THE GAIA INITIAL QUASAR CATALOGUE

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ABSTRACT. We present the latest, updated, and fully corrected version of the Gaia Initial QSO Catalog (GIQC), produced by the CU3 GWP-S-335-13000. It contains 1 248 372 objects, of which 191 802 are considered and marked as Defining ones, because of their observational history and existence of spectroscopic redshift. Also objects with strong, calibrator-like radio emission are included in this category. The Defining objects represent a clean sample of quasars. The remaining objects aim to bring completeness to the GIQC at the time of its compilation. For the whole GIQC the average density is 30.3 sources per sq.deg., practically all sources have an indication of magnitude and of morphological indexes, and 90% of the sources have an indication of redshift and of variability indexes.

1. MOTIVATION

Gaia will operate in survey mode, recordng transits of compact objects in the G magnitude range 6-20, to produce an unbiased census of the stars in the galaxy, but also of solar system constituents and extragalactic objects. Among the latter, there will be about 500 000 QSOs, if not much more (Andrei et al., 2008). The satellite observations imply in proper, in the relativistic sense, reference systems to which the measurements are initially referred. These are the ones described by Bastian (2007), but the final catalogue will comply to the IAU-sanctioned Barycentric Celestial Reference System (BCRS), resulting in the Gaia Celestial Reference Frame (GCRF) materialized by a dense mesh of fiducial QSOs. Notwithstanding, it is also worth to mention that two other quite robust extensions of the GCRF will be produced, to brighter regimens. The one formed by the unresolved galaxies (some 10 million of objects) and the QSOs that did not make it to be in the GCRF (presumably containing several radio-loud quasars). And the one formed the approximately half a billion of stars with highly accurate position and proper motions.

QSOs thus will define the GCRF, and accordingly Gaia own results are capable of classifying them. The QSO classification contains three major orientations: getting a zero-contaminants QSO sample to determine the GCRF; deriving the most complete QSO sample based on the full Gaia data; and determining astrophysical parameters for each QSO. The determination itself of a Gaia source as a QSO is planned to rely primarily on comparison of the photometric output against a template of spectral energy distributions (SED), ands secondarily on astrometric observables, variability analysis and a reliable initial list of known QSOs. Based on the end-of-mission color information, supervised Artificial Neural Networks (ANN) can virtually reject all contaminating stars (including white dwarfs), although the completeness drops to about 20% at G 20th (Bailer Jones et al., 2008). It can deliver the sample of 10 0000 quasars which can stabilize the GCRF to a residual rotation of less than 0.5 μas per year, provided they are well distributed over the sky (Mignard, 2012).

The relatively small number of points actually required to constitute a robust GCRF brings particular relevance for an initial list of known QSOs. This is exactly the purpose of the Gaia work package Initial QSO Catalogue for Gaia (GIQC), under the CU3, Core Processing Coordination (Andrei, 2007). It aims to obtain a clean sample of at least 10 000 quasars, distributed allsky off |20deg| of galactic latitude, with magnitude brighter than V=20 and point-like PSF. This bona fide initial clean sample is useful both for the actual orientation of the GCRF and to enlarge the templates of the recognition scheme. On the other hand, to attain completeness, the GIQC also brings, in separate categories, all objects reckoned as quasars or point like AGNs, even if there is not spectroscopic redshift available. The latest version of the GIQC is considerably enlarged, chiefly for candidates and other quasars. Those have only photometric redshift and occupy mostly the SDSS region. Nevertheless their confirmation, either by Gaia or others, can add importantly to the recognition template library.

2. THE CATALOG

There is no optical type of observation that can deliver quasar's astrometry comparable to Gaia, but this is not required from the GIQC. Its purpose is to provide positions, and to an extent magnitudes, to enable unmistakable matching to Gaia own observations on allsky basis. Therefore the development of a Celestial Reference Frame is not in the scope of the GIQC, but rather it is tackled elsewhere (Souchay et al., 2009, 2012; Andrei et al., 2009). On the other hand, variability and morphology are important when selecting the quasars to form the fundamental Gaia astrometric frame. Since during the Gaia mission each quasar will me measured on average 80 times, with intervals from hours to months, along different directions, those indexes can give a head start or warning for the combination of the observations and understanding of the individual errors.

On forming the catalog, we started from the LQAC2 list (Souchay et al., 2012 - 187 504 objects). Then complemented with the SDSS DR10 (Schneider et al, 2010 - 116 105 objects), the 2dF/2qZ (Croom et al, 2004 - 22 835 objects), and the BOSS selection (Paris et al, 2012 - 87 822 objects). The VLBI QSRs are all important for the GCRF, thus they have been all introduced in the GIQC, naturally without duplicating the already existing entries. Thus entered the ICRF2 (Fey et al., 2010), the VLBA-6th supp calibrator list (Petrov et al., 2008), the VLA-2009 update calibrator list (NRAO, 2012), plus the list of candidates for the future reconciliation between the GCRF and the ICRF (Bourda et al., 2010), amounting to 4 925 objects. Redshift and optical magnitudes were searched in various catalogs and in the available literature, in special searching for matches in the GSC2.3 (Lasker et al., 2008) and the USNO B1.0 (Monet et al., 2003). Finally, were considered the SDSS photometrically selected quasar candidates (Richards et al, 2009 - 887 406 objects). For the remaining QSOs, which come from smaller catalogues, the analysis was made catalog by catalog, up to case by case.

Tables 1 and 2 present the GIQC main features.

Table 1 - Main features of the GIQC positions, magnitudes, and redshifts.

Number of sources	1 248 372
Sources with magnitude	1 246 512
Sources with redshift	1 157 285
Sources brighter than G=20	371 098
Sources fainter than G=21	690 507
Sources with redshift smaller than 1	250 405
Sources with redshift greater than 2	383 487
Astrometry precision	1 arcsec
Magnitude precision	0.5
Redshift precision	0.01
Average density	30.3 sources/deg^2
Average neighbor distance	3.7 arcmin (σ 4.9 arcmin)
Maximum distance to neighbor	5.2 deg
Maximum distance to neighbor (average of 100 larger values)	3.0 deg (σ 0.6 deg)

The GIQC goes beyond the columns appearing in the IGSL (Initial Gaia Source List), which provides the initial identification to the Gaia observed objects. In the GIQC much more information is given, to enable the assessment of the aptitude of a given QSO to form in the core Gaia reference frame. This focus on the reliability of origin catalogues, on the optical pointlikeness, and on the possibility of astrometric jitter. Such aspects, if unaccounted for, give rise to larger astrometric errors than would be expected on basis of the object magnitude, in special when combining measures taken at different times during the mission and at different directions of the Astro line spread function (LSF) over the source. By the same token, when those aspects are warned for and accounted for, they become a useful tool to bring back to the core Gaia quasar frame objects apparently troublesome, or to reject objects to this end using an objective criterion, and finally to postsign thus affected objects as revealed by Gaia observations as interesting astrophysics objects.

Following the magnitudes and redshifts (see Figure 1), there appear morphological indexes based on the comparison of the PSFs of the QSO and of the surrounding stars. There are three indexes, for Skewness, Roundness, and Normalness, referred to the B, R, and I images of the DSS (Digitized Sky Survey). Next, an estimation of the size of the accretion disk and dust regions are presented. These values behave as variability indexes. They indicate the maximum jitter or astrometric variation that can be expected for each QSO. Both the morphological indexes and the variability indexes have been previously presented (Andrei et al., 2012) and are fully discussed elsewhere in these proceedings (Coelho et al., 2013).

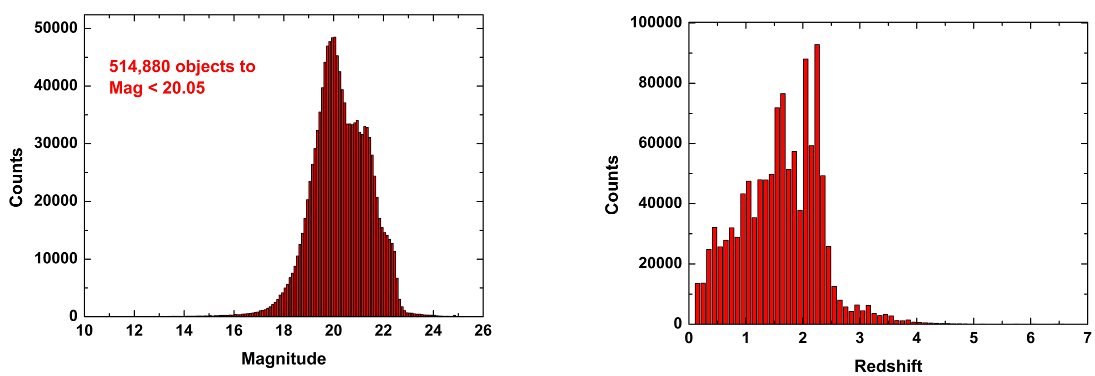

Figure 1: Histogram for the magnitude and redshift contents of the GIQC. Notice that more than half of the sources are beyond magnitude 20. Although this is nominal limit of Gaia, the actual observations may reach probably fainter, and also variability can bring QSOs to brighter magnitudes at times. The redshifts indicate the largest number of QSOs as being nearby ones, which is good in the astrometric sense, but also can result in a considerable number of objects for which the host galaxy is seen.

The Classification scheme follows in two columns. The first column brings the main classification, Defining, Candidate, and Other sources, given by the letters D, C, and O. The second column brings one-letter comments either on the original catalog, radio-loudness, or reliability of the detection. Table 2 summarizes the meaning of the flags.

The Candidate sources share the assuredness of the defining sources, but lack spectroscopic redshift and/or have magnitude fainter than 21. The Other sources are the remaining ones. The Other sources are mostly those which only photometric redshift, plus sources for which the redshift (or even the position) are less precise.

Table 2 - Classification flags in the GIQC.

Flag	**Column**	**Quantity**	**Description**
D	1	191 802	Defining - spectroscopic redshift
C	1	52 954	Candidates - reliable but only photometric redshift
O	1	1 003 616	Other - either magnitude and/or redshift issues
S	2	208 298	SDSS lists belonging
V	2	4 866	VLBI (or long base interferometry) position
L	2	599	Link candidate source, optimal magnitude and radio position
A	2	14 527	AGN, pointlike or core dominated
B	2	512	Bulge dominated extragalactic source
R	2	38 699	Radio position available, although of lower precision
P	2	1 026	Poor observational history, otherwise no issues
U tex	2	960 173	Unreliable detection (for this catalogue purposes)
F	2	5 208	Faint source
E	2	957	Empty field in the optical domain
G	2	13 507	no outstanding characteristic

The catalog presently contains 1 248 372 sources, being 191 802 defining (99.5% with magnitude, and 99.0% with spectroscopic redshift), 52 954 candidate, and 1 003 616 other quasars. Special programs are being developed, mostly as association to LAMOST groups to densify the galactic plane content. Figure 2 bring the spatial distribution.

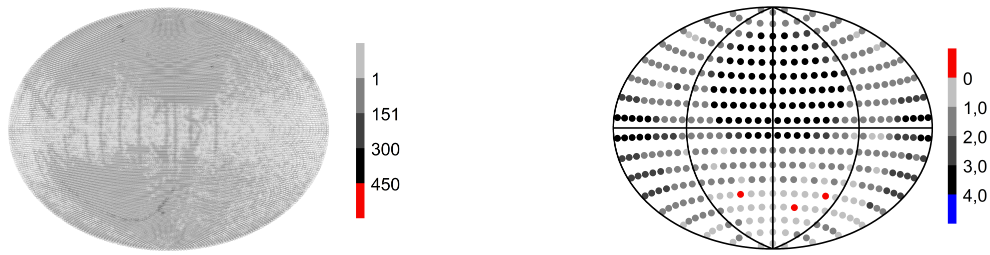

Figure 2: Sky density distribution of the GIQC on equatorial coordinates and logarithm scale. On the left, the contents of the whole catalog in equal area cells of radius 1 deg. On the right, the defining sources only, in equal area cells of radius 10 deg, In both plots the galactic plane is not devoid of points, emphasizing the efforts to densify that region.

3. FUTURE DEVELOPMENTS AND UPDATES

The GIQC is planned to be updated on yearly basis up to the end of the observational part of the mission, that is at least for other 5 years. This is because the last treatment for all the sources, QSOs and the GCRF in special, will reach the best results when all the passages are combined. Therefore there is scope to continue to feed the ANN with new QSOs and mainly with objects coming from different selection criteria. Another important point is to increase the number of objects by the galactic plane, and to obtain good redshifts for the VLBI link objects.

4. REFERENCES

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