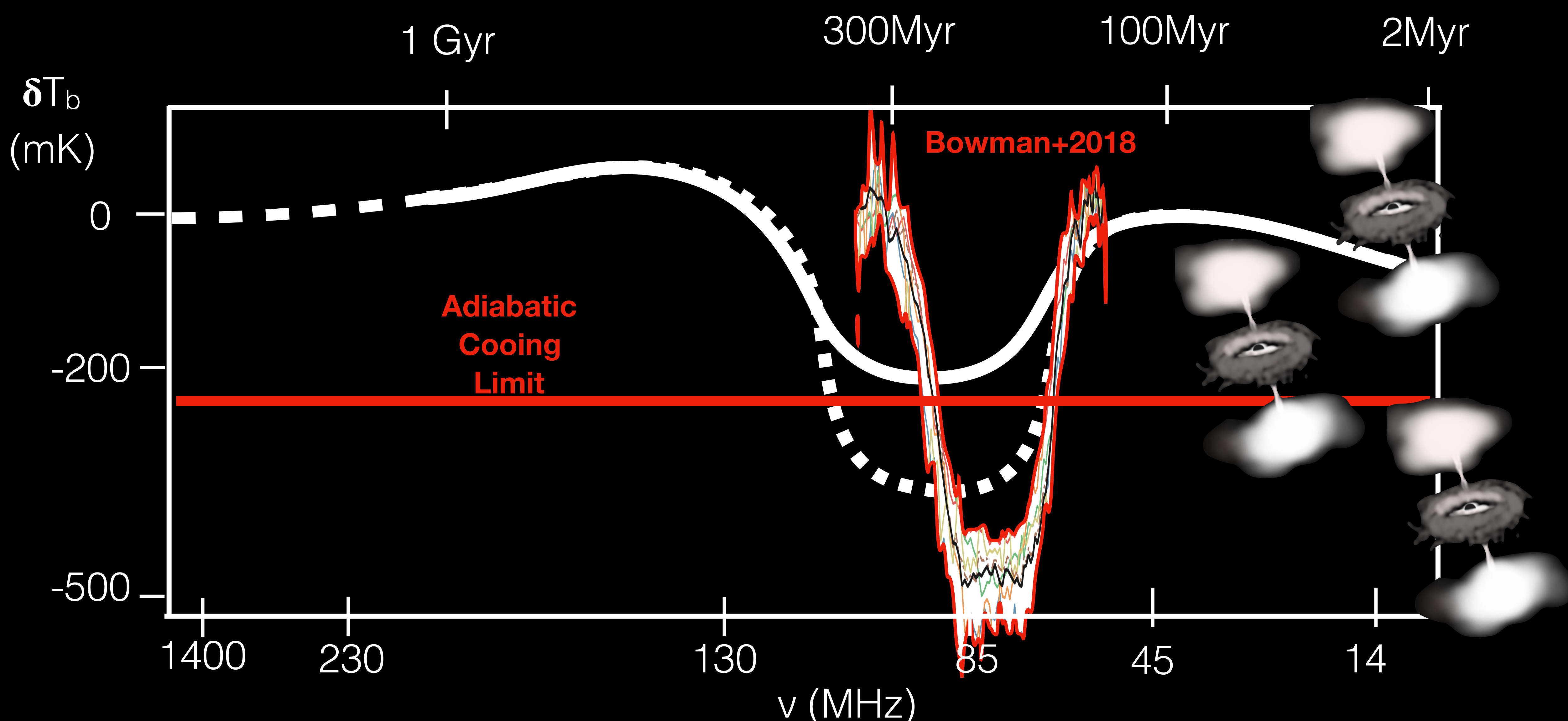
Can we explain the EDGEs Feature with Black Holes?

“The Scream” - Edvard Munch

A Radio Scream at Cosmic Dawn

Aaron Ewall-Wice

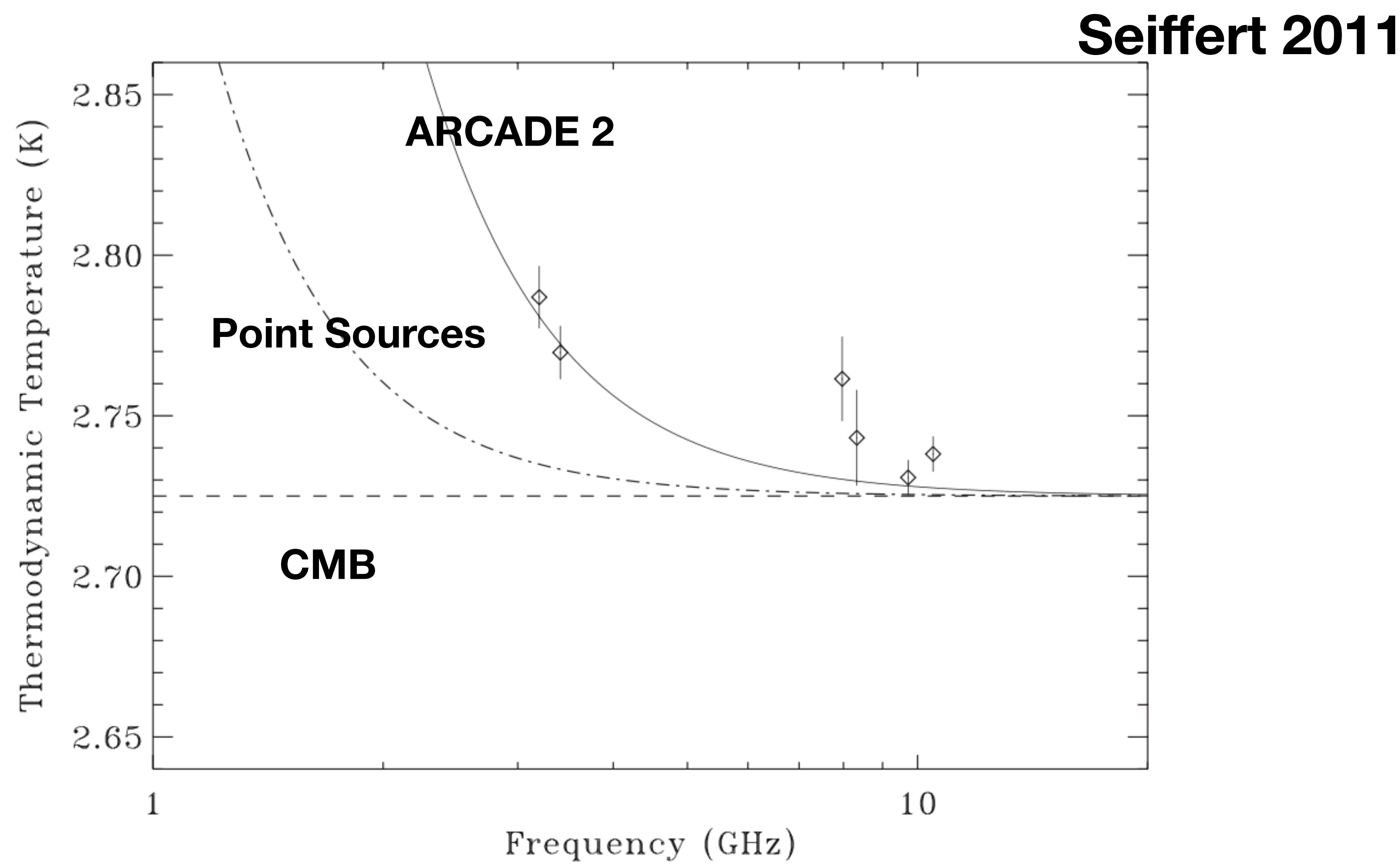
$$\delta T_b \propto x_{HI} \times \rho \times \left(1 - \frac{T_{\rm CMB}}{T_{\rm s}}\right) \uparrow$$



Producing a larger radio background with A new radio source population.

(Feng+2018, AEW+2018/2019, Mirabel+2018, Fraser+2018, Fialkov+2019)

Some Evidence for a new unresolved source population already existed.



Excess radio background claimed by ARCADE-2

Several Candidates:

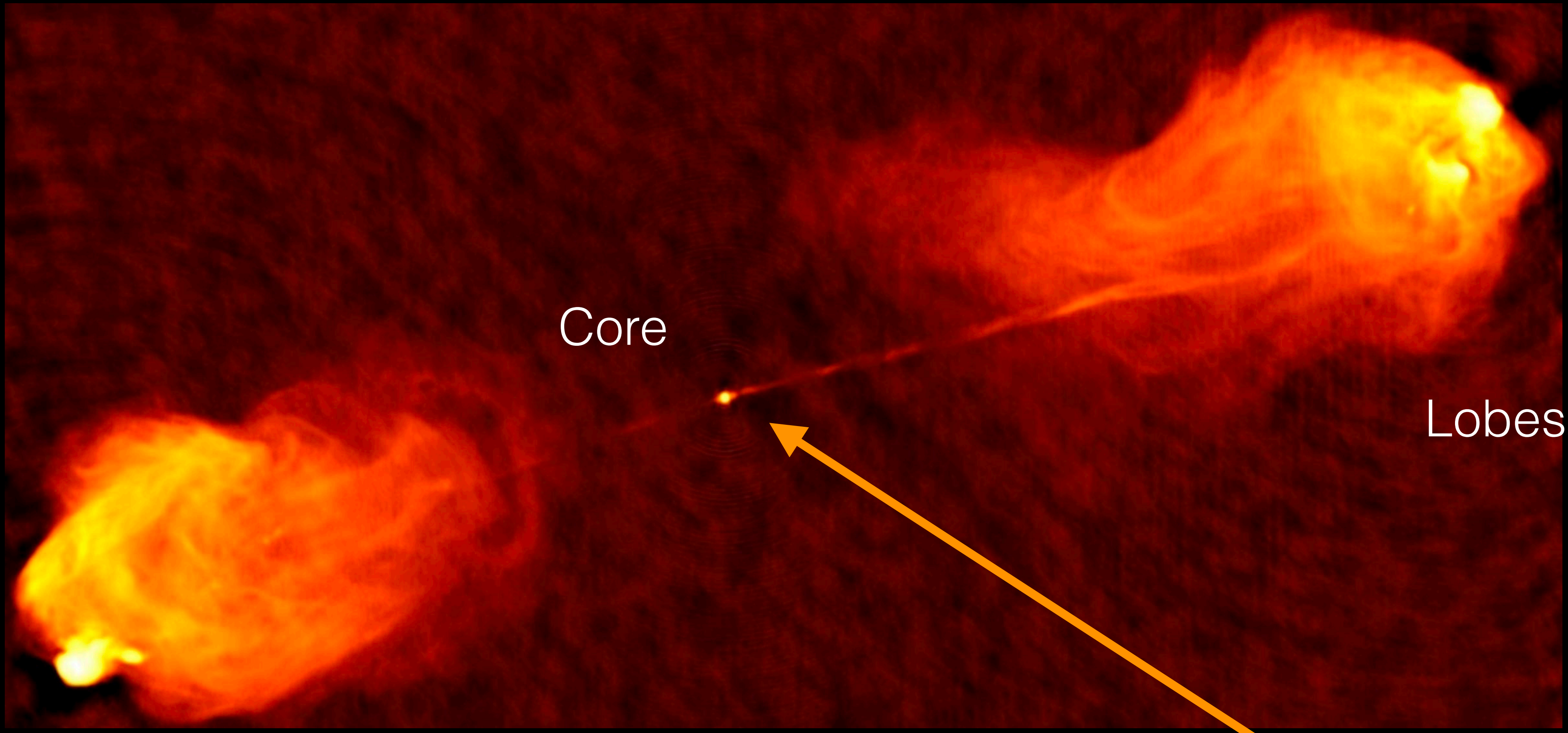
- Star forming galaxies. **(e.g. Mirocha+2018)**
- Annihilation of a μeV dark matter particle. **(e.g. Fraser+2018)**
- Cosmic Strings **(See Bryc Talk)**
- Black Holes. **(This work)**

Why Black Holes?

- AGN constitute the brightest extragalactic low-frequency radio background (aside from the CMB)
- Today, 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 unheated).

An FRII Radio Galaxy in the local Universe

Cygnus A (5 GHz)



R. Perley

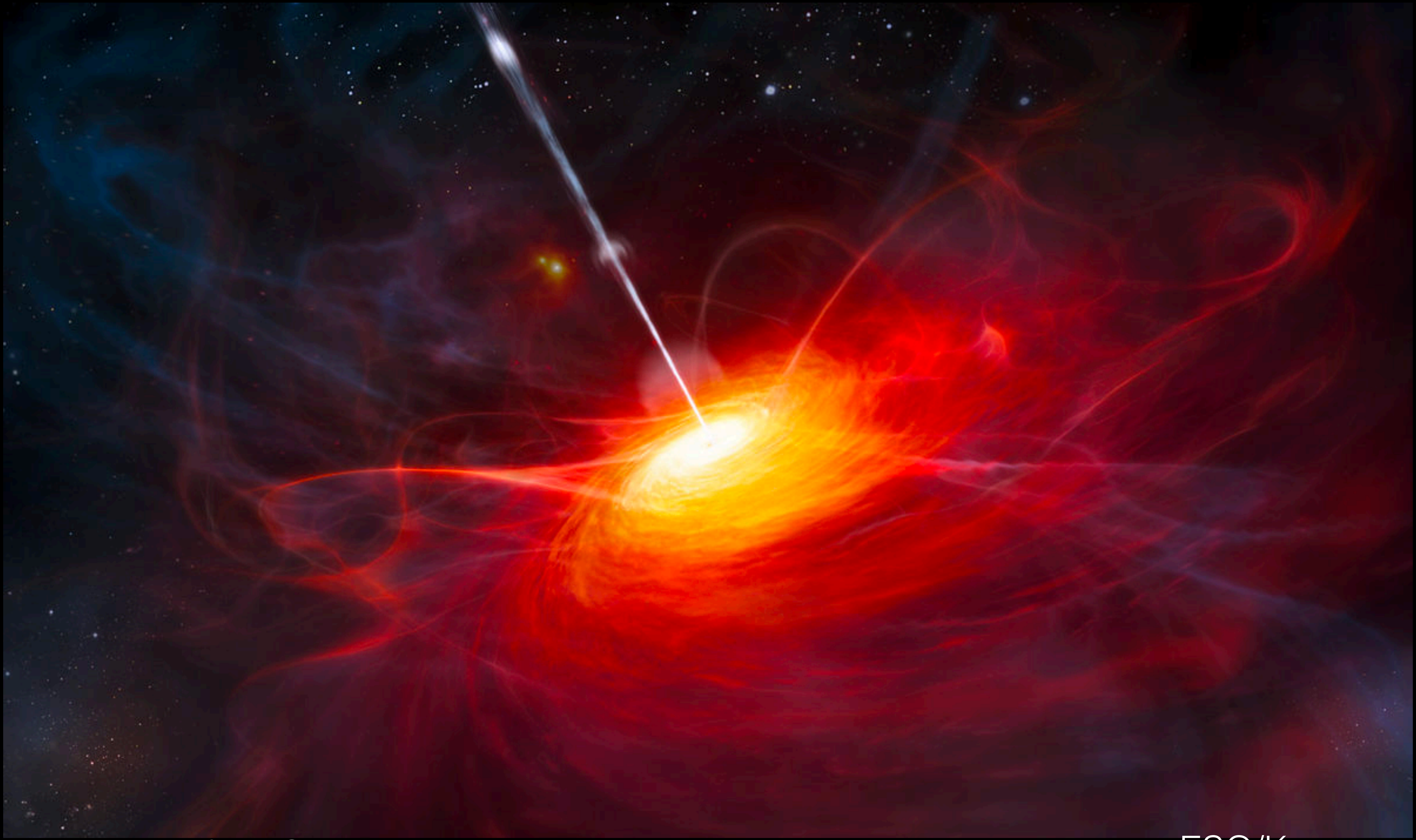
$\sim 10^9 M_\odot$ **black hole**

~2.5 Mpc

Challenges

1. If we generously assume radio-to-black hole mass ratios at low z, are there pathways to enough black holes at z=17?
2. Can we avoid heating/reionizing the gas?
3. Can black holes produce radio emission at z=17?

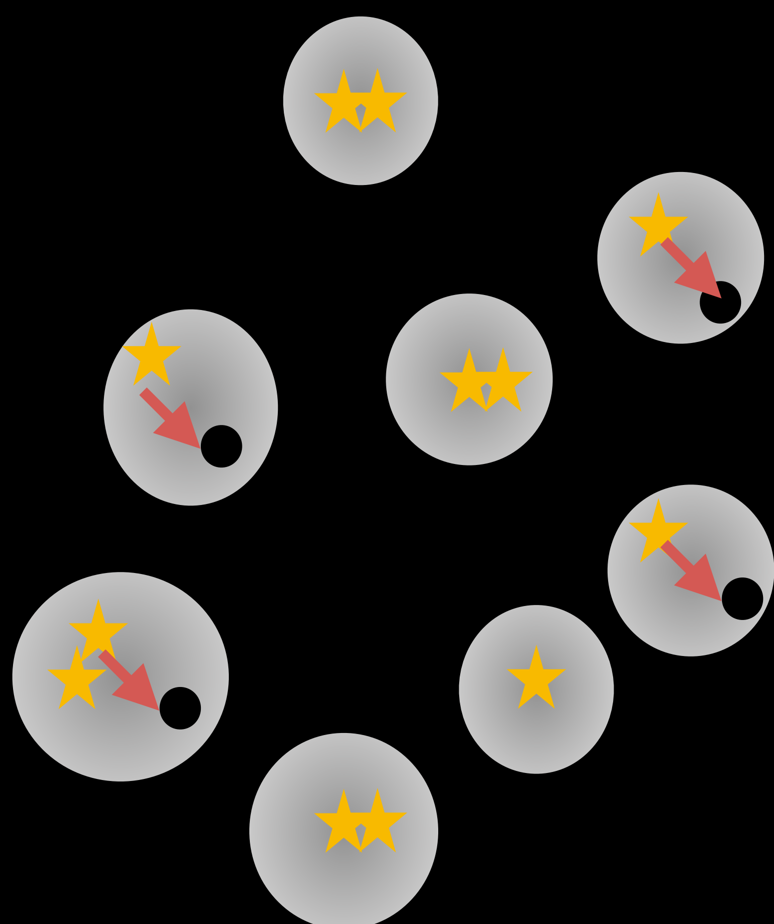
Investigate models that explain the ~billon solar mass quasars at z~7



Artist impression of ULAS J1120+0641

ESO/Kornmesser

Three Scenarios of SMBH Seeds in the early Universe.



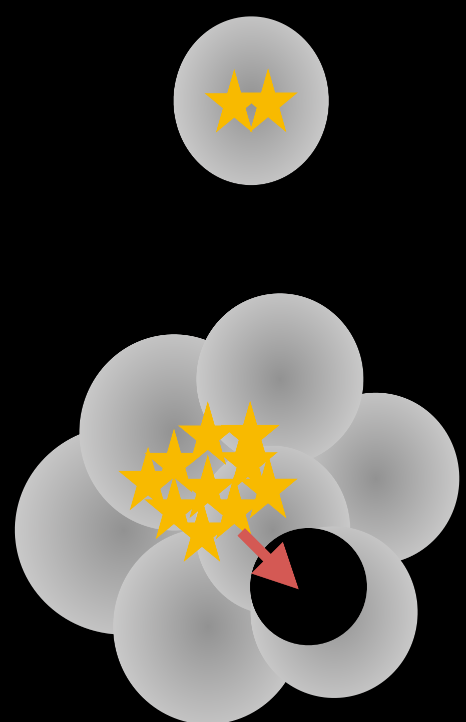
1. Remnants of Population III Stars

(A) Form in ~10^5-10^7 $M_\odot$ halos

(B) Seed mass of ~10-1000 $M_\odot$

Madau+2001 Haiman+2001, Volonteri+2005,2006,2015

Three Scenarios of SMBH Seeds in the early Universe.



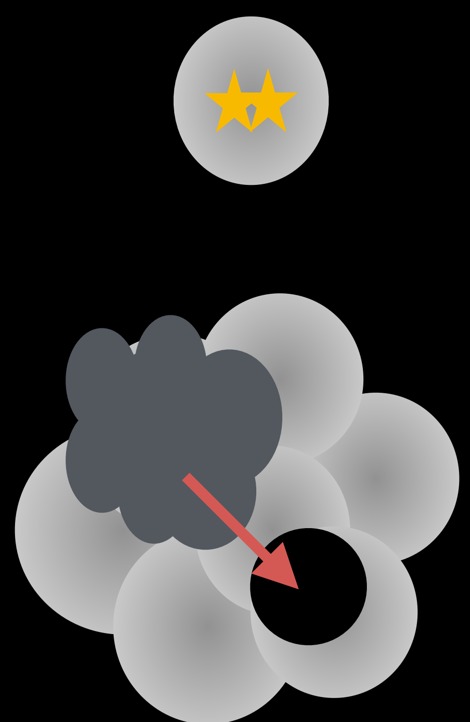
1. Remnants of Population III Stars
2. Cluster Collapse

(A) Form in $\sim 10^8 M_\odot$ halos

(B) Seed mass of $\sim 1000 \quad M_\odot$

Devecchi+2009, Davies+2011, Stone+2017

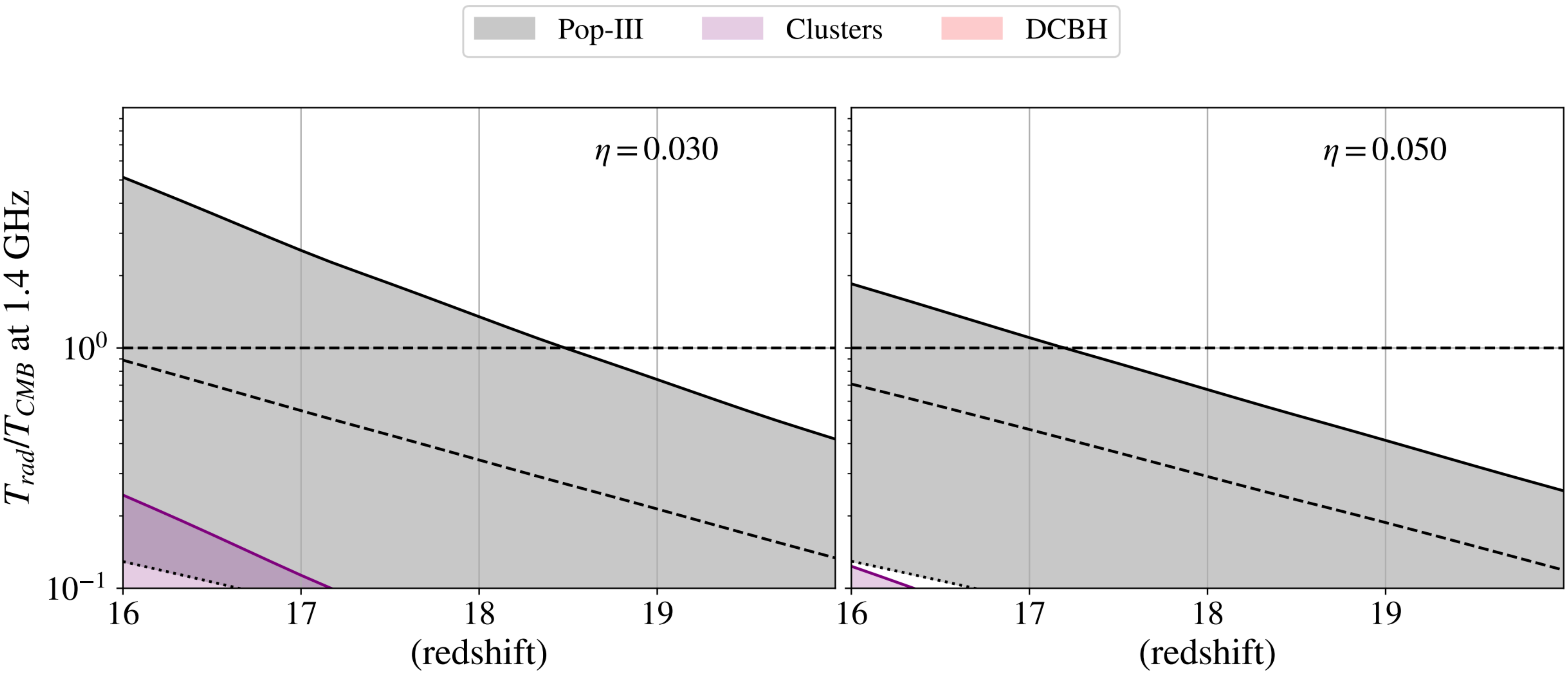
Three Scenarios of SMBH Seeds in the early Universe.



1. Remnants of Population III Stars
2. Cluster Collapse
3. Direct Collapse Black Hole
   (A) Form in $\sim 10^8 \, M_\odot$ halos
   (B) Seed mass of $\sim 10^5 \, M_\odot$
   (C) Require pristine "massive" halos with UV background

Bromm+2003, Shang+2010, Johnson+2012

Can we get enough radio emission? Yes!



10% radio loud

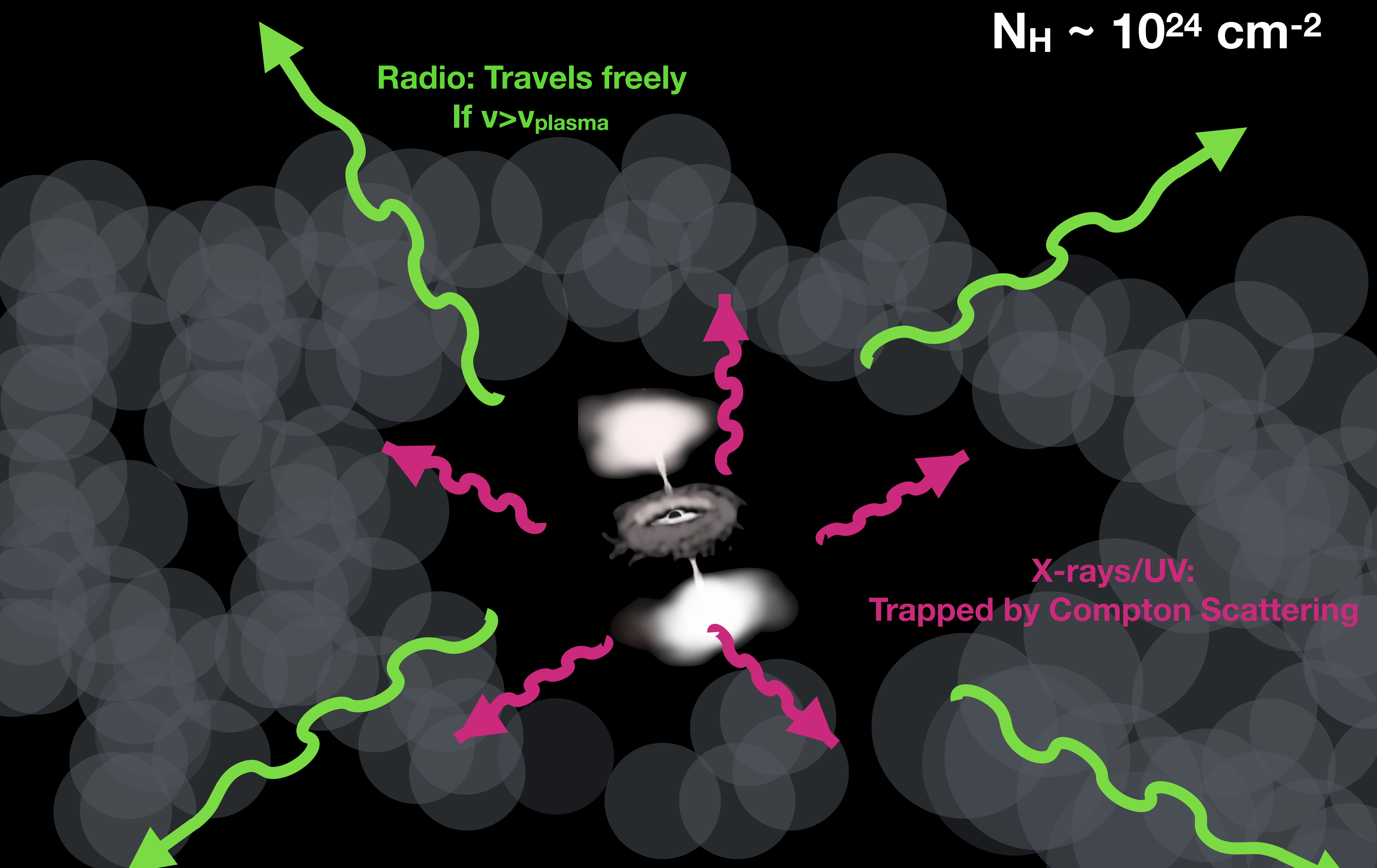
Loudness boost of ~1000

AEW+ 2018

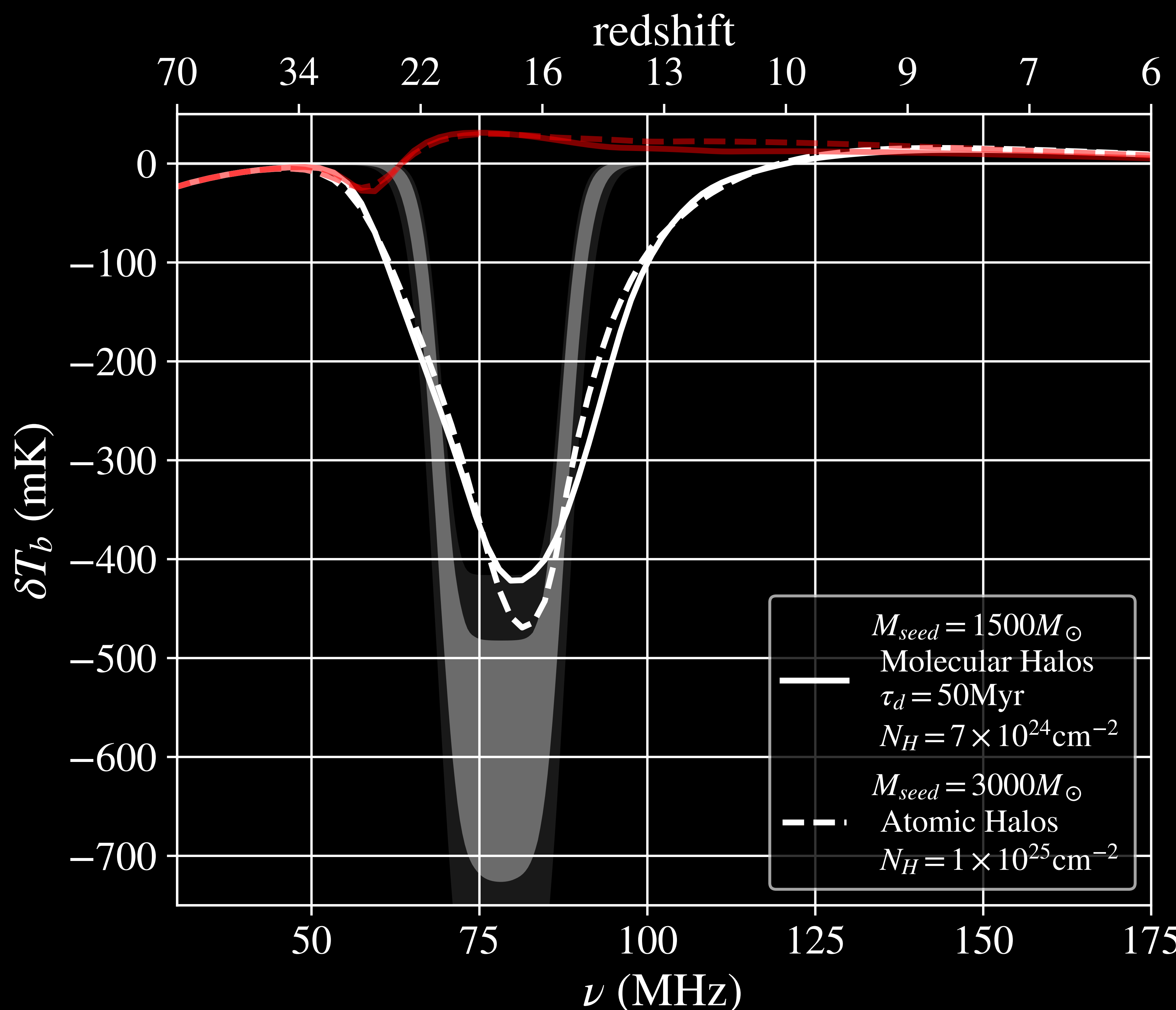
Challenges

1. If we generously assume radio-to-black hole mass ratios at low z, are there pathways to enough black holes at z=17?
2. Can we avoid heating and reionizing the IGM too early?
3. Can black holes produce radio emission at z=17?

Yes, if the sources are Compton thick.



Self Consistent Obscured Models Reproduce EDGEs.

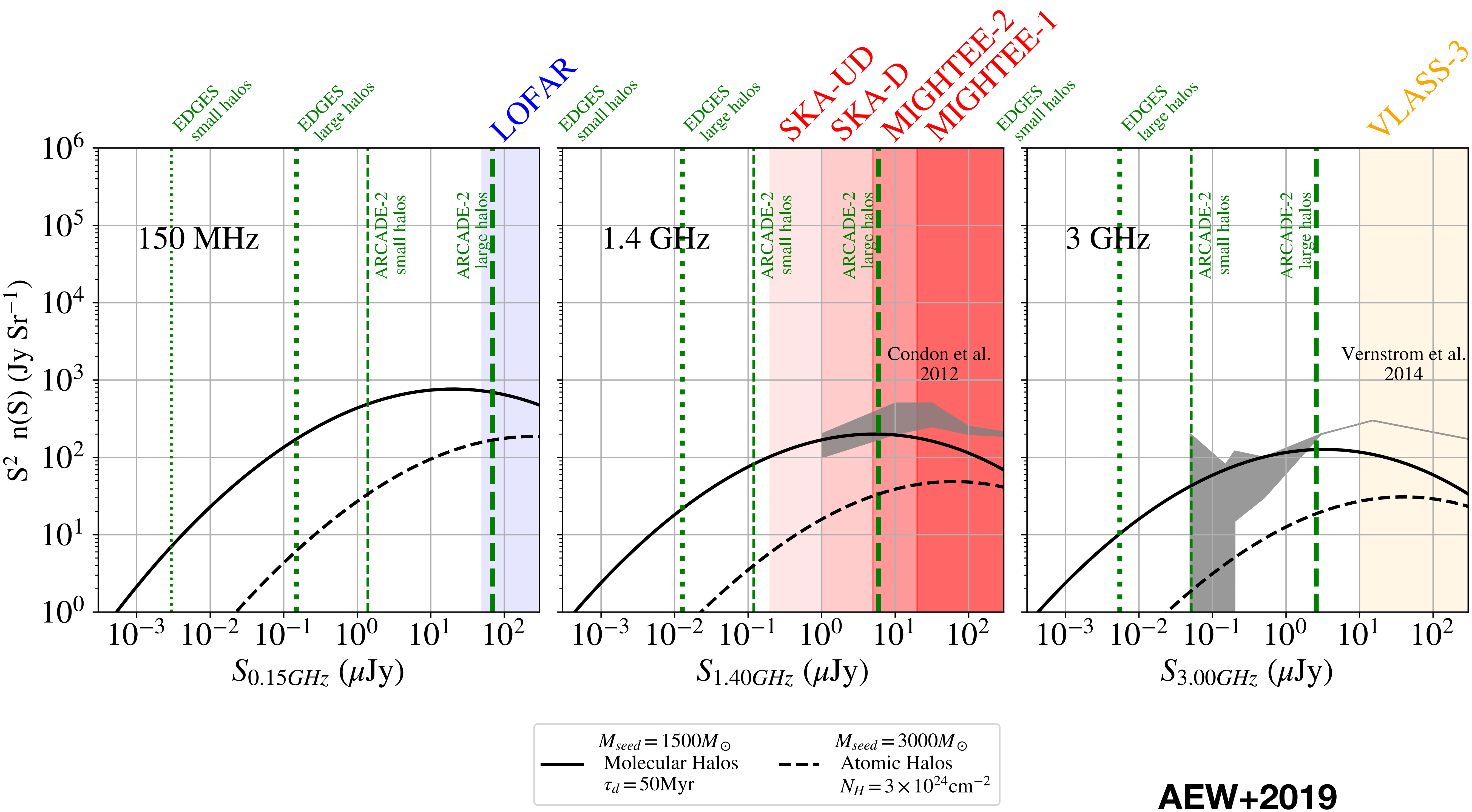


Unobscured.

EDGES typically Requires 20 Myr Growth Times

AEW+2019

Additional Constraints: Radio Source Counts



AEW+2019

Challenges

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An FRII Radio Galaxy in the local Universe

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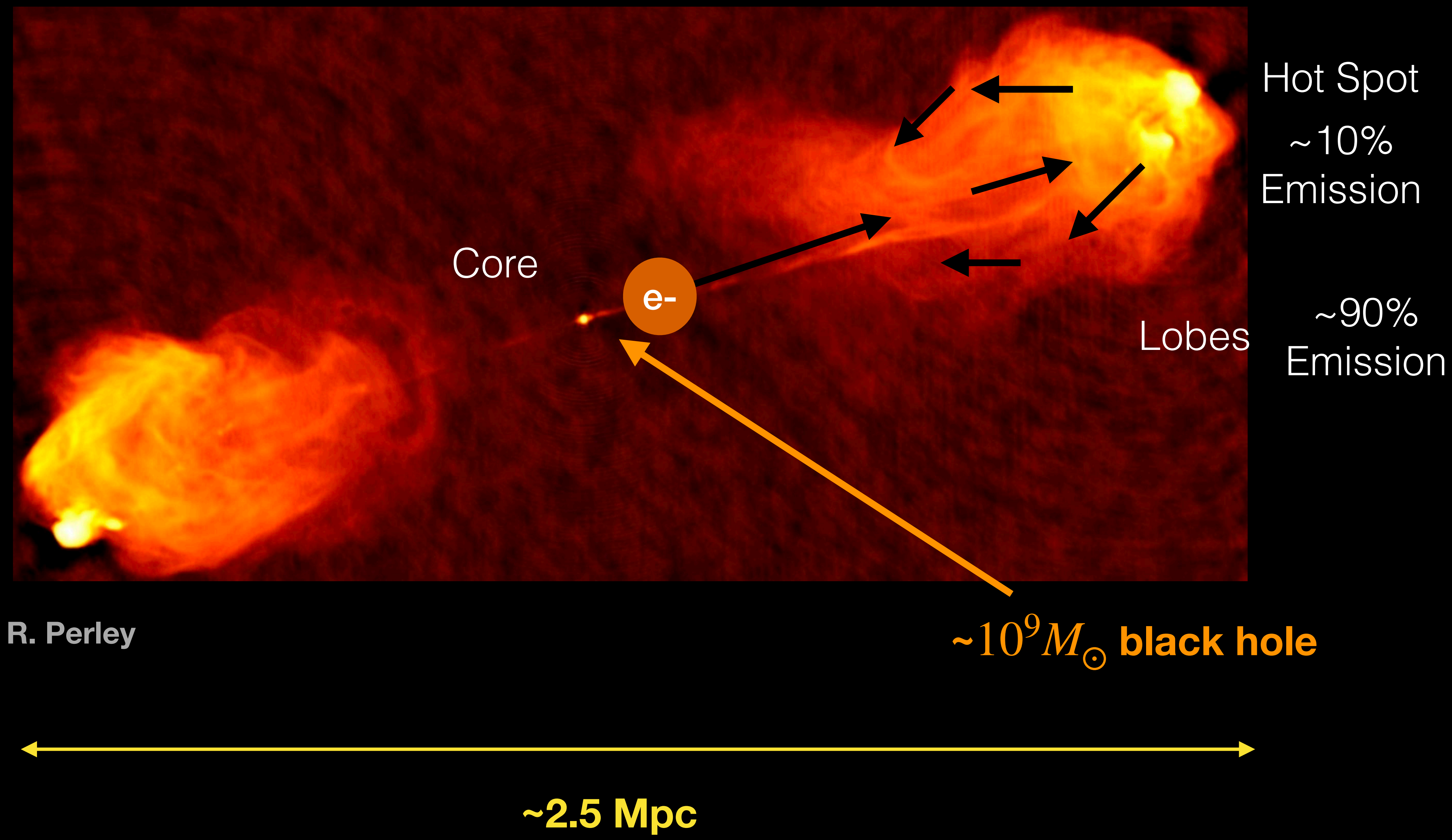
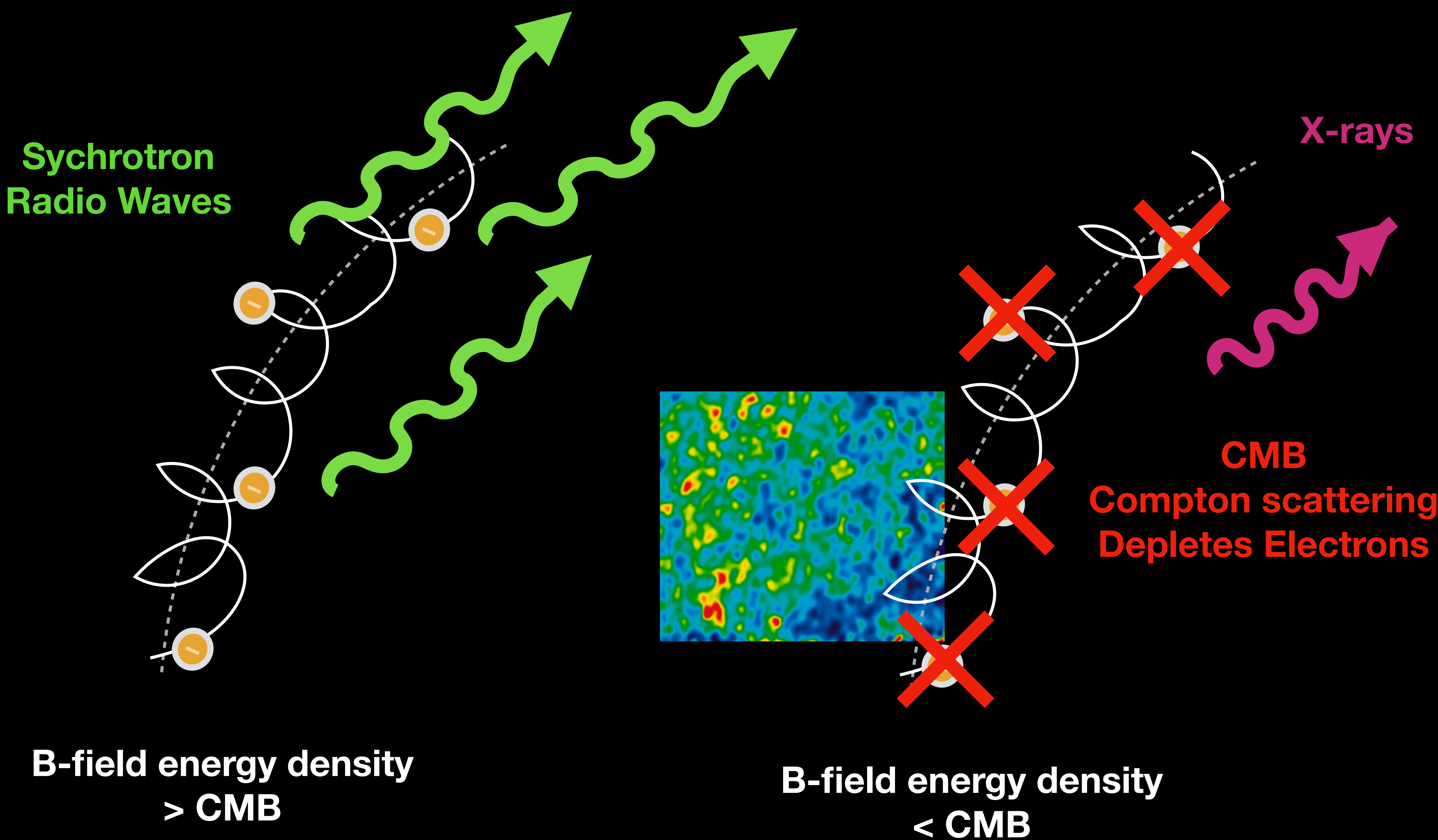


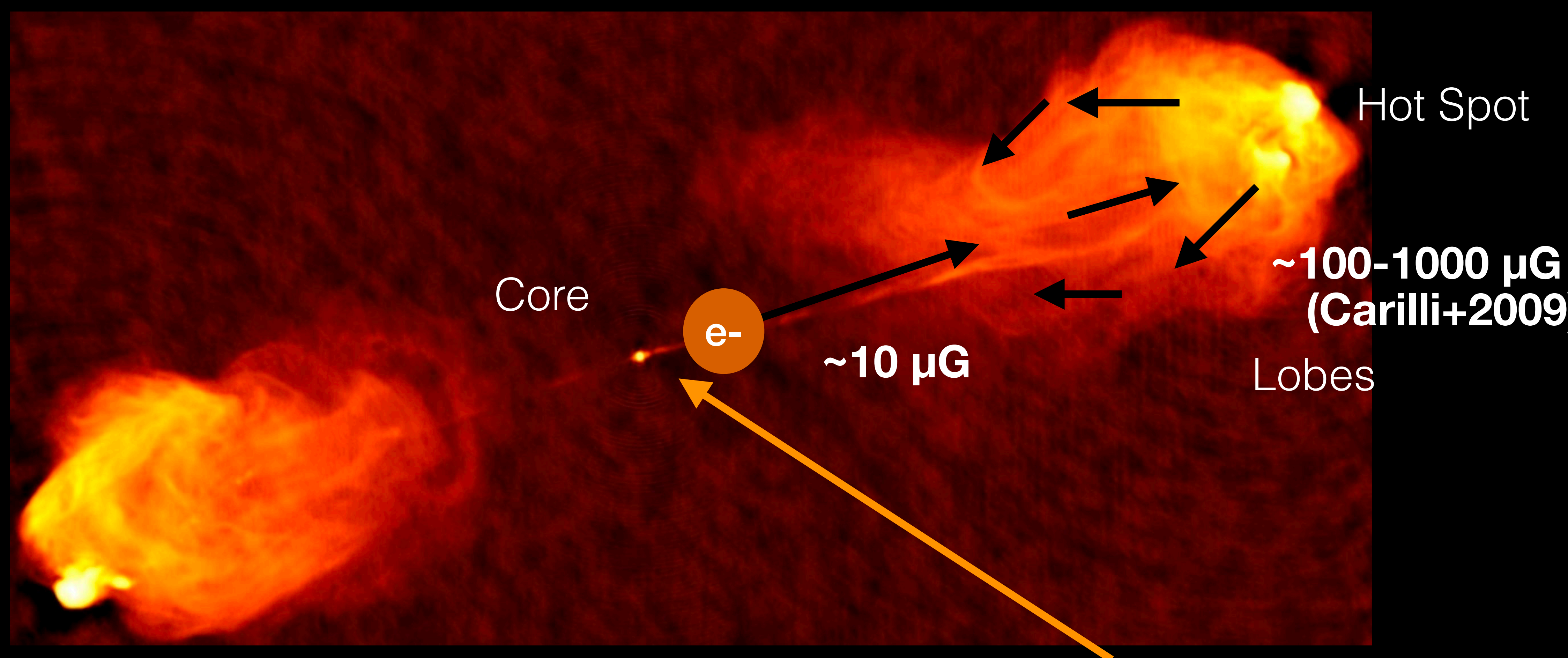
Inverse Compton scattering Competes with Synchrotron Emission



At $z=18$, Synchrotron dominates when $B>1$ mG

Hot Spots in FRII Galaxies are close to this value.

Cygnus A (5 GHz)



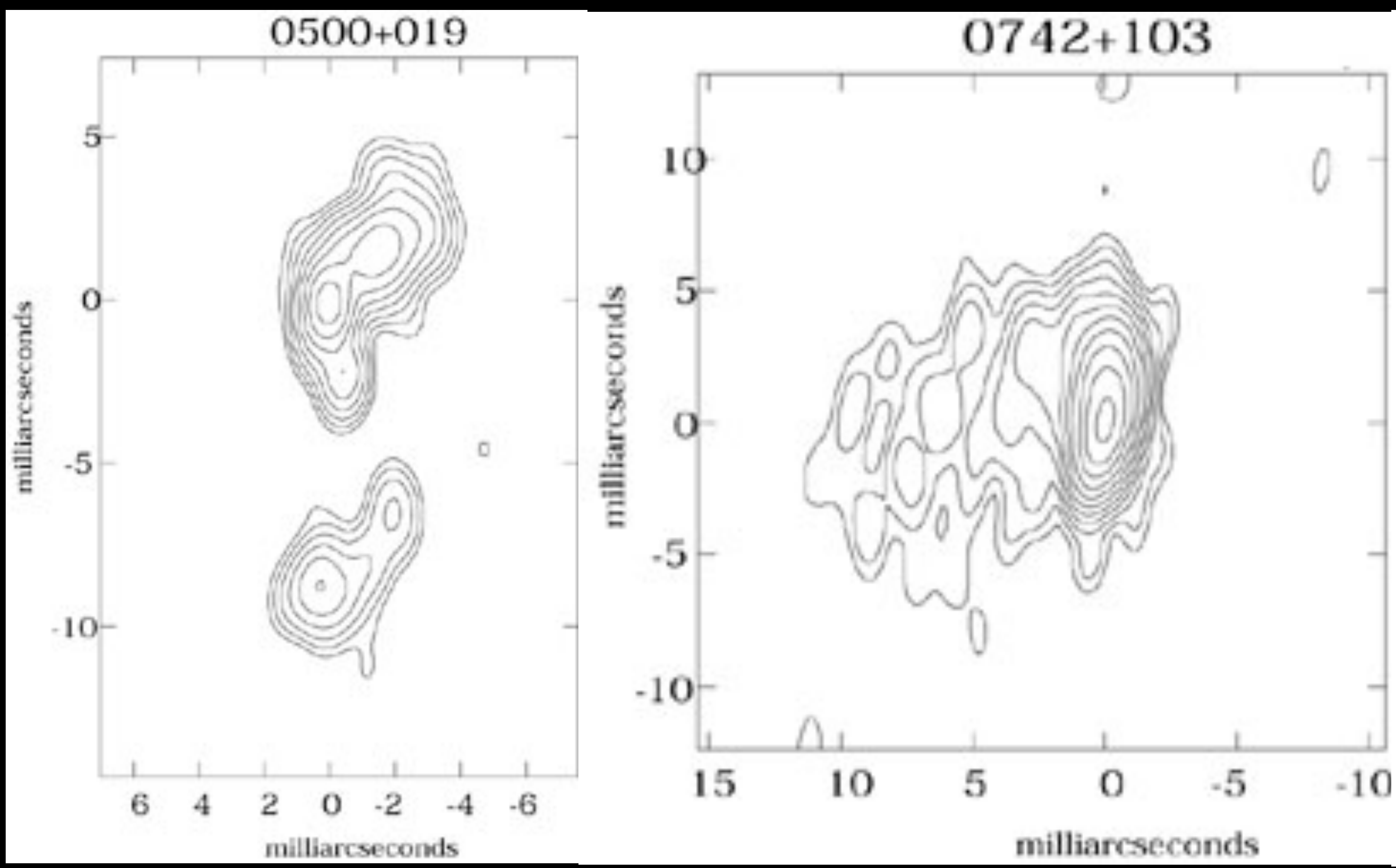
R. Perley

$\sim 10^9 M_\odot$ **black hole**

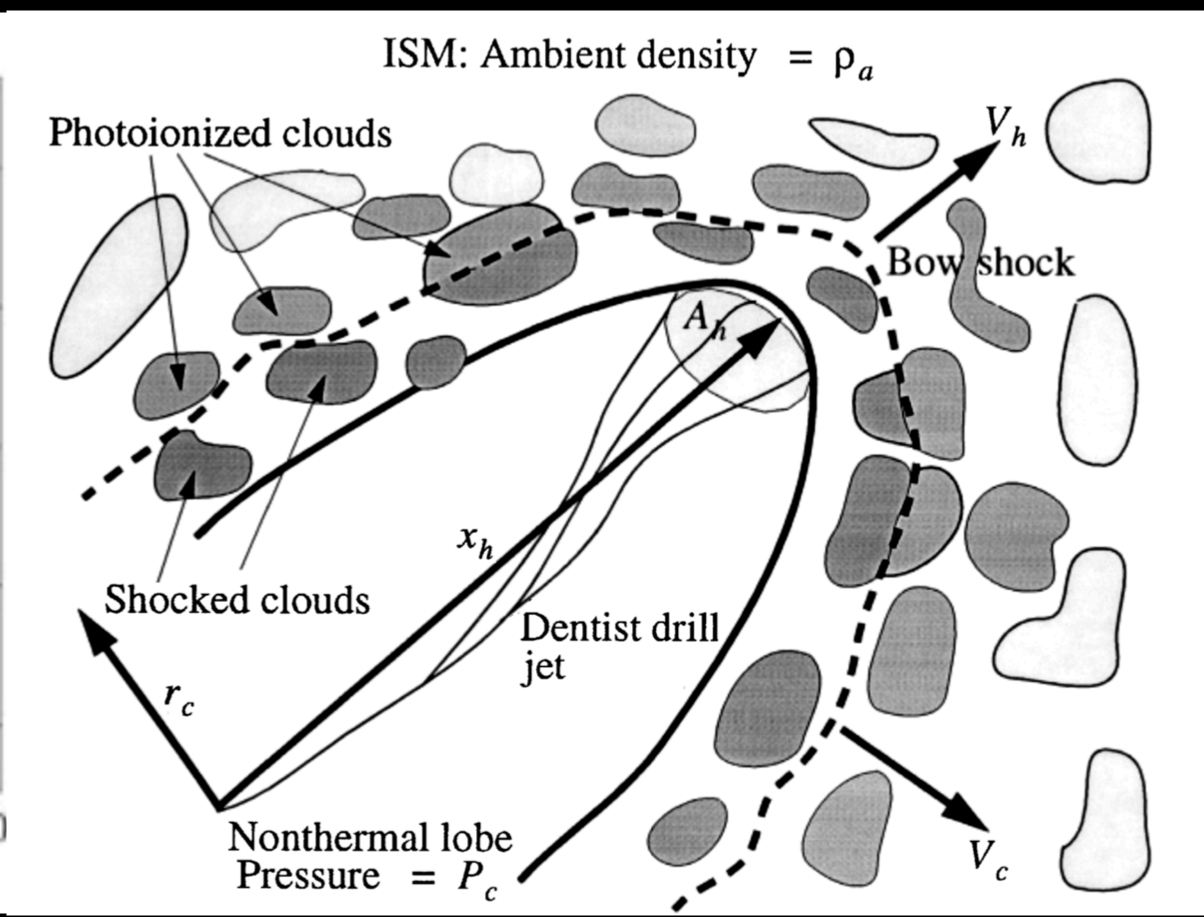
(Synchrotron electron lifetimes in hot-spots ~10⁴ years)

~2.5 Mpc

Compact (<1-10 kpc) Radio Galaxies often exceed 10 mG (GPS, CSS)



Stanhellini — 1997



Bicknell-1997

Problem — They only last for 10^4 - 10^5 years unless confined by ~10^9-10^{10} solar masses of ISM.

Two Possible Mechanisms for a prolonged GPS-like source powered by an IMBH

1. Synchrotron emitting plasma is confined kinetically by the ram-pressure of a high-velocity accretion flow.

2. Intermittent radio-emission episodes where dense gas is resupplied by accretion.

Conclusions

A. Radio emission from SMBH seeds is a plausible EDGEs explanation provided that

   1. ~10% of todays black hole mass is assembled within the first billion years and the accretion is radio loud.

   2. These SMBH seeds formed in Compton thick environments.

   3. New confinement mechanisms are likely needed to address IC problem.

B. Further constraints on these models can be obtained using point source surveys and flucuation measurements.