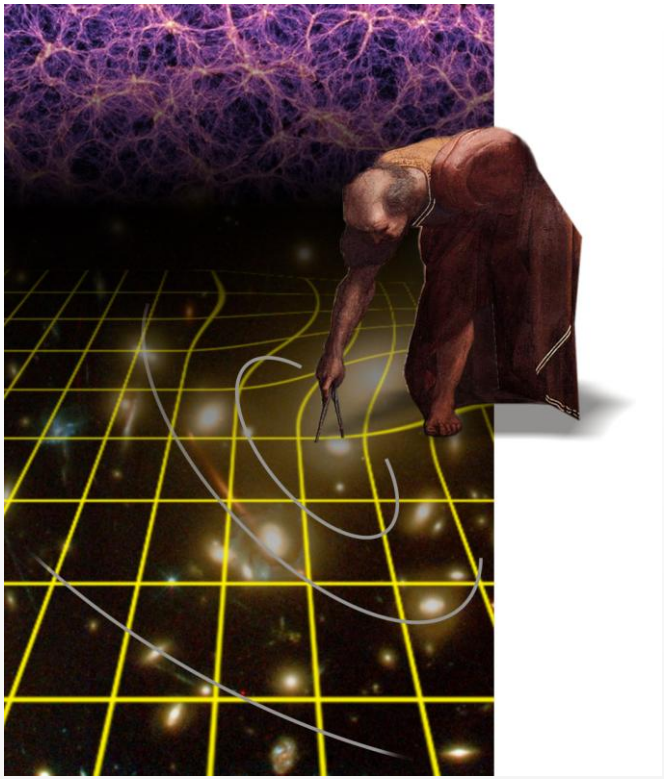


What is Dark Energy ? Cosmology in 2020

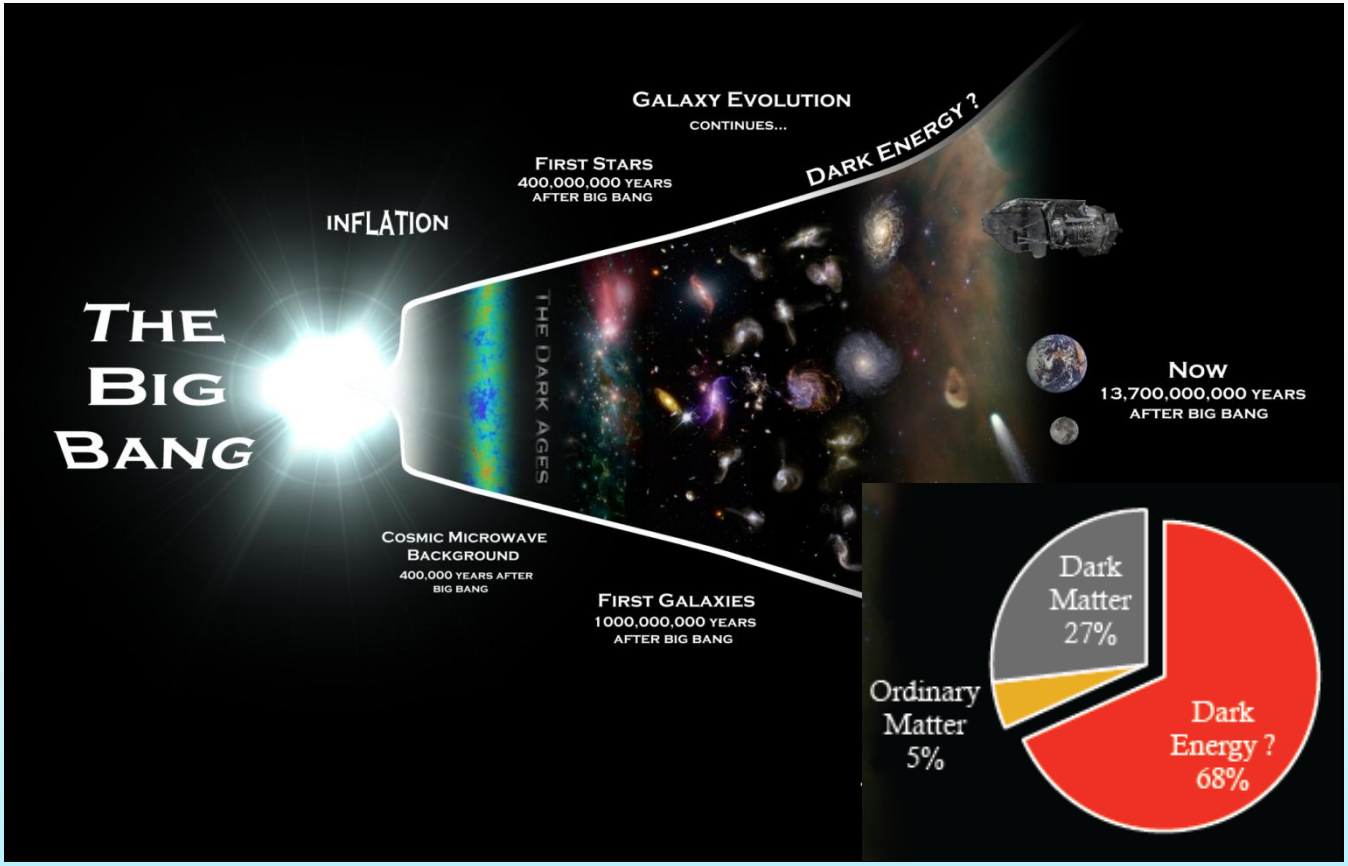
THE EUCLID SPACE MISSION

Olivier Le Fèvre
LAM

Outline

- Understanding the accelerated expansion of the Universe: Dark Energy ?
  - Content of the Universe
  - Probing very large scales back in time
- The ESA-Euclid mission
- The NISP imager and spectrograph
- Euclid: a complex experiment in space

Dark energy: one of the biggest questions of today's Physics



Credit: Planck/Rhys Taylor & Sylvain de la Torre

Accelerated expansion of the Universe

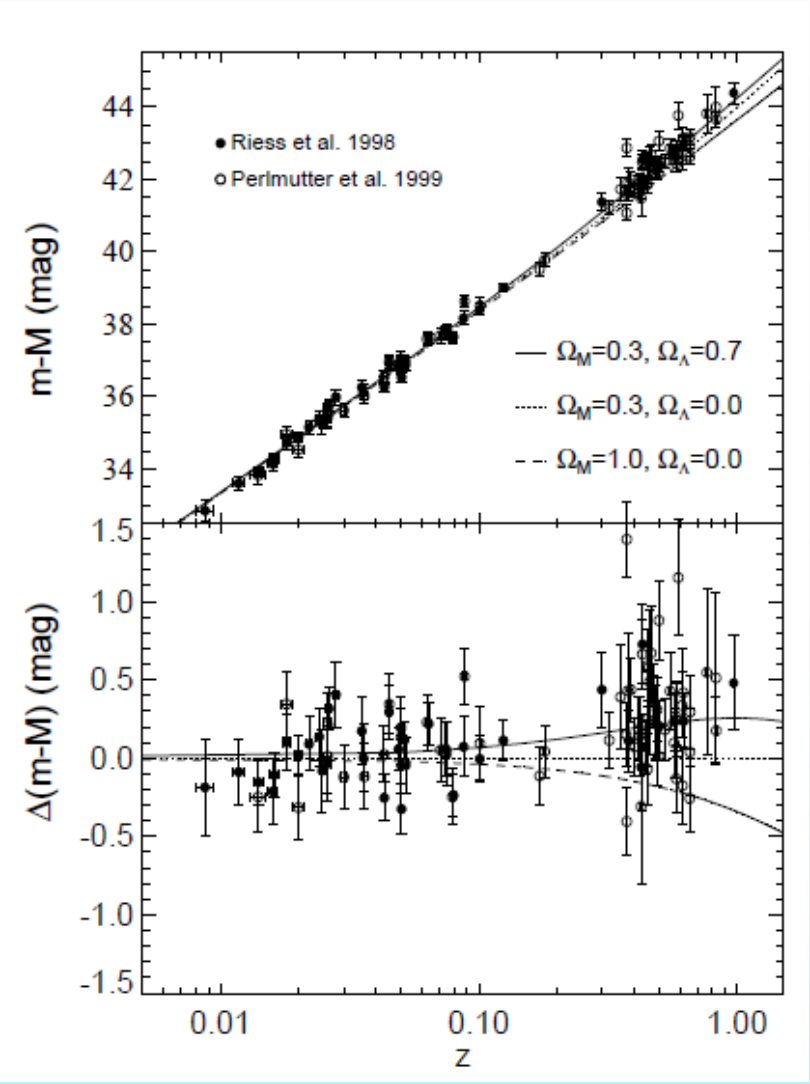
Dark energy

2/3 of the Universe content

What is its origin?

Acceleration of the expansion: An immense surprise…

- Demonstration using Supernovae as *standard candles*
  - Objects with known luminosity
- Observed to be dimmer than in an empty universe
- Postulate: there is a positive vacuum energy to accelerate the expansion



What produces the accelerated expansion ?

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

Cosmological constant = Dark Energy

Nature of Dark Energy ?

or

Modify Gravitation ?

General relativity incomplete ?

Need to probe the Universe on the largest scales

The Euclid mission of the European Space Agency

Why ?

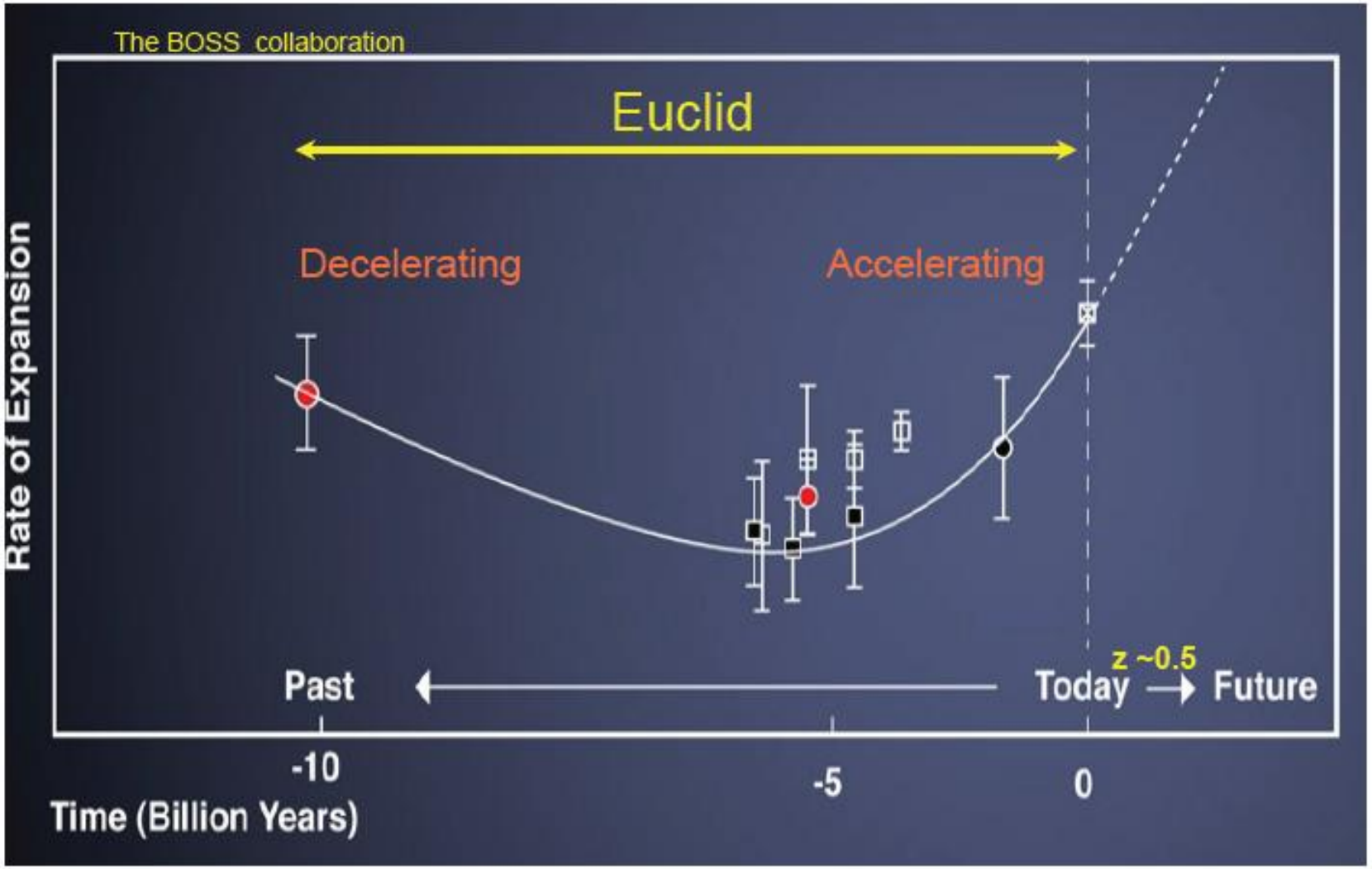
- Map the geometry of the Universe
  - Nature of Dark Energy and Dark Matter
- Employ complementary cosmology probes
  - Baryonic Acoustic Oscillations
  - Weak gravitational lensing
  - Redshift space distorsions

How ?

- 3D map of the Universe: 15000deg² in imaging and spectroscopy
- Back 10 billion years in the history of the Universe

Euclid probing the DM-DE transition era

EUCLID CONSORTIUM



Transition very late, can be explored with visible+NIR telescopes → **Euclid**

Euclid primary probes

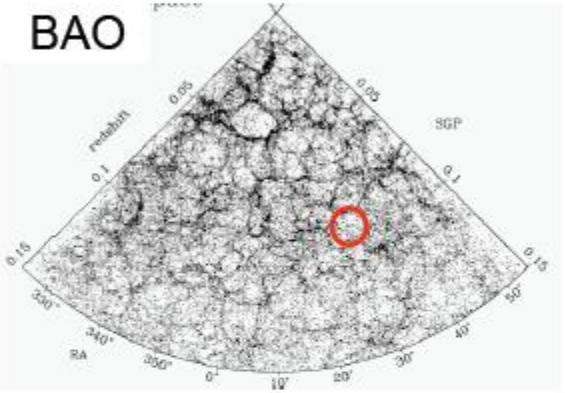
EUCLID CONSORTIUM

BAO, RSD and WL

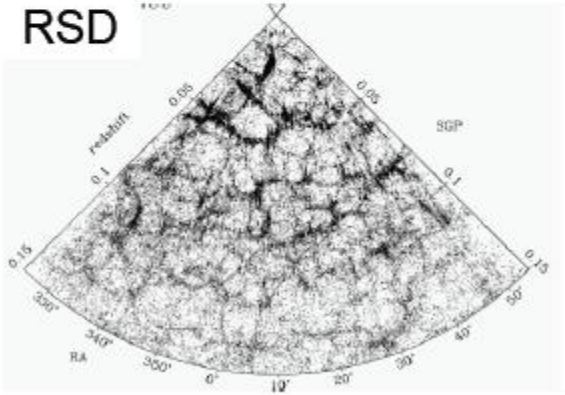
~30 million galaxies with redshifts

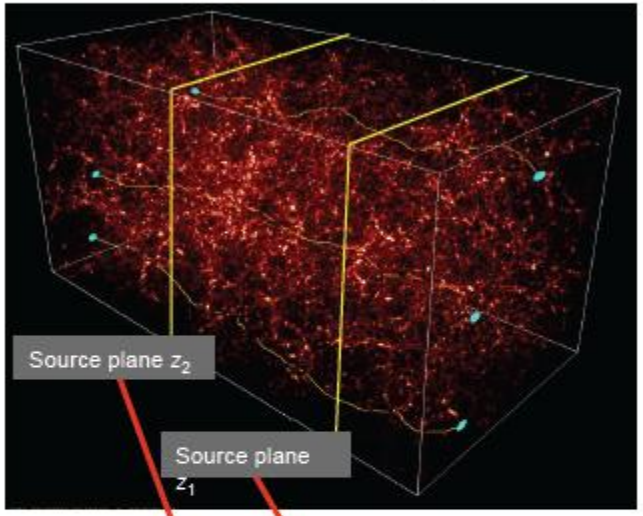
1.5 billion sources with shapes, 10 slices

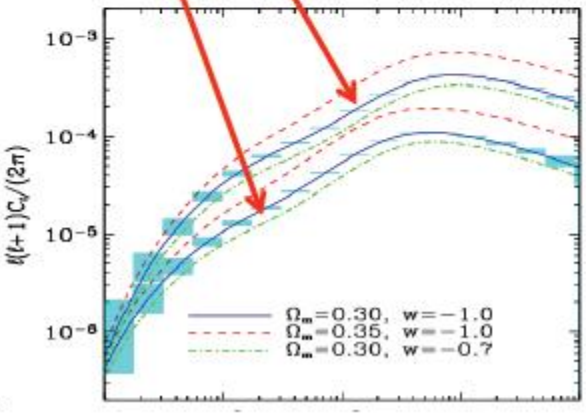
BAO



RSD







From Y. Mellier, Euclid lead

Euclid mission baseline: Launch in 2020

EUCLID CONSORTIUM

Ground based Photometry and Spectroscopy (photo-z)

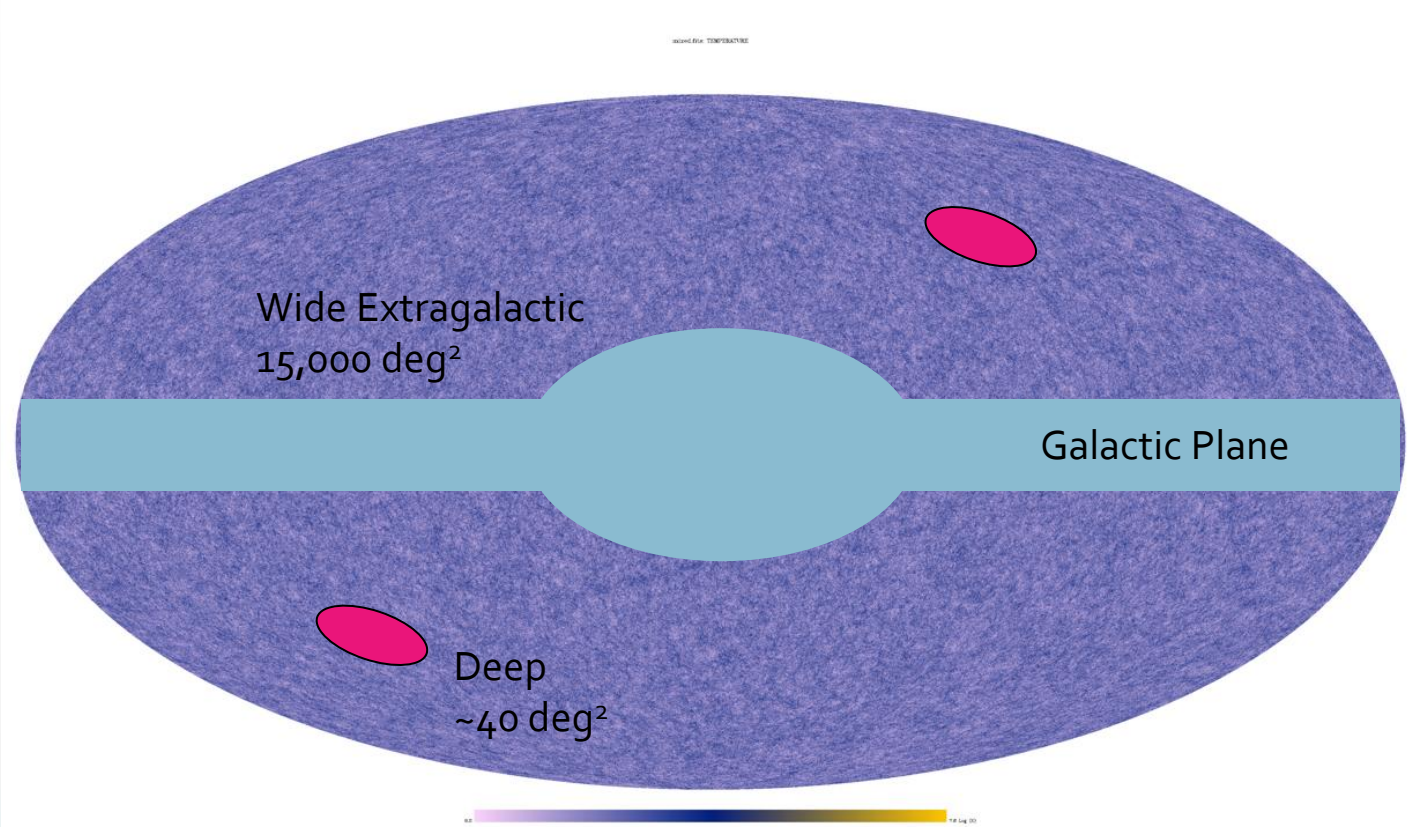
SURVEYS In ~6 years		
	Area (deg2)	Description
Wide Survey	**15,000 deg²**	Step and stare with 4 dither pointings per step.
Deep Survey	**40 deg²**	In at least 2 patches of > 10 deg² 2 magnitudes deeper than wide survey

PAYLOAD					
Telescope	1.2 m Korsch, 3 mirror anastigmat, f=24.5 m				
Instrument	VIS	NISP			
Field-of-View	0.787×0.709 deg²	0.763×0.722 deg²			
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 $n = 1.5 \times 10^9$ galaxies			z of $n=2.5\times10^7$ galaxies	

Possibility other surveys: SN and/or μ-lens surveys, Milky Way (TBC): **after Mission PDR**

Ref: Euclid RB Laureijs et al arXiv:1110.3193

Euclid « All sky » survey



All the extragalactic sky (away from the Milky Way)

> 1 billion galaxy images

> 40 million galaxy redshifts

To z~2: 10 billion years back

Forecasts: Euclid primary cosmology programme

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	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν /eV	f_{NL}	w_p	w_a	**FoM** $= 1/(\Delta w_p \times \Delta w_a)$
Euclid primary (WL +GC)	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 → **6000**
Current (2009)	0.200	0.580	100	0.100	1.500	~10
Improvement Factor	**30**	**30**	**50**	**>10**	**>40**	**>400**

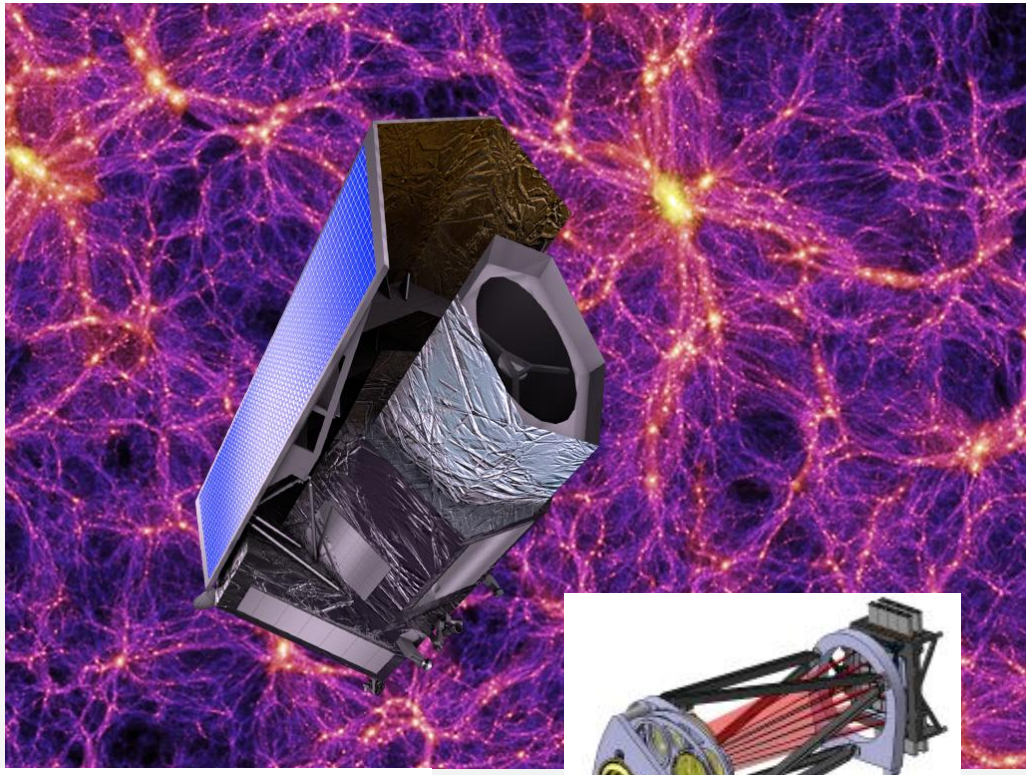
Ref: Euclid RB arXiv:1110.3193

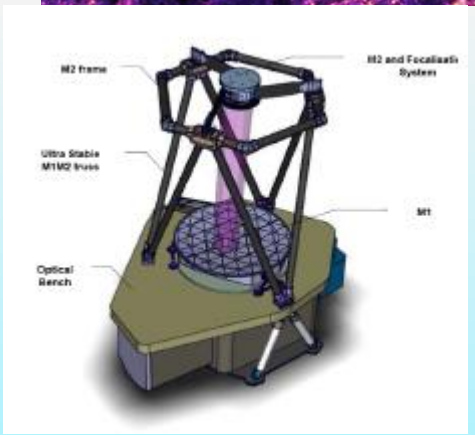
Assume systematic errors are under control

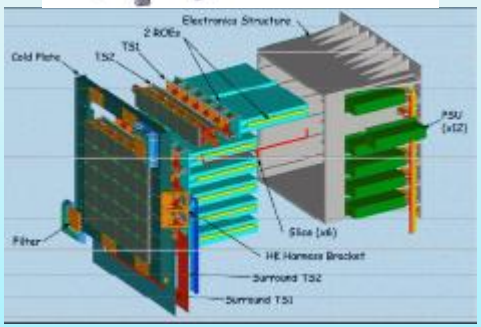
Update based on WL, GC, TH SWGs

A space technology challenge

- Telescope 1.2m diameter
  - Cooled to 100K
- Send at Lagrange L2 point
- Instrumentation:
  - Visible cameraa
  - IR camera
  - IR spectrograph (LAM with CPPM)

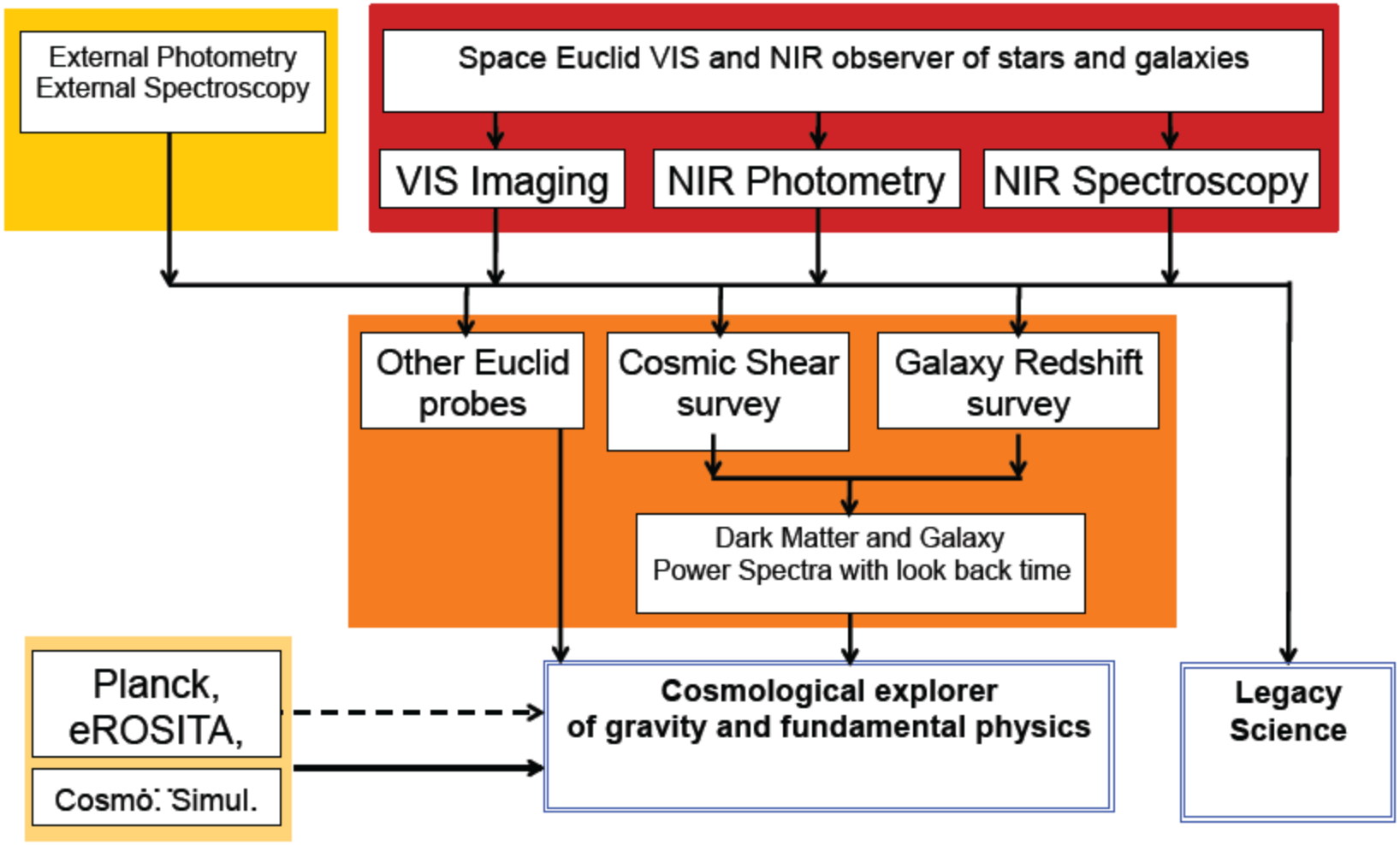






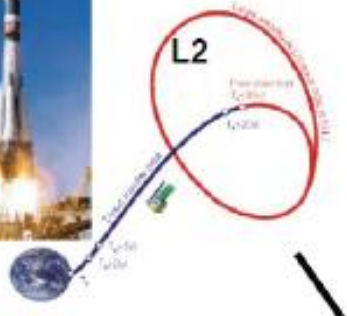
The *Euclid Machine*

EUCLID CONSORTIUM

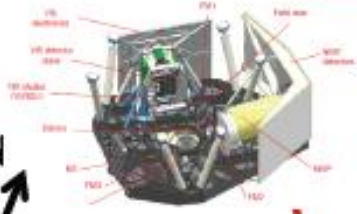


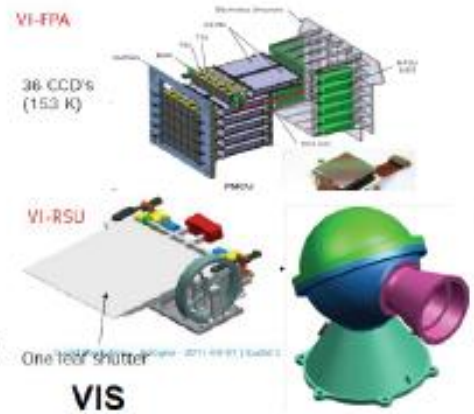
Euclid mission in one slide

Soyuz@Kourou
Q1 2020



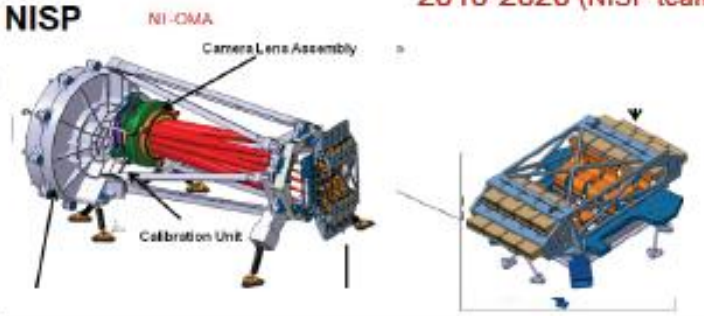
PLM+SVM: 2010-2019



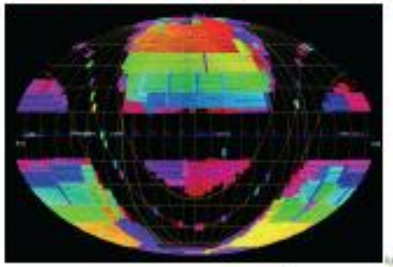


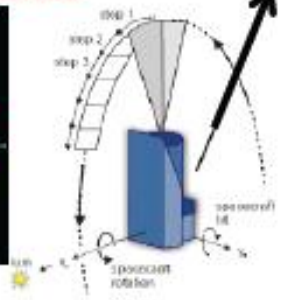
VIS imaging:
2010-2020
(VIS team)

NIR spectro-imaging
2010-2020 (NISP team)



Surveys: 2010-2028 (Survey WG)

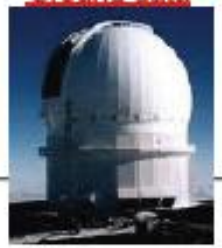




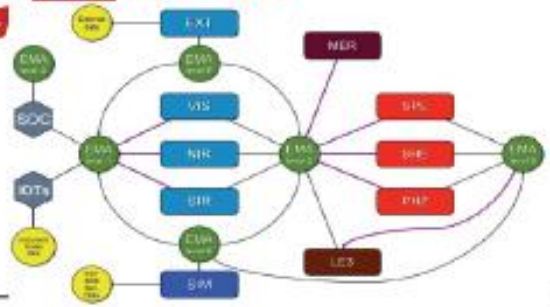
6 yrs - 15,000 deg^2

- Commisionning – SV
- Euclid opération:
5.5 yrs:Euclid Wide+Deep
- +: SNIa, mu-lens, MW?

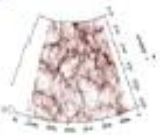
Ground data

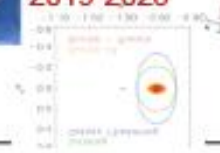


SGS: 2010-2028



SWG:
2019-2028



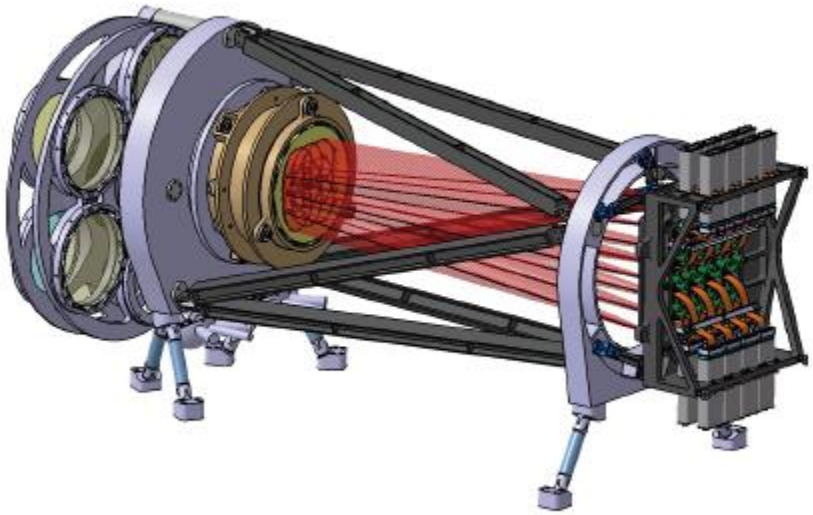


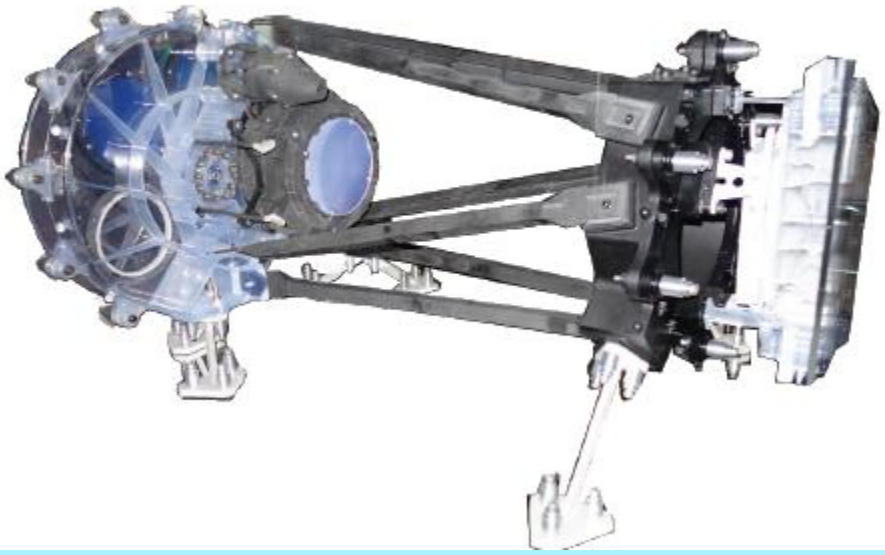
Euclid

20-30 PB data processing (EC-SGS team) — Science analyses

NISP: the Near-Infrared imager and spectrograph

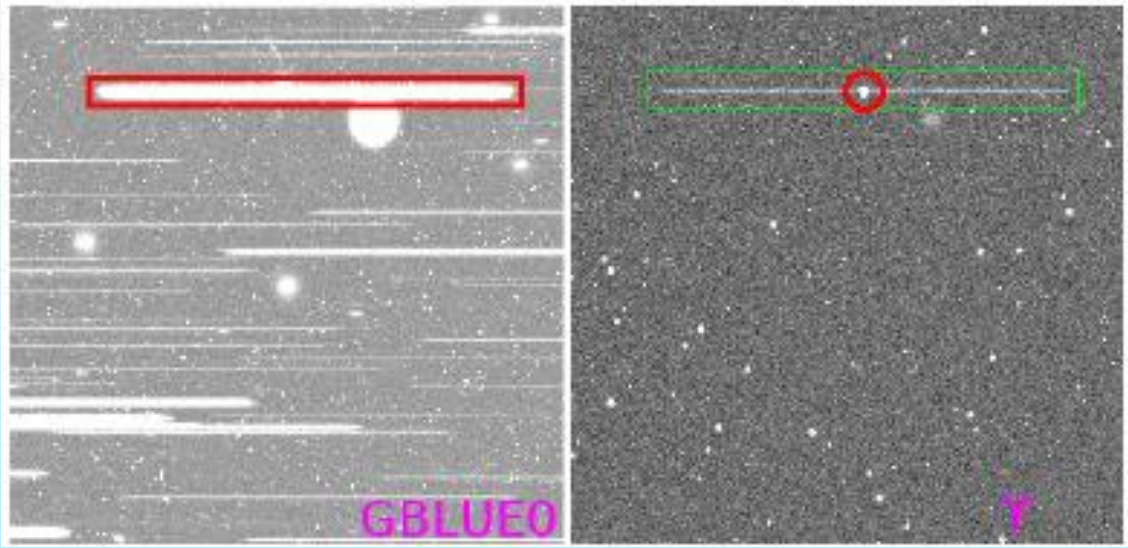
- 0.55x0.55 deg²
- Imager: YJH bands
- Slitless spectrograph 1.2 to 1.85 microns
  - To get Hα

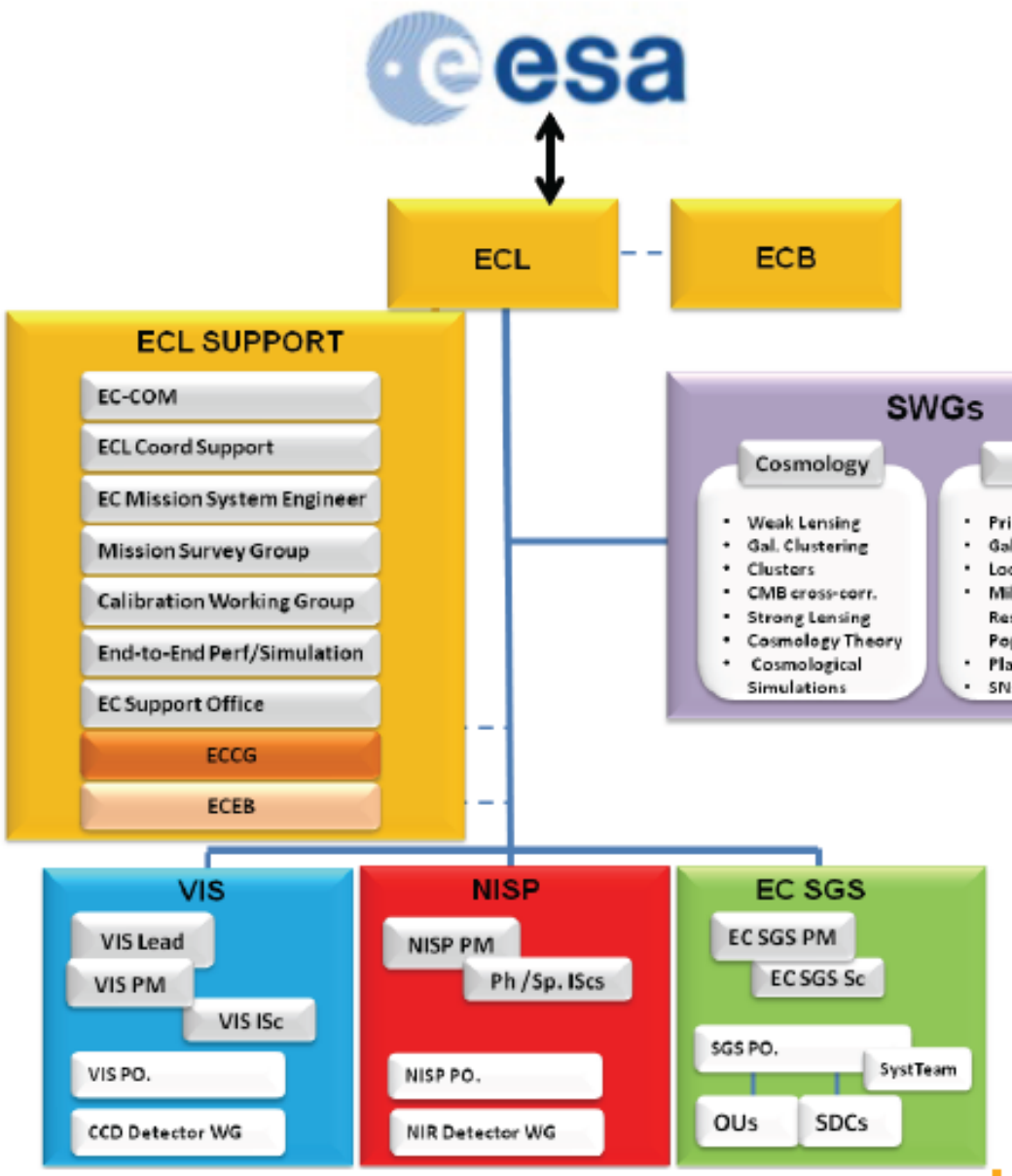




NISP slitless spectroscopy

- 3 red gratings (1.2-1.85μm), 1 blue grating (0.95-1.25 μm)
  - Different orientations to remove overlap
- Wide survey: 3x10^-16 erg/cm²/sec
- Deep survey: 10x deeper





Euclid Consortium

- ~1200 members,
- 130 Labs
- 13 European countries:
Austria, Denmark, France, Finland,, Germany, Italy, The Netherlands, Norway, Portugal, Romania, Spain, Switzerland, UK

+ **US/NASA** and Berkeley labs.

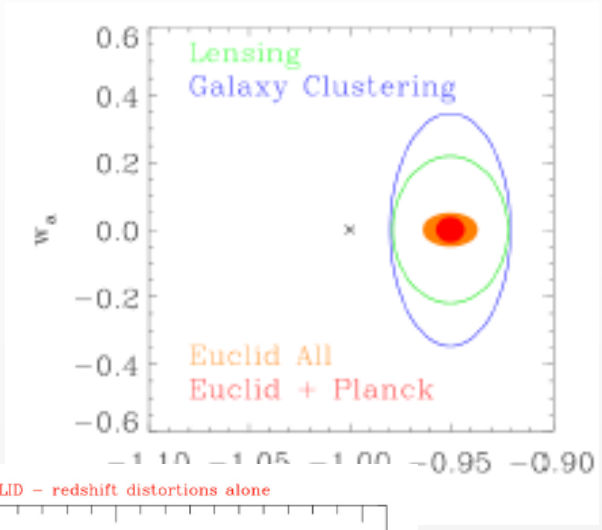
Hope: measure cosmological parameters at % level

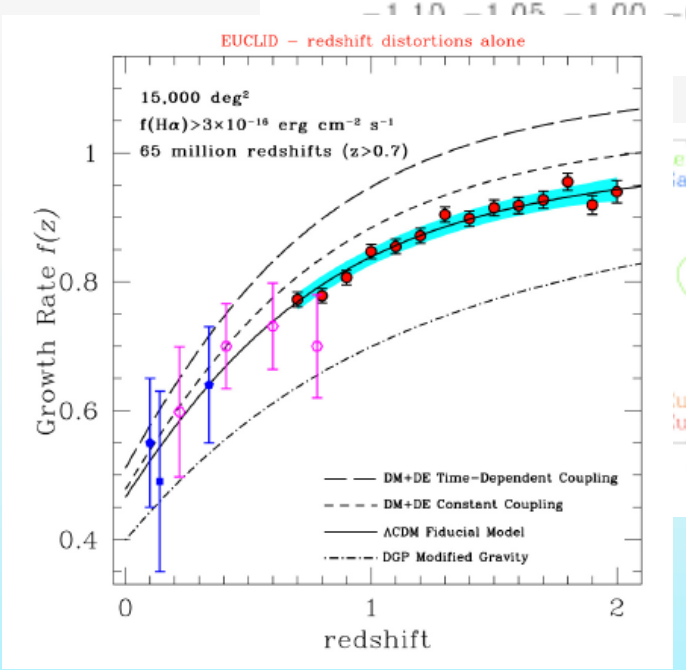
Combining probes

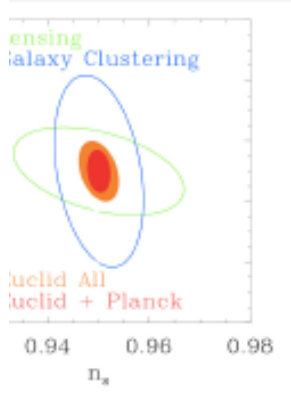
Modify Gravity ?

Towards a new revolution in Physics ?

A very exciting time for Cosmology and Physics







Wait and see !

- Launch 2020
- 7 years nominal survey