Infrared observations of highly variable radio sources in the galactic plane


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ABSTRACT

We have performed a comprehensive infrared imaging survey of 29 radio sources which were first detected by the UBC radio patrol survey of the galactic plane. The sources in our sample are the subset of variable and non-variable 'control' objects which were mapped with the VLA by Duric & Gregory. Since other sources in the original variability survey have been shown to be associated with unusual galactic X-ray and gamma-ray sources, the aim of the present work was to make the first steps towards discovering whether the remaining radio variables represent a hitherto undetected sample of faint, unusual X-ray binary stars. As a result, we have detected infrared sources coincident with seven of these radio objects and have varying degrees of confidence in their status as true counterparts. The infrared objects are typically far redder than surrounding stars in the same fields (J − K ∼ 2.5), and are generally invisible on the optical sky survey plates. In addition to this, as a result of scanning the POSS plates, we have uncovered optical candidates coincident with five radio positions. Most of these optical sources are close to the plate limiting magnitudes and only two objects are common between the sets of infrared and optical candidates.

Key words: surveys -- binaries: close -- infrared: stars -- radio continuum: stars.

1 INTRODUCTION

The University of British Columbia's radio patrol survey of the galactic plane (Gregory & Taylor 1981; Taylor & Gregory 1983; Gregory & Taylor 1986, hereafter GT) was performed over a 5-yr period using the NRAO 91-m telescope. As a result of this, a catalogue of 1274 discrete sources at 6 cm was constructed, of which 59 sources were classified as confirmed or possible radio variables. Variability on time-scales from days to years was seen, with flux changes of up to a factor of ∼ 8 in some cases. Further studies of a subset of the variable objects using the Very Large Array (VLA) (Duric, Gregory & Taylor 1987, hereafter DGT; Duric & Gregory 1988, hereafter DG) resulted in accurate radio positions (< 1 arcsec) as well as evidence for triple, double or extended radio structures in some cases. At the flux levels of these objects, the log N versus log S curve for extragalactic sources is well known, and suggests that many of the variable radio sources must be extragalactic. However, of particular interest is the fact that four of the variable objects in the original survey have been identified (with varying degrees of confidence) with galactic X-ray and γ-ray sources, namely

GT0116 + 622 with Cas γ-1 (Gregory et al. 1986; but see also Margon et al. 1992);
GT0236 + 610 with LSI +61°303 and CG135 +1 (Taylor & Gregory 1982; Cote et al. 1983);
GT2030 + 407 with Cyg X-3 (Gregory et al. 1972);
GT2318 + 620 with 4U2316 + 61 (Taylor et al. 1991).

Similarly, an object such as SS433 (e.g. Seaquist et al. 1982) would also have been detected by this survey had it been in the longitude range covered. Furthermore, it is increasingly apparent that radio emission from X-ray binaries is relatively common (see the review by Hjellming & Johnston 1986), although it may be very weak, as recent VLA observations of two low-mass X-ray binaries in globular clusters have demonstrated (Machin et al. 1990; Lehto et al. 1990). Bearing this in mind, there is the possibility that
other objects in the UBC radio variability survey may be the
counterparts to a previously undetected sample of faint,
unusual X-ray binary stars.

DG state that their initial search of the Palomar Observa-
tory Sky Survey (POSS) plates failed to reveal any secure
optical counterparts to the variable sources observed at the
VLA, except for the well-studied, 11th-magnitude star,
LSI+61°303 (GT0236 + 610). This is not entirely surpris-
ing, since the low galactic latitude of all the objects means
that a strong interstellar extinction is likely for all except
the very nearest. For comparison, Cyg X-3 has A_V = 19 and,
despite being relatively bright in the infrared (K = 11.9,
obtained by one of us using UKIRT, 1991 August), is
invisible in all optical images of the field (e.g. Gottwald et al.
1991). In an attempt to understand further the nature of
these sources, we have undertaken a programme of infrared
observations of all the objects with accurate (<1 arcsec)
radio positions reported by DG. This is a preliminary study
which will lead to further investigations at X-ray, optical and
radio wavelengths.

2 DETAILS OF THE OBSERVATIONS
The objects taken as the basis for this programme were the
28 radio variables and three non-variable control objects
observed with the VLA at both 6 and 20 cm, reported by
DG. Seven of these sources were actually observed on two
occasions at the VLA; during 1983 August and during 1984
December/1985 January (DGT). As noted above, one of
this sample, GT0236 + 610, is already well studied as the
peculiar radio star LSI+61°303, and so was not observed by
us. Also, observations of GT0116 + 62, possibly associated
with Cas γ-1, are reported elsewhere (Margon et al. 1992).
Here we report on infrared observations of the remaining 29
objects.

The majority of the sources were observed using the InSb
58 x 62 pixel imaging array at the 1.3-m telescope of the Kitt
Peak National Observatory (KPNO). The remainder were
observed using a similar device, IRCAM, on the 3.8-m
United Kingdom Infrared Telescope (UKIRT) as service
observations. (NB The work was begun as two separate
projects, by the authors in Seattle and Southampton, and
merged when we discovered each other to be attempting
essentially the same observations.) The log for all of these
observations is shown in Table 1, and indicates the exposure
time in the J, H and K wavebands in each case.
(GT0304 + 575 and GT2134 + 536 were observed at both
UKIRT and KPNO; GT0106 + 613, GT1937 + 215 and
GT2100 + 468 were observed on more than one night at
KPNO.) The instrumental configuration of the InSb detector
at KPNO resulted in an image scale of 1.33 arcsec per pixel,
whilst IRCAM on UKIRT was used in its 1.24 arcsec per pixel
mode. Hence all the observations resulted in the imaging of
an area of sky of roughly 1.2 x 1.2 arcmin^2, although most
of the UKIRT observations were performed as a small mosaic
around the source position to aid in the flat-fielding pro-
cedure. At KPNO, photometric standard stars from the list
of Elias et al. (1982) were observed, whilst the standards
observed at UKIRT were from a list compiled using the
standards of both Elias et al. (1982) and Allen & Cragg
(1982). Flat-fielding, sky subtraction and flux calibration of
the KPNO data were carried out using the IRAF package and
similar analysis of the UKIRT data was performed using the
Starlink IRCAM software (Aspin 1990; Aspin, Emerson &
Currie 1991). The infrared images and the potential counter-
parts they contain are discussed in Section 3.

In addition to these infrared observations, we also had the
relevant POSS plates scanned for each of the fields. We used
these data first to search for any objects coincident with the
radio positions, and secondly to provide astrometry for the
infrared candidates found at KPNO and UKIRT. The
possible optical counterparts for the radio sources are
discussed in Section 4.

3 THE INFRARED IMAGES
An initial inspection of the infrared images revealed objects
apparently coincident with seven of the radio positions given
by DG, namely GT0459 + 415, GT0556 + 239,
GT0630 + 082, GT1937 + 215, GT2100 + 468 and the
non-variable sources GT0007 + 635 and GT2000 + 297.
The K-band images for these fields are shown in Figs
1(a)-(g). In order to determine the precise positions of the
infrared candidates, we used the Starlink ASTROM package
(Wallace 1990) to determine astrometric solutions for each
J- and K-band image. Centroid positions were found for
(typically) six anonymous, reasonably bright, well-separated
stars in common between each POSS and infrared field. Plate
solutions were then determined for the J- and K-band
images in each of the above cases, resulting in solutions for
which the rms residuals are typically ~ 0.3–0.7 arcsec.
Since the candidates are detected at a level of ~ 5σ above
the background and are generally fainter than the stars used
to determine the astrometric solutions, we adopt the larger
value of this range as a typical uncertainty in the position of
each candidate infrared counterpart. This may be compared
with the seeing disc which was determined, by fitting
Gaussians to well-separated stars in each image, to have a
full-width at half-maximum in the range 1.5–2.0 arcsec for
both the KPNO and UKIRT observations. The results of this
astrometry are summarized in Table 2 and the individual
sources are discussed below.

GT0459 + 415 was detected by DG as an unresolved
(<1 arcsec) point source which GT classify as both a short-
term and a long-term variable. The source was observed at
two epochs by the VLA (DGT), during which
time both the integrated spectral index and flux density
increased. Polarized emission was also observed, decreasing
towards longer wavelengths (DGT). H I line observations
(Taylor & Searquist 1984) suggest that the radio source may
be extragalactic, although a galactic origin cannot be ruled
out.

The offset between the VLA radio position and the posi-
tion of the infrared candidate determined here is 0.75 arcsec.
Given the positioning uncertainties discussed above, it is
probable that the radio source and the infrared object are in
fact coincident. In order to investigate the relative colour of
the infrared candidate with respect to surrounding stars,
similar aperture photometry was performed on six other
reasonably bright, well-separated, anonymous objects in
the same image. Each of these was found to have a J – K colour
at least 1 mag lower than that of the candidate star, which
therefore appears to be the reddest object in the field. The
Table 1. Observing log with exposure times.

<table>
<thead>
<tr>
<th>Source Name</th>
<th>Observation Date(s)</th>
<th>Telescope</th>
<th>J exposure (sec)</th>
<th>H exposure (sec)</th>
<th>K exposure (sec)</th>
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<td>KPNO</td>
<td>400</td>
<td>–</td>
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<td>GT0034+626</td>
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<td>1200</td>
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<td>480</td>
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<td>11 Sep 1989</td>
<td>KPNO</td>
<td>400</td>
<td>–</td>
<td>400</td>
</tr>
<tr>
<td>GT0106+613</td>
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<td>KPNO</td>
<td>800</td>
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<td>600</td>
</tr>
<tr>
<td></td>
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<td>KPNO</td>
<td>1200</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
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<td>10 Sep 1989</td>
<td>KPNO</td>
<td>400</td>
<td>–</td>
<td>480</td>
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<tr>
<td>GT0252+574</td>
<td>09 Sep 1989</td>
<td>KPNO</td>
<td>–</td>
<td>–</td>
<td>240</td>
</tr>
<tr>
<td>GT0255+574</td>
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<td>KPNO</td>
<td>800</td>
<td>–</td>
<td>360</td>
</tr>
<tr>
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</tr>
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<td>600</td>
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<td>600</td>
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<td>1000</td>
<td>480</td>
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<tr>
<td>GT2134+536</td>
<td>11 Sep 1989</td>
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<td>400</td>
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<tr>
<td></td>
<td>16 Jun 1991</td>
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<td>GT2157+566</td>
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<td>KPNO</td>
<td>400</td>
<td>–</td>
<td>360</td>
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<td>GT2203+559</td>
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<td>KPNO</td>
<td>400</td>
<td>600</td>
<td>360</td>
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<tr>
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<td>400</td>
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<td>GT2257+577</td>
<td>11 Sep 1989</td>
<td>KPNO</td>
<td>400</td>
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<td>400</td>
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<tr>
<td>GT0007+635</td>
<td>11 Sep 1989</td>
<td>KPNO</td>
<td>400</td>
<td>–</td>
<td>500</td>
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<tr>
<td>GT1945+241</td>
<td>09 Sep 1989</td>
<td>KPNO</td>
<td>–</td>
<td>–</td>
<td>360</td>
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<tr>
<td>GT2000+297</td>
<td>10 Sep 1989</td>
<td>KPNO</td>
<td>800</td>
<td>–</td>
<td>360</td>
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</table>

unique colour of the infrared candidate, combined with its positional coincidence with the radio source, suggests that we have in fact detected the true counterpart to GT0459 + 415.

**GT0556 + 239** is also unresolved in the VLA images, with no significant polarization seen (DG). It was one of the most variable sources observed, varying between ~100 and ~800 mJy over several years (DG) and changing by ~100 mJy in the course of a week (GT).

The infrared images show a very red object ($J-K \sim 2.5$) close to the radio position. However, the astrometric solution to the fields reveals that, although the candidate is in the centre of the infrared image, it is in fact 1.7 arcsec from the point-like radio source. The two are therefore unlikely to represent the same object, but the association cannot be ruled out, since the radio position does lie within the 3σ error radius of the infrared point source.

**GT0630 + 082** appears as a close double with a separation of ~1.5 arcsec in the VLA images given by DG. It was classified both as a short-term and as a long-term variable. DG state that no significant polarization was detected at either 6 or 20 cm (text of paper), although a value of 1 per cent is listed in their table for the polarized fraction at 6 cm. We have also recently obtained a MERLIN 6-cm observation of this target, as part of a high-resolution radio study of a subset of these sources (Unger et al., in preparation). This
Figure 1. $K$-band images of the fields surrounding five of the variable radio sources (plus two non-variable) showing infrared candidates in each case. (a) GT0459+415, (b) GT0556+239, (c) GT0630+082, (d) GT1937+215, (e) GT2100+468, (f) GT0007+635, (g) GT2000+297. The VLA radio positions as quoted by DG are generally within one pixel of the central location of the infrared candidates (see text). In each case north is up and east to the left; scales are 1.24 arcsec per pixel for (a), (b) and (c), 1.33 arcsec per pixel for (d), (e), (f) and (g).
reveals, as suspected by DG, that the source is in fact a triple, with a faint core visible between the two lobes. Clearly, any optical or infrared counterpart would be expected to appear coincident with this core, rather than at the position listed by DG which corresponds to the brighter (southern) lobe.

The infrared field shows a very faint object in both the $J$ and $K$ images apparently coincident with the radio position, although this detection is marginal, with a significance $\sim 2.5 \sigma$. Its $J - K$ colour of $\sim 2.5$ is similar to that seen in GT0459 + 415, GT0556 + 239 and GT2100 + 468, and is again far redder than other objects in the same field. The infrared candidate is 0.7 arcsec from the VLA radio position (i.e. the southern lobe) and 1.2 arcsec from the MERLIN core position. It is possible that this object is the counterpart to the radio core seen using MERLIN, but, since the radio core position lies outside the $1 \sigma$ error radius of the infrared object, the association is not clear.

**GT 1937 + 215** was seen by DG as a complex, extended object stretching over $\approx$ 20 arcsec in an east–west direction. DG also detected a compact point source $\approx$ 3 arcmin to the south of this, which they claimed was suggestive of a potential triple source, but with no third component. The position of the original, variable source seen by GT actually lay between the extended and point sources seen by DG, so could be due to either one or a combination of both. The extended source seen by DG is coincident with the well-studied H II region 4C21.53W (Becker & Helfand 1983), although they did not note this. Furthermore, the millisecond radio pulsar PSR 1927 + 214 (Backer et al. 1982; Djorgovski 1982; Becker & Helfand 1983) is located $\sim 2.5$ arcmin to the south of 4C21.53W and may be the point source noted by DG. The apparent detection of radio variability from an H II region is surprising, although GT list this source as only ‘probably’ variable. DG suggest that, if the variability seen from GT1937 + 215/4C21.53W comes from a point source, then it may have been in a low state during the VLA observation. It seems more plausible, however, that the radio variability seen by GT was due to contamination of the signal by the millisecond pulsar.

The VLA position quoted by DG refers to the maximum flux density of the extended radio object, located towards the north-west of the source. The infrared image reveals a point source exactly at this radio position, as well as another, very red, object just to the east of this and close to the ‘geometrical centroid’ of the extended radio object. Both of these sources are listed in Table 2; note that their magnitudes are uncertain because of contamination of the image of one star by the other. The infrared images also show loop-like extended emission to the west of the radio position, which agrees well with the radio structure in this region (Fig. 1d). Given the nature of the radio source discussed above, it seems unlikely that any direct association exists between the infrared point sources and the variable radio source, despite the coincidence in position.
Table 2. Positions and magnitudes of infrared candidates.

<table>
<thead>
<tr>
<th>Source Name</th>
<th>Radio Positiona</th>
<th>Infrared Positionb</th>
<th>IR Magnitudes</th>
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<td>(RA / Dec : 1950.0)</td>
<td>(RA / Dec : 1950.0)</td>
<td></td>
</tr>
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<td>04 59 06.87</td>
<td>04 59 06.81</td>
<td>J = 16.8 ± 0.3</td>
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<tr>
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<td>+41 35 03.6</td>
<td>+41 35 03.3</td>
<td>K = 14.4 ± 0.3</td>
</tr>
<tr>
<td>GT0556+239</td>
<td>05 56 28.70</td>
<td>05 56 28.58</td>
<td>J = 19.1 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>+23 53 45.1</td>
<td>+23 53 44.6</td>
<td>K = 16.6 ± 0.3</td>
</tr>
<tr>
<td>GT0630+082</td>
<td>06 30 29.67</td>
<td>06 30 29.63</td>
<td>J = 20.2 ± 0.5</td>
</tr>
<tr>
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<td>+08 15 37.5</td>
<td>+08 15 37.2</td>
<td>K = 17.7 ± 0.7</td>
</tr>
<tr>
<td>GT1937+215</td>
<td>19 37 29.54</td>
<td>19 37 29.52</td>
<td>J = 15.2a</td>
</tr>
<tr>
<td></td>
<td>+21 30 35.6</td>
<td>+21 30 35.6</td>
<td>K = 11.5c</td>
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<td></td>
<td>19 37 29.86</td>
<td>J = 14.9b</td>
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<td>+21 30 34.2</td>
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<tr>
<td>GT2000+468</td>
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<td>21 00 33.50</td>
<td>J = 17.3 ± 0.2</td>
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<td>+29 45 23.0</td>
<td>+29 45 22.8</td>
<td>K = 15.7 ± 0.3</td>
</tr>
</tbody>
</table>

Notes: *position of maximum flux density in VLA image (DG) – this is not necessarily the centre of any double/triple lobe structure; †determined from a six-coefficient astrometric solution to the K-band image; ‡there is some contamination between these two stars – magnitudes uncertain.

GT 2100 + 468 is similar in appearance to GT0459 + 415 as an unresolved (< 0.1 arcsec) point source. The two-epoch VLA observations reveal an increase in the integrated spectral index as the flux density decreased (DG). As in the case of GT0459 + 415, it was classified by GT as both a short-term and a long-term variable, and polarized emission was also seen. H I data suggest that this object may be extragalactic (Taylor & Seabquist 1984), although, in the case of GT0459 + 415, a galactic origin is not excluded.

The infrared image clearly shows a relatively bright point source coincident with the radio position. The offset between the two positions is only 0.2 arcsec, well within the measurement uncertainty, and the candidate is once again extremely red (J − K = 2.4). In all respects this object is similar to GT0459 + 415 and we are confident that we have detected the true counterpart to the variable radio source.

GT 0007 + 265 was first observed by DG as a comparison object for the rest of the sample, since GT list it as a non-varying source. At 6 and 20 cm, a classical double-lobed radio structure was seen with no central core.

DG noted an optical object on the POSS plates, close to the centre of the major axis defined by the two lobes. The infrared source detected by us is clearly associated with the optical object, which we also detect using our scans of the POSS plates (see below). The optical/infrared object is 6.0 arcsec from the quoted radio position, but this refers to the northern lobe. Using our astrometric solution, it is also ~2 arcsec from the presumed position of any radio core. This would seem to be too far for the object to be considered as a reasonable counterpart, unless the (undetected) radio core is offset from the symmetry axis of the system.

GT 2000 + 297 was also observed by DG as a comparison, non-varying, object for the rest of the sample. The VLA shows a double structure separated by ~10 arcsec, with some evidence for a bridge of extended emission at 20 cm.

The quoted VLA position for this object refers to the southern and brighter of the two radio lobes (DG). The infrared image reveals a very faint source approximately 1 arcsec from this position, but nothing is apparent at the presumed ‘centroid’ of the radio emission where one might expect to find an optical/infrared counterpart. The association between the infrared object and the radio source is therefore not clear, but seems unlikely.

Other sources observed were found to have no infrared objects coincident with their radio positions. Upper limits to the magnitudes are typically J ~ 21 and K ~ 18, for the 10-min exposures made using UKIRT. For the observations made at KPNO, upper limits to the magnitudes are typically J ~ 18 and K ~ 16.

Although we have detected seven approximately coincident infrared objects, the fields, being close to the galactic plane, are crowded. We must therefore assess the likelihood of the infrared sources being merely chance detections in the same line of sight. The UKIRT/IRCAM fields contain, on average, ~12 sources per square arcmin, each with a full-width image diameter of ~6 pixels. Hence there is roughly a 15 per cent chance of any pixel containing part of the image of an infrared source. If we tighten the tolerance to include only those objects whose central pixel coincides with the radio position, the chance coincidence reduces to only ~1.5 per cent. The fact that we apparently see three coincident sources in the seven UKIRT/IRCAM pointings suggests that some of the infrared candidates are indeed associated with the radio sources. The observations made at KPNO (using a smaller telescope) are obviously not as sensitive as those made at UKIRT, and reveal on average ~8 sources per square arcmin, giving roughly an 11 per cent chance for any pixel to contain part of an infrared source or a ~1 per cent chance coincidence within the central pixel. Four sources in 24 fields (or five in 25 counting GT0116 + 622, see Margon et al. 1992) is higher than may be expected by chance alignment, but we note that the fields in question (i.e. for GT0007+265, GT1937+215, GT2000+297 and GT2100+468) are amongst the most crowded of the infrared images obtained. We also note that the GT0116 + 622 candidate, as discussed by Margon et al. (1992), probably has a superimposed foreground object in a chance alignment.

4 SCANS OF THE PALOMAR OBSERVATORY SKY SURVEY PLATES

DG stated that an initial search of the POSS plates revealed no optical counterparts to any of the variable radio sources in their survey. They noted, however, that the plates for the
non-variable comparison object GT0007 + 635 revealed a 15th-magnitude stellar-like source close to the centre of the double-lobed radio structure. In addition, DGT noted an optical object 3 arcsec away from GT0026 + 627 and two 16th-magnitude objects a similar distance from the northern component of GT2157 + 566. These last three objects seem to be too far away to qualify as genuine candidates for optical counterparts.

In order to perform a more sensitive search than was done by DG, both the blue and the red POSS plates for each of the radio sources in the VLA sample were scanned using the photometric data system (PDS) microdensitometer at the Royal Greenwich Observatory. The resulting digitized images were then processed using the automatic plate measuring (APM) software. In addition to the 15th-magnitude object close to GT0007 + 635 as noted by DG, detailed analysis reveals possible optical counterparts to seven more radio sources, all of which have magnitudes at about the plate limits – typically red ~ 20 and blue ~ 21.5, although these vary from plate to plate. The results of this search are summarized in Table 3. Some candidates are classified as either stars or galaxies by the APM software, as shown in the table; the ‘unclassified’ objects are extremely faint and cannot be sufficiently resolved from the plate noise for classification purposes.

The seeing of the POSS plates is typically ~1 arcsec, hence the final five objects in Table 3 (GT0342 + 538, GT0455 + 421, GT0459 + 415, GT0554 + 242 and GT2257 + 577) can be considered as realistic optical counterparts to the variable radio sources. Four of these sources are listed by DG as unresolved point sources, so the optical candidates are indeed close to the source of radio emission. The final source, GT2257 + 577, is listed by DG as a ‘double source with a jet’, but unfortunately they do not show a map of it in their paper. We can therefore only assume that the radio position refers to some central location of the 30-arcsec structure, although this is by no means certain.

5 DISCUSSION

Of the seven infrared candidates discussed earlier, two are extremely faint and uncertain detections (GT0630 + 082 and GT2000 + 297), two may be too far away to qualify as true counterparts (GT0556 + 239 and GT0007 + 265) and one is probably an obscured young star coincident with the peak radio intensity of an extended H II region (GT1937 + 215). This leaves two objects for which we can be reasonably certain about their link with the respective unresolved radio sources: GT0459 + 415 and GT2100 + 468. Furthermore, both the radio and infrared objects for these sources appear to have very similar properties. Coincidentally, these two sources are amongst the three objects for which Taylor & Seaquist (1984) obtained H I absorption measurements, the results of which led them to conclude that both GT0459 + 415 and GT2100 + 468 are probably extragalactic.

The ultimate aim of this investigation is to discover the nature of the variable radio objects, in particular whether they represent a sample of unusual galactic binaries or whether they are an extreme type of variable extragalactic object. We note that the $(J-K)$ colours of the counterparts we have found are extremely red, and certainly far redder than other objects in the surrounding fields. They are, however, comparable to the colours of, for instance, Cyg X-3 with $J-K = 3.3$ (data obtained by one of us using UKIRT, 1991 August), and SS433 with $J-K = 1.3$ (McAlary & McLaren 1980). As noted by Margon et al. (1992), some of the IRAS galaxies discussed by Sanders et al. (1988) also show comparable infrared colours in the range $J-K = 1.2-2.5$.

Although the infrared imaging so far performed has proved inconclusive with regard to identifying the nature of the variable radio objects, we have now detected a sample of optical and infrared candidates which we can study in more detail at these and other wavelengths. We aim to further this investigation with optical spectroscopic observations of all the candidates, which will enable a determination of whether or not they constitute a sample of galactic or extragalactic sources. An ongoing programme of radio mapping (using MERLIN) will also allow us to extend the baseline for variability studies and to detect fainter, smaller components (such as cores) in many of these objects. The motion of any
components over the ~ 10-yr baseline between the VLA and MERLIN observations, if detected, will also allow some
discrimination between galactic and extragalactic distances
to these objects.

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