The Large Quasar Astrometric Catalogue (LQAC) and the densification of the ICRF through the Large Quasar Reference Frame (LQRF)

J.Souchay, C.Barache,S.Bouquillon,A.H.Andrei,F.Taris
A.M.Gontier, S.Lambert

SYRTE, Observatoire de Paris
Jean.Souchay@obspm.fr

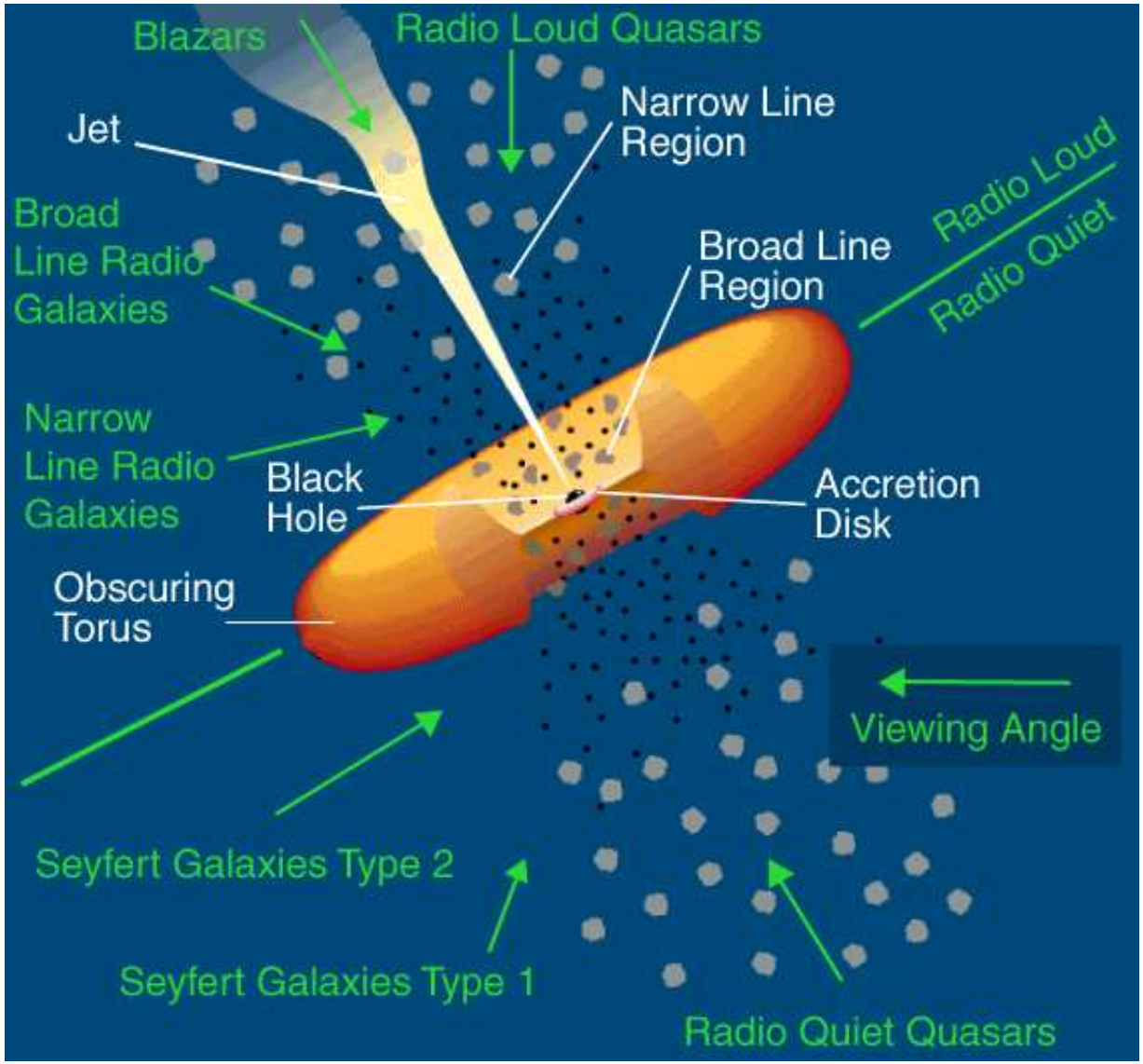
Journées Systèmes de Référence, Paris, Sept. 20-22 2010

Summary

I. Introduction
II. The construction of the LQAC-1 (2009)
III. The construction of the LQRF
IV. Prospects => LQAC-2
V. Conclusion

I. Introduction

AGN : the unified model



AGN : Observational characteristics

Nuclear optical continuum emission => accretion disk, jets, power-law % λ

Nuclear infrared emission => accretion disk obscured by gas and dust

Broad optical emission lines => cold material close to the central black hole

Narrow optical emission lines => more distant cold material

Radio continuum emission => always due to a jet, synchrotron radiation

X-ray continuum emission => both from the jet and from hot corona in a.d.

X-ray line emission => fluorescence, illumination of cold heavy elements

Important remark !!

Some astronomers use the term « QSO » (Quasi Stellar Object) for radio-quiet quasars with well established properties (luminosity much stronger than host galaxy, quasi stellar aspect, broad emission lines etc…) reserving « quasar » for radio-loud objects.

Other astronomers use the term « quasar » with two classes « radio-quiet » and « radio-loud »

Vocabulary AGN

- **Quasars** => acronym « Quasi stellar radio source », object with z > 0.1 with broad emission lines. Energy from a tiny region although > 100 times normal galaxies
  Radio structures often include jets and lobes

- **QSO** => object with optical properties as quasars but not necessarily strong radio source (in fact 10% of QSO's)

- **Seyfert galaxy** => galaxy (spiral) showing too broad lines and ionization too high for being produced by stellar population, often brigh nucleus. Two classes, spectral differenciation, Seyfert I and Seyfert II according to linewidths

- **BL Lacertae** => featureless spectrumand raid strong variability, radio loud, AGN seen along the jets ?

- **Blazar** => weak spectral structure, strong and rapid variability

- **LINER** (Low Ionization Nuclear Emission Line)

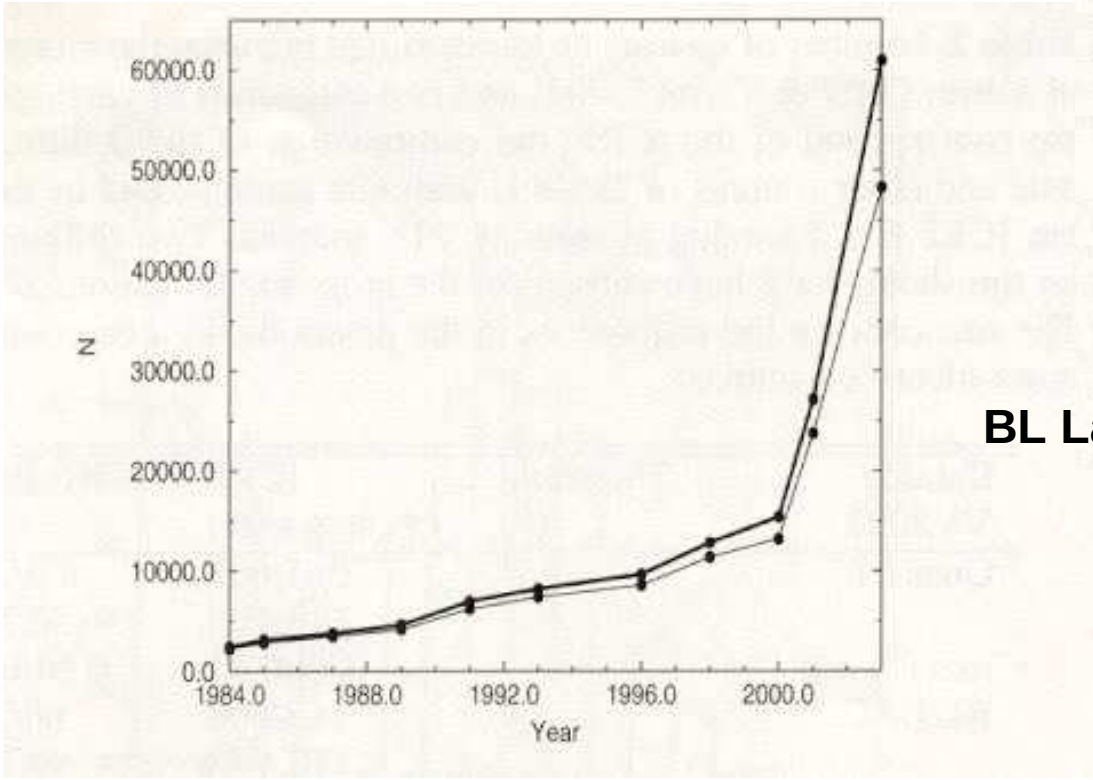
- **OVV** (Optically Violently Variable)

AGN : the unified model

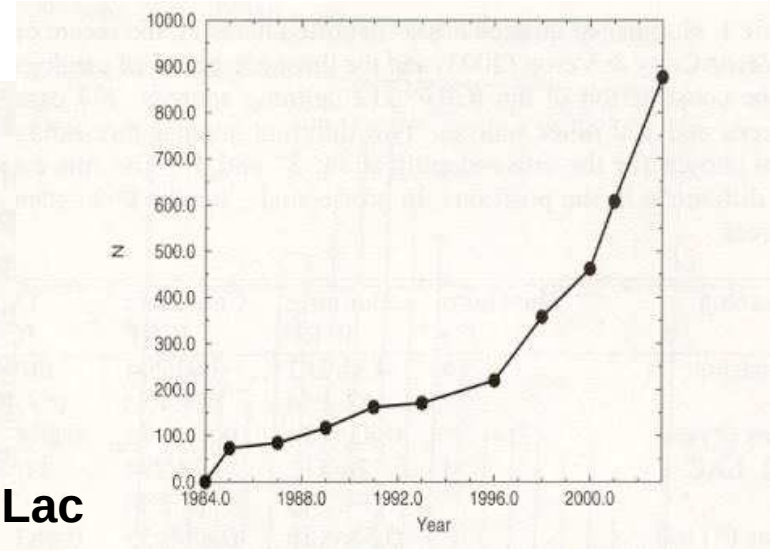
Differences between active galaxy types and normal galaxies.

Galaxy Type	Active Nuclei	Emission Lines		X-rays	Excess of		Strong Radio	Jets	Variable	Radio loud
		Narrow	Broad		UV	Far-IR				
Normal	no	weak	none	weak	none	none	none	none	no	no
Starburst	no	yes	no	some	no	yes	some	no	no	no
Seyfert I	yes	yes	yes	some	some	yes	no	no	yes	no
Seyfert II	yes	yes	no	some	some	yes	no	yes	yes	no
Quasar	yes	yes	yes	some	yes	yes	some	some	yes	10%
Blazar	yes	no	some	yes	yes	no	yes	yes	yes	yes
BL Lac	yes	no	none/faint	yes	yes	no	yes	yes	yes	yes
OVV	yes	no	stronger than BL Lac	yes	yes	no	yes	yes	yes	yes
Radio galaxy	yes	some	some	some	some	yes	yes	yes	yes	yes

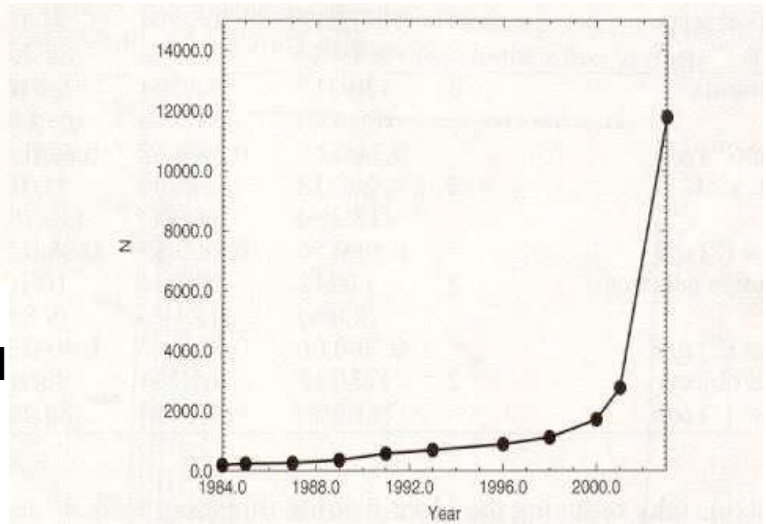
A drastic increase of recorded quasars, BL Lac & AGN



QSO's



BL Lac



AGN

From Véron-Cetty & Véron catalogues

II. The construction of the Large Quasar Astrometric Catalogue

LQAC (2009)

II. The construction of the Large Quasar Astrometric Catalogue

LQAC (2009)

Aim => compiling all the recorded quasars with maximum of information and emphasizing astrometry

QSO'S CATALOGUES

AVAILABLE / Radio

- **ICRF + Ext1 + Ext2** (Ma, et al., 1998; Arias et al.,2004)
  718 radio-loud QSOs and AGNs.

- **VLBA Calibrators** (Beasley, et al., 2007, AJ (in prep.)
  accurate VLBI position for **3,357 radio-stable QSOs and AGNs**.
- **VLA Calibrators** (Benson et al., 2006; www.vla.nrao.edu/astro/calib/)

  radio interferometry astrometry and map information for **1860 QSOs and AGNs**.
- **JVAS Calibrators** (Patnaik et al.,1992; Wilkinson et al., 1998

  radio interferometry astrometry for **2,118 compact QSOs and AGNs**.
- **MERLIN Calibrators** (Patnaik et al., 1992; Wilkinson et al.,1998)

  radio interferometry astrometry for **2,121 compact QSOs and AGNs**.

Etc …….

QSO'S CATALOGUES AVAILABLE

Optical

- **Véron & Véron 12th ed.** (Véron-Cetty, M.-P. & Véron, P.; 2006)

  85,221 QSOs with measured redshift

- **SDSS DR5** (Adelman-McCarthy et al.2007)

  74,869 QSOs, with measured readshift and ugriz magnitudes.

- **2dF + 6qZ** (Croom et al. 2004)

  23,803 QSOs, with measured redshift.and ubr magnitudes

- **FIRST QSO** (White R.L., 2001)

  optical match and redhift information for radio selected **972 bright QSOs**.

- **Hewitt & Burbidge revised edition** (Hewitt A. & Burbidge G.; 1993)

  reference astrometry and magnitude, and redshift information for **7,222** radio-loud QSOs.

- **USNO B1.0** (Monet et al.,2003) J2000 optical astrometry position and proper motions, 5 magnitudes, morphology flag, for 1,042,618,261 objects, complete to magnitude V=21, and all-sky distributed

The 2df QSO Redshift Survey

(Croom et al.,MNRAS 349,2004)

- Pre-selection of QSO candidates on broadband u,b_J,r from UK Schmidt Telescope photographic plates
- 30 UKST fields, arranged in two 75°x5° declination st rips
- Spectroscopic observations at the AAT (Anglo Australian Telescope)
- Multifibre spectrograph

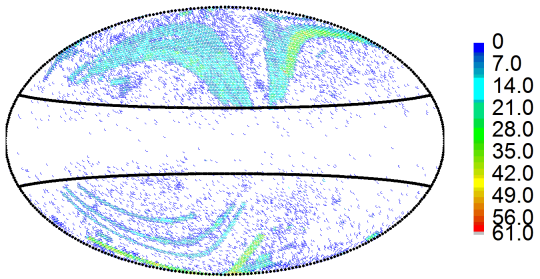
  => simultaneous spectra for 400 objects / 2° field of view
- 44 756 initial objects => spectra classified using automated routines to fit each spectrum to QSO's (stellar, galaxy)
- QSO's selected on broad emission lines (> 1000 kms^{-1})
- Quality flag

The SDSS quasar catalog

(Schneider et al, A.J. 130, 2005)

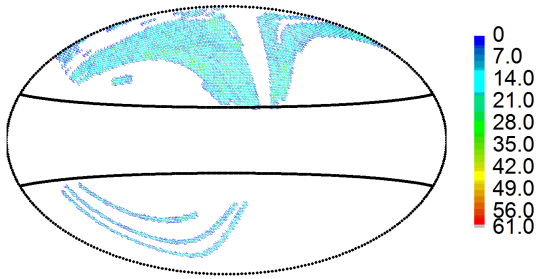
- Dedicated telescope (2.5 m) at Apache Point
- CCD camera => u,b,v,g,r,i,z images over 10 000 deg^2
- Properties of each detected object in the 7 bands
- Photometric and astrometric calibration
- Pre-selection of quasars in multidimensional color space
- Quasar catalog constructed on
    - creation of a quasar candidate database
    - visual examination of the candidates'spectra
    - application of luminosity and emission line velocity
- Luminosity limit of M_i=-22, photometry ~0.03 mag.
- Automated line measuring-routine
- 27 entries for each quasar !

Quasars' sky distribution – 1deg^2 cells count (courtesy A.H. Andrei)



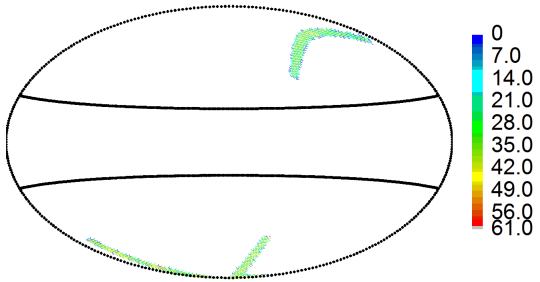
V&V

85,221 sources



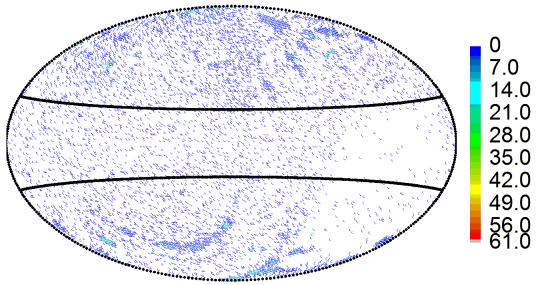
SDSS DR5

74,869 sources



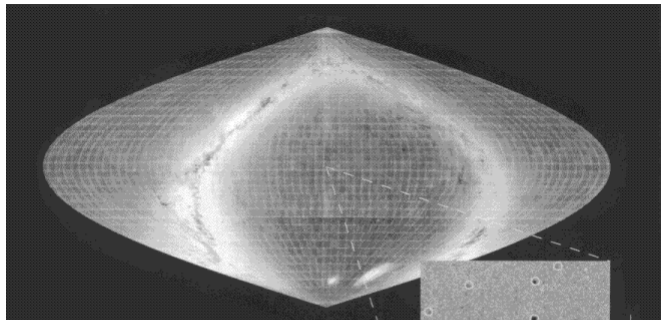
2dF – QSO

23,803 sources



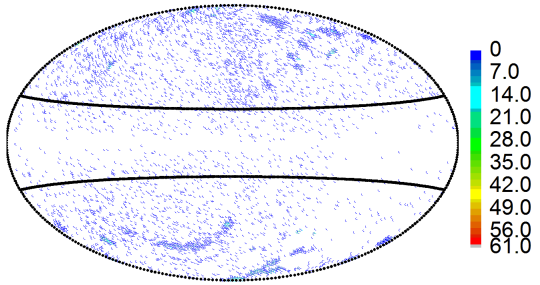
All Radio QSOs

11,781 sources



B1.0

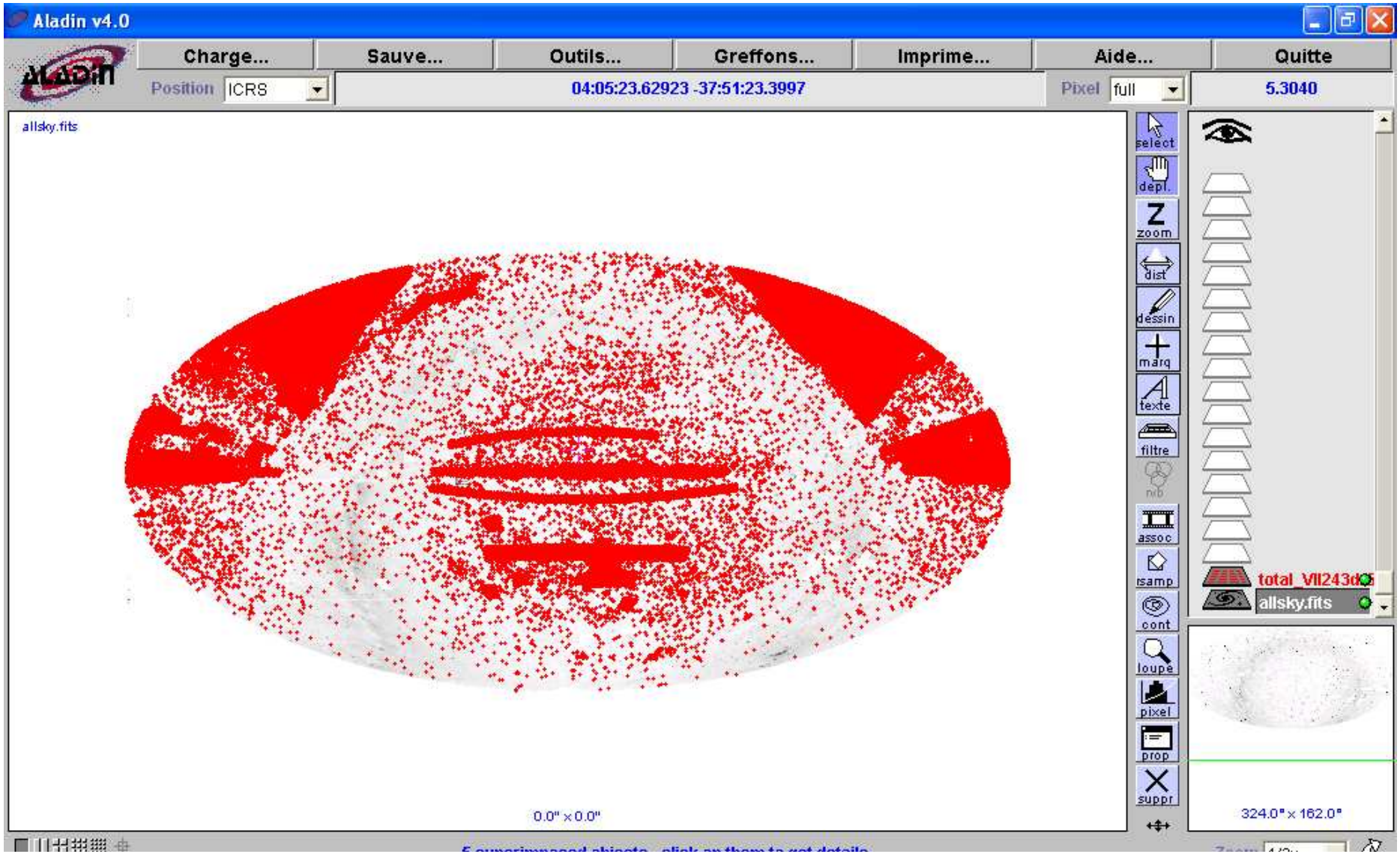
All sky up to V=21



Radio QSOs found in B1.0

6,941 sources

7 QUASARS CATALOGUES



The catalogues of LQAC

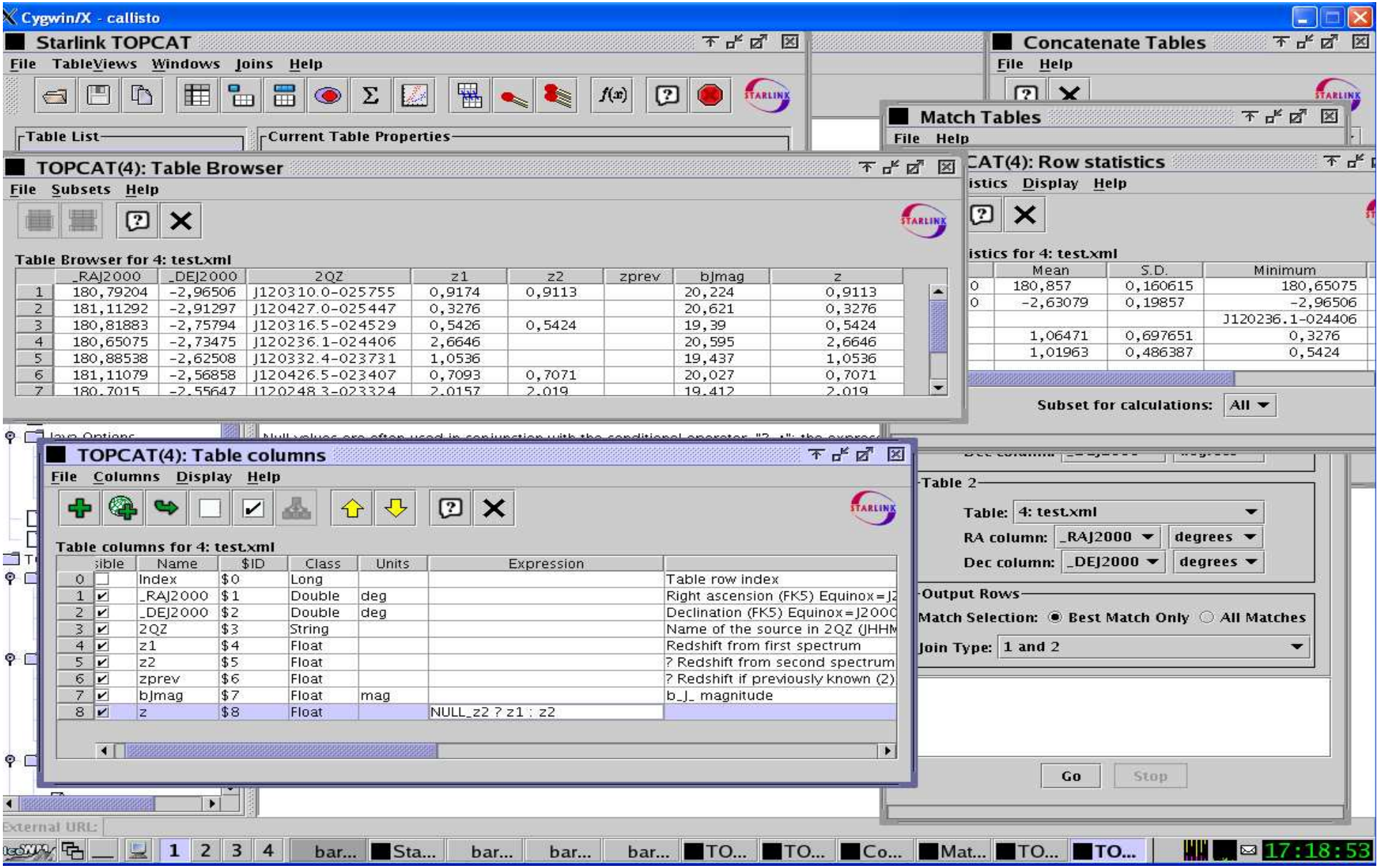
Table 1. Characteristics of the catalogues contributing to the LQAC.

Catalogue	Flag	Wavelength	No. quasars	Accuracy ″	Search radius ″
ICRF-Ext2	A	radio	717	0.001	1
VLBA	B	radio	3 357	0.001	1
VLA-015	C	radio	1 701	0.015	1
JVAS	D	radio	2 118	0.2	1
SDSS	E	optical	74 868	0.2	1
2QZ	F	optical	22 971	0.2	1
FIRST	G	radio	969	0.5	2
VLA+015	H	radio	157	0.2	2
HB	I	optical+radio	7 245	1.5	2-5-30*
2MASS	J	infrared	–	0.2	1
GSC2.3	K	optical	–	0.2	1
B1.0	L	optical	–	0.2	1
VV06	M	optical+radio	85 189	1.0	2-5-10*

* Three different search radii have been considered for the cross-identification.

OV Tools (Topcat)

C.Barache

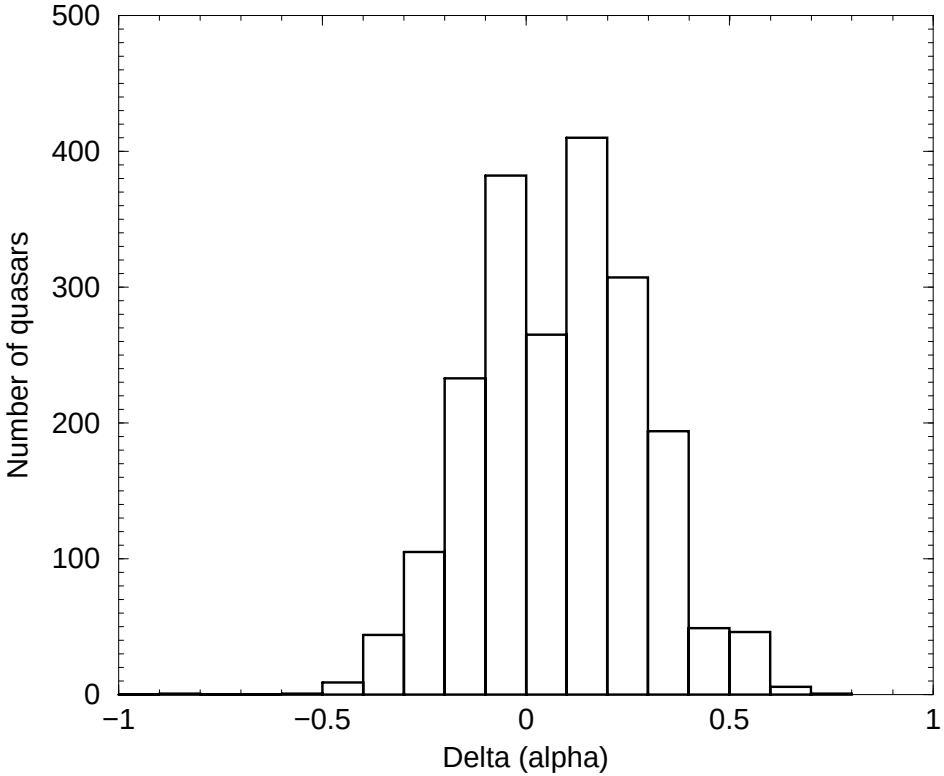


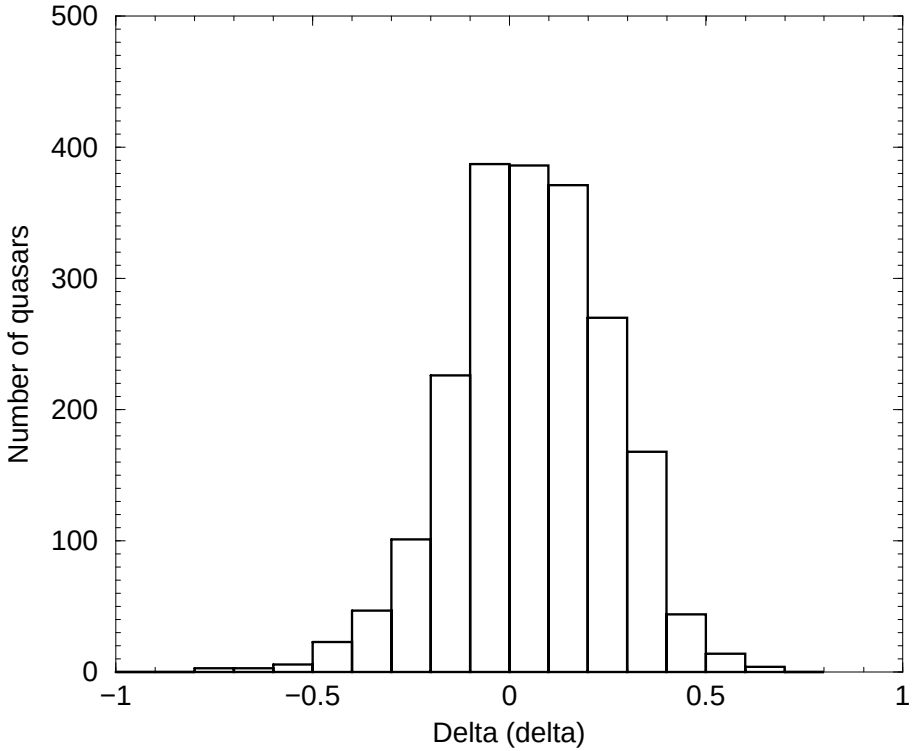
Cross-identification of SDSS/2dF

$\Rightarrow$ Comparison of common data
(astrometry, redshifts, photometry)

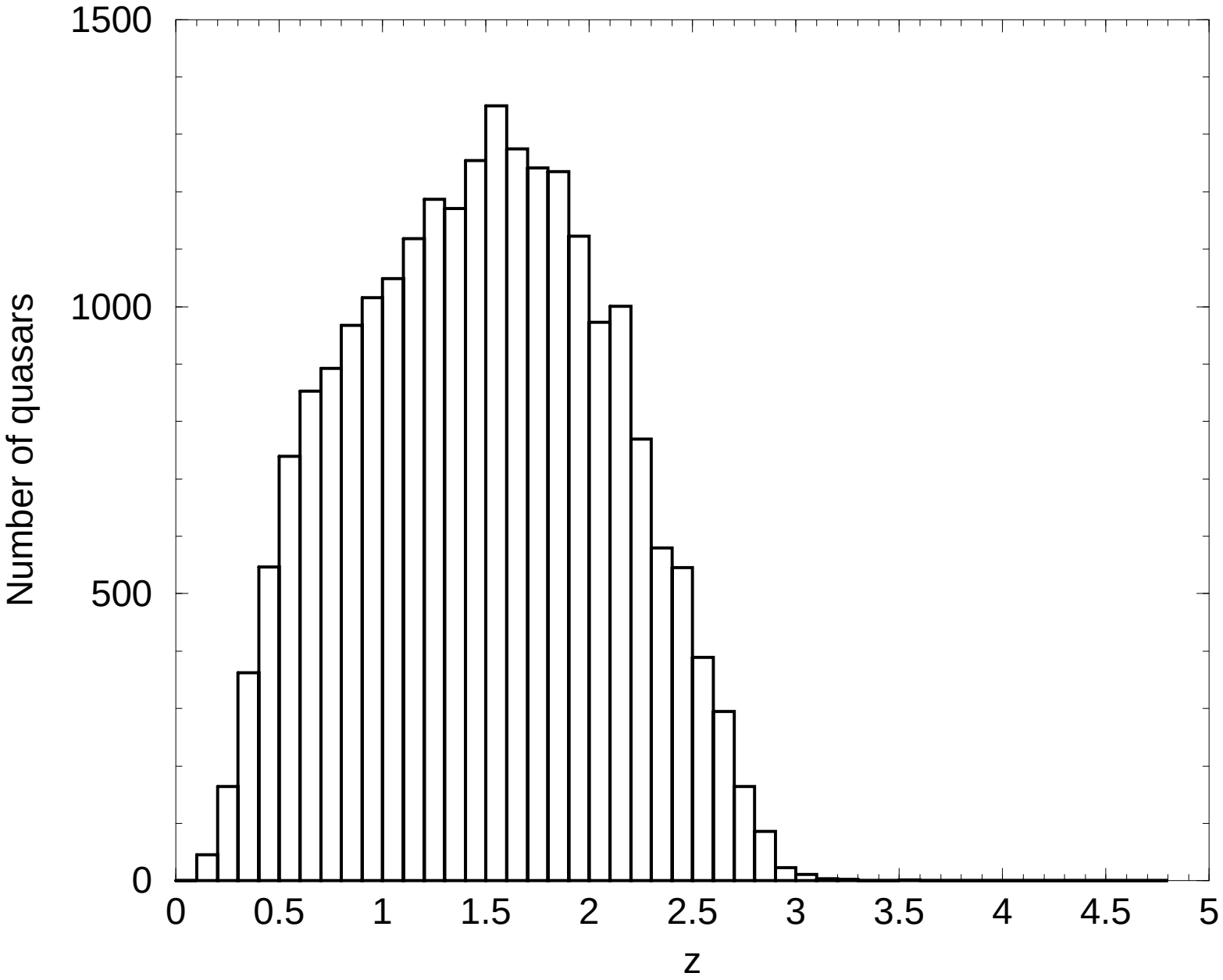
$\Rightarrow$ Complementarity (photometry)

Astrometric differences SDSS%2dF

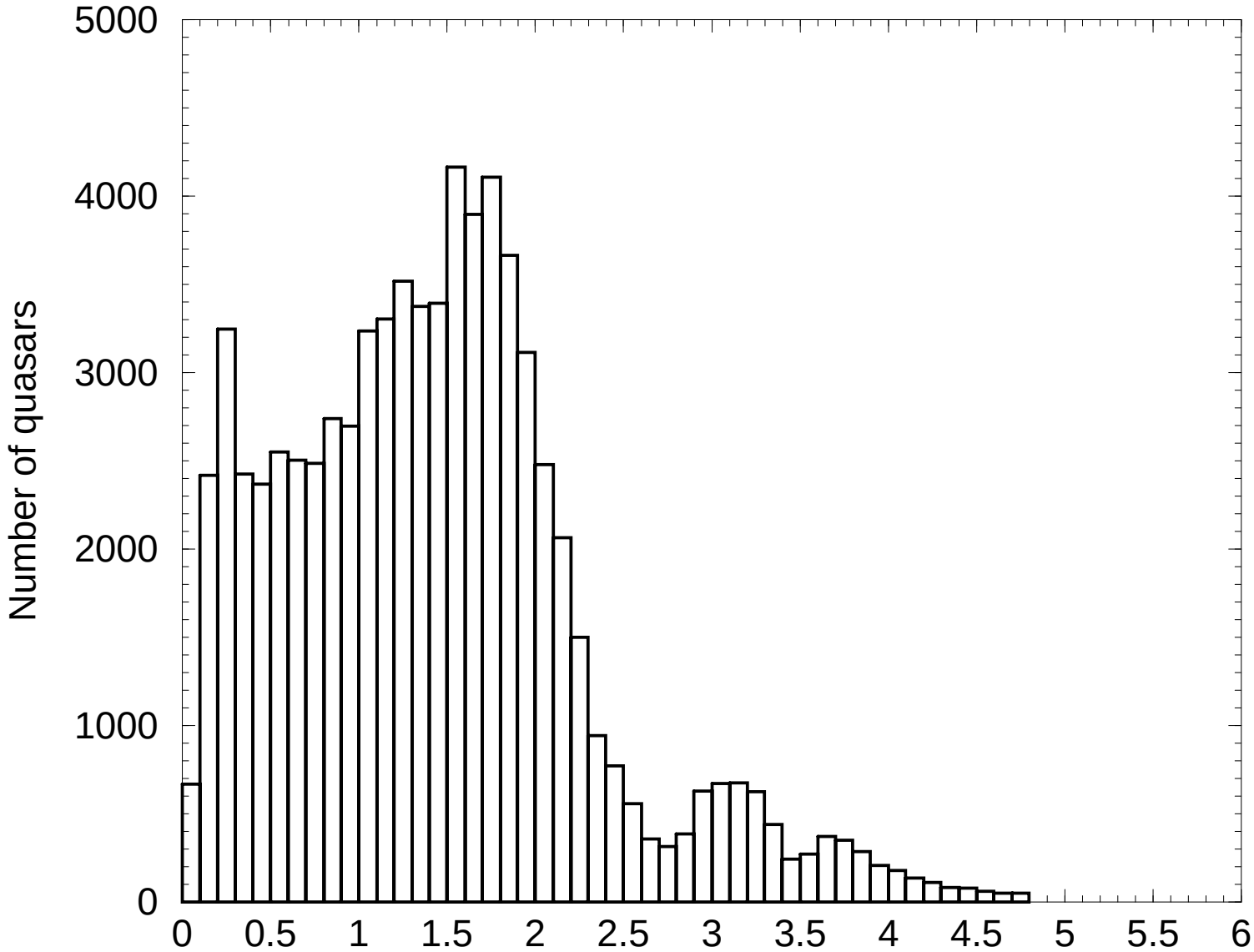




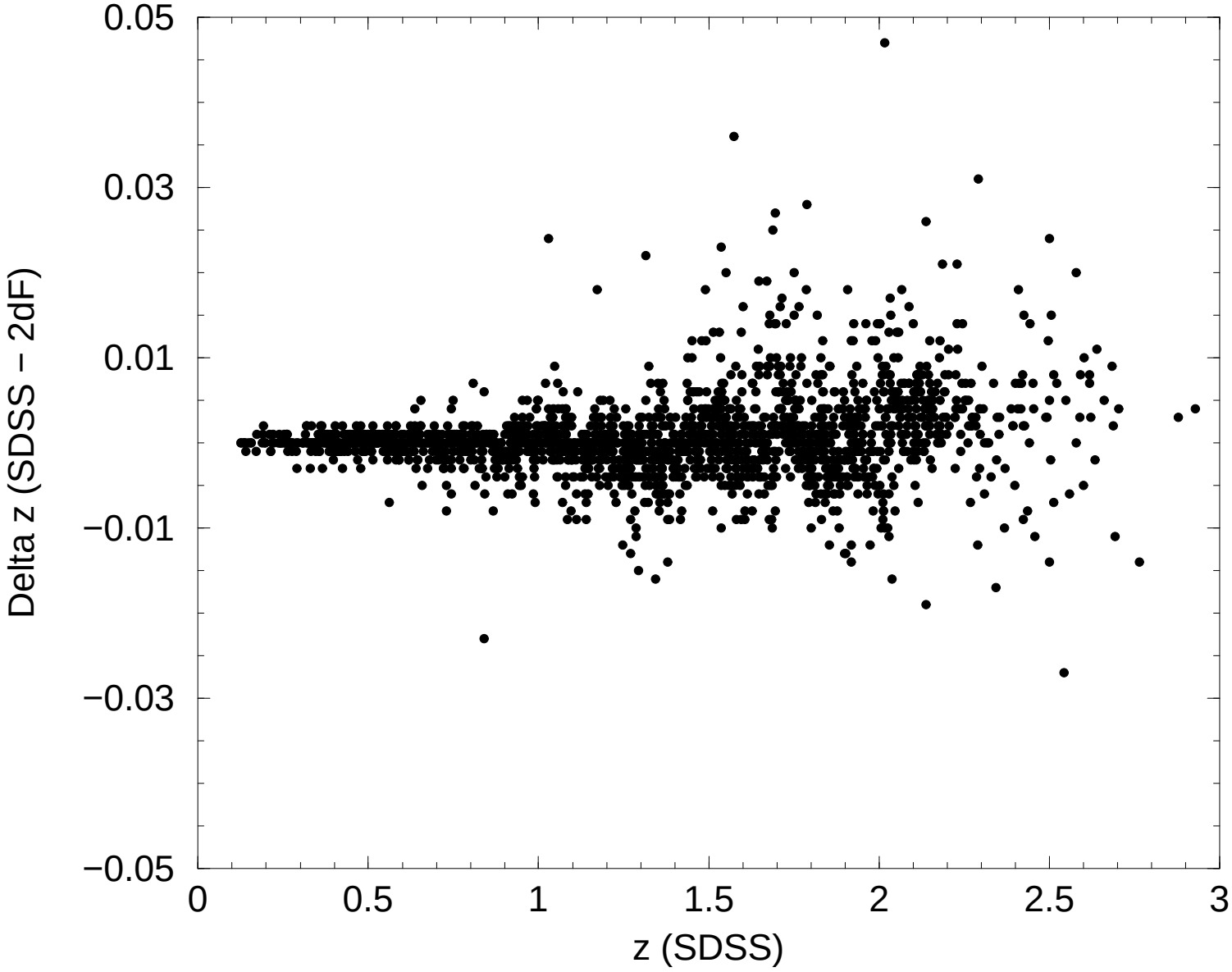
Histogram of redshifts /2QZ (2dF)



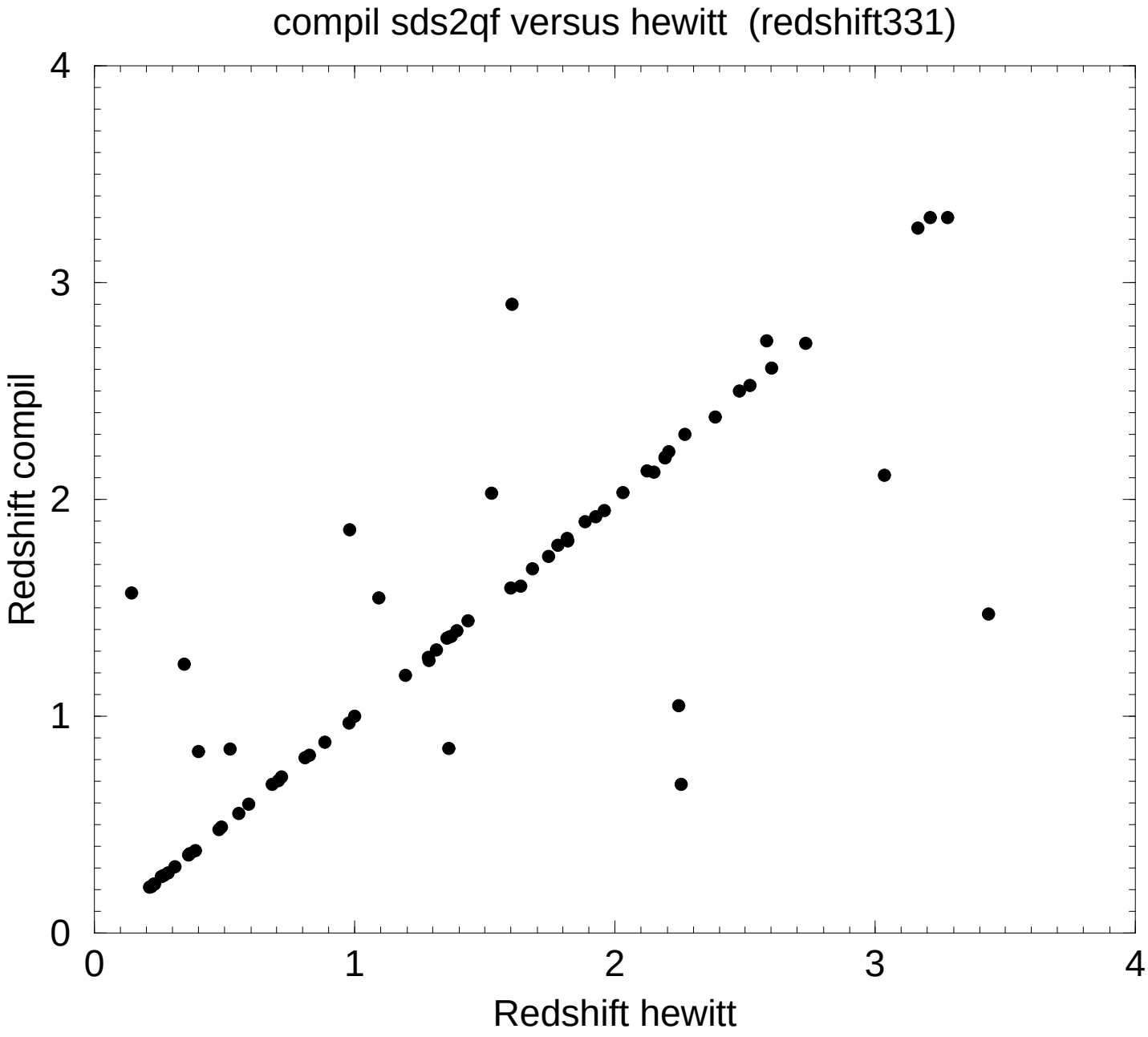
Histogram of redshifts /SDSS-DR5



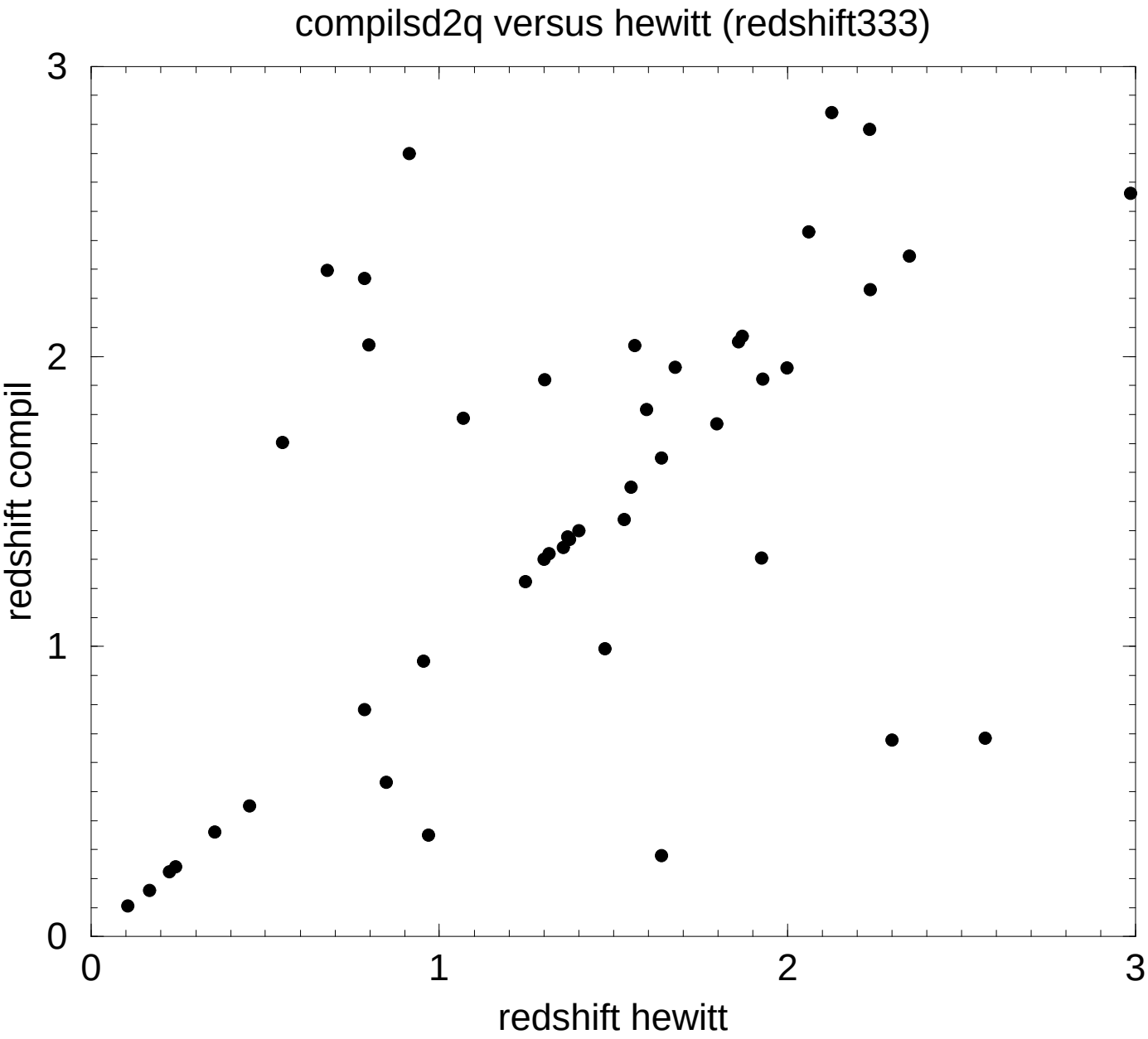
Redshift accuracy



Comparison redshifts 10" < radius < 30"



Comparaison redshifts 30" < radius < 50"



Redshifts for cross-ids

Table 2. Results of cross-identification between A–H and HB.

Condition	Condition	No. common quasars	Flag
$0'' < \rho < 2''$		1 870	
$2'' < \rho < 5''$		227	
-	$z_1 > 0, z_2 > 0$	167	
-	$z_1 > 0, z_2 > 0, \Delta z < 0.1$	156	*
-	$z_1 > 0, z_2 > 0, \Delta z > 0.1$	11	!
-	$z_1 = 0$ or/and $z_2 = 0$	60	!
$5'' < \rho < 30''$		206	
-	$z_1 > 0, z_2 > 0$	150	
-	$z_1 > 0, z_2 > 0, \Delta z < 0.1$	129	x
-	$z_1 > 0, z_2 > 0, \Delta z > 0.1$	21	?
-	$z_1 = 0$ or/and $z_2 = 0$	56	?

LQAC => Cross-identifications

Table 4. Number of cross-identified objects between the 13 catalogues belonging to the LQAC.

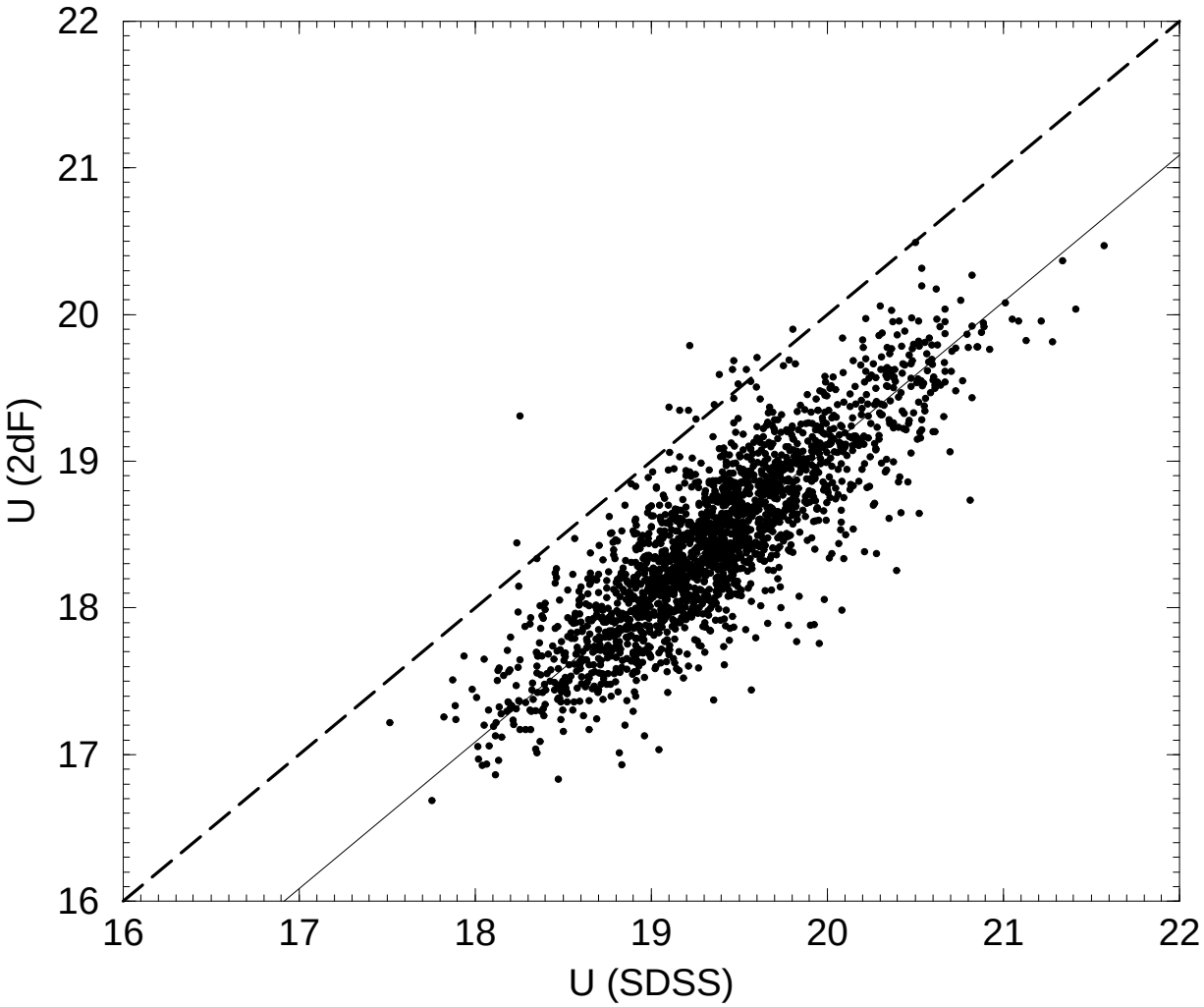
	A	B	C	D	E	F	G	H	I	J	K	L	M
A	**716**	642	582	377	72	6	27	0	327	333	500	480	401
B	-	**3 355**	1 598	1 577	288	33	71	1	522	911	2 034	1 965	1 079
C	-	-	**1 700**	1 272	203	10	52	0	413	576	1 133	1 090	724
D	-	-	-	**2 117**	253	6	53	0	287	547	1 306	1 267	670
E	-	-	-	-	**74 866**	2 053	553	4	1 329	11 735	69 705	62 768	52 261
F	-	-	-	-	-	**22 965**	0	0	495	619	19 504	17 274	20 922
G	-	-	-	-	-	-	**966**	2	142	527	872	796	869
H	-	-	-	-	-	-	-	**154**	19	17	31	35	23
I	-	-	-	-	-	-	-	-	**7 142**	1 175	3 306	3 014	5 879
J	-	-	-	-	-	-	-	-	-	**13 647**	13 243	12 740	5 932
K	-	-	-	-	-	-	-	-	-	-	**91 061**	78 397	65 786
L	-	-	-	-	-	-	-	-	-	-	-	**81 662**	56 730
M	-	-	-	-	-	-	-	-	-	-	-	-	**85 189**

LQAC => items completness

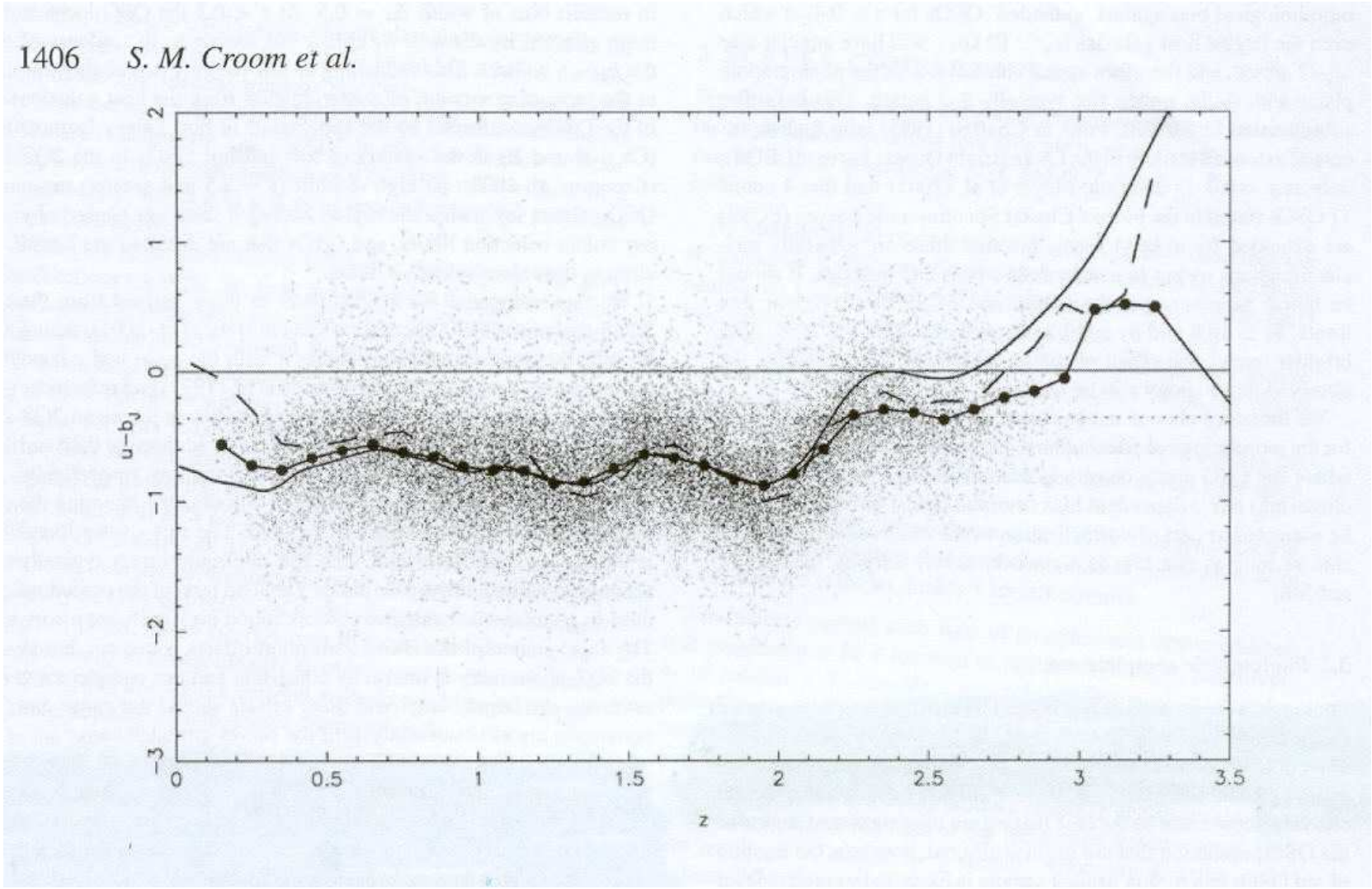
Table 7. Contribution per item of each main individual catalogue to the LQAC.

	A	B	C	D	E	F	G	H	I	J	K	L	Total
u	0	0	0	0	74 861	20 912	0	0	570	0	0	0	**96 343**
b	0	0	0	0	0	22 965	966	0	836	0	69 355	2 131	**96 253**
v	0	0	0	0	0	0	0	0	6 949	0	41 517	0	**48 466**
g	0	0	0	0	74 862	0	0	0	0	0	0	0	**74 862**
r	0	0	0	0	74 861	20 305	413	0	0	0	3 502	455	**99 537**
i	0	0	0	0	74 861	0	0	0	0	0	7 517	3 765	**86 143**
z	0	0	0	0	74 861	0	0	0	0	0	0	0	**74 861**
redshift	0	0	0	0	74 866	20 912	413	0	5 344	0	0	0	**101 535**
J	0	0	0	0	0	0	0	0	0	13 647	0	0	**13 647**
K	0	0	0	0	0	0	0	0	0	13 647	0	0	**13 647**
1.4 GHz	0	0	730	0	0	0	937	144	0	0	0	0	**1 811**
2.3 GHz	0	3 234	0	0	0	0	0	0	0	0	0	0	**3 234**
5.0 GHz	0	0	821	0	0	0	0	41	0	0	0	0	**862**
8.4 GHz	0	3 225	46	570	0	0	0	17	0	0	0	0	**3 858**
24 GHz	0	0	61	0	0	0	0	0	0	0	0	0	**61**

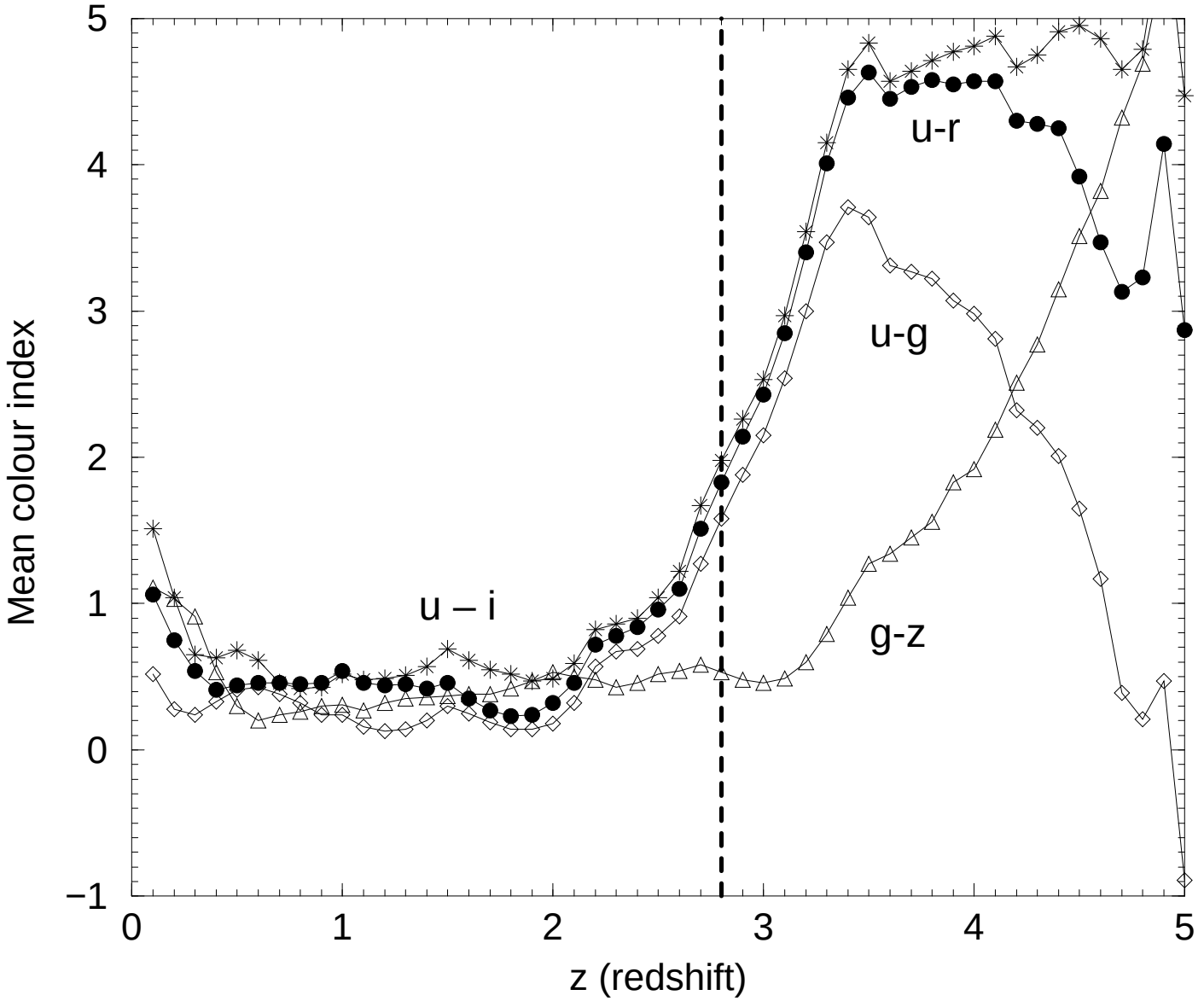
Magnitude differences (u band)



Color vs. Redshift



Mean color as a function of z



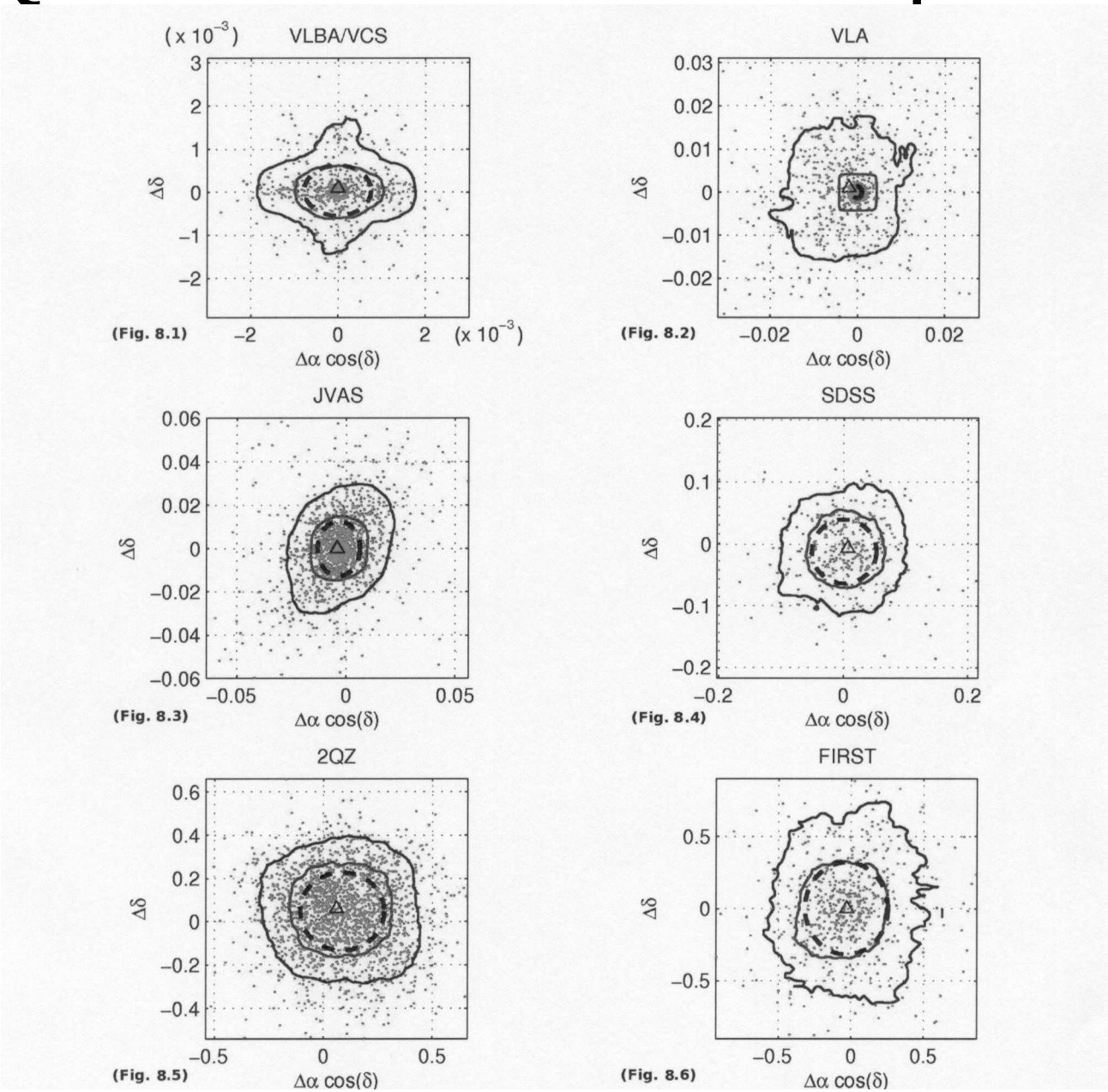
Astrometric comparisons

Table 9. Determination of the astrometric accuracy of the catalogues used in the LQAC.

	Mean (mas)		σ (mas)			
	$\Delta\alpha \cos\delta$	$\Delta\delta$	$\Delta\alpha \cos\delta$	$\Delta\delta$	N_1	N_2
VLBA	−0.010	0.039	0.767	0.585	94	4
JVAS	−0.054	−0.009	1.025	1.391	63	10
VLA	−3.287	−0.081	9.793	12.629	90	5
SDSS	1.210	−12.203	52.022	51.728	96	4
2QZ	86.242	45.991	193.667	181.214	98	3
FIRST	−30.282	0.010	286.750	319.342	96	3
HB	97.800	100.152	726.512	785.789	85	5
VV06	30.393	286.513	582.571	586.322	97	3

N_1 stands for the number of quasars remaining after a 3σ rejection threshold algorithm, and N_2 for the number of necessary iteration.

LQAC : astrometric comparisons



Absolute magnitudes

Cosmological parameters and hypothesis

Friedmann-Lemaître-Robertson-Walker metrics

Ω_k=0, q_0=-0.58, H_0=72 km/s/Mpc

Use of HST and WMAP experiments for constraints

Ad hoc expression for the luminosity distance $D_L(z)$

$$D_L = \frac{(1+z)\,c}{H_0} \int_1^{1+z} \frac{du}{\sqrt{\frac{1}{3}(1-2q_0) + \frac{2}{3}(1+q_0)\,u^3}},$$

M – m *= 5 – 5 log* D_L *– A – K*

A => galactic extinction

K => *K*- term related to the effect of redshift at given bandwidth

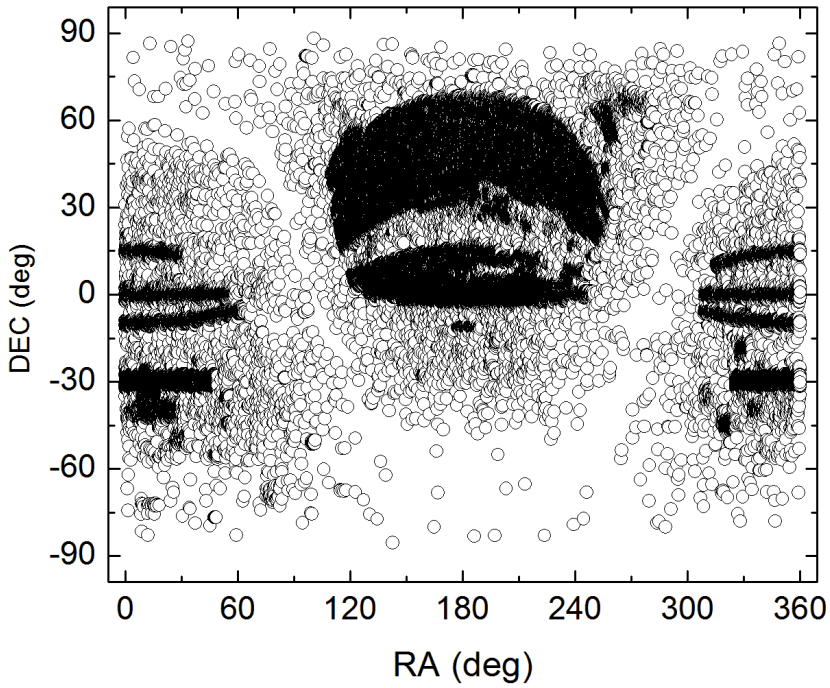
The L.Q.A.C (Large Quasar Astrometric Catalog)

(Souchay et al., A&A, 2009)

- **113 653 quasars**
- **Best determinations of α,δ**
- **Flags & Cross-identifications**

  ex. A - C - - F – H - - J

- **u,b,v,g,r,i,z photometry**
- **Redshift**
- **5 radio flux**
- **Absolute Magnitudes**
- **Regular up-dates (LQAC2=>2011)**



III. The construction of the Large Quasar Reference Frame (LQRF)

The construction of the LQRF

(Andrei et al.,A&A 505, 2009)

12 stages

(1) LQAC entries admitted

(2) LQAC quasars searched for B1.0, GSC2.3, SDSS / DR7

(3) Stellar neighbourhood selected

(4) Stellar neighbourhood searched for in UCAC2,UCACN,2MASS

(5) Plate solutions polynomials in zone around the quasar (at center)

(6) Families of positions are determined for the quasar

(7) In each family quasars of VLBI radio frame (ICRF, etc…)identified

(8) Subsets used to calculate global rotation and zero point % ICRF

(9) Optical and radio positions combined with orthogonal functions in α, δ and M for systematic local departures from ICRF => orthogonal functions applied to positions of quasars in each family

(10) Optical and radio positions in subsets combined in small regions around quasar to derive correction

(11) Total error assigned (high density catalog, local corr., global rotation, bias etc…)

(12) Weight assignement from total error

The construction LQRF

(Andrei et al.,A&A 505, 2009)

Final release

- 100 165 sources [-83.5° - + 88.5°] with improved astr ometry
- On average, neighbour with 10 ’
- Mean offset with VLBI positions : 32,7 mas
- Global orientation towards ICRS (718 sources collected in the ICRF)

$$\Delta\alpha\cos\delta = A1\sin\delta\cos\alpha + A2\sin\delta\sin\alpha - A3\cos\delta$$

$$\Delta\delta = -A1\sin\alpha + A2\cos\alpha + A4$$

A1 = +2.1 +/- 3.4 mas A2 = -0.9 +/- 3.5 mas

A3 = -2.6 +/- 3.4 mas A4 = 0 +/- 2.9 mas

IV. Prospects => LQAC-2

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 180:67–83, 2009 January doi:10.1088/0067-0049/180/1/67

EFFICIENT PHOTOMETRIC SELECTION OF QUASARS FROM THE SLOAN DIGITAL SKY SURVEY. II. ~1,000,000 QUASARS FROM DATA RELEASE 6

GORDON T. RICHARDS[1,2,8], ADAM D. MYERS[3], ALEXANDER G. GRAY[4], RYAN N. RIEGEL[4], ROBERT C. NICHOL[5], ROBERT J. BRUNNER[3], ALEXANDER S. SZALAY[2], DONALD P. SCHNEIDER[6], AND SCOTT F. ANDERSON[7]

[1] Department of Physics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104, USA
[2] Department of Physics and Astronomy, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218-2686, USA
[3] Department of Astronomy, University of Illinois at Urbana-Champaign, 1002 West Green Street, Urbana, IL 61801-3080, USA
[4] Center for Experimental Research in Computer Systems, Georgia Institute of Technology, 240 Technology Square Research Building, 85 5th St. NW, Atlanta, GA 30318, USA
[5] Institute of Cosmology and Gravitation, Mercantile House, Hampshire Terrace, University of Portsmouth, Portsmouth, PO1 2EG, UK
[6] Department of Astronomy and Astrophysics, The Pennsylvania State University, 525 Davey Laboratory, University Park, PA 16802, USA
[7] Department of Astronomy, University of Washington, Box 351580, Seattle, WA 98195, USA
Received 2008 May 1; accepted 2008 September 4; published 2008 December 23

ABSTRACT

We present a catalog of 1,172,157 quasar candidates selected from the photometric imaging data of the Sloan Digital Sky Survey (SDSS). The objects are all point sources to a limiting magnitude of $i = 21.3$ from 8417 deg^2 of imaging from SDSS Data Release 6 (DR6). This sample extends our previous catalog by using the latest SDSS public release data and probing both ultraviolet (UV)-excess and high-redshift quasars. While the addition of high-redshift candidates reduces the overall efficiency (quasars:quasar candidates) of the catalog to ~80%, it is expected to contain no fewer than 850,000 bona fide quasars, which is ~8 times the number of our previous sample and ~10 times the size of the largest spectroscopic quasar catalog. Cross-matching between our photometric catalog and spectroscopic quasar catalogs from both the SDSS and 2dF survey yields 88,879 *spectroscopically* confirmed quasars. For judicious selection of the most robust UV-excess sources (~500,000 objects in all), the efficiency is nearly 97%—more than sufficient for detailed statistical analyses. The catalog's completeness to type 1 (broad-line) quasars is expected to be no worse than 70%, with most missing objects occurring at $z < 0.7$ and $2.5 < z < 3.0$. In addition to classification information, we provide photometric redshift estimates (typically good to $\Delta z \pm 0.3$ [2σ]) and cross-matching with radio, X-ray, and proper-motion catalogs. Finally, we consider the catalog's utility for determining the optical luminosity function of quasars and are able to confirm the flattening of the bright-end slope of the quasar luminosity function at $z \sim 4$ as compared to $z \sim 2$.

Key words: catalogs – quasars: general

Online-only material: color figures, machine-readable tables

1. INTRODUCTION

The number of known quasars has grown exponentially since their discovery by Maarten Schmidt in 1963 (Figure 1). There have been relatively frequent compilations of heterogeneous catalogs over the years and the 100, 1000, and 10,000 quasar marks were reached in 1967, 1977, and 1998, respectively (see Hewitt & Burbidge 1993; Véron-Cetty & Véron 2006, and references therein). Early quasar discoveries were often

by this group's *photometric* sample in 2004 (Richards et al. 2004; hereafter Paper I). Quasar catalogs, used for meaningful statistical analyses, are almost always spectroscopic. This is in contrast to galaxies, for which a wealth of major statistical studies utilized purely photometric catalogs (e.g., Maddox et al. 1990). Historically, this has been due to an inability to obtain ~90% or greater star–quasar separation efficiency to match the typical star–galaxy separation, readily obtainable from morphology. For instance, standard ultraviolet (UV)-excess

The Astronomical Journal, 139:2360–2373, 2010 June doi:10.1088/0004-6256/139/6/2360

THE SLOAN DIGITAL SKY SURVEY QUASAR CATALOG. V. SEVENTH DATA RELEASE

Donald P. Schneider[1], Gordon T. Richards[2], Patrick B. Hall[3], Michael A. Strauss[4], Scott F. Anderson[5], Todd A. Boroson[6], Nicholas P. Ross[1], Yue Shen[4], W. N. Brandt[1], Xiaohui Fan[7], Naohisa Inada[8], Sebastian Jester[9,10], G. R. Knapp[4], Coleman M. Krawczyk[2], Anirudda R. Thakar[11], Daniel E. Vanden Berk[1], Wolfgang Voges[12,13], Brian Yanny[14], Donald G. York[15,16], Neta A. Bahcall[4], Dmitry Bizyaev[17], Michael R. Blanton[18], Howard Brewington[17], J. Brinkmann[17], Daniel Eisenstein[7], Joshua A. Frieman[14,15,19], Masataka Fukugita[20], Jim Gray[21], James E. Gunn[4], Pascale Hibon[22], Željko Ivezić[5], Stephen M. Kent[14,15], Richard G. Kron[15,14], Myung Gyoon Lee[23], Robert H. Lupton[4], Elena Malanushenko[17], Viktor Malanushenko[17], Dan Oravetz[17], K. Pan[17], Jeffrey R. Pier[24], Ted N. Price III[4], David H. Saxe[25], David J. Schlegel[26], Audry Simmons[17], Stephanie A. Snedden[17], Mark U. SubbaRao[27], Alexander S. Szalay[11], and David H. Weinberg[28]

[1] Department of Astronomy and Astrophysics, The Pennsylvania State University, 525 Davey Laboratory, University Park, PA 16802, USA
[2] Department of Physics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104, USA
[3] Department of Physics & Astronomy, York University, 4700 Keele Street, Toronto, Ontario M3J 1P3, Canada
[4] Princeton University Observatory, Peyton Hall, Princeton, NJ 08544, USA
[5] Department of Astronomy, University of Washington, Box 351580, Seattle, WA 98195, USA
[6] National Optical Astronomy Observatory, Tucson, AZ 85726, USA
[7] Steward Observatory, University of Arizona, 933 North Cherry Avenue, Tucson, AZ 85721, USA
[8] Cosmic Radiation Laboratory, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
[9] School of Physics and Astronomy, University of Southampton, Southampton SO17 1BJ, UK
[10] Max-Planck-Institut für Astronomie, Königstuhl 17, D-69117 Heidelberg, Germany
[11] Department of Physics and Astronomy, The Johns Hopkins University, 3400 North Charles Street, Baltimore, MD 21218-2686, USA
[12] Max-Planck-Institut für extraterrestische Physik, Postfach 1312, D-85741 Garching, Germany
[13] Max Planck Digital Library, Amalienstrasse 33, D-80799, München, Germany
[14] Fermi National Accelerator Laboratory, P.O. Box 500, Batavia, IL 60510, USA
[15] Department of Astronomy and Astrophysics, The University of Chicago, 5640 South Ellis Avenue, Chicago, IL 60637, USA
[16] Enrico Fermi Institute, The University of Chicago, 5640 South Ellis Avenue, Chicago, IL 60637, USA
[17] Apache Point Observatory, P.O. Box 59, Sunspot, NM 88349, USA
[18] Department of Physics, New York University, 4 Washington Place, New York, NY 10003, USA
[19] Center for Cosmological Physics, The University of Chicago, 5640 South Ellis Avenue, Chicago, IL 60637, USA
[20] Institute for Cosmic Ray Research, University of Tokyo, 5-1-5 Kashiwa, Kashiwa City, Chiba 277-8582, Japan
[21] Microsoft Research, 301 Howard Street, No. 830, San Francisco, CA 94105, USA
[22] Korean Institute for Advanced Study, 207-43 Cheongryangri-dong, Dongdaemun-gu, Seoul 130-012, Republic of Korea
[23] Department of Physics and Astronomy, Seoul National University, Seoul 151-742, Republic of Korea
[24] Division of Astronomical Sciences, National Science Foundation, 4201 Wilson Blvd., Arlington, VA 22230, USA
[25] 490 Wilson's Crossing Road, Auburn, NH 03032, USA
[26] LBNL, Bldg 50R5032 MS 50-232, 1 Cyclotron Road, Berkeley, CA 94720-8160, USA
[27] University of Chicago and Adler Planetarium and Astronomy Museum, 1300 S. Lake Shore Drive, Chicago, IL 60605, USA
[28] Department of Astronomy, Ohio State University, 140 West 18th Avenue, Columbus, OH 43210-1173, USA
Received 2009 October 6; accepted 2010 March 18; published 2010 April 27

ABSTRACT

We present the fifth edition of the Sloan Digital Sky Survey (SDSS) Quasar Catalog, which is based upon the SDSS Seventh Data Release. The catalog, which contains 105,783 spectroscopically confirmed quasars, represents the conclusion of the SDSS-I and SDSS-II quasar survey. The catalog consists of the SDSS objects that have luminosities larger than $M_i = -22.0$ (in a cosmology with $H_0 = 70$ km s^{-1} Mpc^{-1}, $\Omega_M = 0.3$, and $\Omega_\Lambda = 0.7$), have at least one emission line with FWHM larger than 1000 km s^{-1} or have interesting/complex absorption features, are fainter than $i \approx 15.0$, and have highly reliable redshifts. The catalog covers an area of ≈9380 deg^2. The quasar redshifts range from 0.065 to 5.46, with a median value of 1.49; the catalog includes 1248 quasars at redshifts greater than 4, of which 56 are at redshifts greater than 5. The catalog contains 9210 quasars with $i < 18$; slightly over half of the entries have $i < 19$. For each object the catalog presents positions accurate to better than 0.″1 rms per coordinate, five-band (*ugriz*) CCD-based photometry with typical accuracy of 0.03 mag, and information on the morphology and selection method. The catalog also contains radio, near-infrared, and X-ray emission properties of the quasars, when available, from other large-area surveys. The calibrated digital spectra cover the wavelength region 3800–9200 Å at a spectral resolution of $\simeq 2000$; the spectra can be retrieved from the SDSS public database using the information provided in the catalog. Over 96% of the objects in the catalog were discovered by the SDSS. We also include a supplemental list of an additional 207 quasars with SDSS spectra whose archive photometric information is incomplete.

Key words: catalogs – quasars: general – surveys

Online-only material: color figures, machine-readable and VO tables

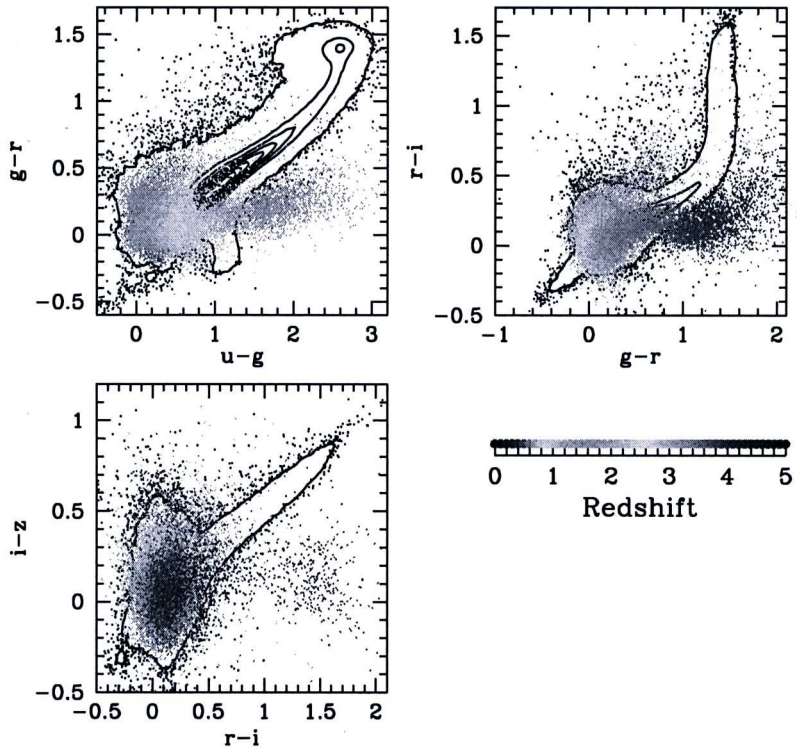


Figure 2. Distribution of unresolved sources (black dots and contours) and quasars (color dots) in SDSS *ugriz* color–color space. The quasars are color-coded by redshift. For clarity, we only show 10% of the $z < 2.2$ quasars in the figure.

(A color version of this figure is available in the online journal.)

A&A 518, A10 (2010)
DOI: 10.1051/0004-6361/201014188

Astronomy & Astrophysics

A catalogue of quasars and active nuclei: 13th edition*

M.-P. Véron-Cetty and P. Véron

Observatoire de Haute Provence, CNRS, 04870 Saint-Michel l'Observatoire, France
e-mail: [mira.veron;philippe.veron]@oamp.fr

Received 3 February 2010 / Accepted 29 March 2010

ABSTRACT

Aims. This catalogue is aimed at presenting a compilation of all known AGN in a compact and convenient form, and we hope that it will be useful to all workers in this field.
Methods. Like the twelfth edition, it includes position and redshift, as well as photometry (U, B, V) and 6 cm and 20 cm flux densities, when available.
Results. The present version contains 133 336 quasars, 1 374 BL Lac objects, and 34 231 active galaxies (including 16 517 Seyfert 1s), almost doubling the number listed in the 12th edition. We also give a list of all known lensed and double quasars.

Key words. quasars: general – galaxies: Seyfert – BL Lacertae objects: general

1. Introduction

The first catalogue of quasars was published in 1971 by De Veny et al. It contained 202 objects. The number of known quasars has since steadily increased until the year 2000 (see Table 1). The release of both the 2dF catalogue (Croom et al. 2001, 2004) and the first four data releases (Abazajian et al. 2003, 2004, 2005; Adelman-McCarthy et al. 2006) of the "Sloan Digital Sky Survey" (Fan et al. 1999) has dramatically increased the number of known quasars justifying the 10th, 11th, and 12th editions of the present catalogue. The recent publication of the last three data releases (5th, 6th, and 7th) (Adelman-McCarthy et al. 2007, 2008; Abazajian et al. 2009) of the SDSS, which has again almost doubled the number of known quasars, made a new edition timely.

This edition contains quasars with measured redshift known to us prior to July 1, 2009. As in the preceding editions, we do not give any information about absorption lines or X-ray prop-

Table 1. Increase with time of the number of known QSOs, BL Lacs, and Seyfert 1s.

QSO	BL Lac	Seyfert 1	Reference
202			De Veny et al. (1971)
2251		190	Véron-Cetty & Véron (1984)
2835	73	236	Véron-Cetty & Véron (1985)
3473	84	258	Véron-Cetty & Véron (1987)
4169	117	358	Véron-Cetty & Véron (1989)
6225	162	575	Véron-Cetty & Véron (1991)
7383	171	695	Véron-Cetty & Véron (1993)
8609	220	888	Véron-Cetty & Véron (1996)
11 358	357	1111	Véron-Cetty & Véron (1998)
13 214	462	1711	Véron-Cetty & Véron (2000)
23 760	608	2765	Véron-Cetty & Véron (2001)
48 921	876	6762	Véron-Cetty & Véron (2003)
85 221	1122	9628	Véron-Cetty & Véron (2006)
133 336	1374	16 517	Present edition

LQAC-2 new targets

- **Id .Number** 13h24mn35,7s +23°05'34'' => Nb. 201.1487 2 3.0927
  => Nb. 1324257.230534

- **Including new catalogues** from 2009-2010 (ICRF2, SDSS DR7, etc…)
- **New cross-identifications** (catalogues, algorithmes)
- **Two columns** for α and δ coordinates (original + **LQRF**)
- **Solving problematic cross-ids** (Hewitt & Burbridge)
- **Compacity index** (0….9)
- **Including AGN's, BL LAC**
- **Etc…**

Expected number of objects => ~ 170 000 – 200 000

V. CONCLUSION