Aust. J. Phys., 1979, **32**, 511–23

Optical Positions for Identifications from the MC2 and MC3 Catalogues

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Abstract

Optical positions measured from the Palomar Sky Survey prints are given for objects identified with MC2 and MC3 radio sources. A comparison with other published optical positions for sources in common suggests an r.m.s. error of $0 \cdot 3''$–$0 \cdot 35''$ arc in each coordinate. Comparison of previously published optical positions from the Sydney measuring machine with subsequent more accurate radio positions indicates an r.m.s. error of $0 \cdot 28''$ arc in each coordinate for the optical positions of stellar objects.

1. Introduction

We present here optical positions accurate to $1''$ arc or better for the objects identified by Hazard and Murdoch (1977) with radio sources from the MC2 and MC3 catalogues (Sutton *et al.* 1974) in the R.A. range $11^h 28^m$–$17^h 00^m$. The original identifications were made on the basis of optical positions with an r.m.s. error $\sim 3''$ arc, which was adequate in relation to the radio errors which ranged from $4''$ to $15''$ arc. More-accurate optical positions are, however, necessary for comparison with accurate radio positions as these become available. This will assist in clarifying doubtful identifications, particularly for stellar objects that are neutral or red in colour.

In general, the positions given here for stellar objects (including BSOs and many of the faint galaxies) have an r.m.s. error of $\pm 0 \cdot 4''$ arc. The remaining galaxies $\geqslant 17^m$ have an error $\sim 1''$ arc although, for brighter galaxies, the errors increase due to the size of the galaxy image. The measurements were made at Sydney, R.R.E. Malvern and Cambridge by methods which are essentially similar but differ in detail. There is a considerable degree of overlap in the measurements in order to ensure adequate uniformity of the results.

2. Optical Measurements

(*a*) *General Remarks*

Since Hunstead (1971) demonstrated that accurate optical positions could be obtained from the Palomar Sky Survey prints, these have been widely used for this purpose. Hunstead (1974) showed that an r.m.s. error of $0 \cdot 3''$ arc is readily achieved. This has been confirmed by subsequent accurate radio positions (see Section 2*b*).

A transparent overlay showing the positions of the nearby reference stars together with the radio source is produced by a computer program which also predicts the x and y coordinates of these objects. Using well-established techniques, comparison between the observed and predicted positions of the reference stars gives six parameters which account for origin shift, linear stretch of scale and rotation of the print relative to the axes of the measuring machine. These are then used in computing the optical position of the candidate object(s) from the measured x and y coordinates. The curvature of the original plates is taken into account in all calculations, but not the Schmidt bending corrections which are unimportant at this level of accuracy.

At least four reference stars are required to give some redundancy and to allow the rejection of cases where the error in either the measurement or the catalogue position is abnormally large. A unique solution is obtained for three stars but with no indication of the accuracy of the fitted parameters. An earlier method due to F. Schlesinger, which uses a fourth star merely as a check, is still used by some observers (e.g. Veron and Veron 1975). Bridle and Goodson (1977) have recently adapted Schlesinger's method to make use of the measurements of all four stars in a reduction program using a desk-top computer.

The chief sources of error in the measurements arise from: (i) the error σ_r in the positions of the reference stars; (ii) the print and plate distortions σ_p; (iii) the setting error σ_s on the reference stars; (iv) the setting error σ_0 on the unknown object. The overall standard deviation σ is then given by

$$\sigma^2 = (\sigma_r^2+\sigma_p^2+\sigma_s^2)/(N-3)+\sigma_0^2,$$

where N is the number of reference stars and $N-3$ is the number of degrees of freedom. Errors (iii) and (iv) can be reduced if desired by repeated measurements. Other possible sources of error include small irregularities in the drive of the microscope assembly and any small movements of the print during measurement. Most of the errors listed above may include a small systematic component, especially the setting errors; although most systematic errors can be eliminated by rotating the print through 180° and repeating the measurement. Any small systematic error in the reference star positions will of course remain.

(*b*) *Sydney Measurements*

The measurements made in Sydney are based on SAO (Smithsonian Astrophysical Observatory) reference stars and were made by a technical assistant. Where possible, eight stars were chosen, two in each quadrant. The reduction program eliminated any stars whose fitted position in either coordinate differed from the predicted position by a predetermined amount, normally set between 0·8″ and 1·0″ arc. For each radio source, the procedure was repeated with the print rotated through 180°. Taking the mean of the two sets of measurements minimized the effects of personal bias in setting the crosshairs on faint objects and also guarded against gross errors.

As a check on the reliability of the Sydney measurements made by the technical assistant, the sources from Hoskins *et al.* (1974) were remeasured using the same reference stars. The r.m.s. differences between the new measurements and those made by D. G. Hoskins (Hoskins *et al.* 1974) was 0·32″ arc in right ascension and 0·39″ arc in declination. This suggests an 'observer error' for the whole procedure of about 0·25″ arc, which should cover all sources of error except σ_r. Such a value is consistent with the corresponding r.m.s. error of 0·27″ arc obtained by Hunstead (1974) from repeated measurements.

An independent estimate of the overall accuracy of the Sydney measurements may be obtained by comparing published optical positions with recent more accurate radio positions by Clark *et al.* (1976) who used VLBI measurements, by Ellsmore and Ryle (1976) who used the Cambridge interferometer and by Wade and Johnston (1977) who used the N.R.A.O. radio link 35 km interferometer. The present comparison is restricted to radio positions accurate to $0\cdot15''$ arc or better, and to radio compact QSOs or BL Lac objects. There are 10 sources which meet these criteria, 8 from Hunstead's (1971) original work and 2 from Hoskins *et al.* (1974). (Results from Hoskins *et al.* (1972) are not included because, as pointed out in that paper, these measurements were only intended to be accurate to $\sim 1''$ arc.) For these 10 common sources, the r.m.s. deviation between the optical and accurate radio positions is $0\cdot28''\pm0\cdot04''$ arc in each coordinate (actually $0\cdot25''$ in R.A. and $0\cdot31''$ in Dec., but the values do not differ significantly). Comparing this with the suggested 'observer error' quoted above of $0\cdot25''\pm0\cdot04''$ arc indicates that the contribution of errors in the reference star positions is minimal.

For the present measurements an estimated total r.m.s. error of $0\cdot35''$ arc seems to be realistic, after making allowance for a small number of cases in which the star distribution is poor or where the forward and reverse measurements differ by more than expected. For galaxies $\geqslant 18^m$ the errors can be expected to be only slightly greater than for stellar objects, and it seems reasonable to suggest an r.m.s. error of $0\cdot4''$ arc for them. For brighter galaxies there will be an increasing error due to the difficulty of defining the optical centre. In some cases the error will also be slightly greater for galaxies at the plate limit.

(*c*) *R.R.E. Malvern and Cambridge Measurements*

Measurements were also made by one of us (N.S.), partly with the Coradagraph measuring machine at R.R.E. Malvern, Worcestershire, and subsequently with a similar machine at the Institute of Astronomy, Cambridge. The R.R.E. Malvern positions were referred to typically five AGK3 (Astronomische Gesellschaft) stars, with at least one in each quadrant. The use of a smaller number of stars here made it more difficult to be sure of eliminating any star with a larger error than normal. Although no measurements were made with the prints rotated through 180°, each reference star was measured with the microscope drive travelling in alternate directions and the average reading was taken. This should have eliminated the largest component of any personal bias. The emphasis in the measurements by N.S. was on achieving an adequate accuracy for the purpose within a minimum time on any one object in order to increase the rate of production. The later Cambridge measurements are all of galaxy identifications and are referred to AGK2 stars. An HP 9820 desk computer was used to carry out the reductions as the measurements were made. These have an estimated accuracy of $\sim 1''$ arc.

Comparison between the Sydney and R.R.E. Malvern measurements for 31 stellar objects gives an r.m.s. difference of $0\cdot6''$ arc in each coordinate. This suggests an r.m.s. error of $0\cdot5''$ arc in the Malvern measurements (which is quite adequate) but indicates that the combined average values should be weighted 2 : 1 in favour of the Sydney measurements. Further support for the above-quoted r.m.s. error in the Sydney measurements (and hence for the necessary weighting factor) comes from a comparison for 17 sources between the Sydney measurements and measurements by A. N. Argue (personal communication), who also used the Coradagraph machine at R.R.E. Malvern, but with a greater number of reference stars.

(d) Possible Systematic Effects

Comparisons of radio and/or optical measurements based on SAO and AGK3 stars have frequently suggested a possible systematic bias in right ascension between AGK3 and SAO positions. These results were summarized by Argue and Taylor (1974). Adgie (1974) found no such effects in a comparison of AGK3 and SAO star positions in the vicinity of 19 radio sources. It is therefore of interest to quote the mean differences and standard errors obtained in the above comparisons between 17 Sydney measurements ($\bar{\alpha}_S, \bar{\delta}_S$) and those of Argue ($\bar{\alpha}_A, \bar{\delta}_A$) and between 31 Sydney measurements and the present R.R.E. Malvern measurements ($\bar{\alpha}_R, \bar{\delta}_R$):

$$\bar{\alpha}_S - \bar{\alpha}_A = 0 \cdot 18'' \pm 0 \cdot 13'', \qquad \bar{\delta}_S - \bar{\delta}_A = 0 \cdot 32'' \pm 0 \cdot 13'';$$

$$\bar{\alpha}_S - \bar{\alpha}_R = -0 \cdot 16'' \pm 0 \cdot 08'', \qquad \bar{\delta}_S - \bar{\delta}_R = 0 \cdot 09'' \pm 0 \cdot 12''.$$

These comparisons could include a small component of personal bias, but there is no evidence of any significant bias in the zero points of either right ascension or declination.

In view of the previous suggestions of a difference between the zero point of right ascension between SAO and AGK3 positions, a comparison (similar to Adgie's (1974) comparison) was made between the SAO and AGK3 stars for 15 of the fields in common with those of Argue. The average number of stars per field was 11, and the average difference SAO$-$AGK3 for the field means was $0 \cdot 08'' \pm 0 \cdot 04''$ arc. However, for 3 of these 15 fields, the mean difference was at least twice the standard deviation, which suggests that the distribution of field means is nongaussian or at least that there are some fields with an unusually large SAO$-$AGK3 difference.* The greatest difference was $0 \cdot 37''$ arc for the mean of 12 stars in the field of 1221+114. It seems likely that the occasional occurrence of somewhat large discrepancies over fields a few square degrees in area would contribute to the apparently significant differences for some samples of sources. For 68 stars in 26 fields of the R.R.E. Malvern measurements the mean SAO$-$AGK3 difference was $-0 \cdot 02'' \pm 0 \cdot 08''$ arc in R.A. and $0 \cdot 14'' \pm 0 \cdot 08''$ in Dec., and again there was evidence that the distribution was nongaussian. A more systematic comparison of SAO and AGK3 stars would seem to be worth while. Nevertheless, it is of no consequence for the present measurements that some are based on SAO and others on AGK3 positions.†

The mean difference 'Sydney optical' $-$ 'accurate radio' for the 10 sources described in Section 2*b* was $+0 \cdot 06'' \pm 0 \cdot 08''$ arc in R.A. and $+0 \cdot 05'' \pm 0 \cdot 10''$ arc in Dec. This is further confirmation that there is no systematic zero point error in either coordinate.

* A similar impression is obtained from examining the detailed results of R. L. Adgie (personal communication).

† Wills (1978) has recently reported a significant difference in SAO$-$AGK3 right ascensions, but this appeared to be due to a group of sources for which the mean SAO$-$AGK3 difference was $0 \cdot 65''$ arc, whilst the remainder clustered about zero difference.

3. Results

Comparison of the Hazard and Murdoch (1977) positions (α_{HM}, δ_{HM}) with the accurate positions (α, δ) gives the following mean differences μ and standard deviations σ:

	μ	σ
$\alpha_{HM} - \alpha$	$1 \cdot 2''$	$3 \cdot 0''$
$\delta_{HM} - \delta$	$0 \cdot 3''$	$3 \cdot 1''$

thus confirming the suggested r.m.s. error of 3″ arc. A small number of cases where the former position has been found to be significantly in error have not been used in the above comparison; these are noted in Table 1.

(*a*) *Table of Accurate Positions*

Optical positions are listed in Table 1 for all suggested identifications except two $\leqslant 13^m$ galaxies (1138+117 and 1414+110), for which positions have been given by Dressel and Condon (1976). Positions are also given for a number of other objects. The measurement code used in column 2 is: M (Molonglo), Sydney measurement; R, R.R.E. Malvern measurement; B (both), weighted mean of M and R (using a weight of 2 : 1 in favour of the Sydney measurements); C, Cambridge measurement. The magnitude m and object description given in columns 5 and 6 are taken from Hazard and Murdoch (1977). The symbols used to classify objects are: E, elliptical galaxy; S, spiral galaxy; cg, compact galaxy; g, galaxy of unspecified type; QSO, confirmed quasi-stellar object; BSO, blue stellar image which is brighter on the O than the E print; St, stellar image other than a BSO. A question mark indicates doubt as to the nature of the object. The relative positions (optical relative to radio) given in column 7 have been revised in accordance with the new optical positions. The symbols used in the Notes column (column 8) are: N (nonidentification), the source has not been suggested as an identification; R (reject), the source was previously suggested as an identification but does not now qualify on the basis of the new optical position; W (weak), the radio flux density is $<0 \cdot 45$ Jy, and hence the source is not part of the complete sample; B, confirmed BL Lac object; PB, probable BL Lac object; P, probable identification based on the more accurate radio position; S, significant change in position from that given by Hazard and Murdoch (1977); T, further notes on this source are given in the text (see following subsection). A more thorough reassessment of the identifications will be possible when current work on more accurate radio positions is complete (C. Hazard and J. J. Condon, personal communication).

(*b*) *Notes on Individual Sources*

1210+121. This object was reported by Hazard and Murdoch (1977) as a star, but more recently as having a featureless spectrum with good signal to noise (J. A. Baldwin, personal communication).

1236+109. Other objects listed by Hazard and Murdoch (1977) are not visible on the Sydney copy of the Palomar prints.

1416+159. This object is well outside the 2σ limit and may not be associated with the radio source.

Table 1. Optical positions for MC2 and MC3 identifications

See Section 3*a* of the text for a description of the symbols and Section 3*b* for additional notes to sources

(1) Source designation	(2) Measurement code	(3) Optical position (1950) h m s	(4) ° ′ ″	(5) *m*	(6) Ident-ification	(7) Opt−Rad position		(8) Notes
1130+106	M	11 30 24·20	10 40 17·1	17·4	QSO	3F	0	
1138+112	M	11 38 14·79	11 14 34·8	15·5	cg	0	15N	
	B	11 38 15·54	11 14 29·4	19·6	BSO	11F	9N	N
1139+105	C	11 39 41·19	10 33 48·2	18	g	1F	18N	W
1140+113	C	11 40 19·46	11 18 14·5	16	g	9P	1S	
1142+112	C	11 42 01·92	11 16 51·6	18	cg?	14P	2S	
1143+108	M	11 43 32·31	10 49 47·9	17·5	g	13P	16N	
		11 43 32·92	10 49 32·8	17·9	St	4P	1N	N
1146+111	B	11 46 13·33	11 11 38·9	18·0	QSO	10P	3S	
1151+102	B	11 46 14·39	10 12 36·8	18·4	QSO	4F	4N	
1157+118	M	11 57 12·59	11 40 30·7	18·9	QSO	6F	1N	
1159+108	B	11 59 14·15	10 53 33·8	19·8	BSO	2F	4S	P
1203+109	M	12 03 22·63	10 59 35·7	17·2	QSO	6F	6N	
1205+117	M	12 05 12·70	11 44 32·0	19·5	BSO	1P	6N	
1207+118	B	12 05 34·20	11 50 34·4	19·4	BSO	1F	4S	
1210+121	M	12 09 59·87	12 07 52·8	17·8	BSO	14P	9N	T
1214+106	M	12 14 28·50	10 36 33·2	18·7	QSO	3F	16S	
1215+118	M	12 15 07·99	11 53 44·9	18·7	BSO	10P	7N	W
1215+113	M	12 15 53·31	11 21 44·6	16·2	QSO	16P	5N	
1221+114	M	12 21 47·43	11 23 59·7	18·8	QSO	3P	1N	
1236+107	R	12 36 11·94	10 44 08·5	18	cg	14P	24N	N
1236+103	C	12 36 30·25	10 22 18·1	18·5	g	8F	3N	
1236+109	M	12 36 58·46	10 59 34·9	19	g	1F	13S	T
1238+113	C	12 38 50·05	11 22 22·4	18	g	17F	17S	
1245+115	M	12 45 46·54	11 33 41·0	12·5	St	8F	2N	N
1245+112	M	12 45 55·19	11 14 28·9	19·8	BSO	12P	1N	N
1248+120	M	12 48 24·12	12 05 23·4	18·5	g	0	0	
1250+119B	M	12 50 42·50	11 55 35·9	18	g	9P	5S	S
1252+119	M	12 52 07·72	11 57 21·0	15·7	QSO	1P	10N	
1253+104	M	12 53 36·78	10 25 07·2	18·8	QSO	0	3N	
1301+118	C	13 01 01·32	11 51 55·0	17	cg	7P	5N	
1301+117	C	13 01 24·86	11 43 35·7	19·2	BSO	15P	14N	N
1303+114	M	13 03 49·25	11 29 41·9	14	E	13P	7N	
1306+107	M	13 06 34·35	10 45 32·4	15·5	E	12P	2S	
1306+115B	M	13 06 47·78	11 33 11·0	19·5	BSO	0	10N	
1307+121	B	13 07 04·35	12 10 22·5	19·1	BSO	5F	9S	PB
1308+120B	B	13 08 45·55	12 02 14·6	19·2	BSO	18F	13S	
1310+119	C	13 10 33·19	11 56 15·2	19	g	5P	7N	
1318+113	B	13 18 49·63	11 22 31·5	19·2	QSO	2F	4N	
1331+170	M	13 31 10·00	17 04 26·0	15·5	QSO	15F	4S	
1334+119	M	13 34 41·28	11 55 27·9	18·9	QSO	8F	12N	
1334+111	B	13 34 51·31	11 09 01·8	18·2	St	5F	14S	N
1336+106	C	13 36 45·96	10 39 34·1	17	cg	22F	19S	R
1340+105	B	13 40 21·93	10 35 36·8	19	cg?	9F	14N	
1345+169	M	13 45 24·62	16 59 58·2	19·5	g	12P	11N	W
1352+164A	C	13 52 16·03	16 29 33·4	18	g	4P	2N	
1354+161	M	13 54 36·68	16 11 29·2	18	g	11P	6S	

Table 1 (*Continued*)

(1) Source designation	(2) Measurement code	(3) Optical position (1950) h m s	(4) ° ′ ″	(5) *m*	(6) Identification	(7) Opt−Rad position	(8) Notes
1354+157	M	13 54 54·20	15 42 07·1	13·5	E	34P 27S	
1357+173A	M	13 57 01·52	17 21 16·6	18	cg?	3F 1N	
1357+104	M	13 57 07·08	10 26 14·3	18	g	3F 14S	
1357+173B	C	13 57 30·51	17 19 36·8	18	g	7F 13S	
1358+116	M	13 58 36·45	11 40 02·5	20·2	BSO	1P 19N	N
1359+103	M	13 59 46·43	10 20 26·4	19·5	g	4F 4N	
1400+162	B	14 00 20·52	16 14 20·9	16·7	St	4P 14S	B
1401+159	M	14 01 38·87	15 57 50·0	16·5	E	11P 4N	
1402+165	C	14 02 43·34	16 30 14·1	17	cg	14P 12N	W
1404+103	M	14 04 33·06	10 23 34·1	16·5	E	4P 27N	
1405+110	M	14 05 45·32	11 02 27·6	19·5	blue g	6P 1N	W
1408+155	M	14 08 46·55	15 32 22·6	18·5	g	17P 9S	
	R	14 08 49·75	15 32 19·5	19·2	BSO?	30F 2S	N
1409+115	M	14 09 47·78	11 33 23·7	19·5	blue g	17P 25N	N
1410+154	M	14 10 18·19	15 29 30·8	19·3	BSO?	23P 2N	R
1415+104	M	14 15 32·88	10 27 23·7	18·5	blue g	25P 3N	N
1415+172	M	14 15 41·61	17 17 12·8	17·7	QSO	6P 2N	
1416+159	M	14 16 27·67	15 54 52·1	17·4	QSO	11P 36S	T
1418+171	C	14 18 02·08	17 11 51·7	18	g	14P 0	
1419+105	B	14 19 15·74	10 30 11·4	18·8	BSO	2F 1S	
1419+113	C	14 19 46·08	11 18 55·1	18	g	1F 7N	W
1421+114	C	14 21 52·65	11 26 53·6	18	g	15P 1S	W
1422+113	C	14 22 11·57	11 18 00·3	17·5	cg?	16F 7S	
1424+169	B	14 24 40·93	16 56 34·1	19·1	BSO	10F 2S	
1425+162	M	14 25 19·89	16 17 42·4	19·3	BSO	1F 10N	
1426+168	B	14 26 07·30	16 53 22·0	19·0	St	3P 1S	PB
		14 26 07·73	16 53 27·8	17·2	St	4F 5N	N
1426+101	R	14 26 50·56	10 11 07·2	17·5	St	0 7N	W
1427+113	M	14 27 39·63	11 22 19·4	17	g	8P 1S	
1427+120	B	14 27 45·64	12 03 13·0	19·3	BSO?	21P 7N	
1428+168	C	14 28 52·54	16 49 49·3	18	g	4F 17S	W
		14 28 52·04	16 49 59·4	18·5	g	4P 7S	
1429+160	M	14 29 53·44	16 01 34·5	19·5	QSO	9F 4S	
1430+109	B	14 30 12·64	10 56 34·1	18·5	blue g	11F 20S	
1431+162	S	14 31 30·94	16 16 09·6	18	g	8P 10N	
1433+177	M	14 33 36·11	17 42 37·7	18·0	QSO	9F 1S	
1435+172	M	14 35 40·63	17 13 42·5	18·1	QSO	2F 4S	
1436+157	M	14 36 39·61	15 43 45·2	16·5	cg	2F 3N	S
1436+115	B	14 36 51·88	11 35 42·9	18·5	BSO	16F 13N	
1437+116	M	14 37 55·74	11 37 57·1	17	g	12F 7N	W
1439+102	M	14 39 52·80	10 14 28·7	18·5	g	7F 11N	
1440+119	M	14 40 21·36	11 56 29·1	18	blue g	1P 4N	
1440+163	B	14 40 40·61	16 19 42·7	17·5	g	15P 12N	
1442+117	M	14 42 26·03	11 44 35·0	18·4	QSO	1P 0	
1442+170	B	14 42 42·38	17 02 05·6	17·5	cg	10F 6N	
1442+101	B	14 42 50·49	10 11 12·0	18·4	QSO	5F 3N	
1446+176	C	14 46 16·96	17 36 47·1	18	g	11F 1S	
1446+177	M	14 46 22·40	17 46 09·9	18	g	10P 2N	

Table 1 (*Continued*)

(1) Source designation	(2) Measurement code	(3) Optical position (1950) h m s	(4) ° ′ ″	(5) *m*	(6) Ident-ification	(7) Opt – Rad position		(8) Notes
1448+169	M	14 48 06·56	16 57 03·7	13	S	17F	4N	W
1448+164	M	14 48 11·54	16 28 08·2	15·5	g	14F	4S	
1449+111	M	14 49 12·11	11 09 37·3	19·7	BSO	3P	14S	N
		14 49 12·13	11 09 54·4	19·8	red St	2P	3N	N
1450+173	M	14 50 03·13	17 19 32·2	13·5	E	21F	32S	
1450+113	M	14 50 59·45	11 17 57·4	19·2	BSO	27F	32S	N
	B	14 50 56·82	11 17 55·9	18·4	St	11P	31S	N
1451+172	B	14 51 35·06	17 12 50·4	18·0	BSO	1F	11S	
1452+165	M	14 52 03·25	16 33 26·3	13	E	37P	10S	T
1452+154	B	14 52 18·59	15 29 24·3	18	g	6P	5S	
1453+170	M	14 53 19·55	17 01 26·7	17·3	BSO	1F	0	
1453+120	M	14 53 31·33	12 03 46·5	13·5	E	2P	7N	
1453+166	M	14 53 45·69	16 38 57·6	17	g	10F	7S	
		14 53 44·40	16 39 08·5	18	g	9P	3N	N
1455+115	M	14 55 28·42	11 30 08·3	16	E	0	7N	W
		14 55 27·62	11 30 00·5	17	E	11P	0	
1501+104	M	15 01 14·43	10 27 44·3	17	cg?	7P	8N	
1501+111	B	15 01 56·53	11 10 48·5	18·9	BSO	1P	7N	
1502+106	B	15 02 00·15	10 41 17·3	19·4	QSO	1P	6S	
1504+105	M	15 04 56·91	10 30 16·3	13·2	St+g	0	7N	
1505+112	B	15 05 15·35	11 15 31·8	17·1	BSO	27F	22N	N
1506+171	C	15 06 57·96	17 10 32·3	18	g	9F	5N	
1508+108	M	10 08 25·27	10 53 53·3	19·3	BSO	20F	21N	
1509+102	C	15 09 05·62	10 12 47·0	17·5	cg?	18F	14S	
1509+158	B	15 09 52·47	15 51 39·3	17·9	QSO	7F	10N	
1509+154	M	15 09 55·46	15 26 21·4	16·7	BSO	11P	12N	
		15 09 55·30	15 26 07·0	16	g	13P	2S	
1511+103	B	15 11 04·56	10 22 15·2	17·5	QSO	16F	24S	
1512+104A	M	15 12 24·76	10 28 08·5	14·5	E	4P	23N	
1515+176	C	15 15 07·23	17 40 17·2	17·5	g	2F	7N	
1515+101	C	15 15 27·18	10 10 22·1	18	g	16F	8S	
1516+107	M	15 16 10·30	10 43 04·9	18·3	St	3P	12S	N
1517+166	B	15 17 47·54	16 39 09·9	18·6	BSO	21P	21N	R
1517+176	B	15 17 57·67	17 36 40·3	17·9	QSO	16F	17S	
1518+156	M	15 18 10·73	15 37 11·8	17·7	St	8F	6N	N, T
		15 18 11·07	15 36 45·5	18·5	g	13F	20S	
1519+108	C	15 19 48·22	10 52 11·4	18	g	4P	3S	
1519+103	C	15 19 52·78	10 23 39·4	18·5	g	9P	1S	
1521+116	C	15 21 04·86	11 41 12·0	17	g	2P	2N	
		15 21 04·62	11 41 01·5	17	g	6P	8S	N
1521+111	M	15 21 33·30	11 06 17·4	18·5	g	1P	2S	
		15 21 33·26	11 06 11·8	19	g	2P	7S	N
1522+155	B	15 22 22·15	15 31 52·0	18·4	QSO	11F	3S	
1522+113	B	15 22 39·46	11 18 14·9	18·3	QSO	4P	15N	T
1523+161	B	15 23 13·05	16 06 30·2	19·2	BSO	25P	13S	R, T
1524+101	M	15 24 21·81	10 09 35·8	18·6	QSO	2F	3N	
1527+158	M	15 27 27·07	15 49 55·6	18·5	g	1F	2S	
		15 27 27·41	15 49 56·6	19	g	5F	1S	
1529+104	C	15 29 39·16	10 24 37·7	18·5	g	4F	24N	R,W

Table 1 (*Continued*)

(1) Source designation	(2) Measurement code	(3) Optical position (1950) h m s	(4) ° ′ ″	(5) m	(6) Ident-ification	(7) Opt−Rad position		(8) Notes
1531+104	C	15 31 54·72	10 26 46·1	17	cg	7P	1S	
1537+162	C	15 37 07·21	16 13 42·0	18·5	blue g?	15F	4S	
1538+117	C	15 38 40·51	11 43 45·1	18	g	9P	7S	
1540+110	B	15 40 33·04	11 04 04·6	19·1	QSO	1F	2N	
1540+154	M	15 40 37·32	15 25 36·9	15·5	E	15P	18N	W
1544+157	C	15 44 09·02	15 45 19·8	18·5	g	16P	17N	N
1544+105	M	15 44 17·70	10 33 29·0	17·2	St	1P	4S	N
1544+118	M	15 44 49·52	11 51 54·4	19·4	BSO?	19F	16N	N
1547+105	M	15 47 35·20	10 33 34·6	17·9	QSO	9F	26S	W
1548+154	M	15 48 02·10	15 25 16·0	16	E	22F	17S	
1548+114	M	15 48 21·20	11 29 47·0	16·9	QSO	0	6S	
		15 48 21·52	11 29 46·5	19·0	QSO	5F	7S	N
1549+102	M	15 49 04·74	10 13 10·2	20·4	BSO	0	4N	N
		15 49 06·05	10 13 34·7	18·7	BSO	20F	29N	N
1549+107	M	15 49 17·12	10 44 45·4	18	g	18F	19S	T
1550+113	B	15 50 02·23	11 21 30·3	17·5	cg?	11F	5N	
1554+107	C	15 54 23·98	10 46 35·9	16	g	5P	5S	
1554+161	M	15 54 35·13	16 10 50·2	17	E	10P	9S	
		15 54 36·23	16 10 41·4	16·5	E	6F	18S	
1556+164	M	15 56 57·12	16 26 26·7	17·5	g	11P	3S	
1558+116	C	15 58 50·94	11 38 09·1	17·5	g	7P	18S	
1559+173	M	15 59 04·63	17 22 36·5	17·7	QSO	1P	5N	
1559+157	C	15 59 05·80	15 45 16·1	18	g	13P	8S	T
1600+158	M	15 59 50·72	15 49 54·9	14	E			T
		15 59 51·82	15 49 12·1	14·5	E			
1600+121	M	16 00 27·69	12 07 57·9	19	blue g	5P	10N	N, T
1601+173	M	16 01 16·43	17 20 07·0	13·5	E	21F	9N	
		16 01 14·73	17 19 53·0	18	g?	4P	5S	N
1604+159	M	16 04 49·41	15 59 32·9	18·7	St	3P	5S	PB
1608+113	M	16 08 11·50	11 23 16·0	18·5	QSO	7P	0	
1612+176	M	16 12 34·55	17 36 41·5	17	E	5F	0	
1617+155	M	16 17 56·42	15 33 52·0	18	g	9F	14S	
1618+177	M	16 18 07·27	17 43 30·0	16·0	QSO	1F	7S	
1618+103	M	16 18 50·39	10 21 12·3	17·5	blue g	27P	10N	N
1618+168	M	16 18 57·76	16 51 16·7	19·5	g	5P	17S	S, T
1620+103	M	16 20 12·33	10 20 11·9	18·8	BSO	0	0	
		16 20 11·60	10 20 05·3	18·5	BSO	10P	7S	
1620+173	M	16 20 37·74	17 21 36·6	18·9	BSO	8P	5S	W
1622+158	M	16 22 57·81	15 52 09·4	18·5	QSO	3F	0	
1623+173	M	16 23 13·52	17 22 06·9	19·0	BSO	3P	18S	
1623+113	C	16 23 49·68	11 20 26·0	18	g	9F	18S	
1624+109	C	16 24 10·25	10 56 23·1	18	cg	10P	7S	
1625+116	C	16 25 25·92	11 40 32·0	17·5	cg	3F	0	
1626+161	C	16 26 03·10	16 10 34·4	19	blue g?	3P	8N	
1628+155	M	16 28 05·64	15 31 51·3	16·4	St	2F	16S	
1629+120	M	16 29 24·55	12 02 24·2	18·5	QSO	1P	8N	
1631+163	M	16 31 30·99	16 20 18·9	18·5	g	4P	9S	W
1633+168	C	16 33 18·53	16 49 02·3	17	g	8F	4N	
1633+162	M	16 33 50·15	16 14 03·5	19·5	g	8F	19S	
1633+160	C	16 34 00·17	16 00 47·9	18	g	15F	10S	
1634+176	M	16 34 02·73	17 41 10·1	18·9	QSO	14F	8S	

Table 1 (*Continued*)

(1) Source designation	(2) Measurement code	(3) Optical position (1950) h m s	(4) ° ′ ″	(5) m	(6) Ident-ification	(7) Opt−Rad position	(8) Notes
1635+119	M	16 35 25·88	11 55 46·4	16·8	QSO	3F 27N	W
1635+159	M	16 35 34·01	15 55 10·9	18·5	g	12F 1S	
1636+118	C	16 36 45·34	11 49 44·6	17	cg?	2P 15S	
1636+115	M	16 36 56·94	11 34 15·3	18	g	13P 11N	
		16 36 56·79	11 33 52·5	19·9	BSO	2P 11S	N
1638+118	M	16 38 38·25	11 49 48·2	15	E	1F 2N	
1638+101	B	16 38 46·28	10 10 28·4	17	g	2P 3S	
1639+155	M	16 39 42·38	15 31 11·5	19·0	BSO	12P 2S	
1641+173	M	16 41 34·60	17 21 19·7	17	E	3F 1S	
1641+118	M	16 41 47·72	11 52 15·3	18	g	8F 11N	
		16 41 48·85	11 52 29·6	17·5	g	24F 26N	N
1642+116	M	16 42 00·91	11 40 16·4	18·4	BSO	1P 19N	
1644+118	M	16 44 03·27	11 49 49·5	15·5	E	4F 7S	
1645+174	M	16 45 27·95	17 25 26·7	18·5	g	4F 8N	
		16 45 28·95	17 25 30·5	18·2	BSO	18F 12N	R
1646+108	M	16 46 42·60	10 52 48·5	17·5	St	7F 12S	
1649+169	M	16 49 19·76	16 57 33·3	18·4	St	15P 2S	
1650+111	M	16 50 41·18	11 10 17·2	18·6	BSO?	5P 23S	
1658+171	M	16 58 52·39	17 07 02·2	18·5	BSO	13P 6N	

1452+165. This object is a double radio source, so that the radio position does not necessarily give an accurate centroid.

1518+156. This object was noted as possibly being slightly blue. The improved position makes it a possible identification (see Section 4*b*).

1522+113. This source is called 1522+112 in the MC2 catalogue.

1523+161. This source ought not to have been claimed as an identification by Hazard and Murdoch (1977).

1549+107. The 20^m galaxy of unspecified type listed by Hazard and Murdoch (1977) is not visible on the Sydney copy of the Palomar prints.

1559+157. See the following note for 1600+158; if the interpretation given there is correct, this identification would not apply.

1600+158. The optical positions given are for a pair of apparently interacting galaxies close to the centroid of this source and 1559+157. These two sources may therefore be associated with the pair of galaxies.

1600+121. The radio declination is wrongly listed by Hazard and Murdoch (1977); it should be 12° 06′ 48″.

1618+168. The object listed is the galaxy marked in the finding chart by Hazard and Murdoch (1977). There is possibly a plate limit object to the north-east closer to the radio position.

4. Discussion

(*a*) *Recalibration of Molonglo Catalogues*

An attempt has been made to improve the calibration of the MC2 and MC3 surveys on the basis of the confirmed identifications. The present comparison is restricted to confirmed QSOs, BL Lac objects, and galaxy identifications which have been confirmed by an accurate Texas radio position (Ghigo and Owen 1973; Douglas *et al.* 1973; Sharp and Bash 1975; Ghigo 1977), and is also restricted to radio sources with $S_{408} > 0\cdot7$ Jy. There are 13 sources from MC2 and 16 from MC3 which meet these criteria. The corrections $\Delta\alpha$ and $\Delta\delta$ implied by the comparison, together with the standard deviations $\sigma_{\Delta\alpha}$ and $\sigma_{\Delta\delta}$, are:

for MC2

$$\Delta\alpha = 1\cdot0''\pm0\cdot9'', \quad \sigma_{\Delta\alpha} = 3\cdot5''; \qquad \Delta\delta = 1\cdot0''\pm1\cdot1'', \qquad \sigma_{\Delta\delta} = 4'';$$

for MC3

$$\Delta\alpha = 1\cdot4''\pm1\cdot8'', \quad \sigma_{\Delta\alpha} = 7''; \qquad \Delta\delta = -1\cdot2''\pm1\cdot5'', \quad \sigma_{\Delta\delta} = 6''.$$

The values of $\Delta\alpha$ and $\Delta\delta$ are given in the sense of the correction to be applied to the catalogue radio positions to align them with the unweighted mean of the optical positions. There is no clear evidence of any need to change the catalogue calibration at this stage.

(*b*) *Revision of Suggested Identifications*

Five sources formerly claimed as BSO identifications are now beyond the 2σ limit on taking into account the accurate positions. Of these, 1523+161 should not have been claimed as an identification, while for 1645+174 it was noted that the galaxy was the correct identification based on a more accurate position (Argue *et al.* 1973). The remaining three objects (1410+154, 1517+166 and 1623+173) are outside the 2σ limit by $< 3''$ arc and still merit further investigation, although they should be discarded from the statistics. A further suggested identification, 1301+117, occurs at the 2σ limit. One BSO, 1505+112, previously beyond 2σ, is now also at the 2σ limit. On the revised position, 1518+156 should be included in the list of possible neutral stellar identifications. Ghigo (1977) listed it as a probable QSO, although the agreement with the Texas radio position is not particularly good. Previously suggested galaxy identifications which are now beyond the prescribed $20''$ arc limit in either right ascension or declination are 1529+104 and 1336+106.

Three BSO identications (1207+118, 1307+121 and 1639+155) are confirmed by Texas radio positions (generally available only for the stronger sources) and the only BSOs rejected on this basis are 1410+154 and 1523+161 already noted above. One BSO, 1210+121, noted by Hazard and Murdoch (1977) as a star is now found to have a featureless continuum in an observation with good signal to noise (J. A. Baldwin, personal communication). Suggested galaxy identifications rendered unlikely by Texas positions are 1359+103, 1509+102, 1537+162 and 1558+116.

(*c*) *Comparison with Other Published Positions*

A comparison of the present optical positions with the published measurements of Veron and Veron (1973, 1975, 1977); Wills *et al.* (1973) and Wills and Wills (1976); and Ghigo (1977) is given in Table 2. In the comparison with the Wills data, one source has not been included where the difference in position is $>2''$ arc in each coordinate, but Ghigo's (1977) measurement of this source agrees with ours. In the comparison with Ghigo (1977), one declination has been rejected where the

Table 2. Comparison between optical positions

Values are given relative to those obtained in the present work

Observer[A]	No. of observations	μ_α (″)	σ_α (″)	μ_δ (″)	σ_δ (″)
Veron	24	$-0\cdot08 \pm 0\cdot13$	$0\cdot63$	$0\cdot08 \pm 0\cdot14$	$0\cdot68$
Wills	10	$-0\cdot04 \pm 0\cdot16$	$0\cdot51$	$-0\cdot04 \pm 0\cdot26$	$0\cdot81$
Ghigo	31	$0\cdot02 \pm 0\cdot08$	$0\cdot43$	$0\cdot02 \pm 0\cdot10$	$0\cdot52$

[A] Measurements are by Veron and Veron (1973, 1975, 1977), Wills *et al.* (1973) and Wills and Wills (1976), and Ghigo (1977).

difference is $>2''$ arc. If one further case where the difference is $1\cdot5''$ arc were rejected, the r.m.s. error would be $0\cdot45''$ arc. Ghigo (1977) suggested that, due to an undiagnosed fault in the Texas measuring machine, his r.m.s. errors should be regarded as being in the range $0\cdot5''$–$0\cdot7''$ arc. The present comparisons would suggest that, apart from two declinations, the r.m.s. error is no more than $0\cdot35''$ arc in either coordinate. In fact the results (apart from the two discrepant declinations) are consistent with an r.m.s. error of $0\cdot32''$ arc in both our measurements and those of Ghigo. The comparisons with Veron and Veron are consistent with their claimed r.m.s. error of $0\cdot5''$ arc.

Acknowledgments

One of us (N.S.) acknowledges an S.R.C. Fellowship, and use of facilities and hospitality at R.R.E. Malvern and the Institute of Astronomy, Cambridge. The other (H.S.M.) thanks the Institute of Astronomy for hospitality during part of this project and acknowledges the support of the Australian Research Grants Committee, the Science Foundation for Physics within the University of Sydney and the University Research Grants Committee. We thank A. N. Argue for communicating unpublished results, R. L. Adgie for details of his SAO–AGK3 comparison and R. W. Hunstead and C. Hazard for profitable discussion. We also thank Mrs K. Burdett and Mrs S. Dowsett for the measurements with the Sydney University measuring machine.

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Manuscript received 16 October 1978