Controlling systematics in spectroscopic GC

P. Monaco, University of Trieste & INAF-OATs, INFN, ICSC/Spoke 3, IFPU

Astronomy & Astrophysics manuscript no. output
September 5, 2024

In preparation

Euclid Preparation. TBD : Controlling data systematics in the Euclid spectroscopic galaxy sample. I: fluctuations of survey depth⋆

Euclid Collaboration: P. Monaco[1,2,3,4]⋆⋆, M. Y. Elkhashab, B. Granett, J. Salvalaggio, E. Sefusatti, C. Scarlata, B. Zabelle, G. Addison, M. Bethermin, S. Bruton, C. Carbone, S. De La Torre, S. Dusini, A. Eggemeier, G. Lavaux, S. Lee, K. Markovich, K. McCarthy, M. Moresco, F. Passalacqua, W. Percival, I. Risso, A. Sanchez, C. Sirignano, Y. Wang, et al.

(Affiliations can be found after the references)

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The optimism fair

Slitless spectroscopy

The most prominent emission line of a star-forming galaxy is Hα, detected in the NIR at z~1-2.

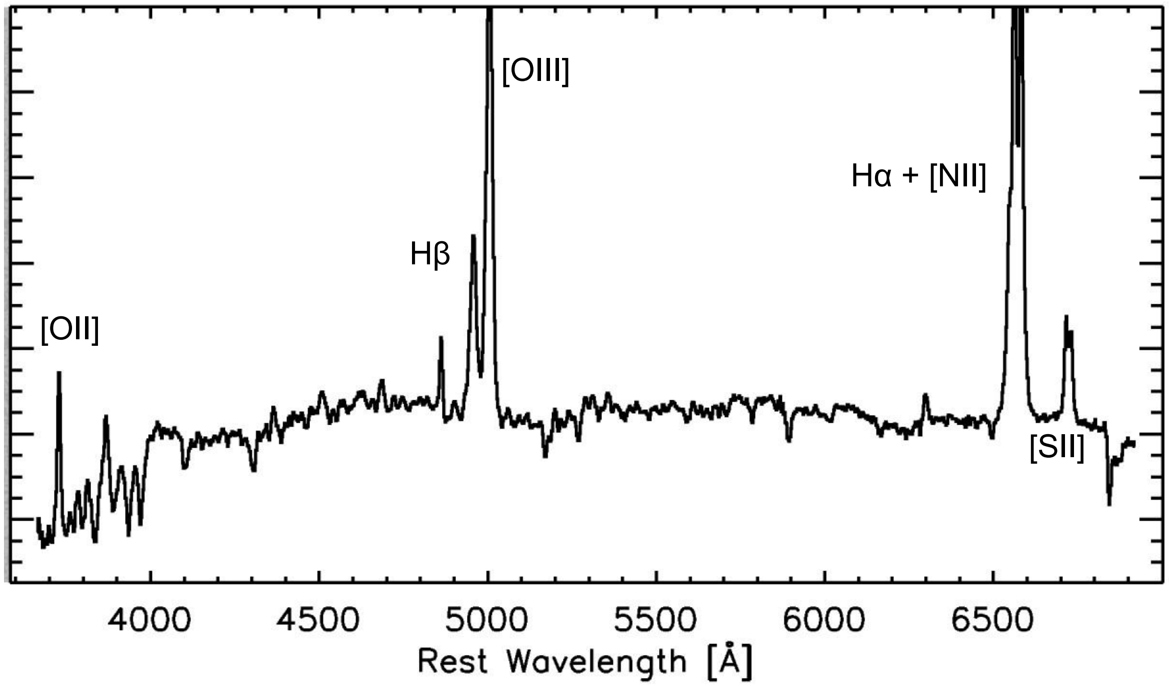
Euclid will be a slitless spectroscopic survey, spectra will be taken for all objects present in a photometric H<24 imaging survey.

It will detect Hα (+[NII]) at 0.9<z<1.8.

No target preselection, no fiber collision!

Confusion will be limited using 4 orientations in a K-shaped configuration

NGC1068



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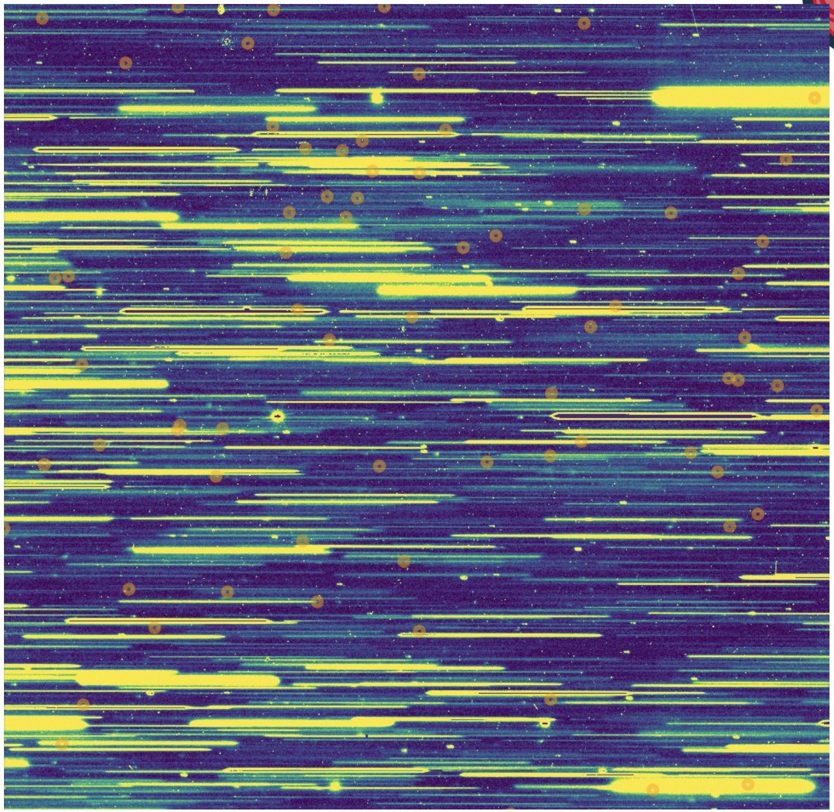

B. Granett, Vincent Le Brun, SGS team

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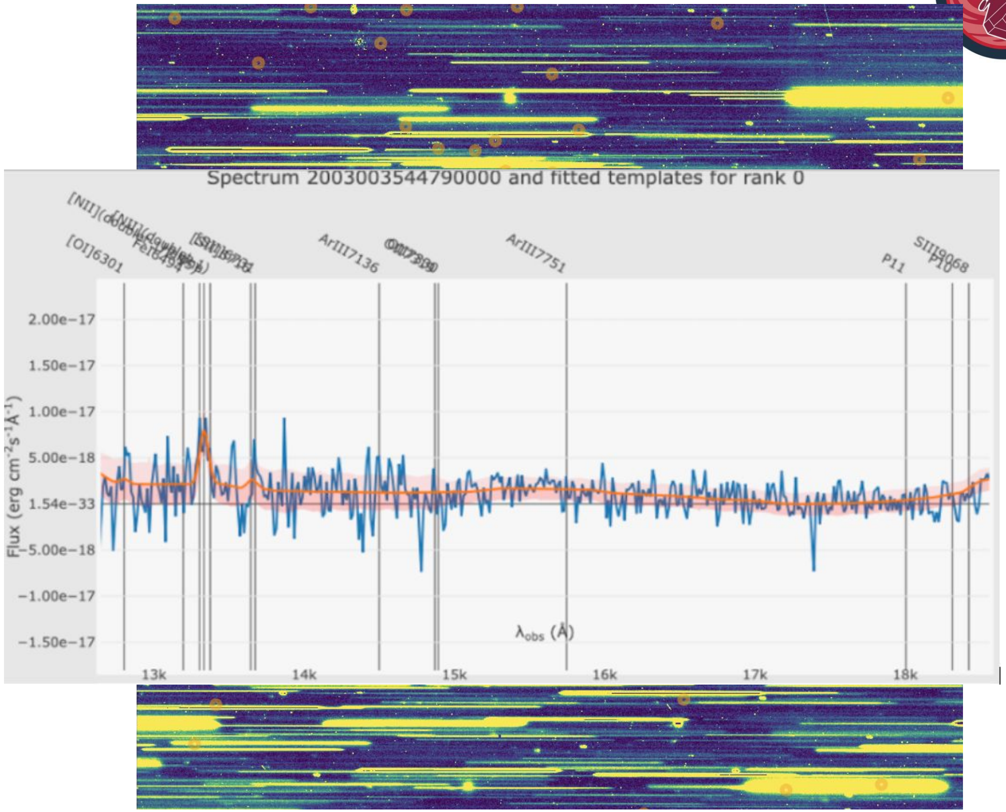

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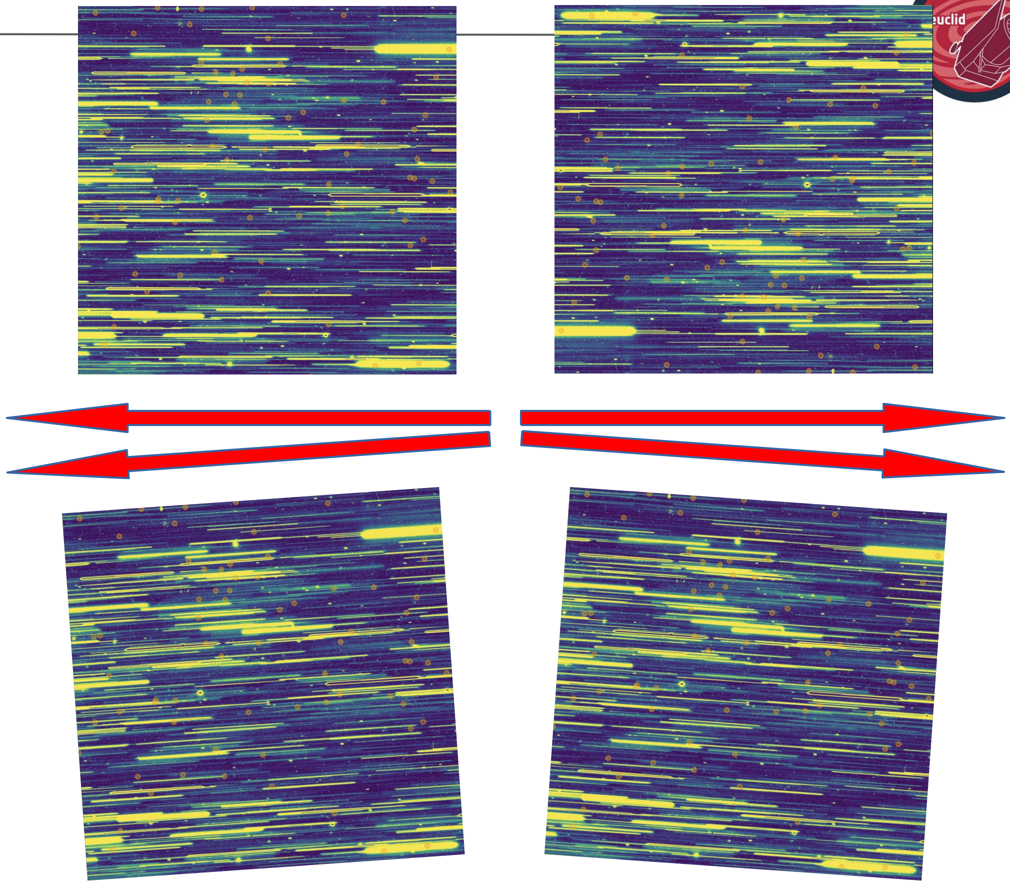
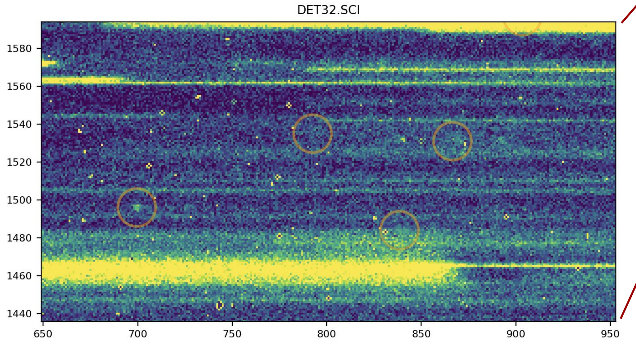
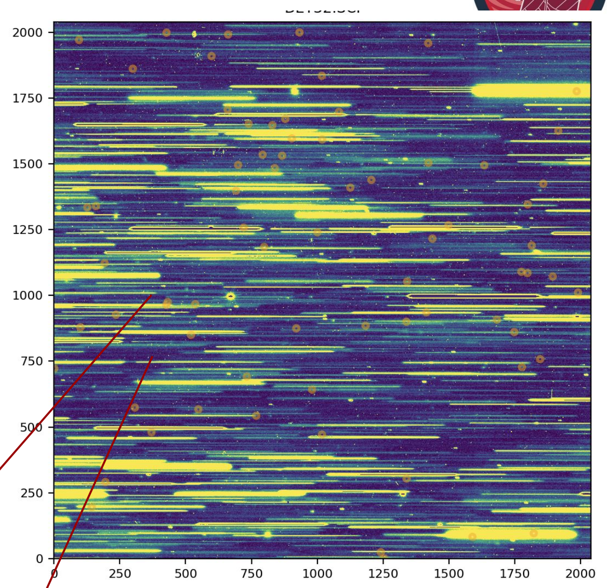


Construction of the random catalog

- take a galaxy from the **deep field**
- place it in a **random sky position**
- take the images of the four NISP **dithers**
- **inject** the source in the four images
- use a **bypass** of the pipeline to estimate its detection **probability**
- **determine** if the galaxy gets into the random

The random catalog is a **forward model** of completeness and purity





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Formalism (ignore luminosity-dependent bias)

target galaxies:
$f > f_0 = 2 \times 10^{-16}$ erg/s/cm^2

observed "good" galaxies:
Hα detected, z in a PDF with $\sigma_z = 0.002$

$$\phi_{\rm local}(f|\boldsymbol{x}) \simeq [1 + \delta_g(\boldsymbol{x})]\, \Phi(f, z)\,,$$

$$n_t(\boldsymbol{x}) := \int_{f_0}^{\infty} \phi_{\rm local}(f|\boldsymbol{x})\, df\,.$$

Completeness function

$$n_{og}(\boldsymbol{x}) = \int_0^{\infty} C(f, z, \{N_i\})\, \phi_{\rm local}(f|\boldsymbol{x})\, df$$

$$\simeq [1 + \delta_g(\boldsymbol{x})] \int_0^{\infty} C(f, z, \{N_i\})\, \Phi(f|z)\, df\,,$$

Redshift errors, interlopers, purity and completeness

$$n_o(\boldsymbol{x}_o) := n_{og}(\boldsymbol{x}) * P_z(z_o|z) + \Sigma_i n_{oi}(\boldsymbol{x}_o) + n_{on}(\boldsymbol{x}_o)$$

$$\bar{n}_{og} = \int_0^\infty \bar{C}(f,z)\,\Phi(f|z)\,df\,,$$

good

$$\bar{n}_{ot}(z) = \int_{f_0}^\infty \bar{C}(f,z)\,\Phi(f|z)\,df\,.$$

good & target

$$\bar{n}_t(z) = \int_{f_0}^\infty \Phi(f|z)\,df\,.$$

target

$$\text{sample purity} = \frac{\bar{n}_{ot}(z)}{\bar{n}_o(z)}\,.$$

$$\text{redshift purity} = \frac{\bar{n}_{og}(z)}{\bar{n}_o(z)}\,.$$

$$\text{sample completeness} = \frac{\bar{n}_{ot}(z)}{\bar{n}_t(z)}\,.$$

$$\text{redshift efficacy} = \frac{\bar{n}_{og}(z)}{\bar{n}_t(z)}\,.$$

Will Percival

(marginalized) Visibility Mask

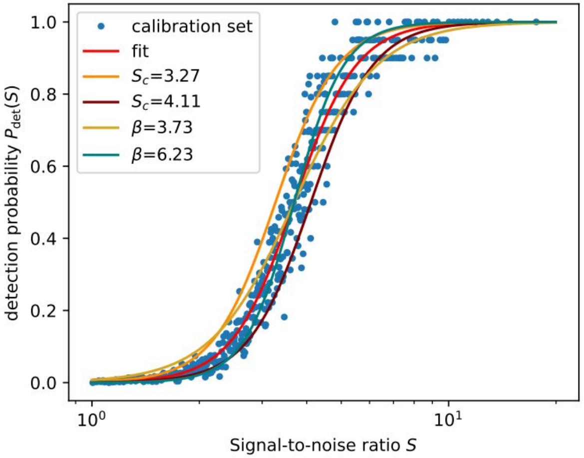
$$C(f, z, \{N_i\}) := \int d^m\mathbf{p}\, P_{\rm det}(f, z, \{N_i\} \,|\, \boldsymbol{p}) \,.$$

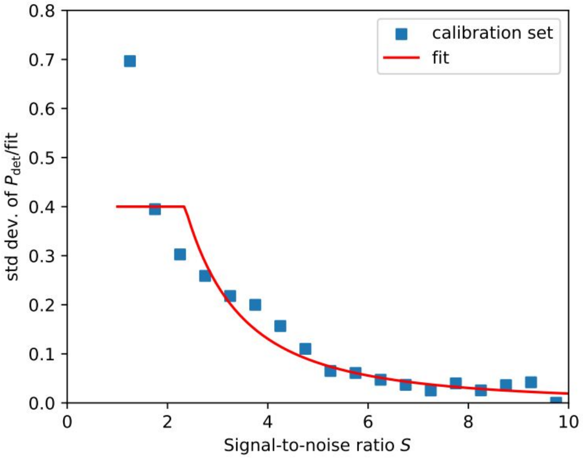
p: vector of galaxy properties

($\{N_i\}$: nuisance maps, see below)

Bypass (pypelid) and detection model

The dependence of detection probability P_{det} on **galaxy and image properties** can be compressed into a dependence on **SNR** of emission lines (detection model)
Using a calibrator set from FastSpec+SPE simulations we estimate the **error on detection model parameters**





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Systematics entry points

going through the SGS pipeline and identifying all possible systematics, as

- **angular systematics**
- **noise interlopers**
- **line interlopers**
- plus other minor effects

mostly mitigated by

- **the random**
- **the model**

The random should represent errors in the photometry

systematic effect	**entry point**	**class**	**consequences**	**mitigation strategy**	**impact**	**risk**
fluctuation of photometric depth + photometric selection	MER +SEL	angular	loss of sources for SIR modulation of catalog	random +photo errors	low	low mild
under-deblending	MER	angular	loss of sources for SIR miscentered sources	none	v. low	v. low
over-deblending	MER	noise int.	fake sources	random	low	low
persistence: spectro to photo	MER	noise int.	fake sources	random	mild	low
zodiacal light	astro	angular	increased background	random	v. high	v. low
nearby galaxies	astro	angular	increased background and confusion	random	low	low
MW extinction	astro	angular	decreased incoming flux	random (incomplete)	high	v. high
MW emission	astro	angular	contribution to background	random	v. low	v. low
flagged pixels (bad pixels, saturated stars, cosmic rays, persistence)	SIR	angular	degraded image quality	random	v. high	low
straylight	SIR	angular	increased noise	random	high	low
persistence: photo to spectro	SIR	noise int.	fake emission lines	random	mild	mild
persistence: spectro to photo, photo to photo spectro to spectro	SIR	angular + noise int.	biased decontamination	none	mild	high
calibration of SIR variance	SIR	angular	modulation of random	none	low	mild
wavelength calibration	SIR	AP-like	redshift bias	none	v. low	v. low
confusion from foregrounds	SIR	angular + noise int.	increased noise in spectra potential interlopers	random	high	low
confusion from $z > 0.9$ sources	SIR	angular	correlated to signal	TBD	low	v. high
coaddition of dithers	SIR	angular noise int.	error propagation	random	mild	low
templates for spectral fit	SPE	AP-like	bias in redshift measure	no	low	low
star-galaxy separation	SPE	noise int.	spurious sources	random	mild	low
redshift uncertainty	SPE	theory	anisotropic smoothing	model	mild	low
line misidentification	SPE	line int.	wrong redshift	model	high	high
spectral reliability selection	SPE +SEL	noise int. + line int.	sub-optimal cleaning of interlopers	random	mild	low
photometric selection	SPE +SEL	noise int. + line int.	introducing photometric systematics	random +photo errors	high	high
galaxy properties	astro	—	marginalized over by model	no	none	none
intrinsic alignments	astro	theory	detection correlated with tidal field	no	v. low	mild
sample variance in EDS	VMSP	radial	fluctuations in $\bar{n}(z)$	random +mocks	mild	low
sample variance in galaxy properties from EDS	VMSP	angular	uncertainty in detection probability	random +mocks	low	low
mapping of SNR to detection	VMSP	angular	uncertainty in bypass	random +mocks	low	low

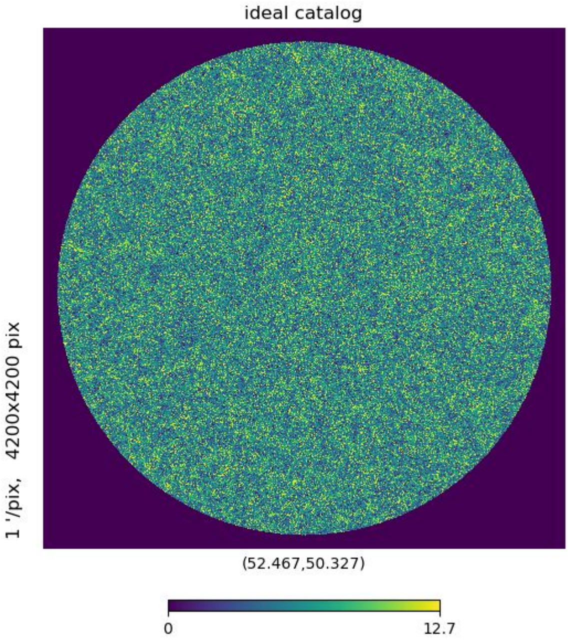
KP-GC-2 papers

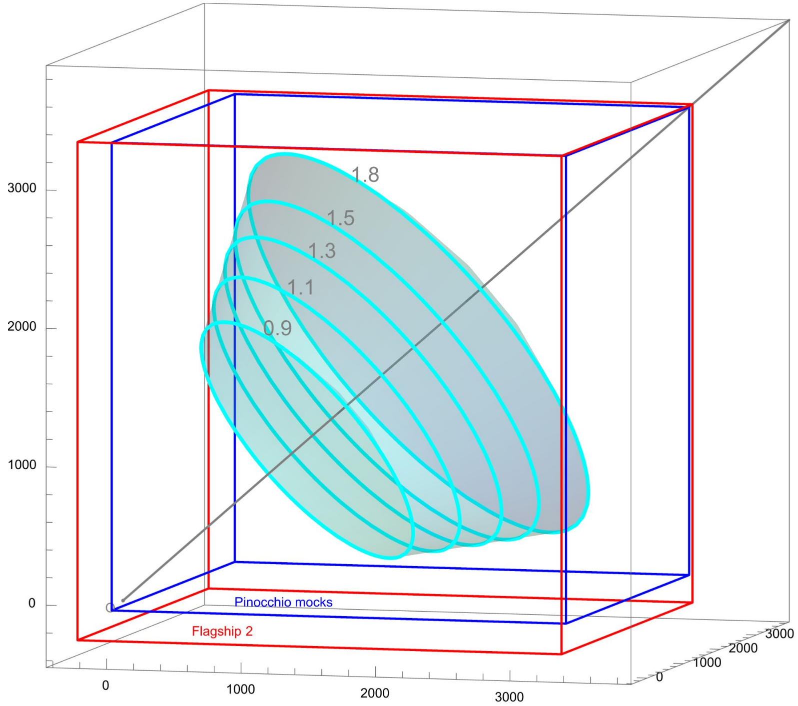
- angular systematics + mock catalogs - Pierluigi Monaco
- angular systematics on the largest scales - **Guilhem Lavaux**
- systematics from deep field - **Sean Bruton**
- redshift interlopers, forecast of their impact - **Graeme Addison**
- redshift interlopers, impact on 2-point CF using galaxy mocks - **Ilaria Risso**
- redshift interlopers, impact on power spectrum using galaxy mocks - **Sujeong Lee**
- impact of confusion on detection probability - **Francesca Passalacqua**
- end-to-end analysis with parallel pipeline - **Kevin McCarthy**

EuclidLargeMocks (3.38 Gpc/h with 6144^3 particles)

30 degree cone (circle of 30° of radius!) survey footprint
1 mock: 2763 deg^2, a bit larger than DR1
5 mocks: ~13800 deg^2, a bit smaller than DR3
we use 50 mocks, averaging over 5 (so we have 10 realizations)
we consider z in [1.1,1.3)

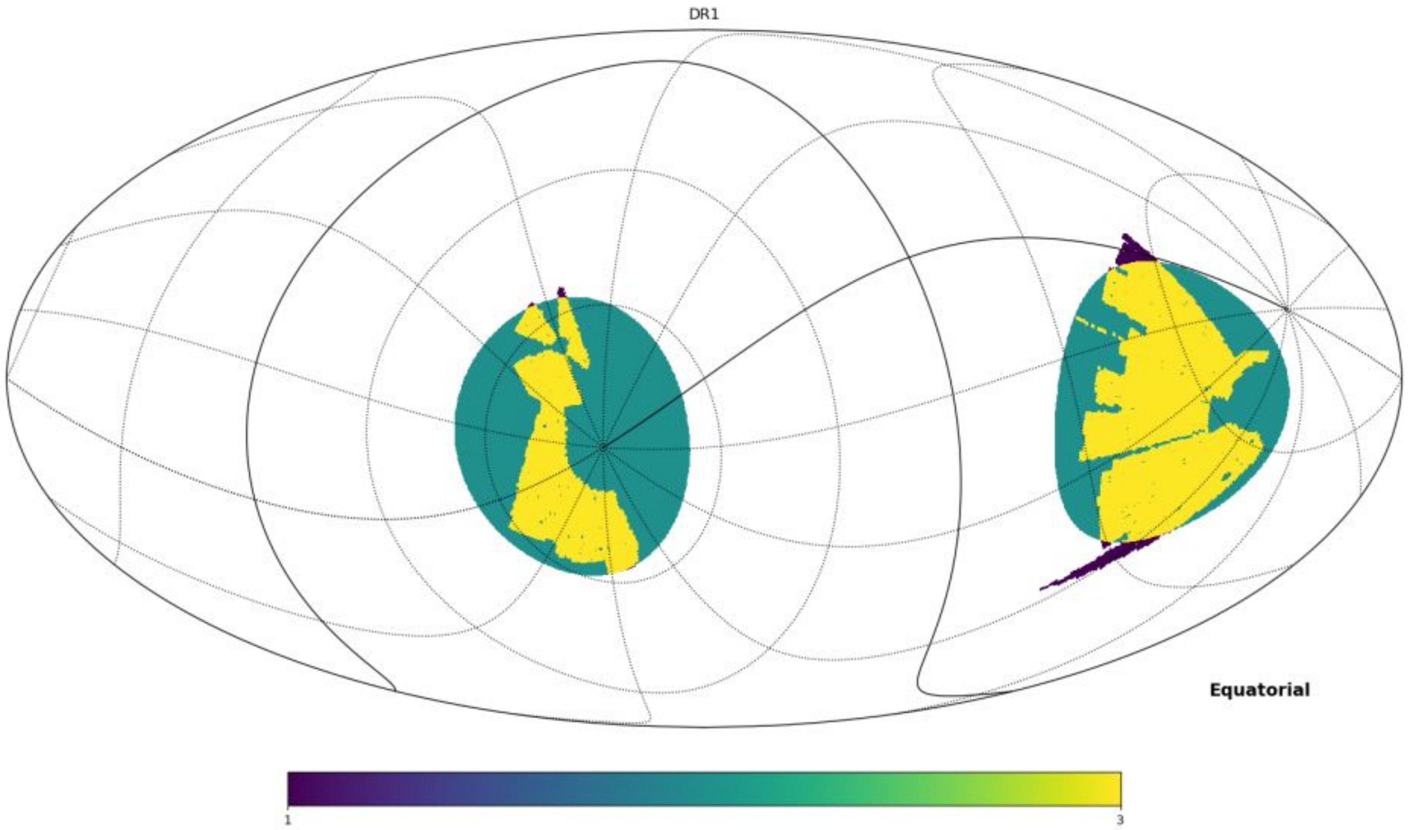
Gabriele Parimbelli



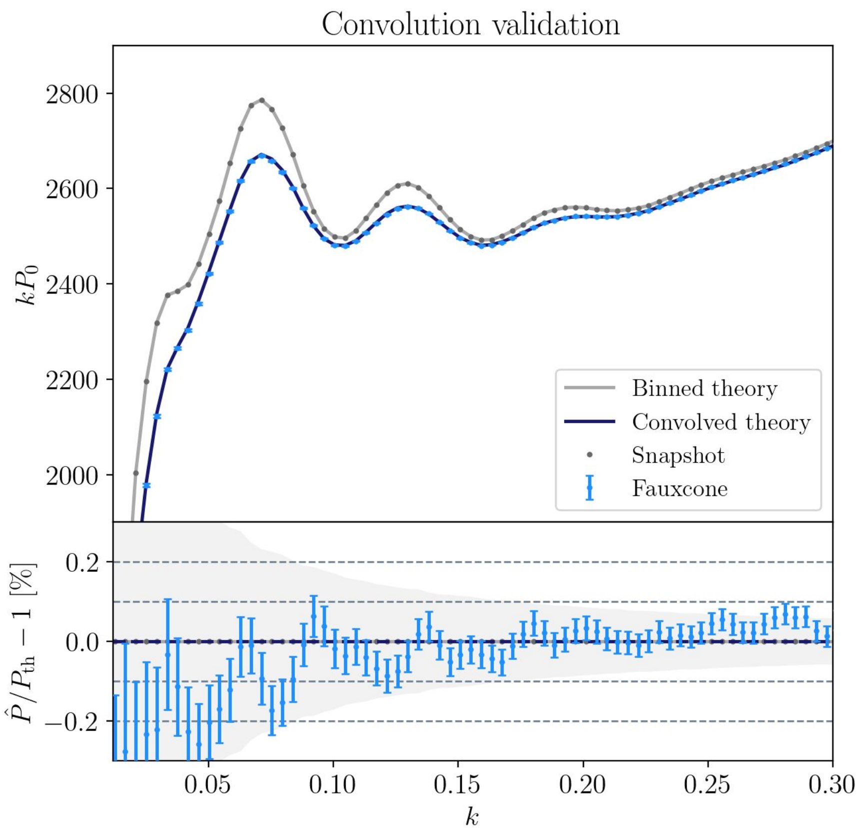


Emiliano Sefusatti

EuclidLargeMocks and (pre-launch) DR1



Window function



$$\tilde{P}_\ell(k) = \sum_{\ell'} \int d^3k' \, \mathcal{W}_{\ell\ell'}(k,k') P_{\ell'}(k')$$

FKP weight

$$W(\boldsymbol{x}) = W_{\rm fp}(\hat{n}) \, w_{\rm FKP}(z) \, \alpha n_r(\boldsymbol{x}) \,,$$

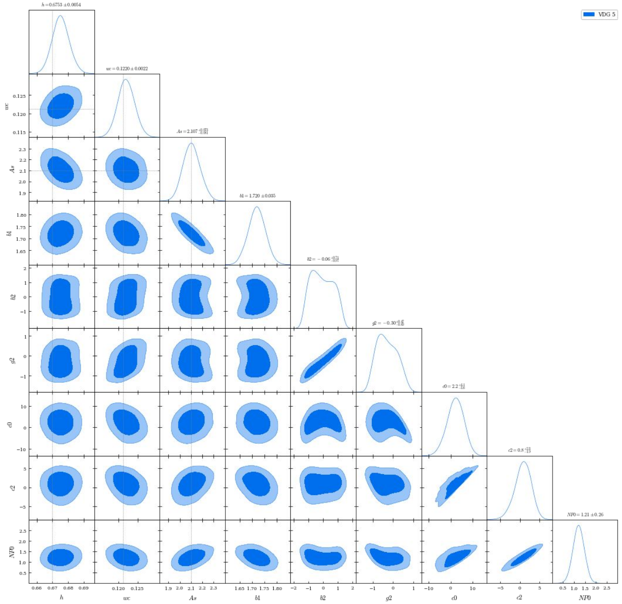
geometric footprint

average density

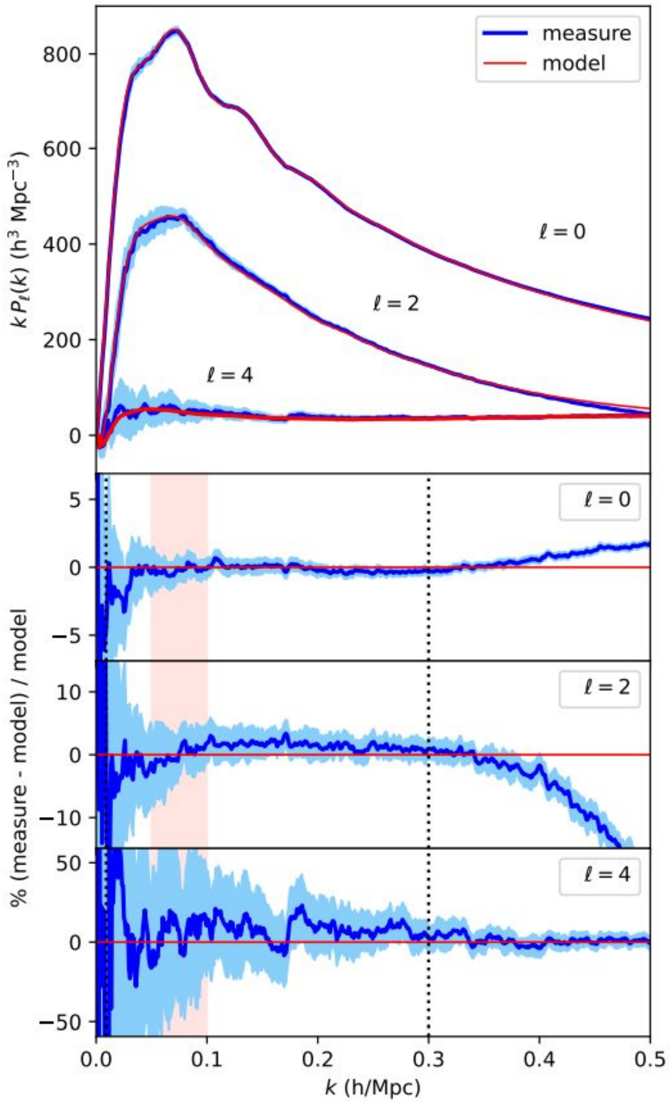
Jacopo Salvalaggio,
Emiliano Sefusatti ...

Fit of PK of target galaxies

We remove luminosity-dependent bias
For the theory we use 1-loop + VDG (comet)
For an ideal mitigation, the convolution of the theory model with the window with systematics should agree with the measurement at the same level



Yousry Elkhashab,
Jacopo Salvalaggio,
Emiliano Sefusatti,
Alex Eggemeier,
Benjamin Camacho



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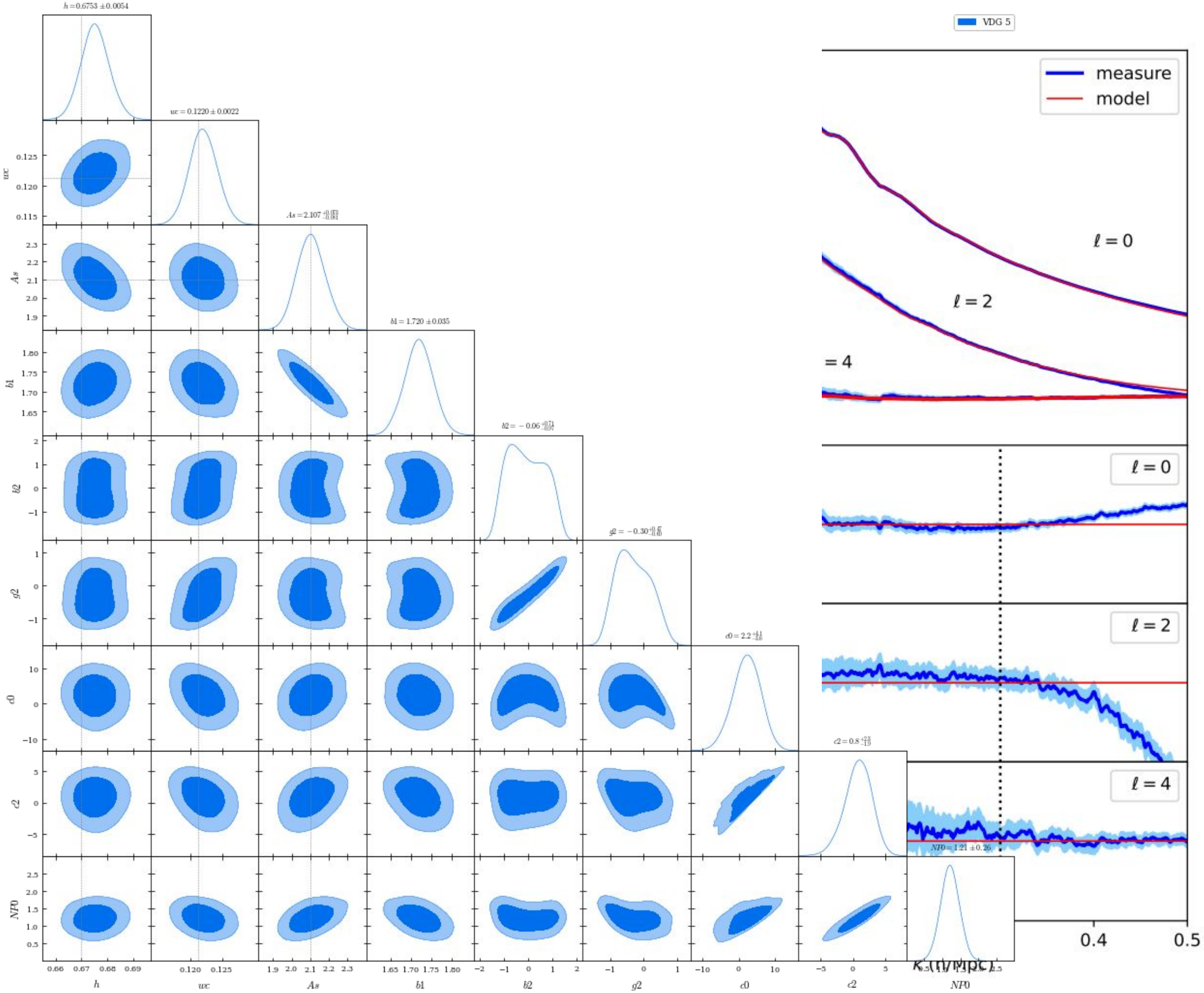
For an ideal mitiga

model with the win

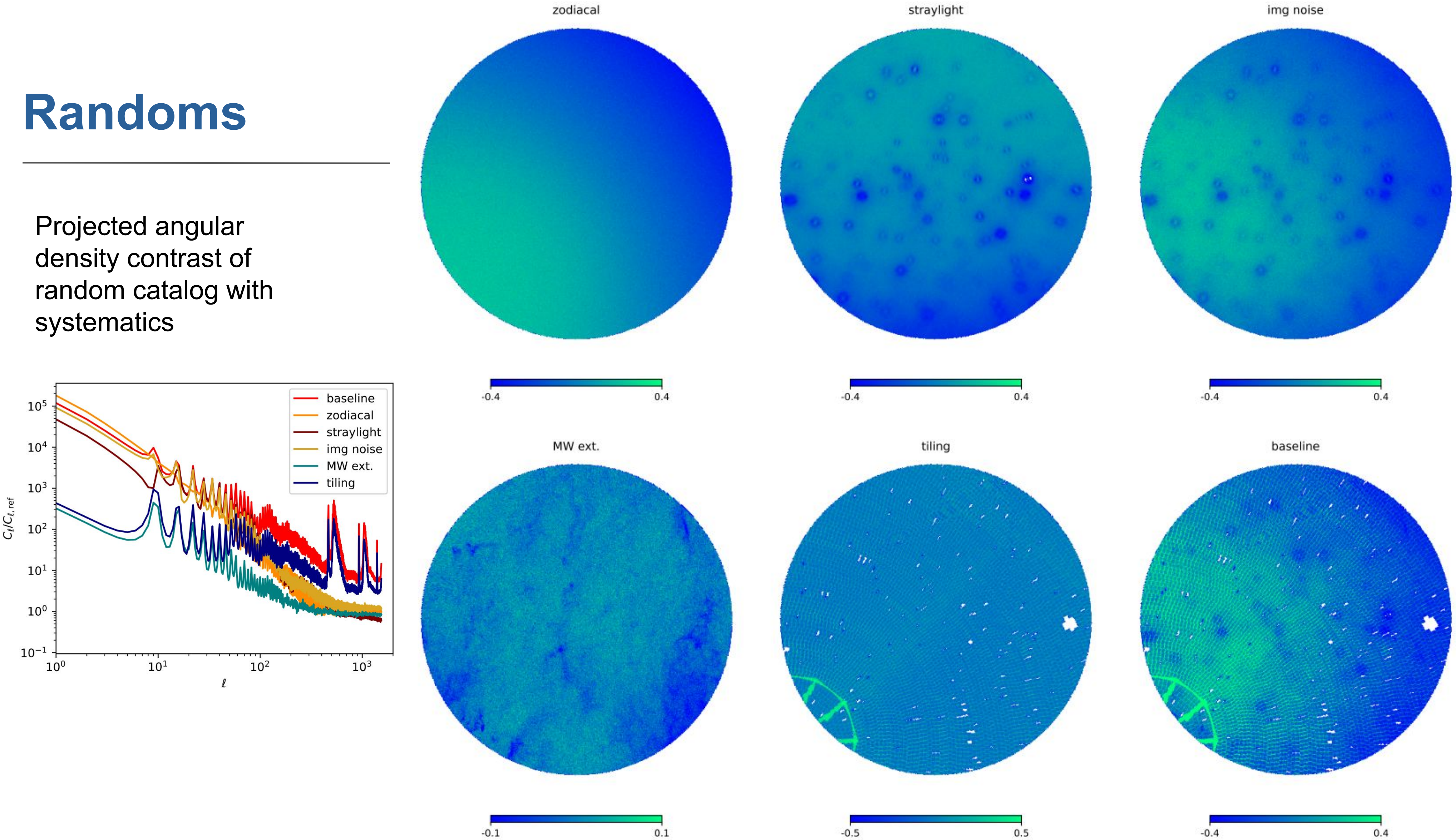
agree with the mea



Yousry Elkhashab,
Jacopo Salvalaggio,
Emiliano Sefusatti,
Alex Eggemeier,
Benjamin Camacho

Randoms

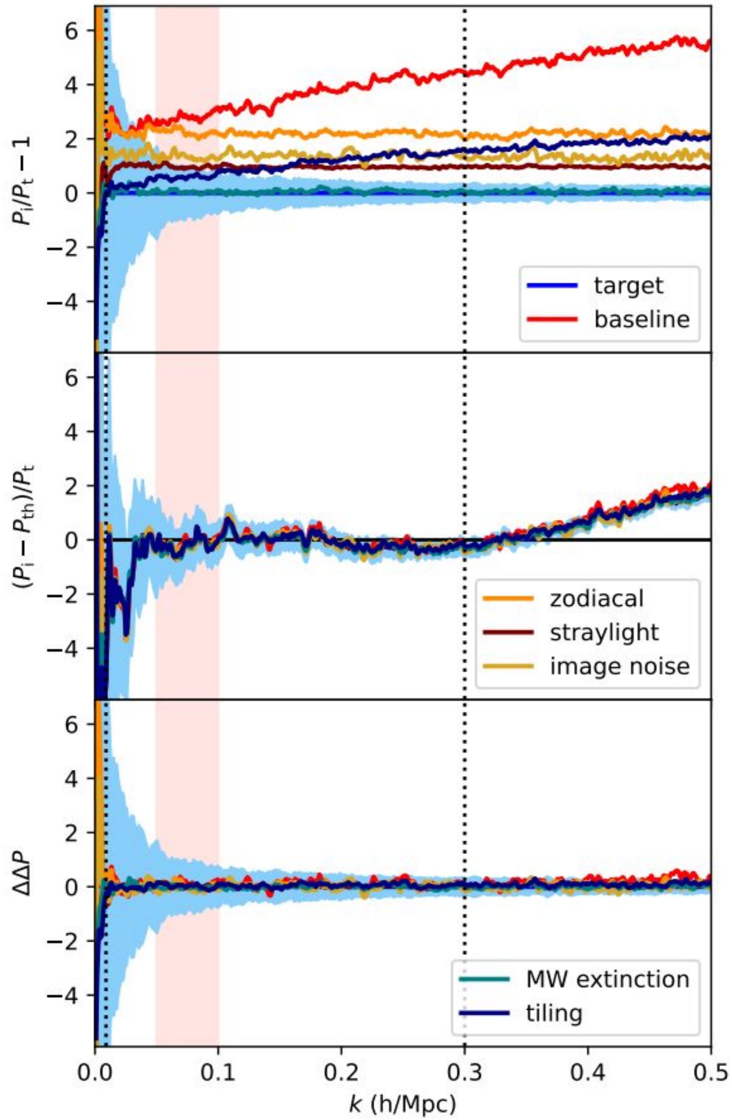
Projected angular density contrast of random catalog with systematics



How the window function works

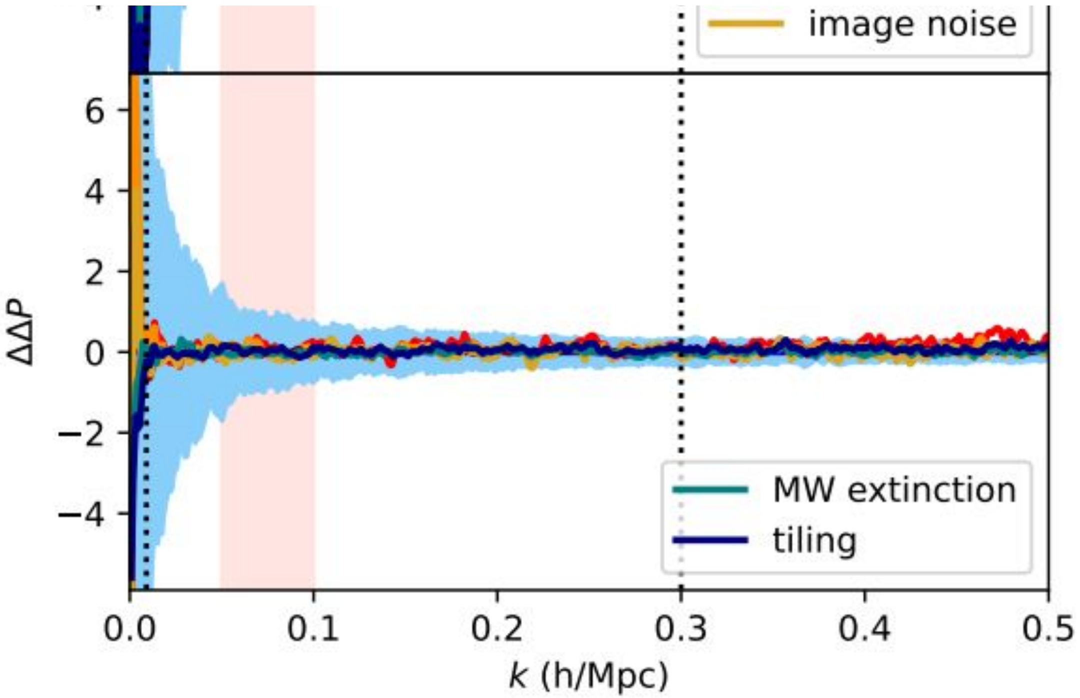
For an ideal mitigation, the convolution of the theory model with the window with systematics should agree with the measurement at the same level

$$\Delta\Delta P := \frac{[(P_{\rm i} - P_{\rm th,s}) - (P_{\rm t} - P_{\rm th,t})]}{P_{\rm t}},$$



How the

For an ideal
theory mode
should agree
same level



$$\Delta\Delta P := \frac{[(P_{\rm i} - P_{\rm th,s}) - (P_{\rm t} - P_{\rm th,t})]}{P_{\rm t}},$$

This is a strong **validation test** of all the pipeline: PK measurement, window measurement, mixing matrix, convolution, angular systematics...

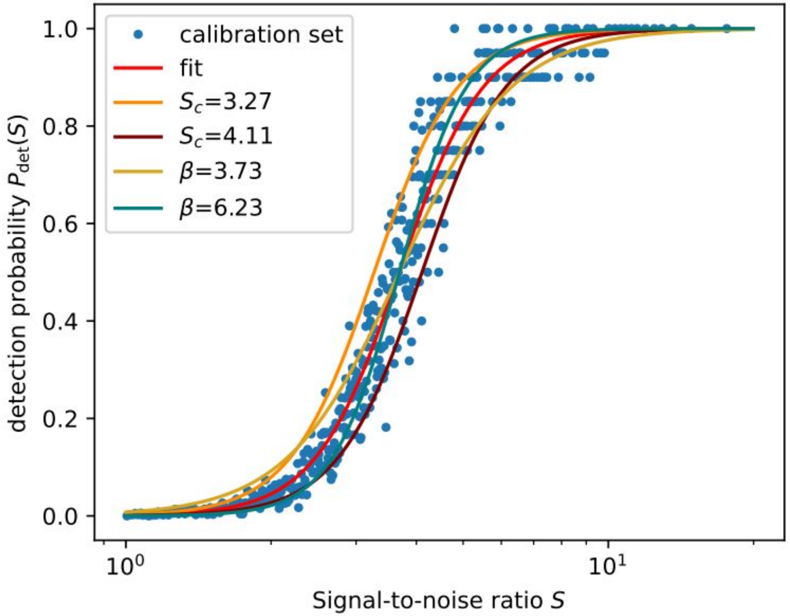
Realistic mitigation

Perturb nuisance maps:

- **exposure time**: it is exact, perturbing it makes **very little difference**
- **image noise**: **very little difference** expected (see below)
- **MW extinction** (Planck 2013 vs Planck 2015 vs SFD)

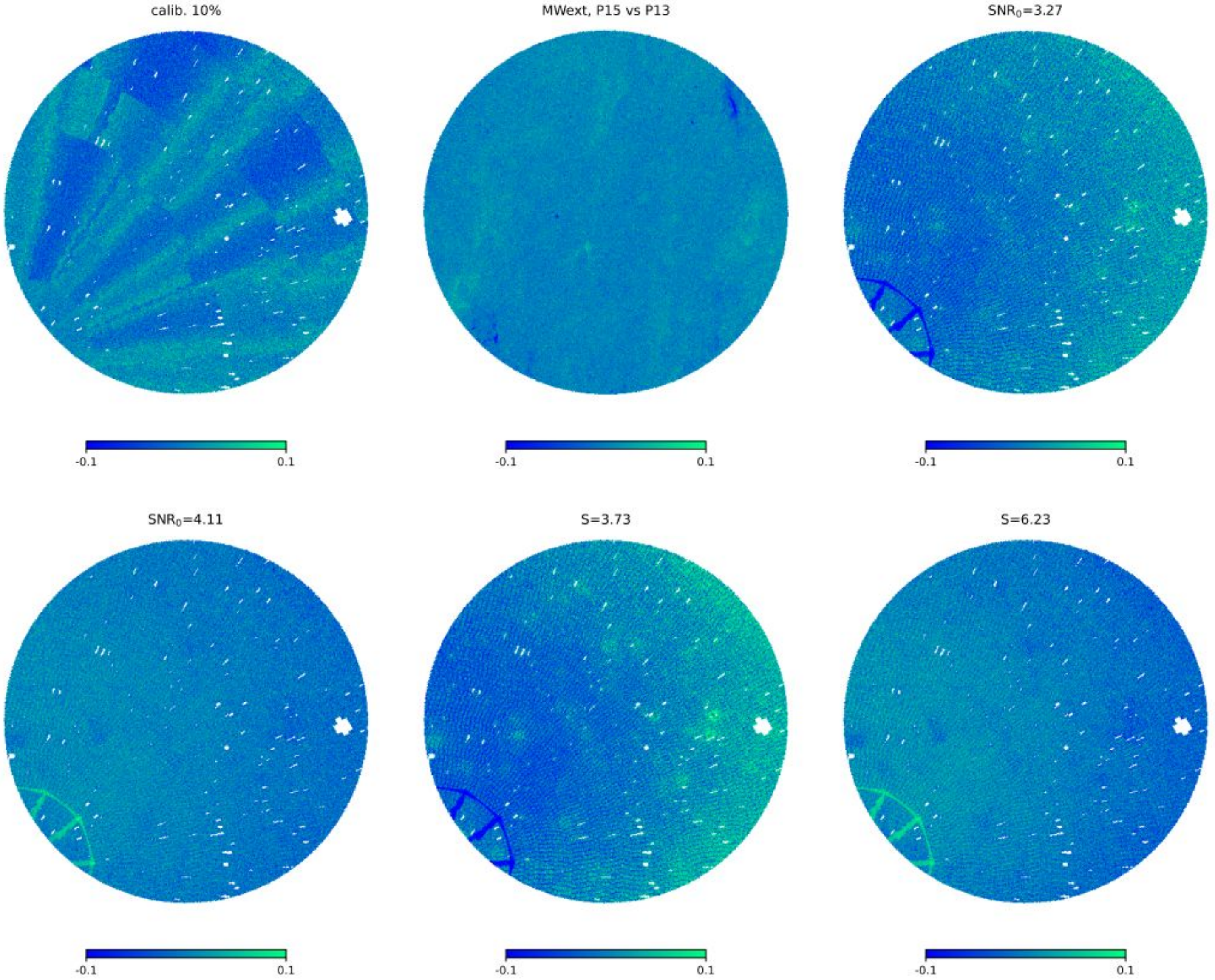
Perturb calibration:

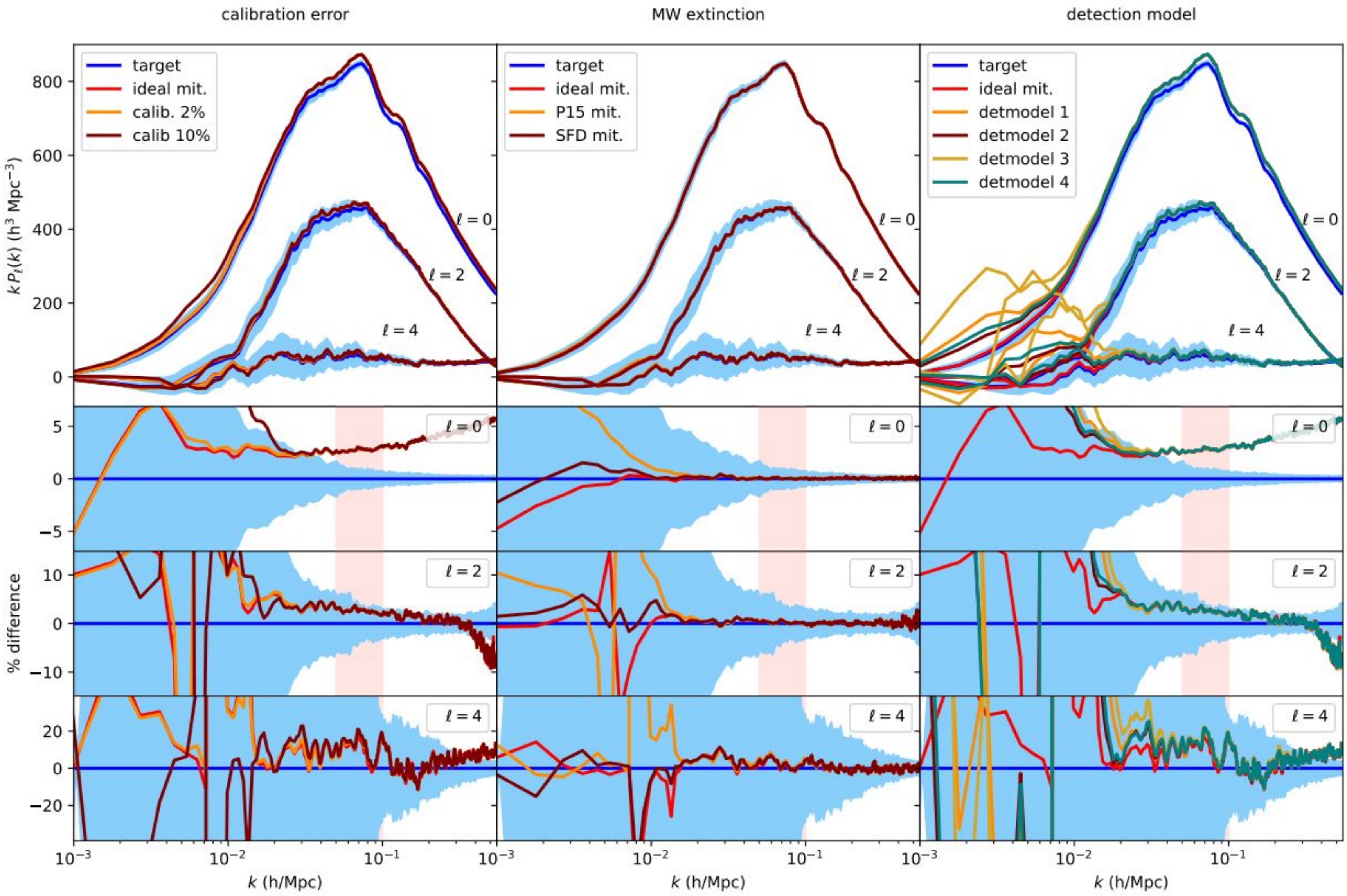
- assume that **zero-point** of NISP drifts between two visits of a calibration field
- assume an **error in the detection model**
- assume **scatter** in the detection model: **very little difference**



Randoms

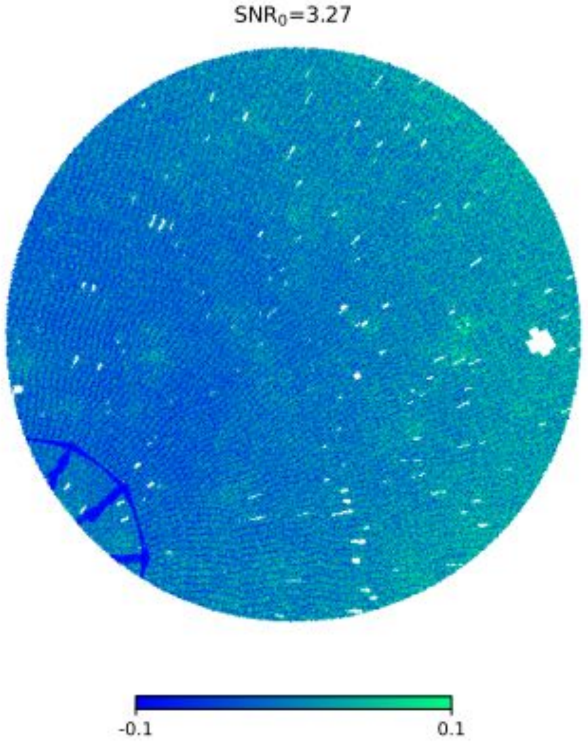
Density contrast of random with perturbed baseline systematics, using the original random as reference

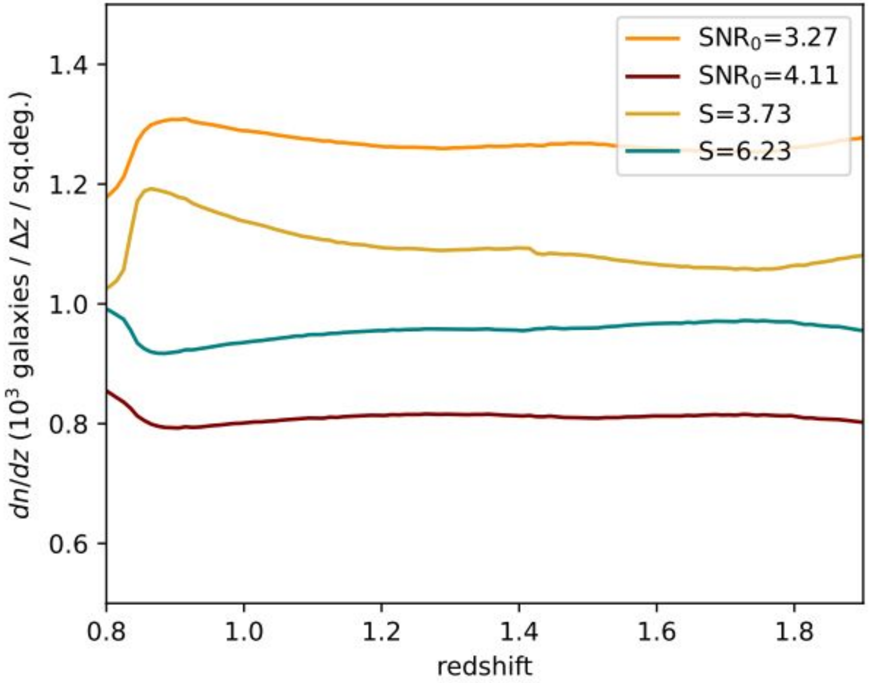




calibration error
MW extinction
detection model
target
ideal mit.
calib. 2%
calib 10%
P15 mit.
SFD mit.
detmodel 1
detmodel 2
detmodel 3
detmodel 4
$k\,P_\ell(k)$ (h^3 Mpc^{-3})
% difference
$\ell = 0$
$\ell = 2$
$\ell = 4$
k (h/Mpc)

Error in detection model is easy to recognise



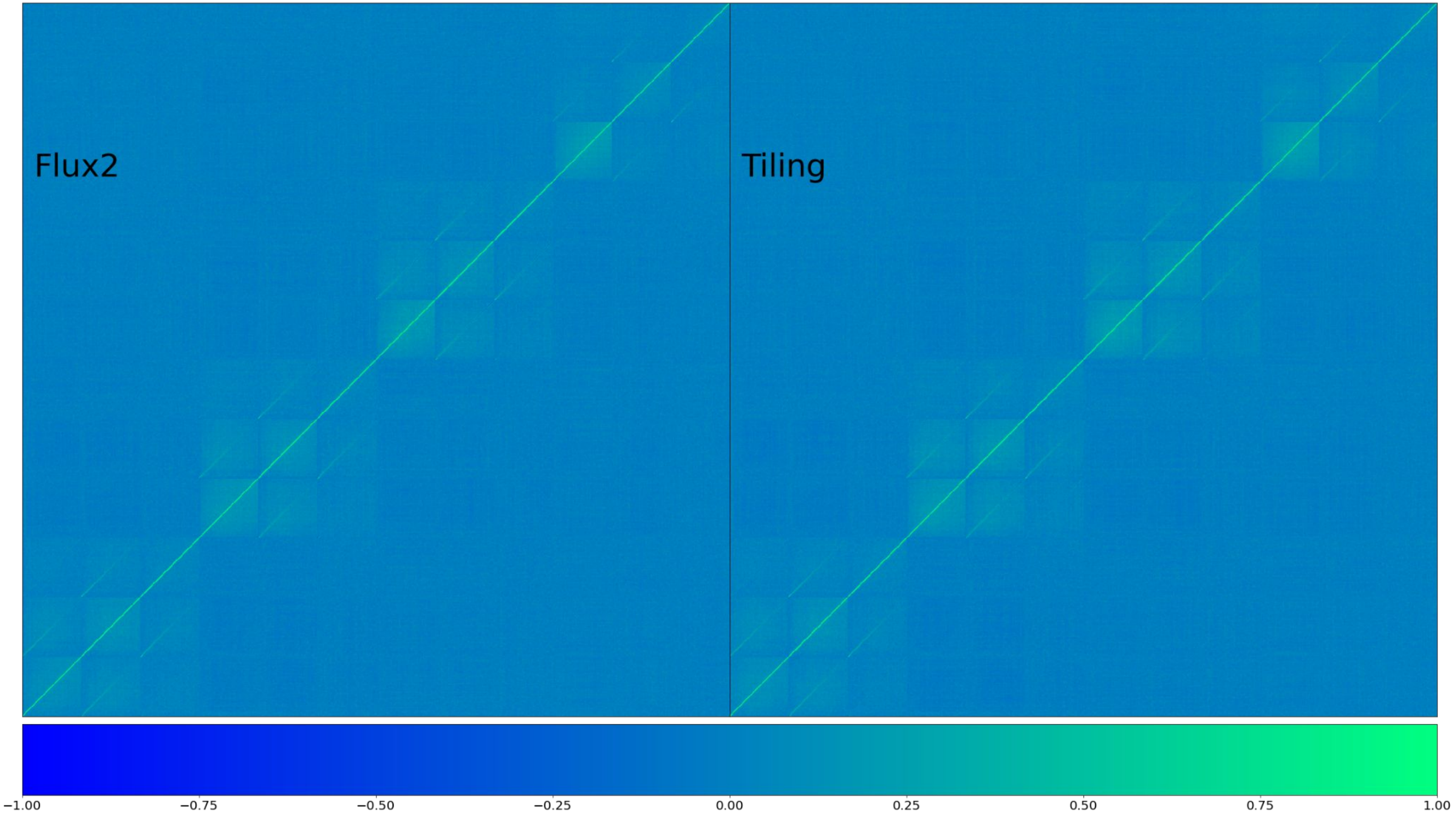


Conclusions: fitting catalogs with systematics

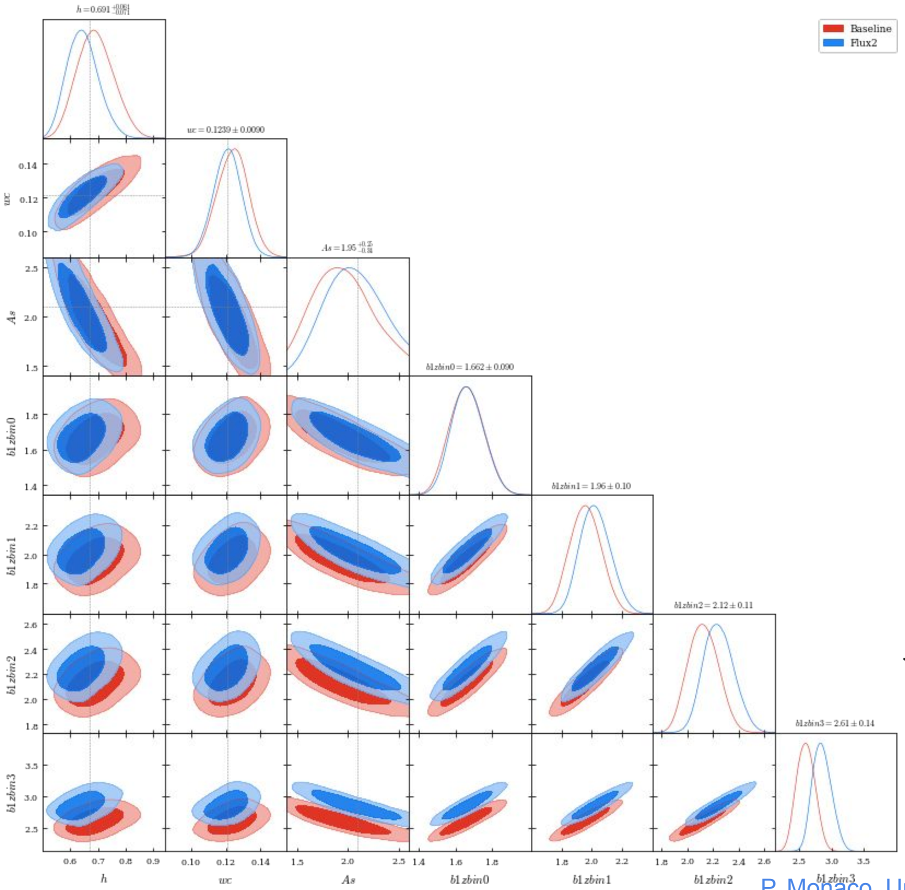
Coming soon...

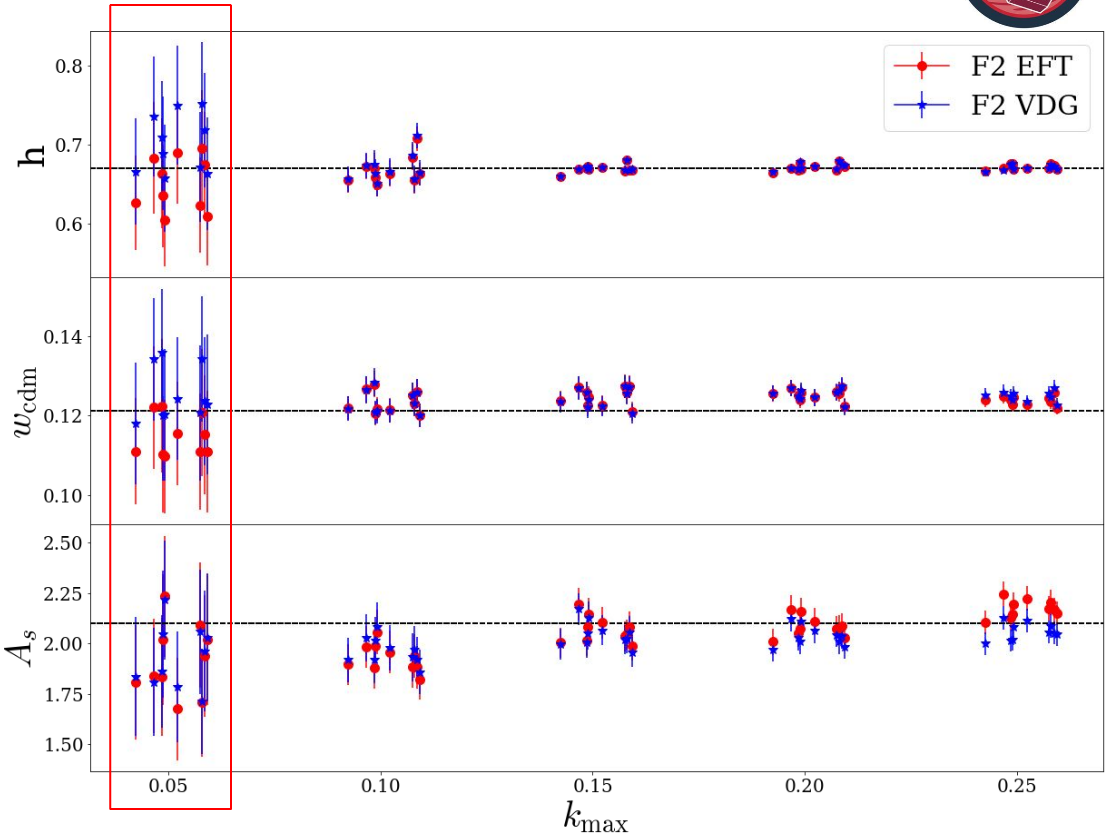
- Standard fluxes, not shuffled (luminosity-dependent bias)
- We fit four redshift bins: [0.9-1.1), [1.1,1.3), [1.3,1.5), [1.5,1.8]
- We fit 5 mocks at a time (~DR3 area), we average over 10 groups of 5 mocks
- We use an EFT model
- Each bin has independent nuisance (bias + shot noise + counterterms) parameters
- We consider ideal, realistic and ad-hoc mitigation
- The covariance matrix is computed from 1000 mocks with baseline systematics

Numerical covariance with systematics (little changes...)



Conclusions: fitting catalogs with systematics





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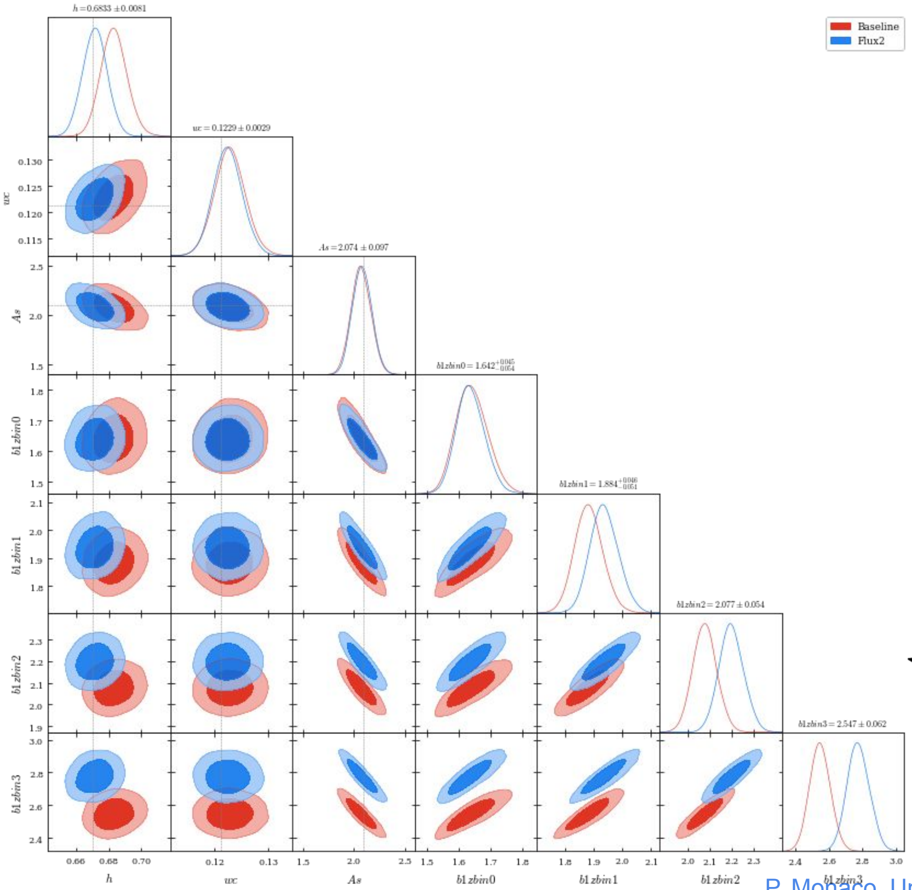
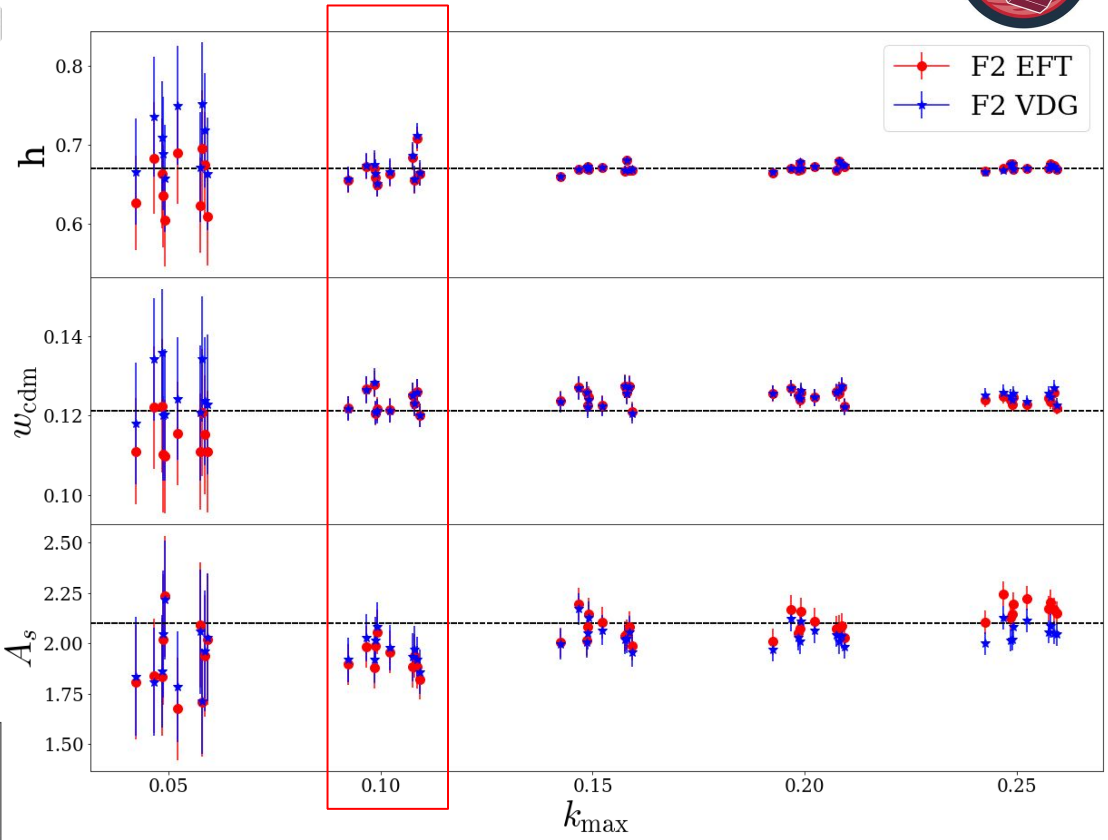
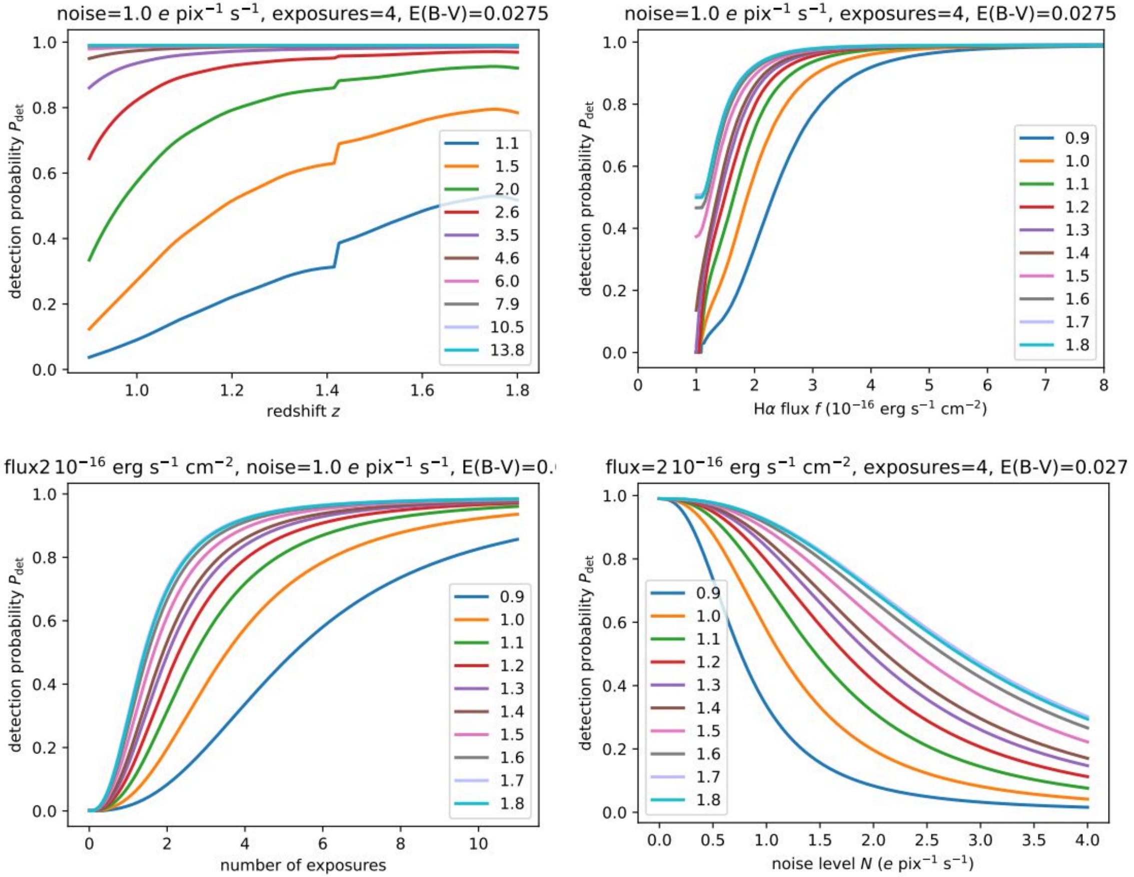




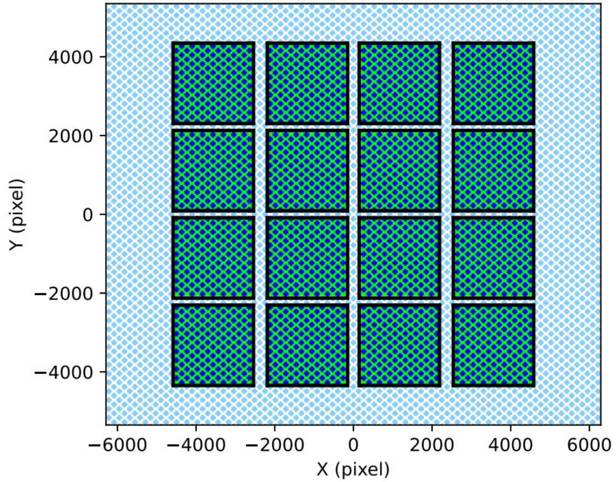
Tabulated visibility mask

computed by processing all flagship galaxie with fixed noise and exposure time, then binning them in flux, redshift and reddening. Other noise levels and exposure times are obtained by rescaling the SNR.

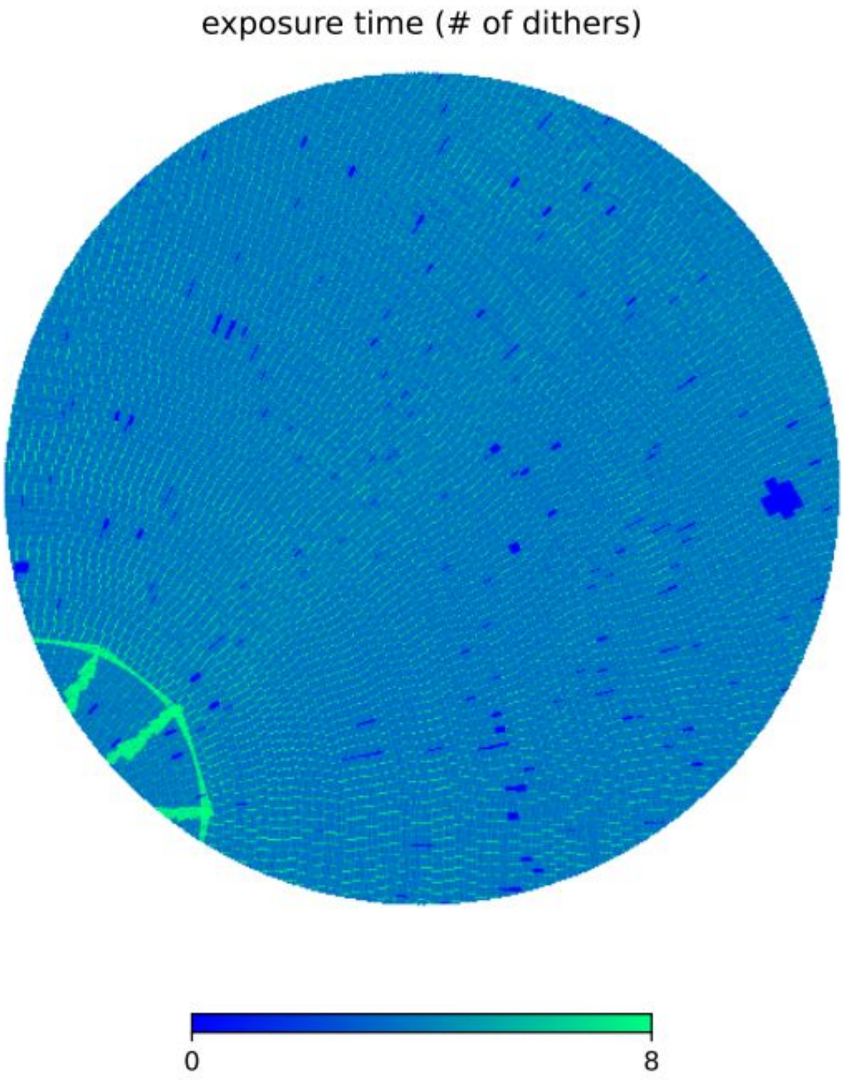
Bonnabelle Zabelle



Nuisance maps



model of NISP detector + pre-launch survey timeline + 30deg cone immersed in largest island in DR3



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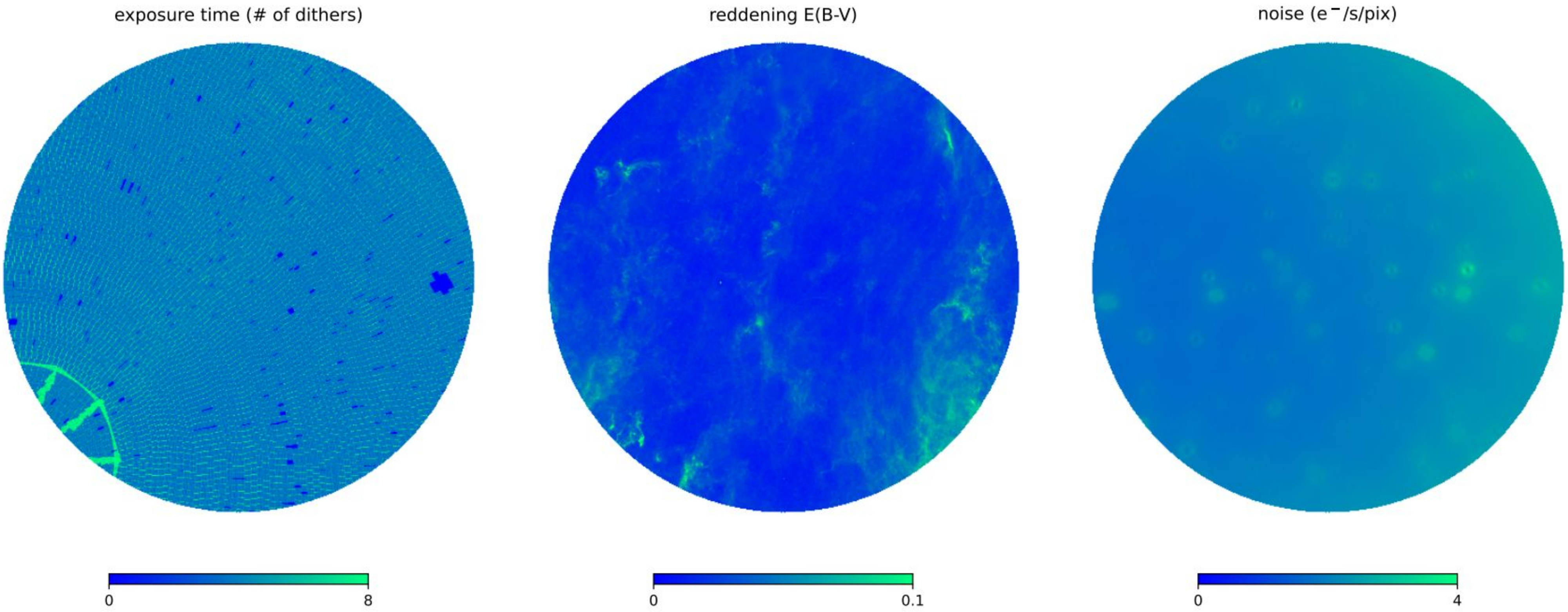
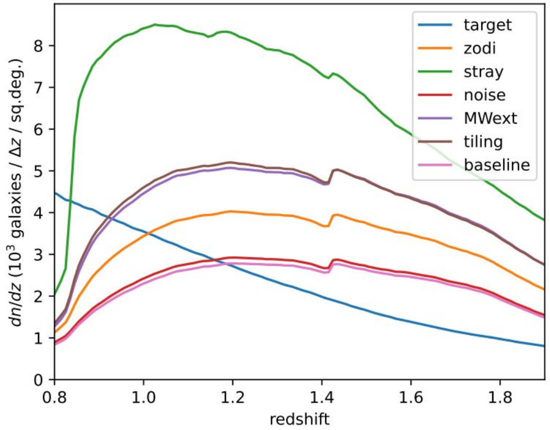
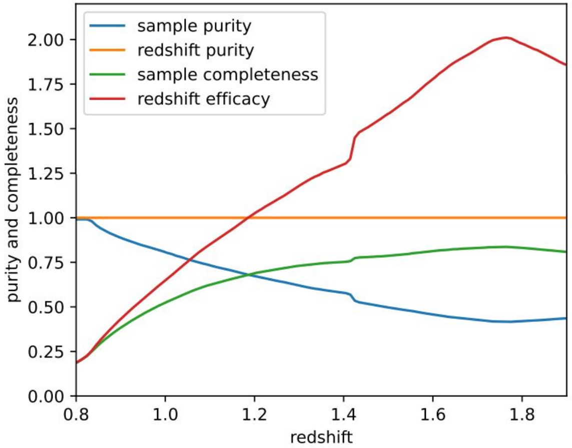
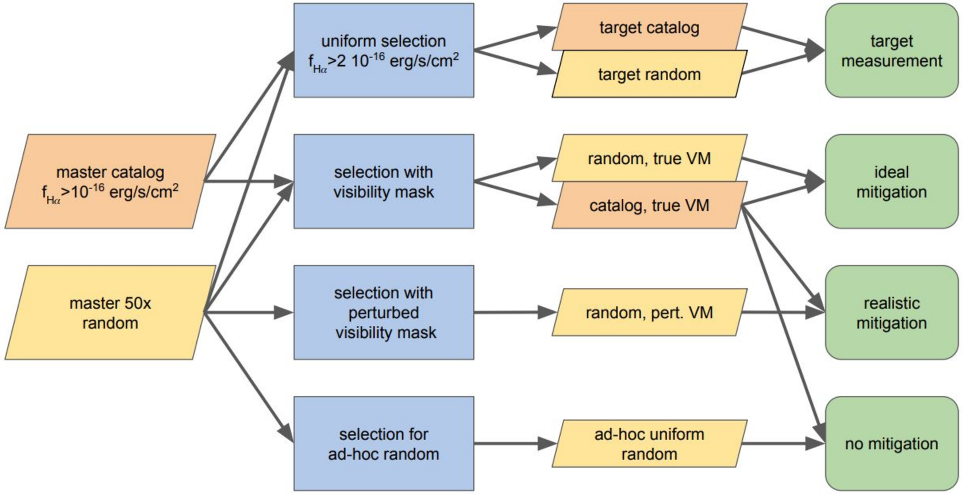


Strategy







case	zodiacal light	straylight	detector noise	MW extinction	exposure time	detection model	calibration error
zodi	yes	no	no	no	4	standard	no
stray	no	yes	no	no	4	standard	no
noise	yes	yes	yes	no	4	standard	no
MWext	no	no	no	P13	4	standard	no
tiling	yes	no	no	no	map@$z = 1.2$	standard	no
baseline	yes	yes	yes	P13	map@$z = 1.2$	standard	no
calib. 2%	yes	yes	yes	P13	map@$z = 1.2$	standard	2%
calib. 10%	yes	yes	yes	P13	map@$z = 1.2$	standard	10%
MWext P15	no	no	no	P15	4	standard	no
MWext SFD	no	no	no	SFD	4	standard	no
detmodel1	yes	yes	yes	P13	map@$z = 1.2$	$S_0 = 3.27$	no
detmodel2	yes	yes	yes	P13	map@$z = 1.2$	$S_0 = 4.11$	no
detmodel3	yes	yes	yes	P13	map@$z = 1.2$	$\beta = 3.73$	no
detmodel4	yes	yes	yes	P13	map@$z = 1.2$	$\beta = 6.23$	no