The HI content of Early-Type Galaxies: I. Catalogued ALFALFA sources in Virgo

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ALFALFA is surveying 7074 sq. deg. for HI sources brighter than $\sim 0.5 \text{ Jy km s}^{-1}$ (i.e. $\sim 3 \times 10^7 \text{ M}_\odot$ at the distance of the Virgo cluster).

We are using ALFALFA to study the HI content of ETG in a uniform and unbiased way, as a function of galaxy mass and environment.

On the Virgo cluster we select a sample of 943 ETG from the Virgo Cluster Catalogue (VCC) in the declination strip from 8 to 16 deg., which contains more than 70% of the VCC galaxies.

We adopt the galaxy type from the GOLDMine compilation (Gavazzi et al. 2003), including E, E/S0, S0, dE, dE/dS0, dS0. Our sample contains 460 ETG brighter than $B_T=18.0$, the completeness limit of the VCC.
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We have searched our sample of 943 VCC ETG for HI detections in the catalogue of detected ALFALFA sources, which is available for the declination strip with $8^\circ \leq \delta \leq 16^\circ$ (Giovanelli et al. 2007).

We found 14 ETG detected in HI, 10 of which brighter than $B_T=18.0$. Only two of these sources were known before to have HI.

The detection rate of HI with $M_{HI} \geq 3 \times 10^7 M_\odot$ for VCC ETG with $B_T \leq 18.0$ is 2.2% (10 out of 460).

Within the accuracy allowed by the number of detected ETG, the detection rate does not depend on luminosity.

Most importantly, more than 800 ETG (390 with $B_T \leq 18.0$) in the VCC have been observed but not detected, so they have $M_{HI} \leq 3 \times 10^7 M_\odot$. 
If one considers the 60 ETG with $B_T \leq 18.0$, which are in the low ALFALFA sensitivity region within 1 deg. of M87, then the detection rate of HI with $M_{HI} \geq 3 \times 10^7 M_\odot$ for VCC ETG with $B_T \leq 18.0$ is raised to 2.5% (10 out of 400). The detected ETG tend to lie at the periphery of the Virgo cluster.
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Table 1. VCC Early Type Galaxies detected in ALFALFA

| ID   | Other Name | $B_T$ | Type<sup>a</sup> | Type<sup>b</sup> | ALFALFA Name | $c_{HI}$ km/s | $M_{HI}$ $10^7 M_\odot$ | Code<sup>b</sup> | S/N | $M_B$  | log($M_{HI}/L_B$) $M_\odot/L_\odot$ |
|------|------------|-------|------------------|------------------|---------------|----------------|----------------|------|-------|---------------------------------|
| VCC 21 | IC 3025  | 14.75 | -3 GM | dS0(4) | HII121025.7+101141 | 485 | 5.3 | 2 | 9.4 | -16.36 | -1.02 |
| VCC 93  | IC 3052  | 16.3  | -1 GM | dE2    | HII121348.0+124125 | 841 | 3.5 | 1 | 6   | -14.8  | -0.58 |
| VCC 209 | IC 3096  | 15.15 | -3 GM | dS0?   | HII121651.2+143041 | 1263 | 3.6 | 1 | 7.4 | -15.96 | -1.03 |
| VCC 304 | IC 3096  | 16.3  | -1 GM | dE1 pec? | HII121842.5+122307 | 132 | 3.2 | 1 | 6.2 | -14.8  | -0.65 |
| VCC 355 | NGC 4262 | 12.41 | 1 GM  | SB0    | HII121929.2+145223 | 1367 | 49.1 | 1 | 53  | -18.70 | -0.99 |
| VCC 421 | IC 421   | 17.0  | -1 GM | dE2    | HII122034.9+133130 | 2098 | 3.4 | 2 | 5.1 | -14.1  | -0.31 |
| VCC 748 | IC 748   | 17.3  | -1 GM | dE4;   | HII122451.1+143503 | 2782 | 2.9 | 4 | 4.3 | -13.8  | -0.26 |
| VCC 881 | NGC 4406 | 10.06 | 0 GM  | S0(3)/E3 | HII122612.0+125636 | -302 | 8.0 | 2 | 6.9 | -21.05 | -2.72 |
| VCC 956 | IC 956   | 18.75 | -1 GM | dE1,N: | HII122655.3+125736 | 2151 | 9.2 | 1 | 10.3 | -12.36 | 0.82  |
| VCC 1142| IC 1142  | 19.0  | -1 GM | dE     | HII122856.1+084835 | 1306 | 4.7 | 1 | 13.7 | -12.1  | 0.62  |
| VCC 1202| IC 1202  | 20.0  | -1 GM | dE?    | HII122930.3+131150 | 1215 | 14.5 | 1  | 8   | -11.1  | 1.51  |
| VCC 1964| IC 1964  | 18.0  | -1 GM | dE4;   | HII124316.2+085700 | 1495 | 4.3 | 4 | 4.1 | -13.1  | 0.25  |
| VCC 1993| IC 1993  | 15.3  | 0 GM  | E0     | HII124417.7+125633 | 925  | 4.5 | 2 | 5.8 | -15.8  | -0.87 |
| VCC 2062| IC 2062  | 19.0  | -1 GM | dE:    | HII124757.2+105823 | 1141 | 32.7 | 1 | 79.9 | -12.1  | 1.47  |

<sup>a</sup> GOLDMine type: -3=dS0 -2=dE/dS0 -1=dE(d:E) 0=E-E/S0

<sup>b</sup> =S0

ALFALFA detection codes:
1≡ S/N≥6.5,
2≡ 4.5≤S/N≤6.5 with optical counterpart of known similar redshift,
4≡S/N≤4.5

The majority of the detected ETG have peculiar or uncertain morphology.
21 cm ALFALFA spectra for the Virgo ETG detected in HI
How much neutral gas per stellar light?

\[ B_T = 18.0 \]
Previous estimates of the HI detection rate in ETG

- Knapp et al. 1985: 15%, 23 detections in 152 E/S0 galaxies from the literature.
- Bregman et al. 1992: 5% to 45%, depending on morphological type, from E to pec.E and S0, from a review of the detections in the literature.
- Conselice et al. 2003: 15%, 7 detections out of 48 dwarf elliptical galaxies in the Virgo cluster with radial velocity, observed in HI, which is half of those present (97).
- Morganti et al. 2006: 75%, 9 detections (4 E + 5 S0) out of 12 observed (4 E + 8 S0). These are the ETG with $\delta \geq 23^\circ$ out of the 24 ETG (12 E + 12 S0) in the field SAURON sample, which in turn are selected out of the 133 field ETG in LEDA with $cz \leq 3000$ km/s, $M_B \leq -18.0$, $-6^\circ \leq \delta \leq 64^\circ$. However they would have detected only 7 ETG (58%) at the higher HI detection threshold of ALFALFA ($3 \times 10^7 M_\odot$) and at their higher absolute magnitude limit ($M_B \leq -18.0$) we would have detected only 2 ETG out of 35, with a detection rate which is still 10 times lower than of Morganti et al. 2006.
Interaction between gas phases

M86 ≡ NGC 4406 ≡ VCC 881

\[ M_{N.G.} = 8 \times 10^7 \, M_\odot \]

\[ \log L_{H\alpha} = 40.58 \, \text{erg/s,} \]

\[ M_{I.G.} \sim 10^6 M_\odot \]

\[ \log L_X = 41.48, \ M_{H.G.} \sim 10^{10} M_\odot \]

Trinchieri & di Serego Alighieri, 1991
Summary and future plans

- We are using the ALFALFA survey to study the HI content of ETG as a function of galaxy mass and environment.
- The cross-correlation of the 943 ETG in the VCC and the catalogue of detected HI ALFALFA sources with $M_{HI} \geq 3 \times 10^7$ in the 8-16 deg. declination strip gives 14 ETG.
- The HI detection rate for ETG down to the VCC completeness limit of BT = 18.0 is 2.5 or 2.2%, depending on whether or not one considers the region of lower ALFALFA detection sensitivity around M87, considerably lower than previous estimates.
- The detected galaxies tend to be at the periphery of the cluster and to have peculiar morphology.
- We are currently improving the HI detection sensitivity and upper limits by a search in the ALFALFA datacubes at the optical positions, and velocities, when available.
- We are also planning to investigate with ALFALFA the HI content of a complete sample of ETG in the field.
Thanks, Edvige, Raffaella & Simone!