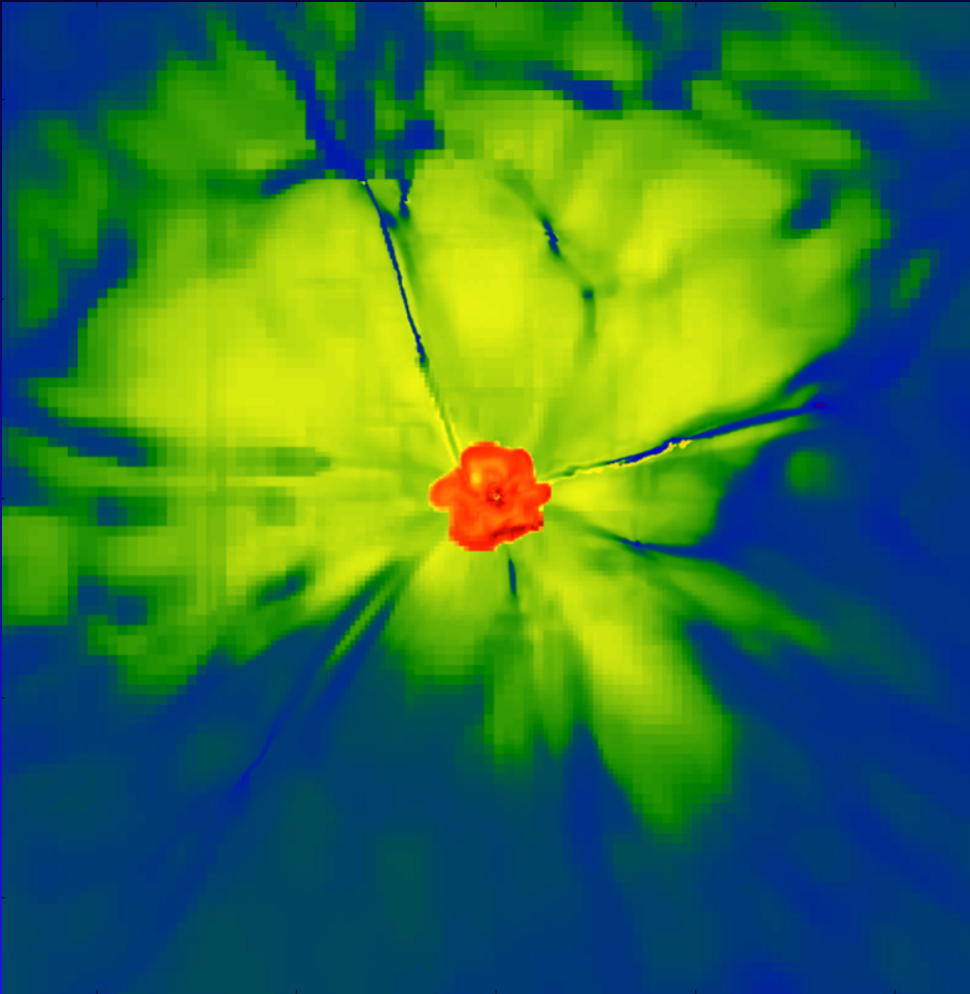


How Supermassive Black Holes Form by $z \sim 7$



Daniel Whalen

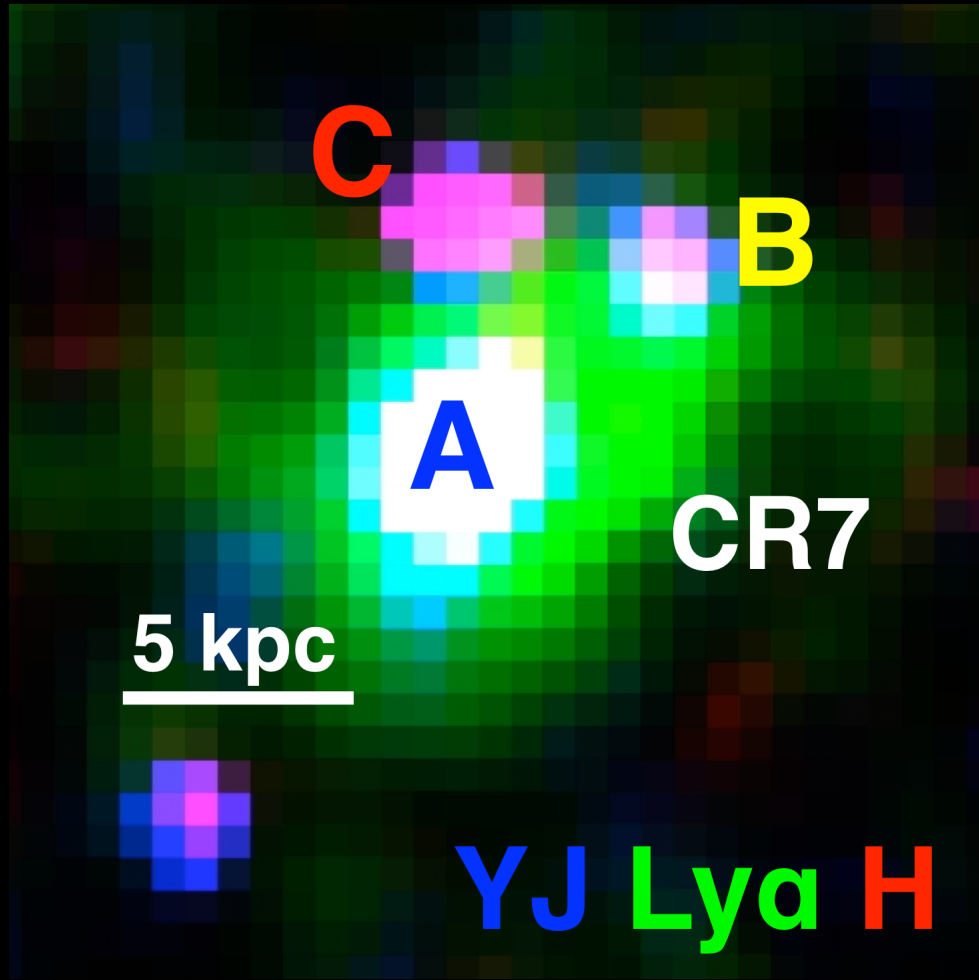
Institute for Cosmology and
Gravitation, University of
Portsmouth

Joe Smidt (LANL), Jarrett
Johnson (LANL), Hui Li (LANL)

Marco Surace (ICG), Carla
Bernhardt (ITA / Heidelberg)

The Case For SMBH Seed Formation by Direct Collapse for $z > 6$ quasars

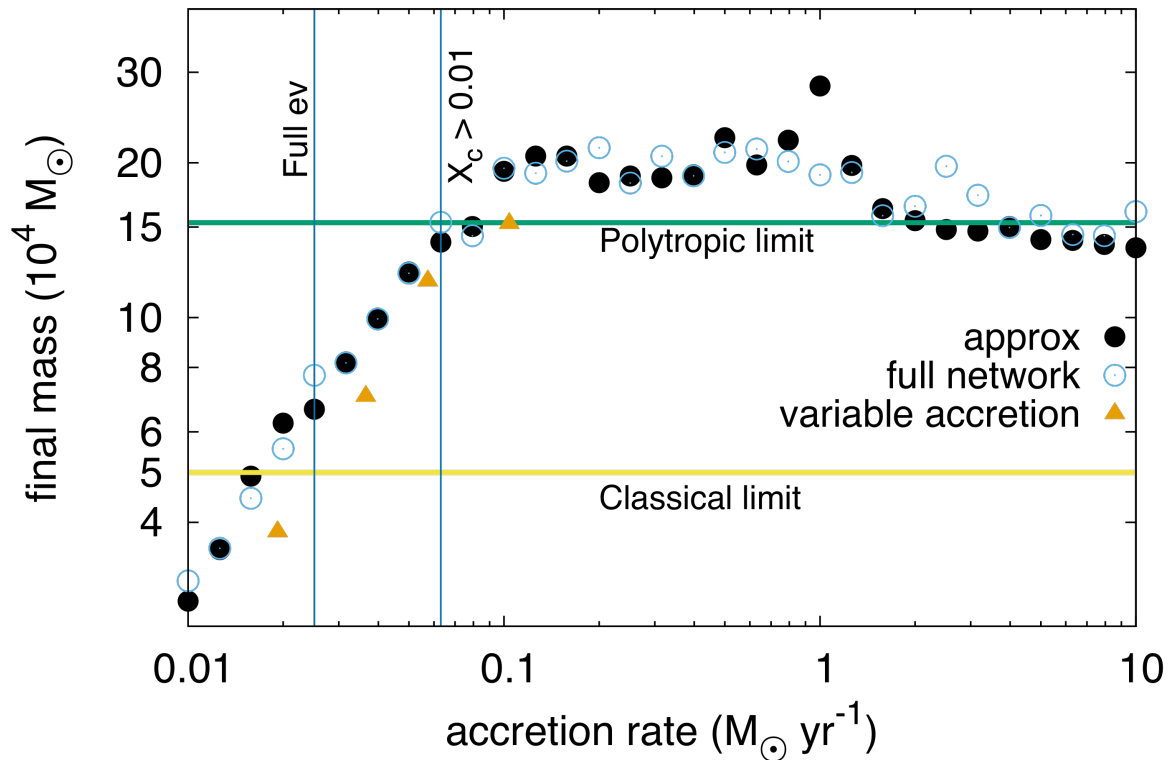
- Pop III BHs are “born starving” (Whalen et al. 2004; Alvarez et al. 2006; Abel, Wise & Bryan 2007)
- once accretion begins, low-mass halos have gravity potentials that are too shallow to retain gas that is heated by x-rays (e.g., Whalen et al. 2004)
- low-mass Pop III BHs are often ejected from their host halos, and thus their fuel supply (Whalen & Fryer 2012, ApJL, 756, 19)



DCBH Candidate: CR7

Supermassive Pop III Stellar Mass at Collapse

Woods + DJW et al. 2016 in prep; Hammerle + DJW et al. 2016

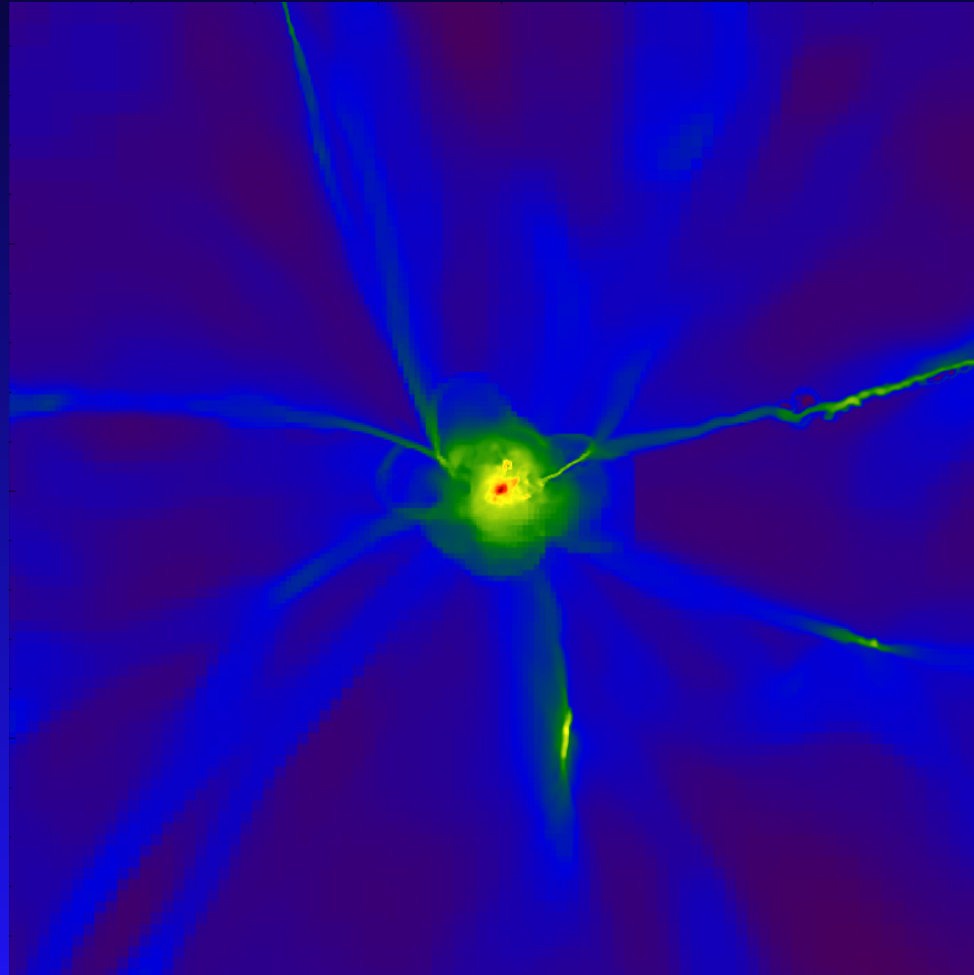


Enzo Supermassive Black Hole Formation Simulations

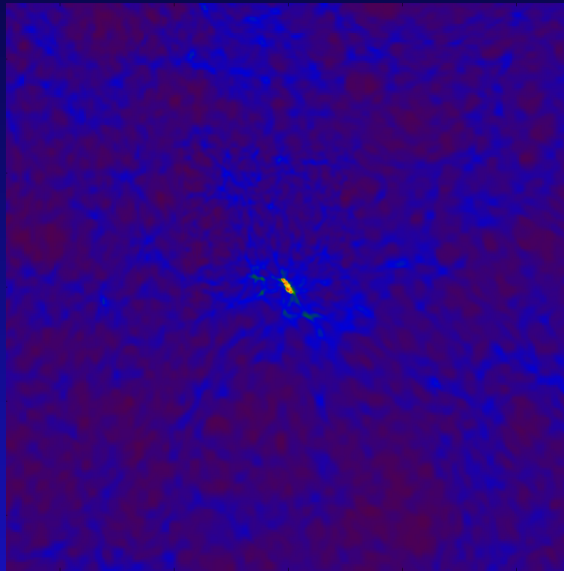
Smidt, DJW et al. 2016 in prep

- 100 Mpc box, initialized at $z = 200$
- x-ray emission from a 10^5 seed in a 5×10^8 solar mass halo at $z \sim 19$
- prescription for AGN jet feedback is included (DeBuhr et al. 2010)
- single photon energy of 1 keV – adaptive raytracing photon transport with the MORAY radiation package
- 10 levels of refinement, resolution of 30 pc
- subgrid alpha disk model of accretion
- multiphase star formation feedback in host galaxy (rad + SN)

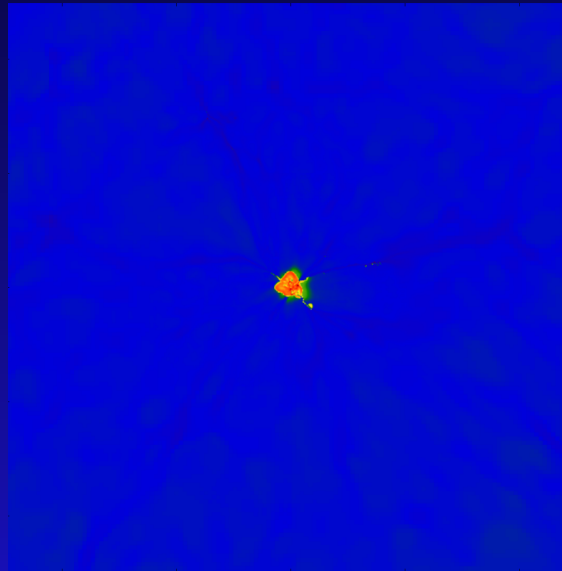
Cold Streams are Key to Formation of the First Quasars



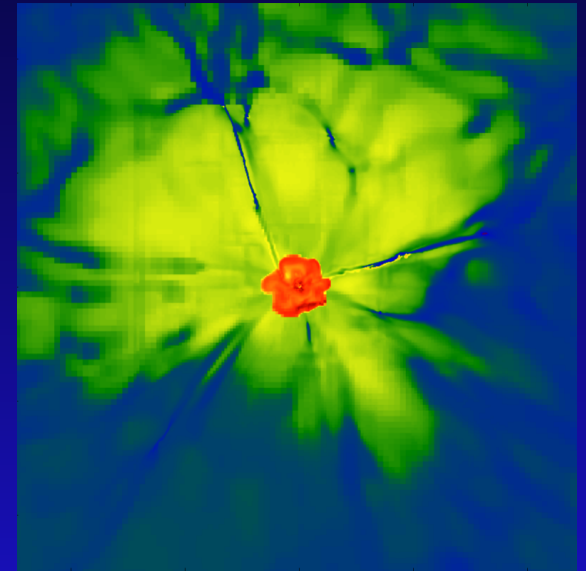
H II Region of the Quasar



$z = 17$

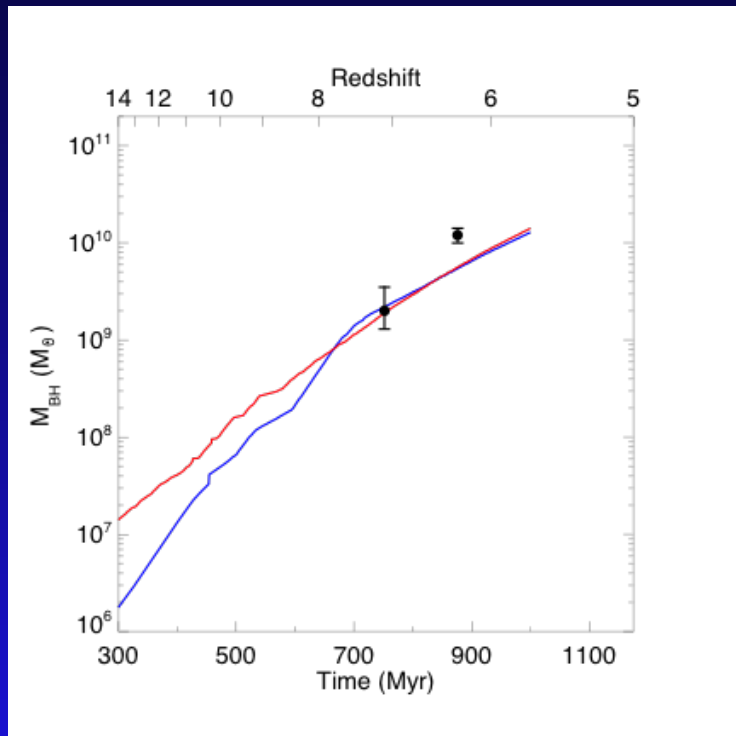


$z = 9.5$

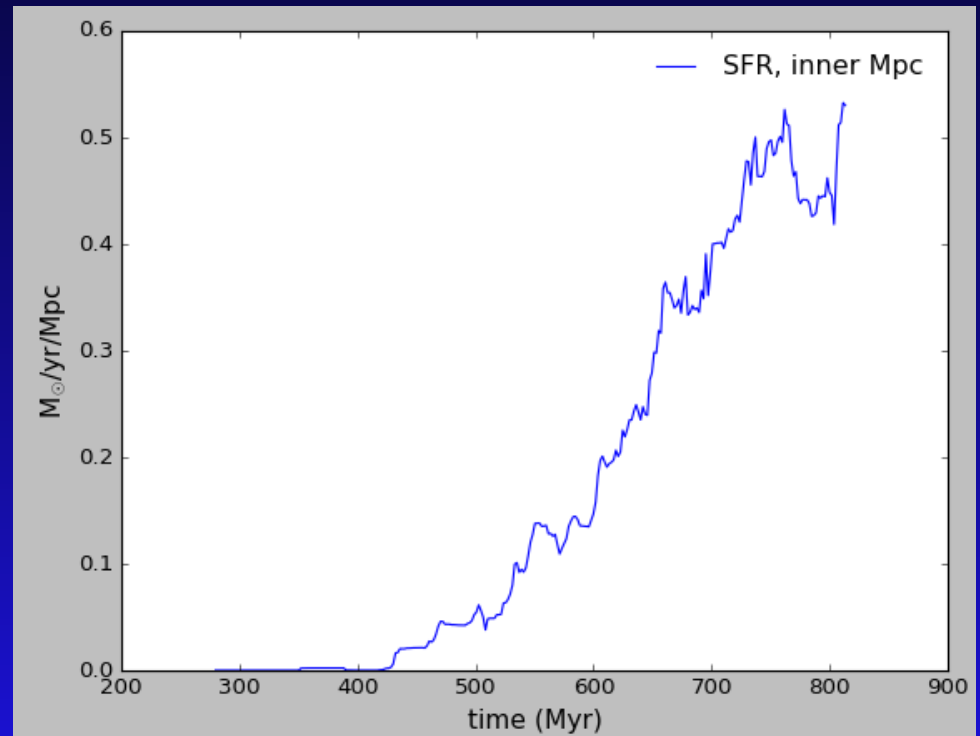


$z = 7$

Primordial Star Formation Regulates SMBH Growth Rates from $z > 10$

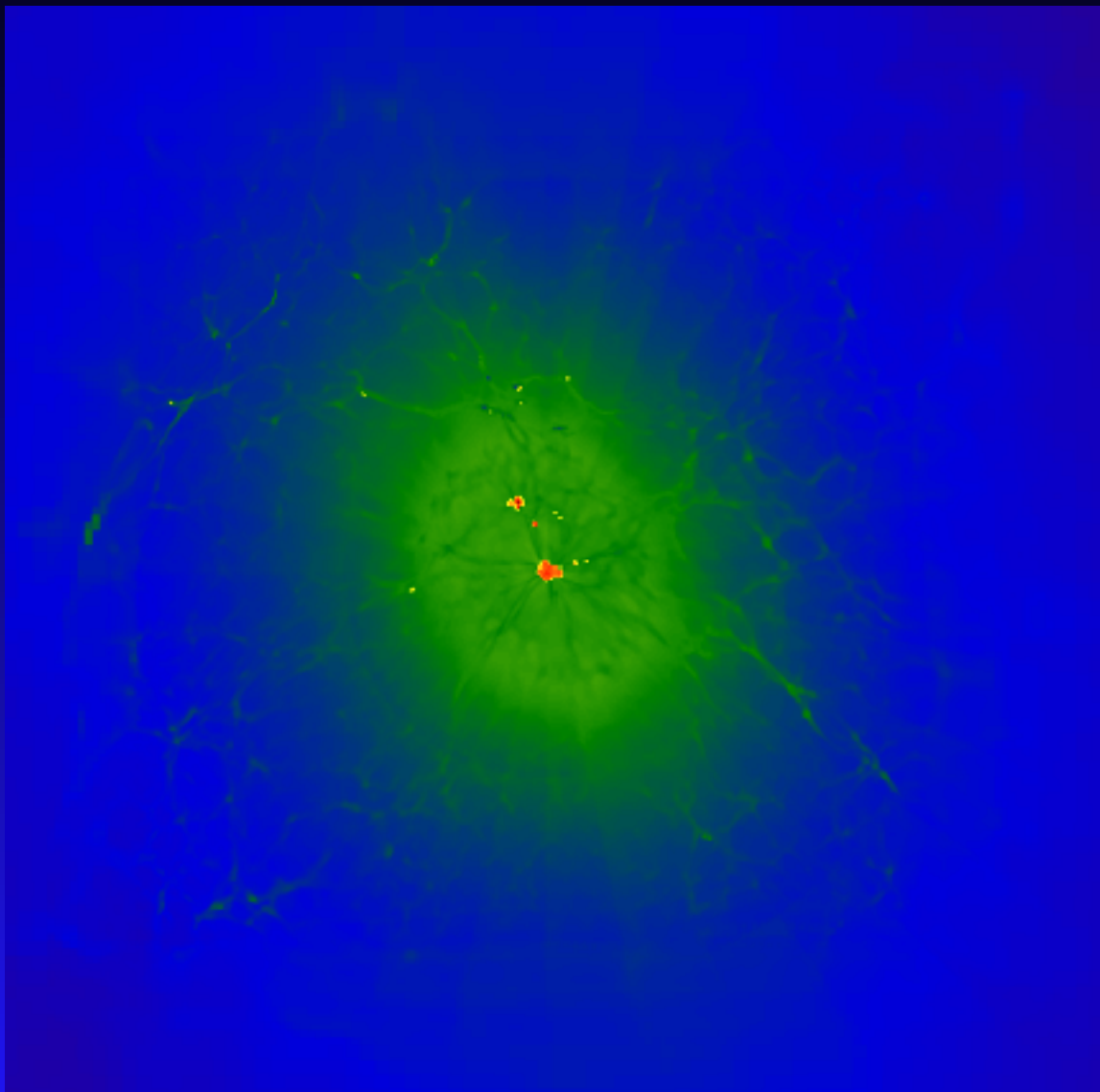


SMBH Mass

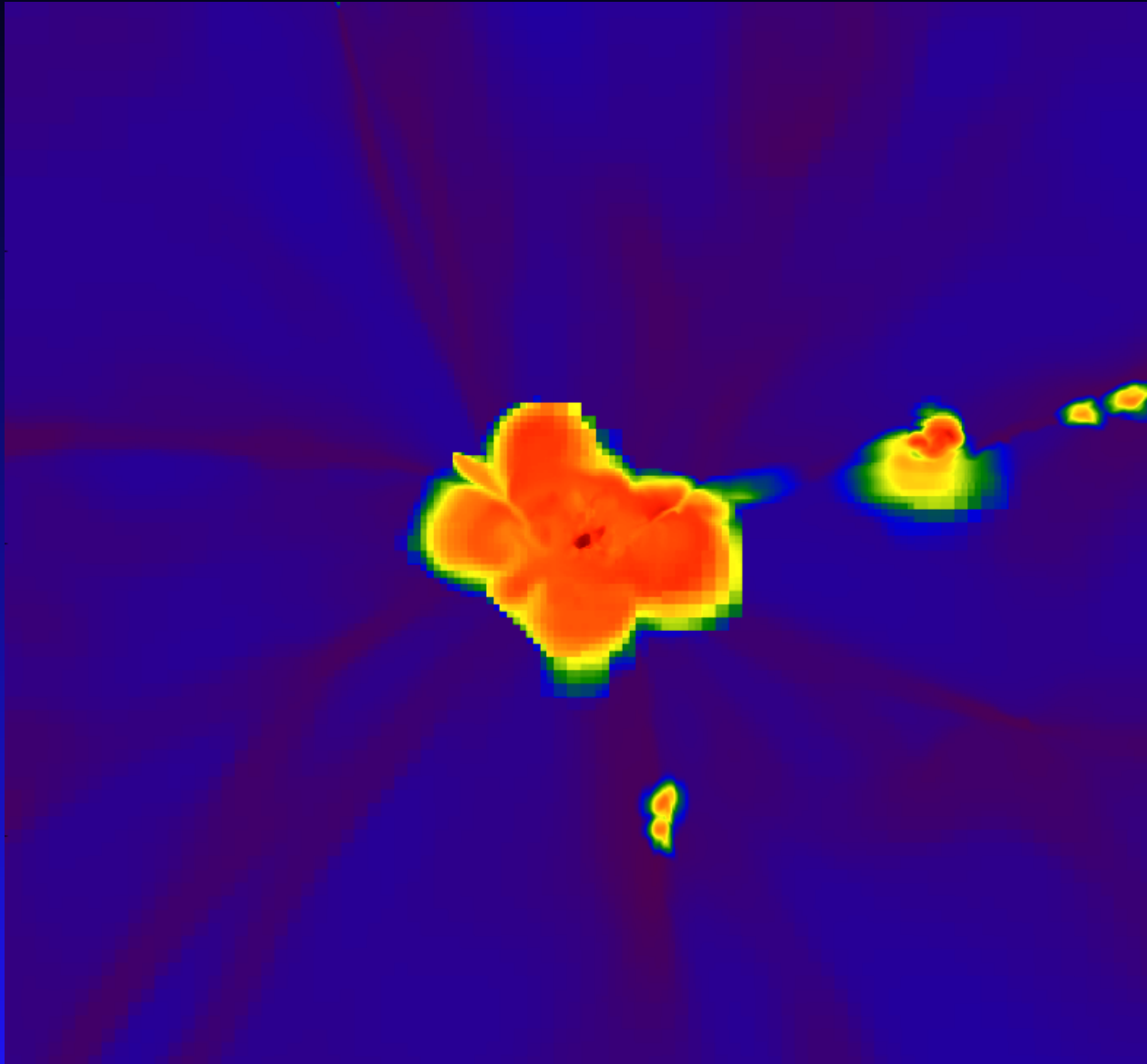


SFRs in the Host Galaxy

Quasar Proximity Zone and SN Feedback



Metal and Dust Enrichment in the Host Galaxy



Conclusions

- x-ray feedback + SF rad / SN feedback can account for the existence of the Mortlock 2011 and Wu 2015 quasars
- Pop III BHs almost certainly cannot be the origin of these two quasars
- BH mergers, while not ruled out by our models, are not required to create the Mortlock or Wu quasars
- cosmological x-ray rad hydro allows us to calculate realistic synthetic observables for the first quasars (NIR continuum, Ly- α , 21 cm)
- next steps are ensemble studies of large numbers of $5 < z < 15$ quasars to study the population at this epoch

SMBH Growth with Thermal Feedback in Massive Black

Feng et al. 2014, MNRAS, 440, 1865

