Euclid Imaging Consortium

Institut de Ciències de l’Espai ICE/CSIC
Institut de Física d’Altes Energies IFAE
Centro de Investigaciones Energéticas, MedioAmbientales y Tecnológicas CIEMAT

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Euclid

“Euclid is a high-precision survey mission to map the geometry of the universe”

“Euclid’s visible-NIR imaging and spectroscopy of the entire extragalactic sky will further produce extensive legacy science to the boundaries of the visible universe”
Outstanding Questions in Cosmology

- the nature of Dark Energy
- the nature of Dark Matter
- testing of General Relativity
- the initial conditions
**Euclid Concept**

- High precision survey mission to map the geometry of the Dark Universe
- Optimized for two complementary cosmological probes:
  - Weak gravitational lensing
  - Barion 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
- Legacy science for a wide range of areas in astronomy
- Survey data public after one year
Imaging the Dark Universe with Euclid
Weak Gravitational Lensing

• Map the distribution of Dark Mater in the Universe

• Measures the mass without assumptions in the relation between mass and light

• Very sensitive to Dark Energy through both geometry and growth

• Need measurements of galaxy shapes and photometric redshifts
**Image instrument and control of systematics**

**Image instrument:** optimized for weak lensing

- Visible imaging channel: 0.5deg², 0.10” pixels, 0.16” PSF FWHM, broad band R+I+Z (0.55-0.92µm), CCD detectors, galaxy shapes

- NIR photometry channel: 0.5deg², 0.3” pixels, 3 bands Y,J,H (1.0-2.0µm), HgCdTe detectors, photo-z’s

**Control of systematics**

- Tight requirements on PSF ellipticity and stability, thermo-elastic distortions, attitude control, detector performance

- Instrument performance simulations

- Integrated data handling and calibration chain

**Euclid Imaging Consortium**

- 130 people, 25 institutes, 7 countries
Euclid Imaging Surveys

Wide Survey: Extragalactic sky (20,000 deg² = 2π sr)

- Visible: Galaxy shape measurements to \( RIZ_{AB} \leq 24.5 \) (AB, 10σ) at 0.16° FWHM, yielding 30-40 resolved galaxies/amin², with a median redshift \( z \approx 0.9 \)
- 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)
- Concurrent with spectroscopic survey

Deep Survey: 40 deg² 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 data.

Possible additional Galactic surveys:

- Short exposure Galactic plane
- High cadence microlensing extrasolar planet surveys could be easily added within Euclid mission
Dark Energy & Cosmology with EUCLID Spectroscopy
3-D Evolutionary Map of the Universe

- For each galaxy: RA, Dec, Redshift
  → 3-D map
- Boxes at different redshifts:
  → Evolution

“For free”: Galaxies, AGNs
WHY SPECTROSCOPY?

Spectroscopic redshifts: $\sigma_z = 0.001(1+z)$

WHY FROM SPACE?

- No atmosphere
- $\approx 500x$ less background
- Stable PSF
- Homogeneous data
- Easy to reach $z \approx 2+$
- Clean selection function
- Unbeatable speed
- Multi-probe experiment

WHY NEAR-IR?

- $0.5 < z < 2$ with Hα
- Less dust extinction
- Higher legacy value
Star-forming galaxies
0.5 < z < 2 (Hα)
F_{line} > 4 \times 10^{-18} \text{ erg/s/cm}^2 (H<19.5)
\sigma_z \leq 0.001(1+z)
Redshift success rate \geq 50%
N(gal) = 7 \times 10^7
Sky coverage = 20,000 \text{ deg}^2
Mission duration \leq 5 \text{ years}
Baryonic Acoustic Oscillations (BAO)

- $H(z)$ (radial)
- $D_A(z)$ (tangential)
- $H(z)$ & $D_A(z)$ depend on $w(z)$
$V_{\text{eff}} = 19 \ h^{-3} \ Gpc^3 \approx 75 \times \text{larger than now (i.e. SDSS)}$

$\omega_g, \omega_b = 2\%, \ 17\% \ (\text{with Planck}) \ (\text{FoM} \approx 300)$

FoM(imaging + spectroscopy + Planck) $\approx 1500$

(150x better than now!)
More cosmology with the ENIS dataset

**Redshift Space Distortions**
- Anisotropy of radial vs tangential clustering
- Impossible with photometric redshifts!
- Test of Modified Gravity theories
- Break degeneracies for models with same $H(z)$

**Full Power Spectrum $P(k)$**
- Primordial fluctuations
- Models of inflation
- Complementary to CMB

![Graphs and diagrams showing redshift space distortions and power spectrum](image)

- ENIS slitless
- Only 20% of the survey!
Immense Legacy Value!

- ≈70 million galaxies & AGNs: >1000x more redshifts than now at z ~ 1 and >70x than SDSS!
- Statistical studies with unprecedented statistics
- ≈ 10,000 clusters of galaxies at z < 1
- Clustering and halo statistics
- The largest unbiased survey for high-z QSOs
- Most luminous objects at z > 7 in Deep Survey
- Our Galaxy (ultracool dwarfs, IMF...), +GAIA
- Synergies: VIS/NIR, multi-λ surveys, JWST
DMD "slit" spectroscopy (optional)

- Deeper spectra (H<22)
- All galaxy types (+E/S0)
- Clusters at z>1
- N(gal) = 2x10^8
- 0 < z < 2.5 (Wide Survey)
- V_{eff} = 50 h^3 \text{Gpc}^3
- >10^8 galaxies at 2<z<10 (Deep Survey)
- Extra gain of cosmology & legacy value

Star forming

Euclid
Why EUCLID?

- "The" high precision Dark Energy & Cosmology mission
- Essential and unbeatable synergy of imaging + spectroscopy:
  - control of systematic errors
  - complementary mapping of the same large scale structure
  - complementary tests of Gravitation
  - dark vs luminous matter clustering
- Immense legacy value
- EUCLID (ima+spec) will impact the whole astrophysics and cosmology for decades to come
Telescope (1/2)

- High resolution imaging across a wide waveband, simultaneously with a spectroscopic channel
- Similar fields of view with >0.5 degree$^2$, and focal scale tuned to existing CCD and NIR detectors
- A common design provided by ESA SRE-P for both industries and consortia
- Teams arranged folding to accommodate a compact Payload Module
Telescope (2/2)

- A **1.2m diameter** Korsch-type telescope with diffraction limited imaging performance
- One industry solution is **SiC** (at 150K) passive thermal control
- Complementary approach uses actively controlled **Zerodur** at the maximum temperature (240K) for acceptable internal background
- Stability \(\sim 20\mu m\) on focus required for PSF stability (\(\sim 10's \ mK\))
NIS

- Slitless spectrometer, $R \approx 500$ from 1 to 2 $\mu$m
- Field of View comparable with Imaging Channel (but displaced $\sim 1.5^\circ$)
- 2 pixels/resolution element requires $2 \times 4$ Hawaii detector arrays
- Passive cooled to $\sim 100$K
- Cryogenic lenses and filter wheel with JWST heritage
- Source confusion minimised with grating orientation changed per field dither
Optical Design

- Optical configuration: Three mirror anastigmat (TMA)
- Primary mirror: 1.2m

<table>
<thead>
<tr>
<th></th>
<th>VIS</th>
<th>NIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Focal length</td>
<td>24753mm</td>
<td>12323mm</td>
</tr>
<tr>
<td>F/number</td>
<td>F/20</td>
<td>F/10</td>
</tr>
<tr>
<td>FoV</td>
<td>1.06x0.53deg</td>
<td>1.12x0.55deg</td>
</tr>
<tr>
<td>Pixel scale</td>
<td>0.10”</td>
<td>0.30”</td>
</tr>
<tr>
<td>Effective FoV</td>
<td>0.466 deg2</td>
<td>0.520 deg2</td>
</tr>
</tbody>
</table>
Optical Design

• Three mirrors (M1, M2 & M3) are conic (no aspherical terms) they are common to VIS and NIP

• In addition NIP has four lenses (L1, L2, L3 & L4)
Optical Design Implementation

- Based on three fold mirrors & a dichroic
- VIS: 6 reflections
- NIP: 5 reflections + 5 lenses
Optical Design Implementation

- Based on three fold mirrors & a dichroic
- VIS: 6 reflections
- NIP: 5 reflections + 5 lenses
Optical Design Performance

- VIS is diffraction limited
- VIS no chromatic aberrations
- VIS FWHM PSF 0.16”
- NIP FWHM PSF 13µm
Radiation Evaluation

- Run extensive simulations

<table>
<thead>
<tr>
<th>Band</th>
<th>Object Magnitude AB</th>
<th>Exposure time (s)</th>
<th>Radiometric SNR in 3 exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>R+I+Z</td>
<td>24.5</td>
<td>450</td>
<td>14.3</td>
</tr>
<tr>
<td>Y</td>
<td>24</td>
<td>62</td>
<td>7.1</td>
</tr>
<tr>
<td>J</td>
<td>24</td>
<td>111</td>
<td>7.1</td>
</tr>
<tr>
<td>H</td>
<td>24</td>
<td>61</td>
<td>7.1</td>
</tr>
</tbody>
</table>

AOCS jitter (time serie)  
AOCS jitter (space serie)
Focal Plane Arrays

- VIS: 4x9 = 36 CCDs (4096x4096 12µm pixels)
- NIP: 3x6 = 18 H2RG IR detectors (2048x2048 18µm pixels)
Observational Strategy

- Area 20000 deg² divided in 50 patches of 20deg x 20deg
- Each patch scanned in strips (step and stare)
- Each strip composed of fields
- Fields observed in 4 dithered pattern
Sky Scanning Strategy

- keep sun aspect angle < 30deg, pointing scans orthogonal to the sun direction

<table>
<thead>
<tr>
<th>n°</th>
<th>Phase</th>
<th>Step size / length</th>
<th>Control Schema</th>
<th>Starting time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Step slew</td>
<td>0.5 [deg]</td>
<td>Fast slew manoeuvre coarse control with STR</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Observation</td>
<td>450 [s]</td>
<td>Fine control with FGS</td>
<td>205</td>
</tr>
<tr>
<td>3</td>
<td>Close shutter</td>
<td>10 s</td>
<td>Fine control with FGS</td>
<td>655</td>
</tr>
<tr>
<td>4</td>
<td>1° dithering</td>
<td>100 [arcsec]</td>
<td>Fast slew manoeuvre with STR</td>
<td>665</td>
</tr>
<tr>
<td>5</td>
<td>Observation</td>
<td>450 [s]</td>
<td>Fine control with FGS</td>
<td>785</td>
</tr>
<tr>
<td>6</td>
<td>Close shutter</td>
<td>10 s</td>
<td>Fine control with FGS</td>
<td>1235</td>
</tr>
<tr>
<td>7</td>
<td>2° dithering</td>
<td>100 [arcsec]</td>
<td>Fast slew manoeuvre with STR</td>
<td>1245</td>
</tr>
<tr>
<td>8</td>
<td>Observation</td>
<td>450 [s]</td>
<td>Fine control with FGS</td>
<td>1365</td>
</tr>
<tr>
<td>9</td>
<td>Close shutter</td>
<td>10 s</td>
<td>Fine control with FGS</td>
<td>1615</td>
</tr>
<tr>
<td>10</td>
<td>3° dithering</td>
<td>100 [arcsec]</td>
<td>Fast slew manoeuvre with STR</td>
<td>1625</td>
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<tr>
<td>11</td>
<td>Observation</td>
<td>450 [s]</td>
<td>Fine control with FGS</td>
<td>1945</td>
</tr>
<tr>
<td>12</td>
<td>Close shutter</td>
<td>10 s</td>
<td>Fine control with FGS</td>
<td>2395</td>
</tr>
<tr>
<td>13</td>
<td>Step slew</td>
<td>0.5 [deg]</td>
<td>Fast slew manoeuvre coarse control with STR</td>
<td>2405</td>
</tr>
<tr>
<td>14</td>
<td>Observation</td>
<td>450 [s]</td>
<td>Fine control with FGS</td>
<td>2610</td>
</tr>
</tbody>
</table>
Instrument Design Prescription

- Instrument starts after M3
- composed of COMA, VIS and NIP
- three electronics boxes: PDHU, PMCU & NIP CCU
Thermal Architecture

- Instrument starts after M3
- Composed of COMA, VIS and NIP
- Three electronics boxes: PDHU, PMCU & NIP CCU

Thermal Mechanical interface
Thermal isolation

Radiator

200 K or 150 K

150 K

200 K

120 K

300 K

150 K

200 K

150 K

300 K

Fold Visible

Common Opto Mechanical Assembly

Dichroic

Focal reducer

Shutter

NIR FPA

PEM

Focal reducer

NIR FPA

PEM

150 K
Instrument subsystems

- **VIS**
  - shutter, calibration source, 12 electronics (ROE), 12 power supplies (PSU), 36 CCDs, heaters + sensors for thermal control

- **NIP**
  - filter wheel (FWA), calibration source, 2 electronics (SIDECARS), 18 NIR detectors, 1 control and compression unit (CCU), heaters + sensors

- **Common**
  - Payload mechanism control unit (PMCU), payload data handling unit (PDHU)
Electrical Design Description
## Power consumption

<table>
<thead>
<tr>
<th></th>
<th>Min Power (W)</th>
<th>Average Power (W)</th>
<th>Max Power (W)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS Imager</td>
<td>-</td>
<td>111.7</td>
<td>122.8</td>
<td>Power consumption</td>
</tr>
<tr>
<td>Detector</td>
<td>-</td>
<td>3.0</td>
<td>4.4</td>
<td>Power dissipation</td>
</tr>
<tr>
<td>ROE 1x</td>
<td>-</td>
<td>5.8</td>
<td>6.3</td>
<td>Power dissipation</td>
</tr>
<tr>
<td>ROE 12x</td>
<td>-</td>
<td>69.6</td>
<td>75.4</td>
<td>Power dissipation</td>
</tr>
<tr>
<td>PSU 1x</td>
<td>-</td>
<td>2.3</td>
<td>3.0</td>
<td>Power dissipation</td>
</tr>
<tr>
<td>PSU 12x</td>
<td>-</td>
<td>39.1</td>
<td>43</td>
<td>Power dissipation</td>
</tr>
<tr>
<td>MIP Imager</td>
<td></td>
<td>31.1</td>
<td>31.1</td>
<td>Power consumption</td>
</tr>
<tr>
<td>Detector + ROE</td>
<td>-</td>
<td>0.12</td>
<td>0.12</td>
<td>Power dissipation</td>
</tr>
<tr>
<td>CCU</td>
<td>-</td>
<td>31.0</td>
<td>31.0</td>
<td>Power dissipation</td>
</tr>
<tr>
<td>PDHU</td>
<td>-</td>
<td>61.4</td>
<td>61.4</td>
<td>Power consumption</td>
</tr>
<tr>
<td>PMC U</td>
<td>15.3</td>
<td>18.3</td>
<td>29.6</td>
<td>Power consumption</td>
</tr>
<tr>
<td>EIC total</td>
<td>222.5</td>
<td></td>
<td>244.9</td>
<td>Power consumption</td>
</tr>
<tr>
<td>EIC total with 20% margin</td>
<td></td>
<td>267.0</td>
<td>293.9</td>
<td>Power consumption</td>
</tr>
</tbody>
</table>
Instrument Telemetry Needs

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Daily telemetry (Mbpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS</td>
<td>509.09</td>
</tr>
<tr>
<td>NIP</td>
<td>209.08 **</td>
</tr>
<tr>
<td>Total</td>
<td>718.17 **</td>
</tr>
<tr>
<td>Total with 3% overhead</td>
<td>739.71 **</td>
</tr>
<tr>
<td></td>
<td>793.56 **</td>
</tr>
</tbody>
</table>
Coma Design Description

- VIS is diffraction limited
- VIS has no chromatic aberrations
- VIS FWHM PSF 0.16"
- NIP FWHM PSF 13 µm

COMA
- Opto-mechanical bench to NIP and VIS
- Dichroic
- Fold mirror
- VIS Calibration unit
- Shutter
- I/F bars towards P/L
Coma Design Description

[Diagram of a Coma Design structure and components, including Dichroic and Fold Mirror diagrams and a Calibration Unit with labels for Cover, Actuation system, Bracket, and M.E. Socket.]
VIS Design Description

- VIS is diffraction limited

CCD

Video hybrid module 85 x 43 mm

Clock & bias hybrid module 80 x 43 mm

FPGA / RAM

Power conditioning & FPGA decoupling

CCD1

MWDM2L-37S SMR

CCD Connector 1

Flex circuit

CCD Connector 2

Video hybrid module 85 x 43 mm

Power conditioning

MWDM2L-21S CBR

SpW test connector

MWDM2L-9S CBR

SpW port 1 connector

MWDM2L-9S CBR

FPGA

Prog header

Buffer RAM

PSU connector MWDM2L-21S CBR

SpW port 2 connector MWDM2L-9S CBR

SpW port 3 connector MWDM2L-9S CBR
VIS Design Description

Harness support integration sequence

ROE and PSU integration sequence
NIP Design Description
# Mass and Power Budget

<table>
<thead>
<tr>
<th>S/S</th>
<th>EIC Mass (margin 20% in kg)</th>
<th>EIC Average Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIS Imager</td>
<td>62 kg</td>
<td>~112 W</td>
</tr>
<tr>
<td>NIP Imager + CCU</td>
<td>96 kg + 17 kg</td>
<td>~31 W</td>
</tr>
<tr>
<td>COMA</td>
<td>107 kg</td>
<td></td>
</tr>
<tr>
<td>PDHU + PMCU</td>
<td>16 kg + 14 kg</td>
<td>~62 W + 18 W</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>~312 kg</td>
<td>~223 W</td>
</tr>
</tbody>
</table>
GS / Distributed Mission Archive 5Pb

- Allows quality control at all levels
  - Operational feedback & monitoring to SOC/MOC
  - all aspects propagation as systematic errors ← IOCs → SDCs
- Connect instrument & science teams
  - Exchange & verify results
  - Connect to Ground based observations & external data – agreements with (e.g.) PanStarrs / DES
  - Connect simulated data
- Euclid Legacy Archive
  - Science ready data → VO
  - Re-processing raw data to the ELA – additional studies
- Building upon experience in ESA missions
  - Planck and Gaia, but also XMM and Integral
EIC organization
EIC Schedule
Spanish participation

- Consortium CoI
- Leading one science WG
- VIS warm electronics
- VIS AIV
- NIP FEE electronics
- Distributed Ground Segment


## Euclid Mission Summary

**Main Scientific Objectives**

*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 $\gamma$ 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.

<table>
<thead>
<tr>
<th>SURVEYS</th>
<th>Area (deg$^2$)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide Survey</td>
<td>20,000</td>
<td>Entire extragalactic sky with galactic latitude $b &gt; 30$ deg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shear measurements for 40 galaxies/arcmin$^2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spectroscopic measurements for 70 million galaxies</td>
</tr>
<tr>
<td>Deep Survey</td>
<td>40</td>
<td>In at least 2 patches of $&gt; 10$ deg$^2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 magnitudes deeper than wide survey</td>
</tr>
</tbody>
</table>
## Euclid Mission Summary

<table>
<thead>
<tr>
<th>PAYLOAD</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Telescope</strong></td>
<td>1.2 m Korsch</td>
</tr>
<tr>
<td><strong>Instrument</strong></td>
<td>Imaging Instrument</td>
</tr>
<tr>
<td><strong>Field-of-View</strong></td>
<td>0.48 deg²</td>
</tr>
<tr>
<td><strong>Capability</strong></td>
<td>Visual Imaging</td>
</tr>
<tr>
<td><strong>Sensitivity</strong></td>
<td>24.5 mag (10σ extended source)</td>
</tr>
<tr>
<td><strong>Detector Technology</strong></td>
<td>36 arrays 4k×4k CCD</td>
</tr>
<tr>
<td><strong>Pixel Size</strong></td>
<td>0.1 arcsec</td>
</tr>
</tbody>
</table>
# Euclid Mission Summary

## SPACECRAFT

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Launcher</strong></td>
<td>Soyuz ST-2.1 B from Kourou</td>
</tr>
<tr>
<td><strong>Orbit</strong></td>
<td>Sun Earth Lagrange point 2 (L2)</td>
</tr>
<tr>
<td><strong>Pointing</strong></td>
<td>35 mas relative pointing error over one dither exposure with VIS</td>
</tr>
<tr>
<td></td>
<td>100 mas absolute <em>measurement</em> accuracy</td>
</tr>
<tr>
<td><strong>Stabilization</strong></td>
<td>Step and stare</td>
</tr>
<tr>
<td><strong>Lifetime</strong></td>
<td>5 years nominal</td>
</tr>
<tr>
<td><strong>Operations</strong></td>
<td>4 hours per day contact, 850 Gbit/day in K band</td>
</tr>
</tbody>
</table>

## MASS and POWER BREAKDOWN

<table>
<thead>
<tr>
<th></th>
<th>Mass (kg)</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payload Module</td>
<td>855</td>
<td>350</td>
</tr>
<tr>
<td>Service Module</td>
<td>691</td>
<td>595</td>
</tr>
<tr>
<td>Propellant</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>Adapter / Harness and PDCU losses</td>
<td>100</td>
<td>58</td>
</tr>
<tr>
<td>Margin (20%)</td>
<td>309</td>
<td>201</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2105</strong></td>
<td><strong>1204</strong></td>
</tr>
</tbody>
</table>
Review Recommendations

- **Mission considered feasible**
- Schedule too optimistic with lean development model assumptions
- Mass is at limit of Soyuz & design uncertainties of payload demand higher margin
- DMD slit spectrometer not compatible with M-class TRL
- **Attention should be given to**: NIR detectors procurement, improved interface definition for testing, pointing performance
- Lacking thermomechanical analysis to confirm the stability w.r.t. sun angles (scanning law)
Imaging the Dark Universe

- **Euclid concept**: high-precision survey mission, optimised for Weak Lensing and BAO, tight control of systematics, strong link between science and instrumentation, matched survey speeds, synergy with ground based surveys.

- **Euclid imaging** will achieve definite constraints on Dark Energy and challenge all sectors of the cosmological model.

- **Euclid imaging** will provide unique legacy science: galaxy evolution, high-z objects, clusters, strong lensing, and with a survey extension exoplanets and Milky Way.

- **Euclid** has received broad support from the European science community: ESA/ESO WG on Fundamental Cosmology, Astronet, National agencies.