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RADIO-OPTICAL REALIZATIONS OF CELESTIAL REFERENCE FRAMES

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Abstract. The ability of existing radio and optical catalogs to realize consistent reference frames in different wavelengths is investigated with the SDSS (optical) and the VLBA Calibrator Survey (radio), in terms of cross-identification and global rotation.

1 Introduction

With the upcoming space astrometry missions like the NASA's SIM (2009) or ESA's GAIA (2011), quasi inertial, optical, celestial reference frames will be defined with a higher precision than the current radio reference frame (ICRF) realized through ground-based very long baseline interferometry (VLBI). Although the radio reference frame will remain useful since VLBI is the only technique providing the orientation of the Earth's crust with respect to space, impacting therefore geosciences and astronomy, a future work will be to tie it to its optical counterpart. In this study we compare a radio realization of a celestial reference frame from the VLBA Calibrator Survey data (VCS) against its optical couterpart taken from the Sloan Digital Sky Survey data (SDSS).

2 Cross-identification of radio and optical catalogs

The fifth release of the VCS (Kovalev et al. 2006) data contains 3,357 extragalactic radiosources. The positions were derived from the analysis of dual-frequency 24-hr VLBI experiments, using the Calc/Solve VLBI analysis software package. A no-net rotation constraint was applied to the 212 ICRF defining sources (Ma et al. 1998). The mean semimajor axis of the error ellipse of the source coordinates is shown to be close to 5 mas (Petrov et al. 2006). The SDSS data release 3 (Schneider et al. 2003) consists in 46,420 objects covering about one quarter of the sky. The astrometric calibration (Pier et al. 2003) yields an accuracy per coordinate of 45 mas when reduced against the USNO CCD Astrograph Catalog (UCAC) and 75 mas when reduced against Tycho-2.

The cross-identification between the two catalogs with a 1-as radius yields 186 sources. The mean radio-optical (R/O) distance is 82 mas with a 65 mas wrms (see also the histogram on Fig 1). These values are consistent with the accuracy of the SDSS estimated by Pier et al. (2003).

3 Global comparison of radio and optical coordinates

We have two sets of coordinates for 186 sources, realized in radio and optical. The coordinate difference is modeled by a global rotation around the axes, represented by three angles A_1, A_2, A_3 and a bias dz in declination (see e.g., Gontier et al. 2001). The bias is for accounting for any systematic error in declination tilting the equator. The estimation of the four unknown parameters is done on the 186 cross-identified sources by a weighted least-squares fit.

The angles A_1 and A_3 and the bias dz appear to be non significant (smaller than 5 mas with a comparable uncertainty). The rotation A_2 around the Y-axis is -20 ± 6 mas and is however statistically significant compared to the VCS error ellipse estimated by Petrov et al. (2005). This rotation still shows up even though the sources which present the largest R/O distances are removed, indicating a systematic effect and not only an effect

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due to some 'outliers'. Since most of the SDSS sources are reparted on one quarter of the sky in the opposite direction of the X axis, this angle means that the SDSS declinations are systematically underestimated relatively to the VCS ones. After correcting the SDSS catalog with the rotation parameters determined above, a new radio/optical comparison yields non significant angles and the bias disappears. The origin of this bias has to be investigated.

As shown on Fig 1 (right part), there is no clear dependence between the R/O distance and the redshift or the visual magnitude obtained by cross-identification of the 186 sources with the 12th edition of the Véron-Cetty & Véron (2006) catalog. Sources with large R/O distances generally exhibit a lower flux. We do not conclude at this stage on a possible discrimination of sources unsuitable to realize an optimal tie between radio and optical using these criteria.

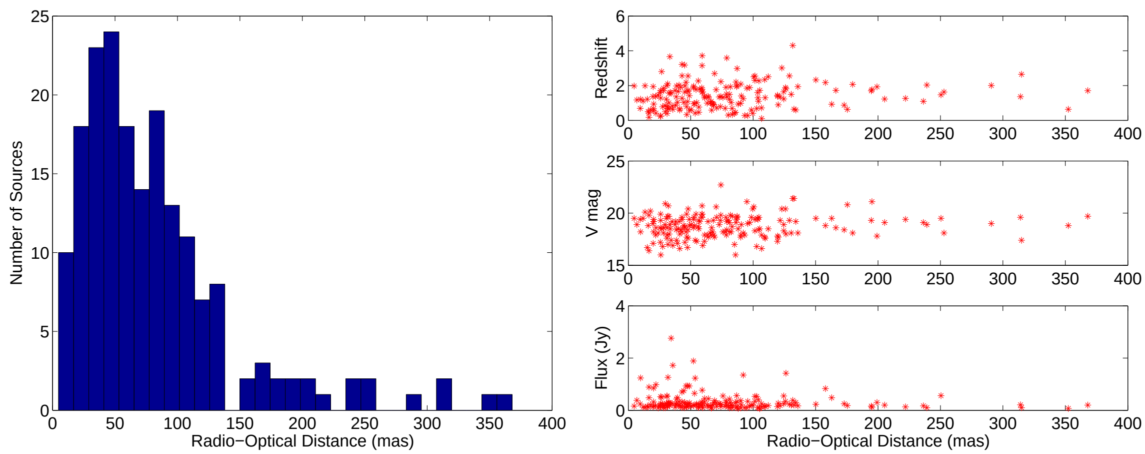

Fig. 1. Number of sources, redshift, visual magnitude and flux at 8.3 GHz versus the R/O distance.

4 Discussion and conclusion

This study shows that a brute comparison of existing radio and optical catalogs VCS and SDSS permits the cross-identification of 186 sources. The accuracy of the SDSS is found at 82 mas, consistently with Pier et al. (2003). A -20-mas rotation of the VCS with respect to the SDSS around the Y axis shows up. This significant effect could originate in a non optimal astrometric calibration of the SDSS (e.g., anomalous refraction, random errors in the primary reference catalogues), and should be addressed for future tying of radio and optical astrometric data sets.

The VCS is a corner-stone among the current densification programs. Nevertheless, the VLBA interferometer is a relatively small network compared to the intercontinental baselines used routinely in the geodetic VLBI networks (e.g., those used for the realization of the ICRF). Observing the VCS sources with a larger array could enforce their astrometric suitability. This could be realized by integrating progressively the VCS sources within the routine geodetic VLBI experiments schedule. Such a perspective would be of great interest for future ties between high-precision optical catalogs brought by future space astrometry missions (SIM, GAIA) to existing radio catalogs.

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