Finding the First Quasars with High-z Surveys

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The First Quasars

- over 160 quasars have been found $z > 6$

- ULAS J1120+0641 is a 2 billion $M_\odot$ BH at $z = 7.1$ (Mortlock et al. 2011, Nature, 474, 616)

- ULAS J1342+0298 is an 800 million $M_\odot$ BH at $z = 7.5$ (Banados et al. 2018, Nature, 553, 173)

- how do BHs this massive form 650 Myr after the Big Bang?
Seeds of the First SMBHs

Volonteri, ARAA, 2010, 18, 279
New Work on the Collapse of Atomically-Cooled Halos

- We model catastrophic baryon collapse in a dozen atomically cooled halos at $z \sim 15 – 20$ with Enzo.
- $1.5 \, h^{-1} \, \text{Mpc}$ box, 15 levels of refinement for max resolution of 0.01 pc.
- 6–species primordial gas chemistry to approximate strong LW backgrounds.
- 9–species chemistry in UV fields to explore intermediate LW fluxes.
- We evolve the atomically cooled disk at the center of the halo for 2.5 – 10 Myr, much longer times than previously done.
- We tally accretion rates at the center of the disk for Kepler models of SMS evolution to determine DCBH masses at birth.
Evolution of the Accretion Disk
Accretion Rates / Toomre Stability Parameter
(6 species)
Evolution of the Disk (9 species, 5000 J$_{21}$)
Supermassive Pop III Stellar Evolution

SMS Mass at Collapse
Red SMS NIR AB Magnitudes


JWST NIRCam

WFIRST
Blue SMS NIR AB Magnitudes


- **2.50 µm**
- **3.56 µm**
- **4.44 µm**
- **4.60 µm**

**JWST NIRCam**

**WFIRST**
Enzo Supermassive Black Hole Formation Simulations

- 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 disk wind 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 (SN)
Quasar H II Region

$z = 17$

$z = 9.5$

$z = 7.1$
Synthetic QSO Spectrum at $z = 7.1$

Euclid H Band AB Magnitudes
Conclusions

• JWST will be sensitive enough to detect every stage of primordial quasar evolution (SMS, DCBH, and SMBH)

• but its narrow survey footprints may not encounter many of these objects

• Euclid and WFIRST can detect these quasars at $z < 12 – 15$

• their large survey areas will probe the evolution of the first quasars at much earlier stages of their growth than previously possible