LINKING GAIA PROPER MOTIONS TO THE EXTRAGALACTIC REFERENCE SYSTEM BY QSO OBSERVATIONS

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ABSTRACT

A direct link to an extragalactic reference system is one of the essentials of the GAIA mission. We used the data presently available from the NASA/IPAC extragalactic database and the latest QSO catalogue of Hewitt & Burbidge (1993) to obtain an estimate on the number of QSO link candidates. We discuss the quality of the present data and expected accuracy of the extragalactic link. At least 150 QSOs, practically all known quasars with $V \leq 16$ mag, must be observed by GAIA to guarantee an accuracy of the link better than 1 μas/year. New observations will be needed before the GAIA launch to reduce uncertainties in the positions, magnitudes and redshifts for some of the known bright quasars. The variability of QSOs with magnitudes near the GAIA observation limit can raise a potential problem which requires further study. Proper motions of nearby QSOs are expected to be much smaller than 2 μas/year and, therefore, will not affect the accuracy of the link in the proposed GAIA mission. On the other hand, in case of the most accurate realisation of the present GAIA mission concept (i.e., using 'direct fringe detection'), even this problem would need to be considered in detail.

Key words: QSOs; space astrometry; extragalactic link; GAIA

1. INTRODUCTION

The Hipparcos reference system must be connected to an extragalactic reference system by additional ground-based and/or space observations. On the contrary, the proposed ESA space mission GAIA reaching 15–16 mag will include a number of QSOs, allowing a direct link to an inertial reference system. The number of QSOs suitable for that task strongly depends on the limiting magnitude of the GAIA observations.

The possibility of QSO observations by GAIA is emphasized by Lindegren & Perryman (1994) but without detailed prospects concerning the number of QSOs to be observed and the expected accuracy of the direct extragalactic link. We therefore just looked into two different data bases containing QSO data in order to provide a rough estimate of what can be expected.

2. THE AVAILABLE QSO DATA

The latest QSO catalogue of Hewitt & Burbidge (1993) (HB93) contains 7315 QSOs whereas in the NASA/IPAC extragalactic database (NED) there are 8414 objects classified as QSOs. Matching the objects of both catalogues by the coordinates one finds only about 6000 QSOs in common. Positional uncertainties are a general problem in QSO catalogues. Determining new positions for 607 active galactic nuclei using Digitized Sky Survey produced by the Space Telescope Science Institute, Véron-Cetty & Véron (1995) found a large number of objects with differences of more than 1 arcmin in comparison to their old position. Statistics of the positional uncertainties of QSOs listed in NED are given in Table 1. Among the QSOs in NED there are 254 (20 of them with $V \leq 16$ mag) with less than 0.01 arcsec positional uncertainties.

Pos. uncertainty (arcsec)	all NED QSOs	NED QSOs with $V \leq 16$
< 1	1042	46
≥ 1 and < 5	3218	79
≥ 5 and < 10	1699	16
≥ 10 and <30	1994	23
≥ 30 and <60	309	0
≥ 60	152	3

Table 1: Positional uncertainties of QSOs given in NED.

Fig. 1 shows the distribution of the brightest QSOs as a function of their magnitude, for the HB93 catalogue and for the NED, respectively. The photometric data of the QSOs in these data bases are not homogeneous, which means that the magnitudes in Fig. 1 are not necessarily V magnitudes. The magnitudes given in HB93 and NED for the same object are often different, in some cases significantly so.

We also note a high percentage of optically-variable QSOs. For instance, with $V < 15.5$ mag we find 30 per cent of 62 NED QSOs and as many as 40 per cent of 53 HB93 QSOs marked as optically variable. Optical variability seems to be a general feature of QSOs according to several investigations (Majewski et al. (1991); Hawkins & Véron (1993); Hook et al. (1994); Meusinger et al. (1995)). We have to consider this variability as a possible complication for the GAIA observations near the magnitude limit.

Finally, there is a surprising fact concerning both HB93 and NED QSOs: for about 10 per cent of the brightest QSOs ($V \leq 16$ mag) redshift measurements are not yet available. All the uncertainties in the photometry, position and redshift of the known QSOs show the need of more detailed investigations of the bright QSOs to be used for the direct extragalactic GAIA link.

3. EXPECTED ACCURACY OF EXTRAGALACTIC LINK BY QSO OBSERVATIONS WITH GAIA

In order to determine the zero point of the GAIA proper motions directly and accurately, a sufficient number of QSOs included in the observation list is necessary. Figs 2 and 3 show the distribution of QSOs selected from HB93 and NED for two possible limiting magnitudes of GAIA observations. There are only 25 (HB93) and 30 (NED) QSOs with $V \leq 15$ mag. With $V \leq 16$ mag we have 156 and 167 QSOs, respectively.

The accuracy of the extragalactic link must be much higher than the individual proper motion accuracy of the stars. Taking the expected accuracies of single observations in dependence on the magnitude from Table 3 (baseline option) in Lindegren & Perryman (1994), we can estimate the accuracy of the extragalactic link just by dividing these values by the square root of the number of QSOs included in the observations. We consider here the more optimistic numbers of QSOs given in the NED. Table 2 lists the results of this estimate. As one can see, the decreasing accuracy of GAIA observations with fainter objects is more than compensated by the rather strong increase of the number of QSOs with fainter magnitudes.

V	GAIA p.m. accuracy [μas/yr]	NED QSOs up to that magnitude	expected link accuracy [μas/yr]
10	1	-	-
12	2	-	-
14	4	7	≤ 1.5
15	6	30	≤ 1.1
16	12	167	≤ 0.9
(18	?	1926	?)

Table 2: Expected accuracy of GAIA link to QSOs with different magnitude limits of the mission.

Discussing the accuracy of the extragalactic link by the use of QSOs, we also consider the following aspect: with an accuracy level of a few μas/year, the proper motions of some 'nearby' and 'fast' QSOs may become significant. The total proper motion $\mu_{\rm QSO}$ of a nearby QSO is given with sufficient accuracy by

$$\mu_{\rm QSO} \propto \frac{HV_t}{z},$$

where H is the Hubble constant, V_t and z are the tangential velocity and redshift of a QSO, respectively. Assuming the extreme case with $H = 100$ km/s/Mpc, $V_t = 3000$ km/s and $z = 0.1$, we obtain $\mu_{\rm QSO} = 2$ μas/year. According to the baseline mission concept, this value is too small to be measured by GAIA, but it will be significant for a 'direct fringe detection' referred to a hypothetical high-resolution detector in Lindegren & Perryman (1994). In any case, we must keep in mind that the nearby QSOs with $z < 0.2$ used for the link may produce some 'noise-effects'. Fig. 4 gives the distribution of QSOs with known z plotted over their magnitude. There are 45 QSOs with $V \leq 16$ mag and $z < 0.2$ (11 of them with $V \leq 15$ mag).

4. CONCLUDING REMARKS

In order to achieve an accuracy of the extragalactic link better than 1 μas/year, a limiting magnitude of the GAIA mission of at least $V = 16$ mag is necessary. Because of the uncertainties in the positions, photometry and redshifts, new observations must be carried out for some of the known QSOs. A catalogue of accurate data for quasars proposed for the extragalactic link is desirable. Especially, the variability of the QSOs which are as faint as the proposed limiting magnitude of the mission should be carefully analysed before the GAIA launch. Depending on the resulting astrometric accuracy of the mission, redshifts can be considered as one of the weighting parameters in the final extragalactic link procedure.

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Figure 1: *Histogram of the optically brightest QSOs in Hewitt & Burbidge (1993) and in the NASA/IPAC extragalactic database (NED), respectively*

Figure 2: *Distribution of QSOs with* $V \leq 15$ *in HB93 and NED, respectively*

Figure 3: *Same as Fig. 2 for QSOs with* $V \leq 16$

Figure 4: *Redshift versus magnitude for the optically brightest QSOs from the NED*