Euclid and ET Synergies

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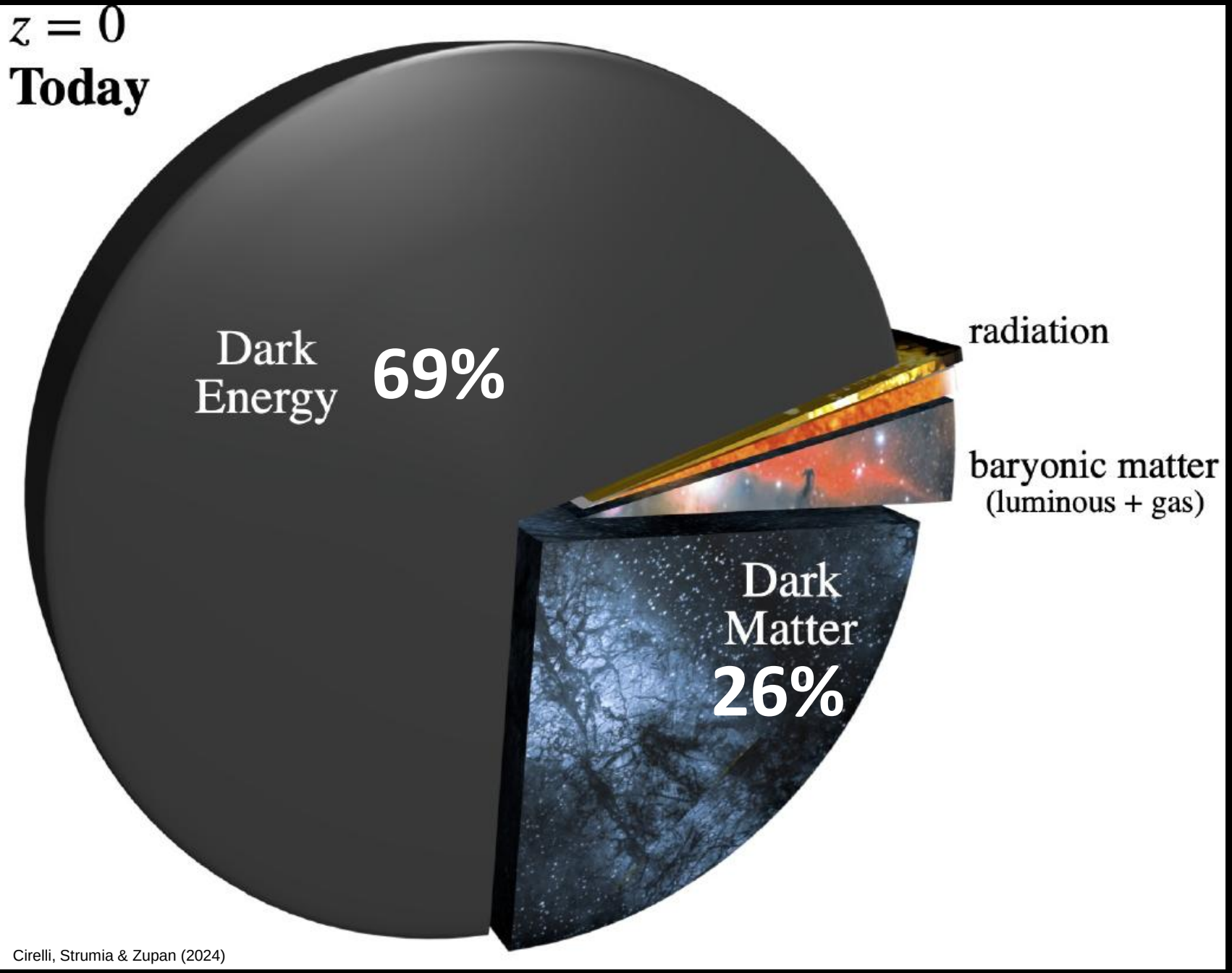
On behalf of the Euclid Consortium

XV Einstein Telescope Symposium - 28/05/2025

Part I

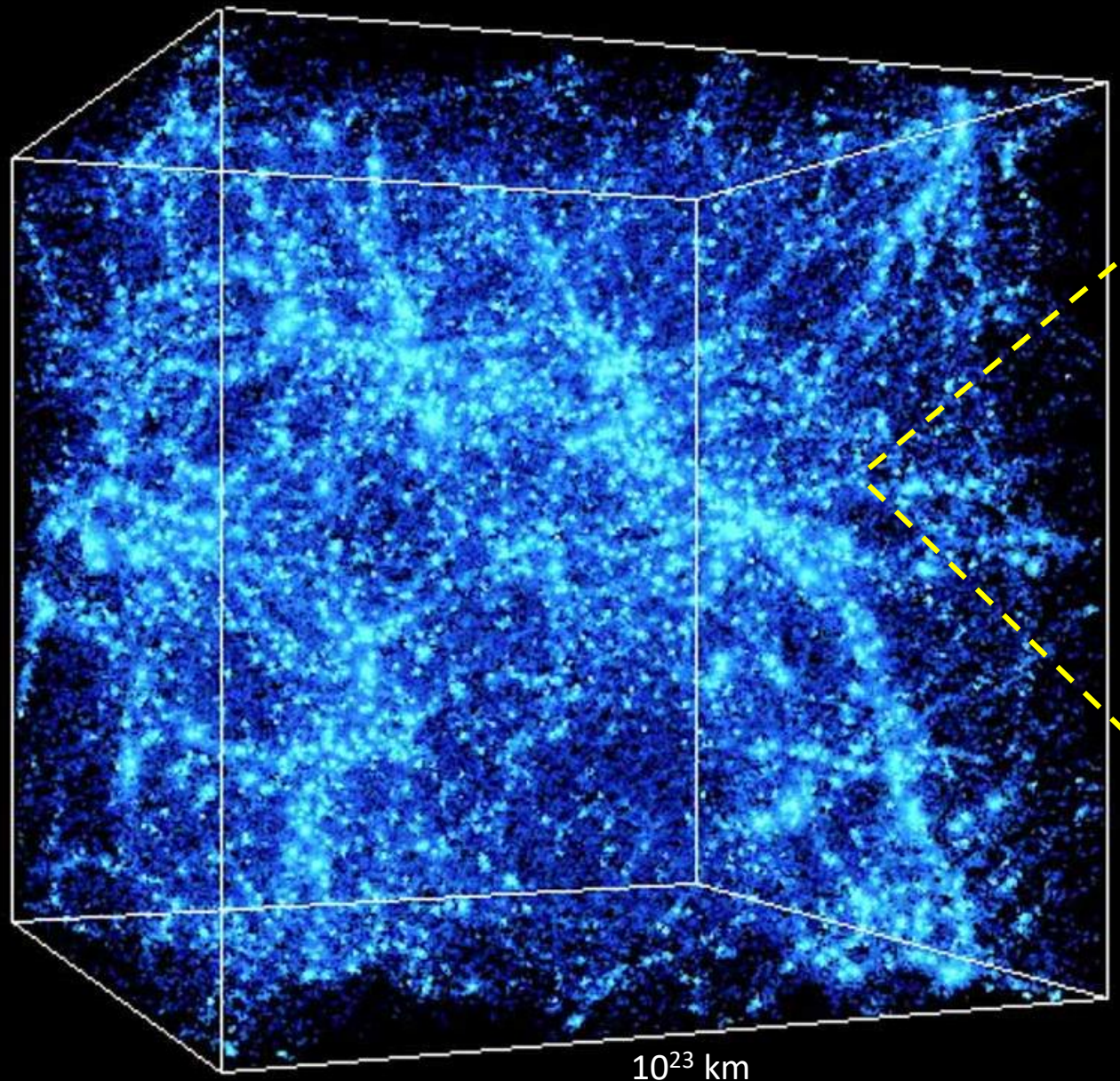
The ESA Euclid Mission

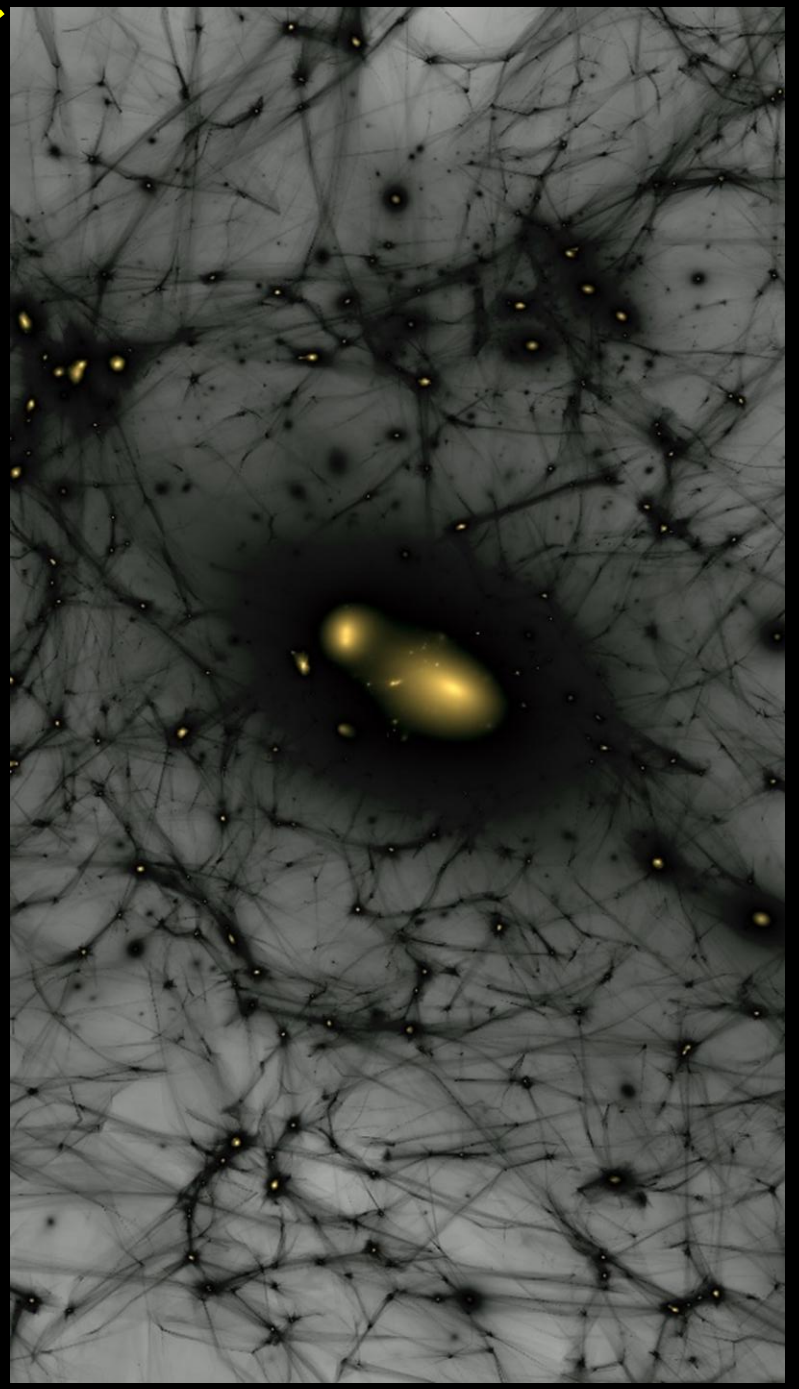


Cirelli, Strumia & Zupan (2024)

We live in a
95% dark universe

The Cosmic Web





Andrey Kravtsov

Ralf Kaehler/SLAC NAL

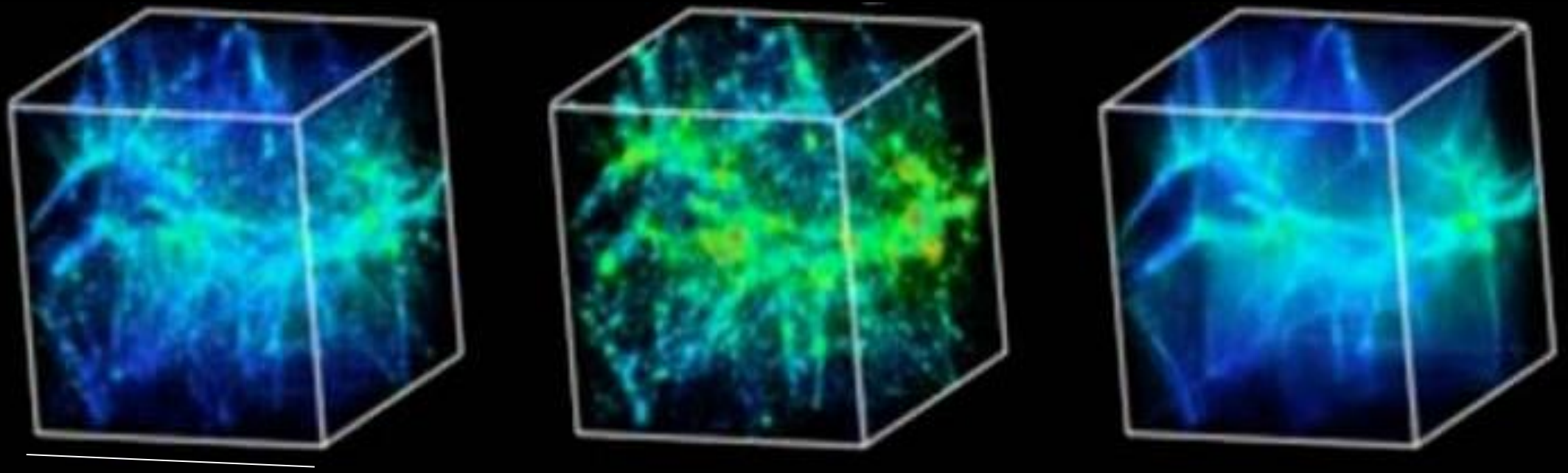
The cosmic web: a gold mine for cosmology and fundamental physics

Example

ΛCDM

CDM No dark energy

Warm dark matter

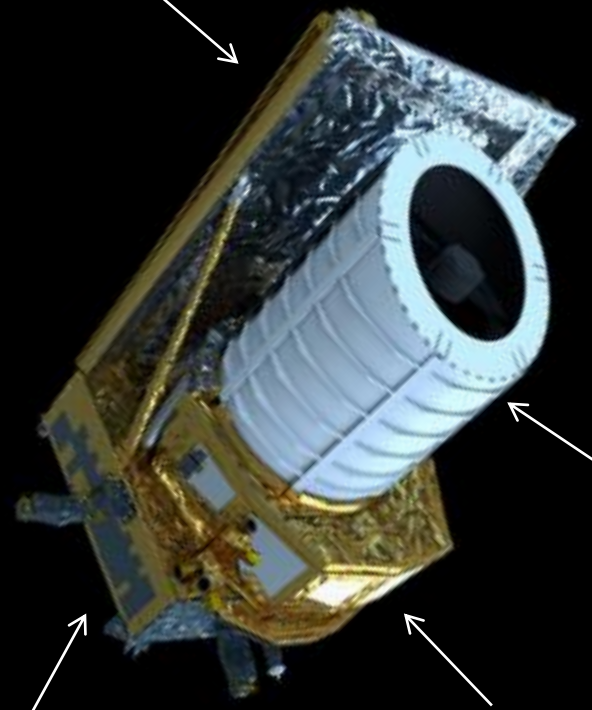


100 Mpc

Euclid

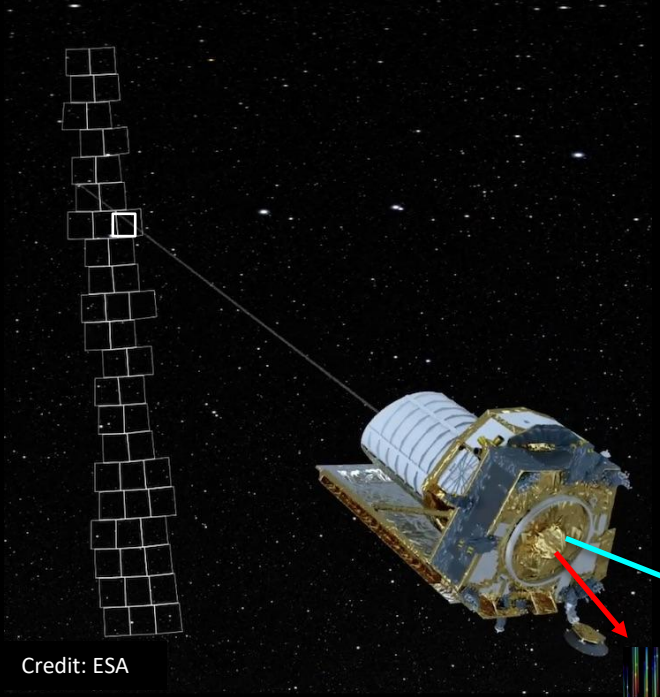
SPACE (PI A. Cimatti) + **DUNE** (PI A. Refregier)
mission concepts - ESA *Cosmic Vision* call (2007)

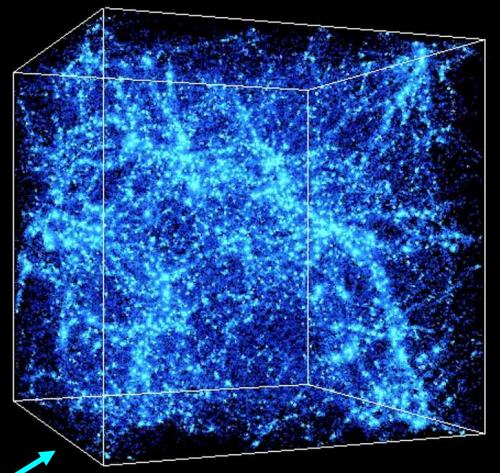
- 2008 – 2009: Assessment Phase
- 2010 – 2011: Definition Phase
- 2012: Adoption
- 2015: PDR → construction
- 2018: CDR
- **2023**: launch (July 1st; L2 orbit)
- Duration: ≥ 6 years
- ESA + Euclid Consortium + NASA + CSA + Japan + Industries



2D sky → 3D cosmic web

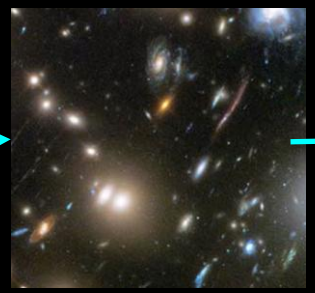
14679 deg^2 (Wide Survey) + 53 deg^2 (Deep Survey)


Credit: ESA

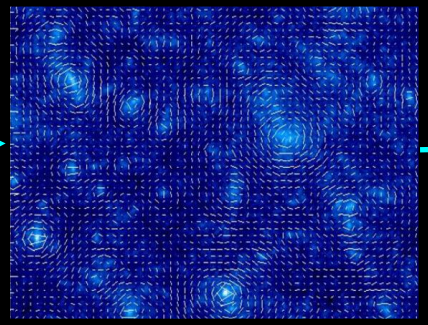


VIS

Shapes of galaxies



Weak gravitational lensing



Distribution of dark and luminous matter

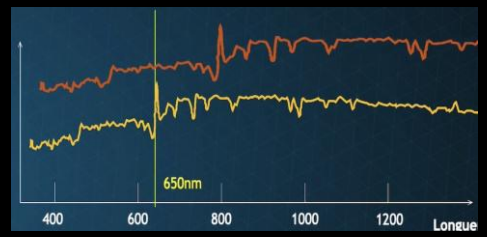
NIS

NIP-Y

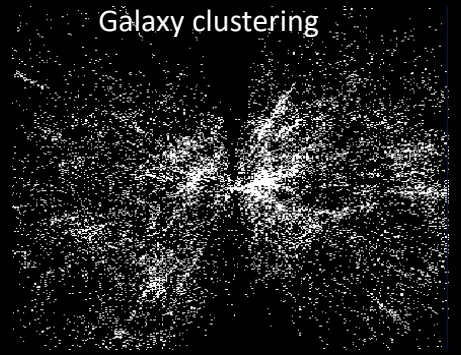
NIP-J

NIP-H

Spectroscopic redshifts



Galaxy clustering



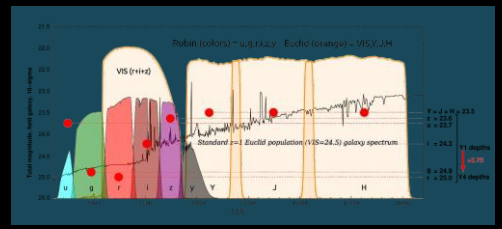
Distribution of luminous matter

Synergy with ground-based telescopes

JPASS, Subaru, PS1/PS2, CFHT, Blanco, Rubin

Ground-based Photometry

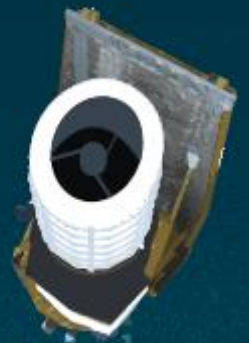
Photometric redshifts



Credit: Euclid Consortium/Cuillandre

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): late 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.

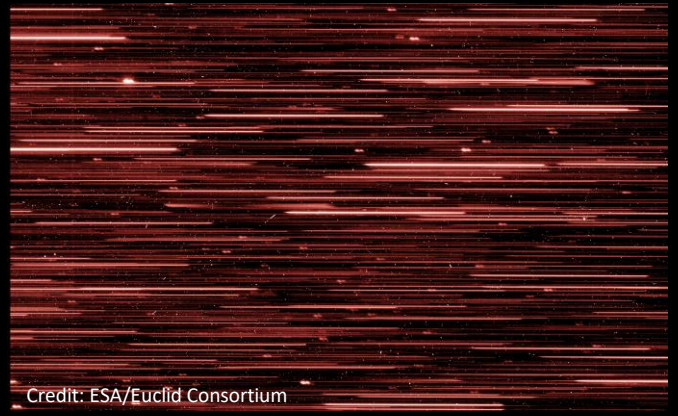
Scientific community

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

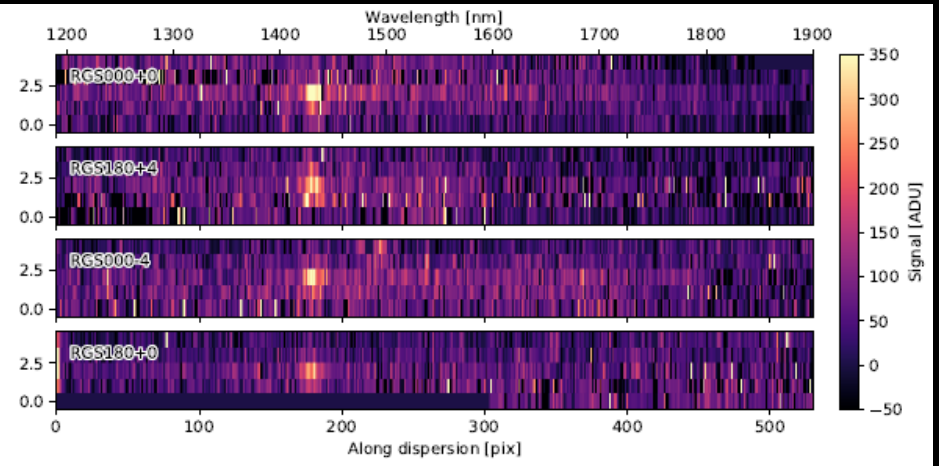
Science

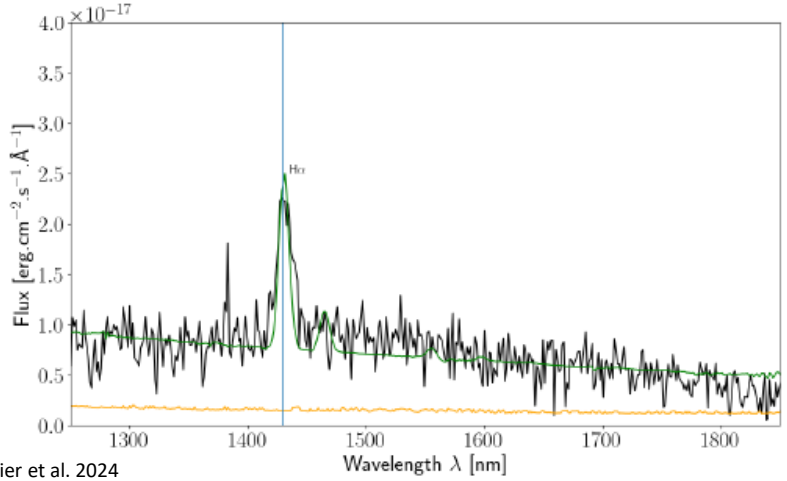
Planning future missions

First Data

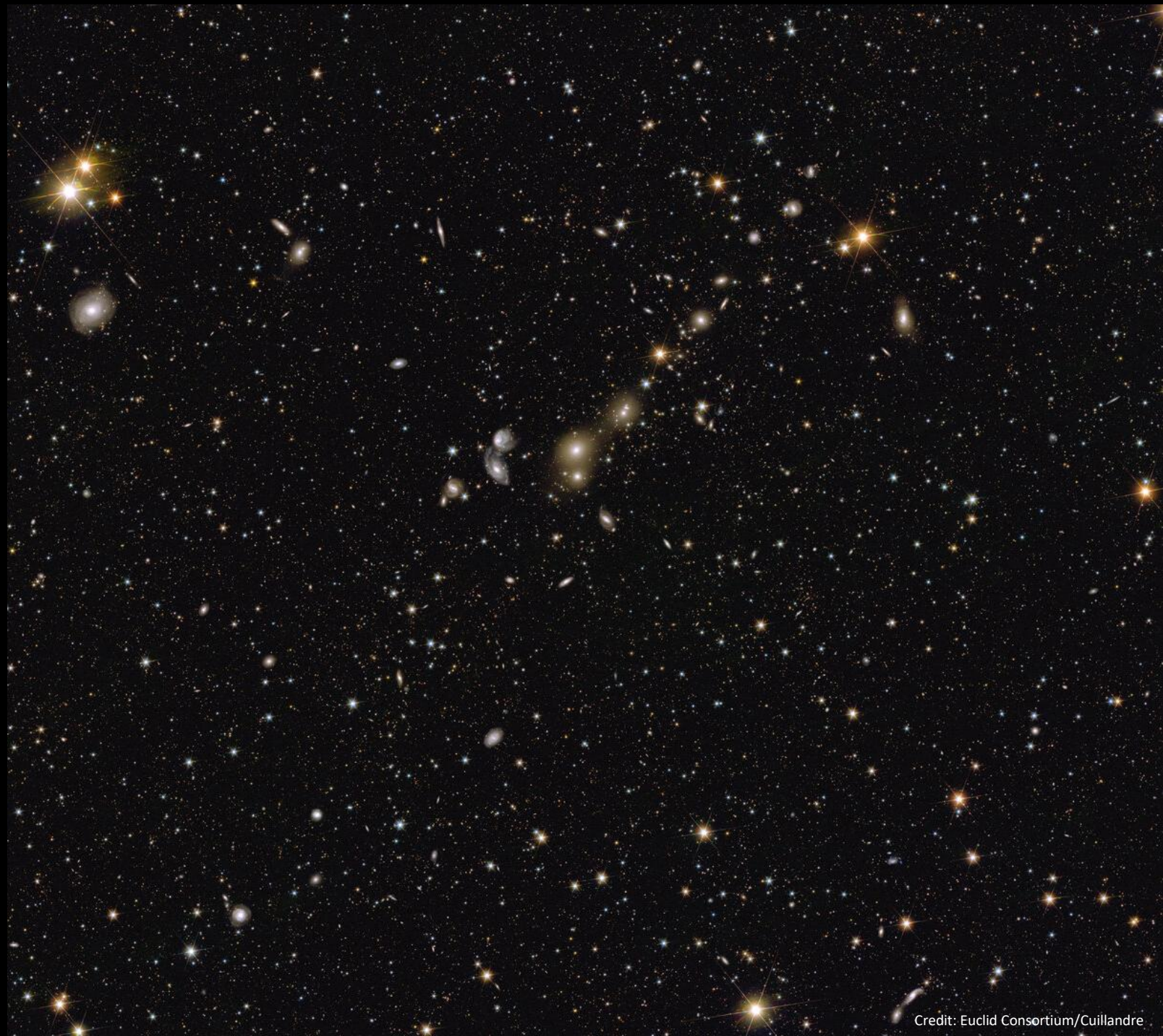


Credit: ESA/Euclid Consortium

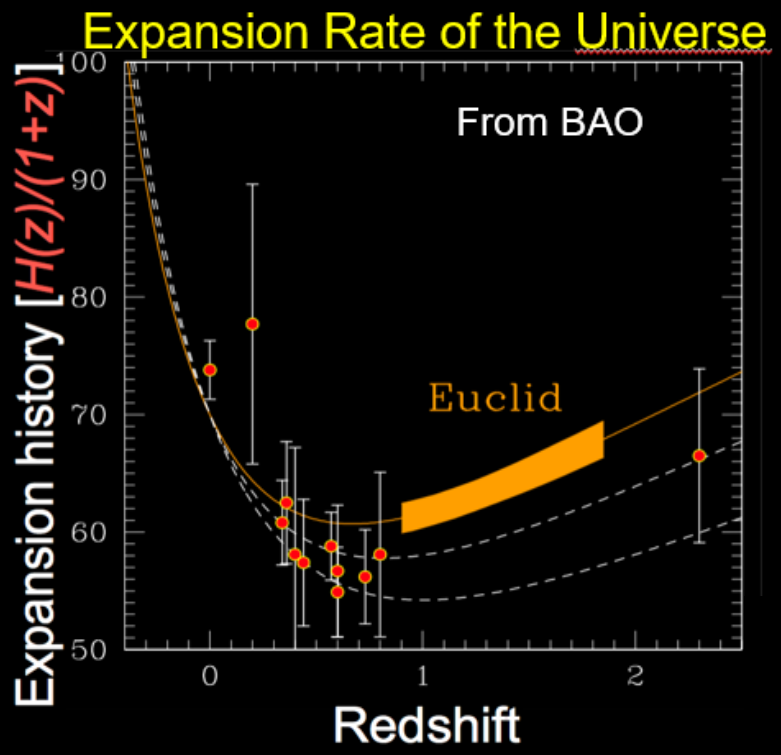


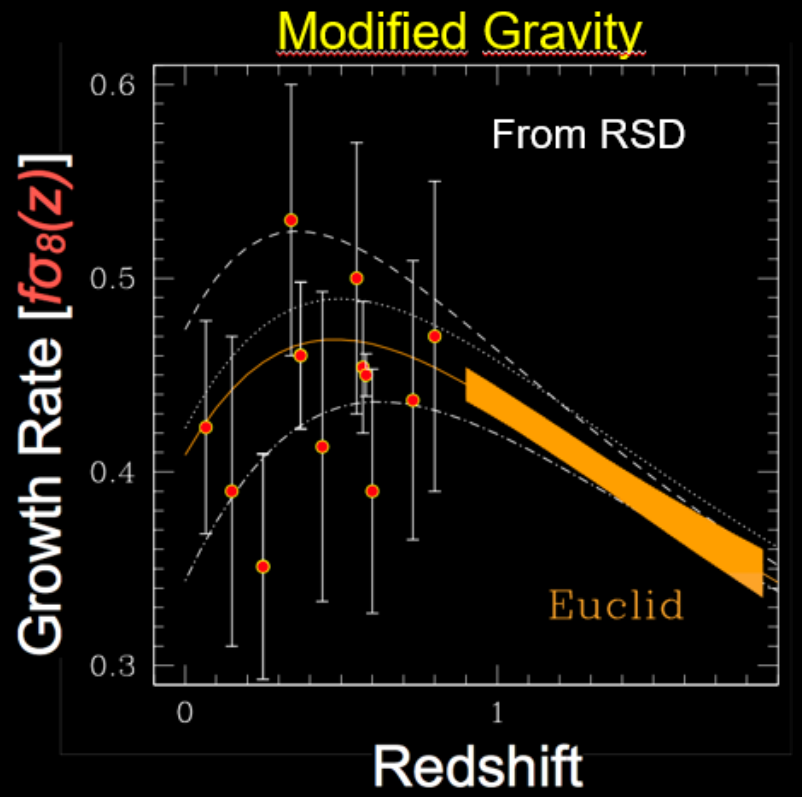


Mellier et al. 2024



Credit: Euclid Consortium/Cuillandre





The Power of Euclid

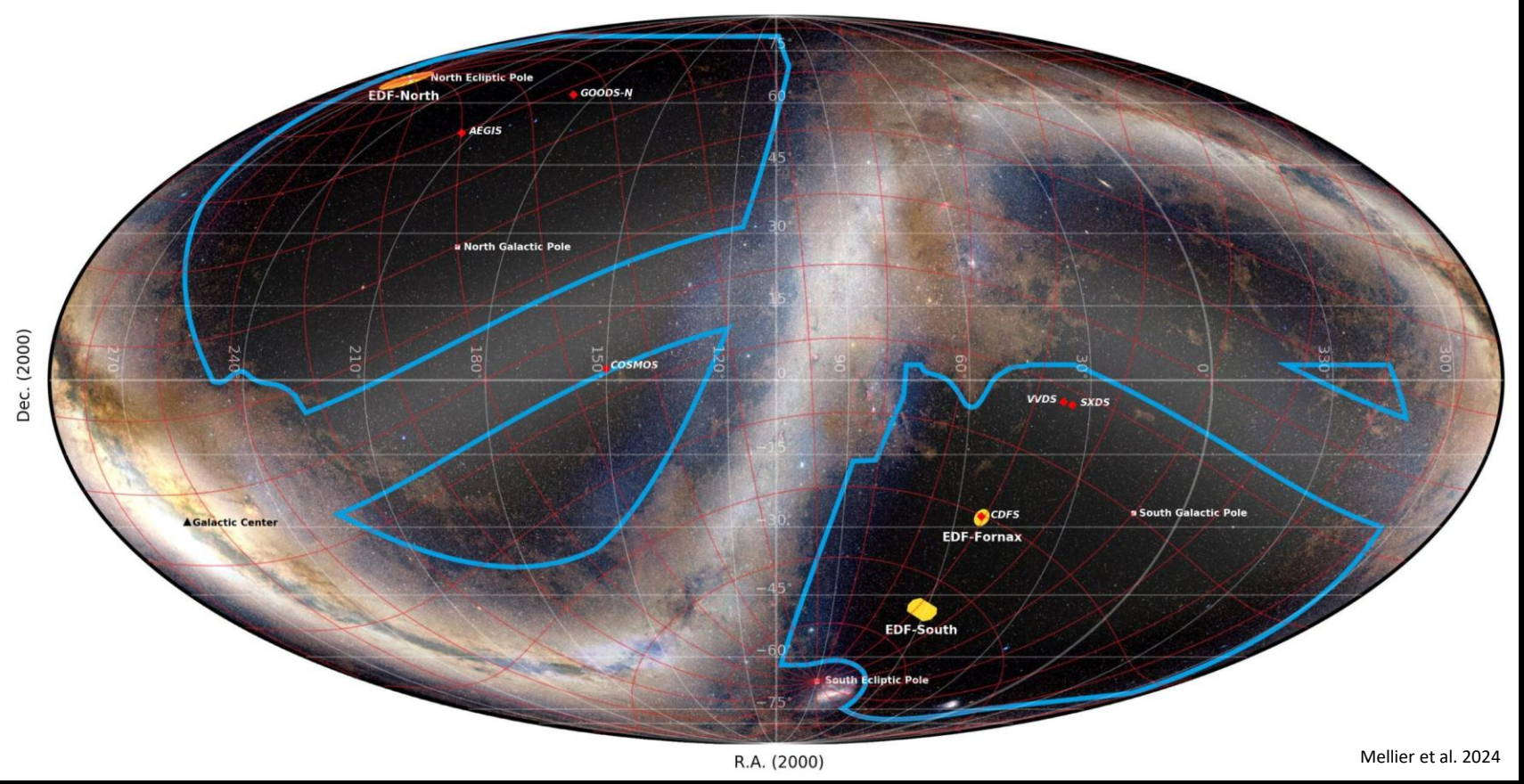
- Multiple cosmological probes
  - *Weak lensing*
  - *Galaxy clustering*
  - *CMB cross-correlations*
  - *Clusters of galaxies*
  - *Strong lensing*
- Mitigation of systematics
- Mitigation of degeneracies
- Improvement of 1-2 dex
- Immense legacy value

Forecasts from Euclid Collaboration, 2020 & L. Guzzo

Part II

Euclid and ET Synergies

Euclid Surveys and Data Products



Mellier et al. 2024

Deep Survey: 53 deg^2

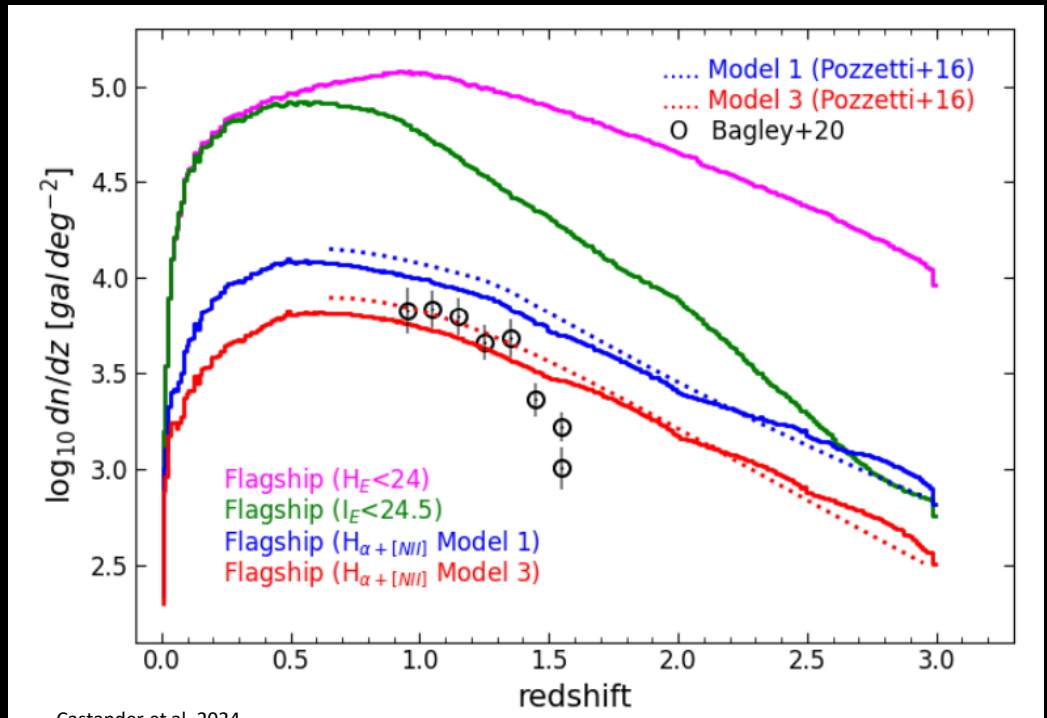
- 3 sky fields
- 2 magnitudes (6.3x) deeper
- Spectroscopic redshifts up to z~7

Wide Survey (extragalactic sky): **14679 deg^2**

- 12 billion sources with m_{AB}<24.4 (NISP) and <26.7 (VIS) at 5σ
- Photometric SEDs: *ugriz* (ground) + YJH (NISP)
- >30 million spectroscopic redshifts mostly at z<1.9 with Hα (z<2.7 with [O III]5007)
- Weak gravitational lensing shear maps
- Galaxy clusters: >10^5, M>10^{14} $M_\odot$, up to z~2
- Morphologies of galaxies (VIS imaging)

The role of the Euclid dataset

- Mission completion by 2030 → good timing for ET
- Space-based data (deep, homogeneous, stable)
- Extended to high redshifts (spectro-z + photo-z)
- **Selected in the near-IR**: mass-selected, all galaxy types, less affected by dust extinction, less biased
- Galaxy physical properties and morphologies
- Galaxy clusters
- Nothing comparable before ET



Castander et al. 2024

Fig. 36. Expected number densities for photometric and spectroscopic emission line flux selected samples as a function of redshift in the *Euclid* Wide survey. Different colours show various selection cuts for the EWS (in I_E, H_E and in the 2 model calibrations for the line fluxes of $f_{H\alpha+[N\,II]} > 2\times10^{-16}$ erg s^{-1} cm^{-2}). The empirical model of Pozzetti et al. (2016) and the data based on slitless HST spectroscopy (Bagley et al. 2020) are also shown.

Some Euclid-ET Synergies

- **GWs with EM counterpart**: host galaxies in a wide redshift range over 1/3 of the sky
- **GWs without EM counterpart**: cosmology with dark sirens and galaxy catalogs
- **Resolved GW**
  - cross-correlations with galaxy clustering
  - cross-correlations with weak gravitational lensing maps
- **Unresolved GW**: cross-correlations of Euclid data with unresolved GW background

Euclid Consortium new **Science Working Group** on **Euclid and Gravitational Waves**

Co-leads: Michele Moresco (Uni. Bologna - DIFA), Miguel Zumalacarregui (MPI for Gravitational Physics)

Example

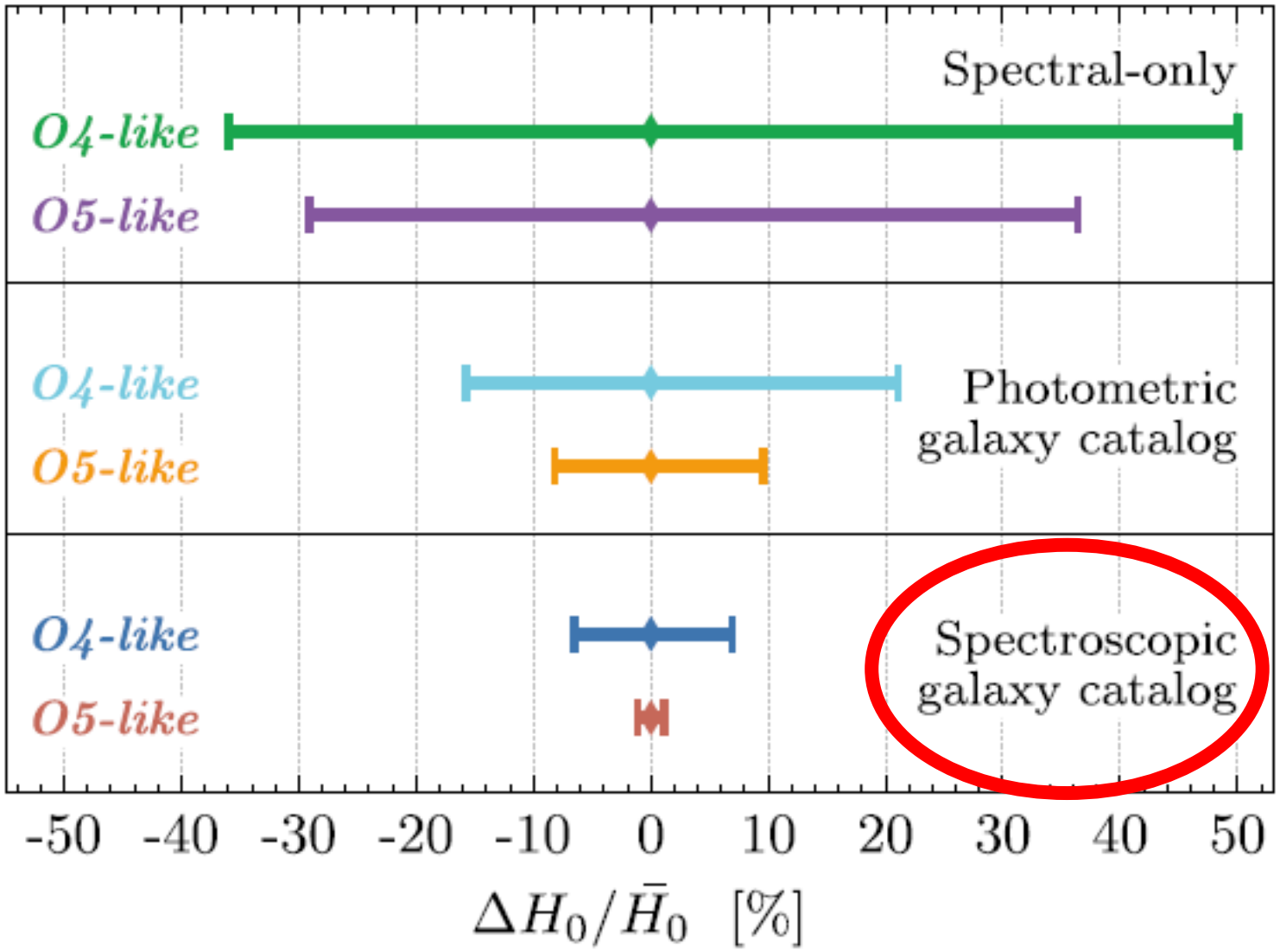


Figure 5. Relative uncertainty on H_0 obtained from spectral-only and full standard sirens analysis of 100 BBHs in the O4- and O5-like network configurations, including a complete galaxy catalog with photometric or spectroscopic redshift uncertainties.

Borghi et al. 2024

Hubble constant
with LVK O4-O5-like

A Schematic Outline of the Cosmic History

Time since the Big Bang (years)

~ 300 thousand

~ 500 million

~ 1 billion

~ 9 billion

~ 13 billion

The Big Bang

The Universe filled with ionized gas

The Universe becomes neutral and opaque

The Dark Ages start

Galaxies and Quasars begin to form
The Reionization starts

The Cosmic Renaissance
The Dark Ages end

Reionization complete, the Universe becomes transparent again

Galaxies evolve

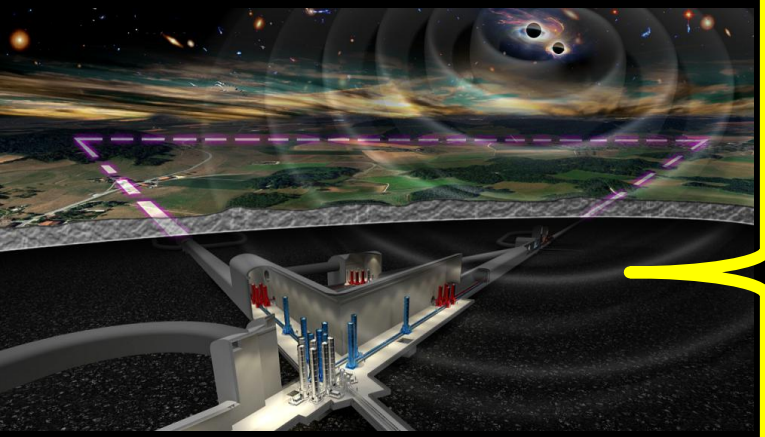
The Solar System forms

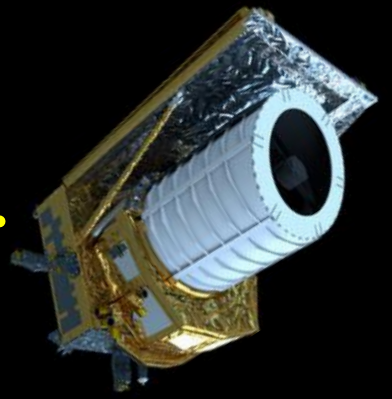
Today: Astronomers figure it all out!

Planck

JWST

Einstein Telescope





Euclid