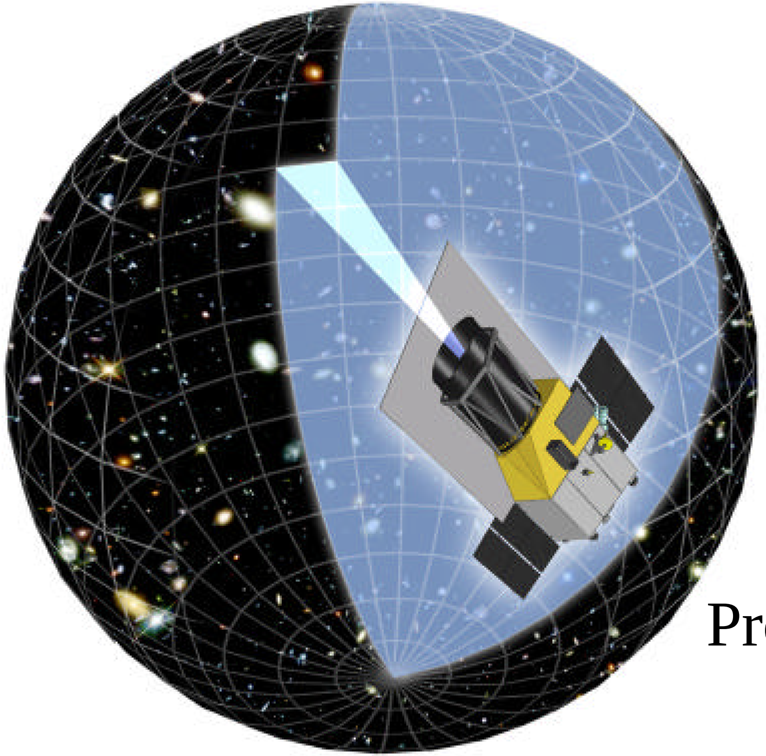
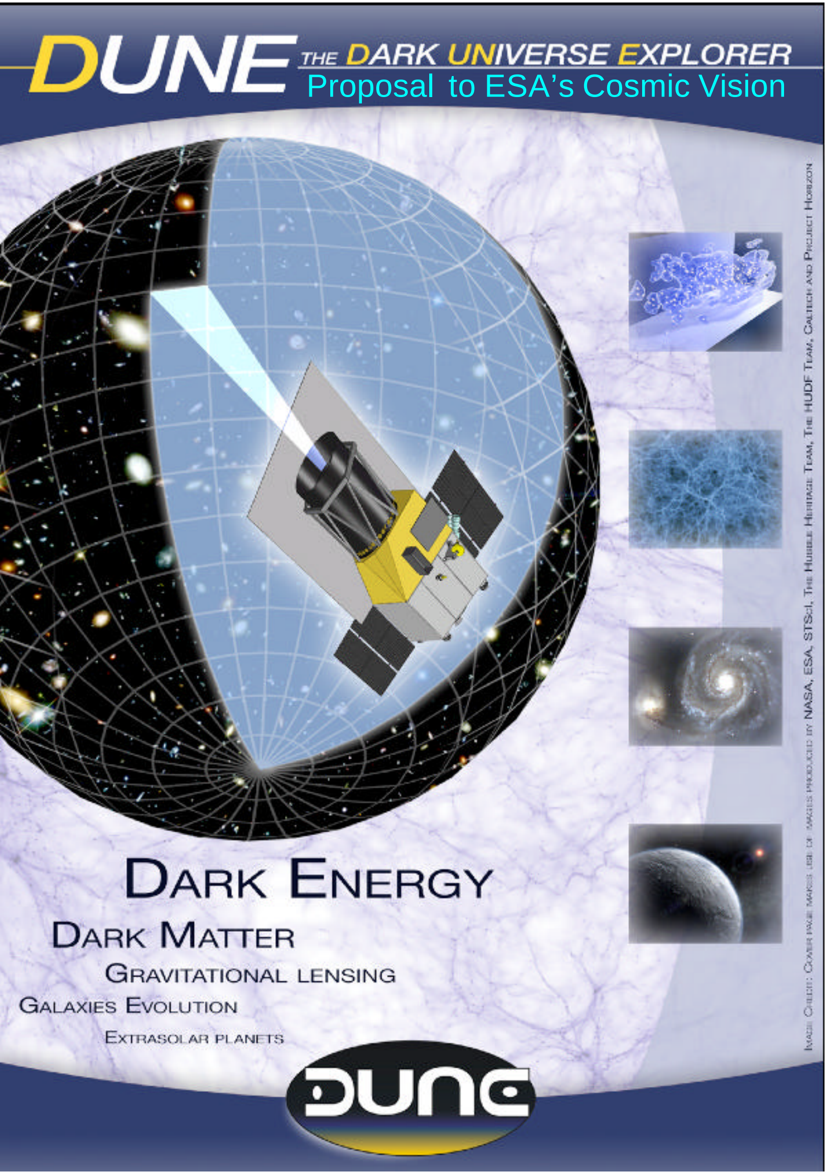
DUNE: the Dark UNiverse Explorer



Nabila Aghanim
(IAS Orsay)
for the DUNE Collaboration

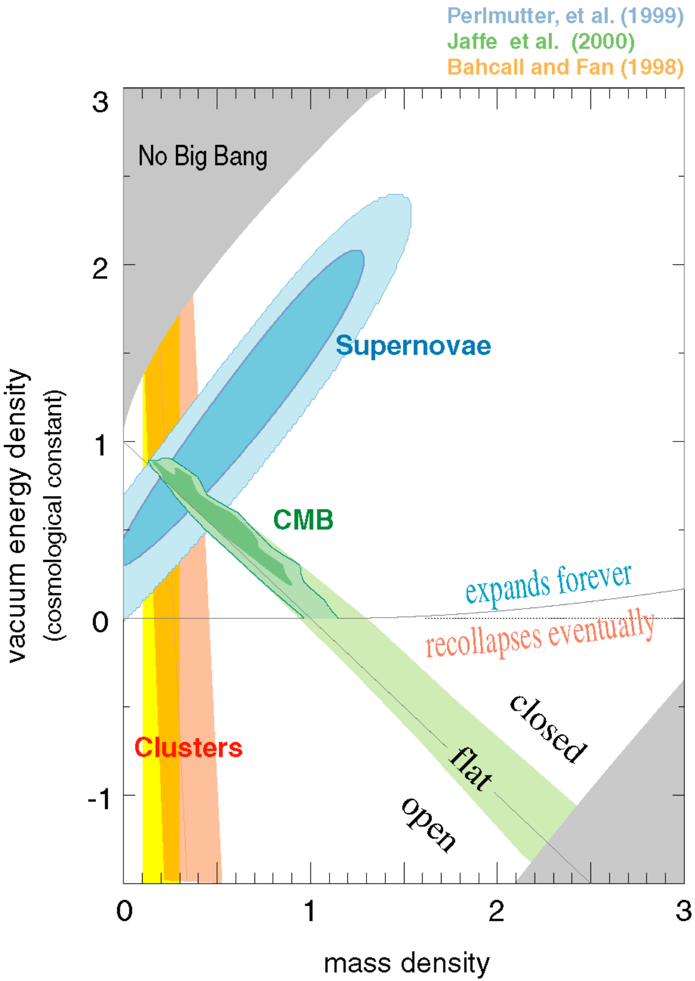
Proposed to ESA's Cosmic vision

Project status



- 2004: Dark Energy proposed as a theme for ESA's Cosmic vision
- 2006-2007: ESO-ESA WG, DETF and Astronet reports

- June 2007: Proposed to ESA's Cosmic Vision as M-class mission, Support from ESO and NASA
- Oct 2007: DUNE selected jointly with SPACE as one of the mission concept study by ESA
- May 2008: New merged concept ***Euclid*** presented to the AWG



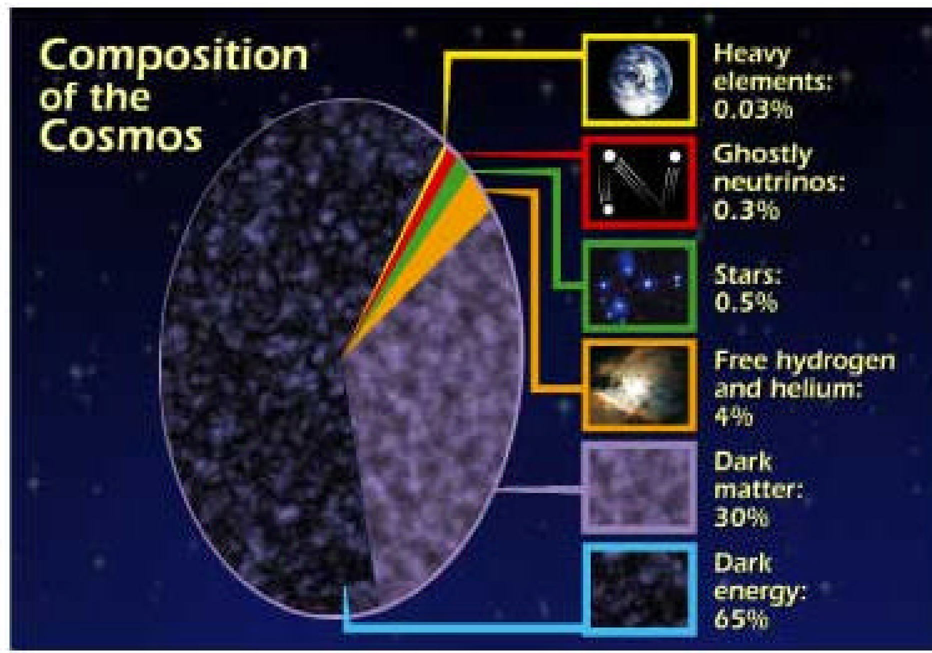
Outstanding questions:

- nature of the dark energy
- nature of the dark matter
- initial conditions (inflation?)

Gravity

→Primary science goals for DUNE

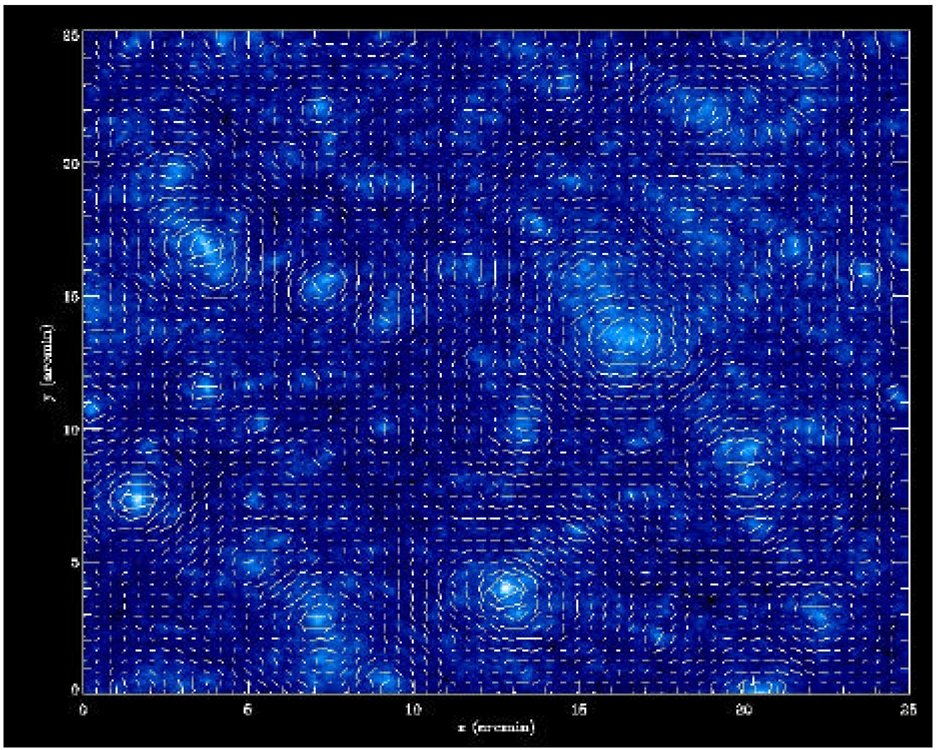
DUNE probes all sectors of the cosmological model



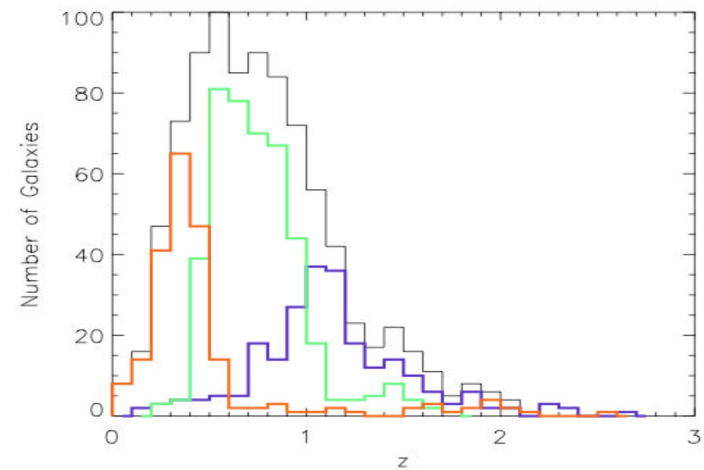
Weak Gravitational Lensing

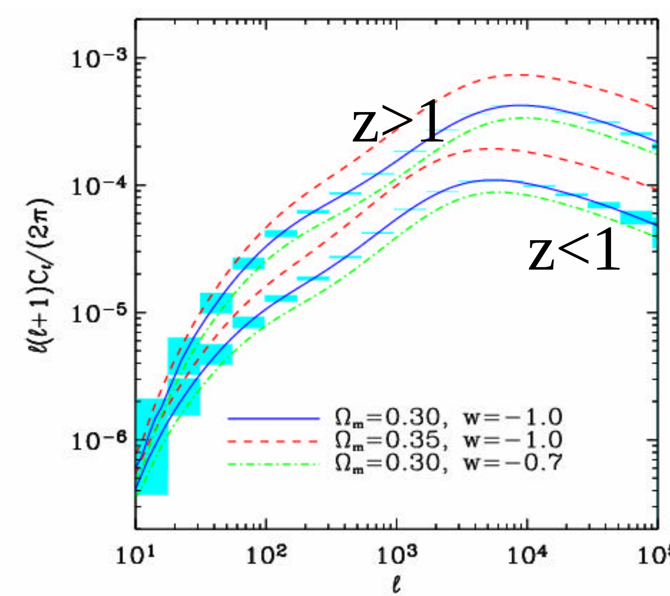
- WL: statistically most powerful probe for Dark Energy (Cf. DETF, ESO-ESA WGFC)
- WL probes both geometry and structure growth
- WL provides a map of the Dark Matter

•⟶ Central probe for DUNE



Weak Lensing tomography





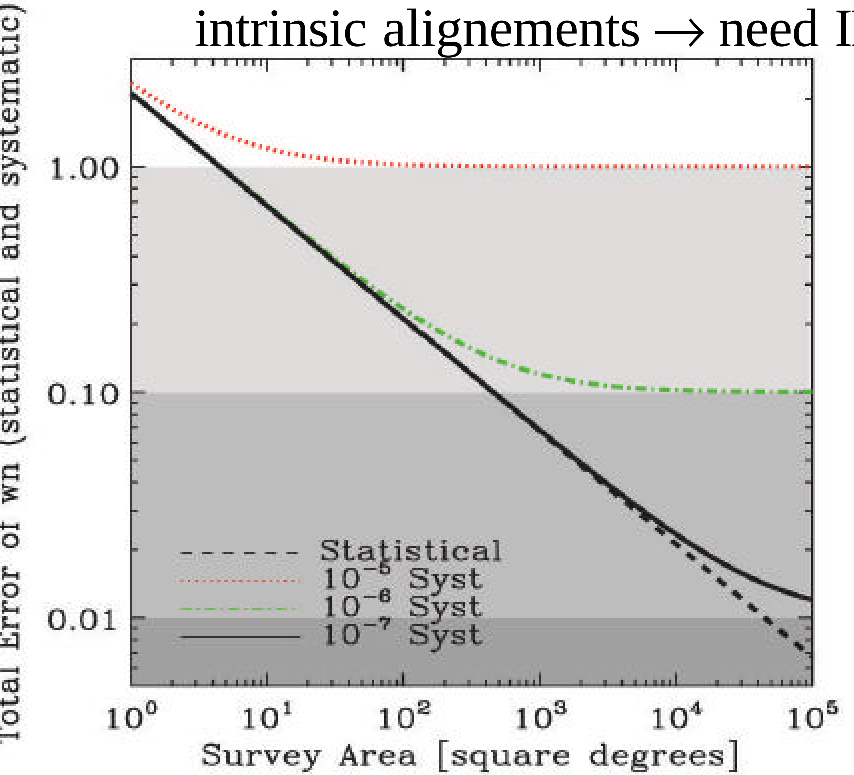
Jain et al. 1997

Requirements for Weak Lensing

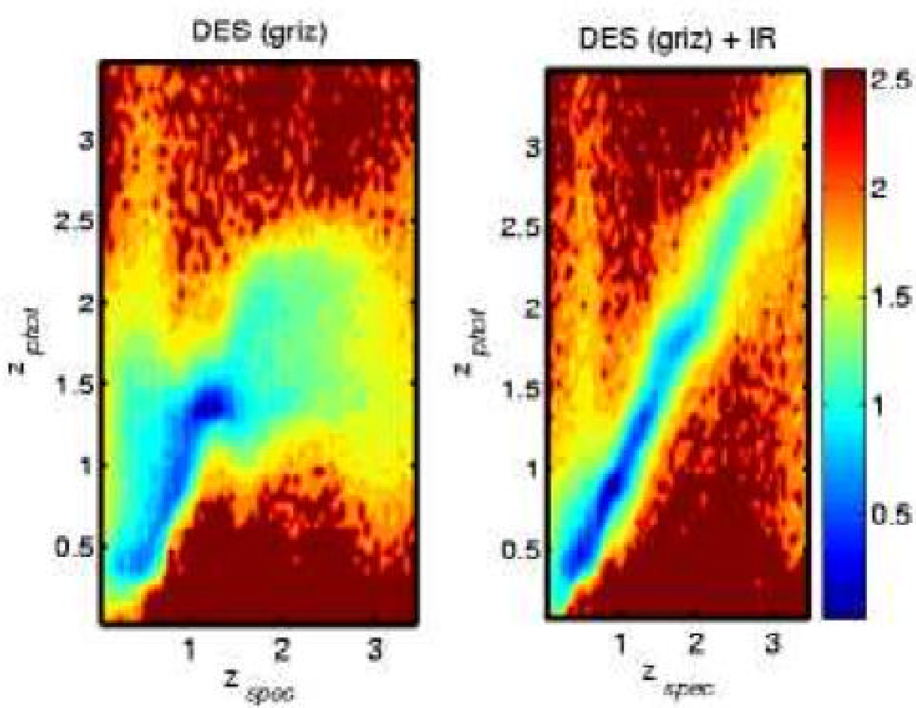
Statistics: optimal survey geometry: wide rather than deep for a fixed survey time, → need 20,000 deg^2 to reach ~1% precision on w

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

Redshift bins: need good photo-z to make redshift bins and to correct for intrinsic alignements → need IR

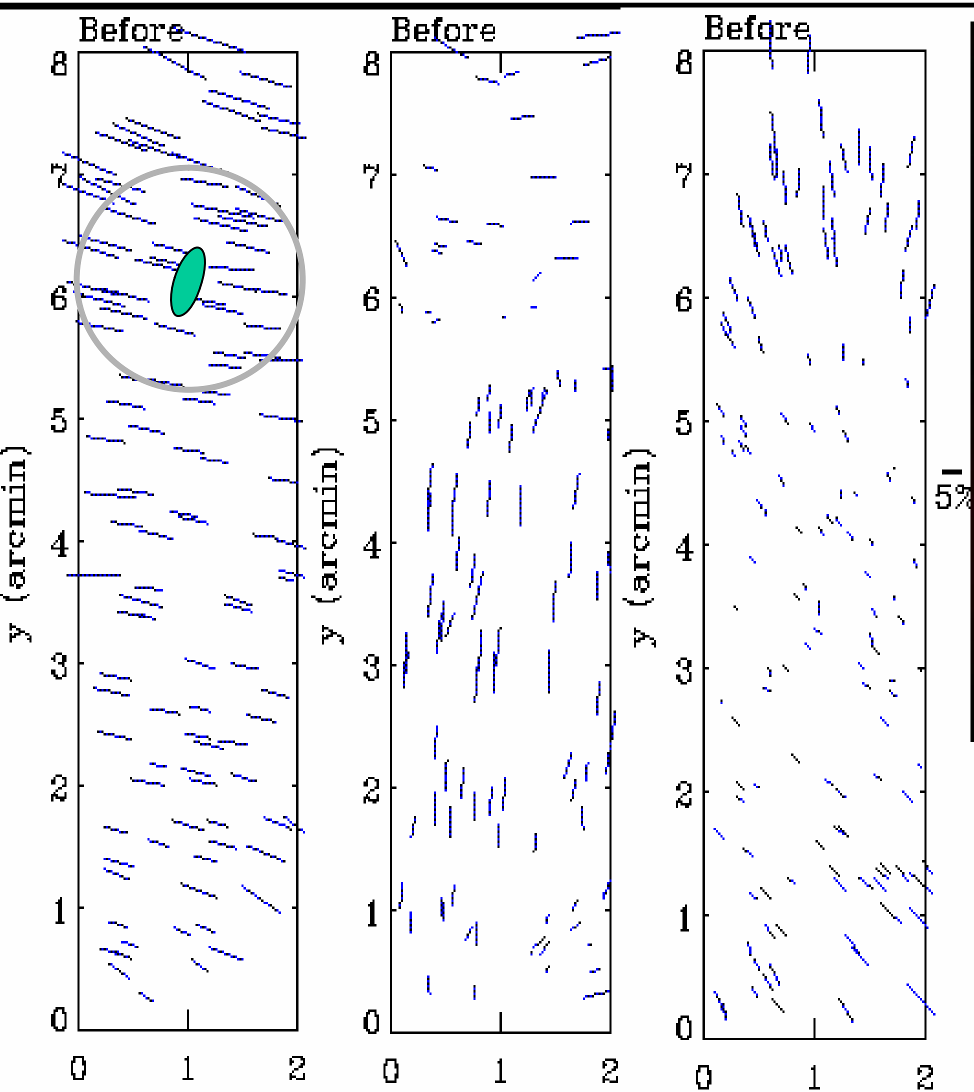


Amara et al. 2007

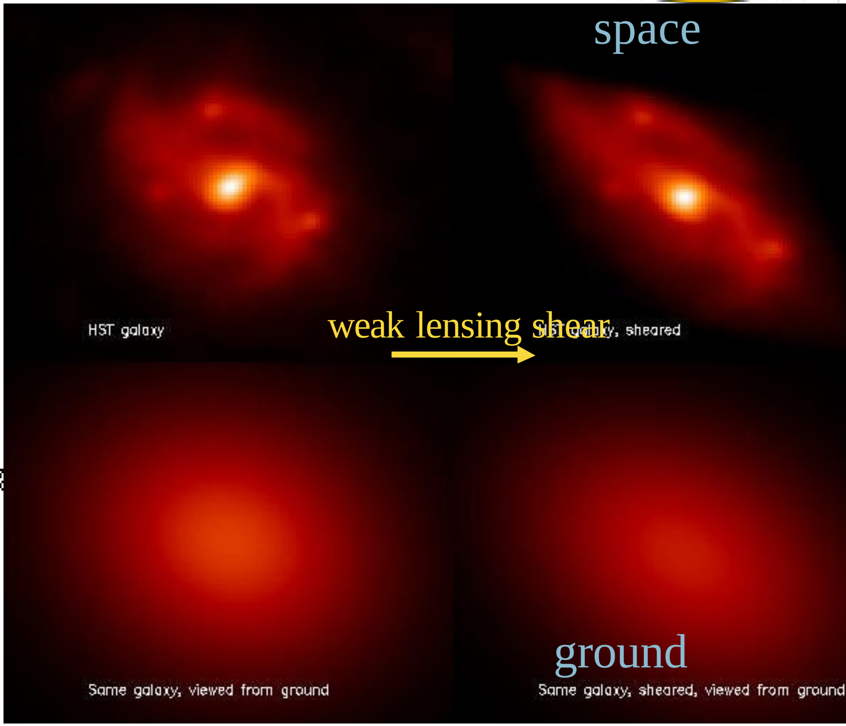


Abdalla et al. 2007

Advantages of Space



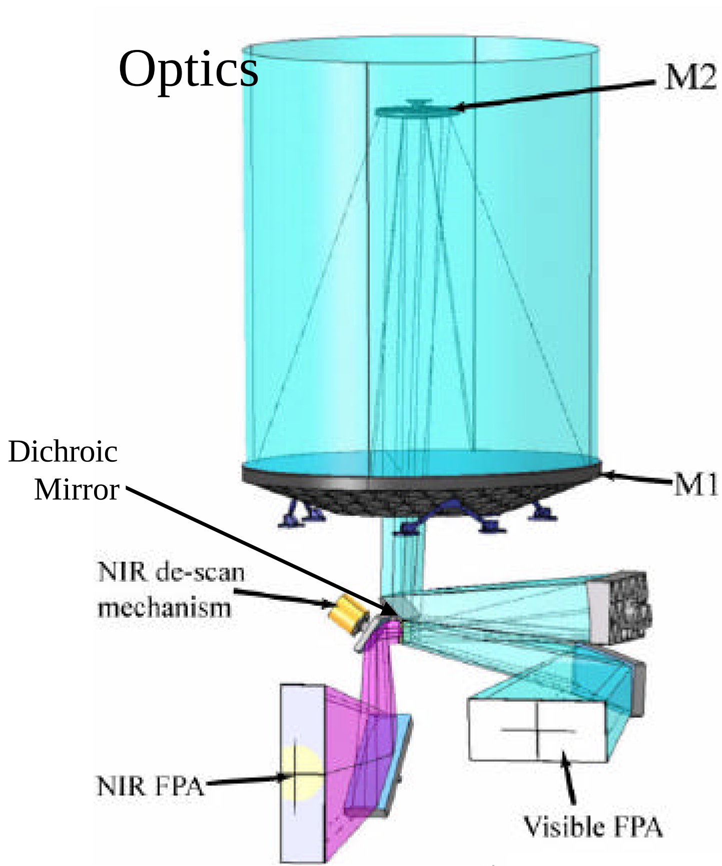
PSF calibration and deconvolution



Space:

- small PSF: larger number density of resolved galaxies, smaller sensitivity to systematics (at fixed depth)
- Stable PSF: → lower residual systematics from better calibration with finite number of stars
- deep NIR photometry: better photo-z's

Mission Baseline



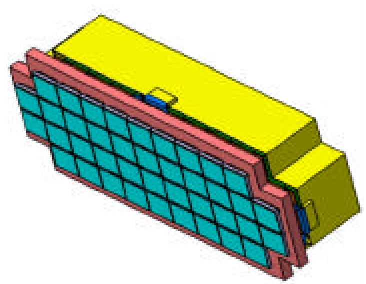
Mission baseline:

- 1.2m telescope
- Visible: 0.5 deg^2, pixels 0.10'', shapes, band: broad R+I+Z, e2v CCDs
- NIR: 0.5 deg^2, pixels 0.15'', photometry, bands: Y,J,H, Teledyne HgCdTe
- Dichroic Mirror
- PSF FWHM 0.23'', 2.2 pix/FWHM (vis)
- GEO (or HEO) orbit with Soyuz Launch
- 4-year mission

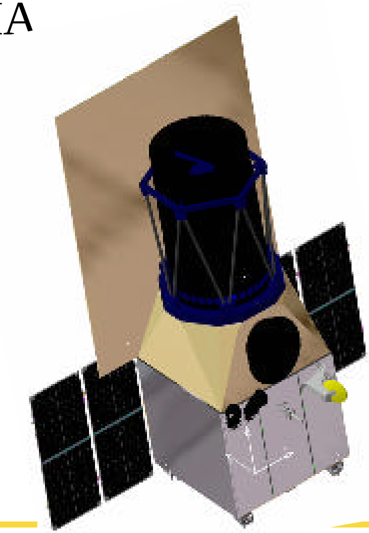
Requirements: Tight control of systematics

→ Synergy with GAIA

NIR Focal Plane



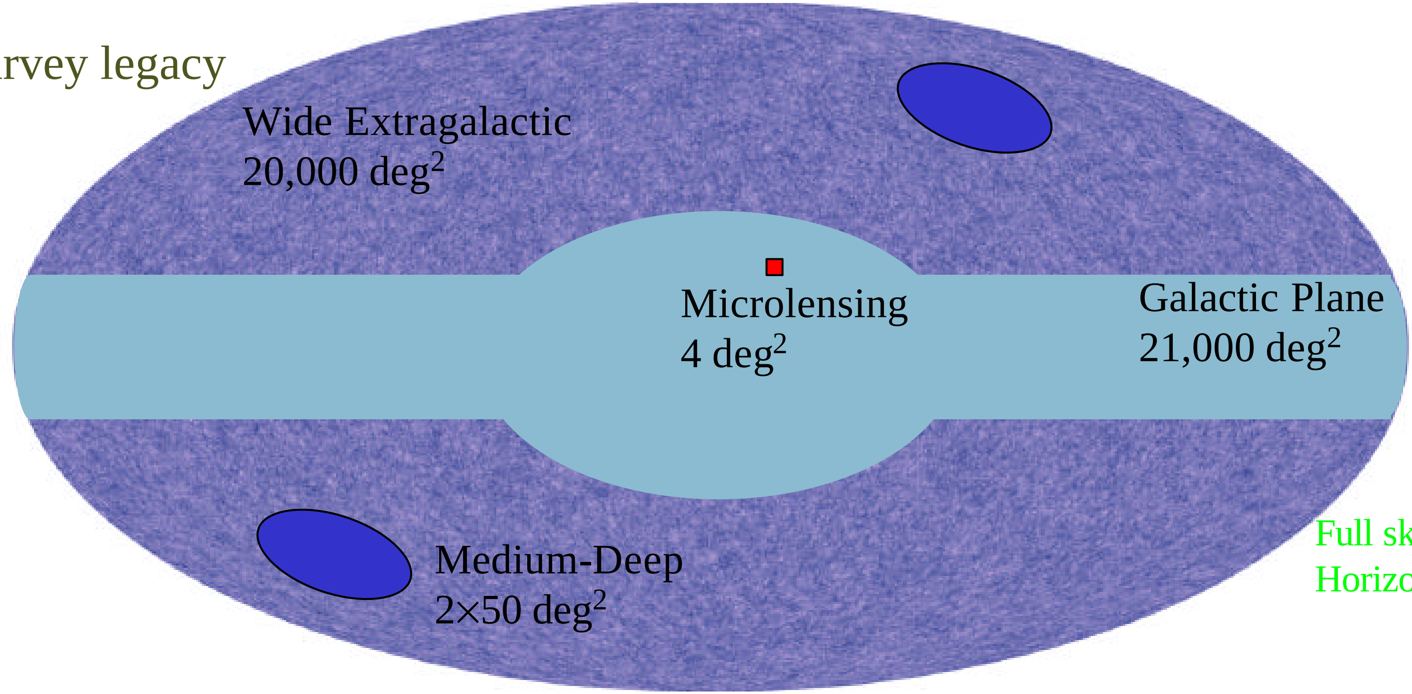
Visible Focal Plane



DUNE Surveys

- DUNE Extragalactic All-Sky Survey: 20,000 deg^2, |b|>30^o, R+I+Z=24.5 (10σ ext.), Y,J,H=24 (5σ, PS), 40 WL galaxies/amin^2, z_m~1, photo-z with ground-based complement, 3 years
- Medium Deep Survey: 2×50 deg^2, R+I+Z=26.5 (10σ extended), Y,J,H=26 (5σ, PS), 6 months
- DUNE Galactic Plane Survey: 21,000 deg^2, |b|<30^o R+I+Z=23.8, Y,J,H=22 (5σ, PS), complete 4π coverage, 3 months
- Microlensing Survey (DUNE-ML): 4 deg^2 in the bulge, visited every 20 minutes over 3 months (Y,J,H~22 per visit), 3 months

Unique 4π survey legacy



Full sky kappa m
Horizon project

Weak Lensing Power Spectrum Tomography

DUNE Wide Survey: 20,000 deg², 40 galaxies/amin², z~1, ground-based complement for photo-z's (PanSTARRS1 (north) and DES (south)), 3 year WL survey

WL power spectrum for each z-bin

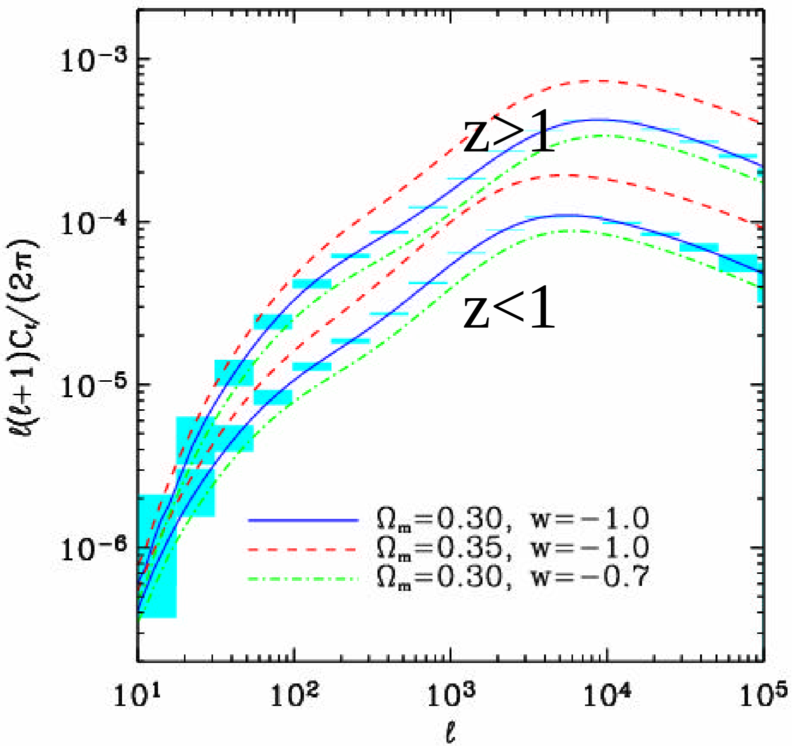
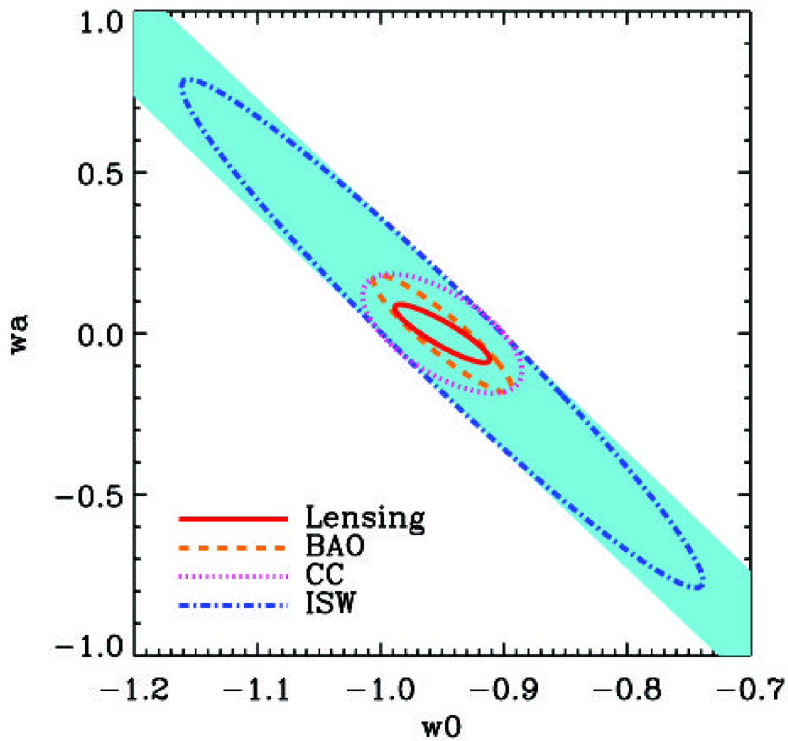
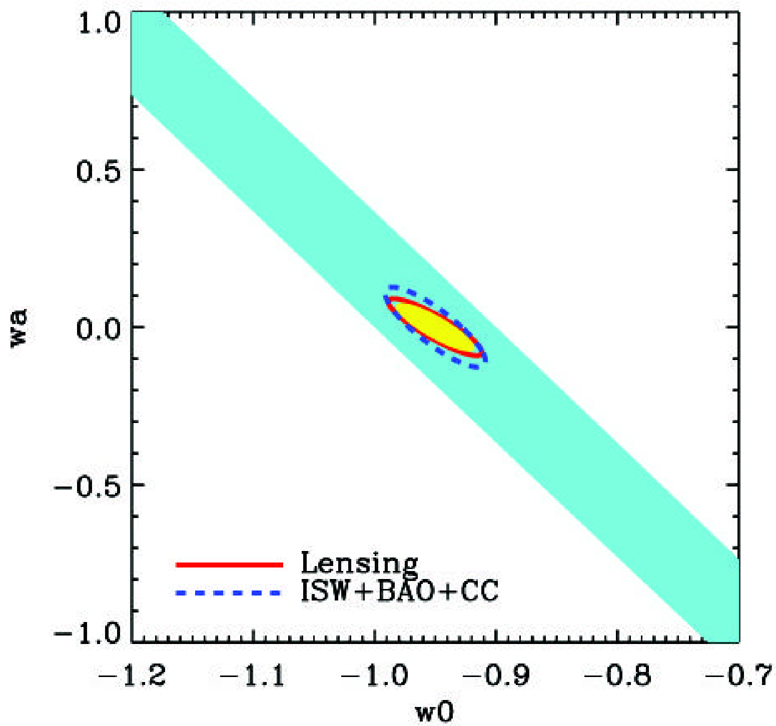


image simulations from 3 groups

Complementary probes for DUNE:

- Baryon Acoustic Oscillations (photo-z based)
- Galaxy Cluster counts (40,000 mass selected clusters)
- Integrated Sachs Wolfe Effect (cross correlation with CMB)





Overall Impact on Cosmology

	DE FoM	Dark Energy			Matter Content		Initial Conditions	
		Δw_n	Δw_a	$\Delta\Omega_v$	$\Delta\Omega_m$	$\Delta\Omega_b$	$\Delta\sigma_8$	Δn_s
WMAP 6	0.13	0.6	13	0.07	0.06	0.008	0.14	0.03
Planck	12	0.03	2.5	0.0036	0.006	0.0009	0.031	0.0037
DUNE Lensing	400	0.02	0.12	0.007	0.004	0.1	0.006	0.011
DUNE + Planck	1600	0.011	0.056	0.0018	0.002	0.0006	0.0020	0.0031

DUNE will challenge all the sectors of the Cosmological model:

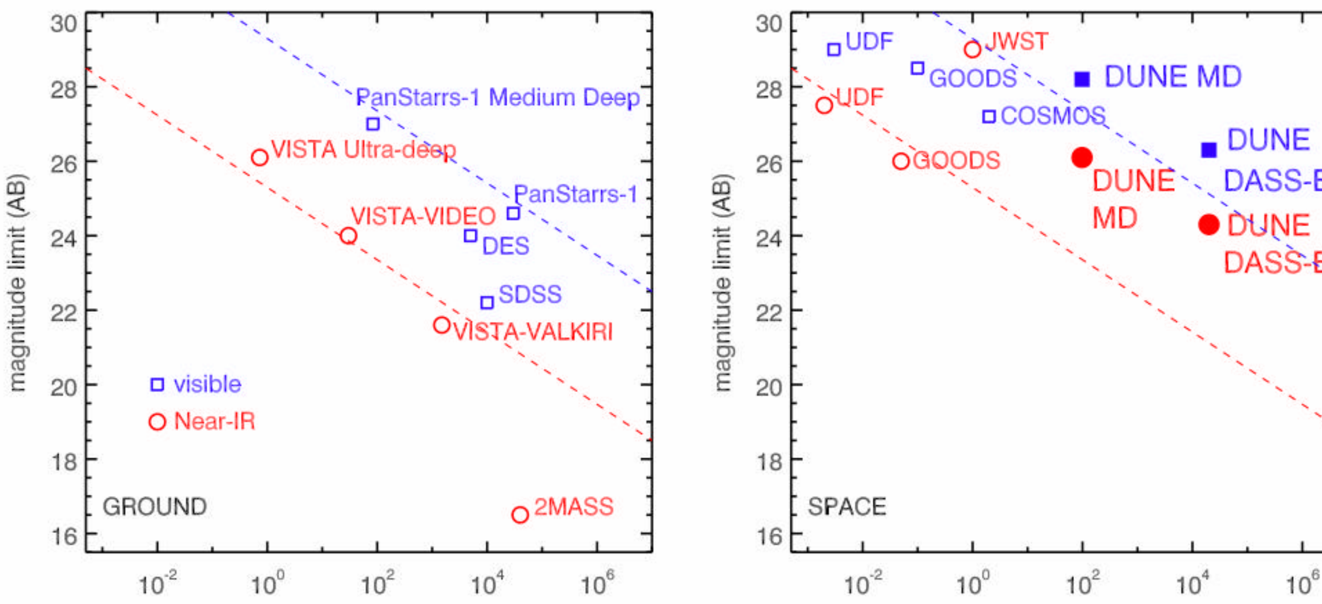
- Dark Energy: w_n and w_a with an error of 2% and 10% respectively
- Dark Matter properties: test of CDM paradigm, precision of 0.04eV on sum of neutrino masses (with Planck)
- Initial Conditions: constrain amplitude, slope and higher order parameters of primordial power spectrum, constrain primordial non-gaussianity
- Gravity: Distinguish GR from simplest modified Gravity theories 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

Legacy Surveys for Galaxy Evolution

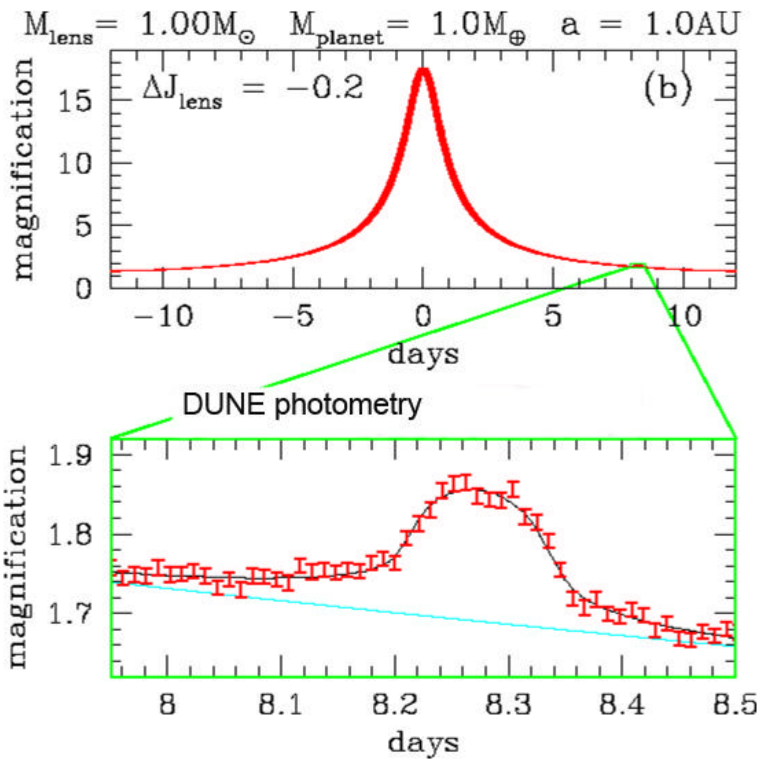
- Map relation between Mass and Light: Correlation of WL mass map with galaxy distribution -> high precision measurement of bias properties b(z, k)
- Constrain drivers of star formation: Galaxy morphology and NIR properties; SNe rate (detection of ~3000 Type Ia and Type II supernovae in MD survey)
- High-z object physics: Using the Ly-dropout technique in MD survey, detect 10^{3-4} star forming galaxies at z~8, 10^{2-3} at z~10; also detect 10^{2-4} quasars at z~7, and 10^{1-3} at z~9
- Galaxy Clusters: NIR detection of several 100 Virgo-like clusters and several 1000 10^{13} M_{sun} at z>2, mass detection of 40,000 clusters at z~0.3-0.7, well matched to eROSITA, XEUS and Planck
- Strong-Lensing systems: ~10^5 Galaxy-galaxy lenses, ~10^3 galaxy-quasar lenses, 5000 strong lensing arcs in clusters.

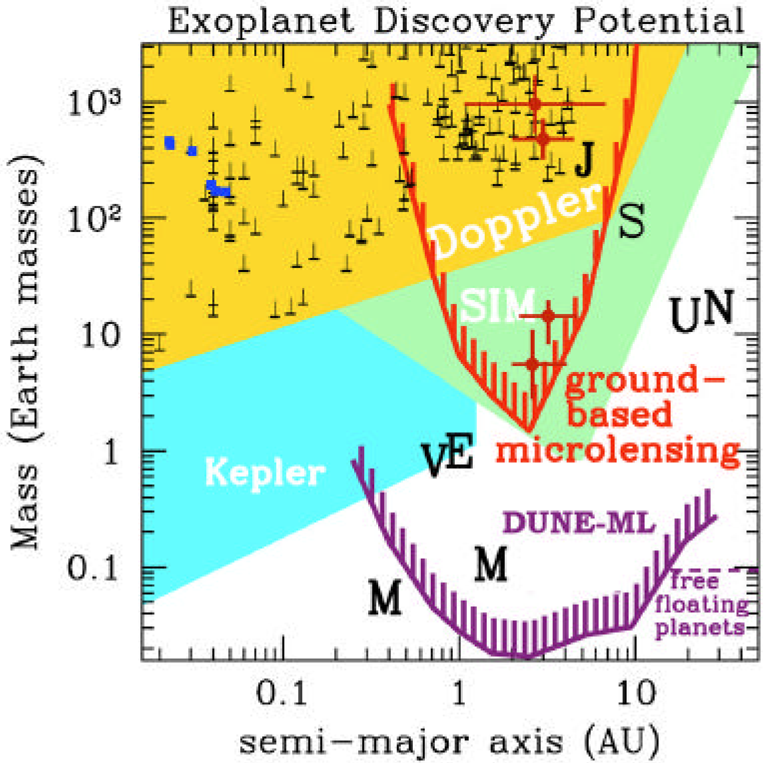
Legacy discovery space of DUNE



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 ~ Earth Mass planets in the habitable zone





DUNE Consortium

France: Alexandre Refregier (PI, CEA Saclay), IAS Orsay, IAP Paris, LAM Marseille, **Germany:** U. Bonn, MPIA Heidelberg, MPE Garching, **Italy:** INAF-OARM, U. Bologna, INAF-OATS, **Spain:** ICE, Barcelona, IFAE Barcelona, CIEMAT Madrid, **Switzerland:** ETH Zurich, EPFL-UniGE, **UK:** IfA Edinburgh, UCL London, MSSL, **USA:** JPL, U. Stanford

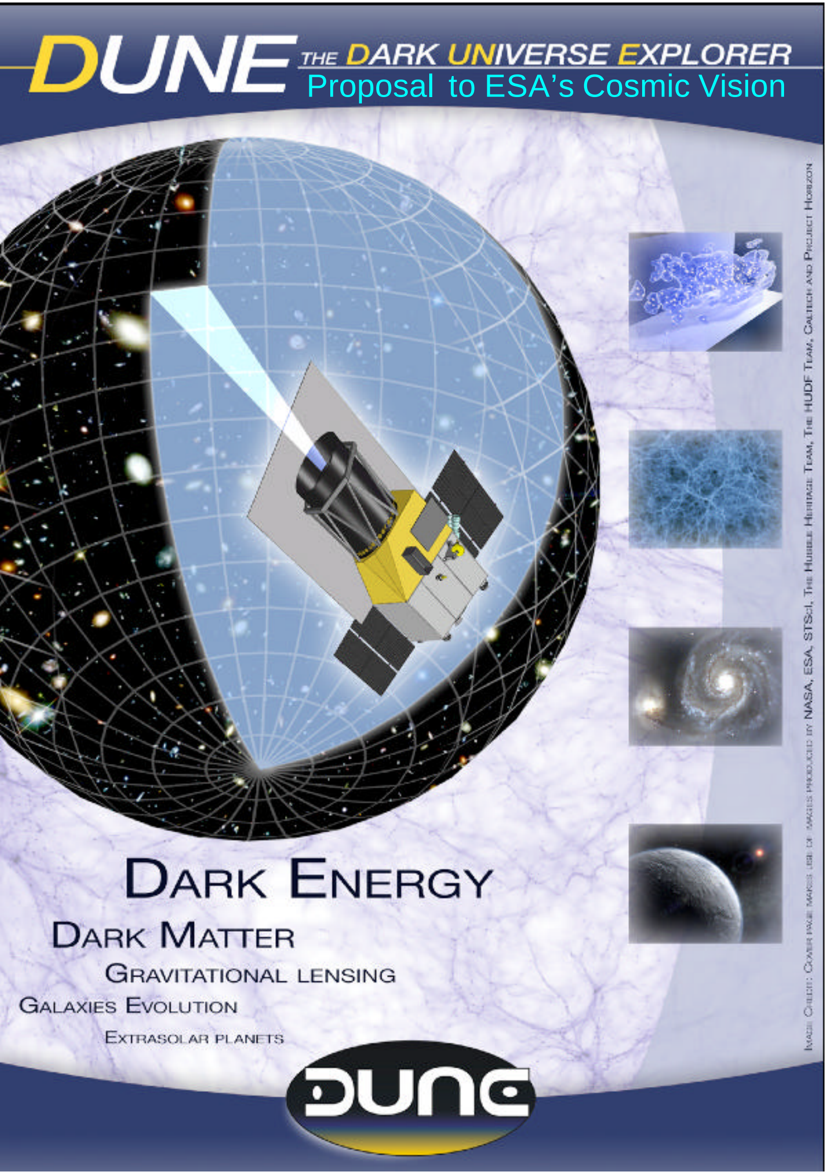
Working Groups:

- **Weak Lensing**
- **BAOs**
- **Clusters/CMB**
- **Strong Lensing**
- **Galaxy Evolution**
- **Galactic Studies**
- **Supernovae**
- **Theory**
- **Photo-z**
- **Image Simulation**
- **Instrument**

Conclusions

- DUNE concept: centered on Weak Lensing, Visible+NIR all-sky coverage, Ground/Space Synergy, heritage from Gaia mission, moderate cost, tight control on systematics
- DUNE optimised to derive decisive constraints on Dark Energy and Dark Matter, and challenge all sectors of the cosmological model from a combination of cosmological probes (WL,BAO, clusters, ISW)
- DUNE will provide unique legacy surveys synergy with Planck, eRosita, XEUS, JWST: 4π survey + deep surveys in visible and NIR for galaxy evolution, search for extra-solar planets
- DUNE is a realisation of the recommendation of the ESO/ESA working group on fundamental cosmology

Project status



- 2005: Pre-study (phase 0) by CNES (V-FP)
- Dec 06-Dec 07: DUNE workshops in Paris, London, and Bonn -> V-FP + NIR-FP
- June 2007: Proposed to ESA's Cosmic Vision as M-class mission, Letters from NASA and ESO
- Oct 2007: DUNE selected jointly with SPACE as one of the mission concept study by ESA

- May 2008: New merged concept ***Euclid*** (V, NIR, NIR spectro) presented to the AWG
- 2008 - 2009: ESA assessment study for a European dark energy mission: ***Euclid***
- 2017: ESA first M-class mission launch