Tracing galaxy environment using the marked correlation function in GAMA

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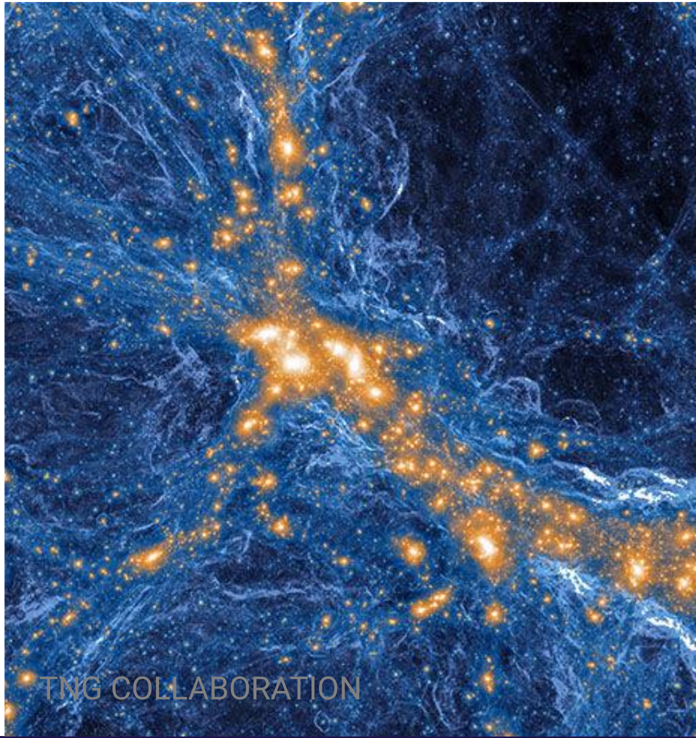
TNG COLLABORATION

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Outline

- Motivation
- Tools
  - Galaxy correlation function
  - Marked correlation function
- Data: Galaxy and Mass Assembly (GAMA)
- Results
- Conclusions

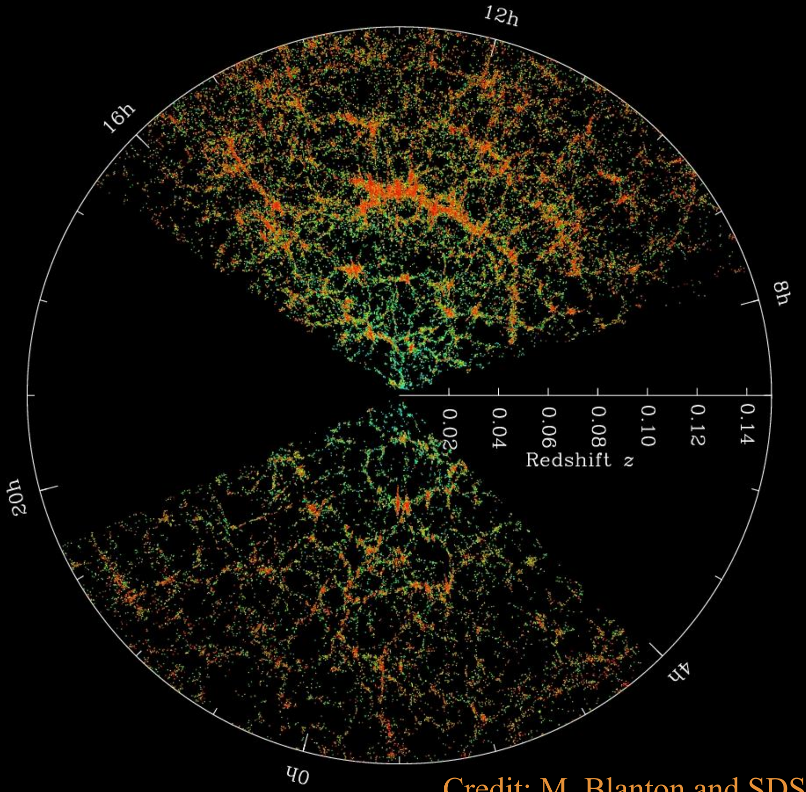
Large scale structure of the Universe

nodes

filaments

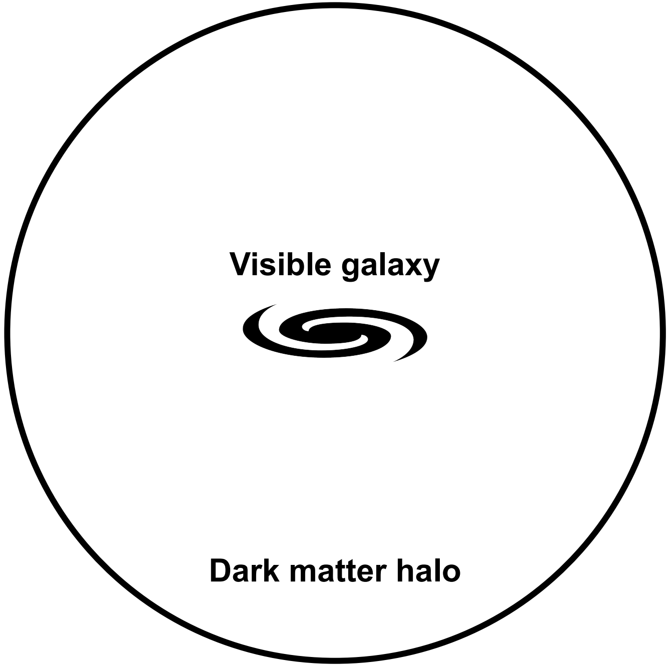
walls

voids



Credit: M. Blanton and SDSS

What do we know?

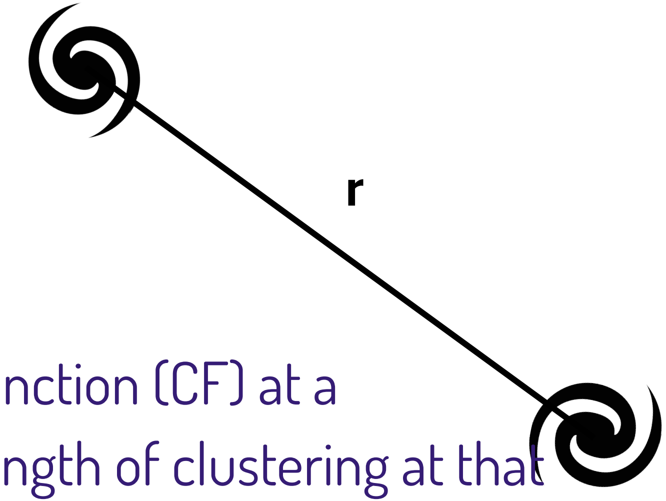


- ★ Galaxies live in dark matter haloes.
- ★ Galaxy properties are majorly defined by the properties of the DM halo in which they live.
- ★ The properties of DM halo correlate with environment (Sheth & Tormen 2004).
- ★ This prompts a correlation between galaxy properties and environment

Environmental dependence of galaxy properties → better constraints on galaxy formation and evolution models

GALAXY 2pt CORRELATION FUNCTION ξ(r)

Excess probability of observing a galaxy pair separated by *r* over the random distribution.



- Greater the value of correlation function (CF) at a particular scale, greater is the strength of clustering at that scale

$$\xi(r) = \left(\frac{r}{r_0}\right)^{-\gamma}$$

Correlation length

Correlation function

$$\xi(r) = \left(\frac{r}{r_0}\right)^{-\gamma}$$

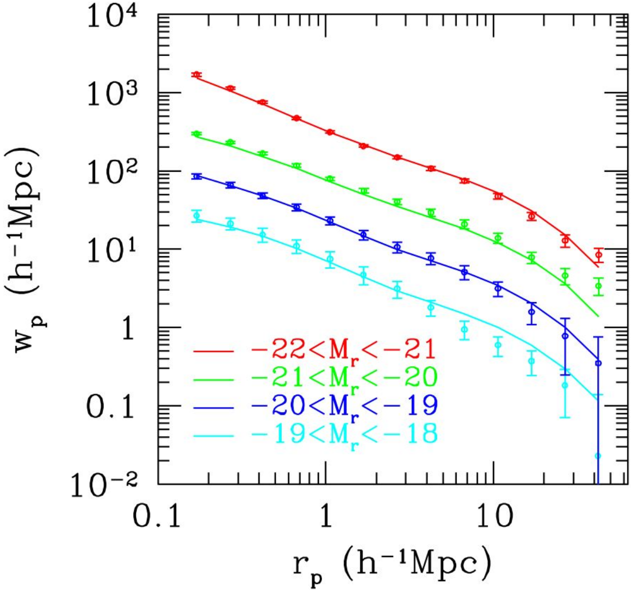
in practice ...

- ➔ RA, Dec and Redshift (z) to estimate distance between galaxies
- ➔ Redshift space distortions
- ➔ **Projected correlation function** $\omega_p(r_p)$ by integrating CF along the line of sight

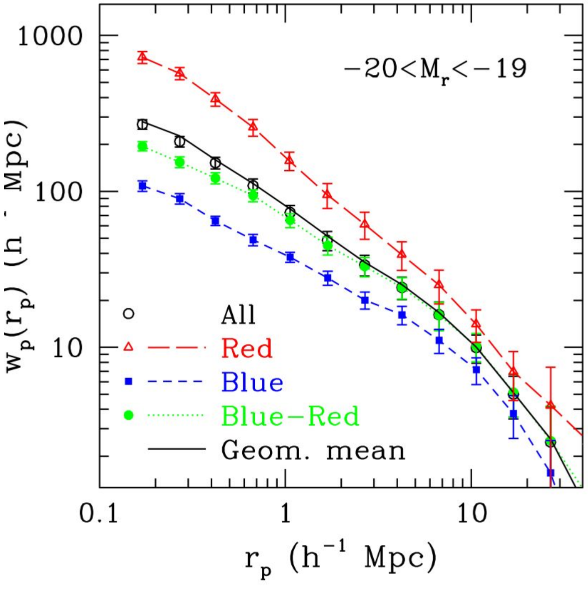
$$\xi(r) \longrightarrow \omega_p(r_p)$$

Dependence of correlation function on galaxy properties

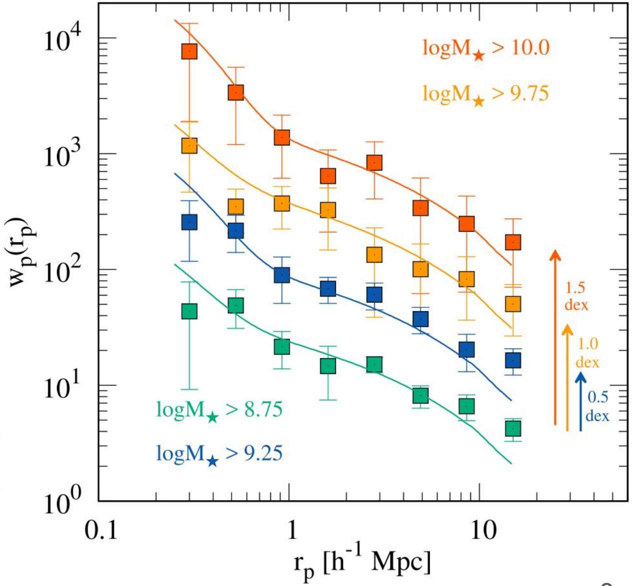
r-band absolute magnitude
Zehavi et al. 2011



Colour
Zehavi et al. 2011



Stellar mass
Durkalec et al. 2018



What are we looking for?

★ **How different properties such as luminosity, stellar mass and star formation rate (SFR) trace galaxy environment?**

★ **To what extent can we use luminosities in various bands as proxies to stellar mass and SFR?**

★ **Does the survey flux limit affect the clustering?**

Marked Correlation Function (MCF)

- We assign a mark to each galaxy in our sample.
- A ‘mark’ can be any measurable property of the galaxy, whose environmental dependence is to be studied (eg: luminosity, stellar mass etc.).
- Strength of MCF for a property shows how strong is that property correlated with environment.

Weighted CF

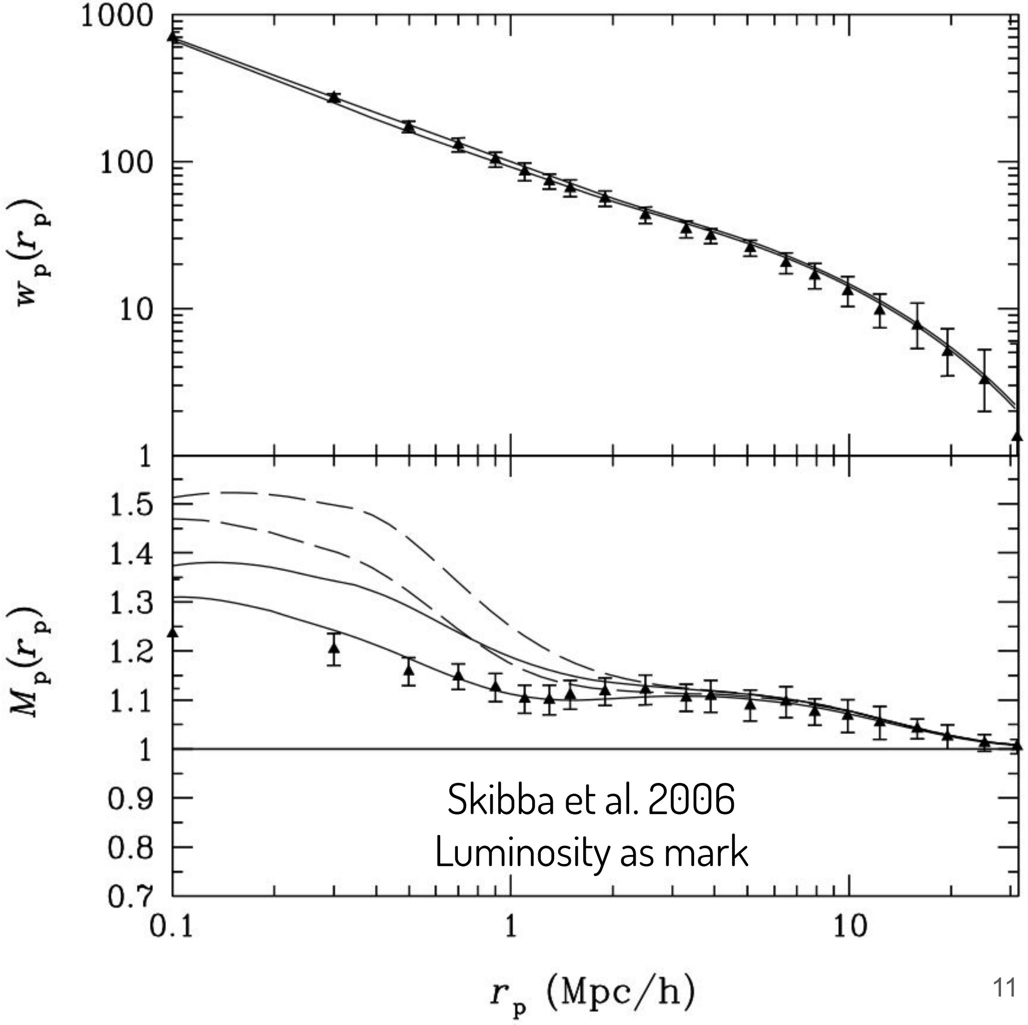
$$M(r) = \frac{1 + W(r)}{1 + \xi(r)}$$

2-point CF

$$M(r) = \frac{1 + W(r)}{1 + \xi(r)}$$

The weight enhances the significance of galaxy pairs in which both galaxies have a given property more pronounced:
E.g., both of them are relatively luminous with respect to the rest of the sample.

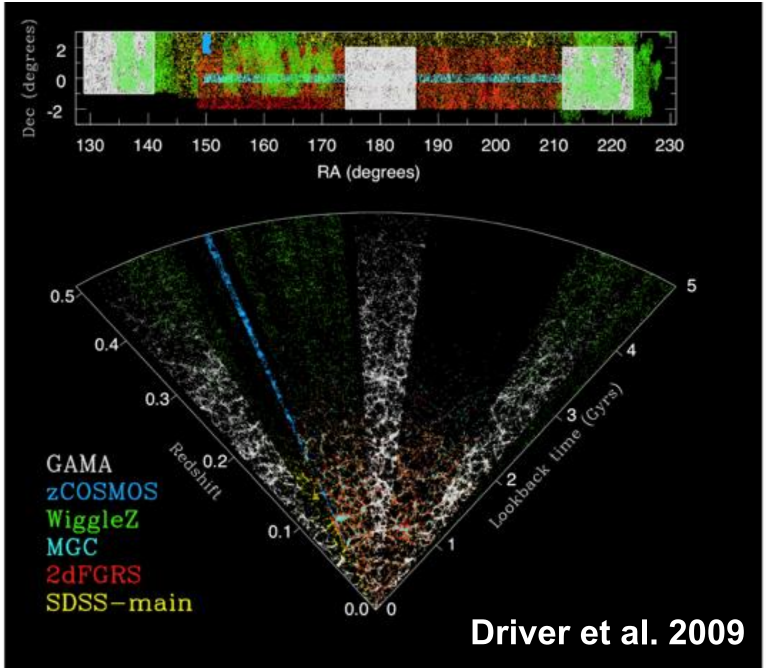
$M_p(r_p)$ is the projected marked correlation function



Skibba et al. 2006
Luminosity as mark

Galaxy And Mass Assembly (GAMA)

- spectroscopic multiwavelength galaxy survey (Driver et al. 2009)
- Redshift z_{median} ~ 0.2 (98 % completeness)
- flux limit : $r < 19.8$ (2 mag fainter than SDSS main galaxy sample)
- covers 5 sky regions of 60 deg^2 each: G09, G12, G15 (equatorial) and G02, G23 (southern)
- we make use of r-band limited data from GAMA II equatorial regions



Driver et al. 2009

Galaxy properties that we use:

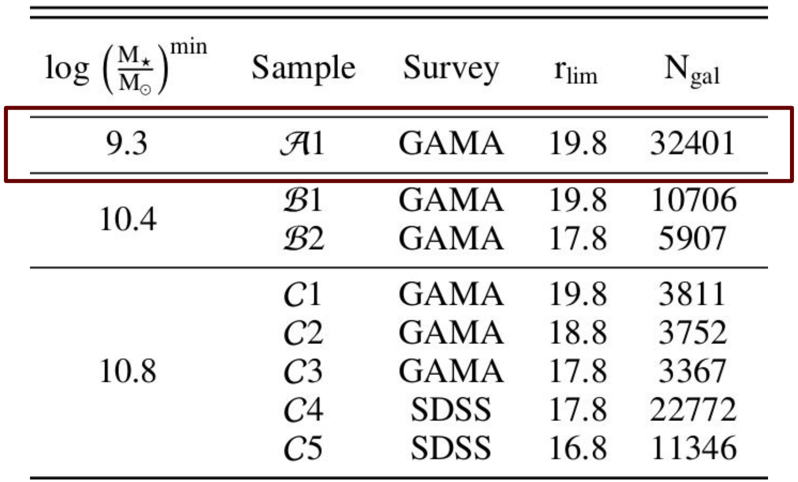
- Luminosities in
  - u-band
  - g-band
  - r-band
  - J-band
  - K-band

Bluer (younger population)

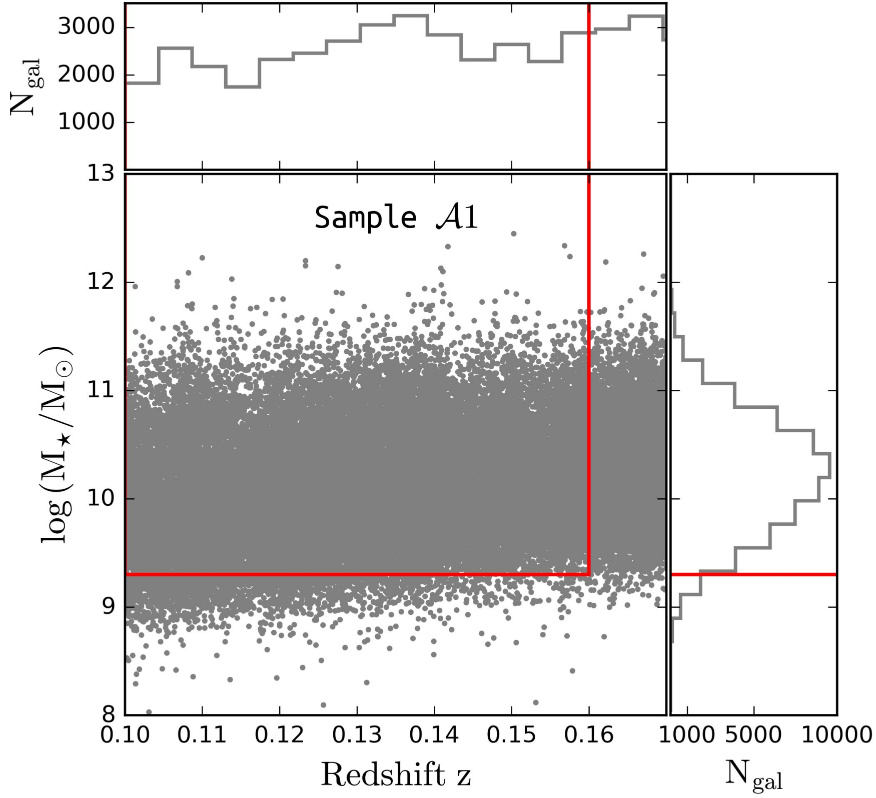
Redder (evolved population)

- Stellar mass
- Star formation rate (SFR)
- Specific star formation rate (SFR per stellar mass)

Our samples : stellar mass selected

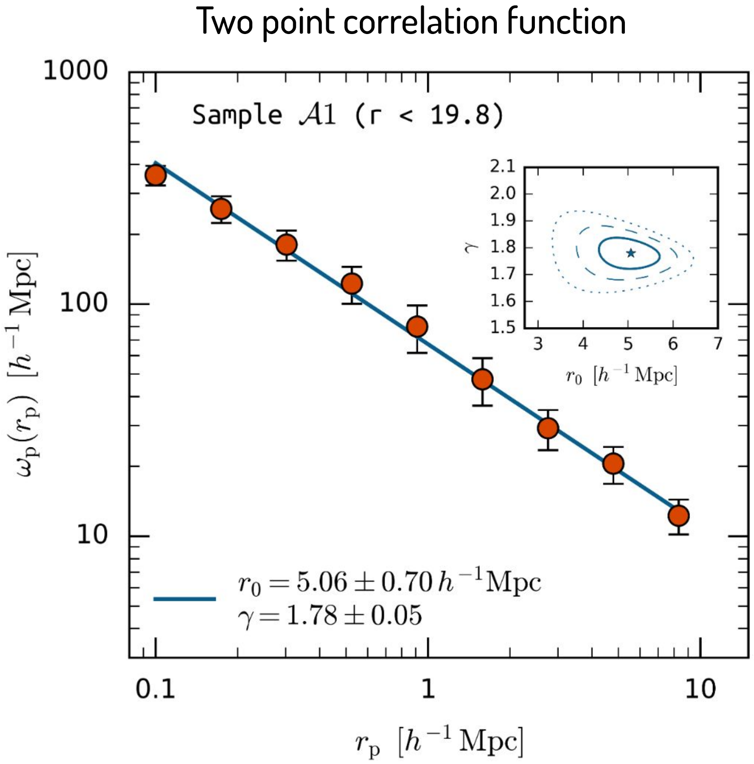


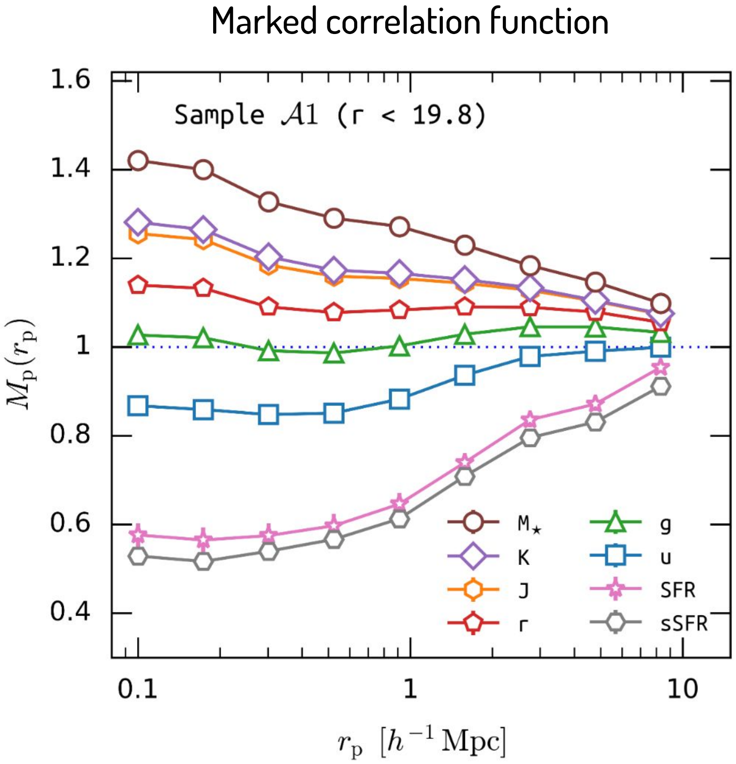
$\log\left(\frac{M_\star}{M_\odot}\right)^{\min}$	Sample	Survey	$r_{\lim}$	N_{gal}
9.3	$\mathcal{A}1$	GAMA	19.8	32401
10.4	$\mathcal{B}1$	GAMA	19.8	10706
	$\mathcal{B}2$	GAMA	17.8	5907
10.8	$\mathcal{C}1$	GAMA	19.8	3811
	$\mathcal{C}2$	GAMA	18.8	3752
	$\mathcal{C}3$	GAMA	17.8	3367
	$\mathcal{C}4$	SDSS	17.8	22772
	$\mathcal{C}5$	SDSS	16.8	11346



Sureshkumar et al. 2021 (A&A, in press)

Environmental dependence of galaxy properties





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Environmental dependence of galaxy properties

In all the scales, stellar mass, g,r,J, K-band luminosity MCFs are above unity

↓

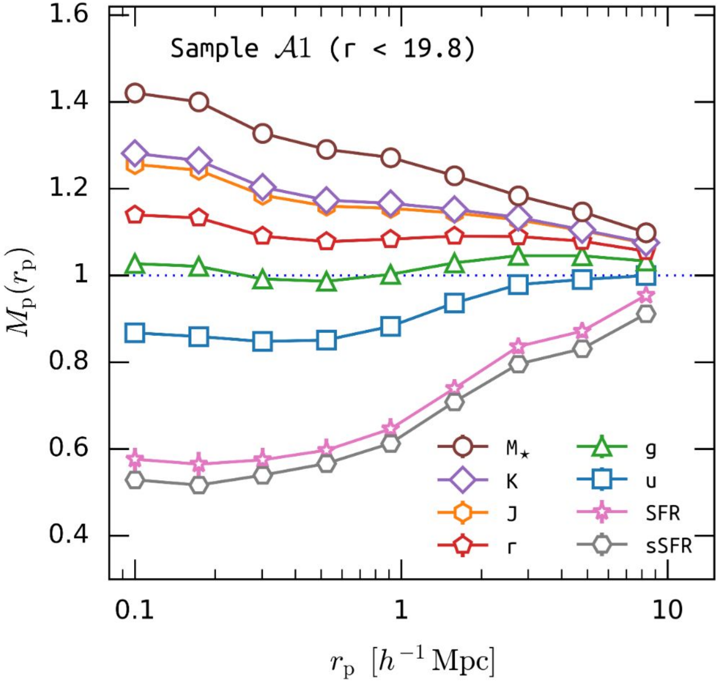
On smaller scales, there is a greater probability of finding galaxy pairs with both the galaxies similarly stronger in these properties.

u-band, (s)SFR MCFs exhibit an opposite behaviour

↓

Galaxy pairs with stronger u-band luminosity and (s)SFR are majorly far separated.

Marked correlation function



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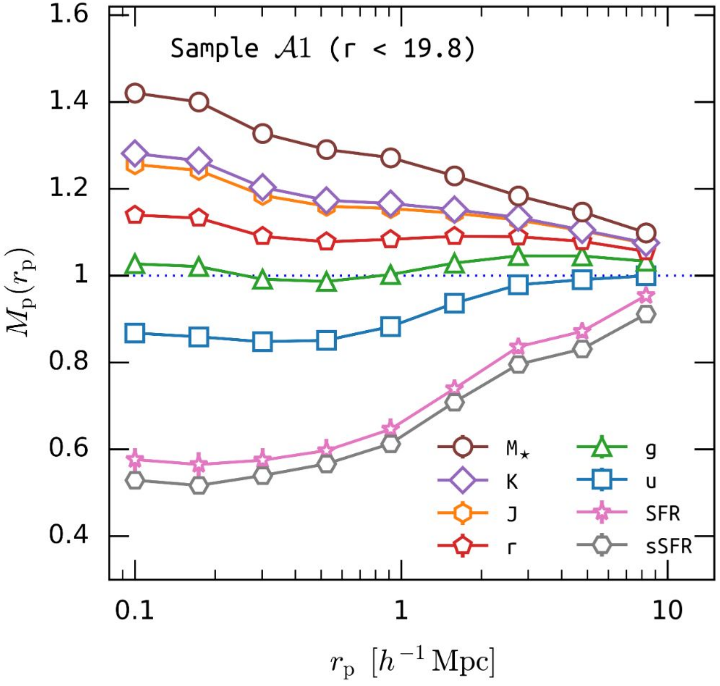
Environmental dependence of galaxy properties

- ★ Stellar mass MCF is stronger than luminosity MCFs, regardless of the passband. Stellar mass proves to be the better tracer of environment than other properties.
- ★ K-band MCF is the strongest one among the luminosity MCFs - K-band has greater correlation with environment.
- ★ K-band luminosity can be a good substitute for stellar-mass-complete sample. But, in such a case we tend to miss closer pairs of evolved galaxies.
- ★ u-band luminosity can be a good, but not a perfect tracer of star formation rate.

Marked correlation function



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Stellar mass incompleteness effect

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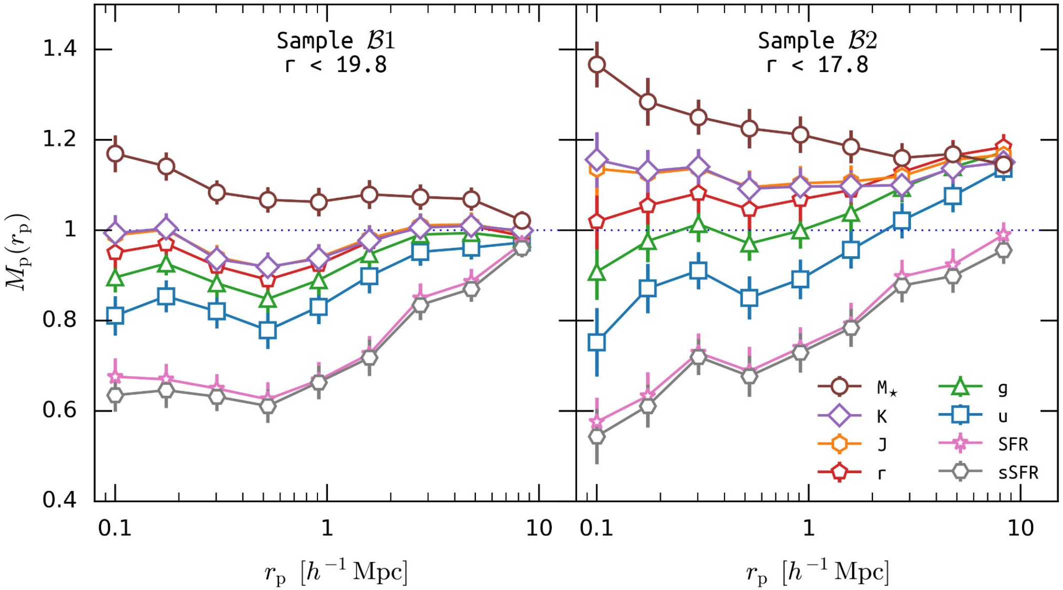

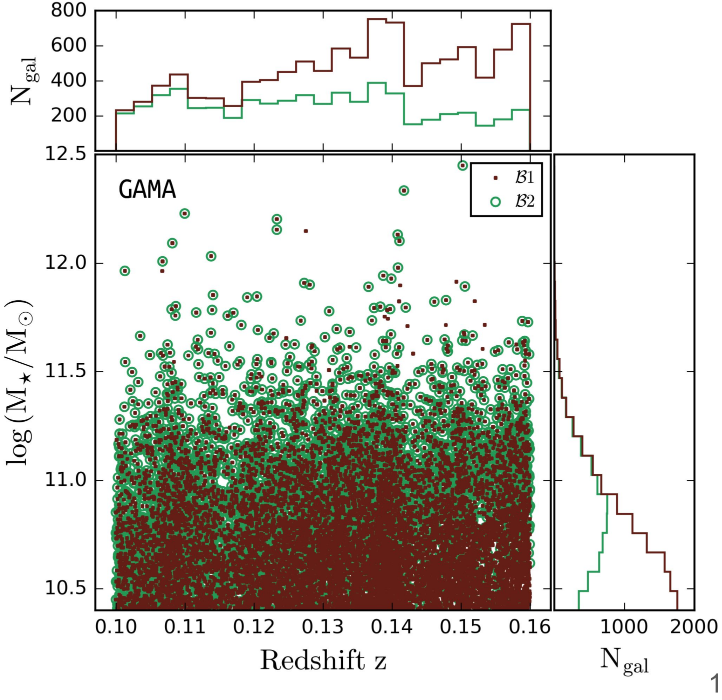

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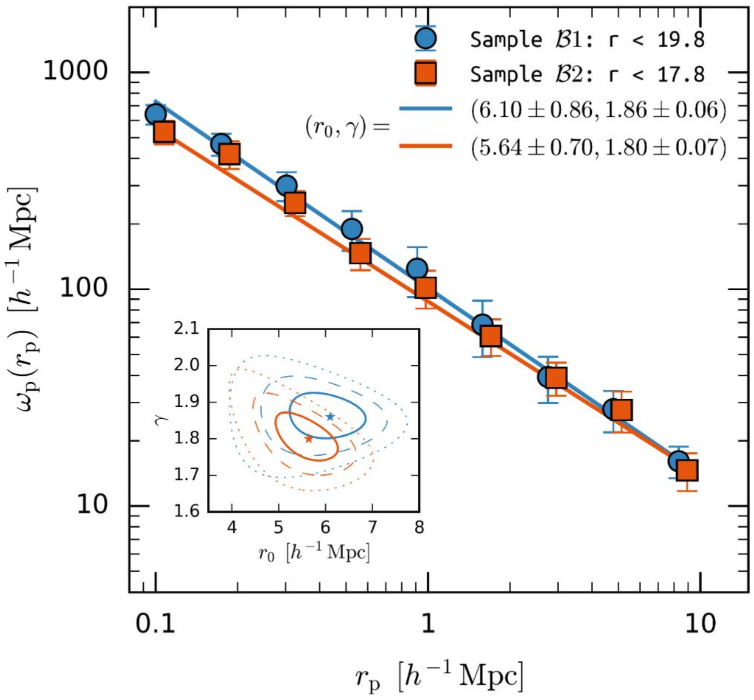

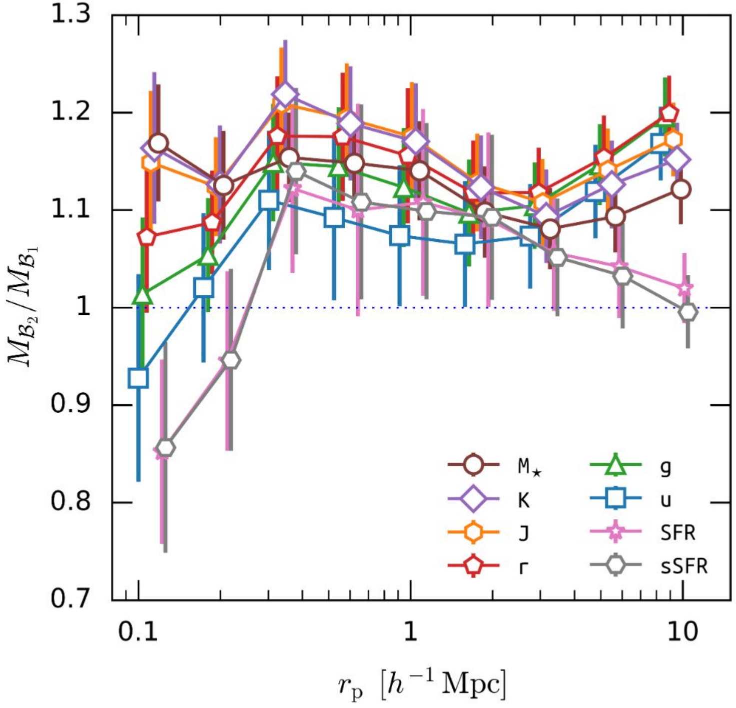

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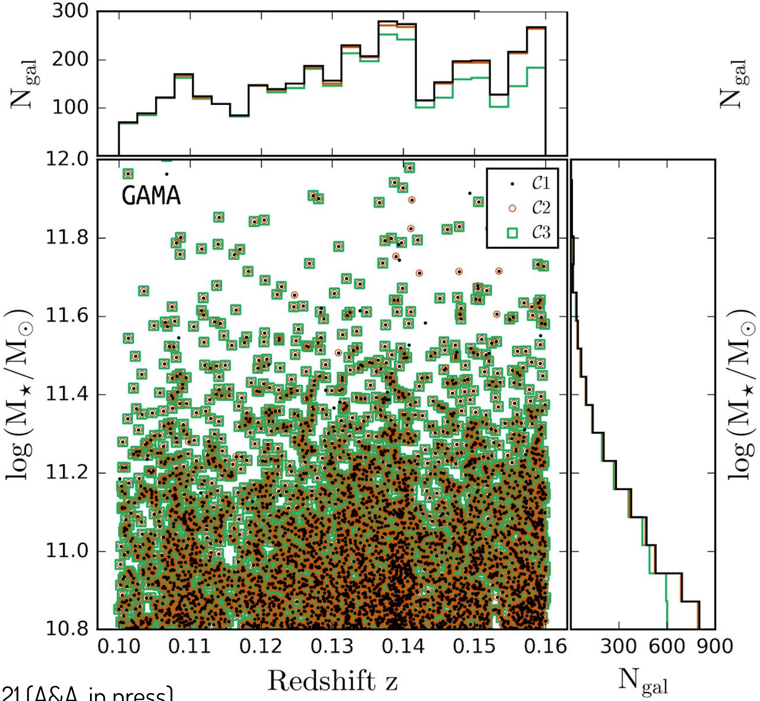

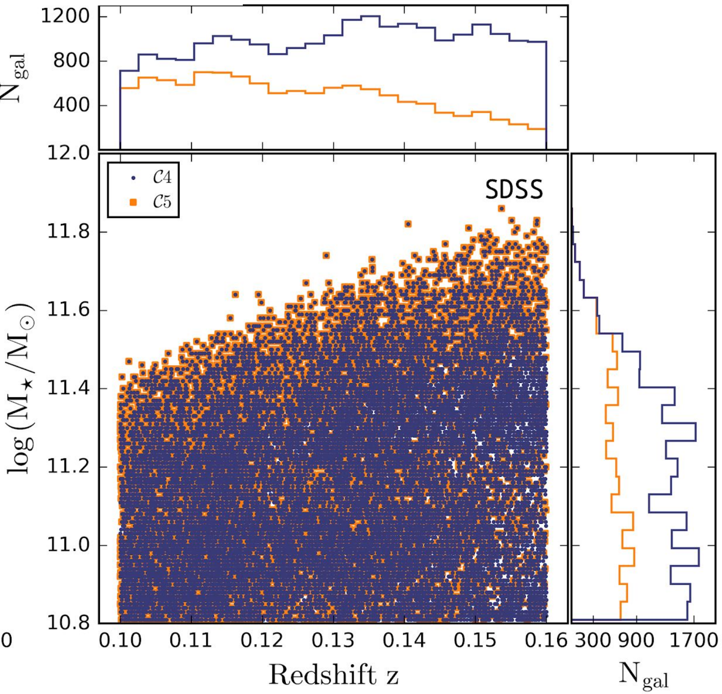

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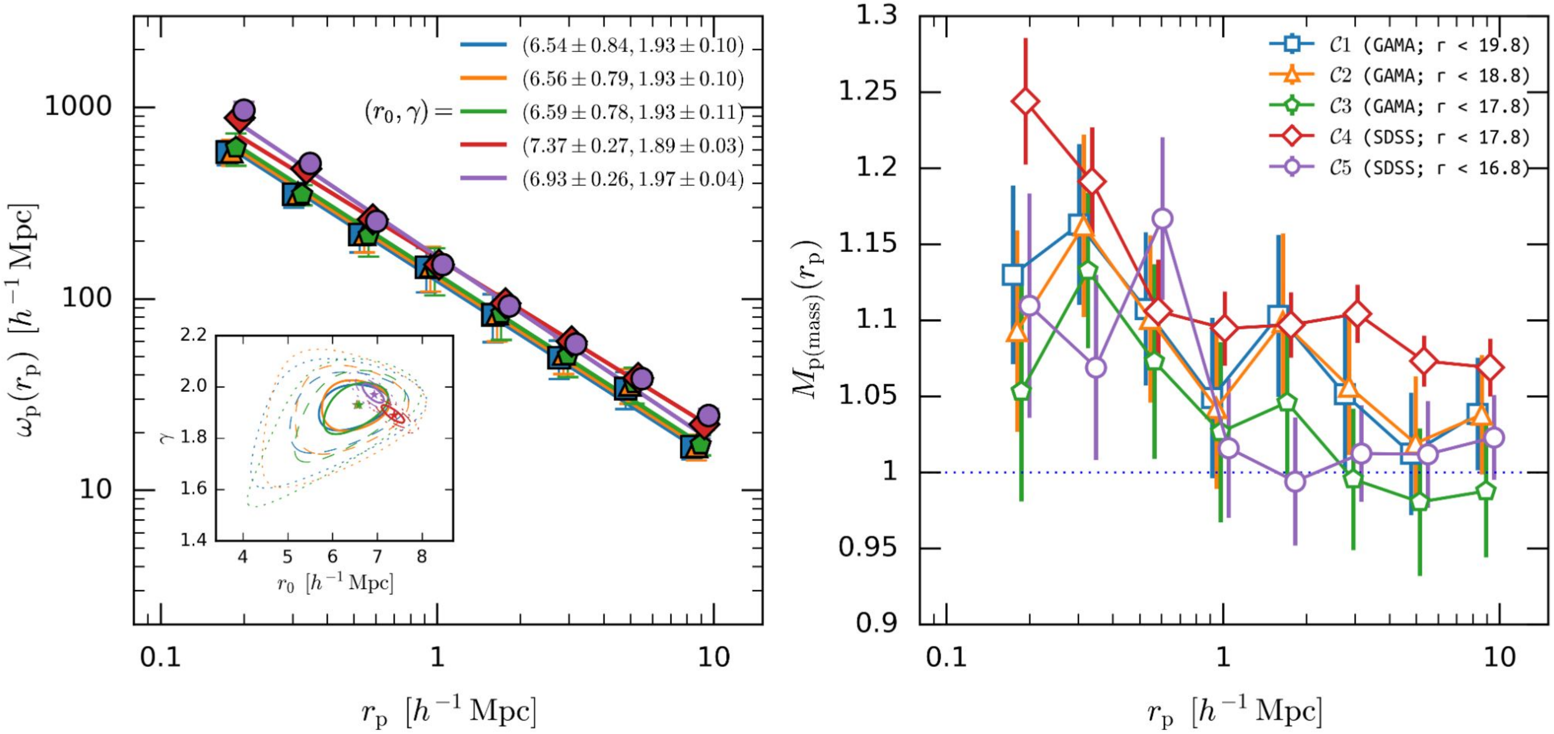

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Conclusions

Using marked statistics in GAMA survey, we observe:

- Different galaxy properties trace environment differently.
- Stellar mass proves to be the better tracer of environment than luminosity and SFR.
- A sample complete in K-band luminosity can be a good substitute for stellar-mass-complete sample. But, in such a case we tend to miss closer pairs of evolved galaxies.
- u-band luminosity can be a good, but not a perfect tracer of star formation rate.
- Survey flux limit imposes incompleteness which affects clustering measurements in stellar mass selected samples.

THANK YOU…!

For more details, please refer arXiv:2102.04177

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