# Optically Unseen HI Detections towards the Virgo Cluster detected in the Arecibo Legacy Fast ALFA Survey

Brian R. Kent[1], Riccardo Giovanelli[1,2], Martha P. Haynes[1,2], Amélie Saintonge[1], Sabrina Stierwalt[1], Thomas Balonek[2,3], Noah Brosch[4], Barbara Catinella[5], Rebecca A. Koopmann[2,6], Emmanuel Momjian[5], Kristine Spekkens[7]

## ABSTRACT

We report the discovery by the Arecibo Legacy Fast ALFA (ALFALFA) survey of eight HI features not coincident with stellar counterparts in the Virgo Cluster region. All of the HI clouds have $cz < 3000$ km s$^{-1}$and, if at the Virgo distance, HI masses between $1.9 \times 10^7$ $M_\odot$ and $1.1 \times 10^9$ $M_\odot$. Four of the eight objects were reported or hinted at by previous studies and "rediscovered" by ALFALFA. While some clouds appear to be associated with optical galaxies in their vicinity, others show no clear association with a stellar counterpart. Two of them are embedded in relatively dense regions of the cluster and are associated with M49 and M86; they were previously known. The others are mostly located in peripheral regions of the cluster. Especially notable are a concentration of objects towards the so-called M cloud, 3° to 5° to the NW of M87, and a complex

[1]Center for Radiophysics and Space Research, Space Sciences Building, Cornell University, Ithaca, NY 14853. *e–mail:* bkent@astro.cornell.edu, riccardo@astro.cornell.edu, haynes@astro.cornell.edu, amelie@astro.cornell.edu, sabrina@astro.cornell.edu

[2]National Astronomy and Ionosphere Center, Cornell University, Space Sciences Building, Ithaca, NY 14853. The National Astronomy and Ionosphere Center is operated by Cornell University under a cooperative agreement with the National Science Foundation.

[3]Dept. of Physics & Astronomy, Colgate University, Hamilton, NY 13346. *e–mail:* tbalonek@mail.colgate.edu

[4]The Wise Observatory & The School of Physics and Astronomy, Raymond & Beverly Sackler Faculty of Exact Sciences, Tel Aviv University, Israel. *e–mail:* noah@wise.tau.ac.il

[5]Arecibo Observatory, National Astronomy and Ionosphere Center, Arecibo, PR 00612. *e–mail:* bcatinel@naic.edu, emomjian@naic.edu

[6]Dept. of Physics & Astronomy, Union College, Schenectady, NY 12308. *e–mail:* koopmanr@union.edu

[7]National Radio Astronomy Observatory and Dept. of Physics & Astronomy, Rutgers University, 136 Frelinghuysen Road, Piscataway, NJ 08854. NRAO is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc. *e–mail:* spekkens@physics.rutgers.edu

of several clouds projected roughly halfway between M87 and M49. The object referred to as VIRGOHI21 and proposed to be a "dark galaxy" is also detected and shown to be a tidal feature associated with NGC 4254.

*Subject headings:* galaxies: intergalactic medium — galaxies: halos — individual:Virgo cluster — radio lines: galaxies — galaxies:clusters — galaxies:interactions

## 1. Introduction

The predictions of the galaxy formation paradigm in the hierarchical scenario requires corroboration by observational data. Optically selected samples of galaxies do not detect low luminosity, and hence presumably low mass objects, in the predicted numbers. This has often been referred to as the "substructure" or "missing satellite" problem (Klypin *et al.* 1999). The possible existence of a statistically significant population of dark matter dominated, optically faint halos would be of cosmological importance (Hawkins 1997; Somerville 2002). While the statistics of halos that are completely devoid of baryons would be difficult to assess, optically faint but gas rich systems could be detected via their 21 cm line emission. ALFALFA, the Arecibo Legacy Fast ALFA extragalactic HI survey (Giovanelli *et al.* 2005) currently underway, will cover 7000 square degrees of sky at $cz < 18000$ km s$^{-1}$. At this time more than half of the solid angle encompassing the Virgo Cluster has been fully surveyed. ALFALFA can detect $\sim 2 \times 10^7$ $M_\odot$ at the cluster distance, which in this paper will be assumed to be 16.7 Mpc. The Virgo Cluster offers a fertile environment for the possible detection of gas-rich, optically faint systems.

A number of extragalactic HI clouds have been reported in the past (e.g. Schneider *et al.* 1983; Sancisi *et al.* 1987; Giovanelli & Haynes 1989; Chengalur *et al.* 1995; Kilborn *et al.* 2000; Ryder *et al.* 2001; Minchin *et al.* 2005a; Oosterloo & van Gorkom 2005); they are however not necessarily identified with optically dark halos. Some have been shown to be tidal appendages or to be associated with optical counterparts, e.g. the NE component of the HI 1225+01 pair of objects (Giovanelli, Williams & Haynes 1991) and the object known as VIRGOHI21 (Davies *et al.* 2004; Minchin *et al.* 2005a,b; Haynes *et al.* in preparation); others are thought to be the result of ram pressure stripping in the cluster environment, e.g. the Oosterloo & van Gorkom feature near NGC 4388. The interactions between sub-groups in Virgo play an important role in the cluster's evolution, acting as a preprocessing step of the material as the galaxies fall into the cluster.

Here we present a catalog of 21 cm line sources detected by ALFALFA in the central portion of the Virgo Cluster region which have no obvious optical counterparts. Parameters of the detections and descriptions of their environments are given. Three of the sources were previously reported and one hinted at by other studies and "rediscovered" by ALFALFA.

## 2. Observations and Source Parameters

The sources presented in this paper are part of the ALFALFA catalog and refer to the region $12^h$ < R.A.(J2000) < $13^h$ and $+8^\circ$ < Dec.(J2000) < $+16^\circ$. Complete source catalogs of this region have been reported by Giovanelli *et al.* (2007) and Kent *et al.* (2007 in preparation); they are accessible at http://arecibo.tc.cornell.edu/hiarchive/alfalfa/. Sources are extracted from the ALFALFA data set via an automated algorithm (Saintonge 2007), successively inspected by eye, measured and classified according to a code which primarily depends on signal to noise (S/N). The objects reported in this paper are all classified as *bona fide* detections (code 1; see Giovanelli *et al.* 2007), typically of S/N $\gtrsim$ 6.5, where S/N is defined as

$$S/N = \left(\frac{1000 F_c}{W_{50}}\right)\frac{w_{smo}^{1/2}}{\sigma_{rms}} \tag{1}$$

where $F_c$ is the integrated flux density in Jy km s$^{-1}$, $w_{smo}$ is either $W_{50}/(2\times 10)$ for $W_{50} < 400$ km s$^{-1}$ or $400/(2\times 10) = 20$ for $W_{50} \geq 400$ km s$^{-1}$ [$w_{smo}$ is a smoothing width expressed as the number of spectral resolution bins of 10 km s$^{-1}$ bridging half of the signal width], and $\sigma_{rms}$ is the r.m.s noise figure across the spectrum measured in mJy at 10 km s$^{-1}$ resolution. All of them have been confirmed by corroborating observations carried out with the Arecibo telescope or with the Very Large Array (VLA) as discussed below. Details of the ALFALFA observations can be found in Giovanelli *et al.* (2005) and Giovanelli *et al.* (2007).

Table 1 contains the observed and derived parameters of the HI clouds. Their velocities indicate that an association with the Virgo cluster is possible for most of them, with the exception of the group associated with NGC 4795/4796. The latter is more likely to be in the background of the Virgo cluster, at a distance of ∼40 Mpc which is assumed for the clouds in that group.

The fields of each of the sources in Table 1 have been inspected in the Sloan Digital Sky

Survey[8] and the DSS2 via *Skyview.*[9] The contents of Table 1 are as follows.
*Col.(1)* - Cloud ID number
*Col.(2 & 3)* - HI source center coordinates (J2000); these positions are typically accurate to within 30″ or better (see Giovanelli *et al.* 2007)
*Col.(4)* - Heliocentric velocity in km $s^{-1}$
*Col.(5)* - Velocity width measured at half peak power in km $s^{-1}$
*Col.(6)* - Integrated flux in Jy km $s^{-1}$
*Col.(7)* - Signal to noise ratio
*Col.(8)* - Base 10 logarithm of the HI mass in solar units, assuming HI is optically thin
*Col.(9)* - Angular distance from M87 in degrees

For three of the sources, we separately list the parameters of several clumps, identified with italic qualifiers. Figure 1 shows locations of the sources within the Virgo cluster region; the grayscale background image shows hard X-ray counts (0.5-2.0 keV) from the ROSAT dataset of Snowden *et al.* (1995), smoothed with a 5′ kernel. The approximate boundaries of the M and W′ clouds are indicated by dashed circles (Binggeli, Popescu & Tammann 1993). We note that the fields of the HI clouds often contain one or several small optical objects; the possibility that one of them may be a small dwarf or low surface brightness galaxy associated with the HI source cannot be excluded at this time. We discuss the characteristics of each HI source below.

*Cloud 1.*–This object, unresolved by the Arecibo beam of $3.3' \times 3.8'$, is near the detection limit of ALFALFA at the Virgo distance; S/N and spectrum used are those of the ALFALFA survey observations. That detection has been confirmed by successive, more sensitive Arecibo observations. This is the object with the lowest HI mass in Table 1. We note that the Irr galaxy UGC 7003 lies 30′ NW of the HI source at $cz = 1286$ km $s^{-1}$, the

---

[8]Funding for the Sloan Digital Sky Survey (SDSS) has been provided by the Alfred P. Sloan Foundation, the Participating Institutions, the National Aeronautics and Space Administration, the National Science Foundation, the U.S. Department of Energy, the Japanese Monbukagakusho, and the Max Planck Society. The SDSS Web site is http://www.sdss.org/. The SDSS is managed by the Astrophysical Research Consortium (ARC) for the Participating Institutions. The Participating Institutions are The University of Chicago, Fermilab, the Institute for Advanced Study, the Japan Participation Group, The Johns Hopkins University, Los Alamos National Laboratory, the Max-Planck-Institute for Astronomy (MPIA), the Max-Planck-Institute for Astrophysics (MPA), New Mexico State University, University of Pittsburgh, Princeton University, the United States Naval Observatory, and the University of Washington.

[9]*Skyview* was developed and maintained under NASA ADP Grant NAS5–32068 under the auspices of the High Energy Astrophysics Science Archive Research Center at the Goddard Space Flight Center Laboratory of NASA.

NGC 4019 group lies 15′ W at $cz = 1524$ km s$^{-1}$ and UGC 7038 lies 32′ NW at $cz = 889$ km s$^{-1}$.

*Cloud 2.*–This object, also unresolved by the Arecibo beam, lies 3.8′ away from a small optical galaxy for which no optical redshift is known. The optical galaxy AGC 220171 at 121035.6+114539, an apparently undisturbed object classified as a BCD, lies 29′ to the SE at a redshift of $cz = 1296$ km s$^{-1}$. A VLA map of the source has been obtained and the results will be discussed in a forthcoming study.

*Cloud 3.*–This object, also unresolved by the Arecibo beam, is located in a crowded field - a host of galaxies are in the surrounding periphery at a comparable redshift. The density of galaxies with known optical or HI redshifts in this region is high and 21 are known with $1800 < cz < 2500$ km s$^{-1}$ within one degree of the HI source. The nearest optical galaxy with similar velocity is AGC 221651 at 121336.4+130201, 8′ N of the HI feature at $cz = 1932$ km s$^{-1}$. A VLA map of the source has been obtained and the results will be discussed in a forthcoming study.

*Cloud 4.*–The HI source is located 3.6′ southeast of M86 (=NGC 4406; $cz = -244$ km s$^{-1}$), the large Virgo S0 galaxy. It was previously reported by Davies *et al.* (2004) as VIRGOHI4. They also suggested that the source could lie behind M86. HI synthesis imaging by Oosterloo & van Gorkom (2005) showed the HI source to be a plume extending from NGC 4388($cz$ =2524 km s$^{-1}$) and possibly resulting from interaction between that galaxy and the intracluster gas. Jacoby *et al.* (2005) indicated that H$\alpha$ filaments detected could be associated with this plume. In the same vicinity ALFALFA makes a separate detection of M86 (Giovanelli *et al.* 2007) at negative velocities with the HI centroid located 18″ to the south. The features reported by Bregman & Roberts (1990) are associated with the ALFALFA HI detection of M86.

*Cloud 5.*–This object was first reported by Sancisi *et al.* (1987). Later, aperture synthesis observations were presented by Henning *et al.* (1993) and McNamara *et al.* (1994). The HI source is located 2.6′ southeast of M49($cz = 997$ km s$^{-1}$) and it is proposed to be related to the interaction between M49 and the dwarf irregular UGC 7636($cz = 276$ km s$^{-1}$).

*Cloud 6.*–Two sources(6*a&b*) are the brightest clumps in a stream found in the vicinity of NGC 4254(M99; $cz = 2407$ km s$^{-1}$). The brightest of the two is an object first detected at Jodrell Bank (Davies *et al.* 2004; Minchin *et al.* 2005a) and more recently mapped at Westerbork by the same team (Minchin *et al.* 2005b). Dubbed "VirgoHI21", it was proposed by that group that the source is a giant "dark galaxy." The ALFALFA observations clearly show the feature to be part of a stream connected to NGC 4254, continuously extending some 250 kpc to the North of that galaxy. The feature appears of tidal origin. A third ALFALFA detection ($6c$) lies 18 ′ west of NGC 4254. A more detailed analysis of the ALFALFA evidence on this object is given in Haynes *et al.* (2007).

*Cloud 7.*–A complex of five HI clouds, it projects between M87 and M49, roughly 3° south of the former. The five clouds, spread in velocity between 480 and 607 km s$^{-1}$, extend over approximately 35′ in the plane of the sky, or 200 kpc at the Virgo cluster distance. In HI mass, the clouds range between $0.5 \times 10^8$ and $2.0 \times 10^8$ $M_\odot$. VLA observations have been obtained and clouds 7c and 7d have been clearly detected. Detailed results of both the ALFALFA and VLA observations are in preparation by Kent *et al.*

*Cloud 8.*–Three clouds comprise an HI complex that surrounds the SB0/a galaxy NGC 4795($cz =$ 2781 km s$^{-1}$) and its dwarf companion NGC 4796($cz =$ 2406 km s$^{-1}$). It was previously noted that a large flux measurement discrepancy between Arecibo and Effelsberg measurements was likely due to an offset of the HI from the center of the NGC 4795/4796 pair (Hoffman *et al.* 1989). Later observations at Arecibo by Duprie & Schneider (1996) are suggestive of an extension of the HI emission from NGC 4796 towards its irregular companions UGC 8042/5, perhaps arising from a tidal interaction. ALFALFA maps show that HI emission surrounds the NGC 4795/6 pair, and that it is indeed connected to the two nearby galaxies, UGC 8045 and UGC 8042, which are respectively at $cz =$ 2801 and $cz =$ 2856 km s$^{-1}$. The HI masses computed in Table 1 assume a distance of ∼40 Mpc. The kinematics of the HI indicate that all the galaxies in this system are at a comparable redshift and are interacting as a group.

## 3. Discussion

The characteristics of the eight sources reported here are quite diverse. They can be grouped into three categories: isolated objects, objects in the vicinity of large galaxies, and disturbed objects that could be remnants of an encounter with a larger system, such as the collective cluster potential. Except for cloud 8, the projected distances to M87 and heliocentric velocities place the HI sources within the canonical boundaries of the Virgo Cluster, as defined by Binggeli, Sandage, & Tammann (1985).

Clouds 4 and 5 have been extensively studied in the past, using higher aperture synthesis data which indicate a clear association with Virgo cluster galaxies M49 and NGC 4388. The proximity to these galaxies and the cluster environment are important in determining their properties. The clouds in the vicinity of NGC 4795 (cloud 8) are most likely the result of tidal stripping in interacting members of a close group, not an uncommon occurrence.

Cloud 6 has raised significant attention, as it was proposed to be a rare representative of a category of massive, yet starless galaxies. The ALFALFA observations clearly show that rather than an isolated "dark galaxy," this object is an extended stream connected to NGC 4254. While no nearby companion with which NGC 4254 may have had a close encounter is clearly identifiable, the origin of the feature appears most likely to be of a tidal nature, an event of "harassment" of the type graphically illustrated in simulations, e.g. by Moore *et al.* (1996) and Lake *et al.* (1998).

ALFALFA observations of clouds 1, 2 and 3 offer no clear hints as to their origin. They are all unresolved by the Arecibo beam, hence their HI is contained within a $\sim$ 10 kpc diameter or less. The HI masses of the clouds are relatively low, especially for clouds 1 and 2, and the lack of a size determination impedes an estimate of their dynamical masses; upper limits for the latter on order of 1–6$\times 10^8$ $M_\odot$ can be obtained if one assumes turbulent or rotational motion amplitudes as indicated by the velocity widths. These objects are projected near or within the boundaries of the M cloud, a loose subclump thought to be behind and falling into the main cluster around M87, although little coherence in the velocities of the trio exists to firmly substantiate such association. At any rate, they appear to be relatively isolated and far removed from the central parts of the cluster so that gravitational, rather than hydrodynamical processes involving the intracluster gas, are more likely to be invoked in explaining their nature. While the mean number density of VCC galaxies in the M cloud region is less than 1.5 $\times 10^{-3}$ (arcmin)$^{-2}$ (Binggeli, Sandage, & Tammann 1985, Schindler *et al.* 1999), cloud 3 lies in a locally overdense region, where galaxy-galaxy interactions may be more frequent. It cannot be excluded however that these clouds may be primordial, low mass halos, perhaps associated with small dwarf or low surface brightness optical counterparts. Analysis of recently obtained VLA data and planned follow-up optical studies will help elucidate this issue.

Cloud 7 is resolved by ALFALFA data into several separate clouds, spread over more than 200 kpc (if located at the cluster distance) and 250 km s$^{-1}$ in extent. With a mean velocity near 540 km s$^{-1}$, the complex could well be located in the foreground of the cluster, although cluster galaxies of similar redshift are found in the vicinity. Most notably, NGC 4424, an SBa at $cz$ = 476 km s$^{-1}$ is located about 40$'$ to the west of the complex. ALFALFA and VLA HI maps of that object (Chung *et al.* 2007), as well as CO maps (Cortes *et al.* 2006) indicate that its structure is disturbed, showing an appendage extending to the south of the galaxy, pointing opposite the direction of the cloud complex. Assuming the whole of the complex is not a gravitationally bound unit, the velocity differences between the individual clouds will separate them at the approximate rate of $\sim$ 250 kpc Gyr$^{-1}$. Differential motions of this amplitude are consistent with tidal forces within the cluster potential and suggest the complex may disperse within a cluster crossing time. A more detailed analysis based on ALFALFA and VLA observations will be explored in a future study (Kent *et al.*, in preparation).

While a detailed statistical study of the ALFALFA catalogs in the Virgo regions awaits completion of the survey effort therein, it is interesting to preliminarily note that ALFALFA does not detect very large numbers of low HI mass sources in the cluster. This is an indication that, at least in the cluster region, the HI mass function faint end slope does not rise sufficiently to significantly contribute to solving the "substructure" problem mentioned in our introduction.

We gratefully acknowledge Dr. Tom Oosterloo for his critical reading of this paper and providing comments. This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. KS is a Jansky Fellow. This work has been supported by NSF grants AST–0307661, AST–0435697, AST–0607007 and the Brinson Foundation.

## REFERENCES

Binggeli, B., Sandage, A., & Tammann, G. A. 1985, AJ, 90, 1681

Binggeli, B., Popescu, C. C., & Tammann, G. A. 1993, A&AS, 98, 275

Bregman, J. N., & Roberts, M. S. 1990, ApJ, 362, 468

Chengalur, J. N., Giovanelli, R., & Haynes, M. P. 1995, AJ, 109, 2415

Chung, A., van Gorkom, J. H., Kenney, J. D. P., & Vollmer, B. 2007, ApJL, 659, L115

Cortés, J. R., Kenney, J. D. P., & Hardy, E. 2006, AJ, 131, 747

Davies, J., Minchin, R., Sabatini, S., van Driel, W., Baes, M. *et al.* 2004, MNRAS, 349, 922

Duprie, K., & Schneider, S. E. 1996, AJ, 112, 937

Giovanelli, R., Haynes, M. P., Kent, B. R. *et al.* 2005, AJ, 130, 2598

Giovanelli, R., Haynes, M. P., Kent, B. R. *et al.* 2007, AJ, 133, 2569

Giovanelli, R., & Haynes, M. P. 1989, ApJ, 346, L5

Giovanelli, R., Williams, J.P. & Haynes, M.P. 1991, AJ, 101, 1242

Haynes, M. P., & Giovanelli, R. 1986, ApJ, 306, 466

Haynes, M. P., Giovanelli, R., & Kent, B. R. 2007, ApJL, in press

Hawkins, M. R. S. 1997, A&A, 328, L25

Henning, P. A., Sancisi, R., & McNamara, B. R. 1993, A&A, 268, 536

Hoffman, G. L., Williams, B. M., Lewis, B. M., Helou, G., & Salpeter, E. E. 1989, ApJS, 69, 65

Jacoby, G. H., Kenney, J. D. P., Tal, T., Crowl, H. H., & Feldmeier, J. J. 2005, Bulletin of the American Astronomical Society, 37, 1392

Klypin, A., Kravtsov, A. V., Valenzuela, O., & Prada, F. 1999, ApJ, 522, 82

Lake, G., Katz, N., & Moore, B. 1998, ApJ, 495, 152

McNamara, B. R., Sancisi, R., Henning, P. A., & Junor, W. 1994, AJ, 108, 844

Minchin, R., Davies, J., Disney, M., Boyce, P., Garcia, D. *et al.* 2005a, ApJL, 622, L21

Minchin, R.F., Davies, J.I., Disney, M.J., Marble, A. R., Impey, C. D., *et al.* 2005b, astro-ph/0508153

Moore, B., Katz, N., Lake, G., Dressler, A., & Oemler, A. 1996, Nature, 379, 613

Oosterloo, T., & van Gorkom, J. 2005, A&A, 437, L19

Saintonge, A. 2007, AJ, 133, 2087

Sancisi, R., Thonnard, N., & Ekers, R. D. 1987, ApJL, 315, L39

Schindler, S., Binggeli, B., Böhringer, H. 1999, A&A, 343, 420

Schneider, S. E., Helou, G., Salpeter, E. E., & Terzian, Y. 1983, ApJL, 273, L1

Snowden, S. L., *et al.* 1995, ApJ, 454, 643

Somerville, R.S. 2002, ApJ, 572, L23

This preprint was prepared with the AAS LaTeX macros v5.0.

Table 1. ALFALFA Optically Unseen Detections

| Cloud ID | $\alpha$ J2000 | $\delta$ J2000 | $cz_{\odot}$ (km s$^{-1}$) | $W_{\rm FWHM}$ (km s$^{-1}$) | $F_c$ (Jy km s$^{-1}$) | S/N | $\log_{10}M_{HI}$ $M_{\odot}$ | d$_{M87}$ deg |
|---|---|---|---|---|---|---|---|---|
| 1[a] | 12 02 44.4 | +14 04 56 | 1121± 1 | 22± 2 | 0.30 ± 0.02 | 5.1 | 7.29 | 7.0 |
| 2[b] | 12 08 45.5 | +11 55 17 | 1230± 1 | 29± 2 | 0.77 ± 0.04 | 11.6 | 7.63 | 5.4 |
| 3[b] | 12 13 41.8 | +12 53 51 | 2235± 2 | 53± 3 | 1.21 ± 0.07 | 9.2 | 8.54 | 4.2 |
| 4[c] | 12 26 19.4 | +12 53 30 | 2246± 5 | 135± 11 | 2.05 ± 0.07 | 14.4 | 8.77 | 1.2 |
| 5[d] | 12 29 54.7 | +07 58 12 | 473± 5 | 30± 10 | 1.13 ± 0.06 | 10.9 | 7.87 | 4.4 |
| 6*a*[e] | 12 17 55.5 | +14 44 45 | 1984± 1 | 128± 2 | 2.09 ± 0.06 | 16.2 | 8.70 | 3.9 |
| 6*b*[e] | 12 17 49.1 | +15 04 52 | 2200± 6 | 40± 13 | 0.52 ± 0.05 | 5.0 | 8.16 | 4.1 |
| 6*c*[e] | 12 17 33.8 | +14 23 47 | 2111± 10 | 65± 20 | 0.57 ± 0.04 | 7.3 | 8.17 | 3.8 |
| 7*a*[b] | 12 29 42.8 | +09 41 54 | 524± 7 | 116± 15 | 1.16 ± 0.07 | 8.6 | 7.87 | 2.7 |
| 7*b*[b] | 12 30 19.4 | +09 35 18 | 603± 4 | 252± 7 | 2.56 ± 0.09 | 13.1 | 8.22 | 2.8 |
| 7*c*[b] | 12 30 25.8 | +09 28 01 | 488± 5 | 62± 11 | 2.48 ± 0.07 | 21.2 | 8.21 | 2.9 |
| 7*d*[b] | 12 31 19.0 | +09 27 49 | 607± 4 | 56± 7 | 0.72 ± 0.06 | 6.5 | 7.67 | 2.9 |
| 7*e*[b] | 12 31 26.7 | +09 18 52 | 480± 10 | 53± 21 | 0.91 ± 0.06 | 7.6 | 7.77 | 3.1 |
| 8*a*[f] | 12 55 04.3 | +08 06 13 | 2629± 3 | 71± 7 | 0.72 ± 0.07 | 6.4 | 8.43 | 7.3 |
| 8*b*[f] | 12 55 10.2 | +08 02 44 | 2754± 14 | 407± 27 | 2.91 ± 0.12 | 9.4 | 9.08 | 7.4 |
| 8*c*[f] | 12 55 13.7 | +08 02 51 | 2771± 4 | 292± 7 | 2.52 ± 0.10 | 10.9 | 9.02 | 7.4 |

[a]Confirmed by follow-up, high sensitivity observation at Arecibo.

[b]VLA maps obtained, processing underway.

[c]VirgoHI4 (Davies *et al.* 2004), VLA map by Oosterloo *et al.* (2005).

[d]Vicinity of M49, Sancisi *et al.* (1987); synthesis data by Henning *et al.* (1993).

[e]Clumps in VirgoHI21, WSRT data by Minchin *et al.* (2005).

[f]NGC 4795/4796 group.

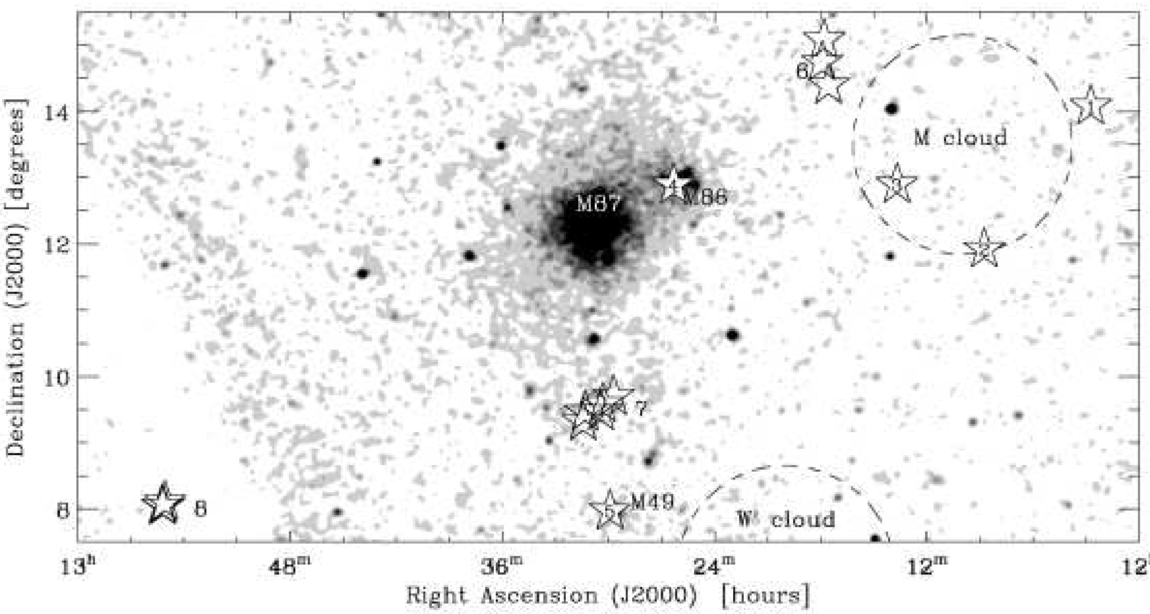


Fig. 1.— Sky distribution of the HI detections (star symbols and corresponding Table 1 numbers) presented in this paper. The X-ray peaks of cluster members M87, M86, and M49 are labeled for reference. The background grayscale image is a hard X-ray counts image from ROSAT (Snowden *et al.* 1995), smoothed with a 5′ Gaussian kernel. The portions of the M and W′ subclouds are indicated by the dashed circles (Binggeli, Popescu, & Tammann 1993).