Near and mid-infrared properties of known $z \geq 5$ Quasars

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4 July 2018

ABSTRACT
Lorem ipsum dolor sit amet, consectetur adipiscing elit. Aliquam porta sodales est, vel cursus risus porta non. Vivamus vel pretium velit. Sed fringilla suscipit felis, nec iaculis lacus convallis ac. Fusce pellentesque condimentum dolor, quis vehicula tortor hendrerit sed. Class aptent taciti sociosqu ad litora torquent per conubia nostra, per inceptos himenaeos. Etiam interdum tristique diam eu blandit. Donec in lacinia libero. Sed elit massa, eleifend non sodales a, commodo ut felis. Sed id pretium felis. Vestibulum et turpis vitae quam aliquam convallis. Sed id ligula eu nulla ultrices tempus. Phasellus mattis erat quis metus dignissim malesuada. Nulla tincidunt quam volutpat nibh facilisis euismod. Cras vel auctor neque. Nam quis diam risus.

Key words: Astronomical data bases: surveys – Quasars: general – galaxies: evolution – galaxies: infrared.

TO DOS

- Almost certainly want to compile M_{BH};
- May well wanna try and get $M_\star$ too...!! ;

1 INTRODUCTION

Very high redshift quasars (VHzQs, defined here to have redshifts $z \gtrsim 5$) are excellent probes of the early Universe. This includes studies of the Epoch of Reionization for hydrogen (see e.g. Fan et al. 2006; Mortlock 2016, for reviews), the formation and build-up of supermassive black holes (e.g., Rees 1984; Wyithe & Loeb 2003; Volonteri 2010; Agarwal et al. 2016; Valiante et al. 2018; Latif et al. 2018) and early metal enrichment (see e.g., Simcoe et al. 2012; Chen et al. 2017; Bosman et al. 2017).

Quasars are also known to be prodigious emitters of infrared emission, thought to be from the thermal emission of dust grains heated by continuum emission from the accretion disc (Hill et al. 2014; Hickox et al. 2017). Observations in the mid-infrared, e.g. $\sim$3-30μm allow discrimation between AGN[1] and passive galaxies due to the 1.6μm "bump" entering the MIR at $z \approx 0.8 - 0.9$ (e.g., Wright et al. 1994; Sawicki 2002; Lacy et al. 2004; Stern et al. 2005; Richards et al. 2006; Timlin et al. 2016) as well as AGN and star-forming galaxies due to the presence of Polycyclic Aromatic Hydrocarbon (PAHs) at $\lambda > 3\mu$m (e.g., Yan et al. 2007; Tielens 2008).

Jiang et al. (2006) and Jiang et al. (2010) report on the discovery of a quasar without hot-dust emission in a sample of 21 $z \approx 6$ quasars. Such apparently hot-dust-free quasars have no counterparts at low redshift. Moreover, we demonstrate that the hot-dust abundance in the 21 quasars builds up in tandem with the growth of the central black hole,

Blain et al. (2013) presented WISE mid-infrared (MIR) detections of 17 (55%) of the then known 31 quasars at $z > 6$. However, Blain et al. (2013) was compiled with the WISE 'All-Sky' data release, as opposed to the superior "AllWISE" catalogs. That sample only examined the 31 known $z > 6$ quasars; our sample has 148 objects with redshift $z \geq 6.00$.

Here we update Jiang et al. (2010) and Blain et al. (2013) (along with Table 8 of Bañados et al. 2016).

We chose redshift $z = 5.0$ as our lower redshift limit due to a combination of garnishing a large sample, adequately spanning physical properties (e.g. luminosity, age of the Universe) and to incorporate what knowledge we've gained over the last couple of decades since $z > 5$ quasars were discovered.

WISE mapped the sky in 4 passbands, in bands centered at wavelengths of 3.4, 4.6, 12, and 23μm. In total the release all sky "ALLWISE" catalog, contains nearly 750 million de-

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[1] Historically, "quasars" and "Active Galactic Nuclei (AGN)" have described different luminosity/classes of objects, but here we use these terms interchangeably (with a preference for quasar) in recognition of the fact that they both describe accreting supermassive black holes (e.g. Haardt et al. 2016).

tections at high-significance[2]. Assef et al. (2013), Stern et al. (2012)

In this paper, we introduce the "WISE W4 Compendium" (WW4C); a detailed study into the objects that were detected in the longest waveband, 20-28μm observed, on the Wide-Field Infrared Survey Explorer (WISE; Wright et al. 2010; Cutri 2013) mission. This study will describe all 40 million objects that are detected in the WISE W4-band, but will concentrate on those objects most affected by radiating dust emission and well described by extragalactic, and AGN, spectral energy distributions (SEDs). The motivations of the WW4C are numerous, but the primary science we will pursue is the identification of bolometric luminous AGN, especially those that might not be observed in X-ray/UV/optical surveys.

Brown et al. (2014), in PASA, is the paper about Recalibrating the Wide-field Infrared Survey Explorer (WISE) W4 Filter,

This paper can be considered an update of Blain et al. (2013) and also an extension of parts of Bañados et al. (2016), with the latter study reporting WISE W1, W2, W3 and W4 magnitudes for Panoramic Survey Telescope and Rapid Response System 1 (Pan-STARRS1, PS1; Kaiser et al. 2002, 2010), but with no further investigation into the reddest WISE waveband for the VHzQs. Bañados et al. (2016) reports and investigates the W1, W2 and W3 properties of quasars at $z > 5.6$.

$M_{\rm BH}, M_{\rm bulge}, M_{\star}$ are the SMBH mass, stellar mass of the bulge and galaxy total stellar mass, respectively.

Because of established conventions, we report SDSS *ugriz* magnitudes on the AB zero-point system (Oke & Gunn 1983; Fukugita et al. 1996), while the WISE W1 4 magnitudes are calibrated on the Vega system (Wright et al. 2010). For WISE bands, $m_{\rm AB} = m_{\rm Vega} + m$ where m = (2.699, 3.339, 5.174, 6.66) for W1, W2, W3 and W4, respectively (Cutri et al. 2011; Brown et al. 2014). We make use of the Explanatory Supplement to the WISE All-Sky Data Release, as well as the WISE AllWISE Data Release Products online. All optical (*ugriz* bands) magnitudes are given in the AB system, all near-infrared ($y/YJHK$) are also given in the AB system. We use a flat ΛCDM cosmology with $H0$ = 67.7 km s-1 Mpc1, $\Omega_{\rm M}$ = 0.307, and Ω_{Λ} = 0.693 (Planck Collaboration et al. 2016) in order to be consistent with Bañados et al. (2016).

2 DATA

Table 1 gives the salient details for the objects used in this study. We use all the $z \geq 5.00$ quasars that have been discovered and spectroscopically confirmed as of the time of writing (2018 June). We report near-infrared ($yYJHK$-bands) and mid-infrared (WISE W1/2/3/4) photometry and give our caculcated M_{1450}

2.1 Very high redshift quasars

In Table 1 we give the discovery reference for the VHzQs noting that some objects were discovered independently and contemporaneously. The redshifts for the VHzQs generally come from the measurement of broad UV/optical emission lines. Where there are far infra-red emission lines e.g. C II 158 micron, we report these, but at the level of our current analysis broadline redshifts are sufficient.

Specifically, we use data from: Fan et al. (2000), Fan et al. (2001), Fan et al. (2003) , Fan et al. (2004), Mahabal et al. (2005), Cool et al. (2006), Fan et al. (2006), Goto (2006), McGreer et al. (2006), Carilli et al. (2007), Kurk et al. (2007), Stern et al. (2007), Venemans et al. (2007), Willott et al. (2007), Jiang et al. (2008), Wang et al. (2008) Jiang et al. (2009) Kurk et al. (2009) Mortlock et al. (2009) Willott et al. (2009) Carilli et al. (2010) Wang et al. (2010) Willott et al. (2010) Willott et al. (2010) De Rosa et al. (2011) Mortlock et al. (2011) Wang et al. (2011) Zeimann et al. (2011) Morganson et al. (2012) Venemans et al. (2012) McGreer et al. (2013) Venemans et al. (2013) Wang et al. (2013) Willott et al. (2013) Bañados et al. (2014) Calura et al. (2014) Leipski et al. (2014) Bañados et al. (2015) Bañados et al. (2015) Becker et al. (2015) Carnall et al. (2015) Jiang et al. (2015) Kashikawa et al. (2015) Kim et al. (2015) Reed et al. (2015) Venemans et al. (2015b) Venemans et al. (2015a) Willott et al. (2015) Wu et al. (2015) Venemans et al. (2016) Wang et al. (2016) Matsuoka et al. (2016) Wang et al. (2016) , Mortlock et al. (2011), McGreer et al. (2013), Venemans et al. (2013), Venemans et al. (2013), Venemans et al. (2015b), Venemans et al. (2015a), Bañados et al. (2016), Matsuoka et al. (2016), Reed et al. (2017), Wang et al. (2017), Mazzucchelli et al. (2017), Ikeda et al. (2017), Tang et al. (2017), Koptelova et al. (2017), Bañados et al. (2018), Matsuoka et al. (2018a) and Matsuoka et al. (2018b).

2.2 Optical Photometry

2.2.1 Pan-STARRS1 (PS1)

We query the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS)[3] Data Release 1 (DR1) Catalog Archive Server Jobs System (CasJobs) service at mastweb.stsci.edu/ps1casjobs/. The PS1 survey observed the 30,000 deg^2 of sky north of declination -30 degrees in five filters *grizy*. Pan-STARRS1 (PS1) is the first part of Pan-STARRS to be completed and is the basis for the DR1. Chambers et al. (2016), Magnier et al. (2016c), Waters et al. (2016), Magnier et al. (2016a), Magnier et al. (2016b) and Flewelling et al. (2016) describe the instrument, survey, and data analyses. The principal science product of the PS1 survey is the catalog accessible through the CasJobs interface.

We query and return the mean PSF magnitudes from the *grizy* filters (`MeanPSFMag`) which are in the AB system for our 425 VHzQ sample. Details of our SQL and links to the main tables are given in B.

2.3 Near-infrared photometry

Due to their selection of being very faint/undetected in the observed-frame optical but bright in the observed frame

[2] wise2.ipac.caltech.edu/docs/release/allwise/expsup/sec2_1.html

[3] https://outerspace.stsci.edu/display/PANSTARRS

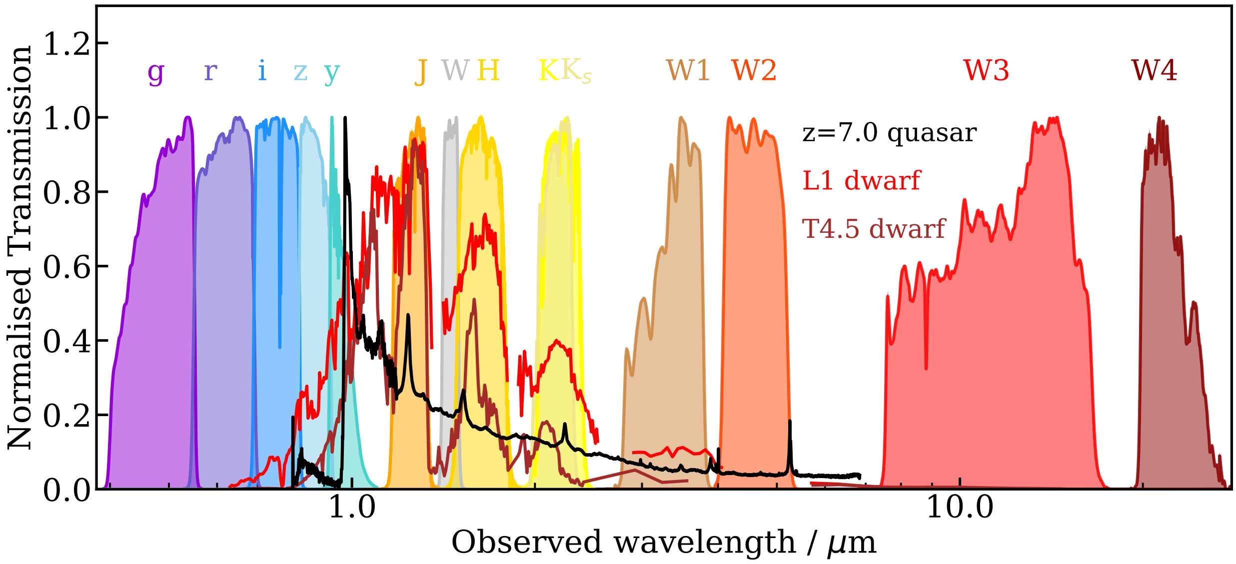

Figure 1. The spectral bands used by different survey telescopes and that are relevant here.

na	desig	ra_hms	dec_dms	ra	dec	redshift	mag	M1450	errM1450	ra_WISE
PSO	J000.3401+26.8358	00:01:21.63	+26:50:09.17	0.34011348	26.83588138	5.75	19.52	-27.16	9.99	0.3400887
SDSS	J0002+2550	00:02:39.39	+25:50:34.80	0.66411726	25.84304425	5.82	19.39	-27.31	9.99	0.6641312
SDSS	J0005-0006	00:05:52.34	-00:06:55.80	1.4680833	-0.1154999	5.85	20.98	-25.73	9.99	1.4683933
PSO	J002.1073-06.4345	00:08:25.77	-06:26:04.60	2.10739	-6.43456	5.93	20.41	-26.32	9.99	2.1073696
SDWISE	J0008+3616	00:08:51.43	+36:16:13.49	2.2142917	36.2704138	5.17	19.12	-27.34	9.99	2.2142355
PSO	J002.3786+32.8702	00:09:30.89	+32:52:12.94	2.37870183	32.87026179	6.1	21.13	-25.65	9.99	2.3787018
SDSS	J0017-1000	00:17:14.68	-10:00:55.4	4.3111666	-10.01539722	5.011	99.99	-99.99	9.99	4.3111476
PSO	J004.3936+17.0862	00:17:34.47	+17:05:10.70	4.39361347	17.08630447	5.8	20.69	-26.01	9.99	4.3936134
PSO	J004.8140-24.2991	00:19:15.38	-24:17:56.98	4.81408	-24.29916	5.68	19.43	-27.24	9.99	4.814116
VDES	J0020-3653	00:20:31.46	-36:53:41.8	5.1311237	-36.8949476	6.9	99.99	-99.99	9.99	5.1311237

Table 1. All 425 $z \geq 5.00$ quasars that have been spectroscopically confirmed as of 2018 June. The first ten objects are given here as guidance to the format of the data table. The full table can be found online.

near-infrared, VHzQs are generally detected in the near-infrared $yYJHK$-bands (≈0.98-2.38μm; e.g., Peth et al. 2011).

We query the WFCAM Science Archive (WSA; Hambly et al. 2008) which reports NIR photometry from the Wide Field Camera (WFCAM; Casali et al. 2007) on the United Kingdom Infrared Telescope (UKIRT). Data from the VIRCAM (VISTA InfraRed CAMera) on the VISTA (Visible and Infrared Survey Telescope for Astronomy; Emerson et al. 2006; Dalton et al. 2006) is also given in the WSA.

Quasars are known to vary (both photometrically and spectroscopically) and very high-z quasars under going super-Eddington accretion during a rapid BH growth phase are prime candidates for this variation. Therefore, with repeat observations over many epochs availble via the WSA, we have a choice to make for how we report the photometry. After tests, we decide to give the NIR photometry averaged on 4 week observed timescales. This time bracket is chosen as a good compromise between maximising signal-to-noise while keeping the cadence high. At our observed redshifts, we sample $\lesssim$ 1week in the rest-frame and luminous quasars are not expected to vary on timescales quicker than this (e.g., Lawrence 2016).

We give our recipe and SQL query syntax in Appendix C.

2.3.1 *UKIDSS LAS*

Use:
dr10plus
lasSource table (merged catalogue), nearest object only; radius 2.0”
424 results returned. Of which...

2.3.2 *VISTA VHS*

Use:
VH5DR5
sourceTable (merged catalogue), nearest object only; radius 2.0”
424 results returned. Of which...

Sample Description	Number in sample	North	South

Table 2.

N.B., a few objects will have both UKIDSS LAS and VISTA VHS photometry...

3 RESULTS

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3.1 Detection Rates

3.2 Variability

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Nunc semper quam et leo interdum vulputate eu quis magna. Sed nec arcu at orci egestas convallis. Aenean quam velit, aliquam vitae viverra in, elementum vel elit. Nunc suscipit aliquet sapien a suscipit. Cras nulla ipsum, posuere eu fringilla sit amet, dapibus ultricies nulla. Nullam eu augue id purus mollis dignissim sed et libero. Phasellus eget justo sed neque pellentesque egestas nec id arcu. Donec facilisis pulvinar sapien et fringilla. Suspendisse vestibulum rhoncus sapien id laoreet. Morbi et orci vitae tortor imperdiet imperdiet. In hac habitasse platea dictumst. Vivamus vel neque id mi ultrices tristique. Integer quam libero, ornare vel gravida in, feugiat a ante. Nam dapibus, tellus vitae pellentesque cursus, dui nisl egestas augue, non fermentum nisl est nec nisi. Vestibulum nec mi justo, eget dapibus velit.

3.3 Very High-z Quasars Detected in WISE

Blain et al. (2013) Cras in laoreet mauris. Vivamus nec nulla a dui commodo adipiscing. Proin vulputate lectus nec arcu iaculis sit amet auctor ligula ultricies. Phasellus condimentum gravida tincidunt. Phasellus et mauris ac nibh vestibulum vehicula. Morbi et augue id purus gravida sagittis quis in sem. Phasellus quis risus bibendum eros luctus auctor.

3.3.1 Very High-z Quasars Detected in WISE W3 and W4

Proin non tempus velit. Etiam laoreet, enim nec scelerisque dictum, tortor massa tempor enim, id pretium justo quam ac lectus. Maecenas diam nibh, interdum at lobortis sit amet, dignissim et quam. Sed tincidunt faucibus risus, congue tempus nisl consectetur eget. Suspendisse venenatis turpis ut risus aliquam interdum. In at velit sed ligula dictum dignissim ut et dui. Curabitur ac scelerisque purus.

3.4 Colours

Pellentesque vel elit neque, in interdum lacus. Quisque sodales, nunc et luctus convallis, nisl dui luctus dui, at congue urna velit a nisl. Ut sit amet sapien a risus dapibus sagittis. Cras sed ultricies erat. Donec id metus sed urna lacinia convallis vel sed enim. Proin nisi libero, ornare vel bibendum eu, sollicitudin sed leo. Cras tincidunt aliquet ultricies. Cras pretium velit leo, in malesuada enim. Duis sagittis ultricies interdum. Proin sit amet sem nec metus feugiat pharetra.

Figure 2 presents the optical colour-redshift trends for Late Type M/L/T dwarfs and the VHzQs.

Figure 2 presents the near-infrared colour-redshift trends for Late Type M/L/T dwarfs and the VHzQs.

3.5 Consequences of evolution of the $M_{\rm BH} - M_{\star}$ relation

From a study of 69 *Herschel*-detected broad-line active galactic nuclei, Sun et al. (2015) find there is no evolution in the $M_{\rm BH} - M_{\star}$ relation from $z \sim 2$ to $z \sim 0$, with the ratio of $\log(M_{\rm BH}/M_{\star}$ constant at -2.85 across this redshift range. If this ratio holds to $z > 5$, and we assume the $M_{\rm BH}$ for the $z > 6$ measured from the e.g. Mg II line, are generally correct, then the galaxy total stellar mass for the $z > 6$ objects should be...

Yang et al. (2018) calculate the long-term SMBH accretion rate as a function of $M_{\rm star}$ and redshift $[BHAR(M_{\star}, z)]$ over ranges of $\log(M_{\rm star}/M_{\odot}) = 9.512$ and $z = 0.44$. Our BHAR(M,z) is constrained by high-quality survey data (GOODS-South, GOODS-North and COSMOS), and by the stellar mass function and the X-ray luminosity function. This BHAR/SFR dependence on $M_{\star}$ does not support the scenario that SMBH and galaxy growth are in lockstep.

3.6 L-z Plane

Having obtained an as-near-to-homogenous set of photometry as we can, we are now in a position to calculate the Absolute Magnitudes of the VHzQ sample and in particulare the absolute magnitude at rest-frame 1450Å' M_{1450}, which is a key physical quantity and goes directly towards the quasar luminosity function and thus the reionization of hydrogen calculation.

At $z = 5.00$, the rest-frame 1450Å emission is redshifted to 8700Å iobserved, i.e., in the z-band, while at

3.7 SEDs and Dust properties of the VHzQs

There are a range of IR SEDs e.g. **?** etc. etc. etc. However, they are, for our purposes all roughly the same.

4 DISCUSSION AND CONCLUSIONS

In this study, we have, for the first time, ompiled the list of all $z > 5$ spectroscopically confirmed quasars. We have assemble the NIR ($y/Y, J, H, K/K_s$) and MIR (WISE

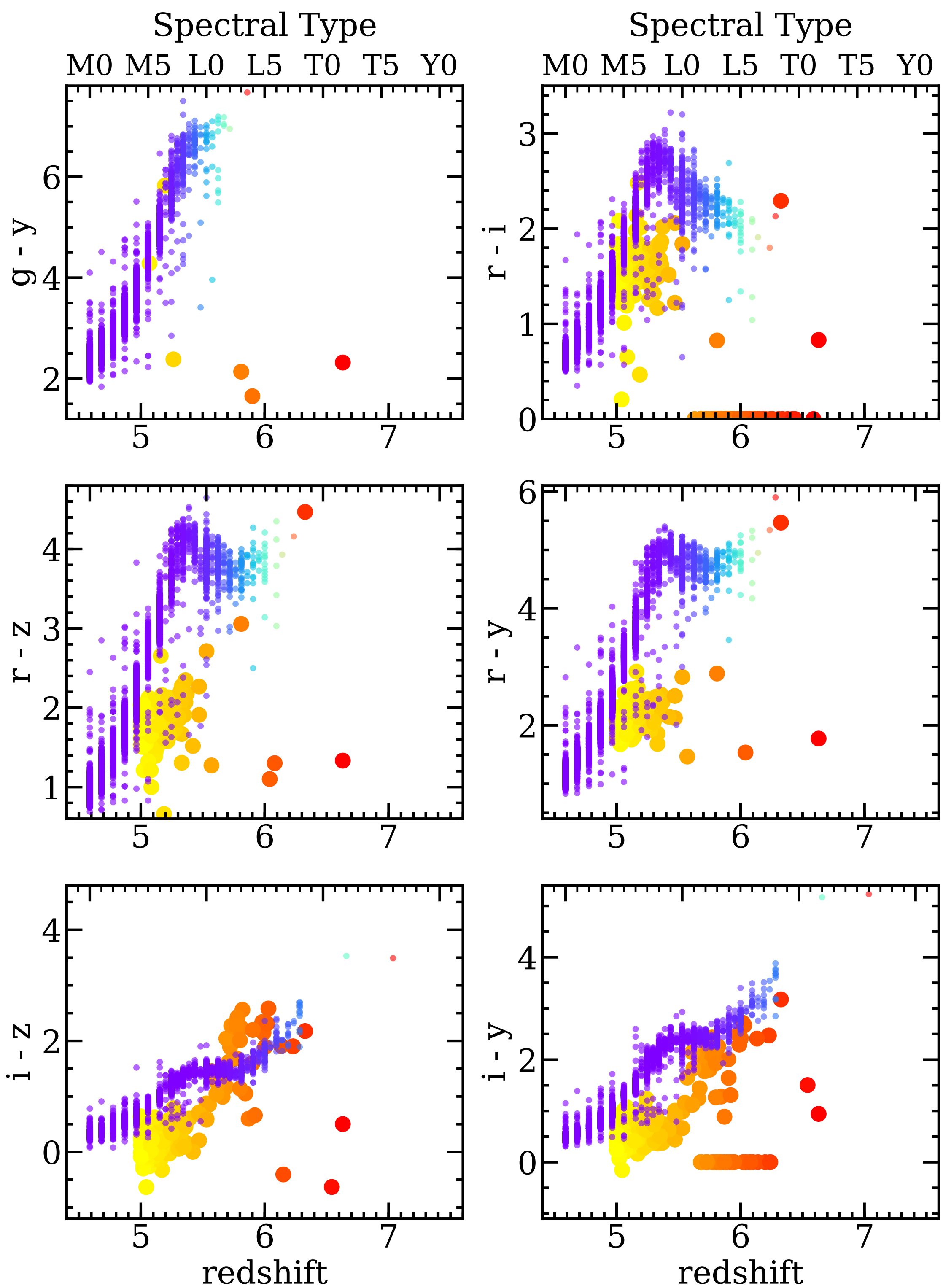

Figure 2. Optical colour vs. spectral type and redshift for Late Type M/L/T dwarfs and the VHzQs. The stars are M, L, and T dwarfs from the **?** PS1-detected catalog. *N.B. Trying to look as good as Fig. 5 from Best et al. (2018). How does one get bigger gaps between subplots??*

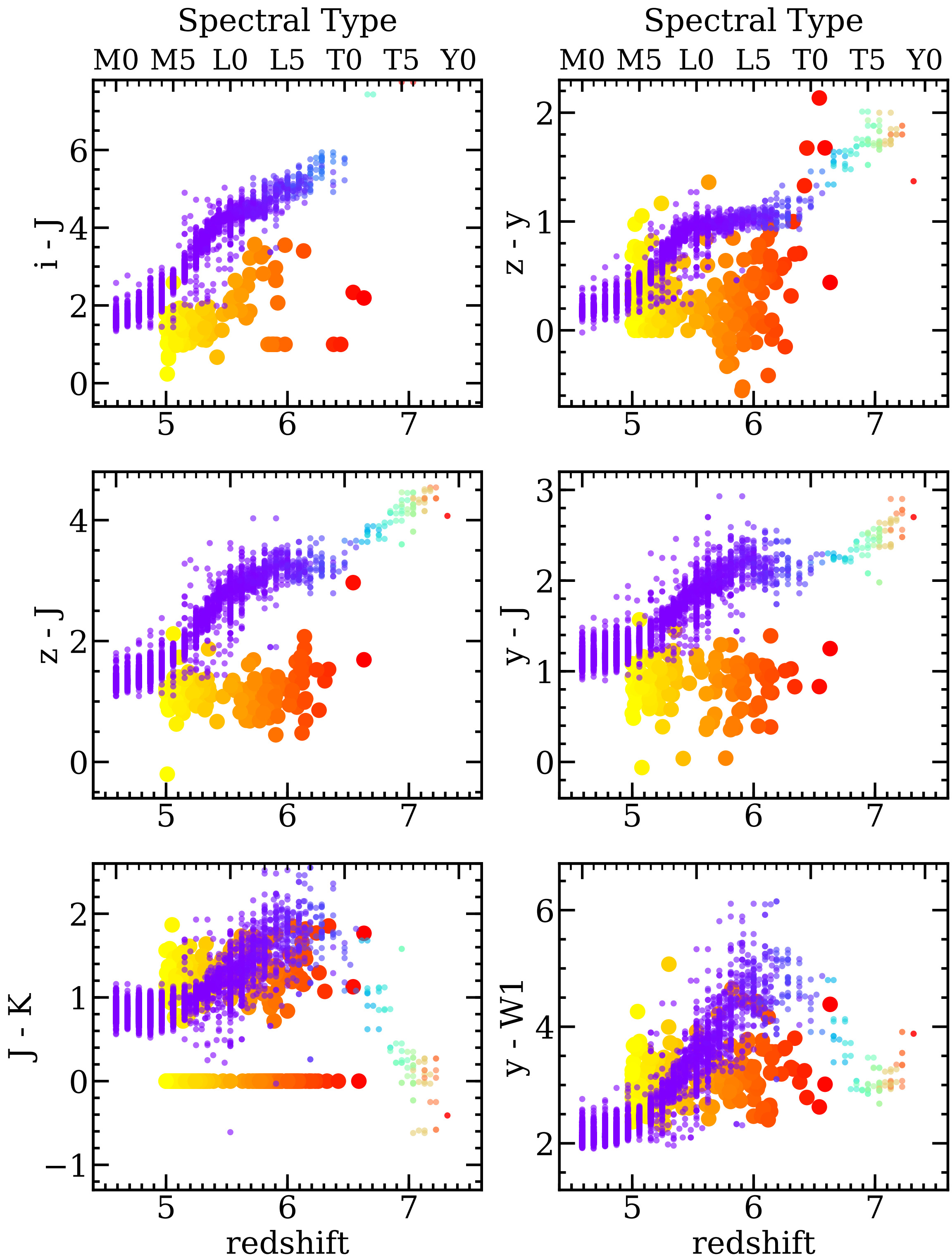

Figure 3. Infrared colour-spectral type and redshift plots for Late Type M/L/T dwarfs and the VHzQs. *NB* I'm really not sure how Best et al. actually get their stellar sequence so clean. There are two types of spectral classification, but restricting it to just SpT_optn or SpT_nir removes the blue or red end respectively. Hmmm....

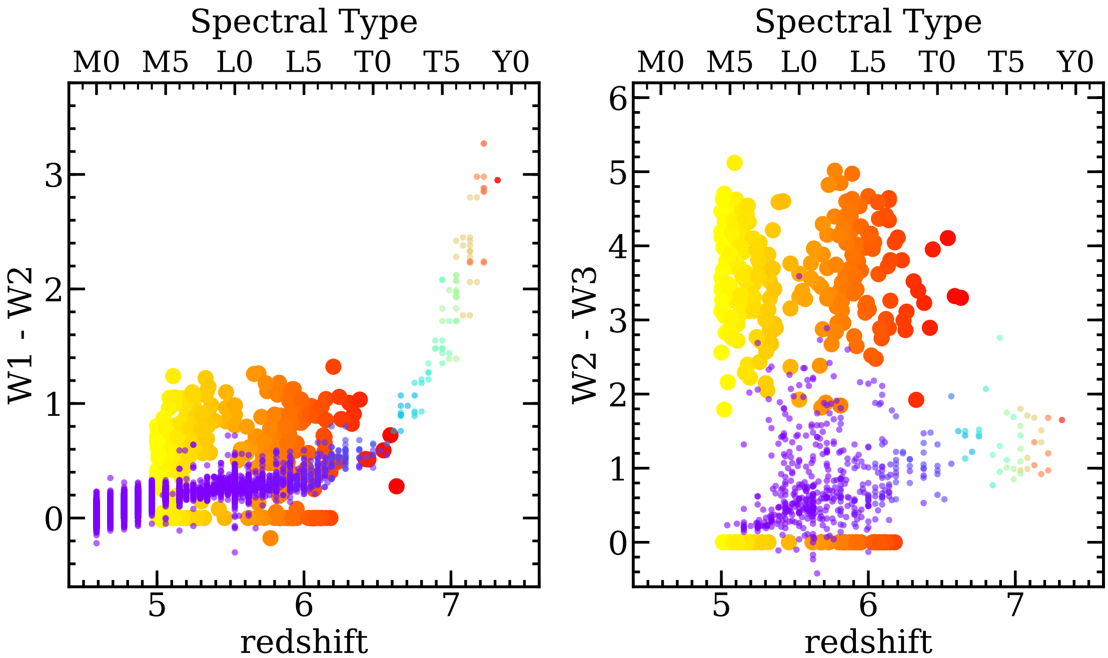

Figure 4. Infrared colour-spectral type and redshift plots for Late Type M/L/T dwarfs and the VHzQs.

W1/2/3/4) photometry for these objects, given their detection rates and SEDs. We find that::

- This sample spans a redshift range of $0.28 < z < 4.36$ and has a bimodal distribution, with peaks at $z \sim 0.8$ and $z \sim 2.5$.
- We recover a wide range of quasar spectra in this selection. The majority of the objects have spectra of reddened Type 1 quasars, Type 2 quasars (both at low and high redshift) and objects with strong absorption features.
- There is a relatively high fraction of Type 2 objects at low redshift, suggesting that a high optical-to-infrared colour can be an efficient selection of narrow-line quasars.
- There are three objects that are detected in the $W4$-band but not $W1$ or $W2$ (i.e., "W1W2-dropouts"), all of which are at $z > 2.6$.
- We identify an intriguing class of objects at $z \simeq 2-3$ which are characterized by equivalent widths of REW(C IV) $\gtrsim$ 150Å. These objects often also have unusual line properties. We speculate that the large REWs may be caused by suppressed continuum emission analogous to Type 2 quasars in the Unified Model. However, there is no obvious mechanism in the Unified Model to suppress the continuum without also suppressing the broad emission lines, thus potentially providing an interesting challenge to quasar models.

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ACKNOWLEDGEMENTS

NPR acknowledges support from the STFC and the Ernest Rutherford Fellowship scheme.

We thank Bernie Shiao at STScI for help with the Pan-STARRS1 DR1 CasJobs interface.

This paper heavily used TOPCAT (v4.4) (Taylor 2005, 2011).

This research made use of `Astropy`, a community-developed core Python package for Astronomy (Astropy Collaboration et al. 2013; The Astropy Collaboration et al. 2018).

The Pan-STARRS1 Surveys (PS1) and the PS1 public science archive have been made possible through contributions by the Institute for Astronomy, the University of Hawaii, the Pan-STARRS Project Office, the Max-Planck Society and its participating institutes, the Max Planck Institute for Astronomy, Heidelberg and the Max Planck Institute for Extraterrestrial Physics, Garching, The Johns Hopkins University, Durham University, the University of Edinburgh, the Queen's University Belfast, the Harvard-Smithsonian Center for Astrophysics, the Las Cumbres Observatory Global Telescope Network Incorporated, the National Central University of Taiwan, the Space Telescope Science Institute, the National Aeronautics and Space Administration under Grant No. NNX08AR22G issued through the Planetary Science Division of the NASA Science Mission Directorate, the National Science Foundation Grant No. AST-1238877, the University of Maryland, Eotvos Lorand University (ELTE), the Los Alamos National Laboratory, and the Gordon and Betty Moore Foundation.

CasJobs was originally developed by the Johns Hopkins University/ Sloan Digital Sky Survey (JHU/SDSS) team. With their permission, MAST used version 3.5.16 to con-

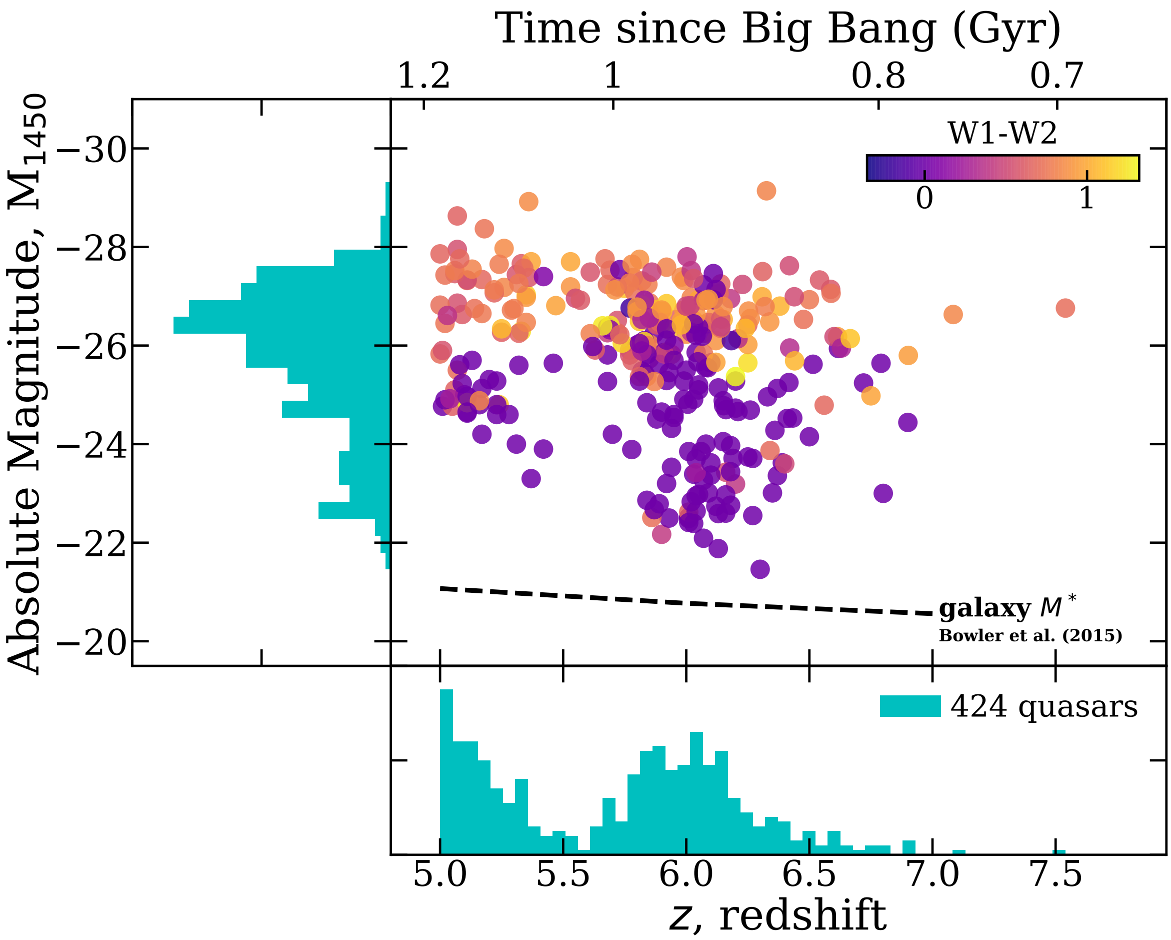

Figure 5. The spectral bands used by different survey telescopes and that are relevant here.

struct CasJobs-based tools for GALEX, Kepler, the Hubble Source Catalog, and PanSTARRS.

This publication makes use of data products from the Wide-field Infrared Survey Explorer, which is a joint project of the University of California, Los Angeles, and the Jet Propulsion Laboratory/California Institute of Technology, and NEOWISE, which is a project of the Jet Propulsion Laboratory/California Institute of Technology. WISE and NEOWISE are funded by the National Aeronautics and Space Administration.

This research has made use of the SVO Filter Profile Service (http://svo2.cab.inta-csic.es/theory/fps/) supported from the Spanish MINECO through grant AyA2014-55216 The SVO Filter Profile Service[4] describes the Spanish VO Filter Profile Service. The Filter Profile Service Access Protocol. Rodrigo, C., Solano, E. http://ivoa.net/documents/Notes/SVOFPSDAL/index.html

[4] Rodrigo, C., Solano, E., Bayo, A. http://ivoa.net/documents/Notes/SVOFPS/index.html

APPENDIX A: FILTER CURVES

FRom the SVO Filter Profile Service[5].

APPENDIX B: PANSTARRS1 SQL QUERIES

The PS1 Casjobs SQL Server is located at mast-web.stsci.edu/ps1casjobs. The top level documentation is given here while the description of tables is given here. The main tables are the `objectThin` and `meanObject` tables.

APPENDIX C: NEAR-INFRARED WFCAM SCIENCE ARCHIVE SQL QUERIES

Here we give the receipe and SQL that returned the near-infrared photometry for the VHzQs.

(i) http://wsa.roe.ac.uk/
(ii) Login

[5] http://svo2.cab.inta-csic.es/svo/theory/fps/

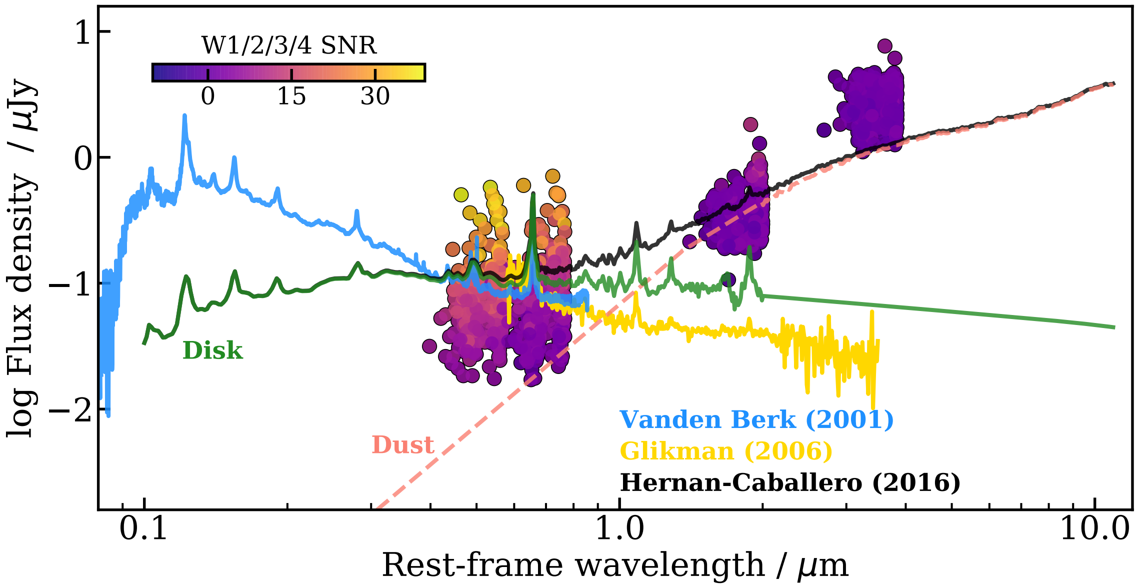

Figure 6. The rest-frame properties of the VHzQs.

(iii) `username: WSERV1000; password: highzqso; community: nonSurvey`
(iv) Freeform SQL Query with WSERV1000v20180327

Then the following SQL will return the values in Table 1.

```
SELECT
qso.qsoName,  qso.ra,  qso.dec,
aver.apertureID,  aver.aperJky3,
aver.aperJky3Err, aver.sumWeight,
aver.ppErrBits, m.mjdObs,
m.filterID, remeas.aperJky3,
remeas.aperJky3Err,
w.weight, remeas.ppErrBits,
m.project

FROM
highzQsoInput as qso,
MapApertureIDshighzQsoMap as ma,
wserv1000MapRemeasAver as aver,
wserv1000MapRemeasurement as remeas,
MapProvenance as v,
wserv1000MapAverageWeights as w,
MapFrameStatus as mfs,
Multiframe as m

WHERE
qso.qsoID=ma.objectID and
ma.apertureID=aver.apertureID and
aver.apertureID=remeas.apertureID and
aver.catalogueID=v.combicatID and
v.avSetupID=1 and
v.catalogueID=remeas.catalogueID and
w.combicatID=v.combicatID and
w.catalogueID=v.catalogueID and
w.apertureID=aver.apertureID and
mfs.catalogueID=remeas.catalogueID and
m.multiframeID=mfs.multiframeID and
mfs.programmeID=10999 and
mfs.mapID=1
order by v.combicatID, m.mjdObs
```

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