Euclid Flagship Mock galaxy catalogue

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On behalf of the Euclid Consortium

Rencontres du Vietnam

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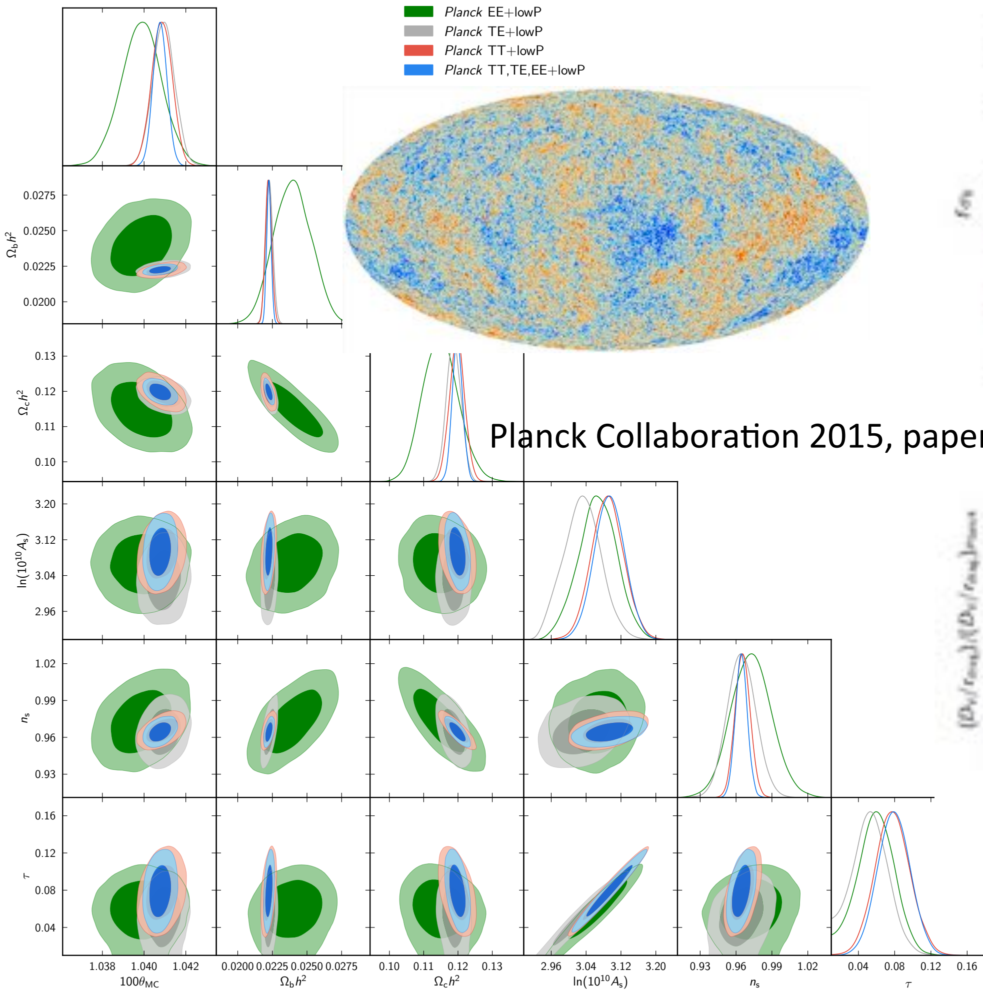
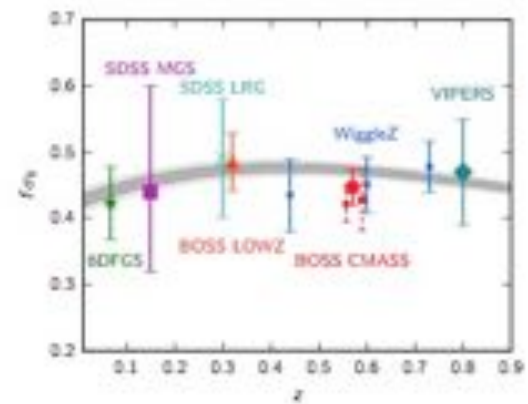
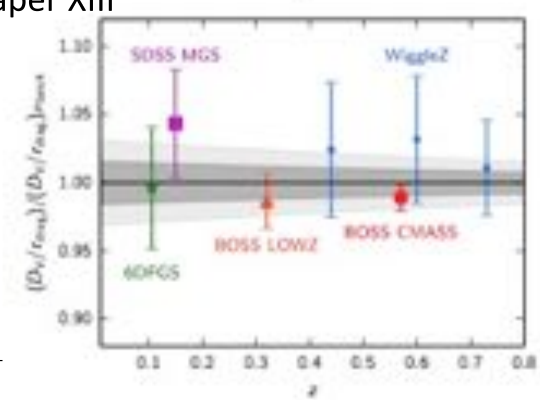
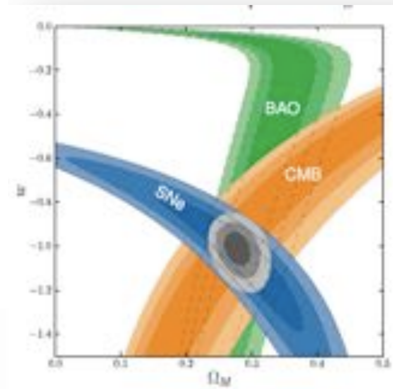
Euclid cosmological motivation



Planck Collaboration 2015, paper XIII







Amanullah et al. 2010
(Union supernovae)

An accelerating Λ-dominated Universe: "concordance", but with a few crucial open questions…

KQ1: Is cosmic acceleration produced by a cosmological constant or by an evolving scalar field?

Evolving equation of state of DE:

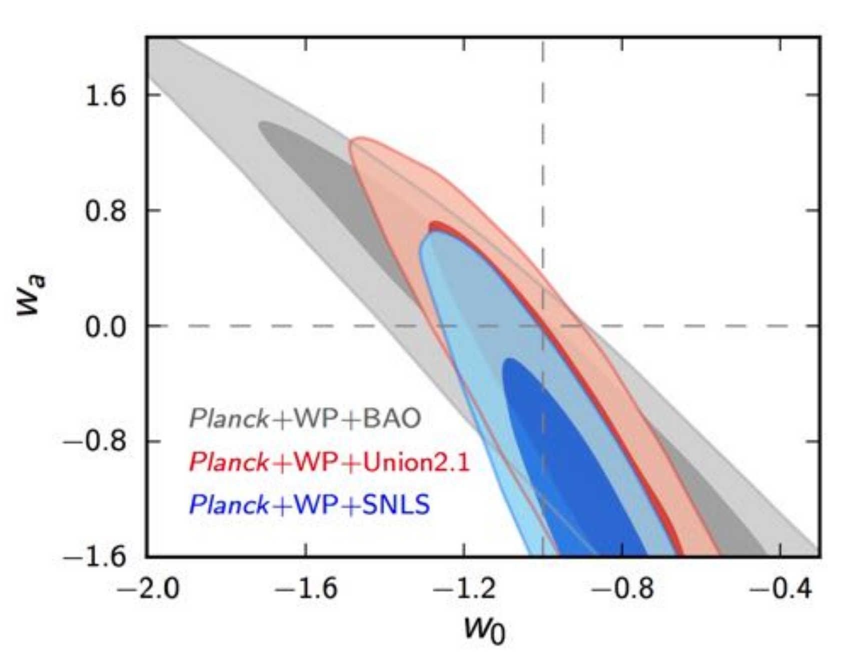
e.g. $$w(a) = w_0 + w_a(1-a)$$

DETF (Albrecht et al. 2006): characterize experiments through a Figure of Merit in (w_0, w_a) plane (or similar):

$$\mathrm{FoM} = 1/(\Delta w_0 \times \Delta w_a)$$

But this reflects chosen parameterization

→ <u>FoMs should be taken with a big grain of salt</u> (e.g. NASA/DOE/ESA FoMSWG report, Albrecht et al. 2009): there is **much more science** in a galaxy survey



Planck Collaboration 2013, XVI

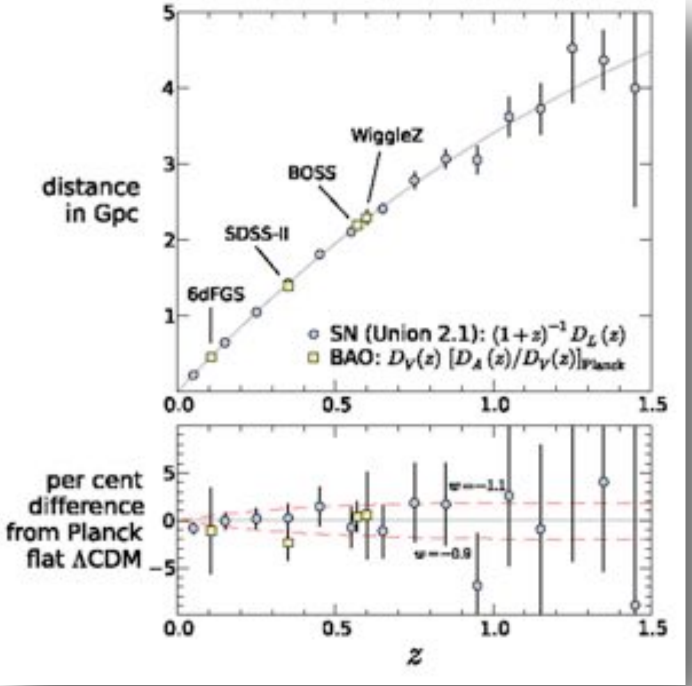
Parameterizing our ignorance

KQ2: Is General Relativity valid on cosmological scales? Can we tell the difference between Dark Energy and Modified Gravity ?

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

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} = -\frac{8\pi G}{c^2} (T_{\mu\nu} + \tilde{T}_{\mu\nu})$$

As a consequence, probing the expansion history of the Universe alone does not allow us to distinguish between a modified gravity (e.g. a Λ-term) and a Dark Energy.



Lohav & Liddle, 2014

Euclid goal is to measure these three quantities in a single experiment

This degeneracy can, at least partially, be lifted by considering perturbation in the cosmic density and velocity field and their evolution. A linearly perturbed FRW metric can be expressed as

Relativistic particles respond to the sum of the two scalar potential.
Probed by e.g. gravitational lensing

$$ds^2 = (1 + 2\Psi)\mathrm{d}t^2 - a^2(t)(1 - 2\Phi)d\vec{x}^2$$

Massive Particles respond to the Newtonian potential.
Probed by e.g. peculiar velocities

Expansion history.
Probed e.g. by BAO

And more …

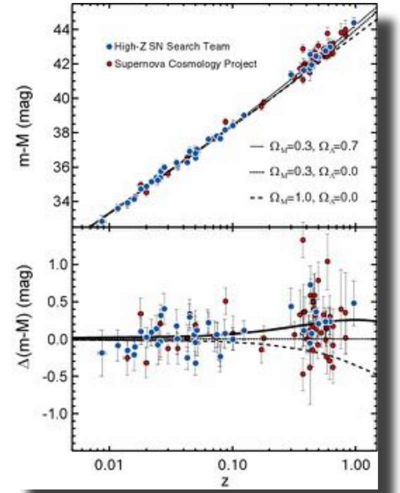
Euclid: answer both questions

1. Measure ***the expansion history H(z)*** to high accuracy, as to detect percent variations of DE *equation of state* w(z) with robust control of systematics:

   Achieve this through **two probes**:

   A. Using the scale of Baryonic Acoustic Oscillations (BAO) in the clustering pattern of galaxies as a standard rod

   B. Using shape distortions induced by Weak Gravitational Lensing



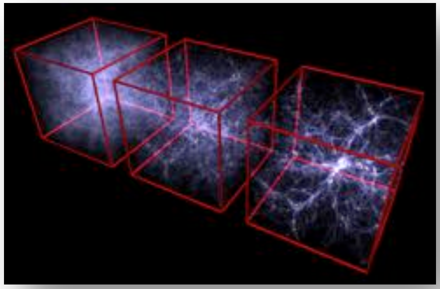
(Perlmutter+ 1998; Riess+ 1999)

2. Measure at the same time ***the growth rate of structure*** from the same probes, to detect modifications of gravity:

   A. Clustering redshift-space distortions (RSD)

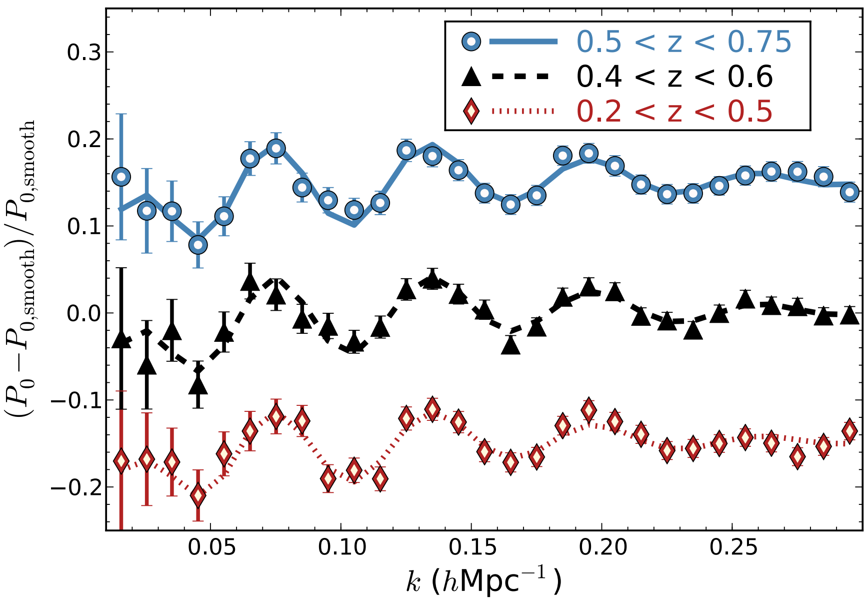
   B. Weak Lensing (WL) Tomography

   → These two probes are differently sensitive to the Ψ and Φ potentials of the perturbed metric, i.e. to deformations of time and space

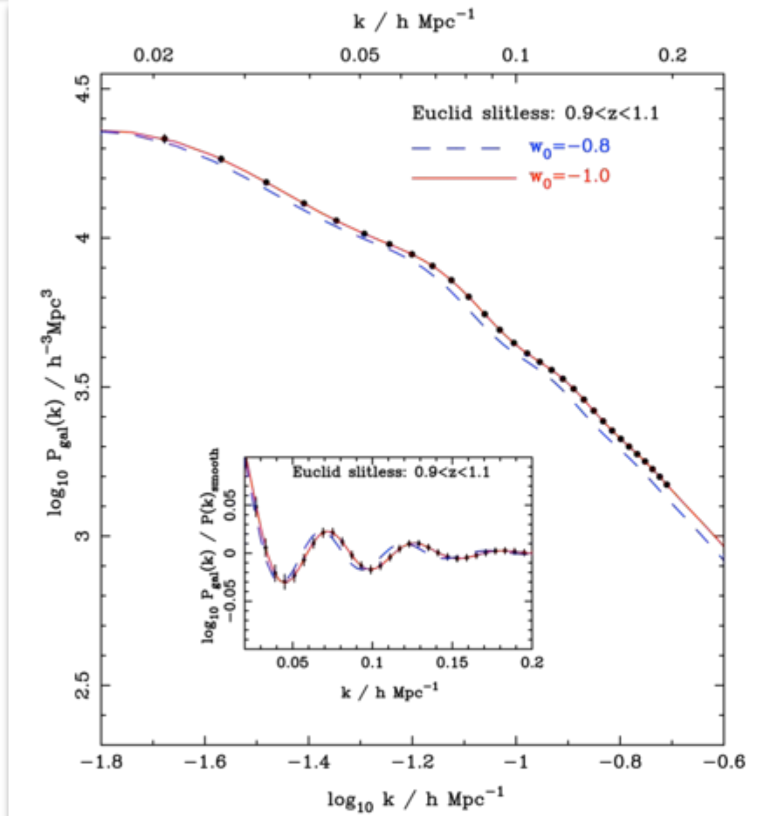


(Credit: V. Springel)

w(z) from BAO



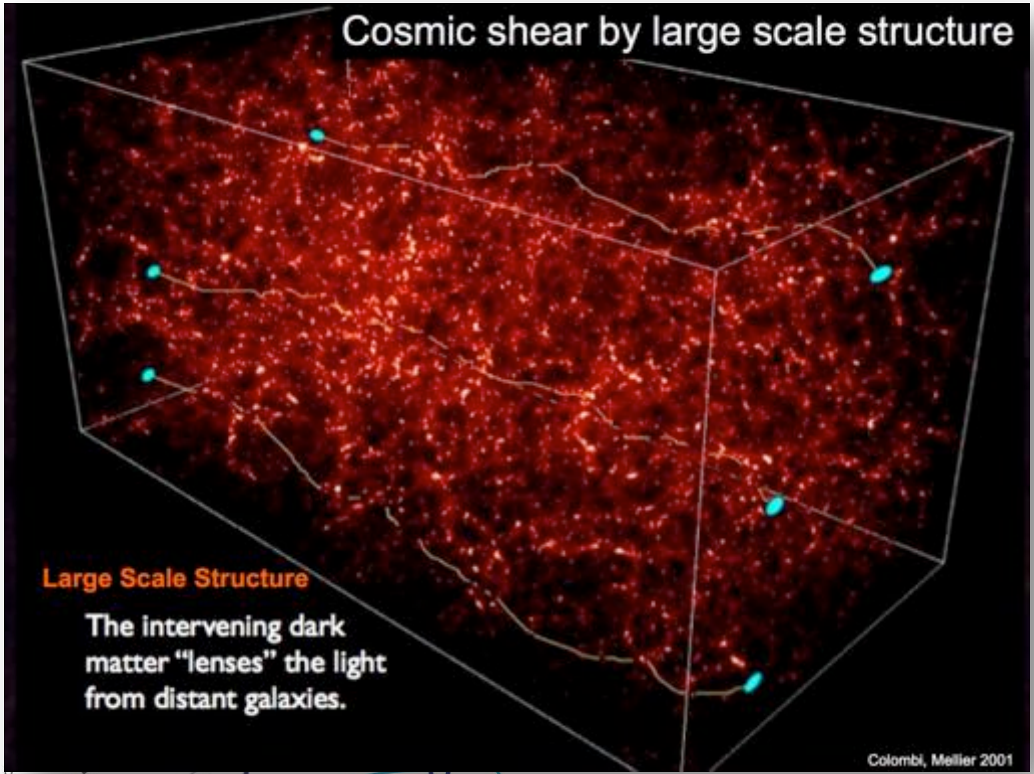
Alam+16
SDSSIII BOSS



20% of the Euclid slitless data at z~1. Total effective volume (of Euclid) V_{eff} = 19.7 Gpc^{3}h^{-3} (Euclid Red Book; credit: Percival, Guzzo & GC Working Group)

Weak Lensing tomography: get matter P(k,z)

- The lensing kernel is most sensitive to structure halfway between the observer and the source. But the kernel is broad: we do not need precise redshifts for the sources: photometric redshifts are fine
- Also, since the kernel is broad the tomographic bins are very correlated. The gain saturates quickly with the number of bins: not many z bins

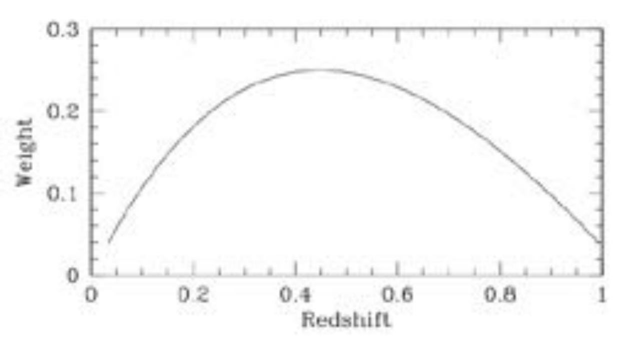


Geometry

Large Scale Structure

$$C_{ij}(\ell) = \int_0^{r_H} \mathrm{d}r\, W_{ij}^{\mathrm{GG}}(r) P_{\delta\delta}\left(\frac{\ell}{S_k(r)}; r\right)$$

Lensing Power Spectrum

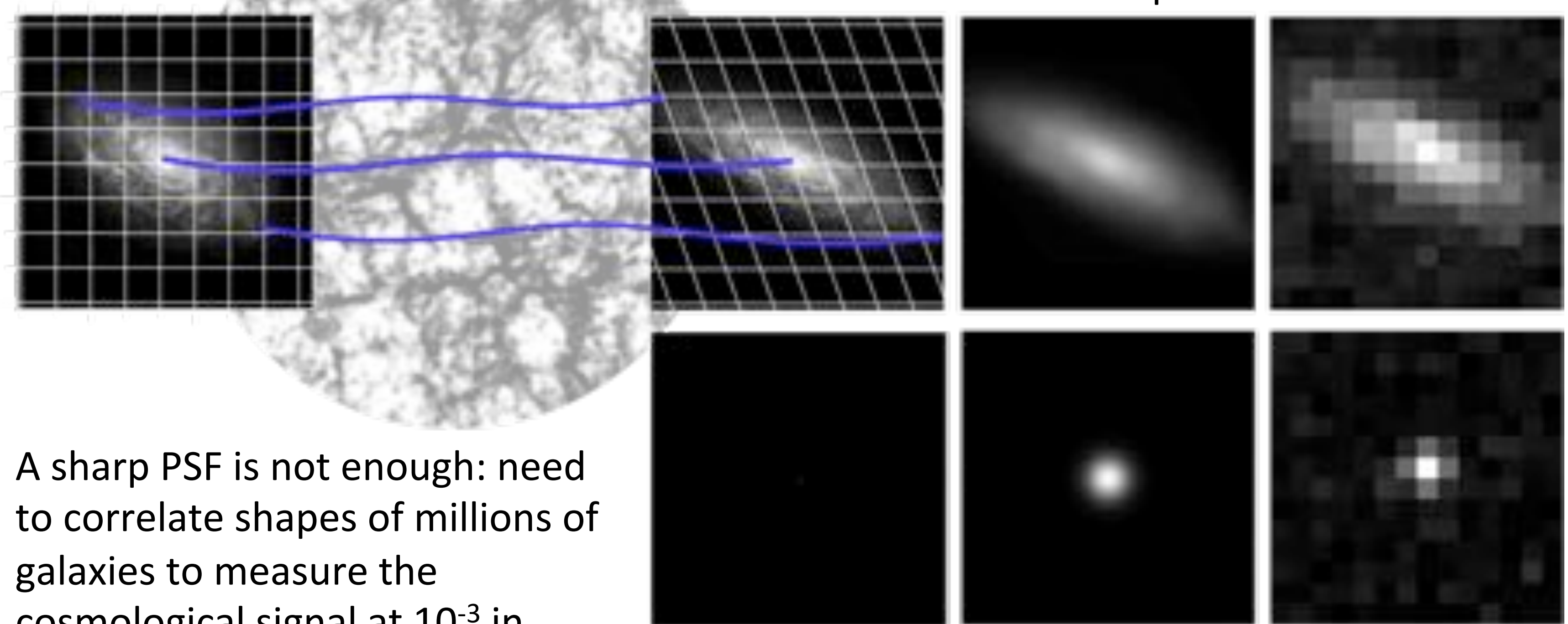


(Euclid Red Book; credit: Hoekstra, Kitching & WL Working Group)

Weak Lensing Probe

Light propagation through large-scale structure results in a lensed image

Telescope Detector



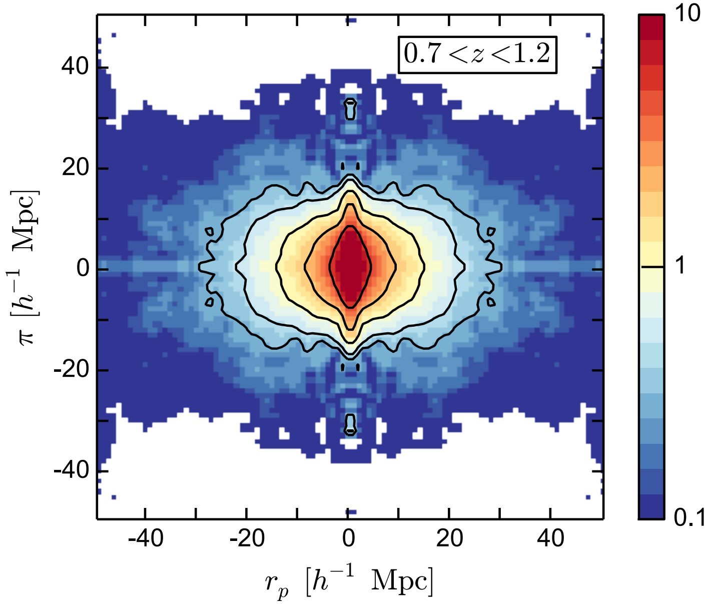
A sharp PSF is not enough: need to correlate shapes of millions of galaxies to measure the cosmological signal at 10^{-3} in ellipticity (+ Photometric redshifts + Color-corrected PSF + …)

Unlensed stars used to measure instrumental effects.

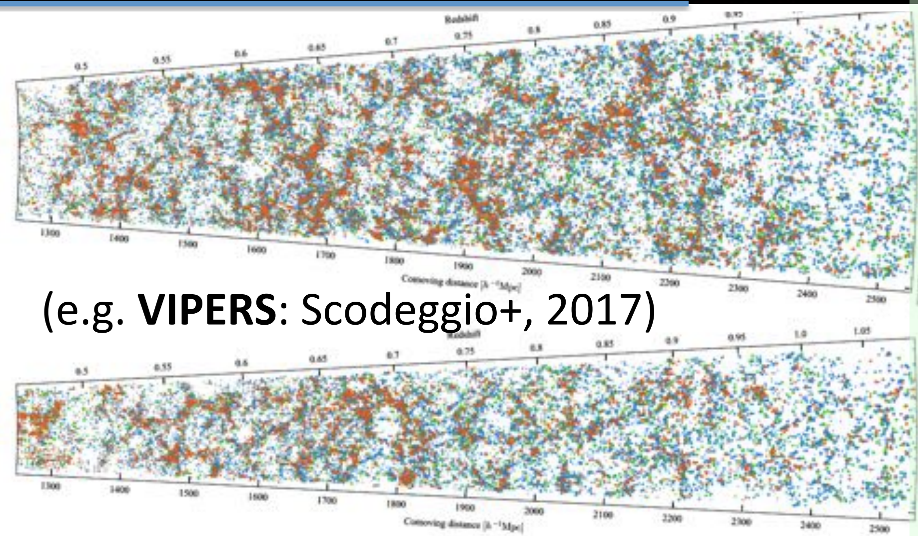
(Hoekstra, Kitching & WL Working Group)

Euclid's Spectroscopic Probes

Z=1.05



Anisotropy of 2pt correlation function
(Pezzotta +, 2017)

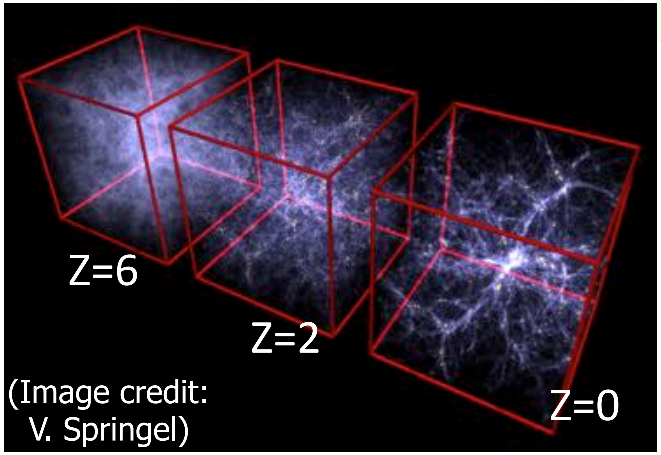


(e.g. **VIPERS**: Scodeggio+, 2017)

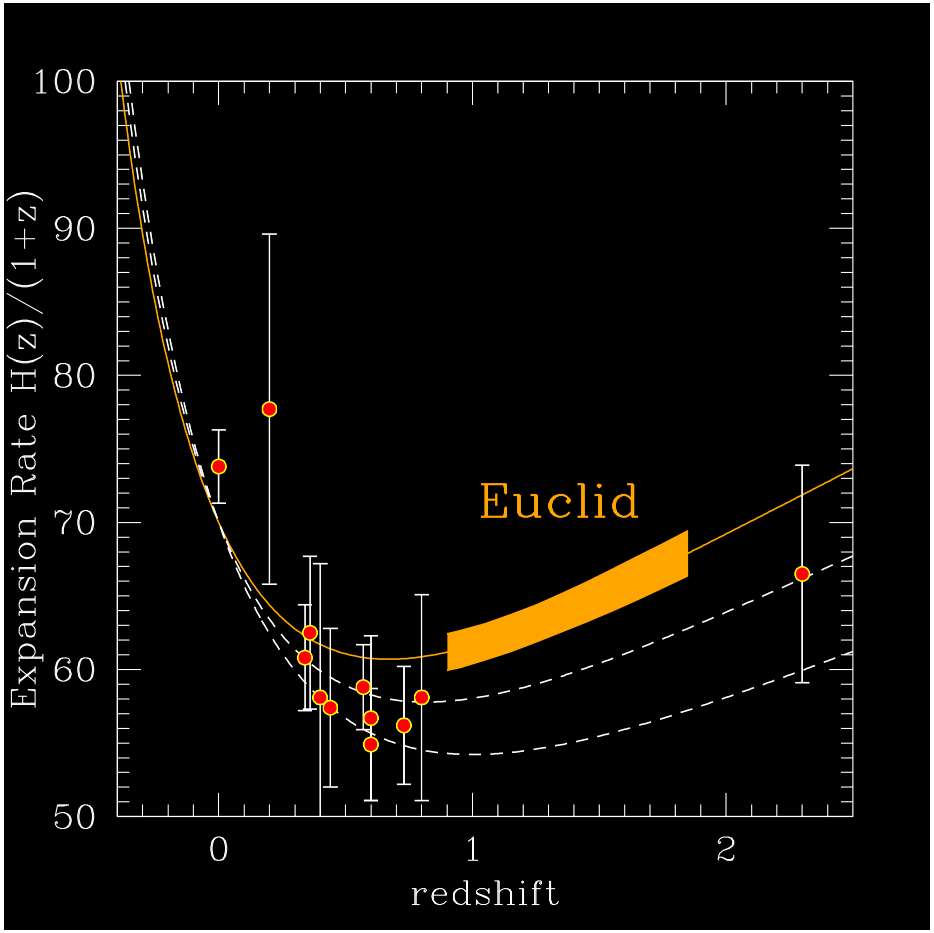
Euclid

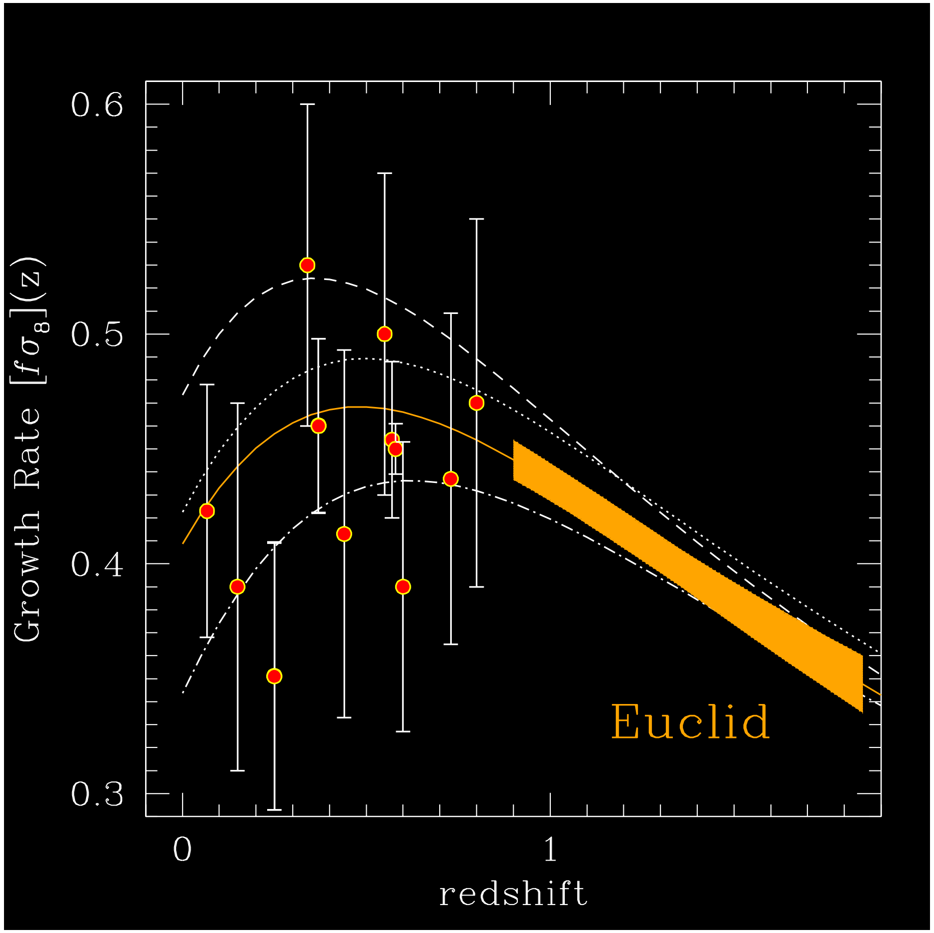
$0.9<z<1.8$

The distortion of the correlation function is sensitive to the growth-rate of structure *$f\sigma_8(z)$* and modifications of gravity theory



Euclid will set new limits





(Credit: Guzzo, Percival & GC Working Group)

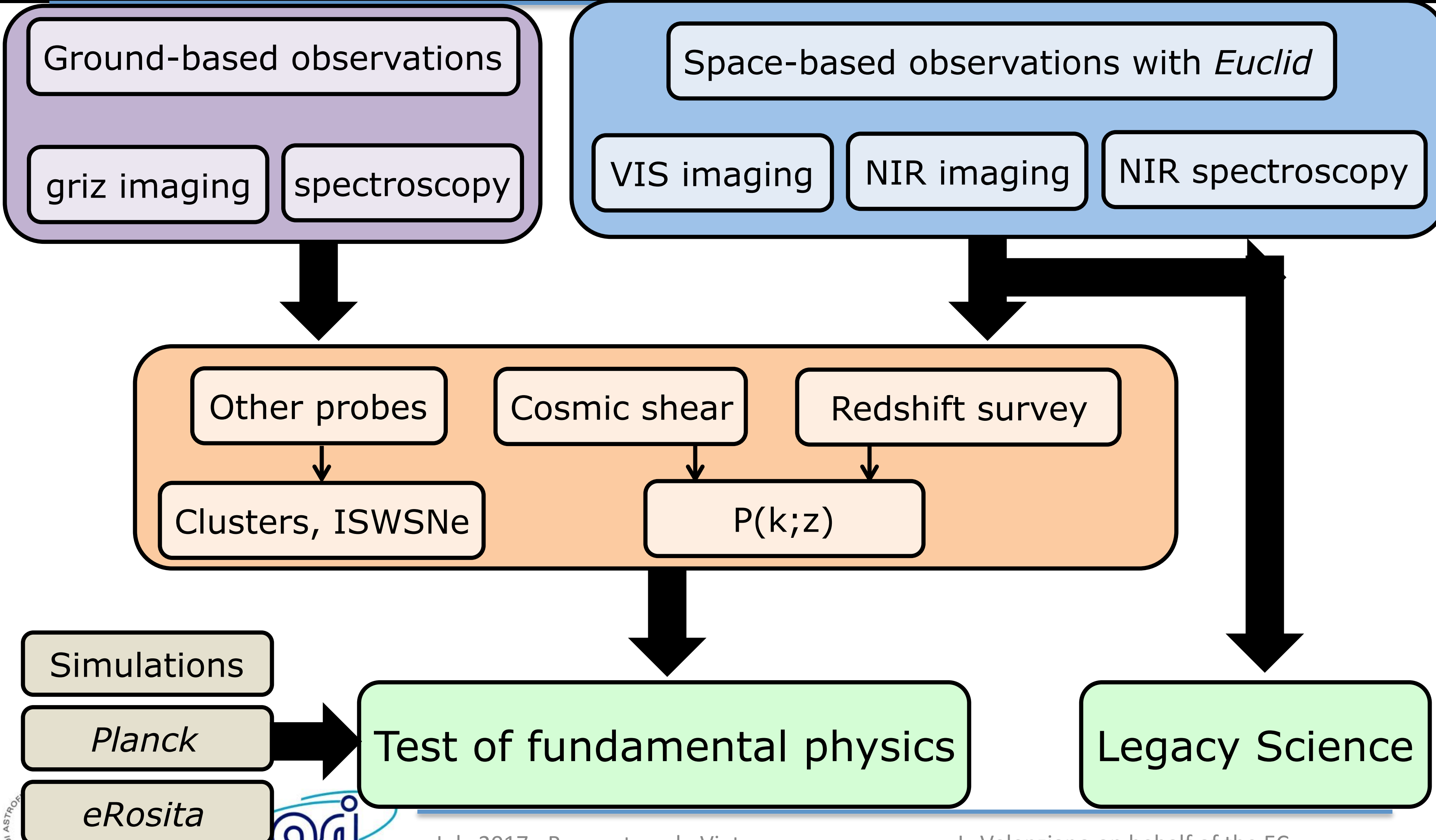
Euclid and DM

- Probing halo mass as a function of z (low-mass tail)
- Survey of clusters (combined with X-rays observations) -> high mass tail
- Galaxy-galaxy interactions (extending the bullet cluster study to 15KSqDeg) will set limits to DM self-interaction cross section (Massey, 2011)
- Euclid WL observations could constraint m_{WDM}<2 keV (Markovic et al, 2010)
- Euclid cosmological constraints on neutrino properties are highly complementary to particle physics experiments (see M. Kuntz talk) – time-varying neutrino mass, sum of neutrino mass (galaxy power spectrum and weak lensing),…-
- DM-DE coupling, Unified Dark Matter, …

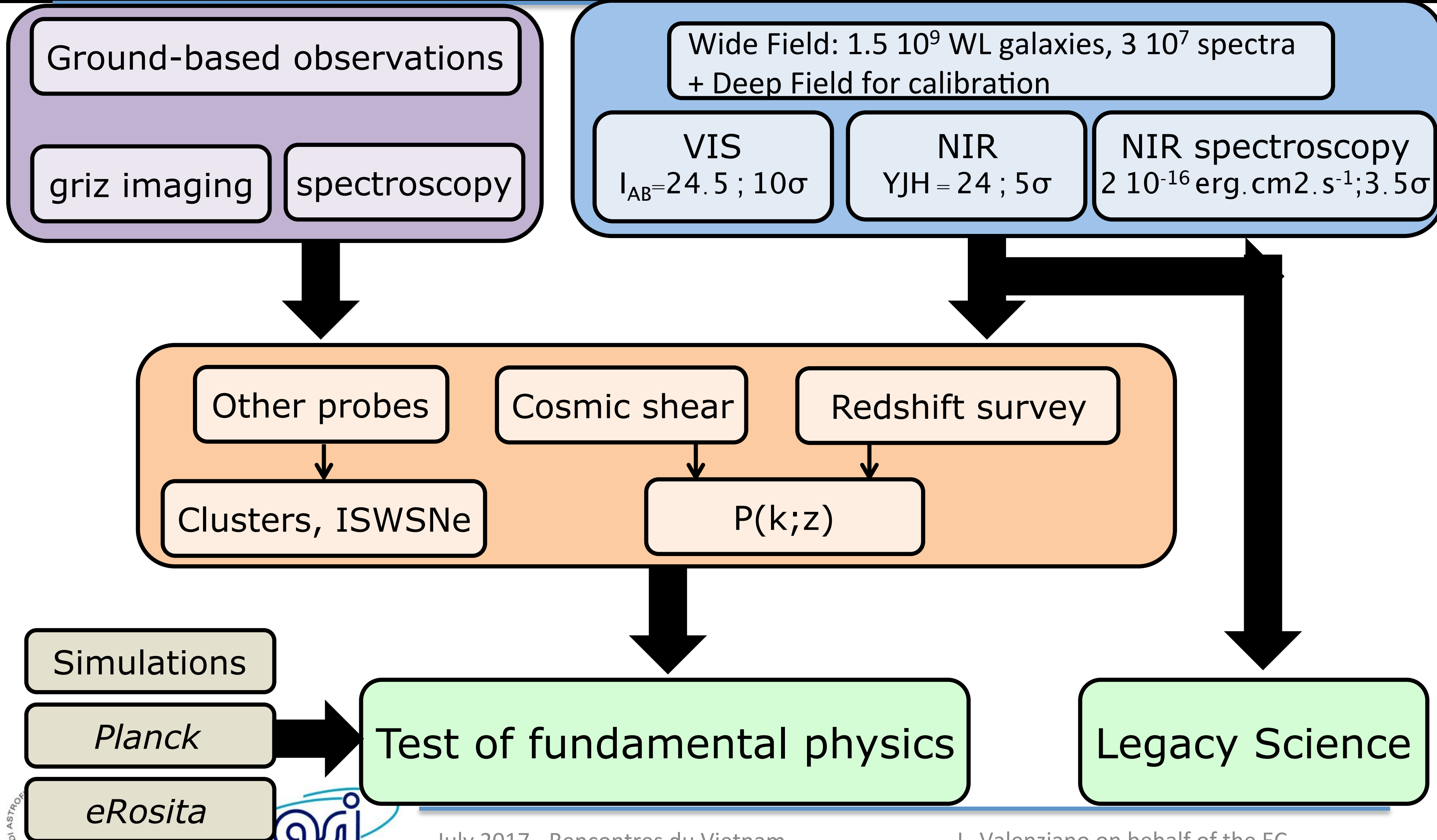
Euclid exquisite (in statistical terms) accuracy will allow disentangling between theoretical predictions and/or confirm direct detection

See Amendola +, 2016, arXiv:1606.00180v1

How to do this with Euclid



How to do this with Euclid

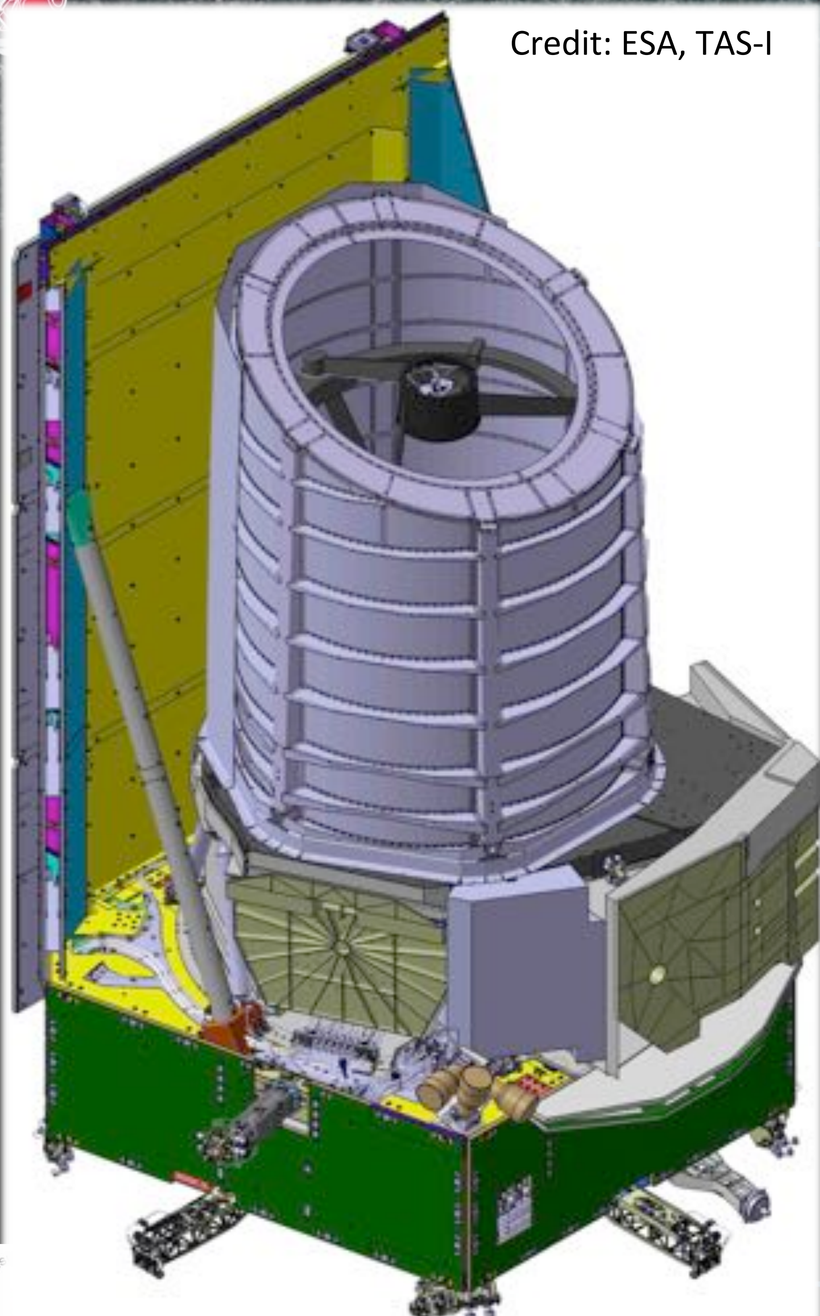


The Euclid Consortium

An artist view of the Euclid satellite – courtesy ESA

- 16 countries +
- More than 120 institutes/ labs
- More than 1200 members

www.euclid-ec.org
sci.esa.int/euclid

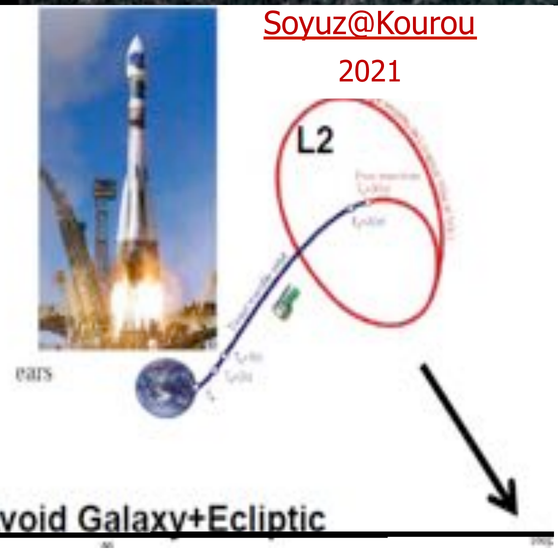


- **ESA mission**
- Selected in Oct. 2011 - Fully funded
- Partners: ESA, TAS-I, Airbus DS, Euclid Consortium (EC)
- Overall mass: ~2020 kg, Power : 1920 W (E0L)
- Data rate: 850 Gbit/day
- Telescope (T=125K, passive):
  - 1.2m aperture primary, 3 mirror Korsch anastigmat
- 2 Instruments (VIS, NISP) – T = 100-140 K (passive)
  - Wide field instrument, VIS: 36 e2v 4kx4k CCDs $0.55<\lambda<0.92$ µm, 576 M pixels, 0.11 arcsec/pix, 0.53 deg^2 FoV
  - Photom. (Y, J, H) +spectrom.: 16 H2GR HgCdTe detectors;
  - 64 Mpixels, 0.30 arcsec/pix, 0.53 deg^2 FoV (=VIS)
  - Grism slitless spectro (1B + 3R grisms) $0.92<\lambda<2.05$ µm, R>250
- Downlink Rate: X/X + K-band to Ground Station 55 Mbits/s. 850 Gbit/day to transfer 4hr/day.
- Ground Segment: ESA (50%,) EC (50%, EC leads science and external data): 1.5 billion galaxies for WL, 30 million redshifts, 12 billion sources (3sigma)
- L2 orbit
- Launch Vehicle – Soyuz-Fregat
- Launch date mid 2021, from Kourou space port
- 6.25 years mission + additional surveys (exopl, SN)
- Main surveys: 15,000 deg^2+40 deg^2 2 mag. deeper
- Science drivers: DE
- Science leads: Euclid Consortium

The Euclid Mission in one slide

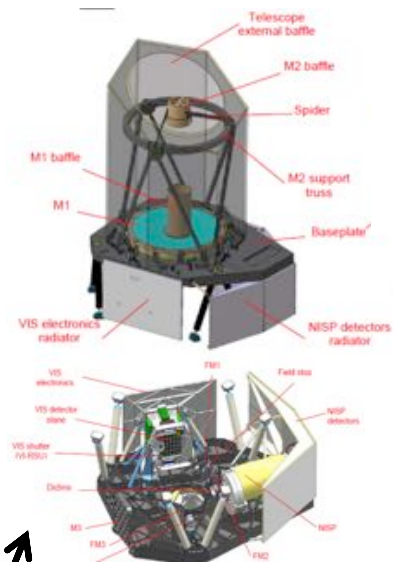
Soyuz@Kourou

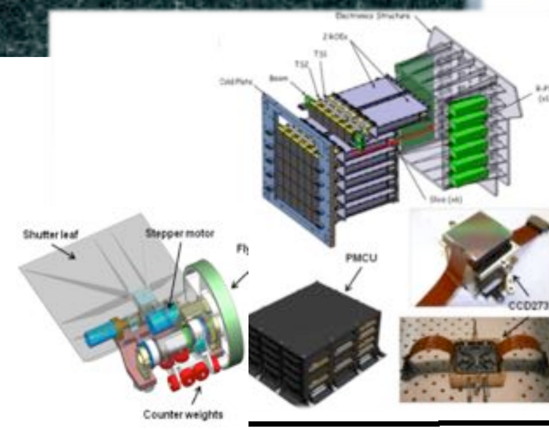
2021



Avoid Galaxy+Ecliptic

PLM+SVM: 2010-2027+



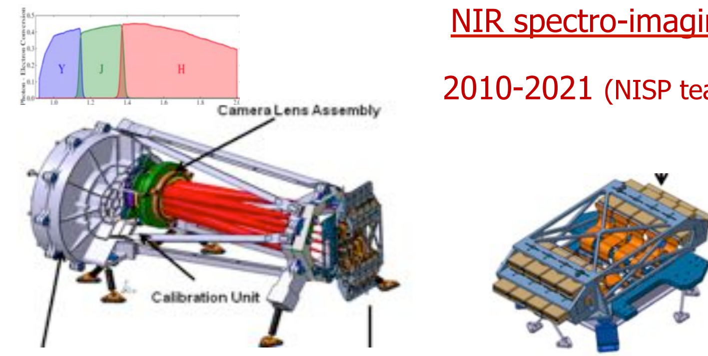


VIS imaging: 2010-2021

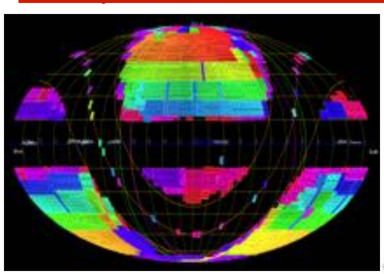
(VIS team)

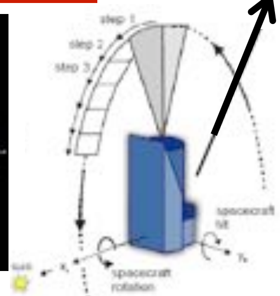
NIR spectro-imaging

2010-2021 (NISP team)



Surveys: 2010-2027+ (Survey WG)





6.25 yrs - 15,000 deg^2

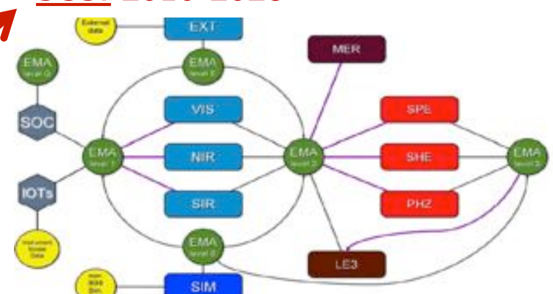
Commisionning – SV

Euclid opération:

>5.5 yrs:Euclid Wide+Deep

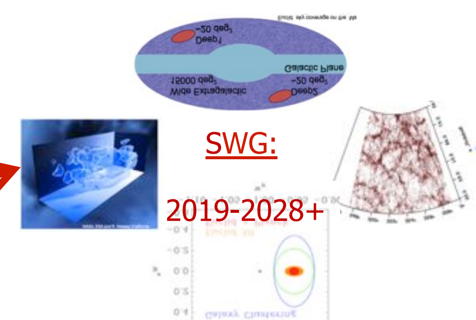
Ground data

SGS: 2010-2028+



SWG:

2019-2028+



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

Summary

- ✓ Euclid is an experiment combining GC and WL: an unprecedented match of an imaging and redshift survey from space, building a sample of $>10^9$ galaxy shapes and ~5 10^7 galaxy distances (and much more).

- ✓ Euclid results may well revolutionize our understanding of physics: for sure it will provide a huge database for unexpected discoveries (legacy).

- ✓ Ideal complementarity to CMB observations and direct/indirect DM search.

- ✓ Euclid is one of the most sophisticated scientific instruments ever launched: large cryo optics, large focal planes, the most powerful on-board data processing.

Acknowledgements

The Euclid Consortium acknowledges the European Space Agency and the support of a number of agencies and institutes that are funding the development of Euclid. A detailed complete list is available on the Euclid web site (http://www.euclid-ec.org). In particular the Agenzia Spaziale Italiana, the Centre National d'Etudes Spatiales, the Deutches Zentrum fur Luft- and Raumfahrt, the Danish Space Research Institute, the Fundação para a Ciênca e a Tecnologia, the Ministerio de Economia y Competitividad, the National Aeronautics and Space Administration, the Netherlandse Onderzoekschool Voor Astronomie, the Norvegian Space Center, the Romanian Space Agency, the United Kingdom Space Agency and the University of Helsinki.

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www.euclid-ec.org