Cluster Redshift Extractor: Color-Magnitude Relation

Clusters are dominated by old, red E/S0 galaxies, these stand out in a color-magnitude diagram as a ridgeline in color, the E/S0 ridgeline. I illustrate how PISCO will detect the cluster Abell 267 and how we can use the color-magnitude relation to determine the cluster redshift.

In Fig. 1 galaxies from the SDSS catalogue within a $32'$ diameter area of the sky around Abell 267 are plotted. Red are the luminous red galaxies with r $<$ 21, blue are galaxies around the cluster redshift of z=0.25 and yellow is the center of the field of view. The are covered is ≈ 7.6 Mpc in diameter and the PISCO field of view, indicated by the black square, is ≈ 1.4 Mpc wide and high, corresponding to the $6.1'$Tony has expanded the field of view to. The cluster can be seen in the field of view as an overdensity of red galaxies, and an overdensity of galaxies at the cluster redshift. From this illustration we can conclude that the PISCO field of view is not too small. The redshift versus radial distance plots for over 15 clusters at redshifts around 0.25 had previously suggested that the PISCO field of view might be too small for the detection of clusters at this redshift.

In Fig. 2 the chronology of the PISCO observation of Abell 267 is illustrated. From Fig. 3 the 8 brightest (r $<$ 19) and reddest (0.27 $<$ g-r $<$ 0.47) galaxies can be identified. They are marked with a green circle. Six of these 8 galaxies have redshifts very close to the cluster redshift (blue circles)! Large black circles mark the 30 galaxies with r $<$ 20 and 1.27 $<$ g-r $<$ 1.47, the 30 brightes and reddest galaxies. Red are the 75 brightest galaxies, with r $<$ 21.

Using this chronology, I have automated the cluster redshift determination for this cluster in the following way: Assuming we have detected all galaxies in the field of view, we selecet the most luminous with r $<$ 19. These are 18 galaxies. For these 18 galaxies, we find the peak in a g-r histogram (cf. Fig. 4), which lies at 1.37. We also find the peak in a photo-z histogram, which lies at 0.237 (the cluster redshift is 0.258). We now select the reddest out of the brightest galaxies, that lie within 1.27 $<$ g-r $<$ 1.47. Those are the 8 galaxies marked by the green circles in Fig. 2. The peak in a photo-z histogram for these 8 galaxies lies at z=0.2498, which is within 3% of the cluster redshift.
This program runs automatically and does not require any input or adjustment from the observer. It could be implemented as an online algorithm, that gets updated with every new galaxy. Since the bright red ones will be detected first, we might be able to increase the observing efficieny and potentially abort observing after the detection of a dozen galaxies.

Appendix A: Plan

1. Process the 15 MaxBCG data sets in the same way and check performance.

2. Cluster models are used to determine the cluster redshift through fitting a linear regression through the color-magnitude diagram. The intercept of this line is then proportional to the cluster redshift. Look into models by Gladders and Yee (2000).

3. When a cluster redshift determination is not possible after first integration, we need to distinguish between close clusters with only very few member galaxies in the PISCO field of view (observing strategy: mosaicking) and a high redshift cluster (observing strategy: longer integration). Using the SZ decrement there are ways to estimate the difference between estimated and observed mass. If these two values differ very much, we might be able to conclude that we are observing a high redshift cluster which requires longer integration.

Appendix B: Solution to Previous Problems

Radial Distance versus Redshift plots:

Problem:
Plotting the redshift of galaxies versus their radial distance to the cluster center did not show the cluster as a spatial overdensity as was expected.

Solution:
A spatial overdensity cannot be expected within the PISCO field of view. Comparinson to other data (Ken Rines, see Fig. 5) shows that a typical redshift versus radial distance plot requires coverage of at leat 3 Mpc in order to show the cluster as a spatial overdensity. PISCO's field of view covers ≈ 1.5 Mpc at z=0.26. As shown above, this field of view is not too small.

Redshift 0.35:

Problem:
Histograms of the photometric redshift of 15 MaxBCG clusters reveal a peak at z=0.35, uncorrelated to the cluster redshift.

Solution:
At z=0.35 the 4000$\mathring{A}$ break moves from the g into the r band. At this redshift, photo-z determination algorithms are prone to errors.

Fig. 1.— 32’ of sky with ths PISCO field of view indicetade by the square. Blue are galaxies at the cluster redshift, red are luminous red galaxies. The yellow dot is the center of the field of view.

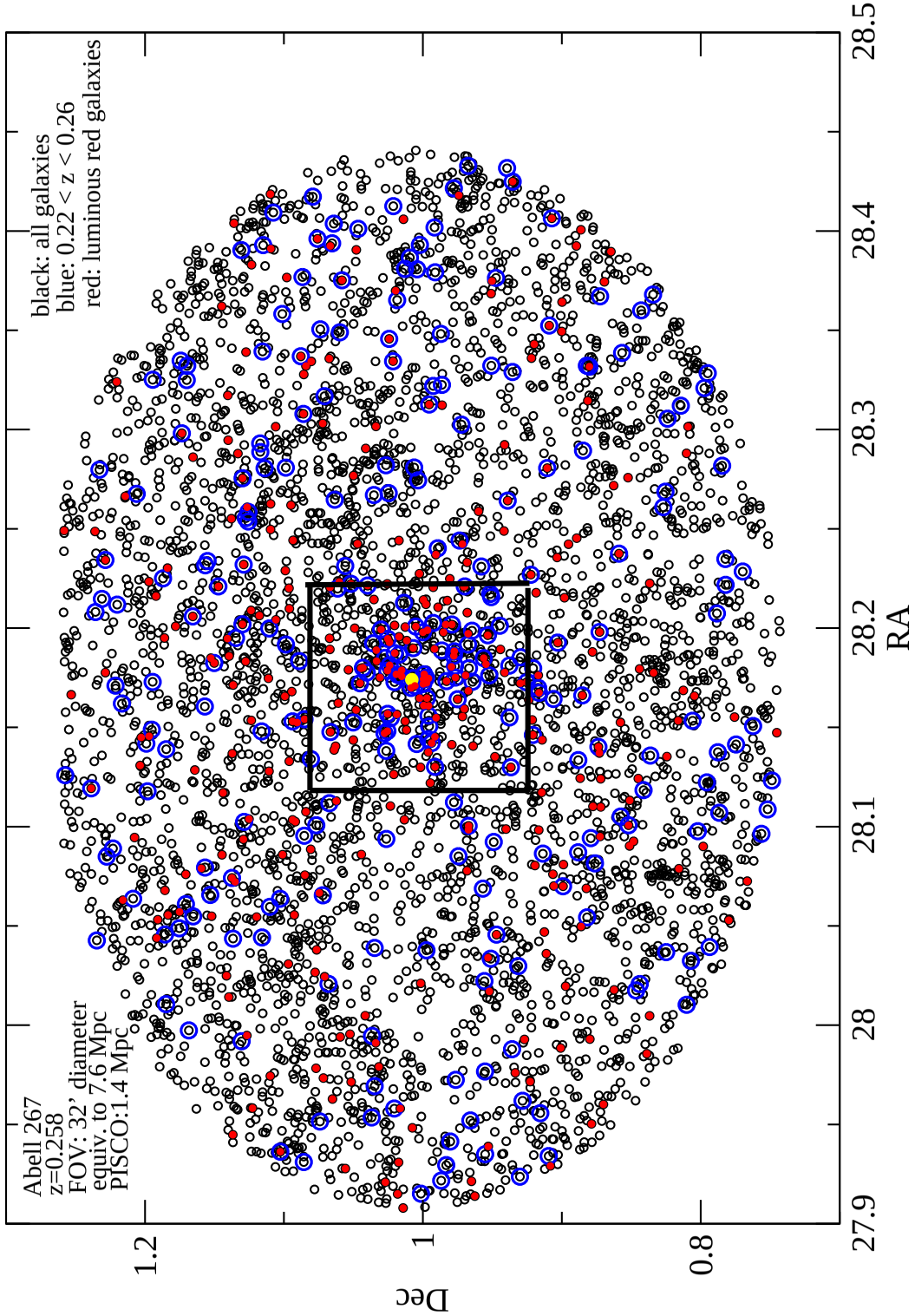

Fig. 2.— Chronology of PISCO detection: the eight brightest red galaxies will be detected first (green), the large black circles mark the 30 brightest red galaxies which will be detected next. Red are the third level of bright red galaxies (75), blue are galaxies at the cluster redshift, yellow is the center of the field of view.

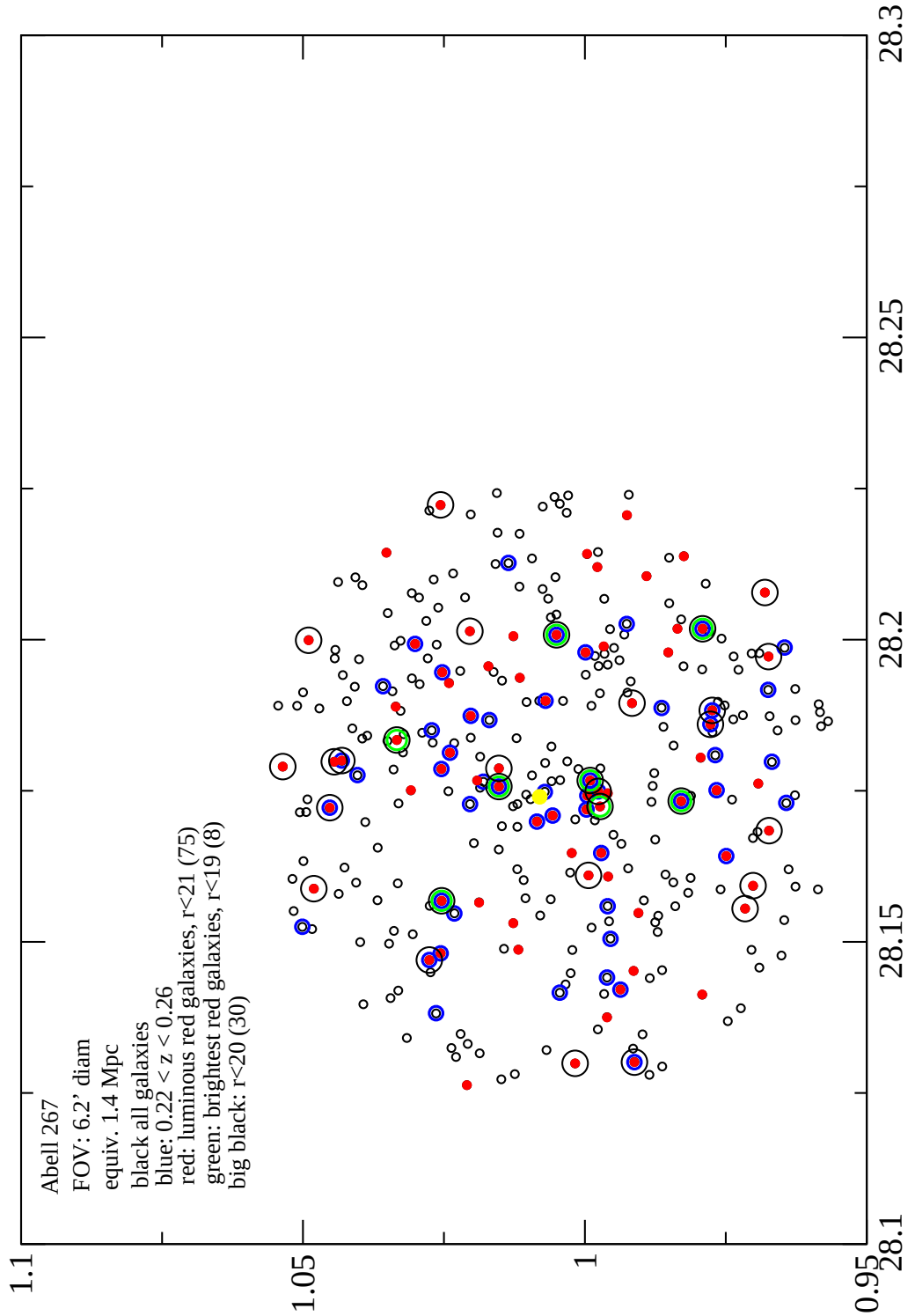

Fig. 3.— Color-magnitude relation.

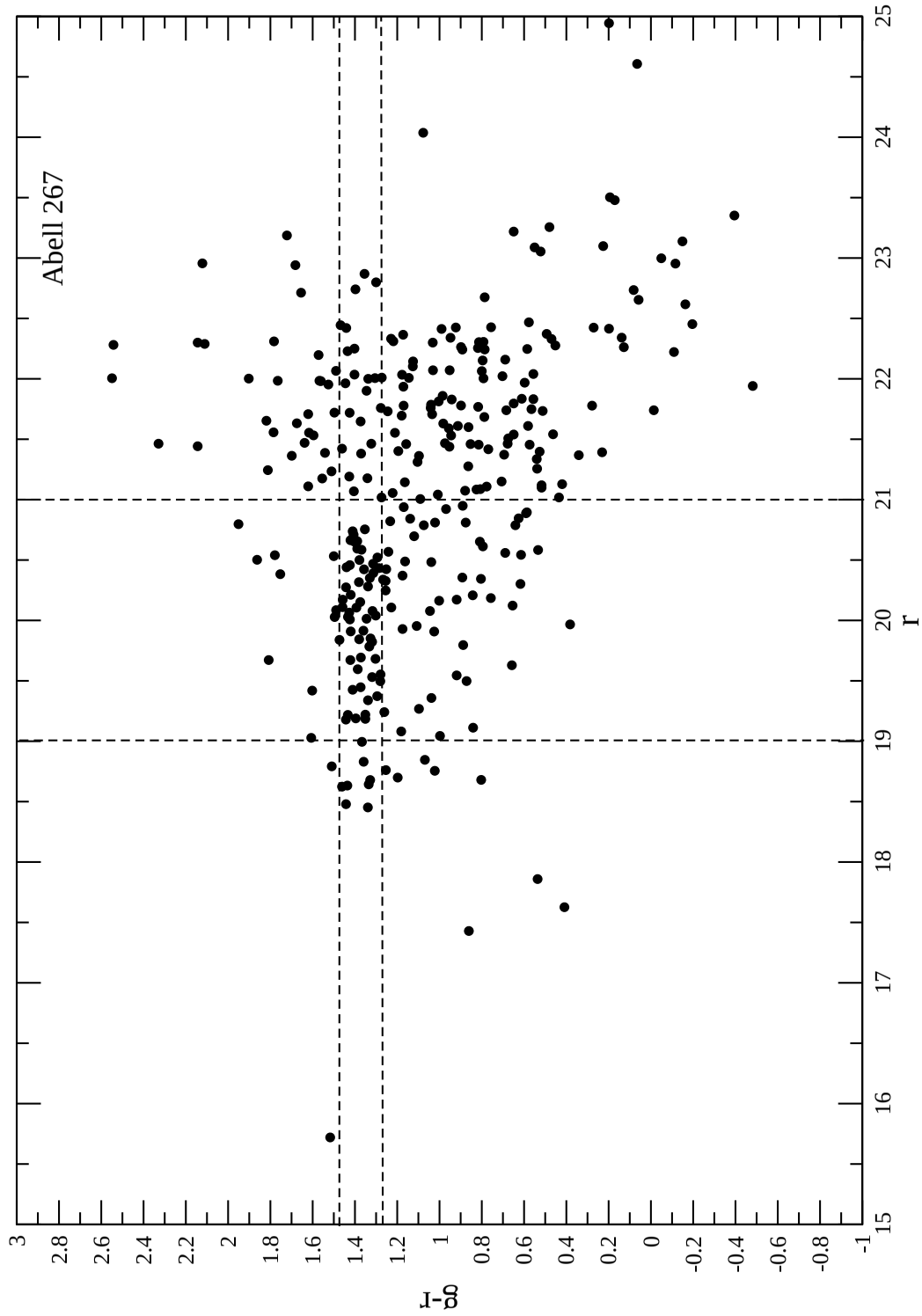

Fig. 4.— Histograms of g-r, photo-z of the first 18 galaxies and photo-z of the g-r confined reddest, brightest 8 galaxies.

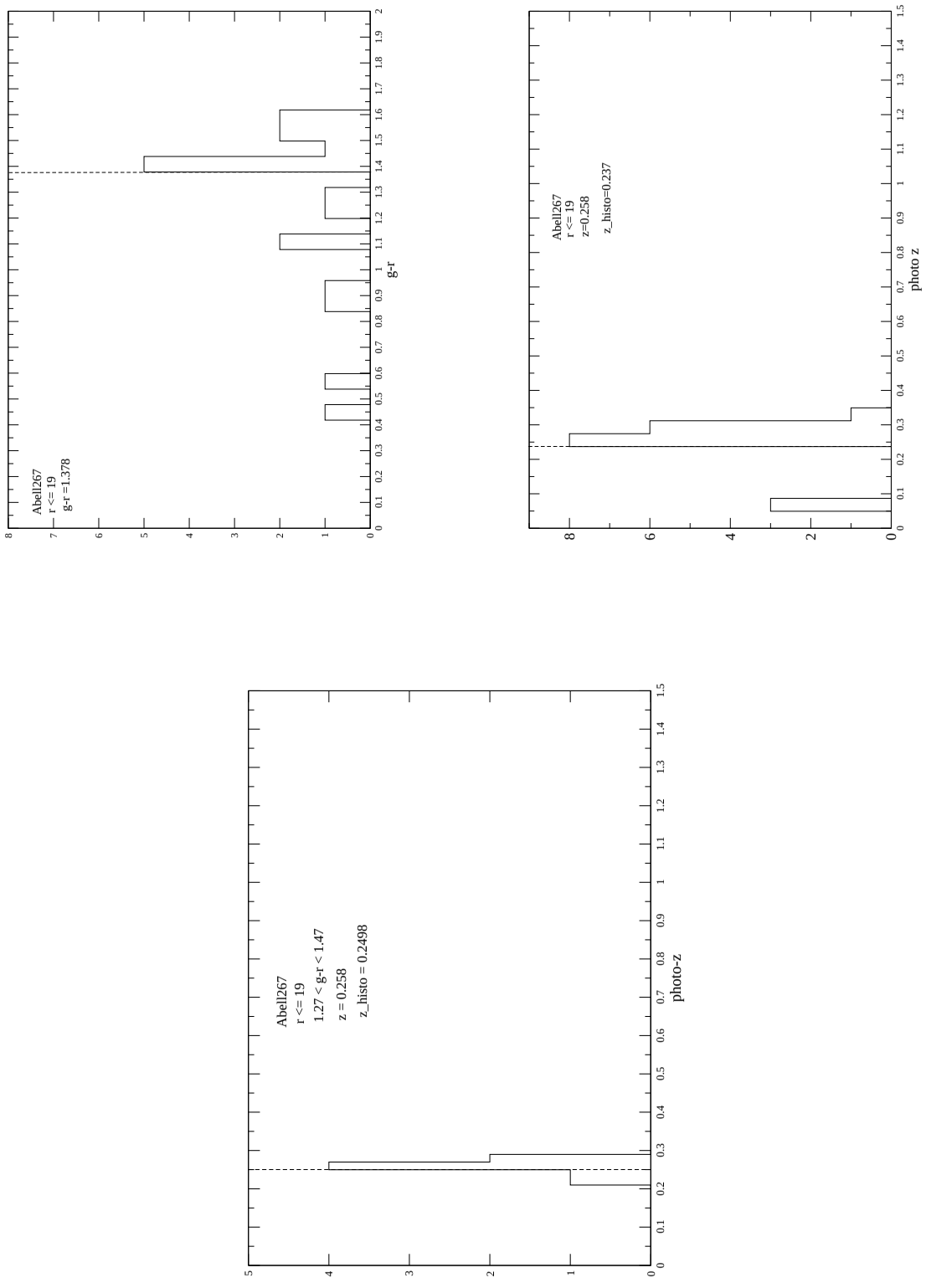

Fig. 5.— Ken Rines, astro-ph/0306538.

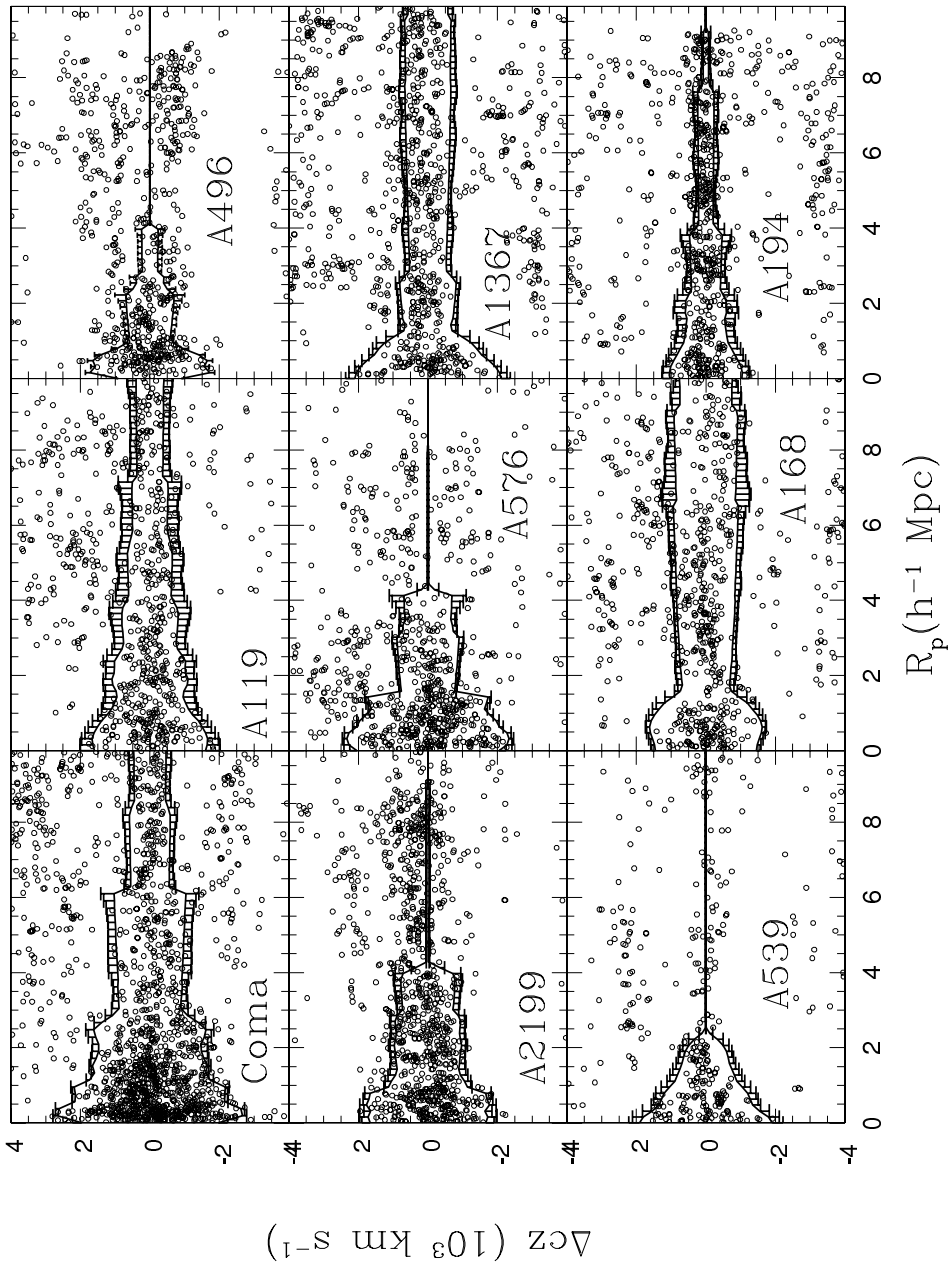

Fig. 2.— Redshift versus radius for galaxies around the CAIRNS clusters. The caustic pattern is evident as the trumpet-shaped regions with high density. The solid lines indicate our estimate of the location of the caustics in each cluster. The errorbars are 1-σ uncertainties and are shown only on one side of each caustic for clarity.