The Euclid Mission

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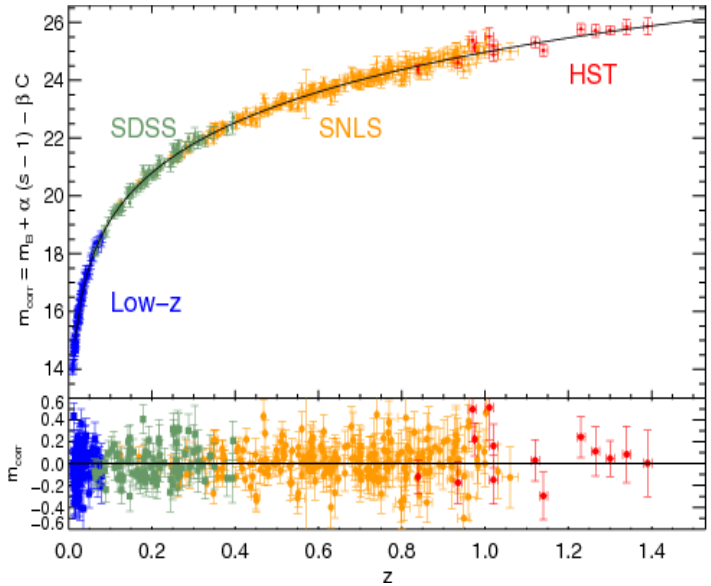
On behalf of the Euclid consortium – `www.euclid-ec.org`

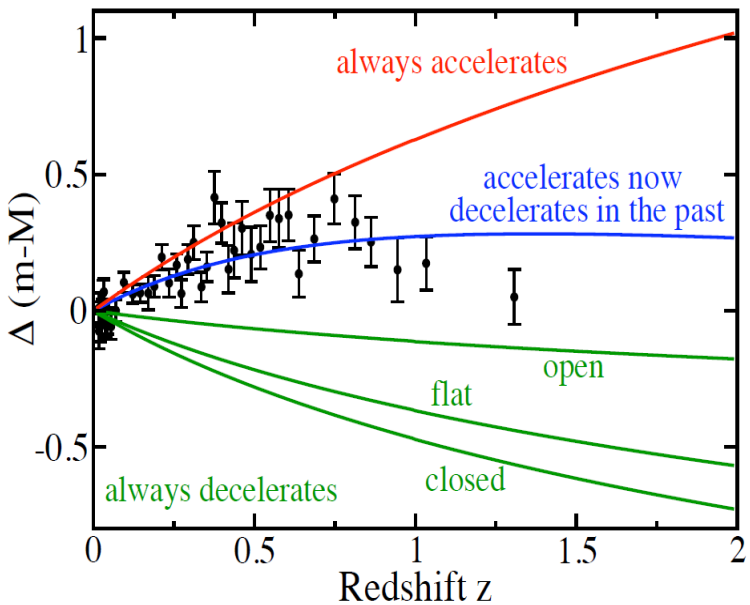
Motivation - I

SNIa observations are pointing toward

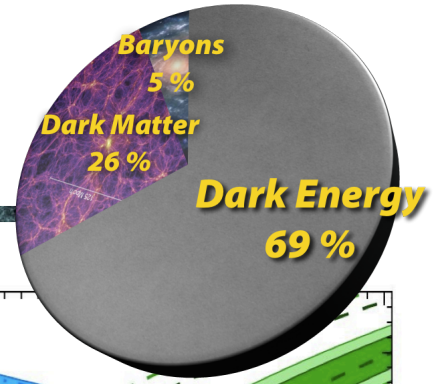
a. An accelerated expansion of the Universe today



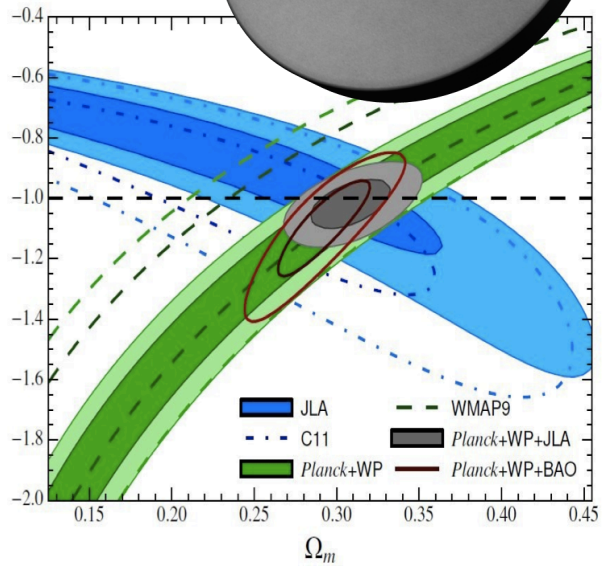
b. A late time acceleration: expansion was decelerating in the past during matter dominated era



Motivation - II



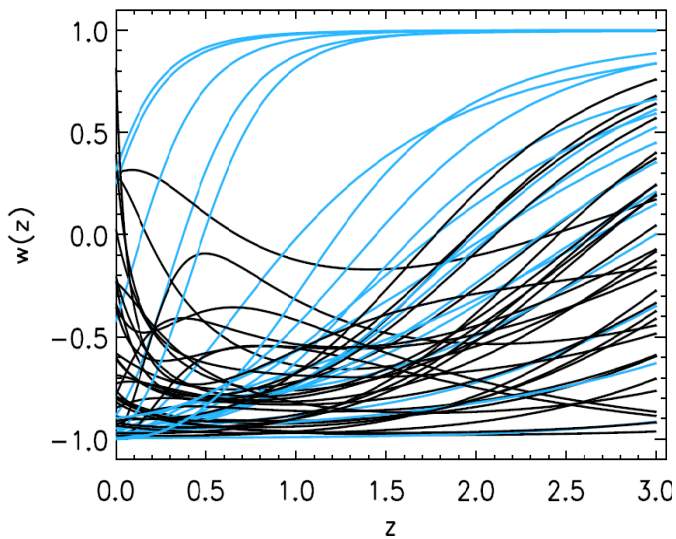
- CMB (Planck) + Geometry probes (SNIa, BAO) (mainly from Planck) point toward large contribution of DE at late time indiscernible from a cosmological constant



- No way from current probes to assess exact nature of the component
  - It could be something different
  - Even in the dynamical DE class, too many models

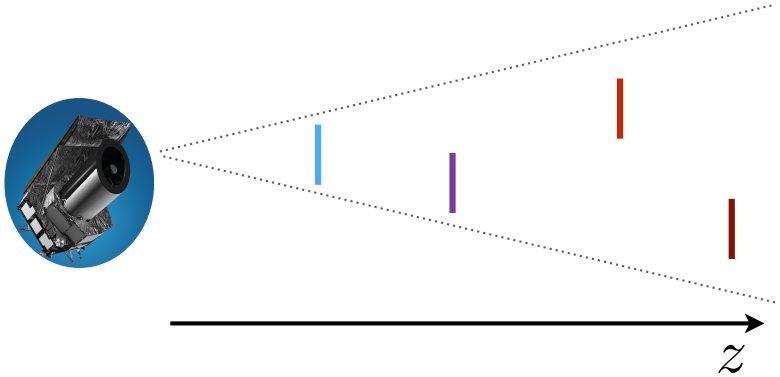
$$w = P/\rho, \quad w(t) = w_0 + w_a(t) + \ldots$$

$w = 0$	*matter*
$w = 1/3$	*radiation*
$w = -1$	*cosmological constant*
$w(t) > -1 \quad (dw/dz > 0)$	*quintessence*
$w(t) > -1 \quad (dw/dz < 0)$	*k-essence*
$w(t) < -1$	*phantom*



How to look for accelerated expansion ?

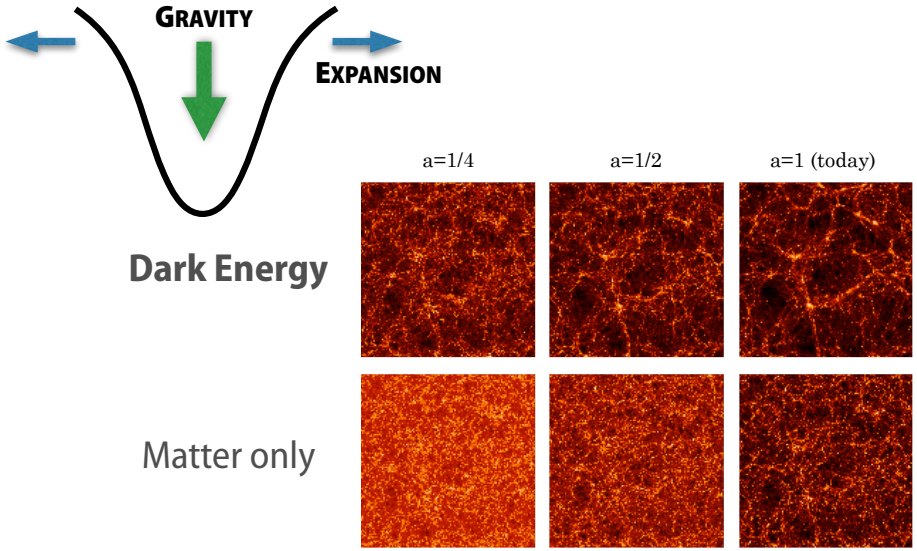
Geometry



Look at how a know scale (from the observer or at fixed depth) is seen at different redshifts.

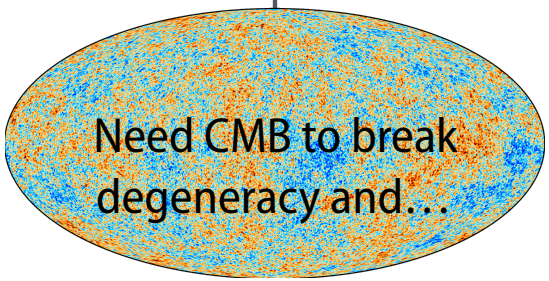
Fix the hubble radius at z=1100

Clustering evolution



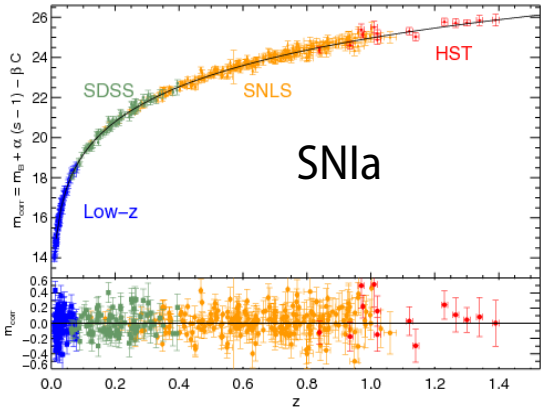
Look at how a the clustering of matter evolve under the joint influence of gravity and expansion.

Measure the amplitude and slope of fluctuation.
Measure energy density of matter.

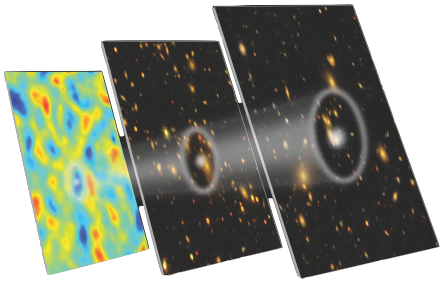


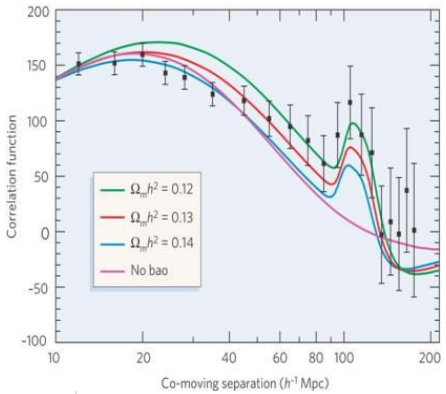
Probes

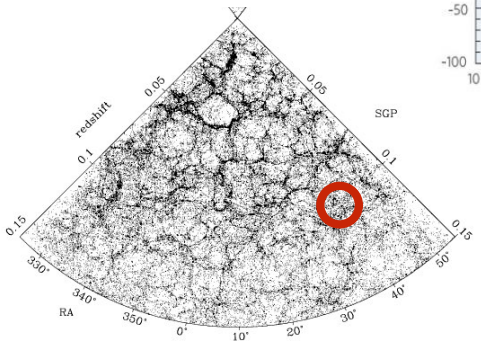
Geometry



SNIa

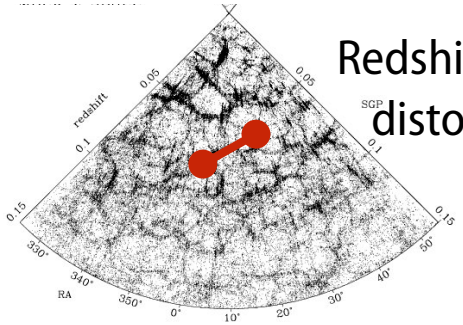




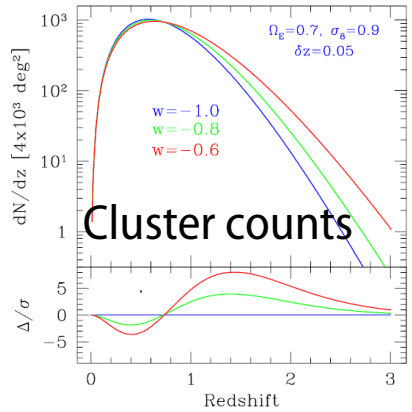


Baryon acoustic oscillations

Clustering evolution



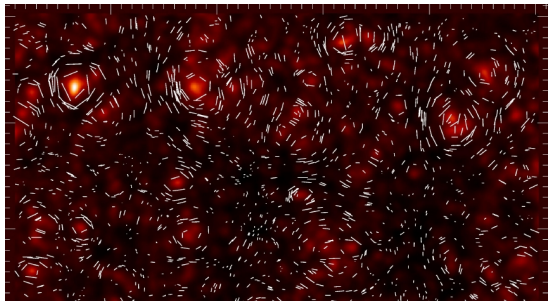
Redshift space distorsions



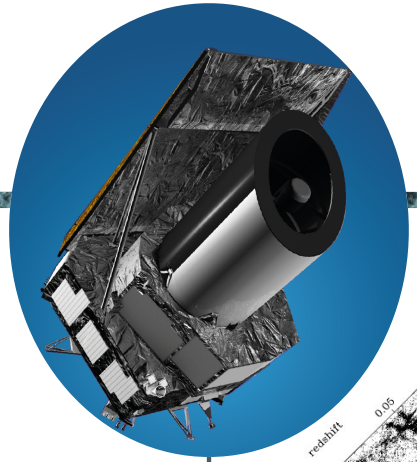
Cluster counts

Strong & weak cluster lensing

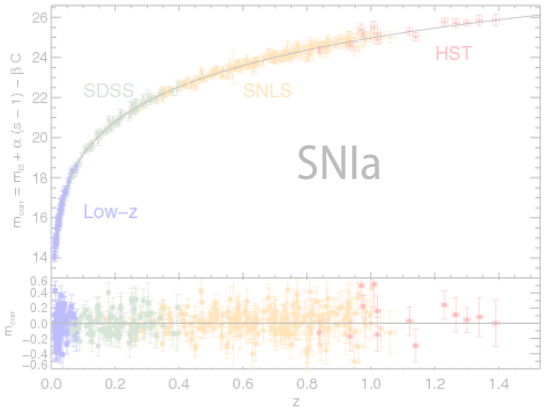
Cosmological weak lensing

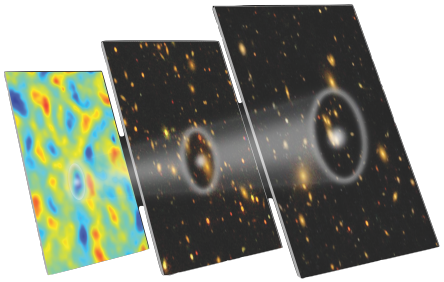


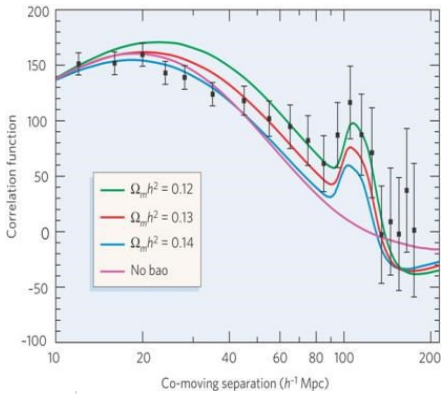
Euclid

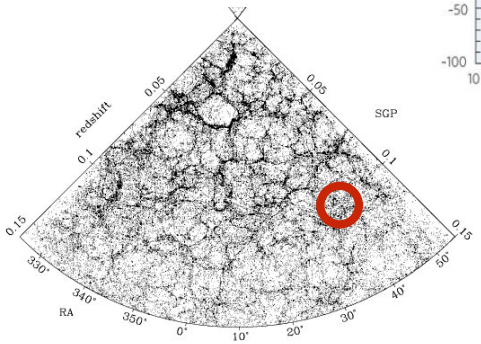


Geometry









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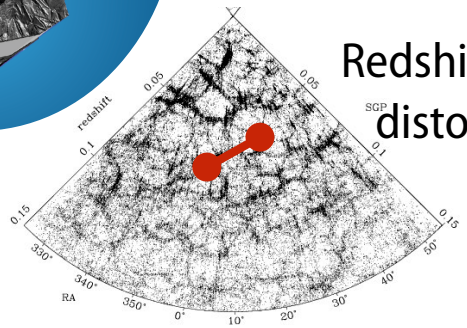
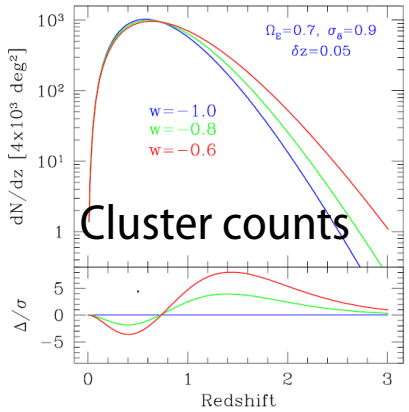


Redshift space distorsions



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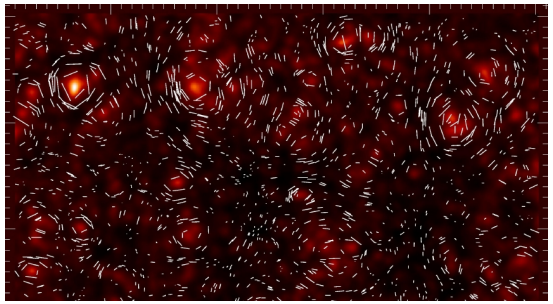
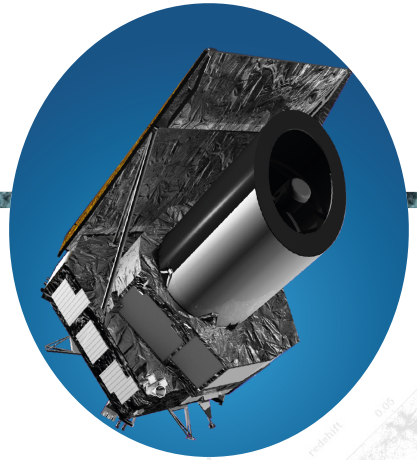
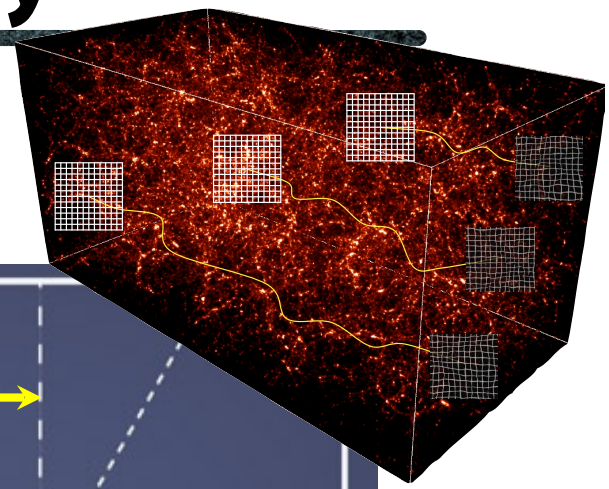


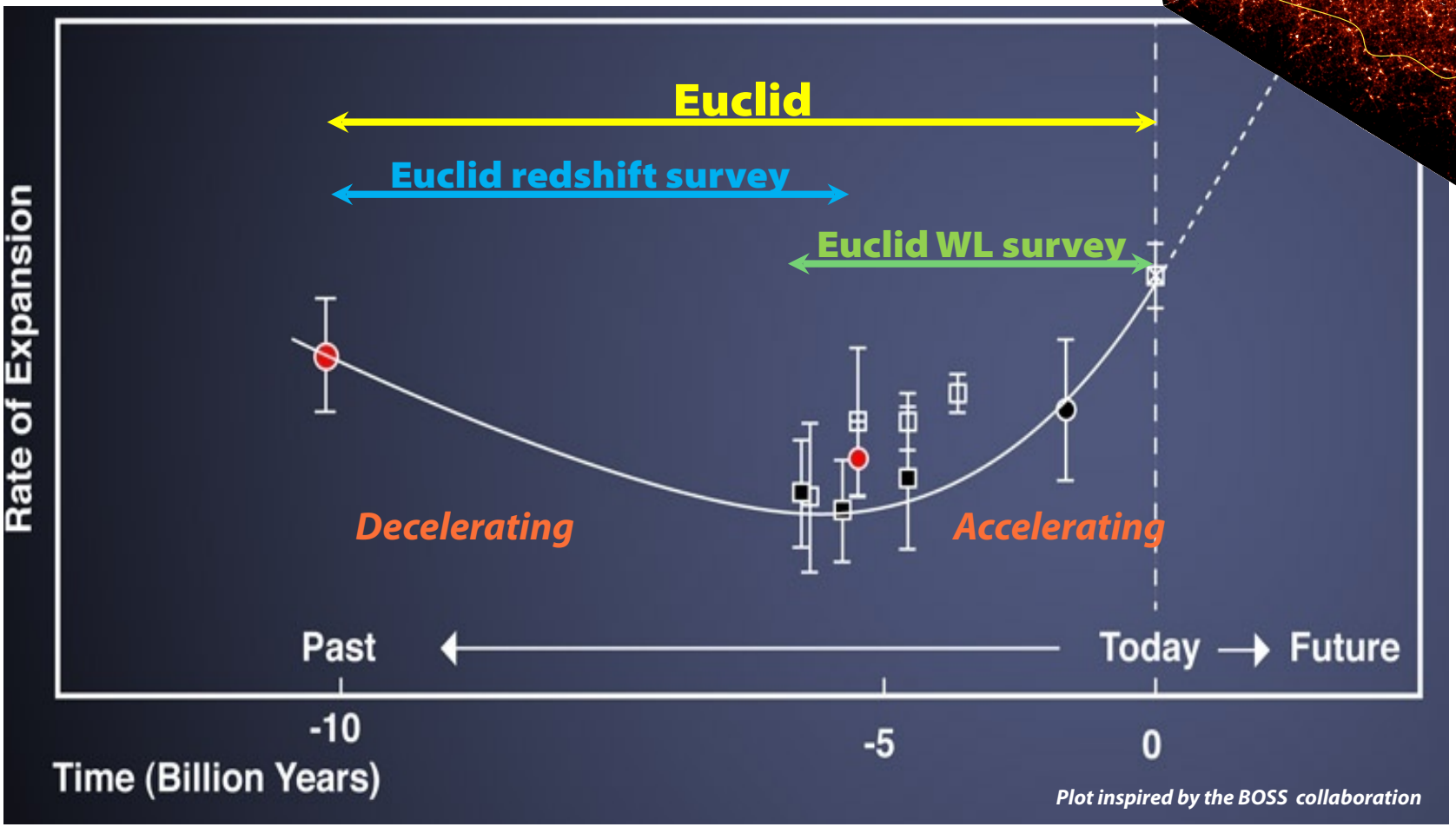
Euclid



- **A single survey providing data for 5 different probes of dark energy**
  - Optimal use of a space observatory
  - Explore both geometry/expansion and clustering evolution/growth of structures
- **Design allow for a single visit to acquire imaging and spectroscopy on wide fields**
- **Main probes are Weak Lensing and BAO/RSD surveys**
  - ***WL: 1.5 10^9 galaxy shapes, shear & photo-z*** (u,g,r,i,z,Y,J,H, $\Delta z = 0.05(1+z)$)
    - 15000 deg^2 , up to z=2
  - ***GC/RSD: 35 10^6 spectroscopic redshifts*** ($\Delta z = 0.001(1+z)$)
    - 15000 deg^2 probing 0.7<z<1.8
  - Great for DE
  - *Fantastic for ancillary astrophysics!*

Euclid surveys complementarity





Euclid Science Requirements

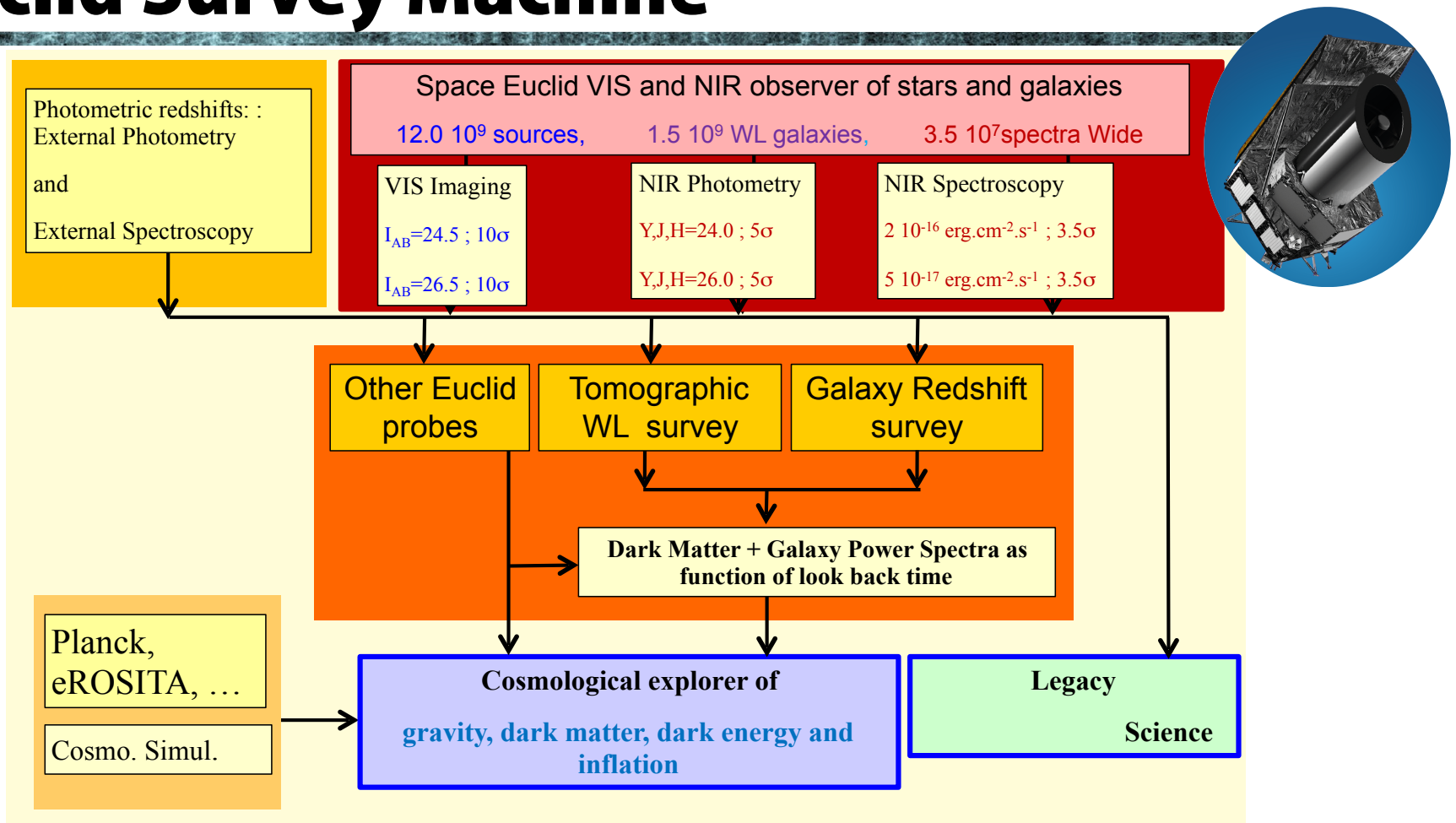
Sector	*Euclid Targets*
Dark Energy	• Measure the cosmic expansion history to better than 10% in redshift bins $0.7 < z < 2$. • Look for deviations from $w = -1$, indicating a dynamical dark energy. • Euclid *alone* to give $FoM_{DE} = 1/(\Delta w_p \Delta w_a) \geq 400$ ($\Delta w_p = 0.02$ & $w_a = 0.1$ marginals) i.e. % precision on ws
Test Gravity	• Measure the growth index, Ω^{γ}, with $\Delta\gamma \leq 0.02$ • Measure the growth rate to better than 0.05 in redshift bins between $0.5 < z < 2$. • Separately constrain the two relativistic potentials. ψ and φ • Test the cosmological principle
Dark Matter	• Detect dark matter halos on a mass scale between 10^8 and $>10^{15}$ M_{Sun} • Measure the dark matter mass profiles on cluster and galactic scales • Measure the sum of neutrino masses, the number of neutrino species and the neutrino hierarchy with an accuracy of a few hundredths of an eV
Initial Conditions	• Measure the matter power spectrum on a large range of scales in order to extract values for the parameters σ_8 and n to a 1-sigma accuracy of 0.01. • For extended models, improve constraints on n and α wrt to Planck alone by a factor 2. • Measure a non-Gaussianity parameter : f_{NL} for local-type models with an error < +/-2.

Forecasts

	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν /eV	f_{NL}	w_p	w_a	***FoM***
Current (2009 - WMAP)	*0.200*	*0.580*	*100*	*0.100*	*1.500*	*~10*
Euclid primary (WL+GC)	0.010	0.027	5.5	0.015	0.150	430
EuclidAll (clusters,ISW)	0.009	0.020	2.0	0.013	0.048	1540
Euclid+Planck	*0.007*	*0.019*	*2.0*	*0.007*	*0.035*	*>6000*
Improvement Factor	***30***	***30***	***50***	***>10***	***>40***	***>400***

Laureijs et al 2011

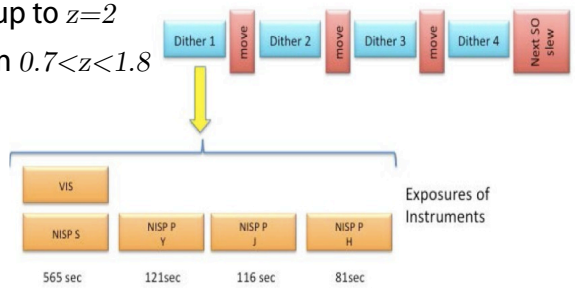
Euclid Survey Machine

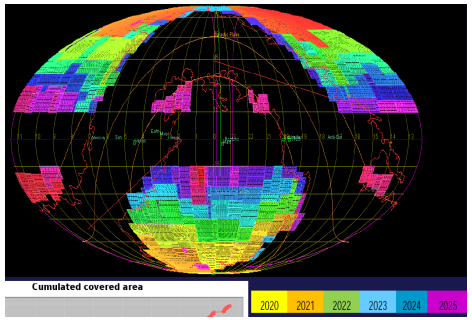


- Euclid mission
  - 2 surveys: wide: 15000deg^2 & deep: 40deg^2
  - 1 space borne observatory + numerous ground based ones
  - Synergy with numerous ancillary experiments (Planck, eRosita…)
  - Dark Energy/cosmology AND great legacy science

Surveys

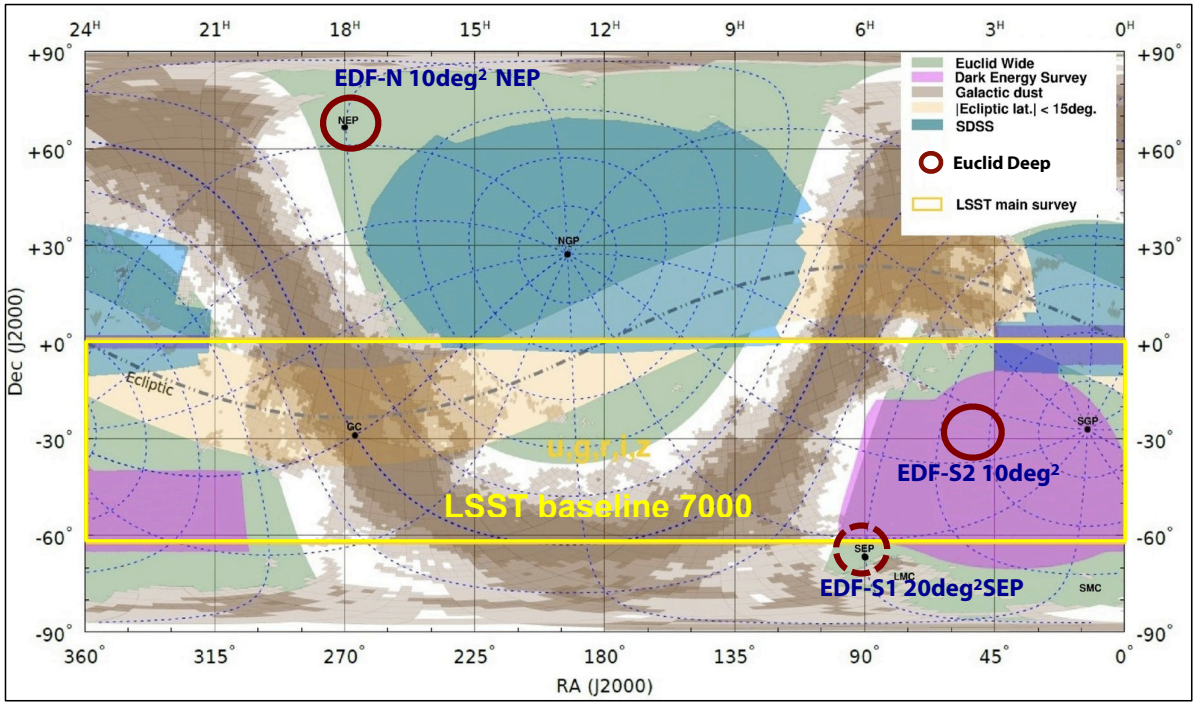
- **Common features**
  - Very accurate morphology (VIS)
  - Visible (u,g,r,i,z) & NIR (Y,J,H) photometry, $\Delta z=0.05(1+z)$ probing up to $z=2$
  - Spectroscopy, R: 260, $\Delta z=0.001(1+z)$ probing H_α galaxies between $0.7<z<1.8$
  - 6 years survey





- **Wide**
  - 15000 deg^2 — 12 10^9 sources (3σ)
  - Photometry
    - 1.5 10^9 galaxies
    - Visible $I_{AB}=24.5$ (10σ)
    - NIR $I_{AB}=24.0$ (5σ)
  - Spectroscopy
    - 35 10^6 redshifts
    - 21 mag
    - Flux line: $2\ 10^{-16}\ erg.cm^{-2}.s^{-1}$ (3.5σ)

- **Deep**
  - 10 (NEP)+20 (SEP)+10 (CDFS) deg^2 — 10 10^6 sources (3σ)
  - Photometry
    - 1.5 10^6 galaxies
    - Visible $I_{AB}=26.5$ (10σ)
    - NIR $I_{AB}=26.0$ (5σ)
  - Spectroscopy
    - 15 10^4 redshifts
    - 23 mag
    - Flux line: 5 $10^{-17}\ erg.cm^{-2}.s^{-1}$ (3.5σ)



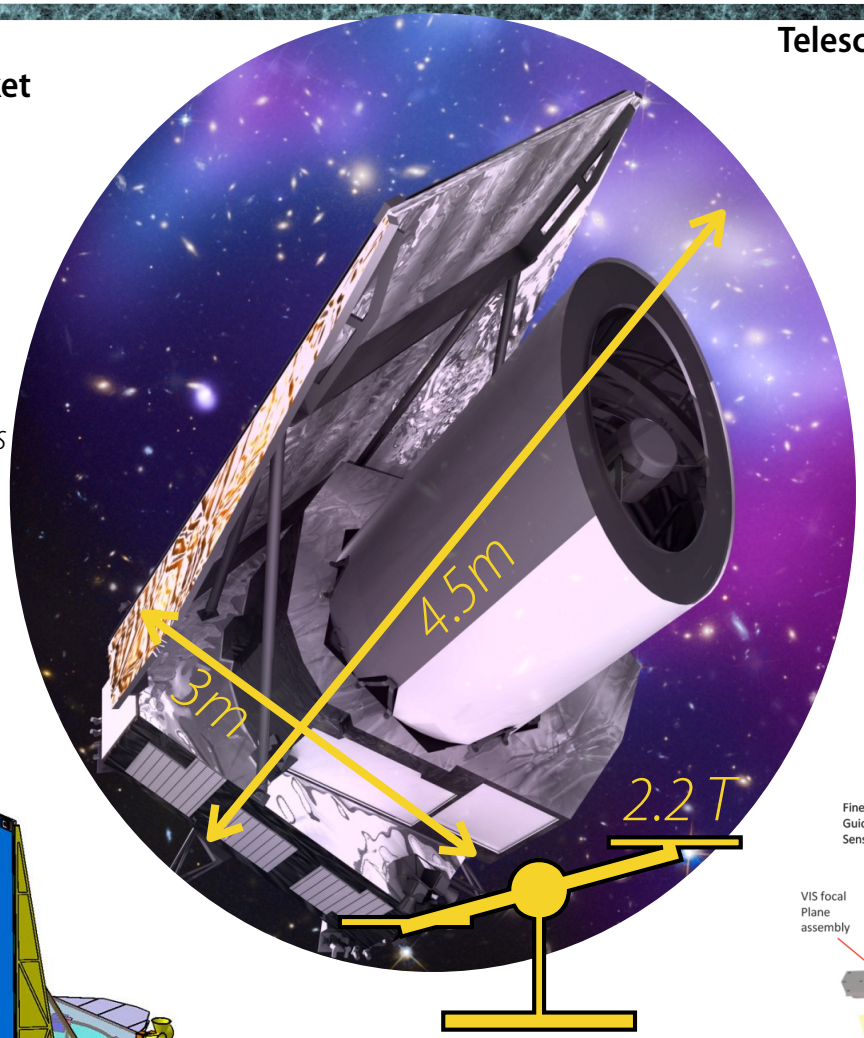
Euclid Satellite

Launch begin 2021 by a Soyuz rocket from Kourou, orbit around L2 (sun/earth) for 6 years of survey

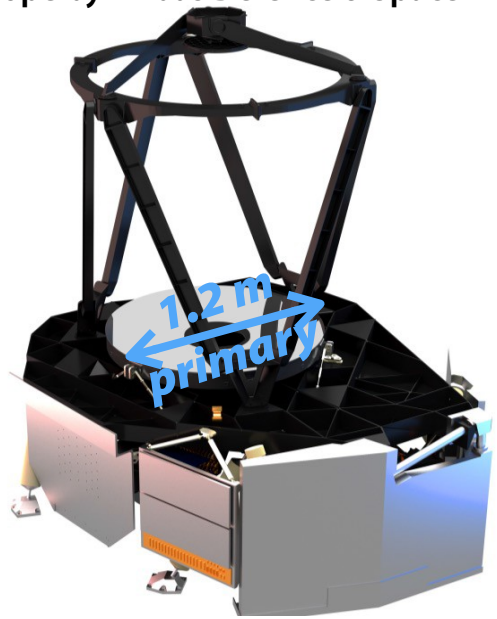
Operation ESA

Large international collaboration (including NASA)

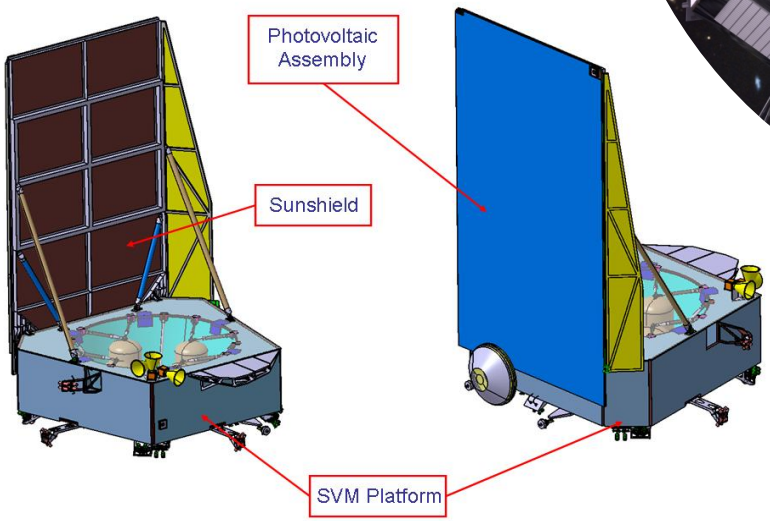
16 countries, 220 labs, 1400 Full members



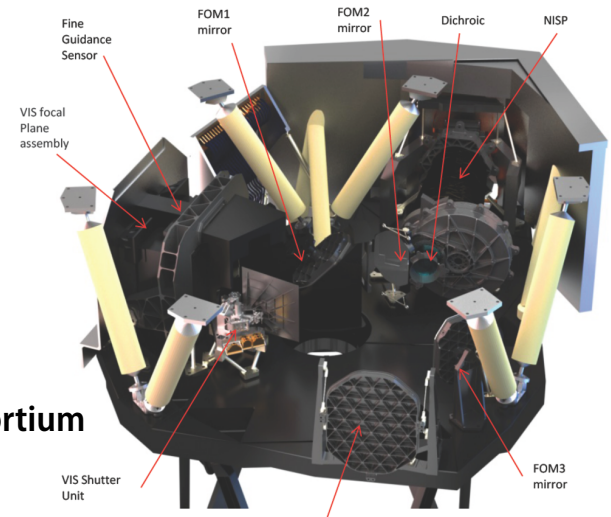
Telescope by Airbus Defence & Space



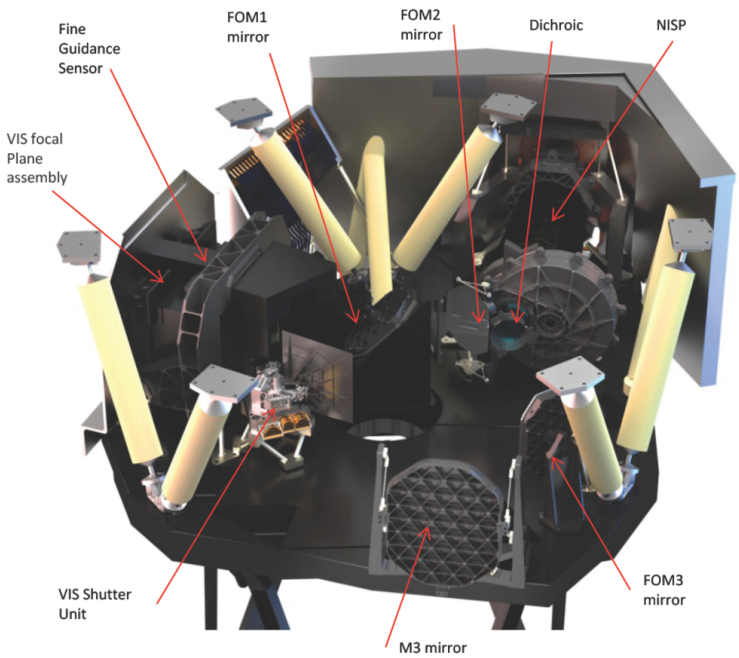
Sun shield and SVM by Thales Alenia Space

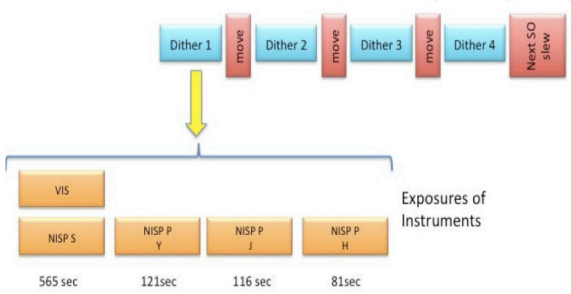


Instruments by Euclid Consortium



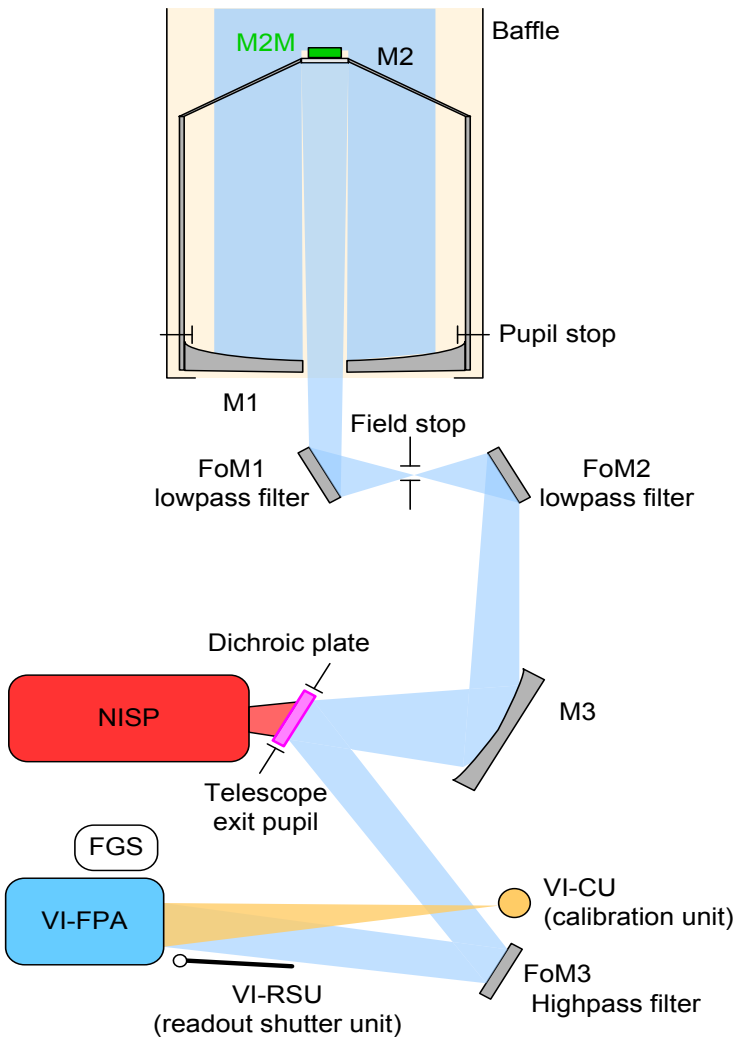
Instruments





Near Infrared spectroscopy and photometry

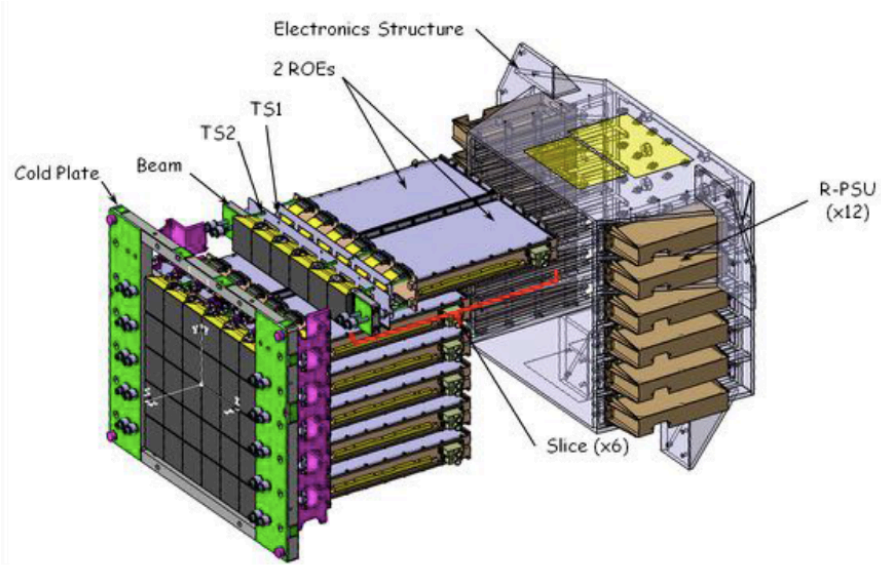
Visible broadband imager



PLM

VIS

VIS CDR on going

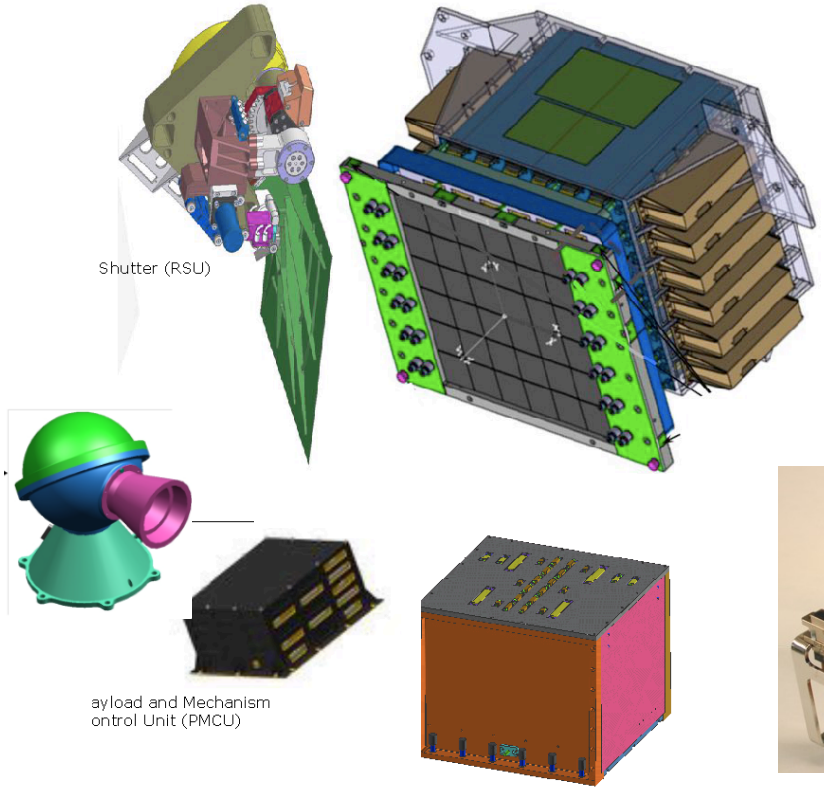


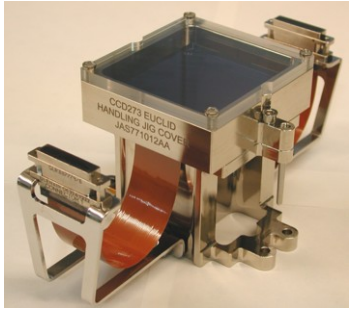
Courtesy: S. Pottinger, M. Cropper and the VIS team

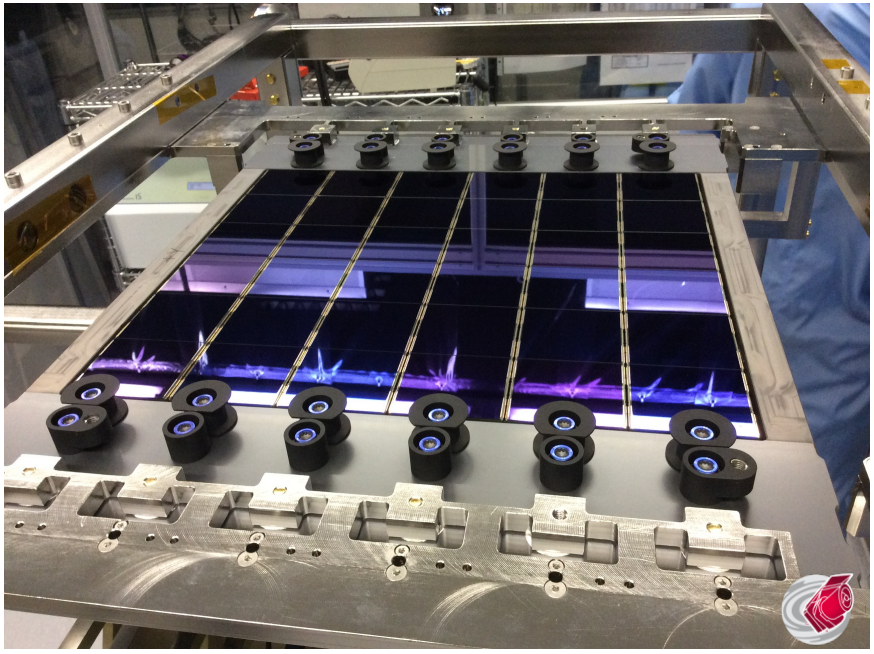
Table 1: VIS and weak lensing channel characteristics

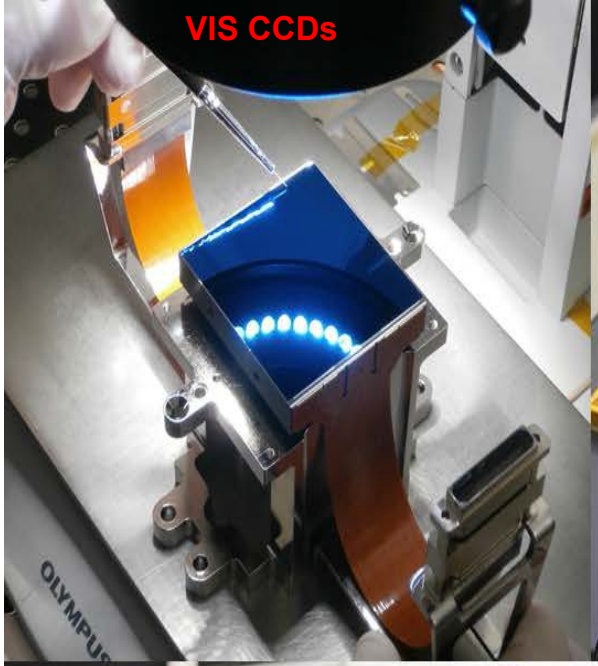
Spectral Band	550 – 900 nm
System Point Spread Function size	≤0.18 arcsec full width half maximum at 800 nm
System PSF ellipticity	≤15% using a quadrupole definition
Field of View	>0.5 deg^2
CCD pixel sampling	0.1 arcsec
Detector cosmetics including cosmic rays	≤3% of bad pixels per exposure
Linearity post calibration	≤0.01%
Distortion post calibration	≤0.005% on a scale of 4 arcmin
Sensitivity	$m_{AB} \geq 24.5$ at 10σ in 3 exposures for galaxy size 0.3 arcsec
Straylight	≤20% of the Zodiacal light background at Ecliptic Poles
Survey area	15000 deg^2 over a nominal mission with 85% efficiency
Mission duration	6 years including commissioning
Shear systematic bias allocation	additive $\sigma_{sys} \leq 2 \times 10^{-4}$; multiplicative $\leq 2 \times 10^{-3}$

Cropper et al 2016:SPIE

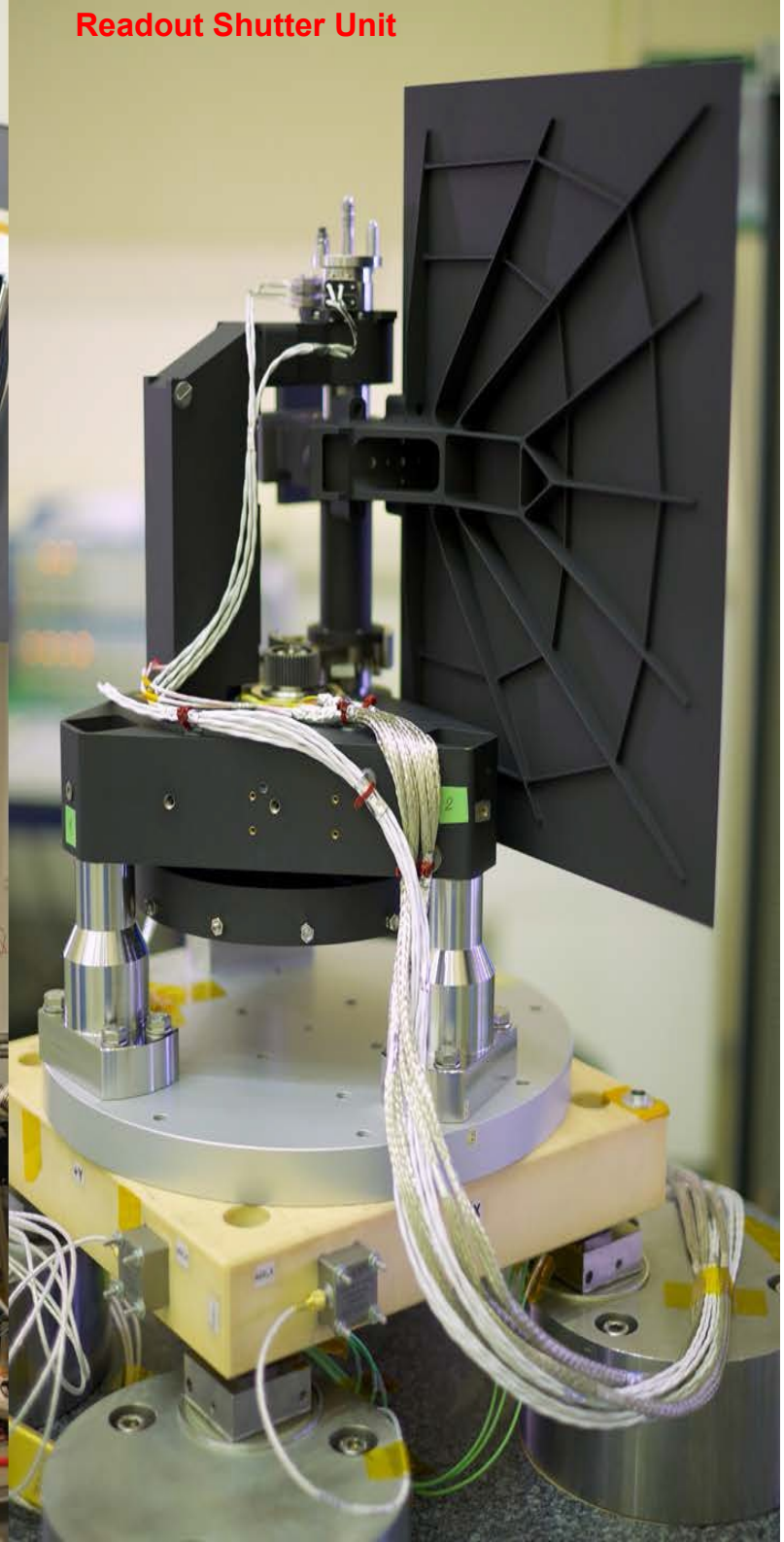






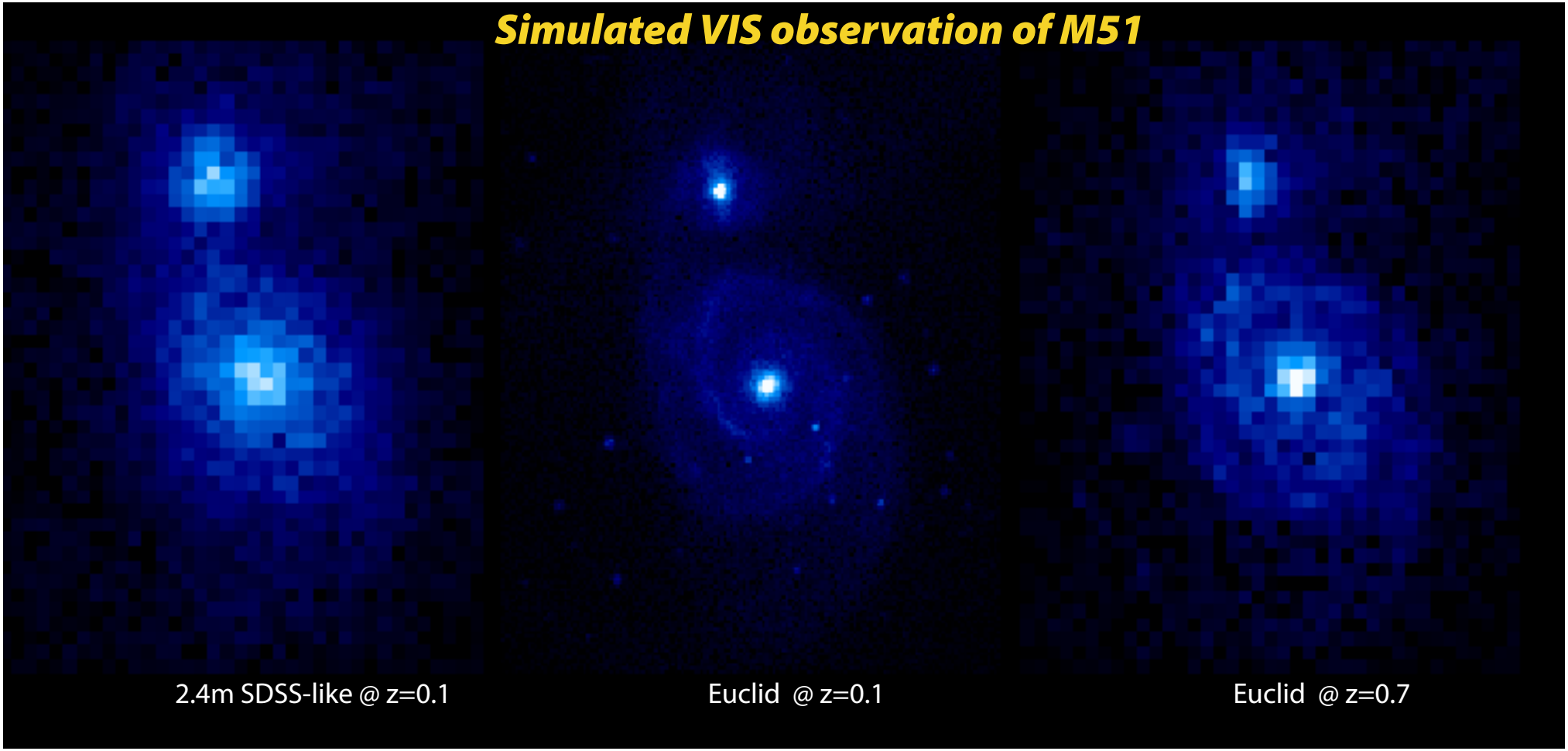

VIS CCDs


Power, Mechanism and Control Unit


Readout Shutter Unit


Focal Plane Assembly


VIS CCD testing



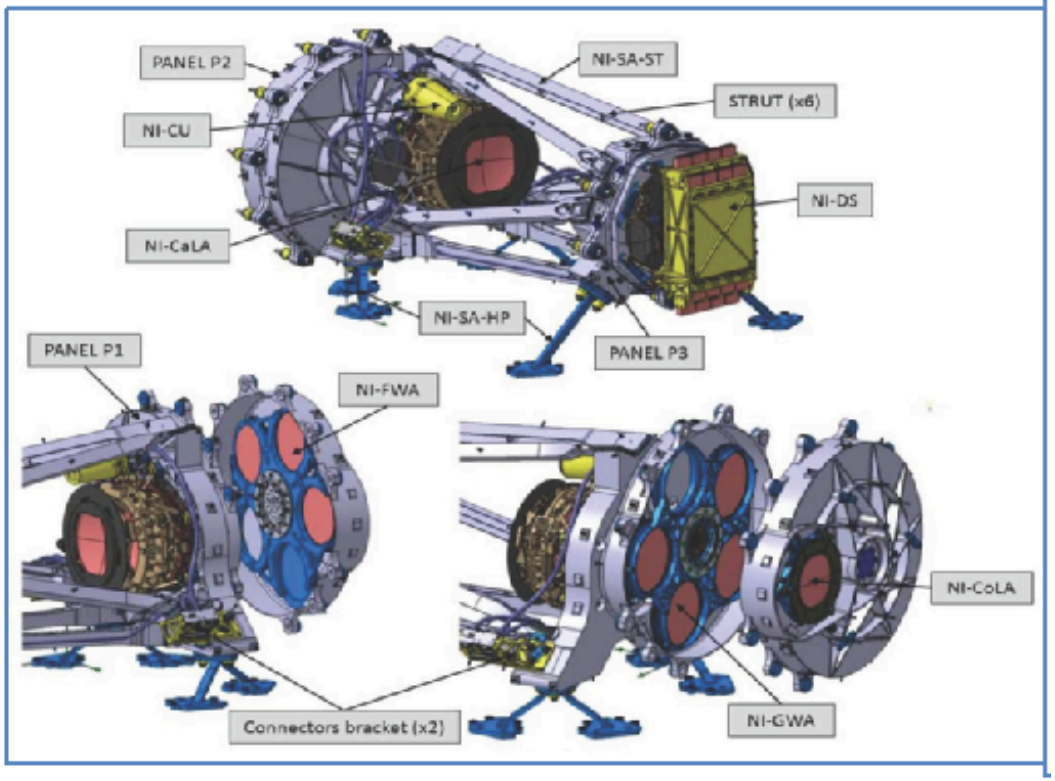
Euclid will get the resolution of SDSS but at z=1 instead of z=0.05.

Euclid will be 3 magnitudes deeper than SDSS

NISP

NISP CDR successful in Nov 2016

Courtesy: T. Maciaszek and the NISP team



- FoV: 0.55 deg^2
- Mass : 159 kg
- Telemetry: < 290 Gbt/day
- Size: 1m x 0.5 m x 0.5 m
- 16 2kx2K H2GR detectors
- 0.3 arcsec pixel on sky
- Limiting mag, wide survey AB : 24 (5 σ)
- **3 Filters**:

•Y (950-1192nm)

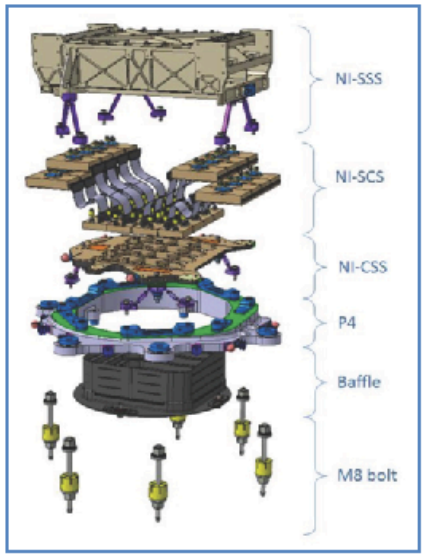
•, J (1192, 1544nm)

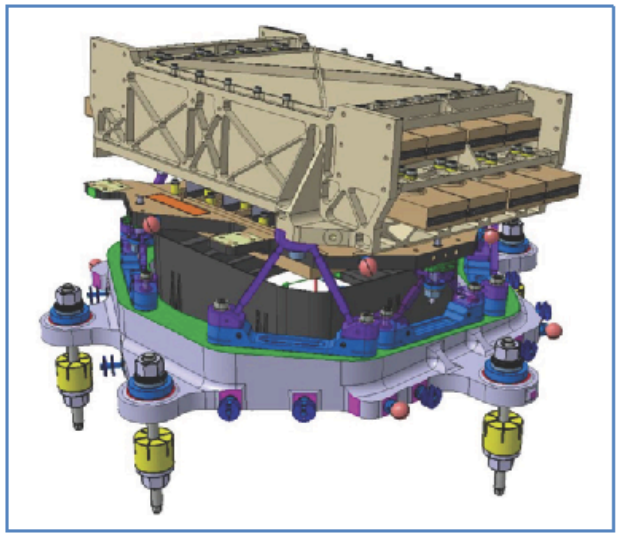
•, H (1544, 2000nm)

- **4 grisms**:

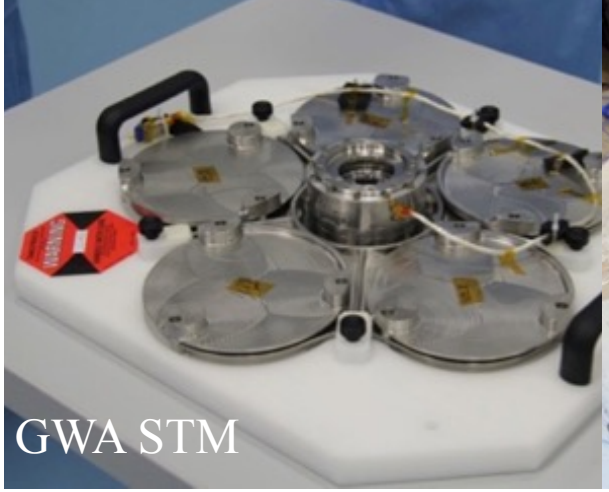
•1B (920 – 1300) , 1 orientation 0°

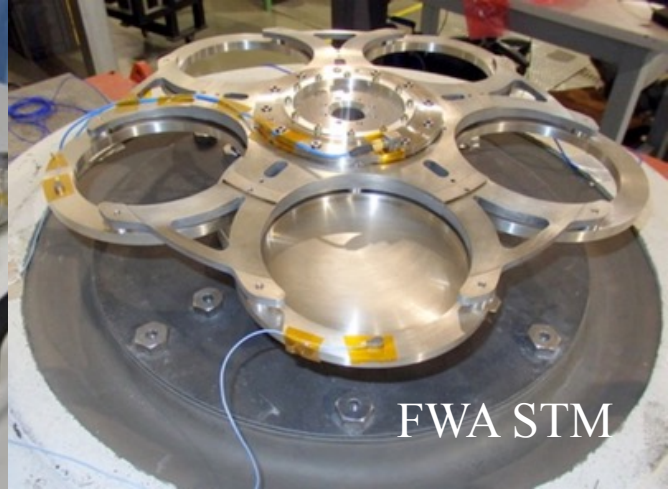
•3R (1250 – 1850), 3 orientations 0°, 90°, 180°

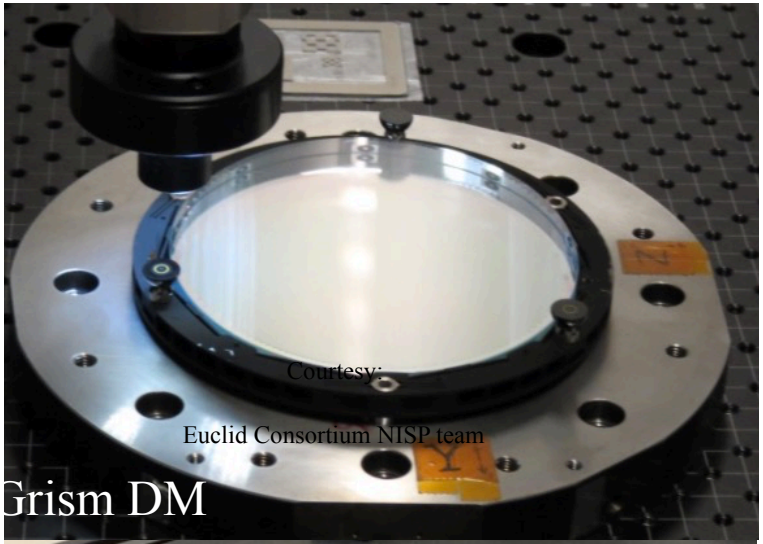


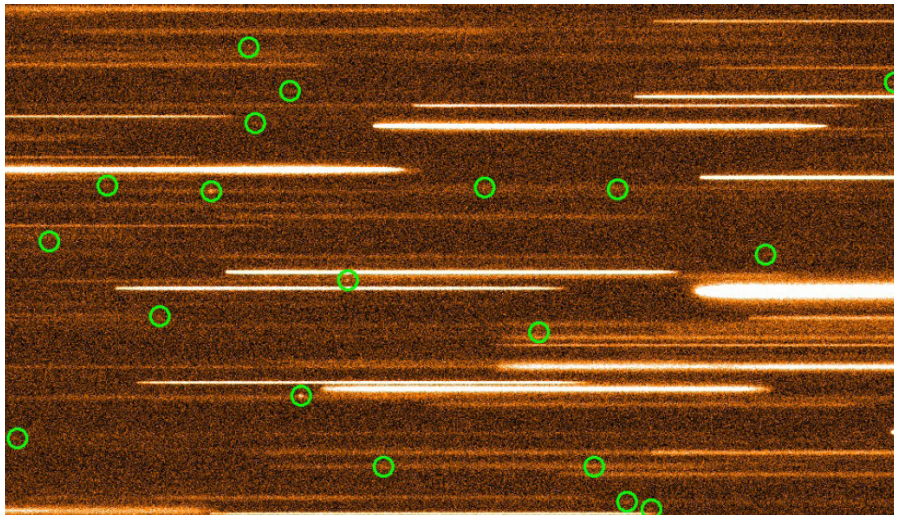


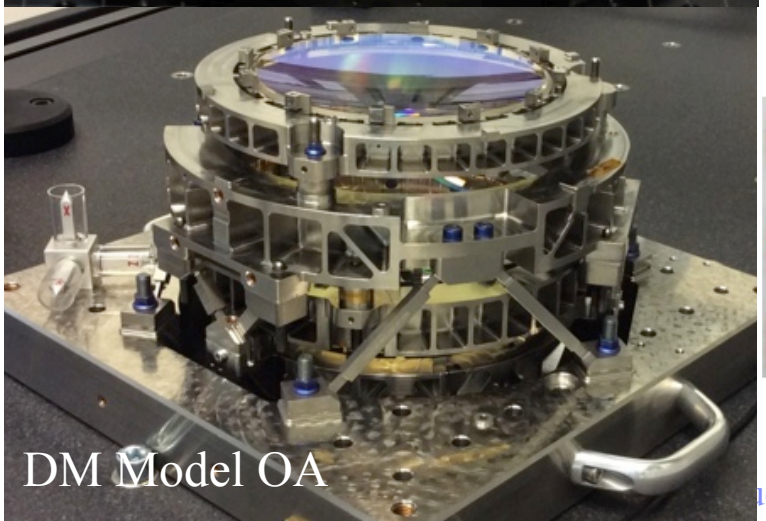
Maciaszek et al 2016:SPIE



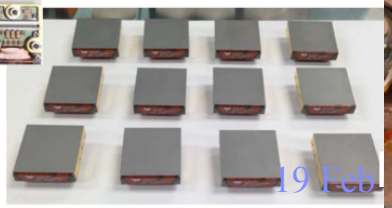


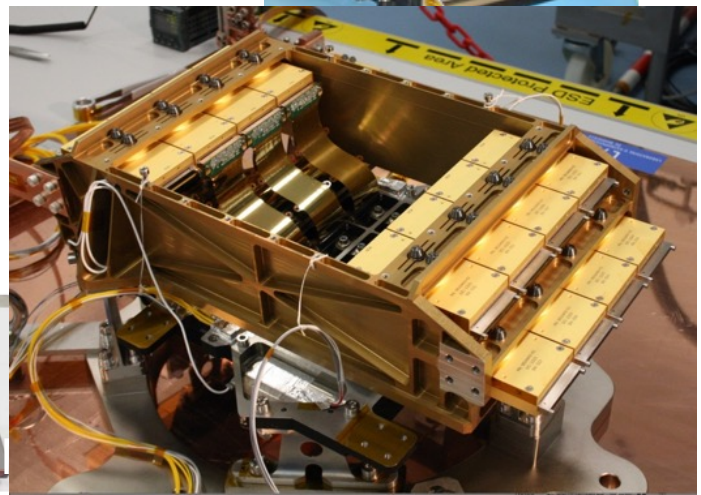






12 flight grade SCA packages were received



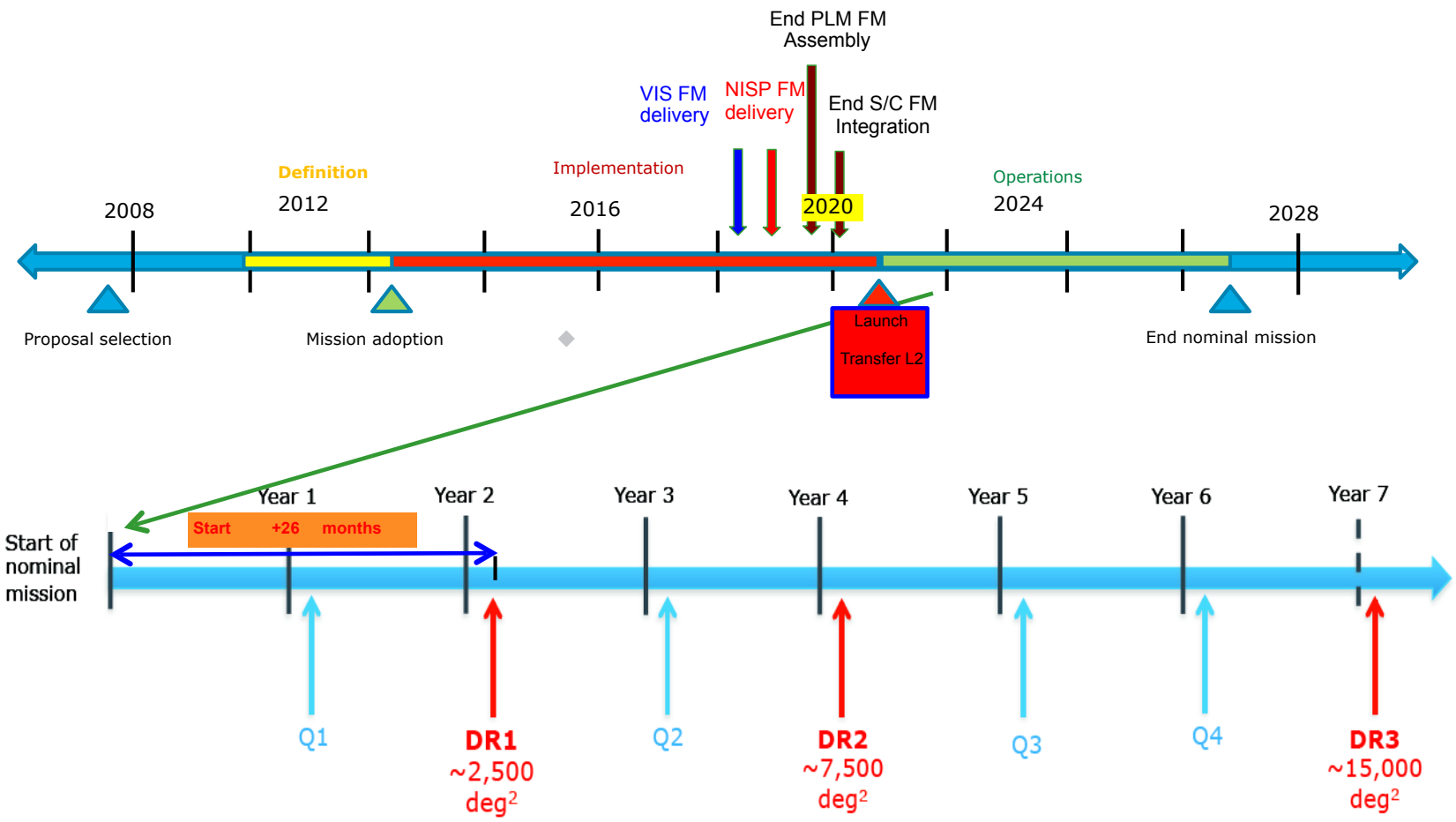


Euclid surveys complementary data

- 45 nights at Keck telescope: spectroscopy on Euclid Wide fields north
- 25 nights at VLT VMOS/KMOS: spectroscopy on Euclid Wide fields south
- 2 nights pilot program at GTC: preparation of a spectroscopic large program

- 5300 hrs of Spitzer satellite, period 13, priority 1 on 2 Euclid Deep field (20 deg2)
- DES+KIDS survey data
- 271 nights at CFHT u-, r- band data on Euclid Wide North
- 110 nights at JST/T250 g- band data on Euclid Wide North
- Discussions on going with other telescopes

Mission Timeline



Science with Euclid will start in 2022 with Q1 and in 2023 with DR1

Summary

- **Euclid Mission**
  - 2 surveys wide and deep, photometry and spectroscopy with optimal usage of space and ground based observatories
  - **1.2m primary space borne telescope with broadband imaging and NIR photometry and spectroscopy**
  - *Large international collaboration*

- **Euclid cosmology core program**
  - **Use 5 cosmological probes, with at least 2 independent test (gerometry and growth of structures)**
  - Percent error on DM power spectrum over a wide range of redshifts and scales
  - Perfect complementarity with Planck: probes and data, cosmic periods
  - Explore the dark universe: DE, DM (neutrinos), MG, inflation, biasing, baryons
  - Explore the transition DM-to-DE-dominated universe period
  - Get the percent precision on w and the growth factor γ
  - *Synergy with New Gen wide field surveys: LSST, WFIRST, e-ROSITA, SKA*
  - *140,000 strong lenses: DM haloes of galaxies, galaxies, groups, clusters*

- **Euclid =12 billion sources, 35 million redshifts, 1.5 billion shapes/photo-z of galaxies**
  - A mine of images and spectra for the community for years
  - A reservoir of targets for JWST, E-ELT, TMT, ALMA, VLT
  - **A set of astronomical catalogues useful until 2040+**

- Big challenges ahead of us: data processing (100-300 Petabytes), cosmological simulations

- **Milestones**
  - Launch 2021
  - **start 2022: 2500 deg2 public in 2023**
  - 7500 deg2 in 2025
  - ***final 2027***