CLUSTERING OF X-RAY SELECTED AGN
and possible dependence on obscuration

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- **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.

The clustering of AGN has been studied with excellent number statistics mainly in the optical particularly in large area surveys such as 2QZ (Croom 2005, Porciani & Norberg 2006) and the SDSS (Li 2006, Shen 2009, Ross 2009)

However optical QSO may represent only the tip of the iceberg

- **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 2004)

- For that reason in order to study the clustering in the total AGN population we need X-ray samples

CLUSTERING OF X-RAY SELECTED AGN

At moderate redshifts employing spectroscopic redshifts (Mullis 2004, Gilli 2005, Yang 2006, Gilli 2009, Hickox 2009, Coil 2009, Starikova 2011, Allevato 2012, Koutoulidis 2013)

At low redshifts (Cappelluti 2010)

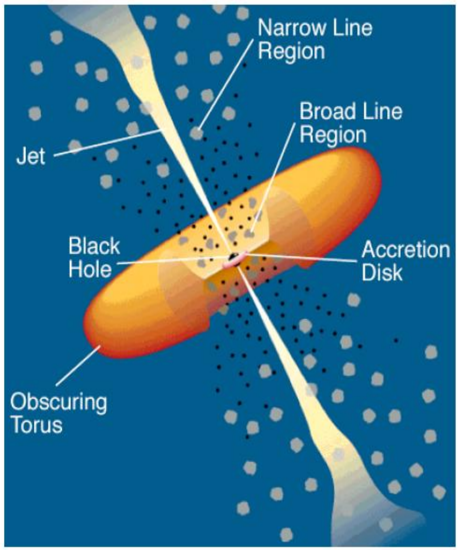
Better statistics can be achieved using cross correlation analysis (Krumpe 2010, Mountrichas 2012) (Mountrichas 2013)

Value of ro ~ 5 – 7.5 h^{-1}Mpc

- **Unified models** **Urry,Padovani** **Evolutionary models (Hopkins 2008)**

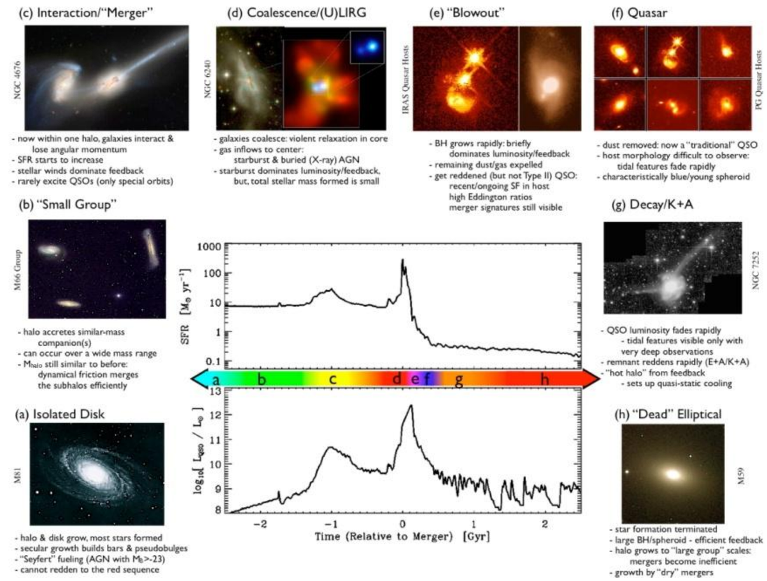
Classification based

(geometry)
Orientation of torus
AGN emission absorbed by torus



C. M. Urry and P. Padovani

(cosmic time)
obscuration represents an early
evolutionary stage of BH growth



Correlation Function

We expect both obs. Unobs AGN
Identical C.F if the orientation of
torus is the only determining factor
Of the AGN phenomenology

Predictions suggest same DM (and ro)
IF obs. are an early stage where BH are
acquiring their final mass then they
would inhabit more massive halos

	METHOD	Survey	Redshift	Obscuration
Coil 2009	Cross-correl	AEGIS	0.7<z<1.4	X
Gilli 2009	Auto-correl	XMM-COSMOS	z=1	X
Mountrichas 2012	Cross-correl	XMM-SDSS	z=0.1	X
Ebrero 2009	angular	XMM	0<z<4	X
Elyiv 2012	angular	XMM-LSS	z=1	√
Hickox 2011	Cross-correl	Bootes	0.7<z<1.8	√
Donoso 2014	Angular	WISE	z=1.1	√
DiPombeo 2014	Angular	WISE	z=1.1	√

- Coil :: No significant difference in the clustering of hard X-ray sources compared to soft X-ray sources
- Gilli:: X-ray obscured and X-ray unobscured AGN do not possess different clustering properties
- Mountrichas:: Did not find a dependence of clustering on obscuration
- Ebrero :: No differences in the clustering between sources with high HR and those with low
- Elyiv:: Sources with hard spectrum are more clustered than soft spectrum ones
- Hickox:: Obscured AGN are clustered at least as strongly as unobscured
- Donoso:: Found that obscured sources are hosted in higher DMH
- DiPombeo:: Remove low quality data found a weaker but significant difference in the bias

- We combine 5 Chandra Surveys, CDFN, CDFS, AEGIS, ECDFS,COSMOS in the 0.5-8keV band in total 730 X-Ray AGN with spec-z ($0.6<z<1.4$)

CDFS: 448 arcmin^2, 2Ms, Luo et al 2008,2009

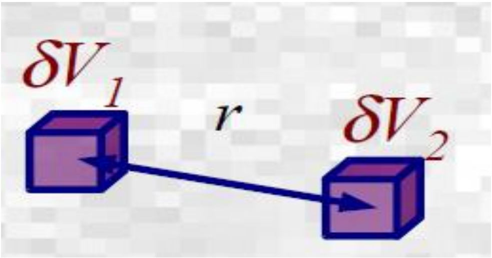
CDFN: 436 arcmin^2, 2Ms, Alexander 2003, spec-z:Trouille et al 2008

AEGIS: 0.67 deg^2 , 200ks, Laird 2009 spec-z: Davis 2001, 2003, Coil 2009

COSMOS:0.5 deg^2, 160/80 ks Elvis 2009, Brusa 2010

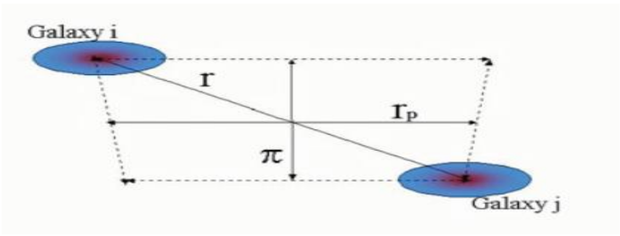
ECDFS: 0.3 deg^2, 250ks Lehmer 2005, Viriani 2006, Silverman 2010

- TWO POINT CORRELATION FUNCTION



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

3D : $dP=n^2[1+\xi(r)]dV_1dV_2$



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

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

is equal to unity: ξ(r)=1, γ slope

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

- As one measures line of sight distances

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

for 3D C.F from redshifts, measurements are 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.

If ξ(r) power law the integral can be evaluated

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

with

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

- However equation strictly holds for πmax=∞

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

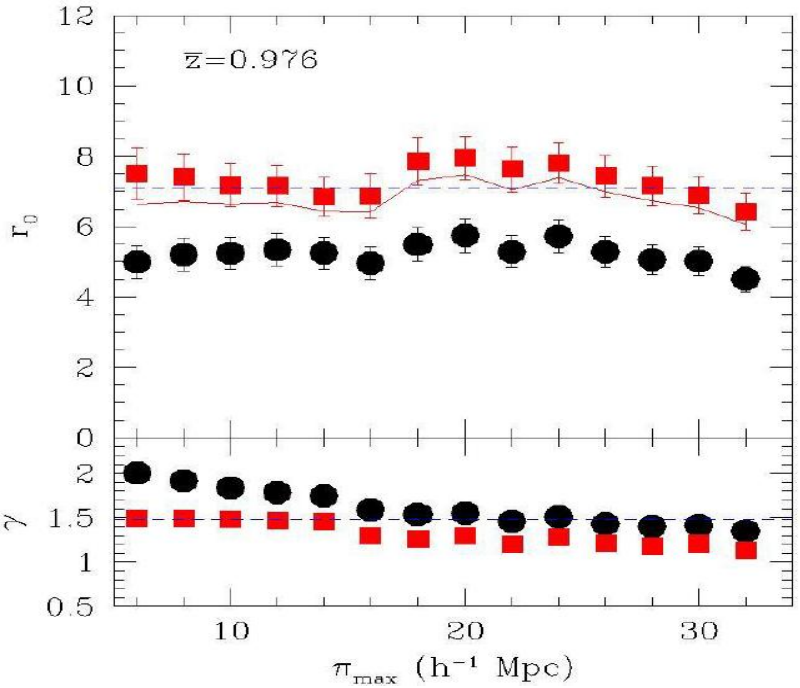
- Practically we always impose a cutoff πmax. This introduces an underestimation for C.F which means that there is a correction function which should be taken .

$$C_\gamma(r_p) = \frac{\int_0^{\pi_{\max}}(r^2-\pi^2)^{-\gamma/2}d\pi}{\int_0^{\infty}(r^2-\pi^2)^{-\gamma/2}d\pi} \qquad \xi(r_p) = \frac{1}{A_\gamma C_\gamma(r_p)}\frac{w_p(r_p)}{r_p}$$

- r_0 and slope γ as a function of πmax

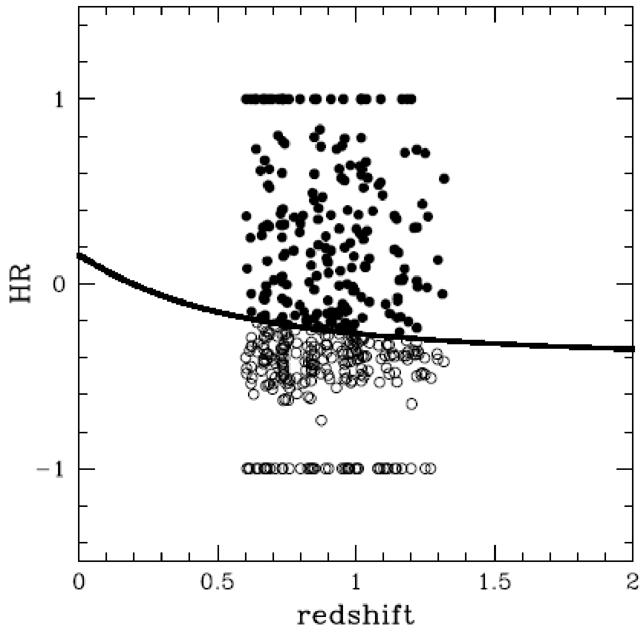
Black circles corresponds to w(rp)

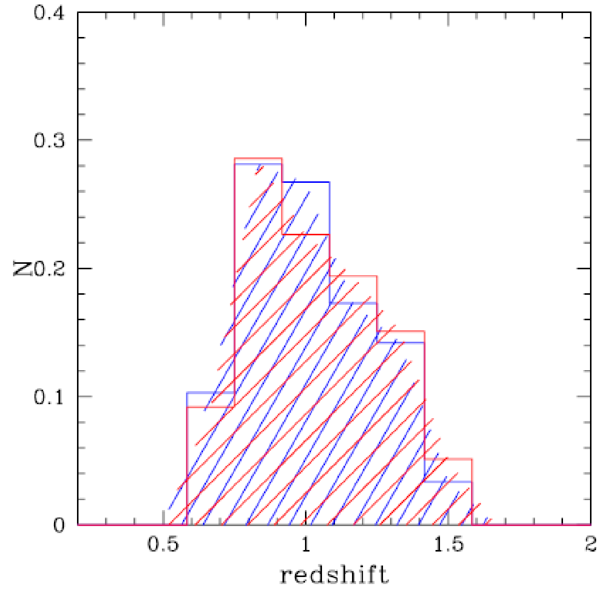
Red squares to ξ(rp)



- Classification of X-ray AGN

As obscured and unobscured X-ray color. Is defined as HR=H-S/H+S where H and S are the observed counts detected by Chandra. Due to the fact that the examined sample of AGN span at redshift 0.6<z<1.4 we derived the HR as a function of redshift. Nh=10^{22} cm^{-2} , Γ=1.8



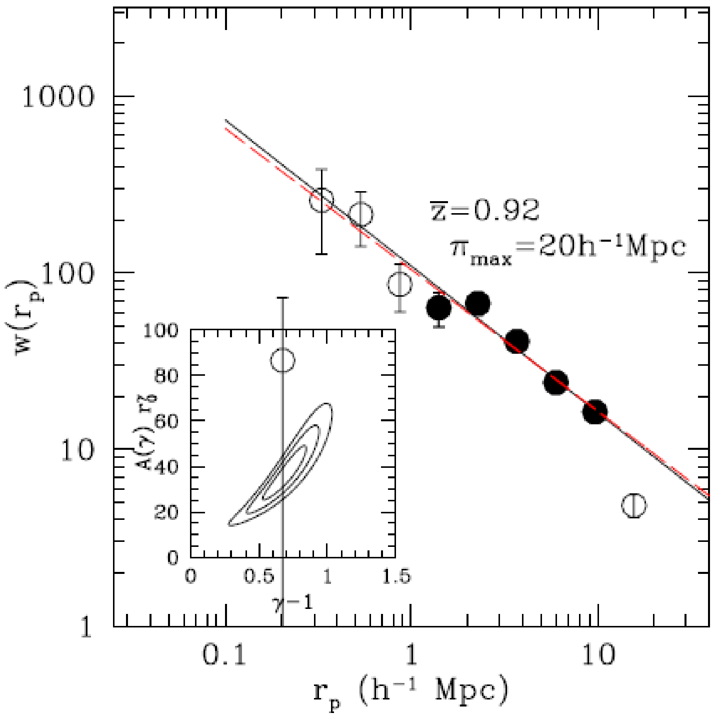


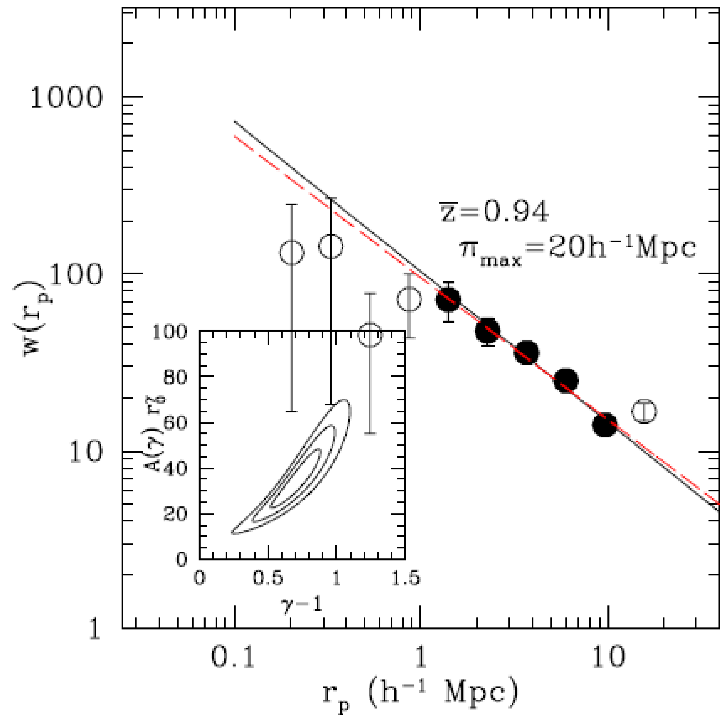
- 359 obscured X-ray AGN and 371 unobs. X-ray AGN

- RESULTS

Left :obscured X-ray AGN(359)

Right: unobscured X-ray AGN(371)





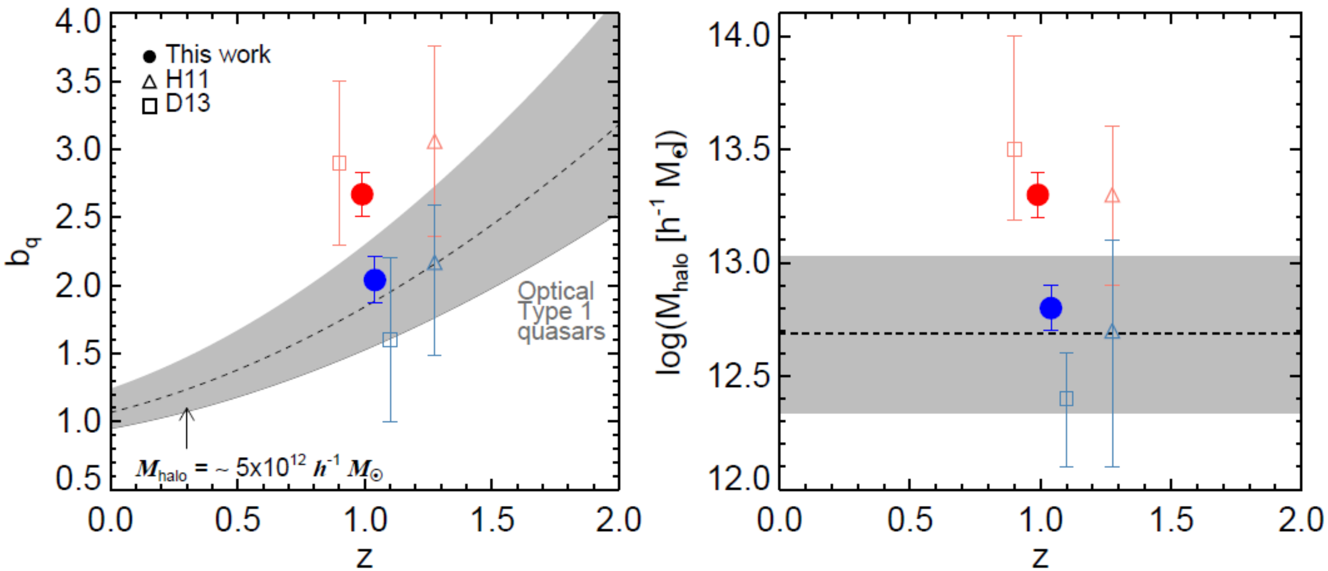
- RESULTS

Unobscured AGN	γ	r_0	r_0 ($\gamma = 1.8$)
$w_p(r_p)$	1.85±0.07	6.2±0.4	6.1 ±0.4
$\xi(r_p)$	1.66±0.20	7.4±0.6	7.1 ±0.5
Obscured AGN	γ	r_0	r_0 ($\gamma = 1.8$)
$w_p(r_p)$	1.83±0.06	6.5±0.4	6.4 ±0.4
$\xi(r_p)$	1.65±0.17	7.8±0.6	7.4 ±0.5

Do not contradict with unified models

- In agreement (Coil et al 2009, Gilli et al 2010) at moderate z, and also (Mountrichas et al 2012) local Universe

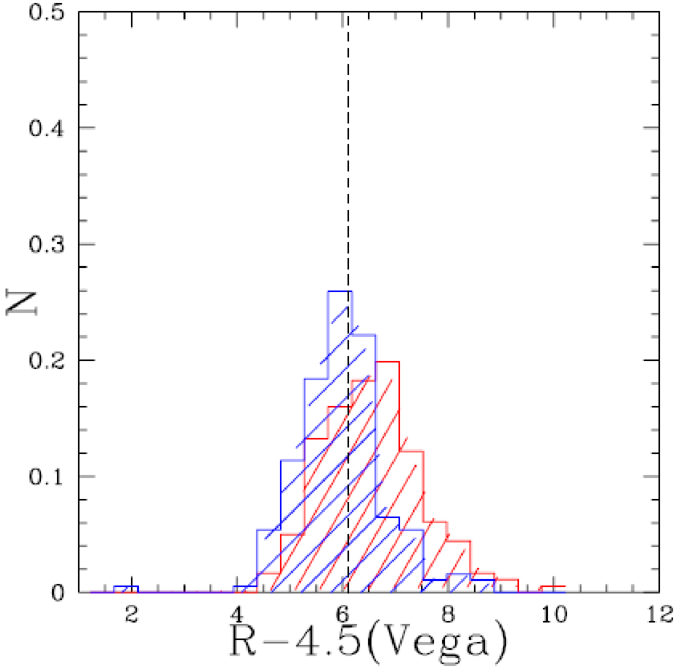
- Classification according to optical/IR color cut at R-[4.5]=6.1 (Vega)



DiPombeo 2014

Obscured AGN inhabit denser environments than unobscured AGN → contradict unified models

- To make the color separation according to optical/IR we match our X-ray catalogue with the correspondings IR/optical catalogues (i.e SIMPLE, Rafferty 08, Xue 10, Capak 10, Elvis 10, Ashby 08, Barmby 08) leaving 181 obscured X-ray AGN and 185 unobscured.



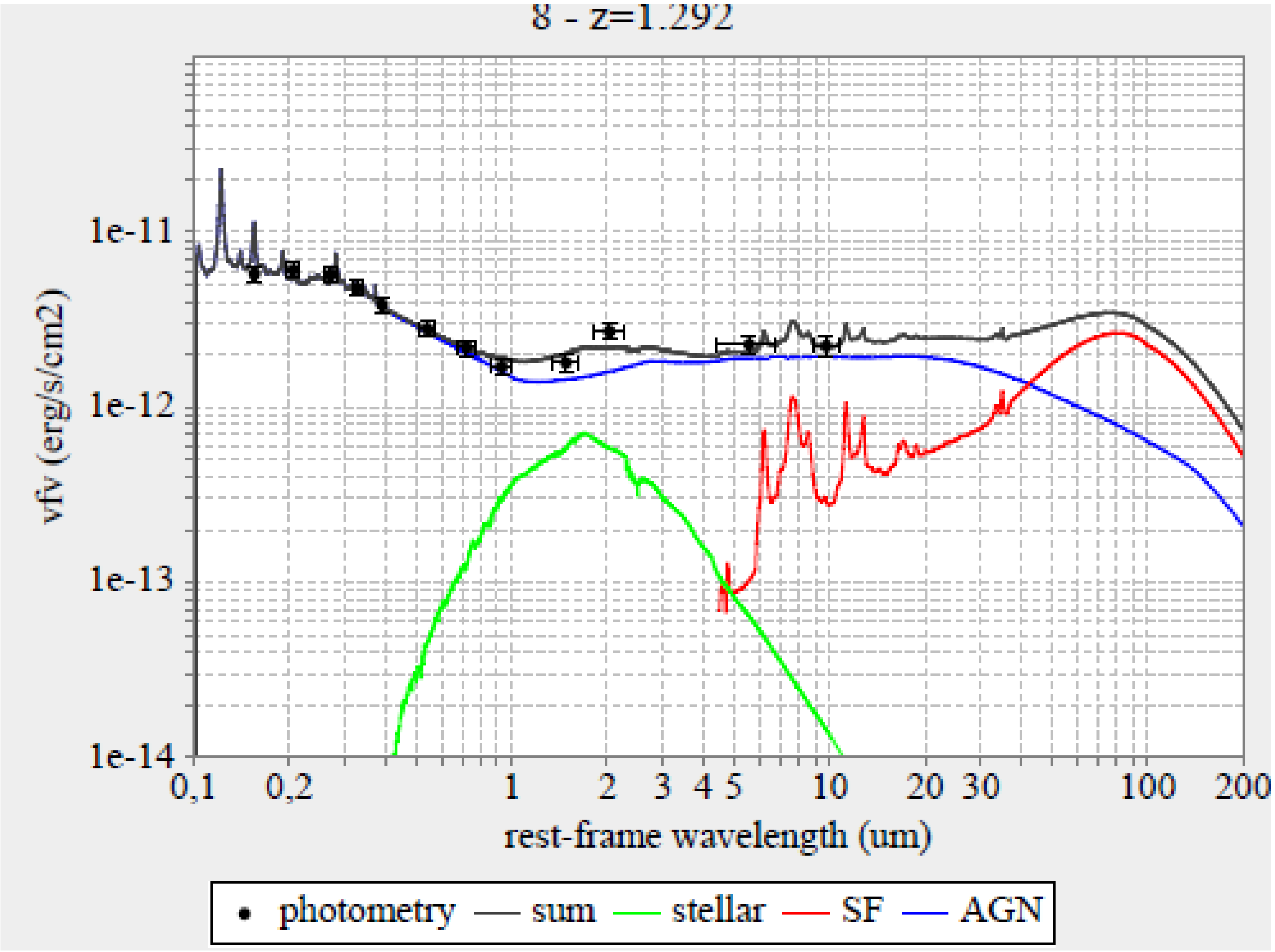
X-ray unobs (185) :: 125 R-4.5<6.1

60 R-4.5 >6.1

X-ray obs (181) :: 111 R-4.5 >6.1

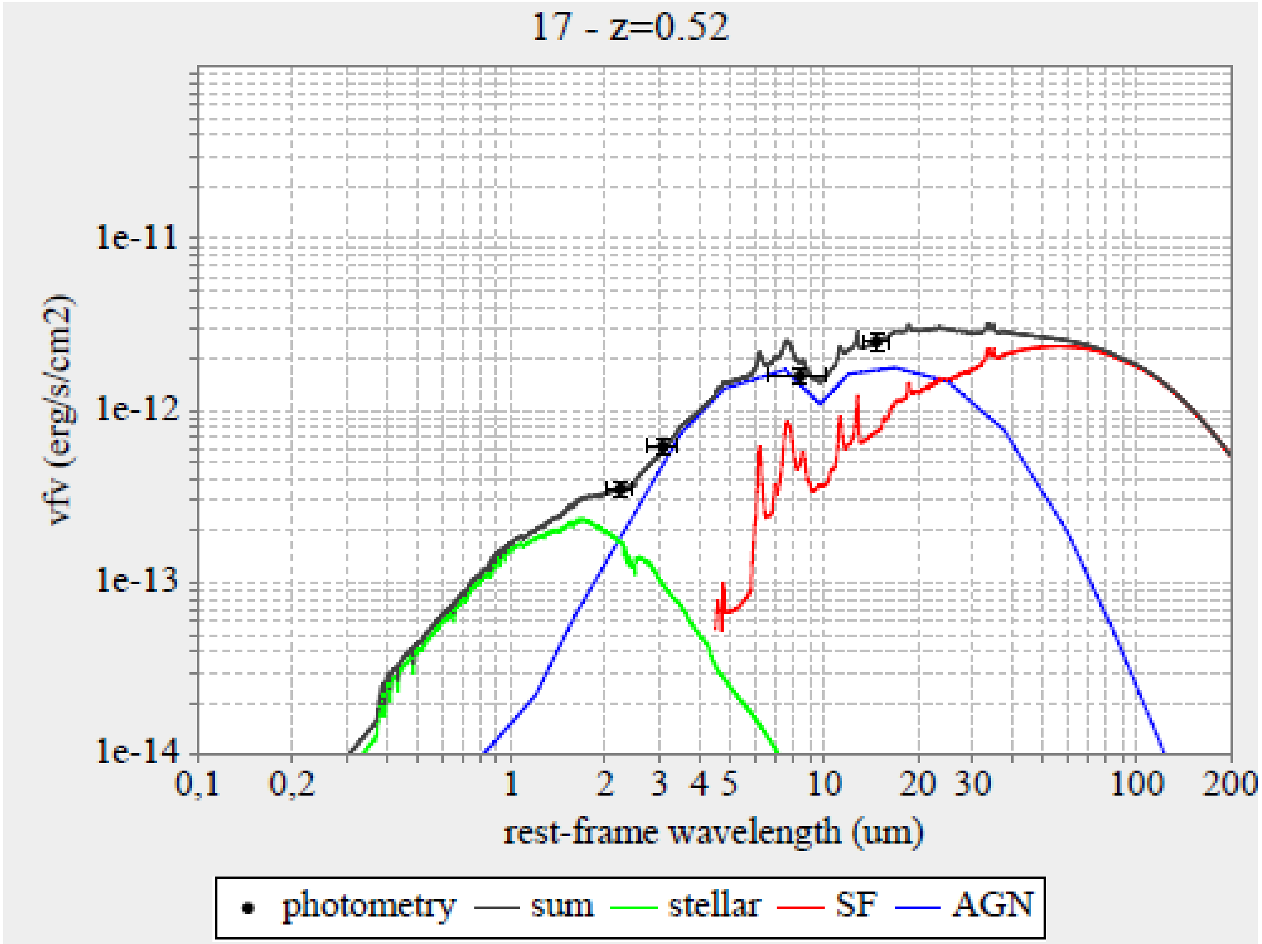
70 R-4.5 < 6.1

- Limitations of R-4.5 Typical SED for type 1 AGN



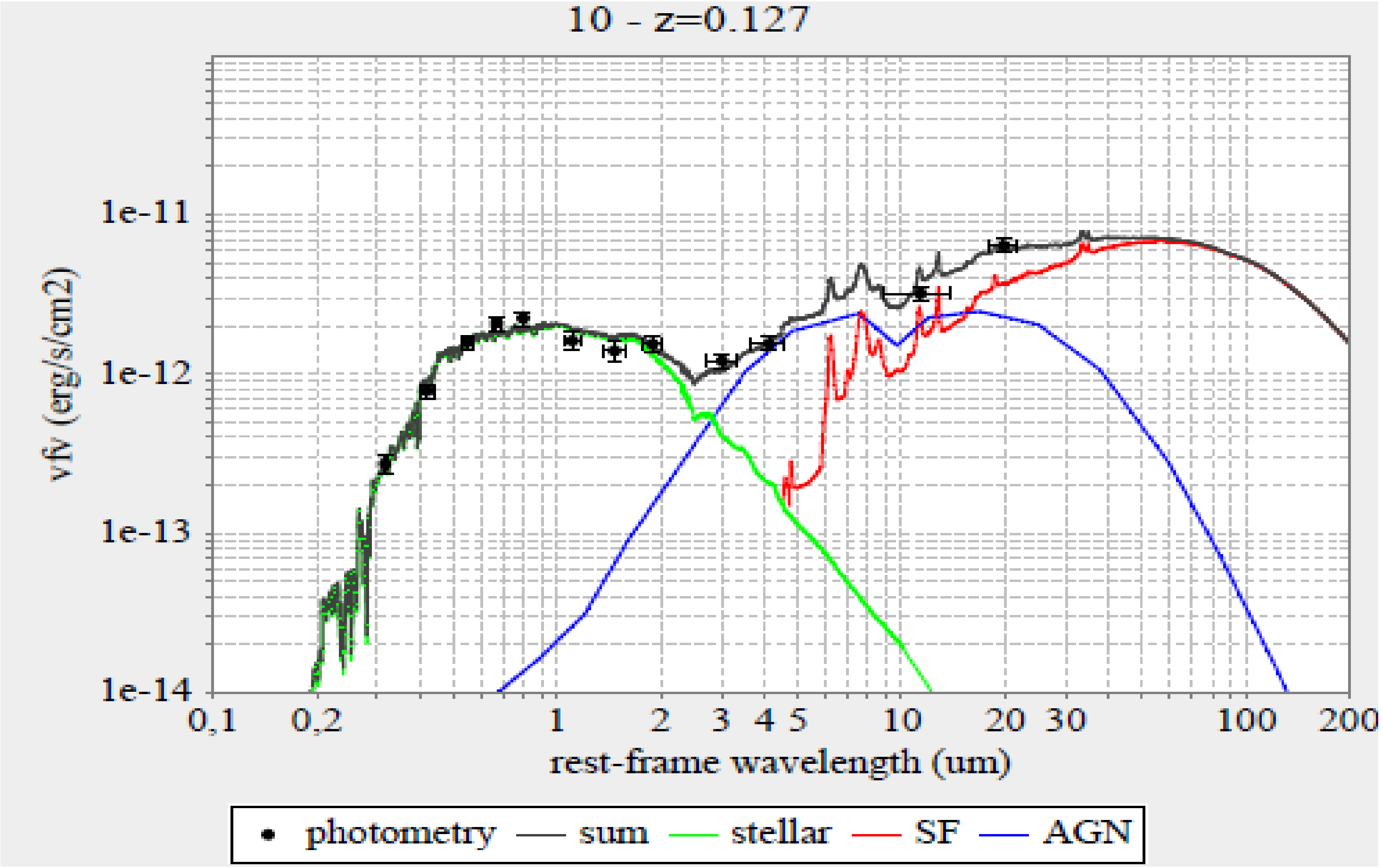
- Rovilos et al 2014

Limitations of R-4.5   Typical SED for type 2 AGN



Rovilos et al 2014

- Limitations of R-4.5 SED of type 2 AGN with excess of stellar



- Rovilos et al 2014

- CONCLUSIONS
- We have accurately determined the X-ray AGN spatial correlation function for 359 X-ray obscured AGN and 371 X-ray unobscured AGN using X-ray AGN with spec -redshift to provide for the usual power law model a clustering length of $r_o=7.2\pm0.6$, $\gamma=1.8$ for both populations.
- The results do not contradict the unified models
- Differences of HR color cut with optical/IR color cut for obscured and unobscured AGN
- Possible explanation through the contamination of the host galaxy of AGN

- Rovilos et al (in prep.)