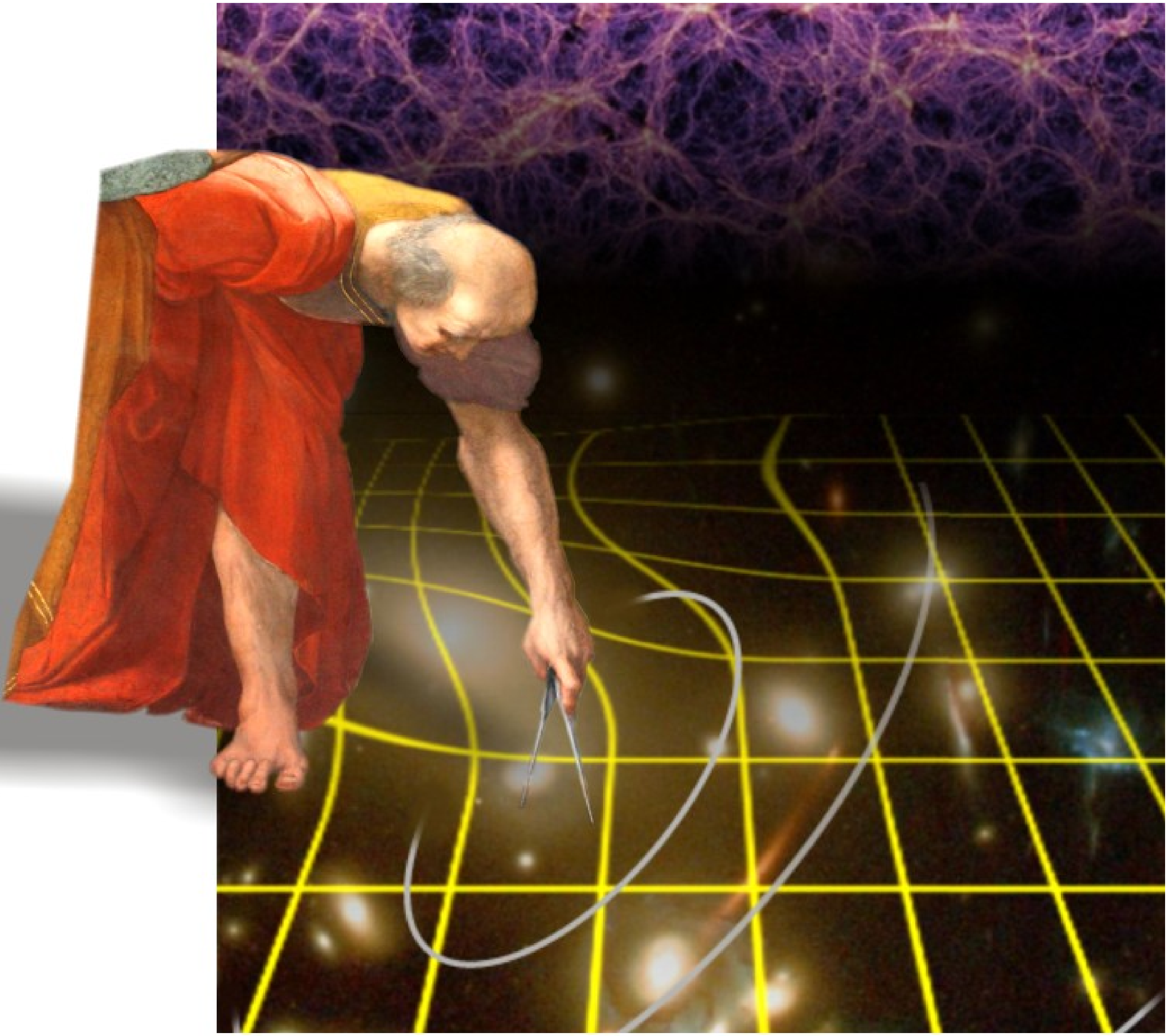


Euclid

Y. Mellier
On behalf of the Euclid Consortium

http://www.euclid-ec.org

Euclid main scientific objectives

- Understand the origin of the Universe's accelerating expansion and
- Probe the properties and nature of dark energy, dark matter, gravity
- Distinguish their effects decisively

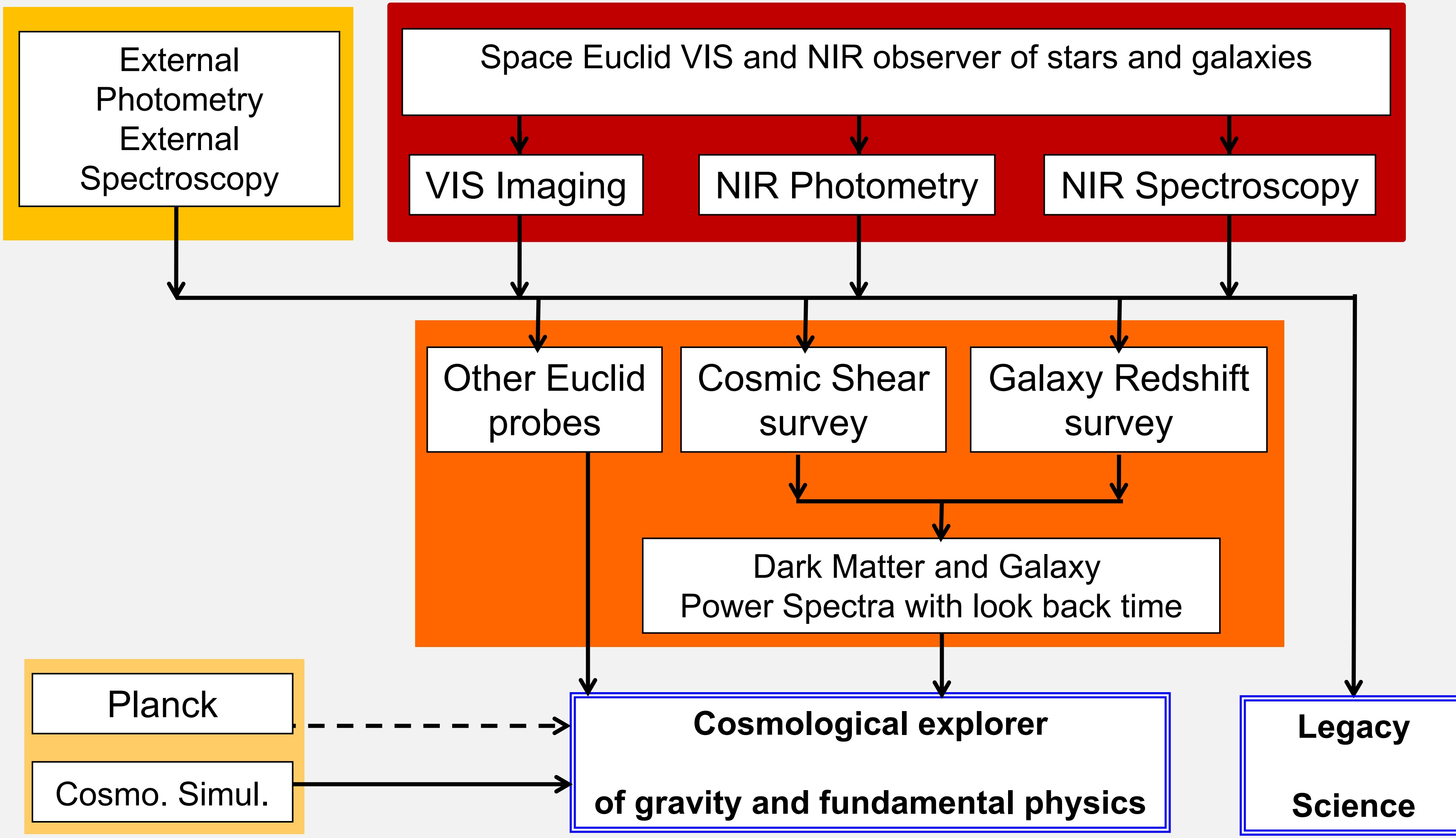
Euclid main scientific objectives

- Understand the origin of the Universe's accelerating expansion and
- Probe the properties and nature of dark energy, dark matter, gravity
  - from the measurement of the cosmic expansion history and the growth rate of structures.

- Distinguish their effects decisively by:
  - Using at least 2 independent but complementary probes
  - Tracking their observational signatures on the
    - geometry of the universe: Weak Lensing (WL) and Galaxy Clustering (GC)
    - cosmic history of structure formation: WL, Redshift-Space Distortion, clusters of galaxies
  - Controling systematic residuals to an unprecedented level of accuracy.

The Euclid Machine

Euclid Consortium



WL and GC with Euclid: optimal to meet top requirements

Weak lensing (WL) :
two-point 3-D cosmic shear over 0<z<2
shapes of galaxies + *photo-z* : shear amplitude, tomography
→ distribution of matter (dark+lum.), expansion history, growth factor: $\Psi+\Phi$.

Galaxy clustering (GC) :
two-point 3-D positions over 0<z<2
3-D distribution of galaxies from imaging + *spectro-z*
→ clustering history of galaxies induced by gravity: Ψ , γ, $H(z)$.

GC <u>and</u> WL :
different data, complementary physical effects with different systematics

CG and WL are *P*(*k*,z) explorers:
→ Halos properties/density peaks: gal-gal lensing, clusters,biasing
→ both probe properties/features in *P(k,z)* → probe dark matter (neutrino) and inflation (non-Gaussianity)

The Euclid Mission: imaging, photometry, spectroscopy

SURVEYS

	Area (deg2)	Description
Wide Survey	**15,000 deg^2**	Step and stare with 4 dither pointings per step.
Deep Survey	40	In at least 2 patches of > 10 deg^2 2 magnitudes deeper than wide survey

PAYLOAD

Telescope	1.2 m Korsch, 3 mirror anastigmat, f=24.5 m				
Instrument	VIS	NISP			
Field-of-View	0.787×0.709 deg^2	0.763×0.722 deg^2			
Capability	Visual Imaging	NIR Imaging Photometry			NIR Spectroscopy
Wavelength range	550– 900 nm	Y (920-1146nm),	J (1146-1372 nm)	H (1372-2000nm)	1100-2000 nm
Sensitivity	24.5 mag 10σ extended source	24 mag 5σ point source	24 mag 5σ point source	24 mag 5σ point source	3 10^{-16} erg cm-2 s-1 3.5σ unresolved line flux
	Shapes + Photo-z of $2x10^9$ galaxies			**z of $5x10^7$ galaxies**	
Detector Technology	36 arrays 4k×4k CCD	16 arrays 2k×2k NIR sensitive HgCdTe detectors			
Pixel Size Spectral resolution	0.1 arcsec	0.3 arcsec			0.3 arcsec R=250

Top level requirements of Euclid

- Distinguish their effects *decisively*
  - Nature of the apparent acceleration

  → distinguish effects of a cosmological constant from those of a dynamical dark energy

  → *FoM*$\geq$400 from Euclid data alone.

  - Effects of gravity on cosmological scales

  → probe the growth of structure and separately constrain the two relativistic potentials, Ψ, Φ

  → absolute 1σ precision of 0.02 on the growth index, γ, from Euclid data alone.

WL +GC – FoM of the Euclid mission

	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν/eV	f_{NL}	w_p	W_a	FoM
Euclid Primary	0.010	0.027	5.5	0.015	0.150	430
Euclid All	0.009	0.020	2.0	0.013	0.048	1540
Euclid+Planck	0.007	0.019	2.0	0.007	0.035	4020
Current	0.200	0.580	100	0.100	1.500	~10
Improvement Factor	**30**	**30**	**50**	**>10**	**>40**	**>400**

These numbers have a meaning only if we can control the systematic errors

Euclid Legacy and other surveys

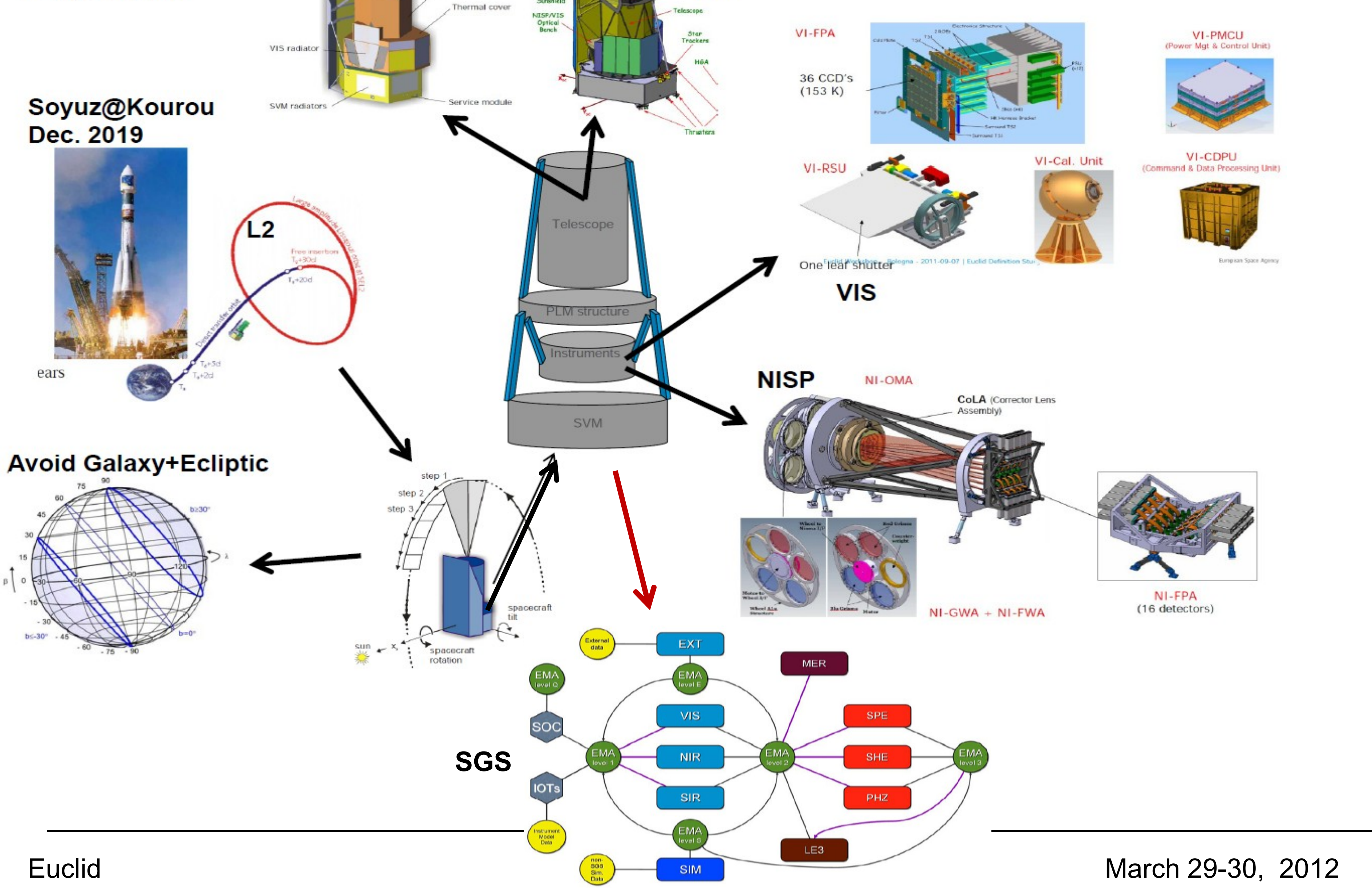
Euclid Consortium

- A unique NIR facility: VISTA would cover the Euclid-Wide sky in 600 yrs and the Euclid-sky Deep in 70 yrs.
- Billions of stars and galaxies
  - Statistics: = a SDSS @ 1<z<3
  - Rare objects
  - High res. imaging of the extragalactic sky,
  - NIR: cool, obscured and high-z sources
    - Wide:15,000 deg^2, YJH_{AB}=24
    - Deep: 40 deg^2 , YJH_{AB}=26
- Synergy: LSST, GAIA, e-ROSITA, Planck
- Targets for JWST, ELT's, ALMA
- e-Euclid: exo-Planets, SN, Galaxy

What	Euclid	Before Euclid
Galaxies at 1<z<3 with good mass estimates	~2x10^8	~5x10^6
Massive galaxies (1<z<3) w/spectra	~few x 10^3	~few tens
Hα emitters/metal abundance in z~2-3	~4x10^7/10^4	~10^4/~10^2?
Galaxies in massive clusters at z>1	~2x10^4	~10^3?
Type 2 AGN (0.7<z<2)	~10^4	<10^3
Dwarf galaxies	~10^5	
T_{eff} ~400K Y dwarfs	~few 10^2	<10
Strongly lensed galaxy-scale lenses	~300,000	~10-100
z > 8 QSOs	~30	None

Euclid: selected as M-class mission by ESA

Euclid

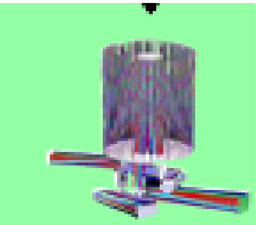


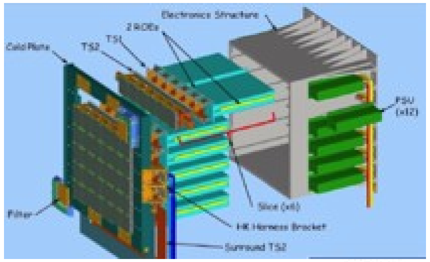
Requirements for implementation

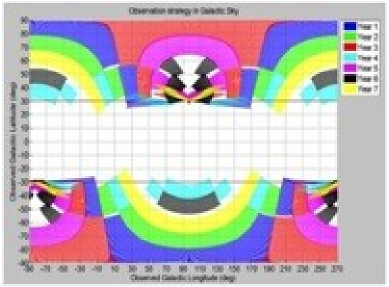
Requirements for implementation

Level 0 | Level 1 | Level 2 | Level 3

- **Weak lensing**
  - **Survey size**
    - **Large FOV**
  - **Shear**
    - **VIS imaging**
    - **Stable, small PSF**
  - **Photo z**
    - **NIR photometry 3 filters**
    - **Ground photometry**
- **Clustering**
  - **Spectro Redshift**
    - **NIR slitless spectroscopy**
    - **Large FOV**
    - **Deep survey**







Requirements for implementation

- The top-level requirements for both GC & WL include
  - large surveys
  - high image quality
  - accessibility to infra-red wavelengths
  - homogeneity of observation, minimum systematics
- Space mission provides all of this
  - low background
  - stability
  - lack of terrestrial atmospheric effects
  - survey speed

Only few example presented in next slides

Shape measurement and WL requirements

The observed lensing signal may be biased:

$$\gamma^{obs} = (1+m) \times \gamma^{true} + c$$

→ Biases in the ellipticity correlation function:

$$C_l^{true} \approx \left[1 + 2\langle m \rangle\right] \times C_l^{obs} + \langle c \rangle^2$$

The FoM must be dominated by the statistical uncertainty, not the systematic biases:

$m < 2 \times 10^{-3}$:	multiplicative bias
$\sigma_{sys}^2 \approx \langle c^2 \rangle < 10^{-7}$:	additive bias

→ Constraints on the spacecraft and the algorithms used to measure shapes
→ Impact on detectors, filters, optical elements.

Multiplicative and additive biases scale as $(\mathrm{PSF})^2$: much easier to measure shapes if the **PSF is small**.

Galaxy clustering requirements

- Well understood sample of galaxies ($0.7<z<2.0$) with accurate redshifts $\sigma_z<0.001(1+z)$
- Need:
  - High and controlled redshift measurement success rate:
    - Angular position (density dependence → spectral confusion)
    - Redshift (wavelength dependence → control flux limit)
  - Control catastrophic redshifts (<20% from L1):
    - Accurately know their fraction (error <1%)
    - Accurately know mean in redshift shell (systematic << statistical)
  - → Control sample of ~2×10^5 redshifts, with purity > 99% at the depth of the Euclid survey → a Deep Field is needed

Requirement summary

	Wide survey	Deep survey
Survey		
size	15000 deg^2	40 deg^2 N/S
VIS imaging		
Depth	Mab<24.5	26.5
PSF size knowledge	σ[R2]/R2<10-3	
Multiplicative bias in shape	σ[μ]<2x10-3	
Additive bias in shape	σ[c]<5x10-4	
Ellipticity RMS	σ[e]<2x10-4	
NIP photometry		
Depth	24 Mab	26 Mab
NIS spectroscopy		
Flux limit ($erg/cm^2/s$)	$3\ 10^{-16}$	$5\ 10^{-17}$
Completness	> 45 %	>99%
Purity	>80%	>99%
Confusion	2 rotations	>12 rotations

WL systematics

→ Knowledge of the PSF size
→ Knowledge of distorsion
→ Stability in time

→ Catastrophic z < 10%
→ (<z>)/(1+z)<0.002
→ external data

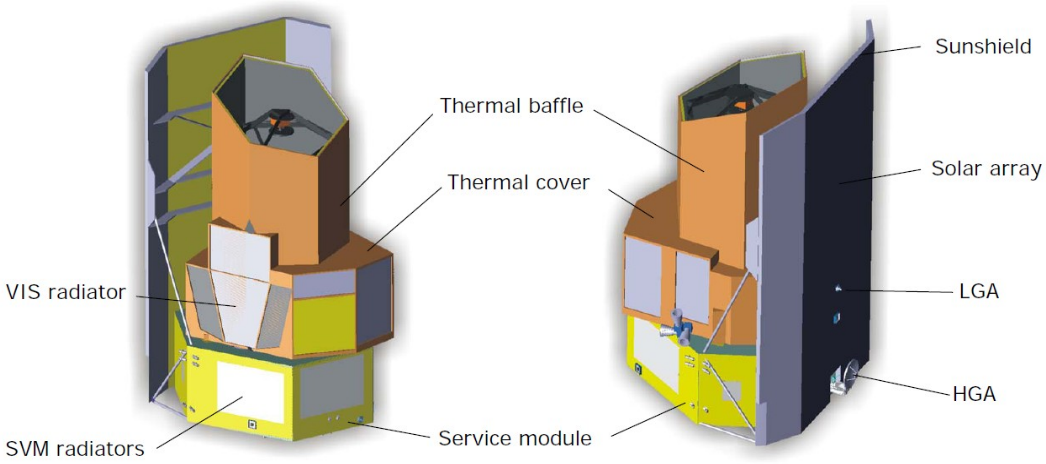
GC systematics

→ Understand selection
- Completness
- Purity

Telescope, optical design

Euclid: telecope concept

Astrium concept



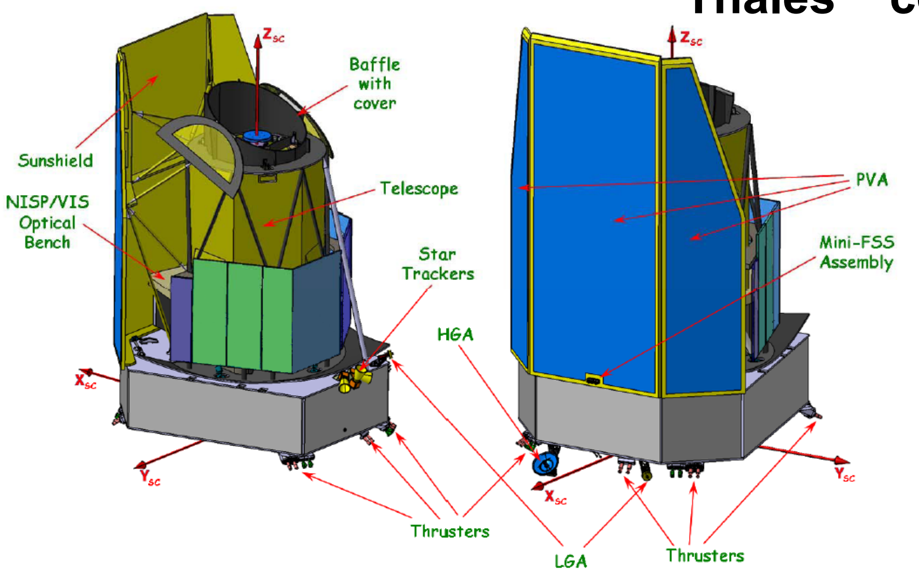
Telescope

- Primary Mirror: SiC
- Cold Telescope (T~150K)
- Passive Thermal Control

AOCS

- Fine pointing: Cold Gas + FGS & Gyro
- Slews: Cold Gas + Star Tracker & Gyro

Thales concept



Telescope

- Primary Mirror: Zerodur
- Cold Telescope (T~240K)
- Active Thermal Control

AOCS

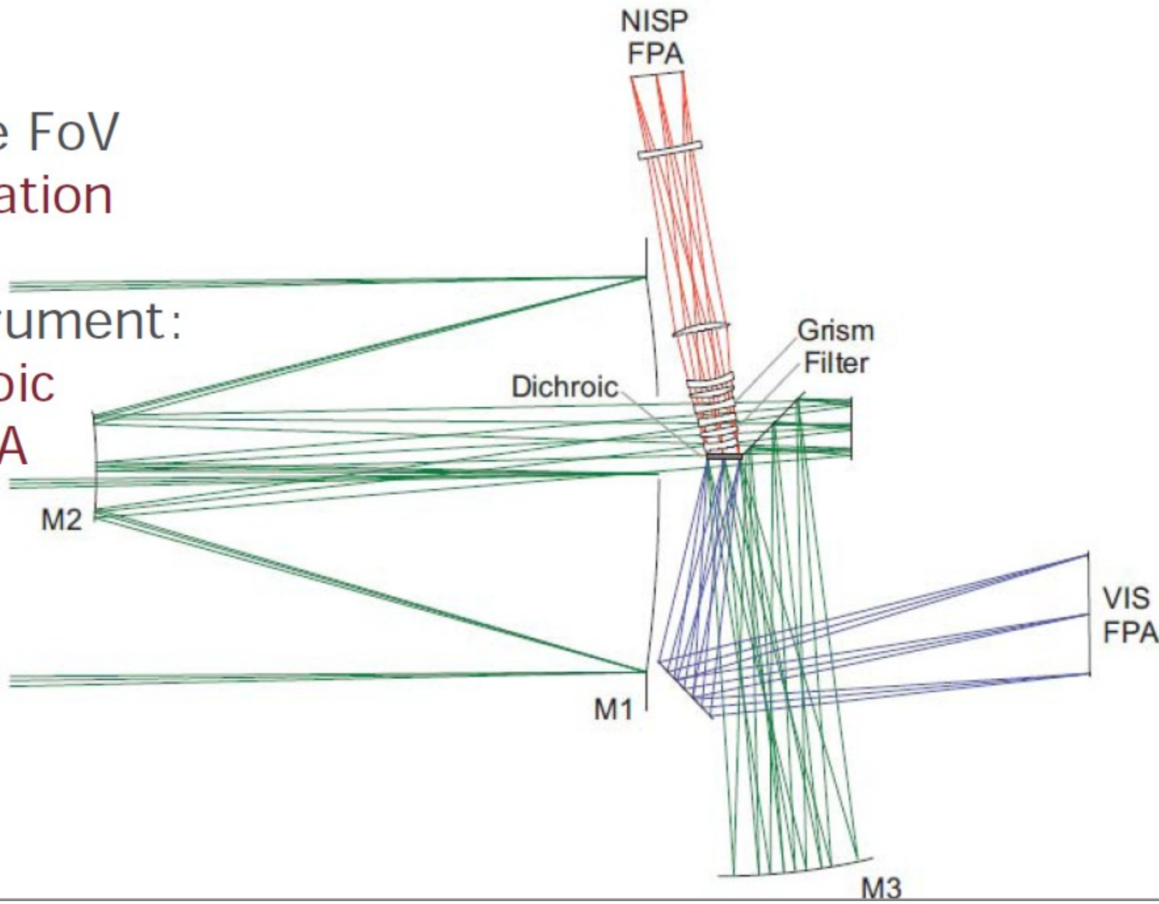
- Fine pointing: Cold Gas + FGS & Gyro
- Slews: Reaction Wheel + Star Tracker & Gyro

Optical design

Telescope design: Korsch
1.2 m primary

VIS and NISP share same FoV
Dichroïc separation

Interfaces telescope/instrument:
NISP: at dichroic
VIS: at VIS FPA

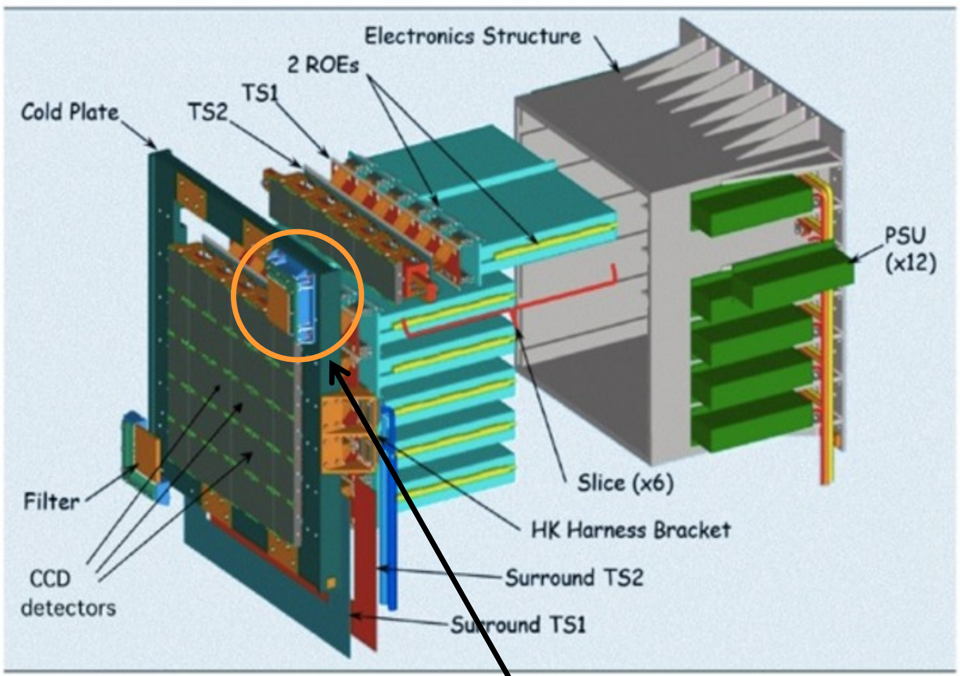


VIS instrument

VIS specifications and units

- VIS specification
  - large area imager – a ‘shape measurement machine’
  - 36 4kx4k CCDs with 12 micron pixels
  - 0.1 arcsec pixels on sky
  - bandpass 550-900 nm – narrow band channel
  - limiting magnitude for wide survey of magAB = 24.5 for 10σ (extended)
  - data volume – 520Gbit/day

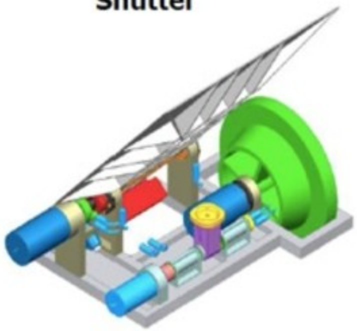
COLD



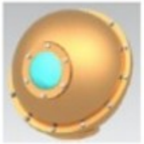
Focal Plane Assembly

Narrow band filter (color gradient)

Shutter

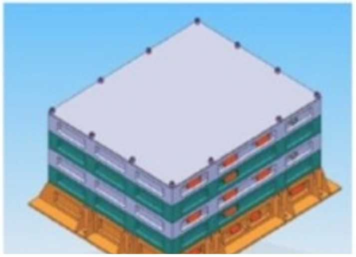


Cal Unit

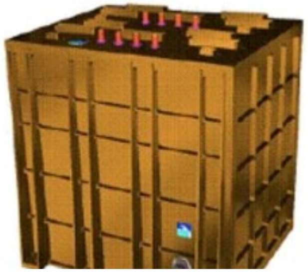


WARM

Power and Mechanisms Control Unit



Command and Data Processing Unit



NISP instrument

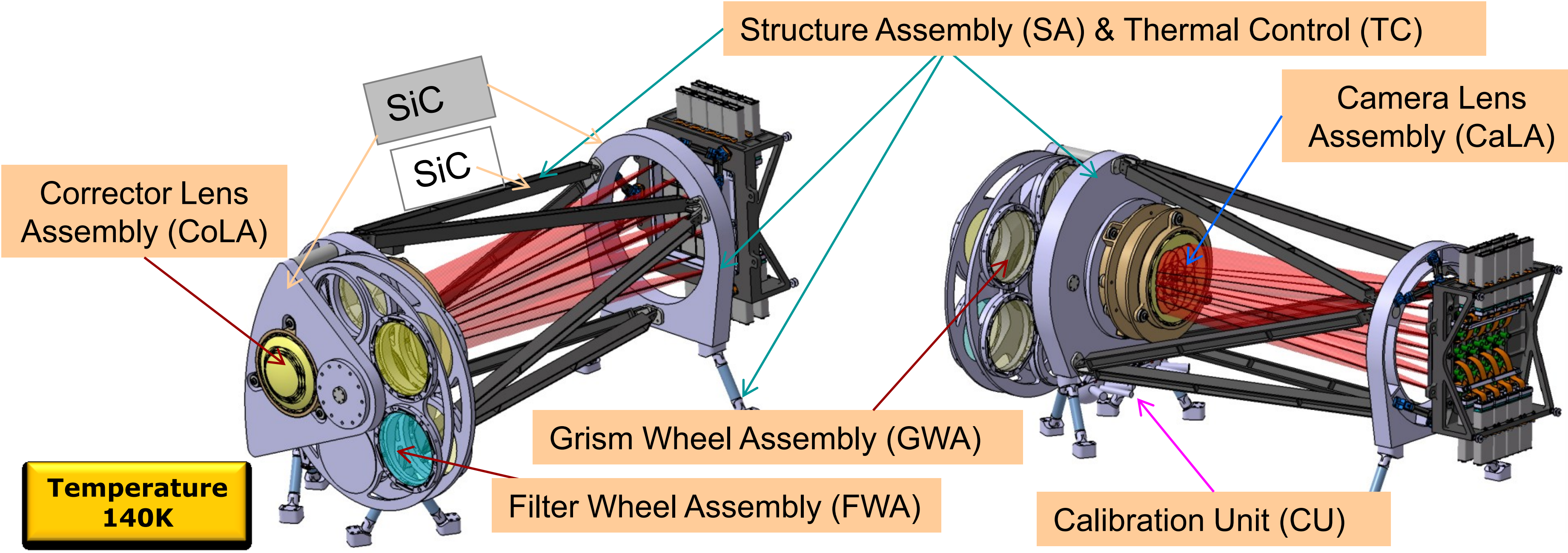
NISP specifications and units

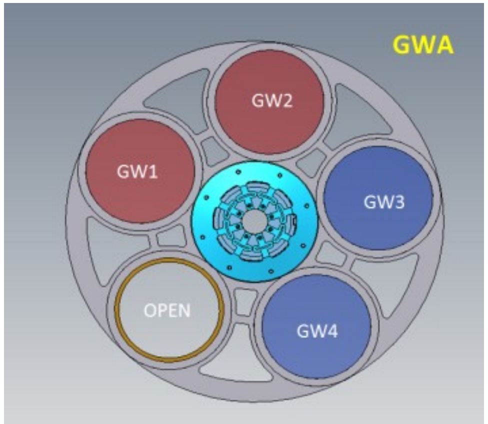
- 16 NIR 2kx2k H2RG detectors
- 0.3 arc/pixel
- 4 Grisms (2 blue, 2 red, rootated by 90 deg.) ; 3 NIR filters: Y, J H
- Telemetry= 180 Gbit/day

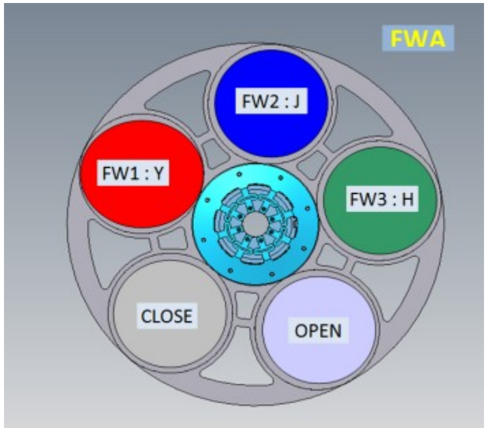
- NI-OMA : Opto Mechanical Assembly (Inside PLM ; T<140K)
- NI- DS : Detection System
- NI-WE : Warm Electronics

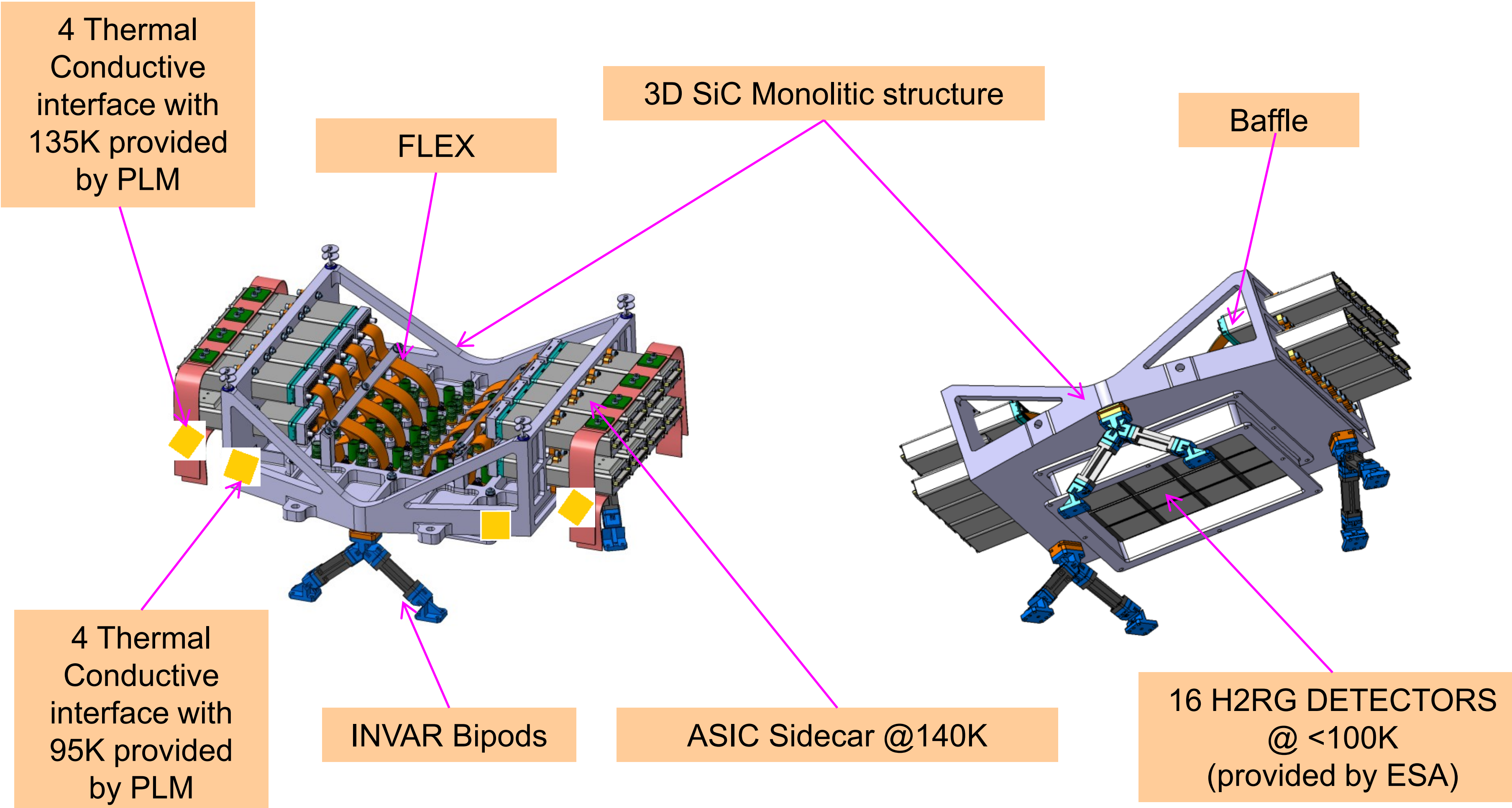
NISP: NI-OMA

Protective structures not shown









Design of FPA made with the help of the Berkeley labs

Science Ground Segment and data distribution

Ground segment: responsibilities

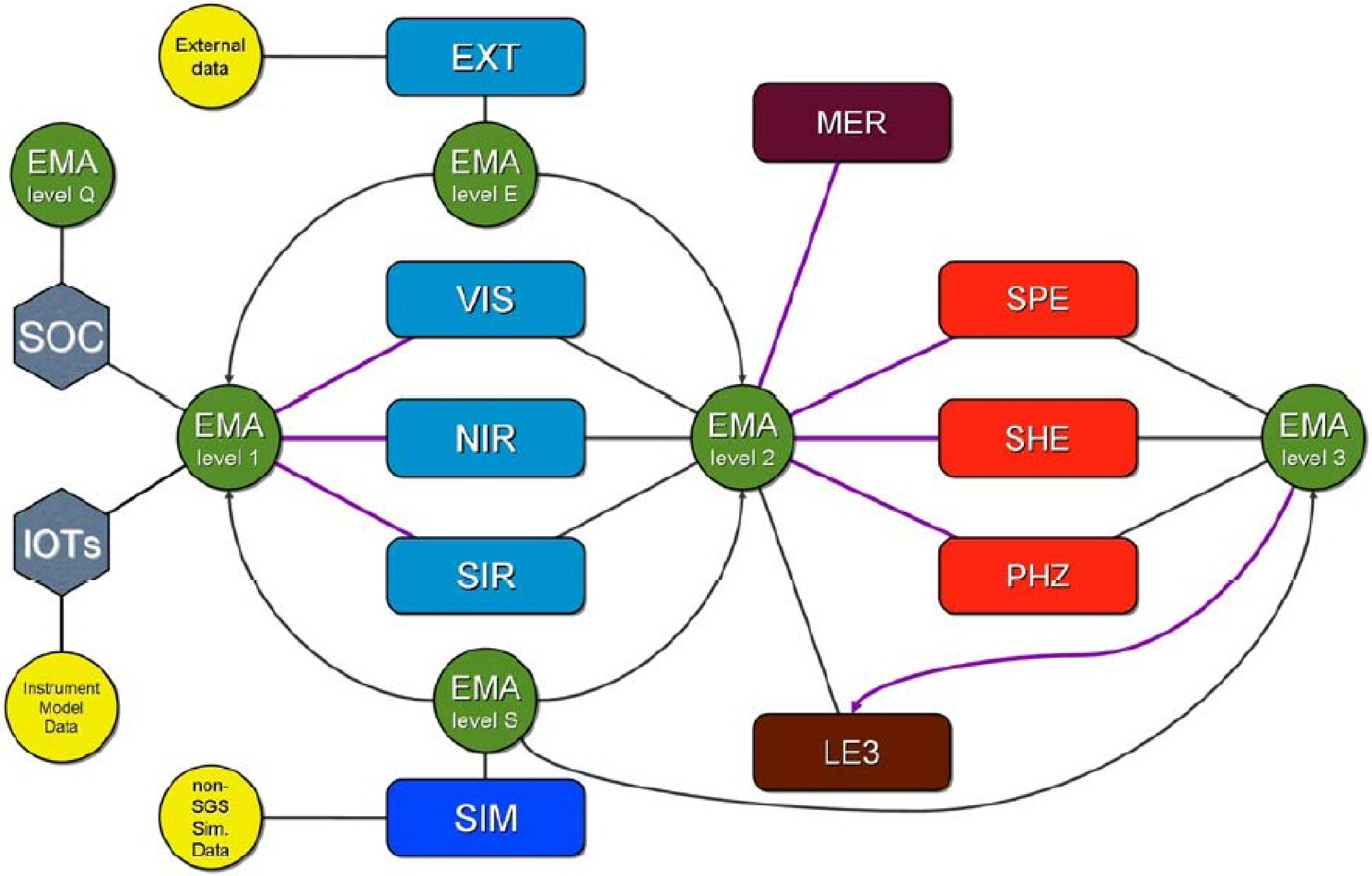
- Instrument specific data processing
- Quality-controlled processed data and higher level mission products for the Euclid Legacy Archive
- Simulations: verification of E2E performances and validation of data processing
- External ancillary data

- Data will be released by ESA after a proprietary period
- The final interpretation and cosmological cosmological analysis is under the responsibility of the science groups

SGS:roles of SDCs, OUs and SWGs

- **Science Working Groups**
  - **turning science objectives into requirements placed on the pipeline products and performances**
  - **verifying that the requirements are met (define V&V procedures)**
  - **final science analyses based on data**
- **Organisation Units**
  - **providing the algorithmic definition of the processing to be implemented by the SDCs and validate the implementation**
- **Science Data Centres**
  - **implementing the data processing pipelines as specified by OUs – procuring local h/w and s/w resources**
  - **different activities: SDC-DEV (development**
  - **i.e. transforming algorithms into robust code) SDC-PROD (integration on local infrastructure, production runs of pipeline)**

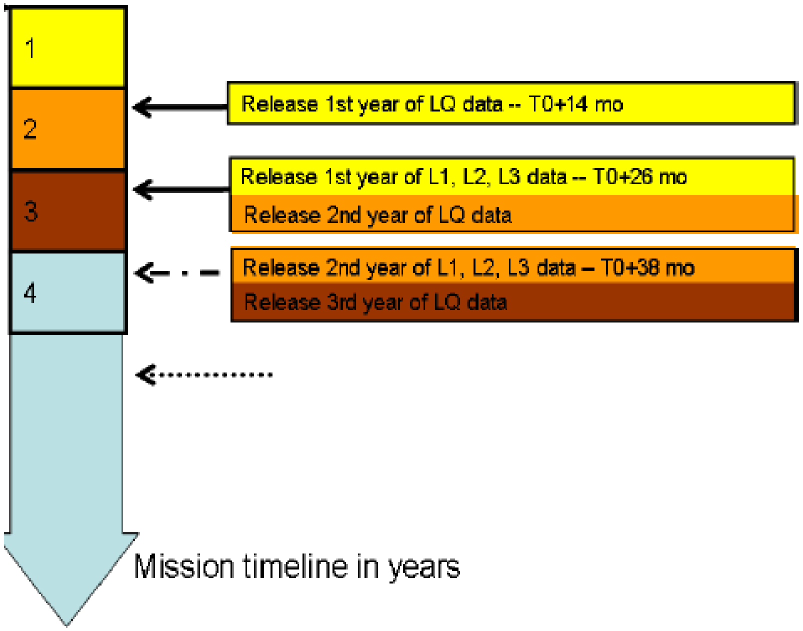
Euclid/SGS flow and Organisation Units



Data products and releases

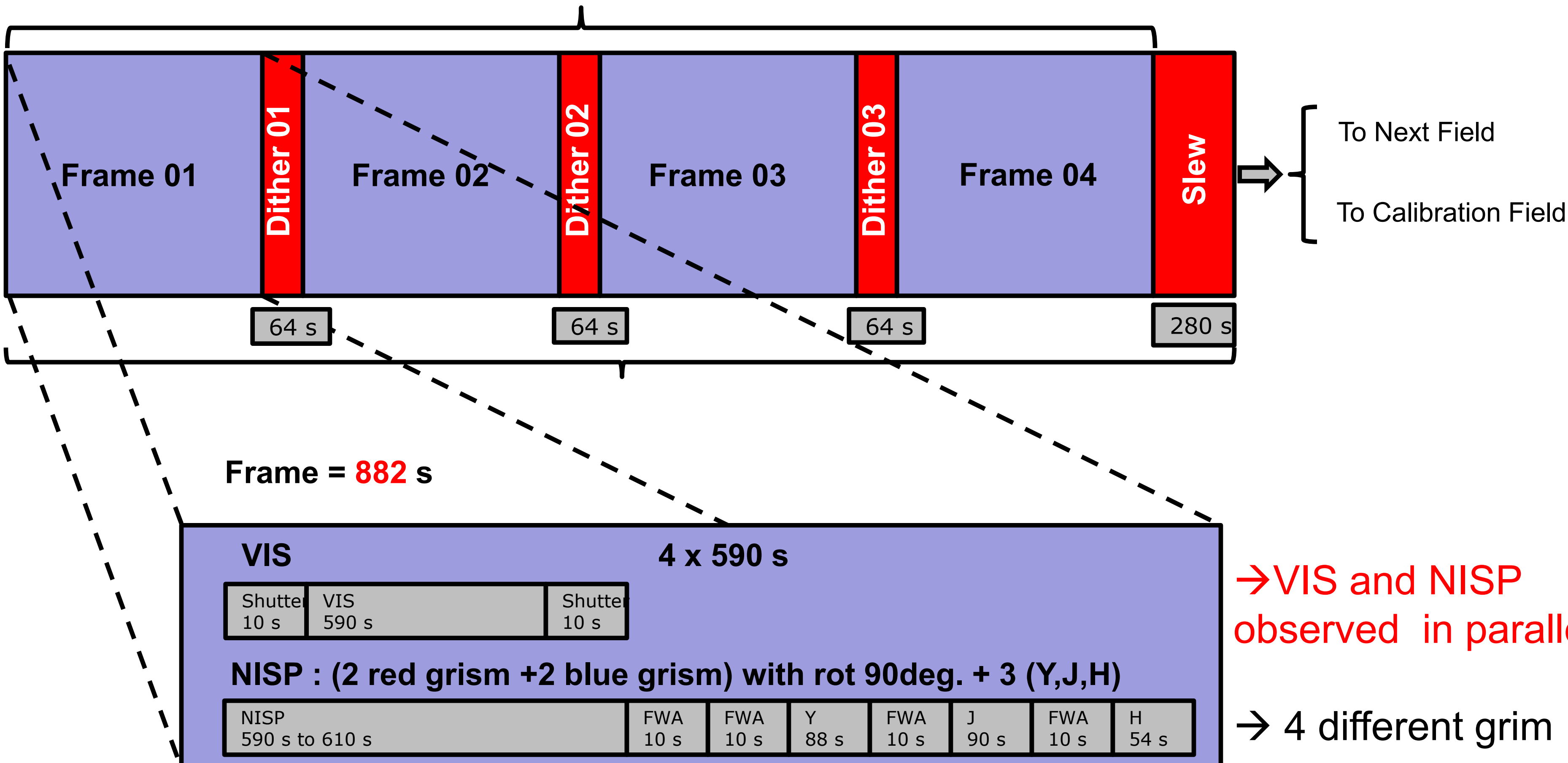
- Level 1 (unpacked, edited telemetry),
- Transients: release TBD, likely immediately (basic position, photometry)
- Level Q (Quick-release data): TBD
- Level 2 (instrumental signatures removed, calibrated data),
- Level 3 (science-ready data).
- Level E (external data)
- Level S (simulations)

- First release Level Q data release: 14 months after the start of the survey (TBC)
- First complete data release with products from all level:12 months later (i.e. 26 months after the start of the survey)
- Then yearly releases



Performances

NISP+VIS field observing sequence



→VIS and NISP observed in parallel

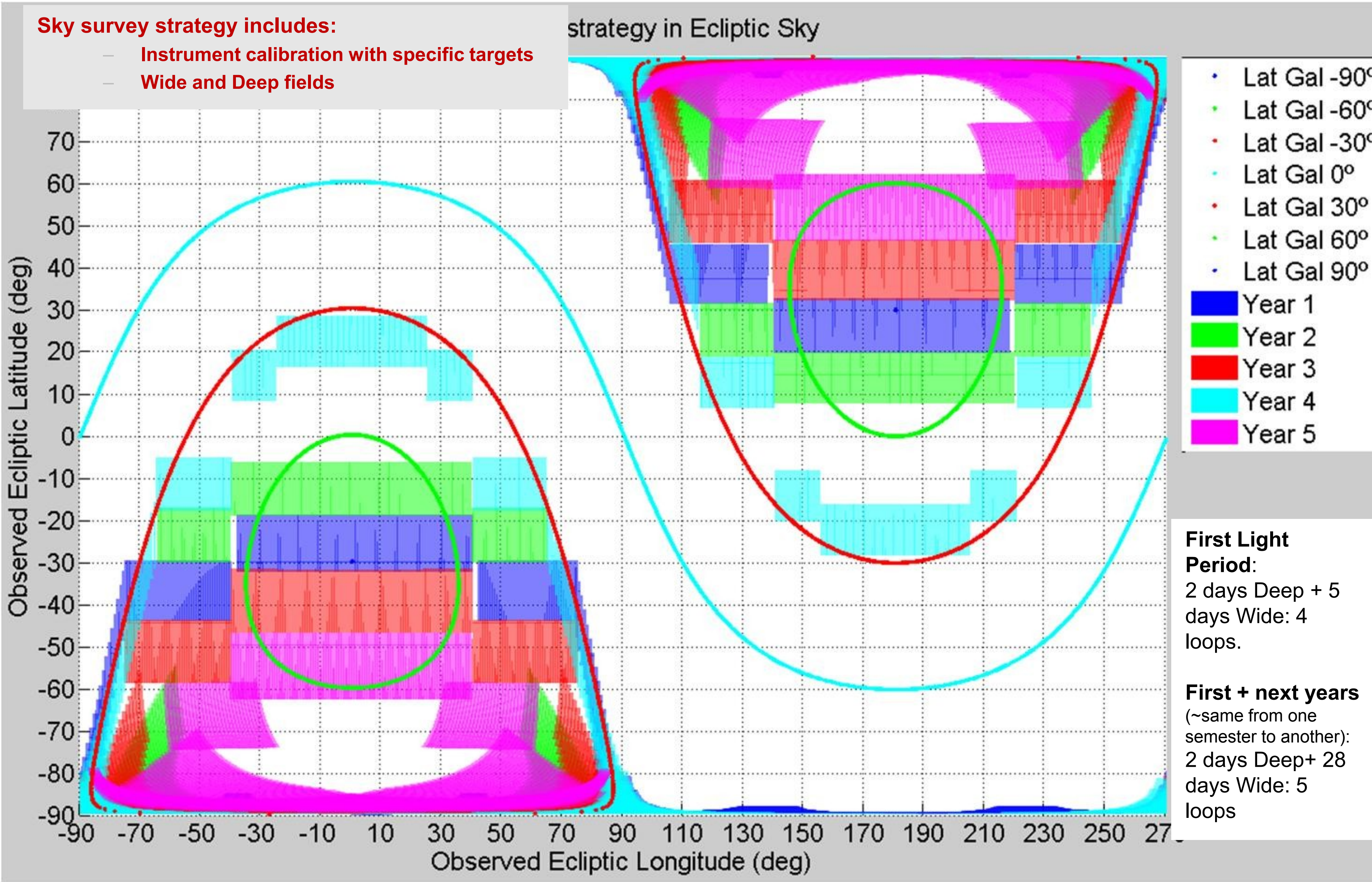
→ 4 different grim exposures

Euclid survey feasible in 6 years

Euclid Consortium

Sky survey strategy includes:

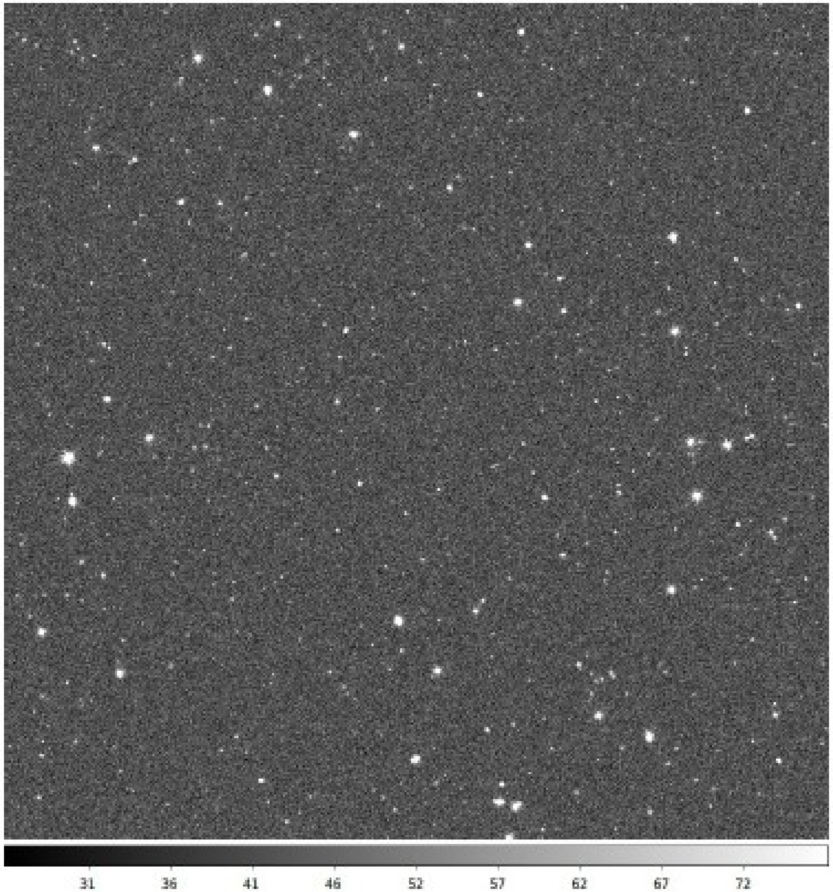
- Instrument calibration with specific targets
- Wide and Deep fields



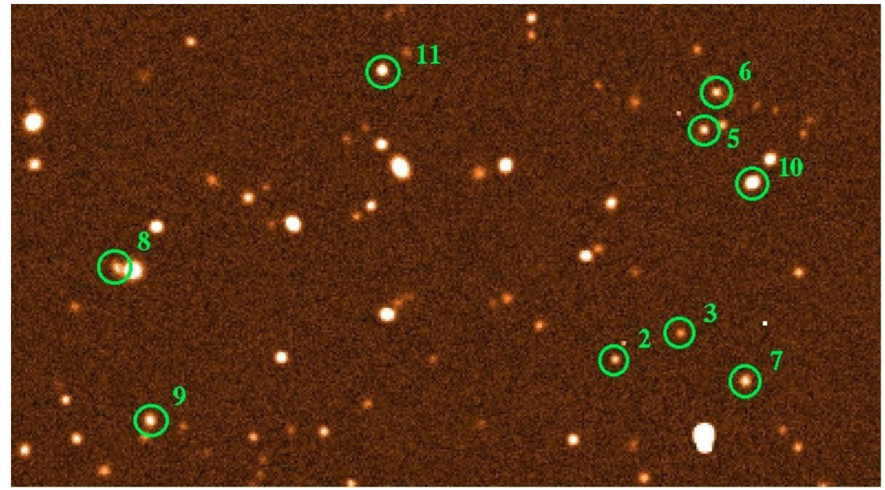
First Light Period: 2 days Deep + 5 days Wide: 4 loops.

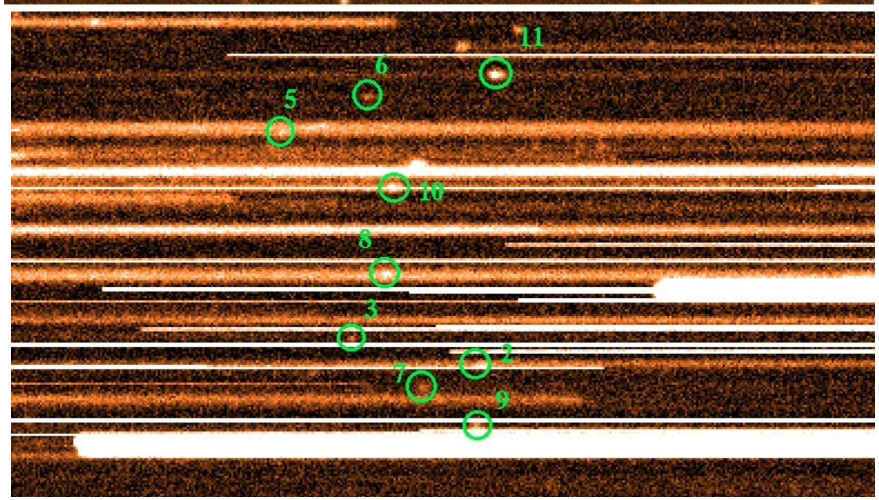
First + next years (~same from one semester to another): 2 days Deep+ 28 days Wide: 5 loops

Performance: NISP images



H band frame, 2040x2040 pixels
Skylens: source image oversampled with 6x6 sub-pixels
imagem: optical and detector effects



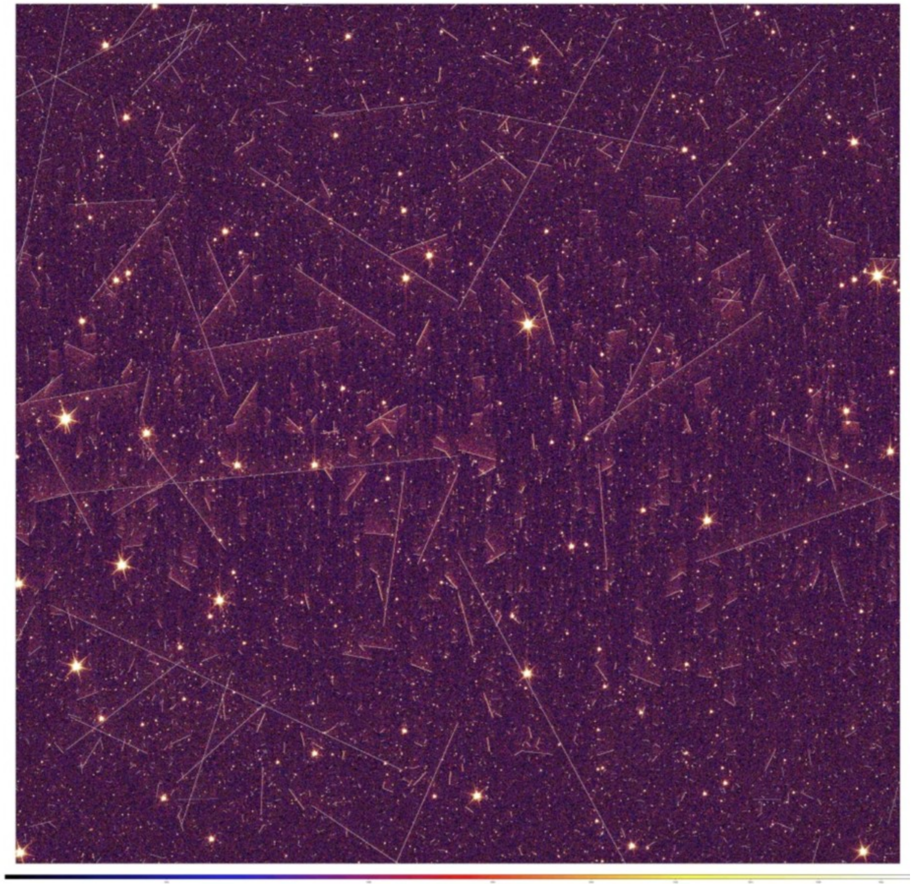


- 1 deg2 of the sky simulated and propagated through end-2-end Euclid spectroscopic simulation
- Shows can meet the required n(z), completeness and purity

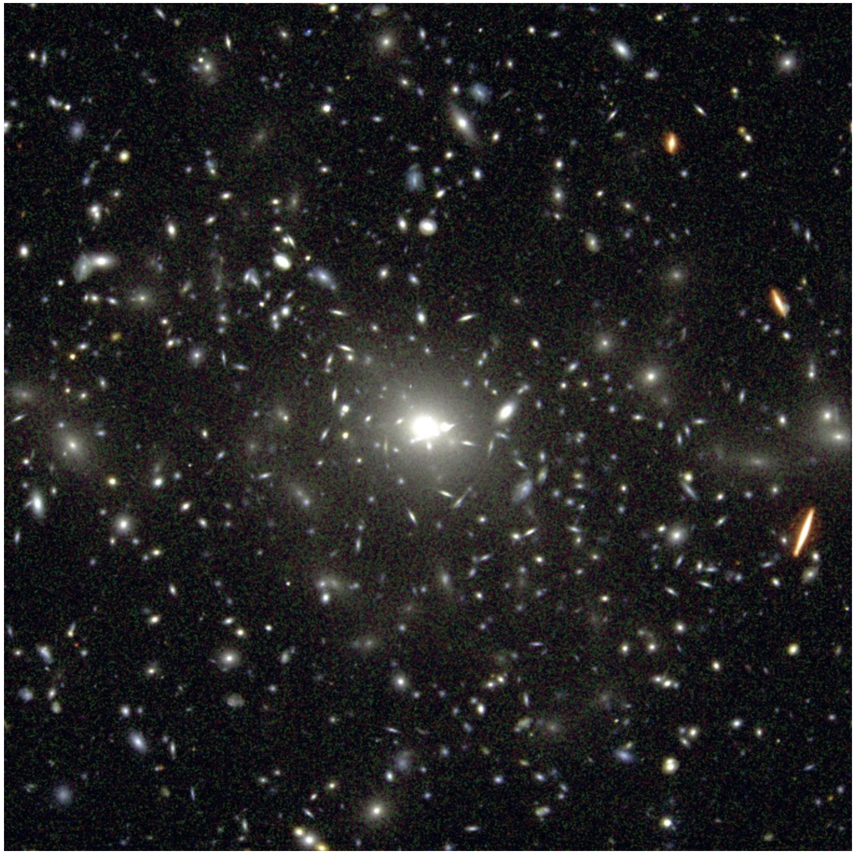
All performances have been verified at image simulation level

Performance: VIS and combined imaging

A 4kx4k view of the Euclid sky



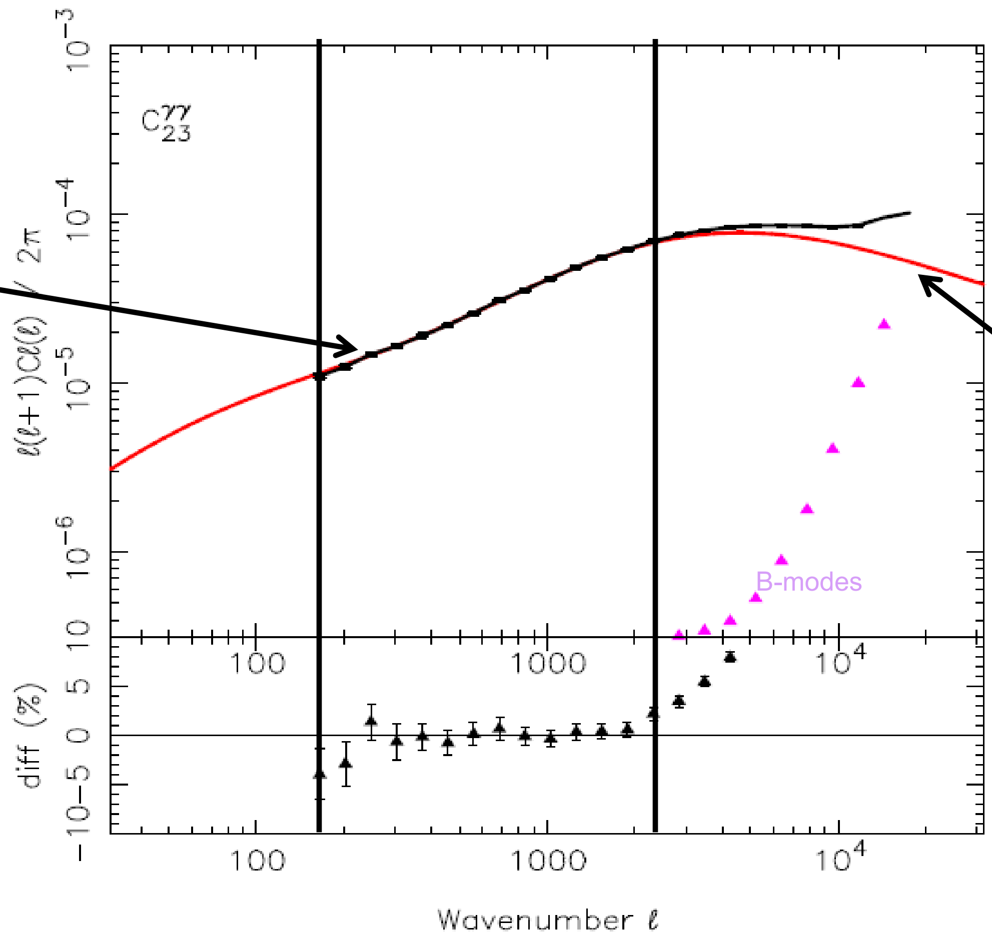
VIS image



VIS+Y+J+K of a simulated cluster

Euclid WL predicted performances

Reconstructed WL with Euclid data + Euclid noise

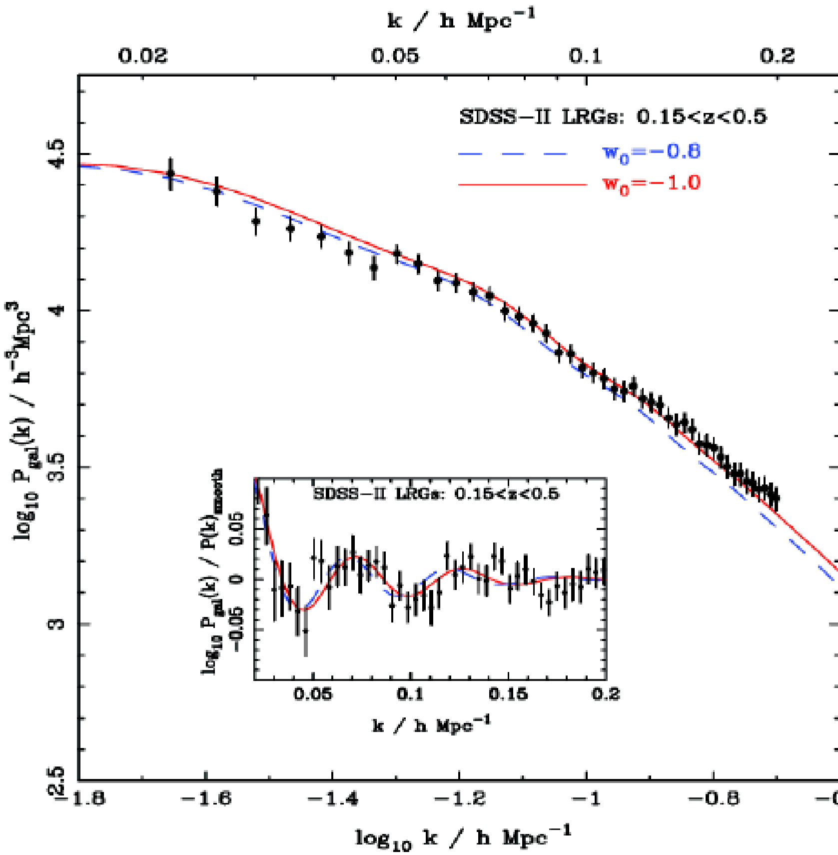


Input P(k)

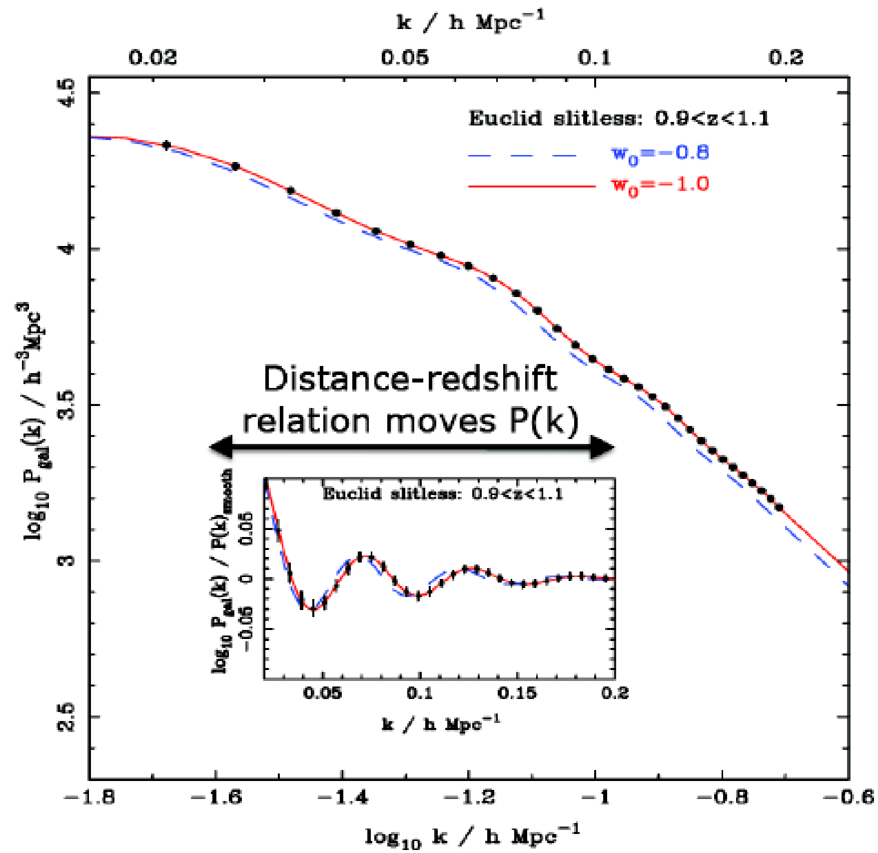
Tomographic WL shear cross-power spectrum for 0.5 < z < 1.0 and 1.0 < z < 1.5 bins.
Percentage difference [expected – measured] power spectrum: recovered to 1% .

Euclid GC predicted performances

Euclid Consortium



Percival et al. 2009; arXiv:0907.1660

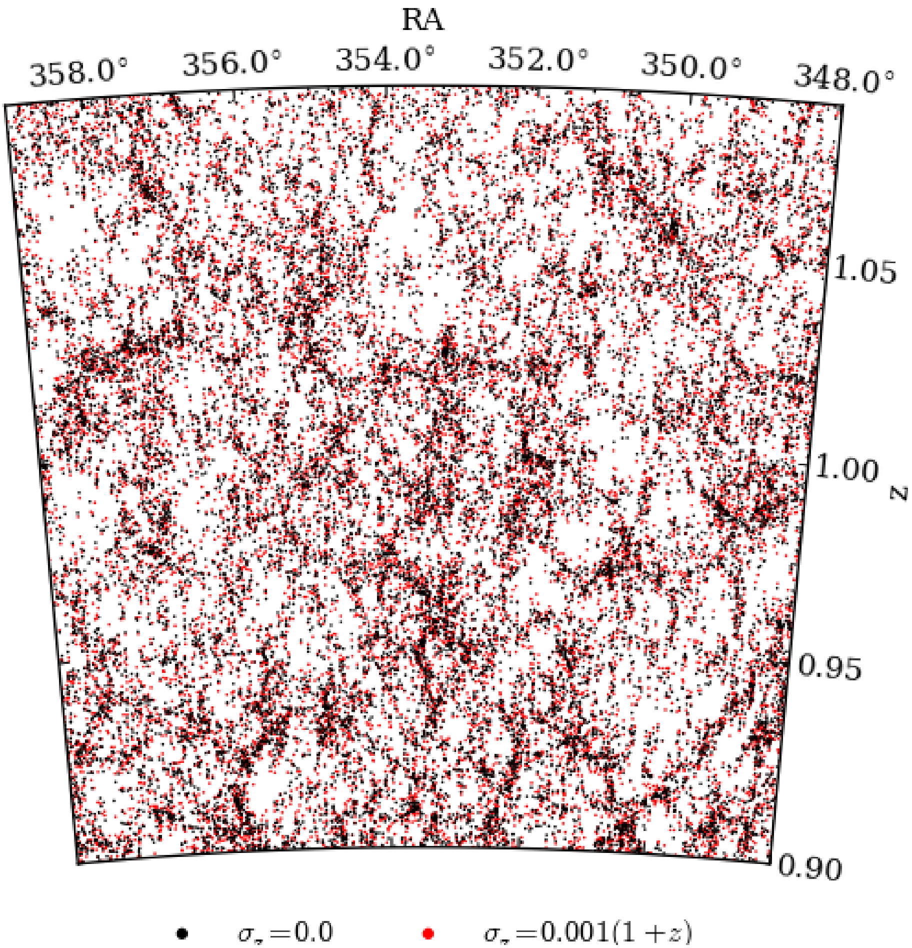


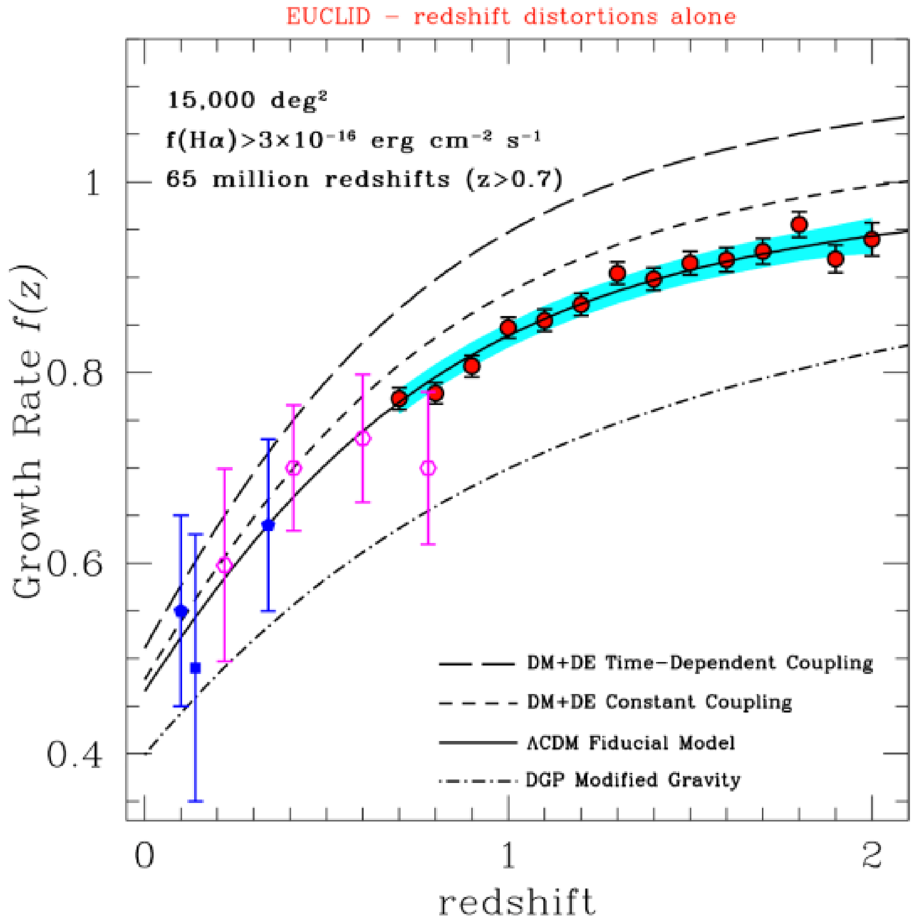
SDSS-II LRG galaxies - Euclid

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

Redshift space distortion

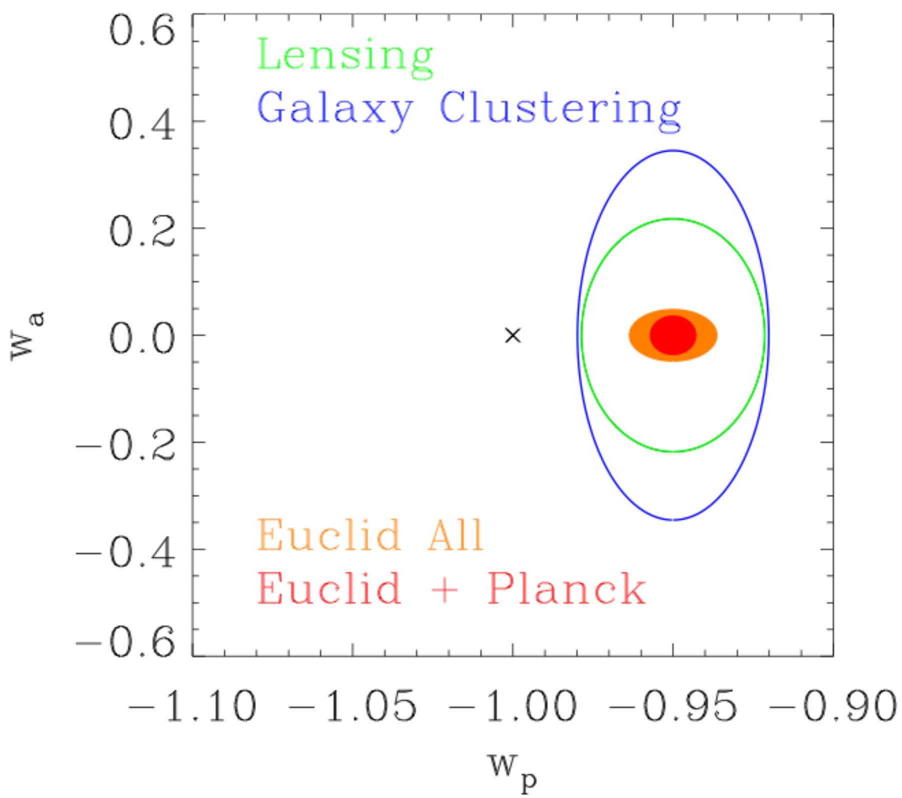
Euclid Consortium



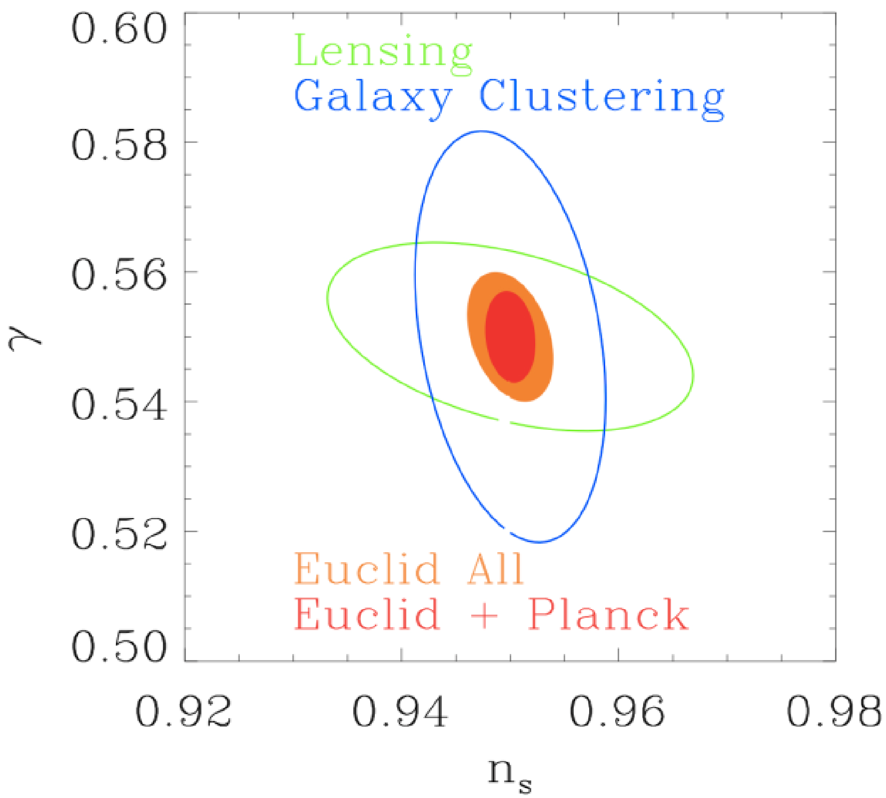


Euclid measurements of the growth rate of structure *f*(z) using RSD

Euclid Cosmo predicted performances



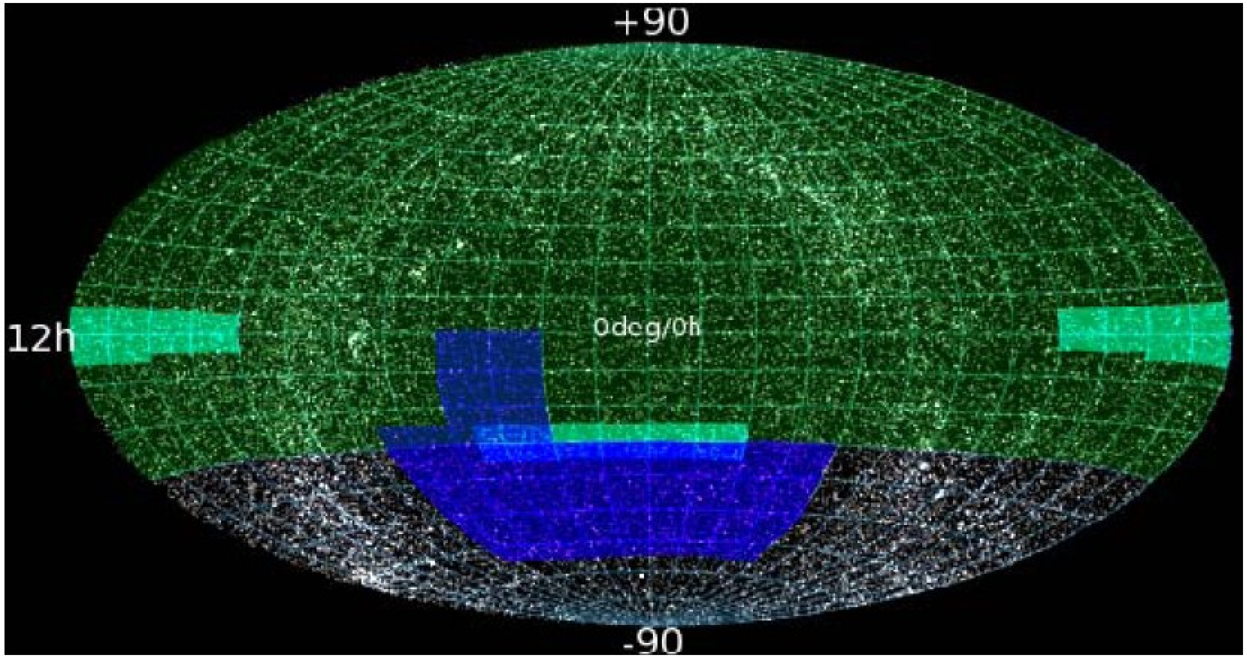
DE constraints from Euclid: 68% confidence contours in the (w_p, w_a).



Constraints on the γ and n_s. Errors marginalised over all other parameters.

Optical data from the ground

Euclid : Ground surveys

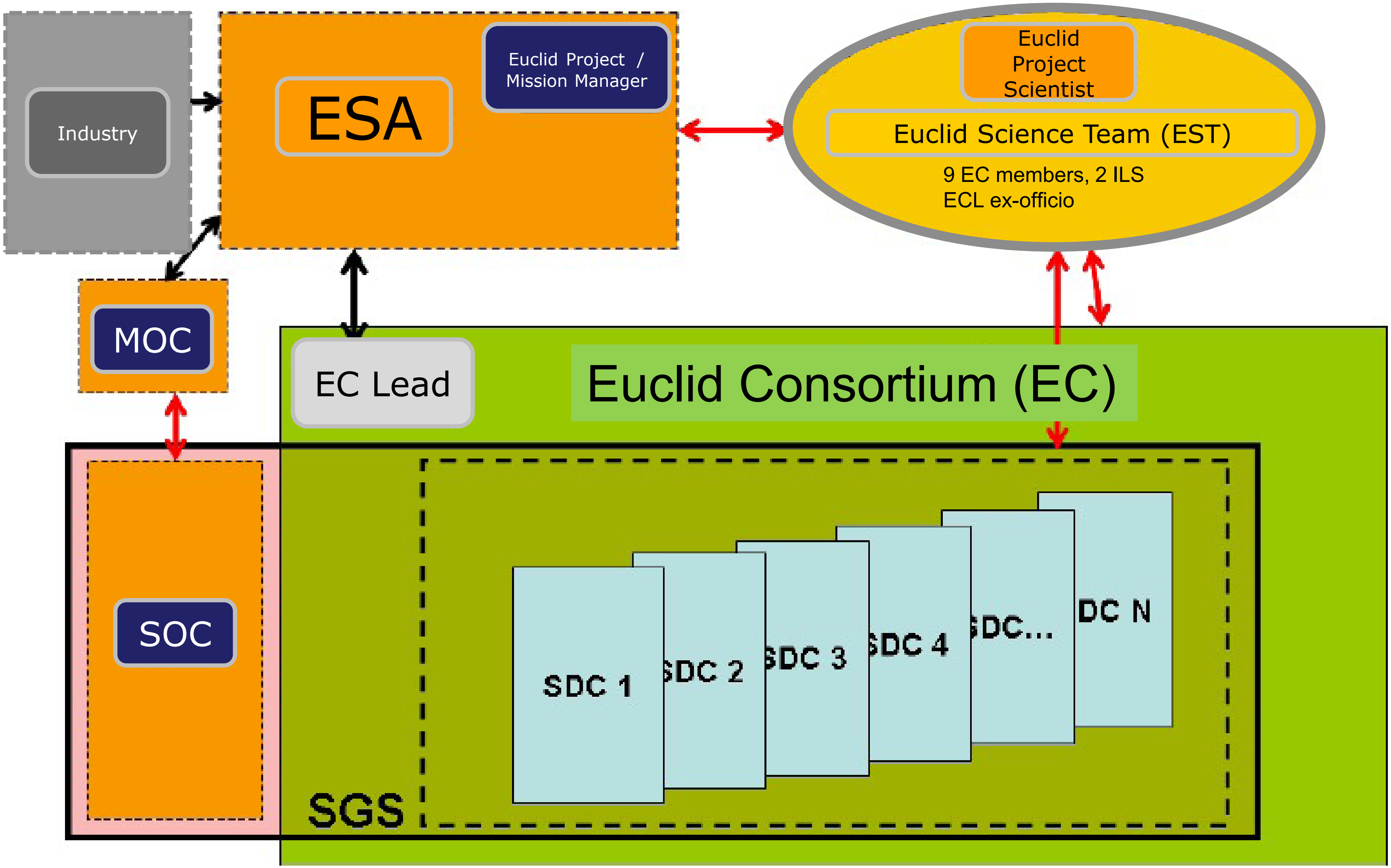


External survey timelines	2011	2012	2013	2014	2015	2016	2017	2018
KiDS-VIKING	Survey underway		VIKING completed	KiDS completed, VIKING final release	, KiDS final release			
Pan-STARRS1	Survey underway		Survey completed		PS1 final release			
Pan-STARRS2				Survey start				
DES		Survey start		1st data release		Survey end	Final data release	
LSST								2020?
HSC+WHT								

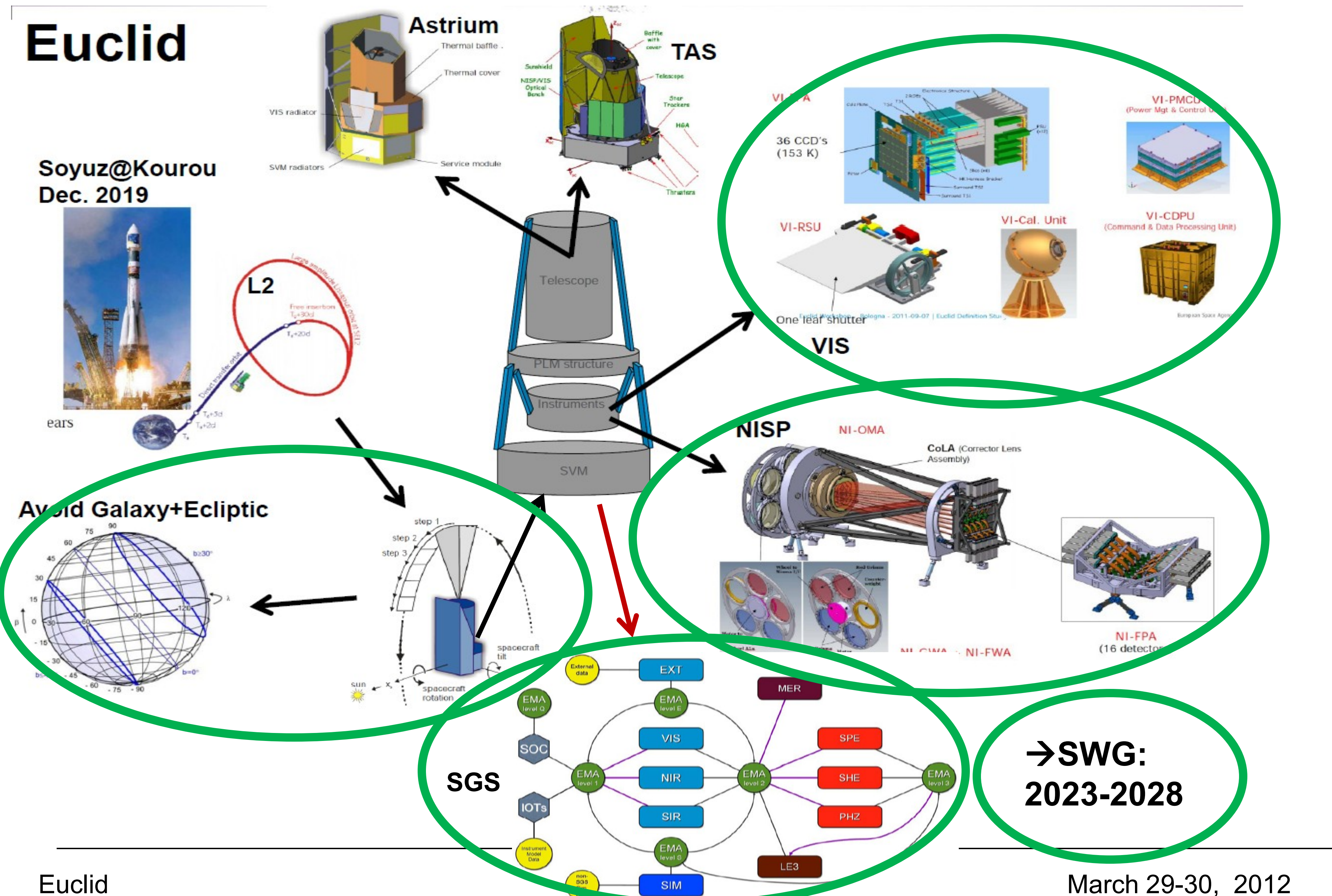
Survey	Area (sq deg)	U	G	r	i	z	Y	J	H	K
KiDS+VIKING	1500 Eq+SGC	24,8	25,4	25,2	24,2	23,1	22,3	22.0	21,5	21,2
Pan-STARRS1	15000 NGC+½ SGC		23,4	23,0	22,7	22,0	20,9			
PS2	15000 NGC+½ SGC		24,8	24,4	24,1	23,4	22,3			
DES	5000 ½ SGC		25,4	24,9	24,8	24,7	22,3			

Organisation and schedule

Euclid mission organisation



Euclid Consortium



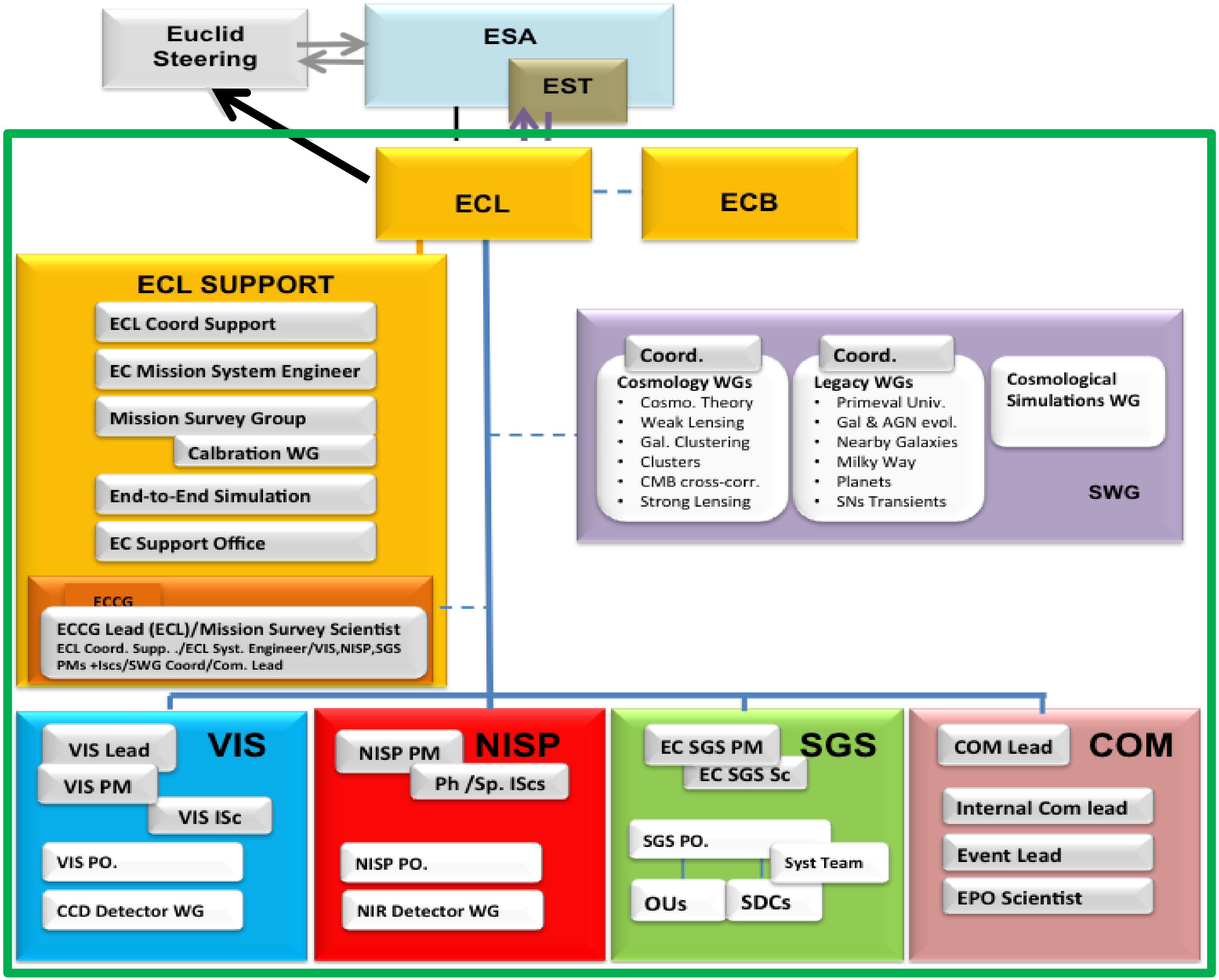
The Euclid Consortium http://www.euclid-ec.org

- The EC: ~900 registered members (10/01/12):
  - ~550 researchers
  - in 109 laboratories/departments

- 13 European countries contributing:
  - Austria, Denmark, France, Finland, Germany, Italy, Netherlands, Norway, Spain,Switzerland, Portugal, Romania, UK
    + Contributions from Berkeley labs.
  - Discussions: NASA/US , Canada, Belgium

- Contribute to ~35% of the total cost (~750 M€) of the mission until completion (~2027)

Euclid Consortium organisation



Schedule

- **October 4, 2011** : Euclid selected as ESA M2 Cosmic Vision
- **Spring 2012** : Completion of the Definition phase (A/B1)

- **Apr.2012-Feb.2014** Instrum. Phase B2
- **June 2012** : Adoption for the Implem. Phase (B2/C/D/E1)
- **July 2014** : ITT release for PLM
- **November 2012** : KO PLM contract
- **December 2012** : ITT release for SVM
- **June 2013** : KO SVM contract
- **October 2013** : Syst. Req. Review (SRR)
- **Q1 2014** : Instrument PDR
- **Q3/Q4 2017** : Flight Model delivery

- **Q4 2019** : Launch (L)
- **<(L+6 months)** : Start Routine Phase
- **L+7 yrs** : End of Nominal Mission
- **L+9 yrs** : End of Active Archive Phase

Conclusion: Euclid

- An outstanding tool to understand the origin of the accelerating universe
- A major space mission for cosmology and fundamental physics
- One of the top European project in physics and astronomy for 2020+