*SF2A 2008*
*C. Charbonnel, F. Combes and R. Samadi (eds)*

# QUASARS COMPILATION AND THE LARGE QUASAR ASTROMETRIC CATALOGUE (LQAC) : TOWARDS A DENSIFICATION OF THE ICRF

Souchay, J.[1], Andrei, A.H.[2], Barache, C.[1], Bouquillon, S.[1], Gontier, A.-M., Lambert, S. B.[1], Taris, F.[1], Le Poncin-Lafitte, C.[1], Arias, E.F.[3], Suchet, D.[1] and Baudin, M.[1]

**Abstract.**
In the recent years a huge and always increasing number of quasars have been detected and identified from various sky surveys. This leads to a large quantity of data with various and inhomogeneous informations in terms of astrometry, photometry, radioastronomy and spectroscopy. Therefore we have decided to make a general compilation of the largest number of recorded quasars obtained from all the available catalogues, with their best position estimates and by retaining the tabulated physical information available both at optical and radio wavelengths. This catalogue compilation named LQAC (Large Quasar Astrometric Catalogue) gives, for each quasar, the equatorial coordinates, multiband photometry, radio fluxes, redshift, luminosity distances and absolute magnitudes (Souchay et al. 2008b).

## 1 Introduction

The drastically increasing number of quasars discovered in the recent years through automatic surveys and very modern techniques as it is the case for the SDSS (Sloan Digital Sky Survey) recently motivated us to construct a complete compilation of all the quasars which have already been reckoned at the present time. This kind of systematic archiving has been successfully done in the last two decades by Véron-Cetty & Véron who up dated on a regular basis their compilation with a number of recorded sources ranging from roughly 2000 in 1984 to more than 85000 for the recent release (Véron-Cetty & Véron 2006). Among the various qualities of this compiled catalogue we can notice that it was regularly updated in order to follow the always increasing number of recorded quasars and it succeeded in being as complete as possible.

For the construction of the LQAC (Souchay et al. 2008b), our goals were similar to that of the aforementioned authors. We gathered the 12 largest quasar catalogues, 4 from radio interferometry programs, 8 from optical surveys and we carried out systematical cross-identifications of the objects. Informations concerning $u$,$b$,$v$,$g$,$r$,$i$,$z$,$j$,$k$ photometry as well as redshift and radio fluxes at 1.4Ghz (20cm), 2.3Ghz (13cm), 5.0Ghz (6cm), 8.4Ghz (3.6cm) and 24Ghz (1.2cm) were also given when available. A small proportion of remaining objects not reckoned by the 12 catalogues and included in the Véron-Cetty & Véron (2006) compilation of quasars are added in our LQAC compilation, with a specific number indicating their catalogue of origin.

The aim of the LQAC was to give useful data concerning any quasar already detected at the present date without exception. Its construction contains some fundamental improvements (Souchay et al. 2008b) that we can summarize as follow : it concerns by far more quasars than in the previous catalogues; It gives the a priori most accurate determination of the celestial positions of the quasars, thanks to a compilation strategy in relation with the astrometric quality of the catalogues; It contains more informations concerning the photometric properties of the objects ; It priviligiates systematically large surveys with respect to small catalogues, for the sake of homogeneity; It gives clear and direct information about the cross-identification between the catalogues involved in the compilation. At last it proposes a determination of the absolute magnitudes of the quasars at two bandwidths ($r$ and $i$) by using very up-to-date models of galactic extinction and new values of cosmological parameters.

[1] SYRTE, Observatoire de Paris, 61, av. de l'observatoire, 75014 Paris
[2] Observatorio Nacional/MCT, Rio de Janeiro // Observatorio do Valongo;UFRJ, Rio de Janeiro
[3] BIPM

**Table 1.** Characteristics of the main catalogs participating in our compilation of quasars named LQAC (Souchay et al. 2008b). The last column indicates the search radius chosen for cross-identifications. The symbol (*) indicates that for the cross-identification 3 different search radius have been considered.

| Catalogue Name | Flag | Nature | Nbs of quasars | **Accuracy** (") | Search radius (") |
|---|---|---|---|---|---|
| ICRF-Ext2 | A | radio | 717 | 0.001 | 1 |
| VLBA | B | radio | 3 357 | 0.001 | 1 |
| VLA-015 | C | radio | 1701 | 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 |
| V&V | M | optical+radio | 85 189 | 1.0 | 2-5-10 (*) |

## 2 Characteristics of the catalogues involved in the LQAC

In the LQAC a flag designates each catalogue participating to the compilation of quasars. The nomenclature of the flags is given by the Table 1. We give in the following some details about each main catalogue of the compilation.

• The ICRF-Ext.2 (Fey et al. 2004), second extension of the International Celestial Reference Frame , is the present realization of the ICRS (International Celestial Reference System) at radio frequencies . It contains 717 extragalactic sources which represent the basic frame with respect to which the position of any object in the celestial sphere should be measured. Although we are exclusively considering quasars in our compilation, we keep some particular objects (10 Active Galactic Nuclei and 10 BL LAC objects ) thanks to their remarkable astrometric accuracy.

• The Very Long Baseline Array (VLBA) Calibrator Survey(VCS) consists in a catalogue containing milliarcsecond accurate positions of more than 3000 extragalacic radio sources, mainly quasars (Fomalont et al. 2003). These positions have been derived from astrometric analysis of dual-frequency 2.3 and 8.4 GHz observations, using the Goddard Space Flight Center Calc/Solve package, with maps of the sources available for a majority of cases.

• The Very Large Array (VLA) consists in 27 radio antennas in a Y shaped configuration at St. Augustin (New Mexico). The 25-m antennas are linked electronically to give the same resolution as an antenna of 36 km across, with the sensitivity of a 130 meter dish (Claussen 2006). The VLA catalogue of quasars contains information concerning the accuracy of source positions. Therefore we decided to separate the original catlog in two parts, one with accuracy better (less) than 0.15" and another containing all the sources with accuracy worse than this value. The first sub catalogue, with flag"C", contains 1701 quasars with an astrometric precision around 10 mas whereas the second one, with flag "H" is much smaller with only 157 quasars with an accuracy

around 0.2". For all objects, fluxes are given at 6 frequencies : 0.3GHz, 4GHz, 5GHz,8.4GHz,15Ghz, and 23GHz. Nevertheless, only a few of these flux determinations are given for the objects.

• The JVAS (Jodrell Bank-VLA Astrometric Survey) catalogue contains 2118 sources with 8.4 GHz flux information (Patnaik et al. 1992; Browne et al. 1998; Wilkinson et al. 1998).

• TheSloan Digital Sky Survey (SDSS) covers about one quarter of the sky, observed from a dedicated 2.5-m telescope located at Apache Point, New Mexico. Images are obtained in five broad optical bands (designated by $u$, $g$, $r$, $i$, $z$) covering the wavelength range of the CCD response from the atmospheric ultraviolet cutoff to the near infrared (see Fukugita et al. 1996 for details). The astrometric calibration (Pier et al. 2003) yields an accuracy per coordinate of 45 mas when reduced against the USNO CCD Astrograph catalogue (UCAC) and 75 mas when reduced against Tycho-2. The SDSS quasars input catalogue is by far the largest one, thanks to the DR5 release. It contains 74 868 objects (Schneider et al. 2005). Moreover it gives extensive photometric information for the quasars with magnitudes estimations in the $u$, $b$, $v$, $g$, $r$, $i$, $z$ colors and a precise redshift evaluation.

• The 2-degree Field (2dF) QSO Redshift Survey, the second densiest one, quoted as 2QZ (Croom et al. 2004) is based on a pre-selection of quasars candidates from well defined criteria based on broadband $u$, $b_j$, $r$ colors obtained from automated plate measurements (APM) of UKST photographic plates. The magnitude of the pre-selected objects is such that $16 < b_j < 20.85$. The survey area comprises 30 fields arranged in two $75^\circ \times 5^\circ$ declination strips, one passing across the South Galactic Cap, centered on $\delta = -30^\circ$ and the other passing across the North Galactic Cap, centered on $\delta = 0^\circ$.

• The FIRST radio survey (Gregg et al. 1996; Becker et al. 2001) has provided a new resource for constructing a large quasar sample, with positions accurate to better than 1", and with high radio sensitivity. One of the main tasks consisted in matching the radio catalogue from the NRAO VLA survey (Becker et al. 1995) with an optical catalogue provided by the Automated Plate Machine (APM) digitization of Palomar Sky Survey Plates. Optical selection was accompanied by several spectroscopic campaigns in order to refine the selection criteria.

• About fifteen years ago Hewitt & Burbridge(1993) have published a catalogue containing all known quasars with measured emission redshifts, complete to 1992, December 31. This catalogue contains 7245 objects, nearly all QSO's, with about 90 BLac objects. The information about the objects is exhaustive and very complete, containing positions, colors, magnitudes, emission-line redshifts, absorption, variability, polarization, as well as X-ray, radio and infrared data. An important problem of this catalogue is the poor accuracy of the equatorial coordinates for a significant proportion of the quasars in the list. In the next section we will describe how we deal with this disadvantage..

• The three catalogues 2MASS (Cutri et al. 2003), GSC2.3 (STScI, 2006) and B1.0 (Monet et al. 2003) do not bring new quasars to our sample, but thanks to cross identifications they enable one to cover gaps concerning photometric informations not provided by the pre-compiled catalogue.

## 3 Discussion and conclusion

Our final catalogue contains 113663 quasars. This is 25% bigger than the number of quasars recorded in the latest version of the Véron Cetty & Véron (2006) catalogue, which was the densiest compilation of quasars up to now. Souchay et al.(2008a) have discussed the external homogeneity of the data by comparing the equatorial coordinates, the redshifts and the magnitudes of objects belonging to two different catalogues. Moreover, they have used up-to-date cosmological parameters as well as recent models for galactic extinction and K-correction in order to evaluate at best the absolute magnitudes of the objects. In table 2, we gather the number of entries per item (magnitude, photometric band etc...). For comparison we present the corresponding number of entries of the Véron-Cetty & Véron catalogue. We plan to build up-dated versions of the LQAC in the future.

## References

Becker, R.H., White, R.L., & Helfand, D.J. 1995, ApJ, 450, 559

Becker, R.H., White, R.L., Gregg, M.D., et al. 2001, ApJS, 135, 227

Browne, I.W.A., Patnaik, A.R., Wilkinson, P.N., & Wrobel, J.M. 1998, MNRAS, 293, 257

Claussen, M., 2006, VLA Calibrator Manual

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

**Table 2.** Number of entries per item for each of the following catalogues : the VV2006 one (flag M) the A to L compilation, and the final LQAC catalogue. The difference between the numbers of the 4th. column and of the 3rd. one gives the contribution of the VV2006 to the LQAC.

| | Véron-Cetty & Véron(2006) (M) | Compilation A to L | Compilation (LQAC) A to M | Percentage of completness |
|---|---|---|---|---|
| u | 74 367 | 96 343 | **99 665** | 87.8 |
| b | 79 488 | 96 253 | **106 801** | 93.9 |
| v | 54 542 | 48 466 | **75 396** | 66.3 |
| g | 0 | 74 862 | **74 862** | 65.9 |
| r | 1 540 | 99 537 | **100 811** | 88.7 |
| i | 101 | 86 143 | **86 238** | 75.9 |
| z | 0 | 74 861 | **74 861** | 65.9 |
| *z* | 85182 | 101 535 | **110 745** | 97.4 |
| J | 9 | 13 647 | **13 656** | 12.0 |
| K | 3 | 13 647 | **13 650** | 12.0 |
| 1.4Ghz | 8 405 | 1 811 | **8 934** | 7.8 |
| 2.3Ghz | 0 | 3 234 | **3 234** | 2.8 |
| 5.0Ghz | 3 585 | 862 | **3951** | 3.4 |
| 8.4Ghz | 0 | 3 858 | **3 858** | 3.3 |
| 24Ghz | 0 | 61 | **61** | 0.0 |

Cutri, R.M., Skrutskie, M.F., van Dyk, S., et al. 2003, NASA/IPAC Infrared Science Archive, http://irsa.ipac.caltech.edu/applications/Gator/

Fey, A.L., Ma, C., Arias, E.F., et al. 2004, AJ, 127, 3587

Fomalont, E.B., Petrov, L., MacMillan, D.S., et al. 2003, AJ, 126, 2562

Fukugita, M., Ichikawa, T., Gunn, J.E., et al. 1996, AJ, 111, 1748

Gregg, M.D., Becker, R.H., White, R.L., et al. 1996, AJ, 112, 407

Hewitt, A., & Burbidge, G. 1993, ApJS, 87, 451

Monet, D.G., Levine, S.E., Canzian, B., et al. 2003, AJ, 125, 984

Patnaik, A.R., Browne, I.W.A., Wilkinson, P.N., & Wrobel, J.M. 1992, MNRAS, 254, 655

Pier, J.R., Munn, J.A., Hindsley, R.B., et al. 2003, AJ, 125, 1559

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

Souchay,J., Lambert,S.B.,Andrei,A.H.,Bouquillon,S.,Barache,C.,Le Poncin-Lafitte,C.,2008, A& A Res. Note,485,299

Souchay, J.,Andrei,A.H.,Barache,C., Bouquillon,S., Gontier,A.M., Lambert, S.B, Le Poncin-Lafitte,C., Taris,F., Arias,F., Suchet,D., Baudin,M. 2008, accepted A&A

Véron-Cetty, M.-P., & Véron, P. 2006, A&A, 455, 773

Wilkinson, P.N., Browne, I.W.A., Patnaik, A.R., et al. 1998, MNRAS, 300, 790