Clues on the cosmic evolution of *radio-AGNs* from their clustering properties

(**Negrello**, Magliocchetti, De Zotti, 2006, MNRAS, 368, 935)

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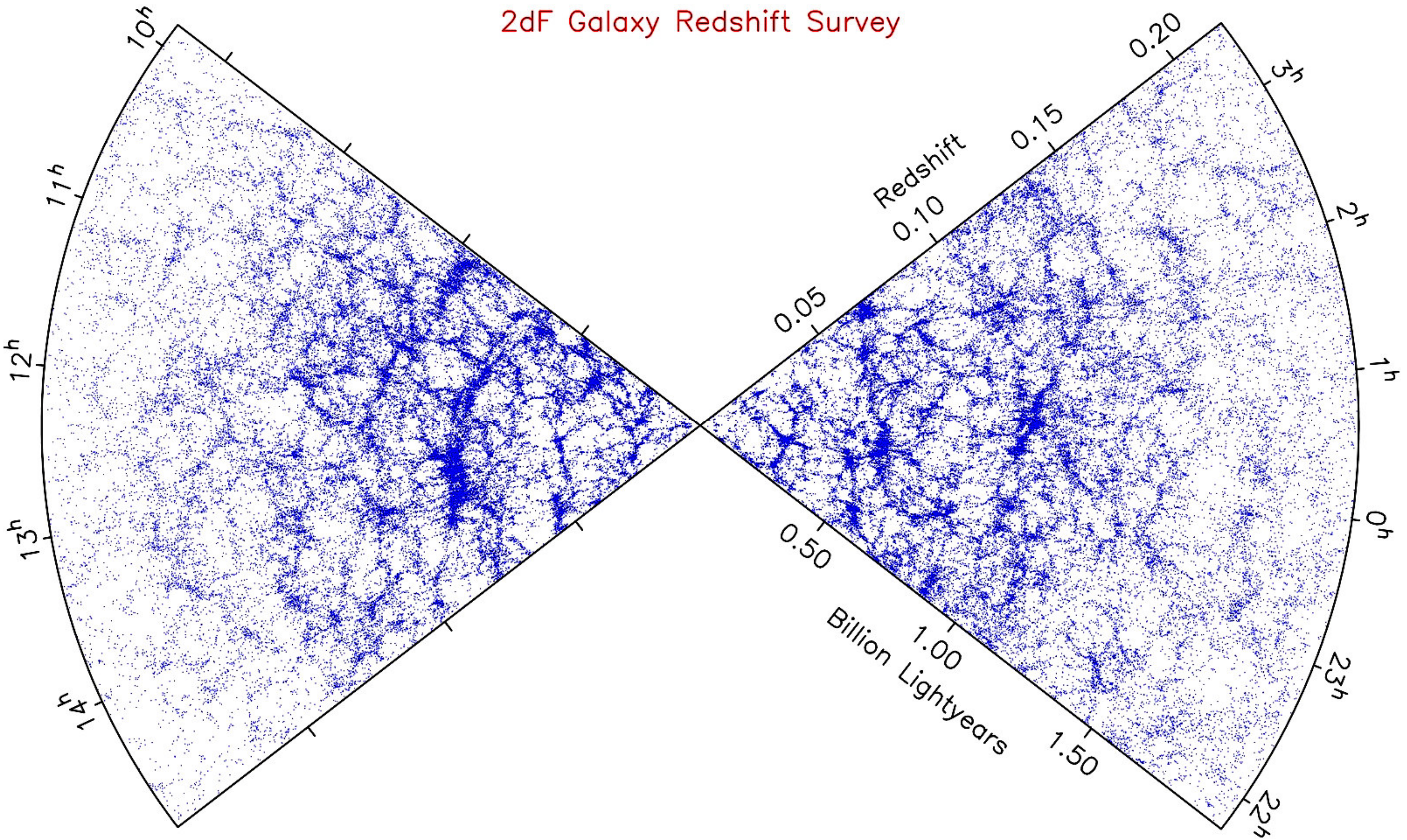
Clustering of extragalactic sources



Clustering of extragalactic sources

- 2-point *spatial* correlation function $\xi(r)$

$$\xi(r) = \frac{DD(r) - RR(r)}{RR(r)}$$

$DD(r)$ = data-data pairs

$RR(r)$ = random-random pairs

- 2-point *angular* correlation function $w(\theta)$

$$w(\theta) = \frac{DD(\theta) - RR(\theta)}{RR(\theta)}$$

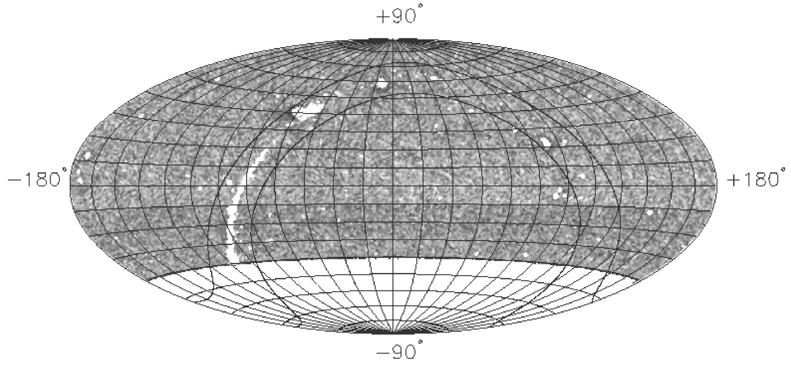
Limber's equation

$$w(\theta) = \frac{\int_{z_{\min}}^{z_{\max}} dz_1 \mathcal{N}(z_1) \int_{z_{\min}}^{z_{\max}} dz_2 \mathcal{N}(z_2) \xi[r(z_1, z_2, \theta)]}{\left[\int_{z_{\min}}^{z_{\max}} dz \mathcal{N}(z)\right]^2}$$

redshift distribution

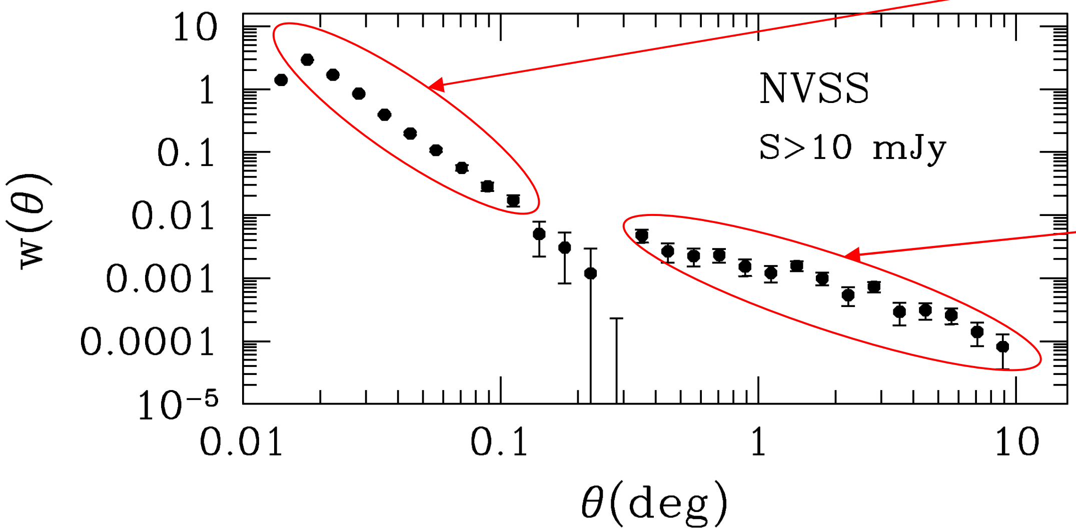
The NRAO VLA Sky Survey (NVSS)

- $\nu = 1.4$ GHz
- FWHM = 45”
- Area ~ 10.3 sr
- $N_{obj} \sim 10^6$ down to 2.5 mJy



$w(\theta)$ of radio sources with S ≥ 10mJy

(Blake & Wall 2002)



small scales: distribution of the resolved *components of single-giant radio sources*

large scales: correlation between *distinct radio sources*

1. Redshift distribution of *mJy radio sources*

2 types of extragalactic radio sources:

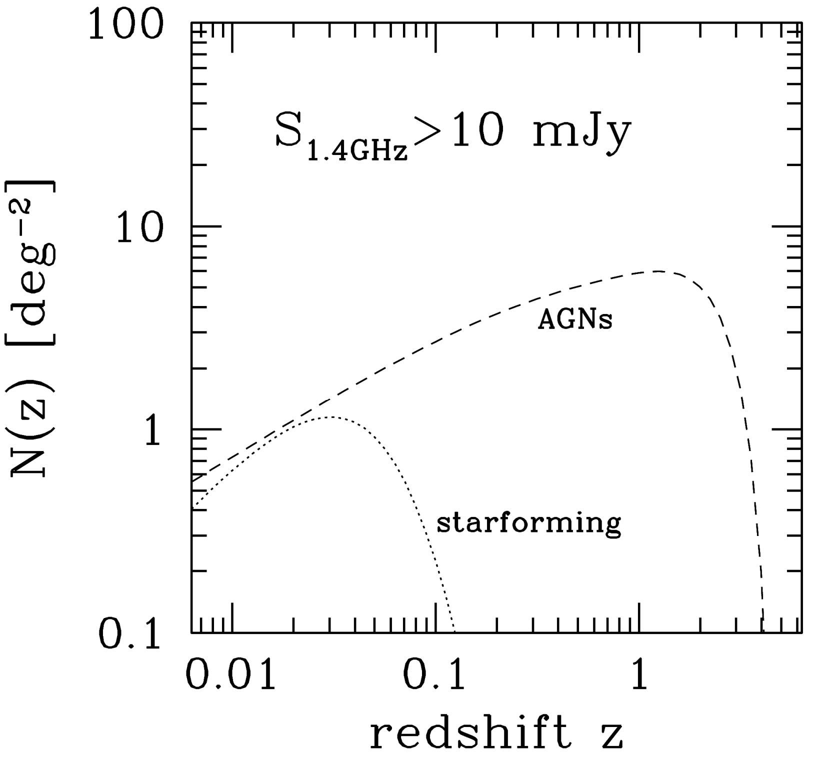
- **AGN-powered radio galaxies**
- **starforming (SF) galaxies**

- Pure Luminosity Evolution model of Dunlop & Peacock (1990) for **steep-spectrum FRI-FRII sources**

  (see Magliocchetti et al., 2002)

- model by Saunders et al. (1990) for **starforming (IRAS) galaxies**

  (see Magliocchetti et al., 2002)



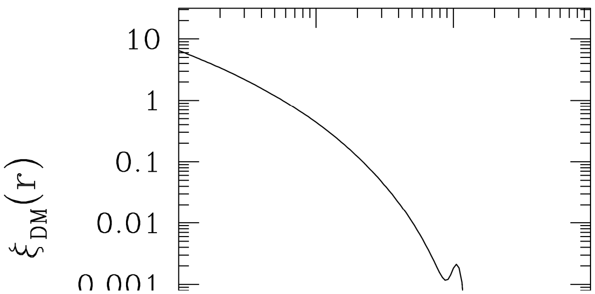
*2. Spatial correlation function of **galaxies***

Galaxies are ***biased* tracers** of the underlying dark matter distribution

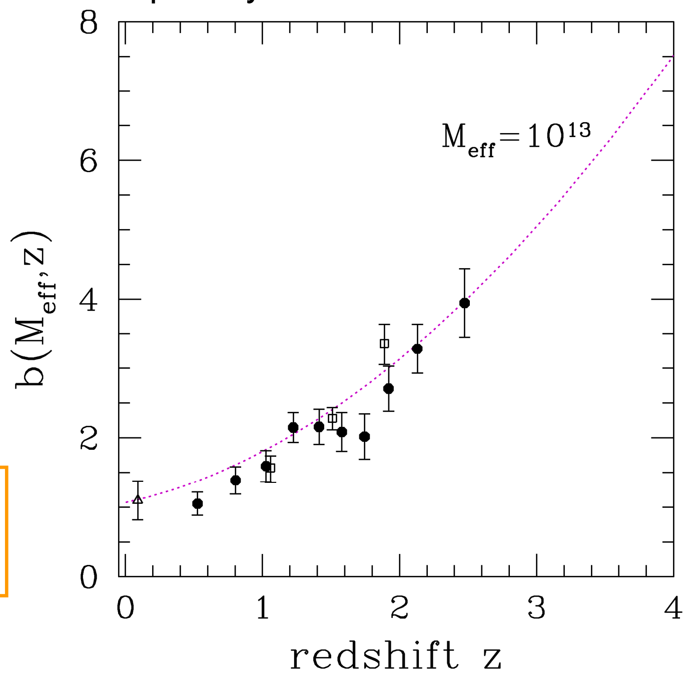
$$\xi_g(r,z) = b^2 \xi_{\rm DM}(r,z)$$

Dark matter
[N-body simulations]

linear bias parameter



Optically-selected QSOs



Galaxies form and reside within
dark matter halos

$$\xi_{\rm halo}(r,z) = b^2(M_{\rm halo},z)\xi_{\rm DM}(r,z)$$

$$\xi_g(r,z) = b^2(M_{\rm eff},z)\xi_{\rm DM}(r,z)$$

The angular correlation function of *mJy radio sources*

AGNs

$$\xi_{\rm AGN}(r,z) = b^2(M_{\rm eff}^{\rm AGN}, z)\xi_{\rm DM}(r,z)$$

$$\mathcal{N}_{\rm AGN}(z)$$

$$w_{\rm AGN}(\theta)$$

Starforming

$$\xi_{\rm SF}(r,z) = b^2(M_{\rm eff}^{\rm SF}, z)\xi_{\rm DM}(r,z)$$

$$\mathcal{N}_{\rm SF}(z)$$

$$w_{\rm SF}(\theta)$$

$$\Rightarrow \quad w(\theta) = f_{\rm AGN}^2 w_{\rm AGN}(\theta) + f_{\rm SF}^2 w_{\rm SF}(\theta)$$

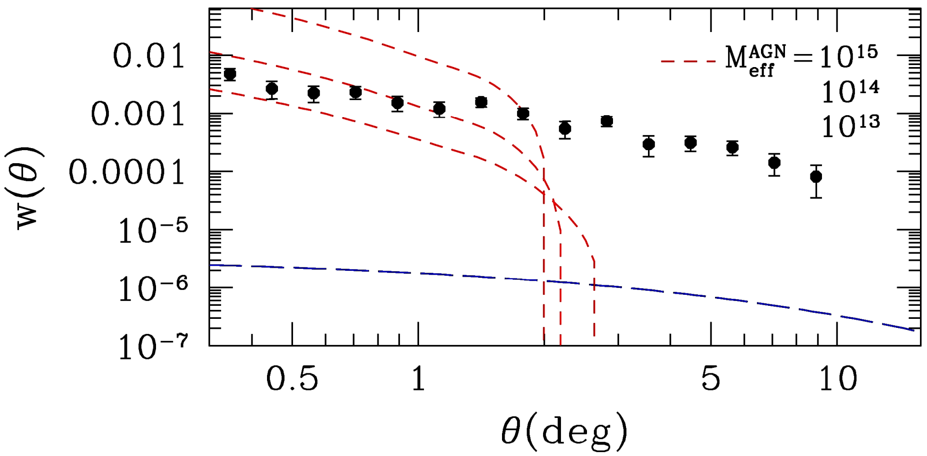
source number fraction: $f_{\rm AGN/SF} = \frac{\int_z dz \mathcal{N}_{\rm AGN/SF}(z)}{\int_z dz \mathcal{N}(z)}$ $\begin{cases} f_{\rm AGN} \sim 1 \\ f_{\rm SF} \sim 5 \times 10^{-3} \end{cases}$

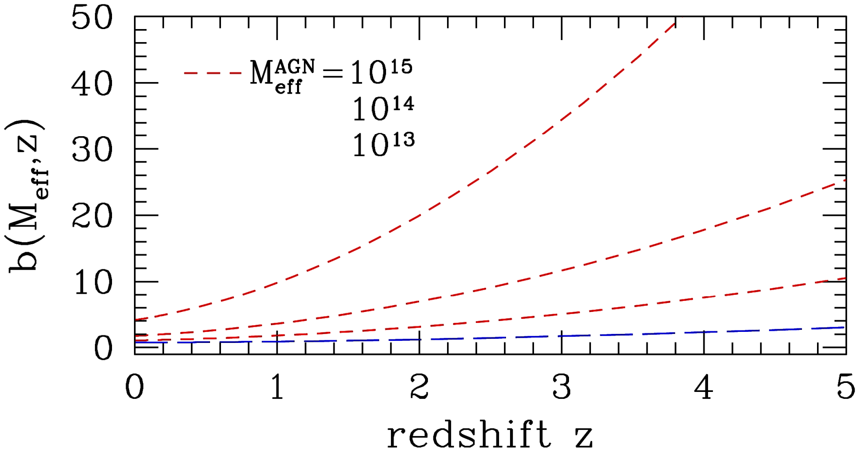
Results I

Hp: $M_{eff}(z)$=const for AGNs
$M_{eff}=10^{11}\ M_{\odot}/h$ for SF

- SF give a negligible contribution to the observed clustering signal at large angular scales.

- $w(\theta)$ cannot be accounted for by AGNs *if they are hosted by haloes of the same mass at every epoch*.



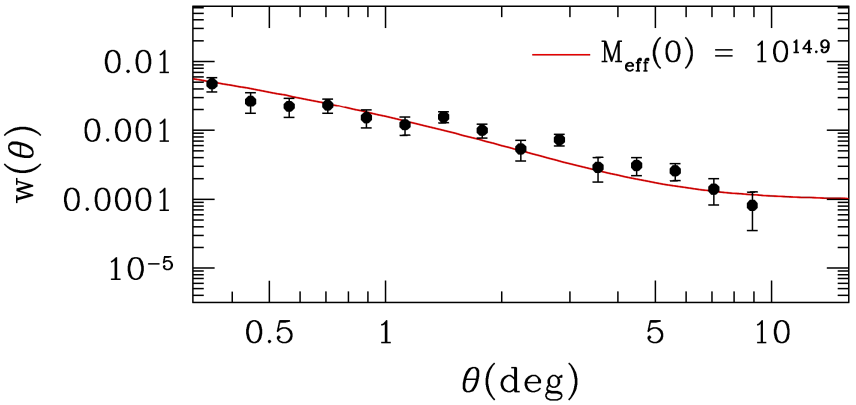


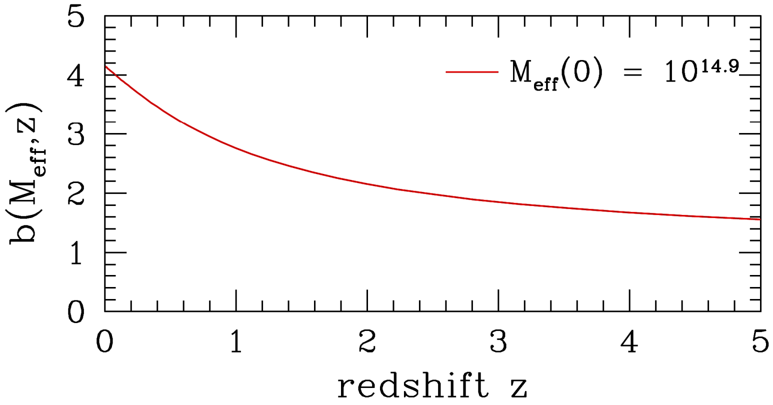
Results II

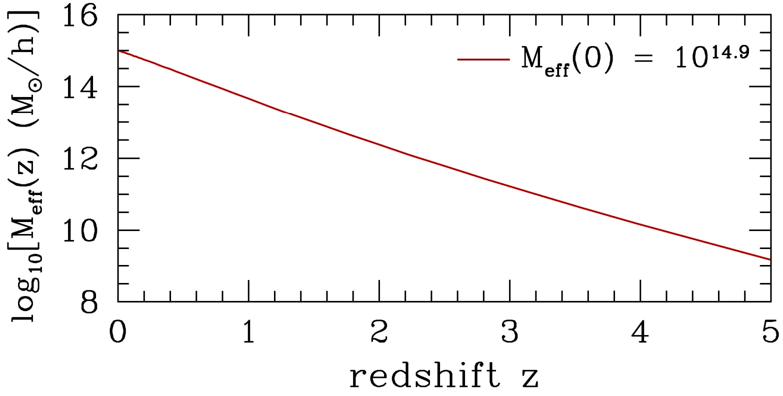
Hp: $M_{eff}(z) = A \times M_{\star}(z)$ for AGNs

$M_{\star}$(z) is the characteristic mass scale for spherical collapse, defined by:

$$\sigma[M_{\star}(z), z] = \delta_c(z)$$







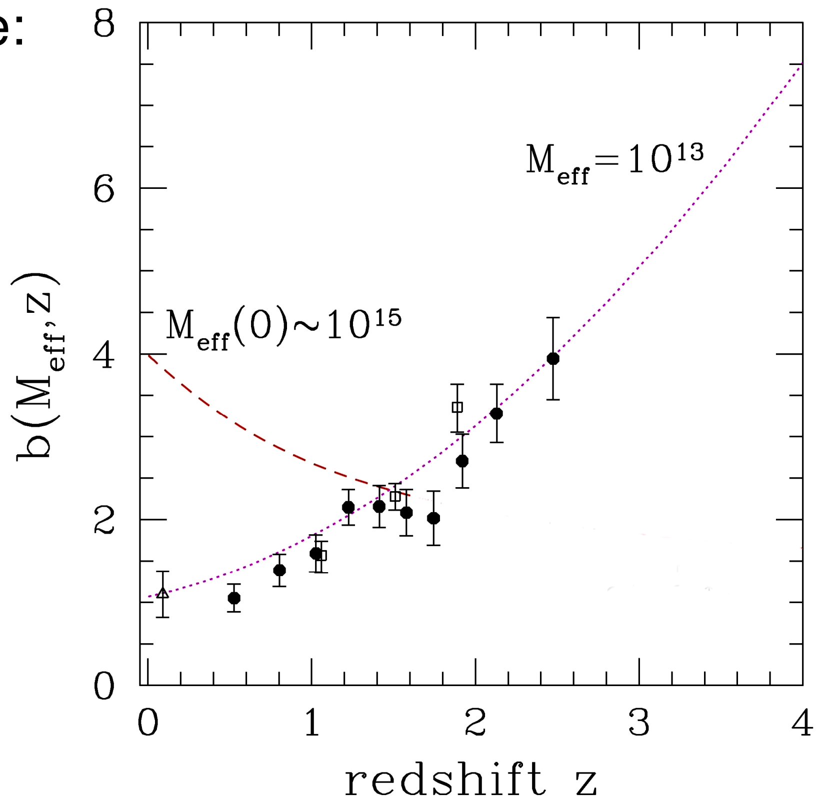
- the measured correlation funtion is now well reproduced up to $\theta \sim 4°$
- data-points at $\theta \geq 4°$ can be accounted for by small systematic variations in the surface density ($\varepsilon \sim 10^{-4}$)

Conclusions

- **AGNs** are responsible for the **large-scale angular clustering** of radio sources, with starforming galaxies providing a negligible contribution.

- radio(-loud) AGNs were increasingly *less* clustered with increasing look-back time:

$M_{eff} \sim 10^{15}\ M_{\odot}/h$ @ $z \sim 0$
$M_{eff} \sim 10^{13}\ M_{\odot}/h$ @ $z \sim 1.5$



Different evolutions for *radio-loud* and *radio-quiet* AGNs (at least for $z<1.5$)