The Clustering of Low-redshift $z \leq 2.2$ SDSS Quasars

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Motivation

- Quasars (luminous AGN) long suspected of being powered by accreting SMBH at galaxy centre (Salpeter, Zel'dovich, Lynden-Bell 1960s; Rees 1970s/80s)
- More recent (local) evidence suggests all **massive** galaxies have SMBH with $M_{BH} \sim L \sim \sigma^4$ (e.g. Magorrian98, Gebhart00) e Galaxy/Star Formation and evolution connection, AGN Feedback (??)
- Clustering measurements can give you $\mathbf{M_{halo}}$, t_Q, e, (Martini01, Wyithe05). Also can give strong constraints for theoretical models/simulations (especially at $z>2$).
- Quasars can be seen to large distances e.g. at $z=2.2$ **80%** age of Universe e evolution of clustering

Motivation

- Quasars relatively rare objects, need to cover large areas
- Mid-1990s, largest quasar samples $\approx 10^3$ objects
- Need: clean photometry, multiplexing instrument, large FoV
- SDSS ideal for large quasar survey:
  - High quality 5-band photometry, select targets
  - Very large area coverage (1000s deg^2)
  - Multi-fibre spectroscopic follow-up, moderate resolution spectra
- Two major quasar surveys over last 10 years:
  - **2dF QSO Redshift (2QZ, Croom'04, 23,338 QSOs)**
  - **SDSS Quasar Survey (>100,000 objects observed)**

Data

- SDSS **DR5** Quasar Catalogue: 77,429 quasars (M_i<-22 and one line >1000 kms^{-1}).
- "Primary" target flag: Selected in

ugri colour-space, *i*<19.1 (*zM*3); *griz i*<20.2 for *z*≥3; or point-source match to FIRST at *i*<19.1

e 55,577 objects, 46,272 at *zM*2.2, 5713 deg^2.

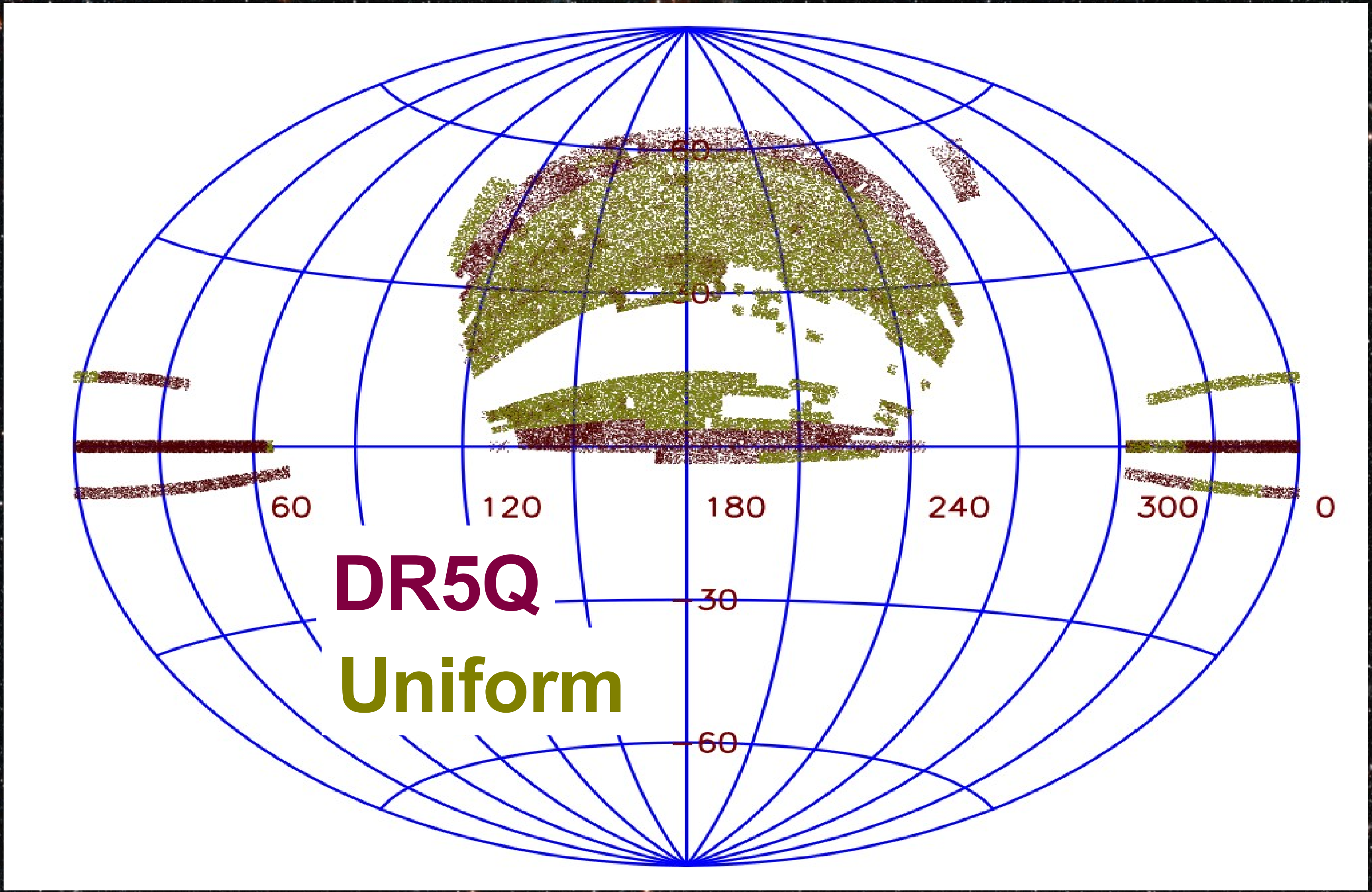
- "**UNIFORM**" (Richards06, Shen07 at *z*>2.9);

e 38,208 objects;

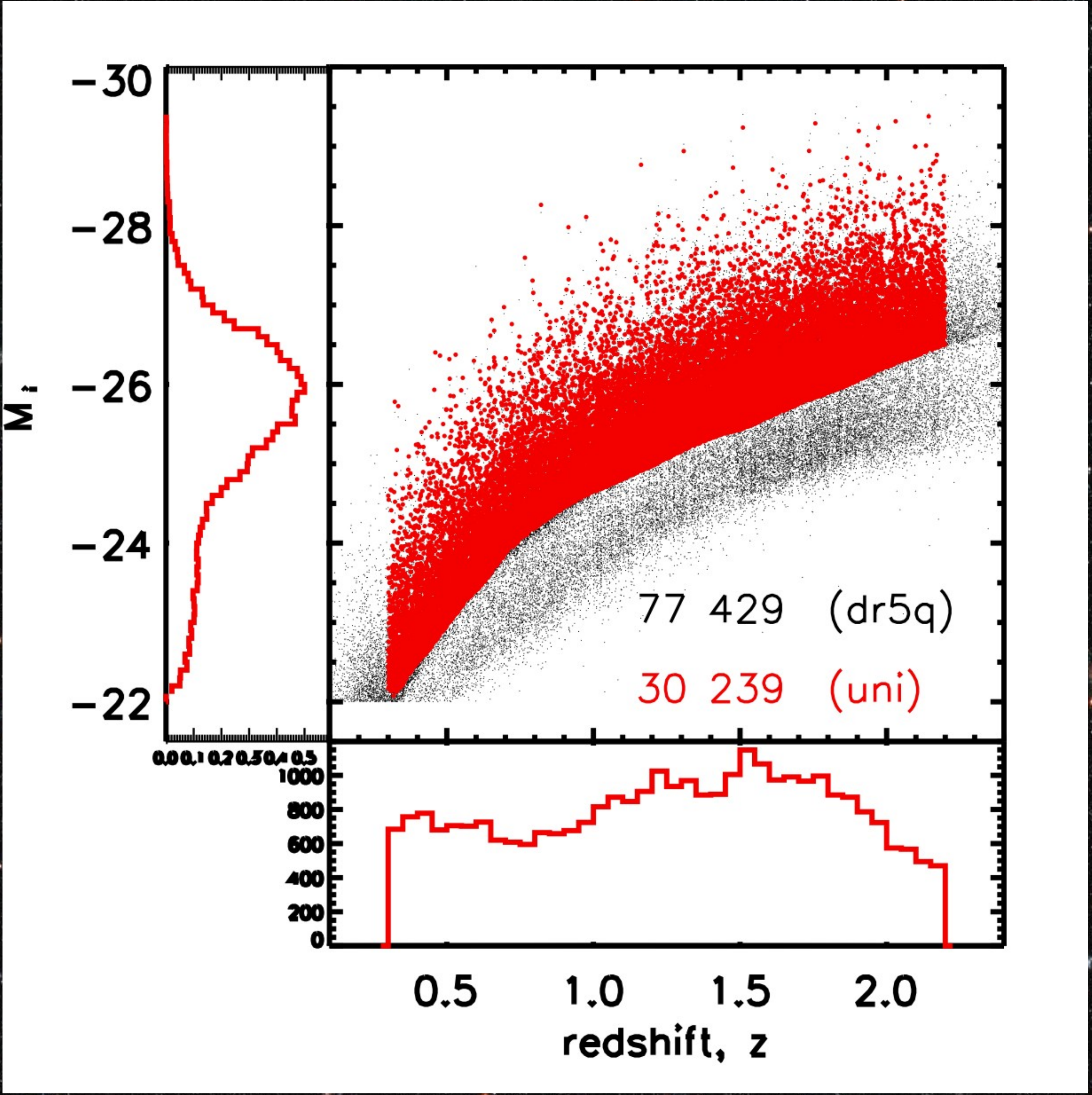
30,239 at 0.3≤*z*≤2.2 over 4013 deg^2

- Avoid 2.2<*z*<2.9 due to low-completeness

Uniform sample coverage



Data



-30
-28
-26
-24
-22
M_i
0.00 0.1 0.2 0.3 0.4 0.5
77 429 (dr5q)
30 239 (uni)
1000
800
600
400
200
0
0.5
1.0
1.5
2.0
redshift, z

The 2-Point Correlation Function

- *e(r)* represents the excess probability of finding a PAIR of objects compared with a random distribution:

$$dP_{12} = n^2\left(1 + x(r)\right) dV_1\, dV_2$$

- Power Law behaviour:

$$x(r) = \left(\frac{r}{r_0}\right)^{-g}$$

r_0 correlation length

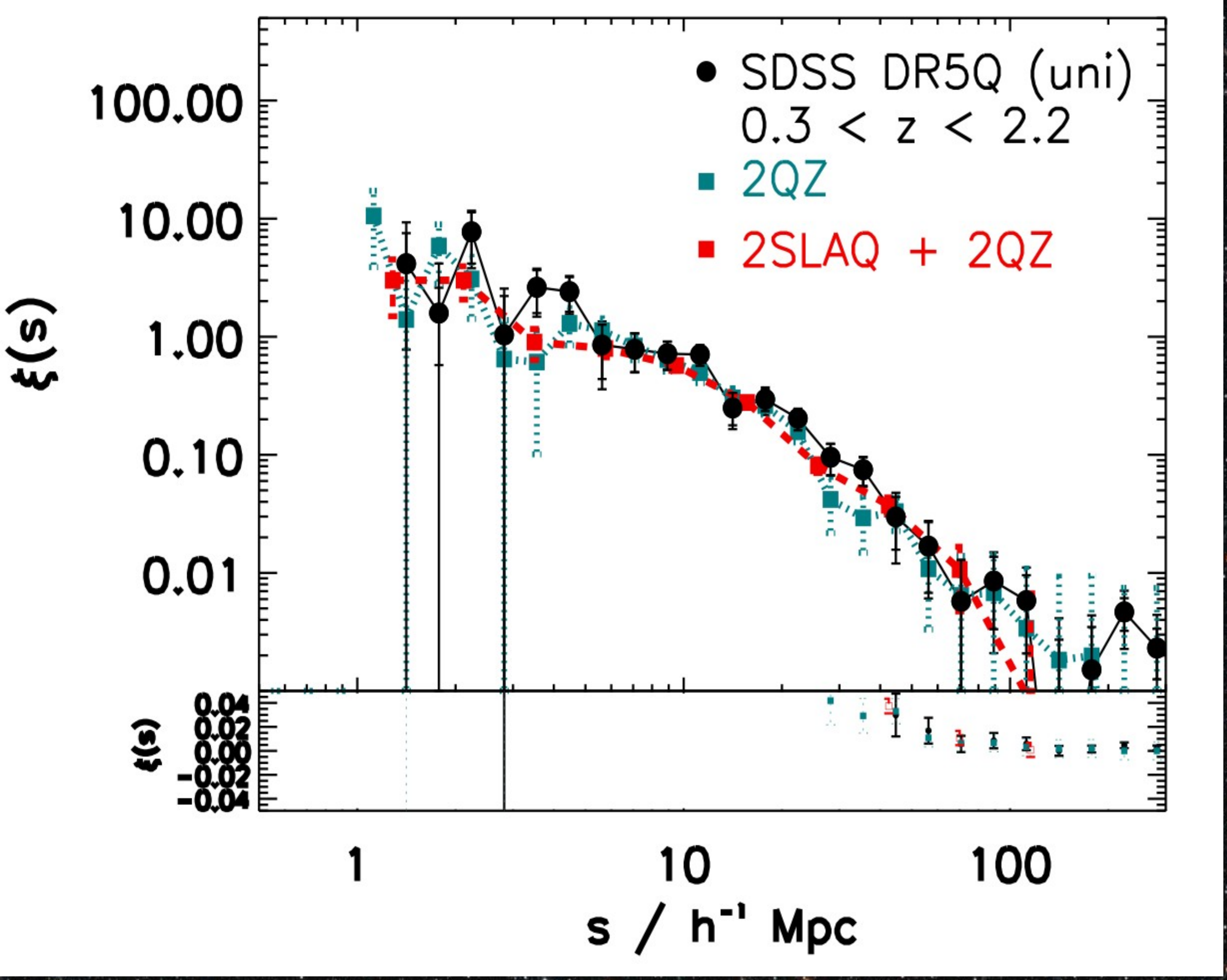
e slope

- Measure the *redshift-space* CF $x(s)$ which include peculiar velocities due to cluster infall and random motions leading to "redshift-space distortions".

- Can measure e in two dimensions, $x(s, p)$ with perpendicular, *e* and parallel, e to line-of-sight where

$$s^2 = s^2 + p^2$$

Results : ξ(s)



•**SDSS** DR5

e(s), *i*<19.1

s_0=5.95e0.45 h^{-1} Mpc

e=1.16e0.14

(also $x(s, p)$)

• **2QZ**

Croom 2005

18.25 <b_J<20.85

(*g*≈20.80, *i*~20.4)

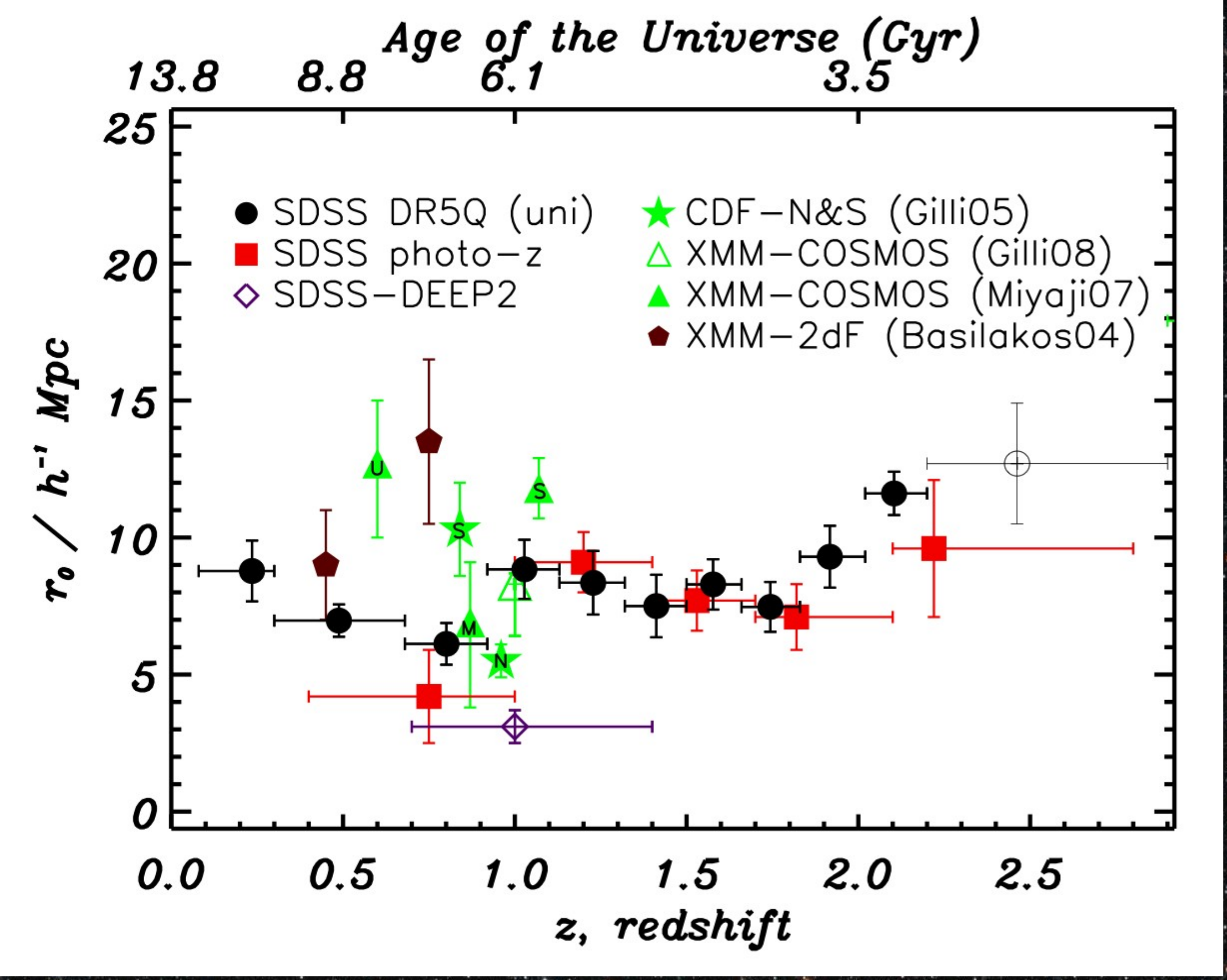
• **2SLAQ**

da Angela 2008

18 < *g* < 21.85

Ross et al. (2008, in prep.)

Results : ξ(r,z)

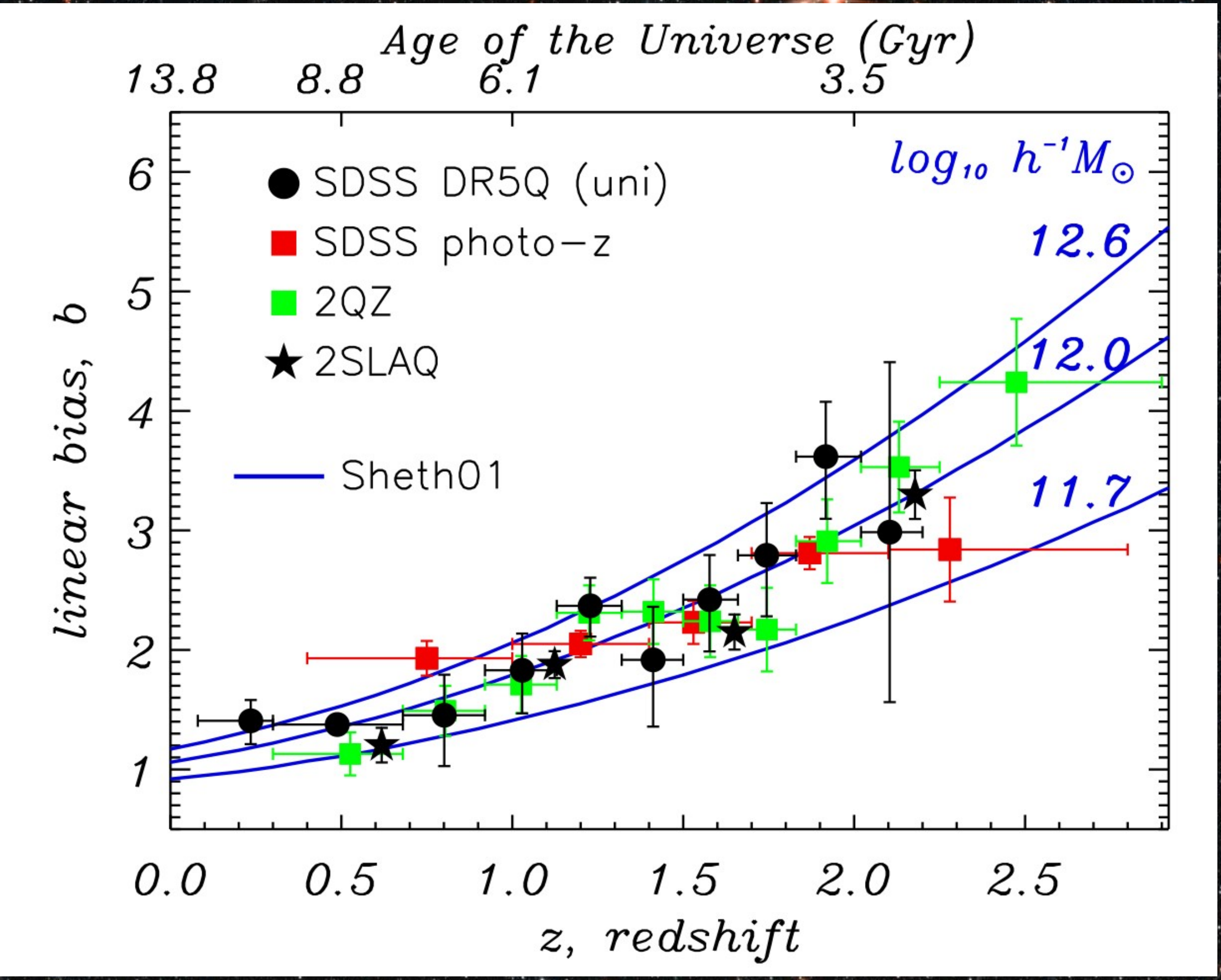


- Evolution of clustering; real-space
- SDSS (optical) quasars

Myers et al. 2006

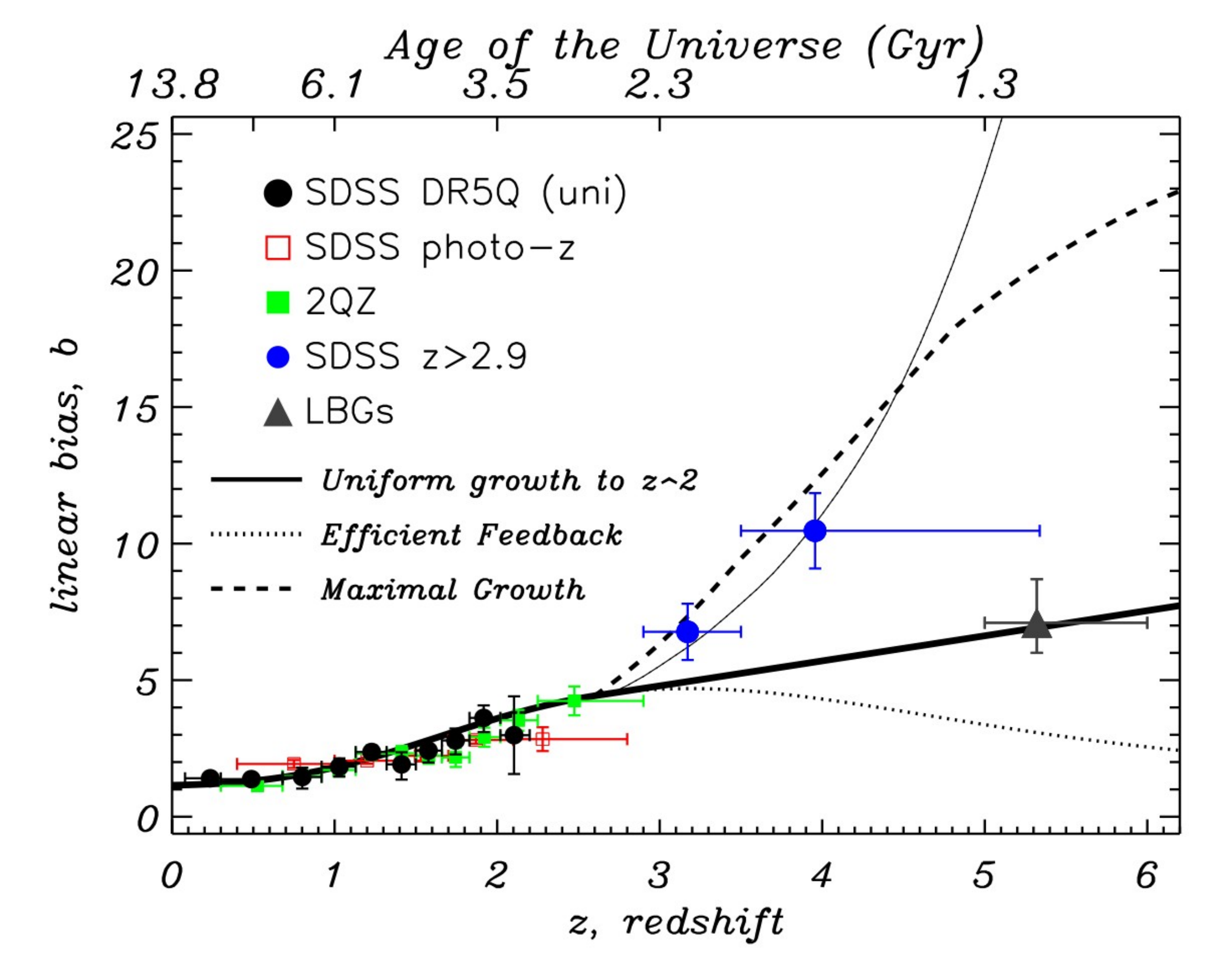
- X-ray selected AGN from ***deep, small*** area surveys e.g. Chandra Deep Fields; XMM-COSMOS

Results: Linear bias *b(z)* (*z*<3)



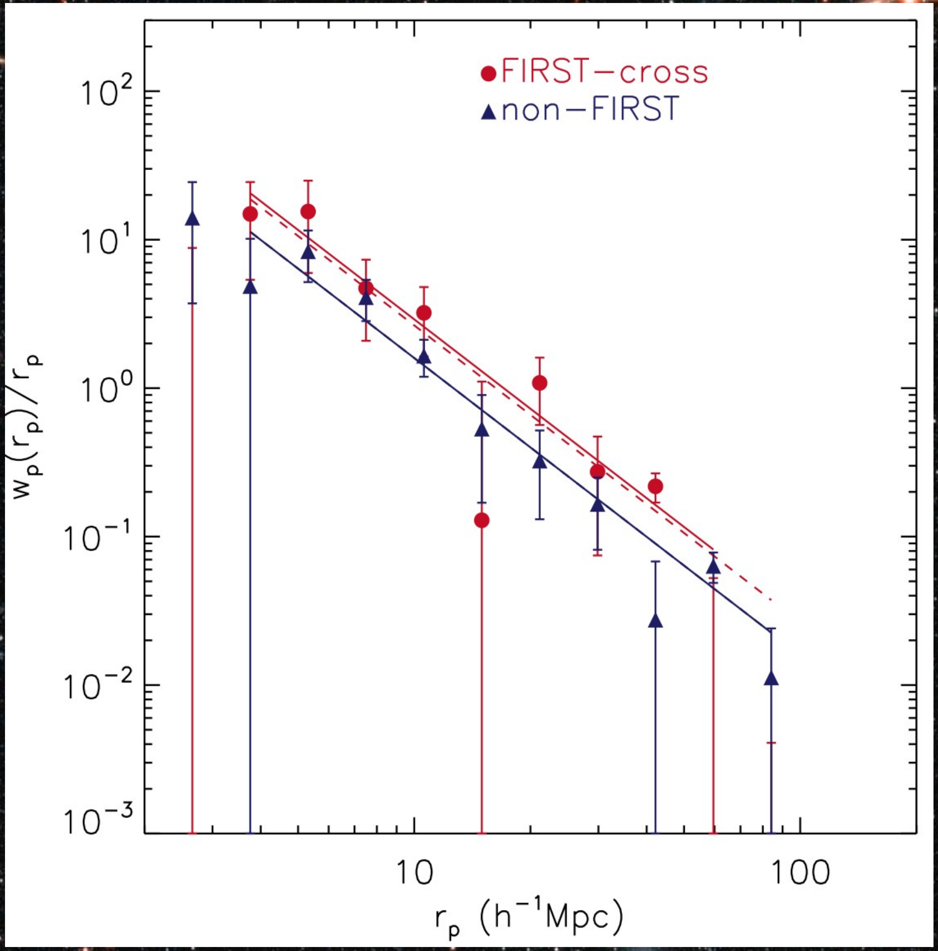
- $\xi_Q = b^2\ \xi_m$
- Basilakos'08 models, *at z<3 gives:* M_{DMH}~$5x10^{12}$ -$1x10^{13}$ h^{-1} M_{sol}
- Jing98: *$5x10^{11}$ - $2x10^{12}$* h^{-1} M_{sol}
- Sheth01: ***$5x10^{11}$-$4x10^{12}$* h^{-1} M_{sol}**

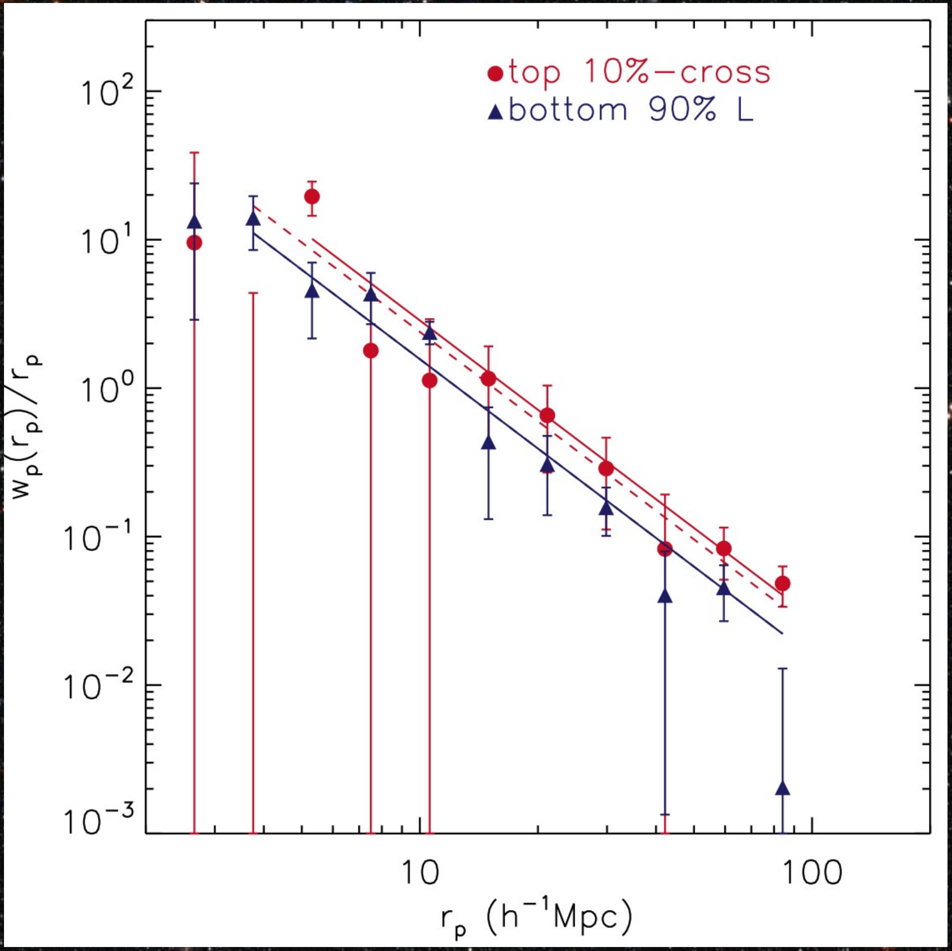
Results: Linear bias *b(z)* *(high-z)*



- High-z quasars from Shen et al. (2007)
- LBGs from McLure et al. (0805.1335)
- Hopkins'07 models e "Uniform Growth"

Results: Radio and Brightest quasars

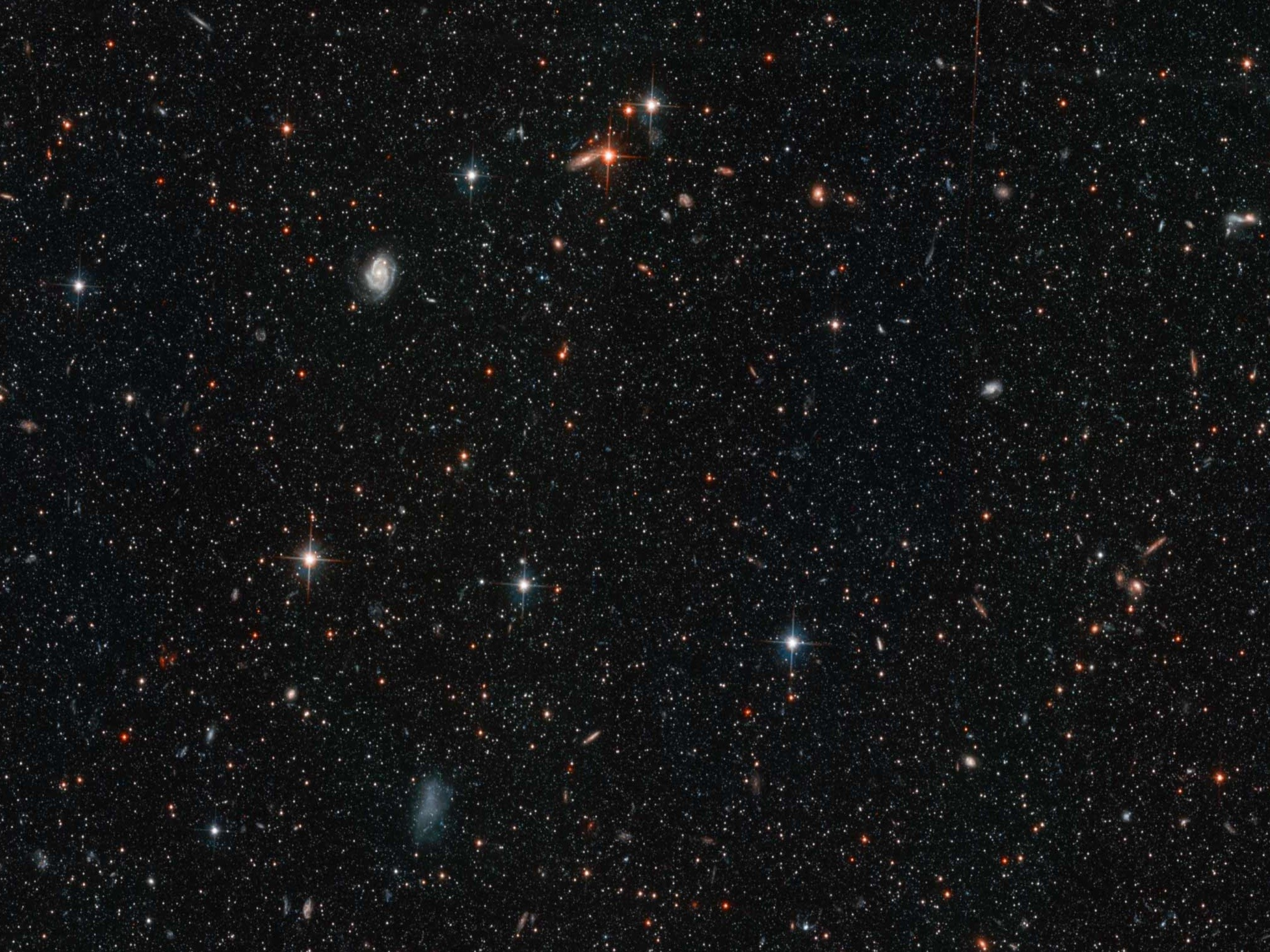




Shen et al. (2008, in prep.)

Conclusions

- Measured clustering of 30,239 SDSS Quasars at *zM*2.2
- Single power-law acceptable fit over 1<s<25 h^{-1} Mpc, s_0=5.95e0.45 h^{-1} Mpc; e=1.16e0.14 and v. similar clustering behaviour to 2QZ and 2SLAQ surveys.
- Evolution of ξ very weak at z<2, stronger at z>2
- r_0 values generally lower than deep X-ray surveys (also see Ryan Hickox talk…)
- Linear bias evolution e M_{DMH}~5x10^{12}-1x10^{13} h^{-1} M_{sol} and "Uniform Growth" model describes high-*z* data very well. LBGs progenitors *L** *z*<2 quasars (?)
- Radio and most Luminous 10% quasars highly-clustered.
- Final SDSS Quasar catalgoue (DR7) doubles no. quasars



Results : ξ(σ,π)

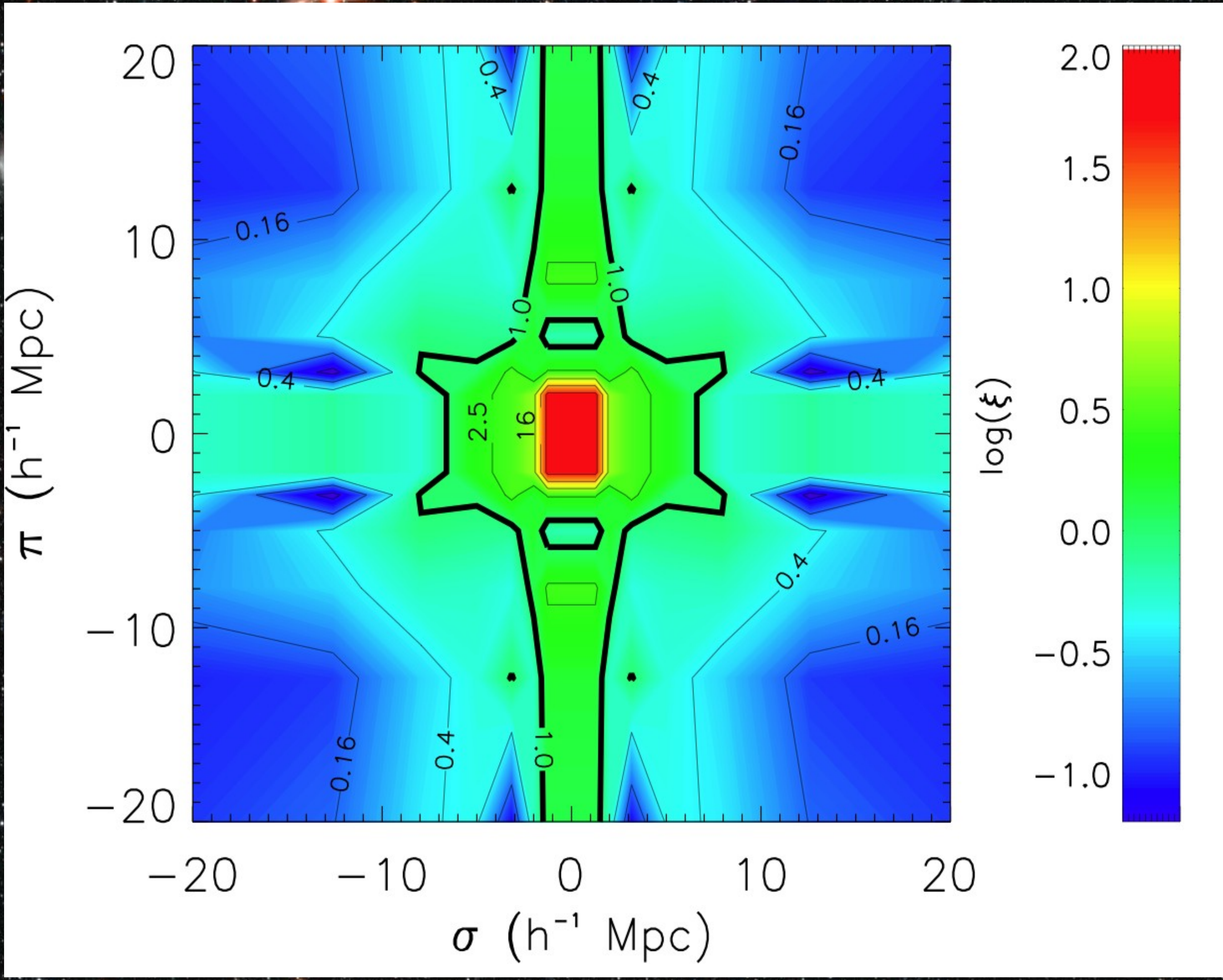
- SDSS Quasar ξ(e,e)
- $e = e_m^{0.6}/b$

  =0.43e0.01

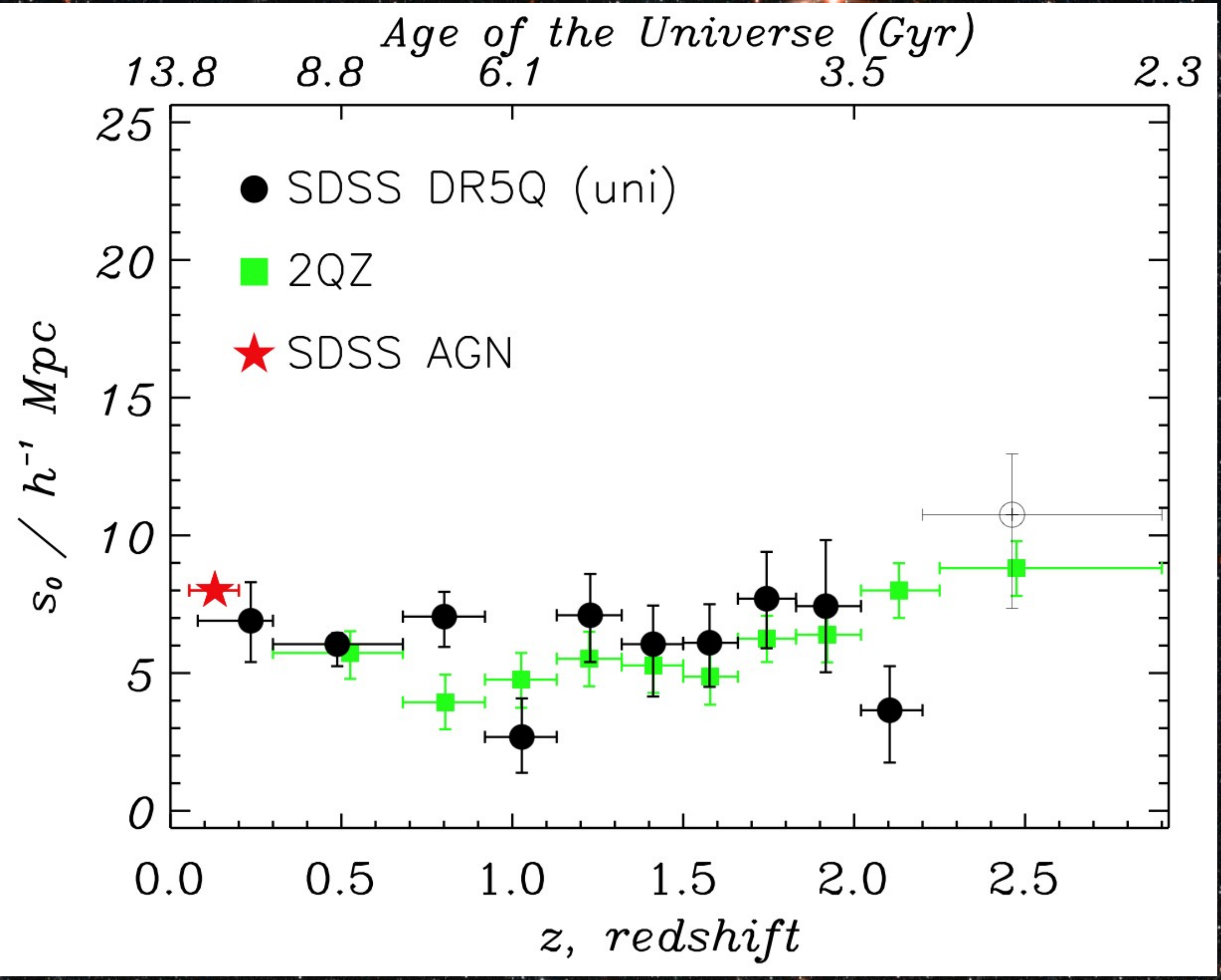
(at z=1.27)

- Potential for cosmology; *growth of structure* but low space-density of quasars

e low S/N

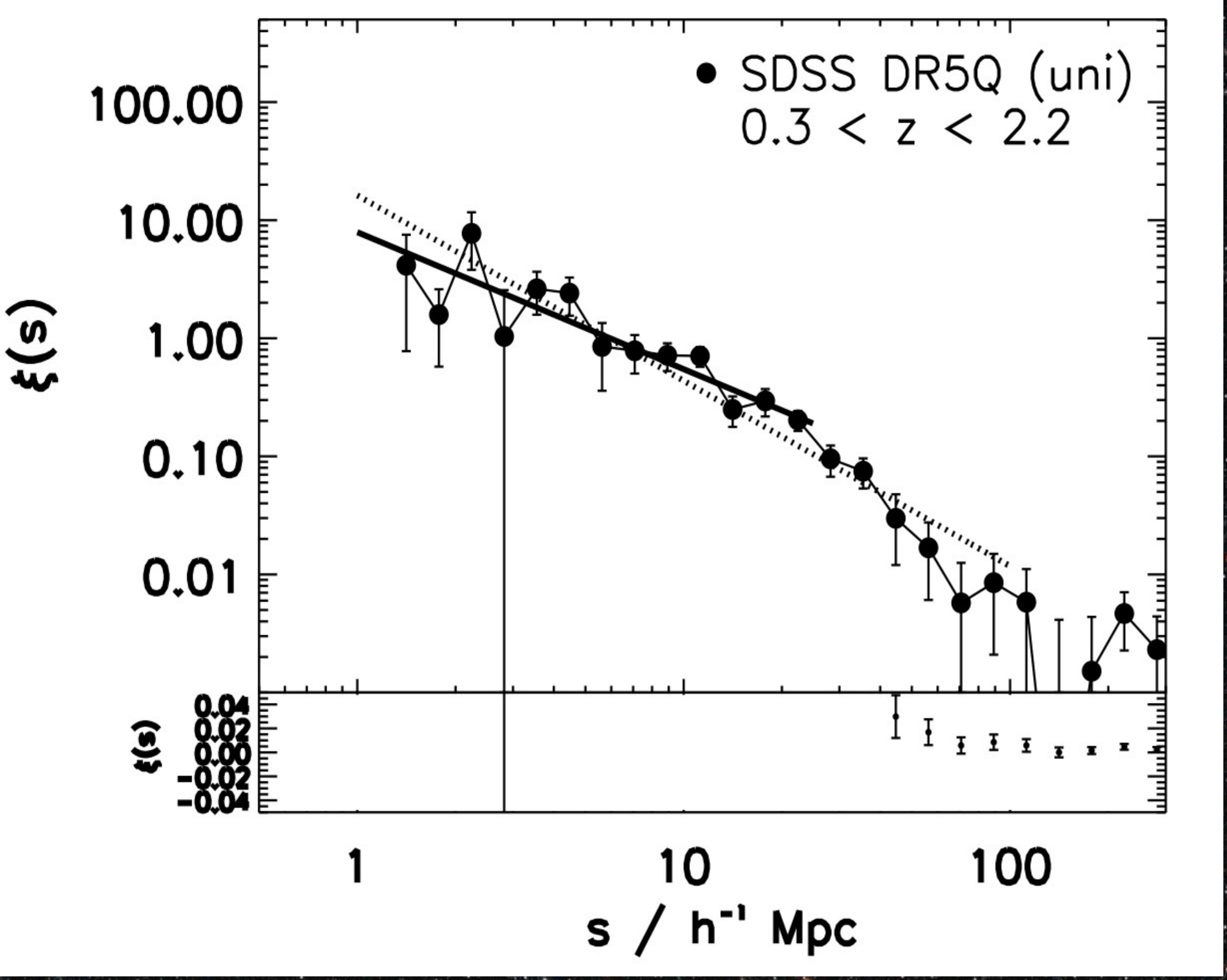


Results : ξ(s,z)



- Evolution of clustering redshift-space
- Not strong, s0=6-7 h^{-1}Mpc
- SDSS Quasars
- 2QZ (Croom'05)
- SDSS AGN (Wake'04)

Results : ξ(s)



- 2-Point Correlation Function; use LS estimator
- Jackknife errors
- Redshift-space
- Singe PL; s0=5.95e0.45 h^{-1} Mpc; e=1.16e0.14

Ross et al. (2008, in prep.)