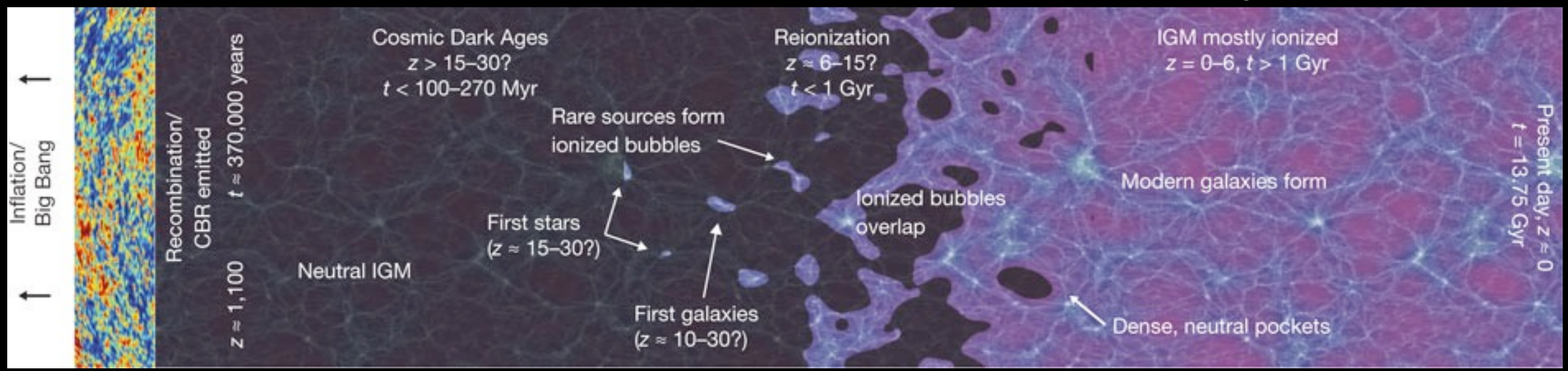


Image from talk by Carmelo Evoli

cosmic dawn

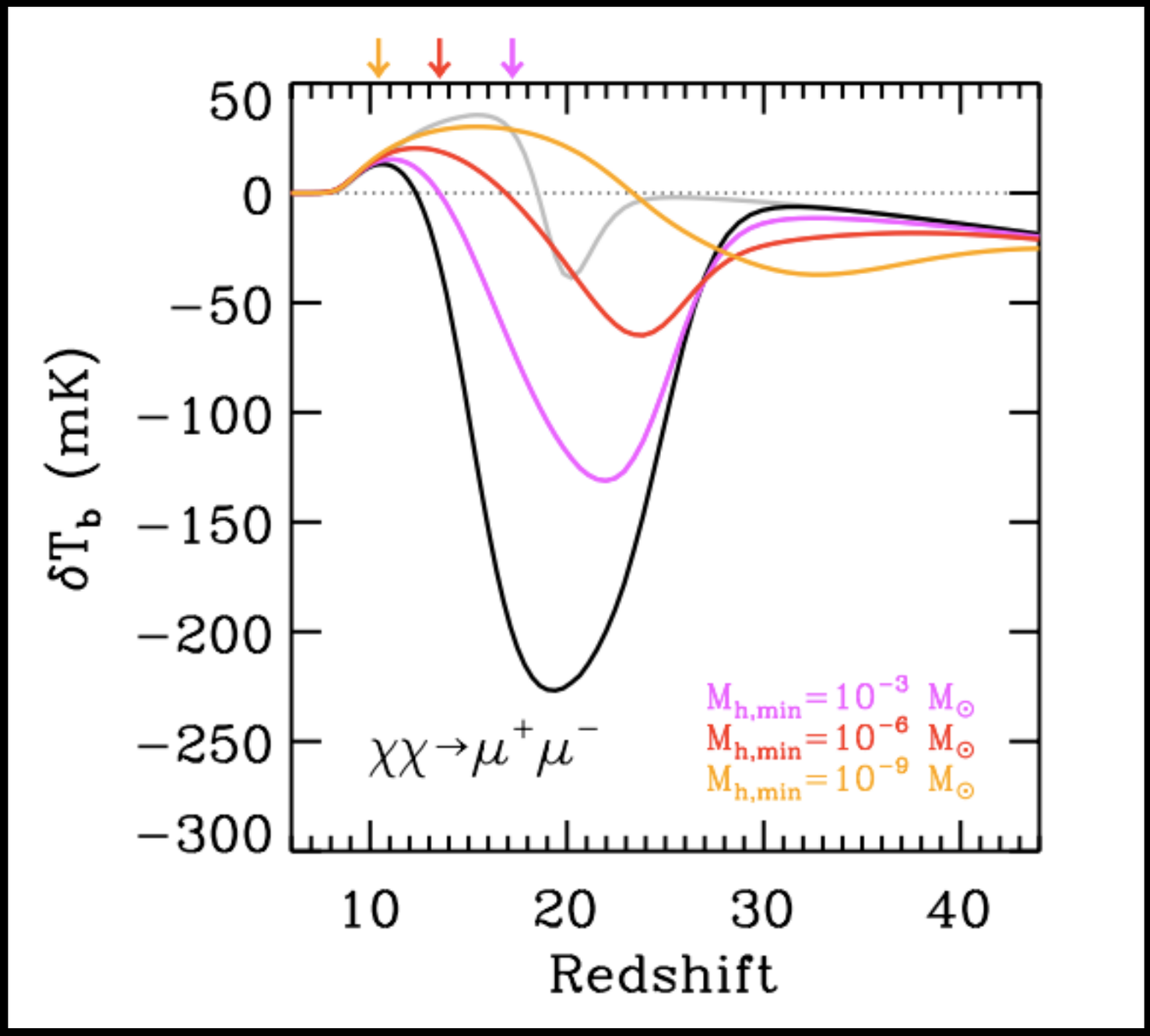
Image: Robertson et al., Nature, 2010



dark matter annihilation can cause heating and ionization during the **cosmic dark ages**

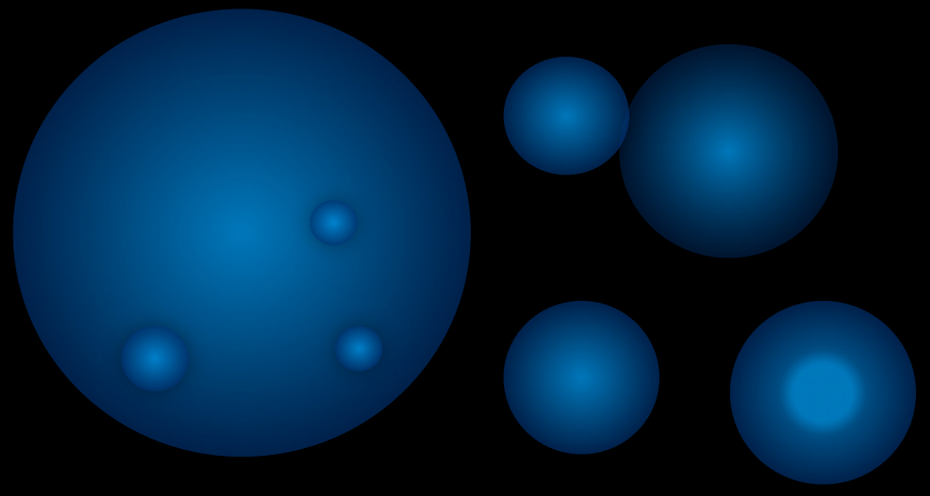
observing the **epoch of reionization** is a **key project for SKA** -- great opportunity to see effects of dark matter particle physics

21cm signal



Evoli, Mesinger & Ferrara, arxiv:1408.1109

the halo problem



- To understand dark matter particle physics, need to understand **dark matter halos**
- Halo properties crucial for
  - **Direct detection** (limits depend on velocities, clumpiness)
  - **Indirect detection** (densities, subhalos, boost factors)
  - **Effects at high redshift** (density distributions, halo mass functions, lower-mass cut-off)

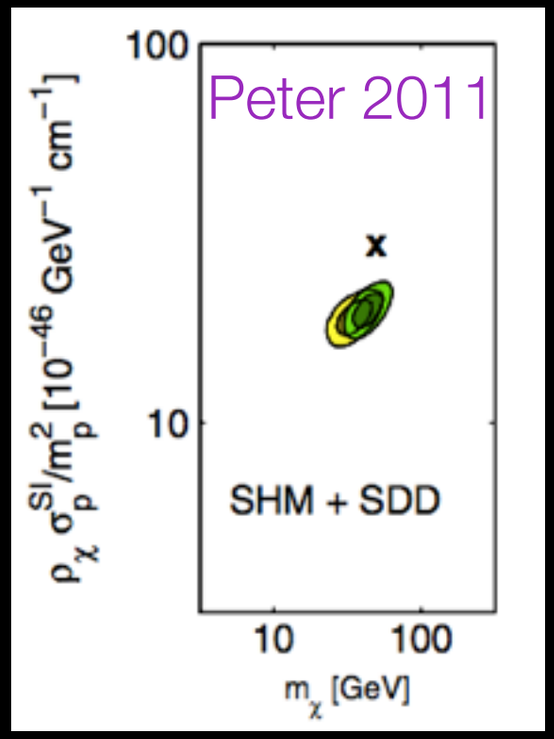
halo models & direct detection

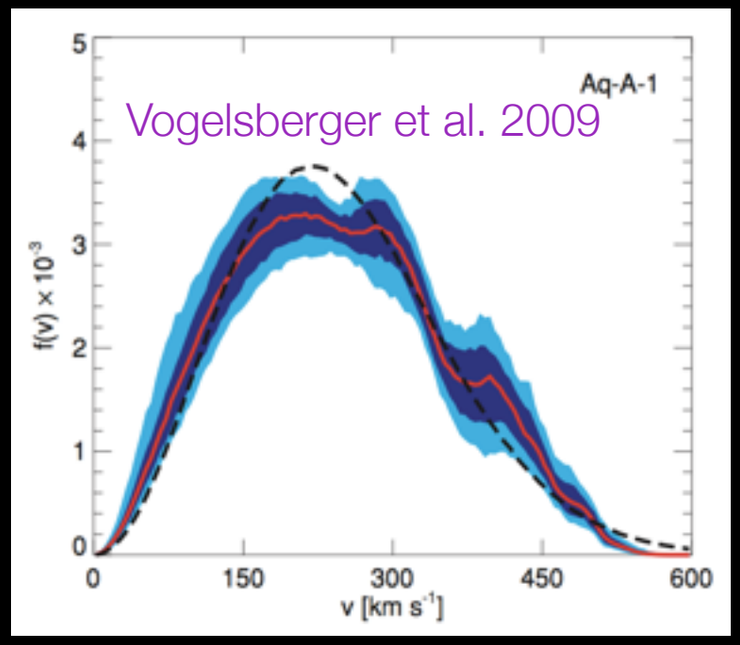
differential event rate

$$\frac{dR}{dQ} = \left(\frac{m_N}{\mathrm{kg}}\right)^{-1} \int_{v_{\min}} d^3\mathbf{v} \frac{d\sigma_N}{dQ} v f(\mathbf{x}, \mathbf{v}),$$

particle physics

local DM distribution function

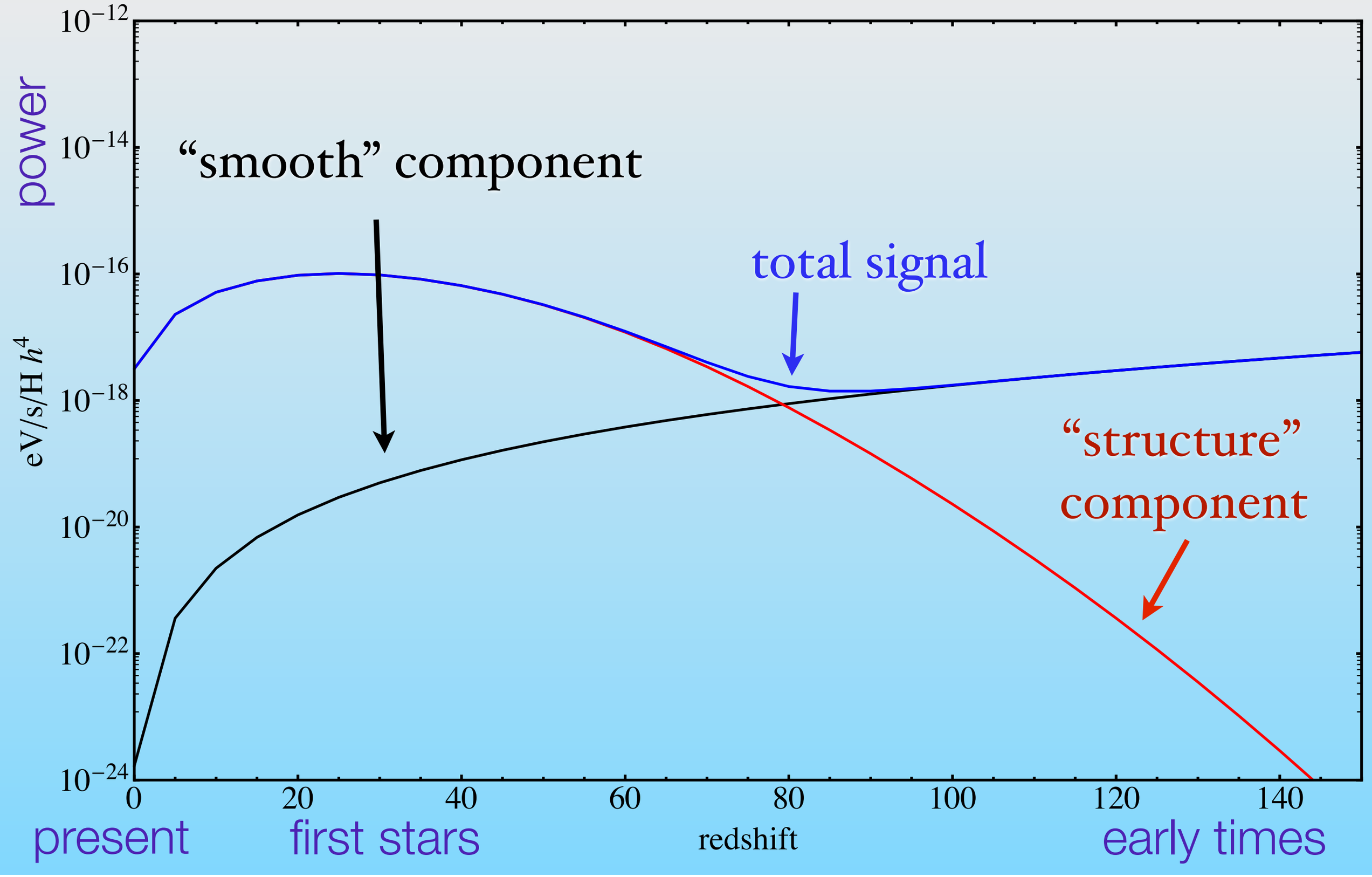




a “big picture” question

How does the **mean dark matter annihilation power** in the Universe vary with time?

annihilation over cosmic time



complications

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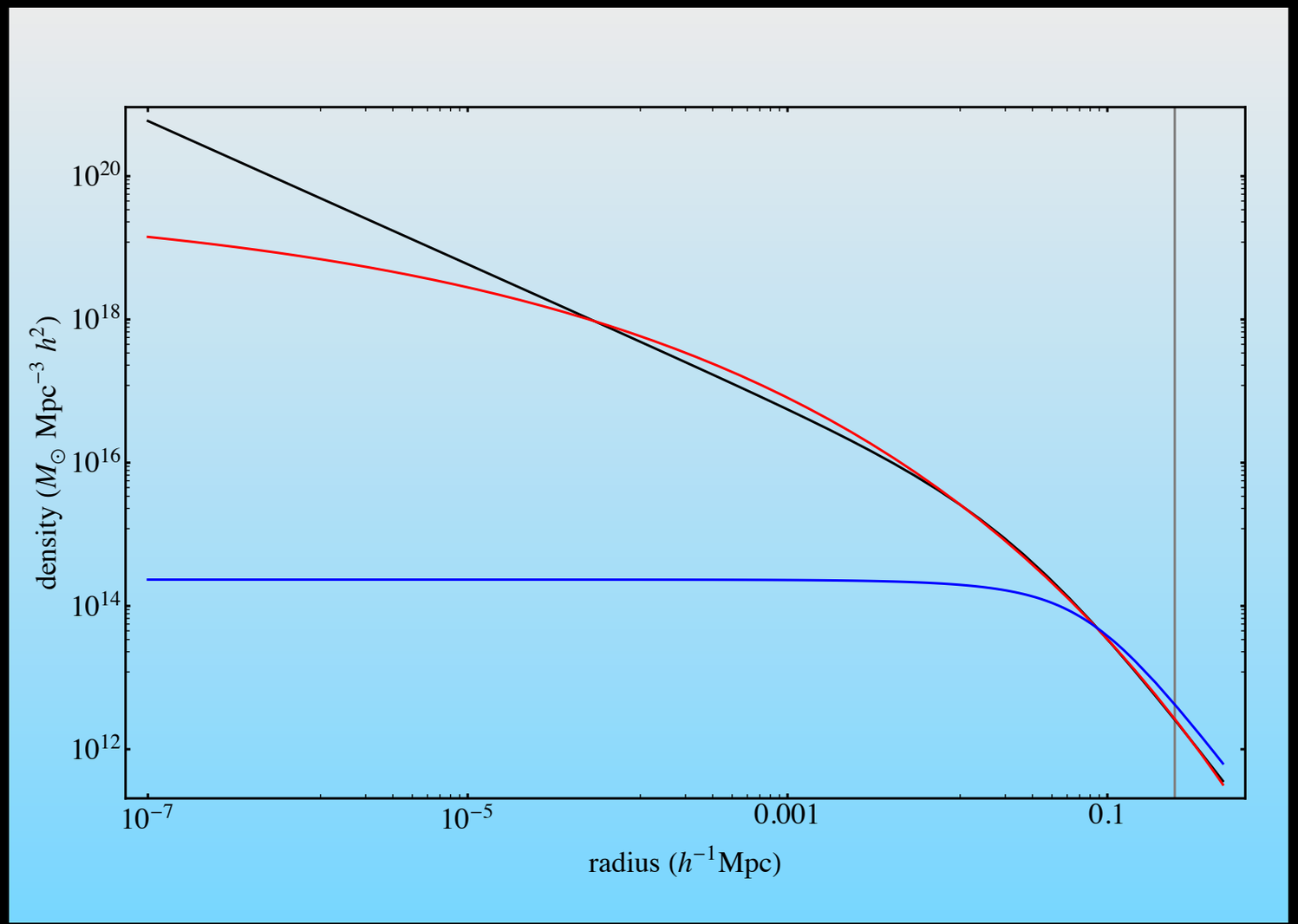
- Dark matter halo **density profile** (NFW? Einasto? Other?)



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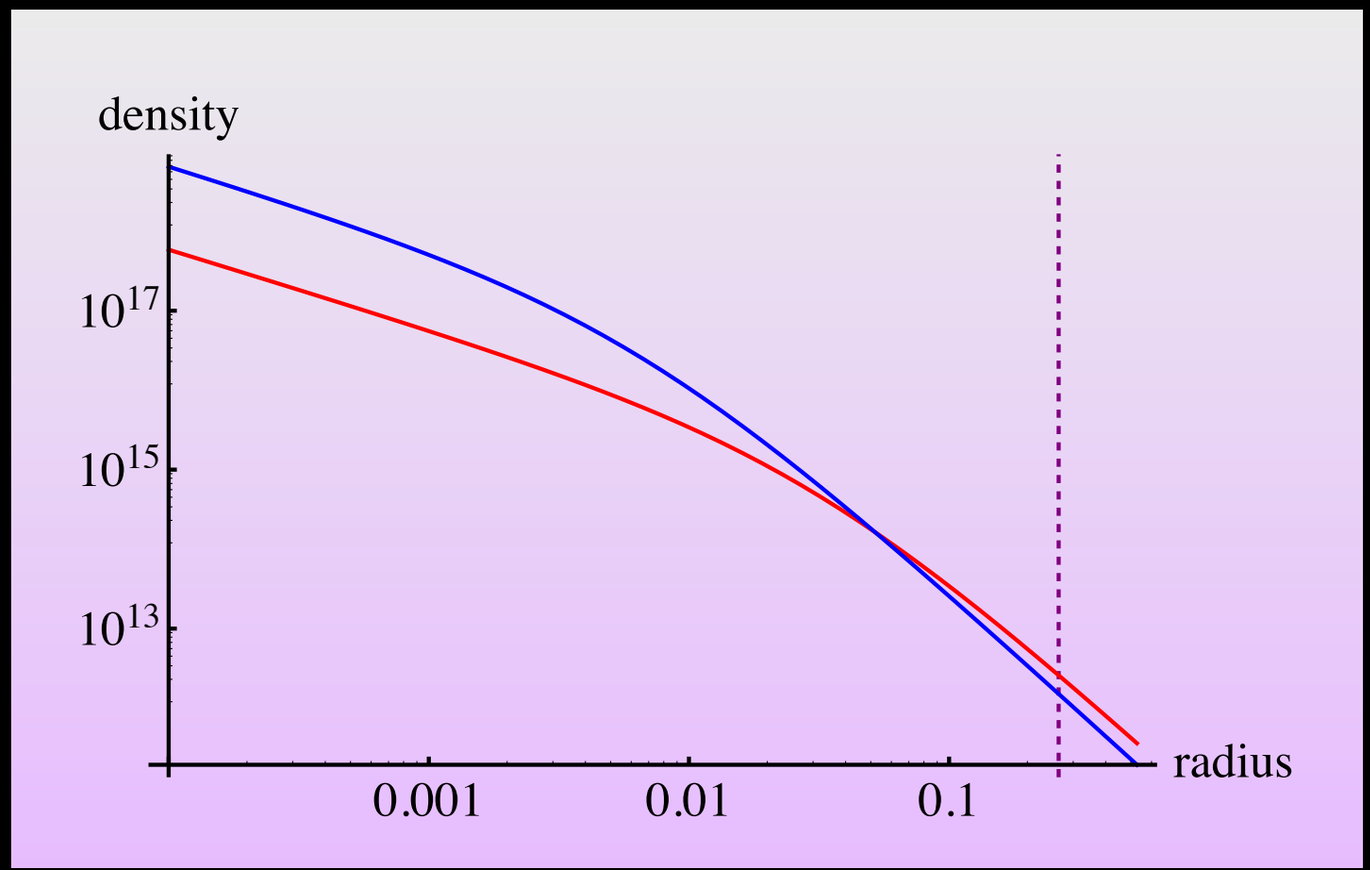
- Mass-**concentration** relation c(M,z)



complications

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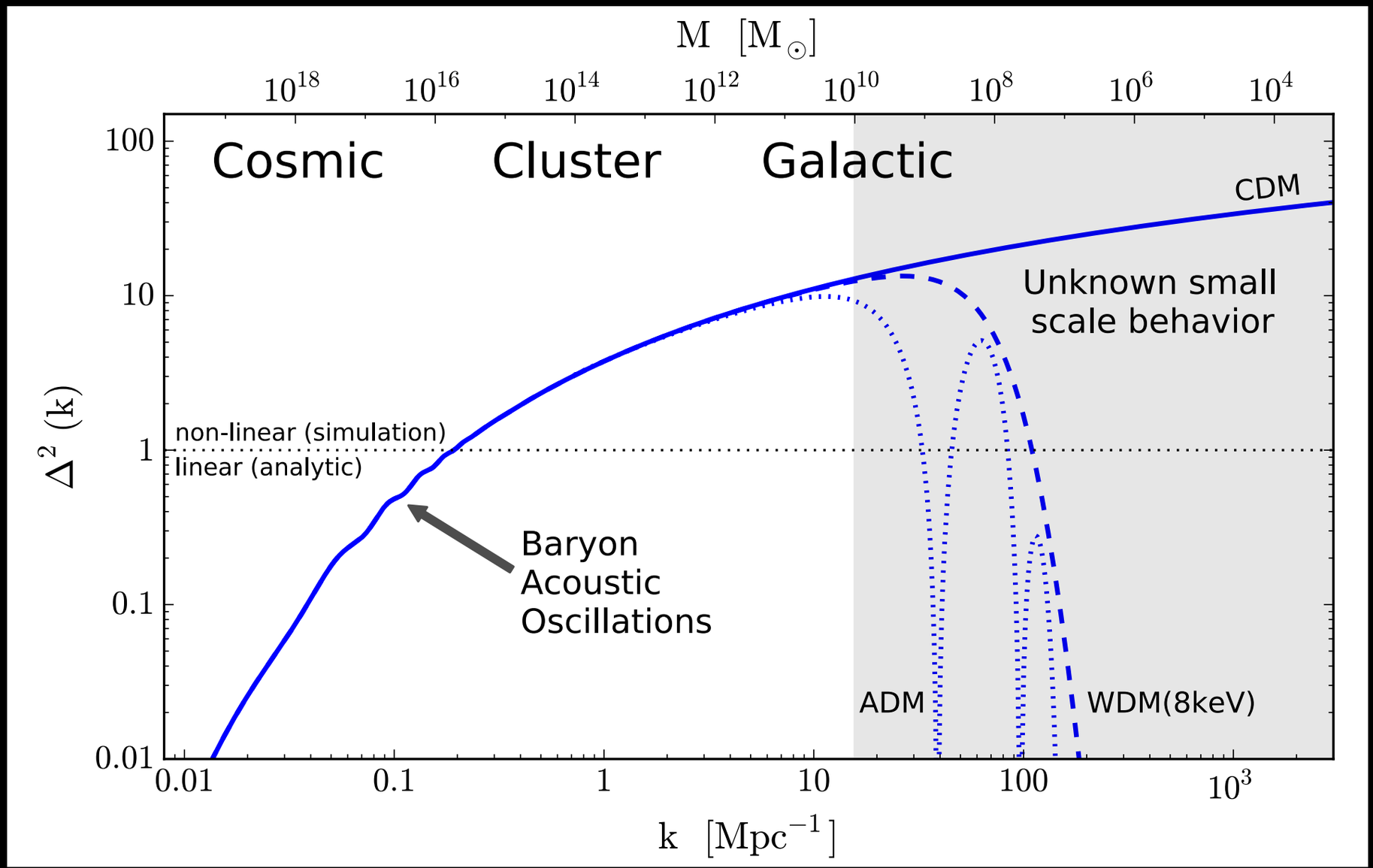
- Lower mass cutoff in **power spectrum**



Kuhlen et al. 2012

complications

- Dark matter halo **density profile** (NFW? Einasto? Other?)
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  - **Baryonic effects** (feedback)

NOAO/AURA/NSF/WIYN

complications

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- Lower mass cutoff in **power spectrum**
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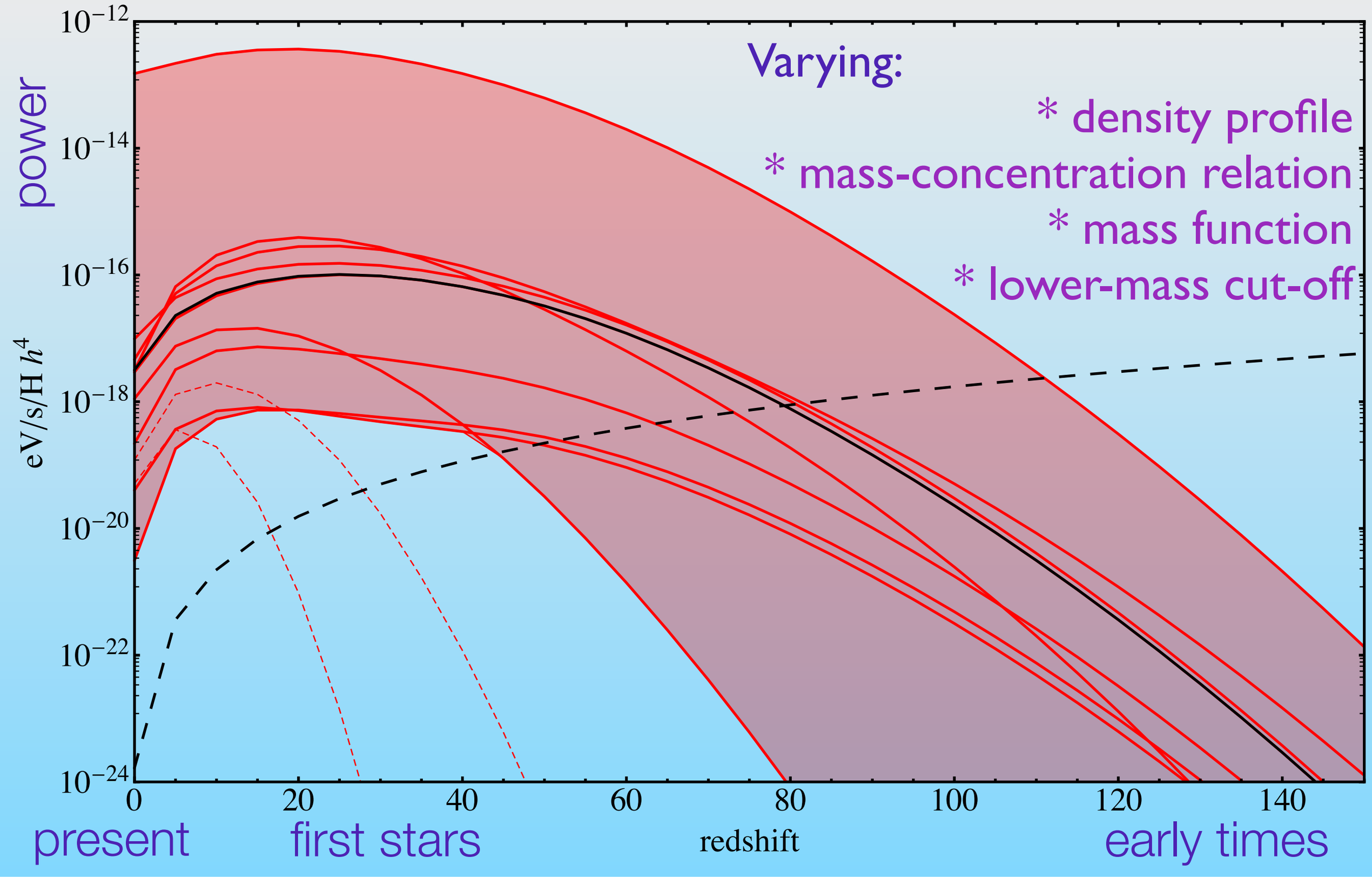
  - **Baryonic effects** (feedback)
  - Halo **formation histories** (low masses / high redshift)

R Jay Gabany (Blackbird Observatory)

annihilation over cosmic time



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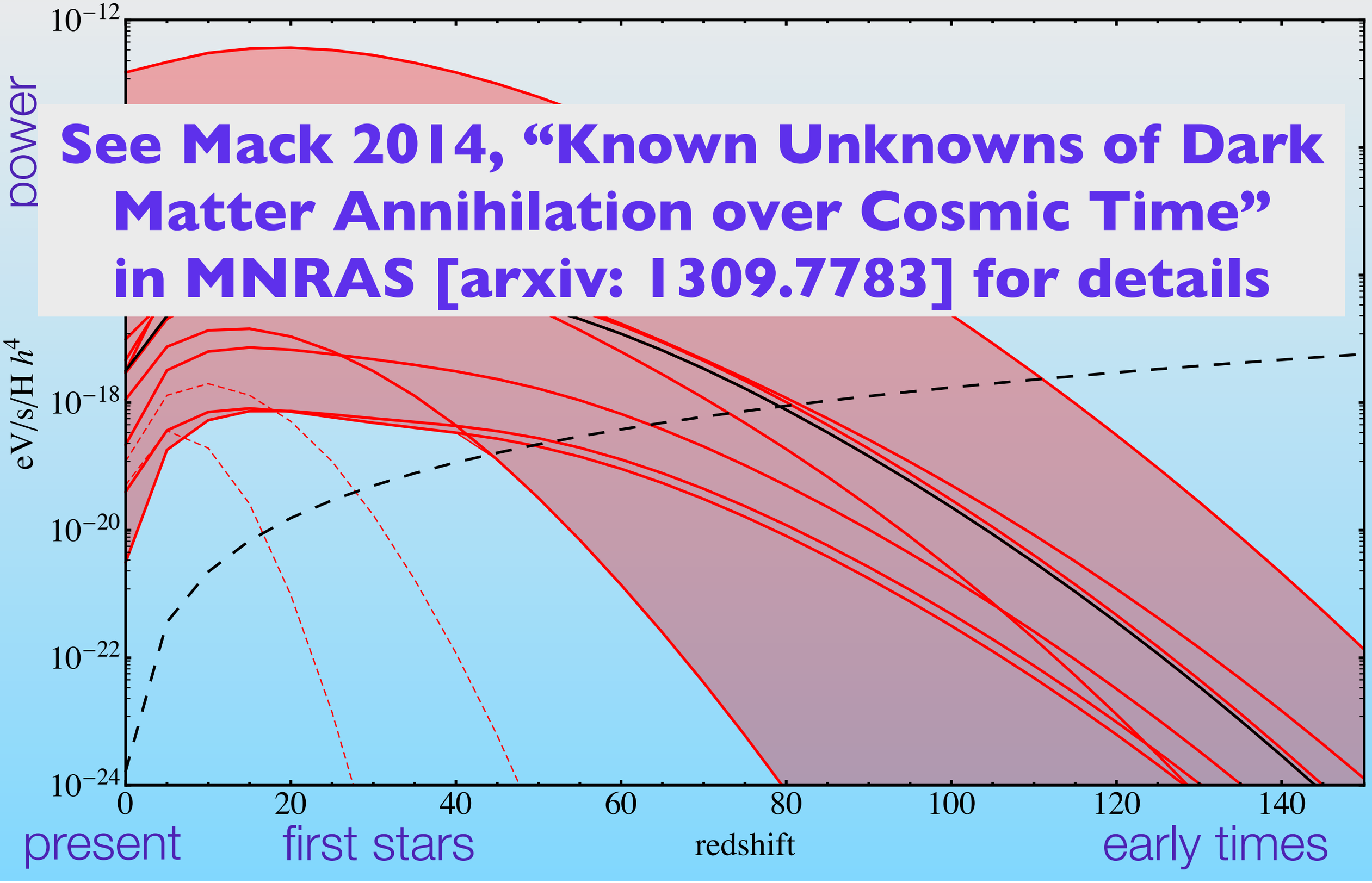
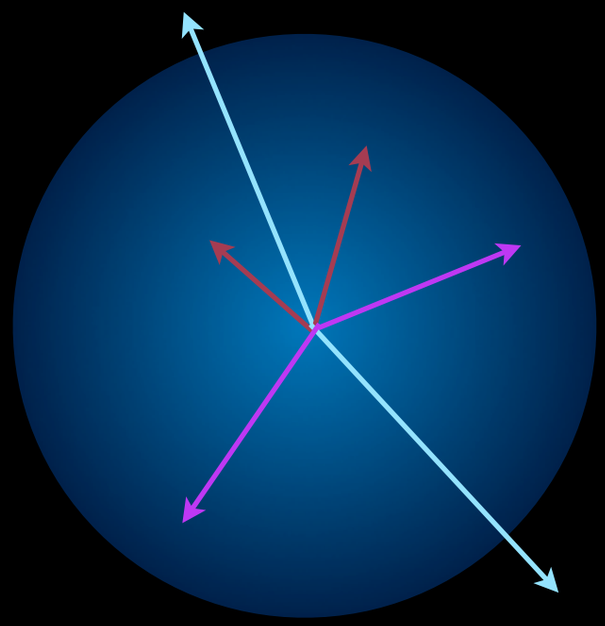


See Mack 2014, "Known Unknowns of Dark Matter Annihilation over Cosmic Time" in MNRAS [arxiv: 1309.7783] for details

annihilation within halos

Question:

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



Resources:

PYTHIA code: dark matter annihilation events

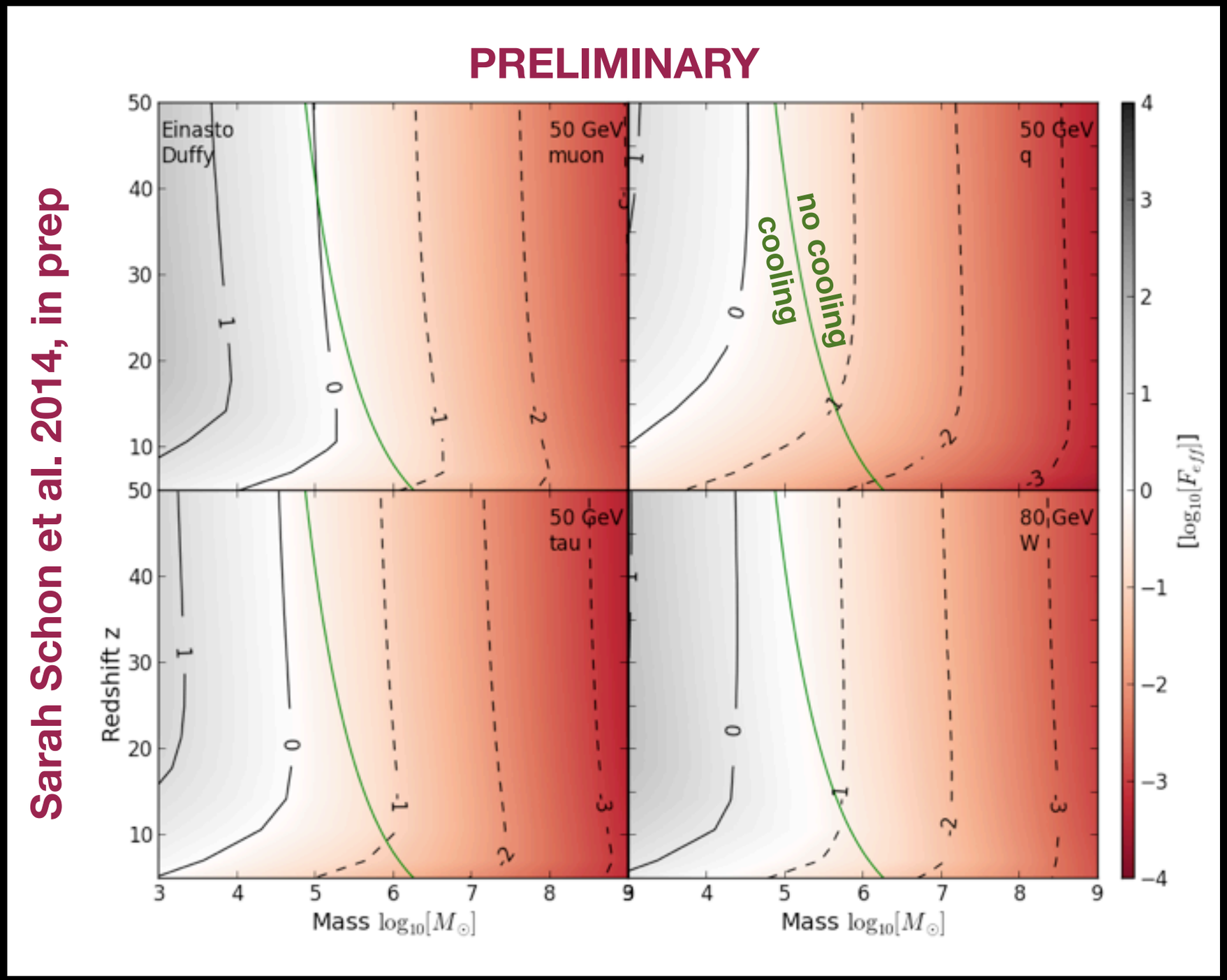
MEDEA2 code: energy transfer to baryons

Halo models: density profile, mass-concentration

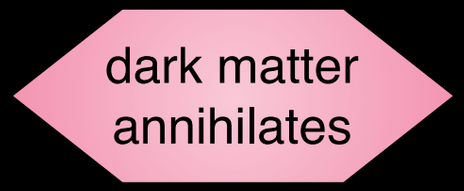
annihilation within halos

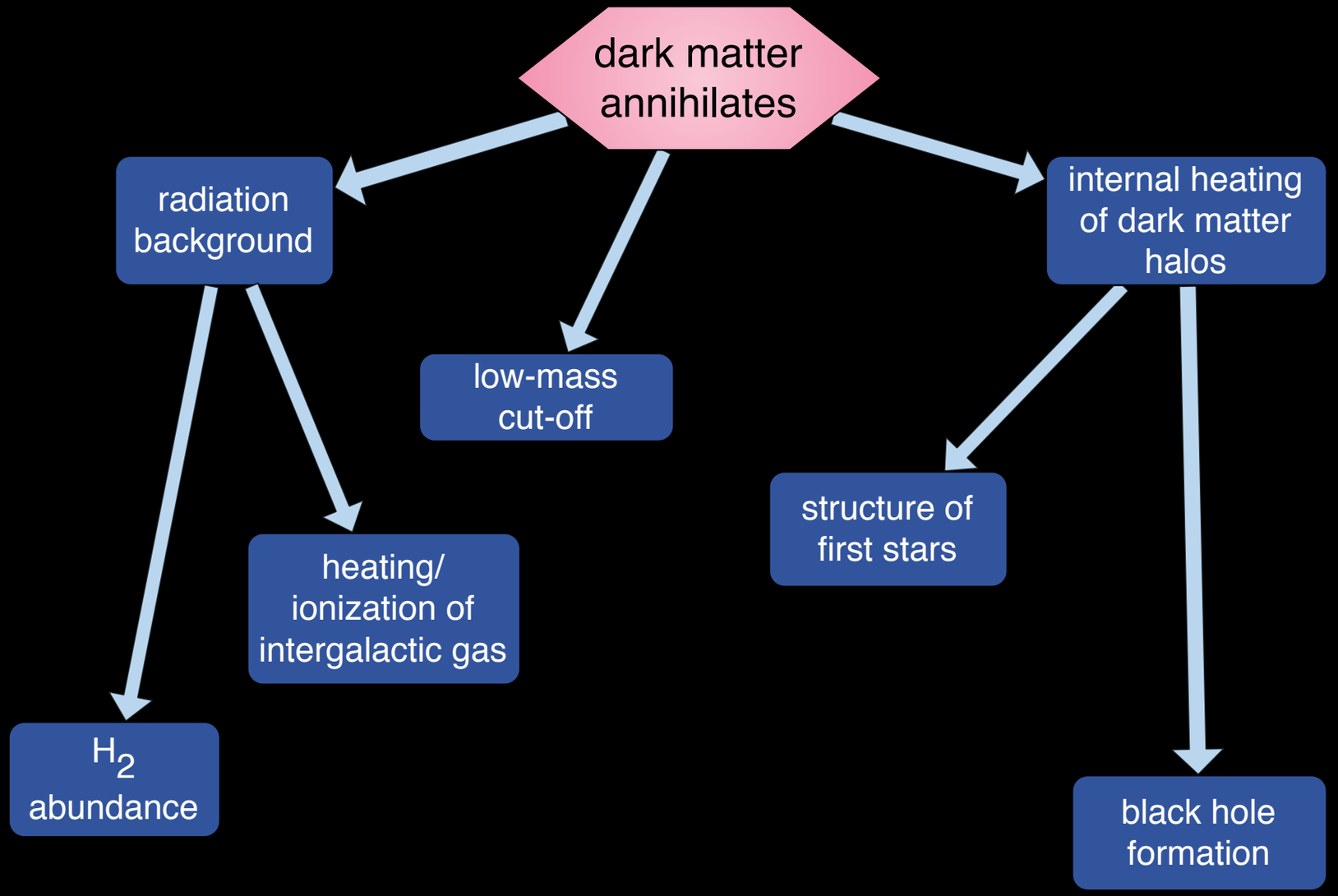
SEE POSTER

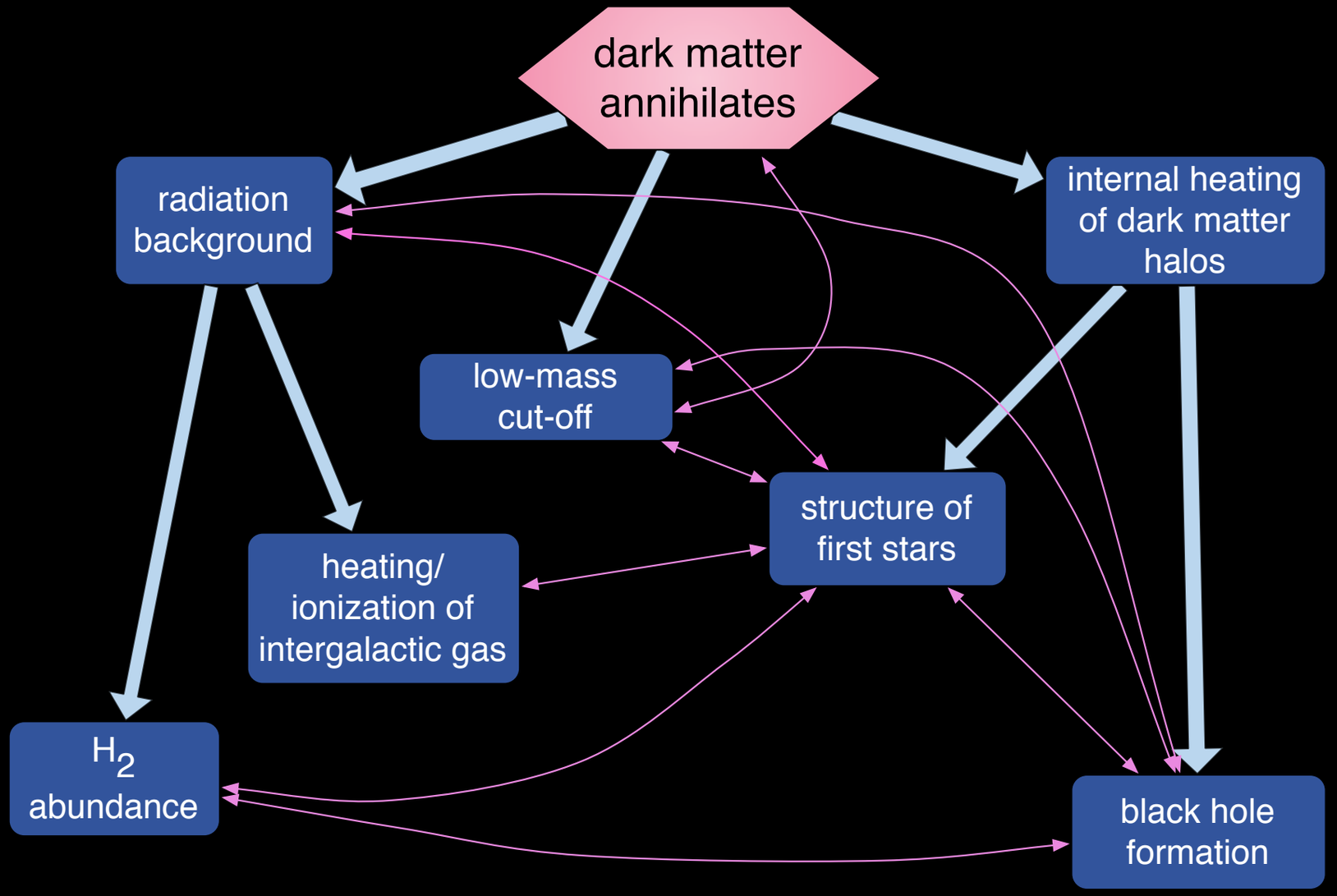
Sarah Schon et al. 2014, in prep



Ratio: **annihilation energy absorbed** (over Hubble time) to **gas binding energy**


dark matter
annihilates


dark matter annihilates
radiation background
low-mass cut-off
internal heating of dark matter halos
heating/ ionization of intergalactic gas
structure of first stars
H_2 abundance
black hole formation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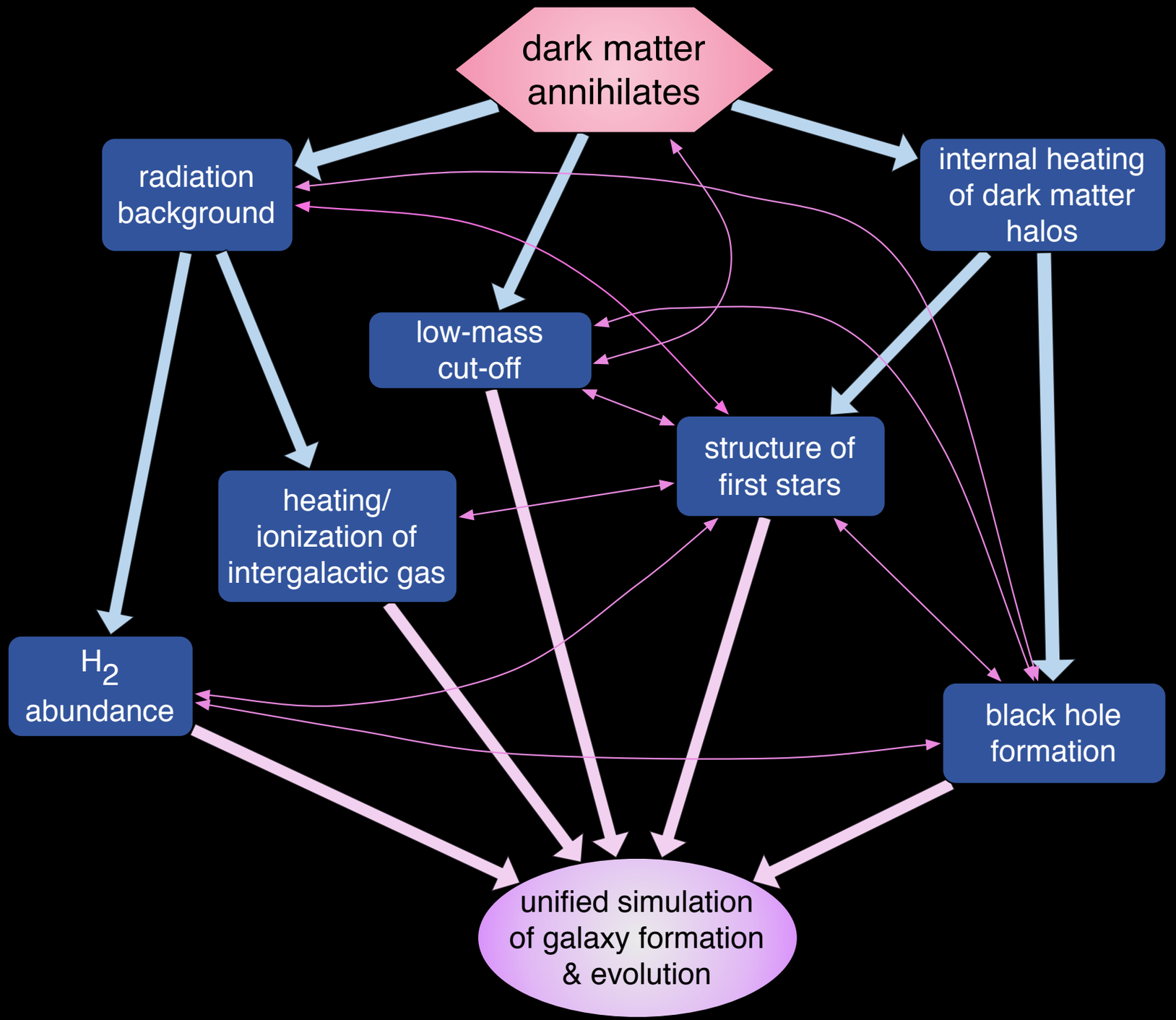
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Image credit: Swinburne/ ICRAR/Cambridge/ASTRON

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Image credit: Swinburne/ ICRAR/Cambridge/ASTRON

JWST

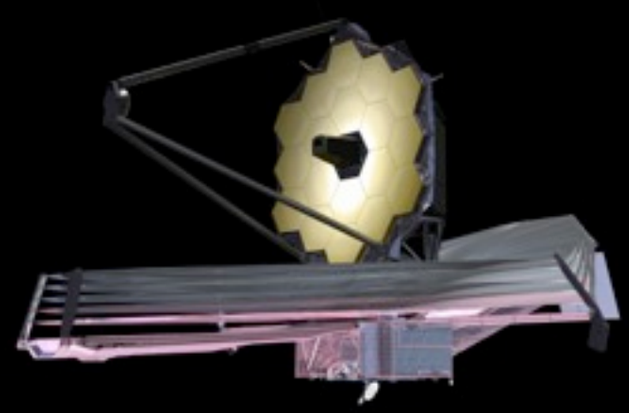

Image credit: NASA

unified dark matter simulation

* **Ultimate goal: Distinguish models/classes of dark matter via their high-redshift astrophysical phenomenology**
  - and make reionization measurements more robust

* Currently working with: PhD student **Sarah Schon**, Professor **Elisabetta Barberio** & Master's student **Cassandra Avram**