Higher-Order statistics

Alfonso Veropalumbo OAB - INAF
on behalf of DR1-GC-KP6

Coordinators: Azadeh Moradinezhad, Alfonso Veropalumbo

Goal of KP6

DR1-KP6 will bridge the gap between theoretical and observed data vector, and provide all the necessary elements to build a likelihood analysis to exploit HOS from spectroscopic Euclid galaxy survey.

- Focused group (~15 - 20 people attending weekly telecons) from different institutions.
- Strong experience coming in the italian community, covering responsibility roles in the activity of this KP.
- Good interface with OUs.

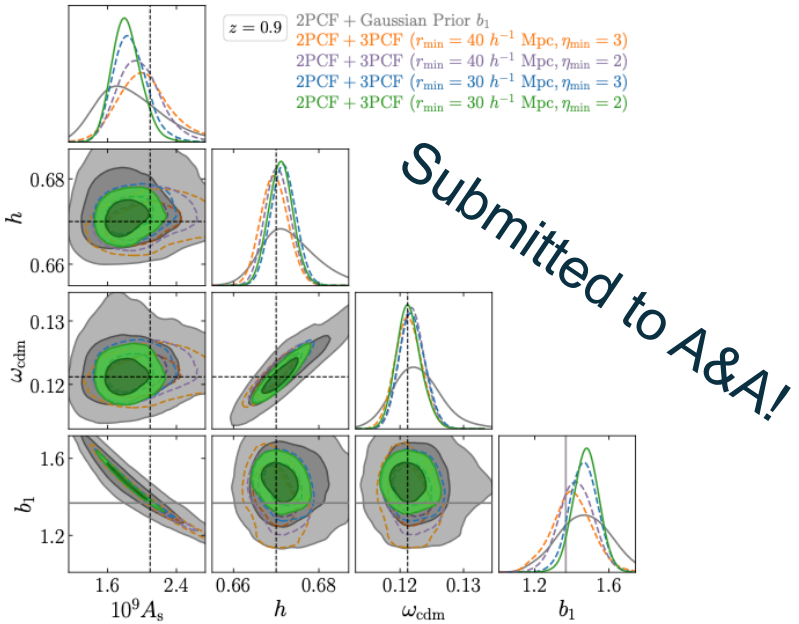
From WP:HO to DR1-KP6

- *Modelling challenge*: comparison of independent theoretical tools for scientific exploitation of and Higher-Order statistics (HOS) in the framework of EFTofLSS alone and in combination with two-point statistics.
- Determination of optimal fitting range for unbiased cosmological constraints.
- Ideal datasets, no selections nor window functions.
    - Flagship I snapshots (Paper 1+3, 2, 4, 8).
    - Abacus snapshot with PNG (fNL=0,30), haloes and Euclid-like catalogues (Paper 8).

- *Paper 1+3.* ***P+B*** **in real & redshift space, Pardede, Eggemeier, Alkanishvili, Sefusatti,** *et al*
- *Paper 2.* **2PCF+3PCF modelling in real space, Guidi, Veropalumbo,** *et al.*
- *Paper 4.* **2PCF+3PCF modelling in redshift space**, **Pugno, Karcher, Veropalumbo, Guidi** *et al.*
- *Paper 8.* ***P+B*** **in redshift space with local Primordial non-Gaussianity, Linde, Moradinezhad** et al.

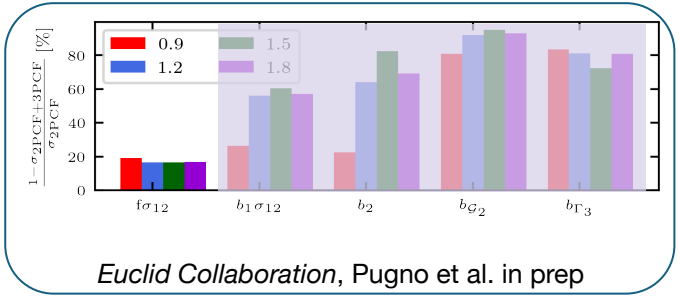
Results from Modelling Challenge

- In **Real Space**, three-point statistics allows to **break b_1-A_s** degeneracy
- The **Figure of Merit** on cosmological parameters **increase** by 50% with respect to two-point stats only.
- Have a look at [arxiv:2506.22257]

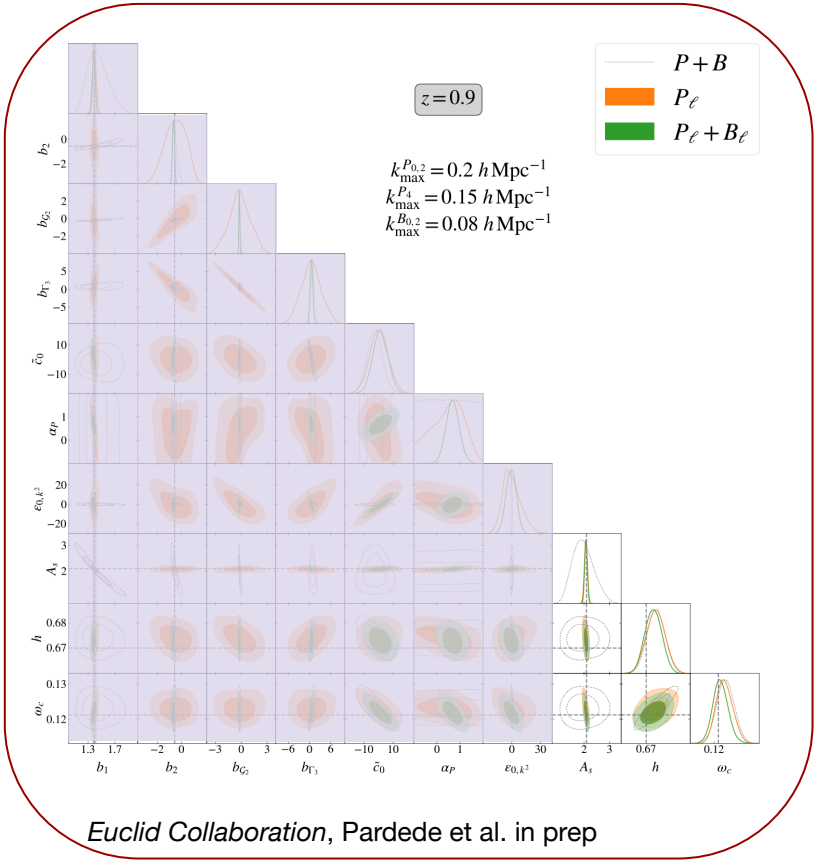


Euclid collaboration, Guidi et al., submitted

- **In Redshift Space the improvement in constraining power on cosmological parameter is less prominent (10%-20%).**
- HOS help in constraining second order bias parameters, alleviating projection effect in two-point only analysis.
- No clear indication of effectiveness of anisotropic HOS information.



Euclid Collaboration, Pugno et al. in prep



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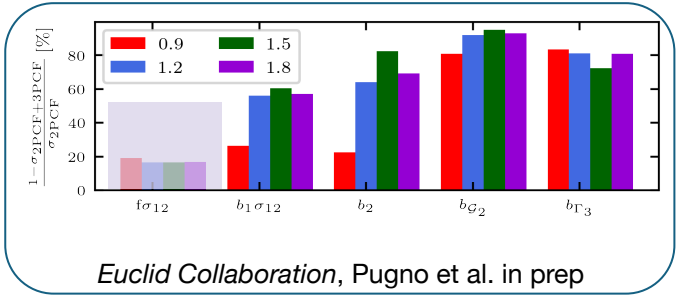

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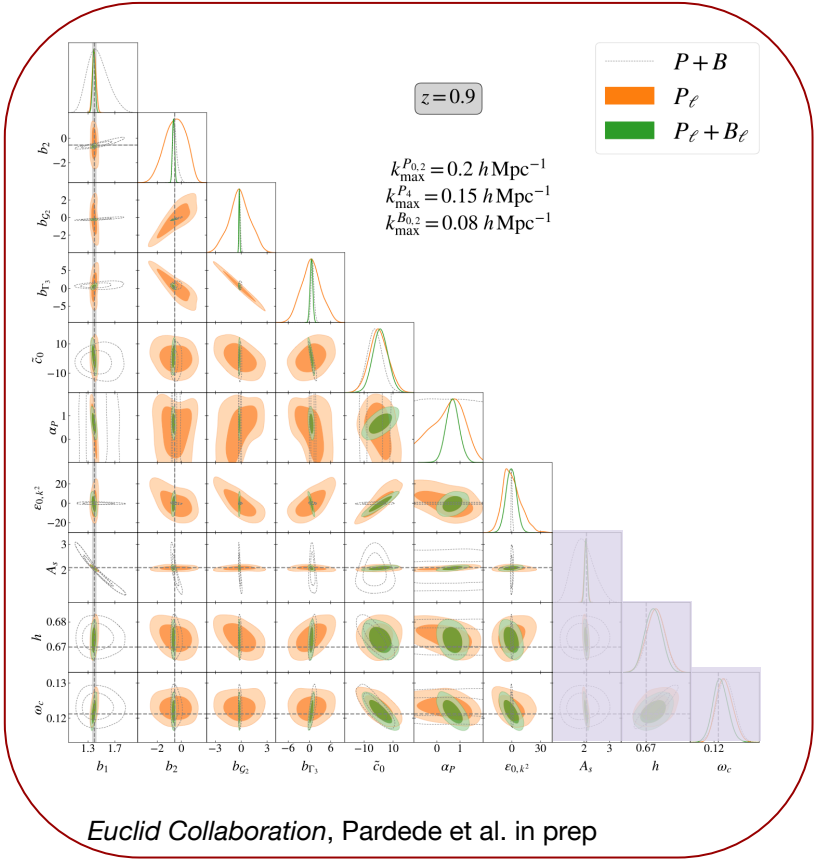

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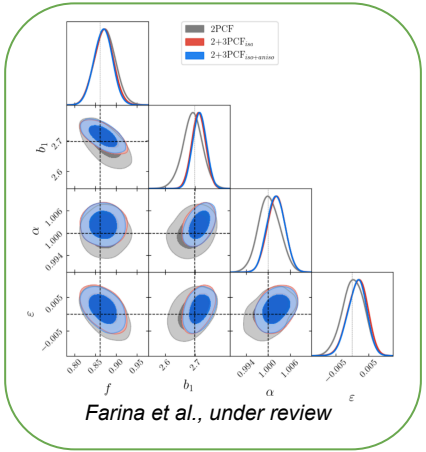
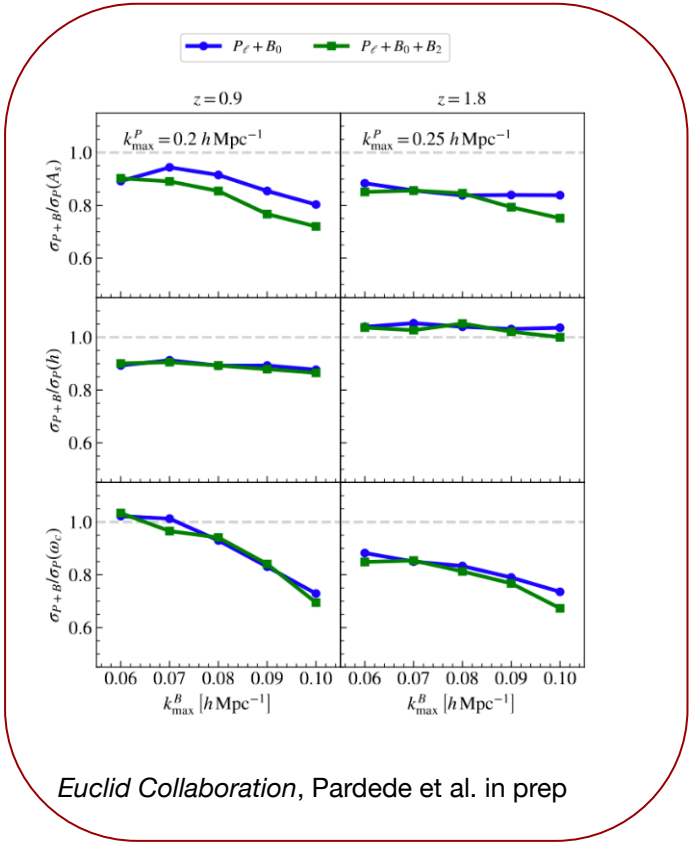


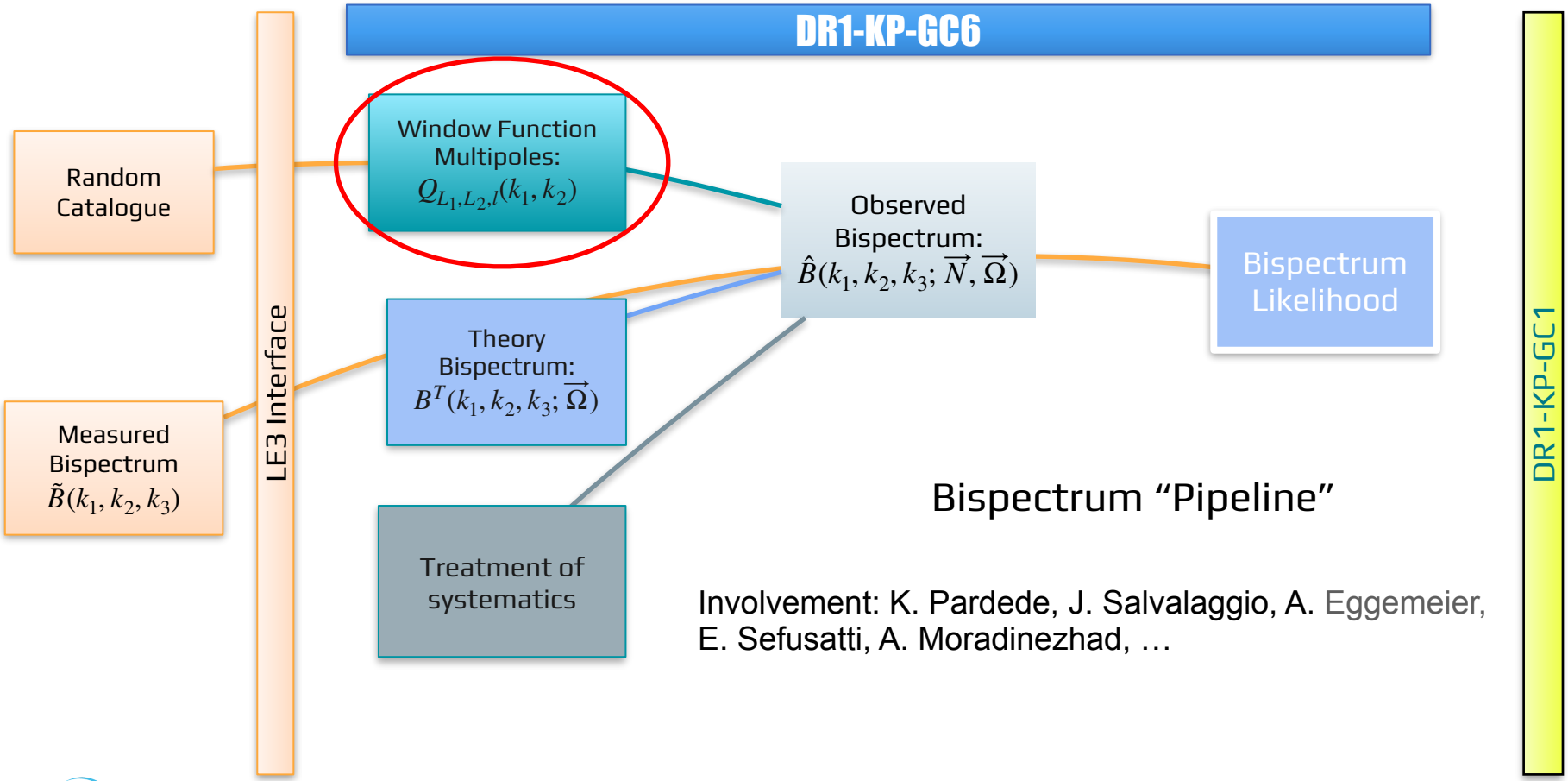
Farina et al., under review



Euclid Collaboration, Pardede et al. in prep

Higher-Orders towards DR1

- The lesson learnt from pre-launch KP, on its way to be finalised, gave use the theoretical tools to run HOS analysis on idealised dataset.
- This KP will provide the necessary tools to fill the gap between theoretical and observed data vector, to build a proper likelihood for the two probes.
- In collaboration with other KP, we will make use of realistic mocks to understand the impact of systematics on HOS and provide a correction at the level of the likelihood.
- **Also, we aim at testing different ways to provide reliable covariance matrix, alternative to fully numerical approach.**

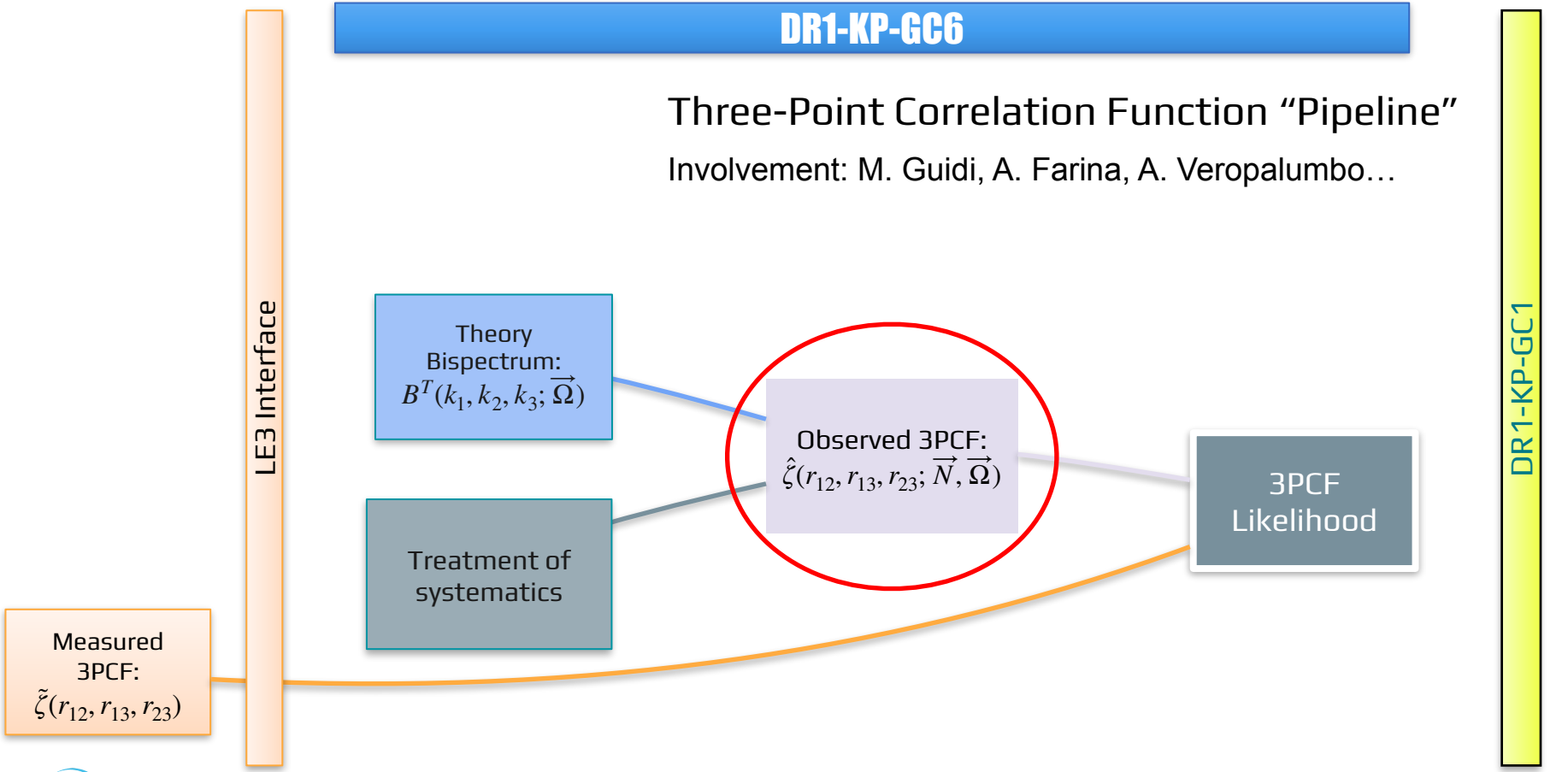


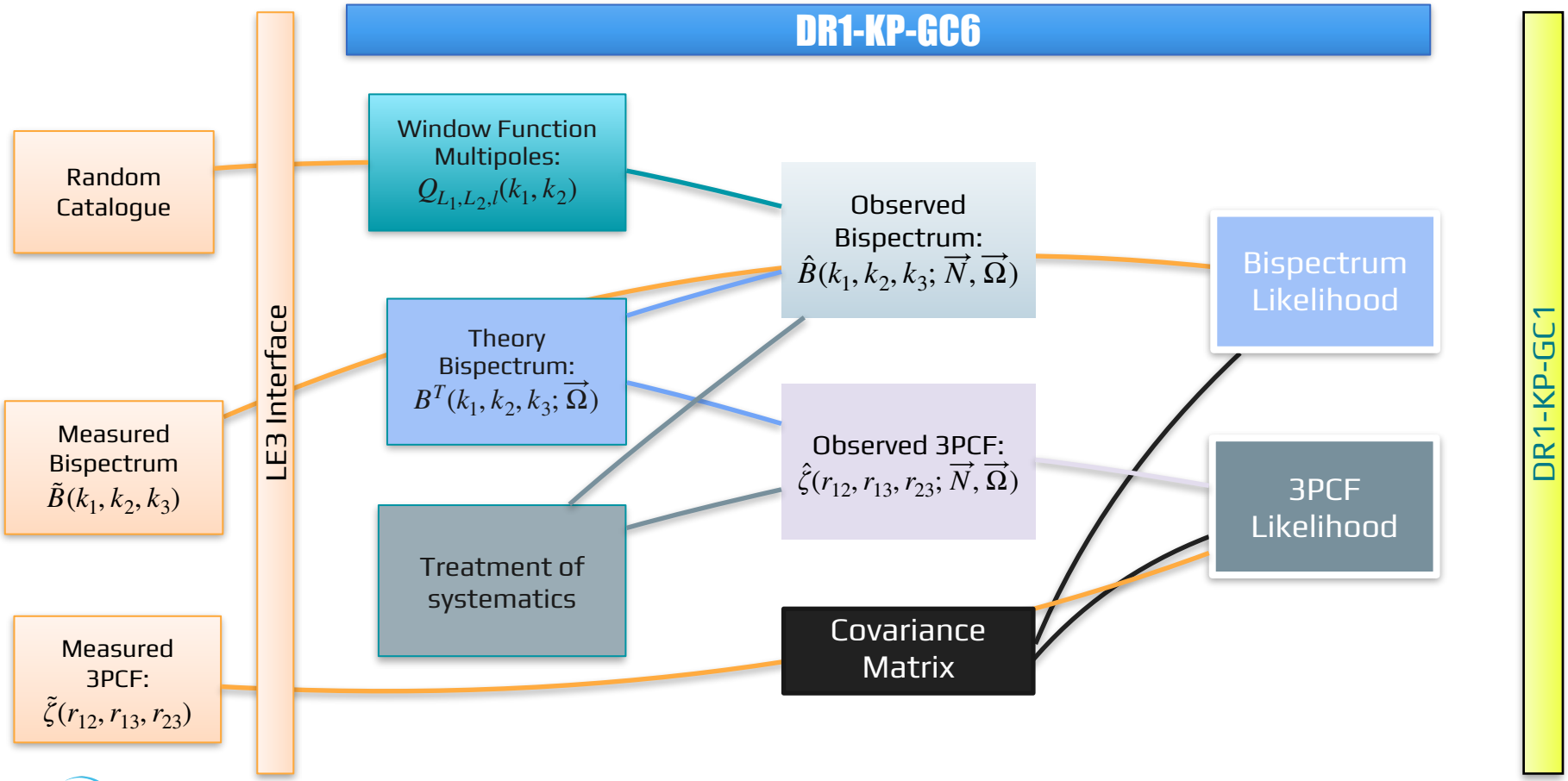
Bispectrum "Pipeline"

Involvement: K. Pardede, J. Salvalaggio, A. Eggemeier, E. Sefusatti, A. Moradinezhad, …

Three-Point Correlation Function "Pipeline"

Involvement: M. Guidi, A. Farina, A. Veropalumbo…




DR1-KP-GC6
Random Catalogue
Measured Bispectrum $\tilde{B}(k_1, k_2, k_3)$
Measured 3PCF: $\tilde{\zeta}(r_{12}, r_{13}, r_{23})$
LE3 Interface
Window Function Multipoles: $Q_{L_1,L_2,l}(k_1, k_2)$
Theory Bispectrum: $B^T(k_1, k_2, k_3; \vec{\Omega})$
Treatment of systematics
Observed Bispectrum: $\hat{B}(k_1, k_2, k_3; \vec{N}, \vec{\Omega})$
Observed 3PCF: $\hat{\zeta}(r_{12}, r_{13}, r_{23}; \vec{N}, \vec{\Omega})$
Covariance Matrix
Bispectrum Likelihood
3PCF Likelihood
DR1-KP-GC1

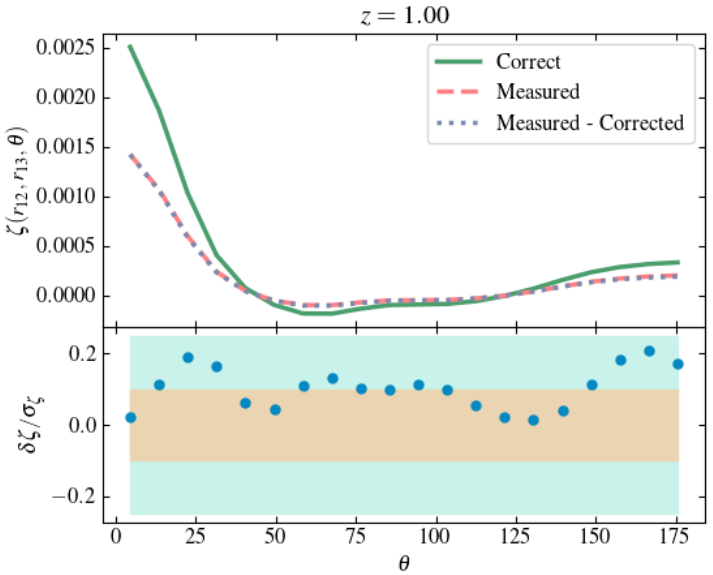
Impact of interlopers fraction

Higher order statistics are equally affected by the presence of interlopers.

$$\zeta_{\mathrm{m}} = (1 - f_i)^3 \frac{R_c R_c R_c}{R_m R_m R_m} \zeta_{\mathrm{c}} + \text{Cross Correlations}$$

- The amplitude gets suppressed by a larger factor with respect to two-point stats.
- The number of auto and cross correlation terms between good galaxies and interlopers (to eventually include in the modelling) largely increase.

- We tested the impact of interlopers on the same mocks used for two-point analysis (Euclid Large Mocks, Monaco et al. submitted to the ECEB).
- This set of mocks allows for a robust determination of the auto covariance of HOS, as well as its cross covariance with two-point statistics.
- The measured signal contains all the auto and cross terms coming from the correct galaxies and interlopers.
- Only accounting for the leading term provide a very good approximation, with baseline contamination ($f_i \sim 20\,\%$).



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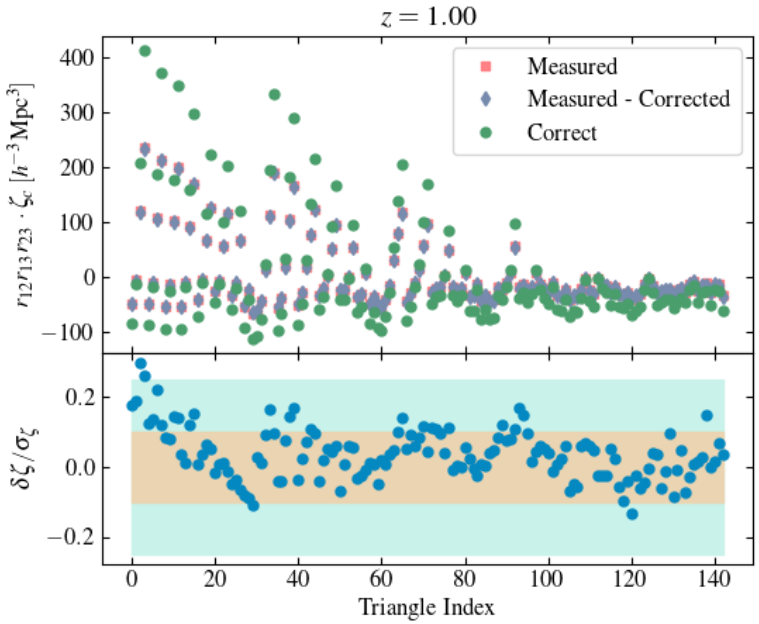
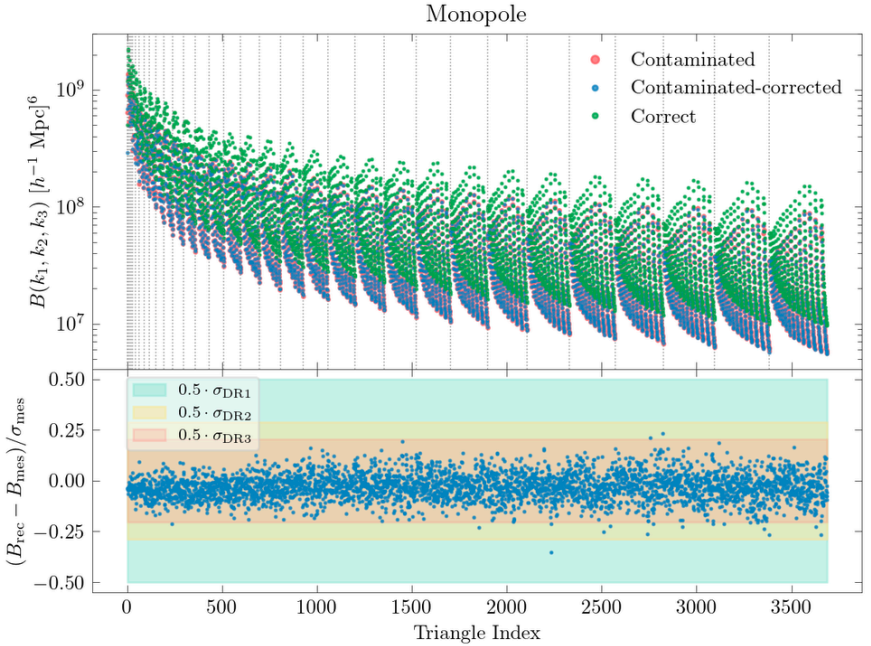
Three-Point Correlation Function



Euclid Collaboration, Principi et al. in prep

Bispectrum



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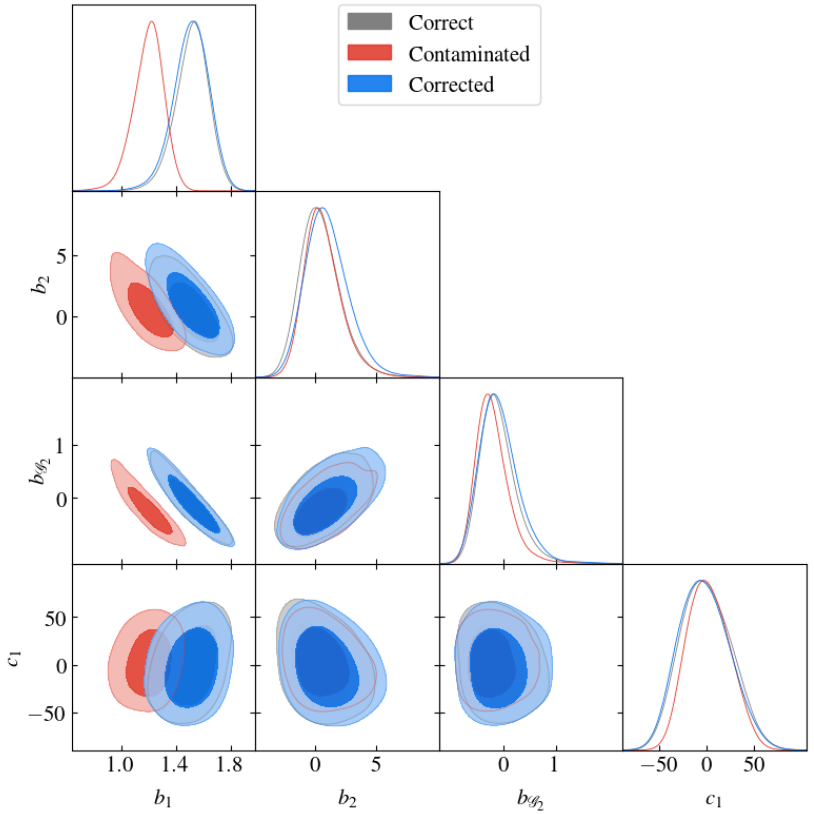
- The measured signal contains all the auto and cross terms coming from the correct galaxies and interlopers.
- Only accounting for the leading term provide a very good approximation, with baseline contamination ($f_i \sim 20\,\%$).
- Similar conclusion can be seen at the level of bias parameters.



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Conclusions

- Results on ELG produced in a Euclid environment are in line with current literature on HOS.
- The path from theory to observed data vector requires additional elements, that will be the main product of this KP.
- Systematics must be considered and accounted for, exploiting realistic mocks for a concrete understanding.
- Production of covariance matrix (auto and joint) can be an issue, from a numerical point of view.