

Blackbody Quasar and Radio Source (BBQSORS): A Candidate of Transitional Little Red Dots with a $T \sim 10^4$ K Blackbody Spectrum

YUXING ZHONG (仲宇星)^{1,2} XIAOYANG CHEN¹ KOHEI ICHIKAWA^{1,3} YOUWEN KONG^{2,4} KENTARO AOKI⁵ SATOSHI YAMADA^{1,3,6}
TORU NAGAO^{7,8} DAISABURO KIDO⁹ TOSHIOHRO KAWAGUCHI¹⁰ YOSHIKI MATSUOKA⁷ TORU MISAWA¹¹ SHOICHIRO MIZUKOSHI¹²
MASAFUSA ONOUE¹³ AYUMI TAKAHASHI¹⁴ AND YOSHIKI TORII^{15,12,7}

¹ Frontier Research Institute for Interdisciplinary Sciences, Tohoku University, Sendai, Miyagi 980-8578, Japan

1.Introduction

Recent scenario for LRDs

- Central SMBH are enshrouded by Compton-thick gas ($N_H >> 1e24/cm^2$)
=> $T=5000-7000K$ BB spectrum
=> red rest-optical continua, Balmer break
=> Suppress X-ray emission
- Number density evolution (sharp decline at $z<4$)
LF has a sharp cutoff at $L_{bol} \sim 1e45$ erg/s ($= L_{edd}$ of $M_{BH} < 1e7$)
=> LRD are early BH growth phase
- Gas enshrouded accretion with $t_{lifetime} \sim 1e7$ yr
=> In the later phase, gas inflow from the host will be hindered, and photospheric temperature rise to $1e4K$
=> Then transit to unobscured quasar.
- Two LRDs at transit phase (possibly) discovered with $T=5000-7000K$ (Fu+25, Hviding+26)

2.Observations

- Blackbody Quasar and Radio Source (BBQSORS)
 - $Z=1.715$
 - A quasar bright in Radio (discovered in VLASS 3GHz survey) and X-ray
 - $T \sim 1e4K$ BB-like UV-Opt continuum
 - V-shaped SED at $\sim 1200A$ (LRDs has 3000-4000A)
 - Transit phase from LRD-like cocoon to quasar?
- HSC SSP imaging
- SDSS cataloged as AGN
- PFF spectroscopy (Fig 1, only optical arms)
 - Broad ($>4000km/s$) CIII]1909, MgII2800
 - Narrow absorption of MgII, AlIII1855,1863
 - Λ -shaped continuum => well fitted by 10471K BB with $A_V=0.3$
 - Strong FeII continuum
- XMM Newton
 - $N_H=1.7e21/cm^2$ (mild obscuration)

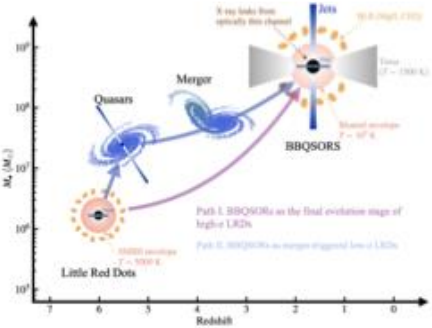


Figure 5. Schematic illustration of two possible evolutionary paths.

- UV-MIR photometry (Fig 3)
 - 9700K BB
 - 1500K BB => Dust torus
 - 850A excess => PL with $\beta=-2$: common in LRDs
 - => V-shape at 1200A
 - => adding typical 5000K BB => Characteristic V-shaped feature at 3400A

3.Discussion

- Red quasar?
 - At $<2000A$, spectrum doesn't match red quasar (Fig 4)
- Transitioning LRD?
 - Theoretical prediction says $T=1e4K$ gas envelope is a critical phase
 - System shifts from envelope-dominated phase to feedback (from SMBH) dominated (blown-out) phase
- Two Speculations: Fig 5
 - (1) SMBH in LRD => BBQSORS
 - (2) SMBH in LRD => quasar => merger => gas inflow over 10-100Msun/yr => thick gas envelope => BBQSORS

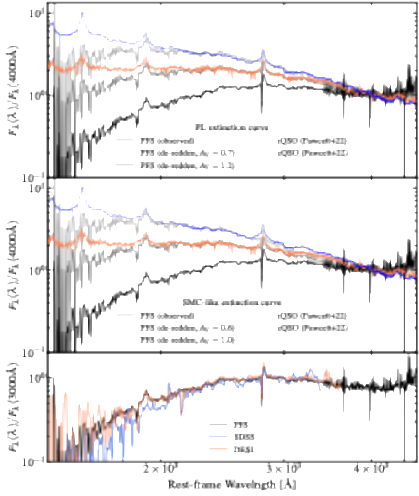


Figure 4. Top: Comparison of the spectrum for BBQSORS

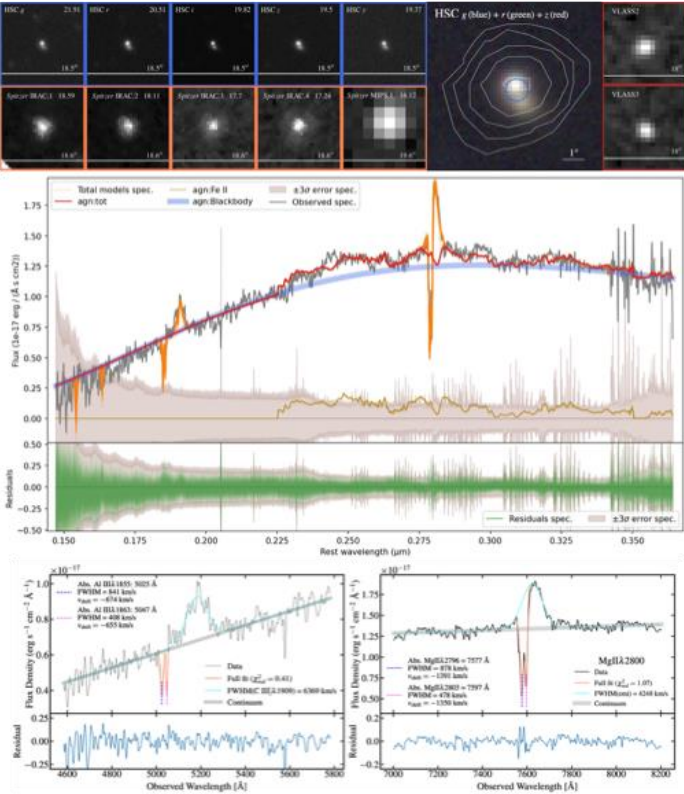


Figure 1. Overview of observations for the radio-loud blackbody quasar BBQSORS. Top: Optical images collected from Subaru HSC-SSP.

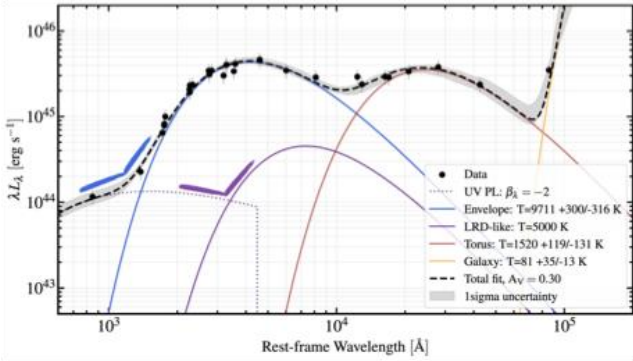


Figure 3. SED fitting for UV-to-MIR photometry with three blackbody components representing the SMBH envelope (blue), AGN dust torus

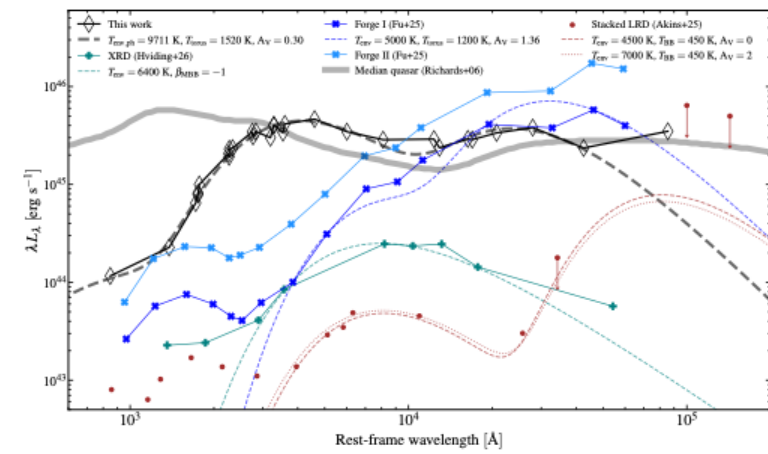


Figure 6. Comparison of the SED of the blackbody quasar BBQSORS (this study; black solid line) with those of the X-Ray Dot (moss-green

- Comparison with other candidates
 - Xray-Dot (XRD) @ $z=3.28$
 - Unusual LRD (Forge I, II) @ $z=2.9$: can have 1200K BB component
 - LRD : $T=4500-7000K$
- SMBH properties
 - $M_{BH}=3.9e10M_{sun}$ (estimated from conventional FWHM_Mg2 and L_2100A method : largely uncertain)
 - Eddington Ratio ~ 0.2 (comparable to Forges)

4.Conclusion

- BBQSORS is transitioning from LRD to normal quasar
 - Gas accretion on the SMBH no longer sufficient to keep the dense gas envelope
 - The gas envelope begins to disperse
 - Strong AGN feedback (radiation, jet) may enhance the mass loss