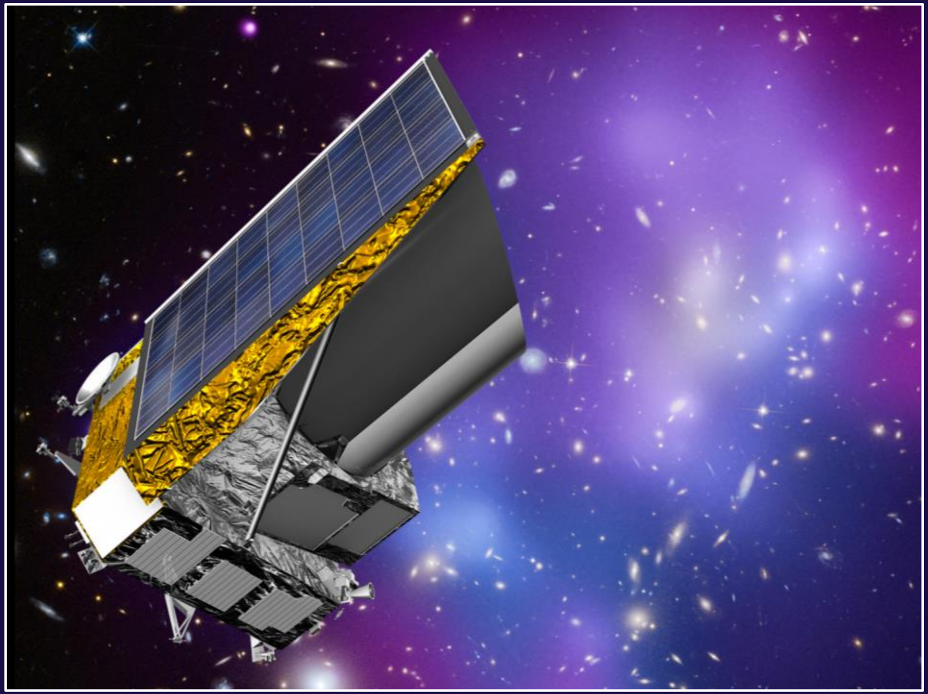
# Science with Euclid

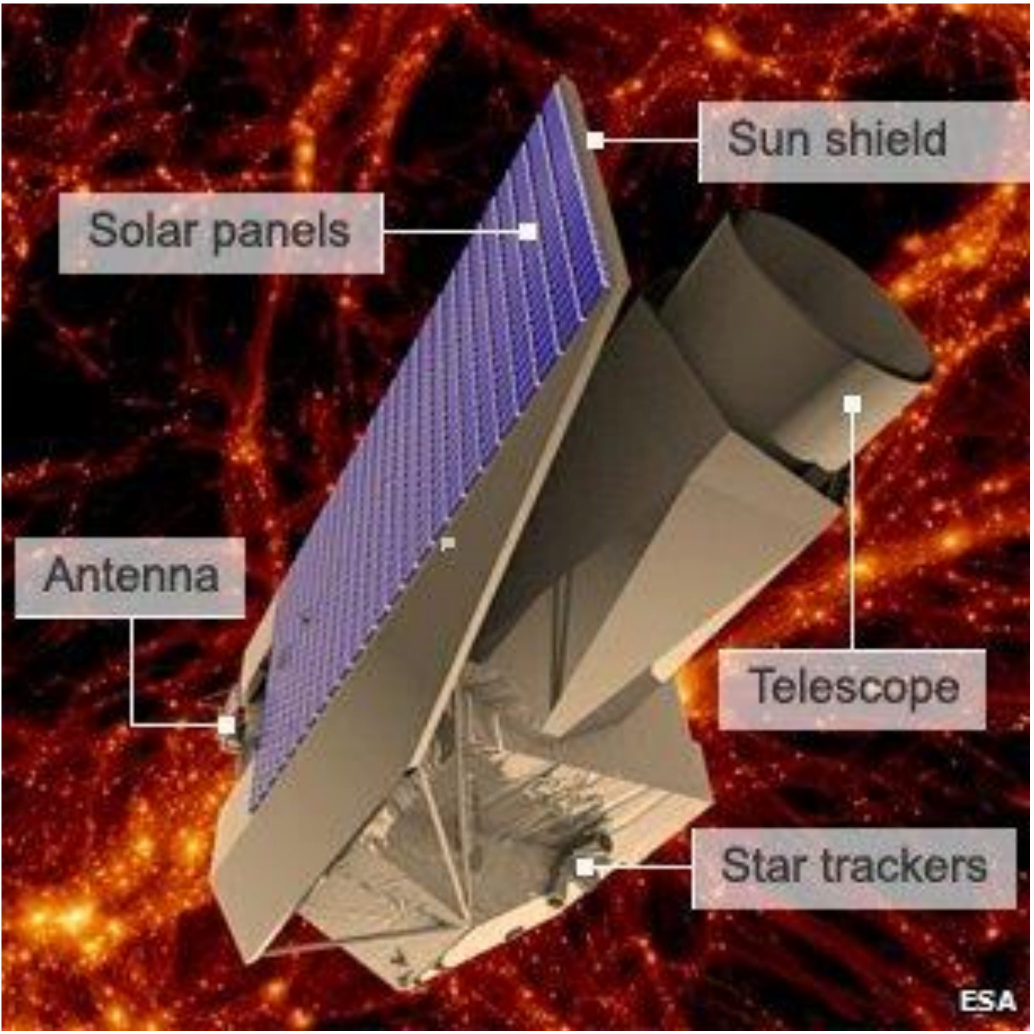


Carmelita Carbone (for the Euclid Consortium)

INAF ISTITUTO NAZIONALE DI ASTROFISICA NATIONAL INSTITUTE FOR ASTROPHYSICS
Istituto di Astrofisica Spaziale e Fisica cosmica di Milano

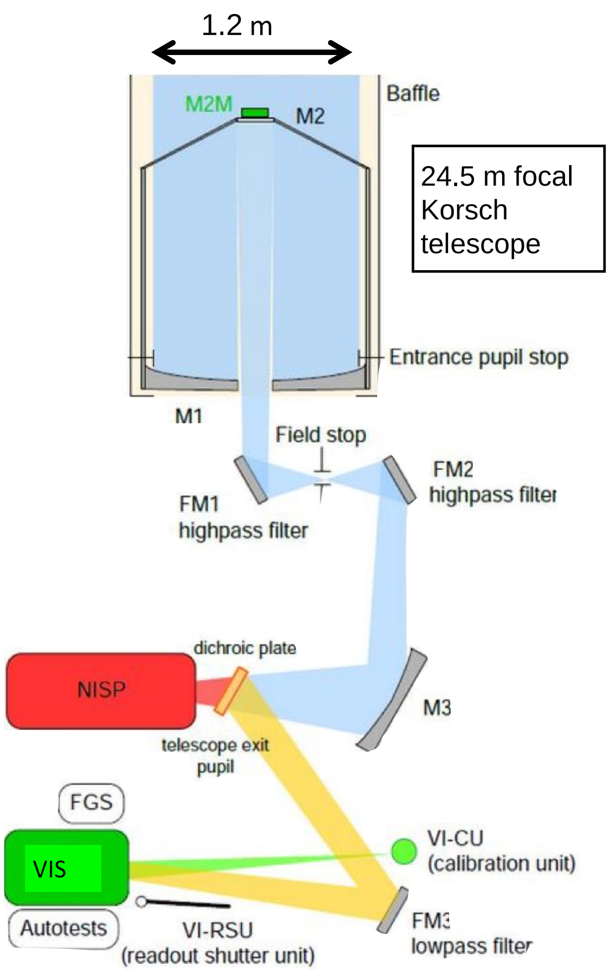
NuPhys2023: Prospects in Neutrino Physics
December 18th, King's College, London

# The Euclid Mission




- Medium-class ESA mission
- 1.2m mirror telescope
- Optical imager (R+I+Z) (VIS)
- NIR-photometer (Y, J, H) (NISP-P)
- NIR-spectrograph slitless (NISP-S)
- **Launch July 2023**, Orbit L2
- Mission duration 6 years
- **Cosmology**
    - **Galaxy Clustering**
    - **Cosmic shear**
    - **Galaxy Clusters**
    - **Cosmic Voids**
    - **CMBX**
    - **Strong Lensing**
- **Legacy Science**

# Euclid payload: two instruments for two probes




*Overview of the PLM sub-systems – Courtesy Airbus Defence and Space.*

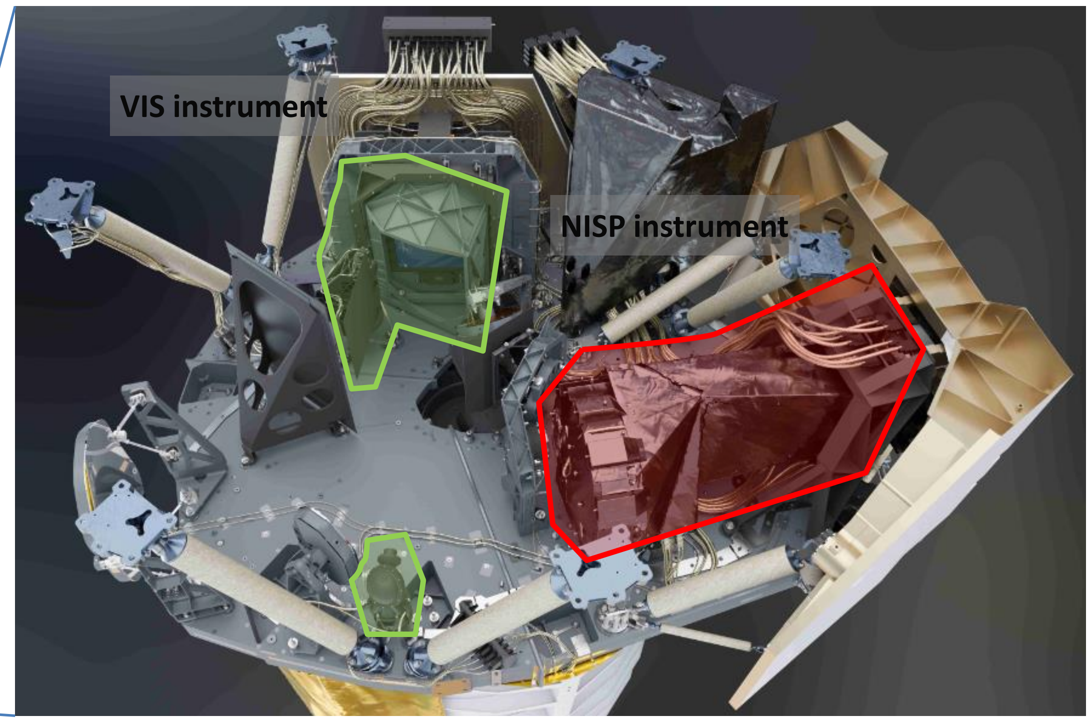
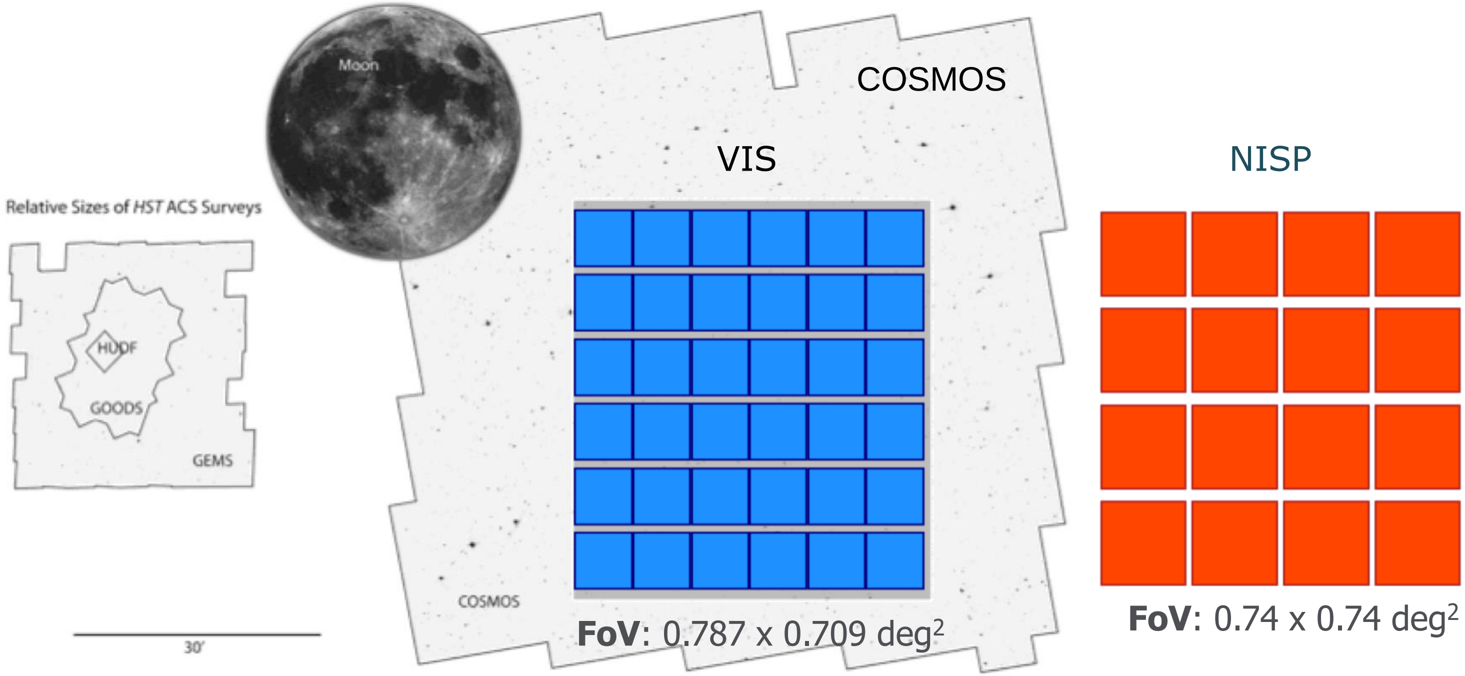



Photo: courtesy ESA/TAS

# Euclid: dual wide-field imager

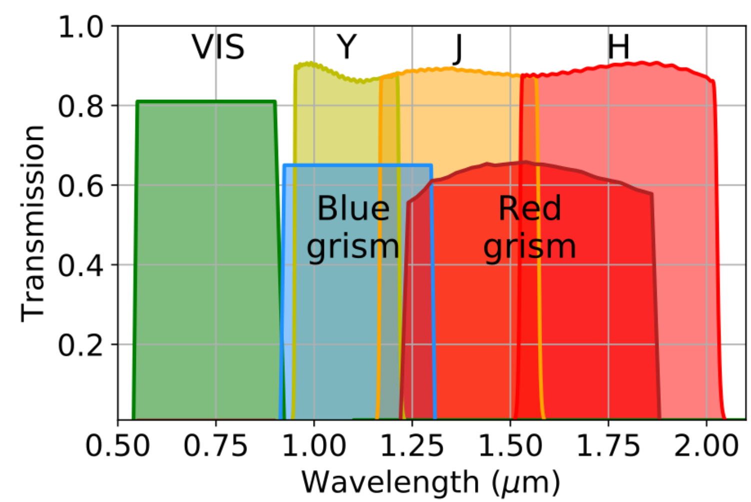



*Credit: Space Telescope Science Institute/Nick Scoville (Caltech)*

VIS and NISP are both wide field imagers covering about 0.55 deg$^2$

VIS has 36 CCDs with pixel size 0.1”, enabling the weak lensing science.

NISP has 16 detectors with pixel size 0.3”.
The spectroscopy resolution will be about 380, which will be well sampled with 13.4”/pixel.



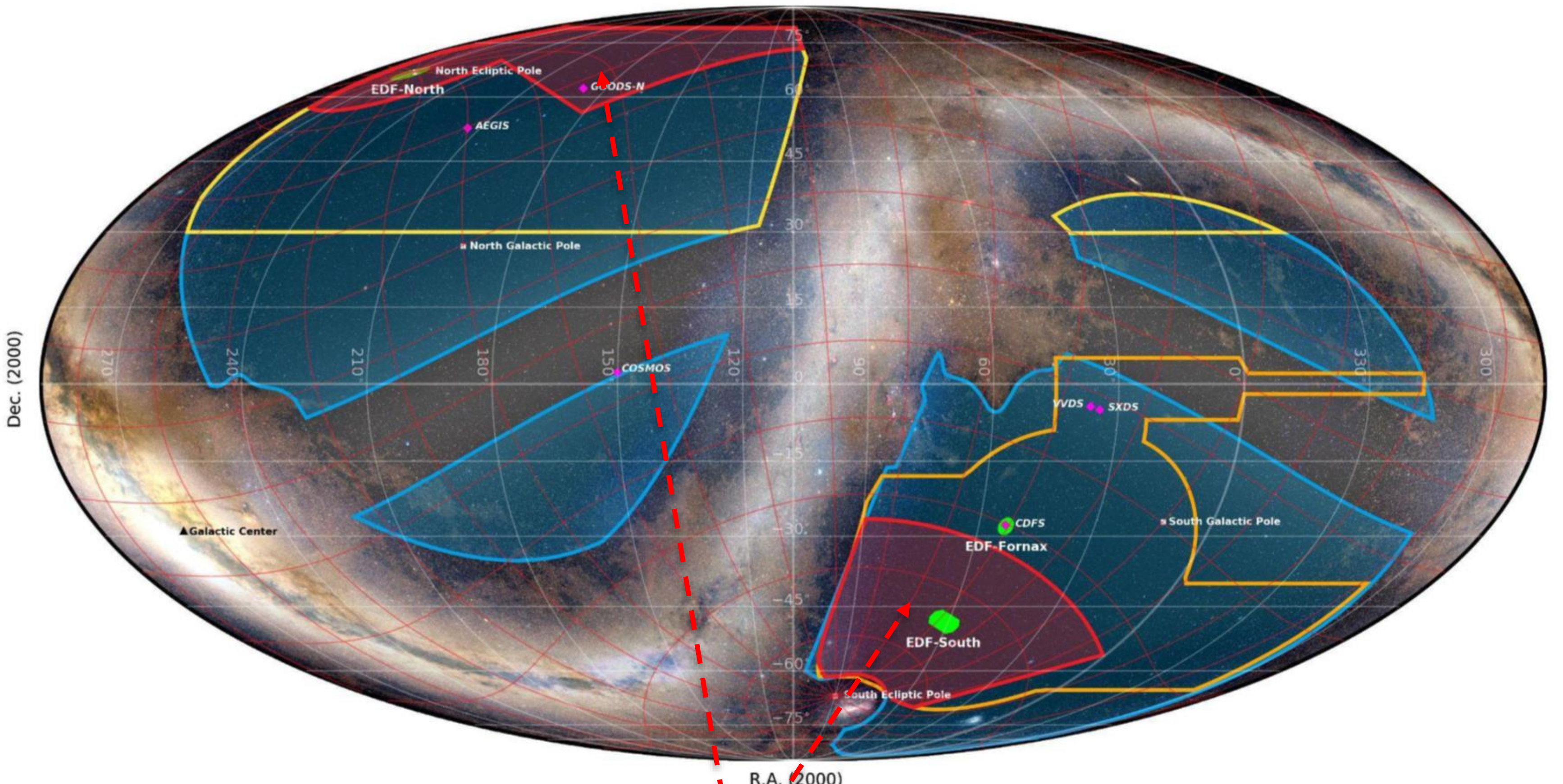

Credits: B. Granett

*Blue grism is exposed on Deep fields only

# Euclid FoV comparison


Credits: Yuzheng Kang

# The Euclid sky



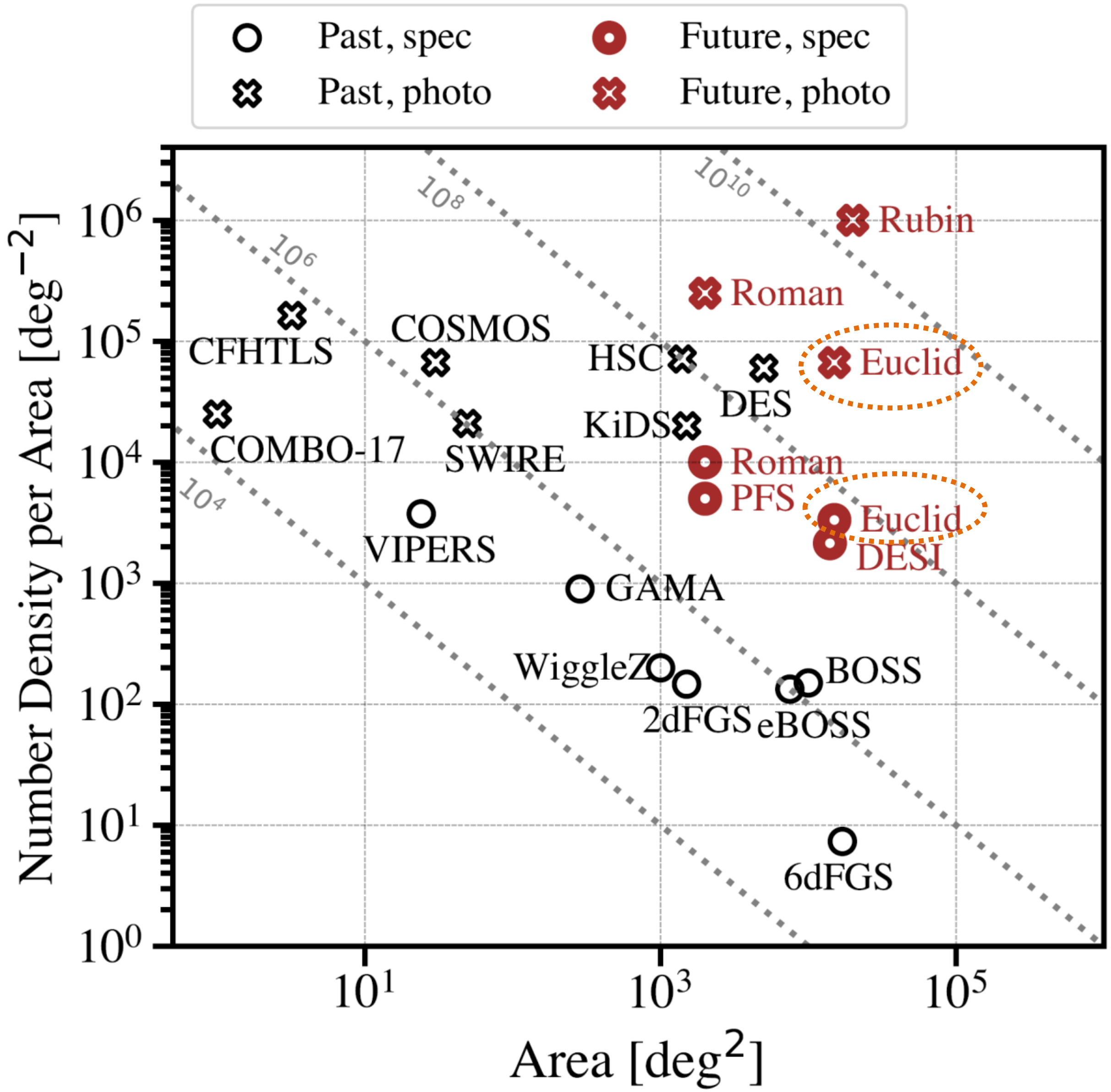

The Euclid Wide Survey DR1 area maximizing the overlap with DES : North = 821 deg$^2$, South = 1657 deg$^2$ [Mollweide Celestial]

- Euclid Wide Survey region of interest : 17,354 deg$^2$
- Euclid DR1 area, 2023 : 2500 deg$^2$
- DES, griz, 2013–19 : 4500 deg$^2$ overlap with the region of interest
- Euclid Deep Fields [total 43 deg$^2$]
- UNIONS [CFIS / JEDIS–g / Pan–STARRS / WISHES], ugriz, 2017–27 : 4800 deg$^2$

*Background image: Euclid Consortium / Planck Collaboration / A. Mellinger*

Credits: J.-C. Cuillandre and the ECSURV team

# The Euclid survey in context




Hou et al. 2023

# The Euclid Launch

**Date**: July 1, 2023

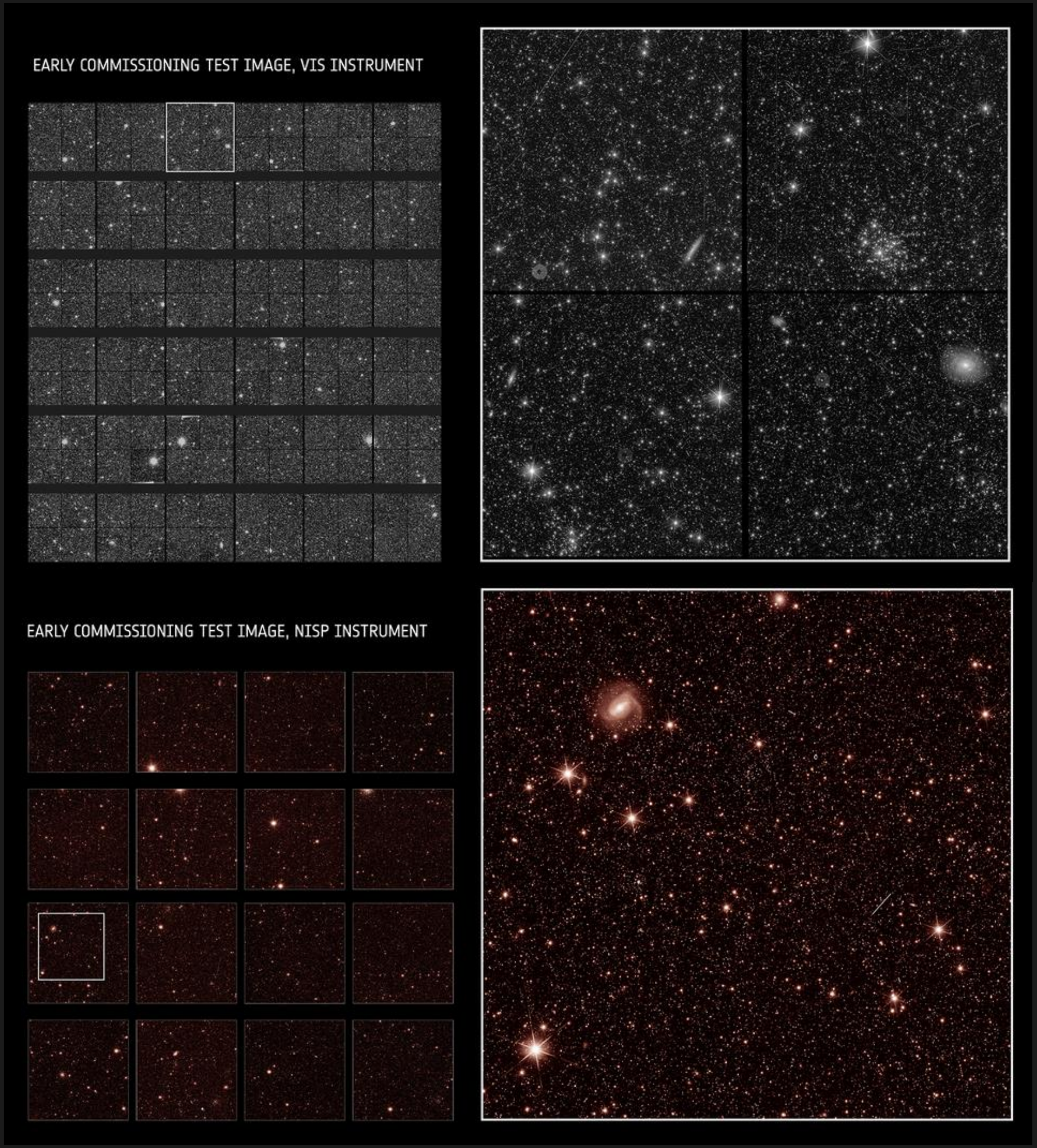
**Launch site**: Cape Canaveral, Florida

**Launch vehicle**: SpaceX Falcon 9

**Destination**: Sun-Earth Lagrange Point 2, 1.5 million km from Earth

**Arrival**: late July

# Euclid early commissioning test images



# Early Release Observations: the dazzling edge of darkness

Spiral galaxy IC 342

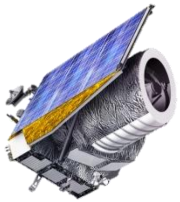
The Horsehead Nebula

Globular cluster NGC 6397

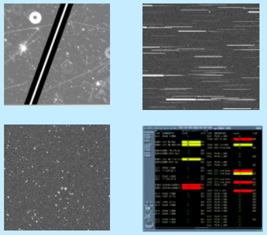
Irregular galaxy NGC 6822

The Perseus Cluster of galaxies

# Euclid Data Products from OUs

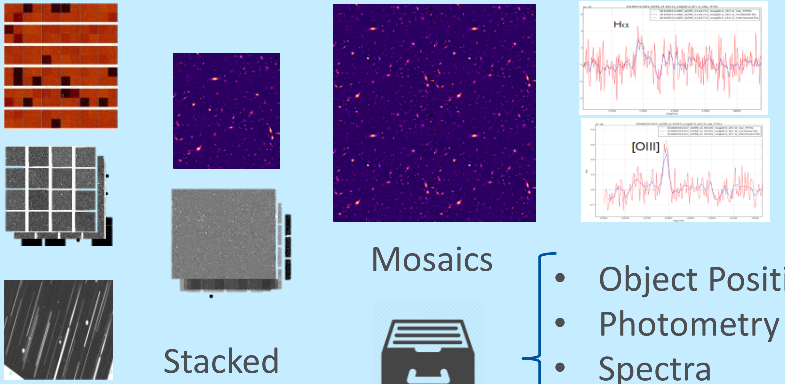


## L1 Products



Unpacked raw science data & telemetry

## L2 Products




Calibrated Frames

Stacked Frames

Mosaics

Catalogues

- Object Position
- Photometry
- Spectra
- Photo-z
- Spec-z
- Ellipticities

THE DARK ENERGY SURVEY

KiDS

Data from external surveys

## L3 Products

Weak Lensing Power Spectrum

Galaxy Clustering 2-point Correlation Function

+ Legacy Science Products

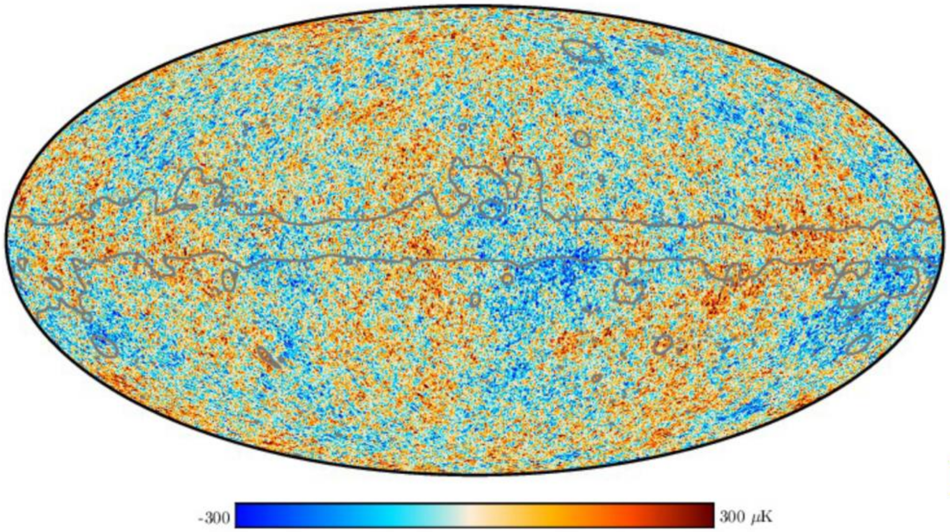
Science-ready data

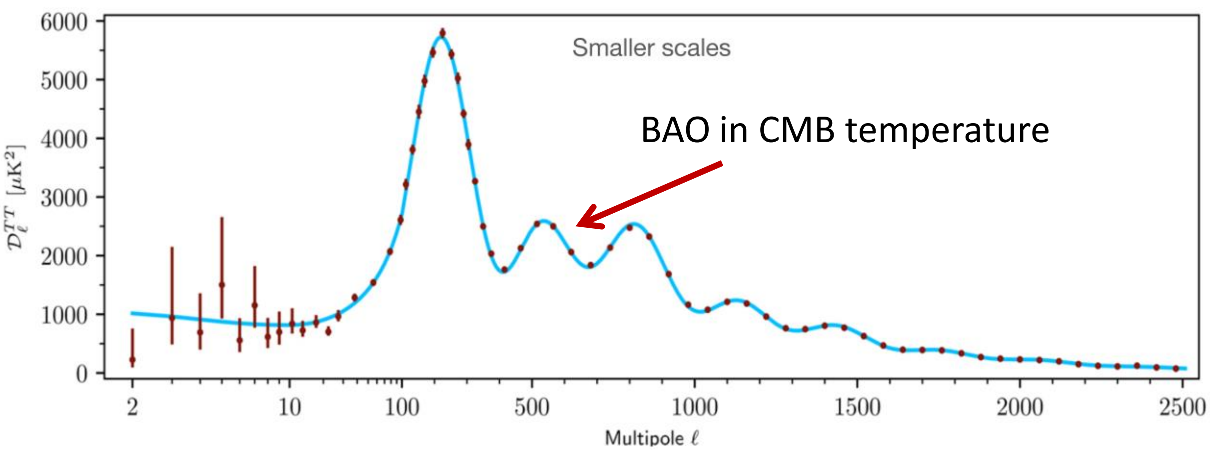
- **Shapes and Photo-z for ~$10^9$ galaxies**
- **Spectroscopic Redshifts for ~$2\times10^7$ galaxies**

Euclid generates a series of data products available to the community via the **Euclid Archive System** (EAS).

# The ΛCDM model from Planck

Planck Collaboration et al (2020):




The best fit model has 6 parameters:

$$\Omega_b h^2 = 0.02237 \quad (0.67\%)$$

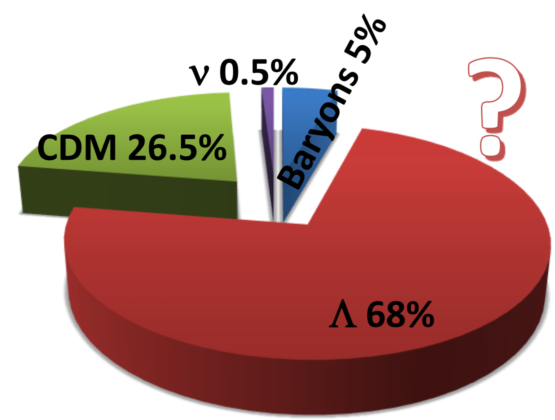
$$\Omega_c h^2 = 0.1200 \quad (1\%)$$

$$\theta_{\rm MC} = 1.04092 \quad (0.03\%)$$

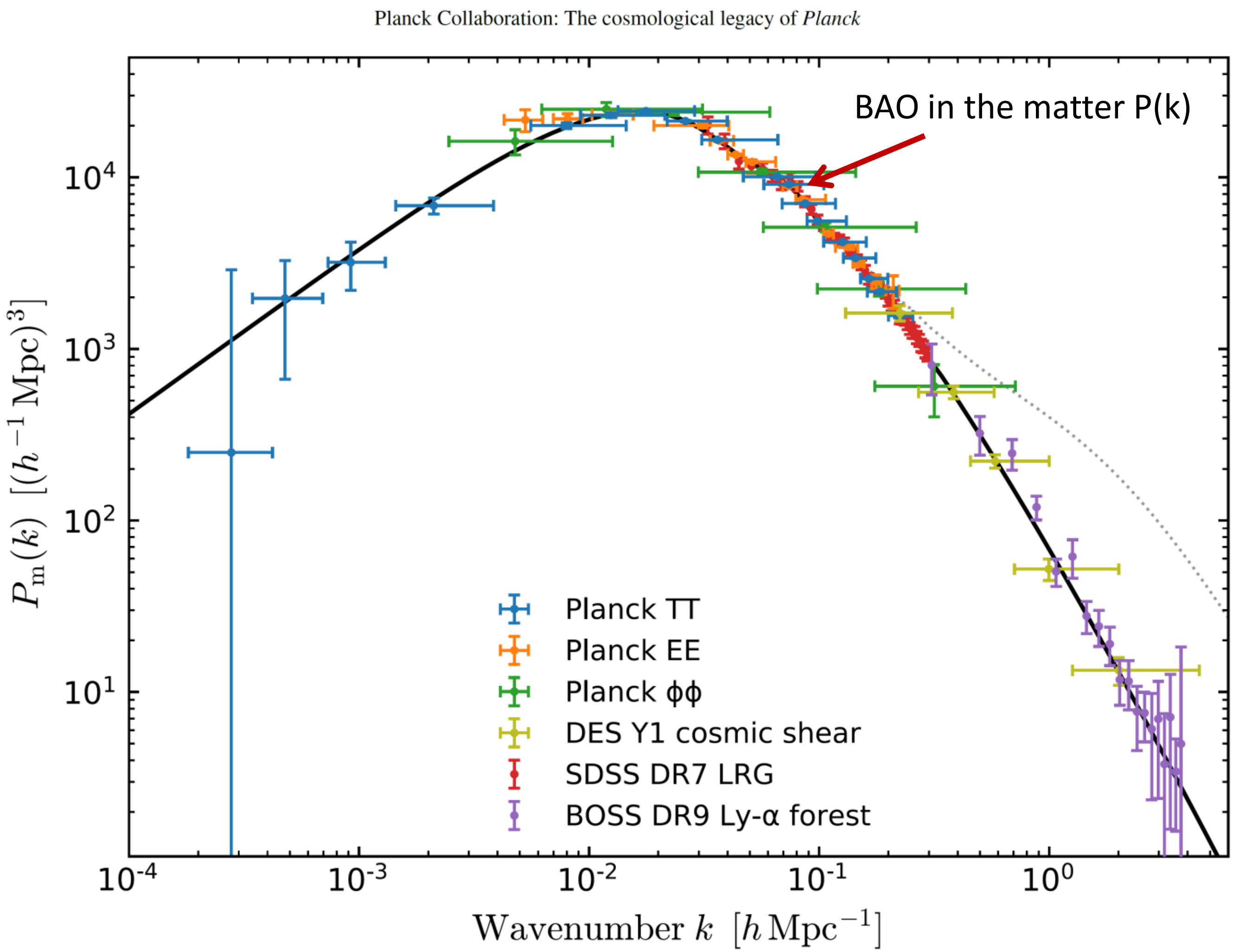
$$\tau = 0.0544 \quad (13.4\%)$$

$$\ln\left(10^{10} A_s\right) = 3.044 \quad (0.46\%)$$

$$n_s = 0.9649 \quad (0.44\%)$$



# The ΛCDM model from Planck & galaxy-surveys: matter power spectrum



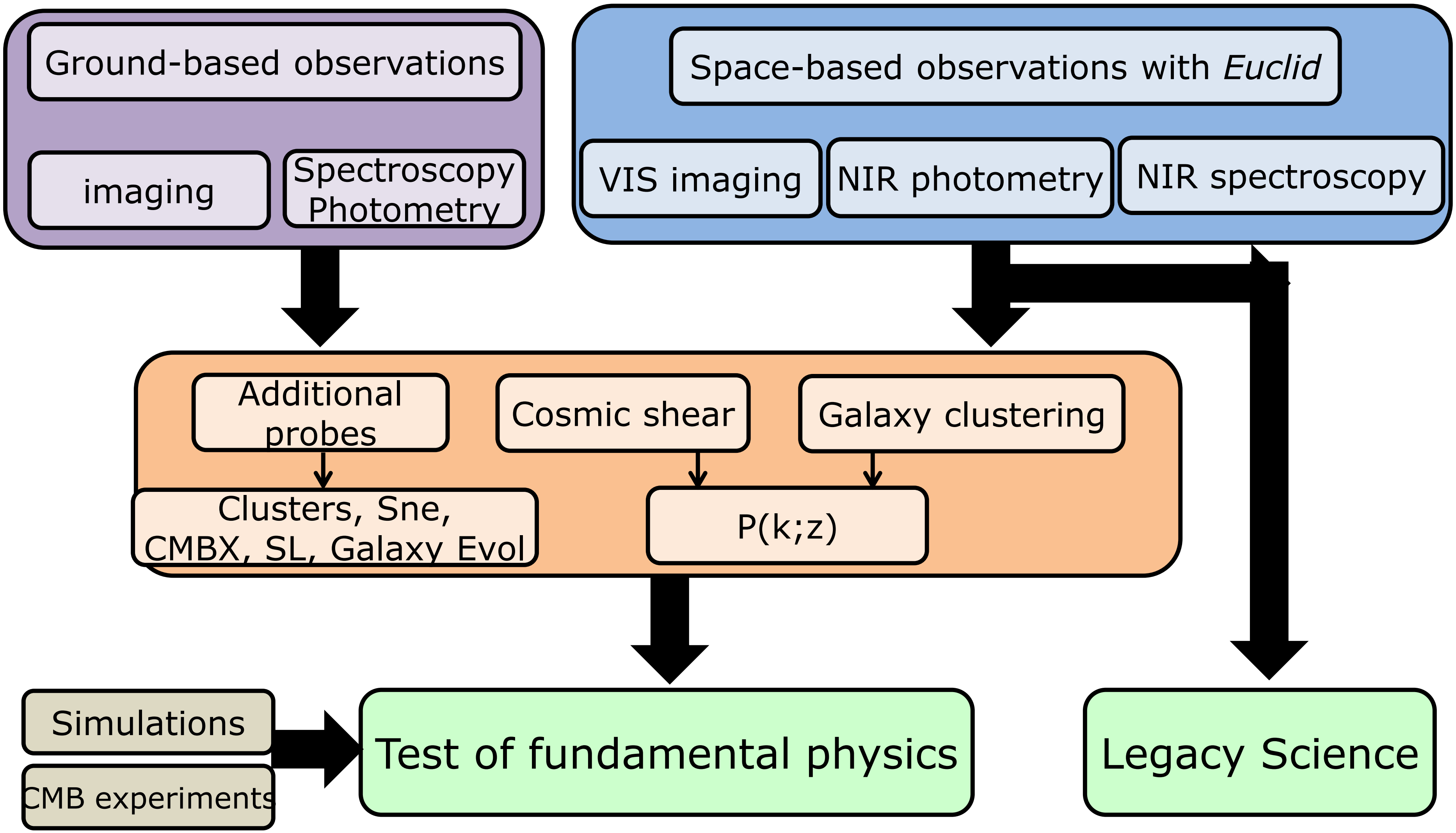
# Euclid Top Level Science Requirements

| Dark Energy | Test of Gravity |
|---|---|
| • Measure the cosmic **expansion history** to **better than 10%** in redshift bins 0.9 < z < 1.8.<br>• Look for **deviations from** $w_0 = -1$, indicating dynamical Dark energy.<br>• Euclid primary probes to give $\mathrm{FoM}_{DE}$ **> 400** ( **1-sigma errors on** $w_0$ **and** $w_a$ **of 0.02 and 0.1 respectively**) | • Measure the growth rate to better than 0.02 in redshift bins between 0.9 < z < 1.8.<br>• Measure the **growth index, γ, with a precision better than 0.02.**<br>• Separately constrain the two relativistic potentials. ψ and φ.<br>• Test the cosmological principle. |
| **Dark Matter** | **Initial conditions** |
| • Detect Dark matter halos on a mass scale $10^8 < M/M_\odot < 10^{15}$.<br>• Measure the Dark matter mass profiles on cluster and galactic scales.<br>• Measure the **sum of neutrino masses with an accuracy of 0.03 eV.** | • Constraint $\sigma_8$ **and** $n_s$ **to a 1-sigma accuracy of 0.01.**<br>• For extended models, improve constraints on spectral indices compared to Planck alone by a factor ~2.<br>• Measure **non-Gaussianity:** $\Delta f_{NL} = \pm 2$. |

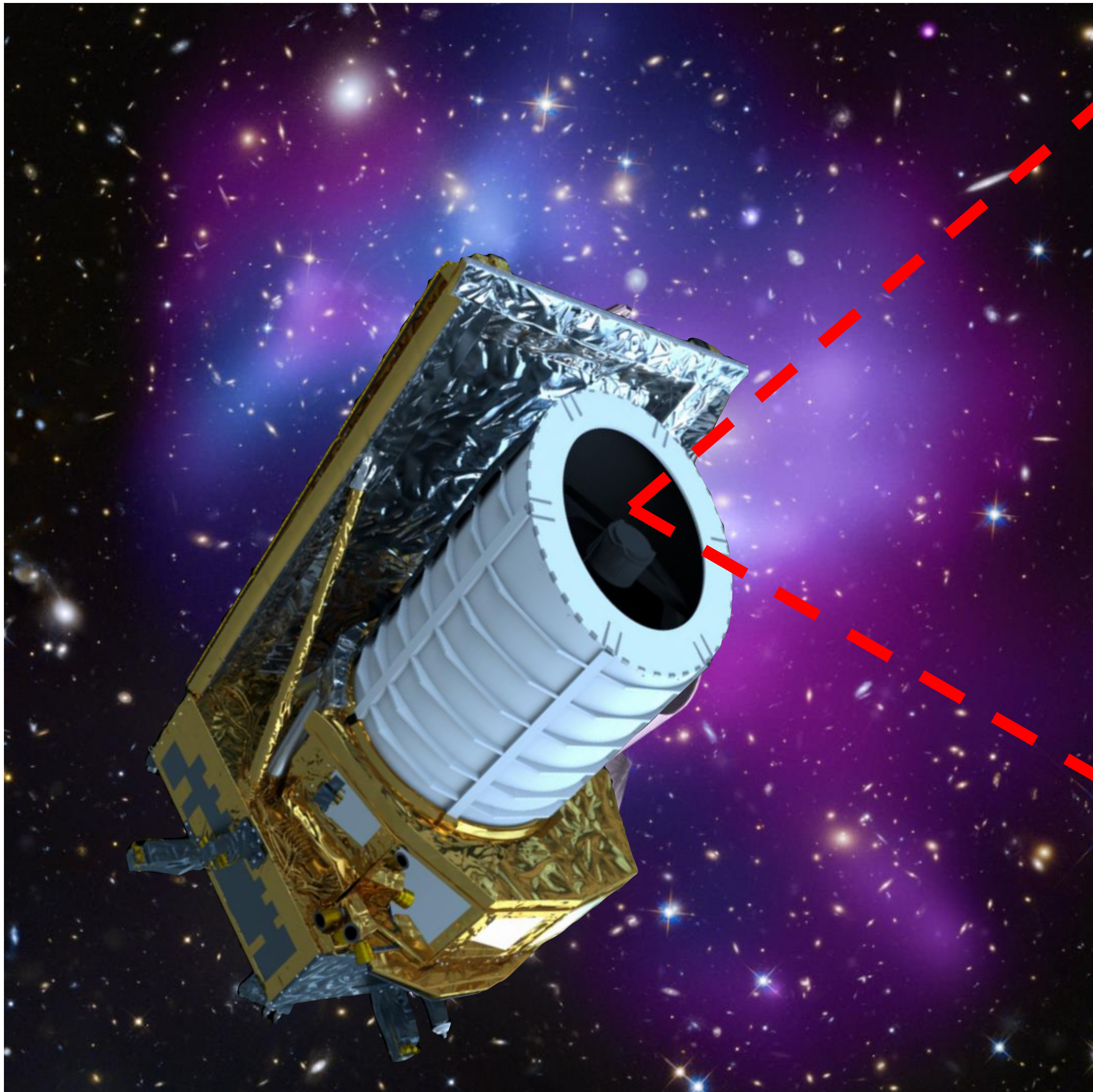
- *DE equation of state:* $P/\rho = w$ *with* $w(a) = w_p + w_a(a_p - a)$
- *Growth rate of structure formation:* $f \sim \Omega^{\gamma}$ *;*
- $FoM = 1/(\Delta w_a \times \Delta w_p) > 400$ → *~2% precision on* $w_p$

**Euclid Redbook 2011**

# How to do this with Euclid

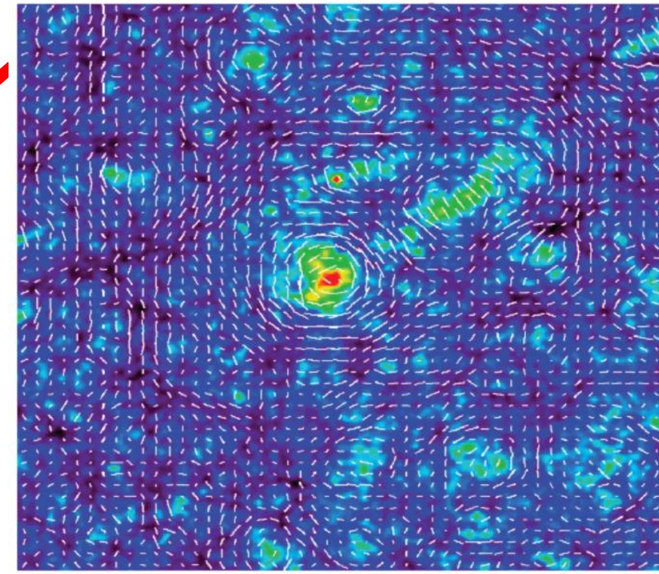


# How to do this with Euclid: double approach to the dark sector

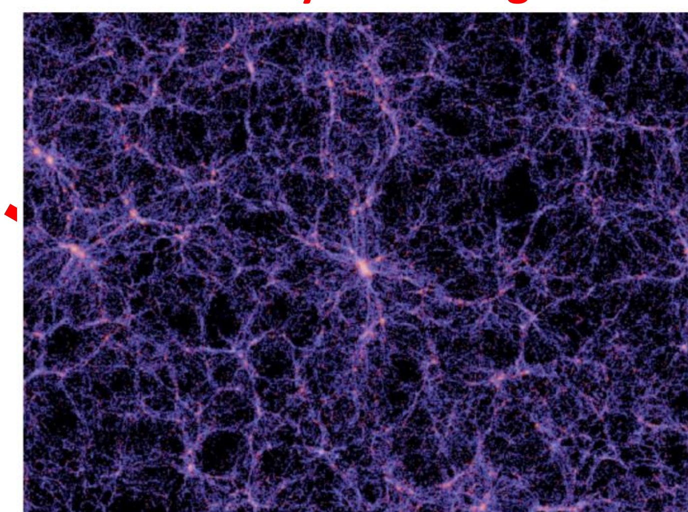


An artist view of the Euclid Satellite – © ESA

Weak lensing



Galaxy Clustering



# Euclid answers both questions

1. Measure **expansion history *H*(z)** to high accuracy, as to detect percent variations of DE *equation of state* w(z) with robust control of systematics. Achieve this through

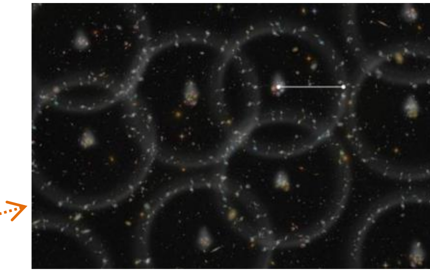
   A. Using the scale of **Baryon Acoustic Oscillations (BAO)** in the clustering pattern of galaxies as a standard ruler

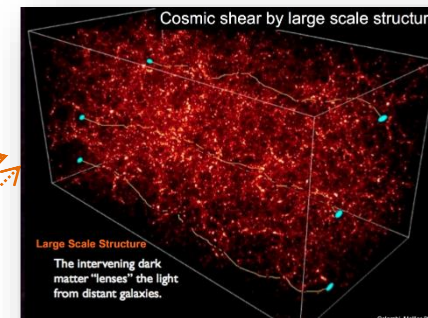
   B. Using **galaxy shape distortions** induced by Weak Gravitational Lensing

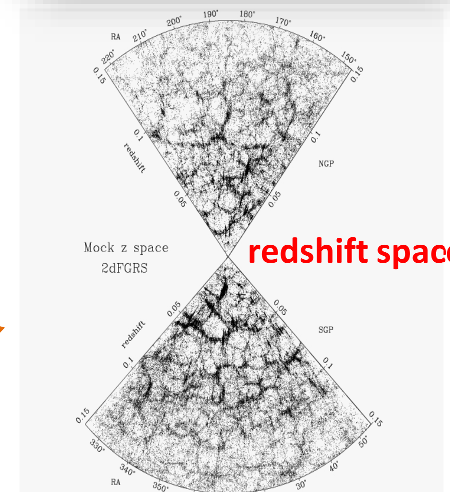
2. Measure at the same time ***the growth rate of structure*** from the same probes, to detect modifications of gravity:

   A. Weak Lensing (WL) Tomography

   B. Clustering **redshift-space distortions** (RSD)





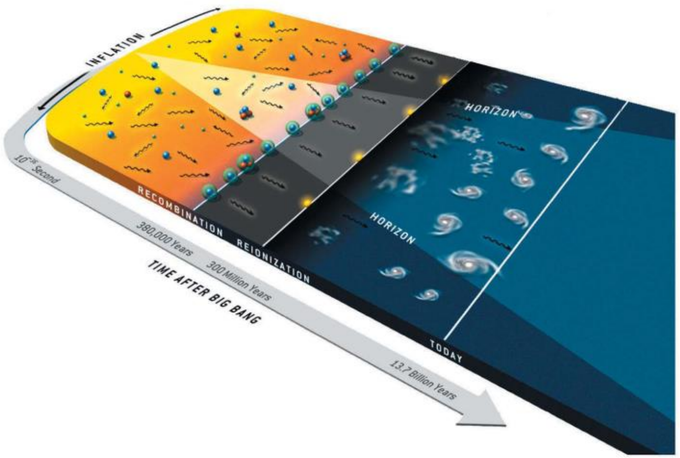



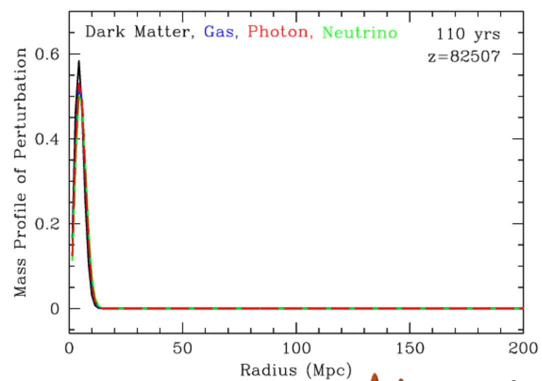

Eke & 2dFGRS 2003

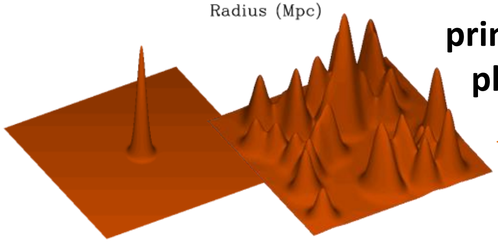
# Baryon Acoustic Oscillations (BAO)

In the early universe prior to recombination, the free electrons couple the baryons to the photons through Compton interactions, so these three species move together as a single fluid.

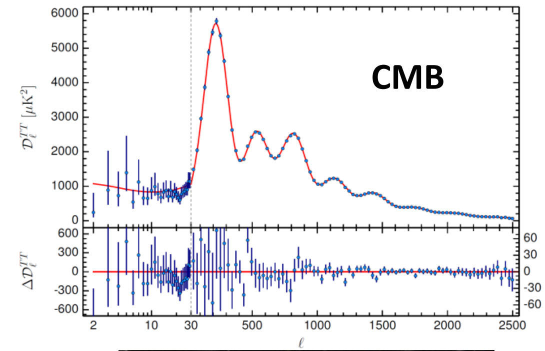
The primordial cosmological perturbations on small scales excite sound waves in this relativistic plasma, which results in the pressure-induced oscillations and acoustic peak.

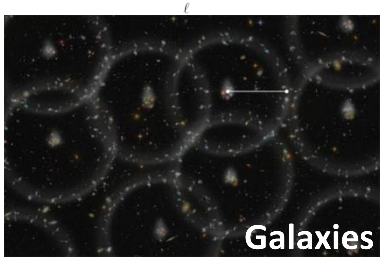


primordial plasma

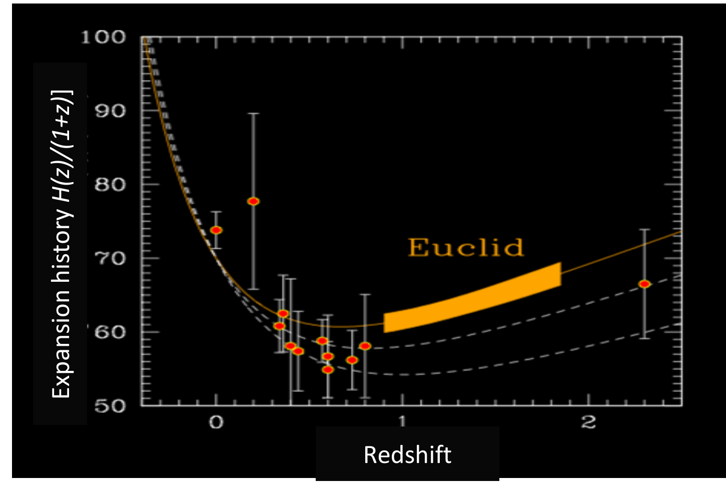



The memory of these baryon acoustic oscillations (BAO) still remain after the epoch of recombination in the ***CMB anisotropies*** and the ***galaxy distribution***.

# *Euclid* GCsp: measuring the background expansion via BAO at 10% precision

Guzzo & GC-SWG (2015)




- **BAO** as a *standard ruler*

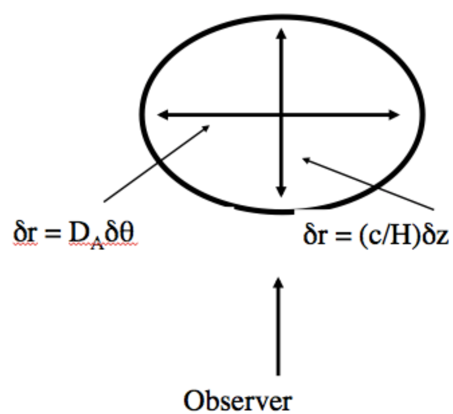
- Sensitive to the expansion history ***H(z)*** and angular diameter distance relation ***D$_A$(z)***

$$r_d = \int_{z_d}^{\infty} \frac{c_s(z)}{H(z)} dz = 147.49 \pm 0.59 \ \mathrm{Mpc}$$

need of precise redshifts

$$r_{\parallel} = \frac{c\Delta z}{H(z)}$$

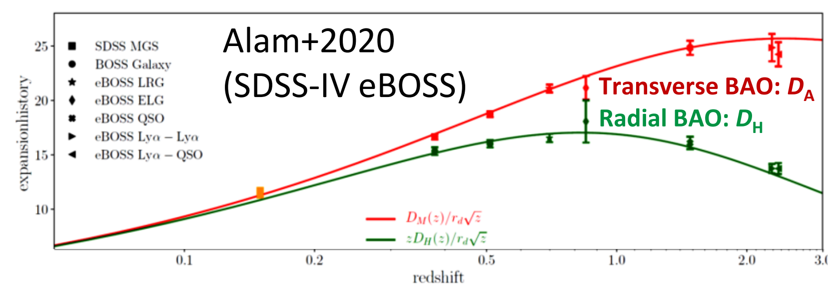
$$r_{\perp} = (1+z) D_A(z) \Delta\theta$$




$$D_A(z) = \frac{c}{1+z}\int_0^z \frac{dz}{H(z)} \qquad D_M(z) = (1+z) D_A(z)$$

$$D_H(z) = c/H(z)$$

$$H(z) = h\sqrt{\Omega_m(1+z)^3 + \Omega_X \exp\left[3\int_0^z \frac{1+w(z)}{1+z} dz\right]}$$




- **Test "beyond Λ" scenario, i.e. an evolving equation of state**

# Redshift Space Distortions (RSD)

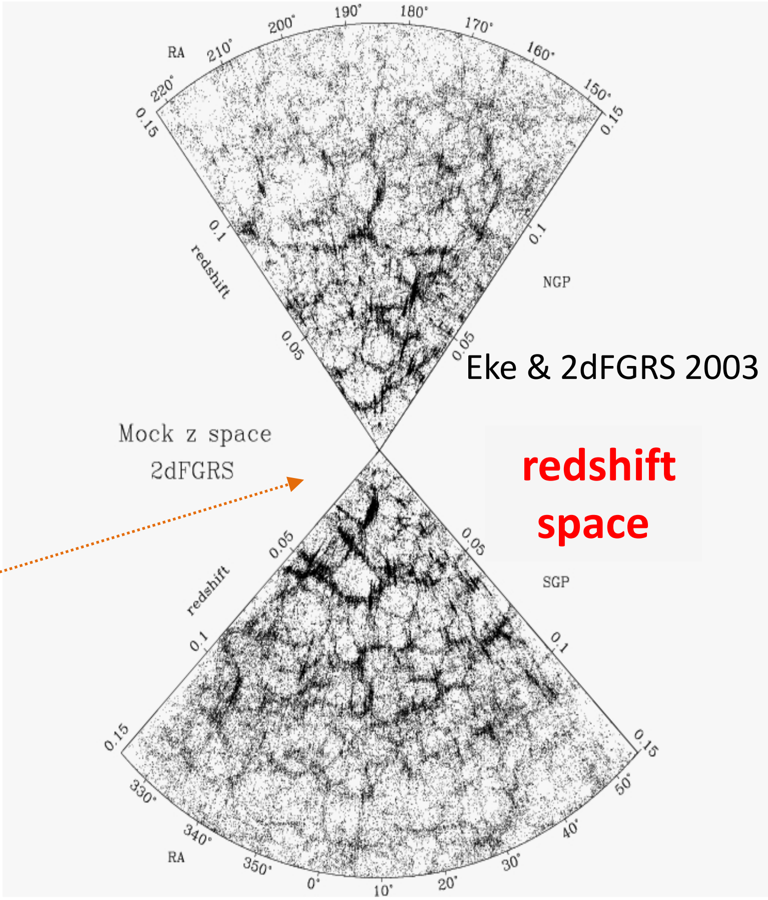
Growth rate produces peculiar velocities, which combine with the cosmological Hubble flow in measured redshifts

$r \equiv H_0 d$ $\quad$ $s = r + v$ $\quad$ $s \equiv cz$

observed distance

**The galaxy correlation function becomes *anisotropic***

Monopole  Quadrupole  Hexadecapole

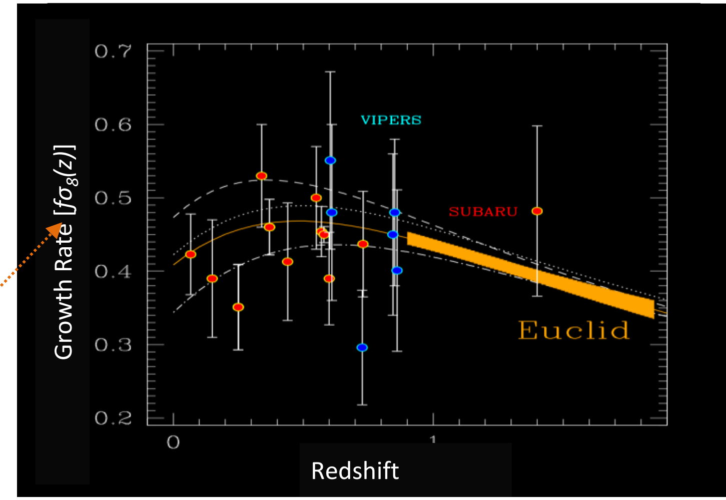



**RSDs:** 1) the **Kaiser effect** which *flattens* the galaxy distribution and is caused by coherent motions of galaxies falling inwards towards the cluster centre. The Kaiser effect is smaller and occurs on larger scales than FoGs.

2) the **FoG (fingers-of-God) nonlinear effect** which *elongates* the galaxy distribution along the line-of-sight, caused by the Doppler shift due to random galaxy peculiar velocities within the cluster

# <u>GCsp</u>: measuring the structure growth with RSD at 2% precision

Guzzo & GC-SWG (2015)




- **RSDs probe the growth rate of structure**

$$z_{\rm obs} = z_{\rm c} + \frac{v_\parallel}{c}(1+z_{\rm c}) \qquad \frac{\xi(s)}{\xi(r)} \overset{\text{linear limit}}{=} 1 + \frac{2\beta}{3} + \frac{\beta^2}{5}$$

$$\beta \;=\; f(z)/b(z) \;\simeq\; \Omega_{\rm m}(z)^{\gamma}/b(z)$$

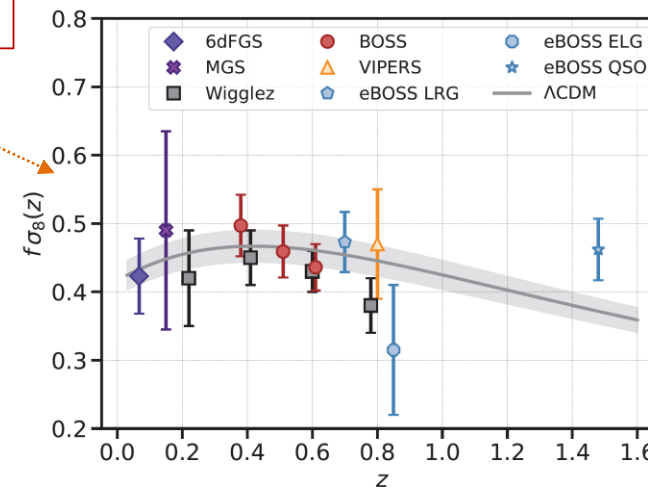
## Observed *anisotropic* galaxy power spectrum

$$P_{\rm zs}(k,\mu,z) = \left[\frac{1}{1+(f(z)k\mu\,\sigma_{\rm p}(z))^2}\right](b(z)\sigma_8(z) + f(z)\sigma_8(z)\mu^2)^2\,\frac{P_{\rm dw}(k,z)}{\sigma_8^2(z)}$$

$$P_{\rm dw}(k,z) = [P_{\rm m}(k,z) - P_{\rm nw}(k,z)]\,{\rm e}^{-g_\mu k^2} + P_{\rm nw}(k,z)$$

BAO only x damping + Broadband

$$g_\mu(k,\mu,z) = \sigma_{\rm v}^2(z)\left[1 - \mu^2 + \mu^2\,(1+f(z))^2\right]$$

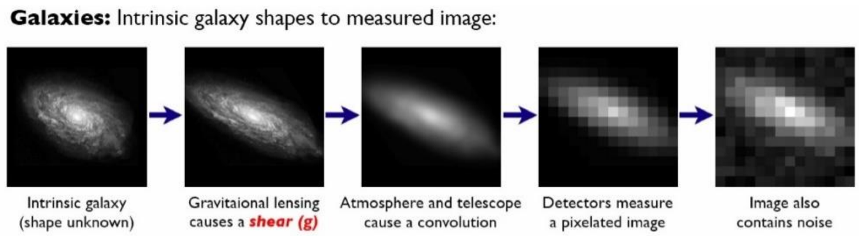



Hou etal 2023

- **Test "beyond Einstein" scenario as alternative to GR**

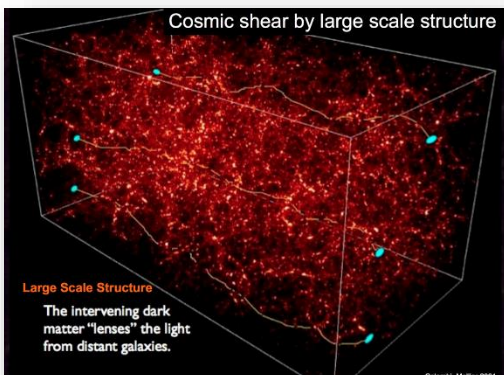
# Weak Gravitational Lensing

- The statistics of shape correlations as a function of angular scale and redshift can be used to *directly* infer the statistics of the density fluctuations and therefore cosmology.




Adapted from Bridle et al 2011

- The lensing kernel is most sensitive to structure halfway between the observer and the source. But the kernel is broad: we do not need precise redshifts for the sources: photometric redshifts are fine
- Also, since the kernel is broad the tomographic bins are very correlated

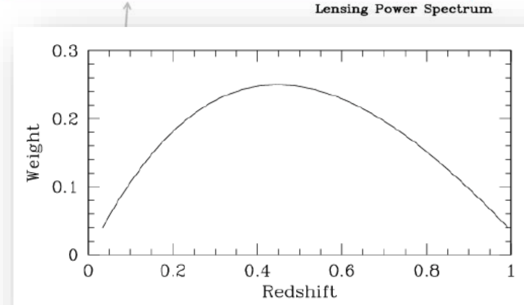



Geometry

Large Scale Structure

$$C_{ij}(\ell) = \int_0^{r_H} \mathrm{d}r\, W_{ij}^{\mathrm{GG}}(r) P_{\delta\delta}\left(\frac{\ell}{S_k(r)}; r\right)$$

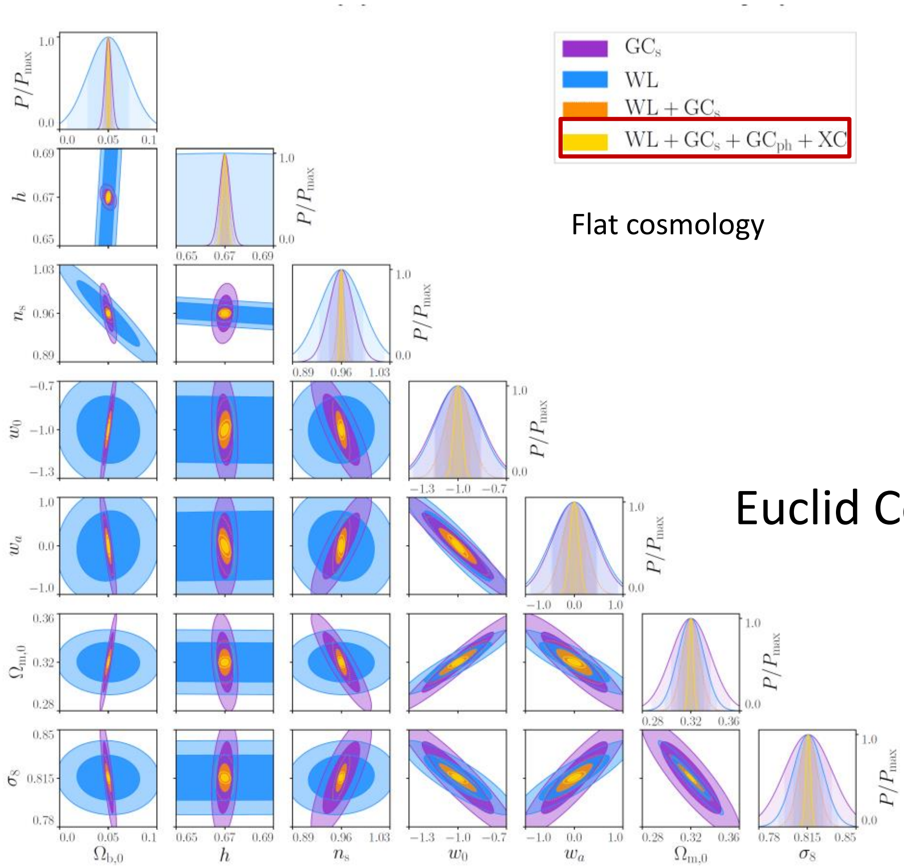
Lensing Power Spectrum




**Measures a combination of geometry (Hz) and growth**

- To achieve the science goals we need to measure the matter distribution as a function of redshift: weak lensing tomography requires redshifts for the sources.

# Forecasts of Euclid scientific performance



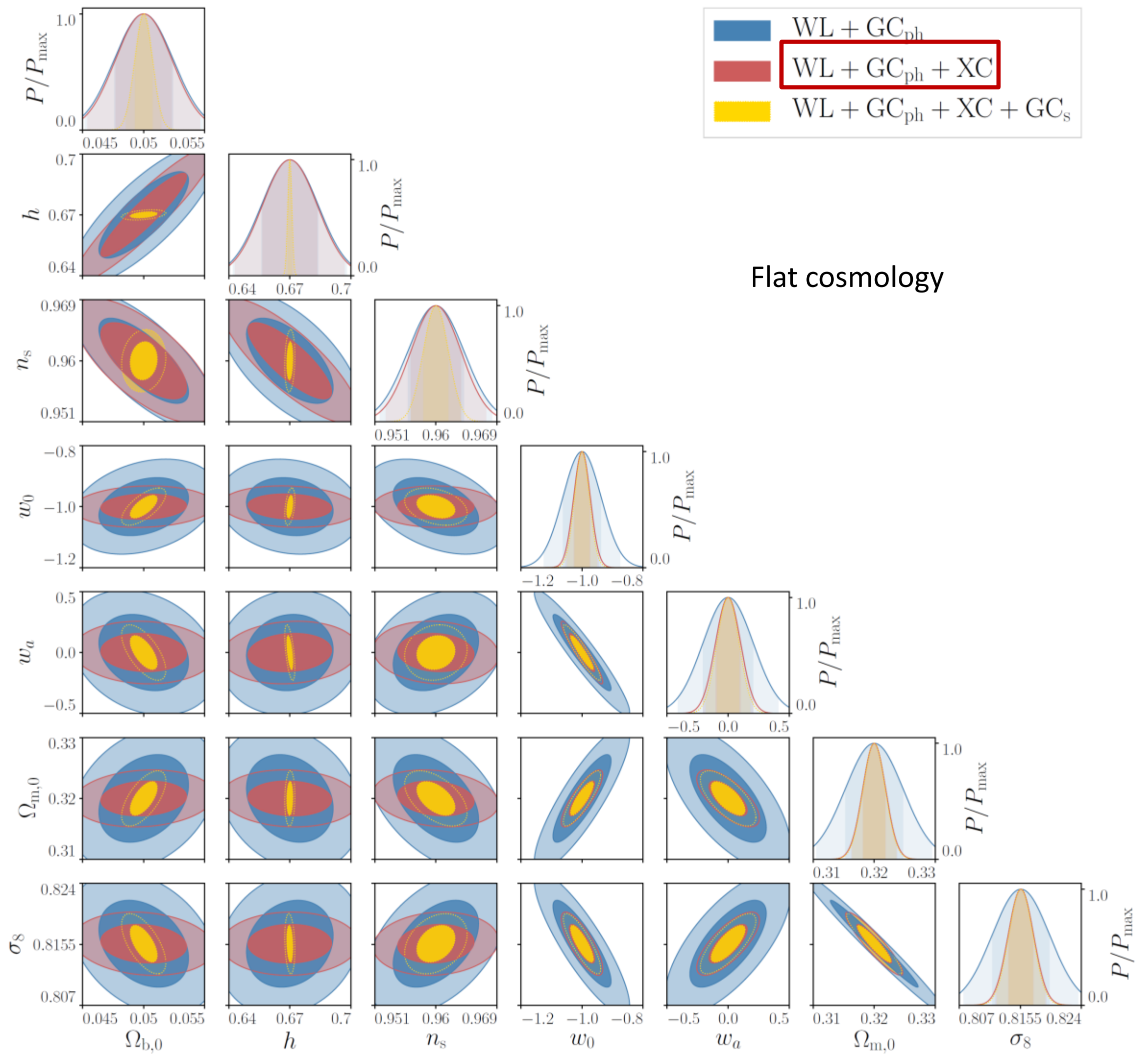

Flat cosmology

REFERENCE PAPER:
Euclid Consortium, arXiv:1910.09273

| All probe combination $GC_s$+WL+$GC_{ph}$+$XC^{(GC_{ph},WL)}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Setting | $\Omega_{m,0}$ | $\Omega_{b,0}$ | $\Omega_{DE,0}$ | $w_0$ | $w_a$ | $h$ | $n_s$ | $\sigma_8$ |
| **ΛCDM flat** | | | | | | | | |
| Pessimistic | 0.0067 | 0.025 | – | – | – | 0.0036 | 0.0049 | 0.0031 |
| Optimistic | 0.0025 | 0.011 | – | – | – | 0.0011 | 0.0015 | 0.0012 |
| **$w_0, w_a$ flat** | | | | | | | | |
| Pessimistic | 0.0110 | 0.035 | – | 0.036 | 0.15 | 0.0053 | 0.0053 | 0.0049 |
| Optimistic | 0.0060 | 0.015 | – | 0.025 | 0.091 | 0.0015 | 0.0019 | 0.0022 |

# Probe combination is key to high precision and accuracy

REFERENCE PAPER: Euclid Consortium, arXiv:1910.09273

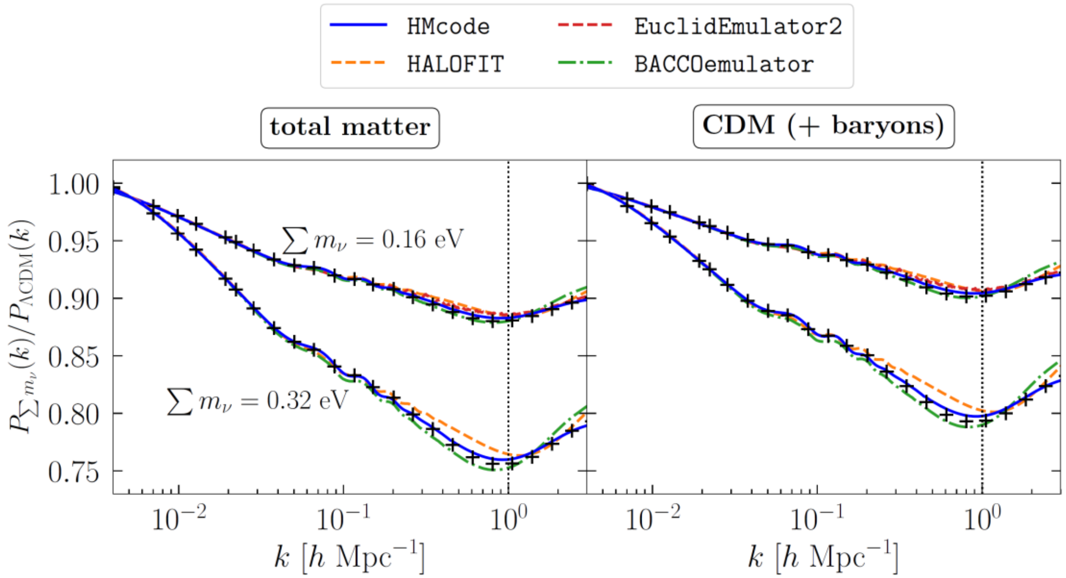



Flat cosmology

# Constraining neutrinos with Euclid

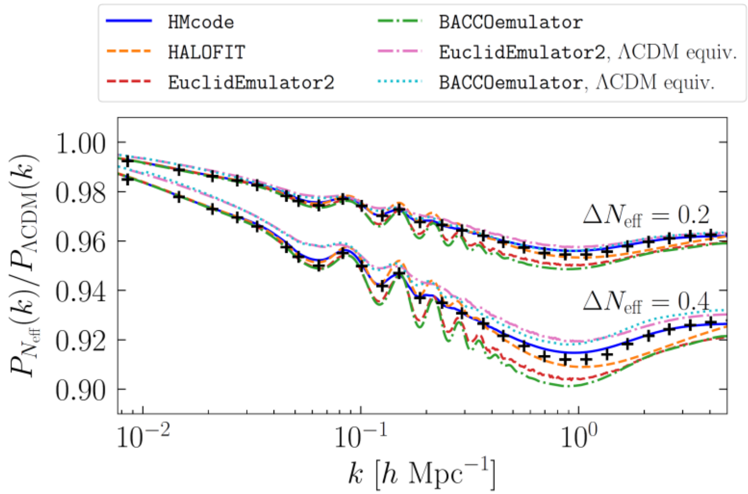
## (pre-launch KP under internal EC review)

**PRELIMINARY**




Nonlinear matter P(k) suppression due to free-streaming massive neutrinos

**Archidiacono et al. in prep**

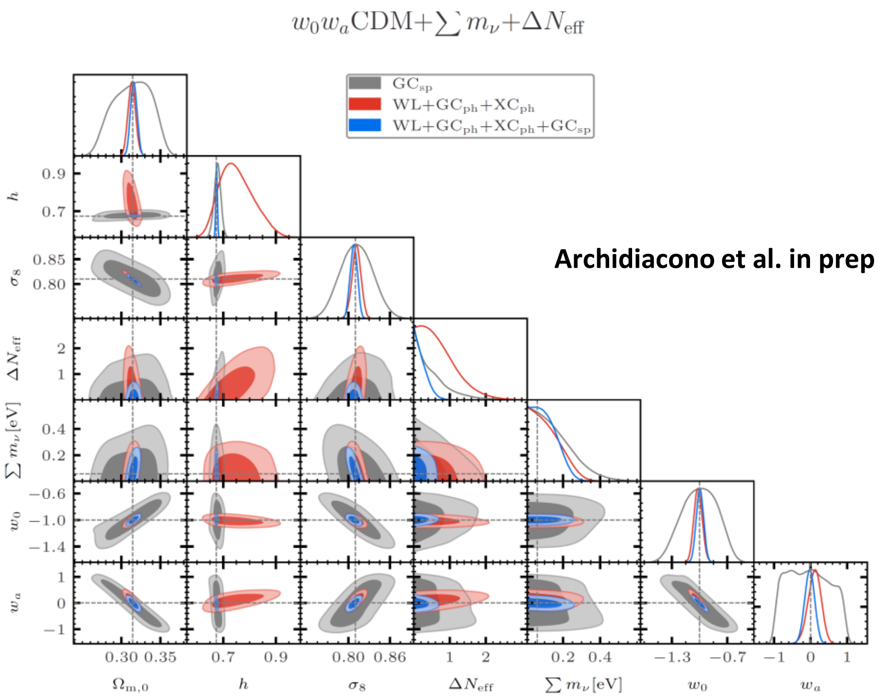


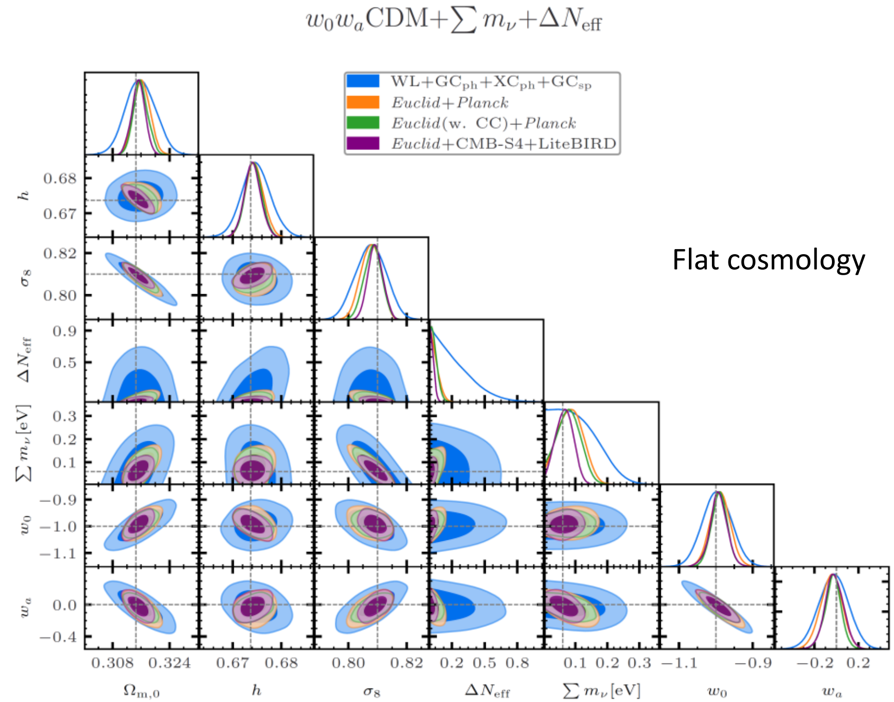

Nonlinear matter P(k) suppression due to the number of relativistic species

# Constraining neutrinos with Euclid

## (pre-launch KP under internal EC review)

## PRELIMINARY



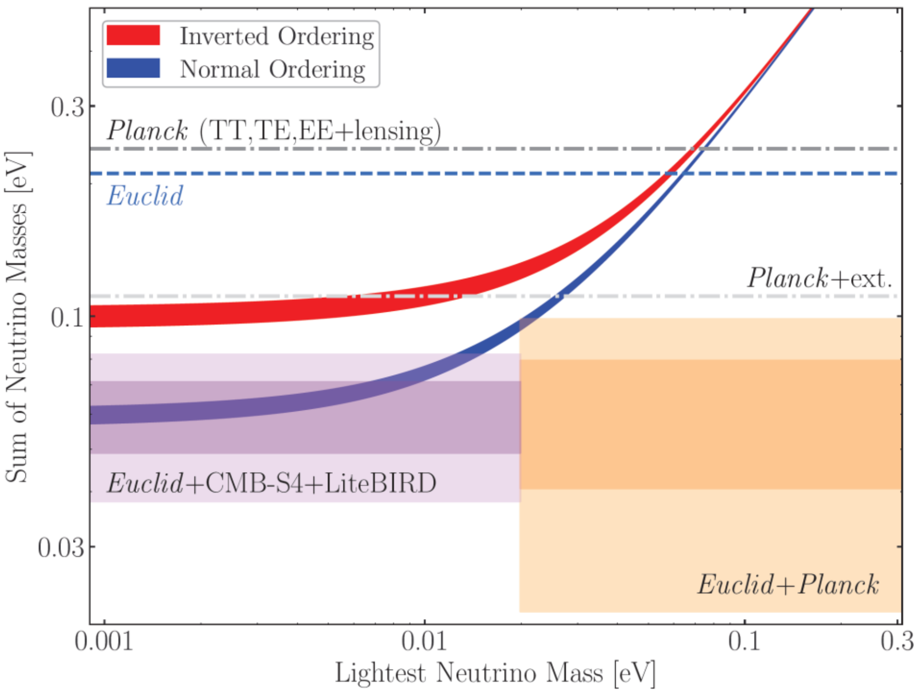



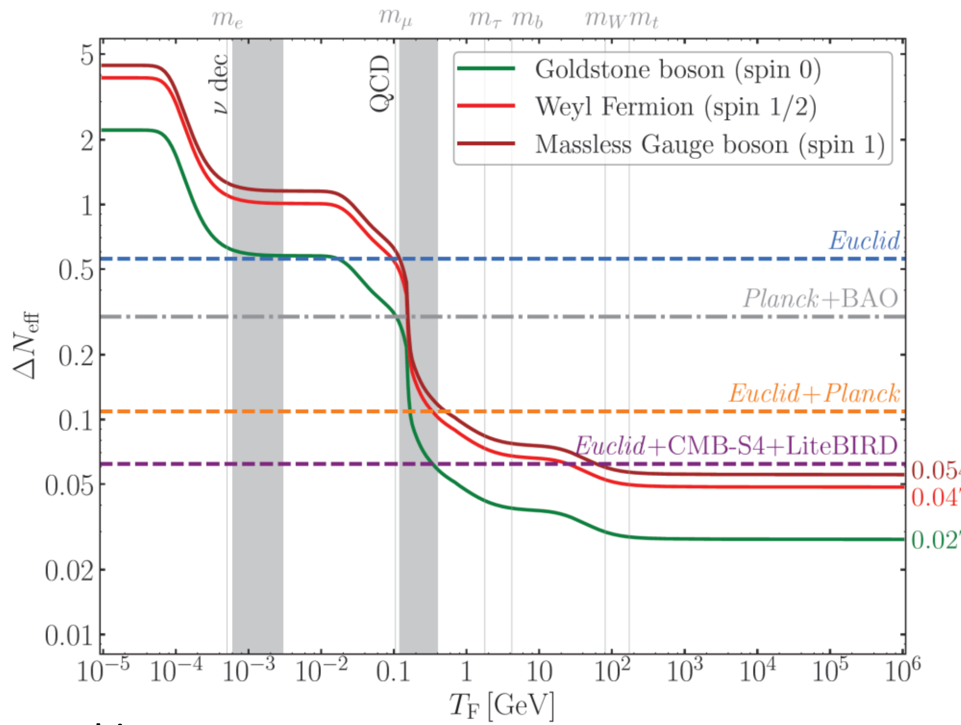

| $w_0 w_a$CDM + $\sum m_\nu$ + $\Delta N_{\rm eff}$ | $\Omega_{\rm m,0}$ | $100\,\Omega_{\rm b,0}$ | $h$ | $n_{\rm s}$ | $\sigma_8$ | $\sum m_\nu$[meV] | $\Delta N_{\rm eff}$ | $w_0$ | $w_a$ |
|---|---|---|---|---|---|---|---|---|---|
| *Euclid*-only | | | | | | | | | |
| $\mathrm{GC_{sp}}$ | 0.0260 | 0.56 | 0.013 | 0.031 | 0.024 | $< 350$ | $< 1.48$ | 0.20 | 0.40 |
| $\mathrm{WL+GC_{ph}+XC_{ph}}$ | 0.0049 | 0.38 | 0.065 | 0.029 | 0.0065 | $< 260$ | $< 1.71$ | 0.05 | 0.18 |
| $\mathrm{WL+GC_{ph}+XC_{ph}+GC_{sp}}$ | 0.0043 | 0.18 | 0.0030 | 0.0059 | 0.0054 | $< 220$ | $< 0.57$ | 0.04 | 0.14 |
| $\mathrm{WL+GC_{ph}+XC_{ph}+GC_{sp}+CC}$ | 0.0030 | 0.14 | 0.0021 | 0.0055 | 0.0043 | $< 220$ | $< 0.48$ | 0.03 | 0.09 |
| *Euclid*+CMB | | | | | | | | | |
| *Euclid*+*Planck* | 0.0022 | 0.033 | 0.0019 | 0.0021 | 0.0034 | 41 | $< 0.13$ | 0.03 | 0.10 |
| *Euclid*(w. CC)+*Planck* | 0.0020 | 0.030 | 0.0016 | 0.0022 | 0.0030 | 39 | $< 0.10$ | 0.02 | 0.08 |
| *Euclid*+CMB-S4+LiteBIRD | 0.0019 | 0.026 | 0.0017 | 0.0015 | 0.0025 | 28 | $< 0.061$ | 0.03 | 0.09 |

# Constraining neutrinos with Euclid

## (pre-launch KP under internal EC review)

**PRELIMINARY**



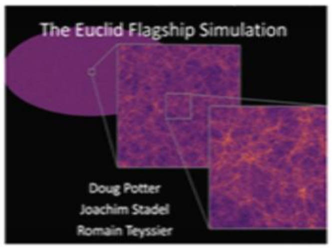

**Archidiacono et al. in prep**

Assuming that the true value of the neutrino mass sum is the minimum allowed by neutrino oscillation experiments in normal ordering, the combination Euclid+CMB-S4+LiteBIRD will rule out the inverted ordering at more than 3σ

# The Role of simulations

## The Flagship galaxy mock: end2end pipeline

**3D particle LC**

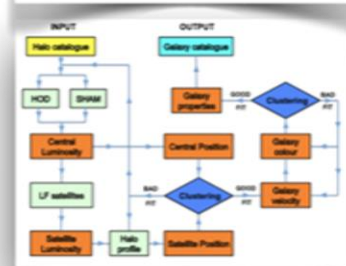



**All-sky Halo catalog**

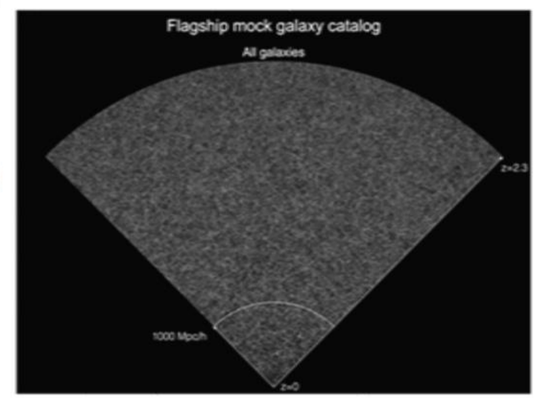

Massive coordinated efforts:

- modular galaxy pipeline
- big-data platform (CosmoHub)
- mock validation

**HOD/SHAM Galaxy assignment pipeline**

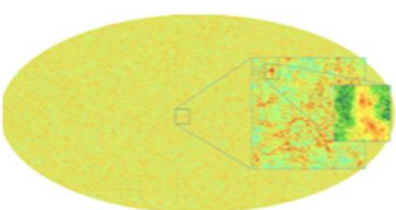



**Flagship galaxy mock**
[Lightcone to z< 3]

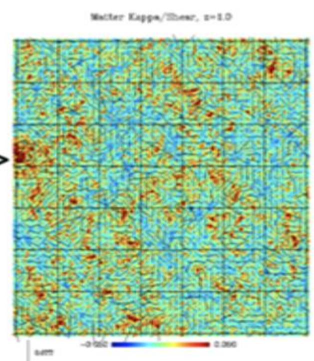



One octant of the sky

**All-sky 2D DM counts maps**



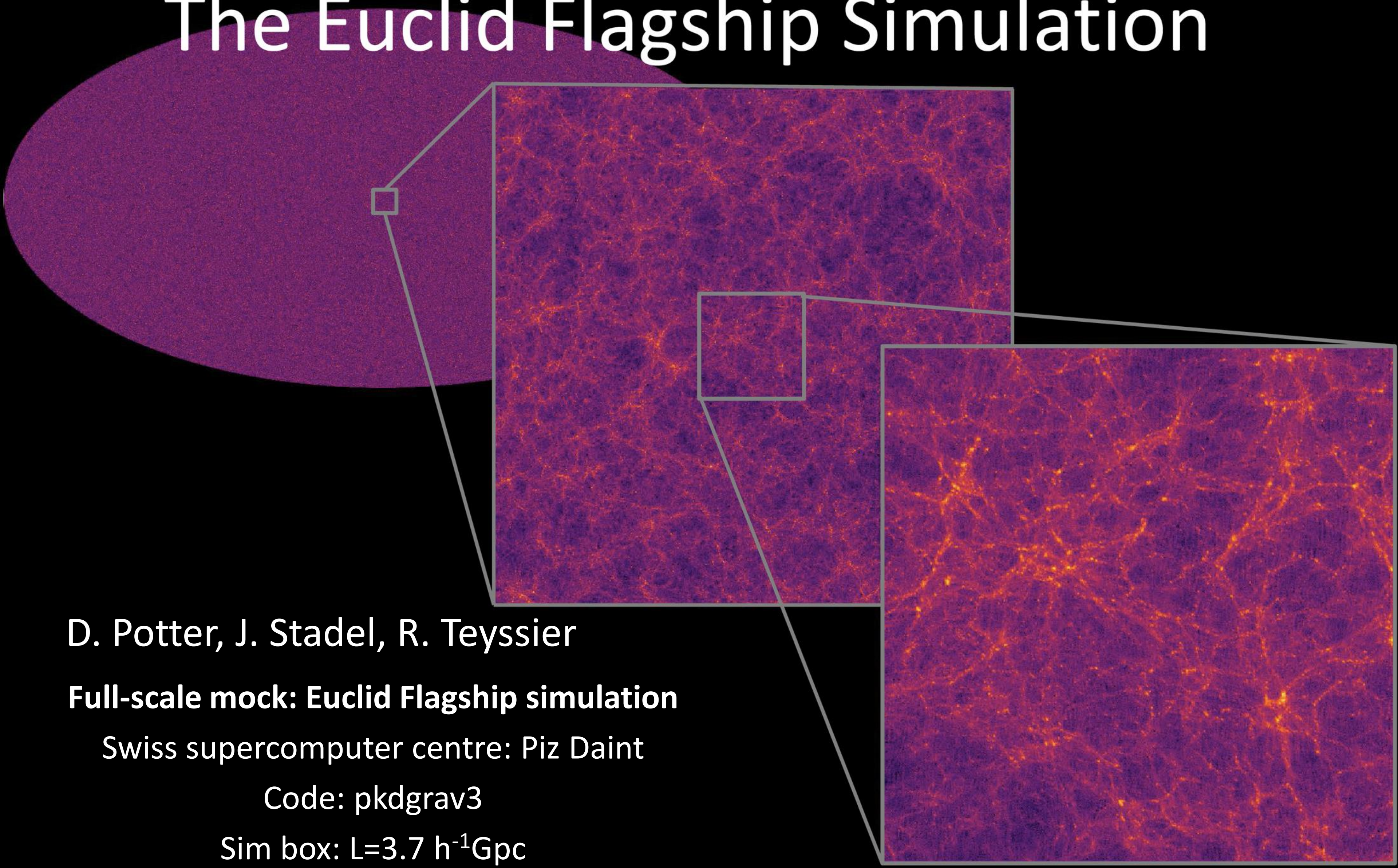
**All-sky Lensing maps**



- Pipeline has been **continuously improved** since first FS1 mock release to EC
- **WIDE survey mock** (~ few billion galaxies) can be **produced in few hours** @ Spanish SDC

Credits: P. Fosalba & the CoS-SWG

# The Euclid Flagship Simulation



D. Potter, J. Stadel, R. Teyssier

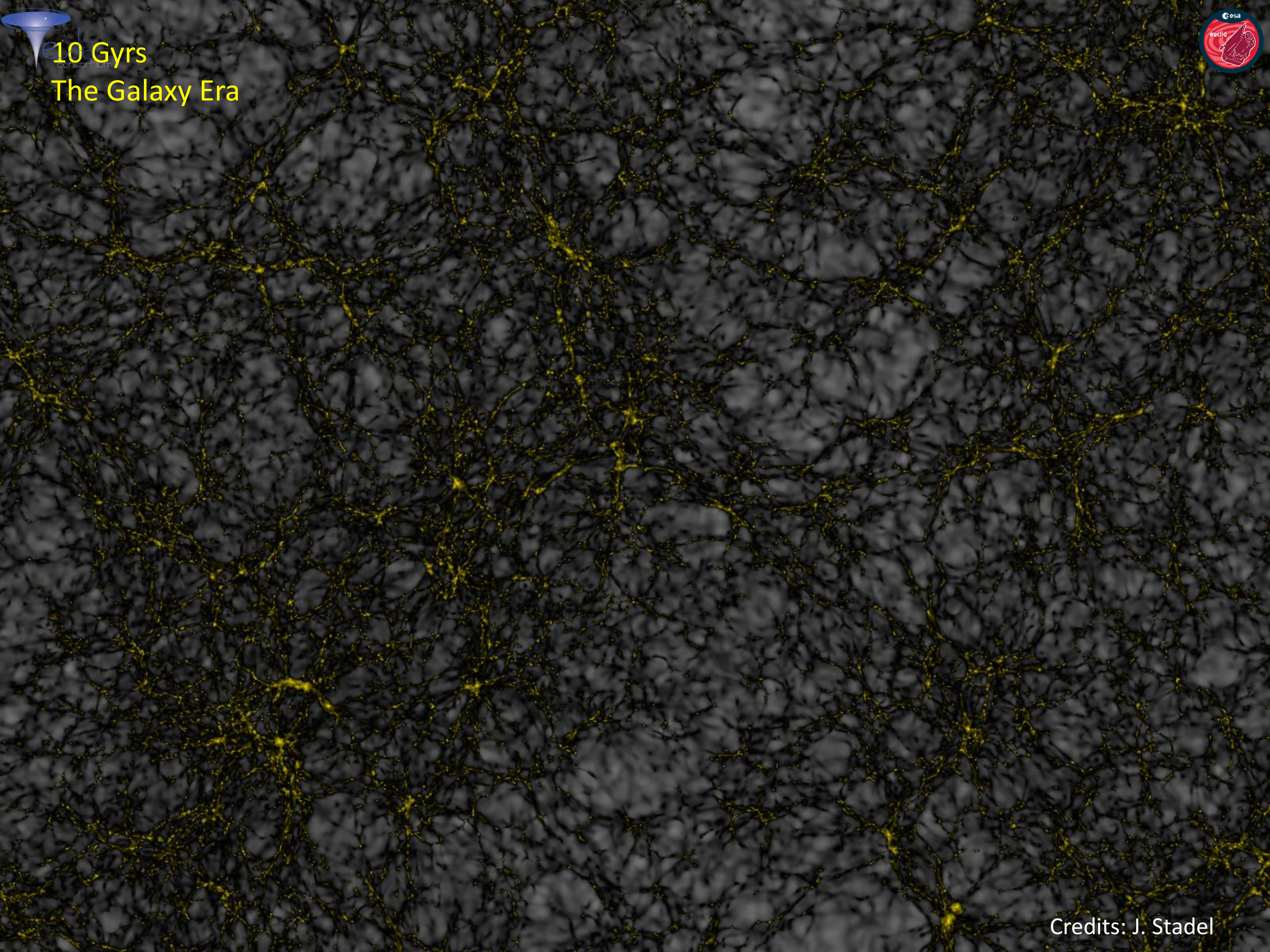
**Full-scale mock: Euclid Flagship simulation**

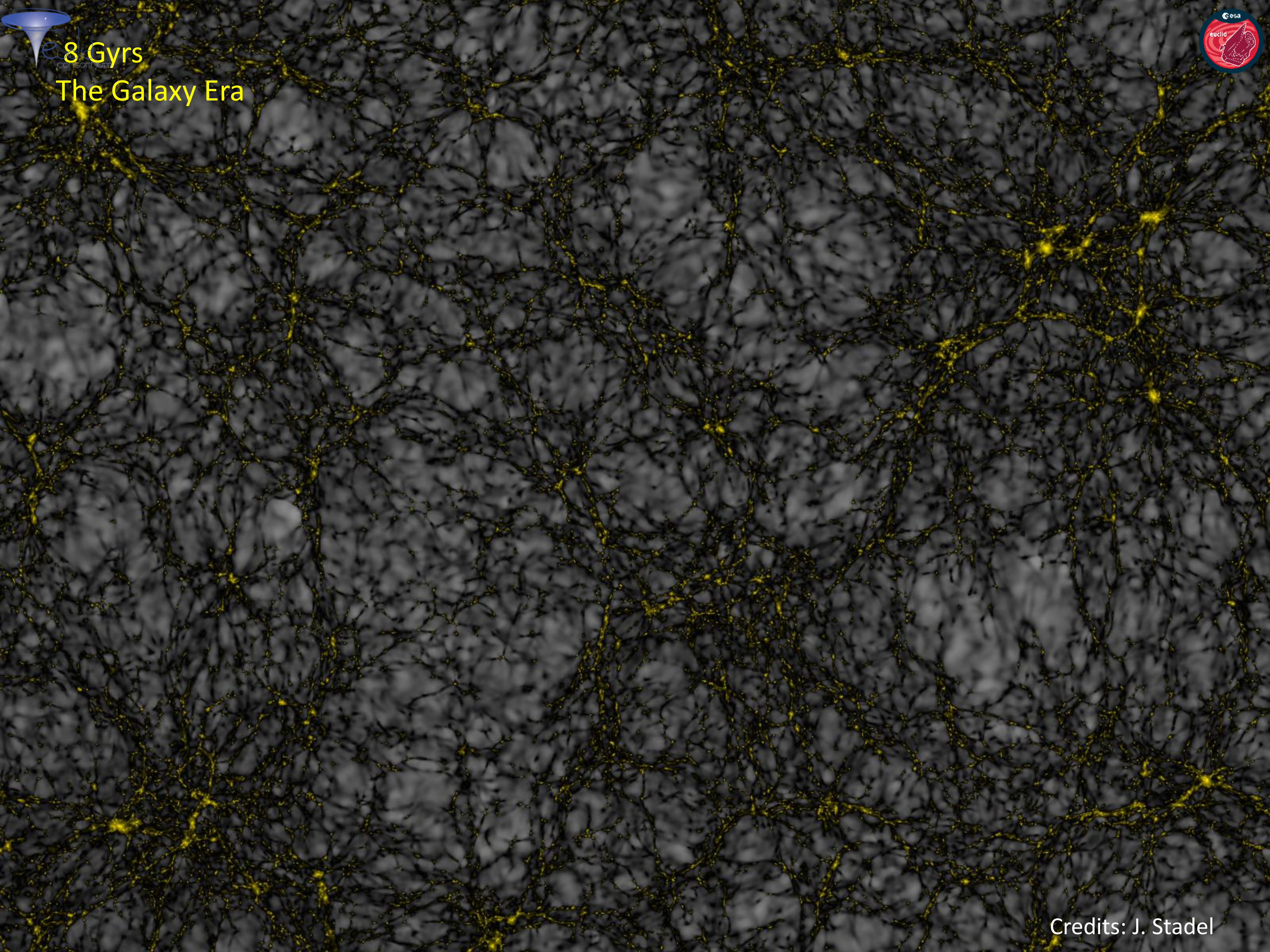
Swiss supercomputer centre: Piz Daint

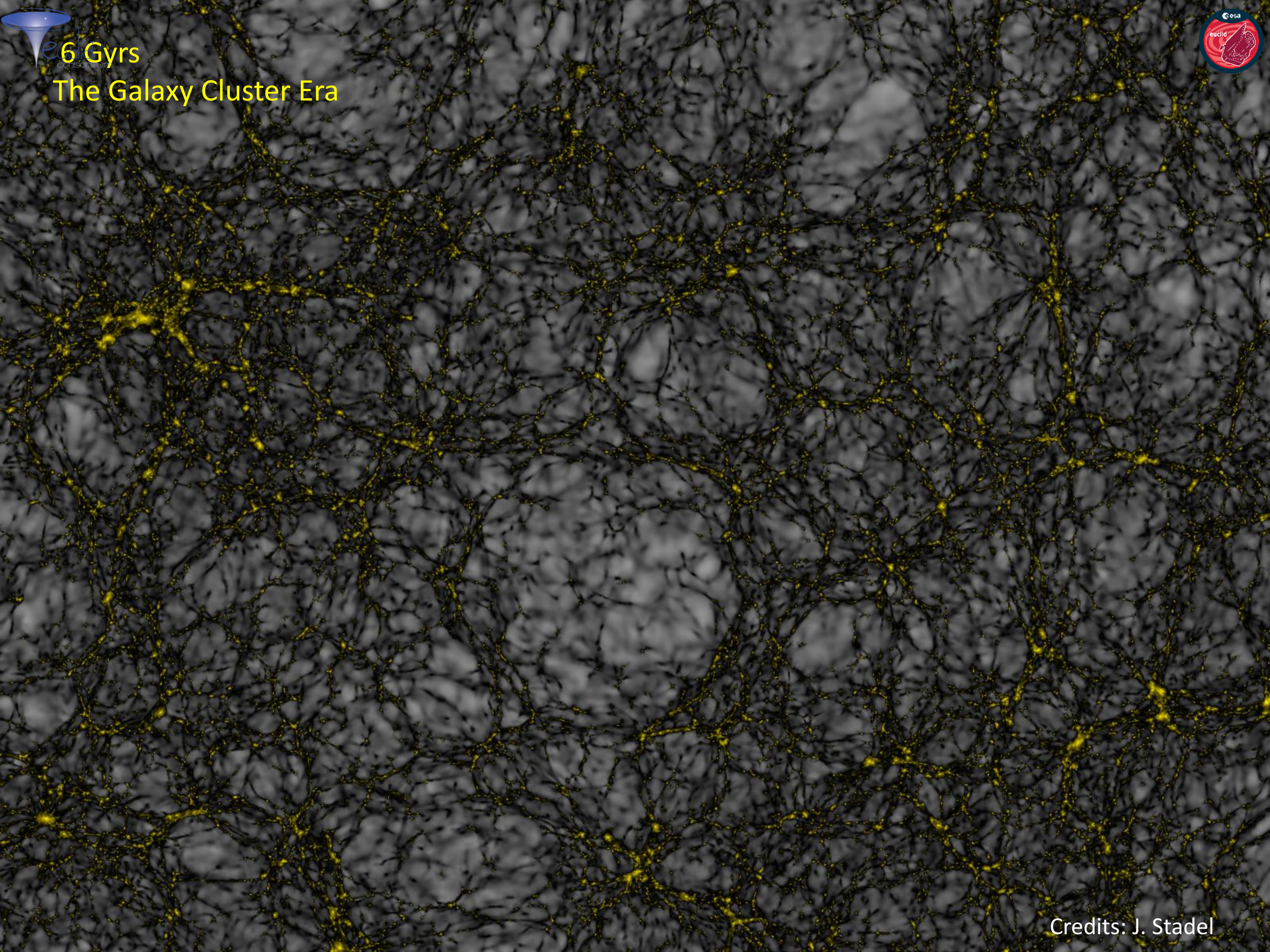
Code: pkdgrav3

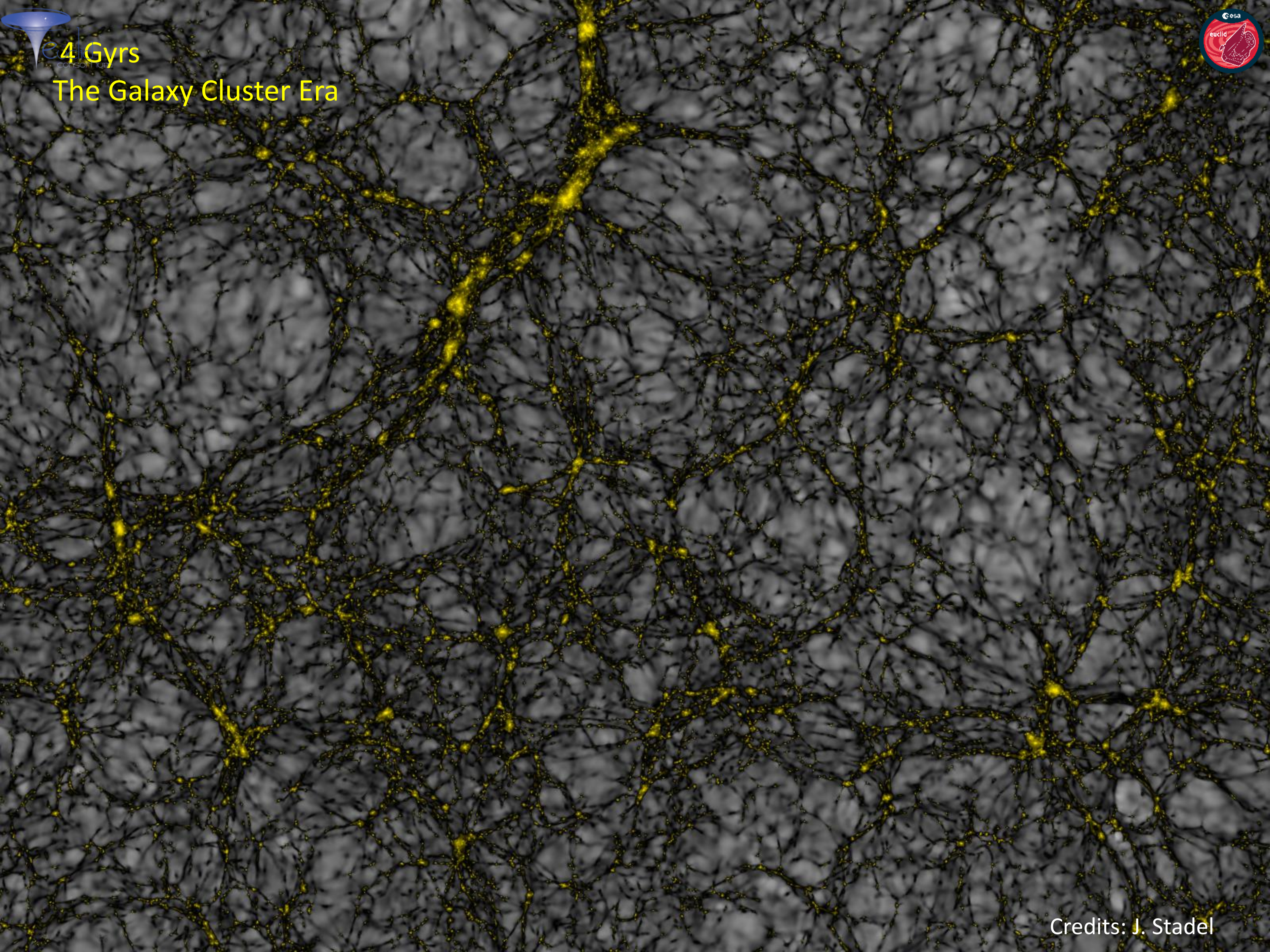
Sim box: L=3.7 $h^{-1}$Gpc

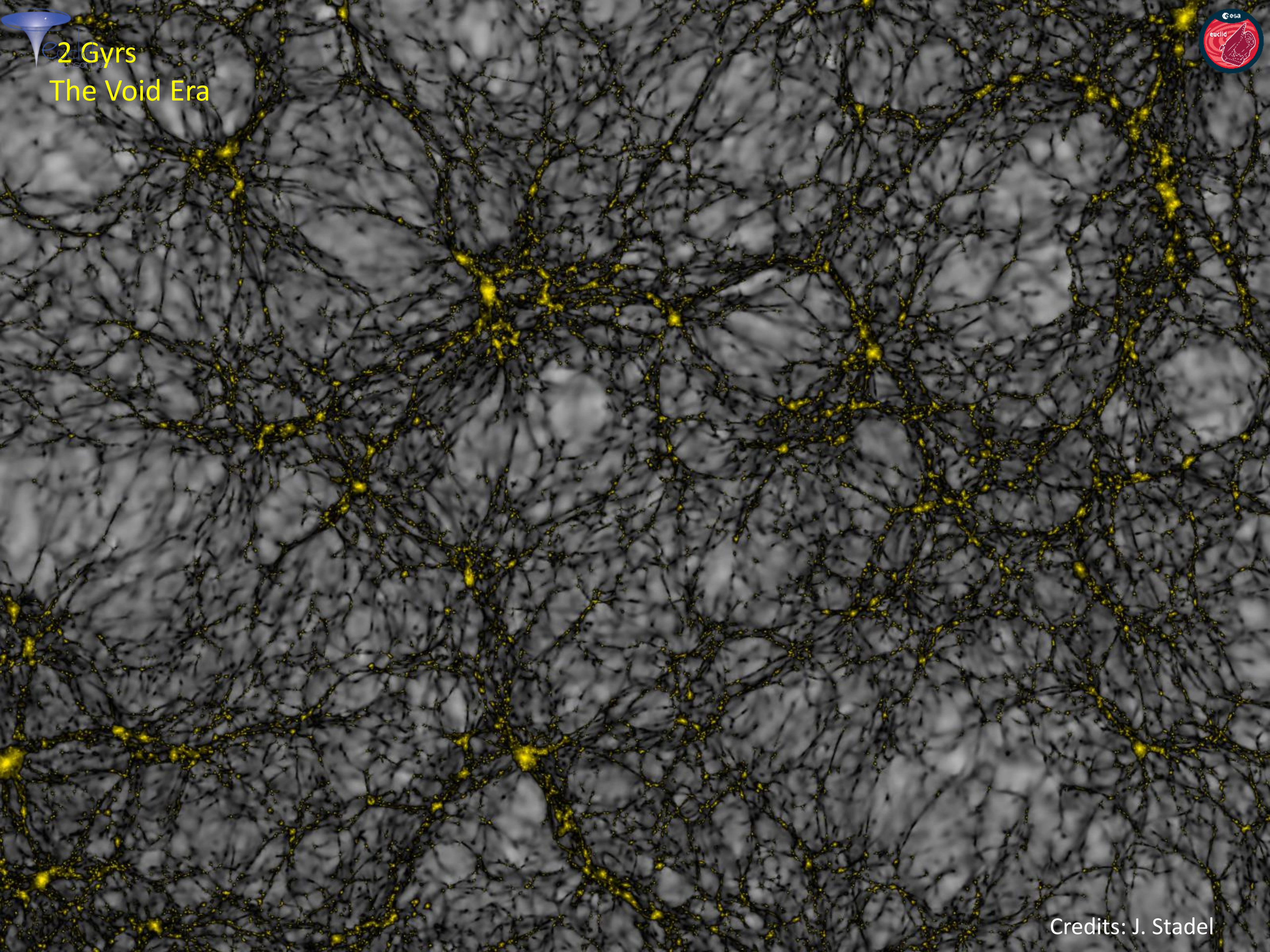
$N_{part}$=2 trillion  $M_p$=2.4 $10^9$ $M_{sun}$


10 Gyrs
The Galaxy Era
Credits: J. Stadel

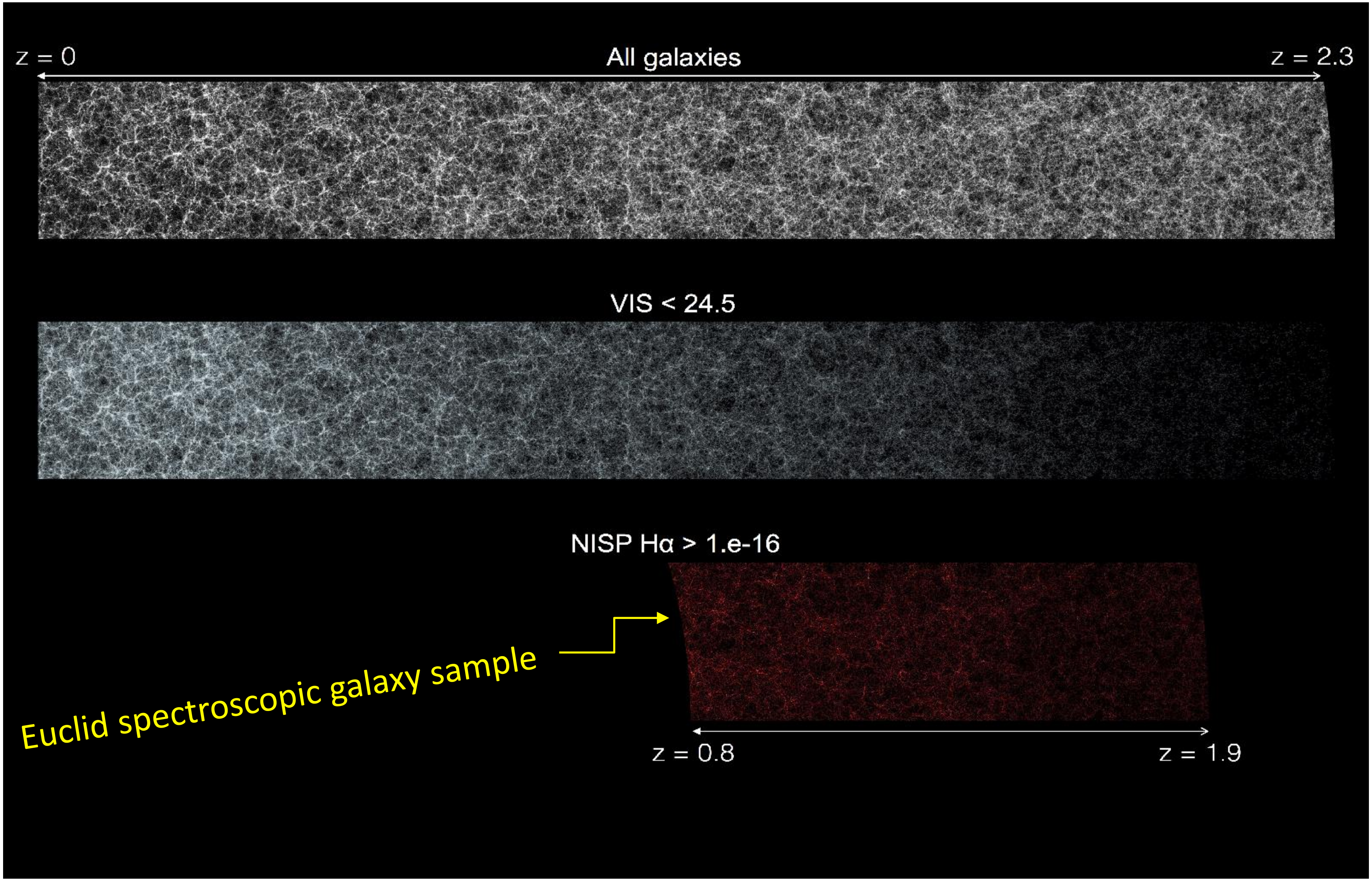

8 Gyrs
The Galaxy Era
Credits: J. Stadel


6 Gyrs
The Galaxy Cluster Era
Credits: J. Stadel


4 Gyrs
The Galaxy Cluster Era
Credits: J. Stadel

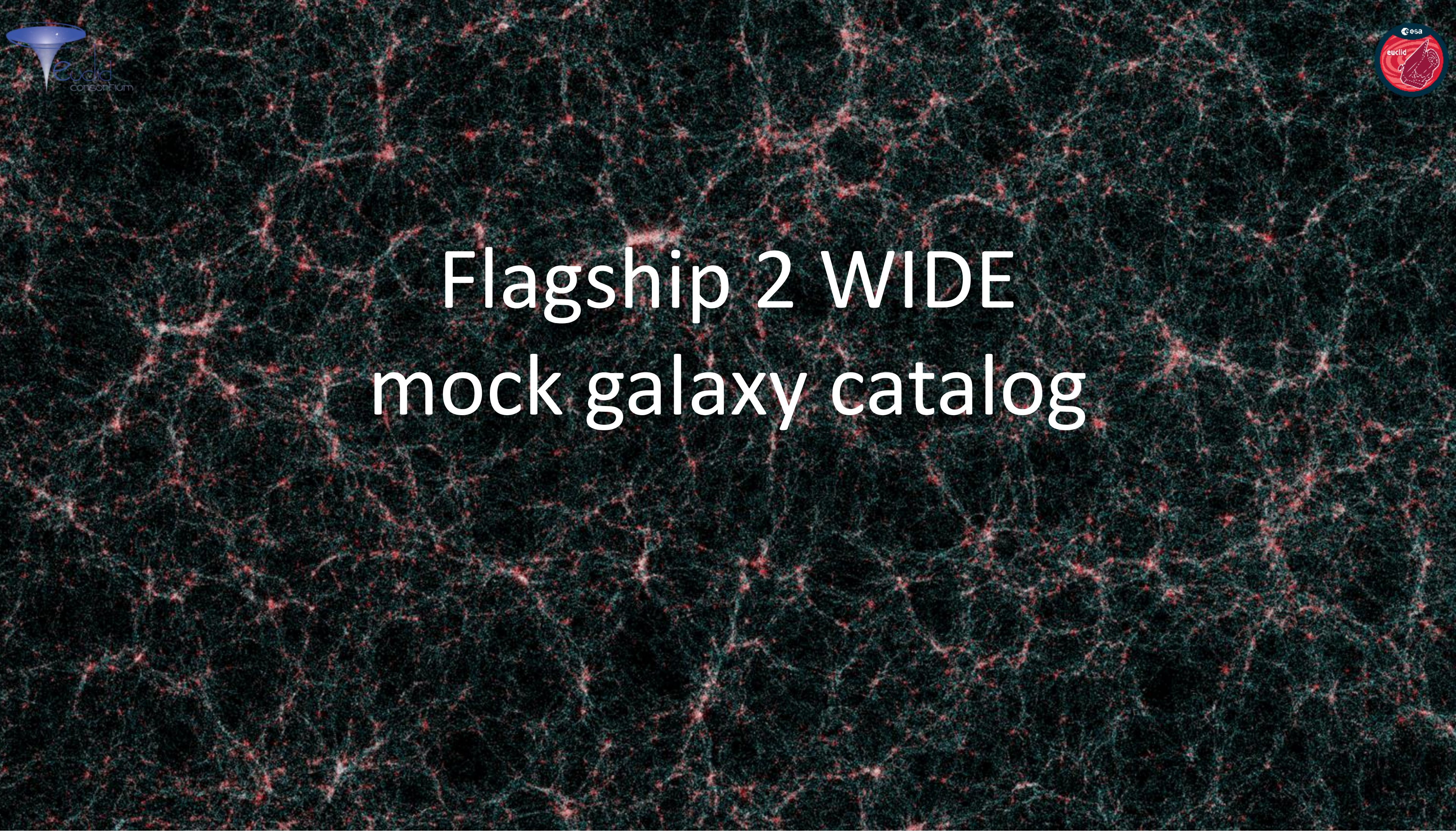

2 Gyrs
The Void Era
Credits: J. Stadel

# Euclid Flagship Simulation 1: mock galaxy lightcones




Credits: P. Fosalba

# Flagship 2 WIDE mock galaxy catalog



Doug Potter Joachim Stadel Romain Teyssier

- WIDE
  4.1 trillion dark matter (DM) particles
  DM particle mass = $10^9$ $M_{sun}/h$
  $L_{BOX}$ = 3600 Mpc/h
- DEEP
  0.9 trillion DM particles
  DM particle mass = $10^8$ $M_{sun}/h$
  $L_{BOX}$ = 1000 Mpc/h

# Specification of the Reference Cosmology

**$\Omega_m$= 0.319**
**$\Omega_b$= 0.049**
**$\Omega_\Lambda$= 0.681 - $\Omega_{RAD}$ - $\Omega_\nu$**
**$\Sigma m_\nu$= 0.06 ev** (minimal, see across)
**$T_{CMB}$= 2.7255 K**
**$A_s$ = 2.1 X $10^{-9}$** (roughly $\sigma_8$= 0.83)
**$k_{pivot}$ = 0.05/Mpc**
**h = 0.67**
**$n_s$= 0.96**
**$w_0$= -1**
**$w_a$= 0**

Using the normal hierarchy with m_1 = 0 and data from https://arxiv.org/pdf/1708.01186.pdf

$\Delta m\_21^2 = 7.55 \times 10^{-5}\ eV^2$,
$\Delta m\_31^2 = 2.50 \times 10^{-3}\ eV^2$,
and so
m_1 = 0 (by choice),
m_2 = 8.68907 X $10^{-3}$ eV,
m_3 = 5.00000 X $10^{-2}$ eV

**mv = [0, 8.68907 X $10^{-3}$ eV, 5.00000 X $10^{-2}$ eV]**
**(giving Σmv = 0.05868907 eV)**

Effects of light neutrinos, photon anisotropies and GR corrections linearly included (Tram et al. 2018) via the realisation of these perturbation fields on a grid, obtained via CLASS and added to the ordinary matter potential grid, in the so-called Nbody gauge (Fidler et al. 2016).

IC are generated at z=200 (1LPT) as well as all the background quantities (H(a), a(t), $\Omega_\nu$(a)…)

Agreement with CLASS on linear scales at 0.1%

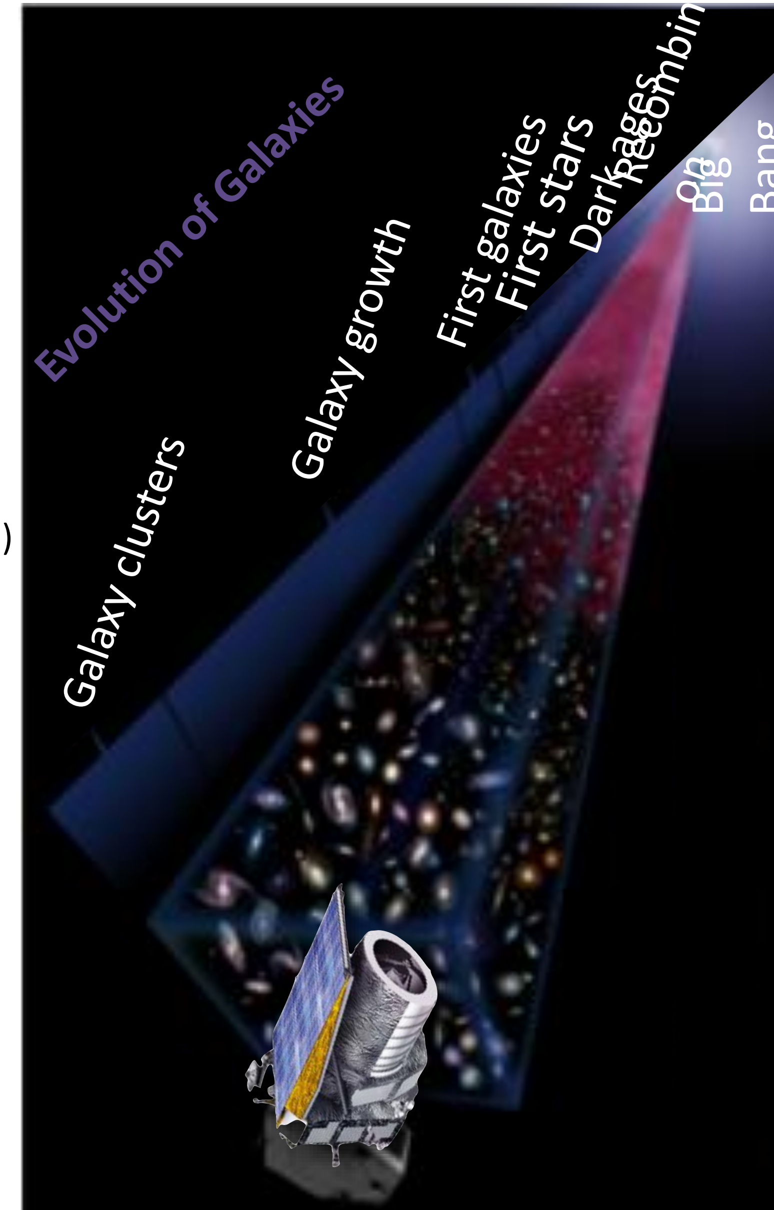
Credits: J. Stadel

# Euclid additional science: beyond the primary probes

- $10^5$ **galaxy clusters** (Sartoris+16)
- **Cosmic Voids**
- **Cross-correlations with CMB**

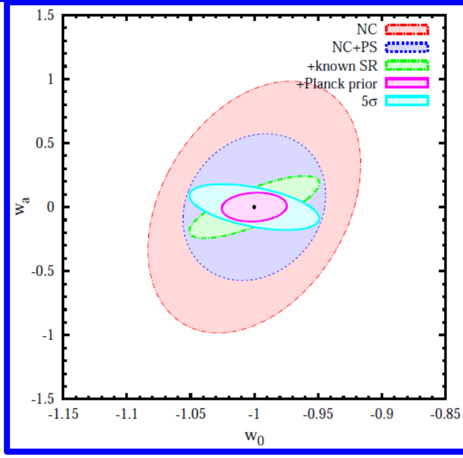
temperature and lensing

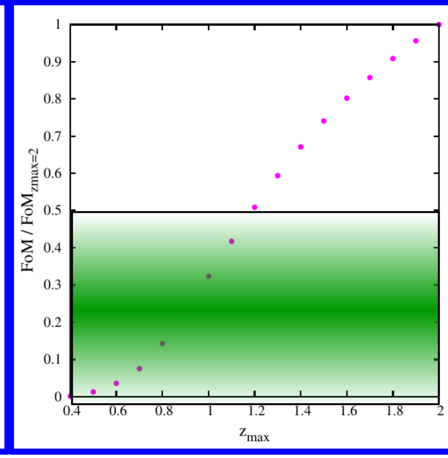
- $10^5$ **strong gravitational lenses**
- Transients in Deep fields
  - ~50 **Super-luminous SNe** / year (Inserra+17)
- Galaxy formation and evolution
  - Census of **AGN** at $1 < z < 3$
  - Galaxy **morphologies** at $z > 1$
  - **Lyman break galaxies** at $z > 7$
  - High-z **quasars**
- Milky Way
  - Census of **brown dwarf** stars
  - **Satellites & environs**

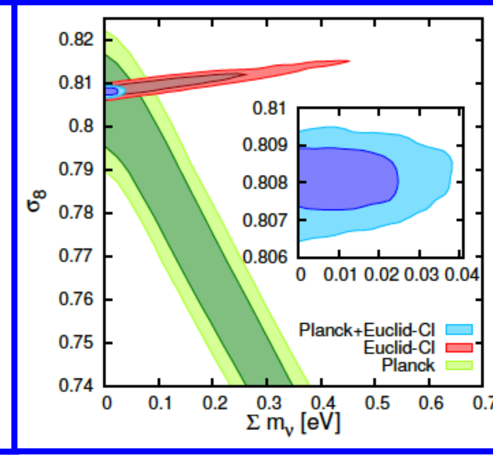


# Euclid Galaxy Cluster Science

Impact of the observable-mass relation uncertainties: Euclid will internally calibrate the scaling relations




Impact of high redshit clusters: Euclid will see clusters at z>1.5.
Adding clusters with 1.2<z<2 double the cluster number counts FoM

Clusters are conceptually and observationally independent of geometrical probes.

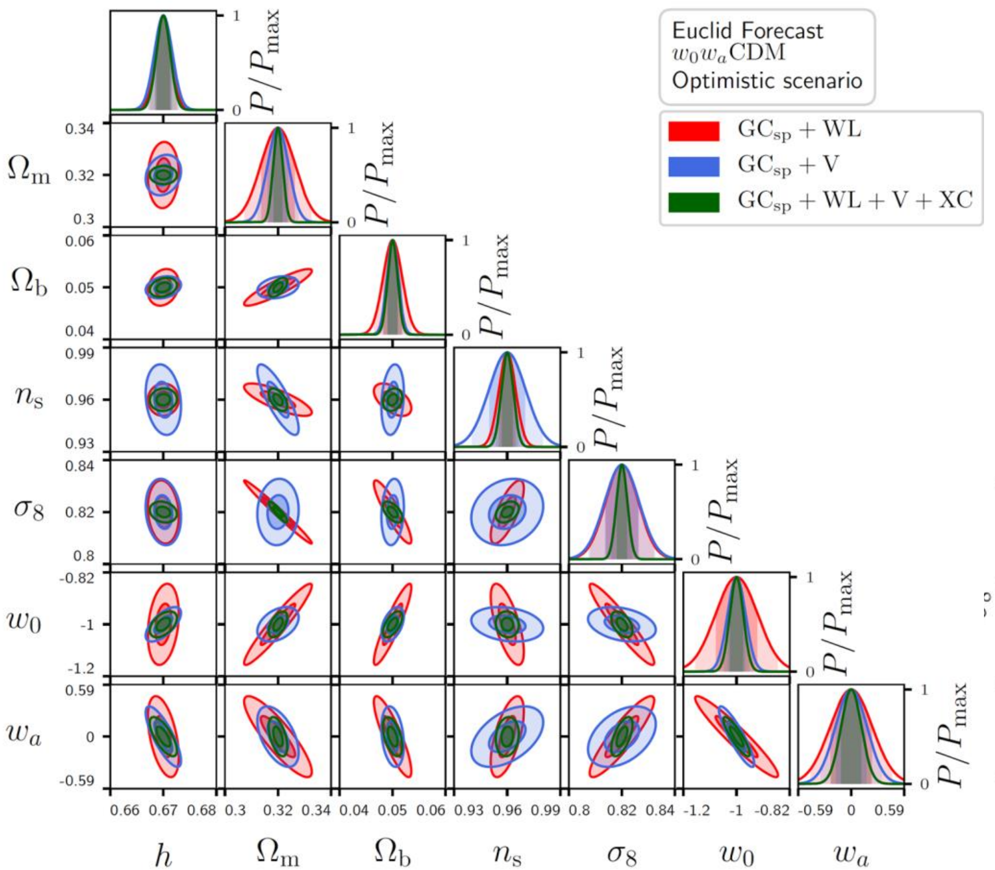
| | Modified Gravity | Dark Matter | Initial Conditions | Dark Energy | | |
|---|---|---|---|---|---|---|
| Parameter | $\gamma$ | $m_\nu$ /eV | $f_{NL}$ | $w_p$ | $w_a$ | FoM |
| Euclid primary (WL+GC) | 0.010 | 0.027 | 5.5 | 0.015 | 0.150 | 430 |
| Euclid All (Including Clusters) | 0.009 | 0.020 | 2.0 | 0.013 | 0.048 | 1540 |
| Euclid+Planck | 0.007 | 0.019 | 2.0 | 0.007 | 0.035 | 4020 |
| Current (2009) | 0.200 | 0.580 | 100 | 0.100 | 1.500 | ~10 |
| **Improvement Factor** | **30** | **30** | **50** | **>10** | **>40** | **>400** |

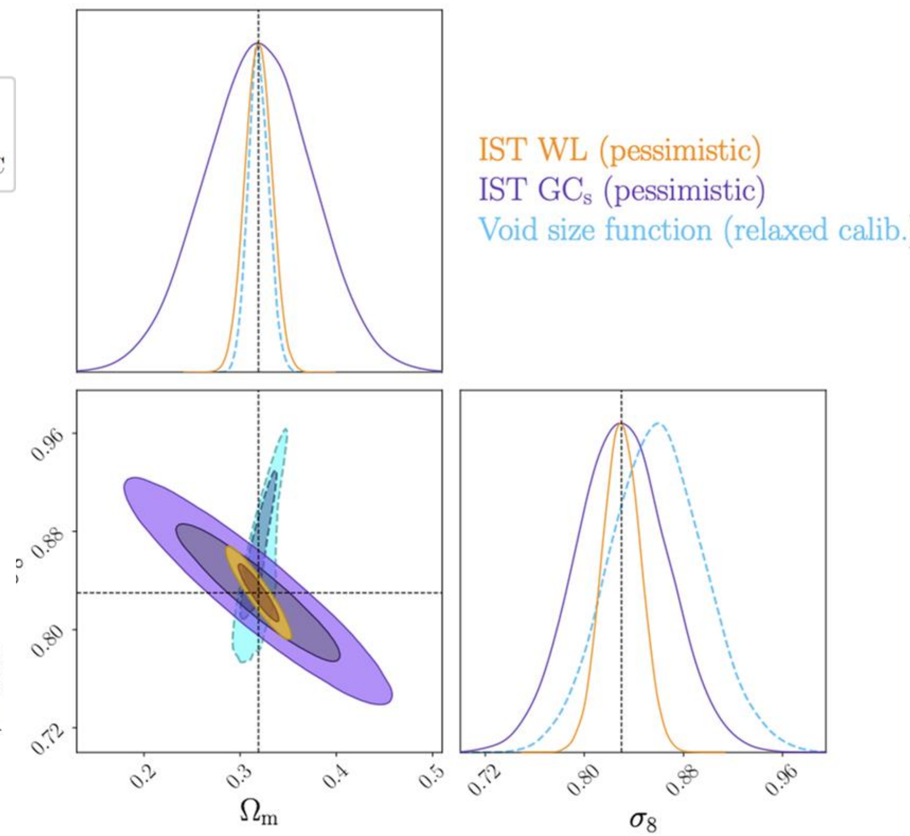
B. Sartoris    Costanzi,BS+13, Sartoris+16

Credits: L. Moscardini

# Cosmic voids!

# Parameter inference from photo&spectro voids




Bonici & EC 2022

Contarini & EC 2021

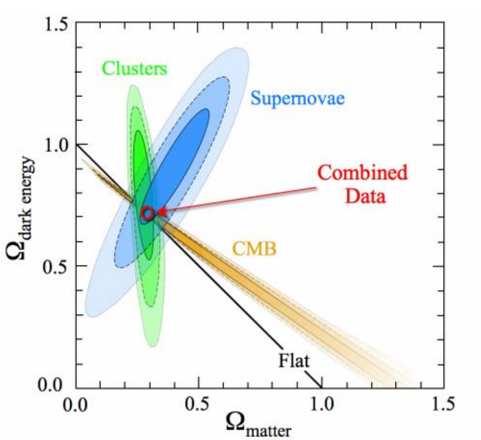
# Euclid cross Planck

Pre-Launch KP: Complementary to forecasts for primary probes
Publication: Ilic & the Euclid Consortium 2021, A&A, arXiv:2106.08346

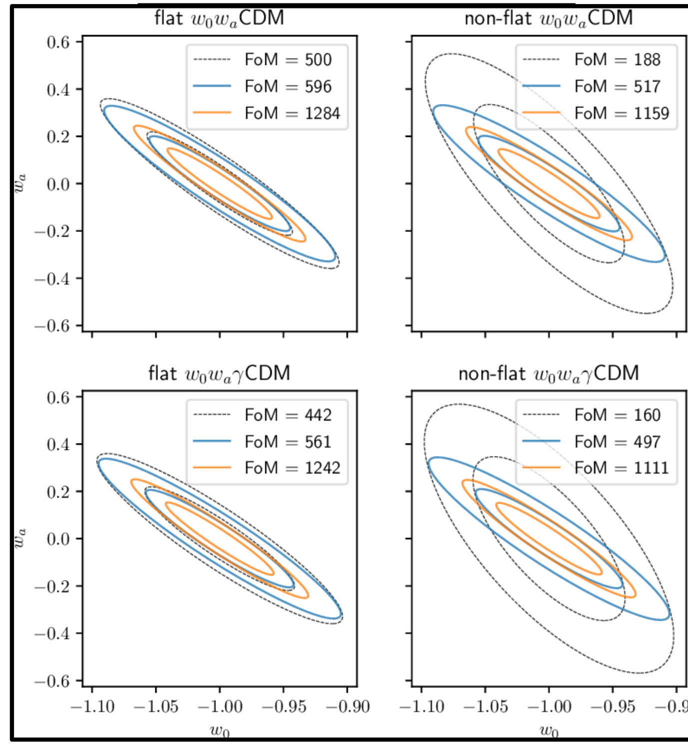
Key figures:

- 3 LSS probes: $GC_{ph}$, $GC_{sp}$, WL
- 3 CMB probes: T, E, $\phi$
- 6 cosmological models (incl. $w_0/w_a$, $\Omega_k$, $\gamma$)
- 2 Euclid scenarii (pessimistic/optimistic)
- 3 CMB setups (Planck-like, SO, CMB-S4)
- 2 scientific cases:
  - Euclid + CMB $\phi$ (all "matter probes")
  - Euclid + full CMB

**$w_0 w_a$ FoM including CMBX >1100**




Pessimistic Euclid + SO

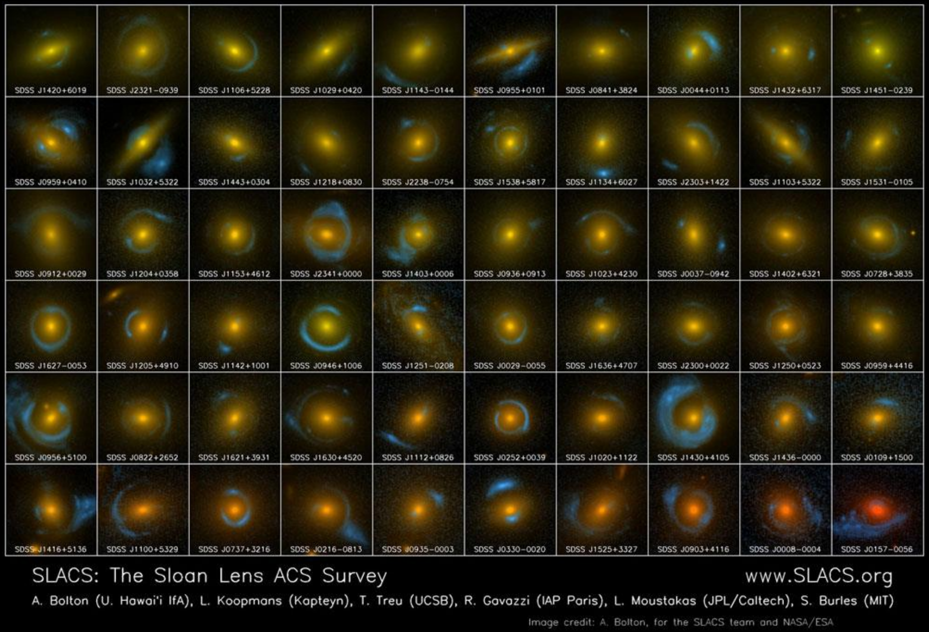



Euclid only
Euclid + CMB $\phi$
Euclid + full CMB

Credits: C. Baccigalupi

# With Euclid VIS: ~3300 such lenses in two months!

SLACS

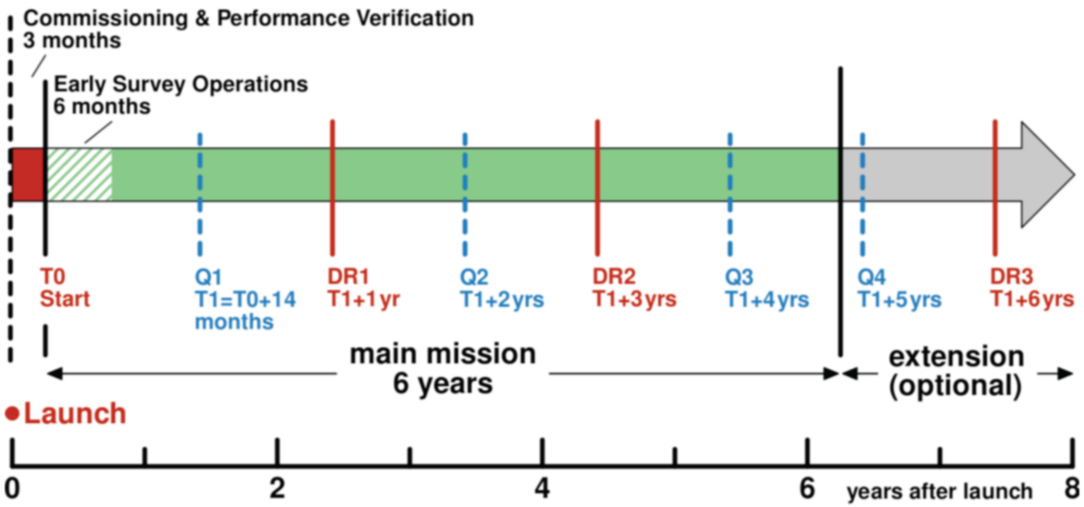



**In the full Wide survey (60 months):**

- **200,000 strong lenses around early-type galaxies;**
- **2300 lensed QSOs, of which ~16% quadruple lenses**
- **9000 cluster arcs with l/w>5 (~1300 with l/w>10)**

**(Euclid Strong Lensing SWG white paper, based on ray-tracing simulations, Boldrin et al. 2016)**

# Euclid Data Releases Timeline




19

**Q1 (~50 deg²)**
**DR1 (2500 deg²)**
**DR2 (7500 deg²)**
**DR3 (15000 deg²)**

- Three public data releases, with an increasing fraction of the survey:
  - DR1: ~ mid 2025 (1/6 of the survey)
  - DR2: ~ 2027 (1/2 of the survey)
  - DR3: ~ 2031 (full survey)
- Each Data Release will be coupled with papers containing results from the official analysis.
- The Euclid consortium web page: https://www.euclid-ec.org/
- ESA's Euclid page: https://www.esa.int/Science_Exploration/Space_Science/Euclid


esa
HAPPY AND
SUCCESSFUL
2024
euclid
consortium