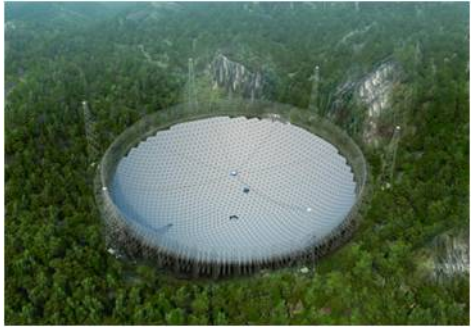


Exploring the Pisces-Perseus Supercluster (PPS) with FAST

Li Xiao

Ming Zhu， Mei Ai （FAST）

Martha Haynes, Riccardo Giovanelli （Cornell）

2014 5.20 GBT

Outline

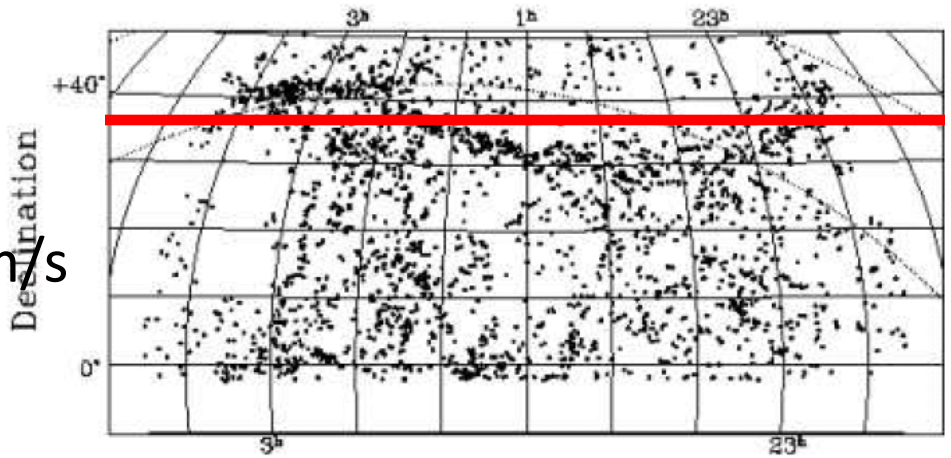
- Overview of PPS
- Infall motion towards PPS
  - Background on peculiar velocities and why they're interesting
  - New I-band Tully-Fisher sample
  - Fit the flow model
- FAST extragalactic HI survey

The Pisces-Perseus supercluster

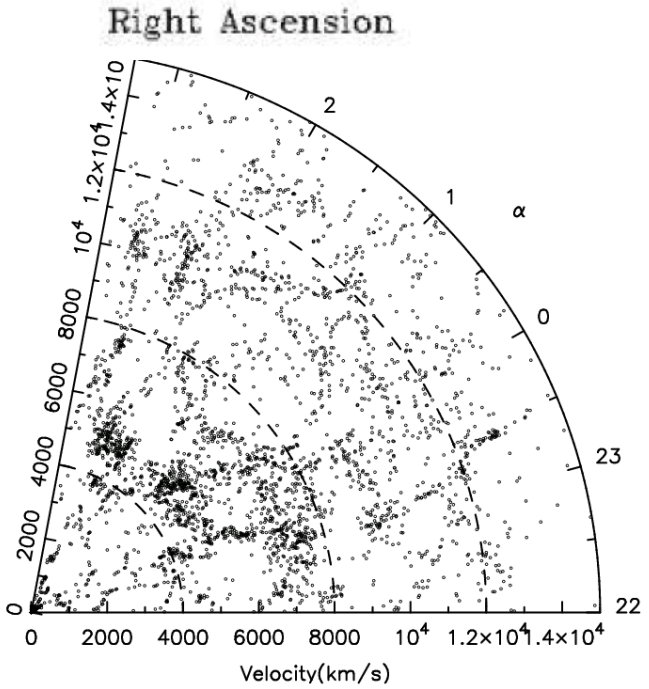
Width: 5-10h^{-1} Mpc

Redshift depth: 250-500 km/s

Distance: 5000 km/s



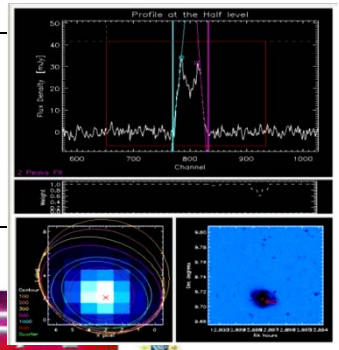
- One of the most prominent large scale features in local Universe
- Strong filamentary overdensity
- Rich clusters in the main ridge
- Voids in the foreground

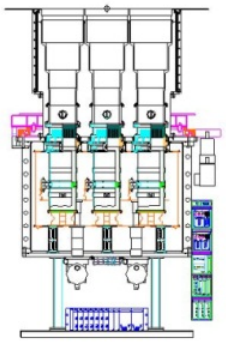


Arecibo Legacy Fast ALFA survey (ALFALFA)

- ALFALFA is designed to explore the HI gas over a cosmologically significant volume with adequate statistics and dynamic range.
- To cover 7000 sq deg of high galactic latitude sky
- Started Feb'05, 4400 hrs of telescope time, 7 years

Survey	Beam	Area	rms	min M_{HI}	N_{det}	t_s
	arcmin	sq. deg.	(mJy @ 18 km/s)	@ 10 Mpc		sec
ALFALFA	3.5	7,000	1.7	4.4×10^6	30,000+	40





The Arecibo Legacy Fast ALFA Survey

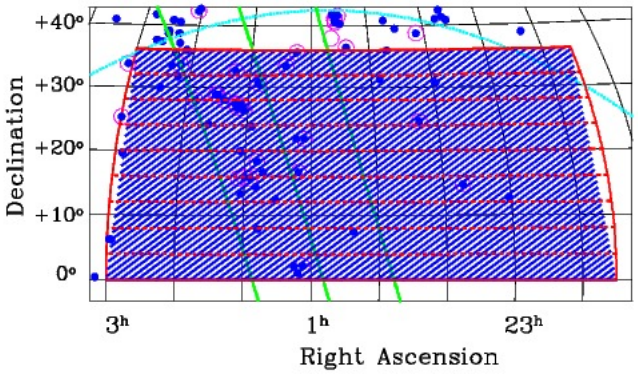
Main People Science Schedule Data Documentation Links Publications Undergrads
Non-experts News/Events Observing/Data Team

Overview

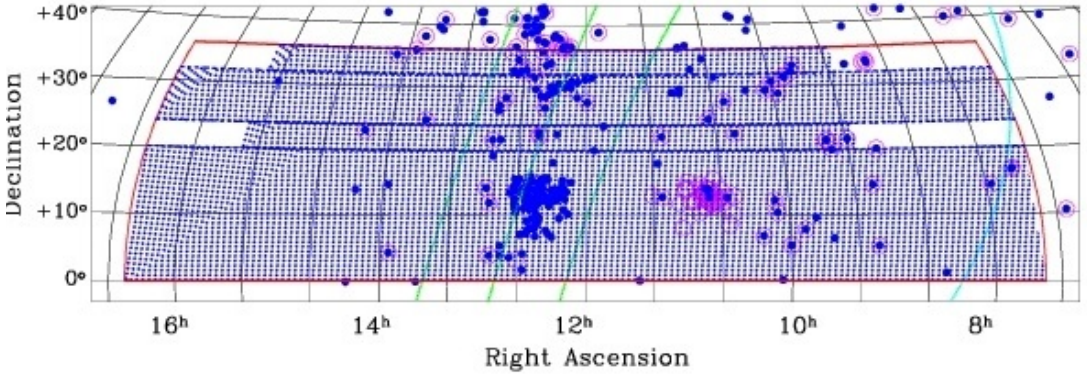
Arecibo is the world's most sensitive radio telescope at L-band. In addition to that all-important sensitivity advantage, Arecibo equipped with ALFA offers important and significant improvements in angular and spectral resolution over the available major wide area extragalactic HI line surveys such as 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

Survey strategy

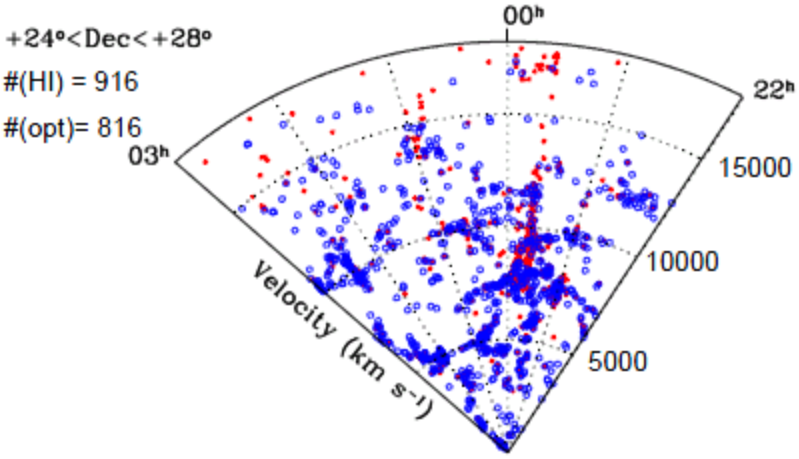
- 1345-1435 MHz (-2000 to +17,500 km/s for HI line)
  5 km/s resolution
- 2-pass drift mode (total int. time per beam ~ 40 s)
  - First pass beams spaced by 14.6’
  - 2nd pass offset from the 1st to give 1.05’ sampling
- Highly efficient: 99% “open shutter” time
- Follow up pointed observations with LBW

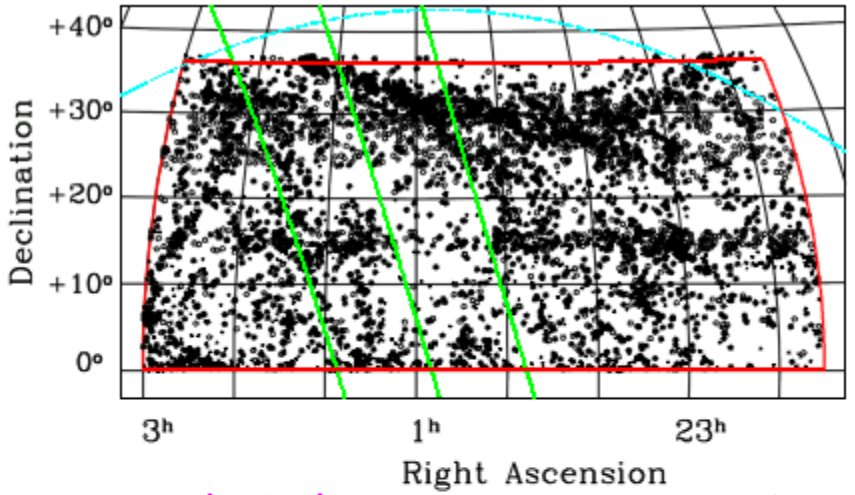


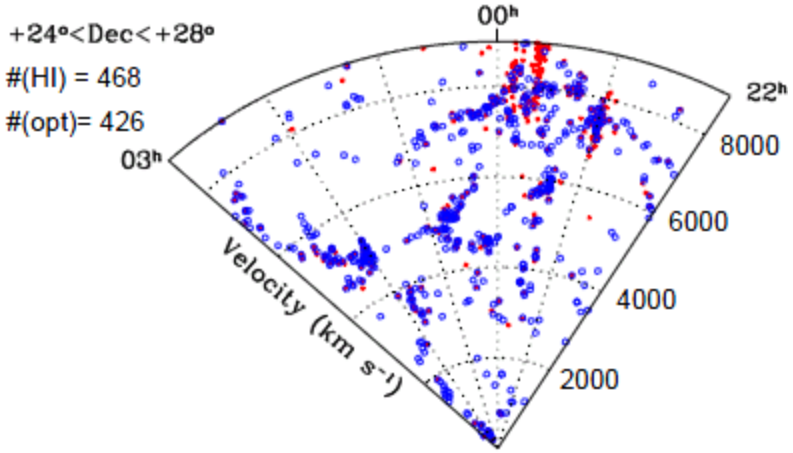
Fall sky

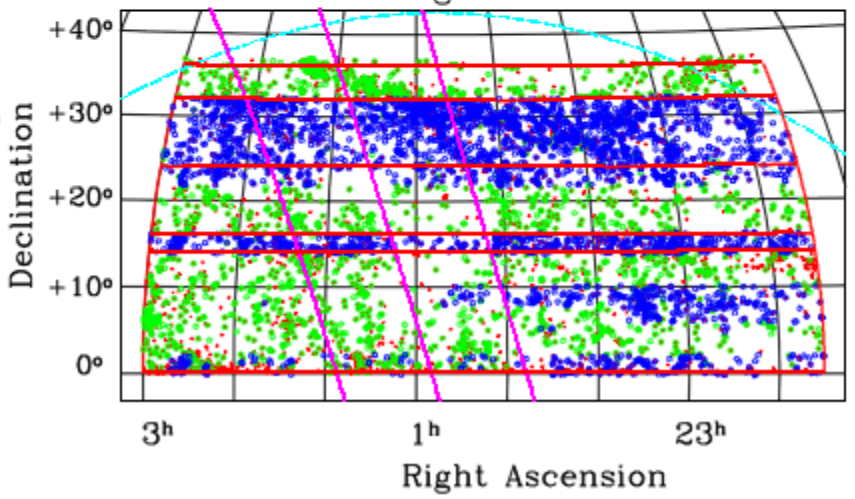


Spring sky


+24°<Dec<+28°
#(HI) = 916
#(opt)= 816
00h
03h
22h
15000
10000
5000
Velocity (km s-1)


+40°
+30°
+20°
+10°
0°
Declination
3h
1h
23h
Right Ascension


+24°<Dec<+28°
#(HI) = 468
#(opt)= 426
00h
03h
22h
8000
6000
4000
2000
Velocity (km s-1)


+40°
+30°
+20°
+10°
0°
Declination
3h
1h
23h
Right Ascension

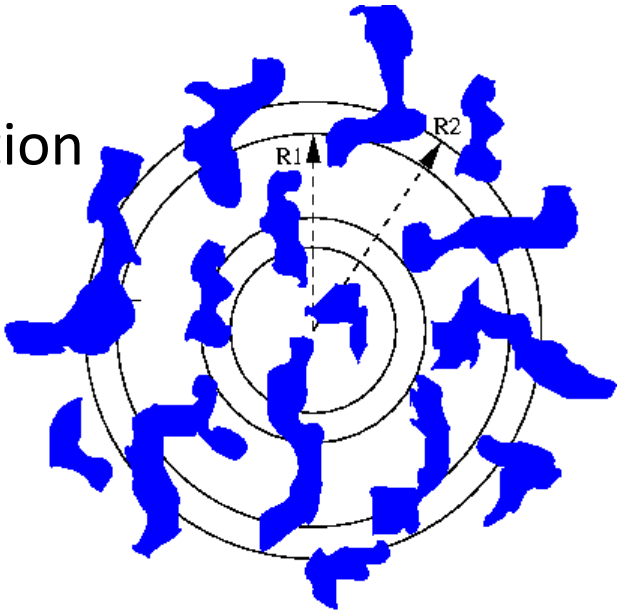
Projects on PPS

- **TF-relation to derive the peculiar velocity field to get the infall motion**
- Find loose groups, and the clustering effect (Mei Ai)
- Properties of Galaxies in Cluster and field galaxies
- Constraints on the local Void population
- Comparison with numerical simulation to see how such long thin structure formed

The Peculiar Velocity

- It's caused by the gravitational attraction of nearby density fluctuations δ(r), separate from the Hubble expansion

$$V_{pec} = \frac{H_o \Omega^{0.6}}{4\pi} \int \delta(\vec{r}) \frac{\vec{r}}{r^3} d\vec{r}^3$$



- Tully-Fisher relation provides redshift independent distances for spirals

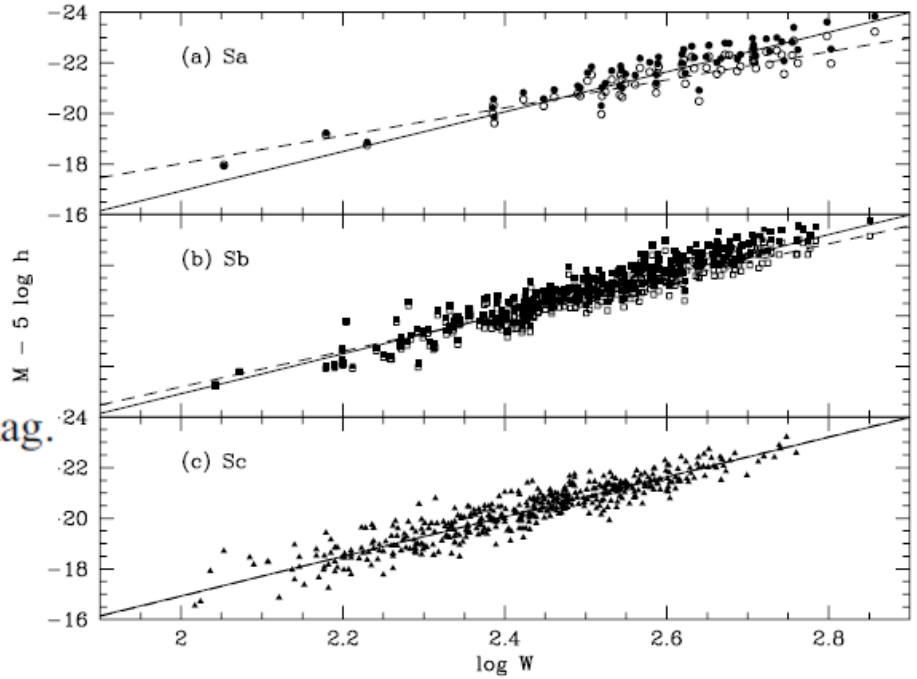
$$v_{pec} = cz - H_0 r$$

- Using the peculiar velocity field to trace mass in the local universe, and the biasing parameter of b=δgal/ δmass

Tully-Fisher (TF) relation

- Need an accurate TF Template Relation, obtained from
  - A cosmological fair sample of gals.
  - A good understanding of Scatter & its sources, Sample biases

- Scatter usually smallest with I-band photometry
- Slope and zero-point vary with morphological types
- SFI++: 807 galaxies in 31 nearby clusters and groups



For S0/Sa/Sab: $-0.32 - 0.9(\log W - 2.5)$ mag.
For Sb: $-0.10 - 0.9(\log W - 2.5)$ mag.
For Sbc/Sc/Scd: no correction.

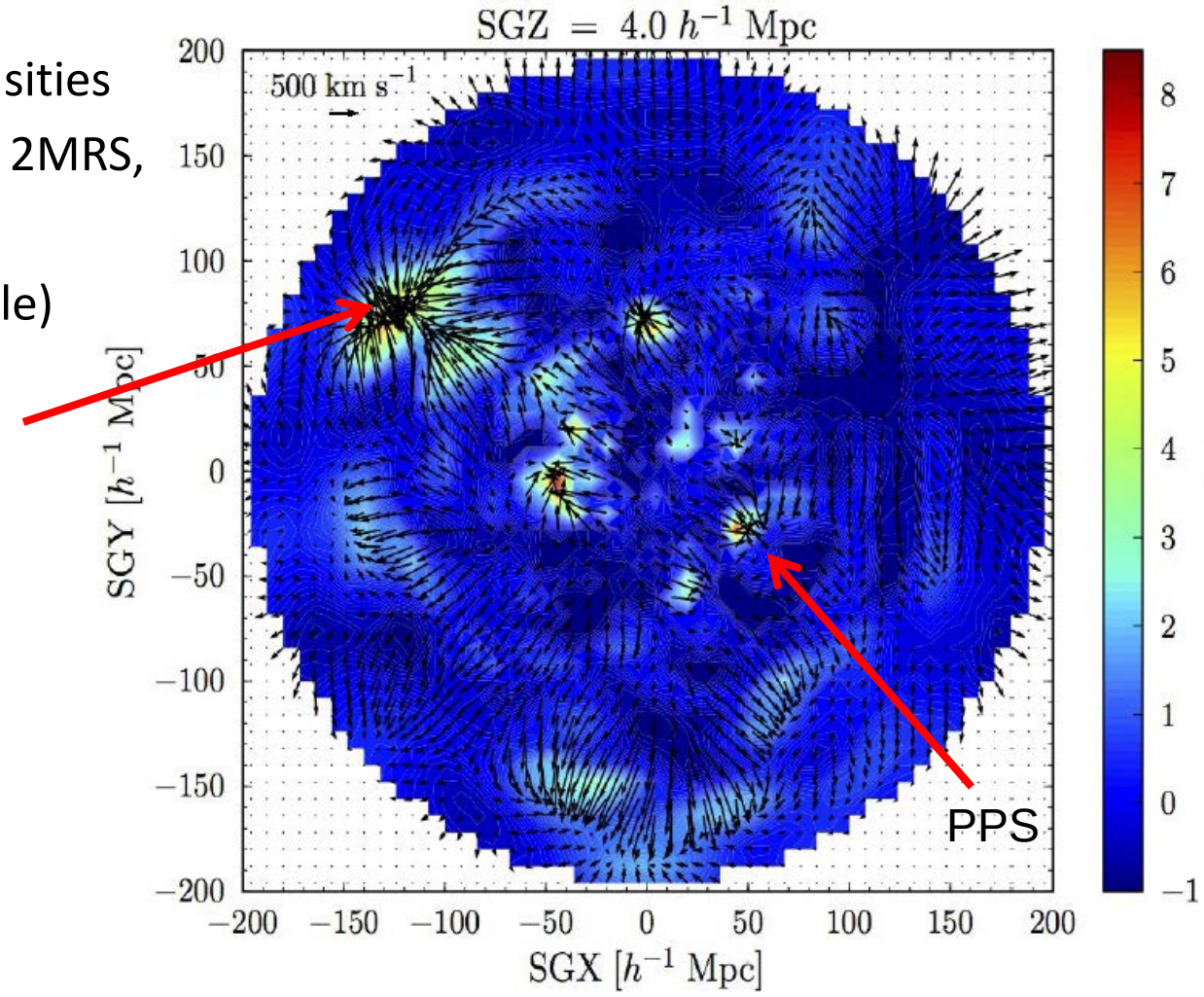
Masters et al. (2006)

2MRS Velocity field model

3D reconstruction of densities and velocities field from 2MRS, out to ~200 Mpc/h (K=11.75 mag limit sample)

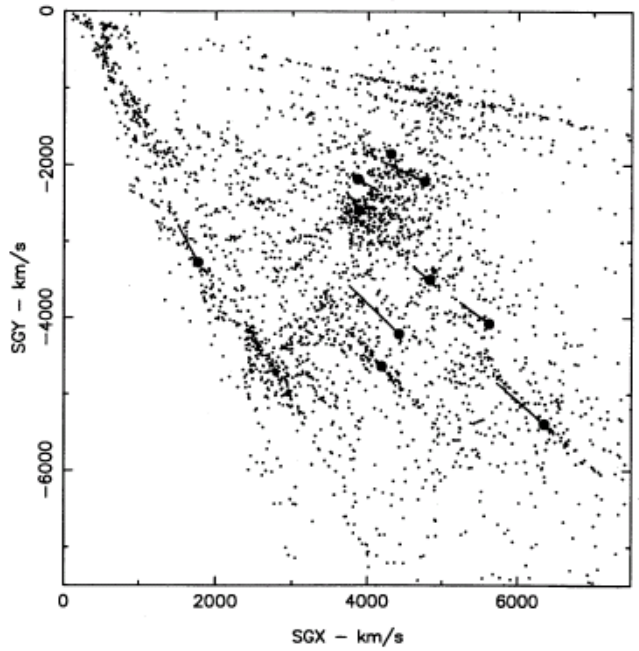
Backside infall on the "Great Attractor"

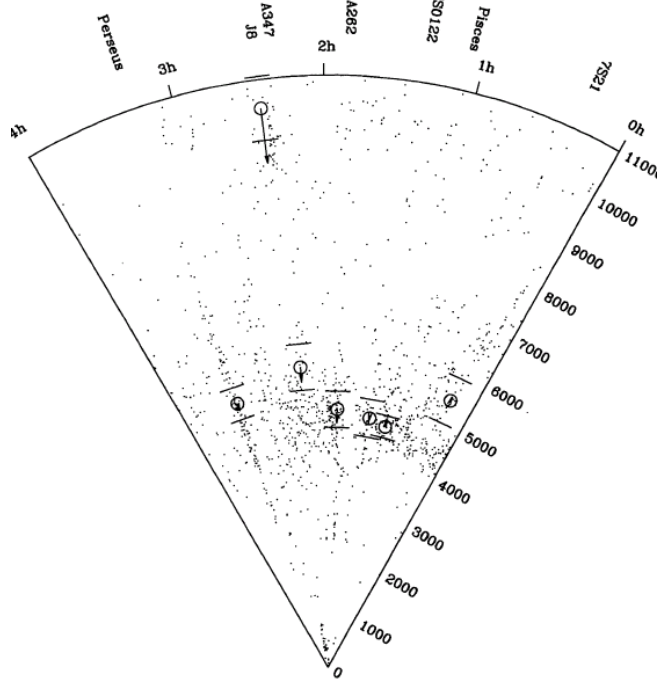
Erdogdu et al. (2014)



Infall towards PPS

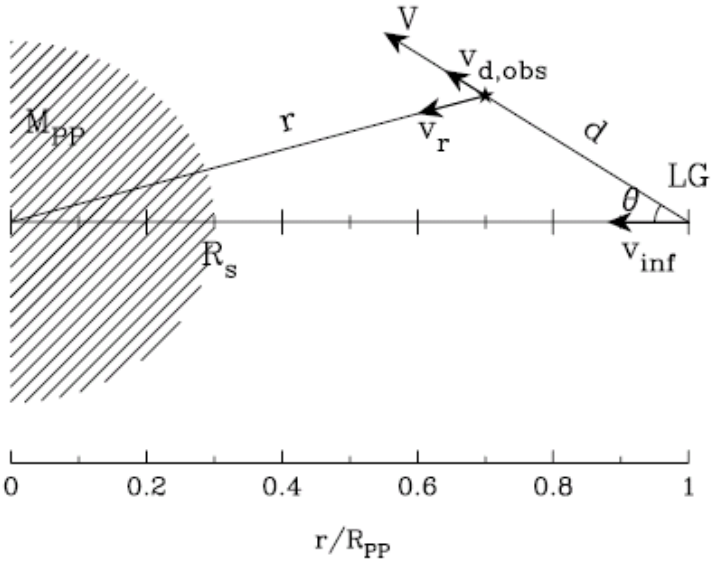
- r-band 355 TF galaxies (Willick 1991; Courteau et al. 1993)
  - join the bulk flow ~350 km/s
- 21 cluster I-band TF sample (Han & Mould 1992)
- 16 cluster inverse FP sample (Hudson et al. 1997)
  - Infall in the backside, bulk motion 420±280 km/s

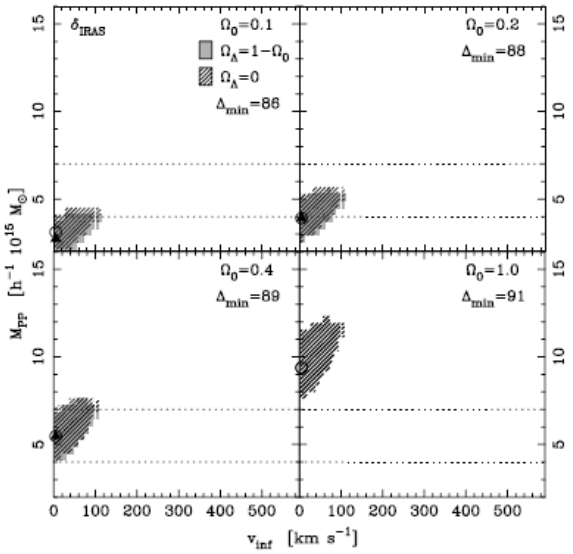




Infall towards PPS

- POTENT reconstruction of ρ and PV field (Mark III)
  - PPS at rest to LG, infall in the frontside (Dekel et al. 1999)
- Monte-Carlo analysis (SFI) (da Costa et al. 1996)
  - no significant bulk flow
    - Tolman-Bondi model (KLUN):Vinf <100 km/s (Hanski et al. 2001)
- Fit the velocity model (SFI++): V~30 km/s (Springob et al. 2005)



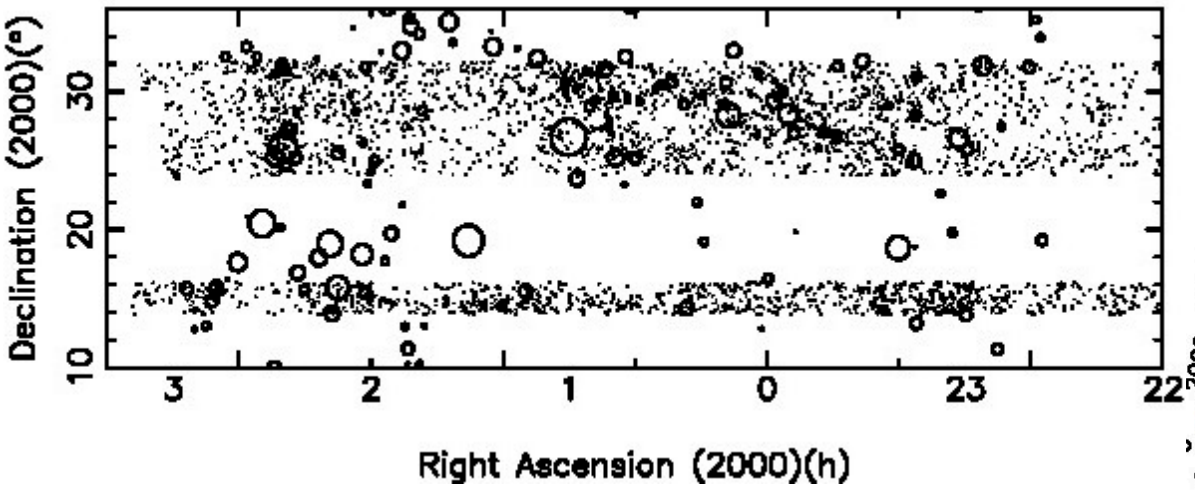


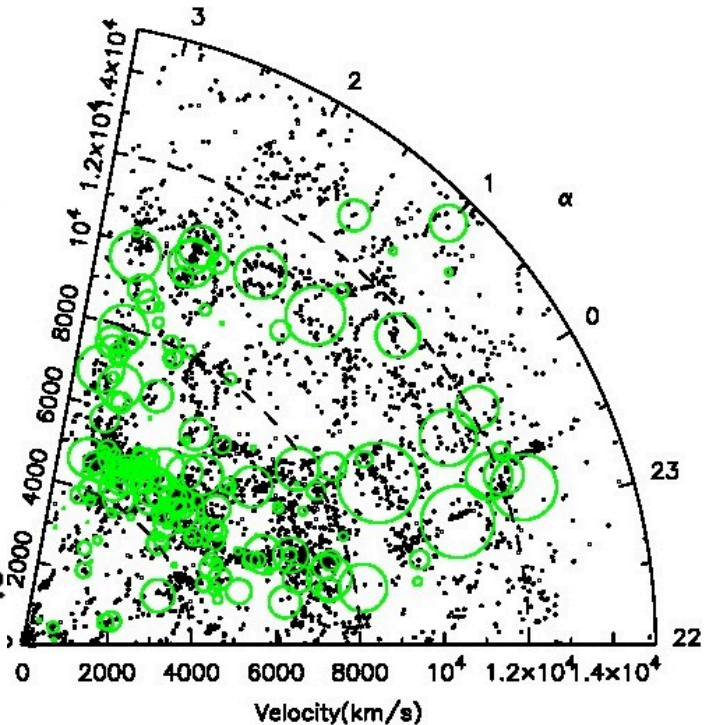
AlFALFA + SFI++ + SDSS

- Tully-Fisher relation-> PPS galaxies distances
- Peculiar velocities $v_{pec} = cz - H_0 r$

- Galaxy groups (“hard points” in PV field)

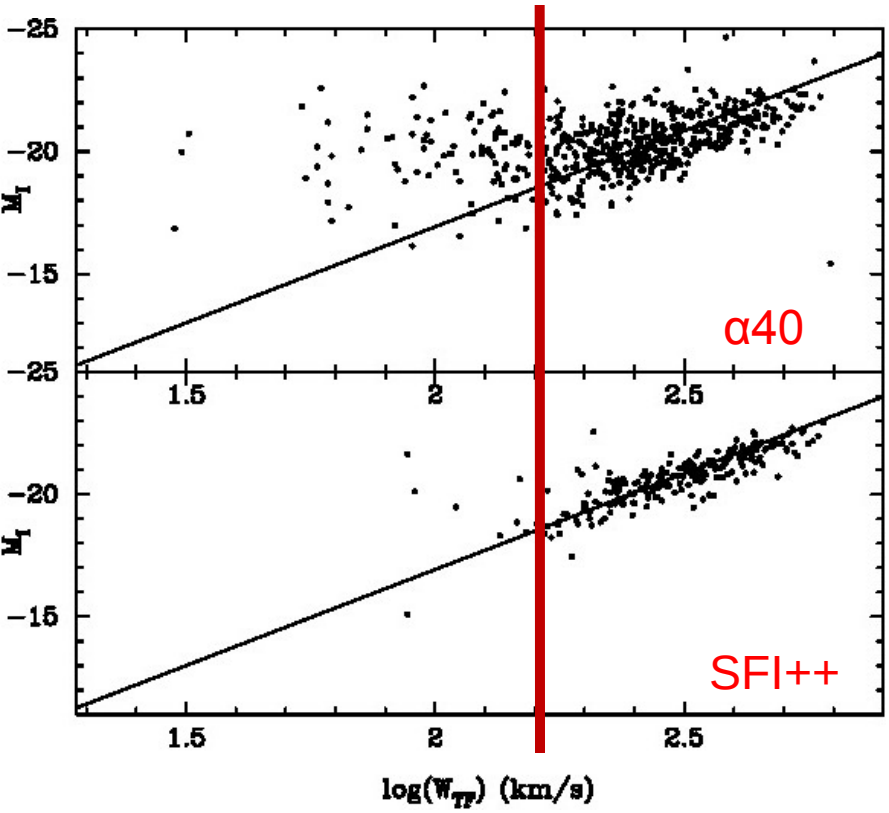
  -> No scatter out, less Malmquist bias effect, on the PPS main ridge

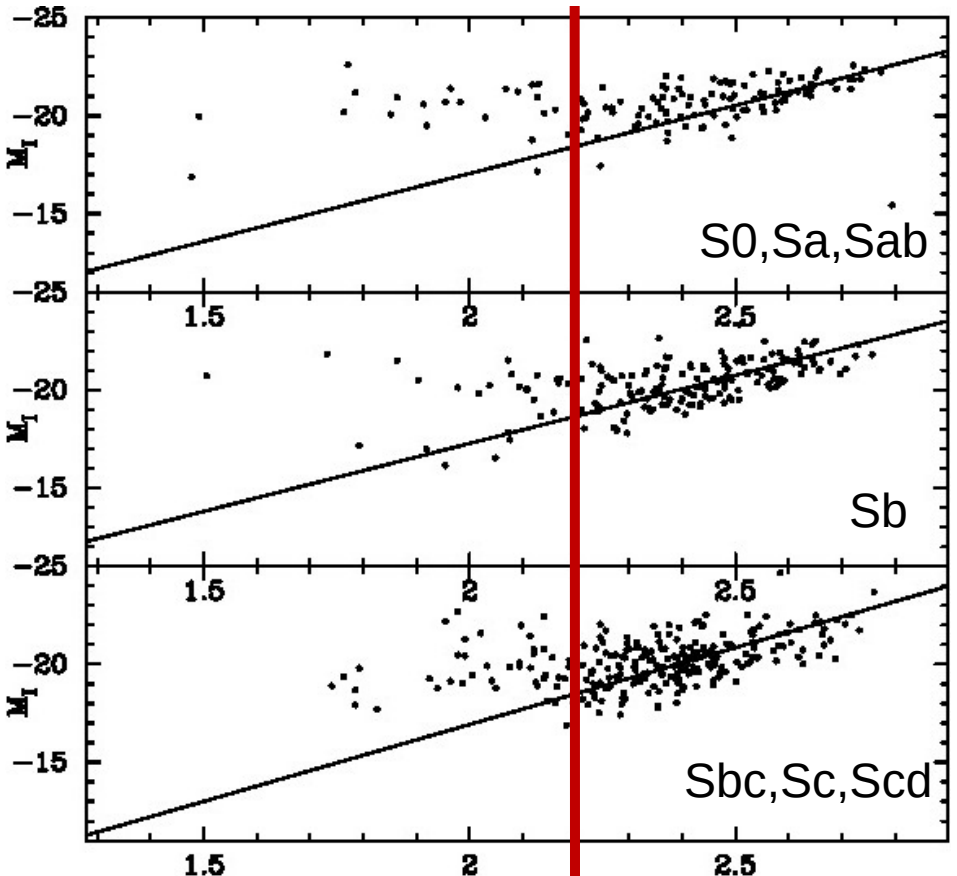




Construct the sample

- 546 α40 spirals (220 SFI++)
- More mass in HI than in M_* at $M_*<10^9\ M_s$
- Explore those points below logW<2.2, especially the “baryonic TF” relation



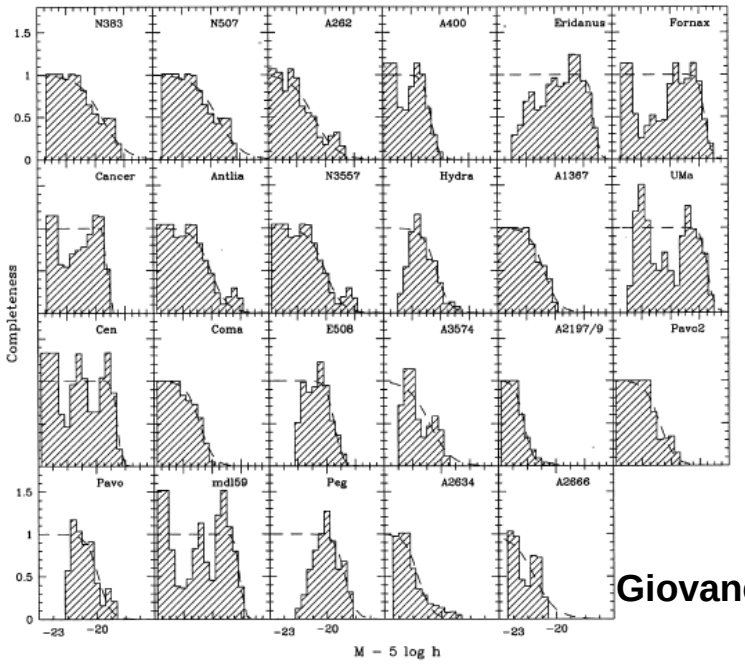


Malmquist bias correction

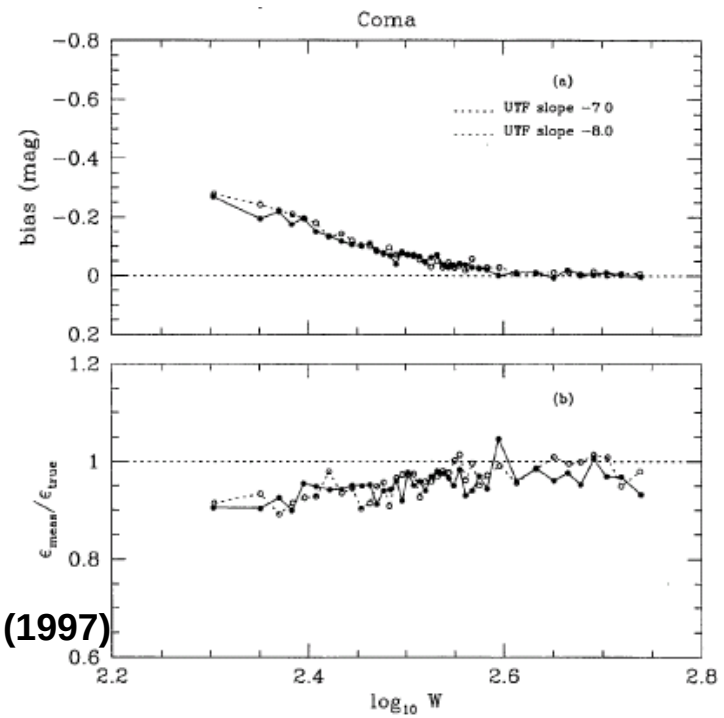
It arises from the coupling between the random TF distance errors (15%) and the density variation along the line of sight

- ✓ Incompleteness bias (Luminosity function)
- ✓ Inhomogeneous Malmquist bias (2MRS density field)

$$p(r_i) = k_1 p_{TF}(r_i) p_{mag}(r_i) p_{lss}(r_i) \qquad r_{gal-malm} = \Sigma_{i=1,41} p(r_i) r_i$$



Giovanelli et al. (1997)



Fit the flow model

- PV field traces mass distribution

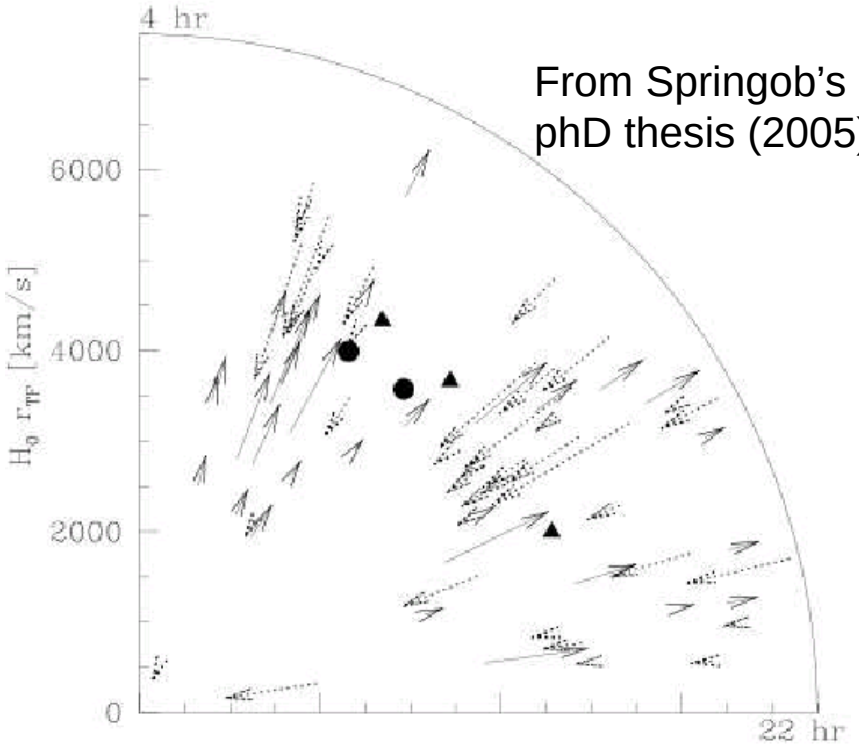
$$V_{pec} = \frac{H_o \Omega^{0.6}}{4\pi} \int \delta(\vec{r}) \frac{\vec{r}}{r^3} d\vec{r}^3$$

- Comparison with the 2MRS reconstructed velocity model

$$\mathbf{v_p(r)} = \mathbf{v_H(r)} + \mathbf{V} + \mathbf{V}_{\text{2MRS}}\mathbf{(r)},$$

1. Hubble term
2. A uniform bulk flow
3. 2MRS velocity field model

   -> Biasing parameter b

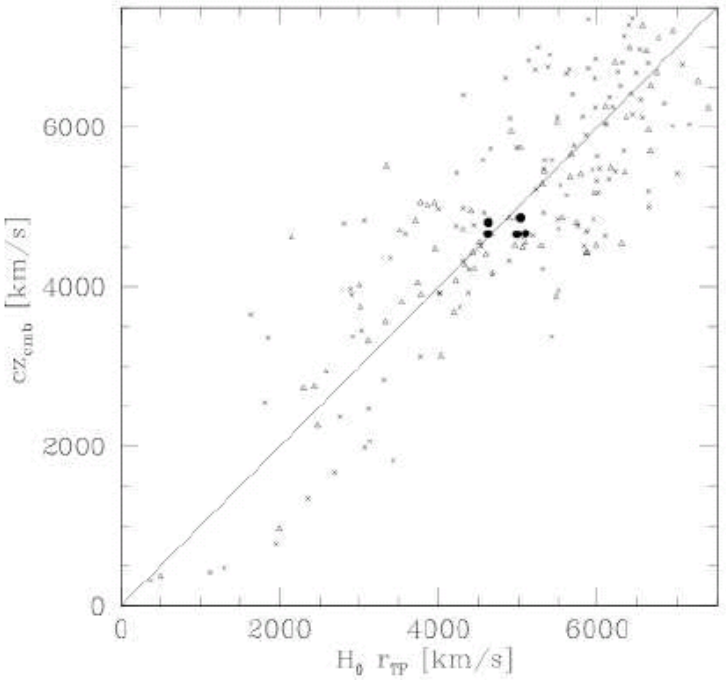


From Springob's phD thesis (2005)

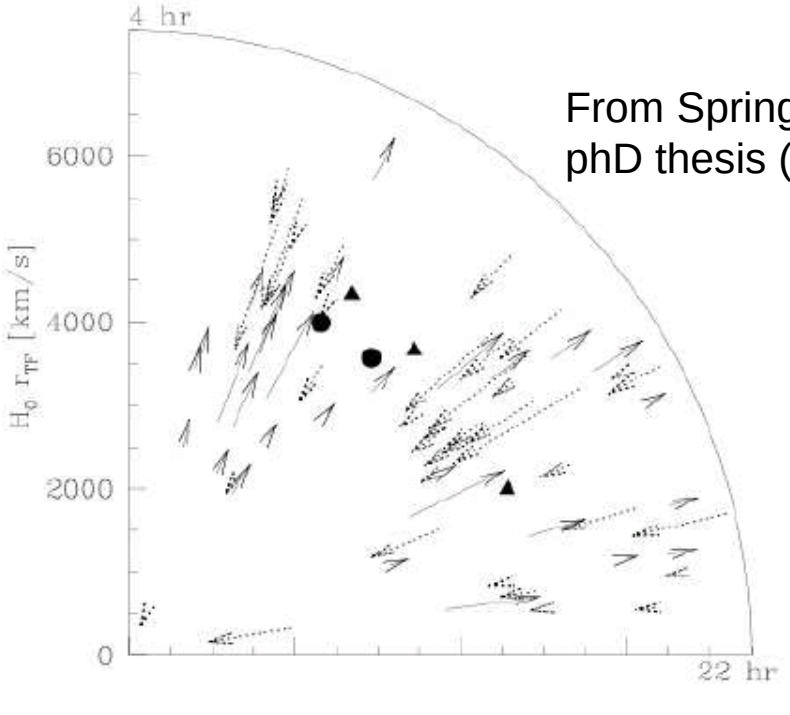
PVs of all Malmquist bias-corrected group

Expected results

- High quality TF distance and PV catalog of PPS
- The bulk flow and infall motion of PPS
- The biasing parameter comparing with the 2MRS model



Hubble diagram

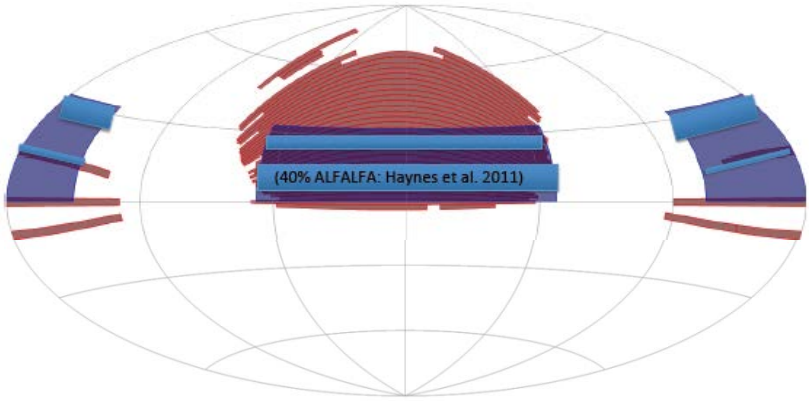


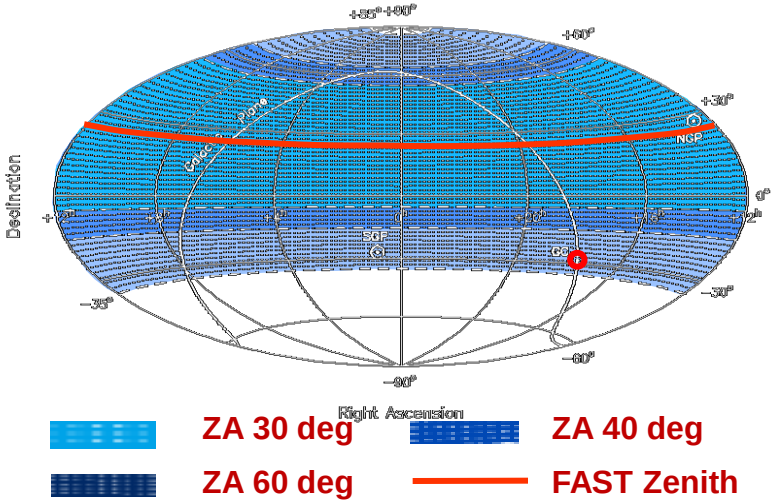
From Springob's phD thesis (2005)

PVs of all Malmquist bias-corrected group

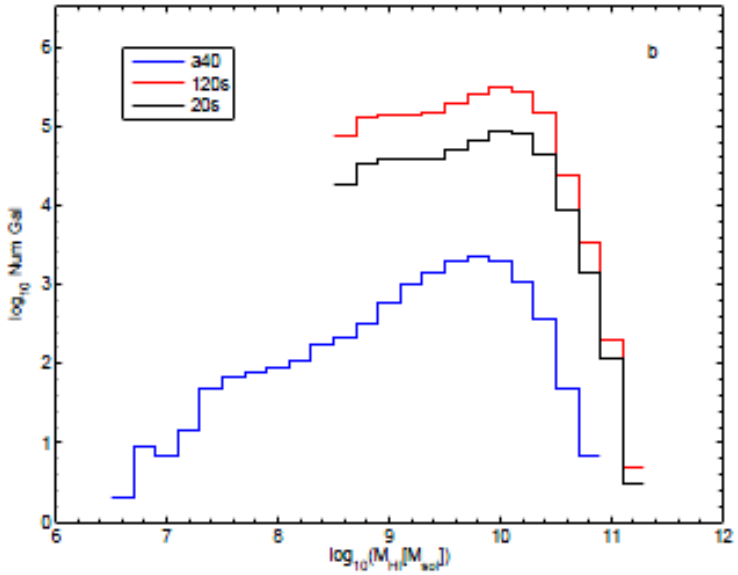
FAST extragalactic HI survey

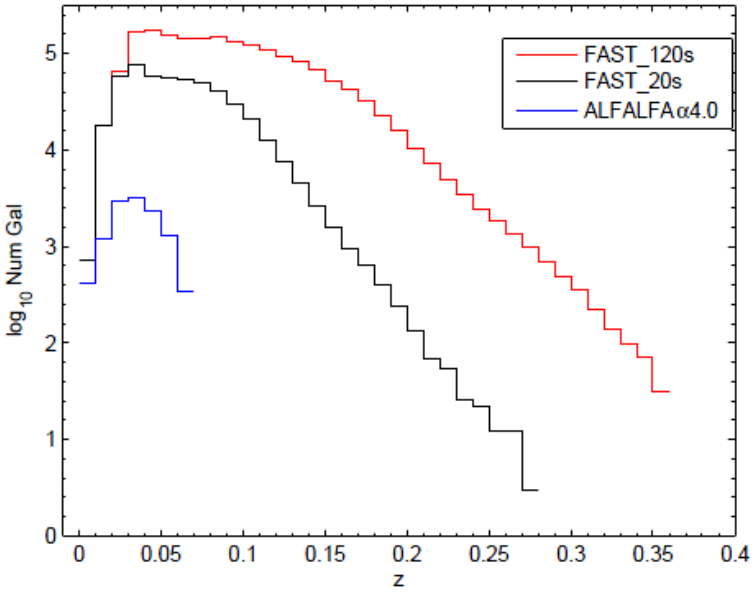
- Using a 19 beam L-band receiver to map 2π steradians FAST sky, resolution 2.9', doable in 1-2 yrs.
  - Freq: 1.05-1.45 GHz
  - Integration time: 20s(drift), 120s per beam
  - Expect about 500,000 detections with $M_{HI} < 10^{11} M_{\odot}$ out to z ~ 0.3 in a range of environments including Coma, Hydra, Ursa Major, Pisces-Persues supercluster plus neighboring voids.
- Extend the Arecibo sky coverage

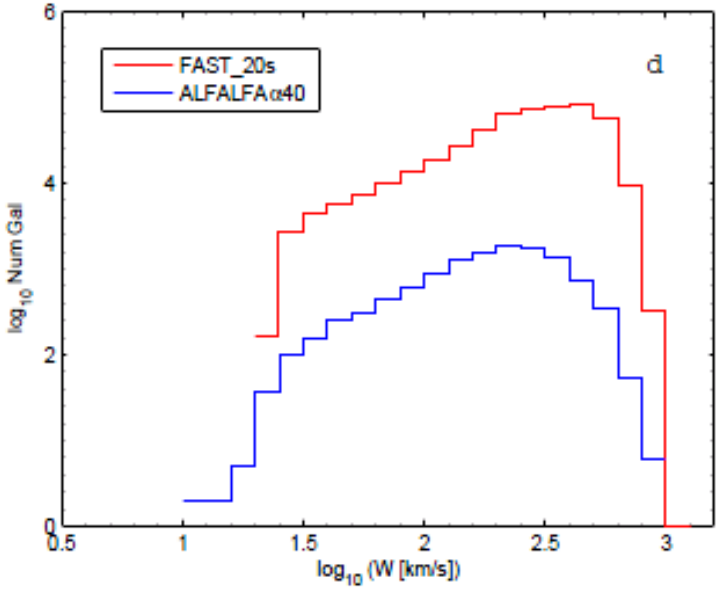




FAST simulation (2013)







Parameter	$\Delta t = 20$s	$\Delta t = 120$s
$1\,\sigma$ noise ($\Delta\nu = 20\mathrm{kms}^{-1}$)	~ 0.7 mJy	~ 0.3 mJy
n_{gal}	495,085	1,826,607
Redshift range	0-0.35	0-0.35
$\bar{z}$ (M)	0.0555 (0.0514)	0.0845 (0.0778)

PPS region: Cover the main ridge
Add more HI detections

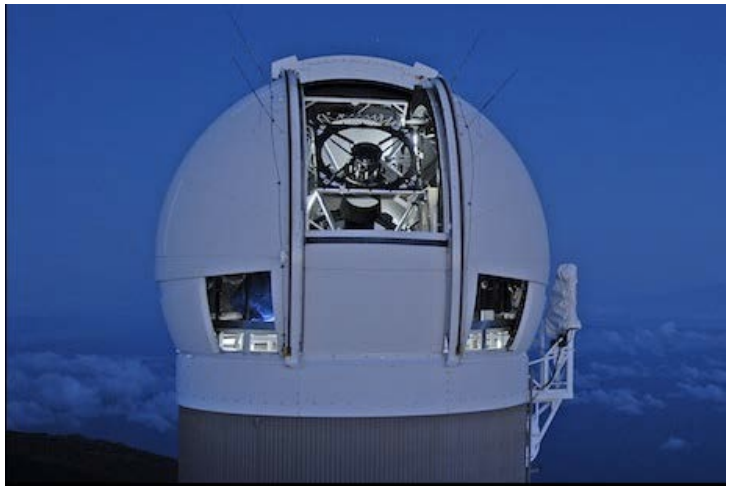
FAST + PanSTARRS

- FAST will add HI redshifts and widths of galaxies for TF and PV field studies

  S/N >7 in 5 km/s bins; i>30 deg; W>80 km/s

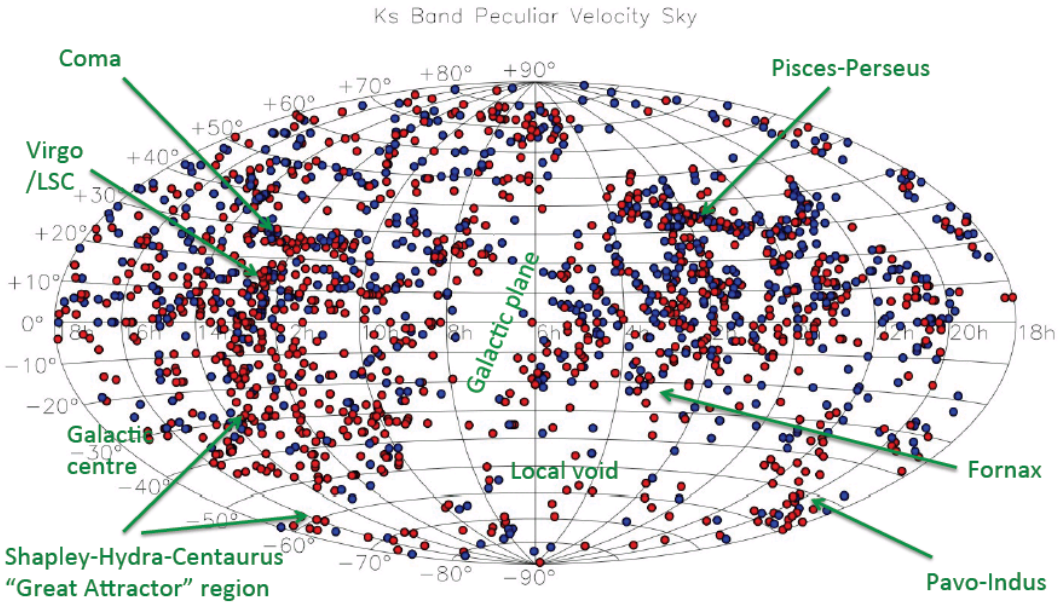
- The Panoramic Survey Telescope & Rapid Response System

  -> Source of photometric data, limit of 29.4 mag



Conclusions

- With high sensitivity and large coverage of the northern sky, FAST will provide much more HI galaxy detections for understanding of the large-scale structure in the PPS region.
- Combine FAST and PanSTARRS, we are able to construct a more dense I-band TF sample, especially including rich clusters in the main ridge, to improve the details of PPS infall motion.
- PPS is an example in the study of large-scale structures in local universe , and there are more superclusters in the FAST sky to explore.



Thank you!