EMU and Euclid: Detection of a radio-optical galaxy clustering cross-correlation signal between EMU and Euclid

Giulia Piccirilli on behalf of EMU-Euclid Cross-correlation Team

Data sets

- *Euclid Deep Field South* (`pgal0.90` and `pstar0.05`)

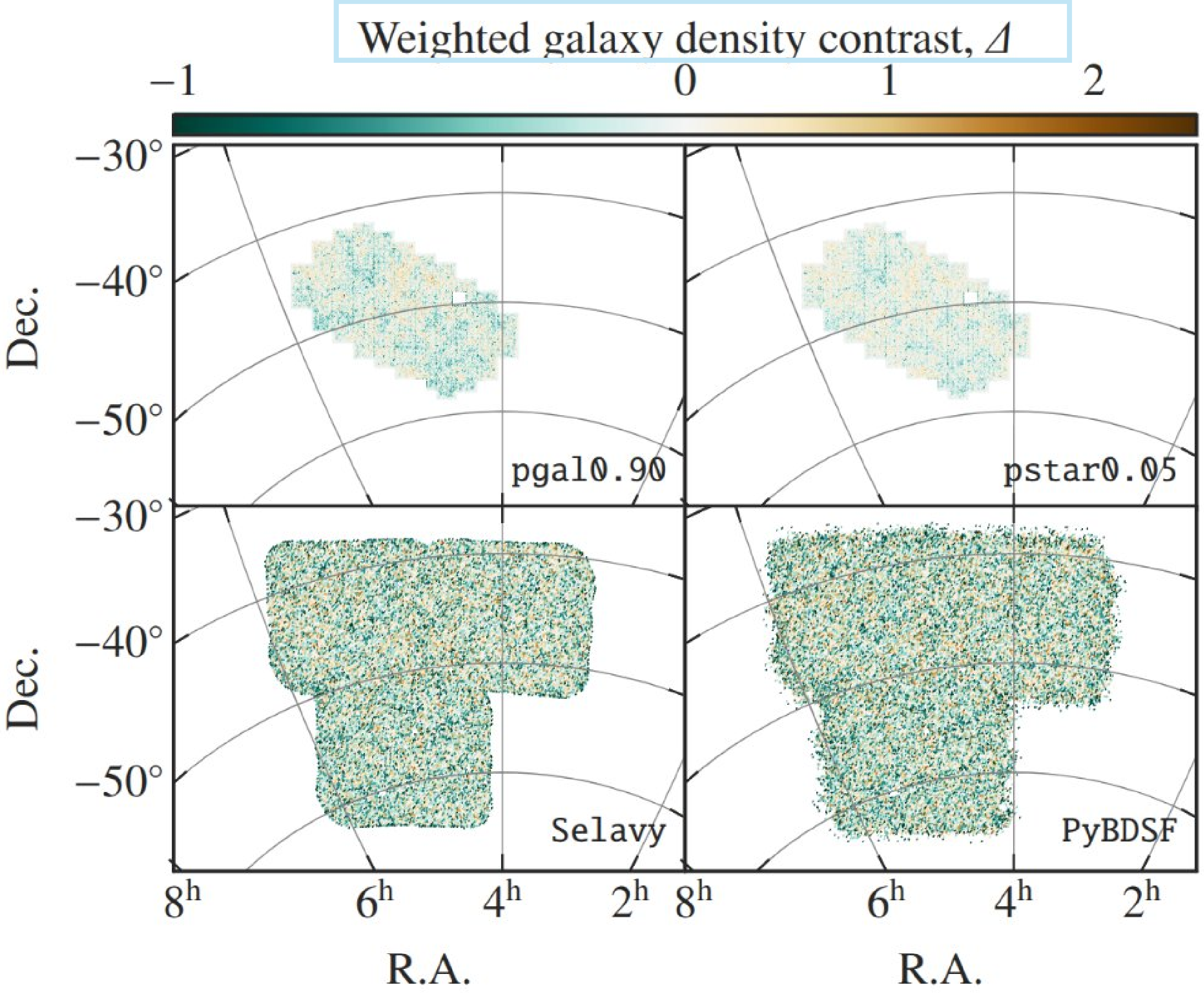
- *Evolutionary Map of the Universe (EMU) Main Survey* data:

  – Survey of radio sources in the Southern Hemisphere with ASKAP at 947 MHz
  – Flux cut at S>0.14 mJy
  – $n_{gal} \sim 0.3\ \mathrm{gal}/arcmin^2$
  – Two source finder algorithms: `Selavy` and `PyBDSF`
  – Weight maps to account for varying completness in the survey

Data sets

- *Euclid Deep Field South* (`pgal0.90` and `pstar0.05`)
- *EMU Main Survey* (`Selavy` and `PyBDSF`)

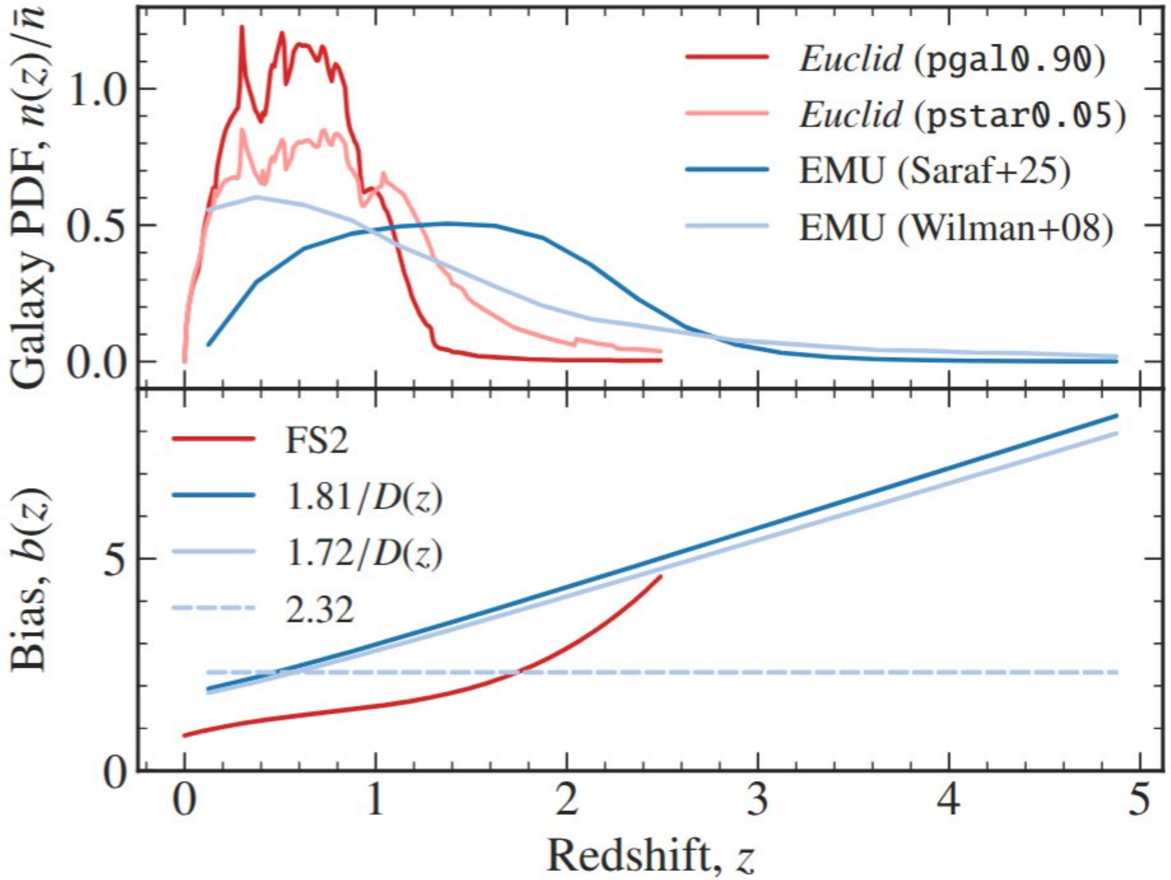
$$\Delta(\hat{n}) = \frac{N(\hat{\boldsymbol{n}})}{w(\hat{\boldsymbol{n}})\,\bar{N}} - 1$$



Theoretical modeling

$$C_\ell^{AB} \simeq \int \frac{c\,\mathrm{d}z}{H(z)}\, W_A(z)\, W_B(z)\, P\left(k = \frac{\ell + 1/2}{r(z)}, z\right)$$

$$W_A(z) = \frac{H(z)\, b_A(z)\, n_A(z)}{c\, r(z)\, \bar{n}_A}$$



– ***Model 1***: analytical $n_{EMU}(z)$ and $b_{EMU}(z) = 1.81/D(z)$ from *Saraf+, 2025*

– ***Model 2***: SKADS $n_{EMU}(z)$ from *Wilman +, 2008* and $b_{EMU}(z) = 1.72/D(z)$ from *Tanidis +, 2024*

– ***Model 3***: SKADS $n_{EMU}(z)$ from *Wilman +, 2008* and $b_{EMU}(z)$ = 2.32$ from *Tanidis +, 2024*

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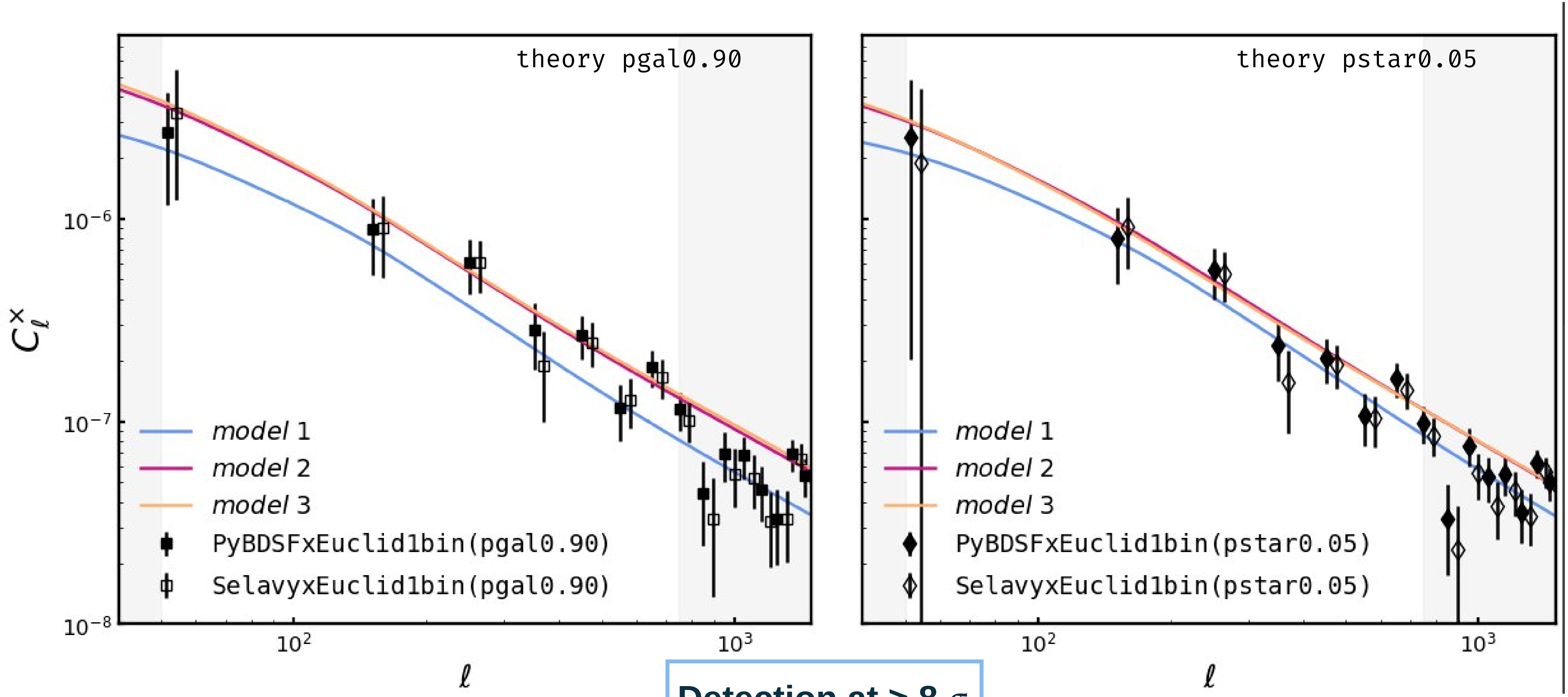
Measured angular power spectra



Detection at > 8 σ

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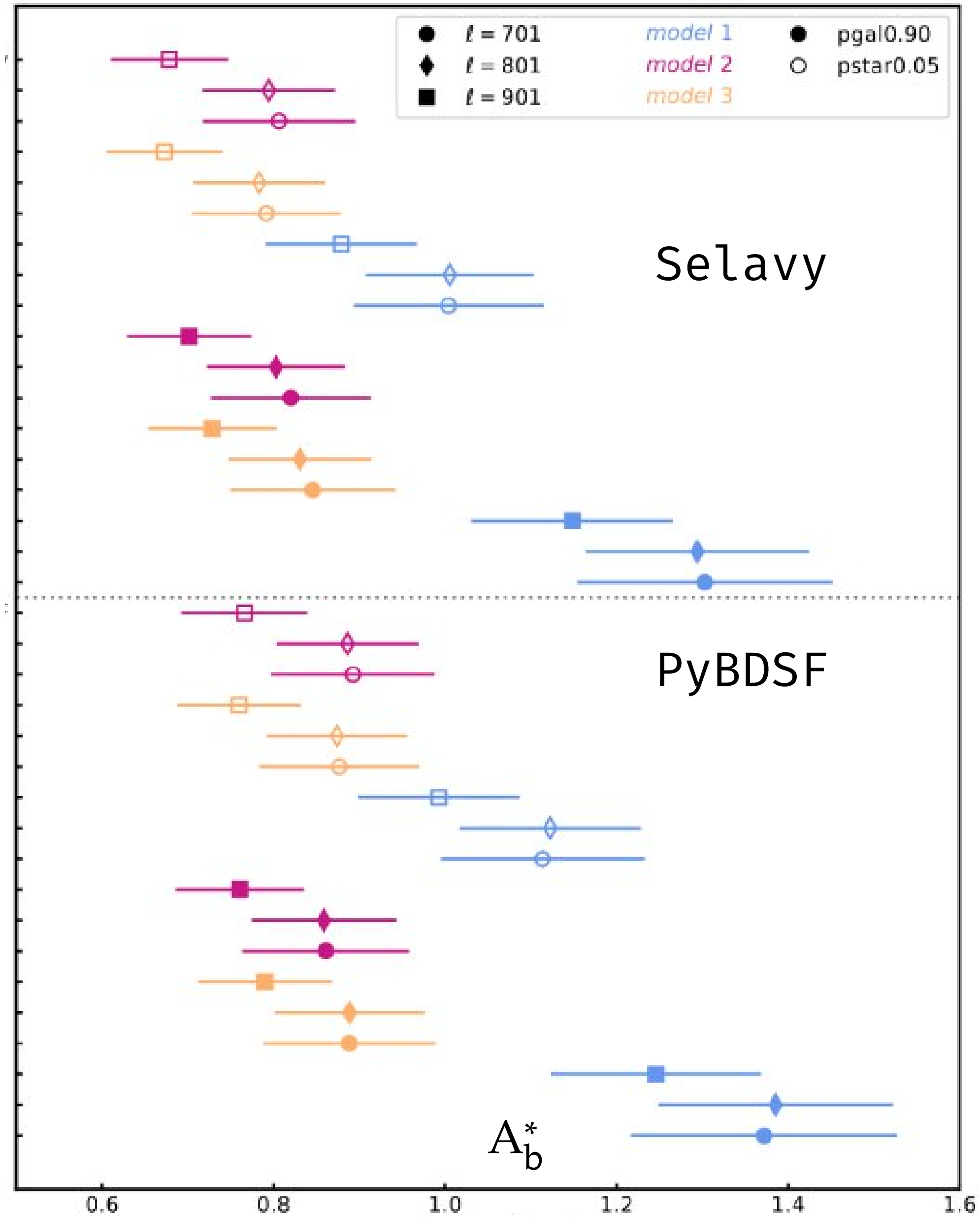
Overall amplitude fitting

$$A_b^* = \frac{\boldsymbol{t}^{\mathrm{t}}\,\Sigma^{-1}\,\boldsymbol{d}}{\boldsymbol{t}^{\mathrm{t}}\,\Sigma^{-1}\,\boldsymbol{t}}$$

$$\sigma_{A_b^*} = \frac{1}{\sqrt{\boldsymbol{t}^{\mathrm{t}}\,\Sigma^{-1}\,\boldsymbol{t}}}$$

- **t** theory vector
- **d** data vector
- **Σ** covariance from data



Cross shot noise estimates

Assuming the samples to be Poissonian, the cross-shot noise is (see *Harrison+, 2016*; *Urban+, 2024*)

$$\boxed{N_\ell^{AB} = \frac{\bar{n}_{A\wedge B}}{\bar{n}_A\,\bar{n}_B}}$$

→ *angular number density of objects in common between the two catalogues*

Being Euclid the densest survey, and since we lack a cross-matched catalogue of EMU sources, we introduce the parameter

$$\boxed{f_\Lambda = \frac{\bar{n}_{EMU\Lambda Euclid}}{\bar{n}_{EMU}}} \longrightarrow \boxed{\frac{f_\wedge}{\bar{n}_{\rm Euc}} \leq \frac{1}{\bar{n}_{\rm Euc}} \approx \begin{cases} 8.0\times10^{-9}\ {\rm sr}^{-1} & \text{for } \texttt{pgal0.90} \\ 4.4\times10^{-9}\ {\rm sr}^{-1} & \text{for } \texttt{pstar0.05} \end{cases}}$$

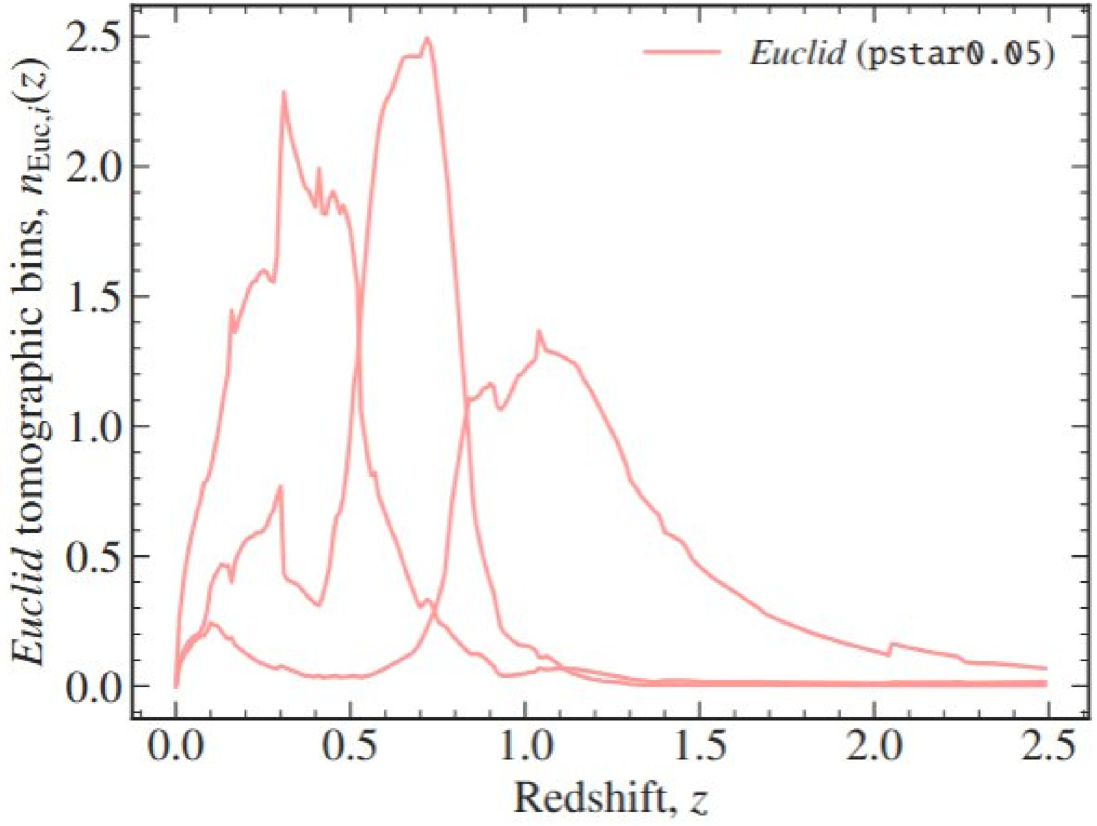
Overall amplitude and shot noise fitting

$$\boxed{\boldsymbol{m} = A_b\,\boldsymbol{t} + C^{\times}_{\text{shot}}} \xrightarrow{\chi^2 \ minimization} \boxed{\boldsymbol{\vartheta}^* = (\mathsf{T}^\dagger\,\Sigma^{-1}\,\mathsf{T})^{-1}\,\mathsf{T}^\dagger\,\Sigma^{-1}\,\boldsymbol{d}}$$

Euclid	EMU	$\ell_{\max}$	$A_b^* \pm \sigma_{A_b^*}$		3-σ bounds on $C^{\times}_{\text{shot}}$ [sr^{-1}]		χ^2/d.o.f.	
			PyBDSF	Selavy	PyBDSF	Selavy	PyBDSF	Selavy
pgal0.90	*Model 1*	901	1.54±0.27	1.53±0.27	<4.93e-08	<3.92e-08	1.21	1.19
	Model 2	901	1.03±0.18	1.04±0.18	<4.45e-08	<3.32e-08	1.23	1.16
	Model 3	901	1.01±0.18	1.02±0.18	<4.30e-08	<3.14e-08	1.23	1.16
pstar0.05	*Model 1*	901	1.29±0.21	1.20±0.20	<3.20e-08	<2.58e-08	1.36	1.57
	Model 2	901	1.06±0.17	1.00±0.17	<2.63e-08	<2.00e-08	1.37	1.56
	Model 3	901	1.10±0.18	1.03±0.17	<2.42e-08	<1.79e-08	1.37	1.55

EMU N(z) estimates

Including Euclid tomographic bins (3bin configuration)



– ***Baseline model*** (*Alonso +, 2021*, and *Saraf +, 2025)*

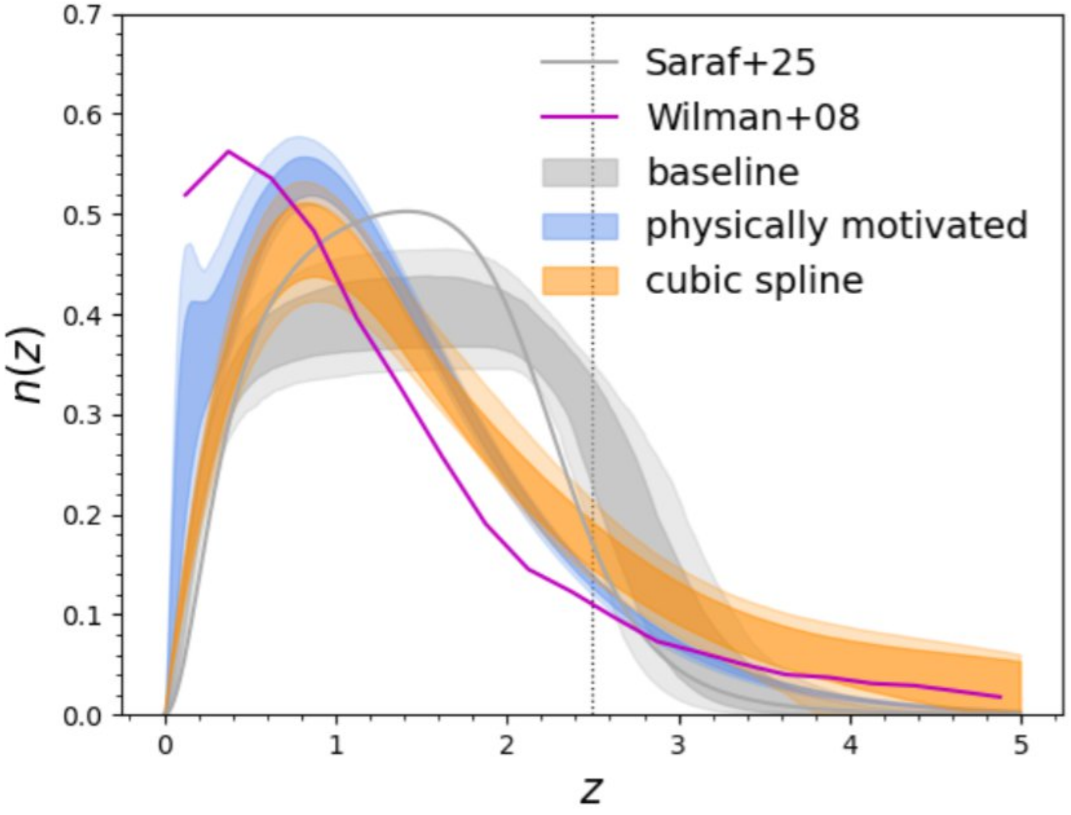
$$n_{\mathrm{EMU}}(z) \propto \frac{(z/z_0)^2}{1+(z/z_0)^2}\frac{1}{1+(z/z_{\mathrm{tail}})^{\gamma}}$$

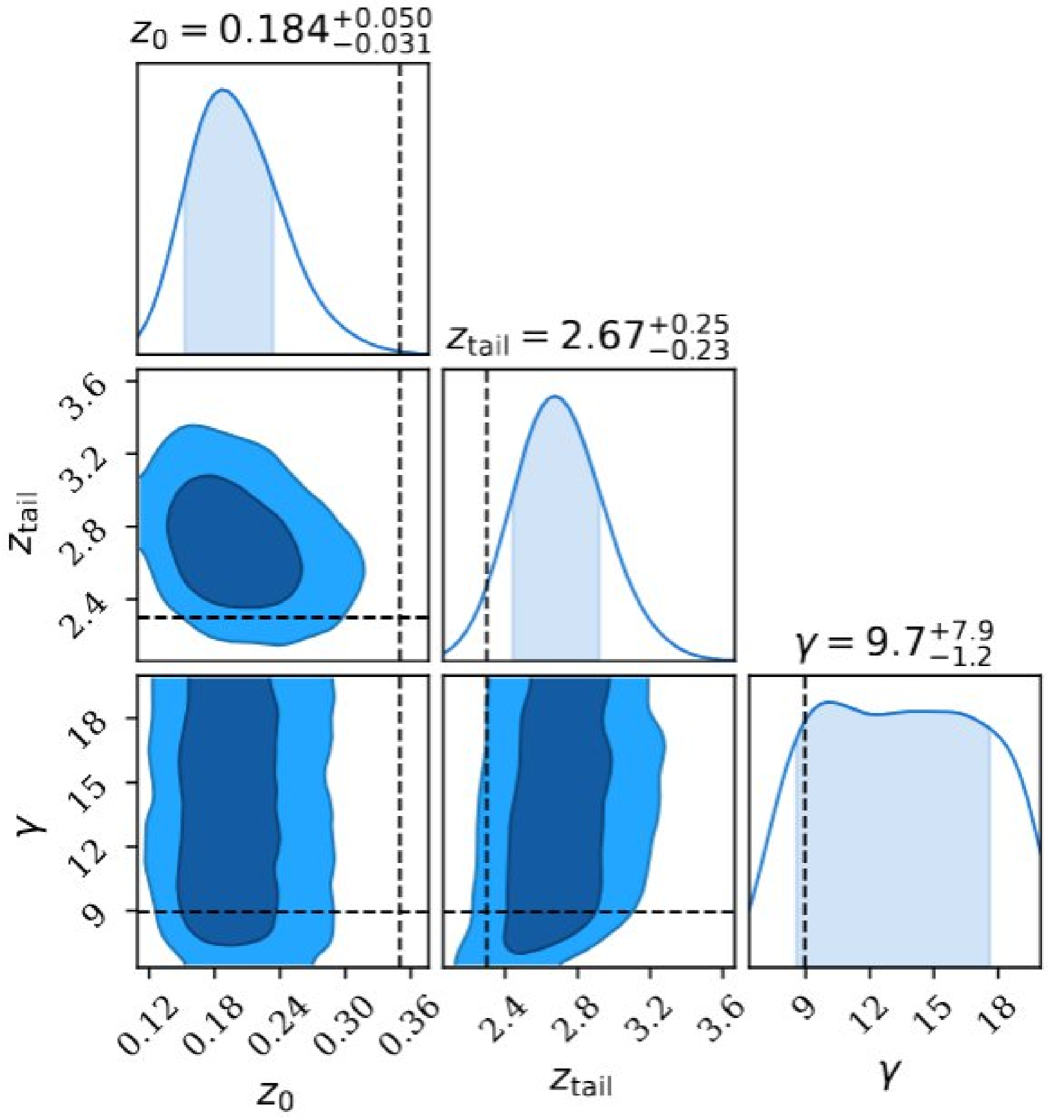
– ***Physically motivated*** including two different populations: SFG and AGNs

$$n_{\mathrm{EMU}}(z) \propto \frac{z^2}{1+z}\left[\exp\left(-\frac{z}{z_0}\right)+\frac{r^2}{(1+z)^a}\right]$$

– ***Cubic spline*** with nodes at the center of redshift bins

EMU N(z) estimates





Conclusions

– First measurement of cross-correlation angular power spectrum between Euclid and EMU

– High significance of the detection for all configurations

– Some final tests before wrapping up the paper (e.g. *covariance estimation*)