IDENTIFICATION MAPS FOR SELECTED SKY FIELDS WITH IR/RADIO SOURCES CONSTRUCTED AT THE BASE OF CCD OBSERVATIONS AT THE ANDRUSHIVKA ASTRONOMICAL OBSERVATORY

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In July 2002 the CCD unfiltered images of eight sky areas with the IR/radio sources from ICRF 1732+389, 1803+784, 1807+698, 1845+797, 1943+228, 2023+335, 2223–052, and 2229+695 were obtained with the Zeiss-600 telescope of the Andrushivka Observatory. This telescope is equipped with a CCD S1C-017 detector; our observations were carried out in integral light only. The processing of images was implemented by the MIDAS/ROMAFOT software. Coordinates and magnitudes down to $B = 21$ mag in $3' \times 3'$ fields were obtained in the USNO A2.0 system. Identification maps in integral light obtained as the result of the CCD image processing are shown.

INTRODUCTION

First we observed eight sky regions in the optical spectral range with a CCD device. These fields have common extragalactic sources identified in the radio and IR ranges. The sources are a part of the list from [4] – total list includes 31 sources which were observed by IRAS (see the IRAS PSC catalog [2]). The purpose of our observations was to check the identifications made both to exclude the possible errors and to answer the question: are there some objects with sufficiently high level of radiation in the optical diapason in that points of sky?

OBSERVATIONS

We made our observations at the Adrushivka Astronomical Observatory in Zhytomyr Region in July 2002. The S1C-017 television digital camera of “Electron Optronic” company (St.-Petersburg, Russia) was mounted in Cassegrain focus of the Zeiss-600 telescope. The S1C device has a wide spectral range and is intended for registering the black-and-white images at low illumination level. The format of images was 1024×1024 pixels or $7.65' \times 7.65'$. Table 1 lists the numerical parameters of the quantum efficiency of the CCD with thermoelectronic microrefregerator as the maker claims. Our investigation showed that it was possible to register the stars down to $V = 20^m$ in the integral light at 10 min exposure, *i.e.*, to observe all objects of our list both in visual and close IR ranges.

First of all, we checked the existence of some objects at the sky points which have coordinates from [4]. In future, to carry out the final verification of identity of ICRF radio sources with their IR counterparts we shall assume to accomplish the *UBVRI* and *UPXYZVS* photometry of IR/radio sources which verification was successful at the first stage. The accuracy of one determination of position and photometry for bright source ($R < 16^m$) is not less than $0.05''$ and 0.03^m, respectively, when the MIDAS/ROMAFOT software is used for processing the CCD star field images.

CCD OBSERVATION PROCESSING

The CCD star field image processing was carried out by the MIDAS/ROMAFOT software (LINUX shell) [1]. The ROMAFOT software is intended for high-precision determination of astrometric (rectangular coordinates X, Y) and photometric (magnitudes, *FWHM* values, *etc.*) characteristics for all objects to be registered on CCD frame digitized images. The use of the MIDAS software gives possibility to automatize the CCD frame processing by organizing the cyclic MIDAS procedures for files in FITS format.

Table 1. Quantum effectiveness of S1C-017 CCD camera as a function of wavelength (nm) according to producer announcement

λ	%	λ	%	λ	%	λ	%	λ	%
230	17.5	380	37.3	530	47.5	680	46.5	830	28.2
250	21.6	400	37.5	550	47.9	700	45.2	850	25.0
270	20.9	420	37.5	570	48.3	720	41.5	870	20.0
290	25.5	440	38.1	590	49.3	740	37.5	890	15.0
310	31.7	460	41.1	610	49.0	760	34.6	910	11.4
330	35.3	480	43.7	630	47.4	780	33.4	930	9.0
350	34.0	500	45.6	650	46.0	800	32.3	950	7.0
370	36.5	520	46.9	670	46.5	820	30.1	970	5.2

The original stage of processing the CCD frames consists of standard subtraction reduction of dark current and reading noise, and then the result division on the flat field. Commonly, when the standard reduction is used, they obtain the frames with a flat field by short exposures of the early morning sky or twilight one, *i.e.*, the flat field frames and star field image frames are exposed separately and at different conditions. In this paper the flat field frames were obtained directly from the star field image frames because the flat field frame was exposed at the same conditions as the star field image frame. To do this, all objects registered were removed from the frame under processing after the subtraction the "dark current" frame from the "raw" frame. By such a way, we obtained the spatial envelope curve from the frame with flat field image. As a result, the frame of true flat field have been created. This frame was undergone to the normalizing procedure, *i.e.*, the division procedure of the flat field on the mean value over whole frame. The frame with normalized own flat field was used for photometric reduction (the correction for optical vignetting and large-scale homogeneity of matrix sensitivity) of the CCD frame of star field image. To obtain the value of residual photometric field error, the above-mentioned new photometric reduction technique of the "raw" CCD frames of star field images was used (the reduction to the flat field). Investigations of observations in a wide exposure range (10–840 s), and comparison with photometric standards over the whole field of matrix of CCD frames did not show the existence of the field photometric error and distortion of magnitude scale. Independent comparison of photometric data obtained by the above technique with results of processing of the CCD frames under standard reduction for the flat field have shown that the procession of both techniques was the same one.

By using the MIDAS software, the bright overexposed objects (when the photometric section in the central part of star has a gap) with $B < 14$–15 mag were marked out and transformed to process by the ROMAFOT software.

REDUCTION OF INSTRUMENTAL VALUES INTO THE USNO A2.0 SYSTEM

Main aim of this work is the determination of equatorial coordinates and magnitudes of objects registered on the CCD frames. The USNO A2.0 catalog was used as a reference one. The reference star rectangular coordinates ξ_i and η_i were determined by rms solution of the equation system

$$\xi_i = a_1 X_i + b_1 Y_i + c_1 + d_1 X_i^2 + e_1 X_i Y_i + f_1 Y_i^2,$$
$$\eta_i = a_2 X_i + b_2 Y_i + c_2 + d_2 X_i^2 + e_2 X_i Y_i + f_2 Y_i^2, \quad (1)$$

where $i = 1, 2, ..., N$ is the number of reference stars from the USNO A2.0 catalog for the field of 7.65×7.65 arcmin, N varies from 40 to 400. The solution rms errors of reduction Equations (1) are 0.2–0.5 arcsec and they depend on N value. As an example, we consider the determination errors of coordinates and magnitudes of ICRS 1943+228 region because this one has the greatest number of stars. First and second panels in Fig. 1 show the differences of rectangular coordinates ΔX and ΔY for all objects on two plates. The CCD frames were obtained consequently at 840 s exposure; the shift between optical centers of stars is approximately 10 pixels. The differences of equatorial coordinates ΔRA and ΔDEC between calculated and reference values are shown on forth and fifth panels of Fig. 1. There were no reference stars with $B < 20^m$ in the USNO A2.0 catalog for this sky region. The origin of magnitude scale was determined according to faint stars ($B = 16$–19^m). The comparison of magnitudes calculated for two frames are shown on third panel of Fig. 1, and at the bottom of the figure such a comparison with B values of reference catalog is shown. The large dispersion of magnitude differences is explained by absence of filters during CCD observations because that were made in integral

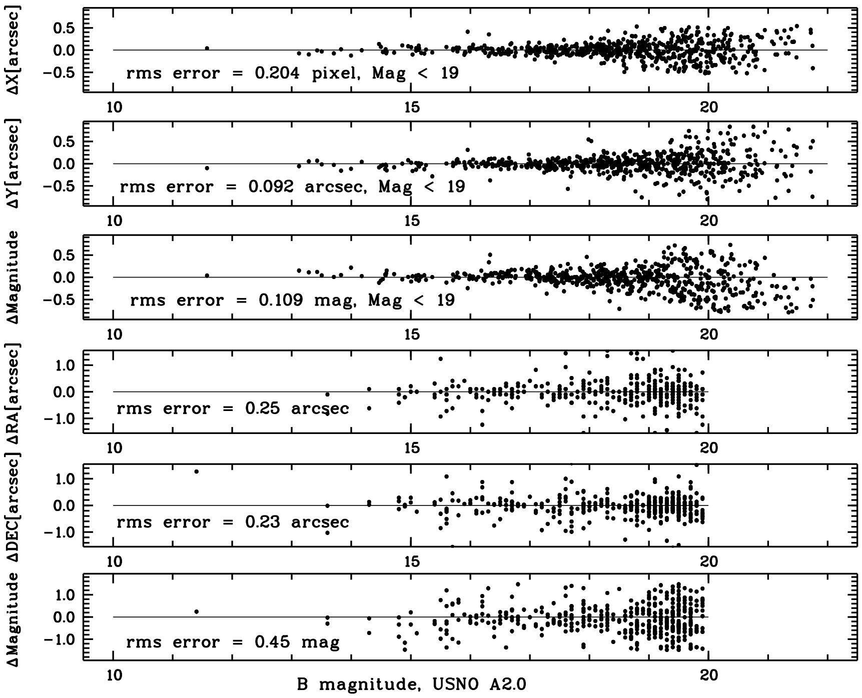

Figure 1. Determination of coordinates and magnitudes errors. Three upper panels demonstrates the differences of rectangular coordinates ΔX, ΔY and magnitudes ΔMag which have been obtained by data comparison for two frames. Three lower panels have the differences of equatorial coordinates ΔRA, ΔDEC and magnitudes ΔMag which have been obtained by comparison of our observations with the data of the USNO A2.0 reference catalog

light. As a whole, the errors of coordinates and magnitudes of objects for eight sky regions investigated were determined of the USNO A2.0 reference catalog accuracy. The determination of the measuring coordinates differences and the equatorial coordinates ones for all stars in eight sky regions gives the possibility to calculate a pixel size in angular units: 1 pixel $= 0.4483 \pm 0.0006$ arcsec.

The sky region maps with IR/radio sources are shown in Figs. 2 and 3. Field size is 3×3 arcmin. The maps are obtained by the MIDAS/ROMAFOT software procession of the CCD frames. The geometrical center of maps to be identified corresponds to the equatorial coordinates (equinox 2000.0) of IR/radio sources' list [4]. The list of objects which have been registered on the CCD frames is quoted in Table 2 (for every region of 60 arcsec size – such a region is marked out on a map).

Table 2. Equatorial coordinates and magnitudes of objects which are candidates to be the extragalactic IR sources (from [4]) according to CCD observations (without filters) made at the Andrushivka Astronomical Observatory in July 2002

RA_{2000}	DEC_{2000}	Mag	B	R
ICRS 1732+389 ($17^h34^m20.5^s$, $38°57'51''$); UT = $23^h49^m46^s$, July 4, $T_{ex} = 840$ s				
$17^h34^m21.696^s$	$38°58'06.04''$	20.1^m	19.9^m	18.5^m
17 34 19.442	38 57 56.30	20.3	–	–
17 34 18.709	38 57 51.55	20.9	–	–
17 34 20.611	38 57 51.34	19.3	19.5	19.2
17 34 19.979	38 57 50.54	21.1	–	–
17 34 20.058	38 57 41.17	19.6	18.5	18.7
17 34 19.201	38 57 39.70	20.3	–	–
17 34 22.680	38 57 32.16	20.7	–	–
17 34 19.269	38 57 30.78	19.9	–	–

RA_{2000}	DEC_{2000}	Mag	B	R
ICRS 1803+784 ($18^h00^m45.6^s$, $78°28'04''$); UT = $0^h15^m30^s$, July 1, T_{ex} = 360 s				
18 00 41.720	78 28 17.01	17.8	17.6	16.6
18 00 46.547	78 28 16.20	20.4	–	–
18 00 45.713	78 28 10.00	18.8	–	–
18 00 52.326	78 28 06.79	20.7	–	–
18 00 45.780	78 28 04.03	16.0	15.5	14.9
18 00 39.747	78 27 46.84	20.4	–	–
18 00 42.302	78 27 46.54	20.7	–	–
18 00 36.753	78 27 44.35	19.8	–	–
ICRS 1807+698 ($18^h06^m50.6^s$, $69°49'28''$); UT = $0^h59^m18^s$, July 1, T_{ex} = 300 s				
18 06 48.652	69 49 51.97	19.6	–	–
18 06 50.178	69 49 51.59	19.6	–	–
18 06 44.884	69 49 41.66	19.4	–	–
18 06 46.589	69 49 33.97	19.5	–	–
18 06 50.683	69 49 27.96	14.5	14.3	11.2
18 06 48.552	69 49 24.94	18.7	–	–
ICRS 1845+797 ($18^h42^m08.9^s$, $79°46'17''$); UT = $22^h35^m59^s$, July 9, T_{ex} = 840 s				
18 42 09.235	79 46 17.26	15.5	15.0	13.0
18 42 13.372	79 46 11.56	19.8	–	–
ICRS 1943+228 ($19^h46^m06.2^s$, $23°00'04''$); UT = $0^h35^m30^s$, July 6, T_{ex} = 840 s				
19 46 05.375	23 00 23.97	20.6	–	–
19 46 07.923	23 00 17.57	19.9	–	–
19 46 04.747	23 00 13.92	20.9	–	–
19 46 08.268	23 00 02.85	18.9	19.4	17.4
19 46 05.811	23 00 00.60	20.7	–	–
19 46 05.040	23 00 00.61	21.6	–	–
19 46 05.957	23 00 00.44	20.4	–	–
19 46 04.115	22 59 58.88	20.6	–	–
19 46 04.375	22 59 52.78	21.6	–	–
19 46 06.889	22 59 51.66	18.3	19.7	15.9
19 46 06.492	22 59 34.69	21.9	–	–
19 46 07.803	22 59 34.33	19.6	–	–
19 46 06.818	22 59 31.77	20.2	–	–
ICRS 2023+335 ($20^h25^m10.8^s$, $33°43'00''$); UT = $0^h43^m34^s$, July 4, T_{ex} = 420 s				
20 25 09.858	33 43 29.51	17.2	17.0	15.8
20 25 09.909	33 43 24.66	18.8	–	–
20 25 10.219	33 43 10.40	20.6	–	–
20 25 11.642	33 43 05.68	17.0	17.7	15.8
20 25 10.044	33 43 05.09	21.0	–	–
20 25 08.497	33 42 59.55	16.1	15.7	14.9
20 25 09.392	33 42 56.40	18.2	18.7	17.0
20 25 12.454	33 42 52.87	17.5	17.3	16.2
20 25 10.008	33 42 52.39	18.4	19.0	17.3
20 25 11.172	33 42 46.75	19.4	19.2	17.4
20 25 11.327	33 42 36.41	18.2	18.1	17.0
ICRS 2223–052 ($22^h25^m47.2^s$, $-4°57'01''$); UT = $0^h04^m54^s$, July 10, T_{ex} = 900 s				
22 25 46.480	-4 56 40.22	20.4	–	–
22 25 45.641	-4 56 41.30	20.9	–	–
22 25 49.045	-4 56 41.76	19.9	19.7	18.5
22 25 45.234	-4 56 59.11	21.0	–	–
22 25 47.234	-4 57 01.02	18.7	17.7	16.7
ICRS 2229+695 ($22^h30^m36.4^s$, $69°46'28''$); UT = $23^h54^m42^s$, July 9, T_{ex} = 840 s				
22 30 33.116	69 46 47.47	21.0	–	–
22 30 30.654	69 46 46.49	21.8	–	–
22 30 32.456	69 46 39.24	21.1	–	–
22 30 37.960	69 46 34.20	21.8	–	–
22 30 35.638	69 46 29.20	20.6	–	–
22 30 33.254	69 46 28.73	19.8	19.1	18.1
22 30 40.649	69 46 21.80	20.8	–	–
22 30 35.294	69 46 10.08	18.5	18.4	17.1
22 30 34.973	69 46 01.39	19.1	18.9	17.6

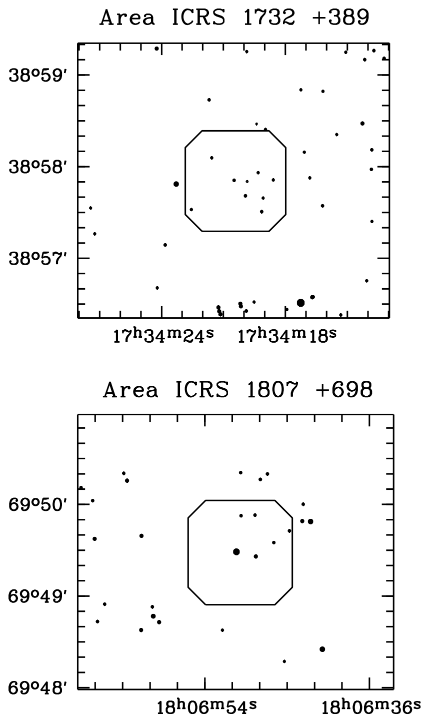

Figure 2. Maps for sky regions which contain IR/radio sources in accordance with optical CCD observations made at the Andrushivka Astronomical Observatory (ICRS 1732+389, ICRS 1803+784, ICRS 1807+698, ICRS 1845+797)

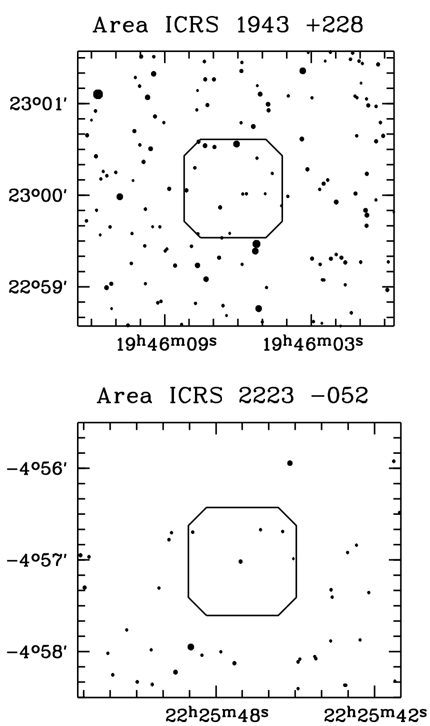

Figure 3. The same as in Fig. 2 for ICRS 1943+228, ICRS 2023+335, ICRS 2223–052, ICRS 2229+695

The list includes equatorial coordinates RA_{2000}, DEC_{2000}, and magnitudes Mag (zero is connected with the B values' scale of the USNO A2.0 catalog) of the objects registered. The B and R values from the USNO A2.0 are also listed (a selection up to $B < 20^m$).

CONCLUSION

The list of optical objects which are candidates to be the IR/radio sources is obtained at the base of CCD observations' processing of eight sky regions.

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