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H I-deficiency in Hickson compact groups of galaxies*

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Abstract. We present HI observations of 54 Hickson Compact Groups (HCG) of which 41 have been detected in the 21-cm line of neutral hydrogen. For 13 objects upper limits have been obtained. The integrated M_{HI}/L_B values of the observed HCGs scatter over a large range of values showing strong HI-deficiencies for a great number of objects.

Key words: galaxies: clusters – galaxies: interstellar matter

1. Introduction

The definition of Hickson compact groups (HCG) by the number of members (N≥4) within three magnitudes of the brightest galaxy (m_0+3), compactness, and degree of isolation (Hickson 1982, 1993) could not decide on the membership of individual galaxies. When redshifts became available for almost all galaxies in HCGs (Hickson 1993) it became evident that most of these compact associations of galaxies were physical groups with only a few by chance projections of field galaxies in the foreground or background. A study of the environment of HCGs (Palumbo et al. 1995) revealed that most compact groups are isolated, only 16% of them seem to be the compact inner parts of larger groups. The mean fraction of spiral galaxies in HCG's is lower than in the field. These results contradict the view that most compact groups are the result of chance alignments. Hickson compact groups are among the densest aggregates in the universe. As such, these systems should be the ideal place to look for galaxies in interaction. Roughly 7% of HCG spirals show tidal tails, which is a signature of strong dynamical interaction. Another claim for interaction is drawn from radio properties of spiral galaxies in HCGs. The radio continuum from the nuclear regions is more than 10 times that from comparable regions in a comparison sample (Menon 1995). Massive inflows of gas towards the centres of galaxies would result in star formation activity at the center yielding supernovae and the subsequent radio emission. However the number of identified merger candidates is extremely low, and although star formation is enhanced with respect to isolated galaxies, the level is lower than in pairs (Moles et al. 1994, Sulentic and Rabaca 1994, Zepf et al. 1991).

There is an increasing amount of theoretical and observational work on Hickson groups (e.g. Mamon 1995). Many of the Hickson groups are detected in X-ray ($M_X \sim 10^{10-12}$, Ponman and Bertram 1993, Sulentic et al. 1995, Pildis et al. 1995, Ebeling et al. 1995). At least a third of the individual galaxies show morphological disturbances in optical light (Hickson 1990). In compact groups where tidal interactions are continuous and dynamically important, perturbations in abundance, morphology and kinematics, together with ejection of atomic gas to produce an intragroup medium are clearly important.

Single dish 21-cm HI observations of a sample of spiral rich HCGs using the Green Bank 300ft and the Arecibo telescopes (Williams&Rood 1987) yielded HCGs to be somewhat HI-deficient (by a factor of 2 on average) compared to loose groups. Subsequent interferometer observations of 9 HI-bright groups (Shostak et al. 1984, Williams and van Gorkom 1988, 1995, Williams et al . 1991, Verdes-Montenegro et al. 1997, in preparation) revealed a wide range of morphologies and kinematics and evidence for close interactions in many cases, including several examples of a single HI cloud containing the entire group (Williams & van Gorkom 1995). Apertur synthesis observations tend to detect additional dwarf members (e.g. Verdes-Montenegro et al. 1997 in preparation) of these groups not included in Hicksons definition ($m - m_1 \leq 3$).

The aim of this project was to complete the HI survey of HCGs and look especially for HI in groups with a high content of S0 and E galaxies. The sample was limited by the telescope's declination limit (-31^0) and to a radial velocity range up to $12000 km\, s^{-1}$ due to sensitivity.

2. H I-observations

Observations were performed using the 100-m radiotelescope at Effelsberg which has a half power beam width of 9.3' at the wavelength of 21cm. The 1024-channel autocorrelator was split into four filter banks (256 channels each) using a bandwidth of 12.5 MHz which yielded a resolution of 12 km/s or 20 km/s after Hanning smoothing. A typical observing time of

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* Table 1 is also, Table 2 is only available in electronic form at CDS via ftp 130.79.128.5

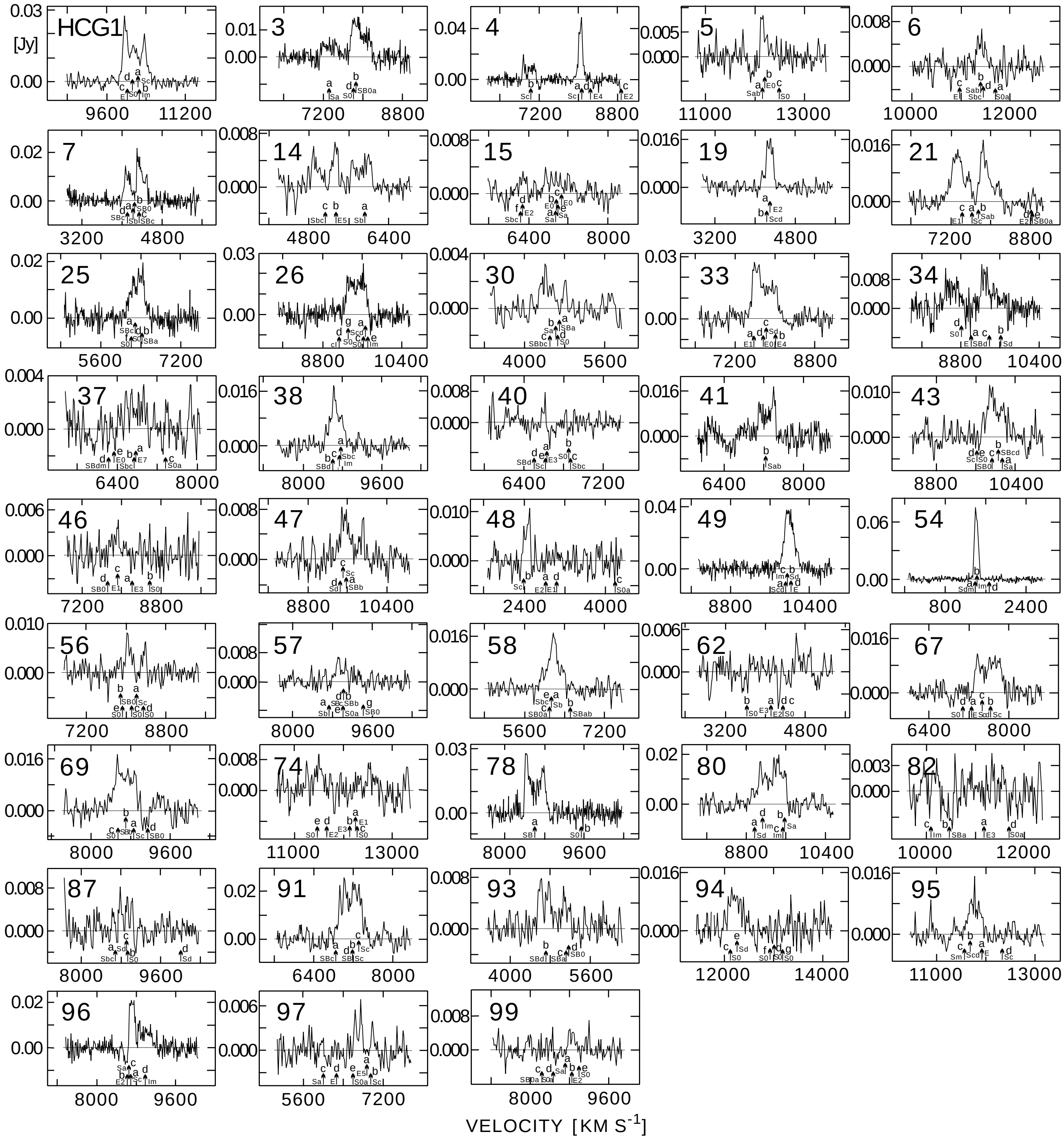

Fig. 1. HI profiles of the 41 detected galaxy groups observed with the 100-m radio telescope at Effelsberg which has a half power beam width of 9.3 arcmin at a wavelength of 21-cm. A few marginal cases have been added. The HCG no. is given in the upper left part of the individual profiles. Optical radial velocities of member galaxies (Hickson 1993) are indicated by vertical arrows and the corresponding identifying letter. The morphological types of these member galaxies are given at the lower end of the arrows. For all groups the observed profile corresponds to the accumulated HI-flux of the member galaxies. For HCG 41 and HCG 78 the HI-profiles correspond to individual galaxies in the velocity range searched for HI. In a few cases the good agreement between optical and radio radial velocities and the separation of HI-profiles allows a tentative identification of individual HI-profiles, e.g. HCG 4, HCG 14, and HCG 48. In HCG 19 radial velocities for only two out of four galaxies are available.

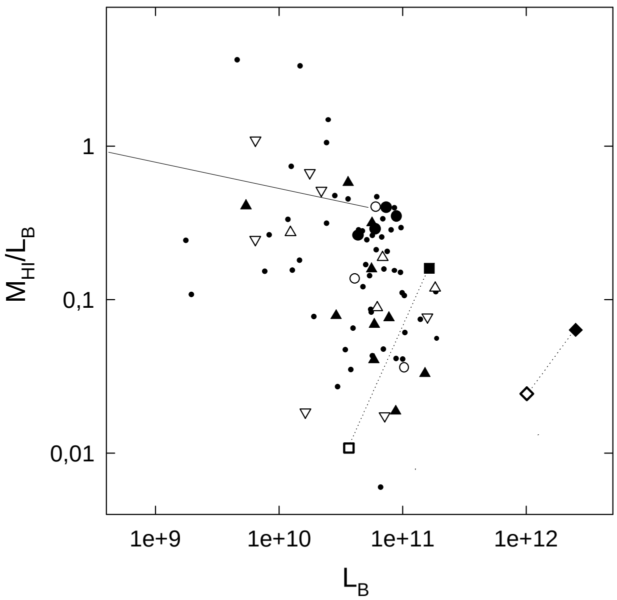

Fig. 2. The relative content of neutral hydrogen M_{HI}/L_B of Hickson Compact Groups of galaxies is plotted versus blue luminosity L_B. Solid symbols represent detections, open symbols upper limits. Circles indicate spiral groups, triangles (up) are mixed spiral-S0 groups, whereas triangles (down) are S0 groups. Four nearby groups are represented by filled circles close to the solid line. The solid line represents the sample of nearby galaxies (HR1). The Coma I group (solid square) contains seven highly HI-deficient galaxies. The open square represents these HI-deficient galaxies. The spirals of the Virgo cluster (solid rhombus) are another examples of an aggregate containing HI-deficient galaxies. These HI-deficient galaxies concentrate towards the cluster's center as can be seen when selecting all spirals within a radius of 1 degree of the center (open rhombus).

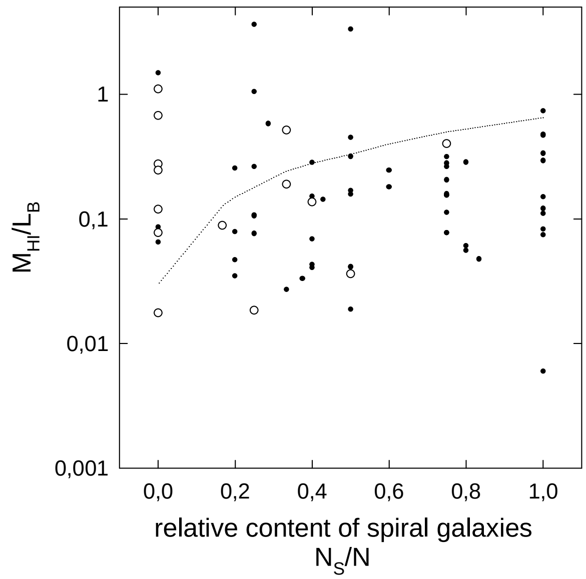

Fig. 3. The relative content of neutral hydrogen M_{HI}/L_B versus relative content of spiral galaxies N_S/N (Table 1) is given for the combined sample of HCGs. Dots are detections, open circles are upper limits. The dotted line was generated by assuming average M_{HI}/L_B ratios for spirals (0.65) and non-spirals (0.03).

60 min per source yielded a r.m.s. noise of 3 mJy (the system noise was 30K). An ON-source position was combined with an OFF-source position every 5 minutes. This total-power mode improves the baseline behavior of the spectra. Regular measurements of well known continuum sources were used to control pointing and calibration of the telescope. Every two to three hours a well known line source (e.g. dwarf galaxies) was observed as a system check. The toolbox software of the MPIfR was used for the data reduction. The observed spectra were corrected for moderately curved baselines only which should not introduce additional errors for the derived velocity and flux measurements.

3. Data

From our searchlist of 54 we detected 41 galaxies. These HI profiles are shown in Fig. 1. Optical radial velocities of member galaxies (Hickson 1993) are indicated by vertical arrows and the corresponding identifying letter. The morphological types of these galaxies are given at the lower end of the arrows. In some cases HI- and optical velocities agree perfectly (e.g. HCG 4 , HCG 41). In many cases the identification between HI-profile and the corresponding galaxy is not possible due to confusion problems. Some profiles resemble the typical two-horned profiles of individual spiral galaxies while others look like strongly confused profiles because of the effect of the overlay of several profiles which are not safely separated in velocity space (e.g. HCG 40). Some of these profiles correspond to individual galaxies, indeed ; for HCG 41, HCG 78 there is only one galaxy within the velocity range searched for HI. Both these galaxies have 'normal' HI abundances (i.e. they are close to the solid line in Fig. 2). In a few cases the separation of HI-profiles allows tentative identification of individual HI-profiles with galaxies (e.g. HCG 4, HCG 14, and HCG 78).

In Table 1 we present the observational data: the HCG number in column 1, R.A. and Dec.(1950.0) in column 2, the optical redshift in column 3, a rough morphological description giving the total number N_S of spirals and the total number N of galaxies in the brightest three magnitudes in column 4, the integrated blue luminosity of all member galaxies later than type E within the velocity interval searched for HI (column 5). The HI data follow; the measured HI flux (column 6), the observed peak of the line and its rms error in column 7 (for non detections only the rms noise is shown), the heliocentric radial velocity derived from the midpoint of the line at 25% and 20% of the peak and its error (column 8), and the linewidths at a level of 50%, 25%, and 20% of the line peak (column 9), and finally the relative HI-content M_{HI}/L_B of the group in column 10.

In Table 2 (which is only available in electronic form) we present a few derived parameter for the combined sample (i.e. data from Williams and Rood 1987 and from Table 1) : the HCG number (column 1), the 1950 position (column 2), the optical redshift (column 3), the heliocentric HI velocity (column 4) is followed by the assumed distance (column 5), the blue luminosity (column 6), the total HI-mass (column 7), and the M_{HI}/L_B ratio in column 8.

Velocity corrections to the centroid of the local group of galaxies have been made following de Vaucouleurs et al. (1990, RC3). Distances have been derived using a Hubble constant $H_0 = 75\, km\, s^{-1}\, Mpc^{-1}$.

The total H I mass has been calculated by

$M_{H\,I} = 2.355\,10^5\, D^2 \int S_v dv$,

where D is the distance in Mpc and $\int S_v dv$ is the integrated HI-flux in $Jy\, km\, s^{-1}$.

4. Discussion

For the discussion of the compact group phenomenon we combine our present sample with that of Willams and Rood (1987). There is some overlap in sources with fine agreement in measured quantities (i.e. radial velocities, fluxes, and linewidths). There is a total of 75 HCGs observed with 61 detections and 14 upper limits.

The (distance-independant) M_{HI}/L_B ratio often has been used to discuss the relative HI content of individual galaxies. In this discussion we will use the integrated HI mass of Hickson Compact Groups and relate it with their integrated luminosities. These values will be compared with the M_{HI}/L_B values of a sample of nearby (individual) galaxies and the integrated values for a selected amount of nearby groups of galaxies.

Assuming elliptical galaxies to possess only few neutral gas by their own we will exclude them when accumulating blue luminosities of all other group members (as given by Hickson 1993). As the HI content of S0 galaxies scatter a lot we marked those groups with at least 50% content in S0 galaxies and those exclusively consisting of S0 galaxies. The result is displayed in Fig. 2 where the integrated M_{HI}/L_B of HCGs is plotted versus their integrated luminosities[1]. Filled symbols indicate detections while open symbols are used for upper limits. Black dots mark spiral groups, triangles(up) mark mixed S0-spiral groups, and triangles(down) mark those groups consisting of S0 galaxies completely. The solid line represents the sample of nearby galaxies (HR1). Solid circles mark some nearby groups (M81-, M101, CnV I-, and CenA-group, data from RH1). The solid square represents the Comaİ group (e.g. Garcia-Barreto et al. 1994), the open square only the seven highly HI-deficient galaxies of this group. The filled rhombus represents the disk galaxies of the Virgo cluster (e.g. HR2), while the open rhombus represents Virgo spirals from the inner region (radius of 1^0) of the cluster. The example of the Coma I group nicely demonstrates the strong HI-deficiency of several HCGs. The four nearby galaxy groups (solid circles) agree well with the regression line of the nearby galaxy sample (solid line) which is not a surprise as these groups are part of the nearby galaxy sample. The scatter of the HCGs in this diagram is enormous, comparable to the scatter of all known galaxies (including elliptical galaxies, which had been excluded from the integrated luminosities of the HCGs).

Among nearby galaxies those with high M_{HI}/L_B values are not frequent but not uncommon either (e.g. HR1). There are a few HI rich HCGs. For compact groups cannibalism and merger events might increase the M_{HI}/L_B values for some galaxies. One could imagine sling-shot events leaving most of the neutral gas within the compact group but not with the expelled galaxy. Accretion of gas from bypassing galaxies or simply additional (not yet detected) HI-rich dwarf members of the HCGs might influence the total M_{HI}/L_B balance of the group.

In Fig. 2 we realize a certain number of groups close to the solid line, their expected place in this diagram. But what is the reason for all those objects with very small M_{HI}/L_B values? For some HCGs we observe an upper limit of about one order-of-magnitude lower than expected! Here we find many of the mixed S0 groups as expected - assuming a rather low M_{HI}/L_B ratio for S0 galaxies. Unfortunately the relatively high upper limits for pure S0 groups are not restrictive enough - higher sensitivity is required in these cases.

In Fig. 3 we compare the M_{HI}/L_B ratio with the relative content of spiral galaxies for our combined sample of HCGs, filled circles mark detections, open circles mark upperlimits. Most compact groups rich in spirals are detected in HI. The detection rate is reduced with decreasing spiral content of the compact groups (N_S/N, where N_S is the number of spirals, N the total number of galaxies within the three brightest magnitudes, Table 1). The dotted line shows 'expected values'. It has been constructed assuming average M_{HI}/L_B ratios for spirals (0.65) and non spirals (0.03 for S0 and E galaxies). This line of expected values would not change much by changing the M_{HI}/L_B values (0.65, 0.03) to (0.46, 0.01) for example. This line is a kind of upper envelope to the measured values except for the spiral-poor groups. Fig. 3 demonstrates that there is a general tendency for HCGs to be HI-deficient, albeit those spiral-poor groups which are greatly overabundent in HI.

Very interesting are the *low* upper limits in the population of HCGs. The strong tidal forces in compact groups might lead to enhanced star formation rates using up much the neutral gas to a high degree and/or yielding a high degree of ionisation by enhanced radiation from the star forming regions. At this point another effect visible with high resolution observations should be mentioned. VLA observations of HCG 95 (Verdes-Montenegro et al. 1997, in preparation) show that most of the observed HI in this group is due to dwarf galaxies that do not fulfill the magnitude restriction (within m_0 + 3) of Hicksons (1982) group definition. Whereas dwarf galaxies do not contribute much to the integrated luminosity of groups their HI-mass might influence the M_{HI}/L_B ratio once the bright group galaxies are of early type. High resolution observations of HCGs will bring more light into the open questions about compact groups of galaxies.

[1] The nonlinearity in the relationship between L_B and M_{HI} (e.g. HR1) has not been taken into account when integrating the luminosities of galaxies in groups as the effect is rather small for small groups and does not influence the discussion. For larger groups and clusters (Coma I and Virgo cluster) the given symbols would shift by their size to the left and downwards

Table 1. Observational data

HCG No.	RA DEC (1950.0)	optical redshift z	Type $N_S N$	blue luminosity $[10^{10} L_\odot]$	HI-flux $[Jy\, km\, s^{-1}]$	S_{max} [mJy]	H I velocity $[km\, s^{-1}]$	H I linewidth $[km\, s^{-1}]$	M_{HI}/L_B
1	00 23 23 +25 26 29	0.0339	2 4	8.57	7.74	28±1.7	10166±20	466 513 547	0.40
3	00 31 00 -07 52 00	0.0255	2 4	3.63	6.15	15.4±2.3	7907±13	403 1029 1057	0.450
4	00 31 44 -21 42 30	0.0280	1 5	6.82	2.12	20.1±3	7507±8	1241	0.254
b		0.0236		1.4	2.12	20.1±3	6996±8	248 277 280	1.24
a		0.0270		5.42	4.77	44.5±3	8044±11	67 113 144	0.18
5	00 36 19 +06 47 00	0.0410	1 4	7.75	0.92	9.2±2	12276±20	154 166:	0.076
6	00 36 40 -08 40 20	0.0379	0 4	5.55	0.88	6.8±1.5	11376±36	224 252:	0.086
7	00 36 45 +00 37 00	0.0141	2 4	8.83	4.58	22±2.1	4272±30	457 484 495	0.041
8	00 46 56 +23 19 00	0.0545	0 4	15.8		±2.3			≤0.077
14	01 57 20 -07 17 00	0.0183	3 4	1.24	1.23	5.5±1.1	5448±30	1217 1231:	0.331
c		0.0172		0.20	1.98	8.1±1.1	5146±30	460 484 520	1.284
a		0.0198		1.04	1.23	5.5±1.1	5849±30	420 444 450	0.151
15	02 05 20 +01 54 00	0.0228	3 6	3.99	1.29	3.8±0.9	6584±40	1048:	0.065
19	02 40 20 -12 37 30	0.0143	3 4	1.28	2.60	16.5±1.6	4293±21	153 173 181:	0.155
20	02 41 20 +25 53 50	0.0484	2 6	2.2		±2.5			≤0.515
21	02 43 05 -17 53 00	0.0251	2 5	8.12	9.61	21±2.5	7621±24	535 1017	0.284
22	03 01 18 -15 48 31	0.0251	2 5	0.77	4.4	48.6±2.8	2570±5	124 142	0.152
24	03 17 55 -11 02 40	0.0305	0 4	1.23		±2.2			≤0.273
25	03 18 10 -01 13 00	0,0212	3 7	5.43	4.68	19.9±2.8	6318±25	243 338 369	0.143
26	03 19 32 -13 49 30	0.0316	1 4	2.42	6.86	25.5±3.6	9474±17	402 487:	1.05
30	04 33 50 -02 57 00	0.0156	4 4	6.67	0.46	2.3±0.8	4665±50	534	0.006
33	05 07 50 +17 58 00	0.0260	1 4	0.46	6.6	20.1±2.5	7795±16	505 561	3.67
34	05 19 06 +06 37 45	0.0307	2 4	1.34	14.03	22.2±2.9	8969±30	979	3.32
35	08 41 56 +44 42 00	0.0542	2 6	6.87		±2.4			≤0.19
37	09 10 38 +30 12 23	0.0223	1 5	3.44	0.81	3.3±1.0	6809±25	966:	0.047
38	09 25 01 +12 30 19	0.0292	4 4	5.62	1.5	10±2.2	8722±20	207 262 265	0.083
40	09 36 23 -04 37 22	0.0223	2 6	2.99	0.47:	5.6±1.8	6582±30	73 86 89	0.027
41	09 54 30 +45 29 00	0.0133	3 4	2.43	3.44	18±3.0	7257±11	348 363 366	0.314
42	09 57 52 -19 23 46	0.0133	1 4	0.83	3.7	20±4.6	3964±10	201 307	0.263
43	10 08 41 +00 11 43	0.0330	3 5	5.16	3.11	11.5±2.0	9996±26	352 426:	0.245
46	10 19 30 +18 06 45	0.0270	0 4	0.64		±1.7			≤0.25
47	10 23 07 +14 00 12	0.0317	2 4	5.0	2.21	8.4±1.6	9689±25	459 482:	0.168
48	10 35 26 -26 49 13	0.0094	1 4	0.20	1.0	11±1.9	2448±19	138	0.108
49	10 53 19 +67 26 55	0.0332	0 4	2.49	8.66	39±3.3	9988±16	197 271 352	1.48
51	11 19 48 +24 34 23	0.0258	1 6	6.22		±3.3			≤0.089
54	11 26 36 +20 51 30	0.0049	0 4	0.18	5.58	70±3.2	1407±3.2	86 113 129	0.243
56	11 29 51 +53 13 30	0.0270	2 5	5.84	0.83	8.4±1.5	8194±40	431	0.041
57	11 35 14 +22 15 34	0.0304	3 8	15.1	1.46	9±1.8	9088±30	209	0.033
58	11 39 37 +10 35 40	0.0207	4 5	10.5	4.14	17.2±1.7	6156±10	166 495	0.061
62	12 50 30 -08 55 40	0.0137	1 4	1.63		±1.5			≤0.018
67	13 46 30 -06 57 00	0.0245	2 4	7.1	4.71	11.6±1.9	7587±30	544 612:	0.158
68	15 19 20 +21 21 43	0.0080	2 5	5.9	17.0	140±6.4	2310±5	301 305 308	0.069
69	13 53 10 +25 18 30	0.0294	2 4	5.65	5.63	17.4±2.6	8669±34	438 547:	0.316
74	15 17 12 +21 04 10	0.0399	0 5	1.77		±3.6			≤0.67
76	15 29 15 +07 29 00	0.0340	2 5	4.1		±2.5			≤0.14
78	15 48 00 +68 22 00	0.0303	4 4	6.94	7.20	28±3.3	8609±8	423 454 458:	0.335
80	15 58 44 +65 21 58	0.0310	4 4	6.18	7.67	20±2.1	9323±20	538 598 604:	0.47
82	16 28 28 +32 55 59	0.0362	2 4	10.3		±1.9			≤0.036
85	18 51 30 +73 17 30	0.0393	0 4	0.64		±2.4			≤1.09
87	20 45 20 -20 01 33	0.0296	2 4	10.0	1.2	8.2±1.7	8849±28	424:	0.041
91	22 06 22 -28 01 18	0.0238	3 4	18.6	9.65	25.8±2.8	7141±28	483 538 634:	0.112
93	23 12 55 +18 41 00	0.0168	2 4	6.6	2.28	7.7±1.6	4842±30	417 676	0.036
94	23 14 47 +18 26 47	0.0417	2 7	3.62	2.48	7.9±2.8	12176±25	280 303:	0.51
95	23 17 00 +09 13 20	0.0396	3 4	7.62	2.59	13.5±2.1	11774±30	278 317:	0.205
96	23 25 30 +08 30 00	0.0292	1 4	10.2	4.57	21.7±2.8	8756±8	219 232 251:	0.149
97	23 44 53 -02 35 00	0.0218	1 5	3.83	0.69	6.9±1.3	6691±35	386:	0.035
98	23 51 39 +00 05 42	0.0266	0 4	7.14		±1.5			≤0.018
99	23 58 10 +28 07 00	0.0290	2 4	8.48		±2.0			≤0.028

HCG 4 b and a : HI-data for the profiles at the optical velocities of components b and a.
HCG 14 c and a : HI-data for the profiles at the optical velocities of components c and a.
HCG 22, HCG 42, and HCG 68 : data from Huchtmeier 1994
HCG 41, HCG 78 : HI data correspond to individual galaxies in the velocity range searched.

5. Conclusions

We observed 54 Hickson Compact Groups, from which 41 were detected in the 21-cm line of HI. The total number of HCGs observed in HI increased to 75. Apart from a few HI-rich groups we find a great number of HCGs to have M_{HI}/L_B ratios in the expected range. However, there are many groups with extreme HI-deficiencies as compared to nearby groups and to aggregates known for HI-deficiency like the Coma I group and the Virgo cluster.

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