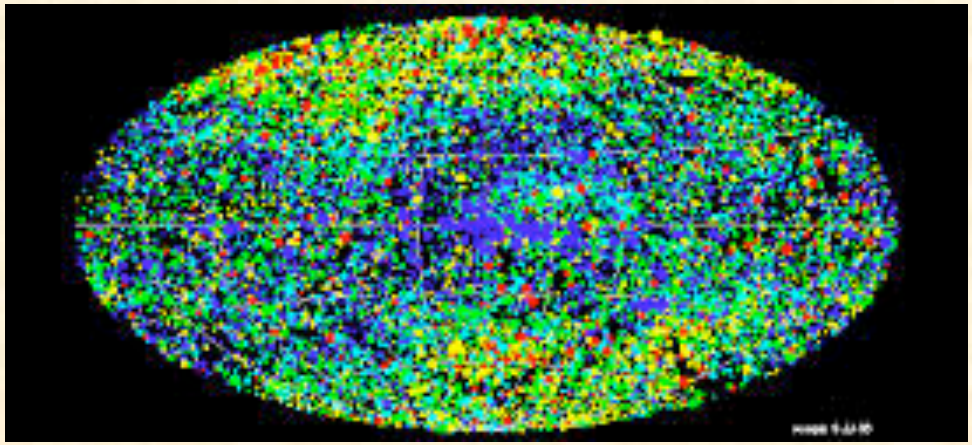
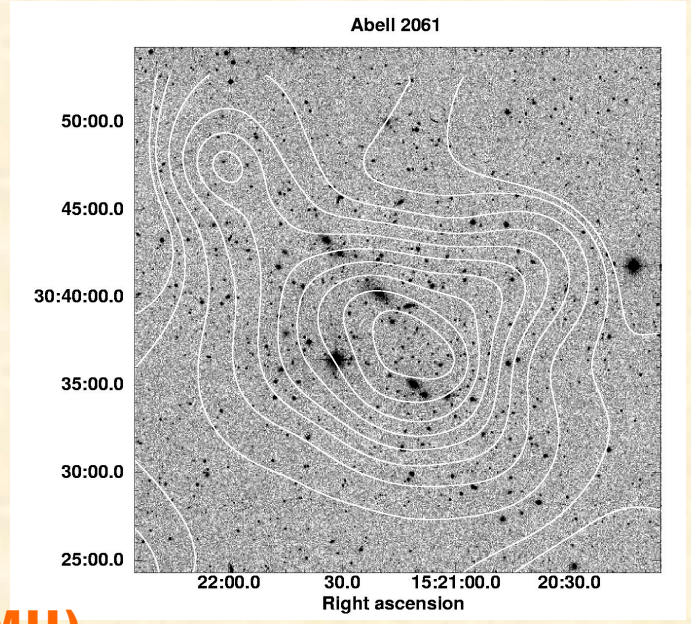
CHARACTERISING THE LOCAL VOID WITH X-RAY CLUSTERS FROM REFLEX II



ROSAT All-Sky Survey Brightest Sources



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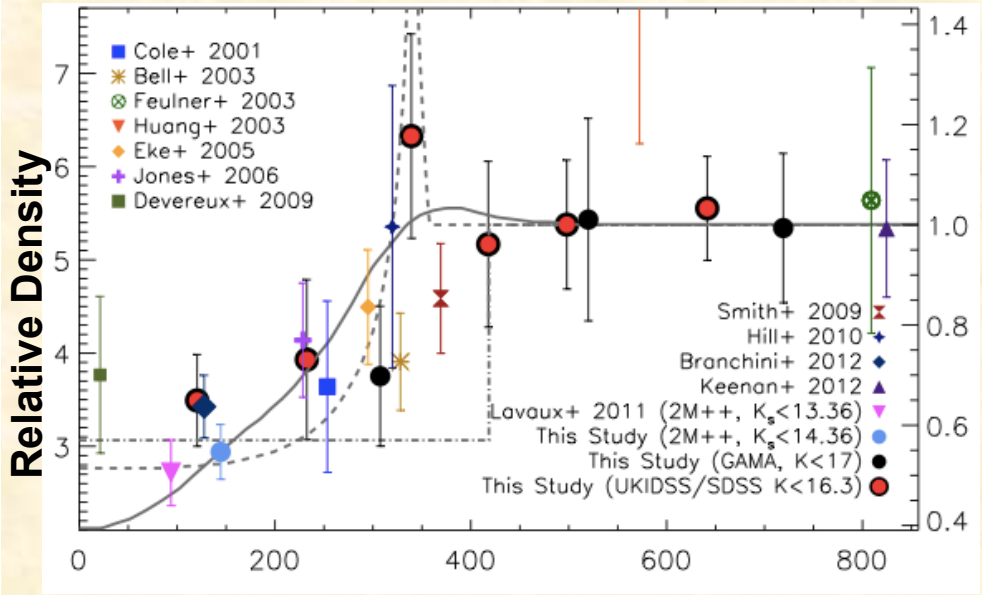
OUTLINE

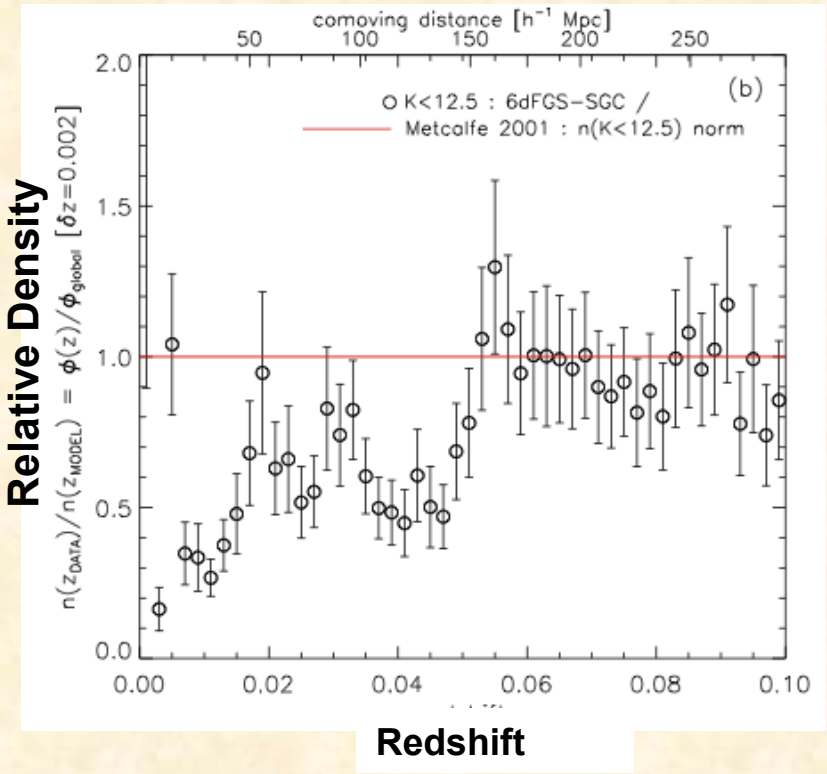
- Motivation
- Properties of REFLEX II
- Under density in Southern Hemisphere
- Density distributions in NGC & SGC regions
- Cosmological context & implications

MOTIVATION

KEENAN+(2013)



WHITBOURN & SHANKS (2014)



Under density from UKIDSS & 2MASS selected galaxies. Spectra from 2dFGRS, 6dFGRS, SDSS, 2MR + GAMA,
35,000 galaxies,
Area: 600 square degrees

Under density in SGC region from K & r band limited n(z) distributions from 6dFGRS and SDSS and number counts
250,000 galaxies
Area: 9,000 square degrees

INVESTIGATING UNDER DENSITY WITH X-RAY CLUSTERS

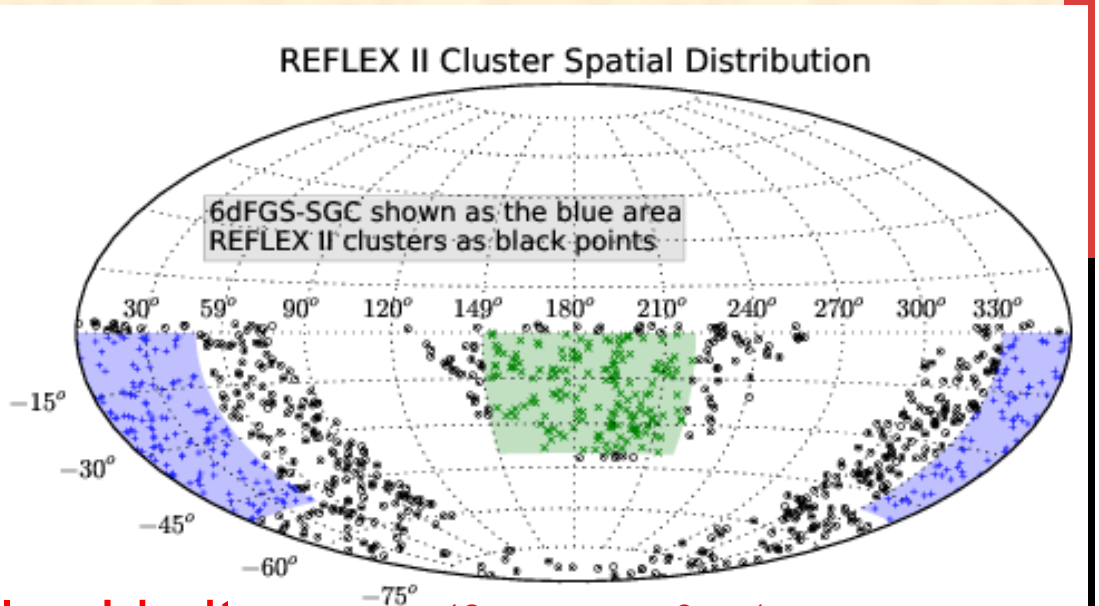
- **Probe large volumes ~10's – 100's Mpc**
- **Clusters are biased tracers, compared to galaxies**
  - ➢ This should amplify any density contrast
- **REFLEX II is a large homogenous X-ray flux limited cluster survey out to z~0.5**
  - ➢ REFLEX II covers entire Southern Sky above $|b| = 20^0$ - one third of entire sky (4.24 sr) !
- **Avoids photometric, aperture, stellar population biases which affect galaxies**
- **However, there a fewer clusters than galaxies !**

REFLEX II

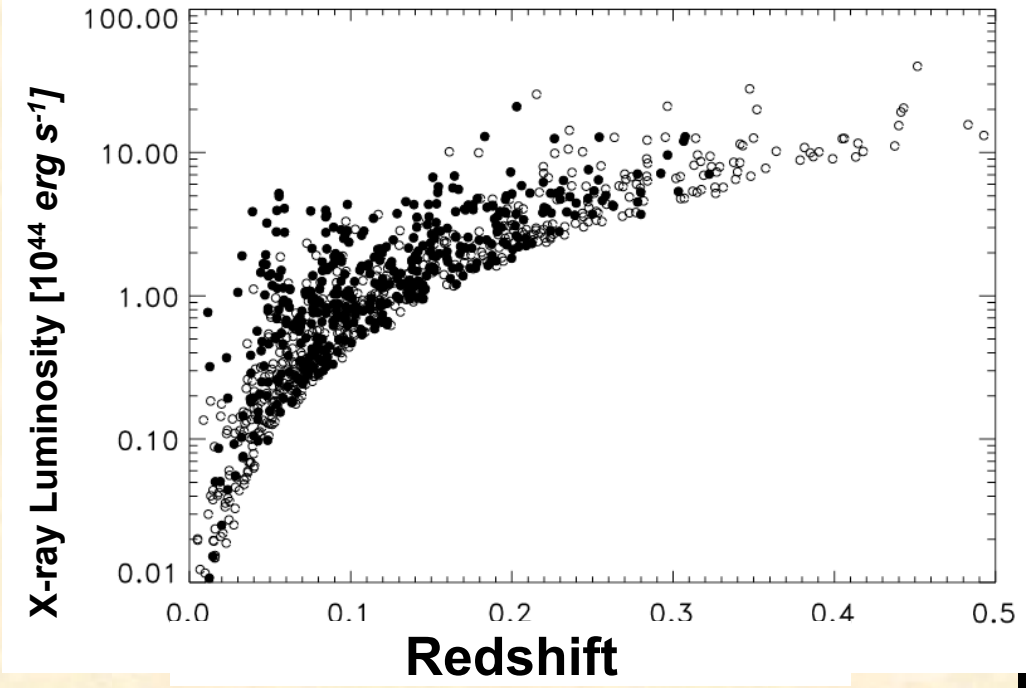
- RASS Based Survey
- Completeness > 90%
- Lx > 10^{42} erg s^{-1}
- 915 clusters/groups

Z:	0-0.05	0.05-0.1	0.1-0.25
N	155	290	372

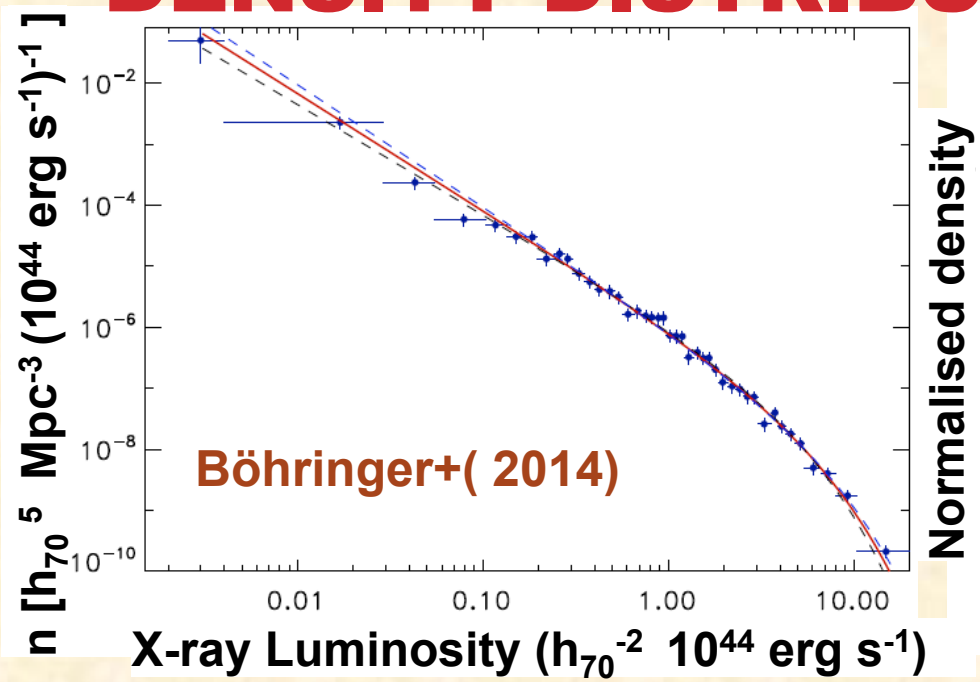
Böhringer+(2013)

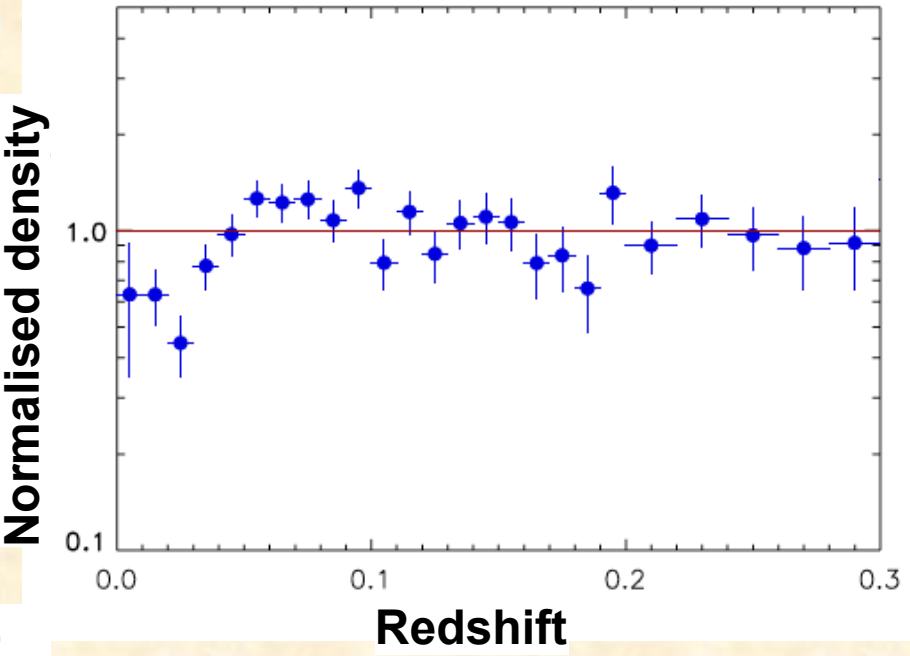


Flux Limit: 1.8x10^{-12} *erg cm^{-2} s^{-1} (0.1-2.4keV)*



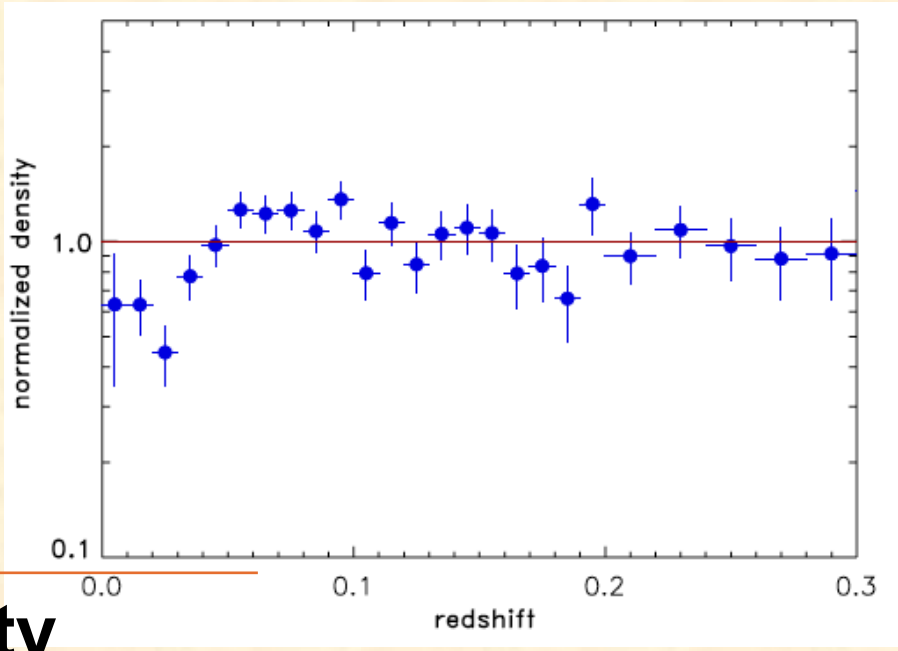
SOUTHERN SKY DENSITY DISTRIBUTION





- Relative density distribution of REFLEX II with best fit Schechter function for - corrected for the ROSAT exposure map.
- Homogeneous distribution with under density 30 +- 6% at z<0.05
- Over density at z=0.05 – 0.07

CUMULATIVE DENSITIES

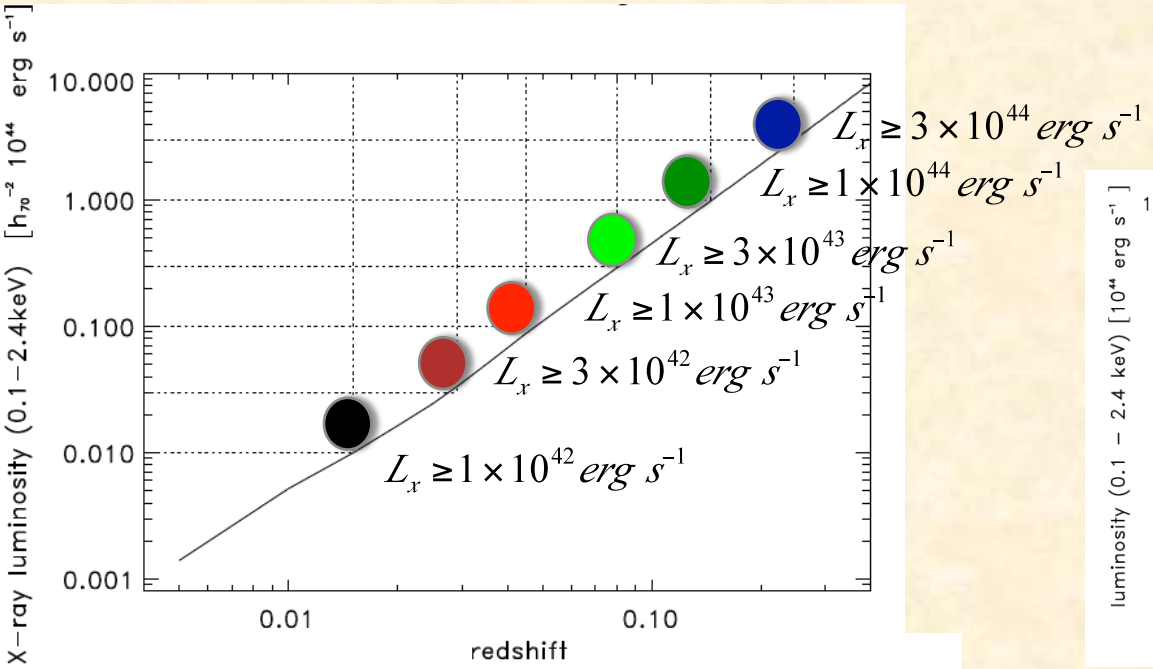


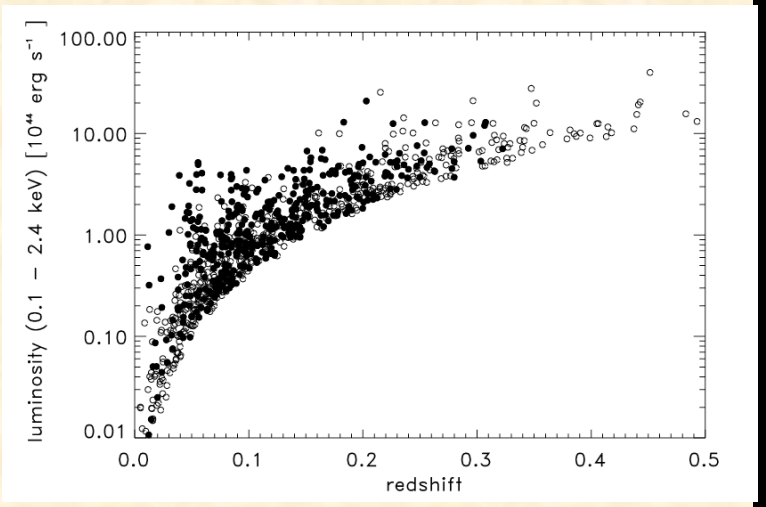
Z_{max}	Density
0.02	0.63 (±0.11)
0.03	0.53 (±0.07)
0.05	0.71 (±0.06)
0.07	0.88 (±0.06)
0.08	0.93 (±0.05)

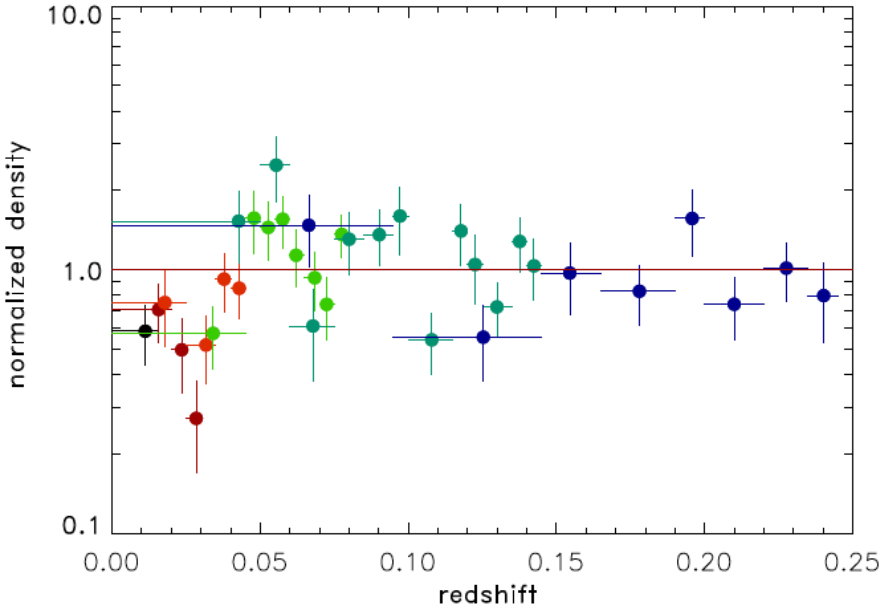
Table showing cumulative ratio of observed to predicted cluster numbers

Using best fitting Luminosity Function with $L_x \geq 10^{42}\, erg\, s^{-1}$

VOLUME LIMITED SUB-SAMPLES





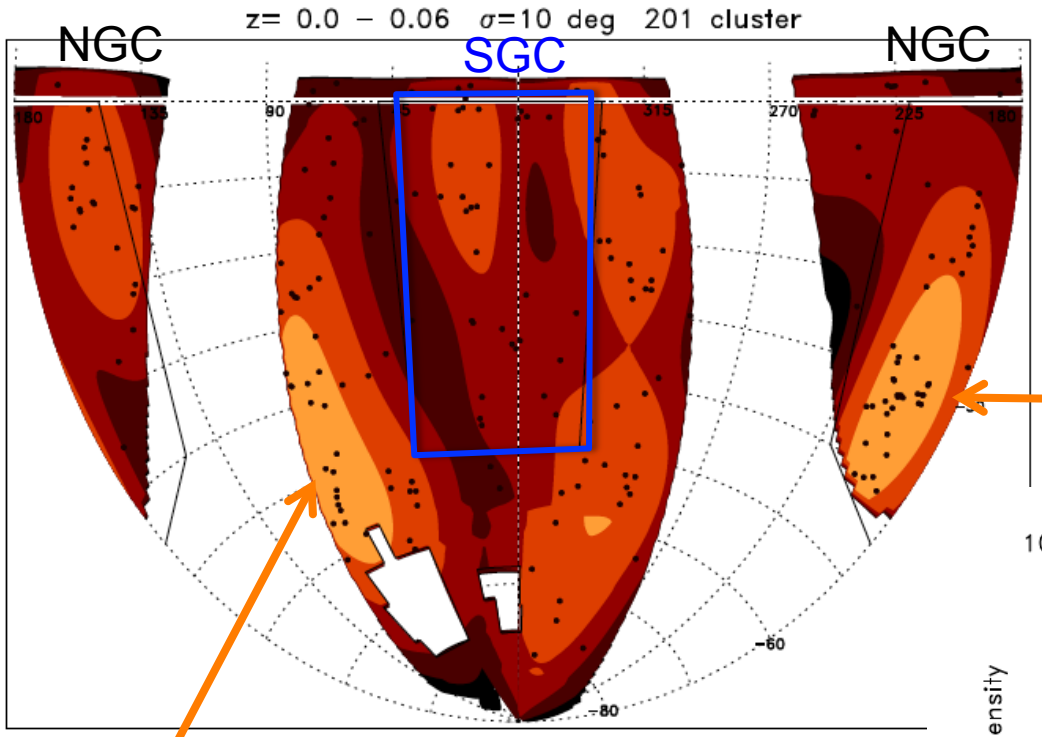


Relative density distribution represented by six volume-limited subsamples. Good agreement where they overlap.

Confidence that local under dense signal is real.

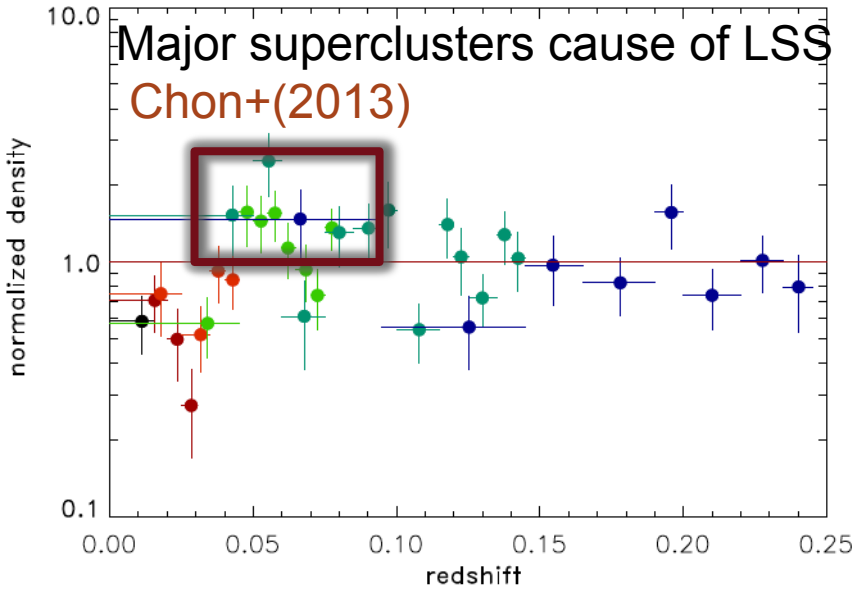
DENSITY VARIATIONS ACROSS SOUTHERN SKY

Density distribution for z=0-0.065
Smoothed by 10° and normalized to 1
- orange (>1)
- light red(1 – 2)
- brown (0.5 – 1)
- dark brown (<0.5)

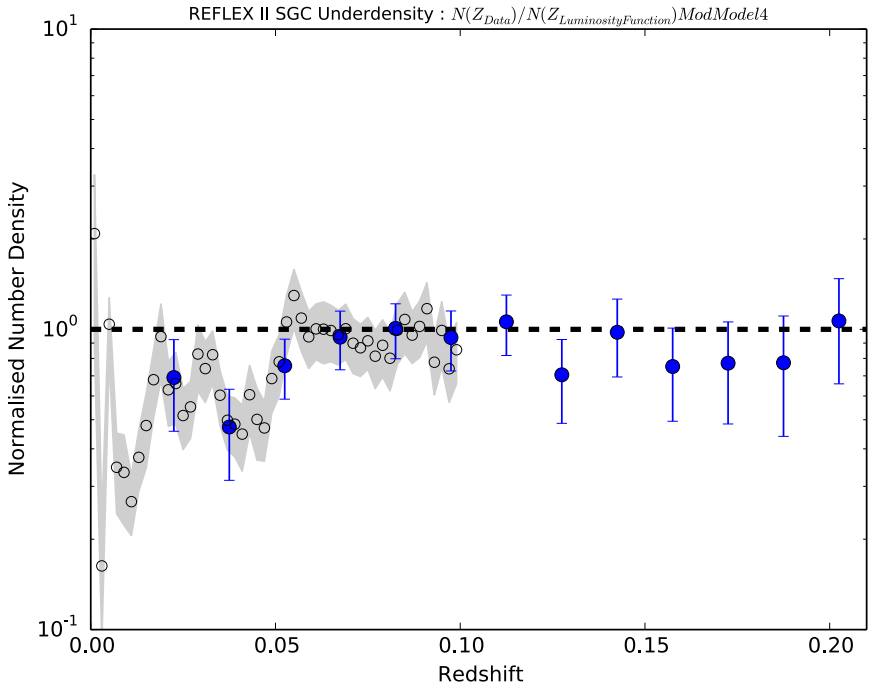


Shapley
$\mathrm{RA} \simeq 200^0$, $\mathrm{DEC} \simeq -30^0$
$z = 0.046$

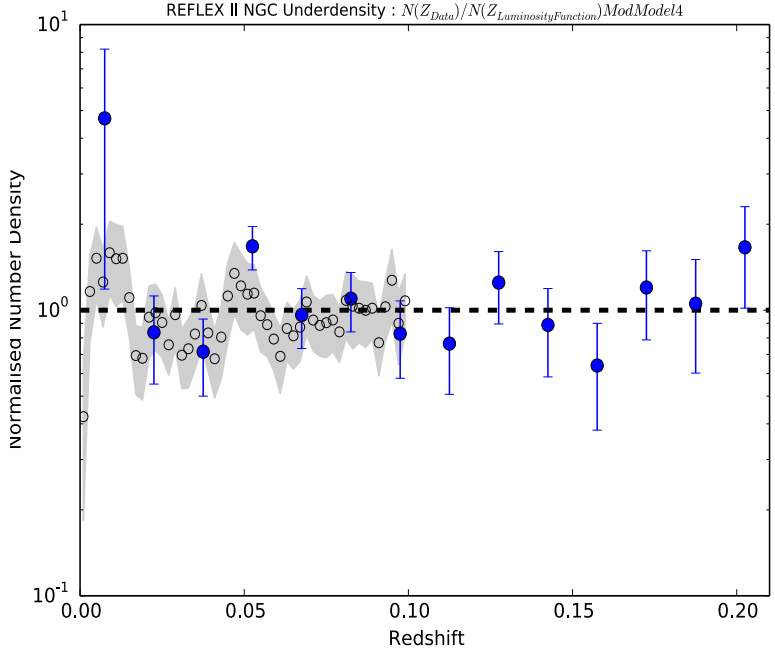
Horologium-Reticulum
$\mathrm{RA} \simeq 50 - 100^0$, $\mathrm{DEC} \simeq -55^0$
$z = 0.065$



UNDER DENSITY TOWARDS SGC & NGC + COMPARISON WITH WHITBOURN & SHANKS (W&S)



South Galactic Cap (SGC)

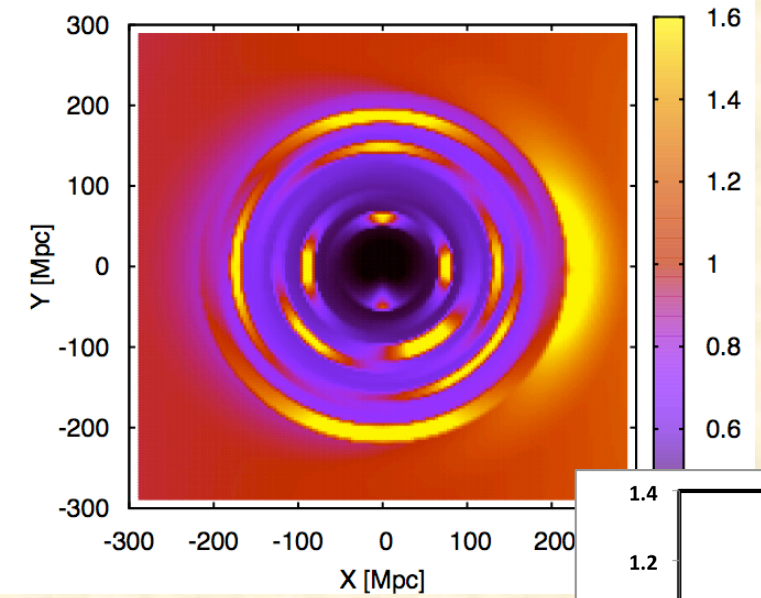


North Galactic Cap (NGC)

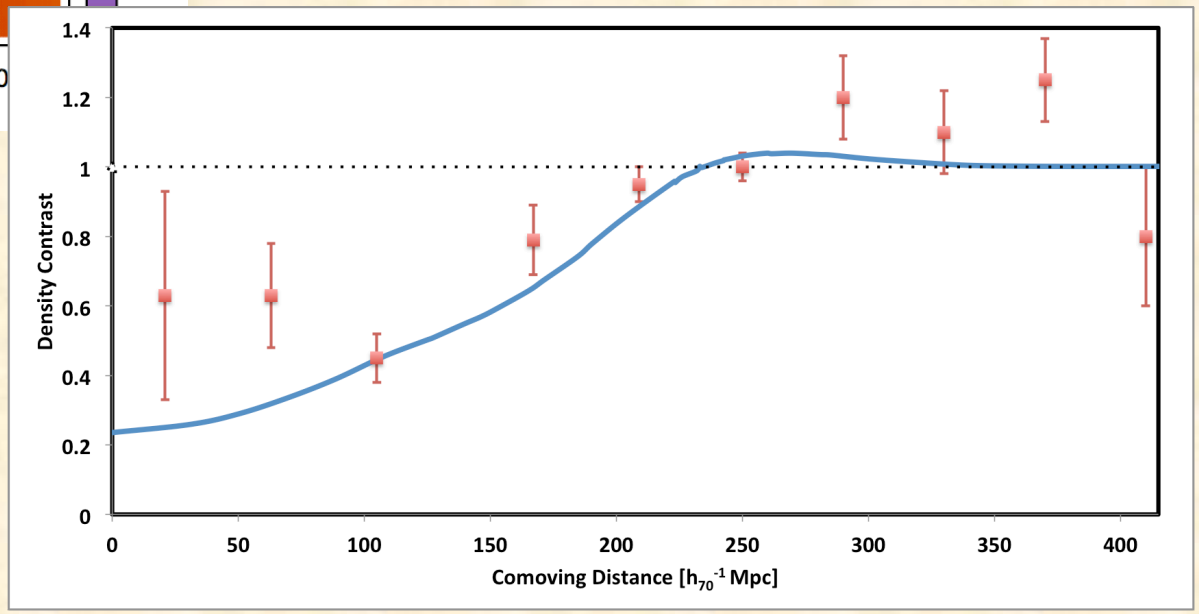
	z < 0.05		z< 0.1	
W&S	**0.60±0.05**	*0.96±0.10*	**0.75±0.05**	*0.94±0.07*
REFLEX II	**0.45±0.10**	*1.02±0.17*	**0.84±0.09**	*1.18±0.12*
	SGC	*NGC*	**SGC**	*NGC*

IMPLICATIONS

- REFLEX II provides new evidence for a rising matter density out to 200-250 Mpc
- It is claimed this size of void can explain SNe-1a results without dark energy
  e.g. Bolejko & Sussman (2011)



"Toy" model which produces a cosmic void profile of radius ~250 Mpc without the need for spherical symmetry.

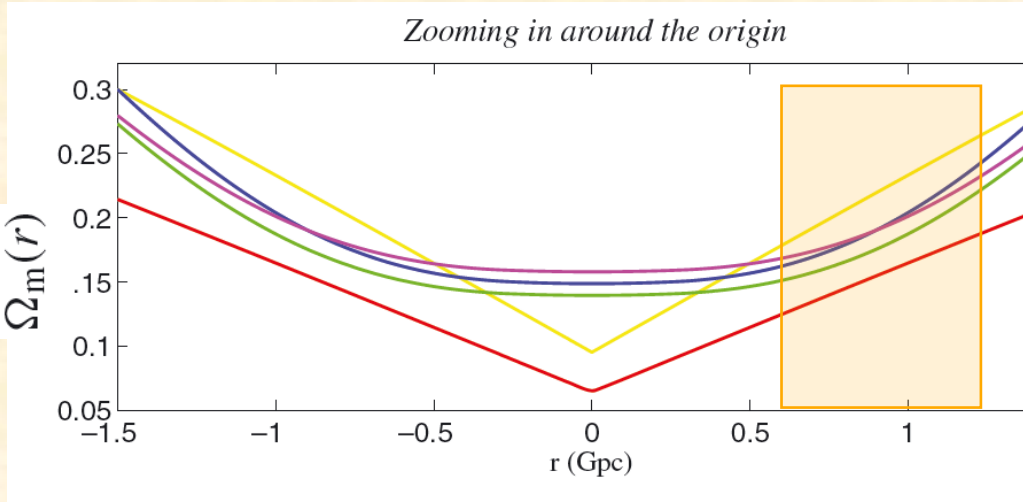


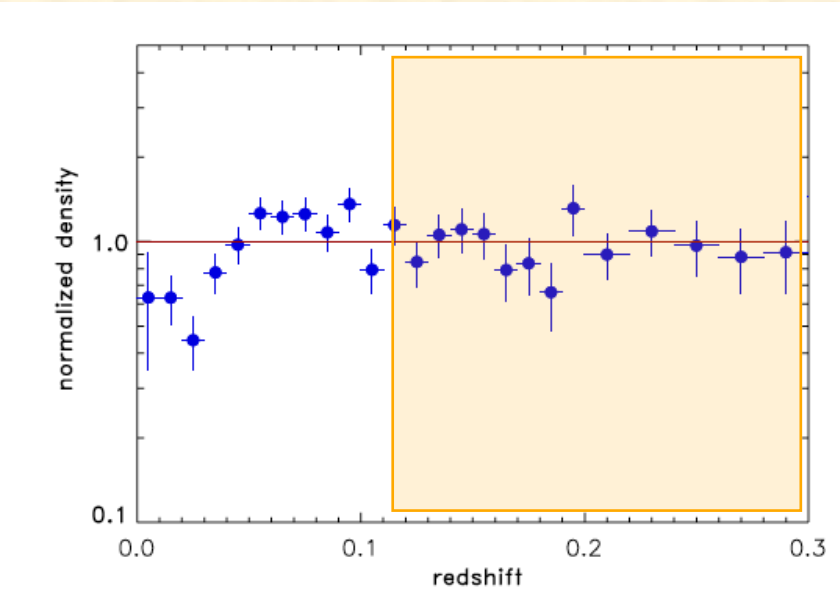
IMPLICATIONS

REFLEX probes LSS on scales z=0.1-0.3 very well

Large voids with rapidly changing potentials over Gpc scales (z~0.2) appear ruled out at least in southern hemisphere

e.g. February et al (2010)





IMPLICATIONS: H_0

Tension in measurement of H_0

1. *Cepheids: Friedman+ (2012)*
2. *SNe Ia & Cepheids: Riess+(2012)*
3. *Planck: Ade+ (2013)*

H_0

74.3±2.1 km s^{-1} Mpc^{-1} [1]

73.8±2.4 km s^{-1} Mpc^{-1} [2]

Local

67.3±1.2 km s^{-1} Mpc^{-1} [3]

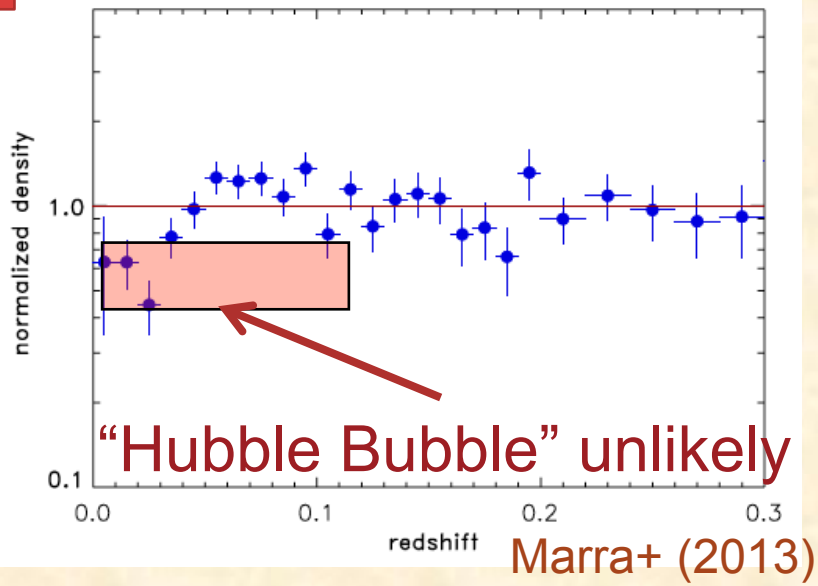
CMB

-9%

Using linear theory

$$\frac{\delta H_0}{H_0} = -\frac{1}{3} \times \Omega_m^{0.6} \times \frac{1}{b} \times \frac{\delta \rho_c}{\rho_c}$$

With b~1.8 for REFLEX II then for 30% under density we expect 2-3% increase in Hubble constant



Marra+ (2013)

CONCLUSIONS

- **There is a significant void 30±6% ~z=0.05 (~200 Mpc) over 4.24 sr**
- **SGC: Large under density**
  - 55±10% out to z~0.05
- **NGC: No under density**
  - 2±17% out to z~0.05
- **Consistent with density profiles models (~250 Mpc)**
- **Large gradients in density on Gpc scales (z~0.2) ruled out by X-ray clusters**
- **Lack of under density to z~0.1 renders "Hubble Bubble" model an unlikely explanation of H_0 tension [Local-CMB]**