Euclid DR1 Cluster Cosmology

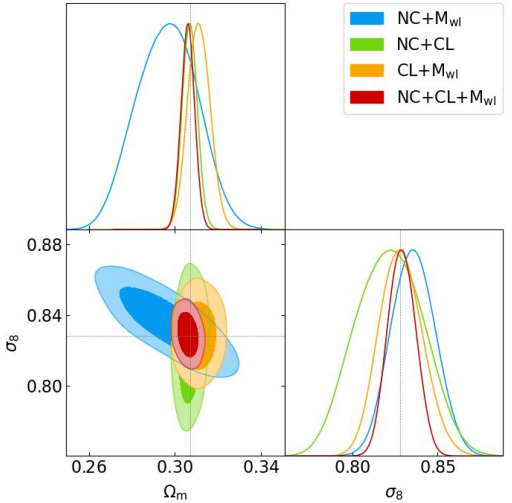
Matteo Costanzi (UniTs) , Matteo Maturi (Heidelberg), Lauro Moscardini (UniBo)
on behalf of the DR1-KP-CG-1

Finanziato dall'Unione europea
NextGenerationEU

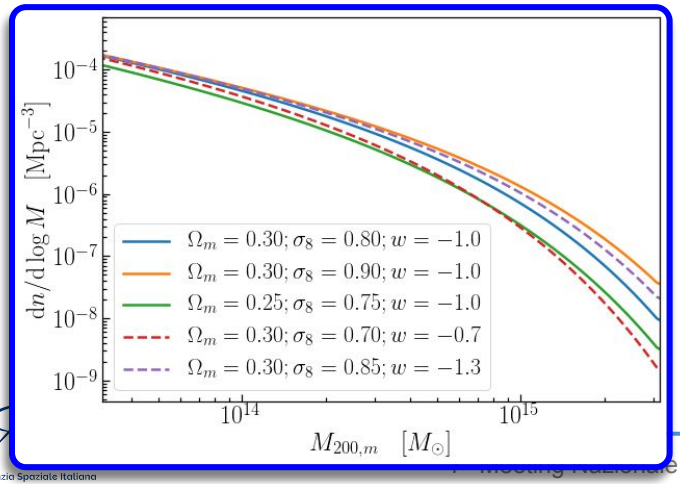
CLUSTER COSMOLOGY WITH EUCLID

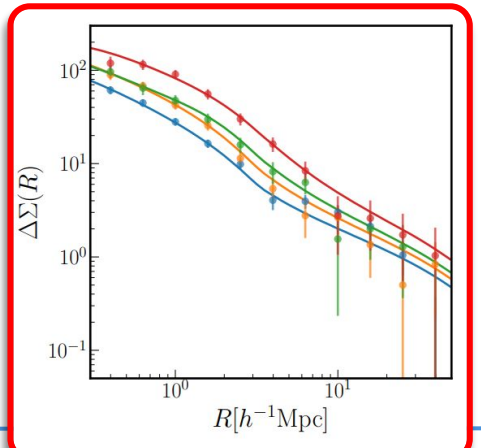
Euclid Cluster Cosmology Probes:

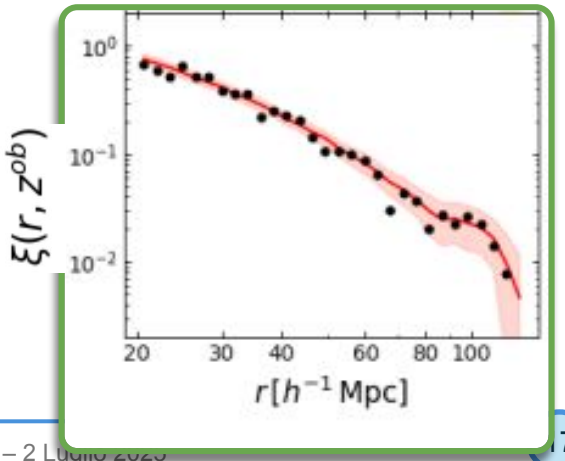
- **Cluster counts as a function of richness and redshift**
  → constraints on $S_8 = \sigma_8 (\Omega_m/0.3)^{1/2}$
- **Stacked Cluster Weak Lensing profile in richness and redshift bins**
  → constrain the richness-mass relation
- **Clustering of clusters (real space) in richness and redshift bins**
  → constraints on Ω_m and σ_8



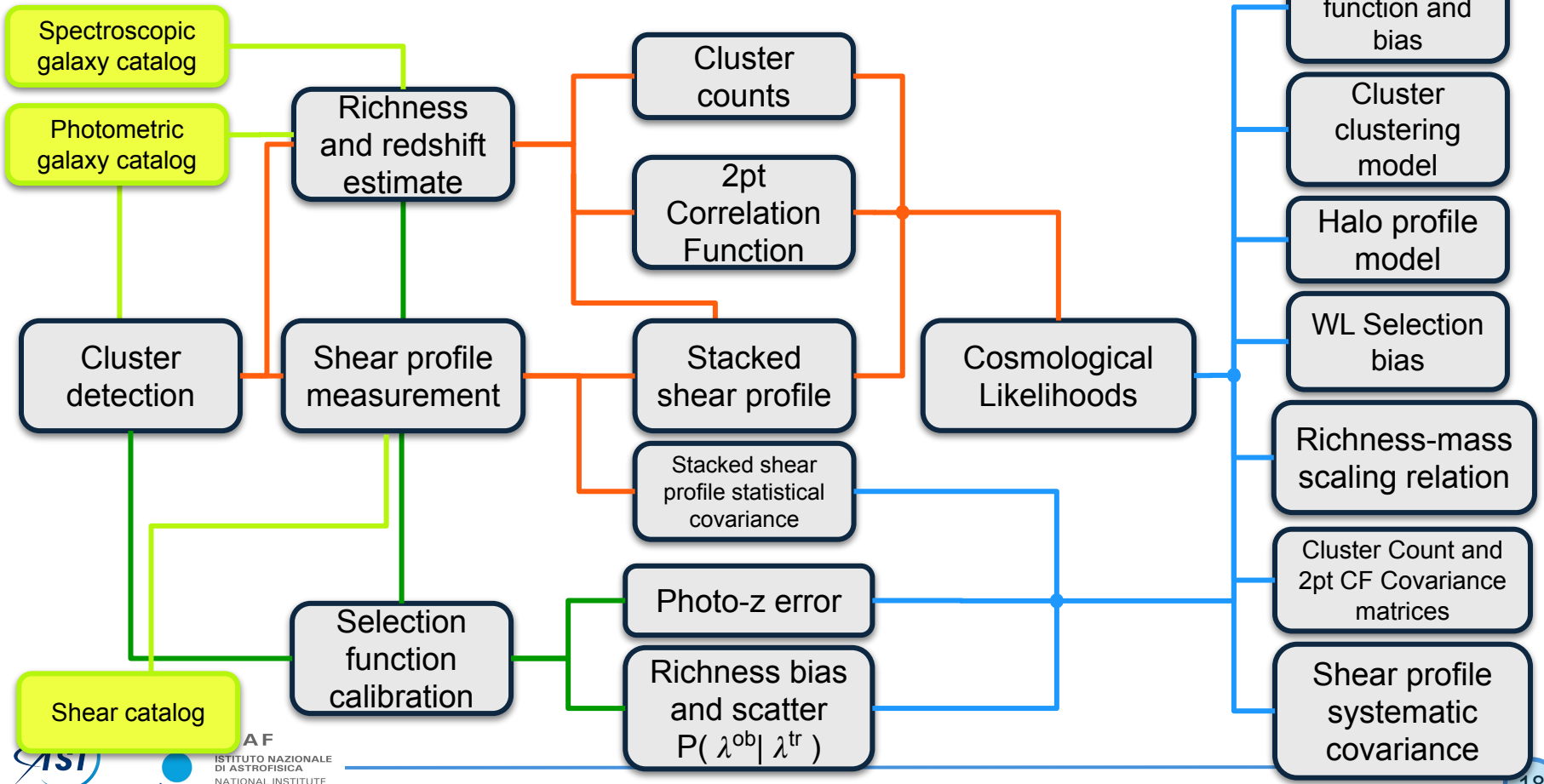
Fumagalli et al in prep.



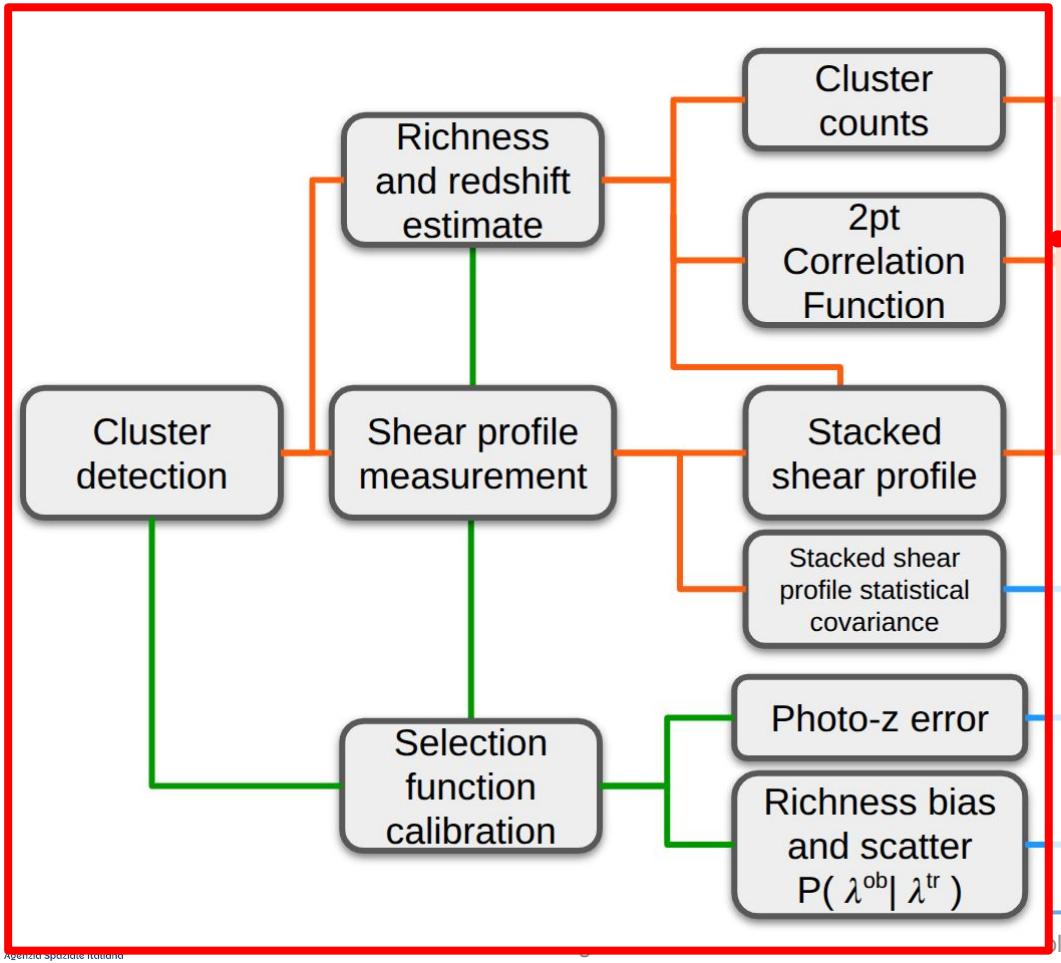




EUCLID CLUSTER COSMOLOGY PIPELINE



EUCLID CLUSTER COSMOLOGY PIPELINE



LE3: Processing function for cluster cosmology (coordinators: **E. Munari**, S. Maurogordato)

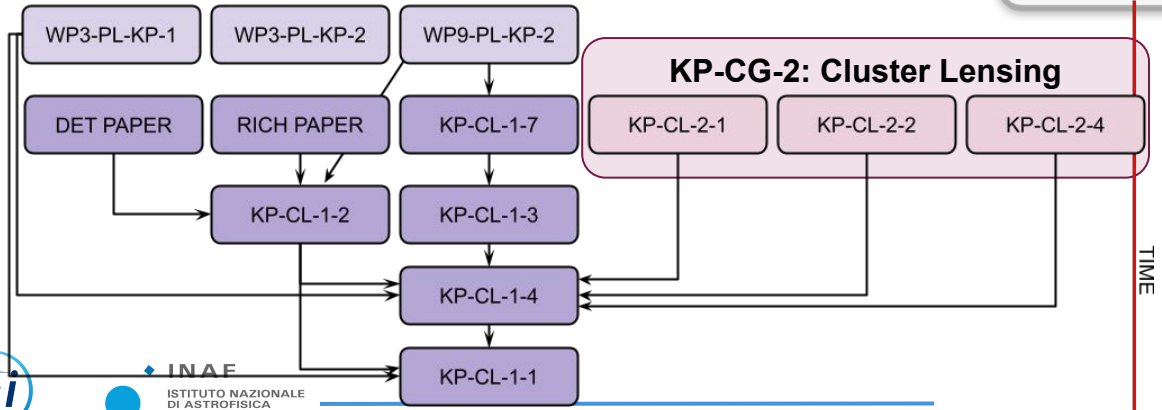
Cosmological Likelihoods

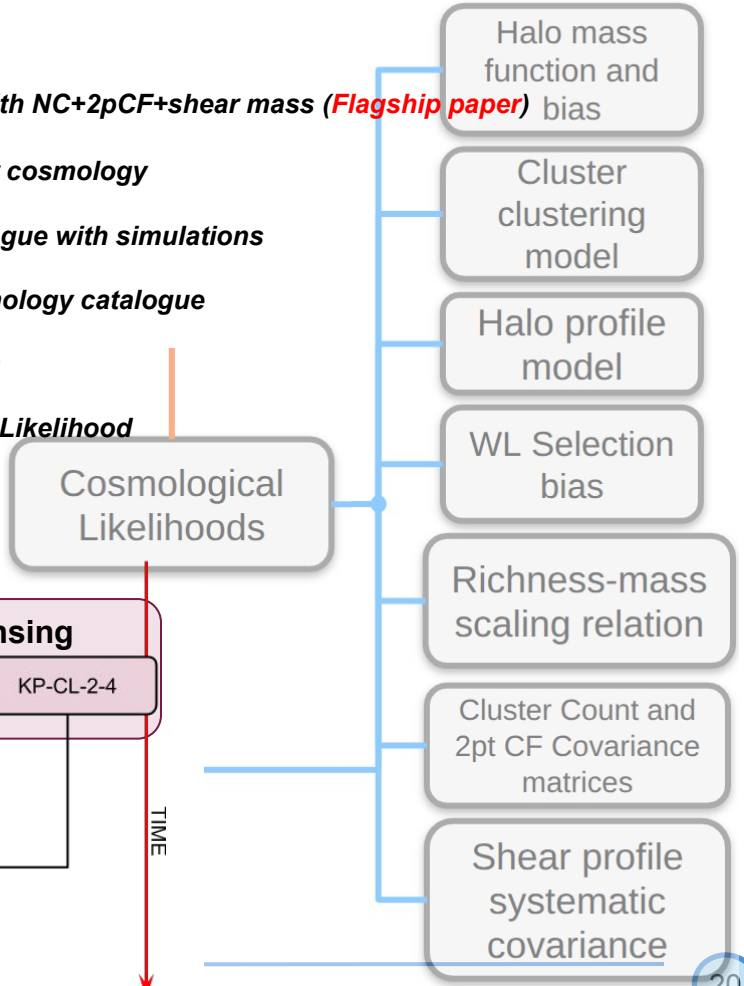
- Halo mass function and bias
- Cluster clustering model
- Halo profile model
- WL Selection bias
- Richness-mass scaling relation
- Cluster Count and 2pt CF Covariance matrices
- Shear profile systematic covariance

DR1-KP-CG-1 PAPERS

- ***KP-CG-1-1: Constraints on vLCDM, vwCDM,w0-wa from cluster catalogues with NC+2pCF+shear mass (Flagship paper)***
  Coordinator(s): **M. Costanzi**, M. Maturi, **L. Moscardini**
- ***KP-CG-1-2: Selection and Characterization of the galaxy cluster catalogue for cosmology***
  Coordinator(s): S. Bhargava, M. Maturi
- ***KP-CG-1-3 : Calibration of optical selection biases in the Euclid cluster catalogue with simulations***
  Coordinators: **R. Ingrao**, C. Murray
- ***KP-CG-1-4: Stacked weak lensing mass calibration of the Euclid cluster cosmology catalogue***
  Coordinators: **G. Lesci**, **L. Baumont**
- ***KP-CG-1-7: Generation of mock Euclid photometric galaxy cluster catalogues***
  Coordinator: **T. Castro**
- ***WP3-PL-KP-2: Modelling and implementation of Euclid Cluster Cosmological Likelihood***
  Coordinators: **A. Fumagalli**, Z. Sakr

***Coordinators from Italian Institutes**





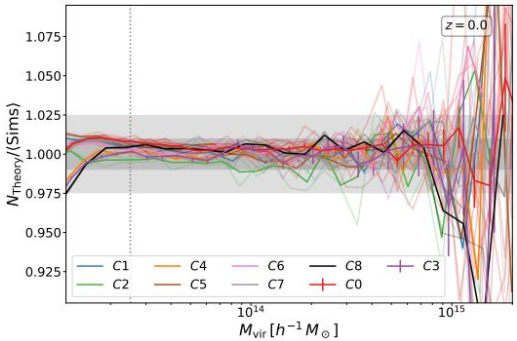
CLUSTER COUNTS AND CLUSTERING MODELING

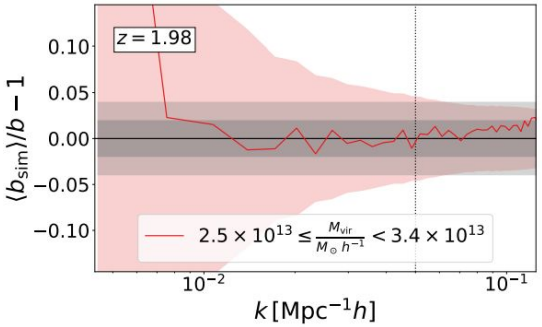
N-BODY SIMULATIONS (Castro+23,24):
3 sets of simulations aimed at studying:
- **Numerical systematics**
- **Departure from Universality**
- **Cosmological dependence**

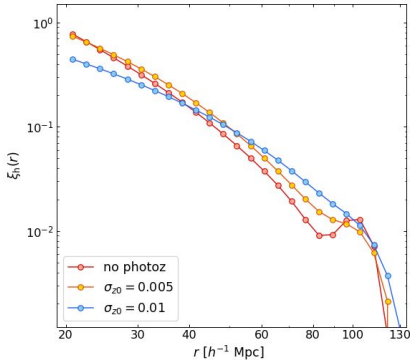
APPROXIMATE MOCKS:
1000 PINOCCHIO (Monaco+13) halo light-cone catalogs at fixed cosmology painted with Euclid-like cluster observables (Fumagalli+22,+in prep)

- **Halo mass function**
- **Halo bias**

- **Cluster counts in observable space**
- **2pt correlation function in observable space**



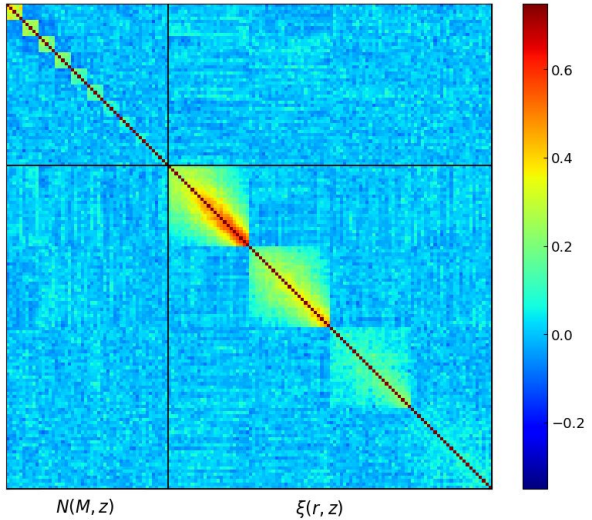




CLUSTER COUNTS AND CLUSTERING MODELING

Top: Cluster counts and clustering auto- and cross-covariance from 1000 mock simulations

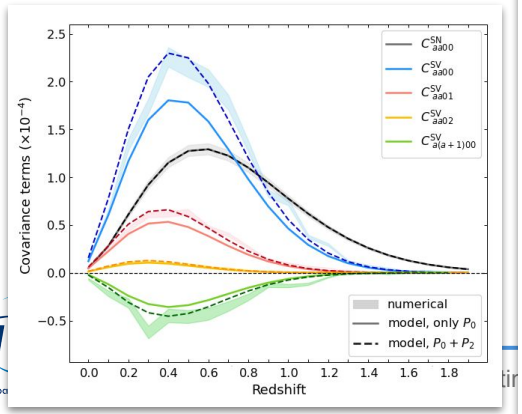
Bottom: Comparison of numerical and analytic cluster counts and clustering covariance terms

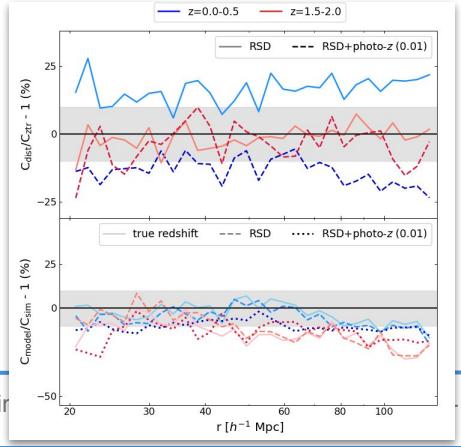


APPROXIMATE MOCKS:
1000 PINOCCHIO (Monaco+13) halo light-cone catalogs at fixed cosmology painted with Euclid-like cluster observables (Fumagalli+22,+in prep)

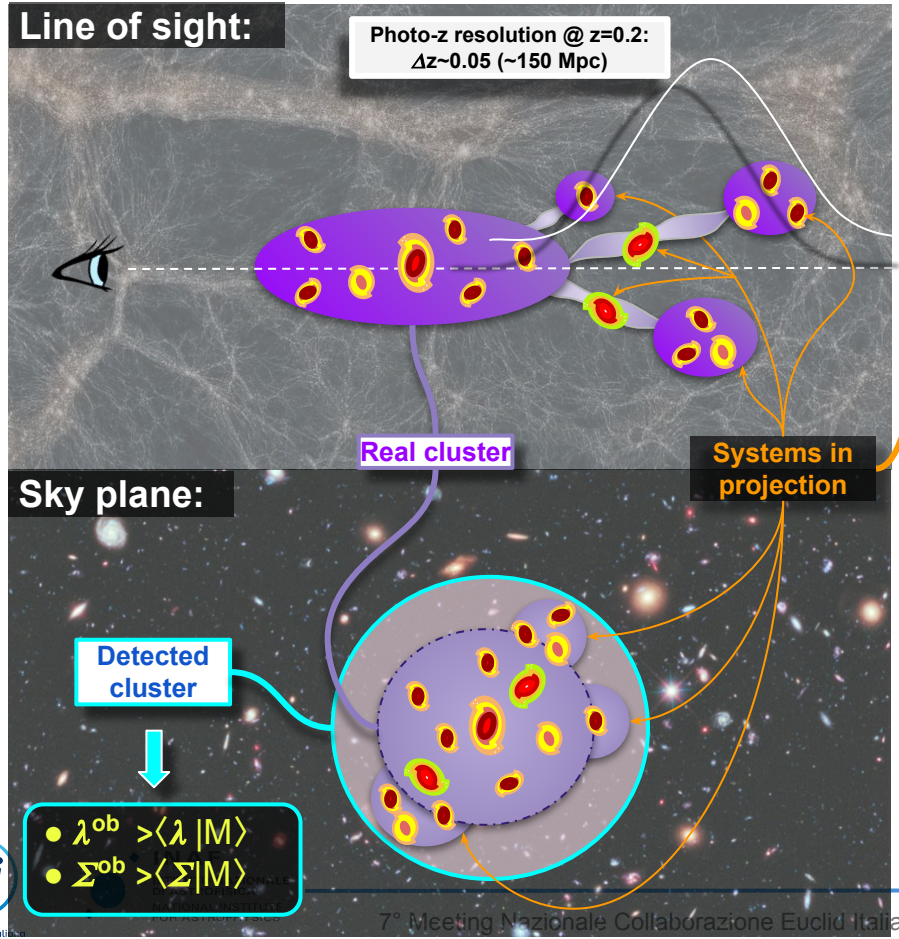
- **Covariance matrix:**
  Cluster counts and 2pt correlation function analytical covariance matrix calibrated and vetted against PINOCCHIO mock catalogs.
  Modeling includes: photo-z uncertainty, richness estimate error and RSD

Fumagalli et al in prep.





OPTICAL SELECTION BIAS



$$\lambda^{ob} = \lambda(M) + \delta\lambda(\lambda, \ldots)$$

$$\Sigma^{ob} = \Sigma(M) + \delta\Sigma(\delta\lambda, \ldots)$$

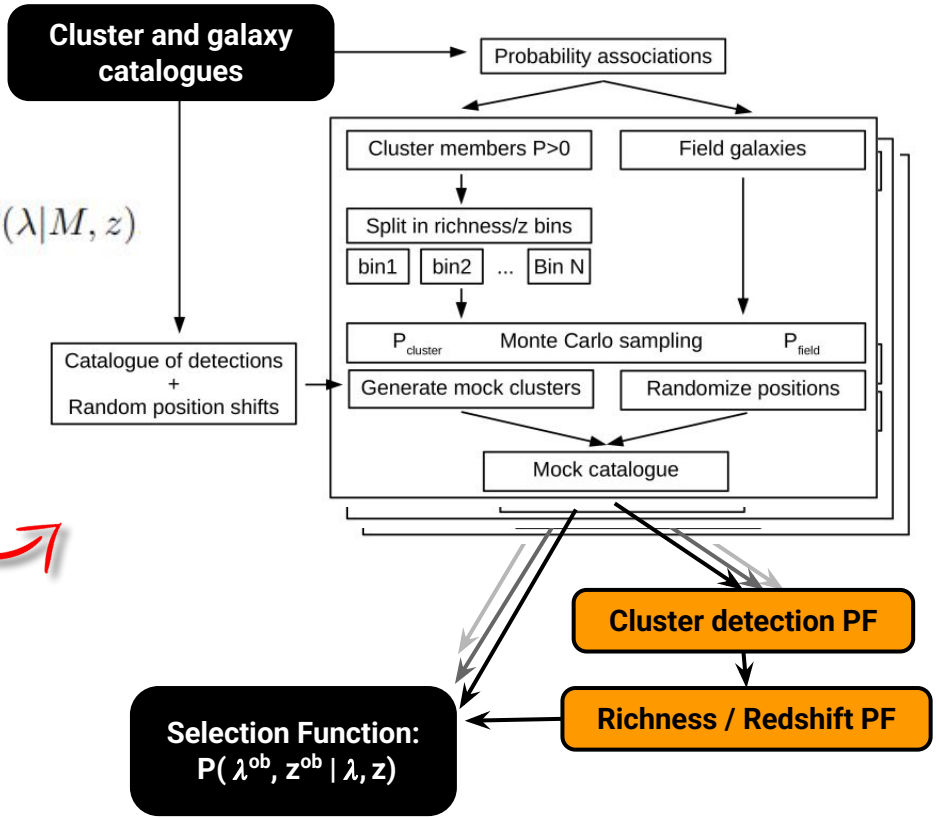
Optical selection bias introduces a correlation between richness and WL signal, which needs to be properly modeled to recover unbiased mass estimates

SELECTION FUNCTION

- **Observed richness-mass relation:**

$$P(\lambda^{\rm ob}|M,z) = \frac{1}{\mathcal{P}(\lambda^{\rm ob},z)} \int_0^\infty d\lambda \mathcal{C}(\lambda,z) P(\lambda^{\rm ob}|\lambda,z) P(\lambda|M,z)$$

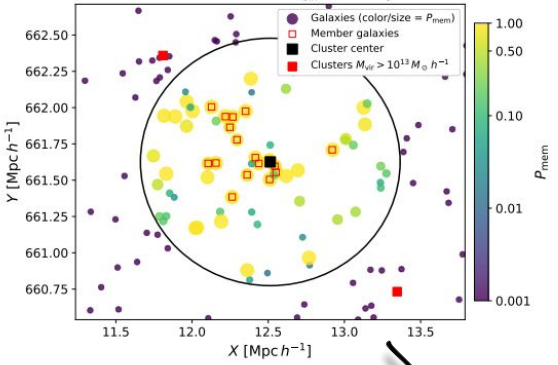
Purity, Completeness and Selection Function empirically calibrated using a simulation based approach applied to the data



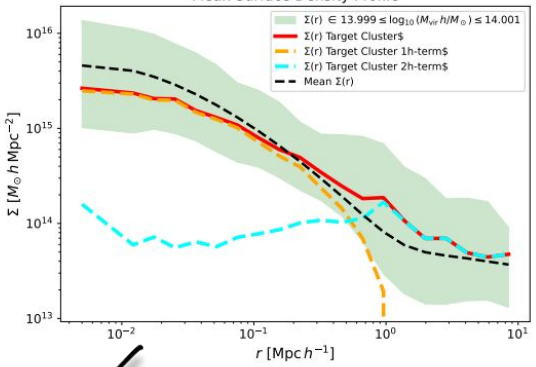
SHEAR PROFILE MODEL SYSTEMATICS

- **CosmoPostProcess:**
  Implemented and validated pipeline to compute *autoconsitently* projected halo density profiles and observed richness in simulations. (***Ingrao et al in prep.***)
- Halos and DM particles from PICCOLO suite of N-body simulations (Castro+23)
- Galaxy membership probability as a function of redshift and radial separation, calibrated on mock detections on Flagship

Projected galaxy distribution around a 10^{14} halo

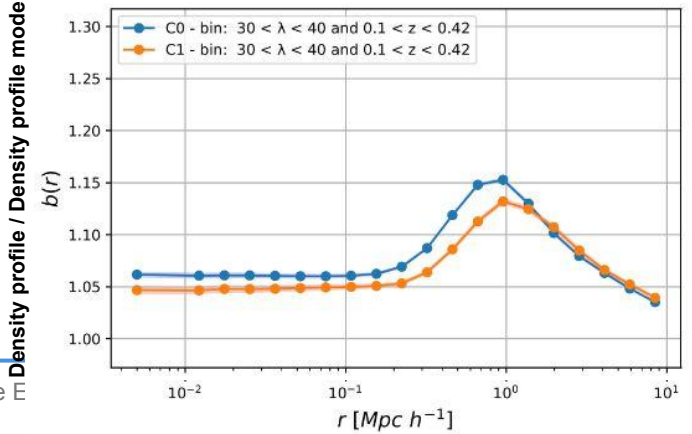


Projected halo density from DM-particles



Calibration of selection bias on lensing profile for different cosmologies and HOD models

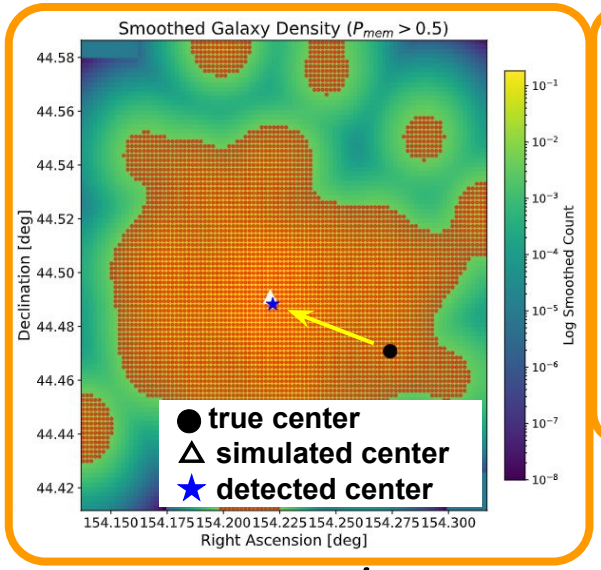
WL selection bias for different cosmologies

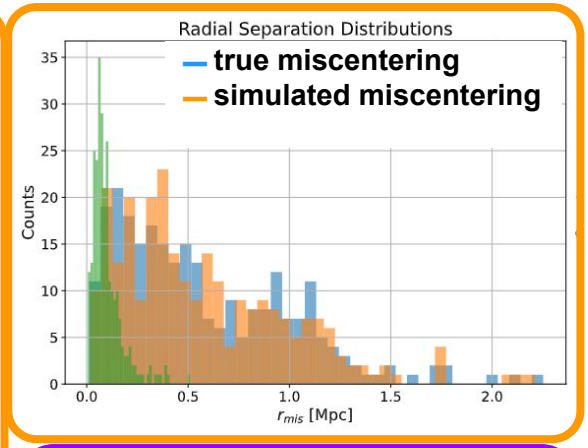


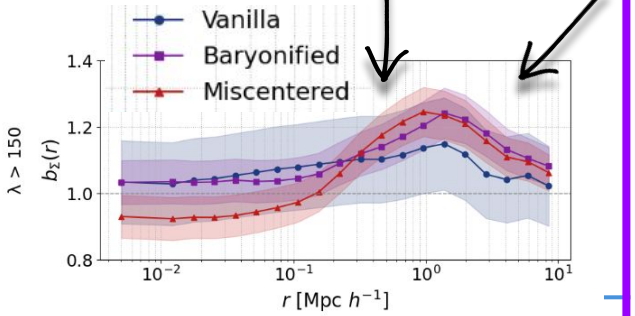
SHEAR PROFILE MODEL SYSTEMATICS

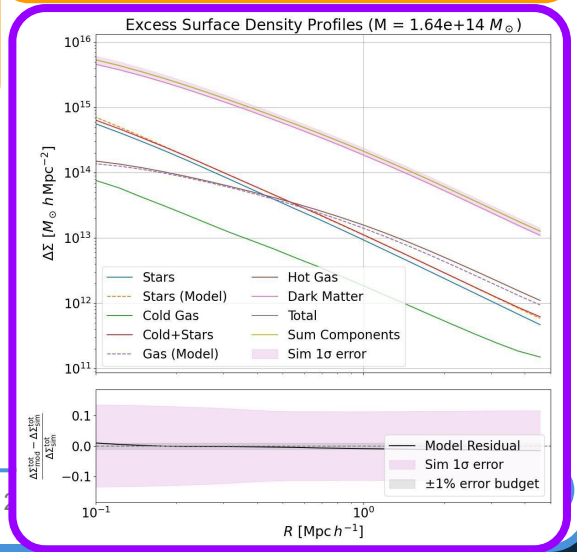
- **CosmoPostProcess:**
  Implemented and validated pipeline to compute *autoconsitently* projected halo density profiles and observed richness in simulations. (***Ingrao et al in prep.***)

  + **Miscentering**: implemented model to produce realistic cluster center offset based on projected galaxy density
  + **Baryonic feedback**:
    Implemented baryonification model (Schneider+19) to modify simulated DM-only profiles to reproduce baryonic suppression









EUCLID CLUSTER COSMOLOGY LIKELIHOOD

cloe-org

Hub for cosmological modeling and statistical inference focused on large-scale structure

Developer: A. Fumagalli, Z. Sakr, G. Lesci, M. Aguena, L. Baumont, …

- **Current status:**
  - Likelihoods for the three probes have been implemented, optimised and tested in CLOE v1
  - Currently working on migration to CLOE v2 (`cloe-org`):
    - Implemented and tested all relevant functions to compute cluster statistics (`cloe-lib`)
    - Finalizing integration of all the above functions for likelihood computation (`cloe-like`)

Mock MCMC test of Euclid Cluster pipeline CLOE v1