Measuring the galaxy bias with Weak Lensing and Galaxy Clustering

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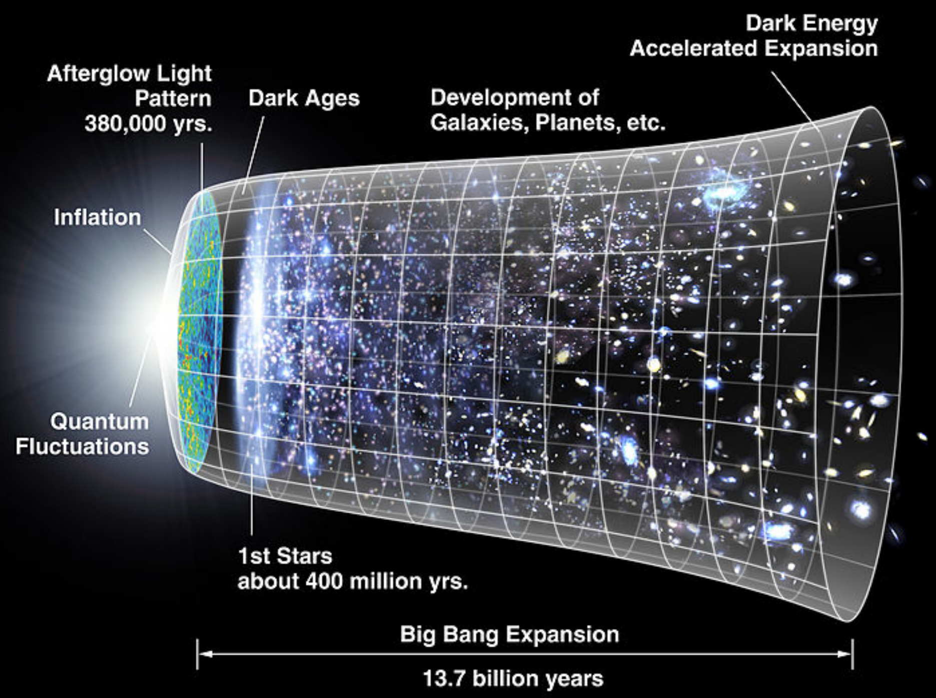
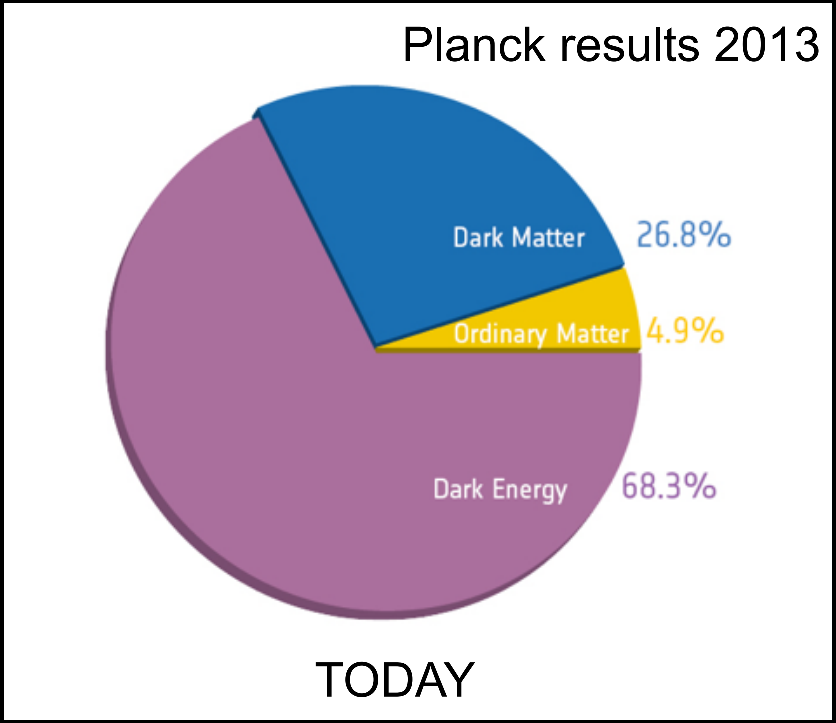
The broad picture





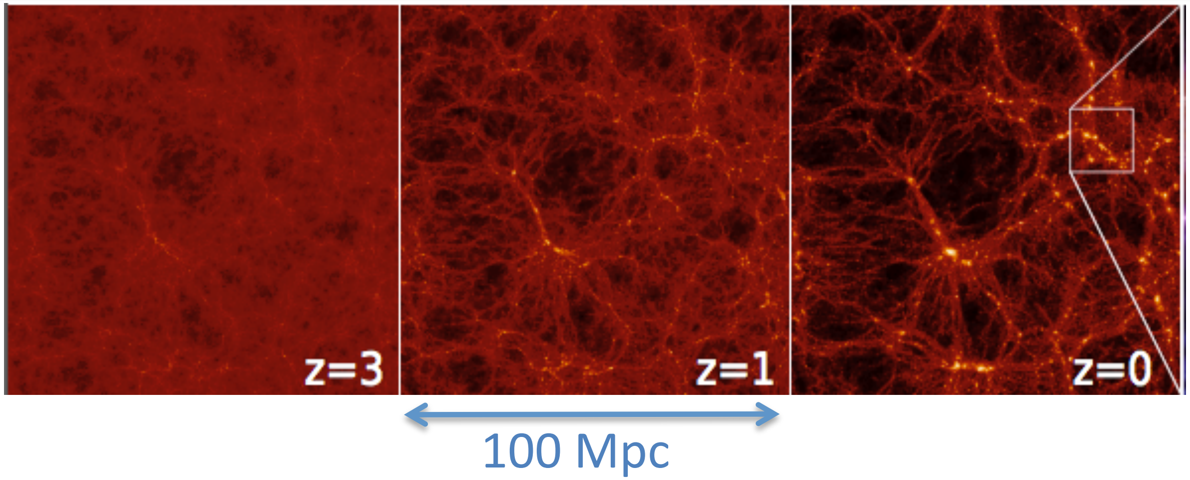
Dark energy

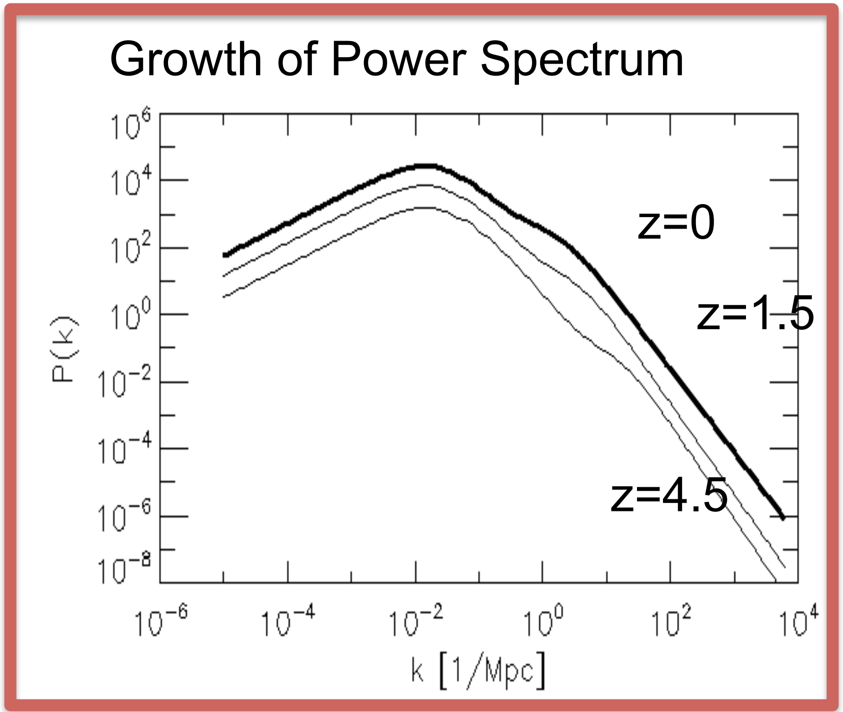
◆Explains the recent acceleration of Universe expansion

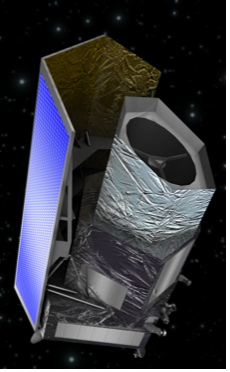
◆Slows down the formation of cosmological structures

The growth of structures

N-body Simulations from Millenium







The Euclid Mission 2020

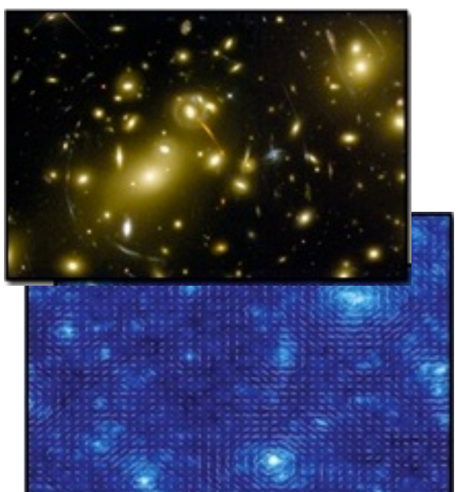
Euclid Consortium

Euclid will explore the following key fundamental questions:

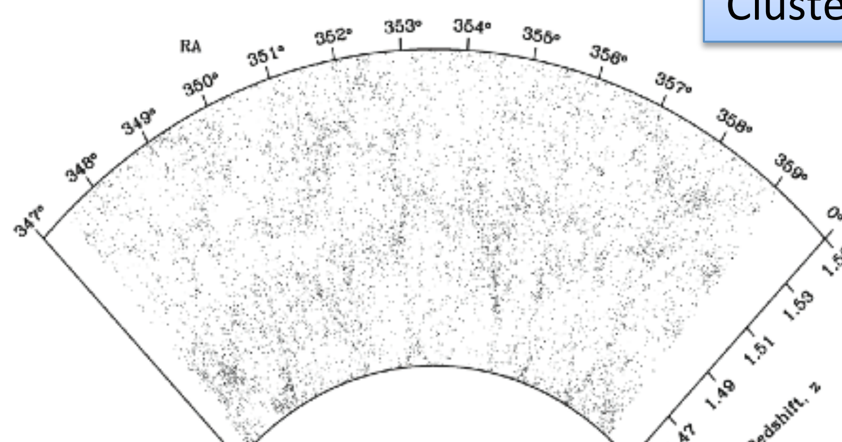
1. **is dark energy merely a cosmological constant, as first discussed by Einstein, or**
2. **is it a new kind of field that evolves dynamically with the expansion of the universe?**
3. **is it a manifestation of a break-down of General Relativity and deviations from the law of gravity?**
4. what are the nature and properties of dark matter?

Euclid is based on 2 main observational techniques

Gravitational Lensing

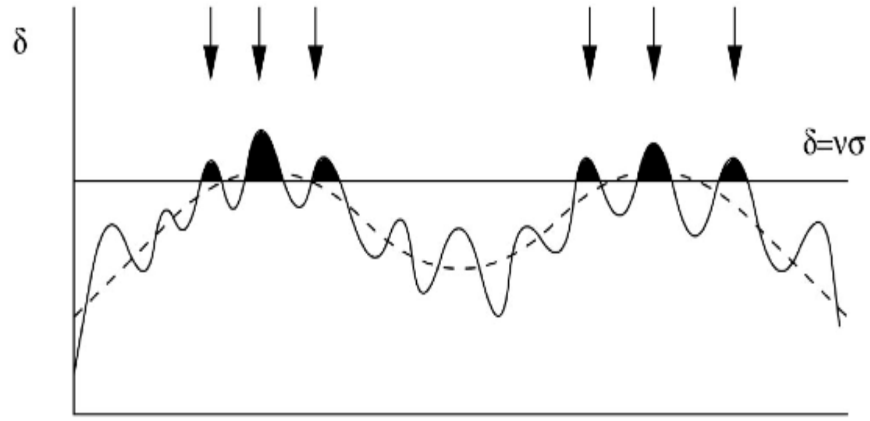


Galaxy Clustering



Merson et al. 2013

Galaxy and Matter clustering



=> Density contrast of matter… and galaxies

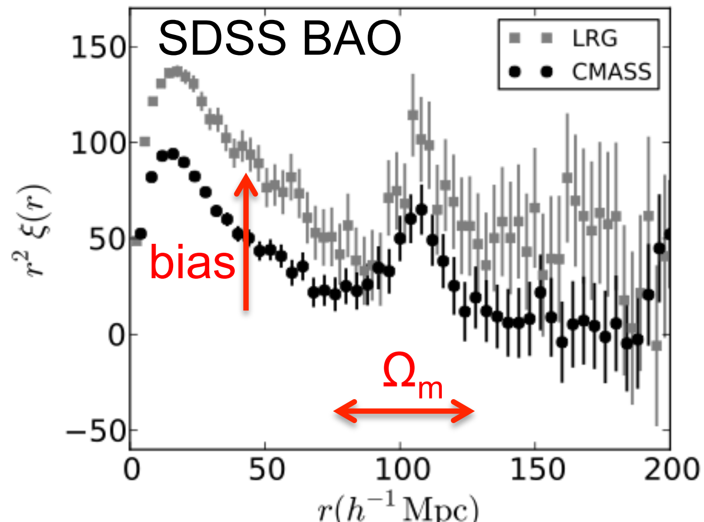
$$\delta(x) = \frac{\rho_m(x) - \bar{\rho}_m}{\bar{\rho}_m} \qquad \delta_g(x) = \frac{\rho_g(x) - \bar{\rho}_g}{\bar{\rho}_g}$$

Galaxy bias is the ratio $b^2 = \frac{\langle \delta_g^2 \rangle}{\langle \delta^2 \rangle}$ or in Fourier $b^2(k,z) = \frac{P_g(k,z)}{P_m(k,z)}$

Why do we care about bias?

⇒ Bias increases the S/N of BAO peaks

$$\mathrm{SN}_{\mathrm{BAO}} \propto n_g P_g \propto n_g b^2 P_m$$

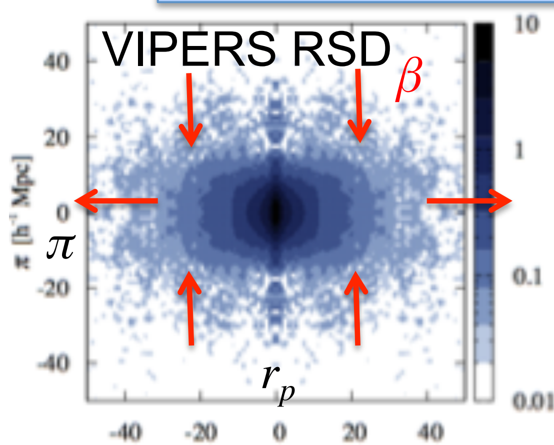


Anderson et al. 2012

⇒ Bias decreases the S/N of RSD ($\beta = f/b$)

$$\frac{\delta\beta}{\beta} \approx 4.9\mathrm{x}10^2\ b^{0.7} V^{-0.5} \exp\left(\frac{1.7\mathrm{x}10^{-4}}{b^2 n}\right)$$

Bianchi et al. 2012

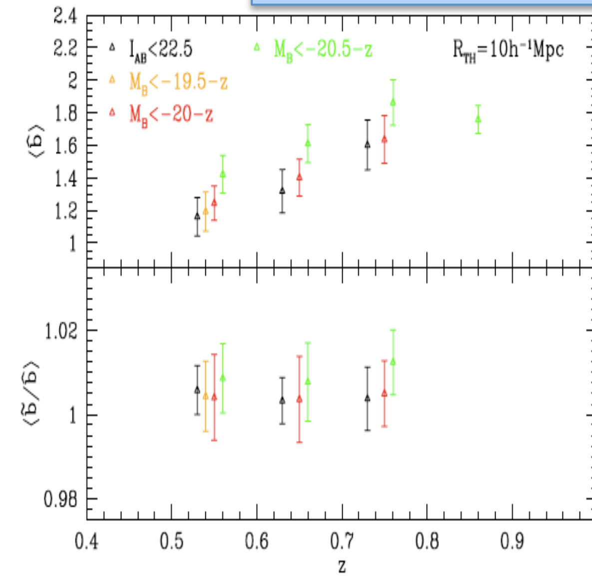


de la Torre et al. 2012

Galaxy bias conditions the type of measurement to do cosmology

Typical Galaxy Bias behavior

Kovac et al. 2009



From COSMOS measurements

⇒ Bias increases with redshift

⇒ Bias increases with luminosity

⇒ At high-z, sBzK are less biased than pBzK at small scales (McCracken+2010)

⇒ Bias is larger for active galaxies at large scales (Tinker+2012)

From SDSS measurements

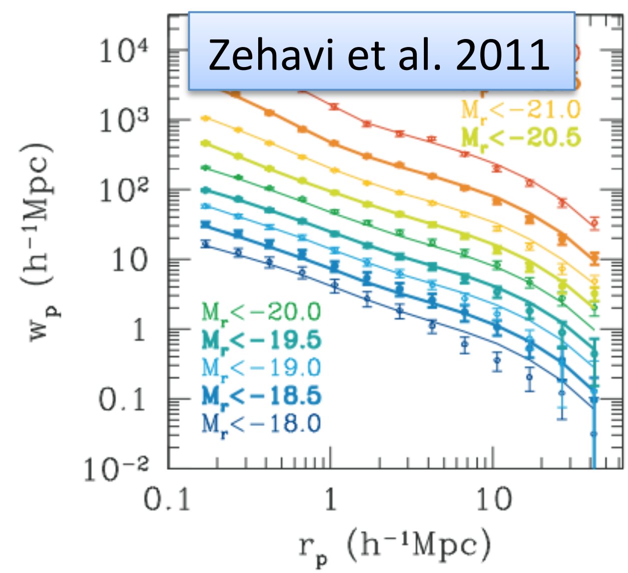
⇒ Bias increases with luminosity (Zehavi+11)

⇒ Bias increases with stellar mass (Li+06)

⇒ Bias increases with halo mass (Johnston+07)

⇒ Bias increases at small scales (Cresswell+09)

Zehavi et al. 2011



From SUBARU DEEP SURVEY

⇒ Bias is large at high redshift (@z=4) (Ouchi+04)

Galaxy bias with WL and GC
(Schneider 1998, Van Waerbeke+98, Hoekstra+ 2002)

=> Aperture statistics is half way between theory and observations

- It is the integral of the projected lensing power spectrum $P_\kappa(l)$ filtered by a Besel function
- It is the integral of the 2-pt correlation function filtered by a compensated function

=> Galaxy bias comes naturally as a ratio of aperture statistics

$$b(\theta) = f_1(\theta, \Omega_m, \Omega_\Lambda) \times \sqrt{\frac{\langle \mathcal{N}^2(\theta) \rangle}{\langle M_{\rm ap}^2(\theta) \rangle}},$$

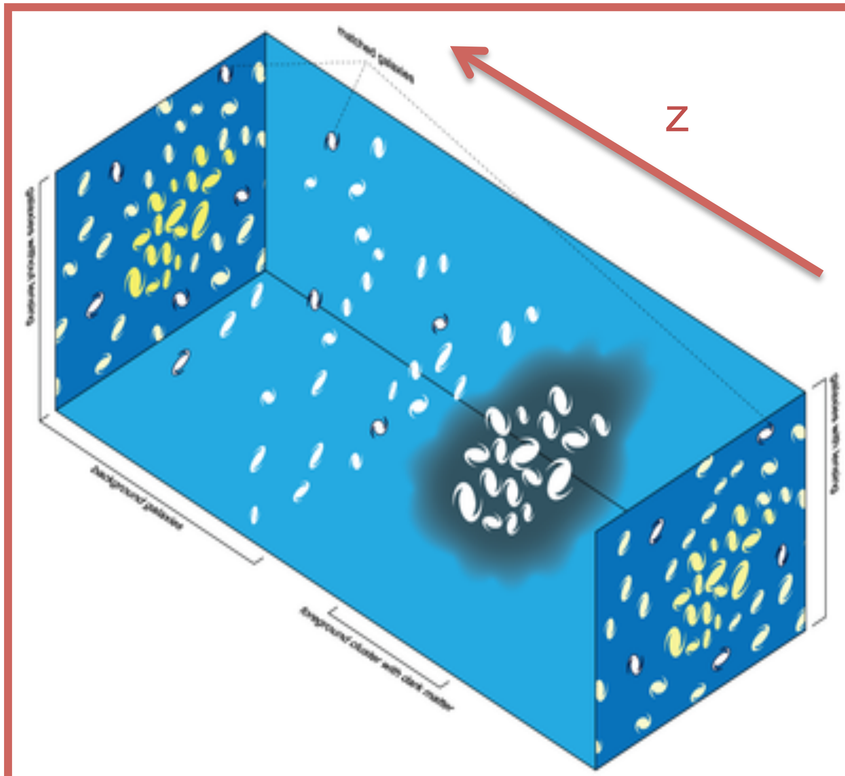


Figure: Lensing of background galaxies (yellow) by foreground structures (white galaxies + dark matter halos)

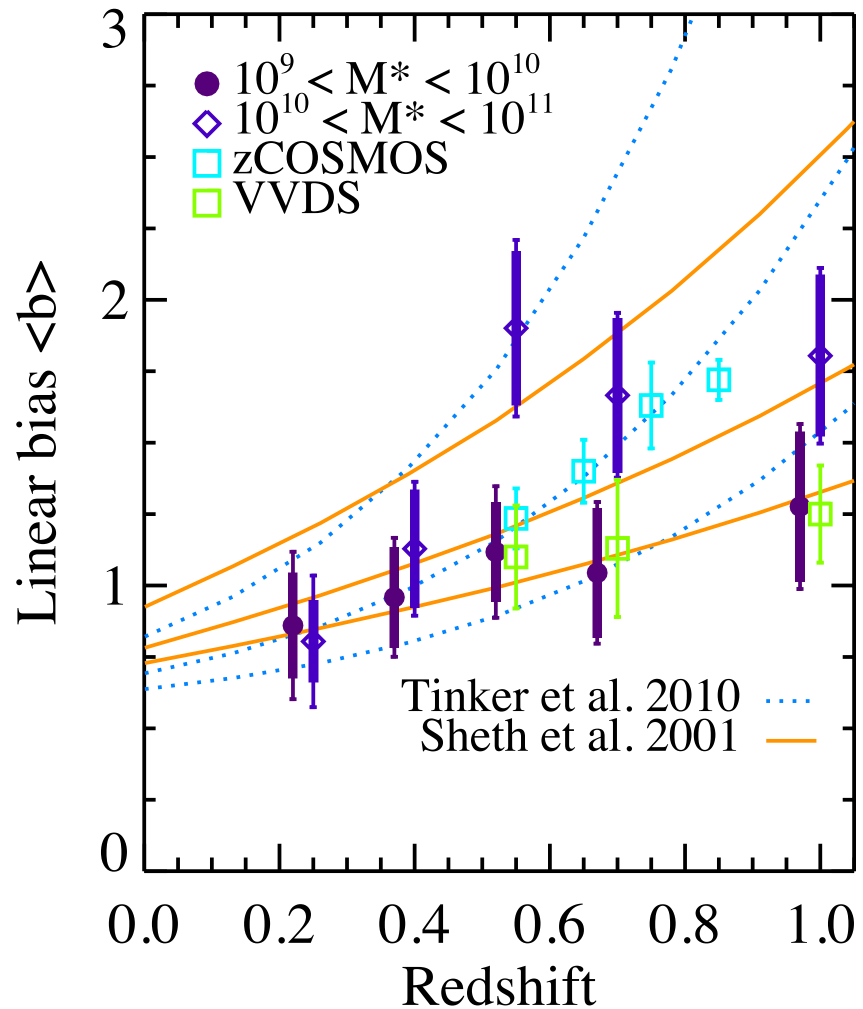
HST-COSMOS (2 deg^2)
The astrophysical dependence

Jullo et al. 2012

- Bias increases with redshift
- Bias increases with stellar mass

- Agreement with theory for halos btw 10^{10} and 10^{12} h^{-1} $M_\odot$

- Agreement with other measurements
  - zCOSMOS (Kovac+09)
  - VVDS (Marinoni+05)

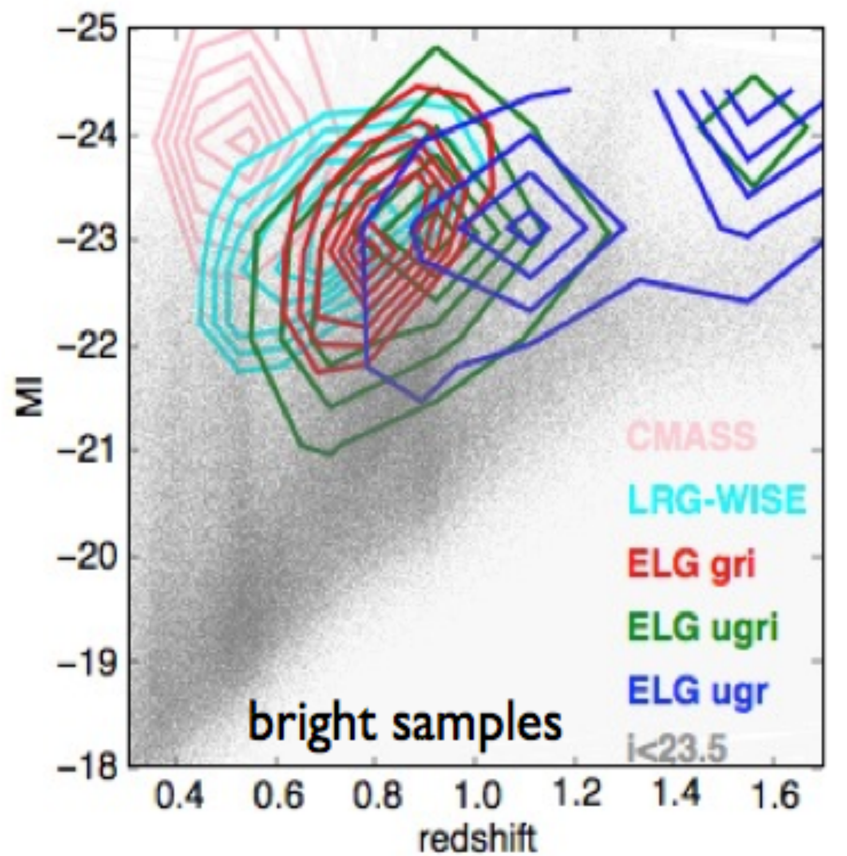


Stripe 82: The most luminous galaxies

Comparat et al. 2013

=> Goal: Measure the bias of the most luminous galaxies in redshift bins

- SDSS-CFHT-Stripe 82 field of 150 deg^2
- SDSS color-color selection of galaxies (~100,000 gal. per sample)
- Lensing catalog available from CFHT-Megacam observations



Are the most luminous highly biased?

Comparat et al. 2013

BOSS-CMASS
(w_0=0.87±0.24, b≈2)
Anderson et al. 2012

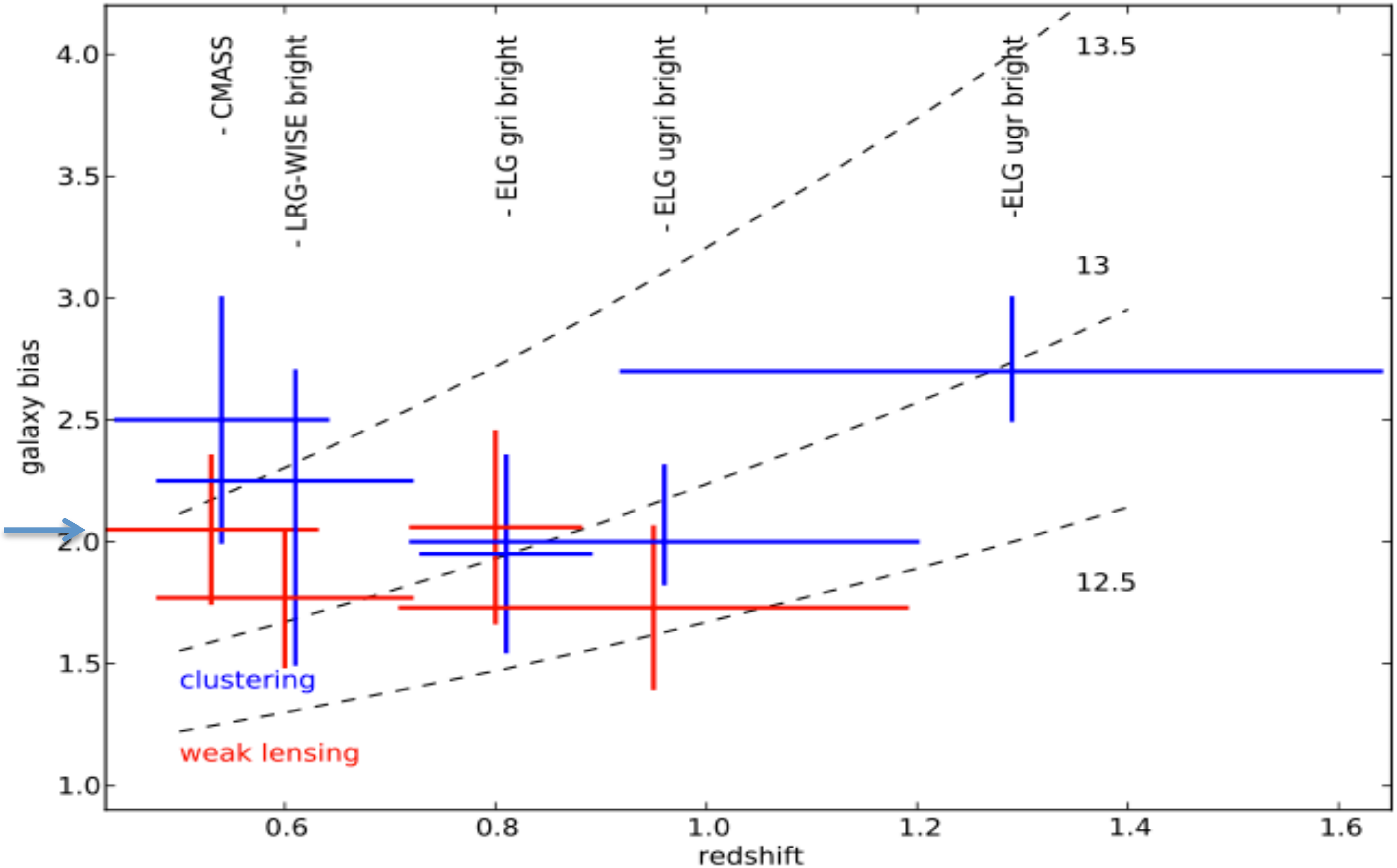


Figure: Galaxy bias of our CC selected galaxy samples. In Blue: Comparison to theoretical power spectrum
Red: Comparison to WL power spectrum measurements

Conclusion

1. Galaxy bias conditions the type of measurement to do cosmology
   - BAO requires highly biased galaxies
   - RSD requires weakly biased galaxies

2. Typically Galaxy bias increases for high-z, luminous and quiescent galaxies (from COSMOS, SDSS, etc.)

3. Combination of WL and GC can measure galaxy bias
   - In COSMOS (2 deg^2), we measured galaxy bias in the following bins
     - In scales $0.2 < R < 15\ h^{-1}$ Mpc
     - In Redshift $0.2 < z < 1$
     - In Stellar mass $10^9 < M_* < 10^{11}\ h^{-2}\ M_\odot$
   - In CFHT-Stripe 82 (150deg^2), we found for luminous galaxies at z ~ 1
     - Bias is roughly equal b = 2 → our color-color selection is good for BAO

Expected constraints from Euclid