The Million Quasars (Milliquas) Catalogue, v6.4

Eric W. Flesch [A,B]

[A]PO Box 15, Dannevirke 4942, New Zealand
[B]Email: eric@flesch.org

Abstract
Announcing the release v6.4 of the Milliquas (Million Quasars) quasar catalogue which presents all published quasars to 11 December 2019, including SDSS-DR16. Its totals are 757 991 type-I QSOs/AGN and approx 1.1M high-confidence (80%+ likelihood) quasar candidates from SDSS-based & AllWISE photometric quasar catalogs, plus all-sky radio/X-ray associated candidates available only here. Type-II and Bl Lac objects are also included, plus candidates/galaxies with double radio lobes (so calculated), bringing the total count to 1 968 377. *Gaia*-DR2 astrometry is given for most objects. The catalogue is available on its home page and on NASA HEASARC.

Keywords: catalogs — quasars: general

1 Introduction

Milliquas is currently the only quasar catalogue to keep abreast of all the latest quasar discoveries from published papers large & small; this edition v6.4 is current to 11 December 2019 and includes the SDSS-DR16 pipeline catalogue which adds ≈160 000 quasars to the literature. The criteria for accepting pipeline quasars and other specifications are as given in the Half Million Quasars catalog (HMQ: Flesch 2015) and references therein, but some modifications are listed below.

Milliquas can be downloaded from its home page[1] or from NASA HEASARC[2] which also provides a query page. Its ReadMe, also available there, gives essential information about the data. If using Milliquas in published research, please cite to this arXiv document.

2 Changes in Milliquas specifications since the HMQ

The processing rules of the HMQ (2015) are still used but have evolved somewhat due to better quality data in recent years, plus more rigorous use of SDSS pipeline subclasses, and handling anti-selection where SDSS/LAMOST pipeline data are not included into their own manually-vetted quasar catalogs.

The optical background has been switched to that of the All-Sky Portable (ASP) optical catalog (Flesch 2017) which is comprised of APM/USNO-B/SDSS sourced data to an astrometric precision of 0.1 arcsecond and a photometric precision of 0.01 magnitude, and also ≈63% of the Milliquas astrometry is now from the very accurate *Gaia*-DR2 (*Gaia* Collaboration, Brown et al. 2018). All radio/X-ray associations have been recalculated onto the optical background of Figure 3 of Flesch (2017). Associations to faint SDSS objects are now calculated onto a usually-higher background density (because of binning by optical PSF & red-blue colour), thus their likelihoods usually reduced and consequently ≈20K candidates fell below pQSO=80% (the acceptance threshold for Milliquas) and so were dropped.

Type-II narrow emission-line galaxies, (NLAGN, class='N') are added as the luminosity class corresponding to the type-I AGN galaxies. High-luminosity type-II NLQSO (class='K') correspond to the type-I quasars. The NLQSO/NLAGN divider is the same luminosity/psf function which demarcates QSOs (optically core dominated) from AGNs (host dominated). Type-II NLAGN include unquantified contamination by legacy NELGs/ELGs/LINERs and probably a few starbursts which eluded removal, so it serves as a catch-all category presented for completeness, rather than as a strict type-II class.

Milliquas sub-classifies quasars by whether they are optically core dominated QSOs (class='Q') or host dominated AGN (class='A'). A new rule for processing SDSS quasars is that those with STARFORMING & STARBURST subclasses, or GALAXY classified by

[1]http://quasars.org/milliquas.htm
[2]https://heasarc.gsfc.nasa.gov/W3Browse/all/milliquas.html

the DR12Q superset, are now taken as being optically host dominated. This is because those spectra show a strong stellar continuum base. About 7000 objects are so reclassed.

LAMOST DR5[3] pipeline quasars which are not included in the manual LAMOST DR5Q (Yao et al. 2019) are therefore anti-selected by that exclusion. This is handled by processing them with the same rules as SDSS pipeline quasars, but the LAMOST subclass field is unpopulated, thus only those with radio/X-ray associations are accepted into Milliquas. However, SDSS/WISE quasar candidates do show LAMOST pipeline redshifts as available.

Where SDSS finds a different redshift for a LAMOST-discovered quasar, if the difference is >0.1z, the name & discovery credit are transferred to SDSS. There are only about 10 of those.

A few gravitiationally lensed images are added as type='L', additional to the already-catalogued brightest one. These are added only where the ASP (Flesch 2017) optical data shows them, to account for any radio/X-ray associations to them.

HMQ classified all QSOs/AGN of z<0.1 as AGN as an *a priori* boundary to handle the absence of local quasars. This boundary is now moved in to z=0.05 because of many core-dominated QSOs between z=0.05 and 0.1, e.g., IRAS 01267-2157 (SDSS J012910.99-214156.8) at z=0.93. HMQ section 5 discusses these luminosity-based boundaries.

3 QSO updates since the HMQ

Positional fixes were done on ≈200 legacy objects, mostly moves of <5 arcsec. Notably, the quasar "Q 1409+732" is moved to the co-ordinates stated by its discovery paper (Anderson & Margon 1987) where a suitable object resides. Confusion came from that paper's discrepant finding chart onto a plate flaw. Also some other positional fixes are recounted in the "Related Postings" section below.

Quasar doublets are now presented with both objects in every case. Sometimes the discovery paper only averred the 2nd quasar without giving any astrometry or photometry, thus necessitating multiple queries to obtain those.

A new quasar was presented by Milliquas v6.2: SDSS J101012.77+560520.0, v=18.7, z=2.136. This object eluded SDSS capture by being in a 2-arcsec doublet with a red star, SDSS J101012.65+560520.4. SDSS-DR3[4] targetted the star and pipeline-classified it as a QSO (z=2.136) due to emission bleed-over from the true quasar, and it was so accepted by SDSS-DR3Q (Schneider et al. 2005) without noticing the doublet. That star was later removed by SDSS-DR9Q (Pâris et al. 2012), probably because of its stellar continuum, and wasn't revisited after. I found this quasar whilst reconciling *Gaia* astrometry to the doublet. SDSS has been notified and they have advised that they may add it into their upcoming SDSS-DR16Q release.

[3]http://dr5.lamost.org
[4]http://classic.sdss.org/dr7/products/spectra/getspectra.html

4 QSO candidate updates since the HMQ

Additional QSO candidates were sourced from the NBCKDE v3 catalog (Richards et al. 2015) and a variability & refraction sourced catalog (Peters et al. 2015). These added about 300K new candidates to Milliquas.

WISE quasar candidates were added from the AllWISE MIRAGN catalog (Secrest et al. 2015); they are 430K candidates over the whole sky for which 2-band optical objects were found within a 2-arcsec radius of the AllWISE detection. I processed those into pQSOs from calibration against the SDSS-DR12Q multi-class superset, and obtained photometric redshifts using the four-colour based method from the HMQ appendix 2. The four colours used were B-R, R-W1, W1-W2 & W2-W3.

A subset of quasar candidates are SDSS-listed eBOSS targets. So far, SDSS-IV hasn't published those investigated targets which were found to be "not quasars", therefore there is a creeping anti-selection built into those candidates. This is now handled by arbitrarily lowering the pQSOs of all eBOSS-targetted candidates (not otherwise qualifying) by squaring those pQSO ratios, e.g., 90% → 81%. Consequently ≈57K eBOSS candidates have fallen below pQSO=80% and so are dropped from Milliquas. SDSS advises that DR16Q will publish a "superset" of all determined classifications in mid-year 2020, so this topic may be revisited then.

5 QSOs dropped since the HMQ

Milliquas excludes low-confidence/quality or questionable objects (so deemed by their researchers), but many such objects were inherited from VCV (Véron-Cetty & Véron 2010) which was more forgiving. They are removed as encountered but a residue remains. The following list shows those recently removed.

- 22 objects from (Boyle et al. 1990), classified by them as "possible" QSOs with "uncertain" redshifts, were removed from Milliquas.
- 42 AGN were flagged by their discovery paper (Mauch & Sadler 2007) as having "not certain" classification, neither did any of those have stellar PSFs nor secure radio/X-ray associations, so they are dropped from Milliquas.
- Reclassifications were done for Milliquas objects deemed by the SDSS-DR14 pipeline to be plain galaxies – these were heavily spot-checked to con-

firm. 16 legacy QSOs, 172 AGN, and 2343 type-II objects were thusly found to be just galaxies and so were dropped, and 433 legacy QSOs were found to be host-dominated and so reclassified to AGN.

- Blazar candidates with neither redshift nor radio/X-ray association, about 30 objects, were dropped. Most were stated low confidence in legacy papers.
- 223 objects from (Iovino/Clowes/Shaver 1996) which had no quasar-like colour/PSF profile nor any radio/X-ray/WISE association were removed, leaving 917 in Milliquas. This resolves a cautionary note given in the HMQ section 2.B.4 end.
- A few duplicates were identified & removed, notably SBS 1315+605 as duplicate to SDSS J131715.46+601533.1, with the original name being transferred over to the SDSS object.

6 Radio/X-ray association updates since the HMQ

Radio/X-ray association likelihoods are now calculated at a granularity of 0.1 arcsecond astrometric offsets for *Chandra*, *XMM-Newton*, & *Swift* X-ray source catalogs and the FIRST radio source catalog.

The 3XMM-DR8 and XMMSL2-2.0 Slew X-ray source catalogs[5] were added and new X-ray associations calculated. Also, high-confidence data from 2XMMi-DR3 were included, recognized as valid by 3XMM-DR5 (Rosen et al. 2016), section 8.2.

The Chandra ACIS source catalog (Wang et al. 2016) was added and new X-ray associations calculated. Also, the Chandra Source Catalog v2[6] is added, but only as a supplement to CSC v1.1 because v2 provides only stacked data for which the optical solution used by Milliquas cannot be calculated.

The 2nd RASS source catalog 2RXS (Boller et al. 2016) replaces 1RXS for the most part (excepting those analogous 1RXS sources which are securely associated to optical objects, with matching associations from other X-ray catalogues), with positional changes up to an arcminute being common. The takeaway is that RASS isn't reliable for optical identification without additional evidence.

Double radio lobes indicate core activity of some kind, even if shielded from view. These are calculated in Milliquas such that many are not identified elsewhere. Thus I've elected to include all double-lobe associations of confidence>80%, 3951 of which are onto classified galaxies included as type=G.

[5]https://www.cosmos.esa.int/web/xmm-newton/xsa
[6]http://cxc.harvard.edu/csc

7 Use of *Gaia*-DR2 astrometry – rules for inclusion.

Gaia-DR2 (*Gaia* Collaboration, Brown et al. 2018) astrometry is now used & flagged for ≈63% of Milliquas (MQ) objects; the ReadMe identifies the flag used. The default astrometry from the 1.163G-object ASP catalogue (Flesch 2017) can have large offsets even if rare, see its paper and Appendix A for a full discussion. *Gaia* sources were matched 1-to-1 with MQ objects on the criteria that the *Gaia* source is that nearest to the MQ object and that the MQ object is that nearest ASP optical to the *Gaia* source. Care was taken to avoid false matchings. 99% of all matchings are within an arcsec offset, but to find valid farther matches I binned all matches by object class and offset distance in 0.1 arcsec bins, with hundreds of targetted spot checks done to refine offset limits and to check objects with anomalous *Gaia* BP-RP colour suggestive of a false match. SDSS quasar candidates could not be matched beyond 1 arcsec offset because they are often optically faint and/or in close groups for which *Gaia* had a different object only. Host-dominated AGN cores match to 1.5 arcsec beyond which *Gaia*, oriented to point sources, often shows nearby stars only. QSOs/Bl-Lacs match well out to within 4 arcsec; for those I spot-checked all matches beyond 2 arcsec offset, and all with off-colours beyond 1 arcsec offset, and identified & removed 14 false matches. However, for *Gaia* sources without BP & RP colours, QSOs match reliably only within 2 arcsec and Bl-Lacs within 1.5 arcsec offsets. X-ray/radio-only candidates (unique to MQ) match reliably out to within 2.5 arcsec offset. In all cases it was paramount to avoid false matchings, thus very many true matchings were lost beyond the offset cutoffs. Table 1 bins the astrometric offsets of *Gaia* data matched to the original ASP data used by Milliquas.

8 Overview of Milliquas – data and structure

Figure 1 shows the Milliquas sky coverage, dominated by the SDSS footprint. The 2QZ stripe is seen at $\delta = -30°$. AllWISE candidates dominate other sky.

Table 2 shows the Milliquas data structure. Each object is displayed with J2000 astrometry (usually from *Gaia*-DR2 precessed to J2000 by CDS[7]), red and blue photometry, redshift, citations, and radio and X-ray associations where present. The HMQ 4-digit citation numbers are retained and supplemented by 6-char citation identifiers which are indexed on the ReadMe.

Table 3 shows the top 20 contributing discovery papers ordered by numbers of name citations. The large candidates catalogues show prominently.

[7]https://cds.u-strasbg.fr/

Table 2 Sample lines from Milliquas

RA (J2000)	DECL	NAME	TYPE	RMAG	BMAG	COM	PSF	Z	REF	ZREF	CONF	X-RAY	CORE RADIO	LOBE or EXTRA 1	LOBE or EXTRA 2
185.3765252	28.0982859	SDSS J122130.36+280553.7	qX	20.93	20.88	pG	- -	2.100	XDQSO	MQ	100	3XMM J122130.3+280553		1SXPS J122130.2+280553	1WGA J1221.5+2805
185.3766415	-2.6924976	2QZ J122130.3-024134	QR2	19.59	20.35	pG	- -	1.277	2QZ	DR14Q	99		FIRST J122130.4-024132	FIRST J122129.4-024135	FIRST J122131.4-024133
185.3770085	54.9975157	SDSS J122130.47+545950.9	Q	20.28	19.48	jG	1 1	0.908	DR14Q	DR14Q					
185.3770504	28.4327796	SDSS J122130.49+282558.0	qX	22.30	22.07	g	- -	2.000	XDQSO	MQ	90	3XMM J122130.5+282558		1SXPS J122130.3+282556	
185.3771347	46.6948314	SDSS J122130.49+464141.3	Q	20.63	20.75	pG	1 -	1.681	DR14Q	DR14Q					
185.3771536	0.6285829	SDSS J122130.51+003742.8	q	21.19	21.11	g	1 1	0.400	NBCKDE	NBCKDE	90				
185.3771628	21.1364320	WISEA J122130.51+210811.1	qX	18.86	19.72	pG	- -	0.400	WISEA	MQ	99	2RXS J122130.3+210751			
185.3773990	33.8261768	LAMOSTJ122130.57+334934.3	Q	18.28	19.48	pmG	- -	0.450	LAMQ1	LAMQ1					
185.3776703	58.4404030	SDSS J122130.64+582625.4	q	21.62	22.01	g	- -	1.500	NBCKv3	NBCKv3	99				
185.3777013	-0.4519631	2SLAQ J122130.65-002707.1	Q	21.57	21.56	g	1 1	1.807	2SLAQ	2SLAQ					
185.3777682	30.0080054	J122130.66+300028.8	X	19.85	21.32	pmG	- -		MORX		95	1SXPS J122130.5+300027		CXO J122130.7+300030	3XMM J122130.6+300028
185.3778300	64.0168882	SDSS J122130.67+640100.7	q	21.49	21.90	g	- -	1.900	NBCKDE	NBCKDE	91				
185.3783897	14.6949636	SDSS J122130.80+144141.9	QX	20.62	20.81	gG	- -	2.673	DR14Q	DR14Q	99	3XMM J122130.8+144142			
185.3784332	-3.1912754	SDSS J122130.82-031128.5	q	20.05	20.19	pm	- 1	1.100	NBCKv3	NBCKv3	98				
185.3785370	-6.9496803	HE 1218-0640	Q	16.28	17.36	pG	1 1	1.403	2086	2086					
185.3786032	41.4909233	SDSS J122130.86+412927.2	qR	20.30	21.88	pmG	1 -	0.400	NBCKv3	NBCKv3	99		FIRST J122130.8+412927	NVSS J122130.7+412927	
185.3786276	33.5466028	SDSS J122130.86+333247.8	q	18.92	20.32	pmG	- -	1.700	NBCKv3	NBCKv3	98				
185.3796010	-13.9004710	PKS 1218-136	ARX	14.80	17.08	p+G	1 -	0.103	1225	1225	94	1SXPS J122131.0-135404	NVSS J122131.1-135402		
185.3802450	-35.5704273	WISEA J122131.25-353413.5	q	19.72	20.18	j	- -	0.700	WISEA	MQ	99				
185.3805549	11.0905578	SDSS J122131.33+110526.0	Q	19.77	20.96	jG	- -	4.118	DR14Q	DR14Q					
185.3819415	-1.3563610	2QZ J122131.6-012124	Q	20.43	20.71	jG	1 -	1.870	2QZ	2QZ					
185.3820427	28.2329168	ON 231	BRX	13.85	14.78	pG	1 1	0.103	0261	0011	100	3XMM J122131.6+281358	FIRST J122131.6+281358	NVSS J122131.6+281358	1SXPS J122131.7+281357
185.3825228	-41.1384915	WISEA J122131.80-410818.5	q	20.64	21.63	j	- -	0.800	WISEA	MQ	99				
185.3832213	45.3013847	SDSS J122131.97+451804.9	Q	21.42	21.68	g	- -	0.953	DR14Q	DR14Q					
185.3833056	27.1774445	J122131.99+271038.8	X	19.96	20.88	p+	- -		MORX		97	CXOG J122131.9+271039			
185.3836159	8.3622767	RXS J12215+0821	KRX	16.43	17.81	p+G	- -	0.132	0139	DR14	99	2RXS J122131.4+082140	FIRST J122132.0+082144	NVSS J122132.0+082143	
185.3844723	29.9308612	J122132.27+295551.1	X	22.65	22.56	g	- -		MORX		92	2XMM J122132.3+295554			
185.3850863	4.5993654	SDSS J122132.41+043557.7	qRX	20.81	20.89	gG	- -	2.100	XDQSO	MQ	100	CXOG J122132.4+043557	FIRST J122132.4+043557	3XMM J122132.4+043557	1RXH J122132.2+043601

Notes on columns (see ReadMe for full descriptions):

- TYPE: 1st char is the object classification: Q=QSO, A=AGN, B=BL Lac type, q=photometric, K=type II QSO, see ReadMe for full list. Extra chars summarize the associations displayed: R=radio, X=X-ray, 2=double radio lobes.
- COM: comment on photometry: p=POSS-I magnitudes, so blue is POSS-I O, j=SERC Bj, g=SDSS green, +=optically variable, G=Gaia-DR2 astrometry, a=faint nuclear activity, m=nominal proper motion.
- PSF: for red & blue sources: '-'=stellar, 1=fuzzy, n=no psf available, x=not seen in this band.
- REF & ZREF: citations for name and redshift; citations are indexed in the ReadMe & "HMQ-references.txt" file.
- CONF: for candidates, calculated pct confidence that it is a quasar. For classified objects, conf that the shown radio/X-ray detection is truly associated to it.
- LOBE or EXTRA: if TYPE shows a '2' (=lobes), then double radio lobe identifiers are displayed here. Otherwise, any additional radio and/or X-ray identifiers are displayed here.

The full table can be downloaded from http://quasars.org/milliquas.htm.

Table 1 Counts of *Gaia* sources matched to Milliquas objects, by astrometric offset – "0.1" means 0.0<offset≤0.1 arcsec, etc.

offset (asec)	count (MQv6.3)	pct	cum pct
0.1	802314	63.60	63.60
0.2	266213	21.10	84.71
0.3	80512	6.38	91.09
0.4	43192	3.42	94.51
0.5	24275	1.92	96.44
0.6	15448	1.22	97.66
0.7	10483	0.83	98.49
0.8	7435	0.59	99.08
0.9	5513	0.44	99.52
1.0	3905	0.31	99.83
1.1	575	0.05	99.88
1.2	377	0.03	99.91
1.3	242	0.02	99.93
1.4	163	0.01	99.94
1.5	138	0.01	99.95
1.6	101	0.01	99.96
1.7	73	0.01	99.96
1.8	75	0.01	99.97
1.9	71	0.01	99.97
2.0	58	0.00	99.98
2.1	50	0.00	99.98
2.2	47	0.00	99.99
2.3	29	0.00	99.99
2.4	42	0.00	99.99
2.5	24	0.00	99.99

9 Related Postings on sci.astro.research

Since publication of the HMQ (Flesch 2015), I sometimes posted on the newsgroup sci.astro.research on issues arising in the ongoing Milliquas releases, especially on further corrections of quasar positions. In one of those, I described the recovery of the lost Cyril Hazard quasar "Q 0440-168" at (J2000) 04 42 40.30 -16 46 27.5, i.e., (B1950) 04 40 25.6 -16 52 05. Extracts from a couple other postings are copied below to illustrate the kind of work done; they were written in an entertaining fashion to draw readers.

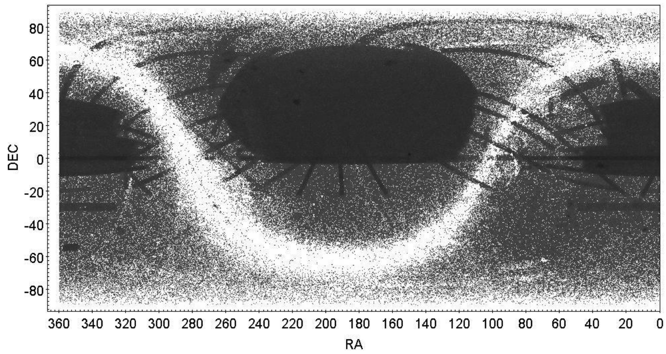

Figure 1. Sky coverage of Milliquas

10-January-2019 – "Tales of Cataloguing XIV – the 0th finding chart":

20th century quasar discovery papers made liberal use of finding charts to display the precise location of new quasars, lest the listed co-ordinates weren't accurate enough. Astrometry had much improved by the 1990s but finding charts were still usually included, more as a tradition than a necessity. That was all fine so long as the listed astrometry and finding chart agreed. But sometimes they didn't. Sometimes they pointed to different objects.

I've given examples of this in earlier postings in this series, notably #VIII "the log of jumping up & down" which is what you do when bad finding charts drive you

Table 3 Top 20 discovery papers for Milliquas v6.4

#	ID	# of objects	# of redshifts	paper
1	SDSS DR14Q manual	513020	525745	Pâris et al. (2018)
2	NBCKDE-v3 candidates	468415	474810	Richards et al. (2015)
3	AllWISE candidates	432070	0	Secrest et al. (2015)
4	SDSS DR16 pipeline	167131	192299	Ahumada et al. (2019)
5	XDQSO candidates	159424	0	Bovy et al. (2011)
6	MORX candidates	52040	0	Flesch, E. (2016)
7	NBCKDE candidates	34598	34487	Richards et al. (2009)
8	2QZ/6QZ	27521	24160	Croom et al. (2004)
9	PGC†	13689	17	Paturel et al. (2003)
10	SDSS DR14 pipeline	12087	14374	Abolfathi et al. (2018)
11	Peters candidates	10555	9468	Peters et al. (2015)
12	2SLAQ	10365	8709	Croom et al. (2009)
13	Milliquas	8684	537048	data unique to Milliquas
14	LAMOST QSO DR5	7998	7997	Yao et al. (2019)
15	LAMOST QSO DR3	6771	6661	Dong et al. (2018)
16	SDSS DR7Q manual	2089	329	Schneider et al. (2010)
17	AGES survey	2046	2046	Kochanek et al. (2012)
18	AAOz survey	1491	1498	Lidman et al. (2016)
19	DEEP2 Redshifts	1435	1395	Newman et al. (2013)
20	3HSP blazars	807	1020	Chang Y.-L. et al. (2019)

† The Principal Galaxy Catalogue (PGC) is not actually a discovery paper, but is used as a reference for names of AGN galaxies.

crazy. But other times it is good finding charts which save the day when the listed co-ordinates are false, e.g., the quasar "TOL 1038.2-27.1" from Bohuski & Weedman 1979,ApJ 231,653, object #23 (last one in the list), 41 arcsec offset from the false listed co-ordinates (unsuitable photometry r=18.0 b=20.1) to the true finding chart object (r=19.2 b=19.5). Another example is the quasar "Q 0111-328" from Savage et al. 1984,MNRAS 207,393, which gave finding charts onto the original prism (grism) plates which are infallibly correct because the actual discovery spectrum is pointed at; the B1950 co-ordinates given in the microfiche were of a nearby object offset by 76 arcsec. Even big names like Schneider/Schmidt/Gunn did this for one object, "PC 0027+0515" in 1999, AJ 117,40, the Table 5 co-ordinates of which pointed near random objects whilst the true object was revealed on the finding chart at an offset of 17 arcsec.

So there were bad finding charts and good finding charts. But then there's this, from Borra et al. 1996, AJ 111,1456, the quasar "Q 13034+2942" (called "130324+294245" in the paper) is the very first one on their list, and their first finding chart. They would make no error on the very first object, right? Of course not. Furthermore, on their Table 4a they lead right off with it as positioned at B1950 130324.21+294245.8, lest there be any mistake. That translates to J2000 130547.40+292643.0 which shows up on the SDSS finding chart as a flattish-spectrum 21-mag stellar-psf which my own data reports as a variable object which was 19th magnitude in the 1960's – so very quasar-like and all good. So why did I previously have it catalogued as a reddish v=22 object 17 arcsec to the South-West? Let's have another look at that finding chart, the first finding chart of the paper.

There it is, but wait, they are pointing to the reddish object (which is probably a red dwarf star). This is one of those finding charts where they don't use a photo, instead they re-create it with ink on paper. Looks like they used a plotter (remember those?) and optical data. Um, guys, your optical data did not include the true object. It's not there at all. They're pointing to the red dwarf because the quasar isn't on the chart. Their very first finding chart for quasar discoveries points to a red dwarf star. Looking at my archived catalogue versions, I originally had the right identification (inherited from VCV) but switched it to the red dwarf just before the publication of my Half-Million Quasars catalogue. Guess I'd looked at one finding chart too many. ...

On a separate note, the Soviet quasar "Q 0752+617" from Afanasiev/Lorenz/Nazarov 1989, SvAL 15,83 does not exist. I've looked for it for years. I've communicated with the lead author and he doesn't know where it is – he knows only the old VCV location which is just the B1950 sky rectangle denoted by "0752+617". There is no radio, no X-ray, no WISE candidate, no suitable bluish optical. The paper stated narrow emission lines – perhaps they measured a galaxy. I give up, it is removed from the Milliquas catalogue as of the next edition. I will gladly restore it if the authors provide its location. (end)

Similarly, the unseen Soviet BAL quasar "SBS 1401+566" was dropped from Milliquas. Its discovery paper 1986 Afanasiev/Erastova/Lipovetsky/Stepanian/Shapovalova, although cited as "in press" by Markarian/Stepanian/Erastova 1987-IAUS-121-25, was evidently never published. This object was only an artifact of the literature.

29-January-2019 – "Tales of Cataloguing XV – last fixes in from the cold":

(1) Abell 293 was originally thought to be a (Parkes) radio galaxy cluster but Gioia et al. 1984-ApJ-283-495, in addition to discovering a background X-ray quasar with z=1.897 and v=19.7, reported that "also present in this field is a strong point radio source PKS 0159+034 whose position is not coincident with any of the X-ray or optical sources discussed here". In spite of this, VCV assigned both the name "PKS 0159+034" and the redshift 1.897 onto the primary Abell galaxy, thus conflating three objects into one. Gioia et al. provided a finding chart of the quasar but didn't name it, however they placed it as the SE component of an Einstein-detected extended X-ray emission named "1E 0159.1+0330", therefore I've added this quasar (not previously catalogued) with name of "1E 0159.1+0330 SE". Furthermore, my Milliquas algorithm shows the radio source PKS 0159+034, aka FIRST J020151.4+034309, to be associated with 98.6% confidence to a r=21.8 g=22.1 stellar source which is furthermore calculated as 96% likely to be a quasar. But it has no redshift so will continue to appear in Milliquas as a candidate only, henceforth annotated with the name PKS 0159+034.

(2) While checking over legacy quasars with unsuitable photometry, I came across the quasar "A4/22" from the "Very Faint Quasar Survey", D. Schade, 1991-AJ-102-869 – the quasar is listed with z=1.045, v=20.00 and b=20.17. But upon inspection on an SDSS finding chart, the near object is seen to be just a small passive galaxy, so how did David Schade come to call that a quasar? I've seen this situation many times before, so I look for nearby objects, and I look North, South, East, West. And sure enough, at 200 arcseconds due South of the designated spot

I see SDSS J110205.85+295914.7 with g=20.00, r=19.71 and u=20.25, a perfect photometric fit. Furthermore, it is a quasar candidate in Gordon Richards' NBCKDE-v3 catalogue (2015-ApJS-219-39) with a photometric redshift of 1.000, well-matched to Schade's spectroscopic redshift of 1.045. Somehow this object got moved 200 arcsec due North in the preparation of the paper – looking at Table 4 of the paper, it looks like the declination of the object a4/5 was accidently copied over to a4/22. These things happen. I have moved the identification of "A4/22" over to J110205.85+295914.7, and the author has been informed.

(3) LMA 15, in the IC 1613 region, was surveyed by Lequeux/Meyssonnier/Azzopardi 1987-A&AS-67-169 who provided a finding chart which however was too coarse to allow precise identification of the designated object. The astrometry was given but only to whole time seconds, so had an uncertainty of ≈15 arcseconds. VCV placed it at the given RA of B010239 (a faint star triplet), the true RA is found to be B010239.9, a blue stellar g=20.7, r=21.2 (PAN-STARRS) for a move of 13.7 arcseconds.

(4) KP 1229.0+07.8 from Sramek & Weedman, 1978-ApJ-221-468, #19 on their list, z=1.93, v=20.5. The B1950 astrometry, duly reported by VCV, pointed to nothing (approx 25 arcseconds away from 3 nearest optical candidates). A coarse finding chart was provided from which, many years ago, I selected the wrong object, SDSS J123134.02+073440.2, a galaxy with r=19.25, g=20.61. I have now moved this to the correct object, SDSS J123134.53+073425.8 with r=21.73, g=21.96, a move of 16.3 arcseconds. Besides the flatter spectrum, it is also clearly a better match to the finding chart, although you do need to stare at it for a while. (end)

10 Conclusion

The Milliquas (Million Quasars) catalogue v6.4 is presented as a complete record of published quasars to 11 December 2019, including the SDSS-DR16 pipeline release. Milliquas presents 757 991 type 1 QSOs & AGN, ≈1.1M high-confidence (80%+) photometric quasars, 2800 BL Lac objects, and 37 116 type 2 objects. Astrometry is 0.01 arcsecond accurate for most objects, and red-blue photometry is of 0.01 magnitude precision. X-ray and radio associations for these objects are presented as applicable, including double radio lobes.

11 ACKNOWLEDGEMENTS

Thanks to non-commercial music (drone, etc.) for adding joy to the long hours. This work was not funded.

REFERENCES

Alam, S., Albareti, F. D., Allende Prieto, C., et al. 2015, ApJS, 219, 12, SDSS DR12 pipeline

Abolfathi, B., Aguado, D. S., Aguilar, G., et al. 2018, ApJS, 235, 42, SDSS DR14 pipeline

Ahumada, R., Allende Prieto, C., Almeida, A., et al. 2019, arXiv, 1912.02905, SDSS DR16 pipeline

Anderson, S. F. & Margon, B. 1987, Natur, 327, 125

Boller, Th., Freyberg, M. J., Trümper, J., et al., 2016, A&A, 588, 103, ROSAT 2RXS

Boyle, B. J., Fong, R., Shanks, T., & Peterson, B. A. 1990, MNRAS, 243, 1

Bovy, J., Hennawi, J. F., Hogg, D. W., et al. 2011, ApJ, 729, 141, SDSS-XDQSO

Chang, Y.-L., Arsioli, B., Giommi, P., et al. 2019, arXiv, 1909.08279v4, 3HSP blazars

Croom, S. M., Smith, R. J., Boyle, B. J., et al. 2004, MNRAS, 349, 1397, 2QZ/6QZ

Croom, S. M., Richards, G. T., Shanks, T., et al. 2009, MNRAS, 392, 19, 2SLAQ

Dong, X. Y., Wu, X.-B., Ai, Y. L., et al. 2018, AJ, 155, 189, LAMOST DR3Q

Flesch, E. 2015, PASA, 32, 10, Half Million Quasars catalogue (HMQ)

Flesch, E. 2016, PASA, 33, 52, Million Optical Radio/X-ray catalogue (MORX)

Flesch, E. 2017, PASA, 34, 25, All-Sky Portable Optical catalogue (ASP)

Gaia Collaboration, Brown, A. G. A. et al. 2018, A&A, 616A, 1, *Gaia* DR2

Iovino, A., Clowes, R., & Shaver, P. 1996, A&AS, 119, 265

Irwin, M. J., McMahon, R. G. 1992, IAUIn, 2, 31, http://www.ast.cam.ac.uk/∼mike/apmcat (APM)

Kochanek, C. S., Eisenstein, D. J., Cool, R. J., et al. 2012, ApJS, 200, 8, AGES survey

Lidman, C., Ardila, F., Owers, M., et al. 2016, PASA, 33, 1, AAOmega XXL-South

Mauch, T., & Sadler, E. M. 2007, MNRAS, 375, 931

Monet, D. G., Levine, S. E., Canzian, B., et al. 2003, AJ, 125, 984, USNO-B, http://www.nofs.navy.mil

Newman, J. A., Cooper, M. C., Davis, M., et al. 2013, ApJS, 208, 5, DEEP2 Redshifts

Pâris, I., Petitjean, P., Aubourg, E., et al. 2012, A&A, 548, 66, SDSS DR9 Quasar

Pâris, I., Petitjean, P., Ross, N. P., et al. 2017, A&A, 597, 79, SDSS DR12 Quasar

Pâris, I., Petitjean, P., Aubourg, E., et al. 2018, A&A, 613A, 51, SDSS DR14 Quasar

Paturel, G., Petit, C., Prugniel, Ph., et al. 2003, A&A, 412, 45, Principal Galaxy Catalogue

Peters, C. M., Richards, G. T., Myers, A. D., et al. 2015, ApJ, 811, 95

Richards, G. T., Myers, A. D., Gray, A. G., et al. 2009, ApJS, 180, 67, NBCKDE

Richards, G. T., Myers, A. D., Peters, C. M., et al. 2015, ApJS, 219, 39, NBCKDE v3

Rosen, S. R., Webb, N. A., Watson, M. G., et al. 2016, A&A, 590A, 1, 3XMM-DR5

Schneider, D. P., Hall, P. B., Richards, G. T., et al. 2005, AJ, 130, 367, SDSS DR3 Quasar

Schneider, D. P., Richards, Ġ. T., Hall, P. B., et al. 2010, AJ, 139, 2360, SDSS DR7 Quasar

Secrest, N. J., Dudik, R. P., Dorland, B. N., et al. 2015, ApJS, 221, 12, AllWISE MIRAGN

Taylor, M. B. 2005, ASPC, 347, 29, TOPCAT software

Véron-Cetty, M.-P., & Véron, P. 2010, A&A, 518A, 10

Wang, S., Liu, J., Qiu, Y., et al. 2016, ApJS, 224, 40, *Chandra* ACIS source catalog

Yao, S., Wu, X.-B., Ai, Y. L., et al. 2019, ApJS, 240, 6, LAMOST DR5Q