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

[Graph showing the relationship between final mass and accretion rate]
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 $5 \times 10^8$ 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-a, 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