Supermassive black hole formation at high redshift

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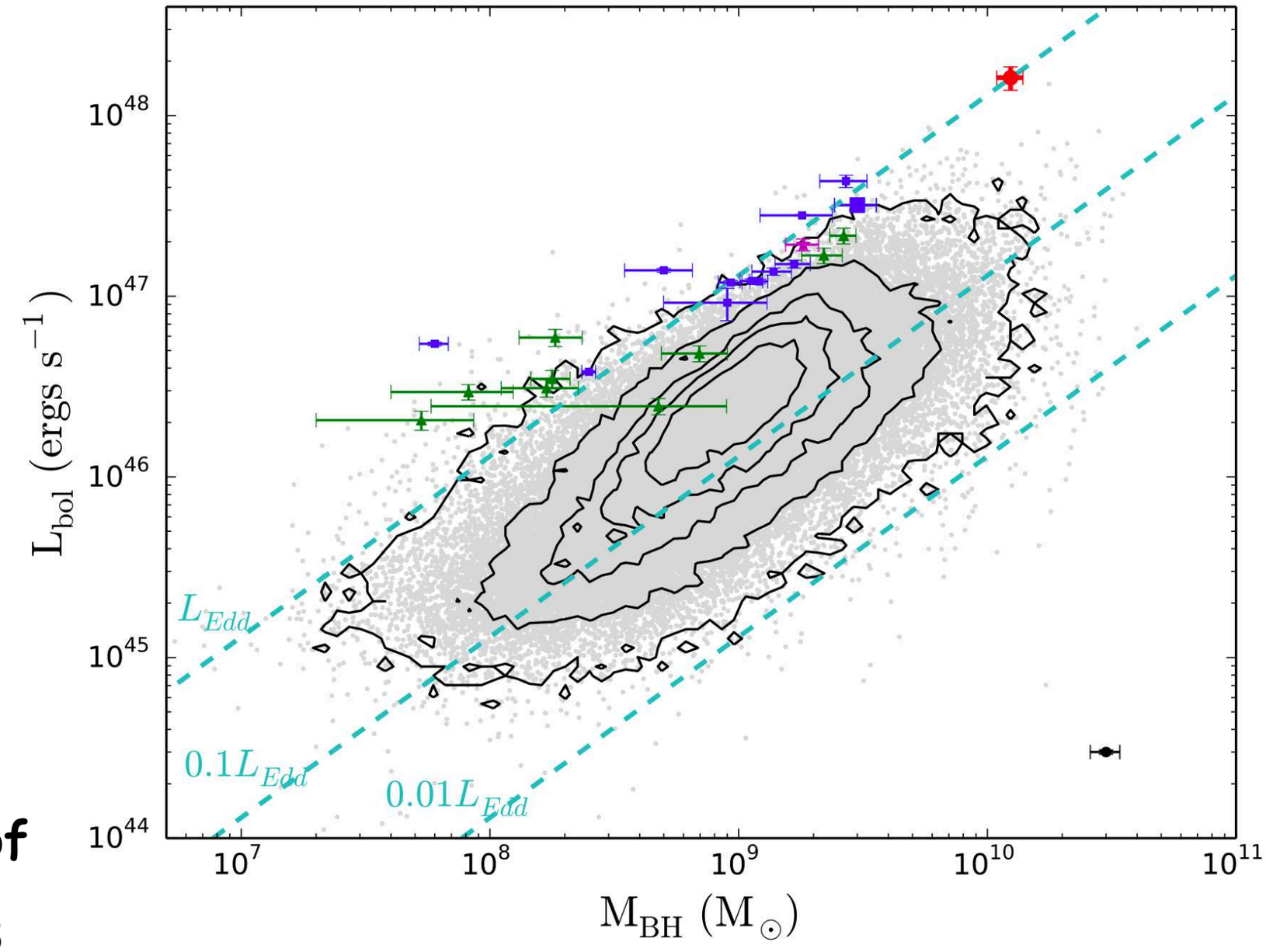
High z Quasars

★ Supermassive black holes with ~10^9 solar masses have been observed at z>6.

★ The highest-redshift black hole currently observed is at z=7.085 and has 2x10^9 $M_\odot$ (Mortlock et al. 2011).

★ The most massive black of 1.3 x 10^{10} $M_\odot$ at z=6.3 (Wu et al. Nature 2015)



Wu et al. Nature 2015

Direct collapse scenario

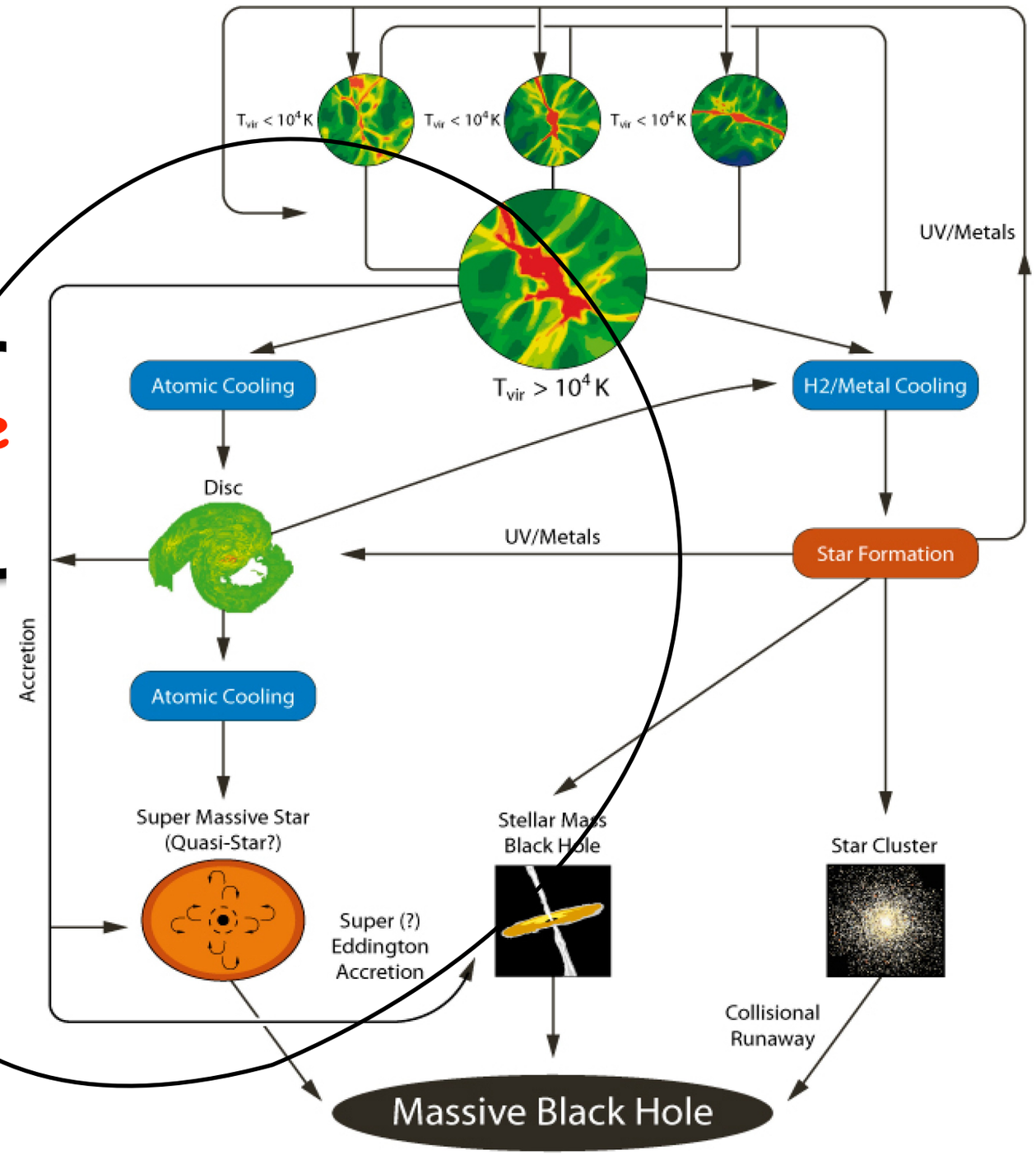
★ Provides massive seeds of 10^5-10^6 $M_\odot$

★ Key requirement is to have large inflow rate of > 0.1 $M_\odot$/yr

★ Isothermal direct collapse with T~ 8000 K

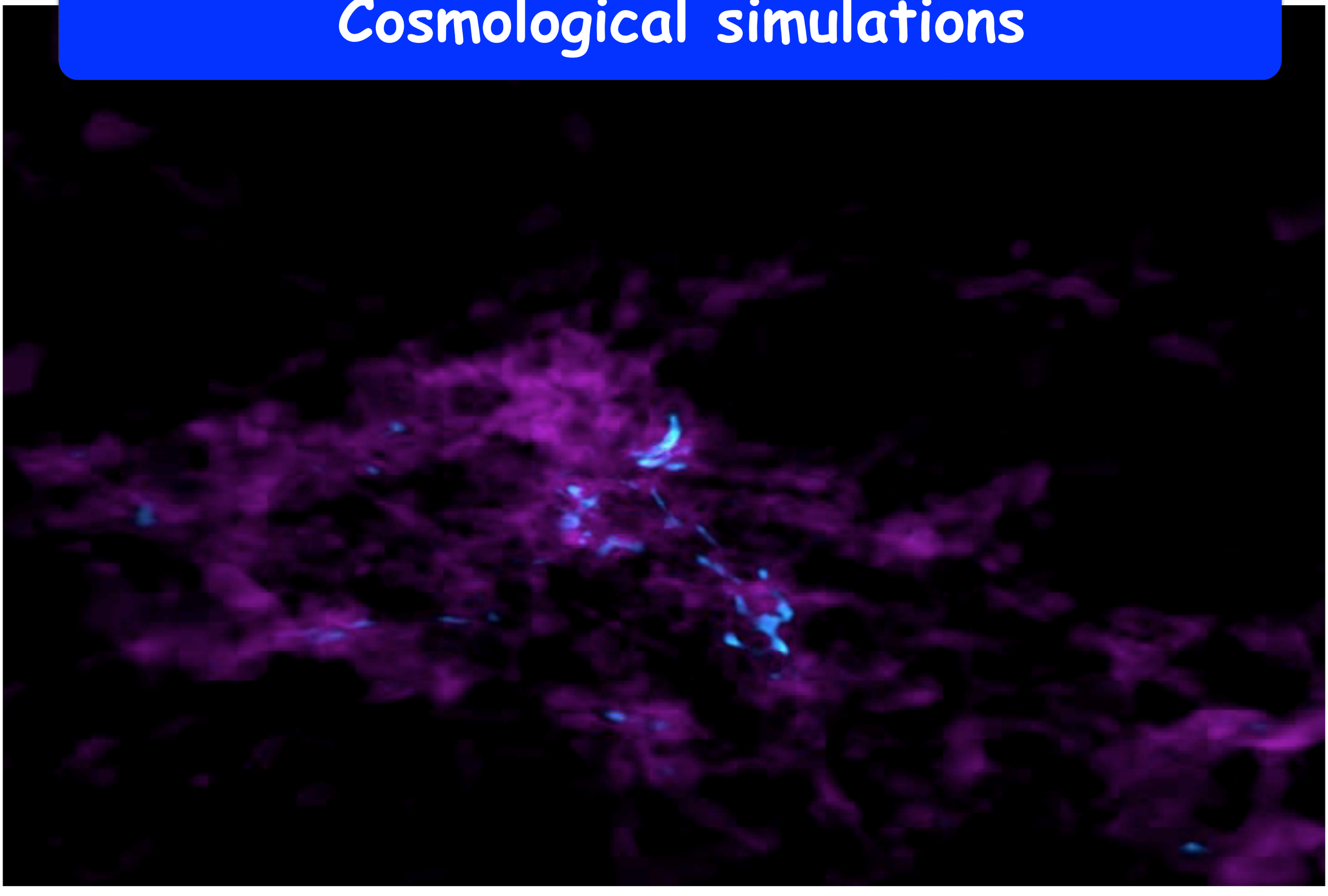
★ Primordial gas composition

★ Requires strong LW flux to quench H_2 formation



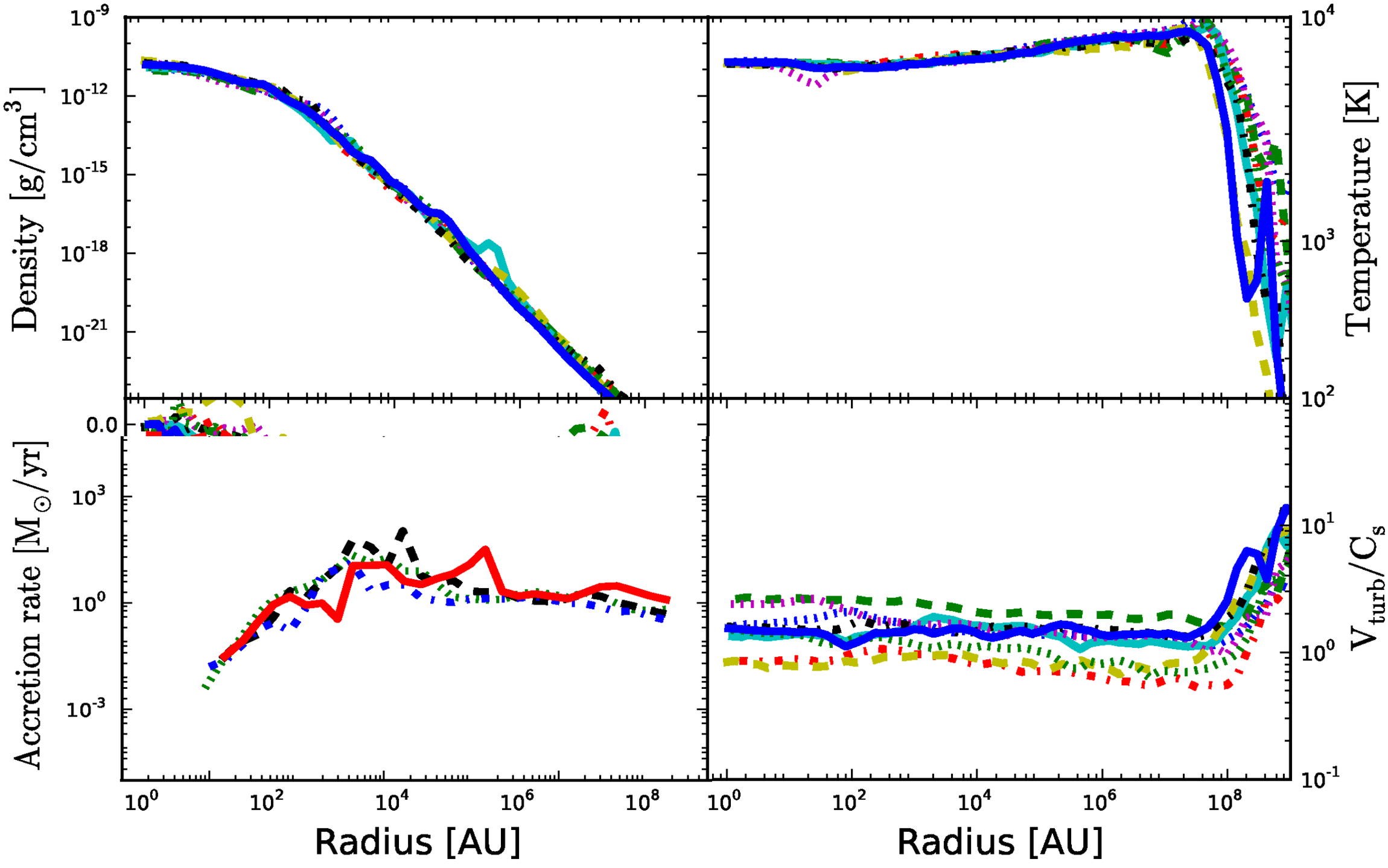
Regan et al 2009

Cosmological simulations



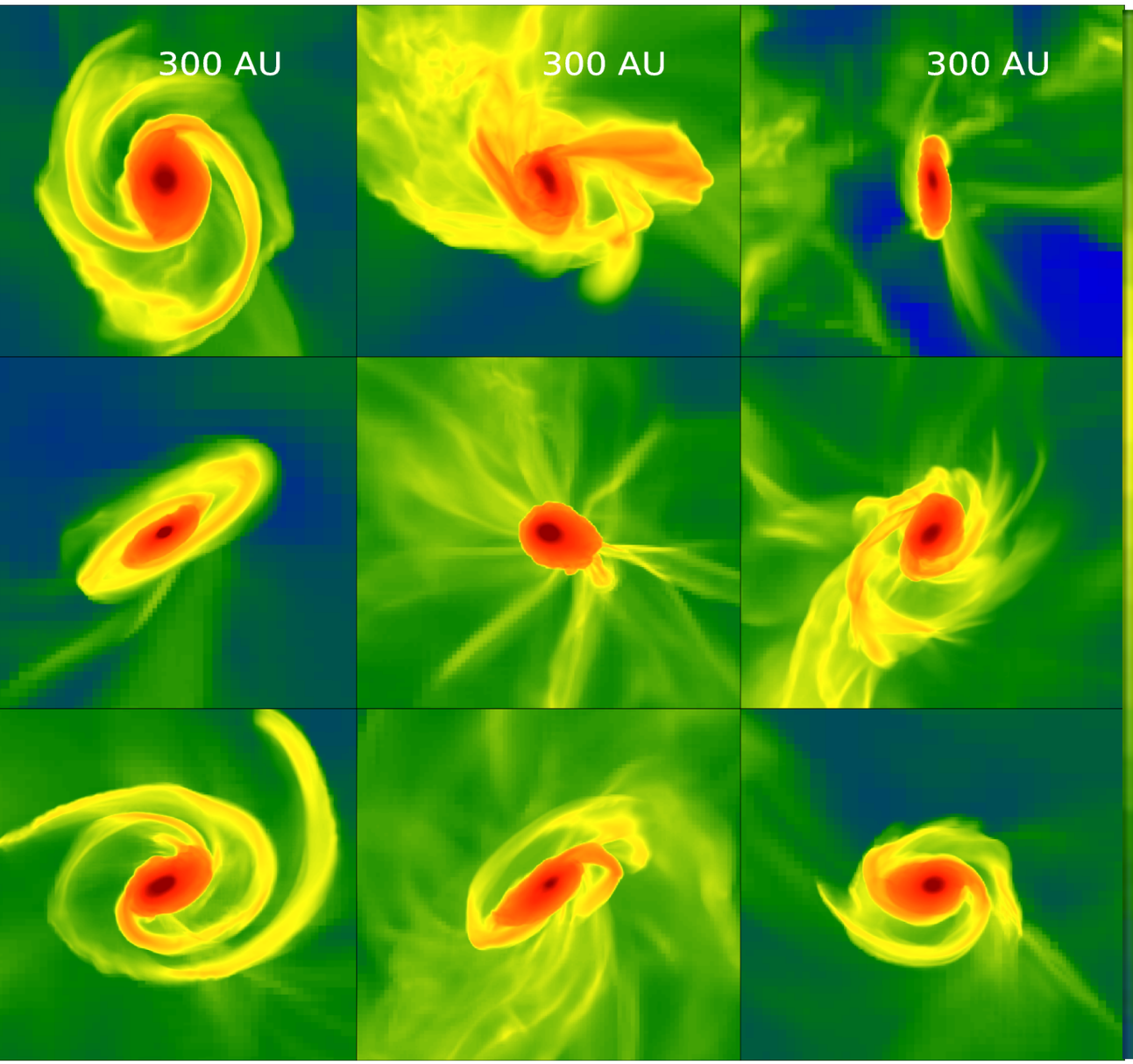
Latif et al. 2013, 2014, 2015

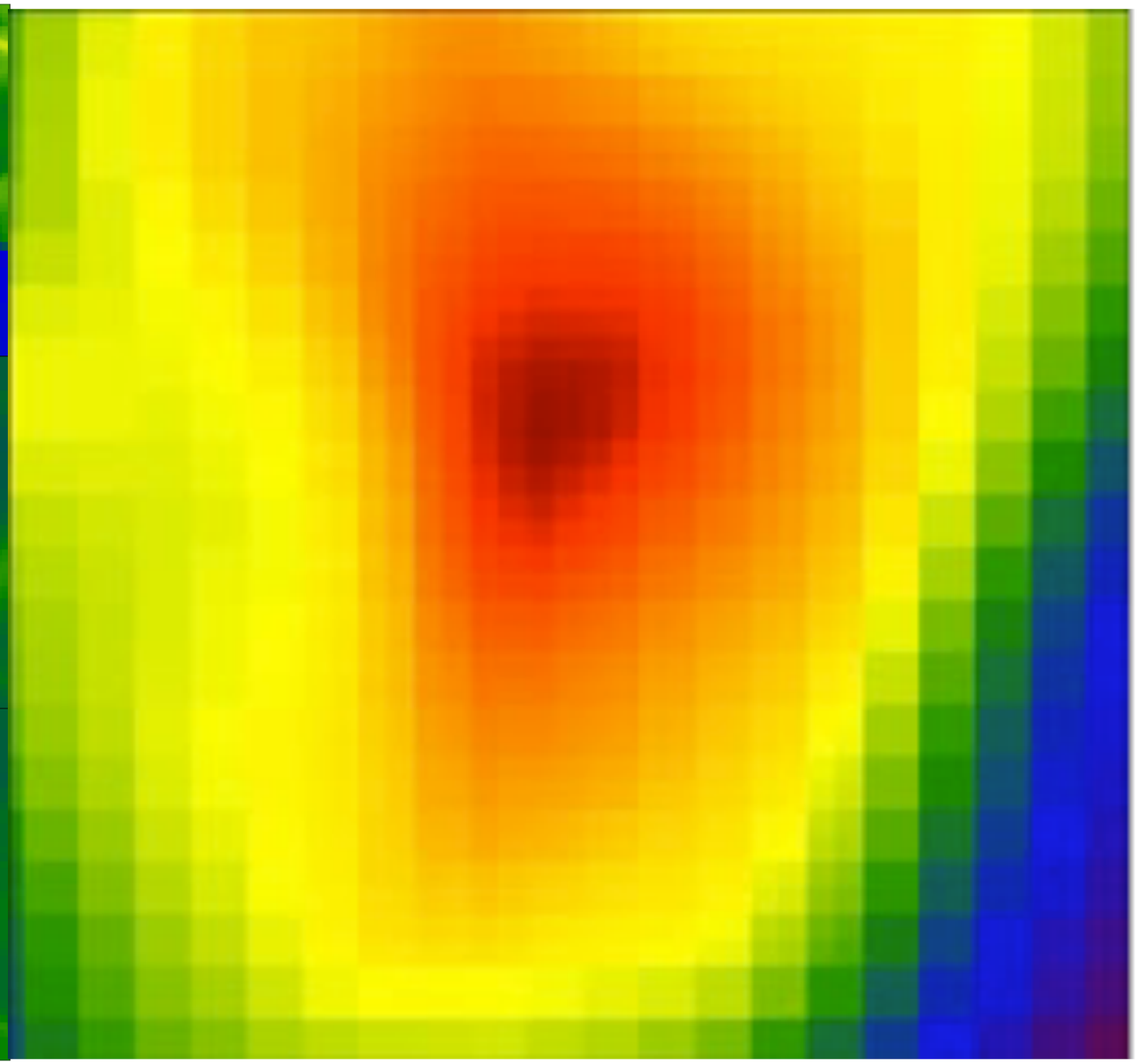
Global properties of simulated halos



Latif et al 2013 MNRAS 433 1607L

Simulations exploring the direct collapse



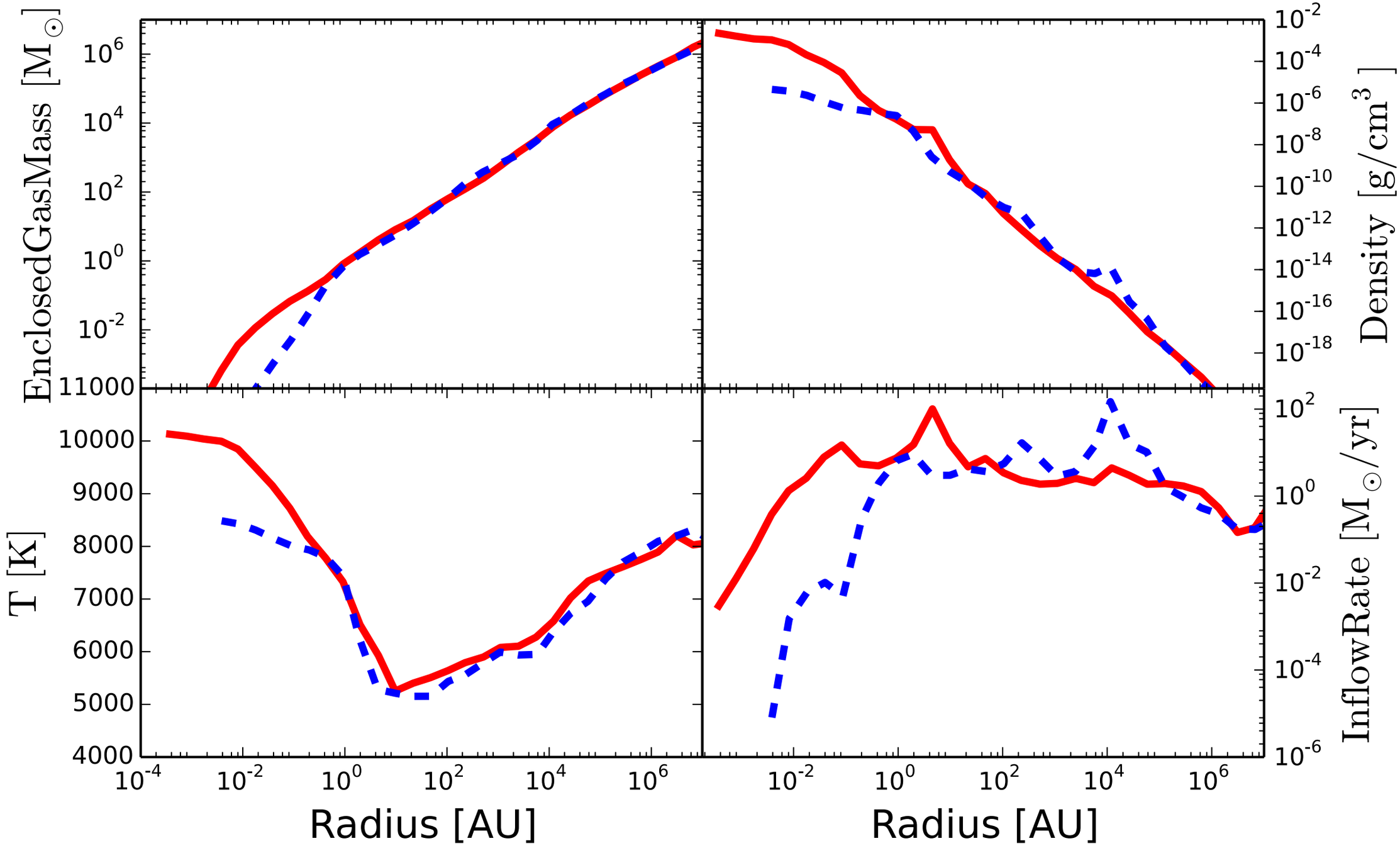


★Collapse occurs isothermally with T~ 8000 K

★Provides large inflow rates of ~1$M_\odot$/yr

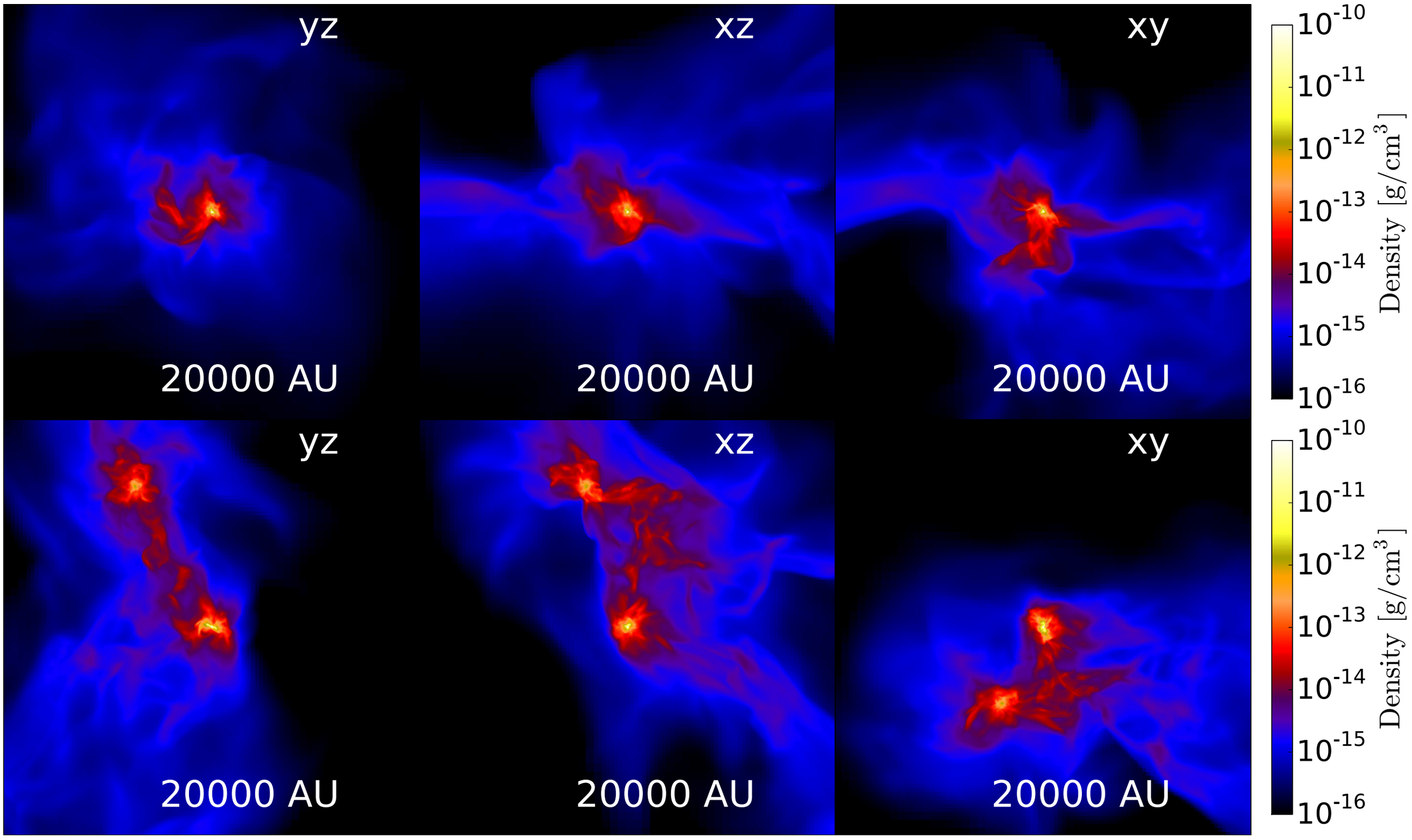
Latif et al. 2013 MNRAS 433 1607L

Impact of H^- cooling & Realistic opacities



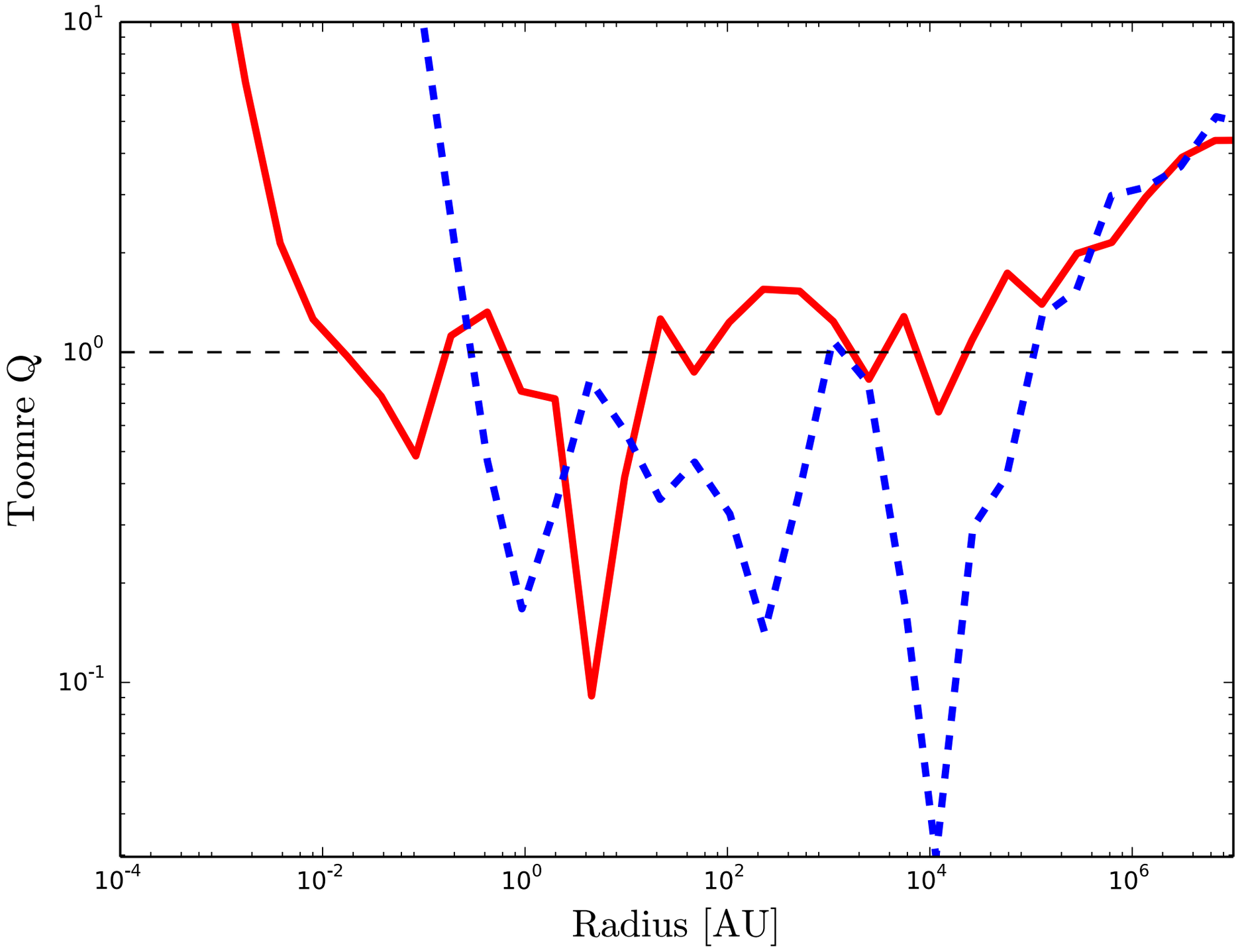
Latif, Schleicher & Hartwig, 2016, MNRAS

Impact of H^- cooling & Realistic opacities



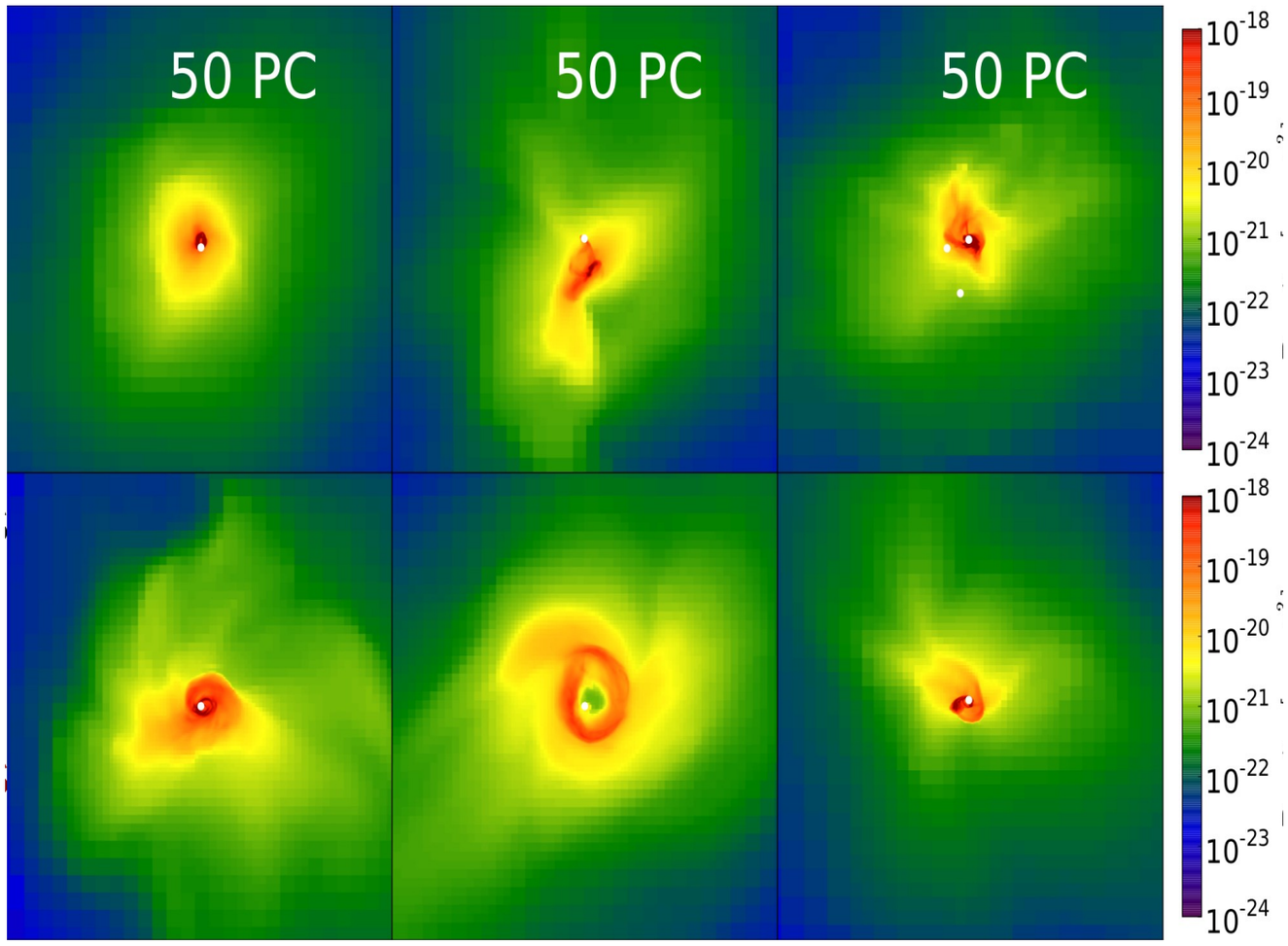
Latif, Schleicher & Hartwig, 2016, MNRAS (arXiv:1510.02788)

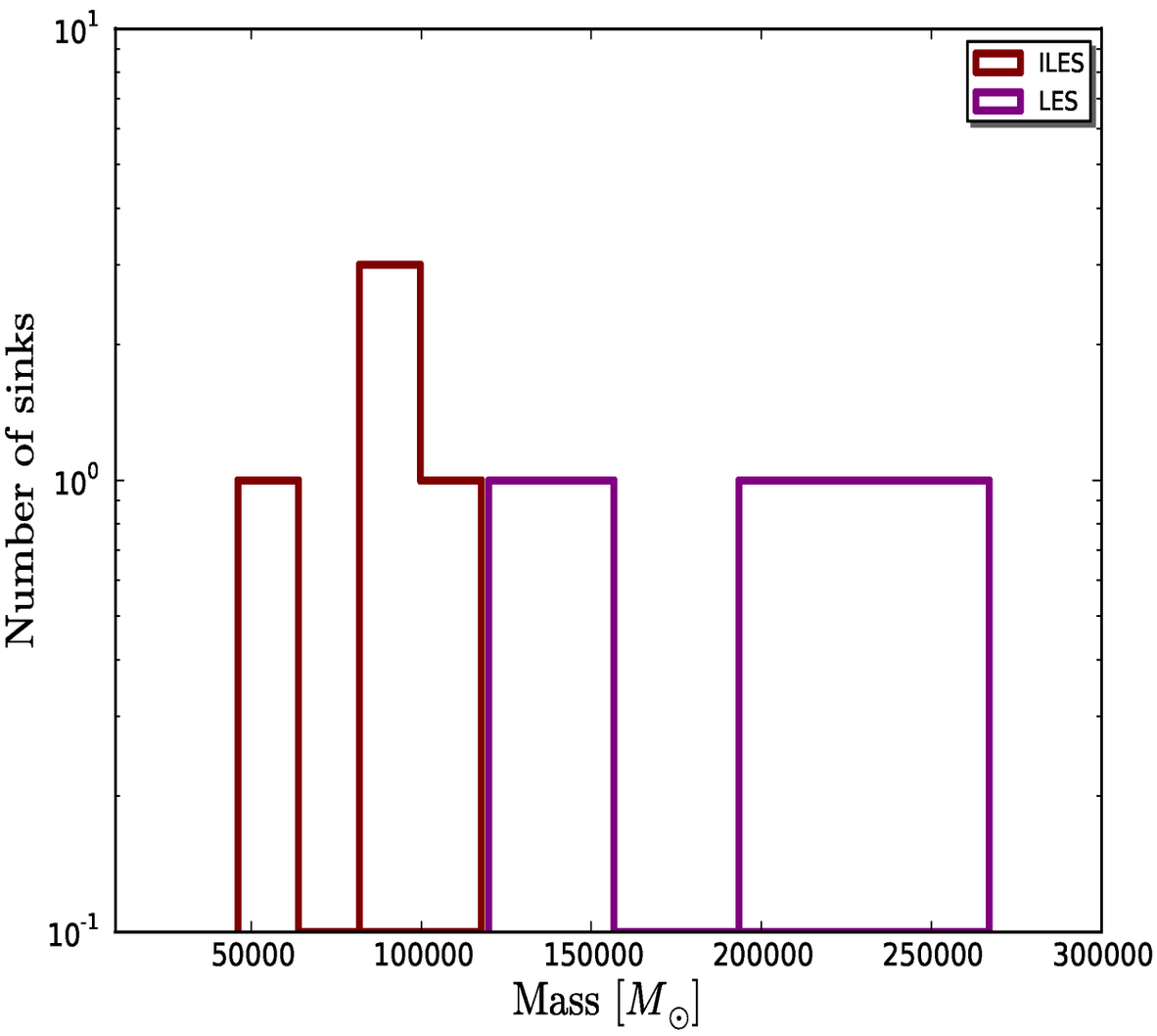
Impact of H^- cooling & Realistic opacities



Latif, Schleicher & Hartwig, 2016, MNRAS (arXiv:1510.02788)

Masses of protostars/sinks

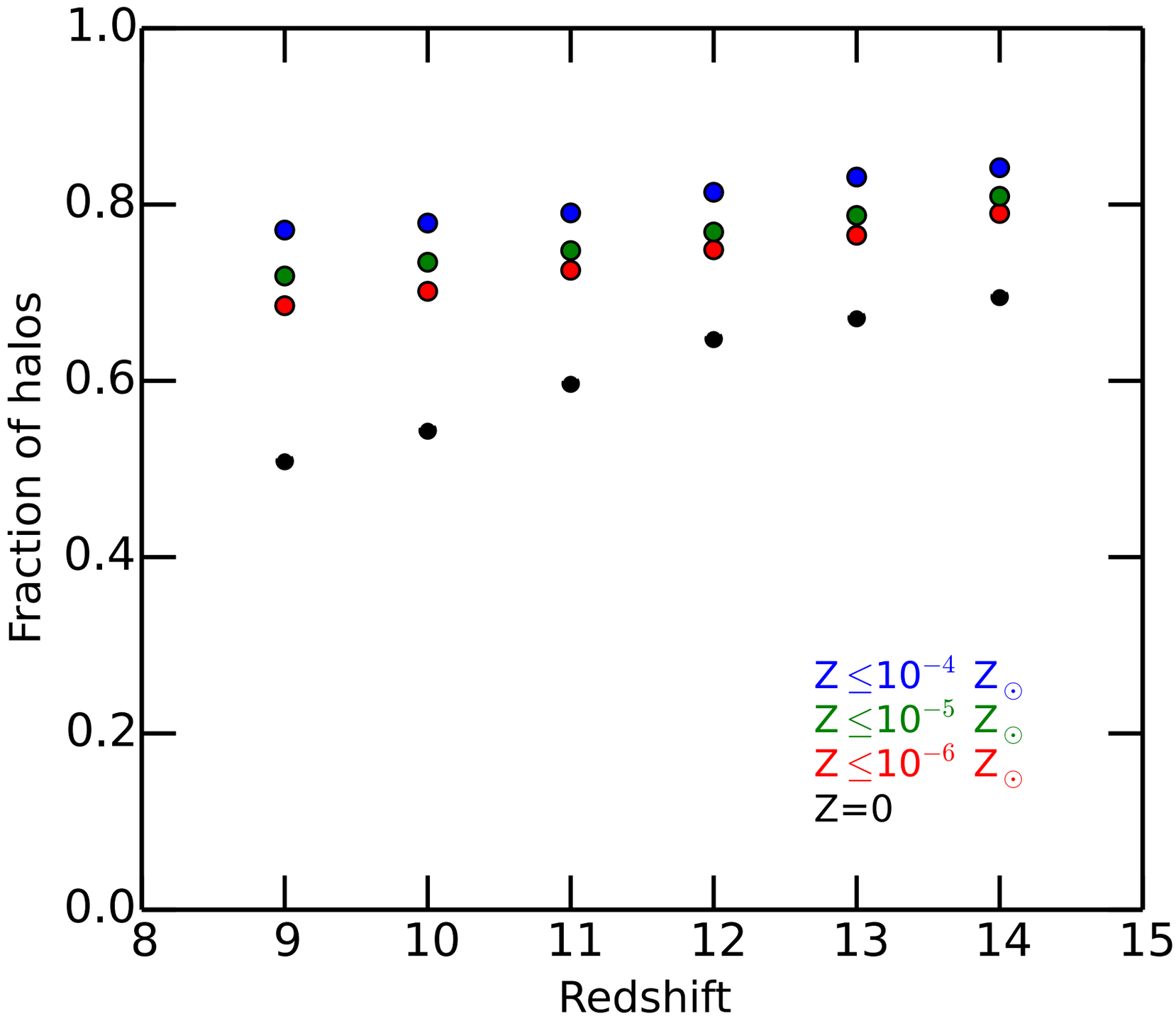




- Employed sink particles and followed the evolution for 200,000 yrs
- Massive protostars of about 10^5 $M_\odot$ are formed

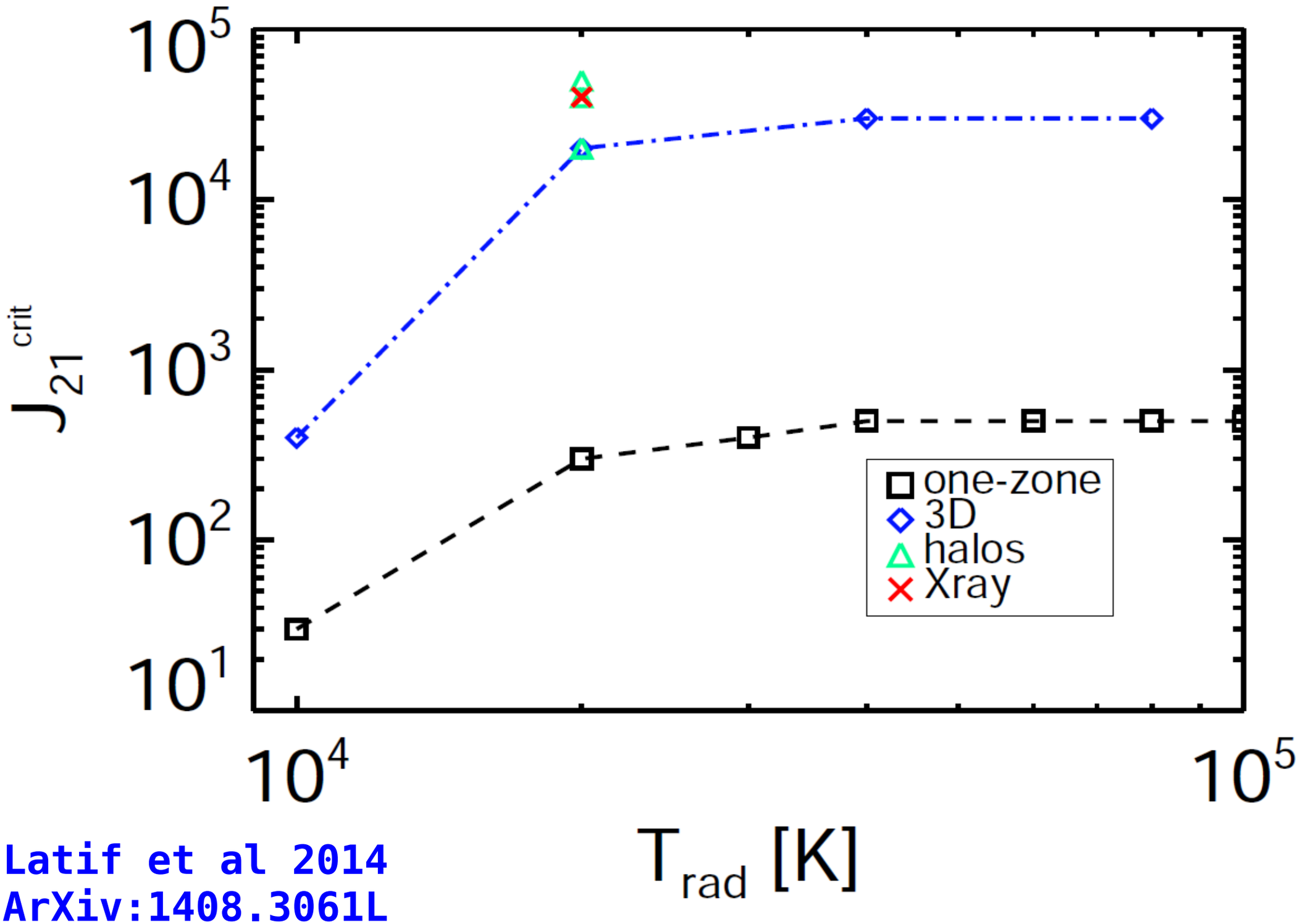
Latif et al. 2013 MNRAS 436 2989L

Fraction of metal free halos



Latif et al. 2016 ApJ resubmitted, See Habouzit, ML et al 2016

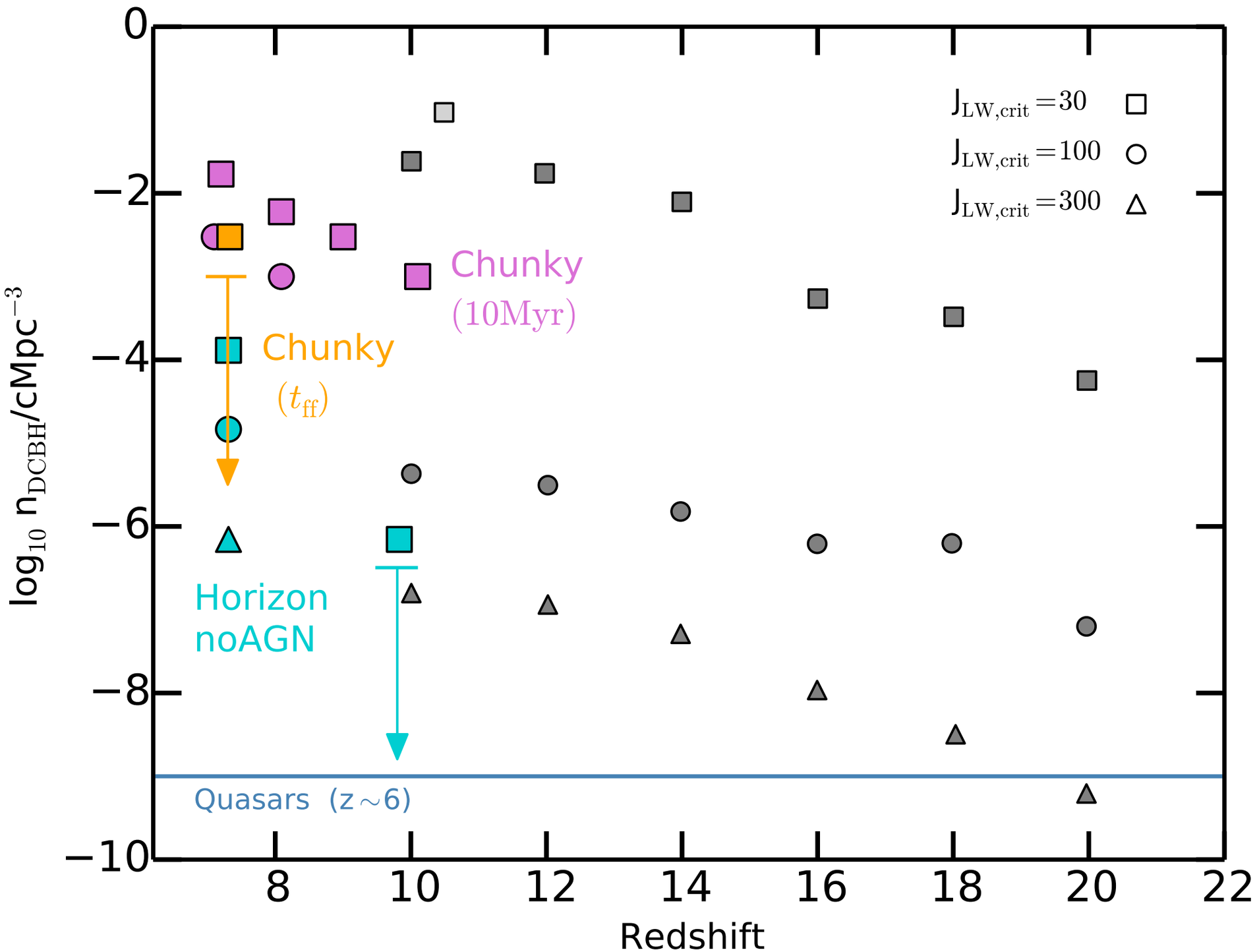
Estimates of J_{crit} from 3D simulations



Latif et al 2014
ArXiv:1408.3061L

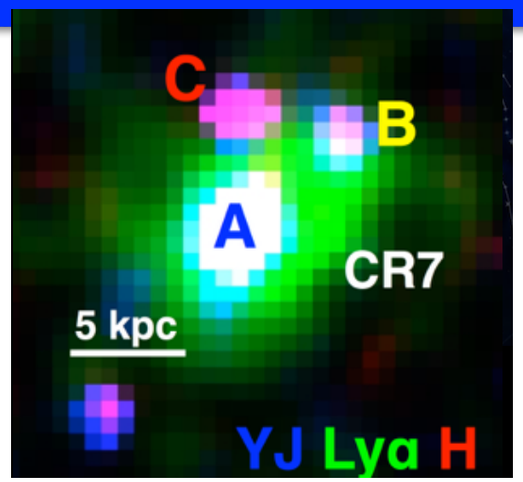
Latif et al. MNRAS 2015 446 3136, Also see Hartwig, ML et al. MNRAS 2015

Number density of DCBHs

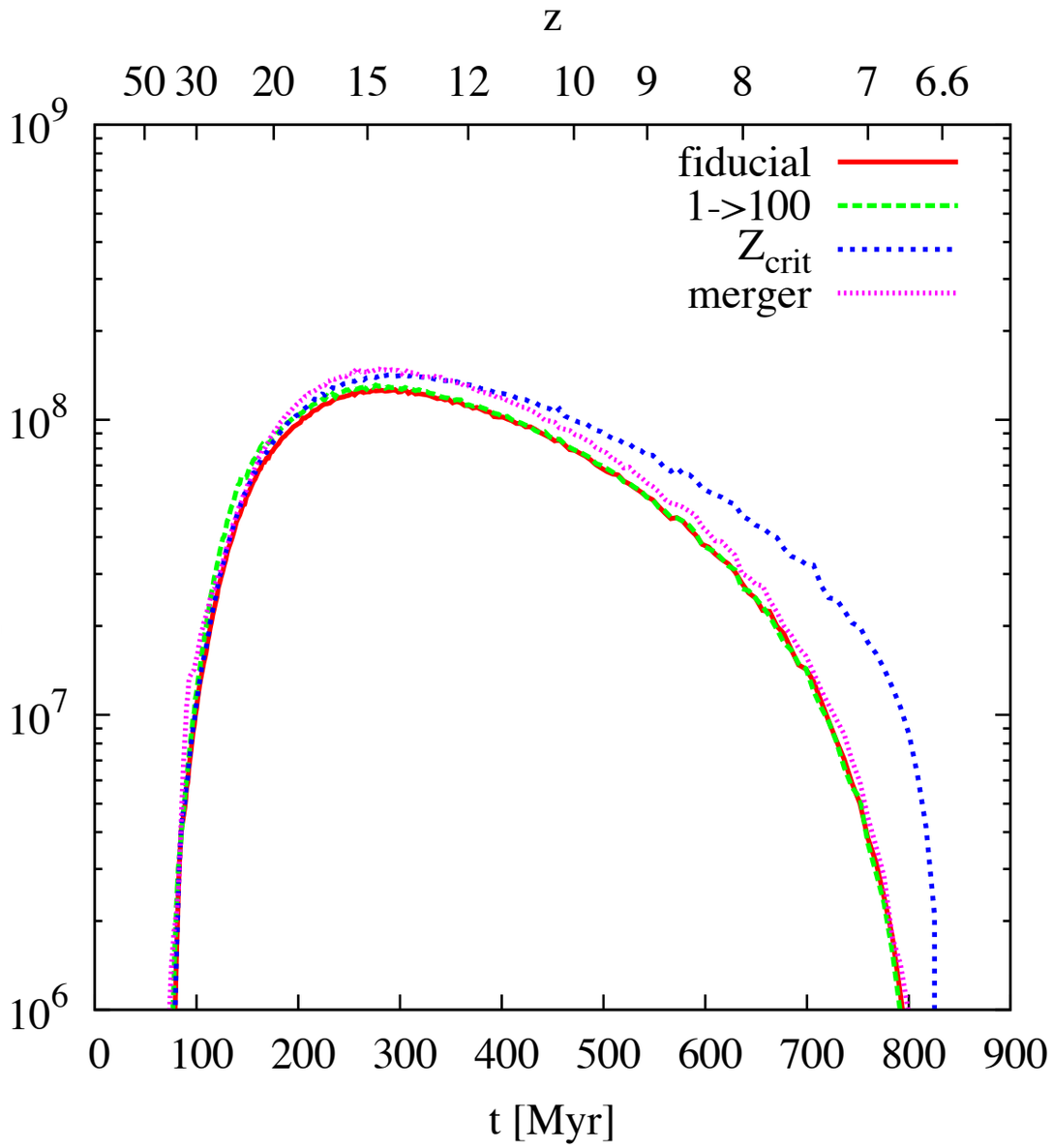


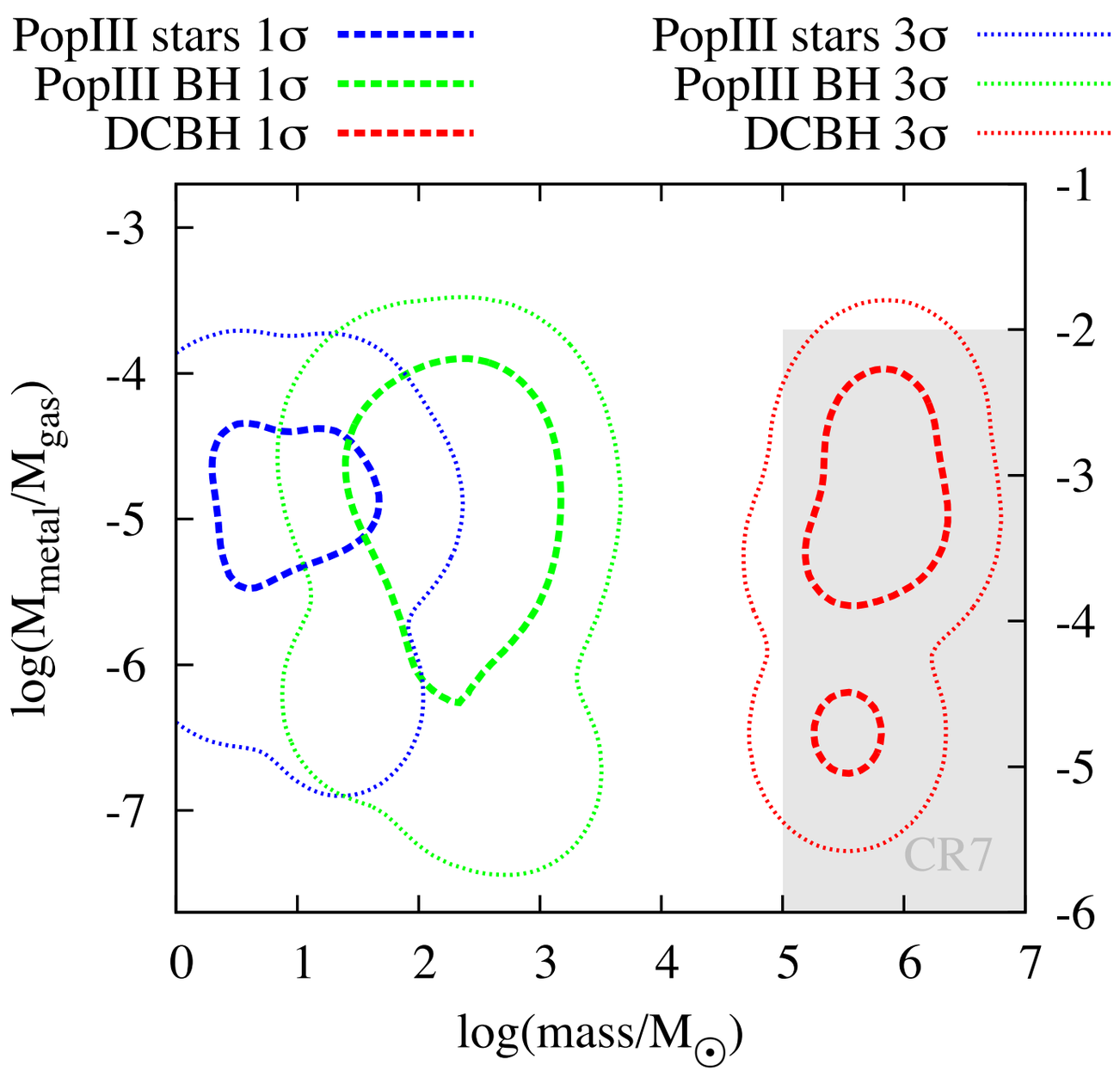
Habouzit,Volonteri, ML et al. 2016, Also see Habouzit, Volonteri, ML et al 2016 & Dijkstra et al. 2014

CR7: Potential host for a DCBH ?



Sobral et al 2015, Pallottini et al. 2015, Agarwal et al. 2015

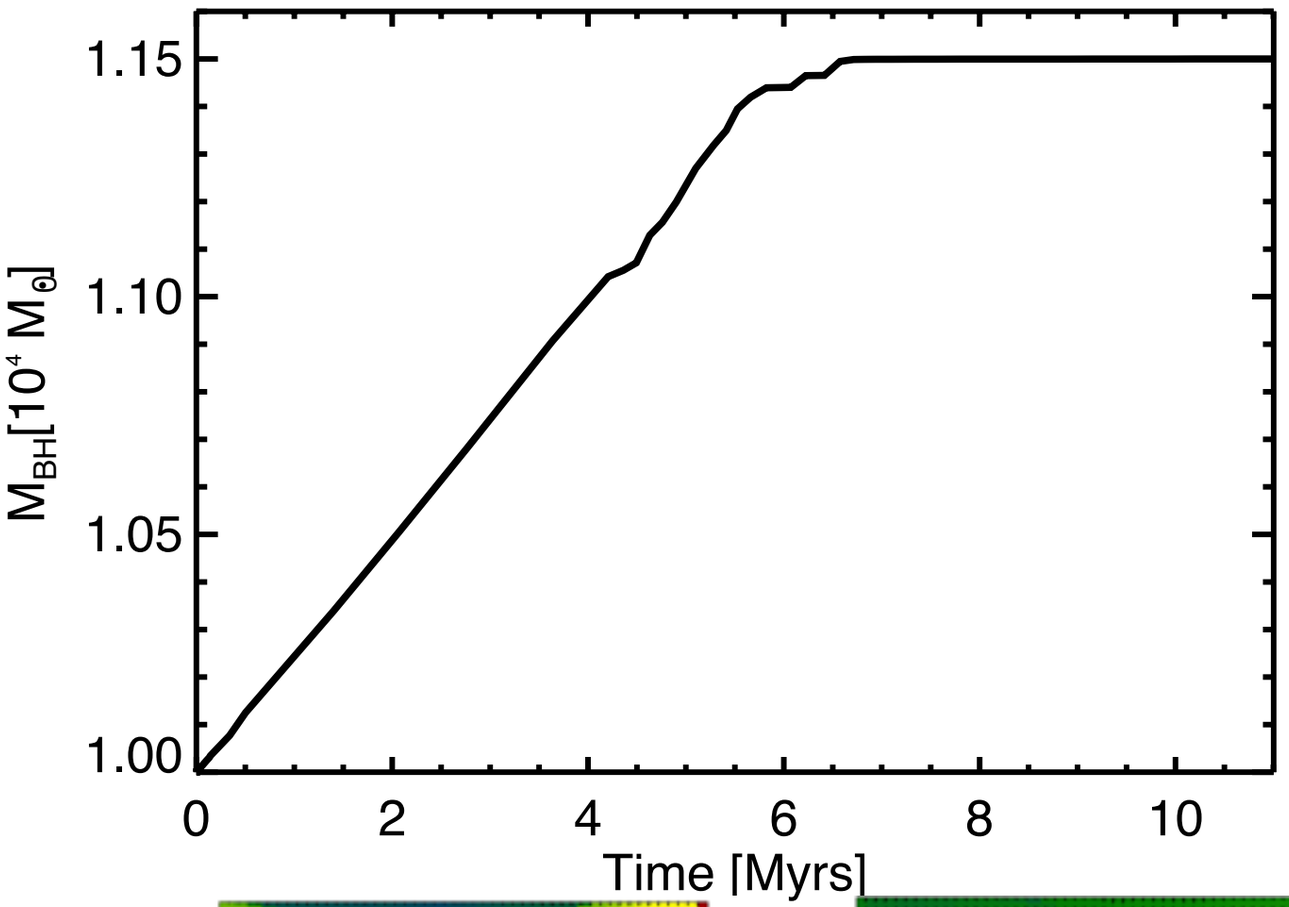


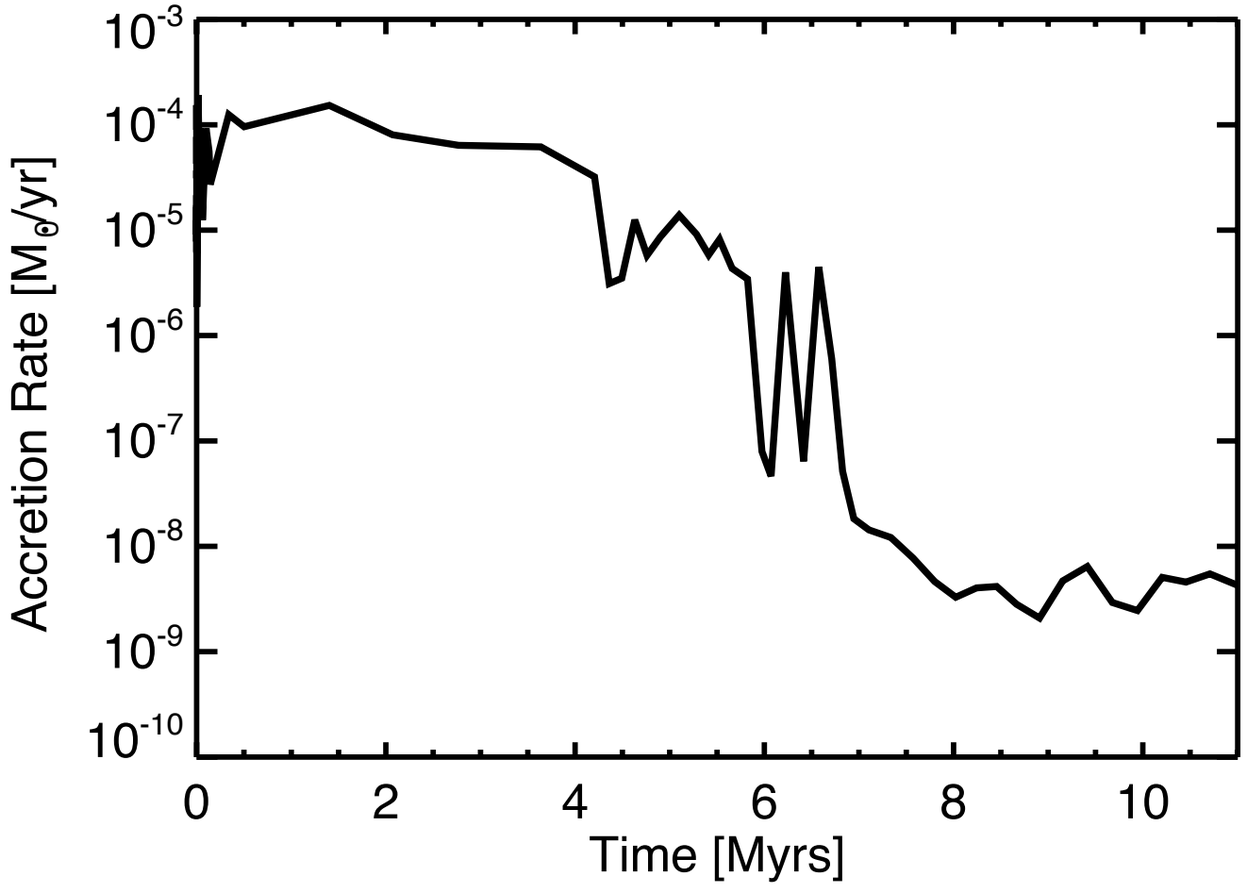


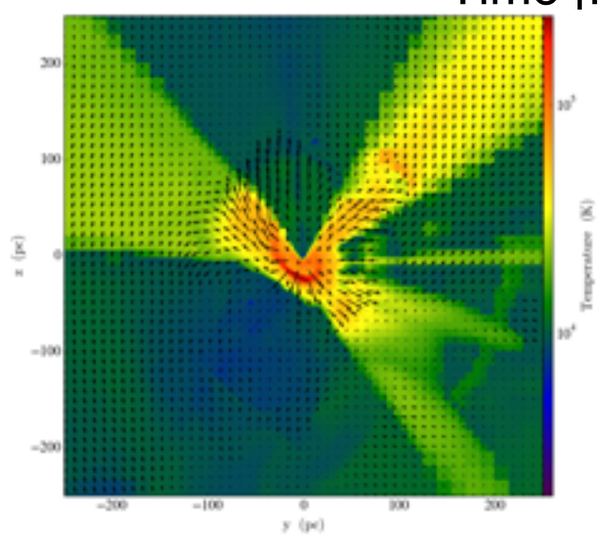
Hartwig, ML et al. 2015

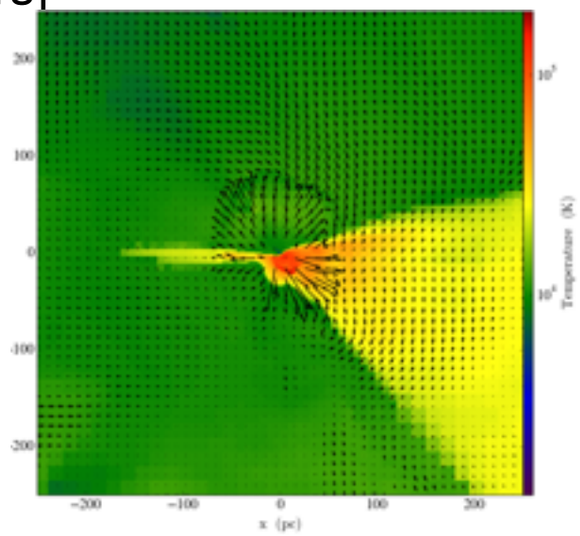
Growth of a DCBH

3D Radiation Hydrodynamical simulations
Include both UV & X-ray feedback (0.1eV-1.1 KeV) from a BH









Latif et al. 2016 in preparation
Also see Johnson et al. 2011
Aykutalp et al. 2014

Summary

- Direct isothermal collapse provides massive seeds of about $10^5\ M_\odot$ but sites are rare
- Large accretion rates of ~0.1 $M_\odot$/yr are found in simulations with moderate UV flux
- Fragmentation occurs occasionally but clumps migrate inwards
- Difficult to grow a DCBH $10^4\ M_\odot$ in an atomic cooling halo
- Radiative feedback from active BH limits its growth

Thank you!