The Red Quasar Crisis:

where do they fit into the QSO population?

Quasars in Crisis, ROE, 6 — 9 August 2019

Lizelke Klindt

Dave Alexander, David Rosario, Elisabeta Lusso, & Sotiria Fotopoulou

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Conventional picture of quasars

Red Quasars: a peculiar subpopulation

Redder colours and spectra: suppressed blue emission.

Evidence for a large undetected population of dust-reddened quasars

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QUASARS have been detected at many wavelengths, but often ones that are bright at one wavelength are very faint or undetectable at other wavelengths. It has therefore been impossible to design a single search technique that would identify all quasars, raising the question of how many may have gone unidentified. Here we show that quasars selected from a radio catalogue have a wide range of optical colours, which we interpret as arising from varying amounts of dust along the line of sight. Most of this dust probably lies within the quasar host galaxy. If the radio-quiet quasars that would normally be detected optically contain as much dust as the radio-loud ones (and have gone undetected at other wavelengths), then

e.g., Webster+1995; Glikman+2004; Urrutia+2009; Glikman+2012; +++

Red Quasars: a peculiar subpopulation

reddening mechanisms

excess emission

dust obscuration

- 1982 — Rieke, Lebofsky & Wisniewski
- 1995 — Webster
- 1998 — Benn+
- 2000 — Francis+
- 2001 — Whiting, Webster & Francis
- 2002 — Gregg+, Ivezić+
- 2003 — Richards+
- 2004 — Glikman+, Urrutia+, Kimball+, Banerji+, Assef+, Ross+, LaMassa+, Zakamska+, Kim & Im, Tsai & Whang, Hamann+, Wethers+, Krawczyk+, Alexandroff+
- 2019 — Goulding+

Proposed origins of red quasars: Orientation vs. Evolution

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Blue quasar

- ❒ Blue unobscured view of BLR
- ❒ Broad emission lines superimposed onto continuum that peaks in UV

Red quasar

- ❒ Grazing view with additional dust along line-of sight.
- ❒ Broad emission lines are still present (Type I), but spectrum is suppressed at shorter wavelengths.

e.g., Antonucci 1993; Urry & Padovani 1995

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In this scenario red and blue quasars would be expected to be intrinsically similar!

e.g., Antonucci 1993; Urry & Padovani 1995

Proposed origins of red quasars: Orientation vs. Evolution

Preferentially obscured

Preferentially unobscured

see e.g., Sanders+1998; Hopkins+2008; Alexander & Hickox 2012; Glikman+2012+++

Proposed origins of red quasars: Orientation vs. Evolution

In this model the "nuclear environments" are effectively different for red and blue quasars

see e.g., Sanders+1998; Hopkins+2008; Alexander & Hickox 2012; Glikman+2012+++

Objectives

- Test between these two proposed models for the existence of red quasars.
- Limitations of previous work is that studies did not uniformly select red and blue quasars from the same parent sample and they were limited in source statistics.
- Aim of our study is to address this via a carefully controlled experiment and to ultimately fit another piece to the red quasar puzzle.

Selecting red and blue quasars

Klindt+2019

SDSS DR7
Schneider+2010
105,783

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➟ Uniform flag
➟ Sole FIRST
pre-selected removed

Colour & radio-uniform sample
60,000

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➟ $0.2 < z < 2.4$

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✦ select red & blue QSOs using g* - i* colour.

z-bins of 1000 sources

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Measure of quasar colour relative to median quasar at the same redshift (e.g., Richards+2003).

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- NIR selected red quasars have dust extinctions of up to $A_V \sim 1 - 6$ mag.

see e.g., Glikman+2004; Banerji+2012

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Radio emission — FIRST 1.4 GHz

Faint Images of the Radio Sky at Twenty-centimeters

frequency = 1.4 GHz

resolution = 5"

projected sizes = 43 kpc at z = 1.5

detection threshold = 1 mJy

Radio emission — FIRST 1.4 GHz

radio-detection rate

radio morphologies

radio loudness

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blue QSO 5 — 10%

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* Match in rest frame 6 μm luminosity and redshift.

Result holds !

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red QSO	17 — 22%

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* Match in rest-frame 6 μm luminosity and redshift.

Result holds !

* Note we don't see significant differences in BH mass and Edd ratio after matching in $L_{6\mu m}$ and z.

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Visually assessed ~1400 FIRST cutouts to classify radio-detected quasars

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Faint

F_{peak} < 3 mJy

Compact

Maj < 5”

Extended

FR II

Compact FR II

Radio morphologies

- Blue & control QSOs have similar fractions in all morphology classes.

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Radio morphologies

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- Red QSOs have similar FIRST detection fractions to the blue and control QSOs in the extended classes.

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Radio morphologies

- Blue & control QSOs have similar fractions in all morphology classes.
- Red QSOs have similar FIRST detection fractions to the blue and control QSOs in the extended classes.
- A factor of 2–6 more rQSOs have either compact radio emission or are radio faint, in comparison to blue quasars.

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Going deeper & resolving smaller scales

* SDSS DR14 — half a million QSOs
* Even when going 2 orders of magnitude deeper we see an enhancement in the radio-detection rate of red quasars.
* Starting to see radio differences at the host galaxy scale.

Radio emission — FIRST 1.4 GHz

radio-detection rate

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Excess of red radio-detected quasars near the detection limit.

footnote: do red quasars have different accretion rates?

* NIR selected QSOs have higher accretion rates (e.g., Richards+2003, Urrutia+2012 & Kim+2015).
* No strong differences in the ***average* accretion rates** between red and blue quasars.
* Further explore this with our X-shooter sample!

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Radio loudness

$R = f_{radio} / f_{optical}$

- Relative ratio of the quasar in the radio band to the overall accretion power.

$$R = \log_{10}(L_{1.4GHz}/L_{6\mu m})$$

- No excess of blue quasars relative to control quasars.

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- Relative ratio of the quasar in the radio band to the overall accretion power.

$$R = \log_{10}(L_{1.4GHz}/L_{6\mu m})$$

- ● No excess of blue quasars relative to control quasars.
- ★ No excess of red quasars relative to control quasars at radio-loud end.
- ★ Excess of red quasars which are radio-quiet or radio-intermediate.

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Radio loudness

Panessa+2019
see also Zakamska & Greene (2014); Hwang+2018

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Radio loudness

Anti-correlation between ionised winds and the radio loudness parameter (Mehdipour+2019).

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Radio loudness

Explore whether the radio emission comes from winds

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e.g., Najita+2000; Ross+2015; Hamann+2017; Morabito+ 2018; +++

The LOFAR view of red quasars

* **LoTSS: image entire northern sky @ 120—168 MHz with 6” resolution.**
* **Confirmation of enhanced radio emission in the red QSO population.**

Rosario+2019, *in prep*

The LOFAR view of red quasars

* LoTSS: image entire northern sky @ 120—168 MHz with 6” resolution.
* Confirmation of enhanced radio emission in the red QSO population.
* At lower R values the enhancement drops.
* Enhancement is due to AGN processes?

Rosario+2019, *in prep*

We think that the majority of red quasars are younger systems...

see also Georgakakis+2012; Glikman+2012; Sobolewska+2018; +++

Red Quasar

Blue Quasar

Future work

XMM-Newton
5 red quasars + archival

VLT/X-SHOOTER
60 quasars

eMERLIN
40 quasars
0.1"

JVLA
38 quasars
0.3"

ALMA
90 quasars

Take home message

* Optically selected red quasars have an enhanced radio-detection fraction.
* These red quasars are preferentially compact and radio-quiet.
* Our results favour evolution over orientation.

"Look up into the heavens. Who created all the stars? He brings them out like an army, one after another, calling each by its name. Because of his great power and incomparable strength, not a single one is missing." — Isaiah 40:26

Thank you
Questions?

Credit: S. Munro & L. Klindt

BackupS...

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Rest-frame $L_{6\mu m}$ vs. redshift

❒ This is the signature that we would expect for dust reddening as the shorter wavelength emission will be more suppressed for a fixed amount of obscuration than longer wavelength emission.

MIR is a more reliable measurement of the intrinsic AGN power !

Rest-frame $L_{6\mu m}$ vs. $L_{bol,Shen}$

MIR is a more reliable measurement of the intrinsic AGN power !

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L1.4GHz vs redshift

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Red synchrotron component?

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The LOFAR view of red quasars

Rosario+ 2019, *in prep*

Going deeper & resolving smaller scales

Fawcett+ 2019, *in prep*

Going deeper & resolving smaller scales

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Sobolewska+2019

radio loudness vs.
radio morphologies