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OPTICAL IDENTIFICATION OF RADIO SOURCES IN A 8°.5 × 8°.5 ZONE NEAR THE SOUTH GALACTIC POLE

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RESUMEN

Se buscaron contrapartes ópticas para las 23 radiofuentes de la Exploración de Parkes en 2700 MHz ubicadas en la vecindad de (00^h53^m, $-28°00'$) dentro de las áreas definidas por (±2 × error cuadrático medio) en torno de sus posiciones de radio, mediante placas Kodak IIIaJ profundas tomadas con el telescopio Maksutov de Cerro El Roble. Se proponen 12 nuevas identificaciones, 7 de las cuales son galaxias, mientras que las áreas de búsqueda de 5 radio fuentes aparecen vacías hasta el límite de la placa. Aunque no se encontraron nuevas contrapartes ópticas de apariencia estelar, se dan posiciones ópticas precisas para las ya conocidas.

ABSTRACT

Optical counterparts for the 23 radio sources of the Parkes 2700 MHz survey located in the vicinity of (00^h 53^m, $-$ 28° 00′) were searched within ±2 rms errors of their improved radio positions using deep Kodak IIIaJ plates taken with the Maksutov telescope at Cerro El Roble. Twelve new identifications are proposed, of which 7 are galaxies, while the search areas of 5 radio sources appear blank to the plate limit. Although no new optical counterparts of stellar appearance were found, precise optical positions are given for the already known ones.

Key words: **RADIO SOURCES – OPTICAL IDENTIFICATION – QUASARS.**

I. INTRODUCTION

Smith and his collaborators in Edinburgh (Clowes *et al.* 1980) have chosen a 40 sq degree field near the South Galactic Pole (1950.0 center 00^h 53^m, $-28°03'$) to carry out a systematic search of QSOs in objective prism plates taken with UK Schmidt telescope in Australia. This same field has been chosen by a group in Santiago to search QSOs through a color technique (Campusano 1981; Torres and Campusano 1981). Another obvious way to search for QSOs is to look for optical counterparts of radio sources with stellar appearance. This motivated a systematic revision of the surrounding areas of all the radio sources positions within an 8°.5 × 8°.5 zone of the sky centered in the above mentioned coordinates, using hypersensitized Kodak IIIaJ emulsion.

Twenty three sources were selected from the sixth and eleventh part of the Parkes 2700-MHz survey (Shimmins and Bolton 1974; Wall, Wright and Bolton 1976). We employed improved radio positions taken from Bolton (1980); Condon, Jauncey and Wright (1978), and Binette *et al.* (1980).

The previous status of the identification of the 23 radio sources is given in Table 1. Column 1 gives the designation of the radio sources from the Parkes 2700-MHz survey. Columns 2 and 3 contain the best available radio positions of the sources. Columns 4 and 5 list the flux densities in Janskys at 2700 MHz and 5000 MHz when available. Column 6 gives the rms error of the radio position inferred from

$$\sqrt{\{8^2 + (4/S)^2\}}$$

for the original Parkes measurements (Wall, Wright and Bolton 1976). Column 7 shows the previous identification of the source. The abbreviations for the identifications are: QSO, quasi-stellar object with measured redshift; BSO, blue-stellar object; N, galaxy type; II, one or more galaxies within the area covered by the possible position errors of the source; III, one or more stars of normal color within the error box; III B, blank field. Column 8 gives the number of the field center in the South Galactic Pole. Finally, column 9 indicates remarks on individual objects.

Although all the known optical counterparts of stellar appearance were rediscovered in our search, no new QSOs were found. However, new results or suggested identifications were attained for 12 radio sources.

II. OBSERVATIONS AND IDENTIFICATIONS

The plate material for this work was obtained with the 70/100 cm Maksutov telescope at Cerro El Roble Astronomical Station of the Universidad de Chile. Each plate covers a field of 5° × 5°, with a scale of 99 arcsec/mm. The surveyed fields are specified in Table 2.

TABLE 1

PREVIOUS STATUS OF THE IDENTIFICATION OF RADIO SOURCES IN THE SELECTED AREA

PKS (1)	(1950) α (2)	(1950) δ (3)	S_{2700} (4)	S_{5000} (5)	rms (6)	Previous identification or field class (7)	In SGP (8)	Notes (9)
0057-321	$00^h57^m32^s8$	− 32°08′35″	0.08		51″	III, 1974	5	
0042-301	00 42 07.8	− 30 09 18	0.10		41	III, 1974	1	
0112-310	01 12 37.0	− 31 02 55	0.13		32	III, 1974	5	
0033-306	00 33 33.6	− 30 39 50	0.15		28	III, 1974	1	
0046-315	00 46 57.9	− 31 32 54	0.15		28	QSO, z = 2.721	1	*,B
0055-256	00 55 30.8	− 25 38 44	0.20		21	II, 1976	4	B
0037-320	00 37 45.2	− 32 00 34	0.22		20	III, 1974	1	B
0102-245	01 02 32.86±.08	− 24 32 33.9±1.9	0.24	0.22		BSO, 1978	4	*,C
0100-270	01 00 31.65±.09	− 27 02 43.1±2.3	0.26	0.24		BSO, z = 1.597	4	*,C
0111-256	01 11 18.74±.09	− 25 39 51.8±2.3	0.26	0.23		BSO, 1978	4	*,C
0046-300	00 46 14.0	− 30 03 38	0.27			IIIB, 1974	1	*
0035-252	00 35 46.09±.10	− 25 15 32.7±2.5	0.28			N(SO), 1978	2	*,C
0104-275	01 04 02.1	− 27 34 45	0.29	0.37	16	QSO, z = 1.69	4	*
0101-275	01 01 11.3	− 27 31 14	0.29		16	III, 1976	4	B
0056-292	00 56 44.0	− 29 16 03	0.29		16	III, 1976	5	B
0042-248	00 42 36.2	− 24 50 40	0.31	0.22	15	IIIB, 1976	2	
0102-256	01 02 28.4	− 25 36 54	0.31	0.16	15	III, 1976	4	
0110-302	01 10 20.8	− 30 15 08	0.31	0.20	15	III, 1974	5	*
0056-242	00 56 02.0	− 24 17 20	0.34	0.21	14	II, 1976	4	
0059-287	00 59 28.26±.08	− 28 47 30.1±1.9	0.44	0.36		IIIB, 1978	5	*,C
0100-277	01 00 19.9	− 27 47 35	0.54	0.31	11	III, 1976	4,5	*,B
0106-291	01 06 15.1	− 29 07 25	0.69	0.37	10	IIIB, 1976	5	*,B
0045-25	00 45 07.0	− 25 33 35	3.52	2.08	8	NGC 253, 1965	2	

Notes:
B: Molonglo radio position from Bolton (1980).
C: Radio position from Condon *et al.* (1978).
0046-315 Finding chart from Peterson *et al.* (1973). Spectroscopy from Peterson *et al.* (1976).
0102-245 Finding chart from Condon *et al.* (1978).
0100-270 Finding chart from Savage and Wall (1976). Spectroscopy from Jauncey *et al.* (1978).
0111-256 Finding chart from Savage and Wall (1976).
0046-300 Radio position in 5000 MHz from Binette *et al.* (1980).
0035-252 Finding chart from Condon *et al.* (1978).
0104-275 Radio position at 5000 MHz from Binette *et al.* (1980). Finding chart from Bolton *et al.* (1980).
0110-302 Radio position in 5000 MHz from Binette *et al.* (1980).

All the exposures were of 40 minutes with Kodak IIIaJ emulsions. The limiting magnitude is estimated to be 22.

The search for optical counterparts was done in two steps within a square area of ±2 rms errors of the radio source positions.

The first one, was the inspection of the list of UV-excess objects of Torres and Campusano (1981), for the selected area in the South Galactic Pole. Only one UV-excess object was found inside the error boxes, rediscovering in this way the QSO associated with the source PKS 0100-270. The other step was the examination of the IIIaJ Maksutov plates with a procedure that is outlined below.

The precise location of the radio sources in the plates was done relative to the reference stars of the Perth 70 catalogue. In relation to the measurement of the optical

TABLE 2

PLATE MATERIAL FOR OPTICAL IDENTIFICATIONS

Field	Plate number	Center (1950) α	Center (1950) δ	Radio sources	UT Date
SGP1	4993	00^h44^m4	− 29°58′	5	9 Sept 80
SGP2	5178	00 44.1	− 25 59	3	10 Sept 80
SGP4	5179	01 01.7	− 25 57	9	10 Nov 80
SGP5	4996	01 02.4	− 29 58	7	9 Sept 80

objects in the deep IIIaJ plates, a net of fainter secondary reference stars was defined in order to obviate magnitude errors (Wroblewski, Costa and Torres 1981). All the position measurements were done with the Zeiss Ascorecord machine of the Observatorio Astronómico de Cerro Calán, while the computations were performed with the IBM 370 computer of the Centro de Computación, Universidad de Chile.

Once the error boxes were located on the plates we proceeded with the identifications. If a galaxy was present in the search area we suggest this one as the optical counterpart, if there were more than one we also include them in our list of identifications for possible later discrimination. When no galaxy was detected, but instead there was a single object of stellar appearance, we suggest this object as the optical counterpart on the basis of positional agreement. In the case where no optical object satisfied the 2 rms errors criteria, above the limit of our IIaJ Maksutov plates we considered the optical field corresponding to the radio source as a blank field.

III. RESULTS

On the basis of positional coincidence we obtained six optical counterparts of stellar appearance, which corresponds to the totality of the published objects of this type in the searched region. We measured precise optical positions for these objects with an estimated accuracy of one half arcsec. Their positions and their corresponding differences with the radio positions are listed in Table 3.

Eight blank fields are listed in Table 4, three of which were already classified as such.

The new optical identifications are listed in Table 5. Columns 2 and 3 contain the measured positions of the optical candidates. Column 4 gives their estimated blue

TABLE 3

PRECISE OPTICAL POSITIONS FOR THE PREVIOUSLY KNOWN IDENTIFICATIONS

PKS	Type	(1950) α	(1950) δ	Optical − radio Δαcosδ (arcsec)	Optical − radio Δδ (arcsec)	Notes*
0046-315	QSO	$00^h46^m57^s.61$	−31°32′47″.9	−3.7	6.1	
0102-245	BSO	01 02 32.72	−24 32 32.5	−1.9 −2.0	1.4 1.4	C
0100-270	QSO	01 00 31.60	−27 02 42.6	−0.7 −1.7	0.5 1.1	C
0111-256	BSO	01 11 18.75	−25 39 51.5	1.2 −1.1	−0.3 0.5	C
0035-252	N(SO)	00 35 46.03	−25 15 32.1	−0.8 −1.8	0.6 1.5	C
0104-275	QSO	01 04 02.05	−27 34 13.6	−0.7	3.4	

* C: Other optical − radio difference from Condon *et al.* 1978.

TABLE 4

BLANK FIELDS TO THE LIMIT OF THE PLATE MATERIAL

PKS	S_{2700}	Adopted 2 rms half box	Remarks on nearest objects
0046-300	0.27	24″	A 20 mag stellar object at $\alpha = 00^h46^m11^s.93$, $\delta = -30°04'11''.5$. Confirms Shimmins and Bolton (1974) result.
0101-275	0.29	32	A stellar object at about 70″ NE.
0042-248	0.31	30	A 19 mag stellar object at $\alpha = 00^h35^m46^s.03$, $\delta = -25°15'32''.1$. 50″ from the radio position. Confirms Wall *et al.* (1976) result.
0102-256	0.31	30	A 15.5 mag stellar object at $\alpha = 01^h02^m28^s.09$, $\delta = -25°36'11''.2$, 43″ from the radio position.
0110-302	0.31	20	Empty out to around 30″. Confirms Condon *et al.* result.
0056-242	0.34	28	A stellar object at about 75″.
0059-287	0.44	4	A cluster of galaxies at about 65″. The brightest galaxy at $\alpha = 00^h59^m32^s.44$, $\delta = -28°46'56''.3$.
0100-277	0.54	22	Two stellar objects at about 70″.

TABLE 5

NEW OPTICAL IDENTIFICATIONS AND OPTICAL POSITIONS

PKS (1)	α (1950) (2)	δ (3)	m (4)	Type (5)	Optical − radio Δαcosδ (arcsec) (6)	Optical − radio Δδ (arcsec) (7)	Adopted 2 rms half box (8)	Remarks (9)
0033-306	$00^h33^m33^s24$	−30°38′51″.1	21	pG	− 4.7	58.9	56″	A stellar object at about 50″ N
0037-320	00 37 48.48	− 32 00 29.1	21	pG	41.8	4.9	40	A fainter diffuse object at about 45″
0042-301	00 42 02.23	− 30 10 29.1	20	pG	− 72.3	− 71.2	82	Also two bright stars within error box
	00 42 02.70	− 30 10 17.3	20.5	pG	− 66.1	− 59.3		
	00 42 02.77	− 30 10 06.3	21	pG	− 65.2	− 48.3		
0055-256	00 55 31.05	− 25 38 49.5	20.5	G	3.5	− 5.5	42	E galaxy. Mentioned by Wall *et al.* (1976)
0056-292	00 56 44.79	− 29 15 54.9	19	G	2.5	8.1	32	Brightest galaxy of three inside error box. In cluster mentioned by Wall *et al.* (1976)
0057-321	00 57 34.15	− 32 09 14.4	21	pG	17.2	− 39.4	102	
	00 57 33.21	− 32 07 33.3	20	pG	5.3	61.7		
	00 57 37.71	− 32 07 11.2	20.5	pG	62.4	83.7		
0106-291	01 06 16.50	− 29 07 31.8	20.5	pG	18.3	− 6.8	20	

magnitudes by comparison with the sequence of Hawkins (1979) in the South Galactic Pole. These magnitudes may be in error by as much as 1 mag for the stellar objects, or more for the galaxies. Column 5 indicates the type of object: G for Galaxy, pG for diffuse images that possibly correspond to galaxies. Columns 6 and 7 give the difference, optical minus radio position, in seconds of arc. Column 8 gives the half-side of the error boxes employed. Column 9 indicates remarks on individual objects.

With this revision of the optical identifications in the selected area of 72 square degrees in the vicinity of the South Galactic Pole, we obtain the following distribution. In the areas defined by the ±2 rms errors from the radio positions of the 23 sources, 6 of them (or 26%) show a stellar object in positional agreement, 8 sources (or 35%) show one or more galaxies, 1 source (or 4%) show two or more stars of normal color, and 8 (or 35%) do not show any object inside and hence are classified as blank fields.

Finding charts for these fields may be obtained at request from the authors.

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