# The Latest on the GA

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## I. Current Status of the Unveiling of the Great Attractor

- History of Discovery of GA
- Results from optical, NIR, FIR, X-ray,
  radio HI ZOA surveys, and some MIR (Spitzer) results

## II. Who is pulling the hardest : the GA-Shapley controversy

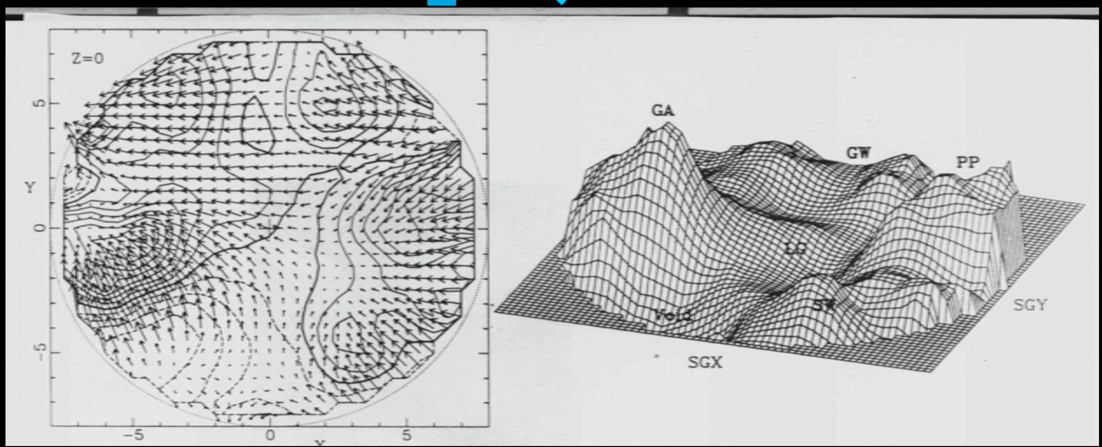
- Recent and Future Surveys
  - NIR (JHK from IRSF) TF analysis of the GA in the ZOA
  - NIR (JHK from IRSF) deep imaging survey of the GA Wall
  - Future SKA Pathfinder HI surveys (ASKAP, MeerKAT)

*Observatoire de Paris-Meudon, 2 March 2011*

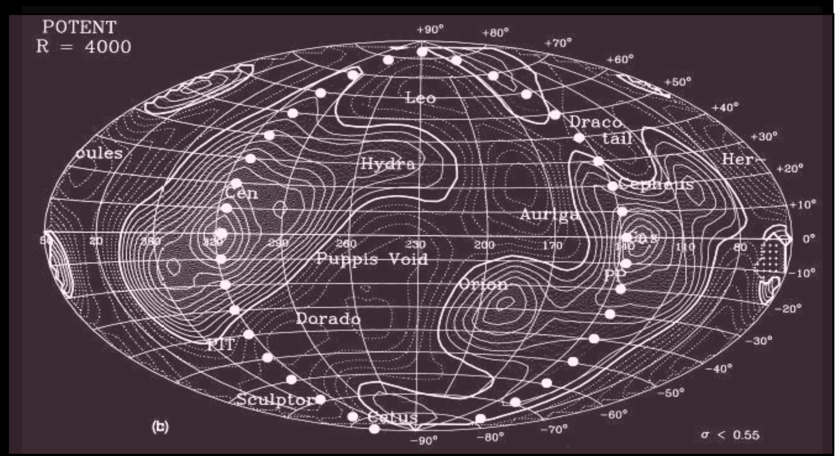
## Discovery of the Great Attractor *(Lynden-Bell 1988)*:

## a prominent mass overdensity (5 x $10^{16}M_{sun}$) in the nearby Universe

**The distribution of mass in the local Universe: -**
**determined from the systematic flow field of ~ 3000 galaxies (peculiar velocities $V_{pec} = V_{Hubble} - V_{obs}$ over the uniformly expanding Universe)**




*Dekel et al. 1994*



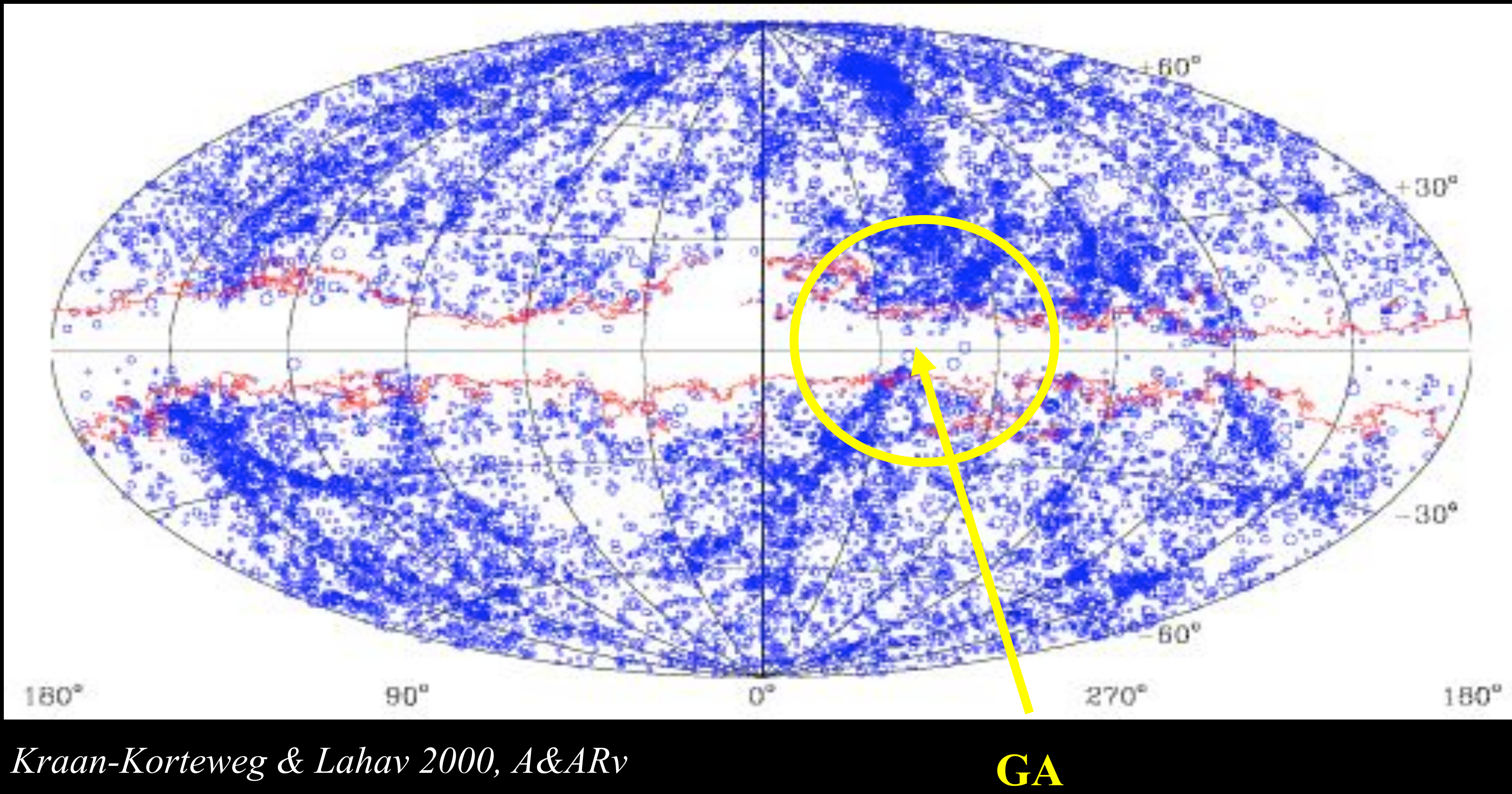

*(Kolatt et al 1995)*

- centered at 4500 km/s right from the LG
- it is the only structure without a counterpart in the distribution of galaxies

The centre of the Great Attractor lies right behind the disk of our Galaxy ($l=320^o$, $b=0^o$)

# The distribution of catalogued galaxies with D ≥ 1.3′

**➔The GA, a region of ~40° x 40 ° centered at l ~320 °, b ~ 0 °, v ~ 4500km/s is largely hidden by the Milky Way**




*Kraan-Korteweg & Lahav 2000, A&ARv*

# The Effects of dust and stars in the Galaxy on external galaxies → smaller and fainter and redder

*Based on near-infrared (J,H,K) observations made with the IRSF at the 1.4m Japanese telescope at SAAO*

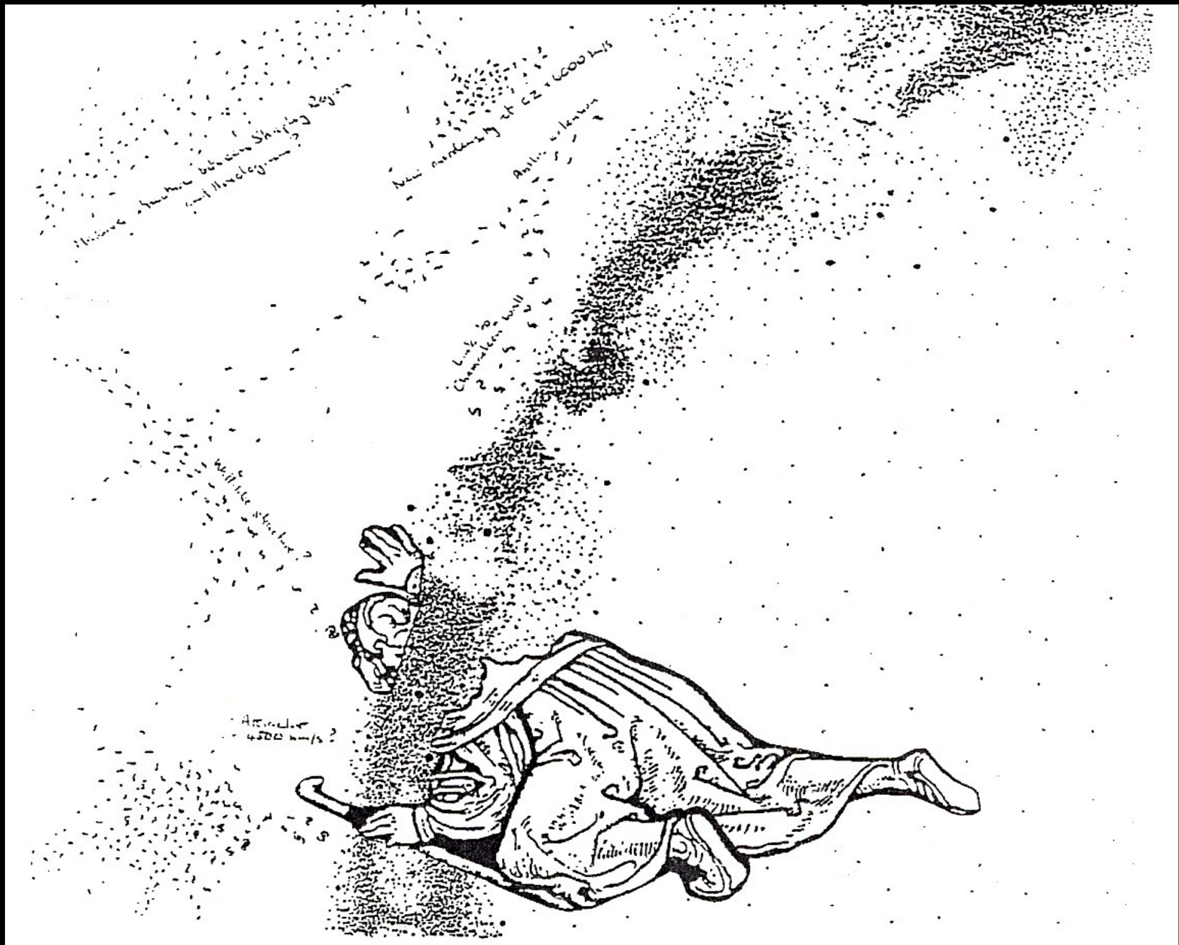
*(where extinction effects are an order of magnitude lower than in the optical)*

***Takahiro Nagayama's PhD thesis 2004***
*(Nagoya University)*


"Sure it's beautiful, but I can't help thinking about all that interstellar dust out there."

# How to resolve this?

## Methods of identifying the galaxy distribution behind the Milky Way

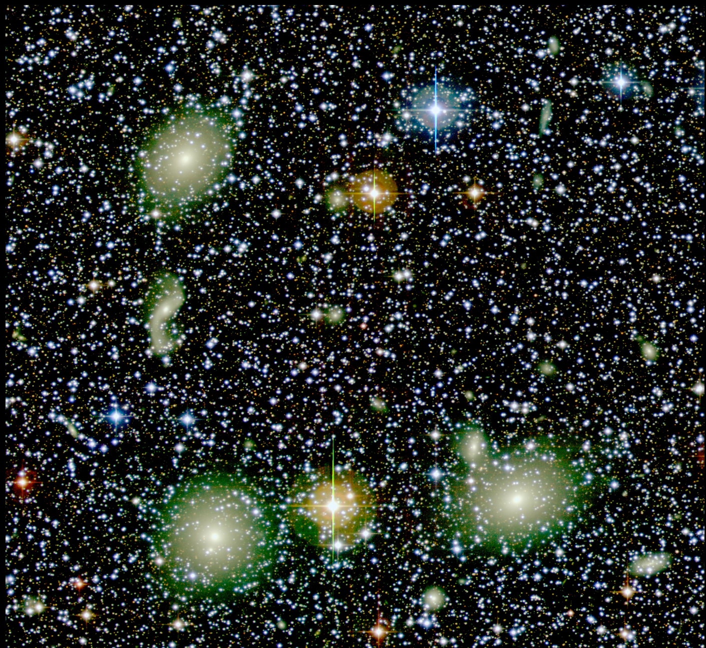


- **Optical: deep galaxy searches (using existing sky surveys)**
  - **reduction of optical ZOA by a factor of f ~ 2.5 ($A_B = 1^m \rightarrow 3^m$)**
  - **follow-up redshift surveys to map distribution in redshift space**
- **NIR surveys (2MASS)**
- **FIRsurveys (IRAS)**
- **X-ray (CIZA)**
- **HI surveys (Parkes)**
- **MIR possiblities (Spitzer)**

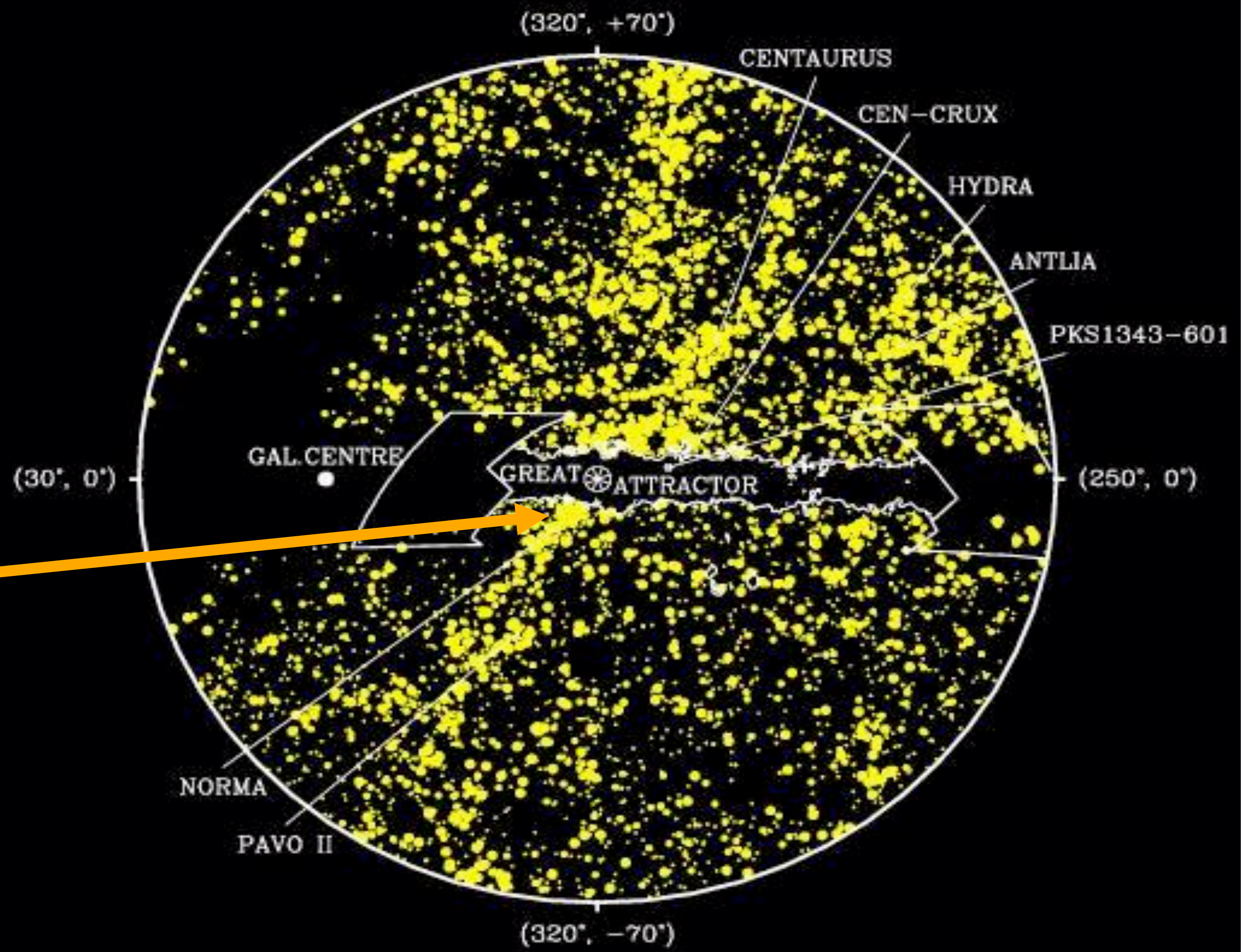
# Distribution of all known galaxies with D° ≥ 1.3′

**including the newly detected ZOA galaxies**

**after correction for the diminishing effects of obscuration** ***(Cameron 1990)***



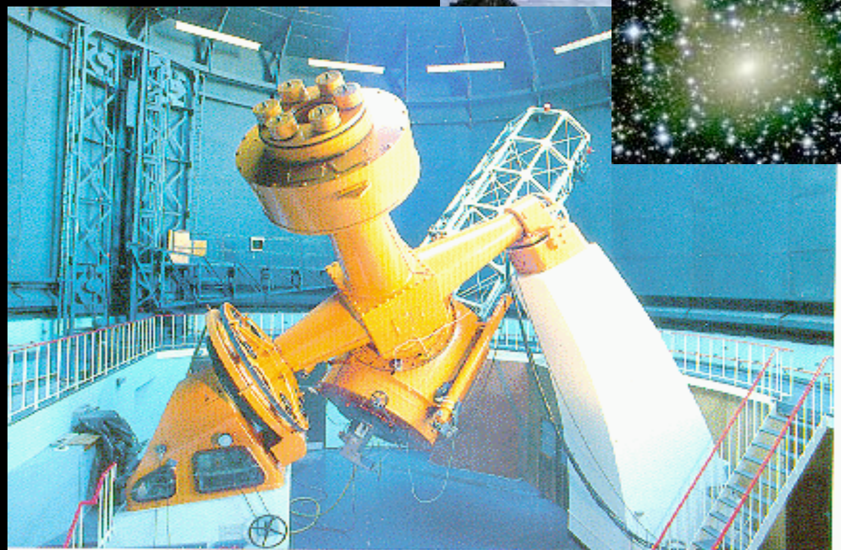
**ACO 3627**
**a rich cluster**



# Determinations of redshifts to map the newly detected galaxies in velocity space

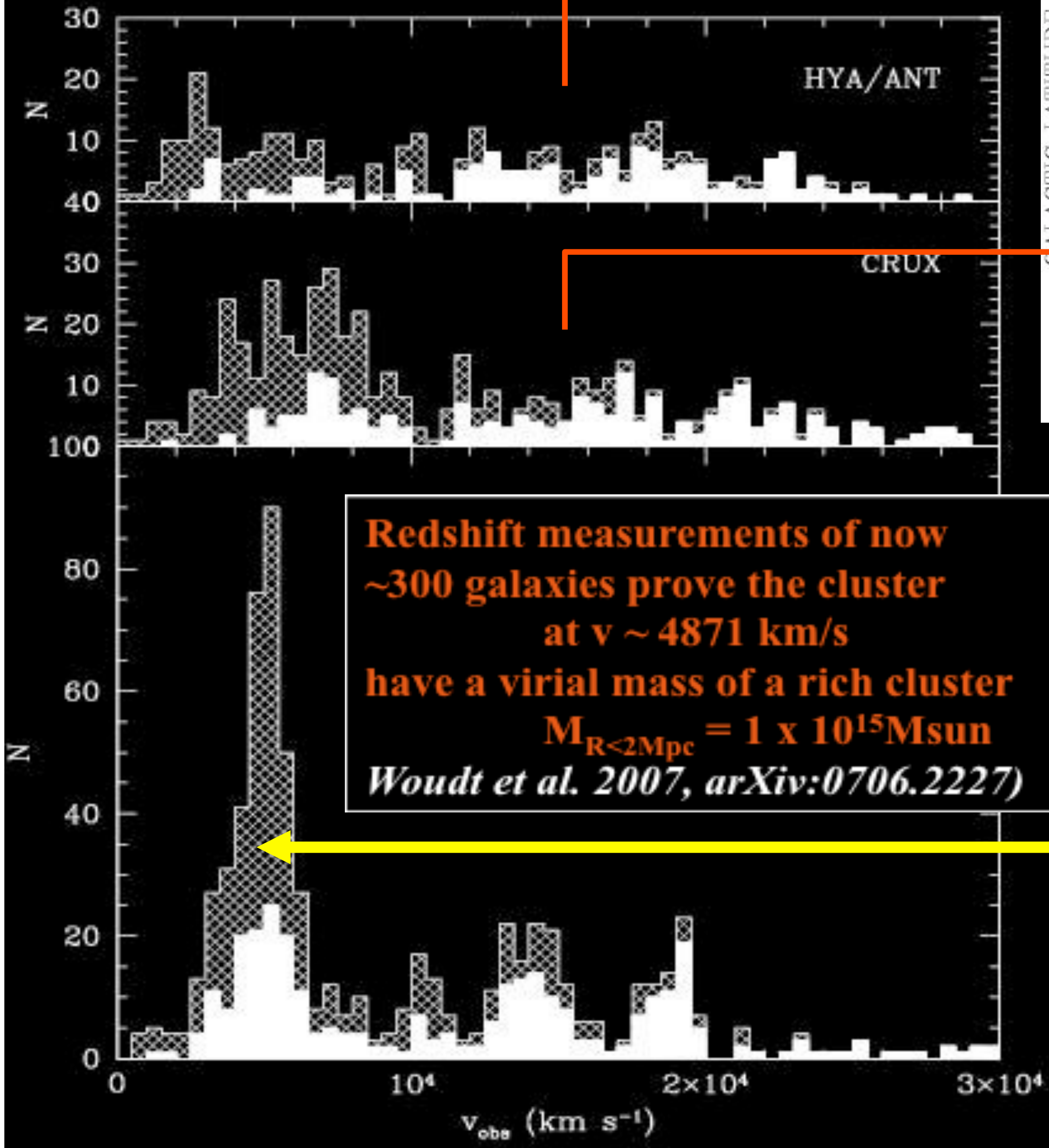

3.6-m telescope (ESO/Chile)
Optopus/MEFOS

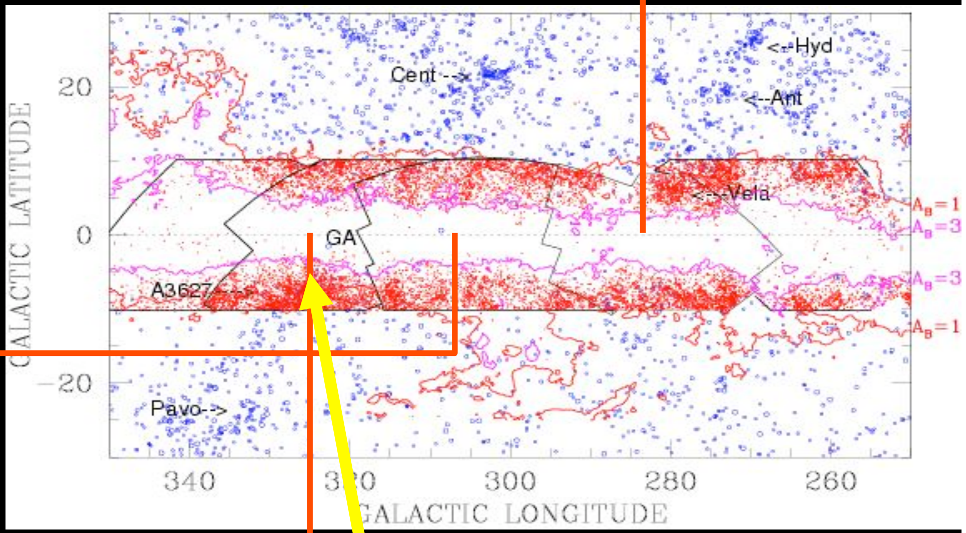
64-m radio telescope
(Parkes, Australia)

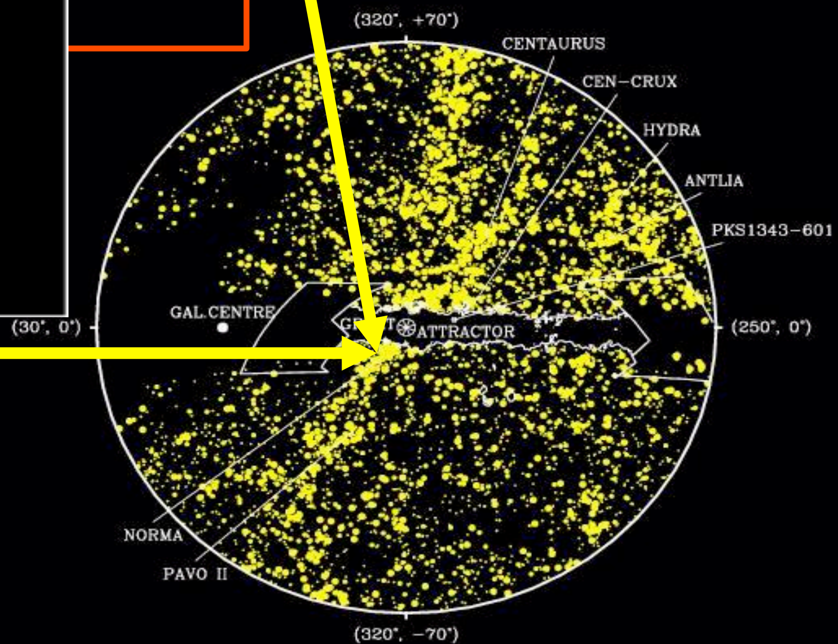


1.9-m (SAAO/Sutherland)

# Results:



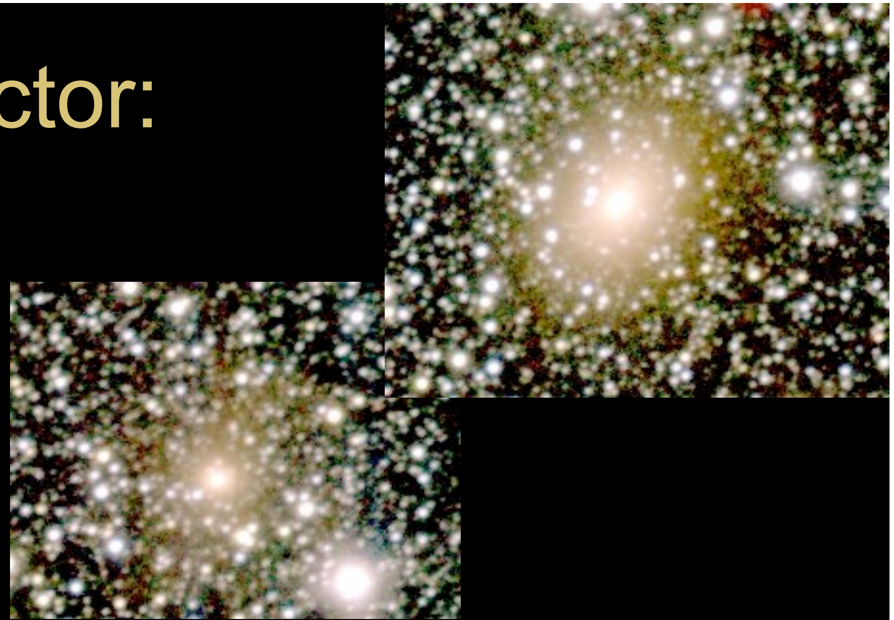

**Redshift measurements of now ~300 galaxies prove the cluster at v ~ 4871 km/s have a virial mass of a rich cluster $M_{R<2Mpc} = 1 \times 10^{15} M_{sun}$**

*Woudt et al. 2007, arXiv:0706.2227)*

# Inventory of the Great Attractor:

At (or close to) its center lies
the nearest rich cluster
in the Universe

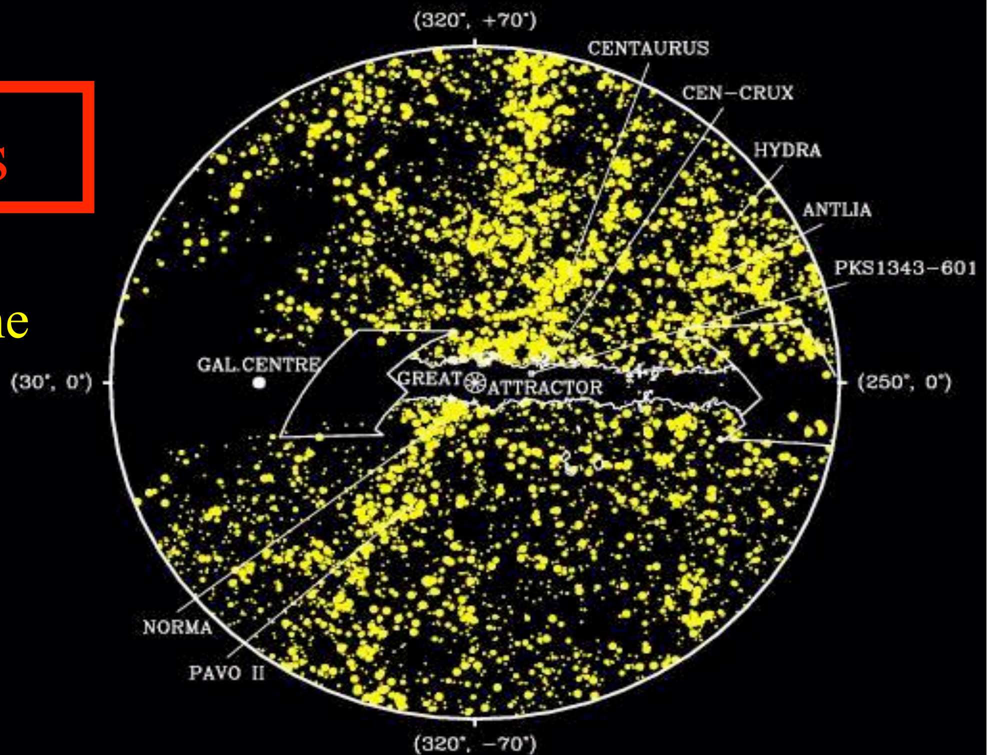
Comparable to the Coma cluster
in its properties (mass, richness, etc.)



**But a Zone of Avoidance remains**

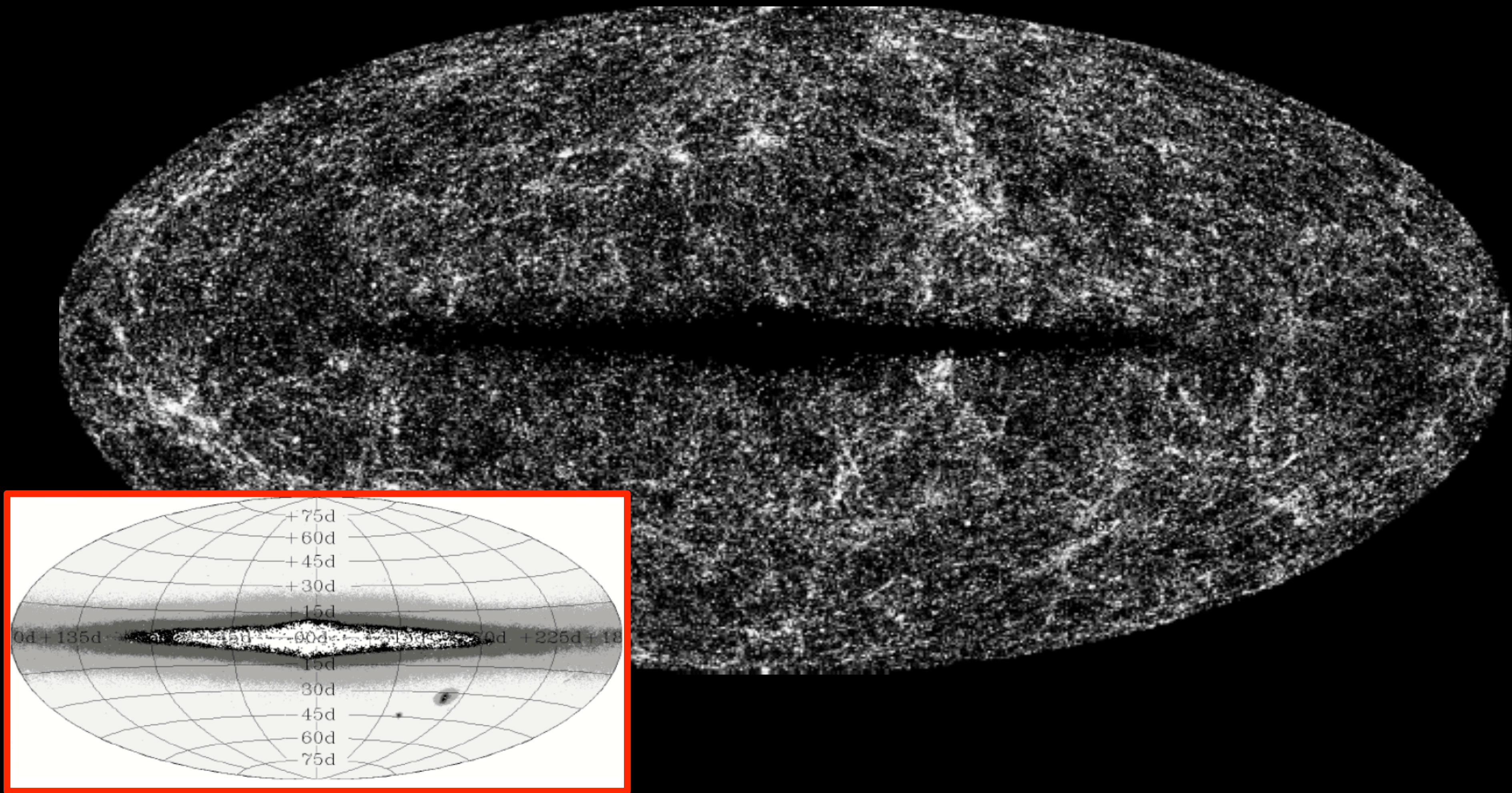
More clusters might remain hidden behind the
inner dust layer of the Milky Way.

→ observations in the infrared
(FIR & NIR, also X-ray)
→ observations in radio



# Distribution of 2MASX: extended objects with Ks ≤ 14$^{m}$

While the galaxy counts are little affected by Galactic extinction; absorption effects low ($A_K = 0.09\ A_B$)

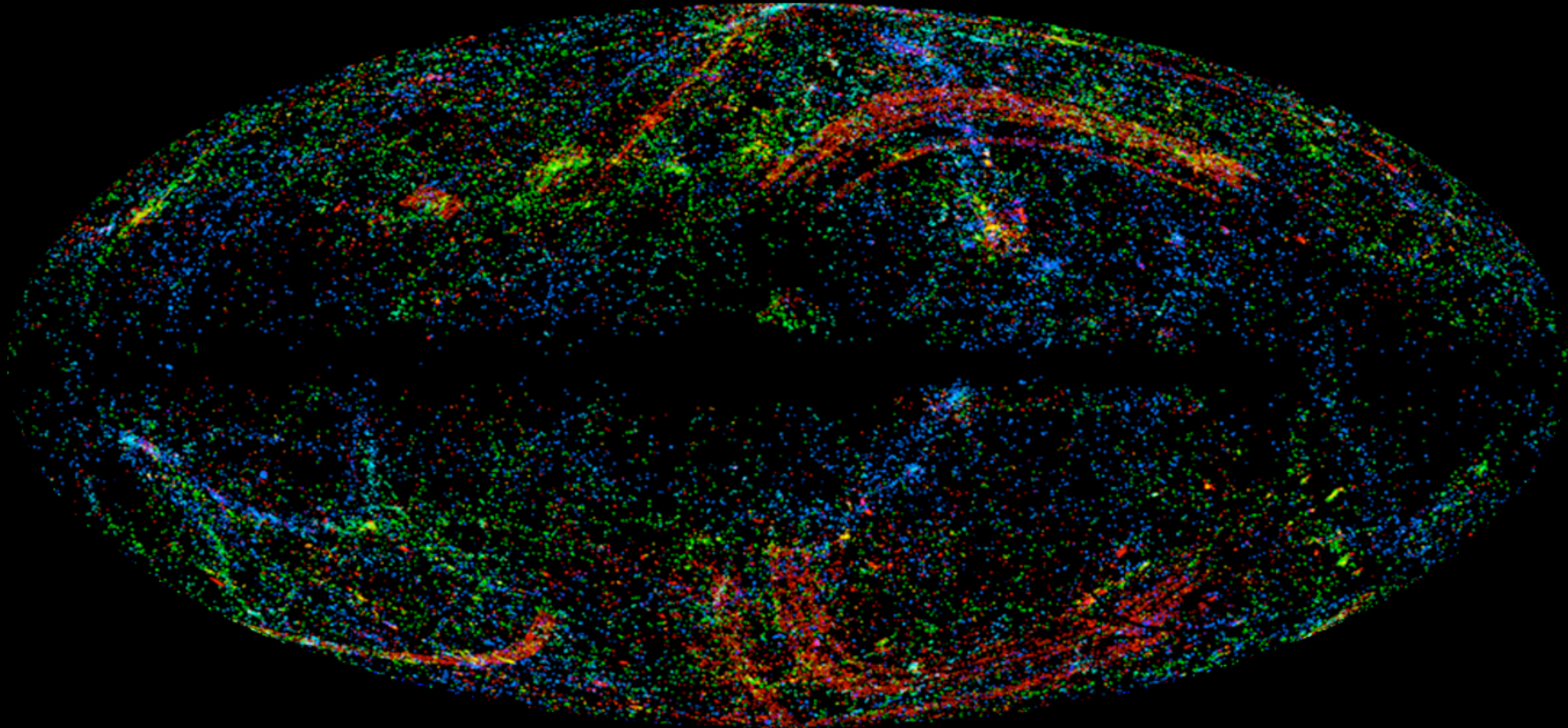



They are limited by star crowding: for 2MASS star densities (Ks < 14$^{m}$)

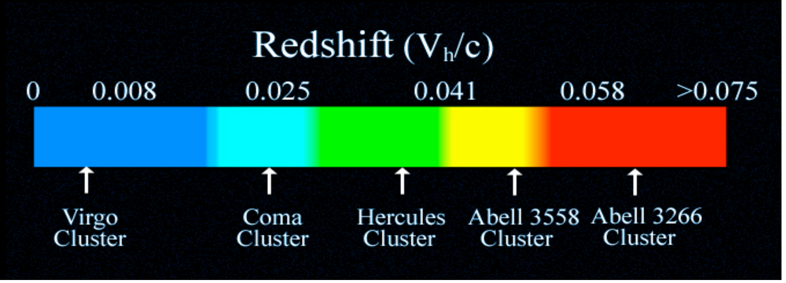
log N > 4 / □° 2MASX is completely blocked → also for GA

# NED matches with 2MASS: A redshift ZOA persists

## For at least ±5 degrees



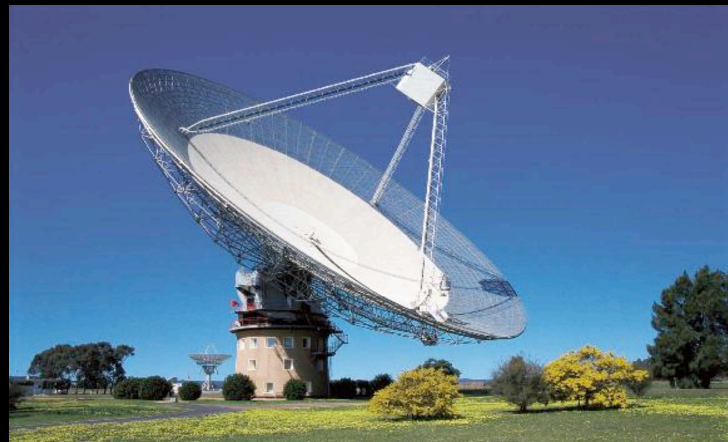
This limitation for $|b| < 5^o$ also holds for
-FIR (IRAS PSC, PSCz; *Saunders et al 2000)*
–X-ray ZOA cluster *survey (Ebeling et al 2005)*



# Parkes MB HI Surveys of the ZOA (|b| < 5º)
plus certain extensions (northern; higher latitudes around Galactic Bulge)

<u>Characteristics of the survey</u>

- Resolution of 14.3´ per beam
- System temperature of 20°K
- Correlator bandwidth of 64 MHz
- 1024 channels
- Channel spacing: 13.2 km/s
- Velocity coverage: -1200 < v < 12700 km/s



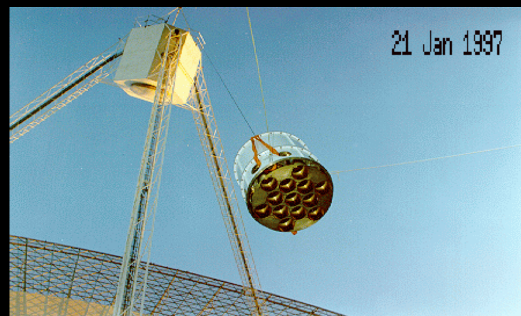
- Integration time: 25 min/beam

  5 TIMES LONGER THAN HIPASS

  → sensitivity of : rms = 6mJy

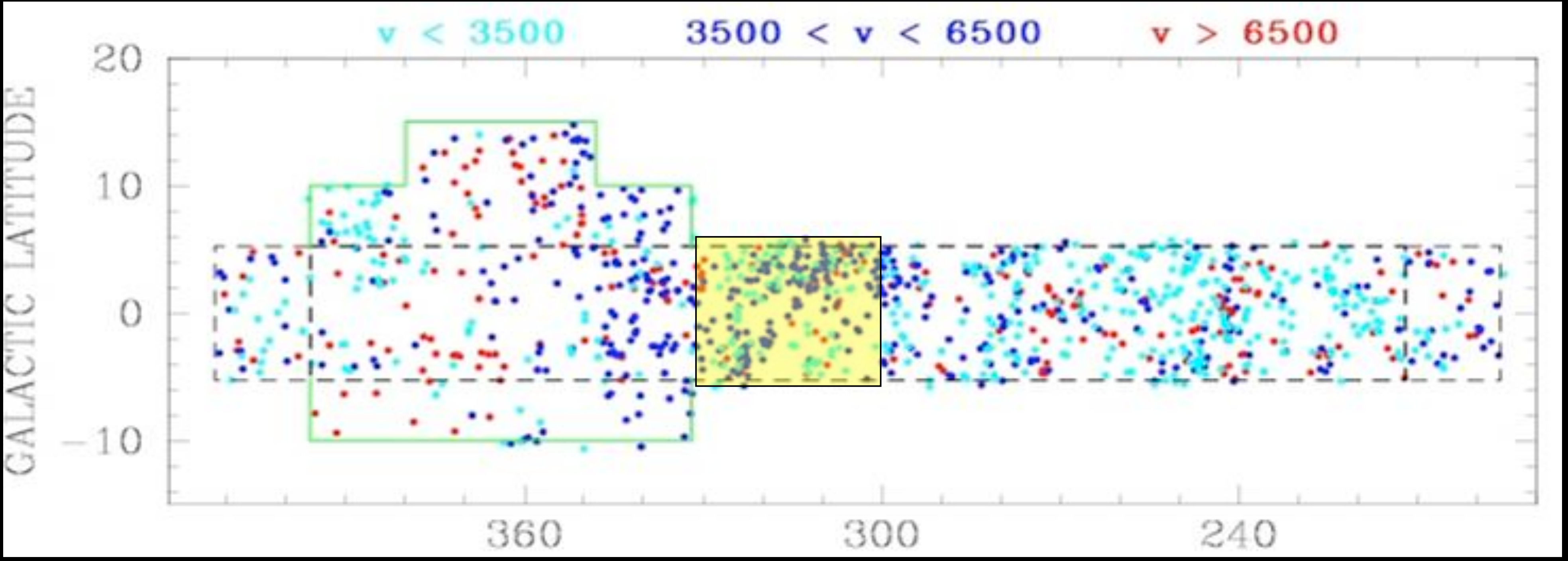
➔ sensitive to normal spiral galaxies

in the GA region



# Results from Parkes ZOA HI surveys: ZOA + NE + GB

**About 3000□° surveyed; ~1100 galaxies detected out to ~ 12'000 km/s**

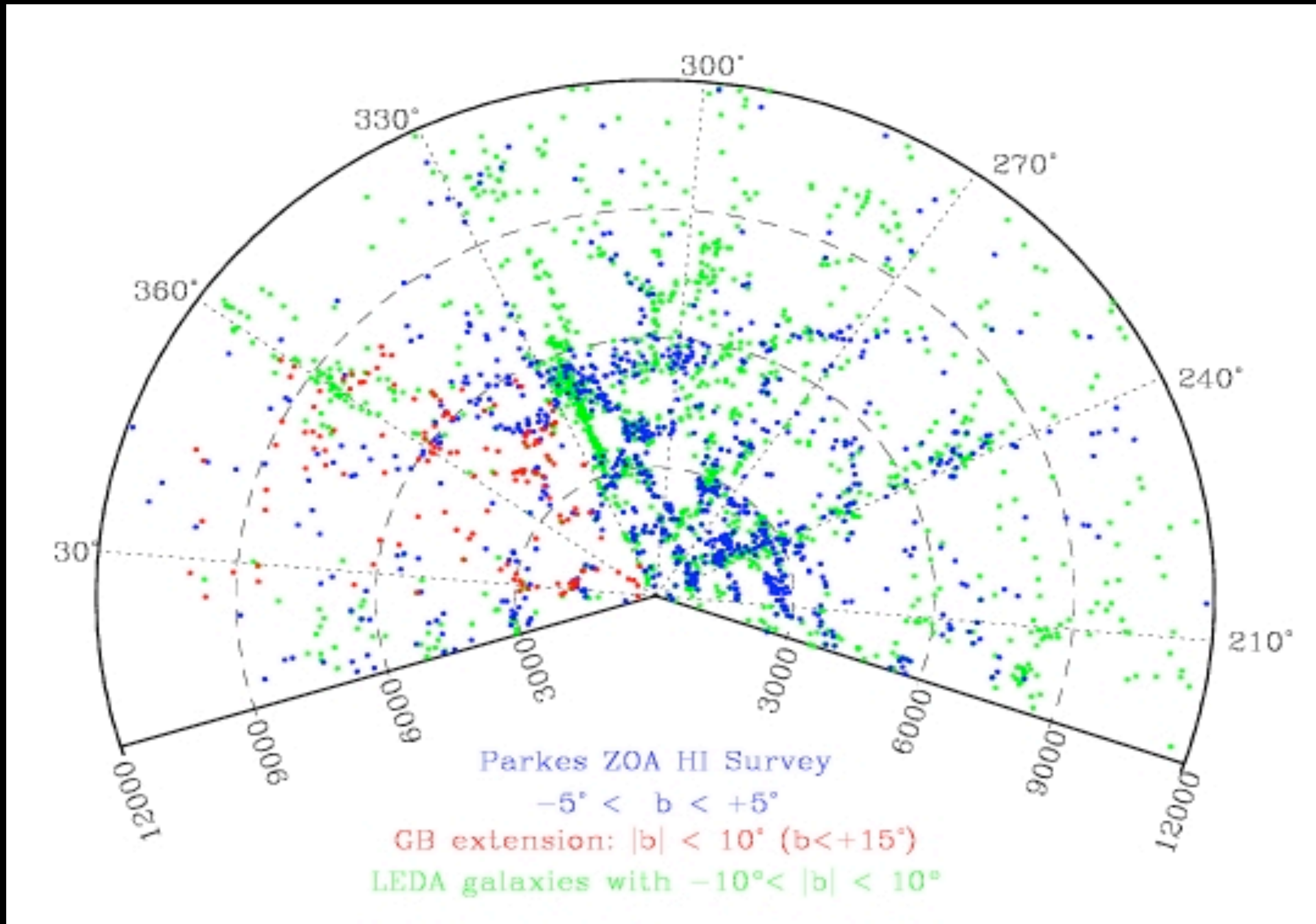



**LV GB GA Hy/Ant Puppis**

***Note: The GB extension data cubes have 20 scans (20 min integration/beam compared to 25 for ZOA + NE)***

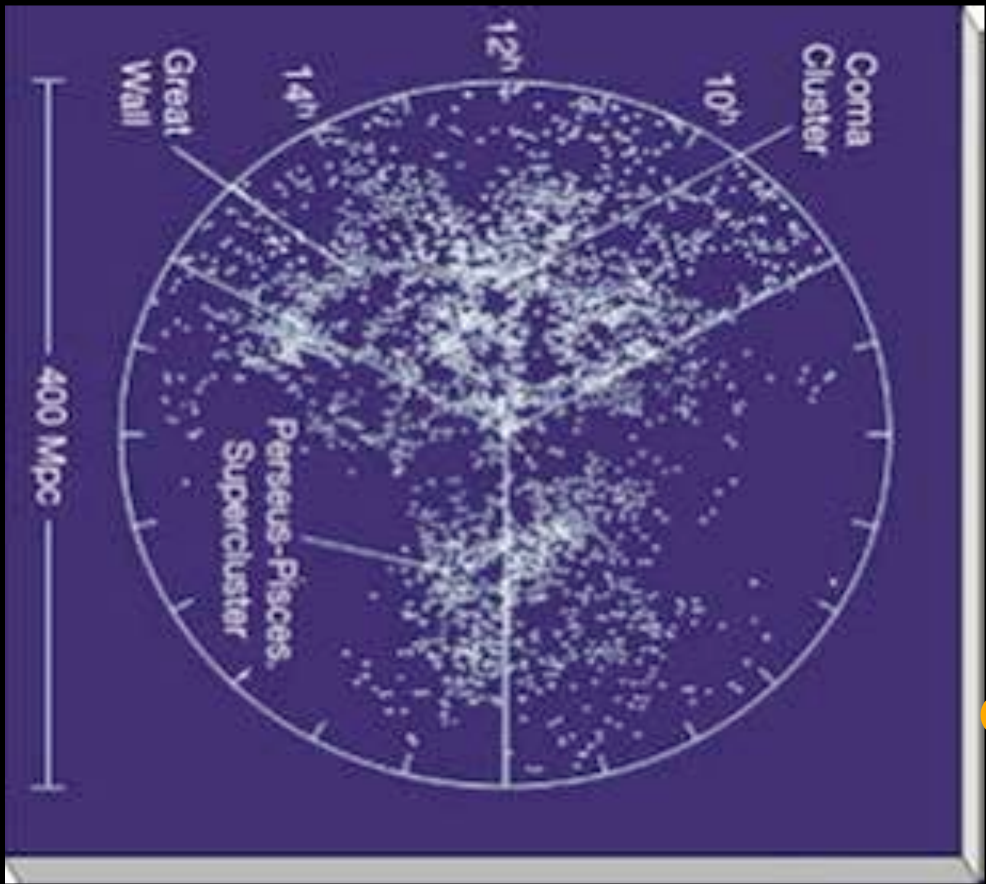
# Galaxies known within b = ±5° before MB survey

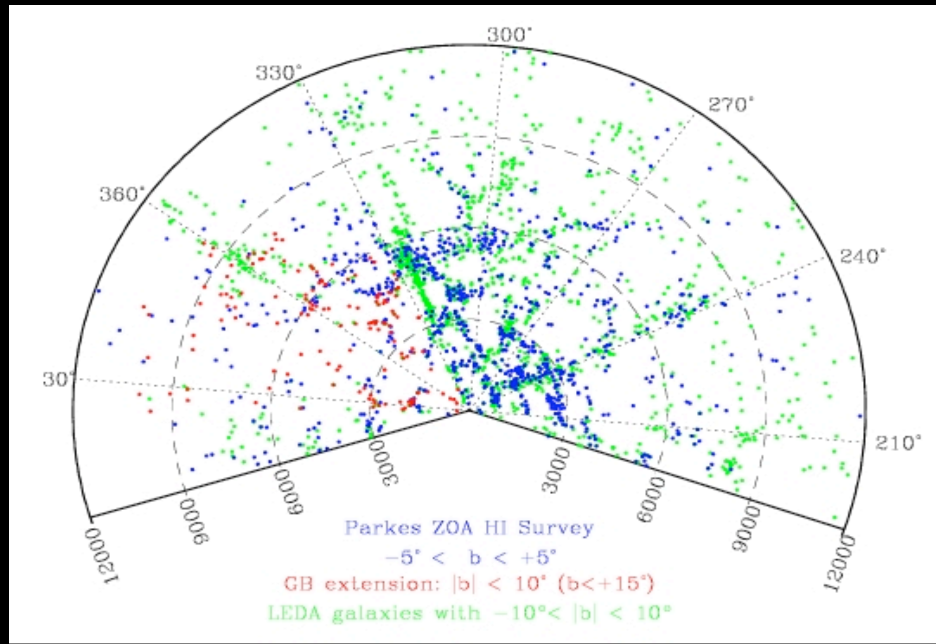
## Galaxies (~1100 in 3000□°) discovered within MB Surveys




➔Great Wall-like structure centered on Norma cluster (Vela, possibly to Oph.cl)

# Comparison of Coma within the Great Wall to the Norma cluster within the Norma Scl




(galaxies behind the Milky Way with |b| ≤ 10°; out to v=12000km/s; D ~340 Mpc)

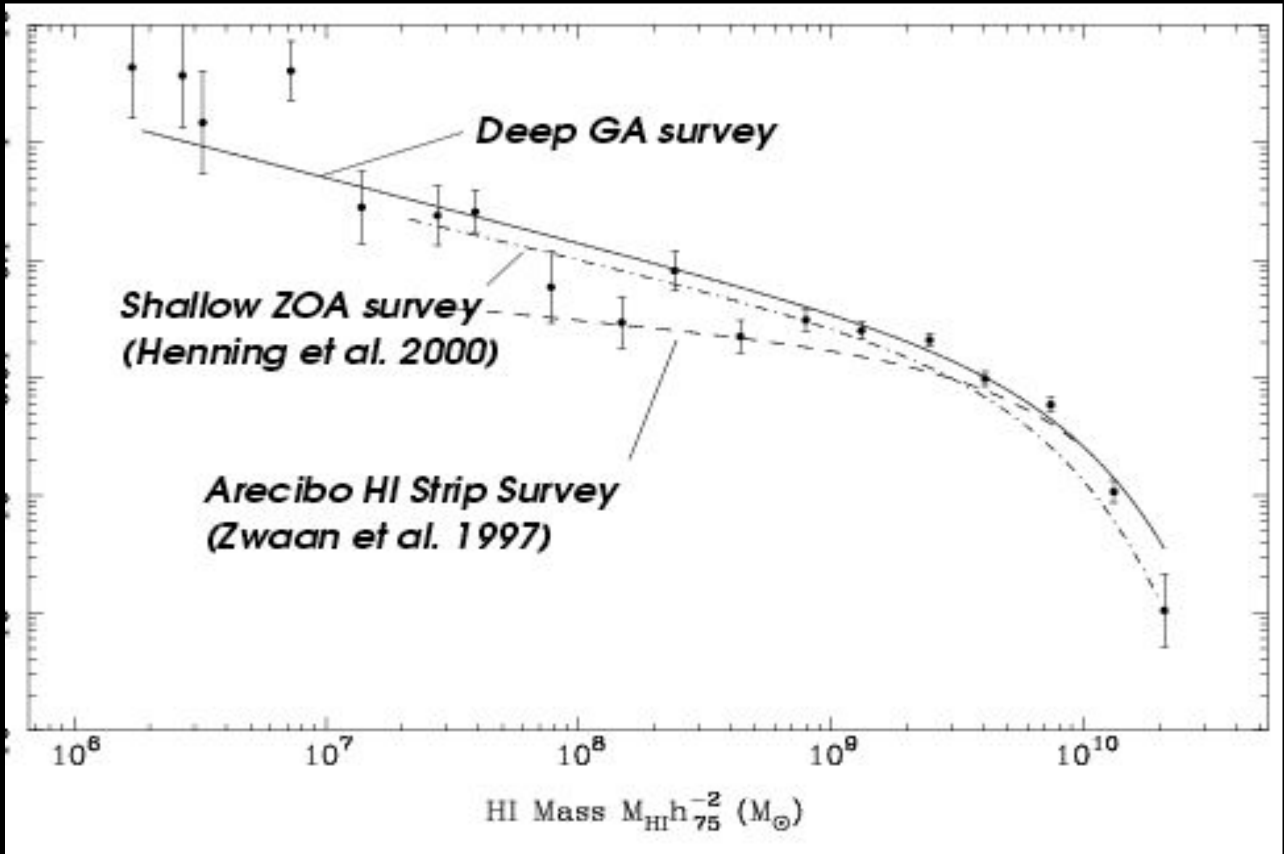
The Coma cluster within the Great Wall
= Supercluster of galaxies

The Norma cluster (A3627) also
is located within a great wall structure,
the Norma Super Cluster

**The Great Attractor ➔ A supercluster of galaxies**

# Deep MB-ZOA results from 4 cubes in the GA

## (300 ° < l < 332°, |b| ≤ 5°)



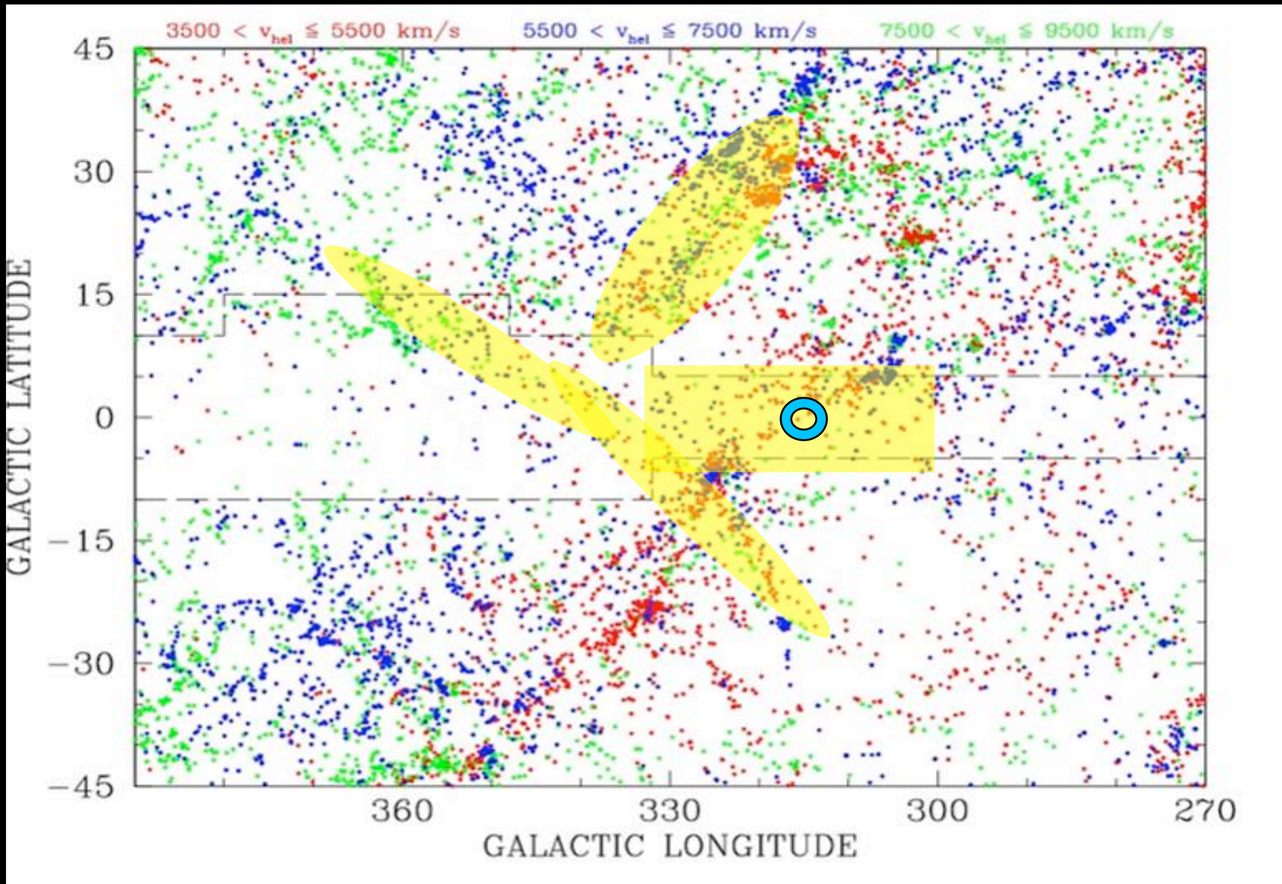

- compared to other HIMF there is a clear overdensity
- the excess mass is significant (~ $2 \cdot 10^{15}\,\Omega o\, M_☼$)
- but much less than predicted from reconstructions (~ $5 \cdot 10^{16}\,\Omega o\, M_☼$)

*Staveley-Smith et al. 2000*

**Maybe 300 ° < l < 332° is not sufficient; GA remains very sparsely sampled: average of ~0.4/deg$^2$ for HIZOA**

**maybe the GA is more extended?**

# MB – data together with other galaxies (Leda) with redshifts




2 galaxies at $A^B$=19m found in GLIMPSE

**Is the GA overdensity more massive yet?**

- **Norma Scl Wall (PIT – Norma - Crux-Cen – Vela)**
- **2nd parallel Wall?**
- **connection to the Ophiuchus SCL?**

# The Spitzer Space Telescope (0.85m)

Launched 25 August 2003

Mid Infrared imaging and spectroscopy

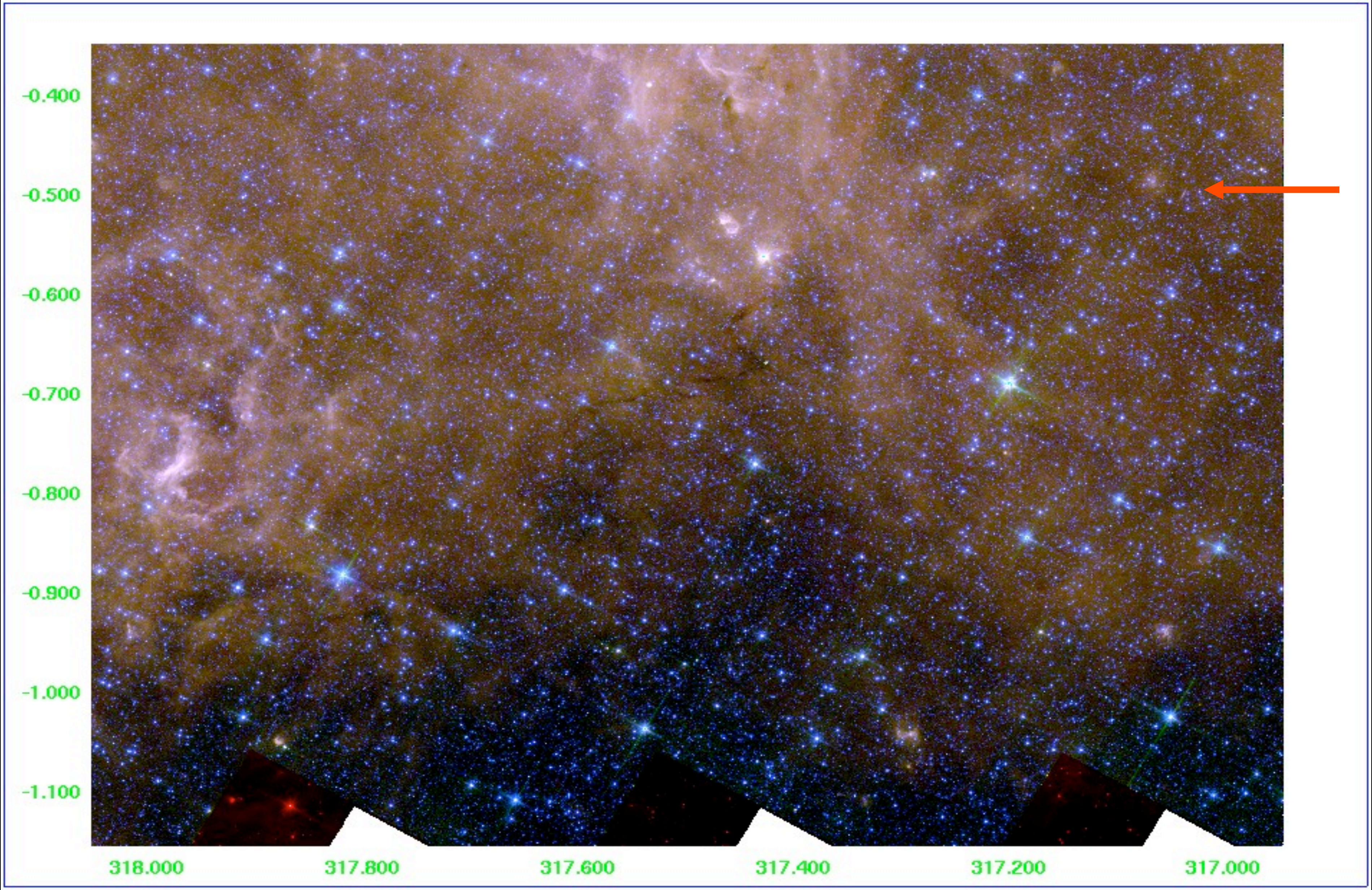
New window for detecting ZOA galaxies
- penetrate thick layer of gas & dust
- sensitive to
  - stellar photospheric emission of early type galaxies
  - interstellar emission of star formation in late type galaxies

## Products of interest: the Spitzer Legacy Survey GLIMPSE:

*(GLIMPSE = Galactic Legacy Infrared Mid Plane Survey Extraordinaire)*

*IRAC imaging in 4 bands (3.6 – 8 μm) of large fraction of Milky Way within $|b| < 1^o$*

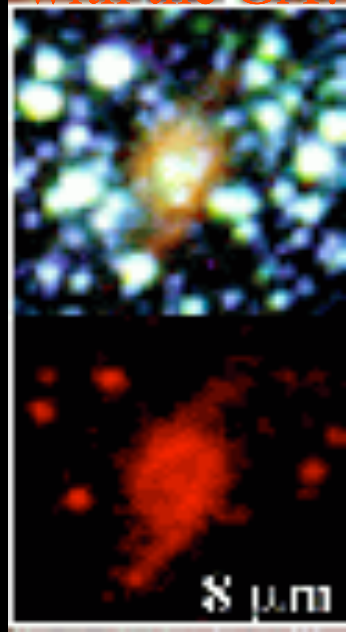
# Zoom-in on GLIMPSE field – edge-on spiral galaxy



## New Mosaic: Two highly obscured ($A_B$ = 19 mag) spiral galaxies

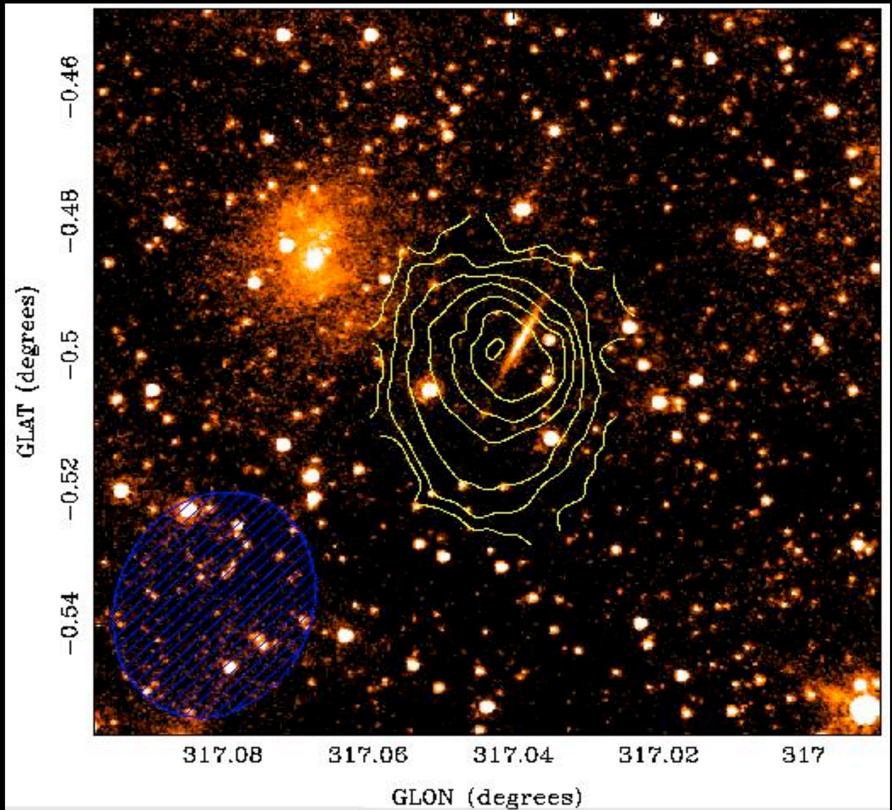
At
l = 317.04, b = -0.50
l = 316,87, b = -0.60
$A_B$ ~19 mag

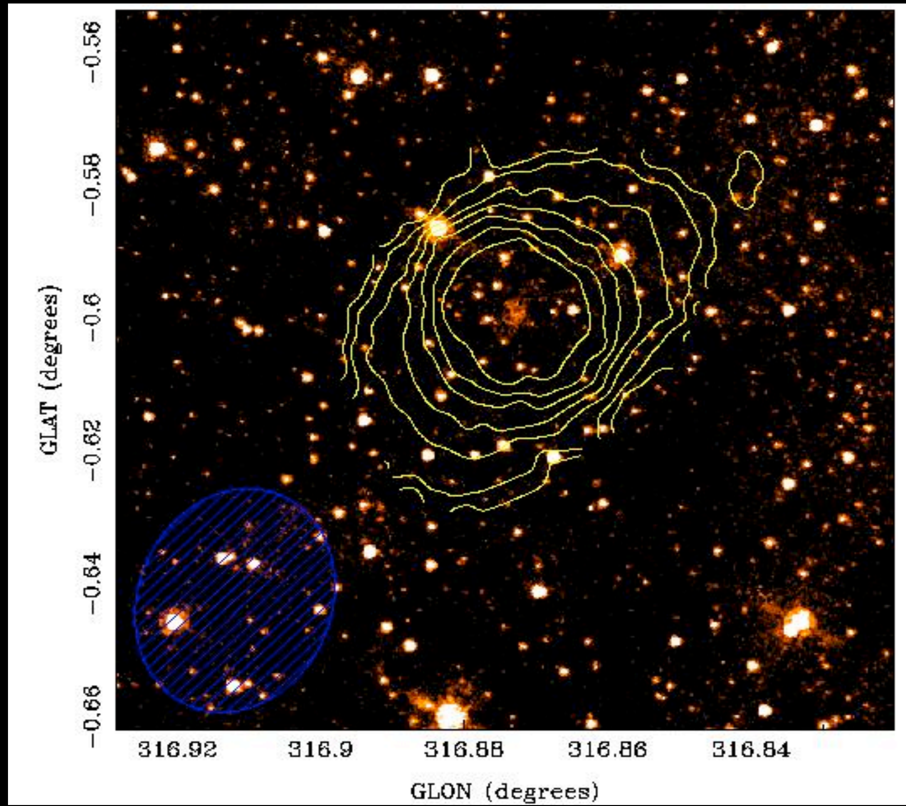
Any connection with the GA?



# Observations in HI with ATCA on 19/20 July 2006:

BW=64MHz, 512 channels, centered on 4750 km/s, 12 hours, beam 34‘




→ the 2 Glimpse galaxies are confirmed

→ they lie at the distance of the GA overdensity

→ they have typical HI masses for normal star-forming Sb or Sc

$M_{HI}$ = 2.2 $10^9$ $M_{sun}$ and 1.1 $10^9 M_{sun}$ respectively ($H_0$=72)

*Jarrett et al. 2007 AJ*

# Part II: Current and Future Surveys

**II. Who is pulling the hardest : the GA-Shapley controversy**

**How massive and extended is the GA really**

**What is the role of the Shapley Concentration at $3xD_{GA}$**

- **Brief Overview of GA_Shapley controversy**
- **Recent and Future Surveys**
  - **NIR (JHK from IRSF) TF analysis of the GA in the ZOA**
  - **NIR (JHK from IRSF) deep imaging survey of the GA Wall**
  - **Future SKA Pathfinder HI surveys (ASKAP, MeerKAT)**

# Is the Great Attractor the only main attractor?

*Plionis et al 2000, Basilakos & Plionis 2006 for clusters (and PSCz)*
*Saunders et al. 2000 for PSCz +BTP*

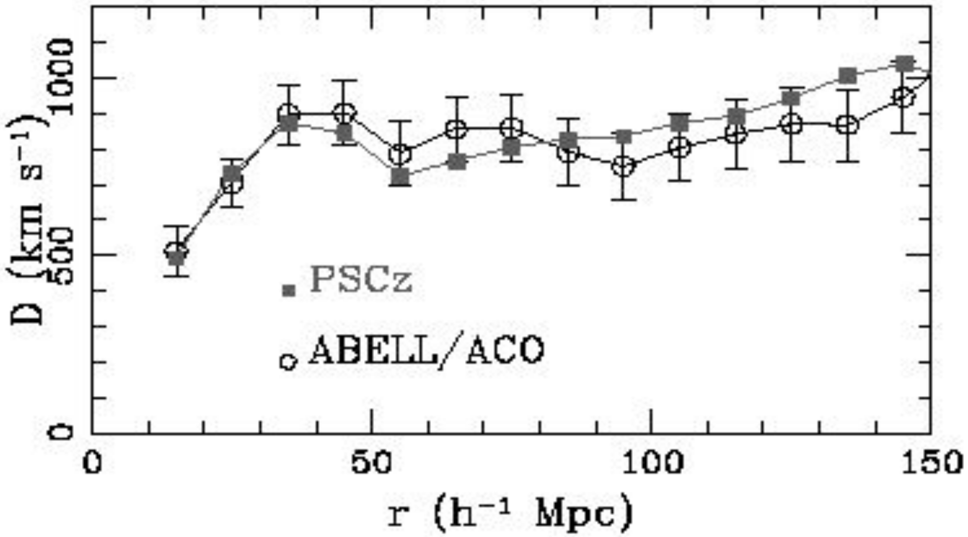
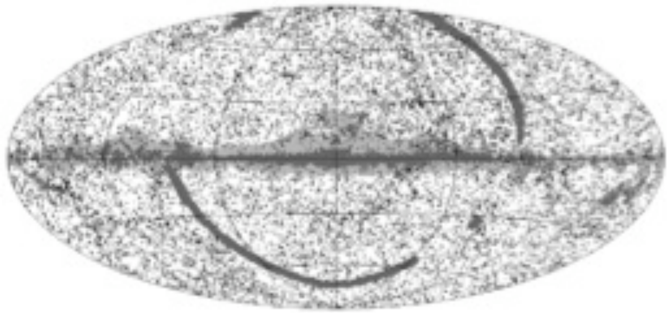



**Figure 5.** Comparison between the PSCz and ABELL/ACO dipoles, after scaling down the latter by a bias factor of 4.3.



Increase out to 15'000 km/s shows 'small' increase after small dip, but not too extreme (though Basalikos & Plionis 2006 results are slightly steeper)

*Scaramella et al postulated as early as 1991 that the Shapley Concentration of galaxy clusters (Shapley 1930) at about 16000km/s contribute to the LG dipole motion*

# CIZA: Clusters in the ZOA *(Ebeling et al. 2005)*

***Complement to the RASS XBSC for galactic latitudes |b| < 20º***

**200 CIZA clusters** ***(BSC flux > 2 x $10^{-12}$ erg $cm^{-2}s^{-1}$ ; spectroscopically confirmed)***

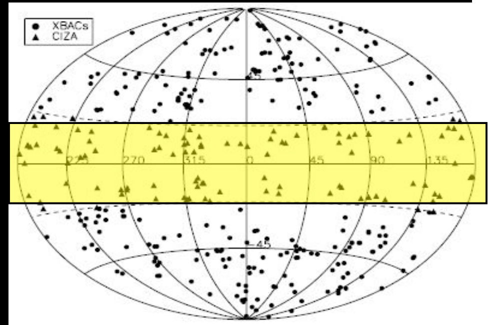
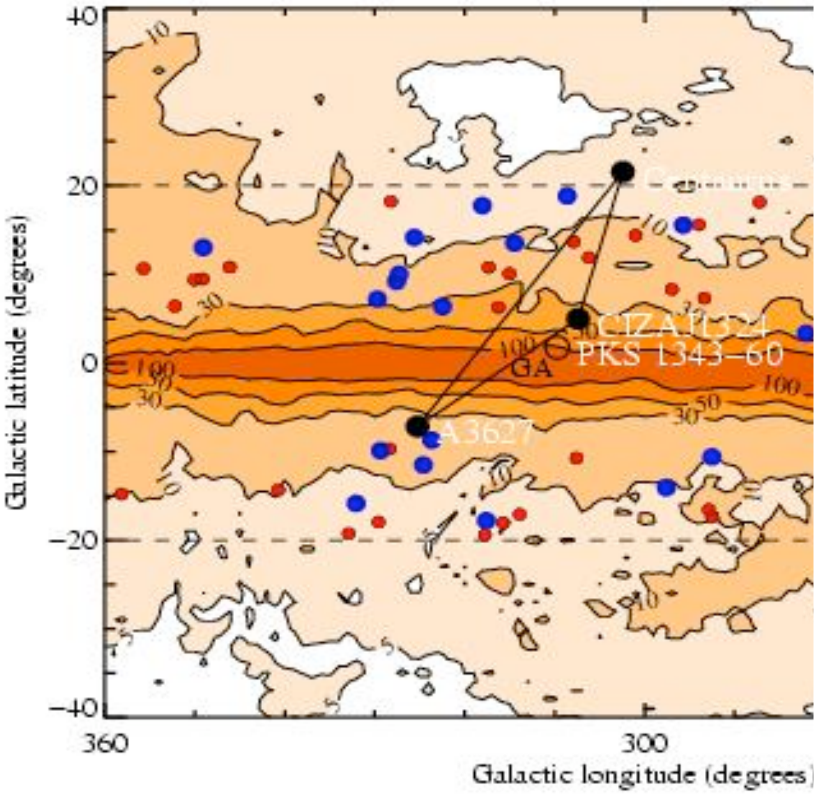
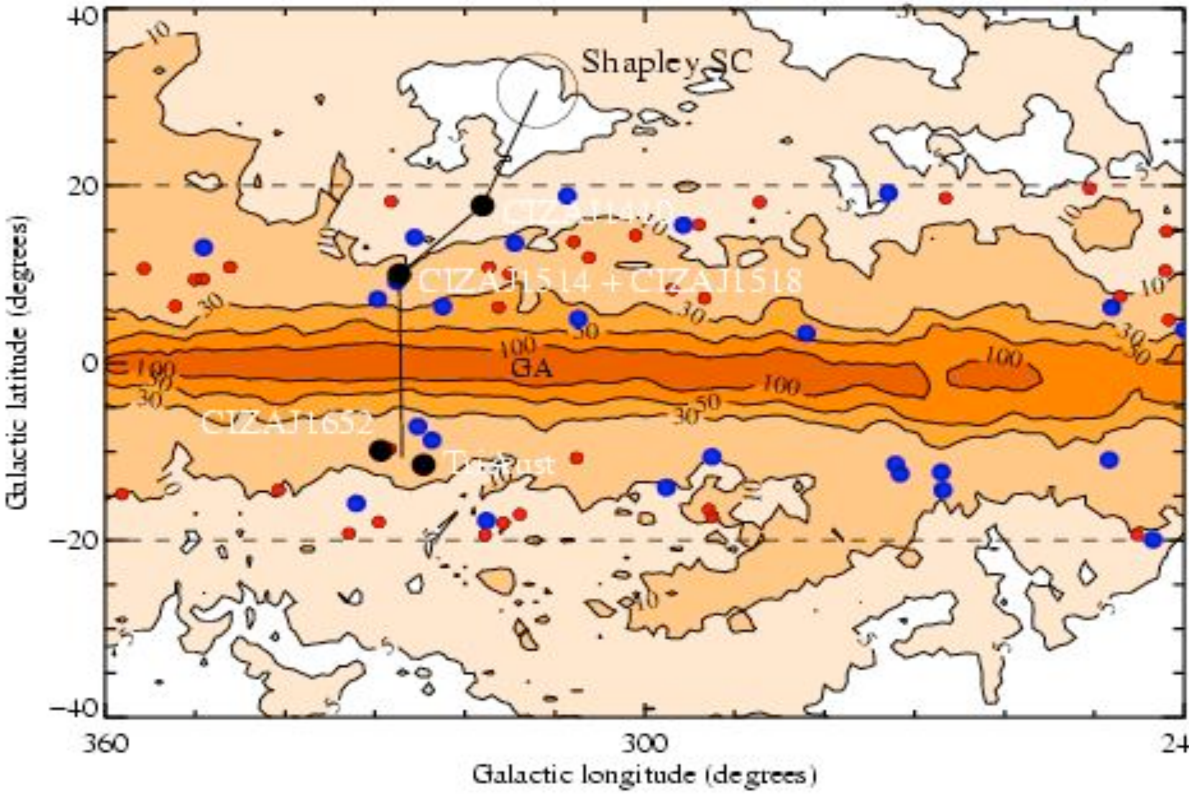



FIG. 1.—Aitoff projection of the XBAC and CIZA cluster catalogs in Galactic coordinates. The dashed lines represent the traditional ZOA (|b| < 20°).




**The 3 highlighted clusters: 3000-6000 km/s**

**Highlighted clusters: ~ 15’000 km/s**

*Kocevski et al.*
*2004,2005*

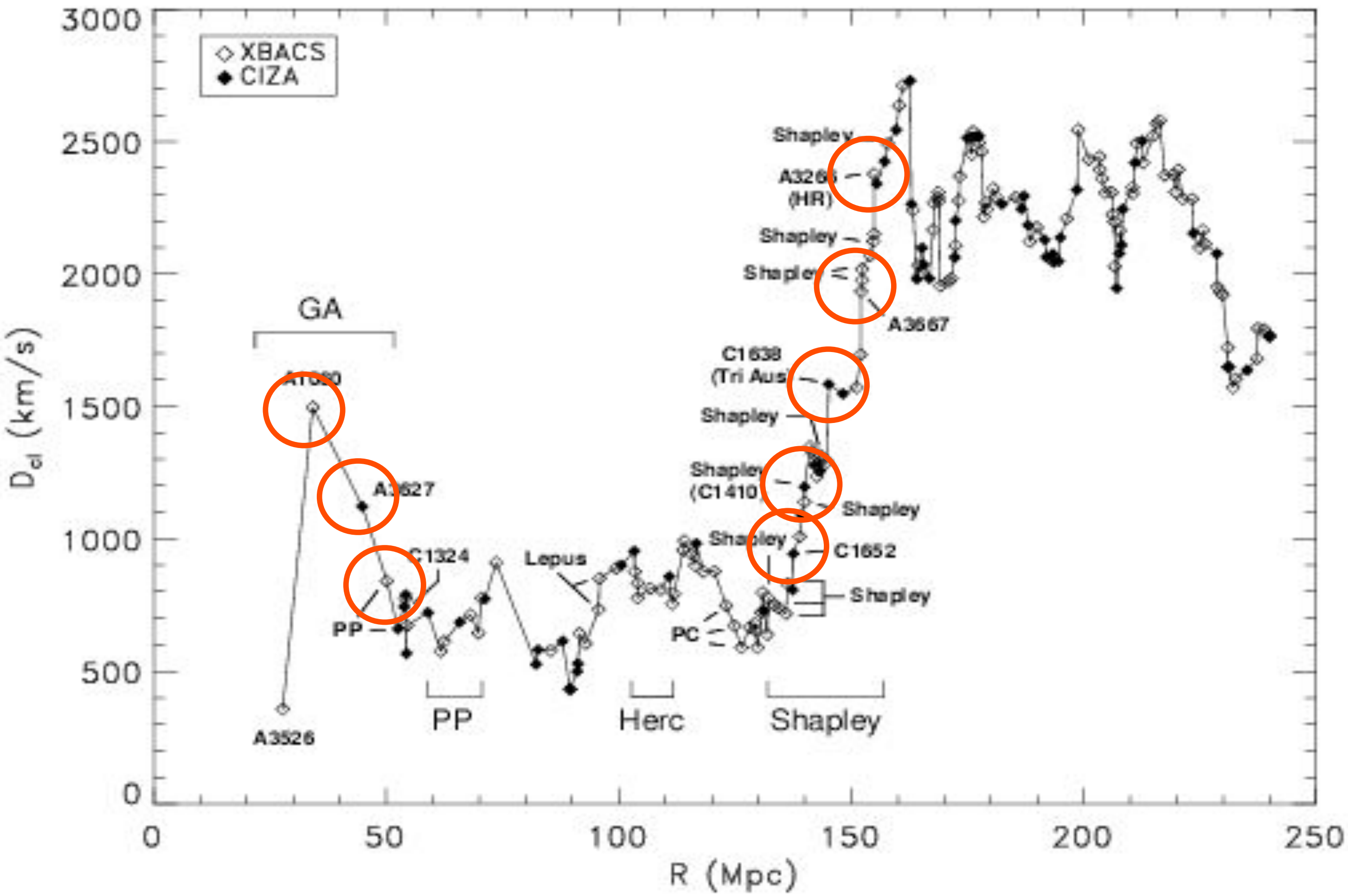



Figure 3. Schematic dipole profile; see text for details. Each symbol represent a cluster used in our analysis. Abell and CIZA clusters begin with the letters 'A' and 'C', respectively. Acronyms are GA: Great Attractor, PP: Perseus-Pegasus, PC: Pisces-Cetus, HR: Horologium-Reticulum. We find that the Shapely concentration is the single supercluster most responsible for producing the increase in the dipole signal between 140 and $160h^{-1}$ Mpc.

**Whereas most recent results from 2M Re**
*(Erdogdu et al. 2006a, 2006b)* **find for 23’200 2**
**with $K^0 < 11.25$ complete with redshifts fo**

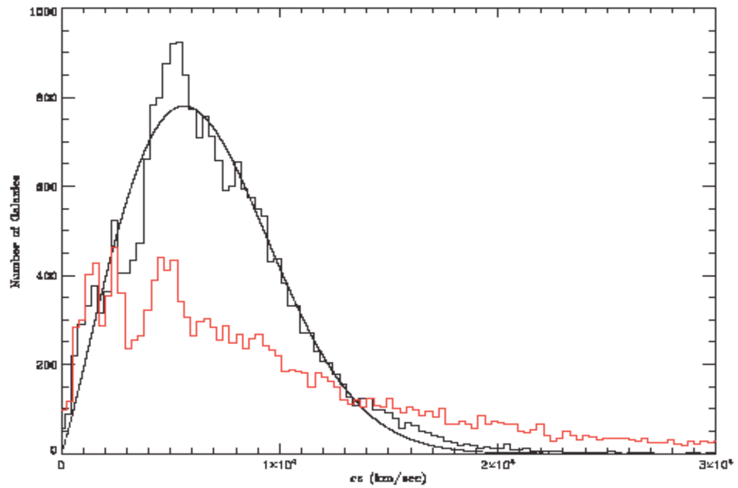
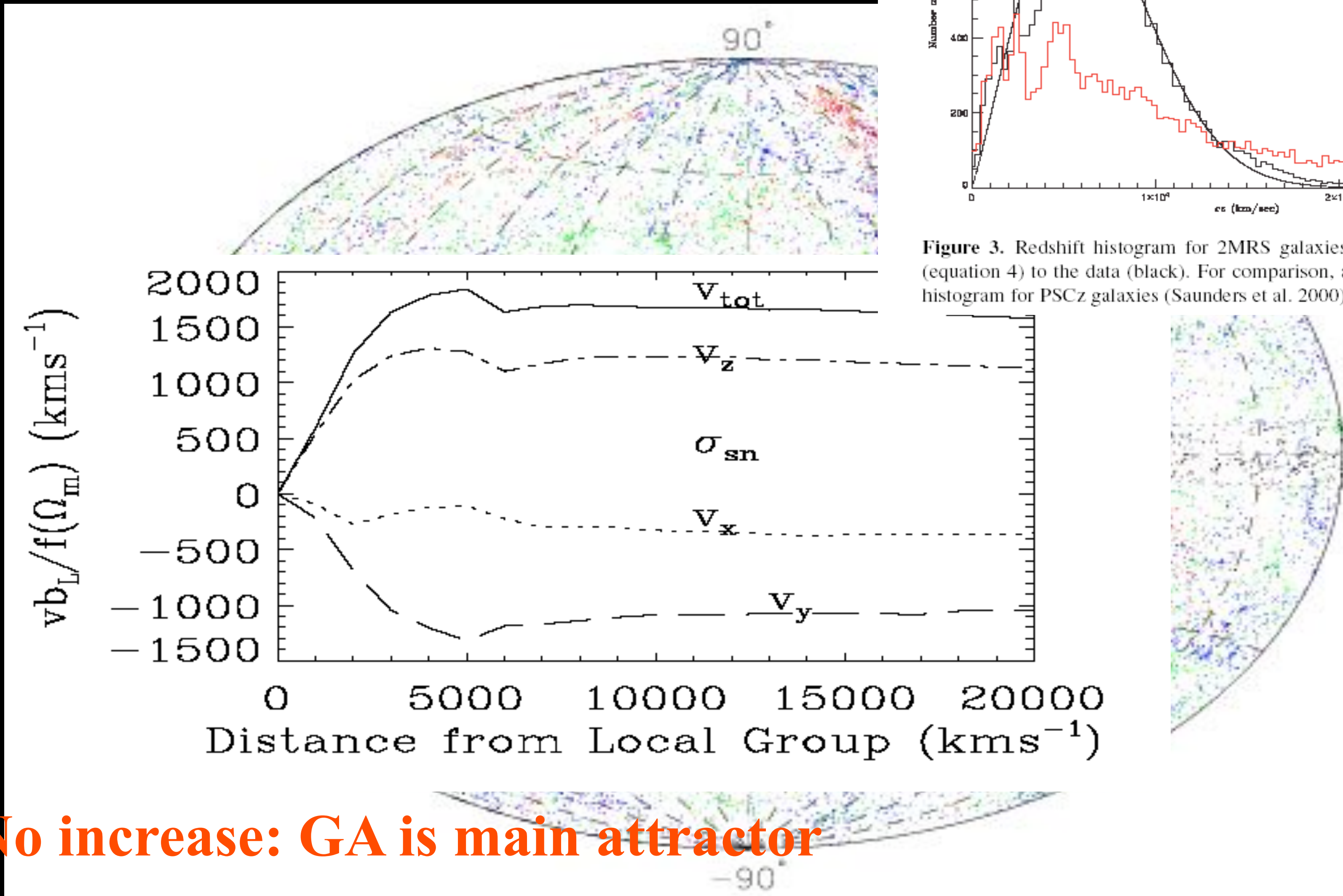



**Figure 3.** Redshift histogram for 2MRS galaxies and a least-squares fit (equation 4) to the data (black). For comparison, also plotted is a redshift histogram for PSCz galaxies (Saunders et al. 2000) (red).



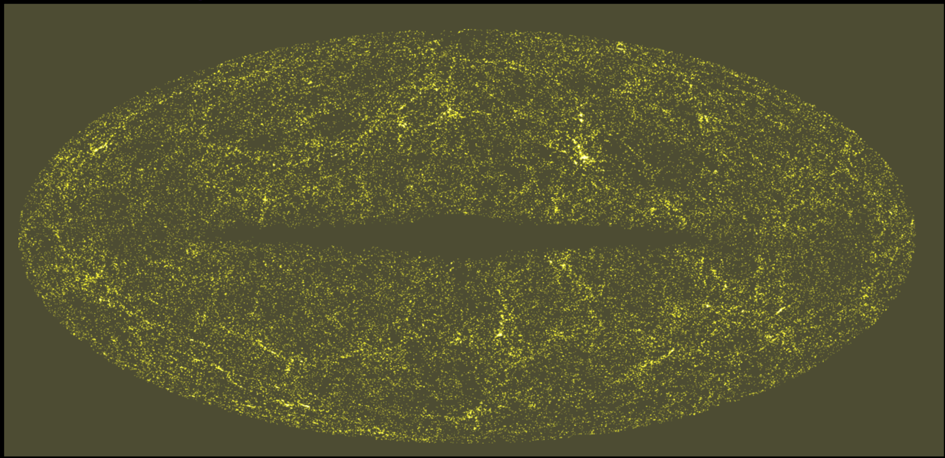

**No increase: GA is main attractor**

# 2MASS Galaxy distributions and density fields

## around the Shapley Concentration distance

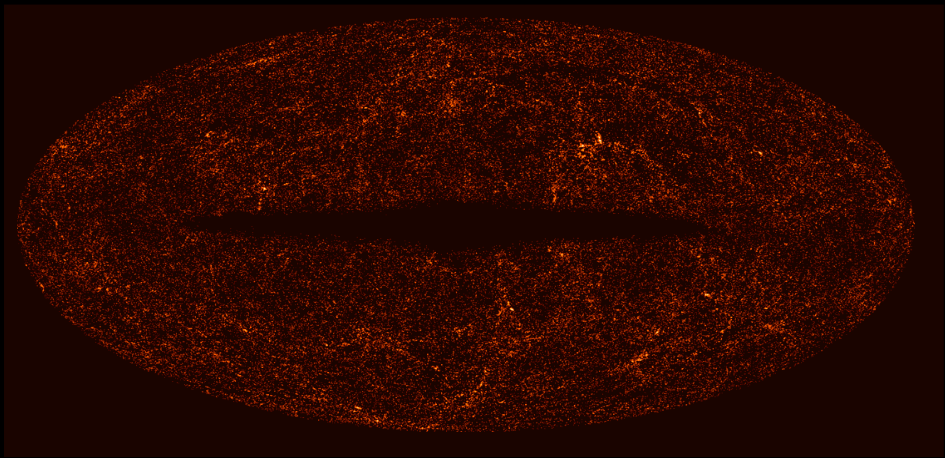
*Jarrett 2004, PASA*

**75,000 total galaxies with 0.04 < z < 0.05; ~12-15000 km/s**



**Shapley Concentration (Abell 3558)**

**113,000 total galaxies with 0.05 < z < 0.06; ~15-18000 km/s**



**Ursa Major      Sculptor Supercluster**

*Erdogdu et al. 2006, MNRAS 368*

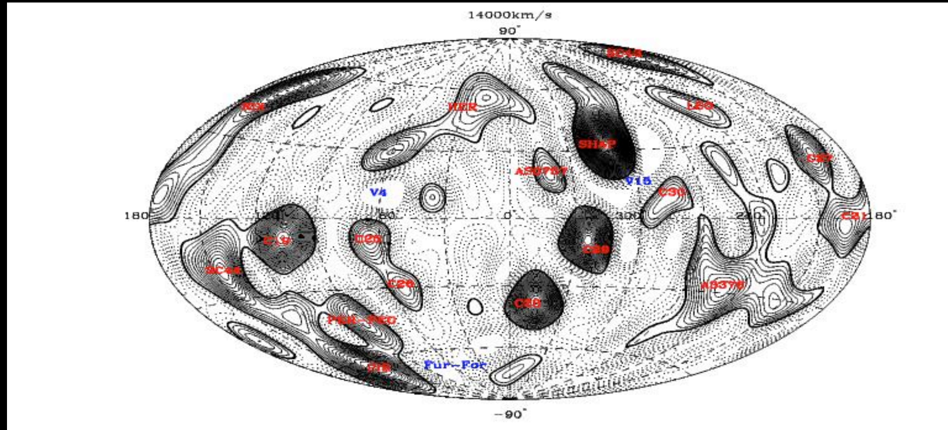



**Figure 9.** Same as in Figure 3 but evaluated at 14000 km $s^{-1}$. The overdensities are Rixos F231_526 (RIX), SC44, C19, Pisces (Pis), Perseus-Pegasus (Per-Peg), C25, C26, Hercules (Her), Abell S0757, C28, Shapley (Shap), C29, C30, SC 43, Leo, Abell 3376, C27 and C21. The voids are V4, Further-Fornax (Fur-For) and V15.

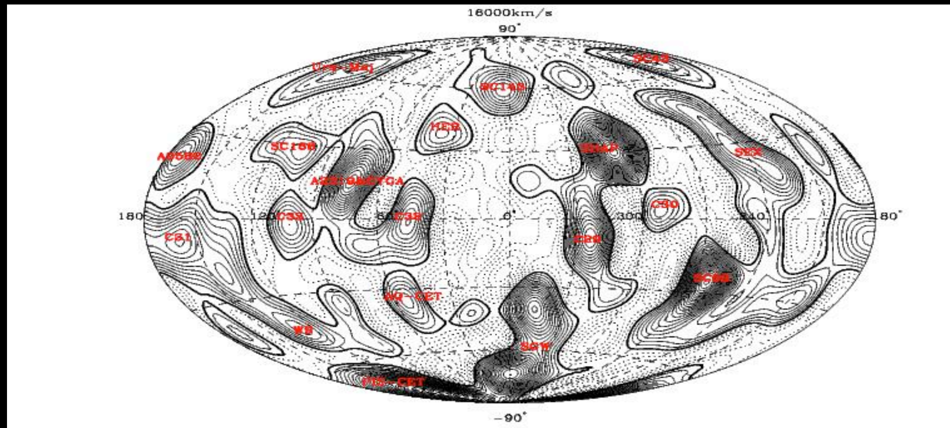



**Figure 10.** Same as in Figure 3 but evaluated at 16000 km $s^{-1}$. The overdensities are Abell 582, C31, Ursa-Major (Urs-Maj), SC168, West 9 (W9), C33, Abell 2319 & Cygnus A (CYGA), Pisces-Cetus (Pis-Cet), C32, Aquarius-Cetus (Aq-Cet), Hercules (Her), SC143, Southern Great Wall (SGW), C29, Shapley (Shap), C30, SC43, Sextans (Sex) and SC68.

# (a) Attempt a NIR TF flow field analysis in the ZOA based on the Parkes HI-ZOA survey

*Wendy Williams, MSc thesis UCT, submitted Feb 2011*

**Simultaneous *J H K$_s$* images**

**IRSF/SIRIUS 1.4m telescope, Sutherland**

**High sensitivity**

**Exposure time: 10 min (2MASS 10 s)**

**→ 2mag deeper in K than 2M**

**High resolution**

**Pixel scale: 0.45''/pix (2MASS 2''/pix)**

**HI positions ~4'**

**FoV: 8' × 8’**

**Sample Selection *v* < 6000 km/s**

**580 of ~850 fields observed**

**→ quite complete around GA**

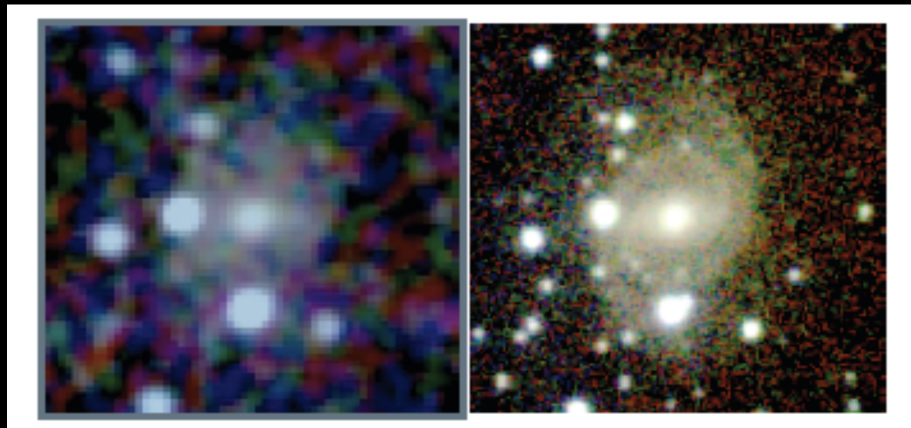


**image scale ~1’x 1’**

# Source Detection

- **Visual search and identification of HI counterparts**
  - **RGB false colour composites** *(galaxies are red & extended)*
  - **Additional information via HI profile**
- **567 detections in 426 fields (73%);** *141 fields with multiple possible counterparts*

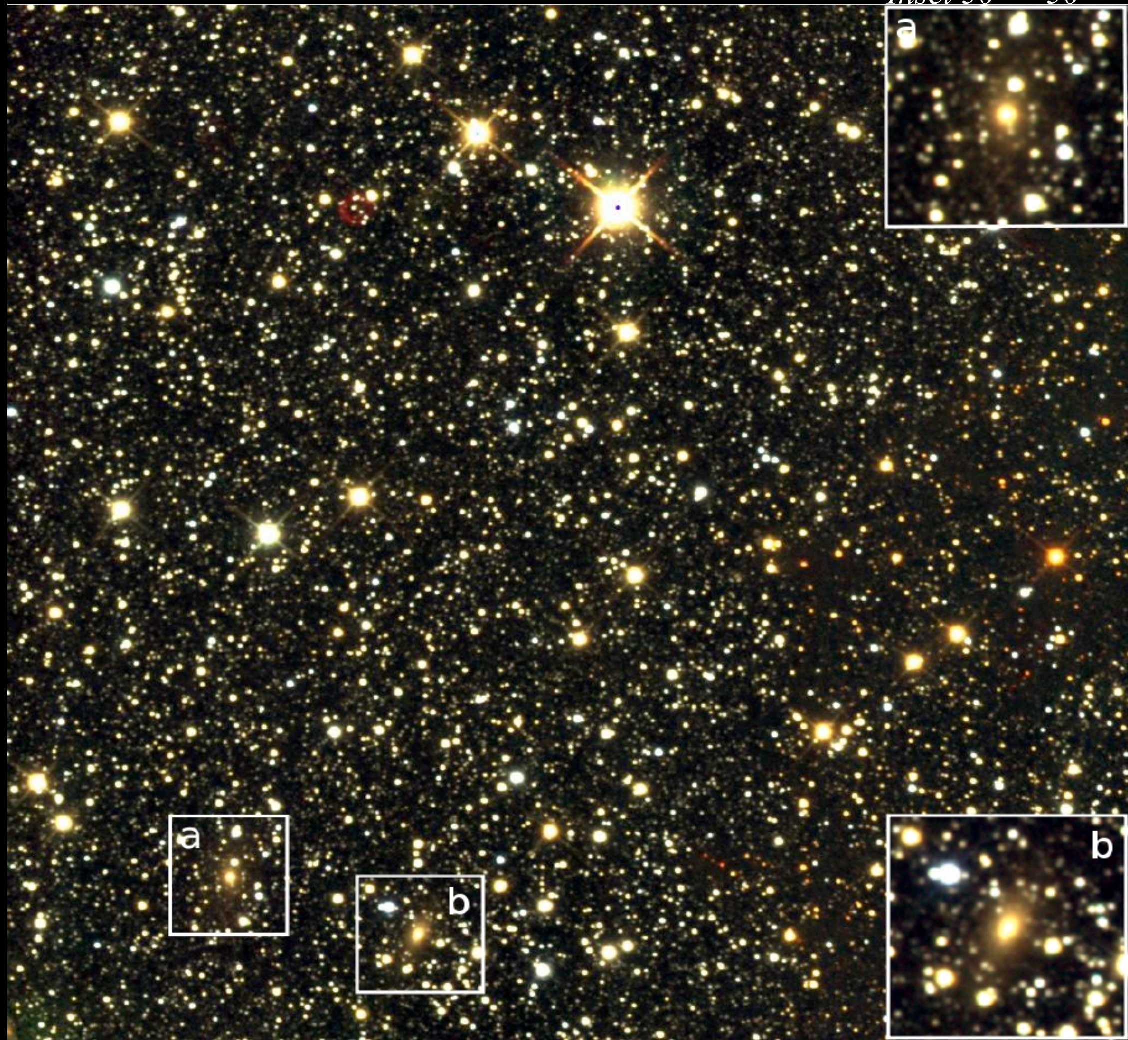
→ **Led to 196 unambiguous counterparts for use in TF, i.e.**

→ **Not too face-on (b/a < 0.72)**

→ **Have reliable linewidths**

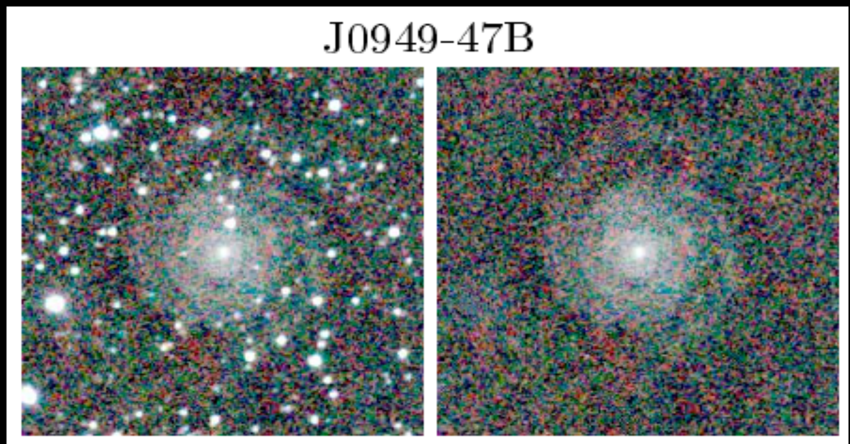
→ **log $W_{50}$ > 1.9**

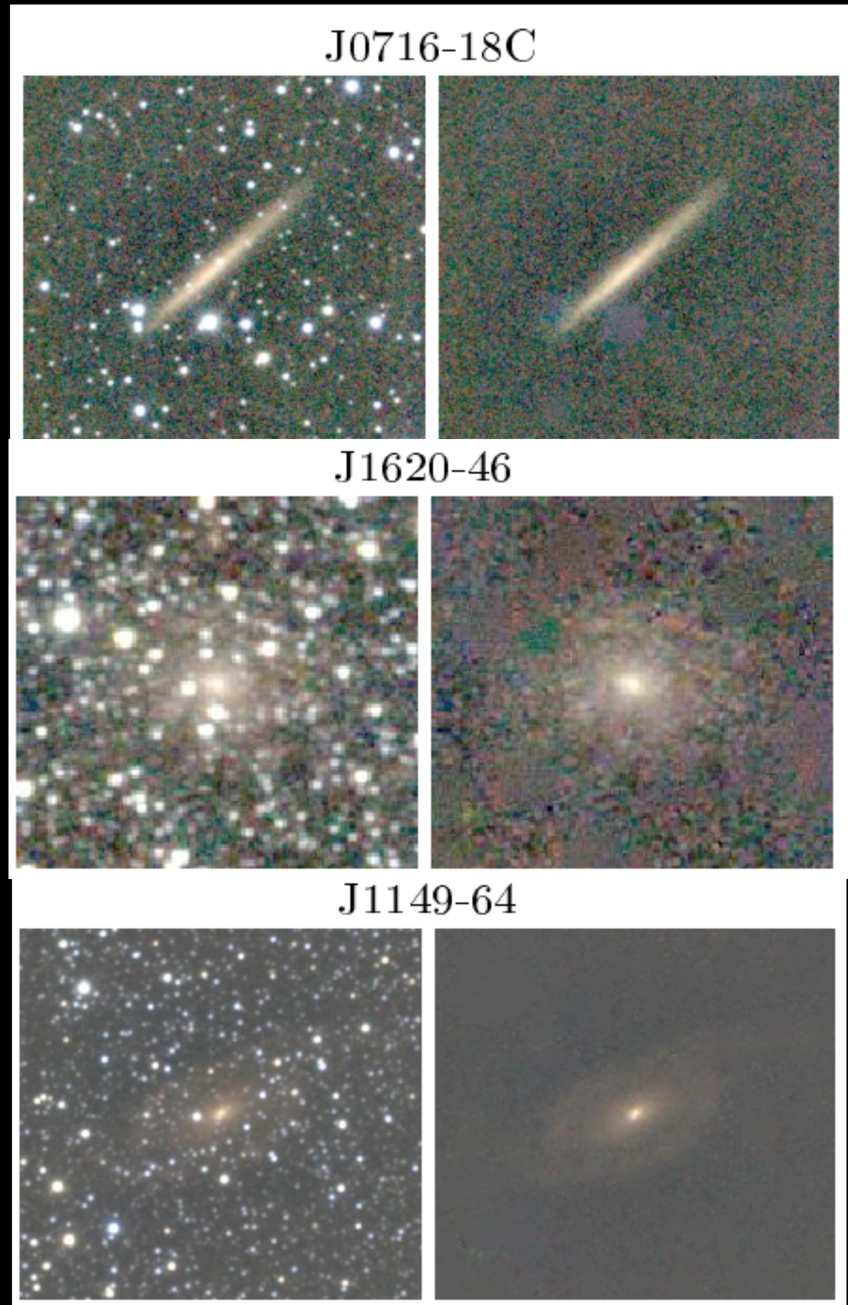
**7.'7 × 7.'7**
*(l,b)* = (319.756,1.226)
$A_V$ = 8.$^m$56
*Inset 50″ × 50″*



# Star Subtraction

- Accurate photometry requires the removal of foreground stars
  - Automated PSF fitting
  - Semi-automated detection and removal of stars using the fitted PSF
    - Modifications to previous routines which removed galaxy structures



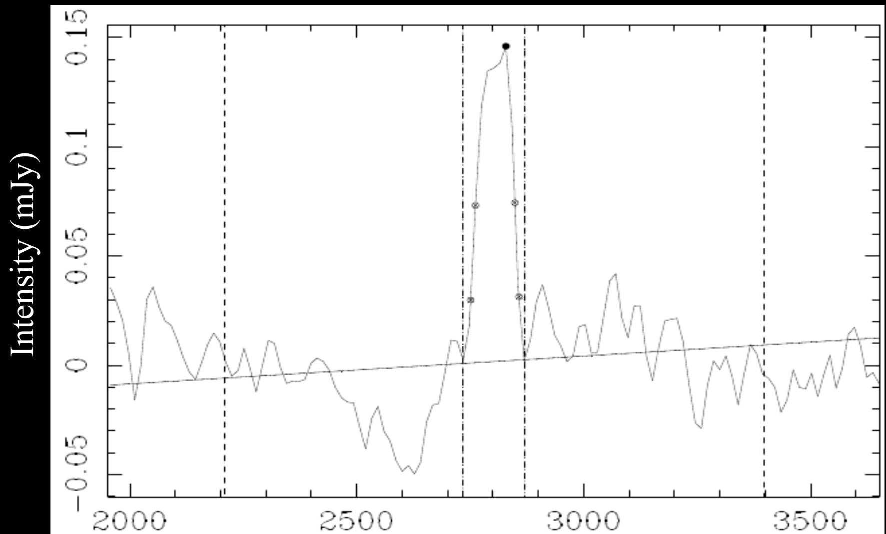
# Narrowband HI Observations

**Improved S/N and velocity resolution for more accurate linewidths**

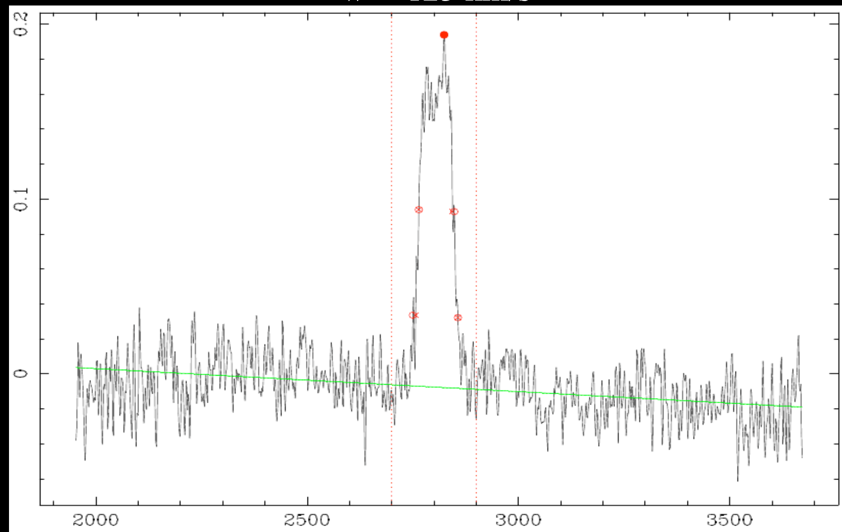
**Narrowband observations (Feb 2010)**

- **70 hrs : 82 galaxies**
- **1.6 – 6.4 km/s channel separation**
- **$\langle t_{exp} \rangle \sim 40$ min**

**J0744-13** (80”)
*(l,b)* = (230.66,5.50)
*v* = 2307 km/s
*w* = 123 km/s




Velocity (km/s)

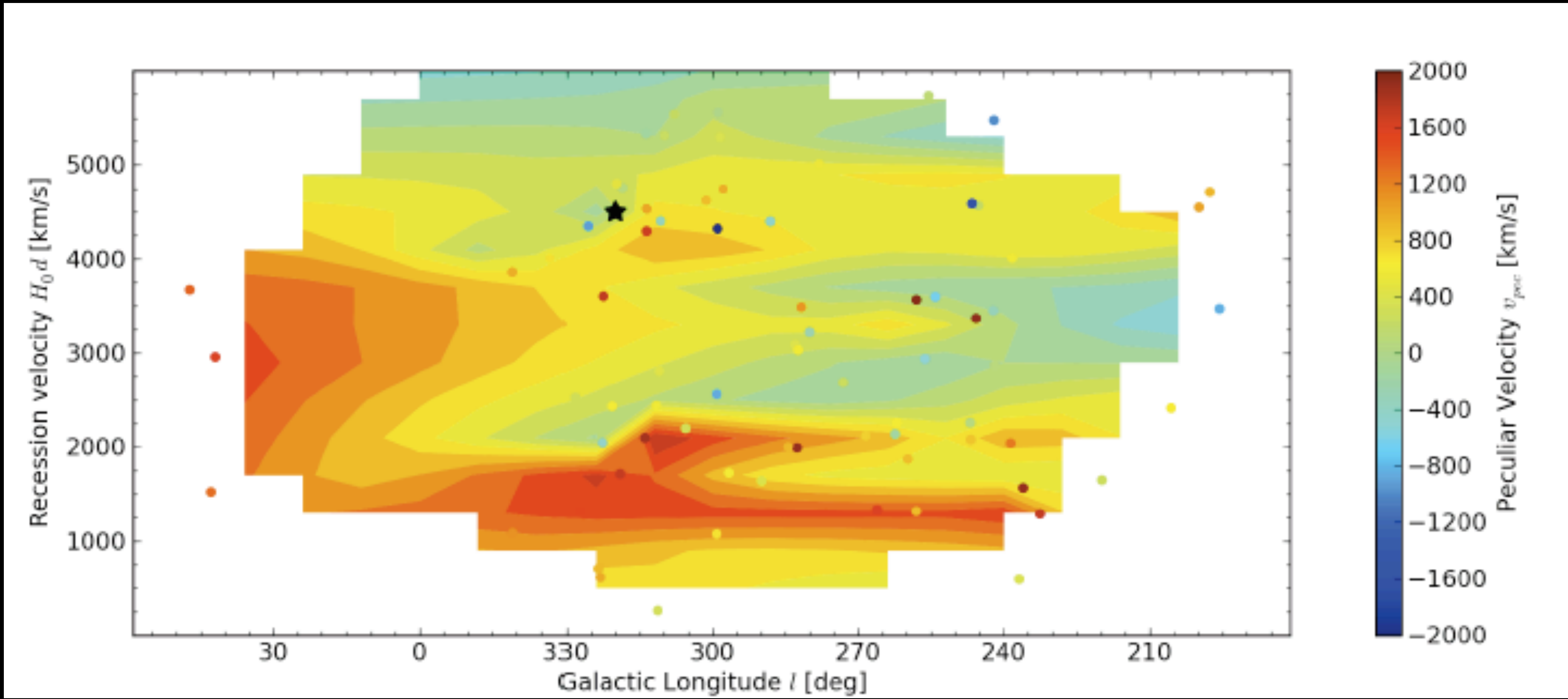



Velocity (km/s)

**→ Derivation of peculiar velocities from NIR-TF relation following precepts and calibration by *Masters et al. 2008* for 2MTF**

# Preliminary flow-field with very constrained data-set

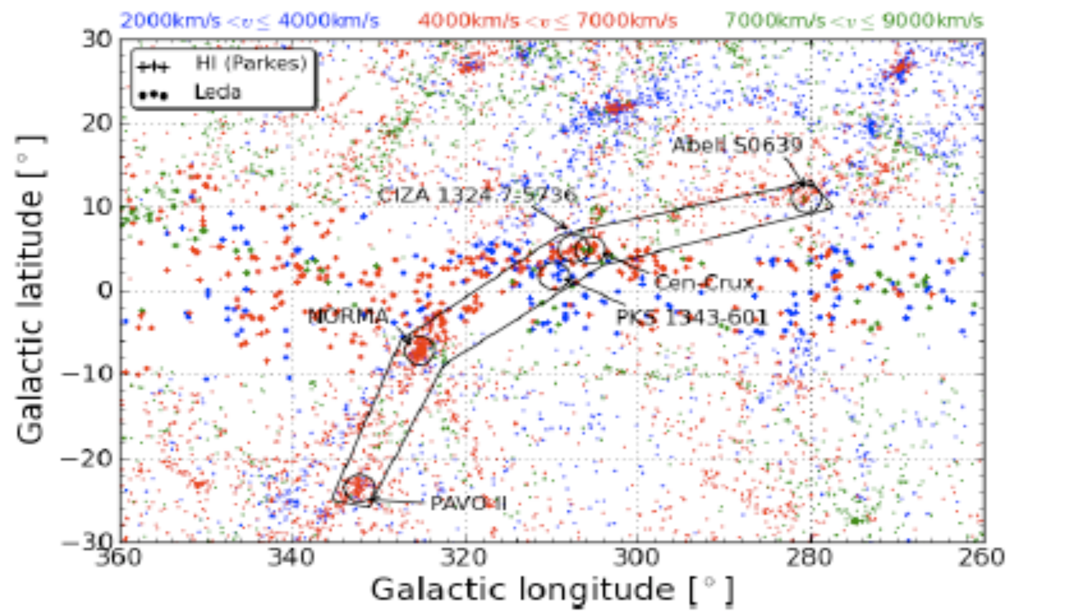
**Only galaxies with lg W > 2.3 and $v_{pec}$ < 2000 km $s^{-1}$ (N=90, mostly new HI data)**
**Nearest neighbour linear interpolation**
**Great Attractor at *(l, b, v)* = (320º, 0º, 4500 km/s)** ***(Kolatt+ 1995)***



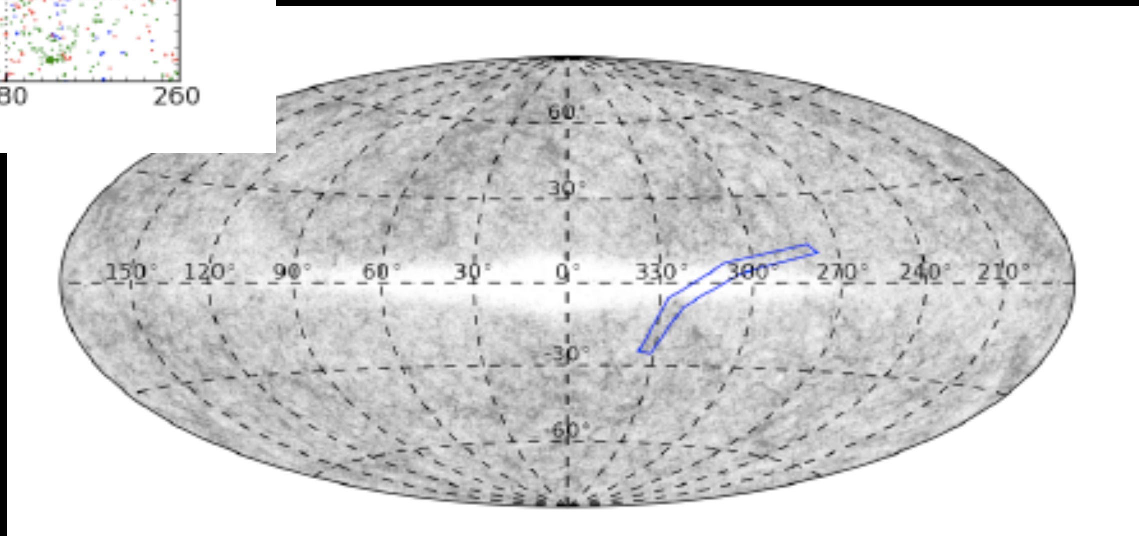

Clear flow from the front towards GA; not seen around Puppis/Vela
Some signature of back flow (stronger in less constrained data subsets).

# (b) The Mass Distribution of the Great Attractor Wall as Revealed by a Deep NIR Survey (IRSF)

*Ihab Riad, PhD thesis 2010, UCT*



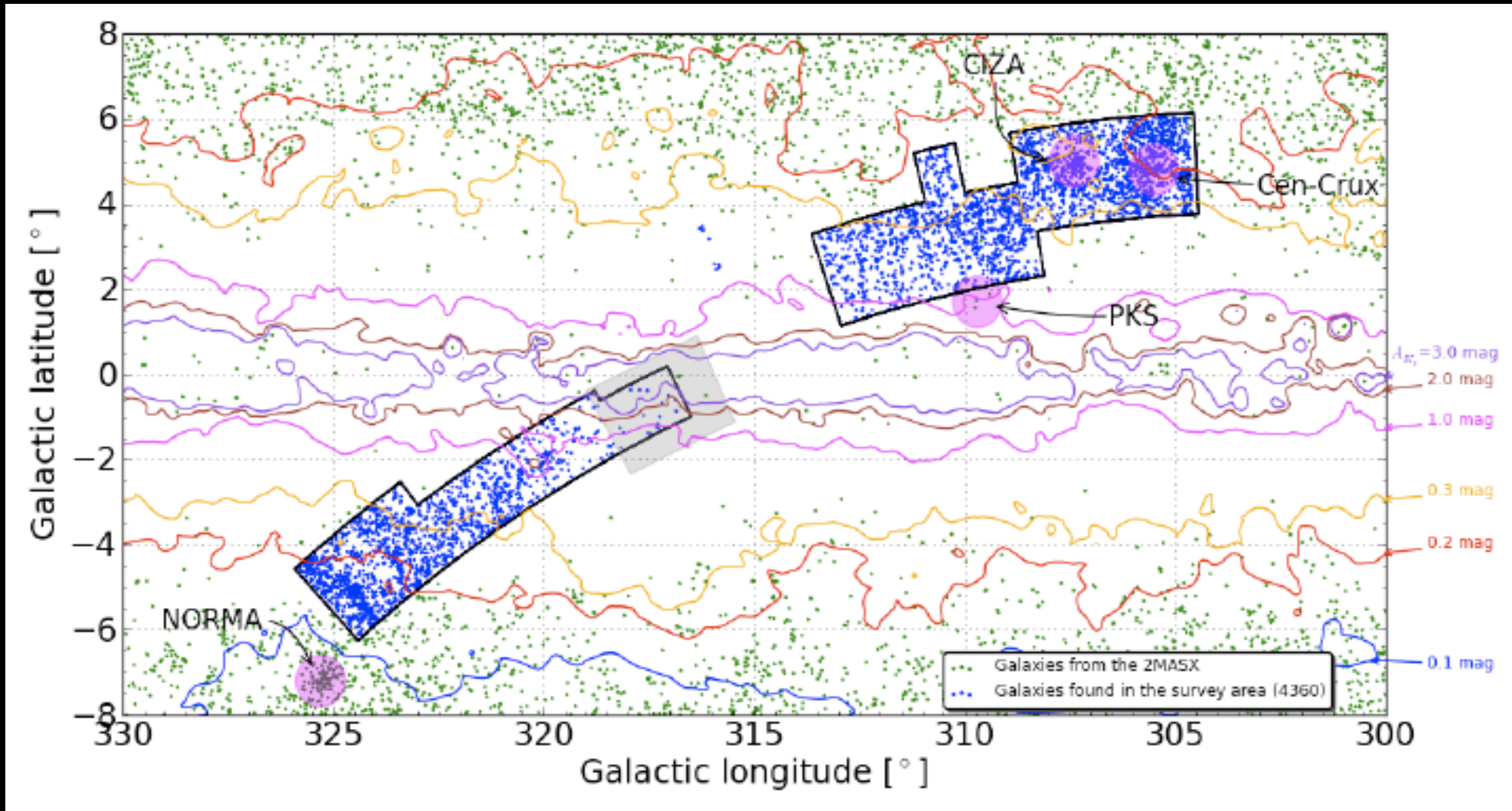

The survey area was selected along the GA Wall Wall (or Norma Wall)
- where optical surveys fail
- HI surveys are sparsely sampled



And where
-2MASX becomes incomplete sampled (b < 7º)
-But star-crowding not too severe

**The Survey:** - about 3000 fields (7.7’ x 7.7’) → 37.5 sq. deg.

- Observations about 4 x 6 weeks from 2006 to 2009
- 10 min exp; 0.45 arcsec pixels




**→ 4630 galaxies identified**

*Galaxies are detected up to Log N=5.0; 89% of galaxies lie in log N <4.72 area*

## A photometric catalogue in J, H, and K was prepared for all 4630 galaxies

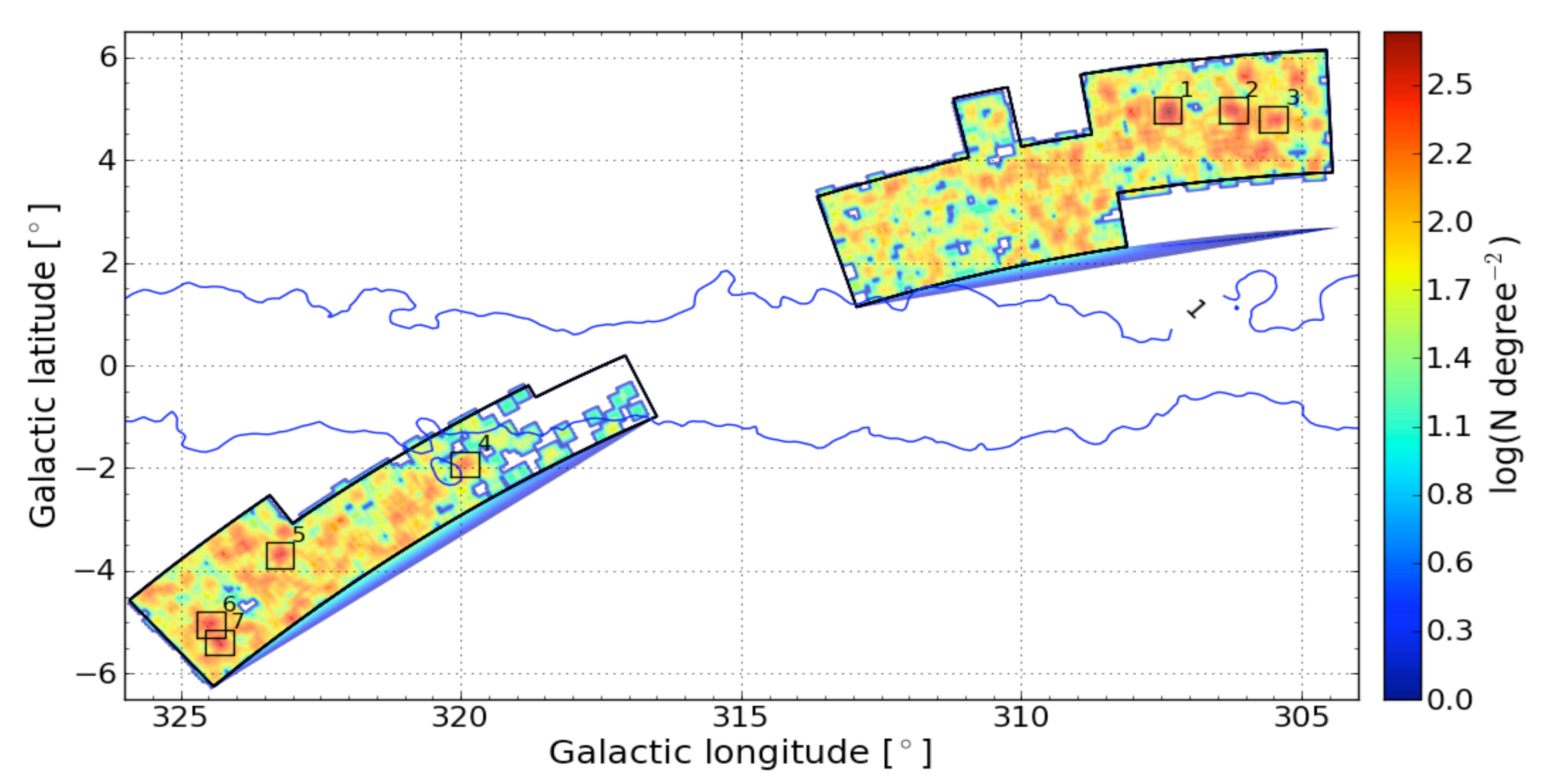
**After a careful analysis of cumulative counts as a function of foreground extinction in each band:**

Observed parameters
Galaxies are complete for $R(K_{20}) > 7''$, and $K_{20} < 15.6$ mag

**Extinction-corrected parameters *(following Riad et al. 2010)*:**
**- The survey is complete for $K^o < 14.8$mag where $A_K < 1.0$mag**
**- 89 % of survey area has $A_K<1.0$mag**
**- the same 89% of the area is in the region where star density affects counts and completeness very little, i.e. log $N_{(Ks<14)}$ /deg$^2$ = 4.7**
**- This area contains 99.2% of the galaxies**

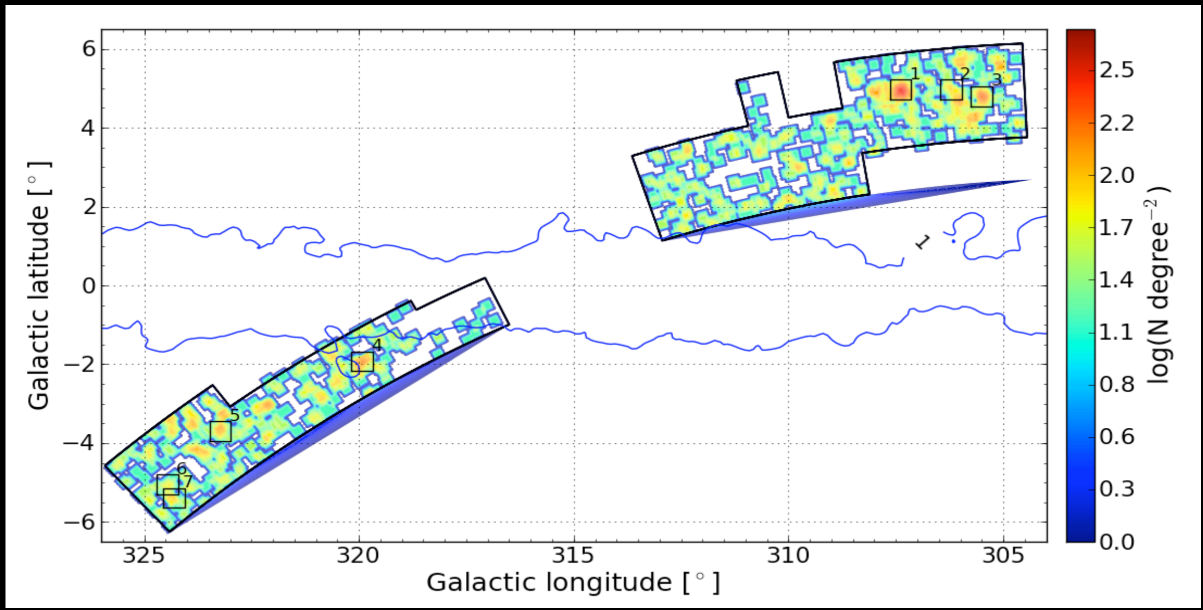
this is actually confirmed when looking at cumulative number counts subdivided into five areas of different extinction and star density

# (a) Analysis of the LSS based on the 2-D distribution of galaxies in the NWS




Density/square degree for all galaxies with $K^o < 14.8$ reveal 7 density peaks

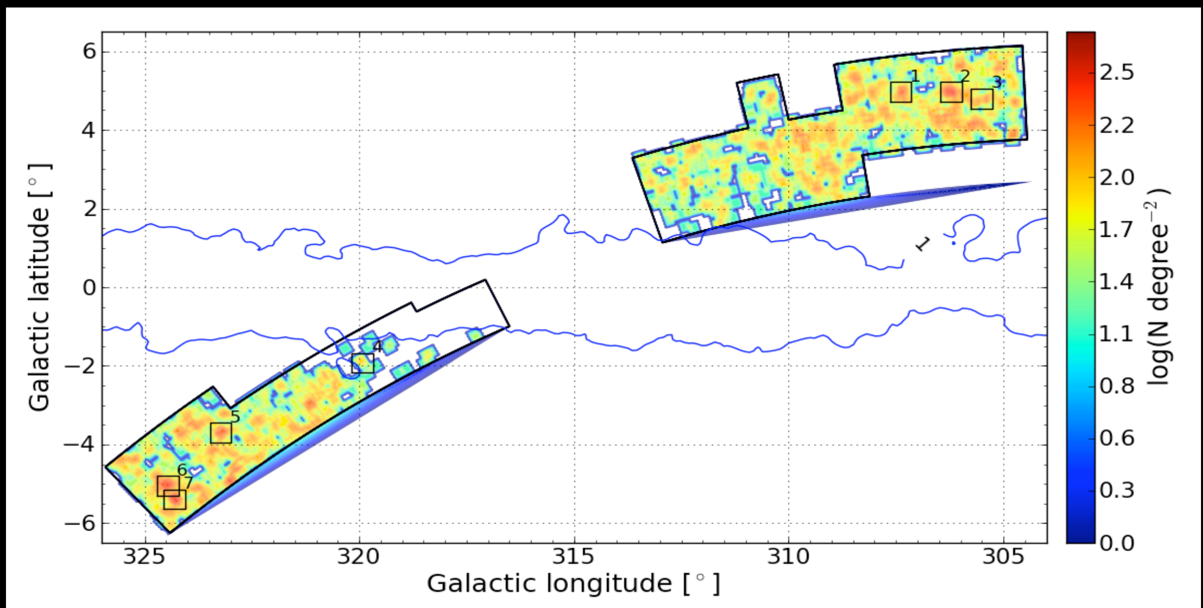
# Subdivision into brighter (nearer) and fainter (more distant) galaxies:




## $K^o < 13.5$:

Three peaks: 1, 3, and 4

1 and 3 coincide with previously identified clusters in GA Wall (CIZA J1324.7-5736 and Cen-Crux)

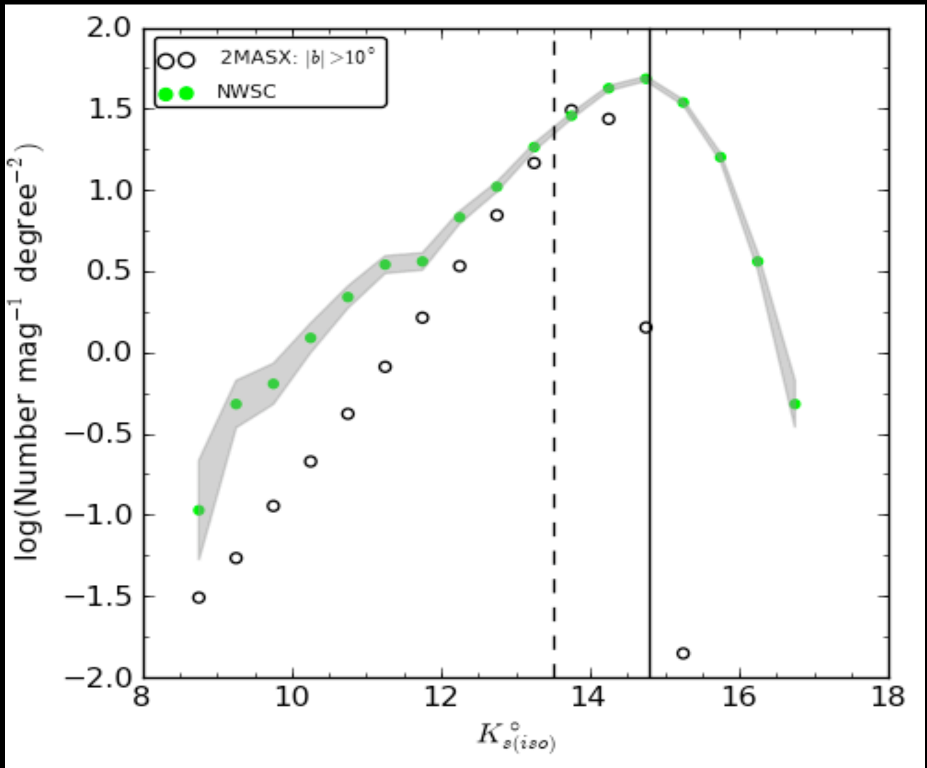



## $13.5 < K^o < 14.8$:

Peaks 2, 4 and particularly 6 and 7 are quite strong;
→ likely to be more distant

# (b) Cumulative number counts of Norma Wall Survey and comparison to 2MASX whole sky survey (|b| < 10°)

Green dots: Norma Wall Survey for completeness limited area ($K^o$<14.8, logN* < 4.72)
Grey band outlines error bars




Note:

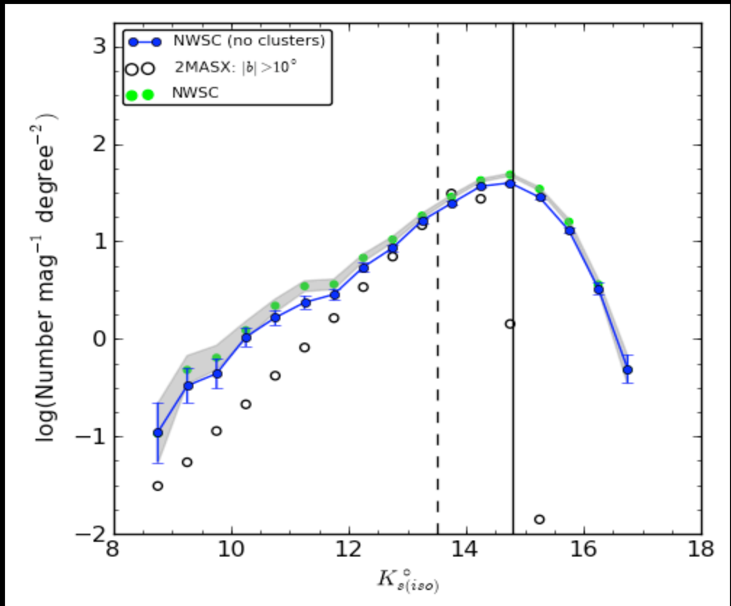
Except for the faintest mags the NWS counts are higher
$8.5 < K^o < 13.5$

This is particularly prominent
$8.5 < K^o < 11.5$

This is not due to the 2 known clusters in the GA Wall→

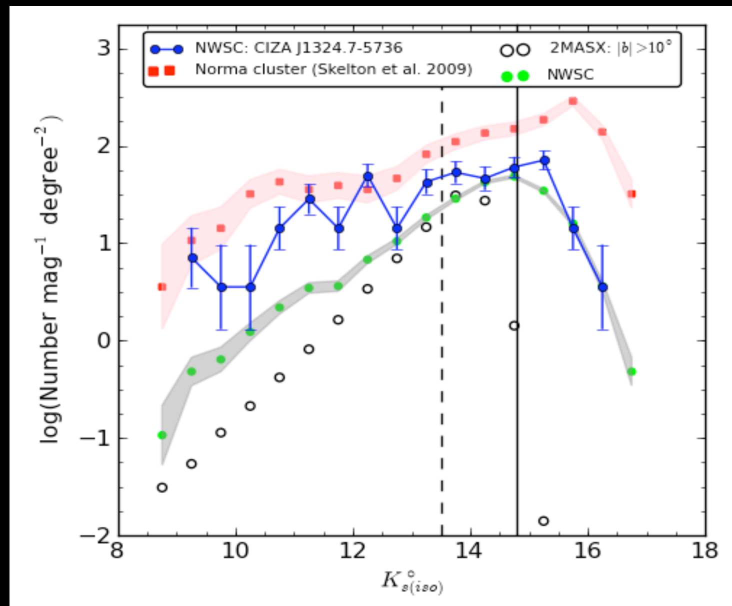
2MASX whole sky survey: excluding |b| > 10°, completeness limit for $K^o$<13.5,

# Comparison to other (field and cluster) surveys



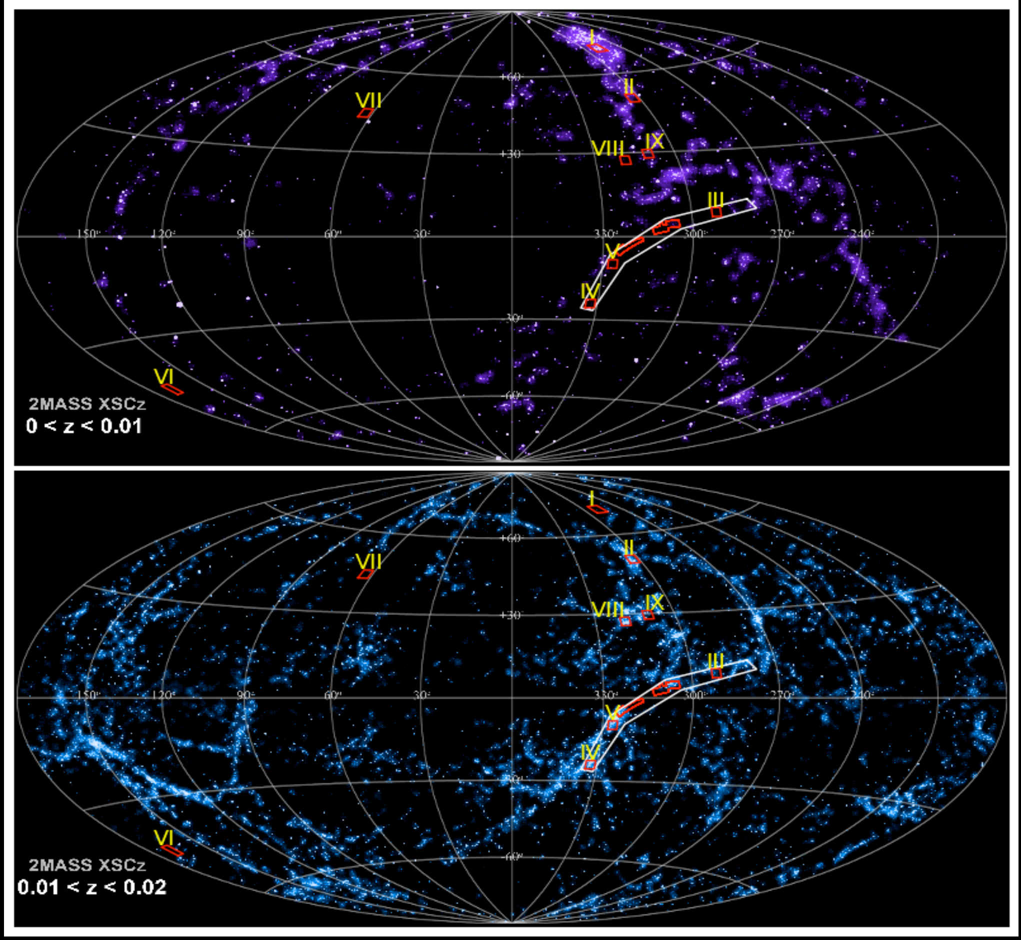

**NWS without CIZA and Cen-Crux cluster**

**→ The 2 clusters hardly effect overall counts**



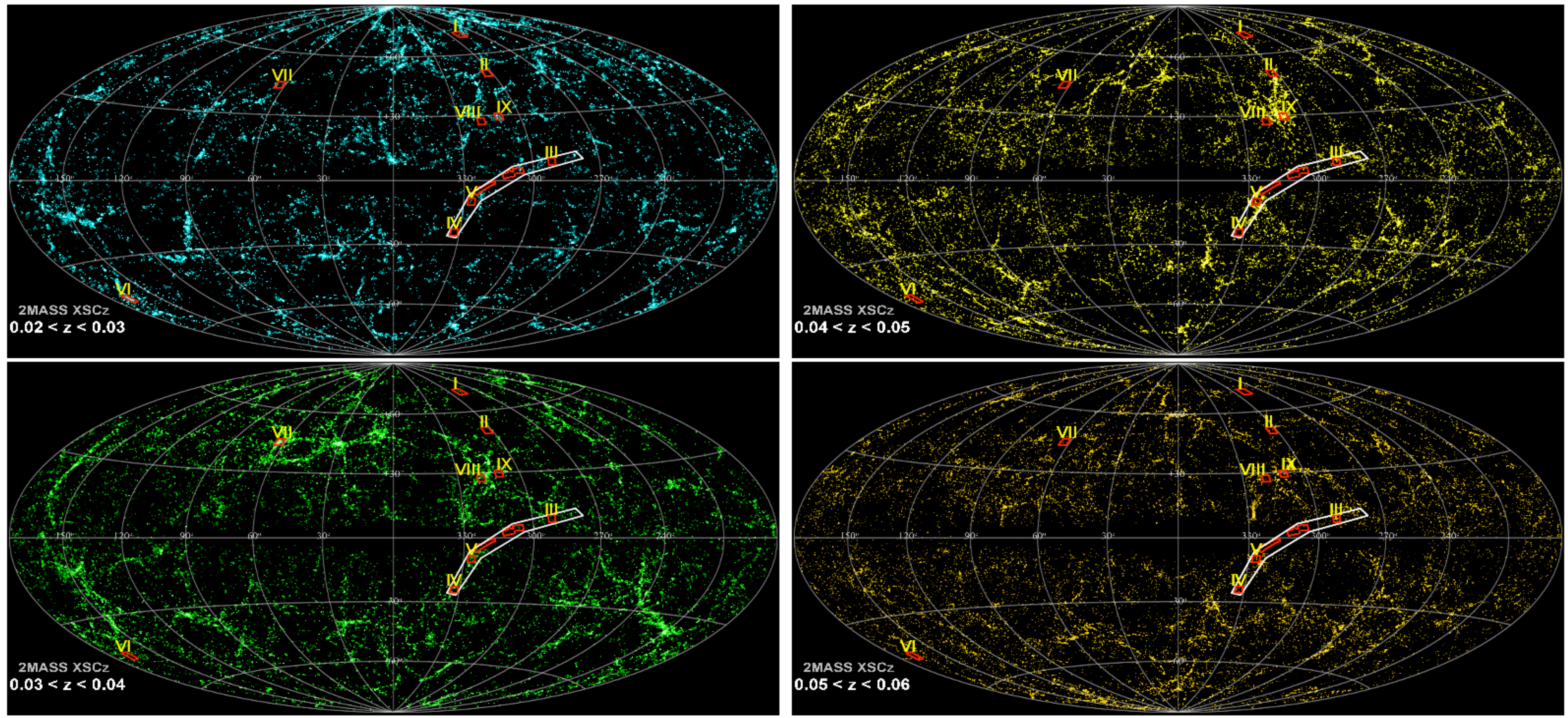

**Cluster counts: Norma and CIZA**

**→ While the counts are higher than 2MASX, the clearly are not representative of cluster densities**




| | |
|---|---|
| I. | 0 < z < 0.01; **1.29** ; close to Virgo cluster (5°) |
| II. | 0.01 < z < 0.02; **1.40** ; overdensity (cluster) within wall/filament |
| III. | 0.01 < z < 0.02; **1.42** : Norma Wall from Ciza -> Abell S0639 (Vela) |
| IV. | 0.01 < z < 0.02; **1.36** ; 0.2° from Pavo cluster (higher density than wall) |
| V. | 0.01 < z < 0.02; **1.40** ; 2.3° from Norma Cluster |
| VIII. | 0.03 < z < 0.04; **1.37** ; but also 0.01 – 0.02; comparable to GA + Shapley |

•

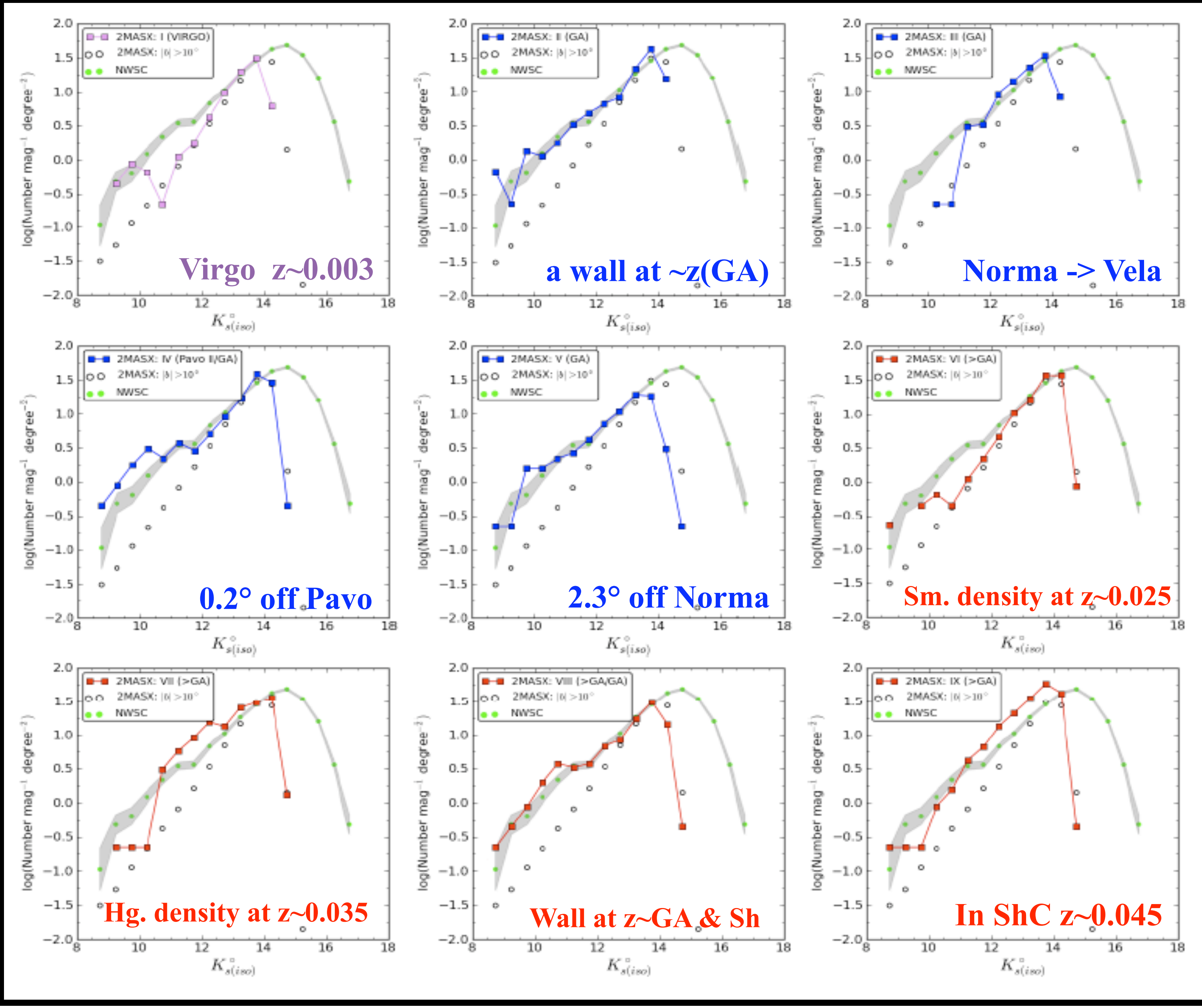



VI. $0.02 < z < 0.03$; **1.26** ; overdensity in the background of NWS *(should have low counts for bright galaxies)*

VII. $0.03 < z < 0.04$; **1.56** ; density enhancement *(should have low counts for bright galaxies)*

VIII. $0.03 < z < 0.04$; **1.37** ; but also 0.01 – 0.02; comparable to GA + Shapley

IX. $0.04 < z < 0.05$; **1.62** ; 2.9°from A3558 (central Shapley cluster)



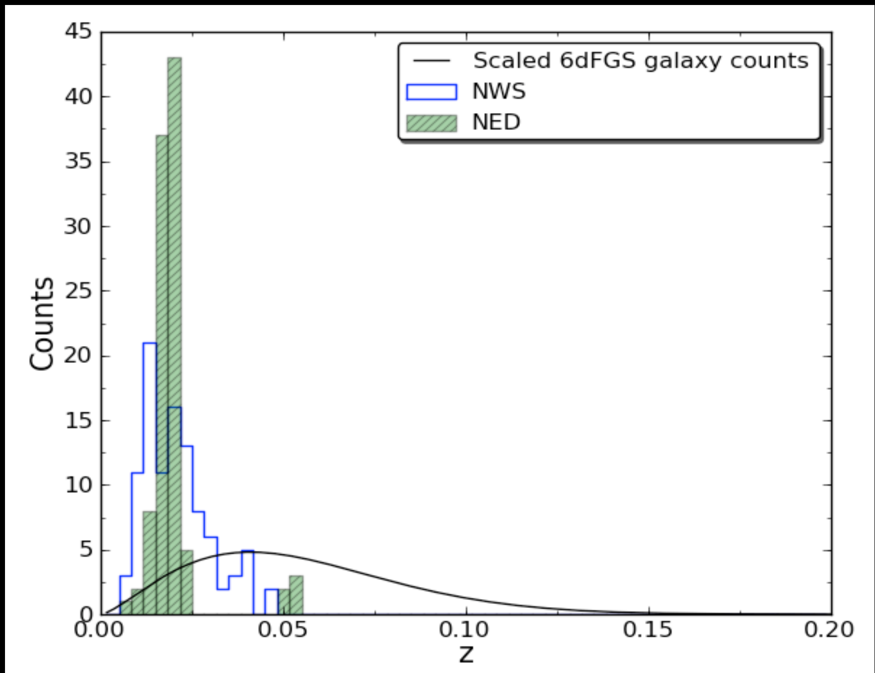
2MASX: I (VIRGO)
2MASX: |b| >10°
NWSC
Virgo z~0.003
2MASX: II (GA)
a wall at ~z(GA)
2MASX: III (GA)
Norma -> Vela
2MASX: IV (Pavo II/GA)
0.2° off Pavo
2MASX: V (GA)
2.3° off Norma
2MASX: VI (>GA)
Sm. density at z~0.025
2MASX: VII (>GA)
Hg. density at z~0.035
2MASX: VIII (>GA/GA)
Wall at z~GA & Sh
2MASX: IX (>GA)
In ShC z~0.045
log(Number mag$^{-1}$ degree$^{-2}$)
$K^{\circ}_{s(iso)}$

## In Summary:

- The NW-Survey reveals a general overdensity over the whole NWS area
- that seems linked to galaxies at the approximate GA distance
- but is not due to any particular cluster(s) → a quite homogenous overdensity
- possibly influenced at the faint end of more distant LSS (related to Ara and Triangulum – possibly linked Shapley?)

## (c) The 3-D distribution of the galaxies in the NWS based on photometric redshifts

N = 128 → 2.9% of NWS galaxy sample
→ all at lowest extinction levels
→ most of them (78%) at GA distance
only 5% foreground, 17% beyond GA,
none z<0.12



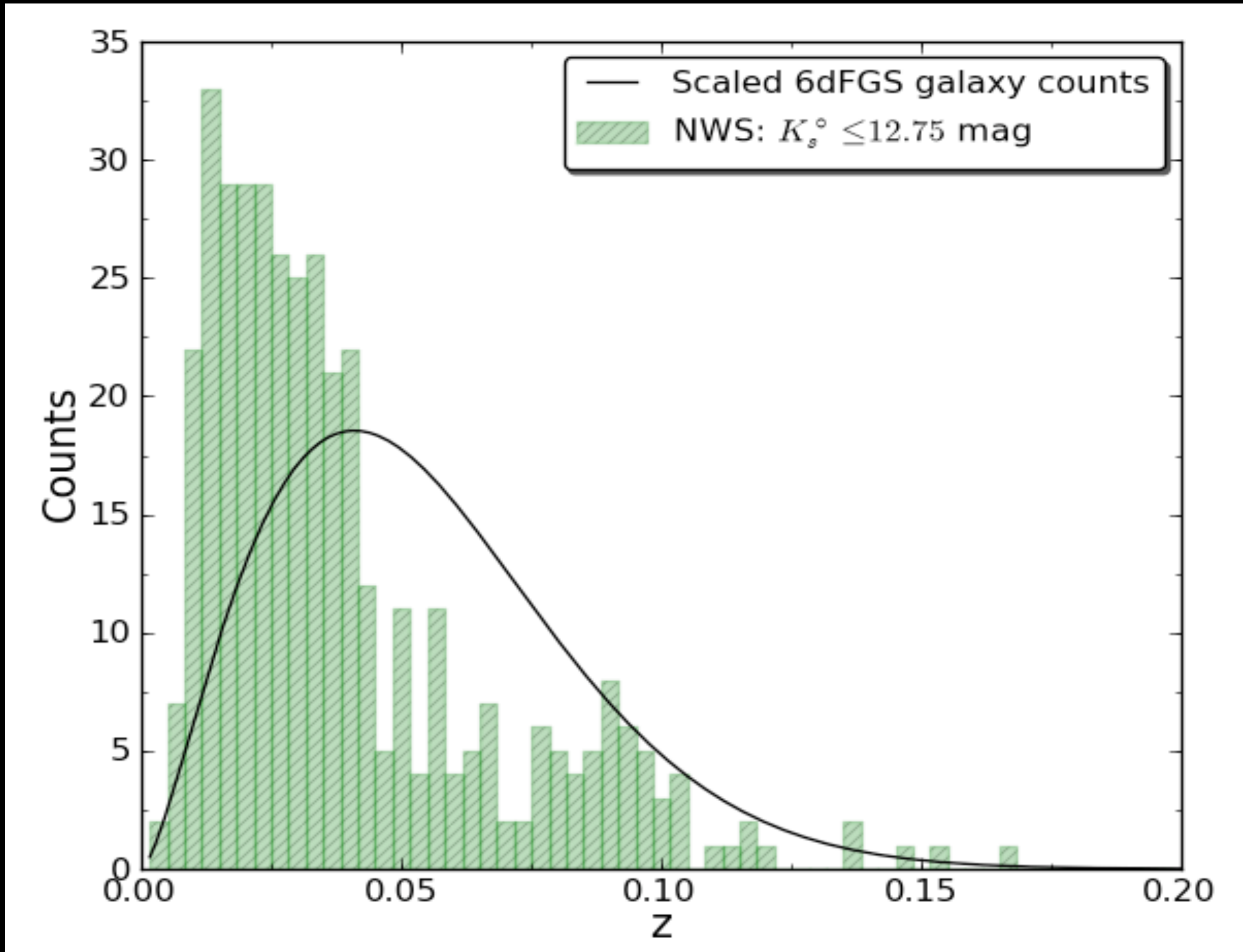

For galaxies with K° > 12.75

Note:

- Phot-z errors are large (30-40%)
- Smears out signature of LSS
- phot-z skewed to higher z

→e.g. most of the galaxies have z-phot
0.02 - 0.03 in $z_{phot}$
Compared to spect-z
0.005 - 0.04 in $z_{spect}$

## Distribution in redshift space of NWS galaxies with K° < 12.75
## and
## Comparison to 2MRS of the southern sky (6dF; complete to K° < 12.75)




Significant 'but smeared out' peak around GA distance compared to 6dF

Would be even higher if not broadened due to phot-z

Scaling 6dF distribution by ignoring GA overdensity

Secondary peak at z~0.09

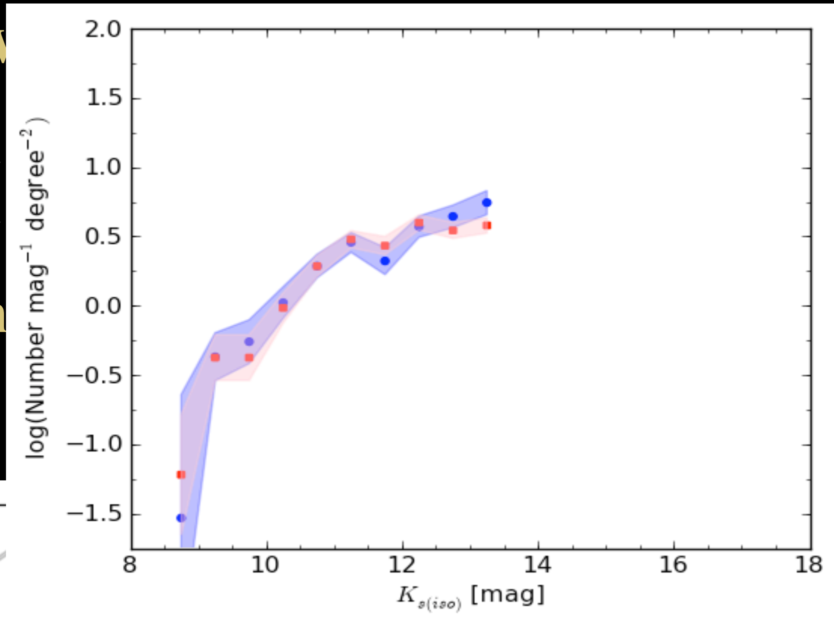
→coincides with peaks 6 and 7 in 2D density maps

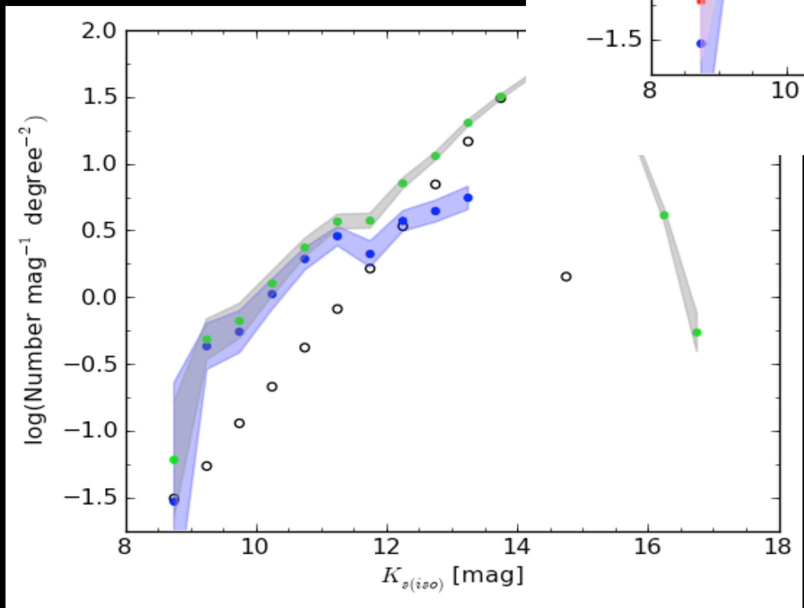
→SIGNIFICANT OVER-DENSITY AT GA DISTANCE CONFIRMED

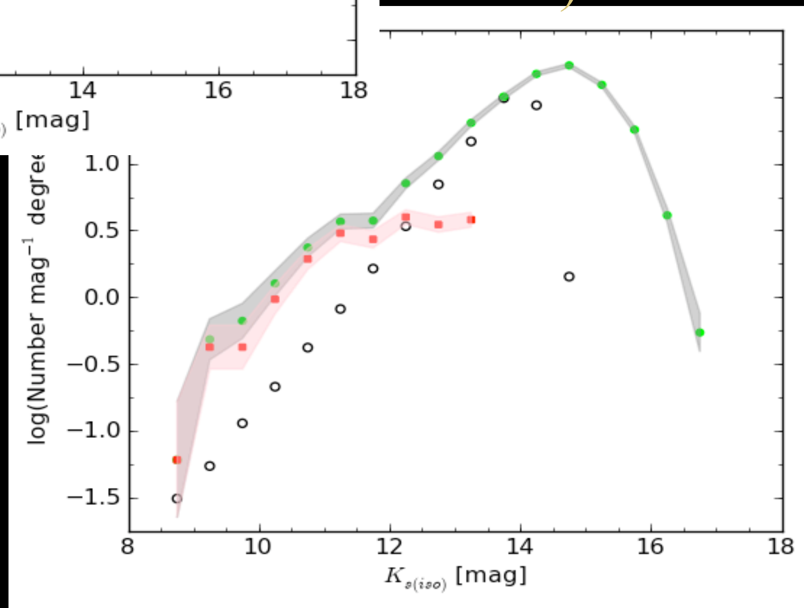
## (d) Determining the mass of the overdensity by fitting a LF w

*NWS: all with $K^o$ < 13.* … *ns A,B,D,E)*
*2M: all with $K^o$ < 13.*

(A) Difference in coun … xies; galaxies
2M minus NWS … h GA according
… 5 - 0.04)



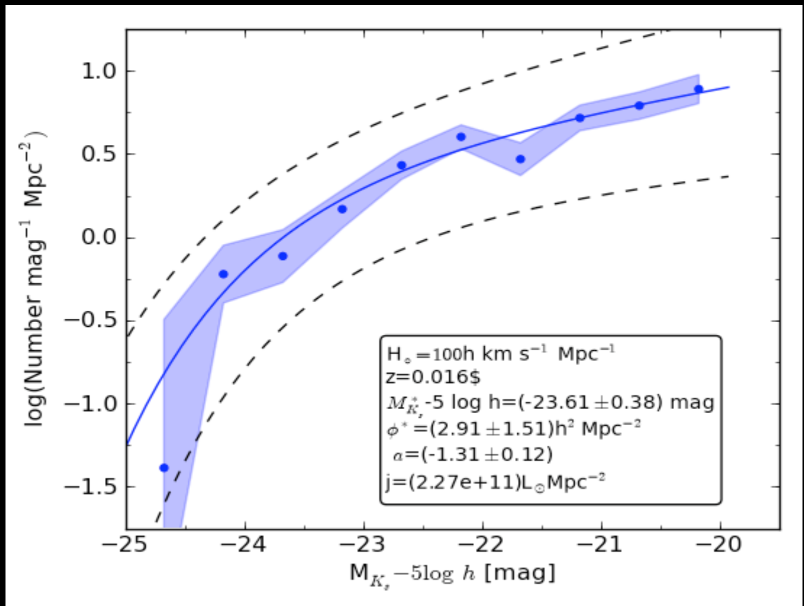

➔ **Excellent Agreement**

# Fitting of Schechter Luminosity Function

$$\phi(M)dM = \phi^* 10^{0.4(\alpha+1)(M^*-M)} e^{-10^{0.4(M^*-M)}}$$

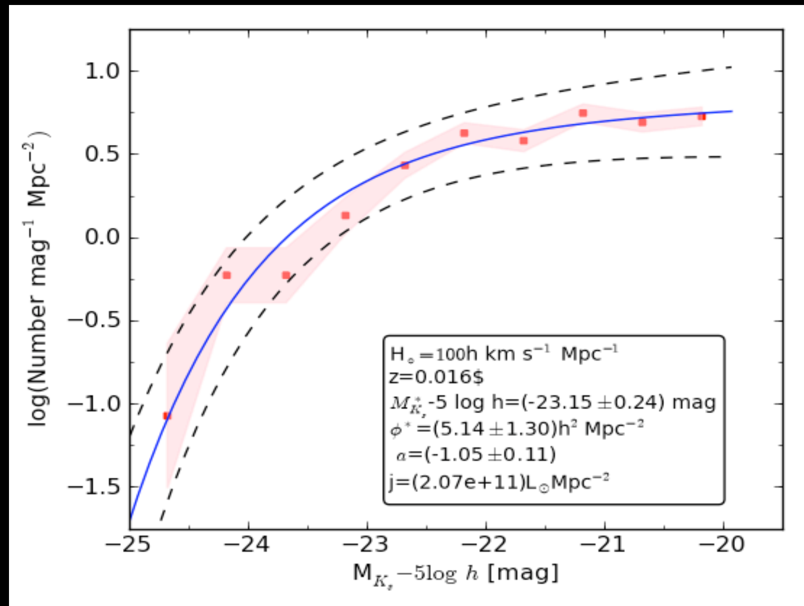
*Absolute magnitudes were derived assuming that all galaxies at the distance of the core of the GA: the Norma cluster: V = 4884km/s, z=0.0165 (Woudt et al. 2008), and are given for h=100*

## (A) Overdensity from counts




M* = -23.61; α = -1.31

## (B): galaxies with GA phot z




M* = -23.15; α = -1.05

Luminosity density: $$\int_0^\infty L\phi(L)dL = L^*\phi^*\Gamma(\alpha+2),$$

LD = 2.27 $10^{11} L_\odot/\mathrm{Mpc}^{-2}$

LD = 2.07 $10^{11} L_\odot/\mathrm{Mpc}^{-2}$

# (e) Estimation of the "uniform" GA mass overdensity

***again adopting H=100km/s/Mpc for all calculations***

What have we found so far:

- the NWS shows a general fairly homogenous overdensity at the GA distance
- with 2 prominent clusters at the GA distance (CIZA, Cen-Crux) (no new ones)

*Following Radburn et al. 2006*

- they find the extent of the Norma Wall to be ~100°, i.e about *85h$^{-1}$*Mpc
- assuming typical filament radius of 2Mpc *(Colbert et al 2005)*
- they determine the NW mass excluding clusters contribution

Excluding the known clusters (CIZA and Cen-Crux) and refitting LF results in slightly lower galaxy counts and hence lum. density:

$$M^* = -23.5;\ \alpha = -1.27 \rightarrow LD = 1.4 \times 10^{11} L_\odot/\mathrm{Mpc}^{-2}$$

Assuming $M/L = 53 M_\odot/L_\odot$ *(from Rines et al 2004 for regions 1-10 Mpc of cluster)*

$$\boxed{M_{GAWall} = 2.5 \times 10^{15} M_\odot \text{ excluding clusters}}$$

# Estimation of the total GA Mass

Contribution of known clusters in GA Wall (in $10^{15}\ M_{\odot}$):

| | | |
|---|---|---|
| - Norma cluster: | 0.80 | *Woudt et al. 2008* |
| - Ciza J1324.7-5736/CenCrux | 0.35 | *Radburn-Smith et al. 2008* |
| - Abell S0639 | 0.12 | *Radburn-Smith et al. 2008* |
| - Pavo | 0.29 | *Girardi et al. 1998* |
| → Total | 1.56 | |

**Grand Total: $M_{GAWall} = 4.1 \times 10^{15} M_{\odot}$**

**Caveats:**

- missing unknown clusters (within $|b| < 2°$, and/or outside of NWS)
- assumption of filament rather than Wall (2Mpc very narrow)

**Other estimates:**

**27 x $10^{15}$** *Lynden-Bell et al 1988 (cosmic flow E)*

**2.5 x $10^{15}$** *Radburn et al (w/o clusters)*

**~2 x $10^{15}$** *Staveley-Smith et al. 2000 (HI in ZOA $|b| < 5$)*

**~2 x $10^{15}$** *Kocevski et al. 2007 (CIZA clusters in GA)*

**4-6 x $10^{15}$** *Bolejko & Hellaby 2008 (non rel. model of SH)*