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A 2 x 2 Degree I-band Survey around PKS 1343−601

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Abstract. Motivated by the possibility that the highly obscured ($A_{\rm B} = 12\overset{\rm m}{.}$) radio galaxy PKS 1343−601 at $(\ell, b, cz) = (309\overset{\circ}{.}7, +1\overset{\circ}{.}8, 3872\,{\rm km\,s^{-1}})$ might constitute the center of a heavily obscured cluster in the Great Attractor region, we have imaged about $2^\circ \times 2^\circ$ of the core of this prospective cluster in the I-band using the WFI at the ESO 2.2 m telescope at La Silla. We were able to identify 49 galaxies and 6 uncertain galaxy candidates. Although their distribution does not resemble a centrally condensed, massive cluster, its appearance – severely influenced by the strong dust gradient across our surveyed region – is entirely consistent with a cluster.

1. Introduction

The Great Attractor (GA), a large extended mass overdensity in the nearby Universe, was discovered from the infall pattern of elliptical galaxies (Dressler et al. 1987). Kolatt et al. (1995) determined its center and found it to ly exactly behind the southern Milky Way at $(\ell, b, cz) = (320^\circ, 0^\circ, 4000\,{\rm km\,s^{-1}})$. Because of the increasing dust absorption at lower Galactic latitudes it has remained difficult to assess whether this mass density is being traced by the galaxy distribution.

The deep optical galaxy search of partially obscured galaxies in the GA region (Woudt & Kraan-Korteweg 2001) revealed the Norma cluster (ACO 3627) at $(\ell, b) = (325.3^\circ, -7.2^\circ)$ to be a region of very high galaxy density in the GA region. Follow-up redshift observations found the Norma cluster to be comparable in size, richness and mass to the Coma cluster, albeit nearer by a factor of 1.4 (Kraan-Korteweg et al. 1996; Woudt et al. these proceedings). It is therefore the most likely candidate to constitute the previously unrecognized bottom of the potential well of the Great Attractor (GA) overdensity.

Is Norma the only massive cluster behind the Milky Way in the GA region or might other clusters form part of a much broader and hence more massive core of the GA? The identification of possible further dynamically important mass contributors to the GA at lower latitudes is problematic, however, because of the high extinction in the optical, star-crowding in the near-infrared surveys DENIS and 2MASS, and even in X-rays – despite the fact that dust extinction and stellar confusion are unimportant – because of the photoelectric aborption at high Galactic HI column densities.

1.1. The PKS 1343−601 Galaxy

PKS 1343−601 is the 2nd strongest radio continuum source in the southern sky ($f_{20\mathrm{cm}} = 79\,\mathrm{Jy}$; Mc Adam 1991 and references therein) and lies at very low latitudes $(\ell, b) = (309.^\circ7, +1.^\circ8)$. Woudt (1998) and Kraan-Korteweg & Woudt (1999) did suspect that this radio galaxy might constitute the central galaxy of a cluster: this galaxy lies behind an obscuration layer of about 12^m extinction in the B-band, as estimated from the DIRBE/IRAS extinction maps (Schlegel, Finkbeiner, & Davis 1998) and is not visible in the optical. With a diameter of 28 arcsec in the Gunn-z filter and, based on the Hα emission line, a recession velocity of $cz = 3872\,\mathrm{km\,s^{-1}}$ (West & Tarenghi 1989), it must be a giant elliptical galaxy (a diameter of about 4 arcmin if corrected for extinction effects using Cameron's (1990) extinction laws). Such galaxies are not generally isolated but found at the cores of clusters.

If PKS 1343−601 marks the dynamical center of a cluster, then the Abell radius, defined as $1.'7/z$ where z is the redshift, corresponds to $R_\mathrm{A} = 2.^\circ2 = 3\,h_{50}^{-1}\,\mathrm{Mpc}$) on the sky at the redshift-distance of PKS 1343−601. In the optical, only a handful of highly obscured galaxies (at the highest latitudes and lowest extinction levels) could be identified within this radius and even 2MASS reveals only 9 galaxy candidates within this radius.

As rich clusters generally are strong X-ray emitters, we searched for evidence of such emission. PKS 1343−601 has not been detected with ROSAT but the soft X-ray emission would be strongly absorbed by the Galactic HI at that position. It has, however, been detected with ASCA (Tashiro et al. 1998) showing slightly extended diffuse hard X-ray emission at the position of PKS 1343−601. The flux of kT = 3.9 keV is quite high for a single galaxy, hence could be indicative of emission from a cluster. However, recent higher resolution X-ray observations with XMM do not support this supposition (see Schröder et al., these proceedings). The extended X-ray emission is thus probably due to the Inverse Compton process in the radio lobes, as already suggested by Ebeling, Mullis, & Tully in 2002.

Interestingly enough, the ZOA Parkes Multi Beam H I survey does uncover a significant excess of galaxies at this position in velocity space (Kraan-Korteweg et al. 2004; Henning, Kraan-Korteweg, & Staveley-Smith, these proceedings).

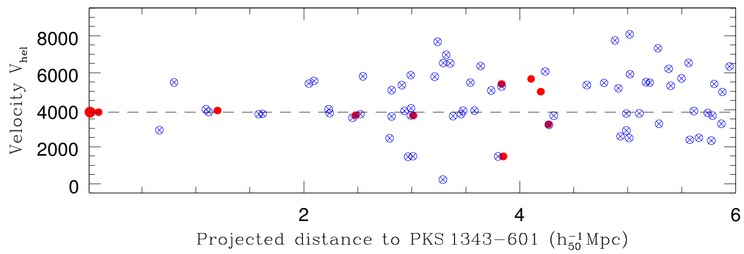

Figure 1. The velocity distribution as a function of distance from PKS 1343−601. The crossed circles are galaxies detected in the Parkes ZOA Multibeam Survey (Henning et al., in prep.), the filled circles from optical velocity data as given in LEDA.

However, no "finger of God" is obvious, the characteristic signature of a cluster in redshift space. Then again, HI is not a good tracer of high-density regions such as cluster cores, since spiral galaxies generally avoid the cores of clusters or are HI depleted (Bravo-Alfaro et al. 2000, Vollmer et al. 2001).

The HI-velocities plus the few known optical velocities within the Abell radius and its immediate surroundings provide some dynamical support for the existence of this cluster. Not only do we find a significant peak in the velocity histogram at the velocity of PKS 1343−601, but the velocities as a function of distance from the cluster center lie within a narrow range of the central radio source and are well separated in velocity space from field galaxies (see Fig. 1).

To verify whether PKS 1343−601 indeed marks the center of an obscured cluster, we have imaged the core of this prospective cluster in the *I*-band in which extinction effects are less severe ($A_{\rm I} = 0.45 A_{\rm B}$) using the Wide Field Imager WFI of the ESO/MPG 2.2-m telescope at la Silla.

2. The 2 x 2 Degree *I*-band Survey

A total of 16 WFI fields, each $34' \times 33'$, covering a total area of about $2^\circ \times 2^\circ$ were observed in May 1999. The surveyed area is outlined in Figs. 3 and 4 together with the Abell radius of the prospective cluster. The field centered on PKS 1343−601 has a slightly higher exposure time (1500s compared to 600s) and consists of 5 dithered exposures to improve the spatial resolution.

After standard reduction with *IRAF*, all the images were inspected visually. The small images of the strongly obscured galaxies and the heavy star-crowding (partly covering the galaxies) make an automatic detection algorithm impossible. A constant changing of the intensity and contrast levels while viewing a field brings out the more extended low surface brightness borders of galaxies and also emphasizes the difference in the light distribution between stars and galaxies. This procedure makes the identification of such obscured objects more feasible.

In this way, 49 galaxies were identified, 25 of them probably of elliptical morphology, in addition to 6 uncertain galaxy candidates. A sample of galaxy images, from the brightest to the faintest galaxies, is displayed in Fig. 2.

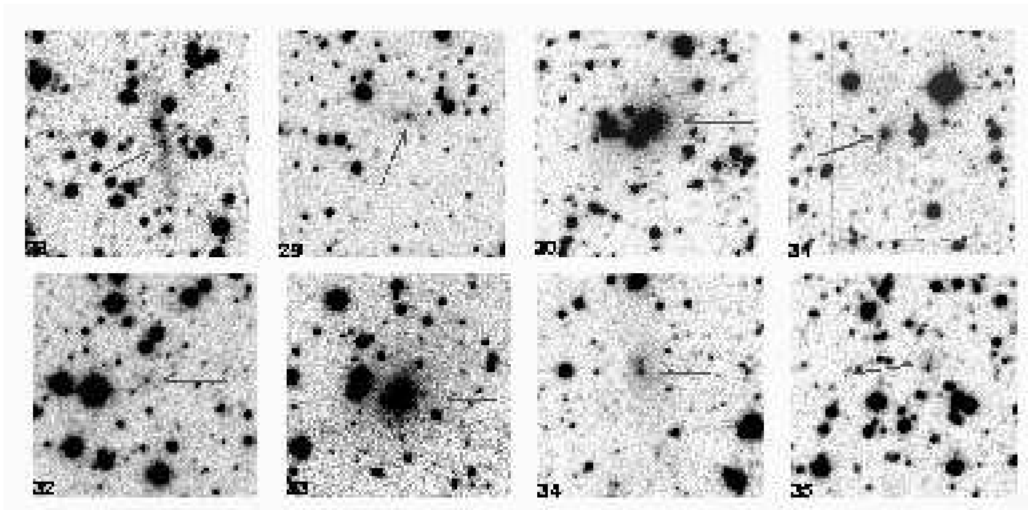

Figure 2. An image gallery of 8 of the 49 certain galaxy candidates identified around PKS 1343−601 on the I-band images. Each image is about $36'' \times 36''$.

Galaxy 33 is the giant radio galaxy PKS 1343−601 ($A_{\rm I} = 5\overset{\rm m}{.}5$). The spiral galaxy (# 28) is by far the largest galaxy identified in this survey but it is located in an area of relatively low extinction ($A_{\rm I} = 2\overset{\rm m}{.}2$). Galaxies 29, 30, 32, 33 and 34 are from the central field and although some of them look like mere smudges (e.g. # 32) all of them are independently confirmed by a NIR survey (J, H, K') of the central $36' \times 36'$ region of this possible cluster using the Japanese/South African Infrared Survey Facility (Nagayama et al. 2004; Nagayama at al., these proceedings). In fact these recent observations reveal the very low surface brightness galaxy # 34 at $A_{\rm I} = 5\overset{\rm m}{.}5$ to actually be a very extended edge-on spiral galaxy.

3. The Detected Galaxy Distribution

The distribution in Galactic coordinates of the unveiled galaxies is shown in Fig. 3. The outlined square region indicates the area imaged with the WFI in the I-band (16 fields of $34' \times 33'$ each) around PKS 1343−601 (large dot), and the circle the Abell radius of $R_A = 2\overset{\circ}{.}2 = 3\,h_{50}^{-1}$ Mpc. The filled circles mark the 25 elliptical galaxies and the crossed circles the 24 spiral galaxies. Note that the morphology is very uncertain due to the heavy obscuration. The open circles show another 6 uncertain candidates.

The distribution shows that is was possible to identify galaxies to extinction levels of $A_{\rm I} \lesssim 5\overset{\rm m}{.}0$, i.e., to similar extinction levels within this photometric passband compared to our deep optical galaxy searches in the B-band where we identified galaxies down to $A_{\rm B} \lesssim 5\overset{\rm m}{.}0$ (Kraan-Korteweg 2000; Woudt & Kraan-Korteweg 2001). Ellipticals are found mainly at higher extinction levels while at lower extinction levels spirals predominate. As the cores of ellipticals and

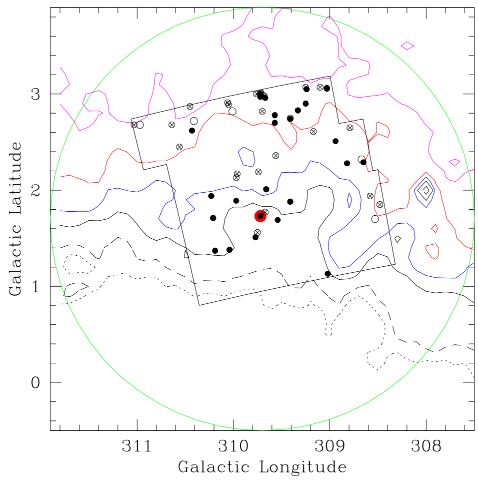

Figure 3. The distribution in Galactic coordinates of the identified galaxies. The surveyed area is marked as the tilted square. The circle corresponds to the Abell radius. Filled, crossed and open circles mark elliptical, spiral and uncertain galaxies. The contours indicate extinction levels in the *I*-band: $A_I = 2\overset{m}{.}0, 3\overset{m}{.}0, 4\overset{m}{.}0, 5\overset{m}{.}0$ (solid), $7\overset{m}{.}5$ (long dash) and $10\overset{m}{.}0$ (short dash) following Schlegel et al. 1998.

bulges of spirals contain mainly the red old star population this trend was to be expected. It is still interesting to note that the density of ellipticals seems to show a concentration around PKS 1343−601, even though the distribution does not match our expectations of a normal, centrally condensed, rich cluster. Its appearance is, however, strongly modulated by the extinction gradient. To assess whether the unveiled distribution really is consistent with a rich cluster hidden behind an increasingly thickening exinction layer, we simulated how a rich cluster would appear at the position of PKS 1343−601.

4. Does the Galaxy Distribution Indicate a Galaxy Cluster?

For the simulation, we have used the deep Coma cluster catalog of 6724 galaxies by Godwin, Metcalfe, & Peach (1983). First we move the rich Coma cluster at the radial velocity of PKS 1343−601. This results in an extension of the cluster size and galaxy diameters by a factor of $f = 1.77$ and an increase in brightness of $\Delta m = 1\overset{m}{.}24$. We then transform the *B*-band magnitudes to the *I*-band with a mean color term of $(B - I) = 2\overset{m}{.}0$ which is representative of early-type galaxies as well as bulges of spiral galaxies. Although it is difficult to assess the magnitude limit obtained with the here used non-standard narrow *I*-band filter ($\Delta\lambda = 275$ Å centered on $\lambda = 9148$ Å), we estimate to be able to find galaxies to a standard *I*-band magnitude of $I_{\rm lim} \approx 17\overset{m}{.}5$. Applying this cut-off would leave us with 1578 galaxies in our surveyed cluster area. The left panel in Fig. 4 shows the resulting distribution, where the symbols are proportional to brightness.

However, we still have to take the effect of dust absorption into account. Even in the *I*-band, the minimum absorption is $A_{\rm I} \approx 2^{\rm m}$ increasing to a maxi-

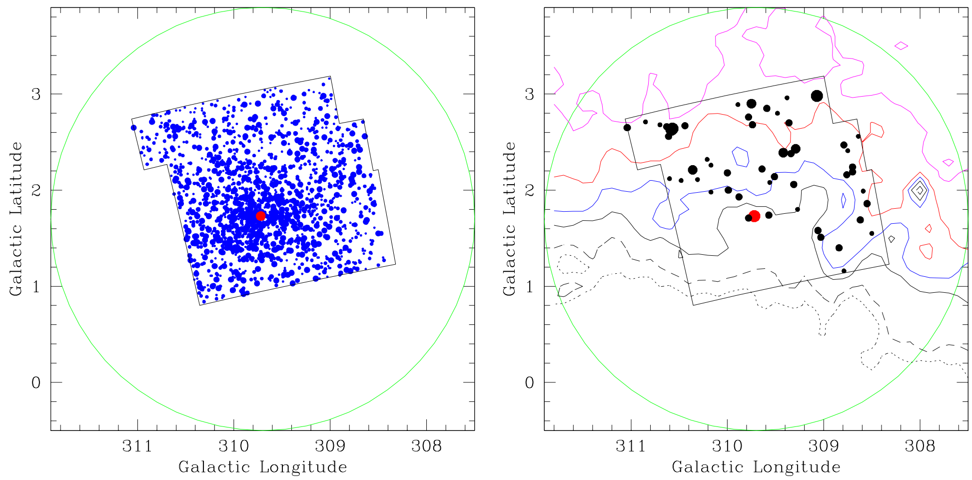

Figure 4. Left panel: Simulation of the distribution of Coma cluster galaxies if it would be positioned at the redshift space of PKS 1343−601, and would have been observed under the same conditions with the with the Wide Field I-band imager at La Silla. Right panel: Remaining galaxies if the cluster galaxies are subjected to the same foreground extinction (extinction contours as in Fig. 3).

mum of $A_\mathrm{I} \approx 10^\mathrm{m}$. Absorbing each galaxy individually according to the DIRBE extinction value at their respective positions (see contour levels in Fig. 3) using the inverse Cameron laws (1990), leaves only 51 identifiable galaxies. Their distribution is shown in the right panel of Fig. 4.

This number is entirely consistent with the number of galaxies identified in our real search (49 certain and 6 uncertain galaxy candidates). The resulting distribution furthermore is a near replica of the actual detections (compare right panel of Fig. 4 with Fig. 3): galaxies are found down to the same extinction level of about $A_I \lesssim 5$m. Only Coma's two cD galaxies peak through slightly thicker extinction layers – similar to PKS 1343−601 – and the galaxy numbers within the various extinction intervals are quite similar.

5. Discussion

The simulation thus seems to suggest that the uncovered galaxy distribution in our I-band survey around PKS 1343−601 is consistent with being due to a galaxy cluster at the position and distance of PKS 1343−601. Care should, however, be taken when interpreting the galaxy simulations. Small changes in, e.g. the estimated I-band magnitude limit, the actual distance, the Cameron (1990) extinction corrections (which are type-dependent and determined for the B-band), assumption of a fixed $B-I$ color term, etc., might alter the simulated galaxy distribution significantly. Furthermore, the fact that no X-ray emission typical of a massive cluster (Ebeling et al. 2002, Ebeling et al., these proceedings, Schröder et al., these proceedings) argues against a very rich cluster. The most likely interpretation therefore is, that there exists a cluster around

PKS 1343−601, but that it rather is an intermediate-mass cluster like Hydra or Centauraus, which is in agreement with the independent analysis by Nagayama et al. 2004, Nagayama et al., these proceedings.

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