The Extragalactic HI Sky

U-ALFALFA, Arecibo

Riccardo Giovanelli, Cornell

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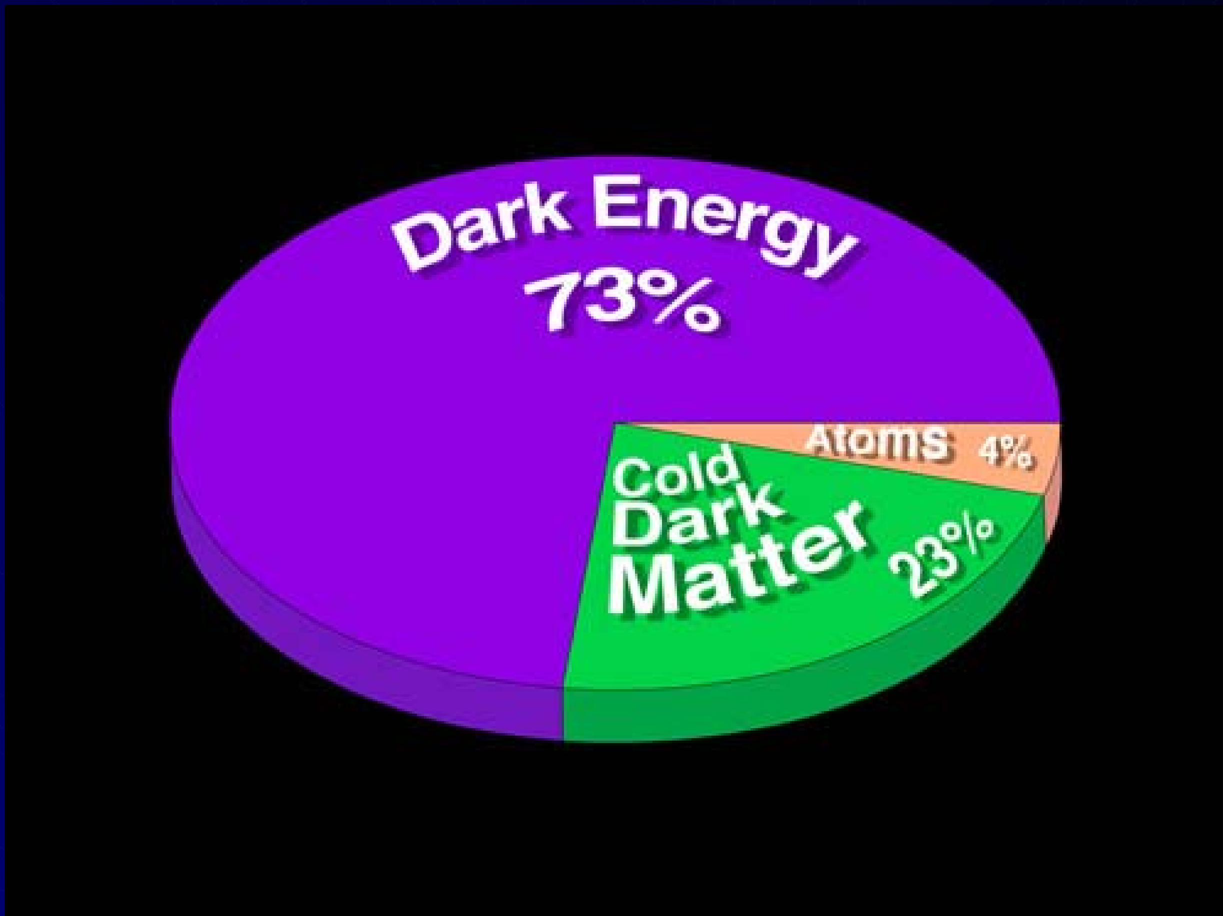
WMAP



The Universe is Flat:

$\Omega = 1$

The current expansion rate is $H_o = 70$ km/s/Mpc

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$\Omega_{baryons}$ = 0.045+/-0.004 ~ (1/6) Ω_{matter}

Coronal + diffuse IG gas~0.037

Stars ~ 0.003

Cluster IGM~0.002

HI is piffling fraction of
cosmic matter, baryons

Cold Gas ~ 0.0008 (~2/3 atomic)

Fukugita & Peebles 2004

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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*

1940

Van de Hulst & Oort make good use of wartime

1950

1951: HI line first detected

1953: Hindman & Kerr detect HI in Magellanic Clouds

1960

Green Bank
Nancay
Effelsberg
Parkes, J.Bank

First 100 galaxies

1970

VLA and WSRT come on line
Arecibo upgraded to L band;
broad-band correlators, LNRs

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

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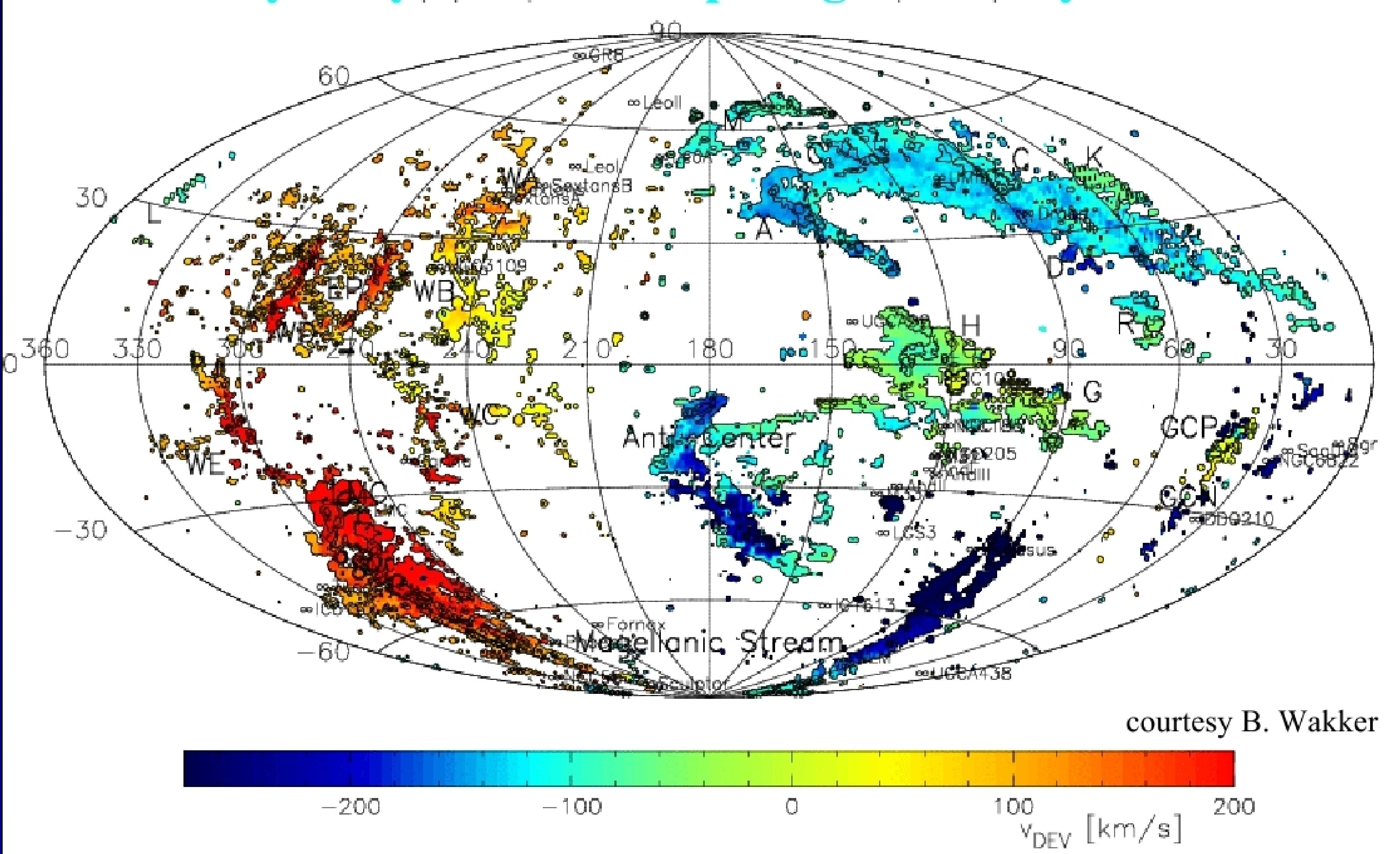
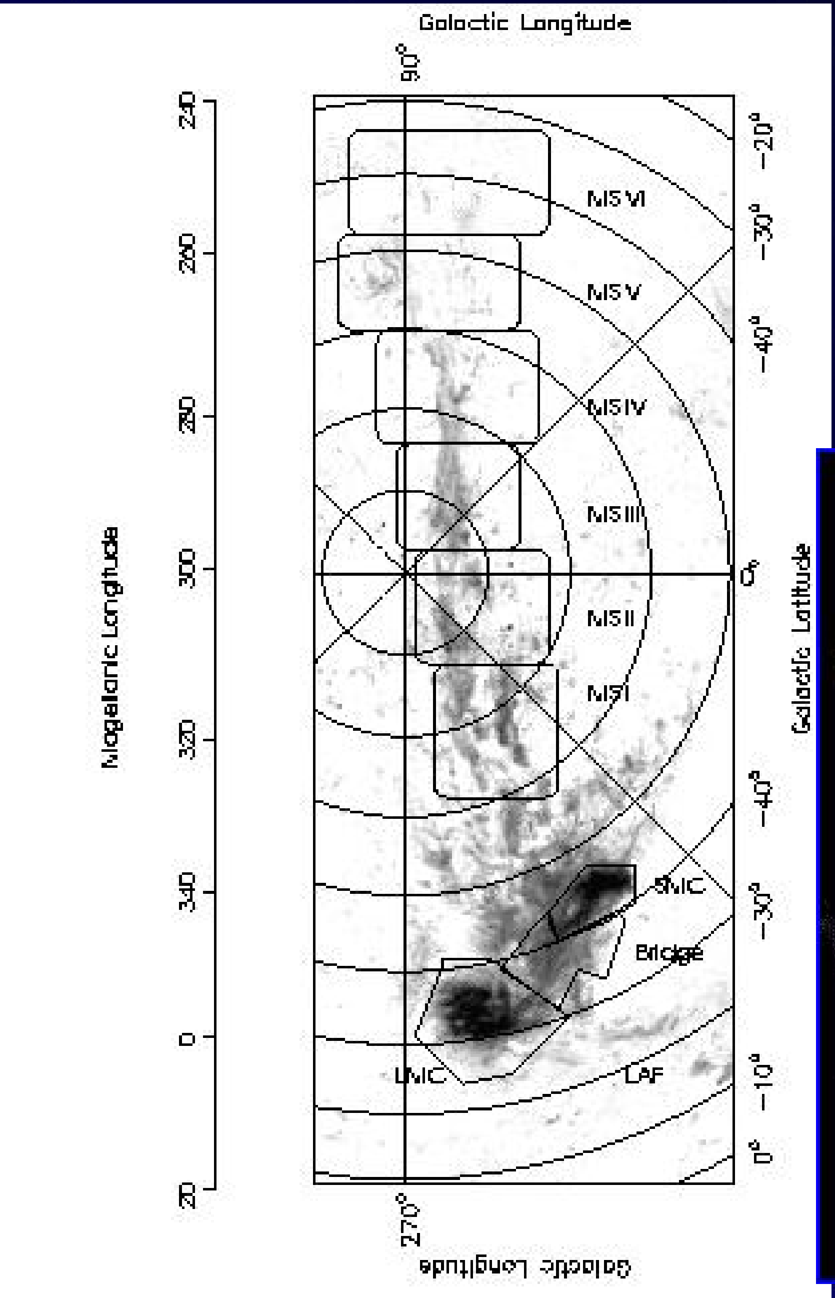
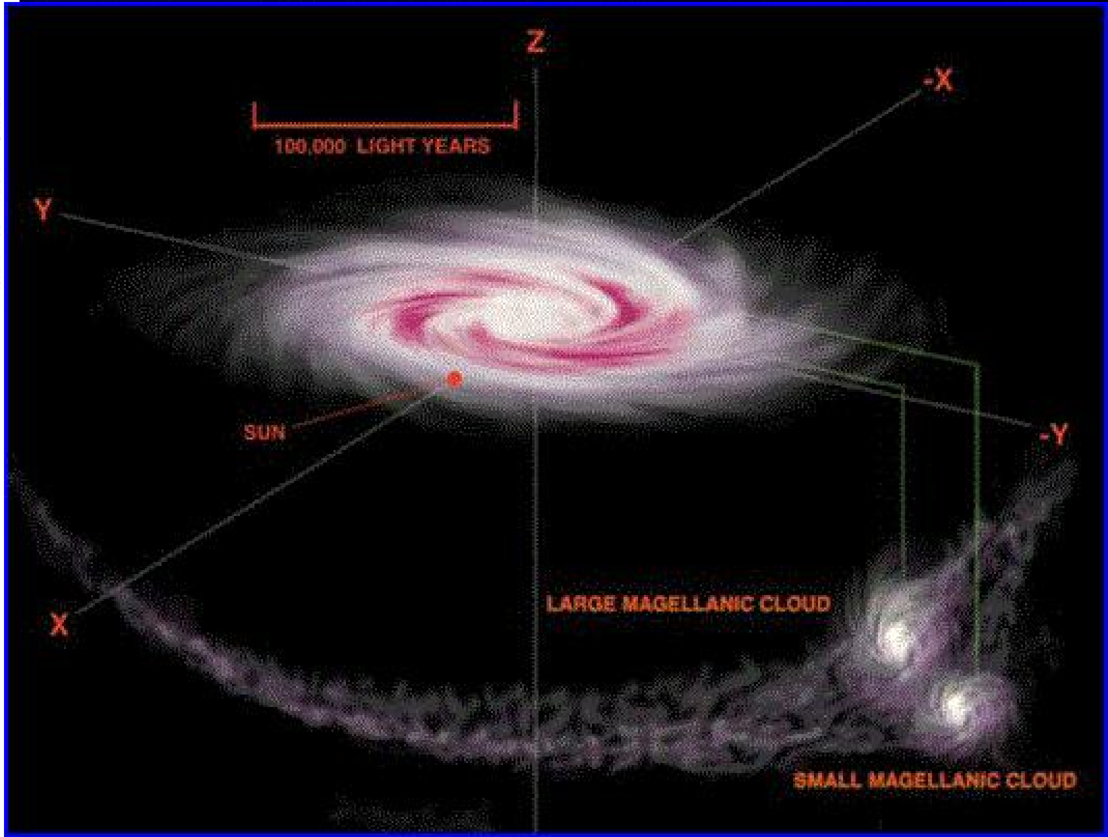


courtesy B. Wakker

The Magellanic Stream (Mathewson et al 1974)





Astron. & Astrophys. 26, 483 – 48[illegible] (1973)

Research Note

Comparison of Rotation Curves of Different Galaxy Types

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

Received November 23, 1972, revised April 13, 1973

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

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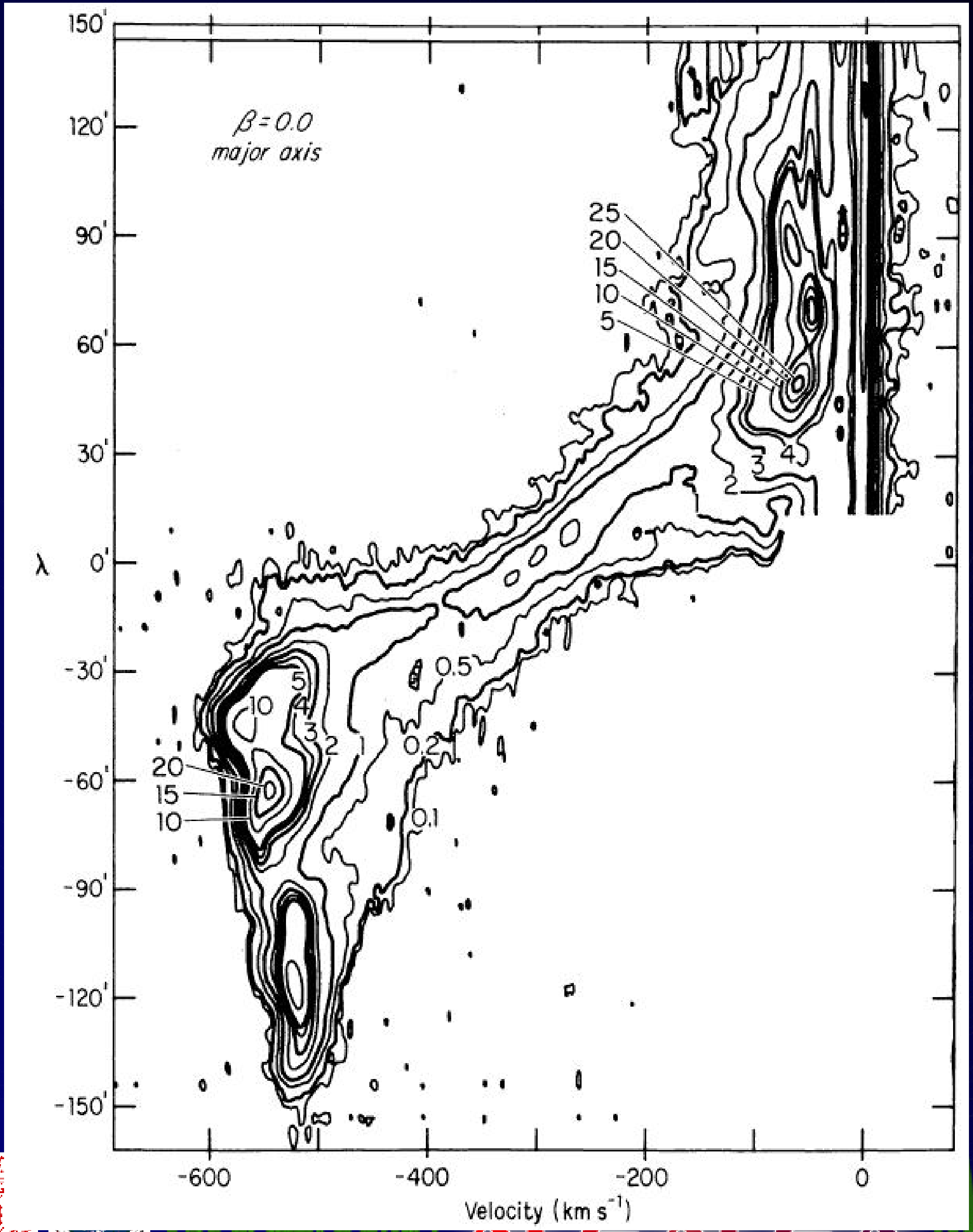
M31
Effelsberg data



Roberts, Whitehurst & Cram 1978

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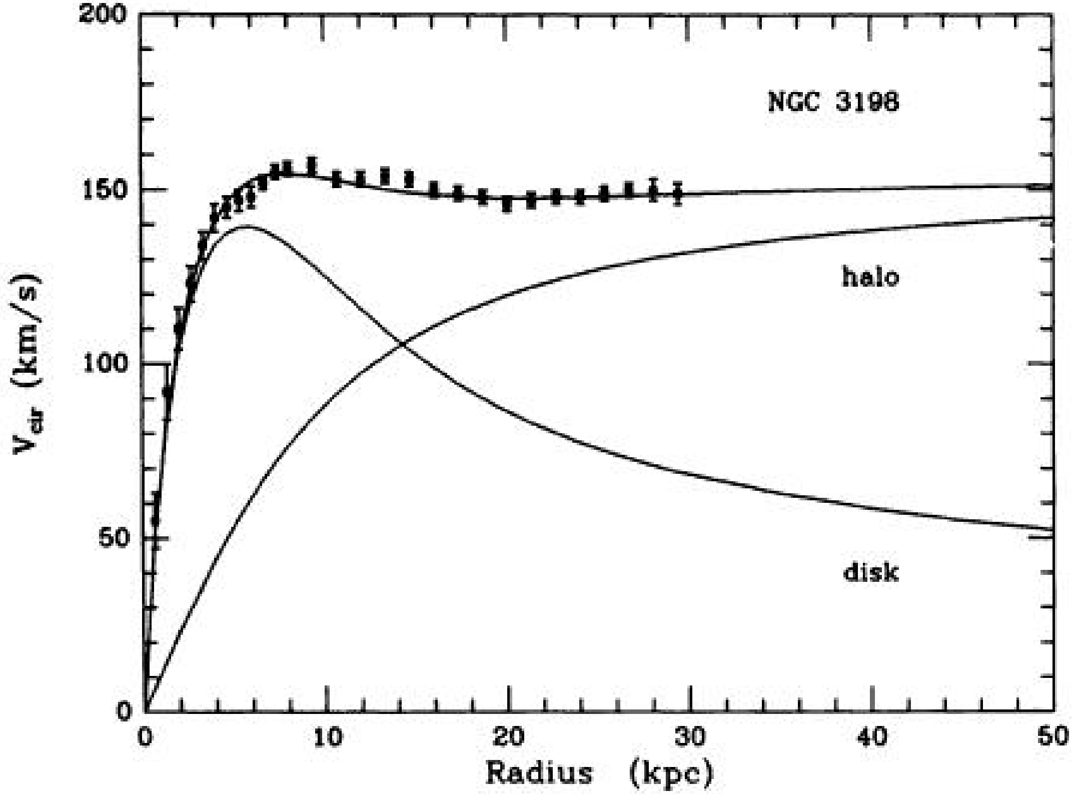

Fig. 4.—Fit of exponential disk with maximum mass and halo to observed rotation curve (*dots with error bars*). The scale length of the disk has been taken equal to that of the light distribution (60″, corresponding to 2.68 kpc). The halo curve is based on eq. (1), $a = 8.5$ kpc, $\gamma = 2.1$, $\rho(R_0) = 0.0040\ M_\odot\ \mathrm{pc}^{-3}$.

[Van Albada, Bahcall, Begeman & Sancisi 1985]

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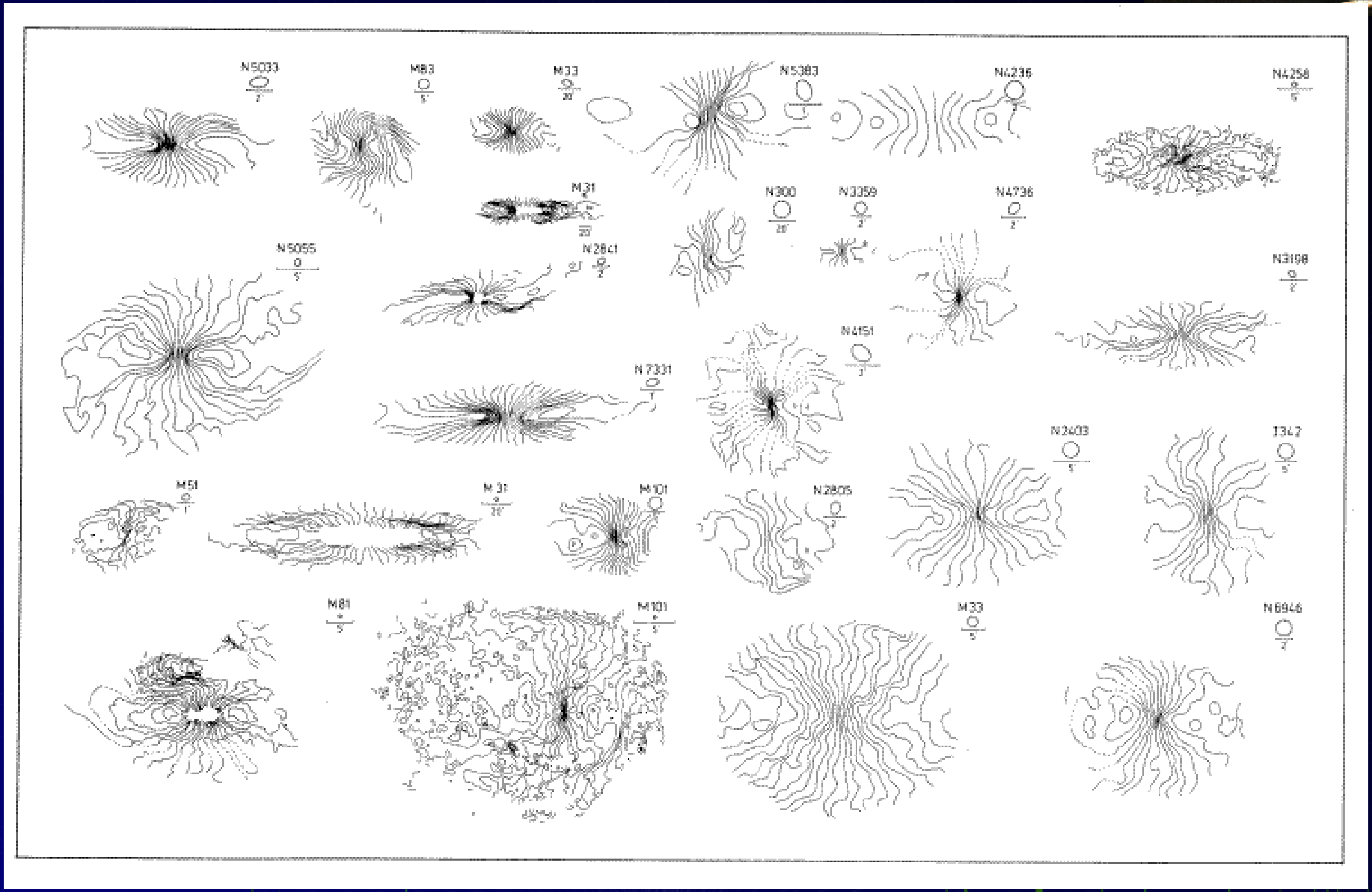
A page from Dr. Bosma's Galactic Pathology Manual



[Bosma 1981]

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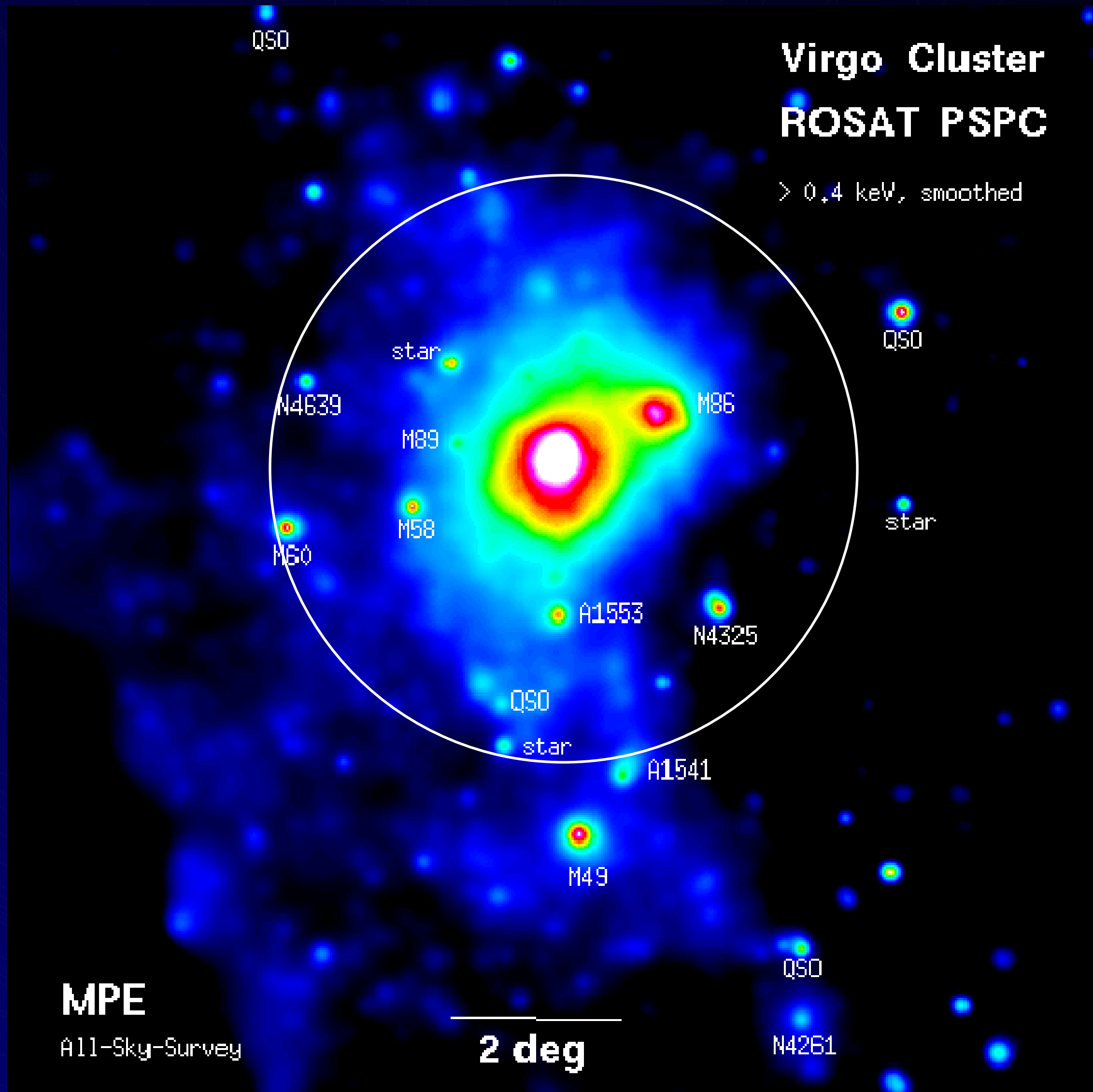
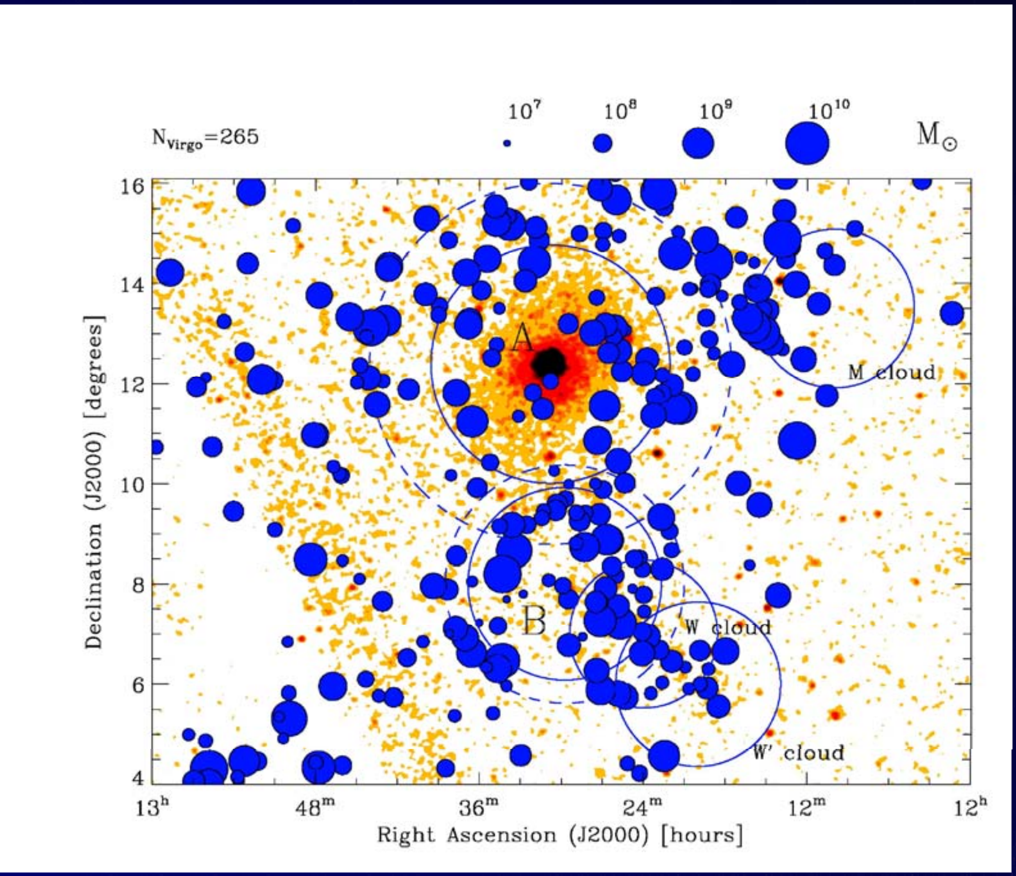
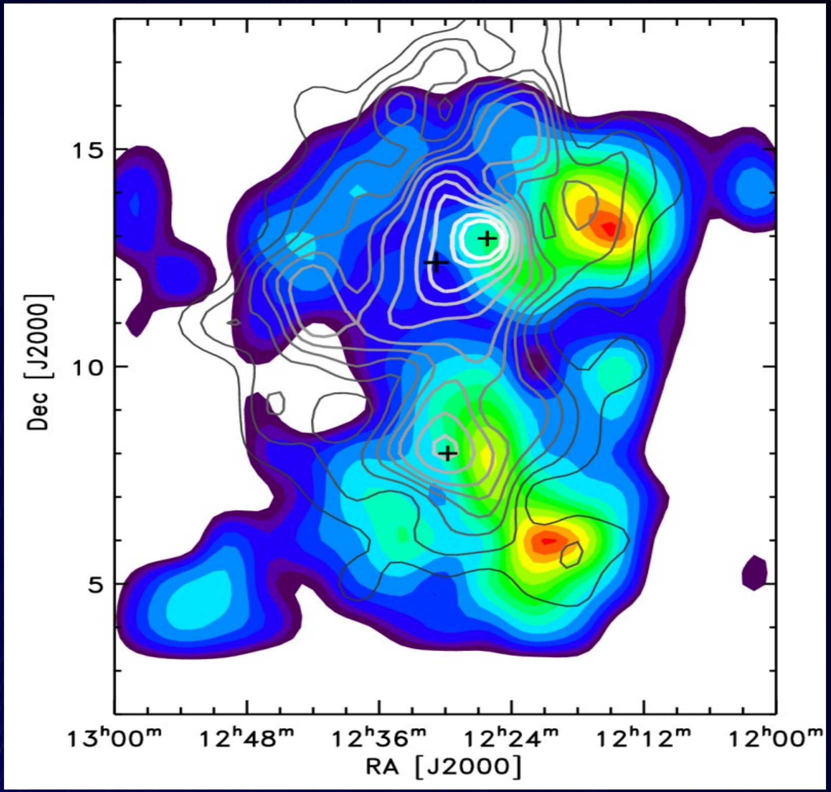


Virgo Cluster
ROSAT PSPC
> 0.4 keV, smoothed
QSO
QSO
star
N4639
M89
M86
M58
M60
star
A1553
N4325
QSO
star
A1541
M49
QSO
MPE
All-Sky-Survey
2 deg
N4261

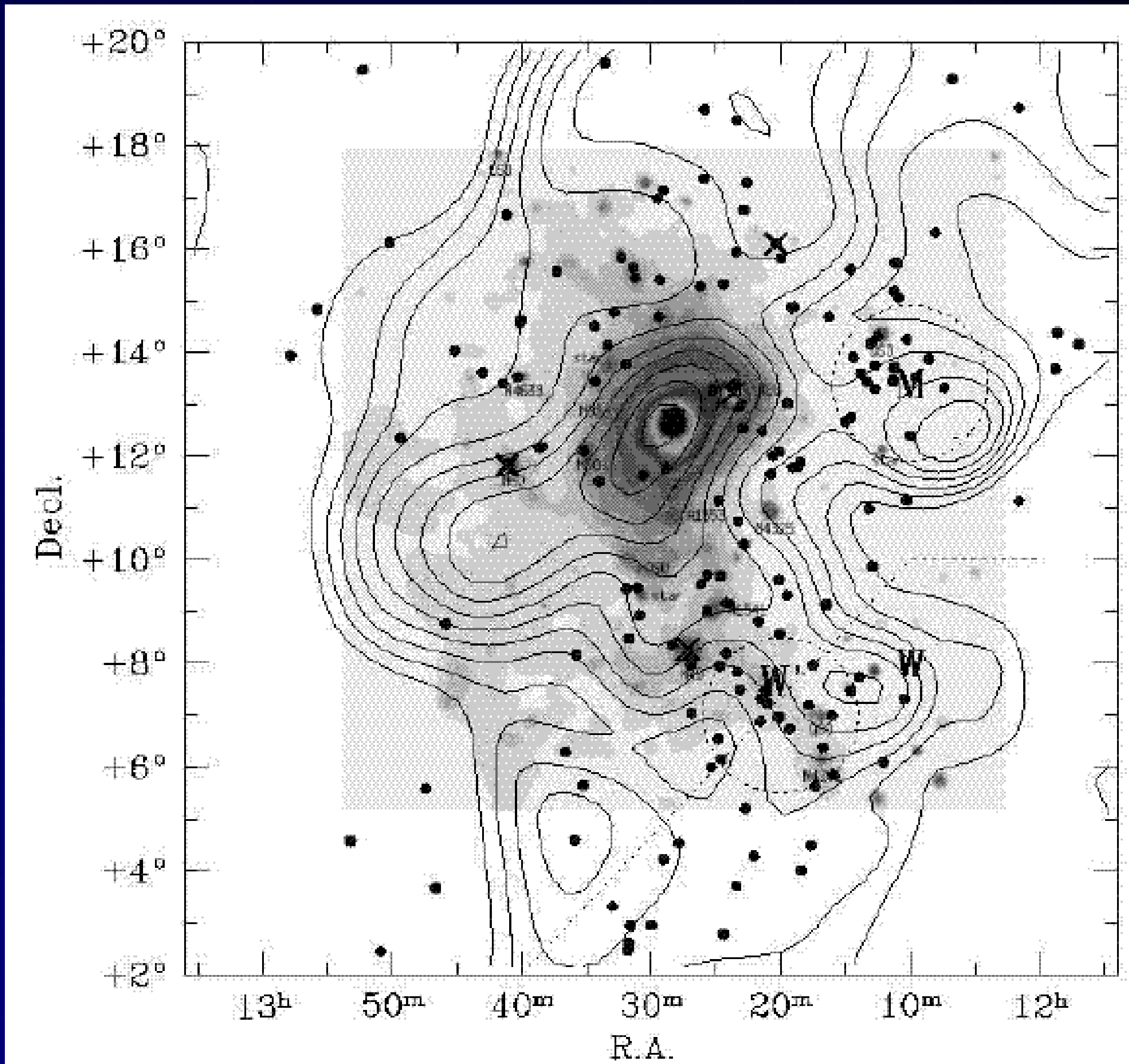
The Faces of Virgo



Credit: Brian Kent



Credit: Amelie Saintonge



VIRGO Cluster

HI Deficiency

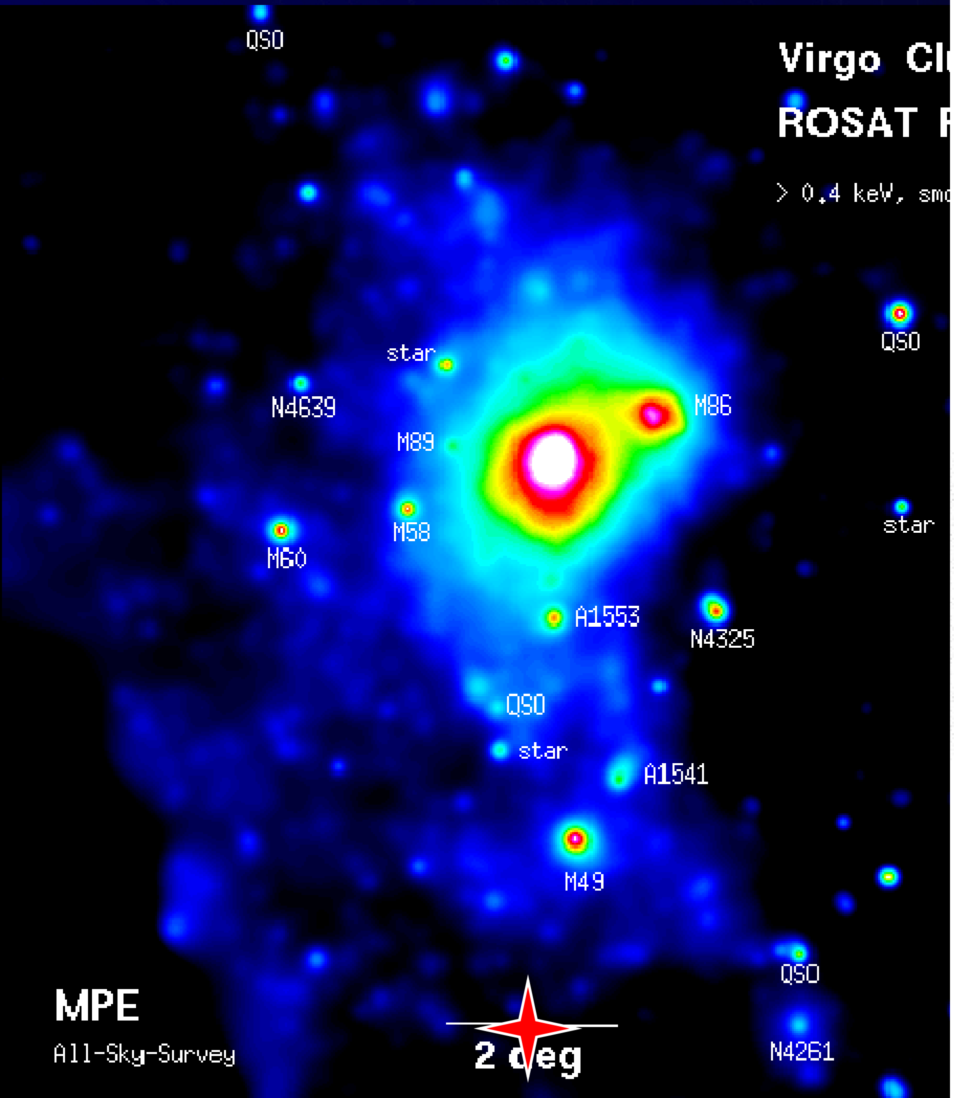
Dots: galaxies w/ measured HI

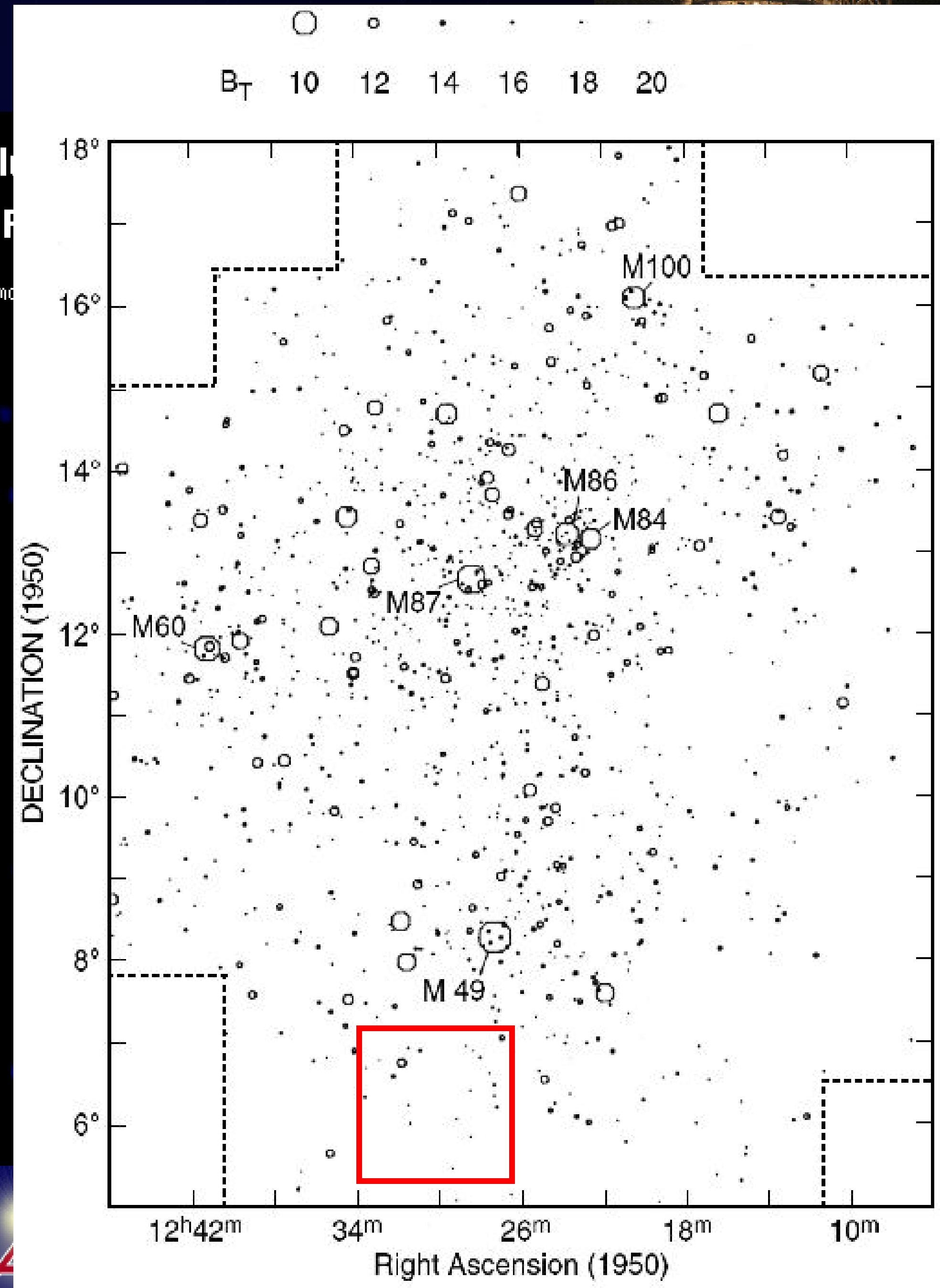
Contours: HI deficiency

Grey map: ROSAT 0.4-2.4 keV

Solanes et al. 2002

A discovery in the ALFALFA data by Koopmann et al (2008)



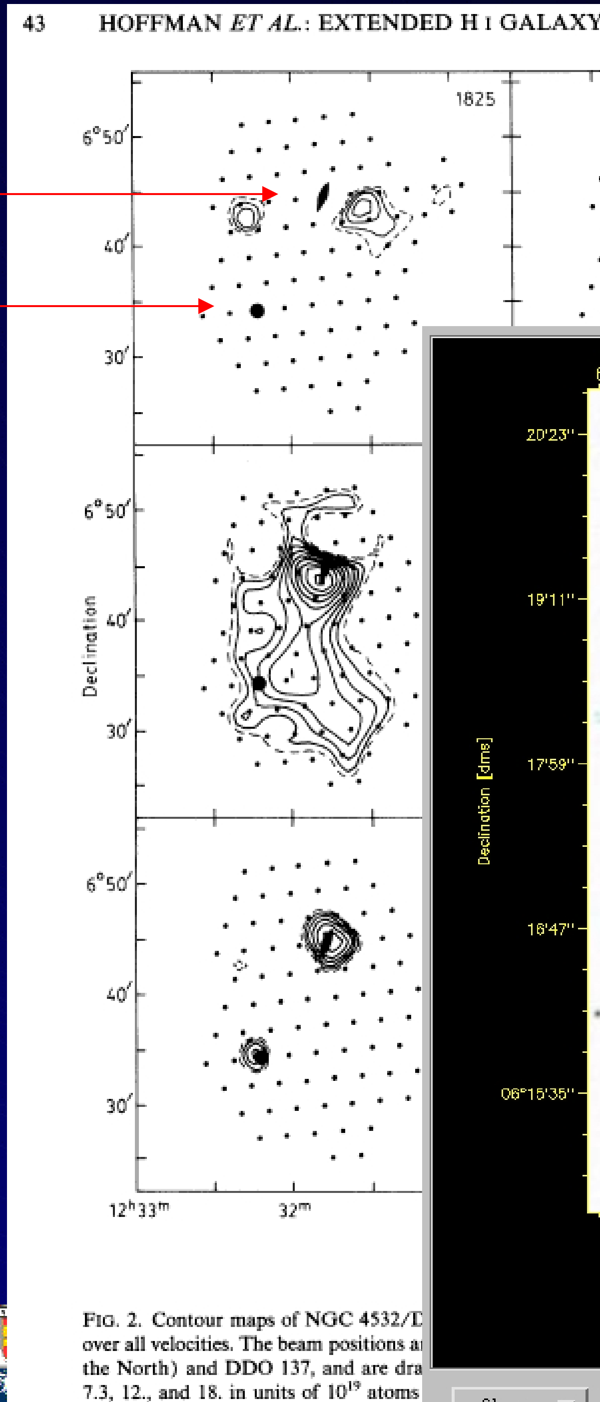


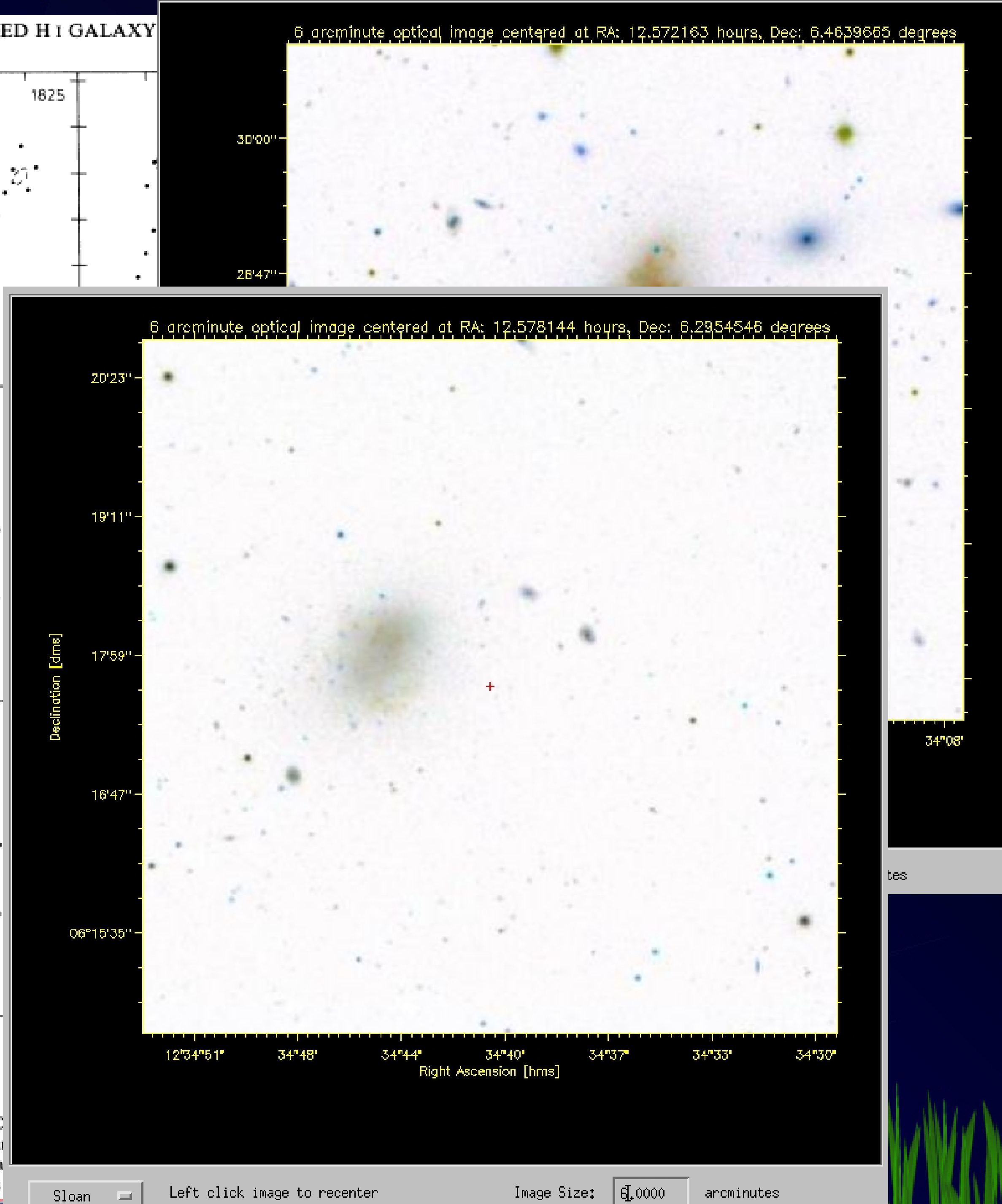
NGC4532

DDO137

Hoffman et al 1993 AJ 106,39

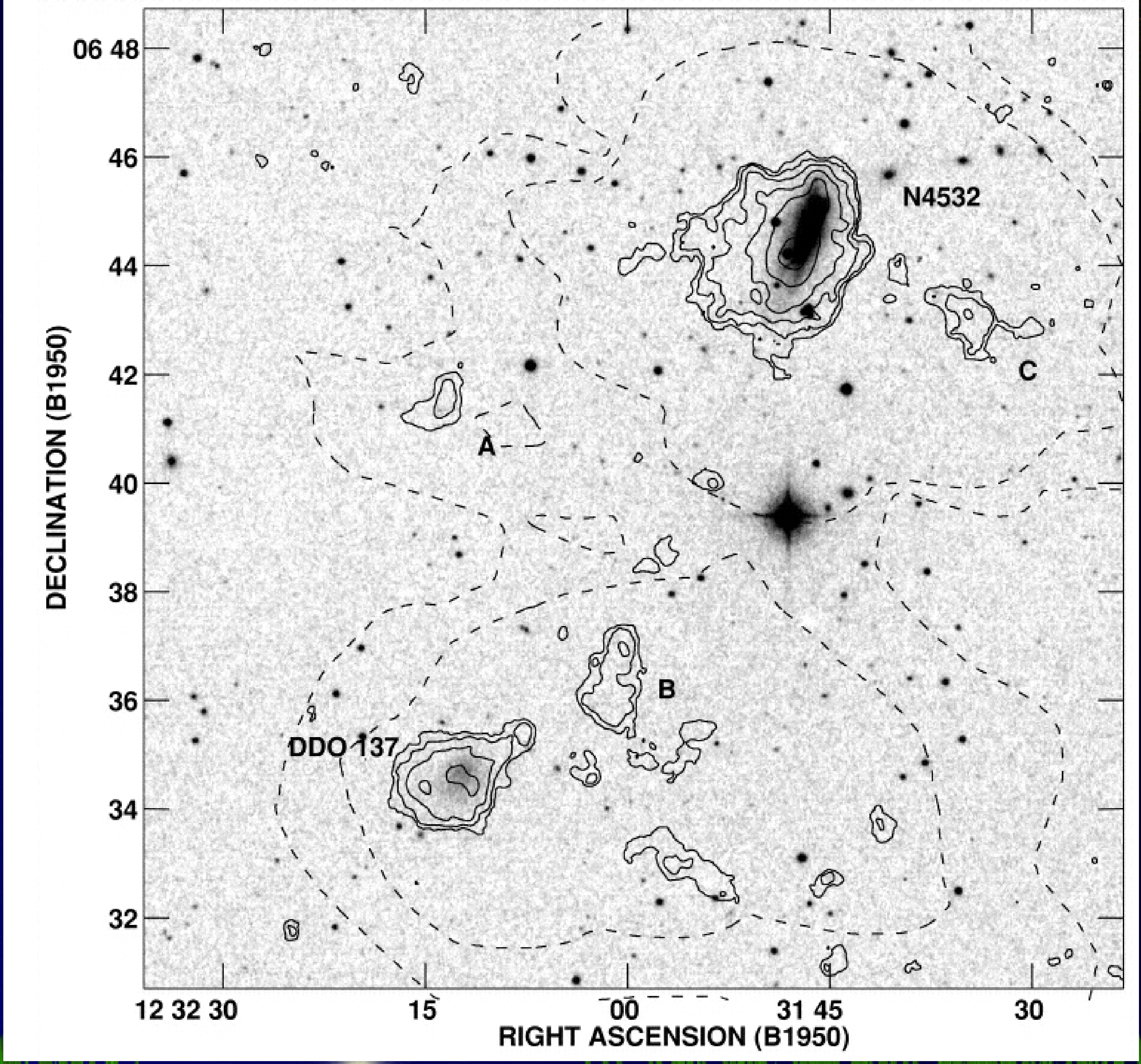
Arecibo HI





Hoffman et al. 1999
AJ 117, 811

VLA HI imaging



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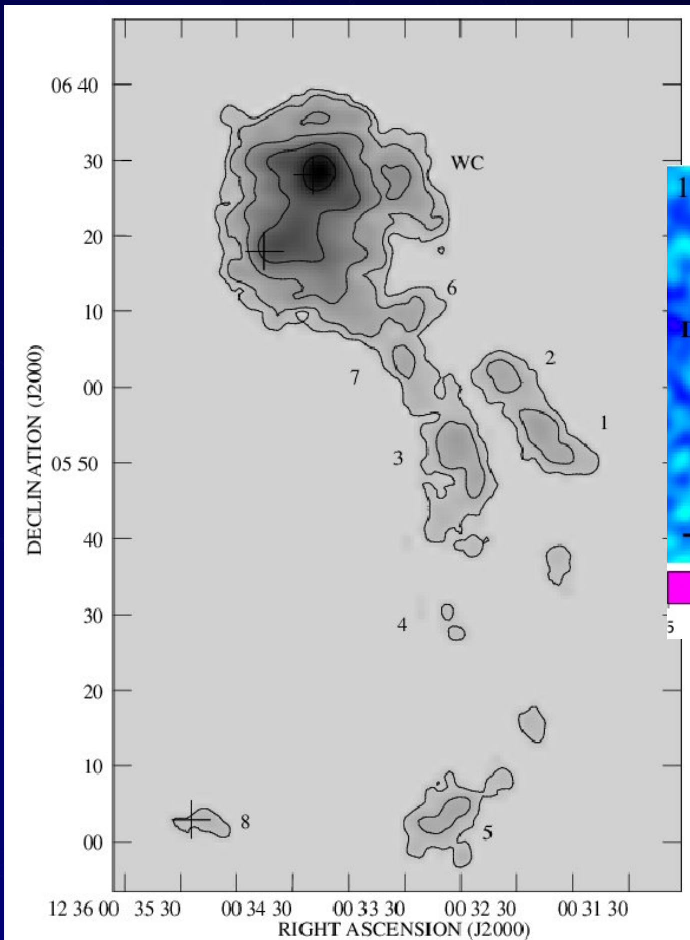
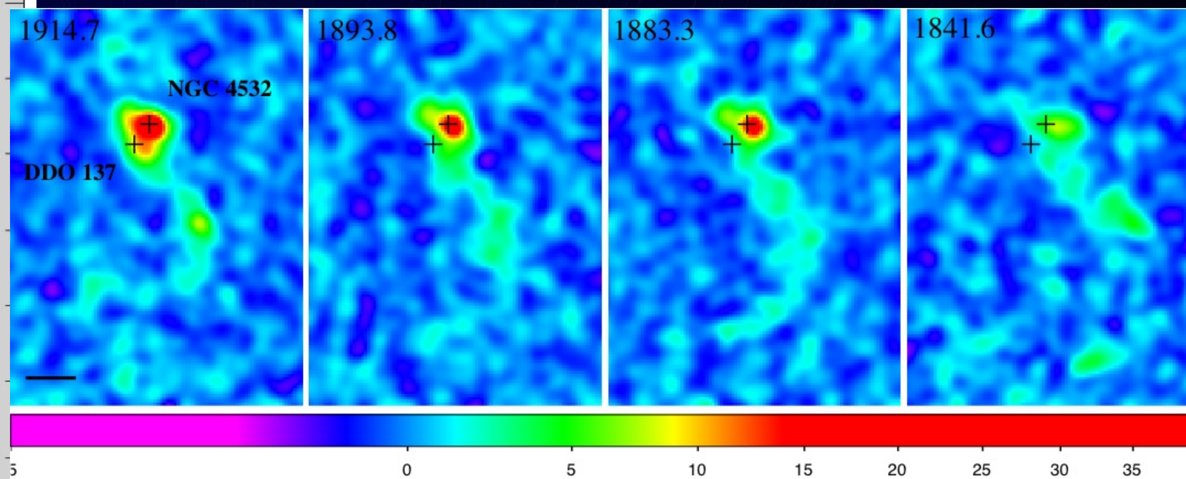
N4532/DDO137 Stream





Koopmann et al. 2008

…500 kpc long stream!!

From L. van Zee's gallery of Pathetic Galaxies (BCDs)

A maps

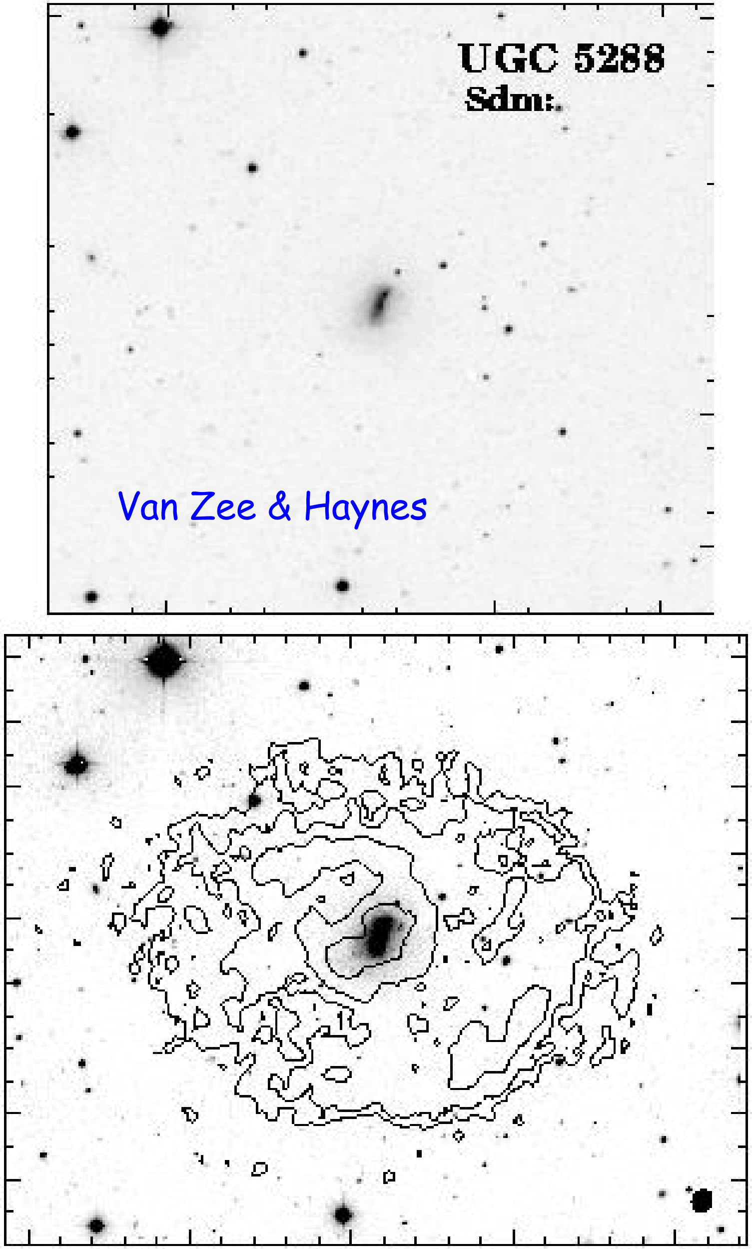


Figure 1. **The Blue Compact Dwarf UGC 5288.**
HI: VLA CS-array, 20.2″ × 16.9″ resolution, contours=8×10^{19} cm^{-2} × 2
Optical: Top: DSS. Bottom: KPNO 0.9m *B*-band. FOV=10′.
Reference: van Zee & Haynes, these proceedings, p. 77.

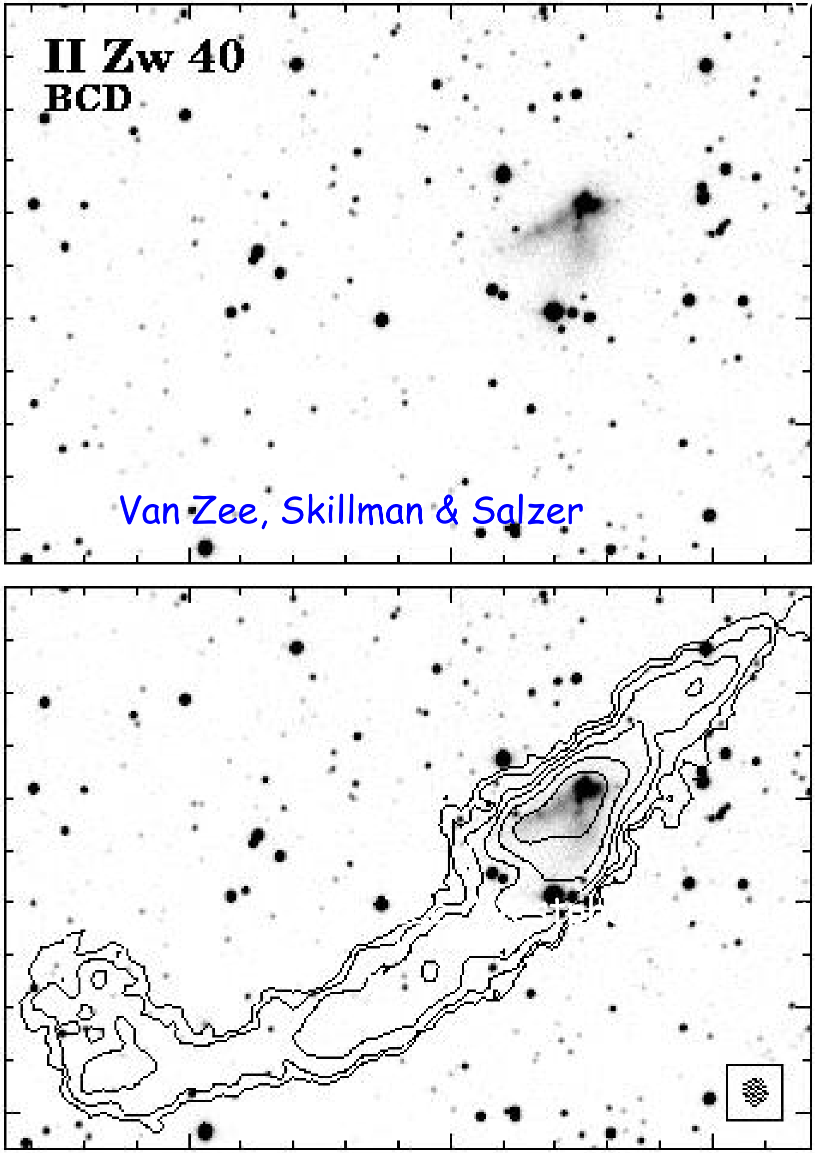
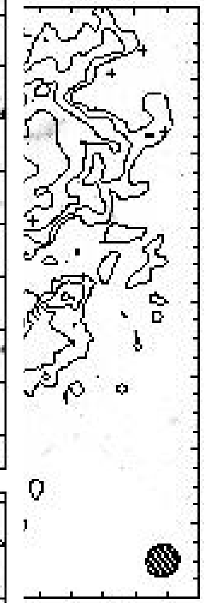


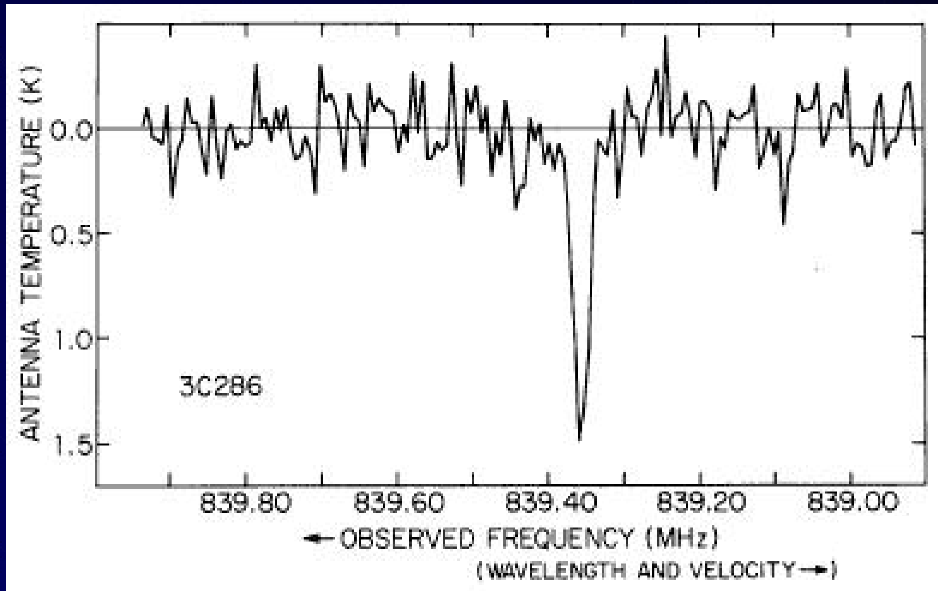
Figure 1. **The Blue Compact Dwarf II Zw 40.**
HI: VLA B+C+CS-array, 17″ × 15″ resolution, contours=8×10^{19} cm^{-2} $\times 2^n$.
Optical: KPNO 0.9m *R*-band, FOV=8′ × 6′.
Reference: van Zee, L., Skillman, E. D., & Salzer, J. J. 1998, AJ, 116, 1186.



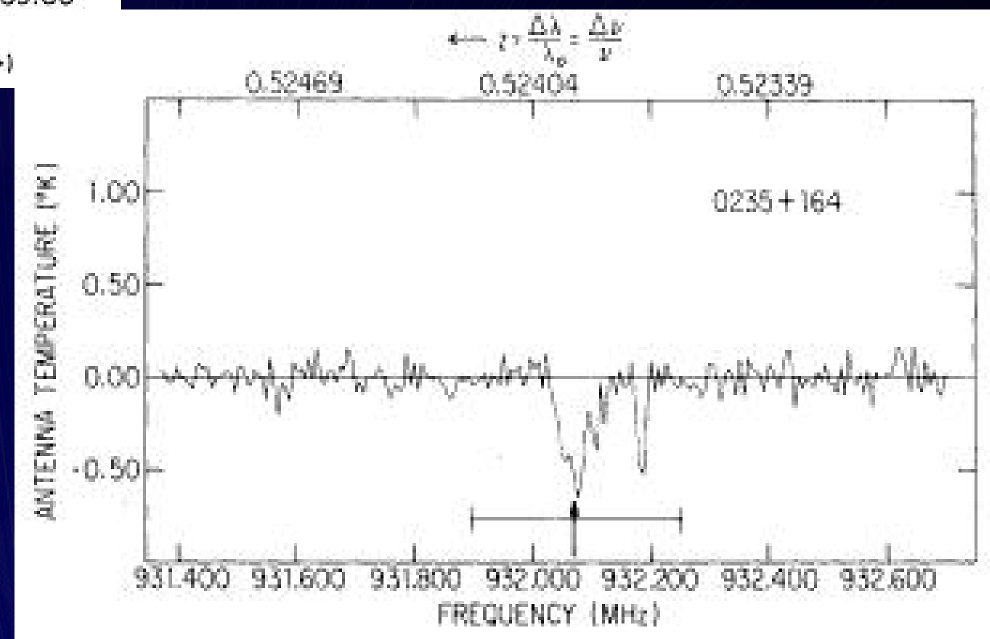
^{19} cm^{-2} $\times 2^n$.

AJ, 115, 1000.

First detection of HI at Cosmological distance



Brown & Roberts 1973



Roberts et al. 1976

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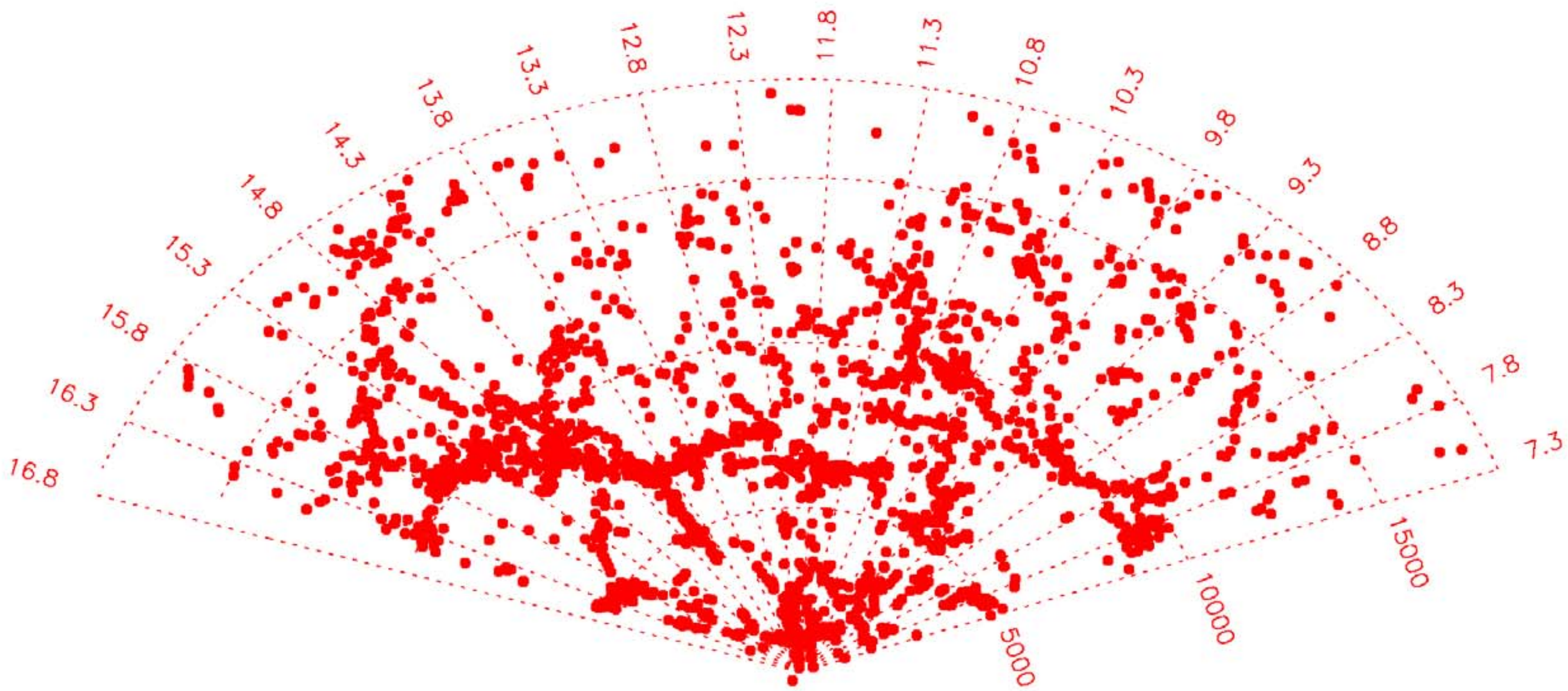
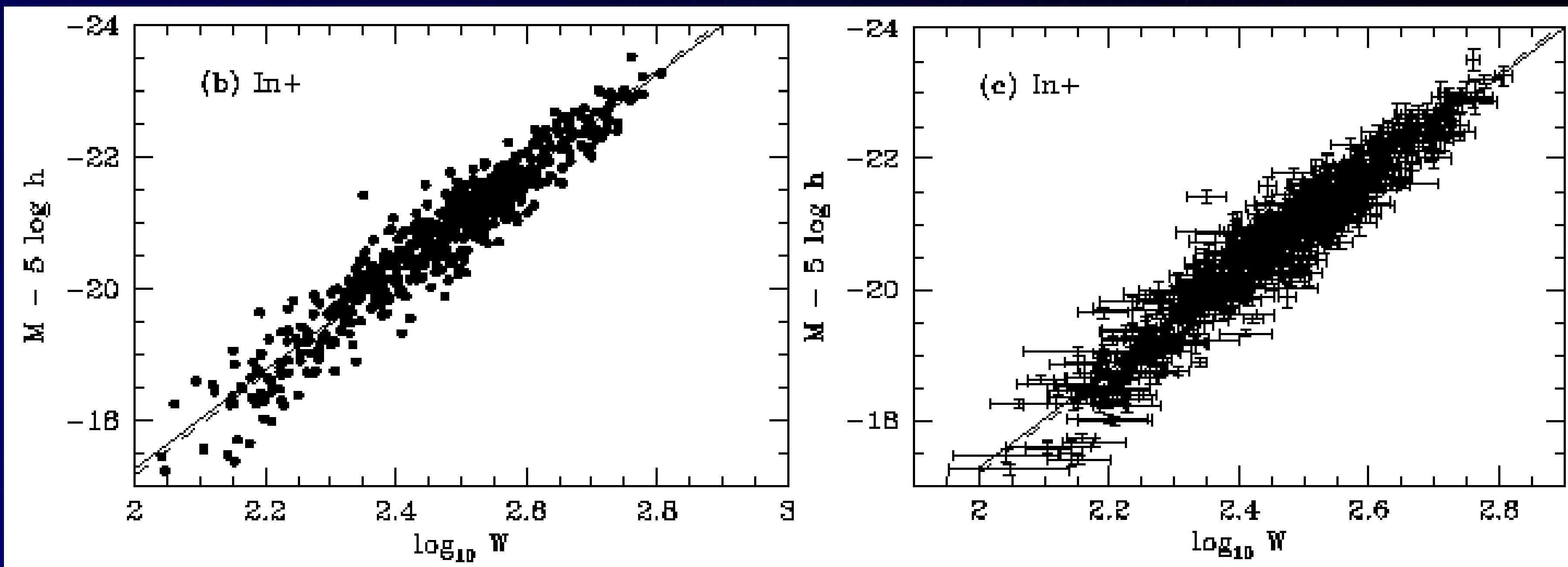
Discovery of filamentary Large Scale Structure…



TF Relation Template



"Direct" slope is −7.6
"Inverse" slope is −7.8

SCI : cluster Sc sample

I band, 24 clusters, 782 galaxies
(Giovanelli et al. 1997a)

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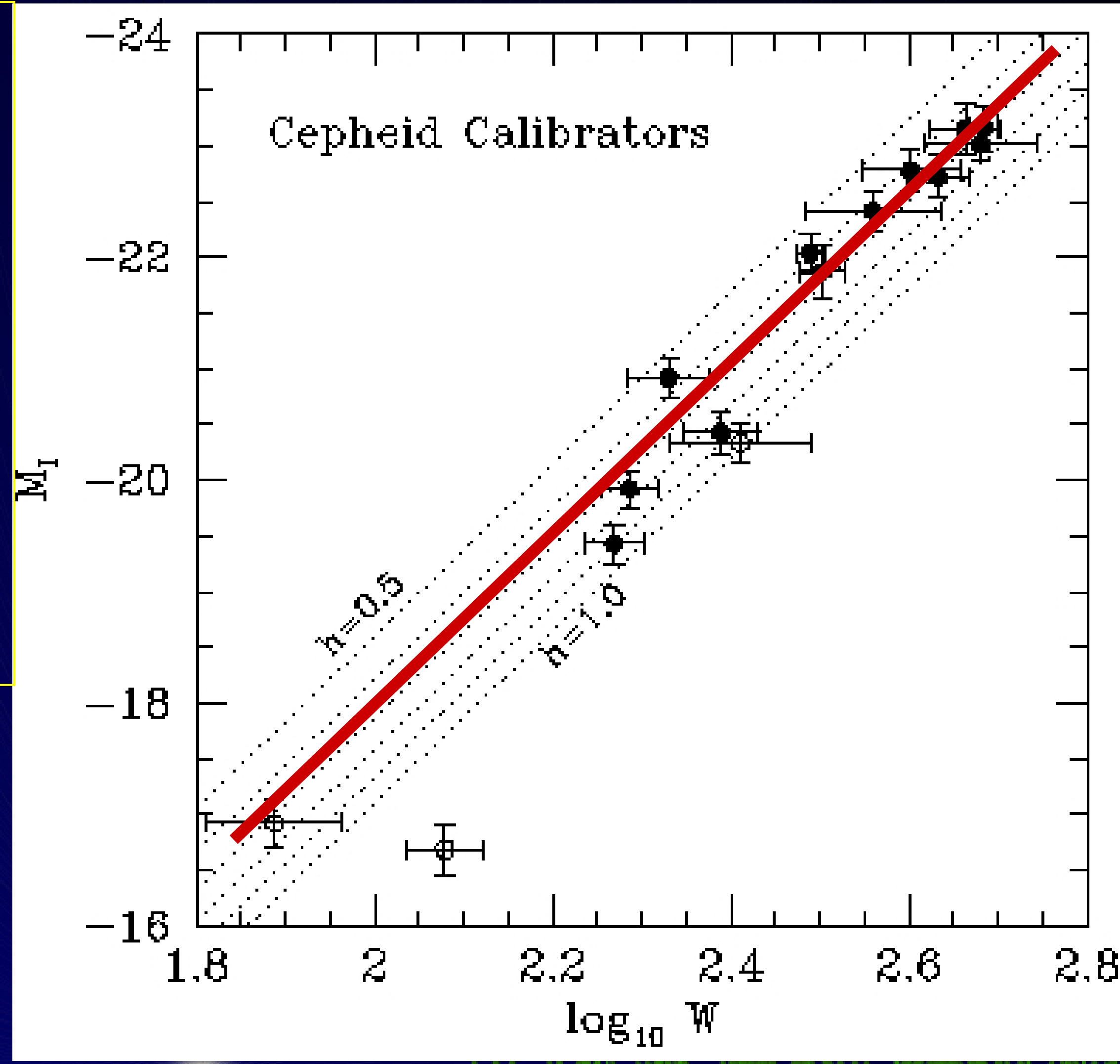
Measuring the Hubble Constant

A TF template relation is derived independently on the value of H_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_not = 69+/-6 (km/s)/Mpc
averaged over a volume of
cz = 9500 km/s radius.



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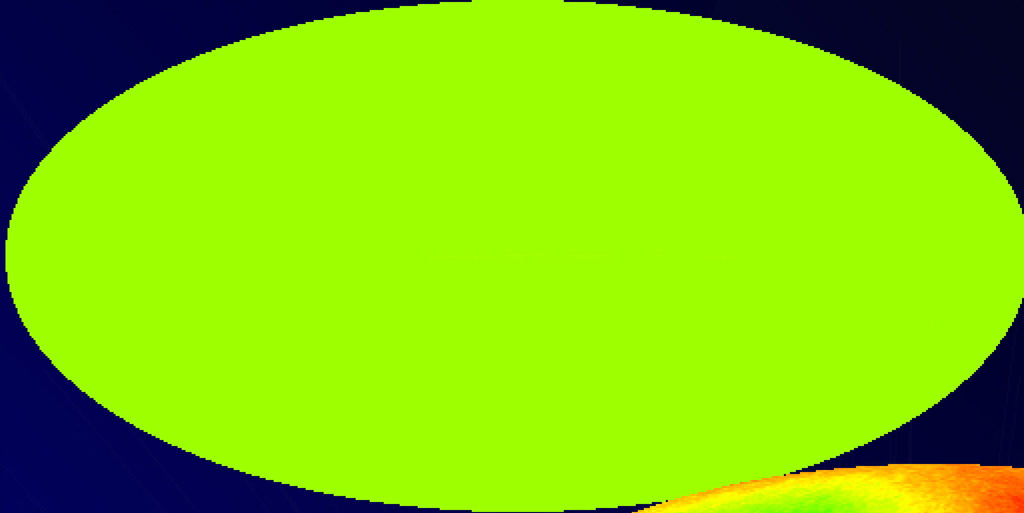
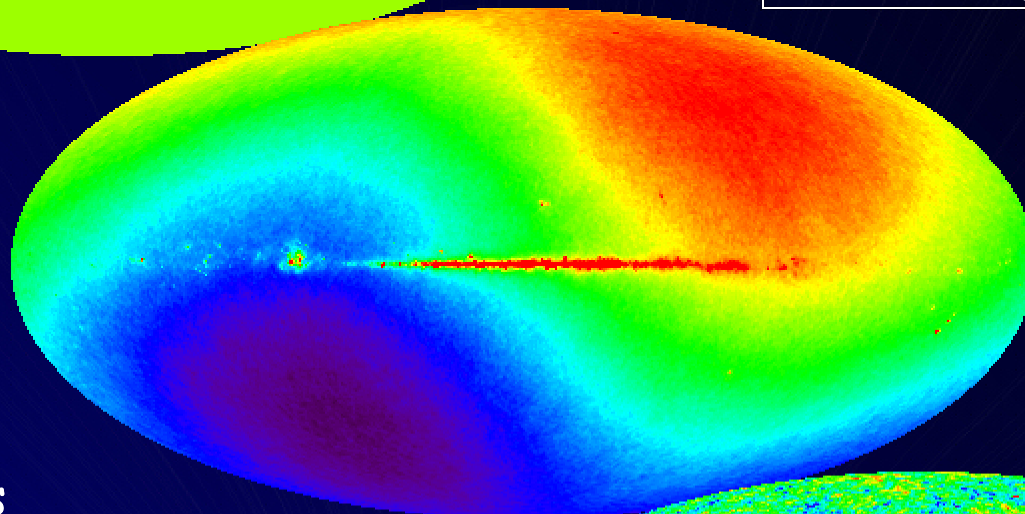


CMB Dipole



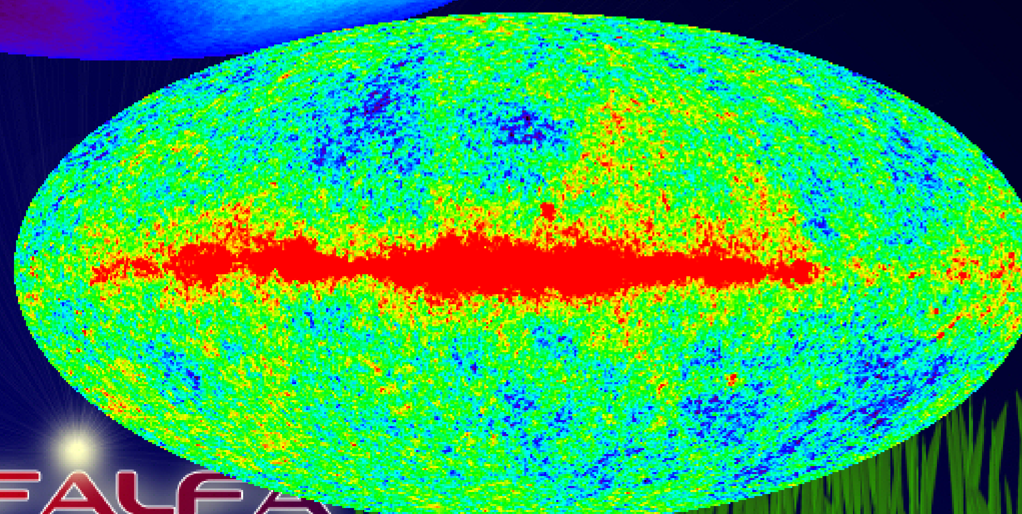
$\Delta T = 3.358$ mK

V_sun w.r.t CMB:

369 km/s towards
l=264°, b=+48°

Motion of the Local Group:

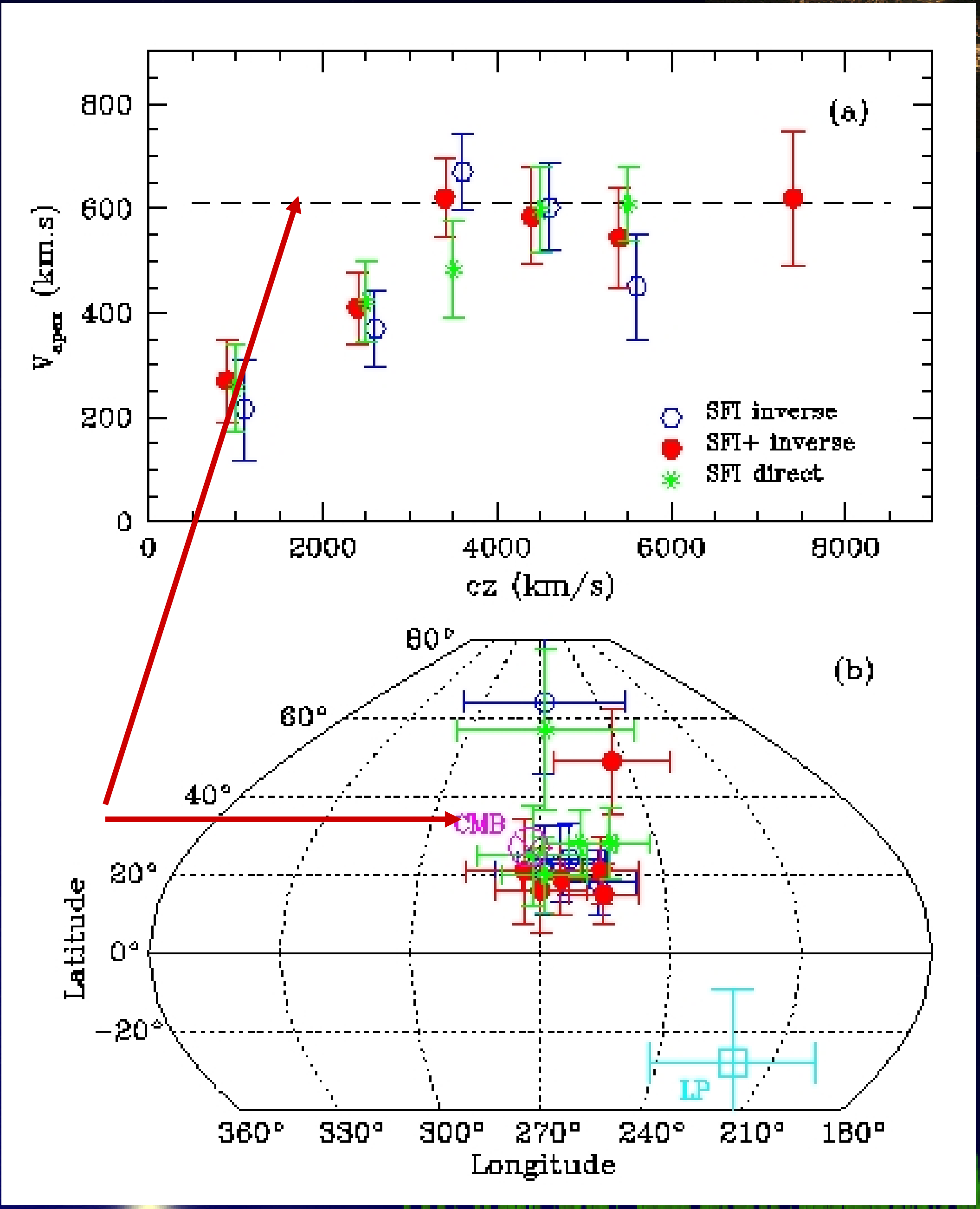
V = 627 km/s towards
l = 276° b= +30°



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 :
<u>convergence with the CMB dipole, both in amplitude and direction</u>, near cz ~ 5000 km/s.

(Giovanelli et al. 1998)



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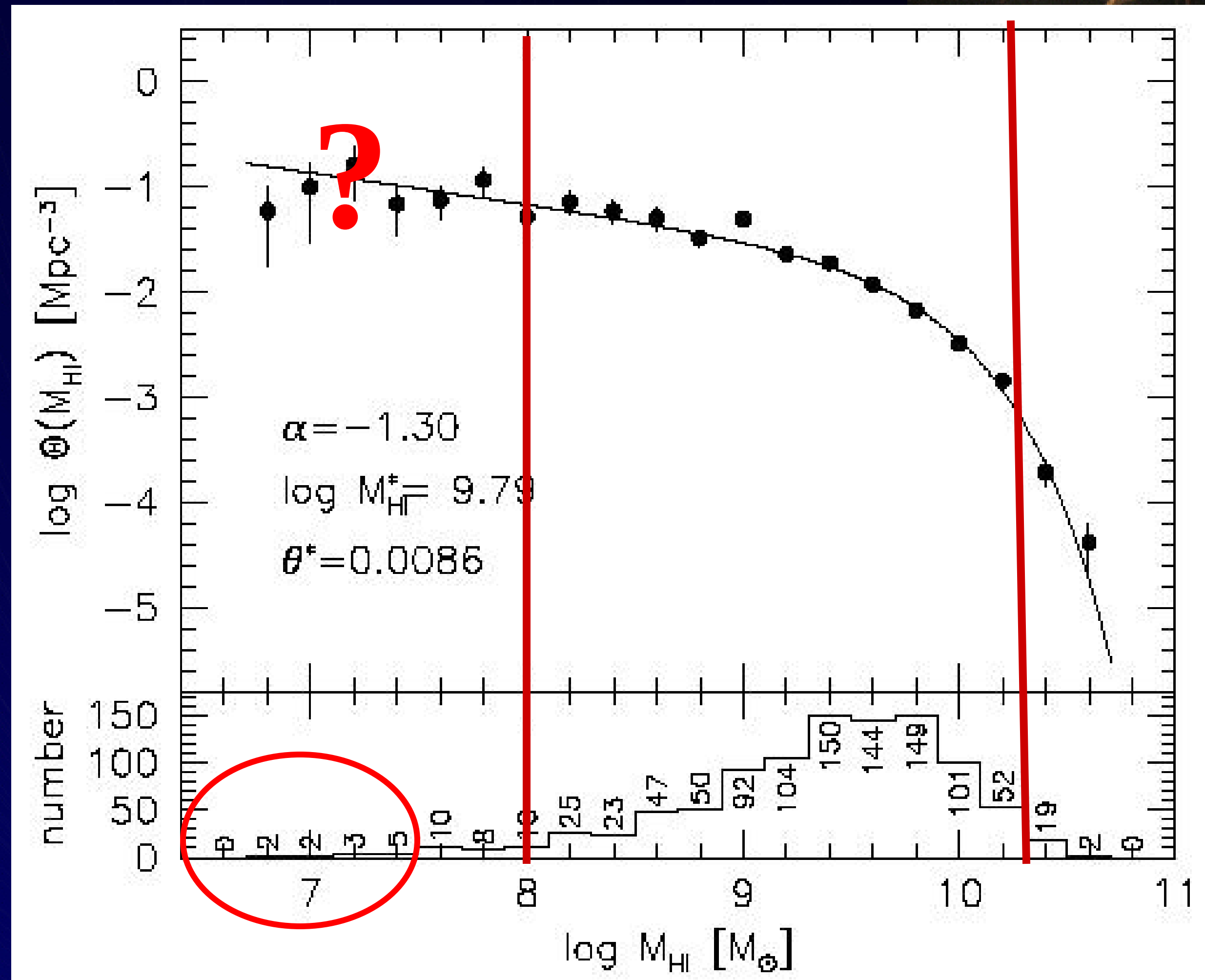
The HI Mass Function



- Previous surveys have included few (if any) objects with HI masses less than 10^8 $M_\odot$.

Parkes HIPASS survey:
Zwaan et al. 2006

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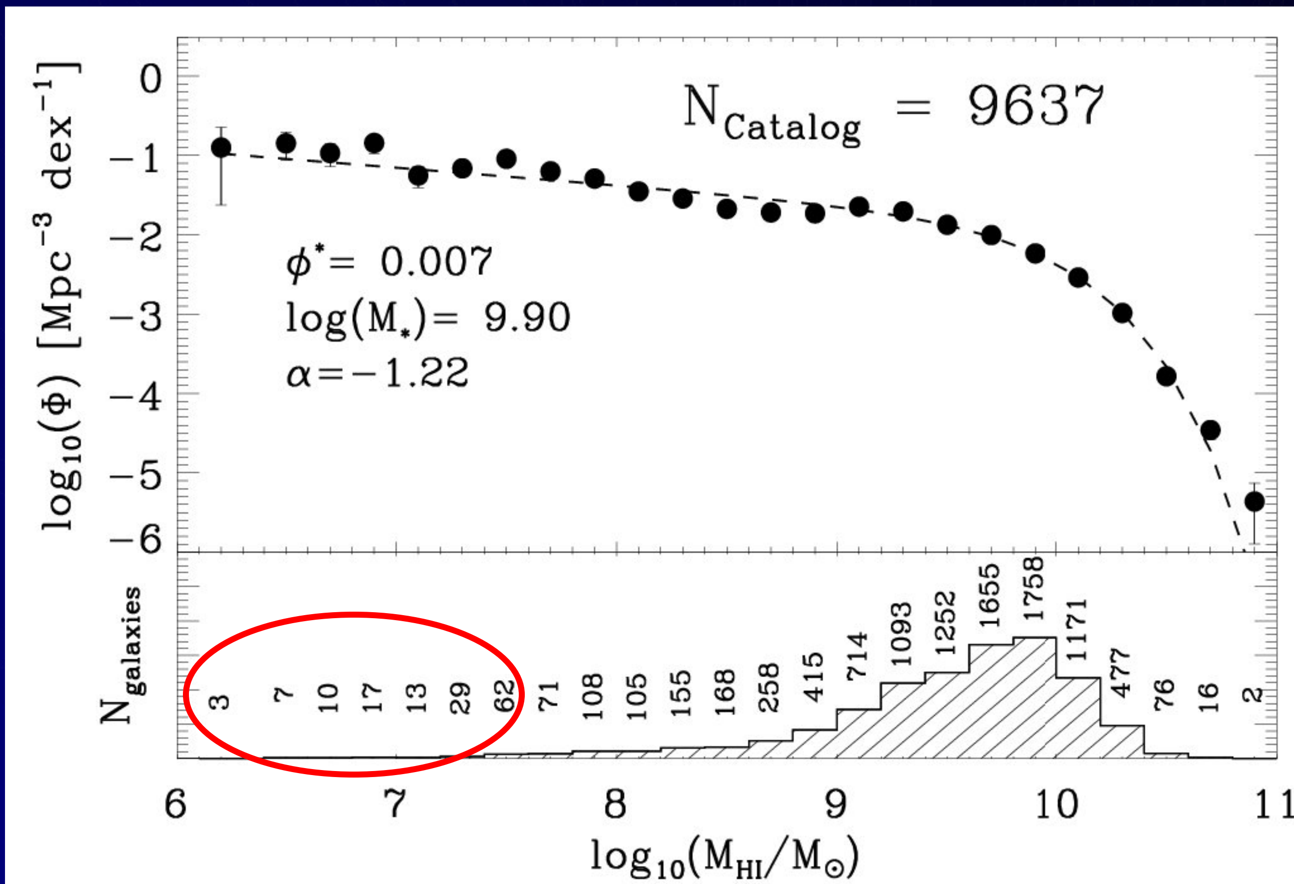
Cornell

NSF

ALFALFA HI Mass Function

Ann Martin 2010
in preparation



The Zwaan et al. 2003 HIMF, based on HIPASS, includes **12** galaxies with

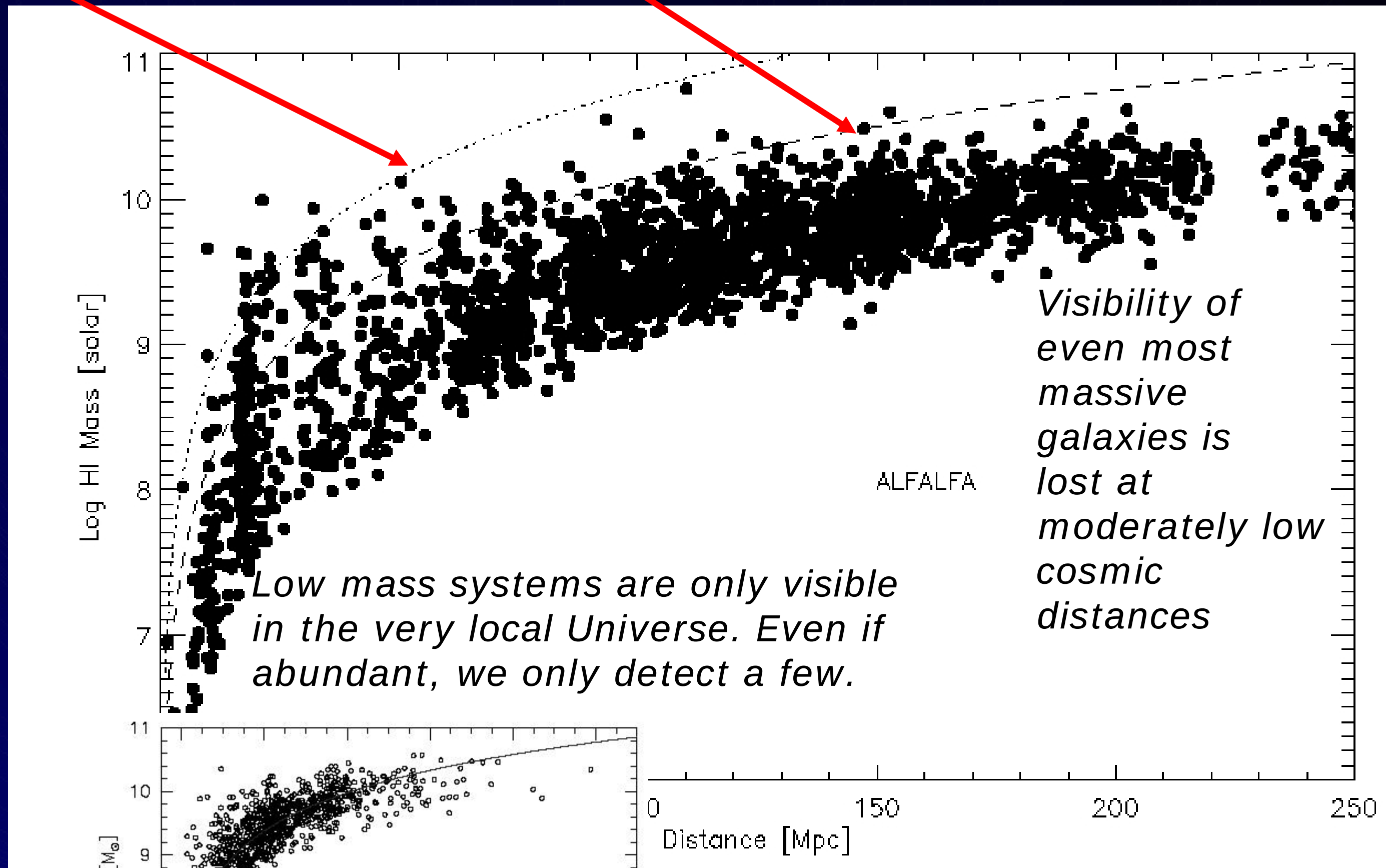
log M_HI < 7.5

With <1/4 of ALFALFA processed, we have **141**

...likewise on the bright end

HIPASS Completeness Limit

HIPASS Limit



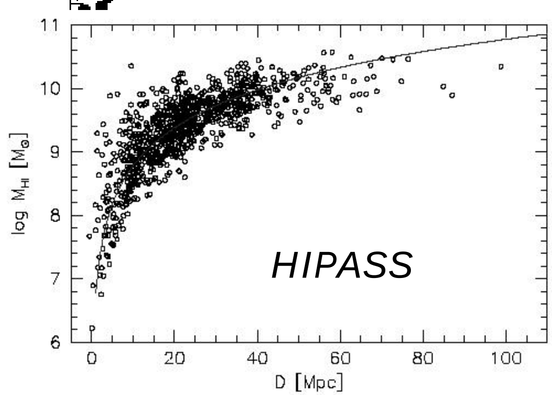
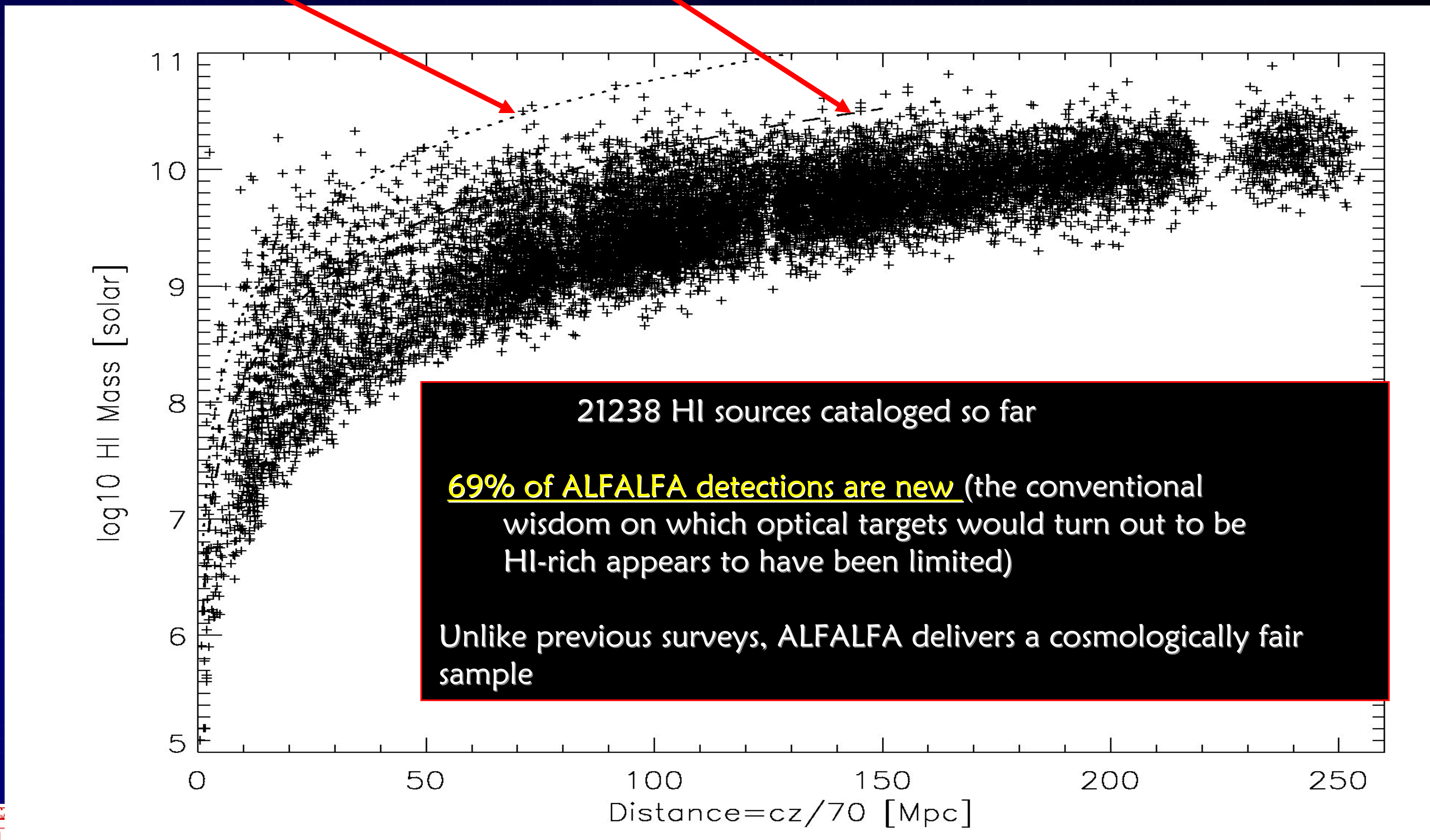


FIG. 11.— H I masses of BGC galaxies as a function of their distance. The solid line indicates an integrated flux limit of 25 Jy km s^{-1} above which the sample is 'complete'.

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

ALFALFA

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

For participation guidelines, see:

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

ALFALFA