A redshift survey between the clusters of galaxies A548 and A3367

G. Andreuzzi1,2, S. Bardelli3, R. Scaramella2, and E. Zucca4

1 Osservatorio Astronomico di Capodimonte, via Moiariello 16, I-80131, Napoli, Italy
2 Osservatorio Astronomico di Roma, via Osservatorio 2, I-00040, Monteporzio Catone (RM), Italy
3 Osservatorio Astronomico di Trieste, via G.B. Tiepolo 11, I-34131, Trieste, Italy
4 Osservatorio Astronomico di Bologna, via Zamboni 33, I-40126, Bologna, Italy

Received ; accepted

Abstract. In this paper we present the results of a spectroscopic survey of galaxies in an area between the two clusters of galaxies A548 and A3367, suspected to be a close and interacting pair. With the use of multifiber spectroscopy, we measured 180 new velocities of galaxies in the central part of A3367 and in the external regions of A548.

The redshift histogram shows the presence of three velocity peaks, at $v \sim 12000$ km/s, $v \sim 30000$ km/s and $v \sim 40000$ km/s, respectively. For these we estimate the density excess, the mean velocity, and the velocity dispersion.

The first clump corresponds to an elongation of A548: in particular we found a correspondence between the features of this peak and the substructures of A548. The second peak has a velocity dispersion which is typical of clusters and the distribution of its members on the plane of the sky corresponds to the highest density peak in A3367. We therefore suggest that the name A3367 has to be attributed to this clump.

Our general conclusion is that, differently from expected, A548 and A3367 do not form a close pair of merging clusters, since the two structures are at significantly different redshifts. Moreover, we found that the complex dynamical structure of A548 has large coherence, with a projected extension in the range of 1-3 h$^{-1}$ Mpc.

Key words: Galaxies: clusters: individual: A548, A3367; Galaxies: clusters of; Galaxies: distances and redshifts

1. Introduction

The determination of the galaxy distribution in clusters provides information on the status and the history of these structures through the study of their dynamics. Detailed studies spanning the entire range of morphologies of rich clusters of galaxies are important for understanding the formation and evolution of these systems. In a class of current cosmological models (e.g. cold dark matter dominated), rich clusters are formed hierarchically, by accretion of smaller subunits.

Several clusters are indeed known to present very lumpy morphologies (see e.g. Kriessler & Beers 1997 and references therein) revealing that these systems are in a merging process. The best studied examples are A2256 (Briel, Henry & Böhringer 1992), where a small group is detected in the X-ray band nearby the cluster center, and Coma, where a number of substructures are revealed (Biviano et al. 1996). Among the most spectacular cases are the encounters between clusters of similar richness, as for the A3558 complex (Bardelli et al. 1994, 1996, 1998a, 1998b), where the dynamical processes reach unusual intensities, or the cluster A3528, which is actually split into two merging X-ray emitting regions of similar properties (Schindler 1996).

The study of merging clusters is important because this process is thought to be responsible for a wide number of properties of the cluster galaxy population. Radio halos and relics of radiosources are found in clusters that visually present some degree of disturbance (Feretti & Giovannini 1996) and Burns et al. (1994) explained as a consequence of a merging event the presence of post-starburst galaxies in the large scale X–ray emitting filament connecting Coma with the NGC4839 group.

A good starting point to individuate merging cluster candidates is that to extract close pairs from supercluster catalogues, as f.i. the list of Zucca et al. (1993), which reports groups of ACO clusters (Abell, Corwin & Olowin...
1989) as a function of the density contrast. In this catalogue, the cluster pairs individuated by a density excess > 200 are very close systems, where often the nuclei are separated by less than one Abell radius (∼ 1.5 h⁻¹ Mpc, hereafter h=H₀/100): one of these pairs is formed by A548 and A3367.

The centers of the two clusters in the ACO catalog are separated on the plane of the sky by 77 arcmin, corresponding to ∼ 2 h⁻¹ Mpc at the distance of A548. The separation in velocity was less clear: in fact the cluster A548 is reported to have a mean velocity of $v = 12394$ km/s (determined on 133 redshifts, Davis et al. 1995), while A3367 had reported a value of $v = 12780$ km/s (based on 6 velocities, Postman, Huchra & Geller 1992). However, Postman & Lauer (1995) reported a velocity of $−25^\circ1727''$, containing 11525 objects to the limiting magnitude $b_J < 21.5$.

Fig. 1 shows the isodensity contours obtained binning the data in 2 × 2 arcmin cells and smoothing with a Gaussian of 6 arcmin of FWHM. For the two clusters circles of one Abell radius have been drawn around their nominal center. Note that it is already evident that A548 is not a smooth cluster with a single central nucleus, but presents multiple condensations. Inside the Abell circle of A3367 we note a single condensation shifted northward with respect to the nominal center. In Fig. 1b, the same isodensity contours are shown with superimposed the OPTOPUS fields positions.

The coordinates of the centers of these fields are listed in columns (2) and (3) of Tab. 1, together with the observation date in column (4).

### Table 1. Observed OPTOPUS fields

| FIELD | $\alpha$(2000) | $\delta$(2000) | Date   |
|-------|----------------|---------------|--------|
| f51a  | 05$^h$49$^m$24$^s$ | −24$^\circ$35'00'' | 25/02/93 |
| f51b  | 05$^h$49$^m$24$^s$ | −24$^\circ$35'00'' | 26/02/93 |
| f52   | 05$^h$49$^m$90$^s$  | −25$^\circ$00'00'' | 25/02/93 |
| f53   | 05$^h$49$^m$24$^s$ | −24$^\circ$10'00'' | 26/02/93 |
| f61   | 05$^h$50$^m$46$^s$  | −25$^\circ$09'47'' | 16/10/93 |
| f62   | 05$^h$50$^m$46$^s$  | −24$^\circ$39'52'' | 17/10/93 |

2.2. Observations

Spectroscopic measurements were obtained using the ESO 3.6m telescope at La Silla, equipped with the OPTOPUS multifiber spectrograph (Lund 1986), on the nights of 1993 February 25-26 and October 16-17. The OPTOPUS multifiber spectrograph is formed by a bundle of 50 optical fibres at the Cassegrain focal plane of the telescope; this field has a diameter of 32 arcmin, and each fibre has a projected size on the sky of 2.5 arcsec.

We used the ESO grating #15 with 300 lines/mm and a blaze angle of 4°18′. This grating allows a dispersion of 174 Å/mm in our wavelength range (3700–6100) Å. We used the detector Tektronic 512 × 512 CCD with a pixel
2.3. Data Reduction

The extraction of the one-dimensional spectra was performed using the APEXTRACT package as implemented in IRAF. Positions and tracing solutions of lamps and objects were determined on the flat field exposures. The procedure we adopted to estimate the relative transmission of each fibre is based on the fitting of a Gaussian profile to the [OII]5577 line in each spectrum and on computing the continuum-subtracted flux of this line (Bardelli et al. 1994). If we assume that the flux and the shape of the spectrum of the night sky remain constant in the telescope field, this value is the same in each spectrum apart from the transmission of the fiber, which is a multiplicative factor. After having normalized the spectra, we can subtract the ‘mean sky’ obtained as the average of the 4 sky spectra.

2.4. Redshift data

We have obtained a total of 276 spectra: 45 were not useful for redshift determination (16% of the total), because of poor signal–to–noise ratio or badly connected fibers, and 51 turned out to be stars (22% of the reliable spectra), leaving us with 180 galaxy redshifts. The galaxies whose spectrum presents detectable emission lines are 79, corresponding to a percentage of 44% of the total.

The radial velocities of galaxies with spectra with absorption lines have been determined using the program XCSAO in the IRAF task RVSAO (Kurtz et al. 1992), which is based on the cross-correlation method of Tonry & Davis (1979). The determination of redshift is done by fitting a parabola to the main peak of the cross-correlation function. Sixteen different templates (eight stars and eight galaxies) were used for the determination of the radial velocities, choosing as better estimate the one which gave the minimum cross-correlation error, defined as:

\[ \epsilon = \frac{3}{8} \frac{w}{(1 + r)} \]  

where \( w \) is the FWHM of the cross-correlation peak and \( r \) is the ratio between the height of the correlation peak and the \( rms \) of the antisymmetric part of the correlation function (Kurtz et al. 1992).

To estimate the redshift of spectra with strong emission lines we used the EMSAO program in the IRAF task RVSAO.

The top panel of Fig. 3 shows an example of a spectrum with strong emission features, with [OII]λ3727, [Hβ]λ4861, [OIII]λ4959, λ5007 lines, while in the bottom...
The panel of Fig. 2 displays a spectrum with only absorption lines presented. A spectrum with strong emission lines ($v = 13954\pm29$ km/s) and its internal error (in km/s), from absorption and emission lines respectively. The code in column (6) indicates the presence of emission lines: the symbols a, b, c, d, refer to [OII]λ3727Å, [Hβ]λ4861Å, [OIII]λ4959Å and [OIII]λ5007Å, respectively.

In Table 2, we list the galaxies with redshift determination. Columns (1), (2) and (3) list the right ascension, the declination and the $b_J$ magnitude respectively; column (4) and (5) give the heliocentric velocity ($v = cz$) and its internal error (in km/s), from absorption and emission lines respectively. The code in column (6) indicates the presence of emission lines: the symbols a, b, c, d, refer to [OII]λ3727Å, [Hβ]λ4861Å, [OIII]λ4959Å and [OIII]λ5007Å, respectively.

We remember that the cross-correlation errors are only internal formal errors. In order to have true statistical errors, these values have to be multiplied for the factor 1.53.
found by Vettolani et al. (1998) comparing multiple observations of the same galaxies: after this correction, the average statistical error on our velocities is \( \pm 95 \) km/s. If one wants to take into account also the uncertainties introduced by the different reduction procedures, the factor is slightly larger and has the value of \( \sim 1.9 \) (see Bardelli et al. 1994).

In order to check the zero point precision of our velocity scale, we considered the histogram of the measured velocities of the stars misclassified as galaxies (Fig. 3), which are expected to have a zero mean velocity. Considering only the 41 spectra with the higher signal-to-noise ratio, we found \( \langle v \rangle = 22 \pm 14 \) km/s (\( \sigma_{\text{stars}} = 90 \) km/s): this small systematic effect will be neglected in the following analysis, since the errors associated to the galaxy velocities are larger. However, we cannot exclude that the value of \( \langle v \rangle = 22 \) km/s is completely due to bulk motions of stars in this region of the sky.

Very recently, Cappi et al. (1998), analysing the ESP survey (Vettolani et al. 1997, 1998), noted a systematic difference between the velocities estimated from the emission lines and the cross-correlation for the same galaxy, with an average difference of \( \langle v_{\text{obs}} - v_{\text{emiss}} \rangle = 93 \pm 6 \) km/s (obtained from more than 700 galaxies). Our observations are taken in the same instrumental configuration of the ESP survey and can give an independent estimate of this effect, although with a smaller sample. On the basis of 10 galaxies, we find \( \langle v_{\text{obs}} - v_{\text{emiss}} \rangle = 60 \pm 30 \) km/s, consistent within the errors with the result of Cappi et al. (1998).

### 3. Discussion

In Fig. 4, the histogram of the galaxy velocities is shown. It is clear the presence of at least three peaks (labelled as A, B, C in the figure): the first is at a velocity of \( \sim 13000 \) km/s, the second and the third at \( \sim 30000 \) km/s and \( \sim 40000 \) km/s, respectively. Peak A is at the same velocity of A548 and presents a clear bimodality.

Although no significant differences (through a K-S test) are found between the overall distributions of galaxies with and without emission lines, a more detailed analysis of the three peaks reveals that the two distributions inside the single peaks are in fact different (see Fig. 5). In particular, for peak A it is evident a separation in velocity, being the population of emission line objects dominant in the clump at lower velocity: the percentage of emission line galaxies with respect to the total in this clump is 54\%, while it is 39\% in the higher velocity clump. Because galaxies with and without emission lines have different luminosity functions (Zucca et al. 1997), it could
be suspected that their different distribution is a consequence of a change in the relative values of their selection functions: however, the width of peak A is relatively narrow (less than 1000 km/s) and therefore this effect is more likely due to a real variation in morphological composition in the two subclumps.

We estimated the dynamical parameters (mean velocity and velocity dispersion) of the three peaks with the biweight estimators of location and scale (Beers et al. 1990). The advantage of these estimators, with respect to the standard mean and dispersion, is that of minimizing biases from interlopers, giving less weight to data with higher distance from the median. The confidence intervals of the two estimators are calculated bootstrapping the data with 100 random catalogs. In order to find the velocity range in which the cluster members lie, we have assumed that the velocity distribution of cluster galaxies is Gaussian, as expected when the system has undergone a violent relaxation (see details in Bardelli et al. 1994).

For the case of peak A, in which the presence of a substructure was suspected on the basis of both a visual inspection of the velocity histogram and the shape estimators \( a, b_1, b_2 \) and \( I \) (see Bird & Beers, 1993), we checked if the distribution is consistent with a single Gaussian or it is bimodal applying the KMM test (Ashman et al. 1994), using the program kindly provided by the authors. This test gives the likelihood ratio between the hypothesis that the dataset is better described by the sum of two Gaussians and the null hypothesis that the dataset is better described by a single Gaussian.

In Tab. 6 we report the dynamical parameters for the velocity excesses found in our sample (see the discussion below). Column (1) refers to the peak identification, column (2) reports the number of velocities used, columns (3) and (4) are the estimated mean velocity and velocity dispersion.

### Table 6. Field 61

| \( \alpha (2000) \) | \( \delta (2000) \) | \( b_j \) | \( v_{\text{abs}} \) km/s | \( v_{\text{em},J} \) km/s | notes |
|-----------------|-----------------|-----|-----------------|-----------------|------|
| 05 51 23.0      | -25 23 13.8     | 15.9| 42806 \pm 44    |                  |      |
| 05 50 15.9      | -25 16 15.4     | 19.0| 11696 \pm 68    |                  |      |
| 05 51 28.1      | -25 24 18.9     | 18.3| 40426 \pm 52    | 40383 \pm 80    | a    |
| 05 51 23.7      | -25 24 59.0     | 19.9| 41583 \pm 58    |                  |      |
| 05 50 22.3      | -25 18 09.2     | 17.2| 11595 \pm 28    |                  |      |

### Table 7. Field 62

| \( \alpha (2000) \) | \( \delta (2000) \) | \( b_j \) | \( v_{\text{abs}} \) km/s | \( v_{\text{em},J} \) km/s | notes |
|-----------------|-----------------|-----|-----------------|-----------------|------|
| 05 50 39.5      | -24 28 33.7     | 19.7| 52479 \pm 121   |                  |      |
| 05 50 56.6      | -24 34 45.0     | 17.8| 11417 \pm 39    | abcd            |      |
| 05 51 38.5      | -24 31 02.5     | 17.5| 13219 \pm 28    |                  |      |
| 05 51 01.0      | -24 38 24.4     | 18.9| 13594 \pm 65    | ad              |      |
| 05 51 20.3      | -24 40 20.0     | 20.0| 53185 \pm 91    |                  |      |
| 05 50 20.8      | -24 48 31.4     | 18.9| 48556 \pm 78    |                  |      |

![Fig. 3. Histogram of the velocities of 41 stars observed by chance in our survey. The superimposed solid curve corresponds to a Gaussian with \( < v > = 22 \text{ km/s} \) and \( \sigma = 90 \text{ km/s} \).](image)
Fig. 4. a) Histogram of the observed velocities in bins of 500 km/s for all galaxies of our sample. b) Close up of panel a); the shadowed histogram represents the distribution of galaxies with emission lines, while the open histogram refers to the galaxies with only absorption lines.

3.1. Peak A

Peak A, formed by 64 galaxies, is at the same velocity of A548 and has $< v > = 12866 \pm 150$ km/s and $\sigma = 869 \pm 78$ km/s. The shape estimators $a$ and $b_2$ revealed a significant deviation from the null hypothesis of Gaussianity (at more than 95% significance level). The KMM test revealed that the distribution is significantly better described by two Gaussians, both in the homoscedastic and in the heteroscedastic case. Assigning the objects to the two groups on the basis of the a posteriori probability given by the KMM algorithm (see Ashman et al. 1994) and estimating the dynamical parameters with the biweight estimators, we found $< v >_1 = 11951 \pm 116$ km/s and $\sigma_1 = 267 \pm 59$ km/s (based on 28 velocities) and $< v >_2 = 13498 \pm 111$ km/s and $\sigma_2 = 260 \pm 52$ km/s (based on 36 objects). Fig. 5 shows a close up of the velocity distribution of galaxies in peak A, with superimposed the two Gaussians of parameters $< v >_1$, $\sigma_1$ and $< v >_2$, $\sigma_2$. No significant differences are found, inside each clump of peak A, between the dynamical parameters of galaxies with and without emission lines.

These mean velocities can be compared with those of the subclumps found by Davis et al. (1995) in A548. Our value of $< v >_1$ is well consistent with their Clump a (see

| Peak     | $N$  | $< v >$ (km/s) | $\sigma$ (km/s) |
|----------|------|----------------|-----------------|
| Peak A   | 64   | 12866±150      | 869±78          |
| Clump 1  | 28   | 11951±116      | 267±59          |
| Clump 2  | 36   | 13498±111      | 260±52          |
| Peak B   | 40   | 30477±107      | 602±148         |
| Peak C   | 17   | 41603±215      | 849±217         |

Table 8. Estimated dynamical parameters

Fig. 5. Velocity distribution of galaxies belonging to peak A with superimposed the two Gaussians with $< v >_1 = 11951$ km/s and $\sigma_1 = 267$ km/s and $< v >_2 = 13498$ km/s and $\sigma_2 = 260$ km/s. Among the 64 objects of the peak, 28 have been assigned to the lower velocity group and 36 to the higher velocity one.
553 km/s respectively, while we estimated \( \sigma \)\( \sim \)a
perspersion. Clumps (1994).

Well in agreement with those reported by Escalera et al. may be reduced to less than 1
in their paper) could be similar to ours, the discrepancy on the Davis et al. determination (not reported
mean velocity of their Clump \( b \) could be an indication of a depen-
dence of the velocity dispersion on the distance from the
group centers. In particular, the subcondensation of peak A at
an extension of the nearby cluster rather than a separated
entity. In particular, the subcondensation of peak A at
lower velocity is part of Clump \( a \), while the higher velocity
group of peak A is associative to Clump \( b \).

In order to see the relative distance of the clumps de-
tected in A548 from our galaxies, we plotted on the isoden-
sity contours the positions of their centers and the distri-
bution on the sky of our sample. In Fig. 6 stars represent
galaxies with 10000 \( < v < 12700 \) km/s and triangles refer
to objects with 12700 \( < v < 15000 \) km/s. The big crosses
are the reported centers of the extended emissions found
in the ROSAT observations labelled as S1 and S2 in table
2 of Davis et al. and coincident with their optical Clumps
\( a \) and \( b \). Their source S3 falls outside the figure. We re-
ported also the position of their Clump \( c \) as an asterisk.

Note the good coincidence between these positions and
peaks in the density field.

The extension in A3367 of Clump \( a \) of Davis et al. seems to have two condensations (see stars in Fig. 6)
\( \alpha(2000) \sim 05^{h}50^{m}, \delta(2000) \sim 24^{\circ}10^{\prime}\) and \( \alpha(2000) \sim 05^{h}50^{m}, \delta(2000) \sim 25^{\circ}00^{\prime}\), at the distances of \( \sim 65 \) and
\( \sim 30 \) arcmin from the corresponding substructure in A548, respectively.

The extension in A3367 of Clump \( b \) (see triangles in Fig. 6) is more smooth and spans all the distances between
1\( ^{\circ} \) and 1.5\( ^{\circ} \) from its center, corresponding to \( \sim 2-3 \) h\(^{-1}\) Mpc.

Finally we note that the mean velocity reported by
Postman et al. (1992) for A3367 is consistent with the
redshift of peak A. The velocity of the brightest cluster
member (Postman & Lauer 1995) reveals that this galaxy
is part of the higher velocity clump of peak A: therefore
this galaxy is probably associated to A548 rather than to
A3367.

3.2. Peaks B and C

The estimated dynamical parameters of the second peak
seen in the redshift histogram are \( < v > = 30477 \pm 107 \)
km/s and \( \sigma = 602 \pm 148 \) km/s, based on 40 velocities.
The percentage of emission line galaxies is 25%. In Fig. 6
the objects belonging to this structure are plotted as black
dots and seem to be concentrated around a density peak
at \( \alpha(2000) \sim 05^{h}48^{m} \) and \( \delta(2000) \sim 23^{\circ}50^{\prime}\). The shape
estimators indicate that the distribution is consistent with
being a Gaussian. Given the fact that this density excess
is the largest one inside one Abell radius from the nominal
center of A3367 and considering that its velocity disper-
sion is typical of a cluster, we suggest that the name A3367
is in fact to be attributed to peak B.

Finally, the estimated mean velocity and velocity dis-
ispersion for peak C are \( < v > = 41603 \pm 215 \) km/s and
\( \sigma = 849 \pm 217 \) km/s, determined with 17 objects. The
Gaussianity of the distribution can not be excluded.

4. Summary

We have presented the results of a redshift survey in an
area between the Abell clusters A548 and A3367. These
two clusters have been suspected to be a close pair and
therefore candidates to undergo a merging process.

We obtained 180 new galaxy velocities with the use of
multifiber spectroscopy, 44% of which presents emission
lines. The redshift histogram shows clearly three peaks at
\( v \sim 12000 \) km/s, \( v \sim 30000 \) km/s and \( v \sim 40000 \) km/s;
for each of them we have estimated the dynamical param-
eters.
The first structure (peak A) is at the velocity of A548 and could be considered as an extension of this clusters. In particular, this peak is formed by two substructures, corresponding to two subclusters in A548 revealed by Davis et al. (1995) both in the optical distribution of galaxies and in a ROSAT X-ray map. The velocity dispersions of our two clumps in peak A are significantly smaller than those determined in the subclumps of Davis et al., while the mean velocities are in agreement.

Peak B has $v = 30477$ km/s and a velocity dispersion of $\sim 600$ km/s; the distribution of its members on the plane of the sky corresponds to the highest density excess of A3367: for this reason we suggest that the name A3367 is in fact to be attributed to this clump. The mean velocity reported for A3367 by Postman et al. (1992) is based on galaxies belonging to peak A, and therefore to an extension of A548 rather than to A3367.

Our general conclusion is that A548 and A3367 is not a close pair of merging clusters, being the two structures at significantly different redshift. However, we found that the complex dynamical structure of A548 has large coherence, with a projected extension in the range of 1-3 h$^{-1}$ Mpc.

Acknowledgements. We thank M. Mignoli and D. Maccagni for having observed fields 61 and 62, and H.Böhringer for his help with the photometric catalogue. This research has made use of the NASA/IPAC Extragalactic Database.

References

Abell, G.O., Corwin, H.G., Olowin, R.P., 1989, ApJSS 70, 1
Ashman, K.M., Bird, C.M., 1994, AJ 108, 2348
Bardelli, S., Zucca, E., Vettolani, G., Zamorani, G., Scaramella, R., Collins, C.A., MacGillivray, H.T., 1994, MNRAS 267, 665
Bardelli, S., Zucca, E., Malizia, A., Zamorani, G., Scaramella, R., Vettolani, G., 1996, A&A 305, 435
Bardelli, S., Zucca, E., Zamorani, G., Vettolani, G., Scaramella, R., 1998a, MNRAS 296, 699
Bardelli, S., Pisani, A., Ramella, M., Zucca, E., Zamorani, G., 1998b, MNRAS in press
Beers, T.C., Flynn, K., Gebhart, K., 1990, AJ 100, 32
Bird, C.M., Beers, T.C., 1993, AJ 105, 1596
Biviano, A., Durret, F., Gerbal, D., Le Fevre, O., Lobo, C., Mazure, A., Szalay, E., 1996, A&ASS 111, 265
Biviano, A., Katgert, P., Mazure, A., Moles, M., den Hartog, R., Perea, J., Focardi, P., 1997, A&A 321, 84
Briel, U., Henry, J.P., Böhringer, H., 1992, A&A 259, L1
Burns, J.O., Roettiger, K., Ledlow, M., Klypin, A., 1994, ApJ 427, L87
Cappi, A., et al., 1998, A&A in press
Davis, D.S., Bird, C.M., Mushotzky, R.F., Odewahn, S.C., 1995, ApJ 440, 48
Escalera, E., Biviano, A., Girardi, M., Giuricin, G., Mardirossian, F., Mazure, A., Mezzetti, A., 1994, ApJ 423, 539
Feretti, L., Giovannini, G., 1996, in Extragalactic Radio Sources, IAU Symp. 175, 175, R. Fanti, Fanti, C., Ekers, R., Padrielli, L., eds, Kluwer Ac. Publ., p.333
Katgert, P., et al., 1996, A&A 310, 8
Katgert, P., Mazure, A., den Hartog, R., Adami, C., Biviano, A., Pera, J., 1998, A&ASS 129, 399
Kriessler, J.R., Beers, T.C., 1997, AJ 113, 80
Kurtz, M.J., Mink, D.J., Wyatt, W.F., Fabricant, D.G., Torres, G., Kriss, G.A., Tonry, J.L., 1992, in Astronomical Data Analysis Software and Systems I, Worrall, D.M., Bienesderfer, C., and Barnes, J., eds., ASP conference series vol.25 p.432
Lund, G., 1986, OPTOPUS-ESO operating manual N.6
Postman, M., Huchra, J.P., Geller, M.J., 1992, ApJ 384, 404
Postman, M., Lauer, T.R., 1995, ApJ 440, 28
Schindler, S., 1996, MNRAS 280, 309
Tonry, J., Davis, M., 1979, AJ 84, 1511
Vettolani, G., et al., 1997, A&A 325, 954
Vettolani, G., et al., 1998, A&ASS in press
Yentis, D.J., Cruddace, R.G., Gursky, H., Stuart, B.V., Wallin, J.F. MacGillivray H.T., Collins, C.A., 1992, in Digitized Optical Sky Surveys, MacGillivray, H.T. & Thomson, E.B. eds., Kluwer, Dordrecht, p. 67
Zucca, E., Zamorani, G., Scaramella, R., Vettolani, G., 1993, ApJ 407, 470
Zucca, E., et al., 1997, A&A 326, 477

This article was processed by the author using Springer-Verlag La\TeX A\&A style file L-\AA\ version 3.