
S. Harris
"I'LL BE WORKING ON THE LARGEST AND SMALLEST OBJECTS IN THE UNIVERSE—SUPERCLUSTERS AND NEUTRINOS. I'D LIKE YOU TO HANDLE EVERYTHING IN BETWEEN."

INDAM - 8 June 2013

Euclid space mission

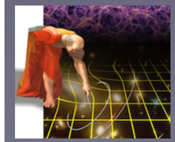
(a few whys and hows)

R. Scaramella (on behalf of Euclid Science Team and E. Consortium)

**(Euclid Consortium, old timer,
Mission Survey Scientist,
member of the EC Board and EST)**

Lots of figures and material courtesy of: EC&ESA (SciRD, CalWG, ECSURV, ESSWG, VIS, NISP, SWGs, OUs ...)

Red Book released in July 2011 (ESA web pages)



kosmobob@oa-roma.inaf.it

Giga structures-years-pc-samples

Giga €...

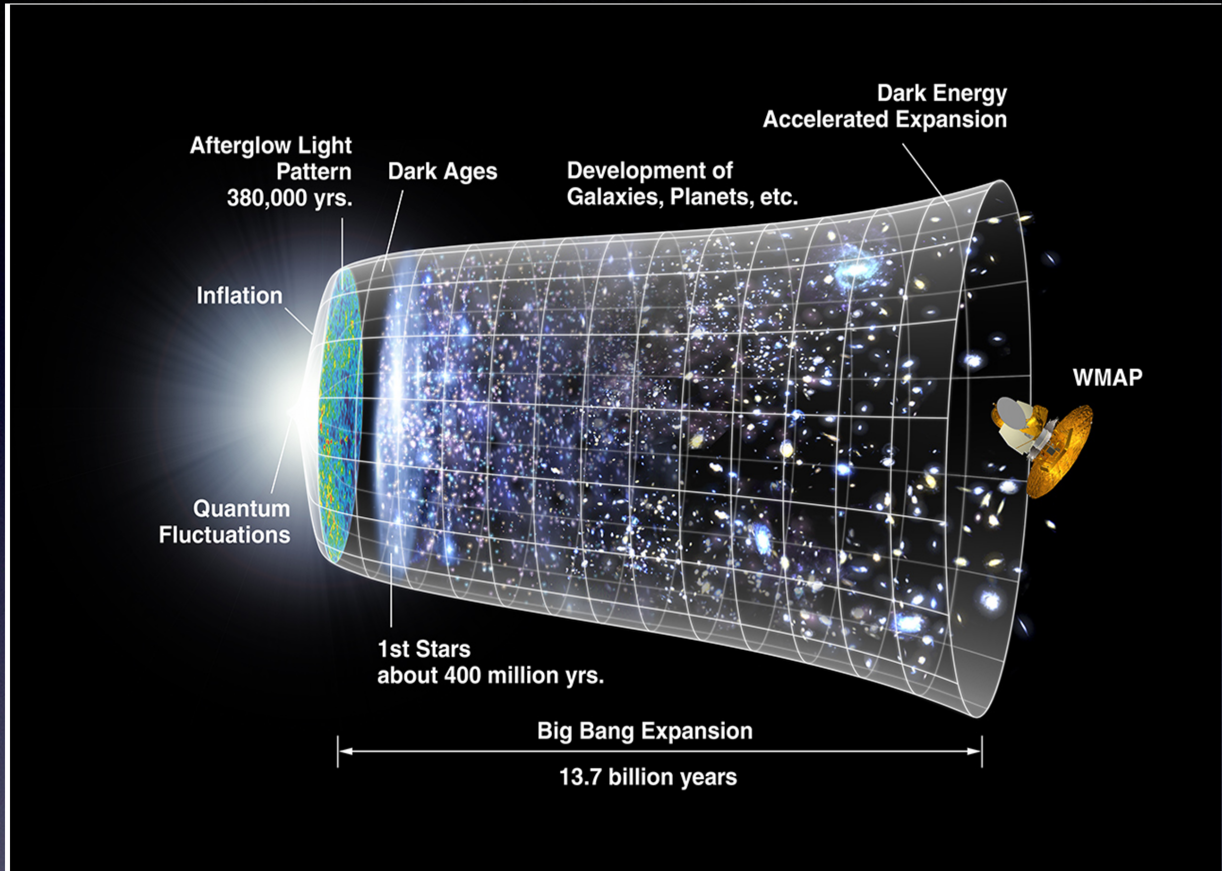
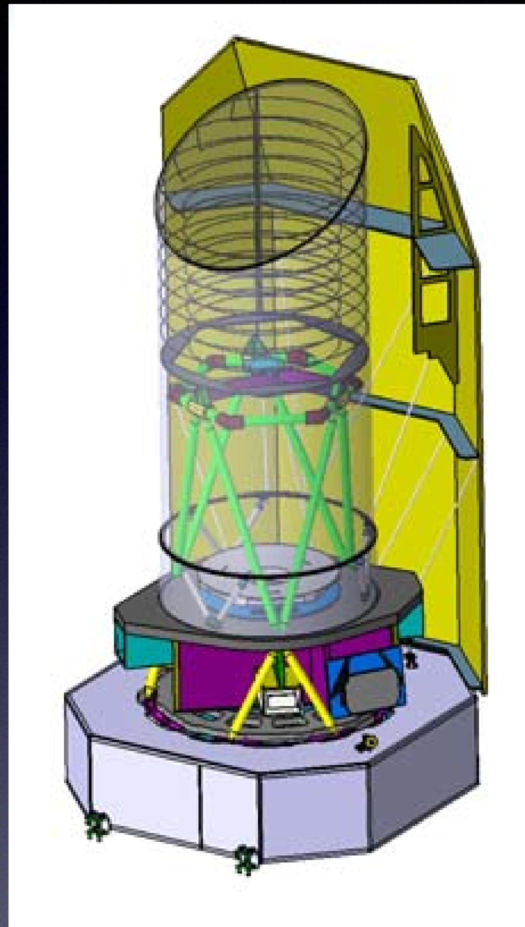


FIGURE 2-5 The cosmic timeline, from inflation to the first stars and galaxies to the current universe. The change in the vertical width represents the change in the rate of the expansion of the universe, from exponential expansion during the epoch of inflation followed by long period of a slowing expansion during which the galaxies and large scale structures formed through the force of gravity, to a recent acceleration of the expansion over the last roughly billion years due to the mysterious dark energy. Credit: NASA Wilkinson Microwave Anisotropy Probe Science Team.



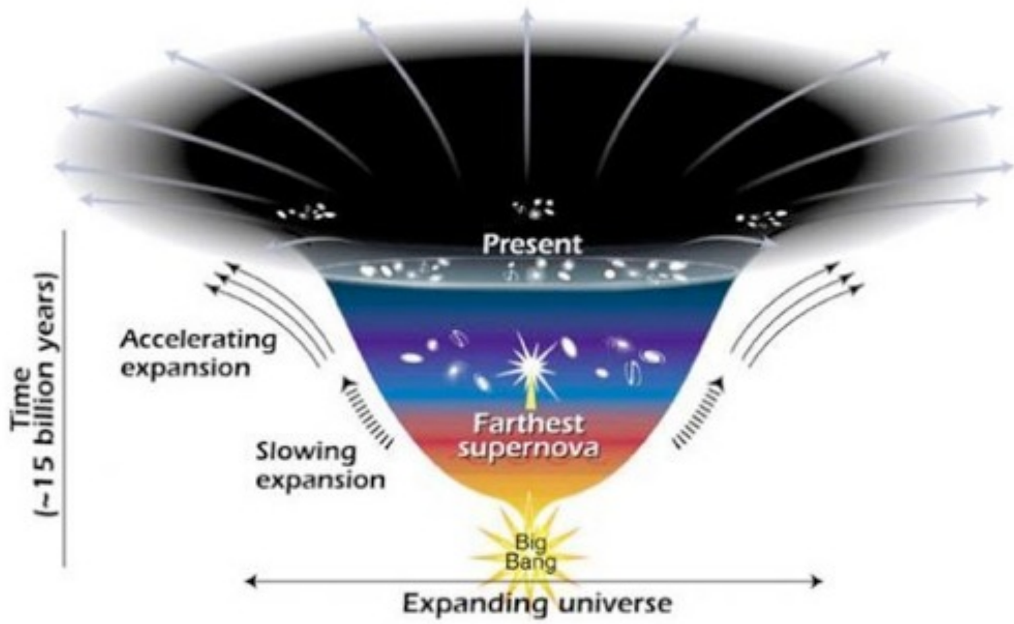
Observed with a **mini** structure: mirror ~1.2 m ∅

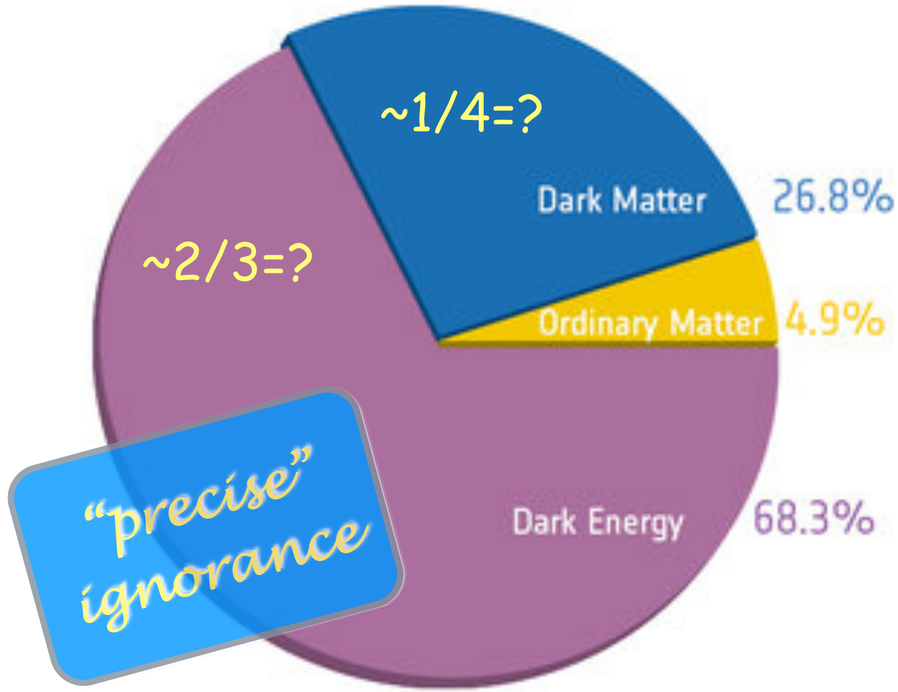
Open Questions in Cosmology

"precise" Cosmology

- Nature of the Dark Energy
- Nature of the Dark Matter
- Initial conditions (Inflation Physics)
- Modifications to Gravity
- Formation and Evolution of Galaxies

Large ignorance on ~95% of Universe content !!





New Worlds, New Horizons in Astronomy and Astrophysics (Decadal Survey 2010)

Ground Projects – Large – in Rank Order

Large Synoptic Survey Telescope (LSST)

LSST is a multipurpose observatory that will explore the nature of dark energy and the behavior of dark matter and will robustly explore aspects of the time-variable universe that will certainly lead to new discoveries. LSST addresses a large number of the science questions highlighted in this report. An 8.4-meter optical telescope to be sited in Chile, LSST will image the entire available sky every 3 nights.

TABLE ES.3 Ground: Recommended Activities—Large Scale (Priority Order)

Recommendation[b]	Science	Technical Risk[c]	Appraisal of Costs Through Construction[a] (U.S. Federal Share 2012-2021)	Appraisal of Annual Operations Costs[d] (U.S. Federal Share)	Page Reference
1. LSST - Science late 2010s - NSF/DOE	Dark energy, dark matter, time-variable phenomena, supernovas, Kuiper belt and near-Earth objects	Medium low	$465M ($421M)	$42M ($28M)	7-29

Space Projects – Large – in Rank Order

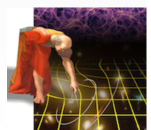
Wide Field Infrared Survey Telescope (WFIRST)

A 1.5-meter wide-field-of-view near-infrared-imaging and low-resolution-spectroscopy telescope, WFIRST will settle fundamental questions about the nature of dark energy, the discovery of which was one of the greatest achievements of U.S. telescopes in recent years. It will employ three distinct techniques—measurements of weak gravitational lensing, supernova distances, and baryon acoustic oscillations—to determine the effect of dark energy on the evolution of the universe. An equally

TABLE ES.5 Space: Recommended Activities—Large-Scale (Priority Order)

Recommendation	Launch Date[b]	Science	Technical Risk[c]	Appraisal of Costs[a]: Total (U.S. share)	Appraisal of Costs[a]: U.S. share 2012-2021	Page Reference
1. WFIRST - NASA/DOE collaboration	2020	Dark energy, exoplanets, and infrared survey-science	Medium low	$1.6B	$1.6B	7-17

DE as TOP priority both for Ground and Space also across the Atlantic



EUCLID

1. **Why**
2. **How**
3. **When**

1. **Dark Energy & Dark Matter (Cosmology) ; Legacy**
2. **Space imaging (morphology & NIR) + Spectra: Grav. Lensing & BAO**
3. ***2020-2025+***

Main Scientific Objectives

Understand the nature of Dark Energy and Dark Matter by:

- Reach a dark energy *FoM* > 400 using only weak lensing and galaxy clustering; this roughly corresponds to 1 sigma errors on w_p and w_a of 0.02 and 0.1, respectively.
- Measure γ, the exponent of the growth factor, with a 1 sigma precision of < 0.02, sufficient to distinguish General Relativity and a wide range of modified-gravity theories
- Test the Cold Dark Matter paradigm for hierachical structure formation, and measure the sum of the neutrino masses with a 1 sigma precision better than 0.03eV.
- Constrain n_s, the spectral index of primordial power spectrum, to percent accuracy when combined with Planck, and to probe inflation models by measuring the non-Gaussianity of initial conditions parameterised by f_{NL} to a 1 sigma precision of ~2.

SURVEYS

	Area (deg2)	Description
Wide Survey	15,000 (required) 20,000 (goal)	Step and stare with 4 dither pointings per step.
Deep Survey	40	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
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

SPACECRAFT

Launcher	Soyuz ST-2.1 B from Kourou
Orbit	Large Sun-Earth Lagrange point 2 (SEL2), free insertion orbit
Pointing	25 mas relative pointing error over one dither duration 30 arcsec absolute pointing error
Observation mode	Step and stare, 4 dither frames per field, VIS and NISP common FoV = 0.54 deg^2
Lifetime	7 years
Operations	4 hours per day contact, more than one groundstation to cope with seasonal visibility variations;
Communications	maximum science data rate of 850 Gbit/day downlink in K band (26GHz), steerable HGA

Budgets and Performance

	Mass (kg)		*Nominal Power (W)*	
industry	TAS	Astrium	TAS	Astrium
Payload Module	897	696	410	496
Service Module	786	835	647	692
Propellant	148	232		
Adapter mass/ Harness and PDCU losses power	70	90	65	108
Total (including margin)	**2160**		**1368**	**1690**

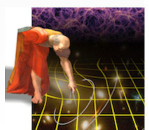
All data you need to know (Red Book)

- **Wide Area** (>10^4 sq deg)
- **Wide Field** (FoV > 0.5 sq deg)
- **Opt. imaging**
- **NIR photom**
- **NIR slitless**

Two instruments:

VIS: optical imager &

NISP: NIR imager + grisms



Recall a few basics

$$H^2(a) \equiv \left(\frac{\dot{a}}{a}\right)^2 = H_0^2\left[\Omega_m a^{-3} + \Omega_r a^{-4} + \Omega_k a^{-2} + \Omega_X a^{-3(1+w)}\right]$$

Evolution governed by components: H(z)⇔Ω_X,w

$$H^2(a) = H_0^2\left[\Omega_R a^{-4} + \Omega_M a^{-3} + \Omega_k a^{-2} + \Omega_{DE} \exp\left\{3\int_a^1 \frac{da'}{a'}[1+w(a')]\right\}\right]$$

Ellipses: uncertainty in parameters via Fisher matrix. An useful *approximation* (curse of dimensionality; also different definitions). Importance of ***Priors***

Usually use Figure of Merit= 1/Area

FoM= 1/(Δw_0 x Δw_a)

a=$(1+z)^{-1}$ expansion factor

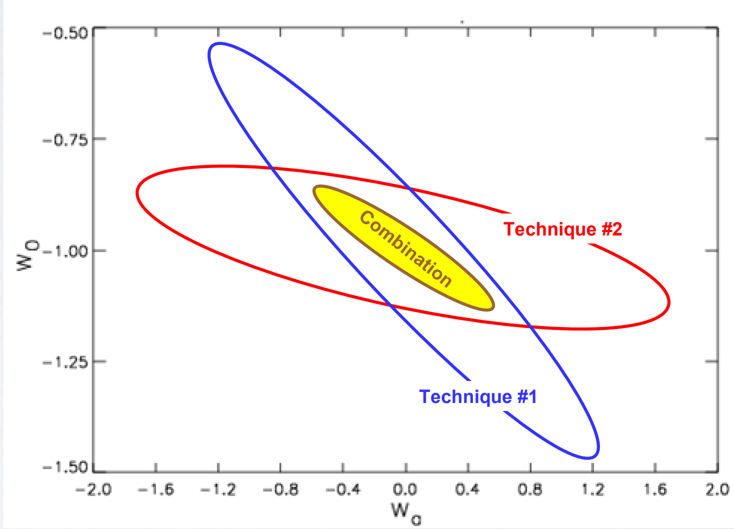
δ = density fluctuation

P(k) = power spectrum of δ(**x**,z)

w = p/ϱ, γ=growth index

w(z)=w_0 +w_a (1-a) $f_{\rm GR}(z) \equiv \frac{d\ln G_{\rm GR}}{d\ln a} \approx [\Omega_m(z)]^\gamma$

Λ: w_0= -1 , w_a =0 , γ~0.55



to get a small uncertainty on power spectrum need:

$$\frac{\sigma}{P} = \sqrt{\frac{2}{n_{\rm modes}}}\left(1 + \frac{1}{P\bar{n}}\right)$$

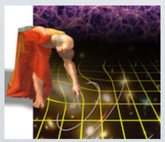
accurate/adequate sampling in number of objects

large volumes to accomodate several Fourier modes

Cosmic Variance ⇔ Volume

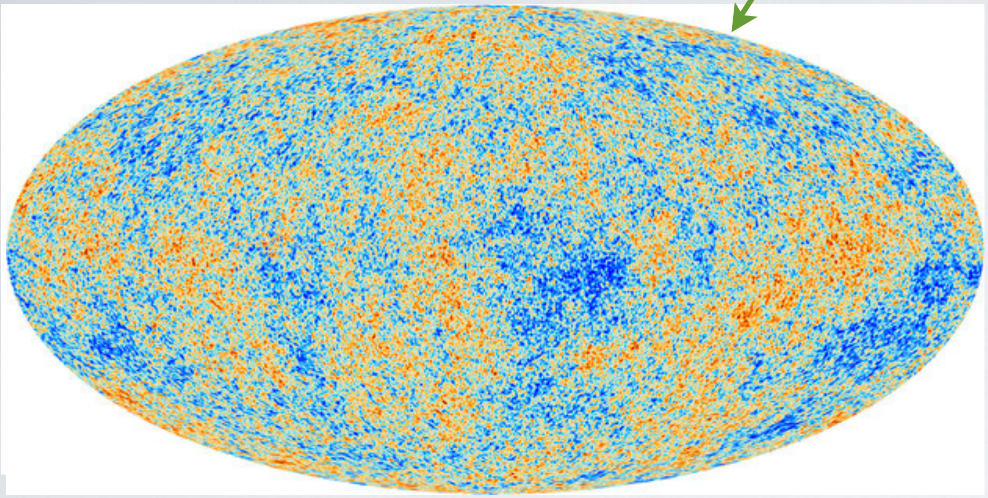
Poisson ⇔ Number

[un]known systematics

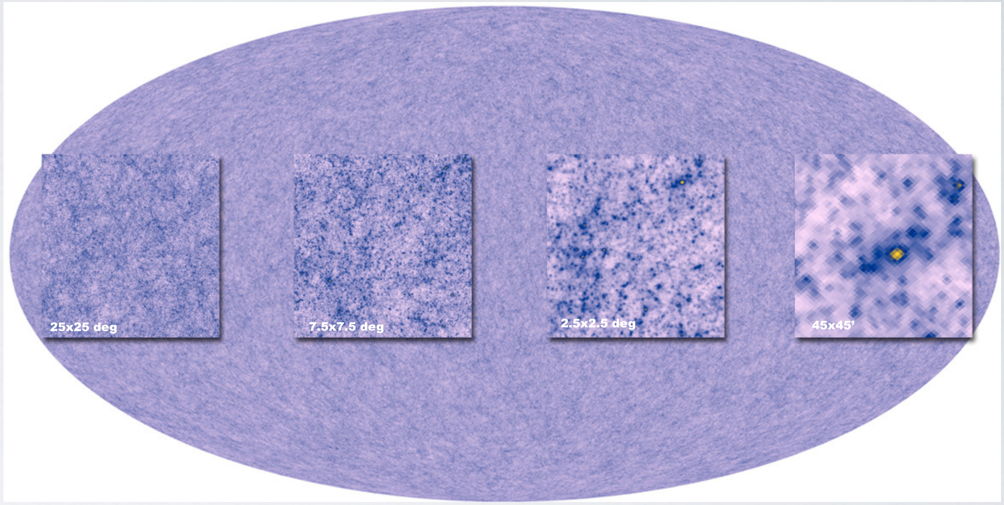


euclid

Synergy with Planck: Universe @z~1000 vs @z~1-3



R. Teyssier et al.: Full-sky weak-lensing simulation with 70 billion particles



WL sims: <1" pixels

Most of the DE effects happen at z < 3

Need also dynamics to further disentagle

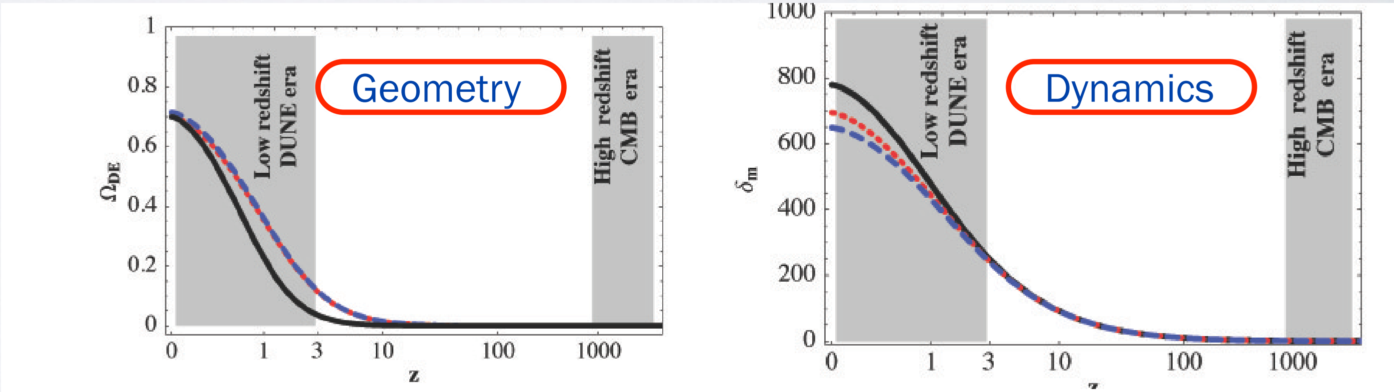
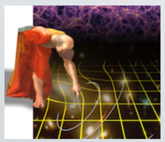


Figure C.1: *Effect of dark energy on the evolution of the Universe.* ***Left:*** *Fraction of the density of the Universe in the form of dark energy as a function of redshift z., for a model with a cosmological constant (w=-1, black solid line), dark energy with a different equation of state (w=-0.7, red dotted line), and a modified gravity model (blue dashed line). In all cases, dark energy becomes dominant in the low redshift Universe era probed by DUNE, while the early Universe is probed by the CMB.* ***Right:*** *Growth factor of cosmic structures for the same three models. Only by measuring the geometry (left panel) and the growth of structure (right panel) at low redshifts can a modification of dark energy be distinguished from that of gravity. Weak lensing measures both effects.*



Want, NEED! several probes for synergies and Xchecks

Observational Input	Probe	Description
Weak Lensing Survey	Weak Lensing (WL)	Measure the expansion history and the growth factor of structure
Galaxy Redshift Survey: Analysis of *P(k)*	Baryonic Acoustic Oscillations (BAO)	Measure the expansion history through D_A(z) and H(z) using the "wiggles-only".
	Redshift-Space distortions	Determine the growth *rate* of cosmic structures from the redshift distortions due to peculiar motions
	Galaxy Clustering	Measures the expansion history and the growth factor using all available information in the amplitude and shape of P(k)
Weak Lensing plus Galaxy redshift survey combined with cluster mass surveys	Number density of clusters	Measures a combination of growth factor (from number of clusters) and expansion history (from volume evolution).
Weak lensing survey plus galaxy redshift survey combined with CMB surveys	Integrated Sachs Wolfe effect	Measures the expansion history and the growth

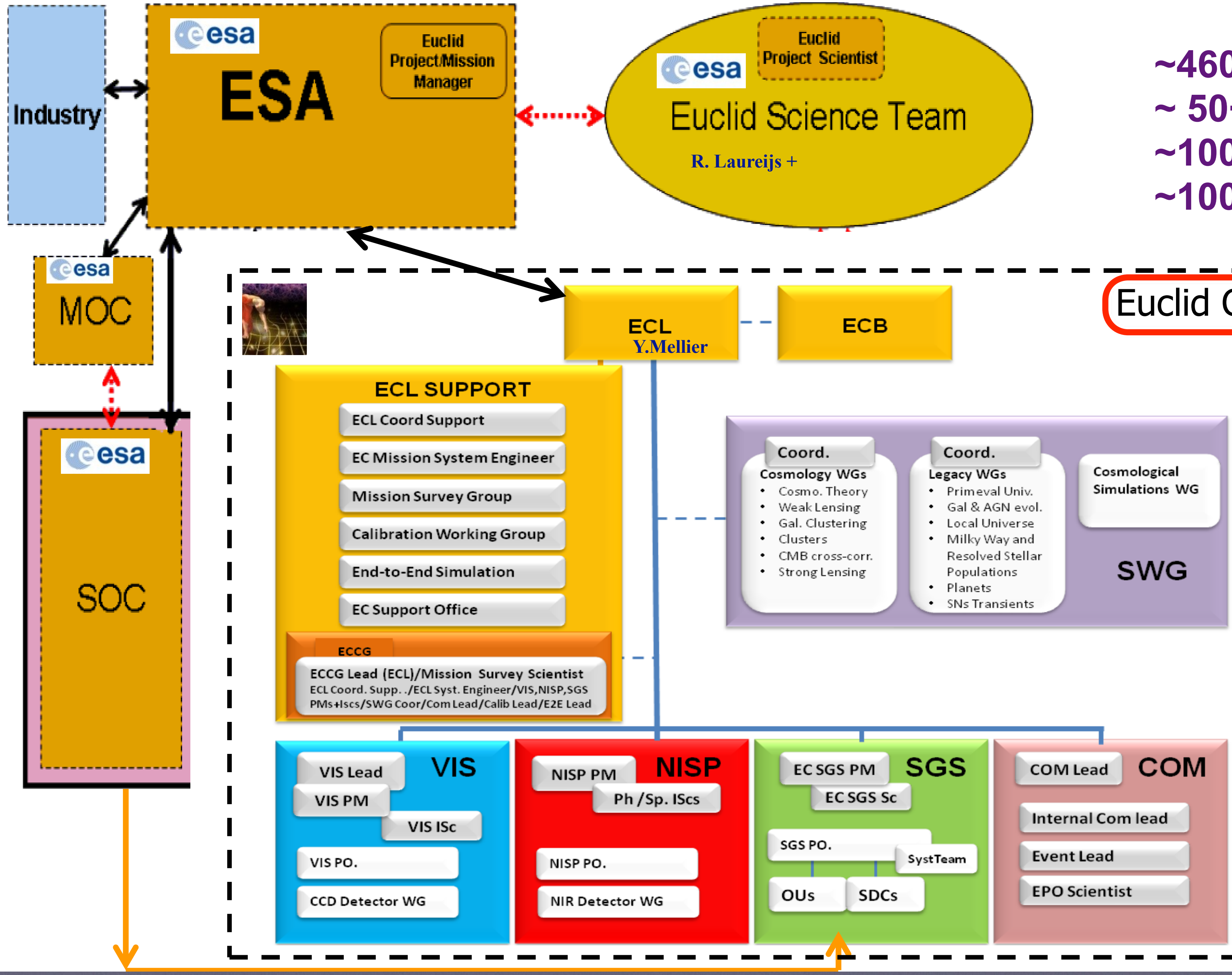
Want to measure expansion factor H(z) - *geometry* -
and growth of density perturbations - *dynamics* -

Legacy

Wide survey: >15,000 sq. deg (visible: 24.5th ABmag 10σ extended; NIR: 24th ABmag 5σ; spectra: Hα line flux > 4×10^{-16} erg s^{-1} cm^{-2}, rate ~35%)

Deep Survey: ~40 sq. deg ~ 2 mags deeper (~40 visits)

~460+ M€ (ESA)
~ 50+ M$ (NASA)
~100 M€ EC instr
~100 M€ EC Gnd Seg



- 1100 members,

- 120 Labs

- 13 European countries:

Austria, Denmark, France,

Finland,, Germany, Italy,

The Netherlands, Norway,

Portugal, Romania,

Spain, Switzerland, UK

+ US/NASA and

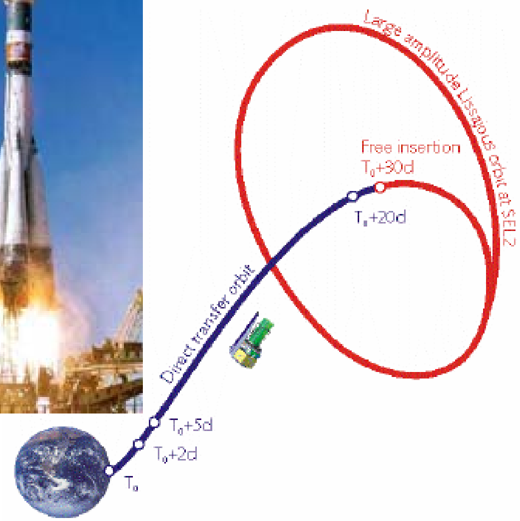
Berkeley labs.

Large participation of Italian community with several key roles and contributions

EUCLID Mission

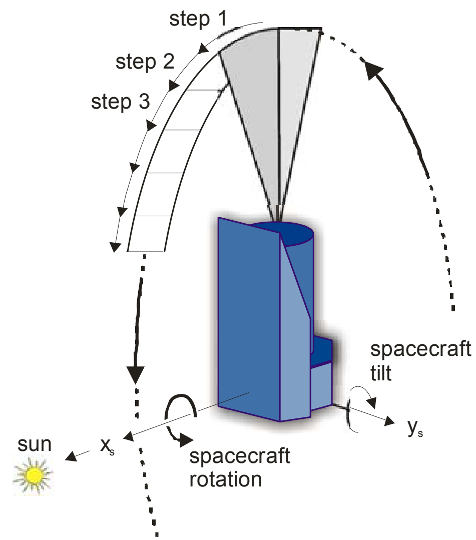
in part OLD

- Launcher: Soyuz ST2-1B from Kourou
- Direct injection into tranfer orbit
  - Transfer time: 30 days
  - Transfer orbit inclination: 5.3 deg
- Launch vehicle capacity:
  - 2160 kg (incl. adapter)
  - 3.86 m diameter fairing
- Launch ≈ 2020
- Mission duration: 6 years



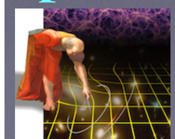
Advanced Studies and Technology Preparation Division

Looks like CMB satellites but with <u>step & stare</u>

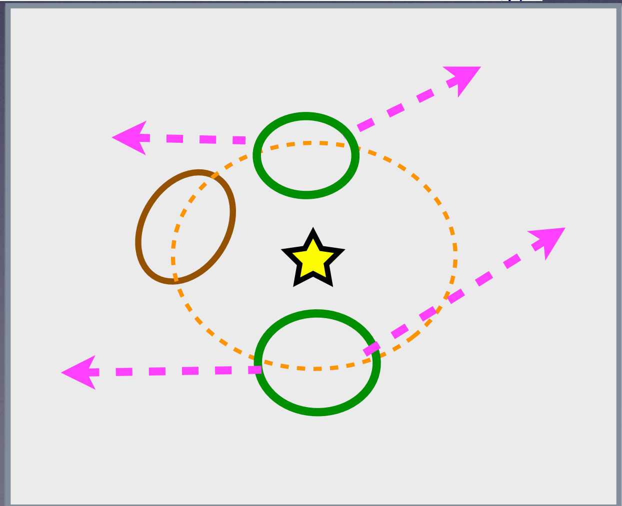


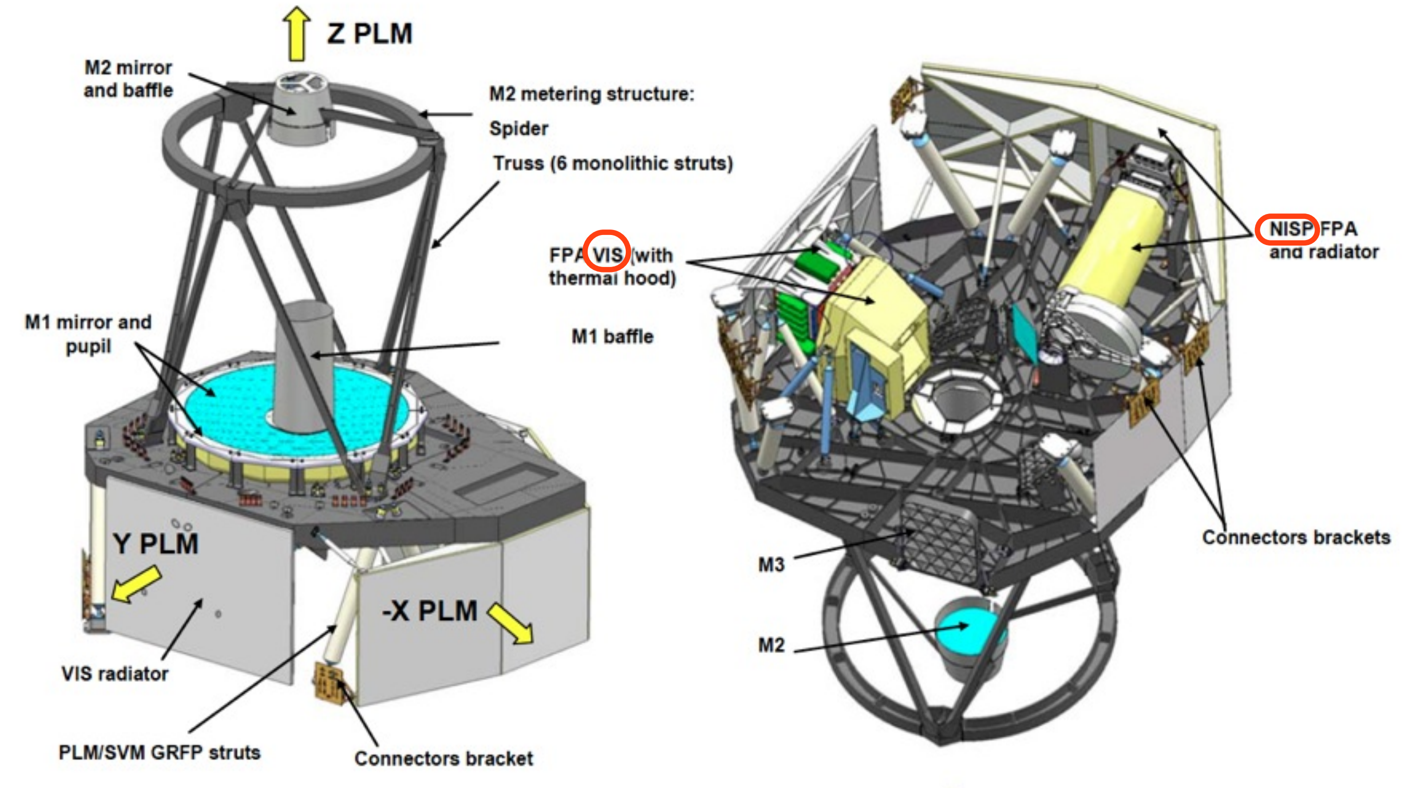
For stability need to always observe orthogonally to the sun

region visibility: twice/yr at ecliptic plane (1deg/day), max at ecliptic poles (always).



spin 2 behaviour





Two instruments:

VIS: optical imager

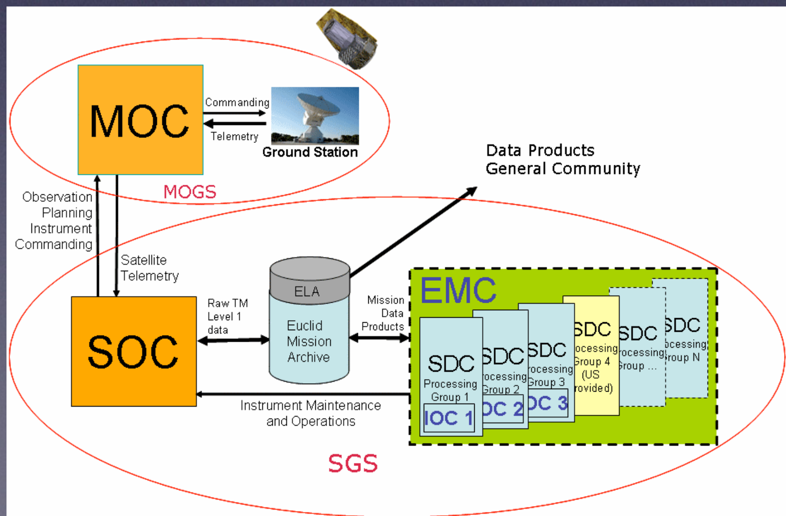
NISP: NIR imager + grisms

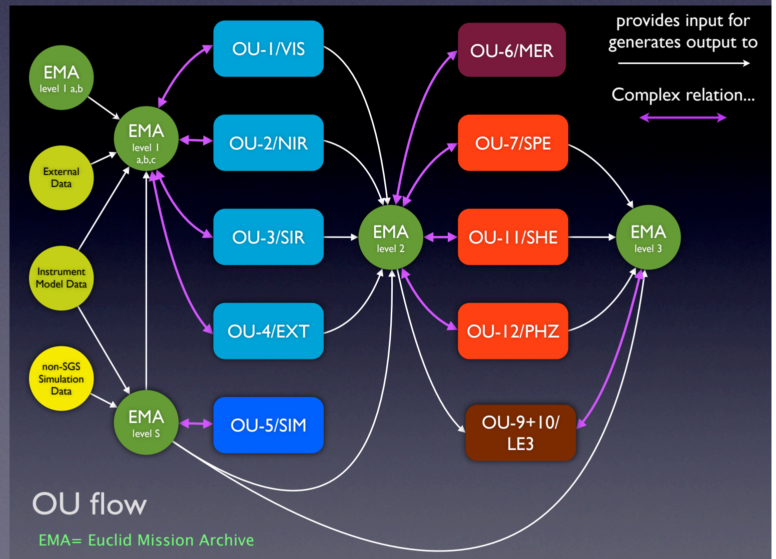
Rome : [IAPS]VIS A. De Giorgio;
[OAR]OU-NIR: A Grazian & OU-MER: A. Fontana

Ground Segment

A few Petabytes...

instruments costs
≈ GS costs





movie made and provided by AIRBUS DS (Ex-Astrium)

The core: ~0.5 sq/degs, VIS & NIR Focal Planes, lots of pixels !!!

The geometrical Field of View is the sky area limited by the contour of the focal plane array of a given instrument (VIS or NISP) projected onto the sky. The contour is defined by the first pixel line or columns of the detectors on the edge of the FPA as indicated on the next figure.

36 (0.1" pix)

16 (0.3" pix)

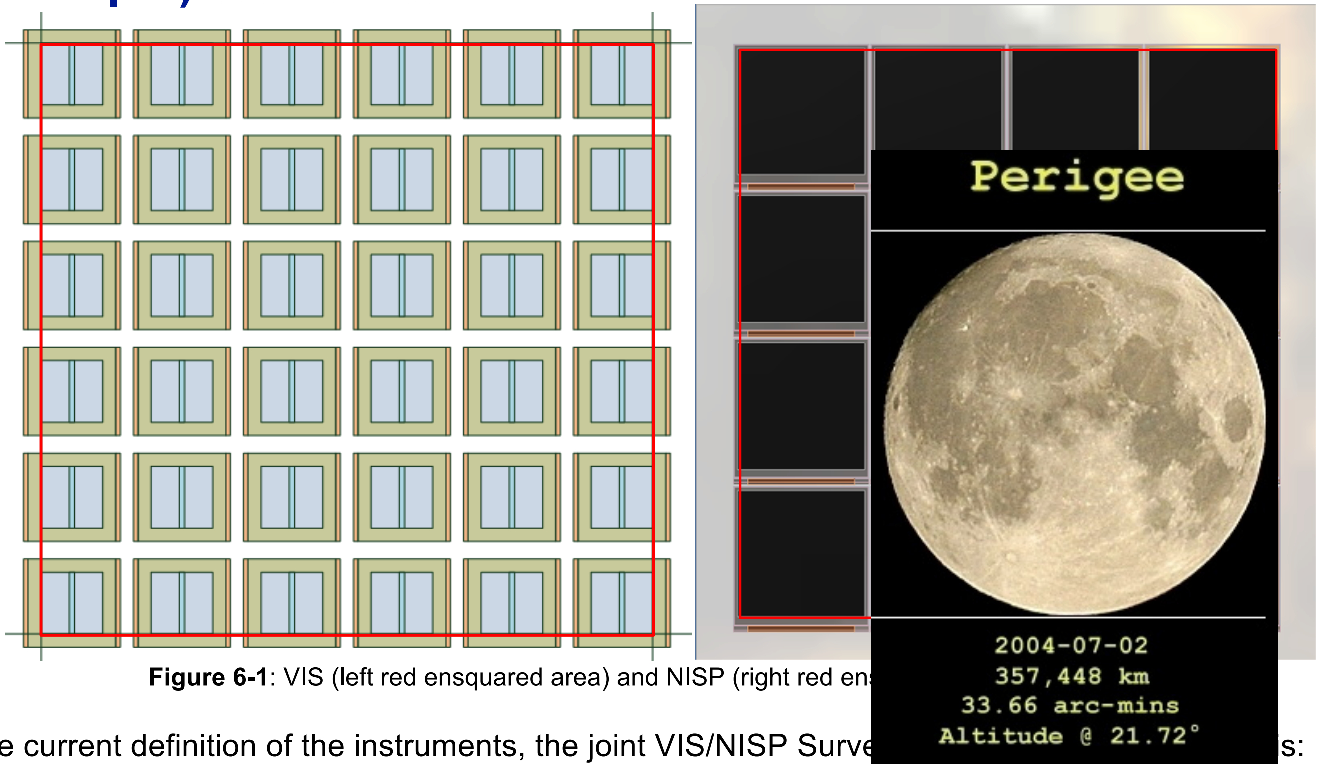


Figure 6-1: VIS (left red ensquared area) and NISP (right red ens

VIS: imaging

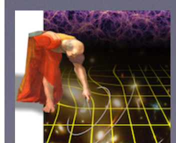
NISP: y, J, H photom + slitless

With the current definition of the instruments, the joint VIS/NISP Surve is:

- JOINT_FOV_x= 0.763°
- JOINT_FOV_y= 0.709°

~44' side

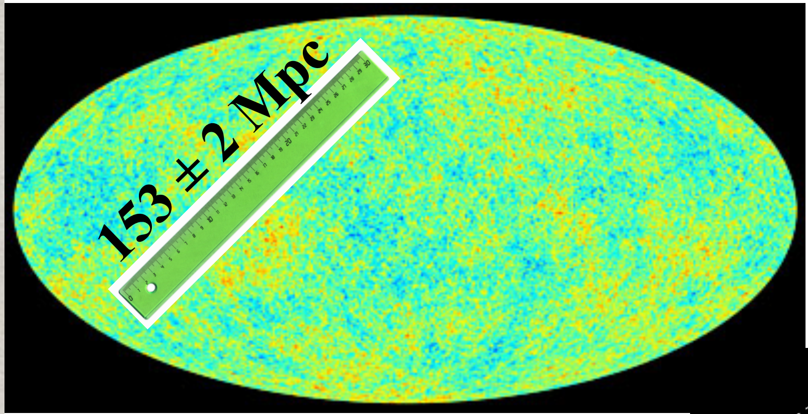
The x and y field orientations are defined in the figure 6-2.

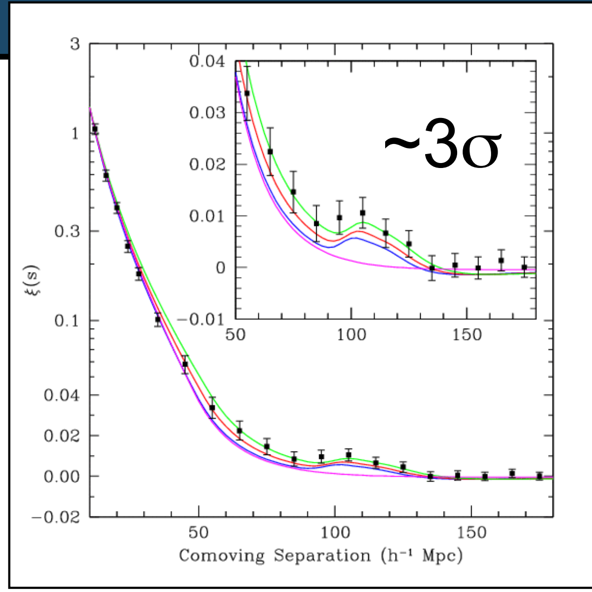


cf Planck: here ~ O(billion) of pixels for one field, plan ~ 30,000 fields

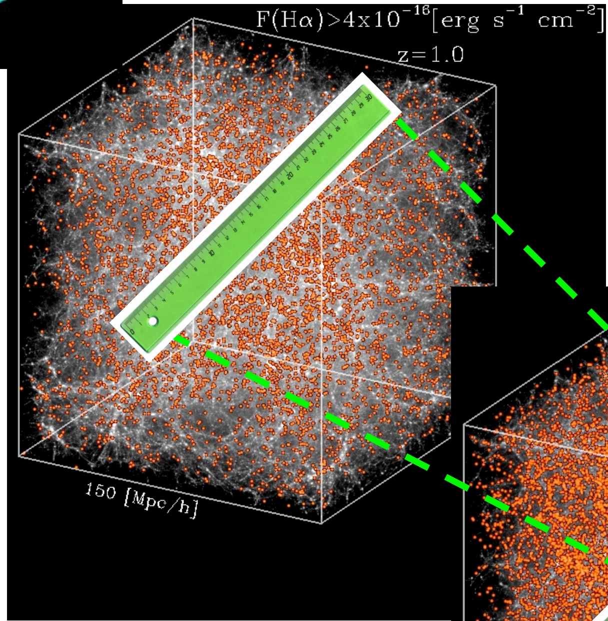
euclid

BAO as standard ruler

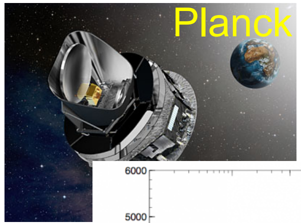


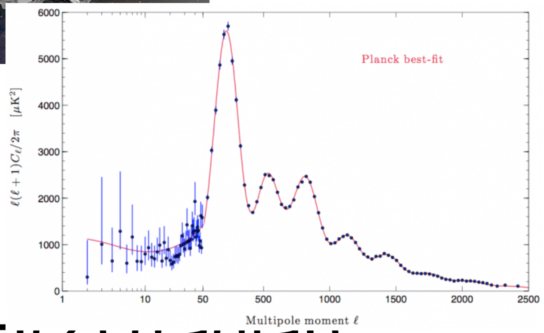


Galaxies (z>1)

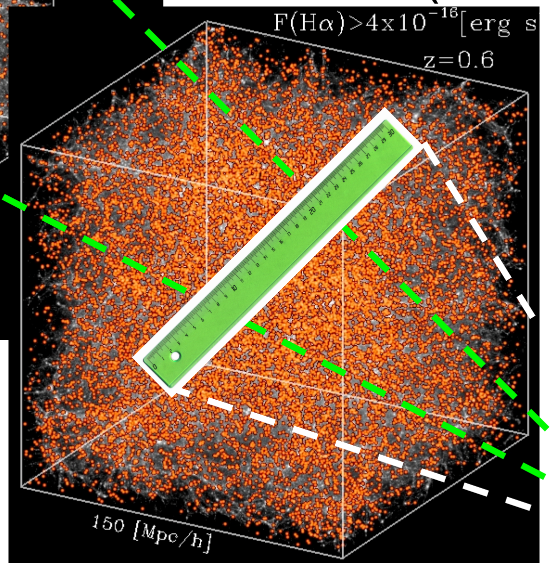


CMB (z≈1000)

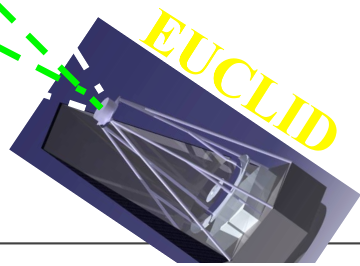




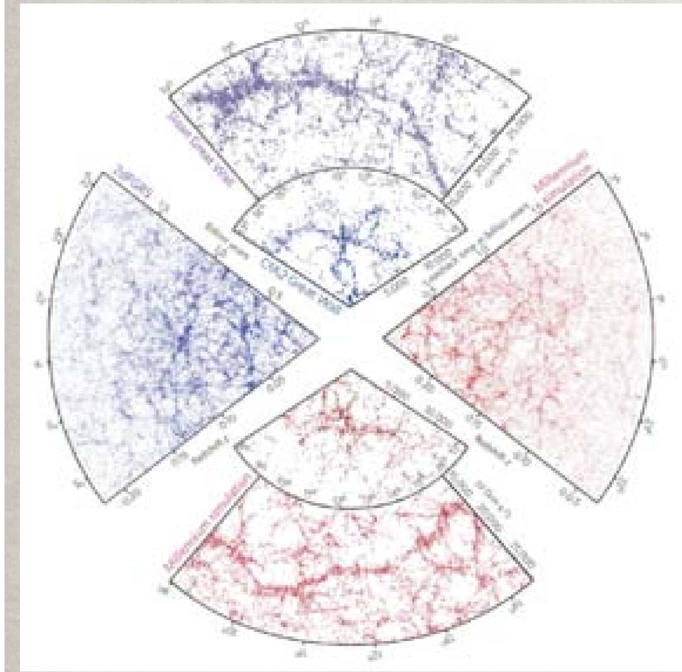
Galaxies (z≈0.35)



- H(z) (radial)
- $D_A(z)$ (tangential)
- H(z) & $D_A(z)$ depend on w(z)



Expansion and Growth Histories through Galaxy Clustering



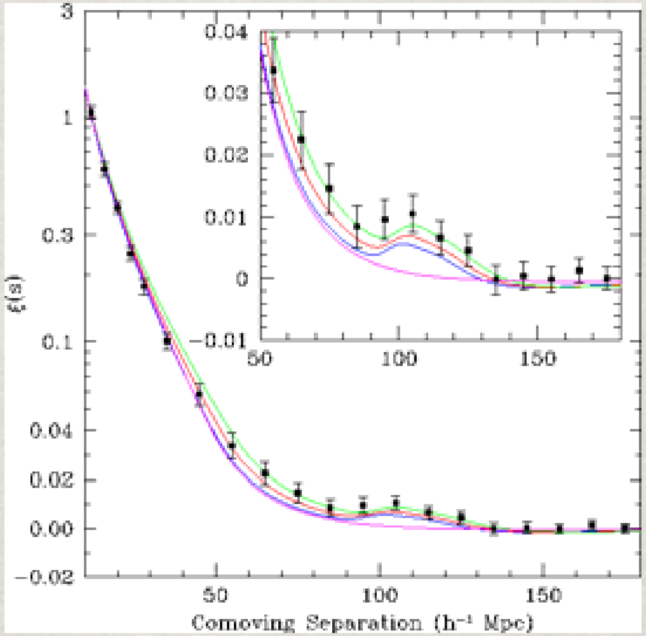
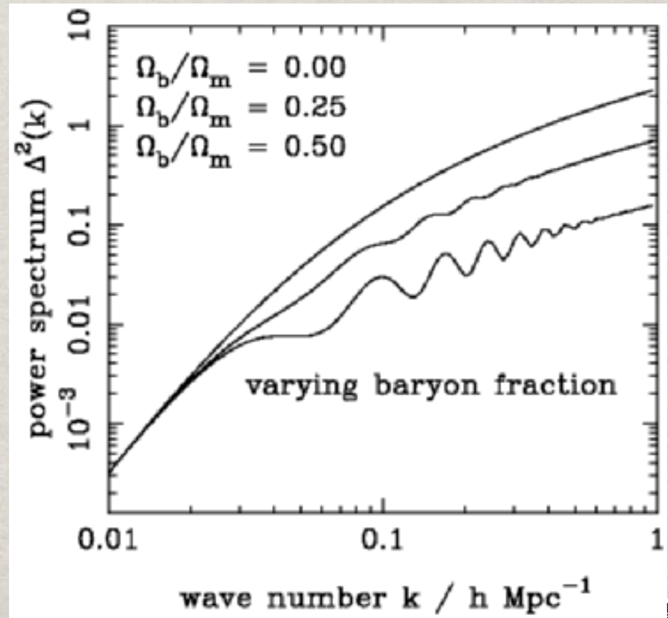


Figure 2.10: a. (Left panel) The galaxy distribution in the largest surveys of the local Universe, compared to simulated distributions from the Millennium Run (Springel et al. 2005); b. (Right panel) The two-point correlation function of SDSS "luminous red galaxies", in which the BAO peak at ~105 h^{-1} Mpc has been clearly detected (Eisenstein et al. 2005).



Clustering reveals features in the power spectrum of density perturbations

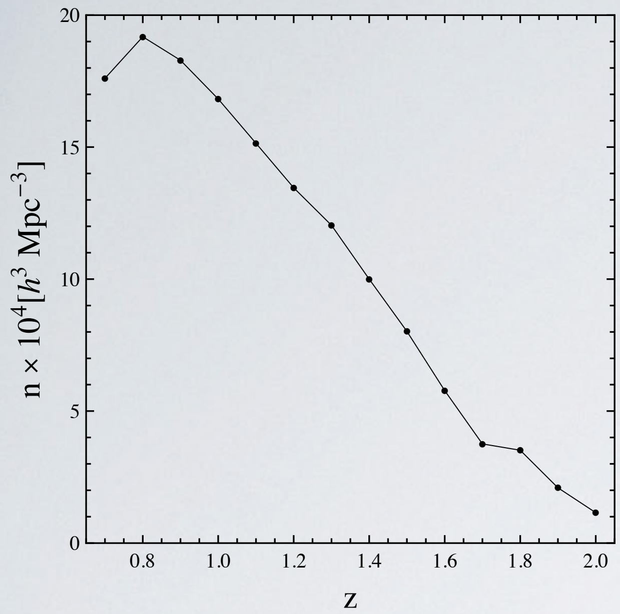
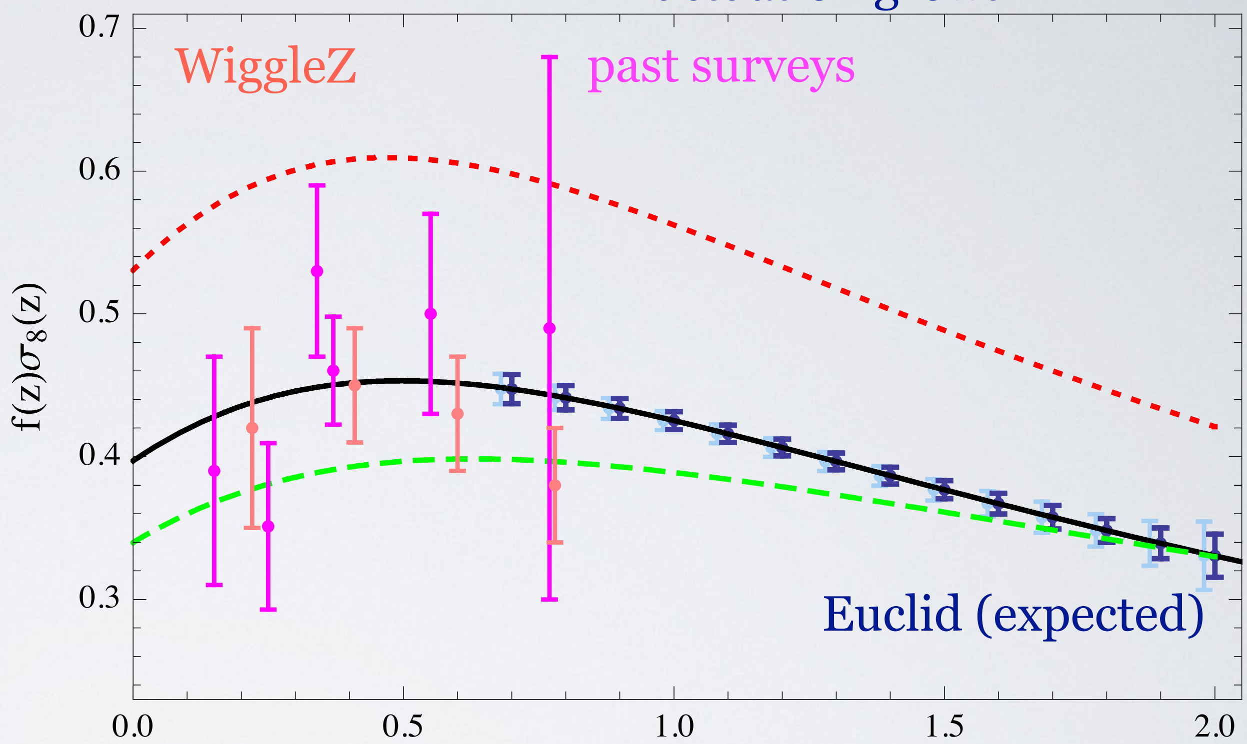
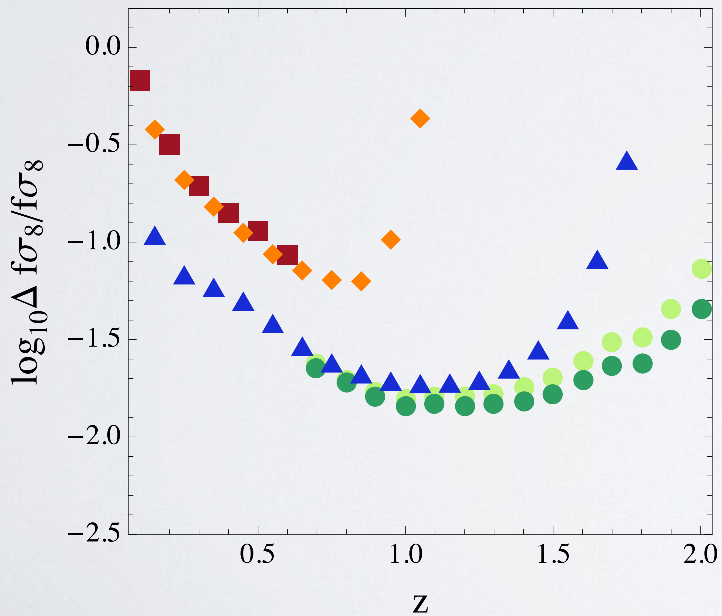


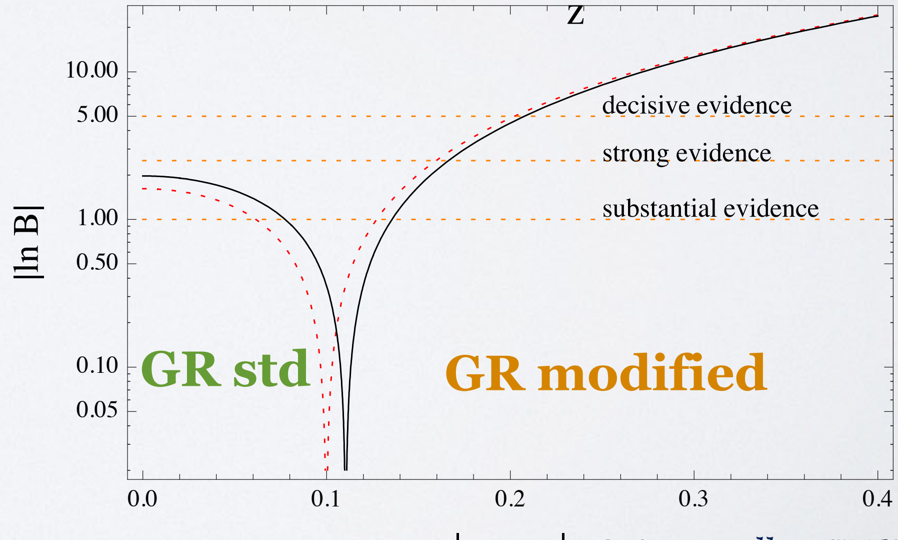
Figure 1. Predicted mean number density of galaxies in each redshift bin centred in z, expected from the baseline Euclid wide spectroscopic survey, given the instrumental and survey configurations and the estimated efficiency.

Elisabetta Majerotto et al. 2012

fluctuation growth







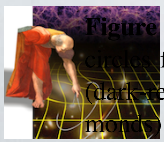
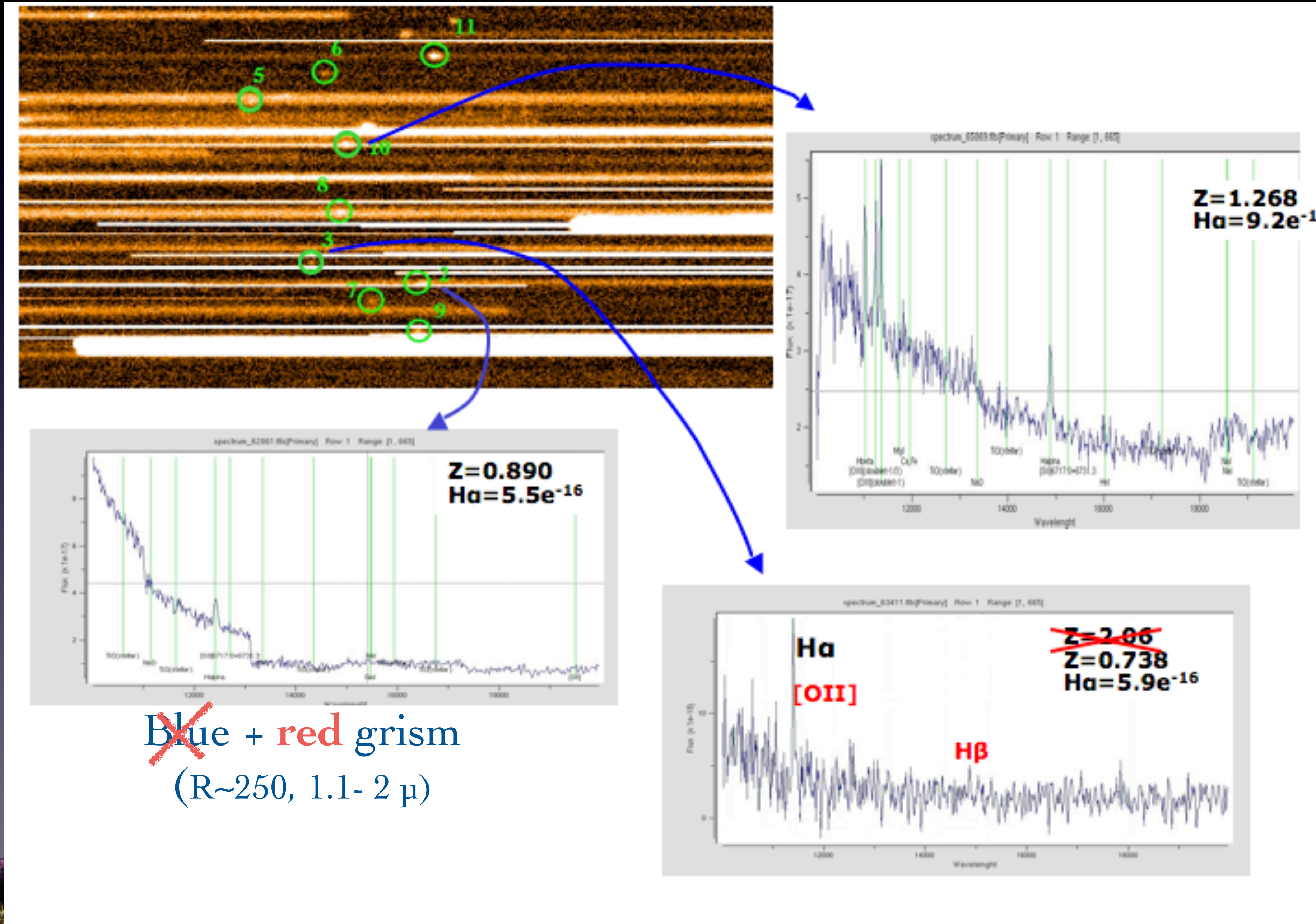
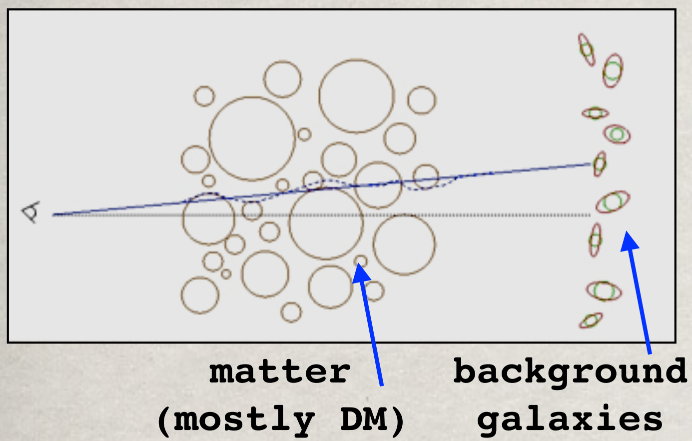


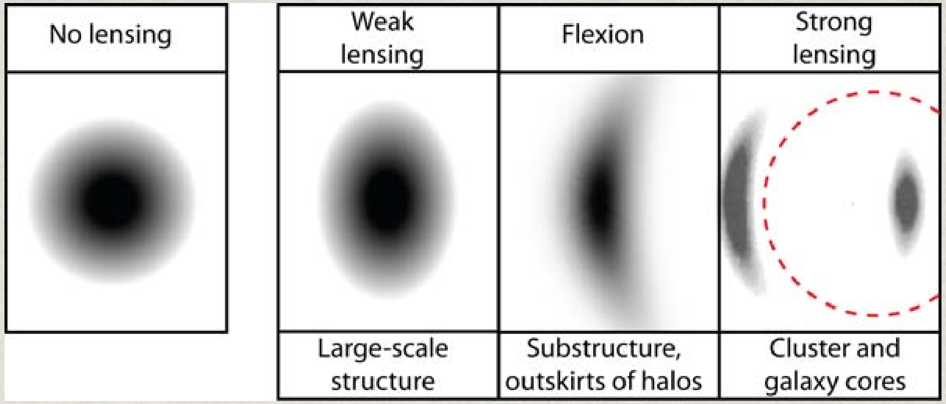
Figure 3. Relative error on $f\,\sigma_8$ of Euclid (dark-green circles, light-green circles for the pessimistic case of half the galaxy number density), BOSS (dark-red squares), BigBOSS ELGs (blue triangles) and LRGs (orange diamonds).

For clustering need spectroscopic redshifts (slitless is not easy)



Expansion and Growth Histories through Gravitational Lensing





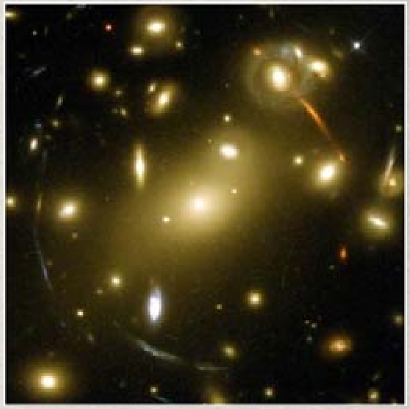


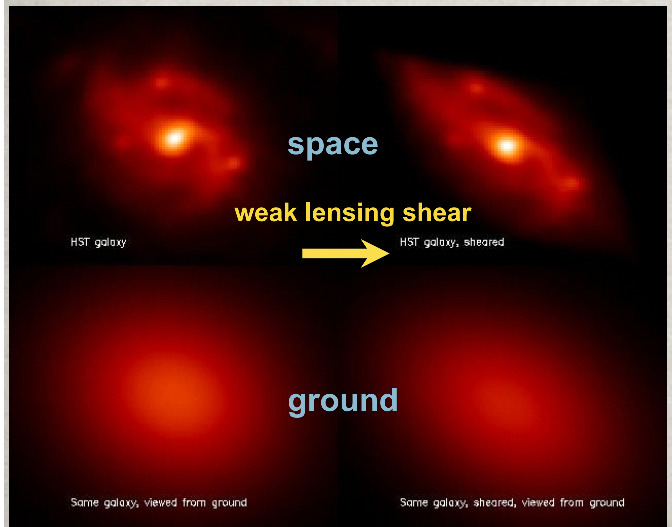
Figure 2.8: a. (Left) Illustrations of the effect of a lensing mass on a circularly symmetric image. Weak lensing elliptically distorts the image, flexion provides an arc-ness and strong lensing creates large arcs

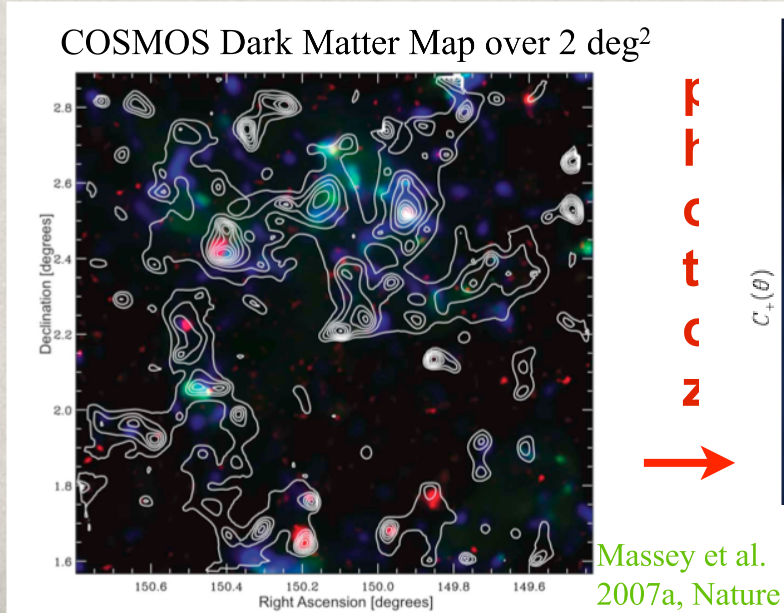
$$\kappa = \frac{3H_0^2\Omega_m}{2c^2}\int_0^{\chi_s} d\chi \frac{D(\chi)D(\chi_s-\chi)}{\chi_s}(1+z)\delta(\chi),$$

observable

distances

density perturbation





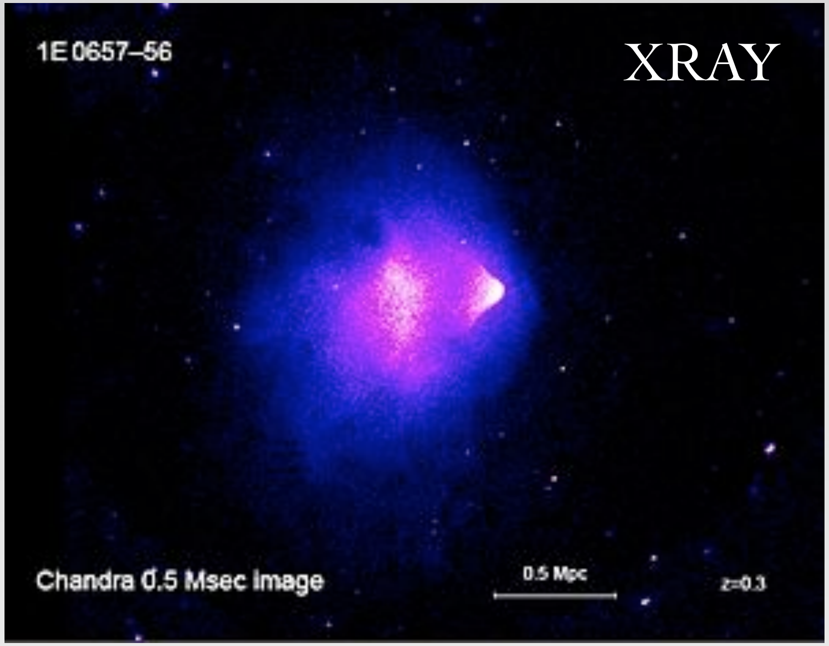
Massey et al. 2007a, Nature

photoz →

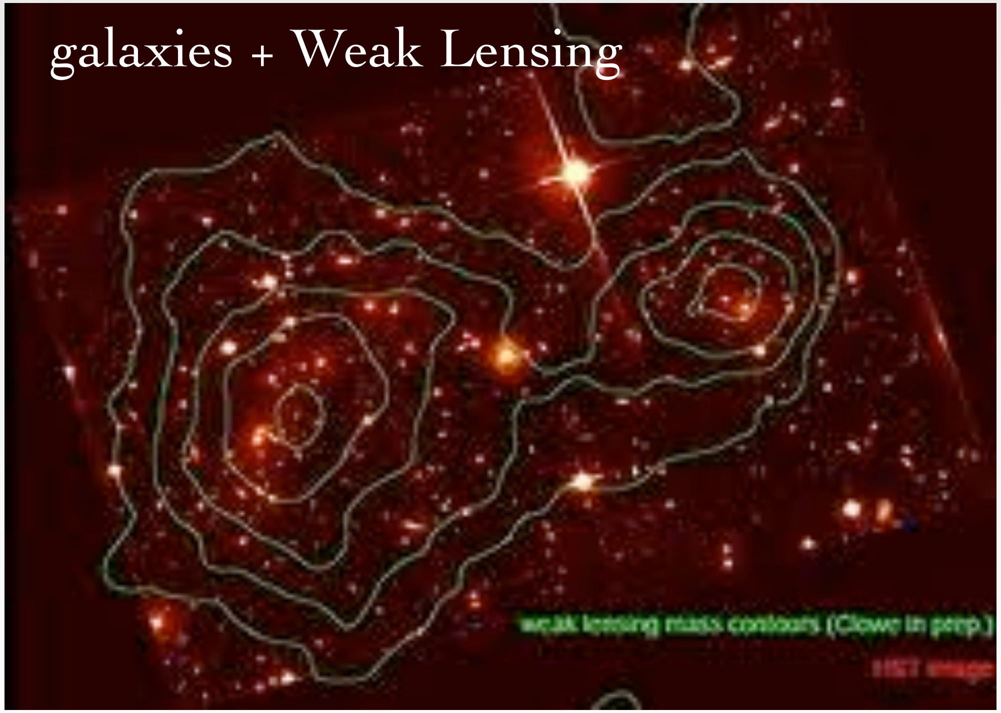
A370 ACS

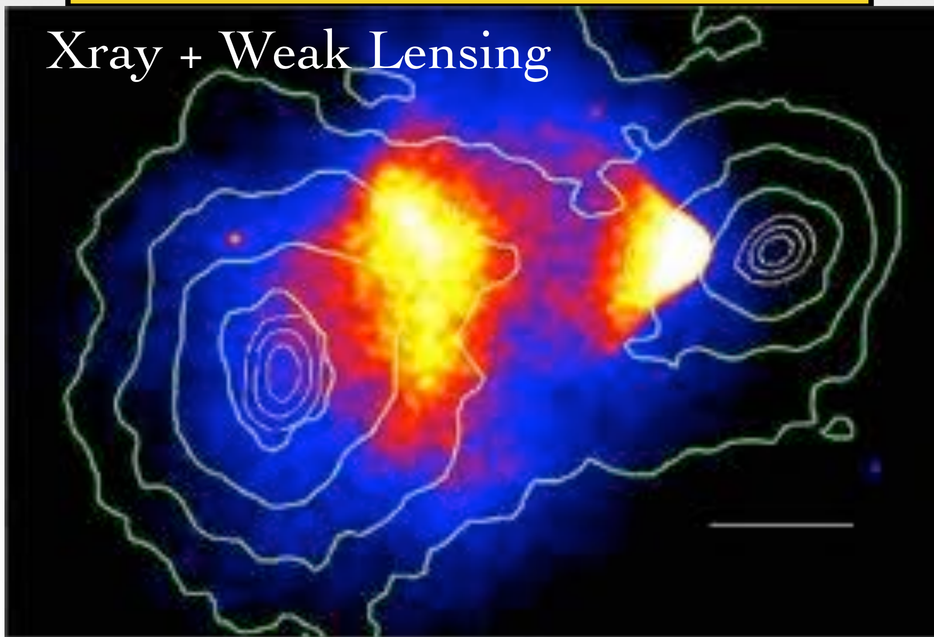
w.r.t. HST will loose a factor of ~2 in resolution, but get all xgal sky!

Bullet Cluster: Dark Matter!



Dominant component not hot gas nor modified gravity





Coe et al.

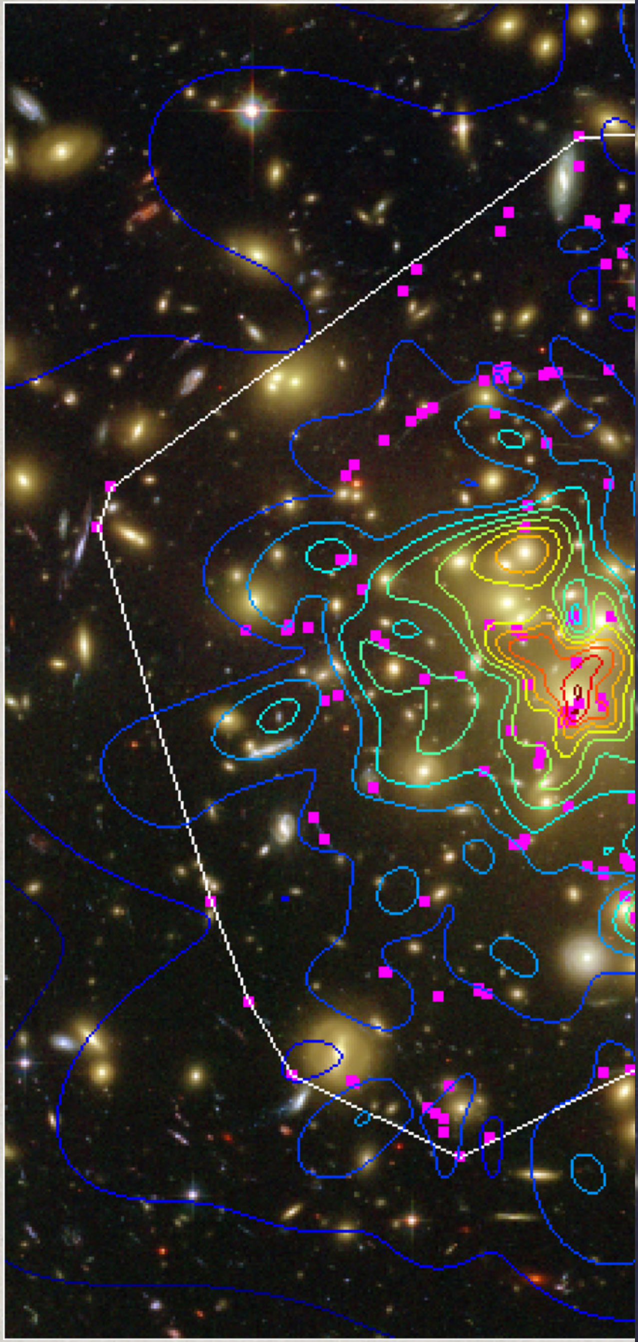
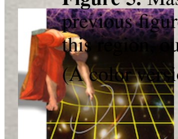


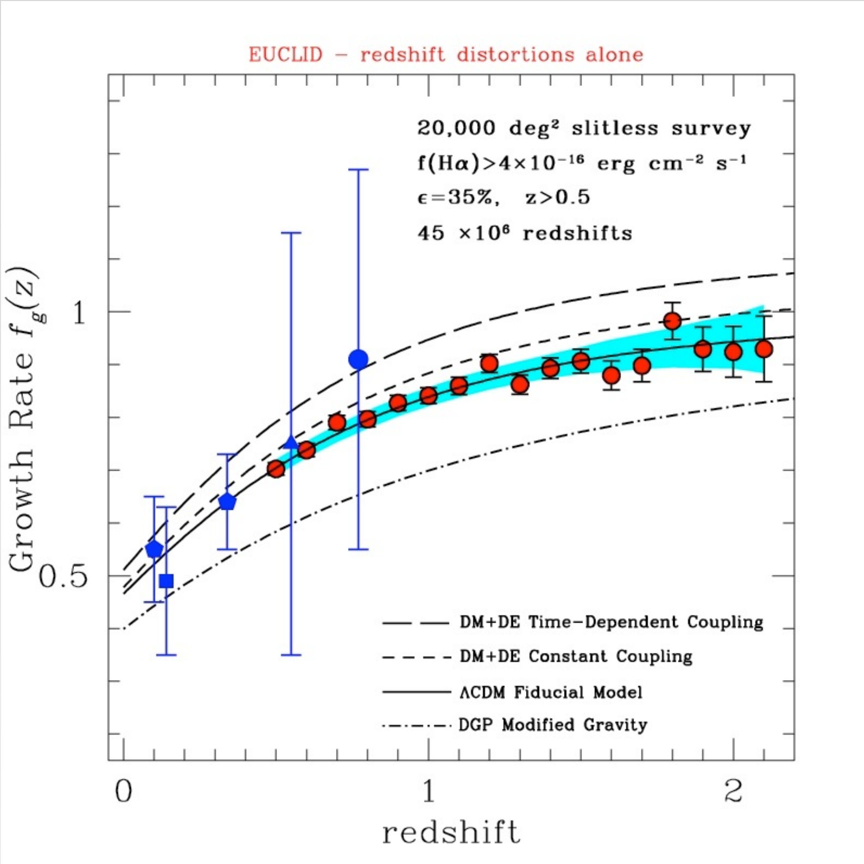
Figure 5. Mass map contours in units of $\kappa_\infty = 1/3$ laid over the 3'.2 × 3'.3 STS
previous figure. Pink squares indicate the 135 multiple image positions all perfectly reproduced by our model, and the white line indicates the convex hull. Outside this region our solution should be disregarded. This solution is not unique but was the "most physical" we found.
(A color version of this figure is available in the online journal.)



Details **on Dark Matter clustering!**

R. Scaramella LNF-OAR Frascati

euclid



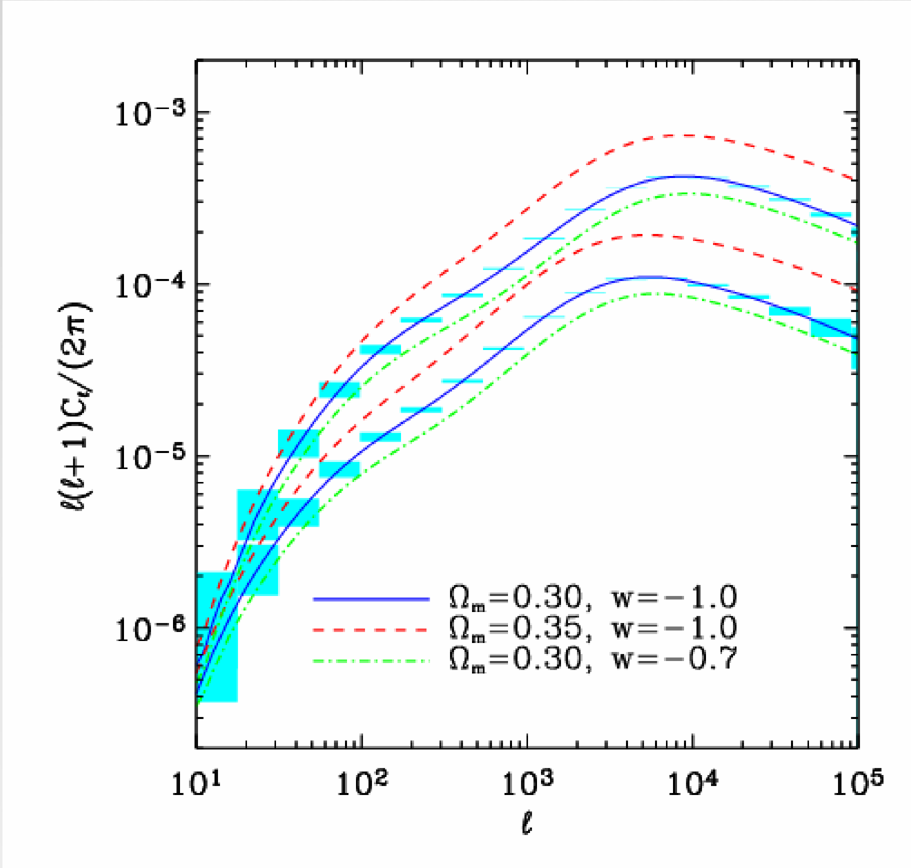


Figure 2.14: a. (left) The growth rate of matter perturbations as a function of redshift. Data points and errors are from a simulation of the spectroscopic redshift survey. The assumed ΛCDM model, coupled dark matter/dark energy modes and DGP are also shown. b. (right): The predicted cosmic shear angular power spectrum at z=0.5 and z=1 for a number of cosmological models

Can discriminate cosmology

[Dark Energy, Dark matter, non std GR]

Does gravity follow standard G.R.? Need experiments with high sensitivity/precision....

(cf. L. Amendola, M. Kuntz, et al Theory SWG, Living reviews)

Weak limit

The most general (linear, scalar) metric at first-order

$$ds^2 = a^2[(1+2\Psi)dt^2 - (1+2\Phi)(dx^2+dy^2+dz^2)]$$

At the linear perturbation level and sub-horizon scales

Full metric reconstruction at first order requires 3 functions

$H(z) \quad \Phi(k,z) \quad \Psi(k,z)$

- modified Poisson's equation $\quad k^2\Psi = -4\pi G a^2 Q(k,a)\rho_m \delta_m$
- non-zero anisotropic stress $\quad \eta(k,a) = \dfrac{\Phi+\Psi}{\Psi}$

std matter

$$G_{\mu\nu} = -8\pi G T_{\mu\nu} - Y_{\mu\nu}$$

Std gravity, new matter

$$Y_{\mu\nu} = X_{\mu\nu} - G_{\mu\nu}$$

New gravity, std matter

$$X_{\mu\nu} = -8\pi G T_{\mu\nu}$$

$$T^{\nu}_{\mu\,;\nu} = 0.$$

Modified Gravity at linear level

▪ standard gravity	$Q(k,a)=1$ $\eta(k,a)=0$	
▪ scalar-tensor models	$Q(a)=\dfrac{G^*}{FG_{cav,0}}\dfrac{2(F+F'^2)}{2F+3F'^2}$ $\eta(a)=\dfrac{F'^2}{F+F'^2}$	Boisseau et al. 2000 Acquaviva et al. 2004 Schimd et al. 2004 L.A., Kunz &Sapone 2007
▪ f(R)	$Q(a)=\dfrac{G^*}{FG_{cav,0}}\dfrac{1+4m\frac{k^2}{a^2R}}{1+3m\frac{k^2}{a^2R}}, \quad \eta(a)=\dfrac{m\frac{k^2}{a^2R}}{1+2m\frac{k^2}{a^2R}}$	Bean et al. 2006 Hu et al. 2006 Tsujikawa 2007
▪ DGP	$Q(a)=1-\dfrac{1}{3\beta}; \quad \beta=1+2Hr_c w_{DE}$ $\eta(a)=\dfrac{2}{3\beta-1}$	Lue et al. 2004; Koyama et al. 2006
▪ coupled Gauss-Bonnet	$Q(a)=\ldots$ $\eta(a)=\ldots$	see L. A., C. Charmousis, S. Davis 2006

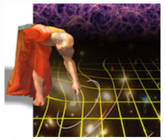
Galaxies, BAO — **COMPLEMENTARITY** — **Photons, WL**

massive particles respond to Ψ

$$\delta'' + \left(1+\frac{H'}{H}\right)\delta = \frac{k^2}{a^2}\Psi$$

massless particles respond to Φ-Ψ

$$\alpha = \int \nabla_{perp}(\Psi-\Phi)dz$$



Need to break degeneracy: *use growth of fluctuations*

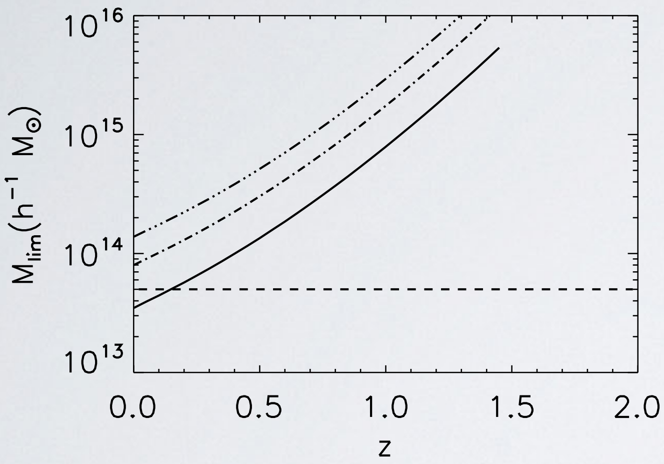
euclid

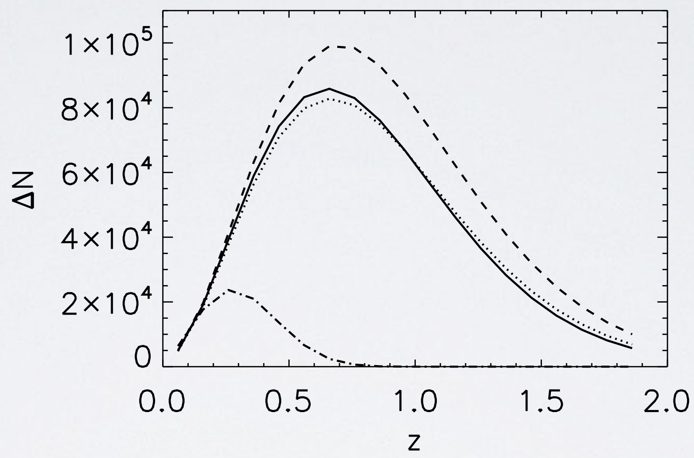
Counts & mass function *(calibrate!!)*

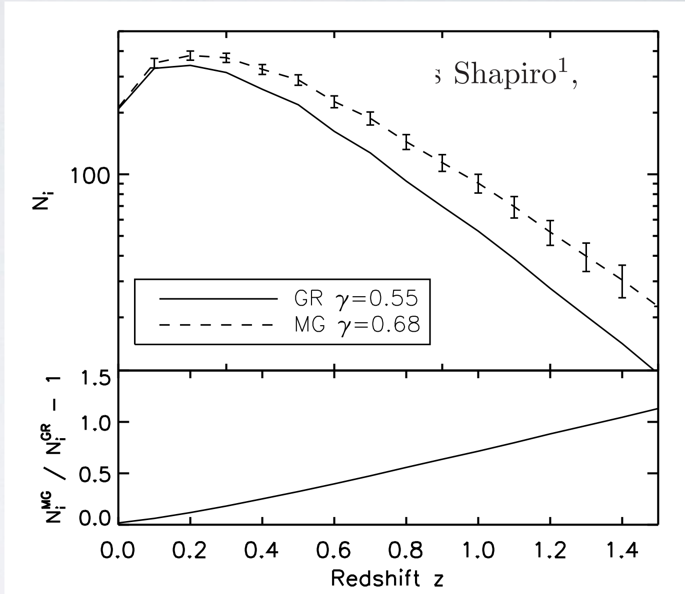
NIR photom (24.5), WL, (vel disp.)

expect N ~ few x 10^5

Clusters of galaxies: interesting and powerful

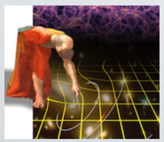


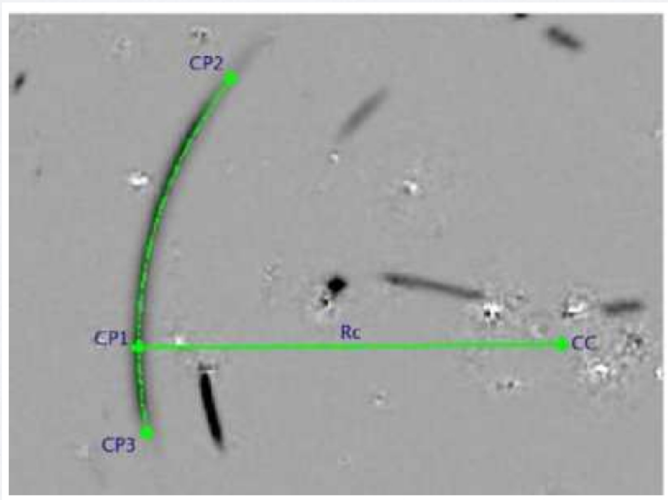


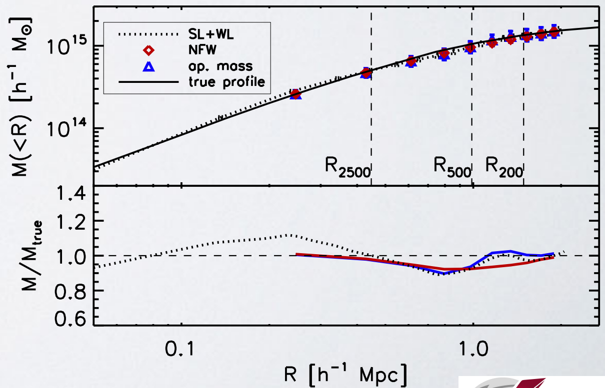


Strong lensing

Mass profile in inner regions; frequency of arcs





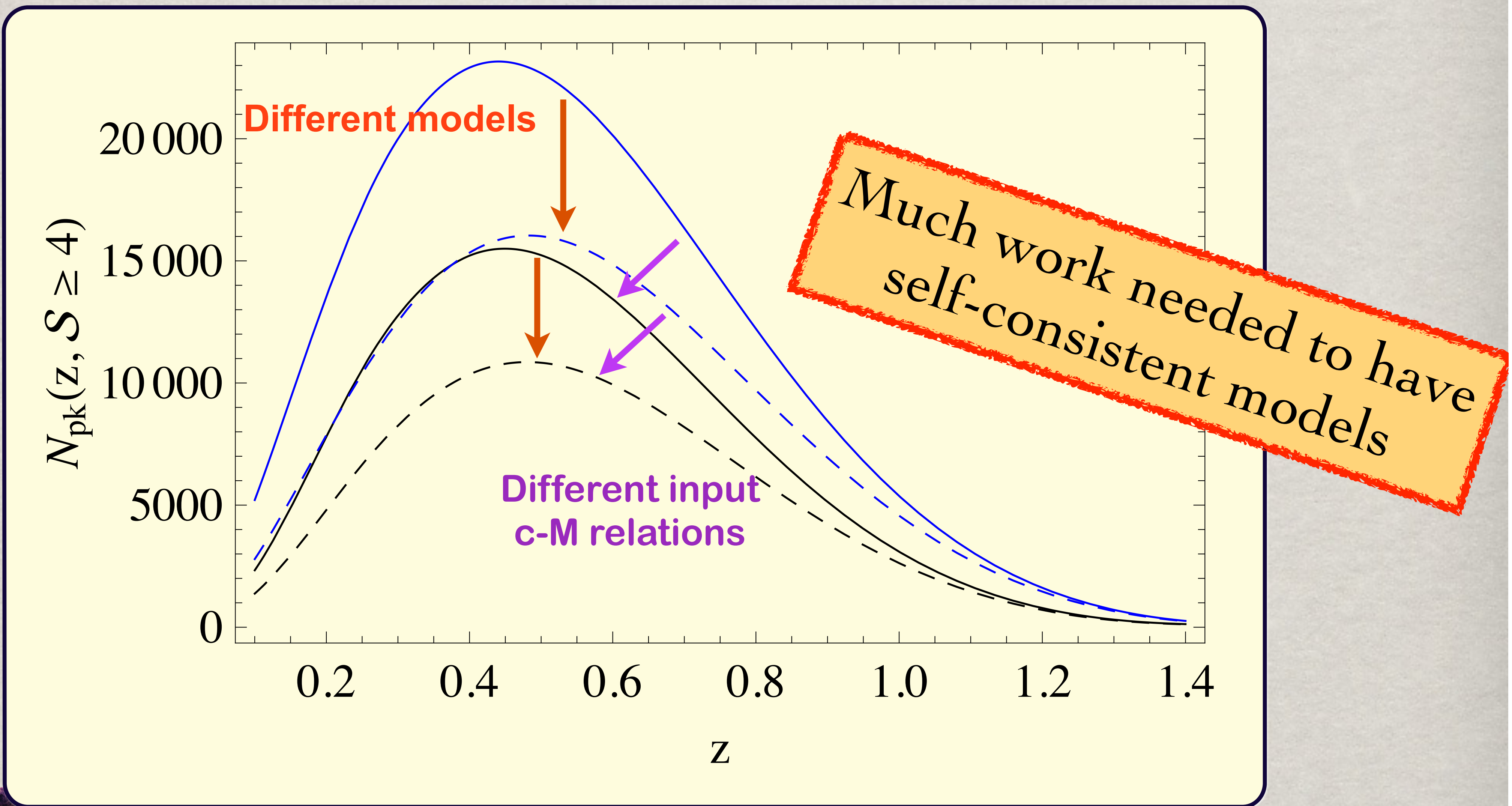


euclid

An example: cluster abundance in modified gravities

8 *V.F. Cardone et al.* arXiv:1204.3148

Weak lensing peak count as a probe of $f(R)$ theories



Integrated Sachs Wolfe
(will use Planck)

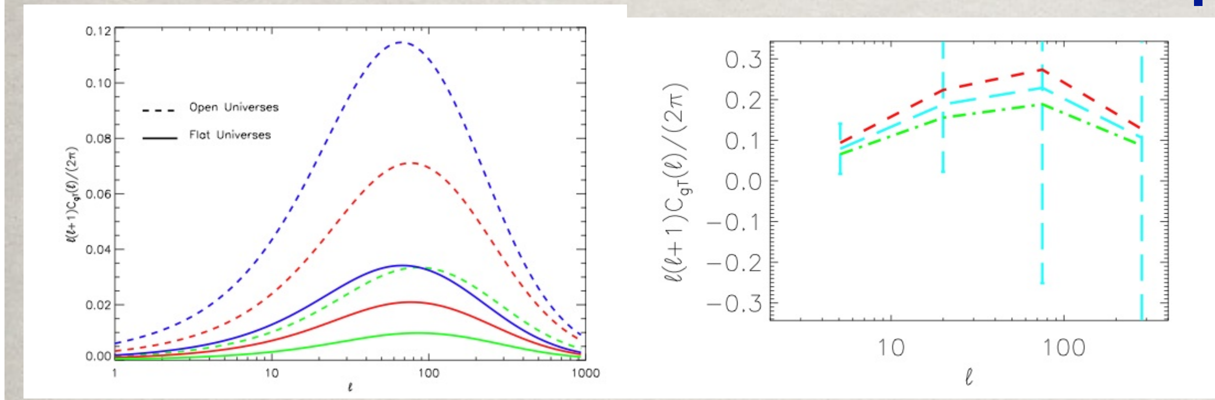
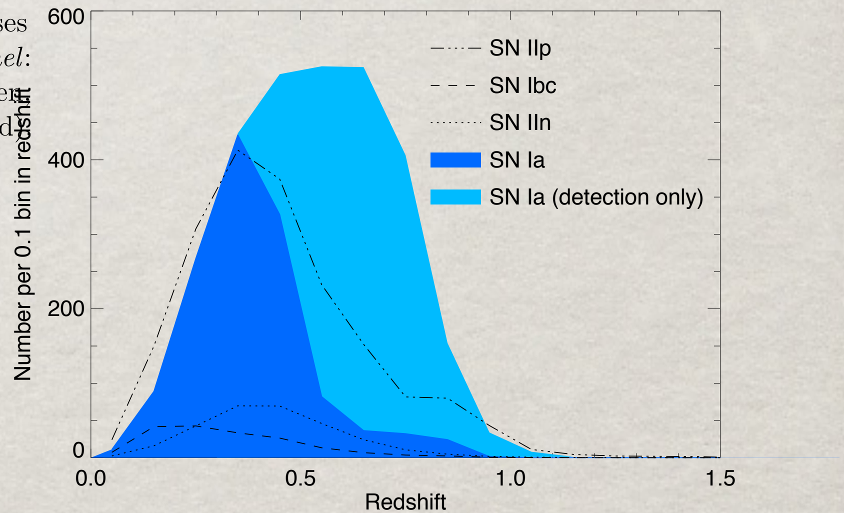


Figure 12.1: *Left Panel*: Prediction of the ISW cross-correlation signal for different values of the dark energy density ($\Omega_{DE} = 0.10$, green line; $\Omega_{DE} = 0.20$, red line; $\Omega_{DE} = 0.30$, blue line) for universes with flat geometry (solid lines) and universes with open geometry and no dark energy. The ISW signal for universes with the same matter density is larger in open universes than in flat universes. The signal is calculated for a Euclid-like photometric survey. *Right panel*: The ISW cross-correlation signal for different values of the growth parameter ($\gamma = 0.44$, green dash-dotted line; $\gamma = 0.55$, blue dashed line; $\gamma = 0.68$, e.g. a DGP model, red short dashed). *Both figures are taken from Rassat (2007).*



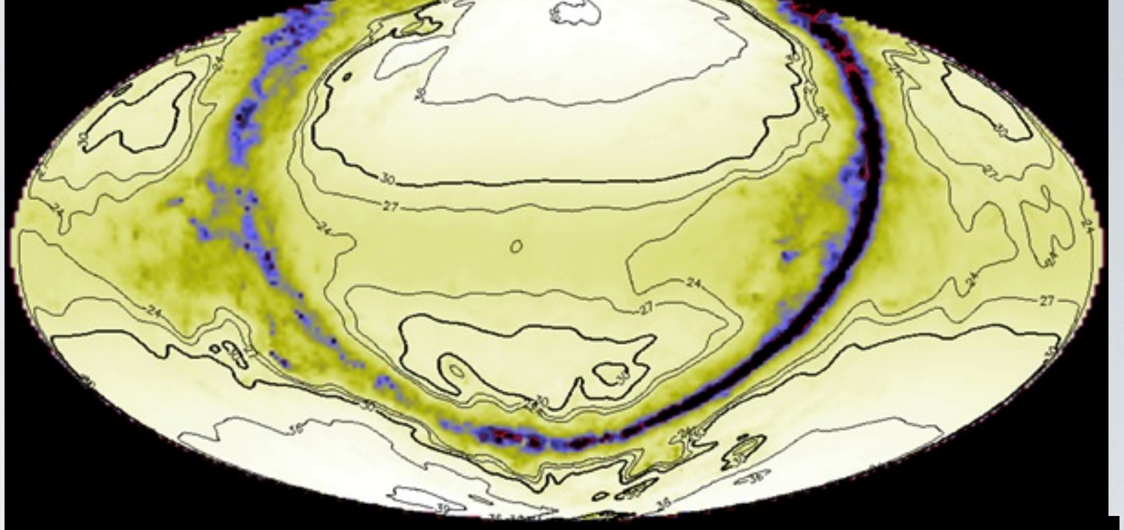
Physics and cosmology from SN

Figure 16.2: Number of SNe of various types that are expected to be detected by Euclid in the J band, as a function of redshift. Estimates for SNe of type Ia (dark blue shaded region), Ibc, IIn and IIp were provided by A. Goobar based on assumptions in Goobar *et al.* (2008), using SNe Ia rates from Dahlen *et al.* (2004) and assuming a 5 year survey that monitors a patch of 10sq deg at any time. These histograms represent the $N(z)$ for SNe with sufficient sampling to measure their lightcurve shapes (i.e. reaching 1 magnitude fainter than the peak brightness). The light-blue shaded region shows an independent estimate of the total number of SNe Ia detections including those only detected at peak luminosity, i.e. without full lightcurve measurements.

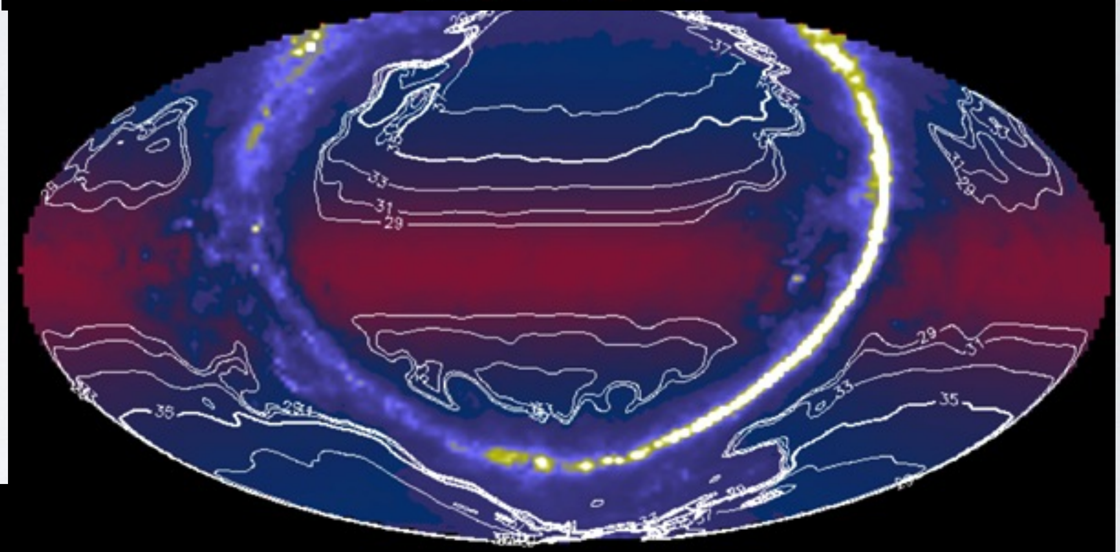
euclid

Euclid Survey Areas,
(~2012)

N~1.5-2 10^9 Weak Lensing sampling



N~5-6 10^7 Being revised ditto for Clustering



R.S & J. Amiaux (ESAC tool)

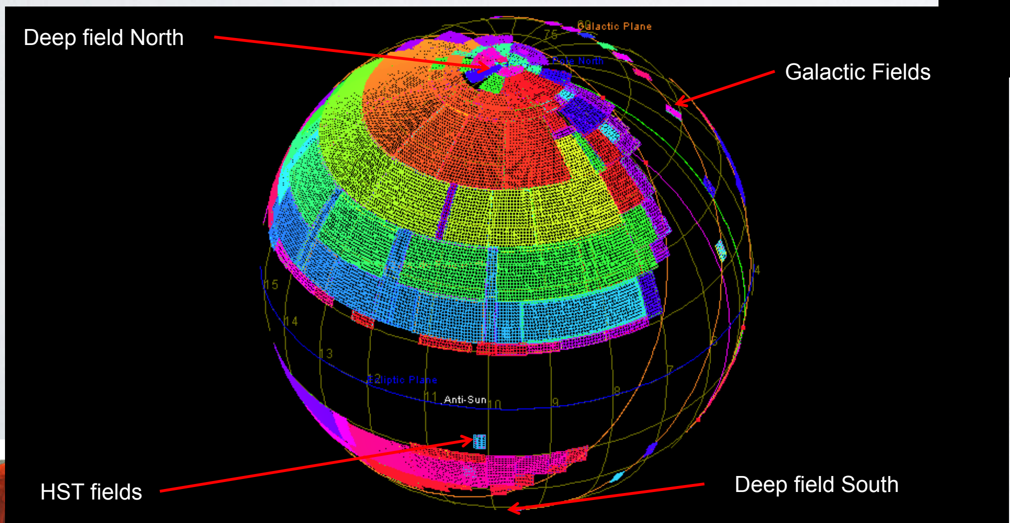


Figure 3.11.4-2: Assumption for locations of main calibrators for building the reference survey and implementation of the fields on the reference survey.

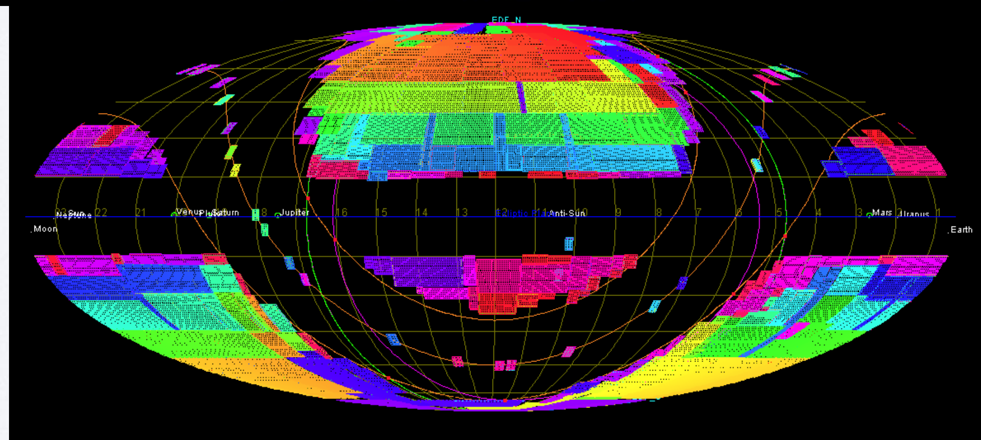


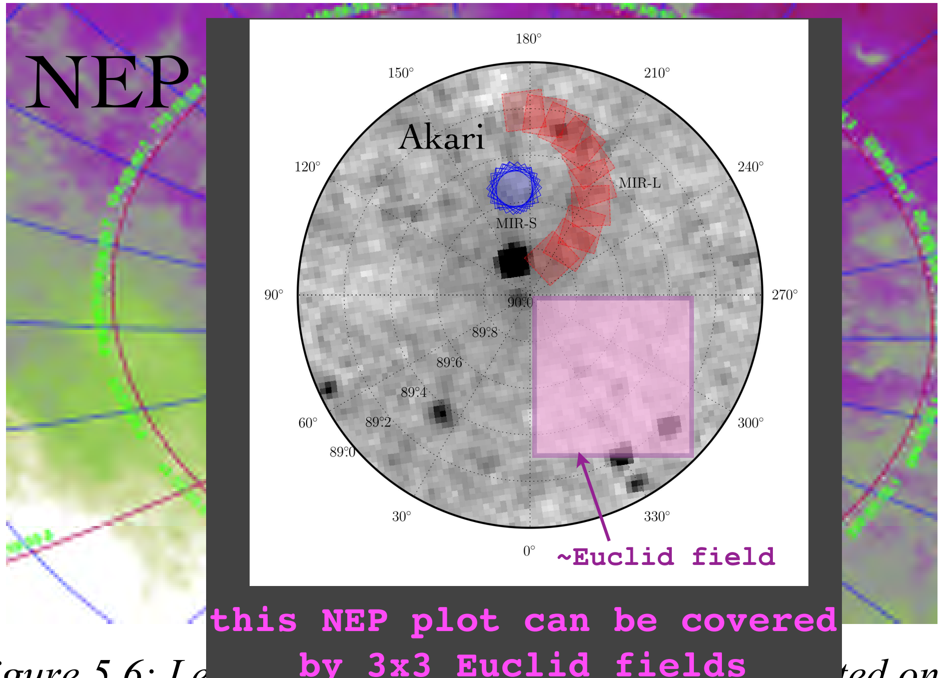
Figure 3.11.4-3: Mollweide representation of the full reference survey (including location of calibration fields).

euclid

Deep Field(s): calibration reqs (*being updated*) + science

Need high ecliptic latitude for observability (want low extinction too)

main requirements:
2x20 sq deg
2 mags deeper than wide



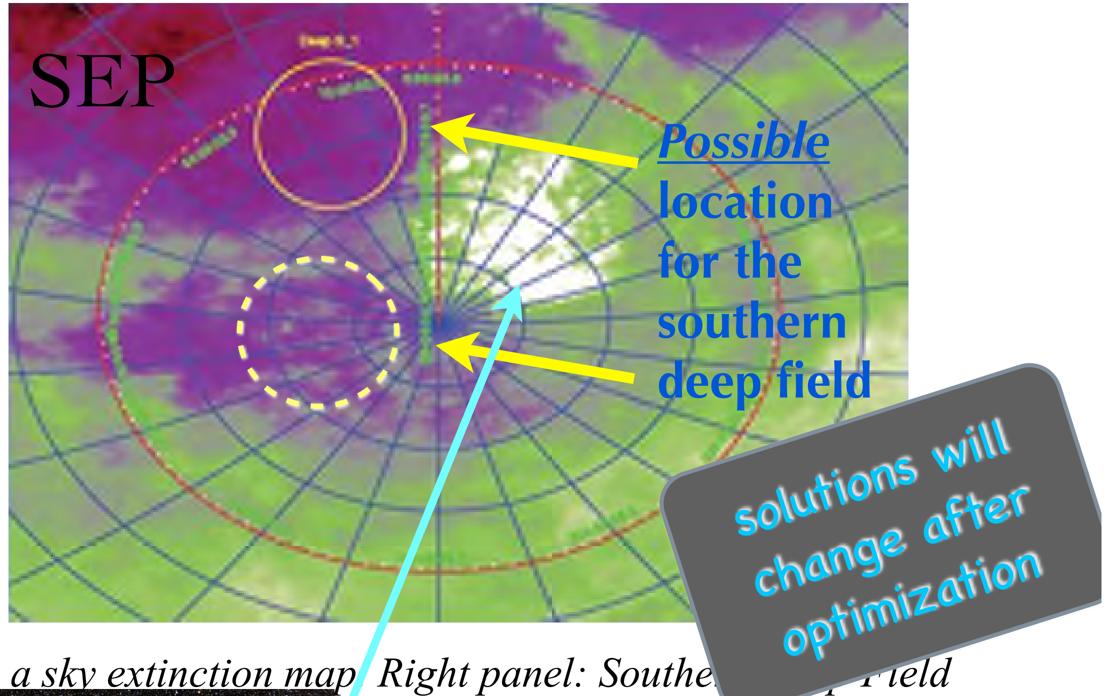


Figure 5.6: Le… panel: Northern Deep Field projected on a sky extinction map. Right panel: Southe… Field

Part of the SEP is covered by the Large Magellanic cloud ...
not good for deep xgal field so need to move (less visibility)

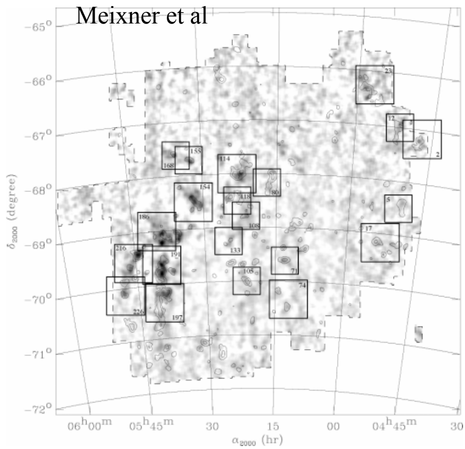


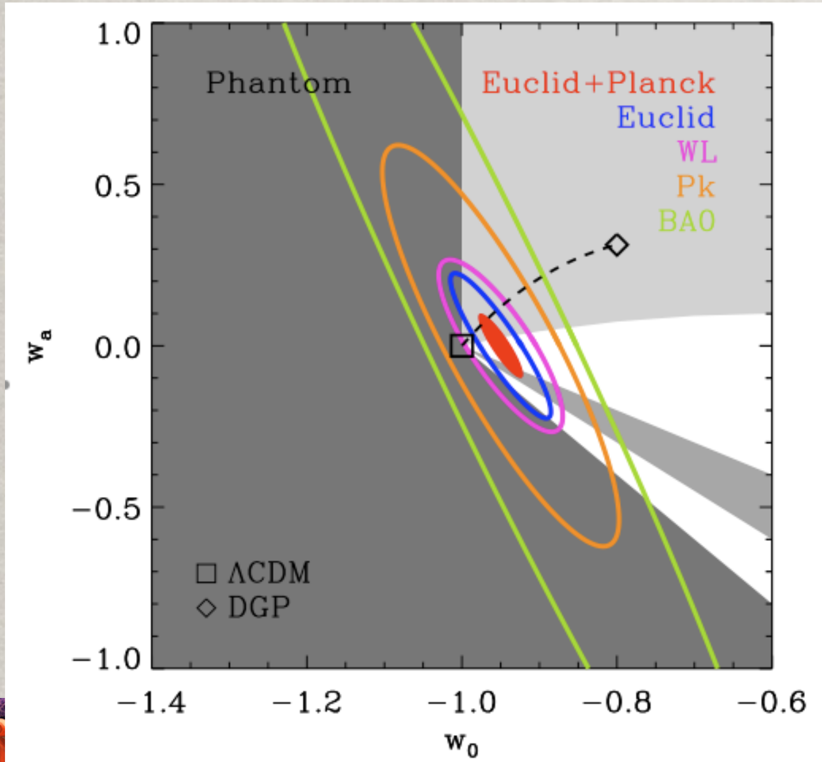
Fig 5: Extinction map of the LMC obtained from star count in the 2-mass catalog overlaid with CO contours. Av ranges from 0 to 5 mag

	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν/eV	f_{NL}	w_p	w_a	FoM
Euclid Primary	0.01	0.027	5.5	0.015	0.150	430
Euclid All	0.009	0.02	2	0.013	0.048	1540
Euclid +Planck	0.007	0.019	2	0.007	0.035	4020
Current	0.2	0.58	100	0.1	1.5	~10
Improv. Factor	**30**	**30**	**50**	**>10**	**>50**	**>300**

$$\text{FoM}= 1/(\Delta w_p \times \Delta w_a)$$

Goals

IMPROVE ~
× 10 ON W
× 20 ON γ



Euclid will **challenge all sectors** of the cosmological model:

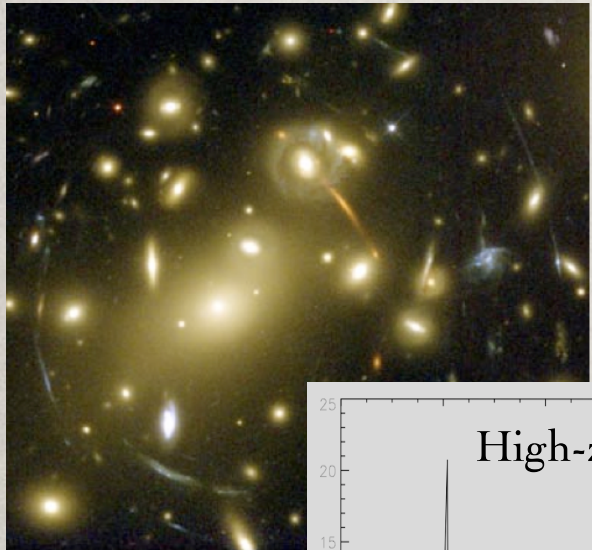
- **Dark Energy**: w_p and w_a with an error of 2% and 13% respectively (no prior)
- **Dark Matter**: test of CDM paradigm, precision of 0.04eV on sum of neutrino masses (with Planck)
- **Initial Conditions**: constrain shape of primordial power spectrum, primordial non-gaussianity
- **Gravity**: test GR by reaching a precision of 2% on the growth exponent γ ($d\ln\delta_m/d\ln a \propto \Omega_m^{\gamma}$)

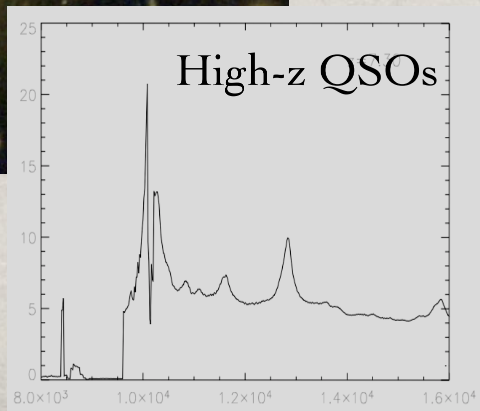
Uncover new physics and map LSS at 0<z<2: Low redshift counterpart to CMB surveys

euclid

- ***Unique* legacy survey**: 2 billion galaxies imaged in optical/NIR to mag >24 Million NIR galaxy spectra, full extragalactic sky coverage, Galactic sources
- Unique database for **various fields in astronomy**: galaxy evolution, search for high-z objects, clusters, strong lensing, brown dwarfs, exo-planets, etc
- **Synergies with other facilities**: JWST, Planck, Erosita, GAIA, DES, Pan-STARSS, LSST, E-ELT etc (e.g. to do NIR from the ground would take several x 10^3 yr)
- **All data publicly available** through a legacy archive

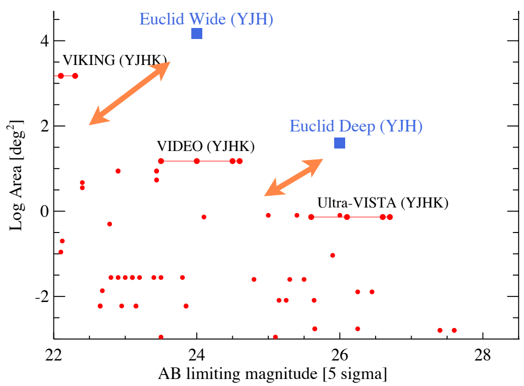
Enormous database to harvest



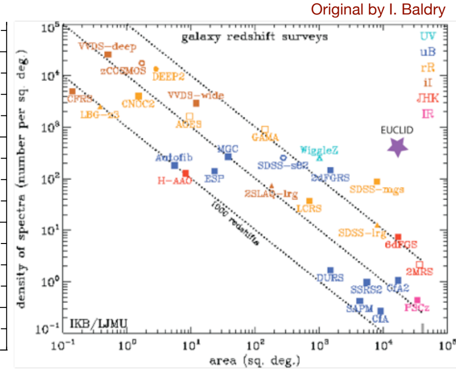


Euclid in context

	VISTA	SASIR	Euclid
Wide survey	680 years	66 years	5 years
Deep survey	72 years	7 years	"5 years"

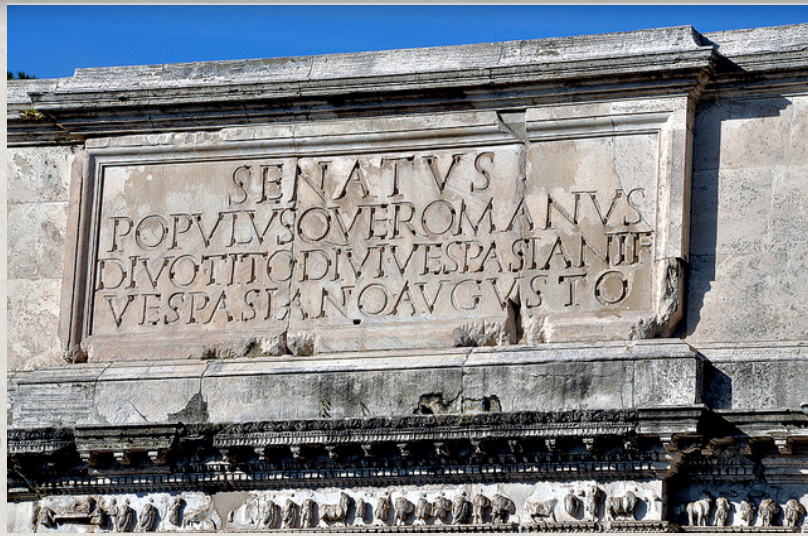


Original by I. Baldry

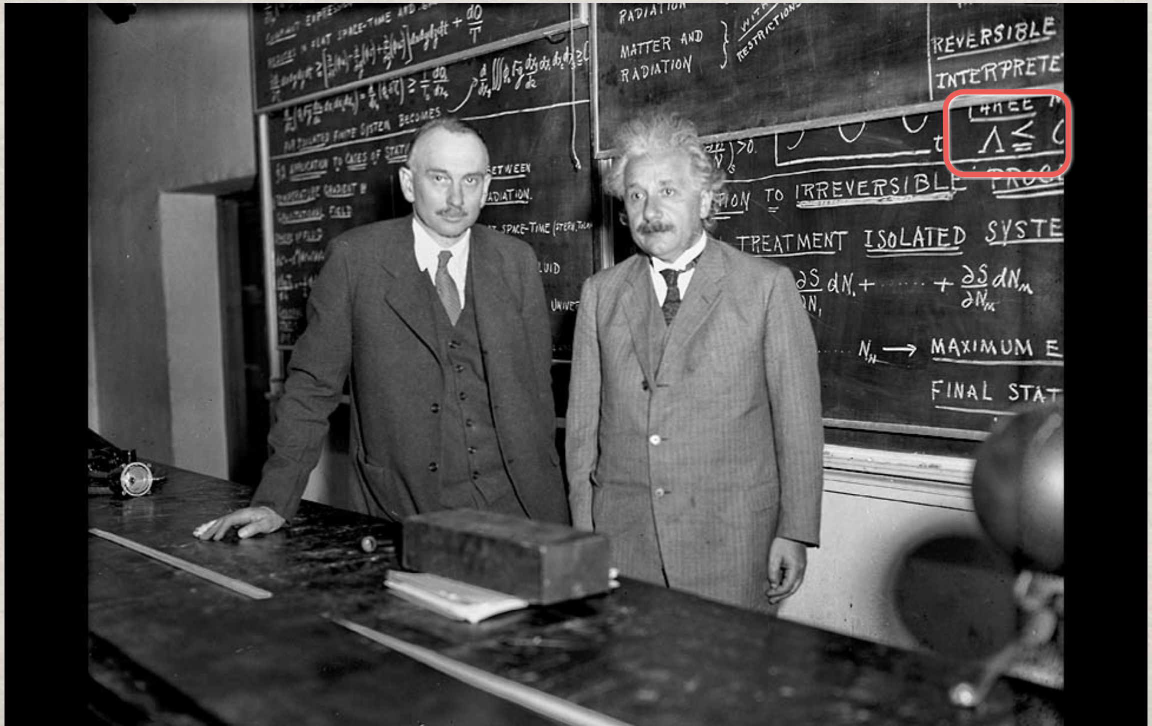


The ubiquitous symbol.. (hex U+039B)

SAMSUNG



one vowel,
one consonant,
one number



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

$\varrho_{vac} = \Lambda / 8\pi \quad \sim 10^{-29}\ \mathrm{g/cm^3}$

$t_{pl} = (Gh/2\pi c^5)^{1/2} = 5.4 \times 10^{-44}\,\mathrm{s}$

$t_U \sim 8 \times 10^{60}$

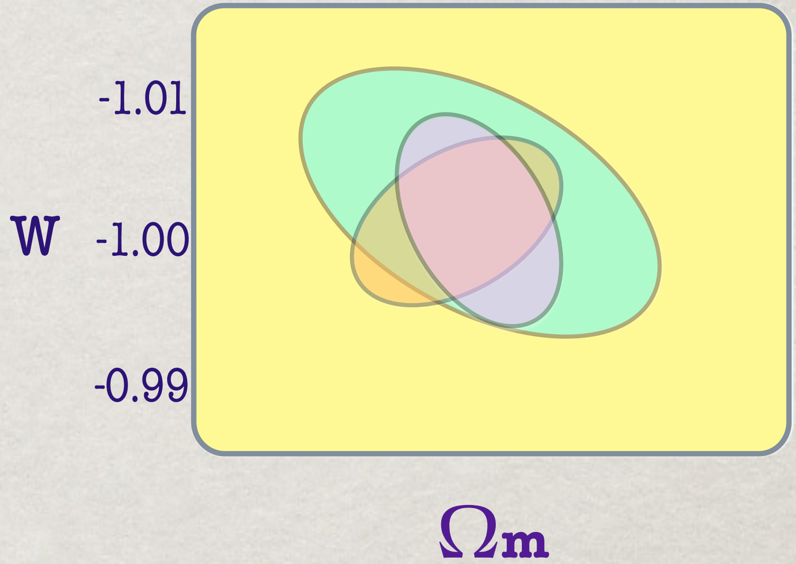
$\Lambda \sim t^{-2} \sim 10^{-122}$

euclid

Possible outcomes.....

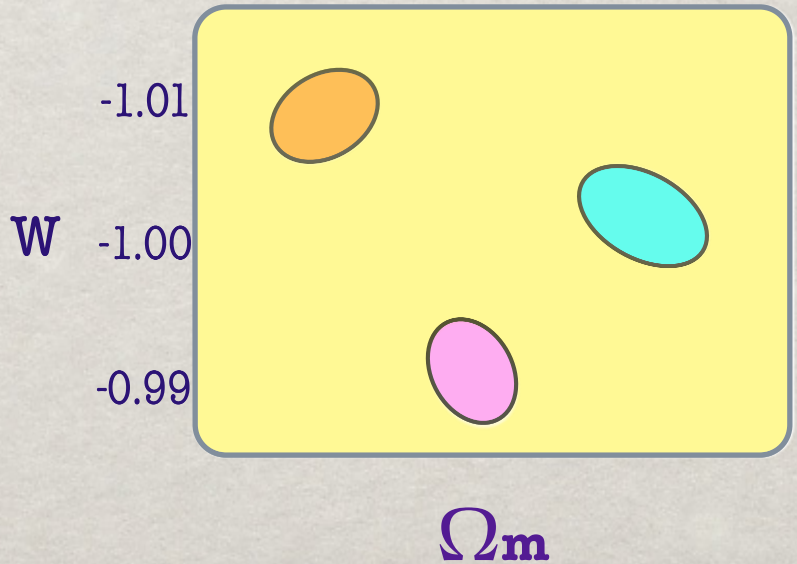
Different probes

Quite useful but
a bit dull....



Λ=const

Much more
interesting!!



?!?!?

Summary:

- ★ ***<u>Best</u>*** science (cf Decadal)
- ★ <u>Enormous</u> Legacy
- ★ <u>Tough</u> but feasible

<u>Stay tuned!</u>