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OPTICALLY UNSEEN H I DETECTIONS TOWARD THE VIRGO CLUSTER DETECTED IN THE ARECIBO LEGACY FAST ALFA SURVEY

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ABSTRACT

We report the discovery by the Arecibo Legacy Fast ALFA (ALFALFA) survey of eight H I features not coincident with stellar counterparts in the Virgo Cluster region. All of the H I clouds have $cz < 3000$ km s^{-1} and, if at the Virgo distance, H I masses between 1.9×10^7 and 1.1×10^9 $M_\odot$. 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 toward the so-called M cloud, 3°–5° to the northwest of M87, and a complex of several clouds projected roughly halfway between M87 and M49. The object referred to as VIRGOHI 21 and proposed to be a "dark galaxy" is also detected and shown to be a tidal feature associated with NGC 4254.

Subject headings: galaxies: clusters: general — galaxies: clusters: individual (Virgo Cluster) — galaxies: halos — galaxies: interactions — intergalactic medium — radio lines: galaxies

1. INTRODUCTION

The predictions of the galaxy formation paradigm in the hierarchical scenario require 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. The Arecibo Legacy Fast ALFA (ALFALFA) extragalactic H I survey (Giovanelli et al. 2005), currently underway, will cover 7000 deg^2 of sky at $cz < 18{,}000$ 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 Letter is 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 H I 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 northeast component of the H I 1225+01 pair of objects (Giovanelli et al. 1991) and the object known as VIRGOHI 21 (Davies et al. 2004; Minchin et al. 2005a, 2005b; M. P. Haynes et al. 2007, 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 subgroups 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 that 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 Letter are part of the ALFALFA catalog and refer to the region $12^h < \mathrm{R.A.(J2000.0)} < 13^h$, $+8° < \mathrm{decl.(J2000.0)} < +16°$. Complete source catalogs of this region have been reported by Giovanelli et al. (2007) and B. R. Kent et al. (2007, in preparation).[8] 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 that primarily depends on the signal-to-noise ratio (S/N). The objects reported in this Letter are all

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[8] They are accessible at http://arecibo.tc.cornell.edu/hiarchive/alfalfa.

TABLE 1
ALFALFA OPTICALLY UNSEEN DETECTIONS

Cloud ID (1)	α (J2000.0) (2)	δ (J2000.0) (3)	$cz_{\odot}$ (km s^{-1}) (4)	$W_{\rm FWHM}$ (km s^{-1}) (5)	F_c (Jy km s^{-1}) (6)	S/N (7)	log $M_{\rm H\,I}$ ($M_{\odot}$) (8)	$d_{\rm M87}$ (deg) (9)
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
6a[e]	12 17 55.5	+14 44 45	1984 ± 1	128 ± 2	2.09 ± 0.06	16.2	8.70	3.9
6b[e]	12 17 49.1	+15 04 52	2200 ± 6	40 ± 13	0.52 ± 0.05	5.0	8.16	4.1
6c[e]	12 17 33.8	+14 23 47	2111 ± 10	65 ± 20	0.57 ± 0.04	7.3	8.17	3.8
7a[b]	12 29 42.8	+09 41 54	524 ± 7	116 ± 15	1.16 ± 0.07	8.6	7.87	2.7
7b[b]	12 30 19.4	+09 35 18	603 ± 4	252 ± 7	2.56 ± 0.09	13.1	8.22	2.8
7c[b]	12 30 25.8	+09 28 01	488 ± 5	62 ± 11	2.48 ± 0.07	21.2	8.21	2.9
7d[b]	12 31 19.0	+09 27 49	607 ± 4	56 ± 7	0.72 ± 0.06	6.5	7.67	2.9
7e[b]	12 31 26.7	+09 18 52	480 ± 10	53 ± 21	0.91 ± 0.06	7.6	7.77	3.1
8a[f]	12 55 04.3	+08 06 13	2629 ± 3	71 ± 7	0.72 ± 0.07	6.4	8.43	7.3
8b[f]	12 55 10.2	+08 02 44	2754 ± 14	407 ± 27	2.91 ± 0.12	9.4	9.08	7.4
8c[f]	12 55 13.7	+08 02 51	2771 ± 4	292 ± 7	2.52 ± 0.10	10.9	9.02	7.4

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.
[a] Confirmed by follow-up, high-sensitivity observation at Arecibo.
[b] VLA maps obtained, processing underway.
[c] VIRGOHI 4 (Davies et al. 2004), VLA map by Oosterloo & van Gorkom (2005).
[d] Vicinity of M49 (Sancisi et al. 1987); synthesis data by Henning et al. (1993).
[e] Clumps in VIRGOHI 21, Westerbork Synthesis Radio Telescope data by Minchin et al. (2005a, 2005b).
[f] NGC 4795/4796 group.

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

$$\mathrm{S/N} = \frac{1000F_c}{W_{50}}\frac{w_{\rm smo}^{1/2}}{\sigma_{\rm rms}}, \quad (1)$$

where F_c is the integrated flux density in Jy km s^{-1}, $w_{\rm smo}$ 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} ($w_{\rm smo}$ is a smoothing width expressed as the number of spectral resolution bins of 10 km s^{-1} bridging half of the signal width), and $\sigma_{\rm rms}$ is the rms noise figure across the spectrum measured in millijanskys 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, 2007).

Table 1 contains the observed and derived parameters of the H I 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.

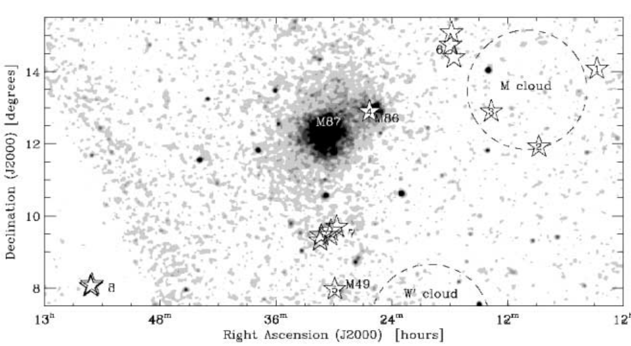

FIG. 1.—Sky distribution of the H I detections (*star symbols and corresponding Table 1 numbers*) presented in this Letter. The X-ray peaks of cluster members M87, M86, and M49 are labeled for reference. The background gray-scale image is a hard X-ray counts image from *ROSAT* (Snowden et al. 1995),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

The fields of each of the sources in Table 1 have been inspected in the Sloan Digital Sky Survey[9] and the DSS2 via SkyView.[10] The contents of Table 1 are as follows: Column (1) is the cloud identification number. Columns (2) and (3) are the H I source center coordinates (J2000.0); these positions are typically accurate to within 24″ or better (see Giovanelli et al. 2007). Column (4) is the heliocentric velocity in kilometers per second. Column (5) is the velocity width measured at half-peak power in kilometers per second. Column (6) is the integrated flux in Jy km s^{-1}. Column (7) is the S/N. Column (8) is the base-10 logarithm of the H I mass in solar units, assuming H I is optically thin. Column (9) is the angular distance from M87 in degrees.

For three of the sources, we separately list the parameters of several clumps, identified with qualifiers. Figure 1 shows locations of the sources within the Virgo Cluster region; the gray-scale background image shows hard X-ray counts (0.5–2.0 keV) from the *ROSAT* data set of Snowden et al. (1995), smoothed with a 5′ kernel. The approximate boundaries of the

[9] 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 US 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 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, the Max Planck Institute for Astrophysics, New Mexico State University, the University of Pittsburgh, Princeton University, the US Naval Observatory, and the University of Washington.

[10] 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.

M and W′ clouds are indicated by dashed circles (Binggeli et al. 1993). We note that the fields of the H I 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 H I source cannot be excluded at this time. We discuss the characteristics of each H I source below.

Cloud 1.—This object, unresolved by the Arecibo beam of 3.3′ × 3.8′, is near the detection limit of ALFALFA at the Virgo distance; the 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 H I mass in Table 1. We note that the irregular galaxy UGC 7003 lies 30′ northwest of the H I source at $cz = 1286$ km s^{-1}, the NGC 4019 group lies 15′ west at $cz = 1524$ km s^{-1}, and UGC 7038 lies 32′ northwest 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 blue compact dwarf, lies 29′ to the southeast 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 H I redshifts in this region is high, and 21 are known with 1800 km $s^{-1} < cz < 2500$ km s^{-1} within 1° of the H I source. The nearest optical galaxy with similar velocity is AGC 221651 at 121336.4+130201, 8′ north of the H I 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 H I 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 VIRGOHI 4. They also suggested that the source could lie behind M86. H I synthesis imaging by Oosterloo & van Gorkom (2005) showed the H I 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 Hα 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 H I centroid located 18″ to the south. The features reported by Bregman & Roberts (1990) are associated with the ALFALFA H I 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 H I 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 (6a and 6b) 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 "VIRGOHI 21," 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 H I 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 H I mass, the clouds range between 0.5×10^8 and 2.0×10^8 $M_\odot$. 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 H I 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 H I 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 H I emission from NGC 4796 toward its irregular companions UGC 8042/5, perhaps arising from a tidal interaction. ALFALFA maps show that H I 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 $cz = 2801$ km s^{-1} and $cz = 2856$ km s^{-1}. The H I masses computed in Table 1 assume a distance of ∼40 Mpc. The kinematics of the H I 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 H I sources within the canonical boundaries of the Virgo Cluster, as defined by Binggeli et al. (1985).

Clouds 4 and 5 have been extensively studied in the past, using higher aperture synthesis data that 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 H I is contained within a ∼10 kpc diameter or less. The H I 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 1.5×10^{-3} arcmin^{-2} (Binggeli et al. 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 H I maps of that object (Chung et al. 2007), as well as CO maps (Cortés 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. If we assume 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 ∼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 (B. R. Kent et al. 2007, 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 H I mass sources in the cluster. This is an indication that, at least in the cluster region, the H I mass function faint-end slope does not rise sufficiently to significantly contribute to solving the "substructure" problem mentioned in § 1.

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REFERENCES

Binggeli, B., Popescu, C. C., & Tammann, G. A. 1993, A&AS, 98, 275
Binggeli, B., Sandage, A., & Tammann, G. A. 1985, AJ, 90, 1681
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, ApJ, 659, L115
Cortés, J. R., Kenney, J. D. P., & Hardy, E. 2006, AJ, 131, 747
Davies, J., et al. 2004, MNRAS, 349, 922
Duprie, K., & Schneider, S. E. 1996, AJ, 112, 937
Giovanelli, R., & Haynes, M. P. 1989, ApJ, 346, L5
Giovanelli, R., Williams, J. P., & Haynes, M. P. 1991, AJ, 101, 1242
Giovanelli, R., et al. 2005, AJ, 130, 2598
———. 2007, AJ, 133, 2569
Hawkins, M. R. S. 1997, A&A, 328, L25
Haynes, M. P., Giovanelli, R., & Kent, B. R. 2007, ApJ, 665, L19
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, BAAS, 37, 1392
Kilborn, V. A., et al. 2000, AJ, 120, 1342
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. F., et al. 2005a, ApJ, 622, L21
———. 2005b, preprint (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
Ryder, S. D., et al. 2001, ApJ, 555, 232
Saintonge, A. 2007, AJ, 133, 2087
Sancisi, R., Thonnard, N., & Ekers, R. D. 1987, ApJ, 315, L39
Schindler, S., Binggeli, B., & Böhringer, H. 1999, A&A, 343, 420
Schneider, S. E., Helou, G., Salpeter, E. E., & Terzian, Y. 1983, ApJ, 273, L1
Snowden, S. L., et al. 1995, ApJ, 454, 643
Somerville, R. S. 2002, ApJ, 572, L23