ALFALFA Follow–up: Enigmatic Virgo Clouds

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Scientific Background: ALFALFA, the Arecibo Legacy Fast ALFA survey of extragalactic HI, initiated observations in February 2005. Among its scientific goals are those of delivering an unbiased view of the local, extragalactic Universe and providing a legacy dataset for the astronomical community at large. The first two papers of ALFALFA results appeared in December 2005 (Giovanelli *et al.* 2005, AJ 130, 2598; AJ 130, 2613). Preliminary results of the survey are accessible through NVO–compatible software tools and 9 presentations of ALFALFA results were given at the Jan. 2006 AAS meeeting in Washington, D.C. (see *http://egg.astro.cornell.edu/pubs/aas06.php*). A number of unexpected discoveries were made during the first year of ALFALFA observations. In particular, ALFALFA has detected several HI cloud complexes lacking optical counterparts in the periphery of the Virgo cluster, near the outer boundary of the hot X-ray emitting gas. They are found at large velocities with respect to the cluster systemic velocity and thus may be moving at high speed with respect to the cluster. If they are located at the Virgo distance, these complexes are very extended structures, ∼200 kpc or even larger, suggesting that their origin may be dramatic examples of galaxy harassment (Moore *et al.* MNRAS, 304, 465; see the "galaxy harassment movie" available at *http://www-hpcc.astro.washington.edu/picture/movies.html* for a simulation of the harassment phenomenon and how extensive the resultant debris field may be), possibly combined with ram pressure stripping by the intracluster medium. Because of its wide areal coverage and surface brightness sensitivity, ALFALFA is able to detect very extended emission much better than interferometers can, thus allowing us a first glimpse at the true extent of HI debris fields in Virgo, in timely coincidence with the recent discovery in very deep optical images of large-scale stellar streamers (Mihos *et al.* 2005, ApJ 631, L41). To complement the ALFALFA survey observations, we request here a modest amount — 20 hrs — of telescope time with the L–band wide (LBW) feed, designed to corroborate and expand on several of the recent ALFALFA findings of enigmatic HI cloud complexes in the Virgo Cluster region. A summary of these objects and the required followup is detailed below.

1. A previously–unknown extensive HI cloud complex in Virgo, composed of 5 clumps totalling $M_{HI} \sim 6 \times 10^8$ $M_\odot$, was discovered by ALFALFA. Follow–up observations were obtained in July 2005 and January 2006 with the VLA, confirming the detection of 2 of the clumps (paper in preparation; see AAS poster by Spekkens *et al.*). Two of the remaining clumps were outside of the VLA field of view; a third clump, within the field, is of too low peak emission to be detectable by our VLA observations. Here, we request telescope time to confirm the detection of the 3 yet unconfirmed clumps and to obtain higher S/N spectra to determine reliable widths and upper limits to their masses. One of the 5 clumps (detected by the VLA) appears to be associated with the tiny, very low surface brightness galaxy VCC1357, although the HI ($1.5'$ across) and optical emission ($10''$ across) are offset from each other by about $2'$ (9 kpc at the Virgo cluster distance); the optical redshift of the VCC galaxy is not known and a first attempt to measure it with the Palomar 5 m telescope yielded no detectable Hα emission. All the other clumps, spread over $40'$ (200 kpc at the Virgo distance), have no known optical counterpart. Approximately 1 hr of LBW time will be required for this set of observations.

2. Discovered first in HIJASS and confirmed in previous Arecibo observations, Davies, Minchin and others (Minchin *et al.* 2005 ApJ 622, L21 and refs. therein) reported the discovery of a "dark galaxy" in the Virgo cluster VirgoHI21. ALFALFA observations demonstrate conclusively that VirgoHI21 is part of a $30'$ long stream of gas connected to the large asymmetric spiral NGC4254. The ALFALFA feature is significantly more extended than shown by the WSRT and previous Arecibo observations of Davies, Minchin and collaborators. Figure 1 shows a moment map of the ALFALFA data, with the recent WSRT map of Minchin *et al.* (astro-ph/0508153) shown for perspective. During the ALFALFA observations, a strong rfi intermod marred some of the data around 2000 km s^{-1} , decreasing significantly the sensitivity in those volumes. We propose to obtain a 1-D spatial map of the $30'$–long stream, by sampling it along its length during one day of observations, and then re-sampling at intermediate locations on the following day. The objective is to corroborate the extent of the feature and to determine accurately its large–scale kinematics. This mapping will require 4 hrs of telescope time.

3. In the vicinity of NGC4192, a Virgo galaxy whose cz is so low that its HI signal is blended with galactic HI, extended emission was discovered by ALFALFA between +70 and +150 km s^{-1} . Initially, the emission was thought to be associated with the known HVC 263+75+101 (Wakker & van Woerden 1991, A&A, 250, 509). However, the resolution of the ALFALFA data clearly suggests a direct connection between N4192 and the emission at +100 km s^{-1} . Unlike most HVCs in the northern galactic cap, the positive velocity clumps near NGC4192 are spectrally broad ($\sim$ 60 km s^{-1}) and many of them are unresolved by the Arecibo beam. Furthermore, the HI of NGC4192 appears disturbed and evidence of an HI countertail is seen at negative cz. If the extended HI emission (see Figure 2 for a moment map) is associated with NGC4192, its extent at the Virgo cluster distance exceeds 500 kpc! ALFALFA observations were carried out in Total Power mode, making the recovery of baseline fidelity near galactic HI uncertain. We propose to investigate the region with LBW in frequency–switched mode in order to verify the possible presence of extended, low column density material in the region. Approximately 5 hrs of LBW time will be required for this purpose.

4. The velocity of the HI clouds near NGC4192 ($\sim$ 100 km s^{-1}) is similar to that of 18 HVCs cataloged by de Heij, Braun & Burton (2002, AA 391, 159; dBB) in the North Galactic Polar region (RA 10-15 hrs, Dec. 0-35 deg, $b > 60°$). It thus would appear likely that the clouds near NGC4192 are HVCs in chance alignment with the galaxy, as mentioned above. However, HVCs with those unusual velocities (which would make the clouds receding rather than infalling in the GSR for that part of the sky) are spatially small and near the limit of the catalog sensitivity (typical T_b of 200 mK or less). Five of those 18 clouds fall within the area already surveyed by ALFALFA; 4 are not detected by us, despite the fact that the listed fluxes are well above the sensitivity limit of our survey; the 5th cloud, dBB853=HVC263+75+101, we detect: it is that associated with NGC4192 and the brightest (400 mK) of the 18. We believe the four unconfirmed dBB clouds (nrs. 869, 882, 899 and 901) to be spurious. We propose to verify the reality of the other 13 dBB clouds with velocities 100–200 km s^{-1} that lie in the North Galactic Polar region. For those we'll be able to confirm, we will measure rough structural properties (widths, evidence for small scale spatial structure; while the Dwingeloo data provide a useful source list, the low sensitivity and large beam inadequately characterize the HVC properties) and compare them with those of the NGC4192 cloud. If the properties of HVCs located $> 10°$ away from the Virgo cluster center are found to be similar to those near NGC4192, the argument in favor of a Virgo association for the ALFALFA clouds would be seriously weakened. In addition, a contribution of importance to the phenomenology of HVCs will be made, especially if most or all the HVCs in the list were shown to be spurious. Seven hours of LBW time will be required for this exploratory task.

5. ALFALFA has also detected several unresolved HI candidate sources in the Virgo cluster region, which have no known optical counterparts. We wish to corroborate those detections. Two hours of LBW time will do the job.

Note: ALFALFA is producing a large number of potentially interesting but marginal detections, worth following up. As discussed in detail in the technical documentation posted in the ALFALFA website (see *http://egg.astro.cornell.edu/alfalfa/docs/rg040702.pdf*, "Confirmation of Marginal Detections and Optimal Sampling Strategy for ALFALFA"), an optimal follow–up observing strategy for the corroboration of those candidate signals requires a high R.A. density of candidates, in order to reduce overhead. We intend to submit a comprehensive proposal for ALFALFA follow–up after completion of the second year of the ALFALFA survey observations. The observations proposed here are deemed of exceptional and timely interest and are concentrated in a small region of sky, thus justifying advanced follow–up work.

Summary of Request:

In total, including overhead, we request 20 hours of LBW time, divided as follows: 4 sessions between the LSTs of 11:00 and 13:30 and two sessions between LST 10:00 and 15:00. Daytime observations are acceptable, provided they are > 3 hrs away from noon. Ideally, these observations would be scheduled in June 2006, before Virgo is too close to the Sun.

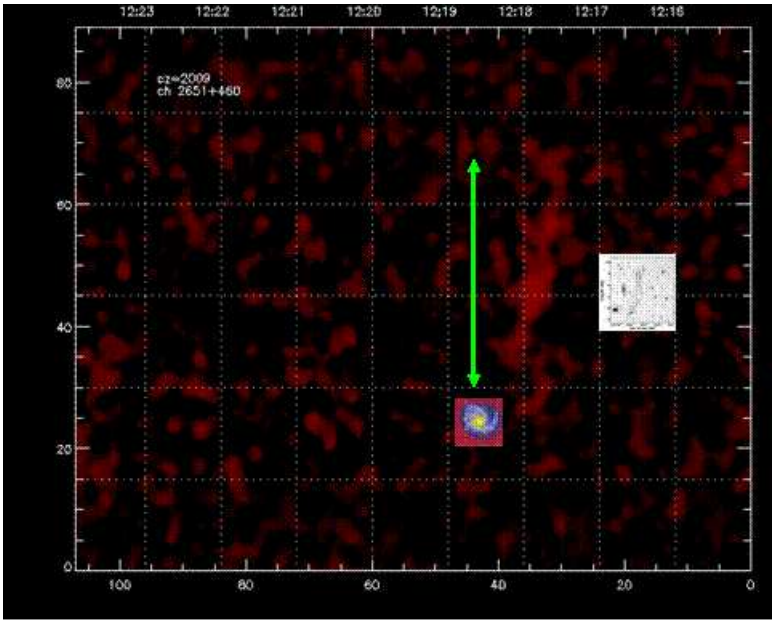

Figure 1: (Above:) Moment map, 25 km s^{-1} wide, centered at $cz = +2009$ km s^{-1} . An optical picture of NGC4254 is inset. The WSRT map of Minchin *et al.* (2005; astro-ph/508153) is also shown, on the same scale, but shifted 1.2 min to the W in RA. The WSRT detection corresponds only to the central region of the stream.

Figure 2: (Below:) Moment map, 10 km s^{-1} wide, centered at $cz = +91$ km s^{-1} . NGC4192 is indicated by the "x" near $(12^h13^m, +14°50')$. The arching stream extending to the North is seen to reach the upper left hand corner of the map at $cz \sim +145$ km s^{-1} , before it disappears. The blob near $(12^h07^m, +15°24')$ is coextensive in velocity with the stream; it shows no connection to the galaxy.