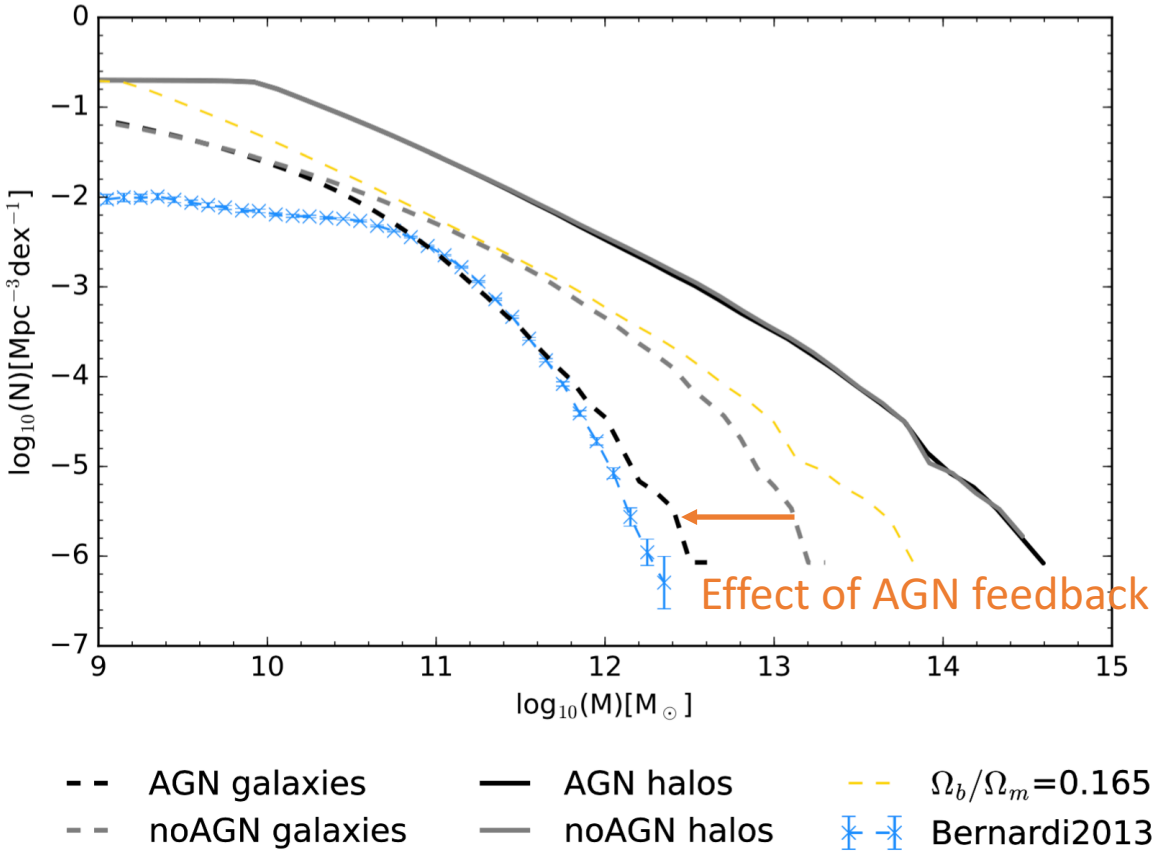
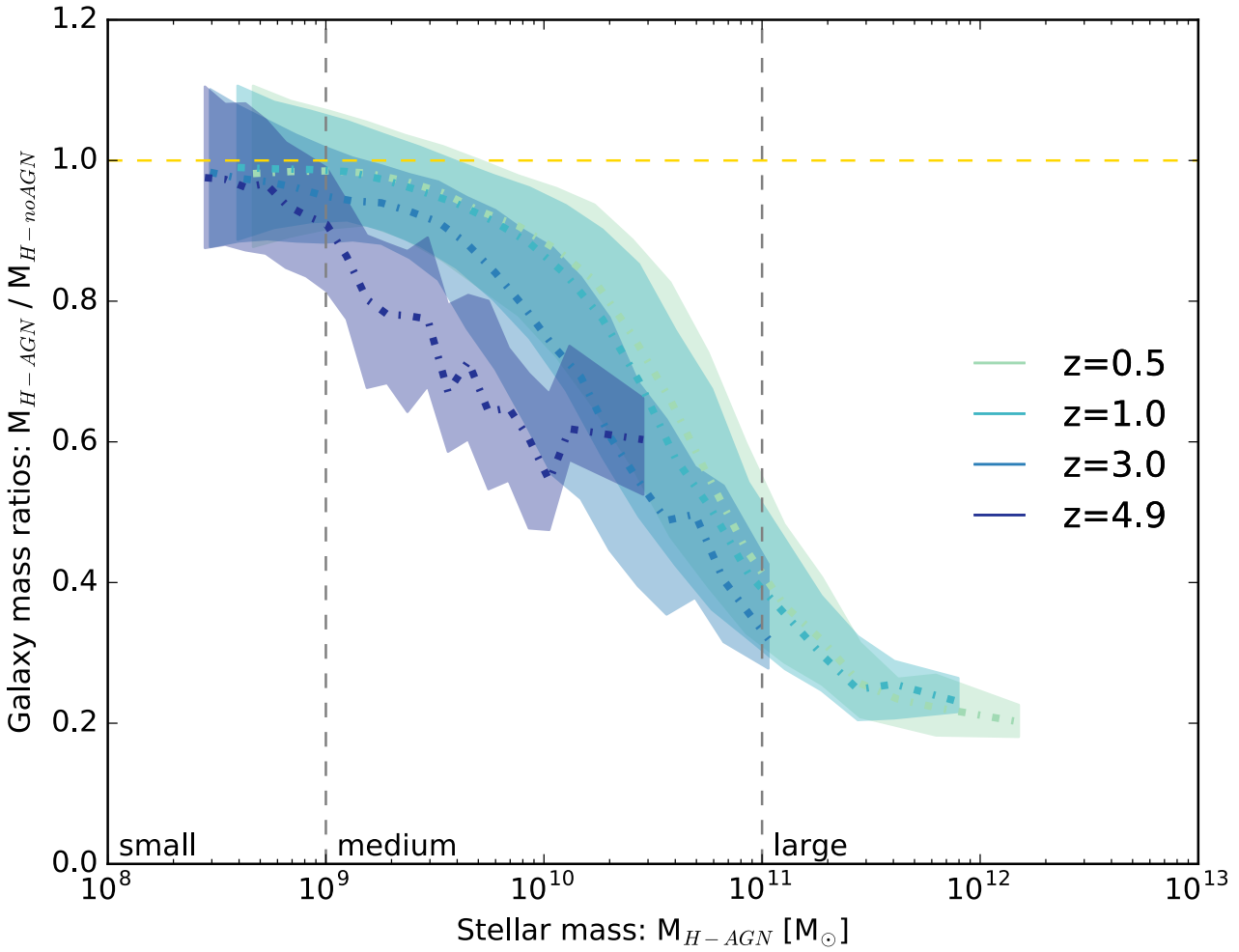
Feedback from massive black holes is responsible for quenched galaxies in the local universe



Data from the HORIZON-AGN & HORIZON-noAGN simulations: Dubois et al 2014, Volonteri et al 2016, Kaviraj et al 2016, Beckmann et al (in prep)

At z=6, massive galaxies are already quenched



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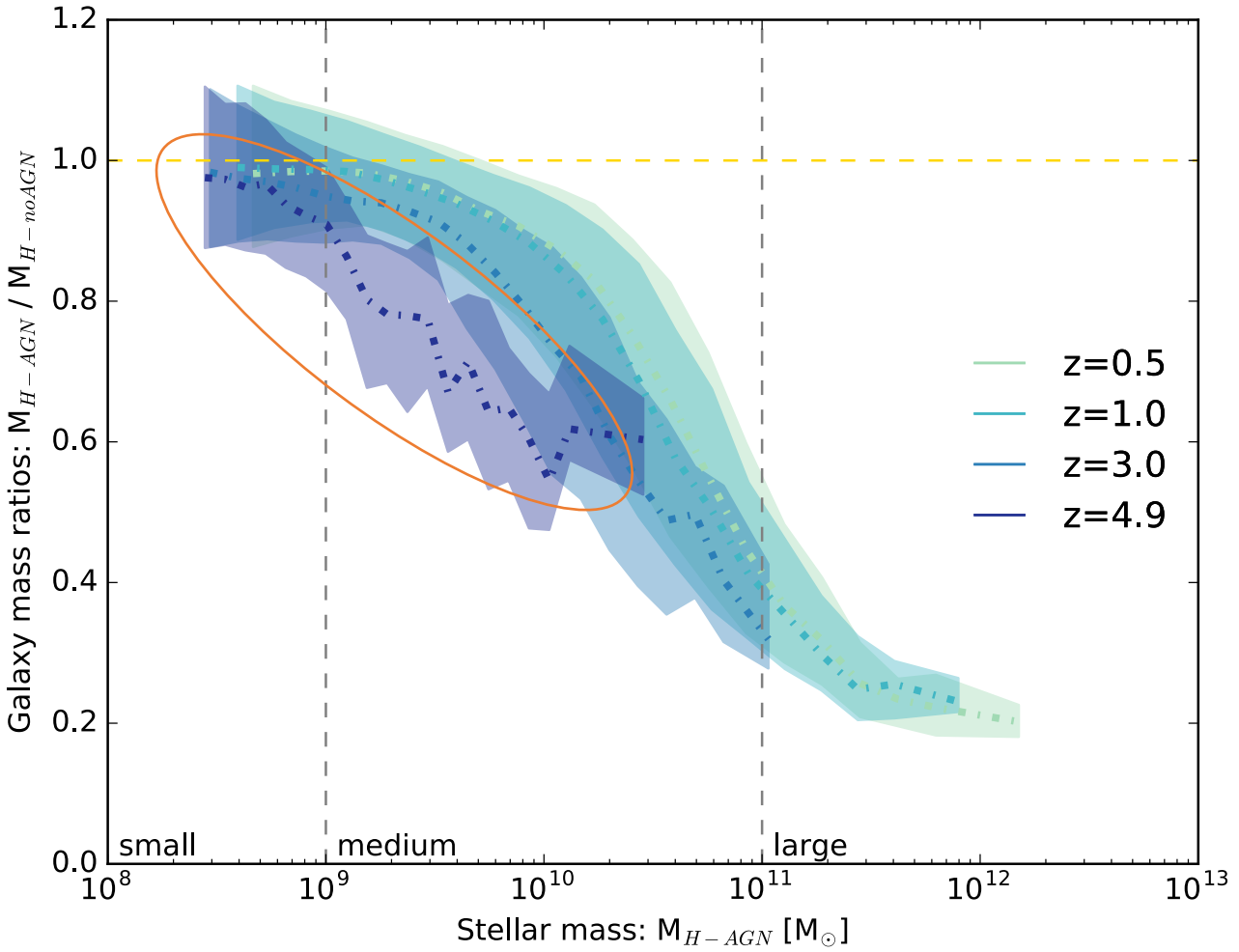
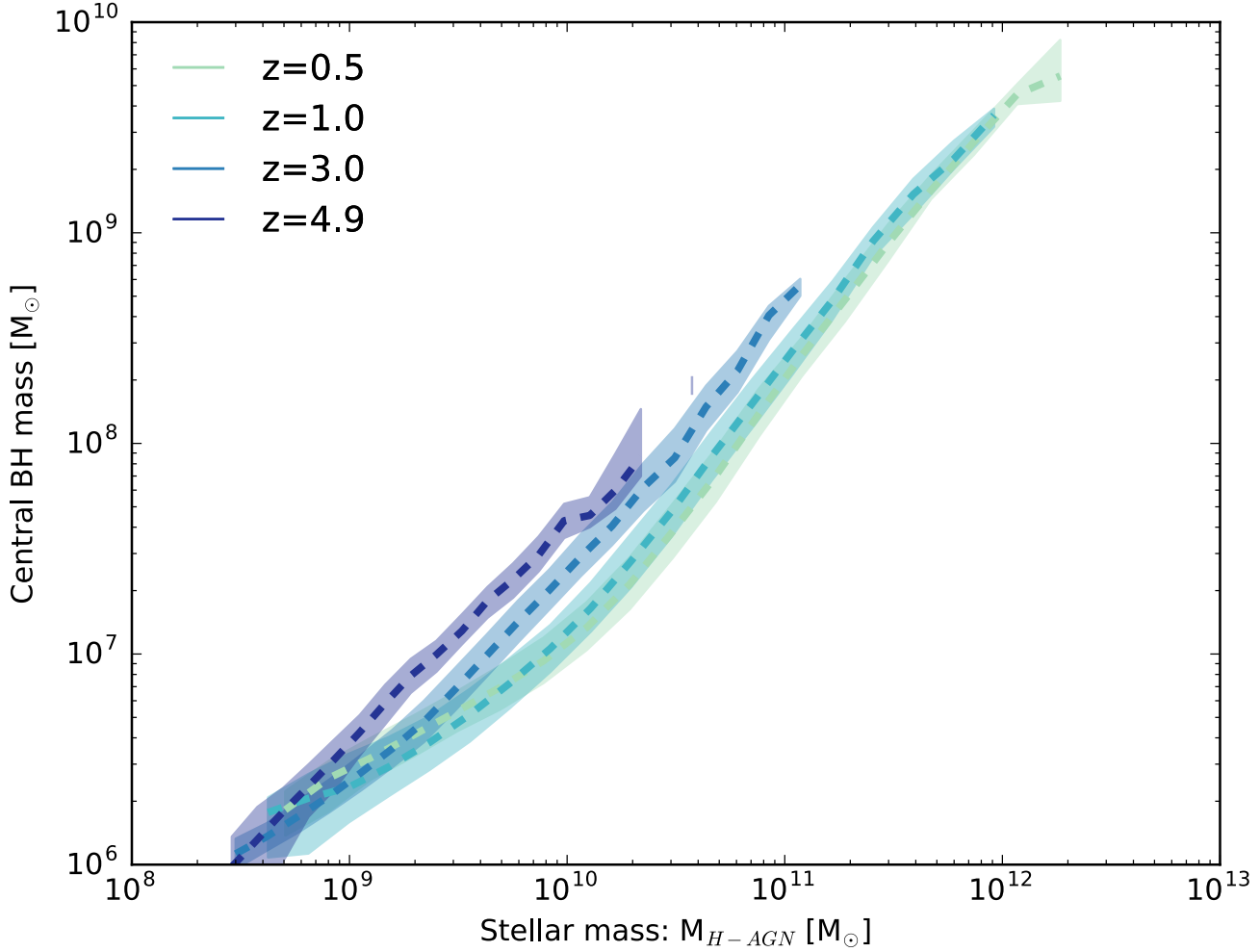


Black holes growth precedes galaxy growth



Black holes in cosmological simulation

In HORIZON (Dubois2014,Welker2015,…)

- Seed the black holes at 10^5 Msun
- Resolve gas flows at 1kpc resolution
- Grow the black holes using Eddington limited Bondi accretion

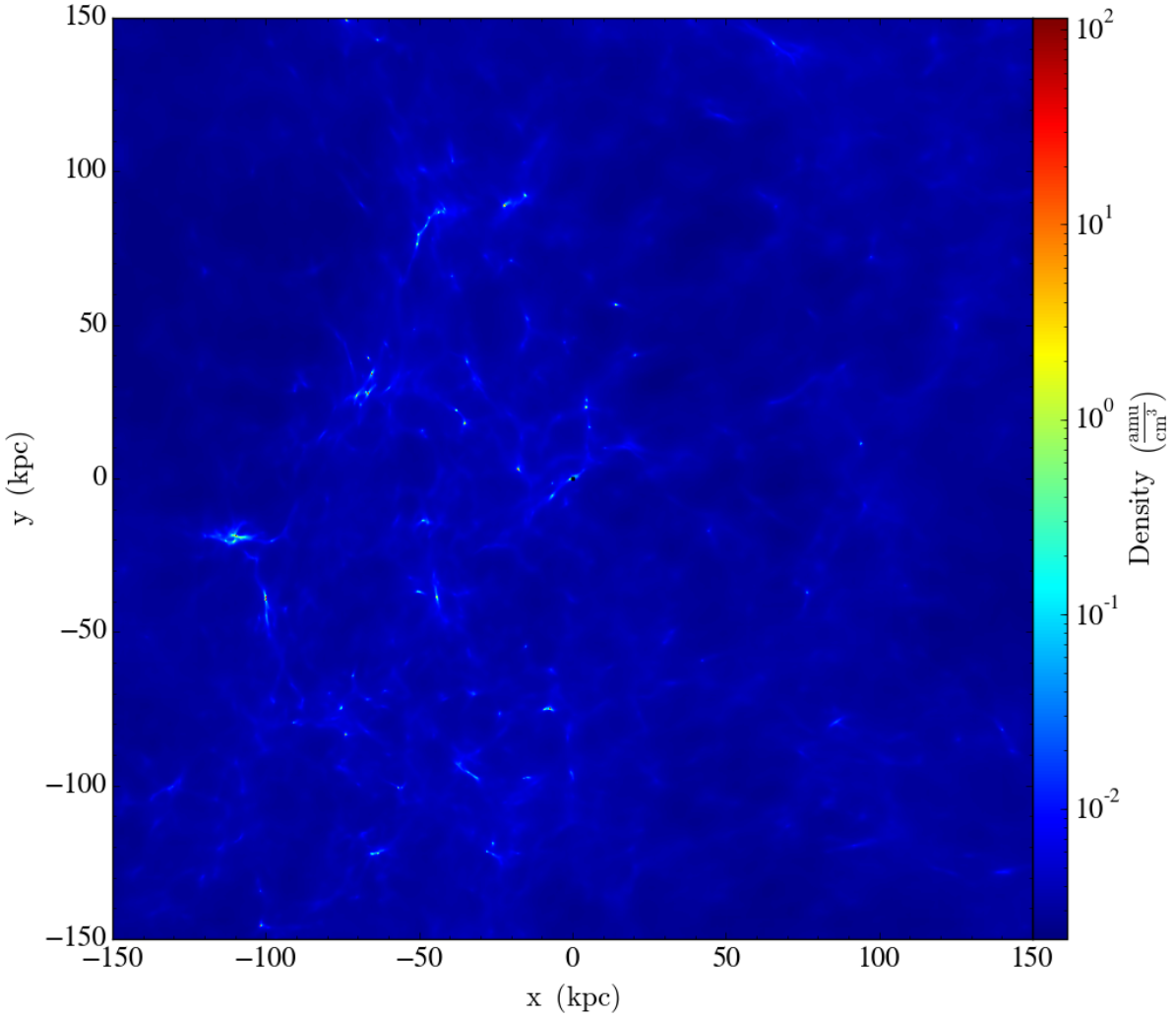
=> Similar picture in other simulations such as Illustris (Vogelsberger2014,Sijaki2015), Eagle (Schaye2015) and Massive Black II (Khandai2014)

Where do these black holes physically come from?

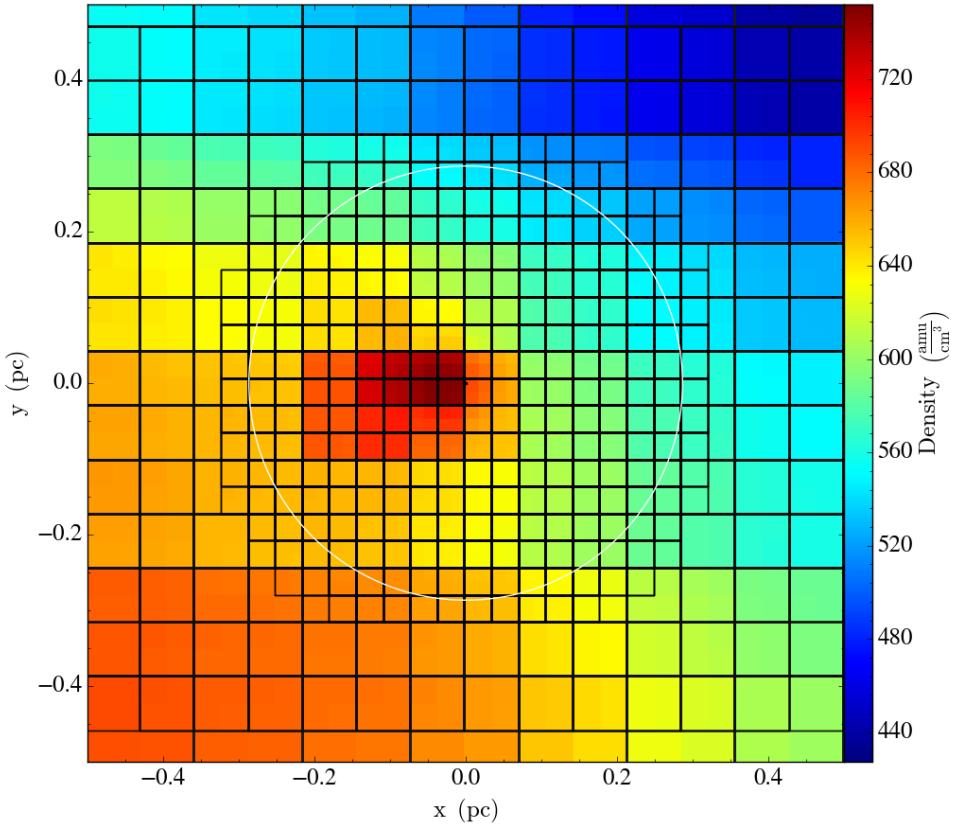
- **Direct Collapse:** 10^5 Msun seeds, needs metal free gas and radiating neighbours (Begelman2006,Latif2013,Habouzit2016)
- **Runaway cluster collapse:** 10^3-10^4 Msun seeds (Omukai2008, Devecchi2009, Katz2015)
- **Stellar mass seeds:** 1-100 Msun, (Haiman2000, Freyer2001,Alvarez2009,Heger2003)

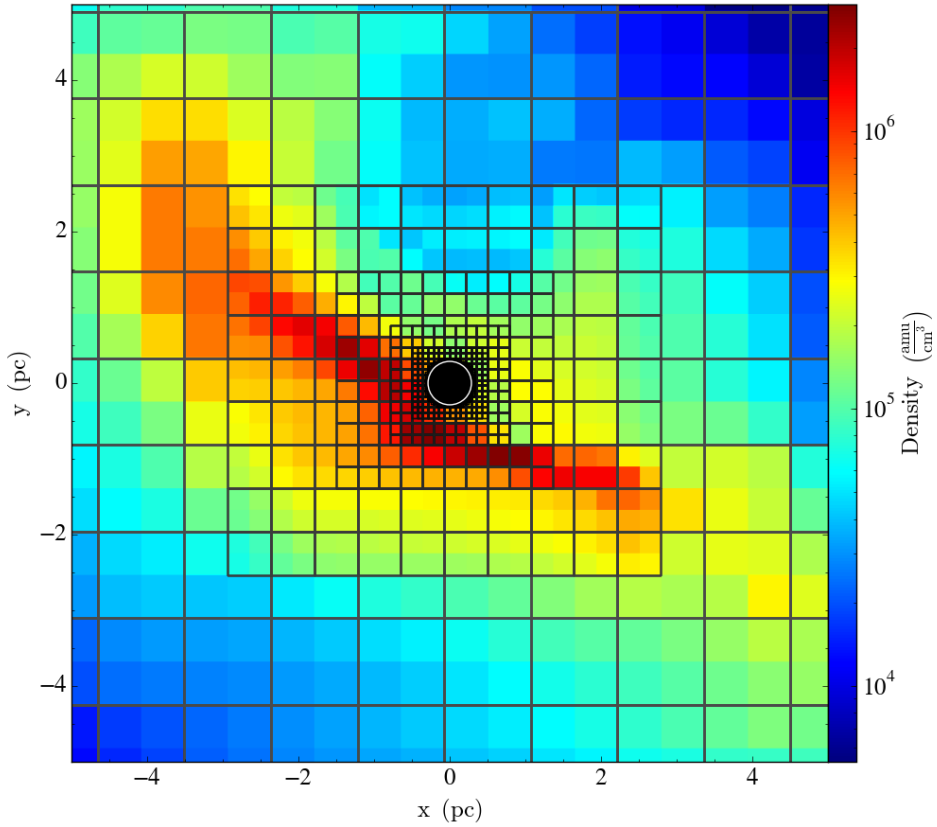
Bridging the gap from seed to supermassive

- stellar mass seed (260 MSun)
- a cosmological context (1Gpc box with 50 Mpc zoom region)
- high resolution (Δx=0.01 pc)
- run to redshift 6
- AMR hydro (RAMSES)

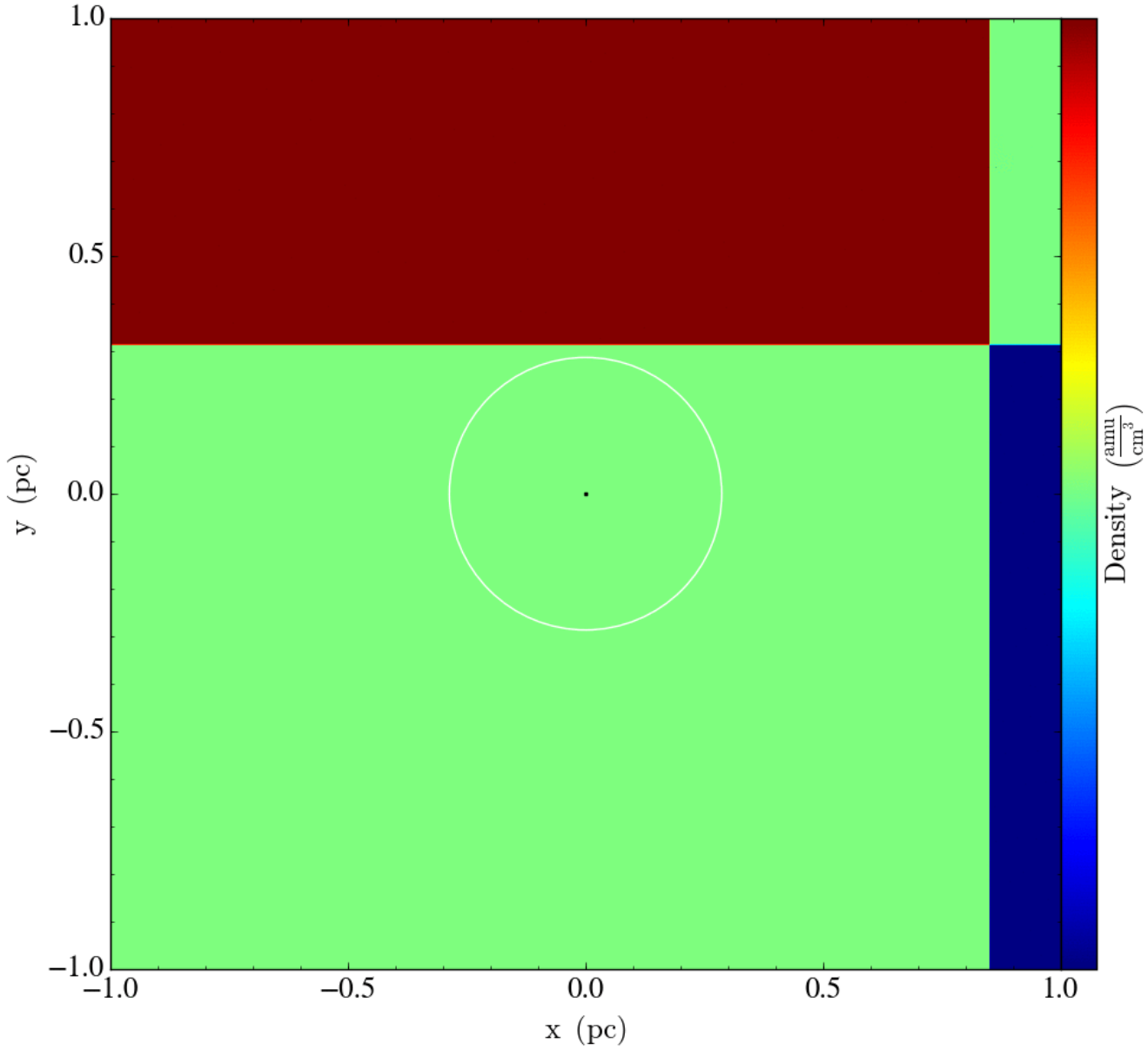


Zoom-within-Zoom

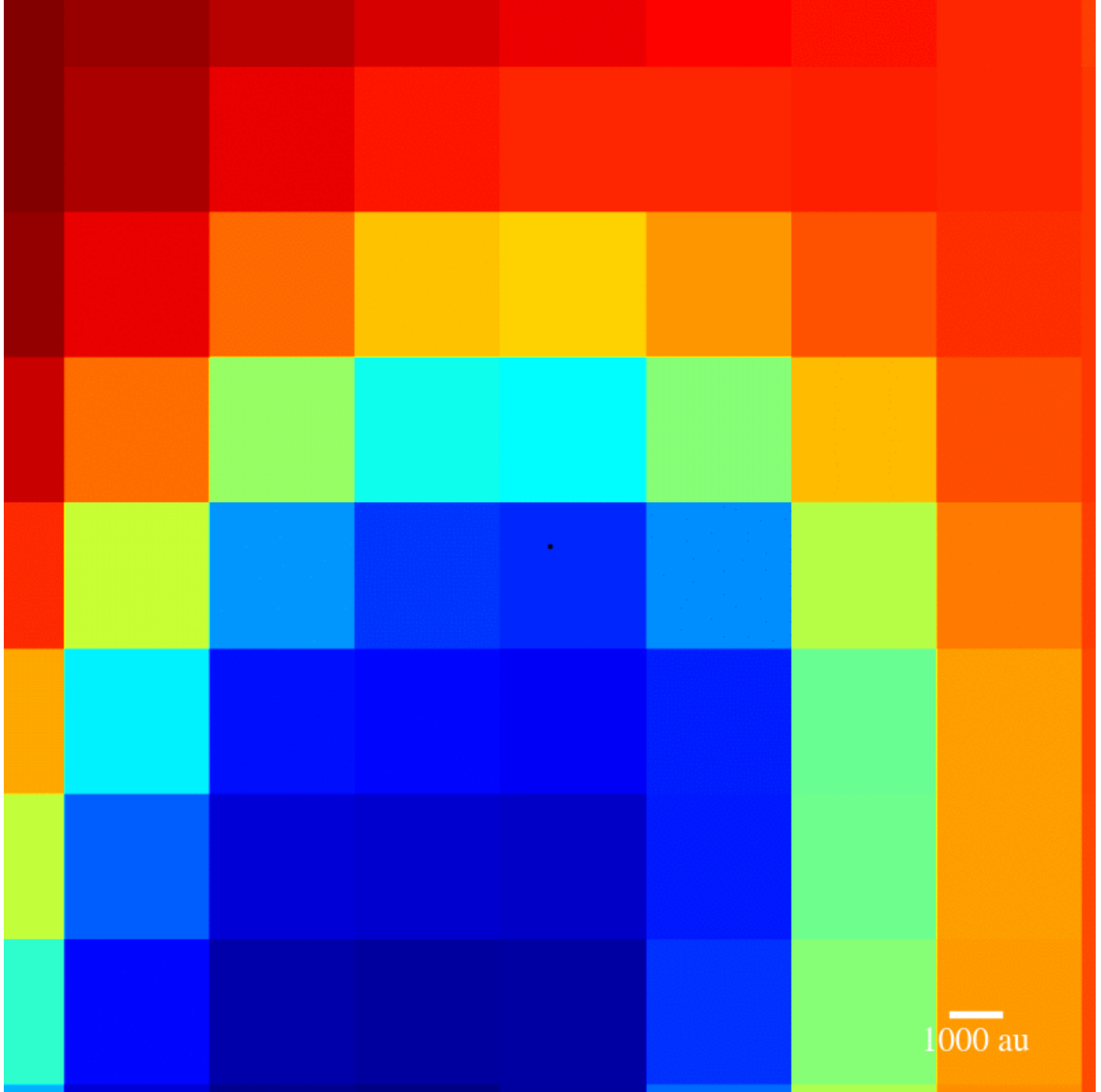




Gradual triggering of levels

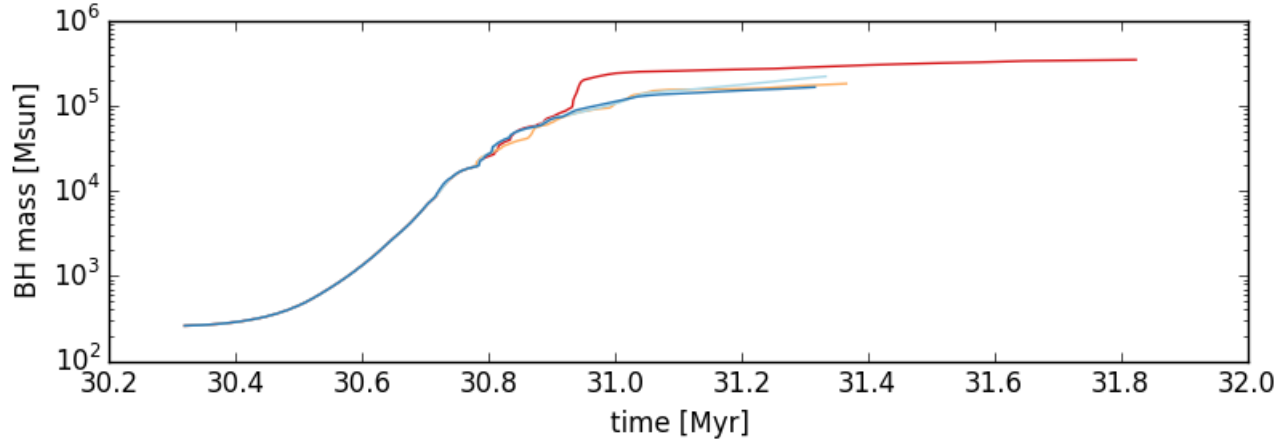


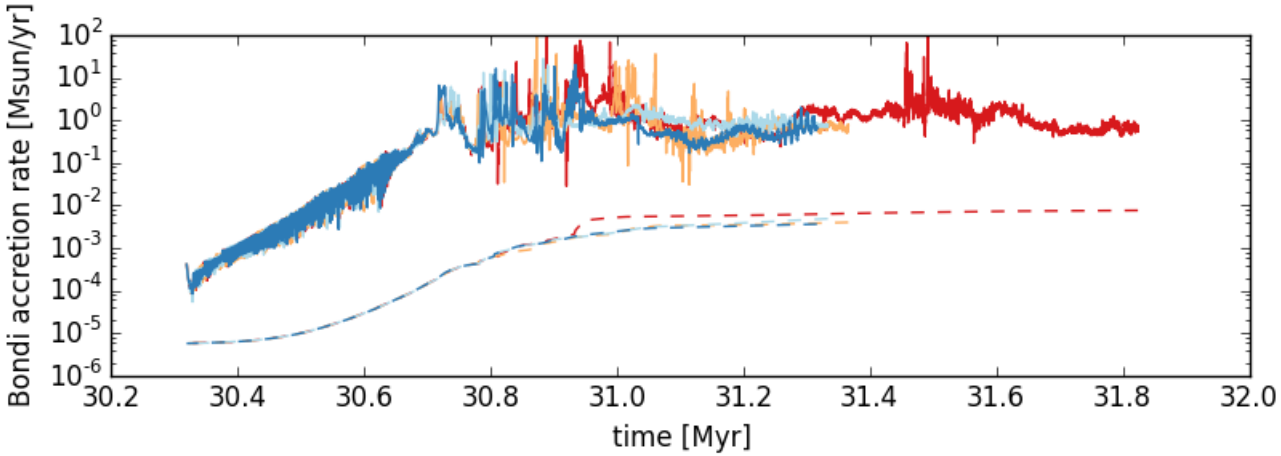
Density

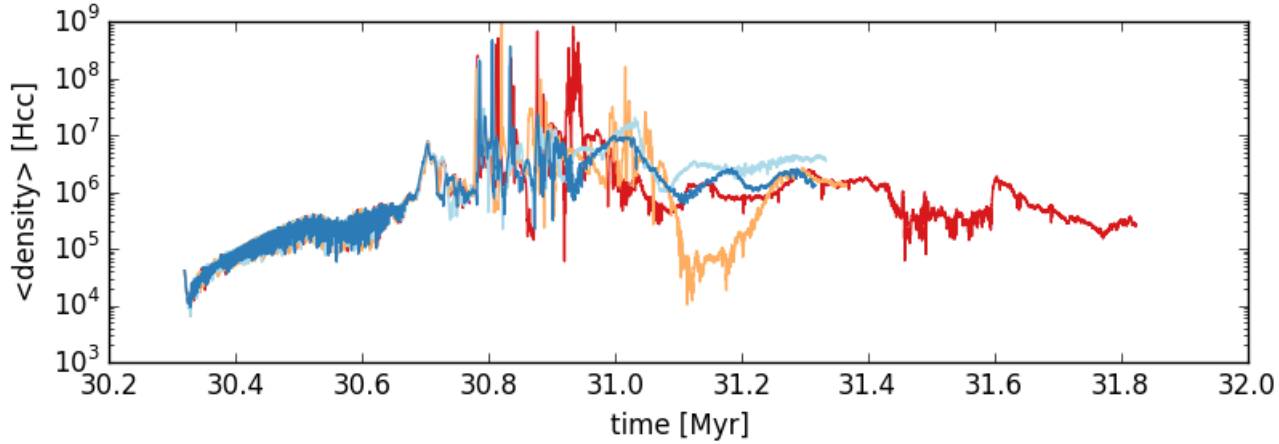


RESULTS

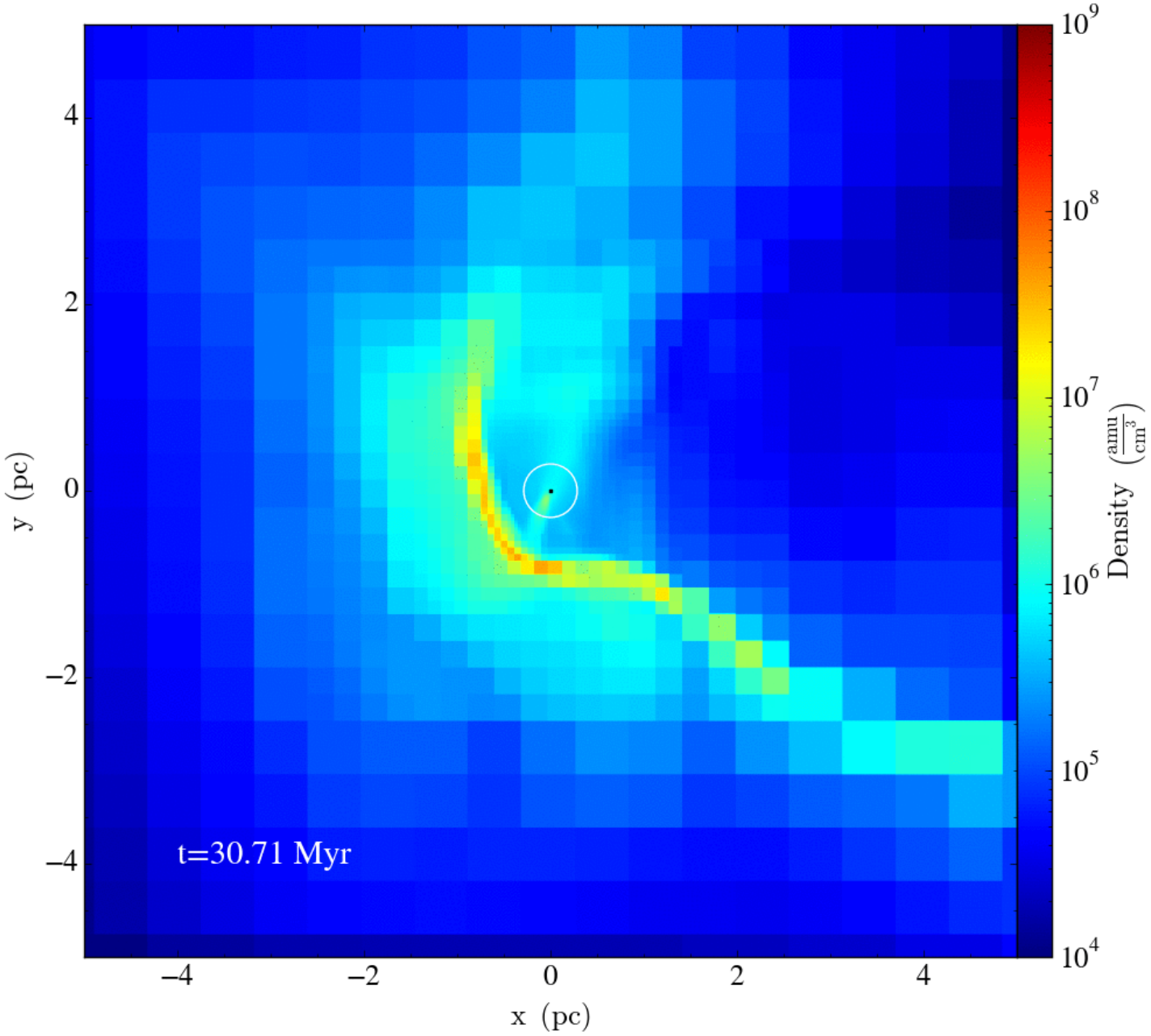
A test case: an isolated disc



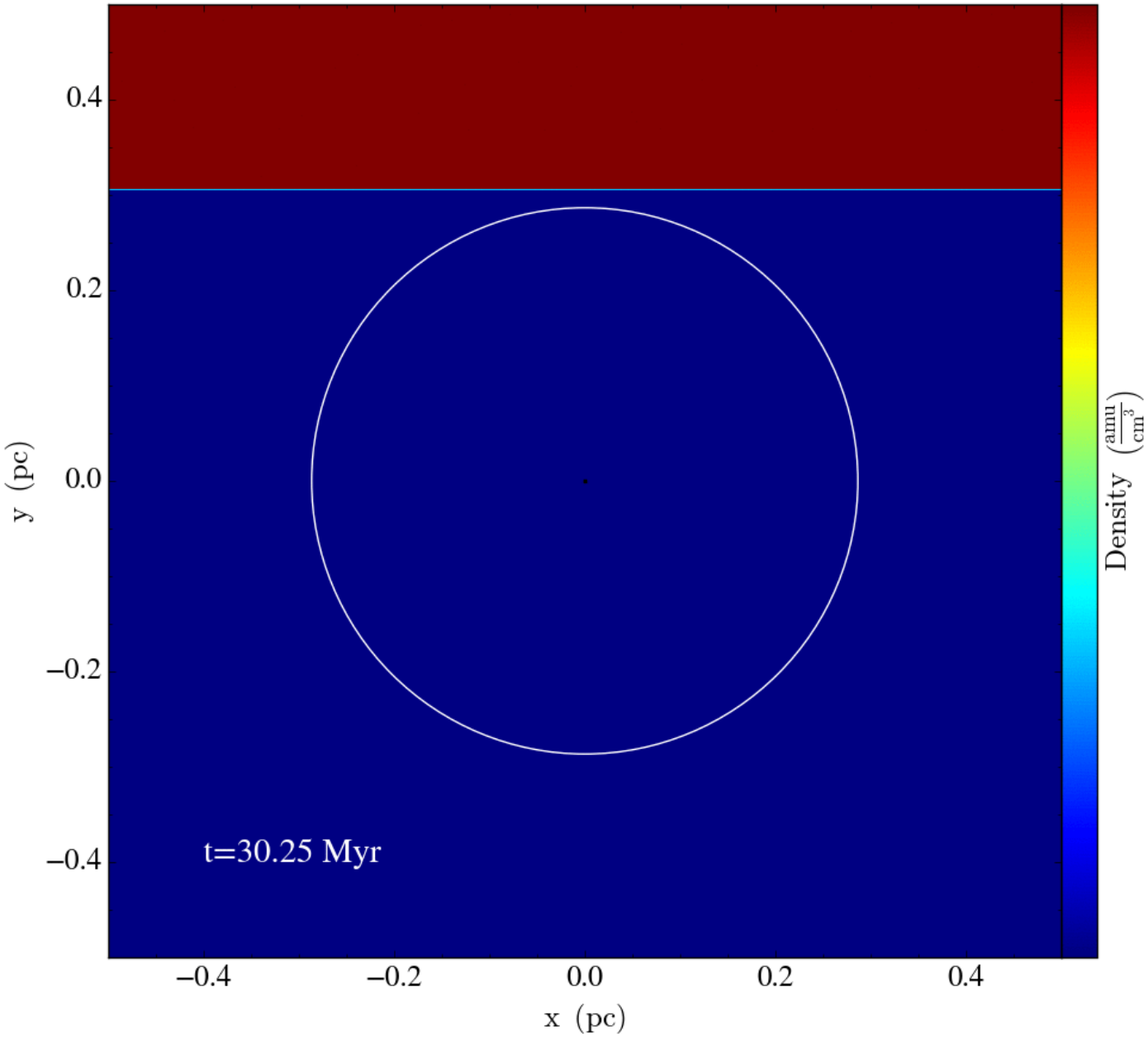




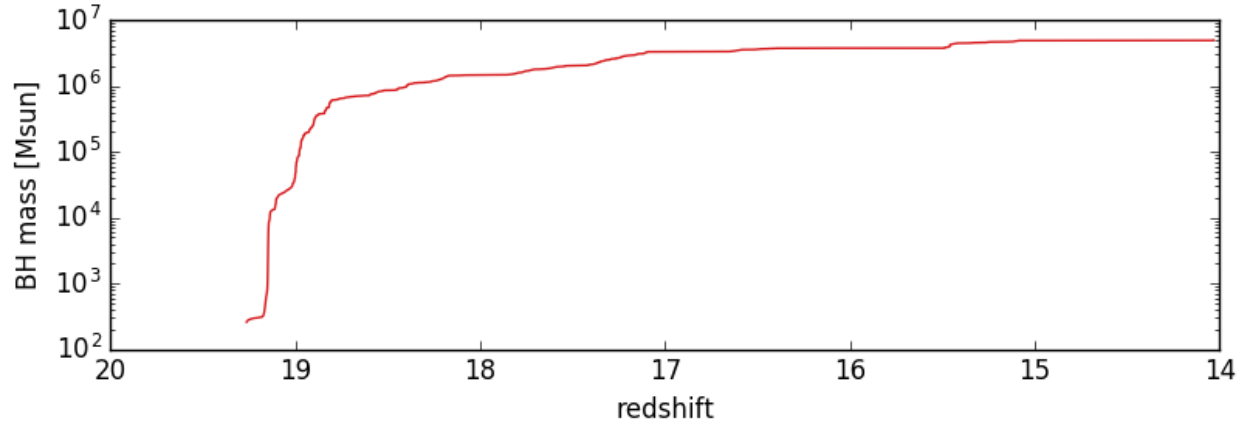
A test case: a sink in an isolated disc

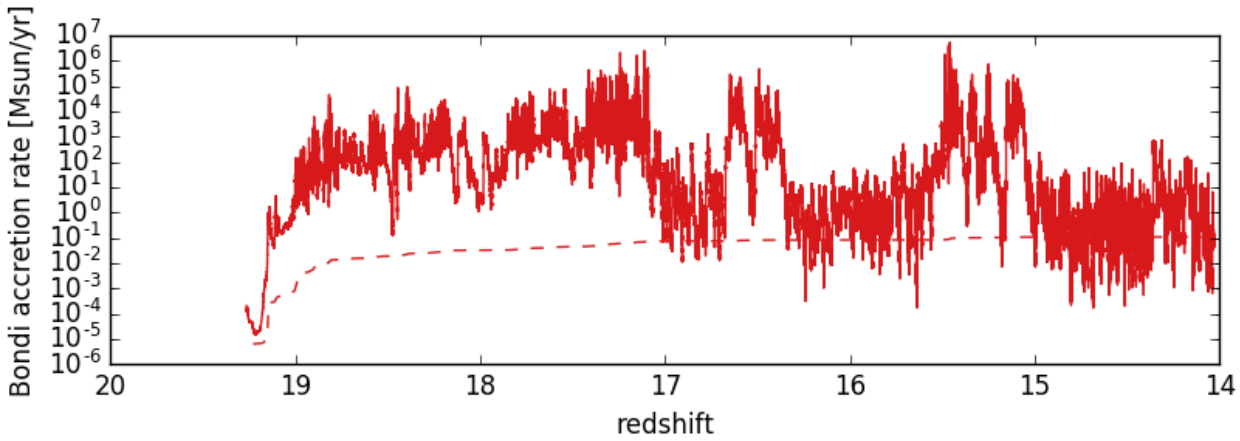


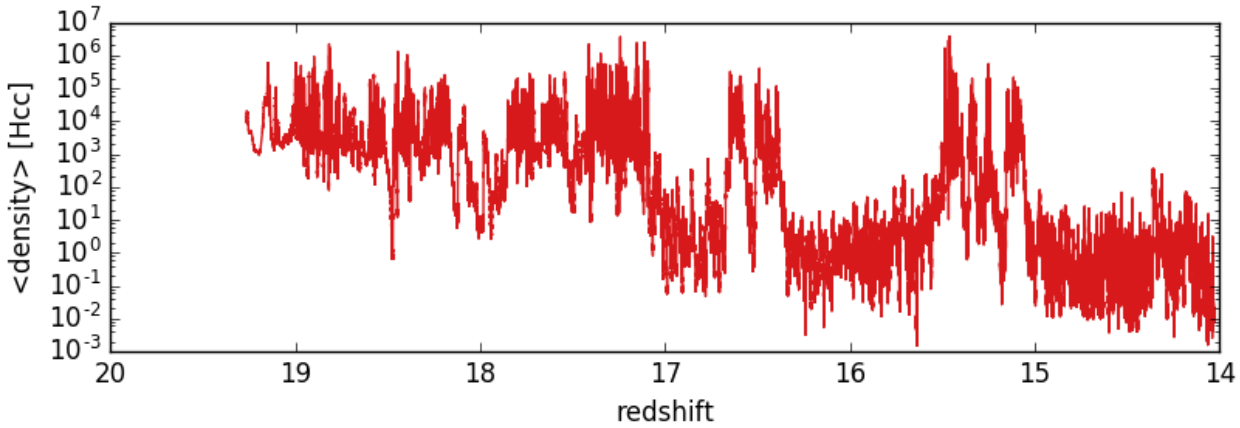
A test case: small scale features



The cosmological simulation







Summary

We are …

- … bridging the gap between cosmological and isolated disc simulations to study the growth of SMBHs during the first billion years of the universe.
- … studying gas flows covering over ten orders of magnitude in scale.
- … getting an unprecedented look at the gas dynamics during black hole accretion, finding subparsec scale accretion structure.
- … seeing steady super-eddington growth and an ample gas supply, suggesting that SMBH masses will be reached by redshift 6.
- ... going to add feedback effects as the next step.

Thank you