What Makes Red Quasars Red?

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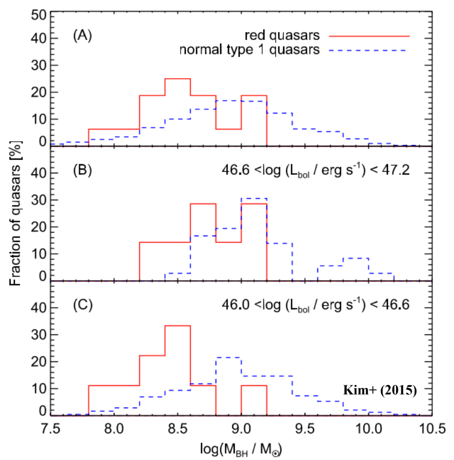
Abstract

Red quasars have red colors in optical through NIR (e.g., *r'-K* > 5 mag and *J-K* > 1.3 mag in Urrutia et al. 2009), and the red colors are possibly due to the dust extinction in their host galaxies as an intermediate population between merger-driven star-forming galaxies and unobscured type 1 quasars. However, the red colors can be explained by alternative mechanisms of (i) an intrinsically red continuum, (ii) an unusual high covering factor of the hot dust component (CF_{HD}), and (iii) a moderate viewing angle, somewhere between type 1 and type 2 quasars. In order to study why red quasars are red, we use optical to NIR spectra of 20 red quasars at *z*~0.3 and 0.7. The $L_{P\beta}/L_{H\beta}$ ratios of red quasars are found to be ~10 times higher than unobscured type 1 quasars, and the $L_{P\beta}/L_{H\beta}$ ratios of ~55% red quasars cannot be explained by any theoretical predictions without adopting the concept of the dust extinction. The CF_{HD} of red quasars are similar to that of unobscured type 1 quasars. Furthermore, we find that the Eddington ratios of red quasars are significantly higher than those of unobscured type 1 quasars. Consequently, these results strongly suggest the dust extinction in the host galaxy as the origin of the red colors of red quasars, as suggested in the merger-driven galaxy evolution scenario.

Eddington Ratio Distributions



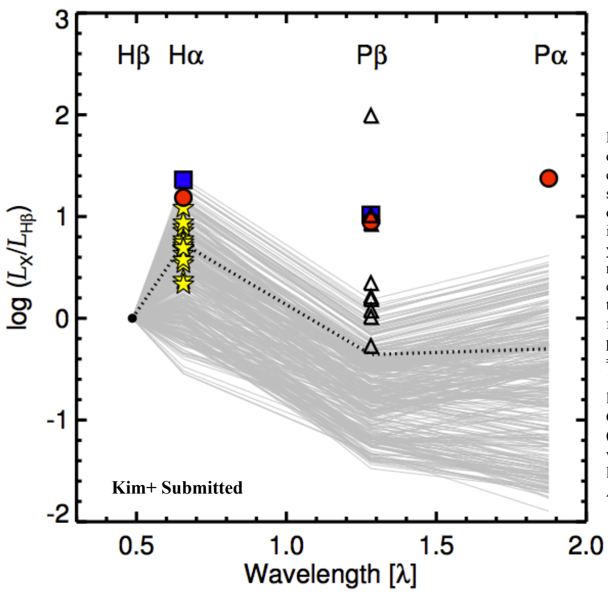
(A) M_{BH} distributions of red quasars and unobscured type 1 quasars. The red solid and the blue dashed histograms represent red quasars and unobscured type 1 quasars, respectively. (B) M_{BH} distributions for high-luminosity quasars. (C) M_{BH} distributions for low-luminosity quasars.

Aims& Methods

(i) To compare line luminosity ratios from Hydrogen Balmer to Paschen lines of red quasars to theoretically expected line luminosity ratios with possible physical parameters using CLOUDY code. If the red colors of red quasars come from an unusual physical condition, the line luminosity ratios of red quasars would be explained by the theoretically expected line luminosity ratios without adopting a concept of the dust extinction.

(ii) To compare Eddington ratios of red quasars to those of unobscured type 1 quasars. If the red colors of red quasars come from the dust extinction, the dust can originates from their host galaxy or dust torus under a moderate viewing angle, somewhere between type 1 and type 2 quasars. The viewing angle is independent of their Eddington ratios.

(iii) To investigate the CF_{HD} of red quasars, we compare the ratios between L_2 (luminosity at 2 μm) and Paschen line luminosities of red quasars to those of unobscured type 1 quasars. The NIR radiation at 2 μm is dominated by the L_{HD} (with a temperature of ~1500K) and the Paschen line luminosities represent the L_{bol}, which will reveals whether or not the red colors of red quasars come from an unusual high CF_{HD}.

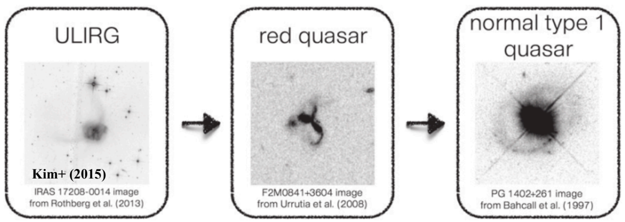


Line Luminosity Ratios

Line luminosity ratios of Hα, Pβ, and Pα with respect to Hβ of two red quasars (1307+2338: the red filled circles; 0036-0113: the blue filled squares). The Pβ/Hβ luminosity ratios of the other nine red quasars are indicated by the open triangles, and the yellow stars are the Hα/Hβ luminosity ratios of the local red AGNs from Rose et al. (2013). The gray lines represent the line luminosity ratios computed from CLOUDY code with various plausible physical conditions, within $\alpha = -2 \sim 2$, $n_H = 10^7 \sim 10^{14}$ cm^{-3}, and $U = 10^{-5} \sim 10^5$. The dotted line is the line luminosity ratio reproduced by CLOUDY code with a set of parameters ($\alpha = -1$, $n_H = 10^9$ cm^{-3}, and $U = 10^{-1.5}$), which is consistent with the line luminosity ratios of unobscured type 1 AGNs (Kim et al. 2010).

Schematic Outline of Galaxy Evolution

Schematic outline of the galaxy evolution scenario from ULIRG to unobscured type 1 quasars.

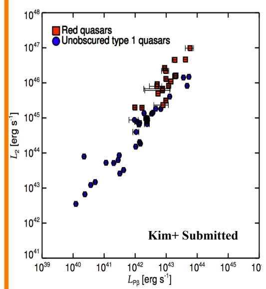


Sample& Data

In this work, we use 20 red quasars at $0.186 < z < 0.842$. The 20 red quasars are a sub-sample of ~80 spectroscopically confirmed red quasars in Glikman et al. (2007) and Urrutia et al. (2009) that were selected to be red quasars based on their broad-band colors (*R-K* > 4 and *J-K* >1.7 mag in Glikman et al. 2007) from radio-detected 2MASS point sources. We compare several properties of red quasars to those of unobscured type 1 quasars from Kim et al. (2010). The unobscured type 1 quasars are nearby (z <0.5) and cover a wide range in the *K* band luminosities (-30.0 < *K* mag < -21.3) that overlaps well with the *K* band luminosities of our red quasars (-30.3 < *K* mag < -25.7).

The optical and NIR spectra of the red quasars come from Glikman et al. (2007, 2012). Additionally, new NIR spectra were obtained for 11 red quasars using the SpeX instrument on NASA Infrared Telescope Facility (IRTF). The observation was performed with a set of the SXD mode (0.8 – 2.4 μm) under a clear weather.

Among them we detect Pβ in nineteen and Pα in two red quasars at S/N of >5. In the 20 red quasars, we detect Hβ in eleven and Hα in three red quasars at S/N of >5.



CF_{HD}

The L_2 values vs. the $L_{P\beta}$ values of red quasars (the red filled squares) and unobscured type 1 quasars (the blue filled circles). Red quasars do not have unusual strong (> 1 dex) hot dust emission than that of unobscured type 1 quasars, although their NIR emission may be somewhat (~ 0.3 dex) stronger than unobscured type 1 quasars.

Conclusion

(i) For the Balmer lines, the line luminosity ratios of red quasars are only moderately different from those of unobscured type 1 quasars. However, the line luminosity ratios of red quasars are significantly different from even the theoretically expected line luminosity ratios when Paschen lines are included. Among them, ~55% of red quasars have higher line luminosity ratios than the maximum line luminosity ratios in the CLOUDY calculation, and which result cannot be explained by without adopting a concept of the dust extinction.

(ii) Red quasars have significantly higher Eddington ratio (~0.69) than unobscured type 1 quasars by a factor of 4-5. Moreover, we find same result in the redshift-, M_{BH}-, and L_{bol}-limited comparisons. The significantly higher BH accretion rates of red quasars cannot be explained by the moderate viewing angle scenario, but which is consistent with the scenario that red quasars are in the intermediate stage between merger-driven star-forming galaxies and unobscured type 1 quasars.

(iii) The mean $L_2/L_{P\beta}$ of unobscured type 1 quasars (2.60±0.59) is slightly smaller than that of red quasars (3.04±0.27), and the mean $L_2/L_{P\alpha}$ of unobscured type 1 quasars (2.54±0.69) and that of red quasars (2.67±0.32) are almost same. Therefore, the red colors of red quasars are unlikely to be from the unusual high CF_{HD}.