

# From seed to supermassive

growing high redshift black holes in cosmological  
simulations

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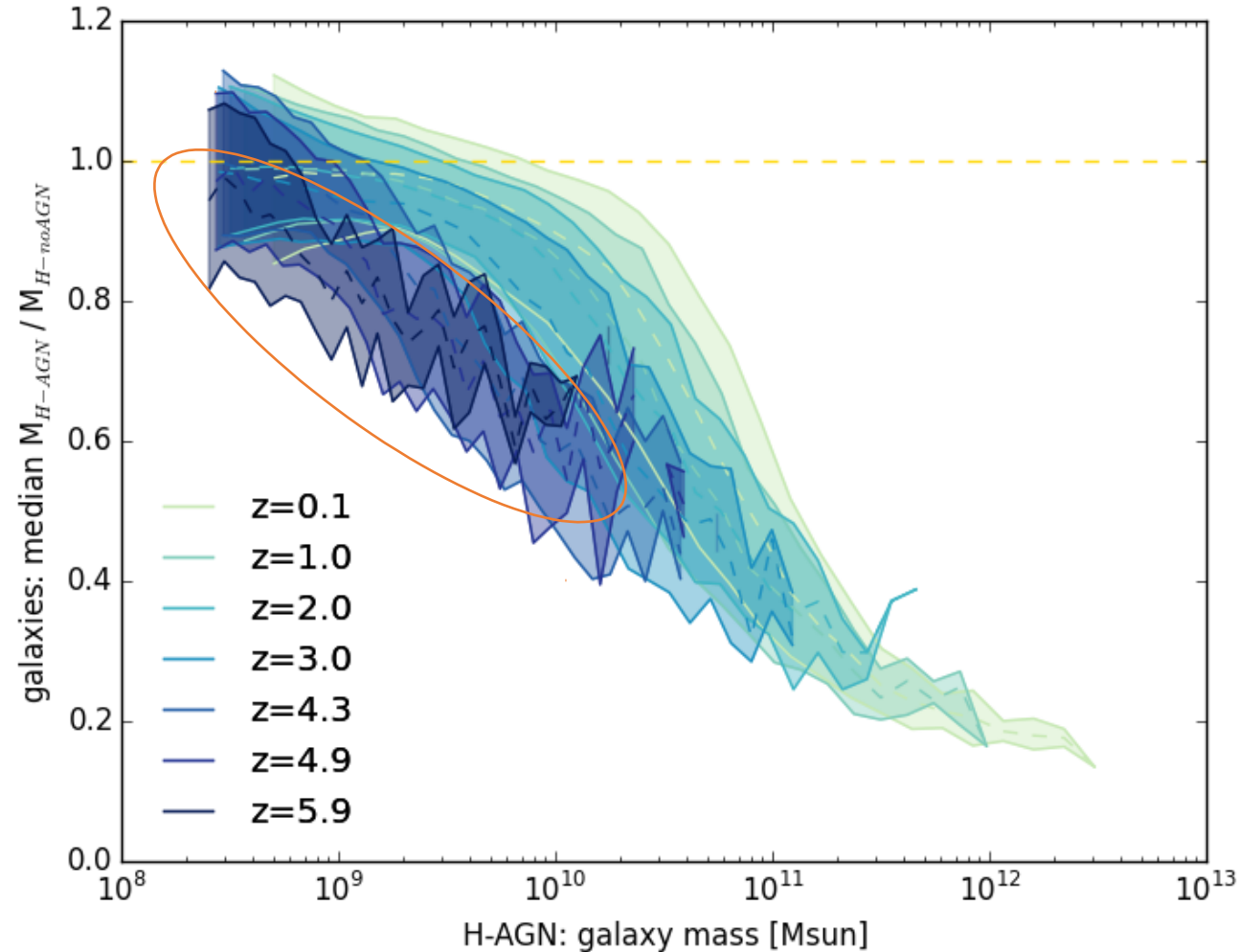
# Feedback from massive black holes is responsible for quenched galaxies in the local universe



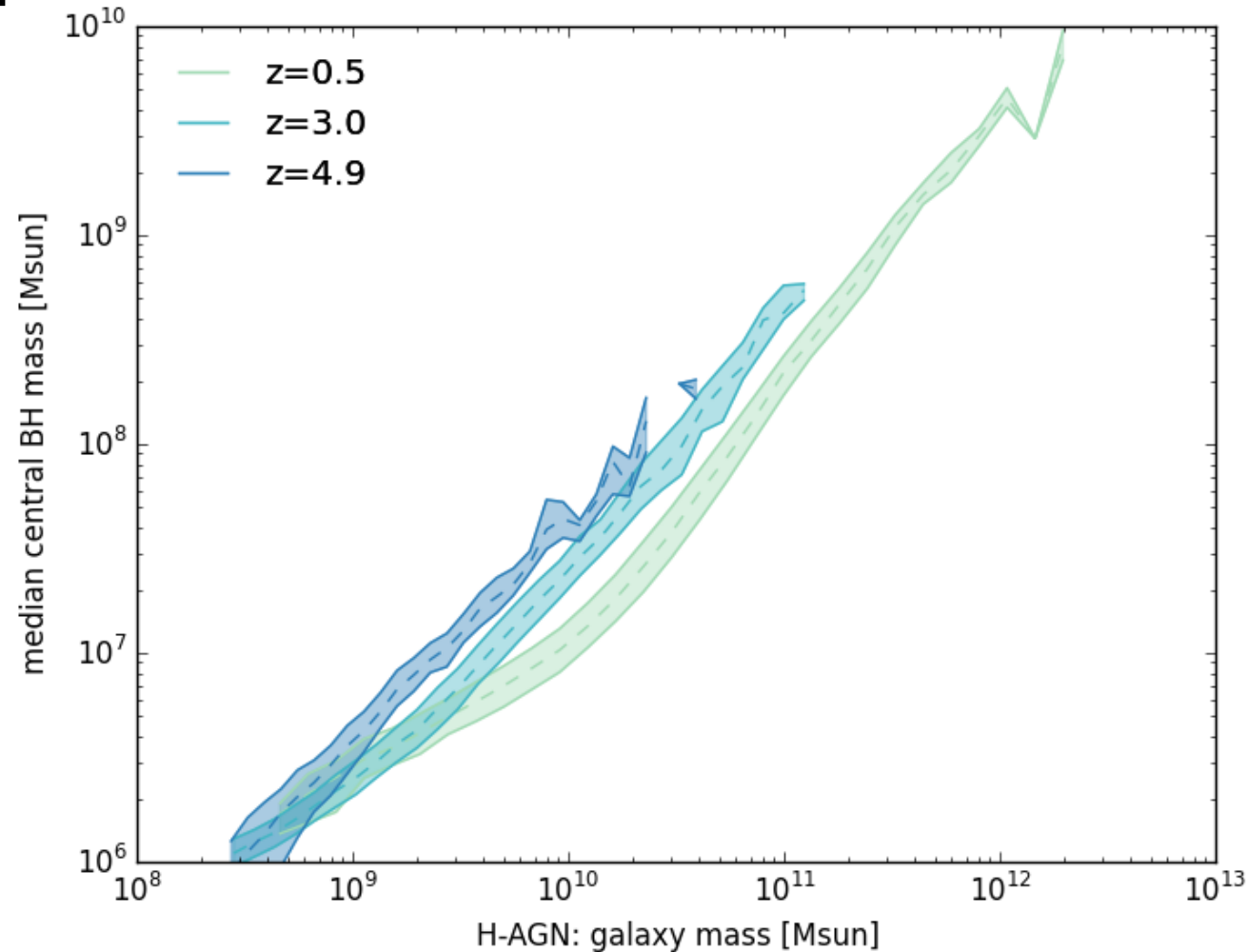
Effect of AGN  
feedback

Data from the HORIZON-AGN & HORIZON-noAGN simulations: Dubois et al 2014, Welker et al 2015, Volonteri et al 2016, Kaviraj et al 2016, Beckmann et al (in prep)

# At $z=6$ , massive galaxies are already quenched



# Black holes growth precedes galaxy growth



# Black holes in cosmological simulation

In HORIZON (Dubois2014,Welker2015,...):

- Seed the BHs at  $1E5 M_{\text{sun}}$
- 1kpc resolution
- Grow using Eddington limited Bondi accretion

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

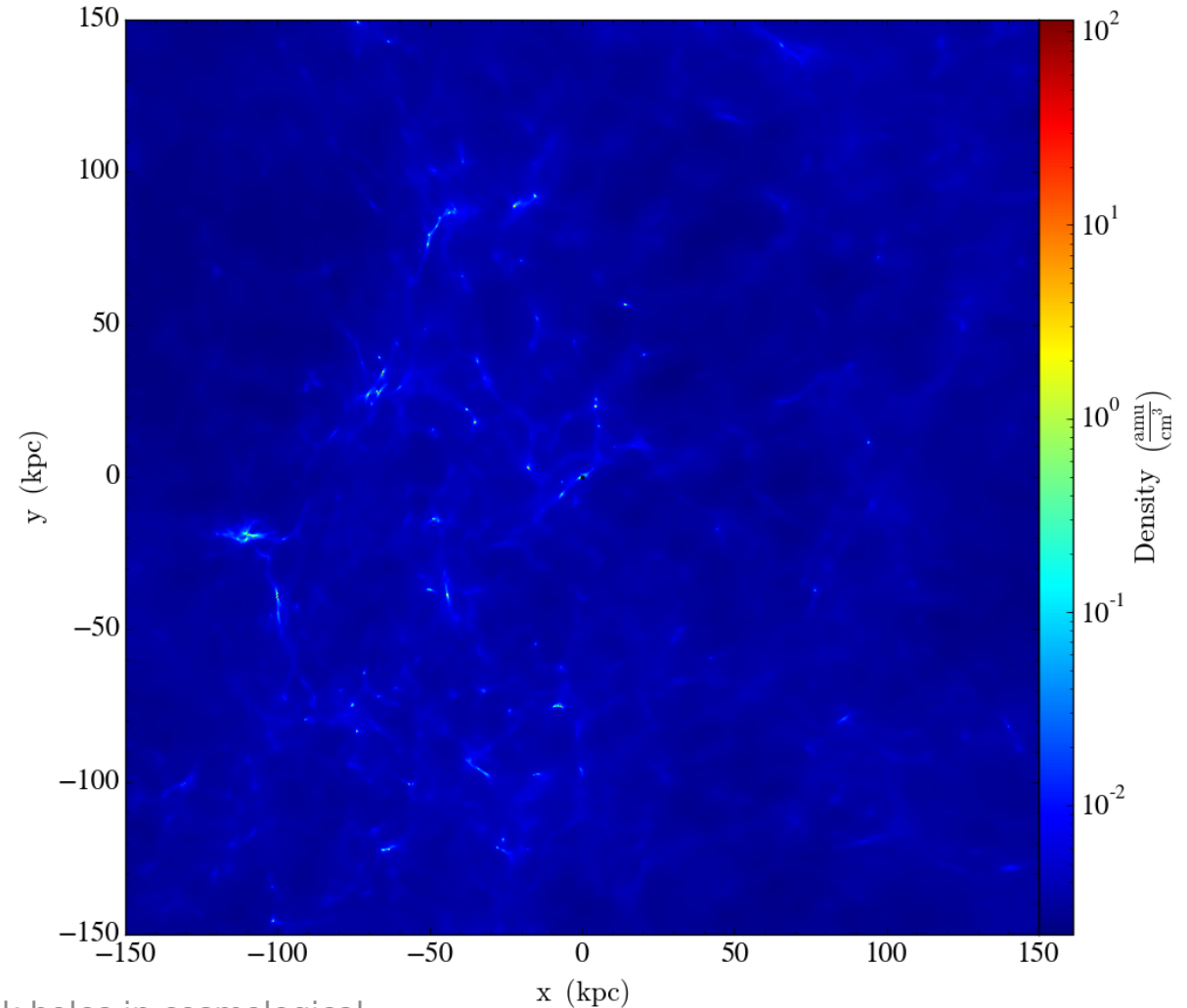
# Where do these black holes physically come from?

## SEEDING MODELS

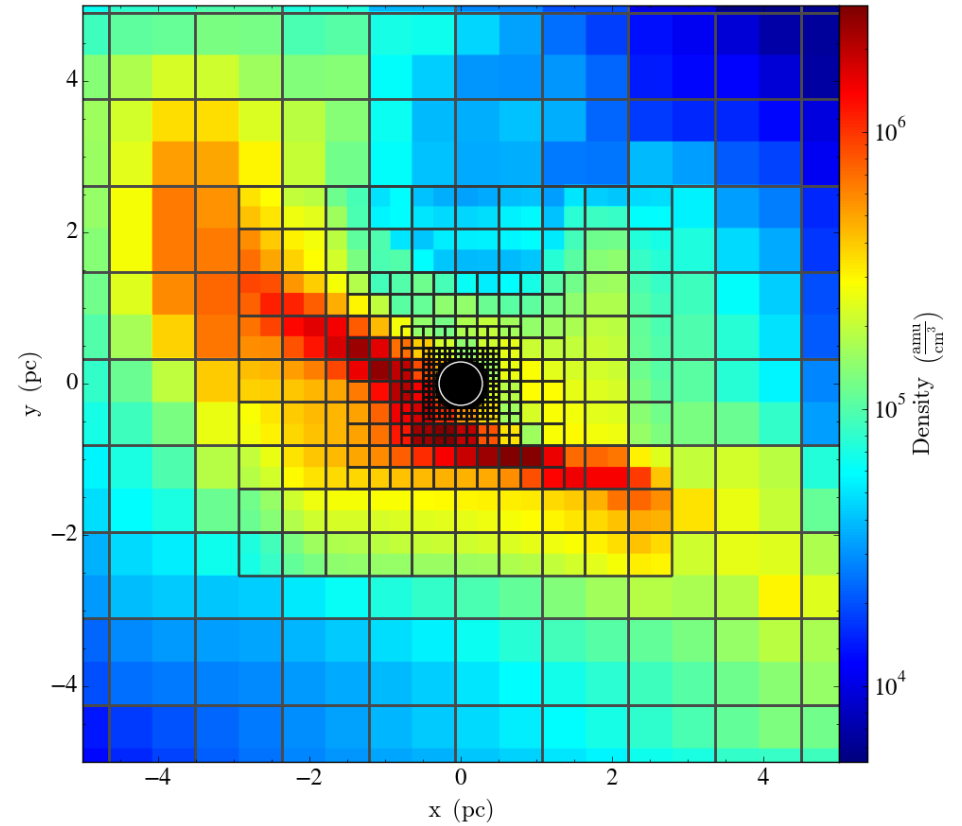
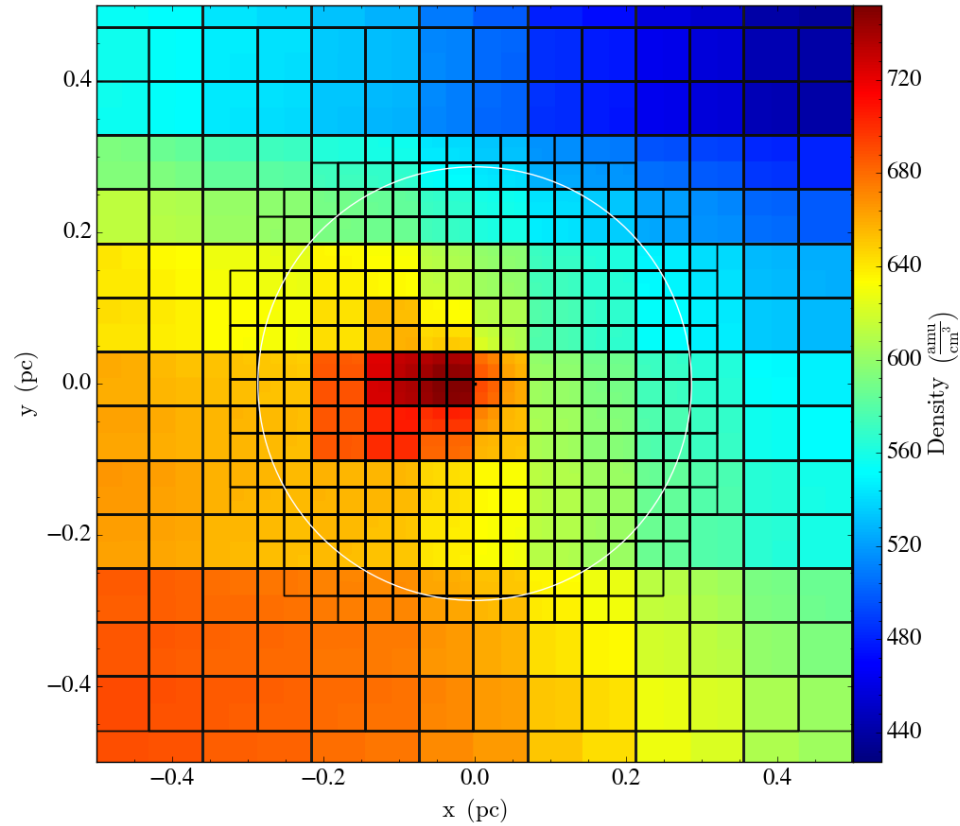
- **Direct Collapse:**  $1E5$  Msun seeds, needs metal free gas and radiating neighbours  
(Begelman2006, Latif2013, Habouzit2016)
- **Runaway cluster collapse:**  $1E3$ - $1E4$  Msun seeds  
(Omukai2008, Devecchi2009, Katz2015)
- **Stellar mass seeds:** 1-100 Msun, (Haiman2000, Freyer2001, Alvarez2009, Heger2003 )

# Bridging the gap from seed to supermassive

- stellar mass seed (260  $M_{\text{Sun}}$ )
- a cosmological context (1Gpc box with 5 Mpc zoom region)
- high resolution ( $\Delta x=0.01$  pc)
- run to redshift 6
- AMR hydro (RAMSES)

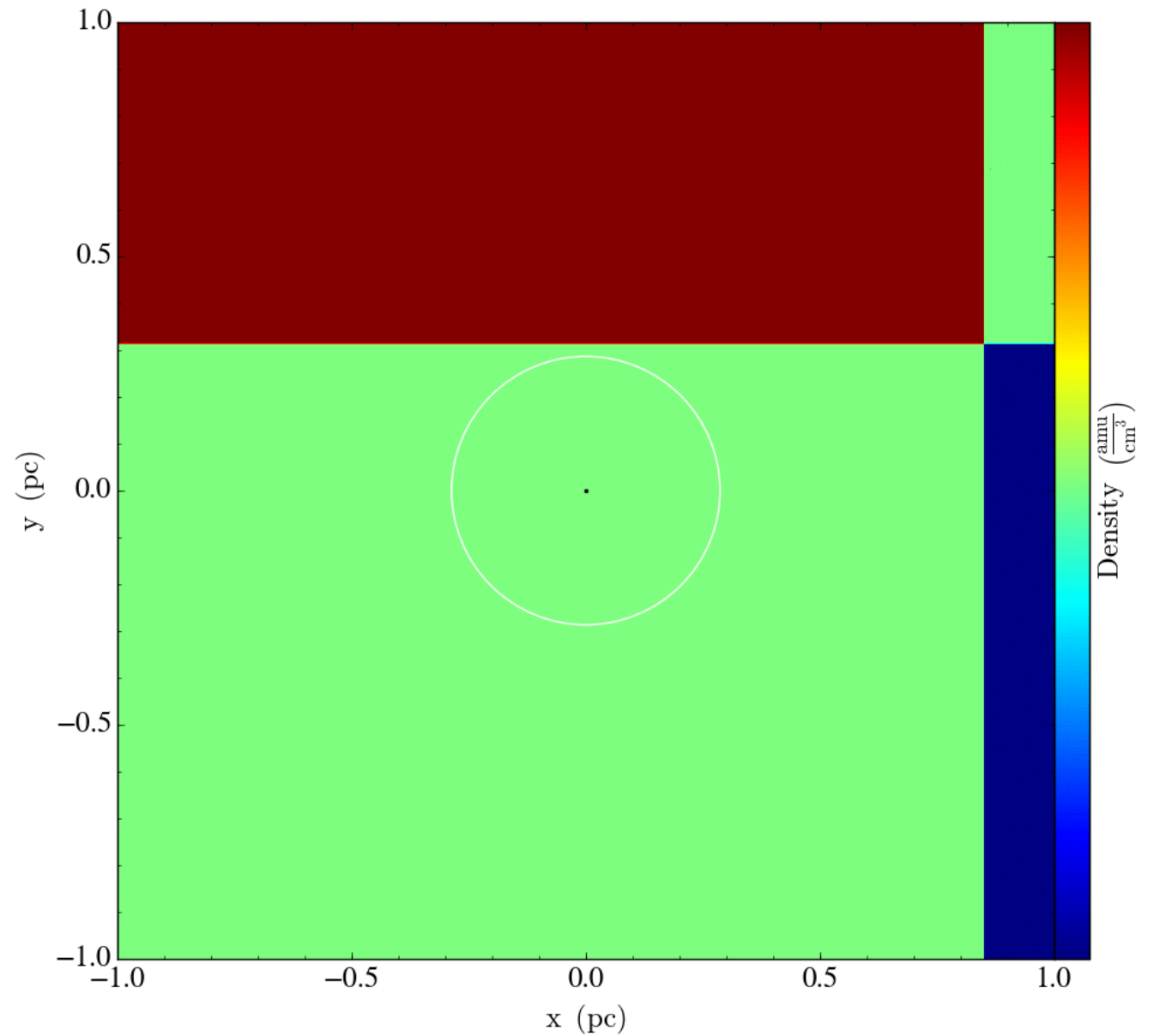


# Zoom-within-Zoom

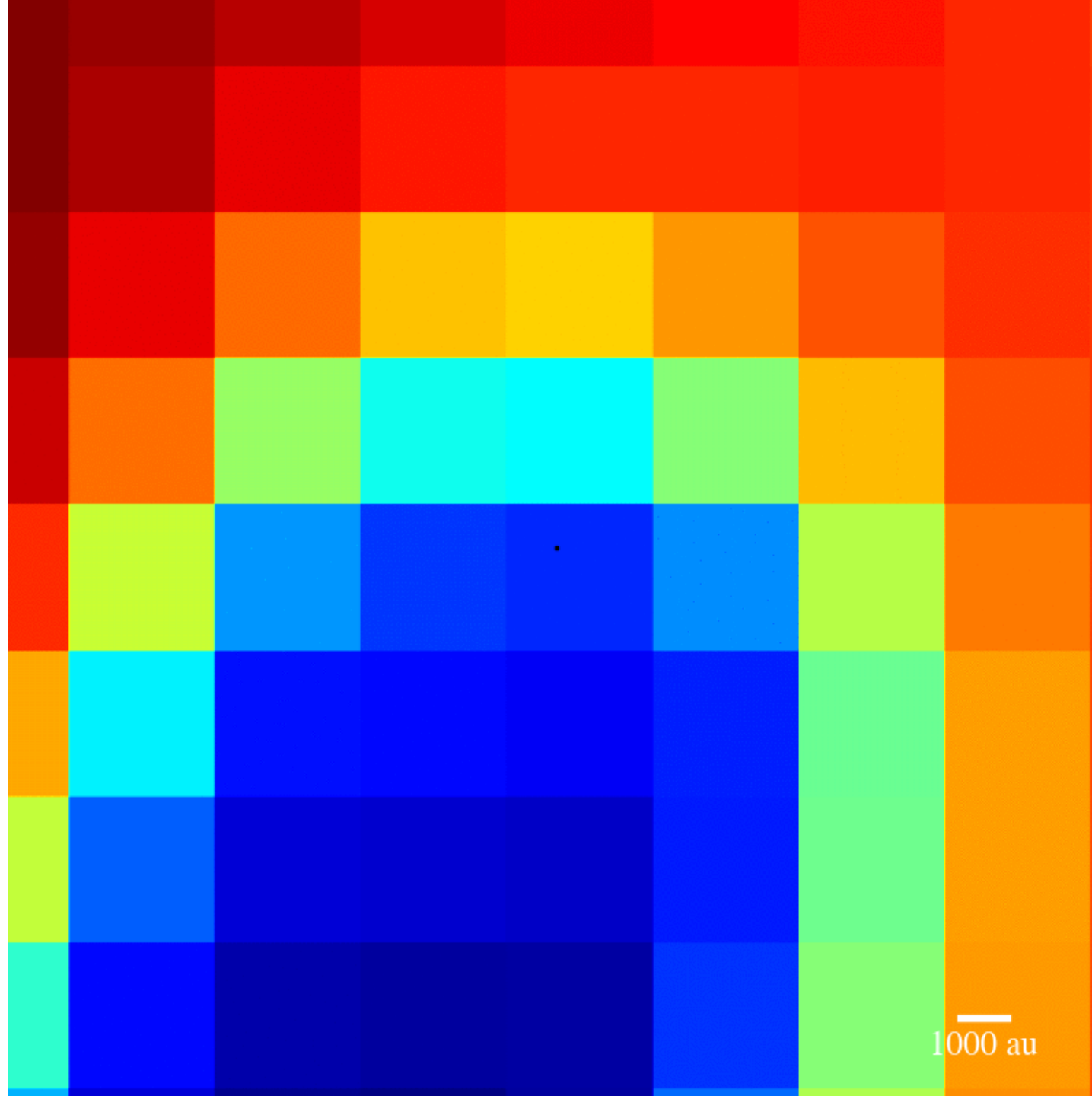




# Gradual triggering of levels

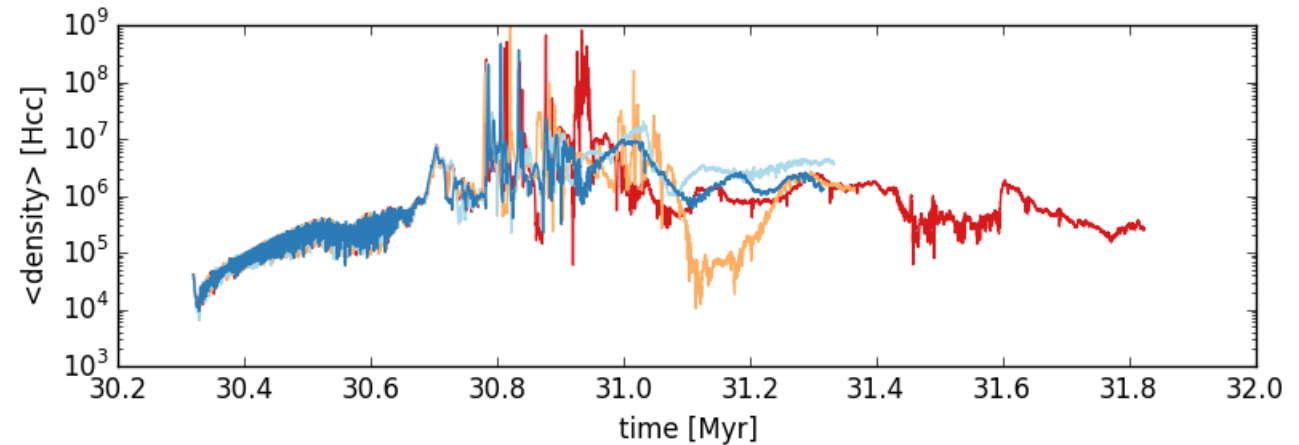
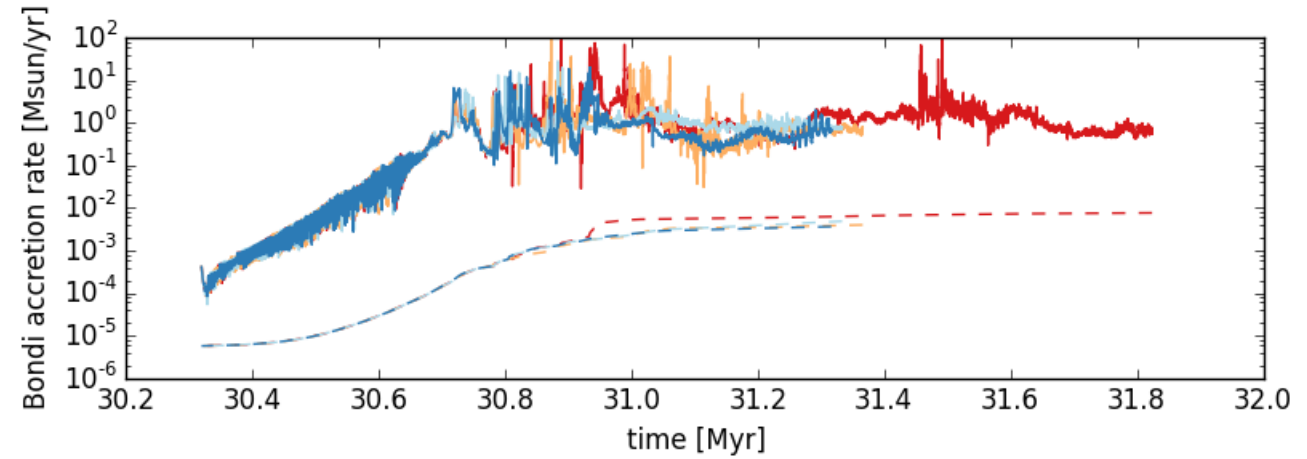
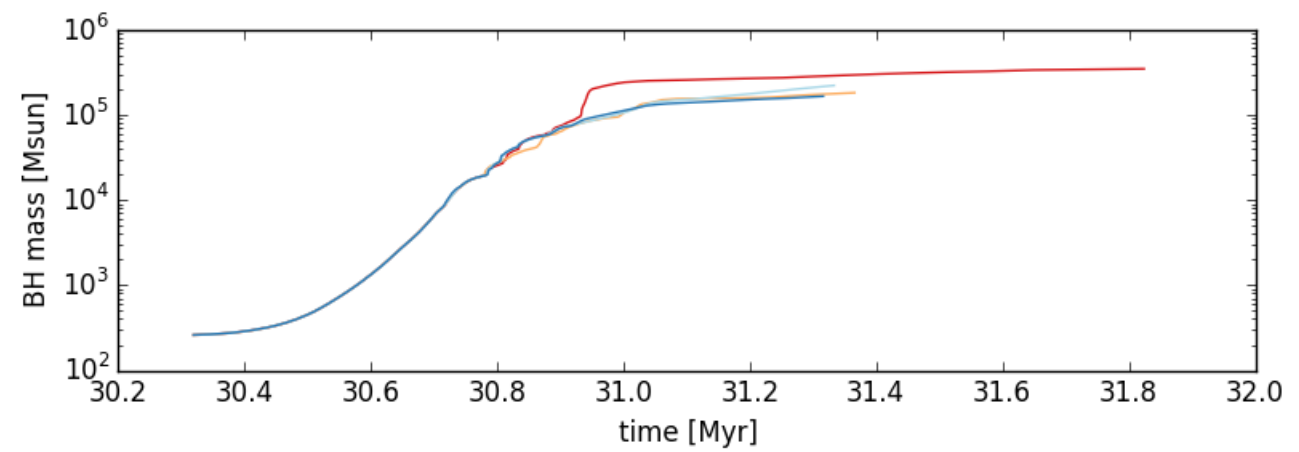


# Density

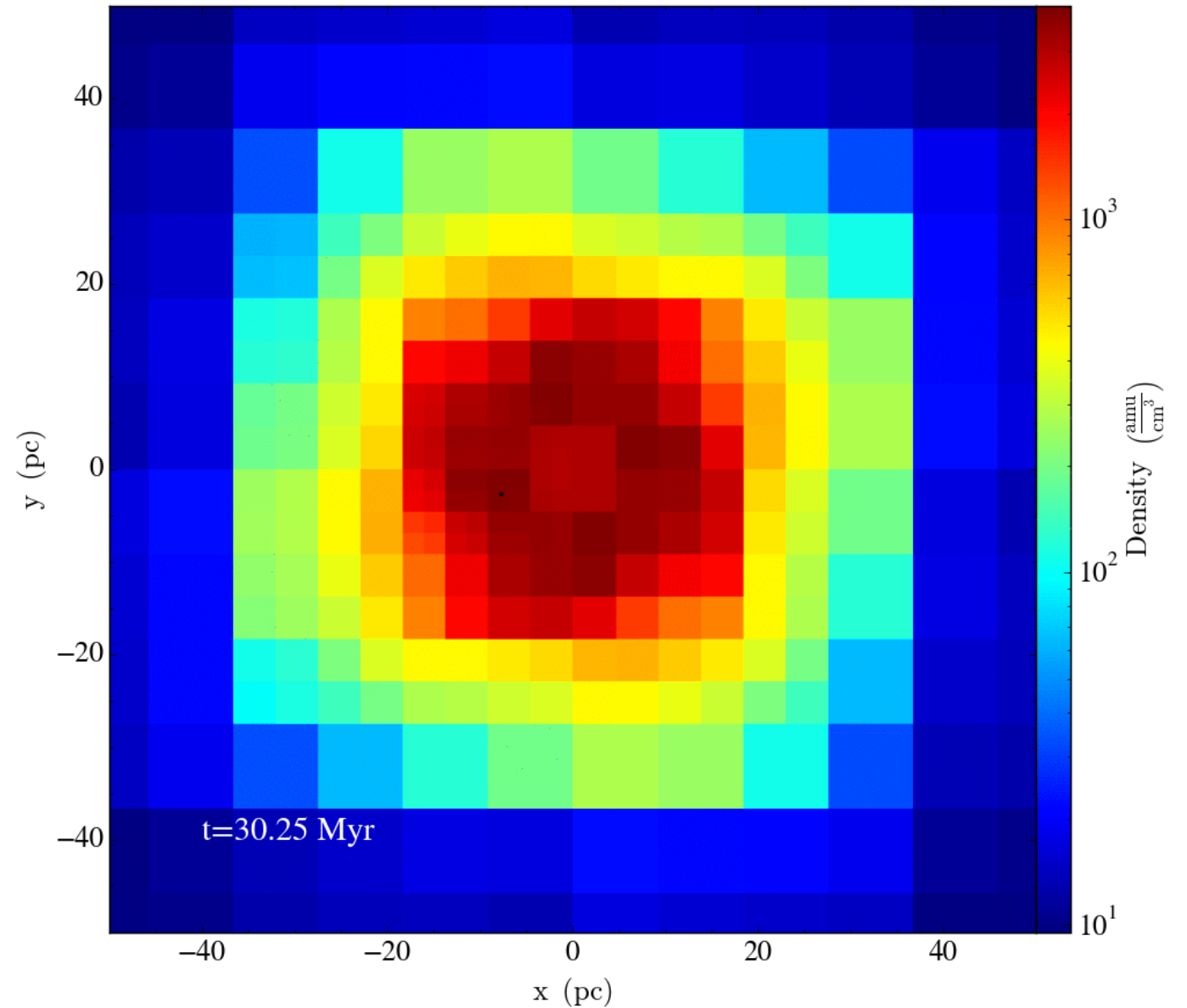


# RESULTS

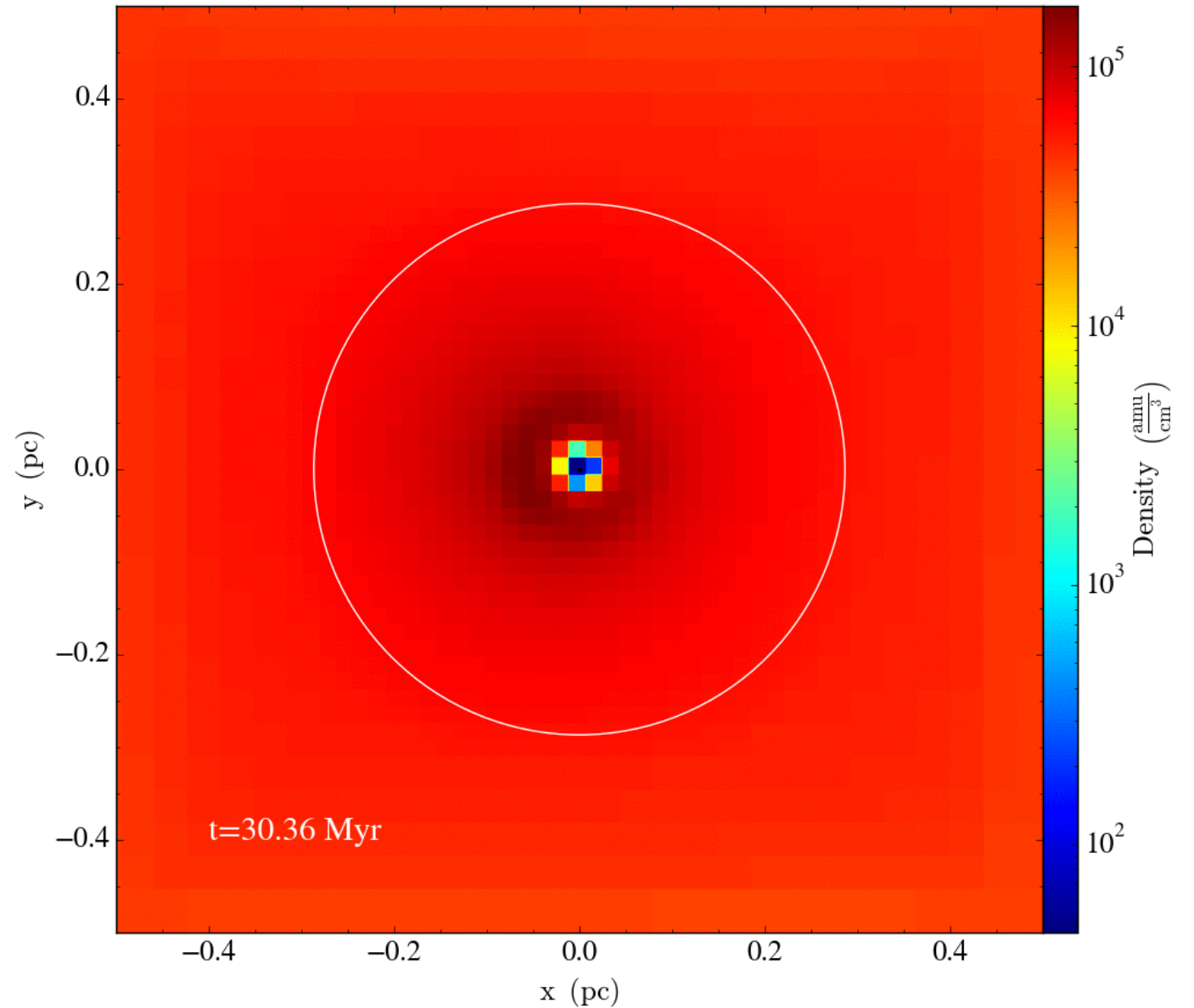
# A test case: an isolated disc



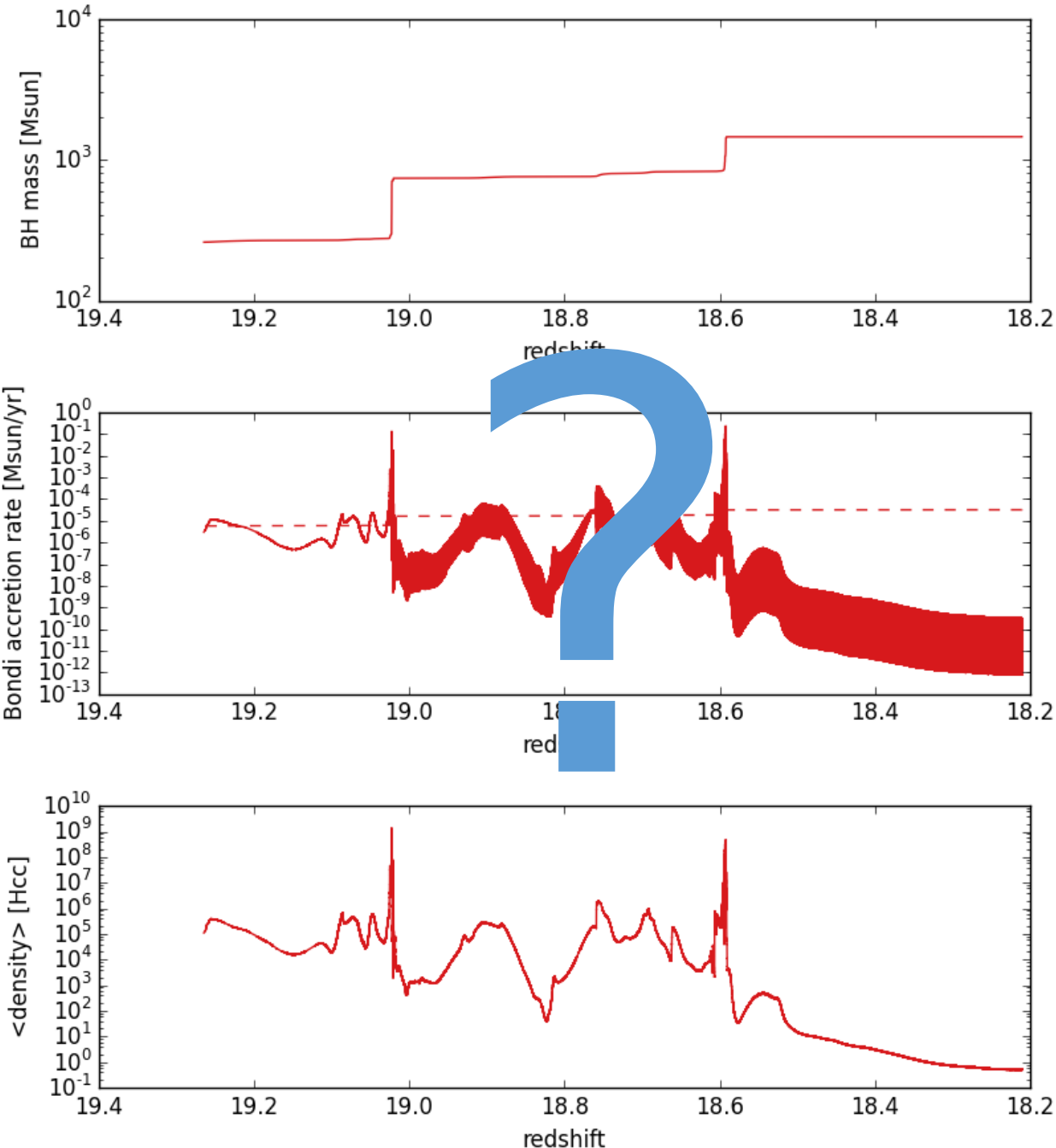
# A test case: a sink in an isolated disc



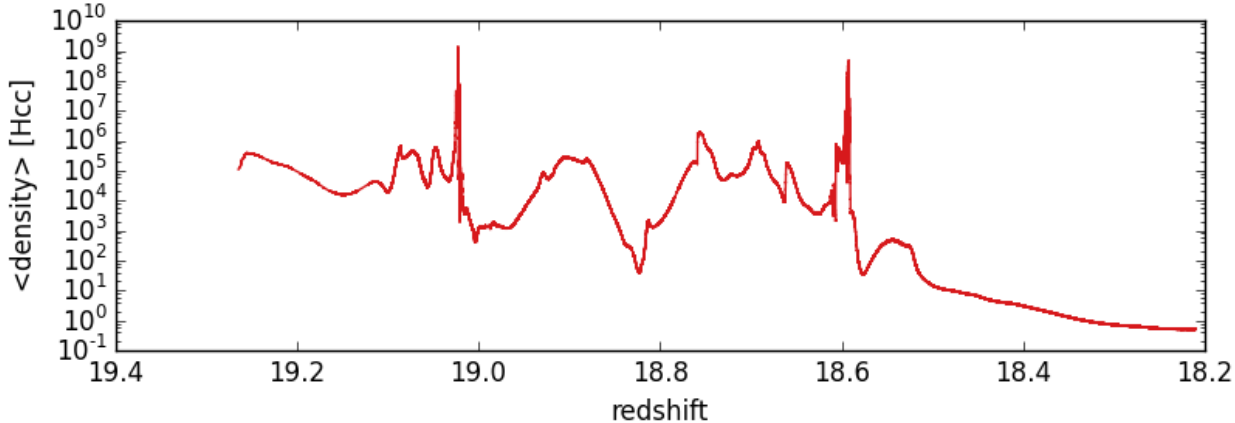
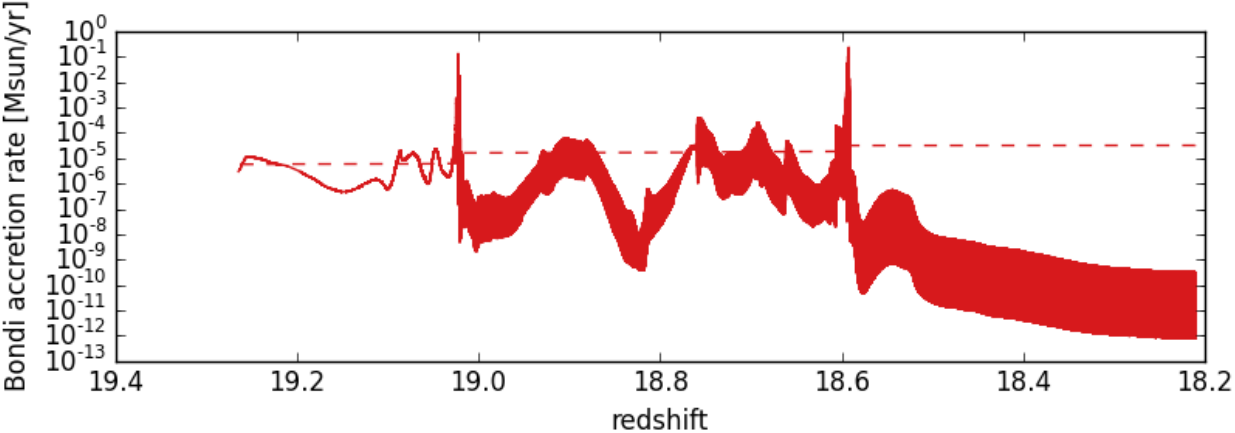
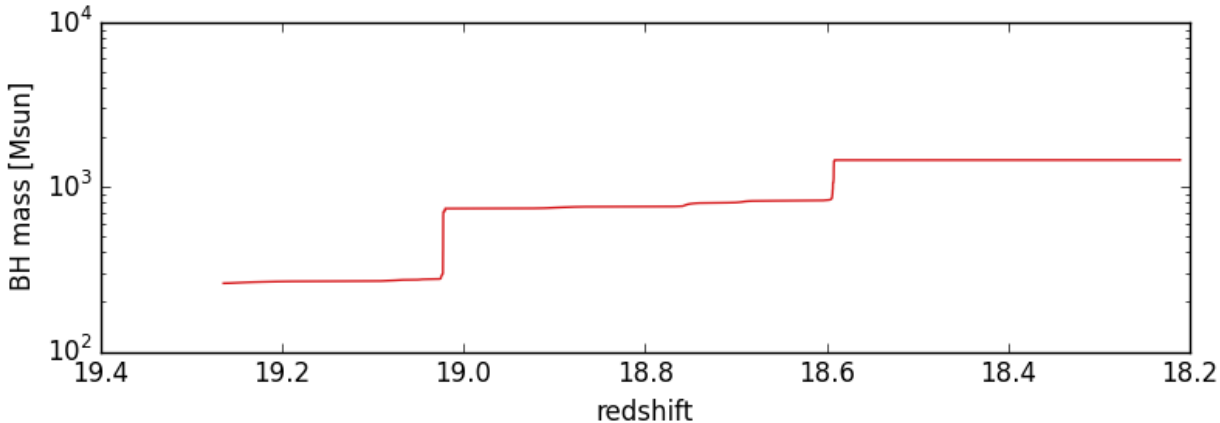
# A test case: small scale features



# The cosmological simulation



# The cosmological simulation





Thank you