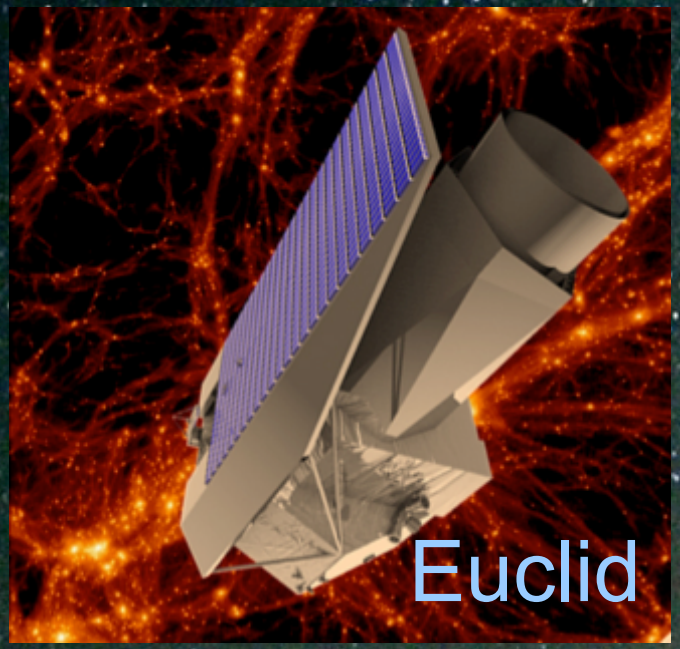


& LSST

Télescopes grand champ
& nature de l'Energie Noire

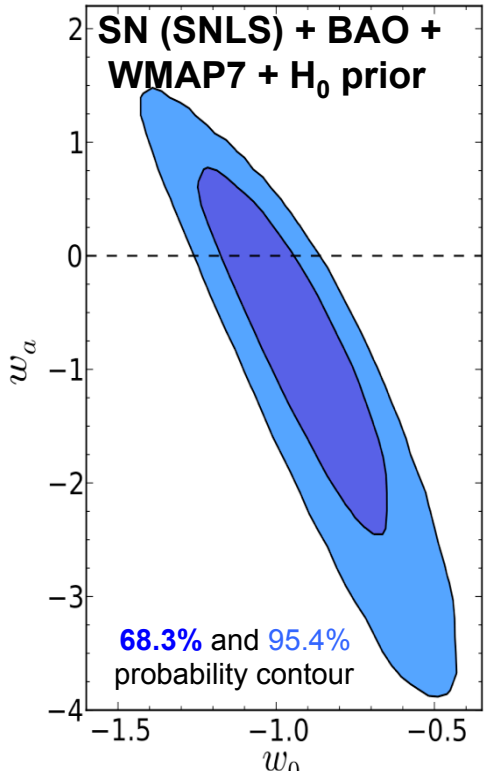
Pierre Antilogus
(PI LSST-France)
Anne Ealet
(PI Euclid-IN2P3)

Prospective CEA-IN2P3 , Giens Avril 2012

Dark Energy : State of the art

Euclid

M.Sullivan, *et al.* 2011



(FoM = 1/area ellipse error)

Today : FoM ~ 11

Dark Energy Equation of state is a function of the universe scale factor « **a** » :

w(a) = w0 + wa(1 − a) = Pressure / density

Measuring this equation is the key to distinguish :
- a constant equation of state
(ex : Quantum vaccum /cosmological constant: wa=0, w0=-1)
- a Dark Energy field / "dynamic" (ex : quintessence: wa#0)

To measure the sensitivity of a project to "w0" and "wa" , the Dark Energy Task Force (DETF) introduced the Figure of Merit (FoM) :

$$\mathbf{FoM} = 1 / \sigma_{w0pivot} \times \sigma_{wa}$$

➔ **goal for next decade : FoM > 400**

➔ **Today 2 such projects selected:**

Euclid (1.2m space telescope)

LSST (8.4m ground telescope)

Euclid & LSST : 2 complementary paths for the same scientific goal(s)

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

Remark : give also constrain on modified gravity and neutrino mass

Method ➔ Large sky Survey (1/2-1/3 of total sky) & deep (24-27 mag)

Observables ➔

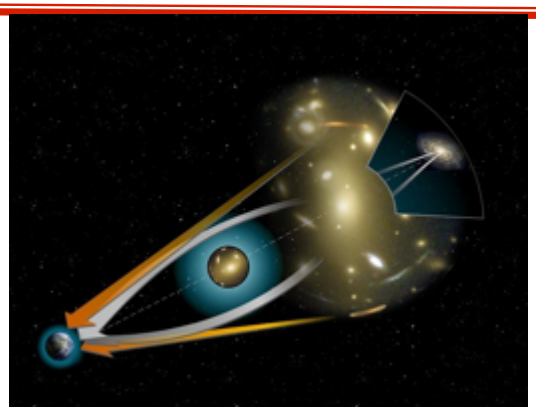
- Weak Lensing : growth of structure
- Galaxy Clustering : growth of structure
- Baryon Acoustic Oscillations : standard ruler
- SuperNovae : standard candle

Key issue ➔ Systematic Errors :

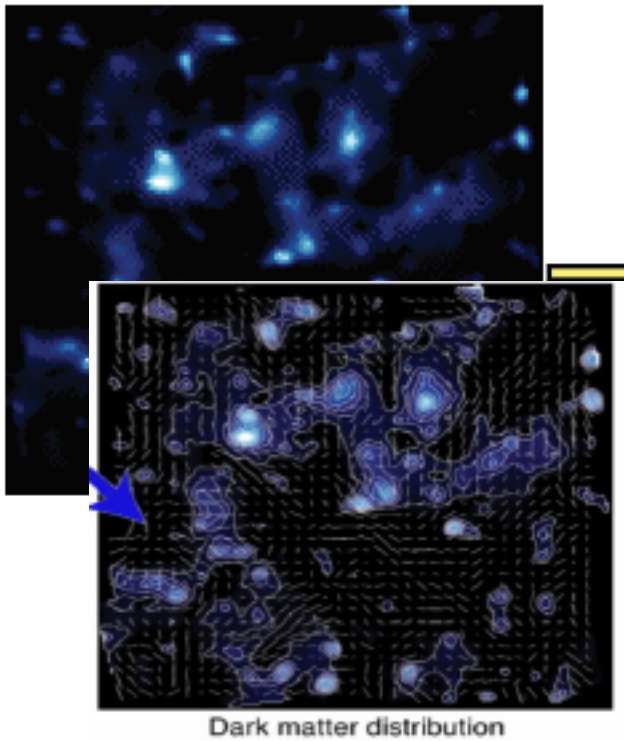
LSST & Euclid have different and complementary approach to address the systematic error issues. For example , to control the weak-shear measure :

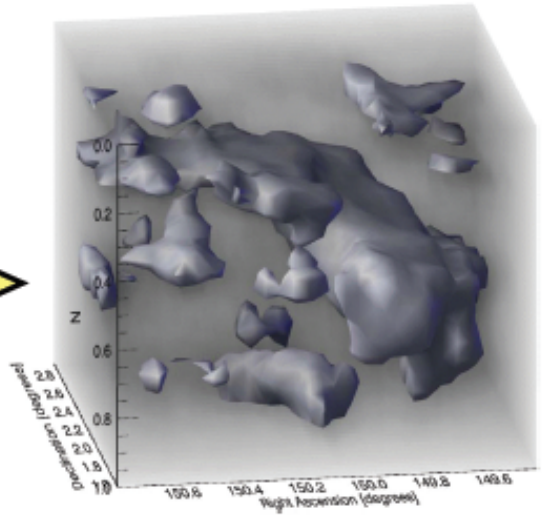
- LSST plan to deconvolve the instrumental & atmospheric distortion by observing the same patch of sky ~1000 of time , each time with the same sensitivity than Euclid
- Euclid ,in space, will avoid the atmospheric distortion and plan a stable instrument.

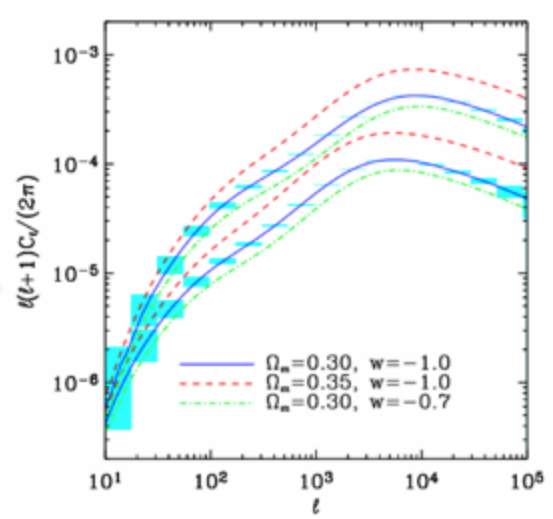
Euclid & LSST one of the main observable : Dark Matter and Lensing Tomography



Density fluctuations in the universe affect the propagation of light rays, leading to correlations in the shapes of neighboring galaxies.



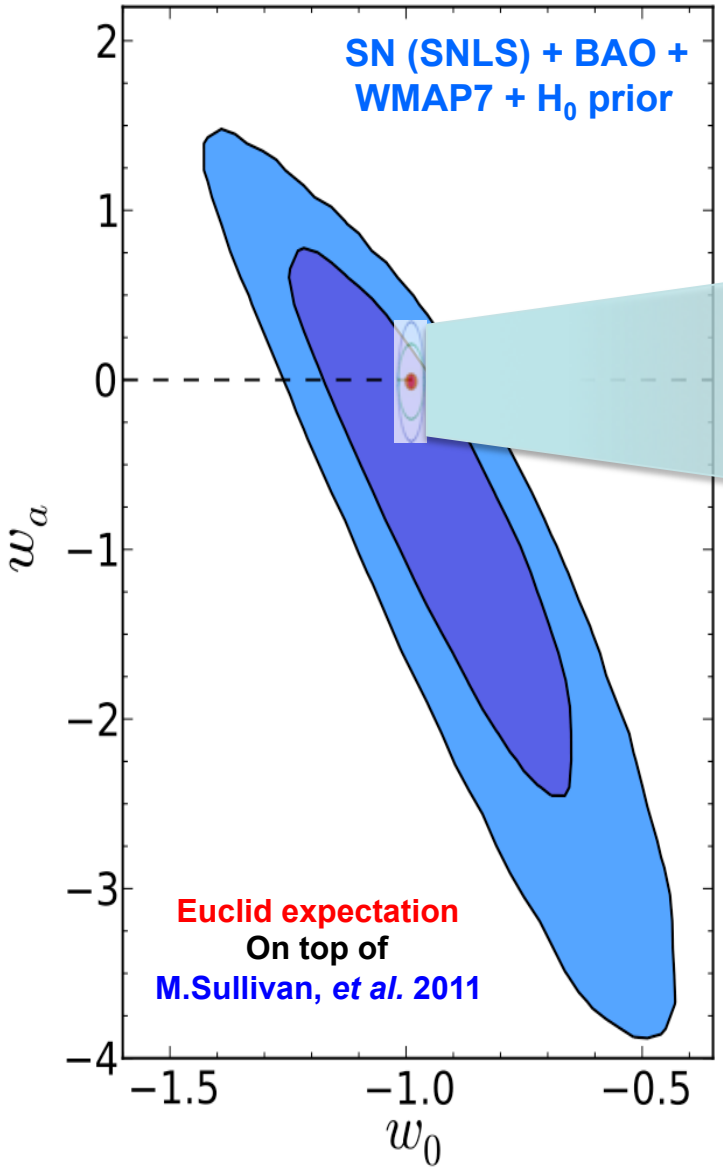


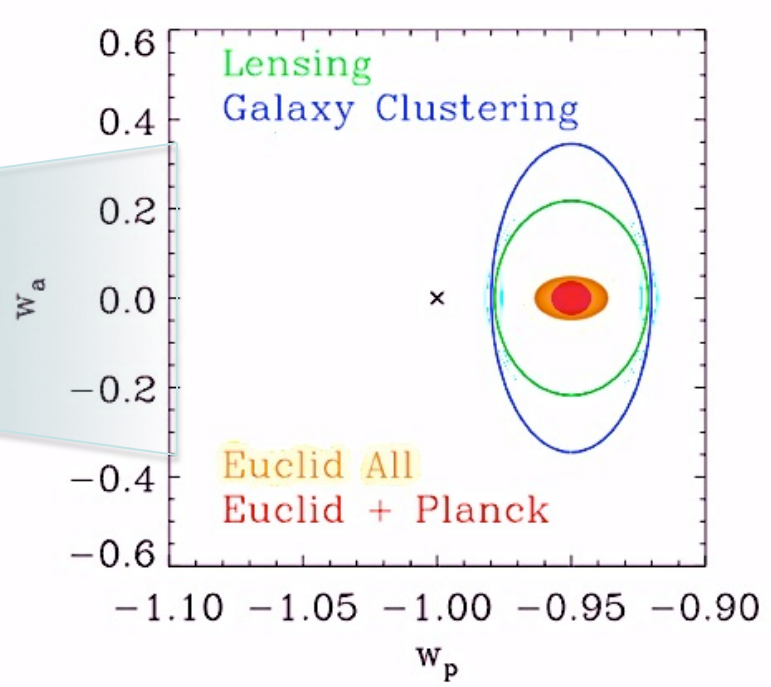


Statistic of shape correlations can directly map the **dark matter** in 3D
Weak lensing is sensitive to
-The expansion of Universe with z - H(z)
- The grow of structure with z - G(z)
The way these structure grow with cosmic time depend of **dark energy.**
This is a powerful observable to constrain DE , modified gravity…

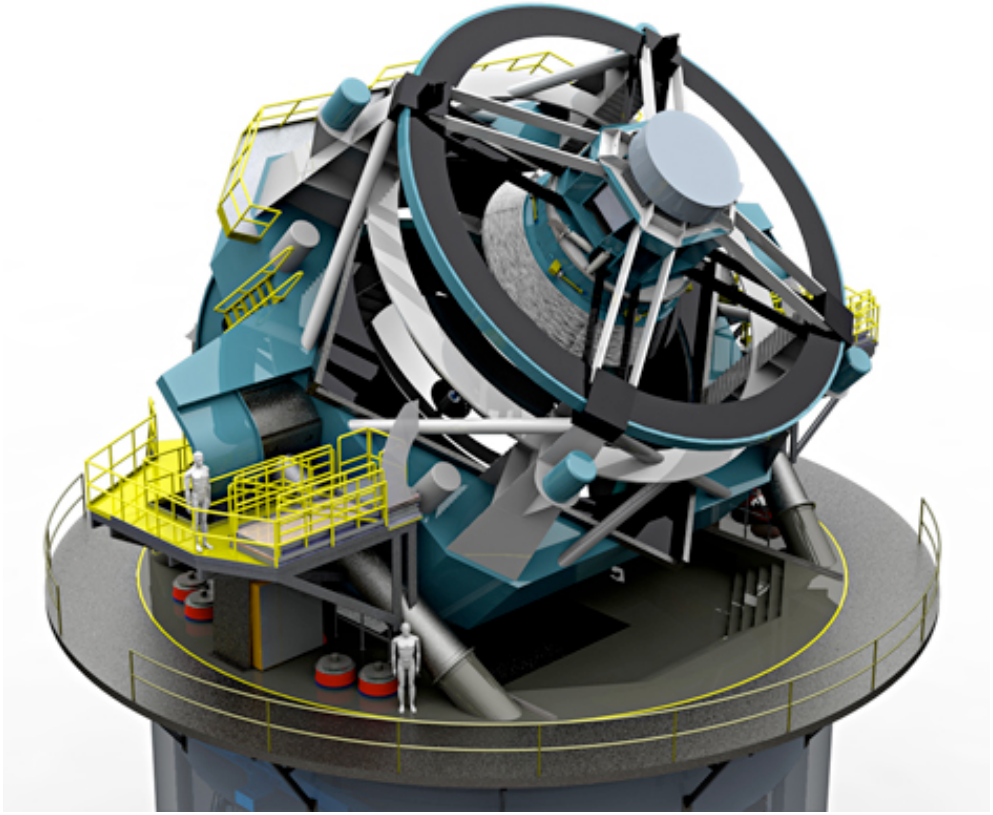
Complementarities between Dark Energy probes

Euclid

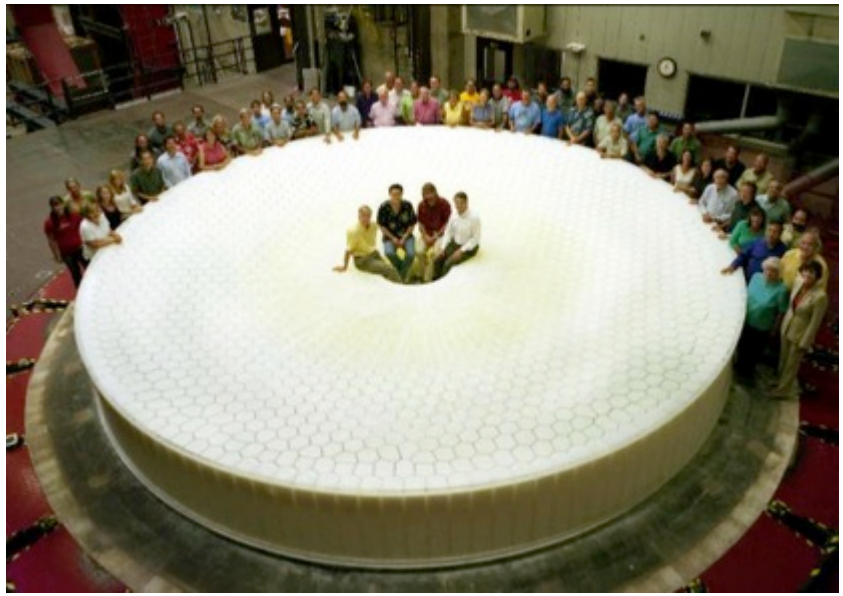




Different Dark Energy probes, reduces the impact of auxiliary parameters ➔ large improvement on the constraints on the Dark Energy equation of state



LSST



LSST : Project & Collaboration & mise en place du projet

- 2003, LSST = internationnal collaboration , multi-agences :
  - NSF main agency : in charge of telescope , site & data management
  - DOE in charge of the camera (Leading lab : SLAC)

- August 2010, LSST selected by « Astro2010 » as The ground project for next decade :
  - NSF & DOE in the US and IN2P3 in France moved on to include LSST in their programs
  - LSST passed with succes major review in 2011 (PDR in August et CD-1 en November)
  - → LSST has a callendar : start construction 2014 + first light 2019 + start science 2020

- France / IN2P3 , for its contribution to the camera, & Chile, for the site, are the only non-US among the 36 LSSTc members . Data acccess is foresseen to a larger non-US community in 2021 , it will help to cover running cost (67 letter of intent received for ~ 450 scientists at 25 k$/year/scientist)

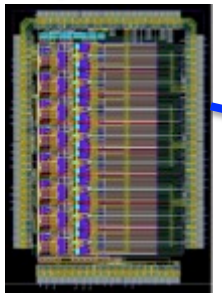
- In 2012 , a HEP like collaboration (detector & computing & science) has been put together under DOE request , LSST DESC (Dark Energy Science Collaboration) , IN2P3 is part of it.

LSST collaboration and French contributions (1 / 2)

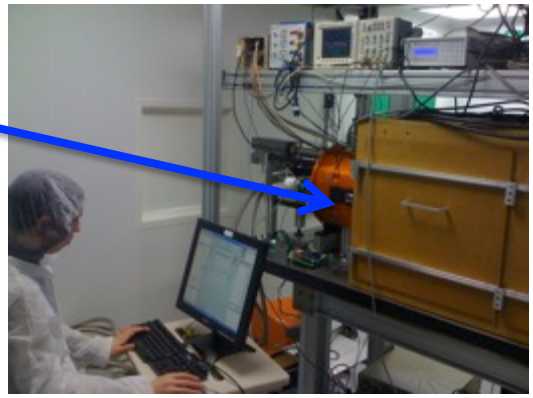
- **France & LSST :**
  - **France (IN2P3 & INSU laboratoires) submitted a letter of intent to LSST in 2006**
  - **Today 8 IN2P3 laboratories (APC, CCIN2P3, CPPM , LAL , LMA , LPNHE , LPCC, LPSC) are involved in the LSST , some since 2007 .**
  - **LSST-France count today :**

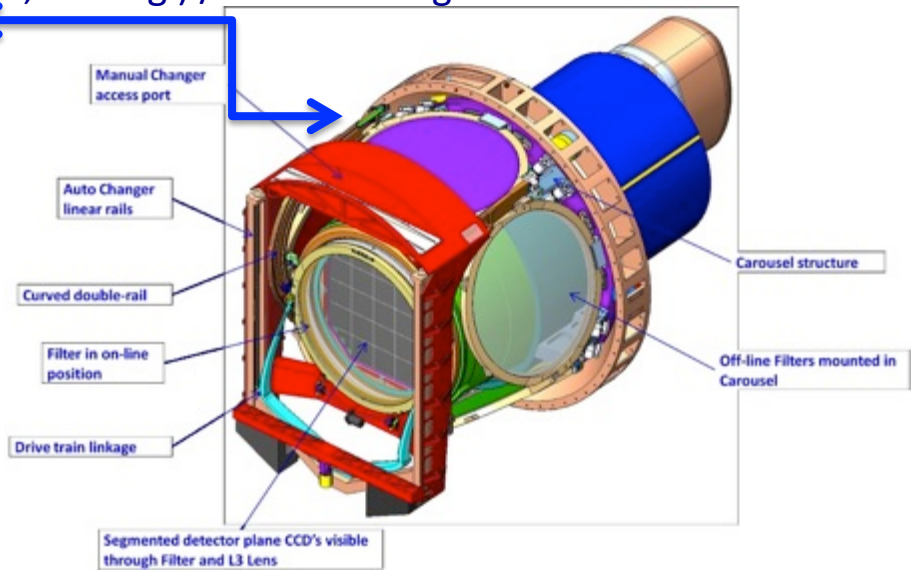
    ~ 40 physicists & 40 ITA , 25 FTE are working today at IN2P3 on the camera

    ~10-15 INSU physicists will also join the project/Dark Energy science at some point.
  - **Contribution to the camera :**
    - CCD qualification/test and CCD electronic readout & control (201 CCD /3216 readout channels)
    - Filter changer (each filter is 70 cm diameter , ~ 25 kg) / Filter coating studies
    - calibration and characterization system



8 channels CCD readout ASICS

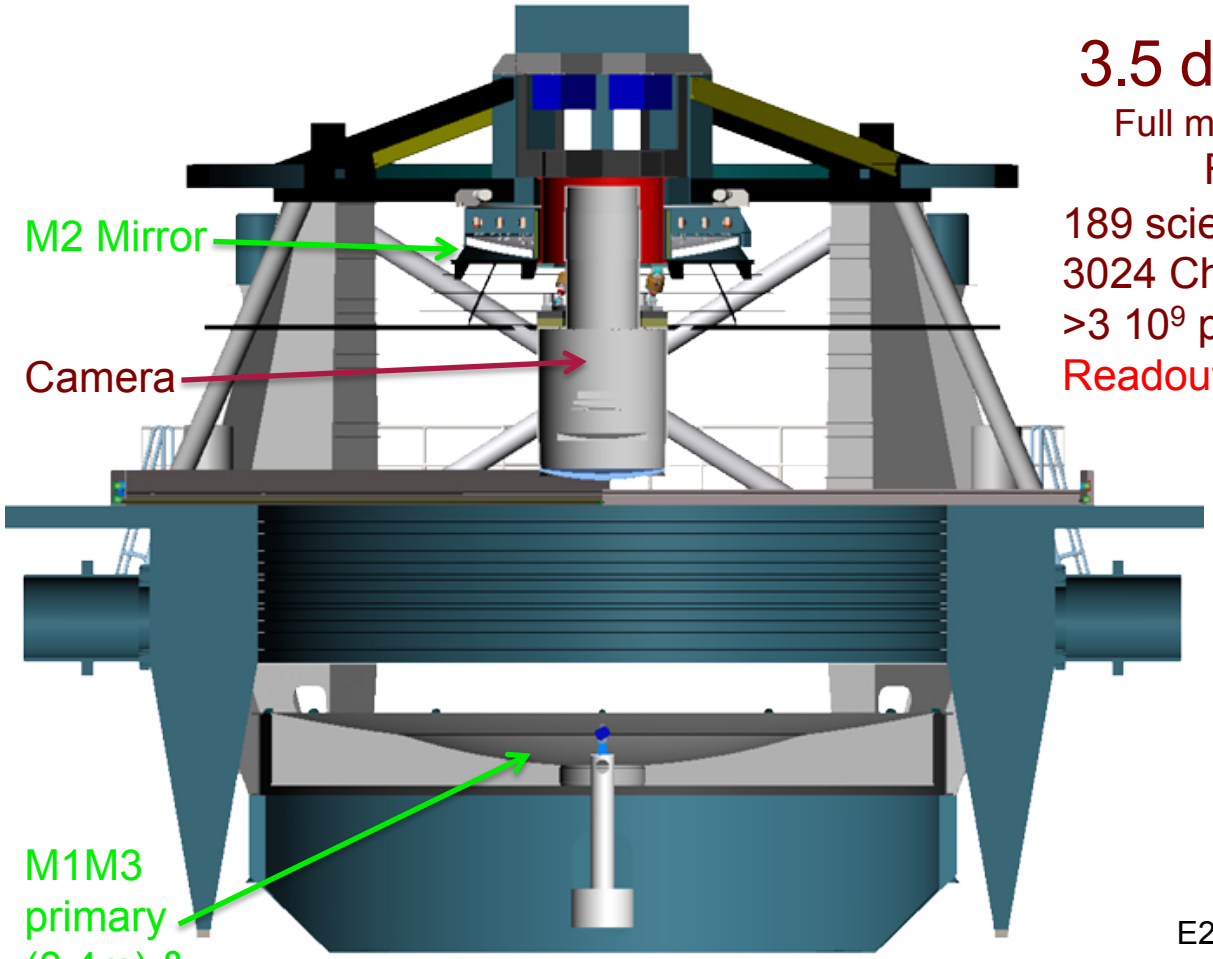




LSST collaboration and French contributions (2 / 2)

- **LSST Cost :**
  - **Construction cost : 617 M$**
    - DOE Camera : Base Budget 115 M$ + Contingency 45 M$
    - NSF/MREFC : Base Budget 370 M$ + Contingency 87 M$ (202M$ telescope&site, 161M$ data management)
  - **Running cost , starting October 2020 : 37 M$/ year**
    - Remark : The computing is a large effort/cost in the project :
      - 15 TB of raw science data / night , 100 PB of total raw data in 10 years
      - Pixel access due to the "non-event" data structure is THE challenge
- **IN2P3 contributions :**
  - **Hardware cost & effort on the camera :**
    - 2007-2011 : 50 FTE and 1 M€ invested (TGIR , P&U , IN2P3)
    - 2012-2017 plan : 150 FTE and
      - 2.5 M€ , for hardware associated to IN2P3 deliverables (IN2P3 direct contribution)
      - + 4 M€ for 25% of the LSST CCD (TGIR contribution)
      - + missions (600 k€)
  - **Computing at CCIN2P3 :**
    - We agreed to provide 50% of the computing needs for the level 1-2 processing (up to the filling of the LSST DB) , estimated cost : ~ 2 M€ / year + 10 FTE for a significant effort starting in 2017
    - Contribution to the Dark Energy , 3rd level processing , not discussed/agreed yet

LSST : Wide , Deep and Fast



Moving Structure 350 tons
60 tons optical systems

Field of view :

3.5 deg (9.6 deg^2 =.023% sky sphere)

Full moon = 0.5 deg = 4.8 10^{-6} of sky sphere

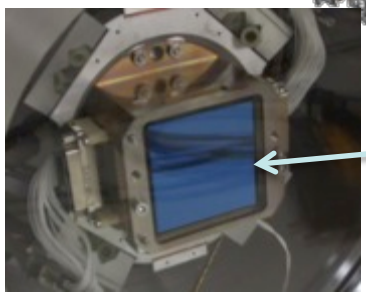
Focal plane diameter : 64 cm

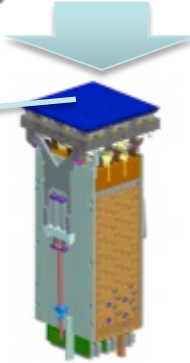
189 science CCD (21 rafts)

3024 Channels

>3 10^9 pixels

Readout: 2s





E2v CCD 250 ,
4kx4k , 10 µm pixels
100 µm deep depleted
UV to IR sensitive
16 channels output
Designed by Dedicated R&D for LSST

1 raft = 3x3 CCD
150 M pixels
(1/2 Megacam)

LSST concept :
a single observation plan

6-band Survey:
ugrizy 320–1070 nm

Survey Area
20,000 square degrees ~ ½ sky with 0.2 arcsec / pixel

Total Visits per unit area and Visits per filter

	u	g	r	i	z	y
Nb Visit	70	100	230	230	200	200
1 visit mag	23.9	25.0	24.7	24.0	23.3	22.1
10 year	26.1	27.4	27.5	26.8	26.1	24.9

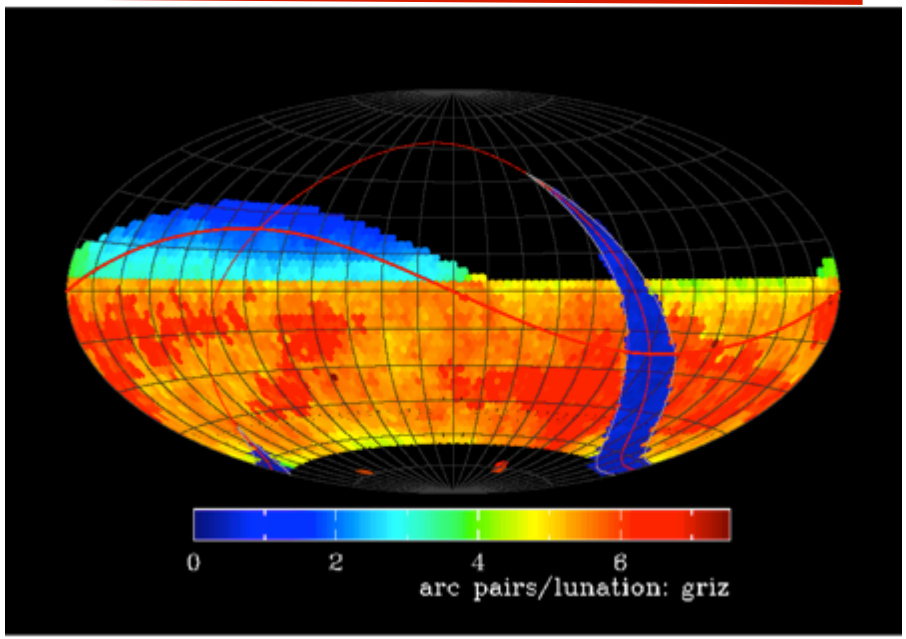


Image Quality
Median seeing at the site is ~ 0.6 arcsec
PSF FWHM < 0.4 arcsec (no atmospheric seeing).
PSF Ellipticity < 0.04
(referenced to 0.6 arcsec FWHM circular Gaussian)

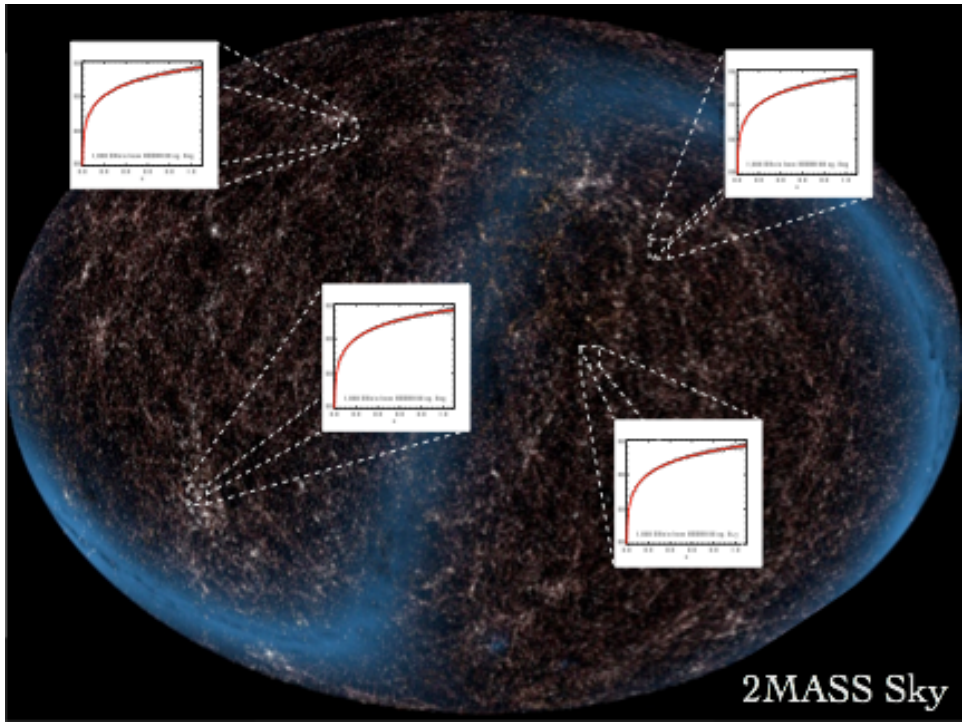
Photometric precision:
0.01 mag absolute; 0.0005 mag repeatability

More than 2.5 10^6 visits & 5 x10^6 exposures
following the sequence:
15 s pose + 1 s shutter + 2 s read + 15 s pose + 1s shutter + 5s new pointing as reading
➔ **Points to new positions in sky every 39 seconds**

Temporal Visit Distribution in Main Survey Area
Revisit after 30-60 minutes
Visit pairs every 4 nights
3 pairs per lunation

LSST : examples of high statistic DE science with SN Ia

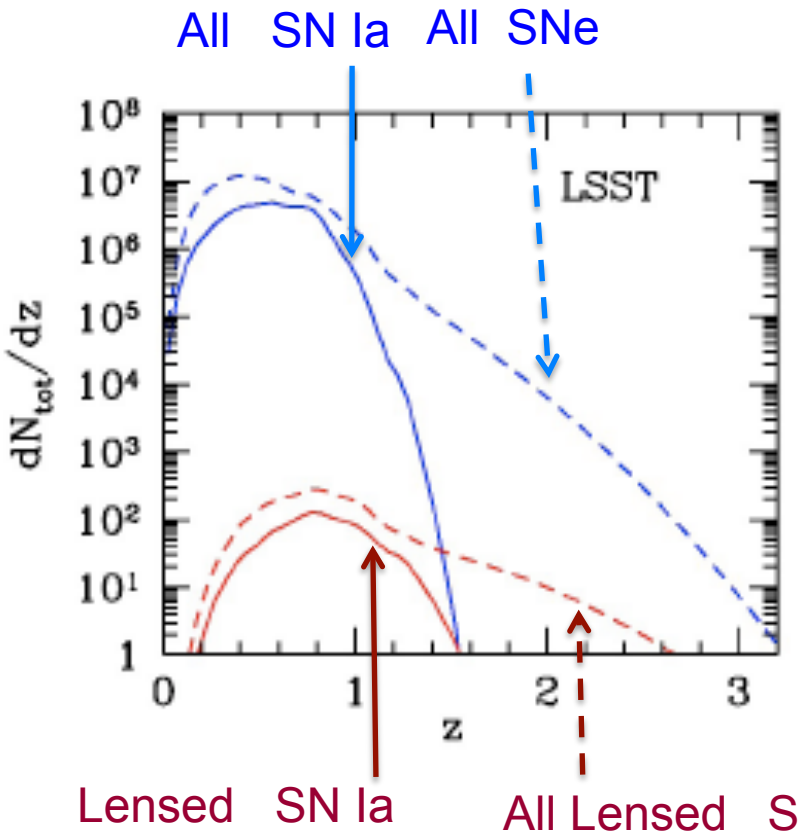
LSST will be able to probe the isotropy of the Dark Energy properties . For example the large SNIa statistic will allow to build SNIa hubble diagram for different directions in the sky.

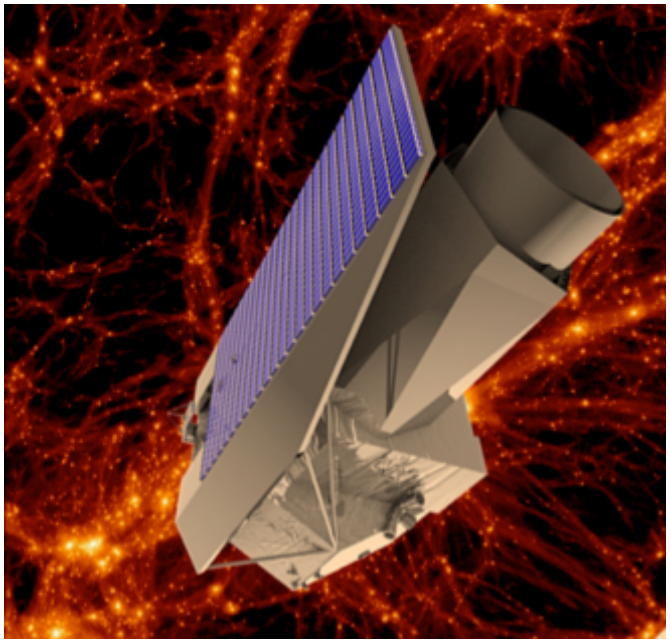


LSST will provide time-dependent imaging of an unprecedented sample of rare strong gravitational lensing events.

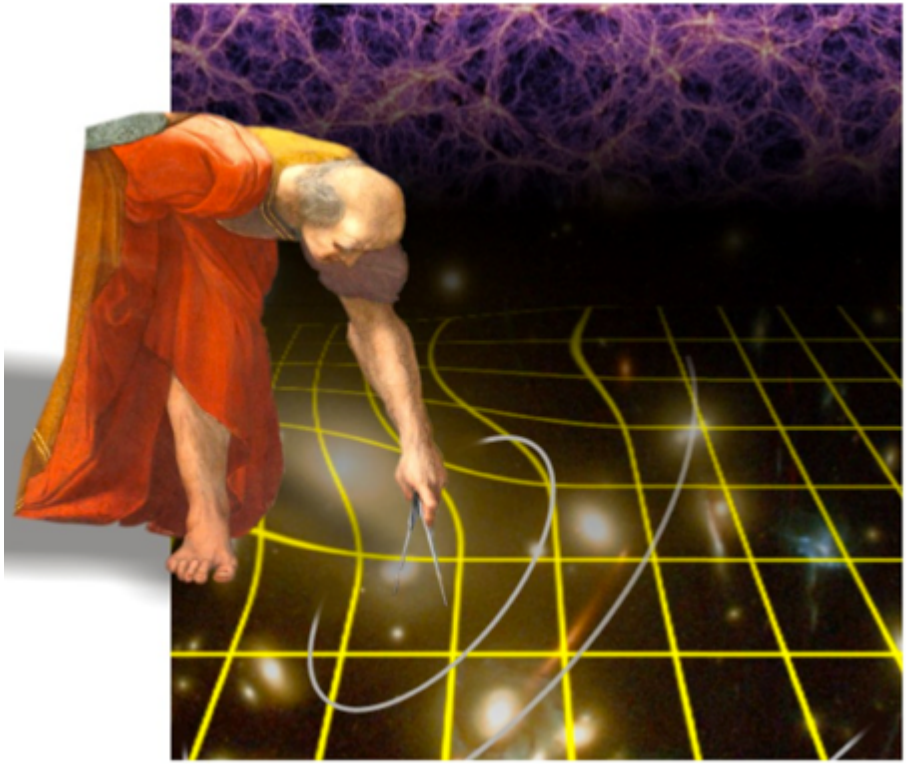
➔Strong lensed SN Ia

= sensitive to H(z) at the lens location





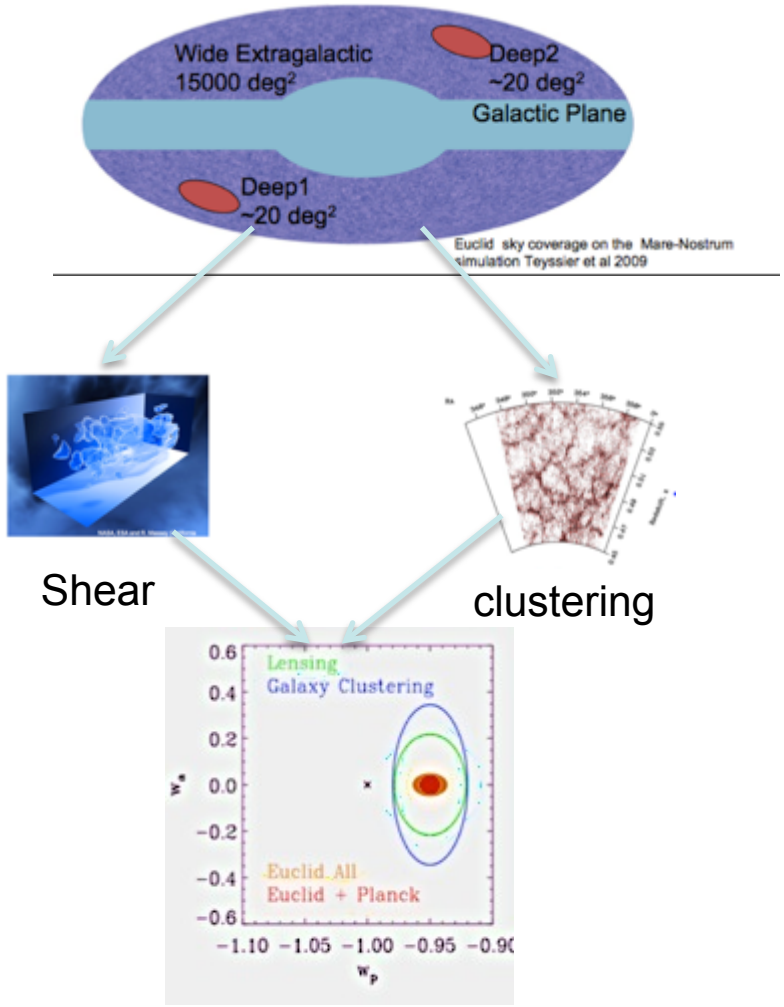
Euclid

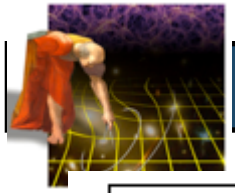


EUCLID an ESA space mission

EUCLID CONSORTIUM

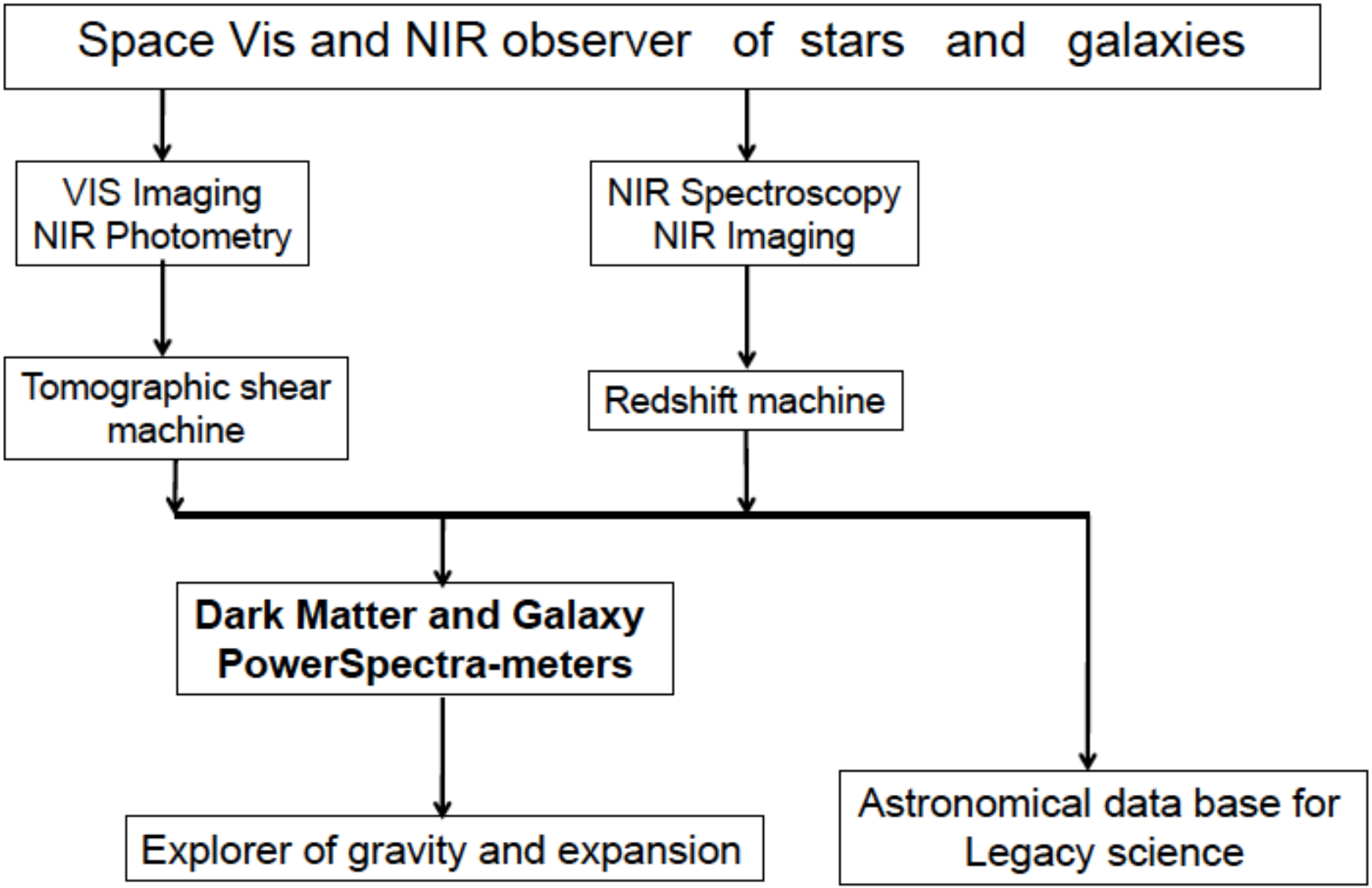
- EUCLID is a space mission with visible and Infrared observations of all sky, both in photometry and spectroscopy
- EUCLID is an ESA mission planned in L2 orbit with 2 instruments (3 channels)
- EUCLID will measure the expansion history H(z) to unprecedented accuracy, with good control of systematic effects:
  - Using Weak Gravitational Lensing from high-resolution imaging survey
  - Using Baryonic Acoustic Oscillations (BAO) in the clustering pattern from a large spectroscopic survey
- EUCLID will have a wide survey of 15000 deg^2 and a deep survey of 40 deg^2



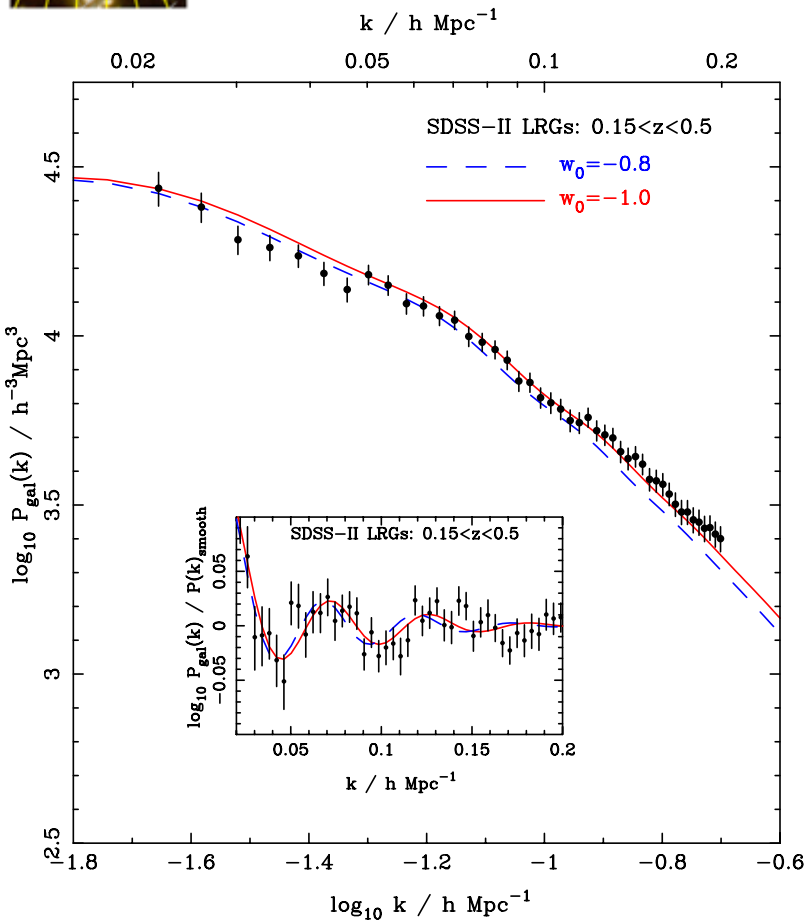


EUCLID: a big machine

EUCLID CONSORTIUM

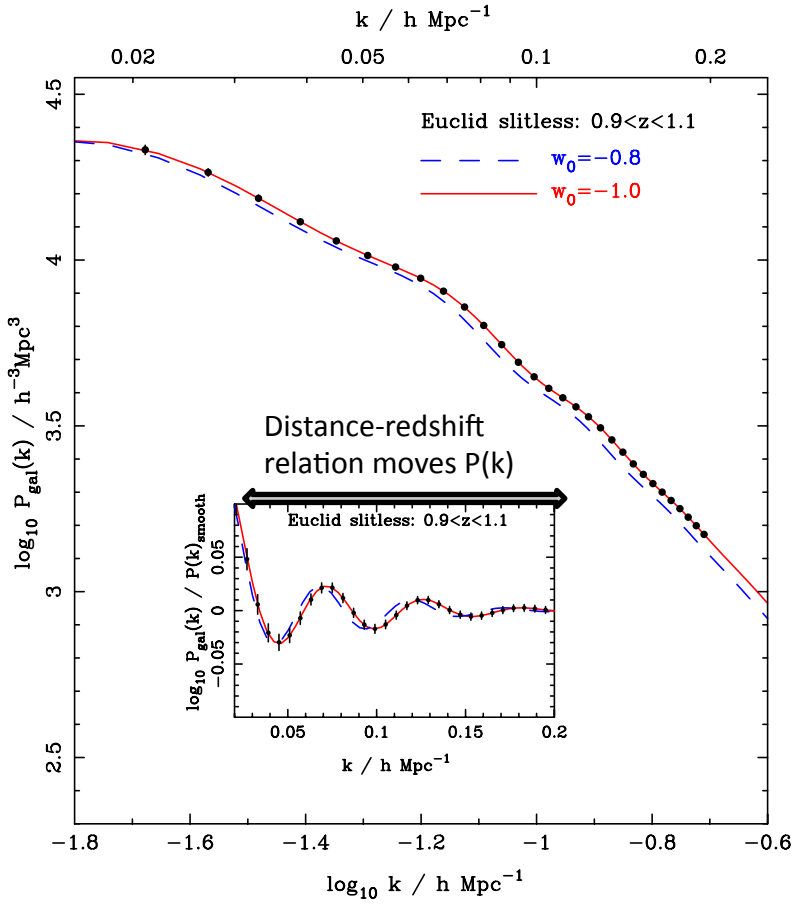


Power spectrum: exemple of precision



SDSS today

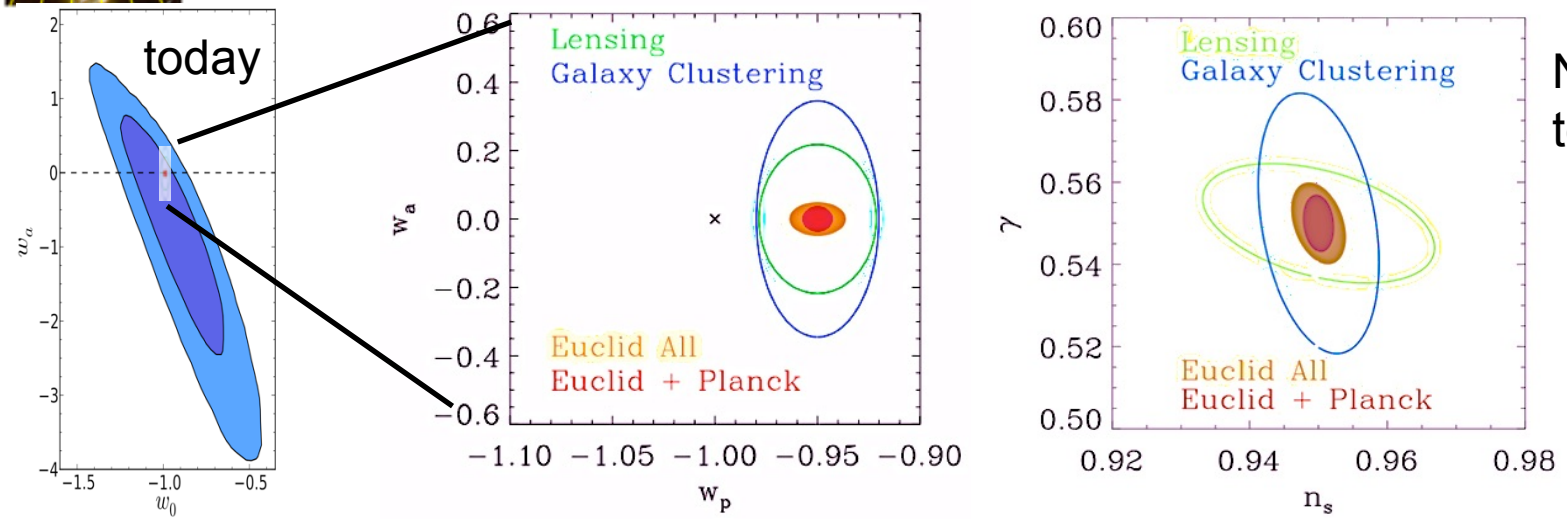
0.15<z<0.5



EUCLID expected

One of five redshift slices (0,7<z<2)
assuming slitless baseline in one slice
z~1

Combining WL +GC – constraining modifed gravity

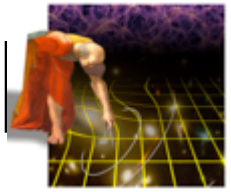


New possible test of gravity

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

	Dark energy			neutrinos	Initial conditions	Modified gravity
Parameter	w_p	w_a	**FOM**	$m\nu$ (eV)	F_{NL}	γ
EUCLID +Planck	**0.007**	**0.035**	**4020**	**0.019**	**2.0**	**0.007**
Current	**0.1**	**1.5**	**11**	**0.58**	**100**	**0.2**
Improve factor	**>10**	**>50**	**>400**	**30**	**50**	**30**

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



The EUCLID mission

EUCLID CONSORTIUM

- An M-class mission with constraints:
  - Launcher : soyouz
  - Maximum duration:7 years
- A Telescope
- 2 channels (Vis, NIR), 3 instruments (VIS, (NIS+NIP)=NISP)
- A mission: Euclid in L2, 2 surveys: Euclid Wide and Deep

EUCLID has been selected by ESA in Oct. 2011 in the cosmic vision program as the M2 mission to be launch in 2019

A space mission:

- Near Infrared access (photometry, spectroscopy)
- Very stable image quality (small and stable PSF)
- Very small background

  ⇒ Systematic control

  ⇒ Homogeneity of selection in the full redshift range

A challenging data computing on ground

Schedule

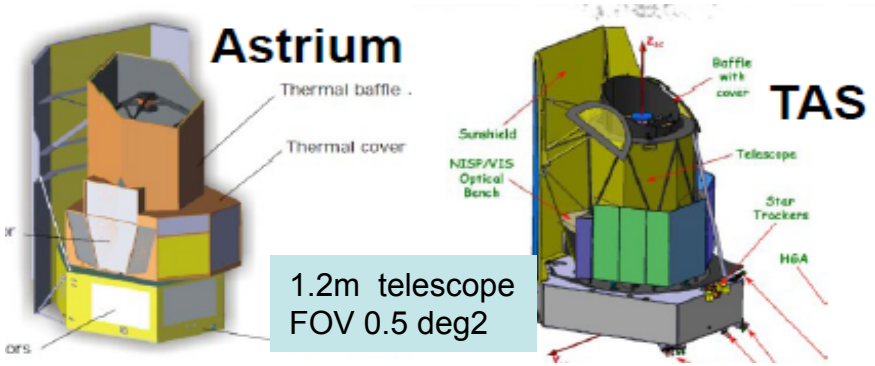
- June 2012
  - Adoption EUCLID by th SPC (MLA = multi agreement ESA/agencies)
  - ITT for spacecraft
- 2012-2013 : Phase B
  - April 2012 : instrument design conceptual review
  - Dec. 2012 : choice of the prime contractor
  - Mars 2014 :instrument preliminary design review
- 2014-2019 Phase C/D
  - End 2016: flight instrument delivery to ESA
  - 2017-2018: integration and tests
- Jan. 2019 : Launch

The EUCLID mission

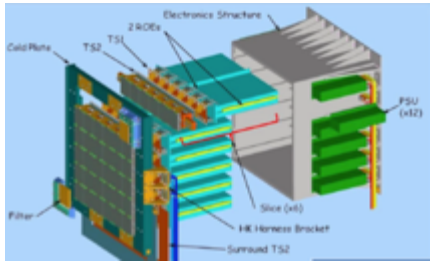
EUCLID CONSORTIUM

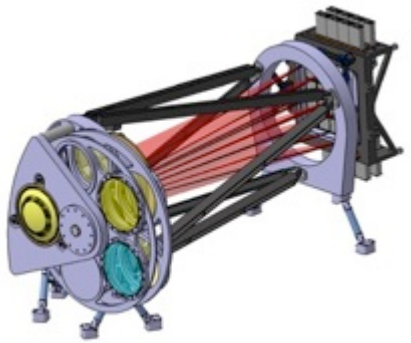
- Euclid is an ESA M mission + country participation
- The countries participation is managed by a consortium

- ESA provides the telescope and detectors (via industry), the satellite, launch and operation centers
- The consortium provide the 2 instruments (VIS and NISP) and the ground segment (data processing)



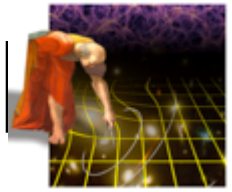
1.2m telescope
FOV 0.5 deg2





The Visible imager (VIS)
36 E2V CCD, 0,1"PSF
1 broad band R+I+Z (550-900nm)

The Infrared spectro/photometer (NISP)
16 H2Rg infra red pixel detectors,0,3" PSF,
3 IR bands Y,J,H (920-2000 nm)
NIR slitless spectroscopy (1100 – 2000 nm) R ~ 350



Data processing on ground

EUCLID CONSORTIUM

The consortium provide the 'ground segment' part responsible of the production and validation of the scientific data at all levels :

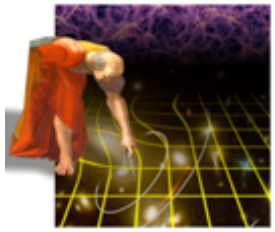
- Processing of the VIS et NISP instrument raw data up to cosmological analyses
- Add external data if needed in adequate format
- Simulation data
- Produce data catalogs to be delivered to the community

Data will be released by ESA after a proprietary period

The final cosmological analysis and interpretation is under the responsibility of the consortium science groups

Science Data Centers (SDC) in each country should ensure the production of EUCLID data

Very complex chain of data production to ensure the needed precision



EUCLID organisation

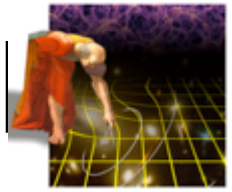
EUCLID CONSORTIUM

- The project is managed by ESA with
  - -an ESA EUCLID science team (EST) (12 members)
  - - a strong scientific consortium

- The scientific consortium = 109 laboratories, 13 countries +NASA/US
  Consortium organization:
  - A core team around a Lead
  - A board (country representatives)
  - 2 instrument teams (VIS,NISP)
  - 1 ground segment organization (data processing)
  - ~ 30 science teams
  - More than 900 members, ~ 250 French members

- Total cost ~ 800 Meuros
  Country contribution ~ 35 % total cost
  France contribution ~ 30 % of country participation

- French participation of IRFU, IN2P3, INSU
- Permanents labos ~480 FTE (2012- 2019, no science activities and CDD)
- CNES endossement : Funding + FTE (NISP management and GS system lead)



French responsabilities

EUCLID CONSORTIUM

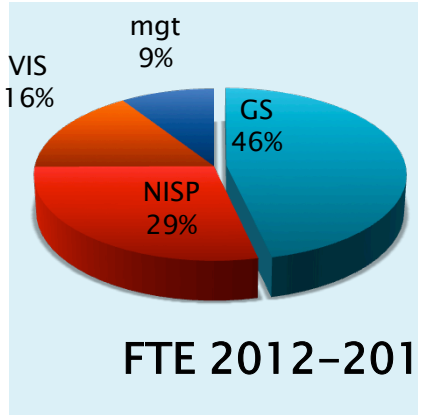
-IRFU
-CNRS/IN2P3 : APC, CCIN2P3, CPPM, IPNL,LPNHE
-CNRS/INSU : IAP, IAS, LAM, IRAP, Cassiope

France has strong management responsibilities in the consortium (EC)

- **EC Lead** : Y. Mellier (IAP)
- **EC Board**(18 members) : Y.Mellier (IAP) ,O.Lefevre (LAM)
- **EST (ESA science team)** (12 members): Y.Mellier (IAP), A.Ealet (CPPM)
- **NISP instrument** responsability management(CNES), Instrument scientist (CPPM), system (LAM)
- **Ground segment scientist** M.Sauvage (IRFU)
- **Ground segment system** lead Ch. Dabin (CNES)

Instrument delivery:

- VIS : integration and calibration of the focal plan IRFU, IAS
- NISP : French management (CNES) + LAM, CPPM, IPNL,IRFU
  CPPM/IPNL in charge of infrared detectors test and integration



Ground segment

- Data center for production : CCIN2P3 France (SDC - Fr)
- Data center for pipeline test : APC (FACe)
- Lead of VIS (IAP), cosmology (IRFU), redshift spectro (LAM)
- Co lead simulations (CPPM)

Science organization: French leads 7 Euclid science groups on 30

French Coordination: national scientific committee: 19 members with identified responsibilities in EUCLID

Conclusion

Euclid

Euclid

&

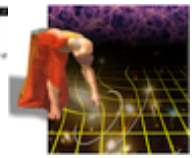
LSST
Large Synoptic Survey Telescope

FoM ~ 1500(WL&Galaxie)-4000 (all)
~ 900 members
European lead project / ESA
Space telescope / 1.2 m mirror
Launch : 2019
Mission length : 6 years
1 exposure depth : 24 mag
Survey Area : 15 000 square degrees (.36 sky)
Filters : 1 Visible(550-900nm)+ 3 IR(920-2000 nm)
+ NIR spectroscopy (1100 – 2000 nm)

FoM > 800 (WL,BAO, SN)
~ 450 Core members + 450 to come
US lead project / NSF-DOE
Ground Telescope / 6.5 m effective mirror
1st light : 2019
Observation length : 10 years
1 exposure depth : 24 mag (i) (~27 in 10 years)
Survey Area : 20 000 square degrees (.48 sky)
Filters : 6 filters (320-1070 nm)

→2 complementary approaches to address the question of the acceleration of the Universe and the nature of the Dark Energy in the next decade.

Major contributions to both projects from French teams



Euclid Consortium organisation