



The evolution of super-massive black holes and their hosts

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+ the 2SLAQ and AUS teams

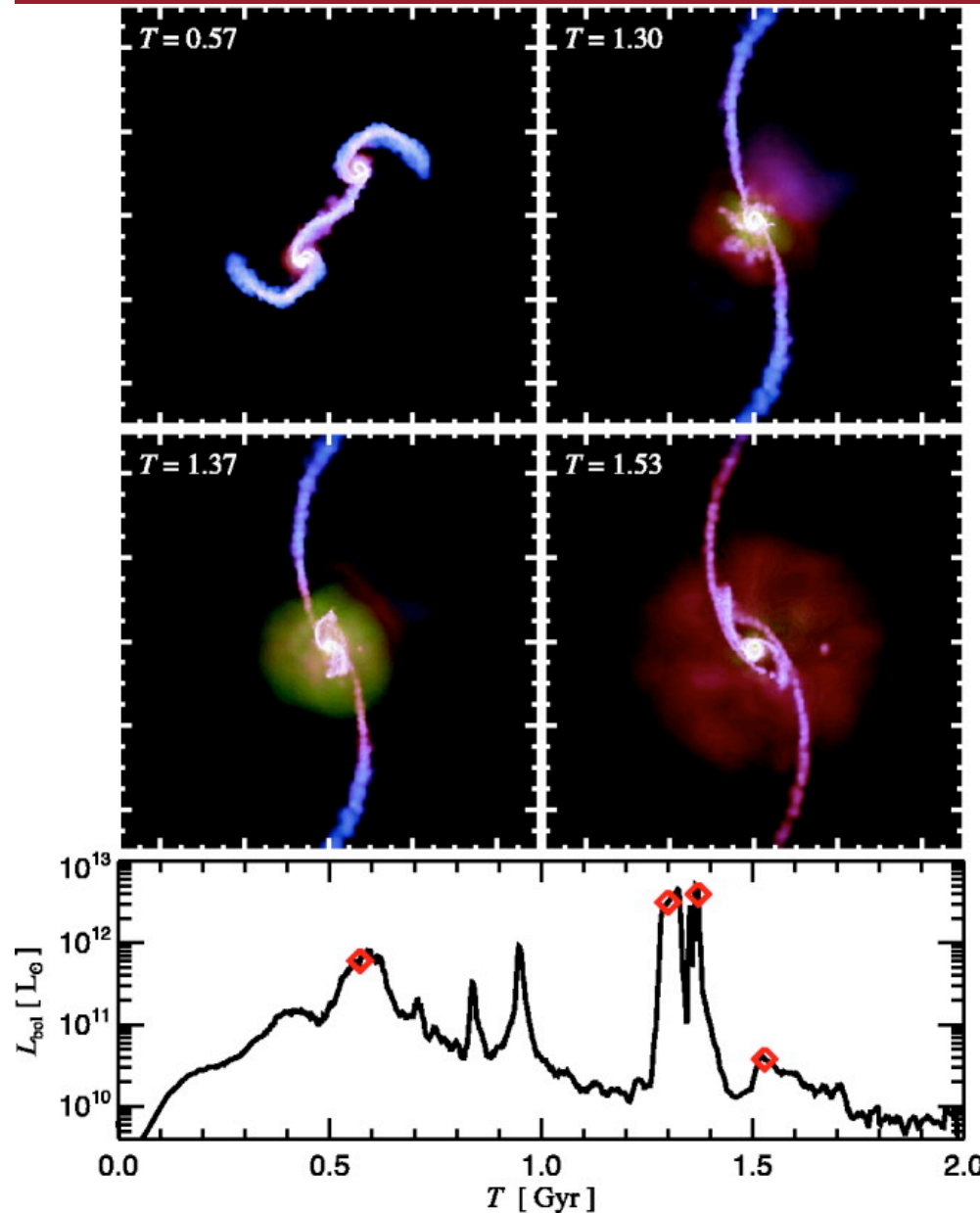


Outline

- SMBHs, galaxy formation and feedback.
- The 2dF-SDSS LRG and QSO (2SLAQ) Survey.
- The QSO luminosity function.
- Clustering, bias and host mass.
- Pushing to higher z ...



Galaxy formation and feedback



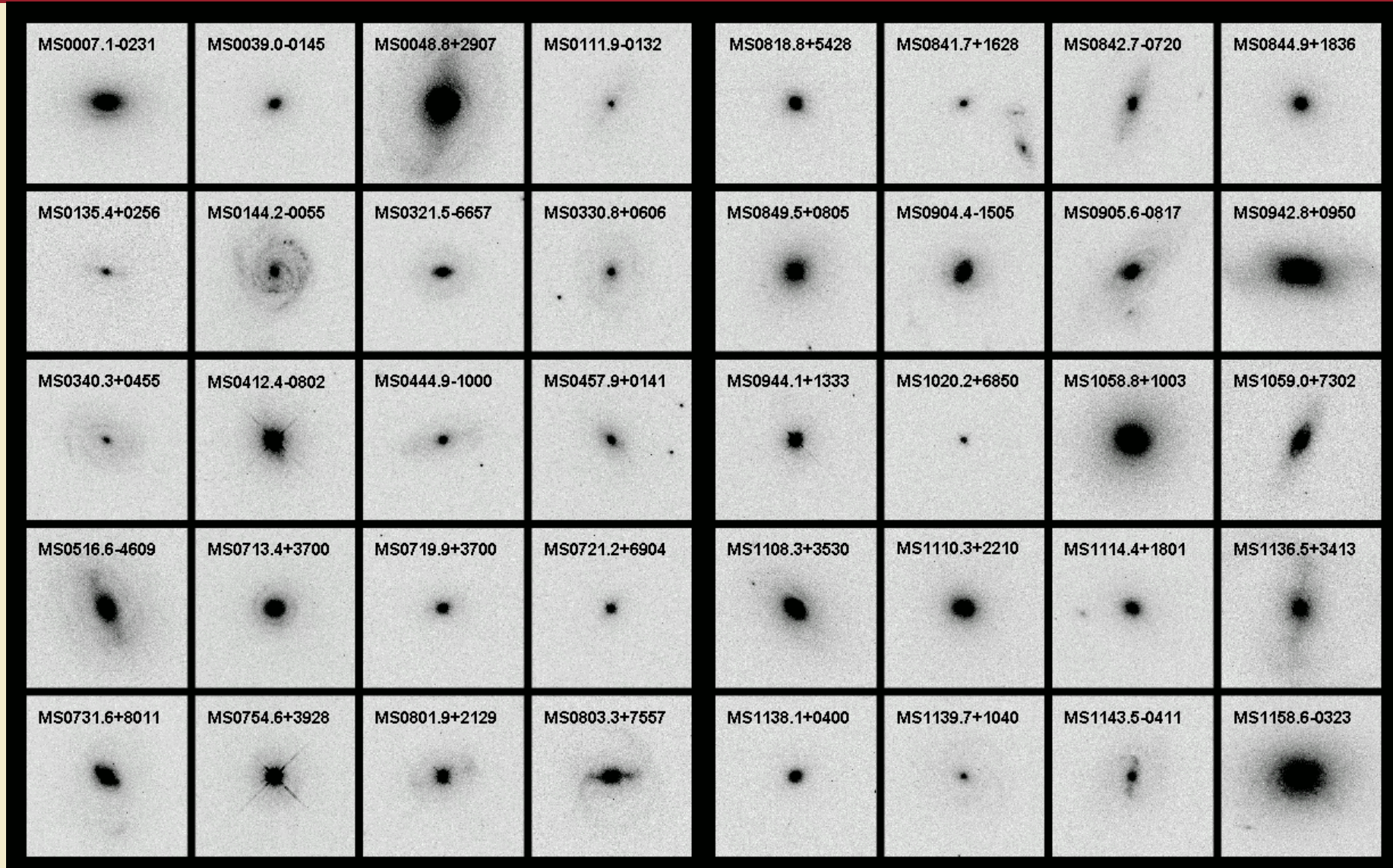
1. After 1st passage.
2. Merger of BHs.
3. Quasar phase.
4. Quasar has ended.

(T = time in Gyr)

Hopkins et al. (2005)



Evidence for mergers



Low-z HST host galaxy imaging (Schade et al. 2000)



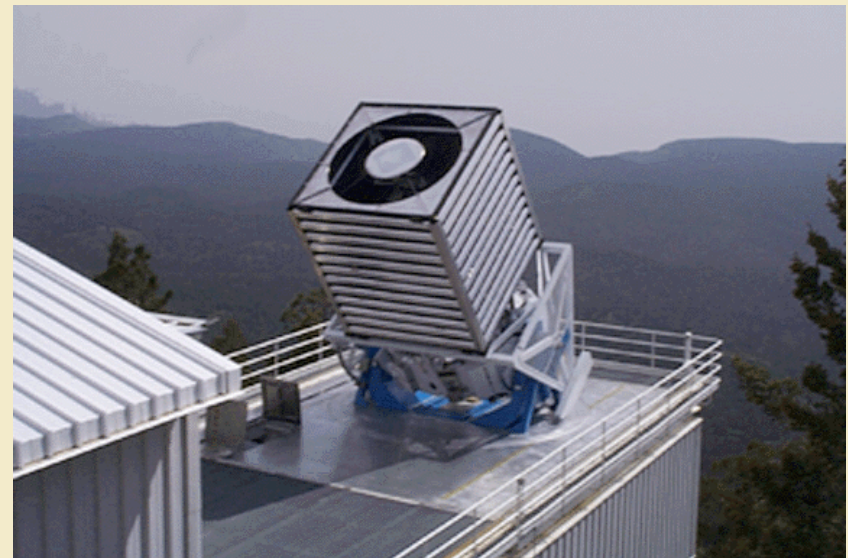
Tests and predictions...

- Bright end of QSO LF:
 - High M + high L/L_{Edd}
- Faint end of QSO LF:
 - high M + low L/L_{Edd}
 - And low M + high L/L_{Edd}
 - (QSOs not just on/off light bulbs).
- QSO clustering has weak dependence on luminosity.
- QSO clustering at high- z depends on the efficiency of feedback.



2SLAQ: Vital Statistics

- SDSS photometry.
- 2dF spectroscopy.
- 192 deg².
- ~10,000 faint QSOs:
g=21.85, z<3.0.
- ~10,000 luminous red gals:
i=19.8, z=0.45-0.7.

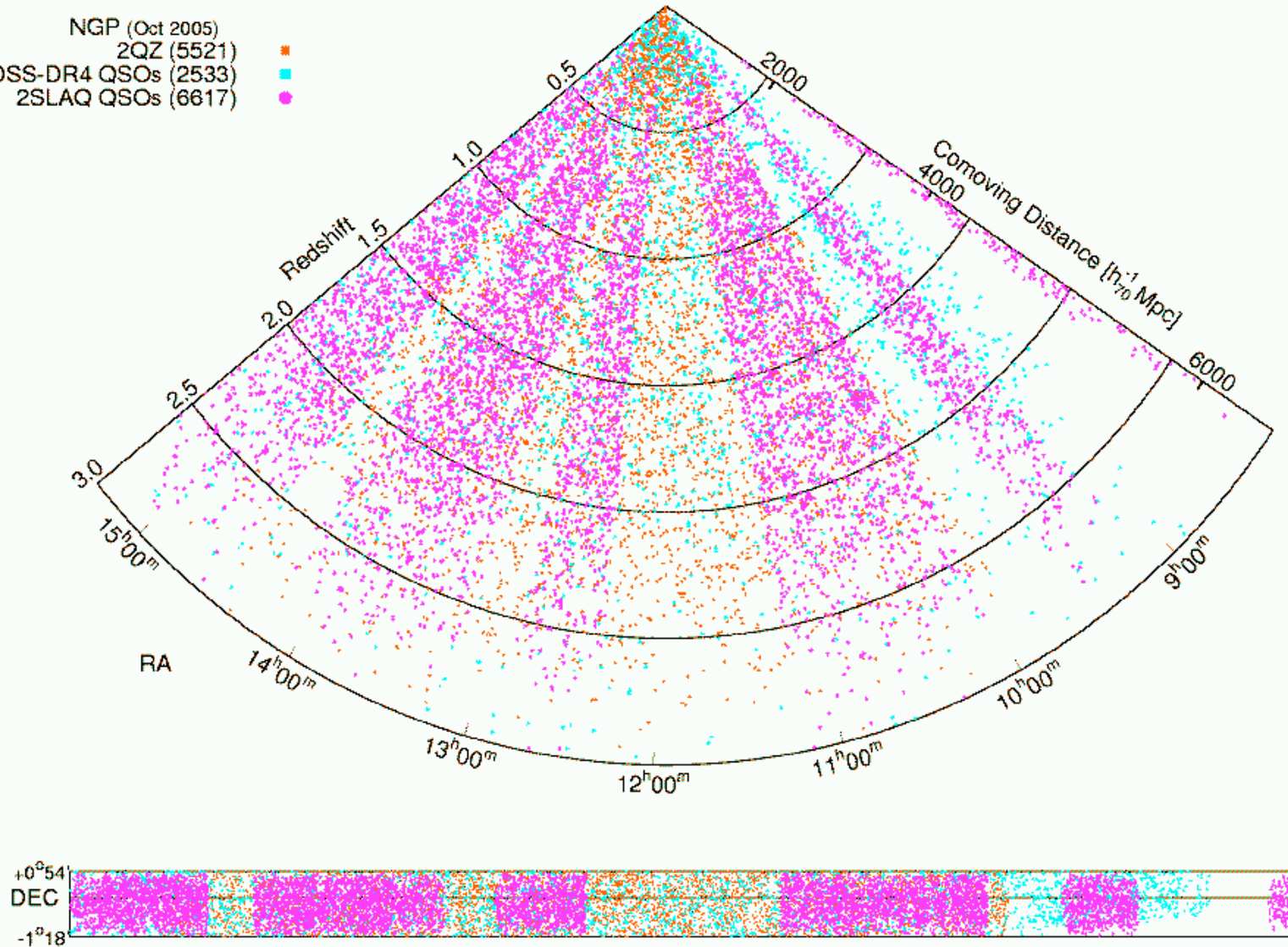




2SLAQ QSOs

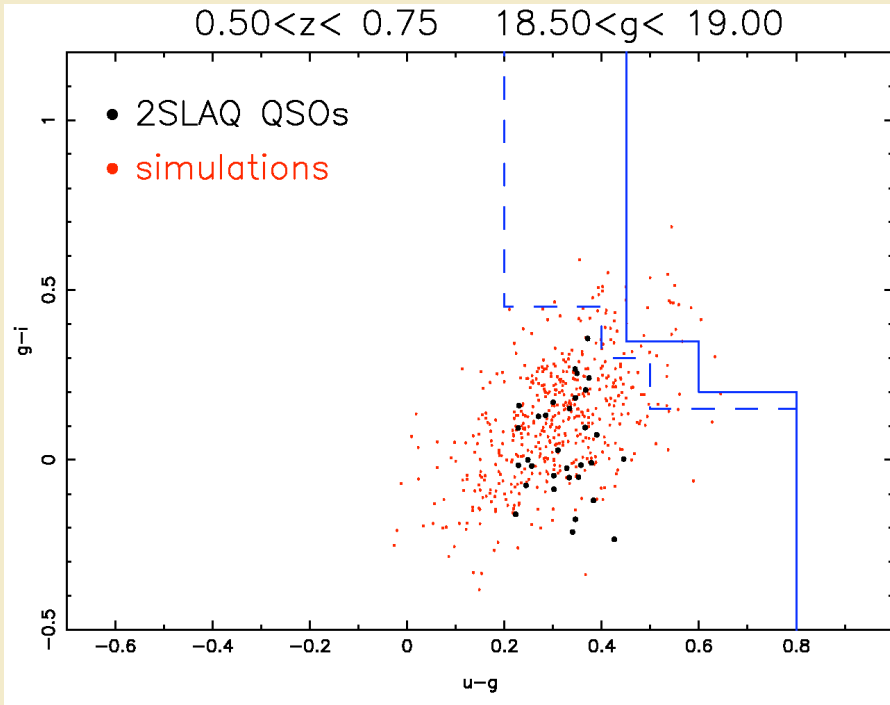
NGP (Oct 2005)
2QZ (5521)
SDSS-DR4 QSOs (2533)
2SLAQ QSOs (6617)

■
■
■



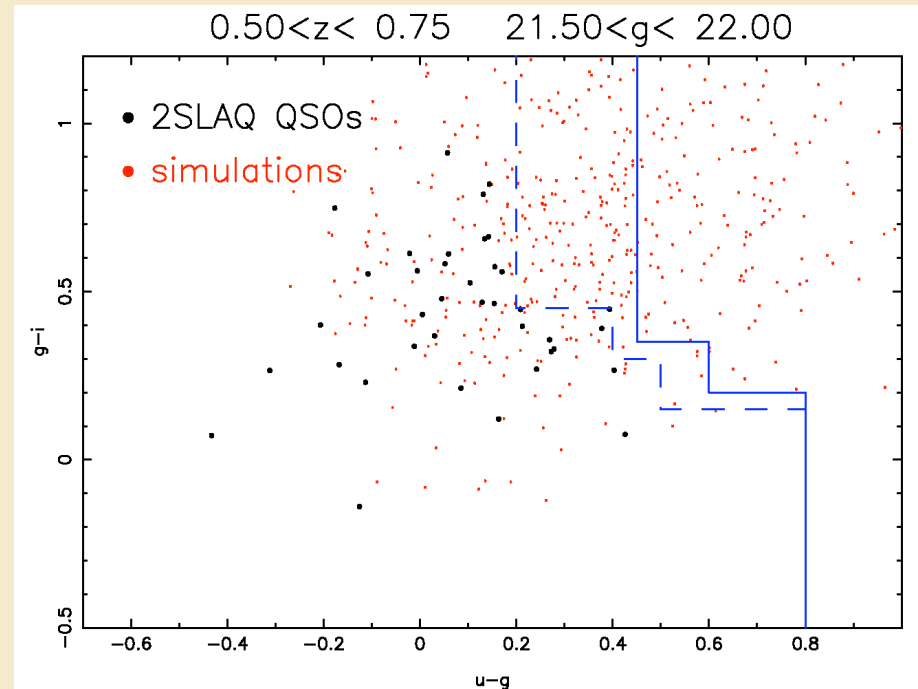


2SLAQ QSO colours



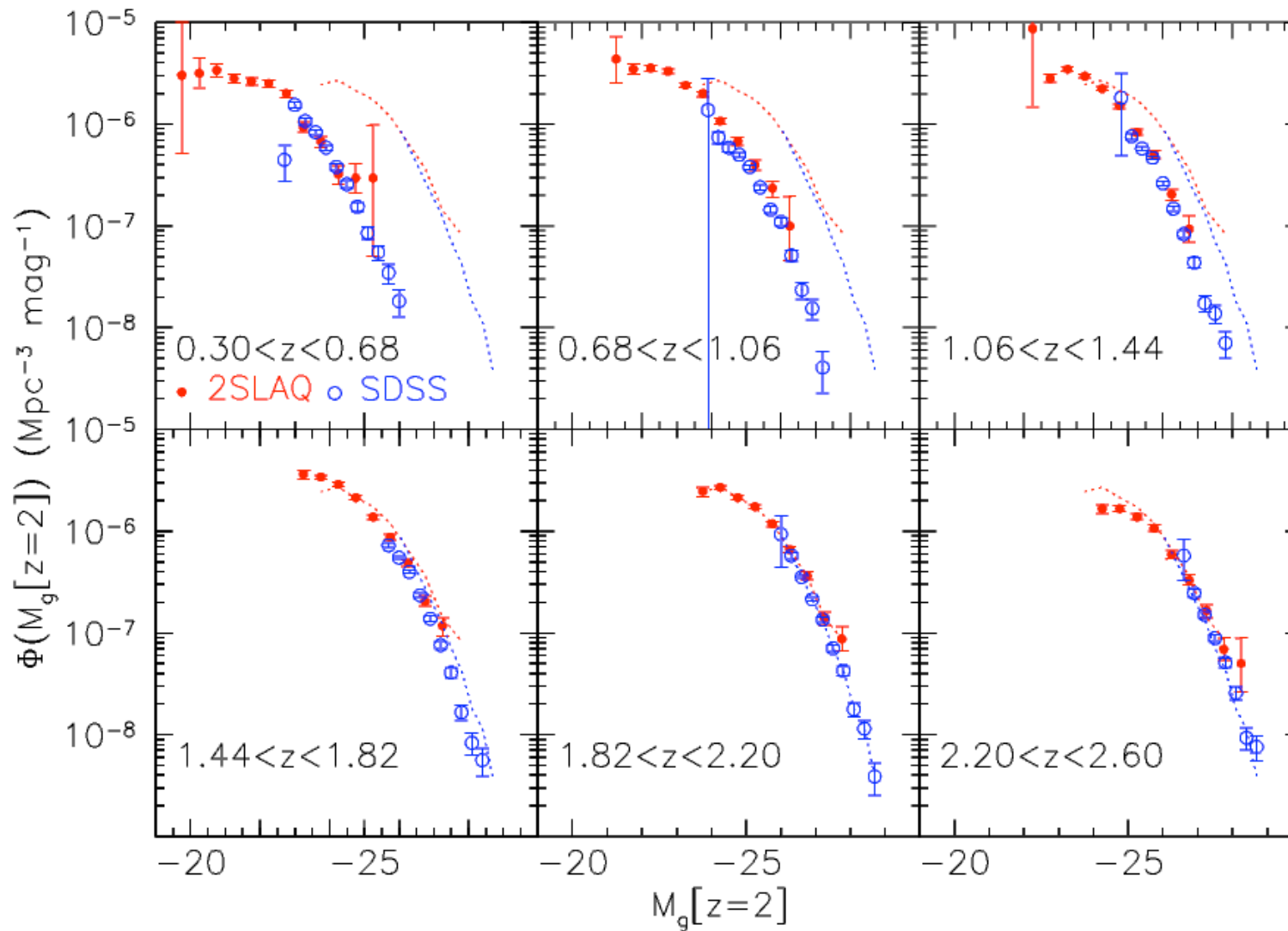
- Bright 2SLAQ selection limits.
- - - Faint ($g > 21.15$) 2SLAQ selection limits.

- Fainter 2SLAQ QSOs are redder in $g-i$.
- QSO+host gal SED accurately models the colours.
- SED ages need to be $>2-3$ Gyr.





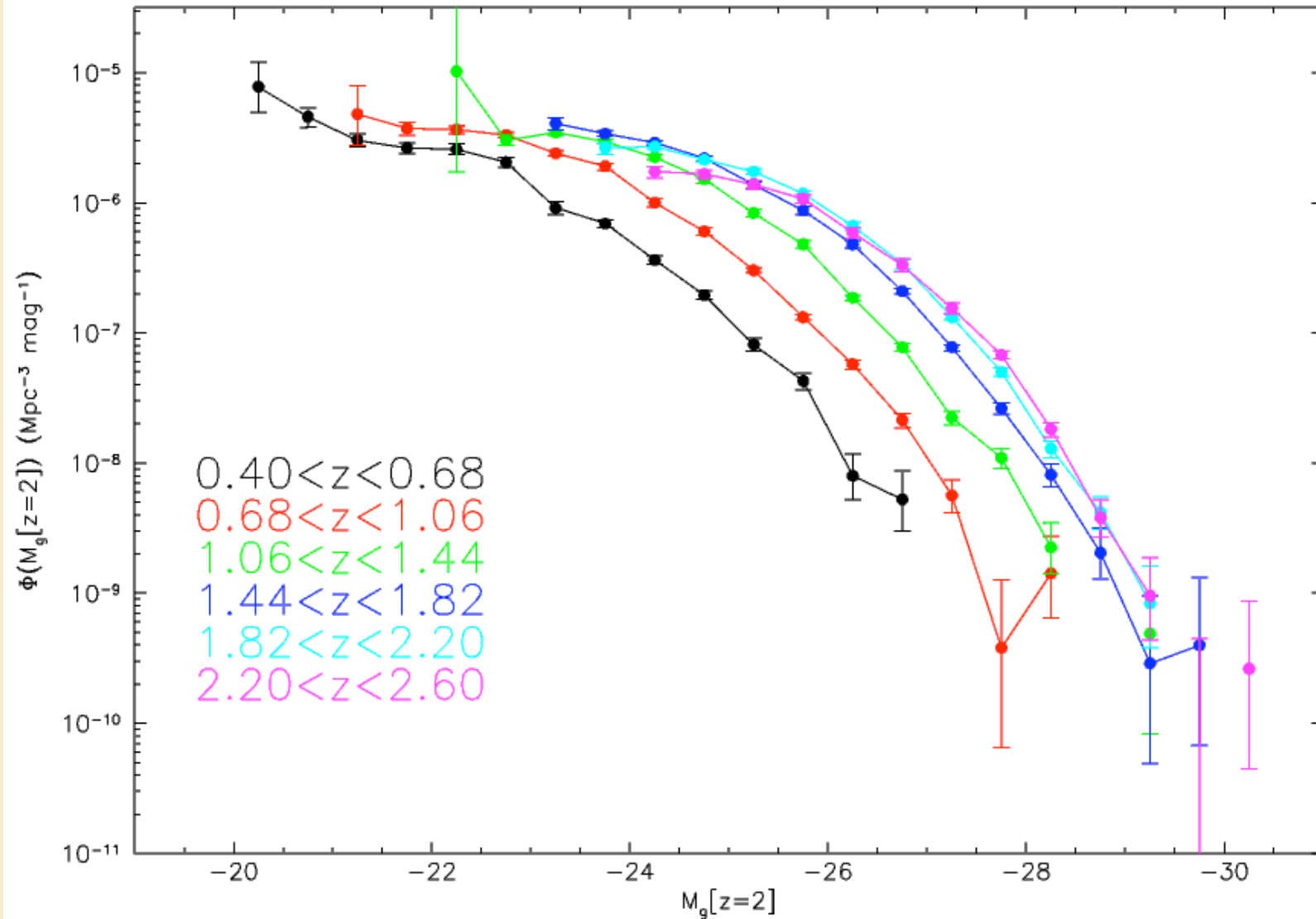
The 2SLAQ QSO LF



(SDSS LF: Richards et al. 2006)

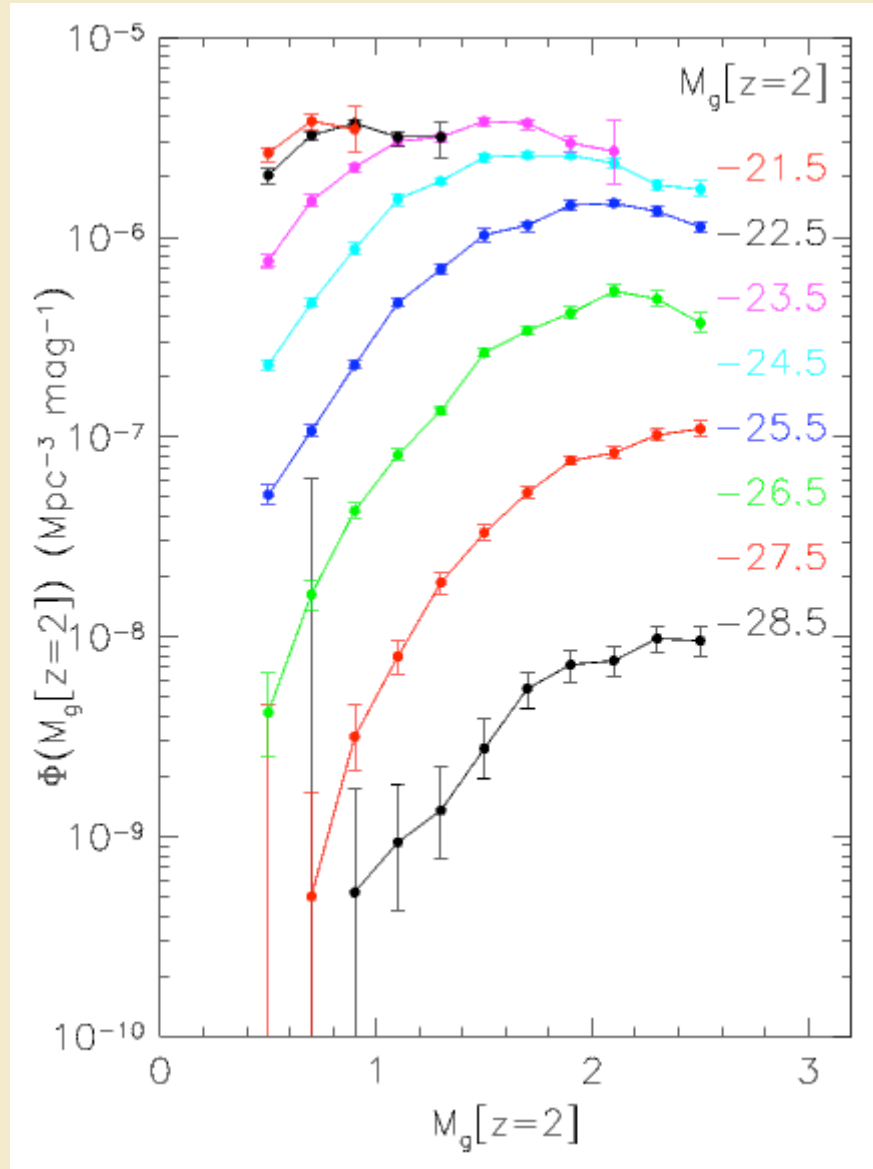


The 2SLAQ+SDSS QSO LF





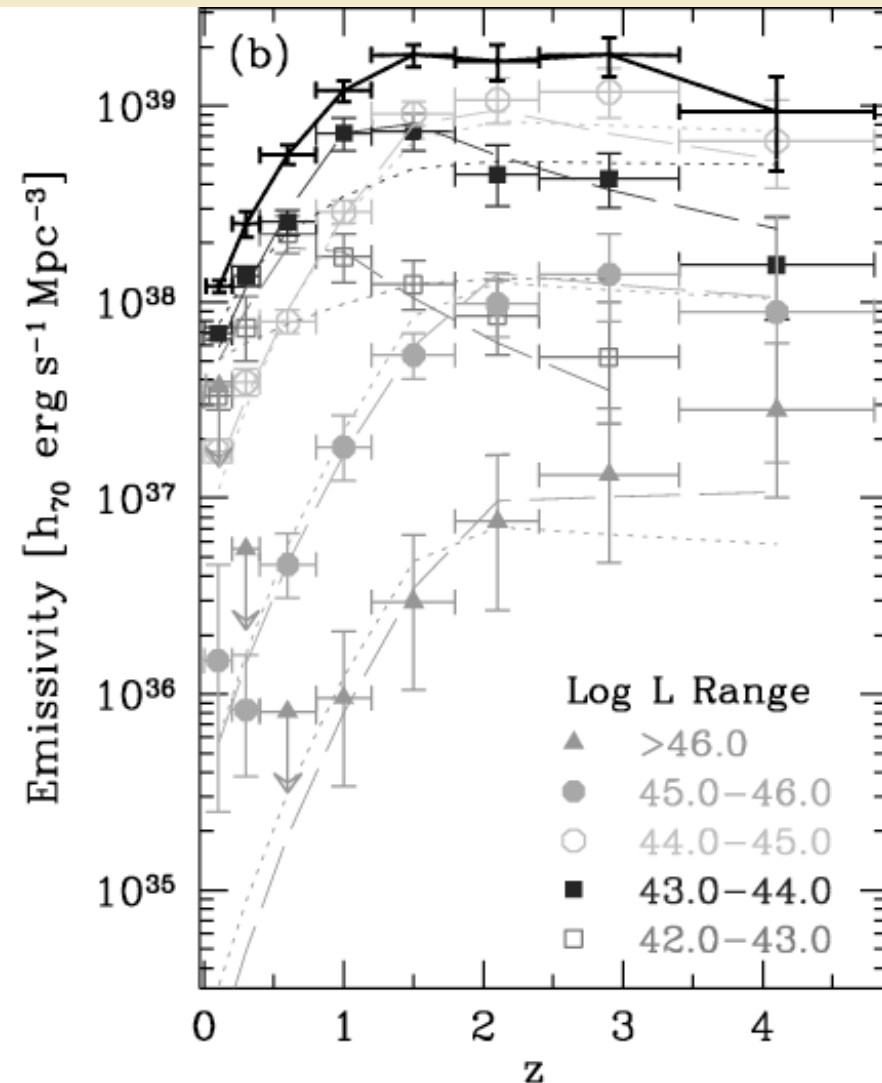
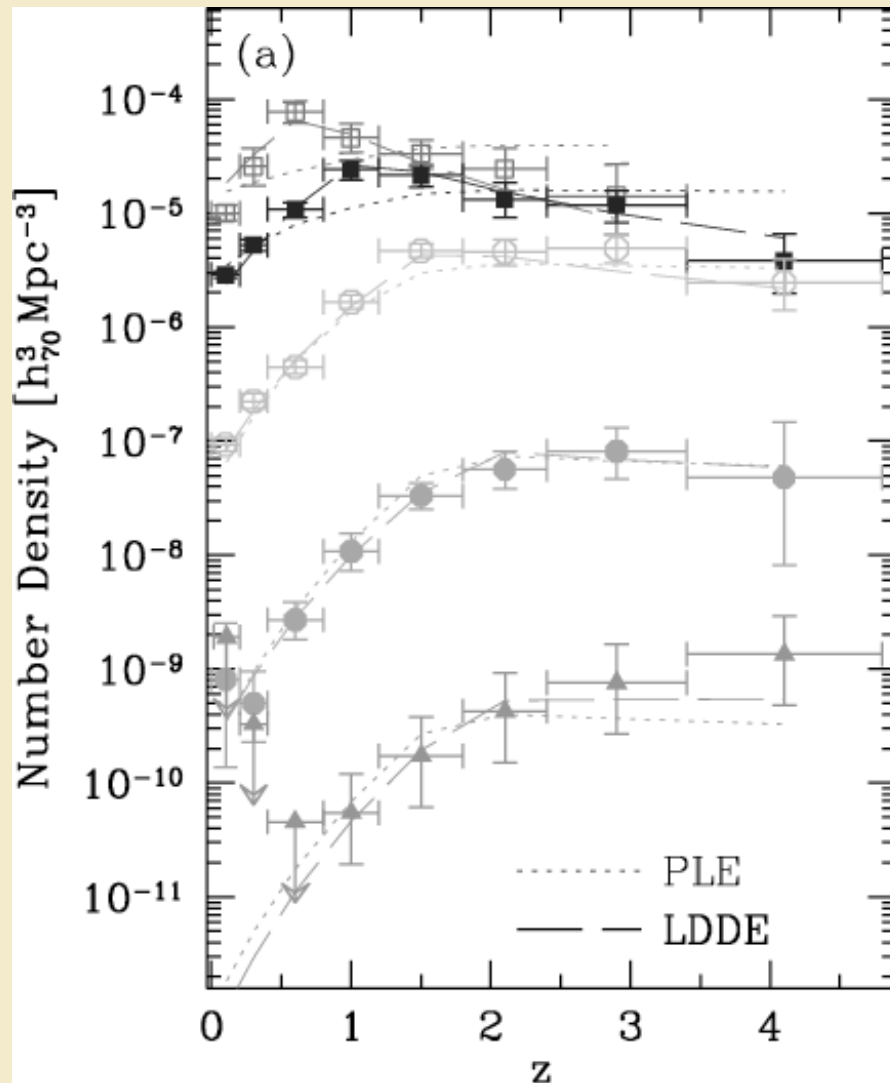
Downsizing...



- Brightest QSOs peak at $z \sim 2.5$ (or higher).
- Faintest QSOs peak at $z \sim 1$ (or lower).



Downsizing... (X-ray)



Hasinger et al. (2005)

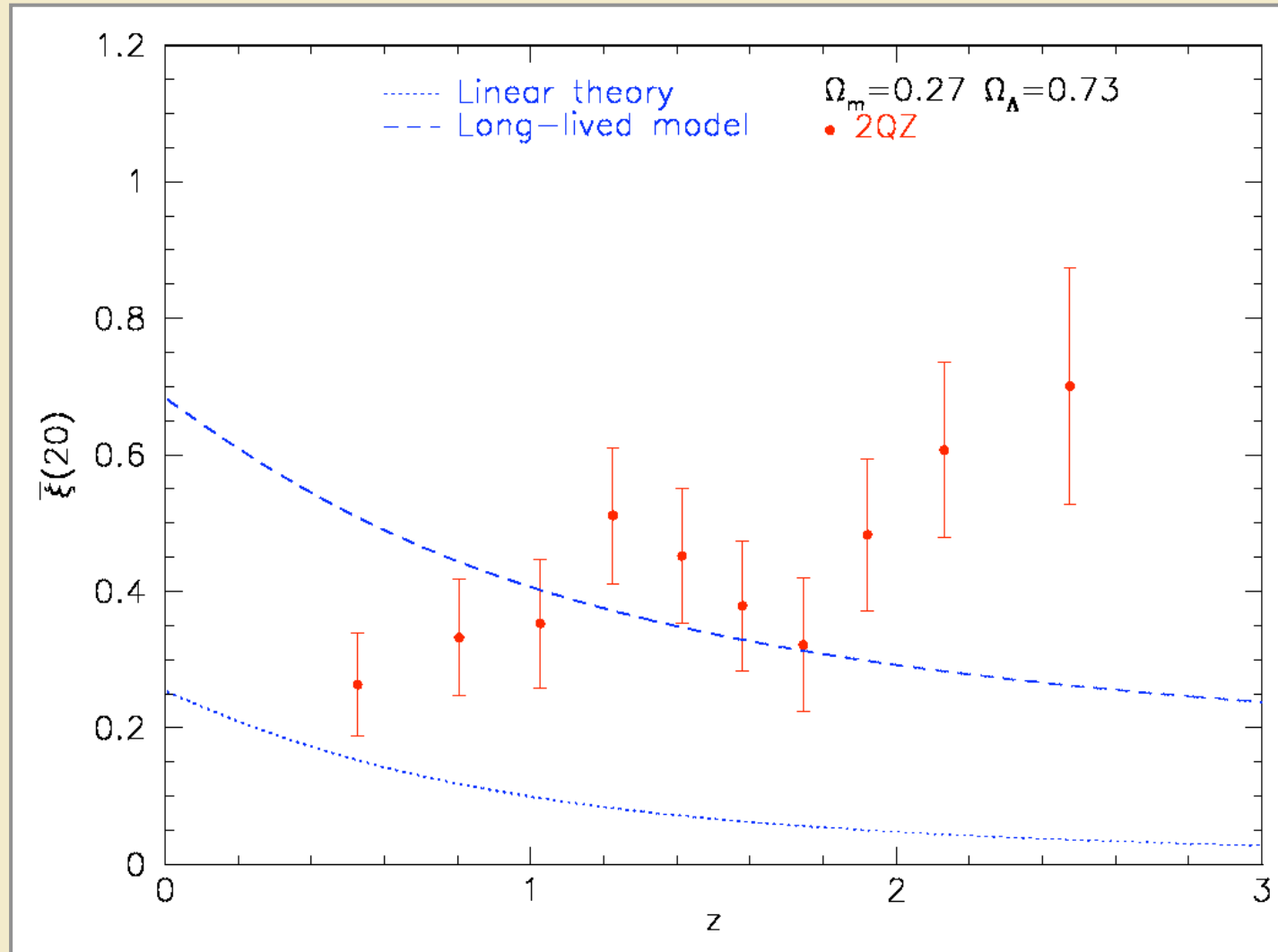


QSO clustering

- Clustering of QSOs related mass clustering via
 - $\xi_Q(r) = b^2 \xi_\rho(r)$
- Simple relation between bias, b , and dark matter halo mass (e.g. Sheth, Mo & Tormen 2001).



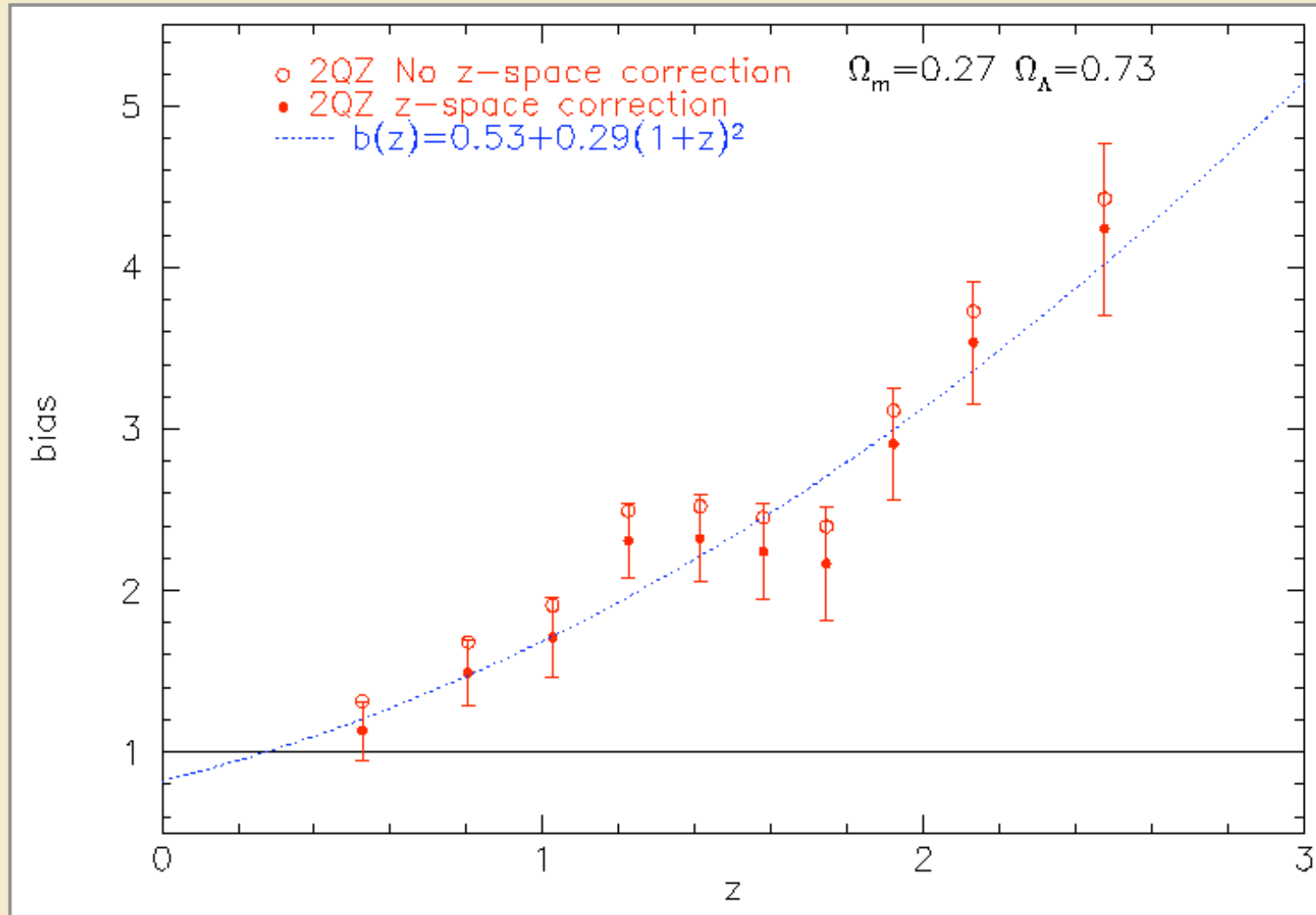
2QZ clustering evolution



Croom et al. (2005)



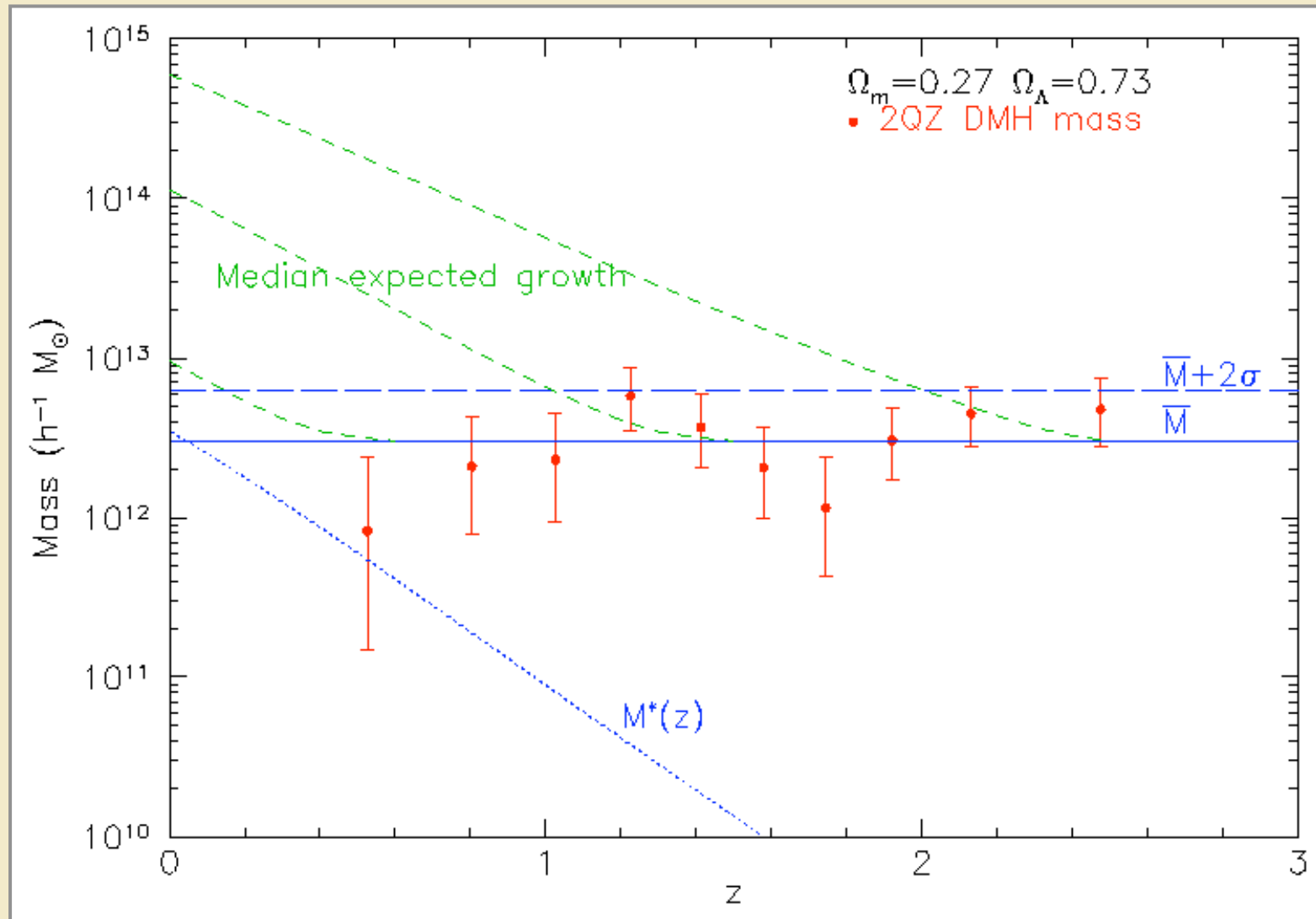
QSO bias



Croom et al. (2005)



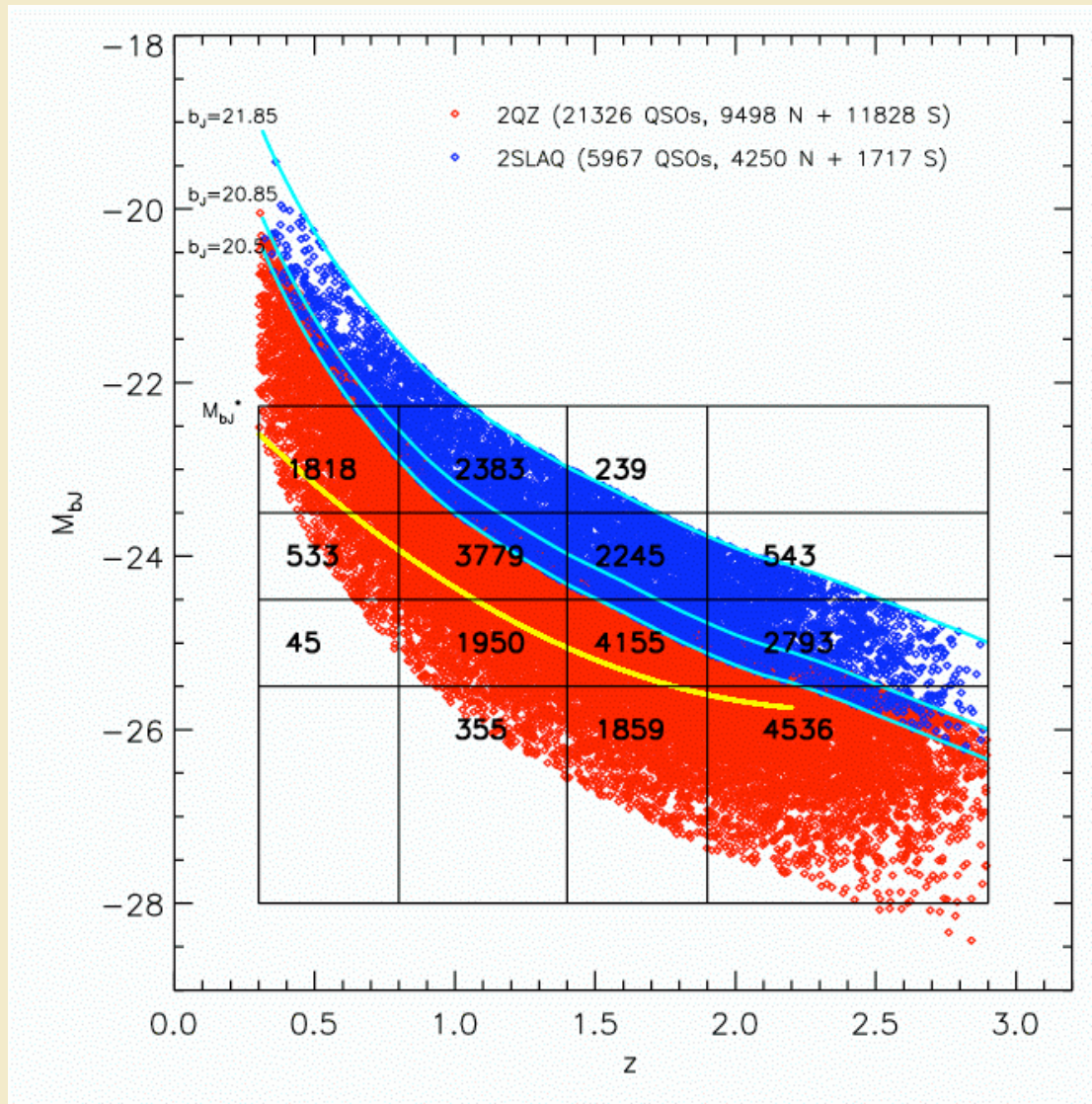
QSO DMH host mass



Croom et al. (2005)



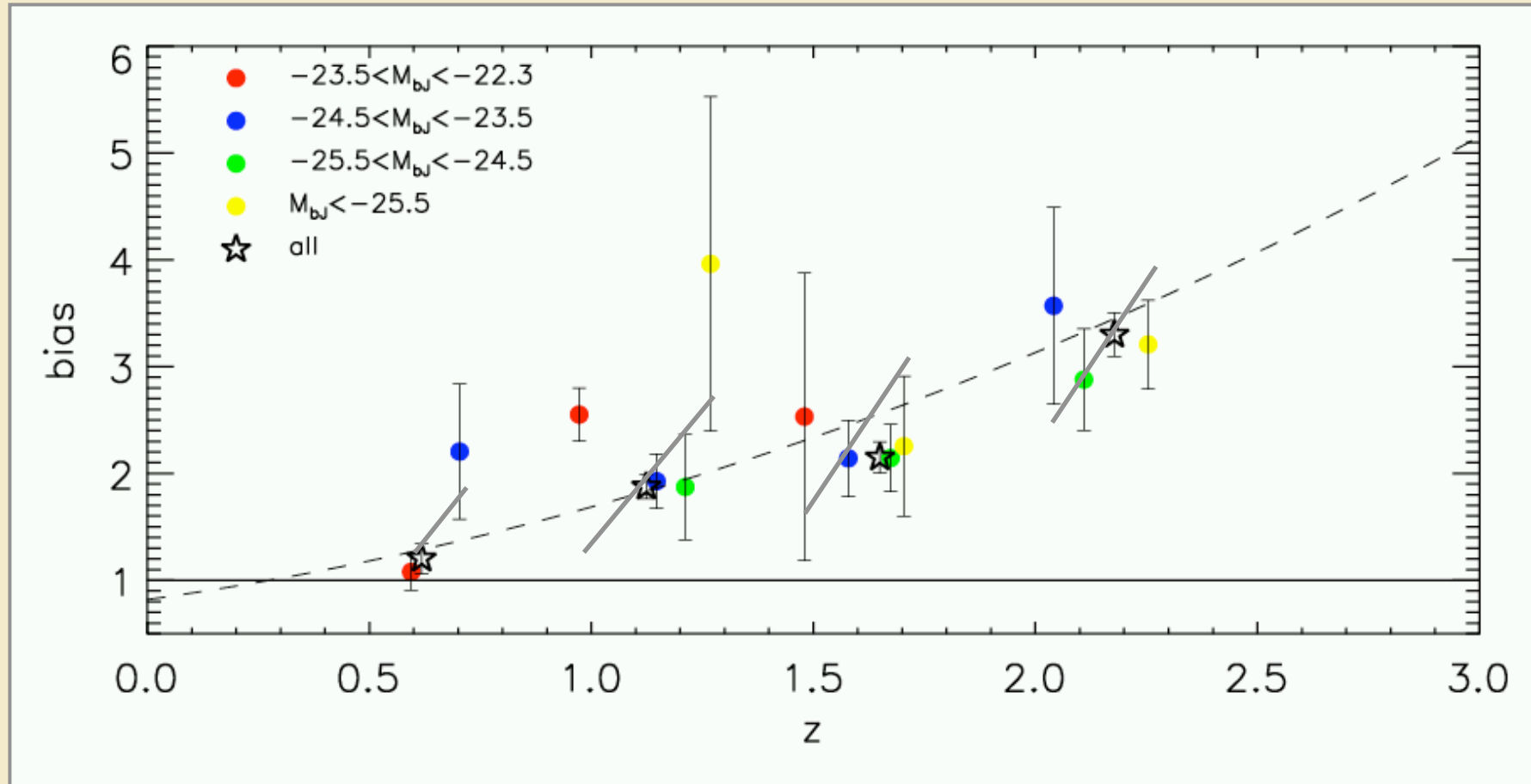
2SLAQ QSO clustering



da Angela et al. (2008)



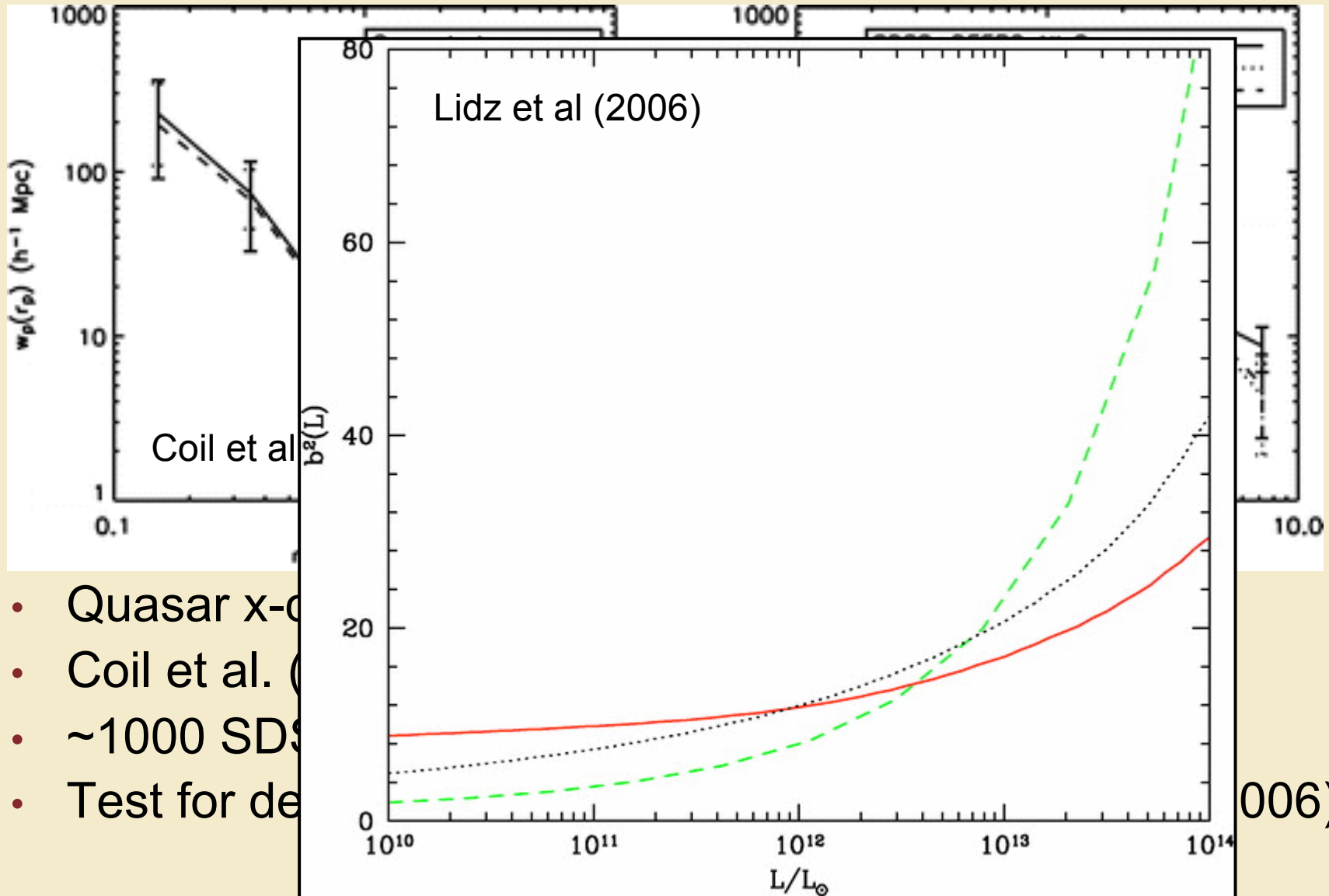
2SLAQ QSO clustering



da Angela et al. (2008)



Improving the clustering signal...



- Quasar x-clustering
- Coil et al. (2006)
- ~ 1000 SDSS quasars
- Test for detection bias

(Lidz et al. 2006).



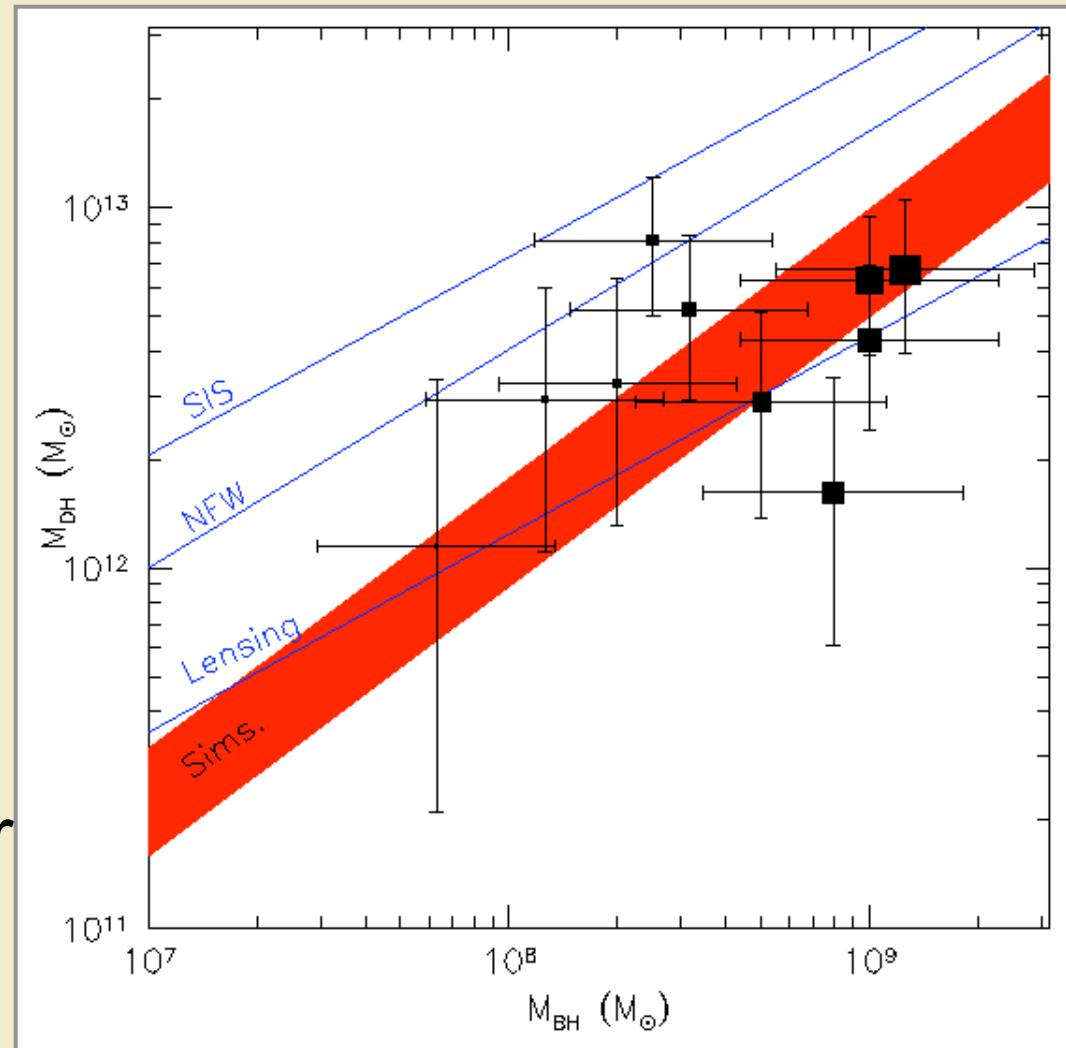
M_{BH} vs M_{DH}

- Broad lines give BH mass via virial estimators (although note caveats in Stephen's talk).
- Combine BH masses with DMH masses from clustering...
- Gives an estimate of the “M-M” relation at $z=0.5$ to 2.5.



M_{BH} vs M_{DH}

- Mean zero-point:
 $\log(M_{\text{BH}})=8.4\pm 0.2$ at
 $\log(M_{\text{DH}})=12.5$
- Well matched to
Robertson et al.
(2006) simulations.
- Bigger points = higher
redshift.



Fine et al. (2006)



Where next?

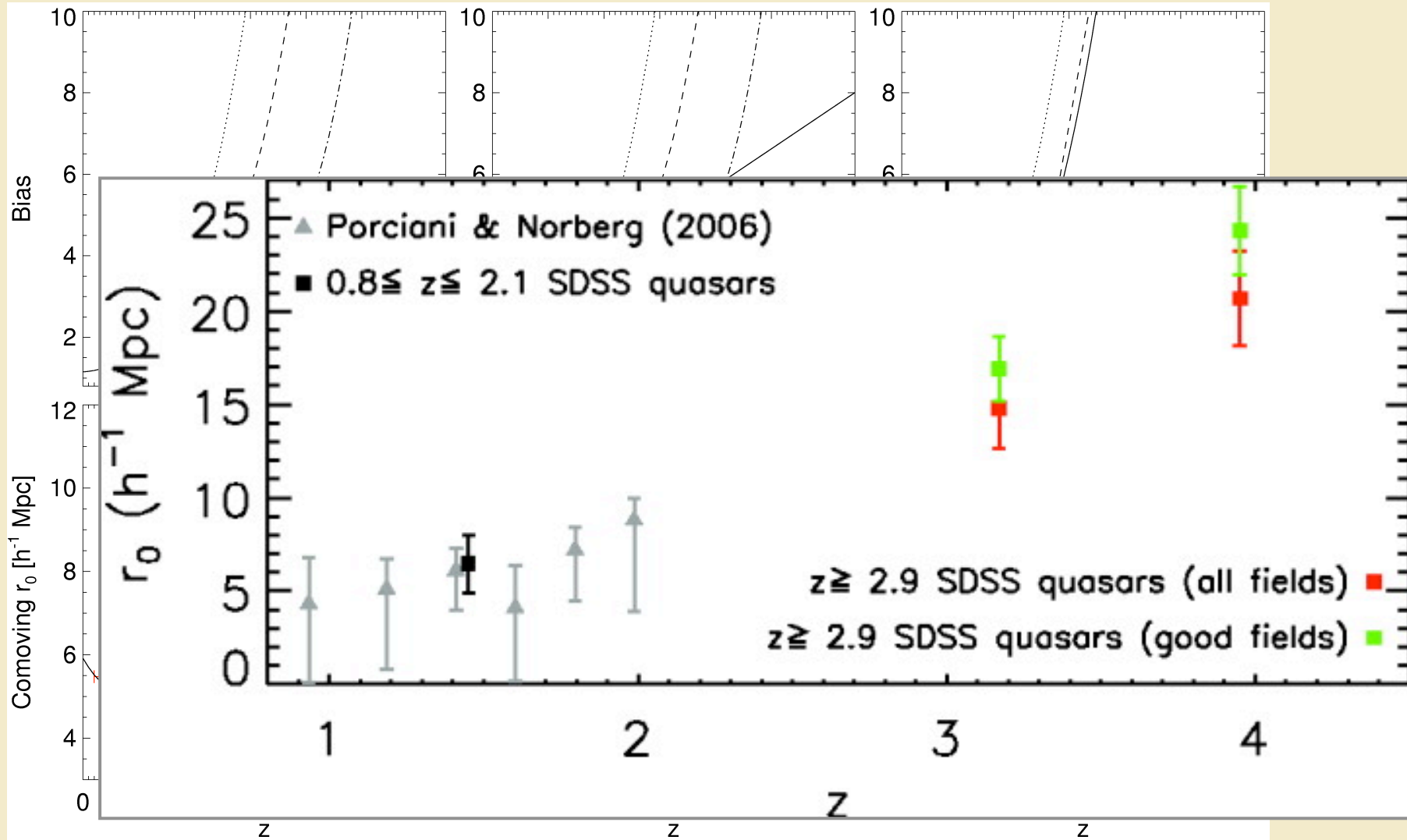
- What happens before the $z \sim 2-3$ quasar epoch?
- Bright high- z QSOs well characterized by SDSS.
- We want to watch the build of SMBHs...

AAOmega-UKIDSS-SDSS (AUS) survey:

- Deep $i \sim 22$ survey using SDSS
“stripe-82” and AAOmega on the AAT.



High-z clustering



Hopkins et al. (2006)

Shen et al. (2007)



Conclusions

- 2SLAQ QSO LF:
 - Not pure luminosity evolution.
 - Significant downsizing: faint AGN peak at lower z .
- QSO Clustering:
 - QSOs inhabit similar dark matter halos at $z=0.5-2.5$.
 - No luminosity dependence found.
 - Implies a range of accretion efficiencies for SMBHs.
- BH mass vs DMH mass:
 - M-M relation not evolving.
- High- z evolution:
 - Need a deep survey, (i-band ~ 22) to test feedback efficiency: AUS survey...