Lesson learned from Q1-CMBX and prospects for DR1

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on behalf of CMBX and CMBX-Q1 team

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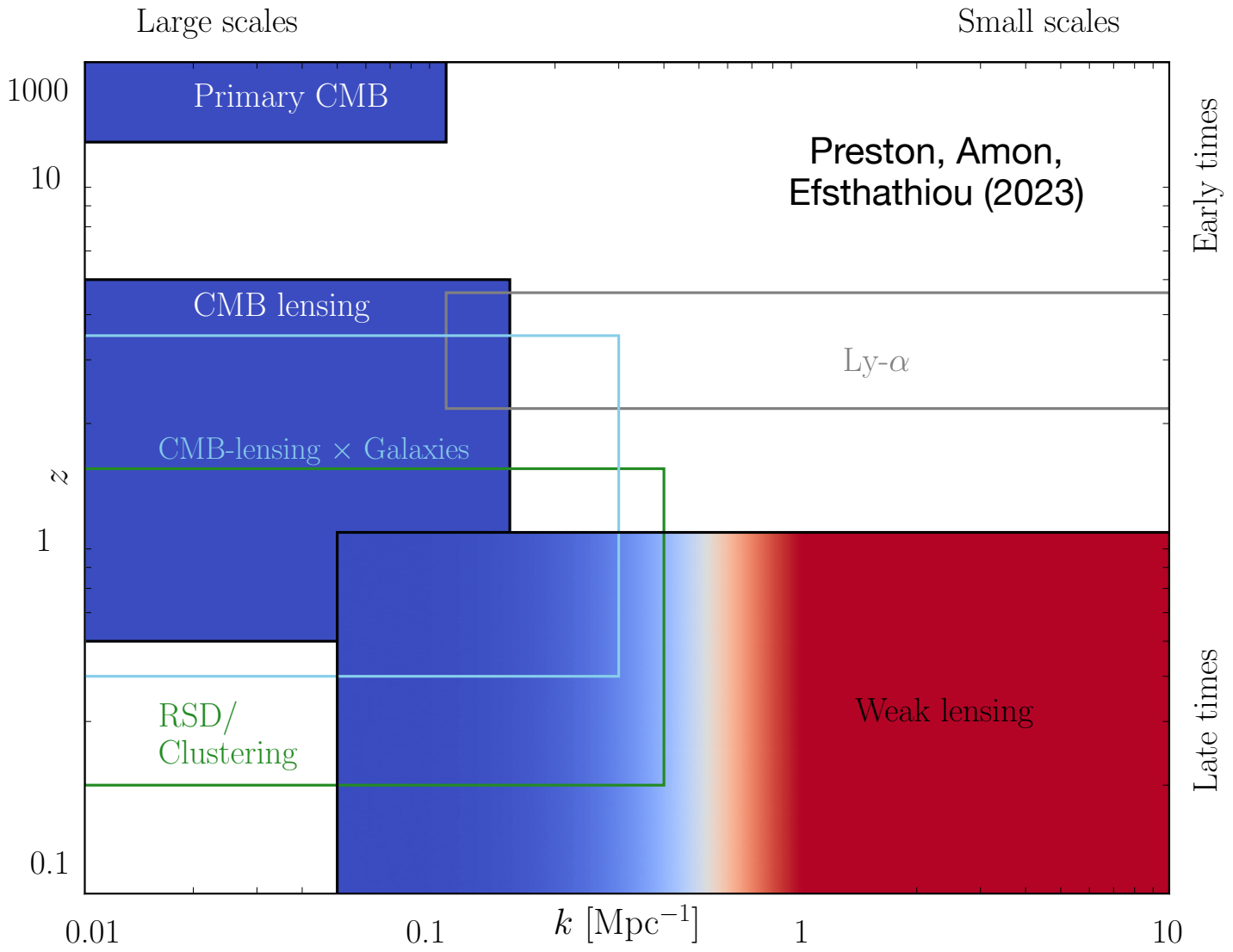
Q1 CMBX: goals and approach

- **Goal 1**: assess the quality of state-of-the-art data processing in Q1
  - No data other than Q1 products used.
  - Focus on photometric sample (though spectroscopic can be similarly tested).
- **Goal 2**: Showcase analysis for KP-CMBX-2 (and KP-CMBX-3):
  - 2x2pt w/ CMB lensing + photometric galaxy clustering.
  - Pipeline / approach validation end-to-end towards DR1 analysis.
- **Approach**: cross-correlation with CMB probes is less prone to systematics
  - Provide reasonable quality tests without compromising on robustness.
  - Multiple strategy to assess robustness (e.g. variation wrt to CMB data, null tests…)
- Focus on CMB lensing but other probes available (kSZ, tSZ…)

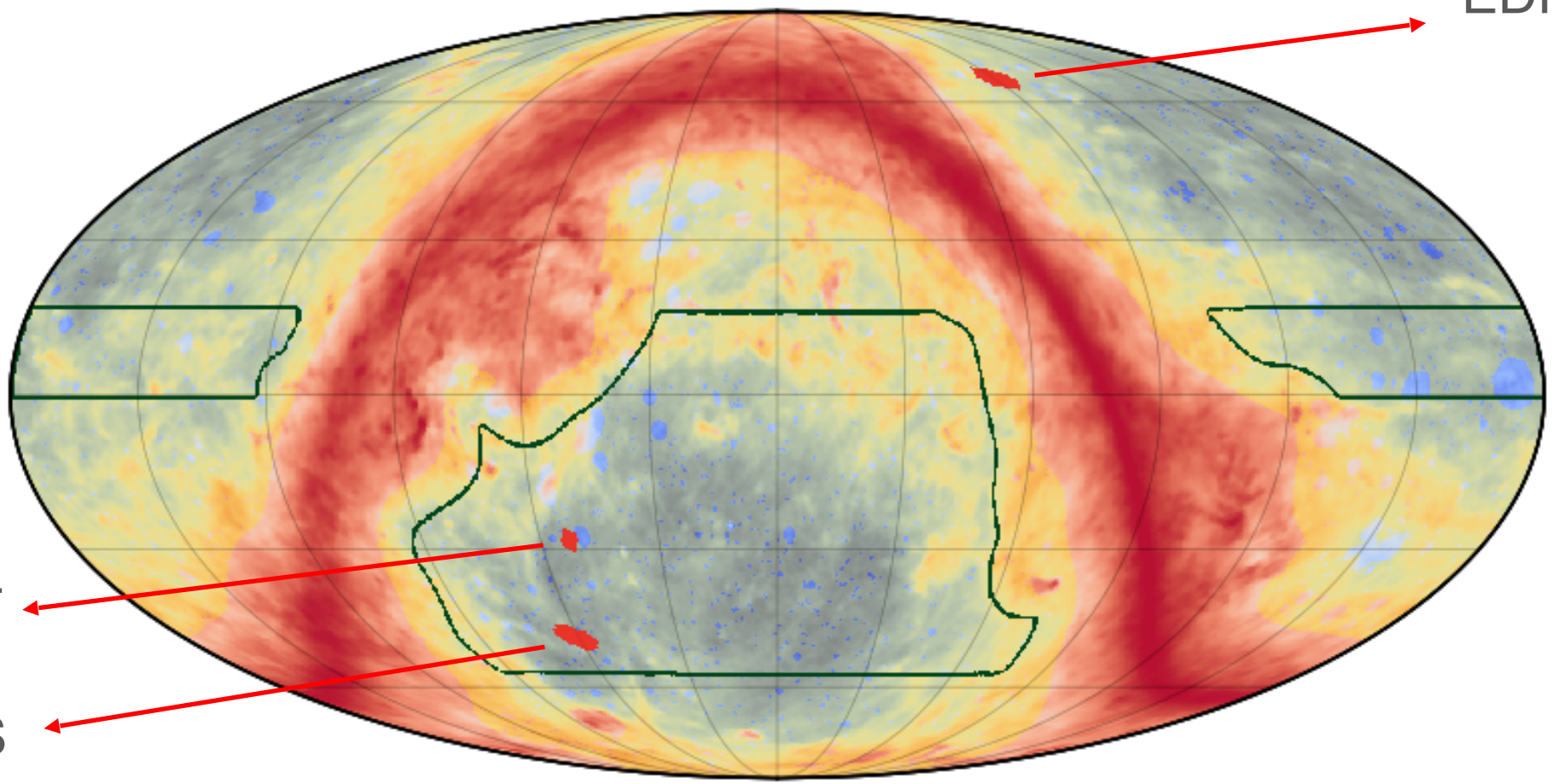
Why do we care?

- Different probes means different scales at different redshift…

- Need to assess if any new physics is real or effects of non-linear physics.

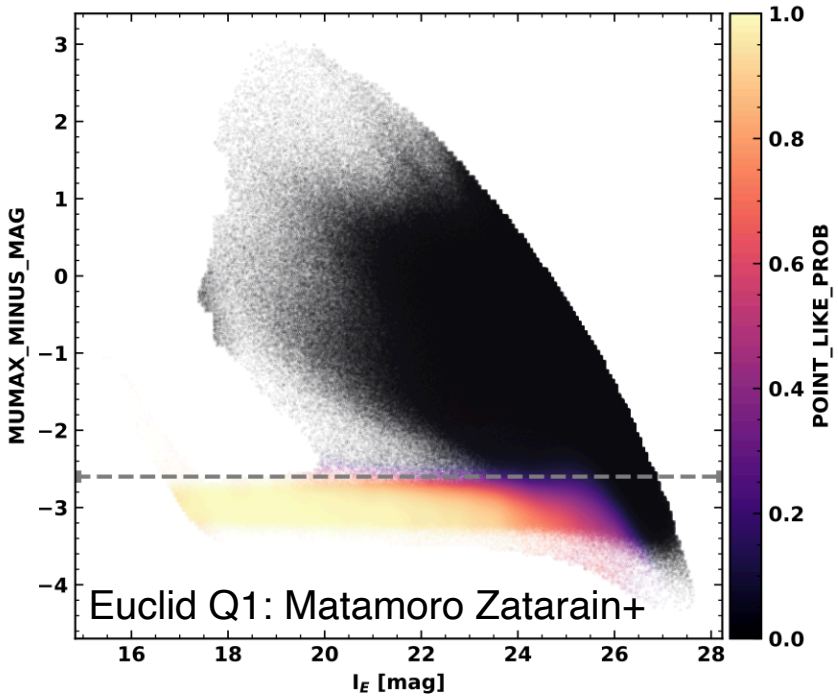


Footprints and sky areas

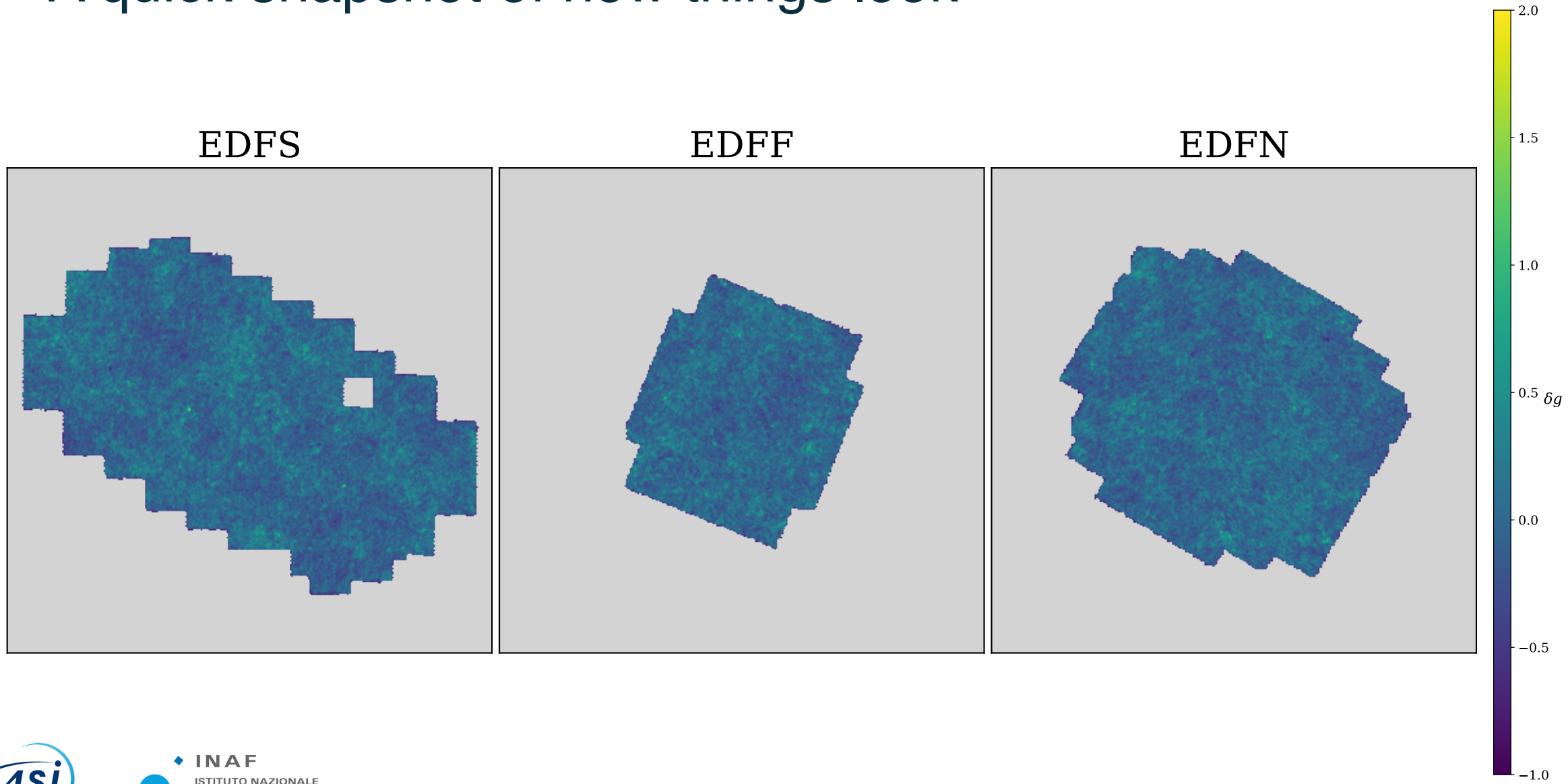


Analysis approach

- Our baseline sample selection (~MAGLIM)
  - Quality cuts MUMAX_MINUS_MAG<-2.6 + detection quality flag
  - Cut at z<2.5 to avoid degeneracy area in PHZ estimation
  - Multiple photo-z estimates for tomography (1,3,6 bins)...
- Pipeline relying on state of the art CMBX analyses
  - Project galaxies on the sky and compute overdensity.
  - Compute C_ℓ with mask deconvolution and Gaussian covariance
- Check consistency with Planck cosmology and maybe push to cosmology if possible
  - Linear bias and magnification bias from SPV3
  - Non-linear bias fitted on Flagship $\{b_1(z), b_2(z)\} + \{b_{s^2}, b_{3nl}\}$ set to co-evolution relations.
  - Compare results on different patches and stability

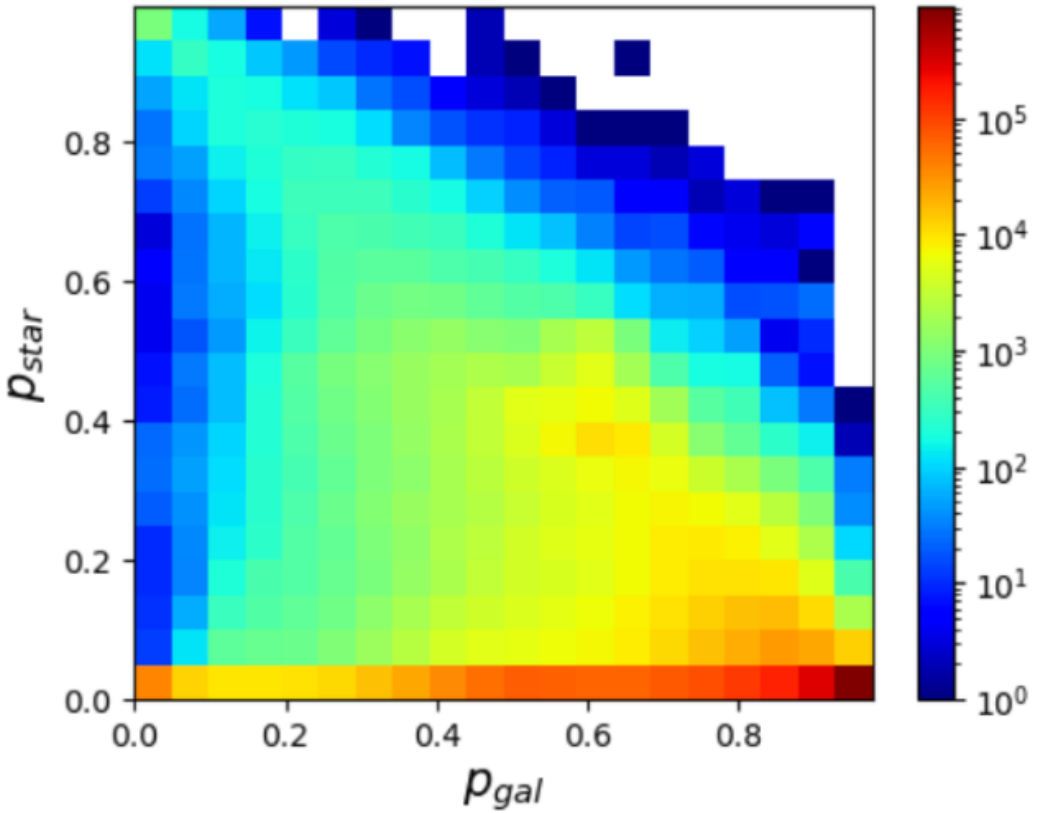


A quick snapshot of how things look



Sample selection

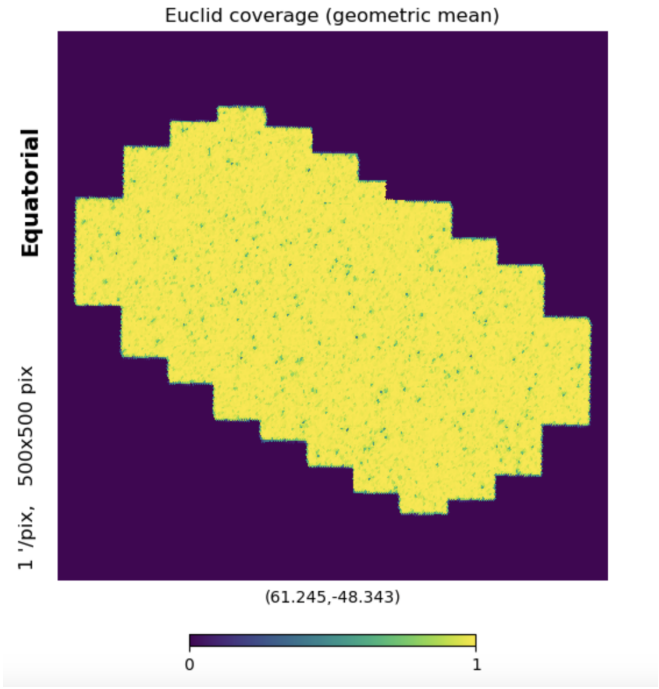
- We investigated several samples selected based on classification purity
  - $p_{gal} > 0.90$ (~11 gal/arcmin^2)
  - $p_{star} < 0.05$ (~20 gal/arcmin^2)
- DES MAGLIM ~0.12 gal/arcmin^2 on 4000 deg^2
- Classification varies by field given difference in available photometry
  - PanSTARR vs DES…
- Classification coupled to PHZ quality:
  - Systematics from EXT….

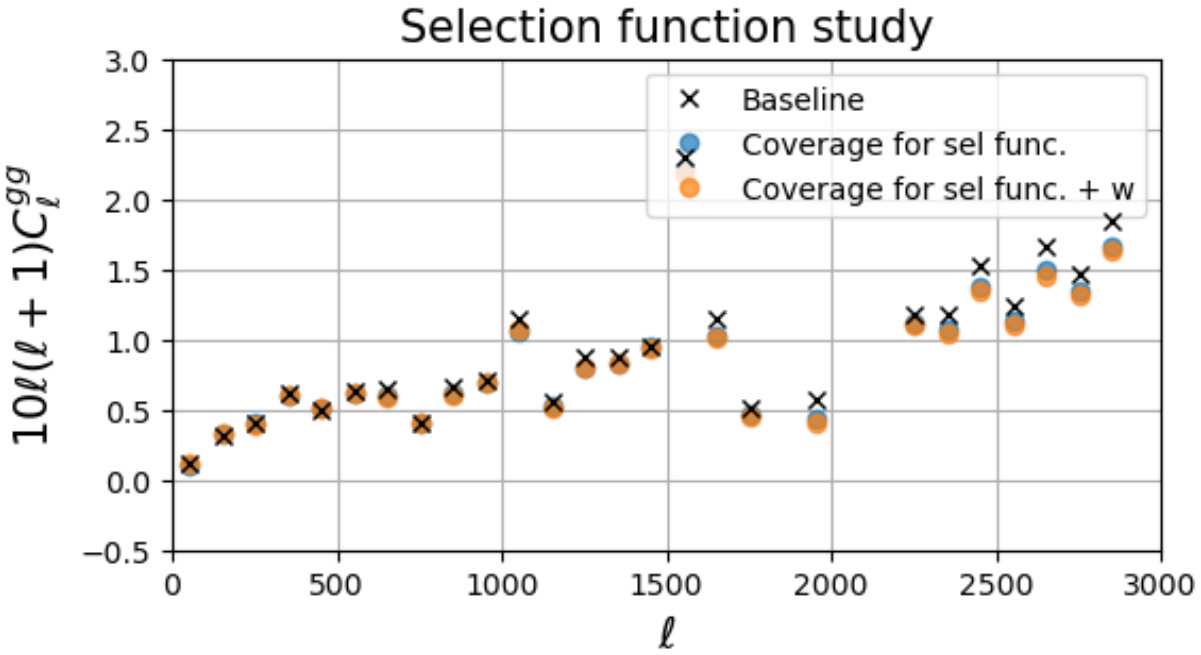


Selection function tests

- No full VMPZ full selection function.
  - **HOWEVER** Euclid is very uniform.

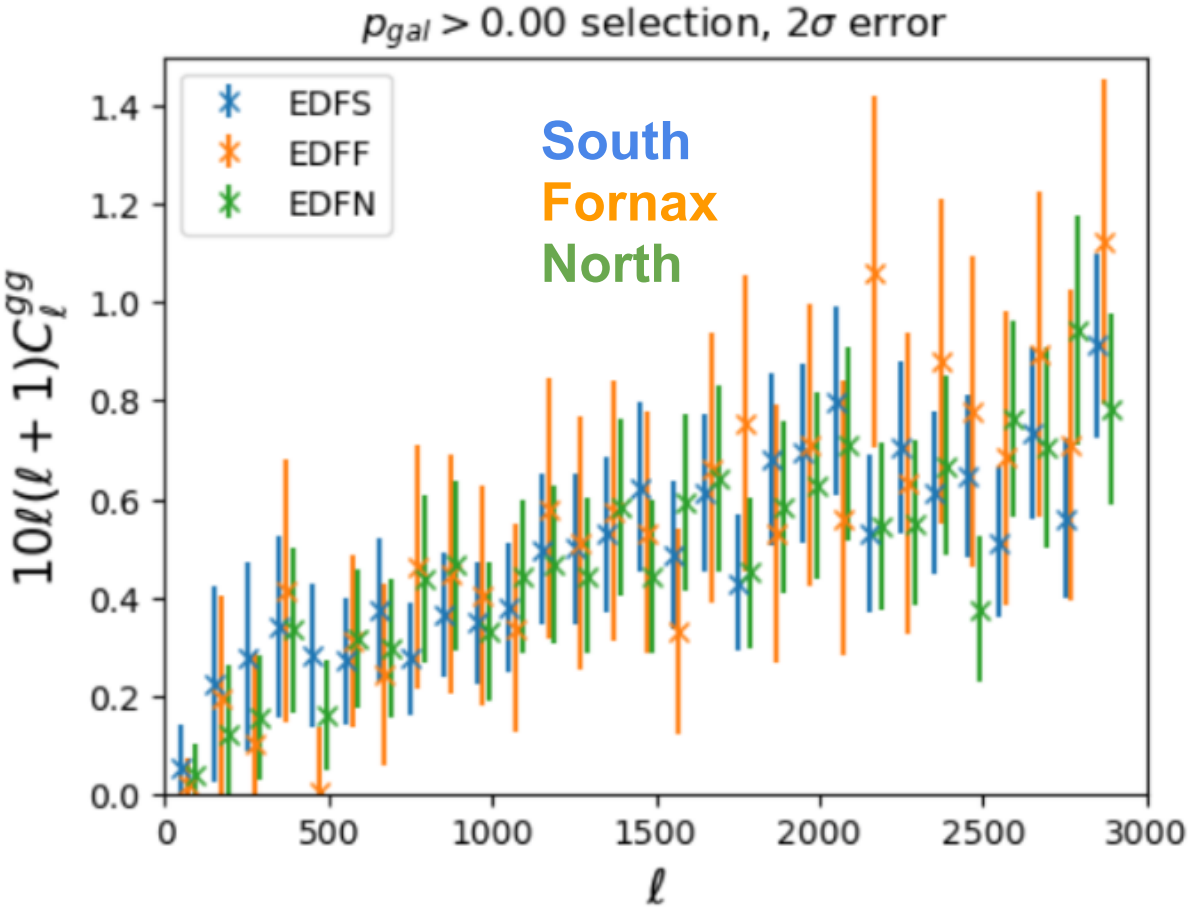
- VMPZ coverage mask as 0-th order selection function:
  - No major effects ℓ<2000 !





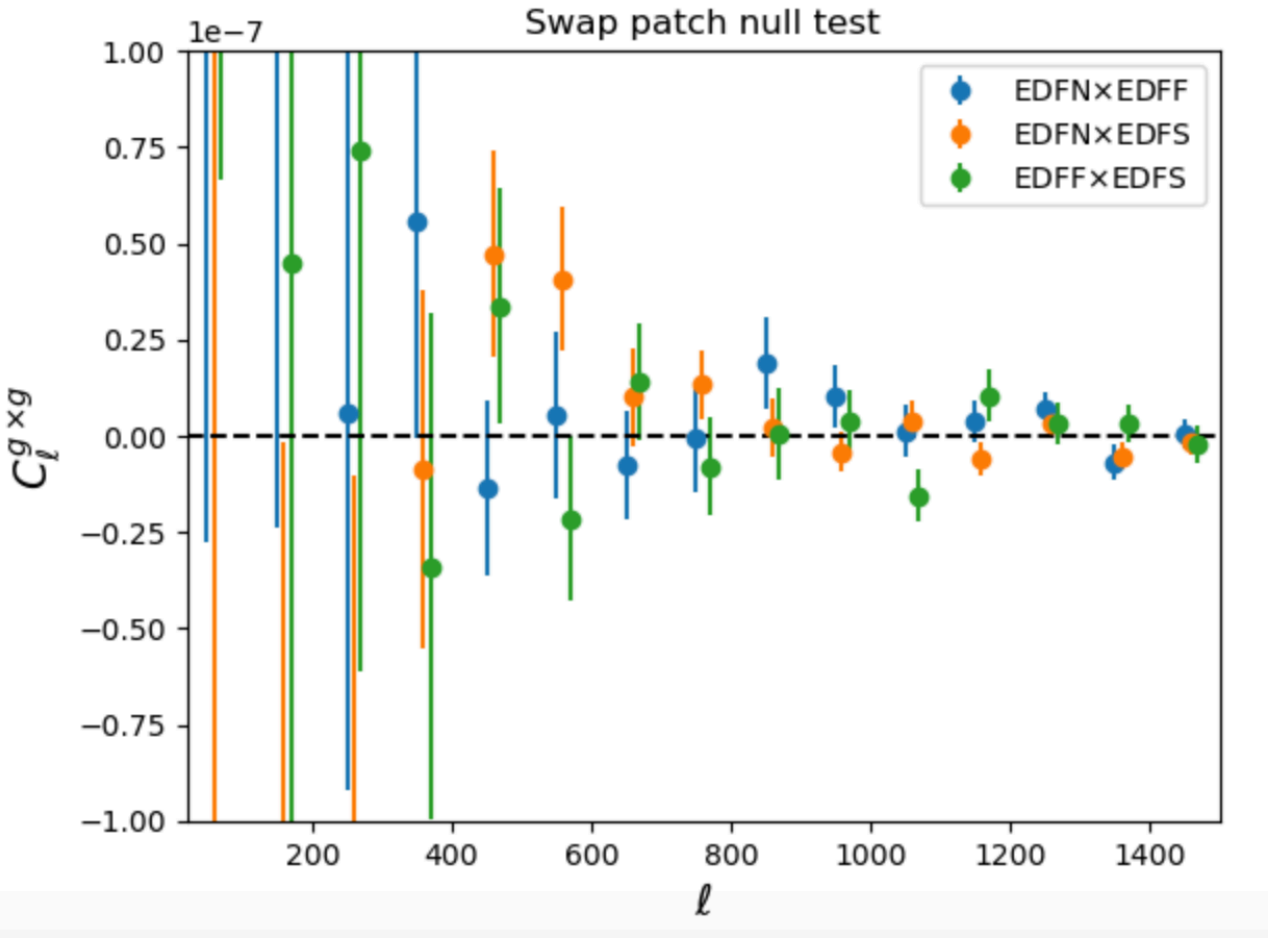
Consistency across footprints (Euclid alone)

- NO differences across footprints identified prior to purity cuts
  - Potential FOV effects at $\ell \sim 500$
- Similar situation when applying purity cuts (p_{gal}, p_{star}).



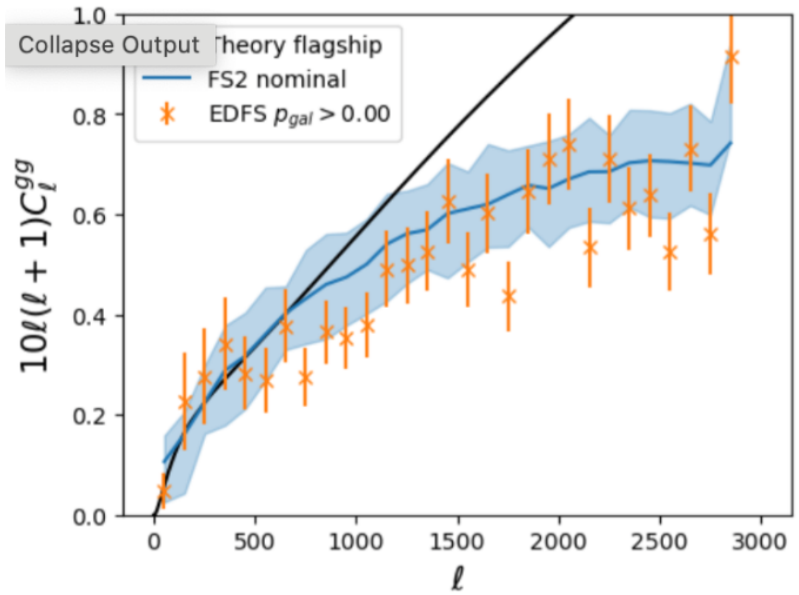
Internal null / consistency tests

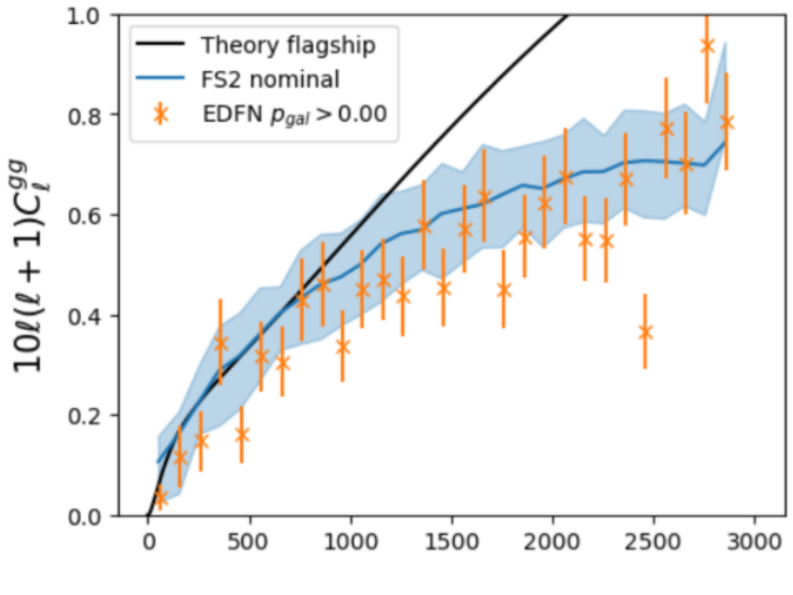
- Everything works!
  - Jackknives null tests
  - Swap field null tests
  - Null lensing map cross-correlation
  - CMB lensing maps internal consistency
  - …

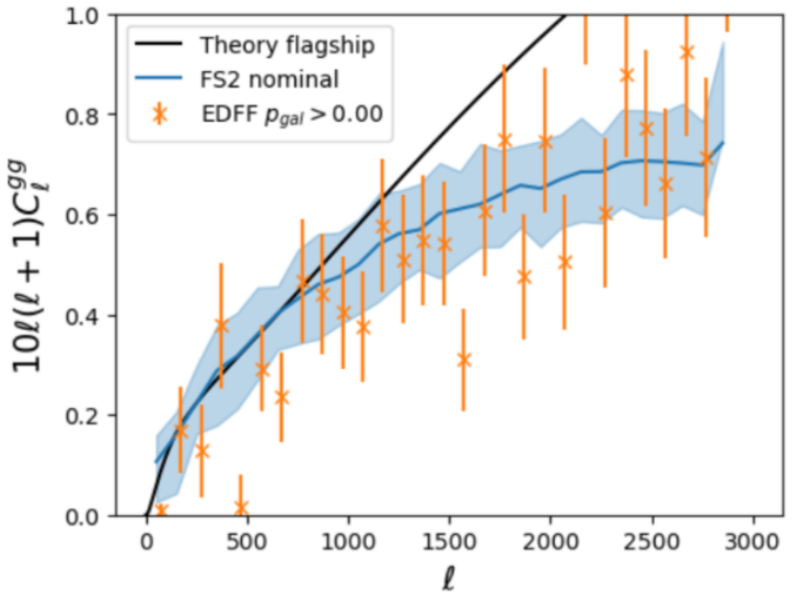


Flagship-2 comparison

- No tomography (galaxies z<2.5 in FS2, no PHZ estimates effects)
- Divide octant in Q1-like patch and compute mean and std as estimate of true expected covariance.
- C_ℓ^{gg} applying no cuts always consistent with FS2 predictions (χ^2test)

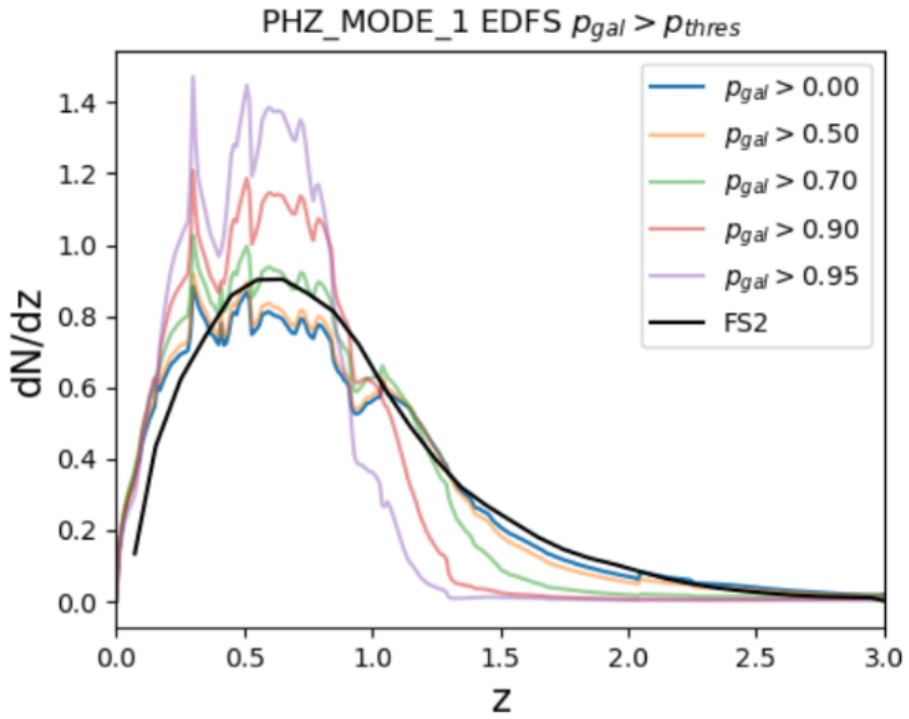


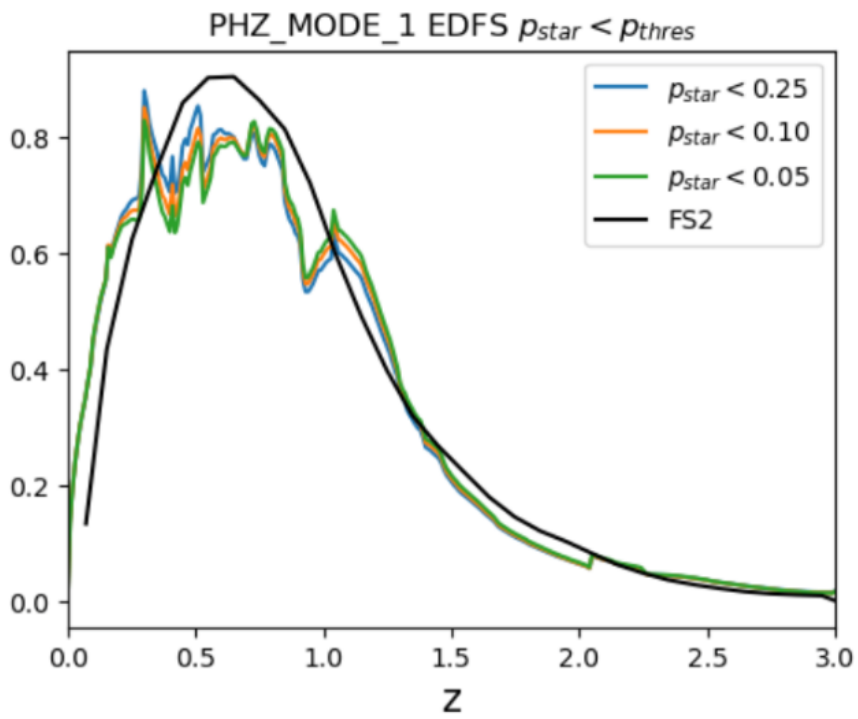




Towards a tomographic analysis

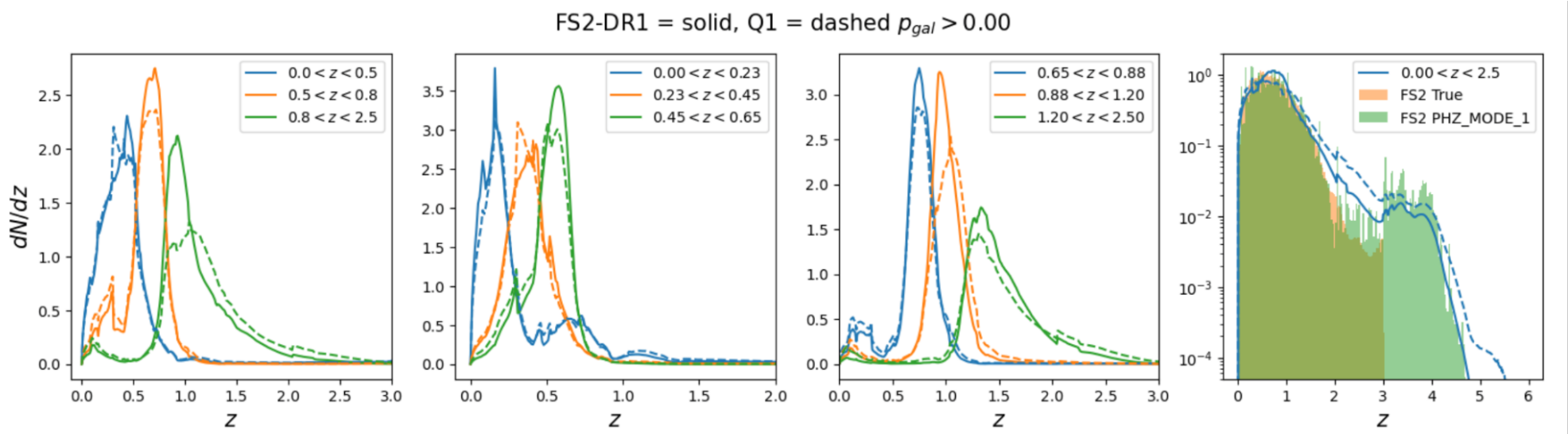
- Cut on purity highly correlates with PHZ quality / depth
- High-z tail removed by galaxy classification selection.
- Problem: inhomogeneous data/PHZ quality…



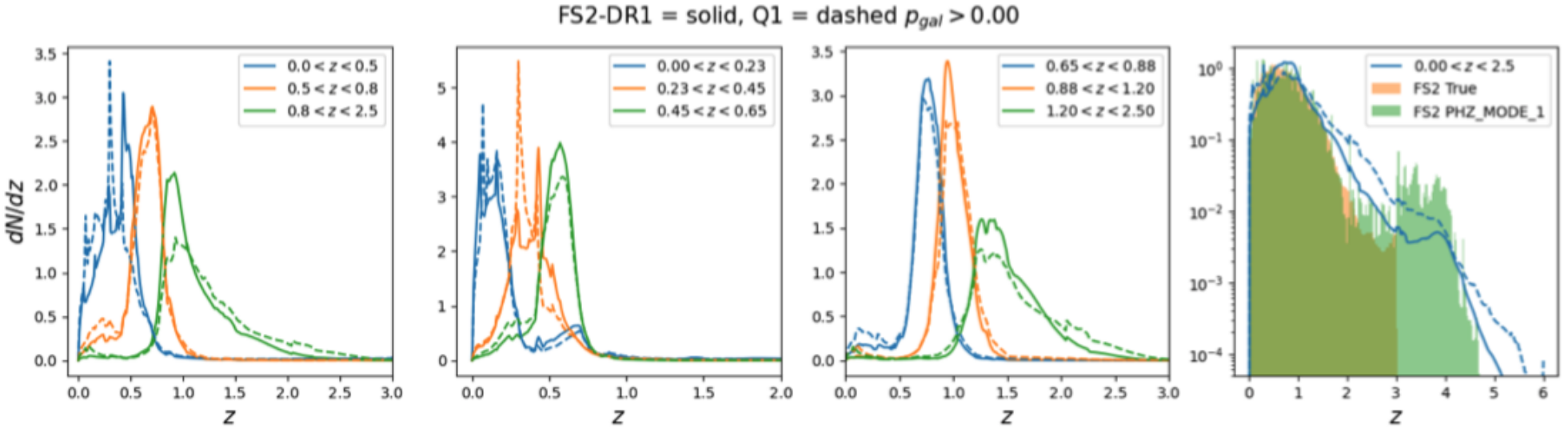


Redshift estimates vs FS2 + Phosphorus

- EDFS



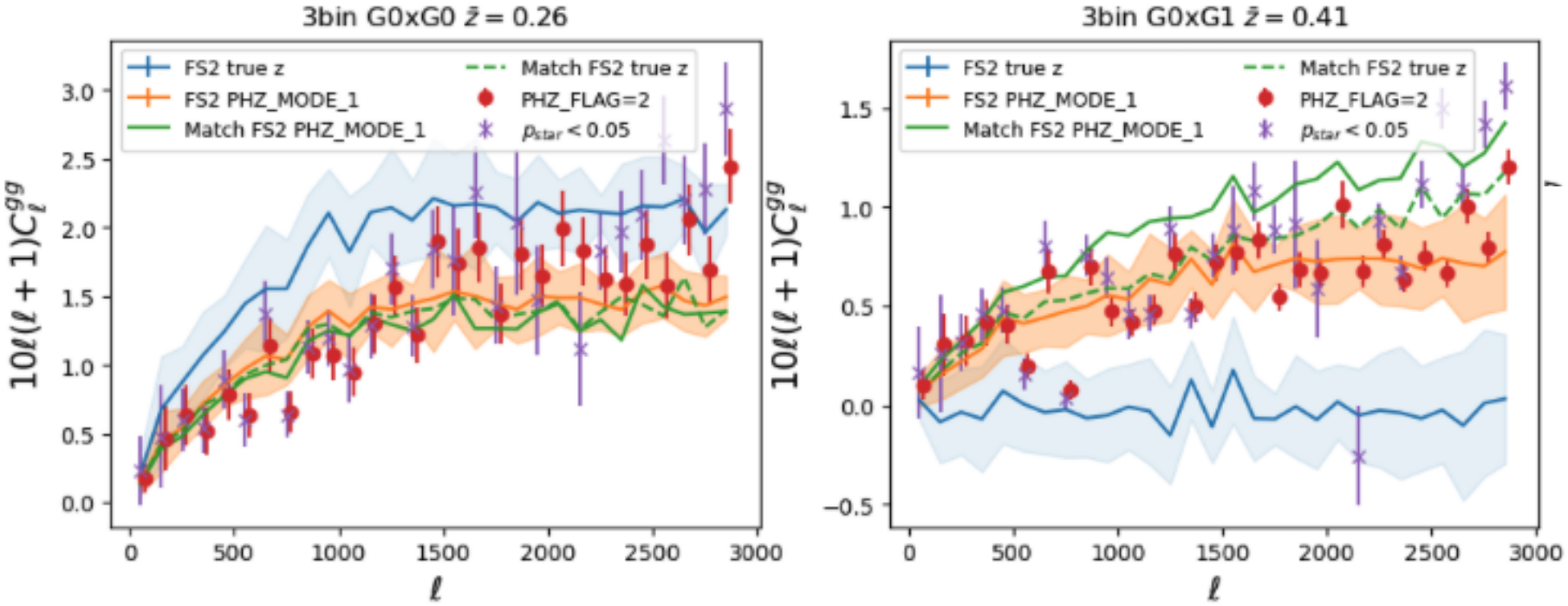
- EDFN



Clustering 3 bins vs FS2+Phosphorus

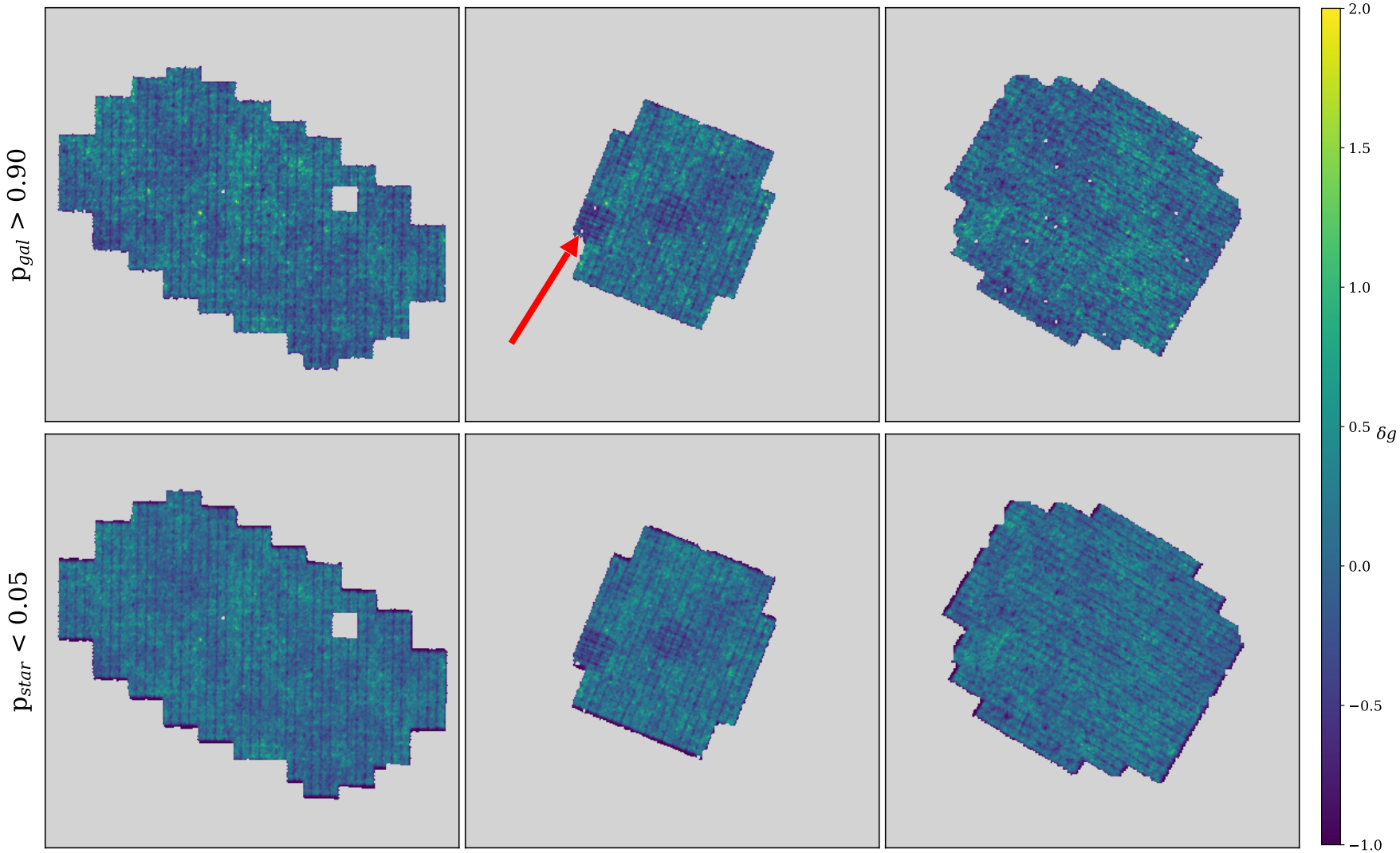
- Quite coherent with expectations from FS2 including PHZ processing
  - Full classifier not ran for simplicity, Difficult to assess specificities of sample…

- PHZ PDF model quite well neighboring bins but further bins are more tricky



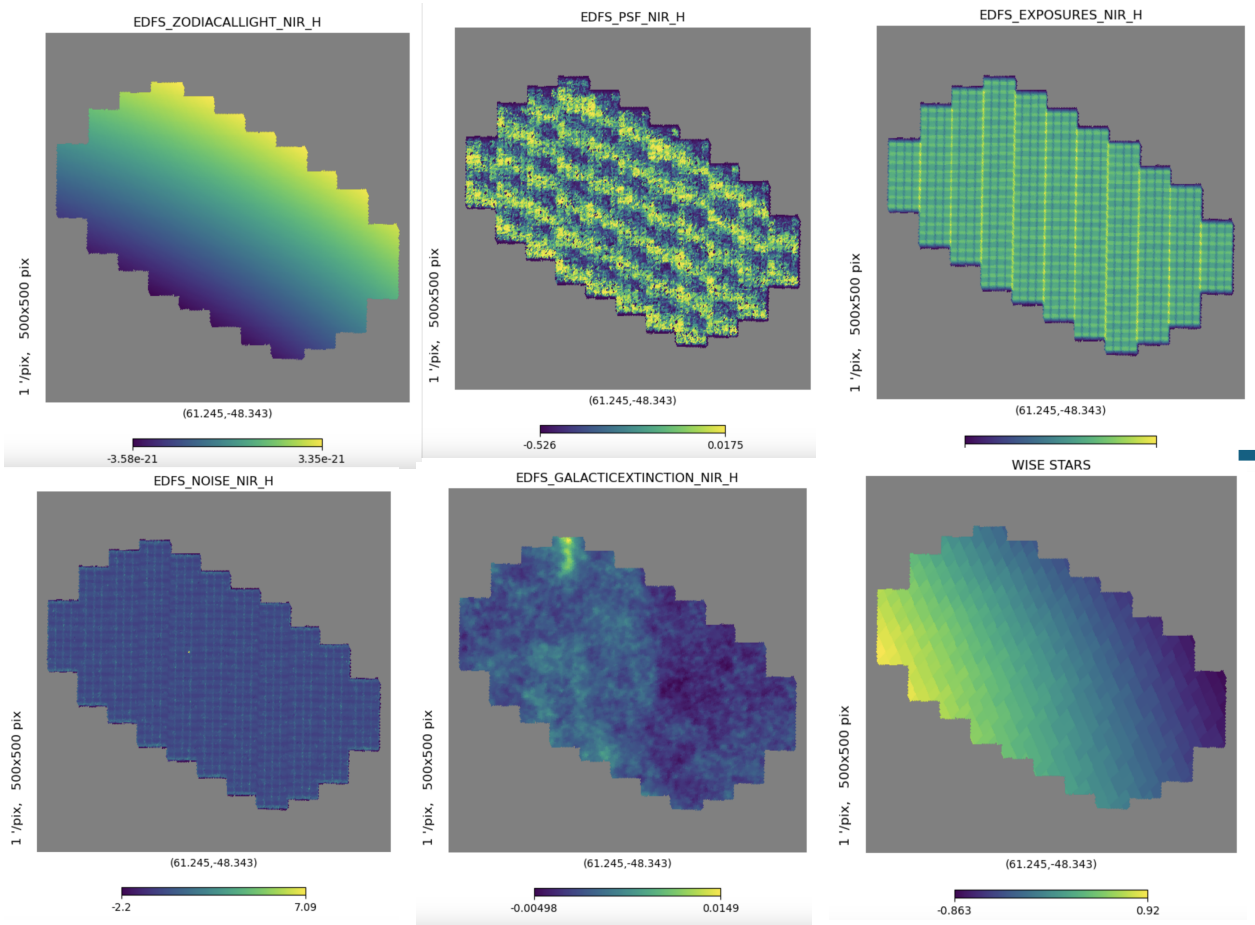
Some technical points

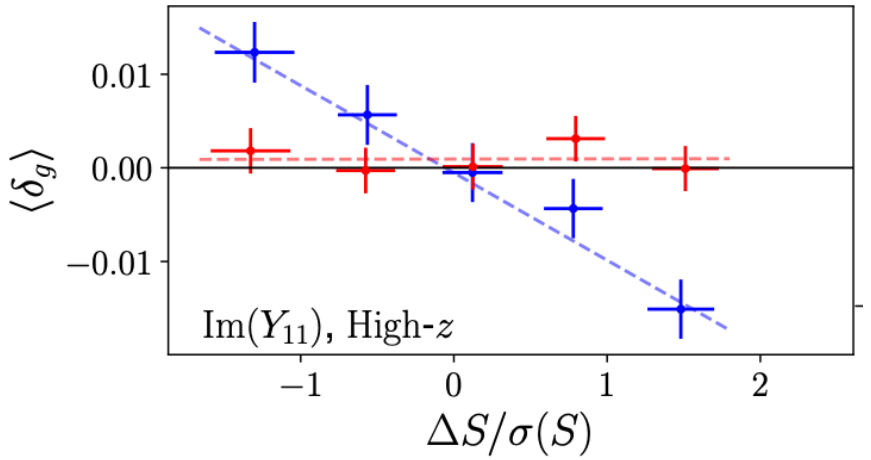
Selection induced systematics



How to use VMPZ templates…

- Linear systematics deprojection using VMPZ masks

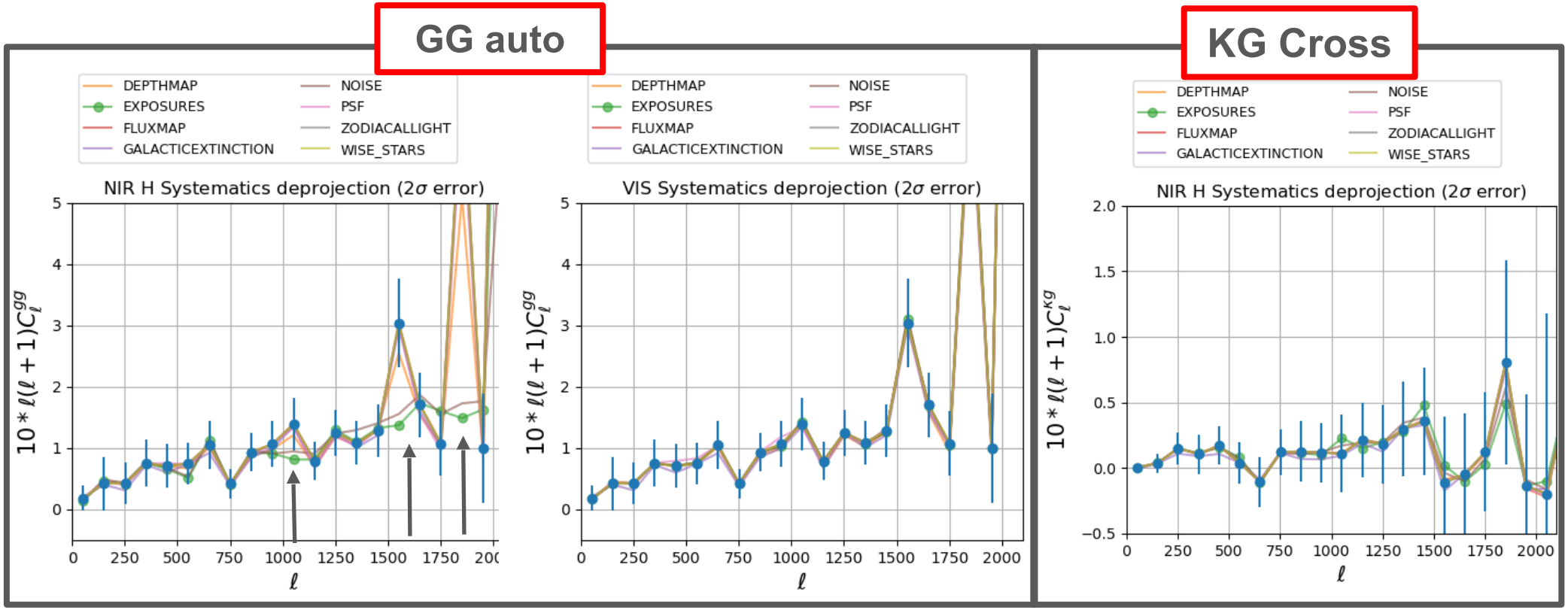




Fabbian, Alonso, Storey-Fisher+(2025)

Systematics deprojection results on power spectra

- Only exposure on NISP shifts points >2σ, No other template seems to matter!
- CMB Cross correlation totally insensitive!



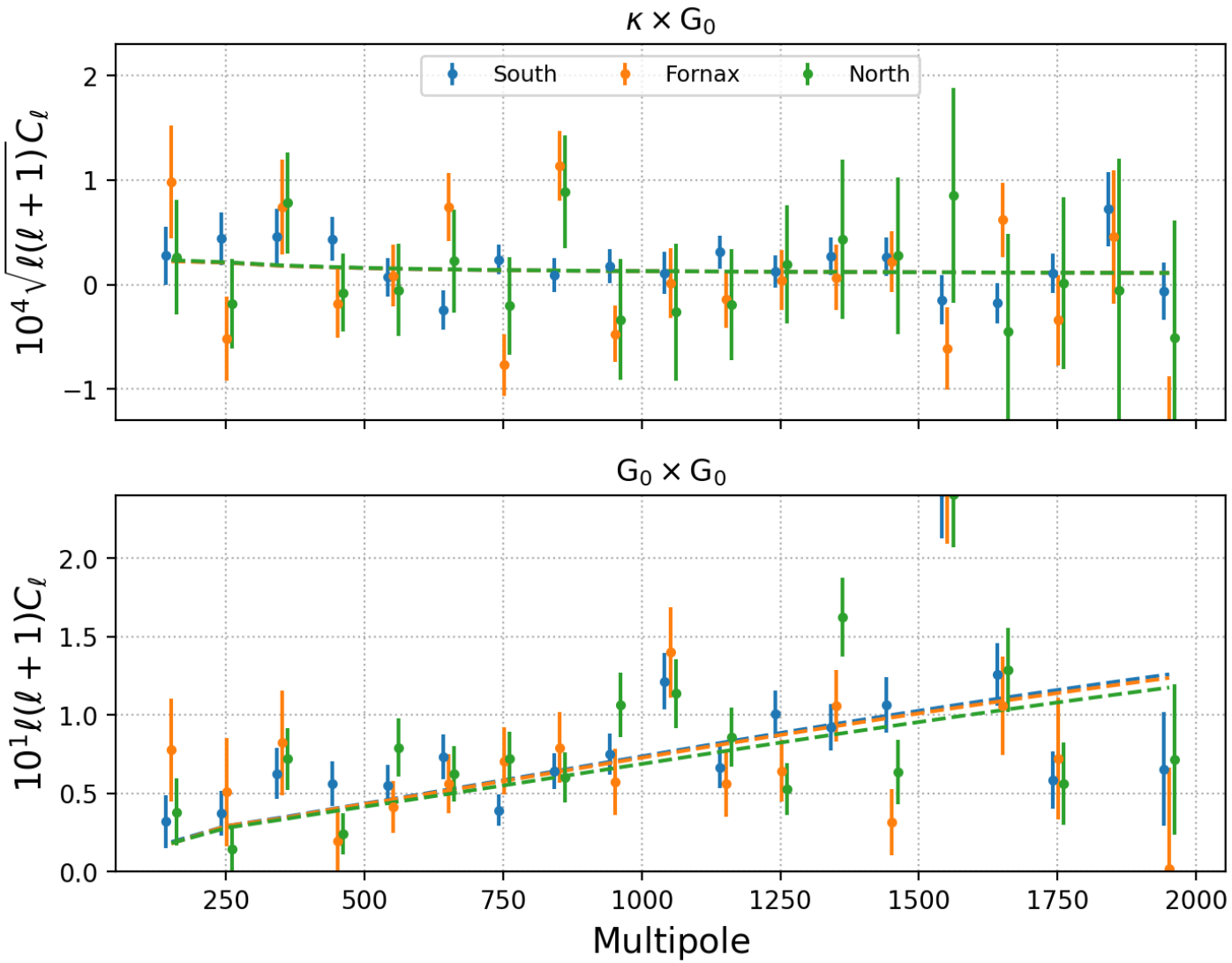
Single bin consistency

WARNING: no theory line is a fit!

$p_{gal} > 0.90$

l = 100 – 1500
PTE = 35.8%
PTE = 0.7%
PTE = 1.4%

l = 100 – 2000
PTE = 0.0%
PTE = 0.0%
PTE = 0.0%

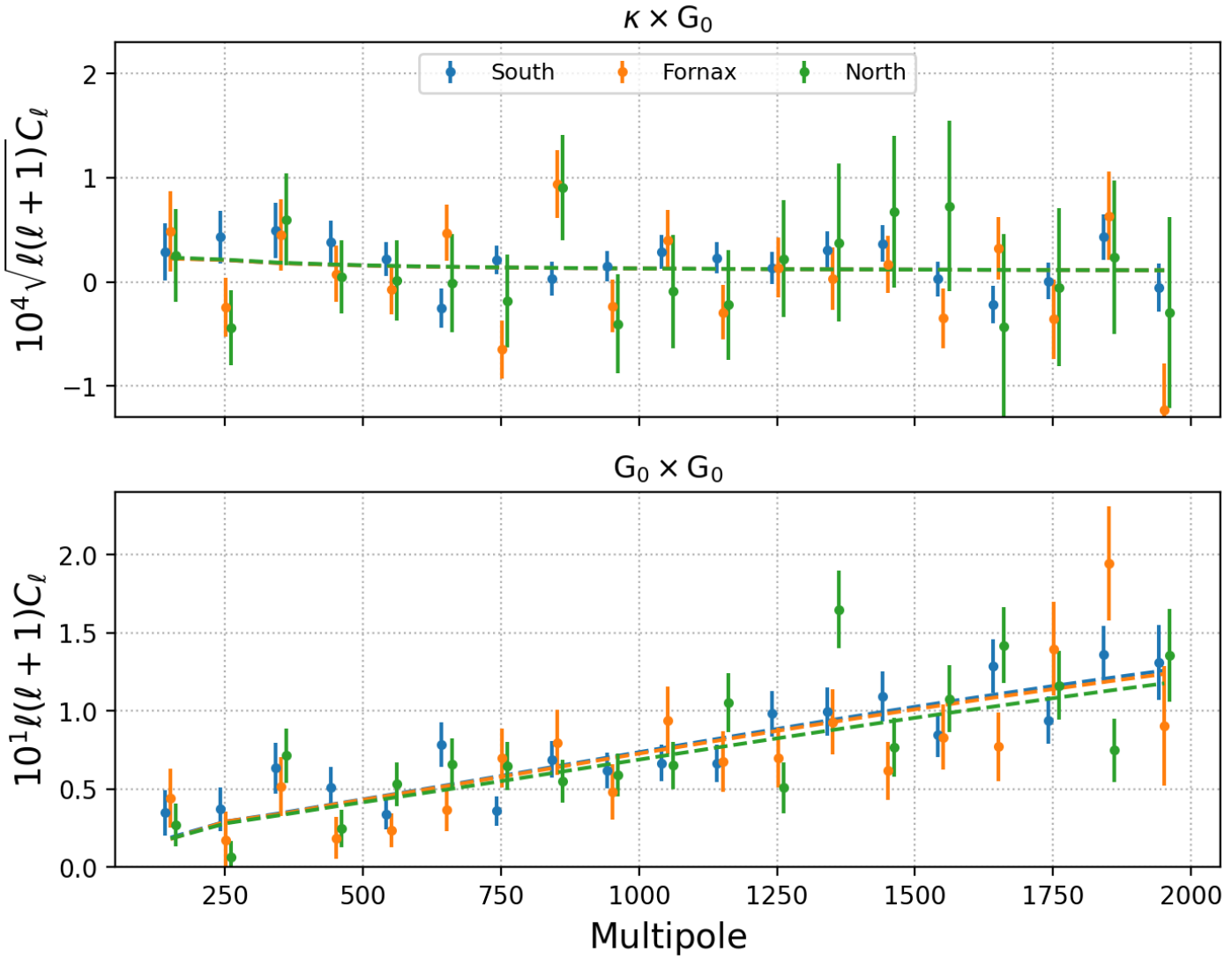


South
Fornax
North

$p_{gal} > 0.90$ – systematics deprojected

l = 100 – 1500
PTE = 30.1%
PTE = 6.3%
PTE = 0.1%

l = 100 – 2000
PTE = 32.8%
PTE = ?%
PTE = 0.7%

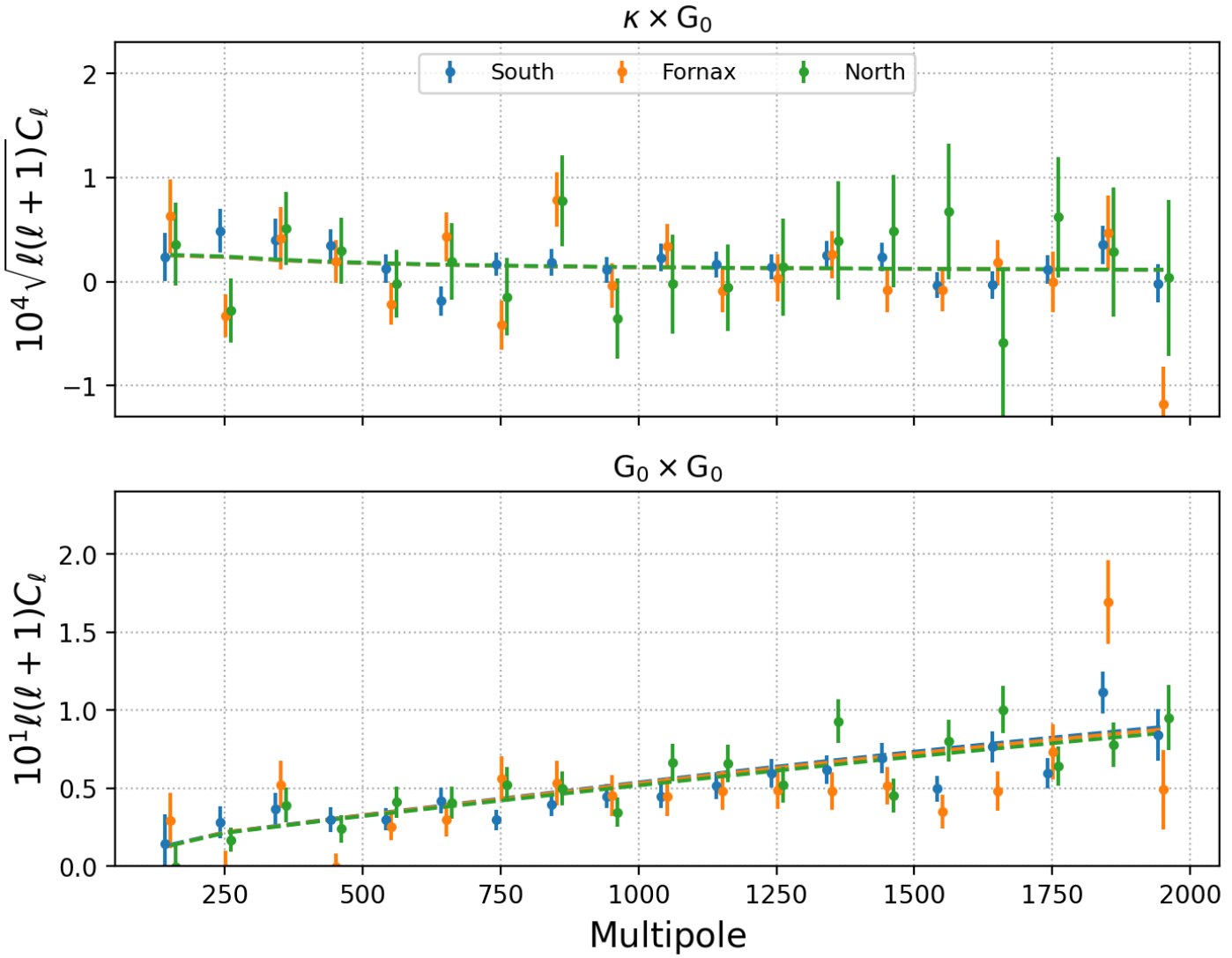


South
Fornax
North

$p_{star} < 0.05$ – systematics deprojected

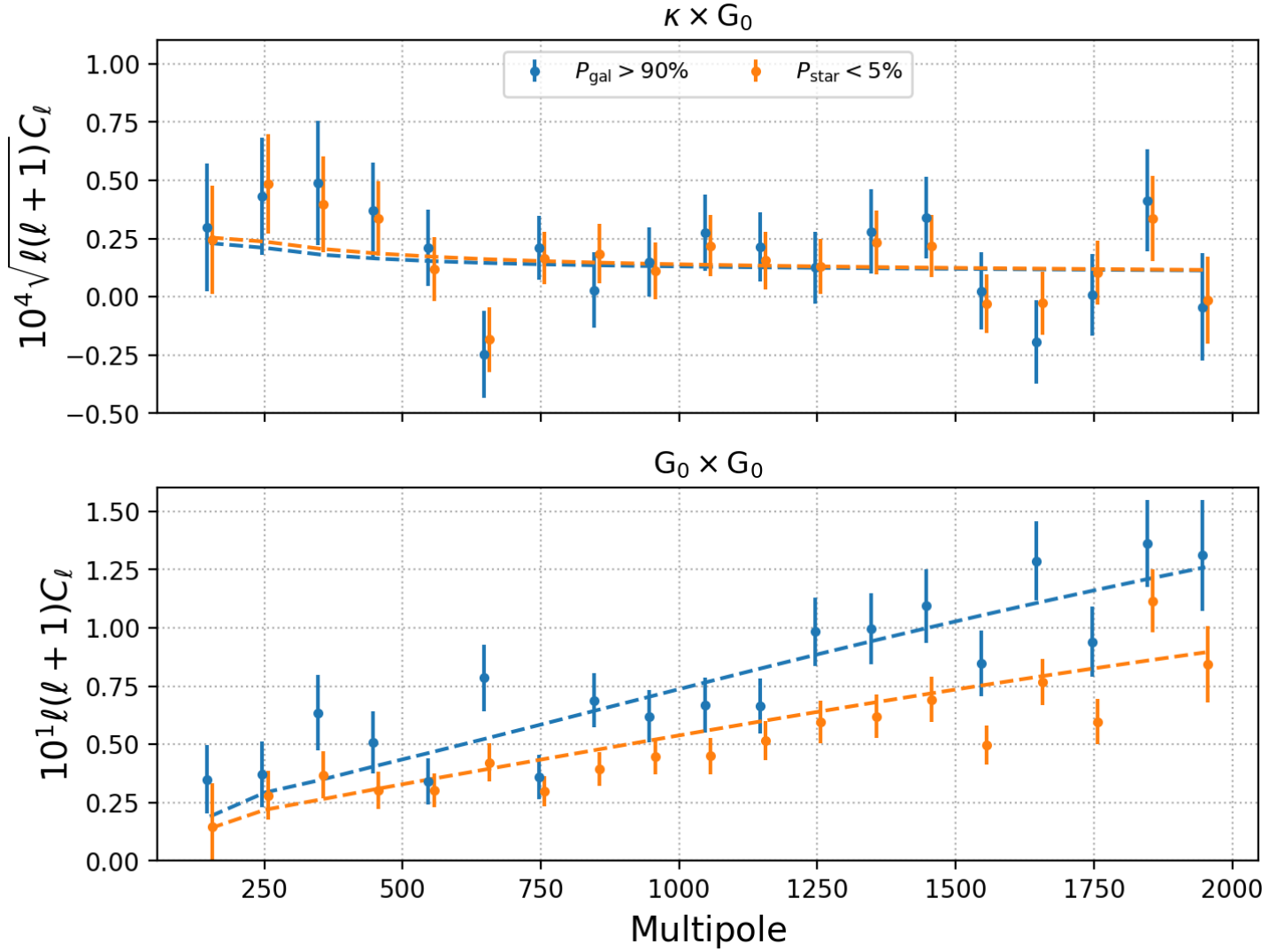
l = 100 – 1500
PTE = 39.4%
PTE = 61.6%
PTE = 3.2%

l = 100 – 2000
PTE = 5.8%
PTE = ?%
PTE = 5.3%



South
Fornax
North

South – $p_{gal} > 0.90$ vs $p_{star} < 0.05$

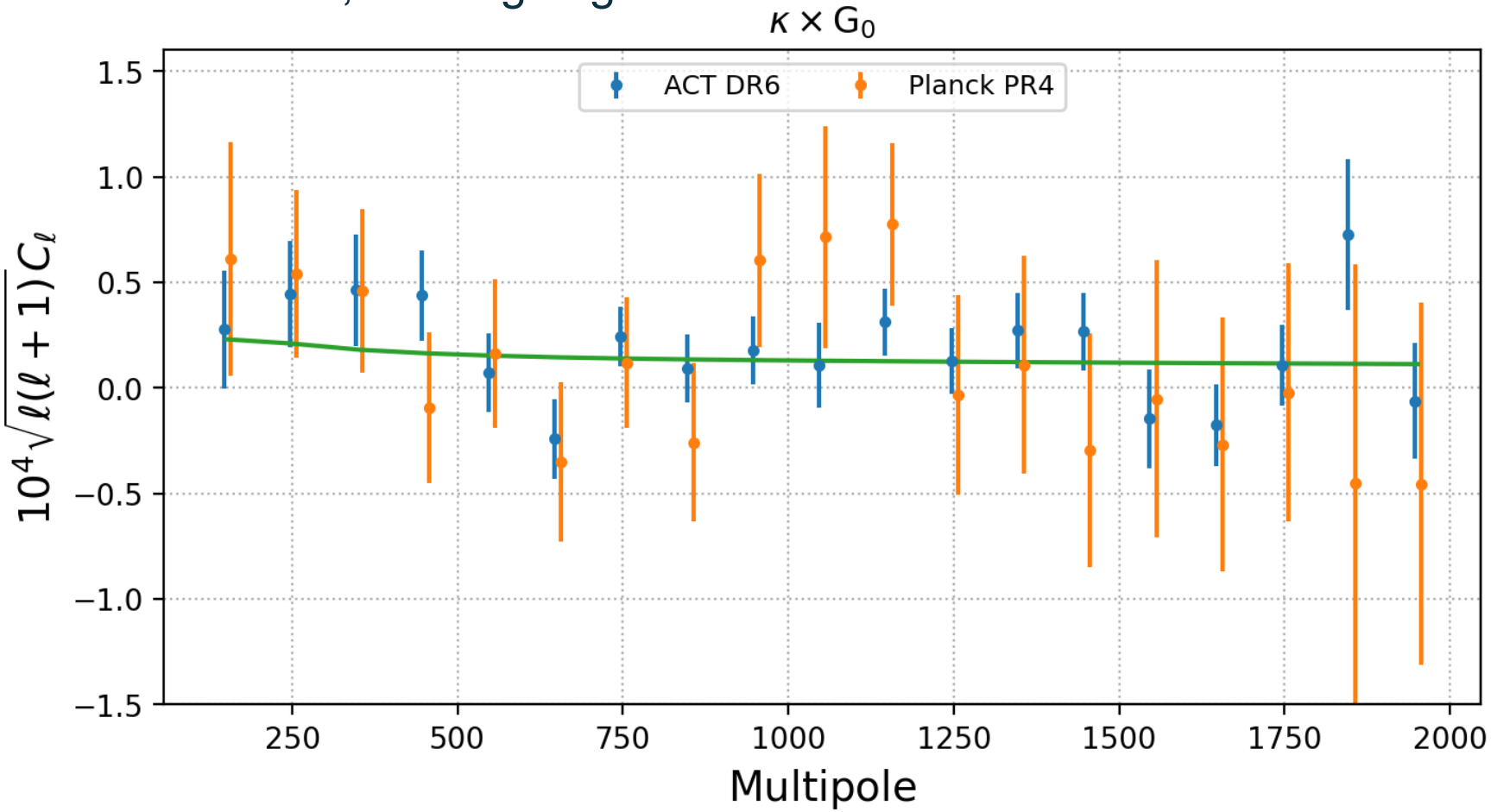


p_{gal} **> 0.90**

p_{star} **< 0.05**

South – $p_{gal} > 0.90$ ACT vs Planck

- We need to (and will!) capitalize on the power of new CMB ground based experiments
  - SPT MoU done, SO ongoing…

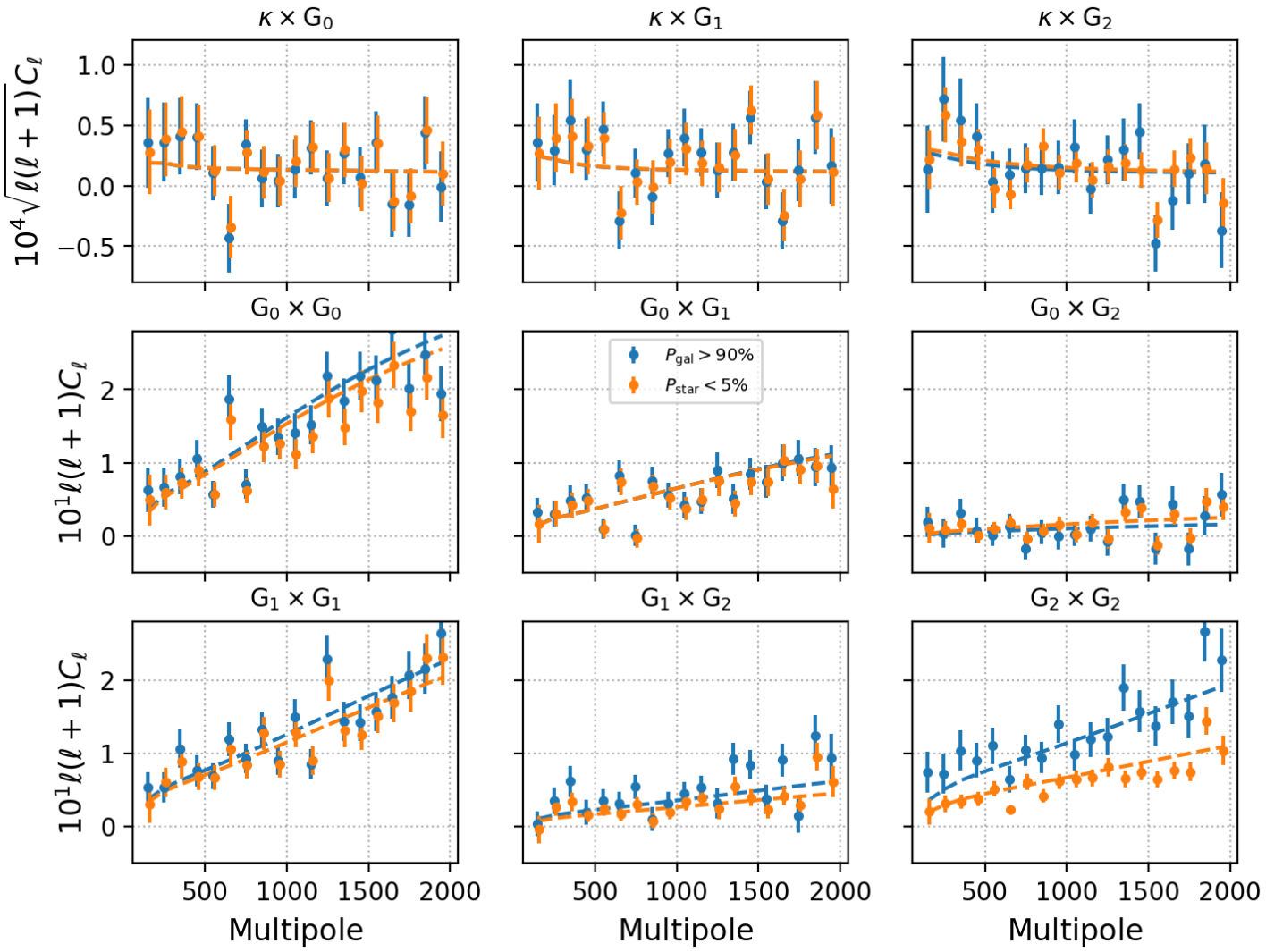


ACT
Planck

Three bins
Consistency

WARNING: no theory line is a fit!

South – $p_{gal} > 0.90$ vs $p_{star} < 0.05$

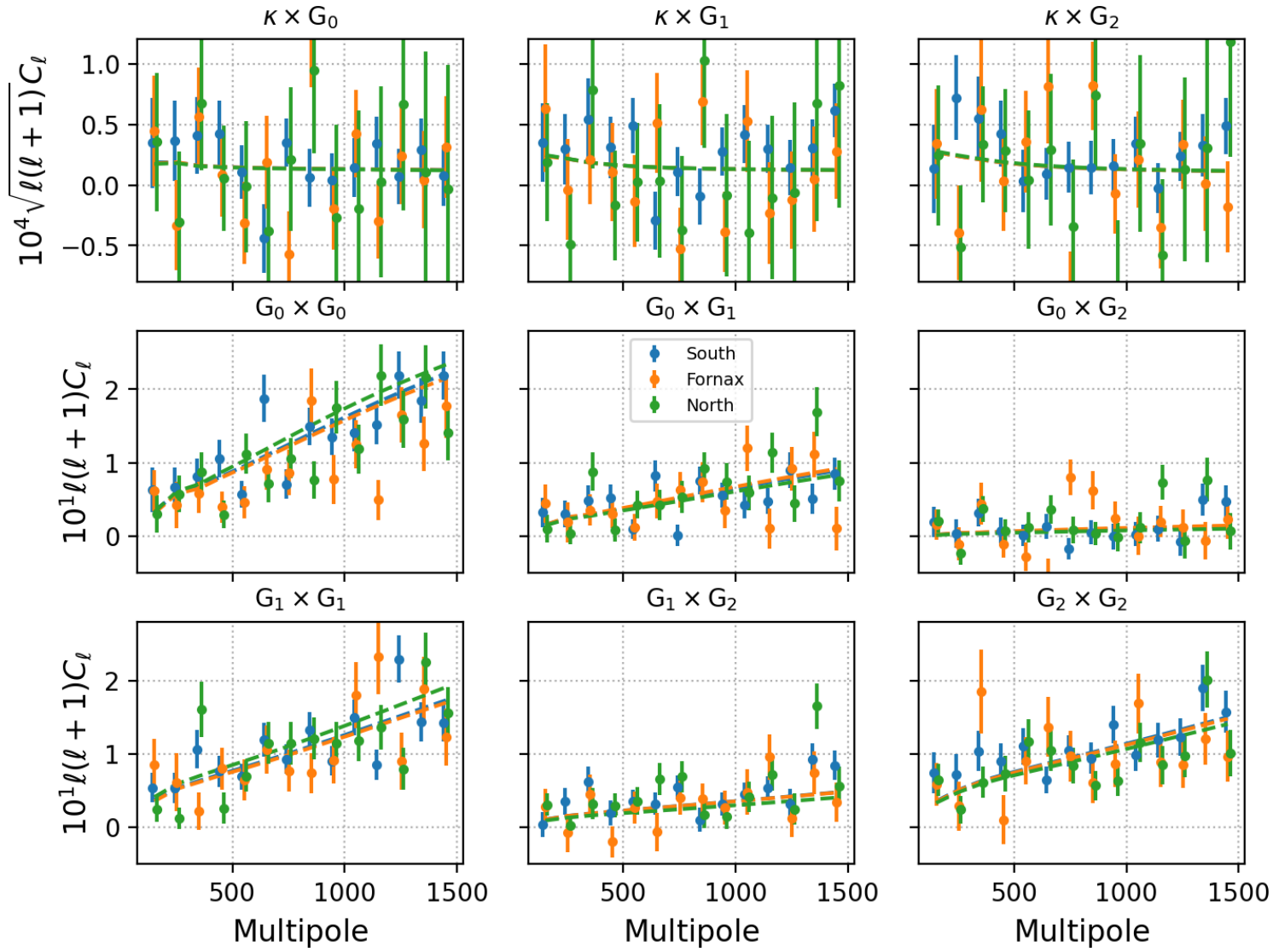


p_{gal} **> 0.90**

p_{star} **< 0.05**

$p_{gal} > 0.90$ – systematic deprojected

l = 100 – 1500
PTE = 17.6%
PTE = 14.7%
PTE = 0.0%



South
Fornax
North

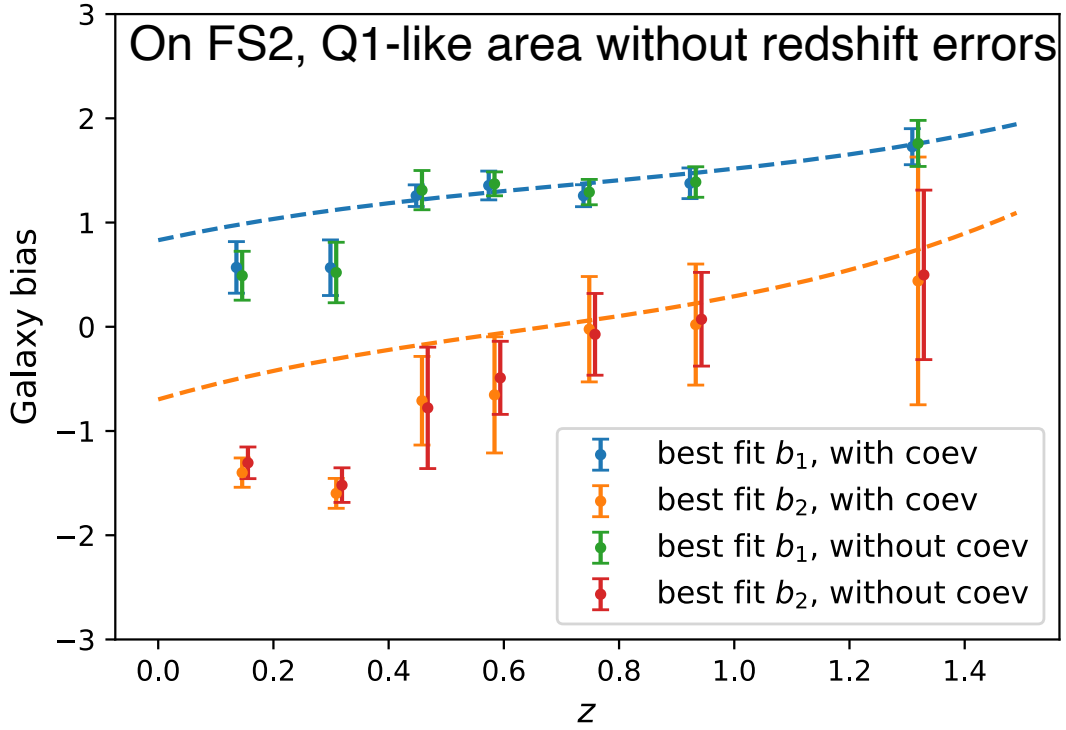
Towards a preliminary cosmological analysis

Investigating the robustness of the bias model

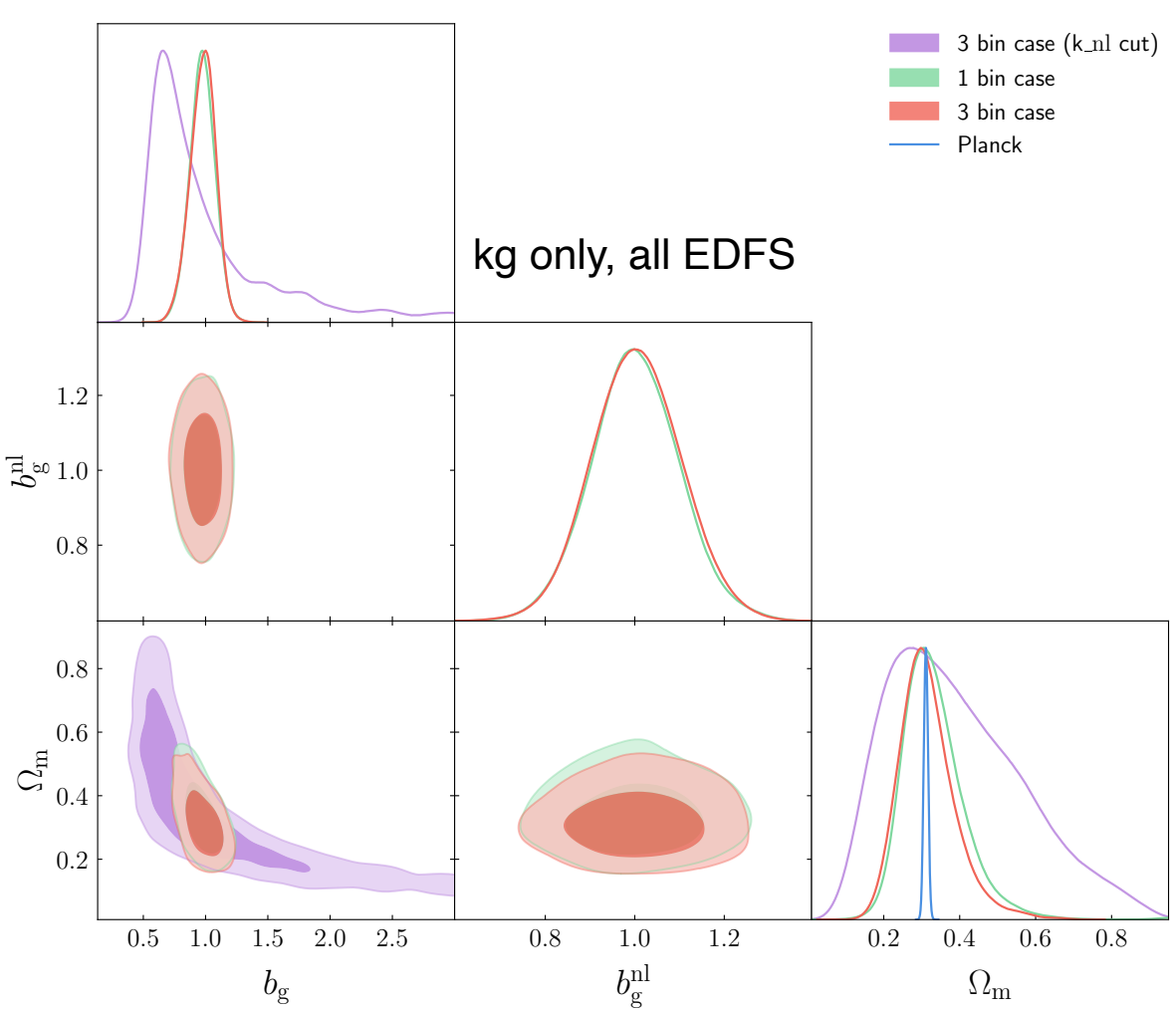
- Fixing the cosmology allows us to self-calibrate the bias model
  - Good data fit for all EDFs (but only with broad-bin tomography)
  - 1 amplitude parameter retrieves good fit agreeing with model at <2-3σ with 2.5% error!
  - We will have to fight for bias modeling accuracy / scale cuts !

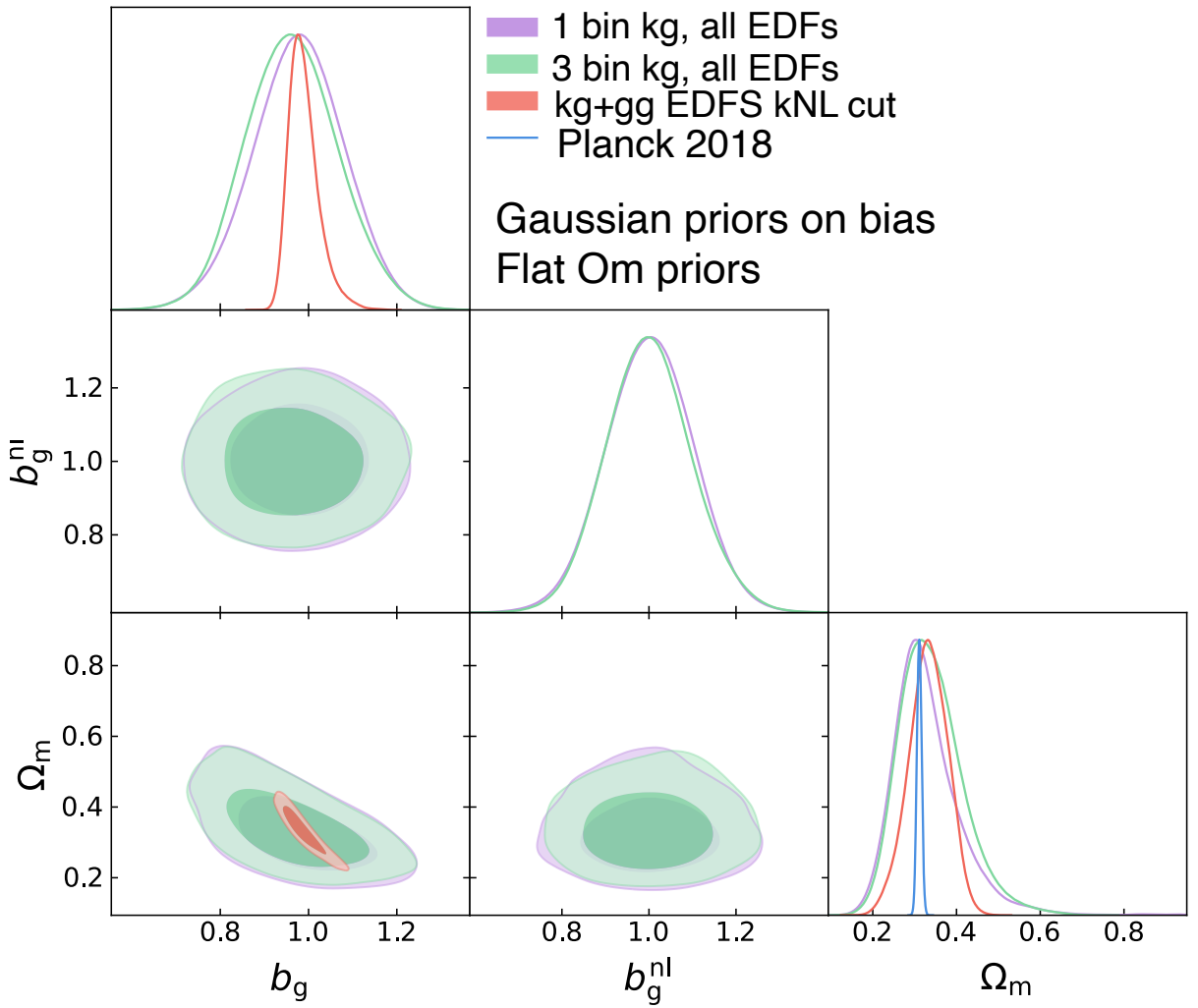
Field	$z$bins	b_g	$b_g^{\rm nl}$
South	1	$0.984^{+0.062}_{-0.020}$	$3.40^{+1.4}_{-0.72}$
	3	1.012 ± 0.012	1.60 ± 0.25
	6	0.799 ± 0.011	1.549 ± 0.092
Fornax	1	$0.90^{+0.21}_{-0.11}$	$1.1^{+3.6}_{-2.8}$
	3	1.062 ± 0.019	2.35 ± 0.38
	6	0.675 ± 0.019	1.32 ± 0.16
North	1	$0.917^{+0.21}_{-0.057}$	$1.9^{+4.7}_{-5.3}$
	3	1.010 ± 0.015	$1.79^{0.27}_{-0.40}$
	6	0.705 ± 0.013	1.31 ± 0.14

W/ kg + gg, flat priors!



Consistency tests on cosmological parameters





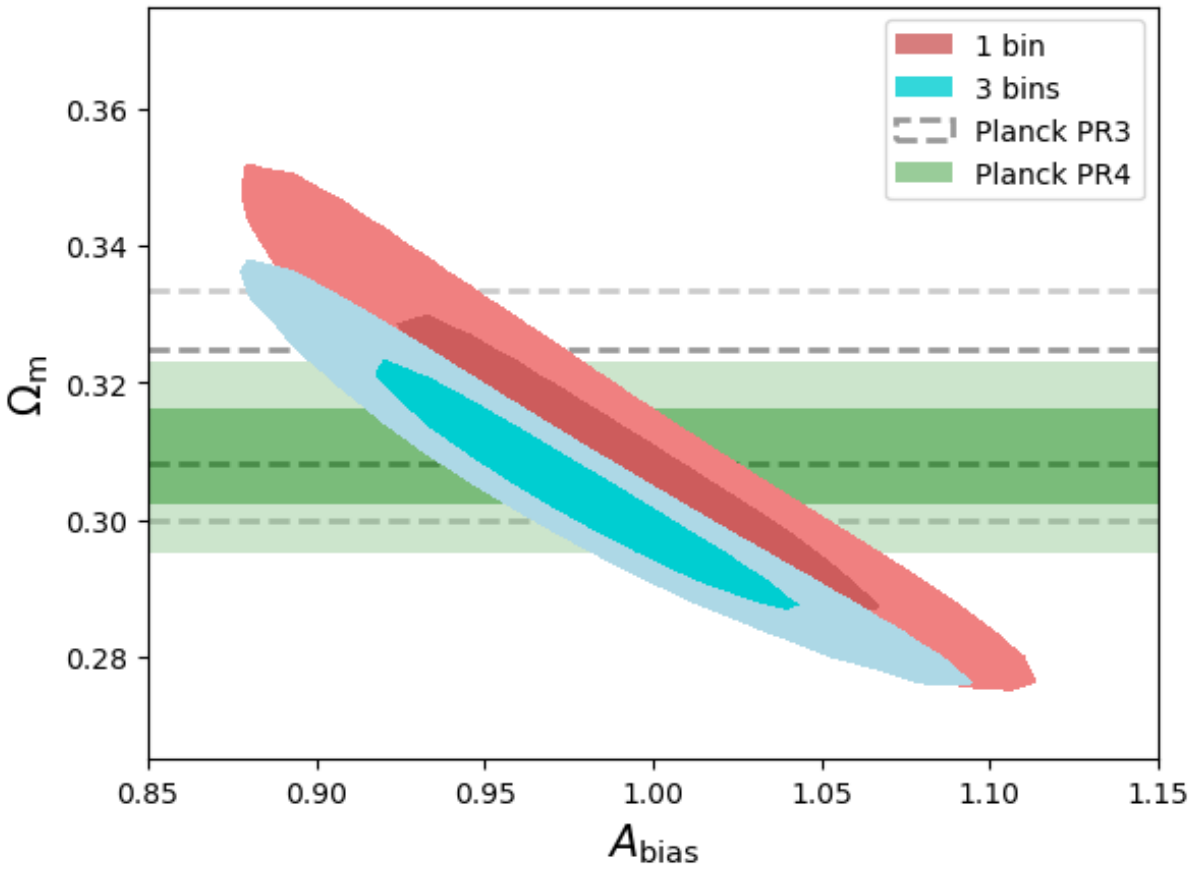
The power of CMB cross-correlation in practice

- Unaffected by scale cuts / z errors…
- 6 bins tomography all EDFs achievable with denser sample!
- We can combine all EDFS where auto-correlation is limited!

		$p_{gal}>0.90$		$p_{star}<0.05$	
Field	z **bins**	**PTE**	**S/N**	**PTE**	**S/N**
South	1	0.470	6.2	0.541	6.7
	3	0.935	7.5	0.802	8.2
	6	0.713	10.1	0.385	10.4
Fornax	1	0.778	3.3	0.653	3.7
	3	0.999	4.4	0.988	4.9
	6	0.978	7.7	0.941	7.7
North	1	0.049	4.6	0.087	5.1
	3	0.370	6.3	0.489	6.9
	6	0.704	8.3	0.567	9.4

A full 2x2pt cosmological analysis : South – $p_{gal} > 0.90$

- Only 2-3x worse than CMB constraints with caveats!



Conclusions and prospects for DR1

- It will be hard (but Q1 gave me hope) !
  - Systematics related to external data are potentially important and need multiple mitigation strategy
  - PHZ estimates seem consistent with expectation with "coarse binning": 6 bins problematic.
  - Sample selection is tricky but Q1 "golden" sample has already 100x more galaxy density than DES.
- CMB lensing Cross-correlation **crucial** additional complementarity
  - Can already do tomography with 6 bins across all 3 fields with SNR~20 for 20gal/am2!
  - For Q1 tomography could be achieved for 3 bins with SNR ~ 30 combined.
  - Allows to recover data for cosmology the more we are systematics limited!
  - More cool data for Euclid to use from SPT and SO on their way!
- It's a multidisciplinary team effort: a unique Euclid strength!
  - Cross-teams / communities / OUs / SWGs expertise needed