Redshifts and Distribution of ACO Clusters of Galaxies

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Abstract. The June 2004 version of our compilation of measured redshifts for clusters in the Abell-ACO catalogue lists redshifts for 3715 clusters/subclusters in 3033 distinct (2396 A- and 637 S-) clusters, 67% of these with \(N_z \geq 3\) galaxies measured. We provide velocity dispersions \((\sigma_V)\) for 1875 (sub)clusters towards 1353 unique ACO clusters. The median \(\sigma_V\) is 650 km s\(^{-1}\) for A-(sub)clusters and 575 km s\(^{-1}\) for S-(sub)clusters, and \(\sigma_V\) clearly increases with both, \(N_z\) and richness, and also, somewhat surprising, with later Bautz-Morgan type of the clusters. We show examples of supercluster properties based on these data.

1. Introduction, Methodology and Problems encountered

Our compilation of measured redshifts for clusters from the catalogue of Abell, Corwin, & Olowin (1989, ACO) has been maintained since 1989 (Andernach 1991; Andernach, Tago, & Stengler-Larrea 1995 (ATS95); Andernach & Tago 1998 (AT98)) and is the only such compilation including both A- and S-clusters. Different from previous compilations (e.g. Struble & Rood 1999, SR99, who include A-clusters only), we systematically scan the literature for galaxy redshifts. Surveys like the LCRS (Shectman et al. 1996), 2dF, 6dF (Jones et al. 2004), and SDSS (Abazajian et al. 2004) prove to be rich in ACO cluster redshifts. Our selection criteria for galaxy redshifts, and the cluster parameters we include in our compilation can be found in ATS95 and AT98.

The number of references contributing cluster redshifts has increased so much that one of us (HA) now compiles all individual galaxy positions and redshifts, so as to ease the merging of different data sources. For clusters with large \(N_z\) and several papers to merge, this work is in progress. Our current compilation is based on 685 references, growing by \(~\text{40 per year.}\) Sixty percent of the 3715 mean redshifts, and 86% of the 1875 velocity dispersions are based on our own calculations, using individual galaxy data. Over 330 redshifts are based on the merging of galaxy data from four or more references. We do not include any photometric redshifts nor any galaxy velocities with errors \(\gtrsim 600\) km s\(^{-1}\).
In order to merge galaxy data from different sources for the same cluster, we need individual galaxy positions, velocities, and errors. Lack of these data prevents the merging of many data sources or calculation of $\sigma_V$ (e.g., we list over a dozen clusters with $N_z \geq 10$ but no $\sigma_V$ reported). Often publications do not state whether redshifts are geo-, helio- or galactocentric. The fact that the data releases of large projects like 2dF, 6dF, SDSS, etc., tend to be cumulative (i.e. each release contains previous ones, often with reprocessed data) rather than incremental, makes the updating of our compilation very tedious.

To calculate $\bar{z}$ and $\sigma_V$ for a cluster, we first search for any relative maxima in the redshift distribution of galaxies within the cluster area. Around each relative maximum we include into a single cluster component all galaxies within $\pm 2500$ km s$^{-1}$ from that maximum. We use this value also as a minimum velocity gap for subclusters closely spaced along the line of sight. Only if subclusters were published with a smaller separation in velocity (mostly due to components separated in the plane of the sky), we adopt them from the literature as is.

Apart from three known pairs of duplicate clusters in ACO, and six further pairs reported by AT98, we propose A3742=S 924 as an additional identity.

2. Current Status

Redshifts (based on at least one galaxy measured) are now available for 59% of all 4076 A-clusters and for 54% of all 1174 supplementary southern S-clusters, which is an almost 4-fold increase over Abell et al. (1989). Only 2.7% of the redshifts are beyond a factor two from their photometric estimates (see Sect. 3). A significant improvement over previous compilations is that 67% (compared to 43% in SR99) of the redshifts are based on $N_z \geq 3$ measured galaxies, and can thus be considered “reliable”. This, as well as the almost 3-fold increase in the number of known velocity dispersions over SR99, is due to our efforts to merge all available data sources, especially in the regime of low $N_z$.

There are 1245 (sub)clusters with $N_z>10$, of which 276 have $N_z>50$ (the typical minimum for dynamical studies), and 95 (sub)clusters have $N_z \geq 100$. The total number of galaxies involved for all our listed (sub)clusters is $\sim 56,800$ (9500 of which in S-clusters), including some overhead for overlapping clusters for which it is not possible to assign galaxies uniquely to one cluster.

We quote $\sigma_V$ for 1353 different Abell clusters (1080 A- and 273 S-clusters, for a total of 1875 subclusters). The median $\sigma_V$ for all 1875 (sub)clusters is $636 \text{ km s}^{-1}$, and their distribution shows an almost Gaussian main peak at $\sim 630 \text{ km s}^{-1}$ with a dispersion of $\sim 275 \text{ km s}^{-1}$, followed by a weak tail out to 2000 km s$^{-1}$ (probably containing some line-of-sight superpositions or mergers).

3. Some Exploratory Analysis

For the rich ACO clusters (A-names) we use the redshift estimate by Peacock & West (1992, kindly provided by M. West), while for the S-clusters we use a function originally proposed by Abell et al. (1989) for southern A-clusters, but scaled down by 30% on the basis of 196 S-cluster redshifts (Andernach 1991). Now, with three times the number of S-cluster redshifts in hand, we confirm S-clusters to have on average 30% lower $z$ than the ACO estimate. It is not
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clear whether this is due to an excess foreground contamination of redshifts, or due to a systematic overestimate of $m_{10}$S of the clusters caused by background contamination. We do not confirm the claim by AT98 that S-clusters suffer more from line-of-sight superposition than A-clusters: currently 16% of both A- and S-clusters appear with more than one redshift entry, and it rather seems that deeper and deeper surveys (like 2dF or SDSS) tend to find more clusters along the line of sight.

Redshifts are now available for all except 60 (1.5%) rich (A-) clusters with estimated redshift $z_{est} < 0.1$, while 17 S-clusters (7%) with $z_{est} < 0.05$ (and 240, or 32%, with $z_{est} < 0.1$) still lack a measured redshift. There is still plenty of high-galactic-latitude sky with galaxies brighter than $15m_{5}$ unexplored in redshift. However, these gaps are getting smaller: e.g., we found that only the increment of 6dF-FDR (Jones et al. 2004) over 6dF-EDR yields new redshifts for ~250 clusters with no previous $z$, about half of these with $z_{est} < 0.1$. Based on now 15 years of compilation experience we anticipate that only in ~10 years from now the redshift completeness of the ACO catalogue may get close to 100%.

The distribution of $\sigma_V$ for the 1875 (sub)clusters depends strongly on $N_z$. We find median values of $\sigma_V$ for 556 km s$^{-1}$ for 651 (sub)clusters with $N_z < 10$, 616 km s$^{-1}$ for 564 (sub)clusters with $10 \leq N_z \leq 20$, and 703 km s$^{-1}$ for 597 (sub)clusters with $N_z > 20$. These medians are slightly lower than those reported in AT98 due to a more careful clipping of outliers. As shown by Plionis et al. (2004) $\sigma_V$ increases with both $N_z$ and with Abell count $N_{Ab}$. This correlation may be partly due to an observer’s tendency to measure more redshifts in richer clusters and thus the $\sigma_V - N_z$ correlation may be a reflection of the known richness dependence of $\sigma_V$.

The morphological classification available for most ACO clusters is the “Bautz-Morgan” (BM) type. Using only subclusters with the highest $N_z$, we find that the mean and median $\sigma_V$ for 664 (sub)clusters of “early” BM type ($\leq$II) are lower by ~45 km s$^{-1}$ than for 614 (sub)clusters of “late” BM type (>II). A Kolmogoro-Smirnov test gives only a 1.8% chance for these samples to be drawn from the same population. The direction of this trend is surprising, as earlier BM types are expected to be more evolved and to have higher X-ray luminosity, and thus to show a higher $\sigma_V$ (David, Forman, & Jones 1999). These authors found that X-ray luminosity is correlated with both Abell richness class $R$ and BM type, but also that $R$ may be overestimated in the southern ACO. Using updated X-ray samples and more cluster parameters, like $\sigma_V$, we plan to shed more light on the relation between cluster dynamics and BM type.

4. Applications: Large-Scale Structure and Superclusters

We used our compilation in the past to establish the presently most complete catalogues of superclusters (SCL) of Abell- and X-ray clusters (e.g. Einasto et al. 2001), and showed that X-ray clusters are more strongly clustered into superclusters than are optical clusters. We used the SCL catalogue to confirm that the richest superclusters occupy a more or less regular lattice of $120h_{100}^{-1}$Mpc grid size (Einasto, et al. 1994, Saar et al. 2002). Based on the current compilation we extended our SCL catalogue out to $z = 0.15$. In particular, several very interesting SCLs were revealed.
The most prominent Abell supercluster crossed by the Northern LCRS slices is SCL 126 \((z=0.084)\) in the direction of Virgo. Four out of a total of seven ACO member clusters of this SCL lie within a sphere of diameter \(\sim 10 \, h_{100}^{-1} \, \text{Mpc}\). Three clusters in this SCL are strong X-ray sources, and four contain radio sources. This makes SCL 126 one of the most unusual superclusters currently known. The shape ellipsoids, based on Abell clusters, on LCRS Loose Groups (LCLG, Tucker et al. 2000), and on LCRS galaxies in SCL 126, all have axis ratios of \(\sim 1:4\), and are located perpendicular to the line of sight (Einasto, M. et al. 2003b). This may be evidence for a “squashing effect” of galaxies falling into SCLs (Kaiser 1987), accompanied by merging and other processes causing X-ray and radio emission from the clusters. The core of SCL 126 may have started to collapse (Gramann & Suhhonenko 2002).

Another prominent SCL is “Horologium–Reticulum” (SCL 48 at \(z \sim 0.064\)), crossed by all southern LCRS slices. This supercluster consists of several concentrations of Abell clusters and LCLGs which are connected by filaments of galaxies, groups and clusters that surround underdense regions (Einasto, M. et al. 2003b; Einasto, J. et al. 2003).

Galaxy groups from the LCRS and SDSS in high-density environments (superclusters of Abell clusters) are also richer and more massive than groups in low-density environments (Einasto, M. et al. 2003a, b; Einasto, J. et al. 2003).

These results indicate that superclusters, as high-density environments, play a major role in the formation and evolution of galaxy systems.

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References
Abazajian, K., Adelman-McCarthy, J. K., Agüeros, M. A., et al. 2004, AJ, 128, 502
Abell G. O., Corwin H. G. Jr., & Olowin R. 1989, ApJS, 70, 1
Andernach, H. 1991, in Large-Scale Structures and Peculiar Motions, eds. D. W. Latham & L. N. daCosta), ASP Conf. Ser. 15, 279
Andernach, H., Tago, E., & Stengler-Larrea, E. 1995, Ap. Lett. & Comm. 31, 27
Andernach, H., & Tago, E. 1998, in Large Scale Structure: Tracks and Traces, eds. V. Müller, et al., Singapore: World Scientific, p. 147 (astro-ph/9710265)
David, L. P., Forman, W., & Jones, C. 1999, ApJ, 519, 533
Einasto, J., Hütsi, G., Einasto, M., et al. 2003a, A&A, 405, 425
Einasto, J., Einasto, M., Hütsi, G., et al. 2003b, A&A, 410, 425
Einasto, M., Einasto, J., Tago, E., et al. 1994, MNRAS, 269, 301
Einasto, M., Einasto, J., Tago, E., Müller, V., & Andernach, H. 2001, AJ, 122, 2222
Einasto, M., Einasto, J., Müller, V., et al. 2003a, A&A, 401, 851
Einasto, M., Jaaniste, J., Einasto, J., et al. 2003b, A&A, 405, 821
Gramann, M., & Suhhonenko, I. 2002, MNRAS, 337, 1417
Jones, H., Saunders, W., Colless, M., et al. 2004, MNRAS, in press (astro-ph/0403501)
Kaiser, N. 1987, MNRAS 227, 1
Peacock, J. A., & West, M. J. 1992, MNRAS 259, 494
Plionis, M., Andernach, H., López-Cruz, O., Tago, E., & Basilakos, S. 2004, submitted
Saar, E., Einasto, J., Toomet, O., Starobinsky, A. A., et al. 2002, A&A, 393, 1
Shectman, S. A., Landy, S. D., Oemler, A., et al. 1996, ApJ 470, 172
Struble, M., & Rood, H. J. 1999, ApJS, 125, 35
Tucker, D. L., Oemler, A. Jr, Hashimoto, Y., et al. 2000, ApJS, 130, 237