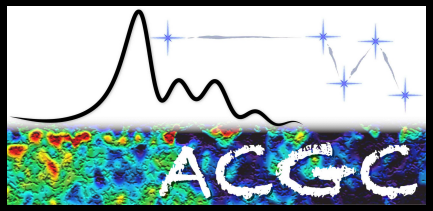
Cosmology with local HI

Cosmic flows & hidden LSS in ZoA



Renée C. Kraan-Korteweg

ACGC (Astrophysics, Cosmology and Gravity Centre), UCT

- **Whole sky-surveys and the ZOA**
- **LSS and dipole/bulk flow controversies**
- **Further major SCL hidden by ZOA**
- **A case for HI-survey with AERA^3**

MFAA Workshop
Stellenbosch, 22 Feb'14

Introduction: Problem setting

Dynamics of Universe remain poorly understood:

Galaxy surveys
Redshift surveys ←→ CMB dipole *(convergence radius/apex)*
Peculiar velocity surveys ←→ Bulk flows

Early discussions:

GA ←→ Perseus-Pisces
Shapley ←→ **Vela**
resp. Hor/Ret <-> Vela <-> Shapley <-> Ara/TriAu

→Recent results:

major fraction of local bulk flow (~400km/s)
- from larger distances (> ~100Mpc) *Feldman et al 2010, ….* *Bilicki et al 2011, ….*

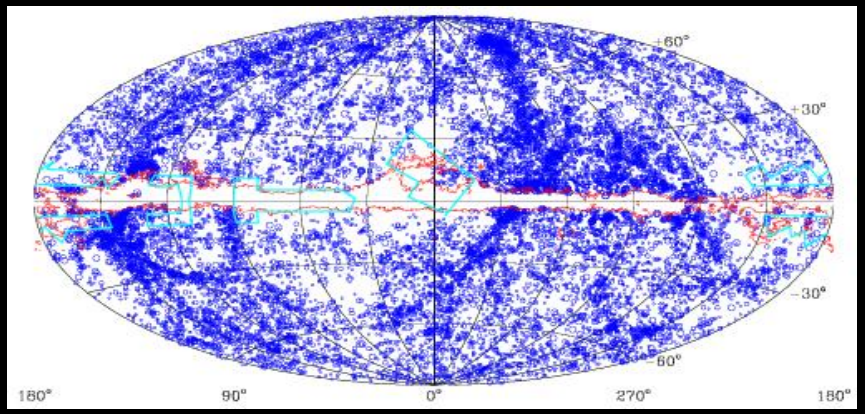
some claim inhomogeneities up to 300Mpc *Kashlinksi et al ….*

Part of problems arises from incomplete sampling:

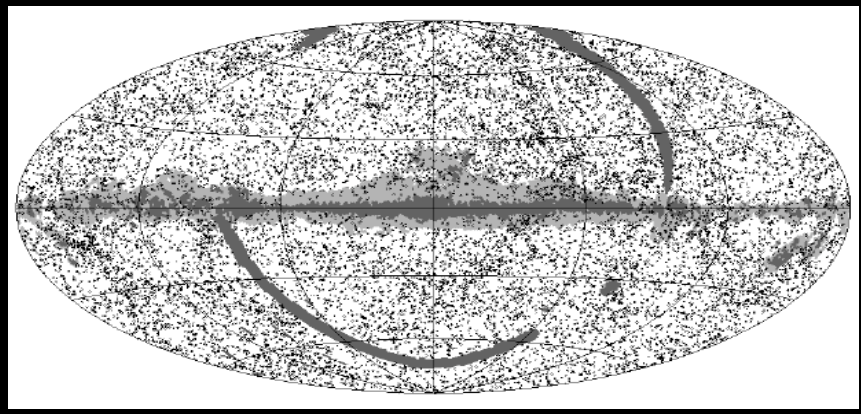
- ZOA
- not enough depth (volume)
- too sparse

“Whole-sky” MWL galaxy & redshift surveys

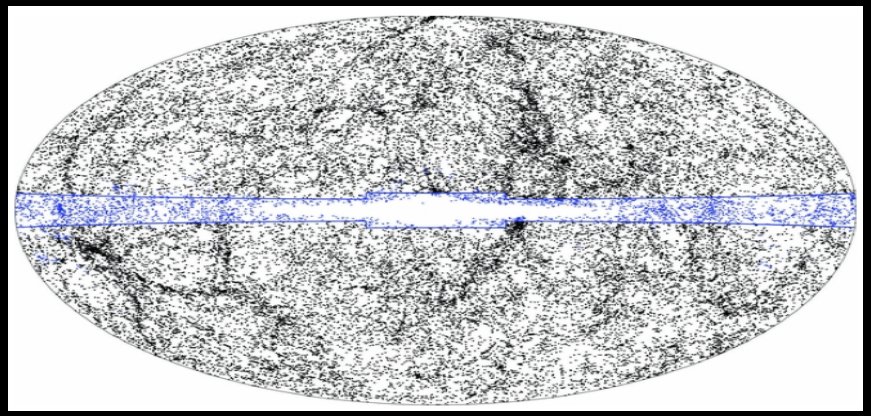
Deep optical surveys and partial z-follow-up



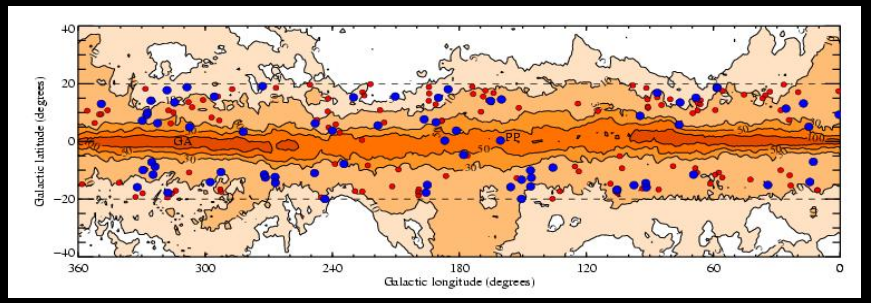
IRAS and BTP redshift survey



2MASX (K < 13.5) and 2MRS (Ko < 11.75)



CIZA X-ray cluster survey



None of the surveys penetrate inner |b| < 5^{o} in a systematic way
→Whereas all derived Bulk Flows have an apex close to or in the ZOA!!

2M++ : Combines 2MRS; SDSS, 6dFGRS
Goal : to reach 200Mpc

Lavaux & Hudson 2012

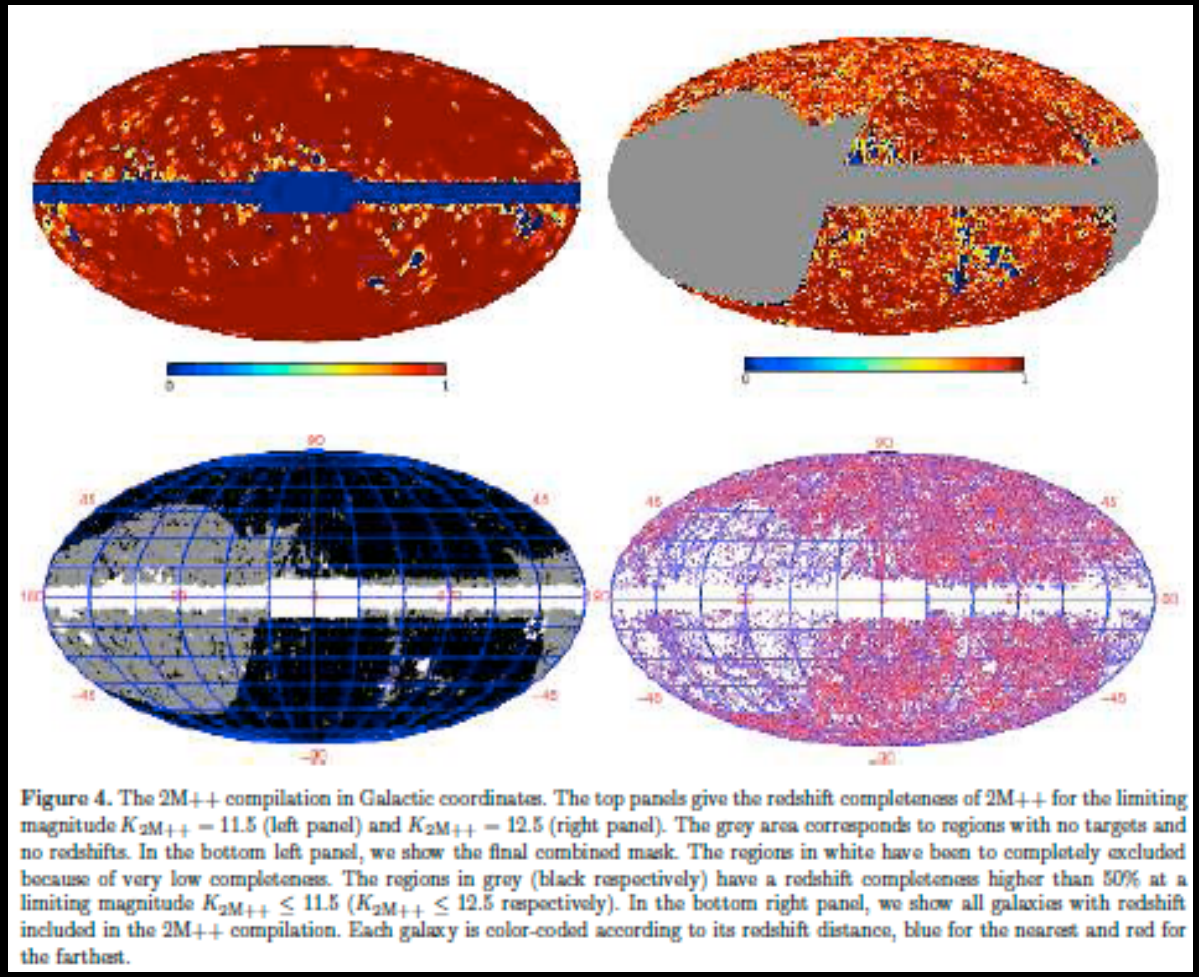


Figure 4. The 2M++ compilation in Galactic coordinates. The top panels give the redshift completeness of 2M++ for the limiting magnitude $K_{2M++} = 11.5$ (left panel) and $K_{2M++} = 12.5$ (right panel). The grey area corresponds to regions with no targets and no redshifts. In the bottom left panel, we show the final combined mask. The regions in white have been to completely excluded because of very low completeness. The regions in grey (black respectively) have a redshift completeness higher than 50% at a limiting magnitude $K_{2M++} \leq 11.5$ ($K_{2M++} \leq 12.5$ respectively). In the bottom right panel, we show all galaxies with redshift included in the 2M++ compilation. Each galaxy is color-coded according to its redshift distance, blue for the nearest and red for the farthest.

Lavaux et al. 2010

Prev results based on 2MRS:

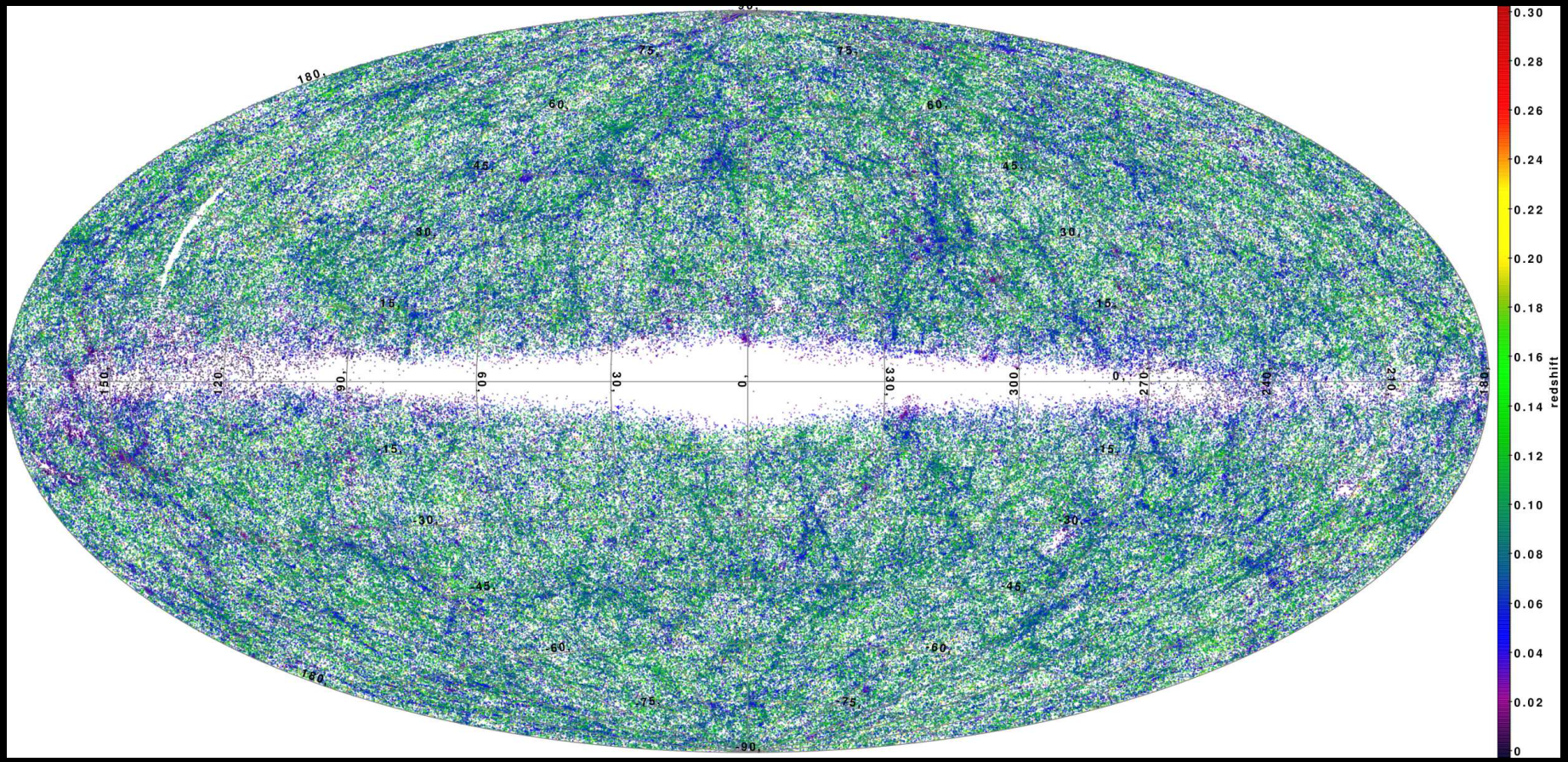
Dipole is generated out to at least a radius of 200Mpc - if not further out!!

→ ZOA-problem perpetuates

2MASS Phot-z redshift Catalog

based on SuperCosmos, 2MASX and WISE

Bilicki et al 2013, arXiv: 1311.5246



About 10^6 objects with median z = 0.2 *(compared to most local spec z samples of z_{med} ~0.03)* color-coded by photometric redshift. The cosmic web is evident despite the tendency of photo-z's to dilute structures.

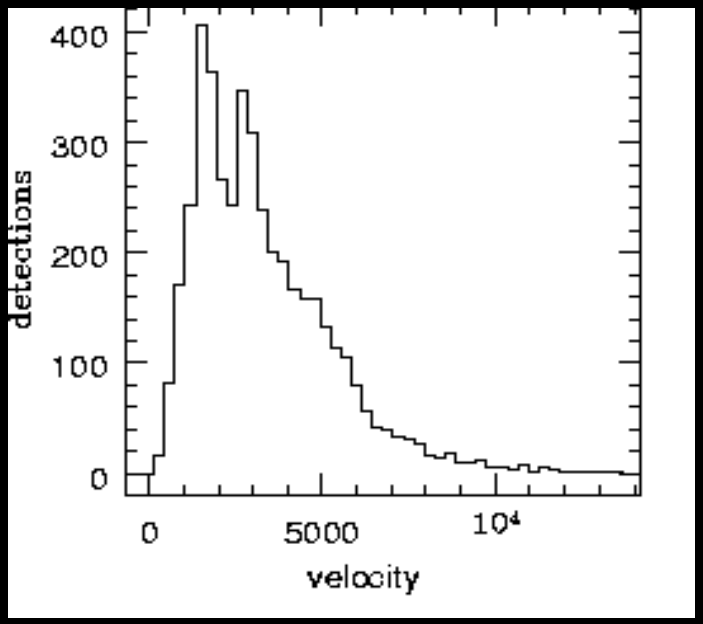
Systematic HI surveys: HIPASS Catalogue

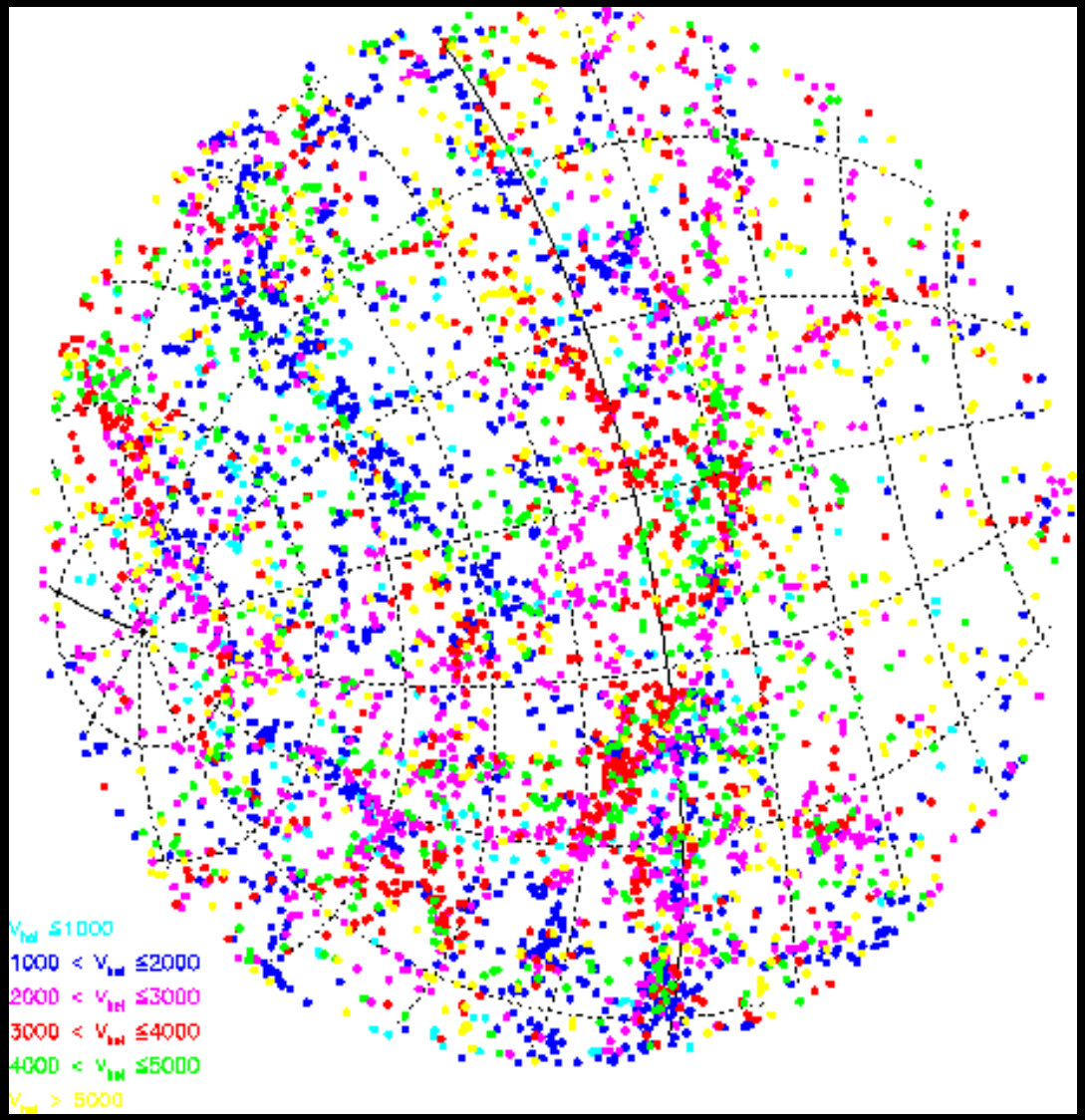
(and HIZOA – 5 x times longer integration)

*Meyer et al 2004, MNRAS, **350**, 1195*

Velocity; –1200 to 12700 km/s
rms: 13 mJy/beam
Data taking 1997-2001

388 southern cubes
4315 galaxies



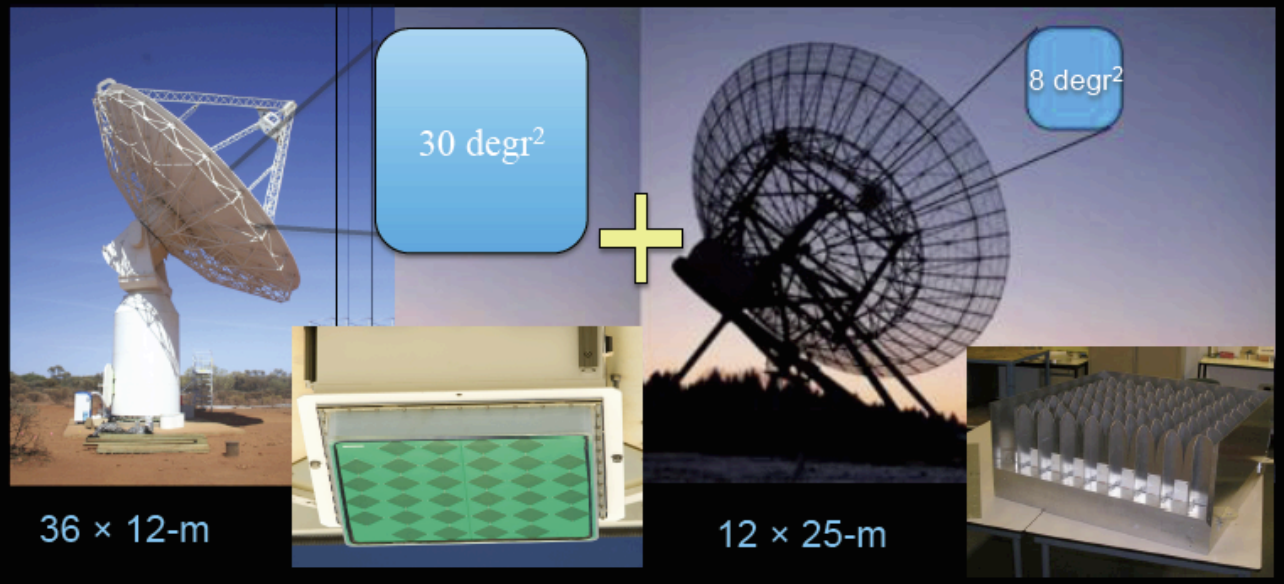


Wallaby and WNSHS

PI': *Staveley-Smith & Koribalksi;* *Josza*

HI (21-cm) All-Sky Survey

ASKAP + WSRT with Apertif



To achieve all-sky coverage we require ≈1200 ASKAP pointings (left), integrate 8h each (δ < 30 degr) + ≈1300 WSRT/Apertif pointings (right), 4h each (δ > 30 degr) to achieve the same sensitivity and resolution.

Wallaby 3pi = south
WNSHS 1pi = north
→ 825'000 galaxies out to z=0.26; <z> = 0.05

Is the Great Attractor the main attractor?

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

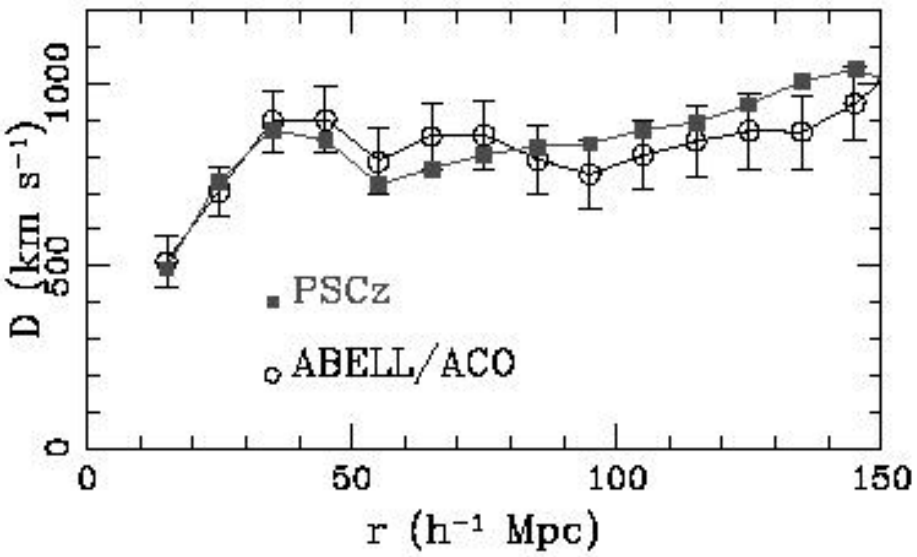
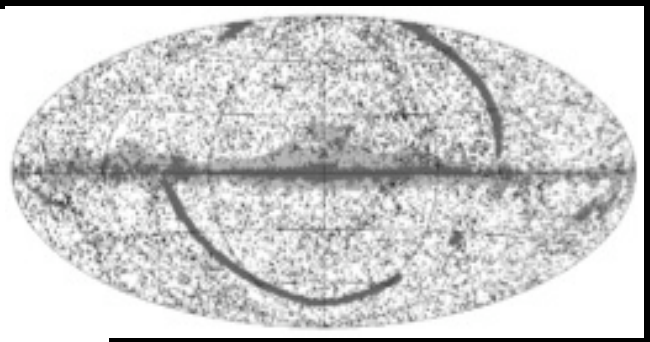


Figure 5. Comparison between the PSCz and ABELL/ACO dipoles, after scaling down the latter by a bias factor of 4.3.



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

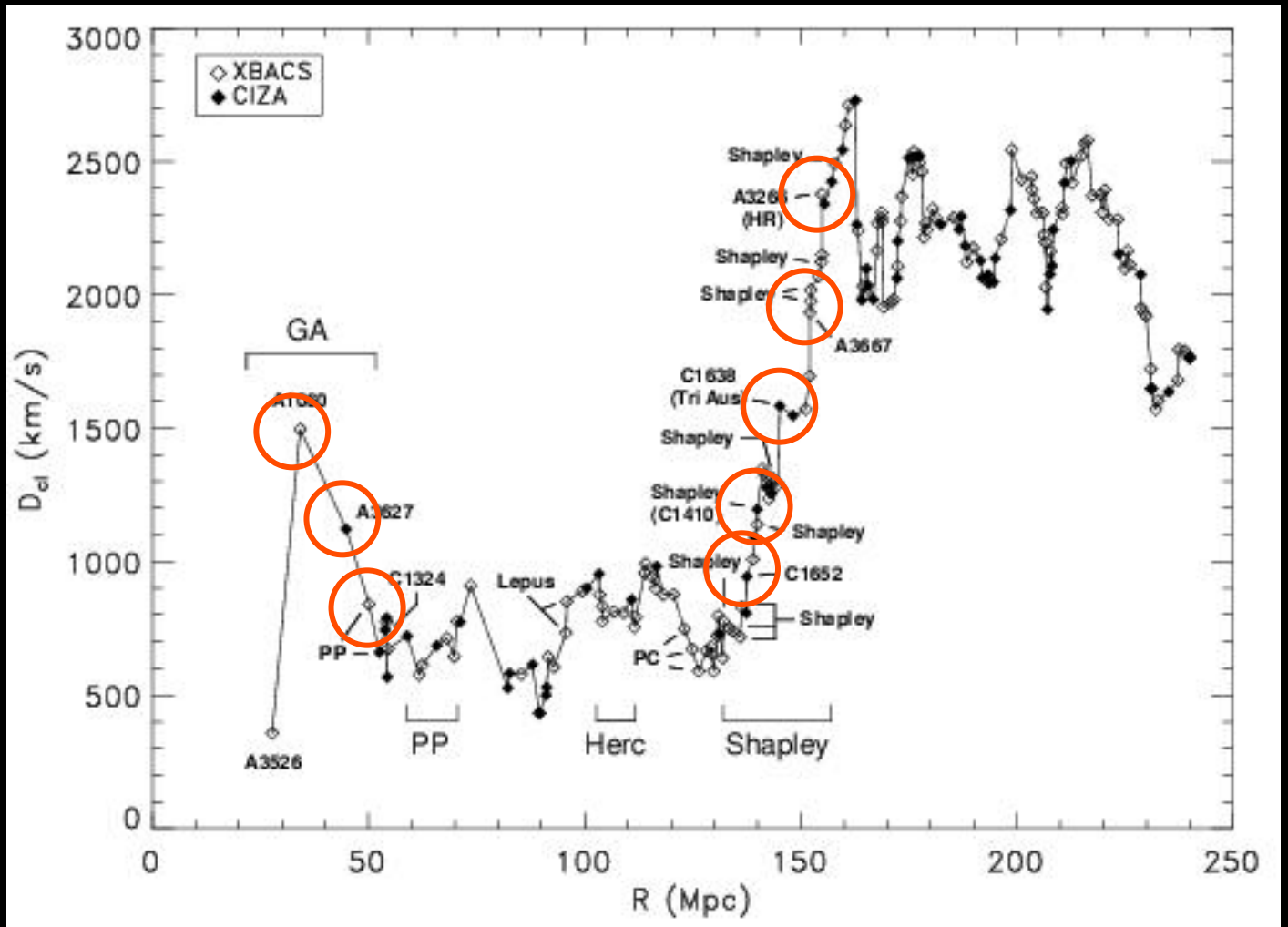


Figure 3. Schematic dipole profile; see text for details. Each symbol represent a cluster used in our analysis. Abell and CIZA clusters begin with the letters 'A' and 'C', respectively. Acronyms are GA: Great Attractor, PP: Perseus-Pegasus, PC: Pisces-Cetus, HR: Horologium-Reticulum. We find that the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

Kocevski et al. 2004,2005,2006

- 44% of dipole due to GA

- 56% by more distant overdensities (130-180Mpc)

- But not only SSC (and HR)

-2.7 x more cluster in south than north

- ZOA!!

Lavaux & Hudson arXiv1105.610
Defining "all-sky" 2M++ (2M + 6df + SDS
For K < 12.5

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)*

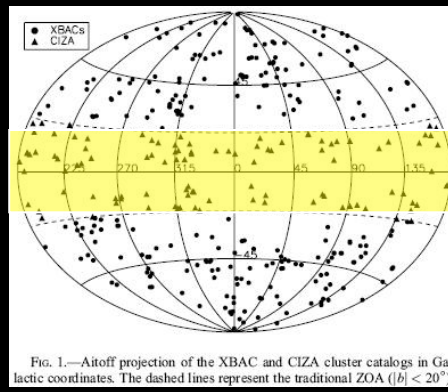
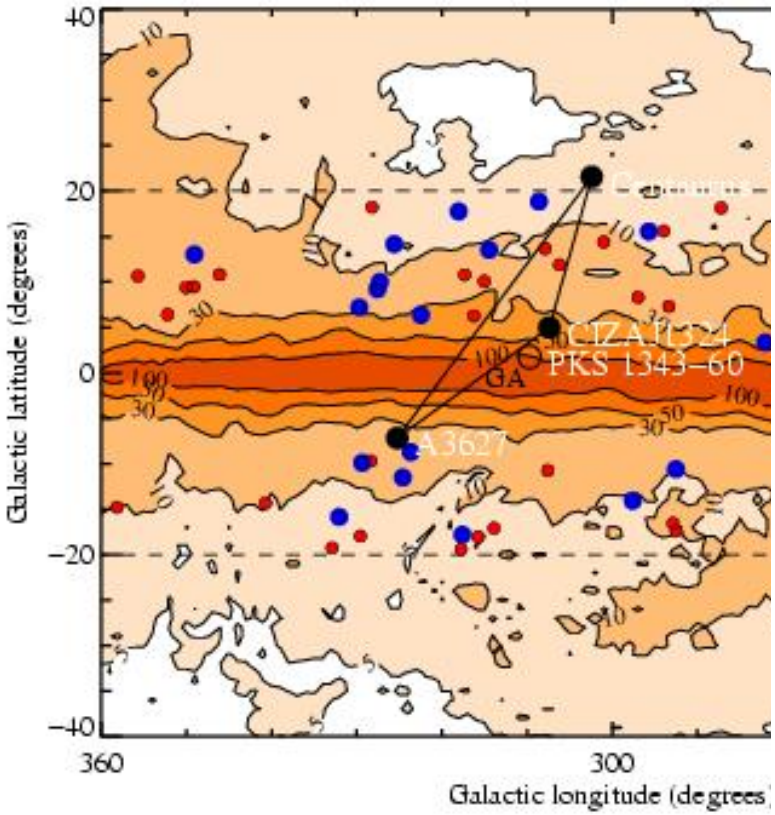
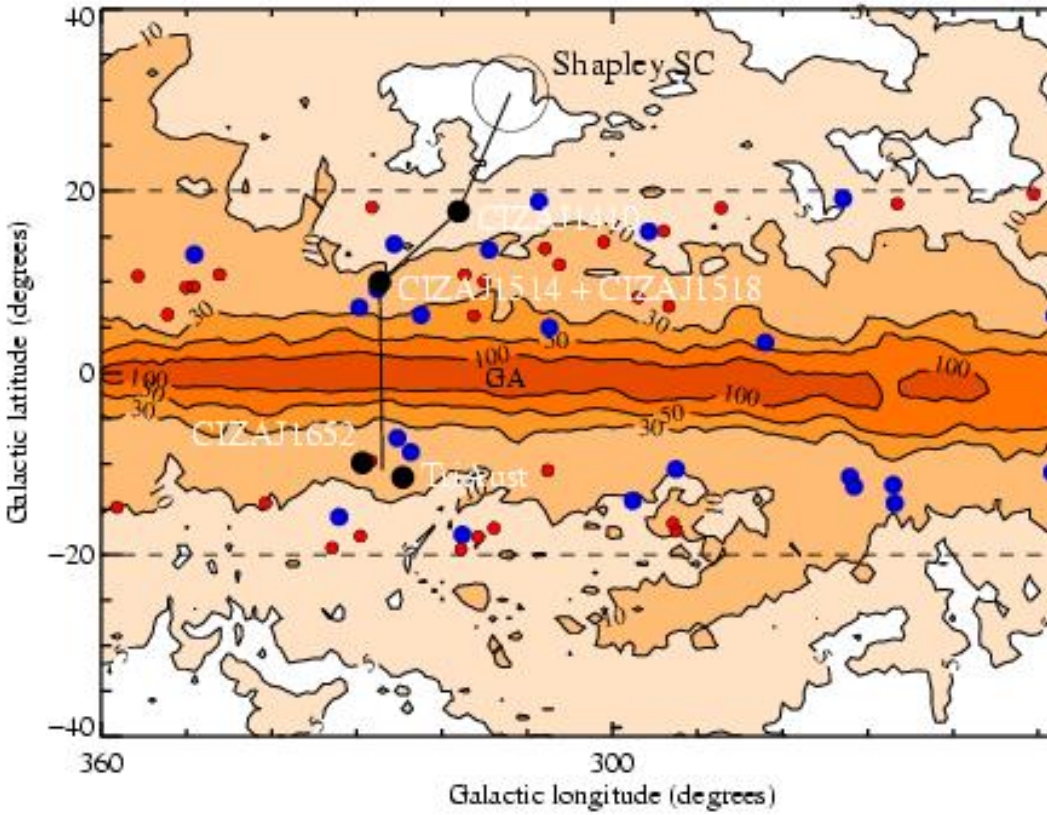


FIG. 1.—Aitoff projection of the XBAC and CIZA cluster catalogs in Ga lactic coordinates. The dashed lines represent the traditional ZOA ($|b| < 20°$



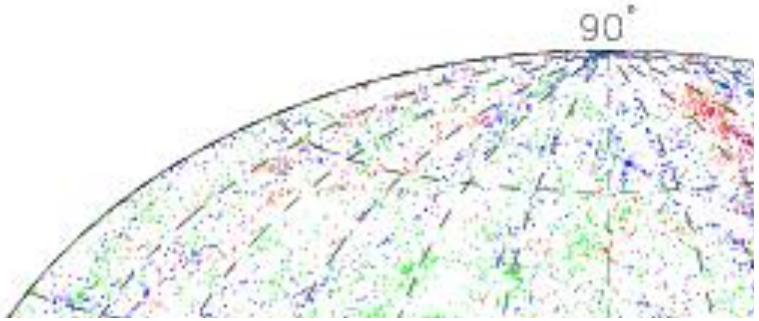


The 3 highlighted clusters: 3000-6000 km/s **Highlighted clusters: ~ 15'000 km/s**

Around same time: results from 2M R

(Erdogdu et al. 2006a, 2006b) **find for 23'2(**

with $K^0 < 11.25$ complete with redshif



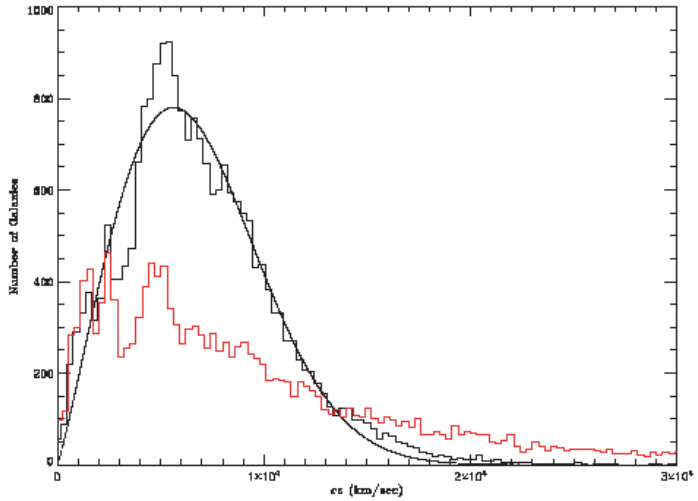
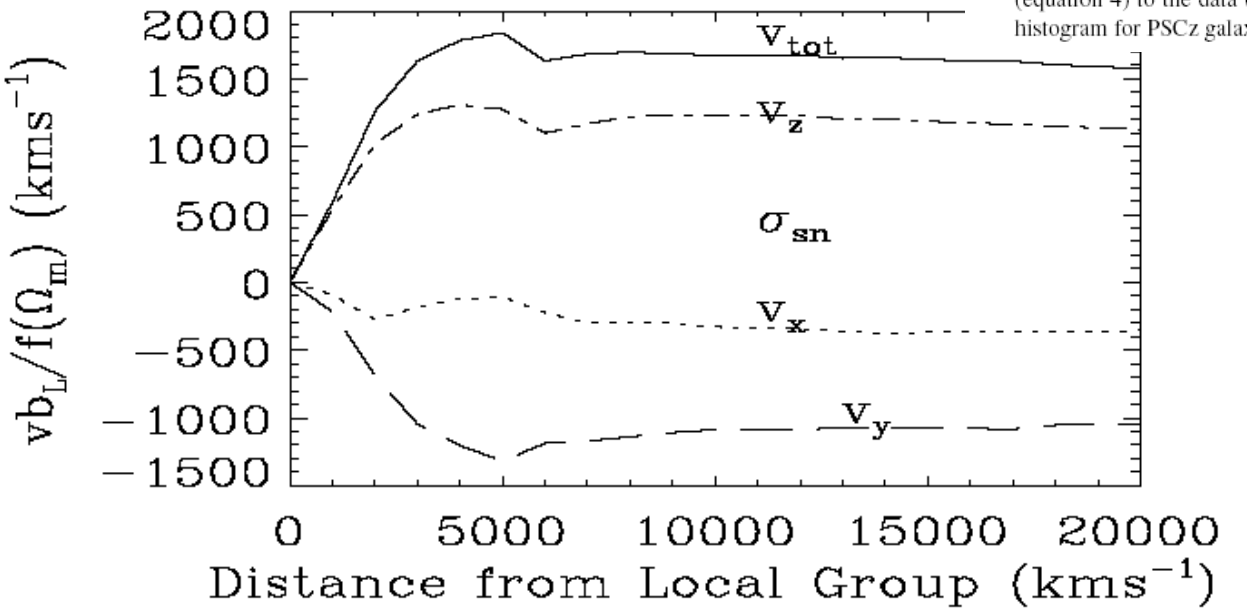


Figure 3. Redshift histogram for 2MRS galaxies and a least-squares fit (equation 4) to the data (black). For comparison, also plotted is a redshift histogram for PSCz galaxies (Saunders et al. 2000) (red).



No increase: GA is main attractor

Further controversy SINCE that time

-Loeb & Narayan 2008 (Kolatt et al 1995): **Comparison of 2MRS dipole and CMB requires an additional velocity vector towards an object in ZOA behind GB** *(Andromeda at 1Mpc, Coma at 20 Mpc, unlikely to be hidden SCL at 200Mpc)*

-Kashlinsky et al. 2008, 2009, 2010, 2011: **X-ray clusters, KSZ at higher z: →large BF (600-1000km/s) out to ~300Mpc, incompatible with LCDM; later even out to z=0.2 (800Mpc) ….** *(tilted Universe???? (also Ma et al. 2011) Huge voids???; but it is consistent with X-ray cluster result out to same depth)*

-Feldman & Watkins 2008, Watkins et al 2009,2010**: STEWS of pec-vel measurements (N-4600) out to ~100Mpc, large BF of ~416km/s,** *not consistent with LCDM + WMAP5, but results are consistent with Kashlinsky for common volume; and various other earlier BF determinations*

-Abate & Feldman (arXiv1106.5791), Thomas et al 2011: SDSS LRG galaxies with z>0.8: huge BF (4000km/s) *but directions consistent with other paper*

All Bulk flows have an apex close to or in the ZOA!!

6dFGSv results: pec velocities from FP (N=9000)

- Bulk-flow within 160 Mpc/h: V = 365 km/s → (l,b) = 313º, 15º
- Residual flow of: V = 292 km/s → (l,b) = 313º, 36º

→ Hints of structure influencing local dynamics outside of survey volume

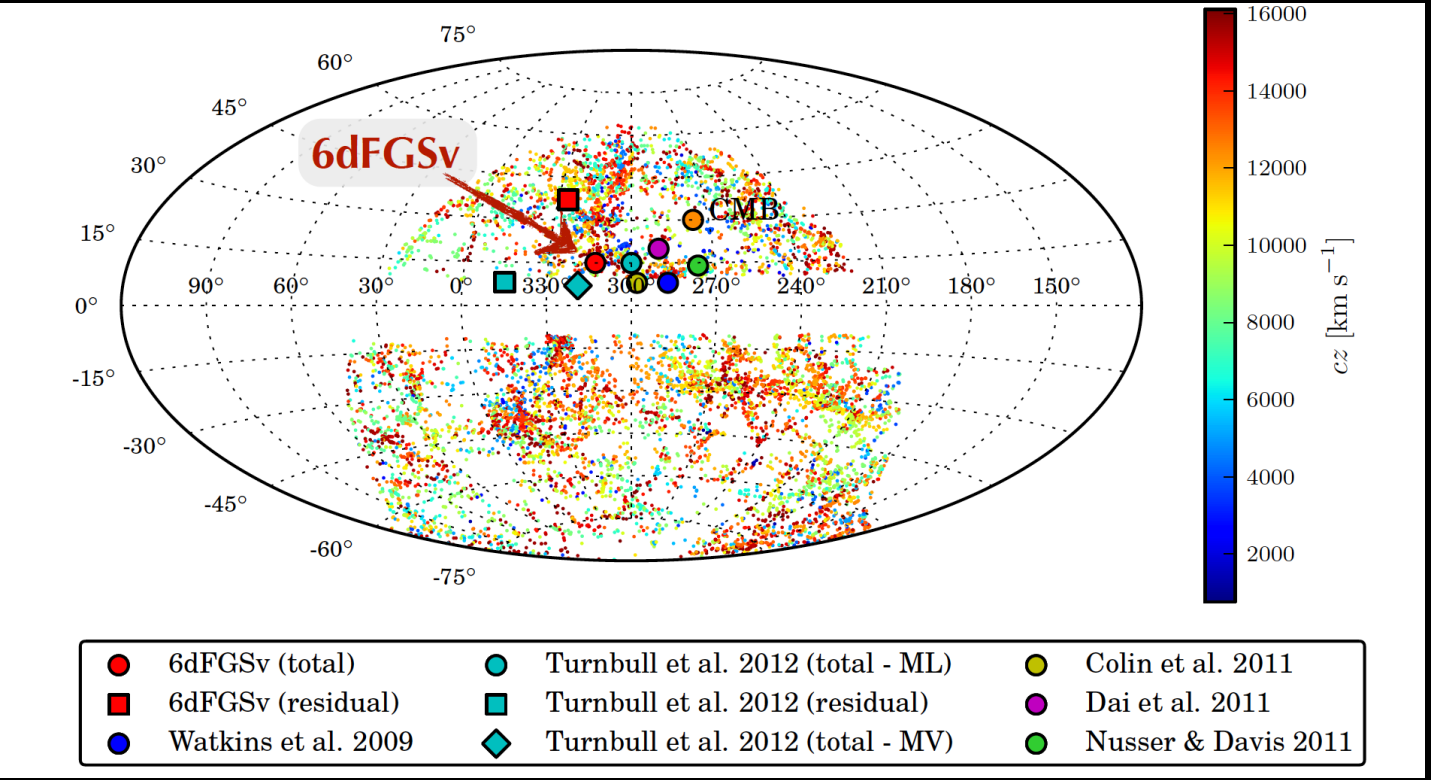
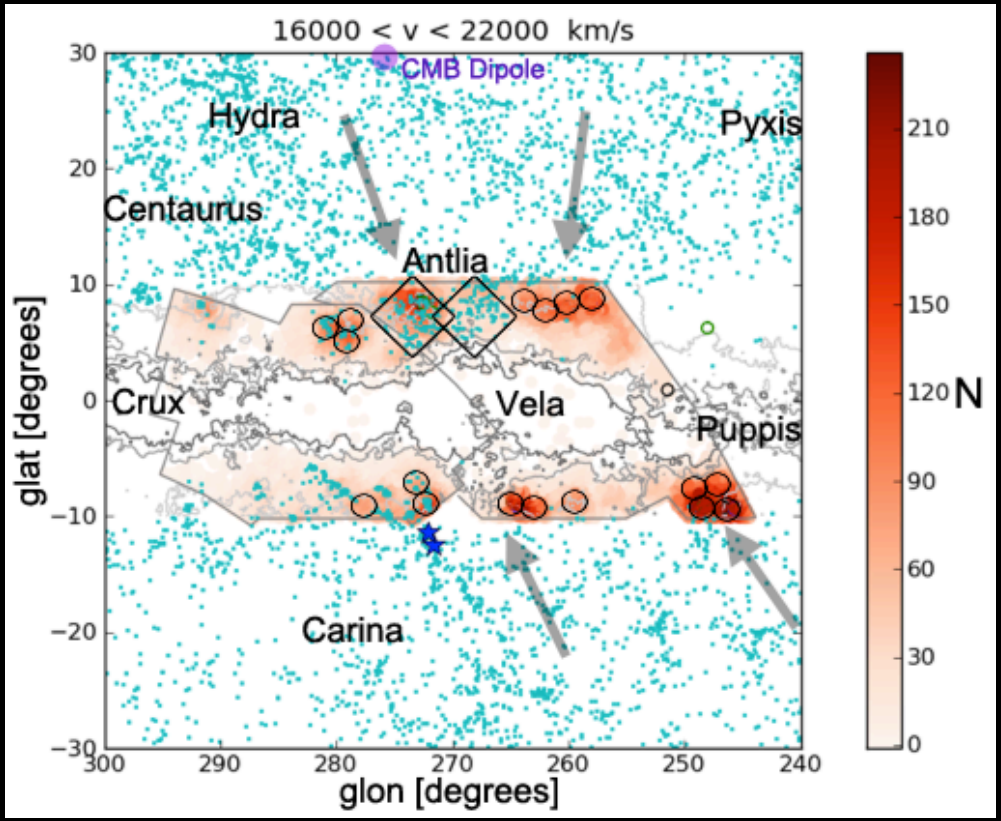


Figure from Magoulas et al, Cosmic Flow meeting, 2013, Marseille

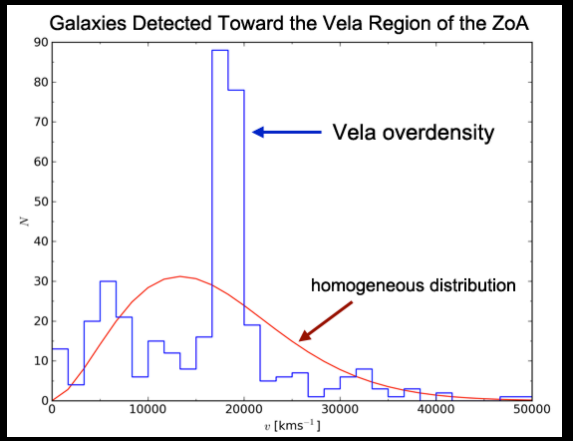
Another potential massive overdensity in ZOA

just beyond boundaries of current surveys 16-22000km/s



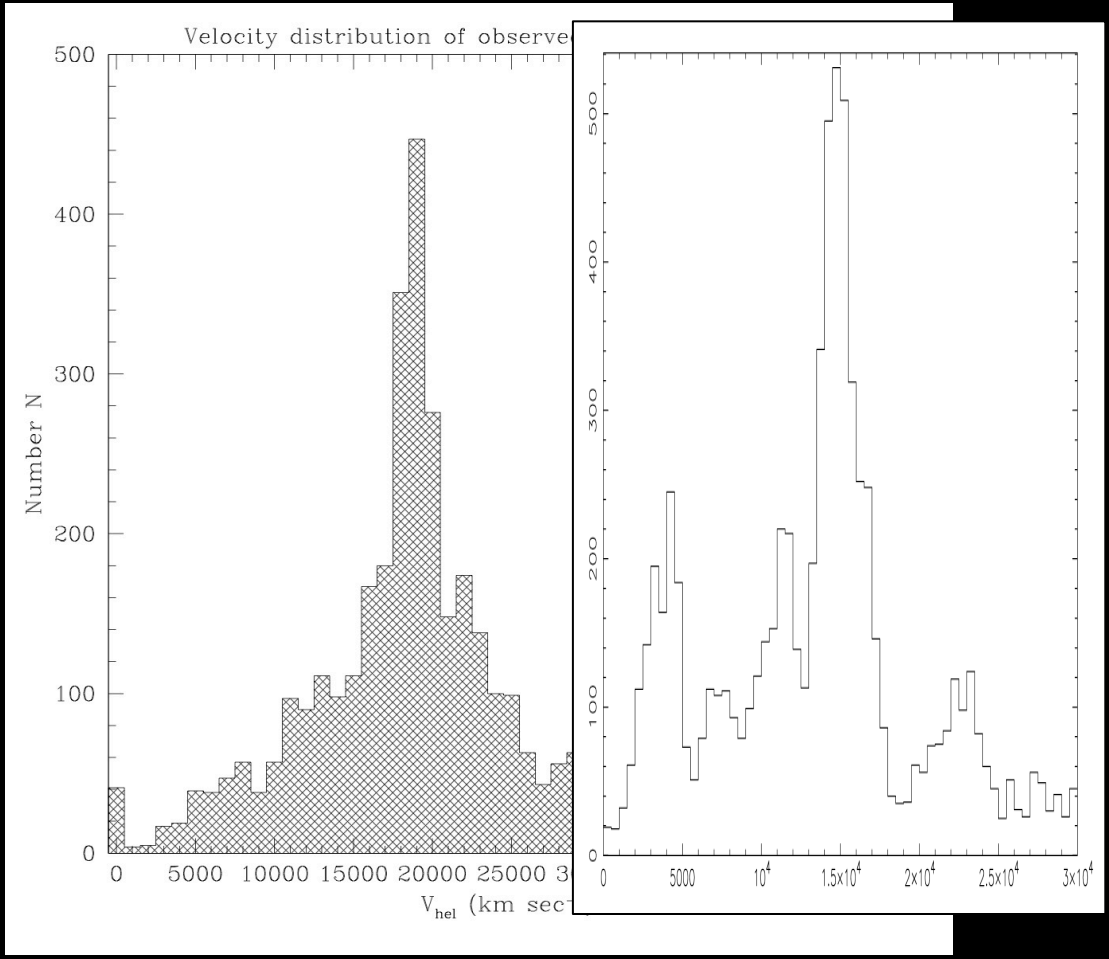
Follow-up redshift observations of optically detected galaxies in ZOA in Vela (KK et al)

With 6dF instrument



→ **AAOmega proposal to consolidate observations and map extent of overdensity** *(with M Cluver, T Jarrett, M Bilicki, M Colless, H Jones)*

Preliminary results from 1 - 6 Feb 2014 AAOmega Observing run:
25 x 2-deg fields observed → N ~ 4300 redshifts
just beyond boundaries of current surveys 16-22000km/s



- Massive overdensity traced over the vast majority of the AAOmega fields (20 o/o 25)
  Numerous clusters at 18-20000km/s
  Embedded in broader wall-like structure (16-24000km/s)

Overdensity equally prominent above an below optical ZOA

Is on par with Shapley SSC *(Proust et al 2006, N ~ 8600)*; also Horologium/Reticulum SCL *(Fleenor et al 2006)*

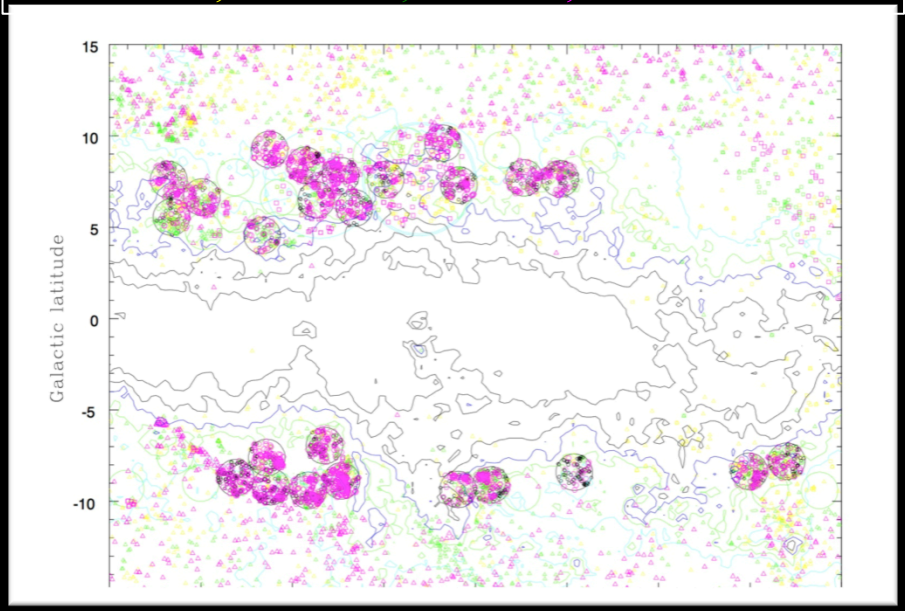
Despite f ~ 1.3 more distant
→ more extended on the sky:
12° x 30° ←→ ~ 20° x 20°
30 x 75 ←→ 70 x 70 Mpc/h

What is the relevance to HI-science with AERA^3 ?

"only" 25 AAOmega fields – sparsely sampled

Where extinction reaches ~A_B = 2mag → hard to get redshifts, even for 2MASX galaxies → Area of ~|b| < ±5-7° unsampled

0 – 10000; 10-16000; 16-2400; black: 24-50000



Modeling of AERA^3 HI survey of about (l x b) = 25° x 16° (~5 FoV)

Assumptions:

- AERA^3 specs as provided by preliminary document with:
- Baseline 1km (→ 45-60"), FOV ~78□°
- rms = 5.5 mJy at 1.4 GHz for 1hr
  for 5km/s channel width
  (but Δv = 10km/s sufficient)

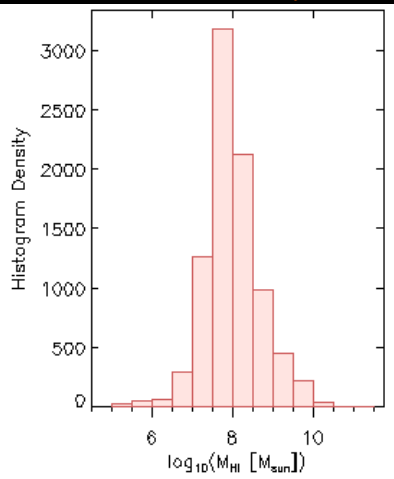
- Duffy et al 2012 simulations of stellar and HI-content of galaxies (Wallaby & Dingo)
- of 4 million galaxies
- within z < 0.44
- over 50 sq deg

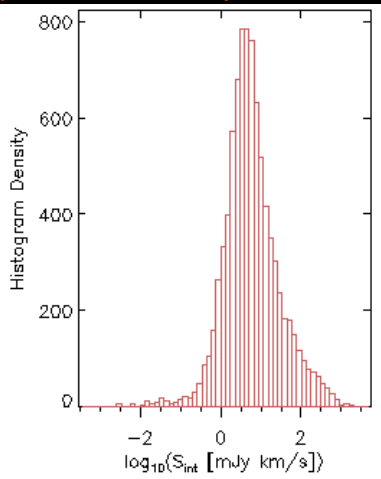
Calculations performed by Ed Elson

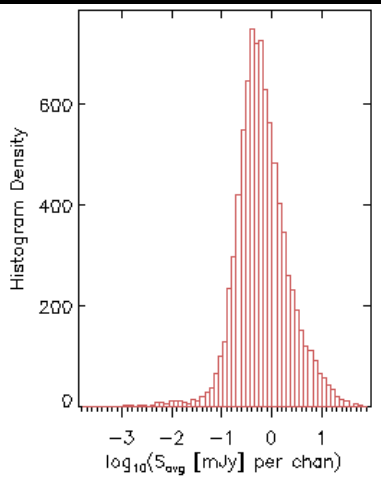
Predicted properties of HI Galaxies within shell of 16000 < v < 22000 km/s (for 50□°)

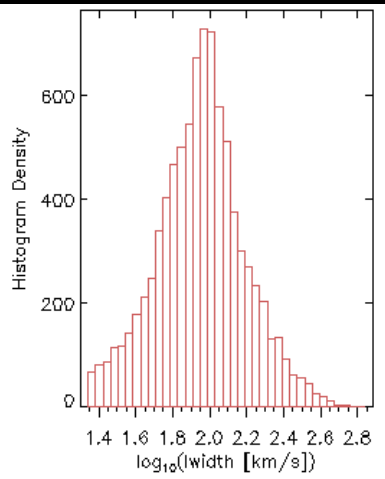
Total number of galaxies: N=8681 *(o/o N=18360 within volume V < 22000km/s)*

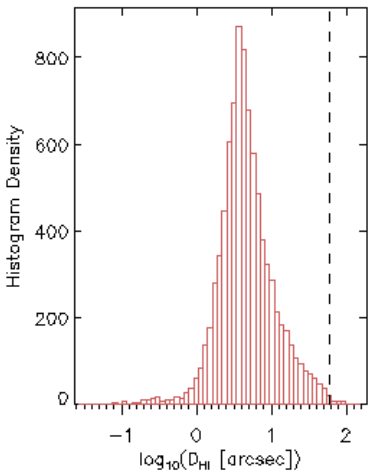
For ZOA survey area of 400□°→ factor 8 more →N ~70000

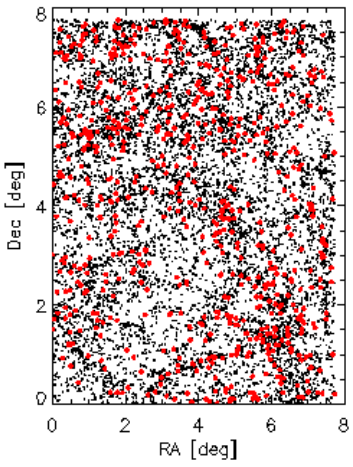


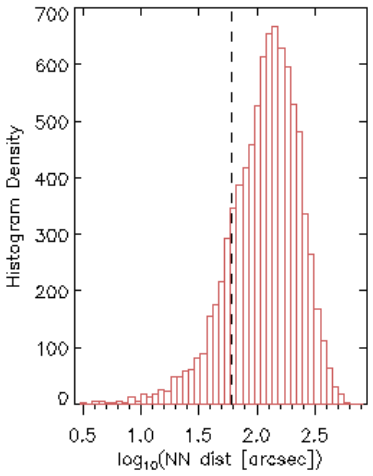










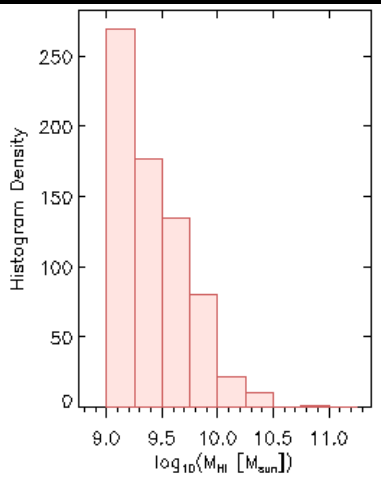


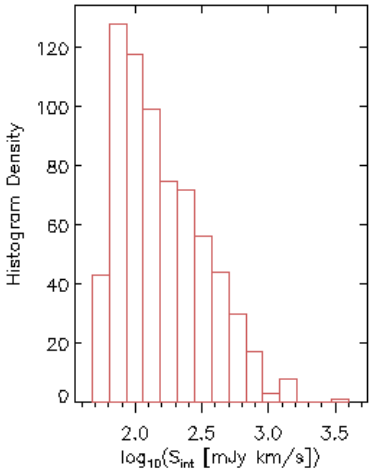
- → **Focus on most massive galaxies**
- → **that will trace clusters, filaments, walls:**
- → **log M(HI) > 9.0**

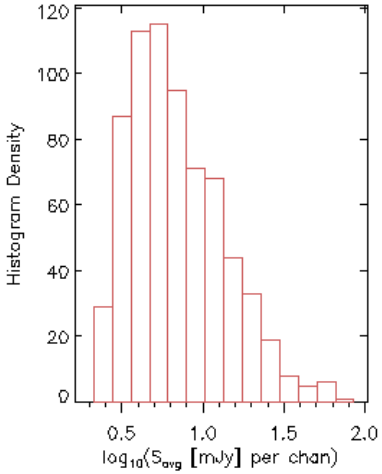
→ Extract all galaxies with log M(HI) > (9.0) 16000 < v < 22000 km/s (for 50□°)

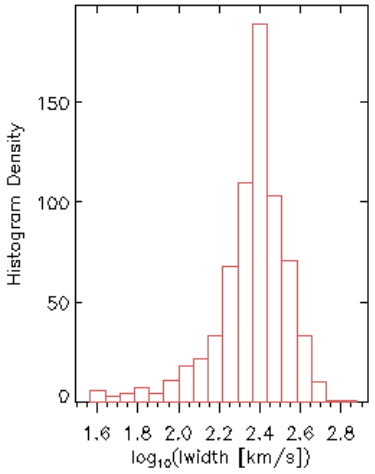
→ **N=696** *(o/o N=1602 within volume V < 22000km/s)*

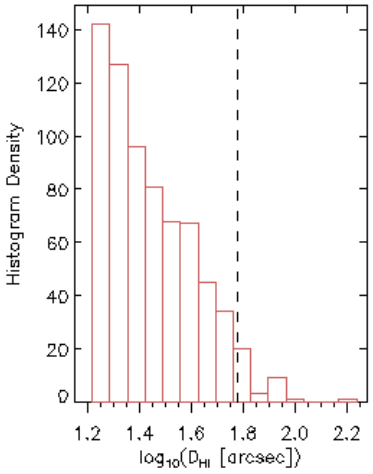
For ZOA survey area of 400□°→N_{gal} ~ 5600

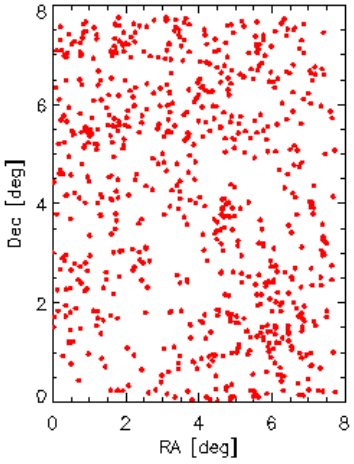


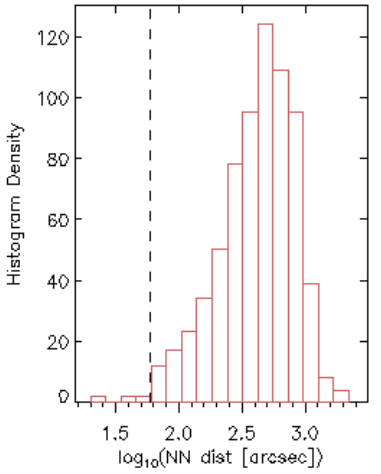












→ **AREA³ HI survey details:**
- **Δv = 10 km/s**
- **T_{int} = 12hrs**

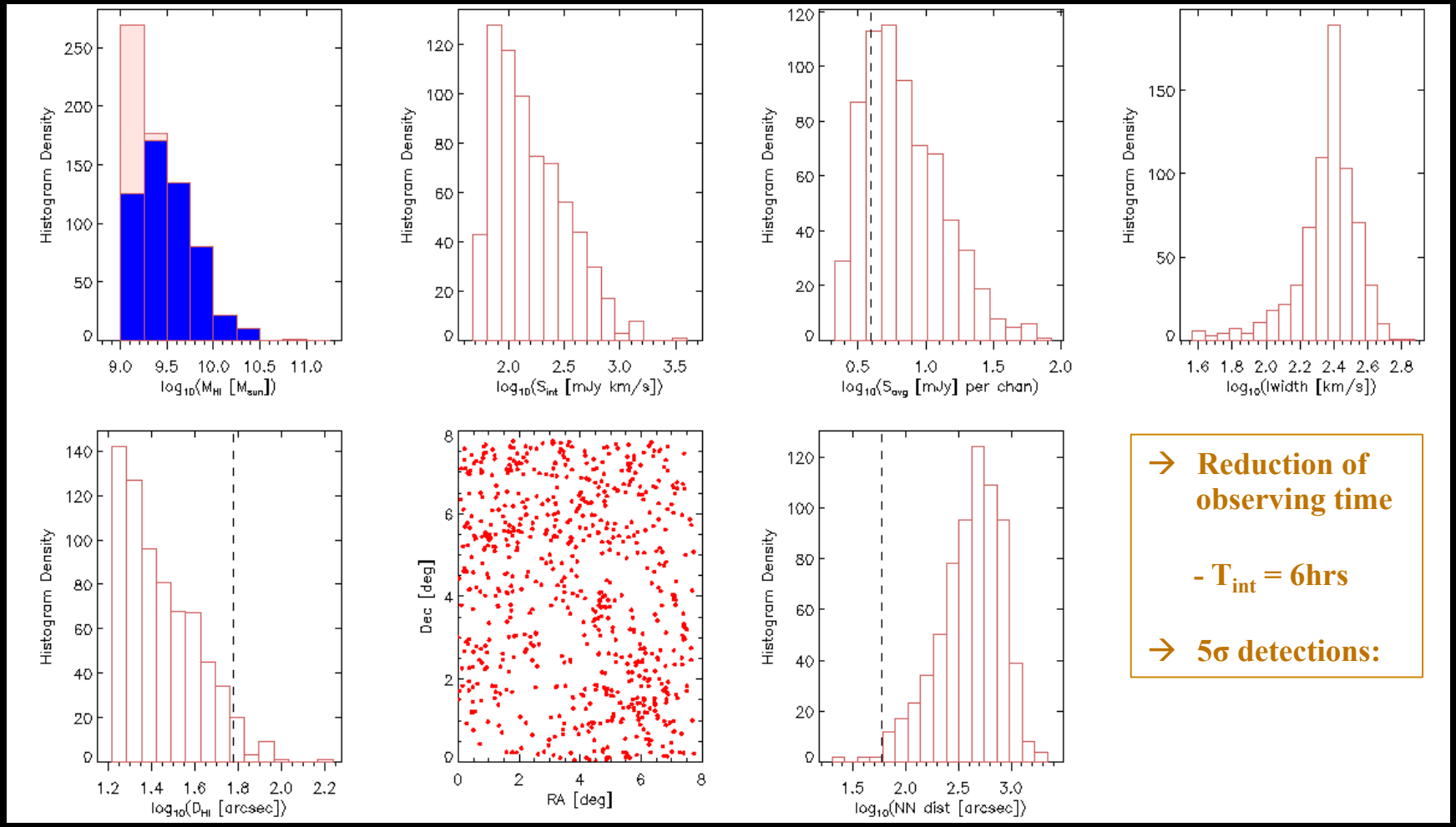
→ **rms ~ 0.95 mJy**

→ **5σ detections:**

5σ detections for such an AERA3 survey
16000 < v < 22000 km/s (for 50□°)

→ **N=545** *(o/o N=1602 within volume V < 22000km/s)*

For ZOA survey area of 400□°→N ~ 4400



→ **Reduction of observing time**

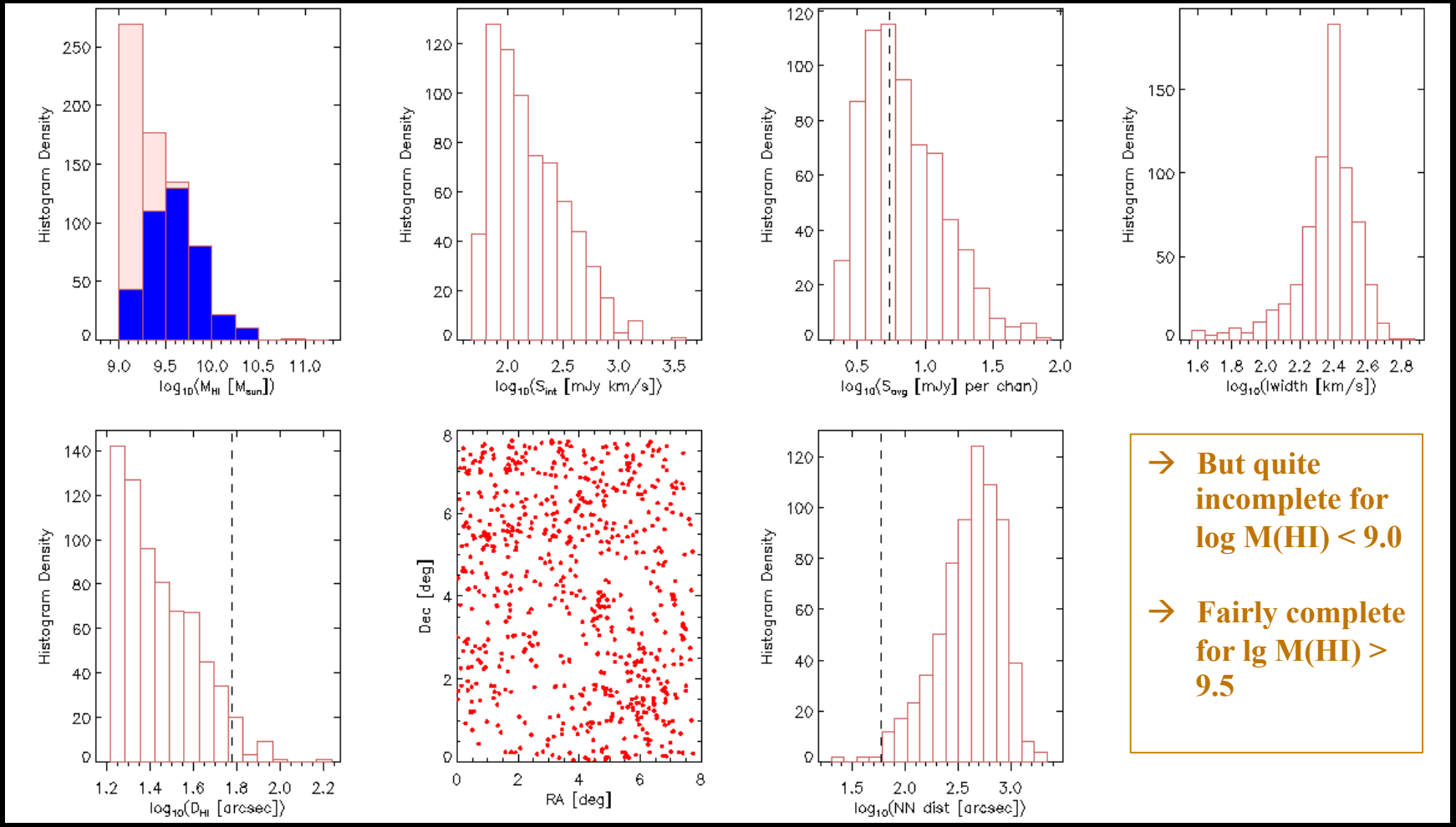
- T_{int} = 6hrs

→ **5σ detections:**

Further reduction of observing time: 12hrs -> 6hrs: 16000 < v < 22000 km/s (for 50□°)

→ **N=396** *(o/o N=1602 within volume V < 22000km/s)*

For ZOA survey area of 400□°→N ~ 3200



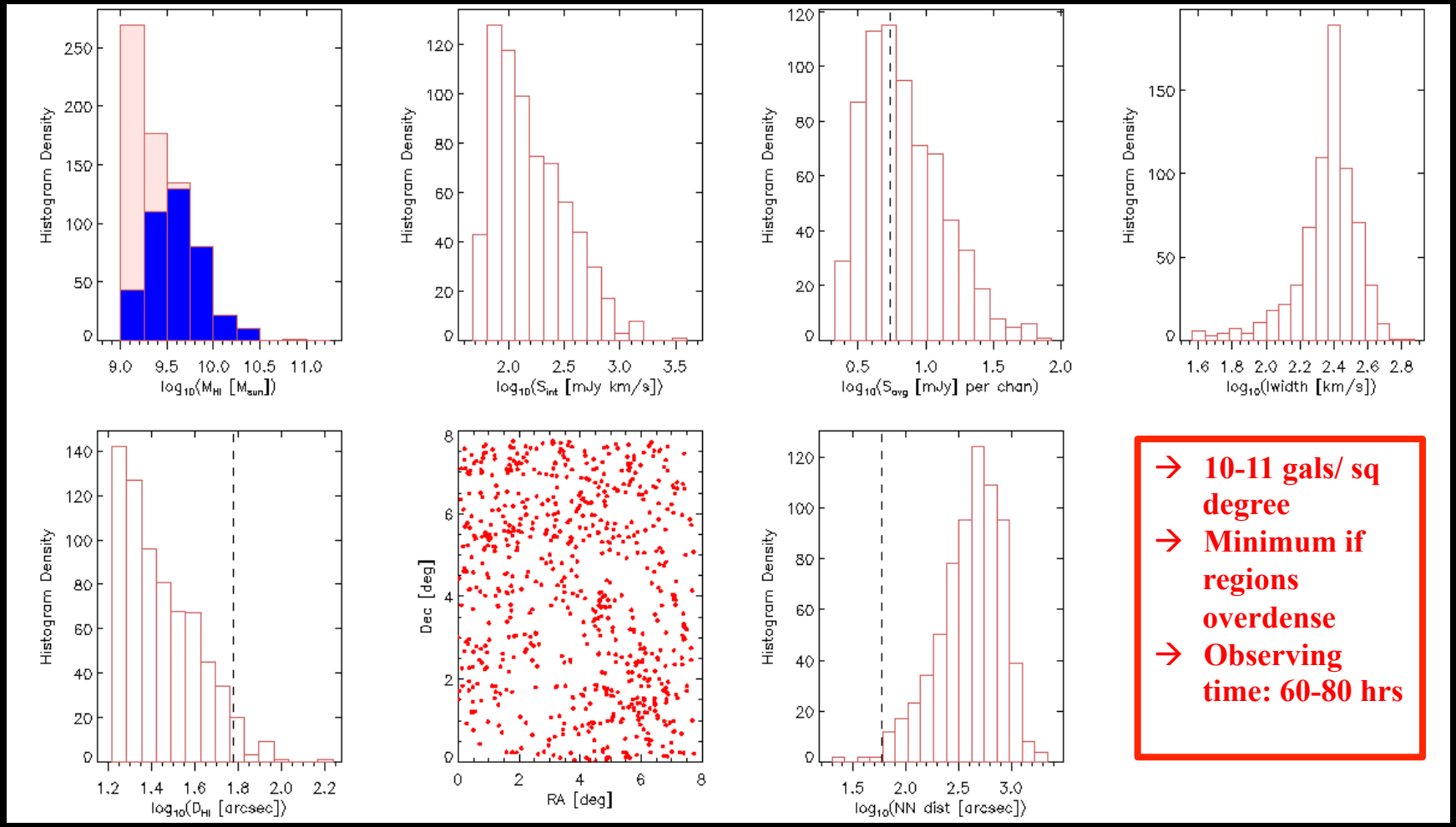
→ **But quite incomplete for log M(HI) < 9.0**

→ **Fairly complete for lg M(HI) > 9.5**

5σ detections for such an AERA^3 survey
16000 < v < 22000 km/s (for 50□°)

→ **N=545** *(o/o N=1602 within volume V < 22000km/s)*

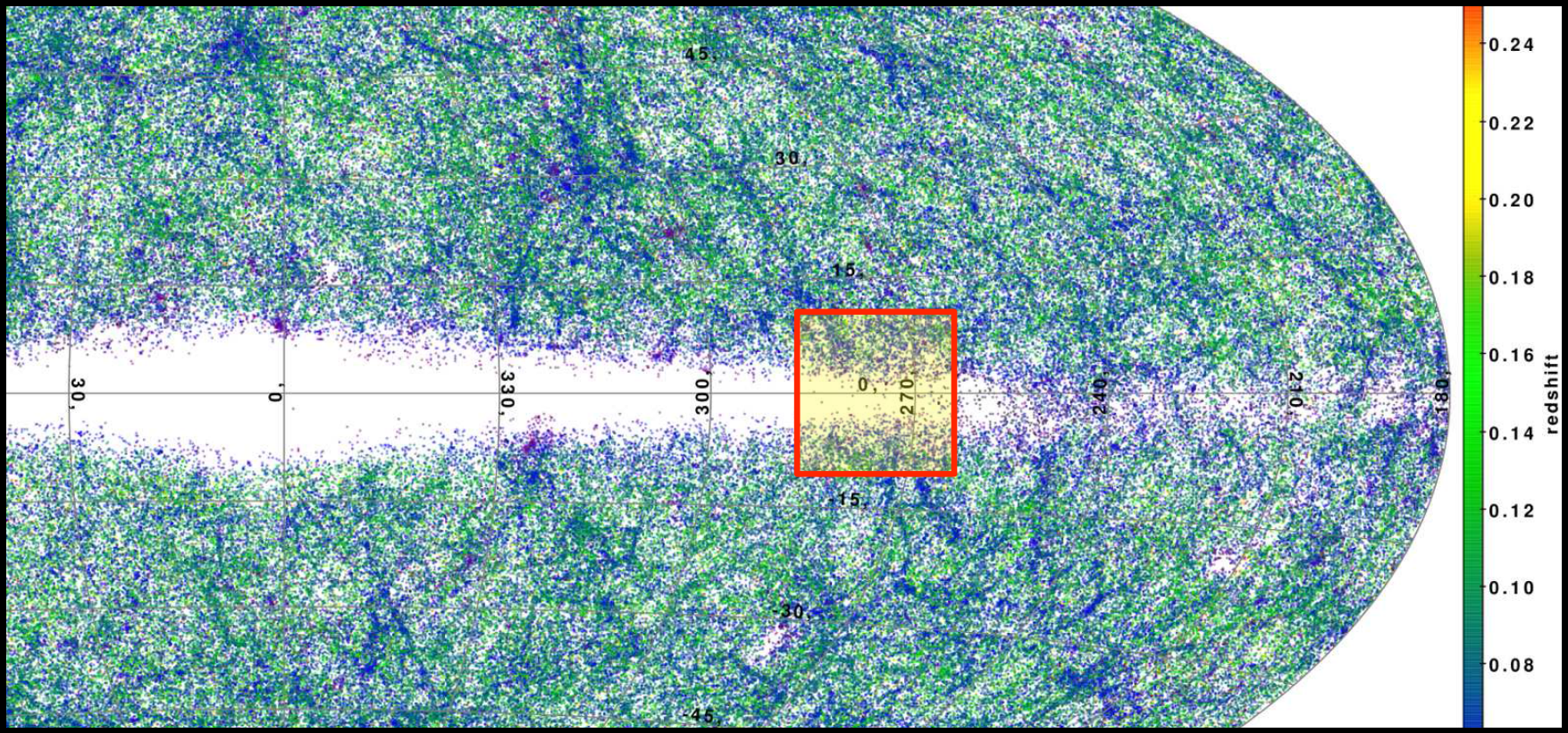
For ZOA survey area of 400□°→N ~ 4400



- → **10-11 gals/ sq degree**
- → **Minimum if regions overdense**
- → **Observing time: 60-80 hrs**

2MASS Phot-z redshift Catalog

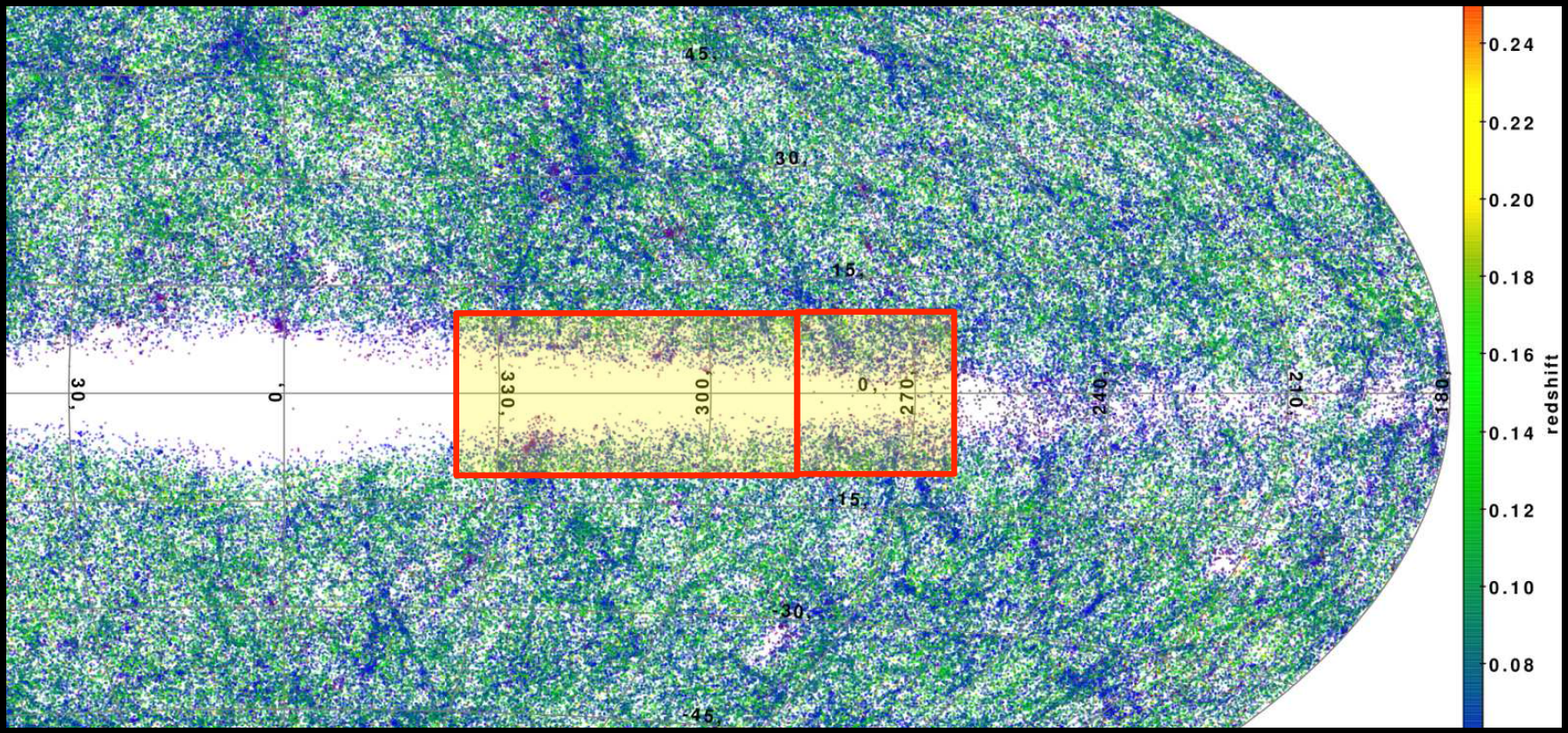
Bilicki et al 2013, arXiv:1311.5246



- 25° x 16°: Confirm extent across ZOA; allows mass overdensity estimate 60 – 80hrs

2MASS Phot-z redshift Catalog

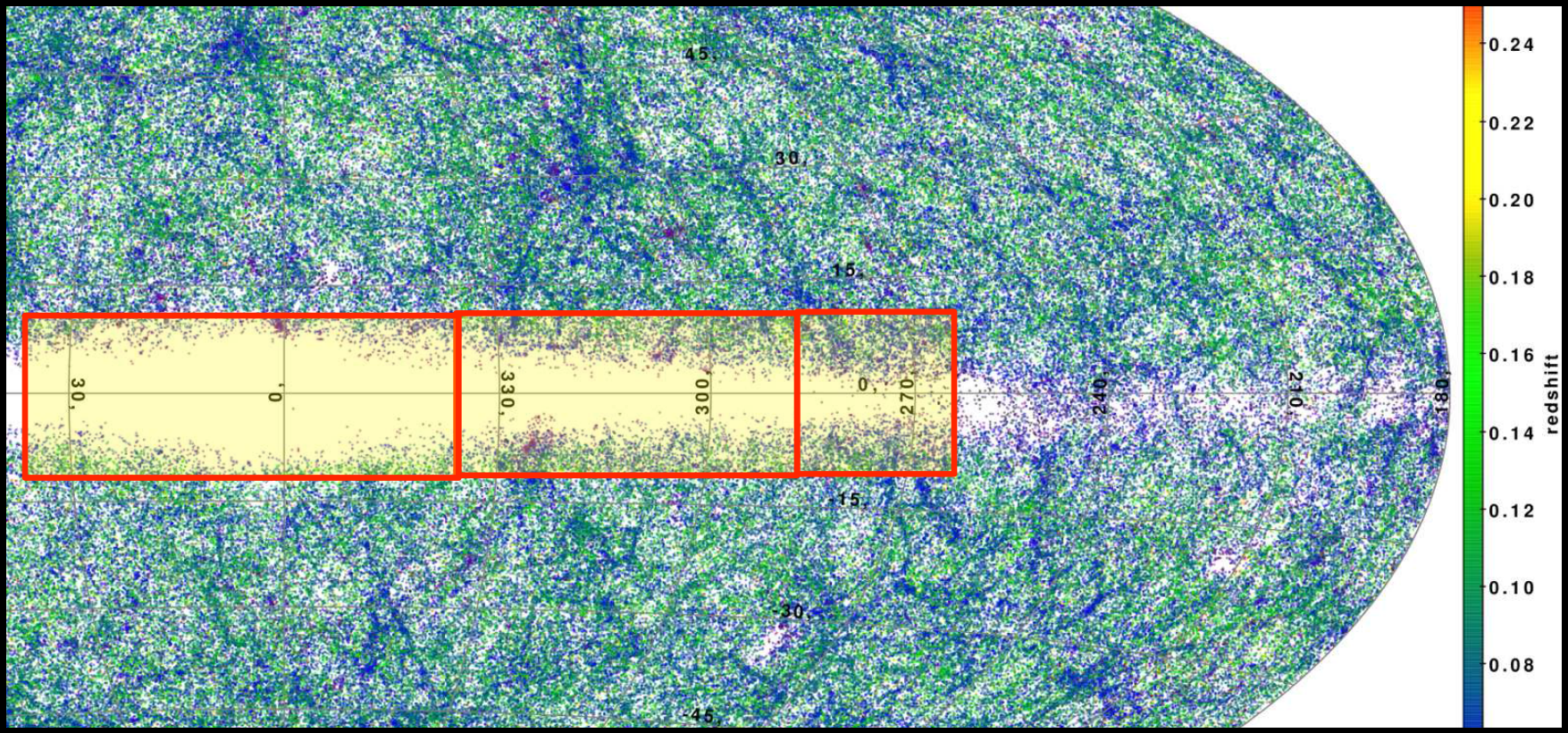
Bilicki et al 2013, arXiv:1311.5246



- 20° x 20°: Confirm extent across ZOA; allows mass overdensity estimate 60 – 80hrs
- 80° x 20°: extension of great circle from Shapley → Ara & TriAustralis ~240 hrs

2MASS Phot-z redshift Catalog

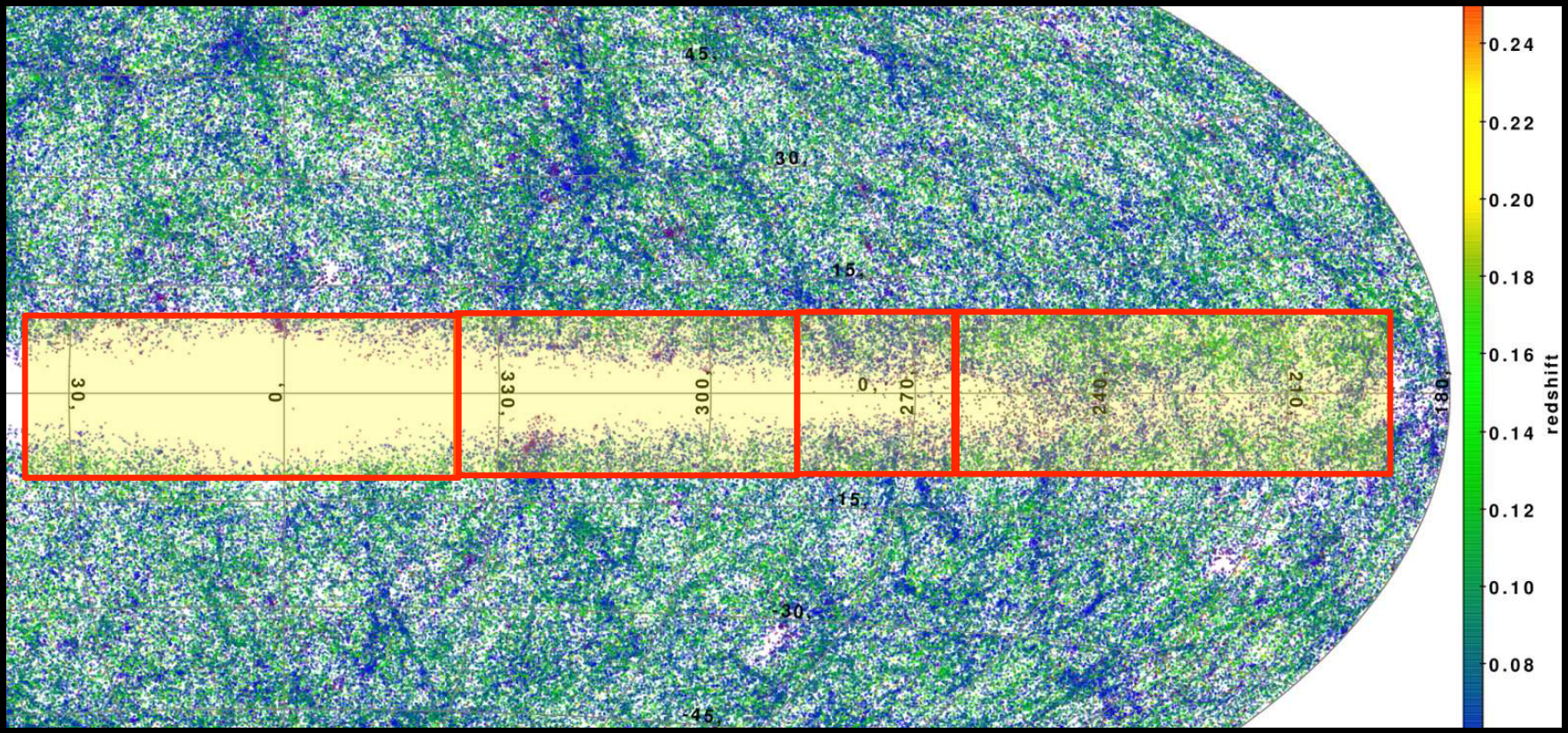
Bilicki et al 2013, arXiv:1311.5246



- 20° x 20°: Confirm extent across ZOA; allows mass overdensity estimate 60 – 80hrs
- 80° x 20°: extension of great circle from Shapley → Ara & TriAustralis ~240 hrs
- 140° x 20°: extension to cover Local Void, outer boundary, Ophiuchus ~420

2MASS Phot-z redshift Catalog

Bilicki et al 2013, arXiv:1311.5246



- 20° x 20°: Confirm extent across ZOA; allows mass overdensity estimate 60 – 80hrs
- 80° x 20°: extension of great circle from Shapley → Ara & TriAustralis ~240 hrs
- 140° x 20°: extension to cover Local Void, outer boundary, Ophiuchus ~420
- Whole southern ZOA? ~500

Conclusions

AERA^3: extremely powerful for HI-surveys of fairly local Universe:

Comparison to HIPASS/HIZOA:

Less than half the time, double the areal survey size in |b| gives

~20000 galaxies with M(HI) > 10^9 out to about 30'000km/s

< 750 (o/o 950) galaxies in HIZO Awith same HI-mass limit out to 12000km/s

- thanks to incredible large FoV (78)

- 12hrs (or 6hrs if larger area envisioned)

- Δv = 10km/s (could be less – can be smoothed)

- max BL of 1km is sufficient, but 60" → 30" would be preferred (for overdense regions, and also including lower z galaxies in smaller volumes

- presentation focus: on shell of contention wrt bulk flow issues

→ Allows for many other science questions to be addressed