Dust Reddened Quasars: A Transitional Phase in Quasar/Galaxy Co-Evolution

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Black Holes Play a Role in Galaxy Formation and Evolution

- SMBHs are a ubiquitous feature of galaxies
- M-σ relation
- QSOs evolve with SF

This suggests a link between the formation and growth of SMBHs and their host galaxies
Merger-Driven Quasar/Galaxy Co-Evolution

Feedback from SMBH growth is required in order to quench star formation.
ULTRALUMINOUS INFRARED GALAXIES AND THE ORIGIN OF QUASARS

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ABSTRACT

An evolutionary connection between ultraluminous infrared galaxies and quasars is deduced from the observations of all 10 infrared galaxies with luminosities $L(8–1000 \, \mu m) \geq 10^{12} \, L_\odot$, taken from a flux-limited sample of infrared bright galaxies. Images of the infrared galaxies show that nearly all are strongly interacting merger systems with exceptionally luminous nuclei. Millimeter-wave CO observations show that these objects typically contain $0.5–2 \times 10^{10} \, M_\odot$ of $H_2$. Optical spectra indicate a mixture of starburst and active galactic nucleus (AGN) energy sources, both of which are apparently fueled by the tremendous reservoir of molecular gas. It is proposed that these ultraluminous infrared galaxies represent the initial, dust-enshrouded stages of quasars. Once these nuclei shed their obscuring dust, allowing the AGN to visually dominate the decaying starburst, they become optically selected quasars. The origin of quasars through the merger of molecular gas-rich spiral galaxies can account for both the increased number of high-luminosity quasars at large redshift, when the universe was smaller and gas supplies less depleted, and the observed “redshift-cutoff” of quasars which represents the epoch after galaxy formation when the first collisions occur.

Subject headings: galaxies: evolution — galaxies: photometry — infrared: sources — quasars

Local ULIRGS are predominantly merging systems

Missing link?

Quasars live in bulge-dominated massive ellipticals

(Dunlop et al 2003, Floyd et al. 2004, 2010)
Dust reddens and dims quasars. Optical (UVX) surveys miss red quasars.
Recipe for finding reddened quasars:
- FIRST radio detection ($S_{20\text{cm}}>1\text{mJy}$)
- 2MASS detection ($K\leq15.5\text{ mag}$)
- No optical counterpart on POSS-I plates ($R>20, B>21.5$)

Glikman et al. (2004)
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Glikman et al. (2004)
The FIRST-2MASS Red Quasar Survey

- 69 Candidates over 2716 deg$^2$
- 54 identifications using optical and/or near-infrared spectroscopy.
- 17 red quasars

Glikman et al. (2004)
The FIRST-2MASS Red Quasar Survey

Expanded Survey Selection Criteria:

FIRST radio detection.

2MASS near-infrared detection.

Optical-to-near-IR colors: J-K > 1.7, R-K > 4

Require a broad emission line with $v \geq 1000$ km/s
The FIRST-2MASS Red Quasar Survey

- 394 candidates over 9033 deg$^2$
- 316 spectroscopic identifications.
- 120 red quasars.

The Space Density of Red Quasars

Space density of F2M red quasars compared with optically-selected quasars (FBQS).

**Observed:** $10 \pm 1\%$

**Extinction Corrected:** $19.2 \pm 2.6\% \ K \leq 14.5$. 
At all redshifts, red quasars are the most luminous objects in the Universe.

→ Opposite direction than for Type I/II quasars.
→ High L/Leff (Urrutia et al. 2012, in press).
→ Not reddened by nuclear obscuration.
→ Red quasars are an evolutionary phase.

Glikman et al. (2012)
Red quasars are a phase in merger-driven QSO/Galaxy co-evolution.

Red quasars are an emergent phase, shedding their dusty environment.

Hopkins et al. (2005)
Red Quasar Host Morphologies

- 13 HST images were obtained with ACS.
- All the images reveal a nearby companion.
- 11 show interacting or disrupted morphologies.

Urrutia et al. (2008)

Hopkins et al. (2006) simulations
AGN component dominates the bolometric luminosity in all cases (LIRG luminosities)

We infer star formation rates from the PAH emission and the far-infrared excesses from the MIPS photometry: $\sim 10 \, M_\odot \, \text{yr}^{-1}$. 
Quasar Accretion/Growth Rates

Fast growing black holes lies below the $M_{BH} -- L_{Bulge}$ relation.
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Glikman et al. (2012)
Red Broad Absorption Line Quasars

- F2M red quasars with $z \geq 1.7$, **all but one** are BALs.
- And **all** but one of these are LoBALs and most are FeLoBALs, displaying some sort of **outflows**.
- FeLoBAL QSOs are a **transition stage** between starburst-dominated ULIRGs and QSOs.
- Evidence for **feedback** quenching star formation (Farrah et al. 2008, 2012)

Urrutia et al. (2009)
Look for Red Quasars with UKIDSS

- Matched FIRST to UKIDSS DR1.
- $190 \text{ deg}^2$
- $K \leq 17 \text{ mag.}$
- Use SDSS optical magnitudes.
- Select $r-K \geq 5 \text{ J-K} \geq 1.5$

- 87 Candidates
- 64 Spectra
- 15 Quasars
The number counts of red quasars rises toward fainter magnitudes: 0.11 deg$^{-2}$

Red quasars make up $\geq 15\%$ of the observed surface density of quasars, compared to 10% in F2M survey.
Where are the heavily reddened quasars at high redshift?
Summary

• Identified a population of dust-obscured red quasars whose fraction is \( \sim 20\% \) of the total quasar population.

• Their space density rises sharply toward lower magnitudes.

• They are the **most luminous** sources at every redshift.

• They reside in highly disturbed, interacting hosts.

• Many are accreting at or above the Eddington limit.

• Many show outflows in the form of LoBALs, suggesting feedback in action.

• Reddened quasars are revealing an emergent phase where the heavily obscured quasar is shedding its cocoon of dust prior to becoming a "normal" blue quasar.

• Based on the fraction of objects in this phase, its duration is \( \sim 20\% \) as long as the unobscured quasar phase, **a few million years**.