Supermassive black hole formation at high redshift

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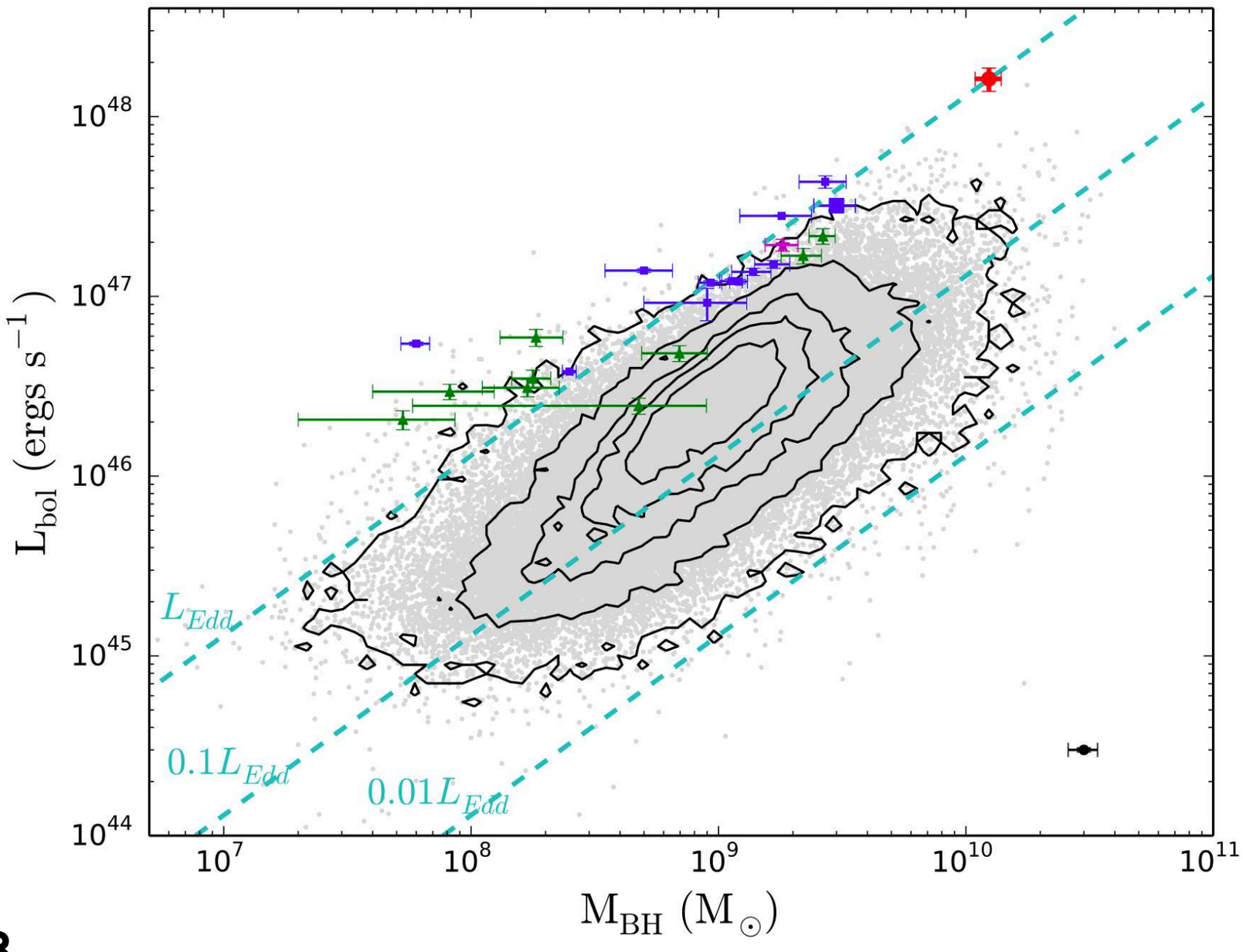
High z Quasars

★ Supermassive black holes of ~10^9 solar masses have been observed at z>6 (Venemans +15)

★ The highest-redshift quasar at z=7.085 hosts a SMBH of $2 \times 10^9 M_\odot$ (Mortlock et al. 2011)

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



Wu et al. Nature 2015

Direct collapse scenario

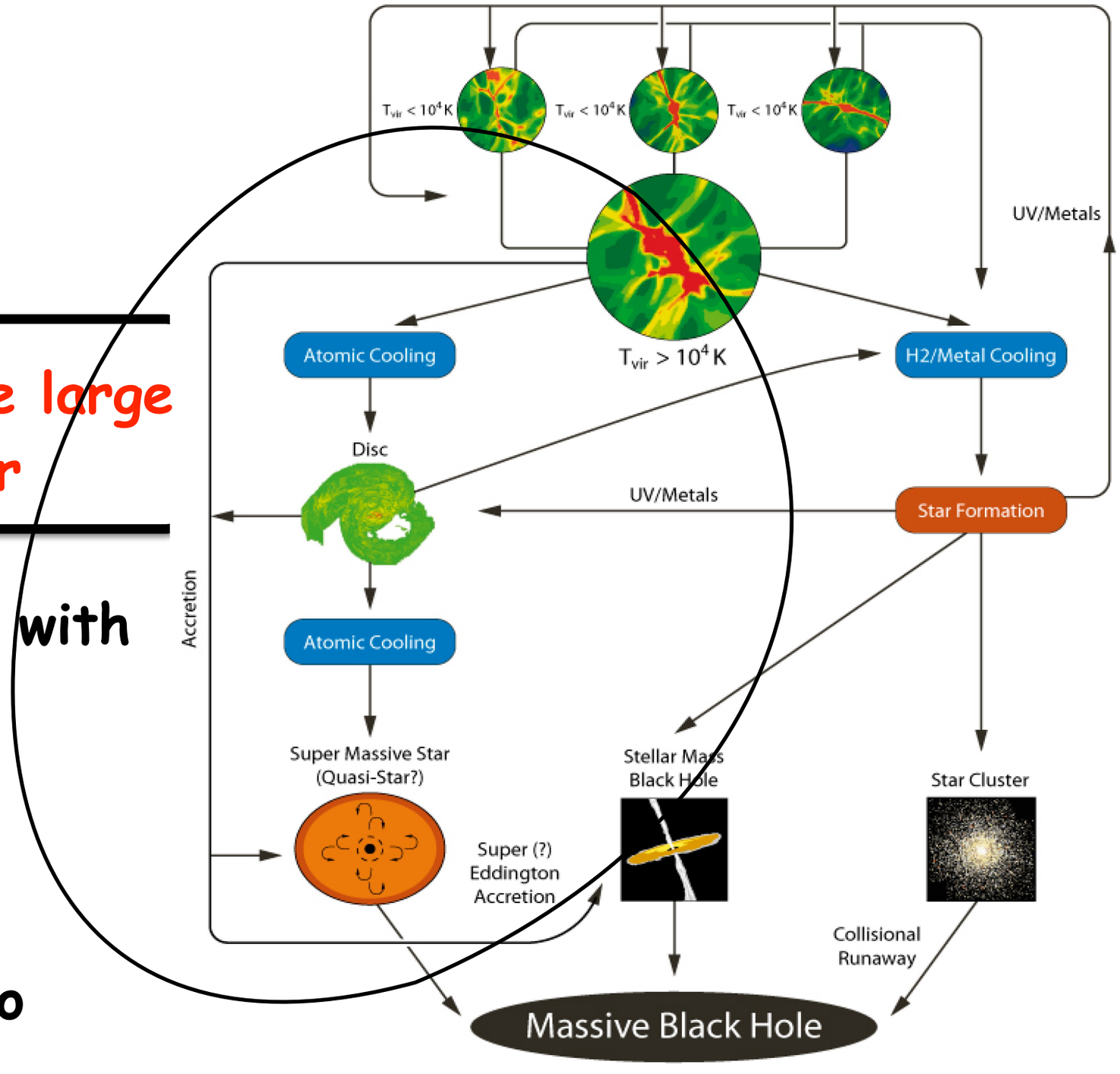
★ Provides massive seeds of 10^5-10^6 $M_\odot$

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

★ Isothermal direct collapse with T~ 8000 K

★ Primordial gas composition

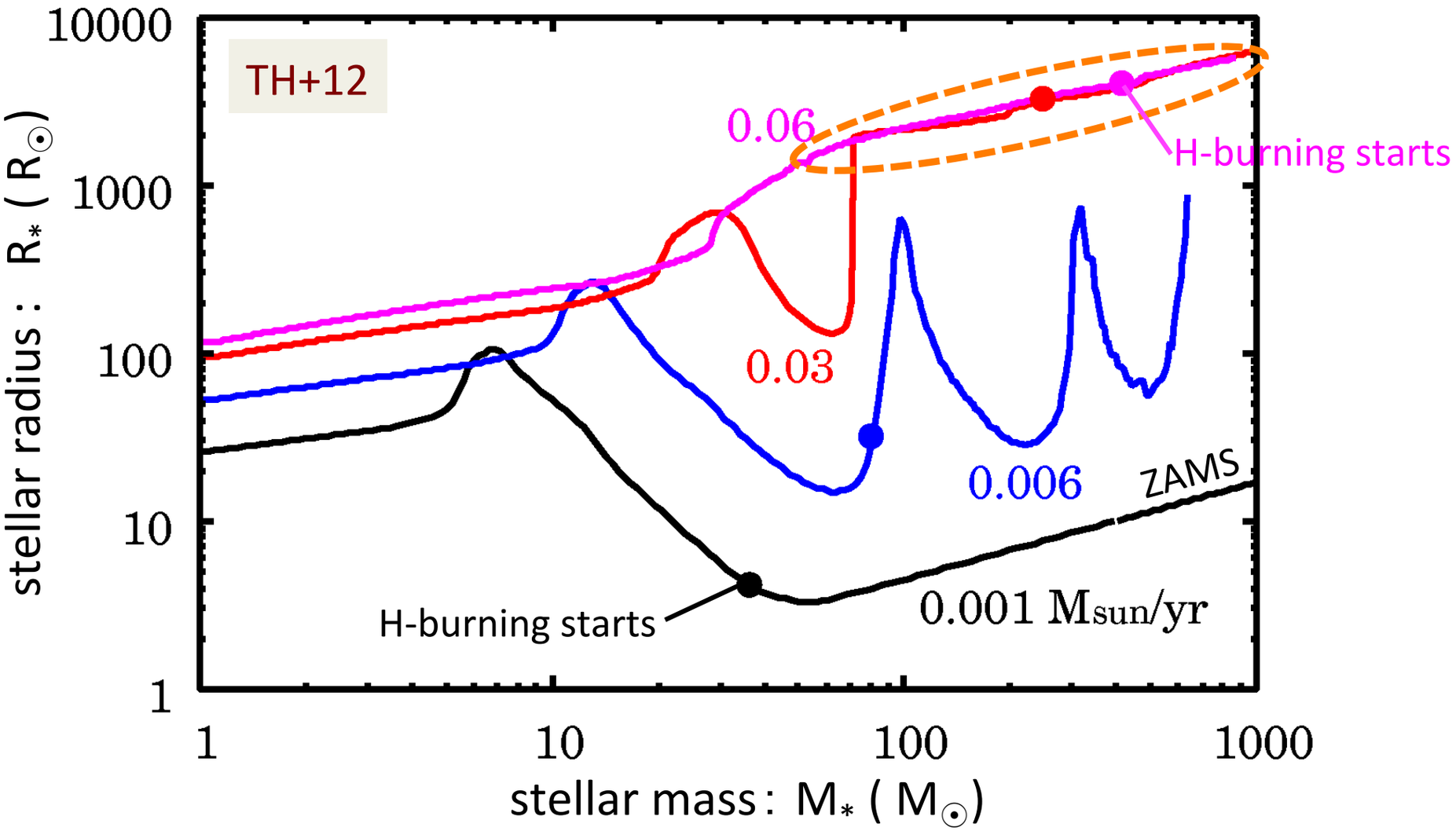
★ Requires strong LW flux to quench H_2 formation



See recent review by Latif & Ferrara 2016 (arXiv:1605.07391)

Regan et al 2009

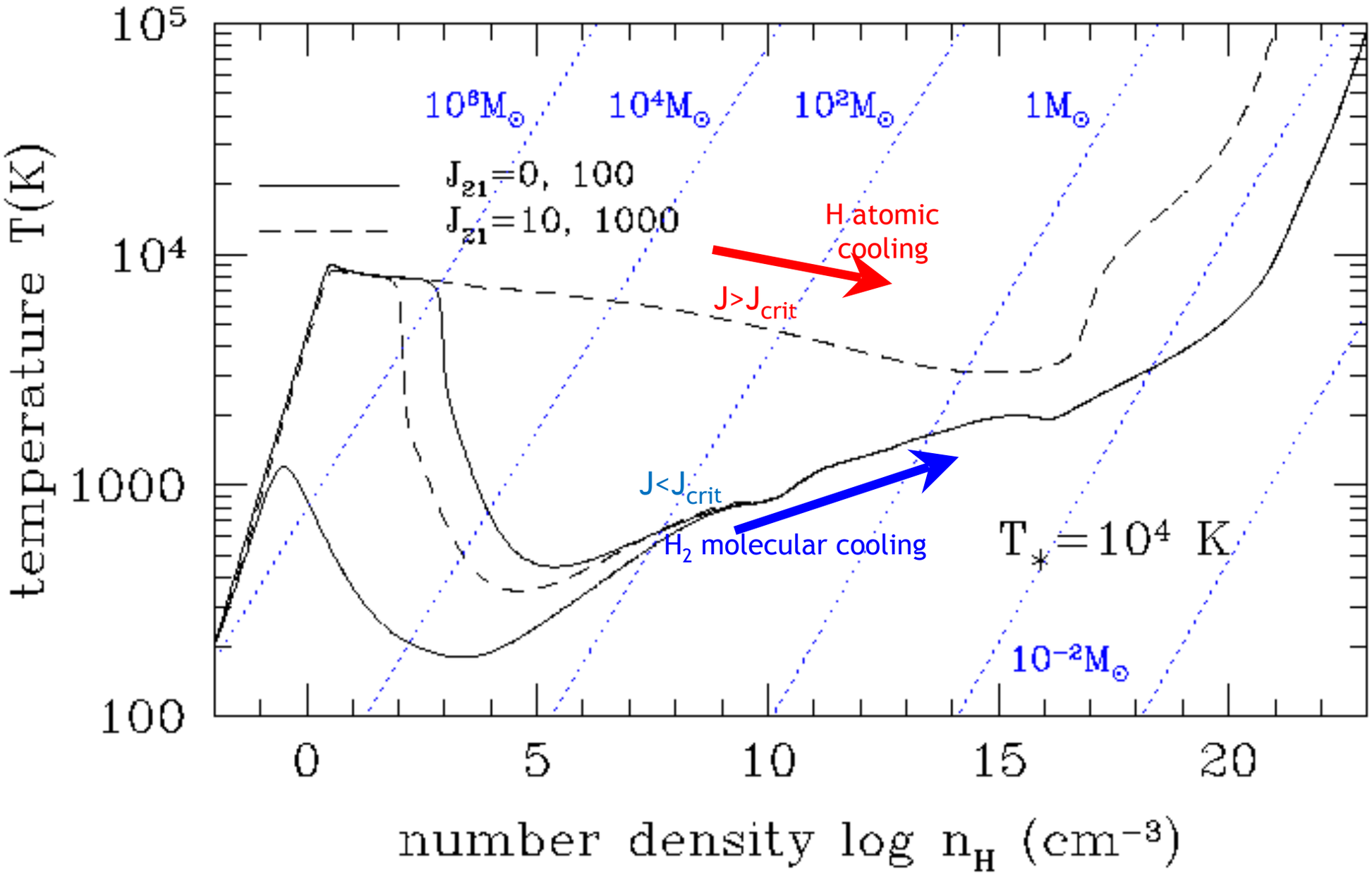
Supergiant protostar



- The protostar never contracts to reach the ZAMS stage, but largely expands with very rapid accretion, > 0.01 $M_\odot$/yr.
- large radius → low effective temperature → weak UV feedback

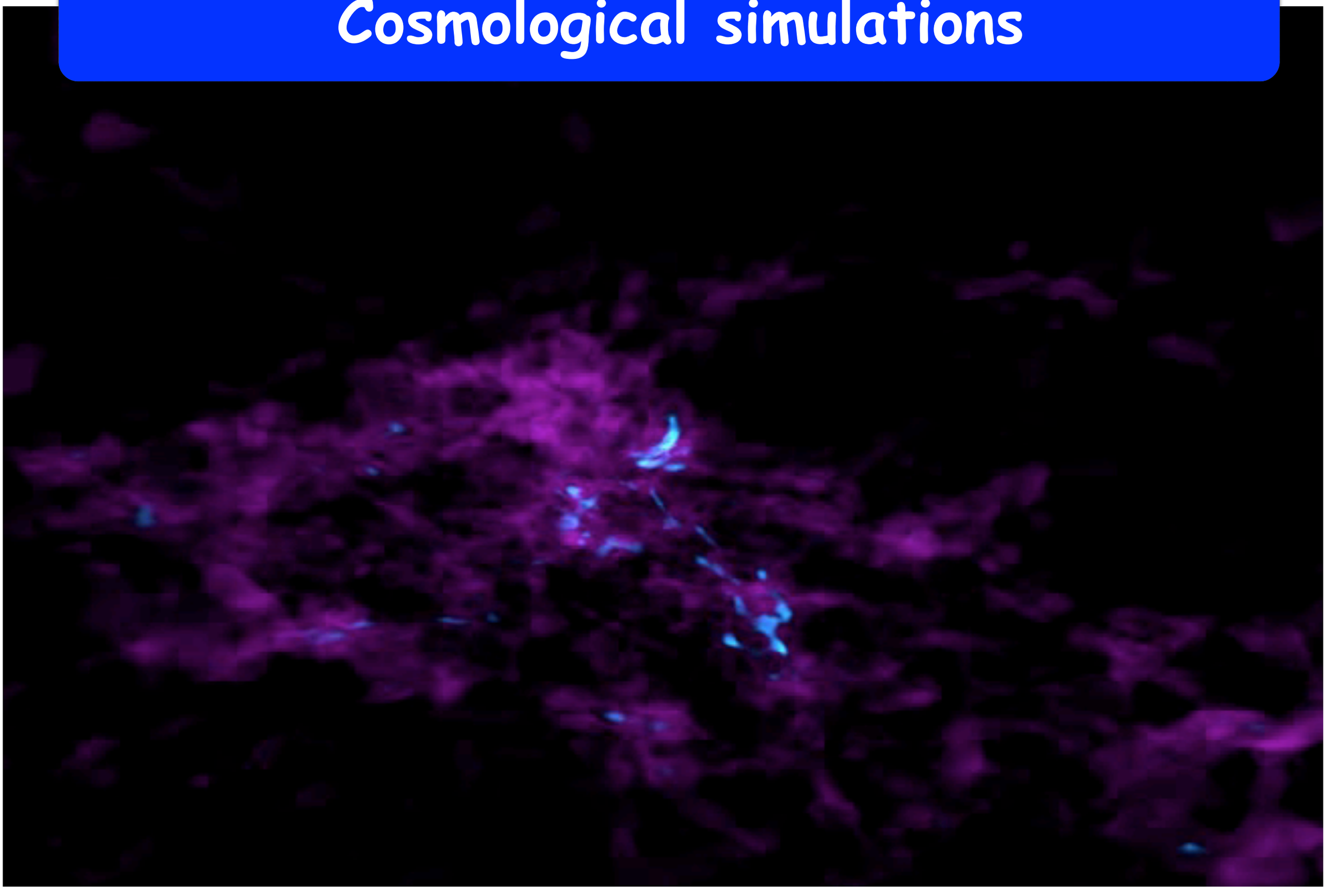
Hoskawa et al. 2012, Schleicher, ML et al., A&A, 2013

Thermodynamics of primordial gas



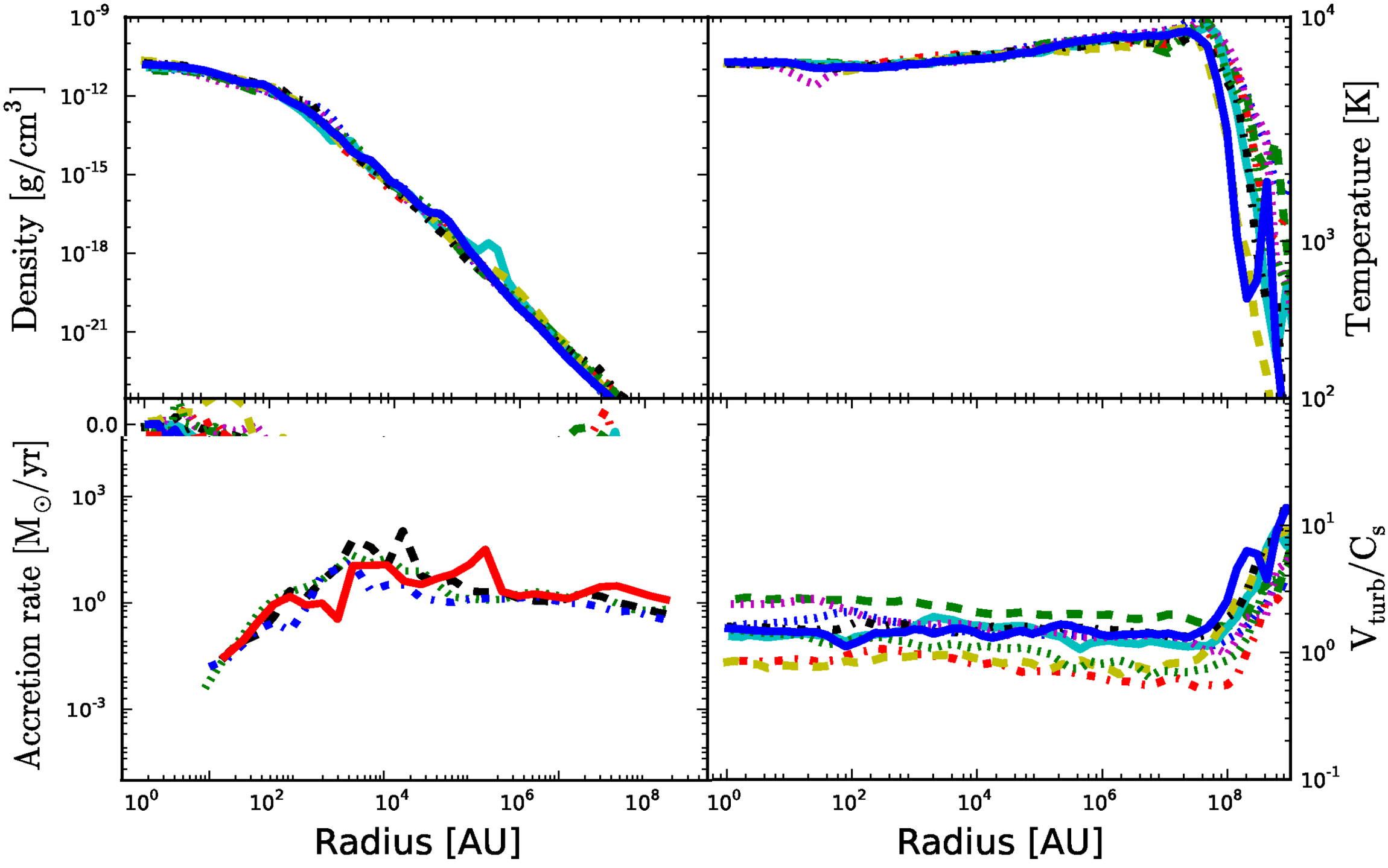
Omukai 01, Also see Latif et. al 2014 MNRAS

Cosmological simulations



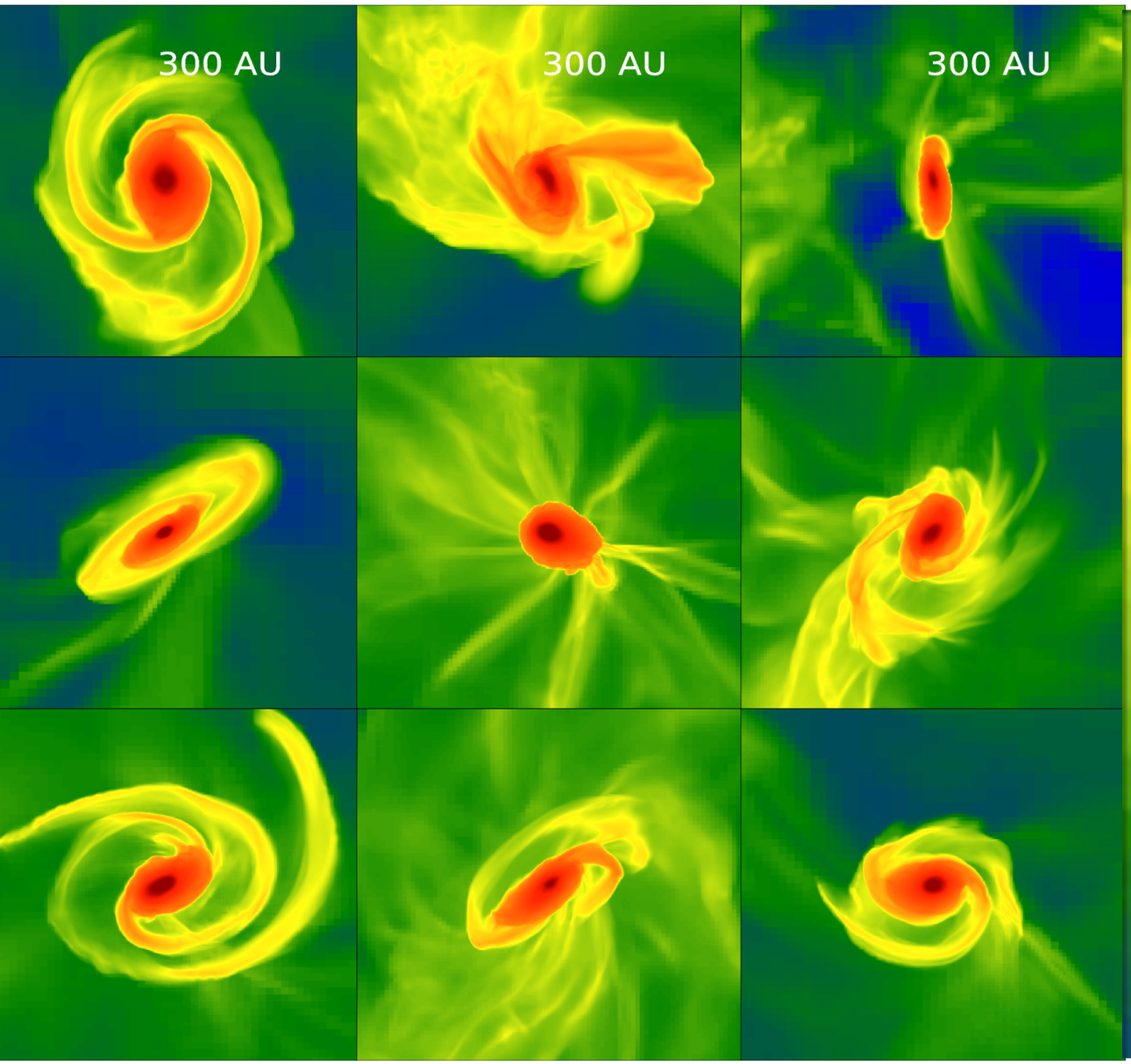
Latif et al. 2013, 2014, 2015

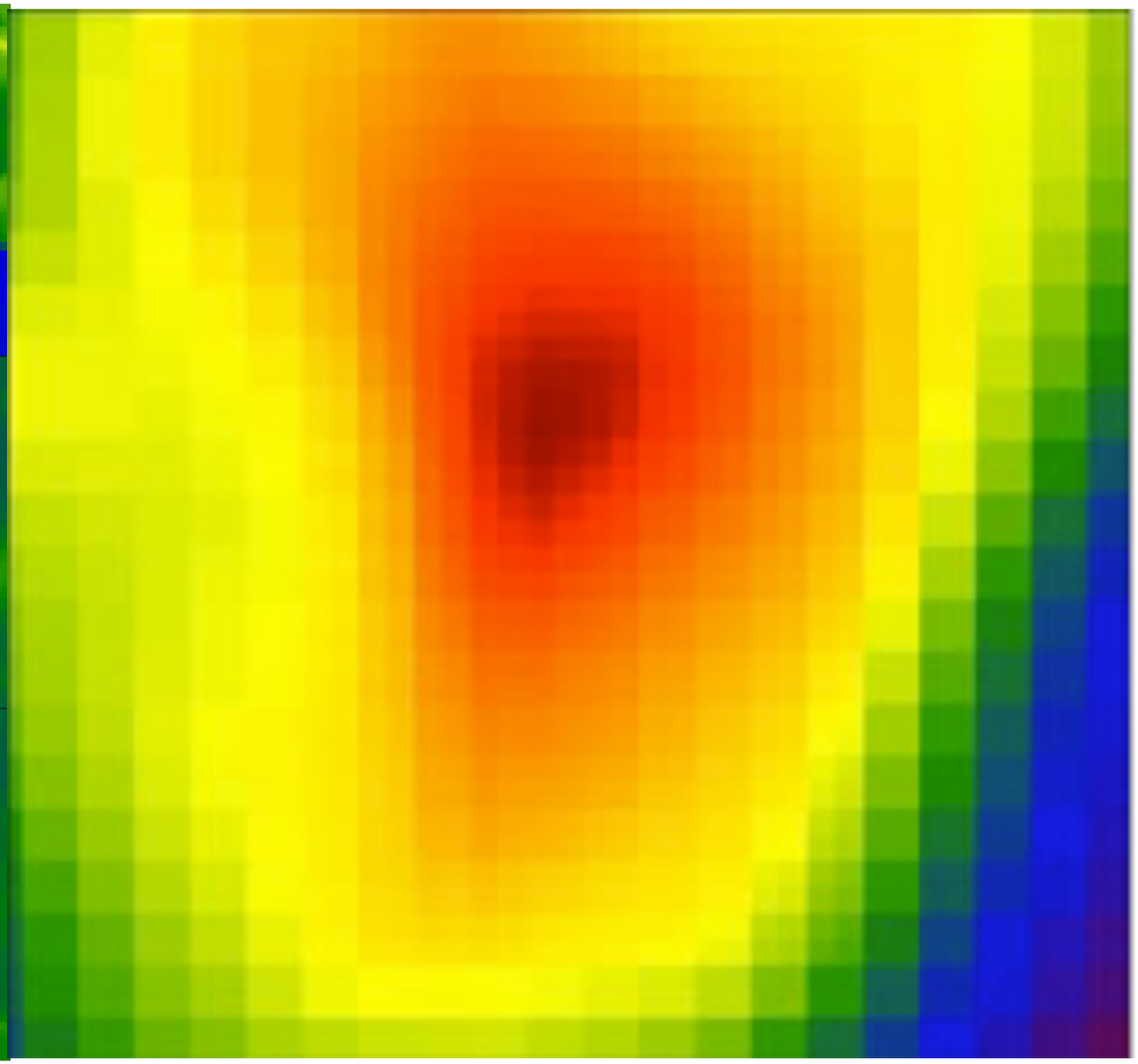
Global properties of simulated halos



Latif et al 2013, MNRAS, 433, 1607L

Simulations exploring the direct collapse



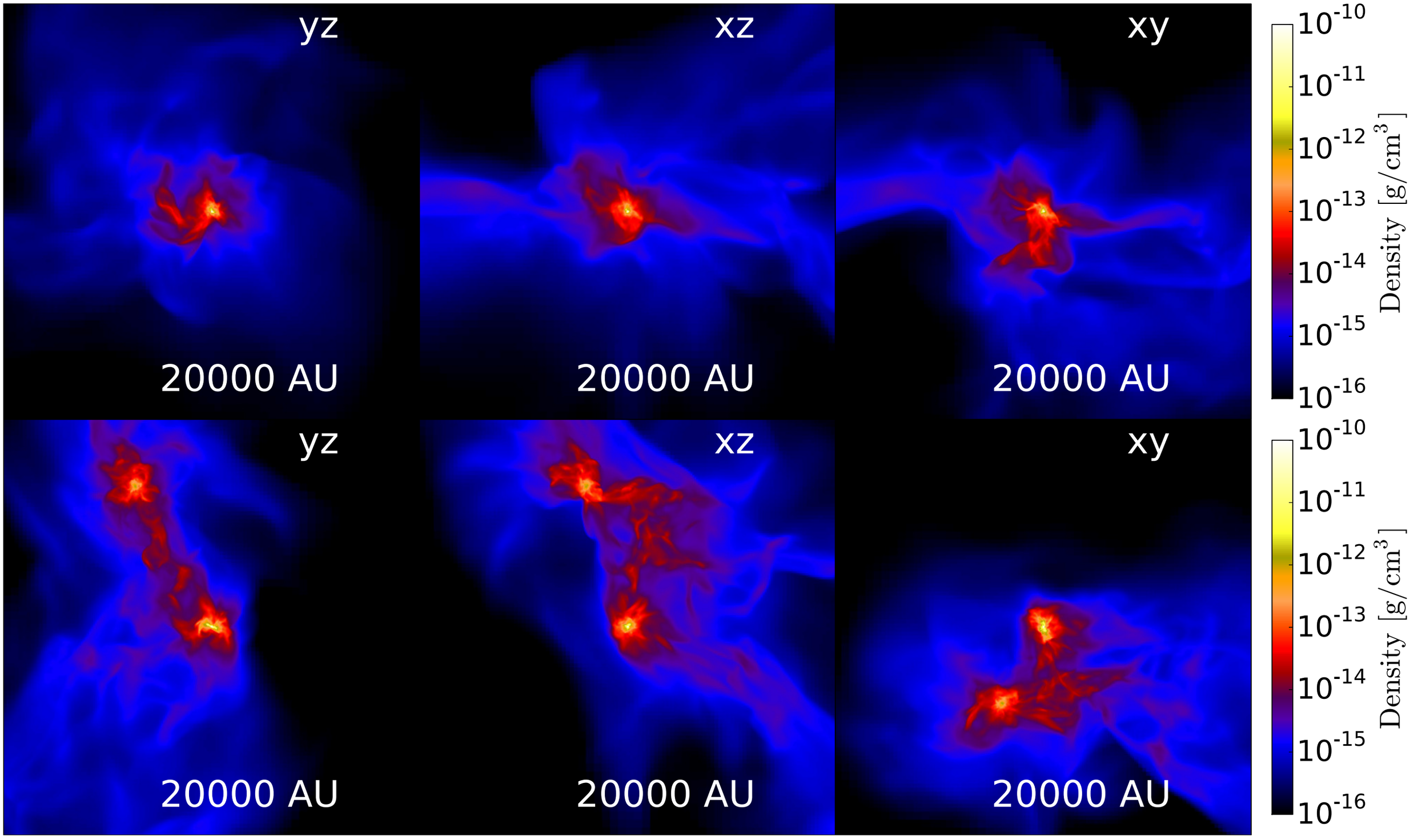


★Collapse occurs isothermally with T~ 8000 K

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

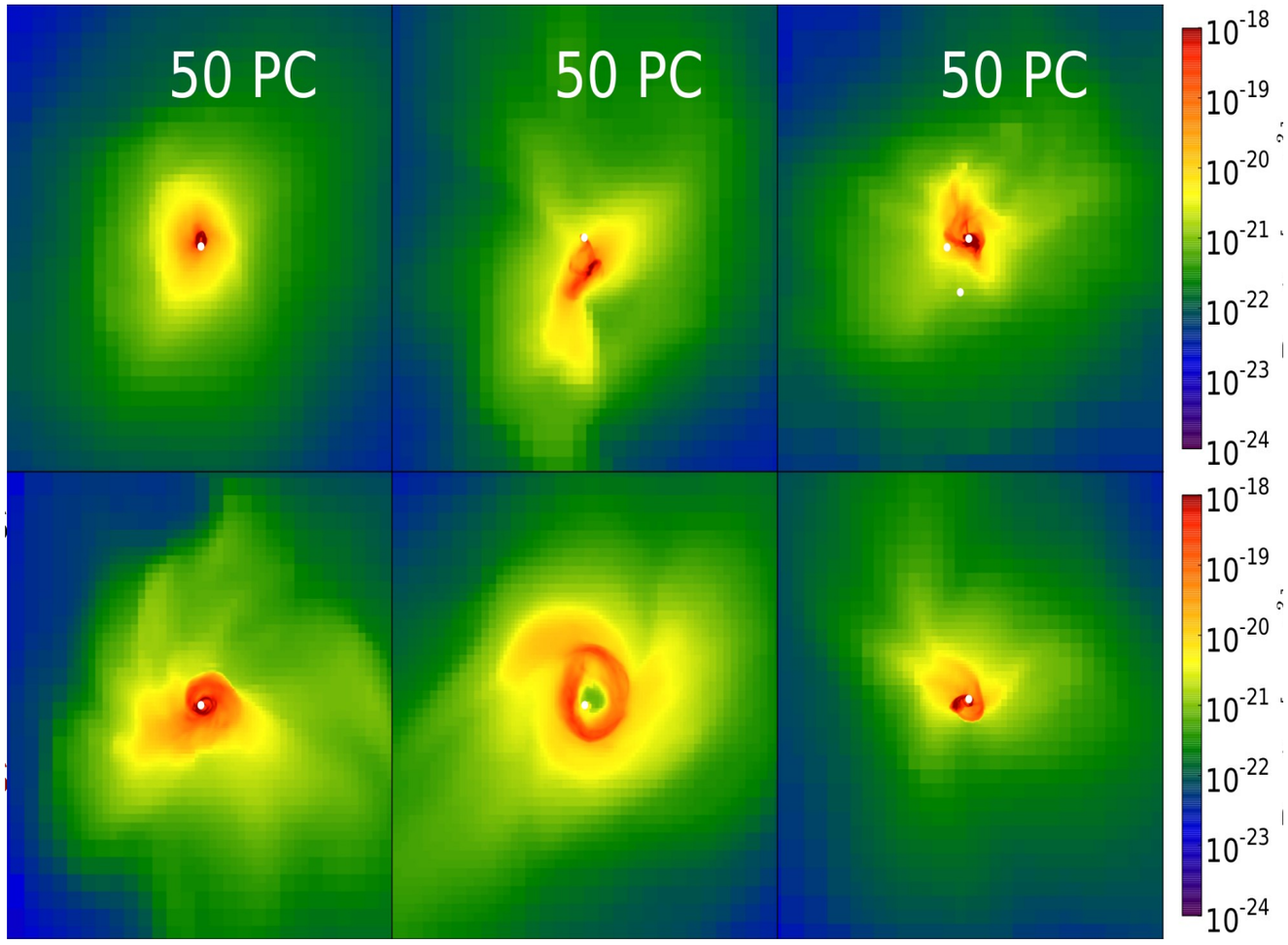
Latif et al. 2013, MNRAS, 433, 1607L

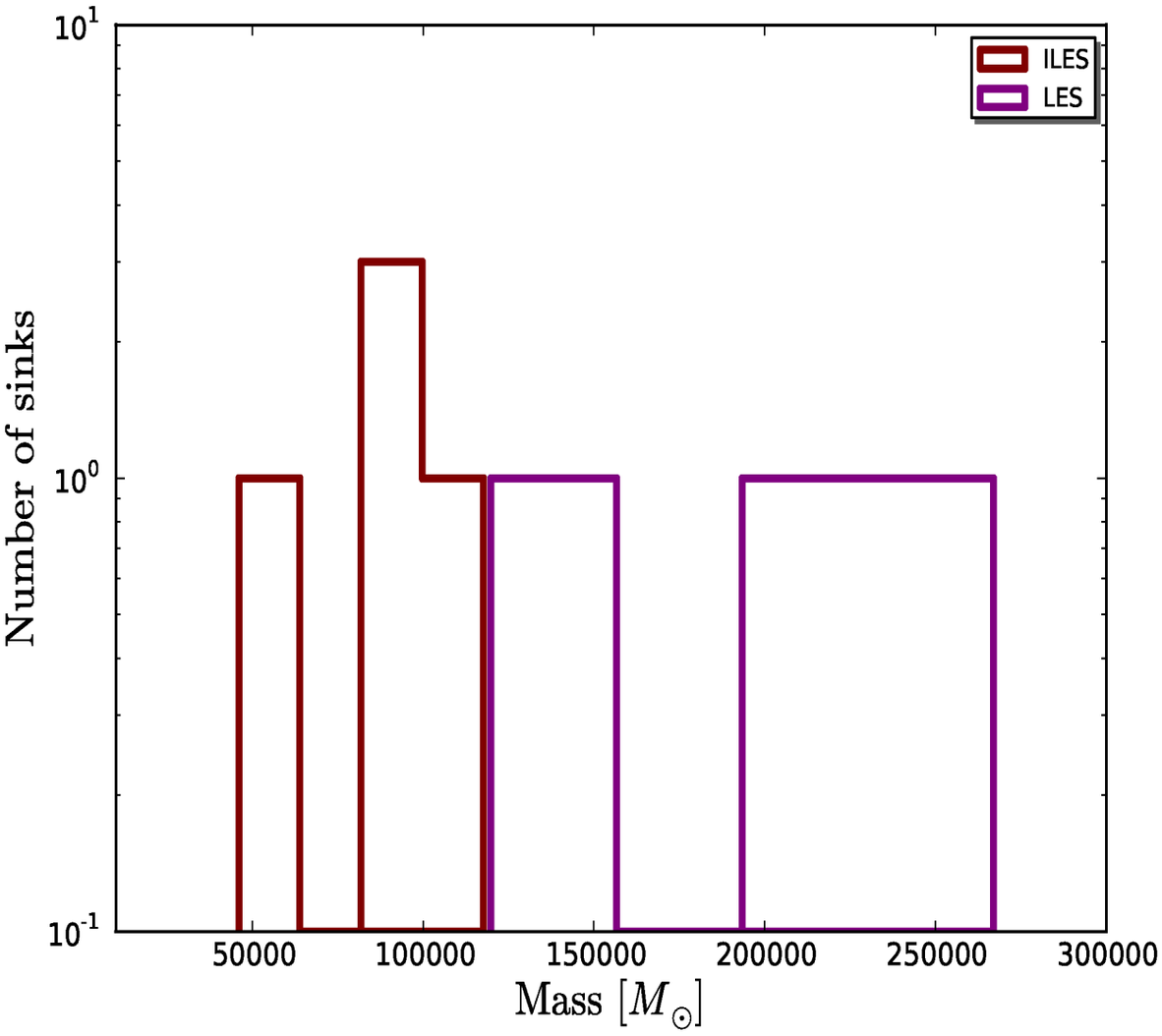
Impact of H^- cooling & Realistic opacities



Latif, Schleicher & Hartwig, 2016, MNRAS, 458, 233L

Masses of protostars/sinks

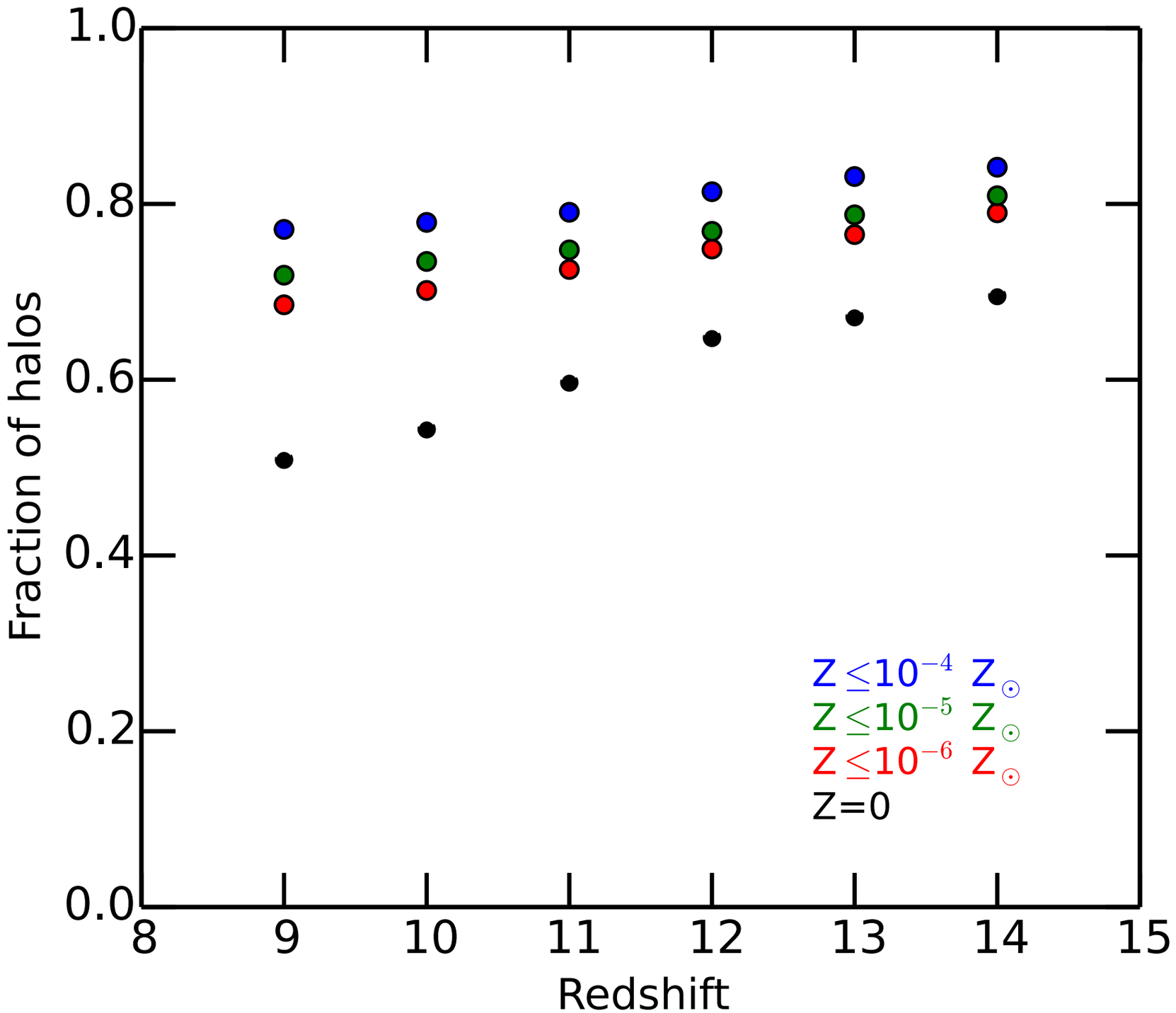




- Employed sink particles and followed the evolution for 200,000 yrs
- Massive sinks of about 10^5 $M_\odot$ are formed

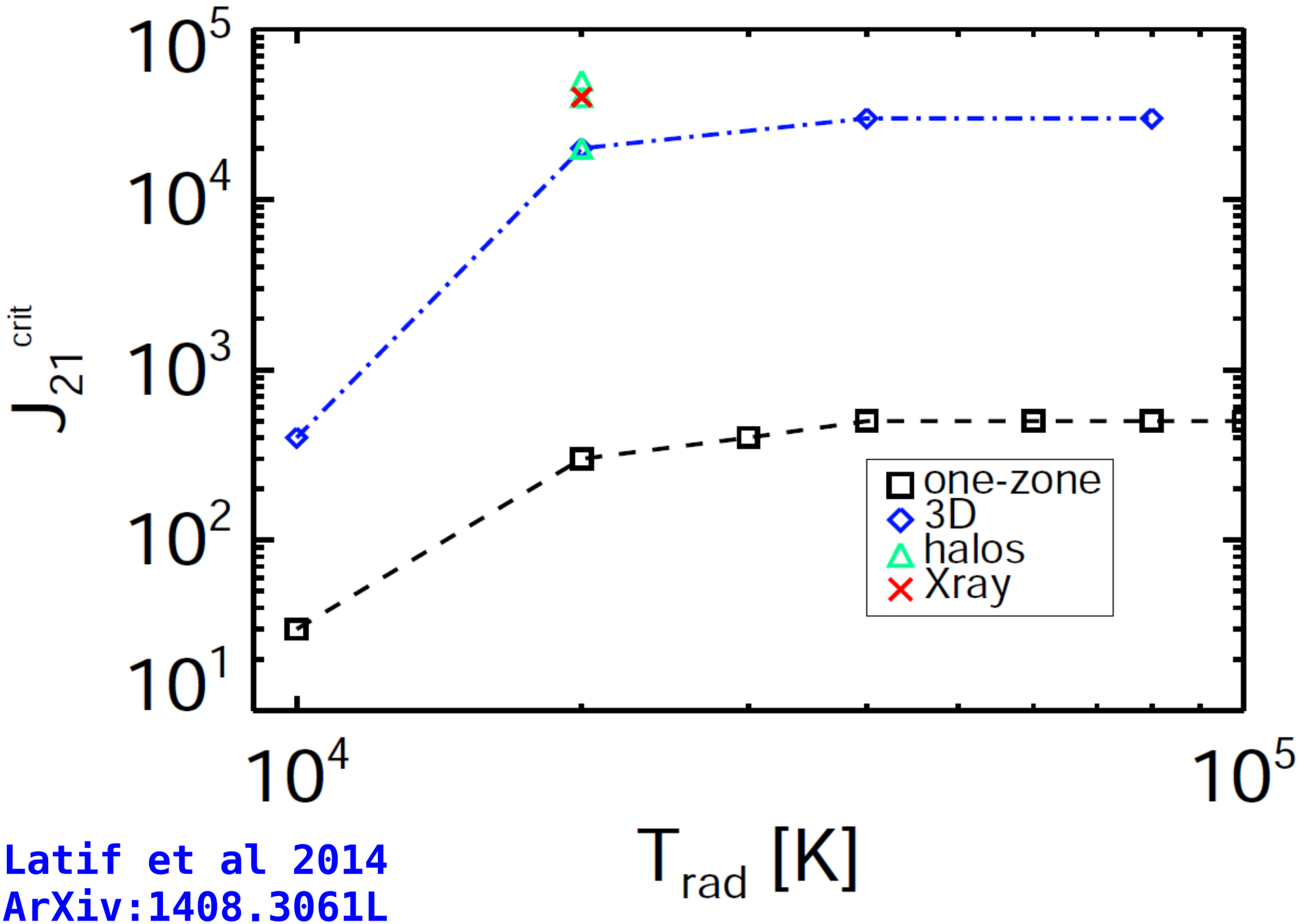
Latif et al. 2013, MNRAS, 436, 2989L

Fraction of metal free halos



Latif et al. 2016 ApJ 823 40 L, See Habouzit, et al 2016

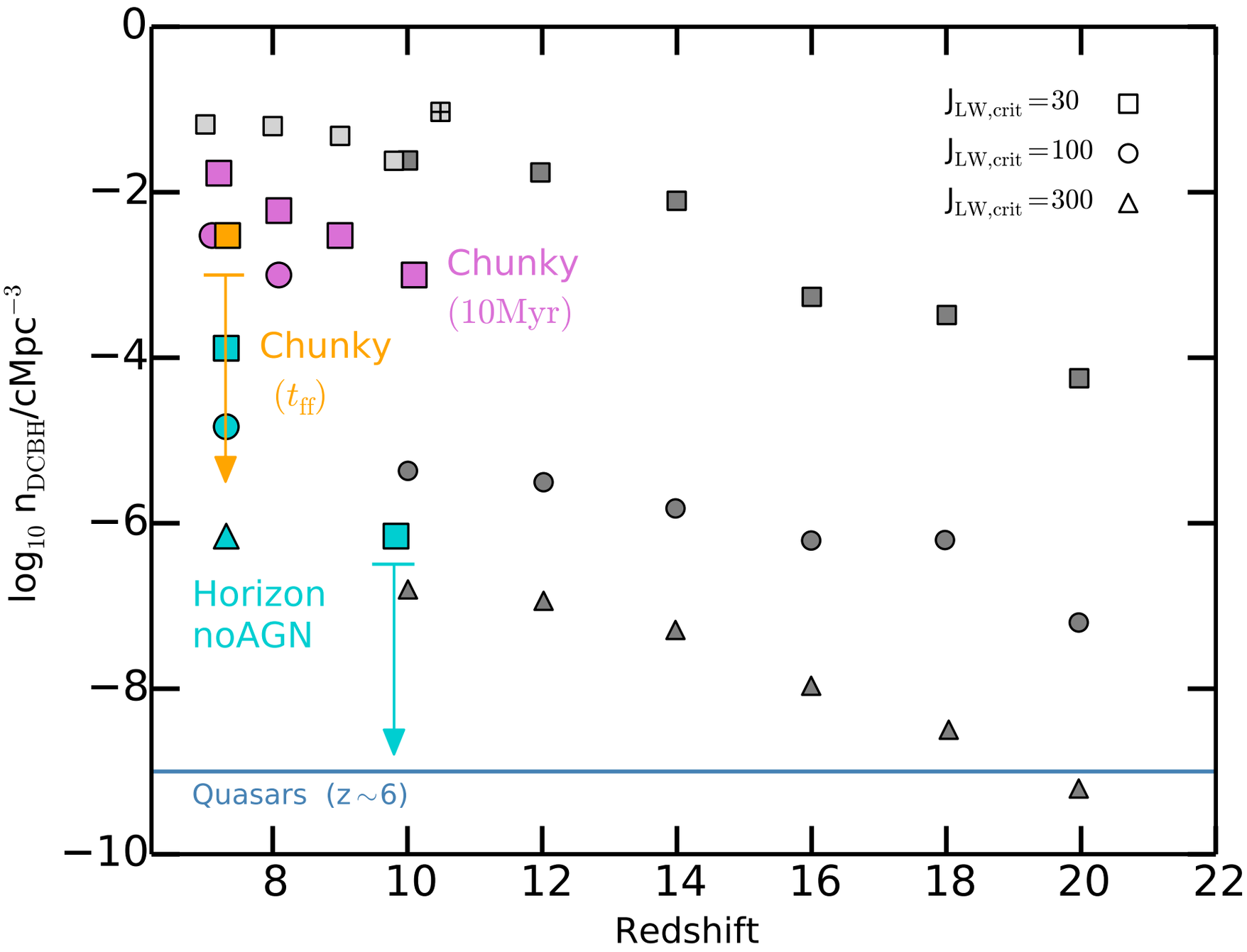
Estimates of J_{crit} from 3D simulations



Latif et al 2014
ArXiv:1408.3061L

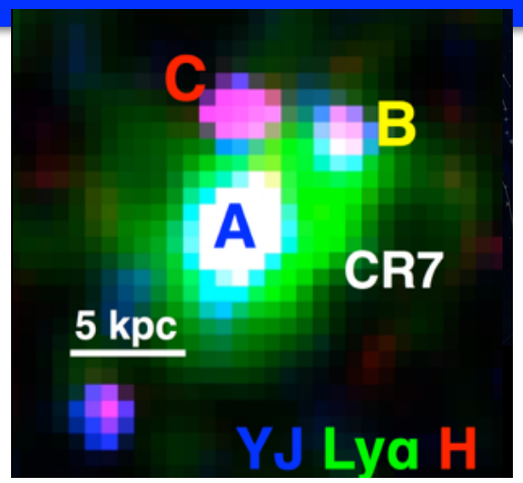
Latif et al. MNRAS 2015 446 3136, Also see Agarwal et al. 2016

Number density of DCBHs

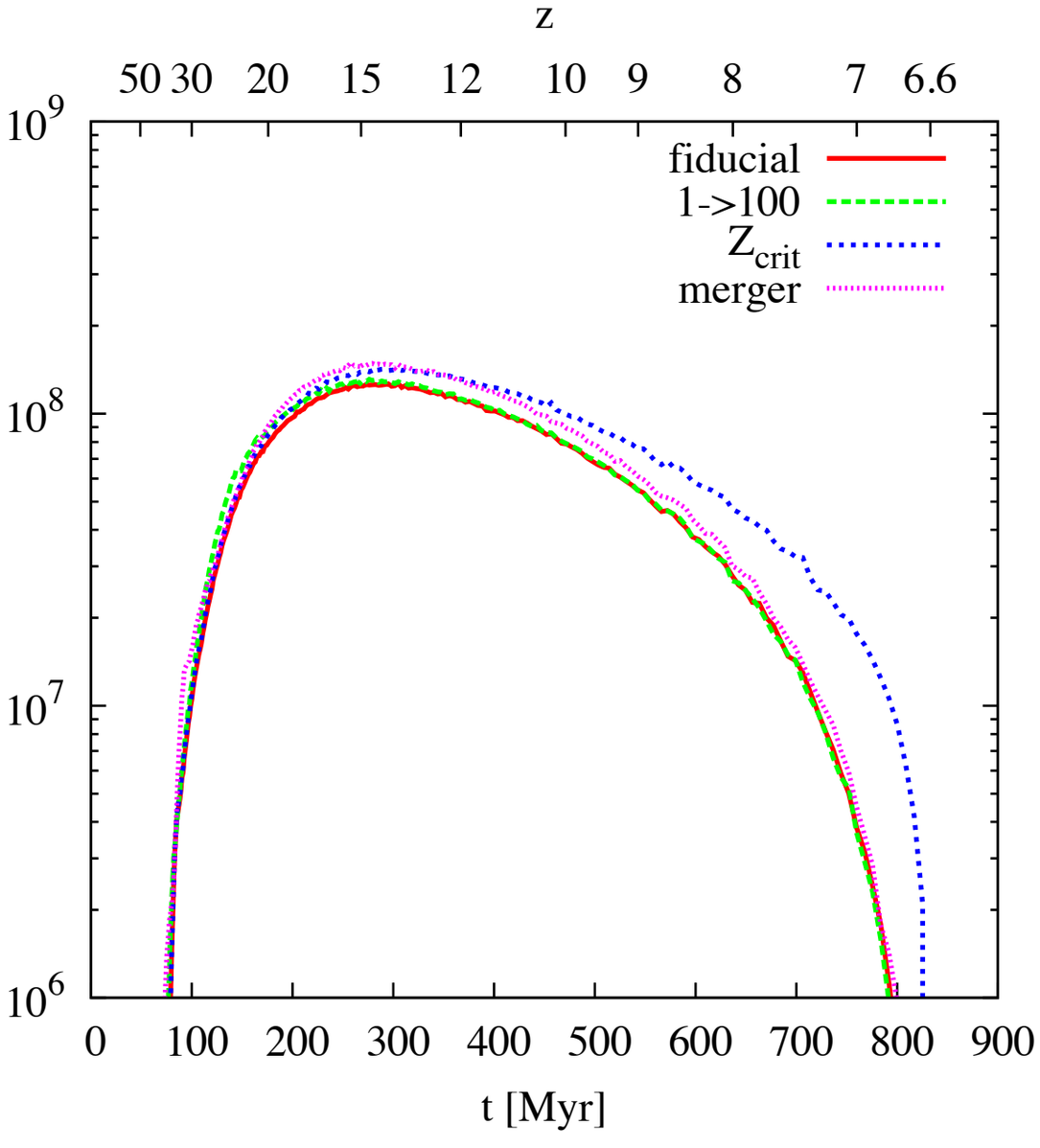


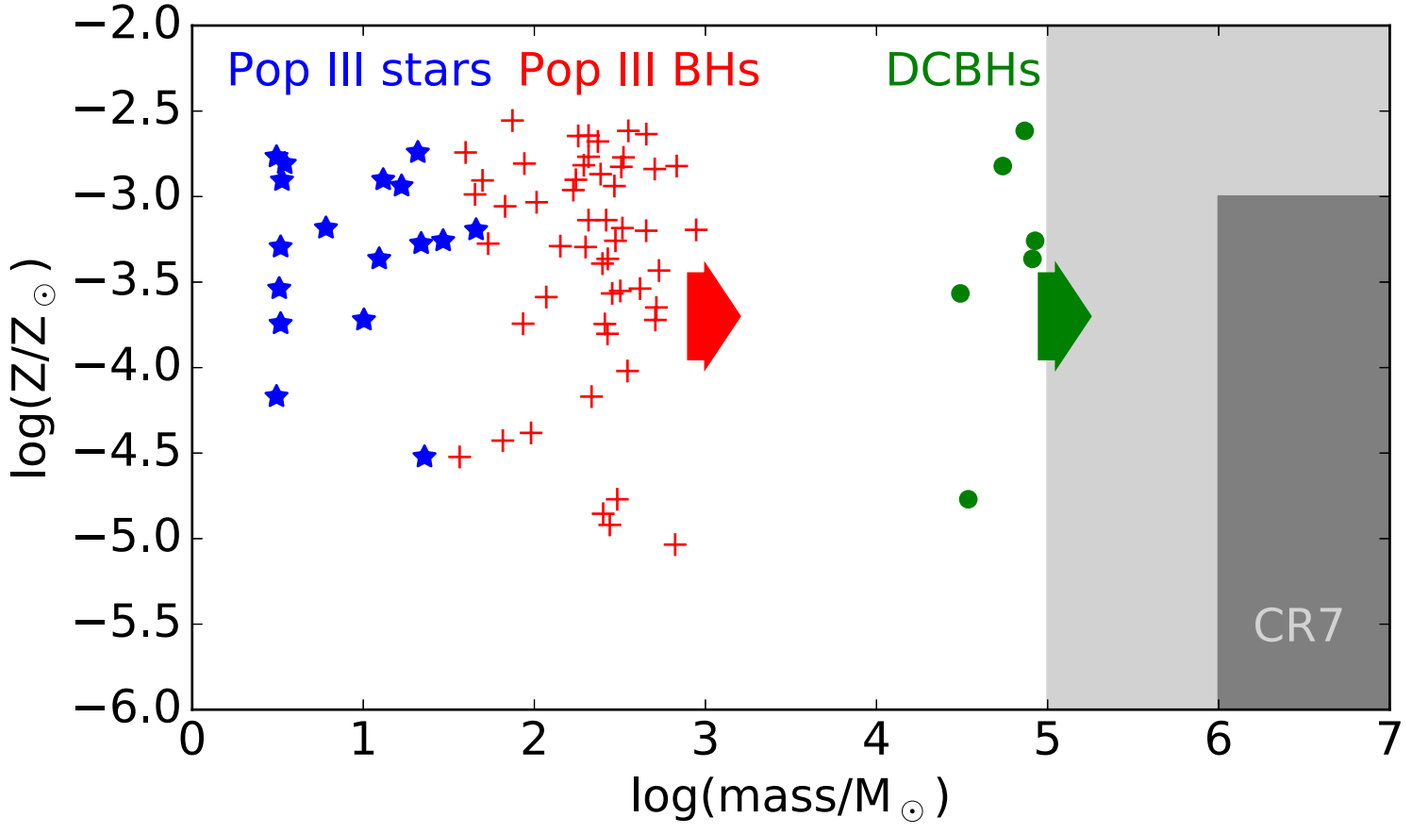
Habouzit,Volonteri, ML et al. 2016, Also see Dijkstra et al. 2014

CR7: Potential host for a DCBH ?



Sobral et al 2015, Pallottini et al. 2015, Agarwal et al. 2016

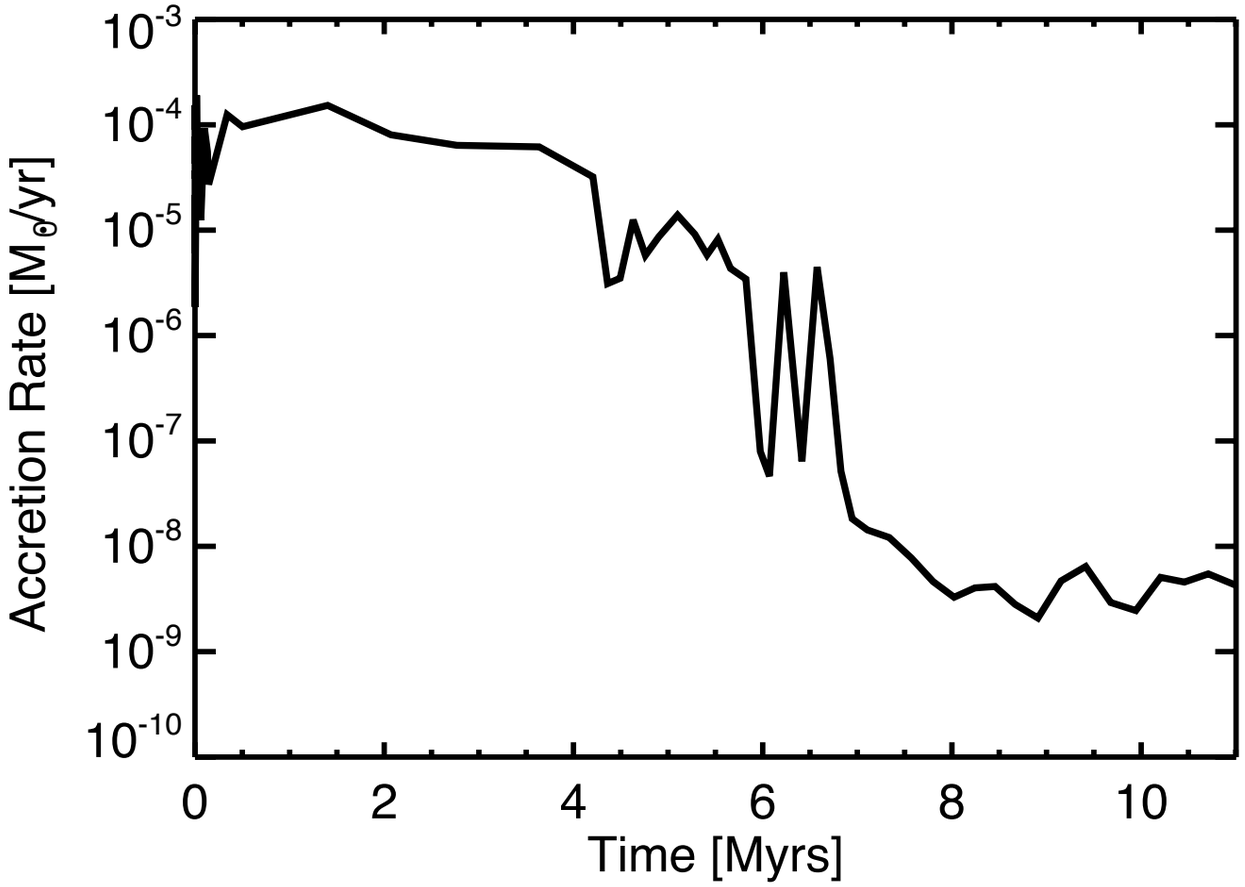


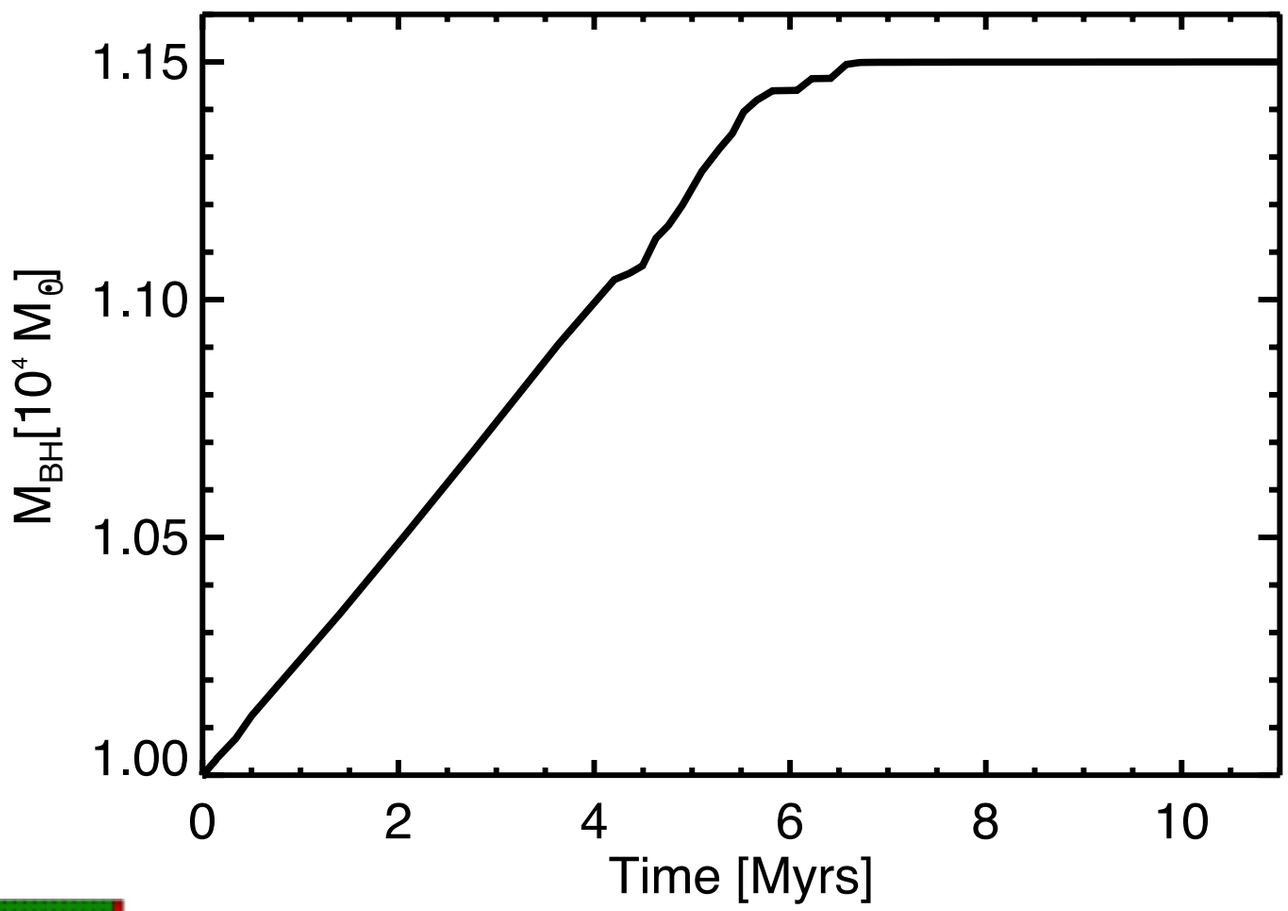


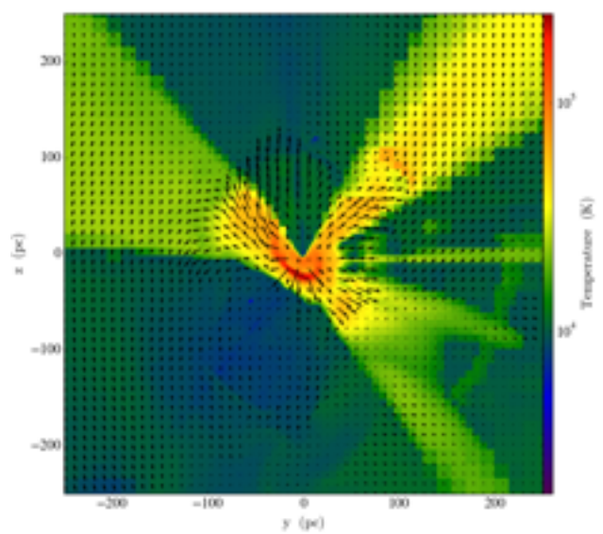
Hartwig, ML et al. 2016 MNRAS, resubmitted

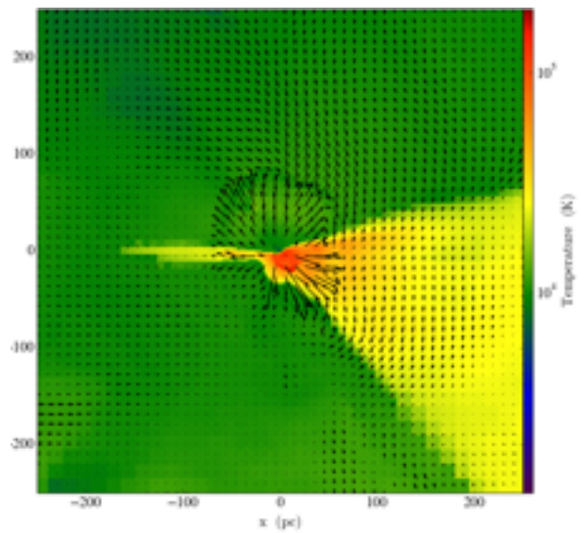
Growth of a DCBH

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









Latif et al. in preparation

Summary

- Direct isothermal collapse provides massive seeds of about $10^5\ M_\odot$
- Large accretion rates of ~0.1 $M_\odot$/yr are found in numerical simulations
- Direct collapse model seems feasible
- Difficult to grow a DCBH $10^4\ M_\odot$ in an atomic cooling halo
- Radiative feedback from active BH limits its growth

Thank you!