Illuminating the Dark Universe with Euclid

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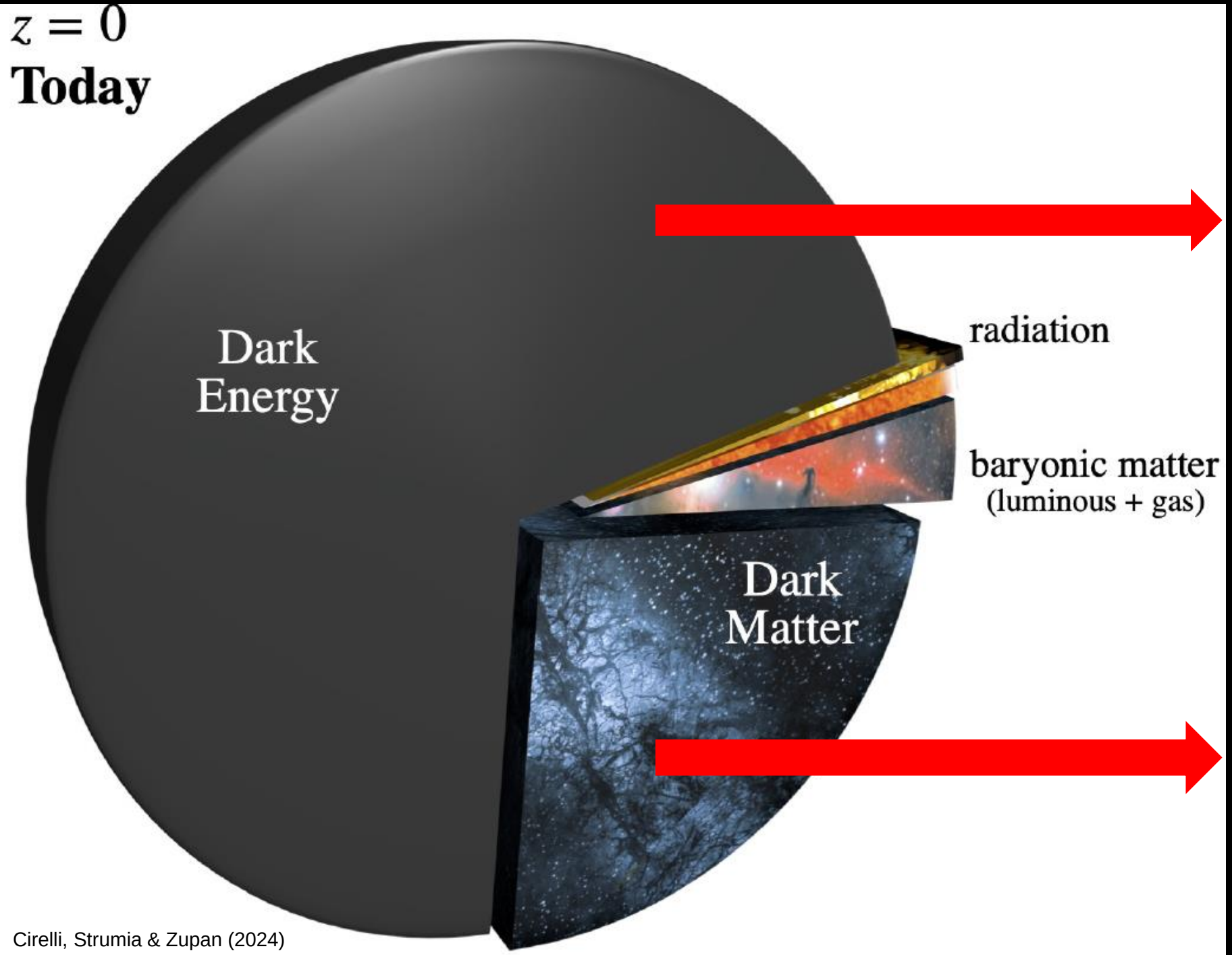
Department of Physics and Astronomy

On behalf of the Euclid Consortium

15th International Workshop on the Identification of Dark Matter - L'Aquila, Italy



Cirelli, Strumia & Zupan (2024)

The Big Questions

- Cosmological constant?
- Scalar field?
- Or breakdown of GR?

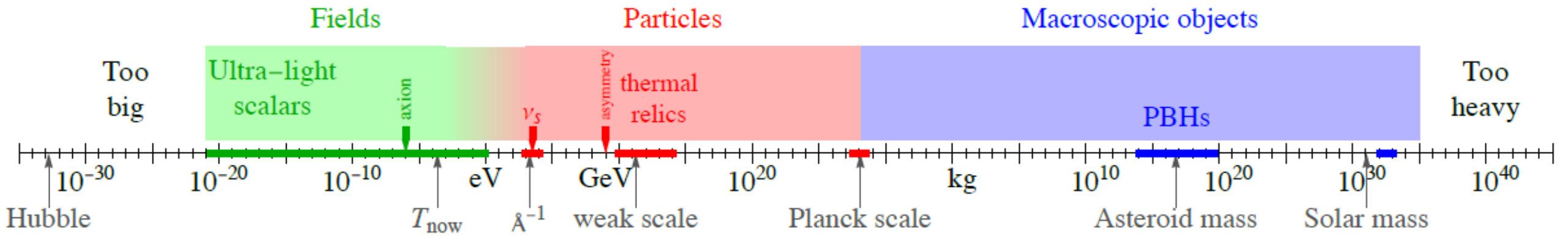
- Nature?
- Or breakdown of GR?

DARK MATTER

• • • Needs confirmation • • •

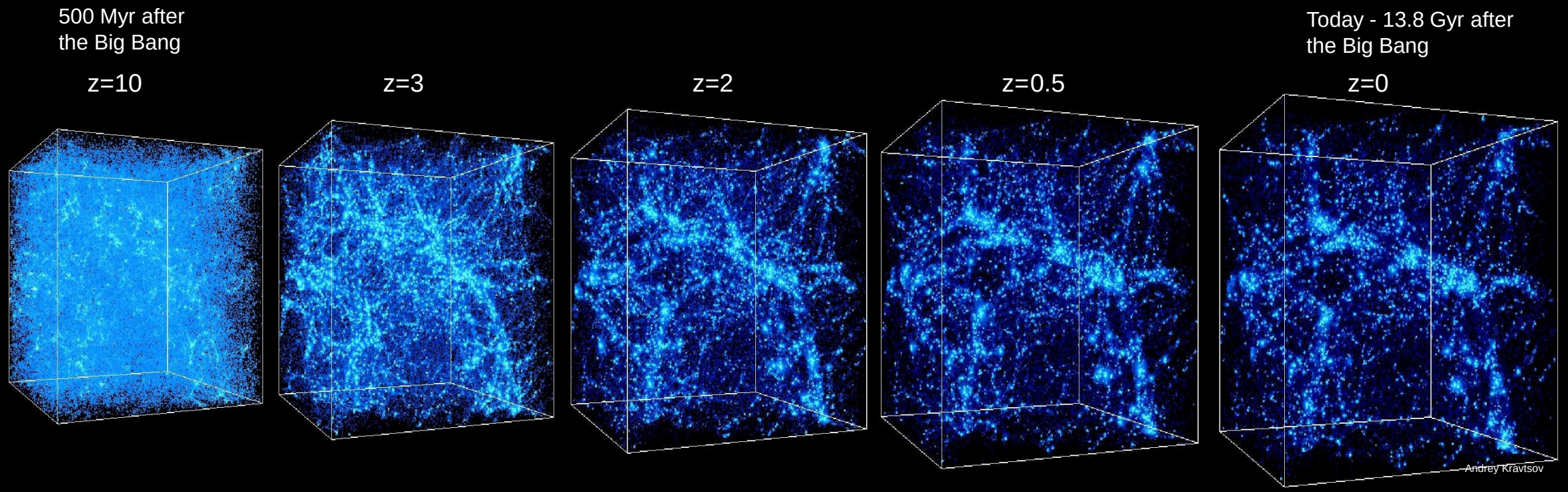
PROPERTIES

$I(J^{PC})$	MASS	WIDTH	DECAY MODES	PRODUCTION
$?(?^{??})$	$? \pm ?$	$? \pm ?$	STABLE ?	$\sigma(?? \to ??) = ?$



Cirelli, Strumia & Zupan (2024)

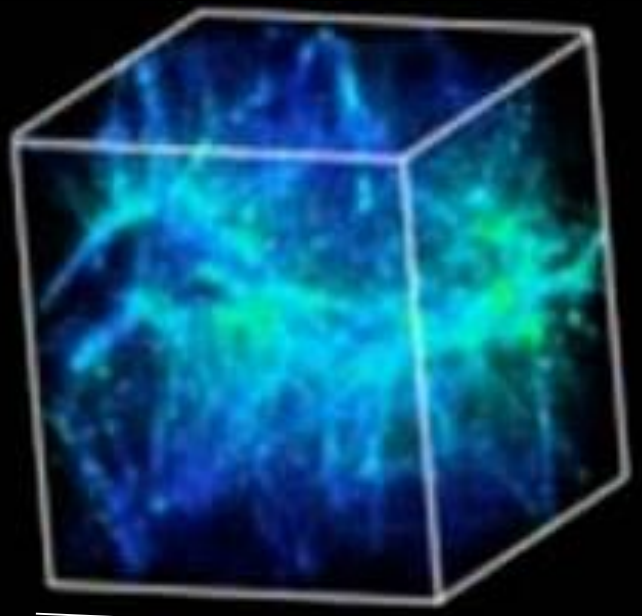
The Cosmic Web as a Laboratory



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

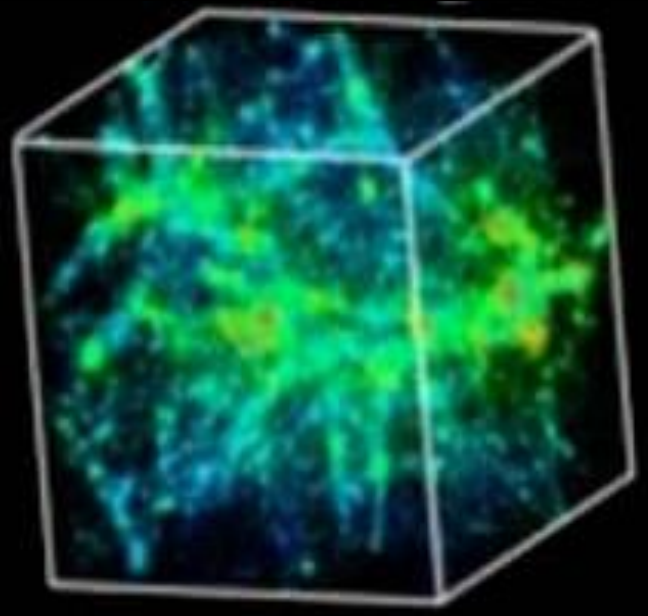
Examples at a Fixed Redshift

ΛCDM

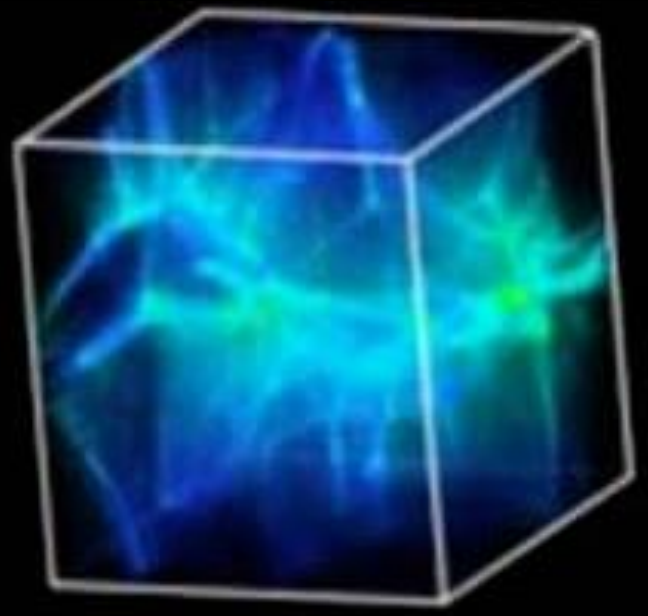


100 Mpc

CDM No dark energy



Warm dark matter



The Promise of Euclid

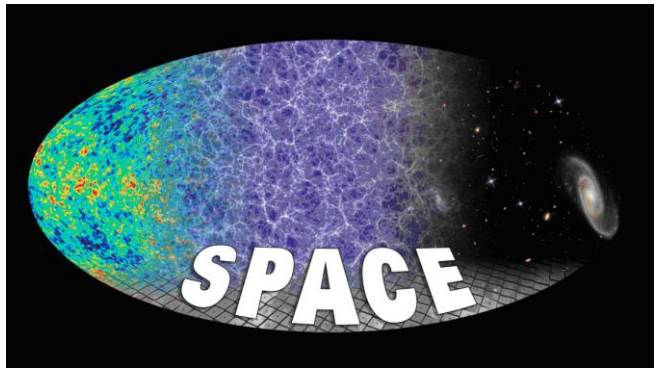
ESA *Cosmic Vision* 2015-2025

2007

DUNE

PI A. Refregier (CEA)

+



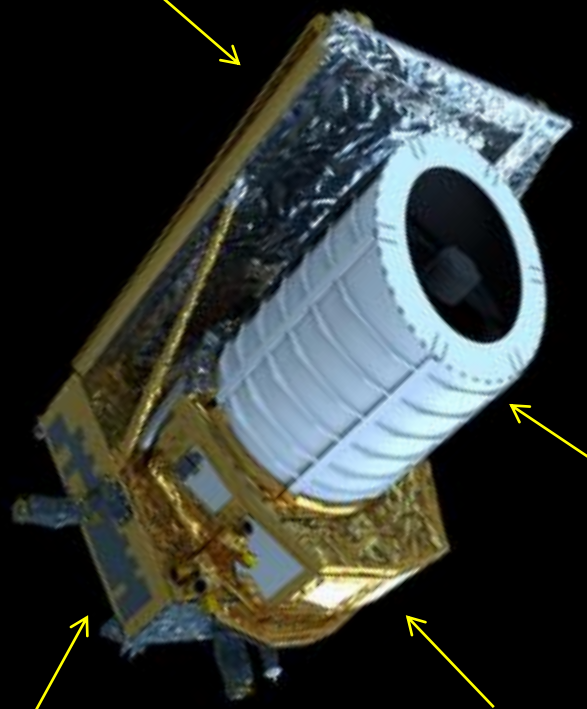
PI A. Cimatti (Uni Bologna)

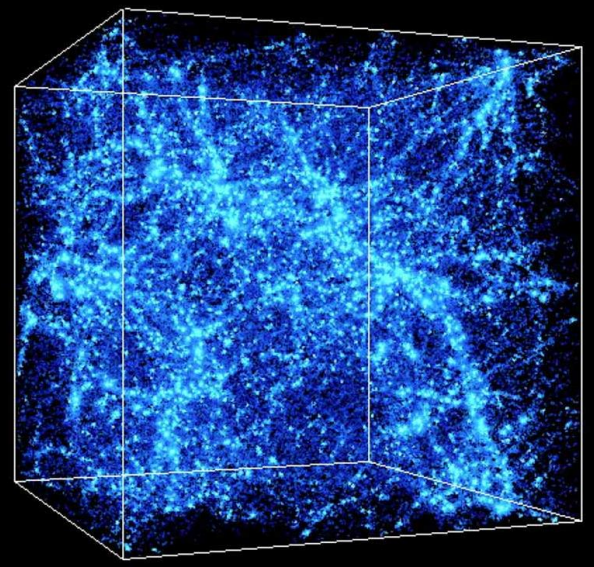
=

2008

Euclid

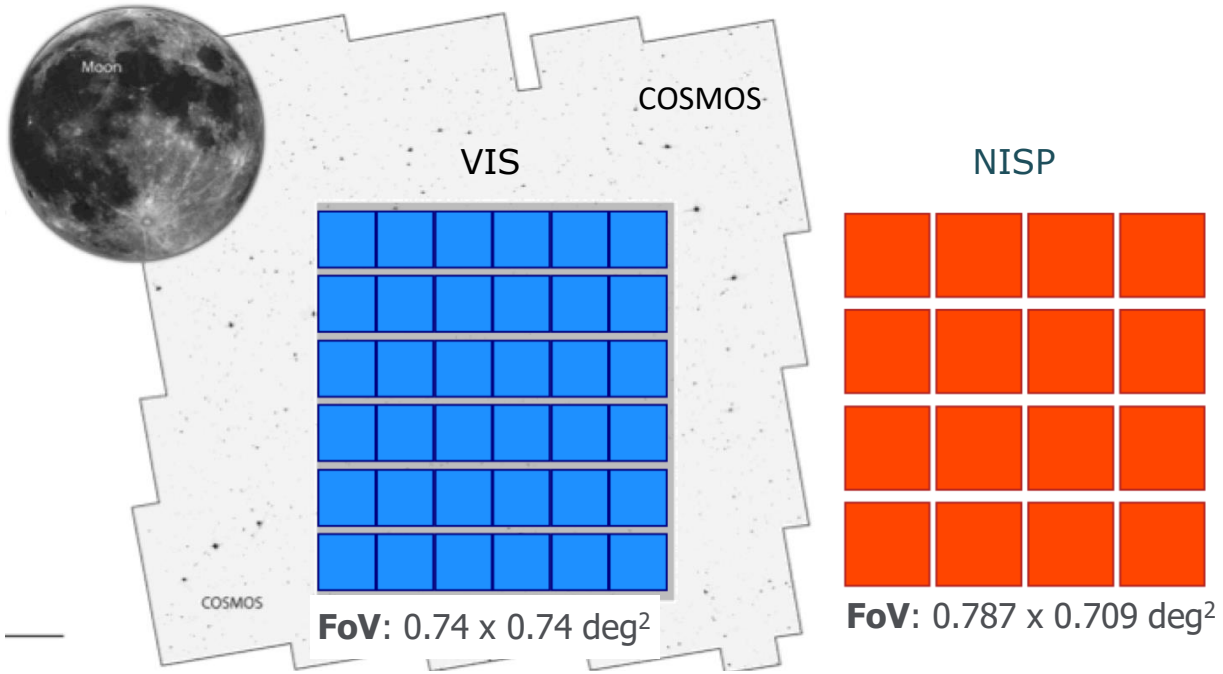
*Merging of **SPACE** (PI A. Cimatti) and **DUNE** (PI A. Refregier) Cosmic Vision proposals (2007) for M2 missions*





- **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 Intruments for Imaging and Spectroscopy



VIS

Imaging

1 filter (red)

36 CCDs

0.1”/pix

$m_{AB} \leq 24.5$

NISP

Imaging & Spectroscopy

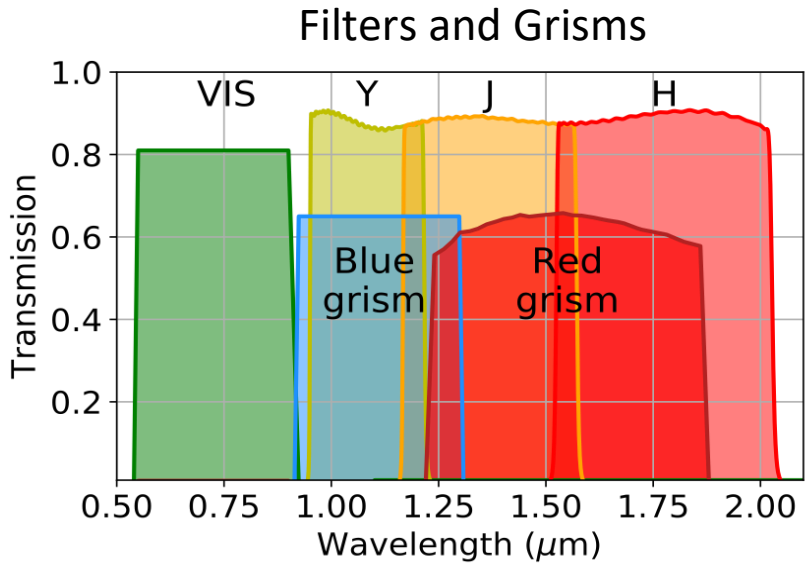
3 filters (YJH) + 2 grisms

16 detectors

0.3”/pix

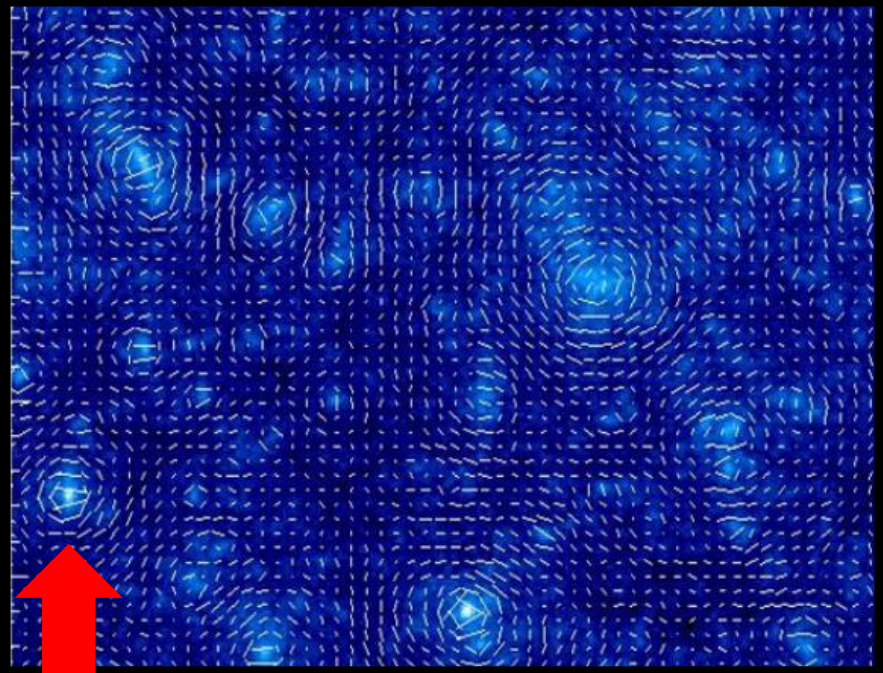
$m_{AB} \leq 24.0$

R~380



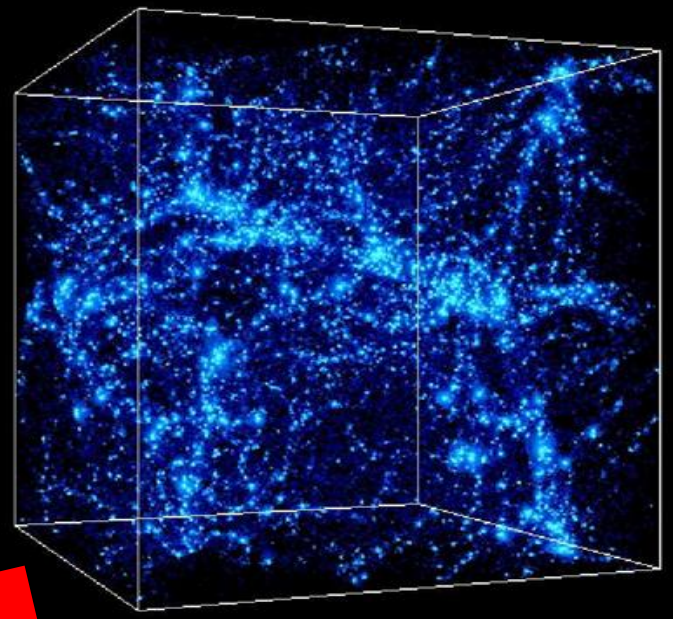
Credits: B. Granett

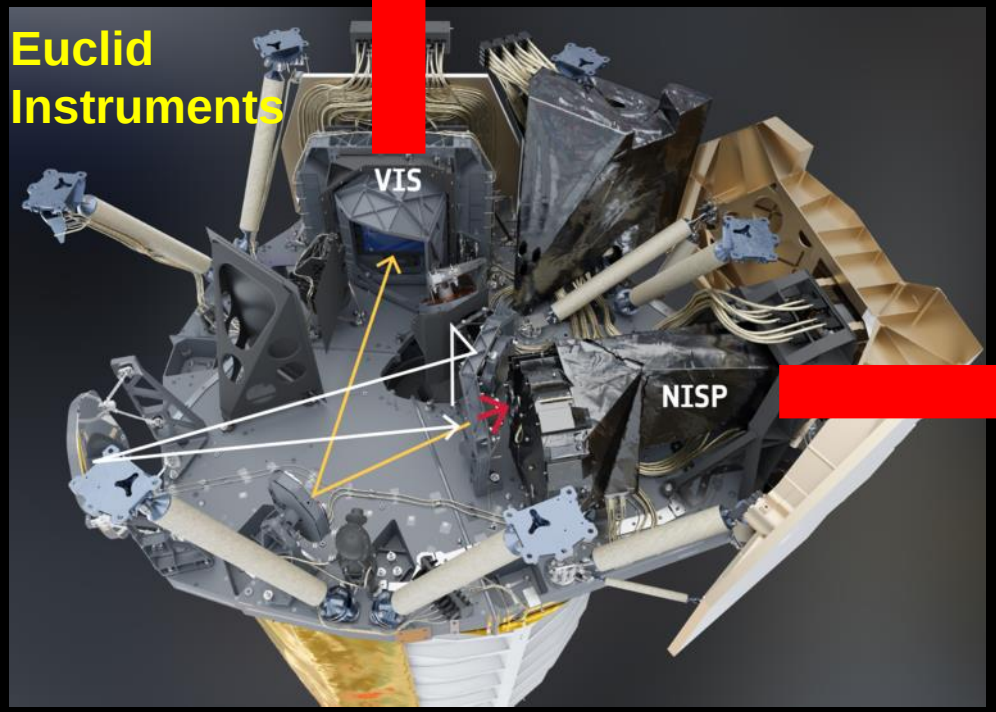
VIS Imaging
Weak Lensing



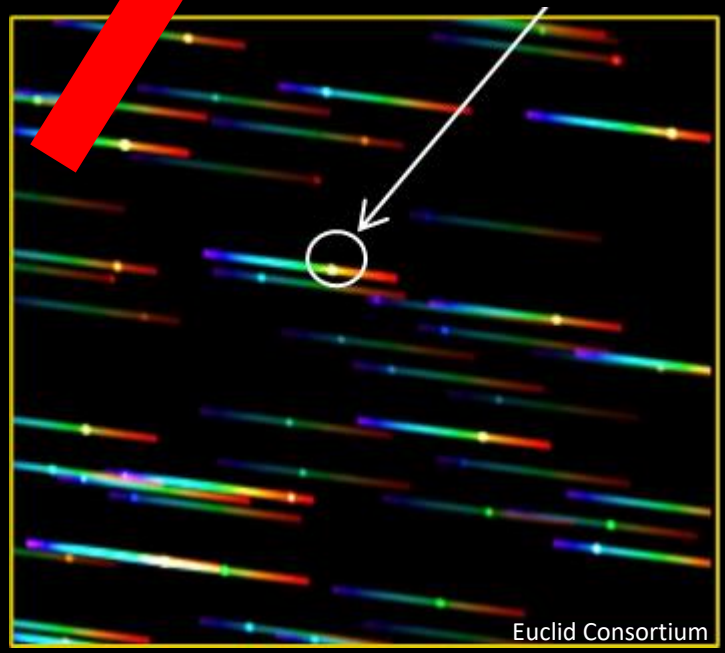
NISP Imaging
Photo-z

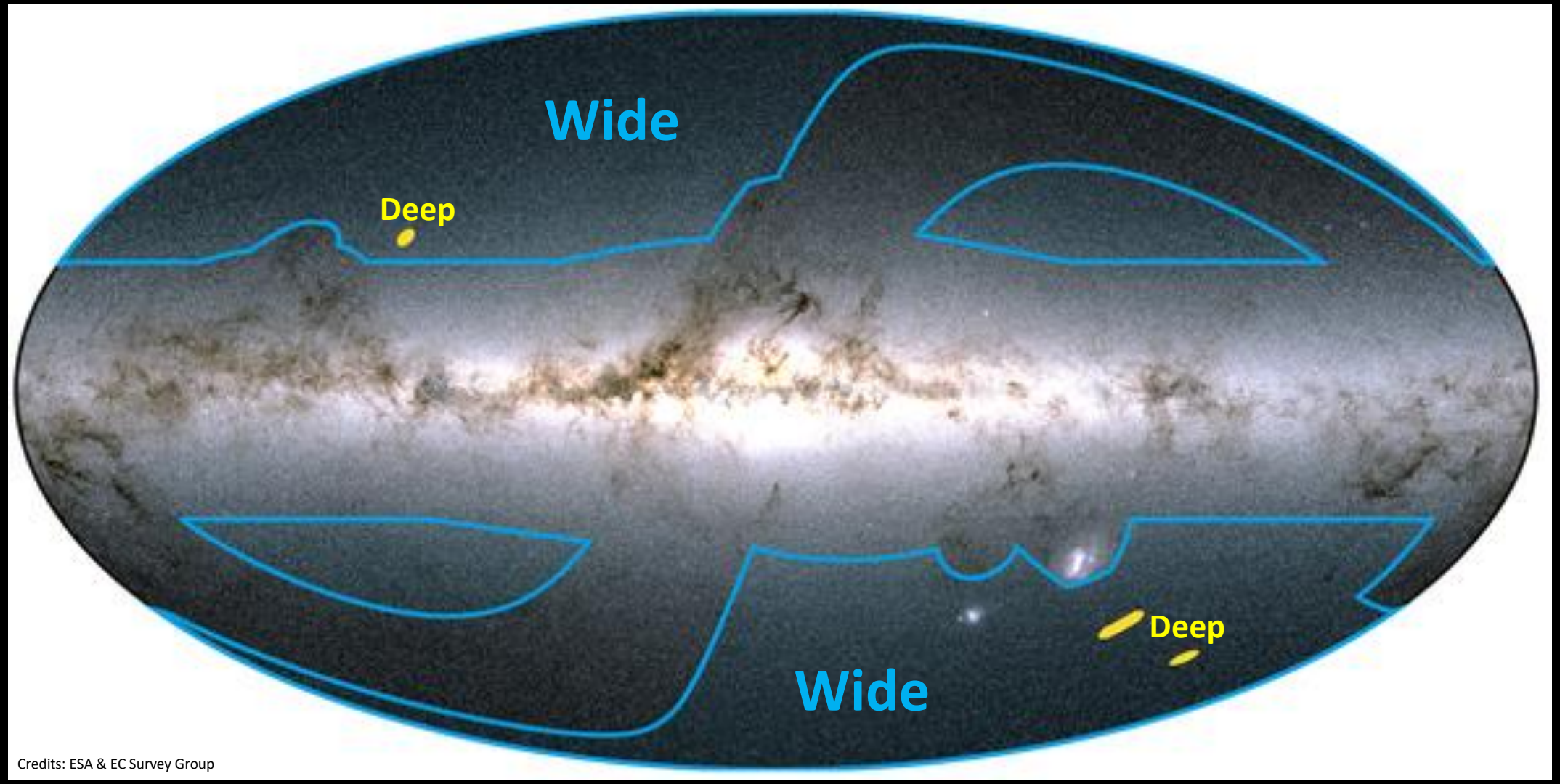
Reconstruction of the 3D cosmic web as a function of redshift





NISP Spectroscopy
Galaxy clustering



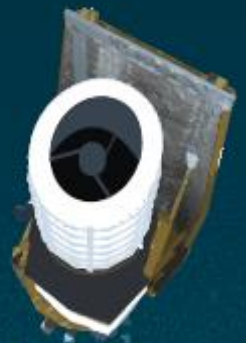


Wide Survey: **15,000 deg²**
Cosmological survey
Imaging + spectroscopy (red grism)

Deep Survey: **53 deg²**
6x deeper than Wide Survey
Imaging + spectroscopy (blue & red grism)
Calibrations and Legacy Science

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

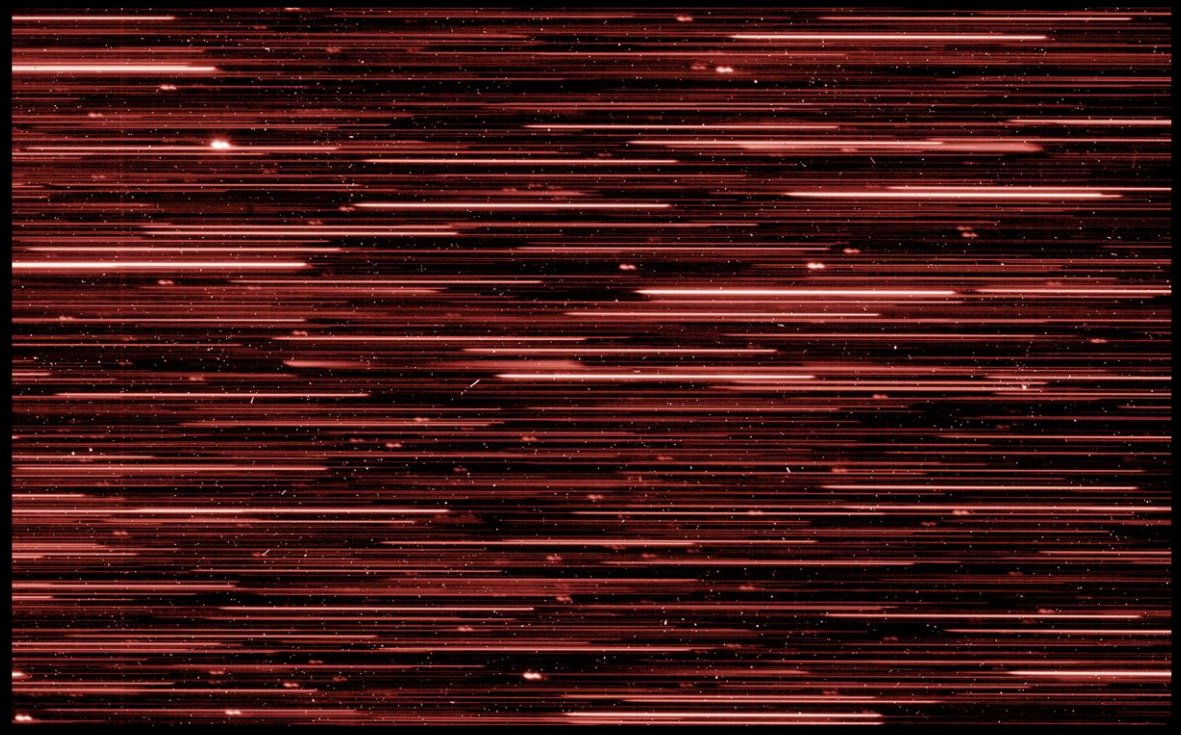
Planning future missions

First Euclid Data!

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

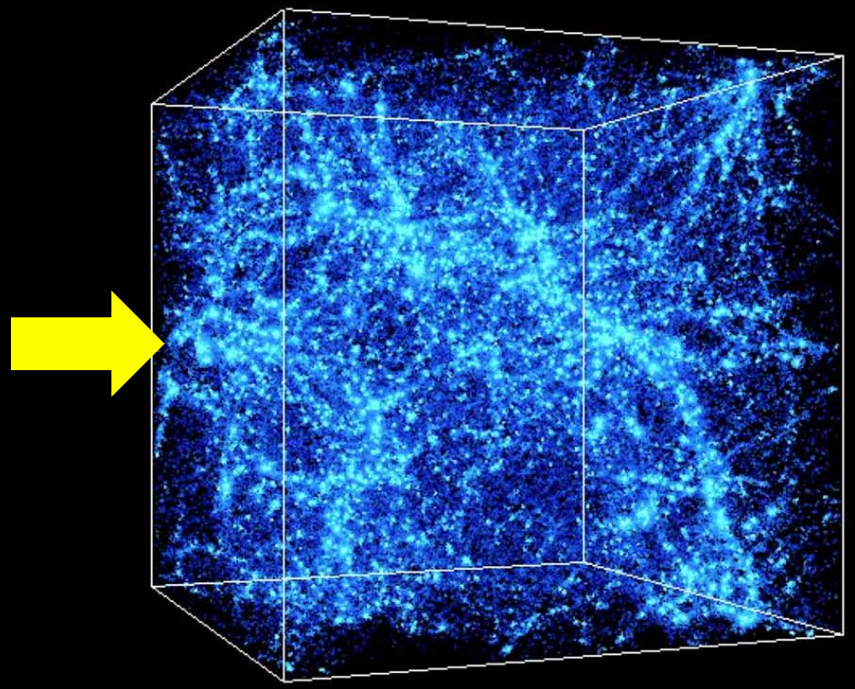
VIS and NISP perform as expected!

ESA - 31/07/23, 07/11/23, 23/05/24



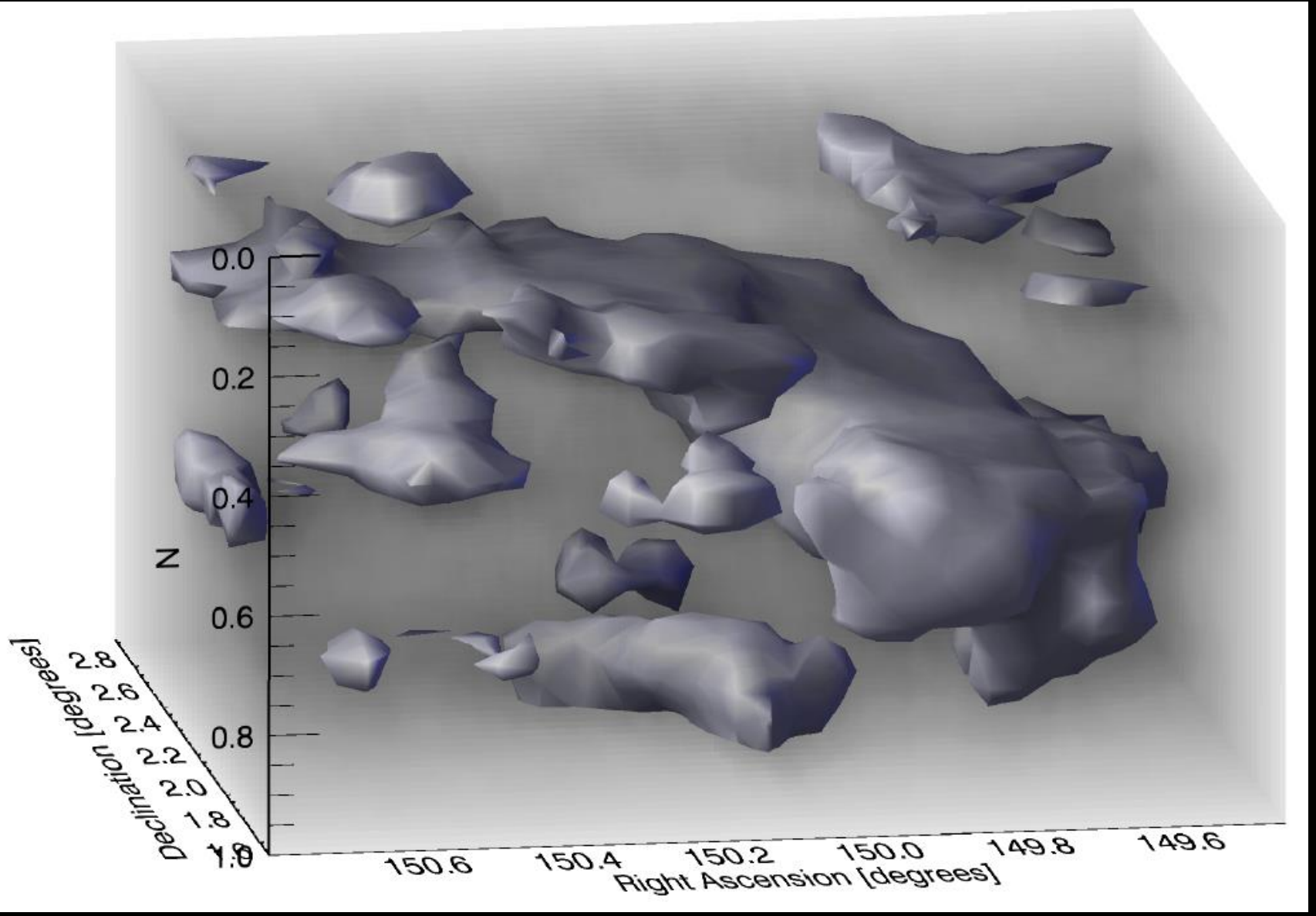
What Do We Expect?

- Same mission
- Different datasets
- Multiple Experiments



- 3D Cosmic web evolution (last 10 Gyr)
- Evolution of the Hubble parameter
- Matter power spectrum
- Nature of Dark Energy
- New constraints on Dark Matter
- Verification of General Relativity
- Properties of neutrino
- Formation and evolution of galaxies and supermassive black holes
- … and much more!

Weak gravitational lensing

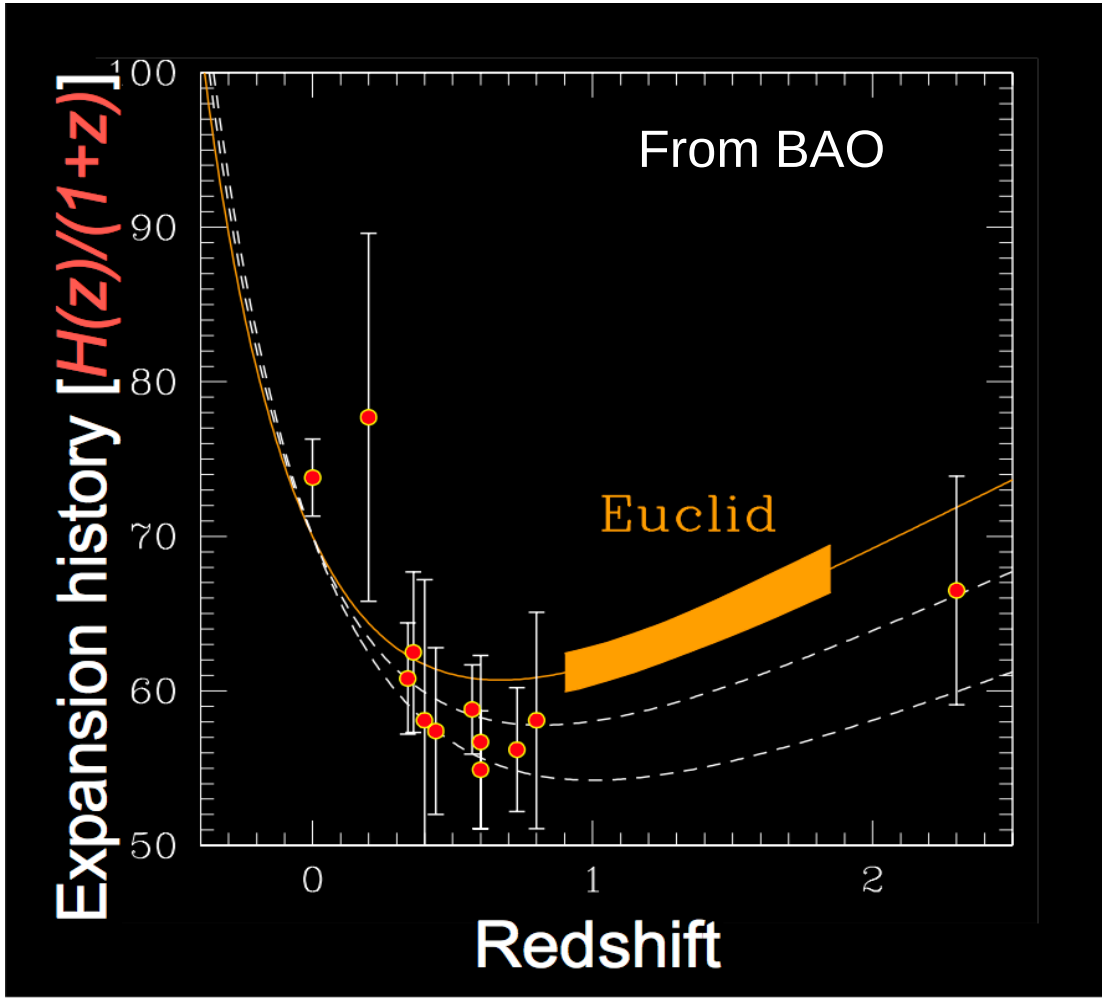


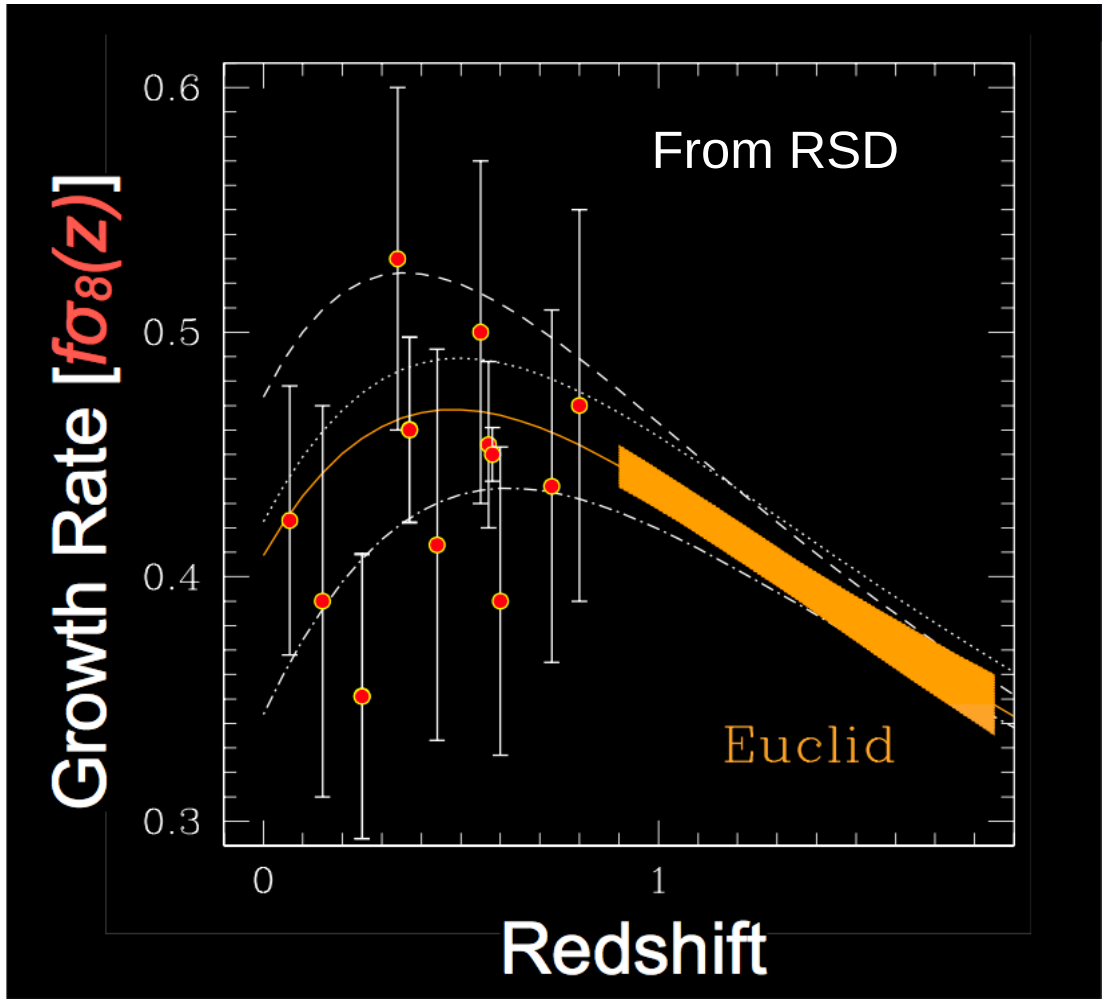
HST data
COSMOS field

Massey et al. 2007

Clustering of Galaxies

Baryonic Acoustic Oscillations and Redshift-space Distorsions

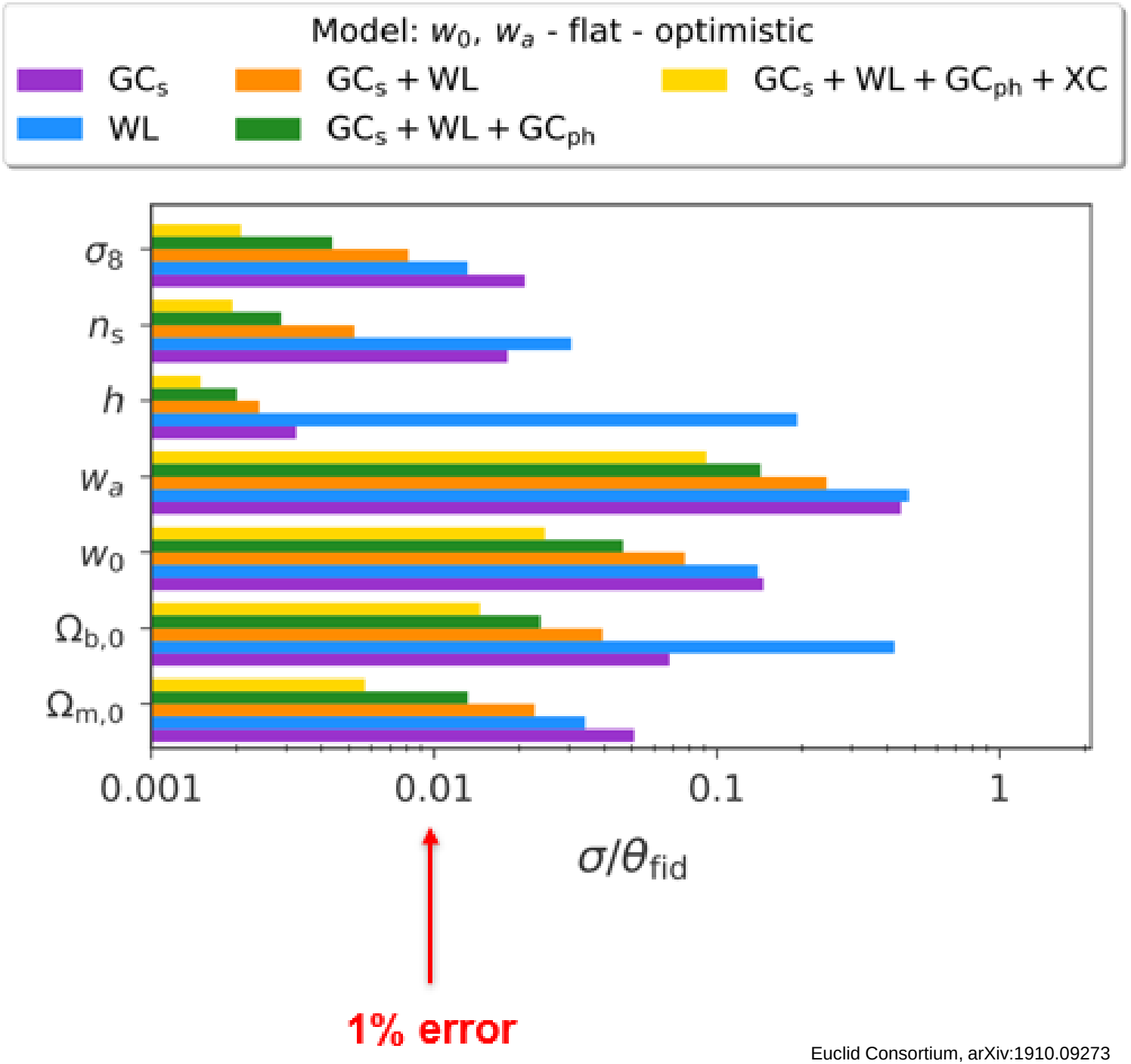




Forecasts from Euclid Collaboration, 2020, A&A, 642, A191

Credits: L. Guzzo

The Power of Euclid



- Space-based data!
- Multiple 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 Consortium, arXiv:1910.09273

Dark Matter with Euclid

Where

How

What

When

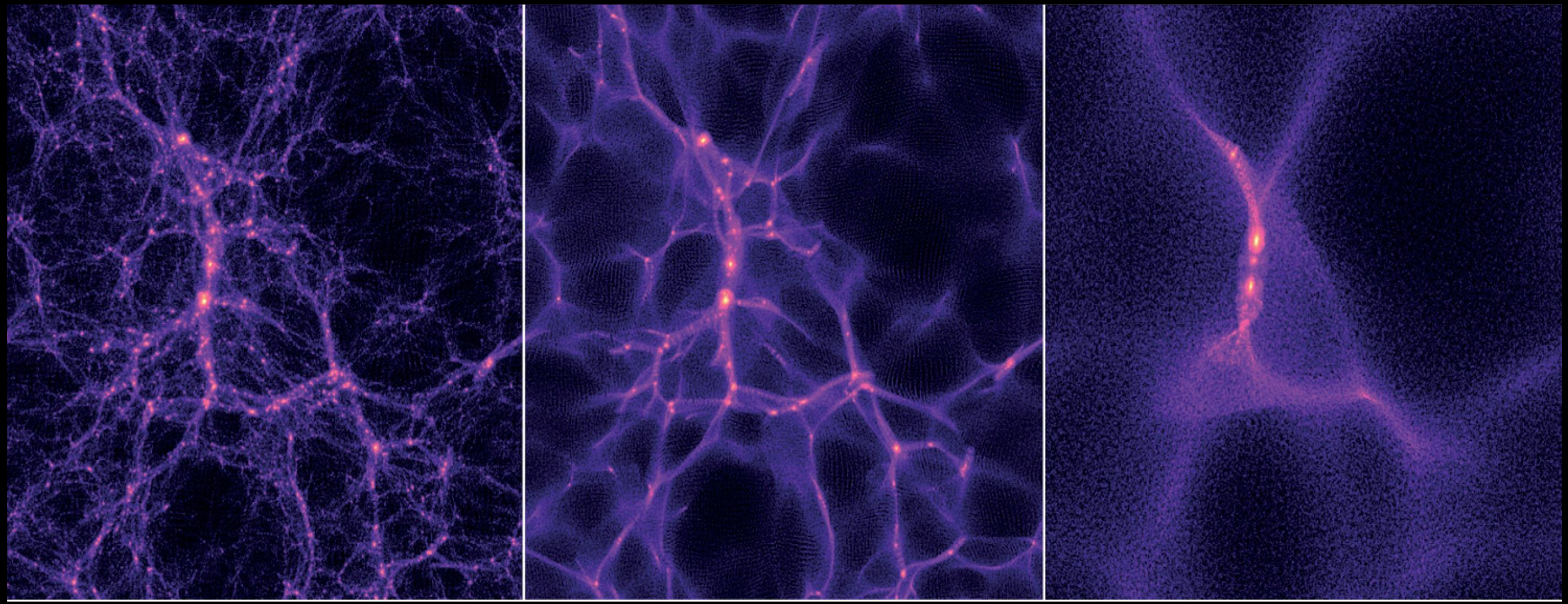
or
Wrong?

Cosmic web and growth of structure depend strongly on DM properties

Cold (m=100 GeV)

Warm (m=0.1 keV)

Hot (m=30 eV)



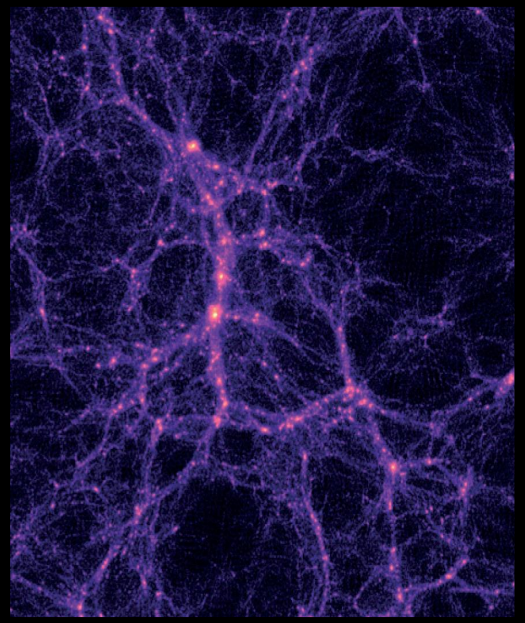
125 Mpc

Marco Baldi, Università di Bologna, Dipartimento di Fisica e Astronomia

Unified DM (DM & DE manifestations of a single dark component): oscillations in the power spectrum

WDM or **CWDM**: suppression in the power spectrum at small scales, halo mass function, clusters number counts, redshift evolution

Ultra-light scalar fields (10^{-33} - 10^{-18} eV): growth of structure and features in the matter power spectrum



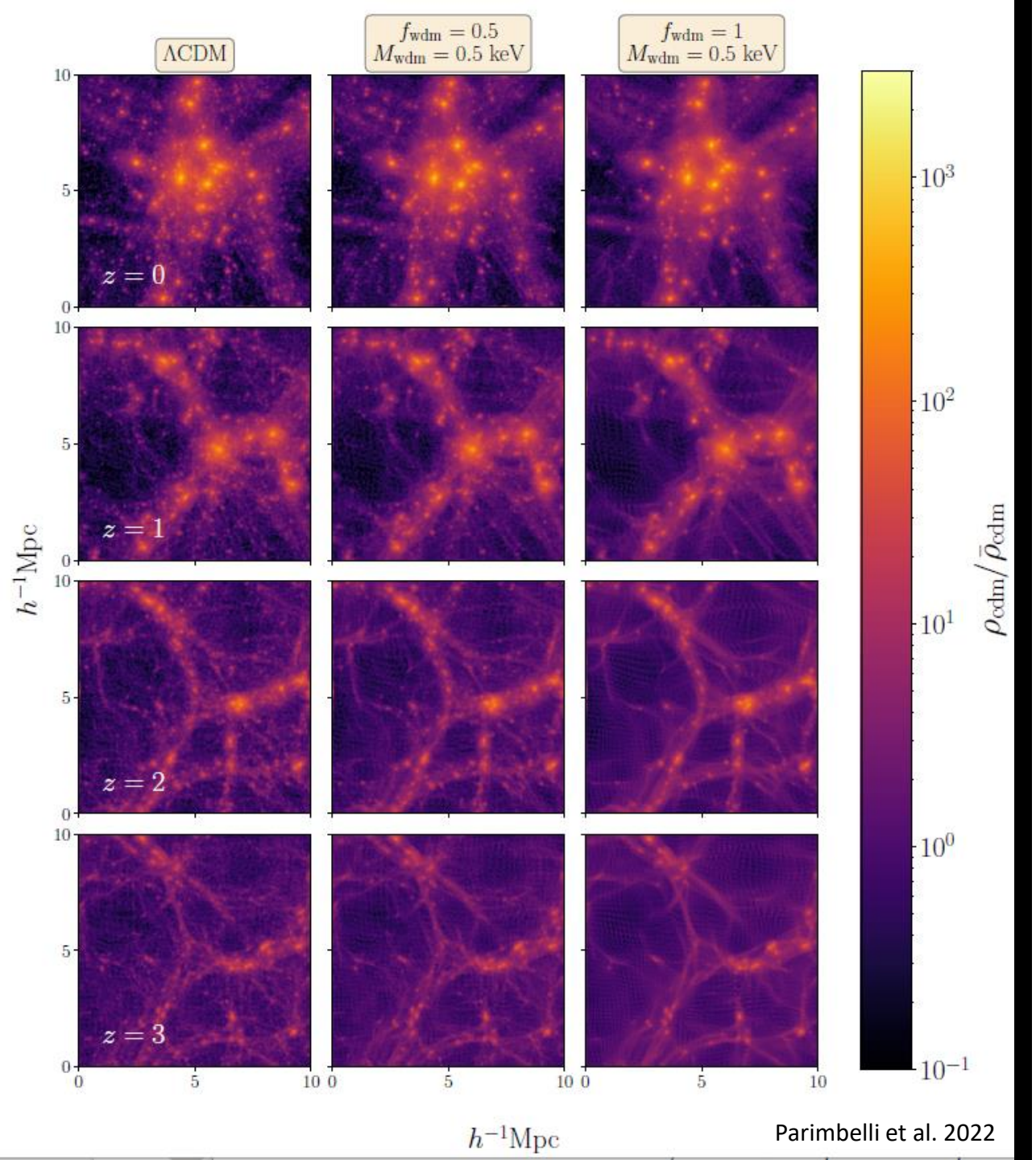
SIDM: upper limit cross section $\sigma/m \sim 10^{-27}$ cm^2 GeV^{-1} (3 dex better than today from the *bullet cluster*)

Properties of the only known (but subdominant) non-baryonic DM particle: **standard neutrino** absolute mass scale, normal or inverted hierarchy, Dirac or Majorana nature

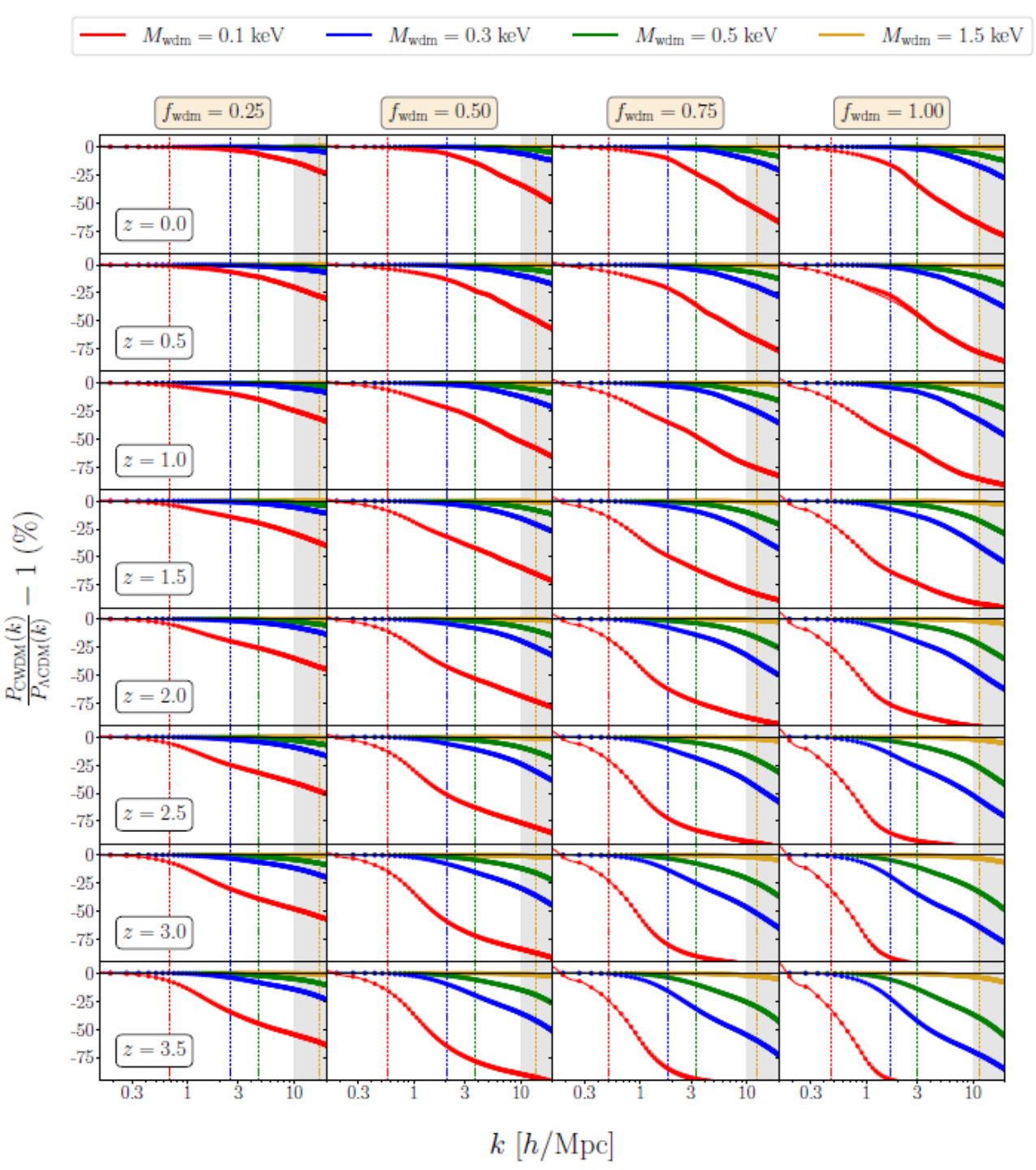
Slope of DM **density profile** within galaxies and clusters with unprecedented accuracy

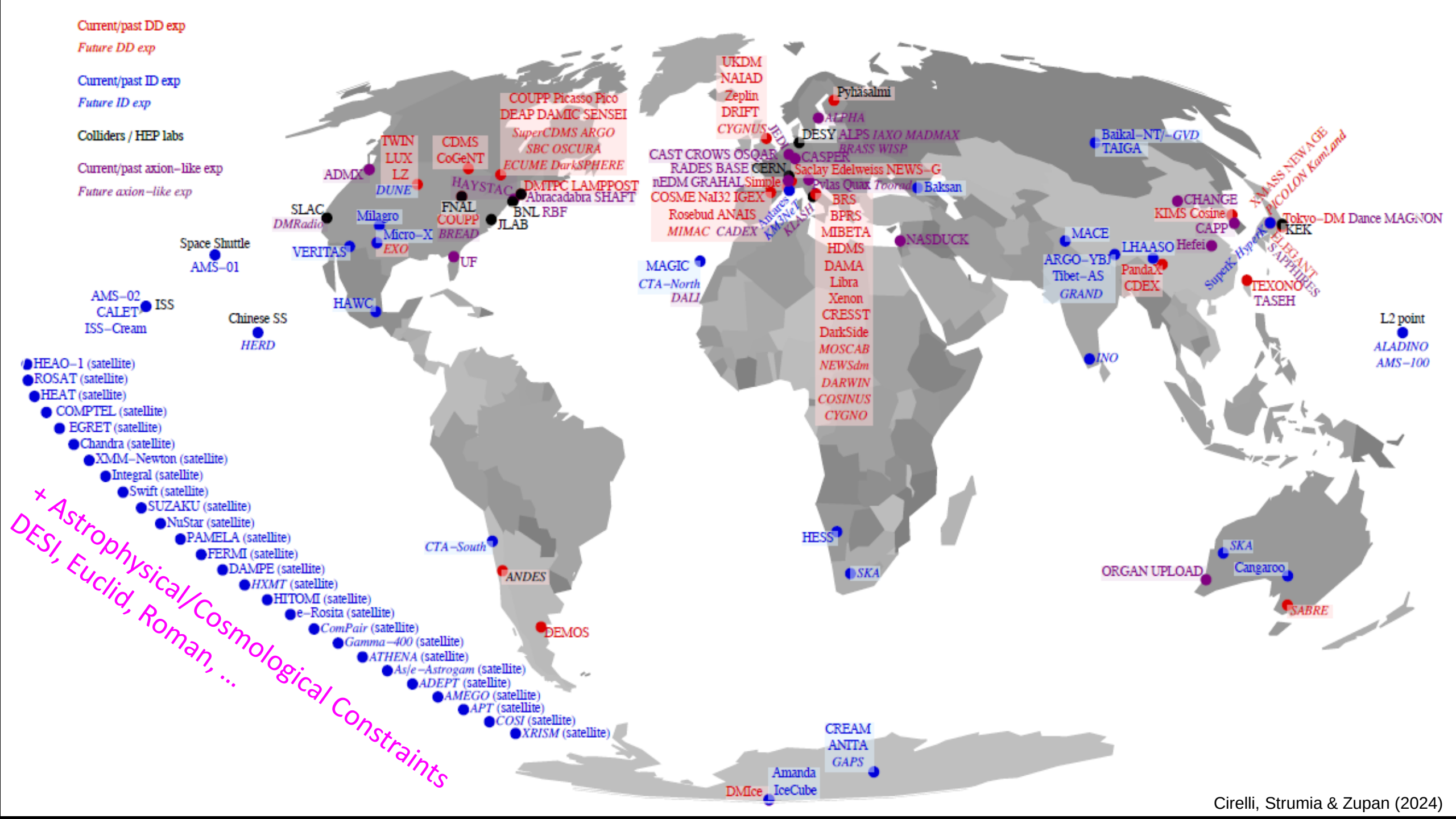
Test of Modified Gravity models

Effects of the DM environment on **luminous matter**, galaxy evolution and structure formation



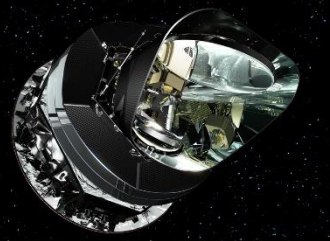
Parimbelli et al. 2022



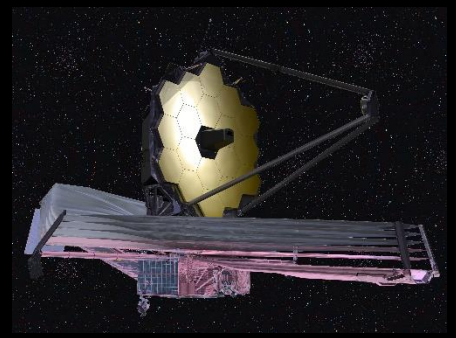


Cirelli, Strumia & Zupan (2024)

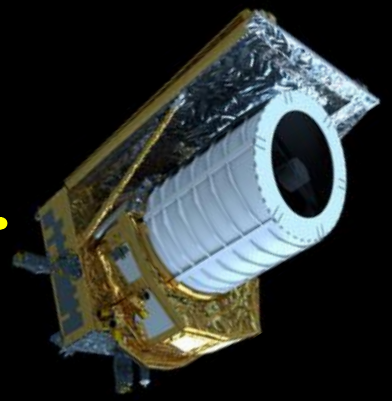
A Schematic Outline of the Cosmic History



Planck



JWST



Euclid