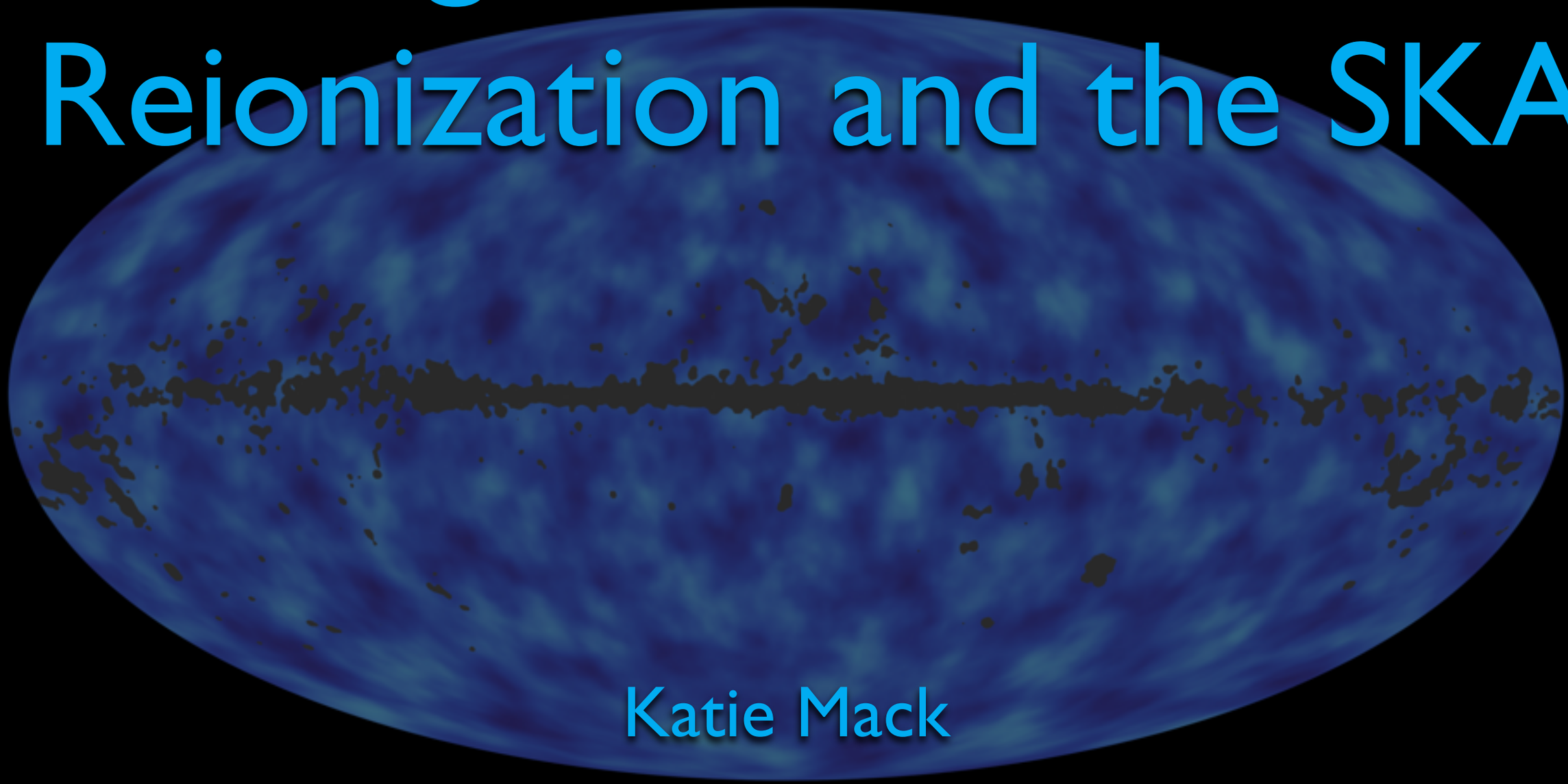
Probing Dark Matter with Reionization and the SKA



Katie Mack

School of Physics, University of Melbourne

www.ph.unimelb.edu.au/~kmack

: @AstroKatie

dark matter

Most likely a **new particle** that is (to first order):
massive, cold(ish?), weakly interacting (collisionless, invisible)

Main candidate: **Weakly Interacting Massive Particle**
a.k.a. WIMP (maybe its own antiparticle)

Three main detection avenues:

- **direct detection** — inconclusive/ controversial
- **indirect detection** — some hints...?
- **collider experiments** — nothing...yet

probing dark matter in the era of structure formation

- Dark matter density field (to first approx: matter density field)
  - angular dependence of 21cm power spectrum
  - lensing convergence
- Structure formation
  - velocity offset between dark matter & baryons
- Small-scale structure and bias (warm or self-interacting dark matter)
- Radio counterparts (axions, annihilation)
- Energy injection (annihilation, decay)

25 Mpc slice

Greg Poole, GiggleZ Simulation

probing dark matter in the era of structure formation

- Dark matter density field (to first approx: matter density field)
  - angular dependence of 21cm power spectrum
  - lensing convergence
- Structure formation
  - velocity offset between dark matter & baryons
- Small-scale structure and bias (warm or self-interacting dark matter)
- Radio counterparts (axions, annihilation)
- Energy injection (annihilation, decay)

25 Mpc slice

Greg Poole, GiggleZ Simulation

energy injection: annihilation

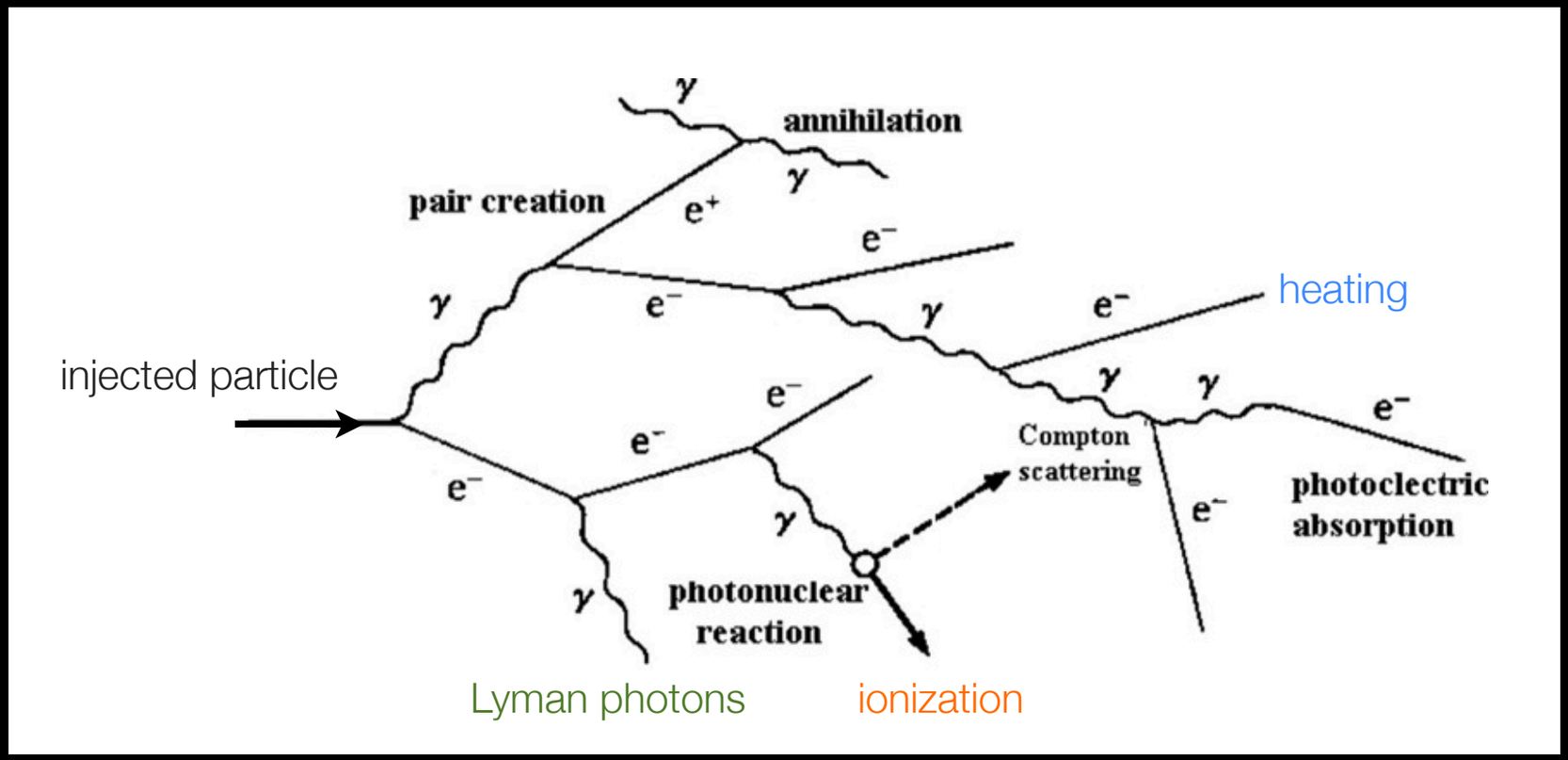
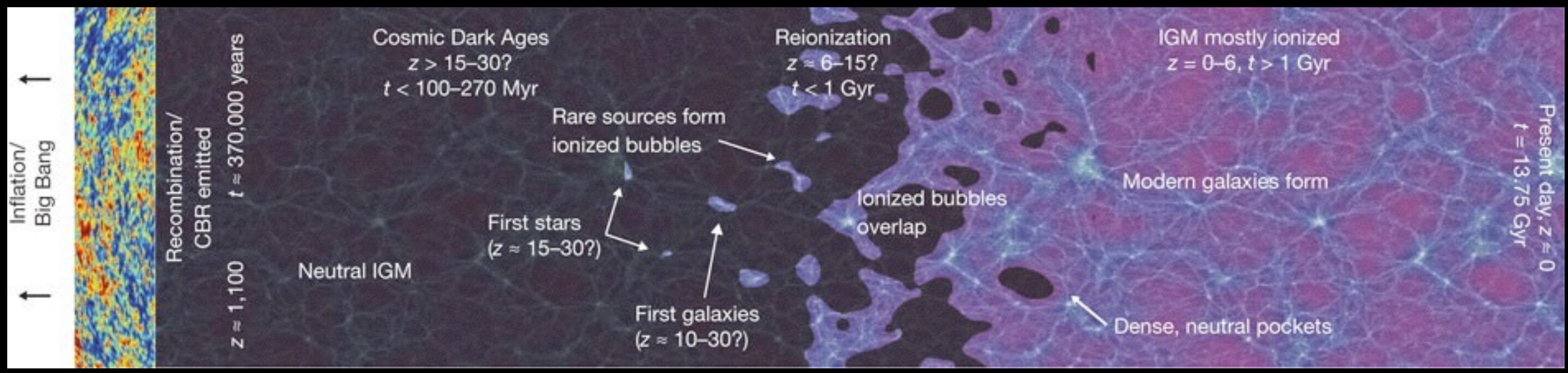


Image from talk by Carmelo Evoli

- annihilation radiation cascades through many channels
- counterparts: heating, ionization, photons

cosmic dawn

Image: Robertson et al., Nature, 2010

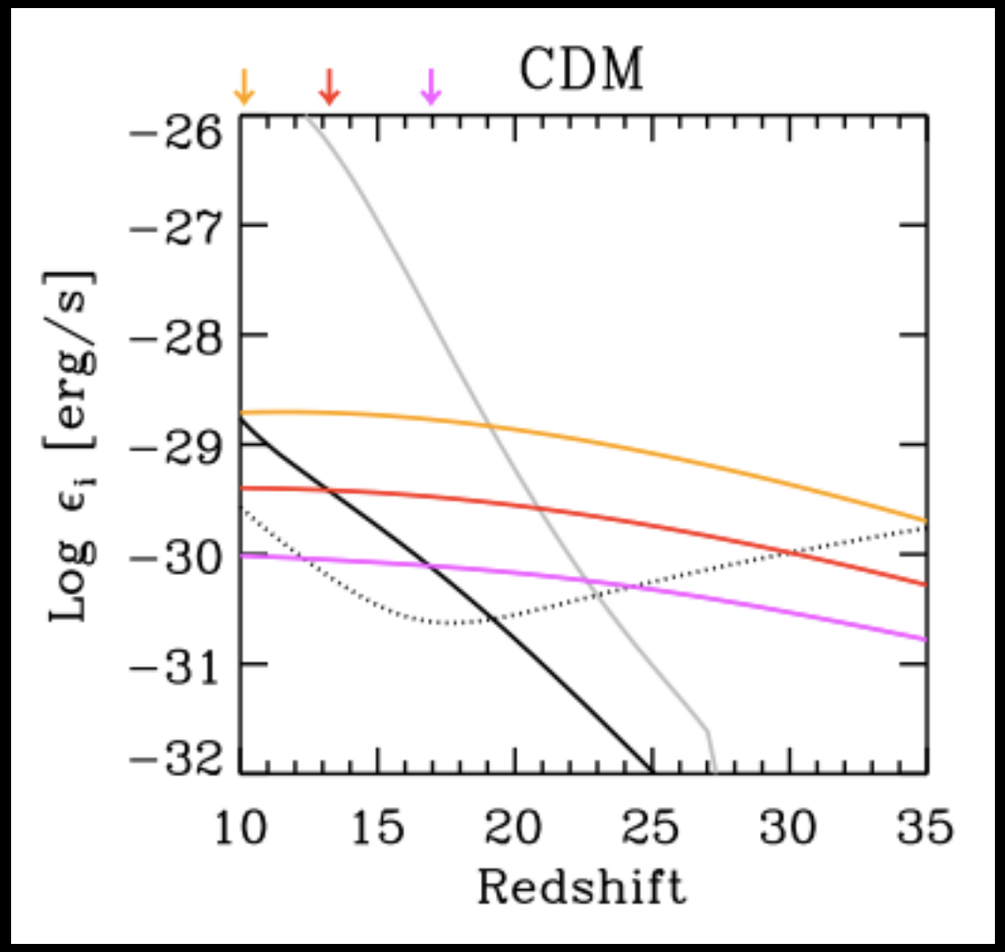


dark matter annihilation can cause heating and ionization during the **cosmic dark ages** **and** **epoch of reionization**

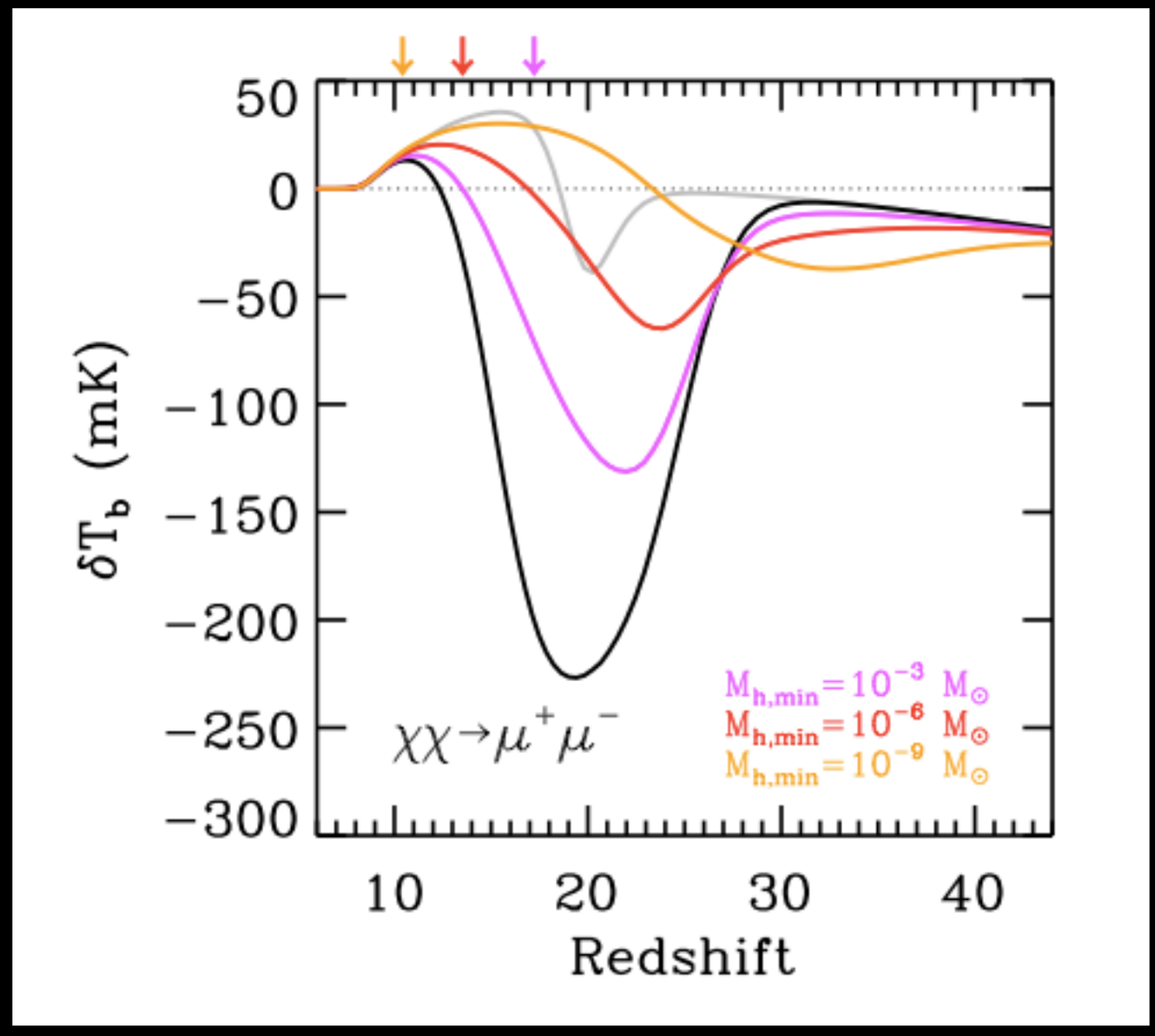
SKA & other 21cm observations will provide a great opportunity to see effects of **dark matter particle physics**

energy injection: global

Evoli et al. 2014



heating rate from models with different dark matter halo small-scale cut-offs; arrows indicate where dark matter heating dominates astrophysical sources



21cm all-sky signal

IGM

halo

halo

halo

halo

IGM

halo

halo

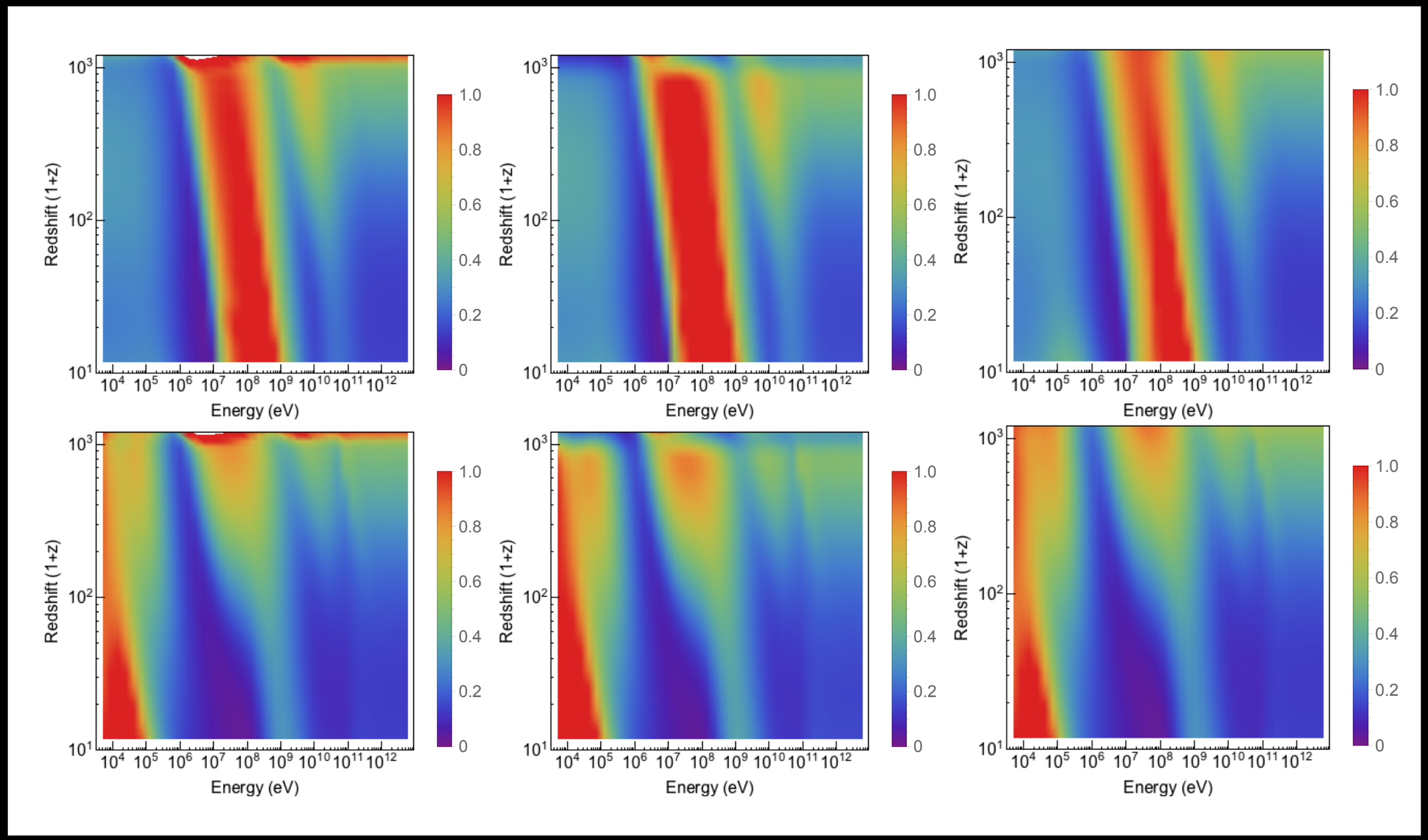
halo

halo

- monolithic halos
- immediate uniform energy deposition

deposition and redshift

energy *deposited* at z ≠ energy *injected* at z

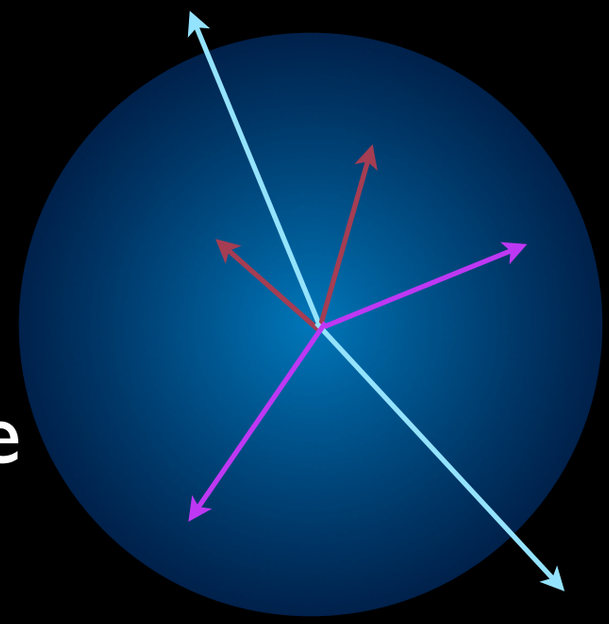


Slatyer 2015

annihilation within halos

Question:

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

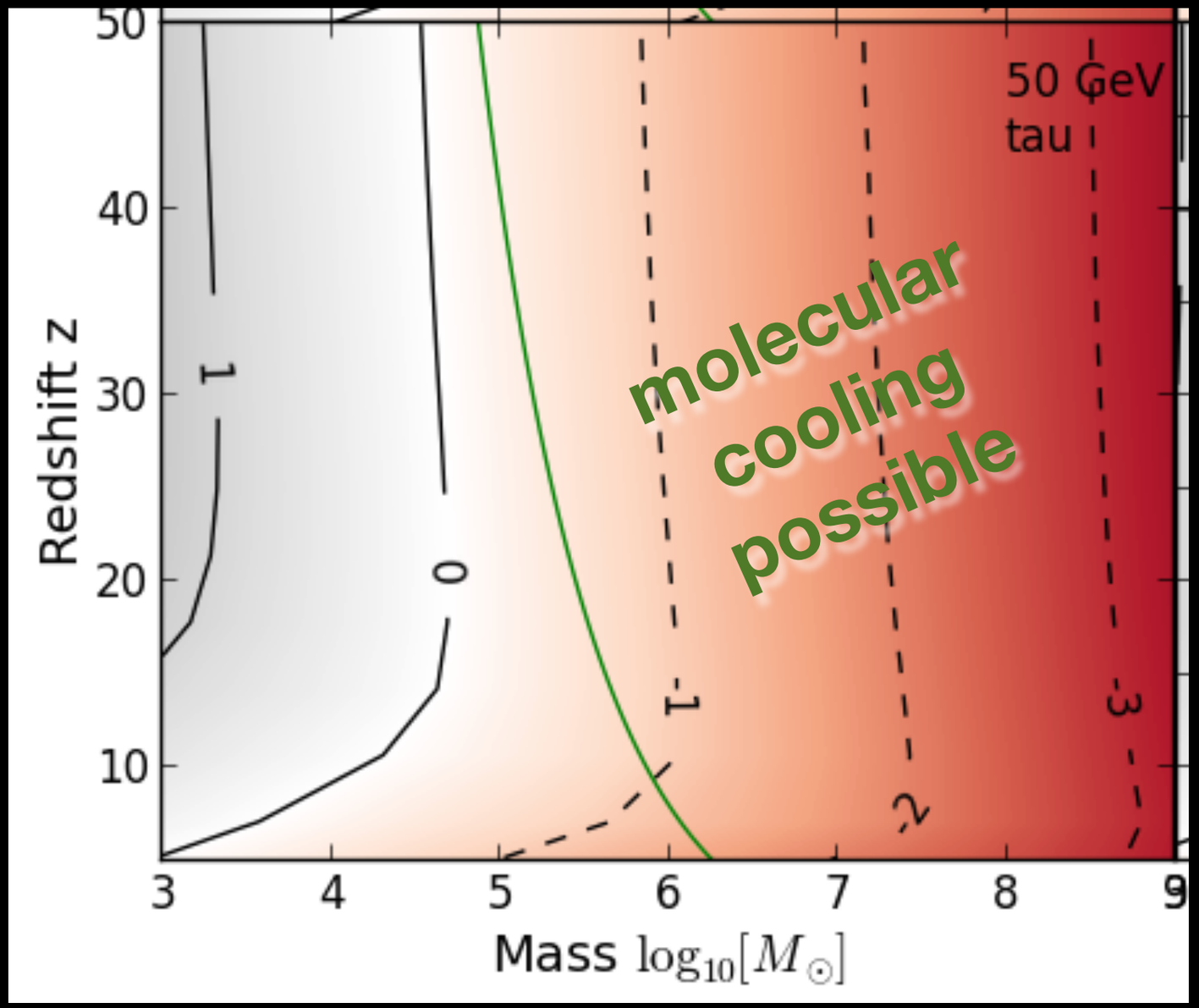


Calculate ratio:

dark matter annihilation energy absorbed

vs

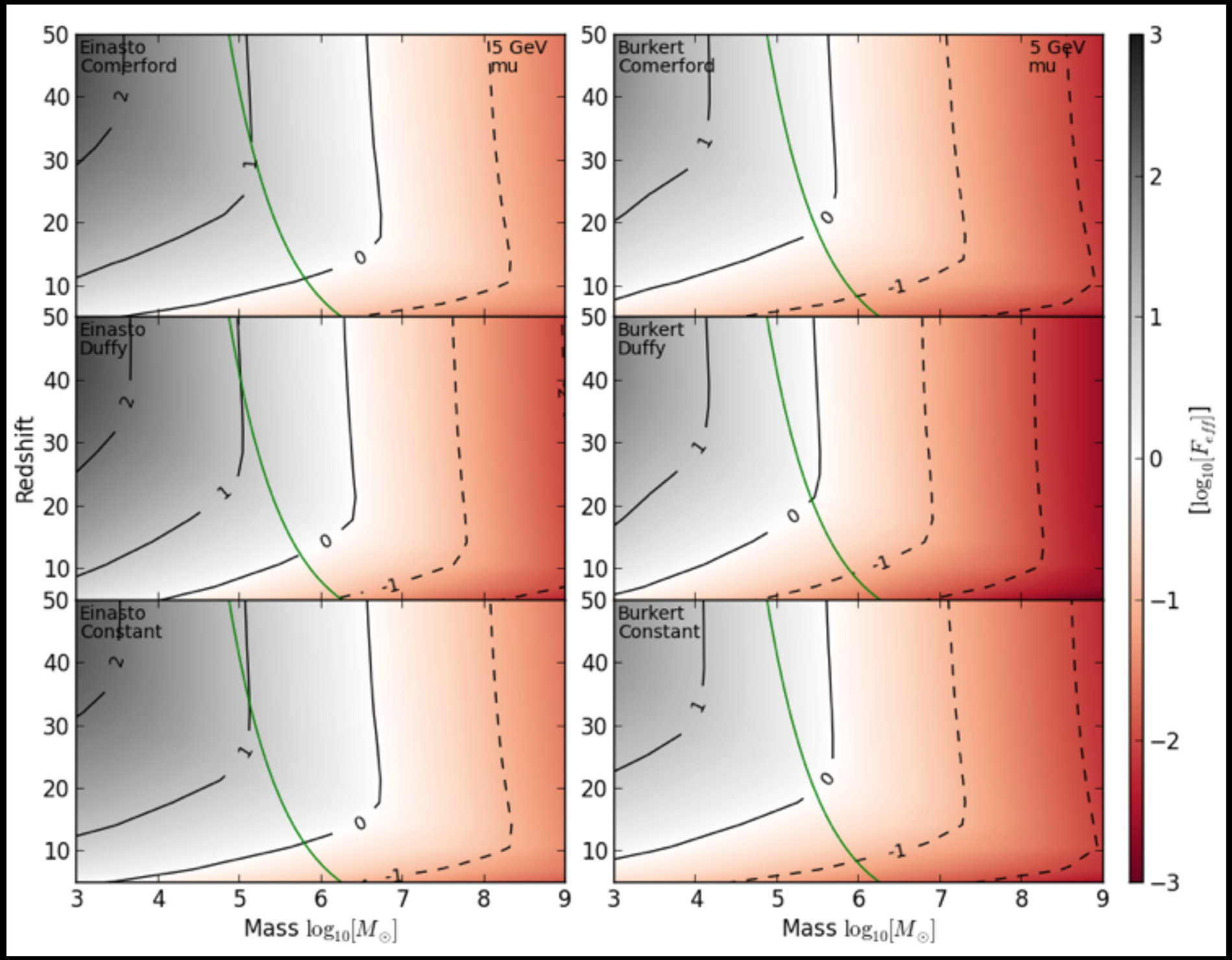
binding energy of halo



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

annihilation within halos

Sarah Schon et al. 2014 MNRAS [arXiv:1411.3783]



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

coming soon

- Schon, KJM, et al. in prep
  - **spatial distribution** of annihilation energy within halos
  - impact on (proto-)**circumgalactic medium**
    - suppression of star formation?
- **Teaming up**
  - Slatyer: (delayed) energy deposition
  - Schon, KJM + : halo filtering and internal effects
  - Evoli & Ferrara: reionization & 21cm modelling

coming soon

- Schon, KJM, et al. in prep
  - **spatial distribution** of annihilation energy within halos
  - impact on (proto-)**circumgalactic medium**
    - suppression of star formation?
- **THE AWESOME COLLABORATION**
  - Slatyer: (delayed) energy deposition
  - Schon, KJM + : halo filtering and internal effects
  - Evoli & Ferrara: reionization & 21cm modelling

dark matter annihilates

Slatyer

Schon, KJM +

radiation background

internal heating of dark matter halos

low-mass cut-off

Evoli, Ferrara

heating/ ionization of intergalactic gas

structure of first stars

H_2 abundance

black hole formation

unified simulation of galaxy formation & evolution

high-redshift 21cm signal

high-redshift galaxies

Image credit: Swinburne/ ICRAR/Cambridge/ASTRON

JWST

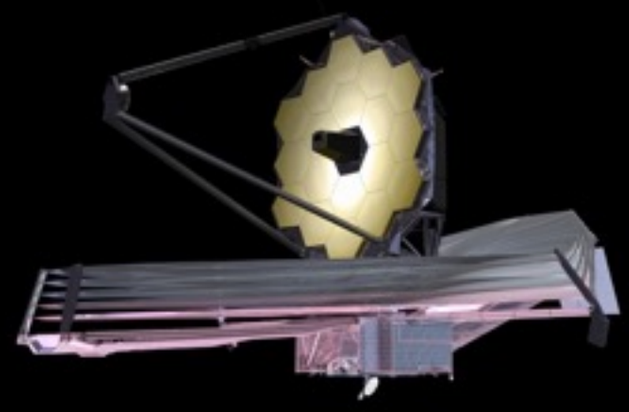


Image credit: NASA

long-term outlook

As SKA comes online, we will need a self-consistent picture of **dark matter's *particle physics* interactions** with baryons in the context of the growth of structure in the Universe.

Requirements:

* New simulations of reionization/galaxy evolution with *theoretically motivated* DM included
* Predictions for SKA and precursor instruments
* **New perspective** on dark matter/baryon interactions