EUCLID

Mapping the geometry of the dark Universe

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PNCG

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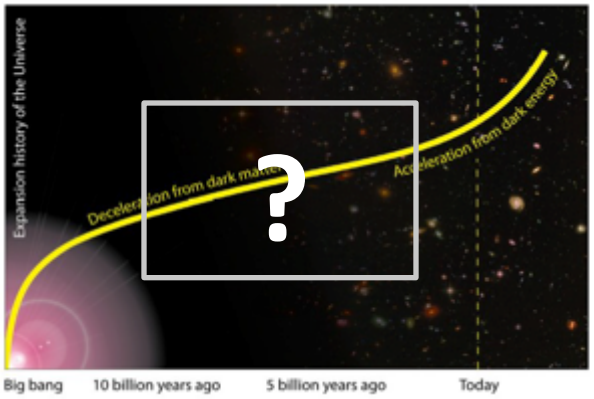
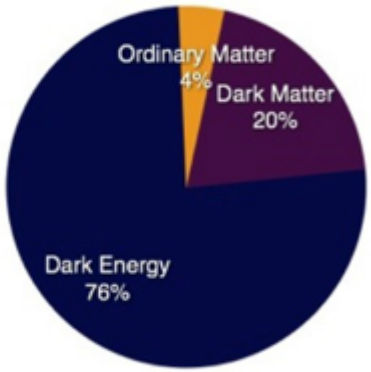
Euclid : the objectives

- EUCLID is a space mission dedicated to understand the origin of the acceleration of the Universe

- Euclid was selected by ESA in Oct. 2011, Adopted in June 2012 in the cosmic vision program as the M2 mission to be launched in 2020

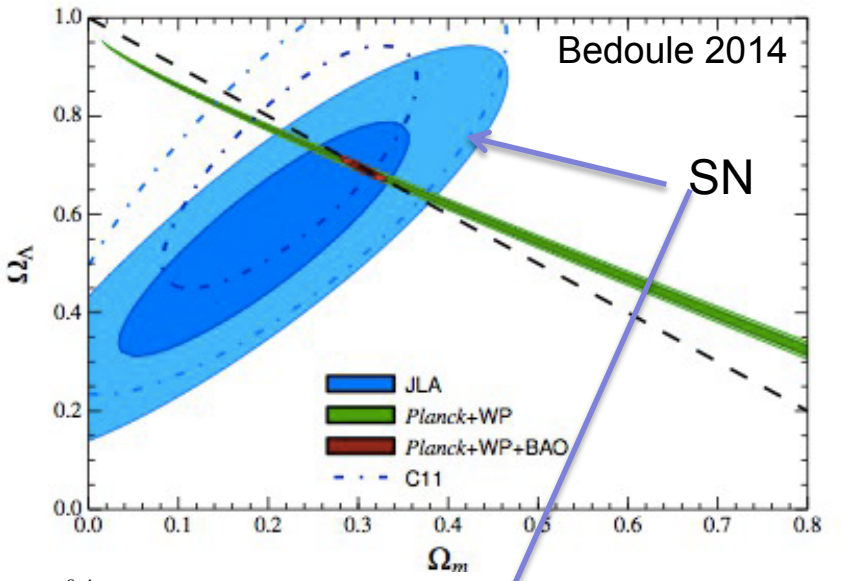
- EUCLID will measure the expansion history H(z) to unprecedented accuracy, as to detect any deviation in observational signatures in geometry/structure from dark matter/energy with full control of systematic effects:





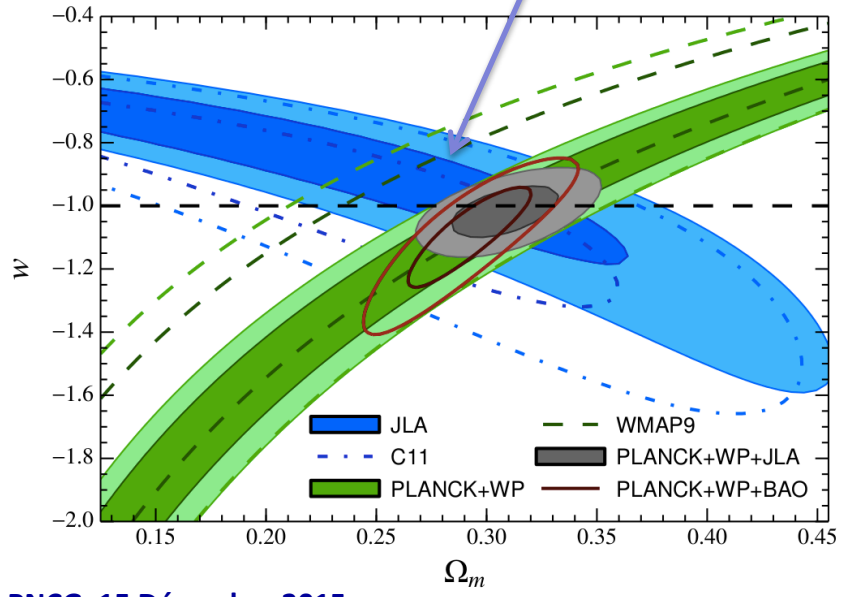
17 years after discovery …what do we know on DE

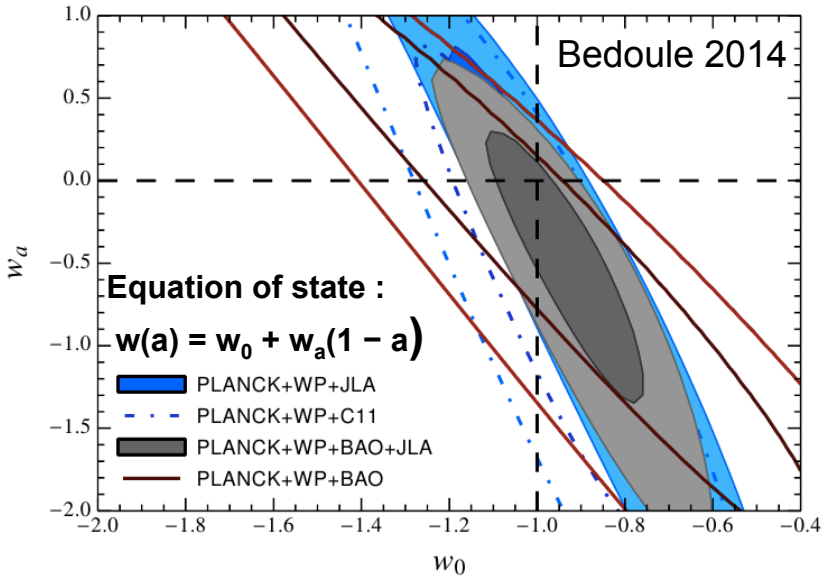
….



Dark energy equation of state:
w = p/ ρ = -1 < 10 % accuracy

A cosmological constant
seems well confirmed
BUT what is Dark Energy ??
Today = NO SENSITIVITY !!!





Two big open questions

Does DE vary with time? (dynamical)
=> Equation of state : w(a)

Is gravity self consistent with the accelerated expansion?
(modified gravity)
=> Verify that growth of structures consistent with ΛCDM

⇒*Observations of both expansion H(z) and growth of structures f(z) at different epochs*

By-product: can constraint very nicely the neutrino mass …

Euclid scientific objectifs

Goal ➔ -reduce by 1 order of magnitude the errors on DE equation of state.

-distinguish from modified gravity

Remark : give also constraint on neutrino mass

Method ➔ *Observations of both expansion H(z) and growth of structure f(z) on large sky and different epochs*

Key issues ➔ Systematic Errors -> data reduction, simulation

➔ Interpretation -> analysis, multi probe interpretation

Observables ➔

- Galaxy Clustering : BAO, RSD, growth of structure
- Weak Lensing : growth of structure
- Cluster counts /voids .....
- Supernovae : standard candle

Main cosmological probes in Euclid

Galaxy clustering (GC): BAO,RSD,AP..

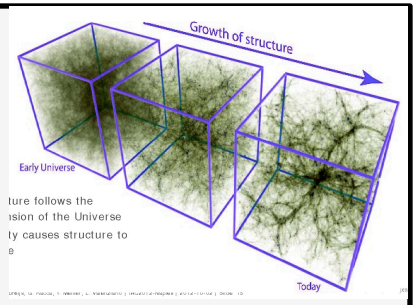
Matter power spectrum +distance at different epochs

3-D position measurements:

0.9<z<2

→ 3-D distribution of galaxies from spectroscopy in NIR range.

→ 50 millions of spectroscopic redshifts



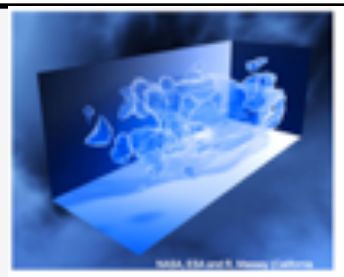
Weak lensing (WL):

Dark matter power spectrum at different epochs

-3-D cosmic shear measurements: 0<z<2

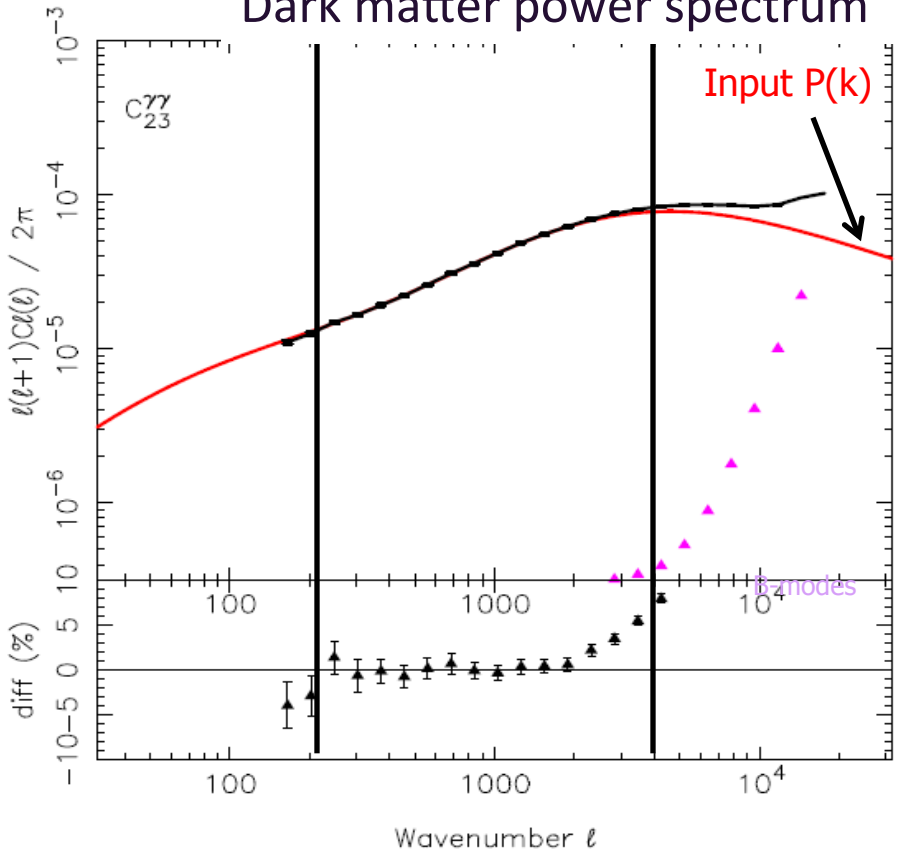
→ Shape measurement and photo-z's from optical an NIR data

→ 1.5 Billions of galaxies



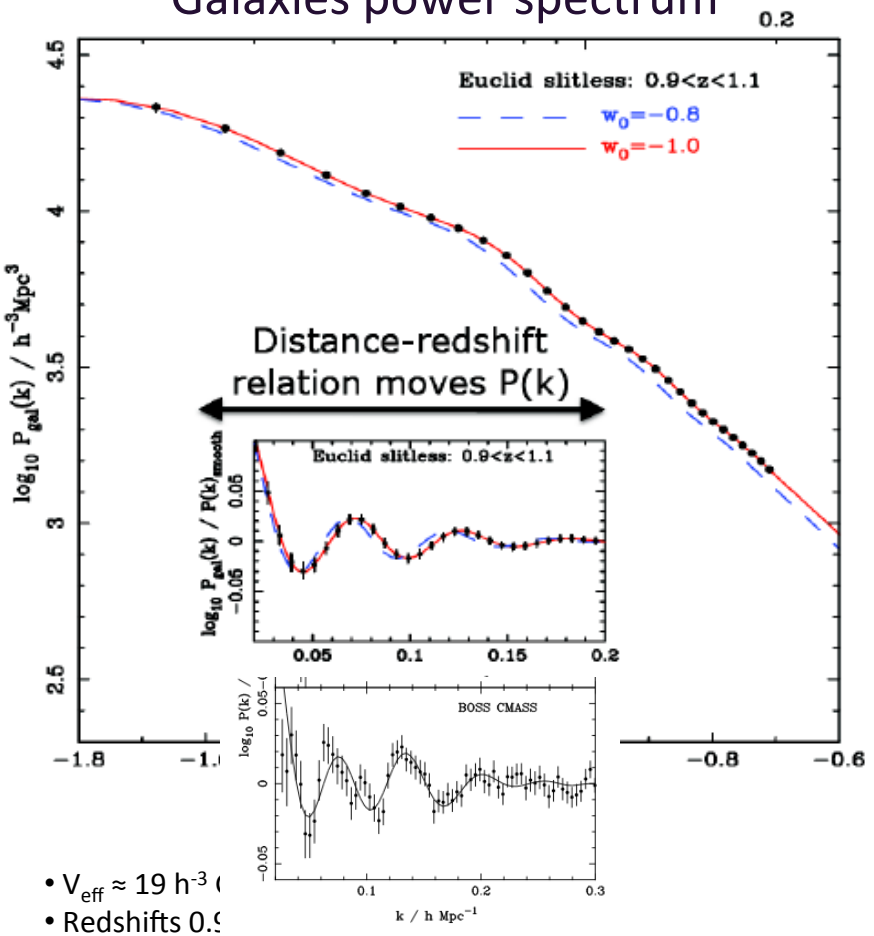
Euclid: Combining WL and GC power spectrum

Dark matter power spectrum



- Tomographic WL shear cross-power spectrum for $0.5 < z < 1.0$ and $1.0 < z < 1.5$ bins.
- Percentage difference [*expected* – *measured*] power spectrum: recovered to 1% .

Galaxies power spectrum



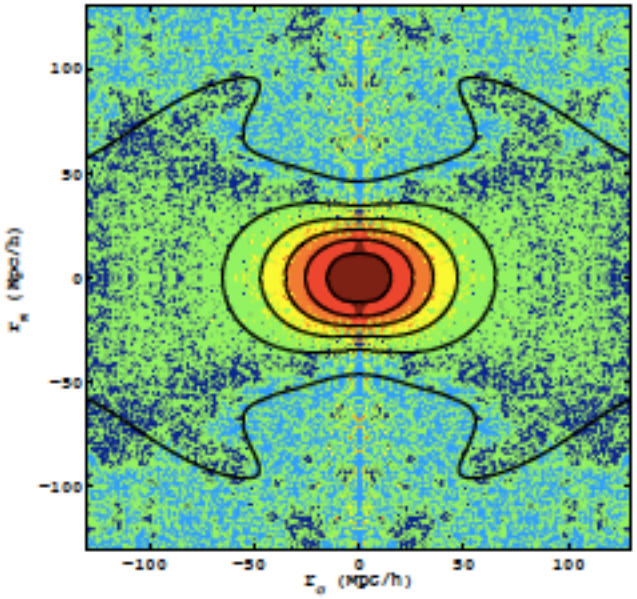
- $V_{eff} \approx 19\ h^{-3}$ (
- Redshifts 0.9

- Percentage difference [*expected* – *measured*] power spectrum: recovered to 1% .

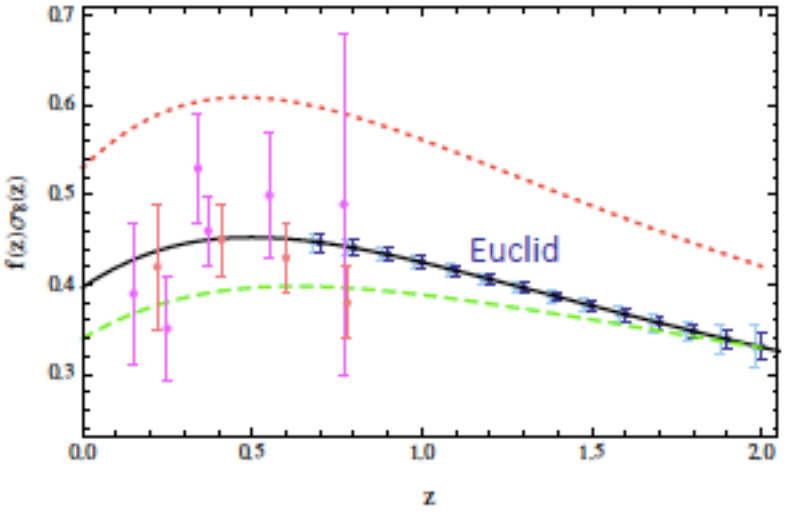
LSS and clustering … beyond BAO

RSD constraints modified gravity

Current and EUCLID measurements of the growth rate *f*



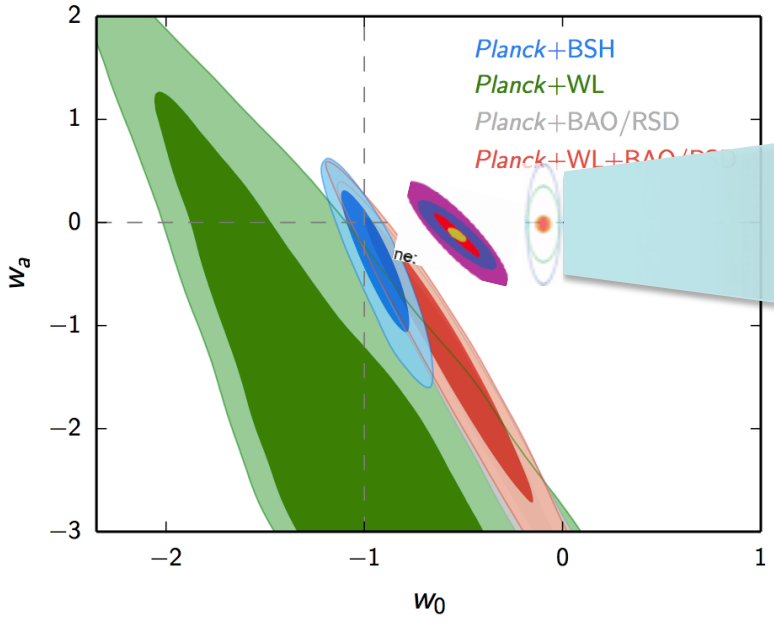
(BOSS, Reid et al. 2012)

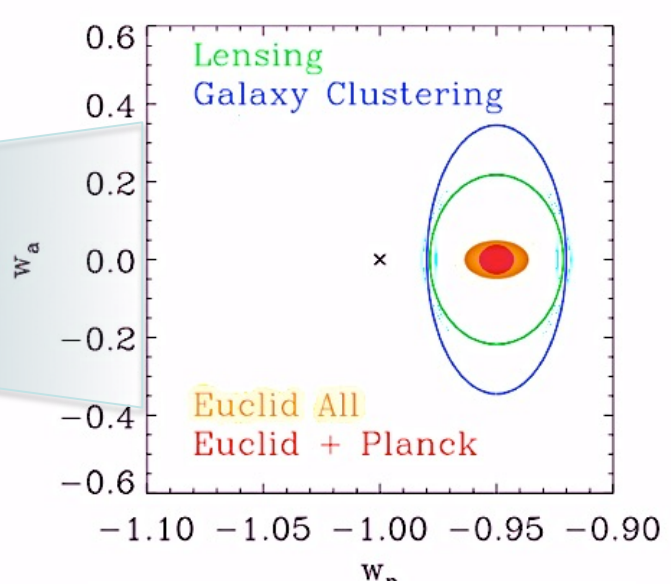


(EUCLID forecast, Majerotto et al. 2012)

Ultimately… need to combine all probes….

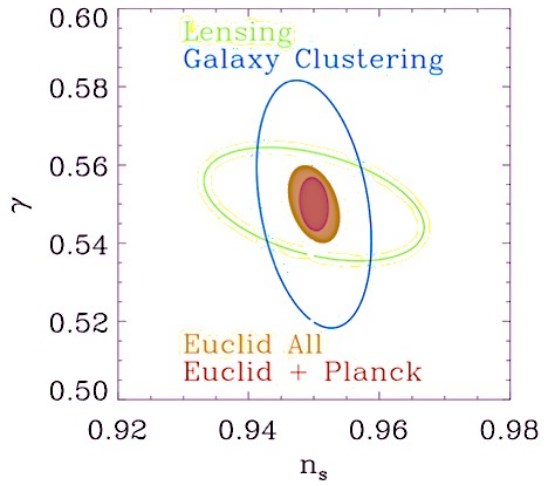
Planck coll 2015.





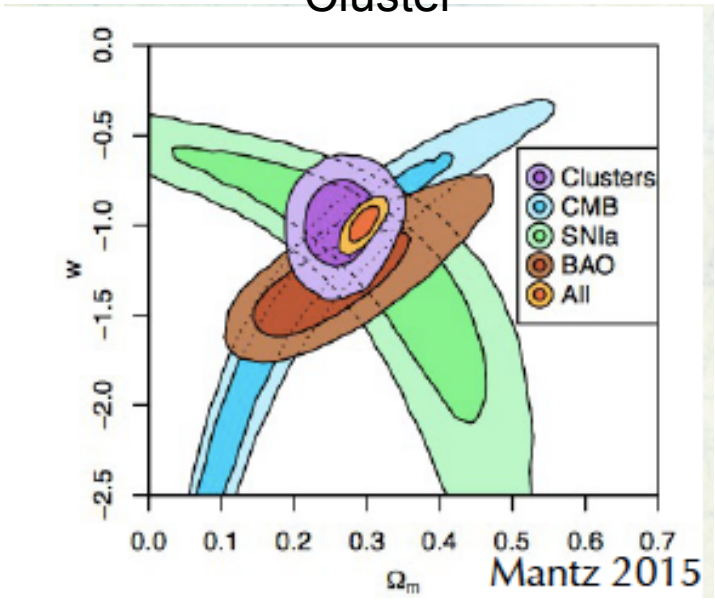
$f \sim \Omega^{\gamma}$; $\gamma = 0.55$?

The growth rate well described by $f(z)=\Omega_m(z)^{\gamma}$.

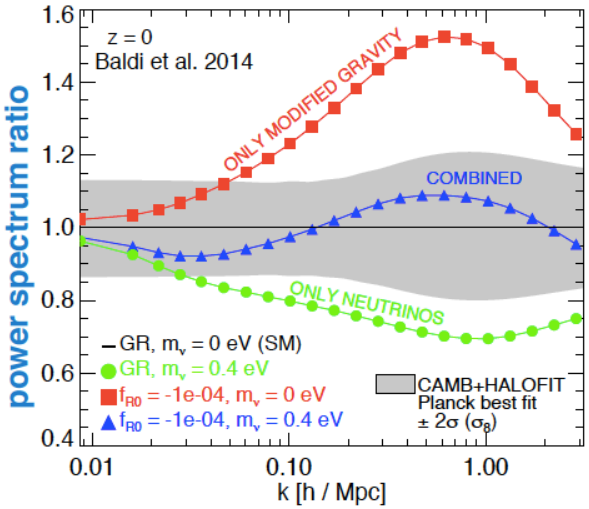


..Many other probes, and many other sciences

Cluster



Neutrinos



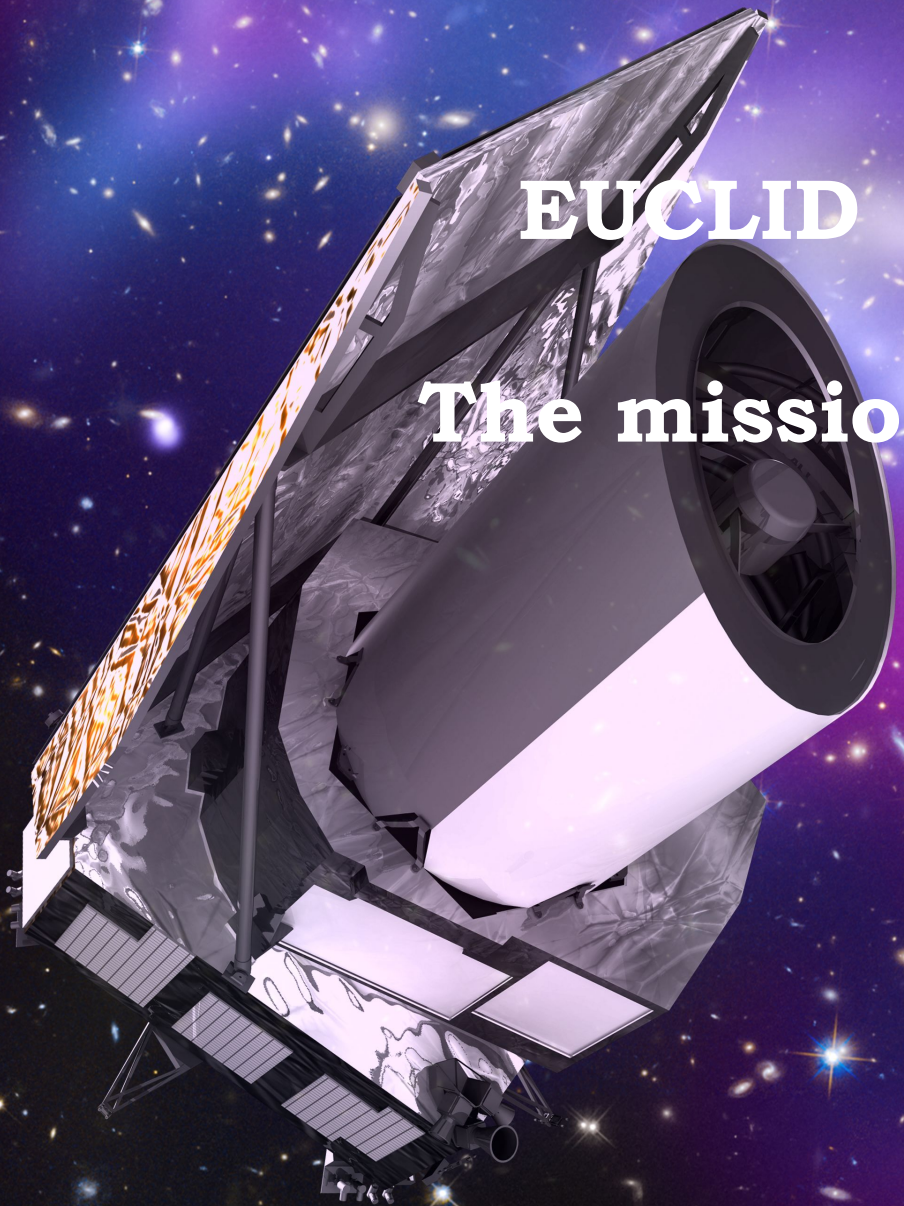
baldi 2015

And…. many other cosmology/legacy sciences from billions of objects and for thousand of scientists :

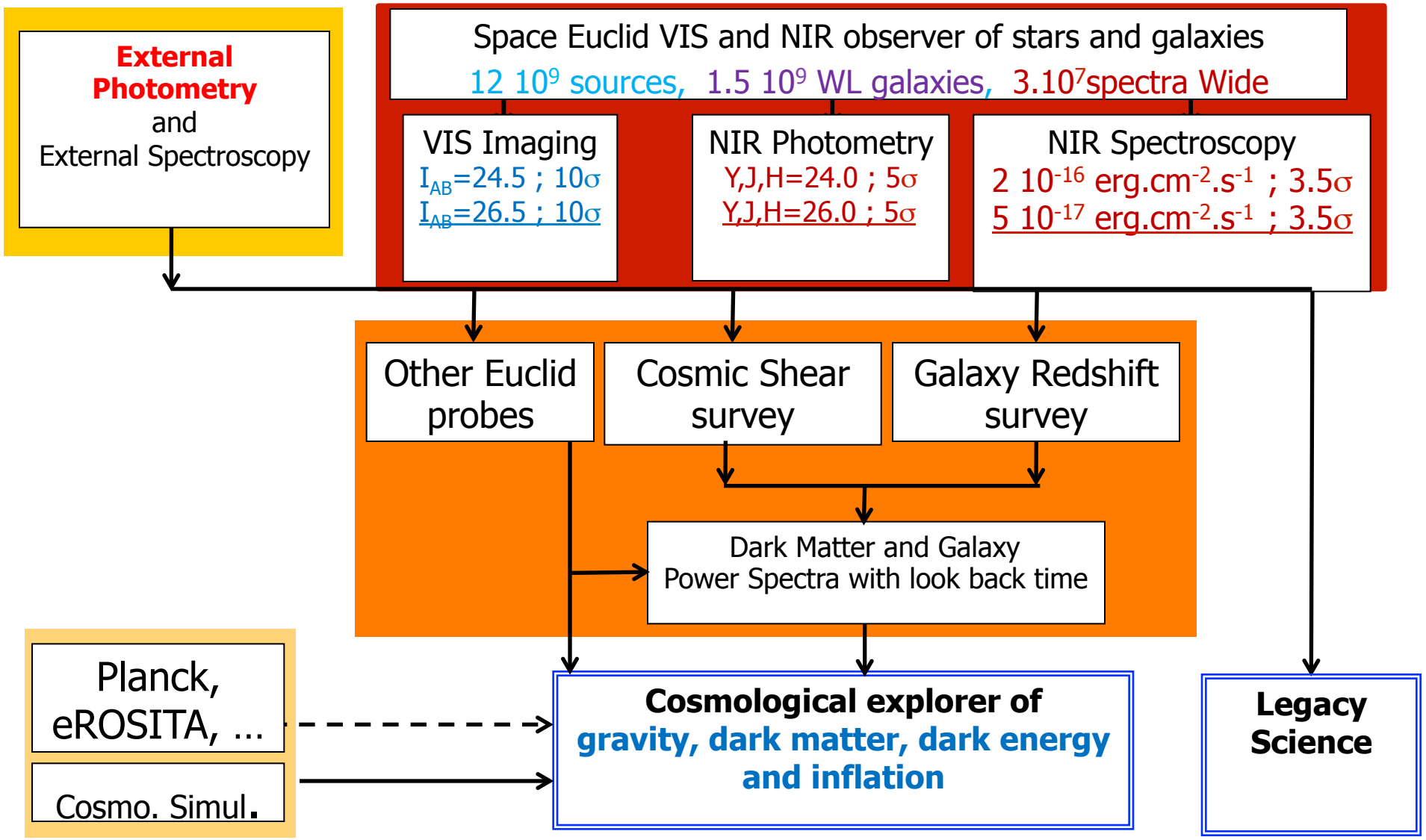
Strong lensing, Voids, Galaxy evolution, First objects , Stars , Transients etc etc ….

EUCLID

The mission



Euclid Survey Machine: 15,000 deg^2 + 40 deg^2 deep

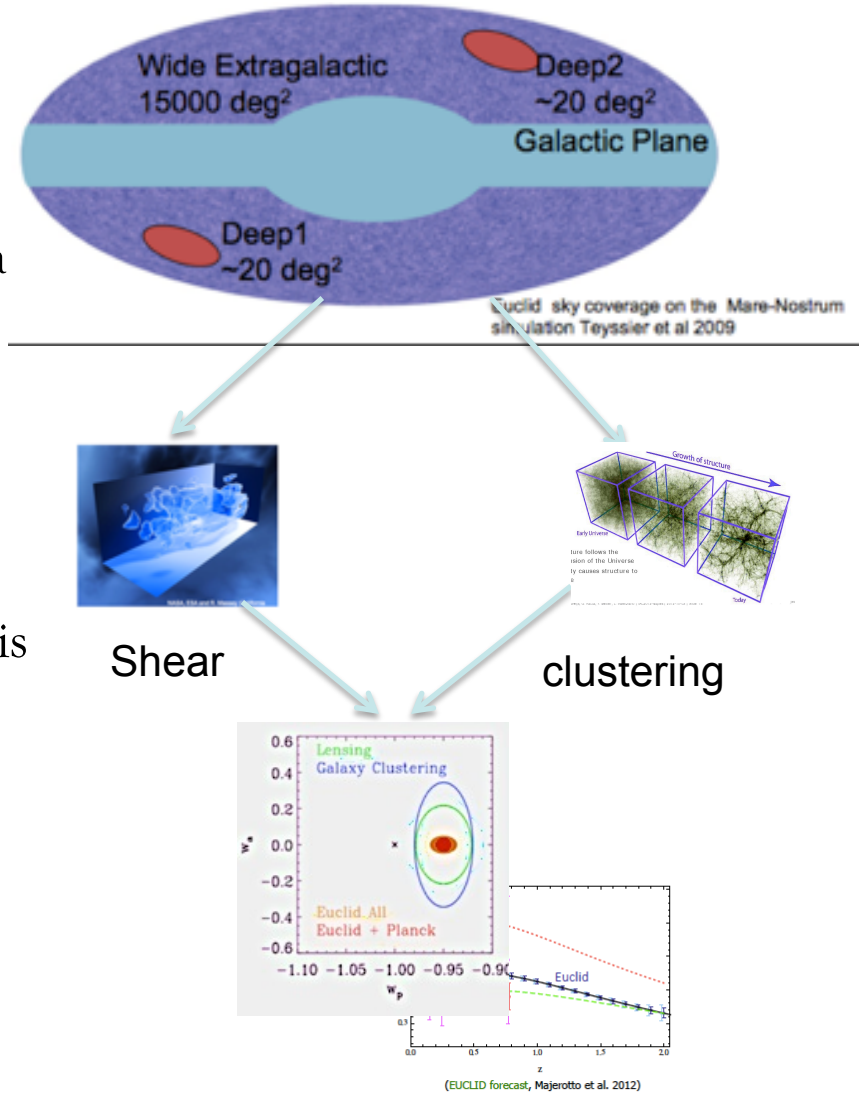


Euclid: an ESA space mission

- Euclid is an ESA mission with a strong scientific consortium

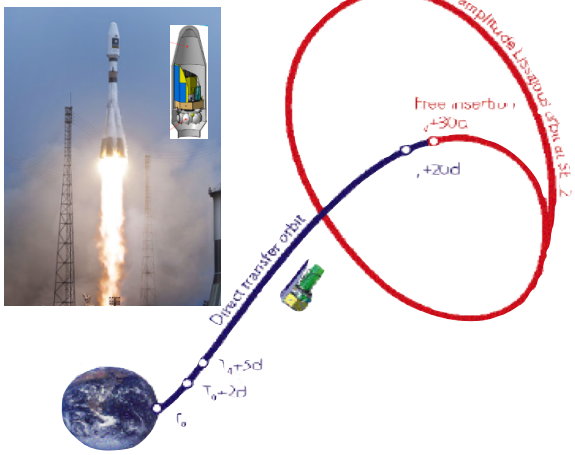
- ESA provides the telescope and detectors (via industry), the satellite, launch and operation centers
- Countries provide the 2 instruments (VIS and NISP) and the ground segment (SGS)

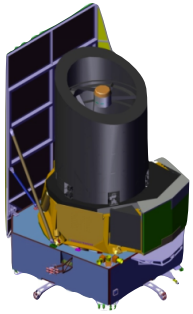
- The ground segment and related computing is a very expensive and challenging aspect of the project



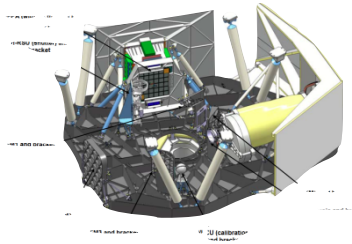
The ESA Euclid mission in one view

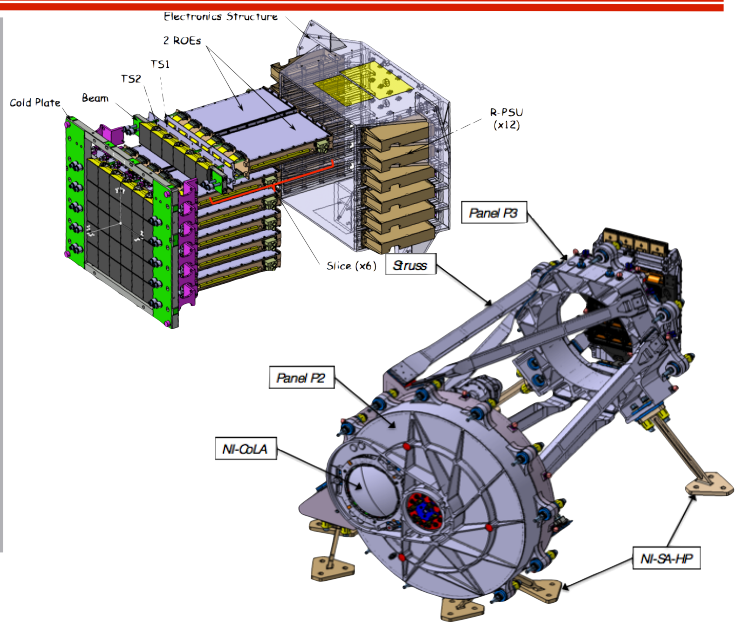
Soyuz@Kourou Q4 2020

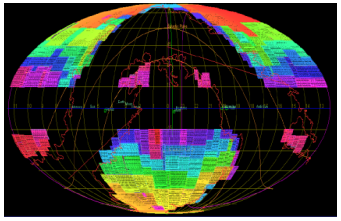


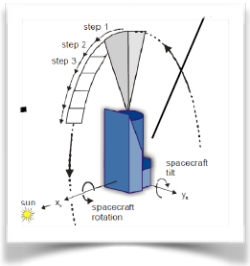


⌀ 1.2m





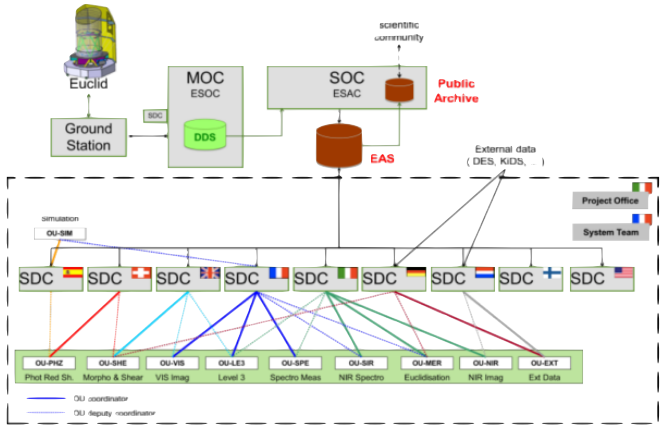




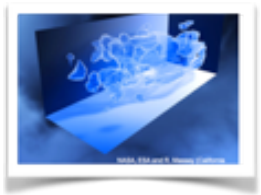
Survey:
6 years - 15000 deg^2

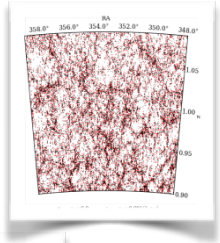
Ground-based photometric and spectroscopic data

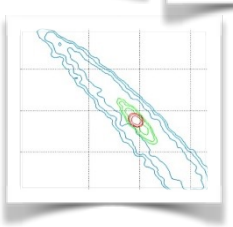
Science Ground Segment (data processing)



Science Working Groups Cosmology and legacy analysis

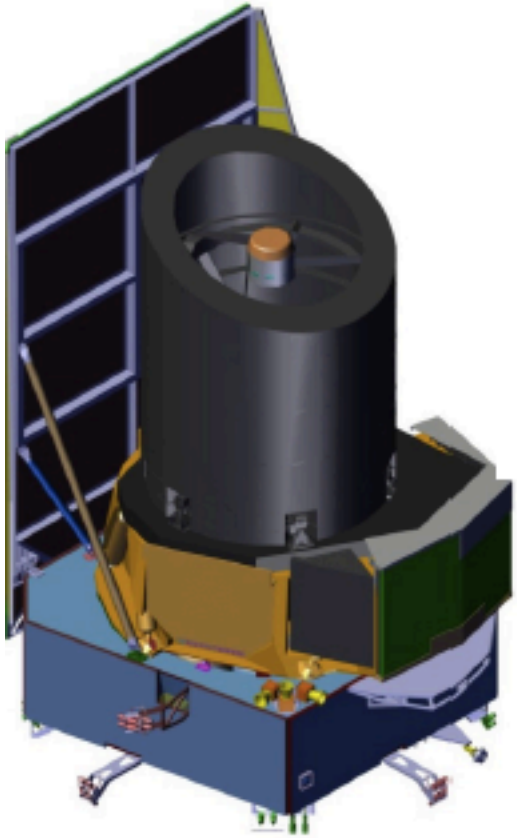


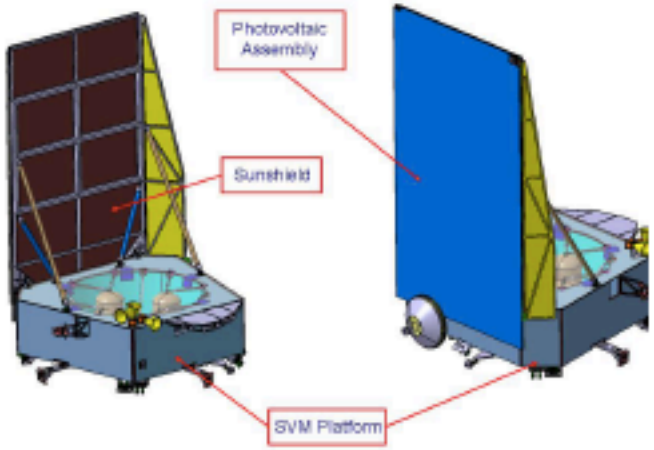


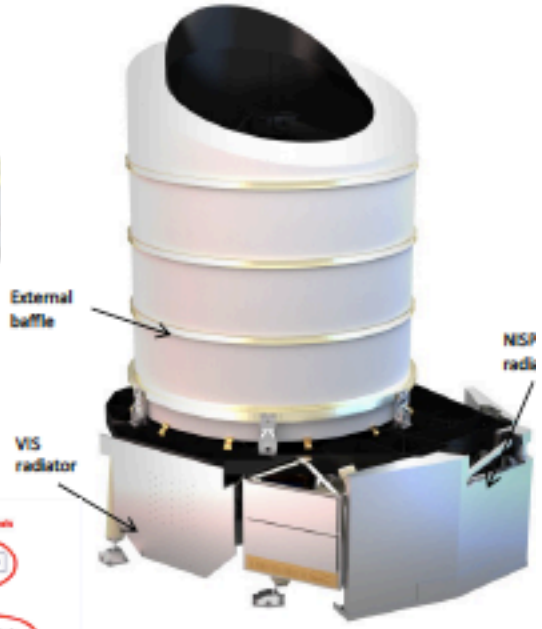


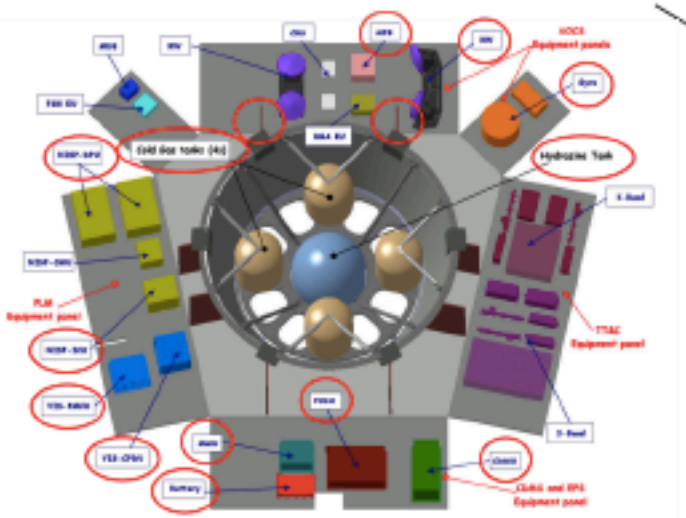
Euclid – Spacecraft Configuration

From Thales Alenia Italy, Airbus DS, ESA Project office and Euclid Consortium









- Télescope 1,2 m: FoV: 0.54 deg^2
- Miror in Silicon Carbide= ultra-stable:

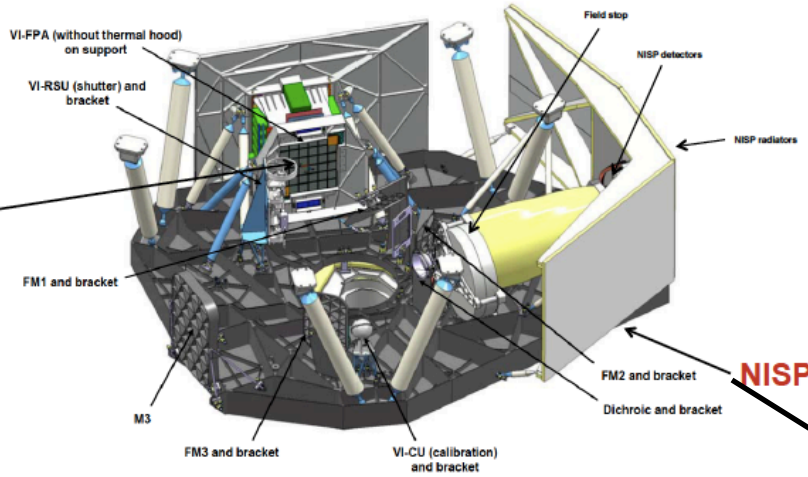
Temp.: -150 deg. Stability +:- 0.05 deg.

- Total mass satellite :

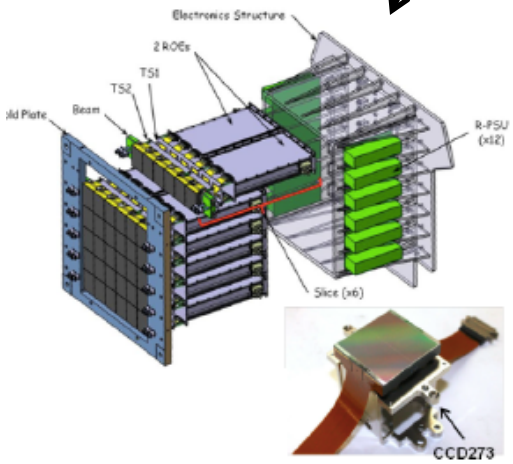
  2 200 kg
- Dimensions

  4,5 m x 3m x 3 m

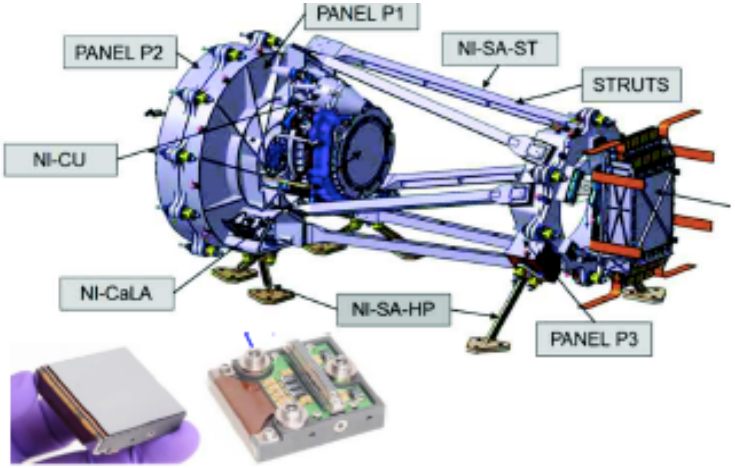
The instruments



Common VIS and NIR FoV = 0.54 deg²

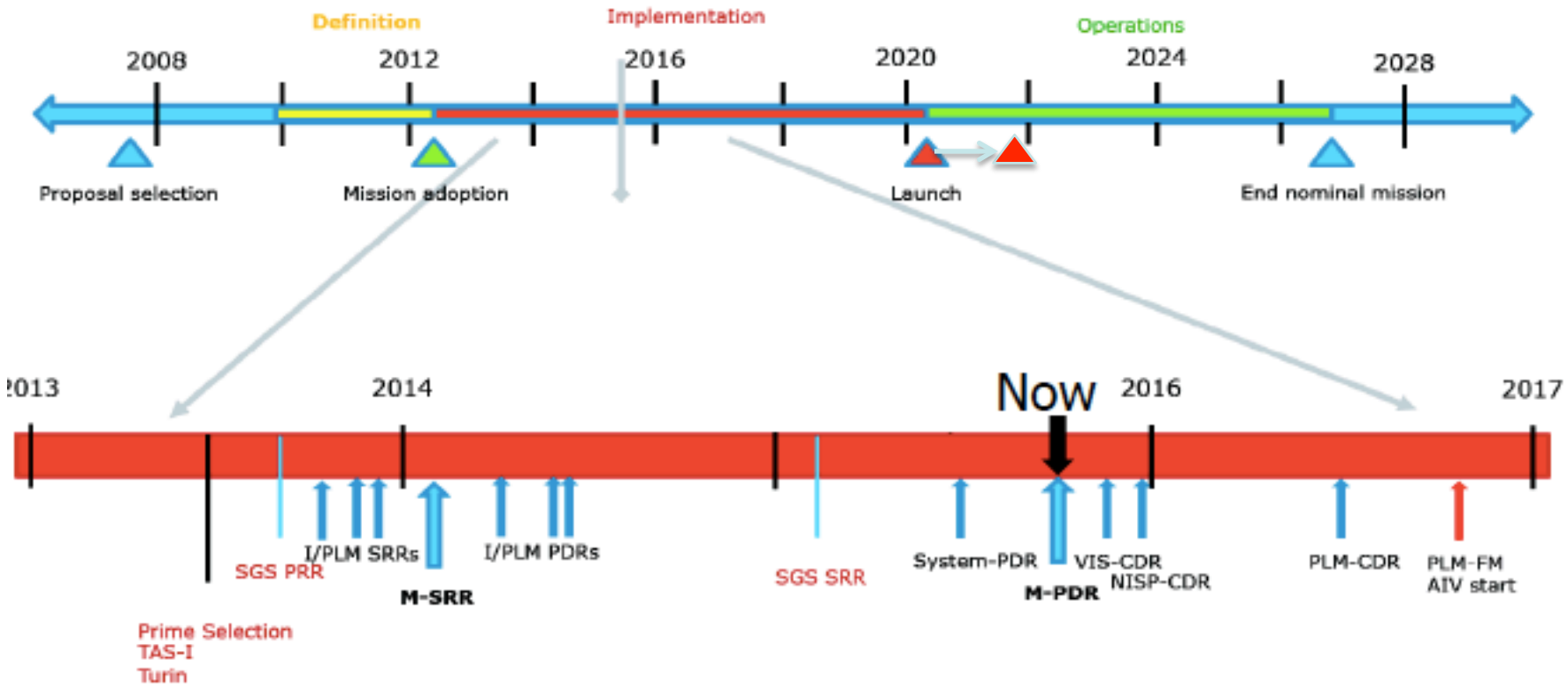


36 CCDs,4kx4k, 12 micron pixels
0,1 arcsec pixel on sky
1 filter Y(R+I+Y)
Bandpass 550-900 nm
Data volume 520 Gbit/day
Mass 135 Kg



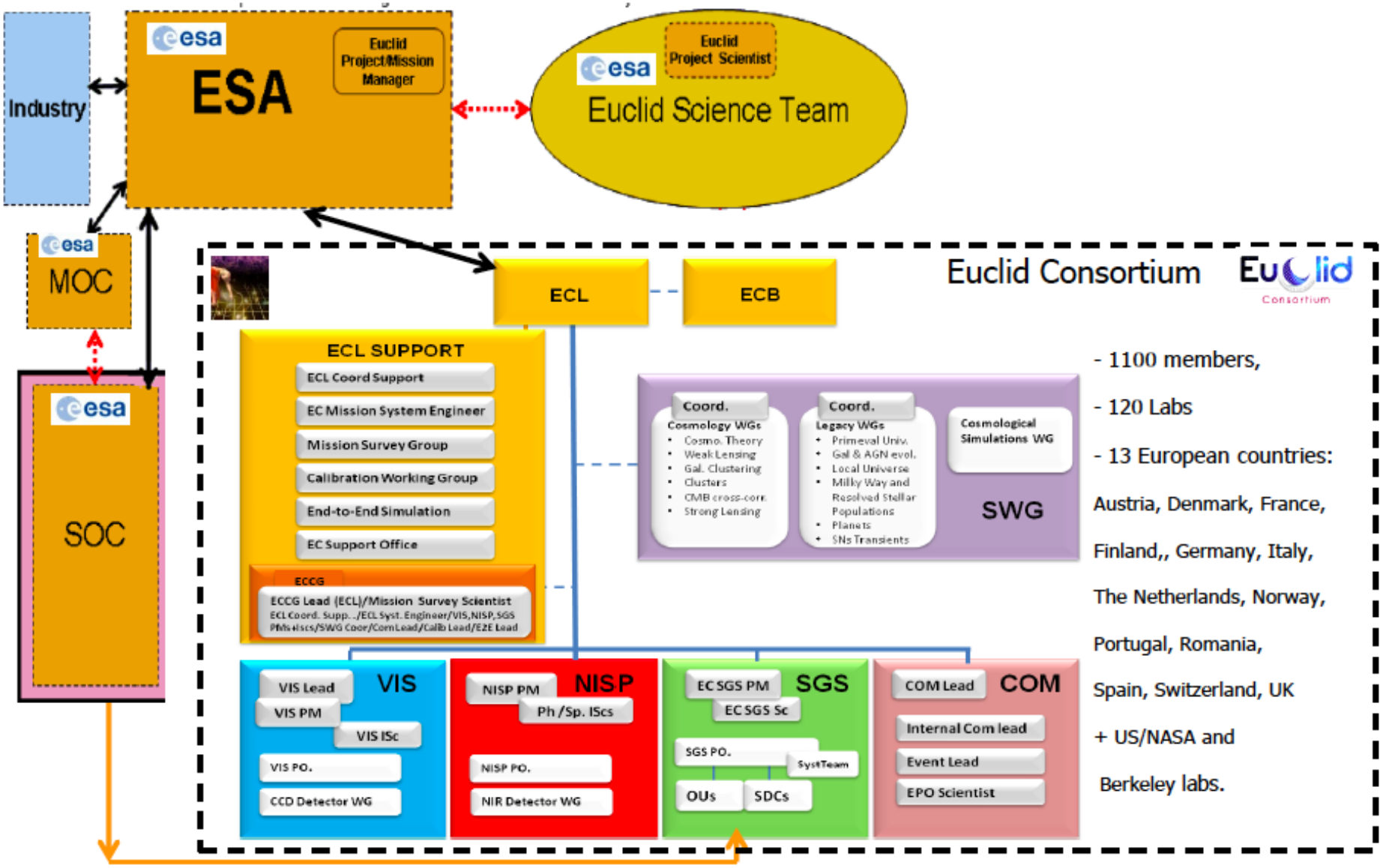
16 2kx2k, H2RG, 18 micron pixels
0,3 arcsec pixel on sky
3 filters Y,J,H
4 grisms 1B(920-1350),3 R(1250-1850)
Data Volume 290 Gbit/day
Mass 159 Kg

Euclid schedule

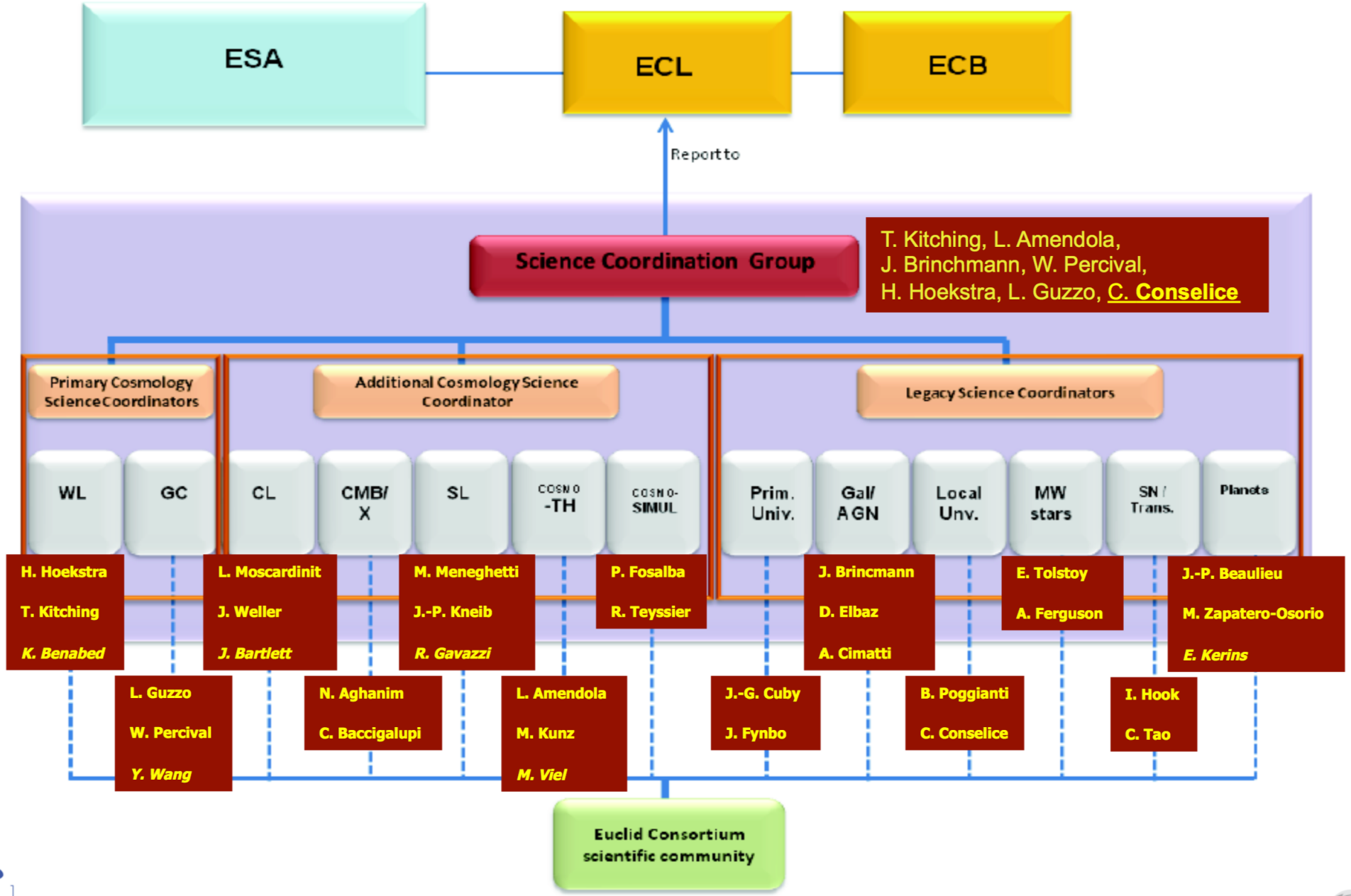


The mission PDR has just ended. No major issues. CDR expected in 2016.

Euclid: organisation

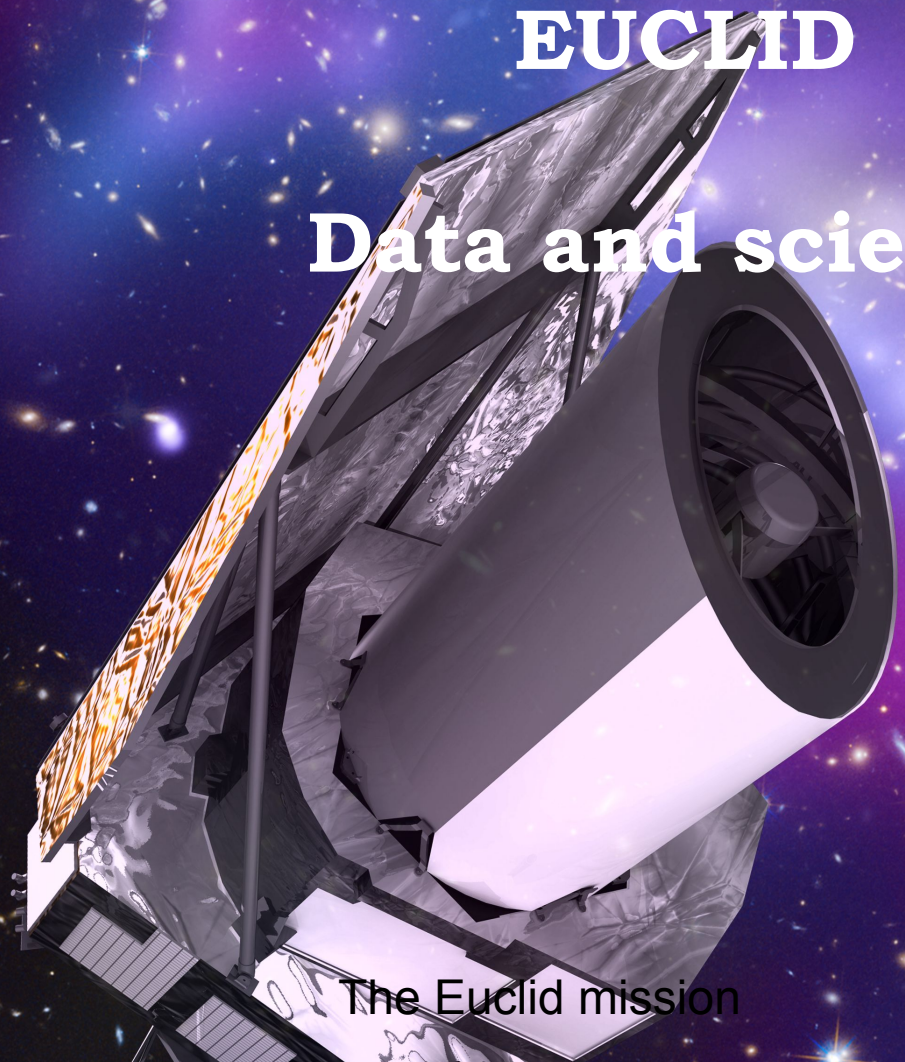


The Euclid science organization

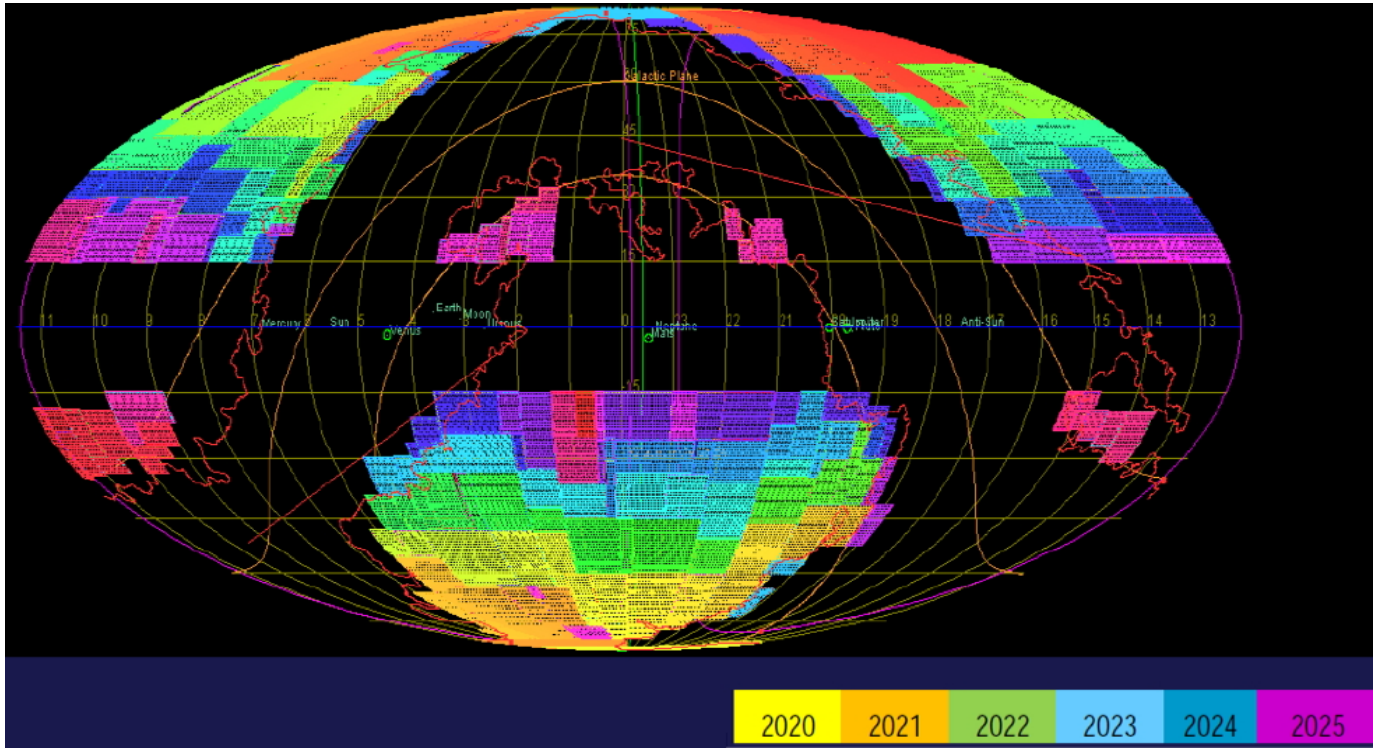


EUCLID

Data and science



The Euclid survey



Euclid is a cosmological survey mission, but unlike CMB experiments, it will only do its survey once!

Survey strategy is constrained by the number of times we can point the satellite!

VIS:
- Imaging
- 36 4k x 4k CCD
- 0.54 deg^2 per field
- 0.1” pixels on the sky
- limiting magnitude: 24.5 AB @10σ
- 520 Gbit/day

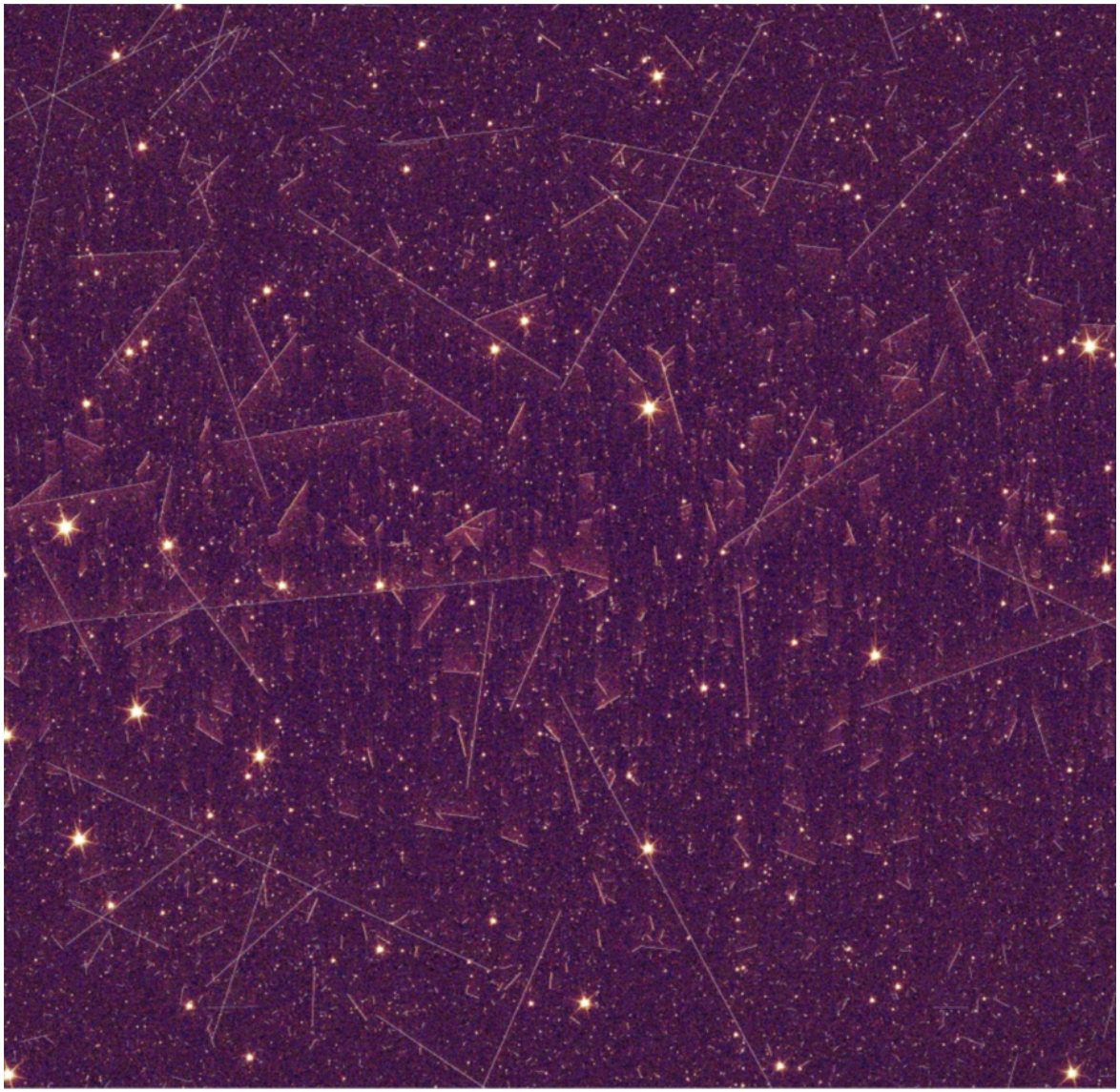
NISP:
- Imaging and slitless grism spectroscopy
- 16 2k x 2k NIR arrays
- 0.55 deg^2 per field
- 0.3” pixels on the sky
- limiting magnitude: 24 AB @5σ
- 240 Gbit/day

Visible and infrared imaging, as well as infrared spectroscopy are obtained “simultaneously”

VIS imaging

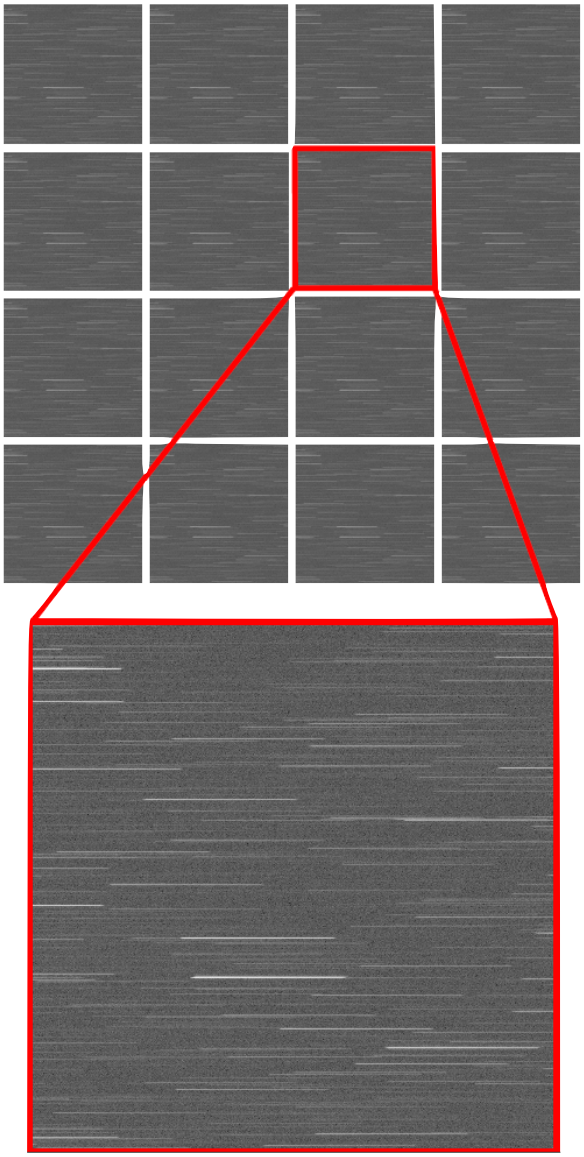
A simulated 4k x 4k view of the Euclid sky

VIS image: cuts made to highlight artefacts

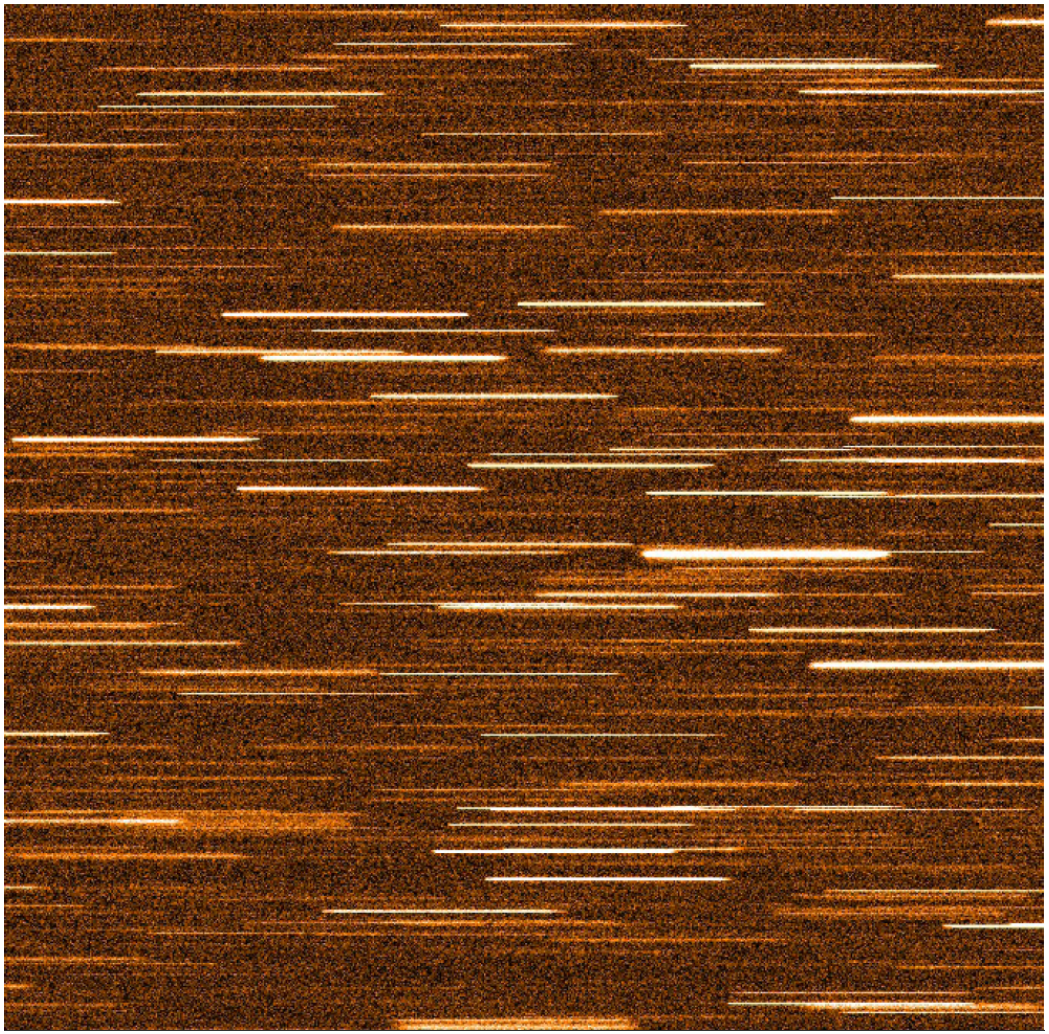


Courtesy: Mark Cropper, Sami M. Niemi (VIS)

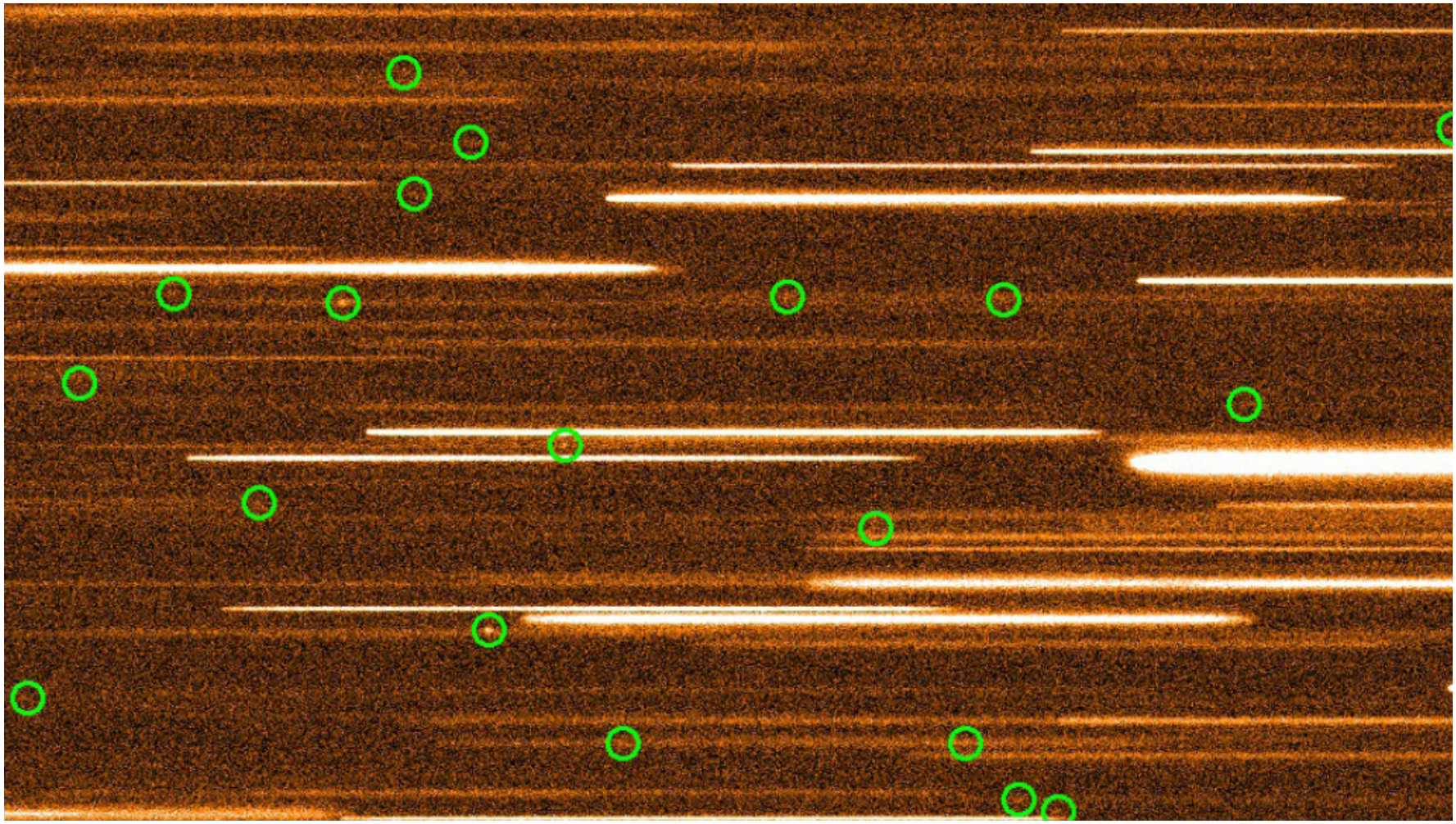
NISP spectroscopy



2015 simulations from P. Franzetti, B. Garilli, A. Ealet, N. Fourmanoit & J. Zoubian



NISP spectroscopy



Circles highlight the presence of emission lines (Hα) in the spectra

From P. Franzetti & B. Garilli

Euclid challenges

Shape measurements/systematics

Control of both multiplicative and additive biases

Photometric redshifts:

Ground based photometry in 4 bands : 15,000 deg^2 (i.e. north and south)

Numerical simulations with power spectrum to a 1% accuracy :

Resolution

Underlying physics: e.g. numerical simulations with baryons

Numerical simulation of a large number of DE, GR models

10^3 to 10^5 simulations to estimate covariance matrices

High order statistics:

Potentials of high order statistics for DE science + Systematics

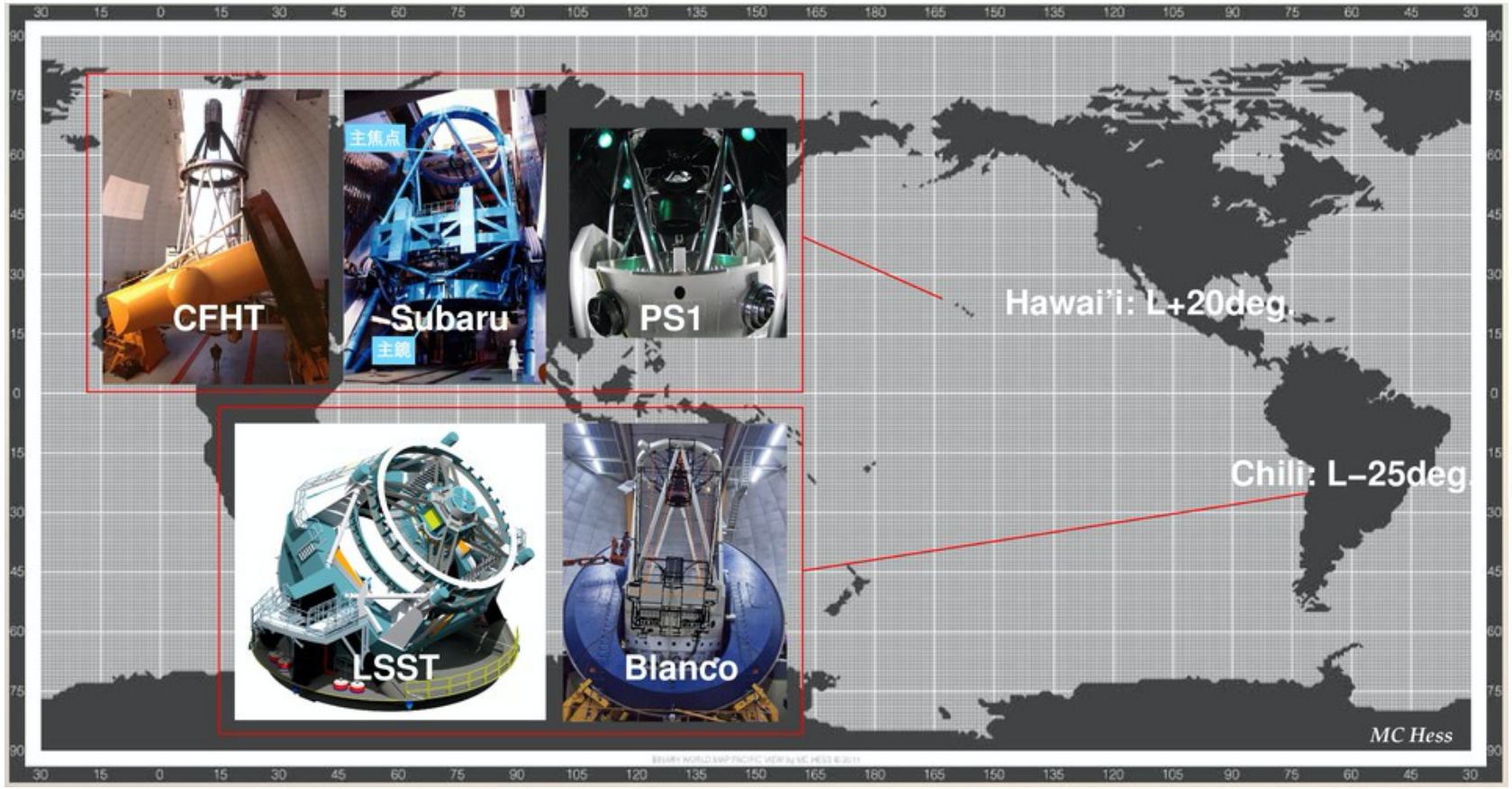
Need Spectroscopics surveys to

Calibrate deep photo-z and

Understand BAO and RSD samples

External photometric surveys

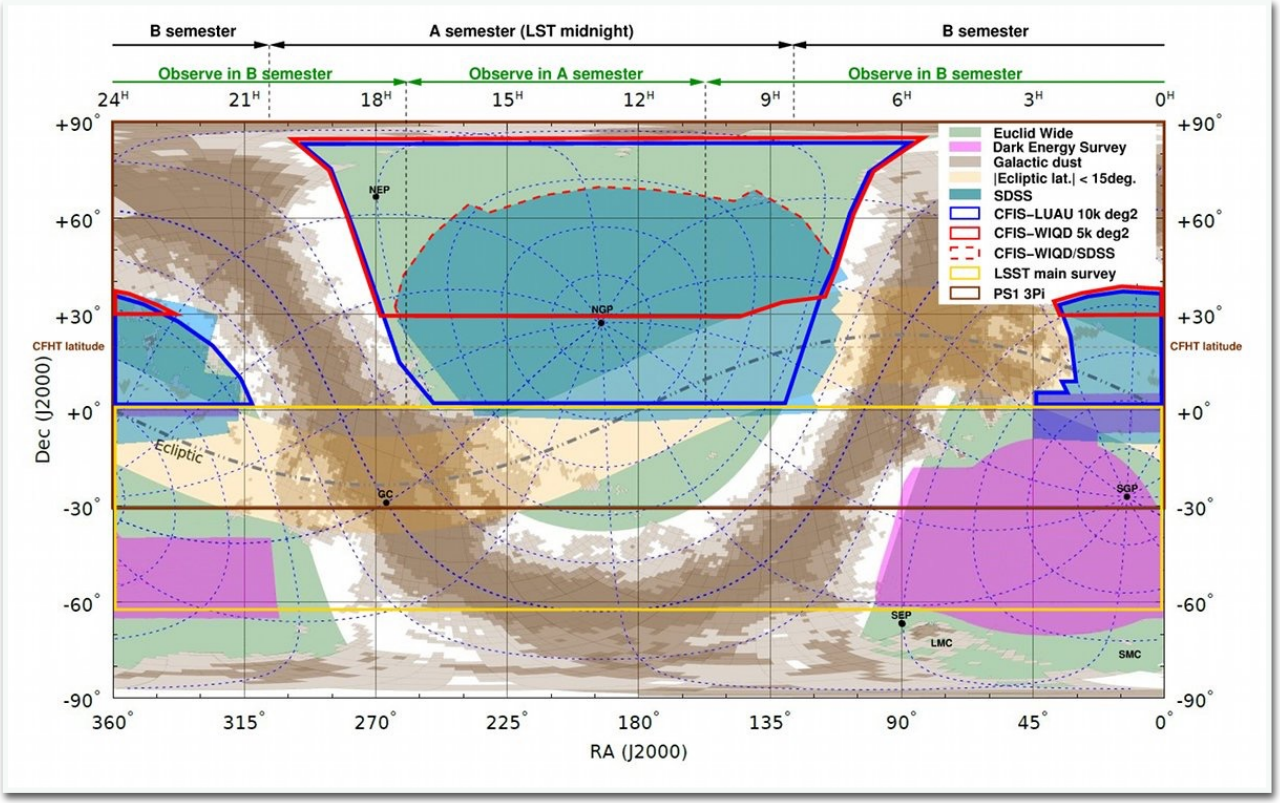
- **The Euclid Weak-Lensing probe cannot reach its objectives without accurate photometric redshifts.**
  - **Space data are not enough to reach this accuracy**



Wide-field imagers across the world are required to build the ground-based complement

External photometric surveys

- **The case of the Southern hemisphere is clear:**
  - **DES and KIDS-VIKINGS data will be part of the Euclid data base, source photometry will be released with the Euclid catalogs.**
  - **LSST is contemporaneous with Euclid. A collaboration is in the works to produce a joint photometric redshift catalog.**
- **The case of the Northern hemisphere is undecided yet:**



- A proposal for a CFHT large program is being made: the CFIS.
- This proposal identifies autonomous science that can be performed without the Euclid data.
- Data from this proposal will become public before Euclid's launch.
- *This is only a first step.*

External spectroscopic surveys

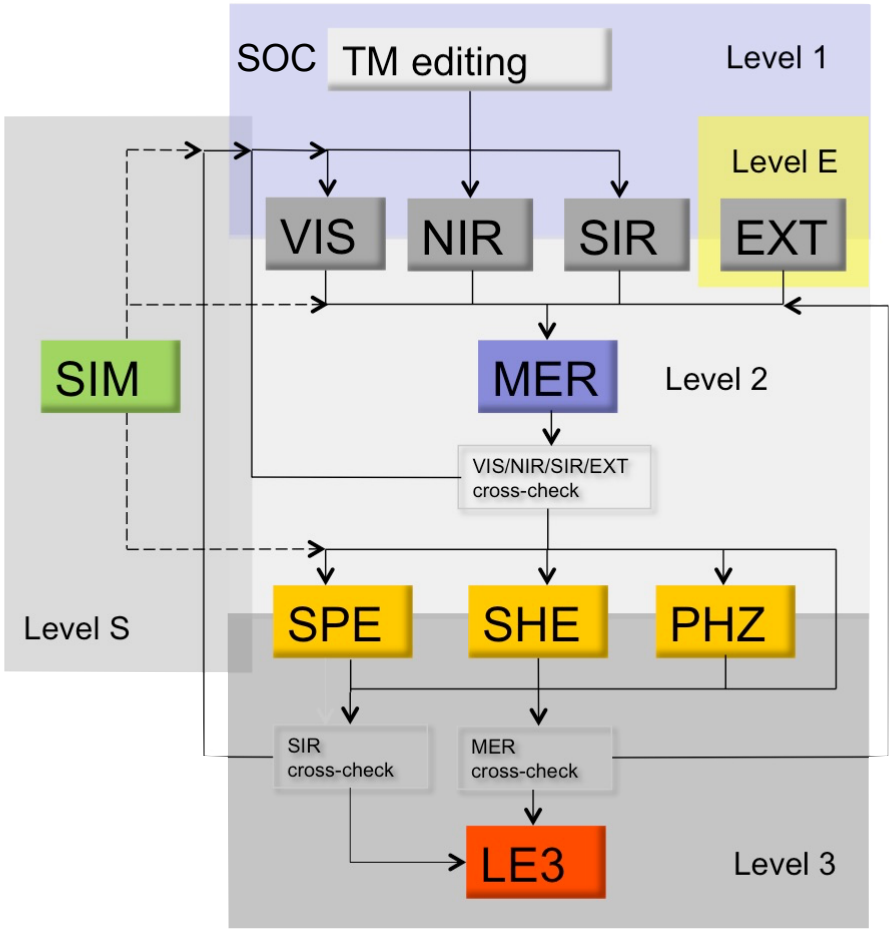
- The Euclid Weak-Lensing probe needs to perform tomography, hence the need for photometric redshifts.
- The accuracy of the mean redshifts per tomographic bin is so high that we need to "calibrate" that with spectroscopic redshifts.
- The spectroscopic Euclid data is not suitable for this (bias toward star forming galaxies).
- We are launching a series of ground-based programs to collect spectra for objects covering the whole color range accessible to Euclid.
  - Includes existing surveys
  - Latest addition is Keck time for spectroscopy.
- We expect to populate the Euclid archive with 10^3-10^4 spectra coming from significant facilities (4-8m class telescopes).

Euclid data processing and release

- Euclid data processing is the responsibility of the Science Ground Segment.
- The SGS will not produce measurements of the Dark Energy EoS, or any statement regarding alternate theory of Gravitation.
- The SGS will not produce statements regarding Galaxy Evolution or the Primordial Universe.
- However, the SGS is tasked with turning the measurements made by Euclid (wide-field photometric exposures and slit-less grism exposures) into data products from which the above results can directly be extracted.
  - Correlation functions, power spectra (and associated "errors") for shear and positions.
  - Source catalogs containing, photometry, spectroscopy (lines and fluxes), redshifts (photometric and spectroscopic), shapes (ellipticities, morphologies), *physical parameters* (for legacy studies).

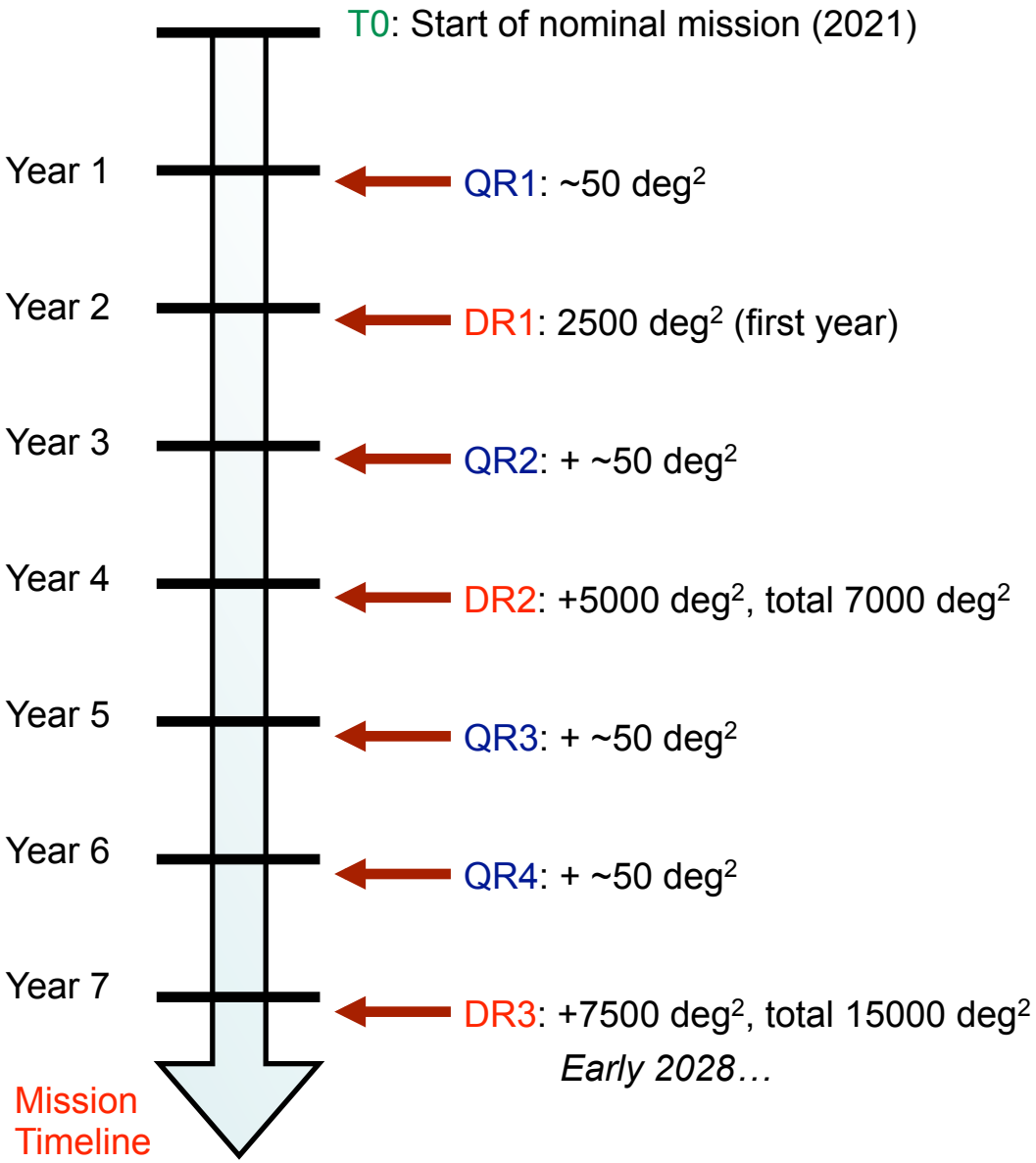
This is the "science" part of the SGS task, data product interpretation is the task of the Science Working Groups in the Euclid Consortium

Steps in data processing



- 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.

Euclid data release schedule



QR: Quick Releases

- No cosmology relevant data products.
- Focussed releases (e.g. highly observed sky fields, catalogs of objects).

DR: Data Releases

- Full release of the Euclid pipeline data products.
- Validated by Science Working Groups (accompanying papers).
- Cosmology relevant.
- Will contain ground-based data but do not supersede actual releases by ground-based teams.
- DR1: first year of data delivered at end of year 2.
- DR2: first 3 years of date delivered at end of year 4.
- DR3: all data delivered 1 year after the end of the survey.

products

SGS Management Plan

Level 1 data:

- Raw VIS and NISP images
- Processed housekeeping telemetry and associated ancillary information such as pointing history files

Level 2 data:

- Calibrated and co-added images from VIS and NISP – validated for cosmology analysis
- PSF model and optical distortion maps
- Co-added spectra

Level 3 data:

- Catalogues (including redshift, ellipticity, shear, etc)
- Dark matter mass distribution
- Shear and galaxy correlation functions and covariance errors
- Additional science catalogues
- Ground based information which was used in the derivation of the data products

Euclid : The french participation

France is a main actor, with 30% of the country contributions

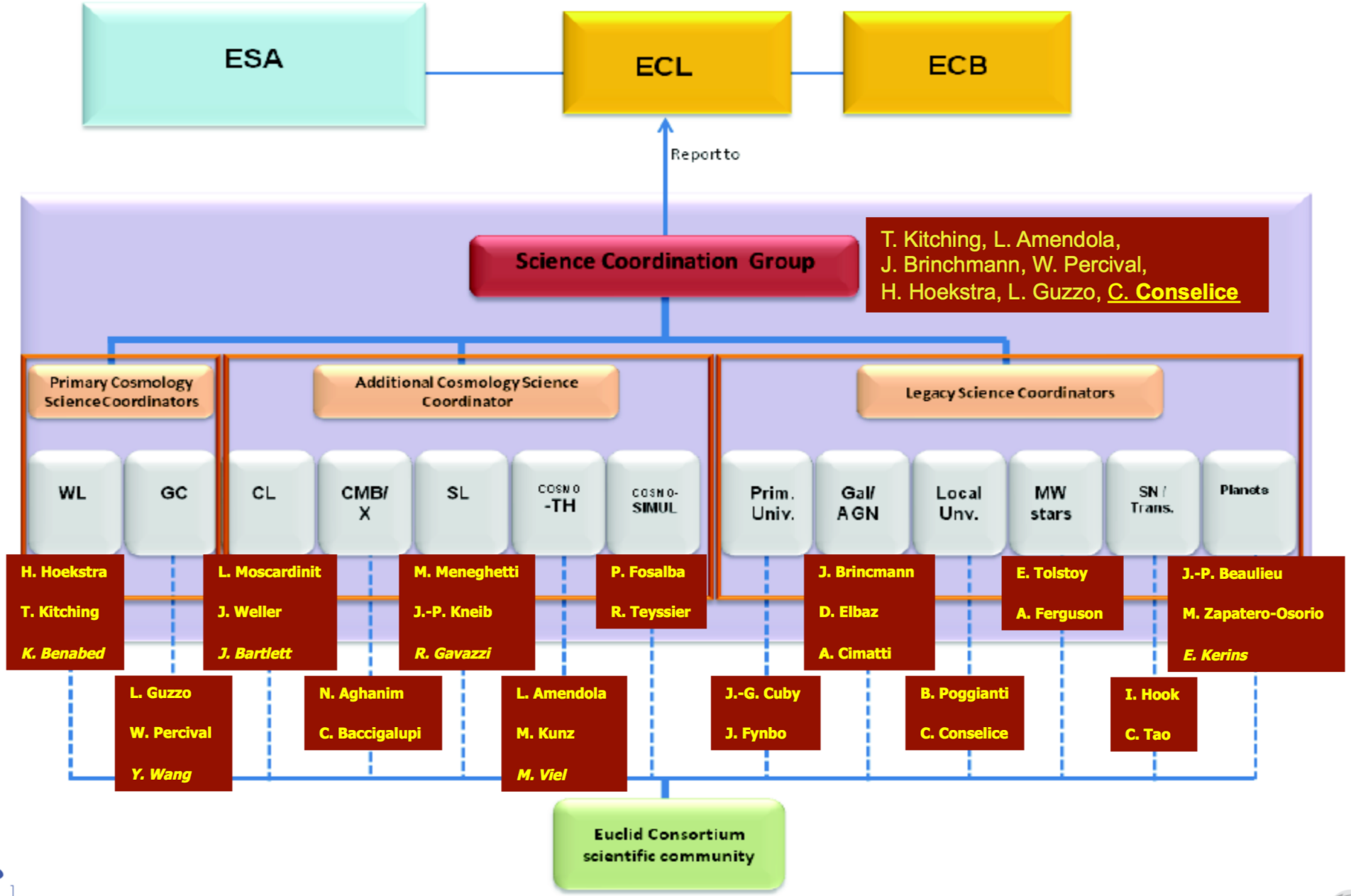
> 250 french members, INSU,IN2P3 and IRFU.

- More than 10 laboratories
  - INSU: IAP, IAS, LAM, IRAP, Lagrange
  - IN2P3: APC, CPPM, IPNL, LPSC, LPNHE
  - CEA/Irfu
  - CC IN2P3

- Very high level of french responsabilities:
  - Lead consortium (Y.Mellier, INSU)
  - Lead NISP instrument (CNES,INSU,IN2P3)
  - Lead of VIS focal plane (IRFU)
  - Scientist of the ground sgment (IRFU)
  - Lead of the SGS system team (CNES)

- A strong CNES support and participation

The Euclid science organization



The scientific organisation

- Science is prepared and developed through the science working groups (SWG, about 15 groups).
  - At this stage the SWGs are identifying the topics they plan to address, and are turning them in work-packages (WP).
- Participation to SWG is based on individual choices: Euclid members can propose to participate or lead a work package (WP) inside the SWGs.
- The SWG WP leads are chosen from existing expertise : need to be an expert and to dedicate enough time to have visibility!

- There a deficit of French scientists in SWGs and of French leads !!

French scientific organisation

The Euclid-France group has decided to promote a French Euclid coordination group to prepare a scientific roadmap and increase the recognition of the French expertise in the project. This is based on 3 science priorities:

1. Cosmological probes : WL, Clustering, Clusters

2. Combination of probes : from Euclid, but also with external data such as CMB, SNe etc..

3. Galaxy formation and evolution

The French group will present the roadmap and the scientific priorities to CNRS, CNES and IRFU.

Summary

- **ESA has selected the only space mission dedicated to understand the acceleration of the expansion of the Universe.**

- **Euclid is a large consortium (more than 1000 members!) where France has an executive leadership.**

- **Euclid includes strong contributions from all national agencies IN2P3, INSU, CEA and is supported by the space agency CNES making France the largest contributor to the mission.**

The science preparation is starting and we need to build a strong expertise and an efficient organization prior to the launch.

Euclid : a fantastic projects for the next generation of scientists

We need to be prepared to explore Dark Energy and the matter of the Universe in the next decade