IDENTIFICATION OF PARKES RADIO SOURCES ON ADH PLATES

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The Parkes Catalogue of Radio Sources (*Ref.* 1 and 2) lists positions of point radio sources in the Southern Hemisphere. By restricting the catalogue to point sources and by avoiding a strip of sky centred on the galactic equator, the survey hoped to detect principally extragalactic objects, which may provide accurate positions to calibrate other surveys if the objects can be identified optically, and thus accurate optical positions obtained. Uncertainties in positions are quoted in the Parkes survey in the range ± 6″ to ± 45″, the most common values being in the range ± 10 — 15″ in both R.A. and Dec. On ADH plates (scale = 68″ per mm) this corresponds to about ±0.2mm. On the Sartorius Iris Photometer at Armagh, positions can be estimated with an accuracy of 0.1 mm, and this instrument is therefore suitable for searching ADH plates for Parkes objects. The illuminated field of the photometer has a diameter of 2′.6 on ADH plates, so the error rectangle of most Parkes objects occupies about 10% of a diameter. This makes for comfortable viewing of the region around the source position on the screen where the illuminated field is projected.

ADH photographs of selected regions were obtained by Bester, Andrews, and Eksteen in the periods May-October, 1966, and June-July, 1967 as part of a programme to search for optical identifications of MSH radio sources (*Ref.* 3). From these, plates with exposures of 60 minutes were selected, of which there were 23 on IIa-0 emulsion without filter, 27 on 103a-0 emulsion with UG2 filter, 13 plates on 103a-E emulsion with Wratten 25A filter, and one plate on IIa-0 emulsion with BG12+GG18 filters. Of these 64 plates, 24 were found to lie near enough to a Parkes object to warrant a search. One further plate (No. 8224) with 25 min exposure and U filter was also searched. The plates searched are listed in Table 1. Each line refers to one Parkes object which is expected to lie on the plates listed on that line. The plate numbers are given in columns headed by the emulsion-filter combination.

Table 1

Numbers of ADH Plates Searched

Parkes Cat. Number	103a-0+UG2	IIa-0	IIa-0+BG12+GG18	103a-E+W25A
1416-49	7976	8012	—	8060
1459-41	8024, 8563	—	—	8067
1839-48	7998	8576	—	8124
1910-55	8581, 8036	8037	—	8149
1932-46	8224	—	—	—
1933-58	8225, 8572	8241	—	8229
2006-56	8043	8044	—	8150
2014-55	8043	8044	—	8150
2020-57	8043	8044	—	—
2253-52	8226	8244	8243	8262

All the 25 plates were taken at zenith distances less than 46°. Differential refraction is less than 0′.1 and, besides, it is taken into account by the linear scale coefficients in reducing the plates. Possible curvature terms due to the optics (the ADH plate is flat) are probably less than 1″ and can be neglected, which allows us to use the standard astrometric reduction analysis given by Smart (*Ref.* 4) (*cf.* also *I.A.J.*, 8, p. 253, 1968).

On each plate 12 standard stars were identified on the Star Atlas of Reference Stars and Nonstellar Objects of the Smithsonian Astrophysical Observatory (SAO), and positions were taken from the associated SAO Star Catalog, relative to the 1950 equinox. (An error was noted on the star atlas. The star Iota Telescopii, SAO Catalog No. 229751, is listed as magnitude 5.0, but appears on the charts as a ninth magnitude star.) A computer programme was written for the ICL 1905 computer to solve for the plate constants using an arbitrary number of standard stars (greater than three) with positions relative to an arbitrary equinox. The standards are first precessed to any desired equinox, and are then used to evaluate the coefficients in the linear least squares equations. To allow for reduction of plates taken on either the ADH or on the Schmidt camera at Armagh (scale = 143″ per mm), the programme allows for a choice of two focal lengths.

Having obtained the astrometric plate constants each Parkes object was treated as four objects at positions ($\alpha \pm \Delta\, \alpha, \delta$) and ($\alpha, \delta \pm \Delta\, \delta$), where the Catalogue position is (α, δ) and $\pm\, \Delta\, \alpha, \Delta\delta$ are the quoted uncertainties. Four pairs of the plate coordinates (x', y') were therefore obtained for each object, defining a rectangle in the field of the photometer. Within these rectangles possible candidates for optical identification are now discussed.

(1) 1416-49.

The list of Shimmins *et al.* (*Ref.* 2) does not quote an uncertainty in declination for this source, so an error rectangle cannot be completed. They claim that a 17th magnitude E galaxy is the optical identification. The object they refer to may be a galaxy which appears on the red plate at position $\alpha = 14^h\ 16^m\ 46^s$, $\delta = -49°\ 21'.9$. The R.A. is within the Parkes uncertainty. The declination is 0′.9 N of the listed figure. They suggest that this source is the same as MSH 14-44 which is listed in *Ref.* 3 as $14^h\ 17^m.6 \pm 0^m.4$, $-49°44'$ $\pm 7'$, and is an extended source. The galaxy on the red plate differs in position from the MSH position by three times the probable error in R.A. and twice the p.e. in Dec. The optical identification must therefore be considered questionable, although the good agreement in R.A. with the Parkes value makes the E galaxy a possible candidate. On the blue plate the galaxy is very faint. On the U plate it is invisible.

(2) 1459-41.

In three colours there is only one object within the error rectangle. This looks like a star with a tail about 10″ long. The tail might be a galaxy partially obscured by the star. This tail is the suggested identification.

(3) 1839-48.

Within the error rectangle there is a star and part of a group of four diffuse objects near the plate limit on both red and blue plates. These may be interacting galaxies with centroid 15″ N and 8″ W of the Parkes position. The group is 30″ by 10″, the longest axis directed NE-SW. The MSH catalogue lists this source (MSH 18-44) as having an angular size greater than 30″. This makes it probable that the elongated group of galaxies is the optical identification.

(4) 1910-55.

On blue and red plates there are two objects inside the error rectangle. One is stellar, the other is fainter, extended, and seems to have a point source within the extended image. The point source is detectable on one U plate, but no surroundings are visible on this plate. This may be a Seyfert galaxy, and is the suggested identification, 10″ SE of the Parkes position.

(5) 1932-46.

Only one plate is available, a U plate. The error rectangle is blank.

(6) 1933-58.

Only one object is within the error rectangle on both blue and red plates. It is non-stellar, seen more clearly in blue, where it suggests a barred spiral. This is a probable identification.

(7) 2006-56.

On all plates the error rectangle is blank. On red and blue plates there is an E4 galaxy 54″ to the west of the Parkes position. Bolton *et al.* (*Ref.* 1) remark that the source extends more than 1′ NS and more than 35″ EW. A rectangle of these dimensions centered on the position of Shimmins *et al* (*Ref.* 2) does not include the E galaxy. The position quoted by Bolton *et al.* is even farther removed from the galaxy, being about 2′ East of the optical object. The galaxy is invisible on the U plate. This source has been previously identified as an S0 galaxy of 17th magnitude. An E4 galaxy seen at shorter exposure might appear like an S0 galaxy, but the position difference between radio and optical objects makes the identification questionable.

(8) 2014-55.

On all three plates only one object is within the error rectangle. It is circular but non-stellar, probably an E0 galaxy. This has been previously identified as a 15.5 mag E galaxy.

(9) 2020-57.

On blue and red plates only one object appears within the error rectangle. It is very faint and stellar in appearance. The MSH catalogue remarks that the radio source has an angular size smaller than 15″. Perhaps a QSO.

(10) 2253-52.

There is an extended non-stellar object on the western edge of the error rectangle at $22^h\ 53^m\ 49^s$, —52° 14′ 51″, visible only on the blue plate. A second object of similar brightness on the blue plate lies 35″ N of the error rectangle. This second object is visible on the red plate but nothing is visible on the location of the first object, which is the suggested identification. The first object is therefore a blue object, but it is too faint to distinguish structure.

Table 2 summarizes the positions of the optical objects suggested as identifications for the selected radio sources.

Table 2

Suggested Identifications for Parkes Radio Sources (1950.0)

Parkes Cat. Number	Radio Source h m s	Position ° ′	Optical h m s	Position ° ′	Remarks
1416-49	14 16 44	—49 22.8	14 16 46	—49 21.9	E galaxy
1459-41	14 59 06	—41 54.0	14 59 05	—41 53.8	Galaxy partially obscured by star
1839-48	18 39 27	—48 39.7	18 39 26	—48 39.5	Optical position is at centroid of four interacting galaxies
1910-55	19 10 14	—55 11.0	19 10 14	—55 11.1	Seyfert galaxy (?)
1932-46	19 32 19	—46 27.5	—	—	No identification
1933-58	19 33 18	—58 45.3	19 33 17	—58 45.3	Barred spiral (?)
2006-56	20 06 24	—56 39.0	—	—	Error rectangle blank; bright E4 galaxy 54″ to the West
2014-55	20 14 05	—55 49.1	20 14 05	—55 49.0	Bright E0 galaxy
2020-57	20 20 23	—57 33.3	20 20 22	—57 33.4	Quasar (?)
2253-52	22 53 51	—52 14.9	22 53 49	—52 14.9	Blue non-stellar object

References

(1) J. G. Bolton, F. F. Gardner, and M. B. Mackey, *Austral. J. Phys.*, 17, p. 340, 1964.

(2) A. J. Shimmins, M. E. Clarke, and R. D. Ekers, *Austral. J. Phys.*, 19, p. 649, 1966.

(3) B. Y. Mills, O. B. Slee, and E. R. Hill, *Austral. J. Phys.*, 13, p. 676, 1960.

(4) W. M Smart, " Spherical Astronomy ", Cambridge Univ. Press, 1949, pp. 283 and 297.

Armagh Observatory,
June 1970.

Note added September 30, 1970.

Optical identifications of Parkes sources on plates taken at the Newtonian focus (f/5) of a 61-inch reflector have been described by Bajaja (*Astron. J.*, 75, p. 667; August 1970). Three objects in the present search overlap with Bajaja's, namely, 1839-48, 1932-46, and 1933-58. Bajaja has a " highly probable identification" of 1839-48 with a "galaxy with an elliptical nucleus surrounded by an extended nebulous envelope". For the other two objects he finds no identifications.

The limiting magnitude quoted by Bajaja for IIa-0 plates exposed without filter for 30 minutes is approximately 18. For the ADH, IIa-0 plates exposed for 30 minutes with a blue filter allow measurement of *B* magnitudes to 17.8 mag (A. D. Andrews, *Tonantzintla Bulletin,* Vol. 5, p. 195; May 1970). The limiting magnitude is probably at least 0.5 mag fainter than this limit. An exposure of 60 minutes without filter is therefore expected to have a limiting magnitude fainter than 19. It is noteworthy that the ADH, aperture 32 inches, has a limiting magnitude about 1 mag fainter than a reflector with about four times the collecting area when the larger telescope is exposed for one-half the exposure of the smaller.

THE INTERSTELLAR MEDIUM AS A DETECTOR OF COSMIC RAYS*

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Cosmic rays are energetic particles detected by a variety of methods in the vicinity of the Earth. From the earliest detection of penetrating "radiation" coming from above the atmosphere by means of simple electroscopes to the very sophisticated ancillary electronics surrounding today's massive spark chambers, the investigators have steadily improved our knowledge of the cosmic rays. Fluxes measured by energy-sensitive detectors are now available as a function of energy from a few times 10^6 electron volts (eV) up to about 10^{20} eV. Relative abundances of different elements in the cosmic rays have emerged as more sensitive discriminants of nuclear charge have been developed.

These techniques, however sophisticated, all have one feature in common, and that is, they all give information on the cosmic rays in the vicinity of the Earth, or at most as far out as the orbit of Mars (*Ref.* 1). It is the aim of the cosmic ray theorist to account for the flux of cosmic rays in the galaxy, as well as the age, chemical composition and possible sources for the flux. The galactic flux is not the same as that measured near the Earth, so a theorist needs a method to obtain the galactic flux from the measured flux before he constructs a theory. He has two choices. One is to understand the processes which prevent the galactic flux from reaching the Earth in its entirety, and then invert the problem to determine the galactic flux which must impinge on the solar system in order to give rise to the flux observed at Earth. The second choice is to look for effects produced by the galactic cosmic rays *in situ* where there are no complications due to solar system effects. The second choice is our primary concern here, but in order to see the conditions in which this choice has an advantage over the first, we consider briefly the first method.

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* Based on a seminar given at University College, Dublin, March 7, 1970.