The Extragalactic HI Sky

U-ALFALFA, Arecibo

Riccardo Giovanelli, Cornell
The Universe is Flat:

$$\Omega = 1$$

The current expansion rate is $H_0 = 70 \text{ km/s/Mpc}$
\[ \Omega_{\text{baryons}} = 0.045\pm0.004 \sim (1/6) \Omega_{\text{matter}} \]

Coronal + diffuse IG gas \(~0.037\)

Cluster IGM \(~0.002\)

Stars \(~0.003\)

Cold Gas \(~0.0008\) (~2/3 atomic)

Fukugita & Peebles 2004
HI: Why do we care?

- Easy to detect, optically thin ➔ cold gas mass
- Good index of SF fertility
- Excellent tracer of host dynamics
- Useful Cosmology tool
- Interaction/tidal/merger tracer
- Can be dominant baryon form in low mass galaxies
Van de Hulst & Oort make good use of wartime

1951: HI line first detected
1953: Hindman & Kerr detect HI in Magellanic Clouds

First 100 galaxies

1975: Roberts review
1977: Tully-Fisher

1980
Cluster deficiency, Synthesis maps,
DLA systems, interacting systems
Rotation Curves, DM,
Redshift Surveys

1990
Peculiar velocity surveys, deep mapping

2000
Multifeed systems: large-scale surveys
The Magellanic Stream
(Mathewson et al 1974)
Research Note

Comparison of Rotation Curves of Different Galaxy Types

M. S. Roberts* and A. H. Rots
Kapteyn Astronomical Institute, University of Groningen

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Summary. Rotation curves extending to large radial distances are now available for 3 spiral galaxies, each of a different type. Differences in shape of the rotation curves indicate a mass distribution that is related to structural type and is in the same sense as the luminosity distribution for these galaxies. The shapes of the rotation curves at large radii indicate a significant amount of matter at these large distances and imply that spiral galaxies are larger than found from photometric measurements.

Key words: galaxies – rotation curves
M31
Effelsberg data

Roberts, Whitehurst & Cram 1978
Fig. 4.—Fit of exponential disk with maximum mass and halo to observed rotation curve (dots with error bars). The scale length of the disk has been taken equal to that of the light distribution (60°, corresponding to 2.68 kpc). The halo curve is based on eq. (1), $a = 8.5$ kpc, $\gamma = 2.1, \rho(R_a) = 0.0040 M_\odot$ pc$^{-3}$. [Van Albada, Bahcall, Begeman & Sancisi 1985]
A page from Dr. Bosma’s Galactic Pathology Manual
The Faces of Virgo

Credit: Brian Kent

Credit: Amelie Saintonge
Dots: galaxies w/ measured HI
Contours: HI deficiency
Grey map: ROSAT 0.4–2.4 keV
A discovery in the ALFALFA data by Koopmann et al (2008)
NGC4532

DDO137

Hoffman et al 1993
AJ 106,39

Arecibo HI

Fig. 2. Contour maps of NGC 4532/DDO 137. The thick contours (and over all velocities) are for NGC 4532, and the thin ones (and over the North) are for DDO 137, and are drawn at -2, 7, 7.3, 12, and 18 in units of $10^{19}$ atoms.
Hoffman et al. 1999
AJ 117, 811

VLA HI imaging
N4532/DDO137 Stream

Koopmann et al. 2008

...500 kpc long stream!!
From L. van Zee's gallery of Pathetic Galaxies (BCDs)

Figure 1. The Blue Compact Dwarf UGC 5288.
- HI: VLA OS-array, 20.2' x 16.9' resolution, contours=8 x 10^19 cm^-2 x 2
- Optical: 2dF. Bottom: KPNO 0.9m B-band. FOV=10'.
- References: van Zee & Haynes, these proceedings, p. TT.

Figure 1. The Blue Compact Dwarf II Zw 40.
- HI: VLA B+C+OS-array, 17'x 15' resolution, contours=8 x 10^19 cm^-2 x 2
- Optical: KPNO 0.9m B-band, FOV=8' x 6'.
First detection of HI at Cosmological distance

Brown & Roberts 1973

Roberts et al. 1976
Discovery of filamentary Large Scale Structure...
SCI: cluster Sc sample
I band, 24 clusters, 782 galaxies
(Giovanelli et al. 1997a)

"Direct" slope is -7.6
"Inverse" slope is -7.8
A TF template relation is derived independently on the value of H\(_{\text{not}}\). It can be derived for, or averaged over, a large number of galaxies, regions or environments. When calibrators are included, the Hubble constant can be gauged over the volume sampled by the template.

From a selected sample of Cepheid Calibrators, Giovanelli et al. (1997b) obtained $H_{\text{not}} = 69 \pm 6$ (km/s)/Mpc averaged over a volume of $cz = 9500$ km/s radius.
CMB Dipole

$\Delta T = 3.358 \text{ mK}$

$V_{\text{sun}} \text{ w.r.t CMB:}$

369 km/s towards $l=264^\circ$, $b=+48^\circ$

Motion of the Local Group:

$V = 627 \text{ km/s towards}$

$l = 276^\circ$, $b = +30^\circ$
The Dipole of the Peculiar Velocity Field

The reflex motion of the LG, w.r.t. field galaxies in shells of progressively increasing radius, shows:
convergence with the CMB dipole, both in amplitude and direction, near $cz \sim 5000$ km/s.

(Giovanelli et al. 1998)
Previous surveys have included few (if any) objects with HI masses less than $10^8 \, M_\odot$. 

Parkes HIPASS survey: 
Zwaan et al. 2006
The Zwaan et al. 2003 HIMF, based on HIPASS, includes 12 galaxies with
\[ \log M_{\text{HI}} < 7.5 \]
With <1/4 of ALFALFA processed, we have 141
...likewise on the bright end
Low mass systems are only visible in the very local Universe. Even if abundant, we only detect a few.
 HIPASS Completeness Limit

HIPASS Limit

21238 HI sources cataloged so far

69% of ALFALFA detections are new (the conventional wisdom on which optical targets would turn out to be HI-rich appears to have been limited)

Unlike previous surveys, ALFALFA delivers a cosmologically fair sample
http://egg.astro.cornell.edu/alfalfa

For participation guidelines, see:

http://egg.astro.cornell.edu/alfalfa/joining.php