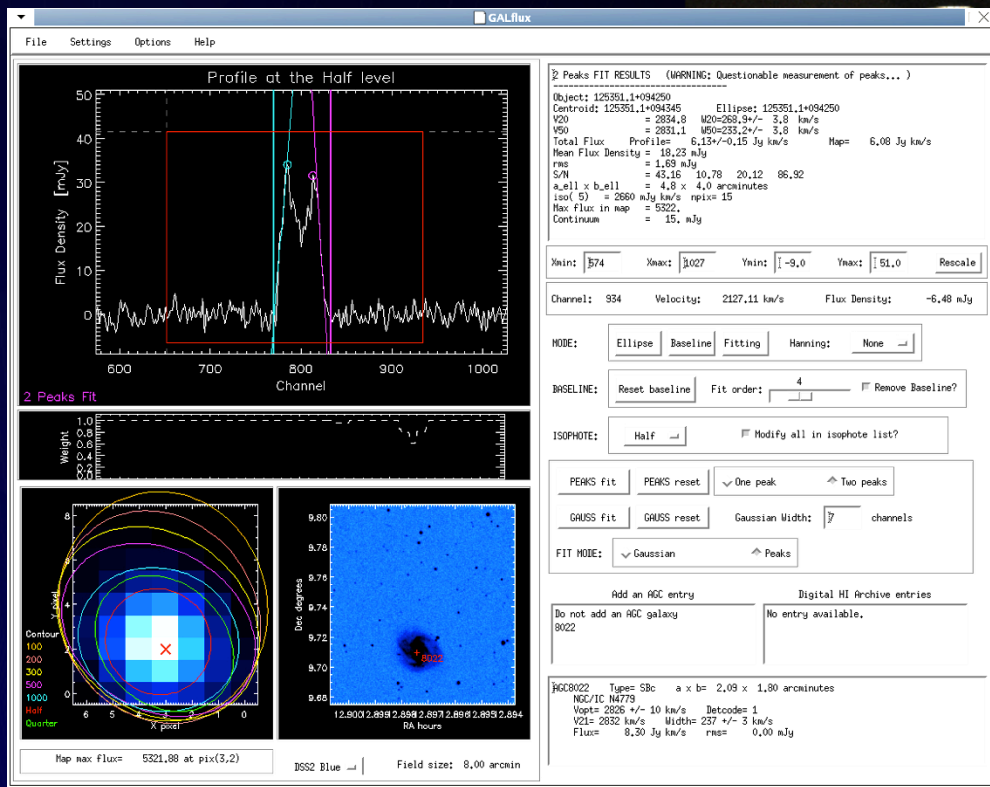
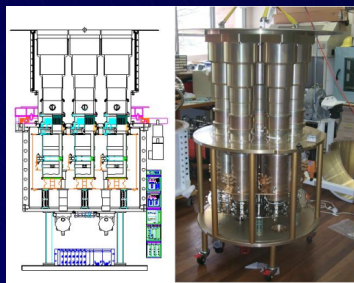


A Census of HI at $z=0$

The Arecibo Legacy Fast ALFA (ALFALFA) Survey



Santa Fe
Mar 8, 2011

Martha Haynes
Cornell University
For the ALFALFA team



ALFALFA

It is a radio "camera"



Arecibo L-band Feed Array (ALFA)



ALFALFA

ALFALFA, a Legacy Survey



The Arecibo Legacy Fast ALFA Survey

[Main](#) [People](#) [Science](#) [Schedule](#) [Data](#) [Documentation](#) [Links](#) [Publications](#) [Undergrads](#)
[Non-experts](#) [News/Events](#) [Observing/Data Team](#)

Overview

Check out the [ALFALFA blog!](#)

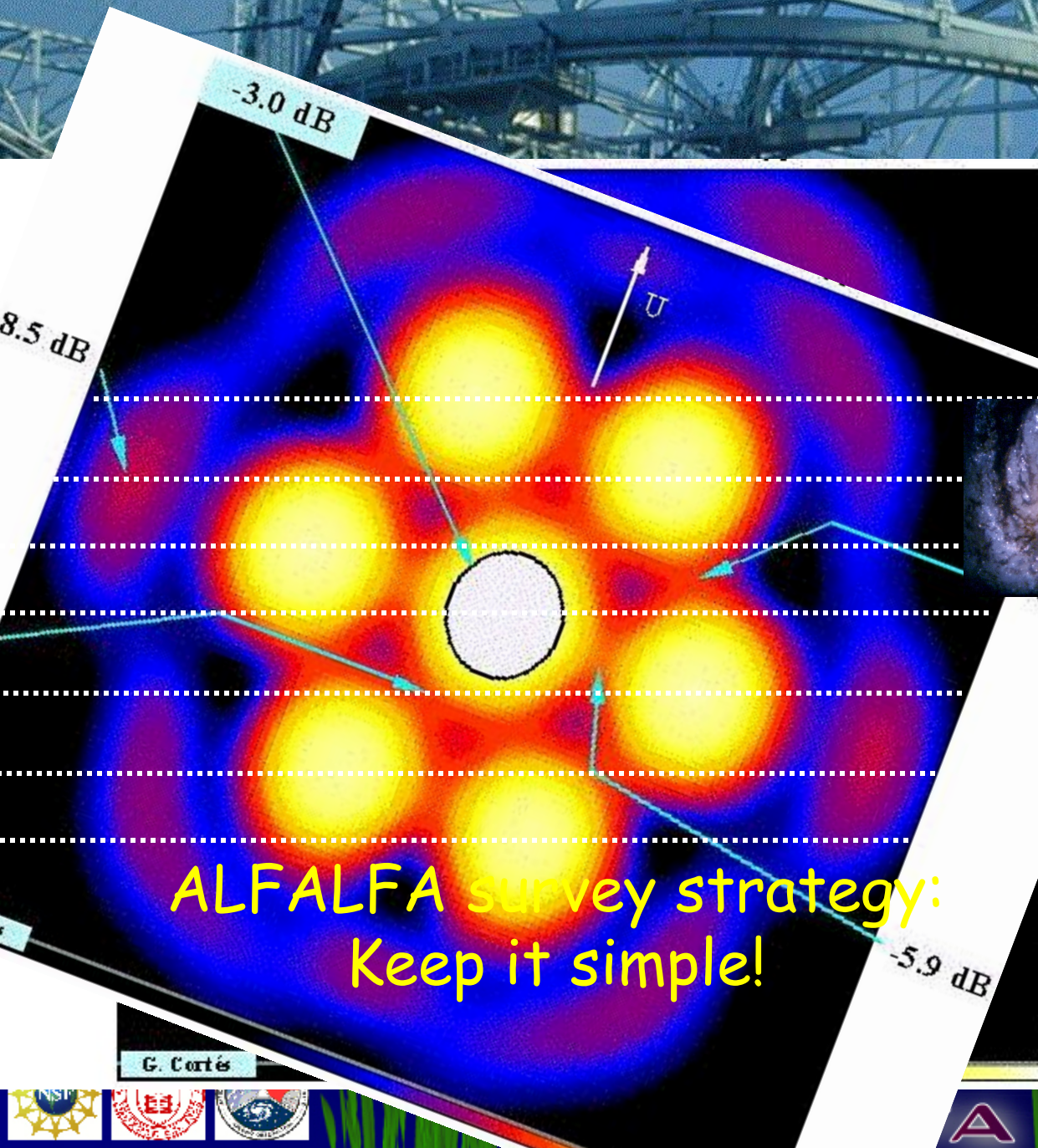


Arecibo is the world's most sensitive radio telescope at L-band. In addition to that all-important sensitivity advantage, Arecibo equipped with ALFA offers important and significant improvements in angular and spectral resolution over the available major wide area extragalactic HI line surveys such as HIPASS and HIJASS. To break ground into new science areas, extragalactic HI surveys with ALFA must exploit those capabilities to explore larger volumes with greater sensitivity than have the previous surveys. The lowest mass objects will only be detected nearby; wide areal coverage is the most efficient means of increasing the volume sampled locally. An extragalactic survey covering the high galactic latitude sky visible from Arecibo will produce an extensive database of HI spectra that will be of use to a broad community of investigators, including many interested in the correlative mining of

<http://egg.astro.cornell.edu/alfalfa>



ALFALFA



The ALFALFA team: An open collaboration



Riccardo Giovanelli PI



Undergrad
ALFALFA
team



Heavy student involvement:

- 5 PhDs to date
- 12 PhDs underway
- Dozens of undergrad thesis/summer projects



38 papers in refereed literature (appeared or submitted)



ALFALFA

ALFALFA Science Goals



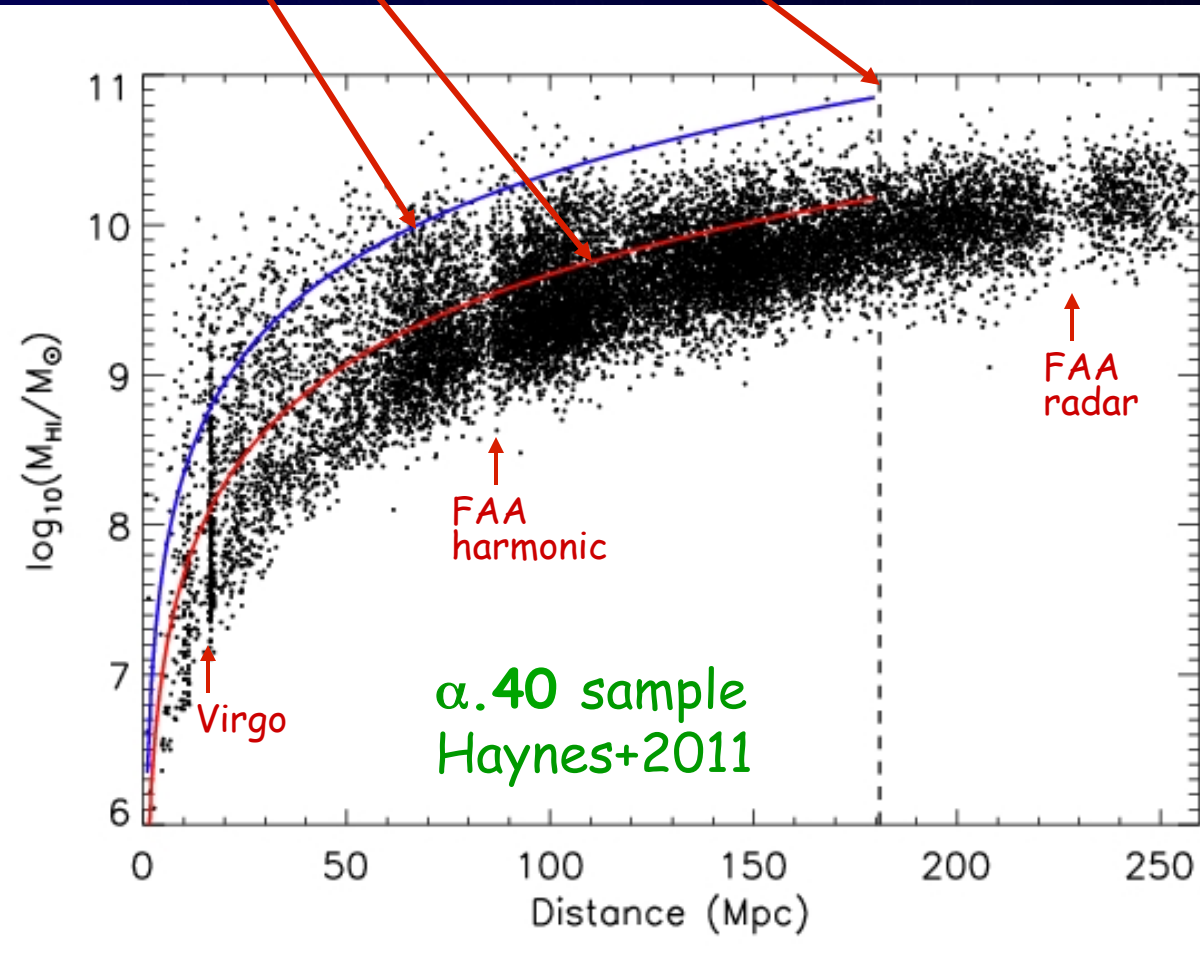
1. Census of HI in the Local Universe over cosmologically significant volume
2. Determination of the faint end of the HI Mass Function and the abundance of low mass gas rich halos
3. Environmental variation in the HI Mass Function
4. Blind survey for HI tidal remnants
5. Determination of the HI Diameter Function
6. The low HI column density environment of galaxies
7. The nature of HVC's around the MW (and beyond?)
8. HI absorbers and the link to Ly α absorbers
9. OH Megamasers at intermediate redshift $0.16 < z < 0.25$



ALFALFA 40% catalog



HIPASS completeness limit
HIPASS detection limit
HIPASS bandwidth edge



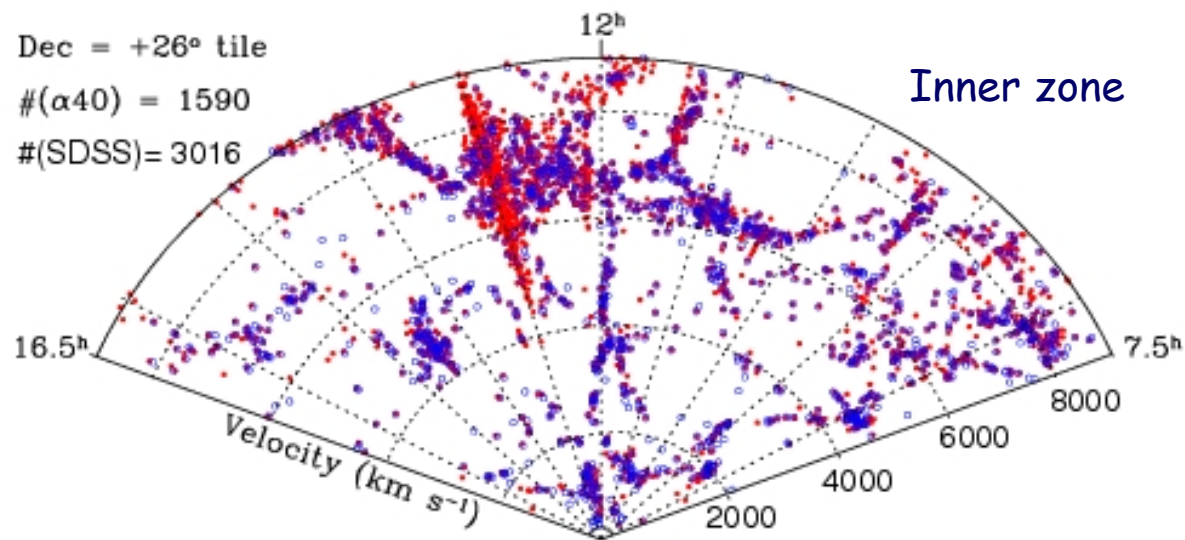
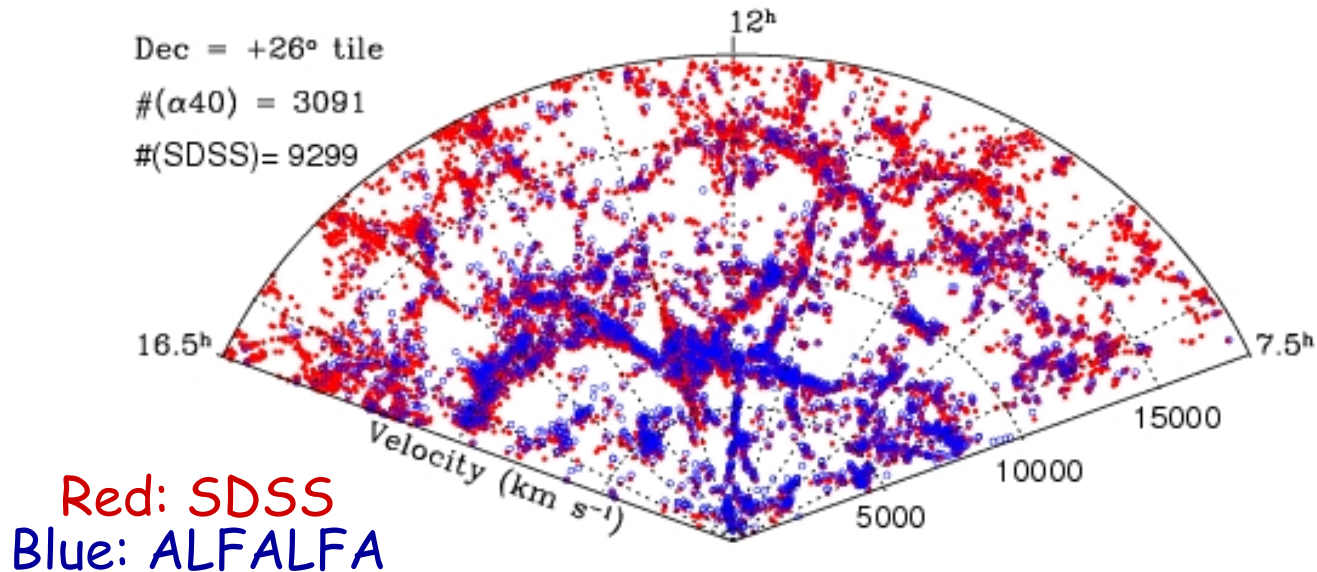
- ALFALFA covers adequate **volume** with adequate **sensitivity**
 - 15000+ **detections**
 - 70% are “**new**”
- In addition to sensitivity, bandwidth and velocity resolution, ALFALFA yields positions to $< 20''$
 - ⇒ Identify most probable **optical counterpart (OC)**
- Continuum/RFI tracked
 - ⇒ Allows **stacking** at arbitrary positions



ALFALFA



- 7000 sqd of high galactic latitude sky with median $cz \sim 8800$ km/s
- Undersamples clusters but traces well the lower density regions
- Large overlapping areas with SDSS and GALEX



4° tile centered at +26°



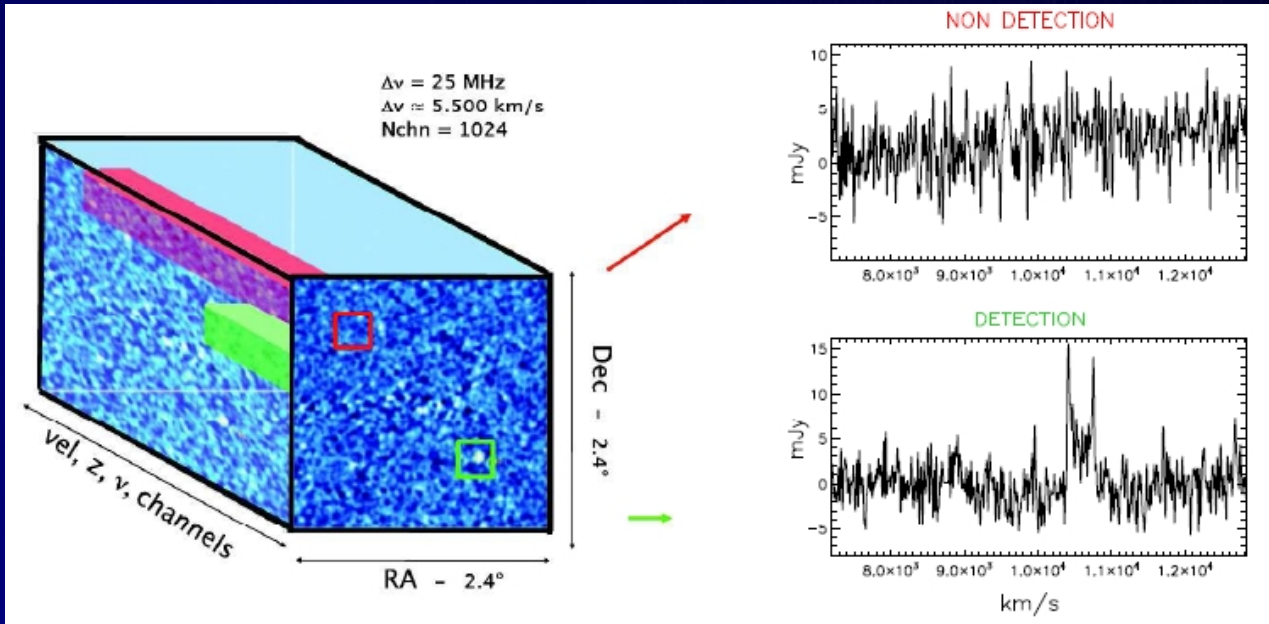
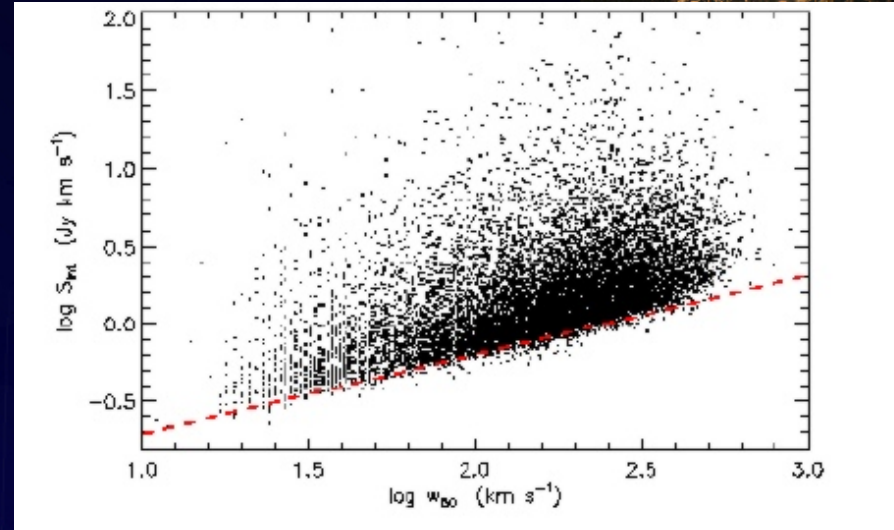
ALFALFA

Mining ALFALFA

Signal extraction done in Fourier domain using matched filter algorithm
(Saintonge 2007, *AJ*, 133, 2087)

HI flux density sensitivity depends on emission width => but well-behaved

Amélie Saintonge
PhD thesis



Fabello+ 2011 *MNRAS*
(in press)

ALFALFA pipeline
tracks RFI/continuum
=> Spectral stacking to
dig deeper.

Silvia Fabello
PhD thesis

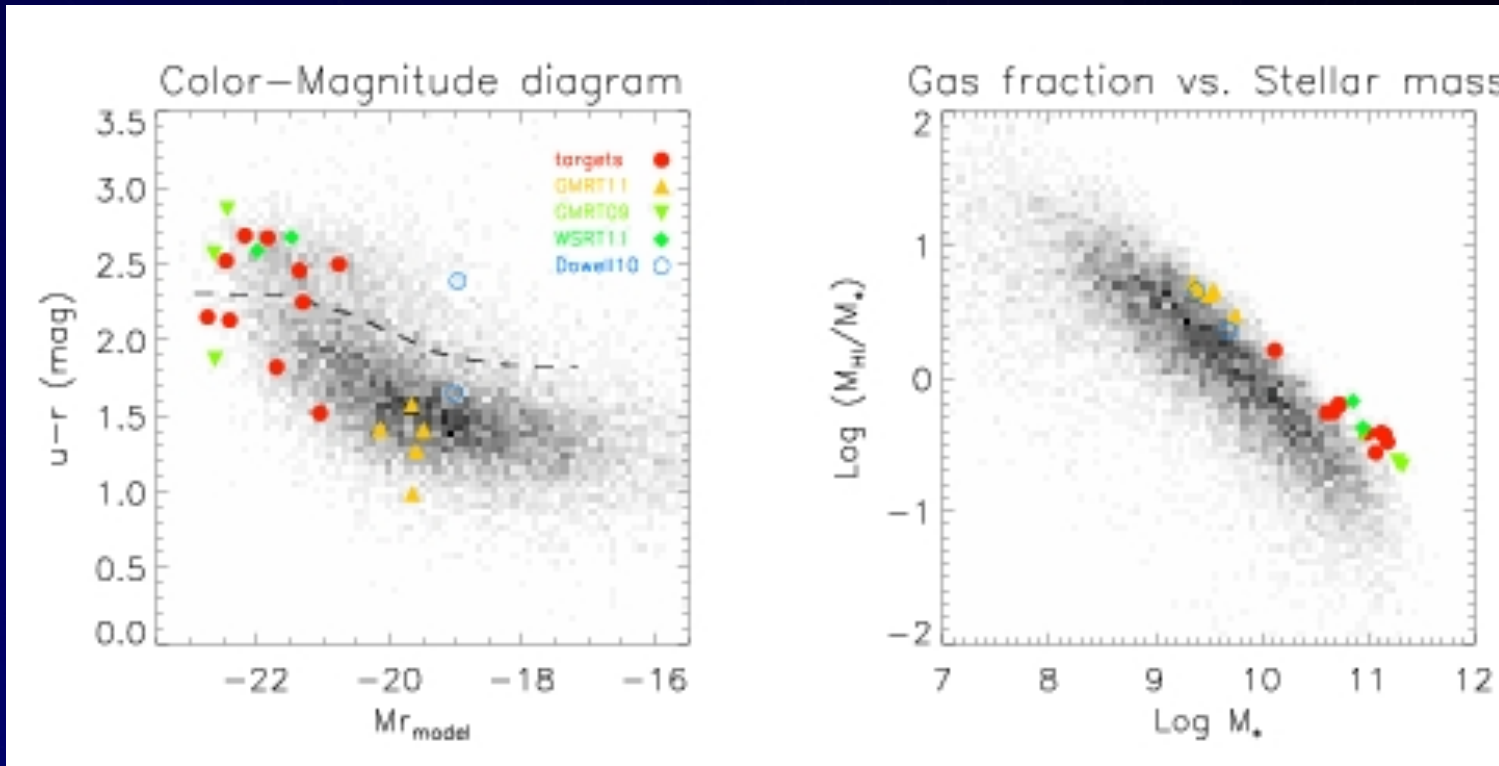


The population of HI-selected galaxies



SED fitting
(SDSS+GALEX)

Shan Huang
PhD thesis



- Gas-dominated systems fill the blue cloud; but some gas-rich red spirals!
- GALEX-Arecibo-SDSS Survey (**GASS**): Schiminovich+ **COLDGASS** (IRAM30m) \Rightarrow scaling relations for massive galaxies
- High gas fraction massive HI disks: **HIghMASS** (colored symbols: stay tuned...)



ALFALFA

HIMF from ALFALFA: Good news for the SKA!



Martin+ 2010 ApJ 723, 1359

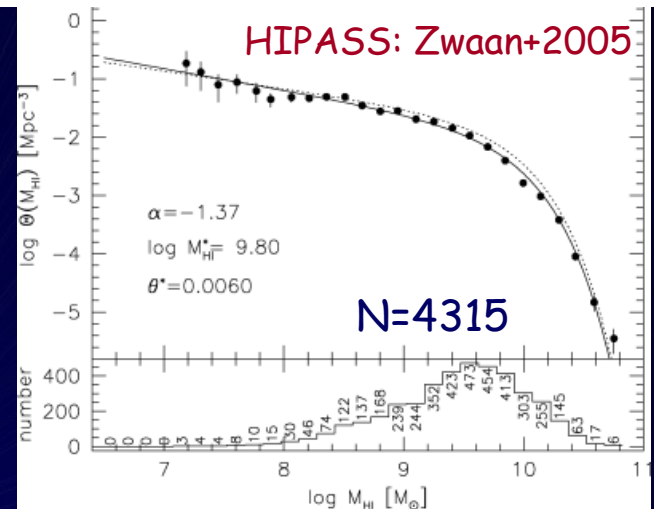
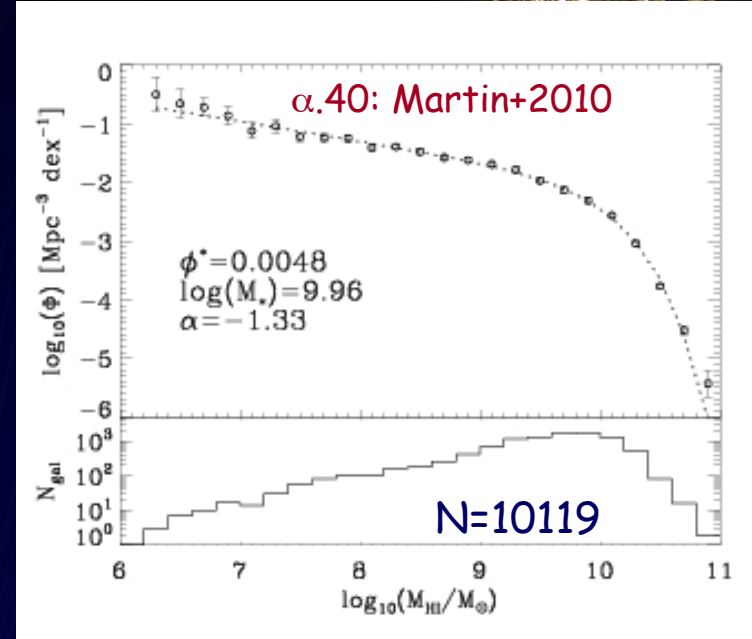
- Based on contiguous regions in Virgo vs anti-Virgo directions (35% of total)
- 10,119 Code 1 (“best”); $cz < 15,000$ km/s
- $\Omega_{\text{HI}} = 4.3 \pm 0.3 \times 10^{-4}$ (16% higher than HIPASS)

HIPASS: Zwaan+ 2005

- Did not sample low/high mass ends
- Issues of confusion
- Error bars are large!
⇒ Survey design must overcome cosmic variance and instrumental/selection bias

ALFALFA is the first blind HI survey to cover adequate volume at both the low and high HI mass ends

Ann Martin
PhD thesis

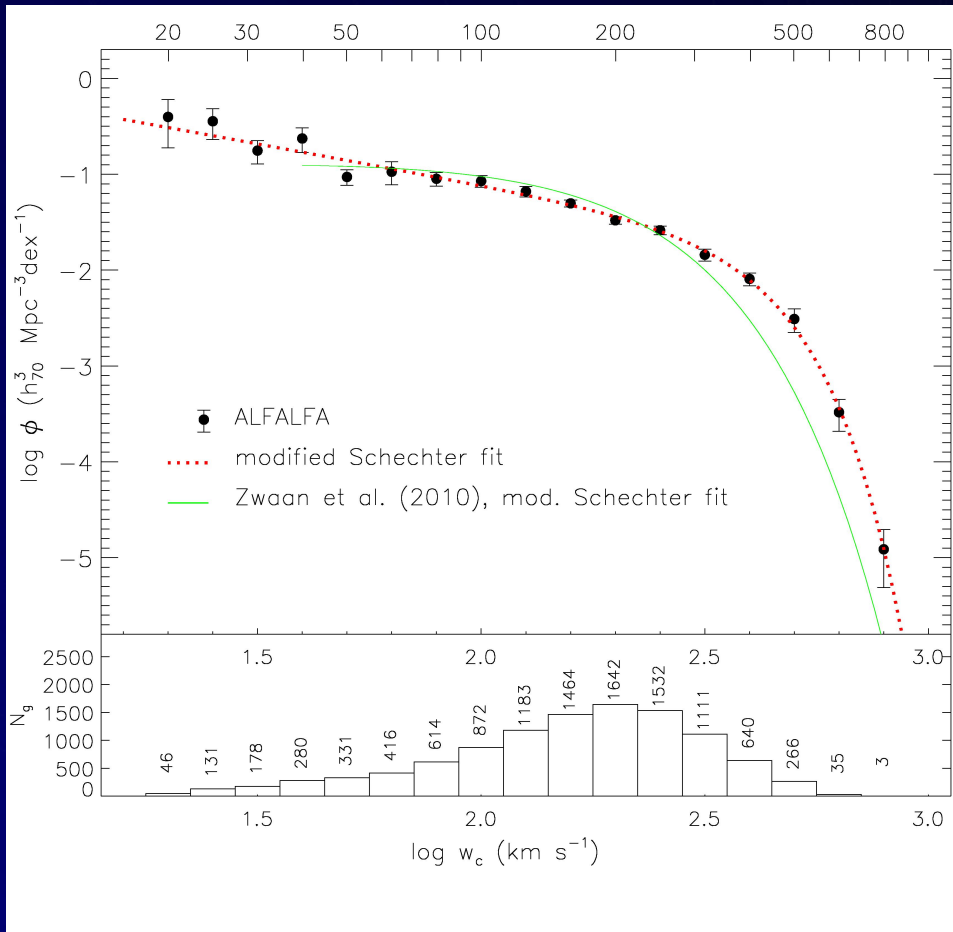


Testing galaxy formation models



Papastergis et al 2011, ApJ submitted

HIPASS also undercounted the massive (fast rotator) systems.

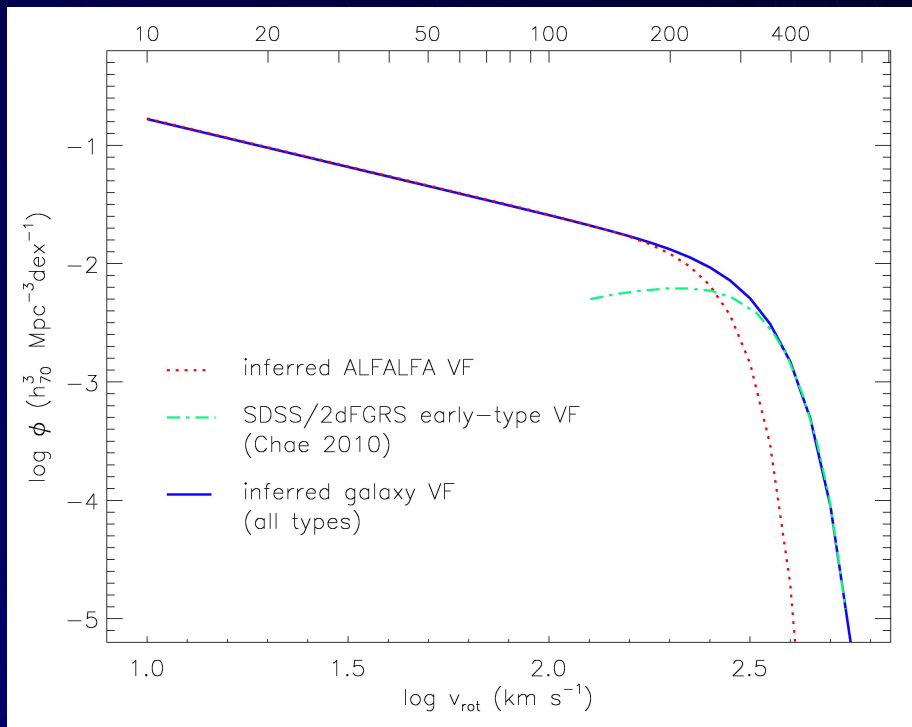


Manolis Papastergis
PhD thesis



ALFALFA

Testing galaxy formation models



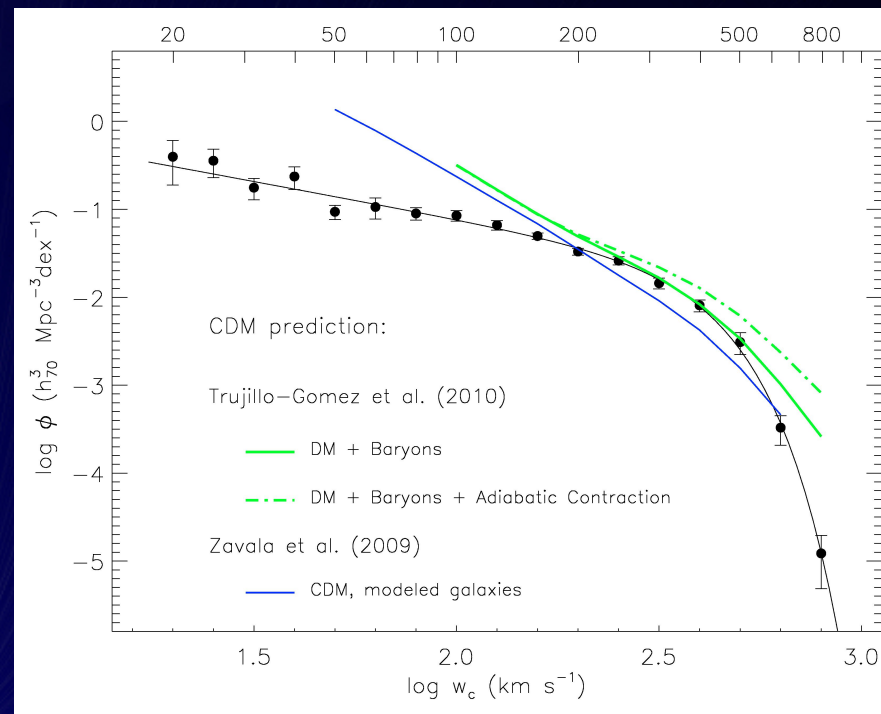
Papastergis et al 2011, ApJ submitted

HIPASS also undercounted the massive (fast rotator) systems.

ALFALFA VF maps nicely onto SDSS VF at moderate-high mass

But, still a large discrepancy with theory at low W

Does HI trace halo V_{rot} ?



Low HI mass dwarfs: on the brink of extinction?

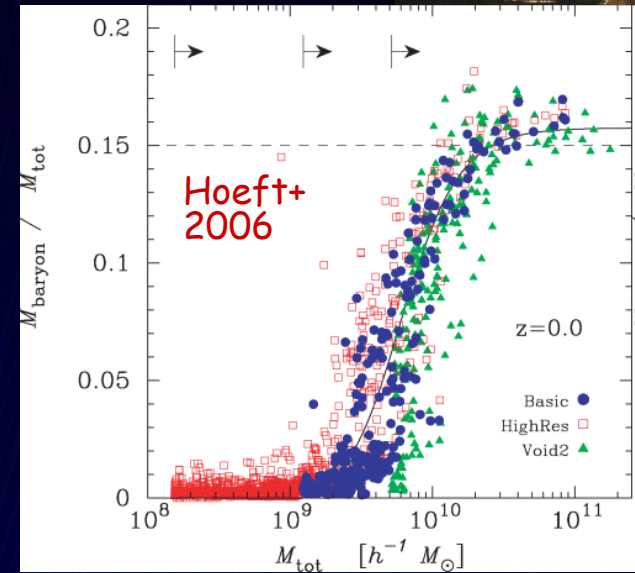


- FIGGS (Begum +): $\langle \log M_{\text{HI}} \rangle \sim 7.78$
- Little THINGS (Hunter +): $\langle \log M_{\text{HI}} \rangle \sim 7.97$
- Leo T: $\log M_{\text{HI}} = 5.44$

SHIELD:

EVLA BCD 2010-2011 \Rightarrow 180 hours

- John Cannon (PI); Betsey Adams (grad)
- 12 galaxies with $\langle \log M_{\text{HI}} \rangle \sim 6.7$
- Resolve HI \Rightarrow SF?
- Trace DM halo

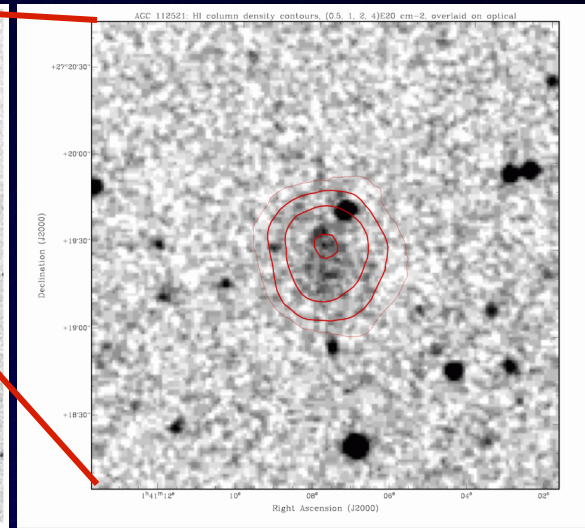
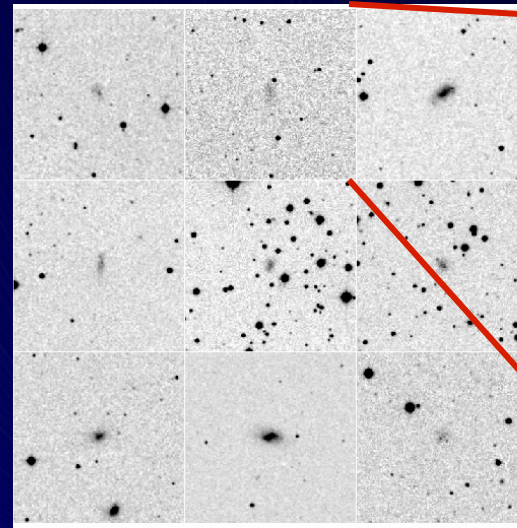


SHIELD

The Survey of HI in Extremely Low-mass Dwarfs
using the
Expanded Very Large Array (EVLA)

EVLA OSRO Program 10B-187

John M. Cannon (PI, Macalester College)
Betsey Adams, Riccardo Giovanelli, Martha Haynes (Cornell University)
Kristy McQuinn (University of Minnesota)
Jürgen Ott (National Radio Astronomy Observatory)
Amelia Santangelo (Max-Planck-Institute for Extraterrestrial Physics)
John J. Salzer (Indiana University)
Evan D. Skillman (University of Minnesota)



ALFALFA UltraCompact HVCs: LG Minihalos?



Leo T as nearby prototype: outside MW virial radius

We have found a subset of the HVC phenomenon that appears to be compatible with the LG minihalo hypothesis.

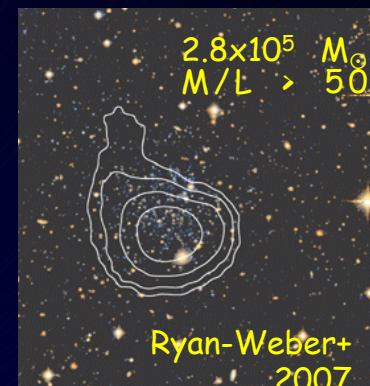
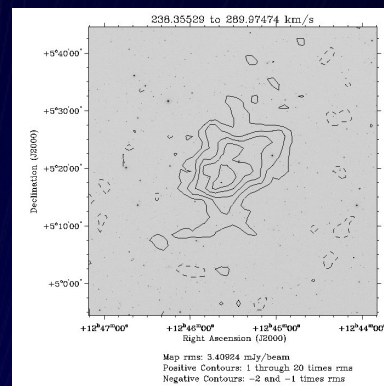
⇒ ****much** smaller** than the Blitz et al. and Braun&Burton CHVCs

$M_{\text{HI}} \sim 3 \times 10^5 M_{\odot}$; size ~ 0.7 kpc

⇒ **Do not violate** astrophysical constraints (Sternberg+ 2002)

On-going work (Betsey Adams, RG, MH, Salzer)

- Optimize signal extraction algorithm ⇒ ALFALFA CHVC catalog
- HI mapping: HI distribution, dynamics
- Distances:
 - TRGB (resolved CMDs)
 - H α : ionized by galactic RF places lower limit



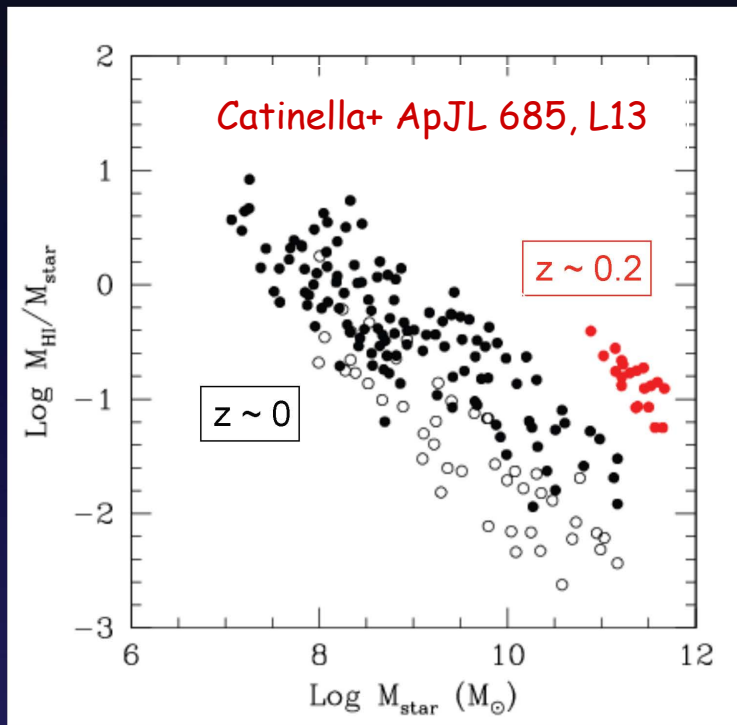
Other interpretations are possible; we have not proved that the candidates are LG minihalos, but that remains a tantalizing possibility.

Betsey Adams
PhD thesis



ALFALFA

HI Massive galaxies: HIghMass Survey



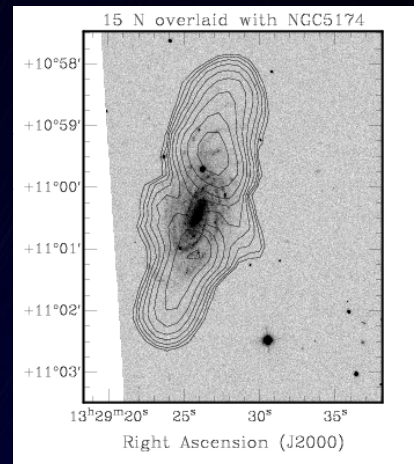
All massive HI disks have optical counterparts

Evolution effects?

Need fair sample of massive (HI, M_*), $z \sim 0$ galaxies for comparison!!

Circles: Goldmine + ALFALFA

Black: Virgo cluster (GOLDMINE + ALFALFA, Gavazzi et al. 2008, A&A submitted)



Chengalur+ GMRT

ALFALFA detects a significant population with $\log M_{\text{HI}} > 10.5$

- Candidates to migrate from BC to RS but not yet reached phase of significant SF?

=> Alternative mode of (late) accretion?

=> higher than average spin parameter?

Huang (PhD: GALEX),
Adams (PhD: GMRT/WSRT),
Hallenbeck (PhD:EVLA)



ALFALFA

ALFALFA: Volume + Sensitivity



- ALFALFA is the first blind HI survey to sample a cosmologically significant volume at $z=0$
 - Robust determination of HIMF at $z=0$
 - Work on $\zeta(r)$, VF and environmental variations on-going
- There are no “dark” HI galaxies with HI masses $> 10^9 M_{\odot}$
- ALFALFA sources provide the means to determine the baryon fraction as fn. of halo mass and test models of dropoff at $M_{\text{halo}} \sim 10^9 M_{\odot}$
- ALFALFA identifies a set of gas-rich Local Group “minihalo” candidates; evidence which will refute or confirm that hypothesis is being sought.
- ALFALFA detects a previously-unrecognized population of very high HI mass galaxies with HI masses $> 10^{10} M_{\odot}$; in some, cool gas contributes the dominant form of baryons. => Good news for SKA!
- There is more ALFALFA to be harvested!



ALFALFA



ALFALFA