Identification of Radio Sources Using Modern Sky Surveys (on the Example of Unidentified Sources of the 3CR Catalog)

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Abstract. The 3CR catalog is one of the most studied sample of radio sources. The uniquely complete data for 3CR sources is an excellent basis for further statistical analysis of the properties of radio-loud AGNs. However, 25 radio sources have not yet been identified in the optical range. With the help of modern optical and infrared surveys, a search was carried out for host galaxies for these objects. We found optical companions for 12 objects from this sample and confirmed the identifications of the recently identified in the X-ray range sources.

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The Third Cambridge catalog (3C) was created based on the Cambridge survey at 159 MHz (Edge et al. 1959), then the coordinates of the sources were refined from the observations at 178 MHz (Bennett 1962) and the Third Revised Cambridge catalog was obtained (3CR). The sources of the catalog began to be identified with the 60s of the last century (Schmidt 1963). One of the main reasons that the identifications were carried out for such a long time was related with the large uncertainty in the coordinates of the 3CR objects.

For the vast majority of 3CR objects, radio maps with high angular resolution were obtained on the VLA and MERLIN radio interferometers, as well as deep optical and infrared images on large telescopes, including the Hubble Space Telescope. Redshifts have been determined for 92% of the 298 objects (Spinrad et al. 1985) included in the latest 3rd version of 3CR. Most of the objects in the 3CR catalog belong to powerful radio sources of the FRII type, of which 73% are radio galaxies and 19% are quasars, about 1% are BLLac, and for the rest the type of host galaxy has not been determined. Unidentified sources were

attributed to galaxies with hidden active nuclei. Recent X-ray studies of unidentified 3CR (Maselli et al. 2016) sources have revealed 13 more host galaxies.

Currently available optical and infrared surveys and archives are deep enough to carry out massive identifications of samples of sources. When identifying a host galaxy, the source morphology is important. The FIRST and TGSS radio surveys with a resolution of 5″ and 25″, respectively, make it possible to fairly confidently identify the source structure. In cases where the source is multicomponent, sky surveys at different frequencies are used to clarify the structure of the radio source, so low-frequency surveys allow clarifying the low-frequency components of the radio source, and high-frequency surveys determine the position of the nuclear part.

Table 1. Positions of 3CR host objects unidentified previosly

3CR	$R.A._{2000}^{opt}$	$Dec._{2000}^{opt}$	3CR	$R.A._{2000}^{opt}$	$Dec._{2000}^{opt}$
3CR 11.1	00:29:44.73	+63:58:42.2	3CR 137.0	05:19:32.52	+50:54:31.5
3CR 14.1(N)	00:29:44.73	+60:13:12.6	3CR 139.2	05:24:27.51	+28:12:56.8
3CR 14.1(S)	00:33:17.10	+58:39:15.4	3CR 152.0*	05:26:44.18	+32:50:25.3
3CR 21.1(N)	00:44:39.42	+68:24:05.4	3CR 158.0	06:21:41.04	+14:32:13.2
3CR 21.1(S)	00:45:41.20	+67:33:21.2	3CR 250.0*	11:08:52.19	+25:00:55.0
3CR 33.2(N)	01:08:36.84	01:08:36.84	3CR 399.1*	20:14:27.62	+23:34:52.9
3CR 33.2(S)	01:08:48.66	+69:08:55.1	3CR 415.2*	20:32:46.03	+53:45:48.7
3CR 91.0 *	03:37:43.08	+50:45:47.6	3CR 428.0**	21 08 22.08	+49 36 41.5
3CR 131.1*	04:53:23.34	+31:29:28.0	3CR 431.0**	21:18:52.34	+49:37:00.4
			3CR 454.2**	22:52:05.48	+64:40:12.5

Based on our experience in identifying the RC (Zhelenkova & Kopylov 2009) and RCR (Zhelenkova et al. 2013) catalogs, we tried to identify those sources of the 3CR catalog for which no hosts has yet been found. Using SDSS, PanSTARRS, DES surveys, archival data from NOAO, UKIDSS LAS and UKIDSS GPS, WISE, as well as the sums of images in several filters, work was carried out to search for host galaxies for 25 unidentified radio sources from Spinrad et al. (1985). Found optical companions for 13 3CR sources that have recently been identified in the X-ray range (Maselli et al. 2016). Note that four more 3CR radio sources were not considered in this work, since they are not associated with NVSS sources within the coordinate errors. The results are shown in Table 1, where the symbol * marks the 3CR sources for which HST images were obtained in the work Martel et al. (1998), but several optical host candidates were found. We were able to select one of the candidates as a hostt based on color indices

of WISE survey. The symbol ** marks the sources for which X-ray companions were found in the work, and we also added optical identifications.

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