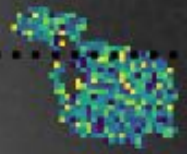
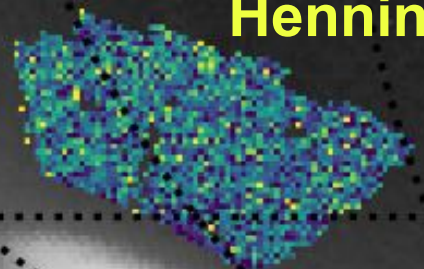
Weak lensing data processing

Giuseppe Congedo
on behalf of SHE + LE3 + SDC-UK
with inputs from: Chris Duncan, Gordon Gibb, Sacha Guerrini, Henning Jansen, Laila Linke, Nicolas Martinet, Nicolas Tessore, Andy Taylor, Andre Vitorelli

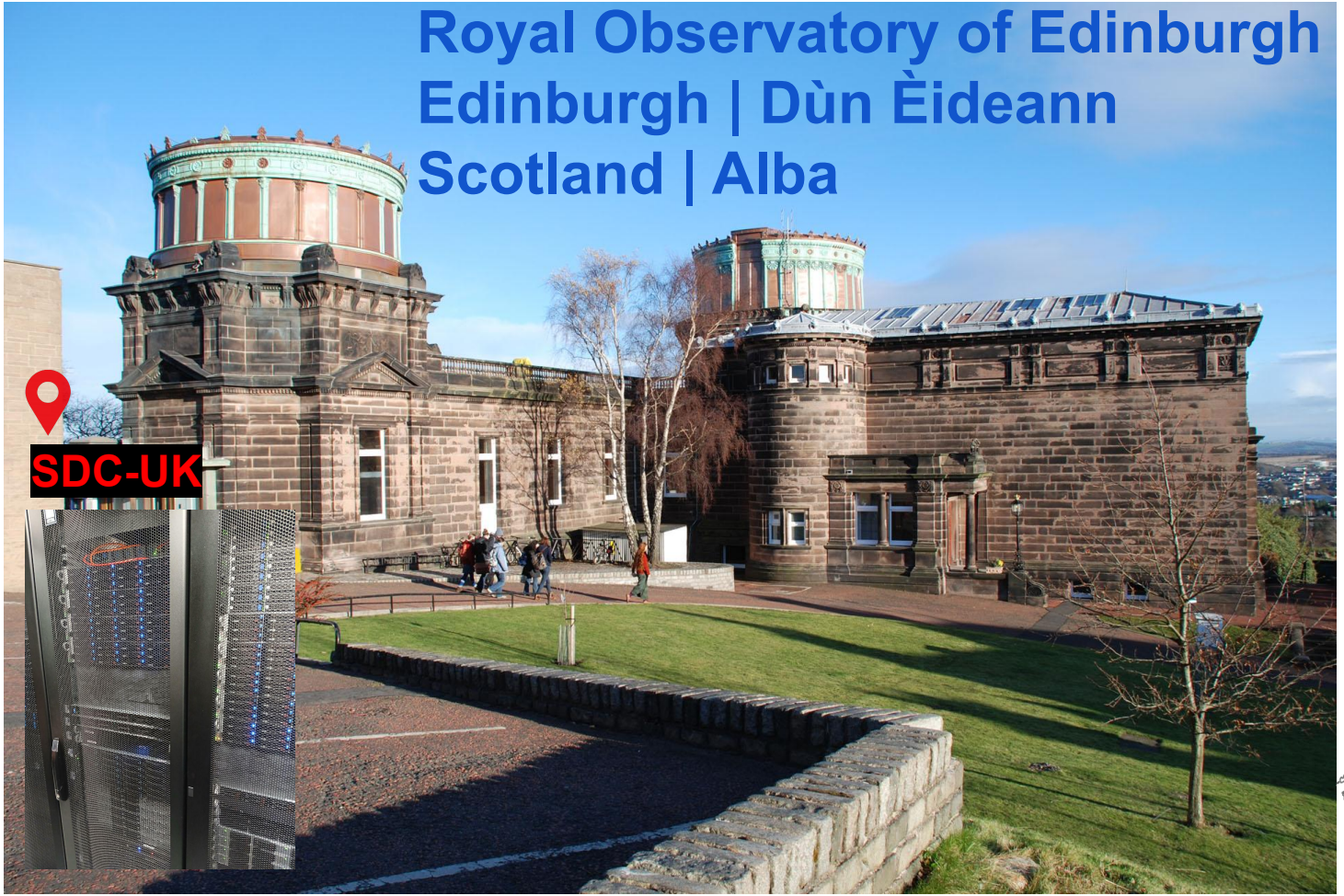


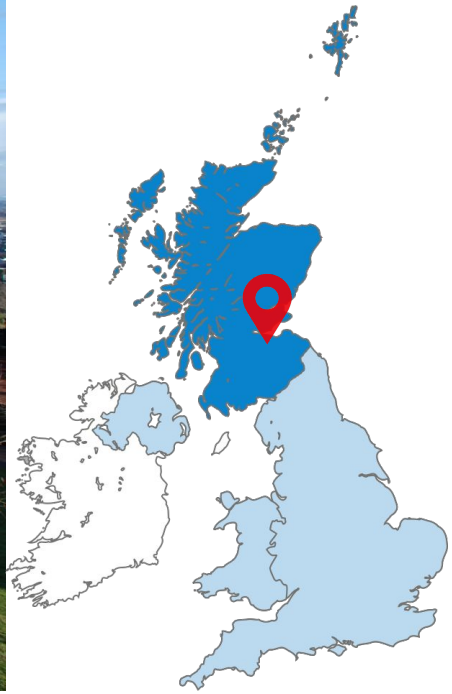


RR2 shear map

Euclid-Italia
Bologna
2 July 2025

Royal Observatory of Edinburgh
Edinburgh | Dùn Èideann
Scotland | Alba



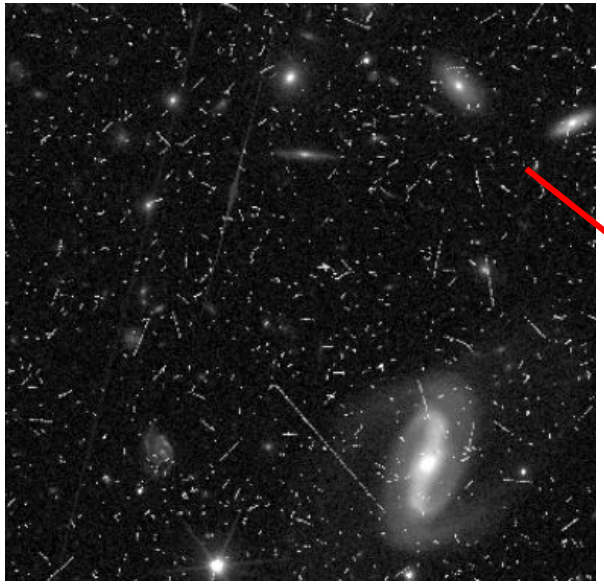


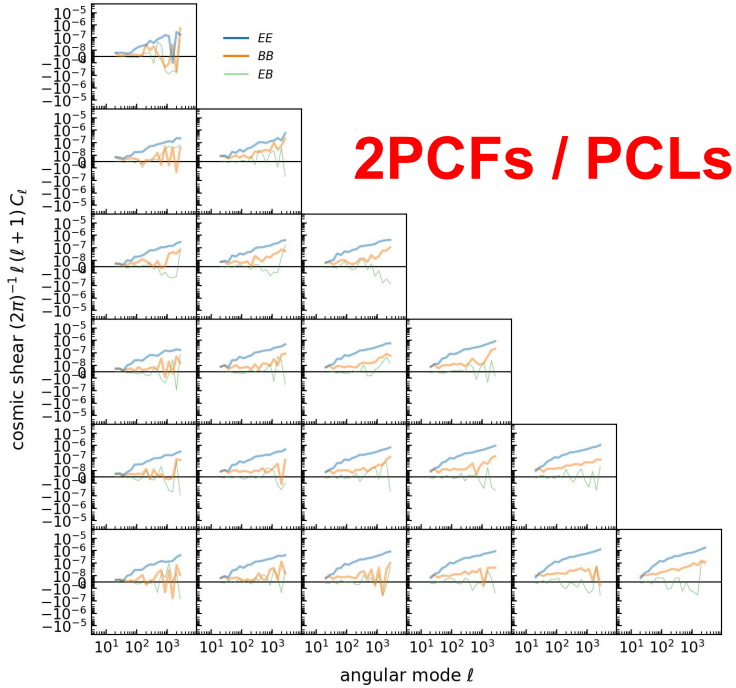
- **SHE Coordinators**: Andy Taylor, Malte Tewes
- **Edinburgh [Shear Measurement]:** Andy Taylor, Shona Matthew, Giuseppe Congedo, Bryan Gillis, Richard Rollins, Isobel Ovens, Niraj Welikala, Rokas Zemaitis, Nisha Grewal
  - **SDC-UK:** Gordon Gibb, Rory Claydon, Keith Noddle, Nick Cross, Mark Holliman, 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

Outline

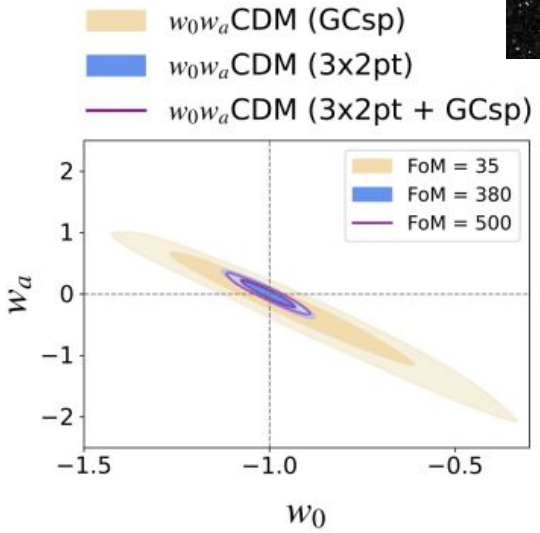
1. PSF modelling and calibration
2. Shape measurement
    a. LensMC
    b. MetaCal
3. Shear calibration
4. RR2 validation
5. Processing update and delays

Raw images





2PCFs / PCLs



Percent-level precision on DE EoS

Weak lensing

observed ellipticity

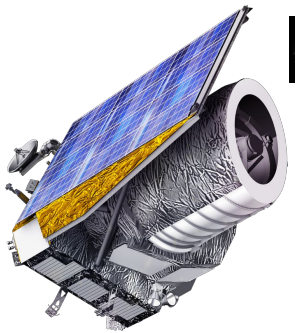
intrinsic ellipticity

cosmic shear

$e \simeq e_s + g$

$g = \langle e \rangle$

statistical average



stars

observed

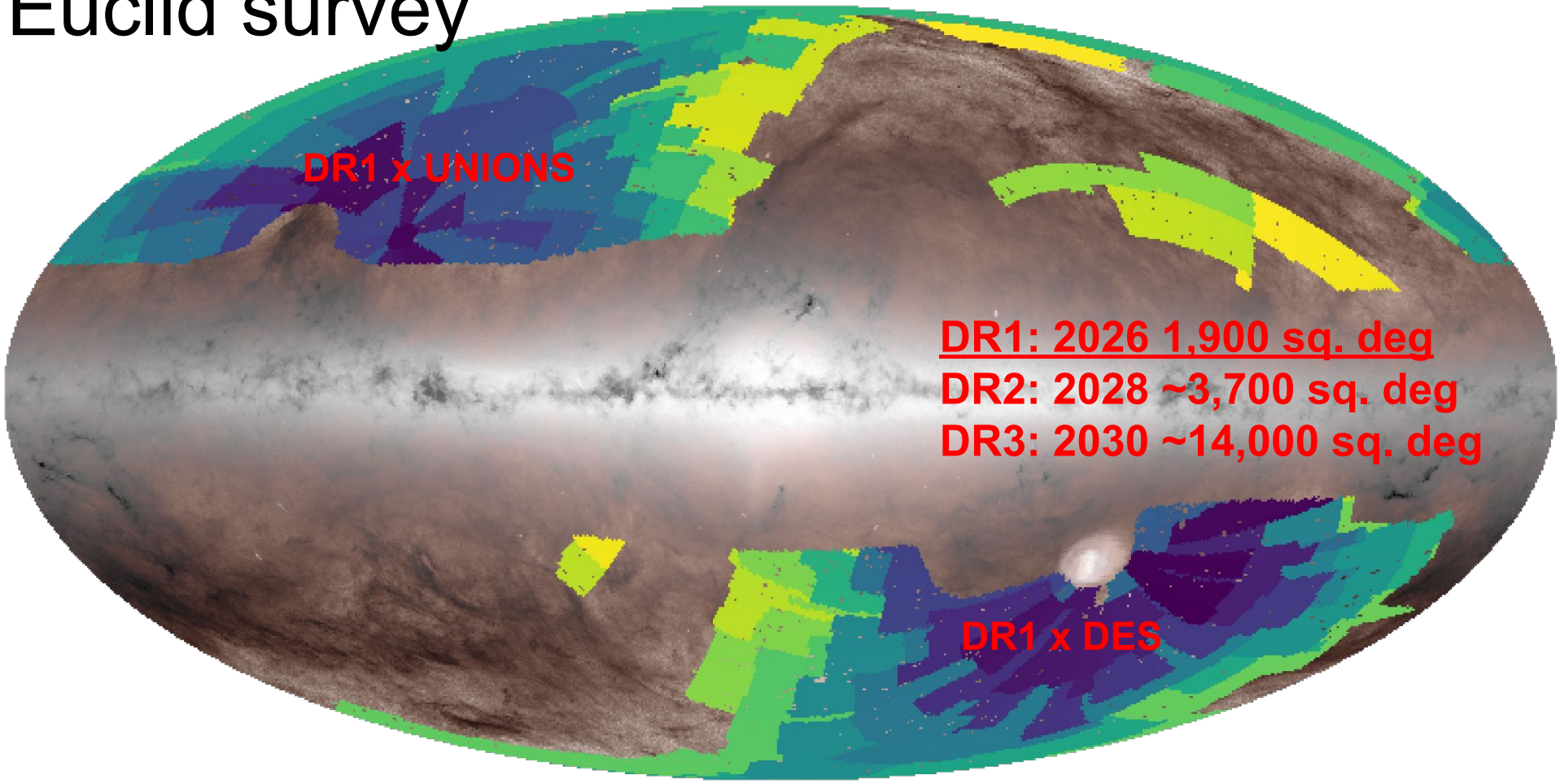
lensed

unlensed

dark matter halos

background galaxies

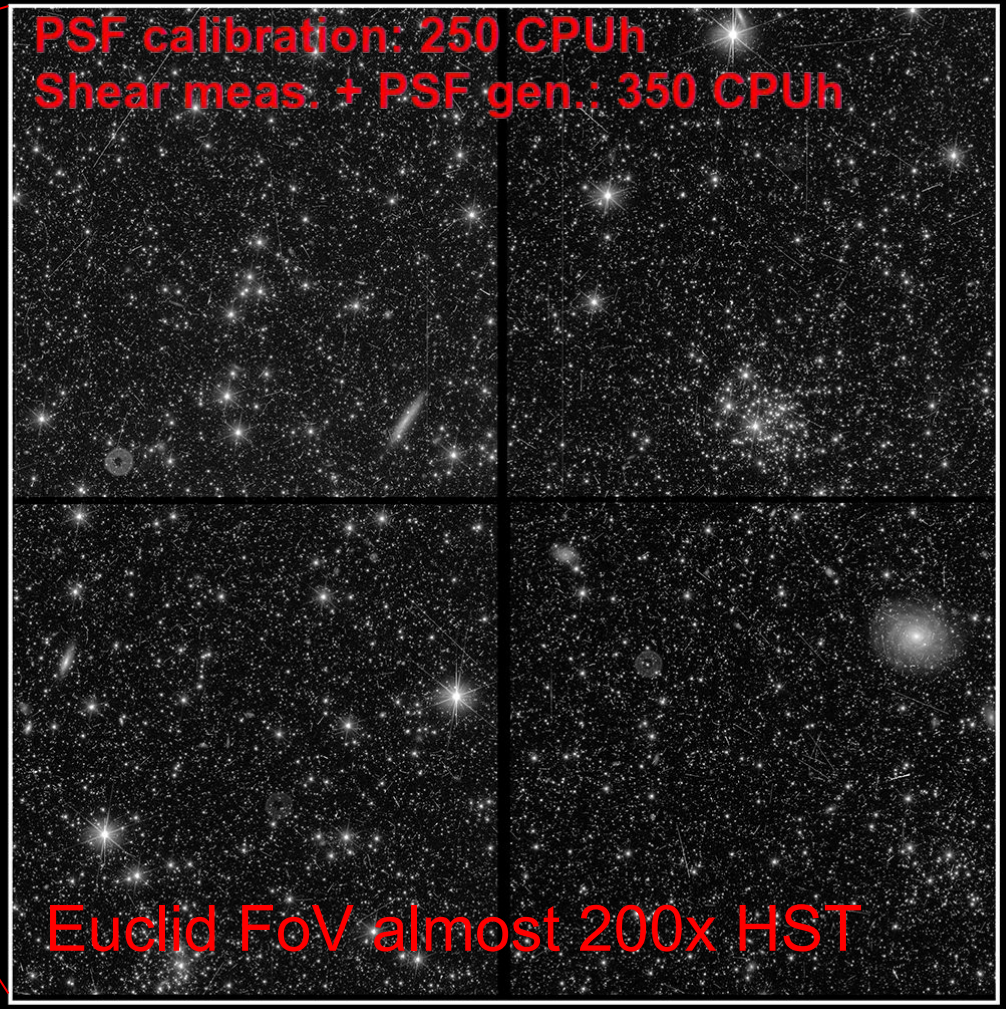
Euclid survey



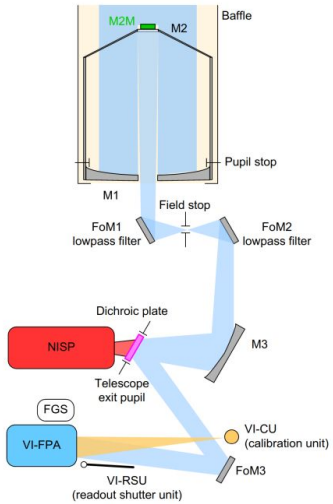
Euclid footprint (rsd2024c) + GAIA DR3 + Planck HFI 857 GHz

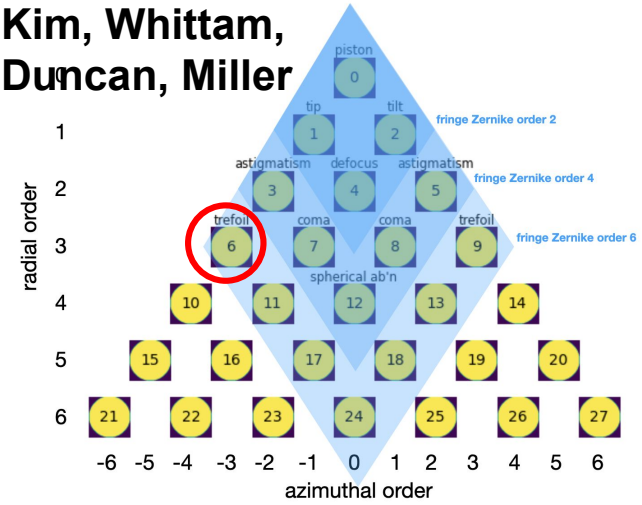
Euclid field of view

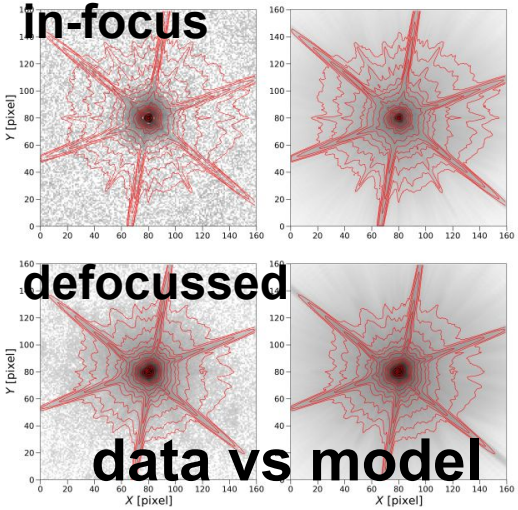
EARLY COMMISSIONING TEST IMAGE, VIS INSTRUMENT



PSF modelling and calibration

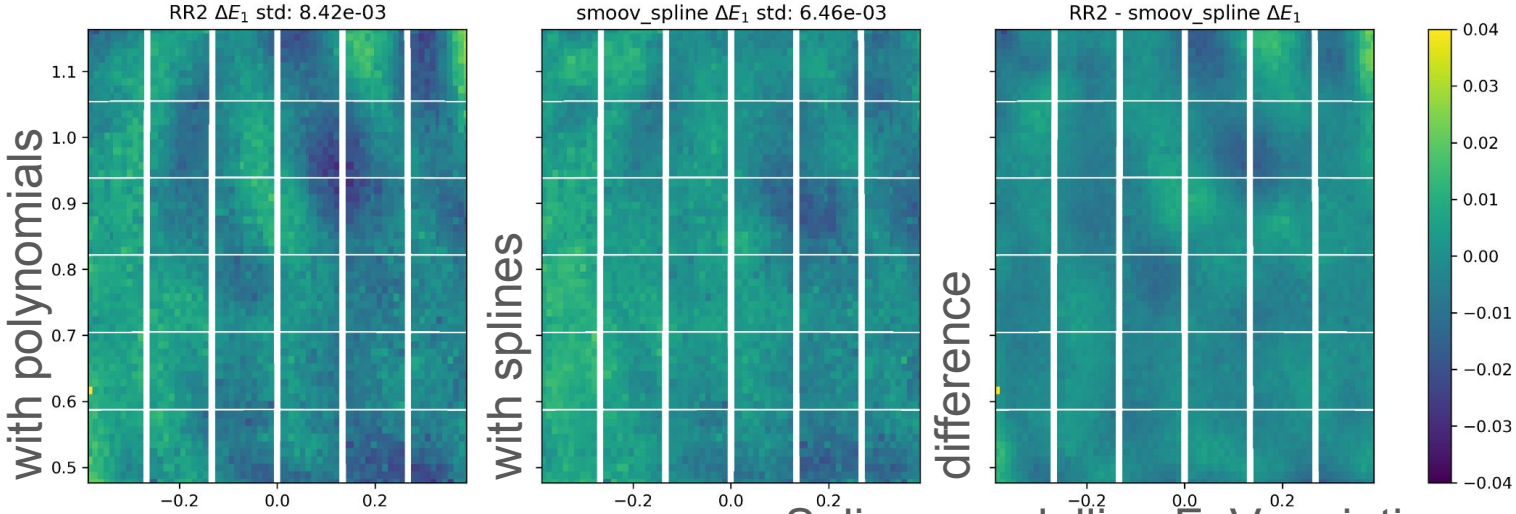


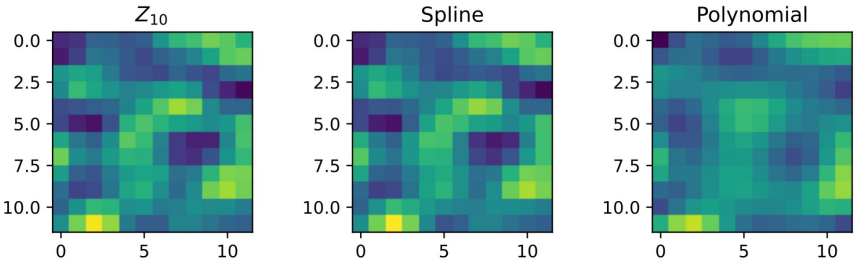




- (Zernike) wavefront modelling w/ chromaticity, FoV variation, polarisation
- Defocussed images break degeneracy when fitting to calibration data
- Dependence on temperature / focus, residual trefoil, and astigmatism: model performing well

PSF validation [Chris Duncan]





- Splines modelling FoV variation
- PSF residuals reduced from ~0.04 to 0.02 (peak values)
- Further improvements to calibration products being tested (ES, wings, spline, FoV bias)

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
- MetaCal: meta-calibration of KSB, heritage from DES
- 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

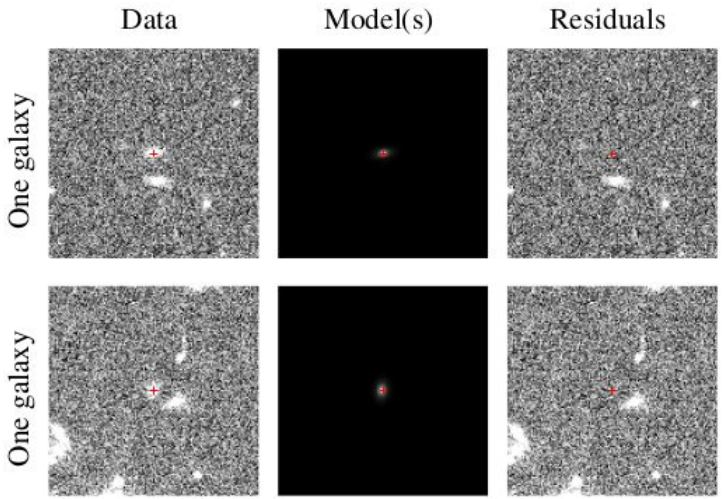
gitlab/LensMC

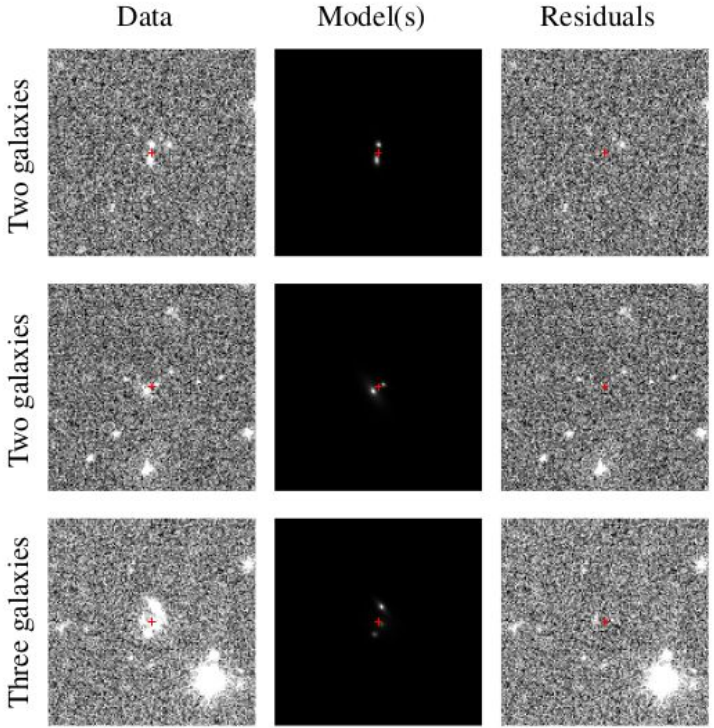
pip install lensmc

arXiv/2405.00669

A&A 691, A319 (2024)

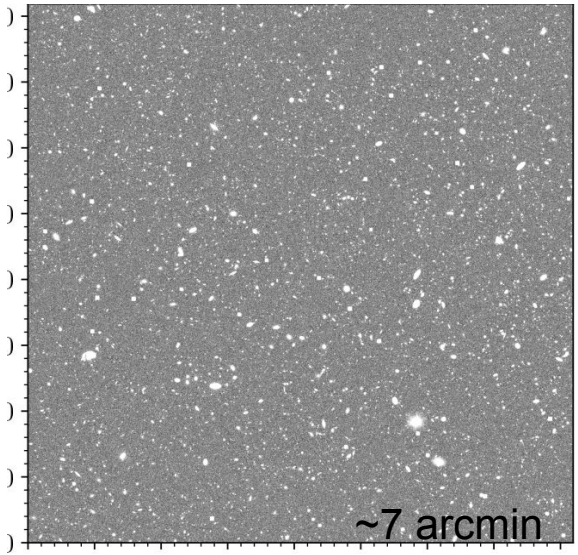
Forward modelling measurement

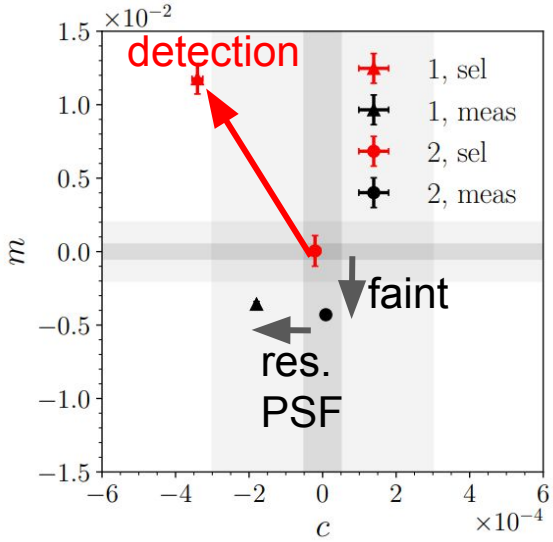




- Can measure one, two, three, … galaxies, jointly
- ***"Recognised blends" dominate shear bias in LSST/Rubin – subdominant in Euclid***

Raw shear bias





Simulations:

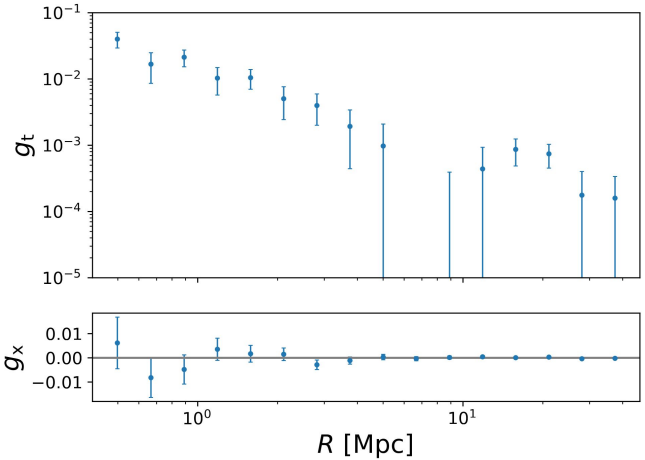
- 1 of 36 CCDs in the Euclid FoV
- 4,500 sq.deg of simulated Euclid sky
- based on Flagship 2

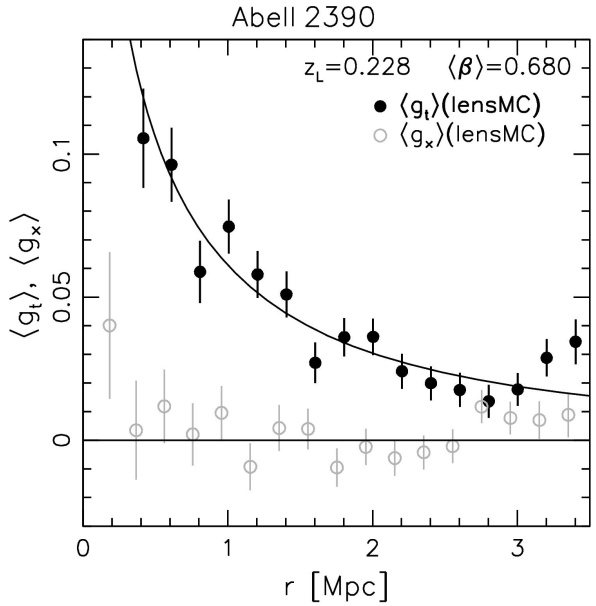
- Bias break-down: detection, faint, and residual PSF
- Low sensitivity on simulation parameters, can be calibrated

LensMC on real data

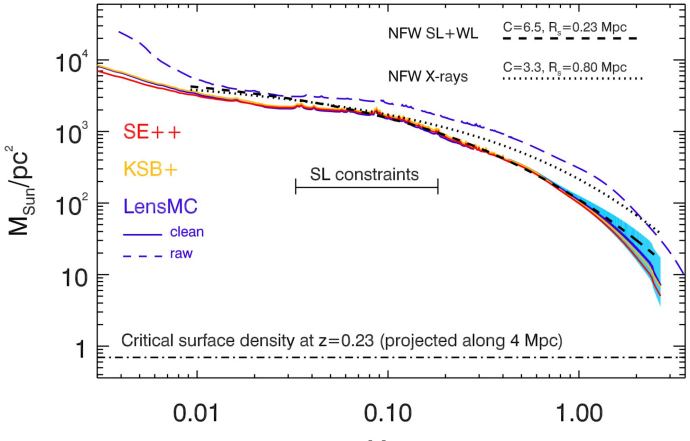
- In the SGS/SHE pipeline on PV, ESOP, RR1+2
- Outside of the SGS on ERO and Q1

Q1 science leads: Congedo, Miyatake, Sereno





Schrabback, Congedo+ 25



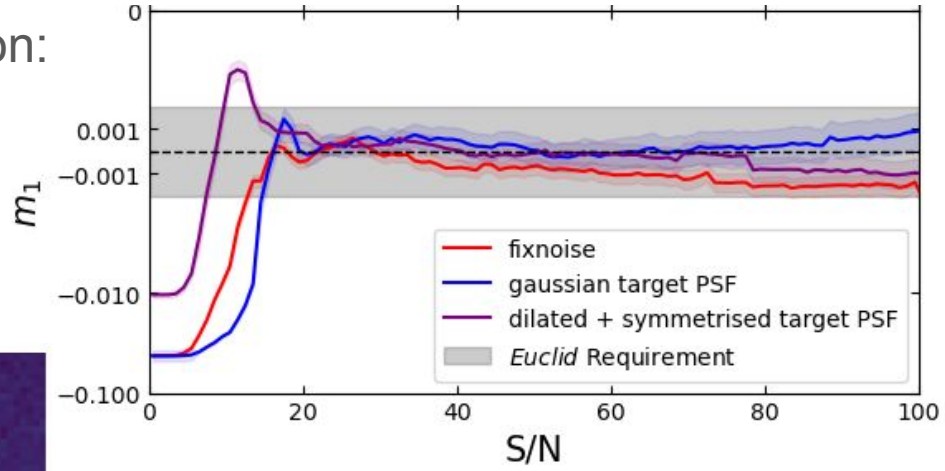
Diego, Congedo+ 25

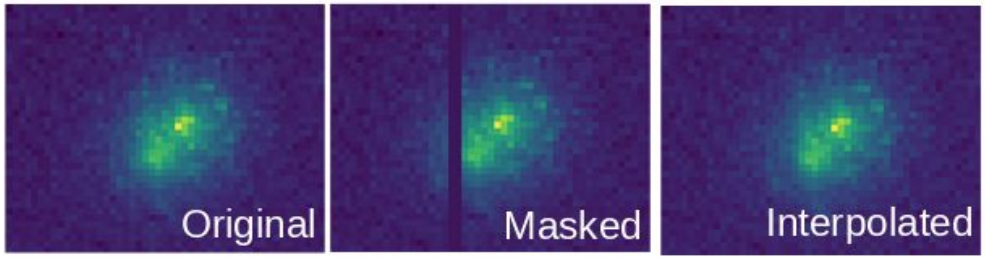
MetaCal validation [Andre Vitorelli]

- Shapes measured by 2nd moments
- Shear response: sensitivity of shear to changes in ellipticity (Huff & Mandelbaum 17, Sheldon & Huff 17)

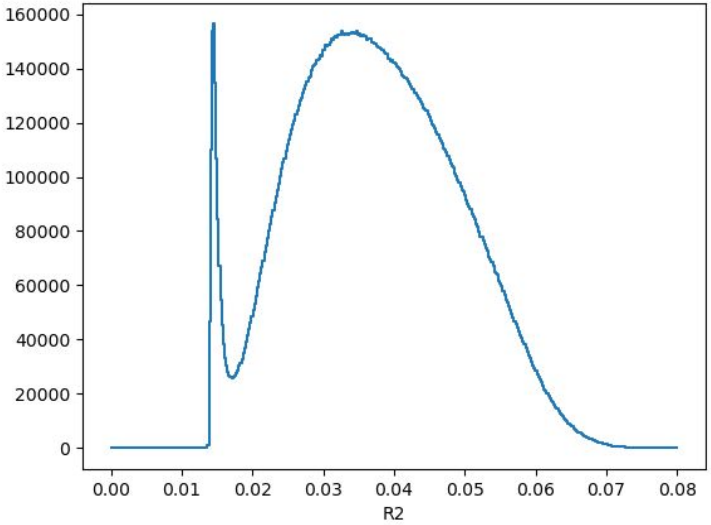
Simulations with shape noise cancellation:

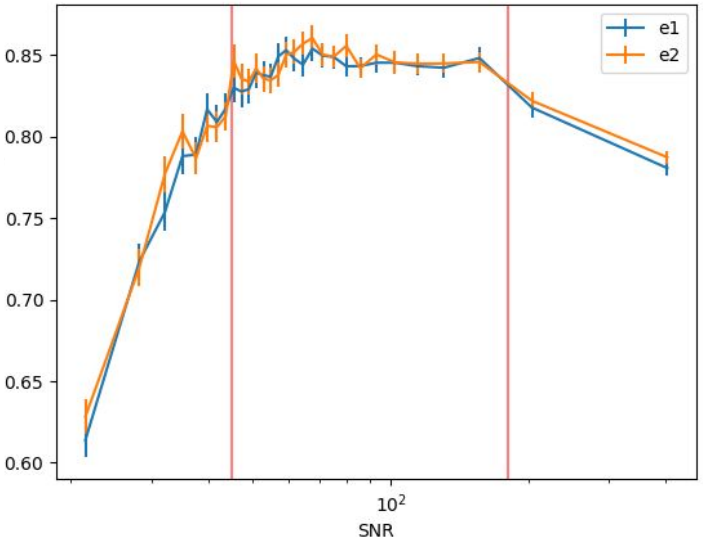
- Cut S/N>20 avoids noise bias
- Interpolation of masked pixels currently under testing





MetaCal on real data [Andre Vitorelli]



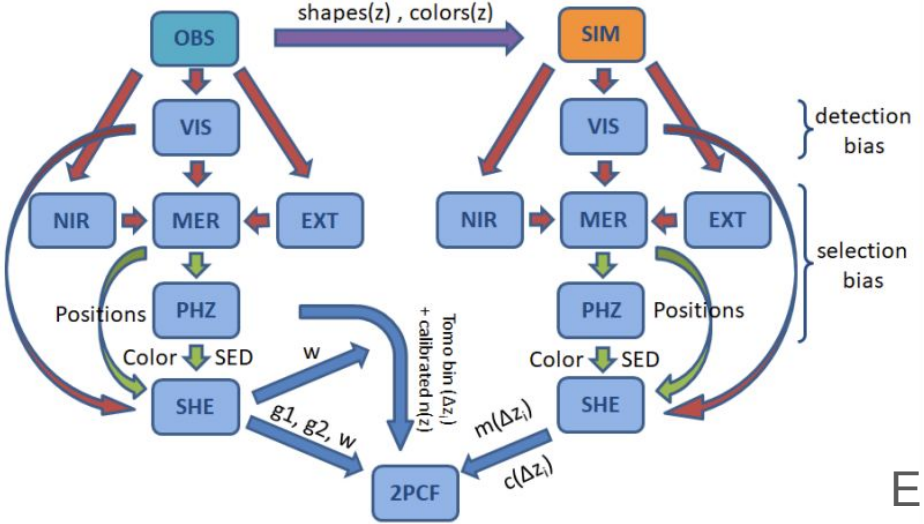


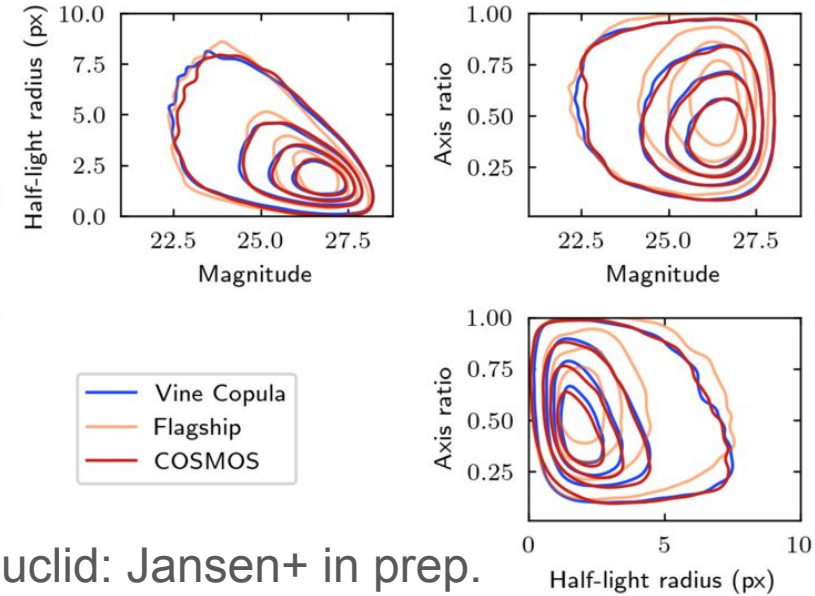
RR2 cuts (keeps 63.1% of RR2):

- R2 (size) cut, selecting objects with 0.017 < R2 < 100
- SNR cut, selecting objects only with 45 < SNR < 180 (updated to SNR>25, changes in SNR calc)

Shear calibration [Nicolas Martinet]

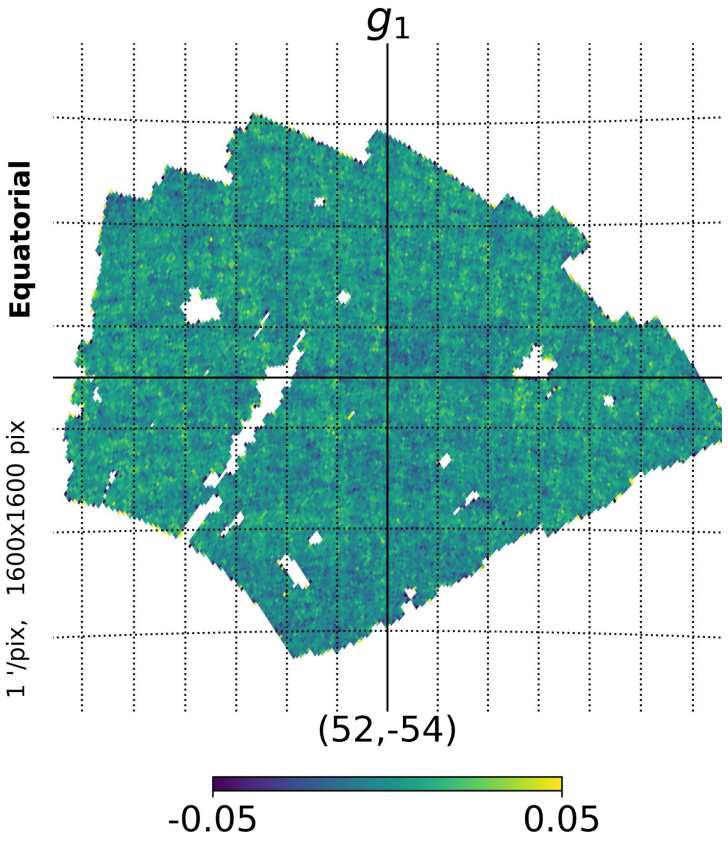
1. Match SIM galaxy properties (5 deg2 a few times, Henning Jansen)
2. Validate SIM survey properties (<50 deg2, Shun-Sheng Li)
3. Fixed shear calibration set (256 deg2)
4. Varying shear calibration set (64 deg2)

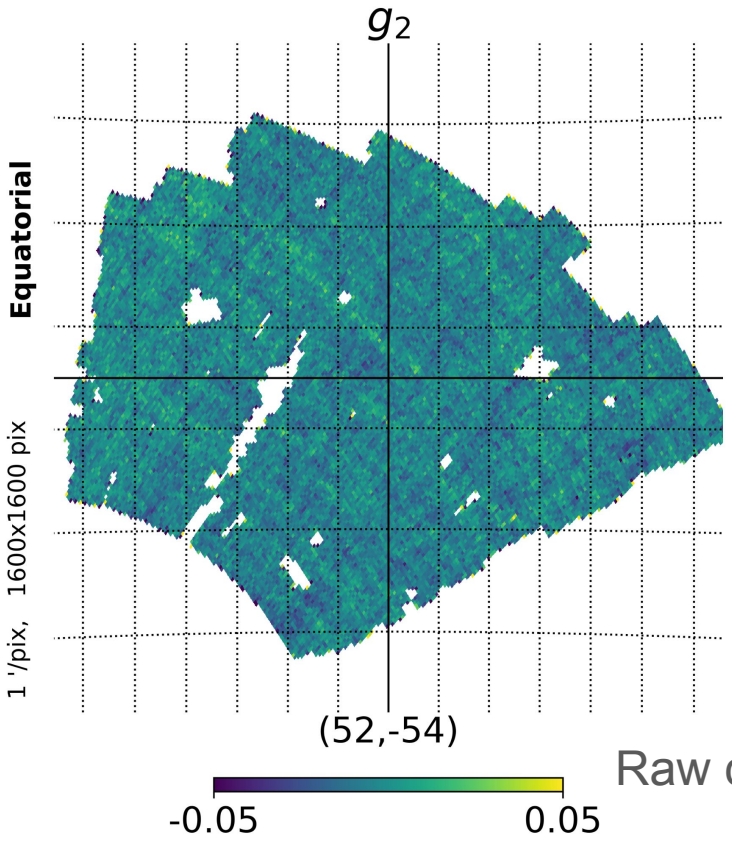




Euclid: Jansen+ in prep.

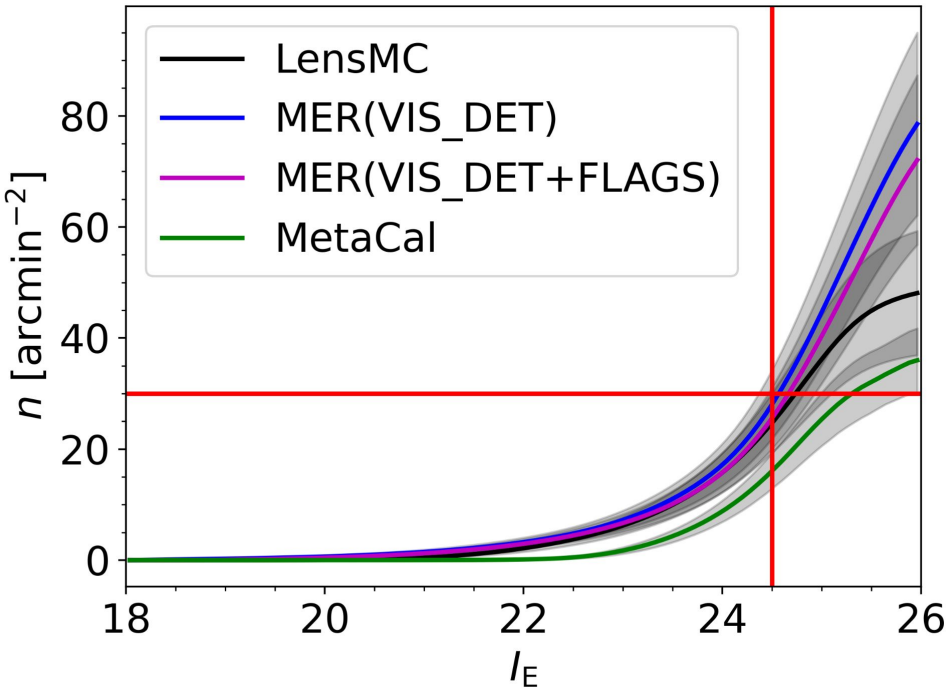
RR2 validation





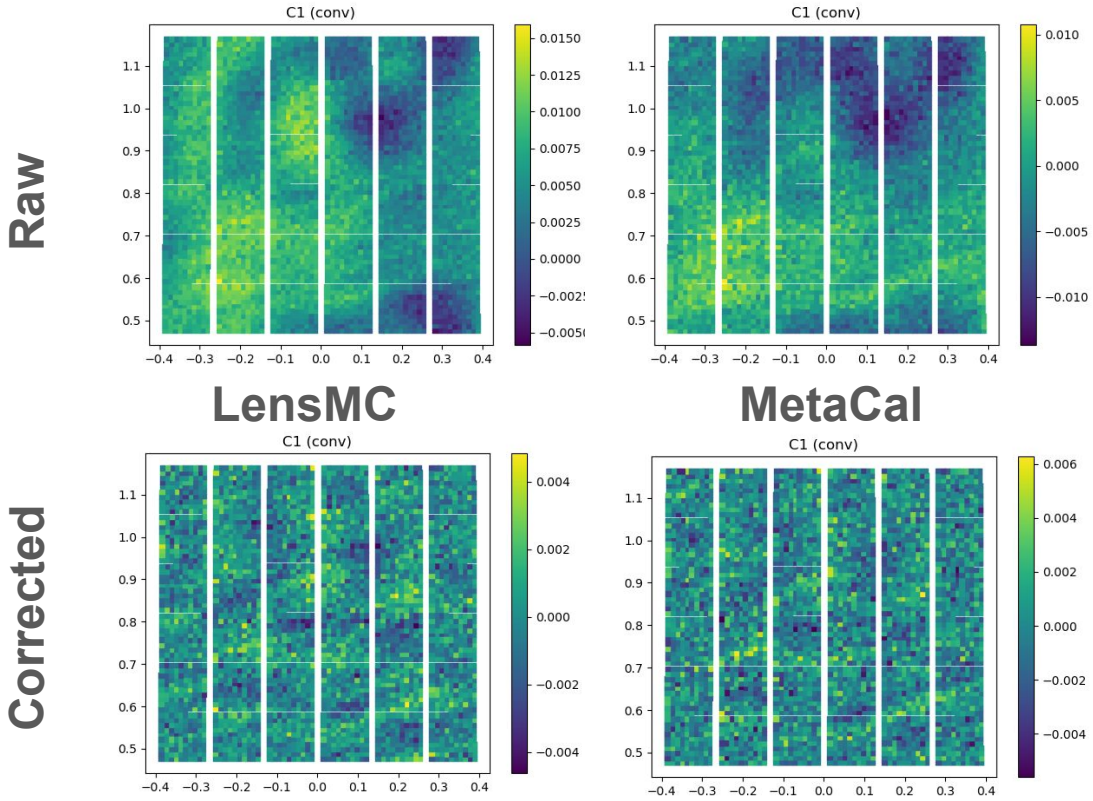
Raw catalogue

Number counts



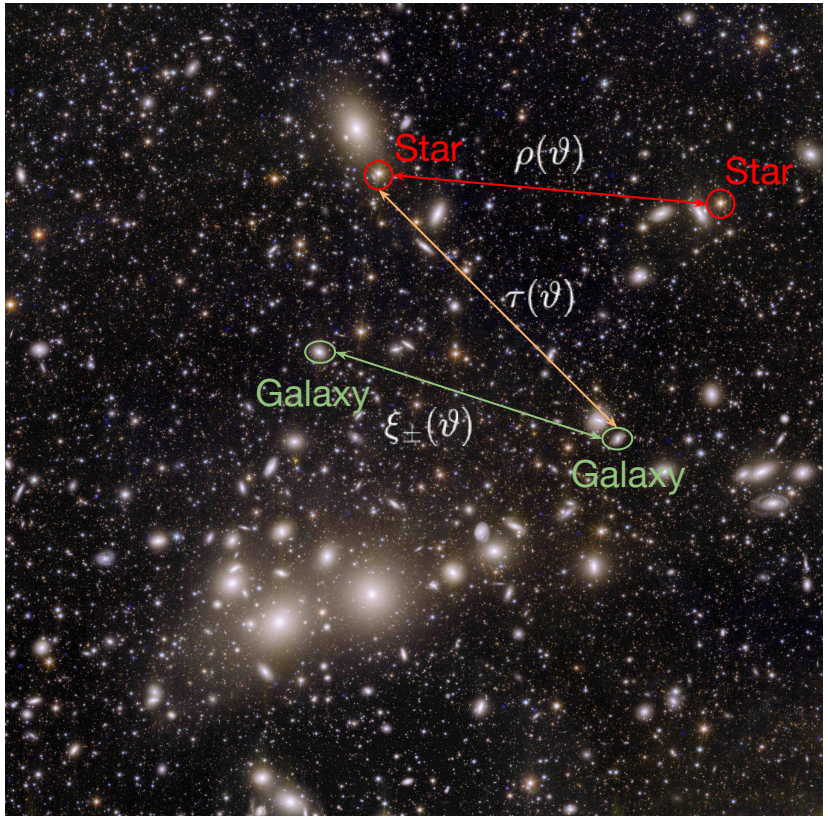
- Number count (IE<24.5):
  - MER: slightly lower than reqs
  - LensMC: similar
  - MetaCal significantly lower
- Discrepancy currently being investigated

FoV bias and calibration [Gordon Gibb]



- Dither-convolved c-bias on FoV plane
- c-bias correction in the SHE pipeline
- Corrected catalogue with <0.5% residual bias

Rho & tau statistics [Sacha Guerrini]

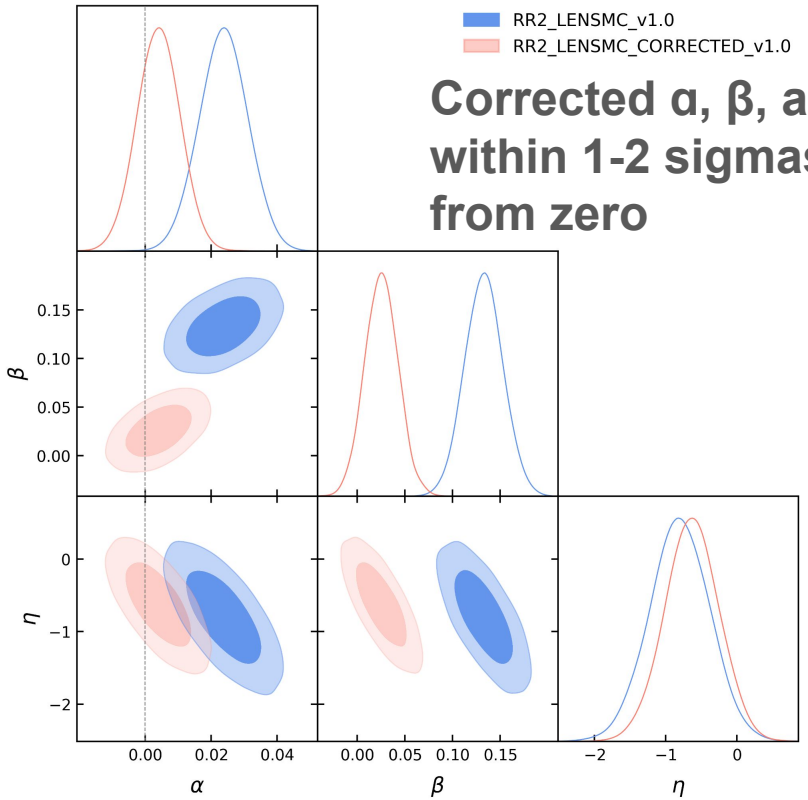


$$\delta\mathbf{e}^{\mathrm{sys}}_{\mathrm{model}} = \alpha \underbrace{\mathbf{e}_{\mathrm{model}}}_{\text{Leakage}} + \beta \underbrace{(\mathbf{e}_* - \mathbf{e}_{\mathrm{model}})}_{\text{Ellipticity error}} + \eta \underbrace{\left(\mathbf{e}_* \frac{T_* - T_{\mathrm{model}}}{T_*}\right)}_{\text{Size error}}$$

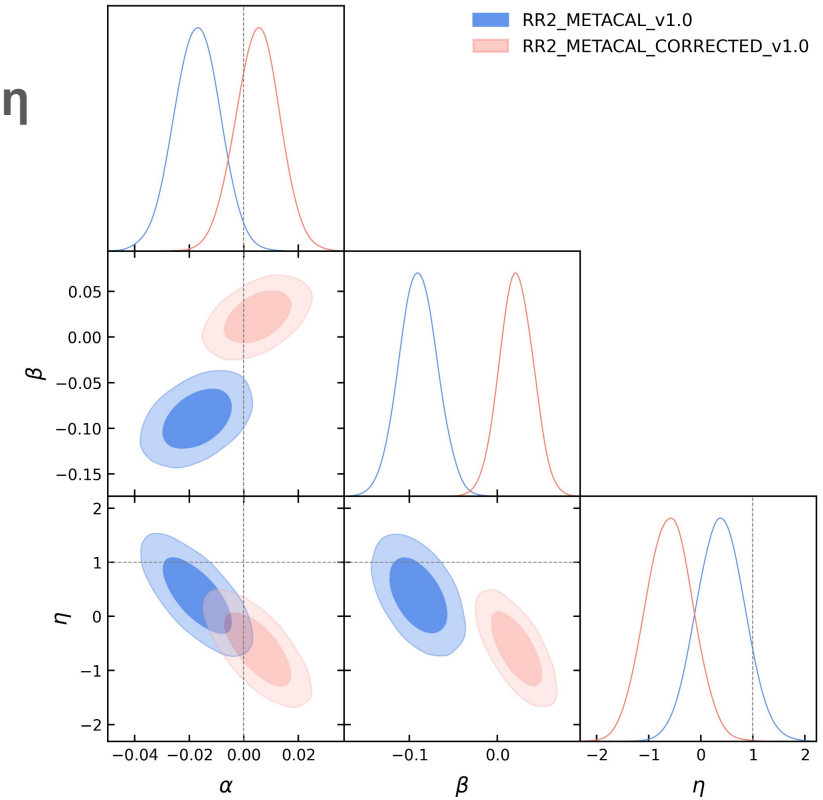
$$\begin{pmatrix} \tau_{0,1} \\ \tau_{2,1} \\ \tau_{5,1} \\ \vdots \\ \tau_{0,n} \\ \tau_{2,n} \\ \tau_{5,n} \end{pmatrix} = \begin{pmatrix} \rho_{0,1} & \rho_{2,1} & \rho_{5,1} \\ \rho_{2,1} & \rho_{1,1} & \rho_{4,1} \\ \rho_{5,1} & \rho_{4,1} & \rho_{3,1} \\ & \ddots & \\ \rho_{0,n} & \rho_{2,n} & \rho_{5,n} \\ \rho_{2,n} & \rho_{1,n} & \rho_{4,n} \\ \rho_{5,n} & \rho_{4,n} & \rho_{3,n} \end{pmatrix} \begin{pmatrix} \alpha \\ \beta \\ \eta \end{pmatrix},$$

$$\xi^{\mathrm{PSF}}_{\mathrm{sys}} = \alpha^2\rho_0 + \beta^2\rho_1 + \eta^2\rho_3 + 2\alpha\beta\rho_2 + 2\alpha\eta\rho_5 + 2\beta\eta\rho_4$$

Rho & tau statistics [Sacha Guerrini]

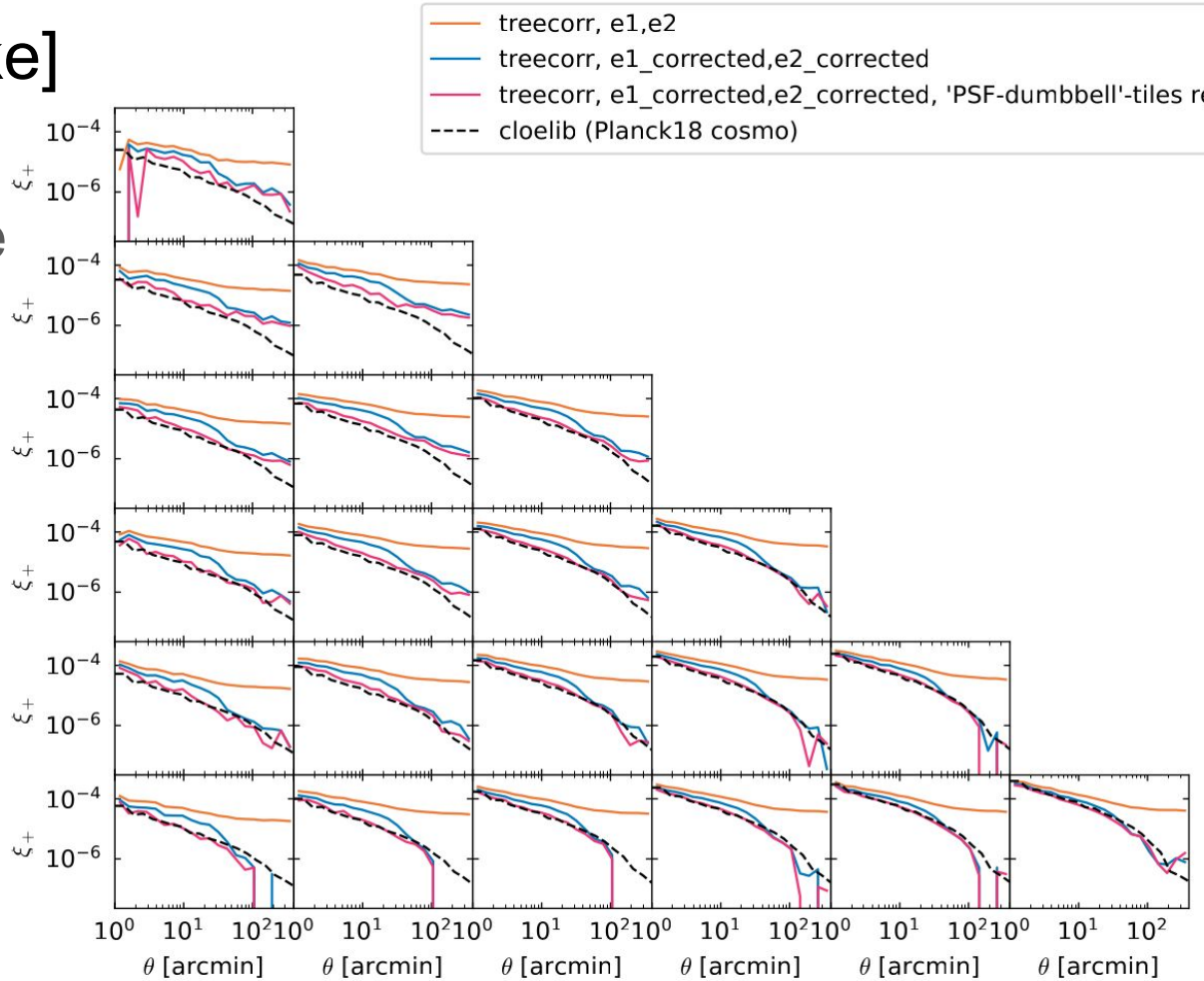


Corrected α, β, and η within 1-2 sigmas from zero



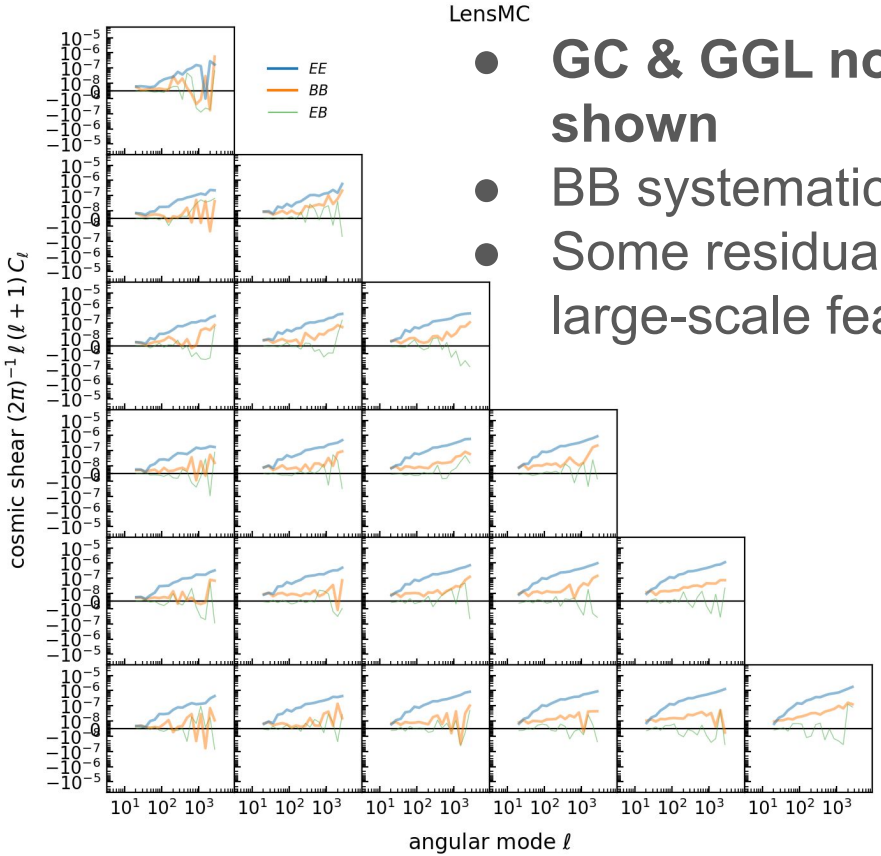
2PCFs [Laila Linke]

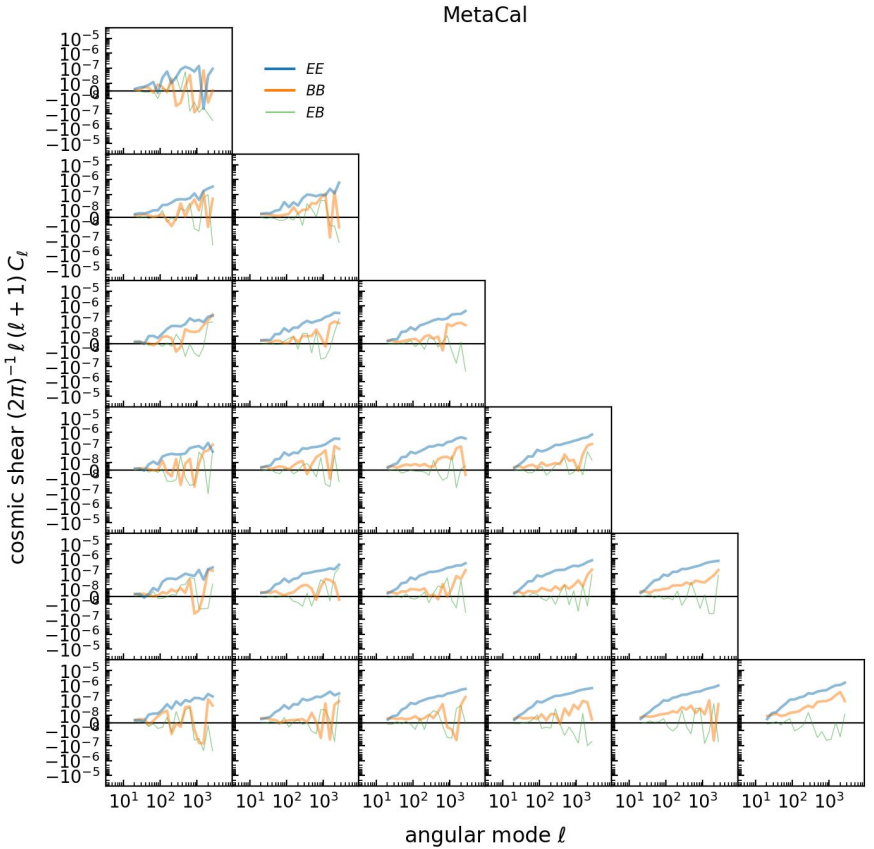
Corrected catalogue (after removal of bad tiles) closely matching a nominal Planck cosmology



LE3 analysis of RR2 [Nicolas Tessore]

- **GC & GGL not shown**
- BB systematic gone
- Some residual large-scale feature





DR1 processing - update, plans, and issues

Timeline:

1. SHE PSF release by July (+ rerun of 100 sq.deg. of RR2)
2. VIS almost completed; VIS+PHZ by end of July; ‘Legacy’ VIS iDR1 in Sept
3. SHE+LE3 from Sept to Nov; iDR1 in Dec

Issues:

1. PSF:
    a. consistently improved and close to requirements
    b. size slightly underestimated
2. Missing u-band in the N; marginal impact on lensing (low-redshift z-bin)
3. Slightly lower number counts
4. Shear calibration slipped by a few weeks, but should be in time for iDR1

Summary

1. SHE+LE3 pipelines up and running
   a. PSF calibration & modelling
   b. Shape measurement (LensMC & MetaCal)
   c. 2PCFs and PCLs
2. Issues/delays being dealt with & with minimal impact
3. SHE+LE3 iDR1 on schedule to be delivered in Dec