Galaxy Candidates in the Zone of Avoidance

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15 July 1997

Abstract

Motivated by recent discoveries of nearby galaxies in the Zone of Avoidance, we conducted a pilot study of galaxy candidates at low Galactic latitude, near Galactic longitude \( l \sim 135^0 \), where the Supergalactic Plane is crossed by the Galactic Plane. We observed with the 1m Wise Observatory in the I-band 18 of the ‘promising’ candidates identified by visual examination of Palomar red plates by Hau et al. (1995). A few candidates were also observed in R or B bands, or had spectroscopic observations performed at the Isaac Newton Telescope and at the Wise Observatory. Our study suggests that there are probably 10 galaxies in this sample. We also identify a probable Planetary Nebula. The final confirmation of the nature of these sources must await the availability of full spectroscopic information. The success rate of \( \sim 50\% \) in identifying galaxies at Galactic latitude \( |b| < 5^\circ \) indicates that the ZOA is a bountiful region to discover new galaxies.

Key words: galaxies - extinction - Milky Way

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1 Introduction

Since the pioneering study of Kerr and Henning (1987) in searching for hidden galaxies behind the Milky Way, a number of studies have been completed where such objects have indeed been detected, e.g., the Sagittarius dwarf (Ibata, Irwin and Gilmore 1994) and Dwingeloo 1 (Kraan Korteweg et al. 1994, Loan et al. 1996, Burton et al. 1996). These studies relied on optical photographic plates, HI 21 cm surveys, infrared searches, or X-ray surveys (for reviews see Kraan-Korteweg and Woudt 1994; Lahav 1994, and Weinberger et al. 1995).

This paper studies some of the objects selected by Hau et al. (1995; hereafter HFLL) as galaxy candidates from a visual search of twelve Palomar Sky Survey (POSS) red (E) plates. The region, which covers $\sim 444$ square degrees of the sky, is centered on Cassiopeia at $l \simeq 135^\circ$ and $|b| \leq 20^\circ$. It has been surveyed with the intention of identifying a connecting structure of the Supergalactic Plane across the Galactic Plane, near the region of the Perseus-Pisces supercluster. HFLL identified 2575 galaxy candidates, one of them being the galaxy Dwingeloo 1, detected at 21cm (Kraan-Korteweg et al. 1994). Our primary motivation in conducting the imaging and spectroscopic follow-up of this study is to check if other nearby ‘obscured’ galaxies appear in the HFLL sample. The other purpose of this study is to estimate the number of galaxies among candidates selected by visual inspection of photographic plates at low Galactic latitude ($|b| < 5^\circ$). Although no obvious nearby galaxy was found, we are convinced that at least half of the candidates we observed are genuine galaxies.

2 Observations

Large objects from the survey of HFLL were scanned with the RGO PDS from the POSS red glass copies. We selected objects from this large galaxy candidate subset that ‘looked’ like galaxies on hard copies of the PDS scans. The subjective criterion was the degree of ‘softness’ of the edges of the candidate object, when compared to the stars in the image; this is the equivalent to the subjective visual selection of the candidates by HFLL, but on a contrast level that can be set to show optimally what we believe are galaxies. Our 18 selected candidates are listed in Table 1. Note that 15 of them are at low Galactic latitude ($|b| < 5^\circ$), a region where both obscuration and confusion with Galactic objects are strong.

Most objects were imaged during four nights in December 1994 at the Wise Observatory (WiseObs); the images were flat-fielded and sky-subtracted at the site. The observations were performed with the WiseObs Tektronix 1024×1024 pixel chip, with 24 $\mu$m pixels, corresponding to 0”.73 at the f/7 focus. Most observations were done in the I-band, as this spectral band samples the continuum in galaxies with $z \leq 0.2$ as well as in local emission nebulae. We expect
galaxies to be bright in the I band because of the strong contribution from late-type stars combined with the Galactic extinction. On the other hand, emission nebulae will usually have only faint continua in the I band, because their light is dominated by emission lines and is mostly in the R-band (H\textalpha, \[\text{NII}\] and \[\text{SII}\]), as well as in the V-band (\[\text{OIII}\] and H\beta). The same is true of reflection nebulae, expected to be abundant close to the Galactic Plane. These would be much fainter in I than in bluer bands. Thus, while galaxies are expected to be bright both on the POSS plates (mainly on the E-plate) and on our I-band images, emission or reflection nebulae will be hardly visible in our images despite being detected on the POSS images. There is one caveat to this explanation; a reddened reflection nebula will appear on both images, but the likelihood of this happening and still have a fairly smooth and symmetrical image is small.

A few objects were observed with the INT CCD camera during service nights in December 1994. These observations, as those from WiseObs, were in the I band. W. Saunders, O. Keeble, R. McMahon and S. Maddox (private communication) kindly provided spectra of a few sources during an INT observing run and a few spectra were also obtained with the WiseObs FOSC (Brosch & Goldberg 1994). Such observations are very useful in disentangling galaxies from emission nebulae.

All our candidates were observed with the Dwingeloo 25 meter radio telescope, in the same 21 cm band and velocity range as originally used for the Dwingeloo Obscured Galaxies Survey (Henning et al. 1997) i.e. 0-4000 km/sec in 1 hour scans (12 × 5 minutes in ON-OFF strategy), with flux limit of 40 mJy (rms per channel). In no case was a meaningful signal detected. We note that a non-detection in 21cm does not necessarily imply that an object is not a galaxy. It may have low HI content or be at recession velocity larger than 4000 km/sec.

We also consulted catalogues for possible counterparts at different wavelengths, specifically searching for IRAS point sources which could discriminate between Galactic dust and extragalactic sources. Any sources that emit at 12.5 and 25\(\mu\)m but not at 60 and 100\(\mu\)m are not galaxies. Hau et al. (1994) remarked on the FIR color segregation of sources that if \(\frac{I_{100}}{I_{60}} > 4\), a source is most probably a Galactic cirrus cloud. Sources with \(\frac{I_{60}}{I_{25}} < 1\) and \(\frac{I_{100}}{I_{12.5}} < 1\) are likely to be stars (Meurs & Harmon 1988).

3 Results

3.1 Individual sources

In this section we discuss the individual sources, based on the PDS scans of the POSS plates and on the images collected at WiseObs. Wherever we have spectroscopic information, we describe this along with the appearance on the images. The PDS images of the objects are shown in
Figures 1 and 2 and the WiseObs linear intensity images are shown in Figures 3-5. Table 1 gives Equatorial and Galactic coordinates of the objects, and our proposed classification. The discussion of individual objects includes also catalog information retrieved from data banks (NED) within a 3 arcmin radius of each candidate. In the following, names of the objects are specified by the HFLL label (e.g., C36), as well as by Galactic coordinates (Gl.l.l±bb.bb).

C36 (G132.45-3.38)

This object was not included in our imaging sample because of the lack of time at the telescope, but its spectrum was fortunately taken with the INT. It has been classified by HFLL as an ‘elliptical’ and identified as MCG 10-04-001, a galaxy with no given redshift, 0.1 arcmin away. Interestingly, it is the only galaxy listed by Vorontsov-Velyaminov & Krasnogorskaja (1962, MCG) on this PSS plate. They call it a 17th mag, 1.5 diameter overexposed image, with traces of structure which imitates the large-nucleus variety galaxy. Weinberger et al. (1995) quote a 0.4 diameter of the red image.

The INT spectrum shows absorption features at λ6670, 5955, and a wide feature at ~5255Å, identifiable as Hα, NaI 5890 and the Mgb band at a redshift of ~0.015. The spectrum has not been flux-calibrated, but has been corrected for atmospheric extinction and is strongly inclined towards the red. The object is probably a reddened galaxy at z≈0.015, either the bulge of an early-type spiral or an E+A type, based on the spectroscopic evidence.

C39D1 (G133.63-3.62)

Classified by HFLL as dwarf elliptical, spiral or noise. This is our best case of a clear-cut galaxy among the sources imaged in this pilot program. The PDS scan and our I-band image are virtually identical, showing a diffuse, round nebulosity centered on a bright, star-like object. The PDS scan shows a nearly round nebulosity; the I-band image is not fully symmetrical, but its Western side is brighter and more extended than the Eastern side. The I-band size of the nebulosity is 40" × 20". It is not clear why this object was not selected as a candidate galaxy by Weinberger et al. (1995).

Unfortunately the INT spectrum is of poor quality. This object warrants additional spectroscopic observations to establish the identification as a galaxy and to measure its redshift.

C41 (G134.09-0.98)

Classified by HFLL as dwarf elliptical or noise. The PDS scan showed at this location a very large, faint surface brightness patch, approximately centered on a group of three stars. The central group is definitely present on both the I and the B images we have for this object, but the diffuse patch is absent on both. It is possible that the object is a large, diffuse emission nebulosity, about 2 arcmin in size, which does not register in our I band. The lack of appearance
on the B image is confirmed by the absence of the object on the O plate of the POSS. This is a case where either R-band or Hα imagery is called for. We can, however, conclude that this is not a good candidate for a galaxy. Note that this is not considered a galaxy candidate by Weinberger et al. (1995).

**D30H15 (G135.74-4.53)**

Classified by HFLL as elliptical or noise. The PDS scan is similar to the Wise I-band image, which shows a source elongated in the North-West to South-East direction. There is a possible slight bending and a segment of a circle or ellipse. The appearance on the PDS scan of the E-plate of the POSS is of a diffuse patch, corresponding more or less to the brighter part of the circular segment in the I image. The source is also visible on the O plate. Based on this, we would classify it as a good candidate for a galaxy.

**C9 (G133.87+2.53)**

This source appears extended on the POSS plates, but our I and B images indicate that the intensity profile is not different from that of other stars in the CCD field. The source consists of two stars, the northern one fainter in both bands than the southern. Both the INT and WiseObs spectra indicate that both stars have Balmer absorption lines, with the fainter star having a comparatively bluer continuum. Based on the presence of strong Hα to Hδ lines in the spectrum of the brighter component, we tentatively classify it as a late-B or early-A star. The Hα detection is confirmed by an INT spectrum, which also shows a NaI absorption line, both at rest velocity. The fainter component must, in this case, be a late-O or early-B star. The C9 candidate can fairly safely be identified as a pair of early-type stars (although classified by HFLL as ‘elliptical’). There is an IRAS PSC source 02272+630 2 0.2 arcmin away from C9. Its FIR colour, $I_{100}/I_{60} \approx 4.0$, probably indicates some cirrus or cold dust contamination in the direction of these early-type stars.

**C26 (G135.91-0.47)**

HFLL classified it as an ‘elliptical’. The PDS scan of this source shows a $\sim 40''$ nebulosity centered on a bright star-like source. Our I band image shows no trace of the nebulosity, although the star-like source is present. In our view, and considering the difference in spectral bands between our I-band and the POSS E plate, this is an indication of an emission nebula, either a planetary nebula (PN), or an HII region. These objects have almost no continuum emission, but only line contribution, where the strongest lines in the yellow-red region are [OIII], Hα, [NII] and [SII]. None will appear in our I band image, thus no nebulosity will be visible. We conclude that, for this source, our best interpretation is that it is some sort of Galactic emission nebula.
C14J14 (G136.21+1.08)

The appearance of this source on the PDS scan (also in Fig 13 of HFLL) is of a diffuse, almost circular patch with a bright centre. HFLL classified it as ‘unknown/elliptical’ (but suggest a spiral based on the PDS scan). The difference between the I-band image and the PDS scan may indicate a real difference in the source aspect when viewed in different spectral bands. An INT spectrum shows that the source has strong Hα absorption at rest velocity and a much weaker NaI, thus it can be safely identified as a star, perhaps A-type; the diffuse source could be connected with this star.

E94K86 (G141.06-9.30)

Classified by HFLL as SB. The central object of the I band image certainly confirms the appearance of the source on the PDS scan (Figures 1 and 2), also shown in HFLL). The bright, small (40" × 20") nebulosity is only the central region of a larger spiral-like nebulosity, whose extension to the South and East can be discerned in the I image. The source coincides with UGC 2209, a 16.5 mag spiral galaxy 1.7 arcmin away with diameters 1.0 × 0.6. Its diameter on the I image (1.4) is larger than listed in the UGC. Our underexposed B image does not show the nebulosity. An INT spectrum shows Na I in absorption at λ ≃ 6055 ± 10 Å and a wide feature at ∼5320 Å, identifiable as Hβ and Mgb, and indicating a redshift of ∼0.028. If indeed at this redshift, its I-band diameter corresponds to ∼34 kpc, suggesting a big galaxy.

K88 and K89 (G141.08-9.22)

Classified by HFLL as 2 ellipticals. Our I-band image of E94K86 shows two other diffuse images which also show up in our shallow B-band image. In Figure 4 the objects can be seen at coordinates (x ∼ 0, y ∼ 350), as two diffuse ‘blobs’, each about 30" in diameter. These look very much like a pair of elliptical galaxies and are listed in HFLL as K88 and K89. We therefore conclude that these are also “real” galaxies.

HFLL proposed that E94K86 may have collided with the K88+K89 system; in absence of redshift information on the binary system, and because of lack of evidence for K88+K89 being disrupted in any way, we cannot comment on this possibility. In addition, if we accept the large extent of UGC 2209 as indicated by our I-band image and its undisturbed appearance, there does not appear to be any link between the objects. K88+K89 could well be its background. Also, close inspection of the PDS scan and of the I-band image reveals a number of faint, diffuse images in the vicinity of K88+K89. This is probably evidence for a distant cluster of galaxies at this location, and the pair K88+K89 could be its brightest central galaxies.

C8 (G135.62+2.76)
This source was given a morphology of ‘star or unknown’ by HFL L. This source is extended on the POSS plates; it was not observed at the WiseObs, but a spectrum was secured at the INT. It shows clear signs of a Galactic emission nebulosity, with Hα, [NII] and [SII] emission at rest velocity. There is a strong somewhat reddish continuum and a hint of Hβ in absorption at the blue end of the spectrum; we classify the object as an early-type star with a compact HII region. IRAS source 02421+6233 with \( I_{100}/I_{60} \approx 1.4 \) is 0.3 arcmin away.

**C11J7 (G135.80+2.72)**

HFL L classified it as unknown/spiral. This source appears as an East-West elongated diffuse streak in the PDS scan. We confirm this aspect from the I image, where the streak is at least two minutes long. The PDS scan (also shown in Fig. 13 in HFLL) indicates the presence of a bright, star-like condensation close to the brighter part of the diffuse streak. It is possible to interpret this as the bulge of a disk galaxy close to edge-on. In this case, and considering the bulge-to-disk ratio, the galaxy cannot be earlier than Sb. We note that under heavy obscuration the disk shrinks more than the bulge because of surface brightness effects. The object may be a member of the Maffei-IC342 group. The INT spectrum is underexposed and, unfortunately, does not allow a classification.

**J17 (G138.97+2.65)**

Classified by HFLL as ‘unknown/SB’. The PDS scan shows here a source with two condensations, that to North-West brighter than the second. A similar aspect is visible on the O-plate. Our I-band image confirms this description. The outer boundaries of the I-band image are about 2′×40″. The location of the bright condensation is not central to the nebulosity; if it is not a superposed star, the more likely alternative is that we are viewing a system of interacting galaxies. The object is similar to Arp 267, or 287, or 309. HFL L remarked that the proximity of this objects to Dw1 (< 3°) suggesting it may be part of the Maffei-IC342 group. The ZCAT lists for this object a velocity of 2350 km/sec (Huchtmeier & Richter 1989), which would argue for the object being in the background of the Maffei-IC342 group. The IRAS PSC shows a nearby source (03067+6055), and the 60-to-100 \( \mu \)m ratio indicates this is a galaxy. Radio source 87GB 030703.3+605537 is 2.4 arcmin away.

**J4 (G139.31+4.84) and J5 (G139.32+4.85)**

We combine these two sources not only because they appear on the same I-band image, but also because we believe them to be parts of the same emission nebulosity. The sources appear as two round condensations on the PDS scan, located nearly symmetrically around a brighter star. There is a faint common envelope around both sources, which is \( \sim 90″ \times 35″ \). The I and R images are shown in Figure 5. Our R-band image is almost identical with this description, but
the I-band image, although with stretched contrast, does not show the source. This is another case where we believe that the sources are parts of an emission nebula, perhaps a two-lobe planetary nebula (PN).

The IRAS PSC lists a source reasonably nearby (03188+6236) with [100]=11.79 and marginal detection at 60 µm; this indicates again the presence of cold dust near the candidate, thus a Galactic origin. Lacking a spectrum of the star we cannot be certain of the nature of the nebulosity; however we tend to believe this to be a small HII region, or a PN. If its size is typical for PNs (∼1pc), its distance could be ∼2.3 kpc.

**J22 (G140.72+3.02)**

Classified by HFLL as noise or dwarf elliptical. This is an elongated patch on the PDS scan, which is visible also on the O plate, but is not visible on our I-band image. Our interpretation is again of an emission nebula, which has no continuum in the I-band.

**J18 (G140.93+3.98) and J19 (G140.98+4.02)**

Classified by HFLL as 'unknown' and 'unknown/spiral' respectively. The two objects appear on the same I-band images and both are good candidates for galaxies. The size of J18 is ∼90″×40″ and the major axis PA is ∼30°. J19 is smaller, only 40″×20″, and its major axis is at PA≃0°. We believe both to be disk galaxies, perhaps Sa or S0.

The INT spectrum is underexposed and shows no features useful for classification. The radio source 87GB 032605.9+605943 is 1 arcmin away and is possibly connected with the two galaxies. The IRAS PSC contains a source IRAS03264+6100 close to the pair. Its FIR colour indicates cirrus emission.

### 4 Discussion

We observed 18 candidate objects from HFLL, selected on basis of their appearance on red images, and classified with reasonable degree of confidence 10 as possible galaxies. Four objects are probably stellar, within the Milky Way, one is a probable planetary nebula, and 2 are of uncertain nature. The ∼50% success rate in finding objects at Galactic latitude |b| < 5° which “look” like galaxies, some of which were confirmed as such by spectra, indicate that the Zone of Avoidance (ZOA) is not completely devoid of clear patches through which one can look out of the Milky Way. We note that in other searches the success rate of classifying galaxies among visually selected candidates in the ZOA was reported to be higher (e.g. 98 %, Kraan-Korteweg et al. 1994).

In retrospect, we recognize the importance of the I-band as the primary determinant of the nature of a source. The images in this band sample only the continuum both for z < 0.2
galaxies and for Galactic nebulae, whereas the POSS E-plates sample not only continuum but also emission line contributions. Combining the information about the aspect of a source on the POSS E-plate and in our I-band images, we were able to recognize which sources were galaxies and which were emission nebulae.

For future studies, it may be useful to add an Hα filter at rest wavelength in place of the R-band used here sometimes. A comparison with the I image would show even better which sources are emission line objects. The proposed Hα survey of the Galactic Plane with the UK Schmidt telescope (Parker et al. 1995) can be used to reject HII regions and Planetary nebulae.

The importance of the search for galaxies and clusters of galaxies in this direction lies in that it samples a region along the Supergalactic Plane, near the Perseus-Pisces supercluster in the opposite direction of the Great Attractor. It will therefore be interesting to probe the space distribution of galaxies there.

Acknowledgements

We thank J. Pilkington for the PDS scans, W. Saunders, O. Keebles, R. McMahon and S. Maddox for obtaining the INT spectra, and P. Henning and B. Burton for their part in the Dwingeloo observations. Observations at the Wise Observatory are supported by a Center of Excellence Award from the Israel Science Foundation. OL acknowledges the hospitality of the Wise Observatory.

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Table 1: Source classification

| Object   | α(1950)    | δ(1950)    | l    | b    | Observations | Proposed classification          |
|----------|------------|------------|------|------|--------------|-----------------------------------|
| C36      | 02:00:50.6 | 57:54:06   | 132.4| -3.4 | Is           | Galaxy                           |
| C39D1    | 02:08:46.7 | 57:19:50   | 133.6| -3.6 | Wi, Is       | Galaxy                           |
| C41      | 02:18:35.7 | 59:41:11   | 134.1| -1.0 | Wi           | No ID: plate defect ?            |
| D30H15   | 02:21:02.4 | 55:47:02   | 135.7| -4.5 | Wi           | Galaxy ?                         |
| C9       | 02:27:14.2 | 63:02:32   | 133.9| +2.5 | Wi, Ws, Is   | Two stars and nebulosity         |
| C26      | 02:33:25.8 | 59:29:34   | 135.9| -0.5 | Wi           | Star+ emission nebula            |
| C14J14   | 02:40:41.2 | 60:47:07   | 136.2| +1.1 | Wi, Is       | Star                             |
| E94K86   | 02:41:02.5 | 49:20:22   | 141.1| -9.3 | Wi, Is       | Galaxy                           |
| K88      | 02:41:18.7 | 49:24:27   | 141.1| -9.2 | Wi           | Galaxy, cluster ?                |
| K89      | 02:41:18.7 | 49:24:27   | 141.1| -9.2 | Wi           | Galaxy, cluster ?                |
| C8       | 02:42:06.7 | 62:33:45   | 135.6| +2.8 | Is           | Star+HII                        |
| C11J7    | 02:43:22.6 | 62:27:06   | 135.8| +2.7 | Wi, Is       | Galaxy ?                         |
| J17      | 03:06:43.6 | 60:55:17   | 139.0| +2.7 | Wi           | Galaxy/interacting pair          |
| J4+J5    | 03:18:55.7 | 62:36:41   | 139.3| +4.8 | Wi           | Planetary nebula/HII region     |
| J22      | 03:20:24.9 | 60:18:56   | 140.7| +3.0 | Wi           | No ID                            |
| J18      | 03:26:13.9 | 60:59:59   | 141.0| +4.0 | Wi, Is       | Galaxy ?                         |
| J19      | 03:26:41.8 | 61:00:07   | 141.0| +4.0 | Wi, Is       | Galaxy ?                         |

Notes to Table 1:

- Wi=WiseObs imaging (mostly in the I band)
- Ws=WiseObs spectra
- Is=INT spectra
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