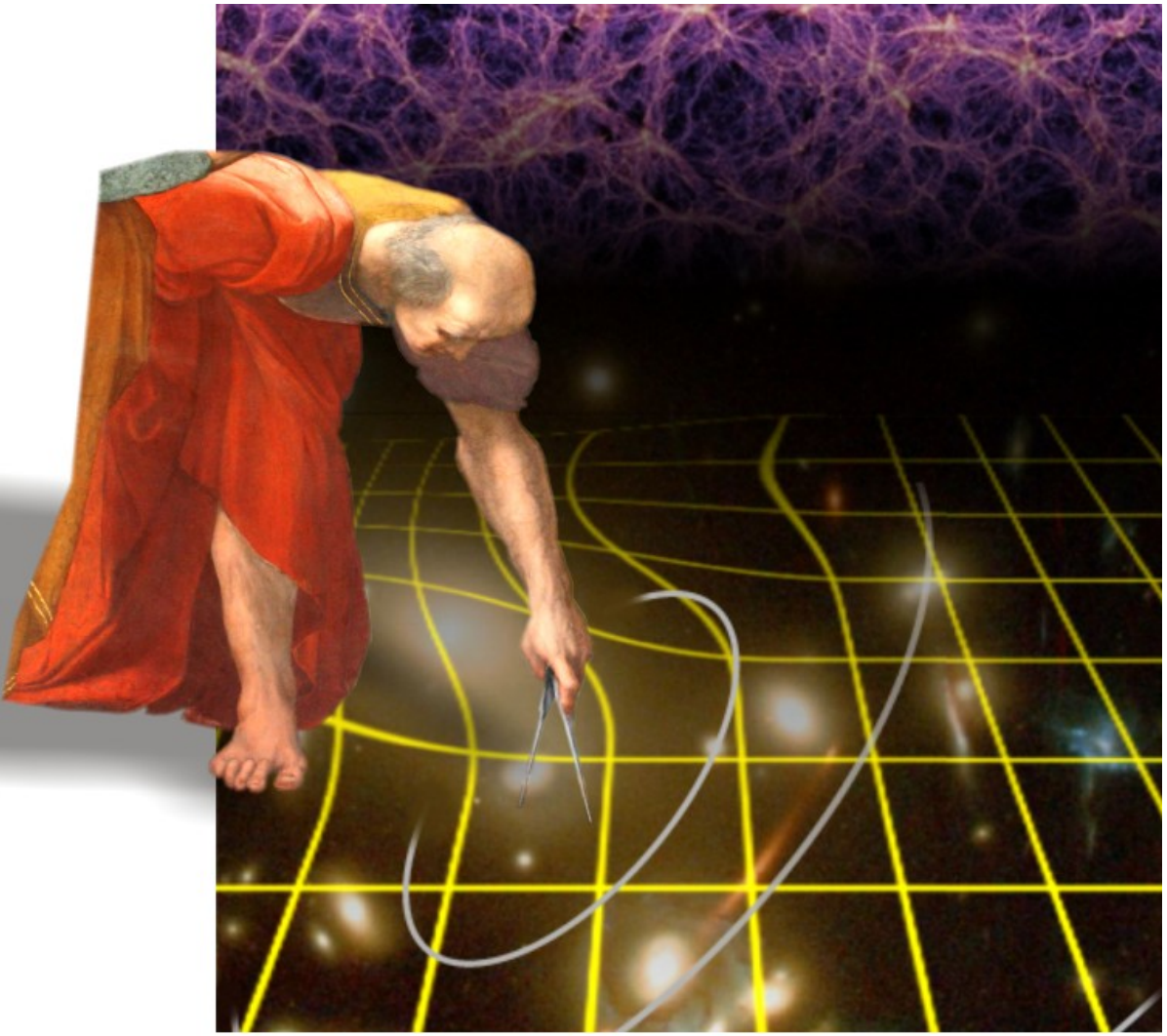


Euclid

Mapping the Geometry of the Dark Universe

Y. Mellier
on behalf of the
Euclid Consortium

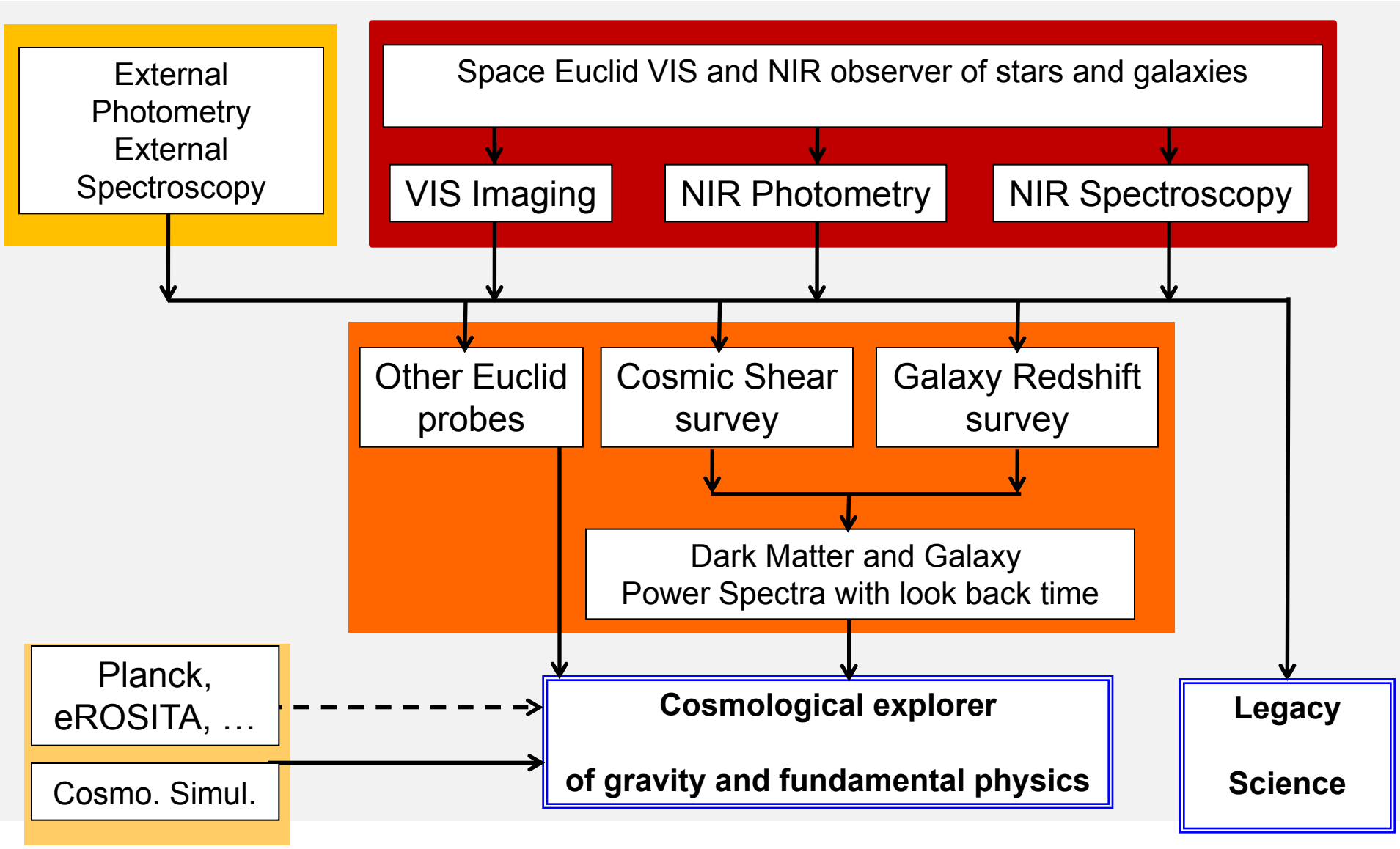
http://www.euclid-ec.org

The ESA Euclid mission: scientific objectives

- Understand the origin of the Universe's accelerating expansion;
- Derive properties/nature of dark energy (DE), test gravity (MG)
- Distinguish DE, MG, DM effects *decisively* by… :
  - using at least 2 independent but complementary probes
  - tracking their observational signatures on the
    - geometry of the Universe:
      - Weak Lensing (WL), Galaxy Clustering (GC),
    - cosmic history of structure formation:
      - WL, Redshift-Space Distortion, Clusters of Galaxies
  - controlling systematic residuals to a very high level of accuracy.

The Euclid Machine

Euclid Consortium



The Euclid Mission: baseline and options

Euclid Consortium

SURVEYS In ~5.5 years		
	Area (deg2)	Description
Wide Survey	**15,000 deg^2**	Step and stare with 4 dither pointings per step.
Deep Survey	**40 deg^2**	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 n = 1.5 x10^9 galaxies			z of n=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

Possibility other surveys: SN and/or μ-lens surveys, Milky Way ?

Ref: Euclid RB arXiv:1110.3193

The Euclid mission

Euclid Consortium

esa

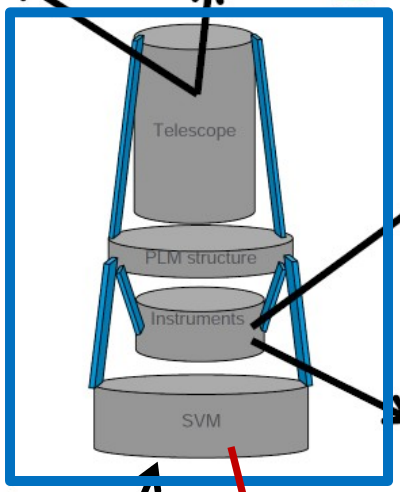
Astrium

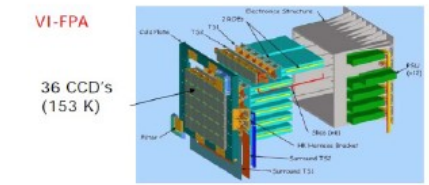
TAS

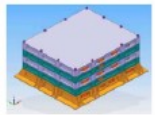
PLM+SVM: 2010-2019

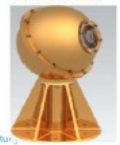
Soyuz@Kourou
Q2 2020

ears



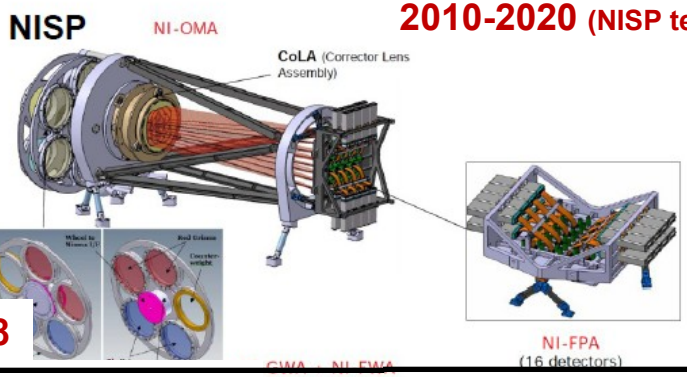




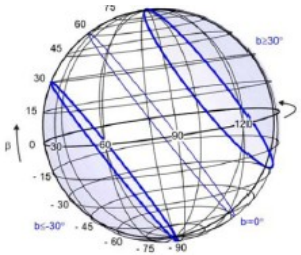


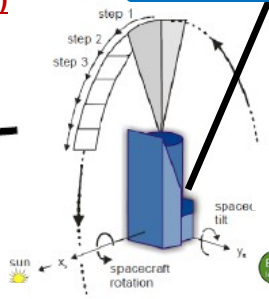
VIS imaging: 2010-2020 (Euclid VIS team)

NIR spectro-imaging
2010-2020 (NISP team)

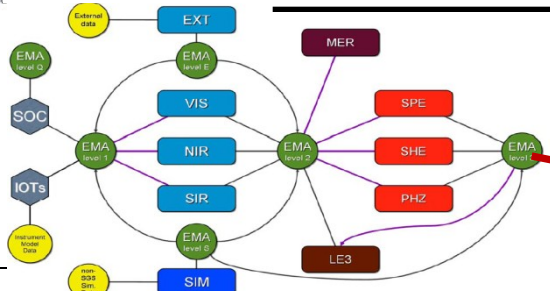


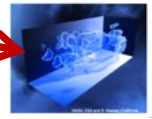
Surveys: 2010-2028 (ESSWG)

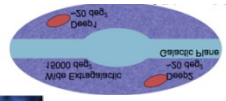


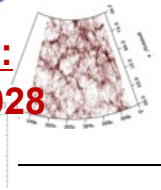


SGS: 2010-2028









SWG:
2019-2028

- Commisionning – Science Verifi.
- Euclid nominal in opération:
5.5 yrs of Euclid Wide+Deep
- Euclid+:
Additional surveys: SNIa, mu-lens, Milky Way?

10PB data processing (EC-SGS team) – Science analyses

Euclid:optimised for shape measurements

Euclid Consortium

M51

Courtesy Jarle Brinchmann, Steve Warren

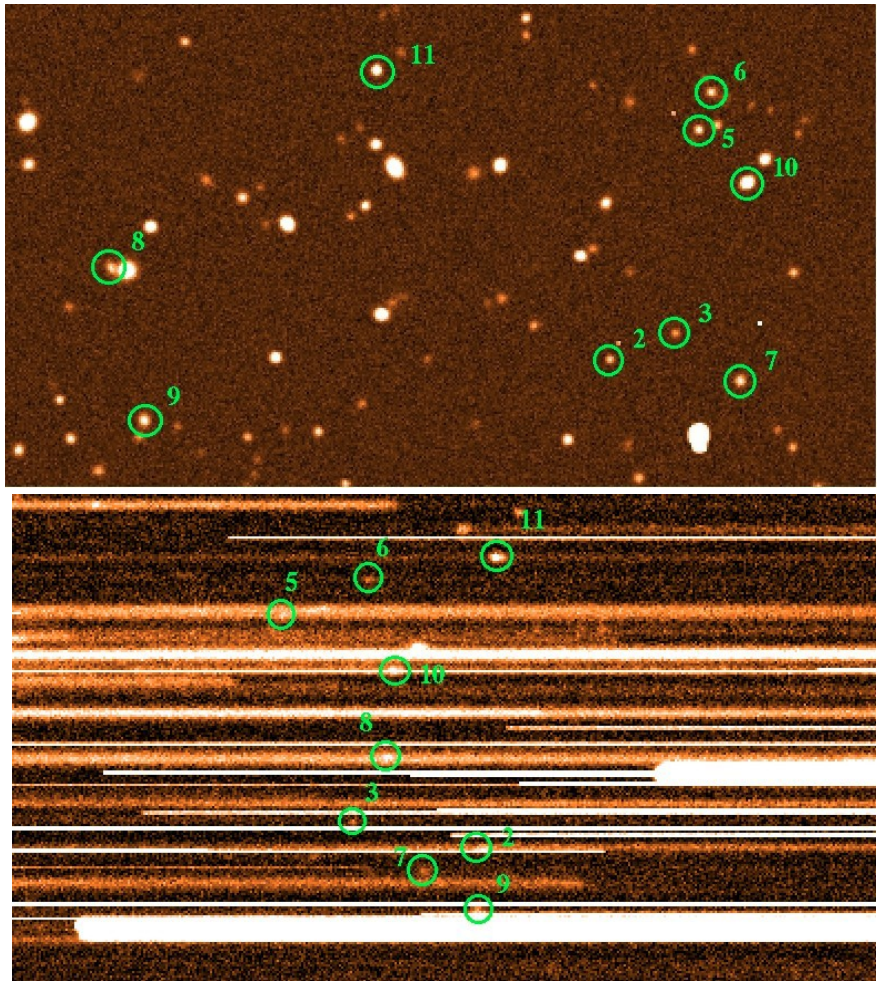
SDSS @ z=0.1 Euclid @ z=0.1 Euclid @ z=0.7

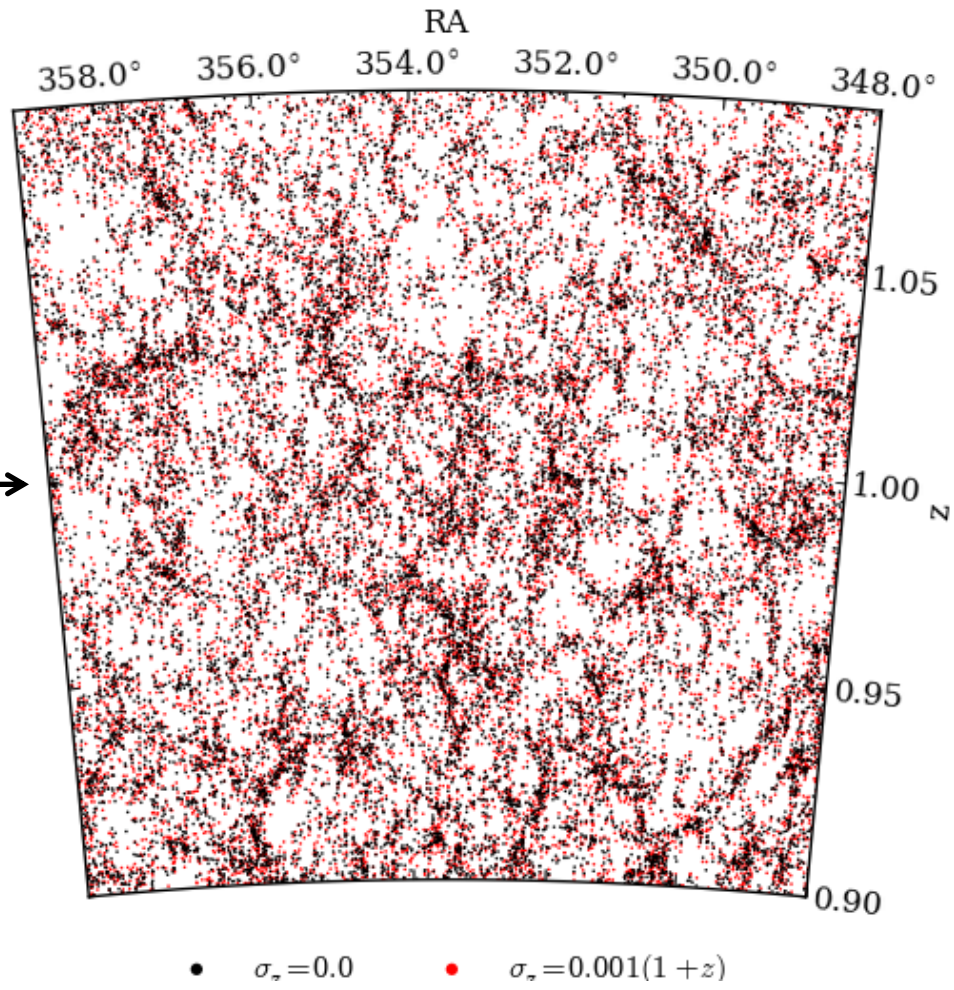
- Euclid images of z~1 galaxies: same resolution as SDSS images at z~0.05 and at least 3 magnitudes deeper.
- Space imaging of Euclid will outperform any other surveys of weak lensing.

NISP Performance: images/spectra/redshifts

Euclid Consortium

Courtesy Anne Ealet, Knud Jahnke, Bianca Garilli, Will Percival, Luigi Guzzo





- 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

True vs. measured redshift

Third Euclid probe: Clusters of galaxies

Euclid Consortium

- Clusters of galaxies: probe of peaks in density distribution
  - number density of high mass, high redshift clusters very sensitive to
    - any primordial non-Gaussianity and
    - deviations from standard DE models

- Euclid data =
  - 60,000 clusters with a S/N>3 between $0.2<z<2$ (obtained for free).
  - more than 10^4 of these will be at $z>1$.
  - ~ 5000 giant gravitational arcs

  → very accurate masses for the whole sample of clusters (WL)
  → dark matter density profiles on scales >100 kpc
    → direct constraints on numerical simulations.
  → 300000 strong galaxy lensing + 5000 giant arcs
    → test of CDM : probe substructure and small scale density profile.
- Synergy with Planck and eROSITA

Cluster with Euclid VIS+NIS imaging

Euclid Consortium

Euclid combined VIS+Y+J+H images of a simulated cluster

Courtesy Massimo Meneghetti

Euclid Legacy and other surveys

Euclid Legacy

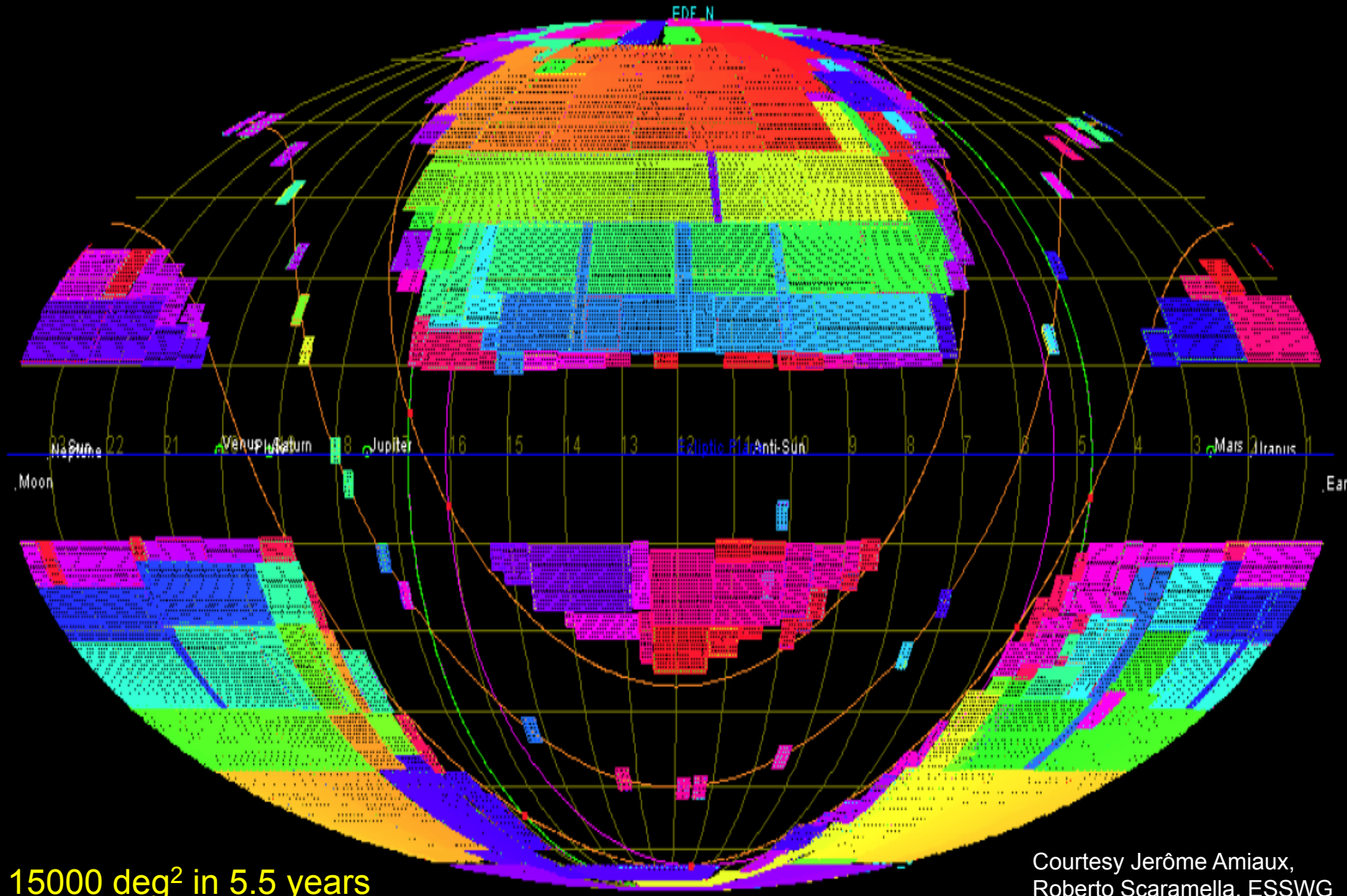
- 12 billion of stars and galaxies
- 50 millions spectra/redshifts
  - Statistics: = a SDSS @ 1<z<3
  - Rare objects
  - High res. imaging of the extragalactic sky,
  - NIR: cool, obscured and high-*z* sources
    - Wide:15,000 deg^2, YJH_{AB}=24
    - Deep: 40 deg^2 , YJH_{AB}=26
- Synergy: LSST, GAIA, e-ROSITA, Planck
- Targets for JWST, ELT's, ALMA

e-Euclid: exo-Planets, SN, Milky Way?

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 Deep+Wide survey model

Euclid Consortium

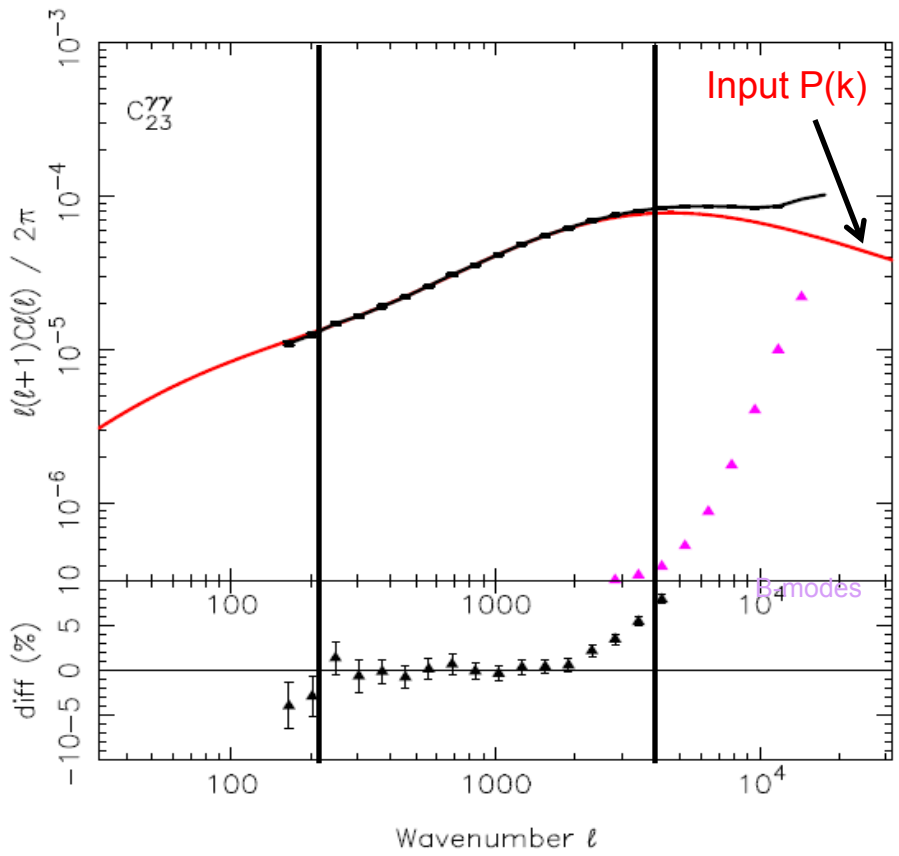


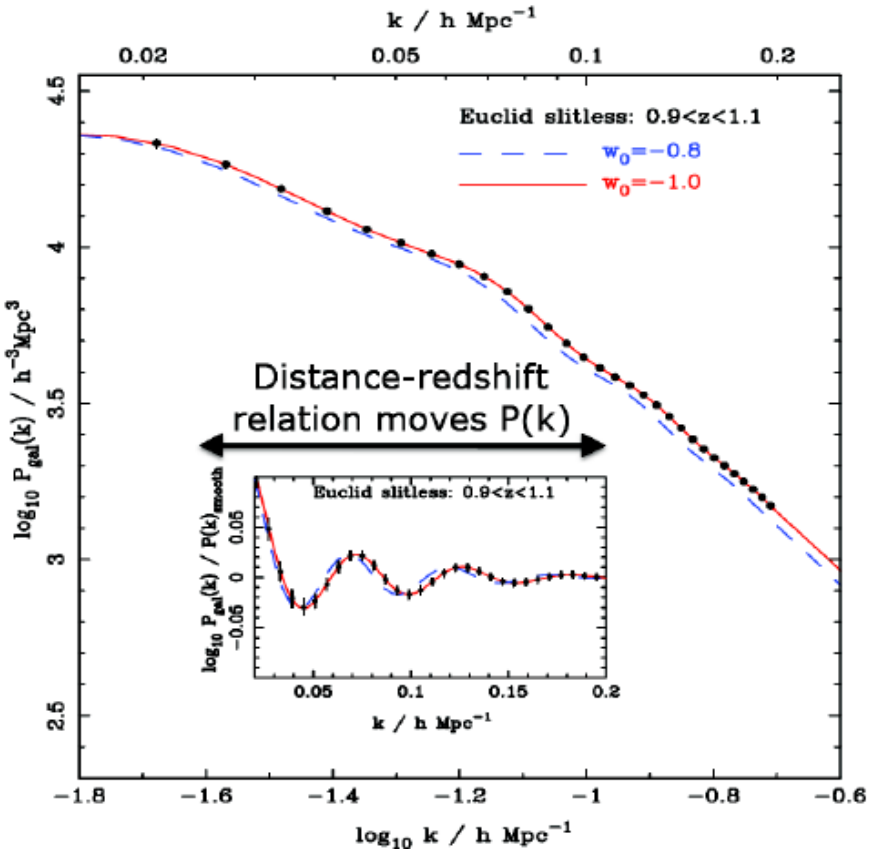
15000 deg^2 in 5.5 years

Courtesy Jerôme Amiaux,
Roberto Scaramella, ESSWG

Euclid: DM and Galaxy reconstructed P(k)

Euclid Consortium





• 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% .

• $V_{eff} \approx 19\ h^{-3}\ Gpc^3 \approx 75x$ larger than SDSS
• Redshifts 0<*z*<2

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

Ref: Euclid RB arXiv:1110.3193 from Euclid SWGs

Predicted FoM of the Euclid mission

Euclid Consortium

	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν /eV	f_{NL}	w_p	w_a	*FoM*
Euclid primary (WL+GC)	0.010	0.027	5.5	0.015	0.150	430
Euclid all probes	0.009	0.020	2.0	0.013	0.048	1540
Current (2009)	0.200	0.580	100	0.100	1.500	~10
Improvement Factor	**30**	**30**	**50**	**>10**	**>40**	**>400**

Ref: Euclid RB arXiv:1110.3193 from Euclkid SWGs
More detailled forecasts given in Amendola et al arXiv:1206.1225

Euclid and External data

- **Analyses and Calibrations:**
  - GAIA data for astrometric calibration of Euclid data (2MASS as backup)
  - Latest high-res. Galaxy extinction correction maps
  - 4-band visible (g,r,i,z) photometry for photo-z: 15,000 deg^2, AB=24.0 , 5-sigma
  - Deep MOS spectroscopic sample for photo-z calibrations: IAB=24.5, 10^5 galaxies, representative sample of galaxies used for weak lensing;
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  - E-ELT/JWST/ALMA/VLT/SKA
    - faint and/or very high-z objects, lensed/lenses;
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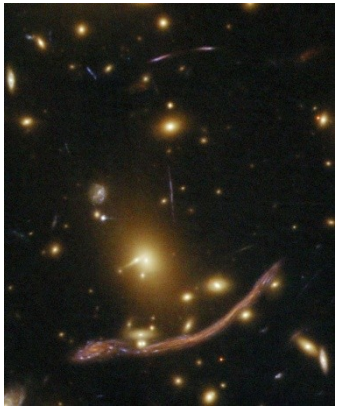
    - IFU for 2-D spectroscopy (galaxies, arcs);
  - E-ELT/VLT/JWST: time domain: light curve SNIa + spectro SNIa
  - E-ELT/JWST for exo-planet candidates.

Importance of redshifts

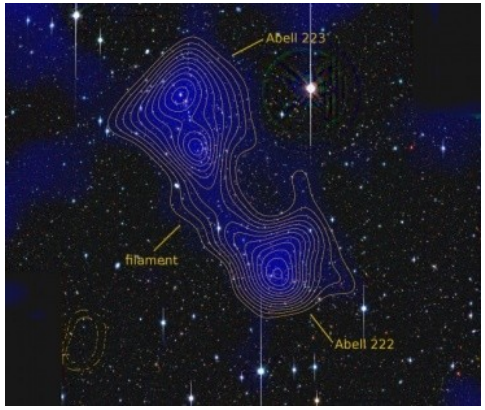
Euclid Consortium

HST/ACS credit NASA/ESA

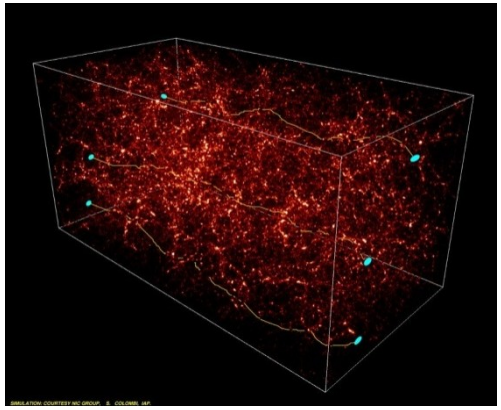
HST/ACS; credit NASA/ESA



Dietrich et al 2012



Colombi/Mellier



Galaxy halos — Clusters of galaxies — Filaments between clusters — Cosmic shear

$$\vec{\alpha} = \frac{2}{c^2} \frac{D_{LS}}{D_{OS}} \vec{\nabla}_{\vec{\theta}_I} \phi_N^{2D}$$

Redshifts of sources and lenses are needed

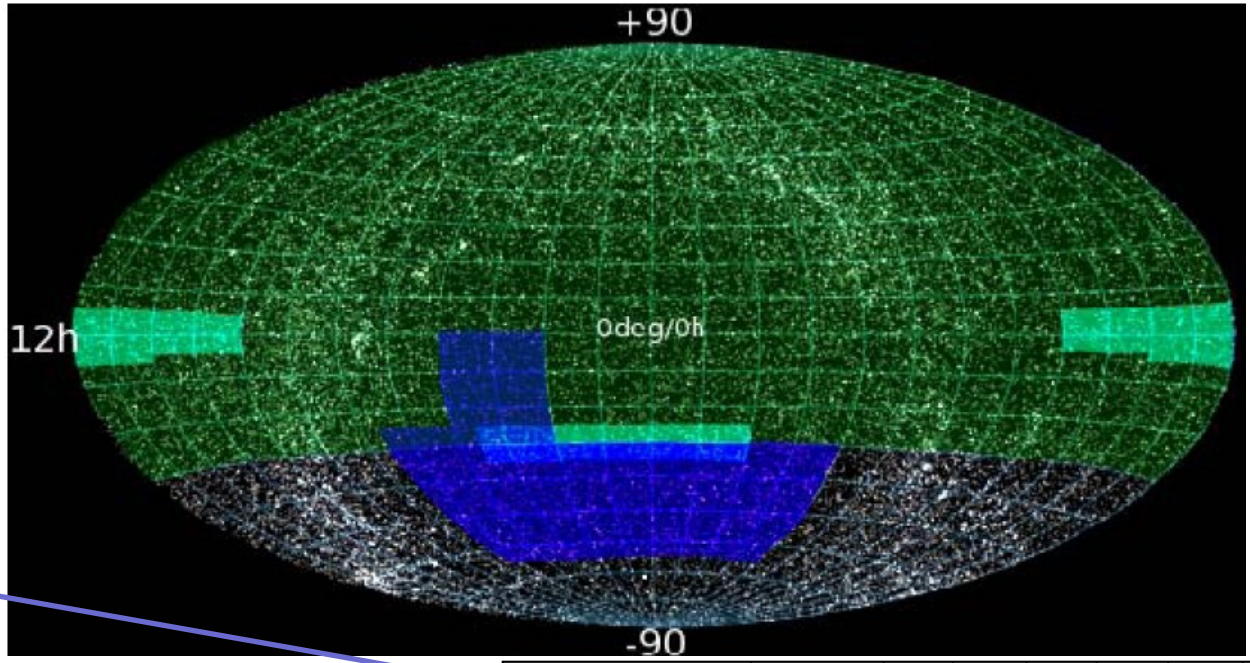
Cosmic shear tomography redshifts are also needed to

- Slice the universe
- Clean contamination by intrinsic alignements of galaxies

Ground surveys: imaging/photometry for photo-z

Euclid Consortium

- No ESO >=4-m class telescope for the visible.
- ESO/VST ? (u)grizY data
- Needed by 2020



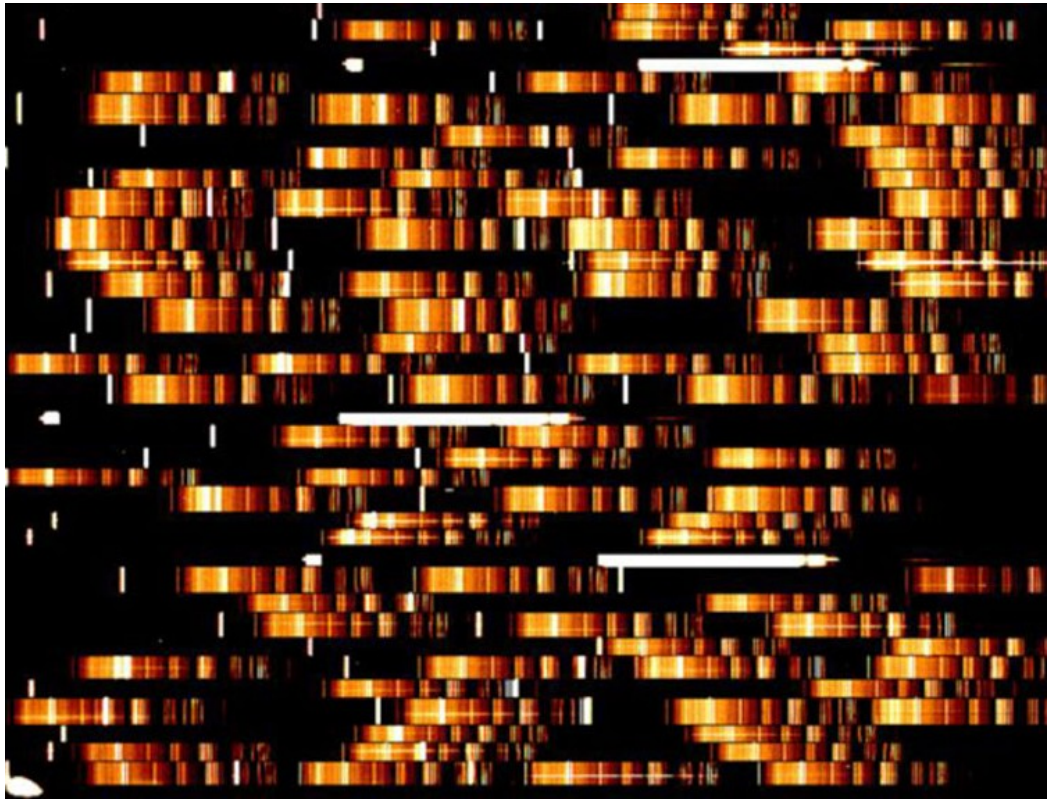
External survey timelines	2011	2012	2013	2014	2015	2016	2017	2018
KiDS-VIKING	Survey underway		VIKING completed	KiDS completed, VIKING final release	, KiDS final release			
Pan-STARRS1	Survey underway		Survey completed		PS1 final release			
Pan-STARRS2				Survey start				
DES		Survey start		1st data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

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			

Need big very-deep spectroscopic samples

Euclid Consortium

ESO PR, Le Fèvre et al 2006



- **CFHTLS : VVDS** with VMOS,
  - 32,000 redshifts to I=22.5 over ~15 deg^2, (Garilli et al 2008)
  - 15,000 to I=24 over ~1 deg^2 (Le Fèvre et al 2005)
  - 1000 redshifts 23<I<24.75 over 0.15 deg^2 (Le Fèvre et al 2012)

- **CFHTLS : VIPERS** with VMOS: ~100,000 redshifts to I=22.5 over 25 deg^2 (Guzzo et al 2012)

- **COSMOS : z-Cosmos** with VMOS:
  - ~ 20,000 redshifts to I=22.5 over 1.7 deg^2 (Lilly et al 2009)
  - ~10,000 redshiifts B<25.25 color selected, over 0.9 deg^2

… How can we get 10^5 redshifts for I=24.5 + subsamples to I>24.5??
MOS: PFS@Subaru, **4MOST and/or MOONS at ESO**?

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  - E-ELT/VLT/JWST: time domain: light curve SNIa + spectro SNIa
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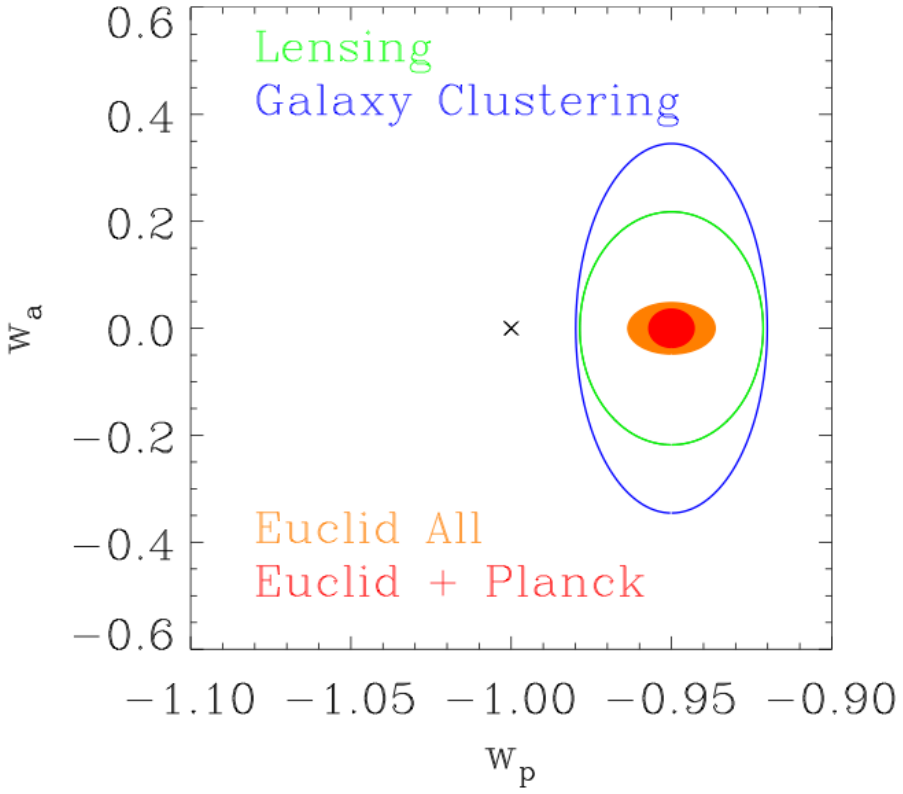
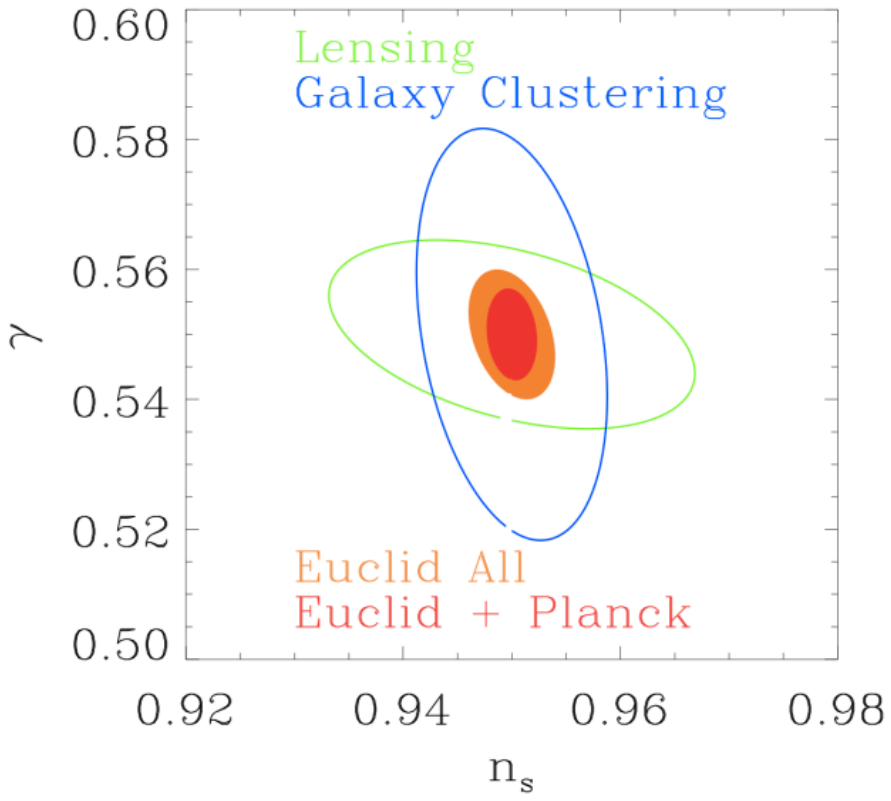
Euclid(WL+GC)+Planck: predicted performances

Euclid Consortium



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.

Ref: Euclid RB arXiv:1110.3193 from Euclid SWGs

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Euclid + Planck	**0.007**	**0.019**	**2.0**	**0.007**	**0.035**	**4020**
Current (2009)	0.200	0.580	100	0.100	1.500	~10
Improvement Factor	**30**	**30**	**50**	**>10**	**>40**	**>400**

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  - E-ELT/JWST for exo-planet candidates.

Euclid Legacy and other surveys

Euclid Legacy

- 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

ESO: VLT, E-ELT, ALMA:
Follow up: deep, ultra deep 1-D and 2-D spectro
Starting by 2020 until ~2040+ …

e-Euclid: exo-Planets, SN, Milky Way? -→ **Follow up needed**

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
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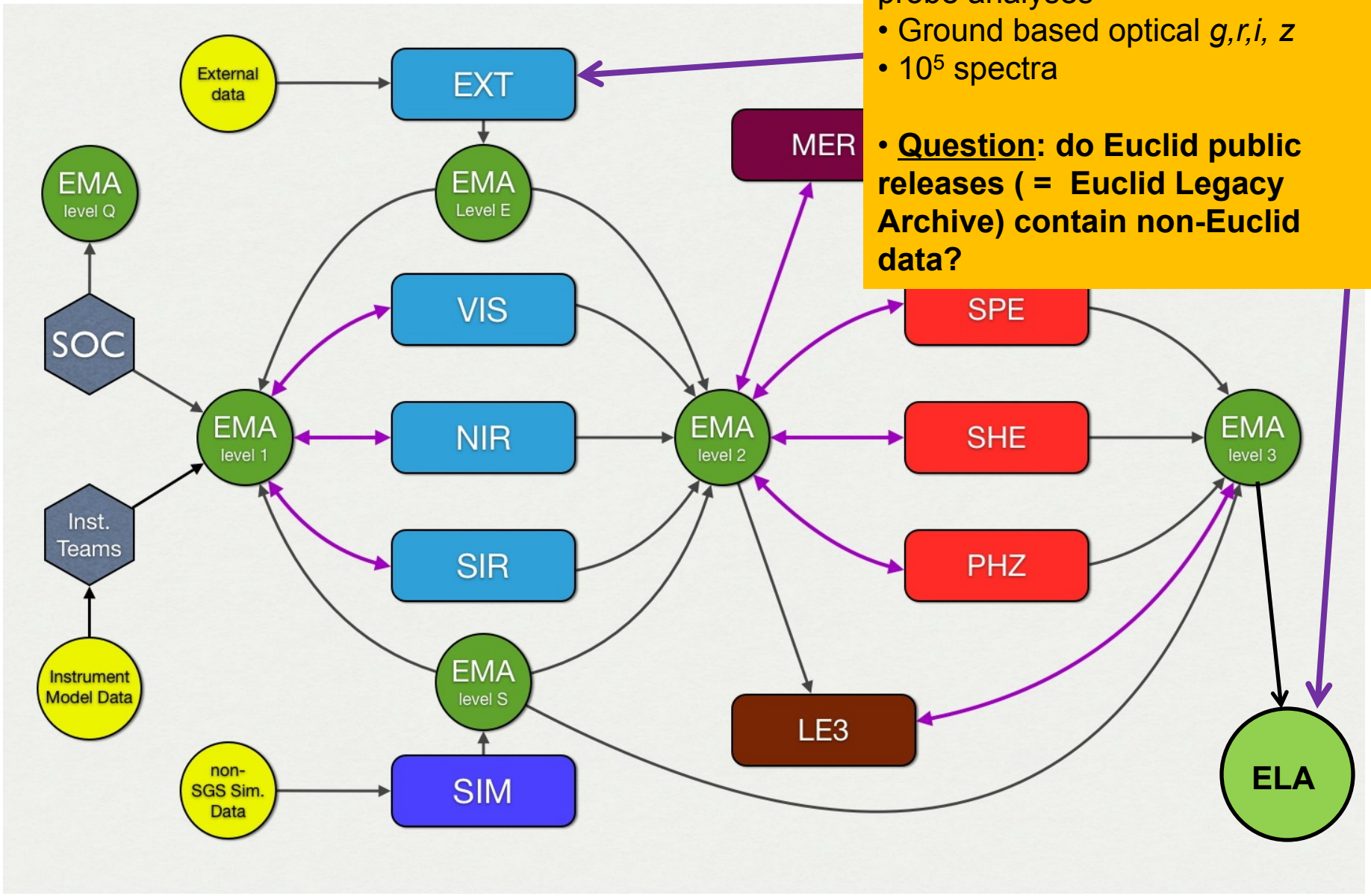
  - Deep MOS spectroscopic sample for photo-z calibrations: IAB=24.5, 10^5 galaxies, representative sample of galaxies used for weak lensing;
  - Ultra-Deep MOS spectroscopic samples for purity of Euclid spectroscopy data: Completeness 99.5%, Number TBC, Depth TBC.
- **Combined analyses with external data:**
  - Planck CMB C_l data;
  - Euclid clusters + CMB (ISW analyses);
  - eROSITA clusters of galaxies.
- **Euclid targets follow up, monitoring:**
  - E-ELT/JWST/ALMA/VLT/SKA
    - faint and/or very high-z objects, lensed/lenses;
    - very red (cold, dust enshrouded) nearby compact objects;
    - IFU for 2-D spectroscopy (galaxies, arcs);
    - MOS follow up of potentially 12 10^9 sources
  - E-ELT/VLT/JWST: time domain: light curve SNIa + spectro SNIa
  - E-ELT/JWST for exo-planet candidates.

Public access to external data

- GAIA, 2MASS, etc.. for calibration
- Planck + eRosita for combined probe analyses
- Ground based optical *g,r,i, z*
- 10^5 spectra

- **<u>Question</u>: do Euclid public releases (= Euclid Legacy Archive) contain non-Euclid data?**



Summary-1: Euclid

- Some Euclid external data are full part of the mission

→ to be planned and consolidated far in advance:

- Visible imaging data for photo-z : before launch and/or in phase with the survey progression… no ESO facility!
- Deep spectroscopic surveys for photo-z calibration: before launch or in phase with first Level-3 release (Launch+26 months).
- Ultra-deep spectroscopic surveys for purity calibration: before launch or in phase with first Level-3 release. Need clarifications (depth, completeness, number).

→There is a clear need for next generation, wide field faint MOS instrument, in operation

1. before Euclid launch date,
2. after launch for MOS follow up of potentially 12 10^9 Euclid (Wide+Deep) sources.

Summary-2: Euclid

- The launch date of Euclid does match E-ELT and JWST first lights:

  → they can be fed by the Euclid Core/Legacy archive.

- External All-sky space data:
  - Planck data: secured,
  - GAIA: we are confident (but we have backups),
  - eROSITA/Euclid synergy looks most promising.

- External All-sky ground based:
  - LSST first light + Subaru/HSC: 2020, visible complement of Euclid (+DES): ESO community access?