Mon. Not. R. Astron. Soc. **000**, 000–000 (0000) Printed 19 February 2015 (MN LaTeX style file v2.2)

An Observational Overview of Quasars

Nicholas P. Ross[1,2]
[1] *Institute for Astronomy, University of Edinburgh, Royal Observatory, Blackford Hill Edinburgh EH9 3HJ, United Kingdom*
[2] *STFC Ernest Rutherford Fellow*
Email: npross@roe.ac.uk

19 February 2015

ABSTRACT
The SDSS-III: Baryon Oscillation Spectroscopic Survey (BOSS) is a 5 year experiment which obtained first light in late 2009. One of the key goals of the BOSS is to obtain spectra of a sample of $\sim$150,000 $z > 2.2$ quasars, in order to measure baryon acoustic oscillations (BAO) in the distribution of the Ly α forest to provide a percent-level measurement of the expansion history of the Universe. In this paper, we describe the BOSS quasar target selection algorithms, and characterize their success, for the first year of BOSS observations only. The magnitude limit of the BOSS Year One Quasar survey was set at $g \leq 22.0$ or $r \leq 21.85$. In Year One, the BOSS Quasar Survey obtained a total of 54,909 spectra from an area of 878.1 deg^2 (including ~ 40 deg^2 of the SDSS deep stripe "Stripe 82") at a mean target density of 62.8 targets deg^{-2}. Of the 33,556 unique objects with good quality spectra, 11,149 had redshifts indicative of stellar spectra, and 13,580 we quasars with redshifts of $z \geq 2.20$. Over 80% of these quasars (11,263) were spectroscopically confirmed for the first time by the BOSS. The $z \geq 2.20$ quasar surface density was 15.46 quasars deg^{-2}, with a global efficiency of 26.0%. However, in areas targeted at the nominal survey target density of 40 targets deg^{-2}, the efficiency rose to $\sim$35%, ($\sim$14 $z \geq 2.20$ quasars deg^{-2}), with our "CORE" selection efficiency being just over $\sim$50% ($\sim$10 $z \geq 2.20$ quasars deg^{-2} from 20 targets deg^{-2}). Finally, we suggest further methods and new, non-optical, data that can be utilized, so that as the survey progresses, BOSS quasar targeting will improve in efficiency.

Key words: galaxies: clustering – luminous red galaxies: general – cosmology: observations – large-scale structure of Universe.

1 INTRODUCTION

Hunt et al. (2004) Richards et al. (2006) Croom et al. (2009b) Croom et al. (2009a) Degraf et al. (2010) Glikman et al. (2011) Glikman et al. (2011)

Martin's point: *(i)* If I had 2-3 slides to present on QSOs for students, what would those be??; *(ii)* a list of key things a decent student should know (about e.g. QSOs). *(iii)* (and from me!) what's the hook/the new thing here... *(iv)* from Joanne, summer school notes.

What this paper is: General overview of the current state of observational QSO work. Empirical and phenomolgy.

What this paper is not: Detailed review article. Heavy on interpretation, or the subtitles on many of the measurements/observations. A theoretical work of any sort.

In Table 1 various definitions are given.

2 PHOTOMETRY

- Point-like in the optical
- Extended
- Can be (very) blue; UVX
- Can be red; Reddening, (Krawczyk et al. 2015)
- Can be very red; high-z
- Can be very red; Obscured Type 1s (Banerji et al. 2014)
- Can be very red; Weirdos...(Ross et al. 2014)
- Vary; light curves, DRW etc. MacLeod et al. (2010, 2011, 2012b,a, 2014)

2.1 X-ray

2.2 Infra-red

$\lambda > 5\mu$m i.e. dust

Term	Definition	Canonical Reference
Quasar	Very luminous object with large redshift, most likely being powered by gravitational accretion onto a SMBH	Schmidt (1963)
SMBH	Supermassive Black hole	Lynden-Bell & Rees (1971)
Unobscured QSO	UV/optically continuum and emission lines from the accretion disk and BLR	
Obscured QSO	UV/optically emission heavily suppressed	
Type 1 AGN	Broad (and Narrow) Emission Lines present	
Type 2 AGN	Broad Emission Lines absent in a flux spectrum	
Compton Thick	AGN with X-ray emission surpressed by $N_{\rm H} \geq 10^{24}$ cm^{-2}	
Type-11 AGN	Unobscured both in optical and X-ray spectra	Merloni et al. (2014)
Type-22 AGN	Obscured both at X-ray and optical wavelengths	Merloni et al. (2014)
Type-12 AGN	Optically unobscured but have X-ray spectra (or HR) consistent with $N_{\rm H} > 10^{21.5}$ cm^{-2}	Merloni et al. (2014)
Type-21 AGN	No X-ray obscuration but no broad lines in the optical spectra or have galaxy optical/UV SED	Merloni et al. (2014)
Seyfert 1.9	broad component is detected only in the $H\alpha$ line and not in the higher-order Balmer lines	**?**
Seyfert 1.8	the broad components are very weak but detectable at $H\beta$ as well as $H\alpha$.	
Seyfert 1.5	the strengths of the broad and narrow components in $H\beta$ are compar able.	

Table 1. But not only (Schmidt 1963)

2.3 Radio

- Kratzer et al.
- blazars vs. Flat-spectrum radio quasars; e.g. Nakagawa&Mori, 2013, ApJ, 773, 177 also e.g. Justin Finke talk from AAS (!!)

3 SPECTROSCOPY

- "Heavily" redshifted
- Broad Emission Lines
- Narrow Emission Lines
- Permitted emission lines e.g. Lyα , C IV , Mg II
- Semi-Forbidden emission lines e.g. C III]
- Forbidden emission lines e.g. [O III] , [Ne V]
- Absorption Lines. Hydrogen, Lyman-α forest
- Absorption LInes and Reionization
- Absorption Lines. Metals
- Double power-law model?? $F_\nu = A\nu^\alpha + B\nu^{-\alpha}$ Kishimoto et al. (2008)
- Big Blue Bump
- Little Blue Bump
- Composites; Francis et al. (1991); Vanden Berk et al. (2001)
- We introduce Coronal-Line Forest Active Galactic Nuclei (CLiF AGN), Rose arXiv:1501.02705v1).

3.1 Dual Black Holes

Quasar Pairs??

3.2 Broad Absoprtion lines

4 LENSING

- "The Quad"
- Japanese group'

5 THE LUMINOSITY FUNCTION

The QLF is defined as the number density of quasars per unit luminosity. It is often described by a double power-law (Boyle et al. 2000; Croom et al. 2004; Richards et al. 2006, hereafter, R06) of the form

$$\Phi(L,z) = \frac{\phi_*^{(L)}}{(L/L^*)^\alpha + (L/L^*)^\beta} \tag{1}$$

with a characteristic, or break, luminosity L_*. An alternative definition of this form of the QLF gives the number density of quasars per unit magnitude,

$$\Phi(M,z) = \frac{\phi_*^{(M)}}{10^{0.4(\alpha+1)[M-M^*(z)]} + 10^{0.4(\beta+1)[M-M^*(z)]}} \tag{2}$$

The dimensions of Φ differ in the two conventions. We have followed R06 such that α describes the faint end QLF slope, and β the bright end slope. The α/β convention in some other works (e.g., Croom et al. 2009a) is in the opposite sense from our definition. Evolution of the QLF can be encoded in the redshift dependence of the break luminosity, ϕ_*, and also potentially in the evolution of the power-law slopes.

- Double Power-law
- PLE
- Evolution of M^* and Φ^*
- Comparison of the QLF at $z = 1, 2, 5$ vs. the galaxy LF
- Comparison of the QLF(z) vs. the SFR, sSFR

Implications of the QLF, Soltan and/on the ExGal backgrounds.... What wiggle room is left? Espeically that Xray-Spitzzer cross-correlation measurement...

6 QUASAR CLUSTERING

The 2pt Function; Clustering

- $\sim$ few $\times 10^{12} M_\odot$ to $z \sim 2.5$
- More-or-less luminosity independent for $L_{rmBol} \gtrsim 10^{45}$ ergs.
- Colour Dependence in e.g. SDSS = none
- Colour Dependence with $r-W2 > 6$ gets v. interesting!!
- a la obscured vs. unobscured
- With Radio Loudness
- With X-ray hardnes?!s
- DM Haloes of Moderate luminosity AGN

7 MORPHOLOGY

- At $z \sim 0$ Bahcall et al. (1997).
- At $z \sim 0.5$ (Stripe 82 stuff??)
- At $z \sim 1$ (Villforth????)
- At $z \sim 1-2$
- At $z \gtrsim 2$???

8 SCALING RELATIONS

- redshift $z \sim 0$, classical relations, $M - \sigma$
- **?**, Magorrian et al. (1998), Ferrarese & Merritt (2000), Gebhardt et al. (2000), Tremaine et al. (2002), Gültekin et al. (2009)
- High-mass end, e.g. McConnell et al. (2011); McConnell & Ma (2013)
- Pseduo-bulges etc.
- Pseduo-bulges etc. and correcting for e.g. orientation/inclination effects, e.g. Bellovary14
- Tremaine et al. (2002) and Novak (2013)
- Mullaney's work??

9 OTHER RELATIONS

- "Type 2" QSOs are not (extra) massive enough to produce the difference in e.g. 250μm SF difference.... Chen, Hickox et al.

10 COSMO BACKGROUNDS

- X-ray
- Optical
- CIB (Marco Viero :-)
- FIR
- Gamma-ray, γ-ray; 80% of Fermi photons from MW; 10% from Pooint sources, 10% background, including the cosmo gamma-ray background. e.g. 100 MeV to 820 GeV. arXiv:1410.3696; Blazars account fo 50% of the EGB. Blazars+Extragalactic Background light (which is what exactly?!) responsible for cutt-off in EGB spectrum e.g. Ajello+15; Blazars plus radio gals plus SFgals account for essentially all the EGB (can put constraints on e.g. DM cross-sections.)
- Fermi actually gives a pretty-to-very good feel for the blazar luminosity function and it's evolution -look this up!!

11 GENERAL ARGUMENTS

- Soltan
- Shankar Continuity??
- QLF+Clustering equals lifetime?!?
- $M_{\rm BH} = f\,\frac{RV^2}{G}$

12 TO BE CONFIRMED

- Emit Gravitational Waves

13 CONNECTION TO DSFGS

Having made a relatively comprehensive list of the observed phenomenology...
is there a connection to DSFGs...???

- Connection of QSOs to Dusty Star-formaig Galaxies...
- aka how wrong is the Hopkins 07 picture...

REFERENCES

Bahcall J. N., Kirhakos S., Saxe D. H., Schneider D. P., 1997, ApJ, 479, 642
Banerji M., Fabian A. C., McMahon R. G., 2014, MNRAS
Boyle B. J., Shanks T., Croom S. M., Smith R. J., Miller L., Loaring N., Heymans C., 2000, MNRAS, 317, 1014
Croom S. M., et al., 2009a, MNRAS, 399, 1755
Croom S. M., et al., 2009b, MNRAS, 392, 19
Croom S. M., Smith R. J., Boyle B. J., Shanks T., Miller L., Outram P. J., Loaring N. S., 2004, MNRAS, 349, 1397
Degraf C., Di Matteo T., Springel V., 2010, MNRAS, 402, 1927
Ferrarese L., Merritt D., 2000, ApJ Lett., 539, L9
Francis P. J., Hewett P. C., Foltz C. B., Chaffee F. H., Weymann R. J., Morris S. L., 1991, ApJ, 373, 465
Gebhardt K., Bender R., Bower G., Dressler A., Faber S. M., Filippenko A. V., Green R., Grillmair C., Ho L. C., Kormendy J., Lauer T. R., Magorrian J., Pinkney J., Richstone D., Tremaine S., 2000, ApJ Lett., 539, L13
Glikman E., Djorgovski S. G., Stern D., Dey A., Jannuzi B. T., Lee K., 2011, ApJ Lett., 728, L26+
Gültekin K., et al., 2009, ApJ, 698, 198
Hunt M. P., Steidel C. C., Adelberger K. L., Shapley A. E., 2004, ApJ, 605, 625
Kishimoto M., Antonucci R., Blaes O., Lawrence A., Boisson C., Albrecht M., Leipski C., 2008, Nat, 454, 492
Krawczyk C. M., Richards G. T., Mehta S. S., Vogeley M. S., Gallagher S. C., Leighly K. M., Ross N. P., Schneider D. P., 2015, ApJS, 999, 4
Lynden-Bell D., Rees M. J., 1971, MNRAS, 152, 461
MacLeod C., et al., 2012a, in American Astronomical Society Meeting Abstracts Vol. 219 of American Astronomical Society Meeting Abstracts, No Quasar Left Behind. p. 243.28
MacLeod C. L., et al., 2010, ApJ, 721, 1014
MacLeod C. L., et al., 2011, ApJ, 728, 26
MacLeod C. L., et al., 2012b, ApJ, 753, 106
MacLeod C. L., et al., 2014, ApJ, 782, 119
Magorrian J., et al., 1998, AJ, 115, 2285
McConnell N. J., Ma C.-P., 2013, ApJ, 764, 184
McConnell N. J., Ma C.-P., Gebhardt K., Wright S. A., Murphy J. D., Lauer T. R., Graham J. R., Richstone D. O., 2011, Nat, 480, 215
Merloni A., et al., 2014, MNRAS, 437, 3550
Novak G. S., 2013, ArXiv e-prints
Richards G. T., et al., 2006, AJ, 131, 2766
Ross N. P., Hamann F., Zakamska N. L., et al., 2014, arXiv:1405.1047v1
Schmidt M., 1963, Nat, 197, 1040
Tremaine S., et al., 2002, ApJ, 574, 740
Vanden Berk D. E., et al., 2001, AJ, 122, 549