EUCLID

L. Valenziano

a nome della collaborazione
italiana in Euclid

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ISTITUTO NAZIONALE
DI ASTROFISICA

INAF highlights in the Euclid mission

Strong points by INAF

- Scientific leadership in
  - Galaxy Clustering Science
  - Clusters of galaxies
  - Cosmological theories (aka *Theory*)
  - X-CMB
  - Strong lensing
  - Legacy Science
    - Galaxy evolution
    - Local Universe
- Scientific & technical leadership (not limited to Euclid)
  - Space missions system activities
  - Mission survey
  - On-board (real-time) SW
  - Product Assurance

In this presentation

- Science (Science Working Group - SWG highlights)
  - Cosmology
  - Legacy Science
- Science Ground Segment (Science Data Center + OUs)
  - Pipeline development
  - Instrument Operation Team leadership (+NISP and VIS IOT)
- Contribution to instruments
  - 3 On-board Application SWs (VIS CDPU, NISP DPU and ICU)
  - HW (provided by industry with INAF/INFN support)
- Euclid Survey Strategy leadership

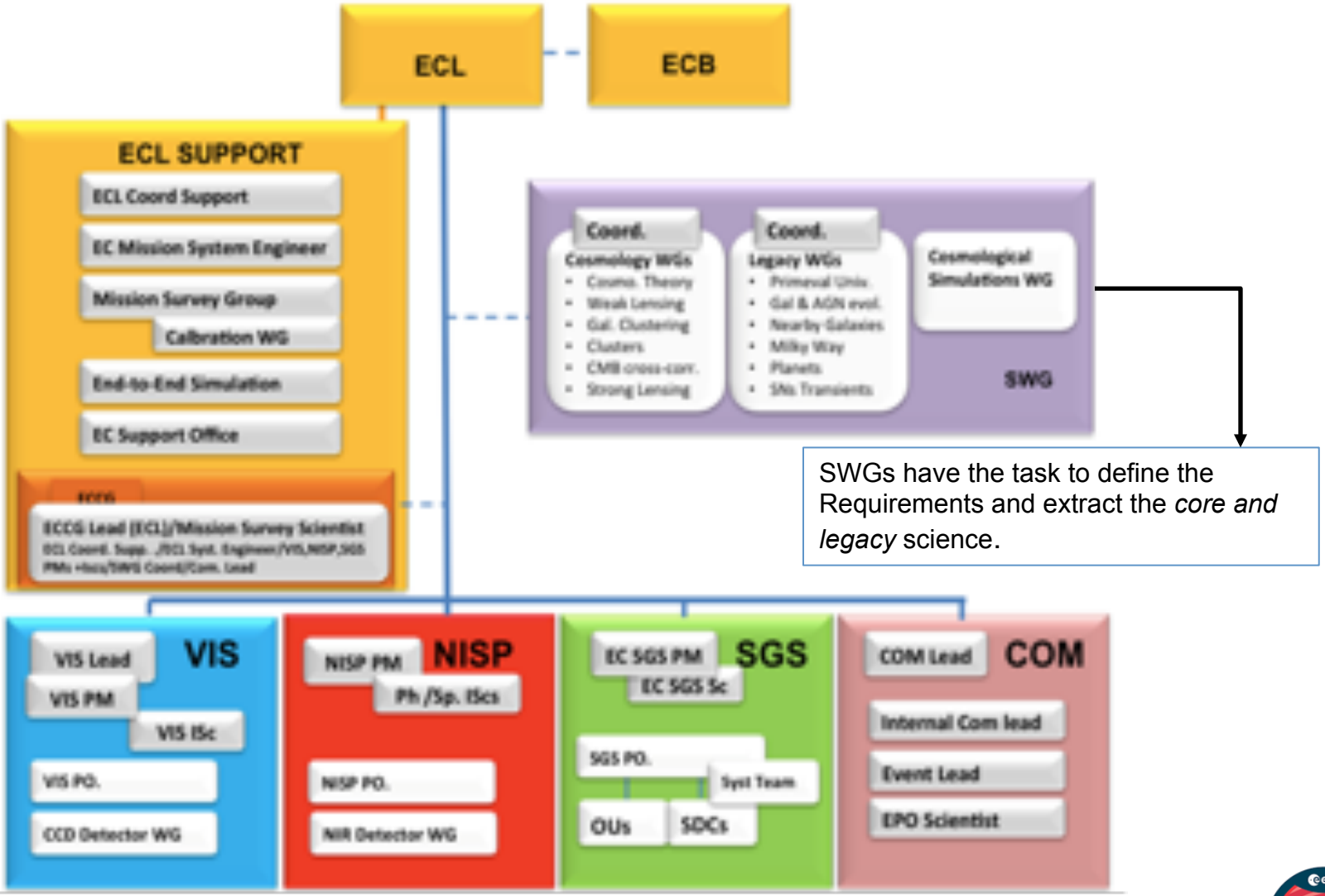
La partecipazione italiana in Euclid è finanziata da ASI

Euclid Satellite

Image: ESA/ADS/ThalesAleniaSpace

Started in 2007 with the SPACE proposal (PI: A. Cimatti) and the DUNE proposal (Co-I: R. Scaramella)
Launch: 2022; 6.5y mission

The Euclid Consortium Organisation Structure



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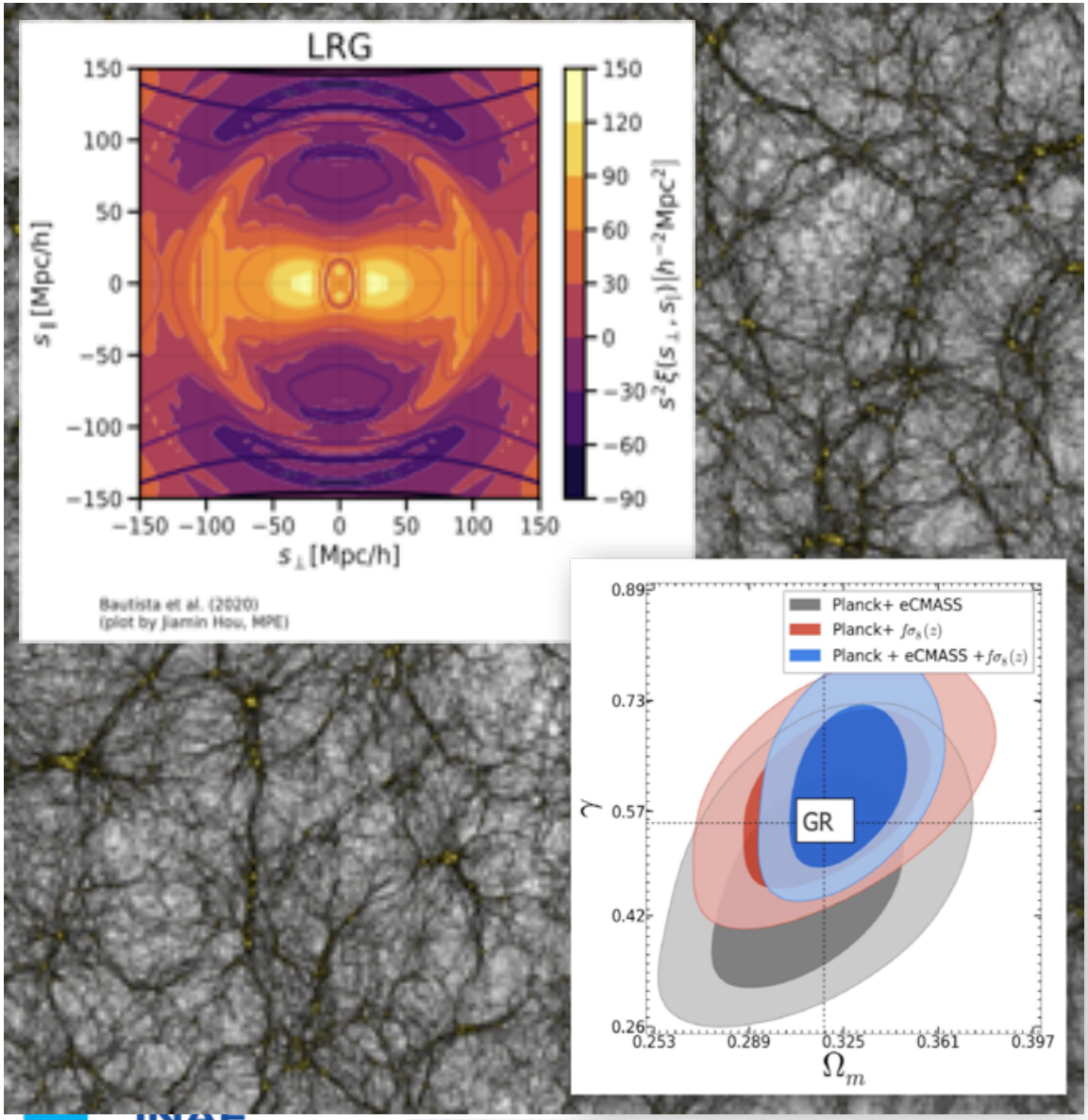
Galaxy Clustering Science



Leadership roles:

1) **Science coordination at EC level: Science Coordination Group (SCG) & ECEB-ECPG-S** (Guzzo)

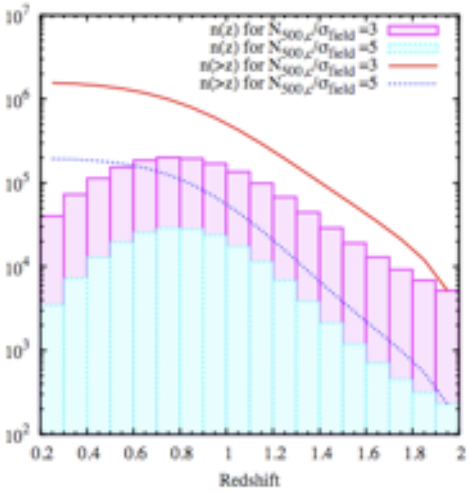
2) **a) GC-SWG coordination** (Guzzo)
   b) 5 WP out of 8 with Italian co-leadership
   - GC Likelihood WP (Carbone*)
   - GC Systematics WP (Monaco)
   - GC end2end WP (Granett*, Moresco)
   - GC Higher-order WP (Sefusatti*)
   - GC Photo-z WP (Camera)

3) **OU-LE3 coordination** (Branchini)

4) **OU-LE3 GC implementation/validation** (Branchini/Viel) and leadership GC-PFs implementation/validation (Marulli, Veropalumbo, Sefusatti*, Rizzo, Moresco, Granett*, Monaco)

5) **Co-leadership of 7 out of 9 Pre-launch Key Projects in GC (GC-SWG + OU-LE3-GC), for a total of 8 Italian scientists (same names as above)**

Clusters of Galaxies



Sartoris et al. 2016

For S/N > 5:

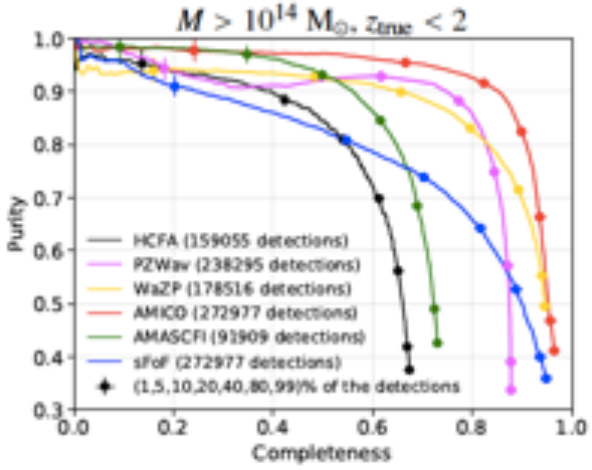
$N_{clusters} \approx 2 \times 10^5$

$N_{clusters} \approx 4 \times 10^4$ **with z>1**

For S/N > 3:

$N_{clusters} \approx 2 \times 10^6$

$N_{clusters} \approx 4 \times 10^5$ **with z>1**



Adam et al. 2019

The best algorithm for cluster detection (**AMICO, Bellagamba et al.**) with very high purity and completeness up to z=2 for objects with $M>10^{14}$ M_{sun}

Strong Italian involvement:

SWG:

125 members, 32% Italian

1 Co-coordinator (Moscardini)

11 Working Packages with 9 Italian co-leads (Mass modelling: Sereno; **Likelihood:** Costanzi, Sartoris; Statistics: Marulli; Validation: Bardelli; Astrophysics: Ettori; **Simulations:** Borgani, Giocoli; Protoclusters: Cucciati).

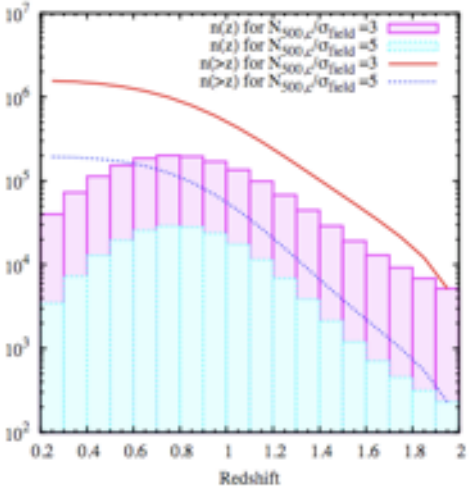
6 KPs with 4 Italian Leaders

OULE3 Clusters:

1 Co-leader (Implementation: Munari)

15 PFs, 13 of them with an Italian lead (Munari, Sartoris, Andreon, Iovino, Girardi, Sereno, Bolzonella, Zucca, Biviano, Castignani, Marulli, Moresco)

Clusters of Galaxies



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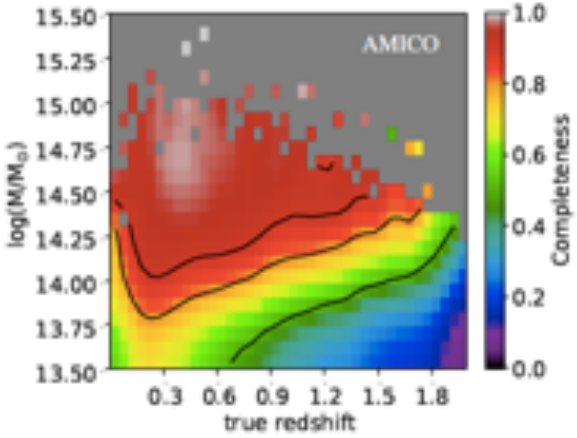

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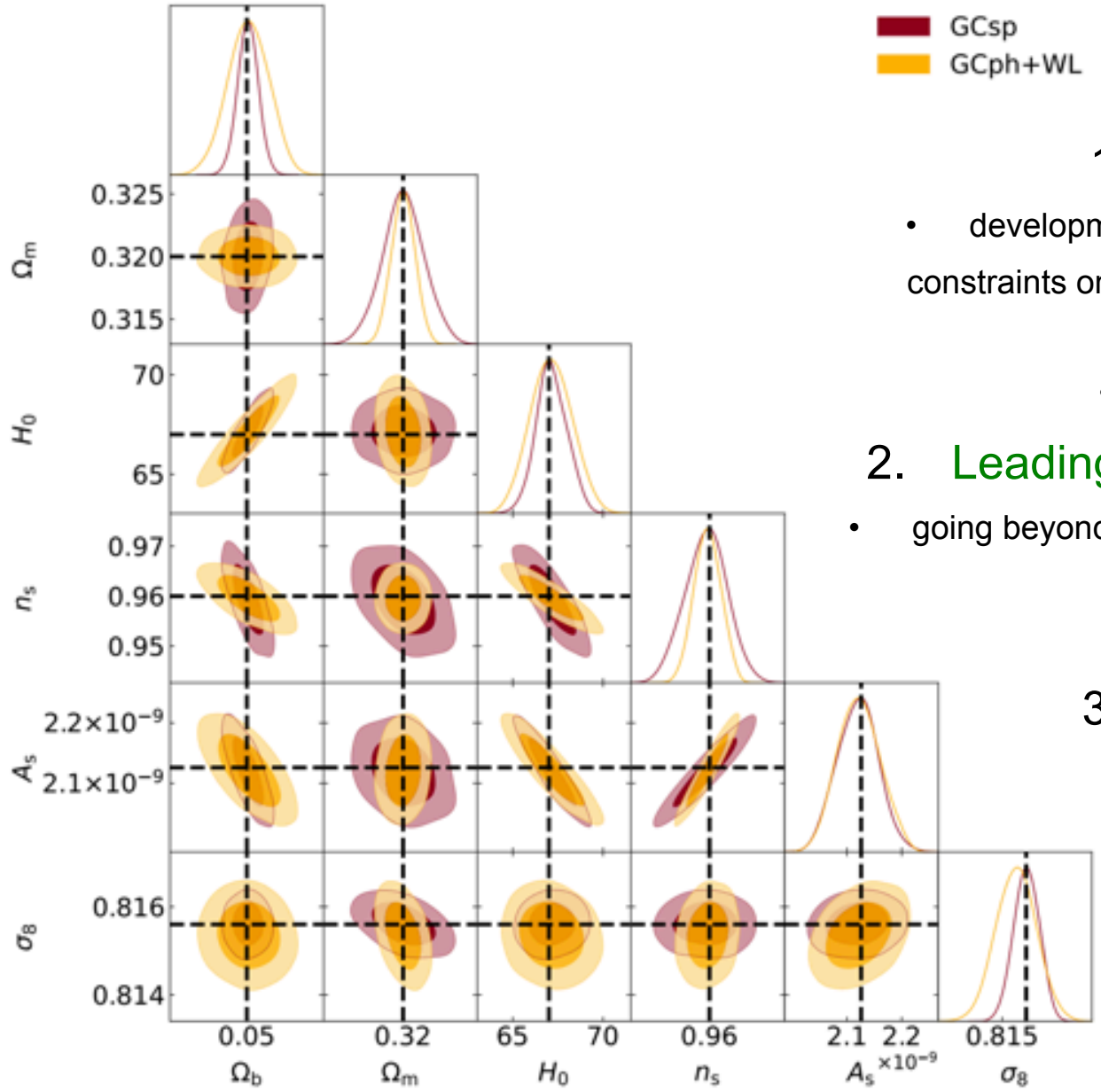
Weak Lensing: Likelihood and Higher Order Statistics



1. Leading IST:Likelihood

- development of the likelihood code for inferring constraints on cosmological parameters from 3x2pt data
- CLOE v1.0 released on April, 12th

2. Leading High Order Statistics WP

- going beyond 2pt probes to improve constraints on cosmological parameters
- HOWLS project

3. Analysis of systematics

- color gradient bias
- EWC H2020 project

Strong Lensing

Galaxy cluster MACSJ0416 seen by HST and Euclid

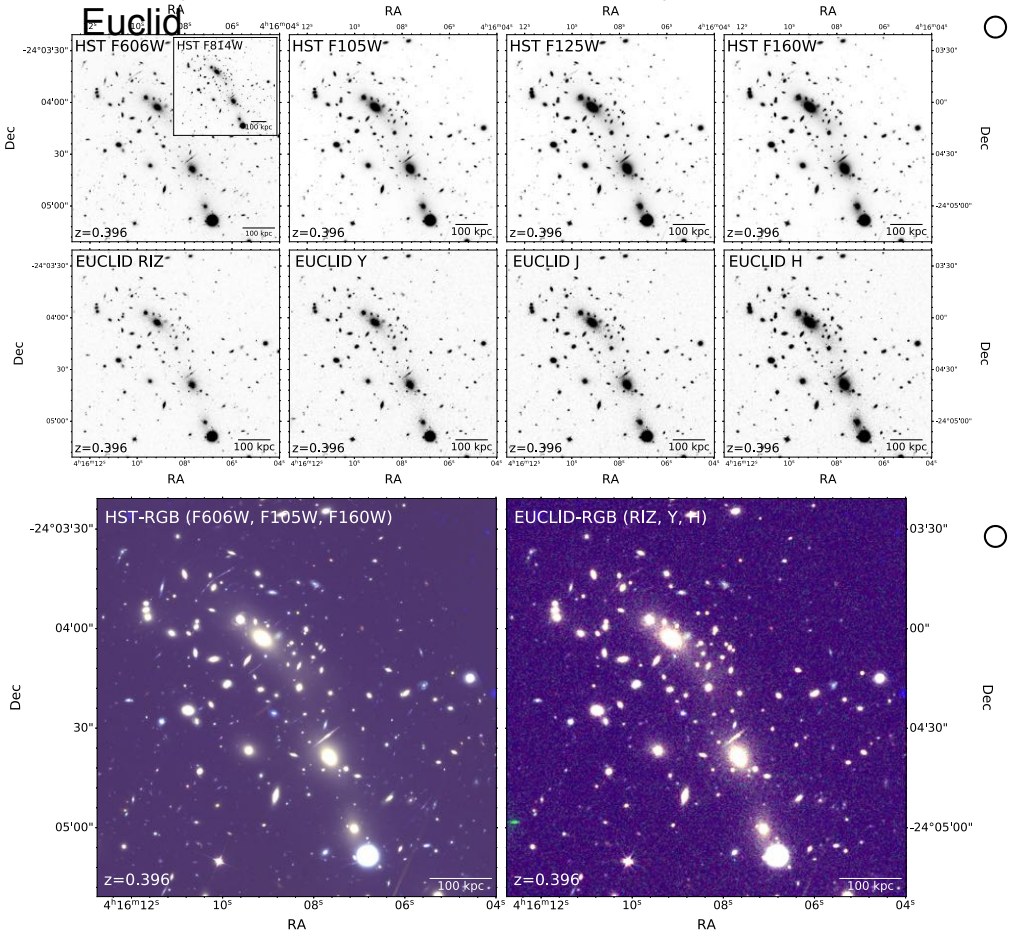
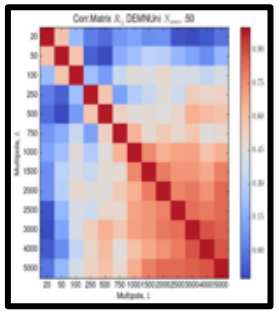


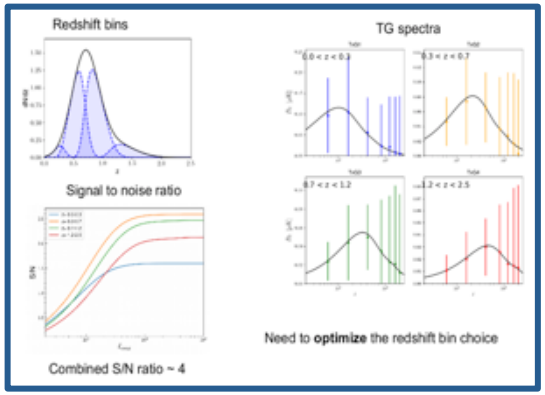
Figure by P. Bergamini

- **Ongoing work**
  - Realistic image simulations of strong lensing galaxies and clusters
  - Algorithms for finding strong lenses
  - Development of lens modeling techniques
  - Information content on the galaxy evolution model
- **Science with strong lenses**
  - Mapping DM in galaxies and clusters
  - Studying the interplay between DM and baryons
  - Constraining the galaxy evolution model
  - Measuring cosmological parameters
  - Strong lensing by cluster substructures

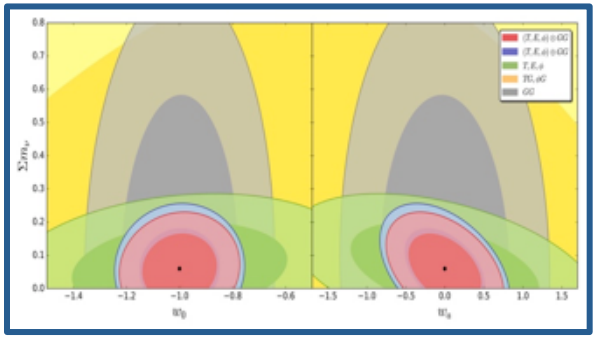
WGs for CMB ⊗ & Theory Euclid



Covariances for CMB Lensing Evaluated over DEMNuni & DUSTGRAIN Euclid N-Body Simulations



Tomographic Analysis and Estimators for Integrated Sachs-Wolfe and Galactic distribution



Constraints on Cosmological Parameters from CMBXC Analyses and Forfecasts

Simulations: national teams lead the development of N-body Simulations dedicated to CMBXC Activities, facing top scientific challenges such as the measurement of observable covariances on simulations (see top Figure).

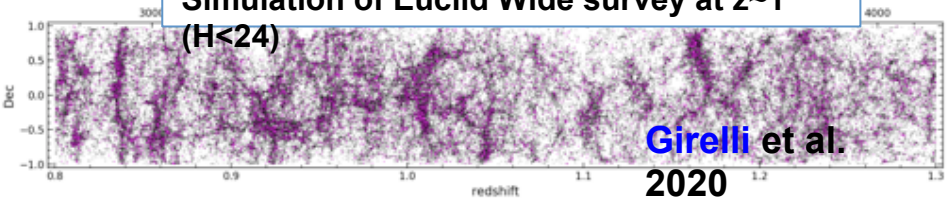
Estimators & Likelihood: Development of a likelihood pipeline for CMBXC, based on validated estimators (see Figure in the middle). Will be fully integrated into the Euclid environment.

CMBX science: development of theoretical predictions and forecast the capabilities for CMB-Euclid cross-correlation for cosmological parameters (see Figure at the bottom for the expected constraints on the neutrino mass with dark energy with a redshift dependent parameter of state).

The Euclid Theory SWG coordinates the theoretical predictions and N-body simulations for cosmology beyond the concordance model, in the directions of modified gravity, non standard models of dark matter and general initial conditions from inflation.

@INAF: F. Finelli, A. Gruppuso, D. Paoletti, M. Ballardini, J. Bermejo, + many others

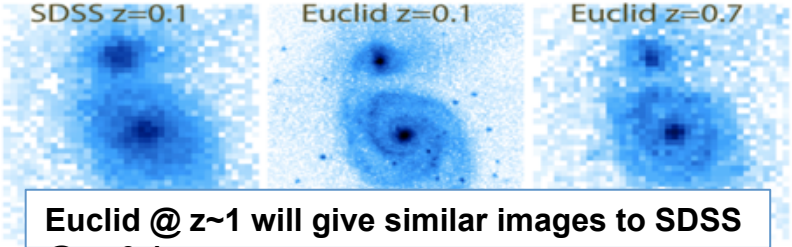
Legacy Science with Euclid



Simulation of Euclid Wide survey at z~1 (H<24)

Girelli et al. 2020

- **The three-dimensional map of the cosmos** produced by Euclid will provide a unique Legacy value to reconstruct galaxy evolution over about 10 billion light-years and **covering at least half the sky with exquisite resolution.**



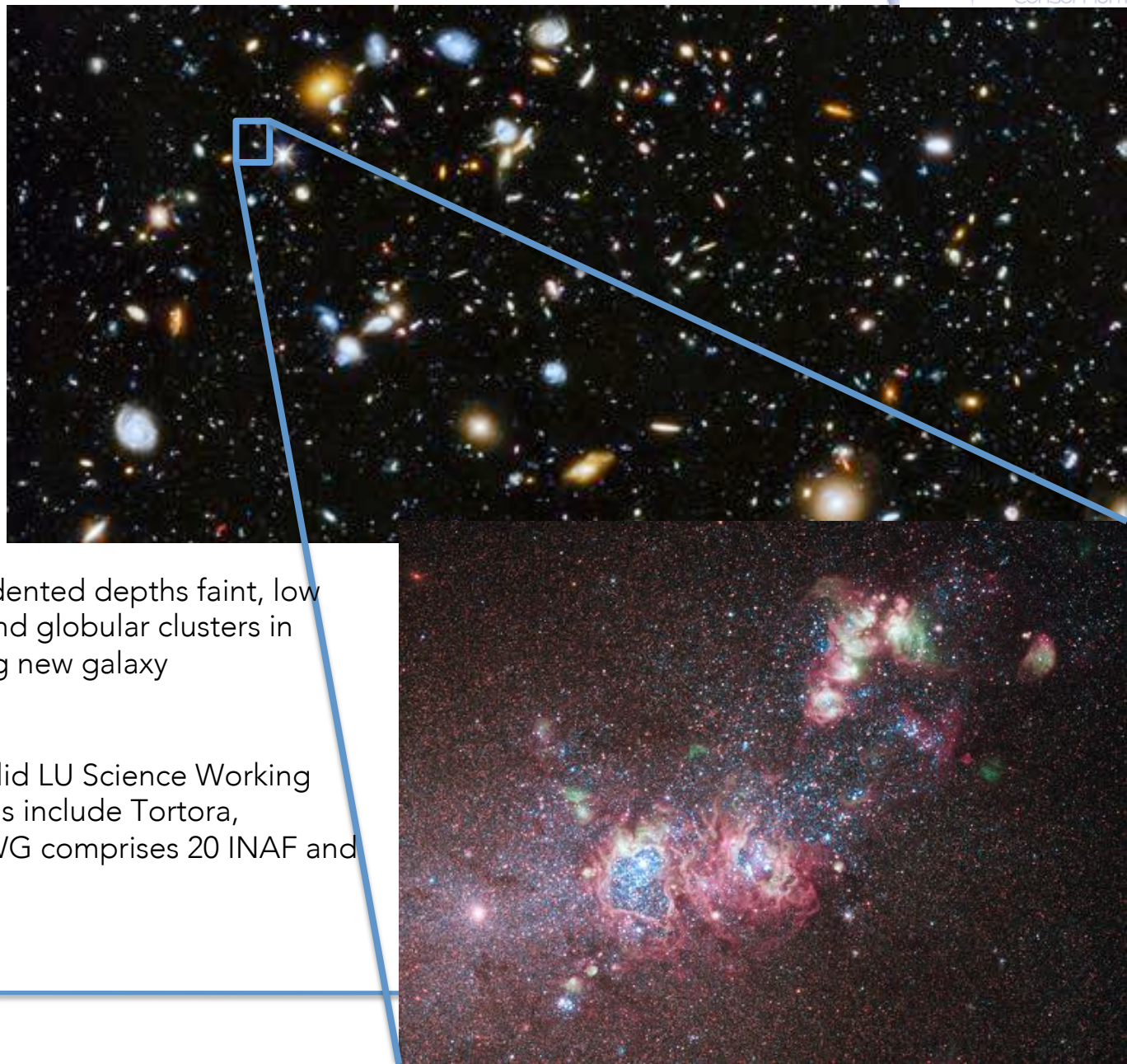
Euclid @ z~1 will give similar images to SDSS @ z~0.1

- The Euclid database will contain **images and photometry for 1.5 billion galaxies** and **spectra for at least 35 millions of them**, to derive their Physical Properties.

- **INAF** and **INAF's associated** covers leading roles in the Galaxy Evolution (GAEV) Working Group (WG, A. Cimatti), involves several leadership of Work Packages (WPs L.Pozzetti, G.DeLucia, M.Magliocchetti, E.Zucca, V.Allevato, M.Talia , M.Moresco, G.Rodighiero) and related Key Projects (KPs) of this SWG and participates to the Primordial Universe (PU) WG.

- The main science goal is reconstructing the **galaxy assembly history in different environments** and the **connection between galaxies and their dark matter haloes** from **low redshift** to **young primordial epochs**, and deriving the **morphological and physical properties of several millions of galaxies and rare objects**.

Euclid Legacy Science in the Local Universe (LU)



Euclid will image to unprecedented depths faint, low surface brightness galaxies and globular clusters in galaxies up to z~0.3, enabling new galaxy demographics.

INAF co-leads (Hunt) the Euclid LU Science Working Group, and INAF LU WP leads include Tortora, Scodeggio. The Euclid LU SWG comprises 20 INAF and INAF-associated members.

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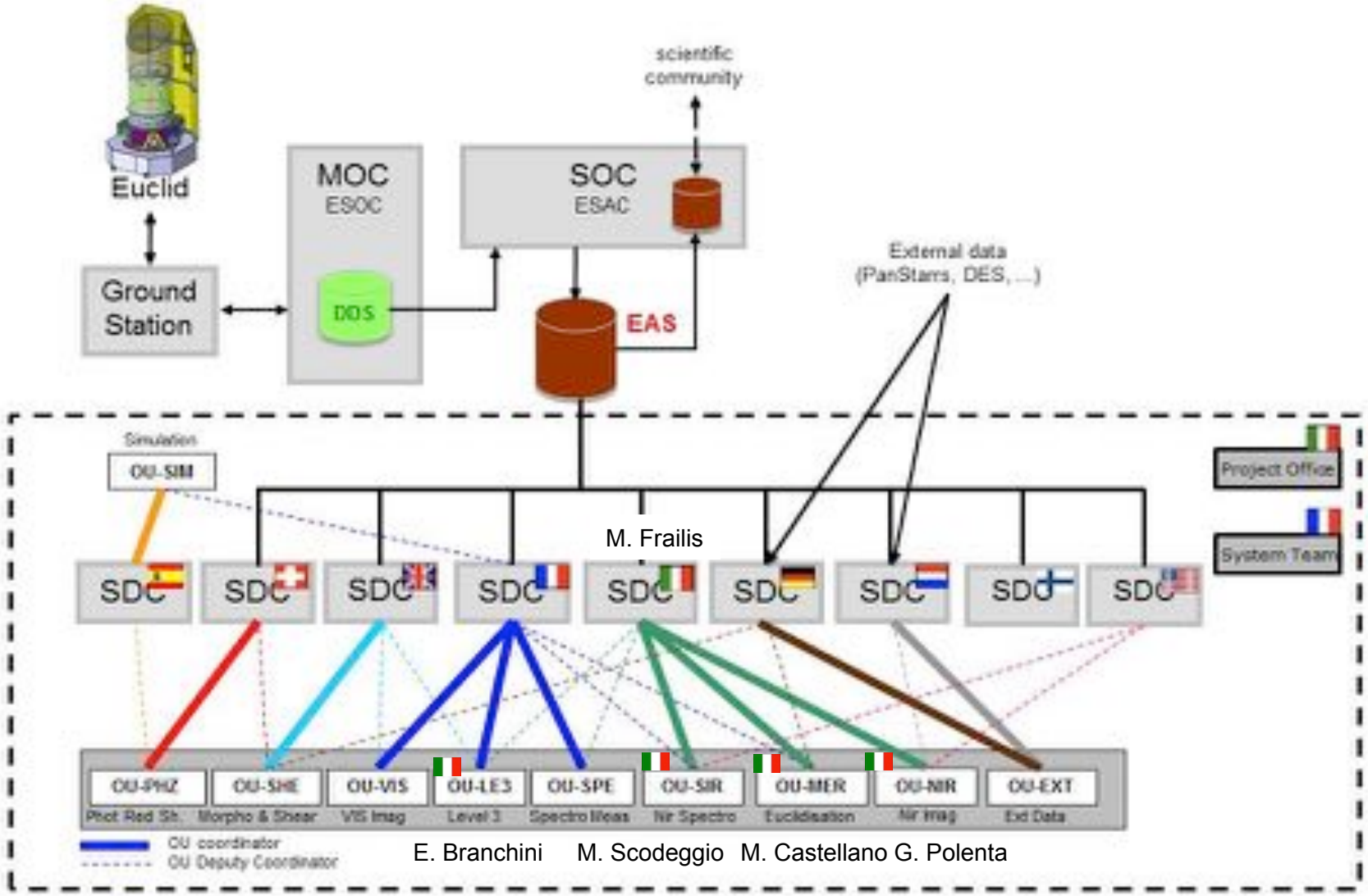
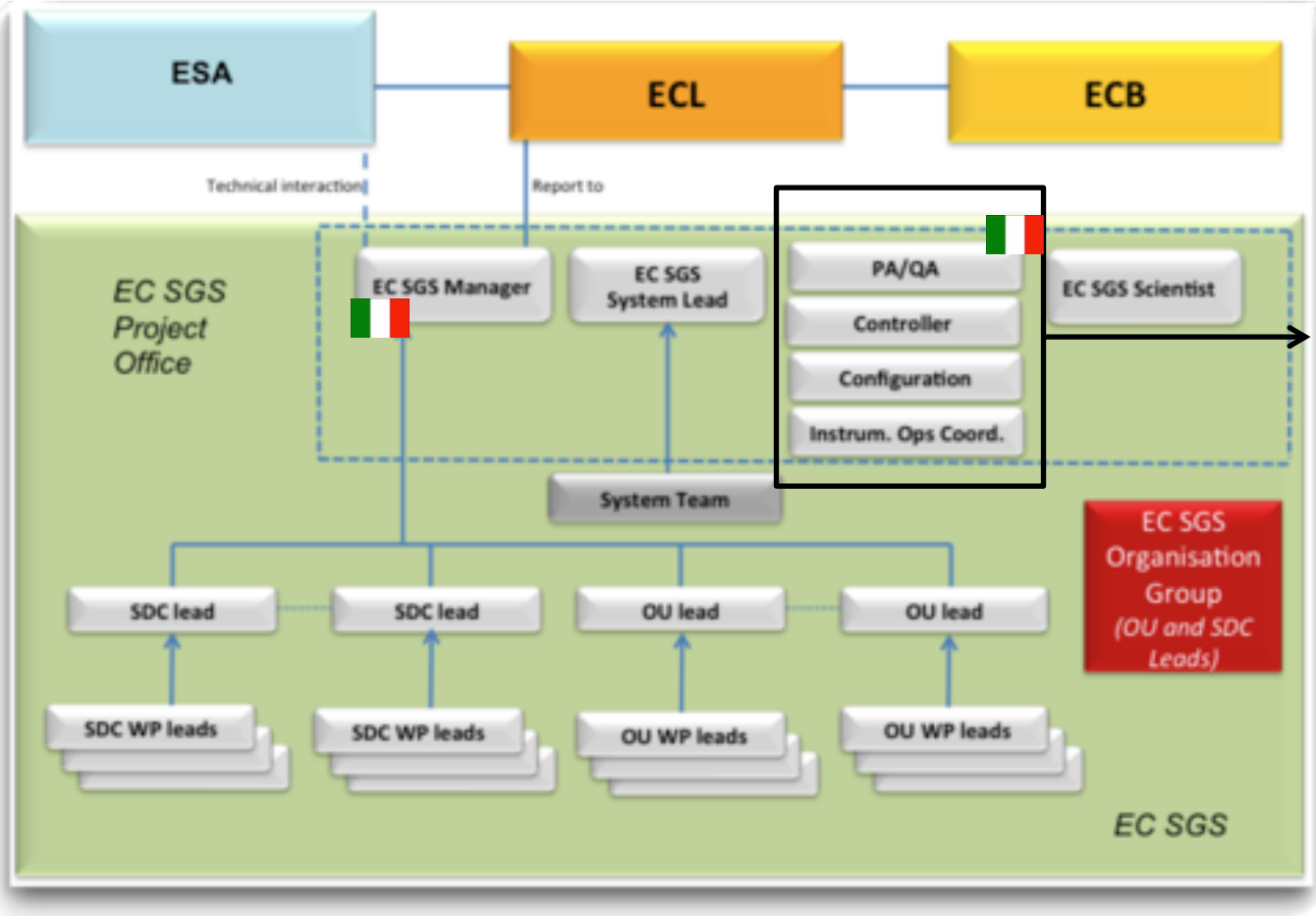
The Ground Segment



The Euclid Ground Segment

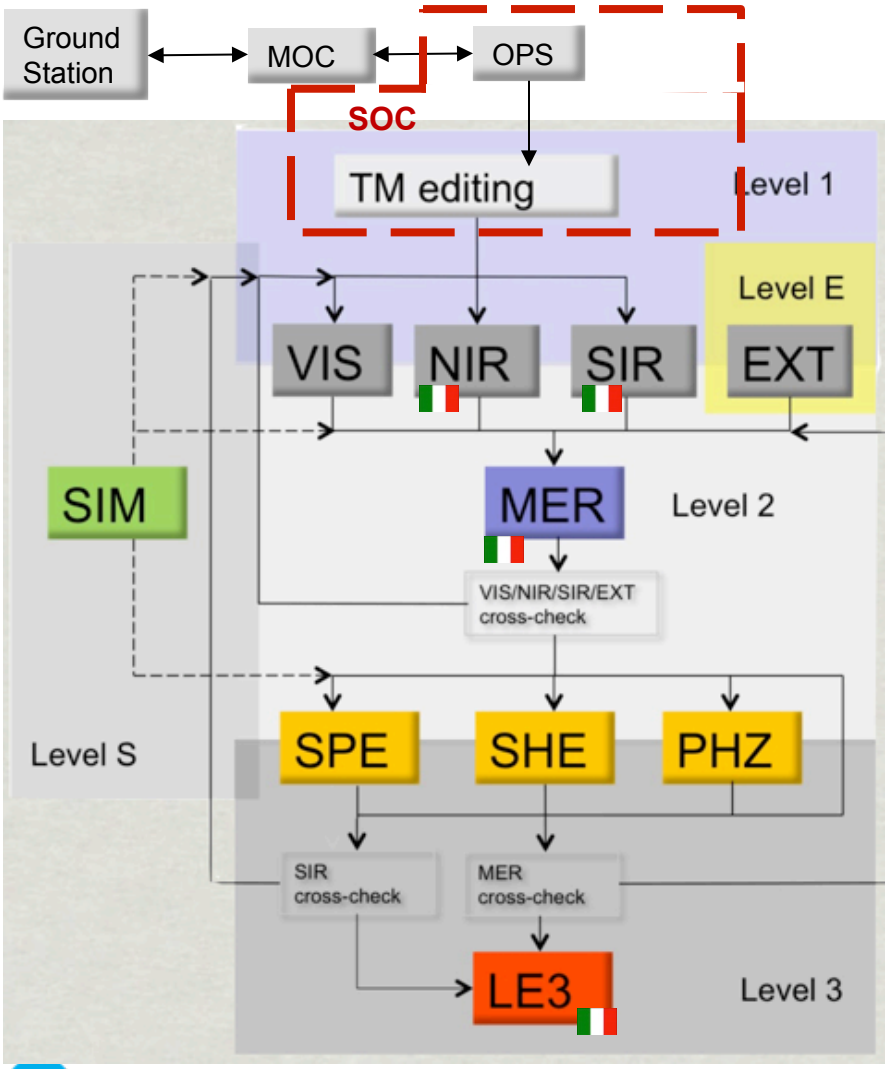
- Euclid SGS is essentially a distributed structure.
- Resources (Italy should provide about 25%)
  - Euclid will produce and use a big amount of data (estimated to be at the end of the mission of the order of hundreds PB). It will be then essential to avoid excessive data transfer, to develop a structure where the code will be moved instead of the data.
  - Euclid will use a huge amount of core (estimated to be 24k)
- Science Data Center (SDC), under National responsibility, are providing different hardware.
- The code development is split in different entity (OU Organization Unit) under National responsibility.
- Two languages (C++ and python) has been selected a Common Data Model and Common Infrastructure (hardware independent) has been built → EACH Science Data Center should be able to run the same code to process the data in parallel and be redundant.
- SGS will take the responsibility of Instrument Operations after commissioning.

The management structure: SGS



PO support Team
Located in Italy.

The mapping of OUs on the pipeline

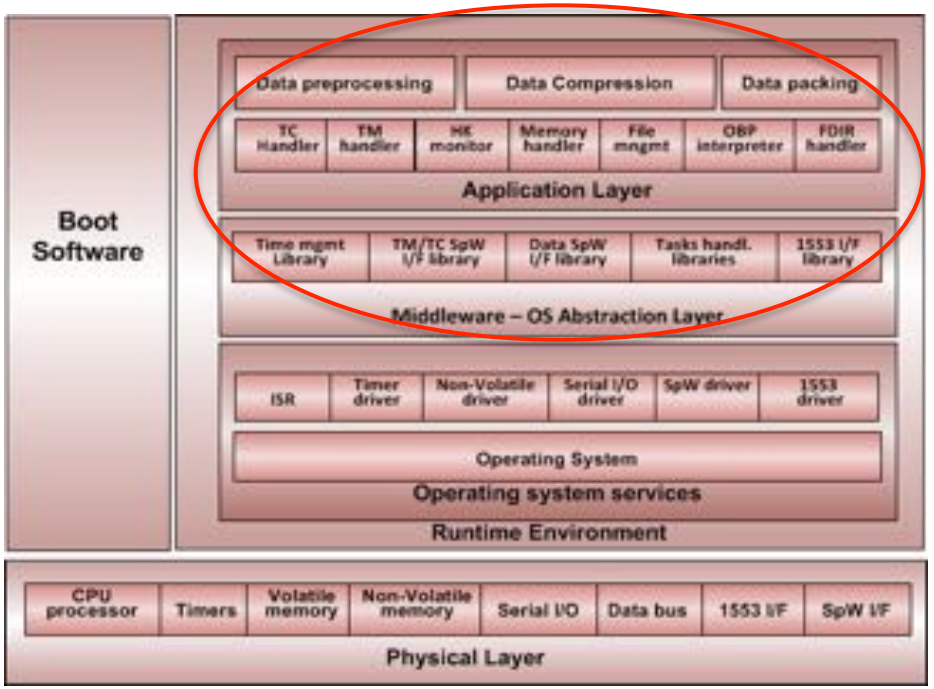


- VIS, NIR, EXT: production of fully calibrated photometric exposures from Euclid and ground-based surveys
- SIR: production of fully calibrated 1D spectra extracted from the NISP spectroscopic exposures.
- MER: production of a source catalog containing consistent photometric and spectroscopic measurements.
- PHZ: production of the photometric redshift for all catalogued sources.
- SPE: production of spectroscopic redshifts for all sources with spectra.
- SHE: measurements of galaxy shapes.
- LE3: production of all high-level science products.
- SIM: production of all the simulated data necessary to validate the data processing stages, and to calibrate observational or method biases.

VIS and NISP SW

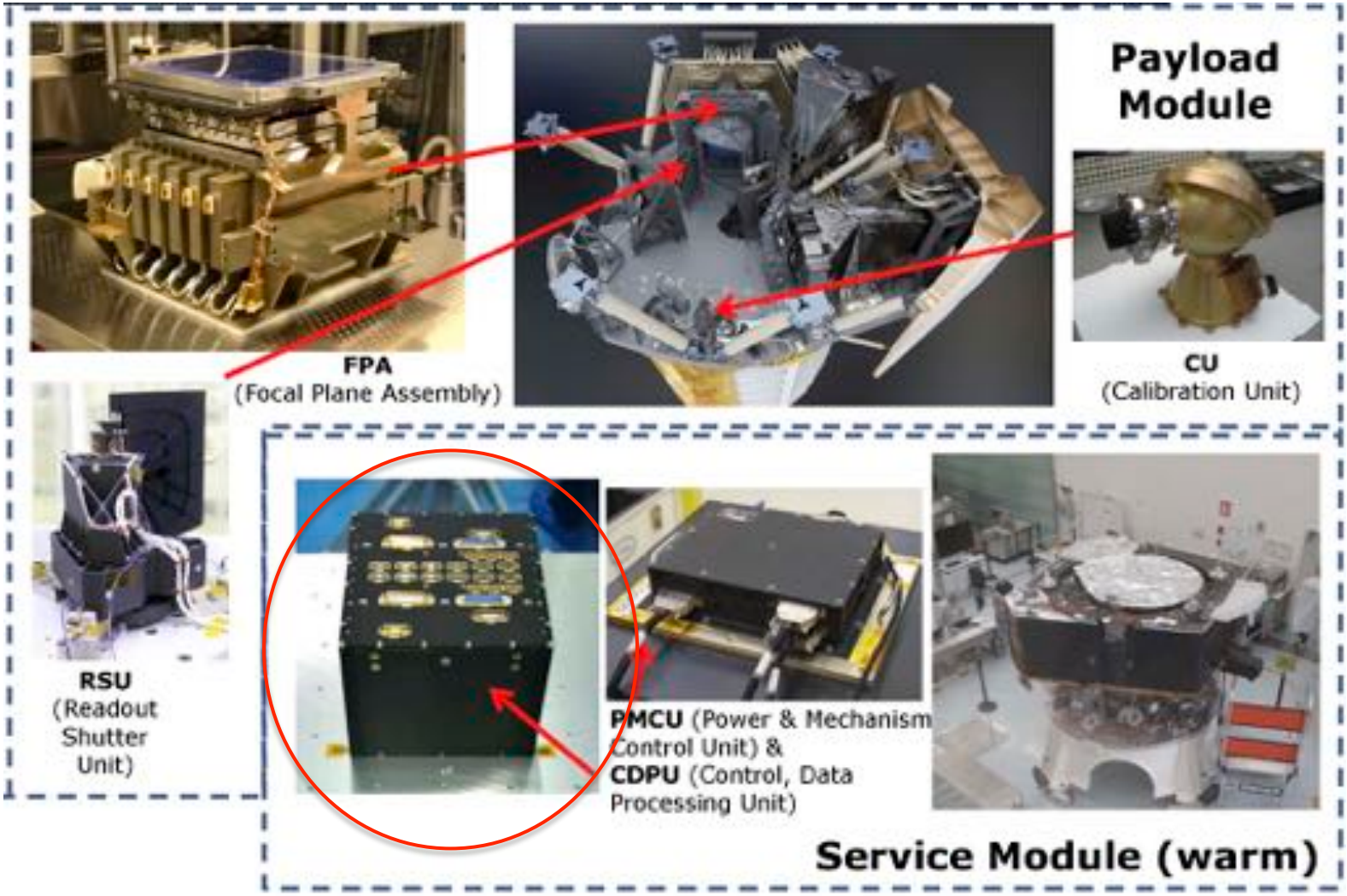
Euclid instruments on board SW design and development

- VIS On Board SW: instrument control and data handling SW (IAPS)
- NISP ICU On Board SW: instrument control and data transfer SW (OATO)
- NISP DPU data acquisition and compression SW (OAPD, OAS)

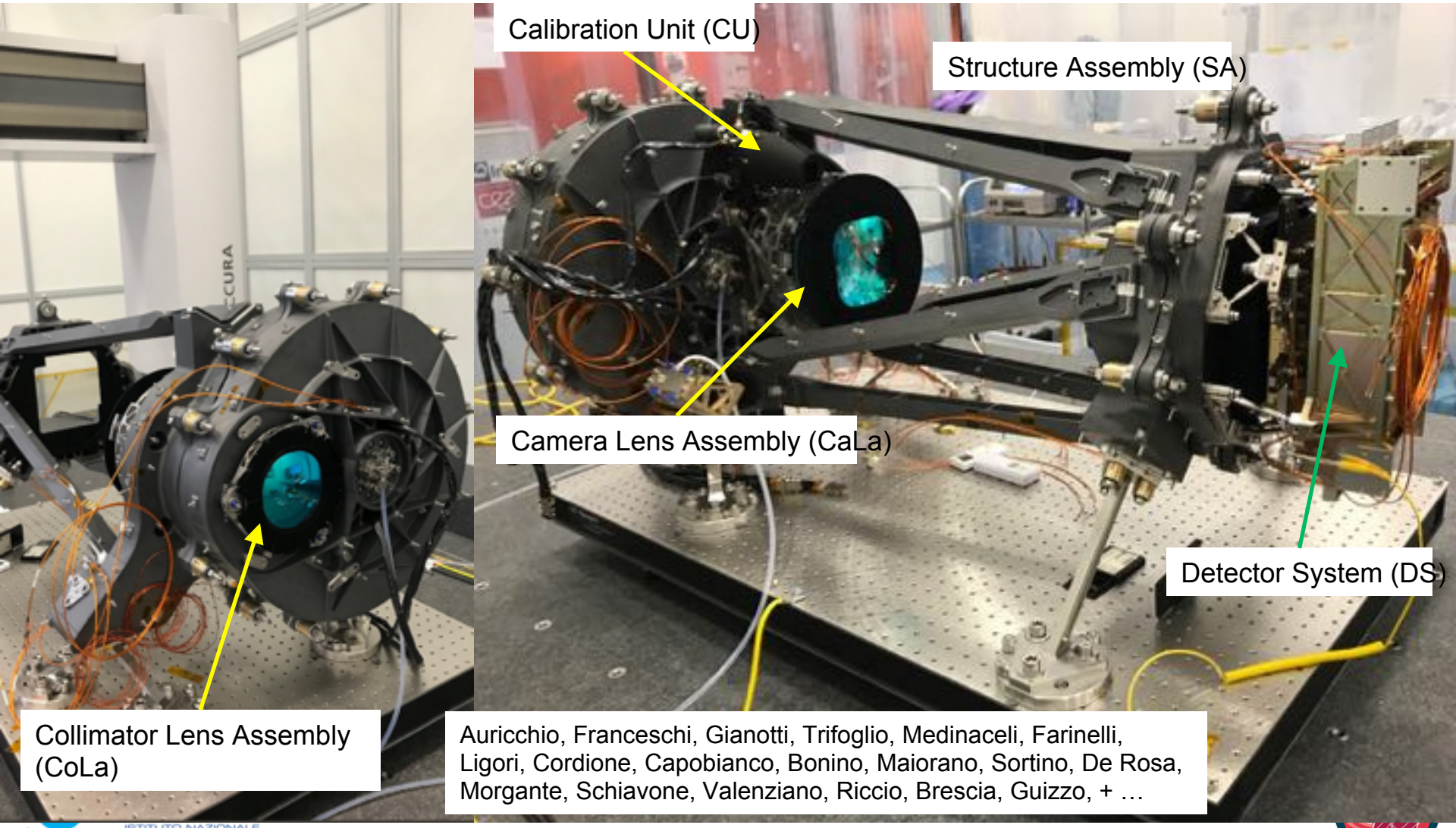


The production of the on-board SW for payload instrumentation is a crucial contribution to scientific space missions, as it allows to have an in-depth knowledge of both the functioning of the instruments and the peculiarities of the acquired data. INAF expertise in this field is an excellence well known at European level that has been further strengthened by the Euclid experience (see also TESICS).

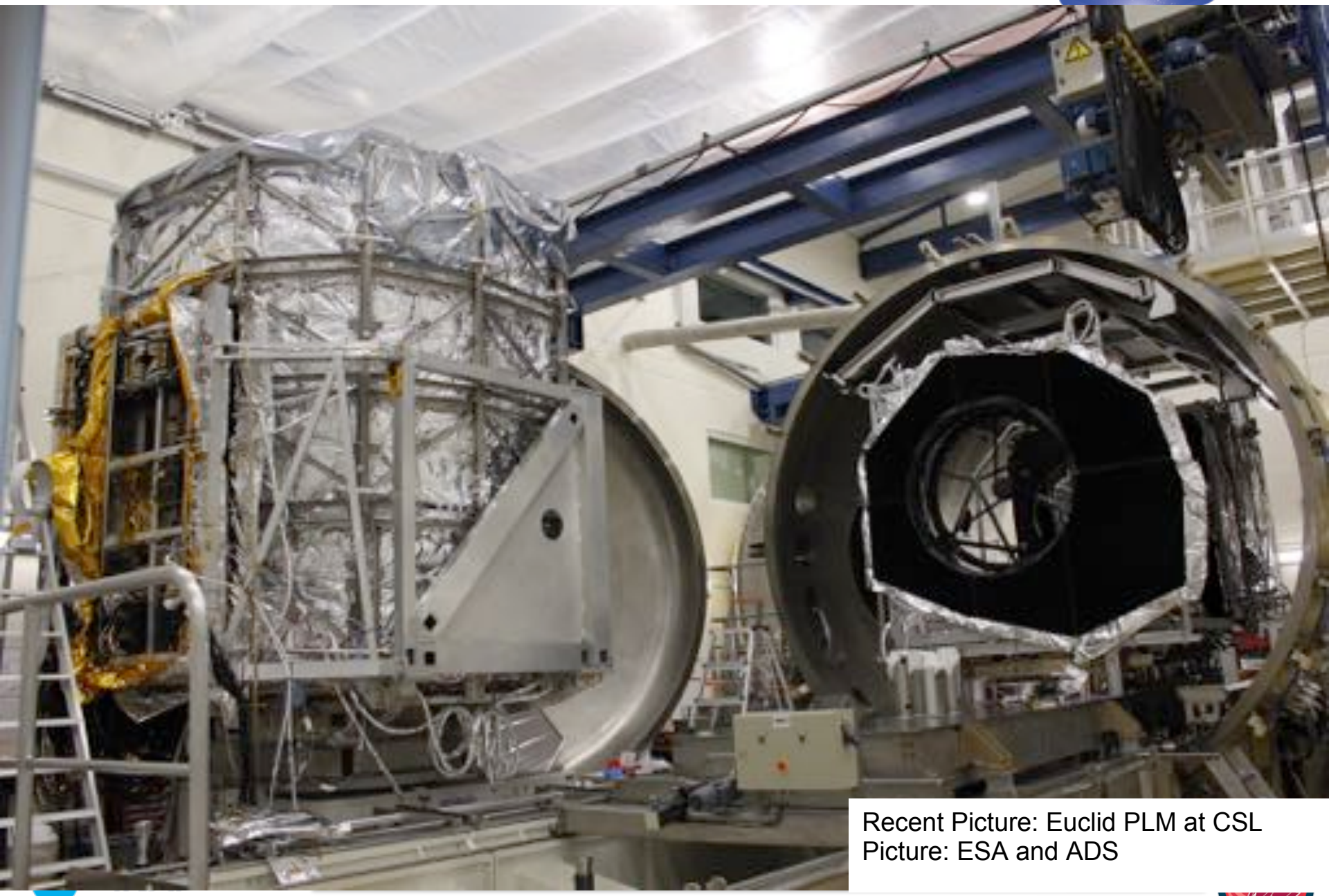
VIS


Payload Module
FPA
(Focal Plane Assembly)
CU
(Calibration Unit)
RSU
(Readout Shutter Unit)
PMCU (Power & Mechanism Control Unit) &
CDPU (Control, Data Processing Unit)
Service Module (warm)

NISP FM

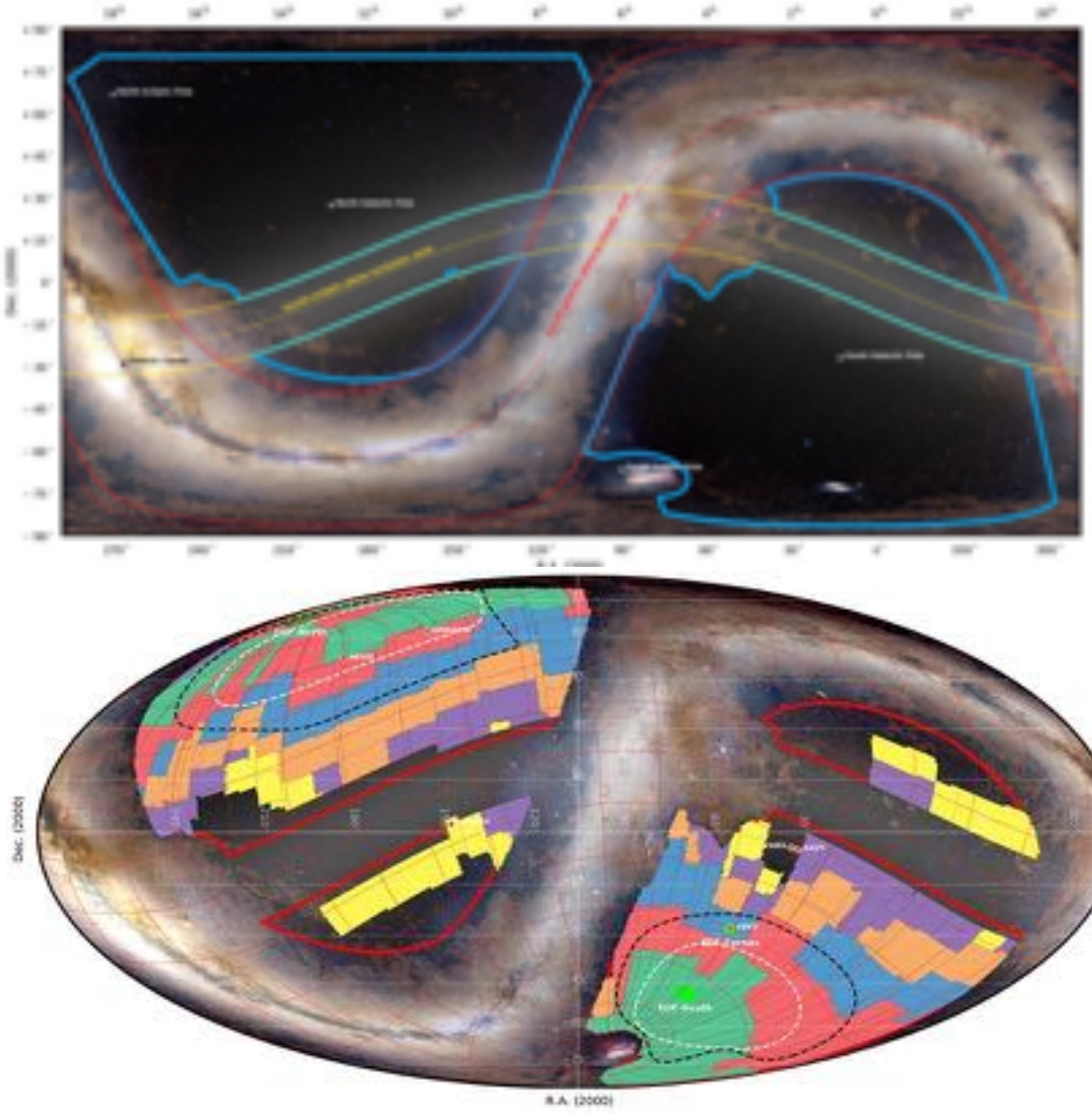


Auricchio, Franceschi, Gianotti, Trifoglio, Medinaceli, Farinelli, Ligori, Cordione, Capobianco, Bonino, Maiorano, Sortino, De Rosa, Morgante, Schiavone, Valenziano, Riccio, Brescia, Guizzo, + …



Recent Picture: Euclid PLM at CSL
Picture: ESA and ADS

Euclid = one 6 year survey



INAF/R. Scaramella: Mission Survey Scientist, Euclid Science Team, EC Board, lead of ECSURV group. Euclid Team Star Prize.

- HUGE constraints on pointing, covred area ~1.5E4 sq deg
- 1 year spent on lot of calibrations and the 3 EUCLID DEEP FIELDS
- Coverage of best extragalactic sky from both space and ground (collection of surveys, synergy with Rubin)

Aree critiche

- Figure professionali specifiche sono necessarie
  - Project Manager
  - Product Assurance Manager
  - System Engineer
  - Electrical/Thermal/Mechanical Engineer

Si formano nel progetto ma non sono sufficienti rispetto alla quantità di lavoro da svolgere

- E' necessario prevedere adeguata valutazione dei profili sperimentali anche nelle carriere da ricercatore;
- E' necessario valutare il lavoro svolto in molti anni per la missione anche negli articoli a molte firme, propri di questo genere di progetti;
- Centro di calcolo INAF adeguato alla gestione di dati missioni come Euclid

Potrebbe aumentare le potenzialità rispetto a nuove missioni

INAF Personnel in Euclid

natalia.auricchio, sandro.bardelli, andrea.biviano, micol.bolzonella, massimo.brescia, enzo.brocato, andrea.bulgarelli, enrico.cappellaro, alberto.cappi, stefano.borgani, carmelita.carbone, vincenzo.cardone, marco.castellano, stefano.cavuoti, leonardo.corcione, stefano.ettori, fabio.finelli, adriano.fontana, marco.frailis, enrico.franceschi, paolo.franzetti, marco.fumana, samuele.galeotta, emanuele.galli, bianca.garilli, fulvio.gianotti, stefano.giuppi, adriano.derosa, anna.digiorgio, anna.gregorio, benjamin.granett, alessandro.gruppuso, leslie.hunt, sebastiano.ligori, andrea.lorenzani, oriana.mansutti, michele.maris, massimo.meneghetti, amata.mercurio, emiliano.merlin, gianluca.morgante, luciano.nicastro, mario.nonino, daniela.paoletti, diego.paris, bianca.poggianti, lucia.pozzetti, valerio.roscani, barbara.sartoris, roberto.scaramella, marco.scodeggio, emiliano.sefusatti, john.stephen, giuliano.taffoni, vincenzo.testa, massimo.turatto, luca.valenziano, claudio.vuerli, andrea.zacchei, elena.zucca, manuela.magliocchetti, giovanni.cresci, carlo.giocoli, vito.conforti, isabella.prandoni, ruben.salvaterra, marco.mignoli, giorgio.calderone, gabriella.delucia, massimo.dellavalle, daniela.vergani, carlo.burigana, elisabetta.maiorano, mario.radovich, crescenzo.tortora, francesca.annibali, laura.bisigello, scige.liu, olga.cucciati, enrichetta.iodice, stefano.andreon, angela.iovino, alessia.moretti, andrea.bonchi, fabiana.faustini, anna.feltre, ronaldo.oliveira, filomena.schiavone, daniele.tavagnacco, deborah.busonero, luigi.spinoglio, benedetta.vulcani, paolo.ciliegi, alberto.moretti, stefano.cristiani, francesca.sortino, paola.battaglia, pietro.bergamini, andrea.balestra, chiara.mancini, gianmarco.maggio, erik.romelli, federico.rizzo, thomas.gasparetto, eduardo.medinaceli, ruben.farinelli, vito.capobianco, giuseppe.riccio, emiliano.munari, jose.bermejo, gabriele.parimbelli, eliana.palazzi, mauro.sereno, maria.botticella, juan.fernandez, maria.farina, martina.vicinanza, fabio.fontanot,

Euclid@INAF

- 118 INAF (25+12 FTE/y)
- 48 Associati (8+4 FTE/y)
- 8 *stabilizzati*
- 12 EC Founders
- 34+ EC Builders
- + altri vincitori concorsi
- + altre persone *formate*

Euclid, come molti grandi e complessi progetti di lunga durata, è una straordinaria palestra di formazione e crescita professionale

	FTE
OAS BOLOGNA	33
O.A. TRIESTE	21
O.A. CAPODIMONTE	7
O.A. ABRUZZO	0
O.A. PADOVA	4
IASF MILANO	6
O.A. ROMA	8
O.A. TORINO	4
IAPS ROMA	7
O.A. BRERA	4
O.A. ARCETRI	2
IRA BOLOGNA	1
Total	97