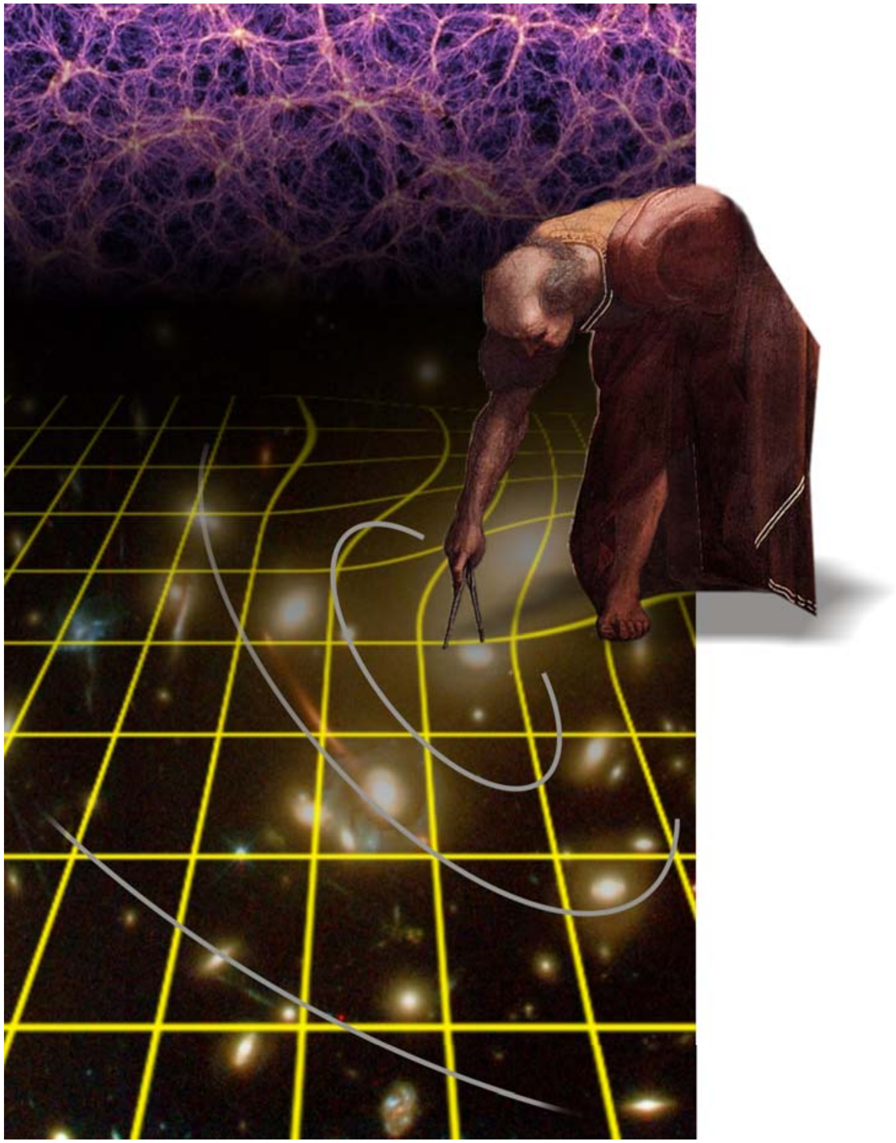


The Euclid Mission

Jason Rhodes
(JPL)

Euclid Consortium

Euclid

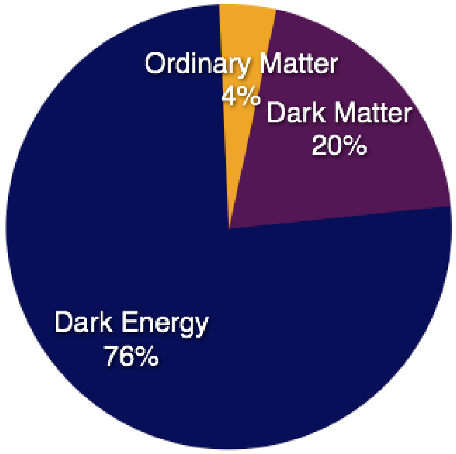
- Merger of DUNE (French led WL) and Space (Italian led BAO)
  - Dune was Vis/NIR imaging
  - Space was NIR spectroscopy
  - Recently NIR instruments were merged into NISP

- Consortium Lead Alexandre Refregier (France)

- 200+ Consortium members (very inclusive)

- Current European member countries: Austria, France, Germany, Italy, Netherlands, Norway, Spain, Switzerland, UK

Outstanding Questions in cosmology **Euclid**



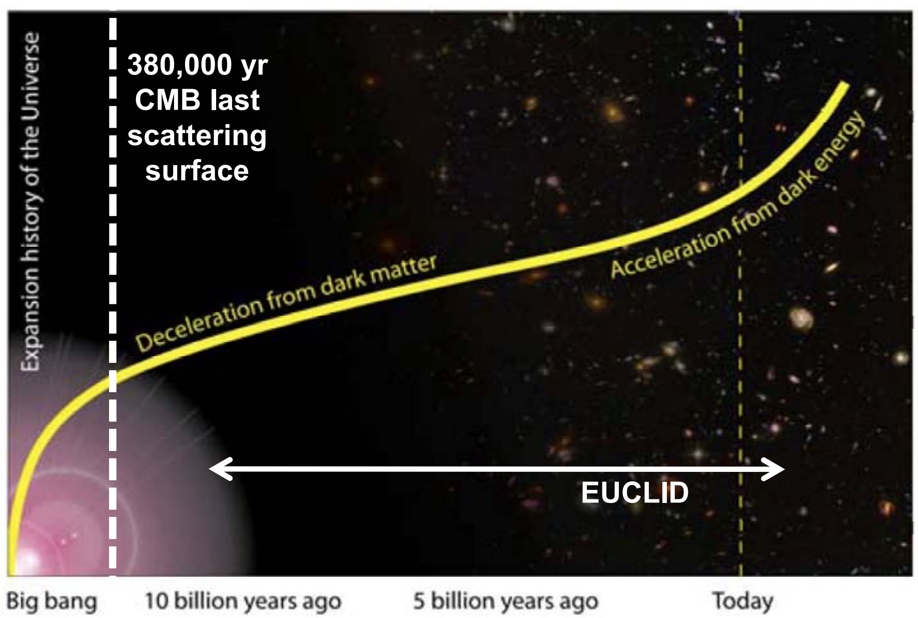
→ Euclid's Primary Science Objectives

Nature of the Dark Energy

Nature of the Dark Matter

Initial conditions (Inflation Physics)

Modifications to Gravity



→ Secondary Science Objectives
Legacy science (NIR)
Microlensing/planet finding enabled

Euclid concept

Euclid

- High-precision survey mission to map the geometry of the Dark Universe
- Optimized for two complementary cosmological probes
  - Weak Gravitational Lensing
  - Baryonic Acoustic Oscillations

  Additional probes enabled with same data: clusters, redshift space distortions, ISW
- Full extragalactic sky survey with 1.2m telescope at L2:
  - Imaging:

    High precision imaging at visible wavelengths

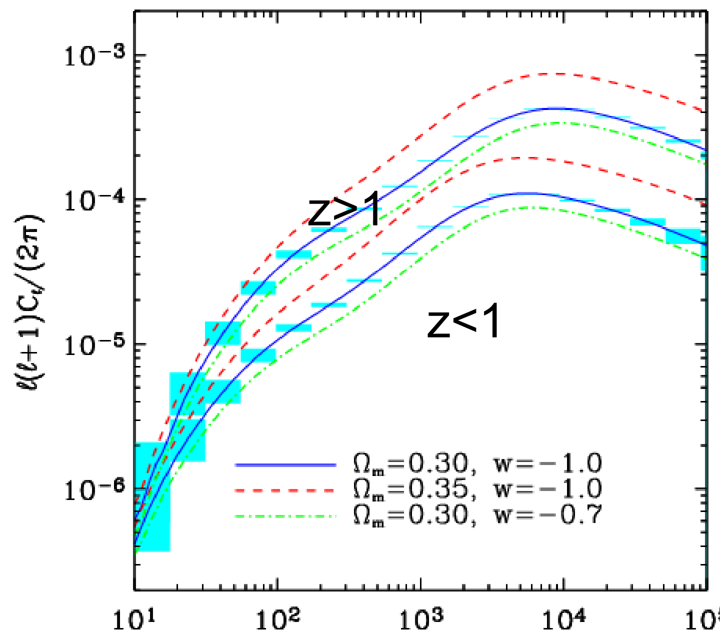
    Photometry/Imaging in the near-infrared
  - Near Infrared Spectroscopy
- Ground/Space synergy to minimize costs and maximize science
- Legacy science for a wide range of areas in astronomy
- Yellow Book for more information http://xxx.lanl.gov/abs/0912.0914

Weak Gravitational Lensing — Euclid

Weak Lensing:

- Map the 3D distribution of Dark Matter in the Universe
- Measures the mass without assumptions in relation between mass and light
- Very sensitive to Dark Energy through both geometry and growth

→ Need measurements of galaxy shape and photometric redshifts



Dark matter power spectrum in 2 redshift bins

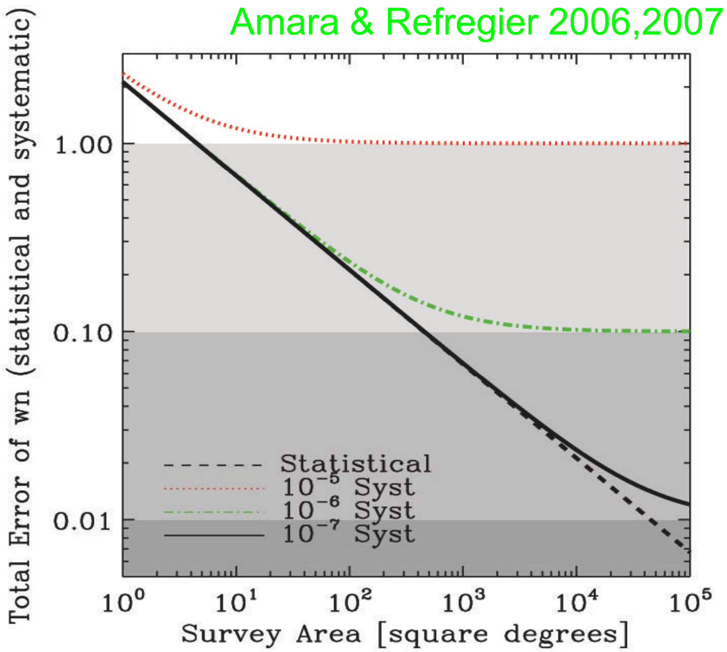
Requirements for Weak Lensing **Euclid**

Statistics: optimal survey geometry: wide rather than deep for a fixed survey time, → need 20,000 deg^2 to reach ~1% precision on w

Redshift bins: good photo-z for redshift binning and intrinsic alignments → need deep NIR photometry

Systematics: must gain 2 orders of magnitude in systematic residual variance → need about 50 bright stars to calibrate PSF

Amara & Refregier 2006,2007



Abdalla et al. 2008

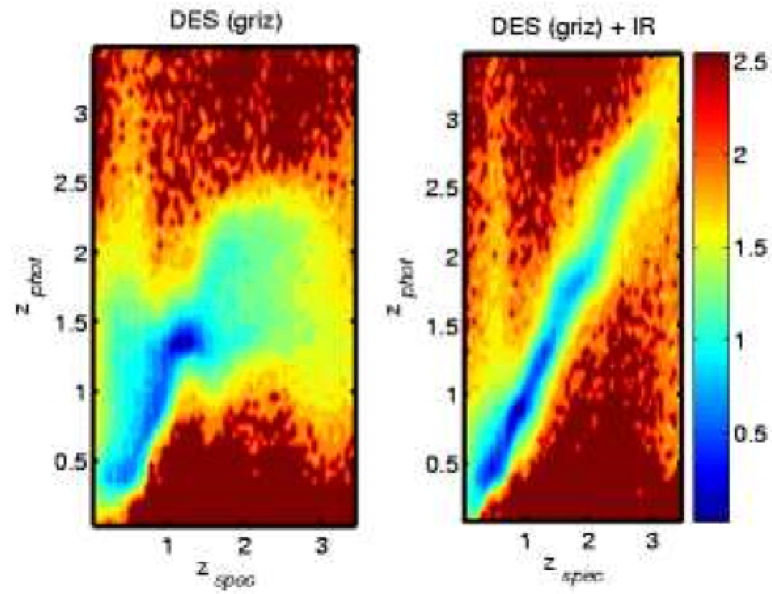
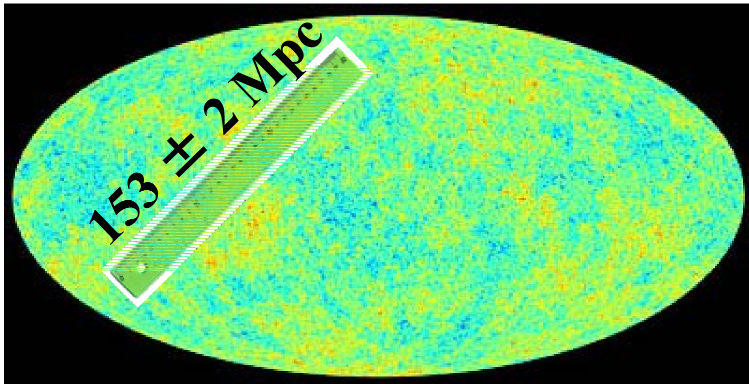


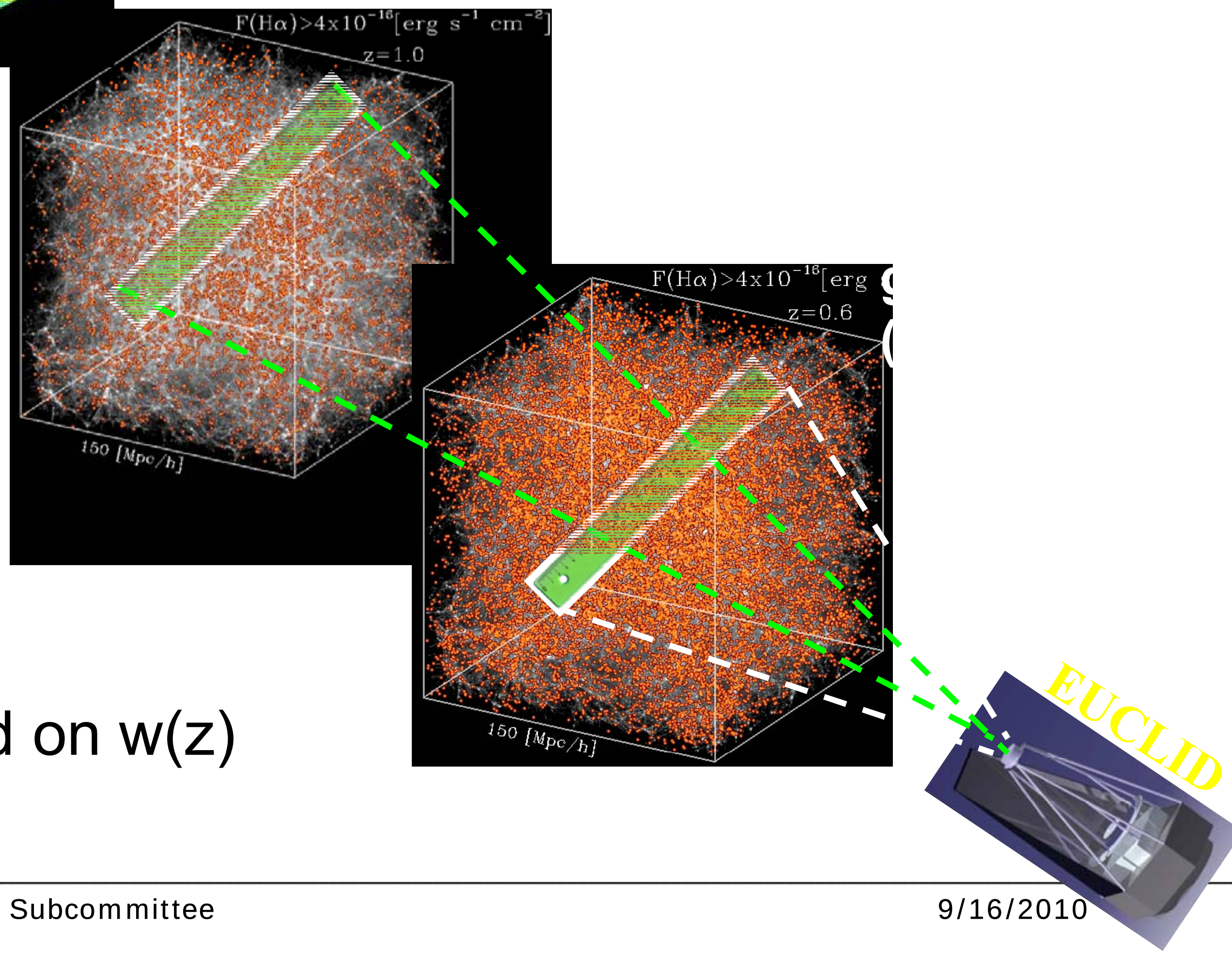
Photo-z errors with and without NIR imaging

Baryonic Acoustic Oscillations **Euclid**



CMB (z≈1000)

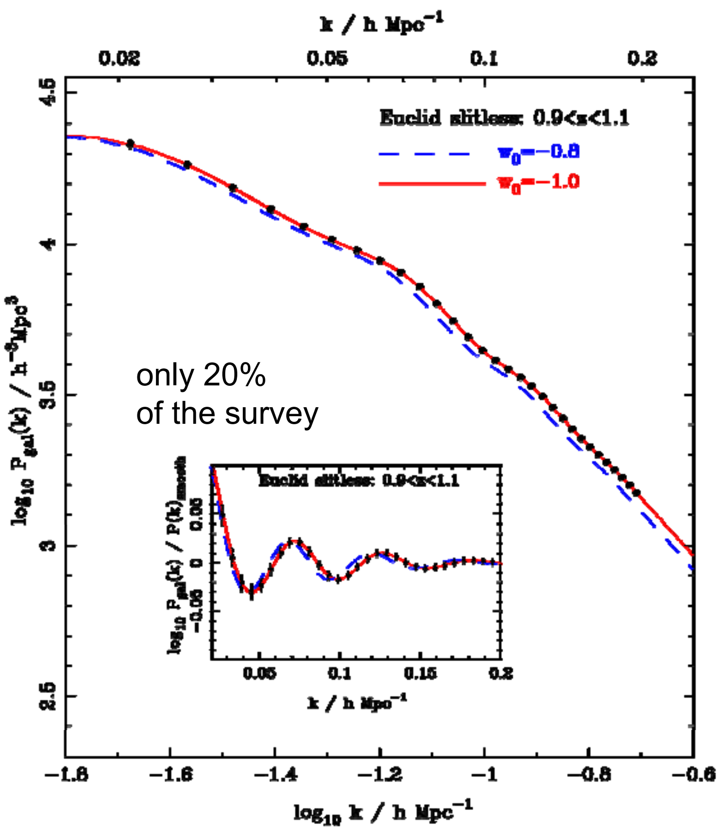
galaxies (z≈1)

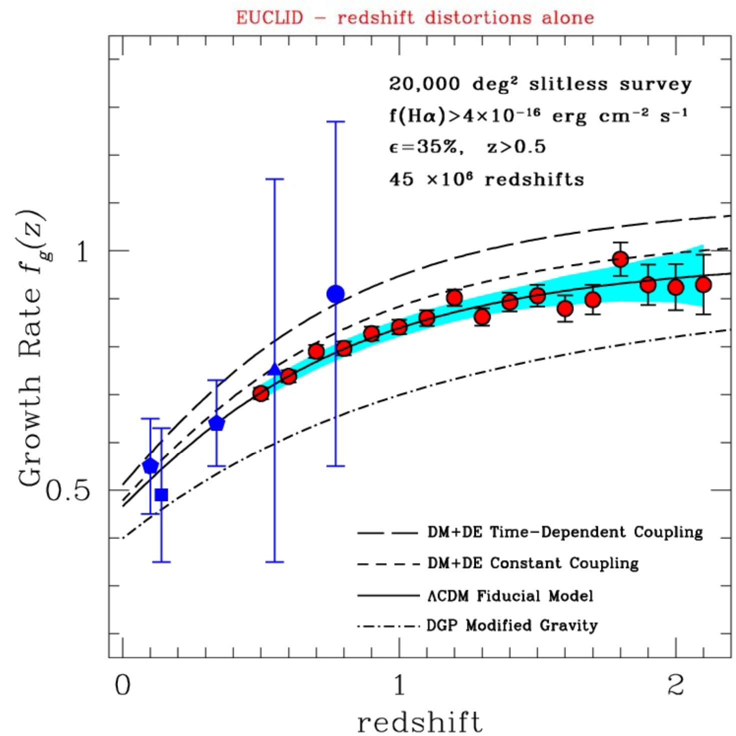


- $H(z)$ (radial)
- $D_A(z)$ (tangential)
- $H(z)$ & $D_A(z)$ depend on $w(z)$

Galaxy Clustering Survey **Euclid**

- Need large volumes ($V_{eff} \approx 19\ h^{-3}\ Gpc^3 \approx$ 75x larger than SDSS)
- Need to probe redshifts 0<z<2
- Use galaxy spectroscopic survey to measure: BAO, full galaxy power spectrum P(k) and redshift space distortions to constrain Dark Energy and Modified Gravity





Euclid Mission Baseline

Euclid

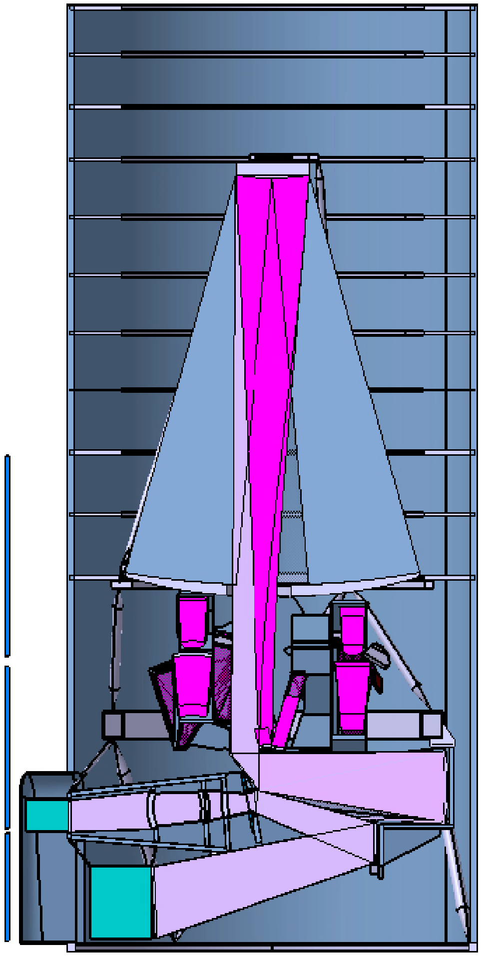
Mission elements:

- L2 Orbit
- 4 -5 year mission (still being optimized)
- Telescope: three mirror astigmat (TMA) with 1.2 m primary
- Instruments:

– VIS: Visible imaging channel: 0.5 deg^2, 0.10'' pixels, 0.18'' PSF FWHM, broad band R+I+Z (0.55-0.92mu), 36 CCD detectors, galaxy shapes

– NISP: NIR channel: 0.5 deg^{2,} 16 HgCdTe detectors, 1-2μm (2.5 μm cutoff devices)

  - Photometry: 0.3'' pixels, 3 bands Y,J,H, photo-z's
  - Spectroscopy: R=500, slitless, redshifts

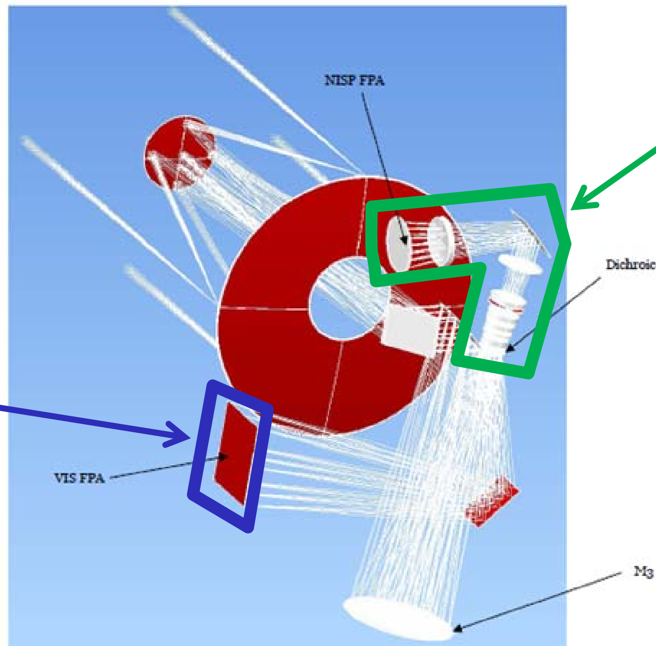


Euclid Focal Planes

Euclid

NISP instrument

VIS instrument



VIS 542s				VIS 542s				VIS 542s				VIS 542s			
NIS1 408s	Y 88s	J 88s	H 88s	NIS2 408s	Y 88s	J 88s	H 88s	NIS3 408s	Y 88s	J 88s	H 88s	NIS4 408s	Y 88s	J 88s	H 88s

10 Sec

100 Sec

Vis exposure time leaves margin (possibly for second filter)

Euclid Surveys

Euclid

Wide Survey: 20,000 deg^2

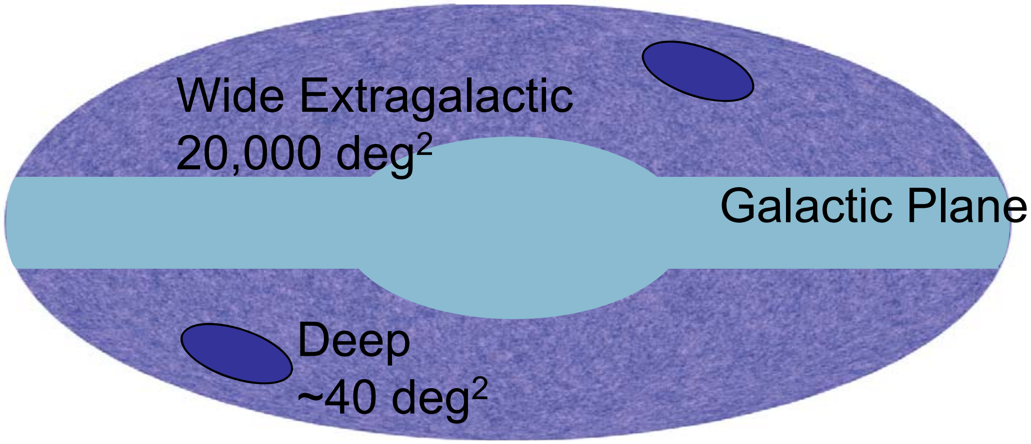
- Visible: Galaxy shape measurements for 2×10^9 galaxies to $RIZ_{AB} \leq 24.5$ (AB, 10σ) at 0.16" FWHM, yielding 30-40 resolved galaxies/amin^2, with a median redshift $z \sim 0.9$
- NIR photometry: Y, J, H ≤ 24 (AB, 5σ PS), yielding photo-z's errors of 0.03-0.05($1+z$) with ground based complement (PanStarrs-2, DES, LSST, etc)
- Spectroscopy: redshifts for 40×10^6 galaxies with emission line fluxes $>4.10^{-16}$ ergs/cm^2/s at $0<z<2$ (slitless)

Deep Survey: 40 deg^2 deg^2 at ecliptic poles

- Monitoring of PSF drift (40 repeats at different orientations over life of mission)
- Produces +2 magnitude in depth for both visible and NIR imaging

Possible additional Galactic surveys (enabled beyond 4 years):

- Short exposure Galactic plane
- High cadence microlensing extra-solar planet surveys

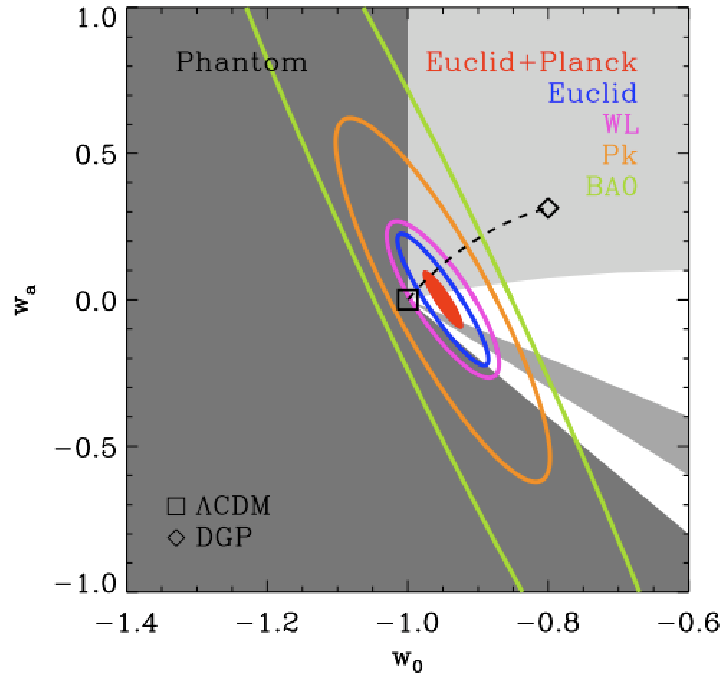


Ground Space Synergy **Euclid**

- Only do from space what must be done from space due to backgrounds or systematics
- To achieve photometric redshift precision, combine Euclid visible/NIR photometry with visible photometry from the ground
- DES+Pan-STARRS2 will meet requirements for depth and sky coverage. LSST+PS4 will provide even better photo-z's
- Collaborations engaged with DES and PS projects

Impact on Cosmology **Euclid**

	Dark Energy		Densities			Initial Conditions		Hubble	DE FoM[2]
	Δw_p	Δw_a	$\Delta\Omega_m$	$\Delta\Omega_\Lambda$	$\Delta\Omega_b$	$\Delta\sigma_8$	Δn_s	Δh	
Current +WMAP[3]	0.13	-	0.01	0.015	0.0015	0.026	0.013	0.013	**~10**
Planck	-	-	0.008	-	0.0007	0.05	0.005	0.007	**-**
Euclid Req.	0.018	0.15	0.004	0.012	0.006	0.004	0.007	0.022	**400**
Euclid Goal	0.016	0.13	0.003	0.012	0.005	0.003	0.006	0.020	**500**
Euclid +Planck	0.010	0.066	0.0008	0.003	0.0004	0.0015	0.003	0.002	**1500**
Factor gain on Current	**13**	**> 15**	**13**	**5**	**4**	**17**	**4**	**7**	**150**



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

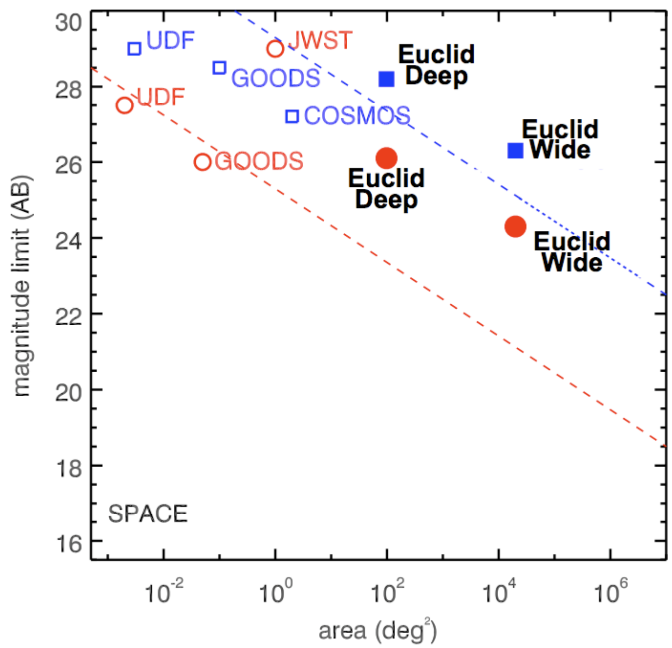
Gravity: test GR by reaching a precision of 2% on the growth exponent γ ($d\ln\delta_m/d\ln a \propto \Omega_m^{\gamma}$)

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

Legacy Science

Euclid

- Unique legacy survey: 2 billion galaxies imaged in optical/NIR to mag 24, 40 Million NIR galaxy spectra, full extragalactic sky coverage, Galactic sources
- Unique datase 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, GAIA, DES, Pan-STARSS, LSST, etc
- All data publicly available through a legacy archive

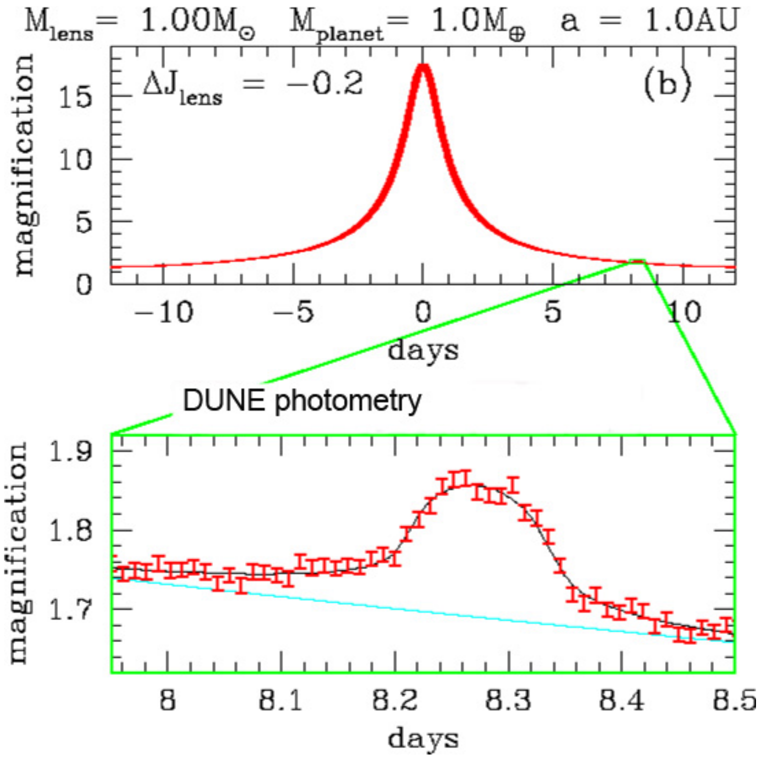


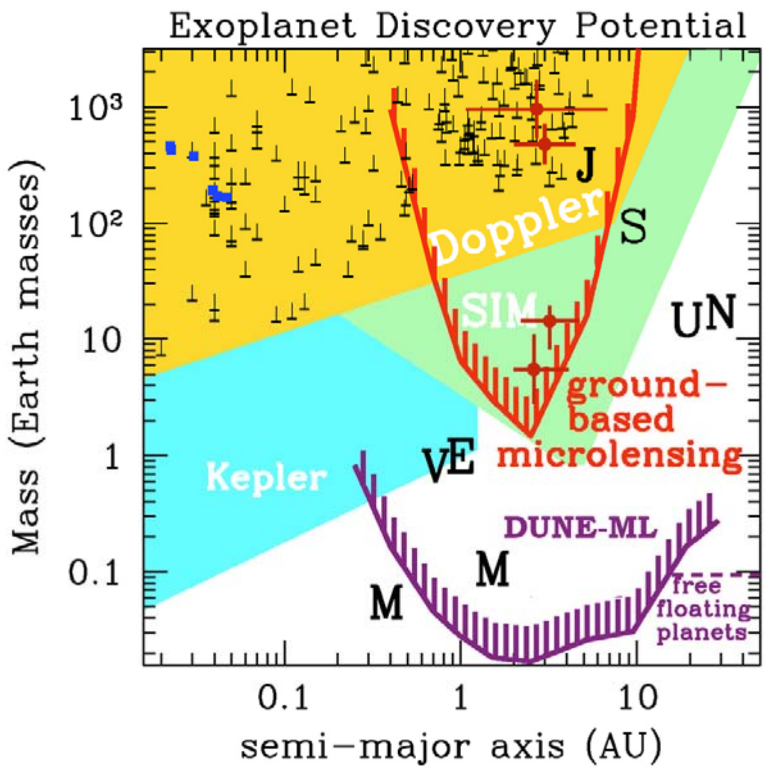
Search for Exo-Planets **Euclid**

Enabled in a possible extended mission

Microlensing survey: 4 deg^2 in the bulge, visited every 20 minutes over 3 months (Y,J,H~22 per visit), monitor 2×10^8 stars

→ Detect ~30 Jupiters, and ~5 Earth Mass planets in the habitable zone





Conclusions **Euclid**

- Euclid is a high-precision wide-field survey mission to map the geometry of the Dark Universe

- Euclid will provide unprecedented accuracy on all sectors of the cosmological model: Dark Energy, Dark Matter, Initial Conditions, Gravity

- Euclid will also provide unique legacy science from its all sky legacy archive and additional surveys

- Complementary and analogous to CMB measurement of Large-Scale Structure at matter-radiation transition epoch: Euclid will provide high-precision map of LSS at matter-DE transition epoch: 3D, non-gaussian, multi-probe

Euclid

Current status of Dark Energy **Euclid**

Dark Energy:

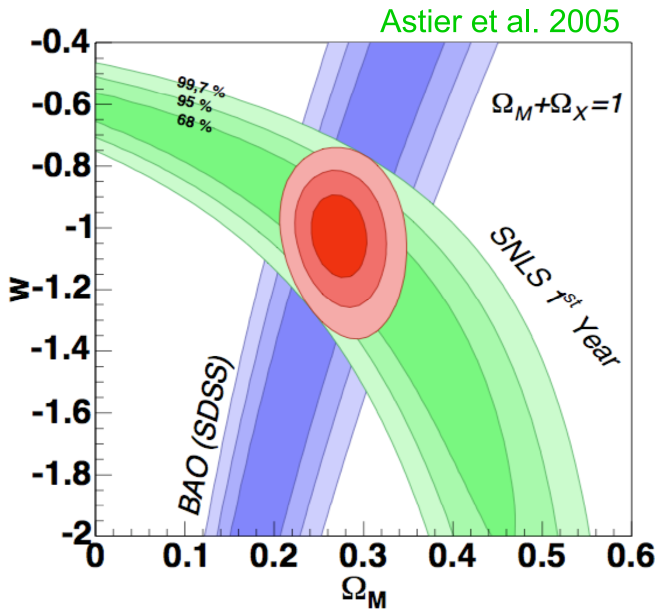
- Affects cosmic geometry and structure growth
- Parameterized by equation of state parameter:

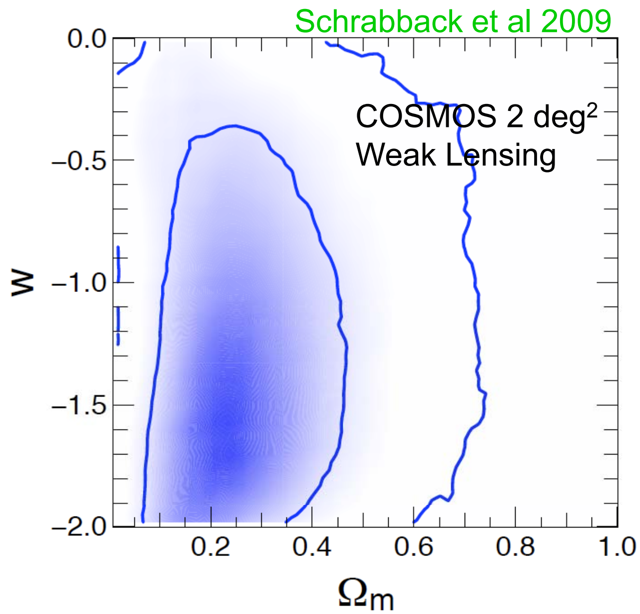
$w(z)=\rho/p$,   constant $w=-1$ for cosmological constant

Current constraints: 10% error on constant w

For definite answers on DE: need to reach a precision of 1% on (varying) w and 10% on $w_a=dw/da$

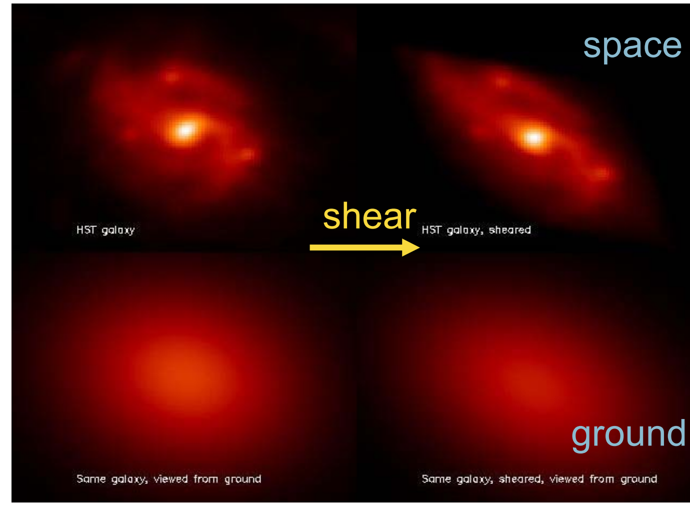
$\rightarrow$ Objective for Euclid





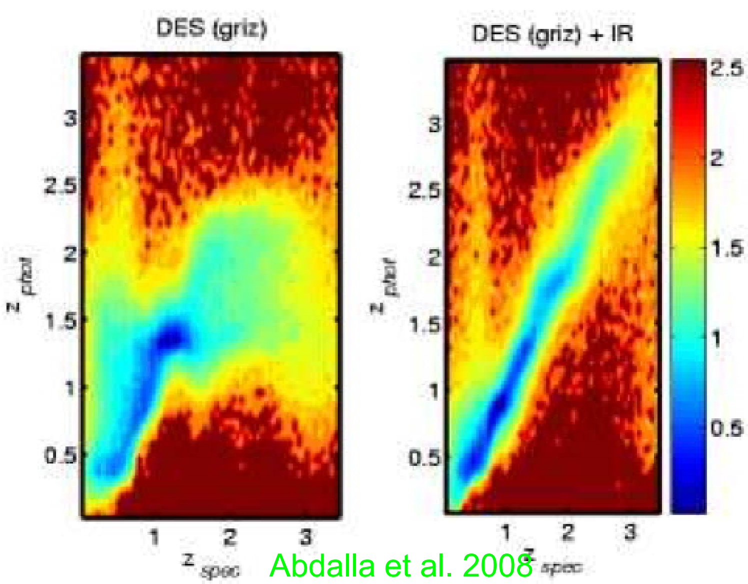
Advantages of Space

Euclid

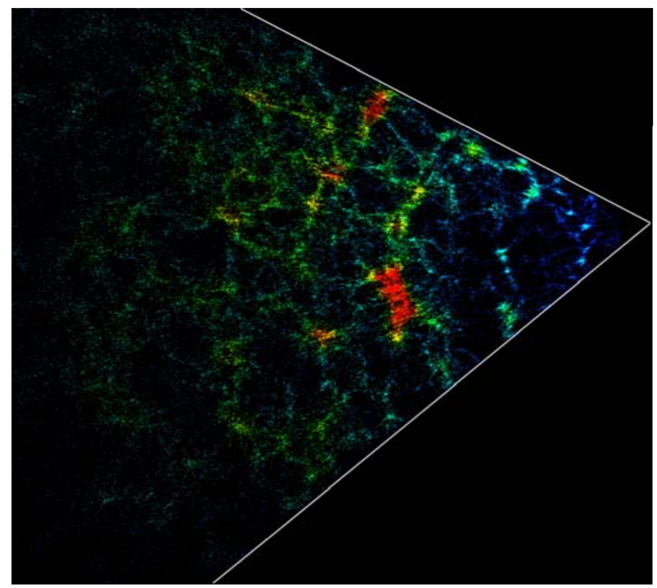


Space observations provide:

- small and stable PSF: larger number density of resolved galaxies, small systematics for Weak Lensing
- deep NIR photometry: better photometric redshifts
- NIR spectroscopy: galaxy redshifts at z>1



Abdalla et al. 2008



2DF redshift survey