DETERMINATION OF GALAXY MEMBERS IN CLUSTERS

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Abstract. A new empirical procedure is introduced to determine the confirmed galaxy members of a cluster. The method depends on both the projected distances of galaxies in the cluster field from the cluster centre and their radial velocities. Galaxies of the main body of the cluster are selected first, then the method works iteratively by increasing the standard values of the relative radial distance and velocity until all galaxies belonging to the cluster are included. The general apparent shape of the cluster will result from the distribution of the celestial coordinates of the cluster members.

Keywords: galaxies redshifts, galaxy clusters: apparent shapes, galactic content

1. Introduction

It is well known that foreground and background in the direction of any cluster galaxies are not uniformly distributed, since the universe is homogeneous and isotropic only in the large scale. This means that their inclusion may give rise to obvious error in finding the cluster apparent orientation. This error is quite small for near and rich clusters such as Coma, particularly when depending on the brightest half of the whole galaxies in the Coma field, since the contamination by the background galaxies will be quite negligible (Bukhari, 1988a). However, for medium rich and far distant clusters the situation is different. It would be more general to obtain the cluster morphology using the cluster members only.

In Yahil-Vidal method (Yahil and Vidal, 1977) the mean radial velocity of all galaxies in the cluster field is calculated, then the galaxy which deviates the most from this mean is removed. The mean and standard deviation are redetermined. If the removed galaxy deviates from the new mean by more than three new standard deviations, the galaxy will be rejected as a contamination. The process would be continued until the tested galaxy is accepted.

The method introduced here simultaneously depends on the projected radial distances r of galaxies from the cluster centre and their radial velocities v corrected to the solar motion. The advantage of this procedure is that galaxies far away from the cluster centre will not accepted as cluster members even if their radial velocity deviations from the mean are small. On the other hand, galaxies whose radial velocity deviations are not exceedingly large and locate near the main body of the cluster are not excluded.

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TABLE I

The general parameters of the sample clusters

Abell	*RA (1950.0) DEC*						ℓ	b	R	D	T_{B-M}	T_{R-S}	z
A1644	12	54	34.16	-17	6	32.5	304.92	45.50	1	4	II	cD	0.0471
A548 E	05	46	41.95	-25	29	48.2	213.30	-24.42	1	1	III	I	0.0410
A548 W	05	43	21	-25	55	33.49	213.31	-25.26	1	1	III	I	0.0424

TABLE II

The observational parameters of the selected clusters

Abell	*Field*	*Exposure time*	*Plate grade*
A1644	646	60	A
A1644	575	110	A
A548 E	488	70	A2
A548 W	488	70	A2

The description of the data is presented in section 2. In section 3 details of the method are displayed, while the application of the procedure to three Abell clusters are given in section 4 in addition to the conclusion.

2. Cluster Selection and Data

The galaxy clusters which are selected to study the membership of their galaxies should have as many galaxies as possible with known heliocentric radial velocities. This condition is satisfied by A1644, A548 E and A548 W clusters. The general parameters of these clusters are given in Table I. Hartog et al. (1996), Postman et al. (1992), Abell et al. (1989) and Struble et al. (1987).

Observations of each cluster have been obtained by the U.K. Schmidt telescope at the Anglo-Australian Observatory in Coonabarabran. The clusters were observed on IIIa-J emulsion through a 395 filter. The exposure time (minutes) and the plate grade are indicated in Table II.

COSMOS data of each galaxy includes right ascension, declination, centroids, semi-major axis, semi-minor axis, area, position angle and B_j magnitude. The heliocentric radial velocities and morphological types of galaxies in the fields of these clusters are taken from the 'Catalog of 1268 radial velocities in 15 rich clusters' by Dressler et al. (1988).

3. Methodology

The radial velocity distribution of galaxies in the fields of the cluster is first plotted. To find the member galaxies the primary aggregations of points in this distribution are plotted in a separate diagram which represents the inner members of the cluster or the first iterative sample. Now we have a 3 dimensional volume in x_{ti}, y_{ti}, v where x_{ti}, y_{ti} are the coordinates of the inner members on the photographic plate. We are trying to confine the part of the volume which includes the final iterative sample as follows:

(i) Evaluate the centroid of the sample of inner members from

$$x_c = \frac{\sum_i x_{ti}}{N}, \quad y_c = \frac{\sum_i y_{ti}}{N}. \tag{1}$$

where N is the number of these members;

(ii) Calculate the averages of both the projected distance r and the radial velocity v of the inner members, $< r >$, and $< v >$ respectively, the standard deviations σ_r, σ_v;

(iii) Determine the maximum deviation of r and v from $< r >$ and $< v >$ respectively, say $\Delta r_{max}, \Delta v_{max}$ and the quantities S_r, S_v from the formulae

$$S_r = \frac{\Delta r_{max}}{\sigma_r}, \quad S_v = \frac{\Delta v_{max}}{\sigma_v}. \tag{2}$$

(iv) Increase both S_r, S_v, by a factor of 10 % to be S_{r1}, S_{v1};

(v) Evaluate the quantities S'_r, S'_v for each galaxy in the cluster field from the relations

$$S'_r = \frac{\Delta r}{\sigma_r}, \quad S'_v = \frac{\Delta v}{\sigma_v}. \tag{3}$$

If $S'_r > S_{r1}$, or $S'_v > S_{v1}$ then the tested galaxy is considered as a field galaxy and would be rejected;

(vi) If there are new galaxies satisfying the conditions $S'_r \leq S_{r1}$, $S'_v \leq S_{v1}$ then they would be accepted as cluster members and added to the first iterative sample to form the second iterative sample;

(vii) The process will be continuously repeated until no new galaxies are accepted.

The blue magnitudes of the confirmed cluster members determined by this technique should be corrected to the Galactic absorption, galaxy redshift and internal absorption Sandage (1973), Sandage et al. (1978), Shanks et al. (1984), Tully et al. (1985). Furthermore, the centroids of the confirmed cluster members follow from equation (1) and the angular distance of the outermost member from this centre is determined say r_{max}.

Since there may be many other faint members with unknown radial velocities it would be important to consider these galaxies in the probable cluster sample which is assumed to have a radius greater than r_{max} by arbitrary factor ranges

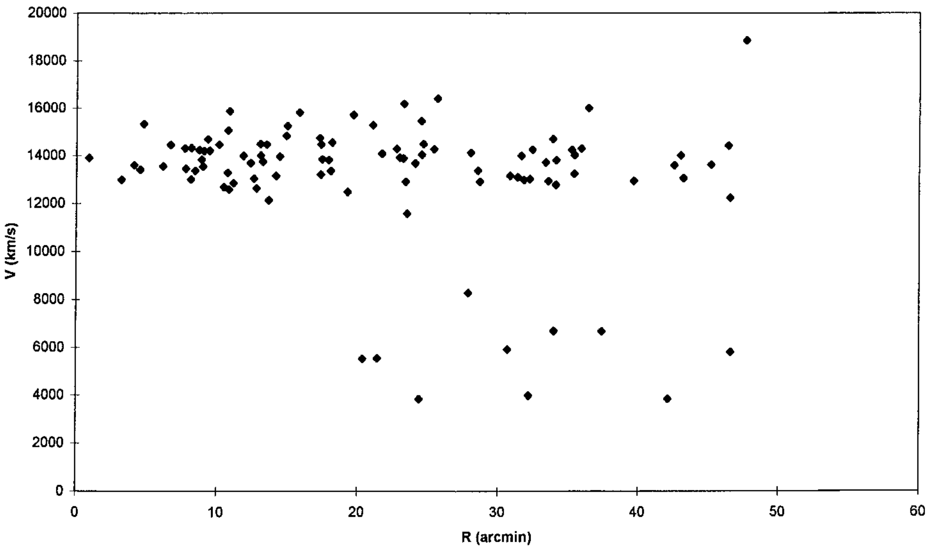

Figure 1-a. The distribution of the radial velocity of galaxies in the A1644 field.

between 10%–20%. In addition, the magnitude mj_{max} of the faintest confirmed member is increased by about 0.2–0.5 magnitude and in general does not exceed 20.0 magnitude to avoid introducing a huge contamination of background galaxies. However, if there is another cluster in the vicinity of the studied one, then mj_{max} would be only increased but not r_{max} to avoid the overlap between the two clusters. The apparent shape of the cluster can be easily obtained from the distributions of the celestial coordinates of both the confirmed and probable cluster members.

4. Results

The methodology of section 3 would be applied to A1644, A548 E and A548 W to find the galaxy members of these clusters in terms of the radial distances from the cluster centre and the radial velocities.

4.1. A1644

Figure 1-a shows the distribution of the radial velocity of 99 galaxies in the field of A1644. When galaxies of noticeable separation from the main body of the cluster are removed then the first iteration members of 77 galaxies will result as given in Figure 1-b. Both the first and second iterations of the empirical method add another four galaxies. Thus the last iteration members of A1644 includes 81 galaxies as far as the observed radial velocities allowed which are shown in Figure 1-c. This

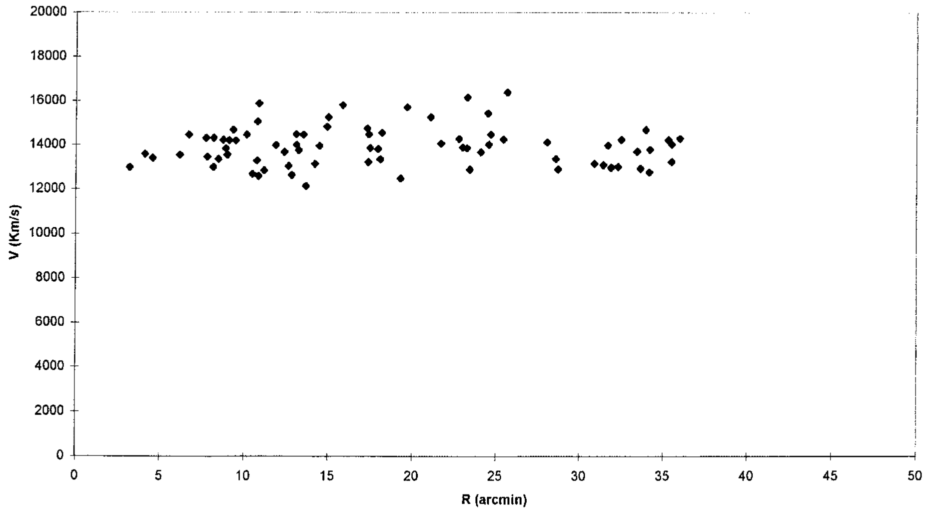

Figure 1-b. The distribution of the radial velocity of the first iteration A1644 members.

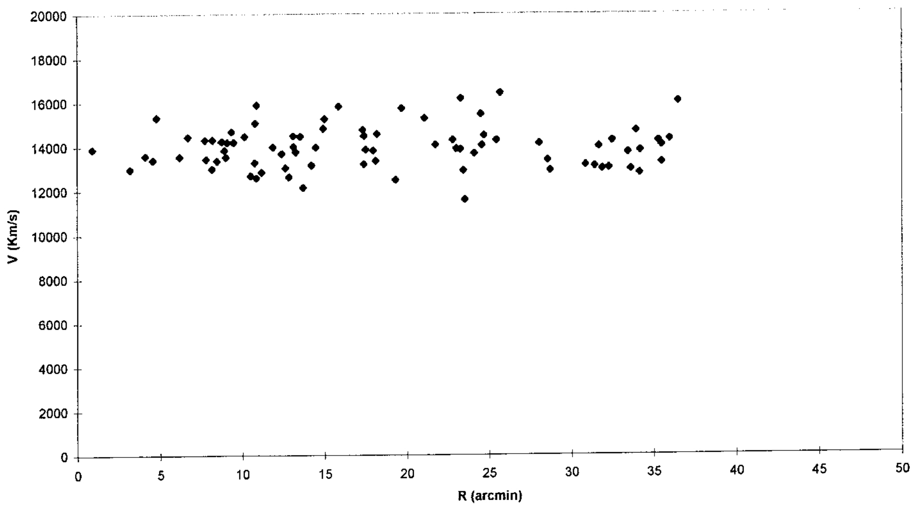

Figure 1-c. The distribution of the radial velocity of the confirmed A1644 members.

number of confirmed members of A1644 is in good agreement with 77 galaxies reported by Biviano et al. (1992) inside Abell radius (3 Mpc h_{50}^{-1}).

The projected distance of the outer most confirmed member of A1644 from the cluster centre was found to be r_{max}= 37.4 arcmin which is equivalent to a linear radius of $\sim$ 3.0 Mpc.

Figure 2-a shows the apparent shape of A1644 obtained from the distribution of the confirmed cluster members within r_{max}. The apparent shape of the cluster

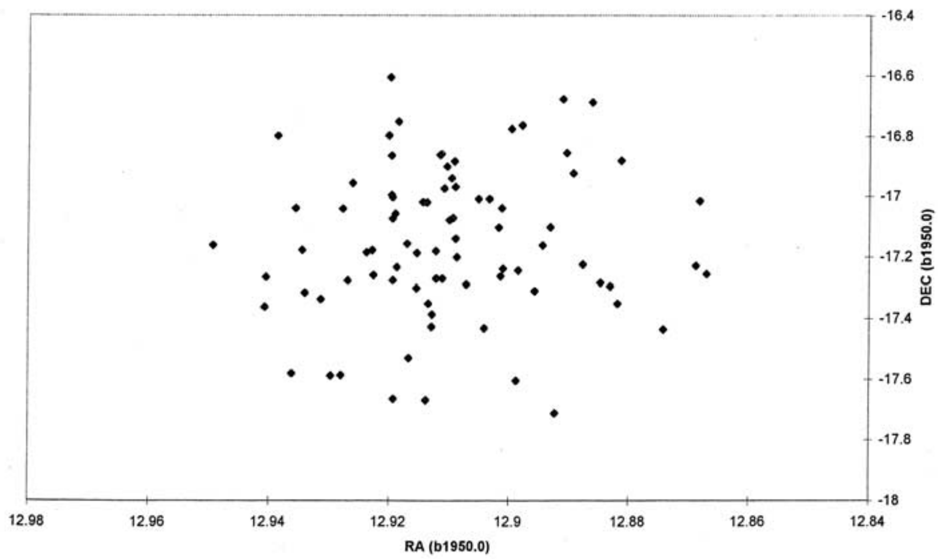

Figure 2-a. The apparent shape of A1644 from the distribution of its confirmed members.

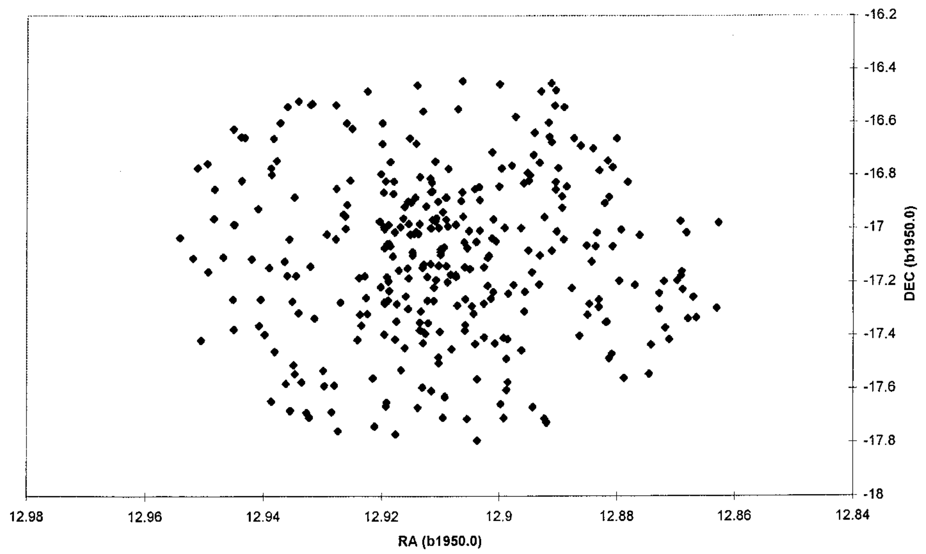

Figure 2-b. The apparent shape of A1644 from the distribution of its probable galaxies.

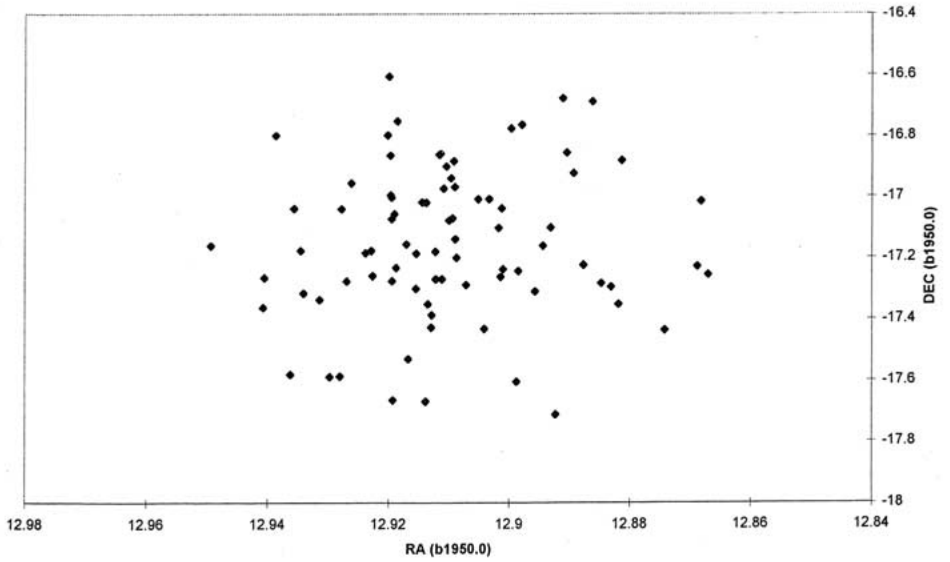

Figure 3-a. The distribution of the radial velocity of galaxies in the A548 E field.

deduced from the distribution of the probable cluster galaxies within a radius of 42.2 arcmin is displayed in Figure 2-b. The later sample contained 329 galaxies and estimated by increasing r_{max} by an arbitrary factor between 10%-20%(the factor used here is about 15%) and increasing the limiting magnitude m_j by 0.5 magnitude more than the faintest confirmed member in order to include faint members whose radial velocities are not known. From these two figures the approximately circular projected shape of the cluster is obvious.

4.2. A548 E

The radial velocity distribution of 70 galaxies in the field of A548 E cluster is exhibited in Figure 3-a. The main body of the cluster after removing the relatively separated galaxies is displayed in Figure 3-b, which includes 60 galaxies. When the empirical method of section 3 is applied, we end up with 64 galaxies after the second iteration which represent the confirmed members of the cluster as revealed in Figure 3-c.

The projected distance of the outermost confirmed member of A548 E from the cluster centre is r_{max} = 21.96 arcmin corresponding to linear radius of 1.54 Mpc. The probable cluster sample contains 272 galaxies obtained by increasing the limiting magnitude m_j of the faintest confirmed member as explained in the previous cluster but without increasing r_{max} to avoid overlap with the neighbour cluster A548 W. The apparent shape of the cluster deduced from the distribution of its confirmed members and its probable galaxies are illustrated in Figures 4-a and 4-b respectively. The cluster is quite irregular.

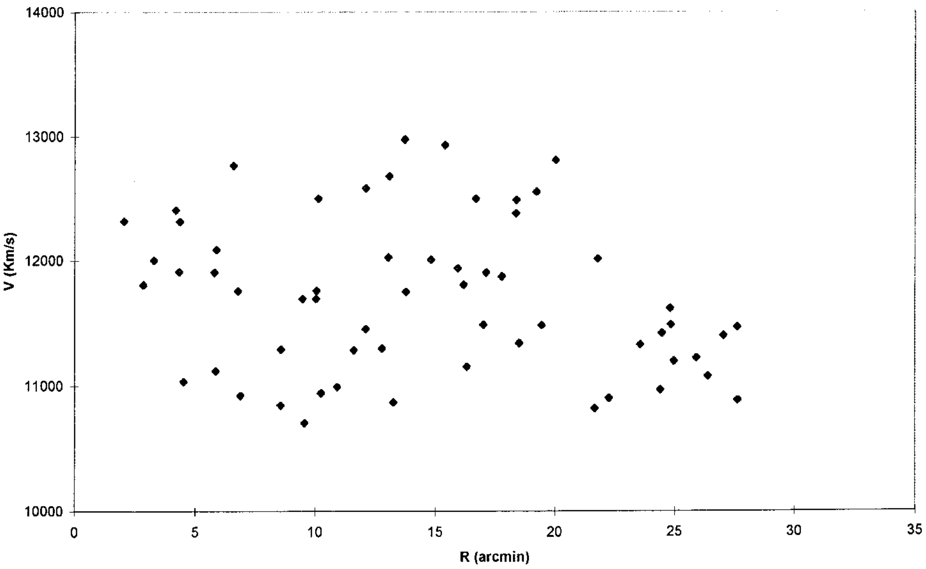

Figure 3-b. The distribution of the radial velocity of the first iteration A548 E members.

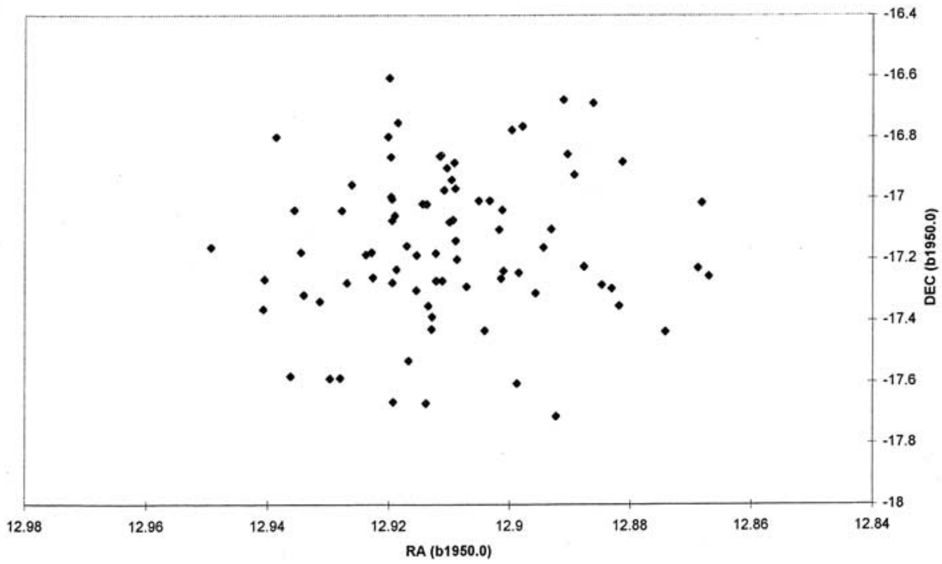

Figure 3-c. The distribution of the radial velocity of the confirmed A548 E members.

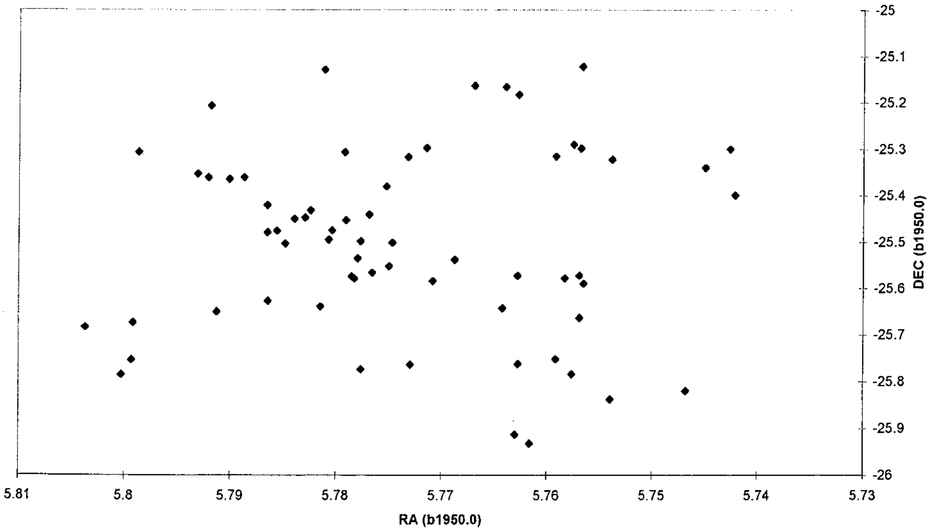

Figure 4-a. The apparent shape of A548 E from the distribution of its confirmed members.

4.3. A548 W

The central distance-radial velocity diagram of 63 galaxies in the field of A548 W is displayed in Figure 5-a. When the relatively separated galaxies were removed, the main part of the cluster included 55 galaxies as shown in Figure 5-b. Using the empirical procedure of section 3, the confirmed cluster members were found to be 58 galaxies after the second iteration as appeared in Figure 5-c.

The projected distance of the outermost member of A548 W from the cluster centre is r_{max} = 16.53 arcmin corresponding to linear radius of 1.20 Mpc. The probable cluster sample contains 158 galaxies determined in the same manner as A548 E. The apparent shape of A548 W obtained from the distribution of the confirmed cluster members and the probable cluster galaxies are presented in Figures 6-a and 6-b respectively which exhibit irregular shape of A548 W.

In conclusion, a new empirical procedure is introduced to determine the cofirmed galaxy members of a cluster. The method depends on both the projected distances of galaxies in the cluster field from the cluster centre and their radial velocities. Galaxies of the main body of the cluster are selected first, then the method works iteratively by increasing the standard values of the relative radial distance and velocity until all galaxies belongs to the cluster are included. The general apparent shape of the cluster will result from the distribution of the celestial coordinates of its members.

It is remarkable to note that the more radial velocities of galaxies are observed in the cluster field the more accurate results are obtained for this method and for the cluster morphology.

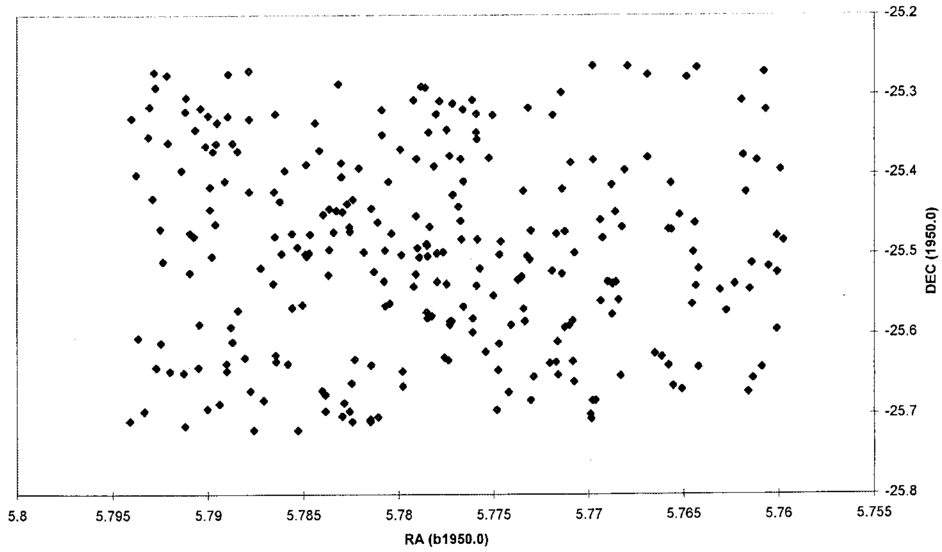

Figure 4-b. The apparent shape of A548 E from the distribution of its probable galaxies.

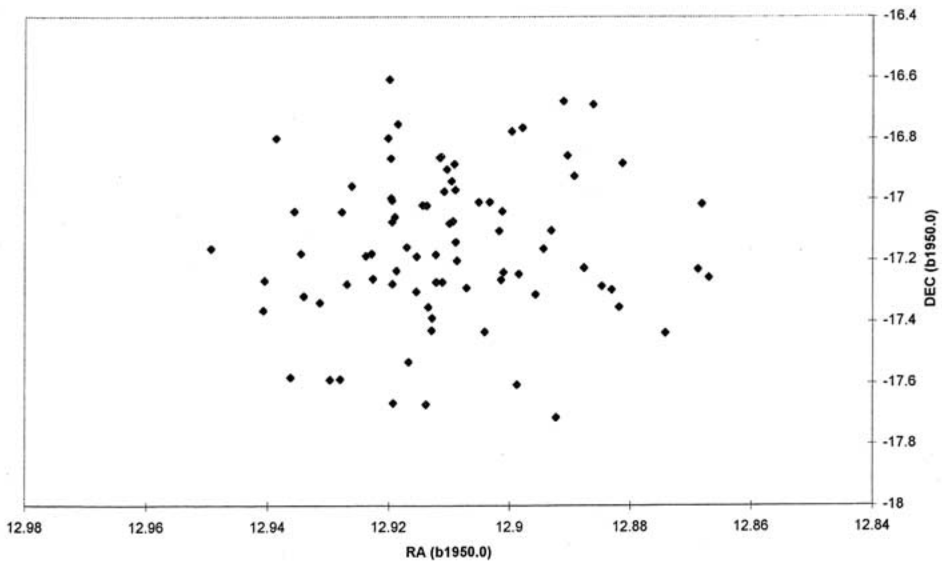

Figure 5-a. The distribution of the radial velocity of galaxies in the A548 W field.

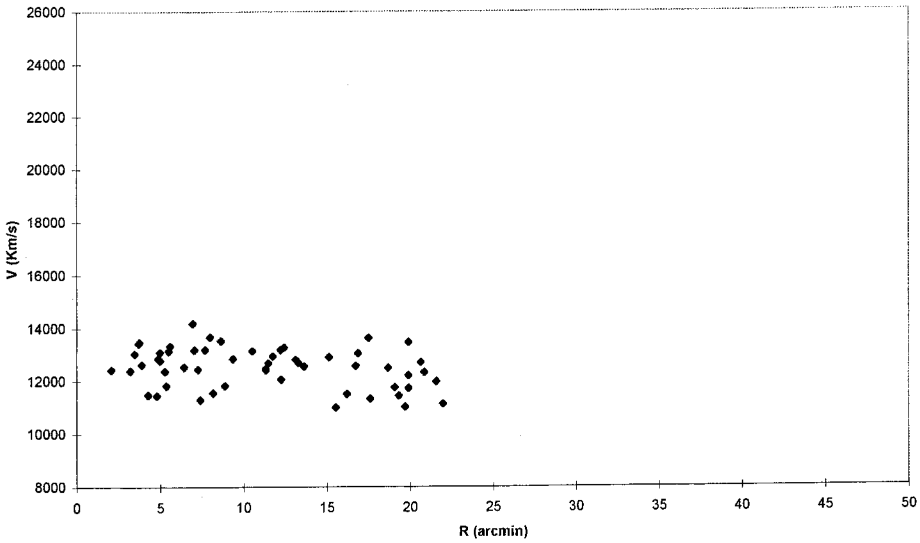

Figure 5-b. The distribution of the radial velocity of the first iteration A548 W members.

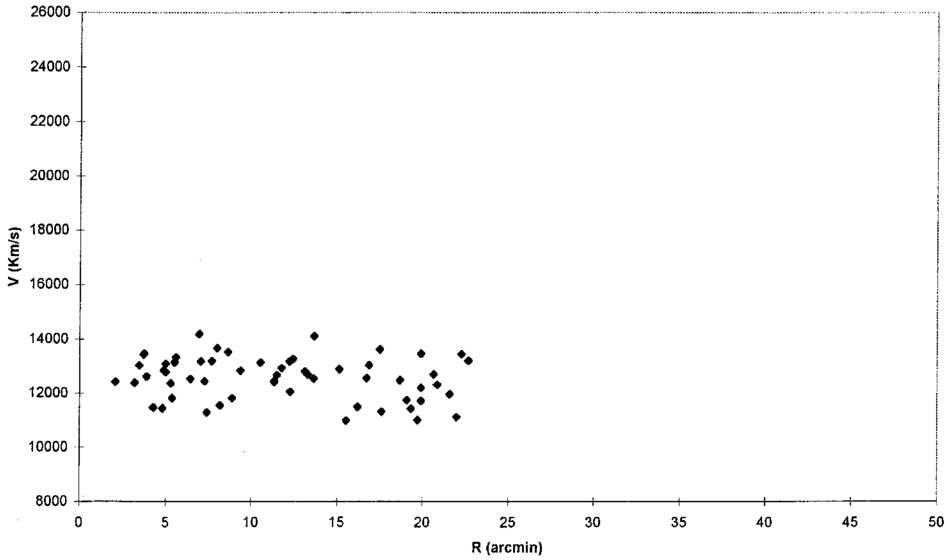

Figure 5-c. The distribution of the radial velocity of the confirmed members of A548 W.

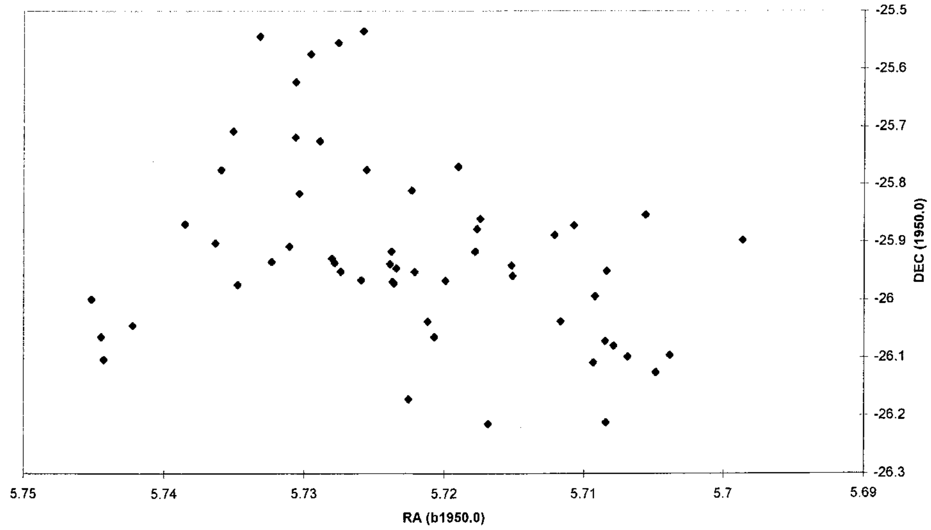

Figure 6-a. The apparent shape of A548 W from the distribution of its confirmed members.

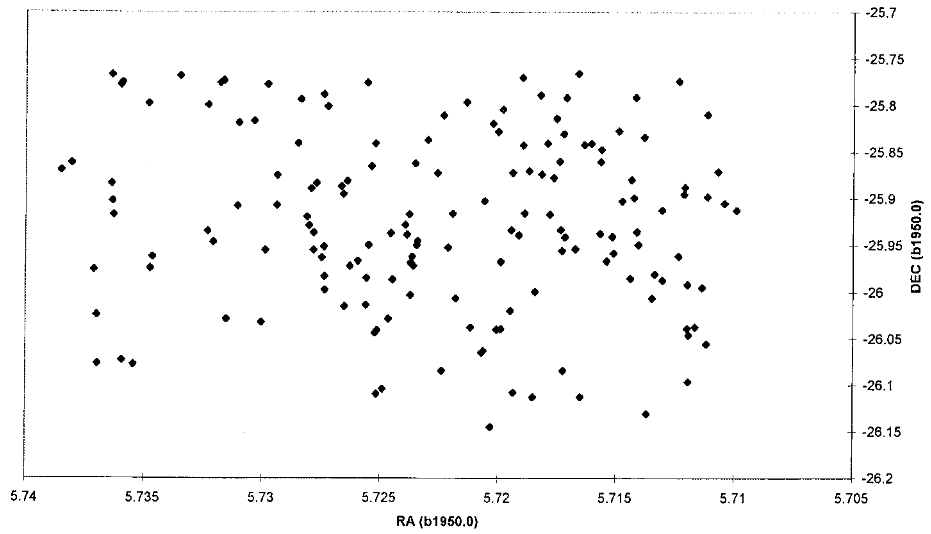

Figure 6-b. The apparent shape of the A548 W from the distribution of its probable galaxies.

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