CLUSTERING OF X-RAY SELECTED AGN

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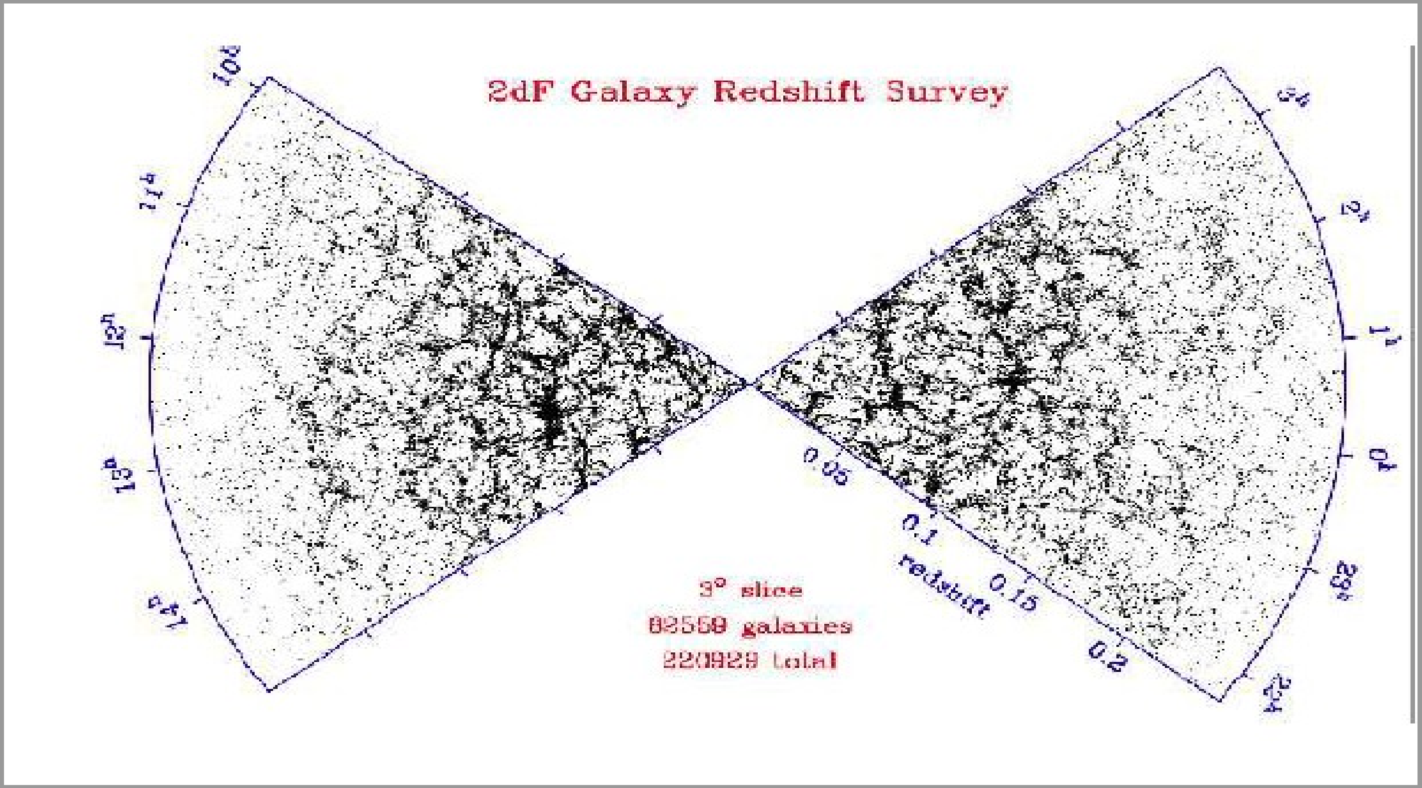
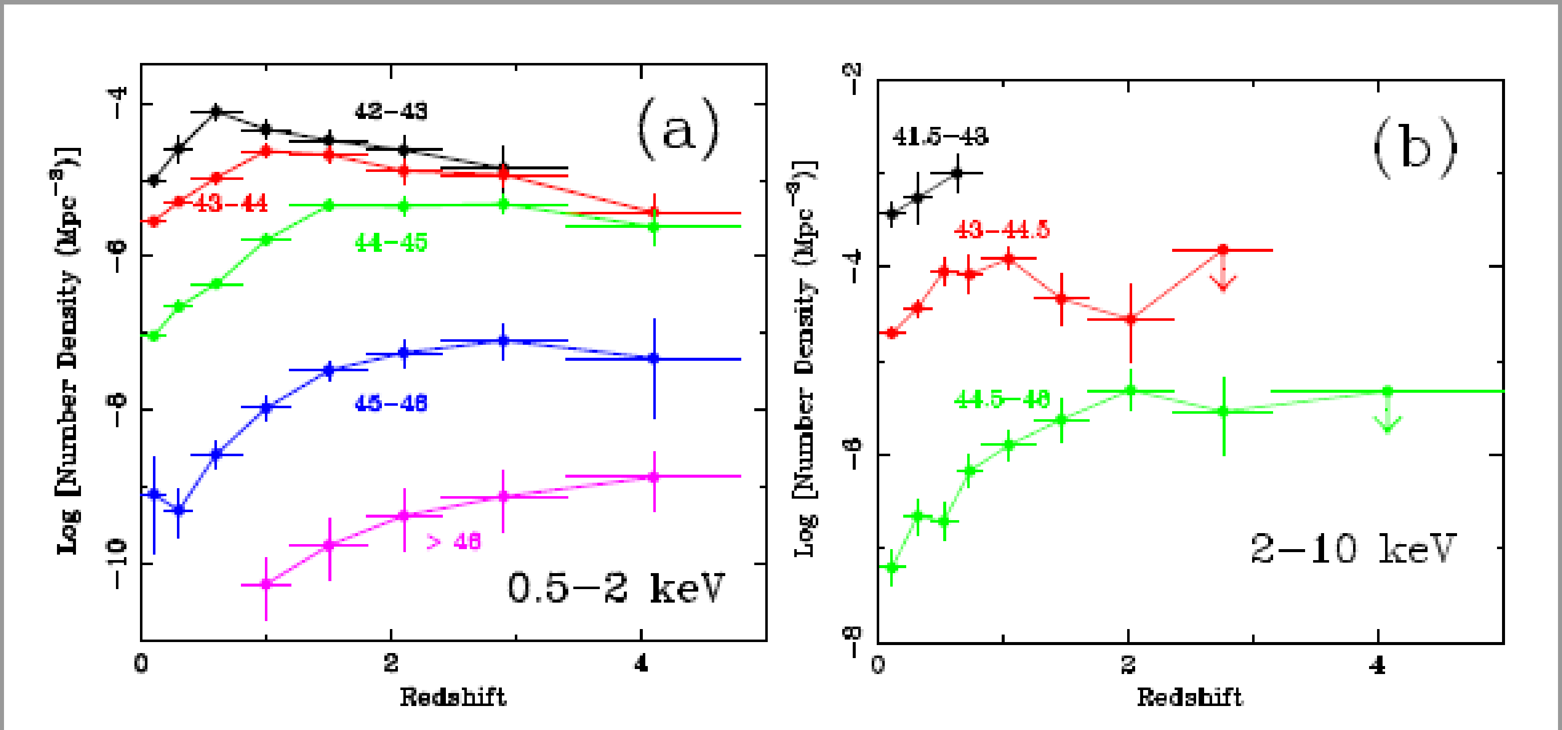
- Galaxies are not randomly distributed in space
- They reside in groups and clusters which lie at the intersections of long filaments
- Vast regions of empty space known as voids
- Large scale structure depends both on cosmological parameters and on formation and evolution of galaxies



The spatial distribution of galaxies as a function of redshift and right ascension (Colless et al 2001)

- To determine the cosmic evolution of black hole growth we must observe how the space density of accreting BH evolves with cosmic time



The comoving space density of X-ray AGN as a function of redshift in the (a) soft and (b) hard band. Lines show the evolution of AGN in different bins of luminosity. Most luminous AGN peaks earlier in cosmic time than for less luminous objects (downsizing) (Brandt & Hasinger 2005)

- **WHY CLUSTERING ?**

Large scale clustering measurements are an independent method to identify and constrain the physical processes that turn an inactive galaxy into an AGN and are responsible for AGN/galaxy evolution.

- **WHY AGN ?**

AGNs are more luminous than galaxies. They allow the study of the matter distribution in the Universe out to higher redshifts. Furthermore their clustering properties can provide important contstraints both on:

structure formation theories, on the relation between AGN activity and DM halo hosts and on Cosmological Parameters.

- **WHY X – RAY AGN ?**

X – ray surveys have allowed for detailed examination of the host galaxies and environments of X -ray AGN providing insight on the role of AGN, since a large fraction of hard X -ray AGN do not show strong optical activity (Barger 2005, Tozzi 2006)

Since all known AGNs are X -ray emitters probably hard X -ray AGNs form a superset of the optical selected AGN population (Mushotzky

- We combine 5 Chandra Surveys, CDFN, CDFS, AEGIS, ECDFS,COSMOS in the 0.5-8keV band in total 1466 X-Ray AGN with spec-z ($0<z<3$)

CDFS: 448 arcmin^2, 2Ms, Luo et al 2008,2009 (N.of.S with spec-z 219)

CDFN: 436 arcmin^2, 2Ms, Alexander 2003(N.of .S with spec-z 243) Trouille et al 2008

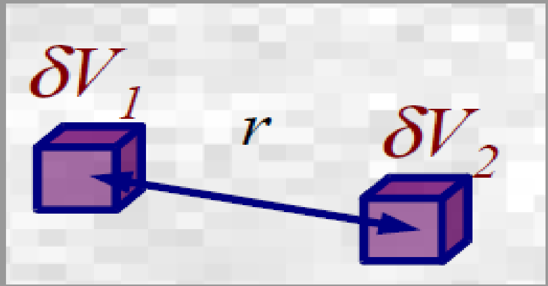
AEGIS: 0.67 deg^2 , 200ks, Laied 2009 (N.of. S with spec-z 392) Davis 2001, 2003, Coil 2009

COSMOS:0.5 deg^2, 160/80 ks (N.of. S with spec-z 417) Elvis 2009, Brusa 2010

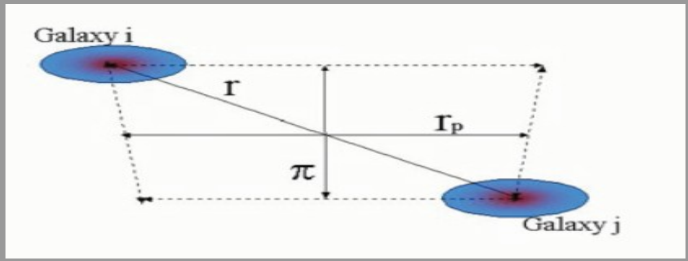
ECDFS: 0.3 deg^2, 250ks (N.of. S with spec-z 288) Lehmer 2005, Viriani 2006, Silverman 2010

- # TWO POINT CORRELATION FUNCTION

> ξ(r): represents the excess probability of finding a pair of galaxies compared with a random distribution.



3D : $dP=n^2[1+\xi(r)]dV_1 dV_2$



- ξ(r)=0 if objects are randomly distributed
- Power law behaviour : $\xi(r)=(r/ro)^{-\gamma}$
- Correlation length ro the scale at which the 2PC

$$s=(r_p^2+\pi^2)^{1/2}$$

$$\xi(s)=\xi(r_p,\pi)$$

is equal to unity: ξ(r)=1, γ slope

- As one measures line of sight distances

for 3D C.F from redshifts, measurements

$$w_p(r_p)=2\int_0^\infty \xi(\sqrt{r_p^2+\pi^2})d\pi=2\int_{r_p}^\infty \frac{r\xi(r)dr}{\sqrt{r^2-r_p^2}}$$

affected by redshift space distortions. To remove this effect deconvolve the redshift based distance s in two components ,one parallel π and one perpendicular rp to the line of sight.

$$w_p(r_p)=A_\gamma r_p\left(\frac{r_0}{r_p}\right)^\gamma$$

If ξ(r) pow

$$A\gamma=\Gamma\left(\frac{1}{2}\right)\Gamma\left(\frac{\gamma-1}{2}\right)/\Gamma\left(\frac{\gamma}{2}\right)$$

eval

with

- However equation strictly holds for πmax=∞

$$w_p(r_p) = 2\int_0^{\pi_{max}} \xi(r_p, \pi)\mathrm{d}\pi$$

- Practically we always impose a cutoff πmax. This introduces an underestimation for C.F which means that there is a correction function w… n

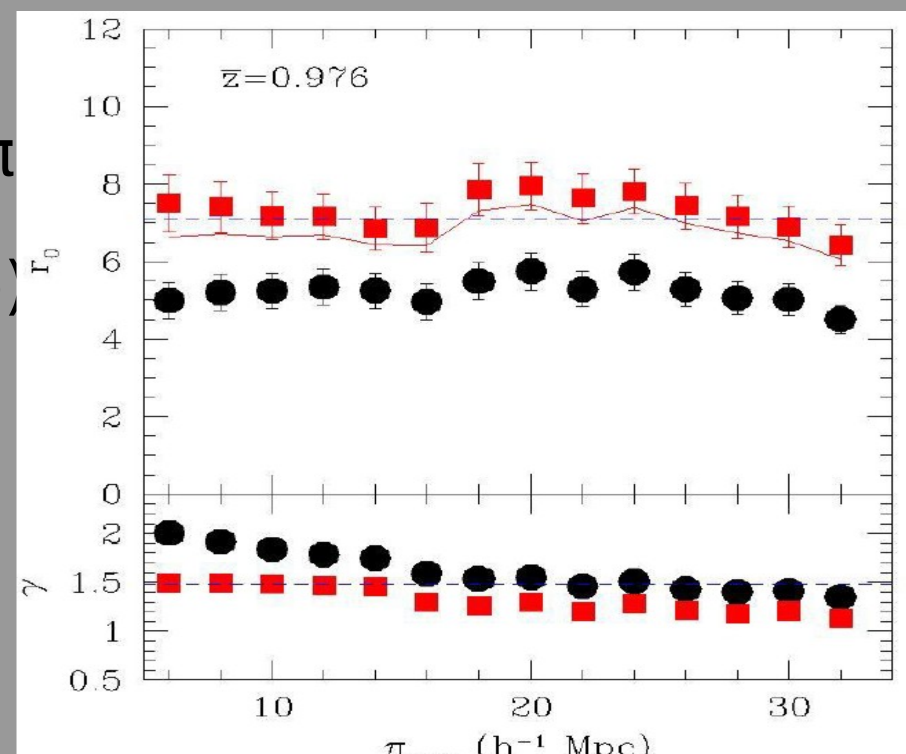
$$C_\gamma(r_p) = \frac{\int_0^{\pi_{\max}} (r^2 - \pi^2)^{-\gamma/2} d\pi}{\int_0^{\infty} (r^2 - \pi^2)^{-\gamma/2} d\pi}$$

$$\xi(r_p) = \frac{1}{A_\gamma C_\gamma(r_p)} \frac{w_p(r_p)}{r_p}$$

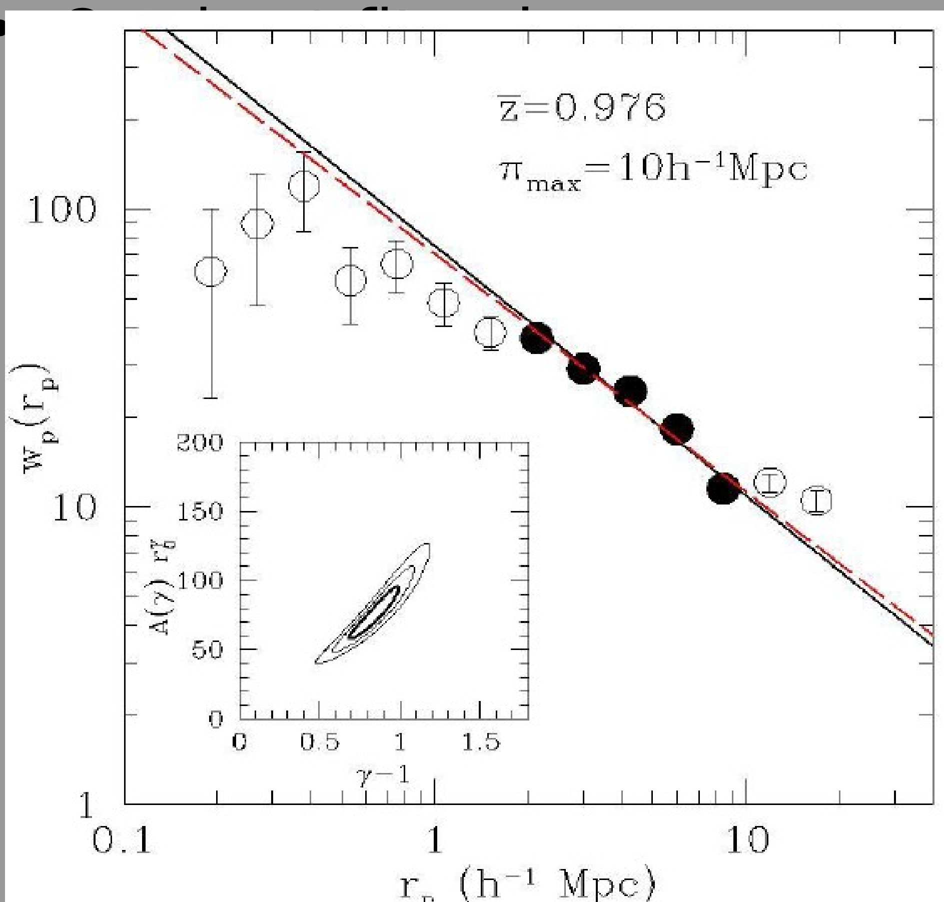
- r_0 and slope γ as a function of π

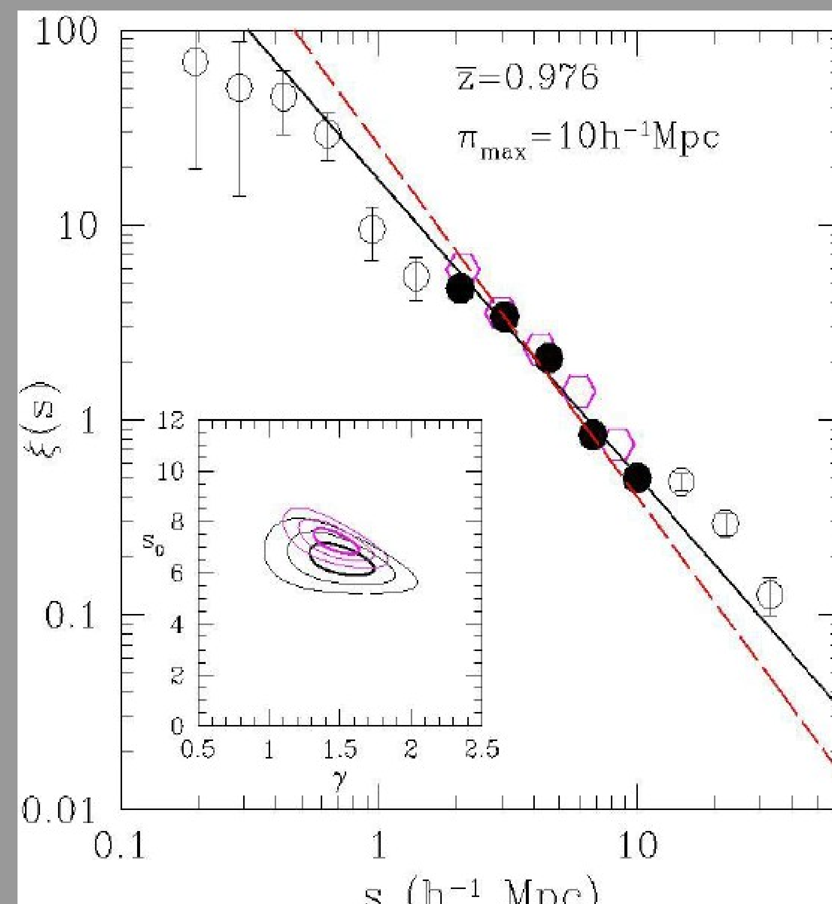
Black circles corresponds to w(rp)

Red squares to ξ(rp)

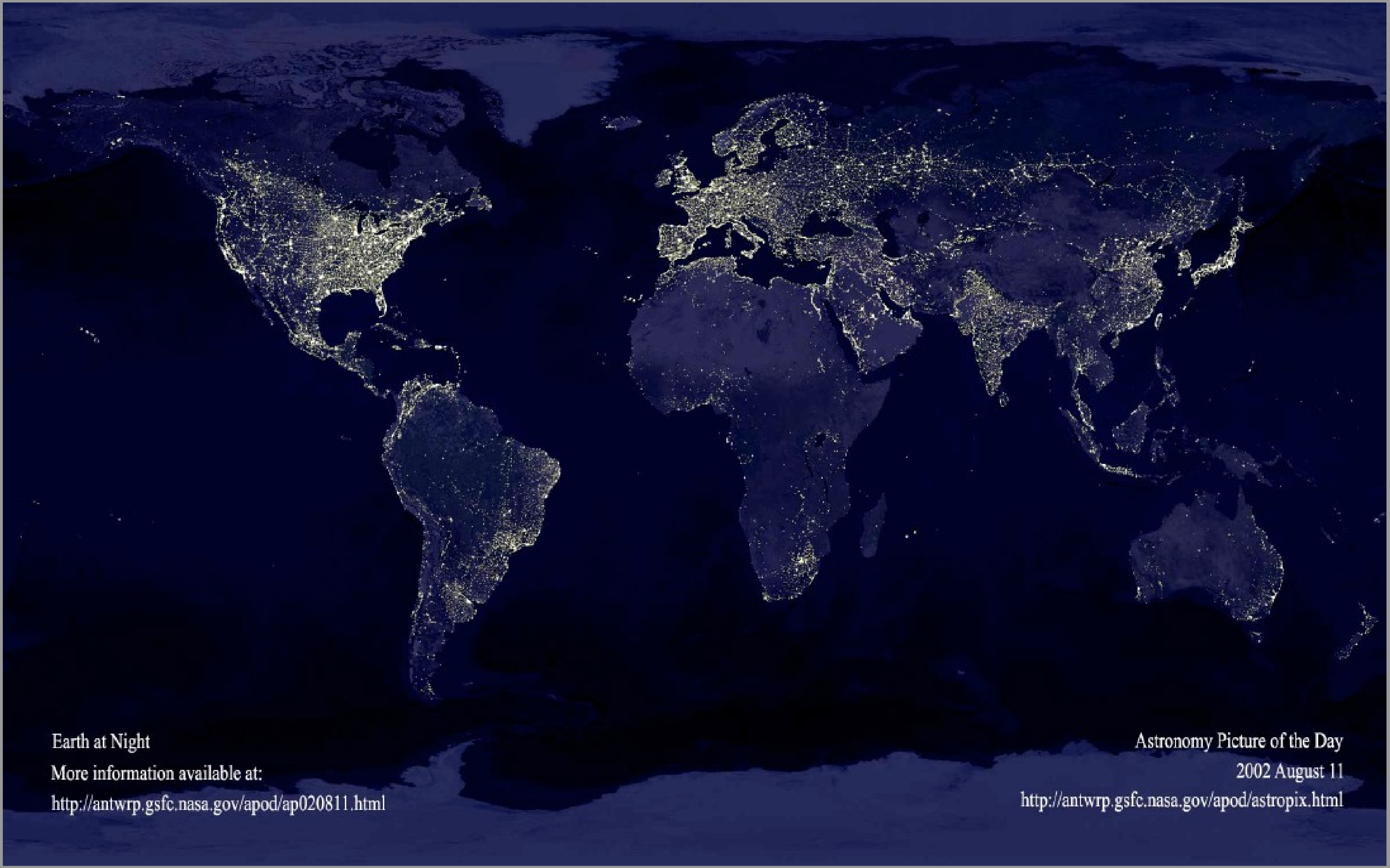


- C.F of the joint X-ray sample of the 5 Chandra Fields for 1466 sources with spec-z.
- Projected w(rp) left figure and z-space ξ(s) right figure
- Filled points indicate the range over which a power law fit was applied
- In order to avoid n $\gamma \simeq 1.5 \quad r_0 \simeq 7.2\ h^{-1}\mathrm{Mpc} \quad \bar{z} = 0.976$ separation
-





Light does not trace the mass



- X-RAY BIAS EVOLUTION AND DARK MATTER HALO MASS
- The relation of how an object class traces the underlying dark matter density is quantified using the linear bias parameter b

$$b = \frac{\delta_{\rm AGN}}{\delta_{\rm DM}}$$

- b:is defined as the ratio of the fluctuations of AGN to th
- In this work, the ratio of variances of the AGN and underlying

mass density fields, smoothed out at some linear s

$$b = \frac{\sigma_{8,\rm AGN}}{\sigma_{8,\rm DM}}$$

where

$$\sigma_{8,\rm AGN} = J_2(\gamma)^{\frac{1}{2}} \left(\frac{r_0}{8}\right)^{\frac{\gamma}{2}}$$

$$J_2(\gamma) = 72/[(3-\gamma)(4-\gamma)(6-\gamma)2^{\gamma}]$$

$$\sigma_{8,\rm DM}(z) = \sigma_8 \frac{D(z)}{D(0)}$$

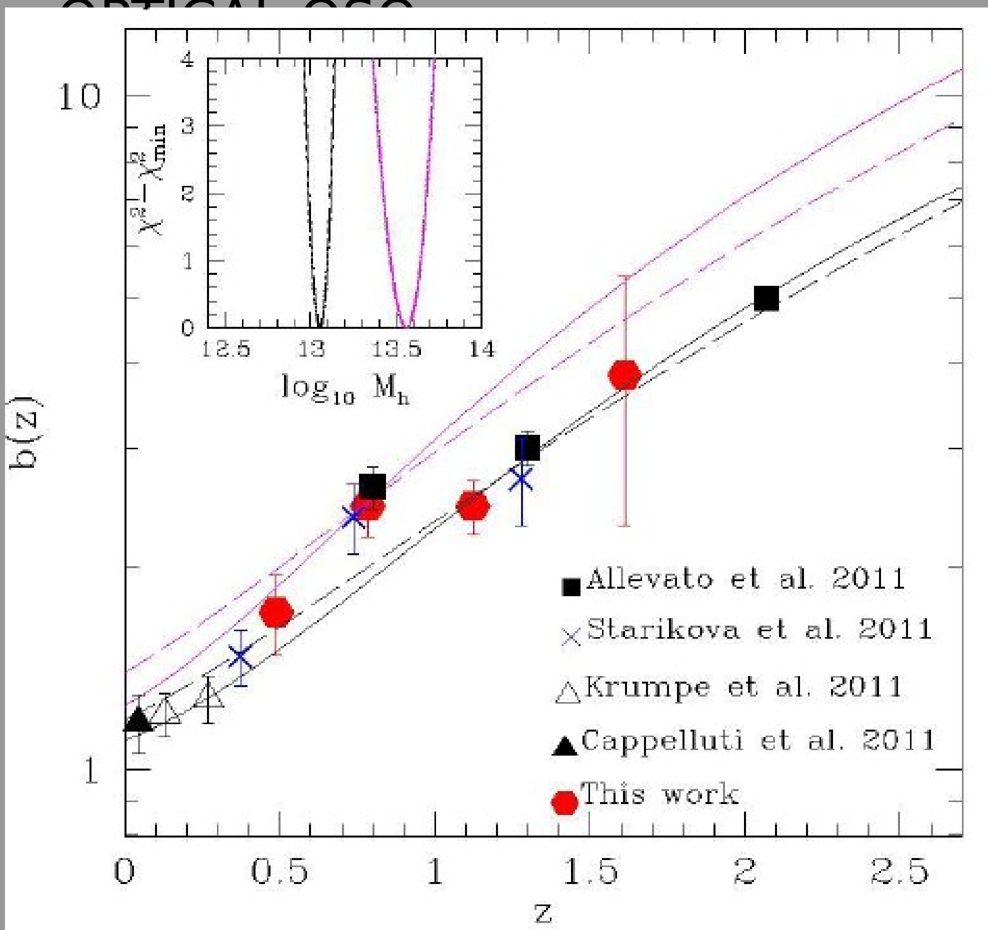
Combining all the above equations we obtain the cosmological of biasing as a function of the power law clustering parameters!

Galaxies form in special high density regions
(dark -matter halos)

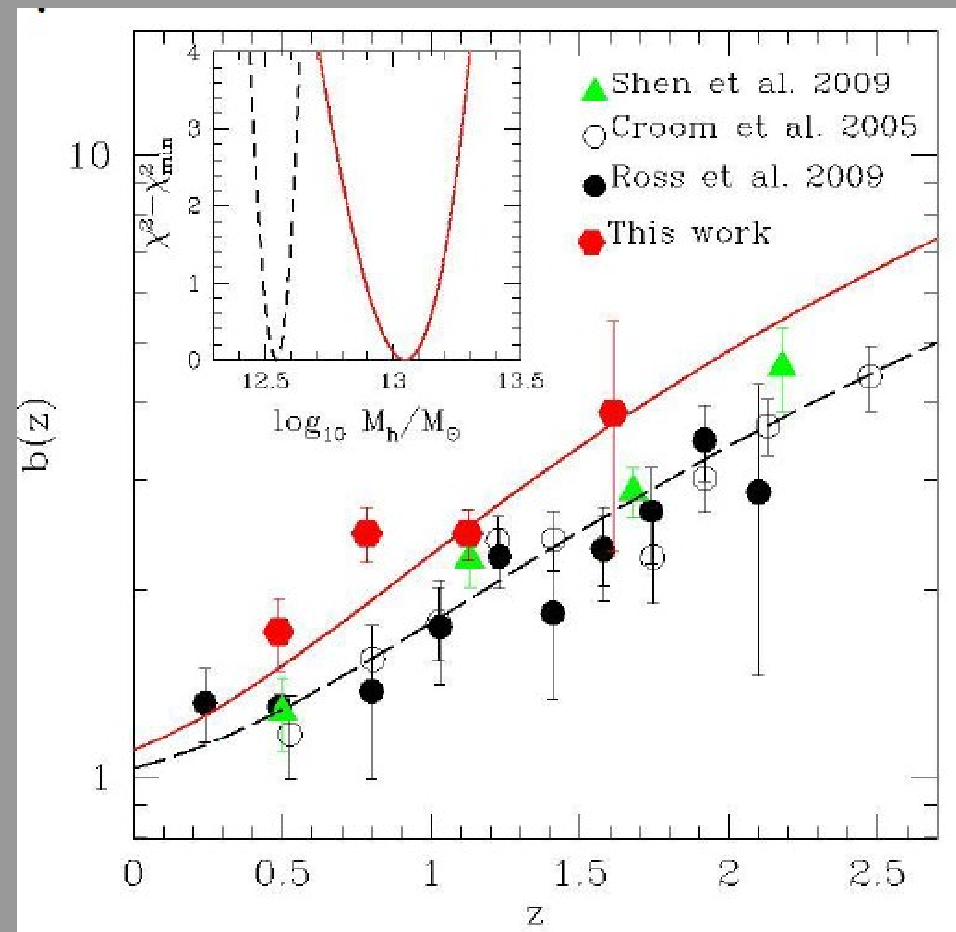
- In order to assign a characteristic DM halo mass to the estimated bias factors we use two bias evolution models. Tinker (2010) Basilakos (2008)

- We split the sample in four bins. If we exclude the deviant point we can assign a characteristic DM halo mass
- It is evident the increase of bias factor with increasing redshift
- X-ray AGN larger bias values and the correspnding DM halo mass than QSO

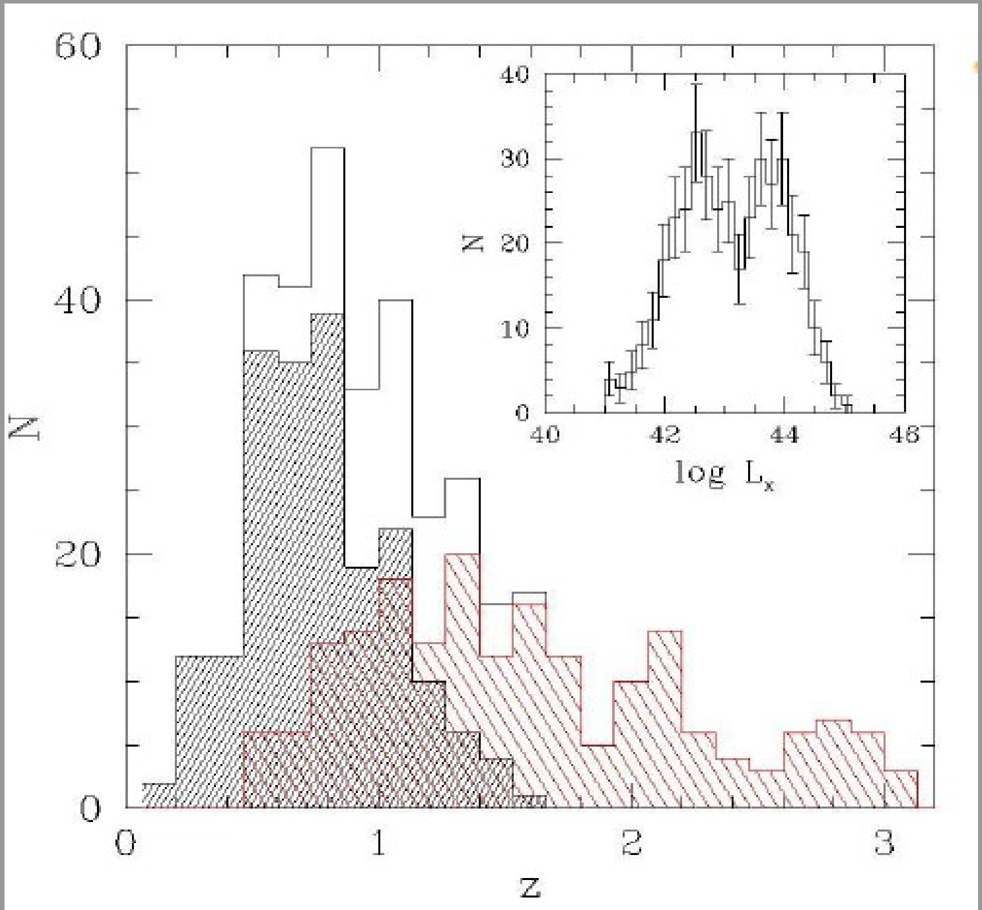
COMPARISON WITH X-RAY SURVEYS

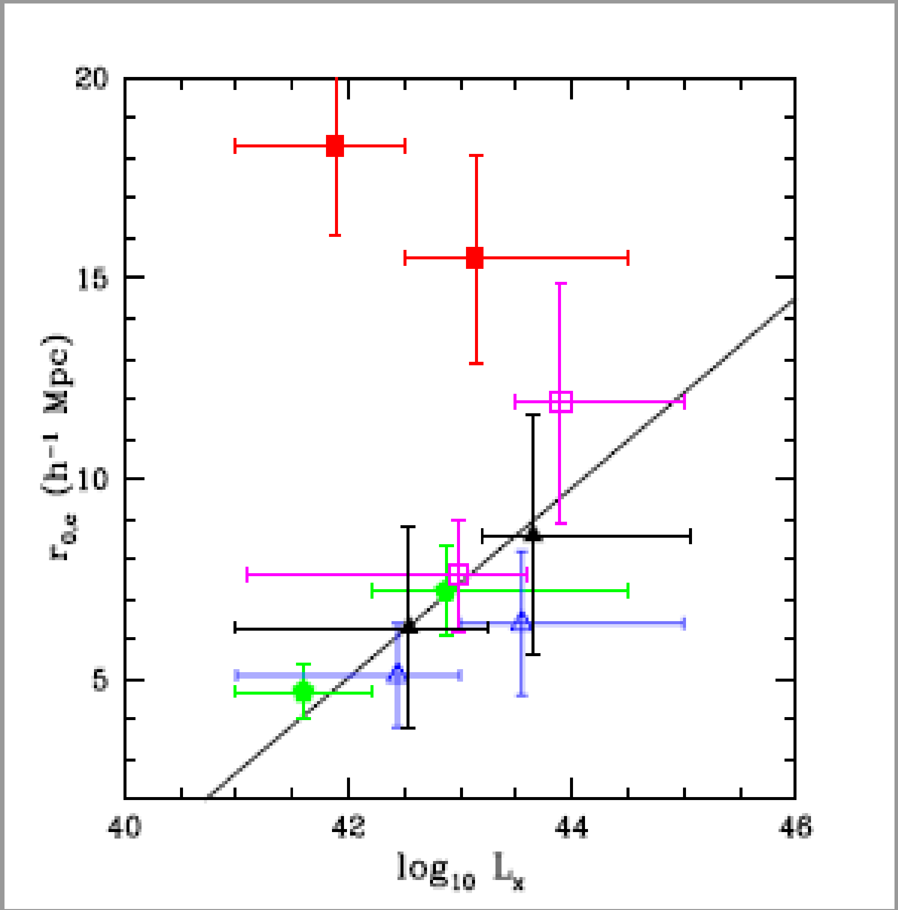


COMPARISON WITH OPTICAL QSO

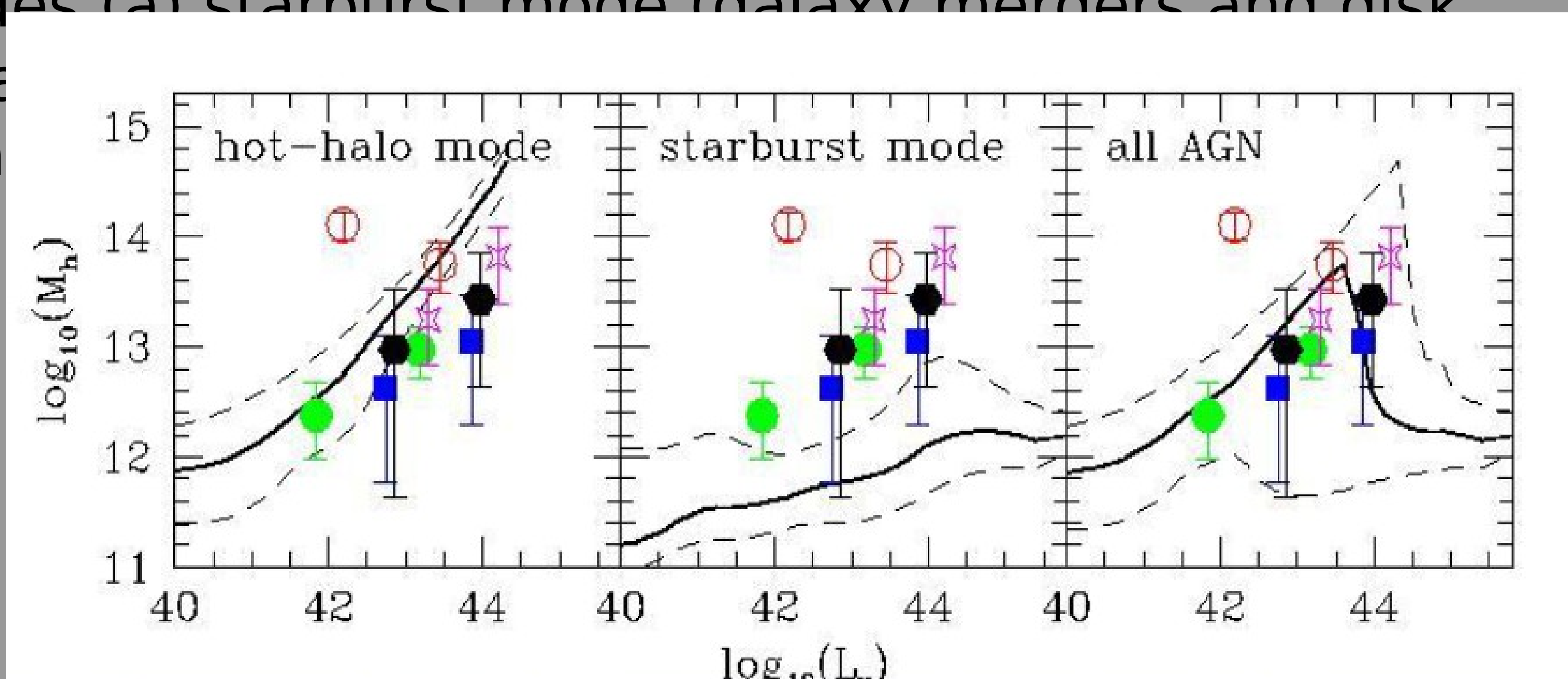


- We examine the possibility of an X-Ray luminosity dependent AGN clustering as suggested first from Plionis et al (2008) and confirmed at low redshifts from Krumpe (2010) and Cappellutti (2010)
- We apply the analysis in each field separate due to different luminosity distributions. To disentagle the Lx and z dependence of clustering we construct a Low-Lx and High Lx subsample for each survey.
- We confirm luminosity dependent clustering





- Semi-analytic models with major mergers as the AGN triggering mechanism predict smaller Mh, consistent with those of optical QSO (Marulli 2009, Bonoli 2009). Furthermore they predict very weak luminosity dependence (Hopkins 2005;Hopkins & Hernquist 2006)
- Mountrichas & Georgakakis (2011) suggest a fueling mechanism similar to Ciotti & Ostriker 2001, based on stellar winds.
- However the recent Fanidakis et al 2012 model with two modes (a) starburst mode (galaxy mergers and disk insta ... ost gala



ANGULAR CORRELATION FUNCTION (2D)

- 3D CF required extensive spectroscopy or high quality photometric-z
- EROSITA will deliver 3 Millions X-ray AGN
- A more simplest way is to measure the ACF and via Limber's to extract the equivalent clustering length

$$\theta_0^{\gamma-1} = H_\gamma \left(\frac{r_0^\gamma H_0}{c}\right) \int_0^\infty \left(\frac{1}{N}\frac{dN}{dz}\right)^2 \frac{E(z)(1+z)^{-3-\epsilon+\gamma}}{D_c^{\gamma-1}(z)} dz.$$

- Where ε parametrizes the type of clustering evolution
- For ε=-3 clustering constant in physical coordinates
- For ε=γ-3 clustering constant in comoving coordinates
- With this method we can use all the available sources not only those having spectroscopic redshifts
- In the x-ray band previous studies provided conflicting results with large ro.
- For the AEGIS field we compare the direct ro from 3D with the angular correlation approach
- As the redhisft distributions are the same we calibrate the ε parameter in order to have equal ro. For the AEGIS field ε=-2 (Koutoulidis et al. In prep.)

- CONCLUSIONS
- We have determined accurately the X-ray AGN spatial correlation function using 1466 X-ray AGN with spec -redshift to provide for the usual power law model a clusterig length of ro=7.2±0.6 , γ=1.48±0.12
- Using different bias evolution models we consistently find an average host DM halo mass of $Mh=10^{13}Mo$ significantly larger than that of optical QSO $Mh=10^{12.5}Mo$
- We find a luminosity dependence clustering of X-ray AGN also at z=1 in agreement with other recent studies at lower redshifts
- Our results (Halo masses & Luminosity Dependence) seem to be explained by a model where what dominates at lower luminosities of X-ray AGN is the hot halo mode