Jet Propulsion Laboratory
California Institute of Technology

A Radio Scream at Cosmic Dawn

Modeling Radio Loud Black Holes and the 21cm signal

"The Scream" - Edvard Munch

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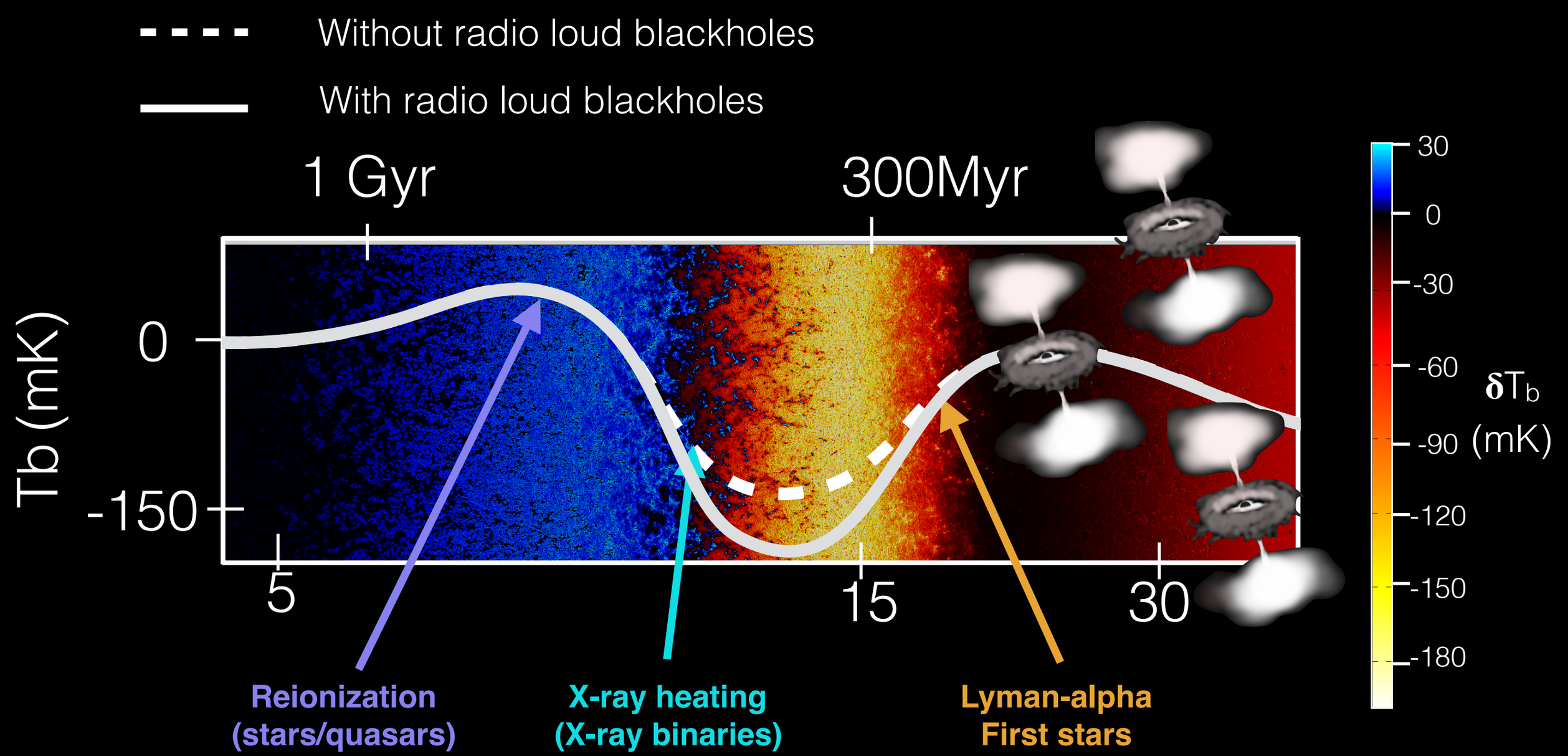
Can we use the global signal to constrain radio loudness in the early Universe?



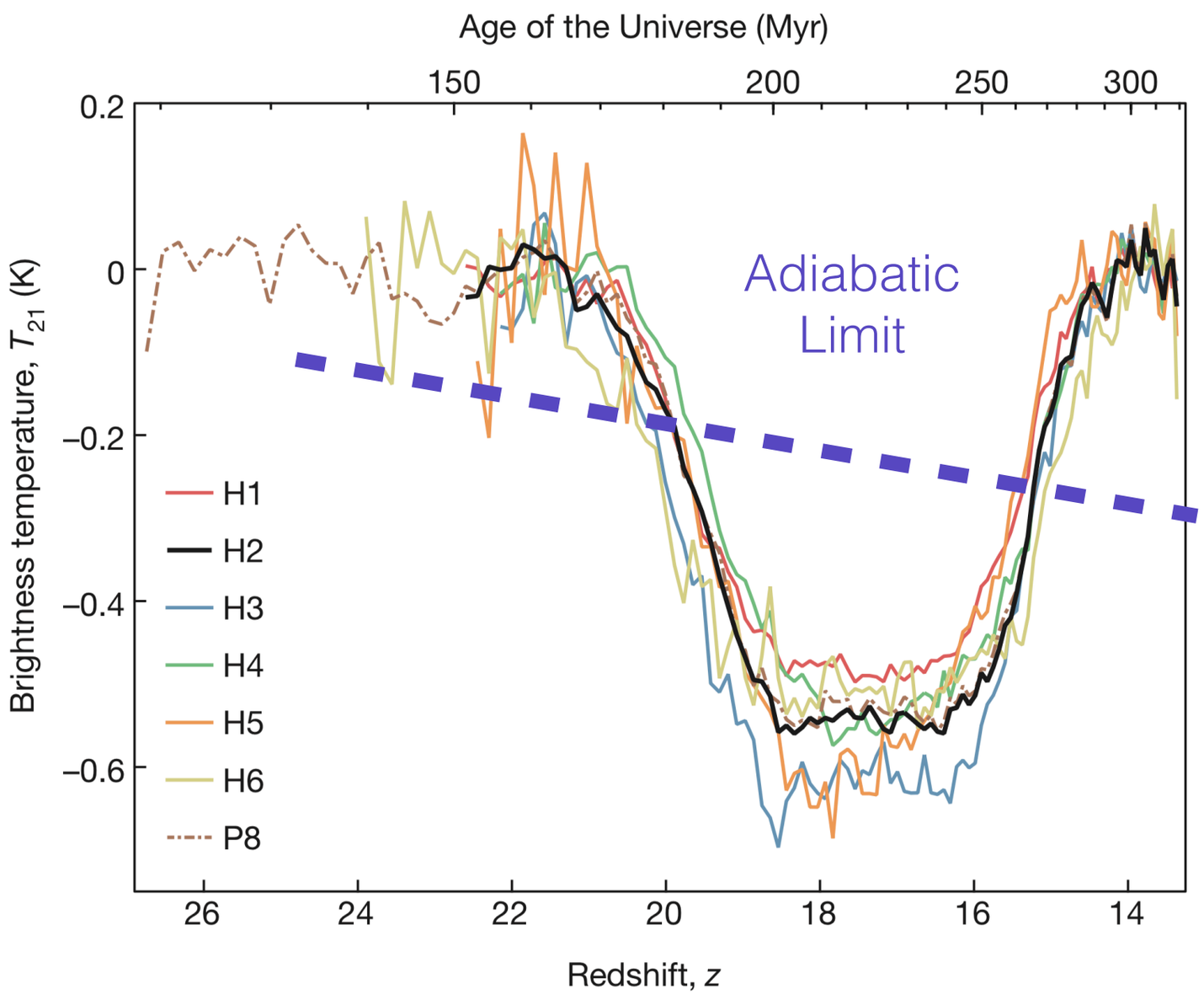
width=1600Mpc

redshift

Eos Simulation: Mesinger et al. 2016

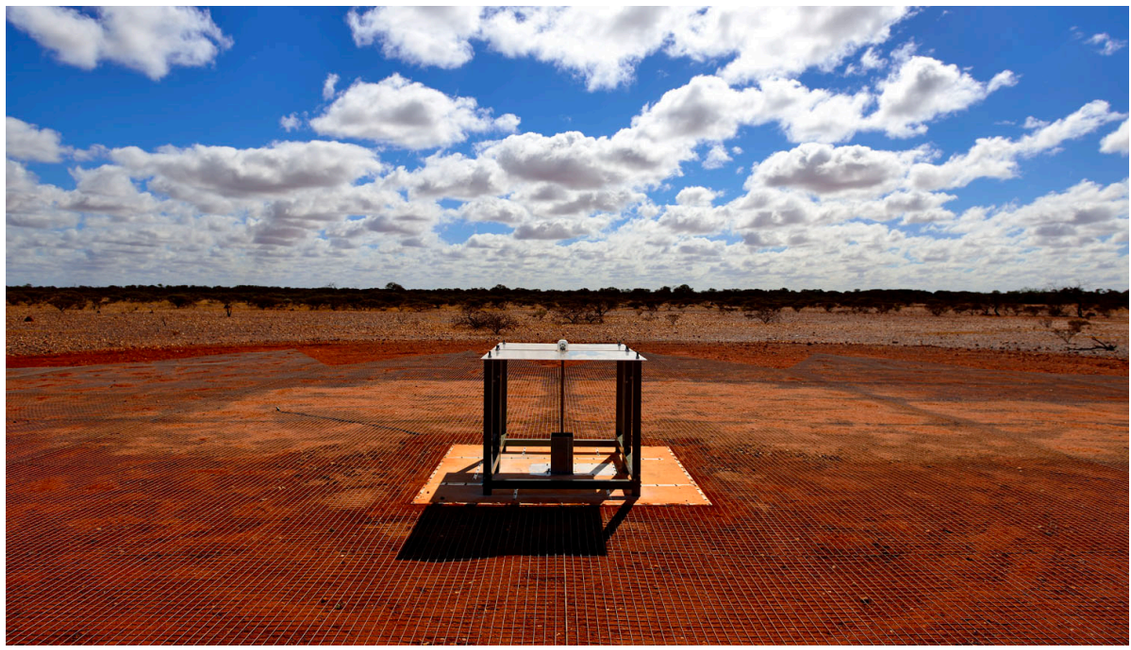
Motivation

A Strange absorption feature?



Bowman + 2018

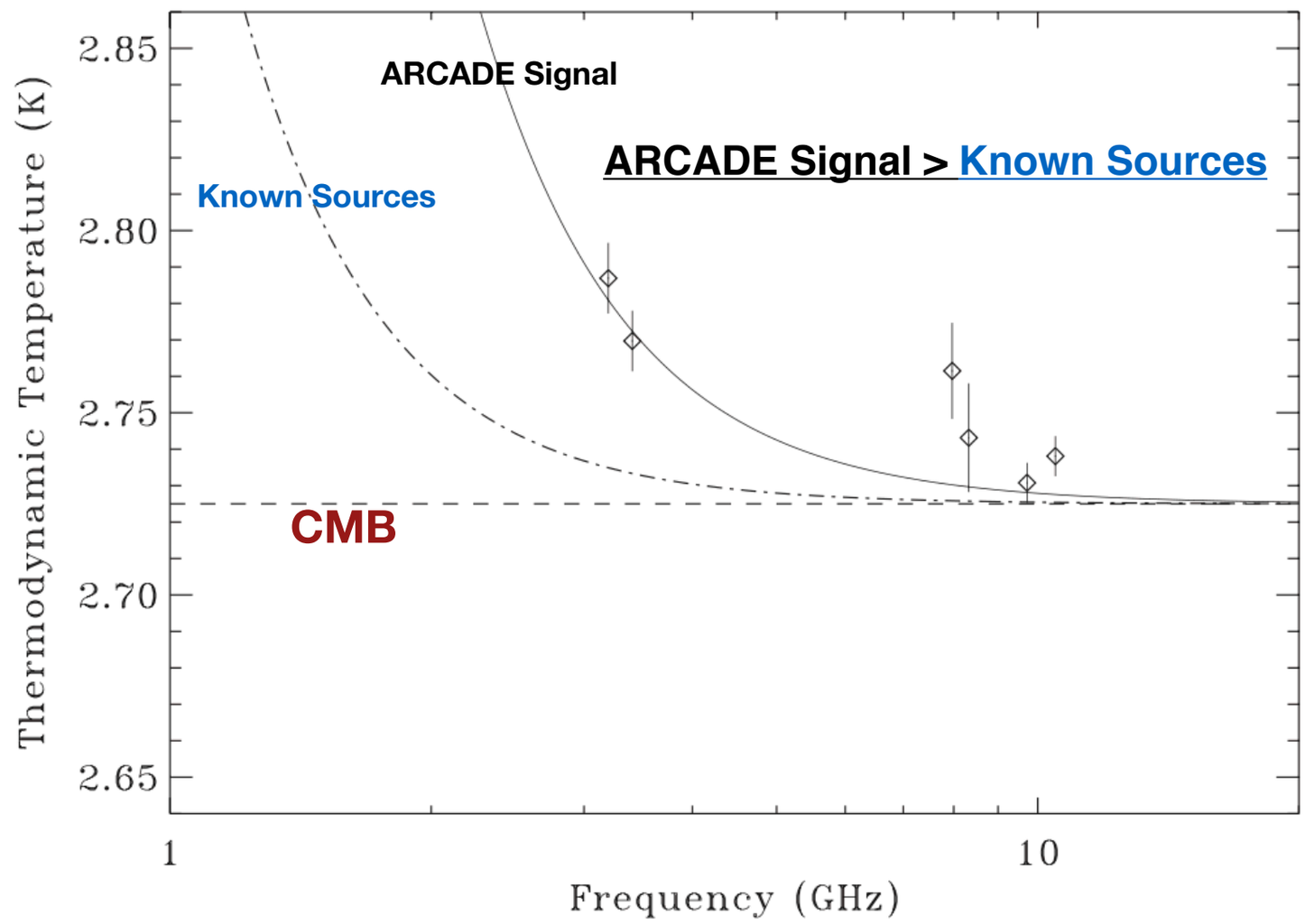
Surprisingly deep
With flat bottom
And steep sides



Motivation

A mysterious Radio Background?

Seiffert 2011

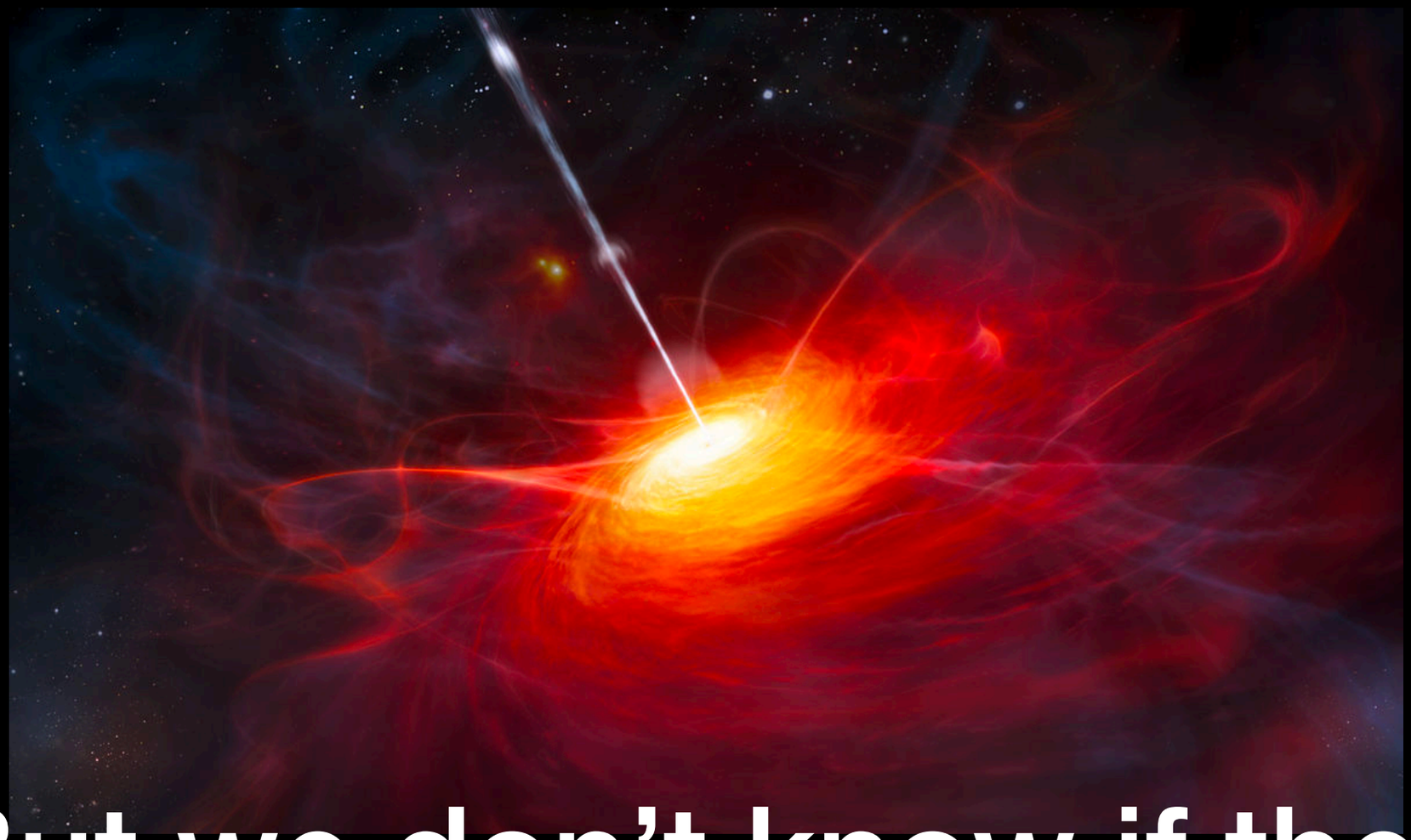


Excess radio background detected by ARCADE-2

Why Black Holes?

- AGN constitute the brightest extragalactic low-frequency radio background (aside from the CMB)
- 5-10% of the CMB (only an order of magnitude away from EDGEs)
- The z $\sim$1 co-moving emissivity of AGN would producing a radio background sufficient to explain the EDGEs amplitude (if the gas is adiabatic).

Black Hole progenitors must have existed at high redshift.



But we don’t know if they produce much radio emission

Artist impression of ULAS J1120+0641

ESO/Kornmesser

Radio Loud Black Holes at z~>6?

No?

- Inverse Compton losses (Saxena+ 2017).
- IC kills off low-density radio lobes responsible for most radio emission in the local Universe.

Yes?

- Black holes in dense, high B-field environments can still primarily emit synchrotron.
- Very radio loud sources (R~>1000) observed at z~6 (Bañados+2018)
- radio-loudness fraction may be similar to today (Bañados+2015)

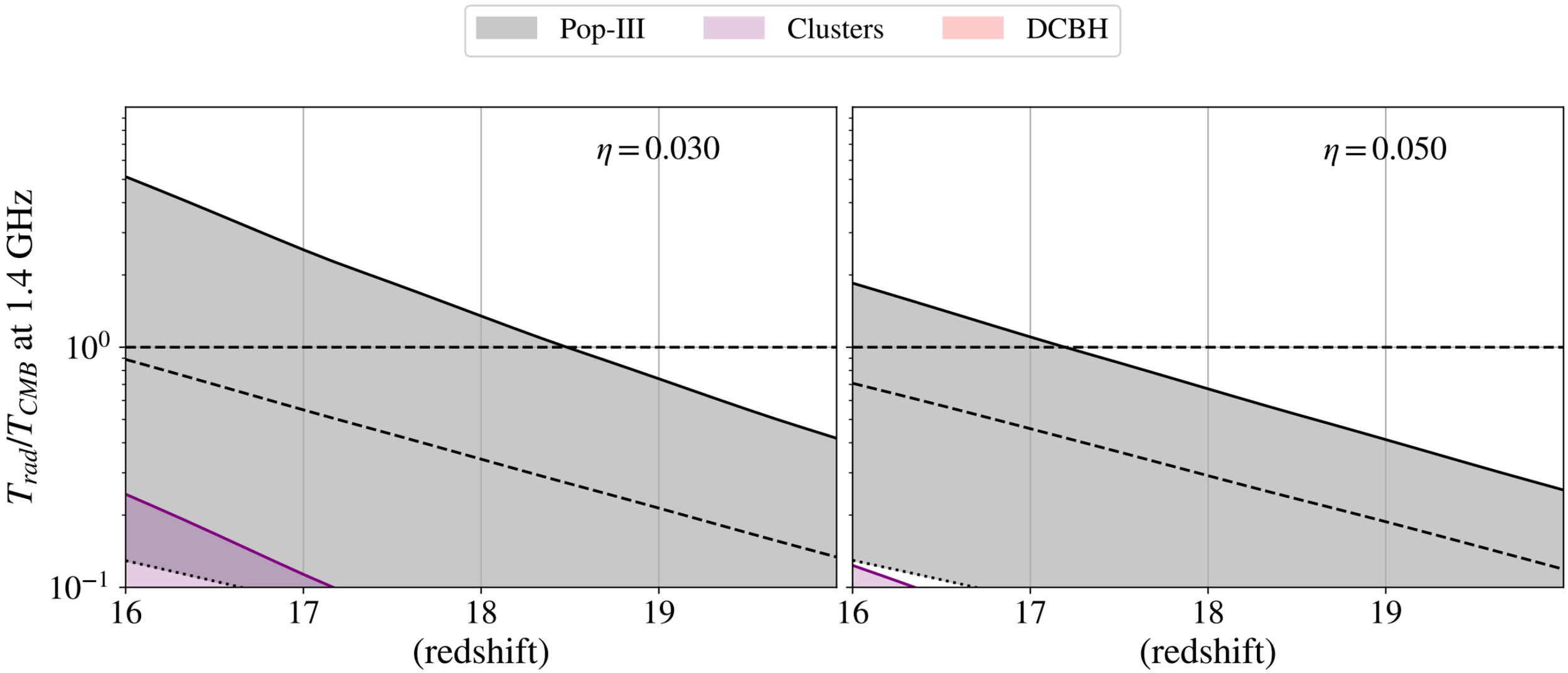
Goals:

1. Construct a model of radio-loud black holes during the cosmic dawn.

2. Can 21cm constrain interesting scenarios?

3. Can orthogonal measurements (point source surveys) constrain these models?

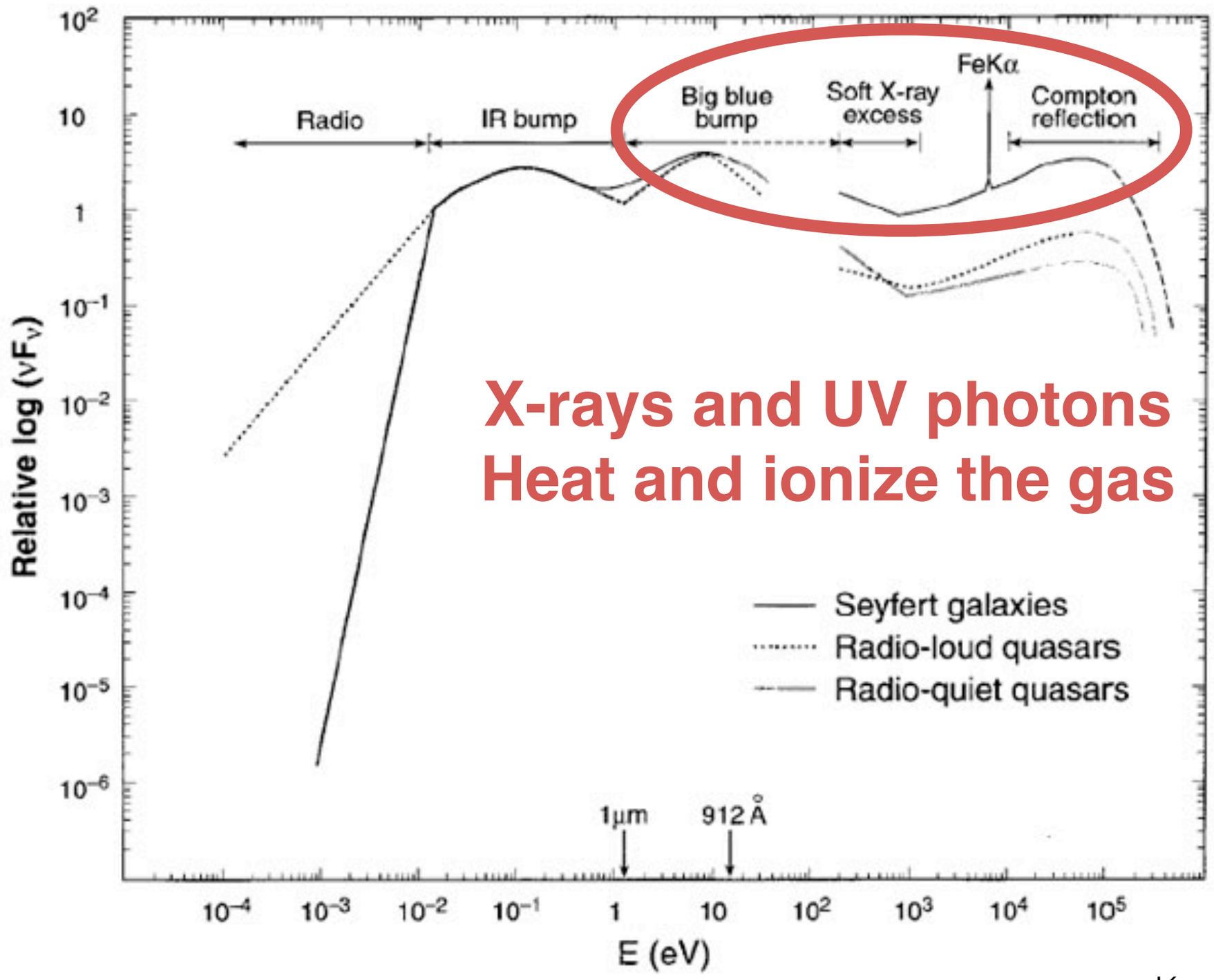
Can we get enough radio emission to explain EDGEs using “somewhat reasonable” blackhole models? Yes!



10% radio loud
Loudness boost of ~1000

arXiv: 1803.01815
ApJ published

Radio isn't the only product!

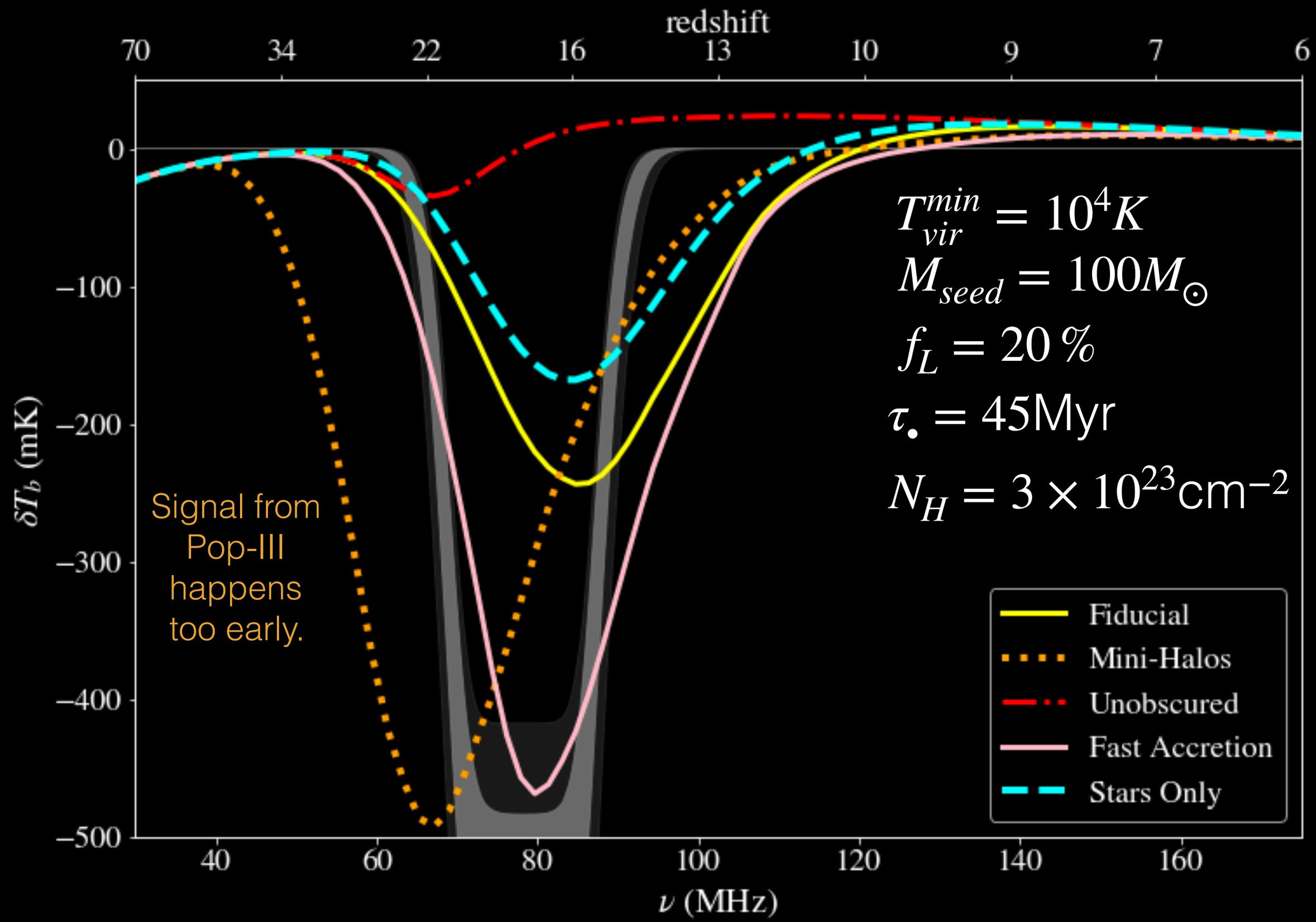


X-rays and UV photons
Heat and ionize the gas

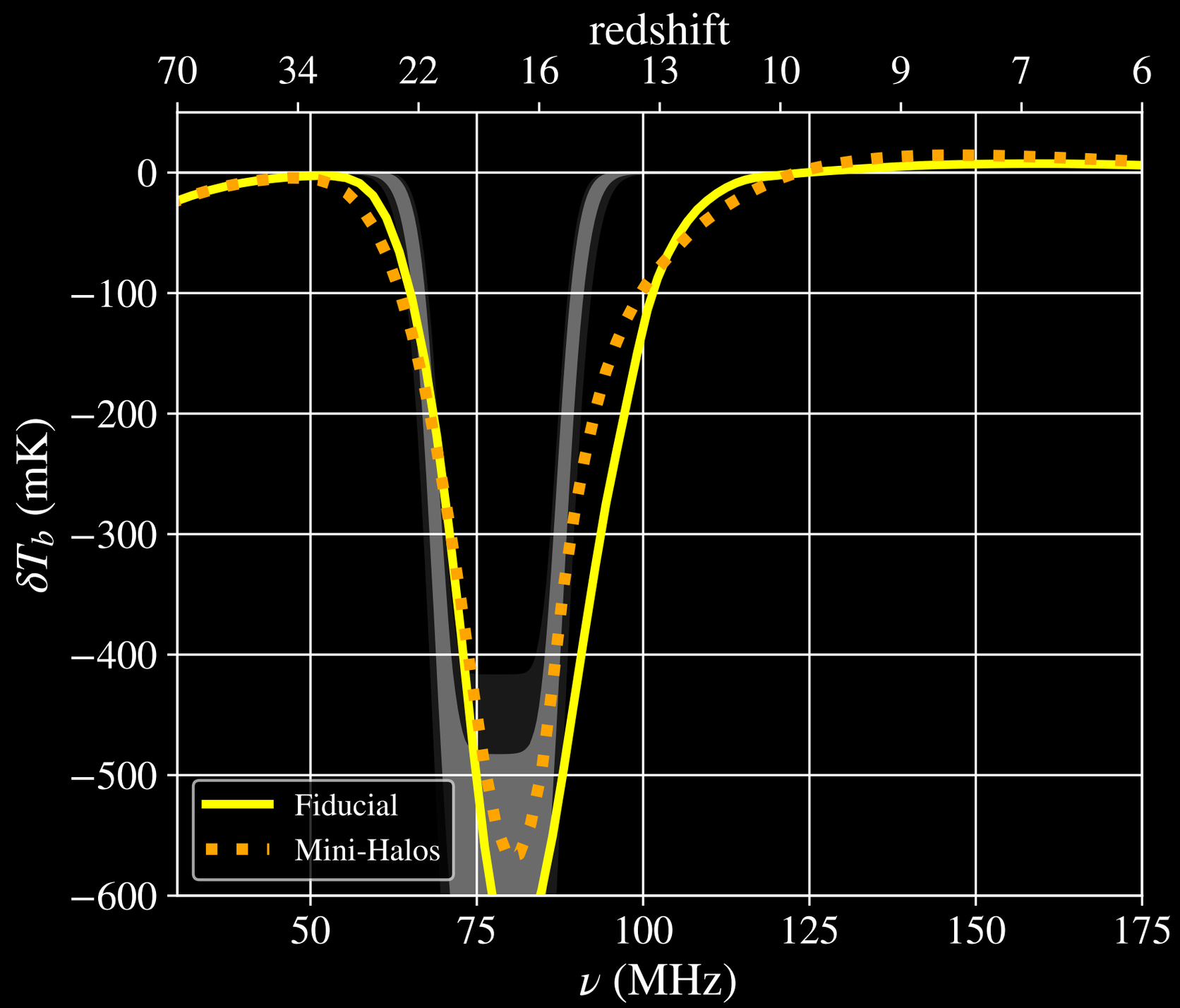
Koratkar and Blaes

Global Signal Results

Coming to arXiv Soon



Some EDGEs-Like Models



Typically Require 10 Myr Salpeter Times

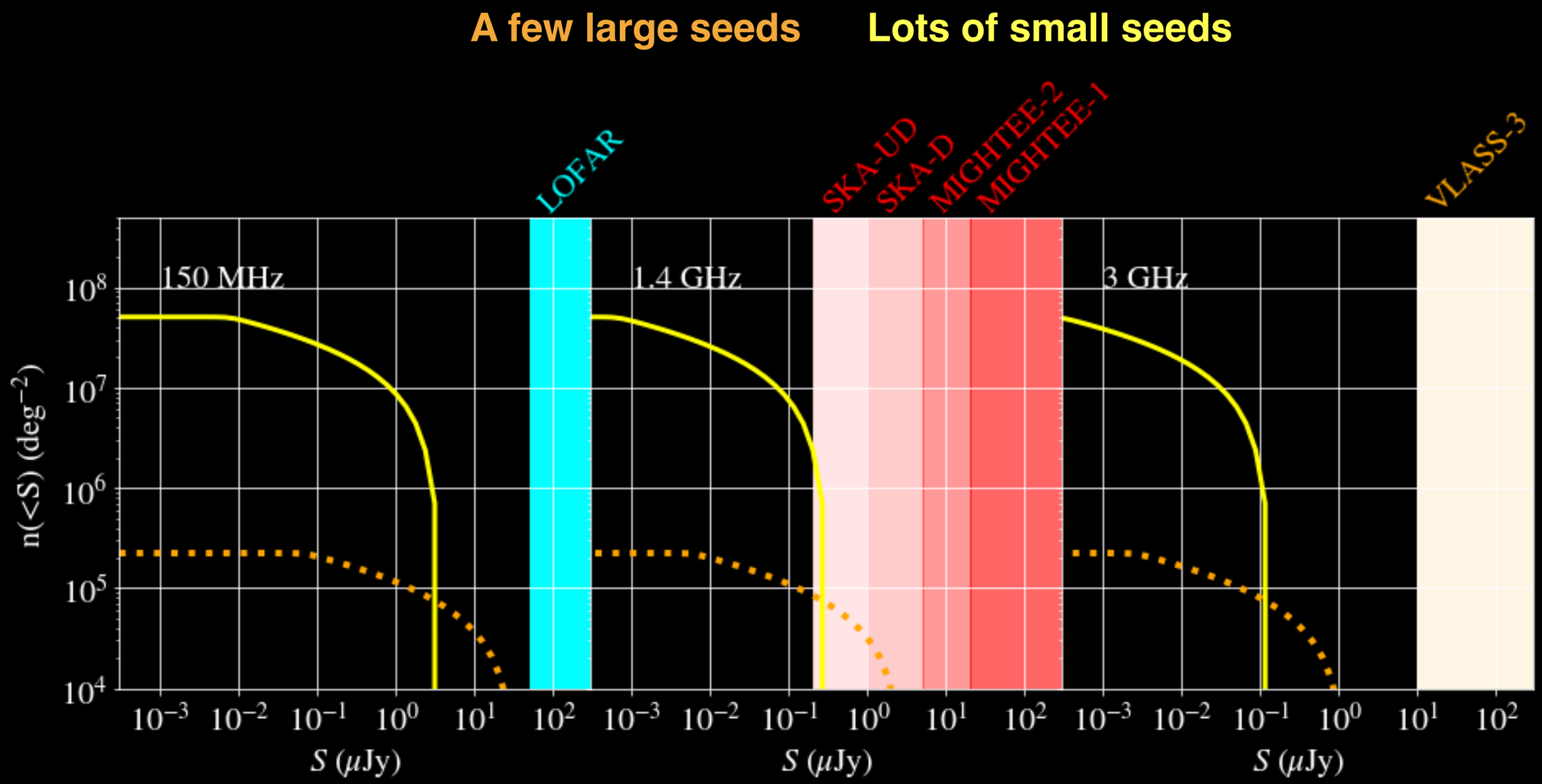
A few large seeds

And

Lots of small seeds

Are pretty degenerate

Mass/Accretion Rate Degeneracy Broken in Source Counts



Sensitivities from Prandoni and Seymour 2015

At 1.4 GHz, things appear to get interesting at ~1 micro Janskies (SKA1-MID)

Conclusions

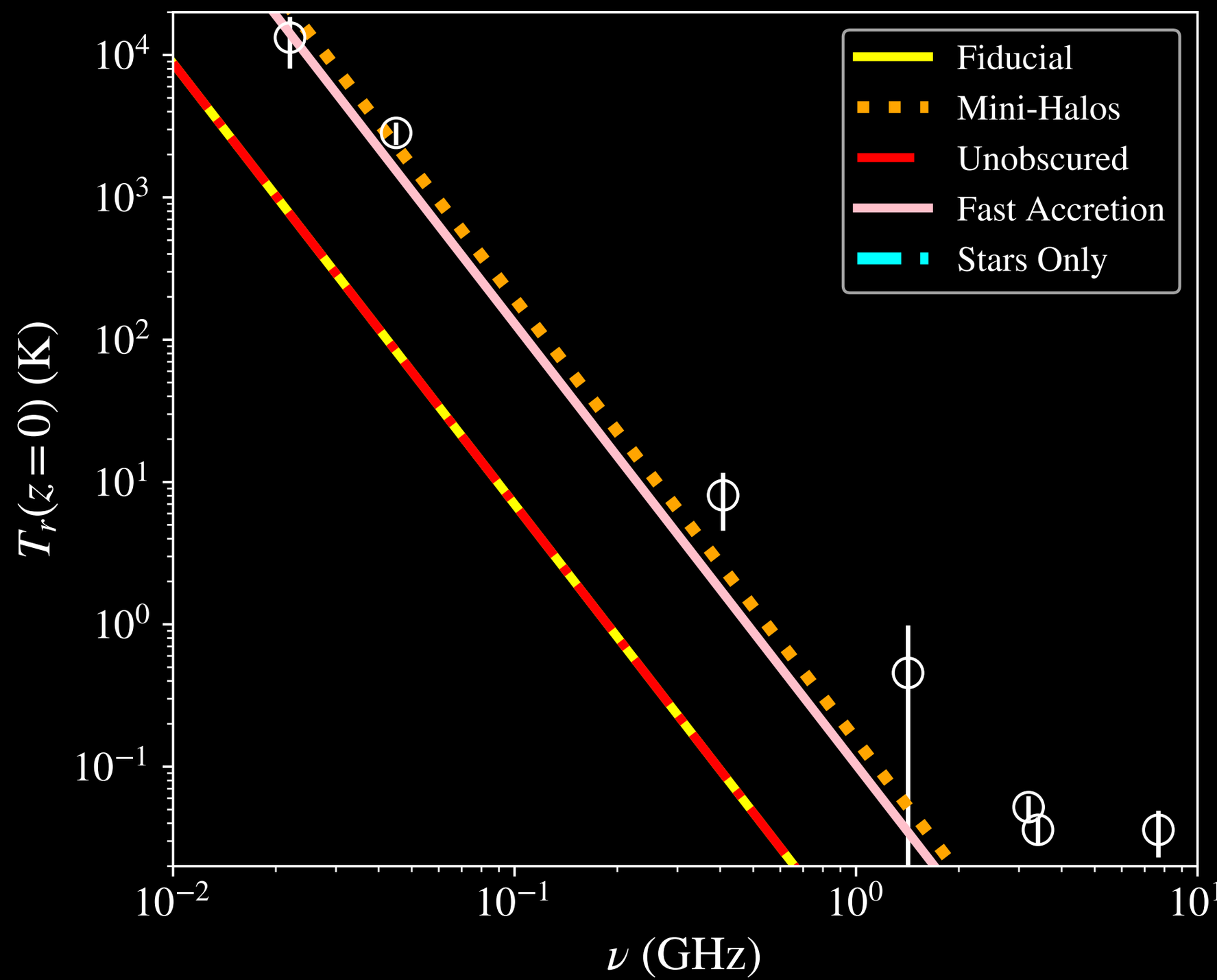
- Compton thick and radio-loud black holes are capable of producing absorption features that are narrower and deeper then previous expectations. This might explain EDGEs.

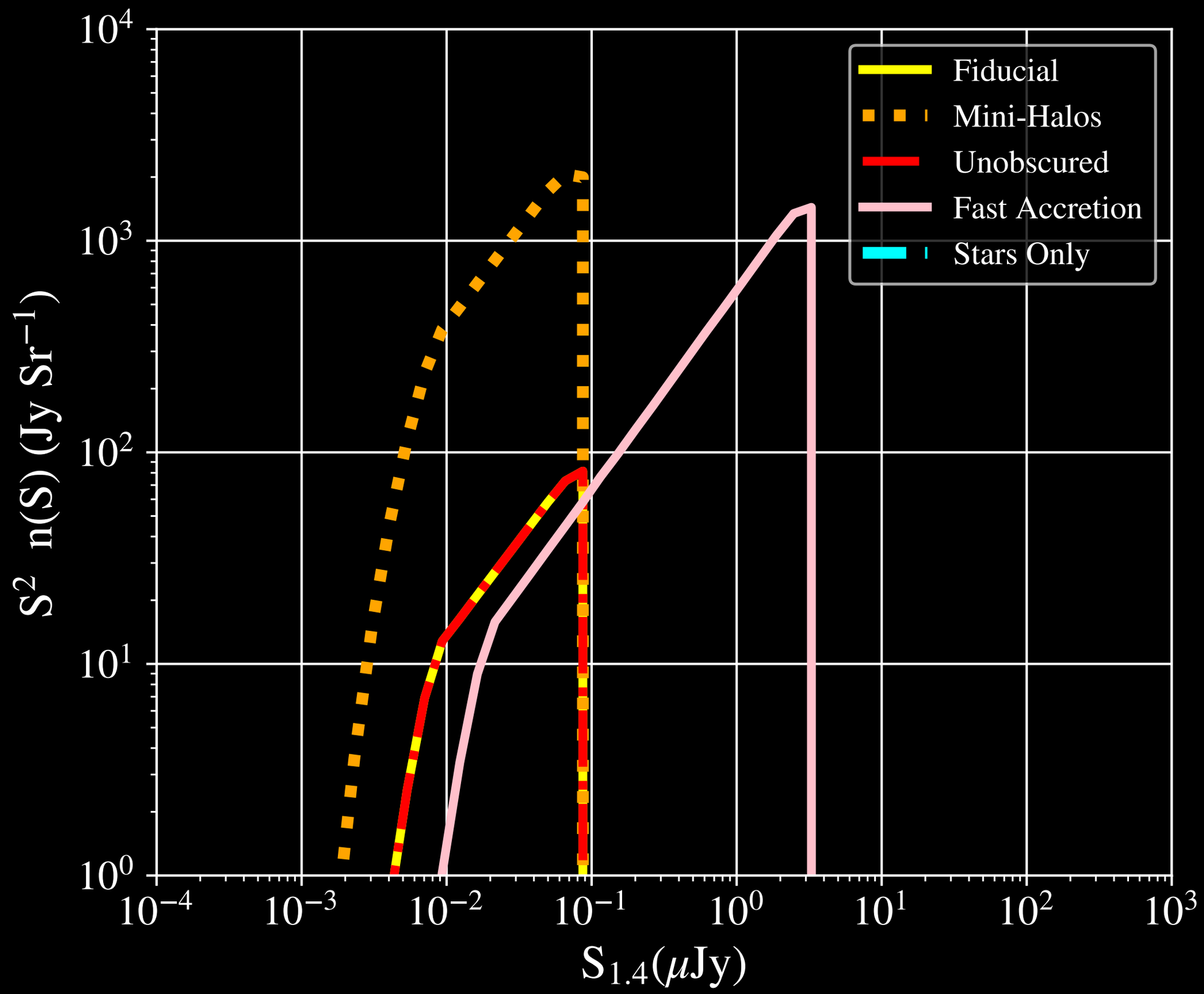
- Point source surveys can confirm/constrain this explanation;

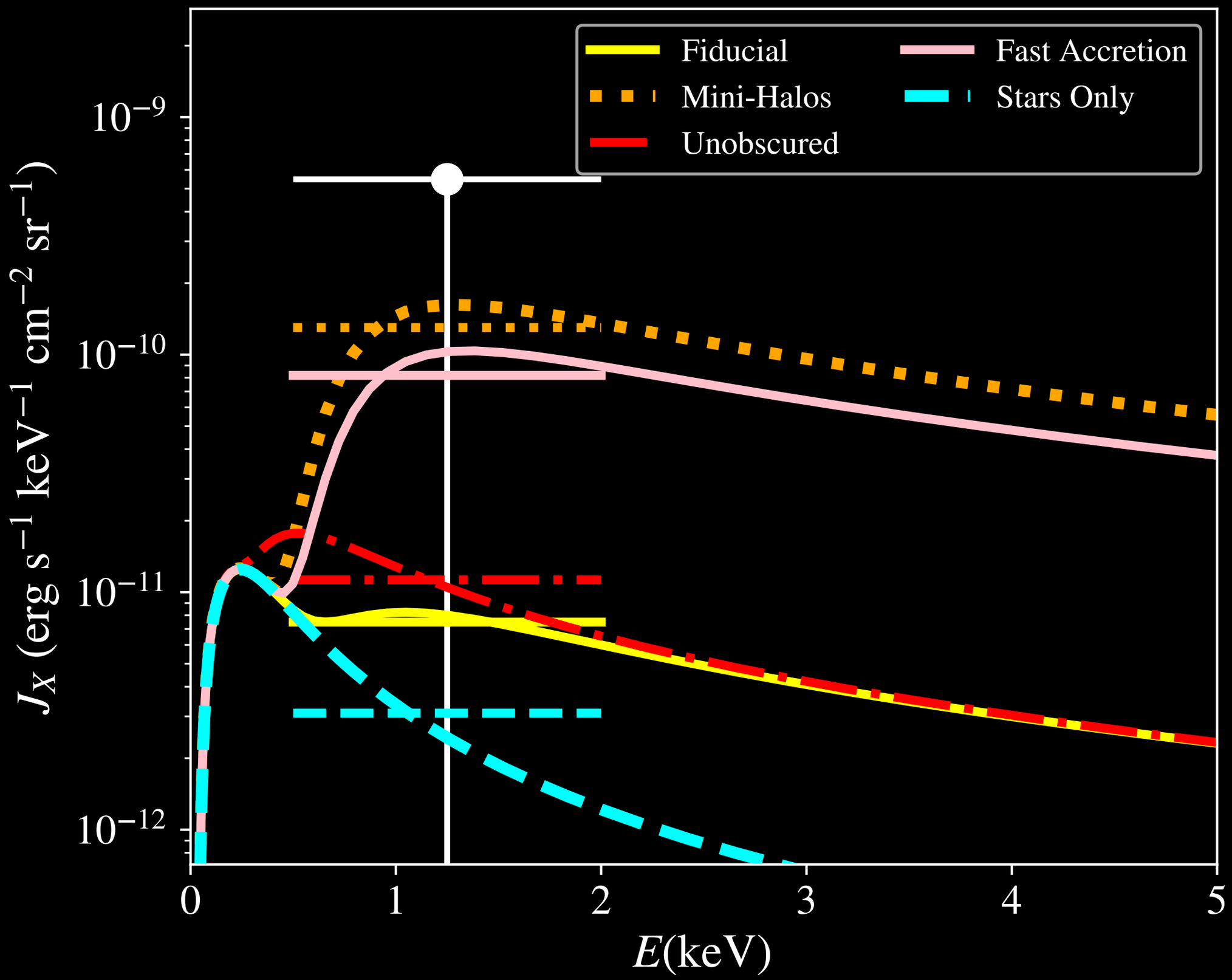
    1. ~< 10 micro-Jansky surveys with SKA1-MID (though it might be easier with a P(D) analysis).

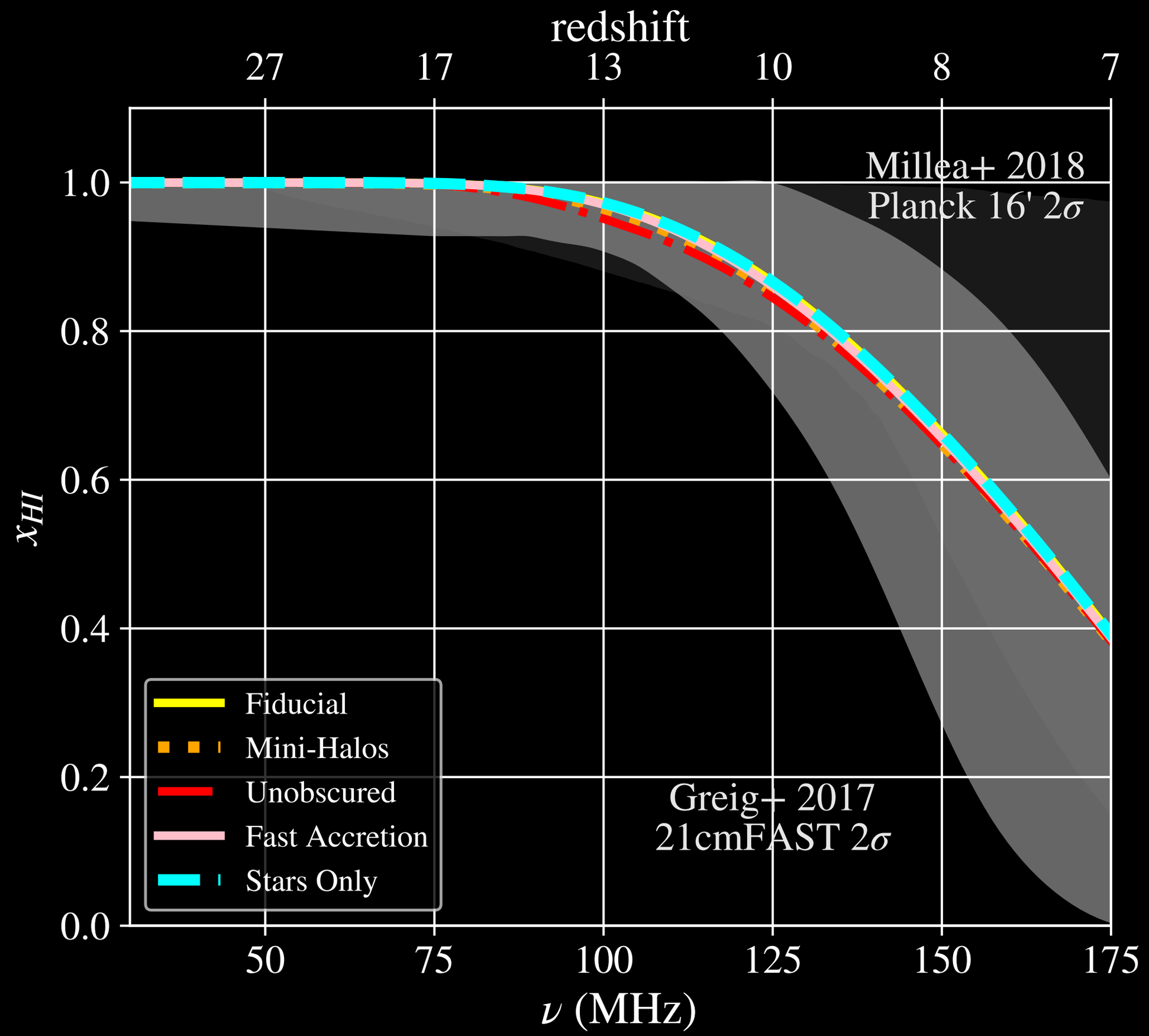
An exciting opportunity for joint science from 21cm and point source surveys!

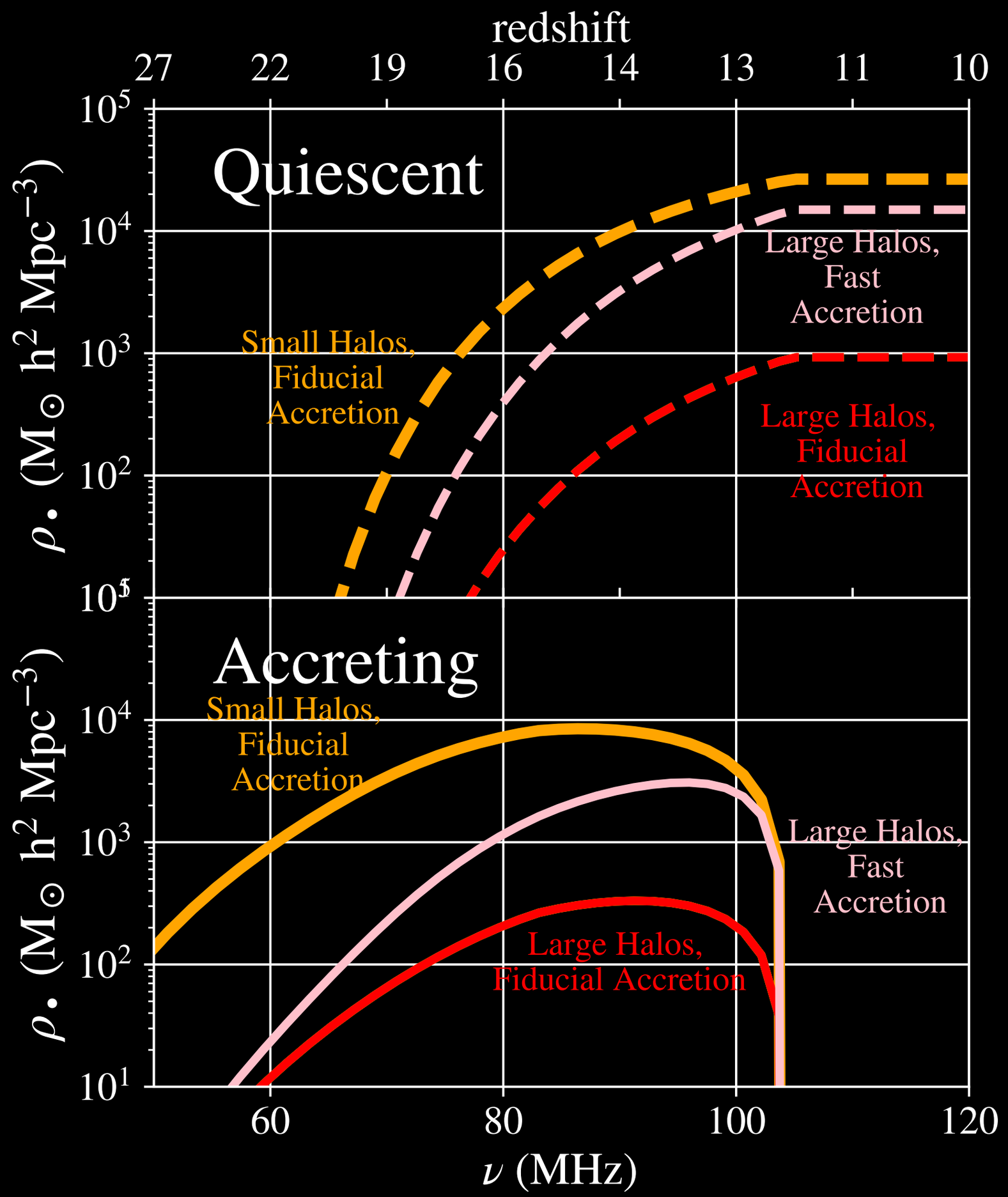
Bonus Slides

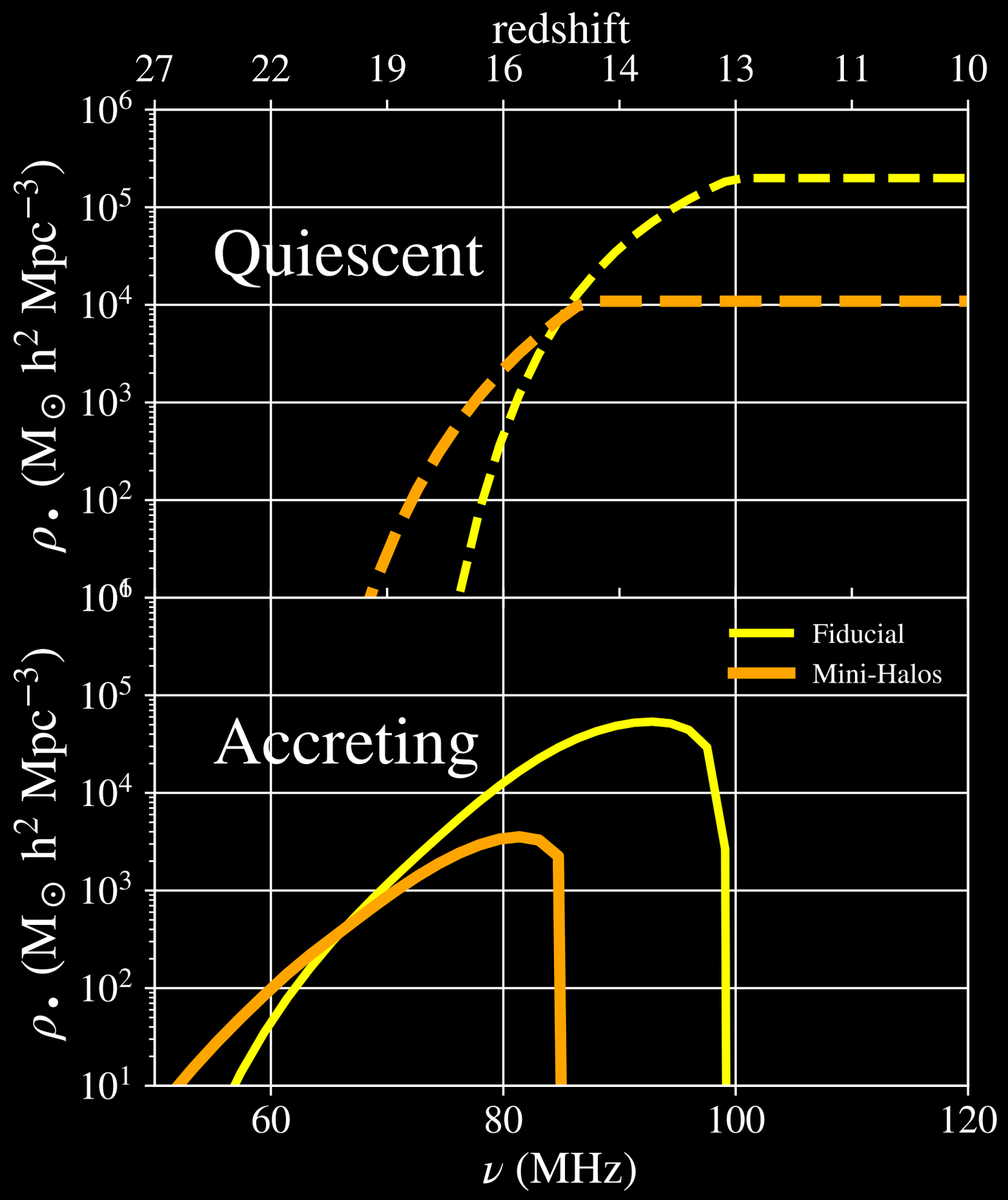

Fiducial
Mini-Halos
Unobscured
Fast Accretion
Stars Only
10^4
10^3
10^2
10^1
10^0
10^{-1}
$T_r(z=0)$ (K)
10^{-2}
10^{-1}
10^0
10^1
ν (GHz)


Fiducial
Mini-Halos
Unobscured
Fast Accretion
Stars Only
10^4
10^3
10^2
10^1
10^0
S^2 n(S) (Jy Sr^{-1})
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3
$S_{1.4}(\mu Jy)$


Fiducial
Mini-Halos
Unobscured
Fast Accretion
Stars Only
10^{-9}
10^{-10}
10^{-11}
10^{-12}
J_X (erg s^{-1} keV^{-1} cm^{-2} sr^{-1})
0
1
2
3
4
5
E(keV)


redshift
27
17
13
10
8
7
1.0
0.8
0.6
0.4
0.2
0.0
x_{HI}
50
75
100
125
150
175
ν (MHz)
Millea+ 2018
Planck 16' 2σ
Greig+ 2017
21cmFAST 2σ
Fiducial
Mini-Halos
Unobscured
Fast Accretion
Stars Only


redshift
27
22
19
16
14
13
11
10
Quiescent
Small Halos, Fiducial Accretion
Large Halos, Fast Accretion
Large Halos, Fiducial Accretion
Accreting
Small Halos, Fiducial Accretion
Large Halos, Fast Accretion
Large Halos, Fiducial Accretion
$\rho_\bullet$ ($M_\odot$ h^2 Mpc^{-3})
10^5
10^4
10^3
10^2
10^1
60
80
100
120
ν (MHz)


redshift
27
22
19
16
14
13
11
10
Quiescent
Accreting
Fiducial
Mini-Halos
$\rho_\bullet$ ($M_\odot$ h^2 Mpc^{-3})
$\rho_\bullet$ ($M_\odot$ h^2 Mpc^{-3})
10^6
10^5
10^4
10^3
10^2
10^1
60
80
100
120
ν (MHz)