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A catalogue of velocities in the direction of the cluster of galaxies Abell 496⋆,⋆⋆

F. Durret[1,2], **P. Felenbok**[2], **C. Lobo**[3], **and E. Slezak**[4]

[1] Institut d'Astrophysique de Paris, CNRS, 98bis Bd. Arago, F-75014 Paris, France
[2] DAEC, Observatoire de Paris, Université Paris VII, CNRS (UA 173), F-92195 Meudon Cedex, France
[3] Osservatorio Astronomico di Brera, via Brera 28, I-20121 Milano, Italy
[4] Observatoire de la Côte d'Azur, BP. 229, F-06304 Nice Cedex 4, France

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Abstract. We present a catalogue of velocities for 466 galaxies in the direction of the cluster Abell 496, in a region covering about $160' \times 160'$ (9.2×9.2 Mpc for an average redshift for Abell 496 of 0.0331, assuming $H_0 = 50$ km s^{-1} Mpc^{-1}). This catalogue includes previously published redshifts by Proust et al. (1987), Quintana & Ramírez (1990) and Malumuth et al. (1992), redshifts from the CfA redshift survey, together with our new measurements. A total of 274 galaxies have velocities in the $7800 - 11800$ km s^{-1} interval, and will be considered as members of the cluster. Abell 496 therefore becomes one of the few clusters with a high number of measured redshifts; its physical properties are investigated in a companion paper.

Key words: galaxies: clusters: individual: Abell 496; galaxies: clusters: general

1. Observations and data reduction

1.1. Description of the observations

The observations were performed with the ESO 3.6 m telescope equiped with MEFOS during 6 nights on November 5-11, 1994 and 2 nights on November 24-26, 1995. A description of the instrument can be found in Durret et al. (1998). The grating used with the Boller & Chivens spectrograph had 300 grooves/mm, giving a dispersion of 224 Å/mm in the wavelength region $3820 - 6100$ Å. The detector was CCD #32, with 512^2 pixels of 27×27 μm.

The catalogue of galaxy positions used in this survey was obtained with the MAMA measuring machine and is presented in a companion paper (Slezak et al. 1999). This catalogue gives very accurate positions, but magnitudes in the photographic b_J band are known with an accuracy of 0.1 magnitude at best. CCD photometry of the central regions of the cluster in the V and R bands was later performed to recalibrate these b_J magnitudes and to obtain R magnitudes for the entire photometric sample. We observed spectroscopically a total of 15 fields, with exposure times of 2×30 minutes, and we obtained 473 spectra in total (plus the same number of sky spectra). The limiting magnitude for the galaxies observed spectroscopically was $b_J = 19$, corresponding to a recalibrated magnitude $R \sim 18.7$ (see Sect. 3).

Out of the 473 spectra obtained, we measured 410 reliable redshifts (the other ones were discarded due to insufficient signal to noise ratio). Since Abell 496 is at a relatively low galactic latitude, the effects of stellar contamination of our photographic plate catalogue are large. Our star-galaxy separation software was imperfect since out of the 410 objects for which redshifts were measured only 305 were galaxies. Such a high degree of contamination of the catalogue is at least partly due to the fact that we preferred to have a galaxy catalogue as complete as possible, in order not to "miss" galaxies. Our catalogue includes these 305 galaxy spectra, plus those previously published by Proust et al. (1987), Quintana & Ramírez (1990) and Malumuth et al. (1992), and some galaxies from the CfA redshift catalogue (Huchra et al. 1992), reaching a total of 466 galaxy redshifts after eliminating objects observed twice.

The positions of the objects for which we gathered reliable spectra (either from our observations or from the literature) are shown in Fig. 1. These positions are

Send offprint requests to: F. Durret, e-mail: durret@iap.fr

⋆ Based on observations collected at the European Southern Observatory, La Silla, Chile.

⋆⋆ Tables 3 and 4 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

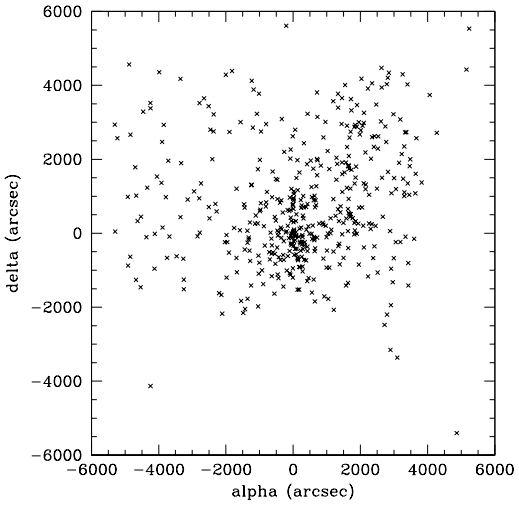

Fig. 1. Spatial distribution of the 466 galaxies with redshifts in the direction of Abell 496 (map limited to ±6000 arcsec from the cluster center)

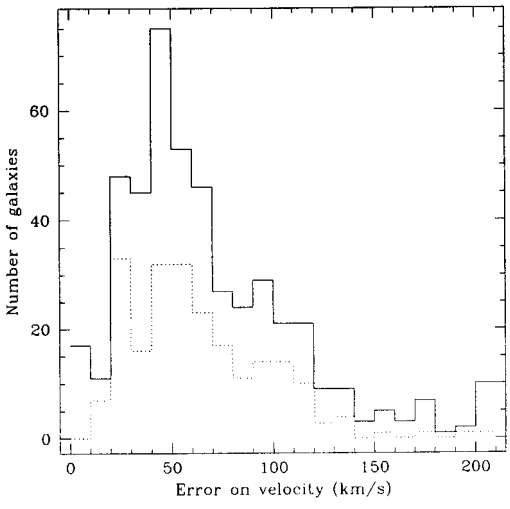

Fig. 2. Distribution of errors on velocities derived from absorption lines for the entire catalogue (full line) and for our data (dotted line)

relative to the cluster center taken to be the position of the maximum X-ray emission (Pislar 1998): $\alpha_{2000.0} = 04^{\rm h}33^{\rm m}37.9^{\rm s}, \delta_{2000.0} = -13°15'47''$. This center is within 7 arcsec of the position of the cD galaxy, a distance which is smaller than the ROSAT PSPC pixel size, and we will therefore consider hereafter that both positions coincide.

1.2. Data reduction

The spectra were reduced using the IRAF software. The frames were bias corrected in the usual way. Velocities were measured by cross-correlating the observed spectra with different templates: a spectrum of M31 (kindly provided by J. Perea) at a velocity of -300 km s^{-1}, and stellar spectra of the standard stars HD 24331 and HD 48381, which were each observed every night during our 1994 run. The cross-correlation technique is that described by Tonry & Davis (1979) and implemented in the XCSAO task of the RVSAO package in IRAF (Kurtz et al. 1991). The errors on the velocities derived from absorption lines are given automatically by this task.

The positions of emission lines, when present, were measured by fitting each line with a Gaussian.

All the redshifts were measured by the same person (F.D.) in a homogeneous way. Redshifts of insufficient quality were discarded (i.e. those with a Tonry & Davis parameter smaller than 2.0, except for three galaxies with respective Tonry & Davis parameters of 1.5, 1.6 and 1.9 where the absorption lines seemed to be well enough defined for these redshifts to be kept in the final catalogue).

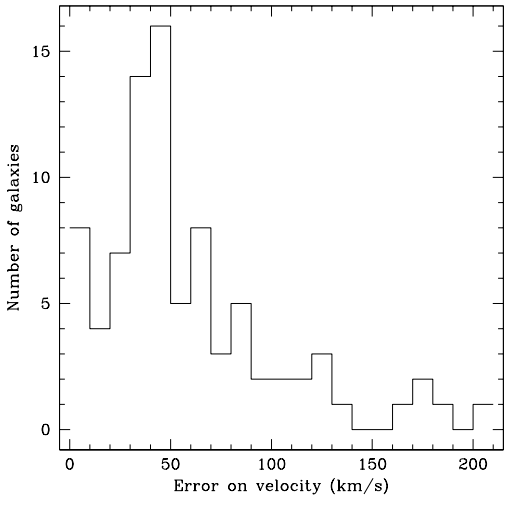

Fig. 3. Distribution of errors on velocities derived from emission lines (our data only)

2. Quality of the data

For galaxies with absorption lines, two velocity standard stars from the Maurice et al. (1984) list were observed each night in order to check the intrinsic quality of our velocity measurements. The errors, derived by cross-correlating the star spectra to the spectrum of M31, range (from night to night) from ±16 to ±23 km s^{-1} for HD 24331, and from ±17 to ±43 km s^{-1} for HD 48381. The mean internal error on velocities derived from the rms in the mean wavelength calibration is 66 km s^{-1}.

For emission line measurements, the errors on velocities were estimated from the dispersion of the velocities derived from the various emission lines present. When only one emission line was present we averaged the emission and absorption line redshifts whenever possible; if no

Table 1. Comparison of galaxy velocities measured by us to those in the literature: QR = Quintana & Ramírez (1990), M = Malumuth et al. (1992)

Coordinates (2000.0)	QR velocity	QR error	QR number	Our velocity	Our error	Our reference	Velocity difference	R magnitude
4 31 3.14−12 58 27.01	10457	33	QR32	10524	22	73	67	14.4
4 34 9.86−13 14 35.63	10044	38	QR358	9932	27	331	−112	16.6
Coordinates (2000.0)	M velocity	M error	M number	Our velocity	Our error	Our reference	Velocity difference	R magnitude
4 31 23.63−13 04 12.39	9797	126	M3	9610	76	90	−187	15.5
4 31 43.06−13 07 09.70	10991	163	M5	11106	43	115	115	17.0
4 32 23.93−12 46 47.45	10700	30	M19	10140	23	164	−560	14.9
4 32 52.84−13 22 33.42	9665	80	M27	9594	21	189	−71	15.7
4 33 00.06−13 15 59.91	11063	51	M39	10967	19	204	−96	15.7
4 33 11.43−13 27 59.68	10689	170	M50	10670	19	218	−19	17.5
4 33 14.38−13 19 48.88	11802	74	M51	11860	27	219	58	17.3
4 33 28.34−13 27 18.83	9806	144	M74	10134	49	249	328	18.1
4 33 33.49−13 18 52.17	11773	56	M83	11754	31	262	−19	17.5
4 33 33.92−13 22 50.20	10235	45	M84	10288	20	264	53	16.5
4 33 38.40−13 02 39.49	16691	136	M93	16808	50	281	117	18.3
4 33 42.78−13 08 46.79	10495	50	M102	10546	58	295	51	17.9
4 33 56.88−13 19 18.75	9561	77	M114	9577	41	313	16	17.7
4 34 03.81−13 27 47.23	8305	42	M121	8316	58	323	11	15.8
4 34 07.25−13 15 14.45	9440	51	M123	9521	22	326	81	16.6
4 34 12.95−13 10 03.83	10836	64	M128	10894	58	335	58	17.3
4 34 35.72−13 21 19.38	10093	27	M139	10100	23	354	7	17.0
4 35 32.37−13 33 22.23	9867	112	M154	10121	23	395	254	15.5
Coordinates (2000.0)	CfA velocity	CfA error	CfA number	Our velocity	Our error	Our reference	Velocity difference	R magnitude
4 31 03.22−12 58 26.12	10519	33	A0428−1304	10524	22	73	−5	14.4
4 31 16.57−12 27 18.90	9582	32	I 376	9224	23	85	−358	14.0
4 31 23.71−13 04 13.44	9797	126	A0429−1310	9610	76	90	−187	15.5
4 31 43.10−13 07 10.74	10991	163	A0430−1253A	11106	43	115	115	17.0
4 32 52.92−13 22 33.43	9581	28	A0430−1328A	9594	21	189	13	15.7
4 33 00.14−13 16 00.08	11062	34	A0430−1322B	10967	19	204	−95	15.7
4 33 14.43−13 19 49.28	11802	74	A0430−1326	11860	27	219	58	17.3
4 33 28.41−13 27 19.68	9806	144	A0431−1333A	10134	49	249	328	18.1
4 33 33.53−13 18 52.51	11773	56	A0431−1325C	11754	31	262	−19	17.5
4 33 33.92−13 22 50.71	10347	34	A0431−1329C	10288	20	264	−59	16.5
4 33 38.46−13 02 39.65	16691	136	A0431−1308A	16808	50	281	117	18.3
4 33 56.93−13 19 19.48	9561	77	A0431−1325E	9577	41	313	16	17.7
4 34 07.24−13 15 14.35	9513	47	A0431−1321H	9521	22	326	8	16.6
4 34 09.94−13 14 35.07	10101	38	A0431−1320D	9932	27	331	−169	16.6
4 34 13.05−13 10 04.09	10836	64	A0431−1316C	10894	58	335	58	17.3
4 34 35.72−13 21 19.45	10191	29	A0432−1327B	10100	23	354	−91	17.0
4 35 32.40−13 33 22.54	9867	112	A0433−1339	10121	23	395	254	15.5

reliable absorption line redshift was available, we estimated the internal error on a single emission line to be the intrinsic value of 66 km s^{-1}. The number of redshifts obtained from emission lines is 85.

The distributions of errors on all the velocities in the catalogue are displayed in Figs. 2 and 3 for absorption and emission line measurements respectively. For the 220 galaxies with absorption lines taken from our observations, the histogram of the Tonry & Davis signal to noise parameter R given by the cross-correlation measure is displayed in Fig. 4 (this quantity is not given in previously published catalogues). The corresponding correlation between the Tonry & Davis R parameter and the error on the velocity is shown in Fig. 5.

In order to check the quality of our redshifts, we also reobserved 2 galaxies from Quintana & Ramírez (1990) and 18 from Malumuth et al. (1992). The results are shown in Table 1. For galaxies observed twice, we chose to give in our final catalogue the redshift with the smallest error (usually our data). The mean absolute difference between our measurements and those of Malumuth et al. (18 galaxies) is 117 km s^{-1}, with a dispersion of

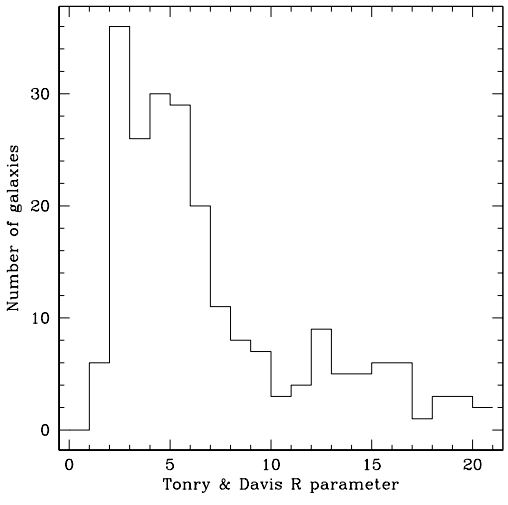

Fig. 4. Distribution of the Tonry & Davis R parameter given by the cross-correlation measure on absorption lines (our data)

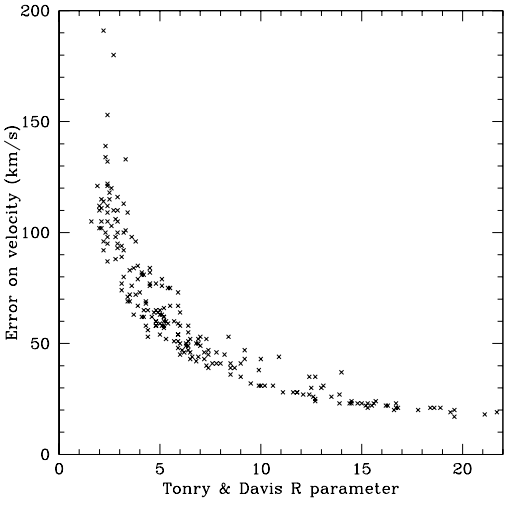

Fig. 5. Relation between the Tonry & Davis R parameter and the errors on velocities derived from absorption lines (our data)

137 km s^{-1}, implying that the general agreement is good. Note that the difference between our velocities and those of the literature does not tend to be larger for fainter magnitudes. The agreement with the two galaxies in common with Quintana & Ramírez (1990) is satisfactory but cannot be tested statistically. A comparison with 17 galaxies in common with the CfA redshift catalogue (Huchra et al. 1992) gives a mean absolute difference of 115 km s^{-1} with a dispersion of 107 km s^{-1}. Notice that there are many galaxies in common in the Malumuth and CfA samples.

The final redshifts derived from our observations given in the catalogue are those derived from the cross-correlation with M31, since this template gave the best results. A correction was applied to correct for the velocity of M31 (-300 km s^{-1}) and to obtain heliocentric velocities.

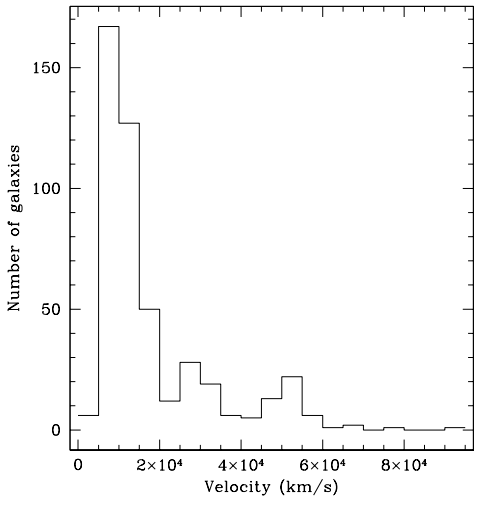

Fig. 6. Velocity histogram of all the galaxies in the catalogue

The histogram of all the velocities in the catalogue is displayed in Fig. 6. It will be discussed in detail in a companion paper (Durret et al. in preparation).

We have estimated the completeness of the final spectroscopic catalogue presented here by comparing the number of galaxies with redshifts to the total number of galaxies from our photographic plate catalogue in the same area. Results are shown in Table 2. Note that the 17 galaxies in our redshift catalogue which do not have magnitudes (see Sect. 3) have been excluded from these statistics, and therefore the catalogue completeness may be slightly larger than estimated in the table.

3. Galaxy magnitudes

The magnitude histograms for the galaxies and stars misclassified as non-PSF-like objects are displayed in Figs. 7 and 8 respectively. The percentage of contamination by stars is very high: about 20%.

For a large fraction of the galaxies taken from the literature, R magnitudes were made available to us by C. Adami (private communication). In order to give magnitudes for all galaxies in the same photometric band, we estimated the R band magnitudes for the galaxies that we observed. This was done by identifying galaxies both in our photographic plate catalogue and in our CCD catalogue, and by finding the best linear fit (see Slezak et al. 1999 for details). This best fit was: $R = b_{\rm J} - 0.28$, with the slope fixed to 1.0, giving an rms fluctuation of 0.04. The galaxies in the literature for which Adami did not have magnitudes were identified with objects in our photographic plate catalogue, and we applied the same relation to derive their R magnitudes from their $b_{\rm J}$ magnitudes. For some of the CfA galaxies, only $B_{\rm T}$ magnitudes were

Table 2. Completeness of the redshift catalogue for different field diameters and for various limiting magnitudes in the R band. Numbers in parentheses indicate the absolute numbers of galaxies with and without redshifts respectively. Note that for galaxies belonging to the cluster 1800″ correspond to 1.732 Mpc with $H_0 = 50$ km s^{-1} Mpc^{-1}

Limiting radius (″) R magnitude	1800	2400	3600	5400
16.0	100.0% (64/64)	98.7% (77/78)	80.7% (96/119)	62.3% (114/183)
16.5	84.3% (75/89)	74.6% (94/126)	65.1% (123/189)	52.1% (146/280)
17.0	81.7% (98/120)	72.3% (128/177)	61.4% (178/290)	51.1% (216/423)
17.5	85.5% (124/145)	74.0% (165/223)	62.0% (230/371)	50.4% (289/573)
18.0	80.6% (158/196)	70.5% (206/292)	57.3% (283/494)	46.0% (354/769)
18.5	78.7% (196/249)	69.1% (250/362)	52.7% (336/638)	40.5% (415/1024)
19.0	62.6% (206/329)	55.5% (263/474)	40.6% (353/869)	30.6% (435/1421)

available; we roughly transformed them to R magnitudes, by calculating the mean $(V-R)$ colour for the 239 galaxies detected in V in our CCD catalogue (Slezak et al. 1999); this mean value is equal to 0.48, and therefore roughly corresponds to a G0 star for which $(V - R) = 0.52$ and $(B - V) = 0.58$ (e.g. Allen 1981), leading to $R \sim B-1.1$; for these CfA galaxies, we therefore took $R = B_{\rm T} - 1.1$.

33 galaxies in our redshift catalogue have no identification with our photometric catalogue: 4 from Quintana & Ramírez (1990), 14 from Malumuth et al. (1992), 1 from Proust et al. (1987) and 14 from Huchra et al. (1992). They are the objects in Table 4 that have labels 2 to 5 in Col. (16), and their corresponding identification number in the literature, but no identification number from our photographic plate catalogue. Note that out of these 33 objects, half are located outside the area covered by our photometric catalogue, and three are located less than 1 arcmin from the cluster center, so we cannot separate them from the cD. The reason for the lack of identification of the other objects is not clear, since in all the cases where we did identify galaxies from our sample to galaxies in the literature the coordinates matched within a few arcseconds. The most likely explanation is that the coordinates given in the literature for these objects are not accurate; the fact that they may have not been detected in our photographic plate scan is unlikely since they are all very bright ($R \leq 16.8$).

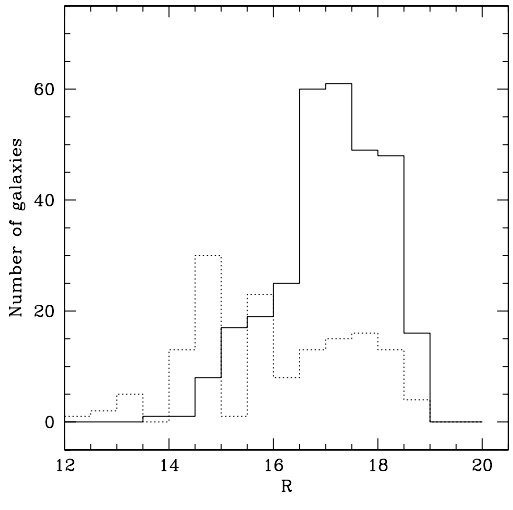

Fig. 7. Magnitude histogram in the R band for the 305 galaxies for which we measured velocities (full line) and for the 144 galaxy redshifts taken from the literature (dotted line). The 17 missing galaxies are those for which no magnitude is available

4. The catalogues

The coordinates and $b_{\rm J}$ magnitudes of the 101 stars misclassified as galaxies are given in Table 3 (available in electronic form only), to avoid further observations of these objects in galaxy surveys.

The velocity data for the galaxies in the field of Abell 496 are given in Table 4 (available in electronic form only). The meaning of the columns is the following:

(1) running number;
(2) to (4) right ascension (equinox 2000.0);
(5) to (7) declination (equinox 2000.0);
(8) heliocentric velocity (cz) in km s^{-1};
(9) error on the velocity in km s^{-1}; for velocities derived from absorption lines, the error is either that stated in the literature or, for our own measurements, that given by the RVSAO IRAF package; for velocities derived from several emission lines, the error was estimated from the dispersion between the velocities derived from the different emission lines; when only one emission line was present and no absorption line redshift was available, the error on the velocity was taken to be the mean internal velocity error;
(10) R band magnitude (see Sect. 3);

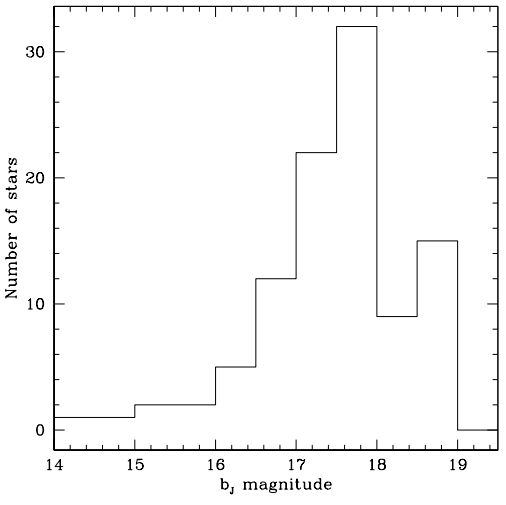

Fig. 8. Magnitude histogram in the b_J band of the 101 stars initially misclassified as galaxies in the photometric sample used for our target selection

(11) and (12) X and Y positions in arcseconds relative to the center assumed to have coordinates:
$\alpha_{2000.0} = 04^h33^{mn}37.9^s, \delta_{2000.0} = -13°15'47''$;
(13) distance to the cluster center in arcseconds;
(14) Tonry & Davis parameter;
(15) label indicating the means of determination of the redshift: 0=derived from absorption lines, 1=derived from emission lines;
(16) label indicating the origin of the data: 1=our data, 2=Quintana & Ramírez (1990), 3=Malumuth et al. (1992), 4=Proust et al. (1987), 5=Huchra et al. (1992); note that the catalogue by Malumuth et al. (1992) includes previous measurements by Quintana et al. (1985) and Zabludoff et al. (1990);
(17) reference to the galaxy number in the various catalogues; for our own data (label 1 in Col. 16), the number appearing in this column is that of the photographic plate catalogue by Slezak et al. (1999), Table 1; for data taken from the literature, the first number is that of the previously published catalogue (or the name for CfA galaxies), the second that of the photographic plate catalogue by Slezak et al. (1999) whenever the identification was possible.

5. Conclusions

This redshift catalogue will be used, together with our photometric catalogues (which include both the large field catalogue obtained by scanning a photographic plate and the small CCD field catalogue, Slezak et al. 1999), to give an interpretation of the properties of Abell 496 (Durret et al. in preparation). They will be compared to the results already obtained from ROSAT PSPC X-ray data (Pislar 1998).

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