# The Arecibo Galaxy Environments Survey (AGES)
# A precursor proposal

Davies (Cardiff), Auld (Cardiff), Boselli (Marseille), Bothun (Oregon), Briggs (ANU), Brosch (Wise Observatory), Brinks (Mexico), Catinella (Arecibo), Disney (Cardiff), de Blok (Cardiff), Gavazzi (Milan), Giovanelli (Cornell), Haynes (Cornell), Henning (New Mexico), Hoffman (Lafayette), Irwin (Queens), Karachentsev (Moscow), Kilborn (Swinborn), Koribalski (ATNF), Linder (Cardiff), Minchin (Cardiff,) Momjian (Arecibo), O'Neil (NRAO), Putman (Michigan), Rosenberg (Colorado), Sabatini (Rome), Schneider (Massachusetts), Spekkens (Cornell), van Driel (Meudon).

### Abstract

**In this Extragalactic ALFA consortium precursor proposal we are requesting 100 hours of observing time to test observing strategies, define the necessary calibration procedures and obtain data that can be used as initial input into our data reduction software. In addition the proposed observations have been designed to guarantee high calibre early scientific results.**

## 1 Introduction

With the advent of 21cm multi-beam instruments on single dish radio telescopes, it has become possible to carry out fully sampled surveys over large areas of sky. The HI Parkes All Sky Survey (HIPASS) has completed a survey of the southern sky to a sensitivity of about 13 mJy per beam and a similar depth survey over a smaller area of sky is being undertaken by Jodrell Bank (HIJASS). These surveys have been used to construct the first HI selected catalogues of galaxies (Koribalski et al., 2004, Meyer et al. 2004), identify extended HI structures and HVCs in the Local Group (Putman et al., 2002; Putman et al., 2003)), place limits on the faint end of the HI mass function (Kilborn 2000; Zwaan et al., 2003), to identify a population of gas rich galaxies (Minchin et al., 2003), to place limits on the numbers of previously undetected HI clouds and extended HI features (Ryder et al., 2001; Davies et al., 2004; Ryan-Weber et al., 2004), to measure the HI properties of cluster galaxies (Waugh et al., 2002; Davies et al., 2004) and to measure the cosmic mass density of neutral gas (Zwaan et al., 2002). Although, these surveys have been extremely successful in many ways, they have suffered from rather poor sensitivity (a $5\sigma$ HI mass limit of $1.2 \times 10^8$ $M_\odot$ for a 30 $km\ s^{-1}$ velocity width source at the Virgo cluster distance of 16 Mpc), velocity resolution ($\approx$ 18 $km\ s^{-1}$), and spatial resolution ($\approx$ 15 arc min). They have, however, set a bench mark by which other surveys can and will be measured.

The ALFA instrument fitted to Arecibo now offers an opportunity to survey large areas of sky at improved sensitivity, and velocity and spatial resolution. This in itself does not guarantee new science, but by utilising the unique properties of this instrument on the worlds largest single dish telescope, we here propose to carry out surveys that do probe a new and unique parameter space. The EALFA Arecibo Galaxy Environment Survey (AGES) is designed specifically to study in detail (low HI masses and column densities) the atomic hydrogen properties of different galactic environments. These environments range from apparent voids in the large scale structure of galaxies, isolated spiral galaxies and their halos, extending to the galaxy rich central regions associated with galaxy clusters and filamentry structures. Our intention is to explicitly investigate the HI mass function in each environment, to measure the spatial distribution of HI selected galaxies, to identify individual low mass and low column density objects and to compare our results with expectations derived from QSO absorption line studies and simulations of galaxy formation.

The very nature of survey work, and particularly a rather deep survey like this, is the long length of time required to complete the project. This requires both a commitment by NAIC to see the project through and a commitment by the proposers to provide direction and project management over a long length of time. We believe that we have put in place within EALFA a large consortium of interested, enthusiastic scientists along with a co-ordinating committee that will lead this project to a successful conclusion. This commitment is to both the exploitation of scientific data and to the essential data reduction software and associated archiving facilities that are required to make the project a success.

The Extragalactic ALFA consortium (EALFA) has been split between four separate surveys for which separate long term proposals will be submitted. The shallow Arecibo all sky survey (ALFALFA) will carry out a drift scan survey of the whole Arecibo sky. The Ultra-deep survey will carry out extremely long integrations of a small area of sky. The Zone of Avoidance survey will concentrate on extra-galactic studies within the region of the Galactic plane. The survey described in this proposal is known as AGES. This survey is designed to extend the integration times per point compared to the ALFALFA survey to look for lower mass and lower column density objects in certain well defined environments (including regions in the zone of avoidence).

## 2 Brief out line of the survey

The full survey will concentrate on a number of environments situated at all RAs to provide observing opportunities at all times of the year. The exact observing times and areas covered will be defined after assessing the results from this precursor proposal. Local environments in the full survey will include:

1. **The Virgo Cluster** - we will select a region of the Virgo cluster (possibly two regions, one in the center and one at its edge) to make a comparison of the HI properties of cluster galaxies with those in the field. These observations will be compared with models of how the cluster environment affects galaxy evolution (tidal, ram pressure stripping etc.). We will be able to search for low mass galaxy companions or cluster dwarf galaxies and for previously unidentified HI clouds. We will be able to measure how the cluster baryonic material is divided between its individual components (stars, x-ray gas, neutral gas) and compare this with field galaxies. With 300s integrations we expect to be able to detect HI masses that extend down to $6 \times 10^6$ $M_\odot$ ($5\sigma$ and velocity width 30 $km\ s^{-1}$) more than an order of magnitude lower than that achieved by HIPASS.

2. **A Local Void** - we will select a region locally devoid of bright galaxies and search for HI signatures that might be associated with very low surface brightness galaxies or with HI clouds devoid of stars. The data will be compared with observations made by HIPASS so that by correlating the data we can look for coincidences that will enable us to reach the lowest mass limits possible.

3. **The Virgo Southern extention** - we will compare a field in the Virgo southern extension with the void and Virgo cluster data. If current galaxy formation theories are correct galaxies fall into clusters along filaments like the Virgo southern extention. Thus these galaxies should be in an intermediate state between galaxies in the field and those in the cluster. For example there are far more dwarf galaxies per giant in the cluster and almost all optically identified cluster dwarfs are gas poor (current limit is about $M_{HI} < 10^7$ $M_\odot$). Field galaxies tend to have fewer dwarf galaxy companions and a higher fraction of them are gas rich. When does the transformation begin ?

4. **Galaxy groups and individual galaxies** - to make the comparison complete we will observe a number of nearby isolated galaxies and other groups and clusters (for example the Pegasus I and II groups). This will provide the bench mark to which all the other observations can be compared. Two specific issues are the possible link between dwarf galaxy companions and High Velocity Clouds (HVC) and our ability to trace the HI distribution to large distances from the centre of galaxies (HI column densities down to a $4 \times 10^{18}$ $cm^{-2}$). We will target a number of very different morphology galaxies, of which N2903 is our first target and, as part of a coordinated effort with the N2903 group, is part of a separate precursor proposal.

We have used as our bench mark the Virgo cluster and intend to ensure that we reach an HI mass limit for the cluster (approx 16 Mpc) of $6 \times 10^6$ $M_\odot$ at this distance. We intend to observe all the other prime target nearby environments to this limit or better or where there is no well defined structure, with the same integration time as that for the Virgo cluster. In this way we will be able to characterise the HI content of different environments to the same sensitivity in HI mass. The $6 \times 10^6$ $M_\odot$ limit has been chosen because it extends by an order of magnitude the last point of the HI mass function (HIPASS) derived by Zwaan et al., (2003) and is significantly deeper than that proposed for the ALFALFA survey. For objects in groups and clusters we can also use the line-of-sight velocities to measure the velocity structure and estimate the total group/cluster mass. Individual galaxy total masses can be measured from their velocity widths. In addition to all of the above we will also have a number of relatively deep observations of the more distant Universe. These will each be at least five times deeper than that of the ALFALFA survey. Thus within more distant clusters and filaments, beyond the local Supercluster, we will be able to measure further down the mass function (see below).

**The AGES strip** - an extended strip, in RA, is the optimum way to build up sensitivity given the design of the Arecibo telescope. We plan to observe an extended region to sample the galaxy population in general and to measure the the HI mass function beyond the Local Supercluster. The 'universal' HI mass function remains poorly characterized based on current HI surveys. Even though the Parkes survey (Zwaan et al. 2003) has improved the statistical uncertainties substantially, they find significant and systematic differences in the mass function in different quadrants of the sky, even for sources with HI masses up to $10^9$ $M_\odot$. Similarly, Rosenberg & Schneider

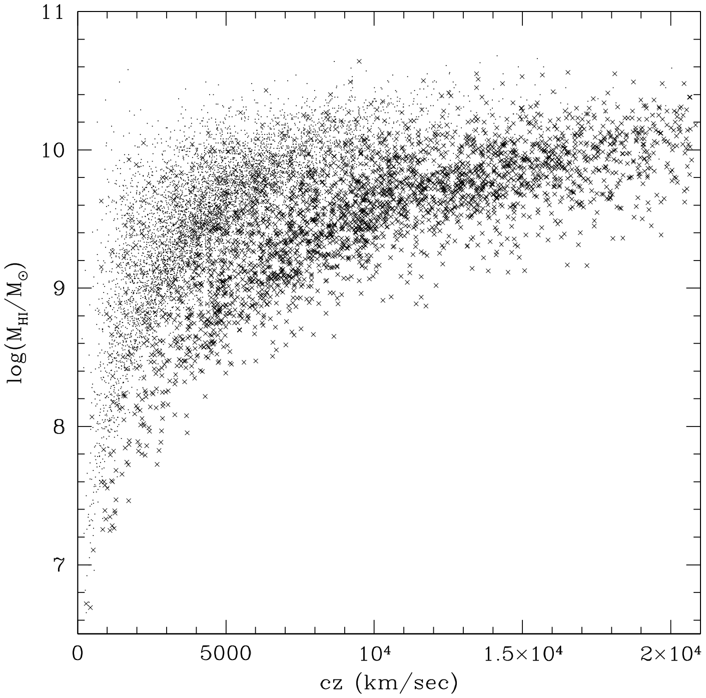

Figure 1: Masses of detected HI sources against their redshift distance for the 12s integration ALFALFA survey (dots) and the proposed 300s integration AGES survey (crosses).

(2002) found significant differences in the quadrant of the sky containing Virgo versus the rest of the Arecibo sky. The effects of cosmic variance are still not well quantified, and the largest surveys to date, and even surveys like ALFALFA, remain firmly rooted in exploring the mass function well inside the Local Supercluster. The best estimate of the source of damped Ly-alpha absorbers is that they arise mostly from HI sources in the neighborhood of $10^9$ $M_\odot$ galaxies (Rosenberg & Schneider, 2003), so connecting our understanding of the evolution of these absorbers and the nearby population of HI emitters requires a better understanding of the HI mass function and its variance. It is important therefore that we carry out a deeper survey to determine if the local environment is typical.

Figure 1 illustrates the difference between a large shallow survey and a medium deep survey by plotting the masses of detected HI sources against their redshift distance. It is based on a simulation using the Parkes HI mass function ($\alpha = -1.3$), and includes realistic distributions of galaxy rotation speeds, inclinations, detection thresholds, and completeness rolloff. The model successfully reproduces the distribution of characterisitics and detection rates found by Rosenberg & Schneider, and it has been modified here to simulate the sensitivies and coverages that we might expect with approximately 1000 hours of observing in:

1. the 12s ALFALFA-type driftscan mode (which is quite similar to Rosenberg & Schneider) shown by simple points in the plot.
2. the proposed 'medium deep' (AGES) observations with 25 times longer integrations per point and 25 times less area of the sky covered, shown by x's in the plot.

In the shallow survey, nearly 7000 sources are detected, while the deeper survey detects nearly 3000 sources. Our ability to characterize the HI mass function at any distance can be estimated by looking at vertical cuts through the distribution of points in this diagram. Note that the choice of 12 s and 5 min integrations complement each other quite well in terms of neither leaving a significant gap in mass coverage at any redshift nor in overlapping each other so heavily that we give up sensitivity to lower mass sources. The shallow survey detects many more lower-mass sources, but they are also nearby. It can characterize the HI mass function for sources down to about $10^{8.5}$ $M_\odot$ within the Local Supercluster (out to $cz \approx 2000$ $km\ s^{-1}$). Complemented with the medium deep survey, we are able to characterize the population within this distance down to about $10^{7.8}$ $M_\odot$. Likewise, the shallow survey can provide good statistics on the mass function near $10^9$ $M_\odot$ out to $cz \approx 3000$ $km\ s^{-1}$, but the medium deep survey carries this out to about 7000 $km\ s^{-1}$ - the distance of the Coma Cluster and beyond the redshift of the Great Attractor. This will provide us with a much more complete understanding of the mass function and its possible variations outside of our nearby environment, and allow us to tie our results more clearly to the damped Ly-alpha absorber results.

**Zone of Avoidance** - The obscuration due to dust and the high stellar density in our Galaxy varies from place to place within the Milky Way. Overall, it blocks our optical view of the extragalactic Universe over ∼20% of the sky, somewhat less in the infrared. This 'Zone of Avoidance' (ZOA) was recognized even before the nature of the spiral nebulae themselves was understood. This sky coverage limitation does not pose a problem for the study of galaxies themselves, as there is no reason to believe that the population of obscured galaxies should differ from those in optically unobscured regions. Yet an accurate knowledge of the mass distribution within our neighborhood is essential if we are to understand the dynamical evolution of the Local Group from kinematic studies (e.g., Peebles et al., 2001). In addition, the discovery of previously unknown nearby galaxies will further help efforts to understand the local velocity field (see Kraan-Korteweg 1986 and Karachentsev et al., 2002). Mapping more distant hidden galaxies allows the connectivity of large-scale structure across the Galactic plane to be explored.

The ZOA has been successfully narrowed by deep searches in the optical and infrared, but both fail in regions of high extinction and stellar confusion. However, galaxies which contain HI can be found in the regions of thickest obscuration, and worst IR confusion. In the northern hemisphere, the ZOA within ±5 degrees of the Galactic plane has been searched at 21cm, but only at the high noise level of 40 mJy beam$^{-1}$, sensitive only to nearby, massive objects [The Dwingeloo Obscured Galaxies Survey: 43 galaxies uncovered (Henning et al., 1998; Rivers, 2000)]. The situation in the southern hemisphere is better, with the completion of the HI Parkes Zone of Avoidance Survey, at 6 mJy beam$^{-1}$ rms, which has detected about one thousand galaxies (Donley et al., 2004, Henning et al., in prep.)

While the intention of the EALFA consortium is ultimately to submit a proposal for ZOA studies separately from the AGES survey, we include here a precursor observation to test the feasibility of commensal observations for the ZOA survey with a low-Galactic-latitude pulsar survey. This meshes with the AGES precursor tests since we also will be observing to a depth of 300s per pointing, and will be testing similar modes at high Galactic latitudes.

**Summary of science issues**

1. The HI mass function in different environments - around large galaxies, in groups, clusters and beyond the Local Supercluster - comparison with galaxy evolution models.
2. The contribution of neutral gas to the baryonic mass density - 'missing' baryonic matter.
3. The nature of and possible link between HVC and dwarf galaxies - a solution of the CDM sub-structure problem ?
4. The identification of gaseous tidal features as signatures of galaxy interactions and mergers - the importance of mergers as a mechanism for the assembly of galaxies, gas removal mechanisms in clusters and groups.
5. The velocity dispersions of galaxies in groups and clusters. - dark matter
6. The dynamical masses of galaxies - galaxy rotation curves - dark matter.
7. The low column density extent of large galaxies - ionisation by the metagalactic radiation field.
8. The identification of isolated neutral gas clouds - remnants of the galaxy formation process.
9. A comparison of the atomic hydrogen detected by QSO absorption line and 21cm observations - consistency between different observations that measure the same thing.
10. The spatial distribution of HI selected galaxies - particularly in the ZOA.
11. A comparison with numerical models of galaxy formation - provide input into the simulations.
12. Serendipitous discoveries - with a survey like this, that will cover large areas to low mass limits and column densities, we would hope to find many new and unexpected things.

## 3 Description of proposed precursor observations

This proposal is for precursor observations for the period October - January 2004/5. We plan to extend the integration times per point obtained by the ALFALFA survey to 300s per point and investigate and compare observing strategies.

**Drift scanning** - for the scanning experiment we have chosen a region of sky which will already have been observed to a depth of 60s by ALFALFA precursor observations. This is the nearby galaxy group centered on NGC628 (M74). The group lies at about 10 Mpc from us and so we should be able to reach a mass limit of $M_{HI} \approx 3 \times 10^6\ M_\odot$, more than an order of magnitude better than HIPASS. NGC 628 together with its companions UGC1104, UGC1171, DDO13(UGC1176), UGCA20 and KDG10, and also a peculiar spiral NGC660 (with its companions UGC1195 and UGC 1200) form a group similar to the Local Group (Sharina et al., 1996). The group is well placed for observations in the October-January period (NGC628 - 01h36m42s +15d47m00s, j2000). We propose to use and extend the method used by ALFALFA. We will carry out twenty 20min scans ($5^o$) across each declination strip and combine five 12.6 arc min strips. When combined with the all sky data this will give us an area of 5 × 1 sq deg with an integration time of 300s per point. We request 20 nights at 1.75hrs per night on source, 5×(20min + 1min slew), 2 hours with start up and stand down. Some of the additional time could be dedicated to making beam maps (see technical case), but we hope that additional time will be made available for this essential calibration work. At the distance of NGC628 $5^o$ is about 1 Mpc and each beam will cover about 10 kpc. This is an extended strip compared to the size of NGC628, our intention is to not only look at the galaxy but also its immediate environment. NGC628 is so close that we are sensitive to low HI masses, but its velocity (657 $km\ s^{-1}$) is high enough to be well separated from local HI (local HVC have velocities of less than 150 $km\ s^{-1}$ in the direction of NGC628 at HIPASS sensitivity). The peak flux of NGC628 is 6.7 Jy (see fig 2.) and it has a very narrow 50% peak flux velocity width of 52 $km\ s^{-1}$. One might expect hydrogen gravitationally bound to NGC628, but not rotating in the disc, to be in the range $\pm 200\ km\ s^{-1}$ of the line-of-sight velocity and associated HVC at even higher velocities, thus this gives us excellent velocity separation. This experiment has a number of advantages over other modes of observing. Firstly, data from ALFALFA are constructed in a similar way and should be compatable and easily comparible - the well tried 'wedding cake' approach. Secondly, we will be able to see how the noise changes when going from 12s-60s-300s and so predict how it might change for even longer drift scan integrations. In summary the NGC628 group consists of two spiral galaxies and a number of star forming dwarf irregular galaxies. Thus it is a very gas rich environment and particularly suited to precursor observations with a new instrument. It offers us the chance to make a direct comparison with the Local Group in terms of the gas content of the known galaxies. We might hope to detect low column density gas between the galaxies resulting from tidal interactions. There is the posibility of detecting 'HI' dwarf galaxies, one such object (0137+1541) was detected by Briggs (1986). HVC will hopefully be well separated in velocity from gas in the disc of the galaxy. Thus there are numerous opportunities for early science. Note that these observations will explore an important part of technical parameter space intermediate between that of the ALFALFA survey and that described in our deeper N2903 precursor proposal.

**Total time requested is 40 hours**.

**Leapfrog mode** - We intend to expore this mode of observing because it will allow commensal, efficient, observing for pulsars. In order to reach 300s per beam requires approximately 25 driftscan passes. In step-and-stare patterns, we have a variety of possible interleavings of the beam footprint pattern. For example, pattern 2 being considered by P-ALFA (http://www2.naic.edu/ pfreire/tiling/) interleaves the 7-beam footprint pattern four times to achieve about 2.7' spacing between beams in the final map. This requires 68 pointings per square degree, and to reach 300s per beam requires 20 passes for fixed declination strips. (The smaller number of passes required is because the resulting map is more sparsely sampled than the drift-scan maps.)

In particular we want to test the 'leapfrog' mode employed by Spitzak & Schneider (1998) in their Arecibo HI survey. In this mode, the telescope is kept near the meridian. Individual pointings are tracked for 50 sec (for example) and then the telescope is shifted by 1 minute in R.A to the next footprint position. By making the telescope track through the same az-el configuration, every scan is effectively an off for every other scan, and it is possible to achieve many of the same efficiencies as are possible with a drift scan, such as combining multiple offs to achieve lower noise levels. This pattern would also be suitable for commensal observing to search for pulsars. We will test the different interleaving modes and different integration times. Because the footprint centers are spaced by about 1 min in RA, the integration times should be chosen in multiples of this spacing after allowing a sufficient overhead time for slewing and settling. Note that we expect slightly less overhead when the integration times are longer, but it still requires approximately the same number of days to reach the same total integration time since a 2-minute integration, for example, would require us to "leap over" every other footprint position and come back to them on a second day. Multiple passes over the same points also allow us to shift the center beam position on each pass so that the gain at each position is more equalized, and the multiple observations will allow us to improve on interference excision. To completely equalize the gains, 7 repeats would be necessary. This would set a natural total integration time closer to 7 minutes, and would require 28 days to complete after shifting the center beam to each of the 7 possible footprint positions and completing each of the 4 interleaved footprint locations. This type

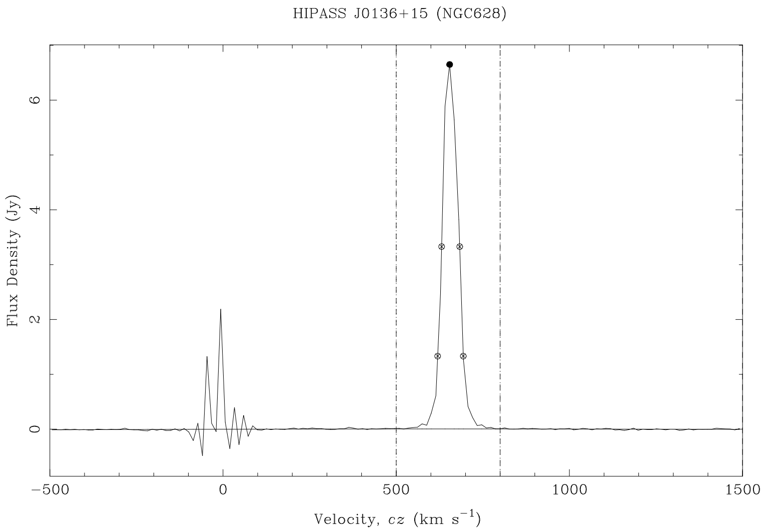

Figure 2: The HI spectra of NGC628 taken from the HIPASS northern extension data. The galaxy has an extremely narrow velocity width (50 $km\ s^{-1}$ at 50% peak height) helping us to distinguish atomic hydrogen associated with high velocity clouds and/or inter-galactic hydrogen at relatively small velocities compared to the main galaxy.

of strategy would be best for wider-declination regions because the beam spacing will become sparse along the northern and southern edges of the region surveyed.

Early tests during commisioning (see http://www.naic.edu/ emuller/EALFA) suggest the observing efficiency is likely to be between 80 and 90%. We will test how this varies with declination, and develop off-meridian strategies for declinations close to the latitude of Arecibo, where slewing would otherwise take too long. We will also determine the efficiency of this style of observing for different interleaving patterns, and track the rate at which the rms noise improves as a function of integration and actual telescope time. There is a greater likelihood that baseline problems will show up in this mode than are expected for drift-scan observations, and this will be tested too and compared to observations. The region of sky to be observed is not important, and can be flexible, as we are mainly interested, for this experiment, in galaxies beyond the Local Supercluster (section 2). These precursor observations will cover almost the same total area of sky, and to slightly better sensitivity, as the central beam of the extensive Arecibo drift scan survey of Zwaan et al. (1997). We hope to observe a field already observed by the ALFALFA precursor observations so, that we can look at methods of adding leapfrog (stop and stare) data to drift scan data, thus making use of the increased signal-to-noise.
**Total time requested 40hrs**.

**Zone of Avoidance** - We propose here to observe a declination strip across the Galactic plane, 1 hour in RA, reaching beyond ±6 degrees in Galactic latitude. Using the leapfrog technique, we propose doing 5 one-minute integrations, with 4 pointings per footprint, again mimicing the PALFA pattern 2, where no sky is surveyed at less than half power. This will require one hour for each of 20 days. This integration time is the same as the PALFA plan, and also, would suit the Galactic ALFA radio recombination line survey, thus we are testing, potentially, for a 3-survey commensal opportunity. (The possibility to piggyback with a Galactic ALFA low-b drift HI survey is being tested separately, since the precursor study 'Initial HI Survey Observations with ALFA in Drift Mode', A1946, will test drift scans across the Galactic plane.)

The declination strip will run across an obscured, newly-discovered galaxy, uncovered by the northern extension of the HI Parkes Zone of Avoidance Survey (Donley et al. 2004). We chose the strip to ensure detection of at least one HI galaxy, and to compare performance of the Arecibo ZOA observations to Parkes, in the overlap region. We expect these ALFA observations will reach significantly lower noise than the Parkes survey (6 mJy beam$^{-1}$), and need to quantify the performance before proposing the full survey. The $1^h$ strip, covering position 06h30m09s, 08d22m37s (J2000) includes the nearest of the newly detected Parkes galaxies, at a heliocentric velocity of only 367 ±1 km s$^{-1}$. This galaxy lies near the center of what was defined as the Orion Void, suggesting this might not be a void at all. It is possibly a member of the Orion group of galaxies. It contains $1 \times 10^7$ M$_\odot$ of hydrogen, if at the uncertain distance of 3 Mpc (estimated in the absence of peculiar velocities), with mass increasing with

increasing distance. Little is currently known about the galaxy (it has no optical or 2MASS counterpart) although its 50% velocity width of only 33 ±4 km $s^{-1}$ is consistent with the dwarf-like mass estimate. Observing it at the improved Arecibo resolution (3 arcmin corresponds to 2.6 kpc at 3 Mpc) should give an indication of its HI diameter, hopeless now with only the coarse Parkes resolution. Inspection of the LEDA database indicates only 7 other known galaxies in this strip, with only one of these having a measured velocity. Of course, we expect few cataloged galaxies in the literature, since this is in the ZOA.
**Total time requested is 20 hours**.

**Summary** - In all of the above cases the data will be compared with HIPASS observations of the same region to check for consistency in the signals detected and in calibration. Included in this proposal are members of the HIPASS team that have access to the as yet unpublished HIPASS northern extension. We will compare observing techniques before deciding on the strategy for our full survey application.**Total time requested is 100hrs (Drift scanning - 40hrs, Leapfrog - 40hrs, ZOA - 20hrs)**. Raw data will be made publicly available and reduced data as soon as possible.

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# 4 Technical issues and survey techniques

**Calibration Strategy** - The standard gain curves for the ALFA beams, as provided by Arecibo, will be used to calibrate our observations. To insure no system changes have increased (or decreased) the telescope SEFD, we will take a cross scan on 3-4 standard calibrators, located at the same right ascension as our observations, at the beginning and end of each night's observations. The same calibrators will be used each night.
**Beam maps** - To remove effects from the various beam shapes (drift scanning) we will start each set of five scans at the same AZ and ZA each day. We will need to construct a library of beam shapes at the declination of NGC 628, which will be convolved with our observations. We will ask Arecibo staff to obtain beam maps at the five different positions in zenith angle during the ALFA comissioning. Ultimately these beam maps will be combined with those obtained by the other precursor proposals (such as the E-ALFA precursor proposal to look at NGC 2903) to develop a complete beam map library of the ALFA beams across the Arecibo sky. The final library will be used by all future E-ALFA surveys, such as the AGES survey, and is an essential calibration tool for all ALFA data.
**Baselines** - will be obtained from the outer strips of the survey, using the method outlined in Robishaw et al.(2001).

**RFI** - This survey will cover the frequency range 1325 - 1425 MHz. At Arecibo, the only RFI for that range are from the FAA Pico de Este radars (1330, 1350 MHz), the Puntas Salinas frequency hopping radar and the GPS L3 satellite (1381 MHz). The coordination agreement, which exists between Arecibo and Puntas Salinas, restricts their frequencies to outside our observing range. To avoid problems with the San Juan radar, we will employ the radar blanker available at Arecibo. Finally, as the GPS L3 satellite transmits only twice a day (for 2-3 minutes each time), any data which contains GPS L3 transmissions will be removed in the data analysis stage.

**Signal extraction** - We have already developed techniques for automated signal extraction (Davies et al., 2001). We have recently been extending these using Fourier techniques originally used for the identification of signals in gravitational wave data.

**Leapfrog Data Analysis** - This requires a different analysis strategy than driftscans, especially in the case of sparsely-sampled maps. It does not make sense to put the data into cubes, interpolated onto a fine-mesh grid, when a map is undersampled. In some ways the data analysis is simpler, being more similar to the reduction of individual spectra, but the indexing procedure and cross referencing to neighboring beam positions becomes more complex. Each spectrum will have multiple observations, aiding in the identification of interference, and six neighboring spectra taken at different times on different tilings, further aiding in the identification of interference. This type of dataset still permits accurate position and flux reconstruction. For example, Spitzak & Schneider used a similar 7-point hexagonal pattern to determine the centroid of the HI for each of their detected sources, achieving an rms position error of 0.3' (about 1/10th of a beam). The tools for analyzing these data will work on a point-by-point strategy, keeping all of the individual spectra for each point as well as the current 'best' cleaned, combined spectrum. It will be important to be able to test alternate strategies for off-scan subtraction (particularly in the Galactic plane) and interference excision, so the original uncleaned spectra will be maintained for each point. With cross-indexing by time and position, it will be possible to generate spectra on the fly from the existing data, and to accumulate additional data into the same grid at later times.

## 5 Software development

Using the data from this precursor survey, we plan to develop the complete data reduction pipeline for the AGES survey. Our current intention is to make as much use as possible of software currently available. Our preferred route is to make use, where possible, of the AIPS++/HIPASS software currently being used to reduce HIPASS and HIJASS data. We have put together an AGES computing group (O'Neil, de Blok, Minchin, Auld, Kilborn) who have experience of writing, installing and using the AIPS++/HIPASS software. We will modify the code to accommodate the ALFA data format and the unique calibration needs of the Arecibo/ALFA system. For the leapfrog data we may use similar software and indexing as previously developed by Spitzak & Schneider. The goals of this precursor program will be to generalize these tools and make them portable to the community, and to test their ability to identify and extract sources.

## 6 Co-ordination with other ALFA and EALFA projects

Our survey is designed specifically to build on the all sky survey (ALFALFA) so that we can add the ALFALFA data to our data to achieve the highest signal-to-noise for the shortest total observing time. It is hoped that the ZOA survey will primarily use data collected commensally with the PALFA surveys. It is the brief of the EALFA coordinating committee to ensure that all of the surveys fully inter-leave with each other.

## 7 Synergy with other projects

We are fully aware of the importance of multi-wavelength data for the interpretation of astronomical observations. Where ever possible we will choose fields that have been well studied at other wavelengths for example, regions covered by the SLOAN survey and those observed by the very deep near infrared (JHK, with $M_K = 18.6$) UKIDSS survey.