First results from Euclid

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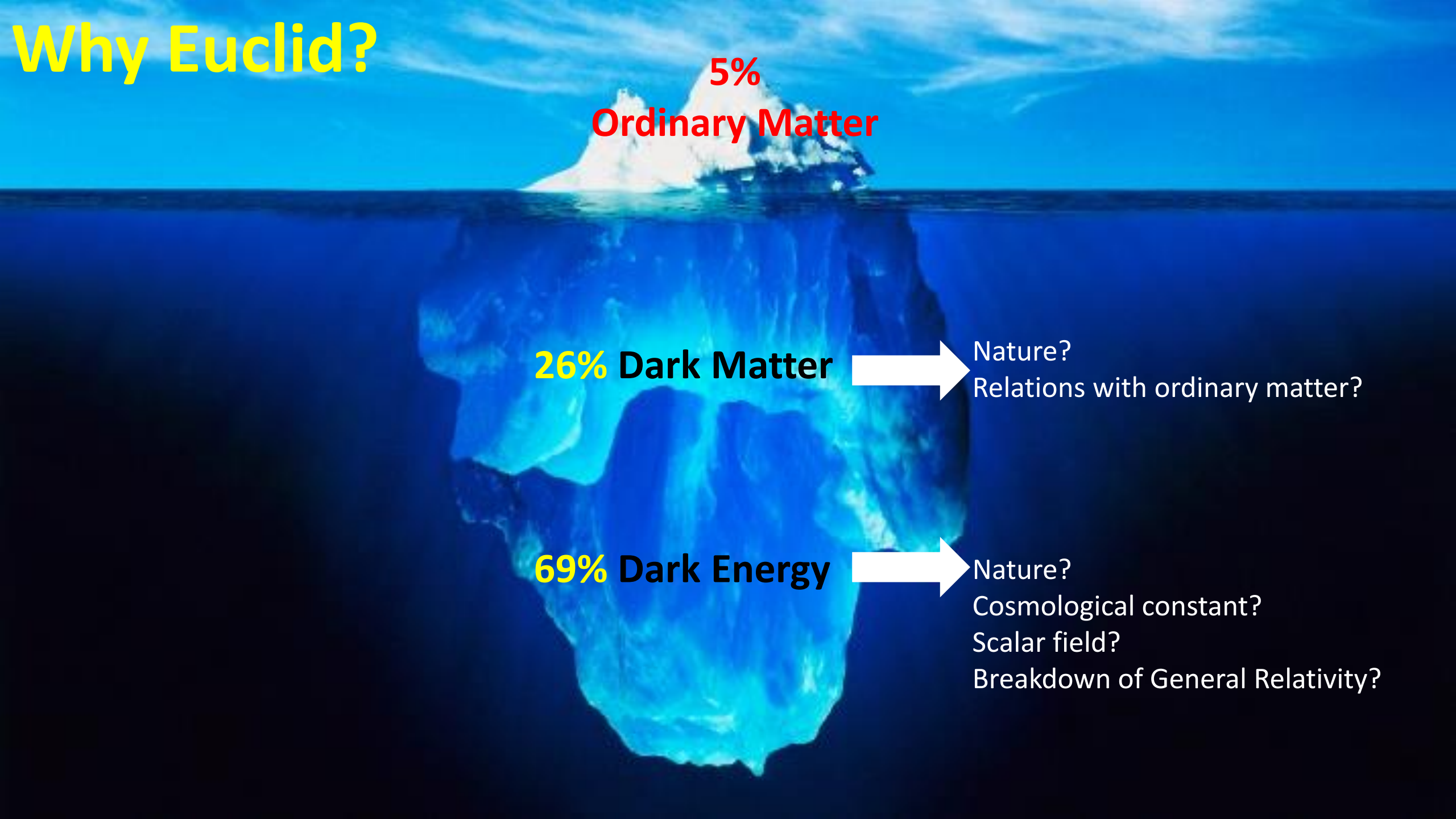
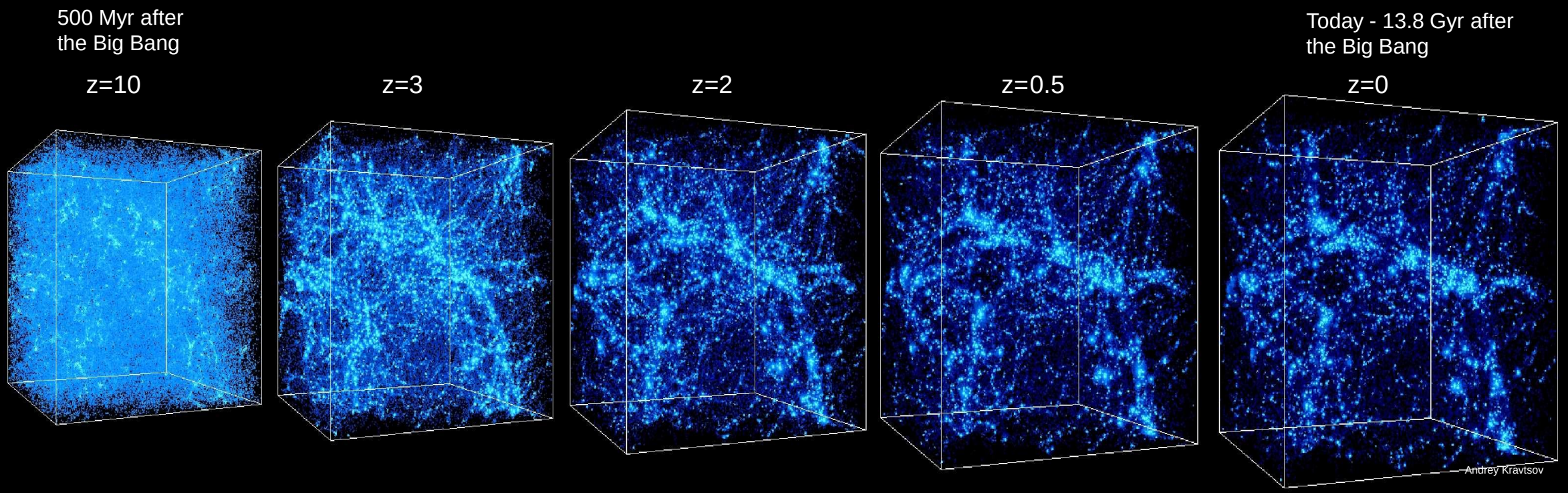
CTAO Science Symposium 2024, Apr 16,, Bologna, Italy

Why Euclid?


5%
Ordinary Matter
26% Dark Matter
Nature?
Relations with ordinary matter?
69% Dark Energy
Nature?
Cosmological constant?
Scalar field?
Breakdown of General Relativity?

The 3D Cosmic Web as a Cosmology Laboratory

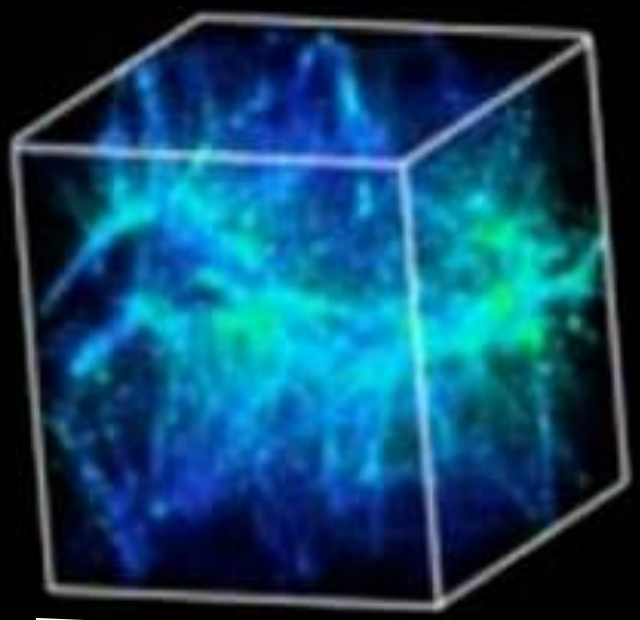


- Expansion of the box → Hubble parameter $H(z)$ → Dark Energy
- Growth of structures inside the box → Dark Matter and Gravitation

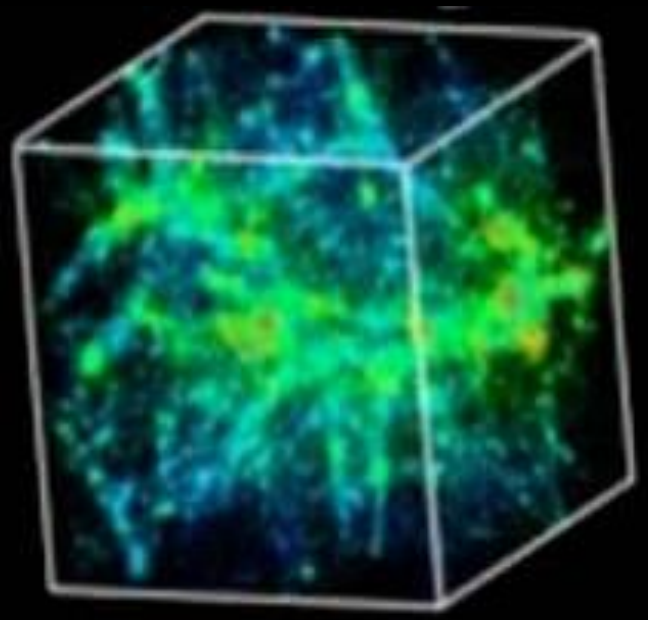
ΛCDM

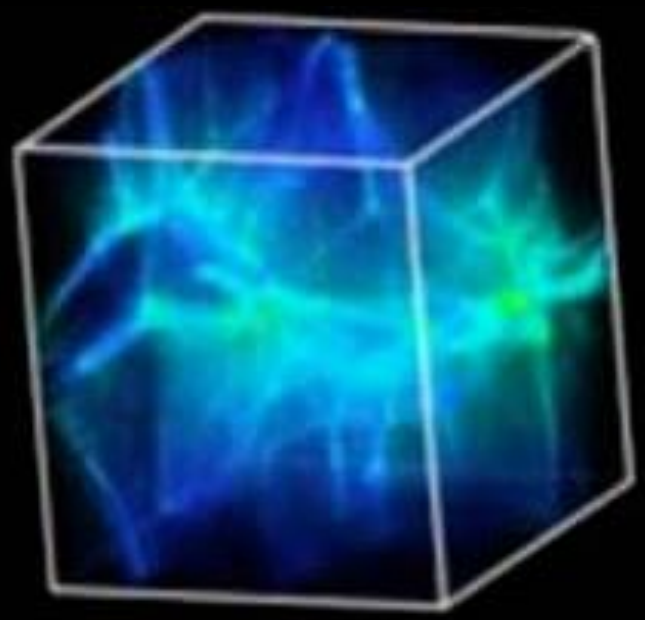
CDM No dark energy

Warm dark matter



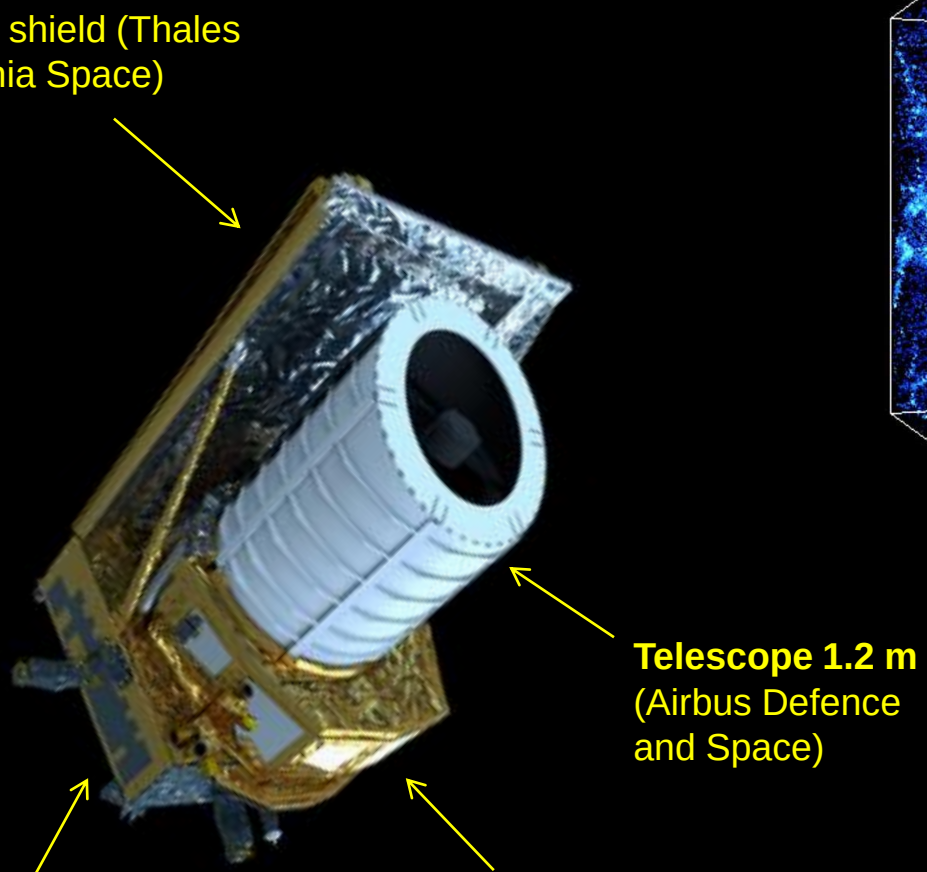
100 Mpc

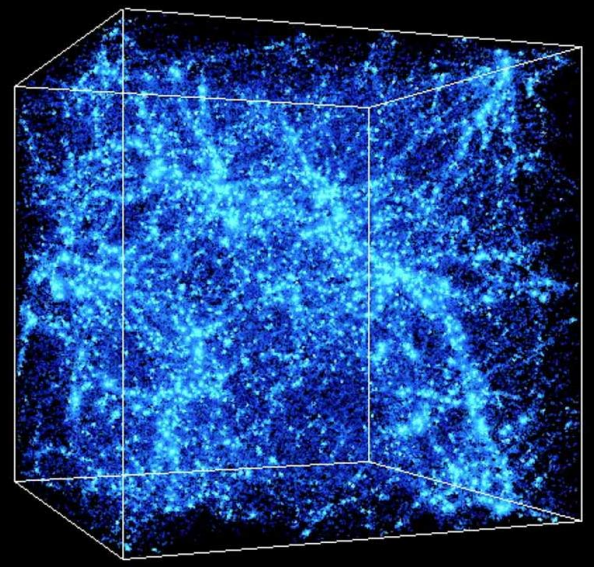




Euclid

*Merging of **SPACE** (PI A. Cimatti) and **DUNE** (PI A. Refregier) Cosmic Vision proposals (2007) for M2 missions*

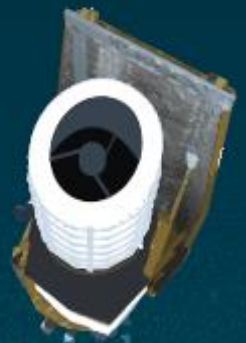




- **2008 – 2009**: Assessment Phase
- **2010 – 2011**: Definition Phase
- **2012**: Adoption by ESA
- **2015**: PDR → construction
- **2018**: CDR passed
- **2023: launch on July 1st** (L2 orbit)
- Survey duration: 6 years
- ESA + Euclid Consortium + NASA + CSA + Japan + Industries
- Global collaboration: 21 countries, >300 institutions, >3500 people

Euclid Ground Segment

ASTRONOMY SCIENCE ARCHIVE: MAXIMISING SCIENCE FROM OUR MISSIONS



Spacecraft data arrive at ESA's European Space Operations Centre (ESOC) in Germany via ground stations around the world

Raw data

Science archive

ESA's Science Operations Centre (ESAC) in Spain

Data products (images, spectra, measurements, catalogues...)

Data Release 1 (2500 deg^2): ~mid 2026

Euclid Consortium (EC)

Raw data are processed by the EC Science Ground Segment, responsible for providing data centres and software.

The **processed data products** include calibrated images and spectra, catalogues of scientific measurements, and documentation.

The EC includes over 2000 international scientists and contributed Euclid's instruments, VIS and NISP.

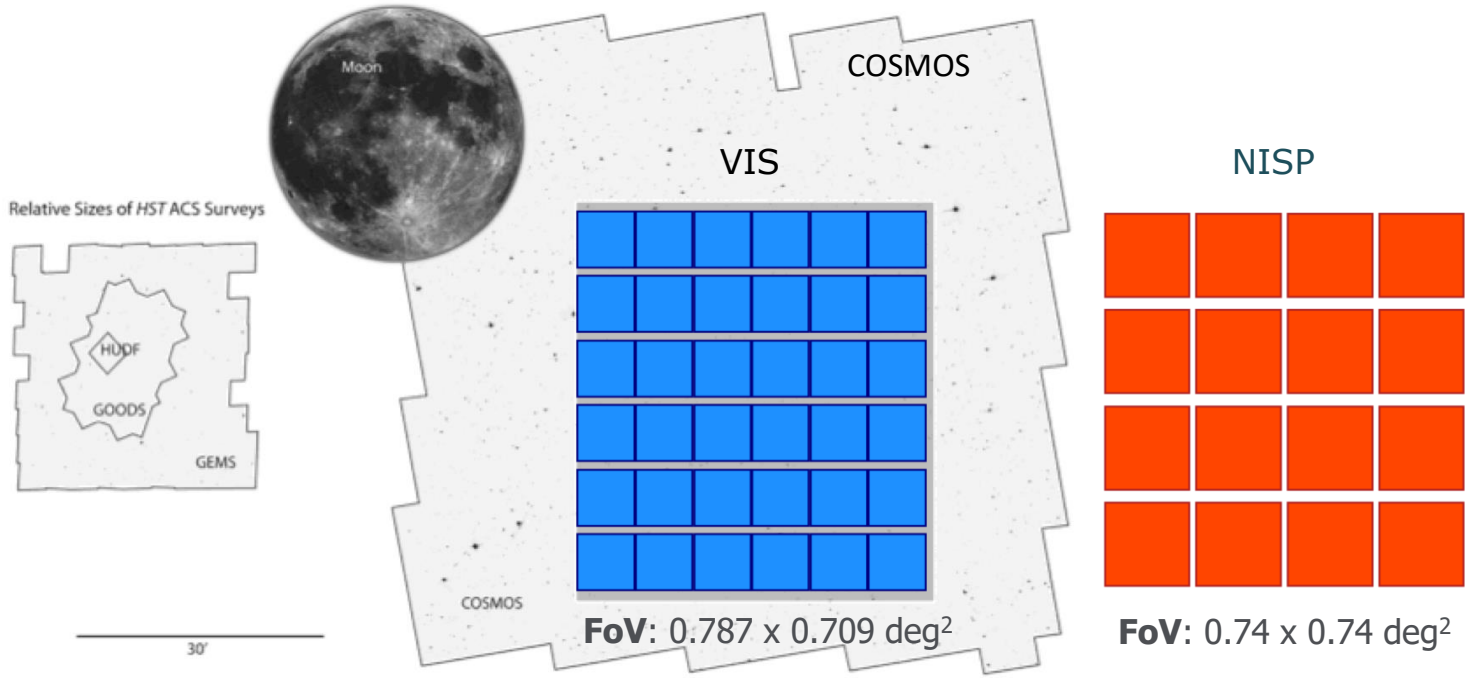
Scientific community

Data are available to all for decades, ensuring long-term science return and supporting future missions

Science

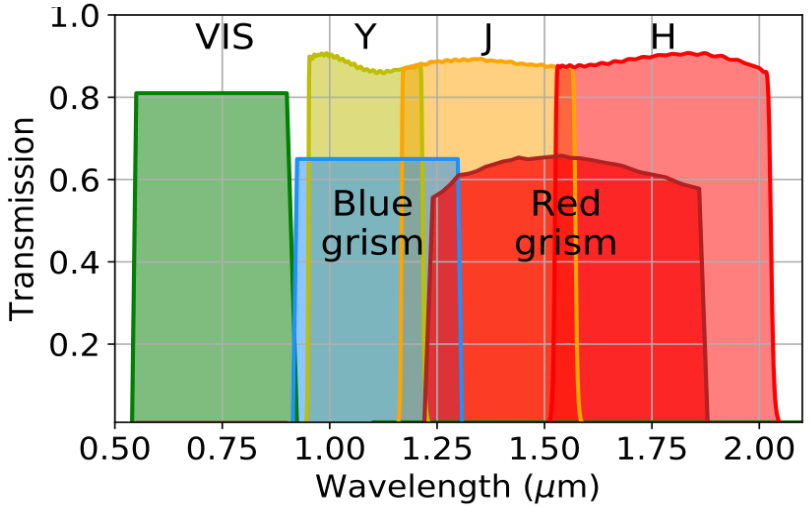
Planning future missions

Euclid Imaging and Spectroscopy



Credit: Space Telescope Science Institute/Nick Scoville (Caltech)

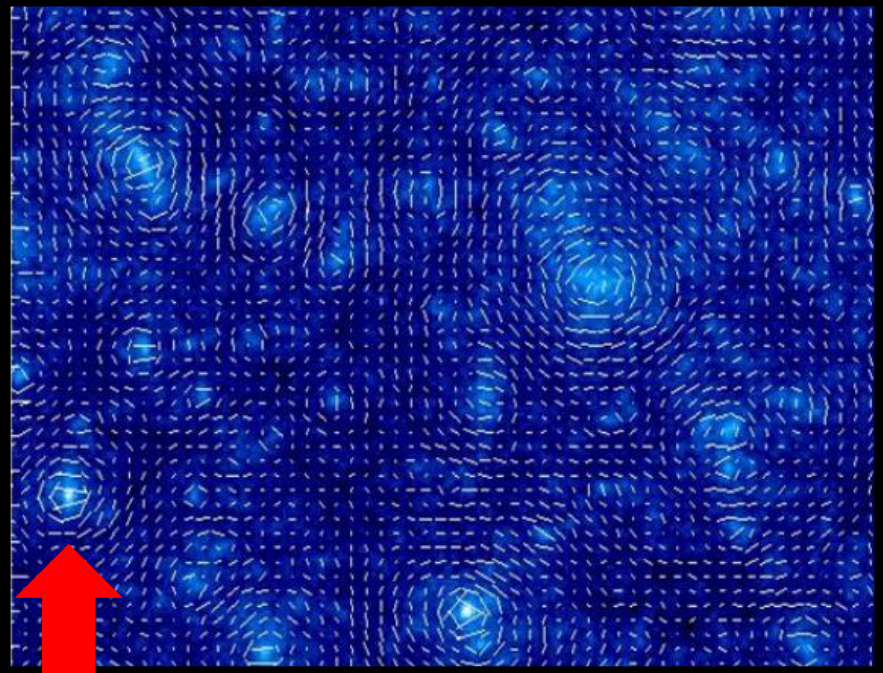
- **VIS** & **NISP**: wide field imagers (0.55 deg² each)
- **VIS**: **imaging** 36 CCDs with 0.1”/pixel, $m_{AB} \leq 24.5$ ➔ **weak lensing**
- **NISP**: **imaging** 16 detectors with 0.3”/pixel, $m_{AB} \leq 24.0$ ➔ **photo-z**
- **NISP**: **slitless spectroscopy** (R~380) ➔ **spectro-z**



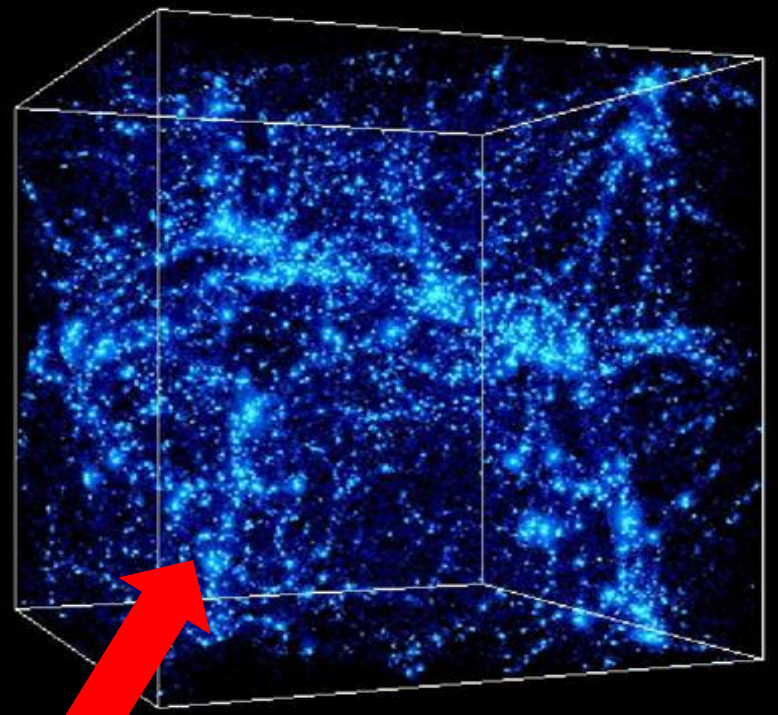
*Blue grism is exposed on Deep fields only

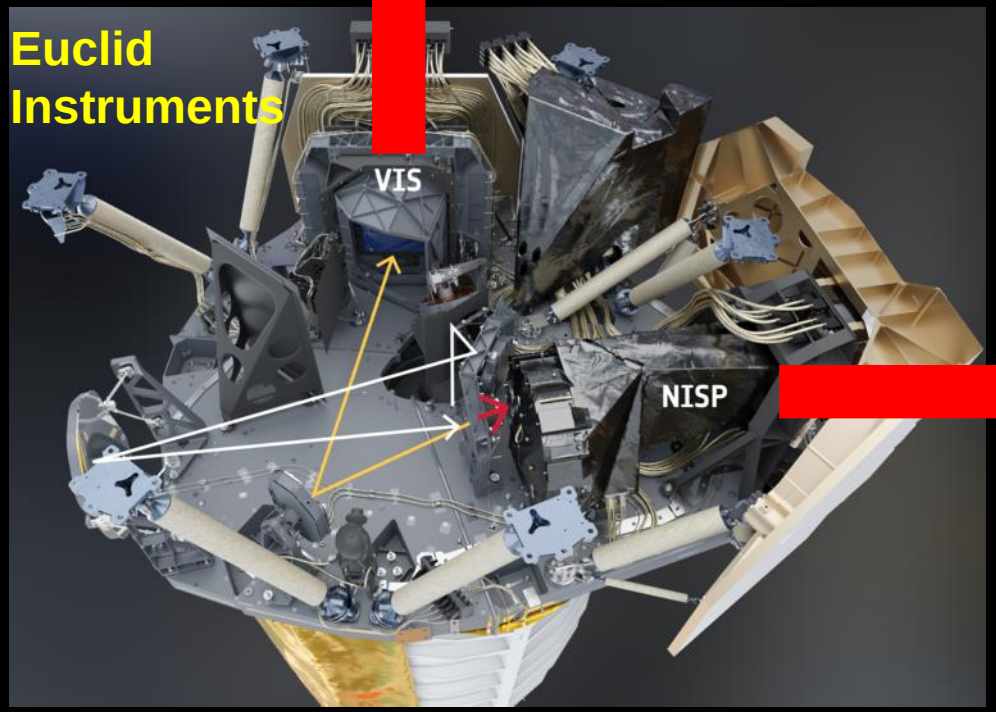
Credits: B. Granett

VIS Imaging
Weak Lensing

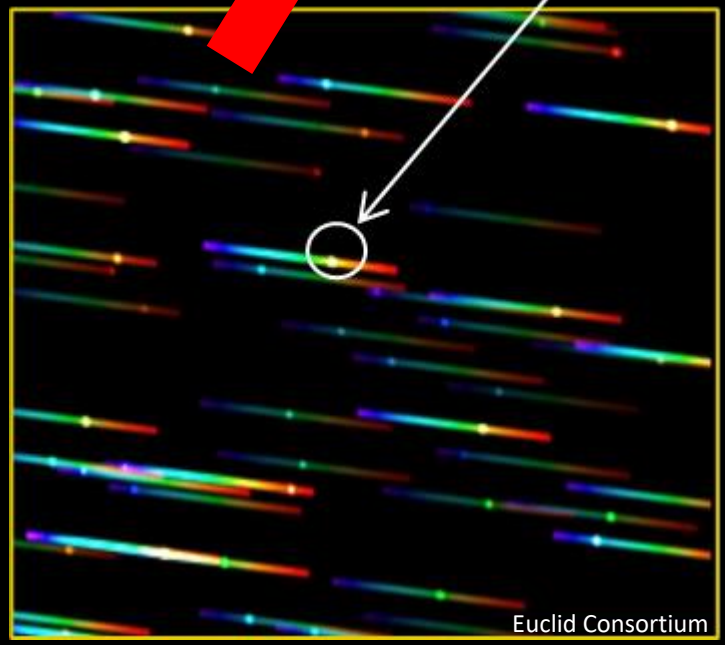


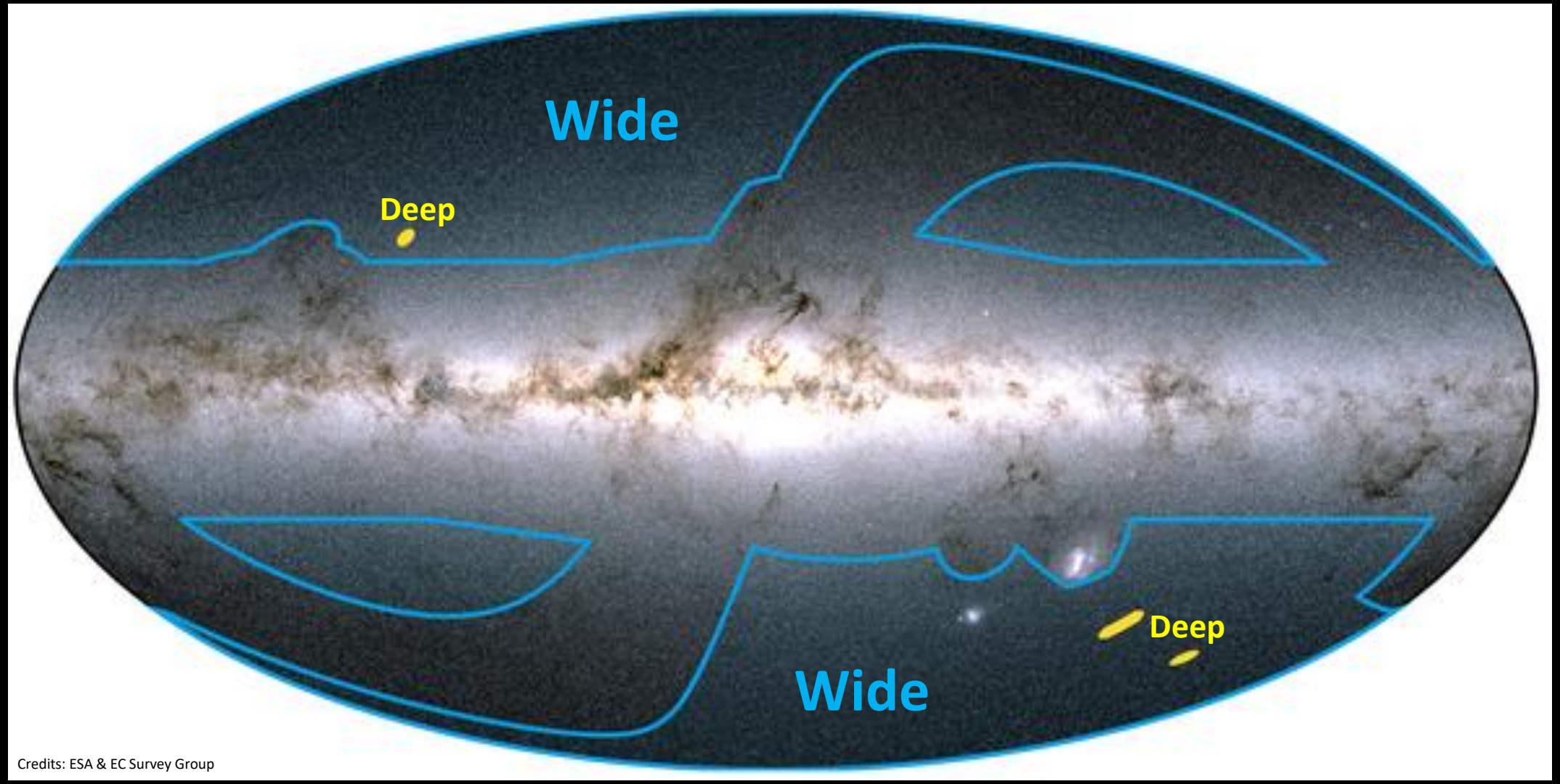
NISP Imaging
Photo-z





NISP Spectroscopy
Galaxy clustering





Wide Survey: 15,000 deg^2
Cosmological survey
Imaging + spectroscopy (red grism)

Deep Survey: 40 deg^2, 2 mag deeper
Imaging + spectroscopy (blue & red grism)
Calibrations and Legacy Science

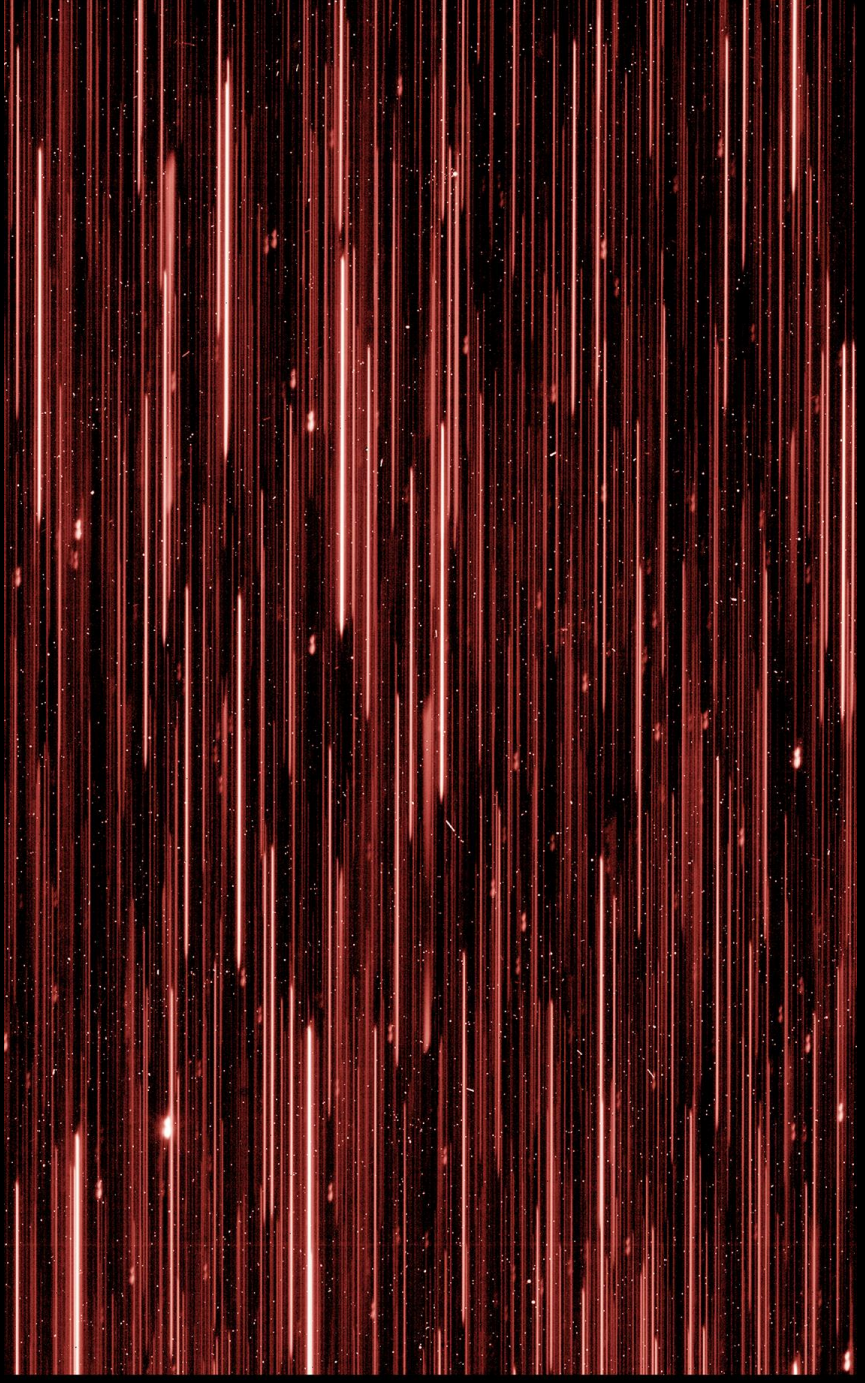
First Euclid Images (VIS+NISP) (ESA - 07/11/2023)

- ✓ PSF
- ✓ Throughput
- ✓ Sensitivity
- ✓ Stability

VIS and NISP perform as expected!

The Treasure of Euclid Imaging (VIS & NISP)

- Galaxy shapes and shear maps
- Weak gravitational lensing
- Strong gravitational lensing
- Photometric SEDs (VIS +YJH +additional photom.)
- Photometric redshifts
- Galaxy morphologies
- Galaxy surface brightness profiles
- Galaxy clusters

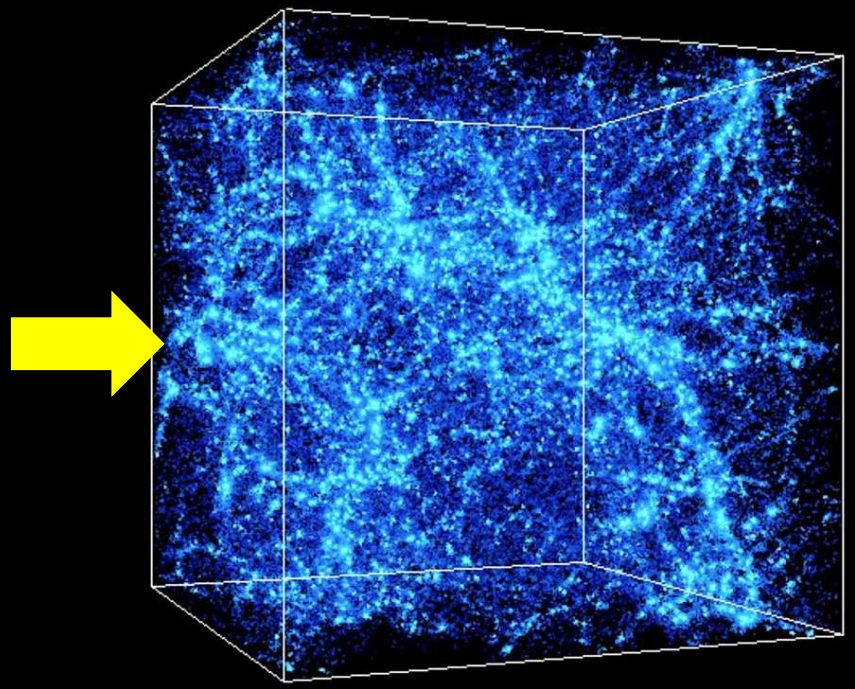


Early commissioning test image, NISP instrument (grism mode)

The Treasure of Euclid Spectroscopy (NISP)

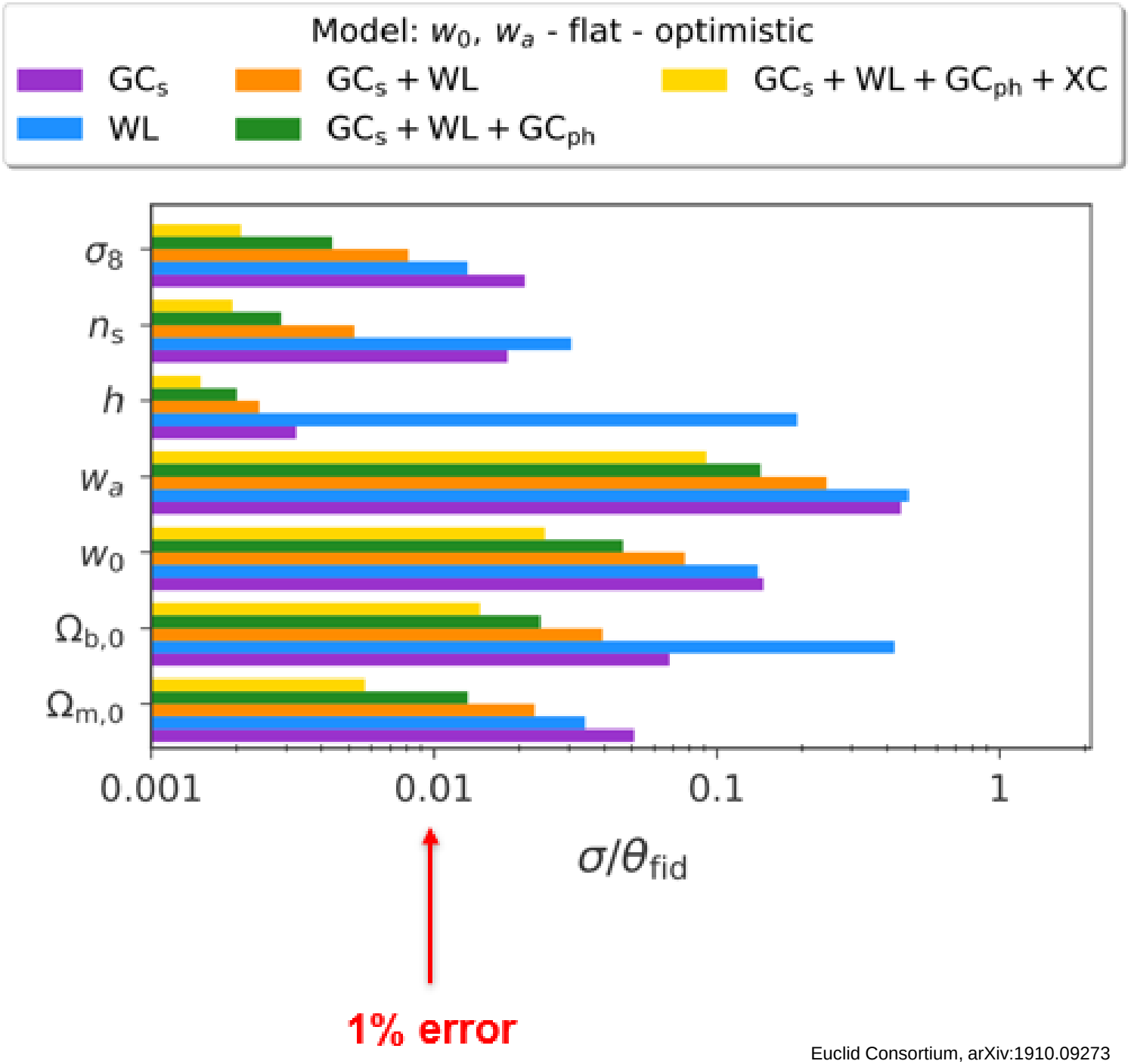
- Spectroscopic redshifts
- Galaxy clustering and 3D cosmic web
- Spectroscopic classification
- Spectral features
- Unbiased AGN survey
- Luminous Lyman-α emitters
- Reionization
- Photometric redshift calibration/training

What Do We Expect?



Same mission
Different datasets
Multiple Experiments

- 3D map of cosmic matter (cosmic web)
- Cosmic web evolution (last 10 Gyr)
- Evolution of the Hubble parameter *H*(*z*)
- Nature of Dark Energy
- New constraints on Dark Matter
- Verification of General Relativity
- Neutrino mass
- Future of the Universe
- First galaxies and supermassive black holes
- Evolution of galaxies and AGNs
- … and much more!

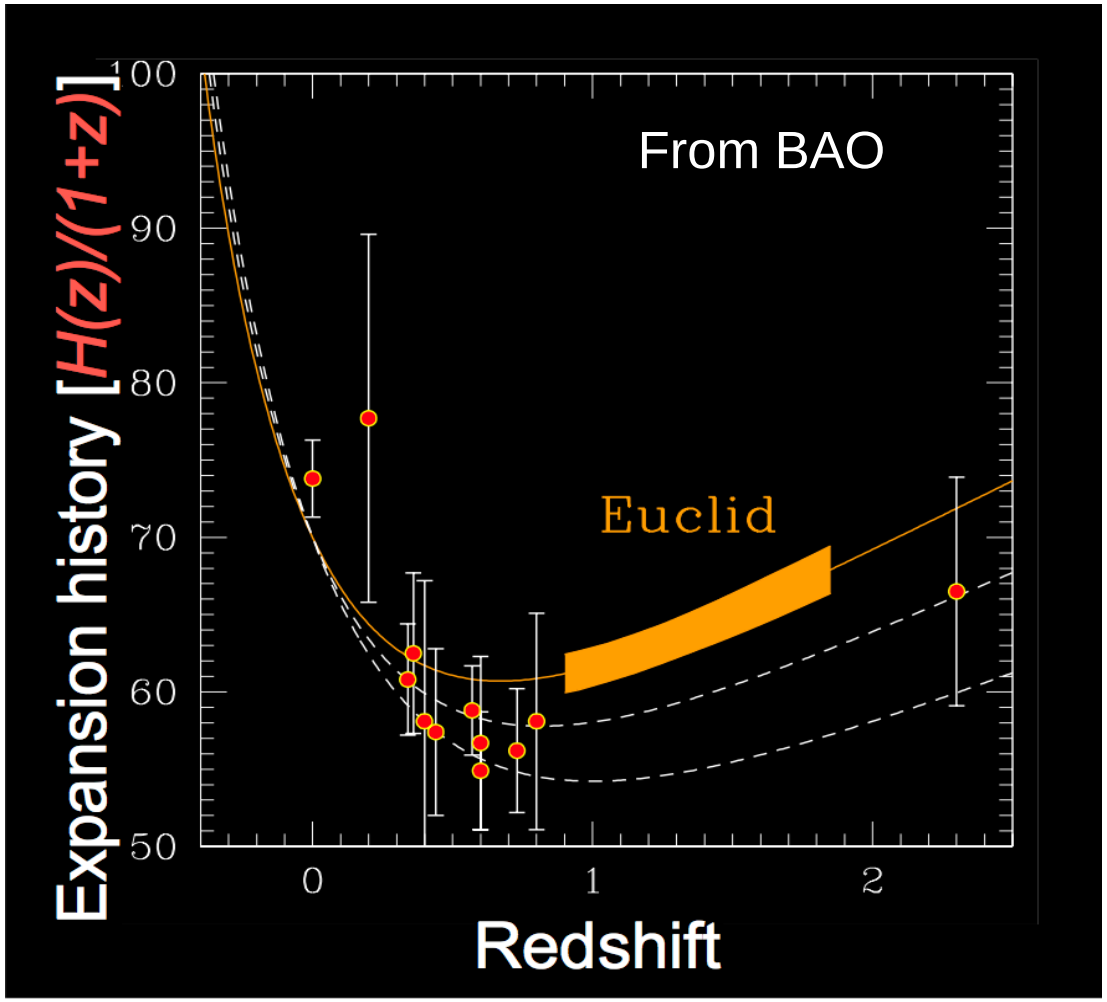


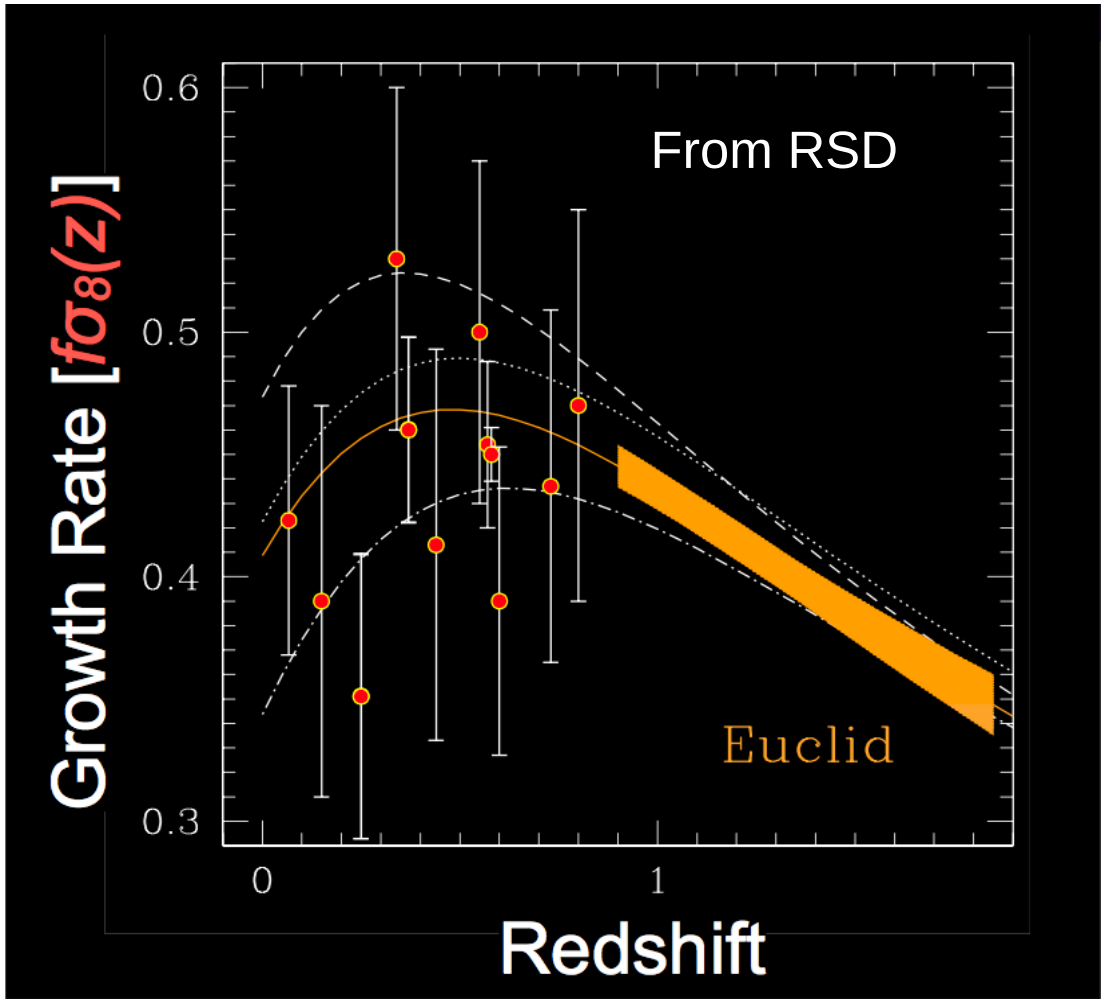
Euclid Consortium, arXiv:1910.09273

The Power of Euclid

- Space-based data!
- Multiple cosmological probes:
  - Weak lensing
  - Galaxy clustering
  - CMB cross-correlations
  - Clusters of galaxies
  - Strong lensing
- Mitigation of systematics
- Mitigation of degeneracies
- **Improvement**: **1-2 dex** with respect to current constraints

Euclid galaxy clustering predictions





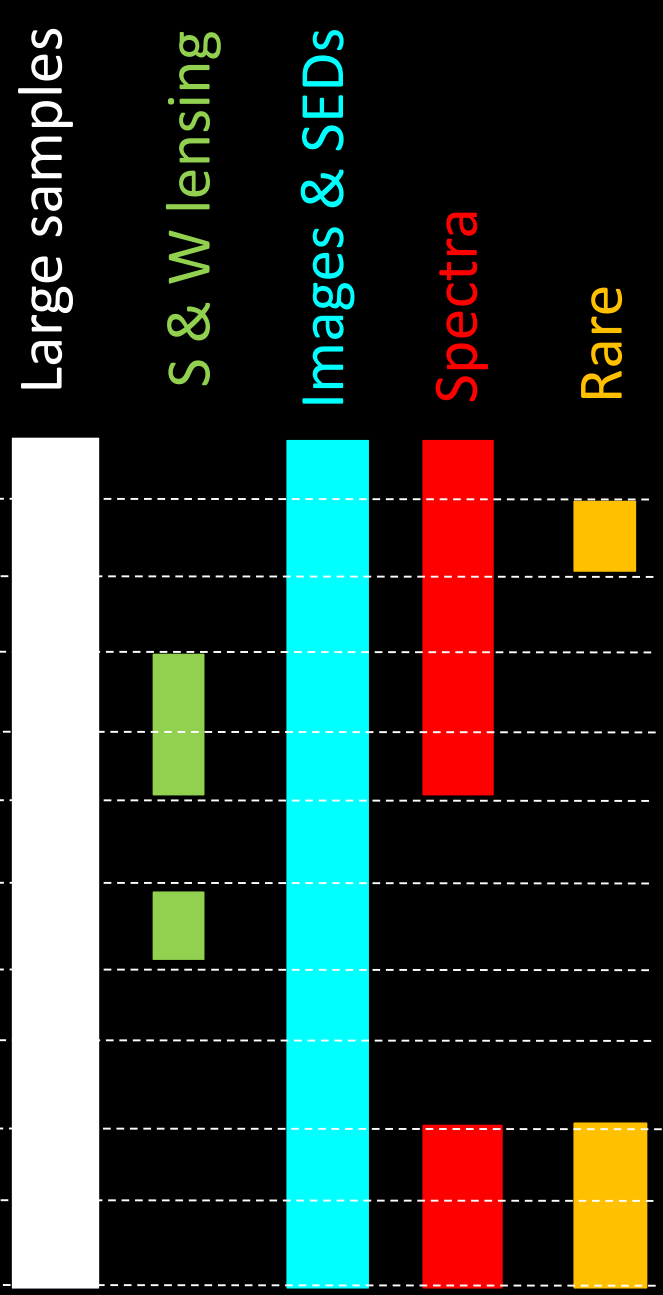
Forecasts from Euclid Collaboration, 2020, A&A, 642, A191

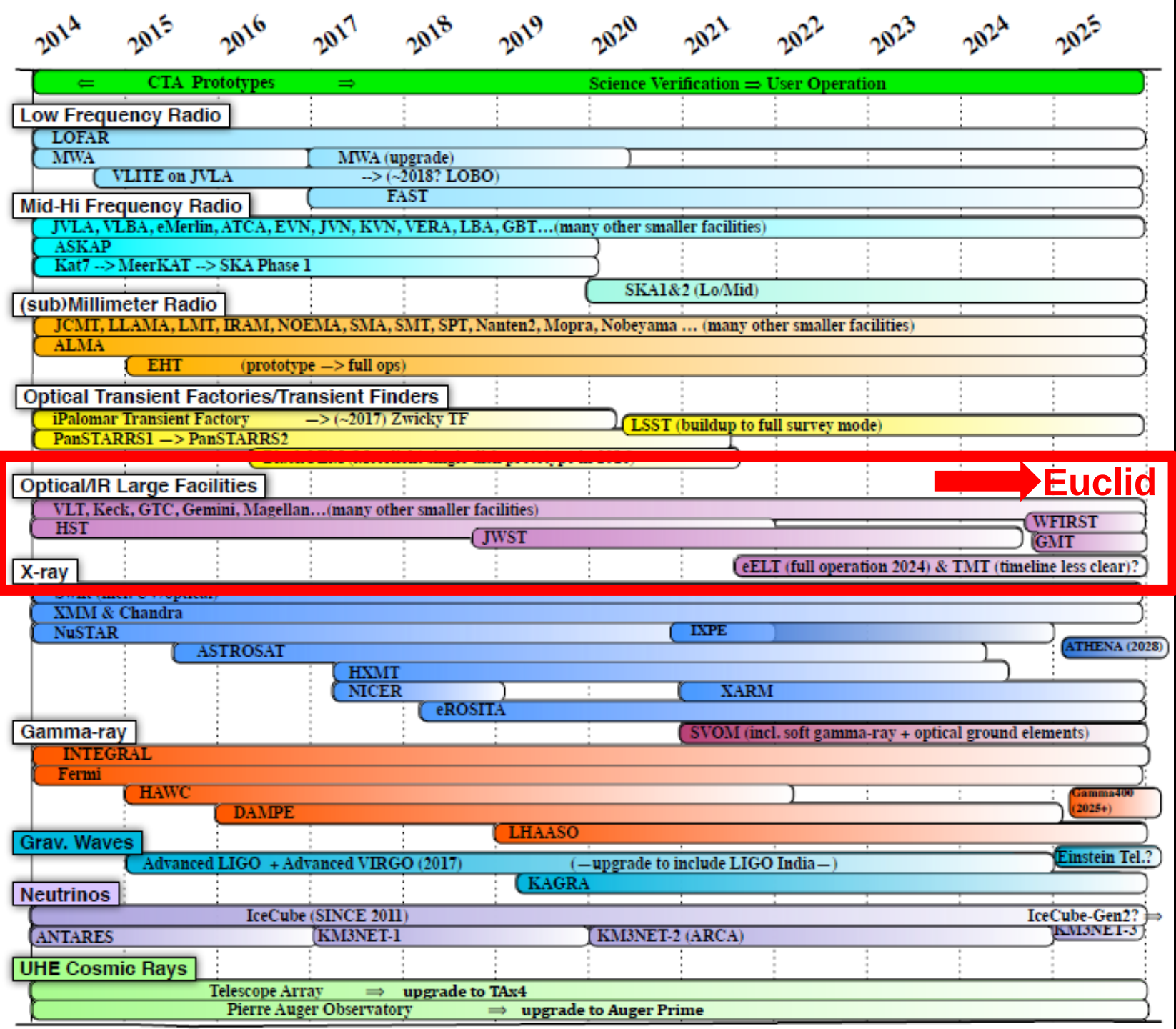
Credits: L. Guzzo

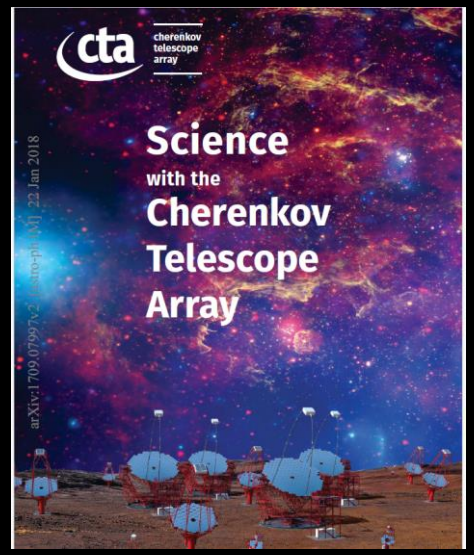
Not Only Cosmology

Evolution of Galaxies and AGNs

- Multi-dimensional distributions of physical parameters
- The growth and evolution of quiescent high-z galaxies
- Galaxy evolution as a function of environment
- Galaxy evolution at fixed halo mass
- Baryon to star conversion efficiency
- Properties of galaxy halos from strong lensing
- Intrinsic alignments and galaxy properties
- Galaxy merger evolution
- Morphology evolution
- AGN evolution up to high redshifts
- High-z galaxies and Reionization







Synergies with CTA?

Theme 1: Understanding the Origin and Role of Relativistic Cosmic Particles

- Sites of high-energy particle acceleration
- Role and feedback (galaxy evolution)
- AGN
- Clusters of galaxies

Theme 2: Probing Extreme Environments

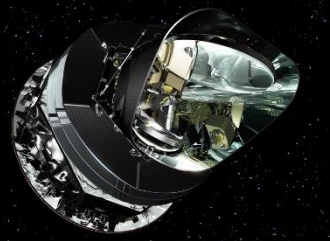
- Cosmic voids and Extragalactic Background Light

Theme 3: Exploring Frontiers in Physics

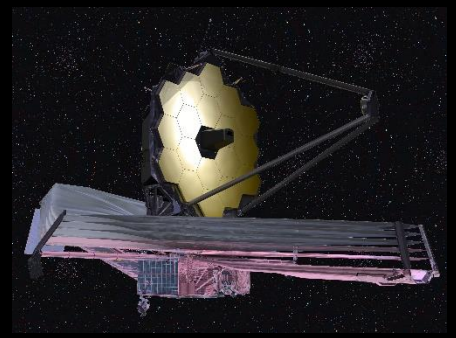
- Nature, mass, distribution of dark matter

Multi-messenger Astrophysics

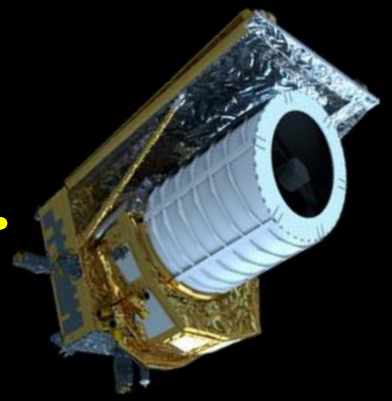
A Schematic Outline of the Cosmic History



Planck



JWST



Euclid