Active galactic nucleus feedback in simulations

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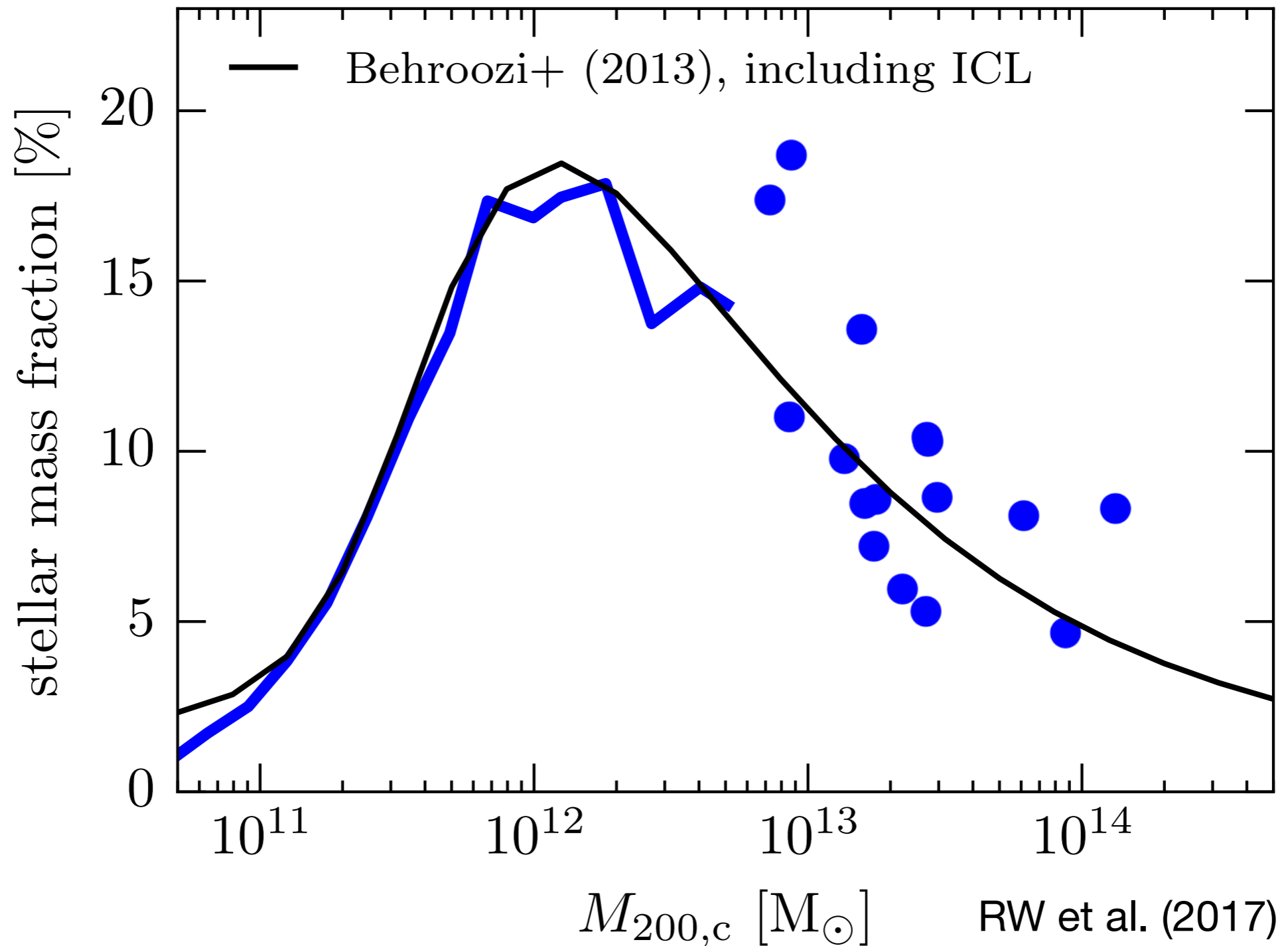
15th Potsdam Thinkshop —September 6th, 2018
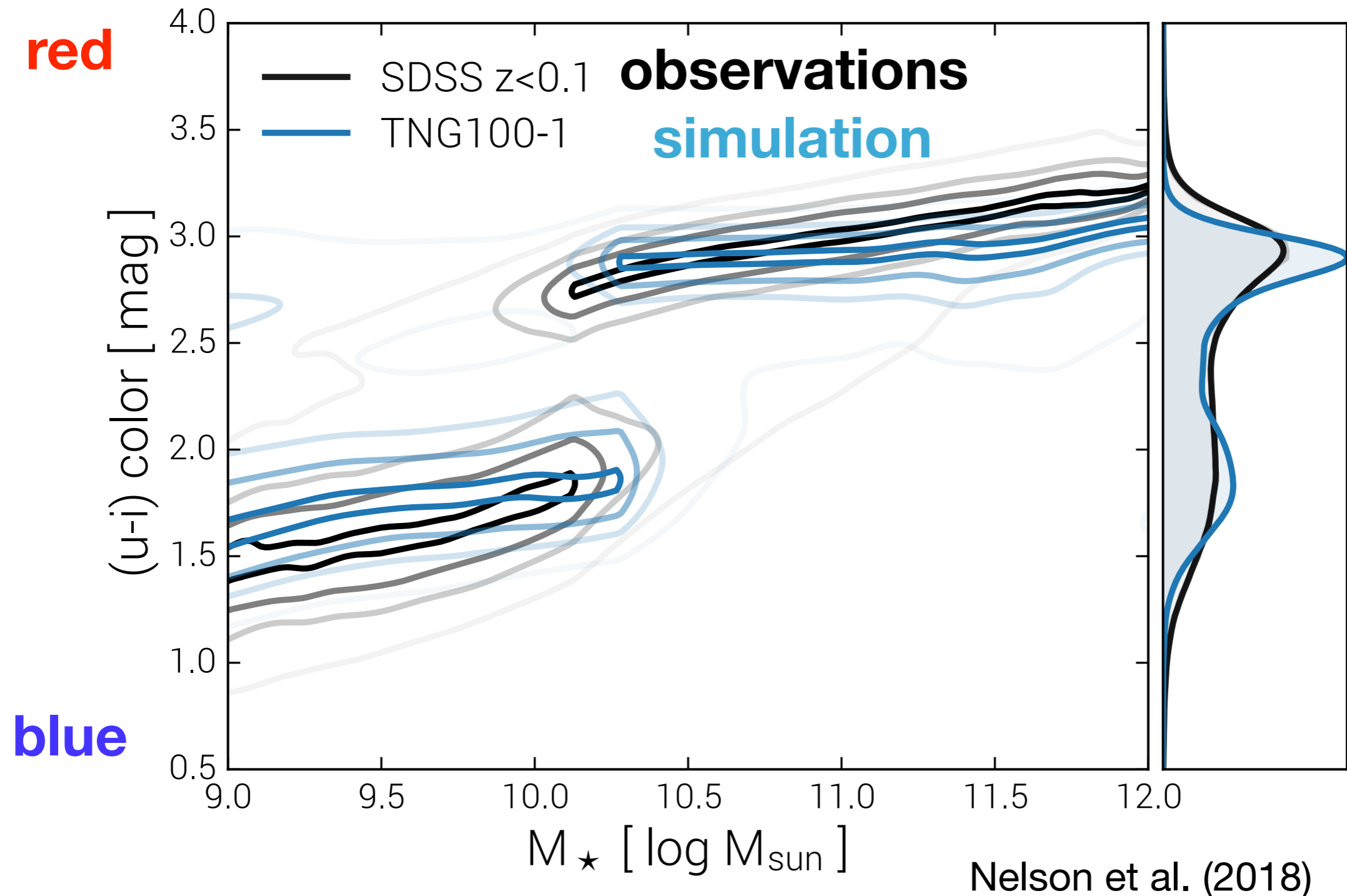
in collaboration with:
Kristian Ehlert, Christoph Pfrommer (AIP)
Volker Springel, Rüdiger Pakmor, Dylan Nelson (MPA),
Lars Hernquist, Jill Naiman, Federico Marinacci (CfA),
Paul Torrey, Mark Vogelsberger, David Barnes (MIT),
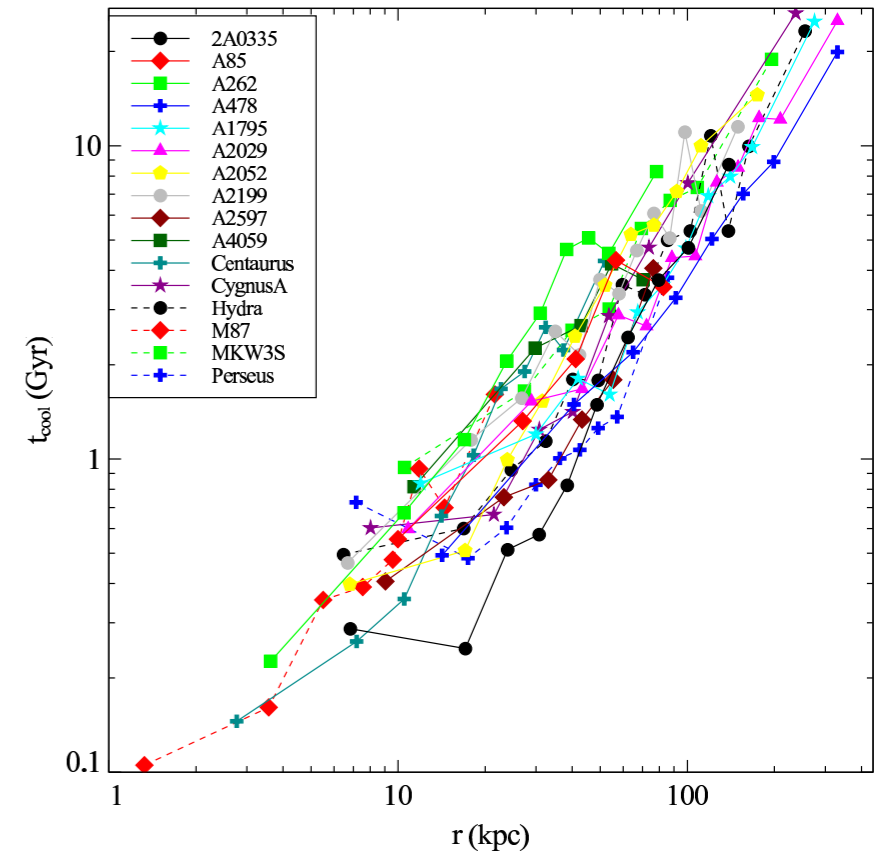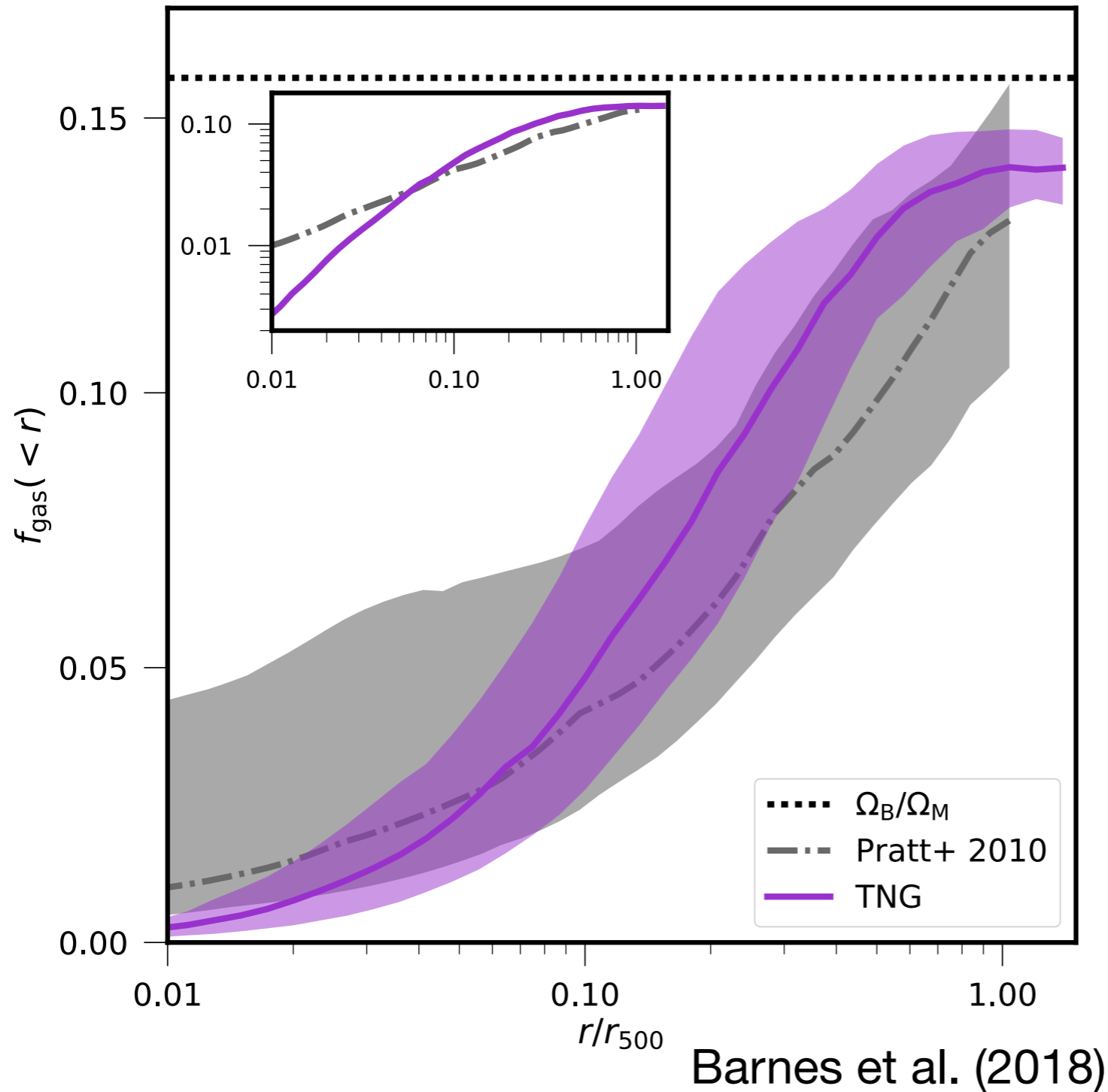Annalisa Pillepich (MPIA), Shy Genel (CCA)

Institute for Theory and Computation

The need for feedback from AGN — stellar mass

Figure axes: $M_{200,c}$ $[\mathrm{M}_\odot]$ (x-axis), stellar mass fraction [%] (y-axis). Legend: Behroozi+ (2013), including ICL. RW et al. (2017)

The need for feedback from AGN — recent SFR

red

blue

observations

simulation

SDSS z<0.1

TNG100-1

(u-i) color [mag]

M$_\star$ [log M$_{sun}$]

Nelson et al. (2018)

The need for feedback from AGN — (hot) gas content

Barnes et al. (2018)

Dunn and Fabian (2006)

The IllustrisTNG project

	TNG50	**TNG100**	**TNG300**
L	52 Mpc	106 Mpc	303 Mpc
N	2160^3	1820^3	2500^3
dm-softening	0.3 kpc	0.7 kpc	1.5 kpc
target mass	8×10^4	1.3×10^6	10^7 Msun

- Cosmological volume simulation

- Include the physics effects that we believe to be important for galaxy formation

- Star formation + feedback
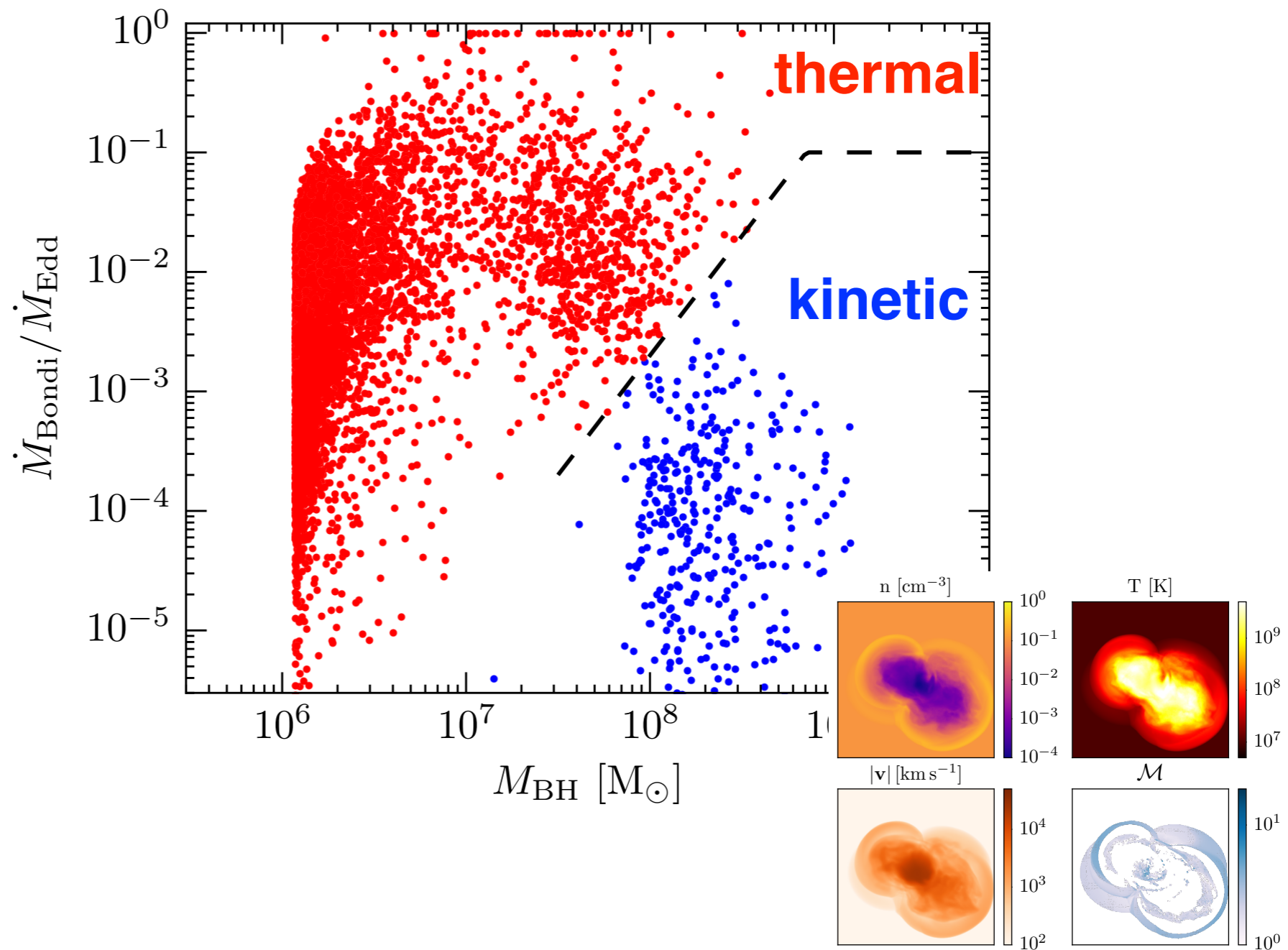
- SMBH growth
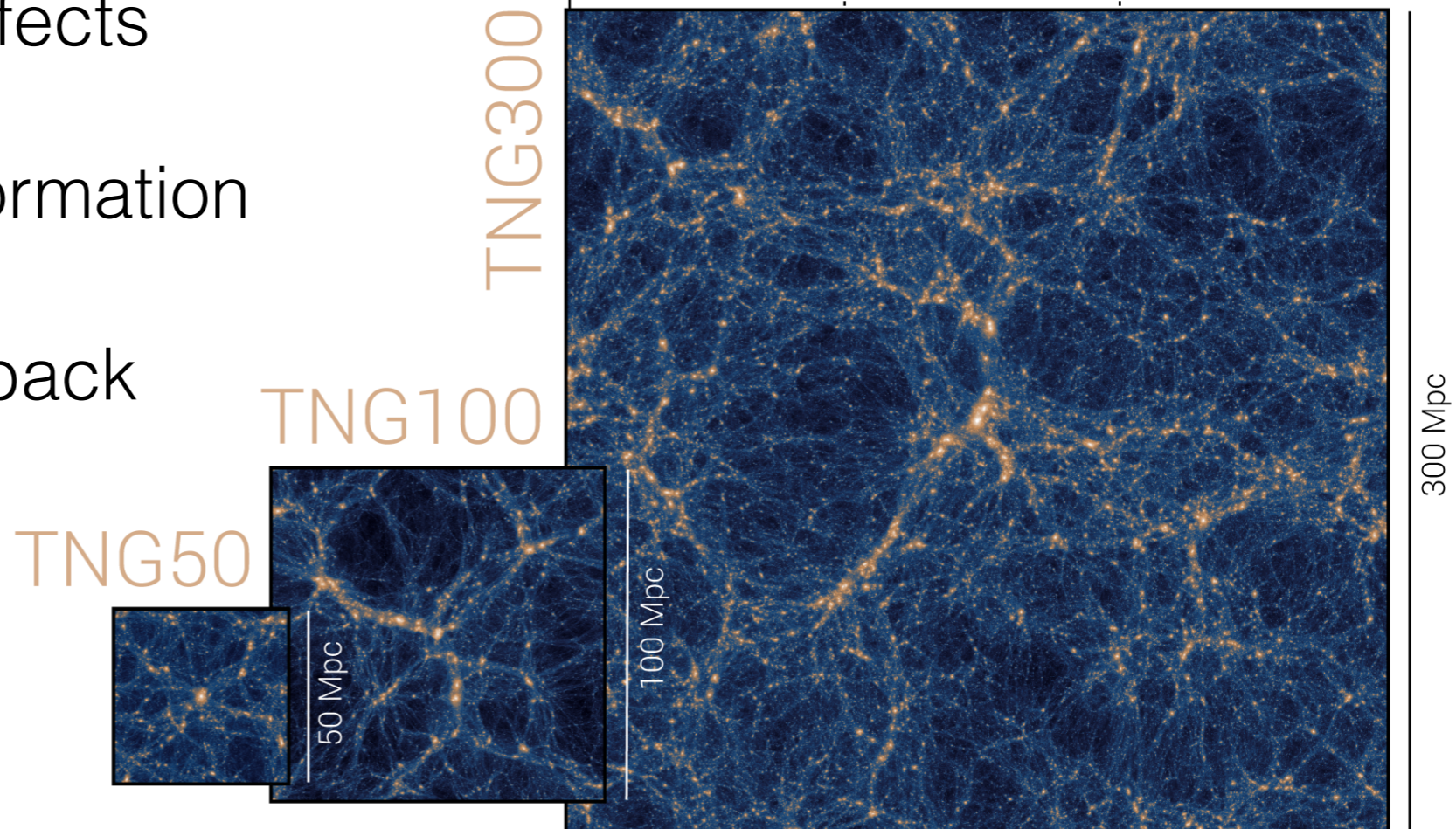
- AGN feedback

The IllustrisTNG model — AGN feedback
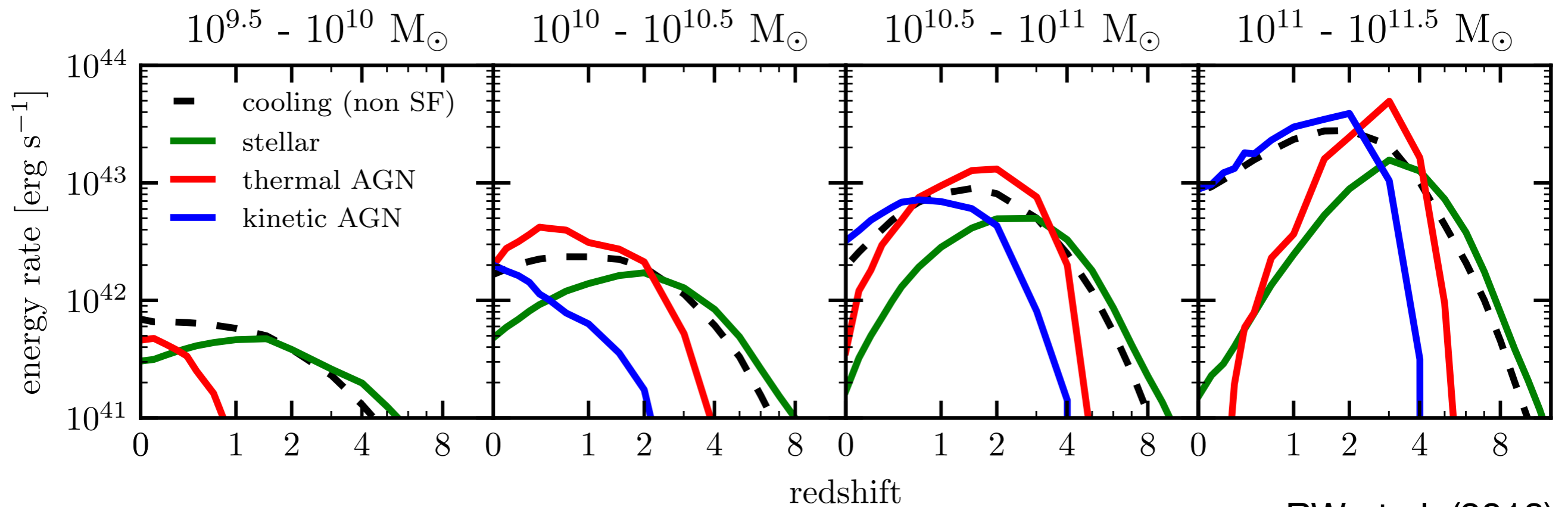
two-mode AGN feedback

- low mass, high accretion rate: **thermal** (rather inefficient)

- high mass, low accretion rate: **kinetic** (very efficient)

RW et al. (2017a)

Simulations - IllustrisTNG Results

$10^{9.5} - 10^{10} \ M_\odot$ $10^{10} - 10^{10.5} \ M_\odot$ $10^{10.5} - 10^{11} \ M_\odot$ $10^{11} - 10^{11.5} \ M_\odot$

energy rate [erg s^{-1}]

cooling (non SF)
stellar
thermal AGN
kinetic AGN

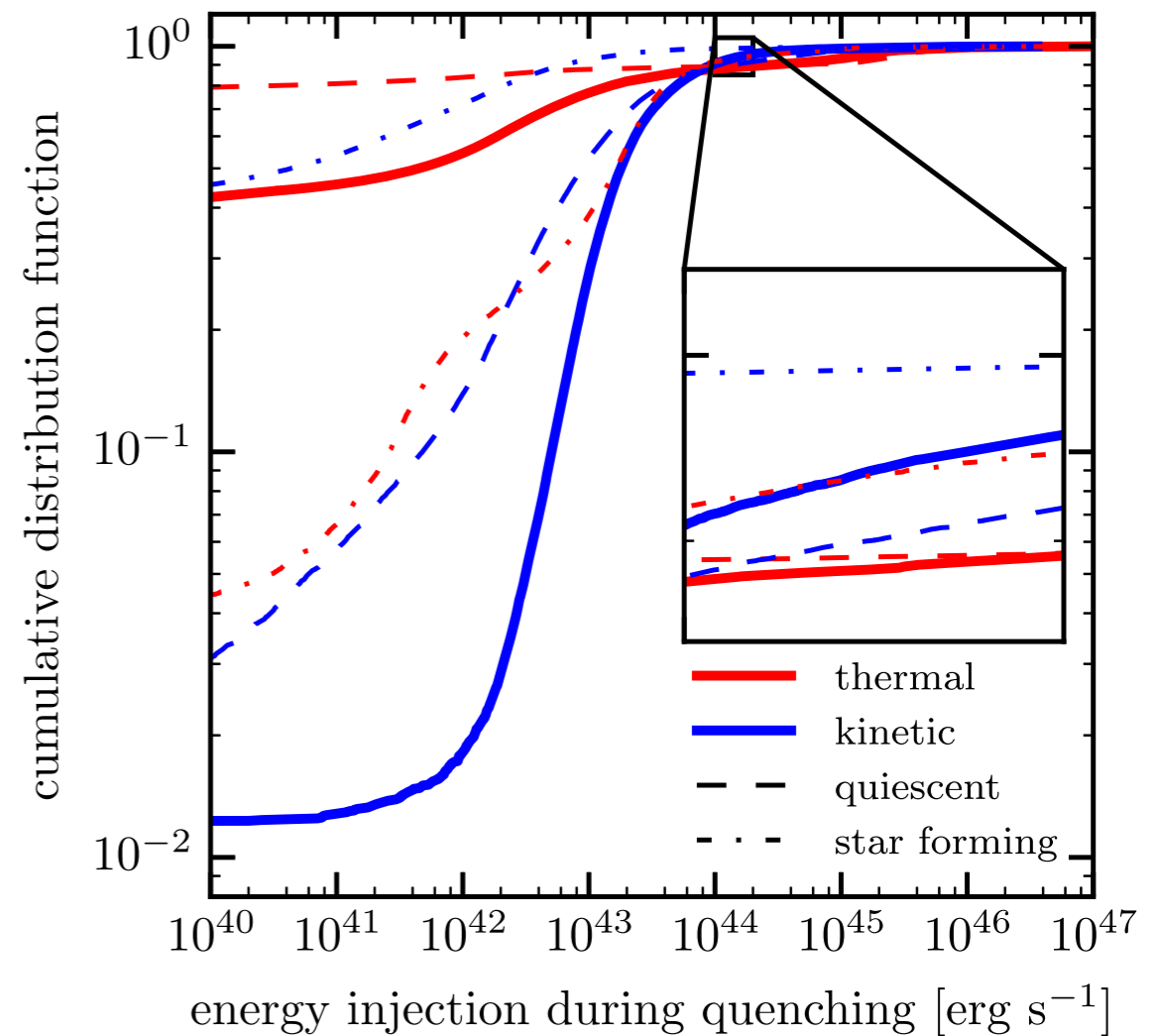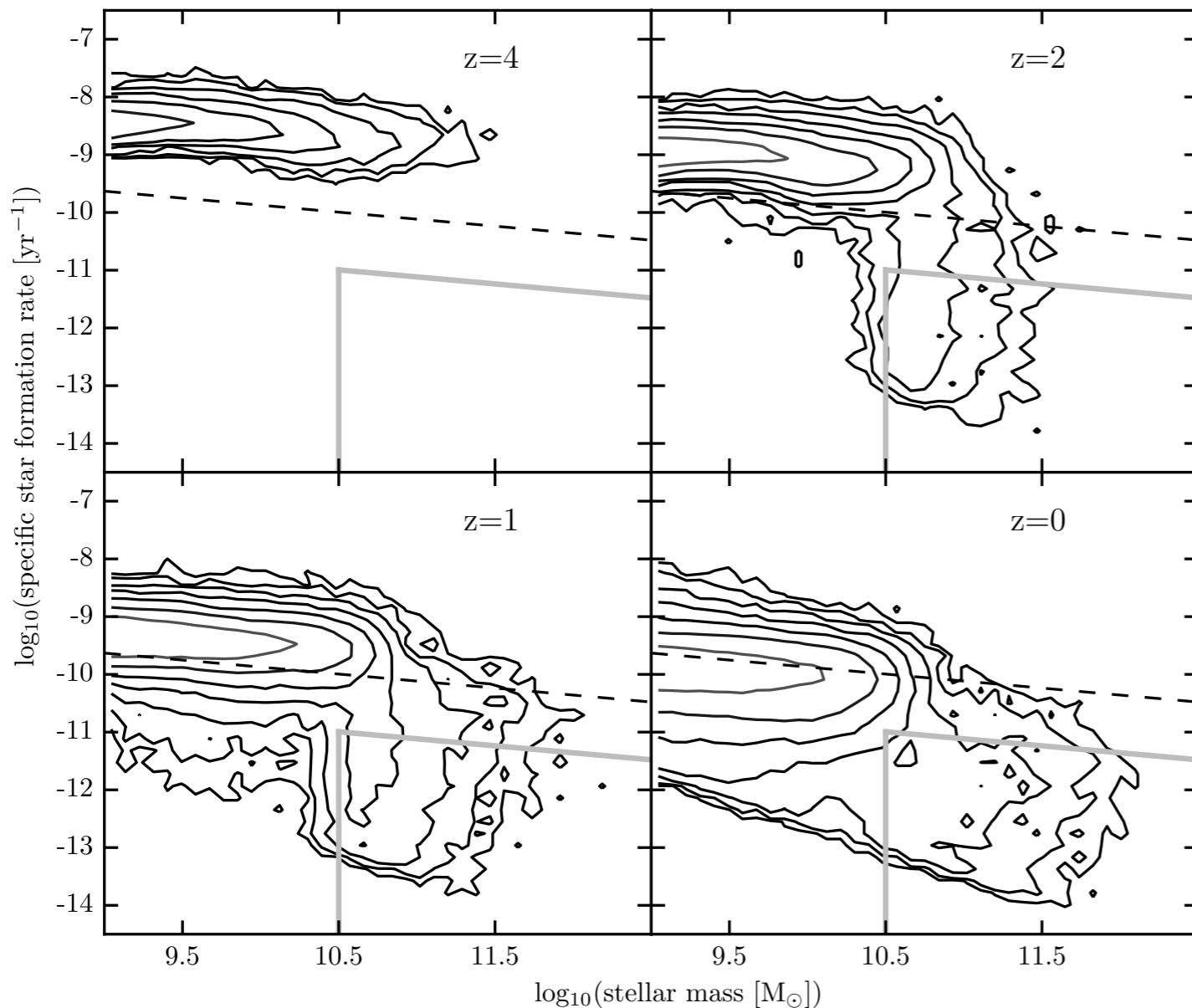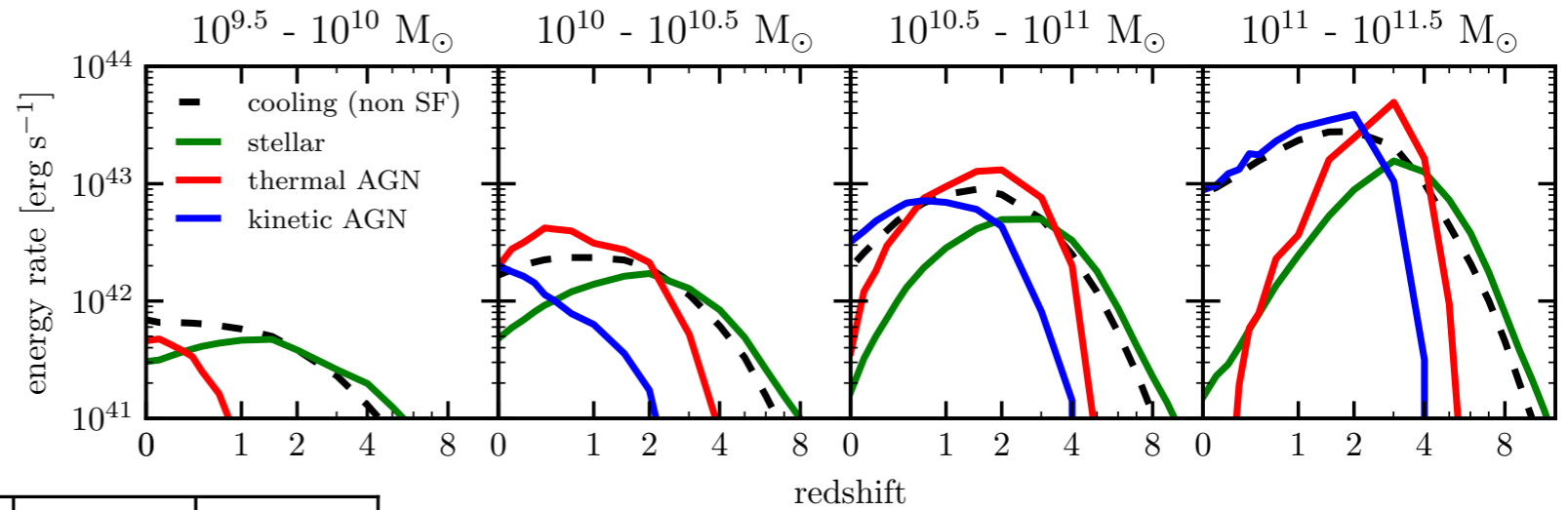redshift

RW et al. (2018)

Simulations - IllustrisTNG Results
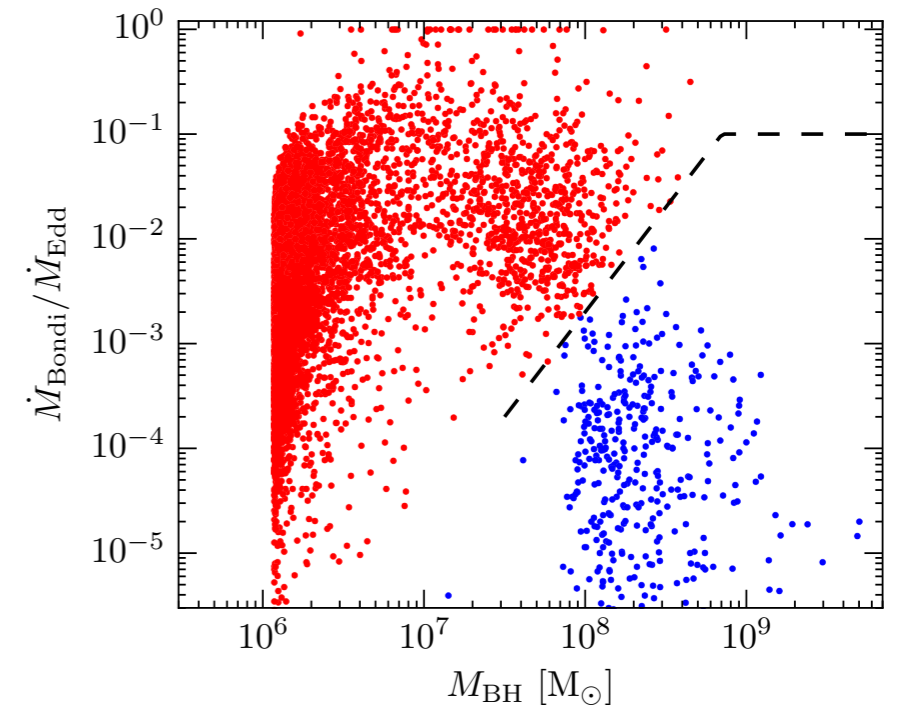

RW et al. (2018)

Simulations - IllustrisTNG Results


RW et al. (2017a)

- Kinetic feedback quenches galaxies

- To quench a galaxy, the accretion rate needs to decrease.

- Weak correlation with gas-rich galaxy major mergers

- Quenching events decoupled from quasar luminosity function

Simulations — IllustrisTNG quasar luminosity function

- reasonably reproduced

- high mass SMBH (log(M) > 9) only enter at high redshift

- SMBHs that enter here are not responsible for galaxy wide quenching

RW et al. (2018)
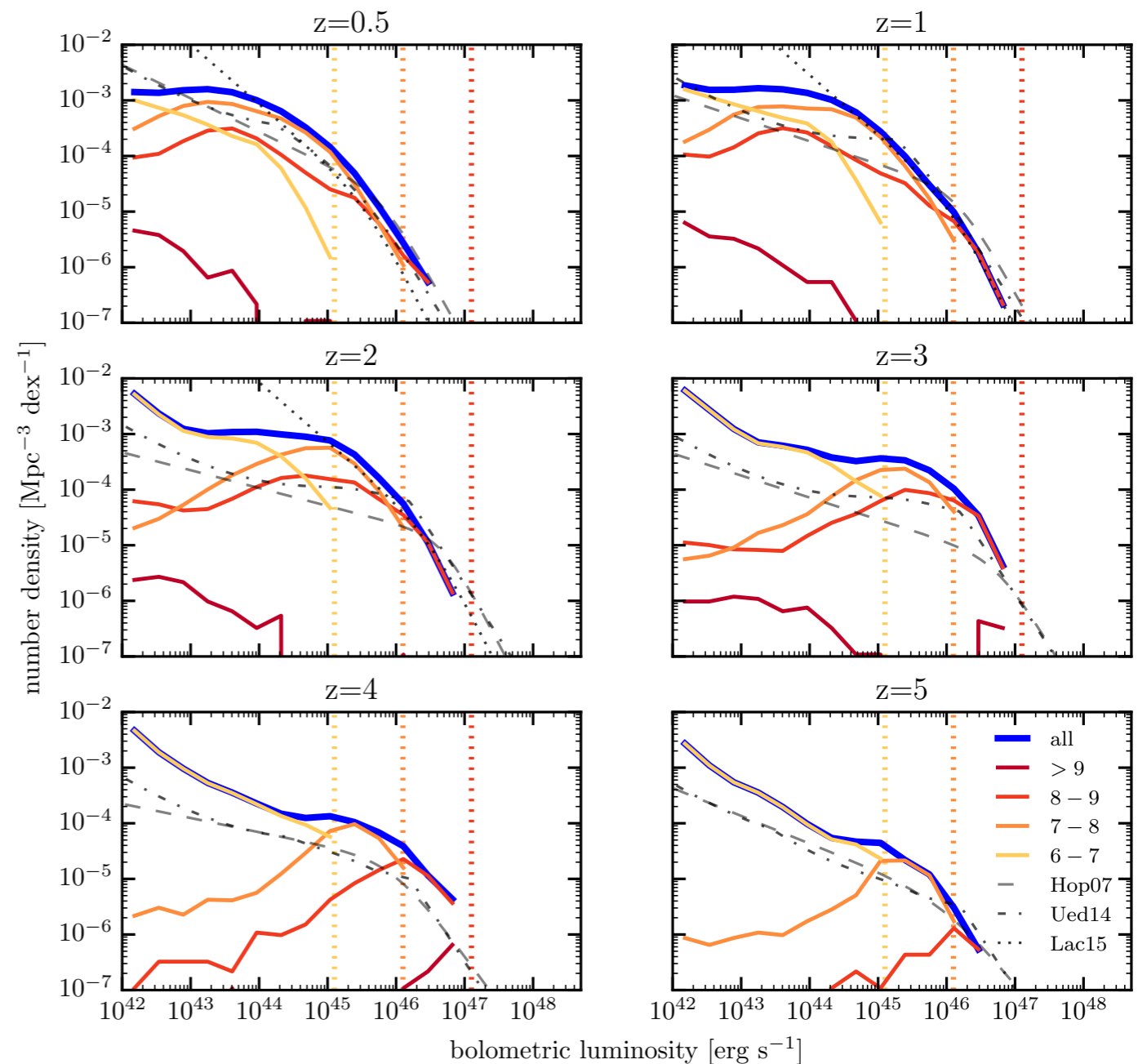
IllustrisTNG — what have we learned?

- AGN (radio) feedback generally can work, adequately reproducing galaxy properties and correlations, as far as tested so far.

- More comparisons with observations needed and on the way

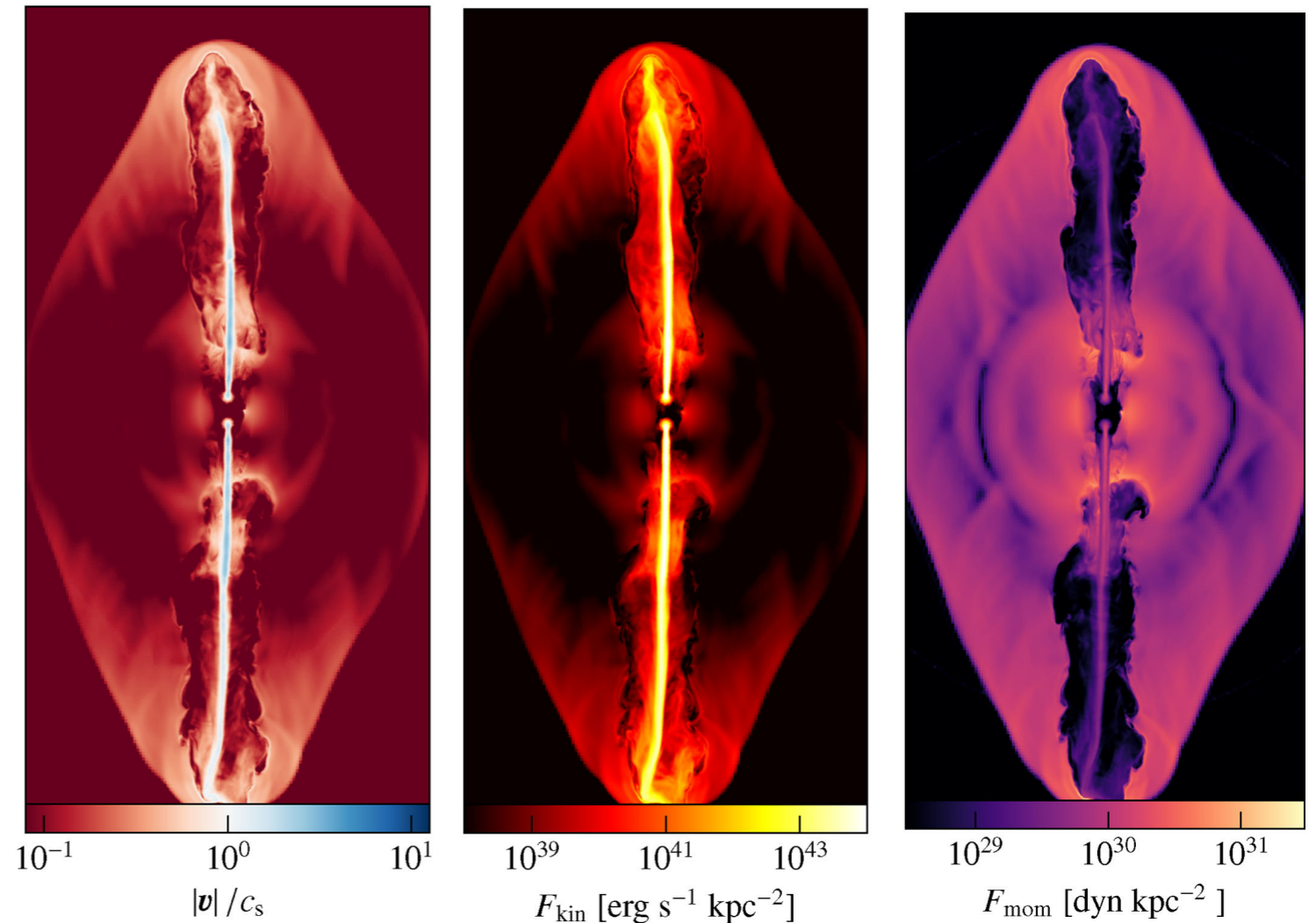- Some problems remain (gas profiles in clusters, low luminosity AGN too abundant, …)

Simulations - IllustrisTNG
Open questions

- Transition to kinetic mode — what is the origin?

- Exploration of different observables, both galaxies and AGNs — do they show a coherent picture?
  public data release TNG100/300: Dec 7th, 2018 !!!

- **Is the model and parameters we use realistic? Are the efficiencies achievable?**

Simulations - radio jets in galaxy clusters

- jets in galaxy clusters

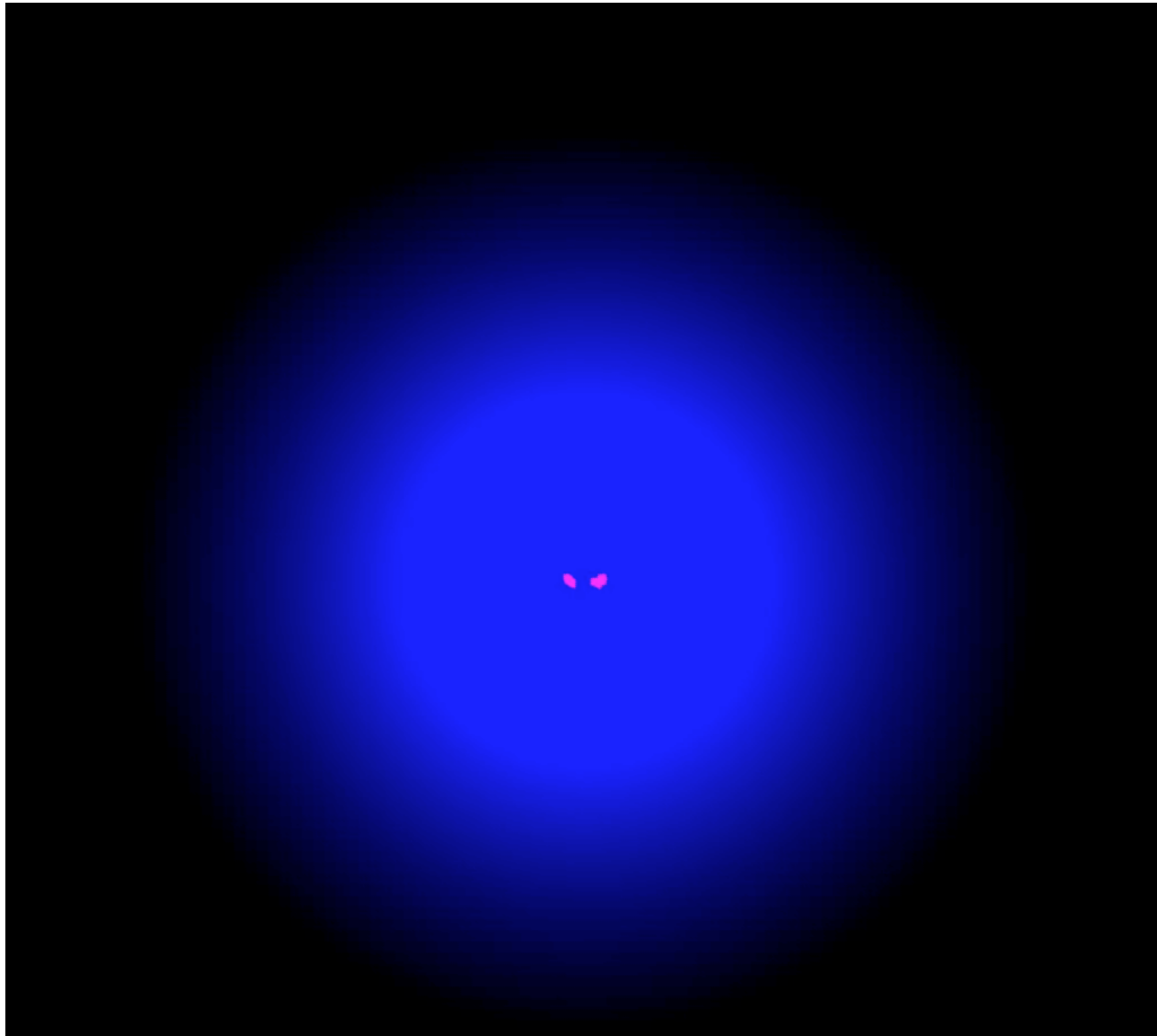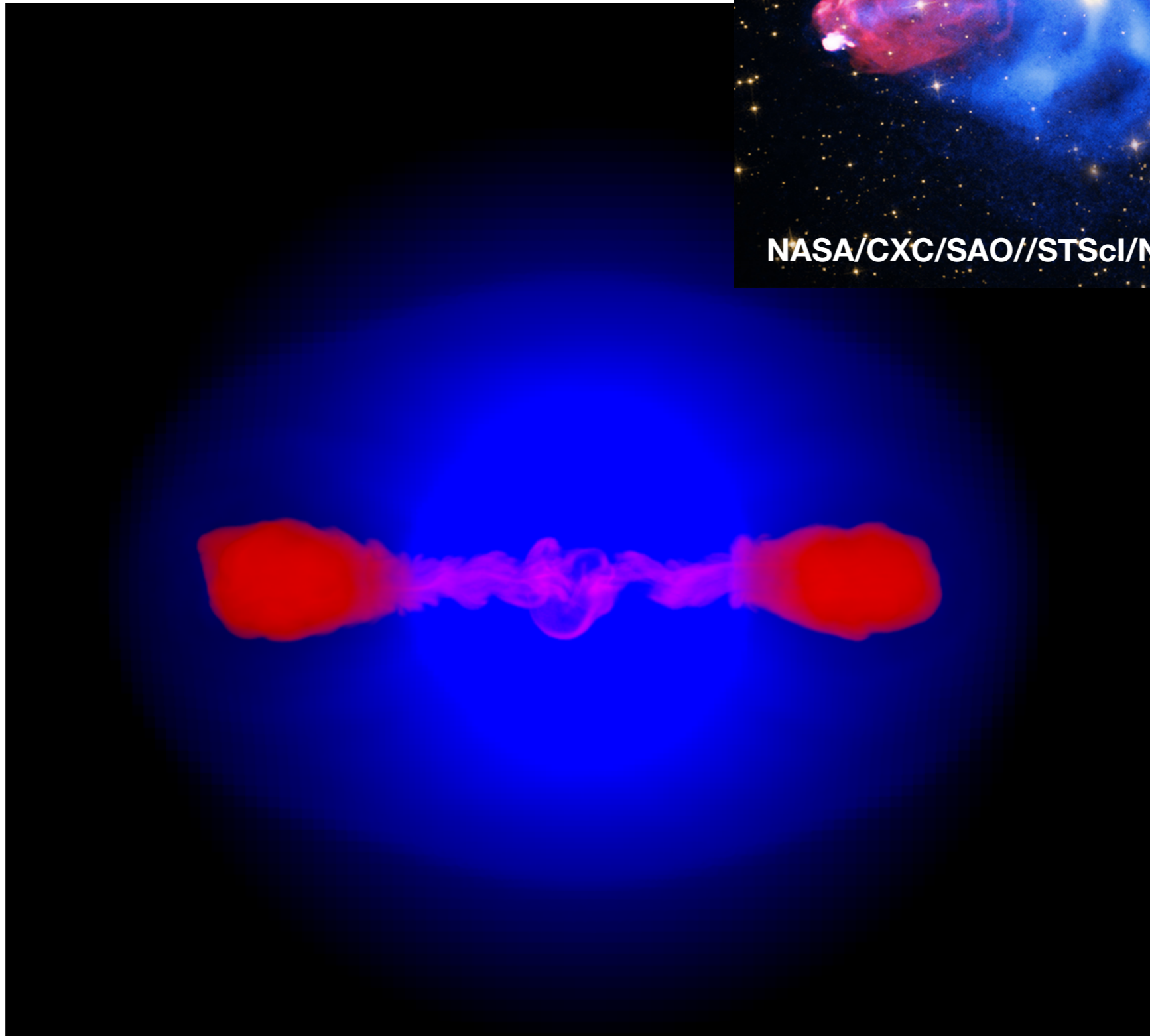- supersonic

- hydrodynamic, not ballistic

10^{-1} 10^{0} 10^{1}
$|\boldsymbol{v}|\,/c_{\mathrm{s}}$

10^{39} 10^{41} 10^{43}
$F_{\mathrm{kin}}\ [\mathrm{erg\ s^{-1}\ kpc^{-2}}]$

10^{29} 10^{30} 10^{31}
$F_{\mathrm{mom}}\ [\mathrm{dyn\ kpc^{-2}}]$

RW et al. (2017b)

← 100 kpc →

3e44 erg/s jet active for 42 Myr

Simulations - energy deposition

Simulations - energy deposition

NASA/CXC/SAO//STScI/NSF/NRAO/AUI/VLA
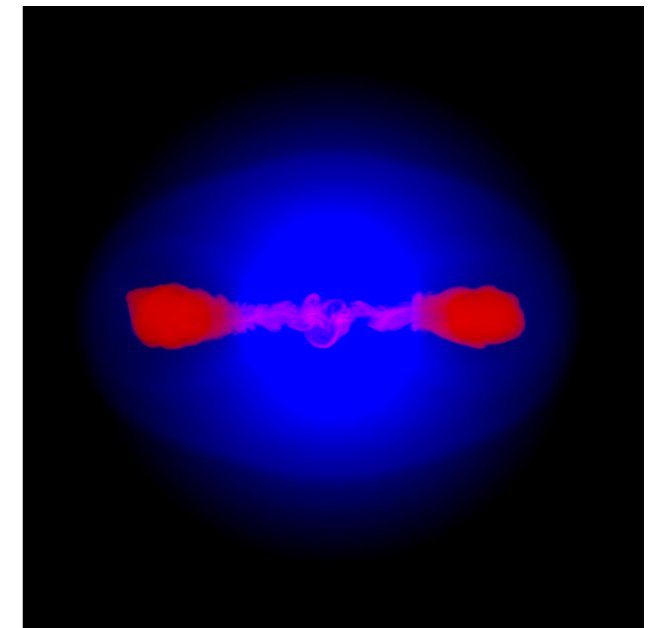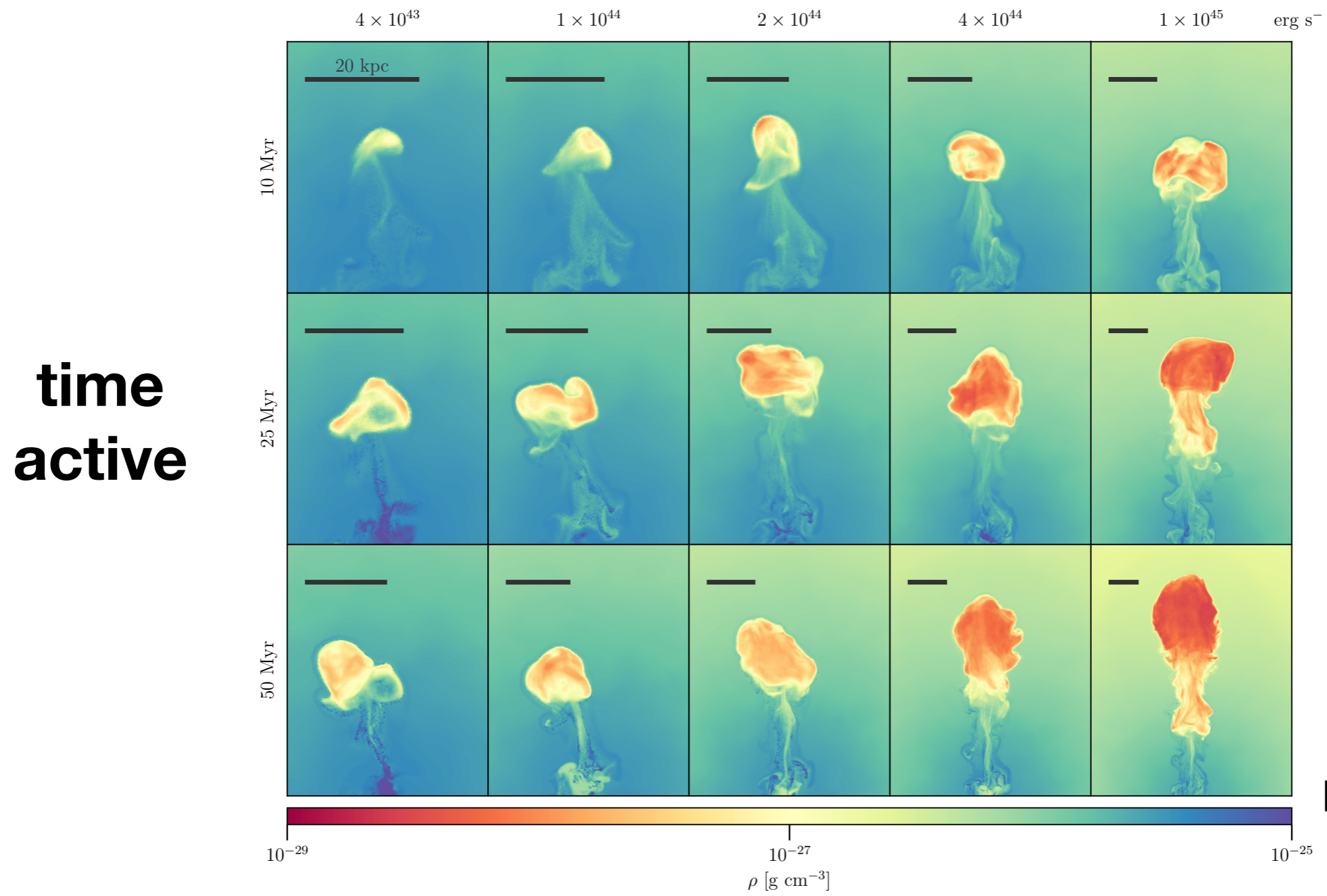
Simulations - energy deposition
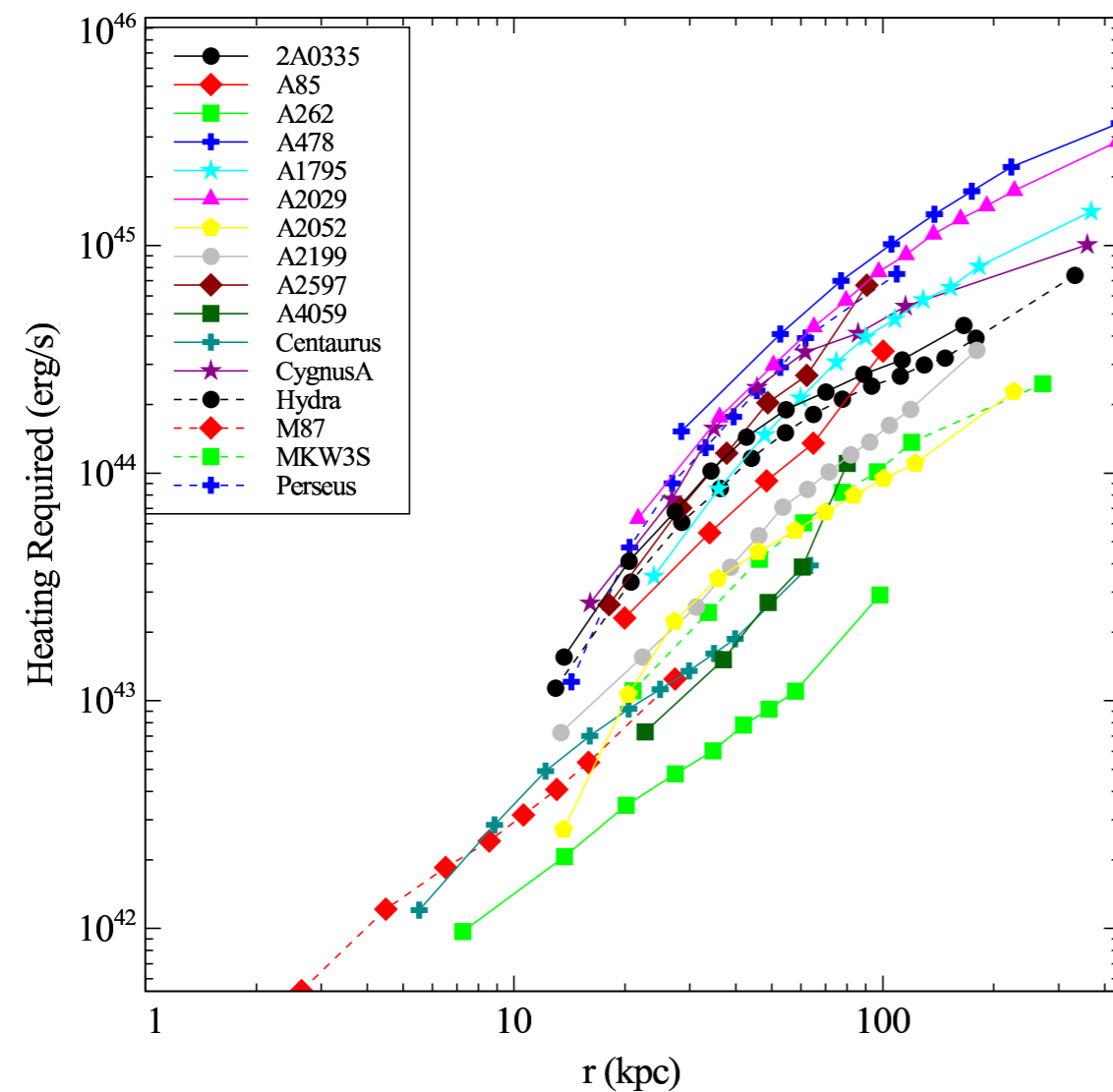
Dunn and Fabian (2006)
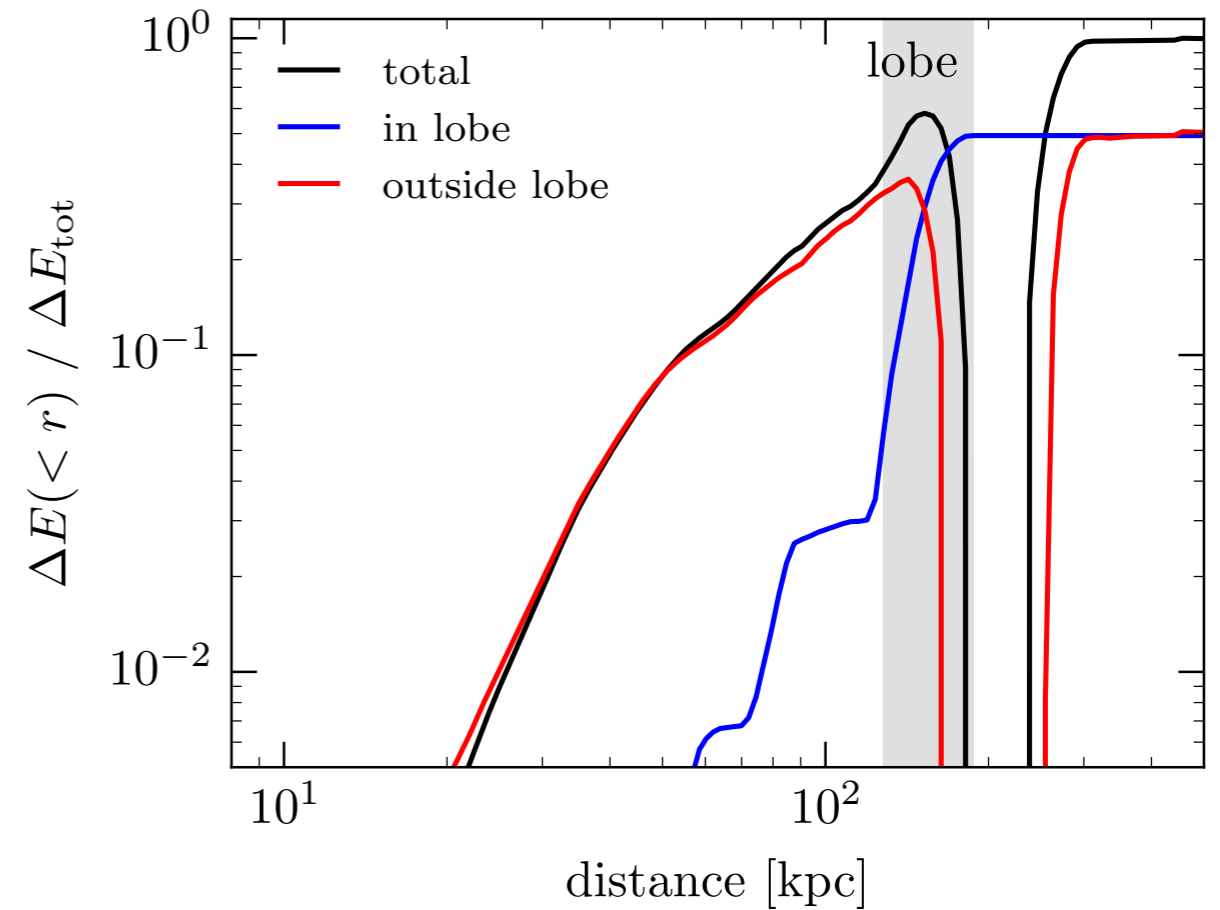
RW et al. (2017b)

Simulations — morphology of lobes

Jet Luminosity

Ehlert et al. (2018)

Simulations — shocks
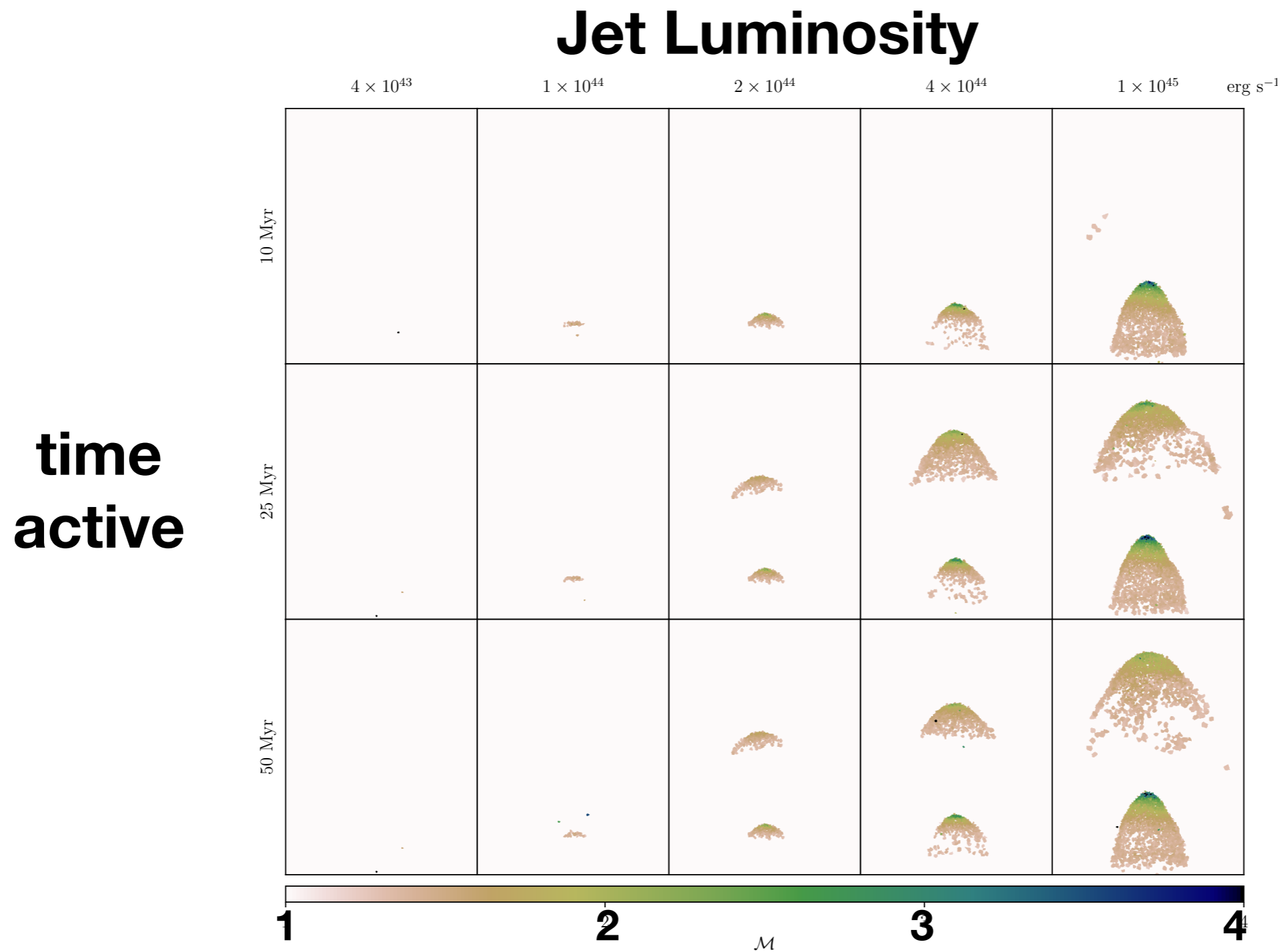
Jet Luminosity

Ehlert et al. (2018)

Radio jets — parameters

- jet luminosity

- width of jet -> self collimation not resolved!

- degree of magnetisation

- jet density/external mach number

- cosmic ray acceleration efficiency

Summary

- AGN feedback still is the most convincing candidate to shape the high mass galaxy population

- Cosmological simulations can be used to facilitate the interpretation of observations

  - Requires a deep understanding of the employed model

- Use isolated, more controlled simulations to test efficiencies and nature of interaction

  - Requires understanding about the limitations of the setup