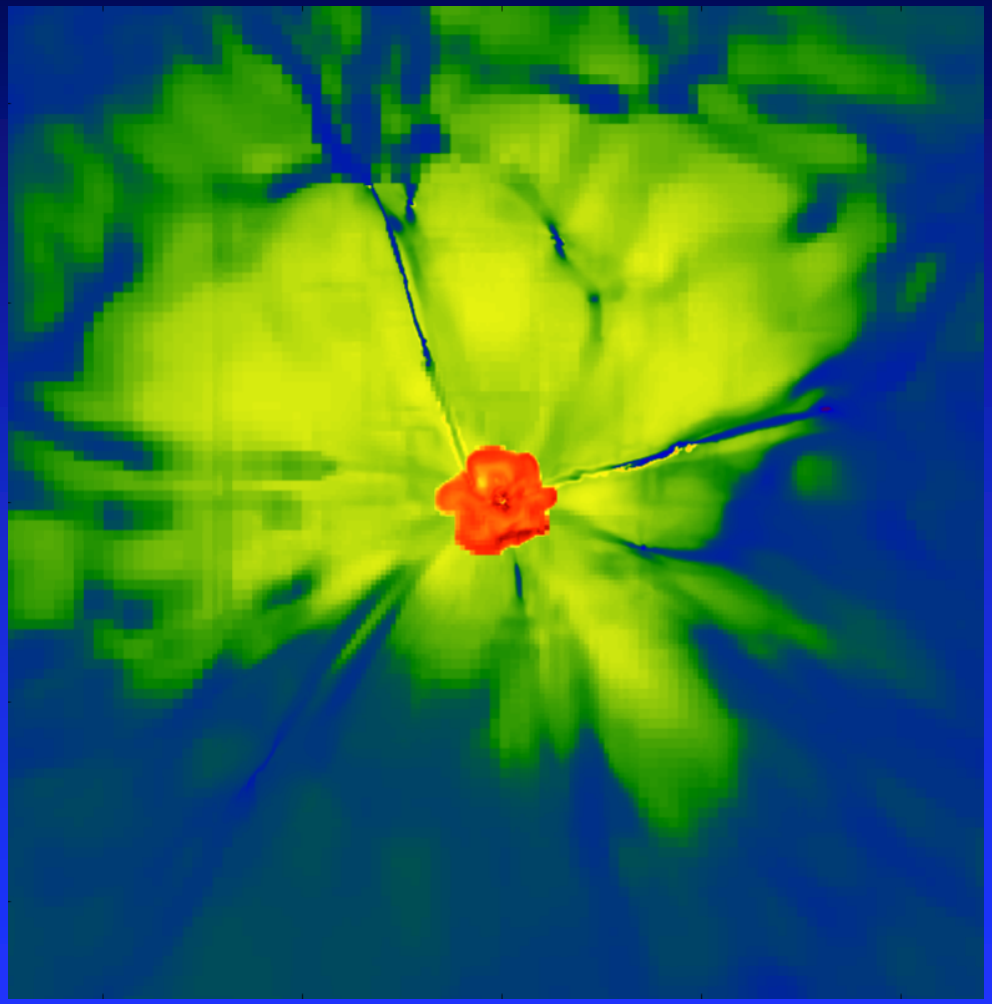
Finding the First Quasars with JWST, Euclid and WFIRST



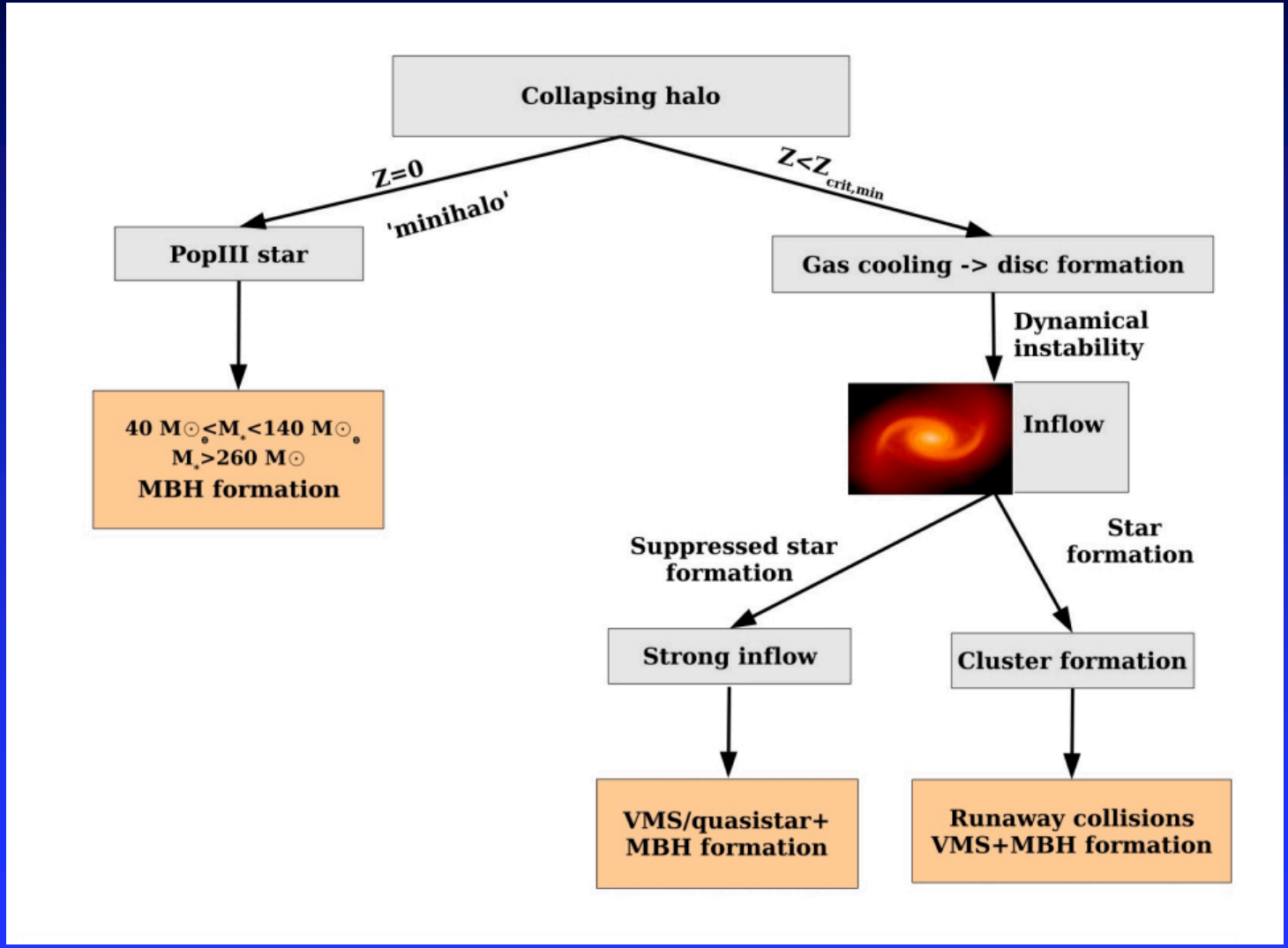
Daniel Whalen
ICG, Portsmouth

Supermassive Black Holes: Environment and Evolution, Corfu, 19-22 June 2019

The First Quasars

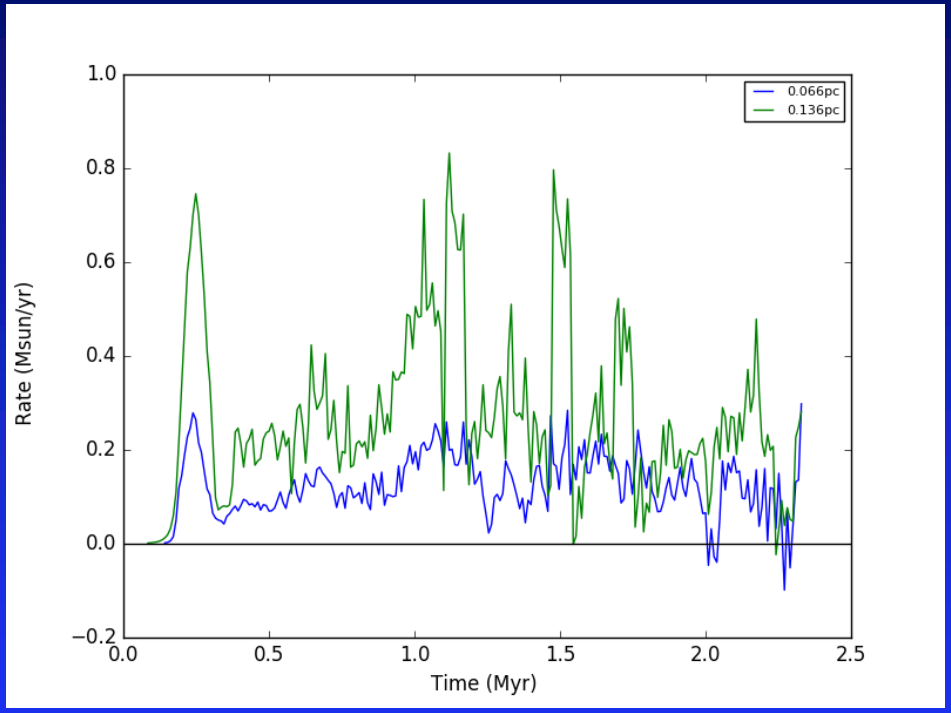
- over 160 quasars have now been found at $z > 6$
- ULAS J1120+0641 is a 2 billion $M_\odot$ SMBH at $z = 7.1$ (Mortlock et al. 2011, Nature, 474, 616)
- ULAS J1342+0298 is an 800 million $M_\odot$ BH at $z = 7.5$ (Banados et al. 2018, Nature, 553, 173)
- how do BHs this massive form 650 Myr after the Big Bang?

SMBH Seed Formation Pathways



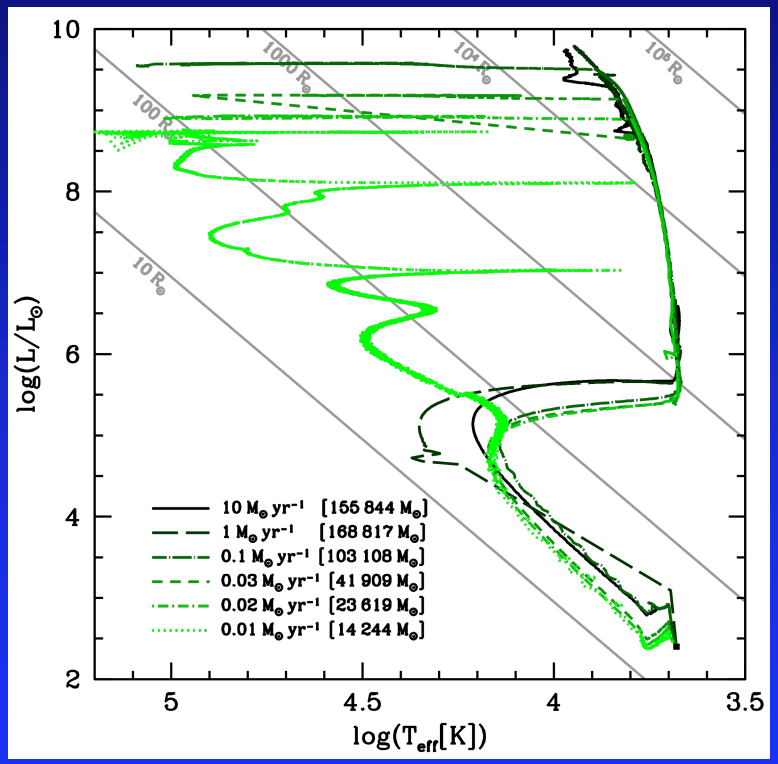
from Volonteri, ARAA, 2010, 18, 279

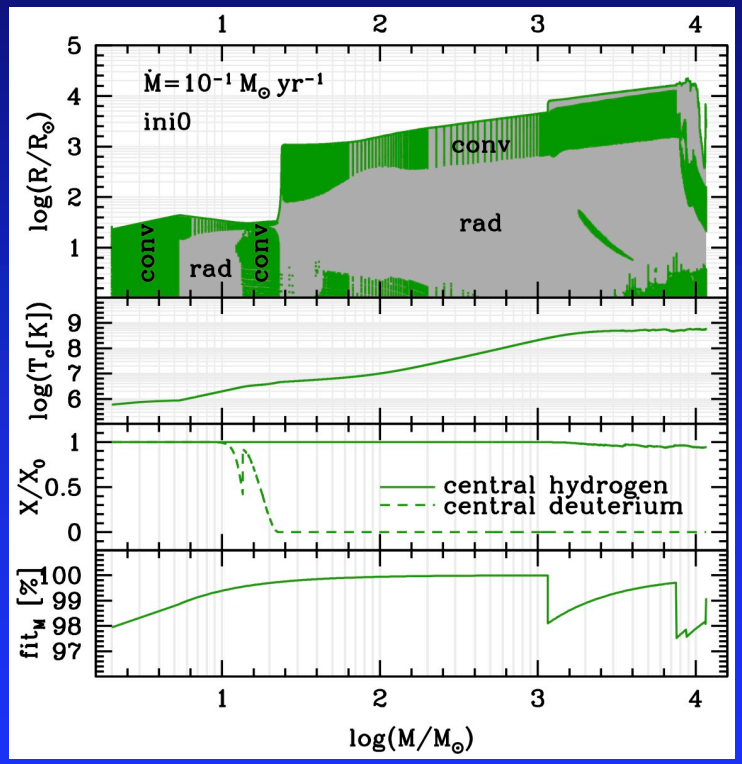
Atomic Cooling and Supermassive Primordial Star Formation



Supermassive Pop III Stellar Evolution

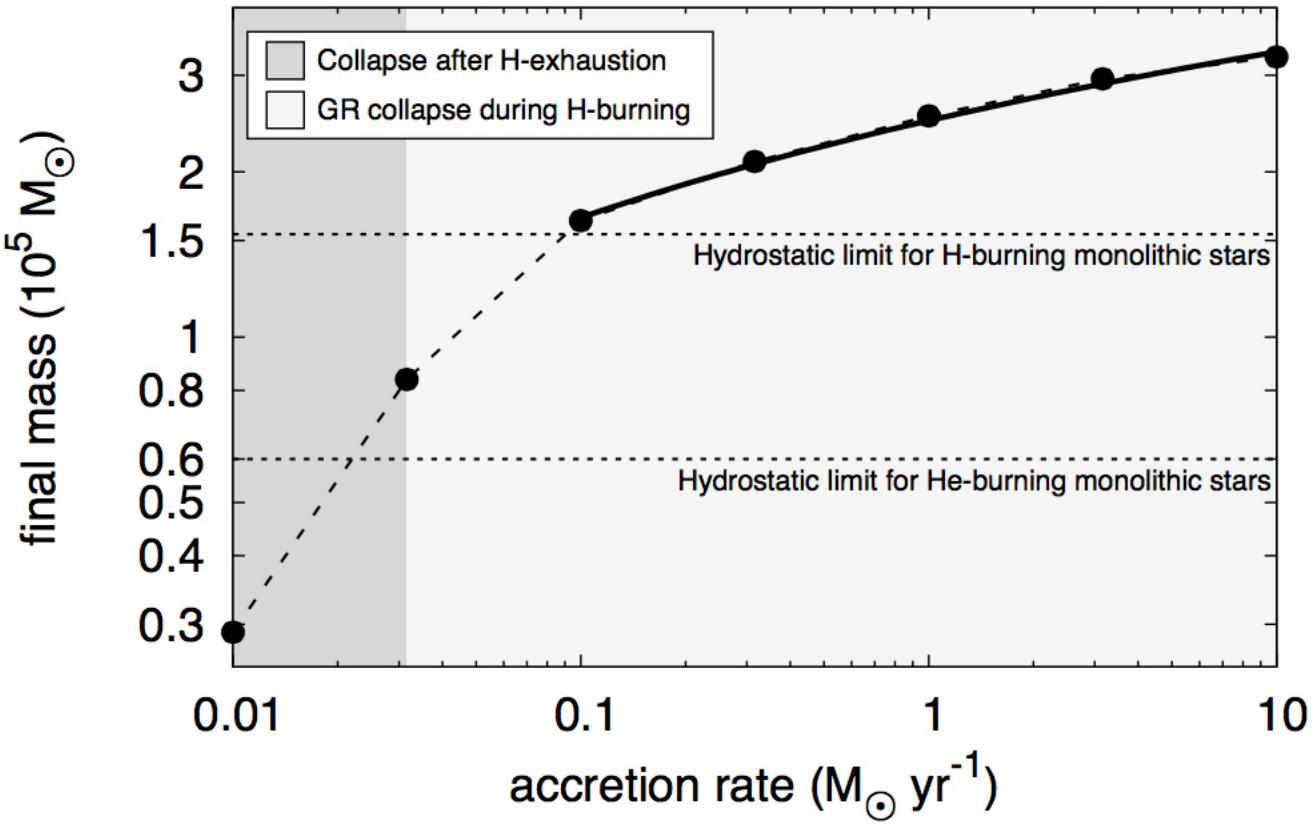
Haemmerle + DJW 2018 MNRAS, 474, 2757





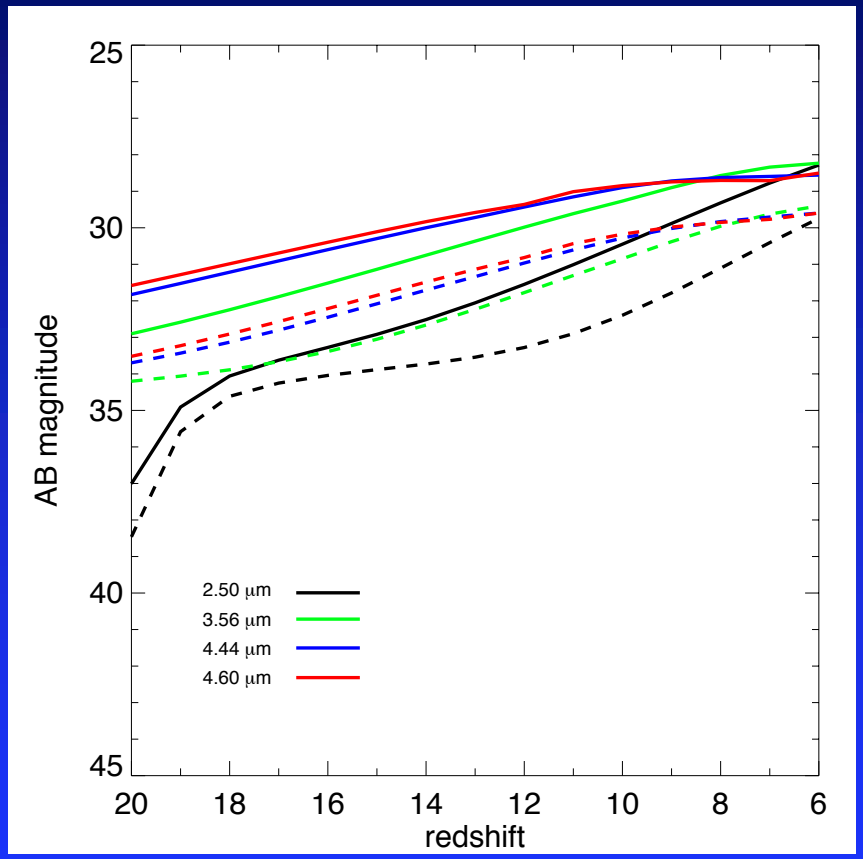
Supermassive Pop III Stellar Mass at Collapse

Woods + DJW+ 2018 ApJL, 842, 6

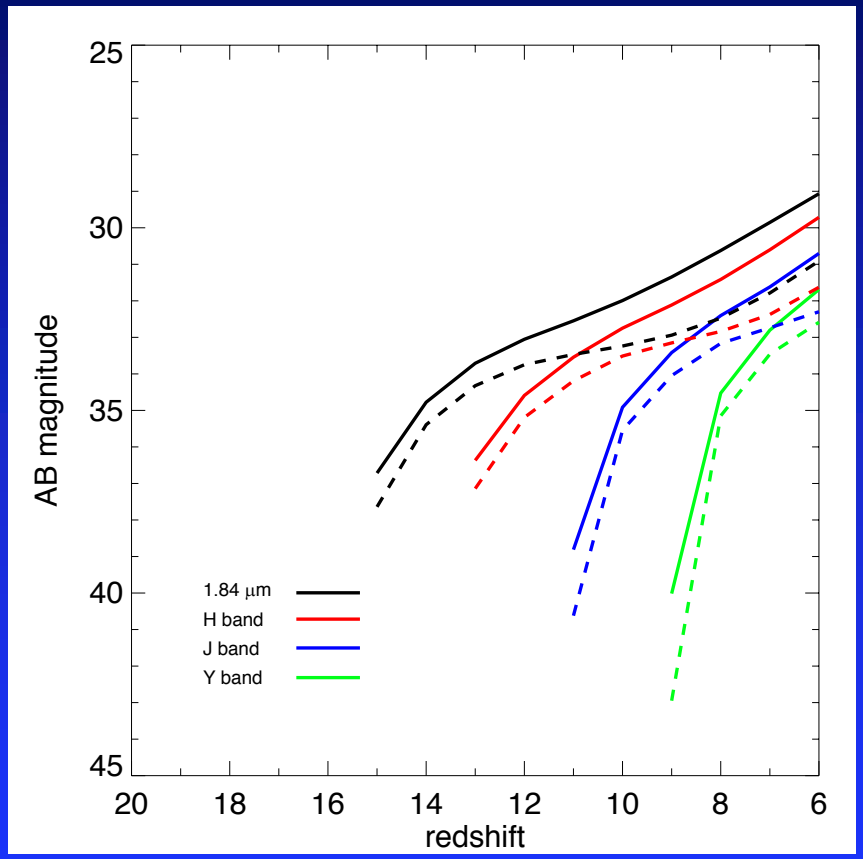


SMS NIR AB Magnitudes

Surace, DJW+ 2018, ApJ, 869L, 39
Surace, DJW+ 2019, MNRAS in rev

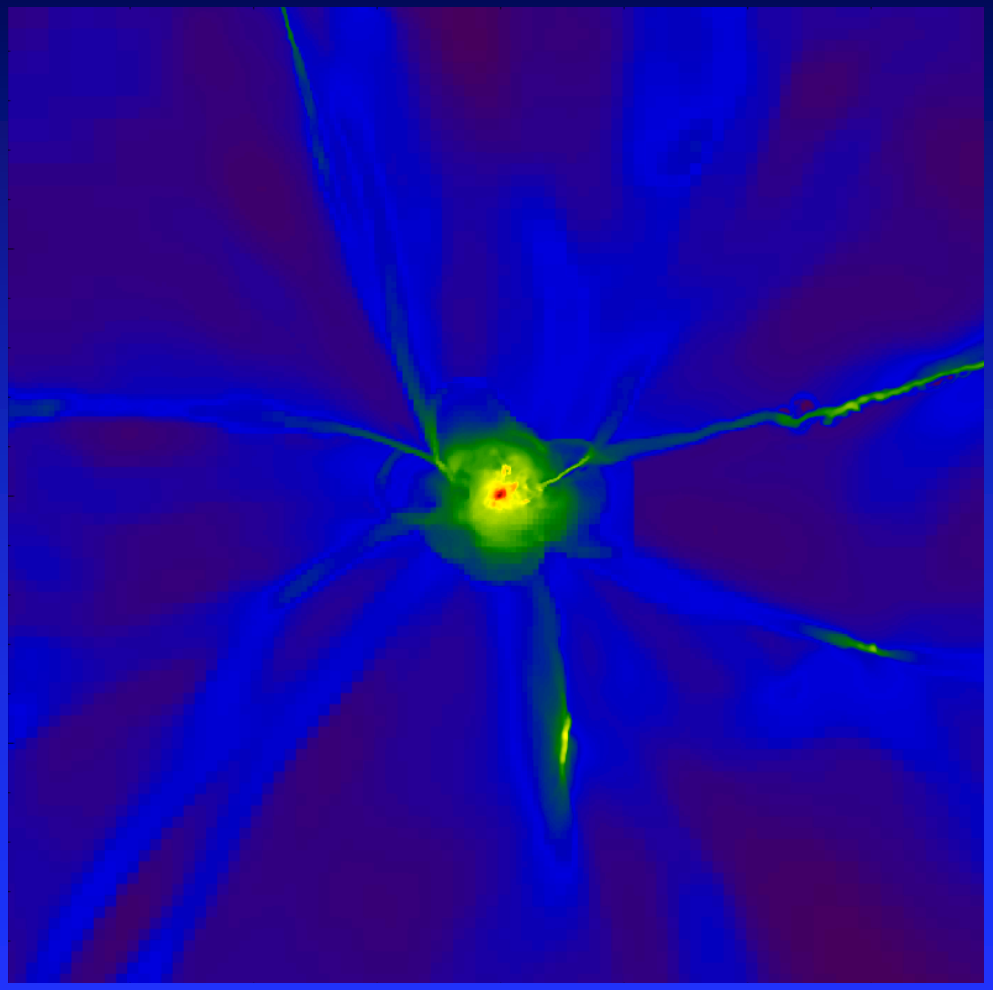


JWST



WFIRST

SMBH Growth in Cold Accretion Flows

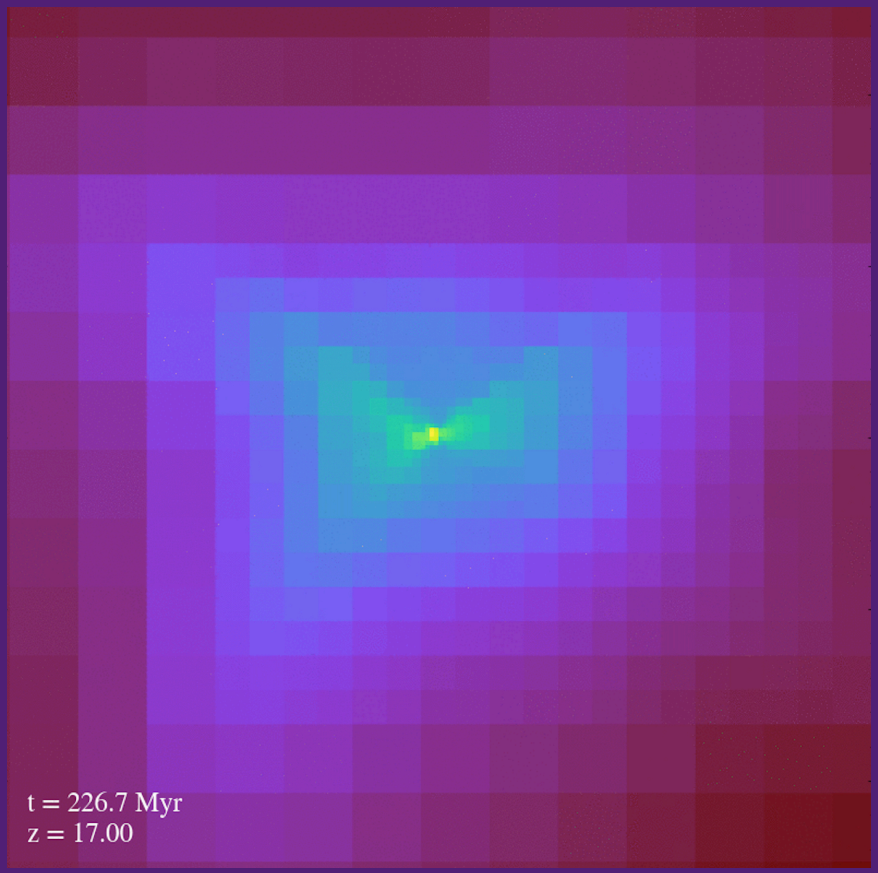


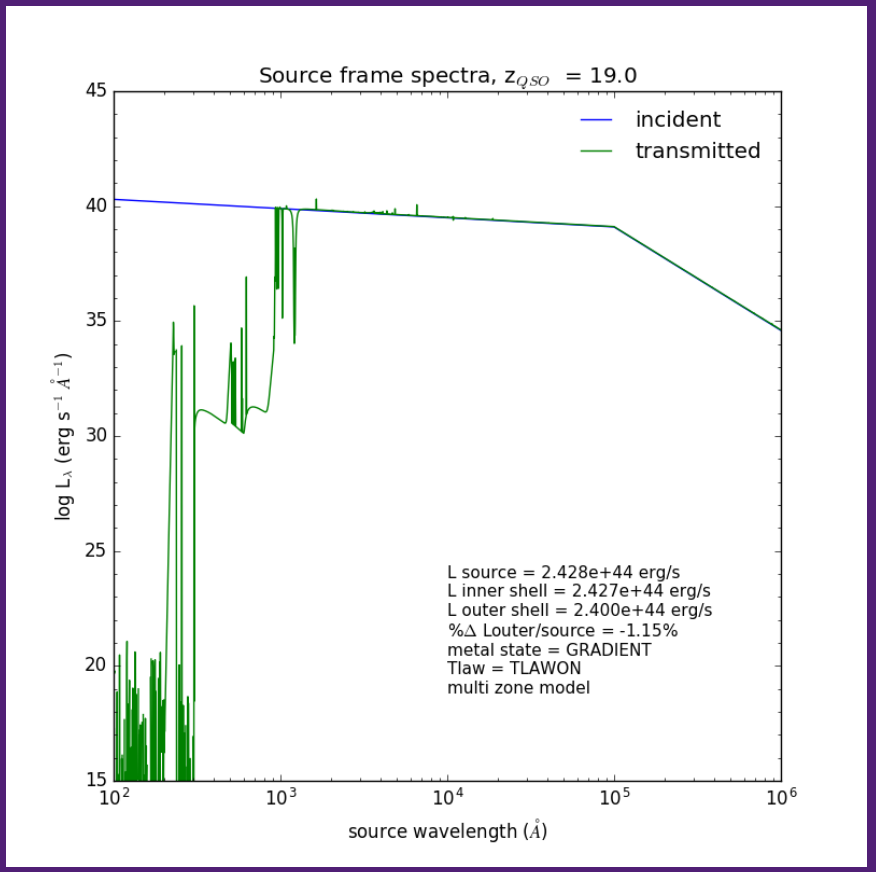
Enzo Supermassive Black Hole Formation Simulations

Smidt, DJW et al. 2018, ApJ 865, 126

- 100 Mpc box, initialized at z = 200
- x-ray emission from a 10^5 seed in a 2 x 10^8 solar mass halo at z ~ 19
- 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 in host galaxy (SN)
- stellar winds, ionizing UV and SN feedback due to SF in the host galaxy of the BH are included

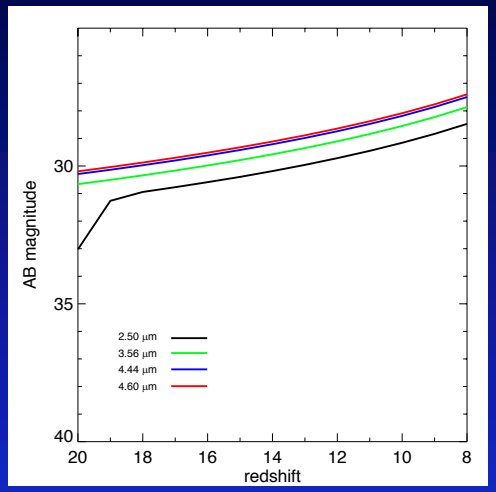
DCBH Birth


t = 226.7 Myr
z = 17.00

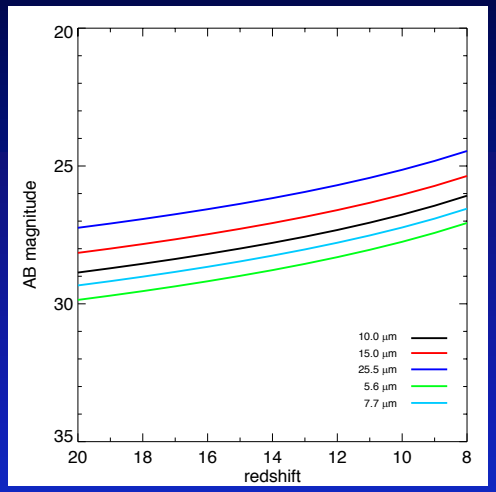

Source frame spectra, z_{QSO} = 19.0
incident
transmitted
log L_λ (erg s^{-1} $\AA^{-1}$)
source wavelength ($\AA$)
L source = 2.428e+44 erg/s
L inner shell = 2.427e+44 erg/s
L outer shell = 2.400e+44 erg/s
%Δ Louter/source = -1.15%
metal state = GRADIENT
Tlaw = TLAWON
multi zone model

DCBH NIR AB Magnitudes at Birth

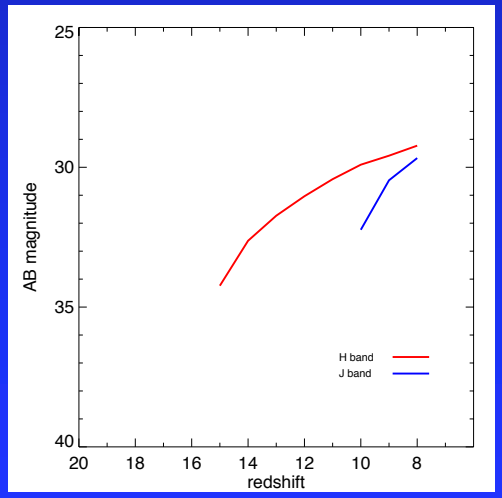
Whalen, Bernhardt, Surace, Hirschmann & Ziegler 2019 in prep



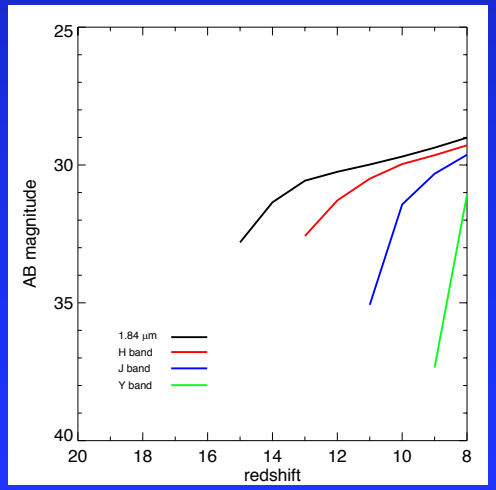
JWST NIRCam



JWST MIRI

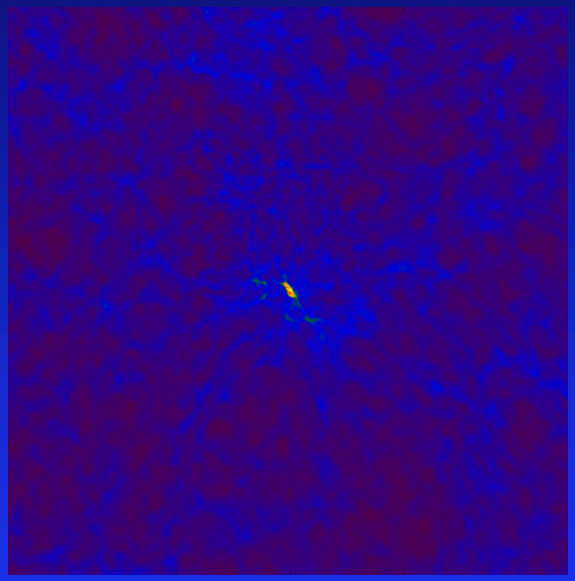


Euclid

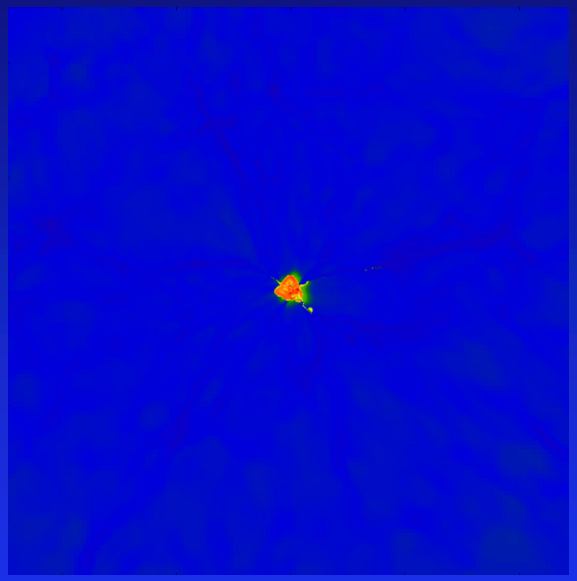


WFIRST

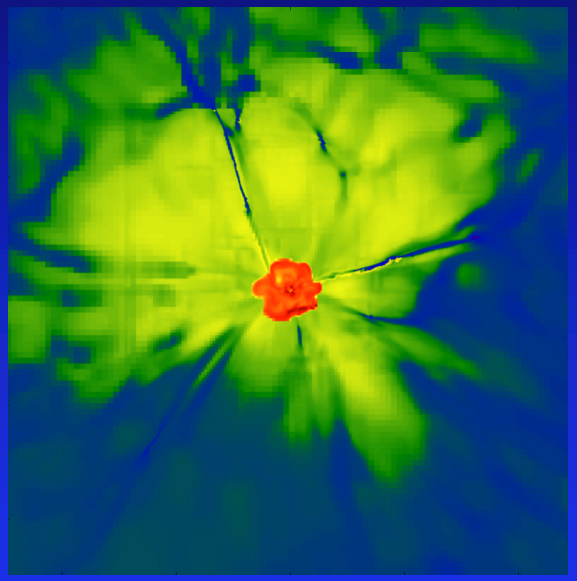
H II Region of the Quasar



z = 17

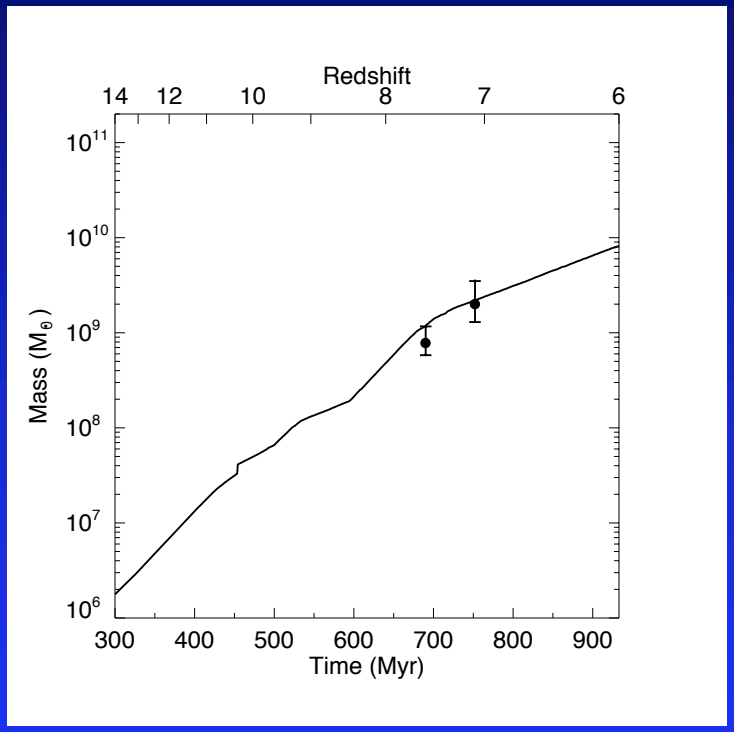


z = 9.5

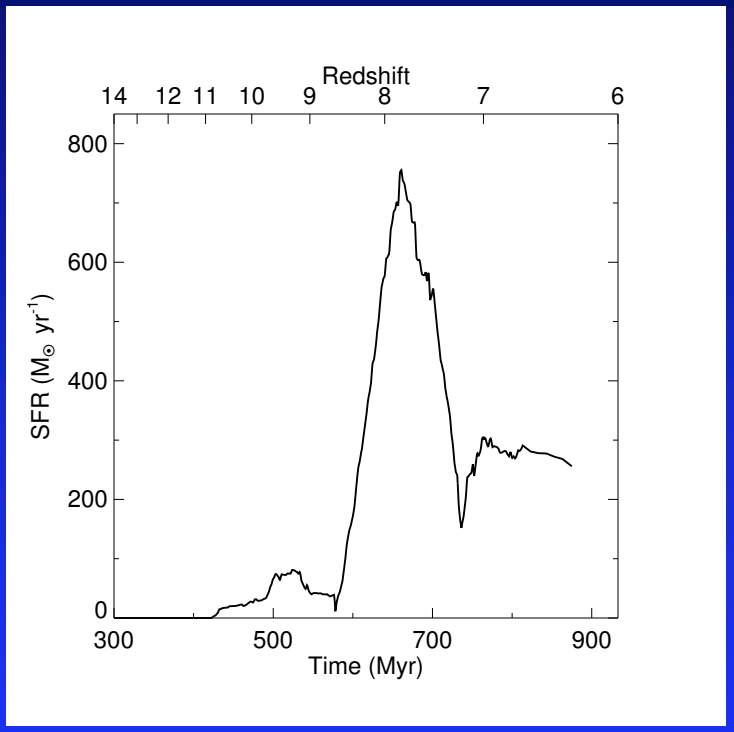


z = 7

Primordial Star Formation Regulates SMBH Growth Rates from z > 12

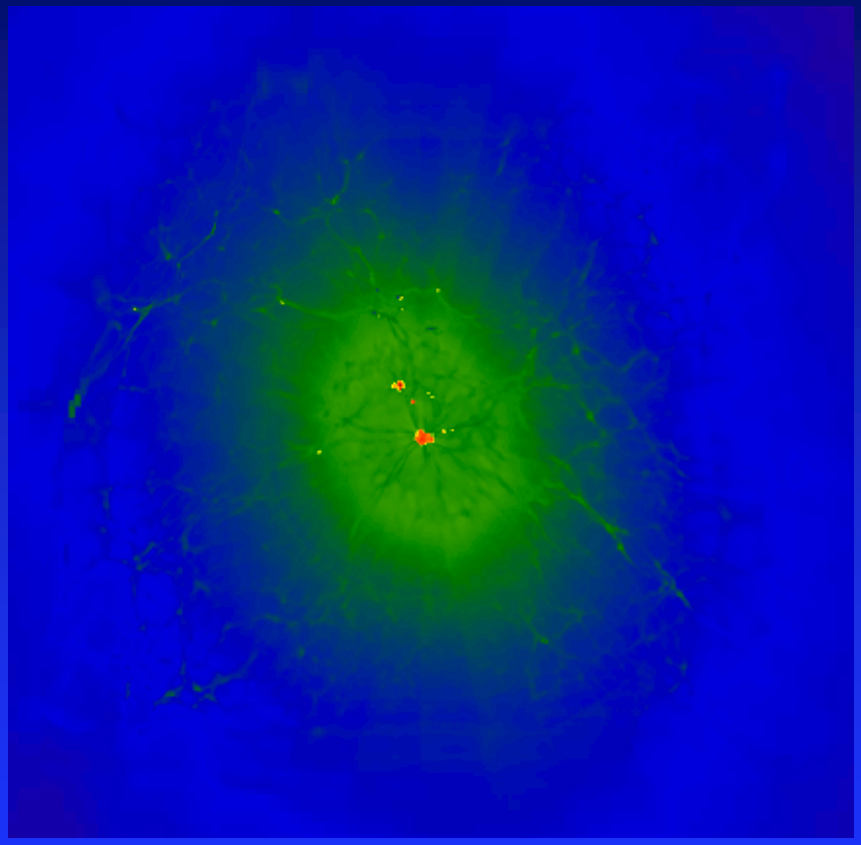


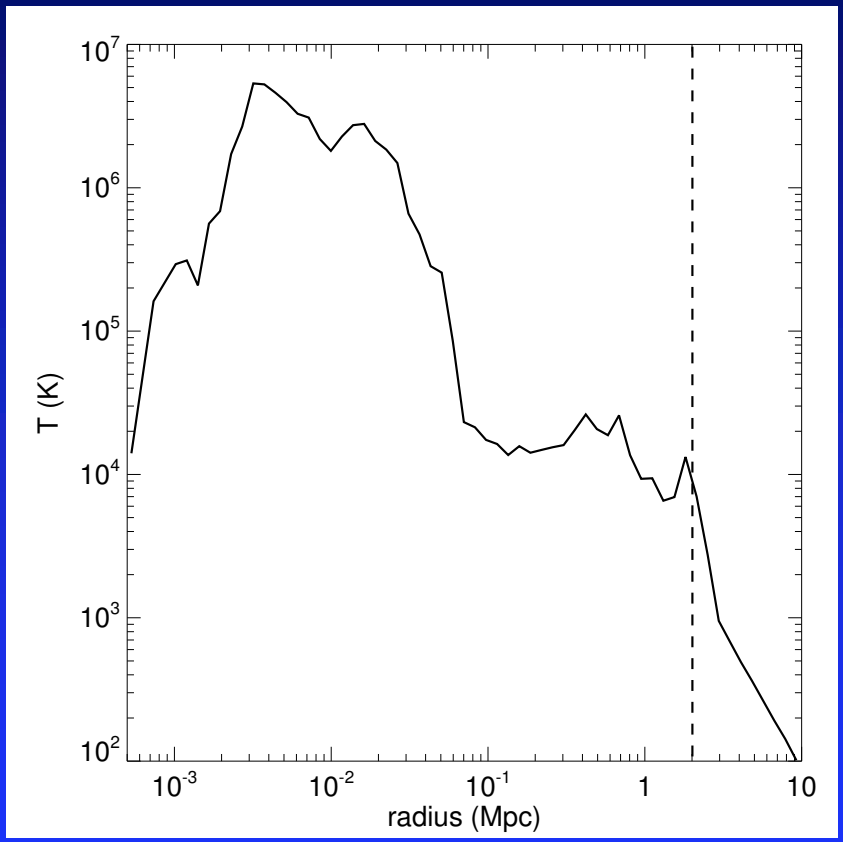
SMBH Mass



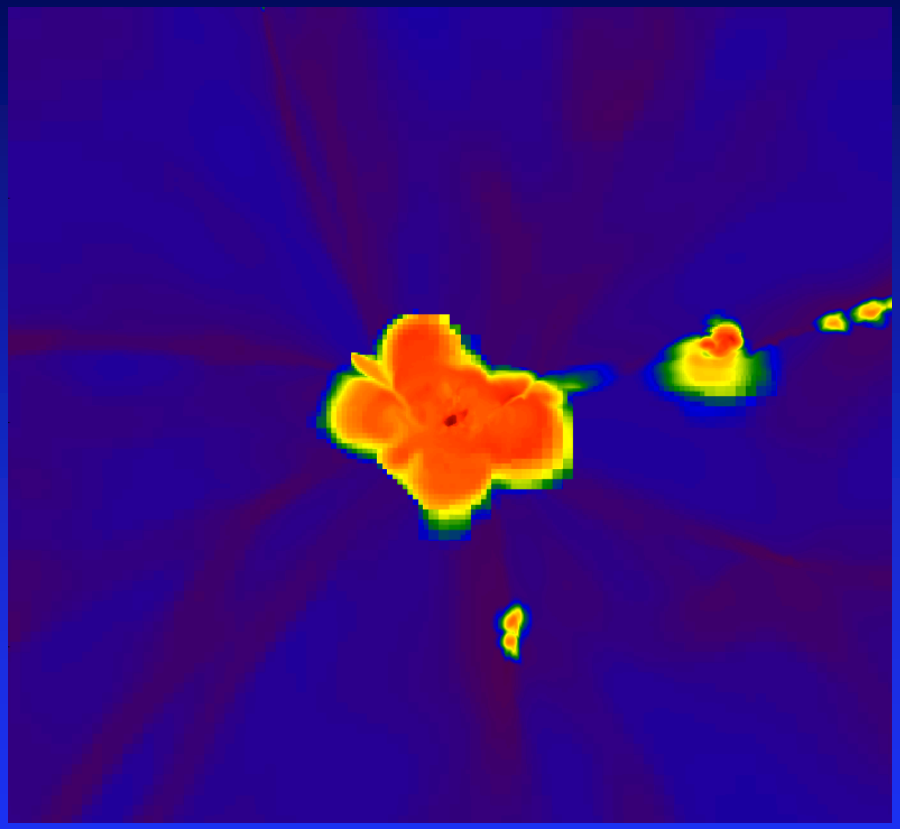
SFR ~ 250 $M_\odot$ in the host galaxy at z = 7.1, in agreement with obs (Barnett et al. 2015, A&A, 571, 33)

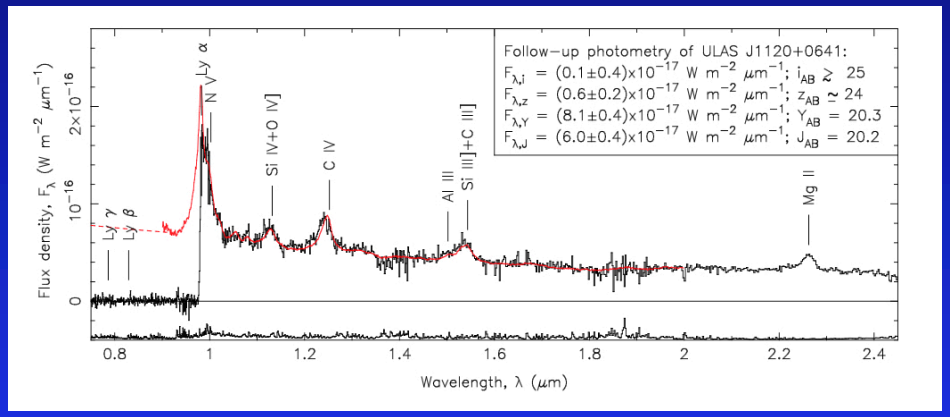
J1120 Quasar Proximity Zone at z = 7.1





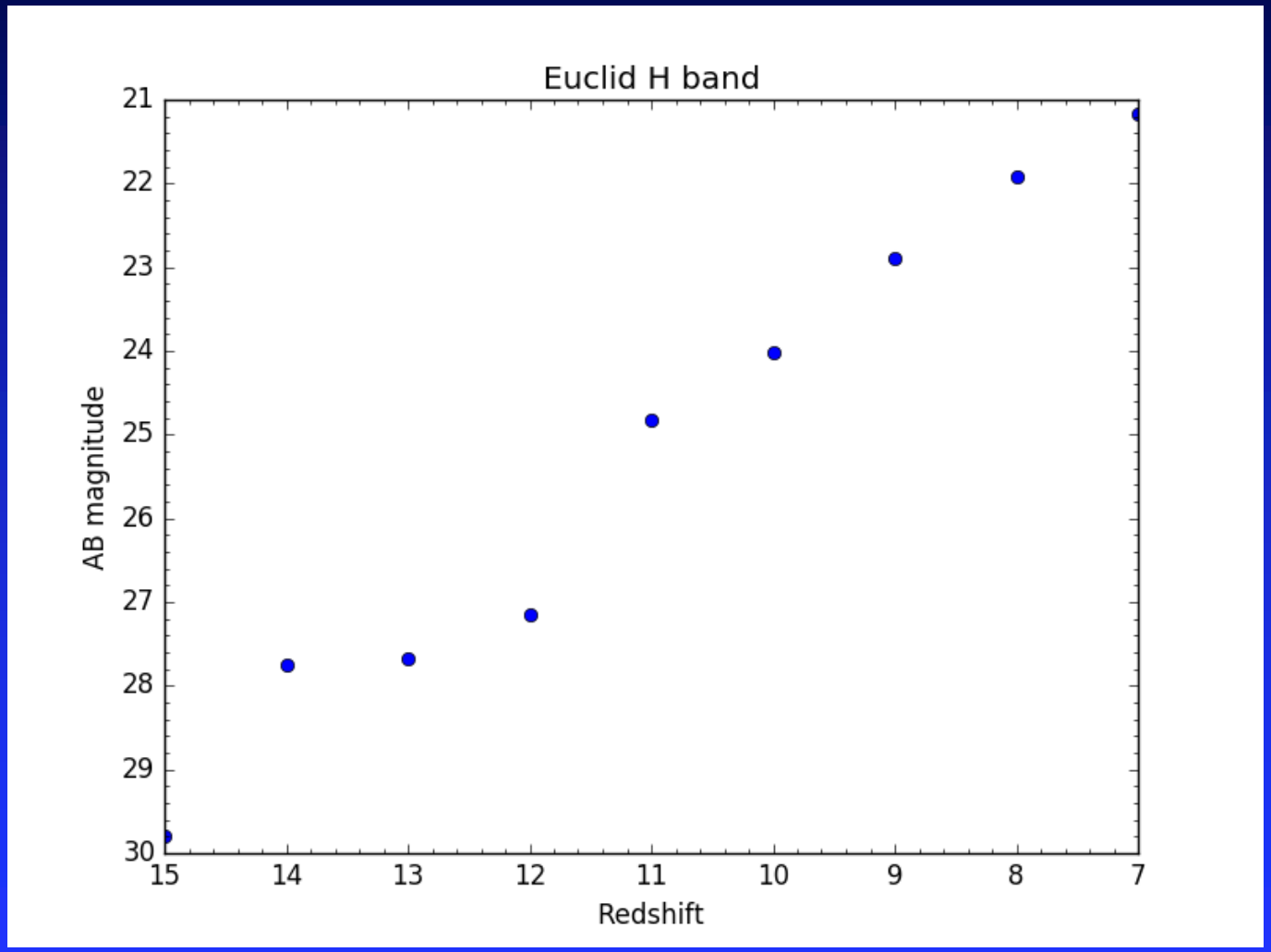
Metal and Dust Enrichment in the Host Galaxy





The metallicity in the host galaxy at z = 7.1 is approximately solar, in agreement with strong C lines (Dunlop 2013)

Euclid H Band 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
- WFIRST and Euclid can detect these quasars at $z \sim 12 - 14$
- their large survey areas will probe the evolution of the first quasars at much earlier stages of their growth than previously possible