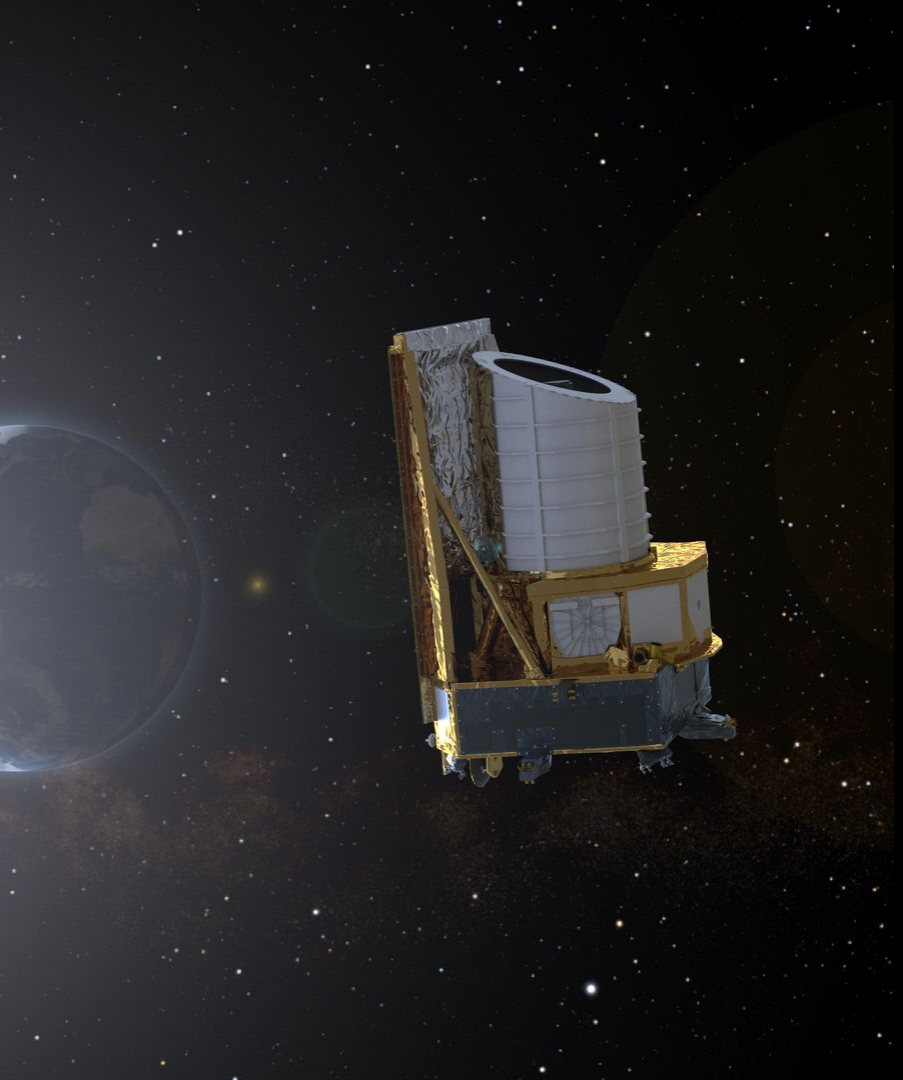


Cosmological Likelihood and Theory pipeline overview

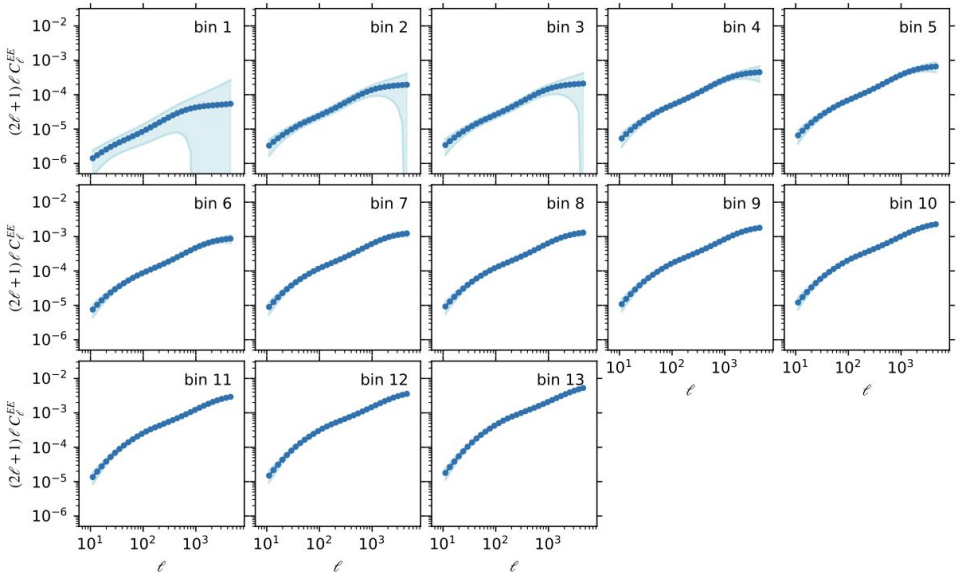
Martin Crocce

IST:likelihood : IST:nonlinear : GC SWG : WL SWG

euclid consortium

The Core Cosmology Science of Euclid

From VIS (photometric science)



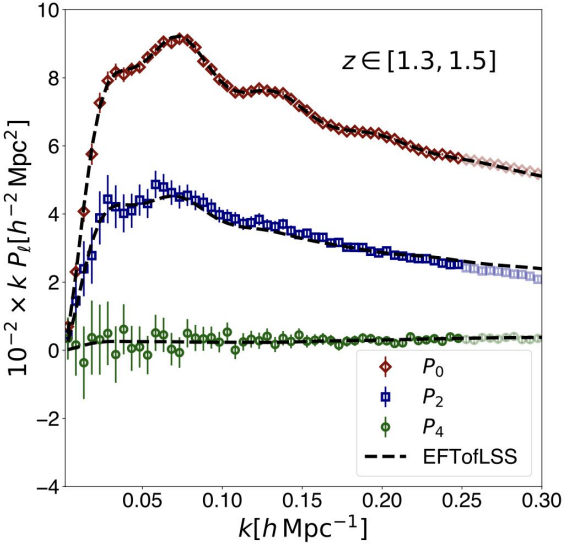
- 2-pt correlation of background shapes (WL)
- 2-pt correlation of foreground positions (GC phot)
- 2-pt cross-correlation of position - shape (XC)

⇨ **3x2 analysis in 0 < z < 2**

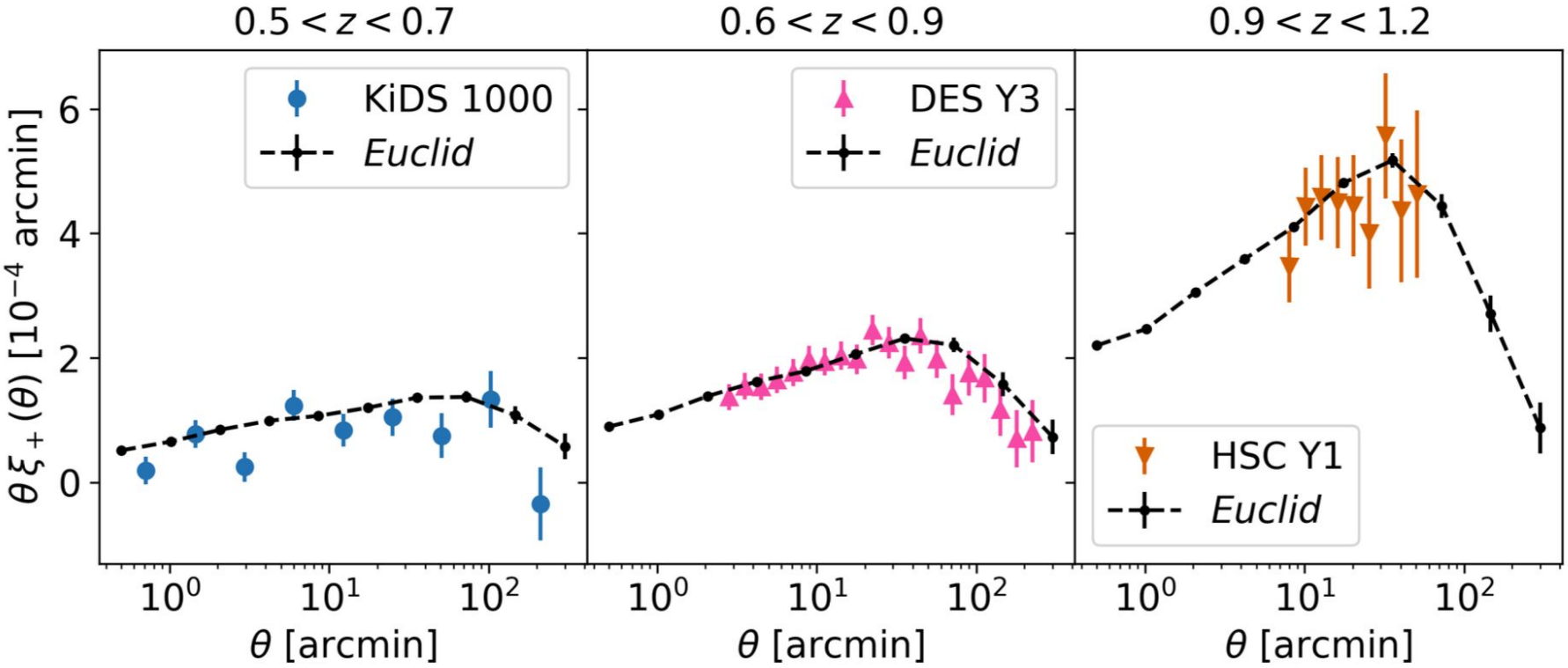
From NISP (spectroscopic one)

GC spec in 1 < z < 2

- Growth Rate = Anisotropic clustering of galaxies
- Baryon Acoustic Oscillations



Stage III to Stage IV challenge



CREDIT = Euclid Review paper

From the satellite

to cosmology …

Read Data Vectors as input
e.g. 2pt functions provided the Euclid Ground Segment LE3

+ other data specifications
redshift distributions, mask

Produce Theory Models
Rely on P(k) at nonlinear scales

Specify Cosmological Model
LCDM, wCDM, w0waCDM, etc

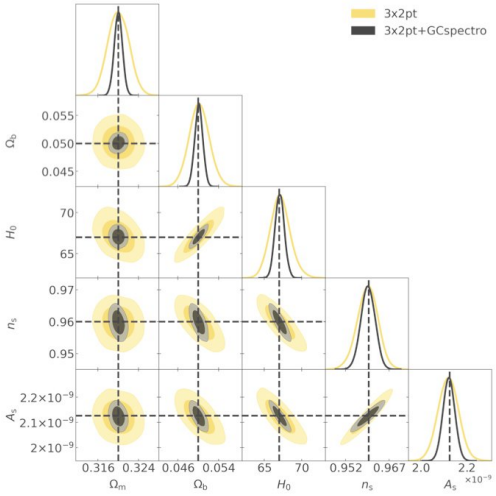
Input Estimated Covariance
Distribution of stat + syst error
Analytical or based on Mocks

Likelihood Computation
Compare theory and data weighted by the estimated errors via the likelihood function

$$-2\log \mathcal{L}(\boldsymbol{d}|\theta, M) = [\boldsymbol{d} - \boldsymbol{t}(\theta)]^{\mathsf{T}}\ \mathsf{C}^{-1}\ [\boldsymbol{d} - \boldsymbol{t}(\theta)]$$

→ **MCMC runs**
Sample the parameter space

Estimate Confidence Intervals



The likelihood pipeline : Cosmological Likelihood for Observables in Euclid

- ★ Fully written in python and validated against external codes (pyccl, cosmosis)
- ★ Observables considered
  - ○ Weak Lensing (Cosmic Shear)
  - ○ Photometric Galaxy Clustering
  - ○ Photometric Galaxy - Galaxy Lensing
  - ○ Spectroscopic Galaxy Clustering (angular power spectra and correlation functions)
- ★ Other secondary probes available: clusters of galaxies, cross-correlations with CMB
- ★ Boltzmann solver for the background physics: CAMB | CLASS | HiCLASS | EFTCAMB
- ★ Statistical analysis: **Cobaya (Metropolis Hastings & Polychord)**, CosmoSIS
- ★ Development in the **Euclid Consortium Gitlab** following good coding practices
- ★ Several systematics considered to marginalise over (photo-z's, contamination, shear bias, etc)

The theory pipeline : A library of Nonlinear models

Weak Lensing and 3x2

- BACCO linear theory emulator
- Nonlinear Dark matter = HMCode 2020 Emulator + BACCO v2 + Euclid Emulator 2
- Baryonic suppression factors from baryonification emulators = BACCO + BCEmu (7 params each)
- Baryonic suppression from halo model = HMCode 2020 emulator (1 param)
- Intrinsic Alignment =
    - Nonlinear Alignment Models (NLA)
    - Tidal Alignment Tidal Torquing (TATT) model (w/ FastPT)
- Nonlinear Galaxy Bias = eulerian one loop expansion (w/ FastPT)

Spectro Galaxy Clustering (**EFTofLSS** baseline in DESI)

- Nonlinear galaxy bias and dark matter = Perturbation Theory to one loop (w/ FastPT)
- BAO damping Infrared resummation using Wiggle-no Wiggle Split + Direct Sine Transforms
- Redshift Space Distortions = counter-terms (option to adopt parametric functions)

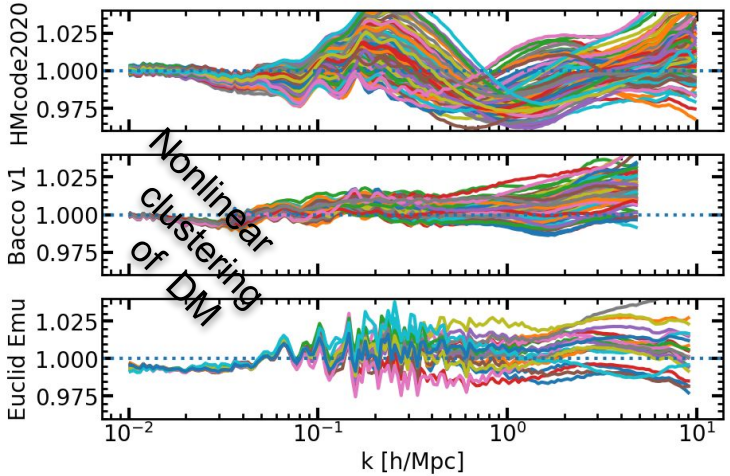
Analytical covariance

- Improved version of PySSC : SpaceBorne 3x2pt covariance
- Improved version of CovaPT : clustering multipoles covariance

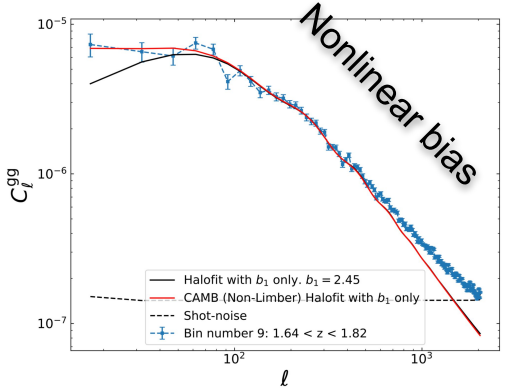
★ Development in the **Euclid Consortium Gitlab** following good coding practices + external validation

The theory pipeline : A library of Nonlinear models

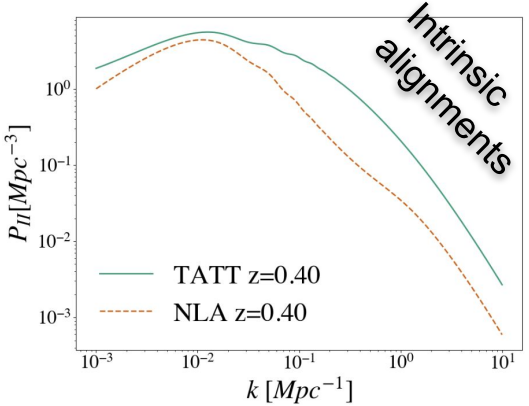
CREDIT = Raul Angulo & BACCO group

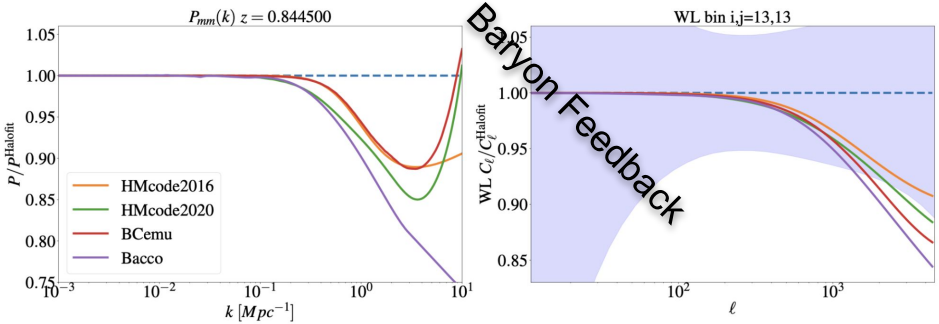


CREDIT = Sylvain G Beauchamps et al

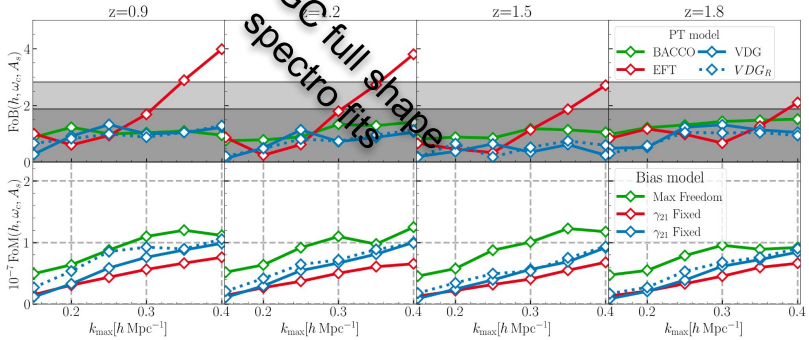


CREDIT = David Navarro et al





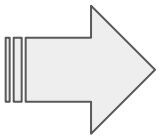
CREDIT = Pedro Carrilho et al



CREDIT = Benjamin Camacho, Andrea Pezzotta, Chiara Moretti et al

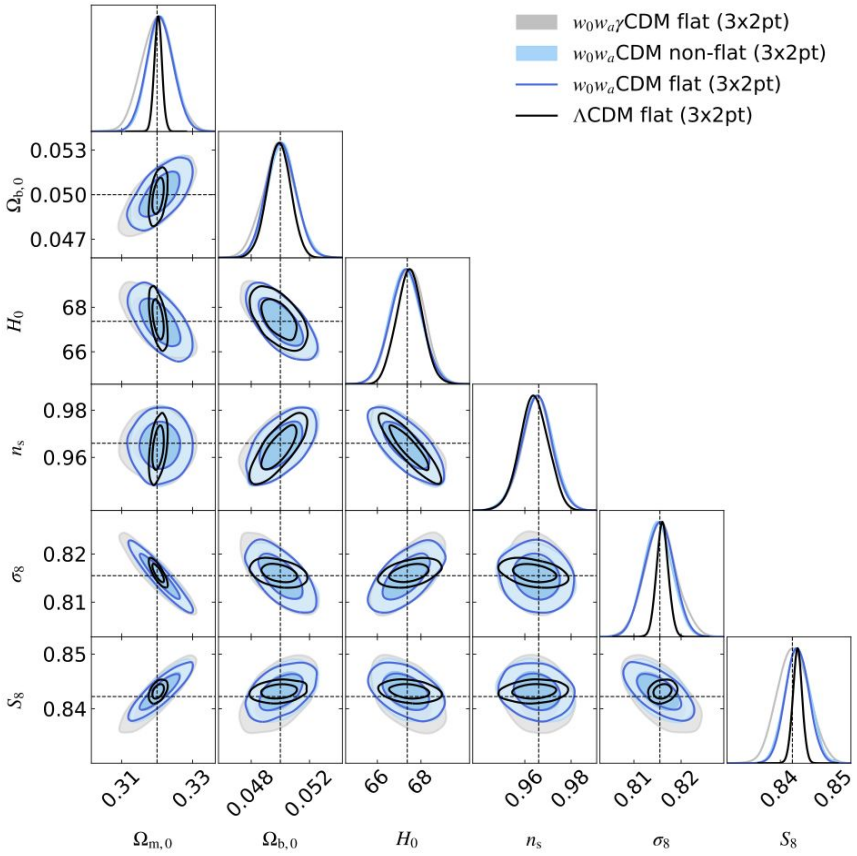
The pipeline is running - 3x2 chains

- **Cosmological models: LCDM, w0waCDM, w0waγCDM**
- **Probes**: WL, 3x2pt (harmonic space)
- **Scale cuts**: l_{max} = 3000
- **Covariance matrix**: gaussian + SSC
- **Non-linear model**: HMCode (2020) with baryonic feedback
- **Intrinsic alignment model**: NLA
- **Systematics**: galaxy bias, magnification bias, multiplicative shear bias, shift in mean redshifts
- **Boltzmann code**: `CAMB`
- **Sampler**: `polychord`
- Assuming full survey area and 13 tomographic bins → almost 380 2-pt functions being fitted
- Self-generated synthetic data with CLOE assuming 32 logaritmically-spaced l values

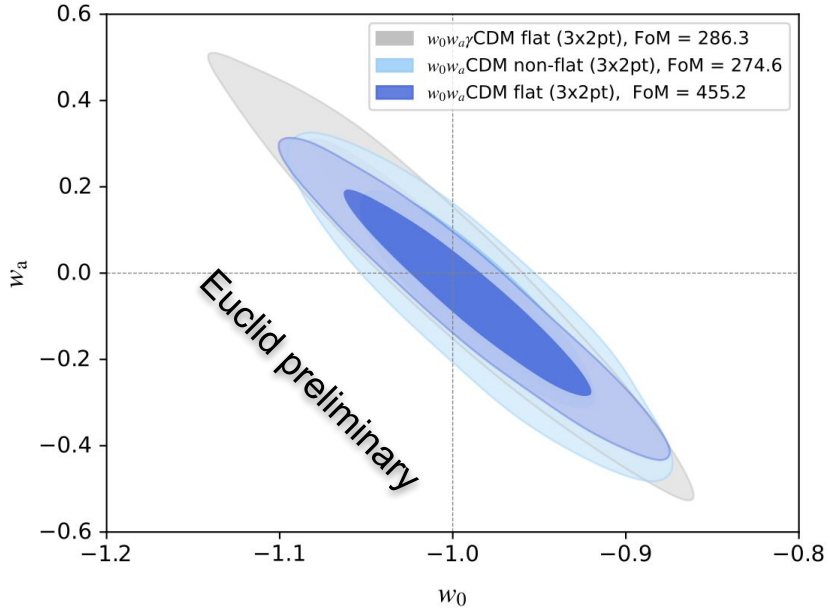


Need to sample over 60 parameters !! (cosmo+nuisance)

The pipeline is running - 3x2 chains (full mission, DR3)

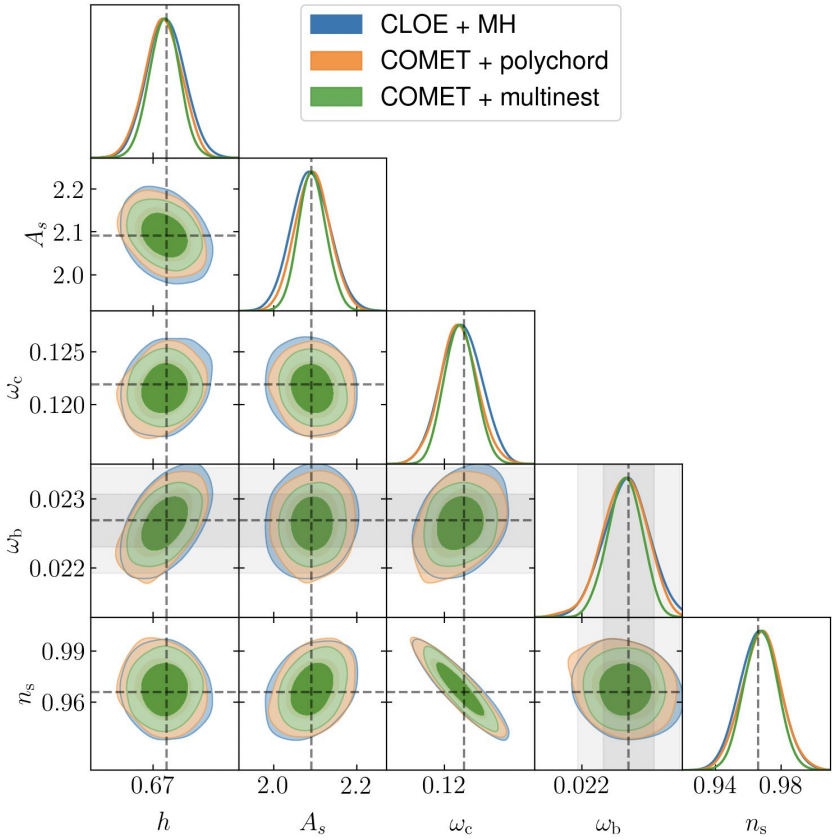


CREDIT = Guadalupe Cañas Herrera



Model	ISTF (pessimistic)	ISTF (optimistic)	CLOE
w_0w_aCDM (flat)	367	1033	455
w_0w_aCDM (non-flat)	59	326	274

The pipeline is running - GC spectro chains (full mission, DR3)



CREDIT = Andrea Pezzotta

- **Cosmological models: LCDM, wCDM**
- **Probe**: Power Spectrum multipoles (P0, P2, P4)
- **Scale cuts**: $k_{max} = 0.3$
- **Covariance matrix**: gaussian
- **Non-linear model**: EFTofLSS
- **Parameters :** galaxy bias (linear, nonlinear, nonlocal), redshift space distortions, noise [5 per z-bin]
- **Intrinsic alignment model**: NLA
- **Systematics**: purity, incompleteness, redshift errors
- **Boltzmann code**: `CAMB`
- **Sampler CLOE**: `polychord`
- Comparison to public COMET emulator
- Assuming 4 redshift bins [1 < z < 2] tomographic bins
- Self-generated synthetic data with CLOE

The IST:likelihood + IST:nonlinear teams responsible for all these ..

- Amandine Le Brun
- Andrea Pezzotta
- Davide Sciotti
- Domenico Sapone
- Fabien Lacasa
- Emiliano Sefusatti
- Felicitas Keil
- Guadalupe Cañas Herrera
- Isaac Tutusaus
- Jesus Torrado
- Konstantinos Tanidis
- Linda Blot
- Lisa Goth
- Marco Bonici
- Matteo Martinelli
- Samuel Farrens
- Santiago Casas
- Shahab Joudaki
- Stefano Camera
- Stefano Davini
- Sylvain G. Beauchamps
- Vincenzo Cardone
- Valeria Pettorino
- Alkistis Pourtsidou
- Benjamin Camacho
- Carlo Giocoli
- Carmelita Carbone
- Chiara Moretti
- David Navarro
- Giovanni Aricò
- Jonathan Blazek
- Pedro Carrilho
- Raul Angulo
- Alex Eggemeier
- Anna Porredon
- Jacopo Salvalaggio
- I’m sorry if I missed you

Summary

CLOE v2.0 : a 5 years project involving two teams of incredible students and postdocs, and synergies / feedback from many science teams across EC.

Running now in realistic settings [various clusters across Europe & ESA Datalabs]

Still a good way ahead to confront DR1

Optimising speed up of likelihood evaluations, samplers, extensions, and usability

Currently comparing nonlinear models vs. simulation measurements (including Flagship) for all main probes and covariances.

DR1 Key Projects will be announced soon, this pipeline will play a central role if all goes well 🤞

Data Release 1 key projects structure