Euclid: performance on main cosmological parameter science

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Contents

- Introduction
- Cosmological constraints from the main probes
- Beyond the main probes
- Towards data analysis
- Conclusions
Introduction

Expansion and large-scale structure — dark matter and dark energy:

+ dark matter
- dark energy

+ structure

Main summary statistic: matter/galaxy power spectrum
**Introduction — galaxy clustering**

- **Baryon acoustic oscillations (BAO):**
  - provide a **cosmic ruler**
  - sensitive to the **expansion** history and the angular-diameter distance

- **Redshift-space distortions (RSDs):**
  - sensitive to the **growth rate** of structures
  - tests of **modified gravity**

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[Alam et al. 2016]

[Pezzotta et al. 2017]
Spectroscopic vs photometric galaxy clustering:

- loss of radial information
- higher number density & different systematic uncertainties
- source of cosmological information

[Stothert et al. 2018]
Introduction — weak lensing

Weak lensing (WL):

- information about **mass distribution** imprinted on galaxy images
- sensitive to **matter density**, initial conditions, and **growth of structures**

[Figure courtesy of M. Sachs]
Euclid is the ideal survey for a combined analysis:

GCs, GCp, WL, and 3 cross-correlations (XC)
Cosmological constraints from the main probes

Task-force to produce homogenised and validated forecasts:

- Great complementarity between probes: breaking of degeneracies

Dark energy figure-of-merit of 1257 (500) for a flat (non-flat) cosmology

Modified gravity constrained at 5% and curvature at 1%

Cross-correlations improve constraints by a factor 4

Cosmic microwave background — lever arm of different epochs
[Ilic, Aghanim, Baccigalupi]

• Euclid main probes + Simons Observatory CMB lensing (blue)
• Euclid main probes + all Simons Observatory CMB probes (orange)

Improvements up to a factor of 10

[Euclid Collaboration XV. A&A 657, A91 (2022)]
Towards data analysis

Development of cosmological simulations to develop the analysis pipelines:

- Flagship galaxy catalog [Carretero, Castander, Fosalba, Neissner, Pozzetti, Stadel, Tallada++:

  - WIDE: $10^9 \, M_{\text{sun}}$ resolution (4.1 trillion particles, 3600 Mpc/h box)
  - DEEP: $10^8 \, M_{\text{sun}}$ resolution (0.9 trillion particles, 1000 Mpc/h box)
Towards data analysis

Complex measurements: End-to-end simulations — spectroscopic galaxy clustering

[Slide courtesy of B. Granett and GC end-to-end group]
Towards data analysis

Complex measurements: End-to-end simulations — weak lensing & photometric galaxy clustering

Catalogue

Survey

Intrinsic shape Shear PSF Detector Observed

Reference spectra $C_R(\ell)$

Perturbed spectra $C_P(\ell)$

Analysis

Measurement

Cosmological inference

[Bridle et al. 2008]

[Euclid Collaboration VI. A&A 635, A139 (2020)]
Simulations:

• more volume and resolution, emulators
• end-to-end pipelines

Modelling of the observables:

• nonlinear modelling of the matter and galaxy power spectra, including RSDs
• magnification and other relativistic contributions

Towards the coming data:

• addition of systematic uncertainties and mitigation techniques
Euclid will provide unprecedented constraints on dark matter, gravity at cosmological scales and will constrain dark energy better than all current observations together:

\[
\sigma(w) \sim 3\%
\]

\[
\sigma(w_0) < 3\% \text{ with } w_a \text{ free}
\]