Highlights from the SLWG

Massimo Meneghetti

INAF-OAS

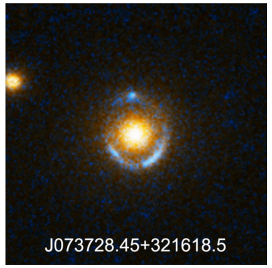
With contributions from:

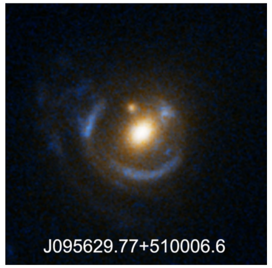
G. Angora (UniFe), P. Bergamini (UniMI), G. Covone (UniNA), F. Gentile (UniNA/UniBo), B. Metcalf (UniBo), P. Rosati (UniFe), C. Tortora (INAF-OAC)

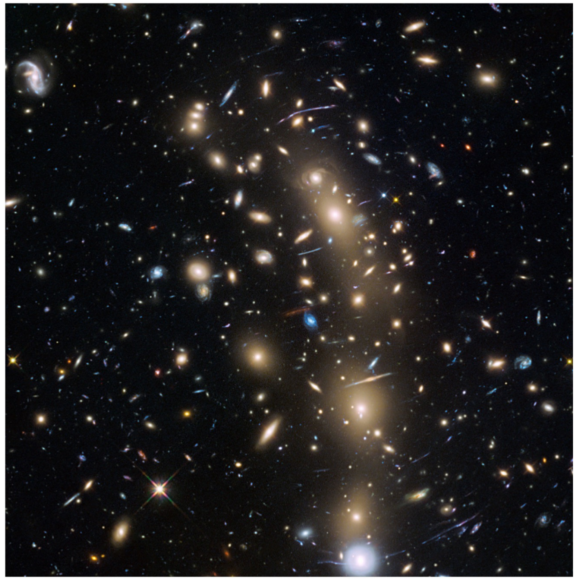
Key projects coordinated by the SLWG

- **KP-SL-1: Galaxy-scale Strong Lenses** (*GAEV-SWG, OU-SHE*)
  - Realistic image simulations of strong lensing galaxies
  - Algorithms for finding strong lensing galaxies
  - Lens modeling techniques
  - Information content on the galaxy evolution model

- **KP-SL-2: Cluster-scale Strong Lenses** (*WL-SWG, CL-SWG, GAEV-SWG, OU-SHE*)
  - Realistic image simulations of strong lensing clusters and groups
  - Algorithms to find strong lensing features in galaxy clusters and groups
  - Lens modeling techniques
  - Strong lensing by cluster substructures

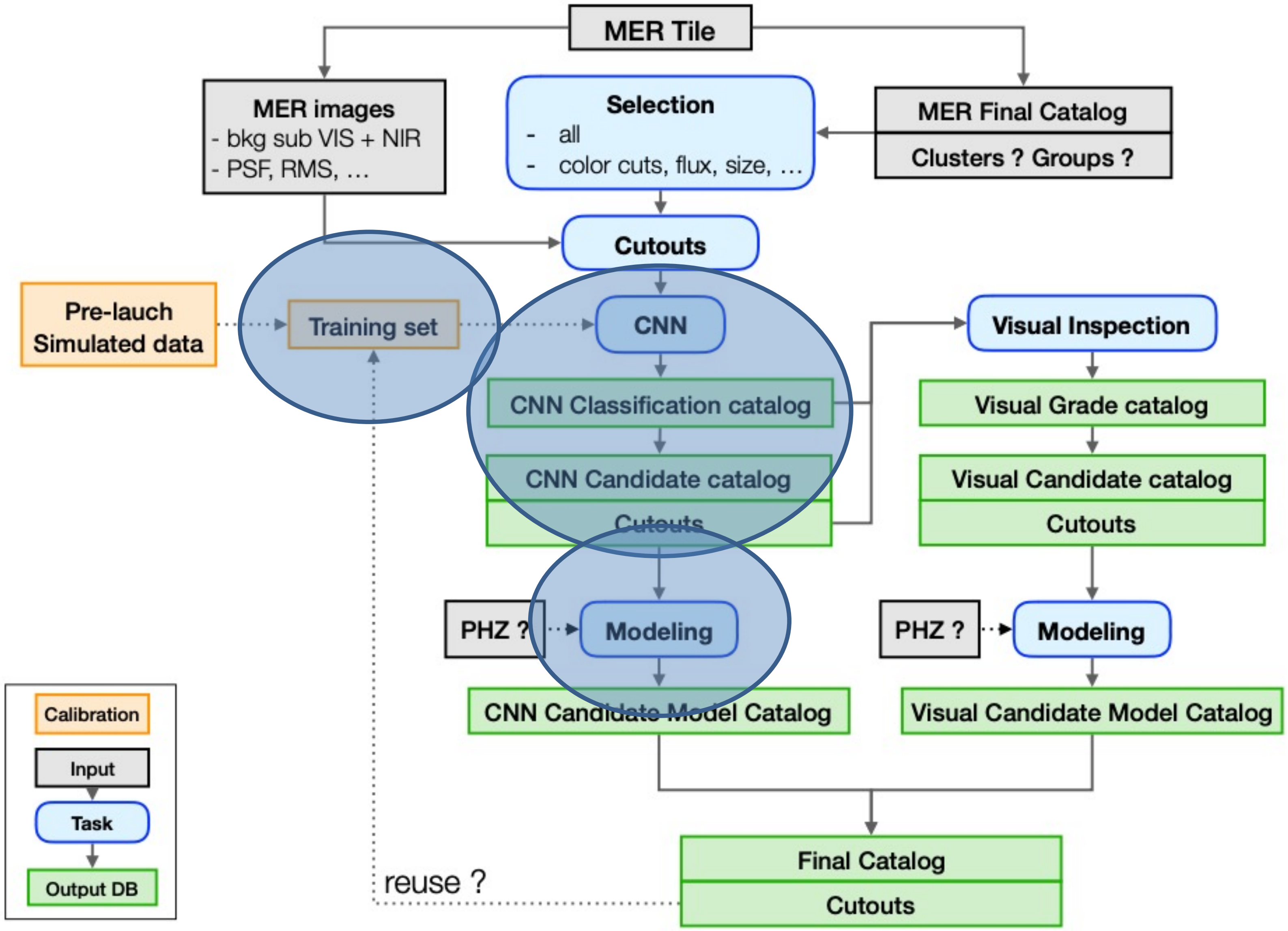






SL finding and modeling pipeline

OU-SHE (B. Clément, F. Courbin, H. Gaudenzi+) + SDC-CH + SLWG



Galaxy-Galaxy Strong Lensing in SC8

R.B. Metcalf (UniBO), B. Clément, E. Jullo + OU-SIM

Simulation pipeline has been established for producing realistic mock lenses.

flagship simulation

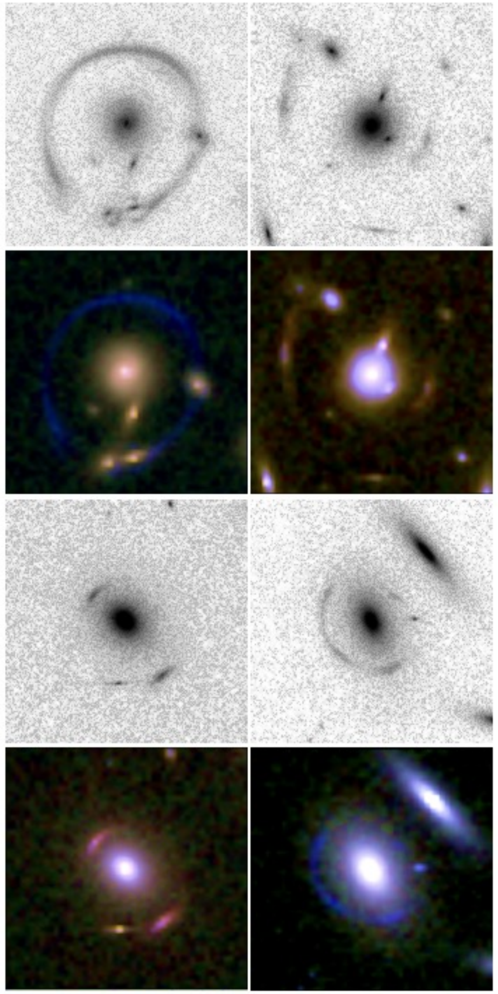
Add analytic model for baryonic & dark matter components of all galaxies

Add realistic source at higher redshift

ray-shooting through entire light cone of simulation

image of lensed source with colors and consistent with foreground objects

images are sent to OU-SIM were they are processed through the image simulation pipeline

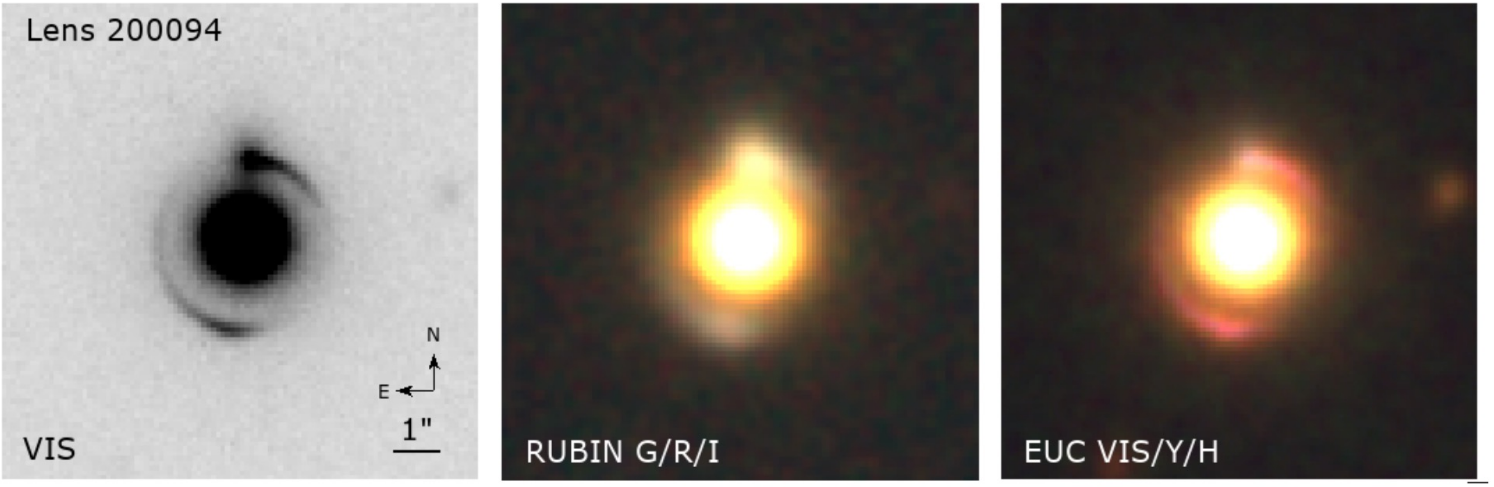


285 lenses in 216 MER Tiles of SC8 Main

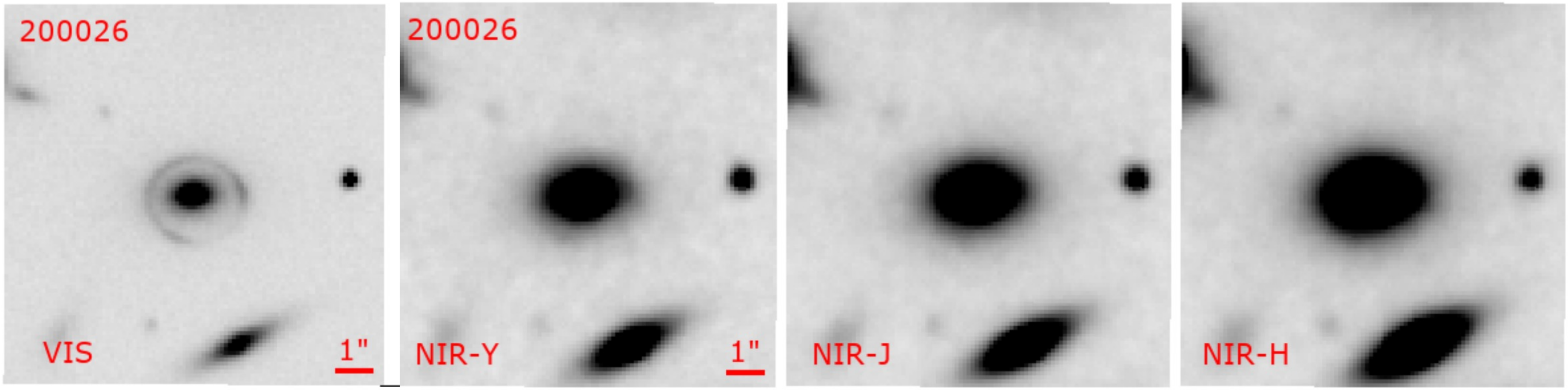
6 in SC8 Deep

Natural density of strong lenses on the sky limits the number of lenses to numbers which are too small for application such as training lens finding algorithms and lens fitting. We are currently developing a pipeline that will increase the numbers of lenses by two orders of magnitude for these purposes.

SC8 WIDE



SC8 DEEP

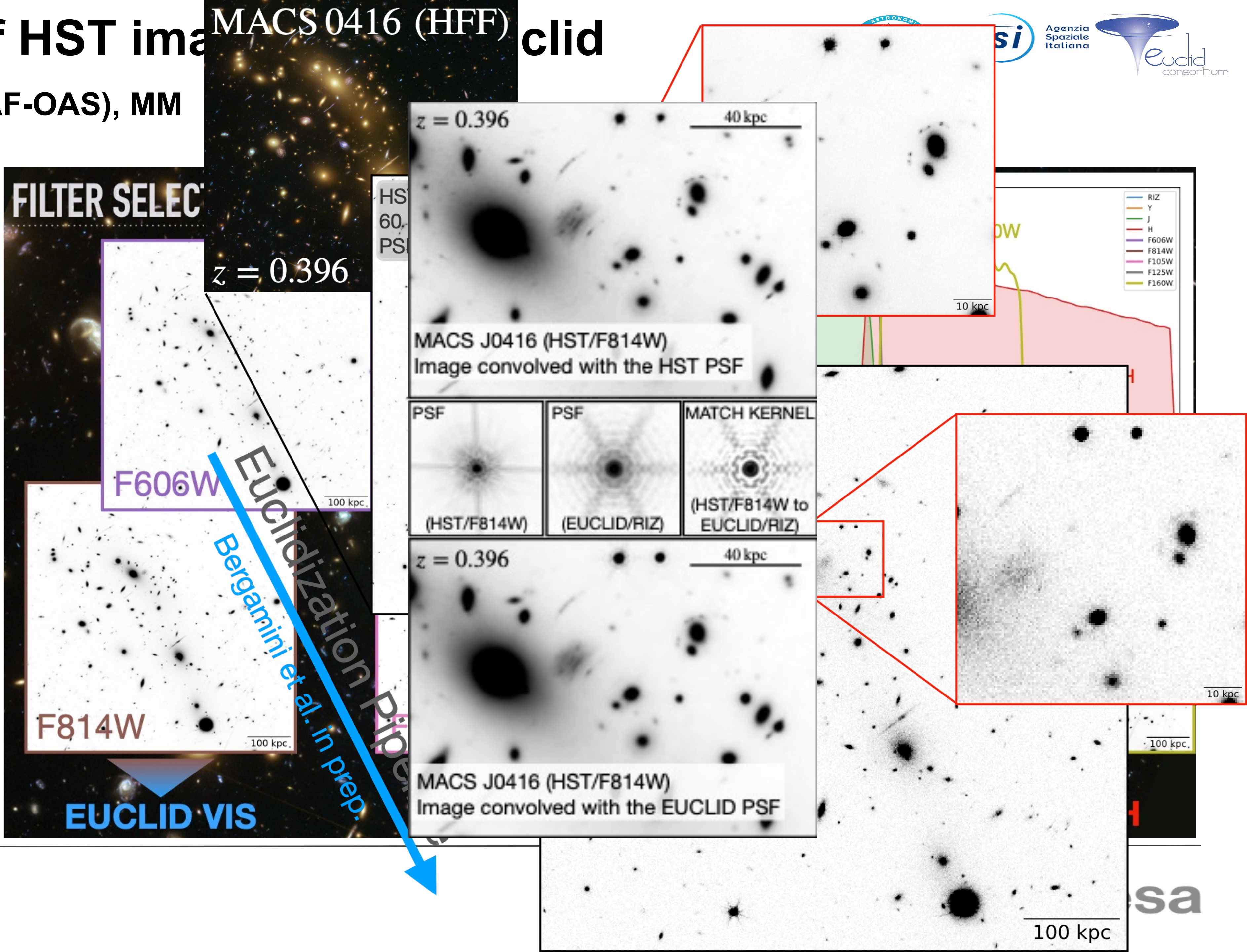


Euclidization of HST ima... clid

P. Bergamini (UniMI/INAF-OAS), MM

A tool for “Euclidizing” existing HST observations:

1. select deep HST observations that best match the Euclid bands
2. Use a kernel to transform the HST PSF into the Euclid PSF
3. Combine HST observations and project on the Euclid headers
4. Rescale fluxes and add noise to reproduce the expected S/N

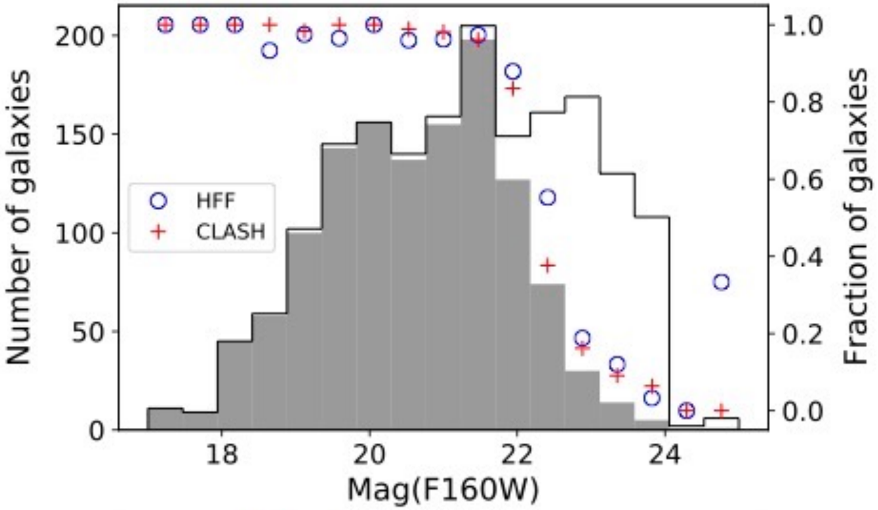


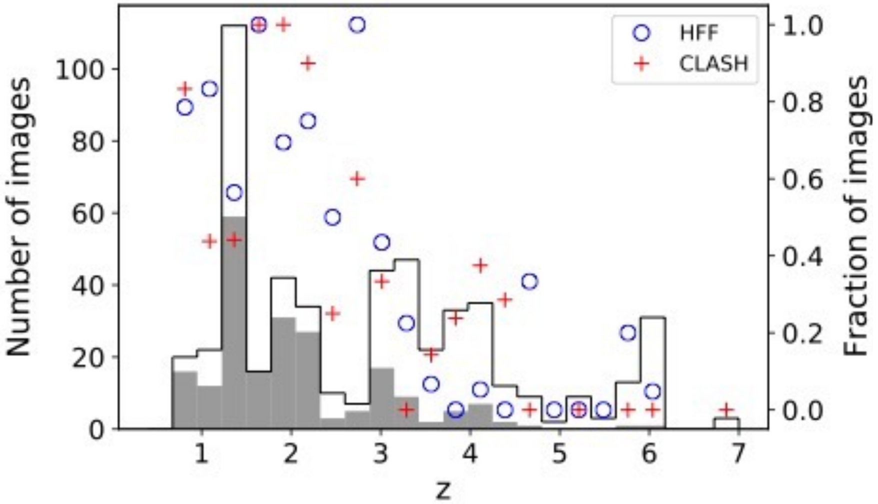
Euclidization of HST images: HST2Euclid

P. Bergamini (UniMI/INAF-OAS), MM + Zooming Project (UniFE, OAS, OAC, OATS, UniBO, UniMI)

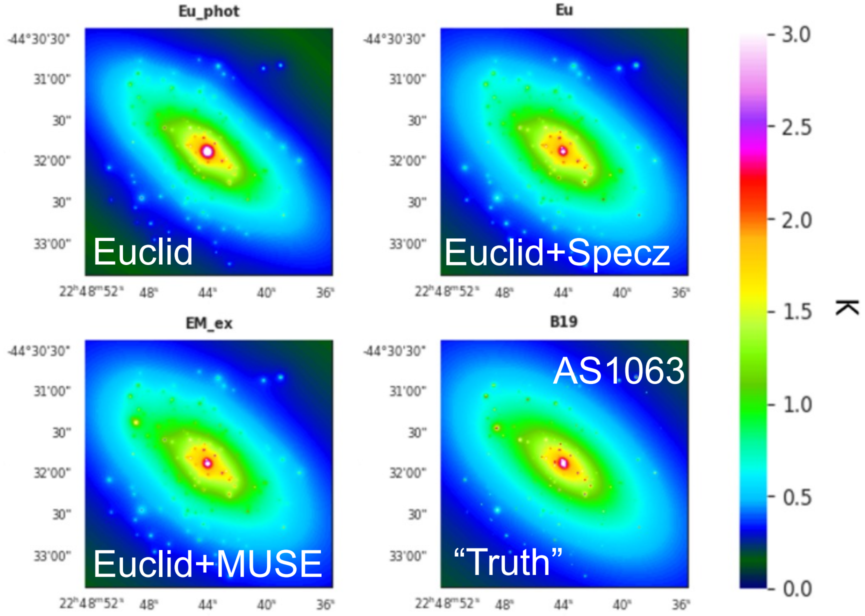
Multiple possible usages:

1. We used it to create a database of Euclidized images of strong lensing clusters (CLASH and HFF)
2. We used the images to forecast the number of strong lensing constraints/cluster that will be available in the wide and deep surveys
3. Test mass modeling with Euclid (+other instruments)
4. Flexible tool to be shared with whoever is interested in the consortium: for example, LU-SWG (**see talk by Leslie Hunt**)



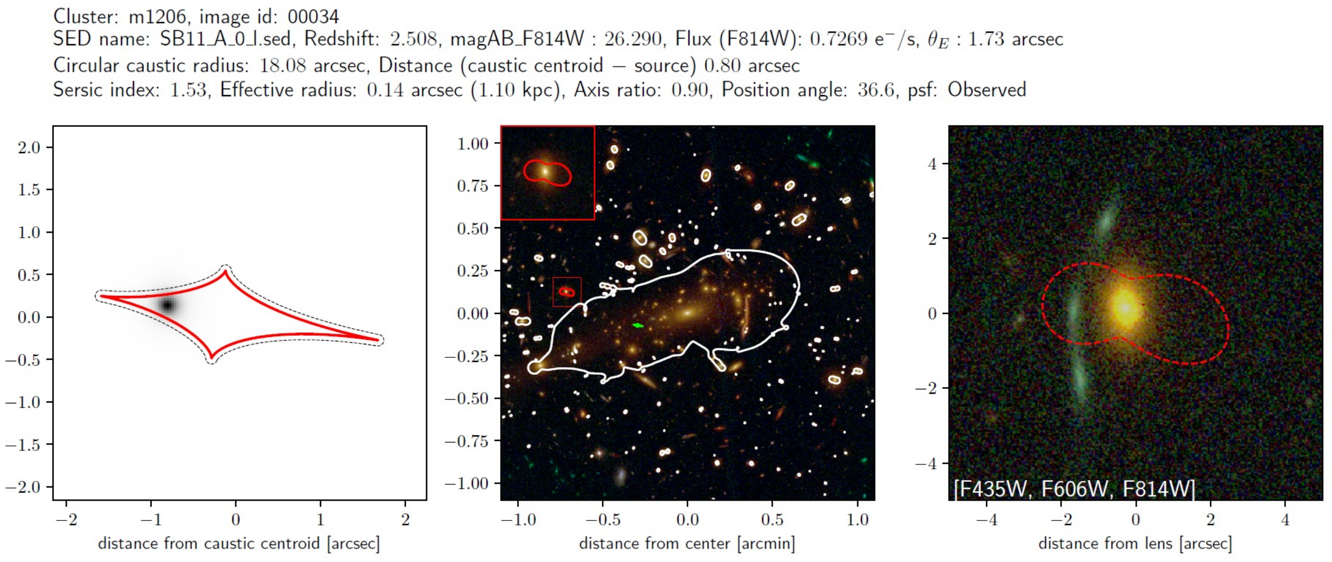


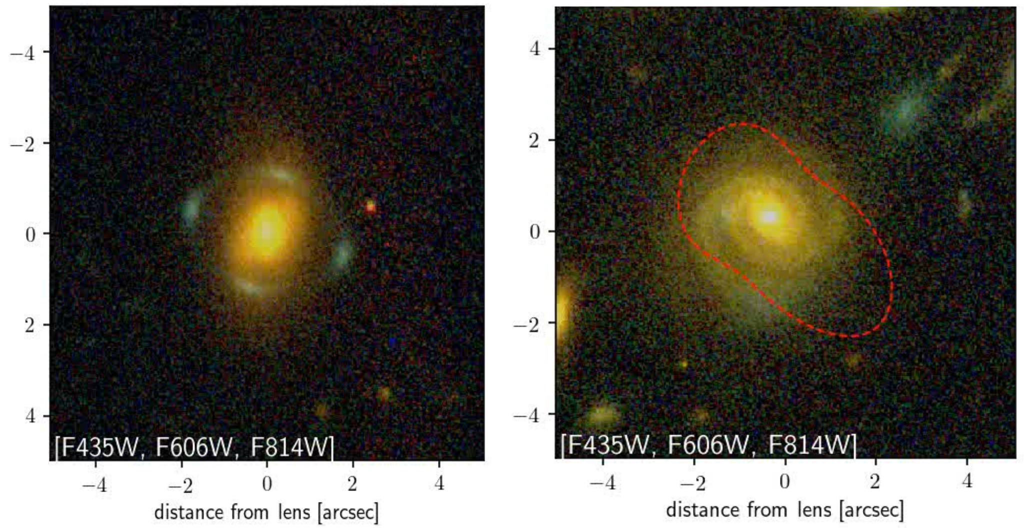
These clusters have extended **spectroscopic complement** and **accurate lens models** (Zooming Project, CLASH-VLT, P.I. Rosati + several MUSE follow-up programs)



GGSL in galaxy clusters

G. Angora (UniFE), P. Rosati (UniFE), A. Mercurio (OAC), M. Brescia (OAC), MM

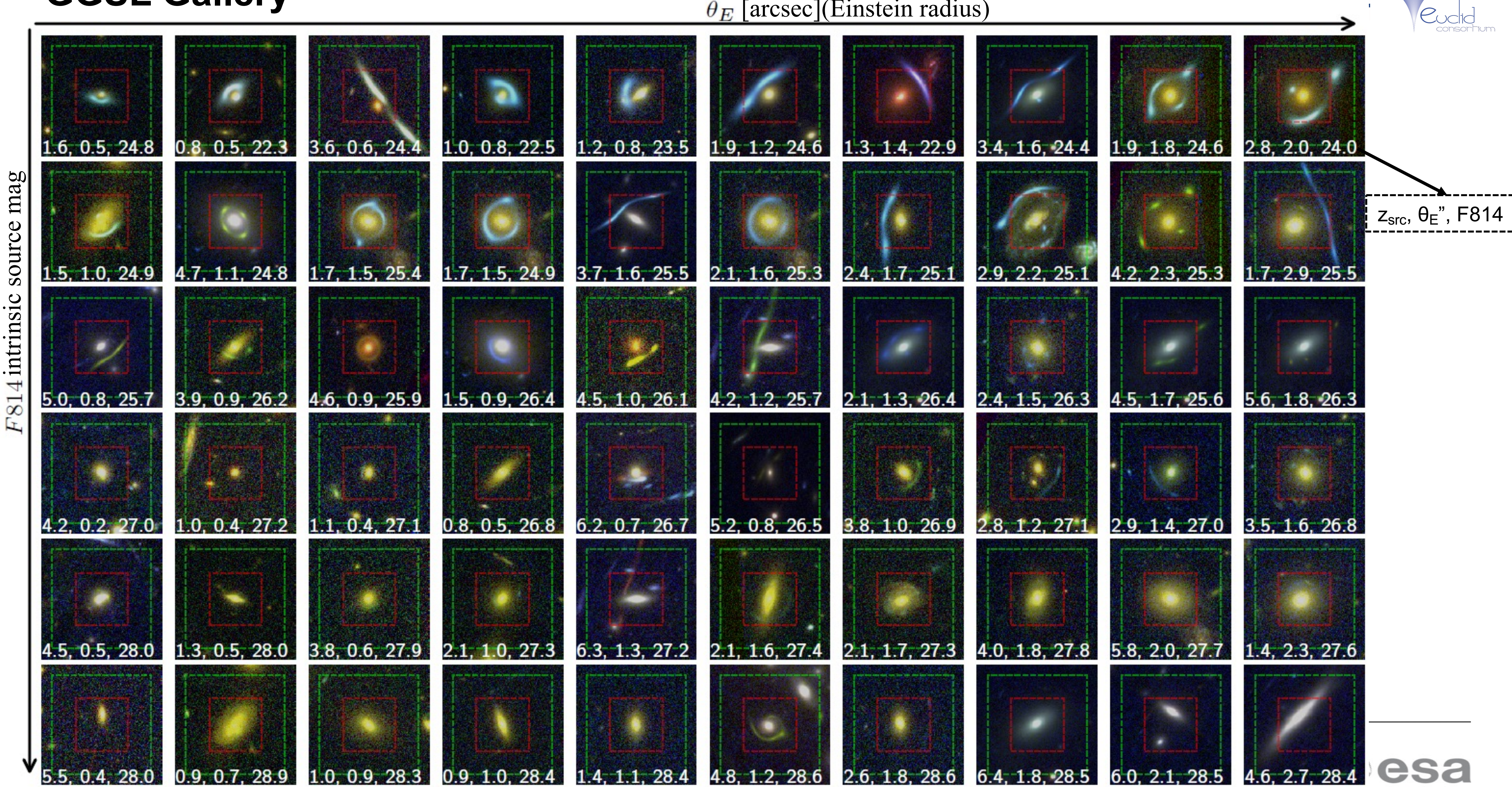




<u>Injected galaxies parameters</u>:

- source plane position → Random extraction within a buffer surrounding the caustic (width of $0.5r_e$)
- z_{source}, magnitude(e.g. F814) → Sample n(m,z) distributions from COSMOS 2015/Deep HST fields
- effective radius → $r_e(z \le 1) = 2.5kpc, r_e(z > 1) = B(1+z)^{\beta}$ [Shibuya +2015]
- Sérsic index → Extracted from uniform distribution (1.0, 2.0)
- Axis ratio → Extracted from uniform distribution (0.2, 1.0)
- Position angle → Extracted from uniform distribution (0.0, π)

GGSL Gallery



Networks performances overview

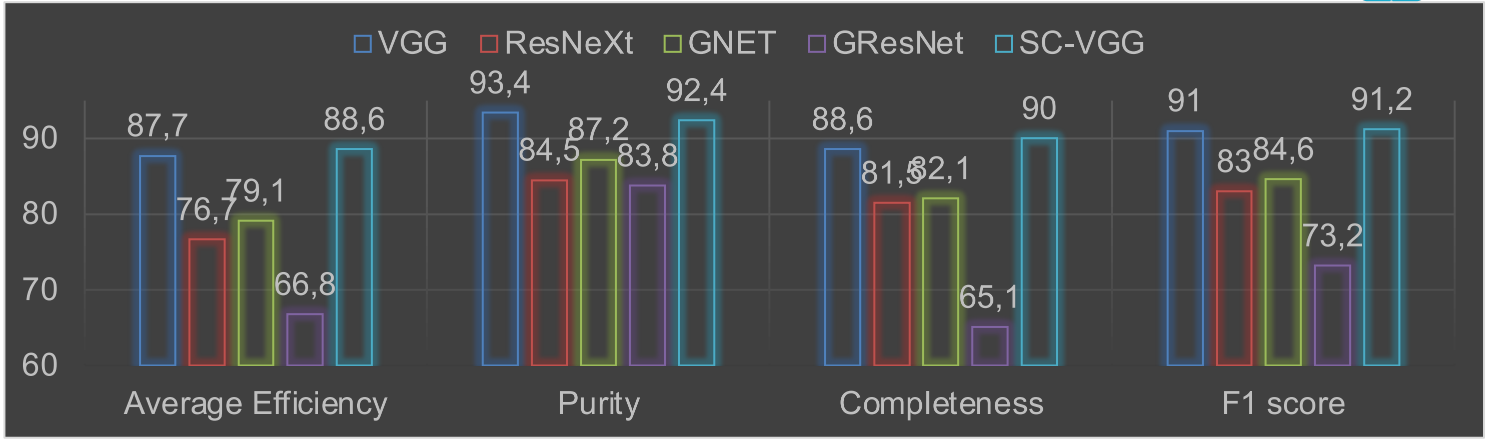
Performance metrics:

$$AE = \frac{TP + TN}{TP + TN + FP + FN}$$

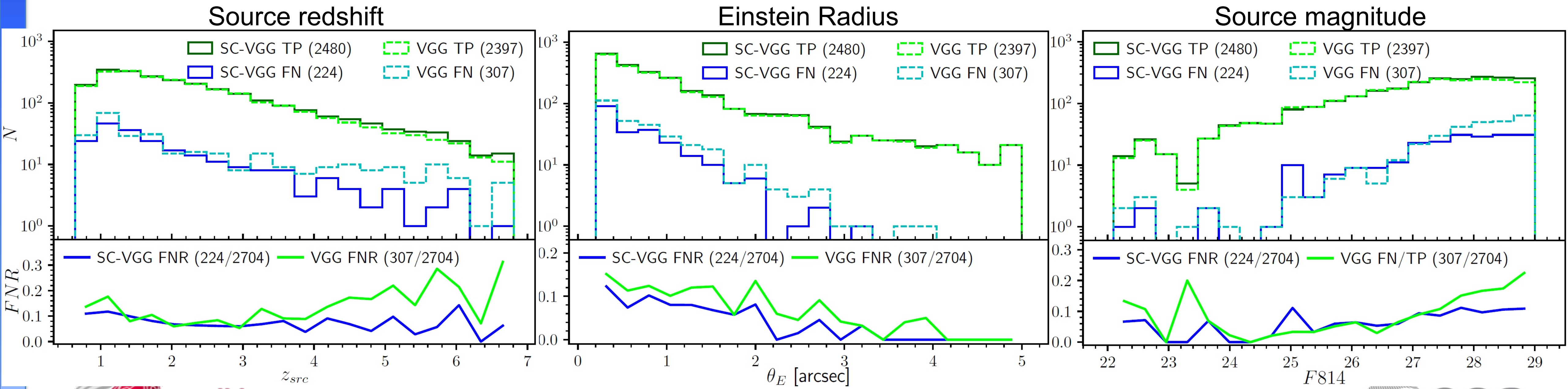
$$Pur(ity) = \frac{TP}{TP+FP} = \frac{TP}{P}$$

$$Compl(eteness) = \frac{TP}{TP+FN}$$

$$F1(score) = 2 \cdot \frac{pur \cdot compl}{pur + compl}$$



False Negative distributions:



euclid

esa

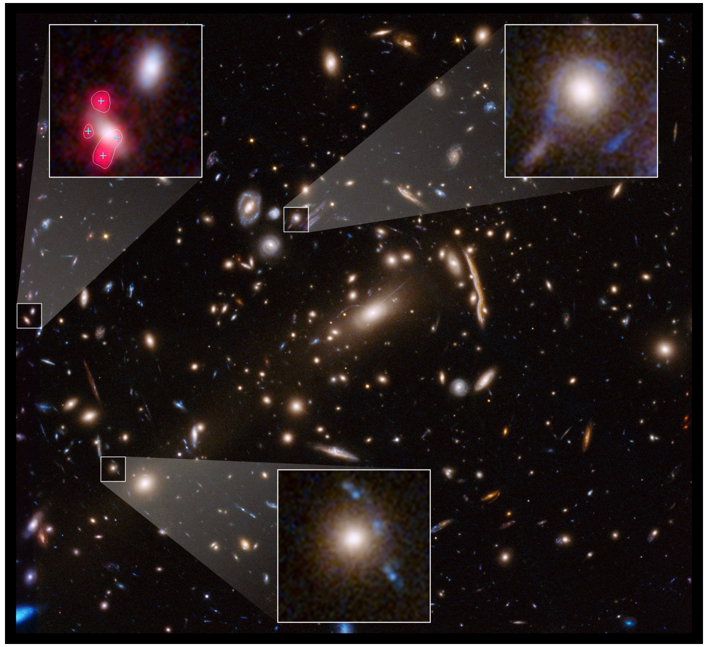
Probing DM and gal. form. with GGSL in galaxy clusters

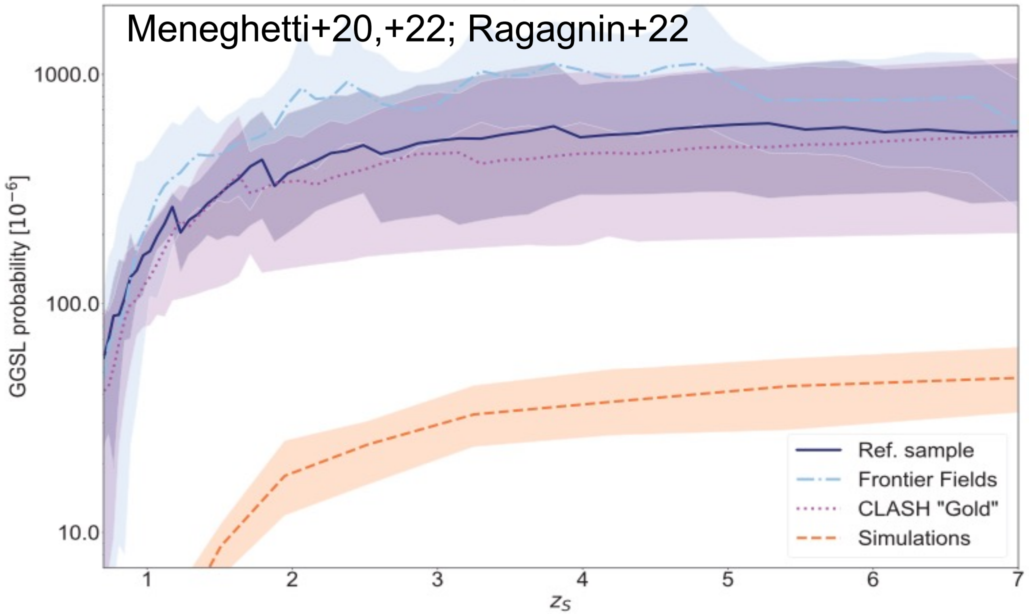
MM, G. Angora (UniFE), P. Bergamini (UniMI), S. Borgani (OATS), F. Calura (INAF-OAS), C. Giocoli (OAS), C. Grillo (UniMI), A. Mercurio (OAC), B. Metcalf (UniBO), L. Moscardini (UniBO), M. Nonino (OATS), A. Ragagnin (UniBO), E. Rasia (OATS), P. Rosati (UniFE)

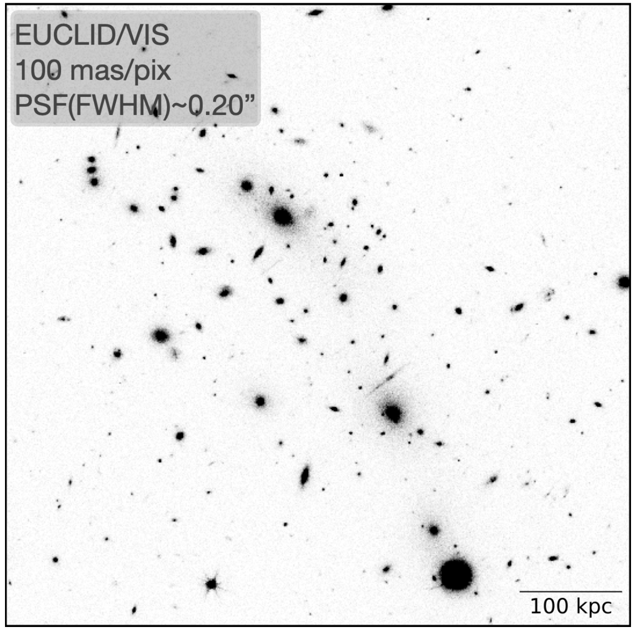
Motivation:

- Probe the small scale structure of galaxy clusters cores. Probe galaxy formation (KP-SL2, paper 4)
- Recently, we have dectected **an excess of GGSL in galaxy clusters** compared to expectations in the LCDM model.

Angora+22: a catalog of GGSL events in the CLASH, HFF and RELICS data. Next step: working with euclidized images.







Modeling galaxy lenses

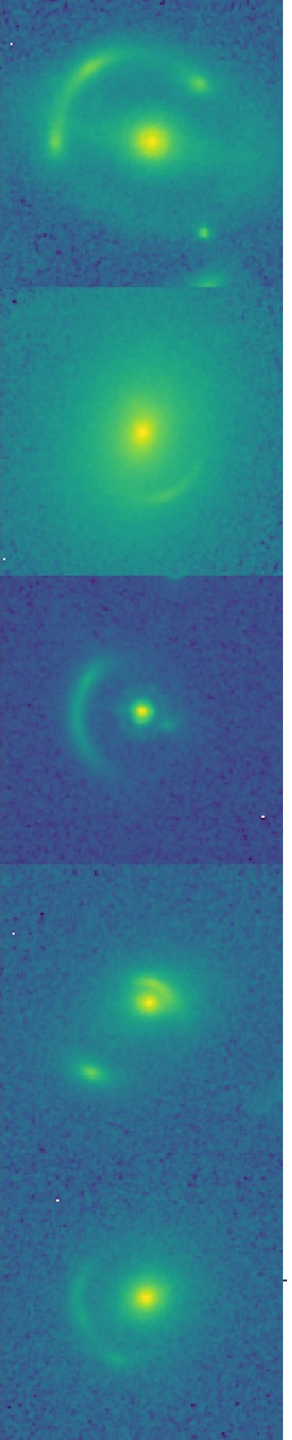
Modeling Euclid lenses will be very challenging:

- Input: images, perhaps photo-zs
- Mass model of the lens galaxy (mass, small-scale structure, Einstein radius, ellipticity, external shear, …)
- Light model of the lens galaxy (magnitude, Sérsic model,…)
- Source light (magnitude, morphology, small scale structure,…)
- 100000+ lenses

So far: no single study has modeled 100 lenses…

Approach:

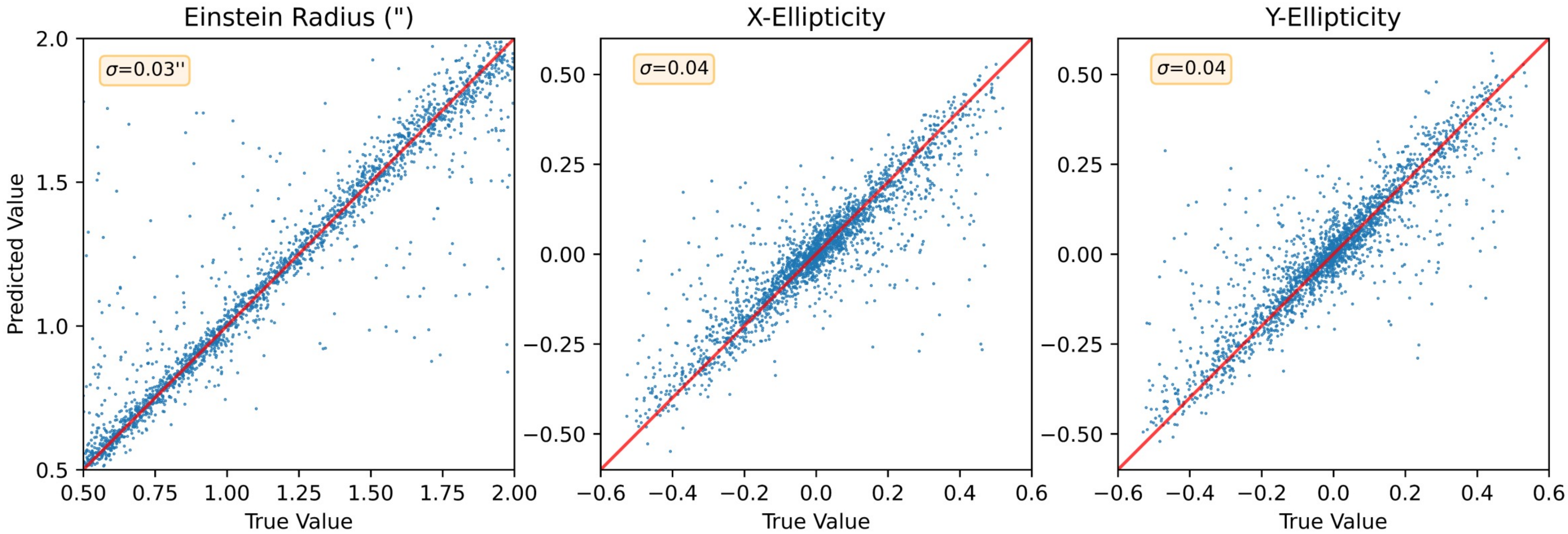
- A quick modeling of the lenses to extract basic lens parameters should run automatically in the pipeline
- Use multiple codes, following different approaches (parametric lens inversion, free-form modeling, deep-learning)



LeMoN: Lens Modelling with Neural Networks

F. Gentile (UniNA), C. Tortora (INAF-OAC), G. Covone (UniNA)

- Fast Automated Analysis of strong gravitational lenses performed with Bayesian Neural Networks (BNNs)
- Estimate of lens galaxy parameters (e.g. Einstein radius and ellipticity) with reliable uncertainties
- Accurate modelling of 10^4 gravitational lenses in a few minutes ($\sim 1h$/lens required with “traditional” algorithms)



Other ongoing/future work

- Creating a large database of weak and strong lensing simulations (**M. Meneghetti**, C. Giocoli, S. Borgani, E. Rasia + The 300 project + CLSWG)
- Searching for strong lensing galaxies with CNNs (**F. Gentile,** C. Tortora, G. Covone)
- Development of Faster R-CNN model to find SL features in clusters (**G. Angora**, P. Rosati)
- Comparison of CNN architectures to classify strong lenses (**L. Leuzzi**, G. Angora, L. Moscardini, R. B. Metcalf, P. Rosati)
- Improve accuracy of SL modeling combining imaging and spectroscopic data (**P. Bergamini**, **A. Margheri**, P. Rosati, G. Granata, C. Grillo, M. Nonino, A. Mercurio, A. Acebron, E. Vanzella)
- Forward modelling of strongly lensed galaxies (**P. Bergamini**, P. Rosati, C. Grillo, U. Mestrîc E. Vanzella)
- Sub-pc cosmological hydrodynamical simulations of high-redshift sources and their strong lensing analysis (**F. Calura**, E. Vanzella, A. Zanella)