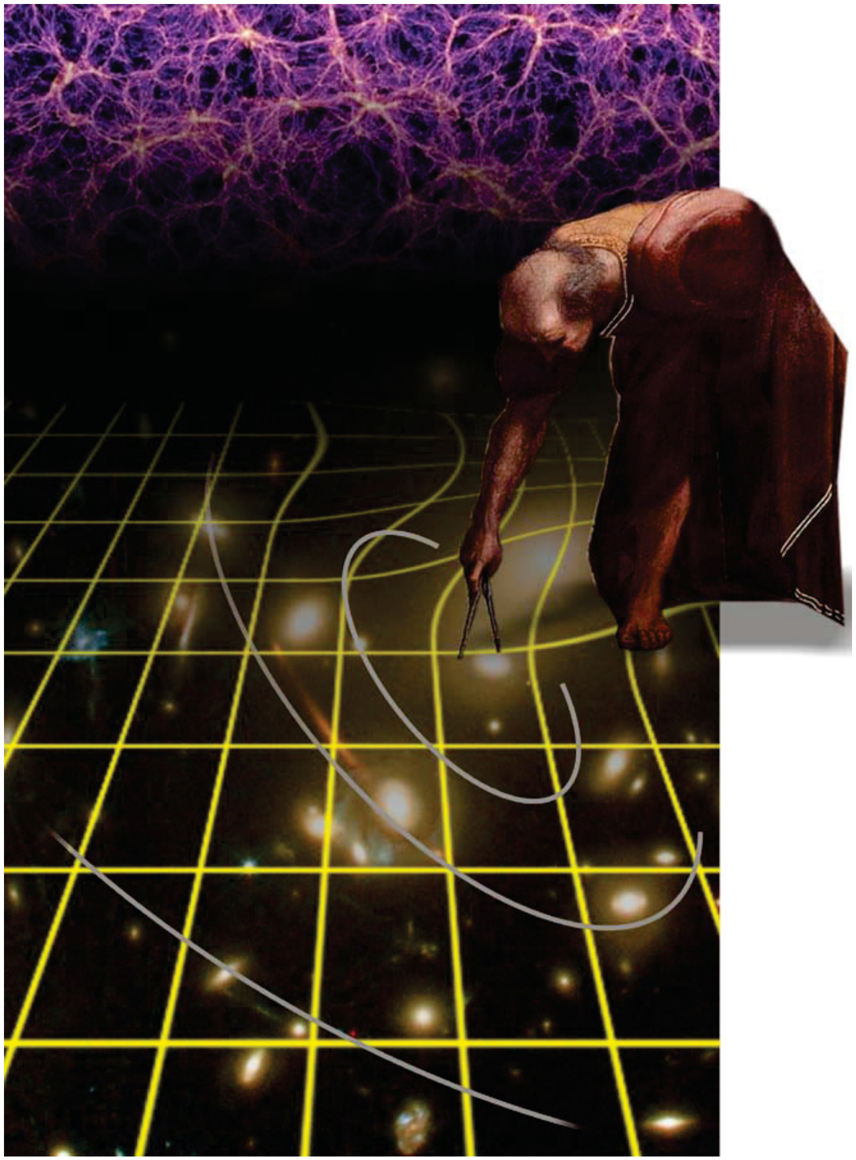


Euclid

Mapping the geometry of the Dark Universe

Mission and Consortium Status

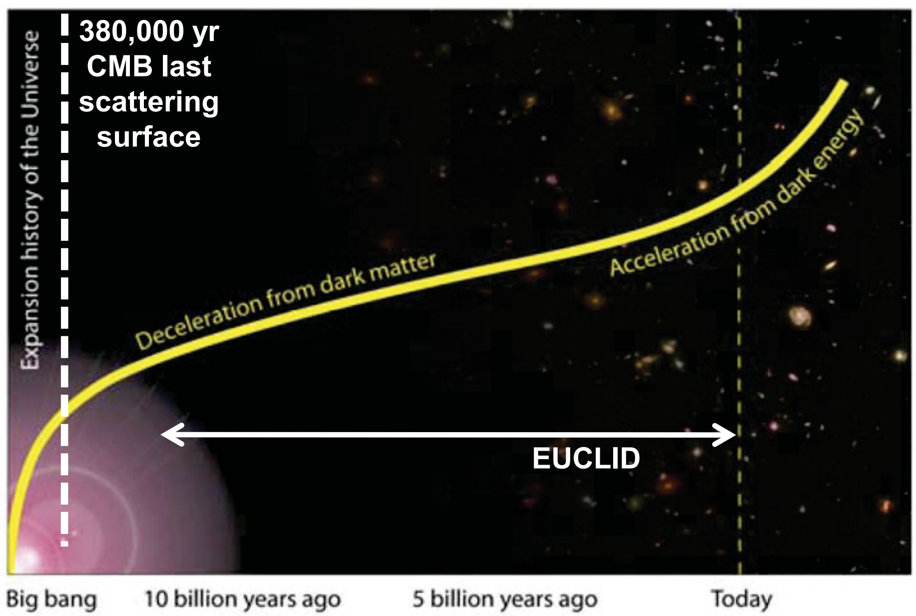
Jason Rhodes (Jet Propulsion Laboratory, California Institute of Technology)

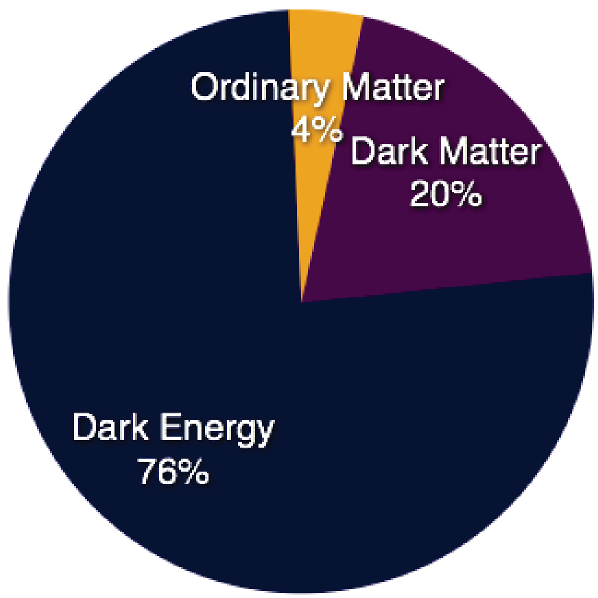
Open Questions in Cosmology

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

    → Euclid's Primary Science Objectives

    → Legacy science





Euclid concept

- 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: 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
- Synergy with ground based surveys
- Legacy science for a wide range of areas in astronomy
- Survey Data public after one year

Euclid goals

Understand the nature of Dark Energy and Dark Matter by:

•Measuring the DE equation of state parameters w_0 *and* w_a to a precision of 2% and 10%, respectively, using both expansion history and structure growth.

•Measuring the growth factor exponent γ with a precision of 2%, enabling to distinguish General Relativity from the modified-gravity theories

•Testing the Cold Dark Matter paradigm for structure formation, and measure the sum of the neutrino masses to a precision better than 0.04eV when combined with Planck.

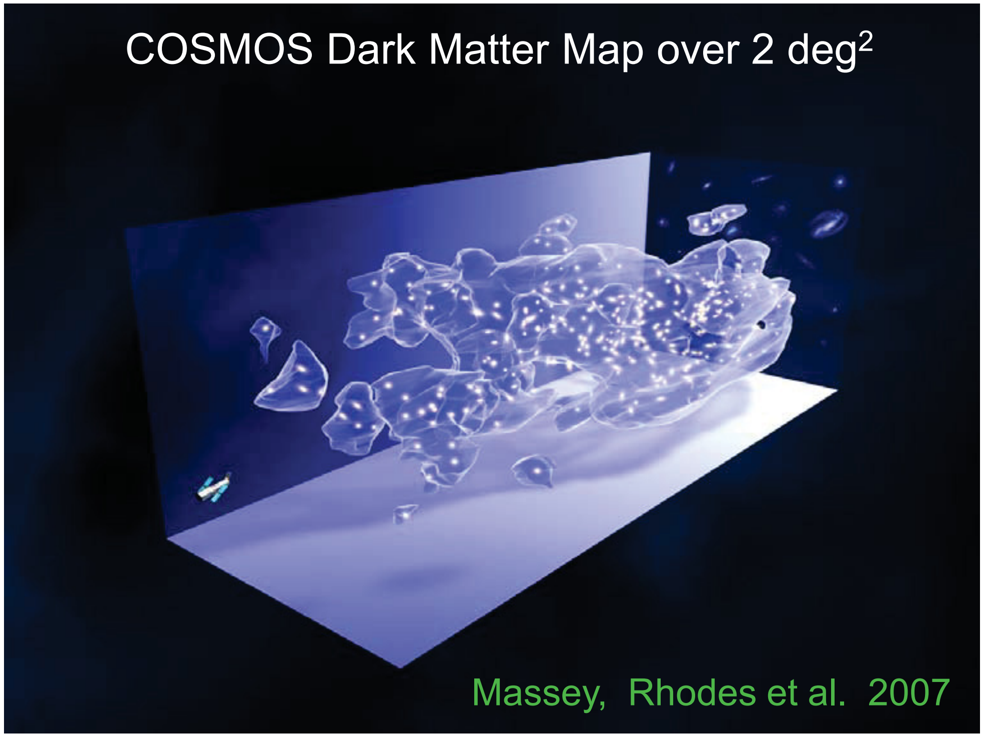
•Improving by a factor of 20 the determination of the initial condition parameters compared to Planck alone.

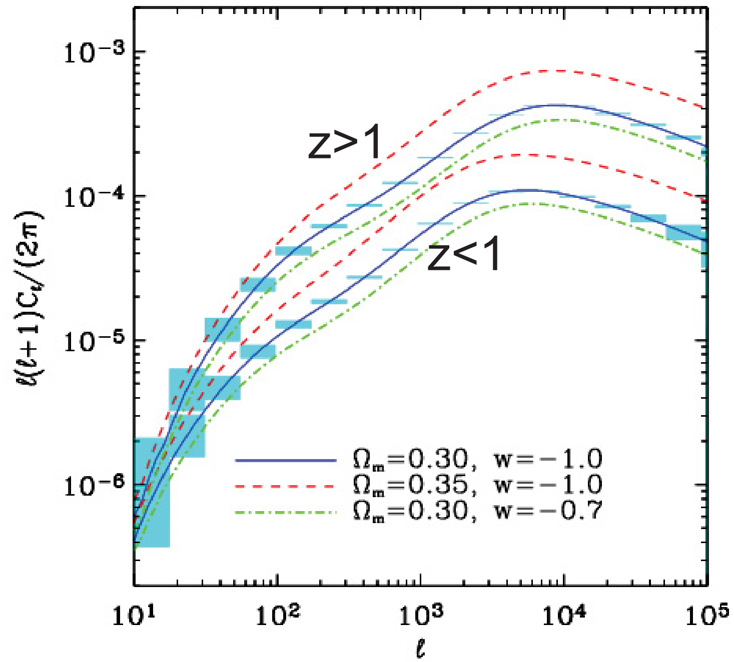
Weak Gravitational Lensing

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

$\rightarrow$ Need measurements of galaxy shape and photometric redshifts





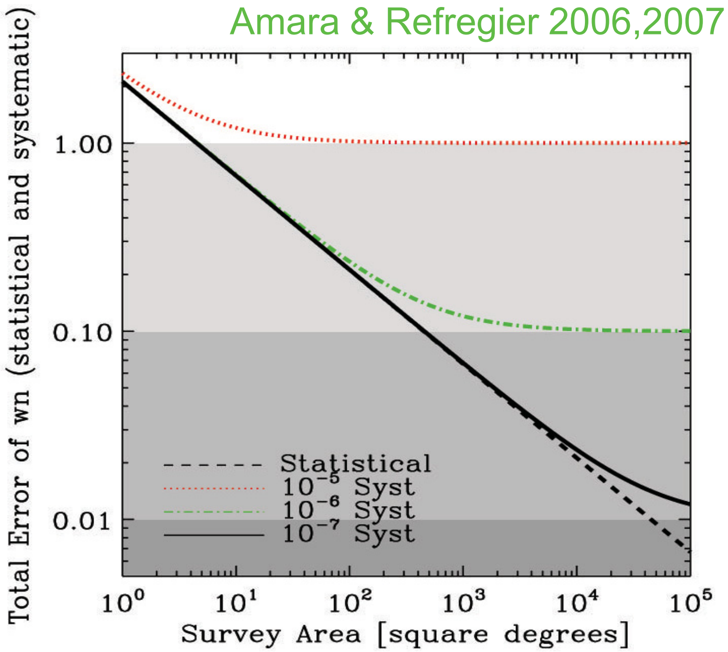
Requirements for Weak Lensing

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

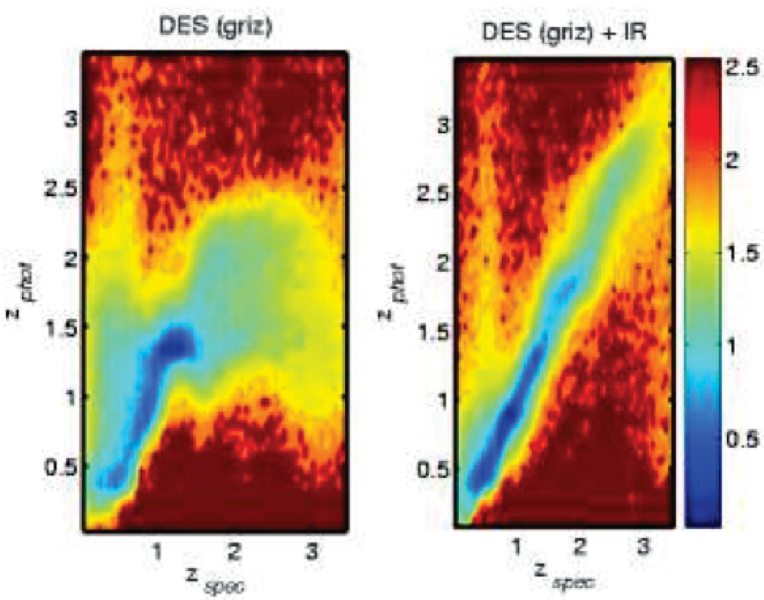
Redshift bins: good photo-z for redshift binning and intrinsic alignments → need deep NIR photometry

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

Amara & Refregier 2006,2007

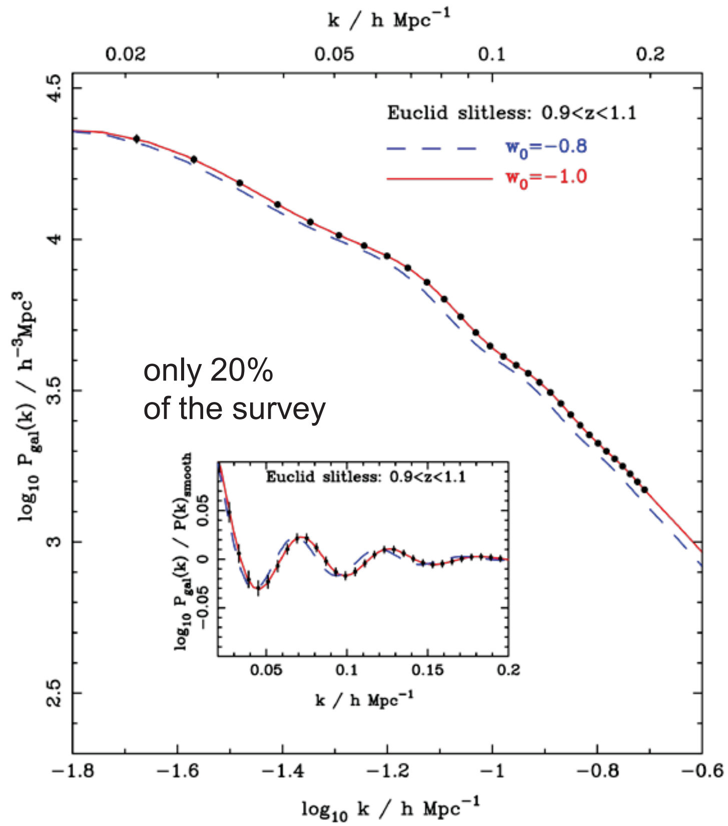


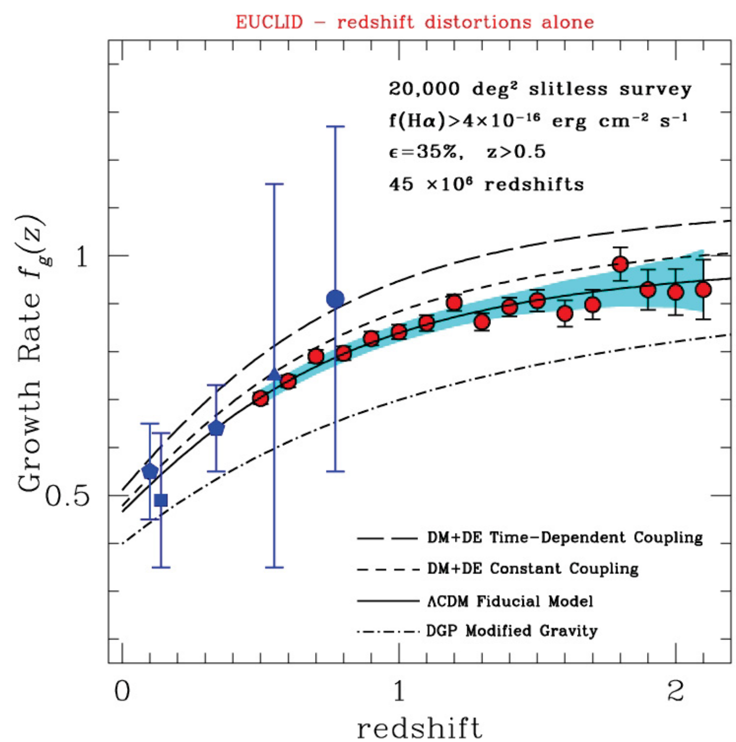
Abdalla et al. 2007



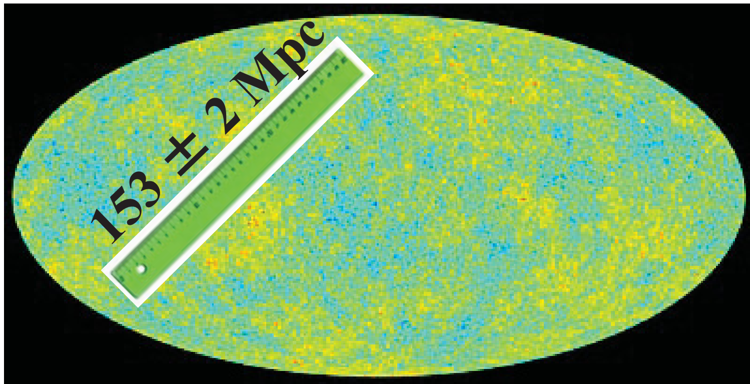
Galaxy Clustering Survey

- 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 (RSD) to constrain Dark Energy and Modified Gravity



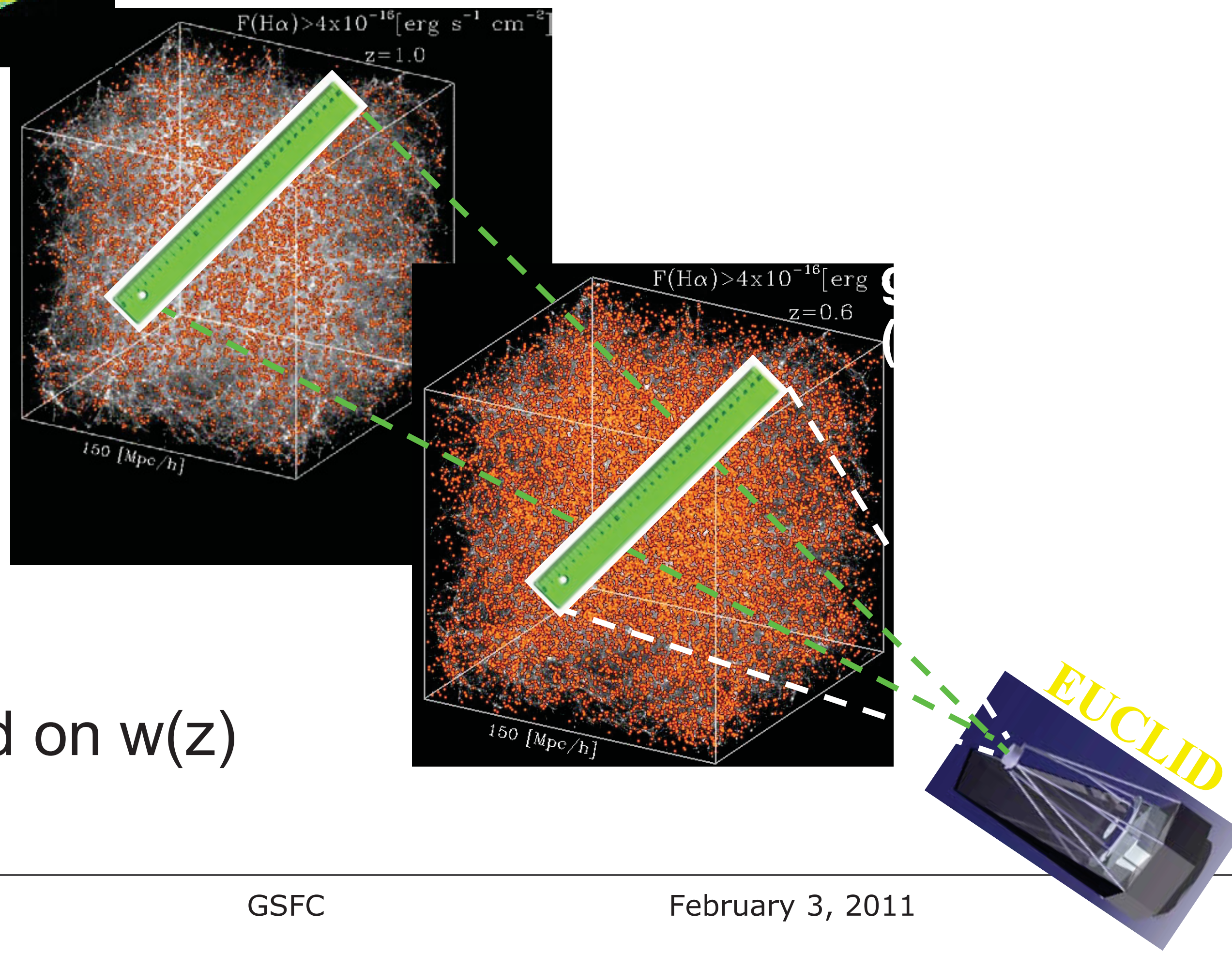


Baryonic Acoustic Oscillations



galaxies (z≈1)

CMB (z≈1000)



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

Euclid Mission Baseline

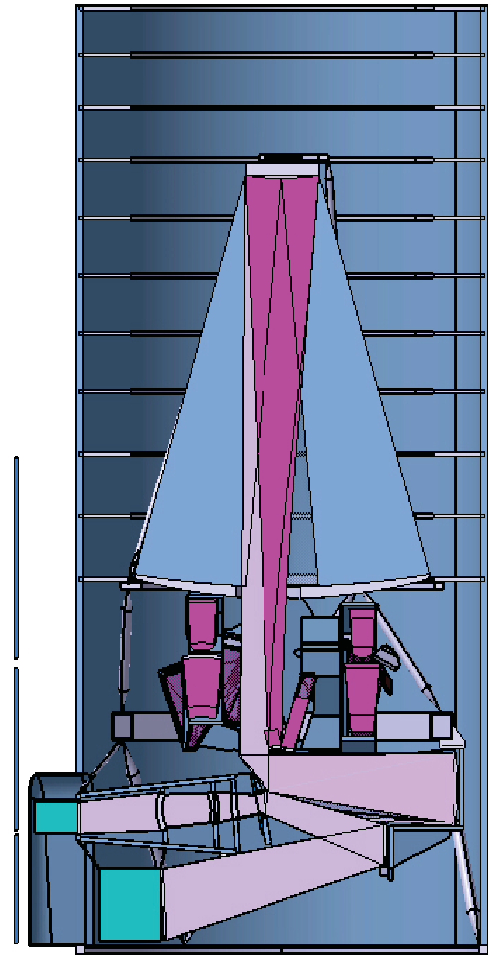
Mission elements:

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

– VIS: Visible imaging channel: 0.5 deg^2, 0.10'' pixels, 0.16'' PSF FWHM, broad band R+I+Z (0.5-0.9mu), 36 CCD detectors, galaxy shapes

– NISP: NIR channel: 0.5 deg^2, 12 HgCdTe detectors, 1-2mu:

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



Euclid Surveys

Wide Survey: 20,000 deg^2

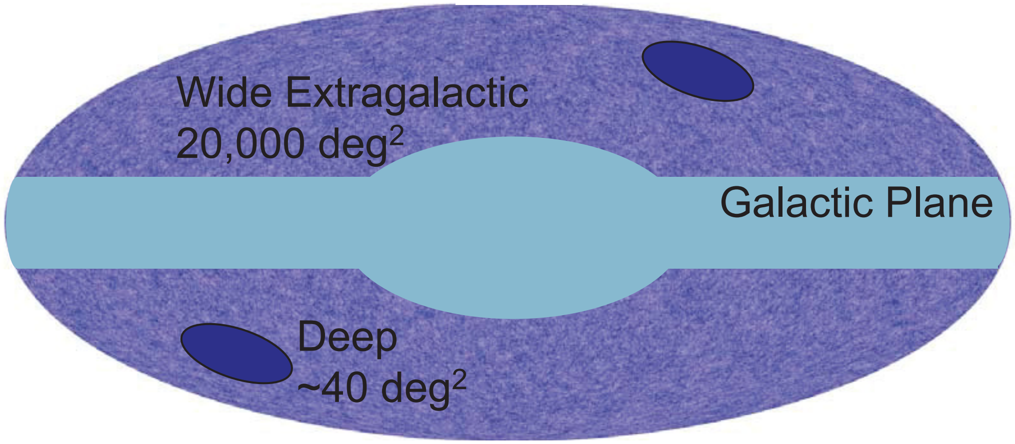
- Visible: Galaxy shape measurements fro 2×10^9 galaxies to $RIZ_{AB} \leq 24.5$ (AB, 10σ) at 0.16" FWHM, yielding 30-40 resolved galaxies/amin^2, with a median redshift $z \sim 0.9$
- NIR photometry: Y, J, H ≤ 24 (AB, 5σ PS), yielding photo-z's errors of 0.03-0.05(1+z) with ground based complement (PanStarrs-2, DES. etc)
- Spectroscopy: redshifts for 40×10^6 galaxies with emission line fluxes $>4 \times 10^{-16}$ ergs/cm^2/s at 0<z<2 (slitless)

Deep Survey: 40 deg^2

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

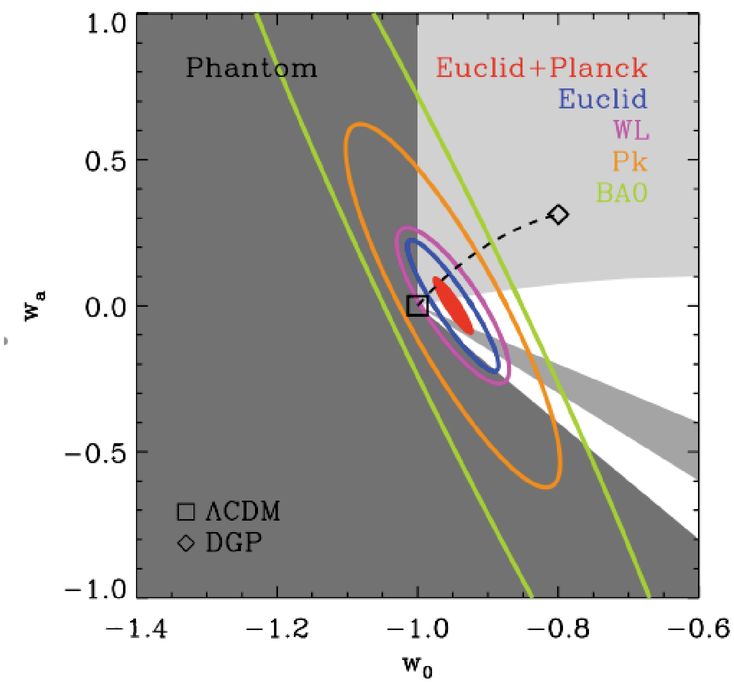
Possible additional Galactic surveys:

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



Impact on Cosmology

	Δw_p	ΔW_a	$\Delta\Omega_m$	$\Delta\Omega_\Lambda$	$\Delta\Omega_b$	$\Delta\sigma_8$	Δn_s	Δh	DE FoM
Current+WMAP	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	-
Weak Lensing	0.03	0.17	0.006	0.04	0.012	0.013	0.02	0.1	180
Imaging Probes	0.018	0.15	0.004	0.02	0.007	0.009	0.014	0.07	400
Euclid	0.016	0.13	0.003	0.012	0.005	0.003	0.006	0.020	500
Euclid +Planck	0.01	0.066	0.0008	0.003	0.0004	0.0015	0.003	0.002	1500
Factor Gain	13	>15	13	5	4	17	4	7	150



Euclid Imaging 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)

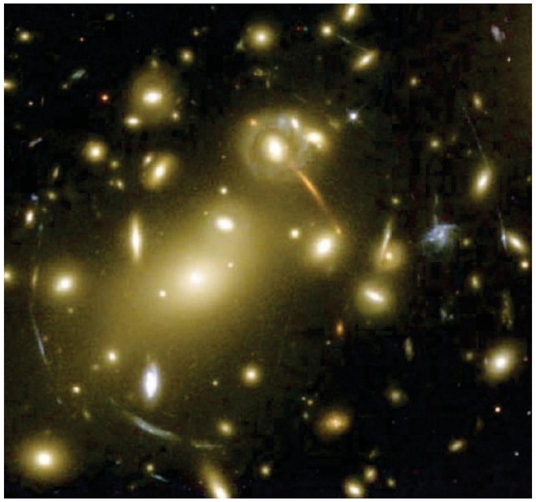
Initial Conditions: constrain shape of primordial power spectrum, primordial non-gaussianity

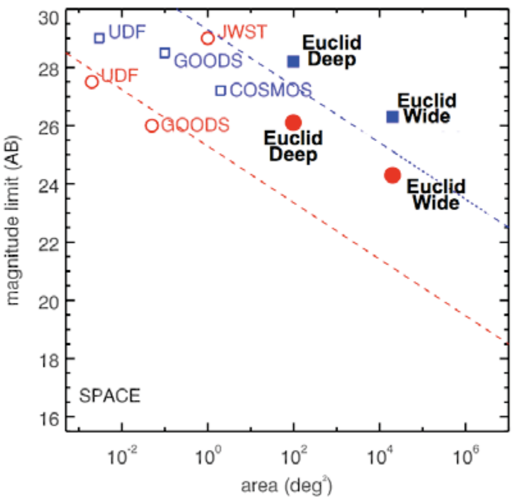
Gravity: test GR by reaching a precision of 2% on the growth exponent γ ($d\ln\delta_m/d\ln a \propto \Omega_m^\gamma$)

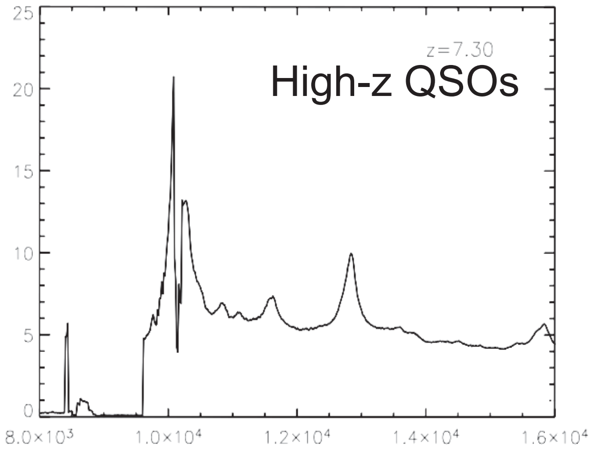
→ Uncover new physics and map LSS at 0<z<2: Low redshift counterpart to CMB surveys

Legacy Science

- Unique legacy survey: 2 billion galaxies imaged in optical/NIR to mag 24, 70 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, Erosita, GAIA, DES, Pan-STARSS, LSST, etc
- All data publicly available through a legacy archive

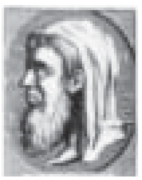






Project Status

- 2004: Dark Universe Mission proposed as a Theme to ESA's Cosmic Vision programme
- 2006: Recommendation of ESO/ESA Working Group on Fundamental Cosmology
- Oct 2007: DUNE and SPACE jointly selected for an ESA Assessment Phase
- May 2008: Validation of the merged concept *Euclid* by the ESA AWG



- Sept 2008: Recommendation from Astronet Infrastructure Roadmap report
- Sept 2008-Sept 2009: Assessment study phase
- 2010-2011: Definition phase
- March-May 2010: Baseline optimisation (incl. merging of NIP and NIS)
- April 2010: Formation of single Euclid Consortium
- July 2010: Definition phase AO (+ ongoing discussions with NASA)
- December 2010: NASA Call for 2 US Euclid Science Teams
- February 2011: Formation of Euclid Science Team
- **Sept/Oct 2011: M1/M2 Cosmic Vision Selection**
- 2012-2017: Implementation phase
- 2017-2018: ESA launch of the Cosmic Vision M1/M2 missions

Organization

•Consortium lead is Alexandre Refregier

•ESA provides spacecraft, telescope, launch, some data processing

•Euclid Consortium (EC) provides instruments, some data processing, science

•Contributions from Austria, France, Germany, Italy, Netherlands, Norway, Spain, Switzerland, UK

•Strong US participation since DUNE/Space including Rhodes and Wang

•Baseline mission assumes 20% US contribution for equivalent science return, but has backup plan if US does not participate

•10 member Euclid Science Team will be formed in one month, possibly with US scientists