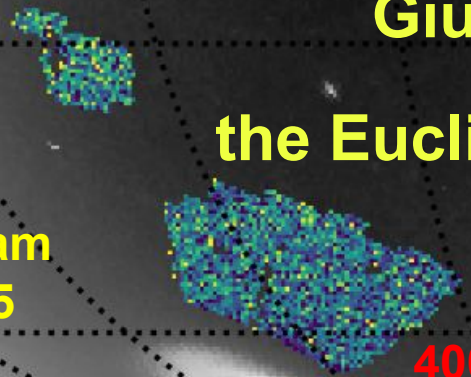
Weak lensing cosmic shear measurement in the era of Euclid

Giuseppe Congedo
on behalf of
the Euclid cosmic shear team

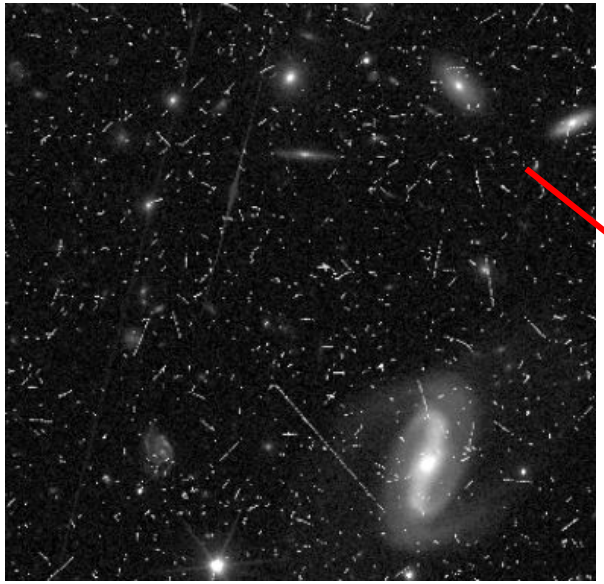
NAM, Durham
11 July 2025



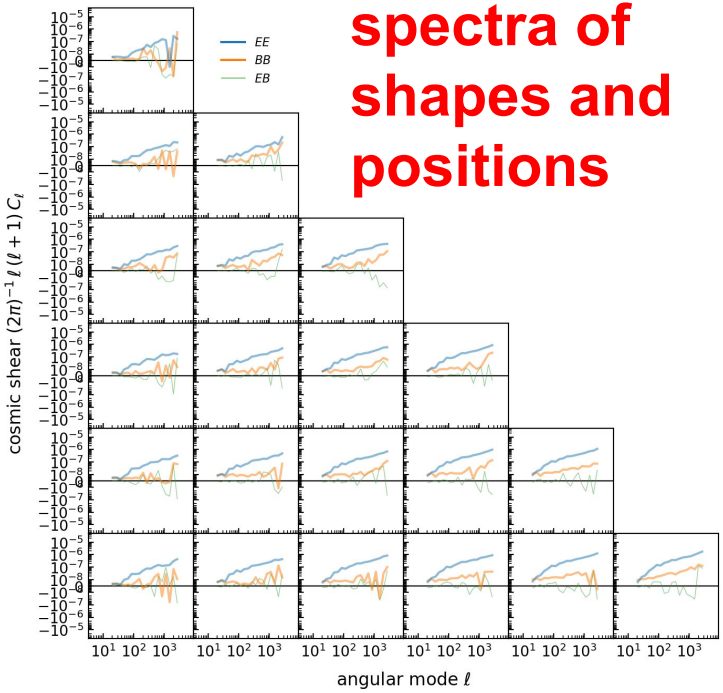
400 sq.deg. of Euclid survey

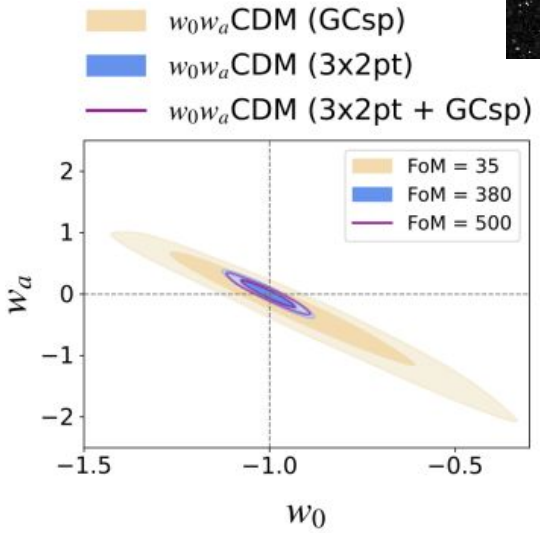
- **Coordinators**: Andy Taylor, Malte Tewes
- **Edinburgh [Shear Measurement]:** Andy Taylor, Shona Matthew, Giuseppe Congedo, Bryan Gillis, Richard Rollins, Isobel Ovens, Niraj Welikala, Rokas Zemaitis, Nisha Grewal
  - **SDC-UK:** Gordon Gibb, Rory Claydon, Keith Noddle, Nick Cross, Mark Holliman, Rob Blake, Ross Collins, Hon Wah Yeung
- **Oxford** [**PSF**] Lance Miller, Chris Duncan, Imogen Whittam, Jinhyub Kim**,** Denis Cutajar, Charlie Townsend-Rose
- **Durham [CTI]**: Richard Massey, James Nightingale, Andrew Robertson, Jacob Kegerreis, Gavin Leroy, Maximilian von Wietersheim-Kramsta
- **Open University [CTI]** Jesper Skottfelt, Matt Wander
- **Bonn [Shear Measurement]**: Malte Tewes, Ole Marggraf, Andres Navarro Alsina, Hannah Zohren
- **Innsbruck [Shear Calibration]**: Tim Schrabback, Henning Jansen, Benjamin Csizi
- **Marseille [Shear Calibration]**: Nico Martinet
- **CNES [PSF]**: L. Bernard, Edoardo Cucchetti, Christophe Latry, Nicolas Theret, Pierre Alain Goulm
- **Malta [PSF]**: Alessio Magro, Ian Fenech Conti
- **Paris [Validation/PSF]**: Martin Kilbinger, Jean-Luc Starck, Tobias Liaudat, Jennifer Pollack, Sam Farrens, Pierre-antoine Frugier, Nada Moukaddem, Ezequiel Centofanti
- **JPL [MetaCalibration]**: Eric Huff, Andre Vitorelli, Diana Scognamiglio
- **Bochum [Shear]**: Mijin Yoon

Raw images



Power spectra of shapes and positions





Percent-level precision on Dark Energy Equation of State

Weak lensing

observed ellipticity

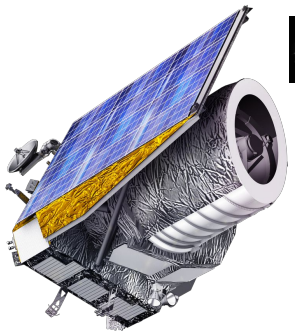
intrinsic ellipticity

cosmic shear

$e \simeq e_s + g$

$g = \langle e \rangle$

statistical average



stars

observed

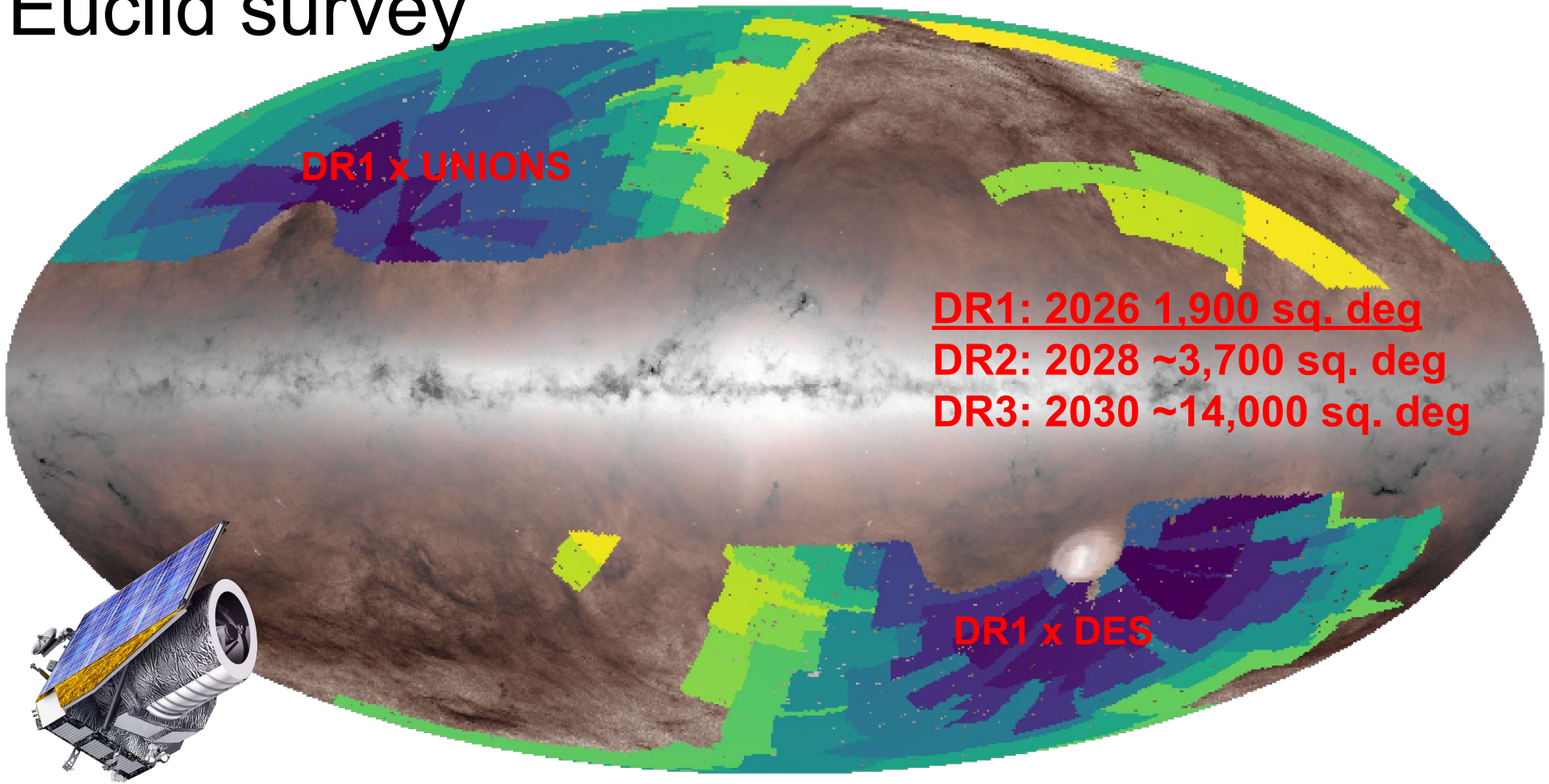
lensed

unlensed

dark matter halos

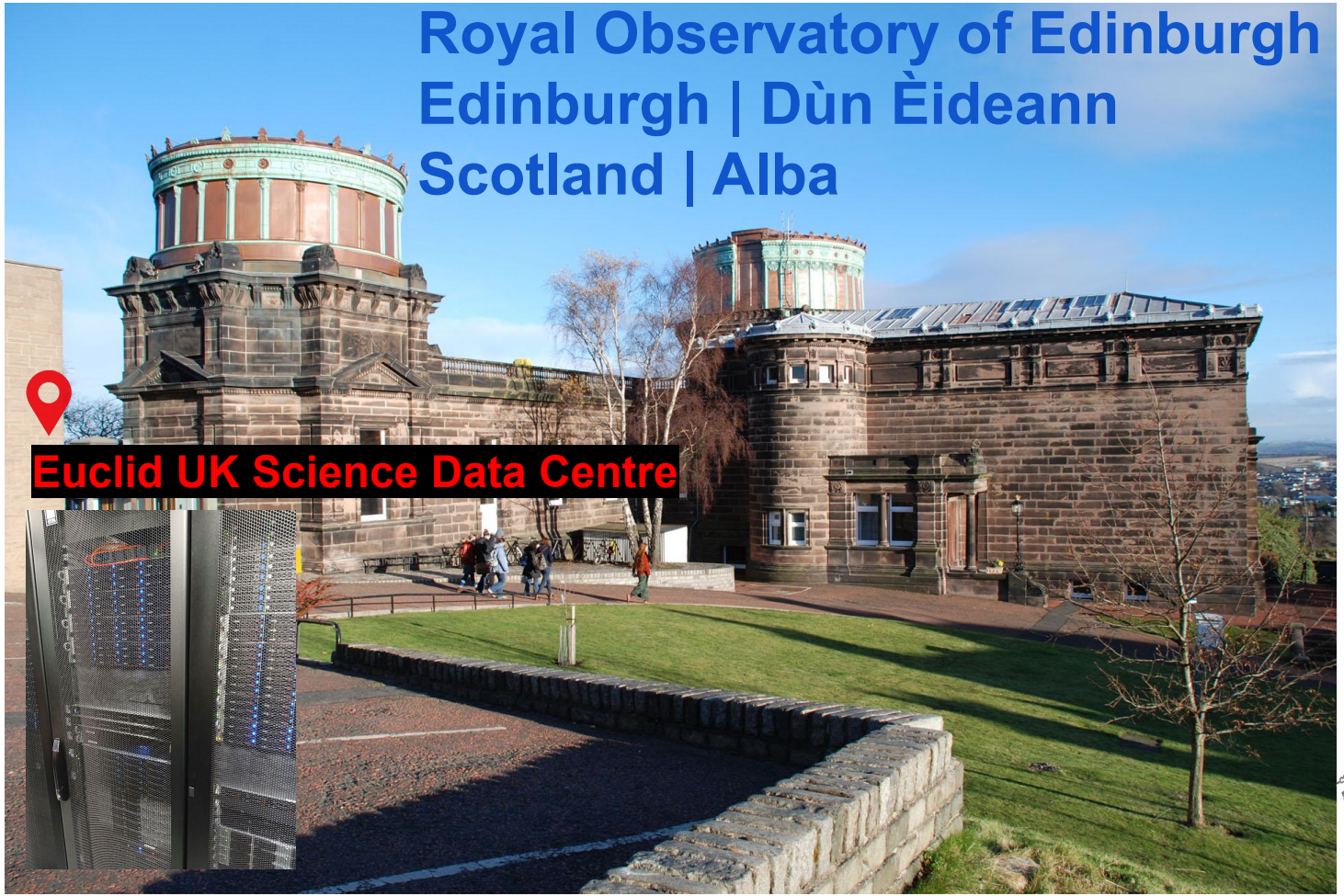
background galaxies

Euclid survey

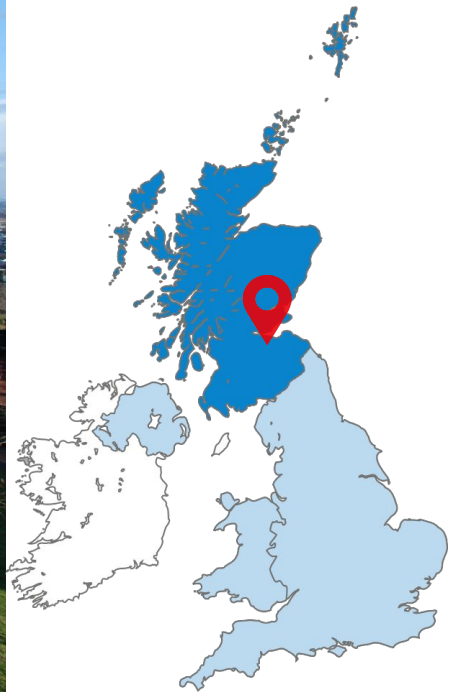


Euclid footprint + GAIA DR3 + Planck HFI 857 GHz

Royal Observatory of Edinburgh
Edinburgh | Dùn Èideann
Scotland | Alba

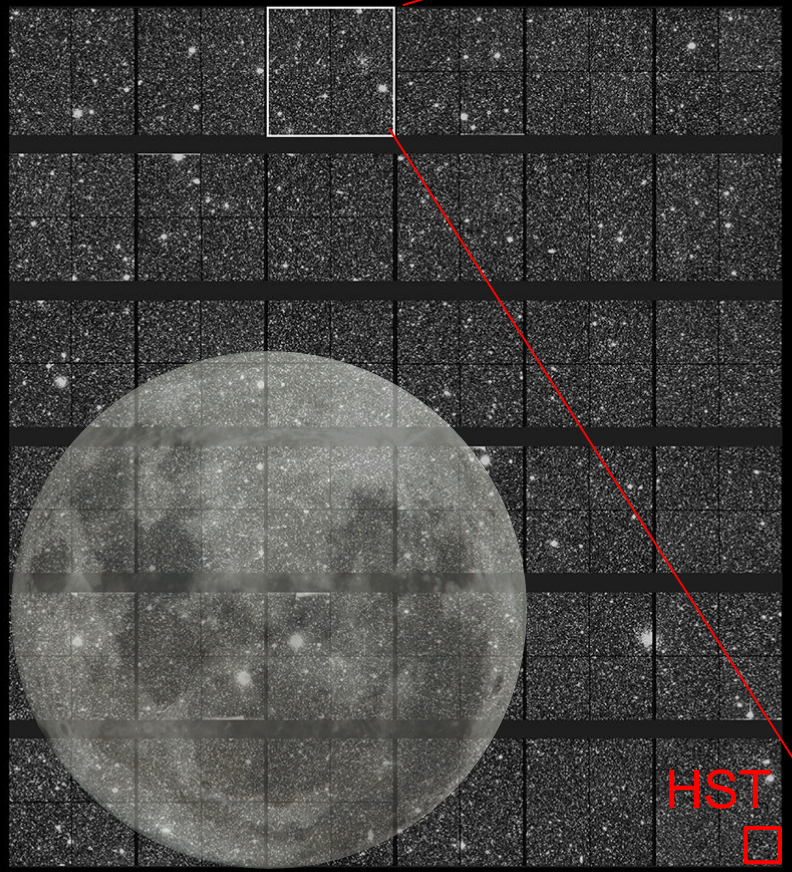


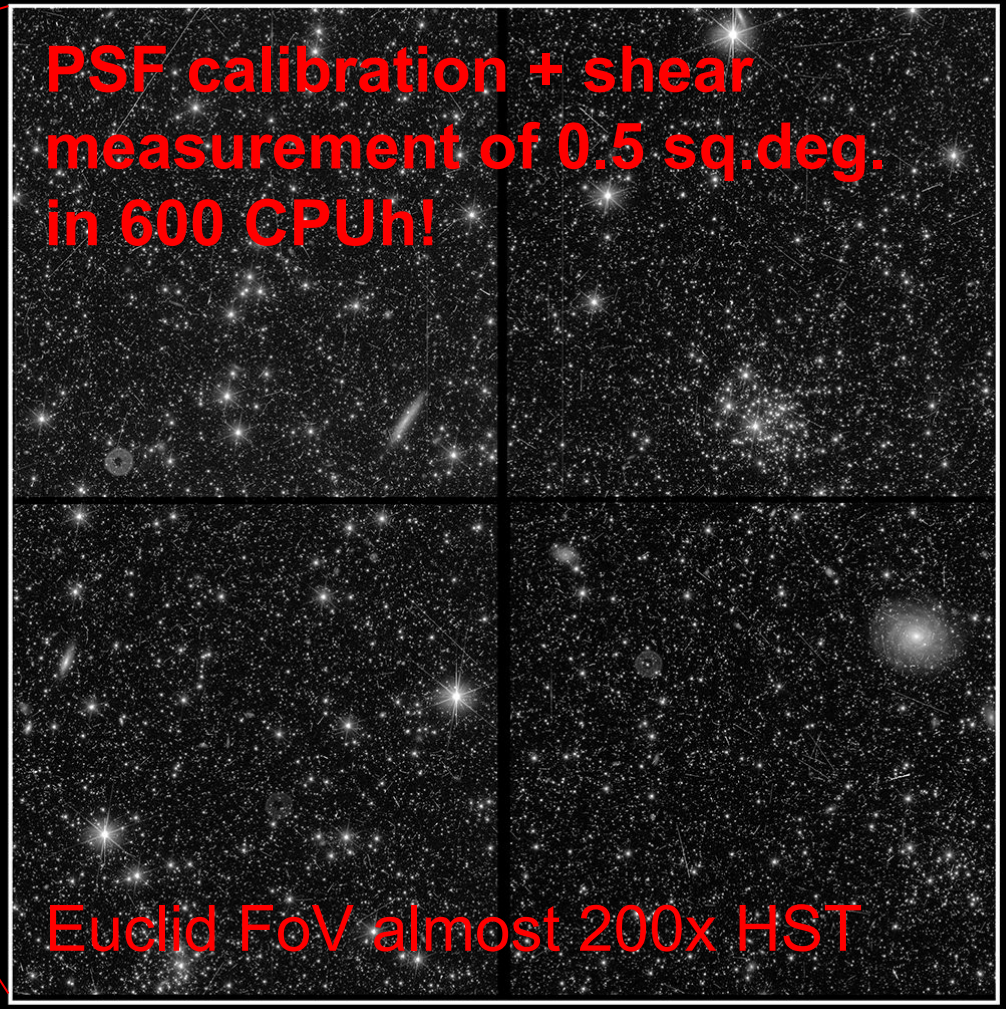
Euclid UK Science Data Centre



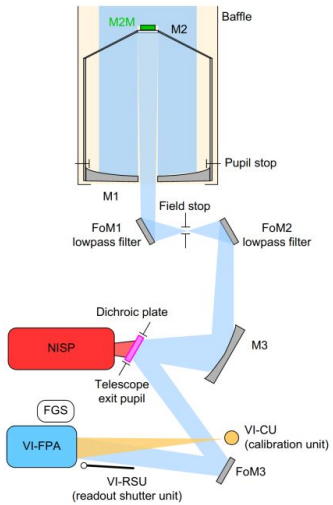
Euclid field of view

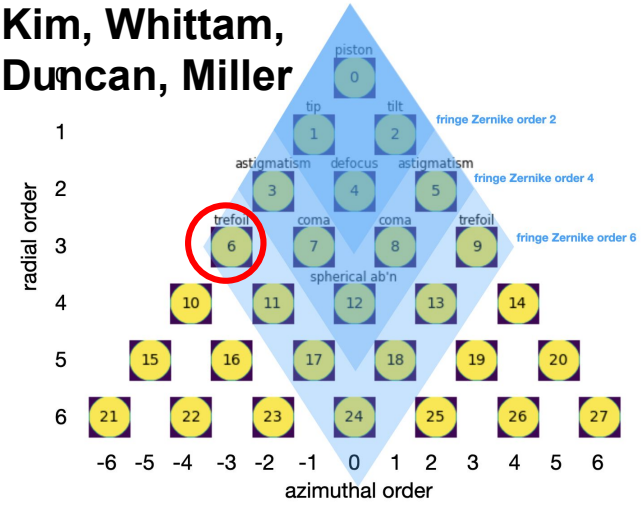
EARLY COMMISSIONING TEST IMAGE, VIS INSTRUMENT

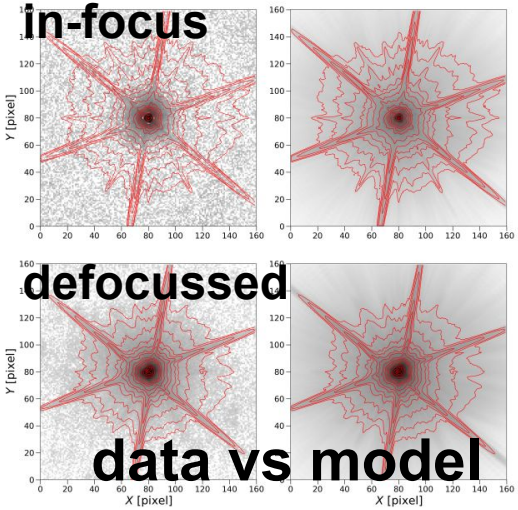




PSF: modelling the telescope







- (Zernike) wavefront modelling w/ chromaticity, FoV variation, polarisation
- Defocussed images break degeneracy when fitting to calibration data
- Dependence on temperature / focus, residual trefoil, and astigmatism: model performing well

Shear measurement and calibration

- Investigated a number of methods, but narrowed down to two for DR1
- **LensMC**: galaxy forward modelling, MCMC, heritage from KiDS/CFHTLens (UK based; Congedo+ 24)
- MetaCal: meta-calibration of KSB, heritage from DES (developed at JPL; Huff & Mandelbaum 17, Sheldon & Huff 17)
- Helps checking for cross-validation
- Empirical and simulations-driven calibration

Euclid preparation

LIII. LensMC, weak lensing cosmic shear measurement with forward modelling and Markov Chain Monte Carlo sampling

Euclid Collaboration: G. Congedo*[1], L. Miller[2], A. N. Taylor[1], N. Cross[1], C. A. J. Duncan[3,2], T. Kitching[4], N. Martinet[5], S. Matthew[1], T. Schrabback[6], M. Tewes[7], N. Welikala[1], N. Aghanim[8], A. Amara[9], S. Andreon[10],

& 200+ more authors

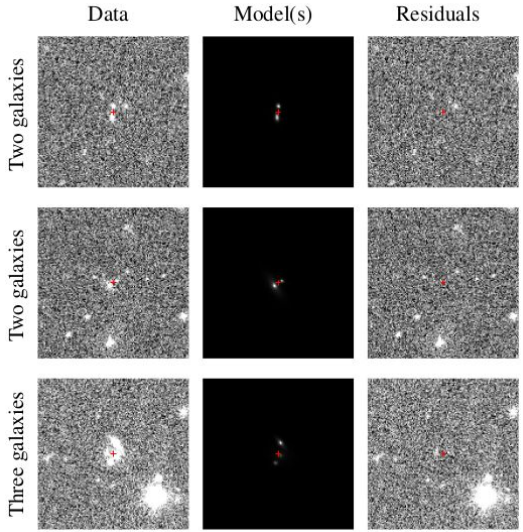
- Shapes, positions and morphological parameters
- MCMC on a massive scale, 30 /arcmin^2 (mag<26), ~1.5 billion galaxies
- Only 5 sec/galaxy/exposure/core; no fine tuning

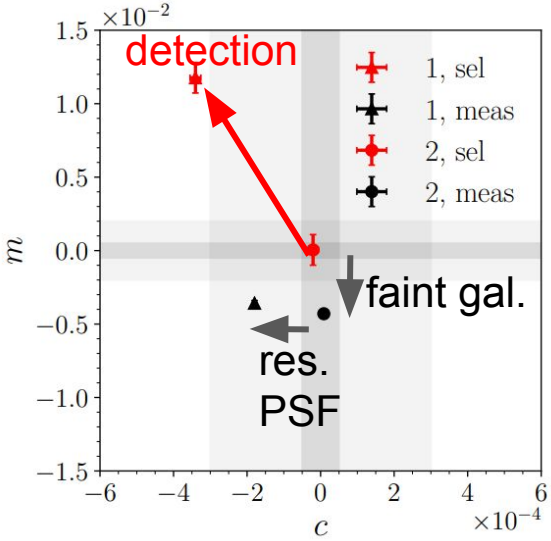
Bias around 2×10^{-3}; low sensitivity; calibrate if necessary

gitlab/LensMC
pip install lensmc

arXiv/2405.00669
A&A 691, A319 (2024)

Forward modelling measurement



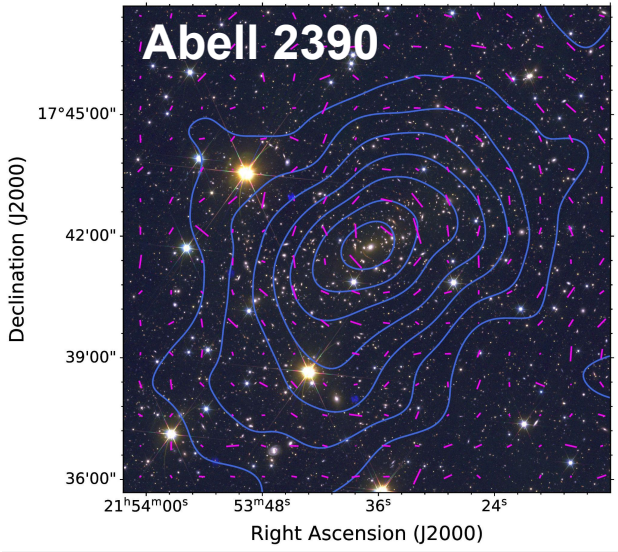


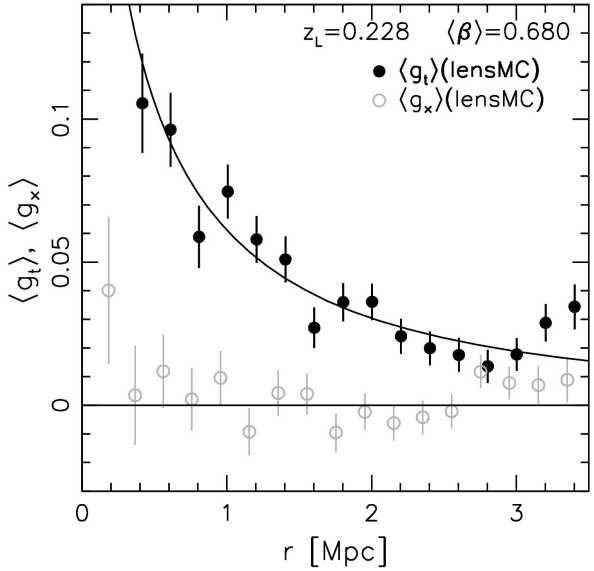
- Can measure galaxies, jointly
- ***"Recognised blends" dominate shear bias in LSST/Rubin – subdominant in Euclid***

- 4,500 sq.deg of simulated universe
- Bias break-down: detection, faint, and residual PSF
- Low sensitivity: can be calibrated

LensMC on real data

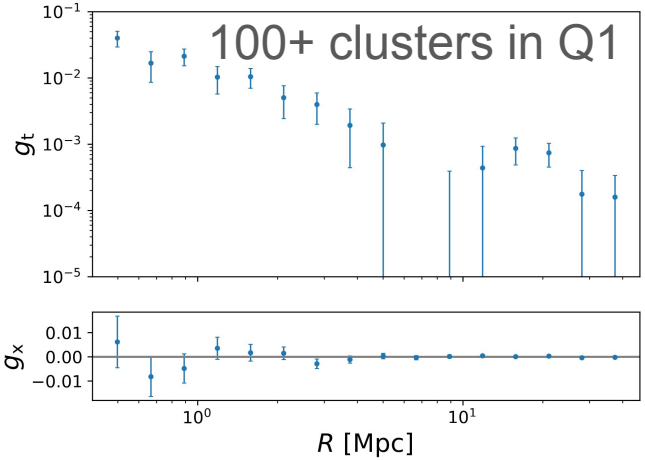
- Early science data
- ERO and Q1



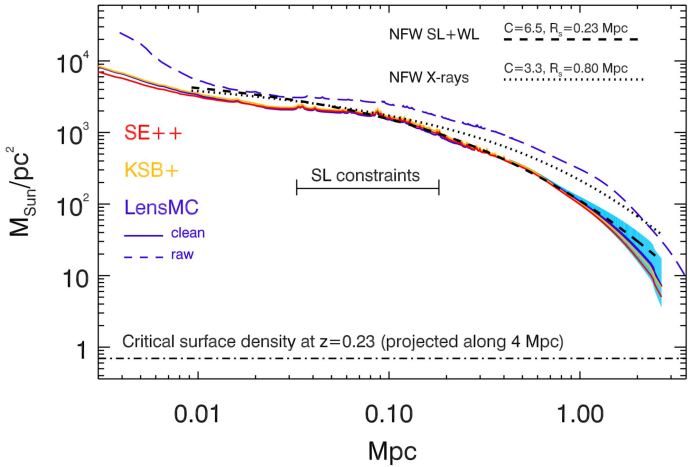


Schrabback, Congedo+ 25

Q1 science leads: Congedo, Miyatake, Sereno



More on Q1→ Sotiria Fotopoulou + other talks



Diego, Congedo+ 25

Summary

1. Weak lensing cosmic shear: primary cosmological probe in Euclid
2. Released 400 sq.deg for internal processing
3. DR1 going well:
   1,900 sq.deg of
   images processed
4. Cosmic shear pipeline:
   Sep-Nov 2025
5. Internal DR1: Dec 2025
6. Public DR1 of ~2,000 sq.deg: Oct 2026
7. Exciting cosmological results to come!