VINCENZO F. CARDONE

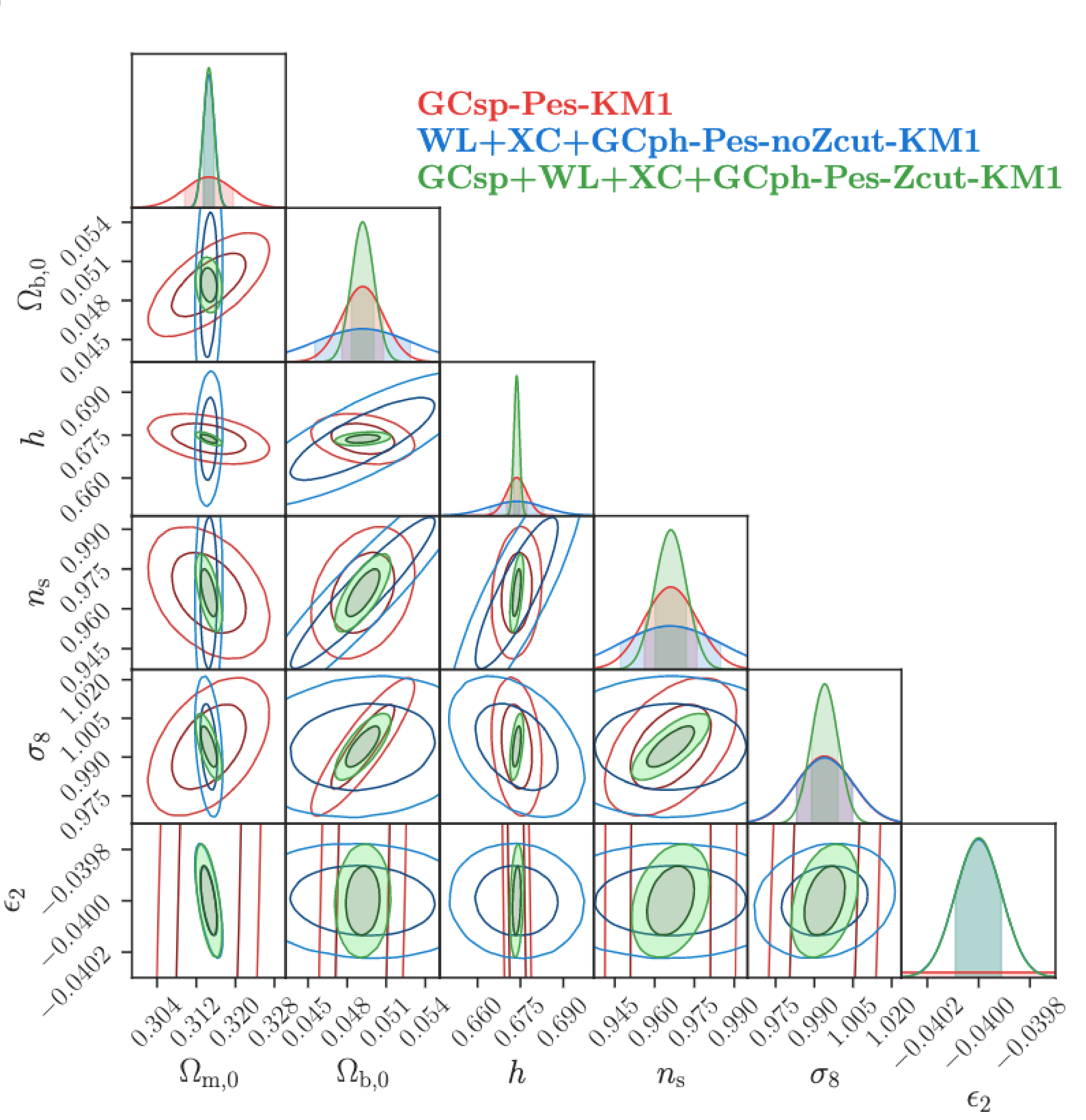
WEAK LENSING

V Euclid Italia Meeting - 24 Febbraio 2022

Current WLSWG Activities

ONLY THOSE WITH ITALIAN PARTICIPATION

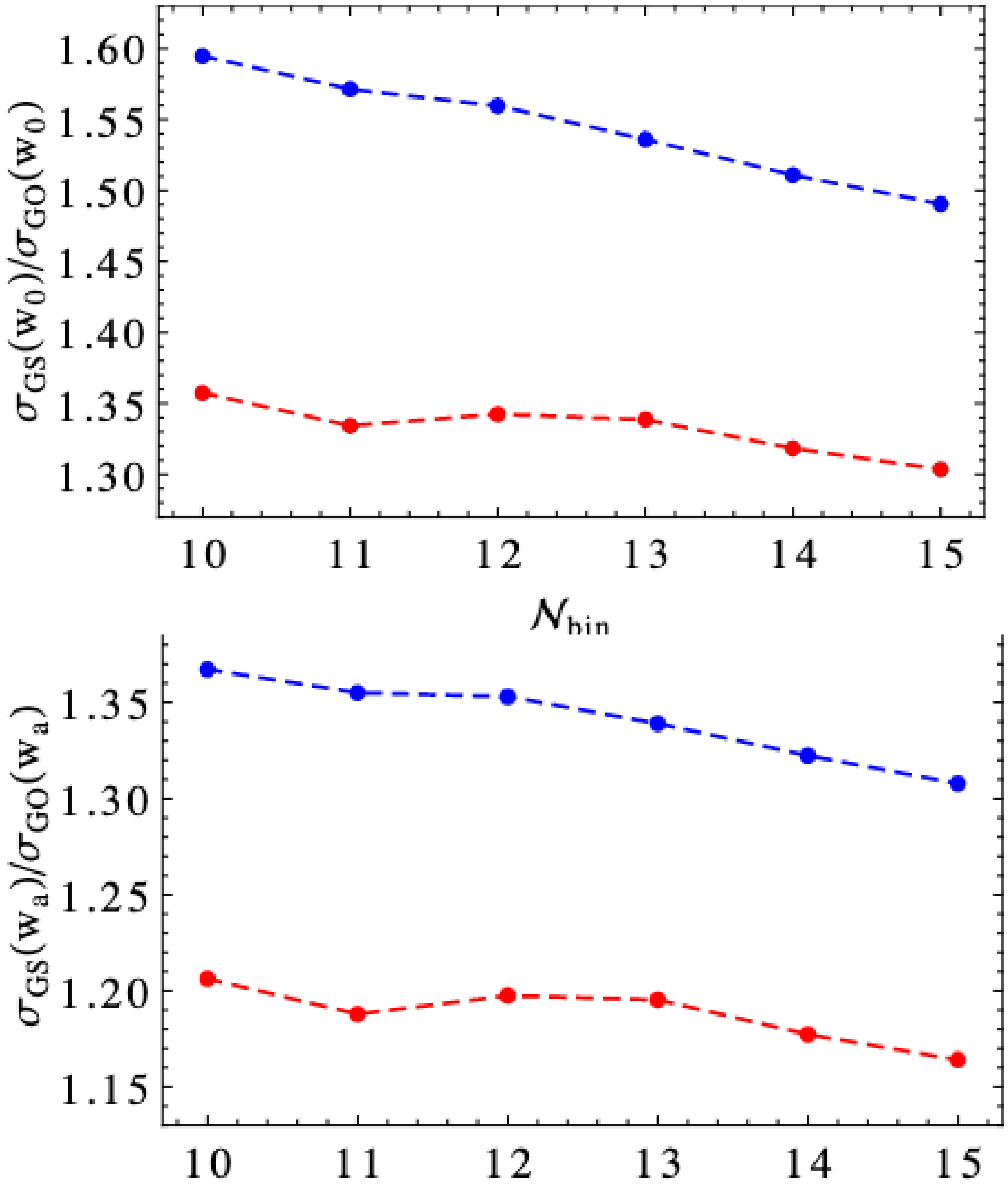
- Forecasts for extended models (jointly with TWG)
- E2E pipeline to evaluate the impact of systematics
- High Order Statistics (HOWLs Key Project)
- Weak Lensing simulations (see Carlo Giocoli talk)



Forecasts for MG

SCALE INDEPENDENT MODELS

- *three cases: DGP, JBD, k - mouflage*
- *two different sets of fiducial parameters*
  - consistent with Planck data
  - quasi LCDM
- *3x2pt + GCsp*
  - quasilinear/nonlinear
  - pessimistic/optimistic
  - single/joint



FORECASTS FOR DARK MATTER

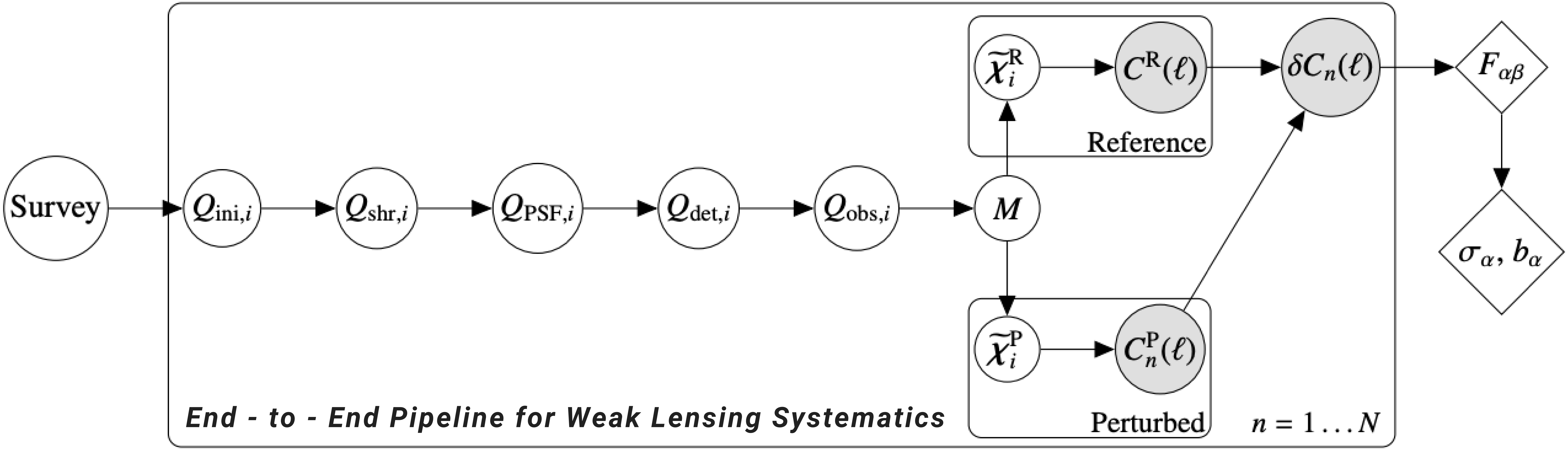
- massive neutrinos (both in GR and MG)
- particle dark matter
- generlised dark matter models
- primordial black holes

SUPER SAMPLE COVARIANCE

- impact of SSC on 3x2pt forecasts
- included in 6x2pt forecasts (see M. Carbone talk)
- Gaussian + SSC covariance (see C. Giocoli talk)

ITALIAN PARTICIPATION

- WP leads: Maria Archidiacono, Stefano Camera
- Key Project Paper leads: M. Bonici, D. Sciotti
- Participating: M. Bonici, C. Carbone, V.F. Cardone, C. Giocoli, M. Martinelli, F. Pace, G. Parimbelli, D. Sciotti



AIM

evaluate the impact of residual systematics

METHOD

emulate moments estimate adding systematics

REMOVE

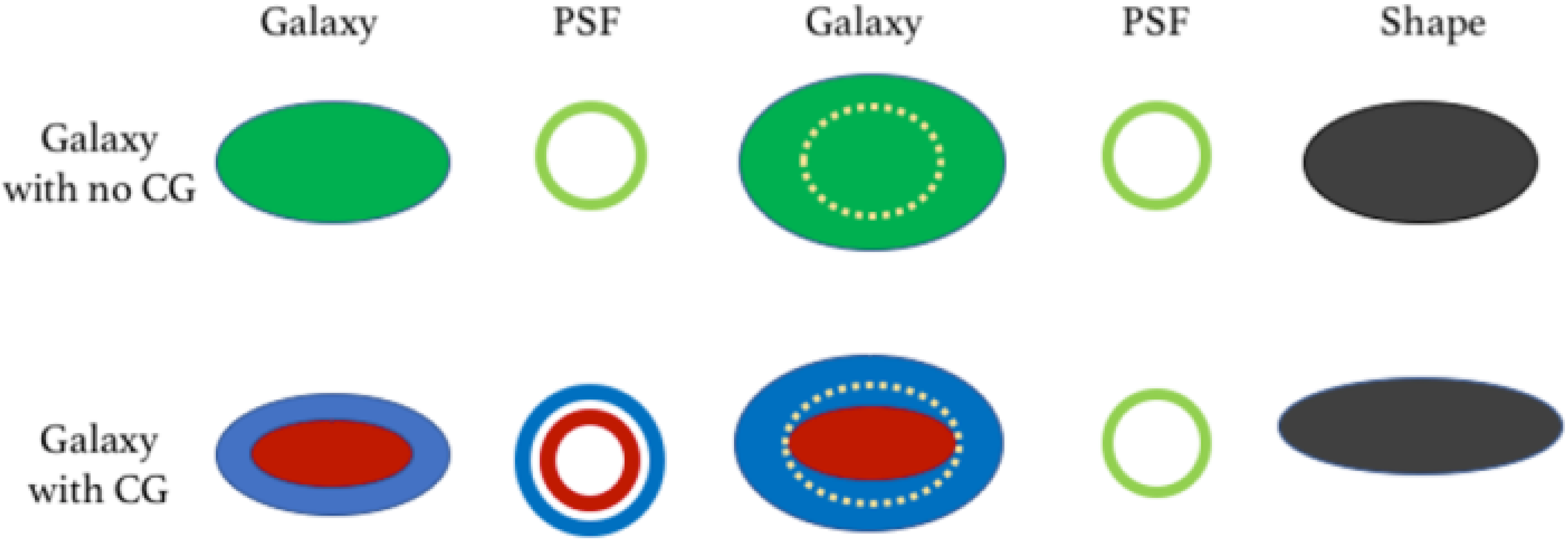
use a fiducial model to remove systematics

PERTURB

remove systematics with a perturbed model

BIAS

compare with the correct model and find bias



ITALY AND E2E

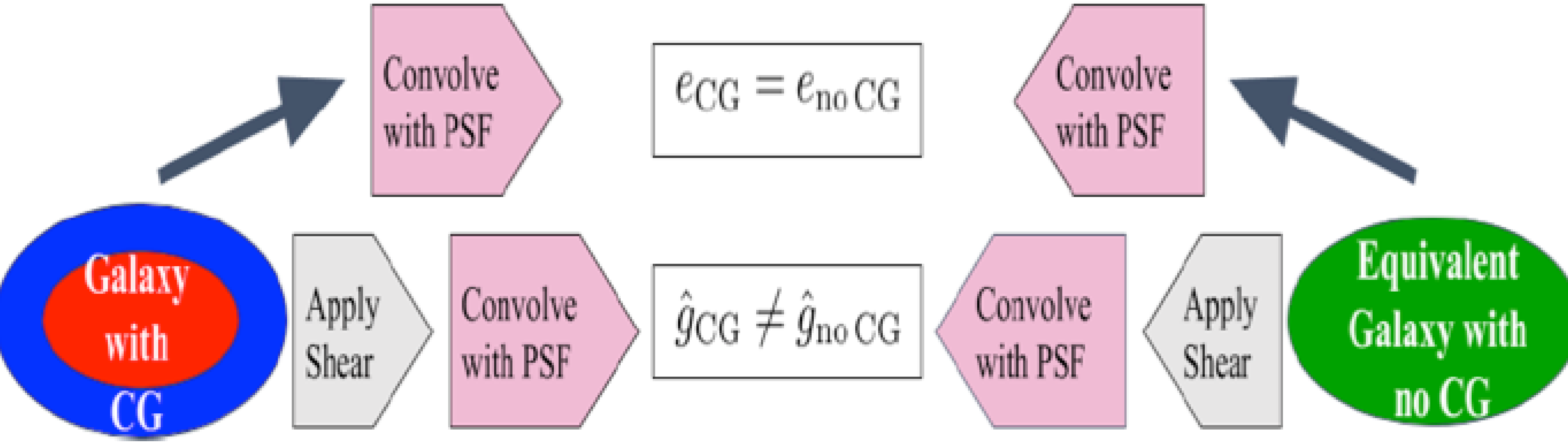
fiducial and perturbed model for color gradient bias correction

CG BIAS

wavelength dependent PSF and spatially varing galaxy SED

CALIBRATION

method tested on simulated galaxies and validated on HST images



CG GALAXY

emulate analytic galaxy according to a B+D model

EUCLIDIZE

simulate galaxy as would be detected by Euclid VIS

NO CG GAL

same shape but without spatially varying SED

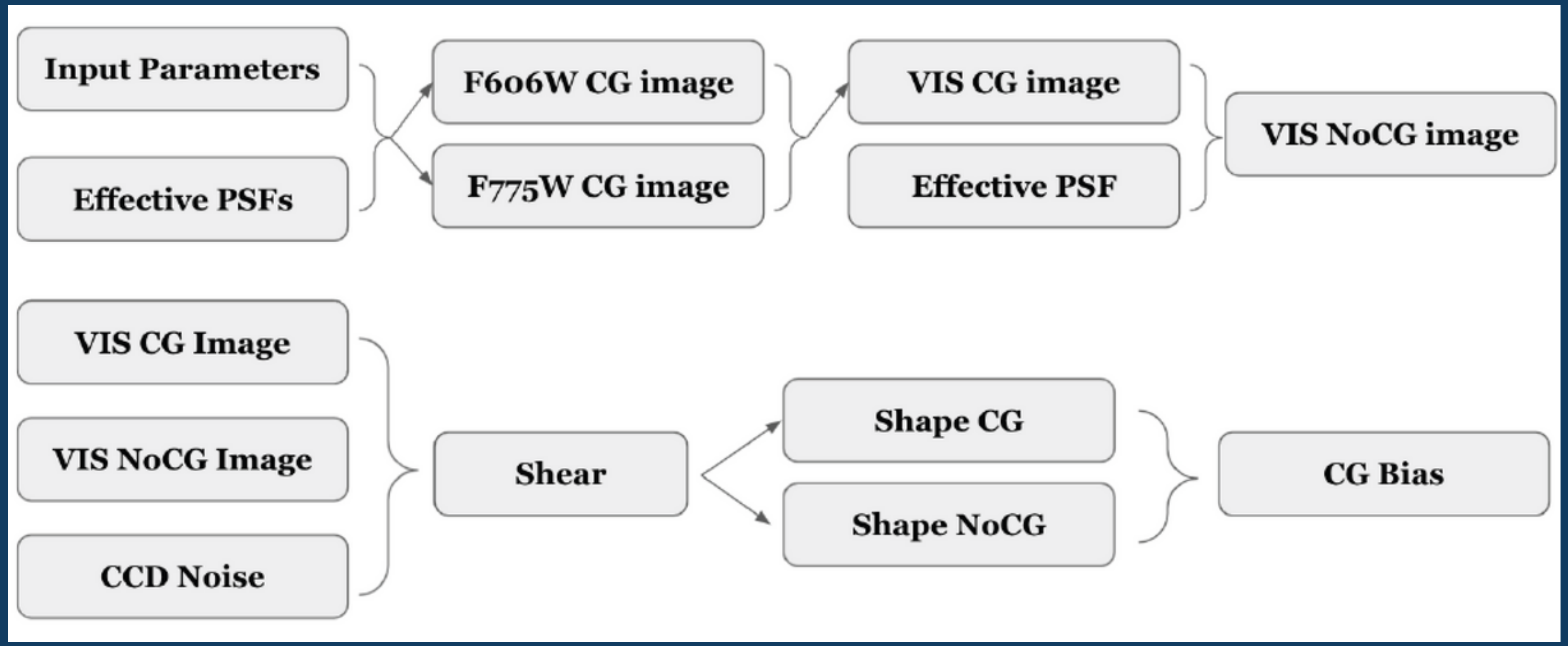
SHEAR

apply shear to both galaxies and measure shape

BIAS

compare the shape to measure CG bias

Color Gradient Bias Calibration



CG BIAS PIPELINE

- input galaxy model from RAGE catalog
- PSF and noise as for Euclid VIS
- simulate galaxies with GalSim
- different shape measurement methods

$$m(x_1, x_2) = \sum_{i=1}^{n_{RBF}} \omega_i \, \phi(\epsilon, r_i)$$

$$r_i = \left[\left(x_1 - x_1^i\right)^2 + \left(x_2 - x_2^i\right)^2 \right]^{1/2}$$

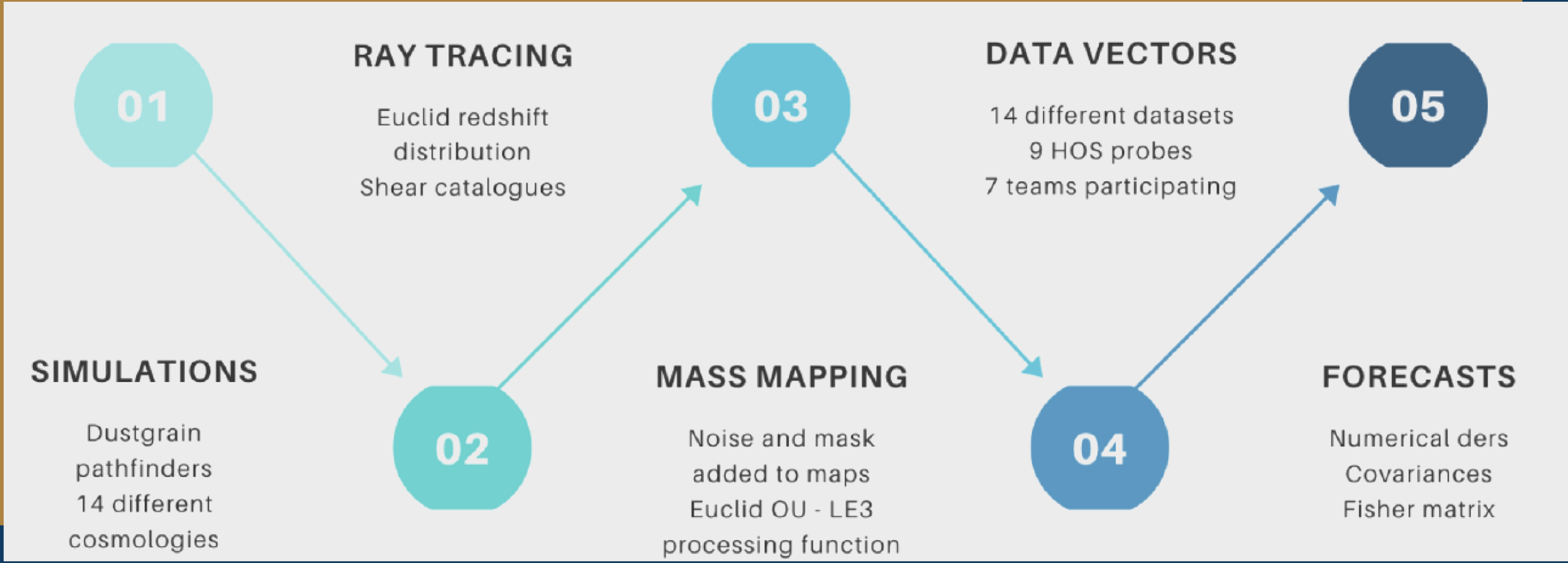
$$\phi(\epsilon, r) = e^{-\epsilon^2 r^2} \; ; \; \phi(\epsilon, r) = \left(1 + \epsilon^2 r^2\right)^{-1} \; ; \; \phi(\epsilon, r) = \left(1 + \epsilon^2 r^2\right)^{-1/2} \; ; \; \phi(\epsilon, r) = \left(1 + \epsilon^2 r^2\right)^{1/2}$$

CG BIAS CORRECTION

- CG bias as function of (S/N, z, log L)
- radial basis function interpolation
- fullfilling Euclid requirements
- validation in course with HST galaxies

Italian members: *V.F. Cardone, M.A. Raj, R. Maoli, R. Scaramella, C. Tortora*

HOWLS - Higher Order Statistics in Weak Lensing



- Key Project of the WLSWG
- Joint project of the Mass Mapping and High Order Statistics WP
- Also involves WL Simulations WP (see C. Giocoli talk)

HOWLS in four steps

SIMULATIONS

- 14 different cosmologies with DUSTGRAIN
- 928 LCDM maps from SLICS
- shear catalogues
- convergence maps with Euclid KS code

DERIVATIVES

- 3 points stencil with 4% step
- 3 points stencil with 16% step
- linear unweighted fit
- linear weighted fit

MEASUREMENT

- Betti numbers
- Convergence PDF
- Homology heatmaps
- Mass aperture 3pCF
- Minkowski functionals
- Scattering transform

FORECASTS

- three parameters varied (Om, w0, sigma8)
- Fisher matrix method
- covariance matrix from SLICS sims
- checking whether the likelihood is Gaussian
- impact of sampling and specifics cut
- estimate of errors on errors

Italian members: M. Baldi, M. Carbone, V.F. Cardone, C. Giocoli, M. Vicinanza, S. Vinciguerra

HOWLS - Fisher Matrix Forecasts

Table 1: HOWLS step 3 forecasts for *Euclid* mocks rescaled to a 15 000 deg^2 area. Covariance computed from 924 SLICS realizations, model from 128 × 6 DUSTGRAIN realizations. Only bins with skewness and kurtosis lower than 0.25 across the SLICS are retained.

cosmo	configuration	scale	probes	δw_0	$\delta\sigma_8$	$\delta\Omega_m$
16 %	ks_nomask_shear	2.34	Minkowski_Simone	1.93 %	0.63 %	1.34 %
–	–	–	–	–	0.55 %	1.12 %
16 %	ks_nomask_shear	2.34	Betti_Simone	2.64 %	1.15 %	2.30 %
–	–	–	–	–	0.79 %	1.50 %
16 %	ks_nomask_shear	2.34	Peaks_Sandrine	17.99 %	3.88 %	7.93 %
–	–	–	–	–	2.32 %	4.34 %
16 %	ks_nomask_shear	4.69	PDF_Cora	–	–	–
–	–	–	–	–	–	–
16 %	ks_nomask_shear	–	kappa2PCF_Simone	93.47 %	22.51 %	26.09 %
–	–	–	–	–	1.81 %	3.11 %
16 %	ks_nomask_shear	2.34	Moments_Simone	–	–	–
–	–	–	–	–	–	–
16 %	ks_nomask_shear	4.69	Moments_Cora	–	–	–
–	–	–	–	–	–	–
16 %	ks_nomask_shear	2.34	ST_Sihao	7.18 %	2.02 %	4.26 %
–	–	–	–	–	1.72 %	3.64 %
16 %	ks_nomask_shear	–	shear2PCF_Nicolas	–	–	–
–	–	–	–	–	–	–
16 %	ks_nomask_shear	–	Map3_LailaSven	–	–	–
–	–	–	–	–	–	–
16 %	ks_nomask_shear	2.34	Betti_Sven	2.52 %	0.77 %	1.49 %
–	–	–	–	–	0.67 %	1.37 %
16 %	ks_nomask_shear	2.34	Heatmap_Sven	10.67 %	5.84 %	6.94 %
–	–	–	–	–	5.65 %	6.92 %
16 %	ks_nomask_shear	–	Map_Lucas	8.40 %	4.00 %	7.68 %
–	–	–	–	–	2.80 %	5.65 %

le 1 without the skewness/kurtosis cut.

probes	δw_0	$\delta\sigma_8$	$\delta\Omega_m$
Minkowski_Simone	1.51 %	0.54 %	1.17 %
–	–	0.49 %	1.04 %
Betti_Simone	2.15 %	0.86 %	1.68 %
–	–	0.67 %	1.26 %
Peaks_Sandrine	1.30 %	0.40 %	0.73 %
–	–	0.33 %	0.65 %
PDF_Cora	1.17 %	0.46 %	0.77 %
–	–	0.45 %	0.70 %
kappa2PCF_Simone	3.68 %	0.78 %	1.07 %
–	–	0.56 %	0.92 %
Moments_Simone	2.79 %	0.33 %	1.19 %
–	–	0.30 %	0.70 %
Moments_Cora	2.68 %	0.27 %	1.09 %
–	–	0.25 %	0.65 %
ST_Sihao	2.51 %	0.63 %	1.23 %
–	–	0.44 %	0.74 %
shear2PCF_Nicolas	3.11 %	0.39 %	0.52 %
–	–	0.37 %	0.50 %
Map3_LailaSven	3.77 %	1.15 %	2.65 %
–	–	0.73 %	1.56 %
Betti_Sven	1.32 %	0.39 %	0.73 %
–	–	0.34 %	0.64 %
Heatmap_Sven	1.50 %	0.72 %	1.14 %
–	–	0.57 %	0.89 %
Map_Lucas	1.24 %	0.24 %	0.41 %
–	–	0.15 %	0.33 %

Table 3: Same as Table 2 for probed combined with shear2PCF_Nicolas.

cosmo	configuration	scale	probes	δw_0	$\delta\sigma_8$	$\delta\Omega_m$
16 %	ks_nomask_shear	–	shear2PCF_Nicolas	3.11 %	0.39 %	0.52 %
–	–	–	–	–	0.37 %	0.50 %
16 %	ks_nomask_shear	2.34	Minkowski_Simone	1.05 %	0.29 %	0.42 %
–	–	–	–	–	0.29 %	0.40 %
16 %	ks_nomask_shear	2.34	Betti_Simone	1.30 %	0.30 %	0.44 %
–	–	–	–	–	0.30 %	0.43 %
16 %	ks_nomask_shear	2.34	Peaks_Sandrine	1.05 %	0.25 %	0.42 %
–	–	–	–	–	0.22 %	0.36 %
16 %	ks_nomask_shear	4.69	PDF_Cora	0.90 %	0.29 %	0.42 %
–	–	–	–	–	0.29 %	0.41 %
16 %	ks_nomask_shear	–	kappa2PCF_Simone	2.71 %	0.36 %	0.44 %
–	–	–	–	–	0.32 %	0.44 %
16 %	ks_nomask_shear	2.34	Moments_Simone	1.42 %	0.21 %	0.35 %
–	–	–	–	–	0.21 %	0.34 %
16 %	ks_nomask_shear	4.69	Moments_Cora	1.36 %	0.17 %	0.31 %
–	–	–	–	–	0.16 %	0.30 %
16 %	ks_nomask_shear	2.34	ST_Sihao	1.54 %	0.29 %	0.47 %
–	–	–	–	–	0.28 %	0.41 %
16 %	ks_nomask_shear	–	Map3_LailaSven	1.16 %	0.26 %	0.44 %
–	–	–	–	–	0.19 %	0.32 %
16 %	ks_nomask_shear	2.34	Betti_Sven	1.07 %	0.24 %	0.40 %
–	–	–	–	–	0.22 %	0.35 %
16 %	ks_nomask_shear	2.34	Heatmap_Sven	1.12 %	0.31 %	0.47 %
–	–	–	–	–	0.29 %	0.42 %
16 %	ks_nomask_shear	–	Map_Lucas	0.94 %	0.19 %	0.32 %
–	–	–	–	–	0.13 %	0.24 %

- *single probes:* no HOS tool particularly better than the others
- *HOS + shear 2PCF:* up to a factor 2 improvement of the error on w0
- some additional work needed to optimise binning and smooting

From Noise in Derivatives to Errors on Errors

- Marginalized errors

$$\sigma^2(\Omega_M) = \frac{F_{22}F_{33} - F_{23}^2}{\det(F)} \qquad \sigma^2(w_0) = \frac{F_{11}F_{33} - F_{13}^2}{\det(F)} \qquad \sigma^2(\sigma_8) = \frac{F_{11}F_{22} - F_{12}^2}{\det(F)}$$

- Fisher matrix elements (i = {1, 2, 3} for $\{\Omega_M, w_0, \sigma_8\}$)

$$F_{ij} = \left(\frac{\partial D_{HOS}}{\partial p_i}\right)^T \cdot \Psi \cdot \left(\frac{\partial D_{HOS}}{\partial p_j}\right)$$

- D_{HOS} = HOS data vector, $\Psi = \{Cov[D_{HOS}]\}^{-1}$ (inverse covariance)
- Derivatives from 3pt stencil method

$$\frac{\partial D_{HOS}}{\partial p_i} \simeq \frac{D_{HOS}\left[p_i^{fid}(1+\epsilon)\right] - D_{HOS}\left[p_i^{fid}(1-\epsilon)\right]}{2\epsilon p_i^{fid}}$$

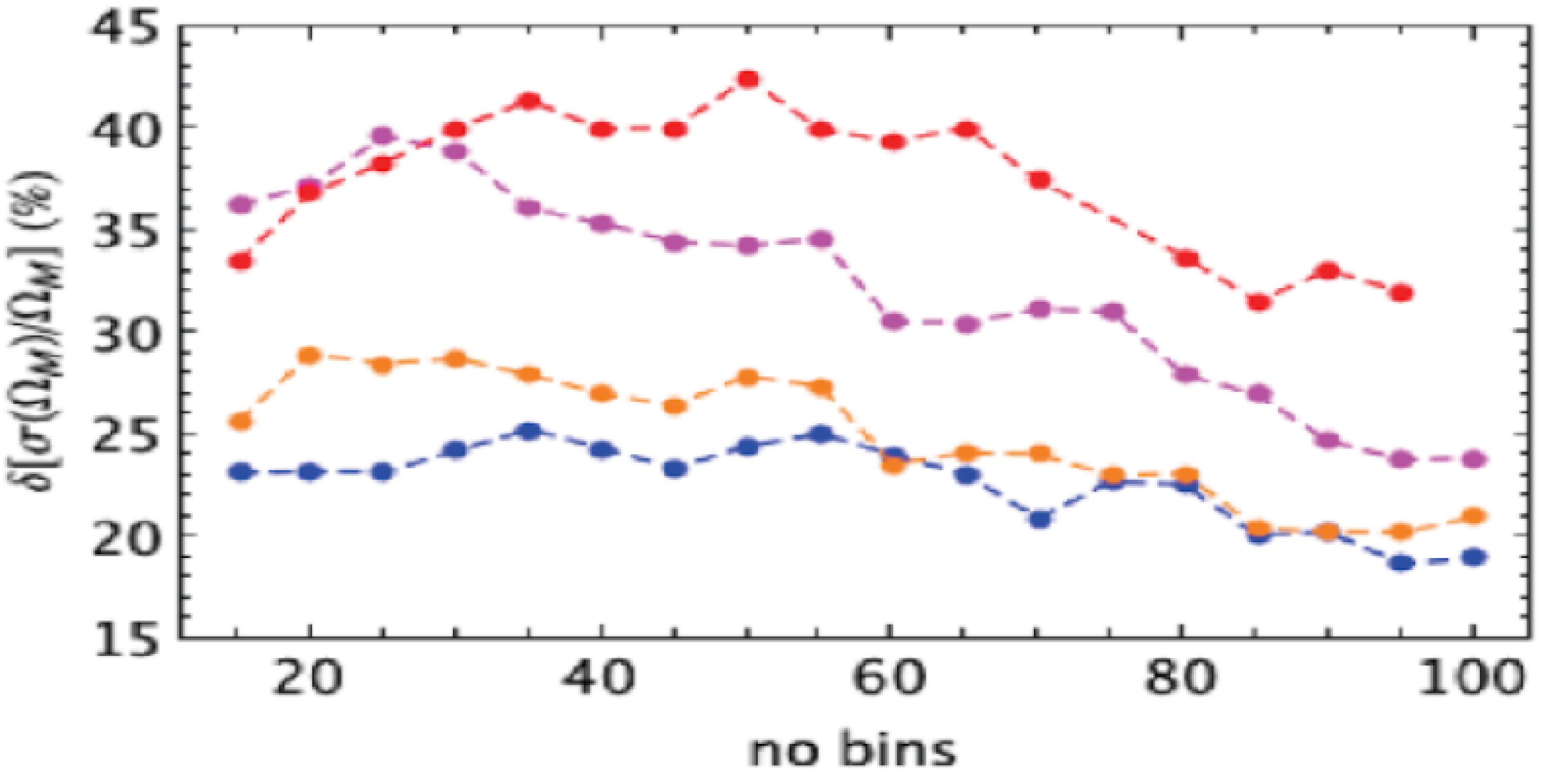
$$Cov\left(\frac{\partial D_{HOS}}{\partial p_i}\right) \simeq \frac{Cov\left\{D_{HOS}\left[p_i^{fid}(1+\epsilon)\right]\right\} + Cov\left\{D_{HOS}\left[p_i^{fid}(1-\epsilon)\right]\right\}}{2\epsilon p_i^{fid}} \simeq \frac{Cov\left\{D_{HOS}\left(p_i^{fid}\right)\right\}}{\epsilon p_i^{fid}}$$

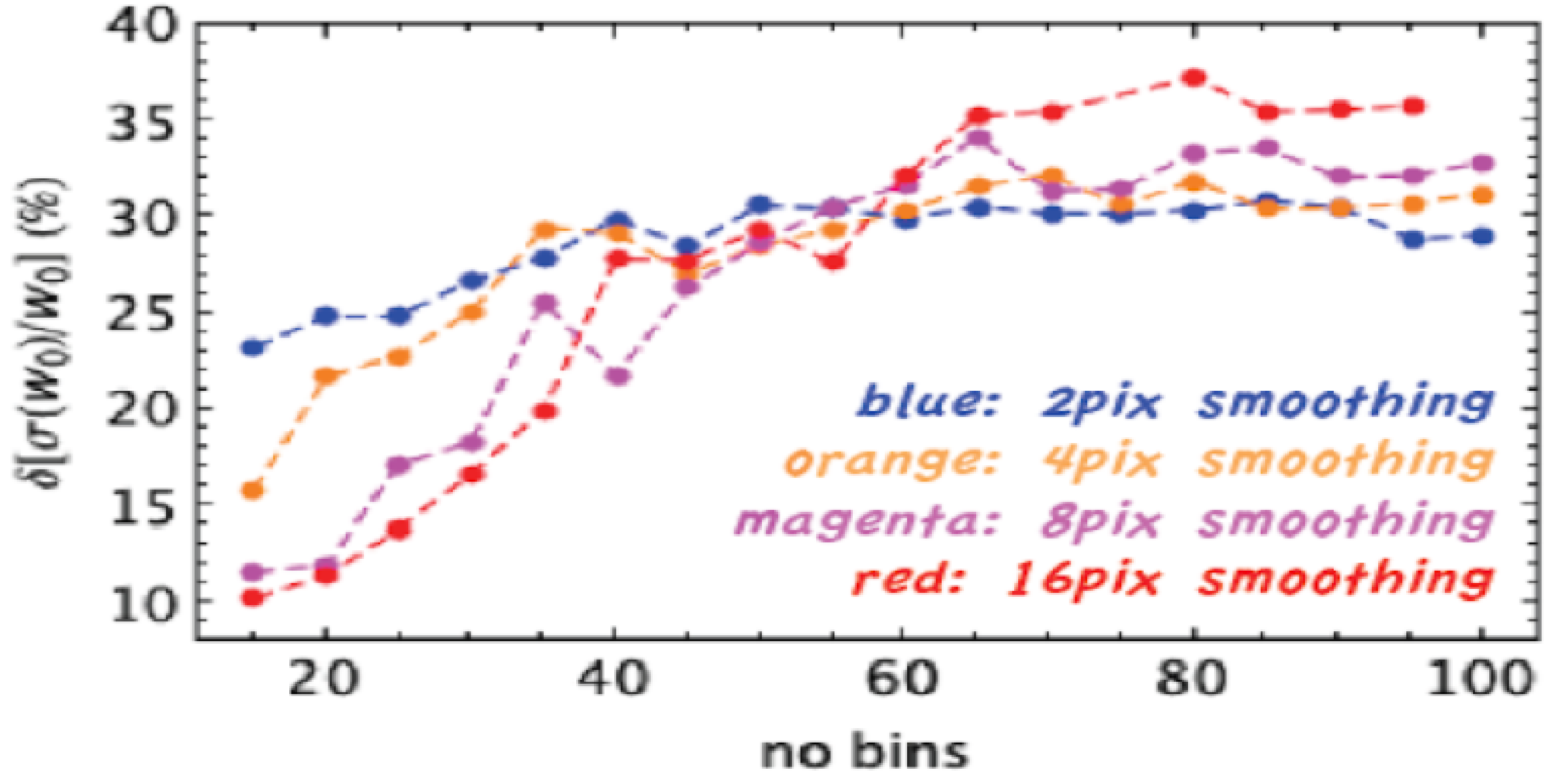
(assuming approximately model independent covariance matrix)

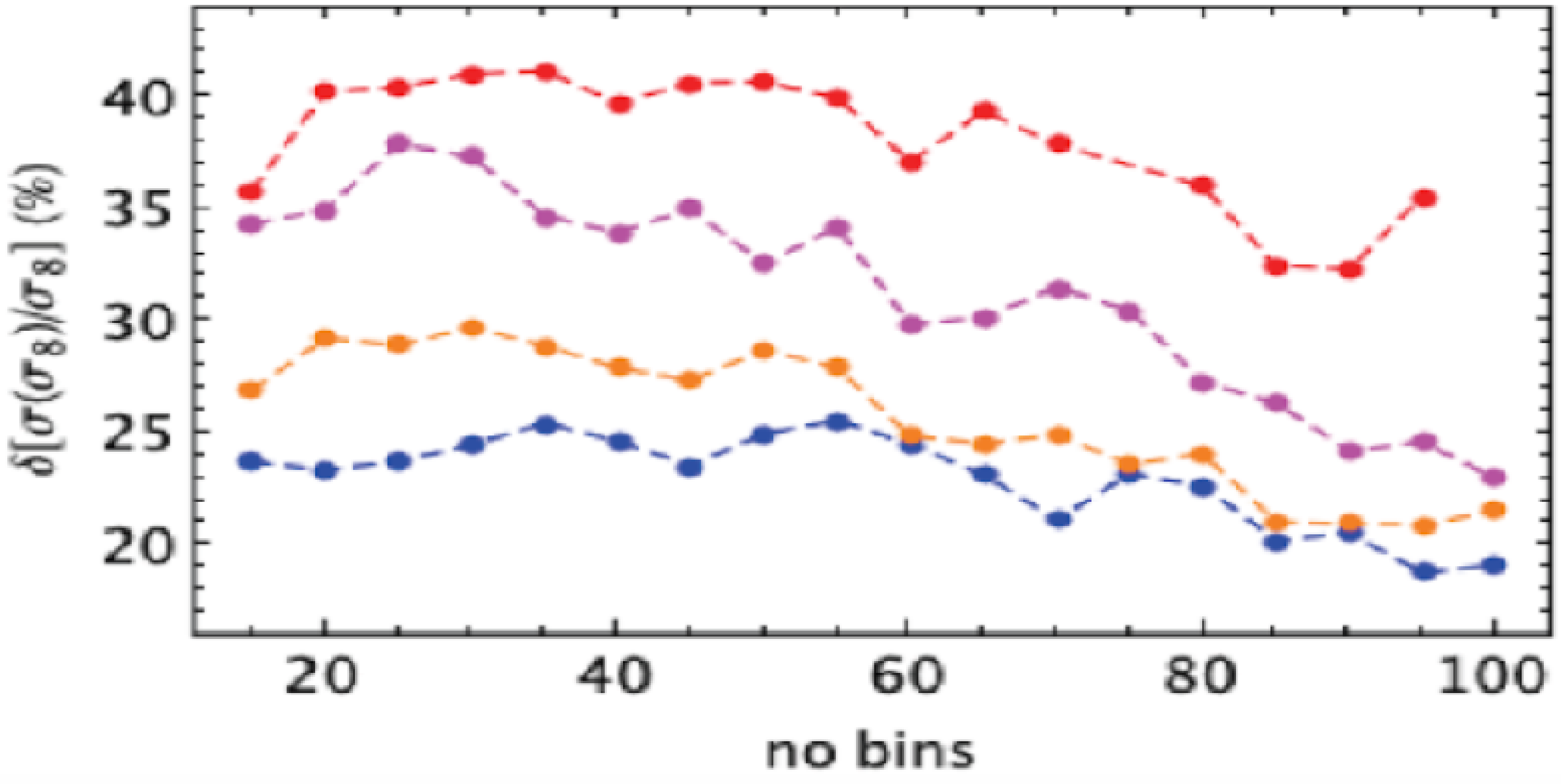
From Noise in Derivatives to Errors on Errors

- *Errors on Fisher matrix elements* $\{F_{11}, F_{12}, F_{13}, F_{22}, F_{23}, F_{33}\}$
  1. generate random dD_{HOS}/dp_i from multinormal distribution
  2. compute $\{F_{11}, F_{12}, F_{13}, F_{22}, F_{23}, F_{33}\}$
  3. estimate covariance matrix of $\{F_{11}, F_{12}, F_{13}, F_{22}, F_{23}, F_{33}\}$
- *Errors on marginalized errors*
  1. generate random F_{ij} from multinormal distribution
  2. remove unphysical samples (e.g. giving $\det(F) < 0$)
  3. compute $C_{11} = \sigma^2(\Omega_M)$, $C_{22} = \sigma^2(w_0)$, $C_{33} = \sigma^2(\sigma_8)$
  4. estimate $\delta[\sigma(p_i)/p_i] = (1/2)\ \sigma(C_{ii})/C_{ii}$ from sample NMAD
- *Underlying assumptions of the method*
  1. unbiased numerical derivatives
  2. cosmology independent covariance matrix

From Noise in Derivatives to Errors on Errors







- *Plots for Minkowski Functionals*
- *Also available for*
  - *Betti numbers*
  - *convergence PDF*
  - *homology heat maps*
  - *peaks count*

Italy and Euclid Weak Lensing

(AND DO NOT FORGET PHOTOMETRIC GALAXY CLUSTERING)

THEORY

- strong involvement in forecasts
- stronger in next MCMC forecasts
- leading the work on covariance
- leading the 3x2pt modelling
- involved in many Key Projects

SYSTEMATICS

- participation to the E2E pipeline
- impact of magnification bias
- modelling of RSD in 3x2pt
- impact of photo - z errors
- modelling of systematics

HIGH ORDER STATS

- coordinating HOS WP
- strong involvement in HOWLS
- stronger for next steps
- semi - analytical methods
- full sky simulations