Constraints from Galaxy Cluster in the photometric Euclid Survey

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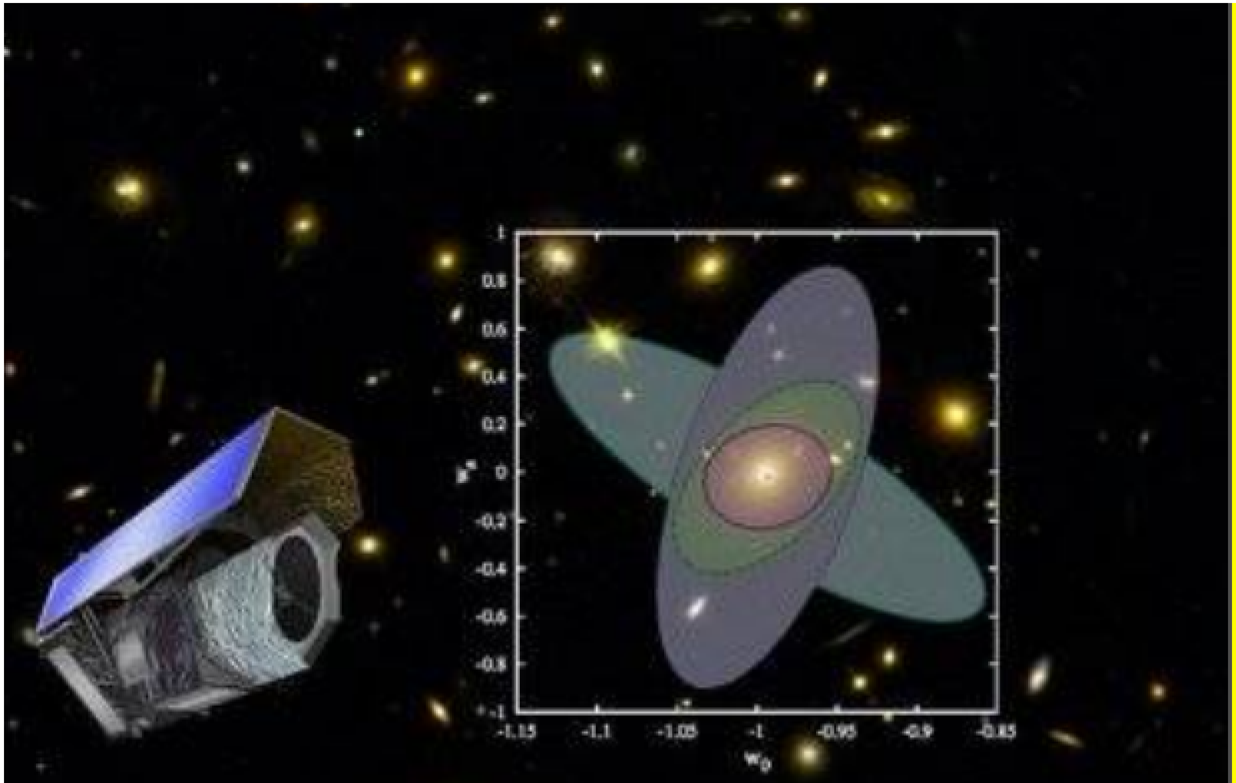
Mykonos, 17 VI 2016

Cluster cosmology



ESA medium mission with the aim of estimate the DE EoS measuring the cosmological Weak Lensing and the galaxy clustering

Launch: 2020

Galaxy clusters are “additional cosmological probes” for Euclid

Three essential tools are required for cluster cosmological:

- an efficient method to identify clusters over a wide redshift range
- a robust observable estimator of the cluster mass
- a method to compute the selection function

(or equivalently the survey volume within which clusters are found)

The Euclid mission

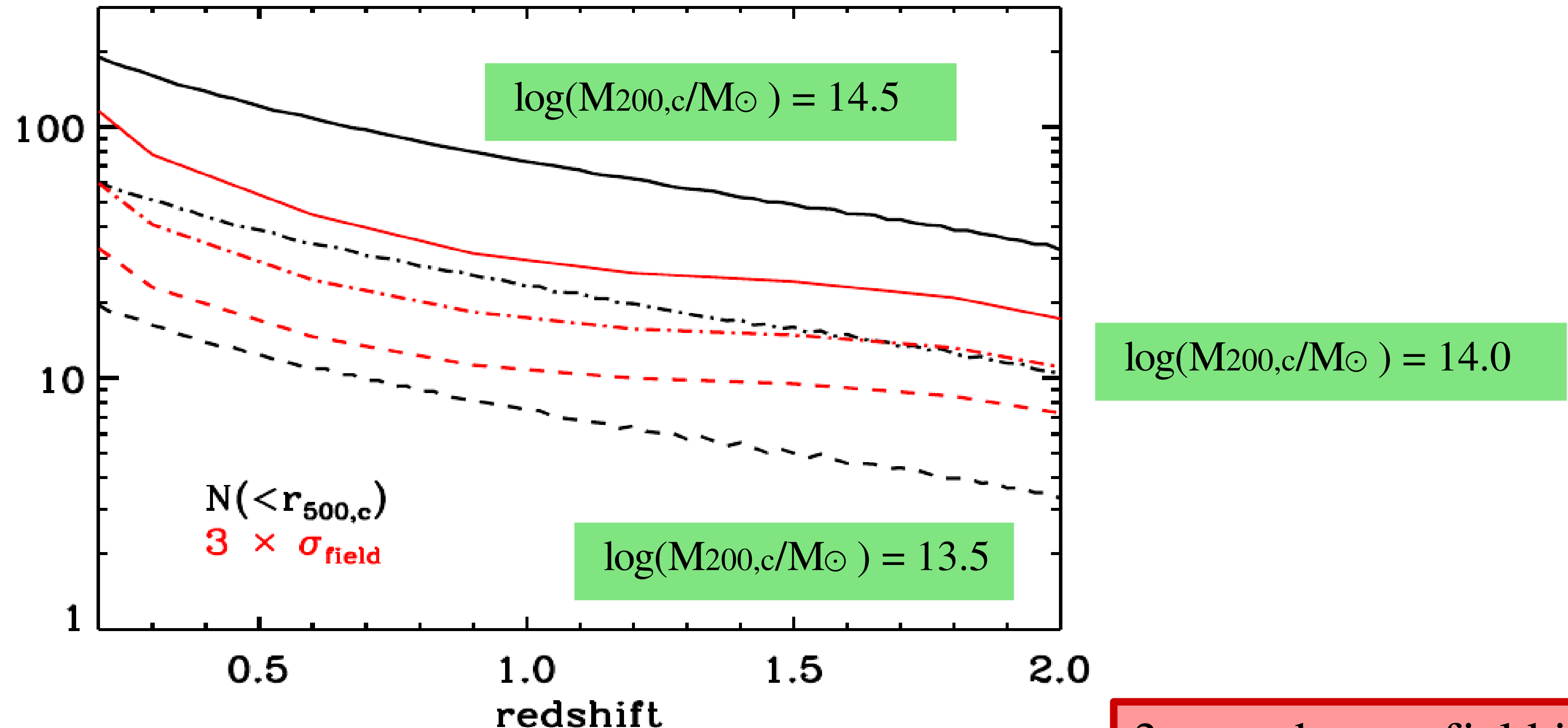
SURVEYS		
	Area (deg2)	Description
Wide Survey	15,000 (required) 20,000 (goal)	Step and stare with 4 dither pointings per step.
Deep Survey	40	In at least 2 patches of > 10 deg^2 2 magnitudes deeper than wide survey

PAYLOAD					
Telescope	1.2 m Korsch, 3 mirror anastigmat, f=24.5 m				
Instrument	VIS	NISP			
Field-of-View	0.787×0.709 deg^2	0.763×0.722 deg^2			
Capability	Visual Imaging	NIR Imaging Photometry			NIR Spectroscopy
Wavelength range	550– 900 nm	Y (920-1146nm),	J (1146-1372 nm)	H (1372-2000nm)	1100-2000 nm
Sensitivity	24.5 mag 10σ extended source	24 mag 5σ point source	24 mag 5σ point source	24 mag 5σ point source	$3\ 10^{-16}$ erg cm-2 s-1 3.5σ unresolved line flux
Detector Technology	36 arrays 4k×4k CCD	16 arrays 2k×2k NIR sensitive HgCdTe detectors			
Pixel Size Spectral resolution	0.1 arcsec	0.3 arcsec			0.3 arcsec R=250

B. Sartoris, A. Biviano, C. Fedeli, J. Bartlett, S. Borgani, M. Costanzi, C. Giocoli, L.Moscardini, J.Weller, B. Ascaso, S. Bardelli, S.Maurogordato, and P. Viana (published on MNRAS

Forecast on constraints from galaxy cluster in the photometric Euclid survey

Selection function of cluster photometric survey



Number $N_{500,c}$ of cluster galaxies within $r_{500,c}$

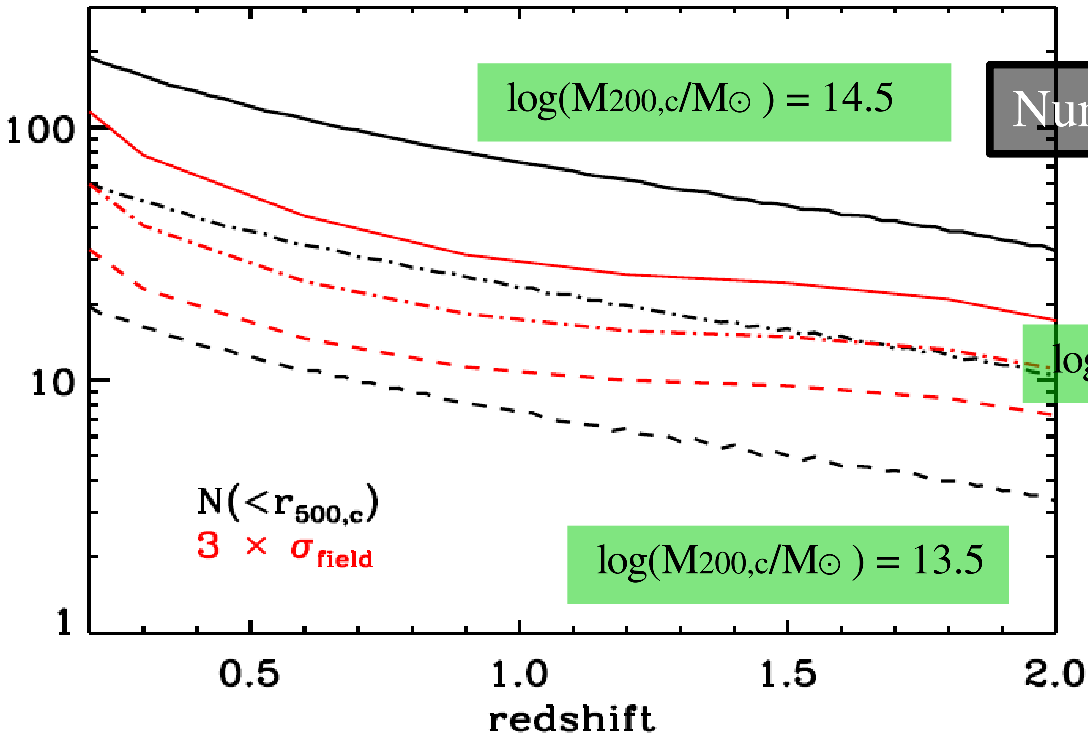
These counts have been obtained integrating the LF of Lin+03 down to the limiting magnitude $H_{AB} = 24$, as a function of redshift for clusters of different masses.

Evolution with z: no redshift evolution of $\varphi_\star$ and α. For $M_\star$ redshift evolution we assume a passive evolution over the full cluster mass range.

$3\sigma_{field}$ where σ field is the rms of the field counts within the same radius, and within the adopted $3\Delta z_p$ cut

Non-cluster members are all those galaxies that are more than $3\Delta z_p$ away from the mean cluster redshift.
Euclid required accuracy of $\Delta z_{phot} \equiv 0.05(1+z_{cl})$, (Euclid phot+ground-based data).

Selection function of cluster photometric survey



log($M_{200,c}/M_\odot$) = 14.5

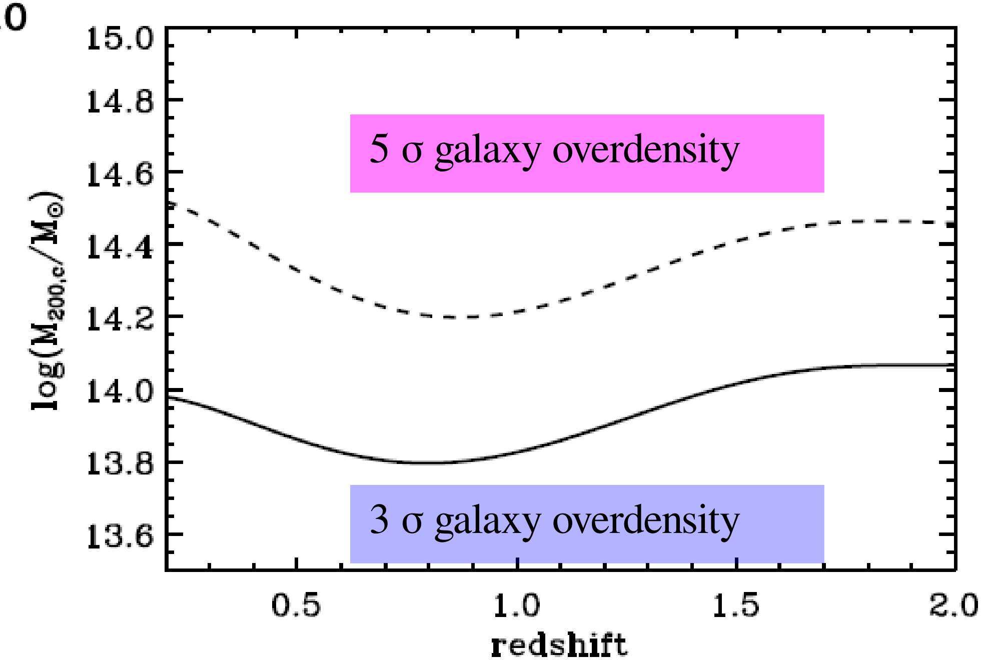
log($M_{200,c}/M_\odot$) = 14.0

log($M_{200,c}/M_\odot$) = 13.5

Number $N_{500,c}$ of cluster galaxies within $r_{500,c}$

$3\sigma_{field}$ where σ field is the rms of the field counts within the same radius, and within the adopted $3\Delta z_p$ cut

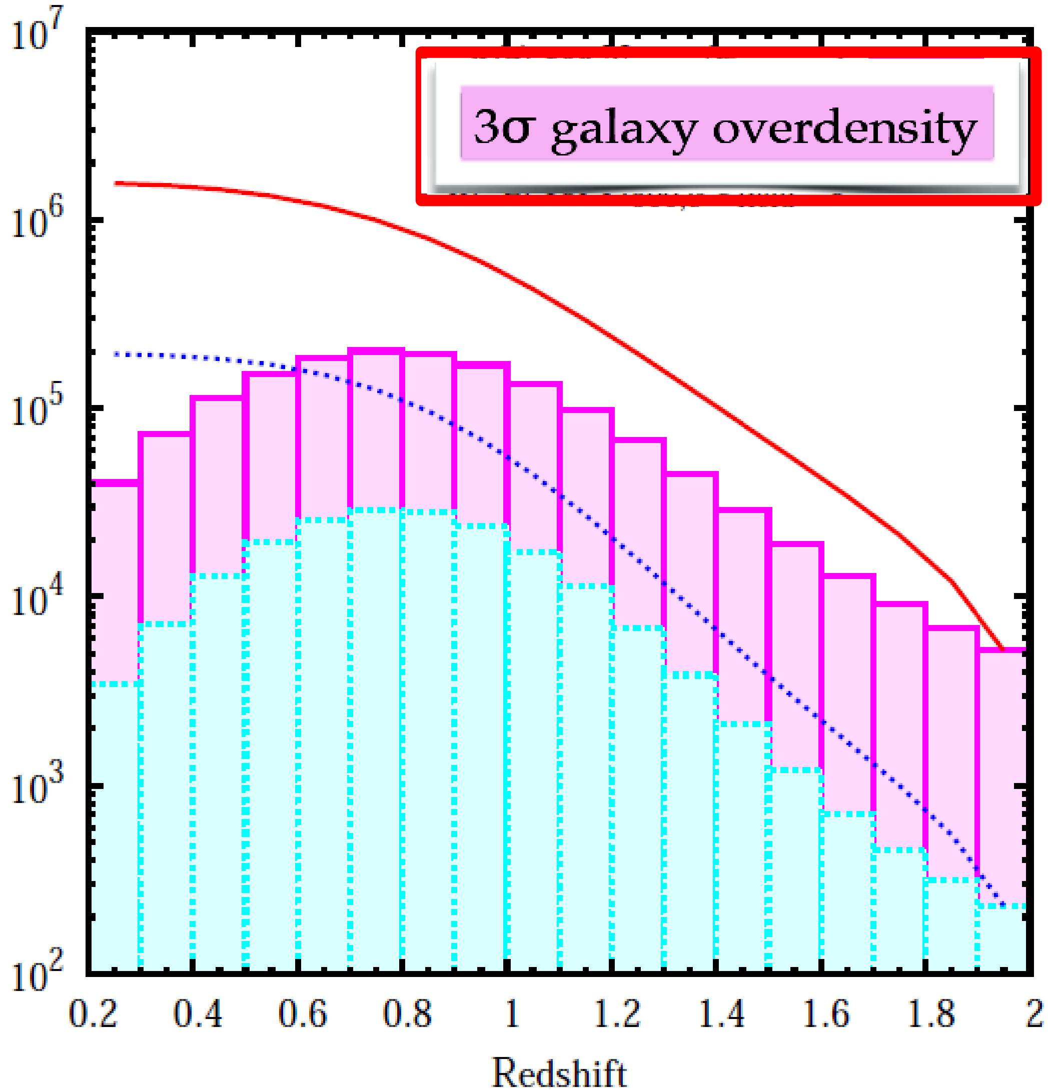
These counts are calculated down to the limiting magnitude H_{AB} = 24, as a function of redshift for clusters of different masses



5 σ galaxy overdensity

3 σ galaxy overdensity

Number of clusters



Euclid will detect
$\sim$ 2 10^5 objects at $0.2 \leq z \leq 2$,
$\sim$ 4 10^4 objects at $z > 1$
for the 5σ selection function.

By lowering the detection threshold down to 3σ, these numbers rise up to an order of magnitude.

5σ galaxy overdensity

15000 sq deg

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Cluster number density

$$N_{l,m} = \Delta\Omega \int_{z_l}^{z_{l+1}} dz \frac{dV}{dz d\Omega} \int_{M^{ob}_{l,m}}^{M^{ob}_{l,m+1}} dM^{ob} \int_0^\infty dM\, n(M,z)\; p(M^{ob}||M)\,.$$

Self – calibration method:
Probability of assigning a mass M_{obs} to a cluster of M_{true} is a lognormal distribution

$$p(M^{ob}|M) = \frac{\exp[-x^2(M^{ob})]}{\sqrt{2\pi\sigma^2_{\ln M}}}$$

where:

$$x(M^{ob}) = \frac{\ln M^{ob} - \ln M_{bias} - \ln M}{\sqrt{2\sigma^2_{\ln M}}}$$

Lima & Hu '05

Nuisance Parameters

$$\ln M_{bias}(z) = B_{M,0} + \alpha \ln(1+z)$$
$$\sigma^2_{\ln M}(z) = \sigma^2_{\ln M,0} - 1 + (1+z)^{2\beta}\,.$$

$$p_{nuisance,F} = \{B_{M,0} = 0, \alpha = 0, \sigma_{\ln M,0} = 0.2, \beta = 0.125\}$$

Sartoris+10

Cluster power spectrum

$$\bar{P}^{cl}_{l,m,i}(\mu, k, z_l) = \frac{\int_{z_l}^{z_{l+1}} dz\, \frac{dV}{dz}\, \tilde{n}^2(z)\, \tilde{P}(\mu, k, z)}{\int_{z_l}^{z_{l+1}} dz\, \frac{dV}{dz}\, \tilde{n}^2(z)}$$

Averaged cluster power spectrum

Comoving volume element

Cluster mass function convolved with the observable mass scaling relation

$$\tilde{n} \;=\; \int_0^\infty dM\, n(M, z)\, [\mathrm{erfc}(x_m) - \mathrm{erfc}(x_{m+1})].$$

$$\tilde{P}\,(k, \mu, z) \;=\; \left(b_{eff} + f\mu^2\right)^2 D^2(z)\, P\,(k)$$

Cluster power spectrum

Majumdar & Mohr '03

Sartoris+12

Cluster power spectrum

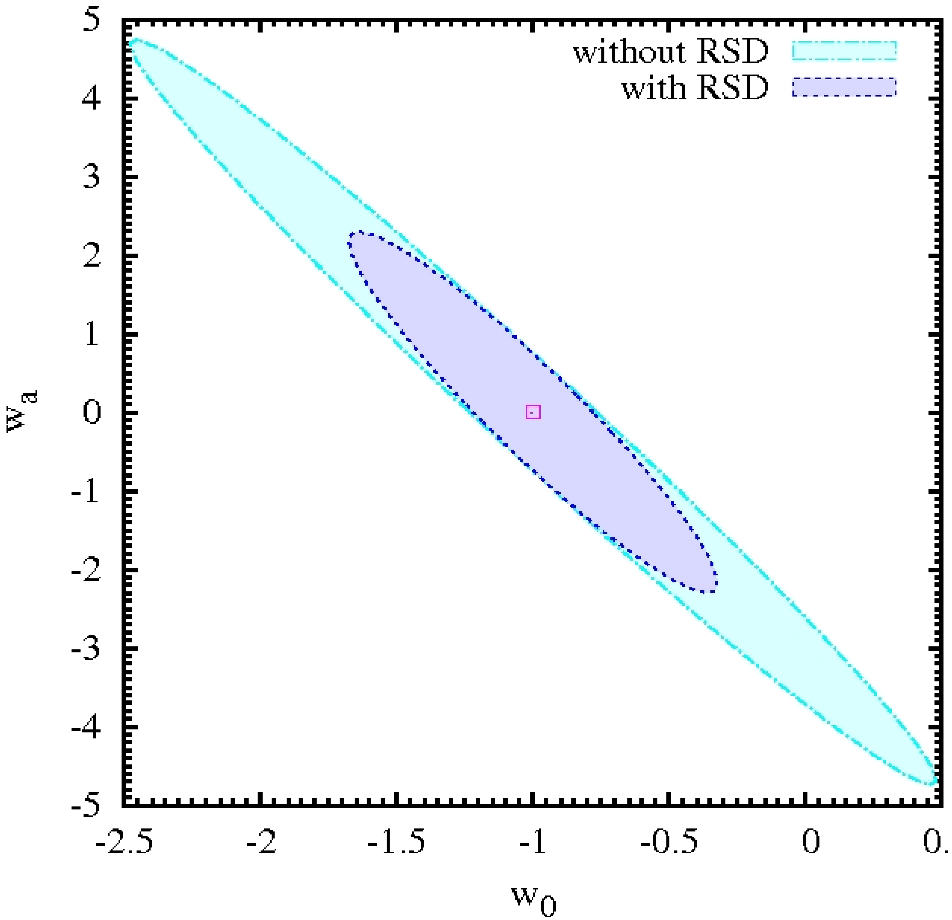
$$\bar{P}^{cl}_{l,m,i}(\mu, k, z_l) = \frac{\int_{z_l}^{z_{l+1}} dz\, \frac{dV}{dz}\, \tilde{n}^2(z)\, \tilde{P}(\mu, k, z)}{\int_{z_l}^{z_{l+1}} dz\, \frac{dV}{dz}\, \tilde{n}^2(z)}$$

Averaged cluster power spectrum

Comoving volume element

Cluster redshift space distosrtion contribution to w0-wa constraitns for a wide X-ray survey (WFXT)

$$\tilde{P}(k, \mu, z) = \left(b_{eff} + f\mu^2\right)^2 D^2(z)\, P(k)$$



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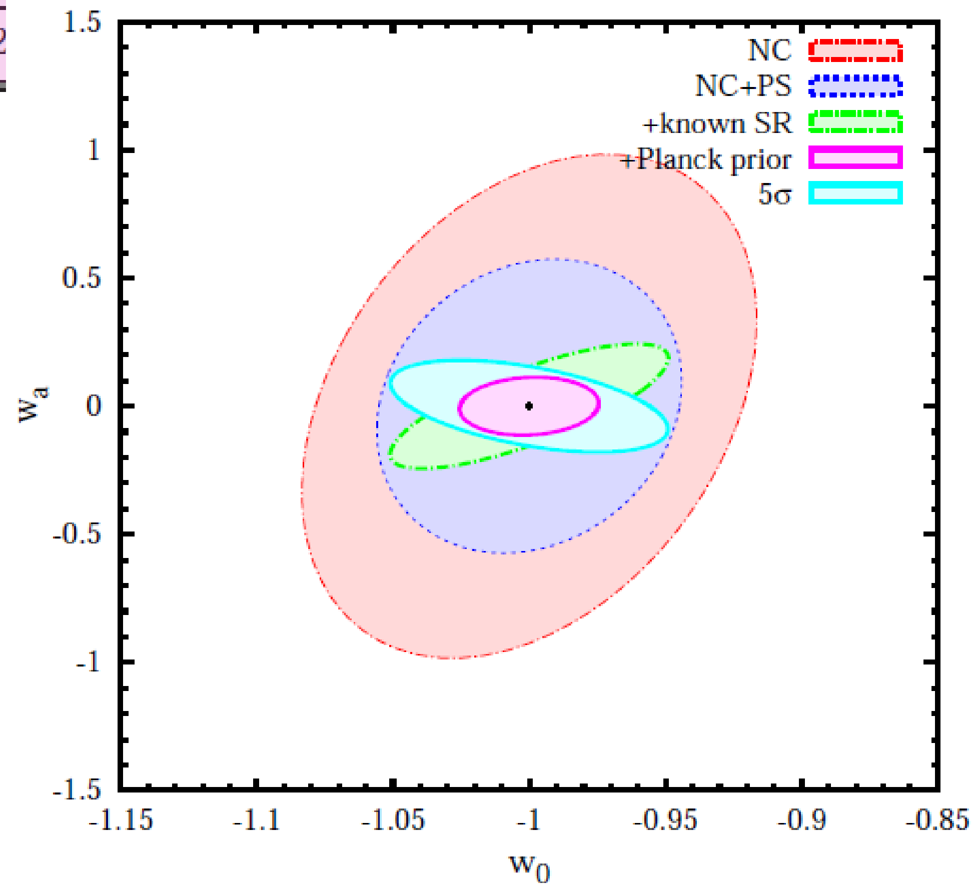
The statistical methods and the constraints on DE

Parameter arrays: Constraints:	Eqs. 16 & 28 FoM	Δw_0	Δw_a	$\Delta\Omega_m$	$\Delta\sigma_8$	Eqs. 22 & 28 $\Delta\gamma$	Eqs. 20 & 28 Δf_{NL}	Eqs. 26 & 28 $\Delta\Omega_\nu$
$N_{500,c}/\sigma_{\rm field} \geqslant 3$ *Euclid* photometric cluster selection								
NC+PS	73	0.037	0.38	0.0019	0.0032	0.023	6.67	0.0015
NC+PS+known SR	291	0.034	0.16	0.0011	0.0014	0.020	6.58	0.0013
NC+PS+known SR+Planck	802	0.017	0.074	0.0010	0.0012	0.015	4.93	0.0012
$N_{500,c}/\sigma_{\rm field} \geqslant 5$ *Euclid* photometric cluster selection								
NC+PS+known SR+Planck	209	0.034	0.12	0.0022	0.002			



Fisher matrix:

$$F_{ij} \equiv - < \frac{\partial^2 \ln \mathcal{L}}{\partial p_i \partial p_j} >$$

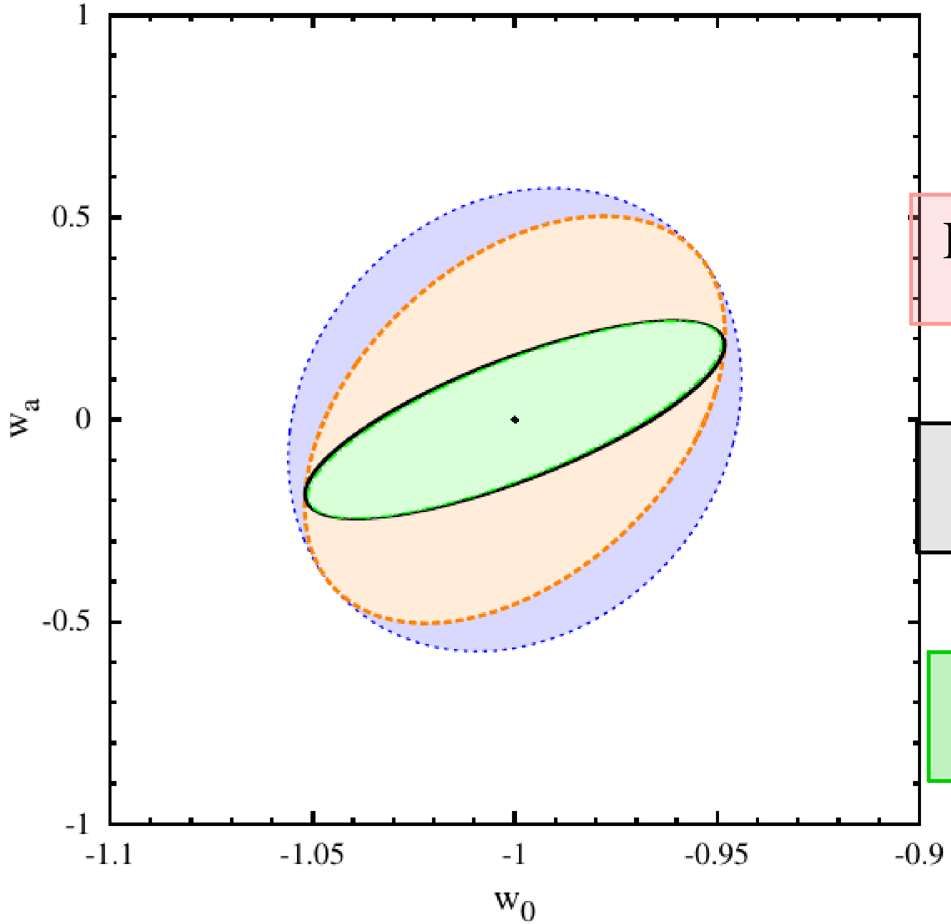
$$\boldsymbol{p} = \{\Omega_{\rm m}, \sigma_8, w_0, w_a, \Omega_k, \Omega_{\rm b}, H_0, n_{\rm S}\}$$

$$w(a) = w_0 + w_a(1-a)$$

Impact of scaling relations

Knowledge of the observable mass relation

No prior



Known scatter evolution

+

Known bias evolution

+

Known scaling relation at z=0

$$p(M^{ob}|M) = \frac{\exp[-x^2(M^{ob})]}{\sqrt{2\pi\sigma^2_{\ln M}}},$$

$$x(M^{ob}) = \frac{\ln M^{ob} - \ln M_{bias} - \ln M}{\sqrt{2\sigma^2_{\ln M}}}.$$

Simple parametrization of the nuisance parameters

$$\ln M_{bias}(z) = B_{M,0} + \alpha \ln(1+z)$$

$$\sigma^2_{\ln M}(z) = \sigma^2_{\ln M,0} - 1 + (1+z)^{2\beta}.$$

We need to know the bias evolution at 1% level

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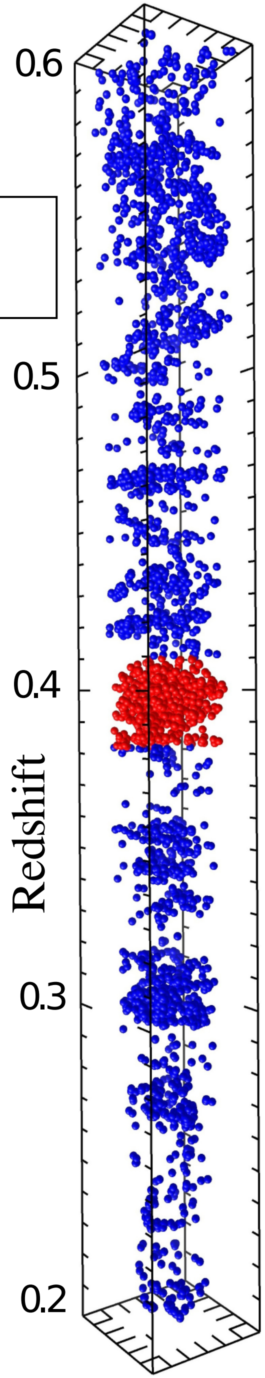
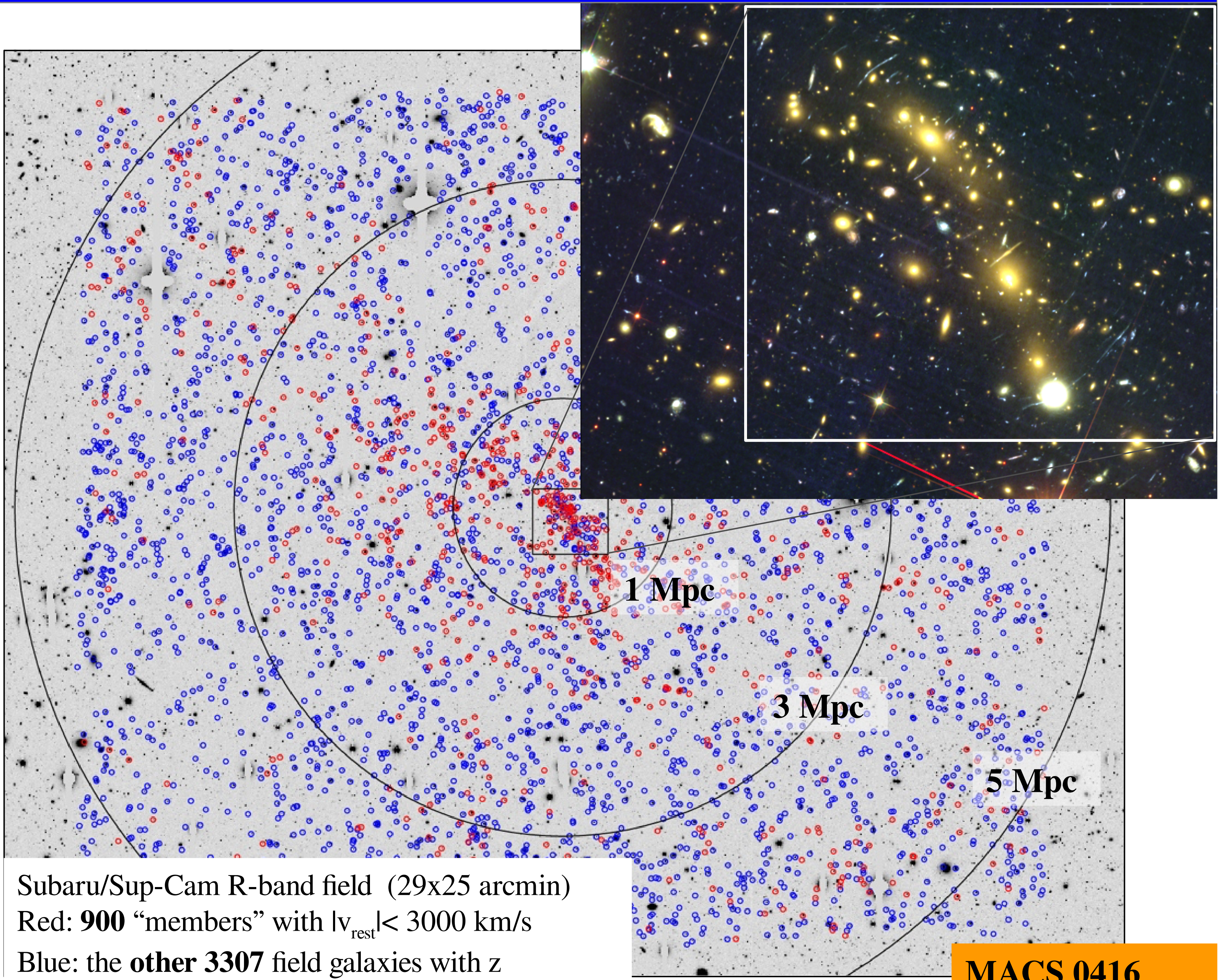
CLASH + CLASH-VLT +Subaru





Subaru/Sup-Cam R-band field (29x25 arcmin)
Red: **900** “members” with $|v_{rest}|$< 3000 km/s
Blue: the **other 3307** field galaxies with z

MACS 0416

Projected mass profiles from different analyses

MACS1206

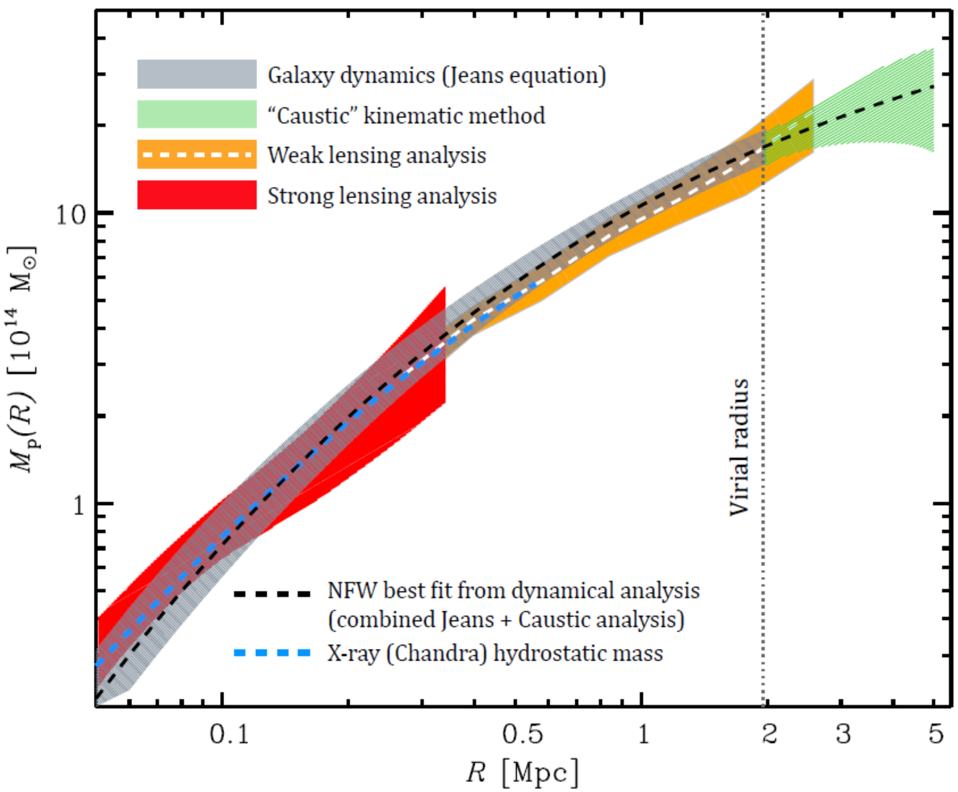
X-ray Chandra archival shallow data

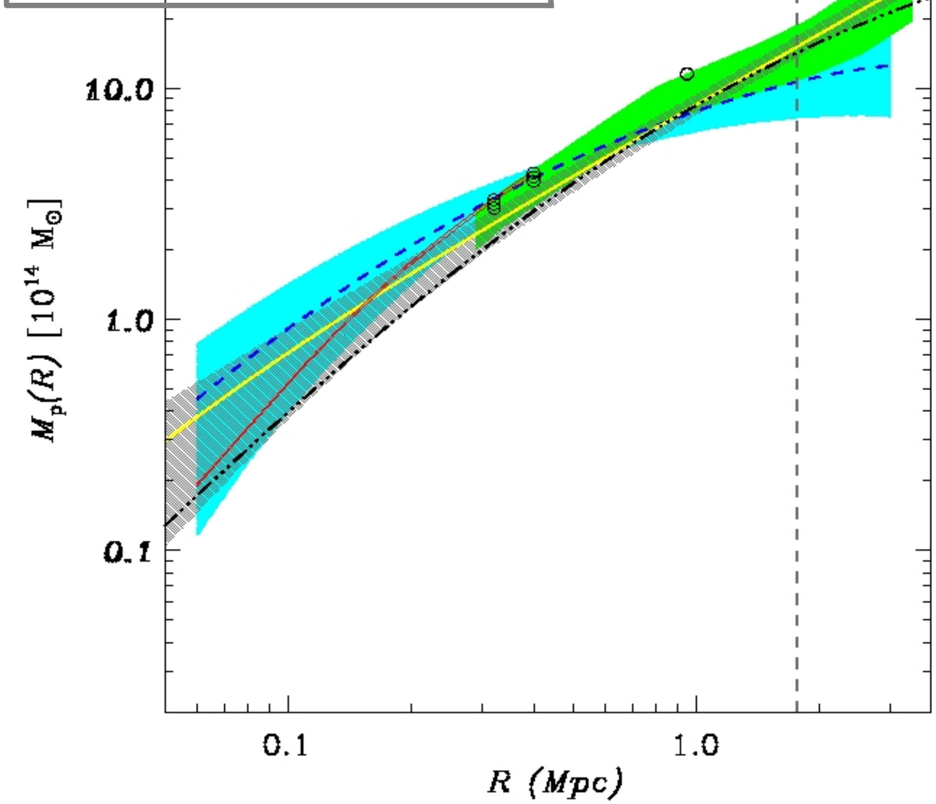
Weak lensing (Umetsu+14)

Strog lensing (Grillo+14)

Dynamic (Yellow+grey)

MACS 0416





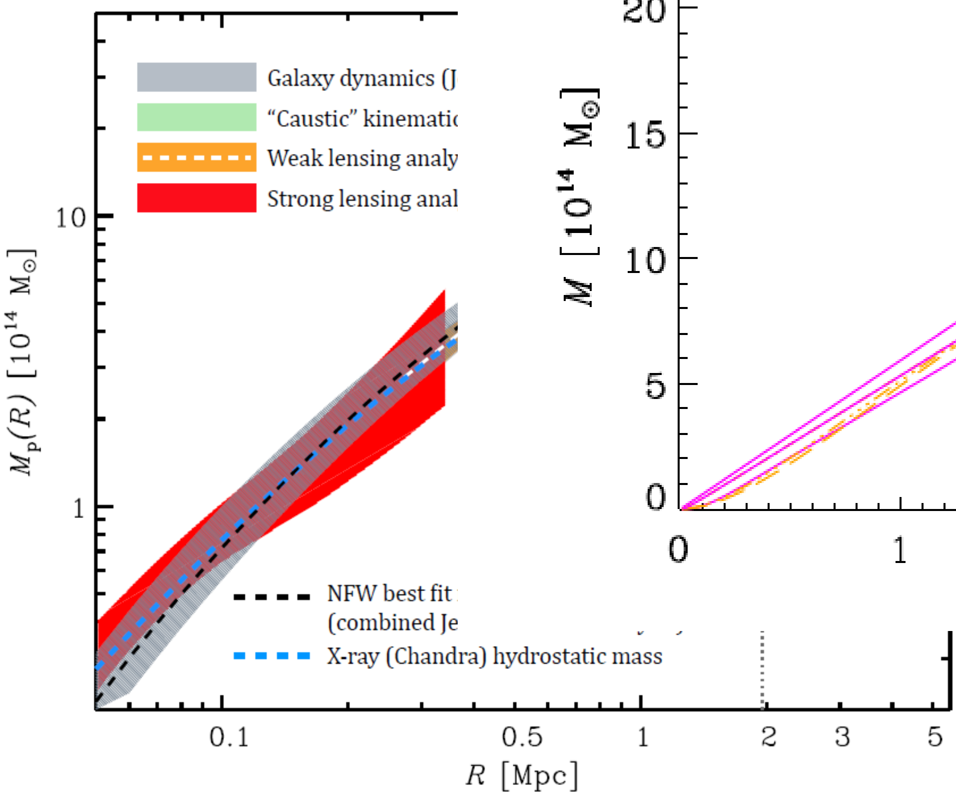
Umetsu+12 Biviano+13

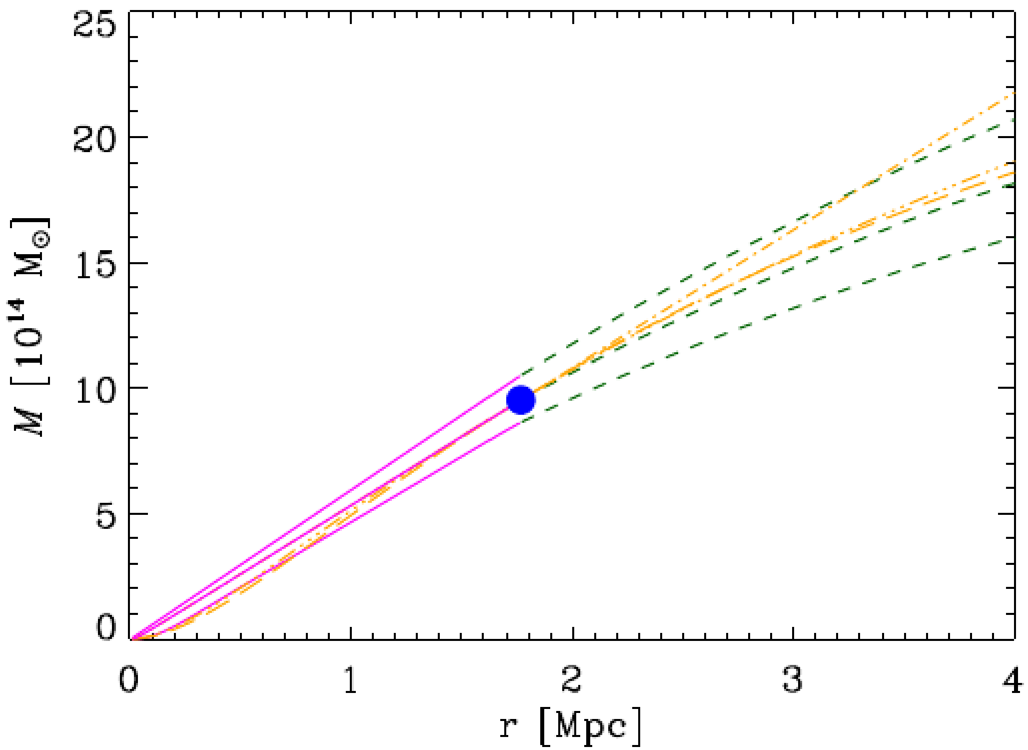
Balestra,BS+15

Projected mass profiles from different analyses

MACS1206

MACS 0416



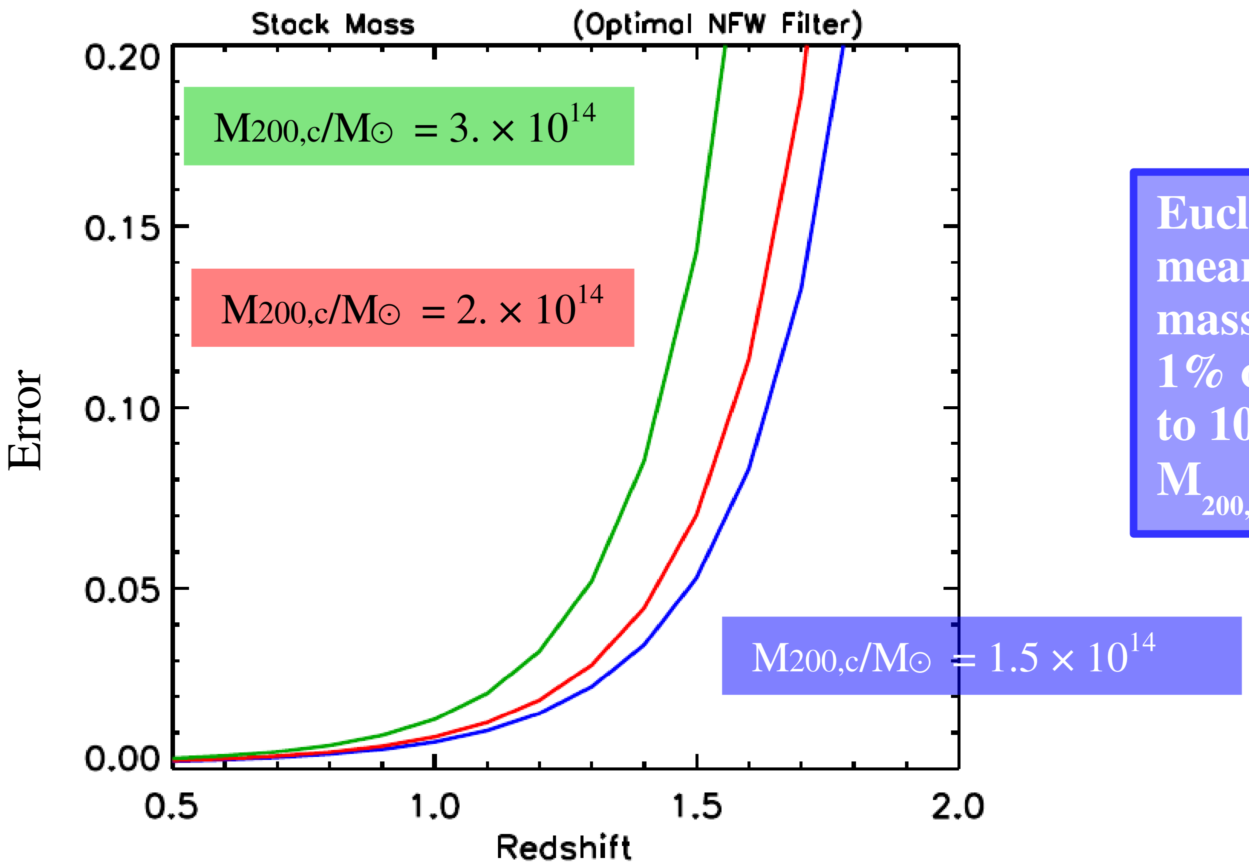


Umetsu+12 Biviano+13

Balestra,BS+15

Observable- mass scaling relation calibration

Errors expected on the mean mass of clusters in bins of $\Delta \log M200,c = 0.2$ and $\Delta z = 0.1$.



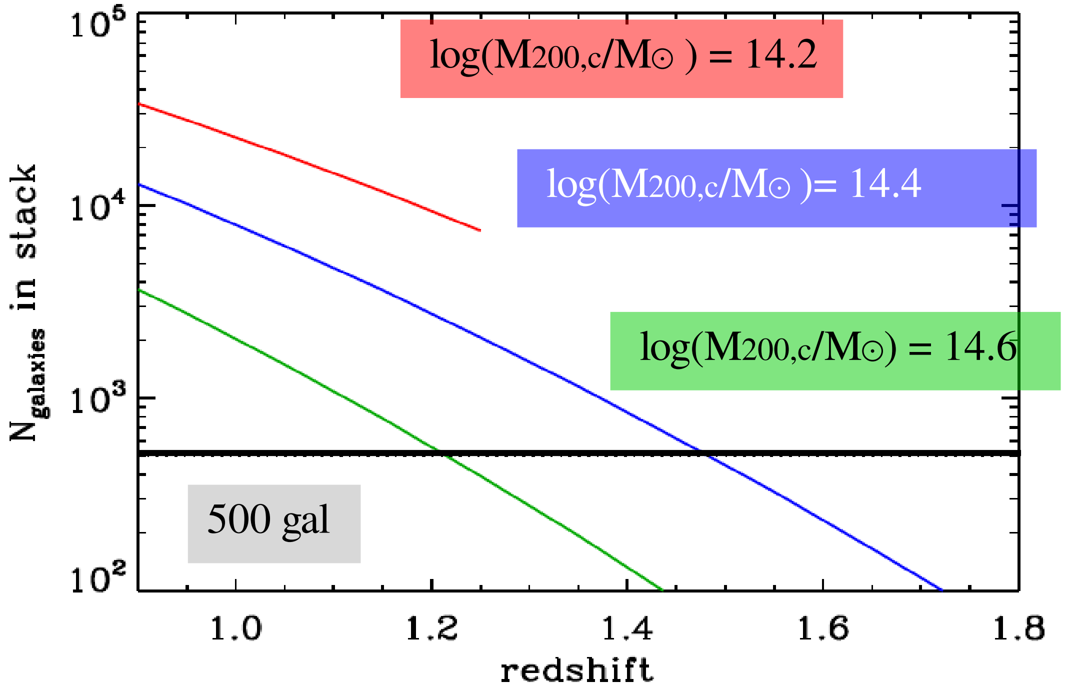
Euclid has the potential to calibrate the mean mass, and hence scaling relations bias, to 1% out to z=1, and to 10% out to z=1.6 for clusters of $M_{200,c} = 1.5 \times 10^{14}\ M_\odot$.

At lower mass systems because their larger number compensates for their lower individual S/N measurements.

Observable- mass scaling relation calibration

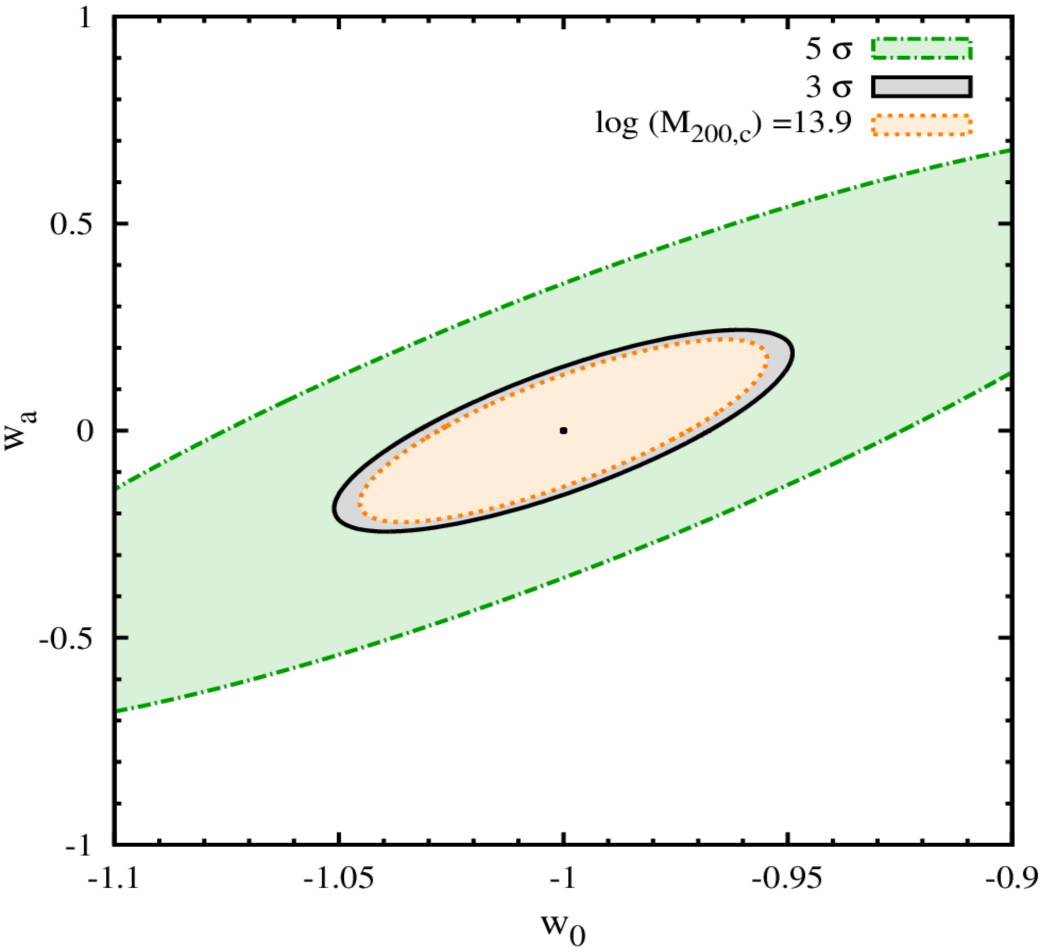
Number of cluster galaxies with spectroscopic redshifts available in stacks of clusters in bins of $\Delta \log M = 0.2$ and $\Delta z = 0.1$, as a function of redshift.

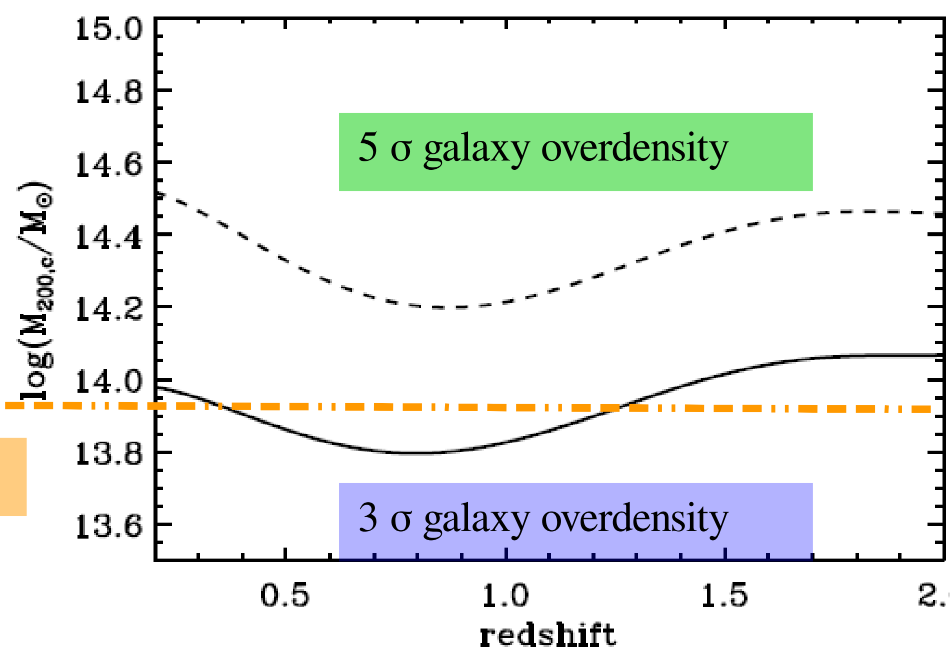
The estimate is done only for clusters with a mass limit above that required for a minimum of 5 members with redshift. → This requirement stops the red curve



The statistical noise in the velocity dispersion estimate of a sample of ~ 500 cluster members translates into a 30% statistical noise in the mass estimate.

Impact of selection function





log(M200,c /Mo) = 13.9

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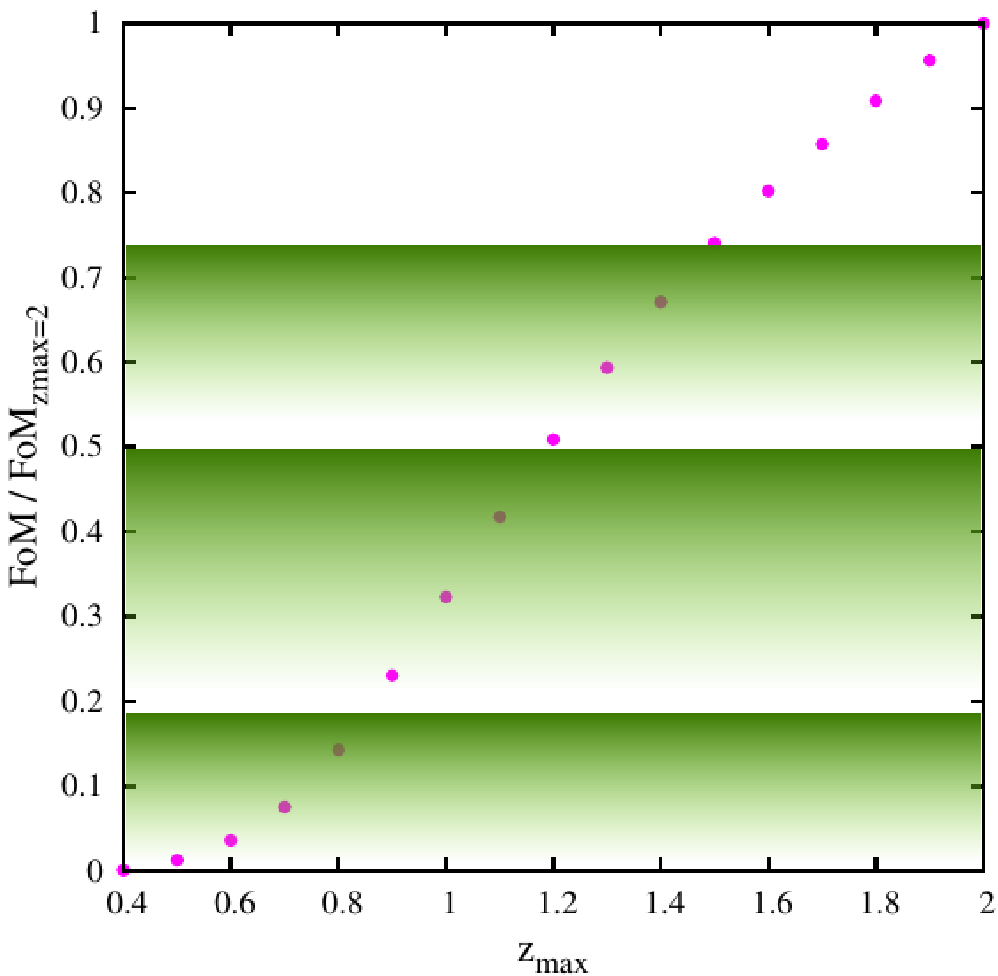
Impact of high redshift clusters

Relative FoM for number counts in the 3σ Euclid photometric cluster selection, as a function of the limiting redshift z_{max} of the survey, i.e. the ratio between the FoM evaluated over $0.2 \leq z \leq z_{max}$ and the FoM evaluated over $0.2 \leq z \leq 2.0$.



$$\mathrm{FoM} = \frac{1}{\sqrt{\det\left[\mathrm{Cov}\left(p_i, p_j\right)\right]}}$$

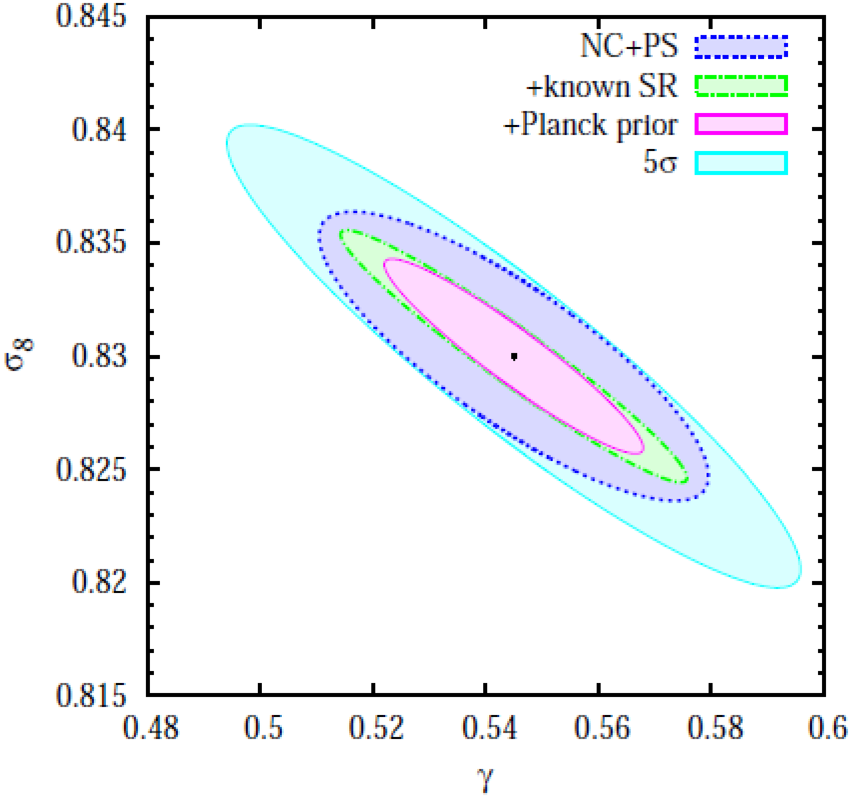
Constraints on deviation from GR

$N_{500,c}/\sigma_{\rm field} \geqslant 3$ *Euclid* photometric cluster selection								
Parameter arrays:		Eqs. 16 & 28				Eqs. 22 & 28	Eqs. 20 & 28	Eqs. 26 & 28
Constraints:	FoM	Δw_0	Δw_a	$\Delta\Omega_m$	$\Delta\sigma_8$	$\Delta\gamma$	Δf_{NL}	$\Delta\Omega_\nu$
NC+PS	73	0.037	0.38	0.0019	0.0032	0.023	6.67	0.0015
NC+PS+known SR	291	0.034	0.16	0.0011	0.0014	0.020	6.58	0.0013
NC+PS+known SR+Planck	802	0.017	0.074	0.0010	0.0012	0.015	4.93	0.0012
$N_{500,c}/\sigma_{\rm field} \geqslant 5$ *Euclid* photometric cluster selection								
NC+PS+known SR+Planck	209	0.034	0.12	0.0022	0.0026	0.034	6.74	0.0020

$$\boldsymbol{p} = \{\Omega_{\rm m}, \sigma_8, w_0, w_a, \Omega_k, \Omega_{\rm b}, H_0, n_{\rm S}, \gamma\}$$

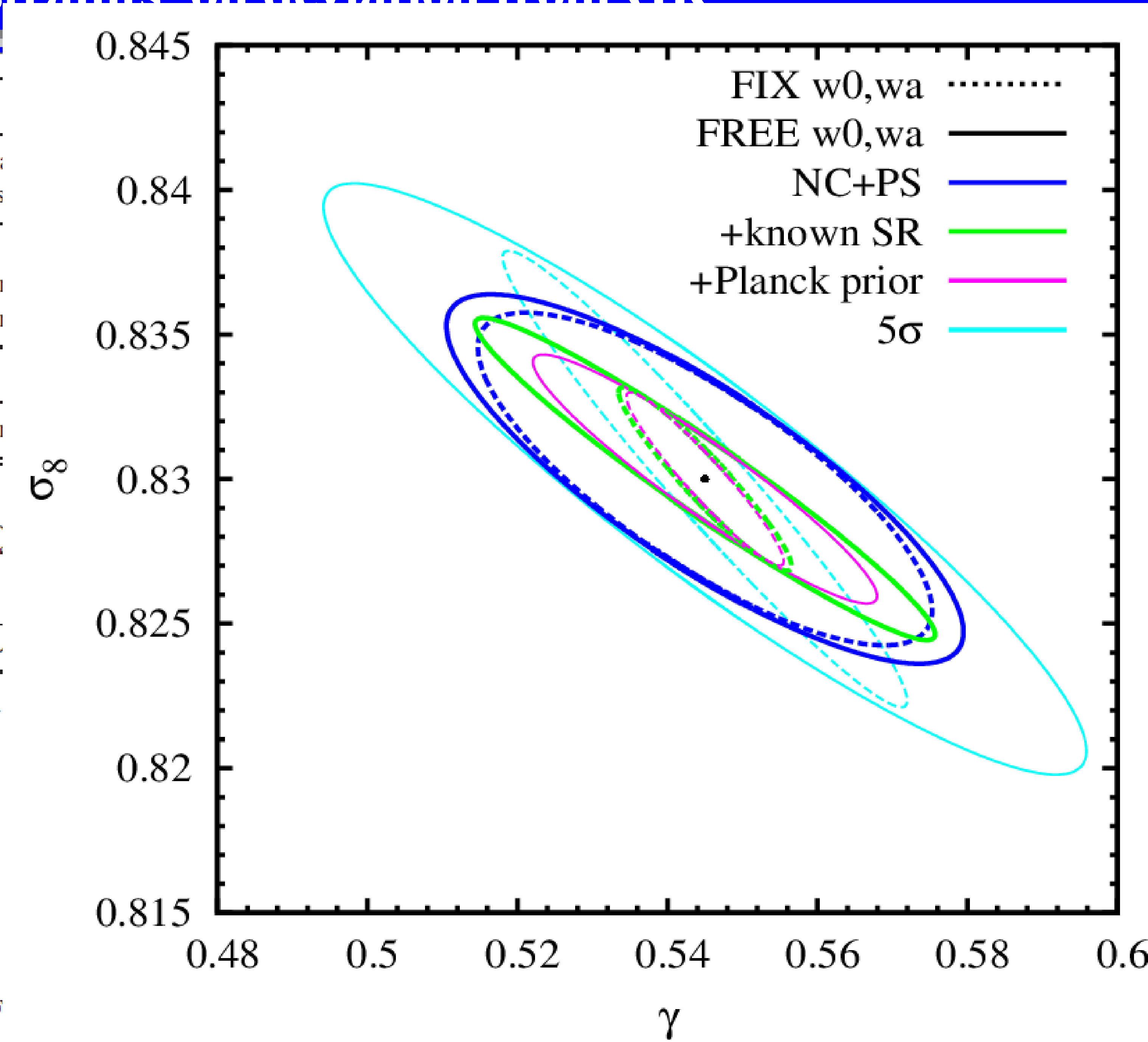
$$\frac{d\ln D(a)}{d\ln a} = \Omega_{\rm m}^{\gamma}(a)$$

$$\boldsymbol{p}_{\rm nuisance,F} = \{B_{M,0} = 0, \alpha = 0, \sigma_{\ln M,0} = 0.2, \beta = 0.125\}$$



Constraints on deviation from GR

Parameter	. 26 & 28
Constraints	$\Delta\Omega_\nu$
NC+PS	).0015
NC+PS+k	).0013
NC+PS+k	).0012
NC+PS+k	).0020



$p = \{\Omega$

$\frac{d \ln L}{d \ln}$

$p_{\mathrm{nuisance, F}}$

Constraints on Non-Gaussianity

Parameter arrays:		Eqs. 16 & 28				Eqs. 22 & 28	Eqs. 20 & 28	Eqs. 26 & 28
Constraints:	FoM	Δw_0	Δw_a	$\Delta\Omega_m$	$\Delta\sigma_8$	$\Delta\gamma$	Δf_{NL}	$\Delta\Omega_\nu$
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NC+PS	73	0.037	0.38	0.0019	0.0032	0.023	6.67	0.0015
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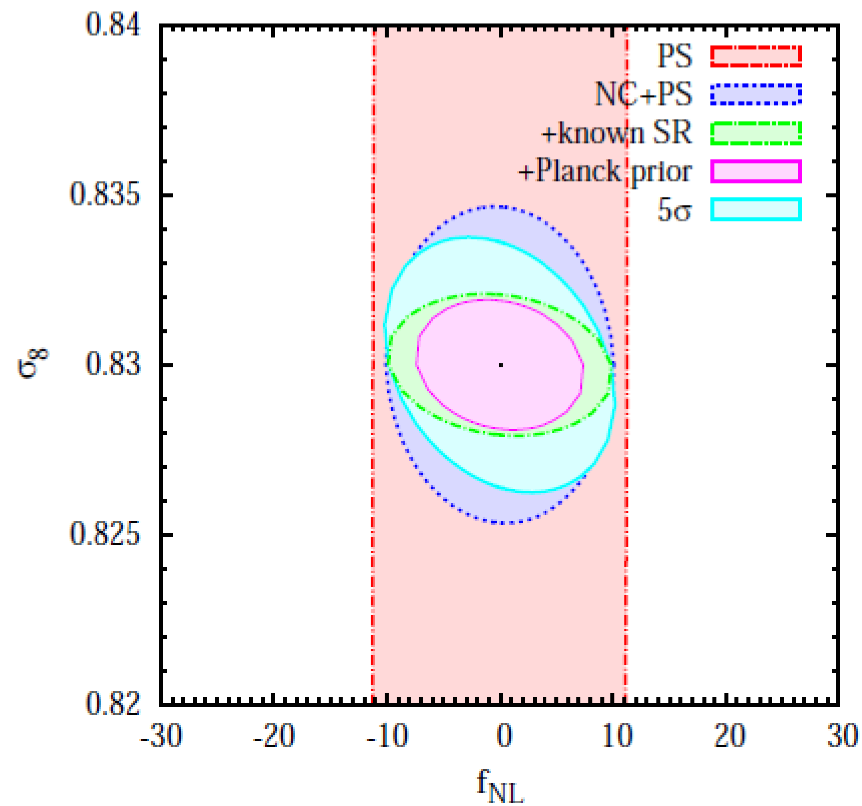
$N_{500,c}/\sigma_{\rm field} \geqslant 5$ *Euclid* photometric cluster selection								
NC+PS+known SR+Planck	209	0.034	0.12	0.0022	0.0026	0.034	6.74	0.0020

$$\boldsymbol{p} = \{\Omega_{\rm m}, \sigma_8, w_0, w_a, \Omega_k, \Omega_{\rm b}, H_0, n_{\rm S}, f_{\rm NL}\}$$

$$\Phi = \Phi_{\rm G} + f_{\rm NL}\left(\Phi_{\rm G}^2 - \langle\Phi_{\rm G}^2\rangle\right)$$

$$\boldsymbol{p}_{\rm nuisance,F} = \{B_{M,0} = 0, \alpha = 0, \sigma_{\ln M,0} = 0.2, \beta = 0.125\}$$



Barbara Sartoris+ arXiv:1505.02165

Constraints on Neutrino mass

$N_{500,c}/\sigma_{\rm field} \geqslant 3$ *Euclid* photometric cluster selection								
Parameter arrays:	Eqs. 16 & 28					Eqs. 22 & 28	Eqs. 20 & 28	Eqs. 26 & 28
Constraints:	FoM	Δw_0	Δw_a	$\Delta\Omega_m$	$\Delta\sigma_8$	$\Delta\gamma$	Δf_{NL}	$\Delta\Omega_\nu$
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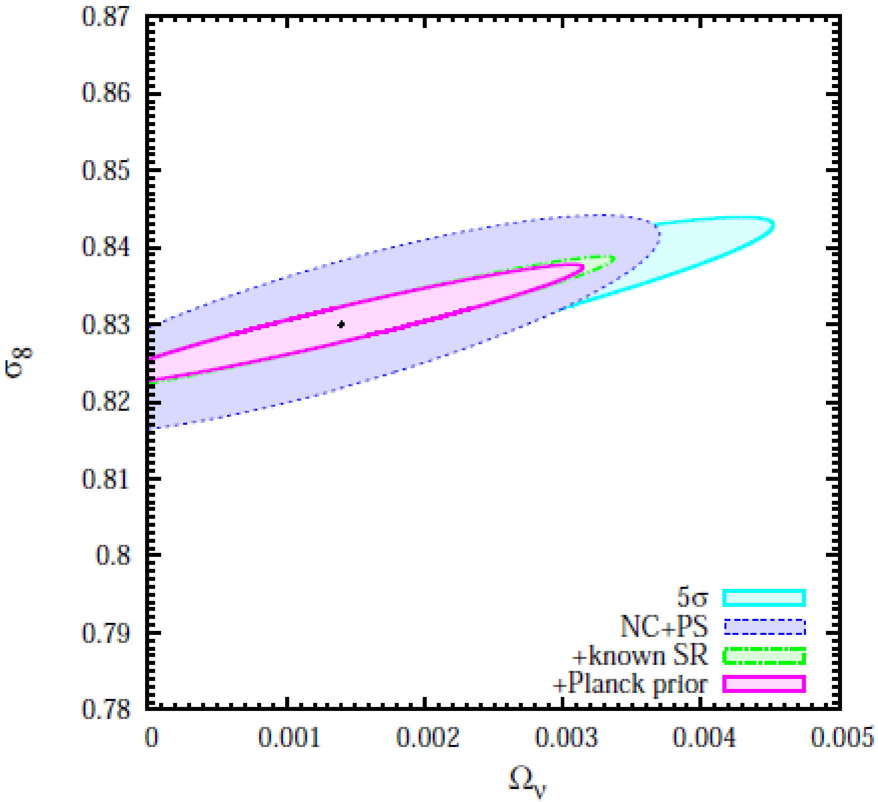
$N_{500,c}/\sigma_{\rm field} \geqslant 5$ *Euclid* photometric cluster selection								
NC+PS+known SR+Planck	209	0.034	0.12	0.0022	0.0026	0.034	6.74	0.0020



$$\boldsymbol{p} = \{\Omega_{\rm m}, \sigma_8, w_0, w_a, \Omega_k, \Omega_{\rm b}, H_0, n_{\rm S}, \Omega_\nu\}$$

$$\Omega_\nu = \frac{\rho_\nu}{\rho_c} = \frac{\sum_i^{N_\nu} m_{\nu,i}}{93.14\,{\rm h}^2\,{\rm eV}},$$

$$\rho_m \rightarrow \rho_{CDM} = \rho_m - \rho_b$$

$$P_m \rightarrow P_{CDM}(k) = P_m(k)\left[\frac{\Omega_{CDM} T_{CDM}(k,z) + \Omega_b T_b(k,z)}{(\Omega_b + \Omega_{CDM})\, T_m(k,z)}\right]^2$$

$$\boldsymbol{p}_{\rm nuisance,\,F} = \{B_{M,0} = 0, \alpha = 0, \sigma_{\ln M,0} = 0.2, \beta = 0.125\}$$