Clustering studies of ROSAT/SDSS AGN through cross-correlation functions with SDSS Galaxies

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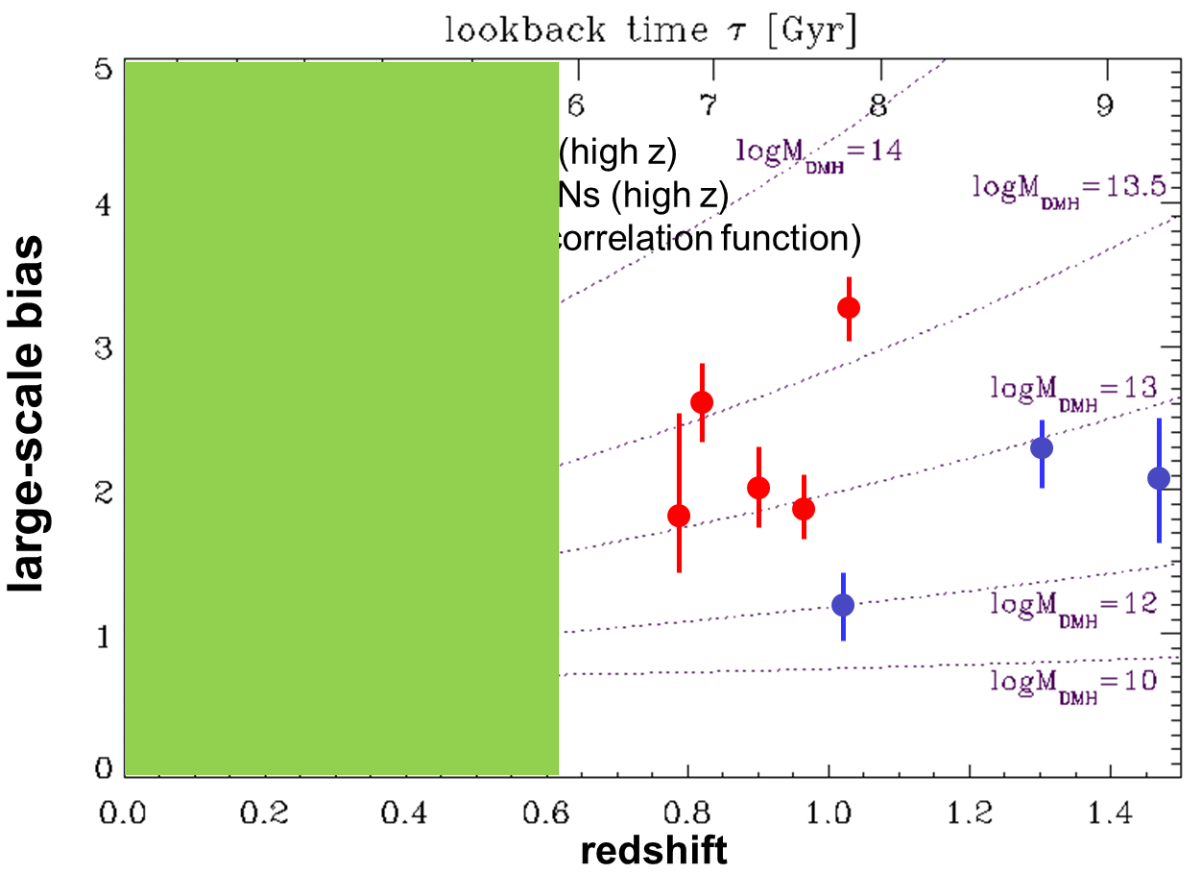
Motivation



Status before 2009:

- bias of broad-line AGN well-known at high z
- evolution with redshift remains unclear

⇨ **measure bias of BL AGN at low redshifts!**

However:
low number density of broad-line AGN at low z

use cross-correlation measurements with galaxies in a large volume

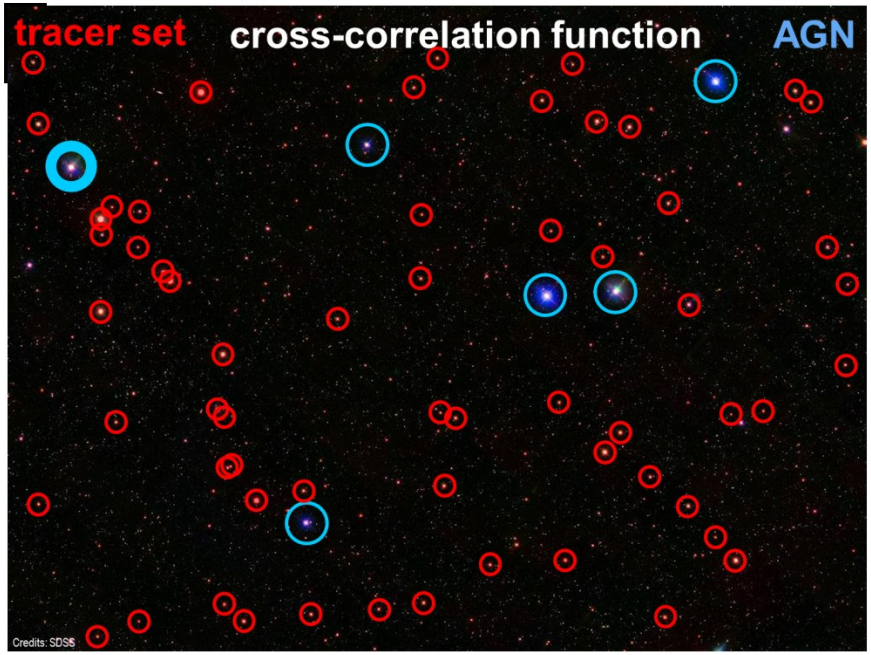
Outline

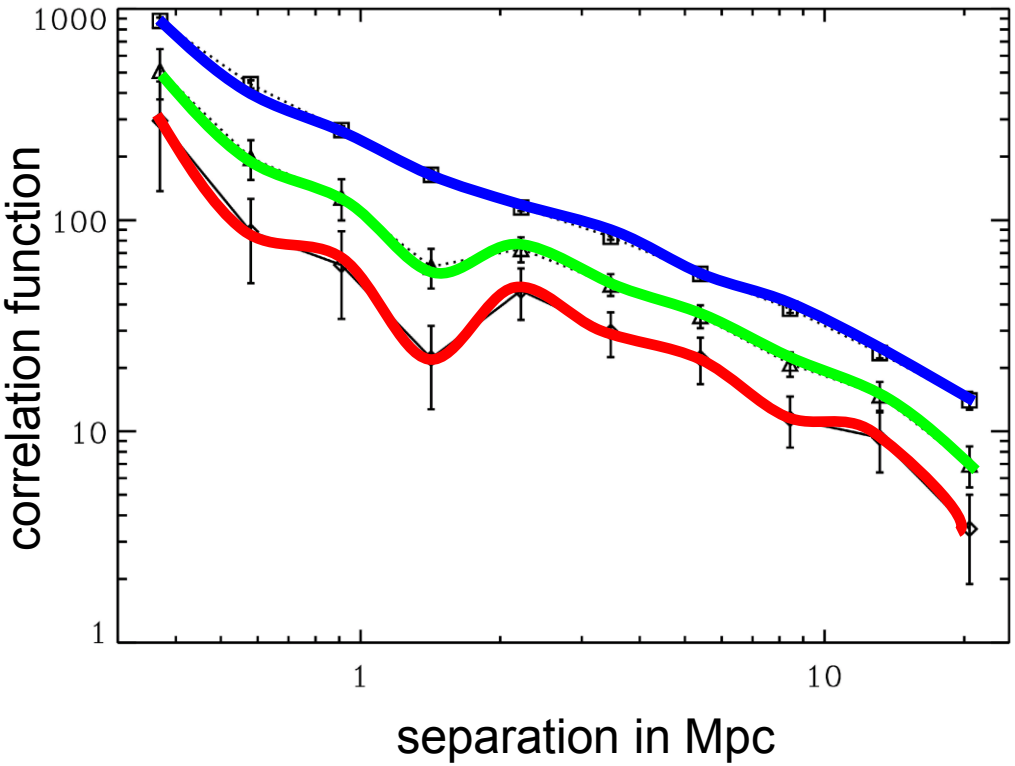
- **Use ROSAT/SDSS clustering measurements to precisely constrain M_{DHM} at low z** (Krumpe et al. 2010)

- **Expand the method to lower and higher redshifts and optically selected SDSS AGN** (Krumpe et al. 2012)

- **Explore clustering dependence in respect to M_{BH} and/or L/L_{EDD}** (Krumpe et al. in prep.)

Method





compute

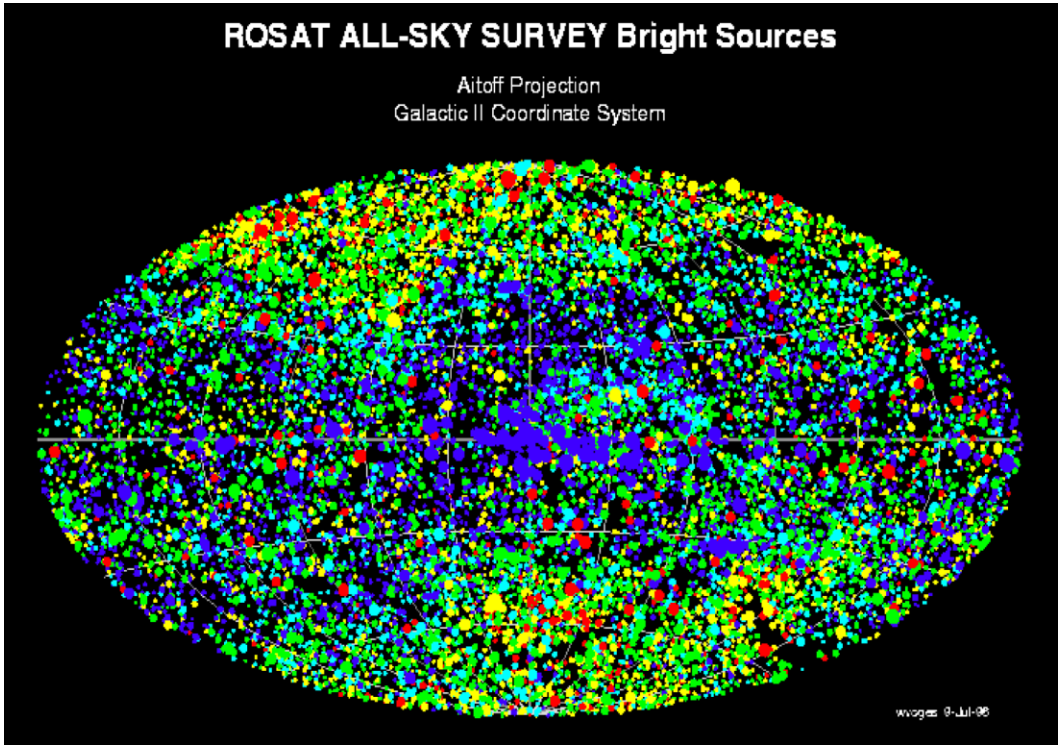
measure

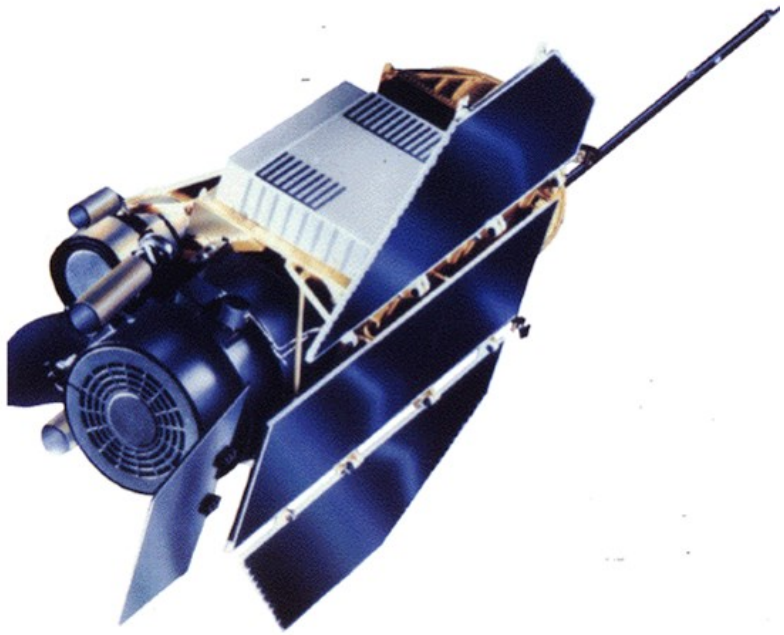
measure

$\xi_{AGN(AGN)} = \xi^{2}_{COR(AGN\text{-}Gal.)} / \xi_{AGN(Gal.)}$

(Coil et al. 2009)

ROSAT All-Sky Survey/SDSS AGN sample





- **still the most sensitive all-sky (soft) X-ray survey, with ~110,000 sources**
  (Voges et al. 1999)

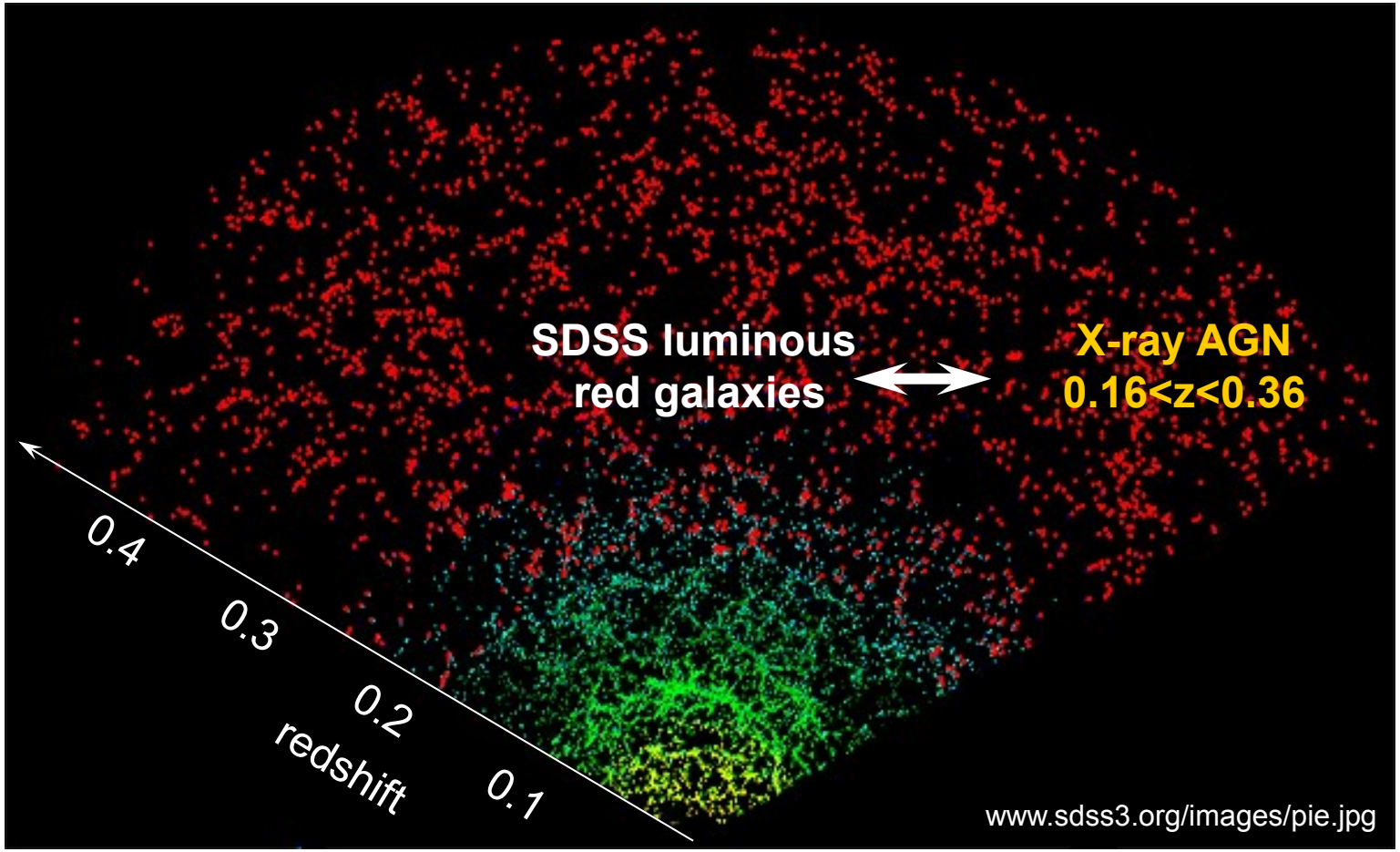
- **6224 broad-line AGN with spectroscopic redshifts from SDSS**
  (Anderson et al. 2003, 2007)

- **L_X~ 10^{42}-10^{47} erg s^{-1}**

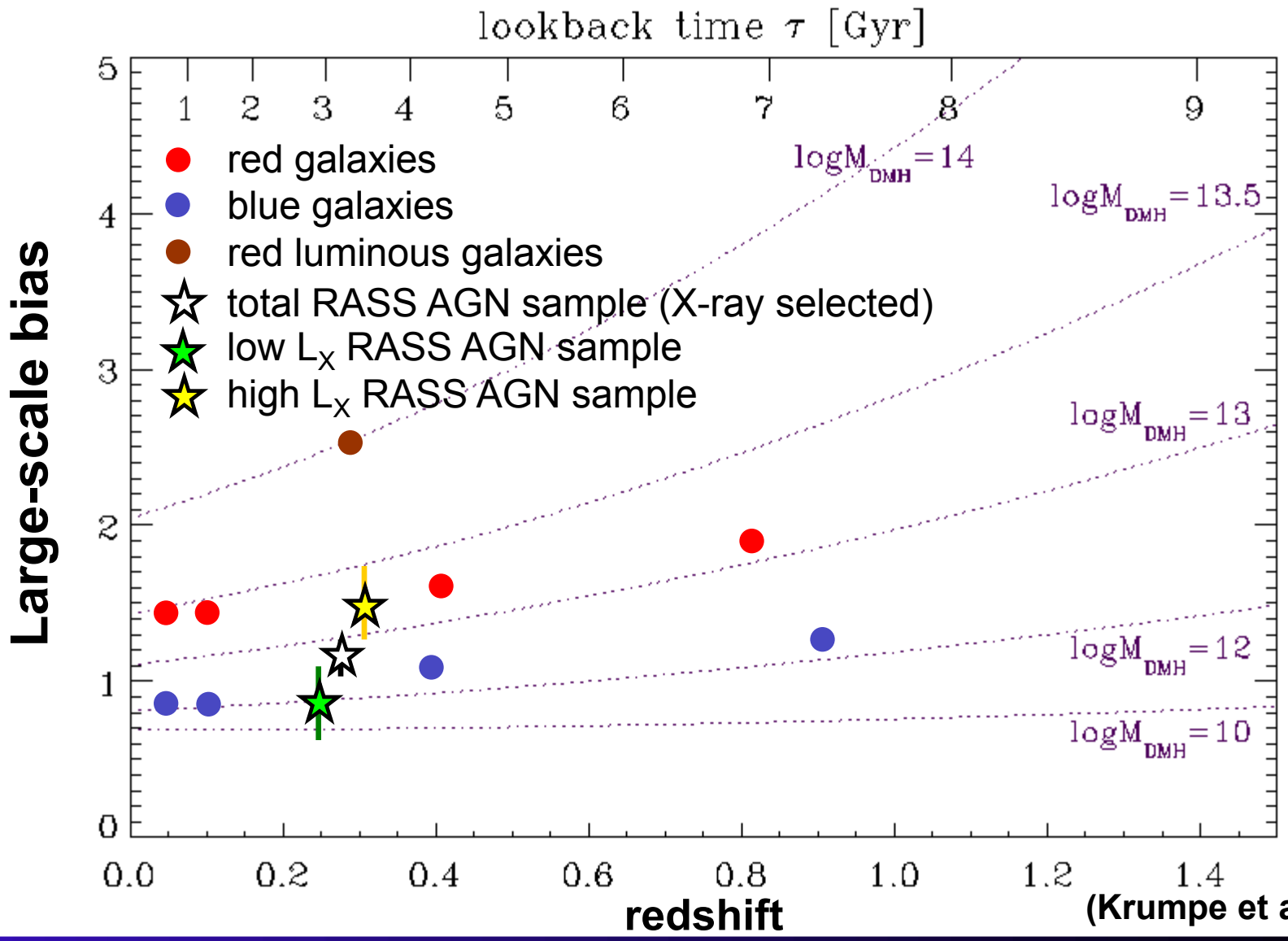
Cross-correlating galaxy sample

requirements for tracer set:

high number density (>> AGN) & well-defined and replicable selection



Clustering strength of low-z AGN

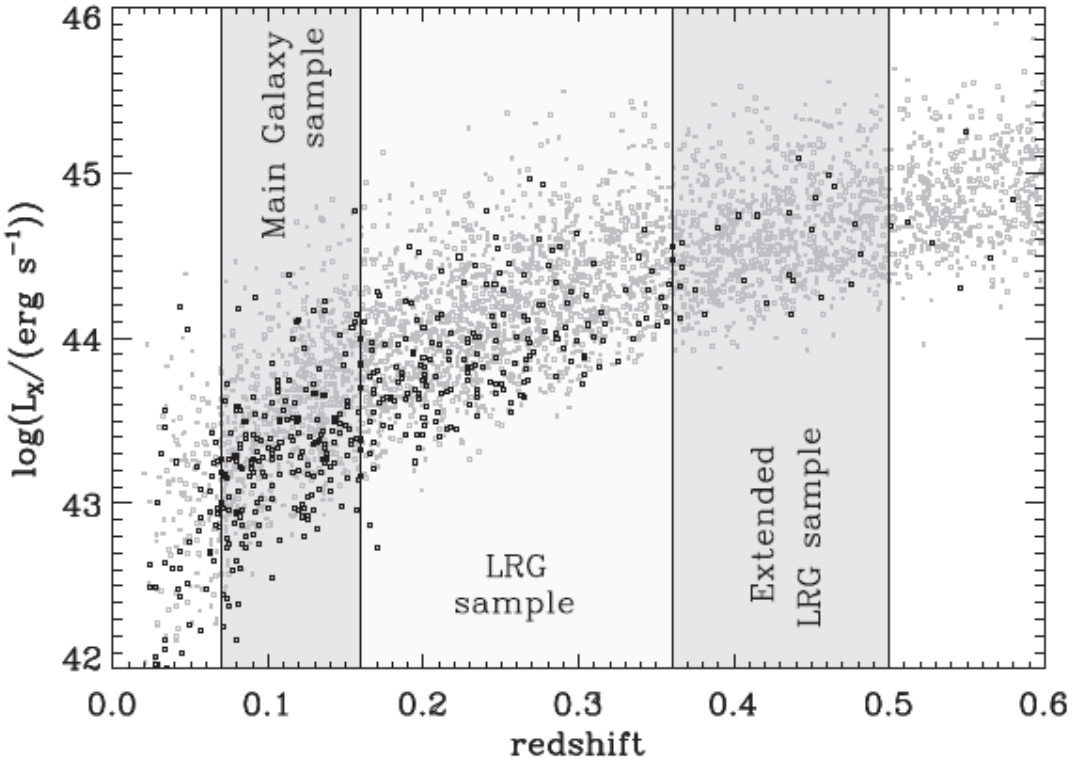


(Krumpe et al. 2010)

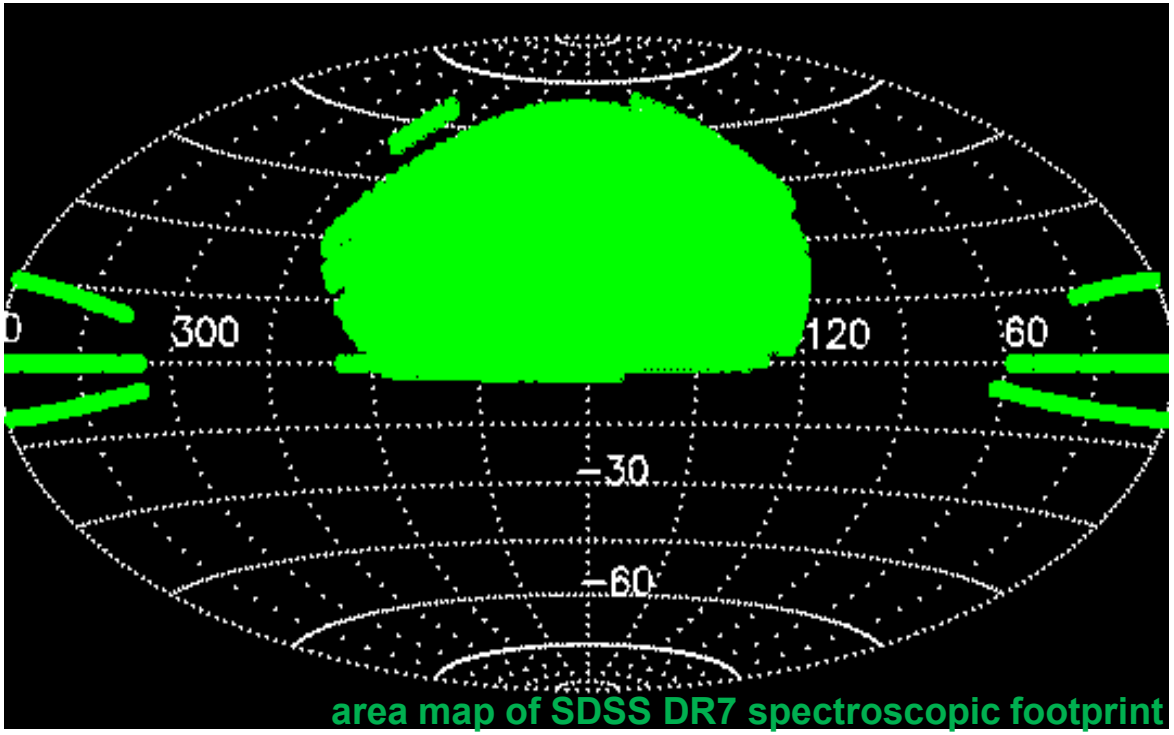
Taking the next steps

Krumpe et al. (2012)

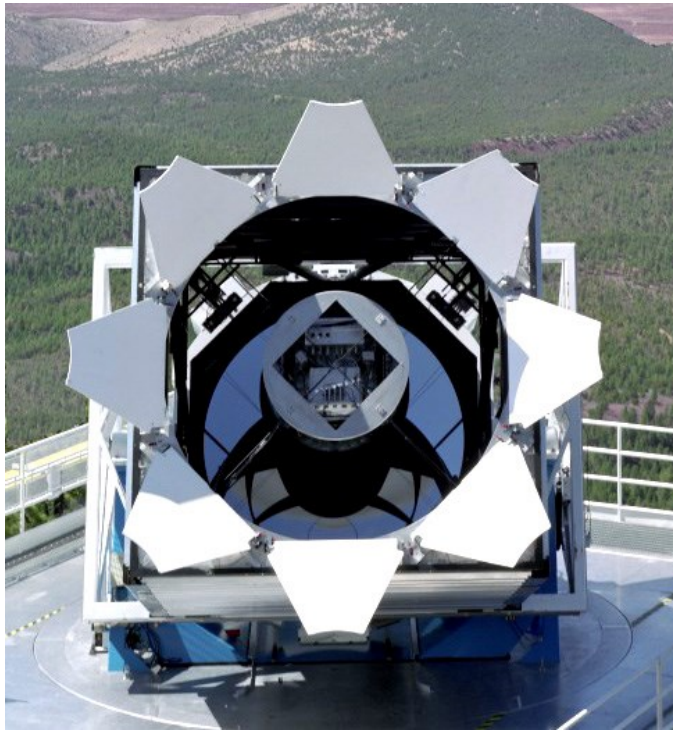
- extend to higher and lower redshifts (z=0.07-0.50)
- X-ray and optically selected AGN samples
- AGN sample selection: radio-quiet, optical without X-ray counterparts, radio-quiet and no X-ray AGN, X-ray no optical
- narrow line X-ray selected AGN



SDSS AGN sample



area map of SDSS DR7 spectroscopic footprint



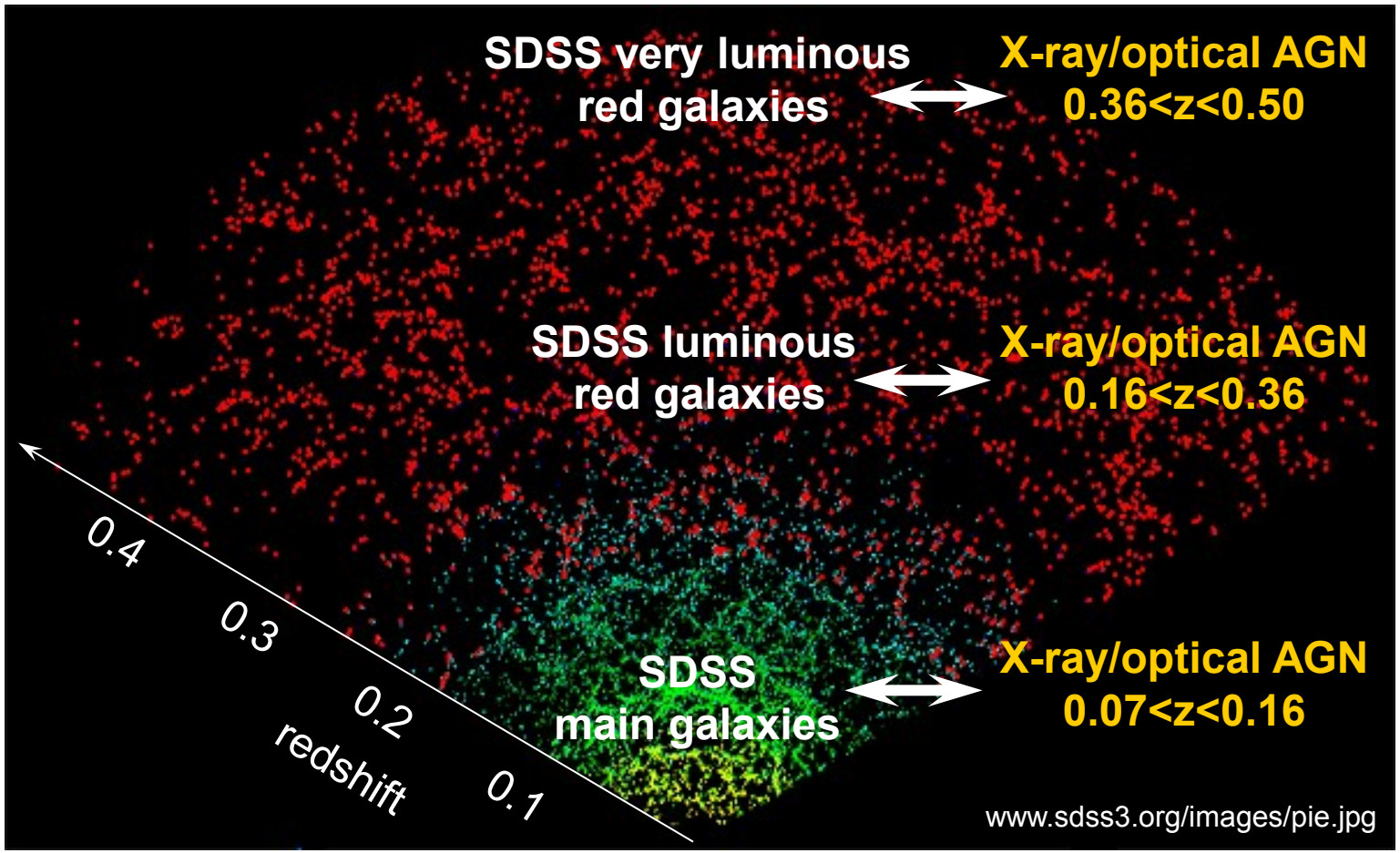
- ~18 candidates per deg^2
- 105,783 broad-line AGN
- fainter than i~15 mag
- M_i brighter than -22 mag

(Schneider et al. 2010, Richards et al. 2002)

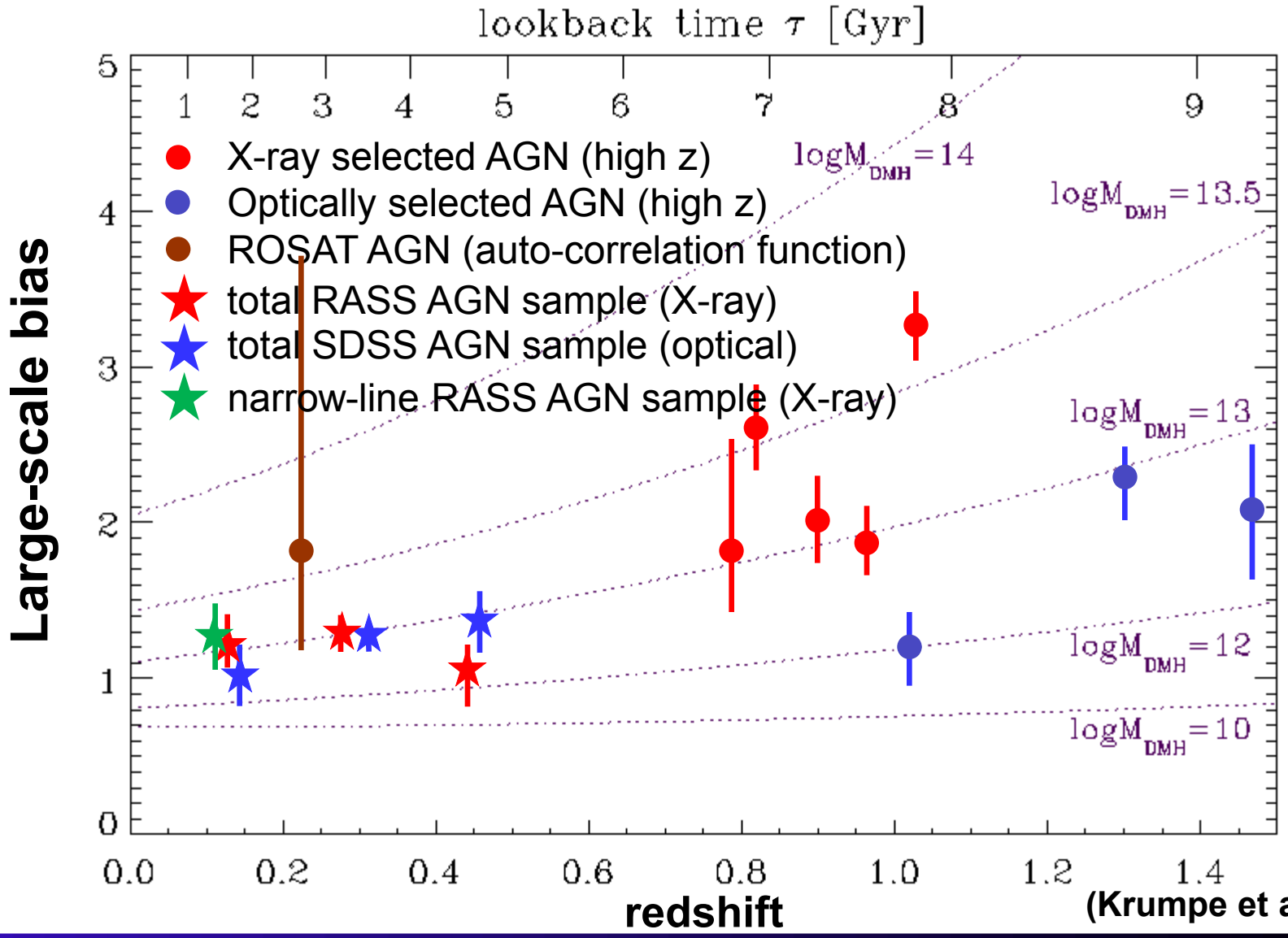
Cross-correlating galaxy samples

requirements for tracer set:

high number density (>> AGN) & well-defined and replicable selection



X-ray vs. optically selected AGN



(Krumpe et al. 2012)

General picture of AGN clustering

over cosmic time AGN reside in $M_{DHM} \sim 10^{13} M_{SUN}$

low redshift (z<0.5)

- broad-line and narrow-line cluster like ≥L^* galaxies or a small galaxy group of ~L^*
- no statistically convincing difference in the clustering of X-ray and optically selected broad-line AGN
- weak luminosity dependence of the clustering for broad-line AGN (high L_X AGN ⇨ cluster higher ⇨ similar to red galaxies)

high redshift

- X-ray selected AGN appear to cluster more strongly than optically selected AGN ⇨ real?
  ⇨ why: different populations, different luminosities?

Origin of the weak L_X dependence of the broad-line AGN clustering strengths at low z

Motivation

Krumpe et al. in prep.

Galaxy clustering measurements:

- clustering strength depends on galaxy properties

(e.g., luminosity, morphological type, stellar mass)

more luminous ⇔ more clustered

⇔ more massive dark matter halos (DMHs)

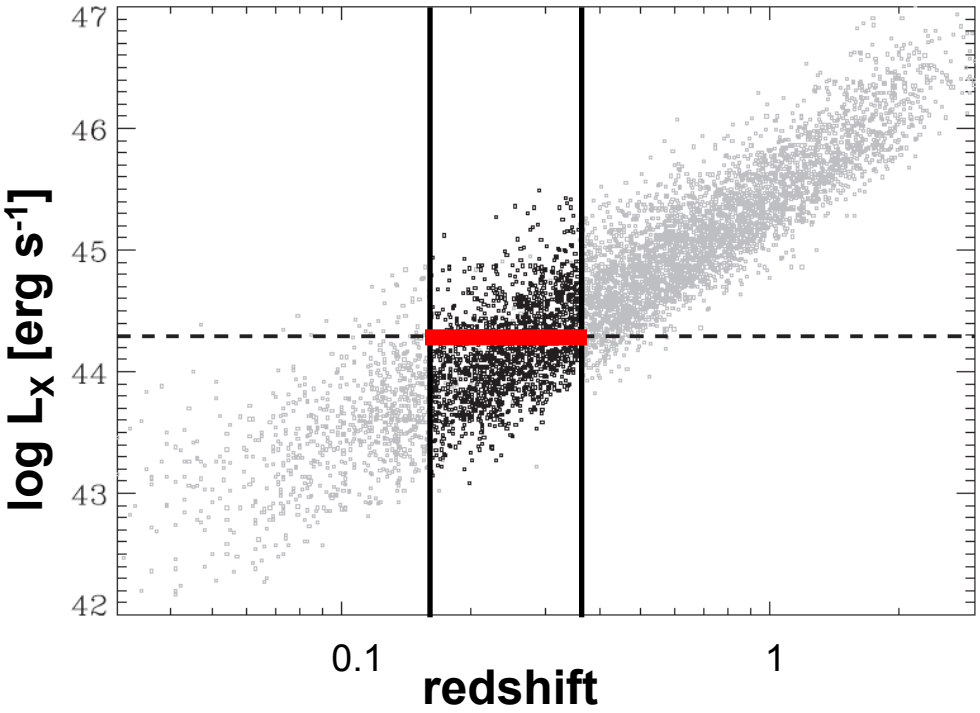
AGN clustering measurements:

- constraints on theoretical models of AGN triggering,

AGN host galaxy properties & cosmological parameters

Do AGN properties correlate with clustering strength?

AGN luminosity dependence of the clustering



Krumpe et al. (2010):

more X-ray luminous AGN cluster more strongly (larger M_{DMH}) than lower-luminosity counterparts

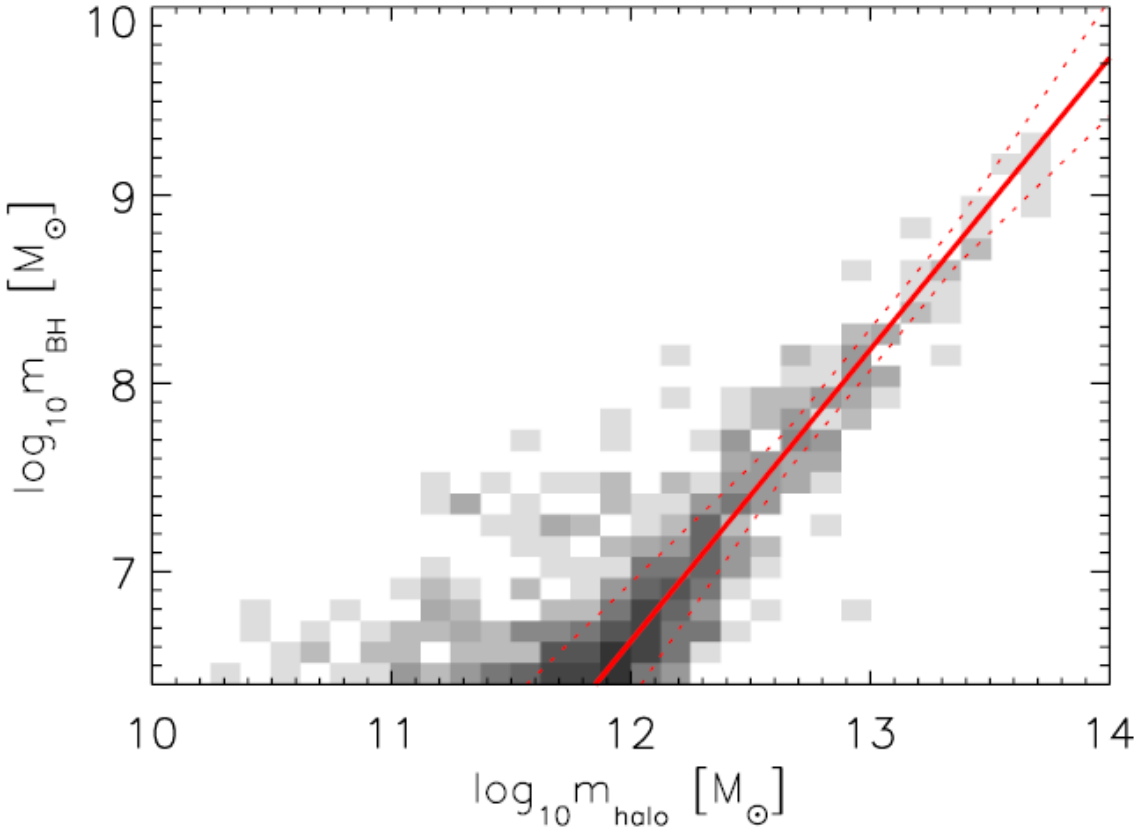
X-ray luminosity depends on:
M_{BH} and L/L_{EDD}

Krumpe et al. (in prep.):

explore physical origin of clustering dependence
$\Rightarrow$ caused by M_{BH} or/and L/L_{EDD}?

What is predicted?

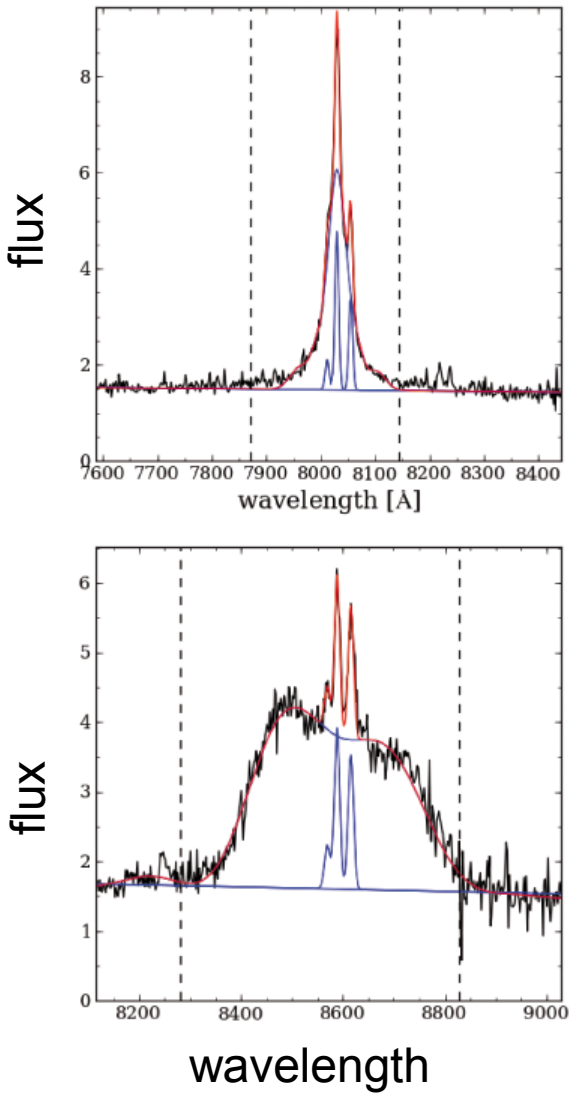
Booth & Schaye (2010): cosmological simulations: $M_{BH} \sim M_{DMH}$



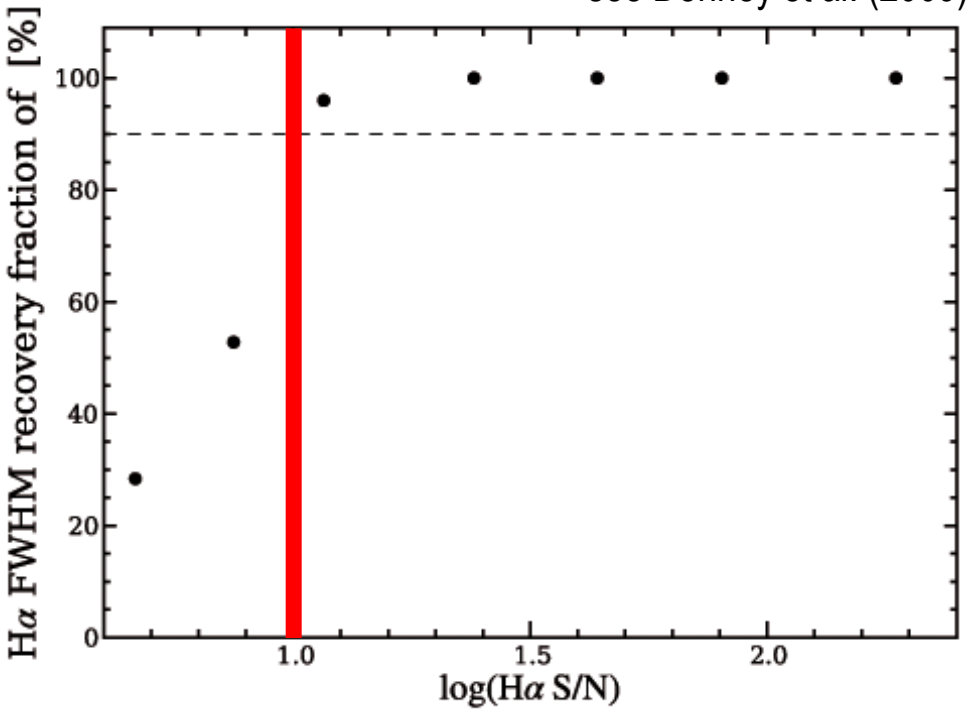
use AGN clustering measurements to test predictions

Determine M_{BH} for the RASS/SDSS AGN sample

Hα bandpass



see Denney et al. (2009)



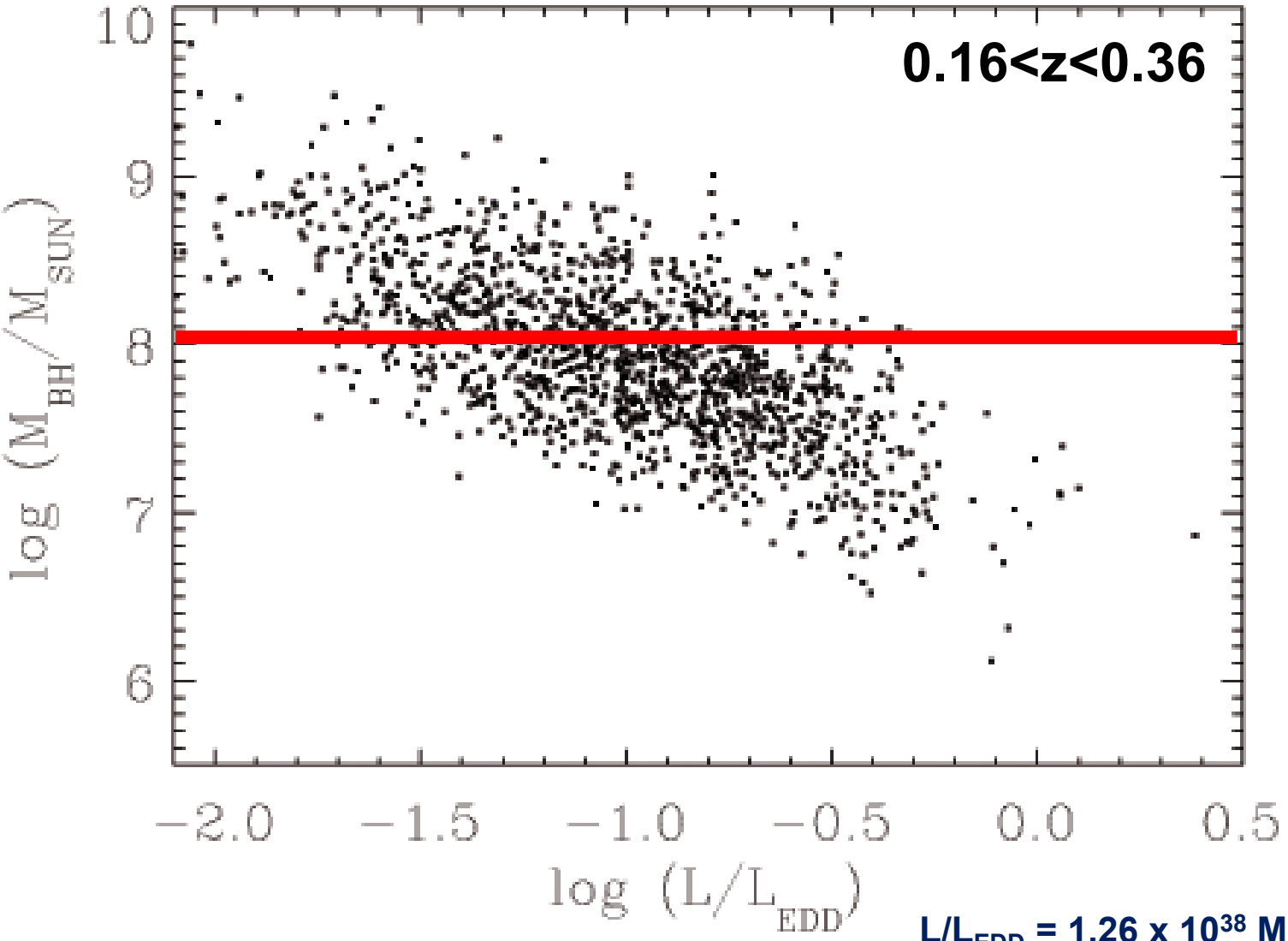
fit the Hα line profile

⇒ determine Hα-FWHM & $L_{Hα}$

⇒ convert to Hβ-FWHM & L_{5100} (Geene & Ho 2005)

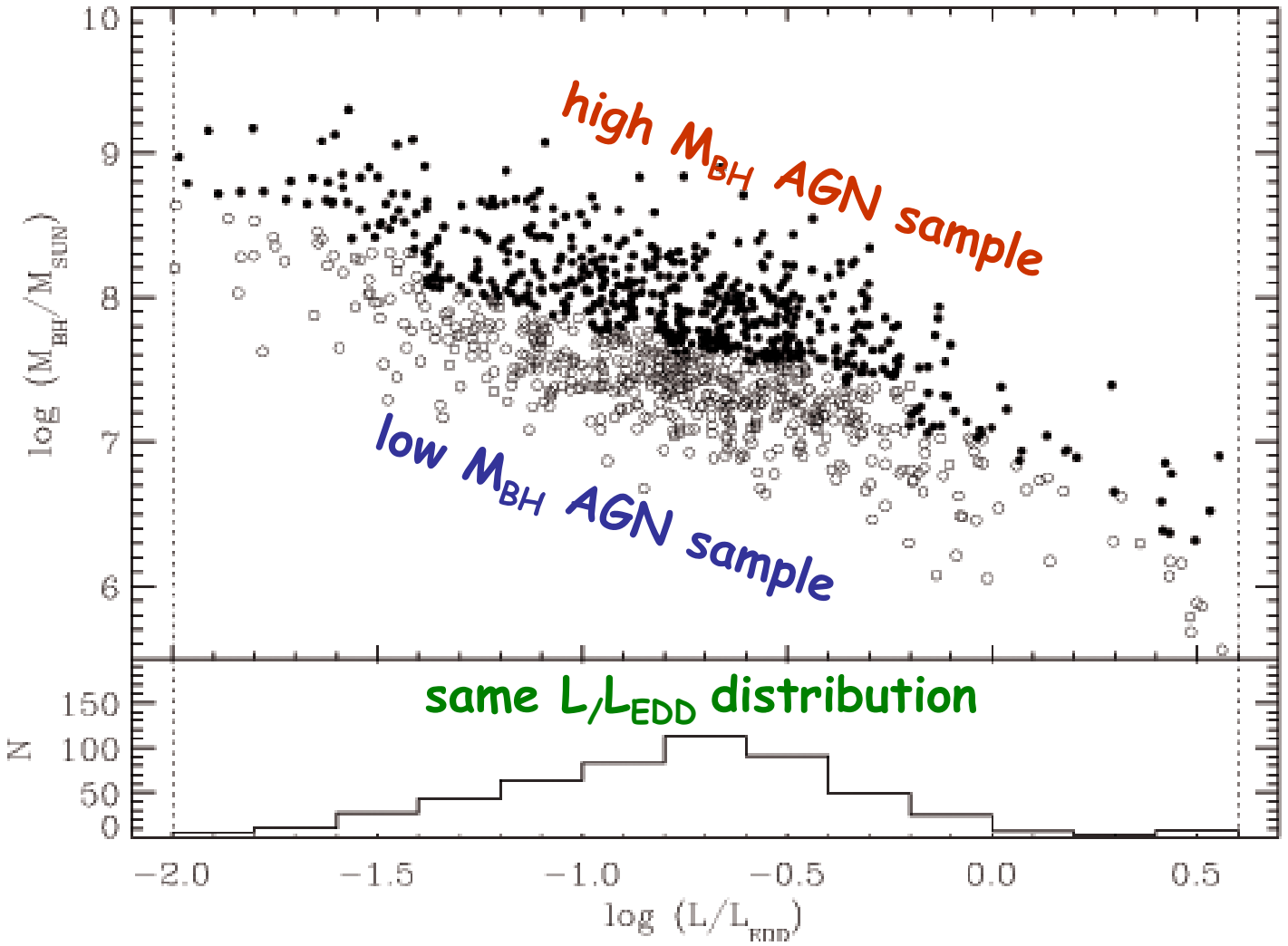
M_{BH}

M_{BH} - L/L_{EDD} plane



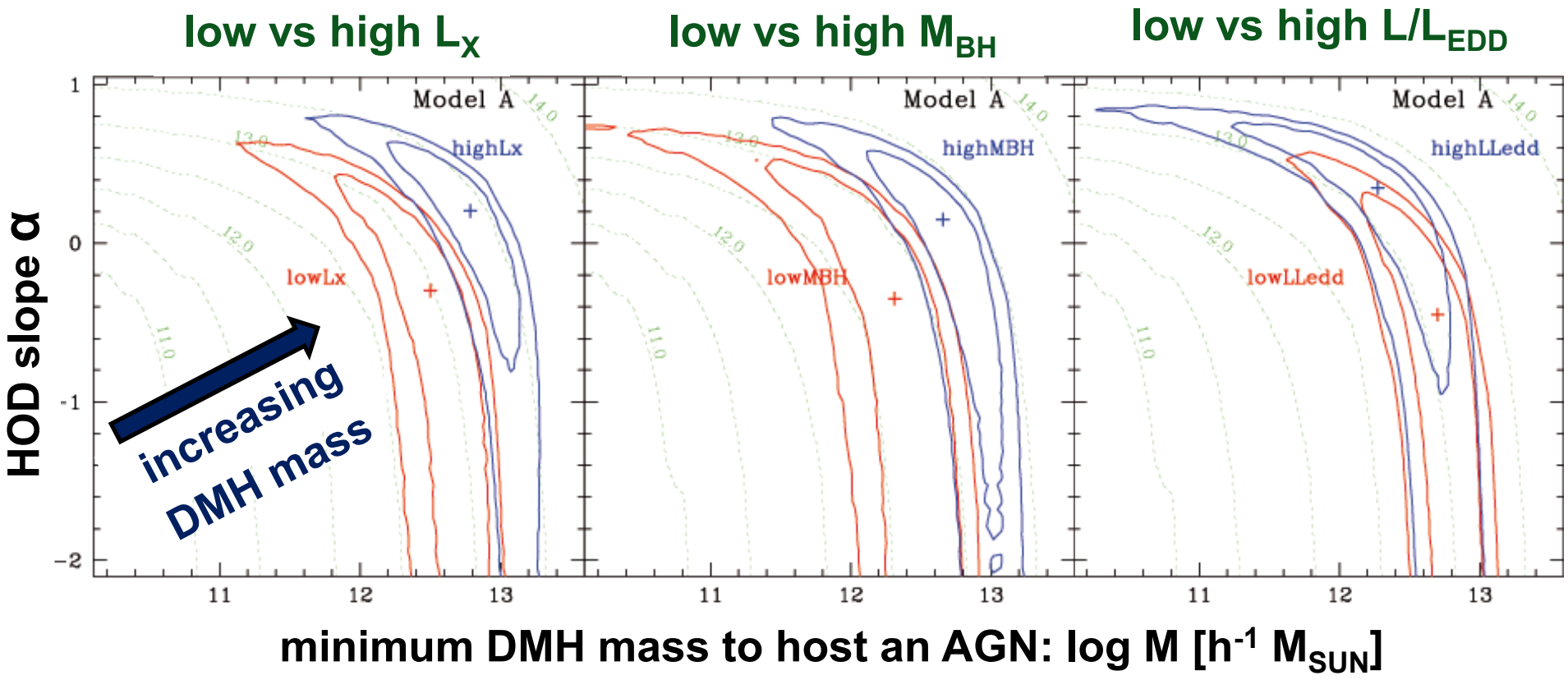
$L/L_{EDD} = 1.26 \times 10^{38} M_{BH}/M_{SUN}$ erg/s

Unbiased split distributions



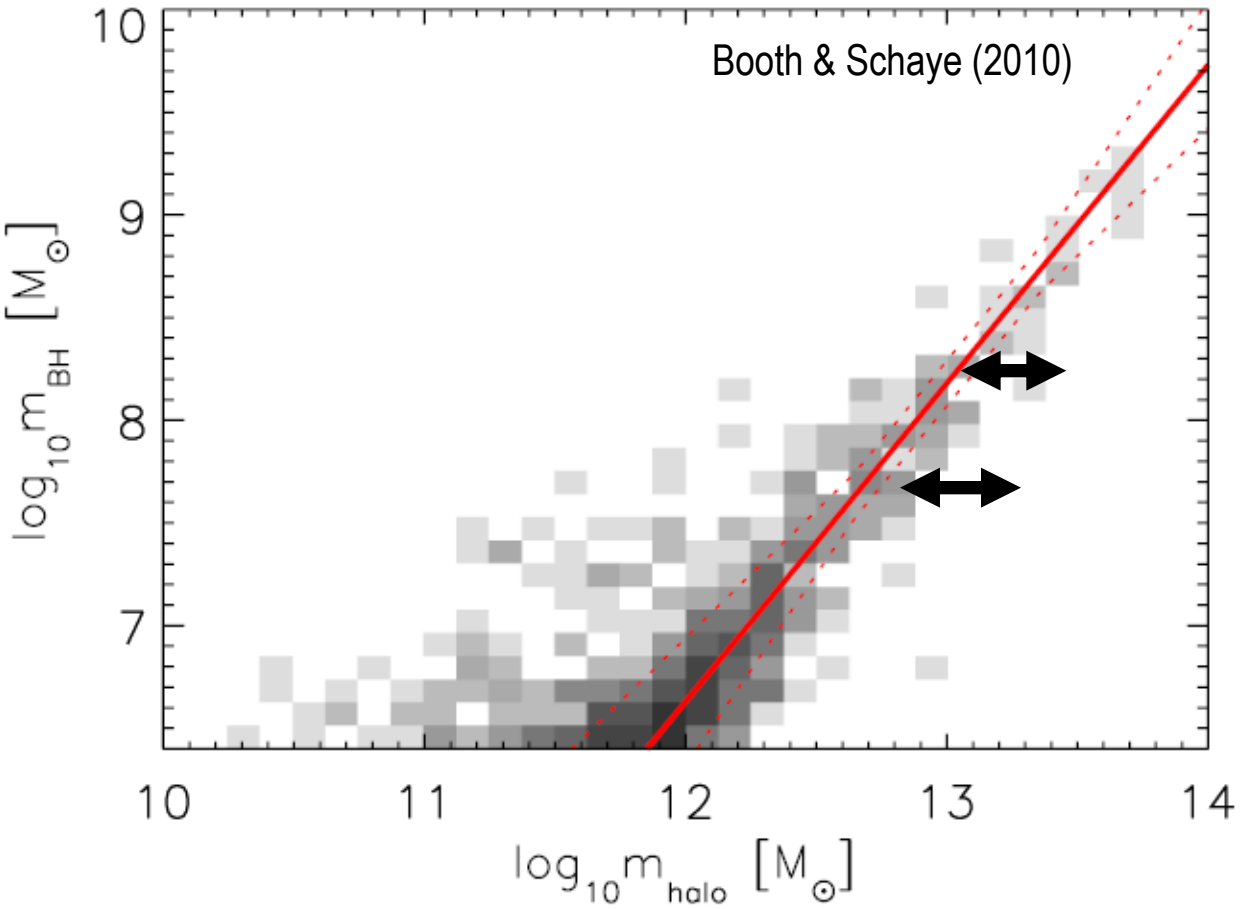
only within each L/L_{EDD} bin, split distributions of M_{BH} values

Main Result: M_{BH} correlates weakly with M_{DMH}



difference is more prominent in 2D parameter space

Theory vs. Observation



reasonable agreement

Consequences

At the luminosity and redshift range studied:

(BL AGN; $L_X \sim 10^{43}$-10^{45} erg s^{-1}; $0.16<z<0.36$)

NO correlation with L/L_{EDD}:

higher densities of galaxies/larger DMH masses
do NOT cause more accretion of matter

Correlation with M_{BH}:

high X-ray luminosity AGN do not require dense environments
$\Rightarrow$ mergers play only a minor role
in the accretion process

Conclusions

• **we accurately measure the clustering of X-ray and optically selected AGN at low redshift through CCFs** (Krumpe et al. 2010, 2012)

Broad-line, luminous AGN (z=0.07-0.5):

• No statistically convincing difference between:
X-ray, optically selected, radio-quiet AGN

• weak L_X dependence of the clustering strength

L_X dependence of the clustering strength is mainly caused by a dependence on M_{BH}

more results of the project will be presented in T. Miyaji's talk