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Optical observations of QSOs for the link of reference systems

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Abstract. This work presents AGN observations with medium size aperture telescopes (1m-2m). One goal of these observations is to provide a list of suitable targets that could be used to establish the link between the ICRF and the future Gaia celestial reference frame.

Key words. Reference systems – Astrometry– Quasars: general

1. Introduction

Optical telescopes involved in this experiment and reference frames are presented in the two following sections. Some results about individual targets in terms of observability, light curve and compacity index are given as examples.

2. Optical telescopes involved in this work

The observations were carried out with four telescopes located in France, Chile and Australia. This section is dedicated to the presentation of these telescopes.

2.1. T120, OHP

The telescope of 1.2m of the OHP (Observatoire de Haute Provence[1], IAU code 511) is located in the south east of France. It was used form March 2010 to February 2011 during 17 nights. It is equipped with a 1.2m mirror of 7.2m focal length. It uses a 1024x1024 px^2 CCD camera with a pixel scale in the focal plane of 0.69 arcsec/px corresponding to a field of view of 10 *squarearcmin* . The seeing during the observations was relatively poor, with a mean value of 3.4 arcsec. The filters used were the V and R Cousins filters.

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[1] see http://www.obs-hp.fr

2.2. TAROT telescopes

TAROT (Klotz., A., Boër, M., Eysseric, J., et al., 2008) is a french acronym which stands for Télescope à Action Rapide pour l'Observation des phénomènes Transitoires. There are two telescopes located for the first one in the south east of France (OCA, Observatoire de la côte d'Azur[2] and for the second one in Chile (ESO). TAROT are robotic observatories that observe with no human interaction. TAROT are two identical 25 cm telescopes F/D=3.4 that cover 1.86x1.86 field of view on the Andor CCD cameras (Marconi 4240 back illuminated). Spatial sampling is 3.3 arcsec/pix. Six filters are available : BVRI, a clear filter and a 2.7 density coupled to V (for Moon and planets). Detection limit is about V=17 in 1 min. exposure. These two telescopes are used for our program since February 2011.

2.3. Zadko telescope, UWA

Zadko[3] is a one meter robotic telescope funded by a donation from James Zadko to the University of Western Australia (UWA). It is a 1-m f/4 Cassegrain telescope located in the state of Western Australia about 67 km north of Perth. It is equipped with an Andor 2048x2048 backilluminated CCD. The field of view is 23.5 $arcmin^2$ and the filters used for this study are g and r Gunn filters. Zadko and TAROT are part of the same robotic telescope network for space debris identification and tracking (Laas-Bourez, M., Coward, D., Klotz., A., et al., 2010). Currently, five robotic observatories are linked to a central observatory coordinator CADOR (Coordination et Analyse des Donnes des Observatoires Robotiques).

3. Reference systems

The current conventional realization of the ICRS (International Celestial Reference System) is the second version of the International Celestial Reference Frame (ICRF) called ICRF2. In the optical domain, the Hipparcos Catalogue is the current international conventional realization but in the future (around 2020) the Gaia catalogue should be the basis of the optical realization of the ICRS. The link between these reference frames, in the radio and in the optical domain, is of course of primary significance. In this section, we present, in a didactic way, all of these fundamental concepts.

3.1. ICRF

The construction of the ICRF2 used almost 30 years of geodetic very long baseline interferometry (VLBI) observations at 3.6 cm and 13 cm wavelengths. The ICRF2 catalogue contains positions of 3 414 compact radio sources. The formal errors σ in source coordinates increased according to $((1.5\sigma)^2 + \sigma_0^2)^{1/2}$ where σ_0 is a noise floor set to 40 μas. The median error in the position of sources observed in more than two sessions is 175 μas. The frame axes are defined by the coordinates of 295 "defining" sources with a stability of $\sim$10μas. The defining sources were chosen on the basis of their high positional stability and low structure index. A subset of 138 defining sources was used to align the ICRF2 catalogue onto the ICRS.

The ICRF2 currently represents the most accurate realization of the celestial system with respect to which the position of any object in the celestial sphere should be measured. We note that the ICRF is epochless and independent of the dynamical frame (ecliptic) and reference point (equinox), and is consistent with previous realizations of the ICRS, including the FK5 J2000.0 optical system.

3.2. GCRF

The European astrometric space mission Gaia will be launched in 2013. It will provide positions and proper motions of around one billion of stars and about 500 000 QSOs with unprecedented uncertainty between the 6th and the 20th magnitude (Lindegren, 2009). The predicted accuracy is a few hundred of μas at 20th magnitude. To prepare the future Gaia ex-

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[2] see http://tarot.obs-hp.fr/tarot

[3] see http://www.zt.science.uwa.edu.au

tragalactic reference frame, a clean sample of at least 10 000 QSOs must be implemented (Gaia initial quasar list). This work is being performed in the framework of the Gaia work-package GWP-S-335-13000 with the aim of giving an initial QSO catalogue. Two catalogues are at the basis of this work, the LQAC (Souchay et al., 2009) and the LQRF (Andrei et al., 2009).

3.3. The link between GCRF and ICRF

Relating the ICRF2 to the Gaia extragalactic reference frame will be a very important task in the near future and some works are currently underway to achieve this.

Bourda et al. (2008) evaluated the suitability of the current individual ICRF-Ext2 (the ICRF catalogue that preceded the ICRF2) extragalactic radio sources for the alignment with the future Gaia frame. They identify 243 candidates among the ICRF-Ext2 sources used to align with the Gaia frame, with an optical counterpart brighter than the apparent magnitude V=18. Among these 243 candidates, only 70 have data of excellent or good astrometric quality (i.e, an X-band structure index value of either 1 or 2) for determining the Gaia link with the highest accuracy. Nevertheless, this index value is perhaps not well suited to determining the best sources in the optical domain in the sense that several sources given by these authors are not point-like sources (for example NGC3031 or Messier81, MARK421, NGC4374 or Messier84).

An investigation of the correlation between long-term optical variability and what is dubbed the random walk of the astrometric centroid of QSOs is being pursued at the ESO Max Planck 2.2m telescope in Chile (Andrei et al., 2008). A sample of quasars has been selected in term of their large amplitude and long-term optical variability. The observations are typically performed every two months. The analysis procedure is completely differential: the quasar positions and brightness are determined starting from a set of selected stars for which the average relative distances and magnitudes remain significantly constant. The preliminary results for four objects bring strong support to the hypothesis of a relationship between astrometric and photometric variability. If verified, the relationship could indicate that high photometric variation would make a given quasar less apt to materialize a stable extragalactic reference frame such as the one provided by the GAIA mission.

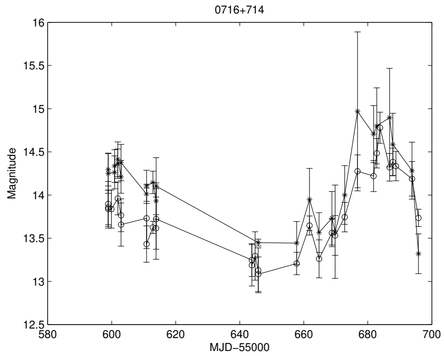

Fig. 1. Light curves (R and V filters) of QSO 0716+714 obtained by Tarot telescope

It is a matter of fact that variations of the radio structure of QSOs degrades the positional accuracy of the radio center's position. It can be also postulate that variations of the photocenter's position could be correlated with magnitude variations. Roughly speaking, for a quasar at the distance of 1Gpc and for an emission region with a size of 1pc (due to the speed of light the magnitude variations occurs in some years) the corresponding angular size in the sky would be 200μas. This value must be compared to the uncertainty about the coordinates in the future Gaia catalogue (few hundred of μas at 20th magnitude).

4. Observed QSOs, light curves and compacity index

Among the 67 targets (the 70 initial targets minus 3, cf supra), 24 of them have been observed elsewhere for a long time and some light curves have been found in refereed papers. For 36 targets (54% of the initial list), the light curves obtained during this work bring new information to our knowledge about them. Among these 36 targets, three (QSO B1508-055, QSO B1725+044, QSO B1954-388) have only one measure of magnitude reported in the literature, one (QSO B2126-158) has only one measure of magnitude plus no variations and two (QSO B0955+326 and QSO B1749+096) have only intranight variability. Seven of the 67 targets remain unobserved in the frame of this work.

Some targets (10 among the 67) were difficult to observe with our small telescopes due to their magnitudes. Another one is very near from a bright star. Consequently these 11 targets will remain difficult to observe with other telescopes.

Fig. 1 gives an example of light curve for a well observed target (Katajainen, S., Takalo, L., Sillanpaa, A., et al., 2000). Our light curve shows a 1.5 magnitude variation (both in R and V band) during one month. Due to the distance of this target (z=0.3) it means that the emission region has an angular (maximum) size of roughly 5 μas. Other curves (Katajainen, S., Takalo, L., Sillanpaa, A., et al., 2000) show the same kind of events but during three month (15 μas). Other target from our work show magnitude variation during 3 months (1147+245, z=0.2, 25 μas). Compacity index has been computed from DSS images for 55 targets of the initial list. For 21 of them, values lower than 0.5 (compact sources) have been found, and for 20 of them, the compacity index is greater than 1 (not compact sources).

5. Conclusions

This work present optical observations of suitable extragalactic targets used for the link between the ICRF and the future Gaia celestial reference frame. Among the 70 targets of the initial list, 55 have been observed easily in the optical wavelength and 11 remain difficult due to the size of the telescope used or to their relative position to bright stars. A large amount of the targets seem to be variable (0.1 to 1.5 mag) with time scales from few days to some months. The astrometric uncertainty due to the emission region is then of the same order of the Gaia astrometric uncertainty. Detailed results about this work will be soon presented elsewhere. Morphology studies with high angular resolution are currently under progress to characterize the host galaxies and to evaluate the corresponding shift of the photocenter with respect to the quasi stellar object one.

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