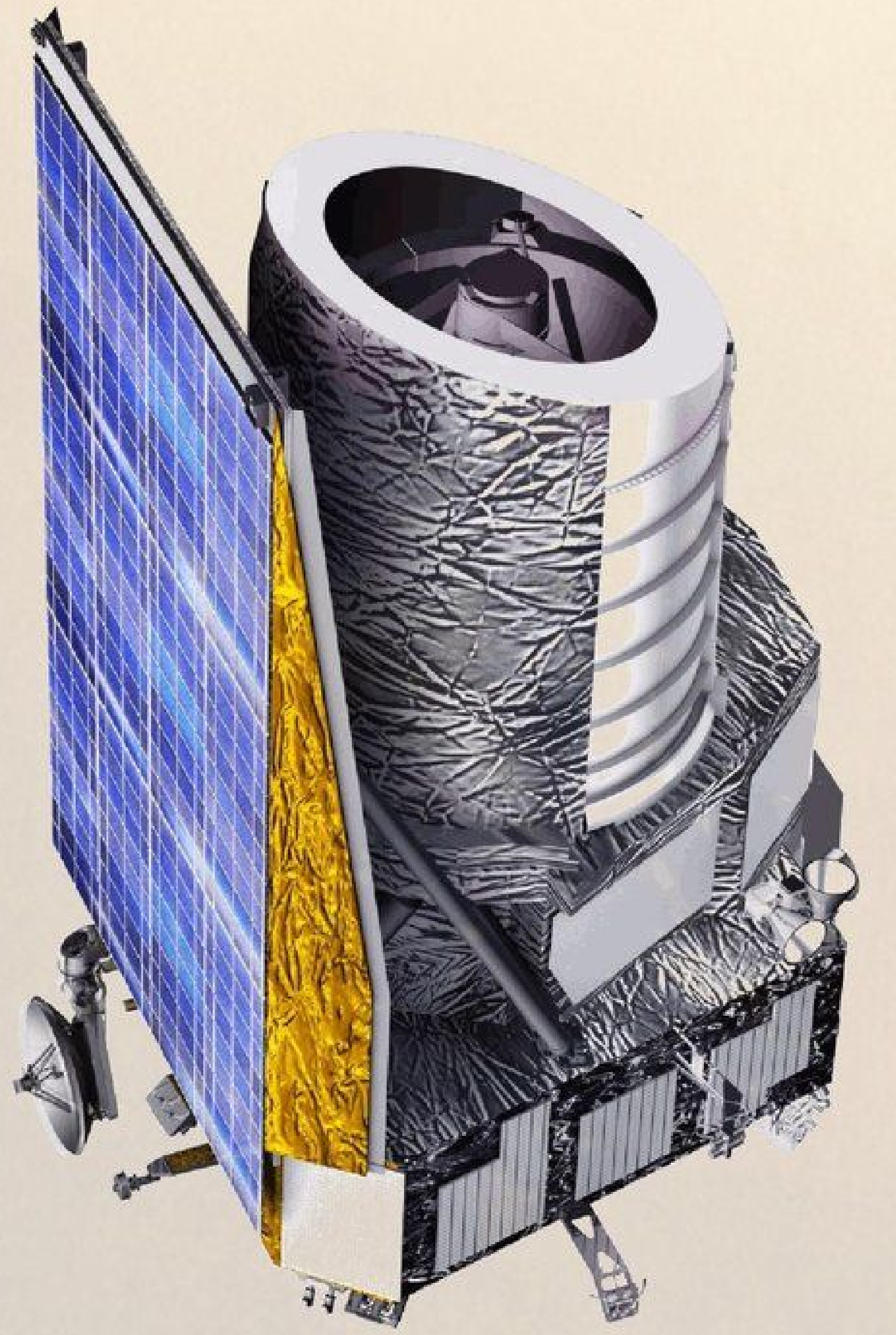
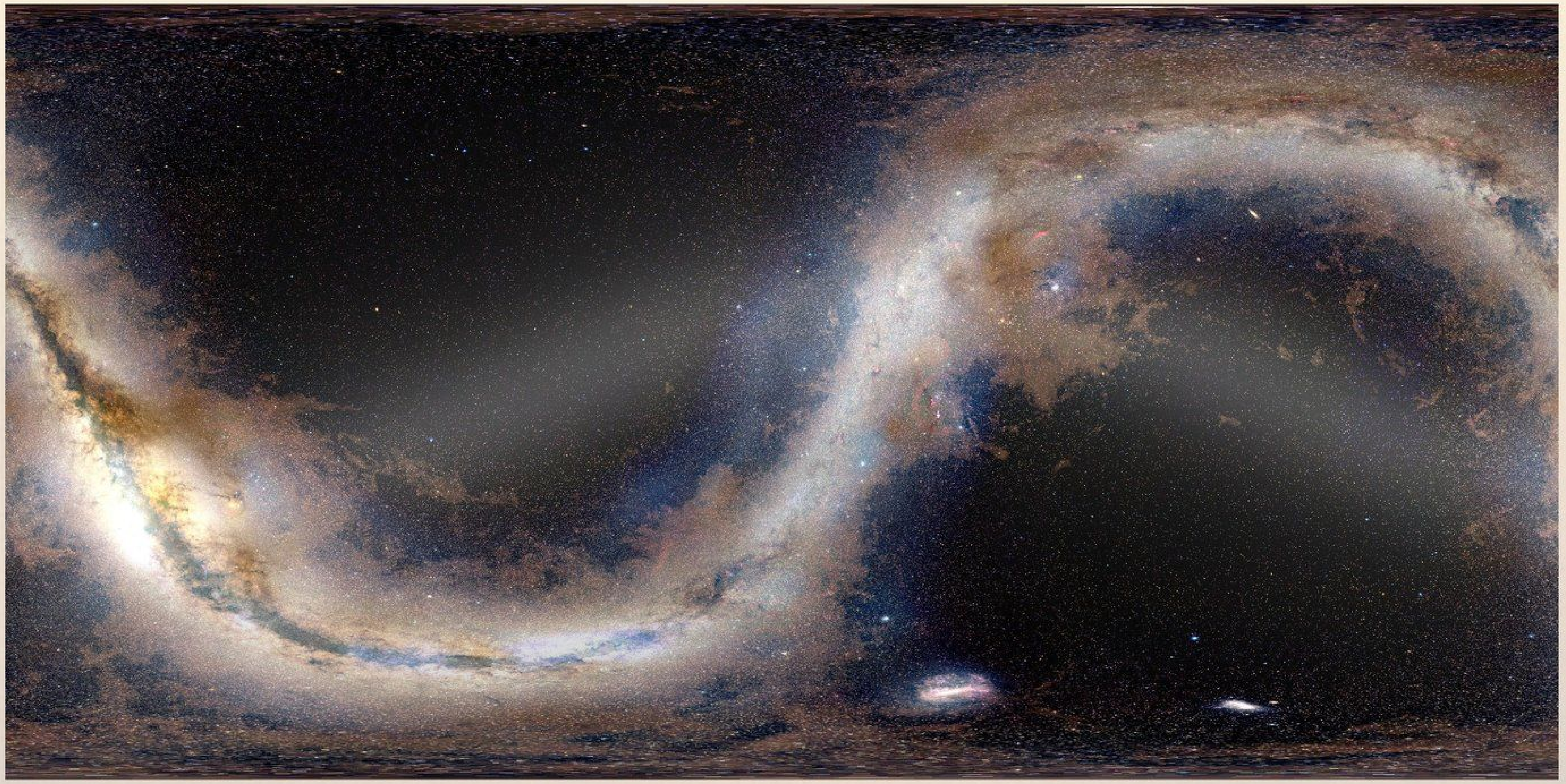
Euclid : mission overview & sky surveys

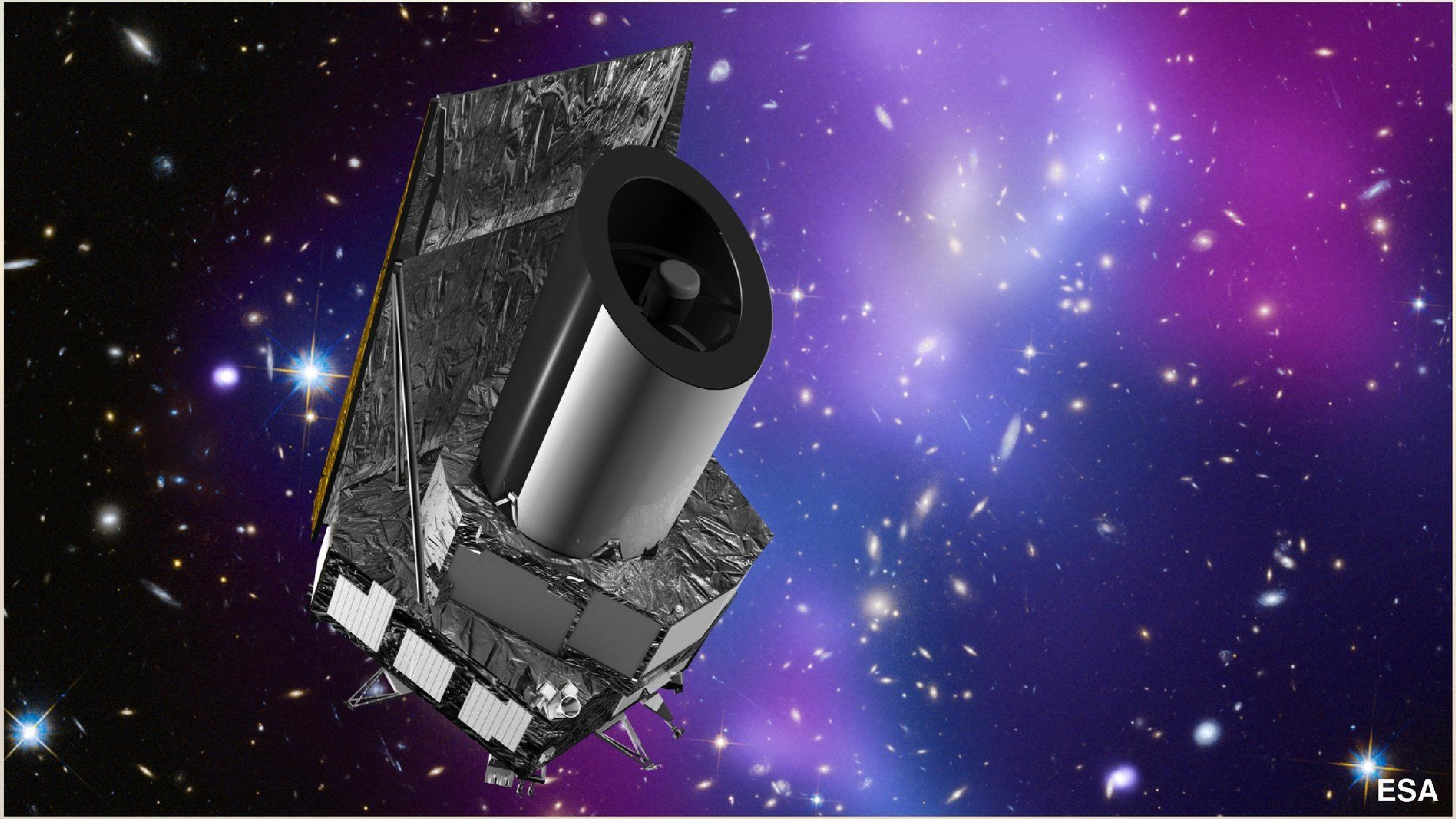
Jean–Charles Cuillandre *on behalf of the Euclid Consortium (EC)*
CEA Saclay / Observatoire de Paris





SKA–France, Paris, November 2018

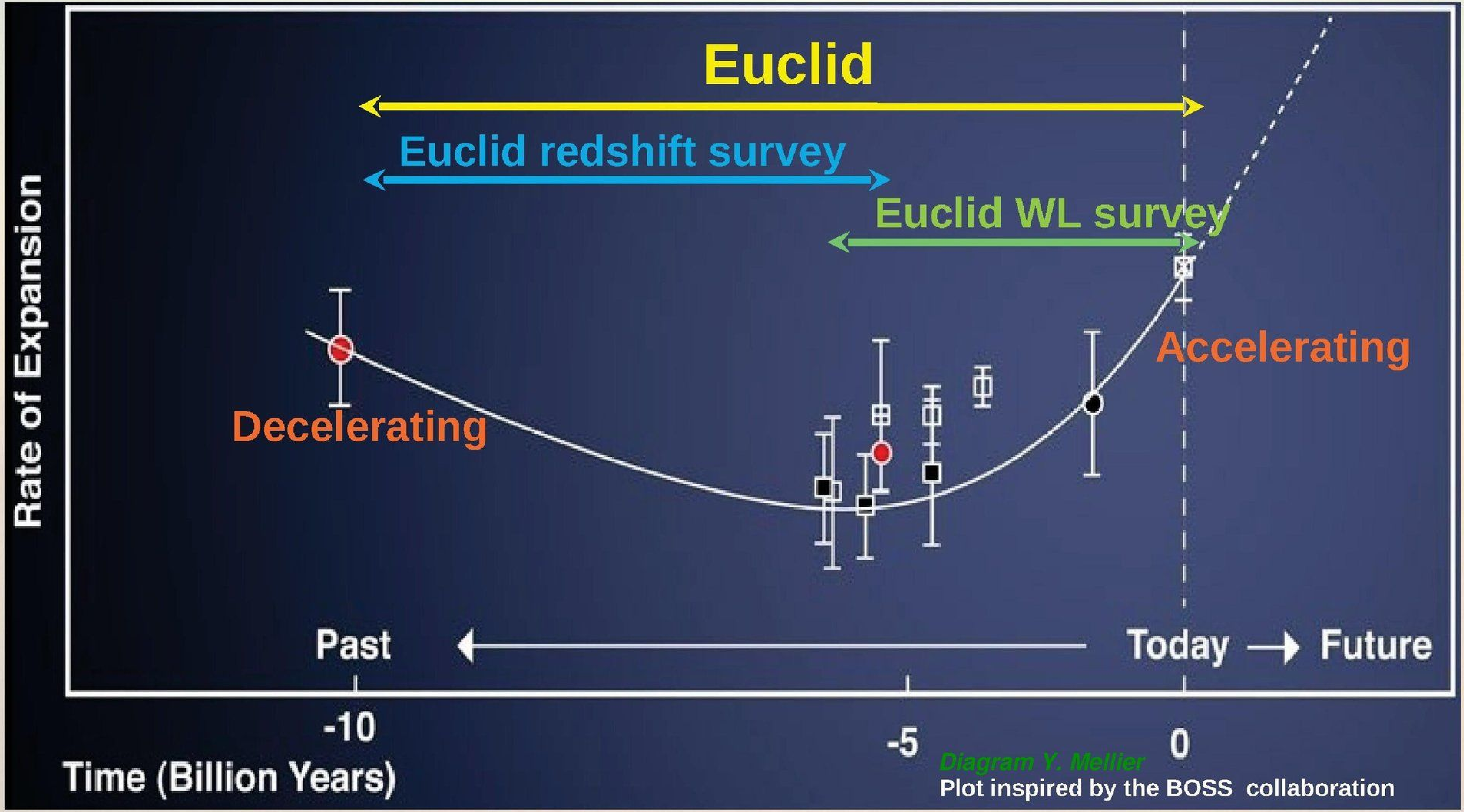
Euclid, a ESA space mission to map the Dark Universe



Launch 2022, final data release ~2030 (DR3)

The mission will enable a staggering amount of legacy science: Sloan in space

Probing the DM vs DE universe dominated transition



Dark matter once dominated the Universe expansion versus dark energy

Euclid is a calibration mission aimed at high precision cosmology

The Euclid Scientific Community

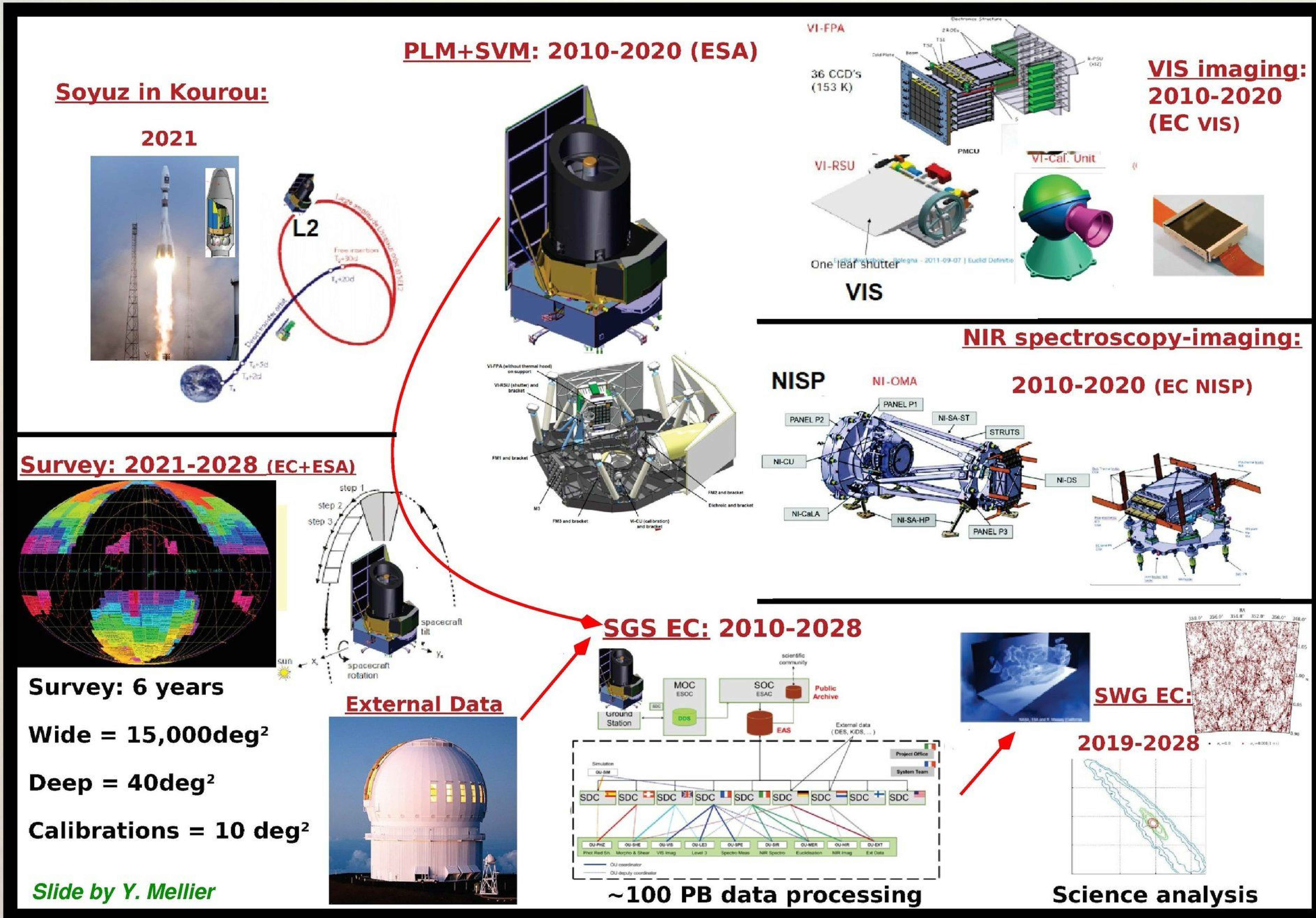
18 countries

285 institutes

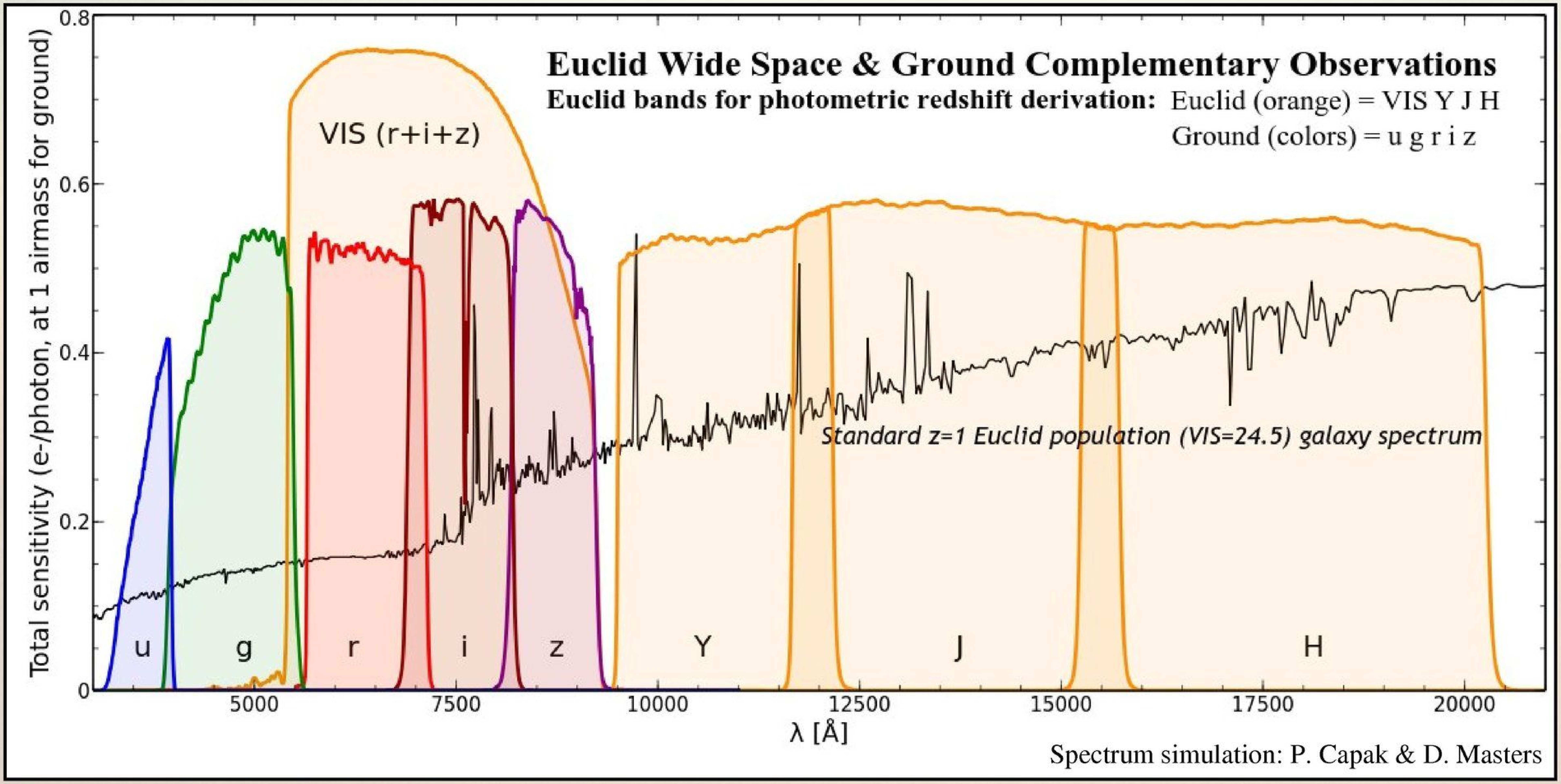
1913 members

France leads the Euclid Consortium

The ESA Euclid mission in a nutshell



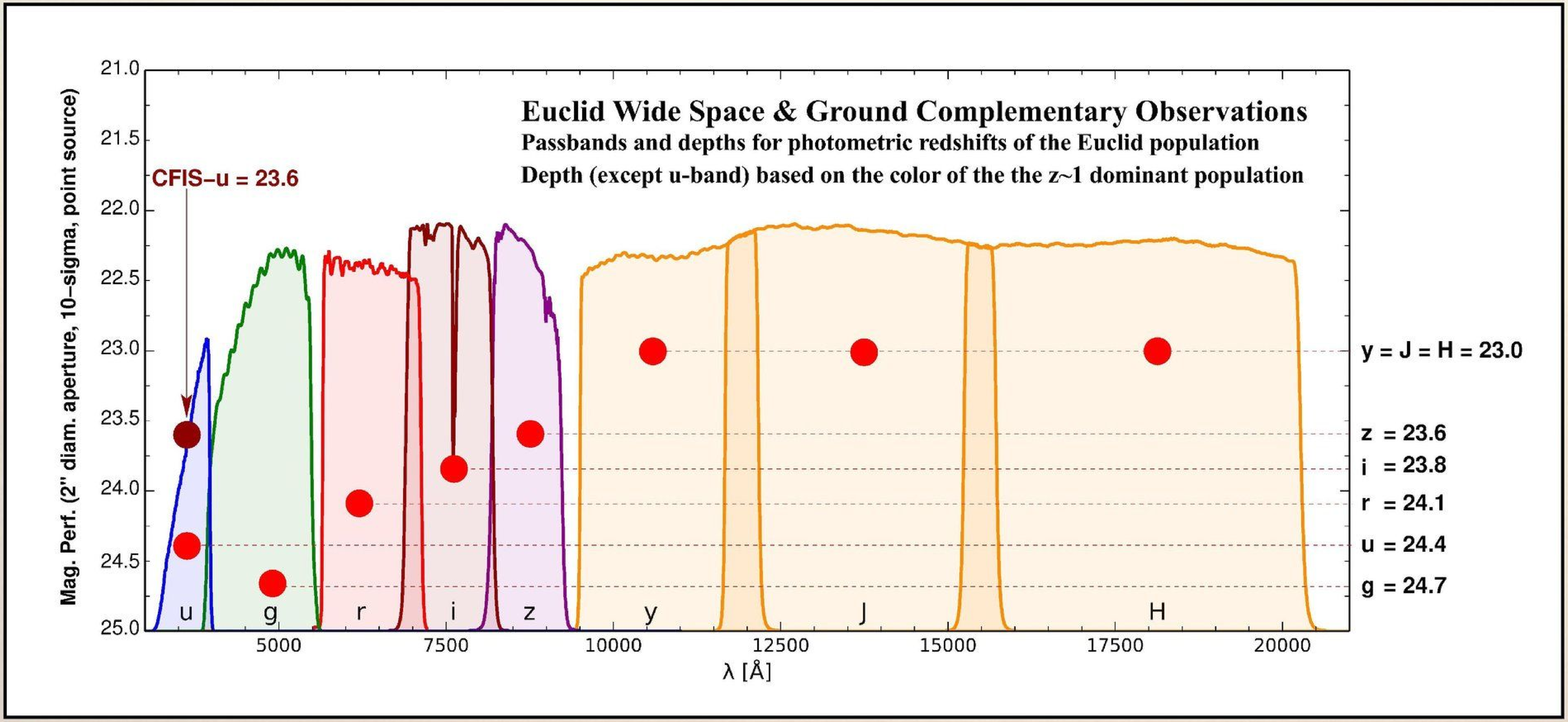
Euclid bands for photometric redshift derivation



Euclid Red Book lists g,r,i,z as essential, u is a great bonus for low−z rejection

4000 A. break at z~1 falls within the VIS band: crucial need for the r,i,z bands

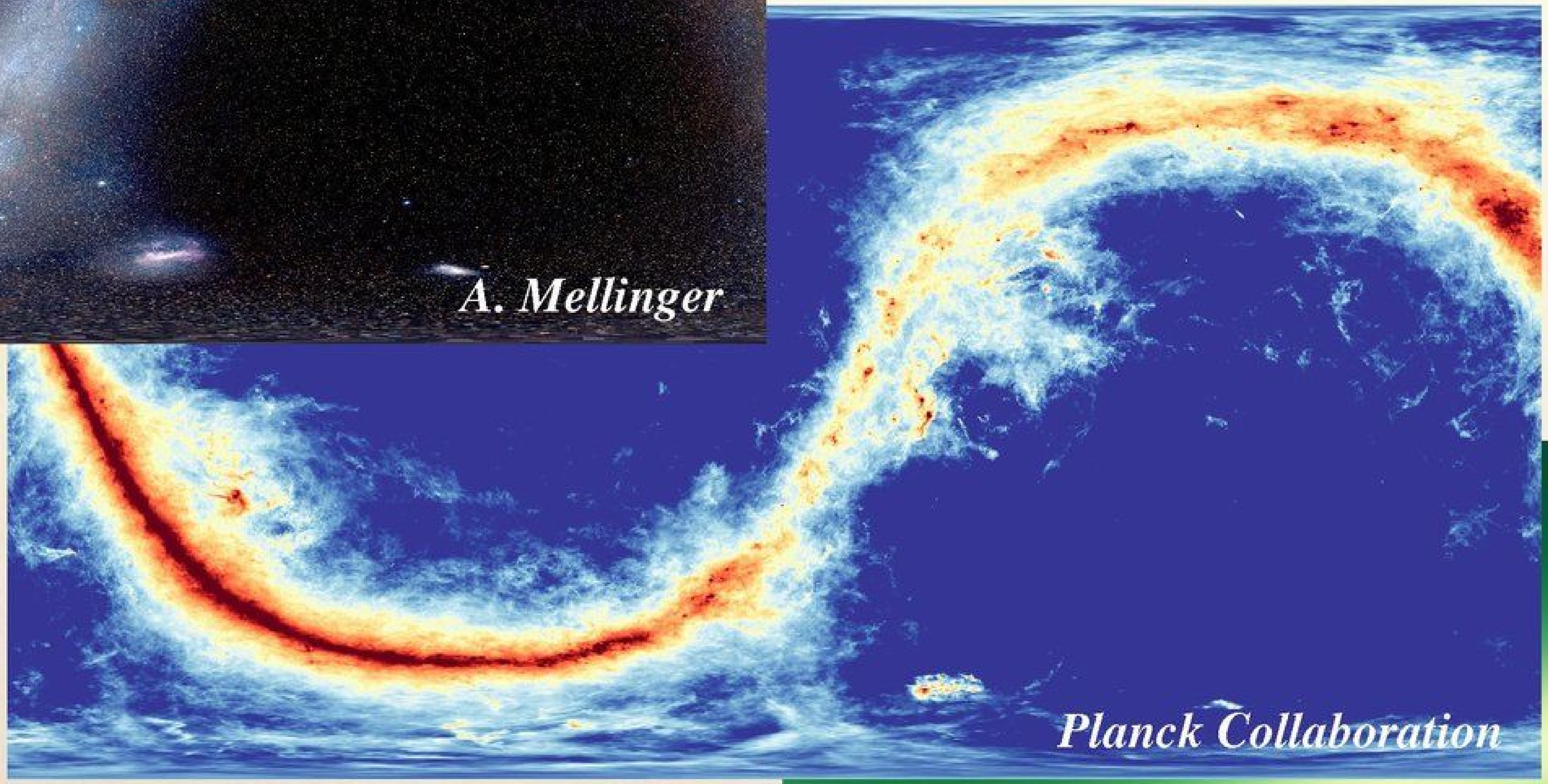
Depths of the Euclid Wide and Deep surveys



The 3 Euclid Deep Fields and 6 Calibrations fields will be ~2 magnitudes deeper

The entire sky: building the Euclid exclusion zones

The Galaxy



Reddening

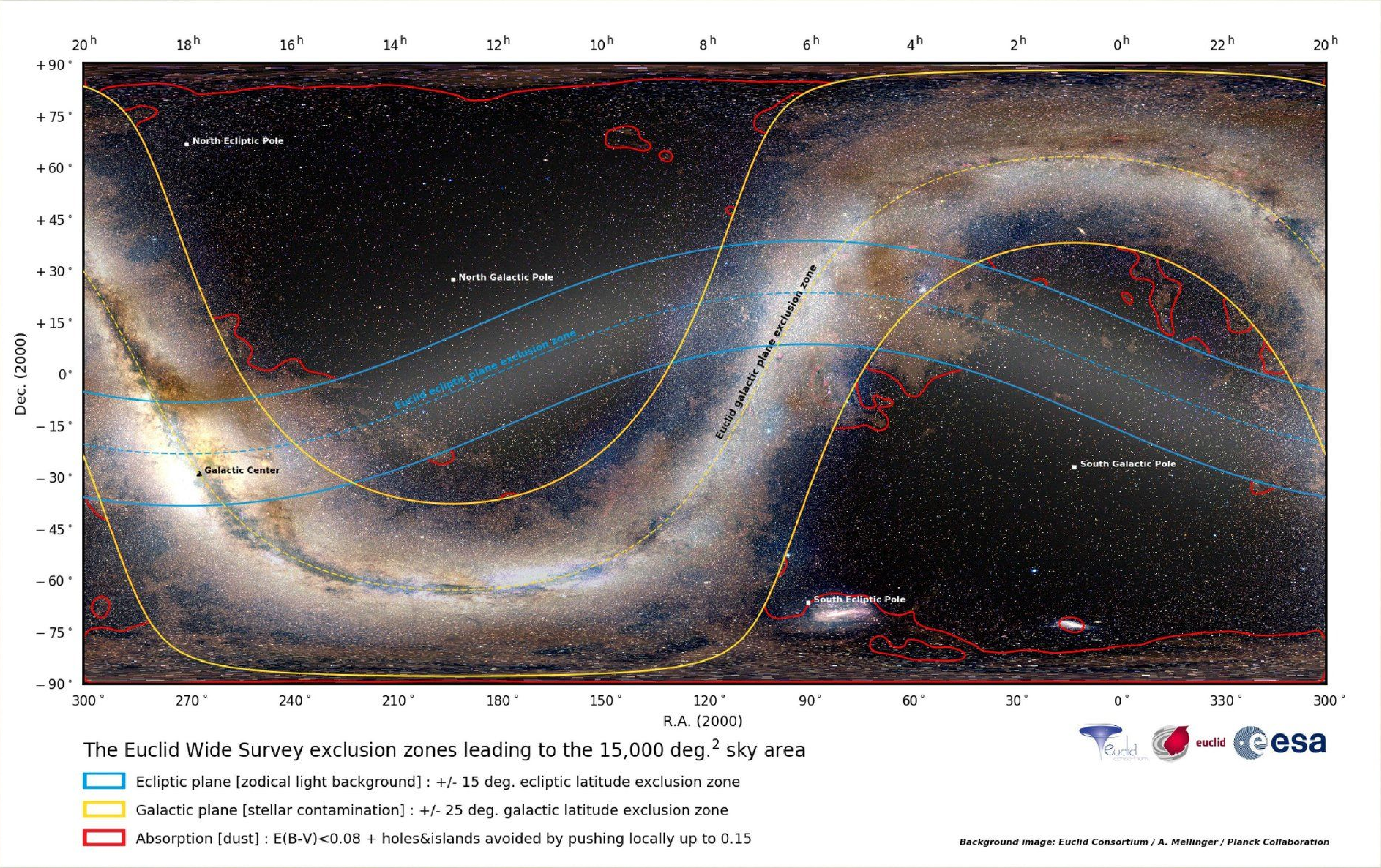
Zodiacal light

Stellar contamination+Straylight+Reddening+Background define the exclusion zones

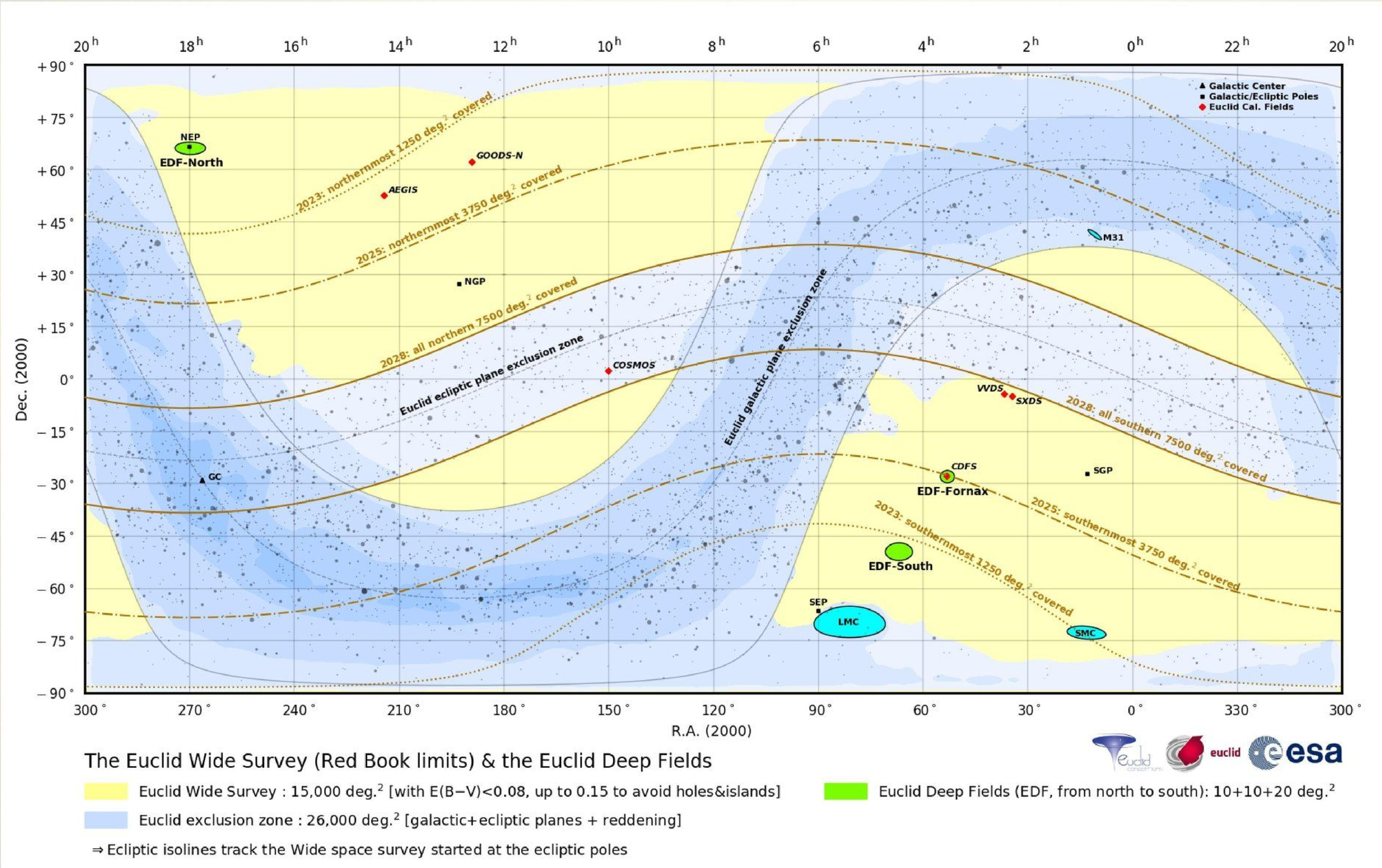
Equatorial coordinates (ground−based astronomy) on an equirectangular projection

Hour angle (RA on x−axis) shift to feature the two galactic caps unclipped

The Euclid Wide Survey exclusion zones



The Euclid reference survey



The Wide+Deep surveys (yellow+green) will be covered within 6 years (2022–28)

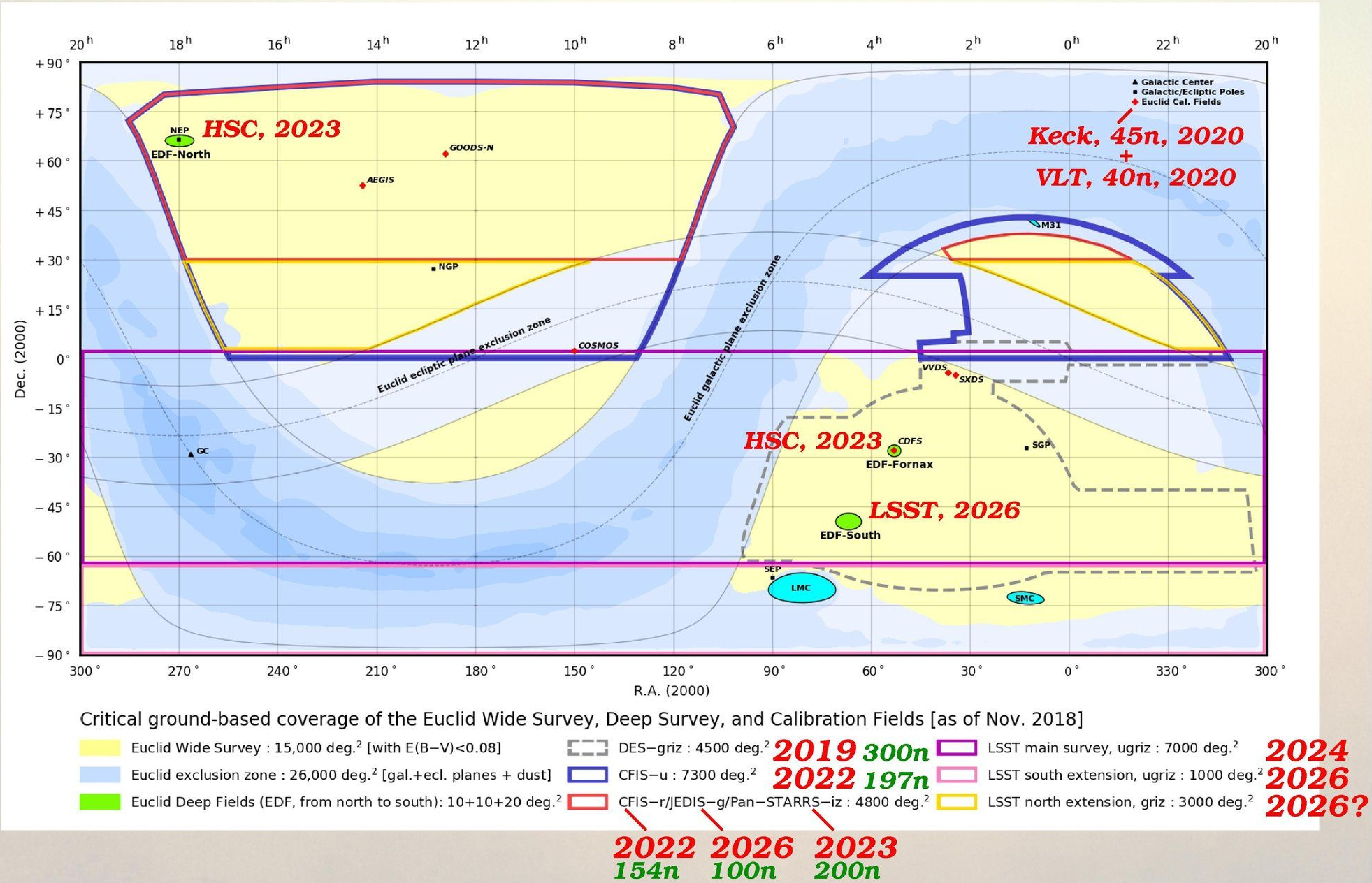
How the Euclid mission should actually be perceived

The ESA mission, 6 years non–stop of space observations

Plus 1,000 nights across several world–class ground–based telescopes

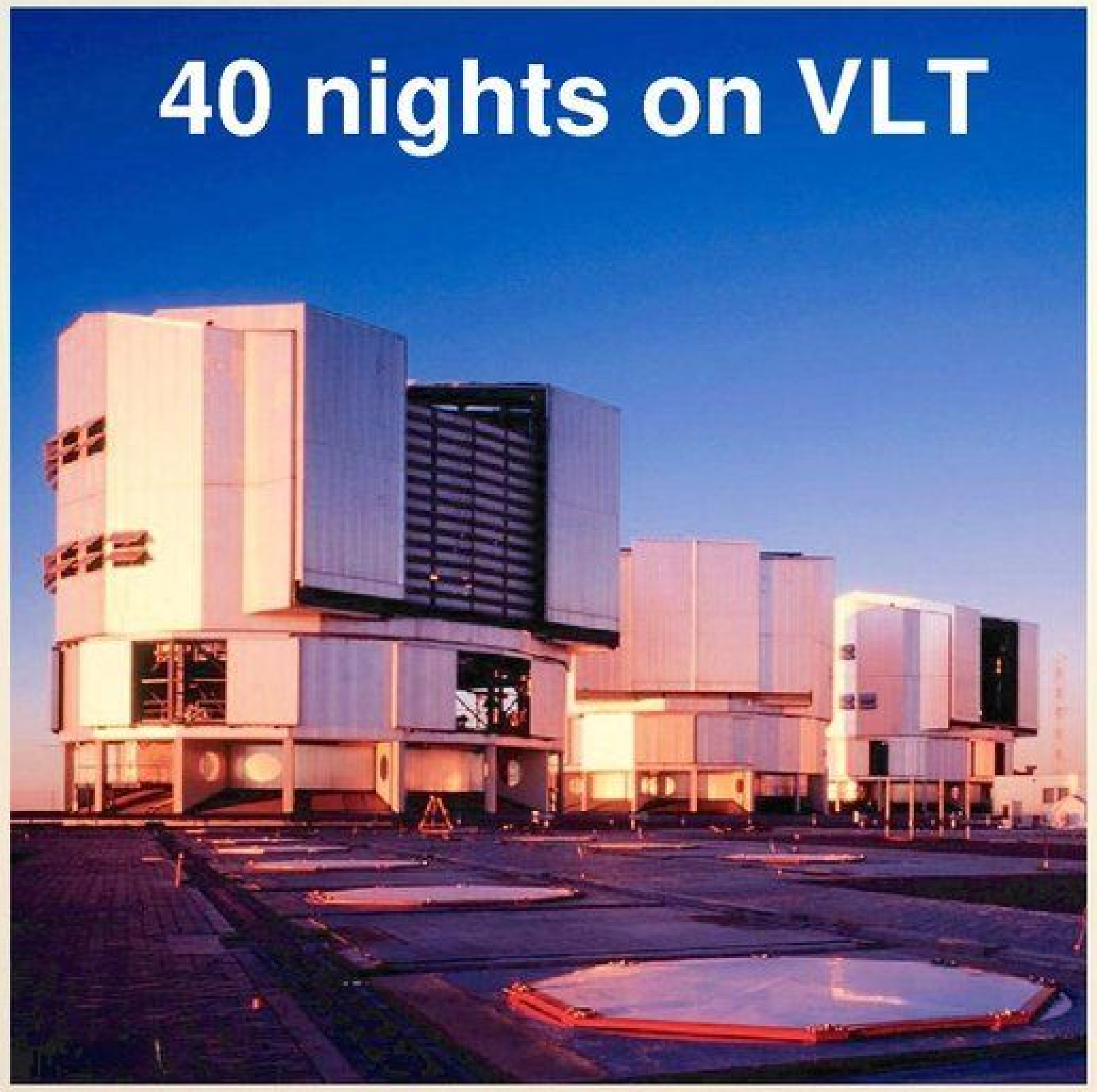
A combo critical to reach the mission core science goals on dark energy

Euclid related ground–based surveys end date estimates

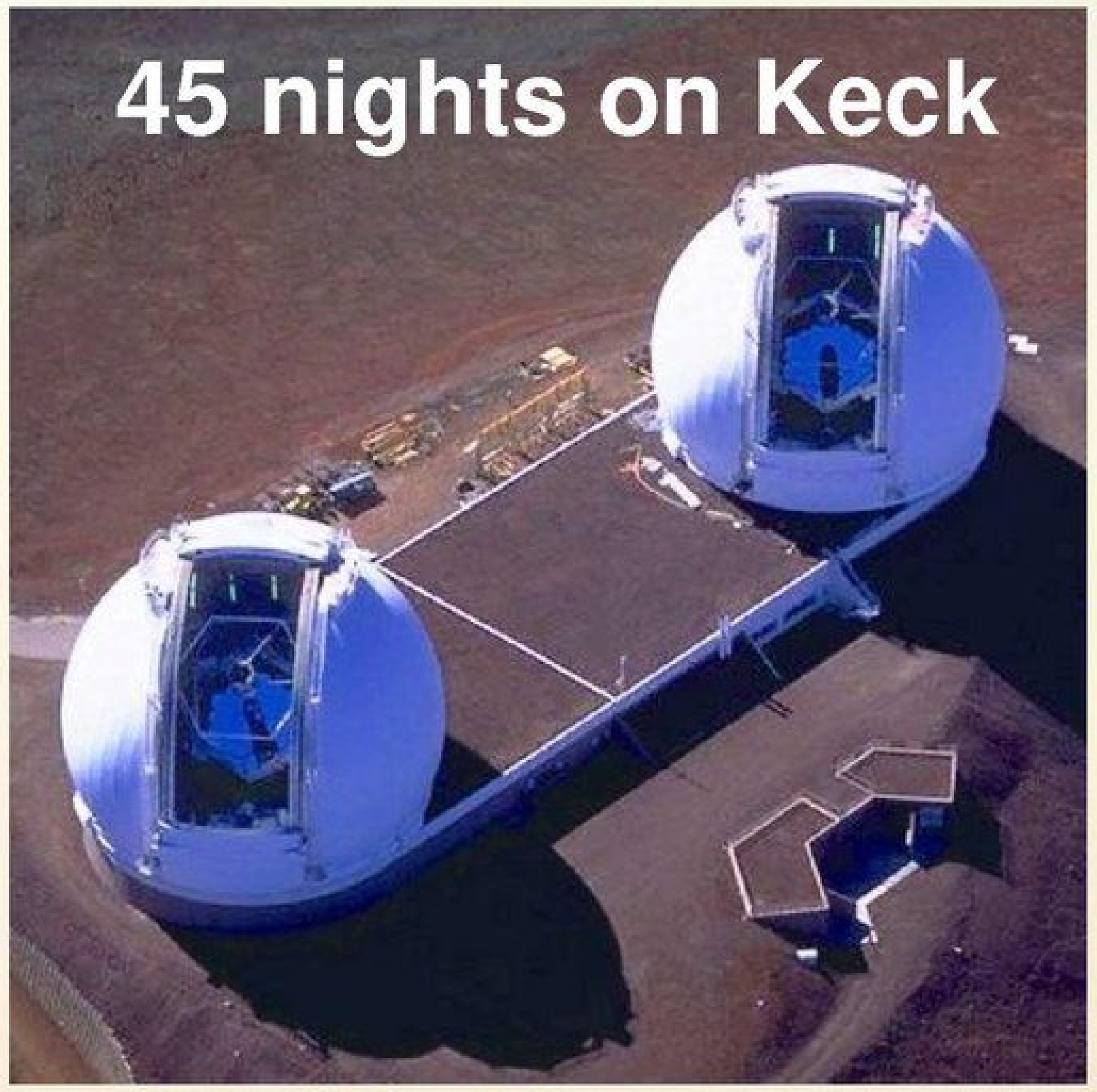


Euclid Complementary Observations: on−going highlights

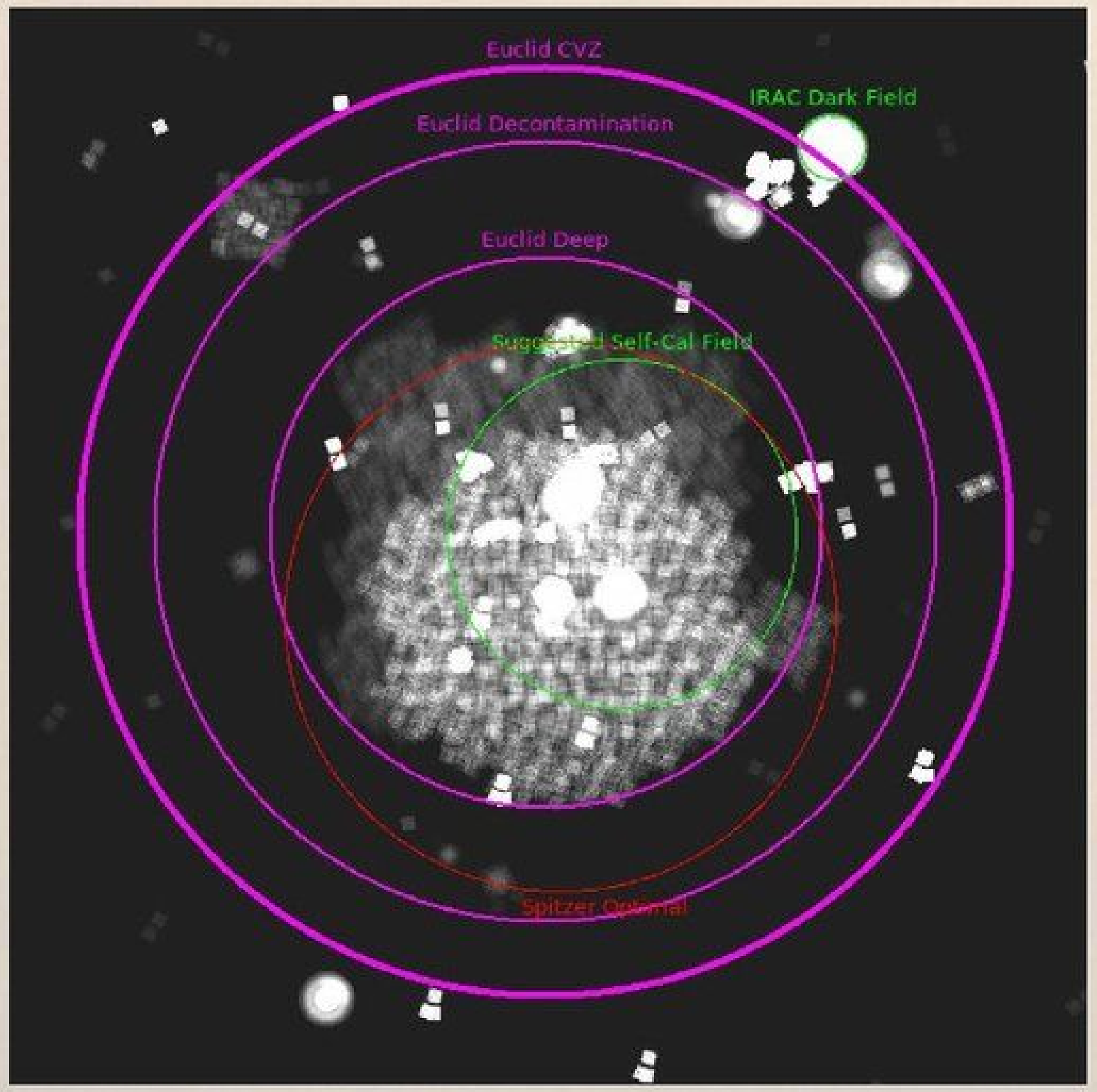
Spectroscopy for photo−z calibration: on the Euclid calibration fields



COMPLEMENTARY
Photo−z calibration

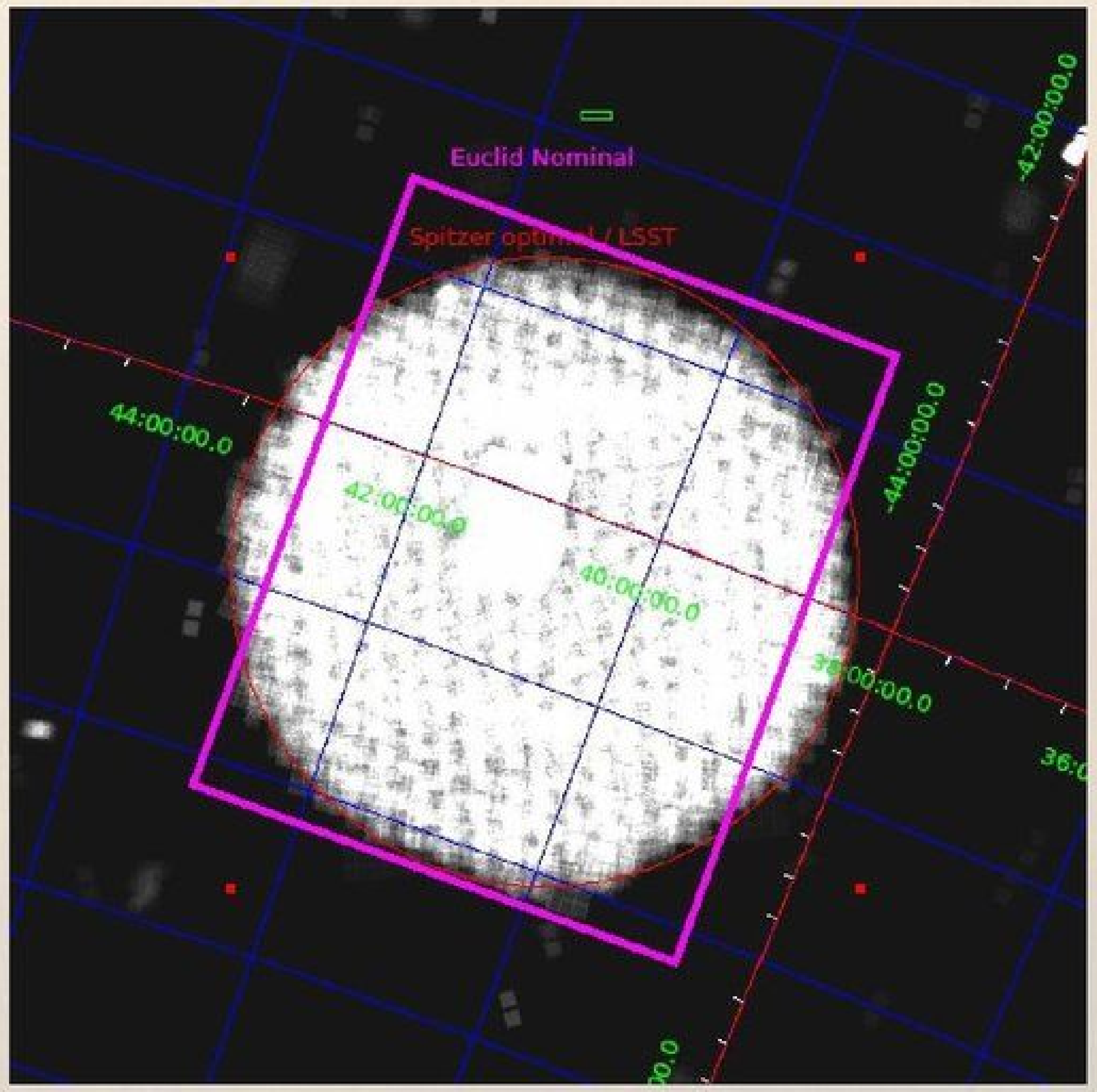


The Spitzer Extragalactic Legacy Survey: 5,300 hours (PI P. Capak)



10 sq.deg. on EDF−N

ANCILLARY
Groundbreaking legacy science

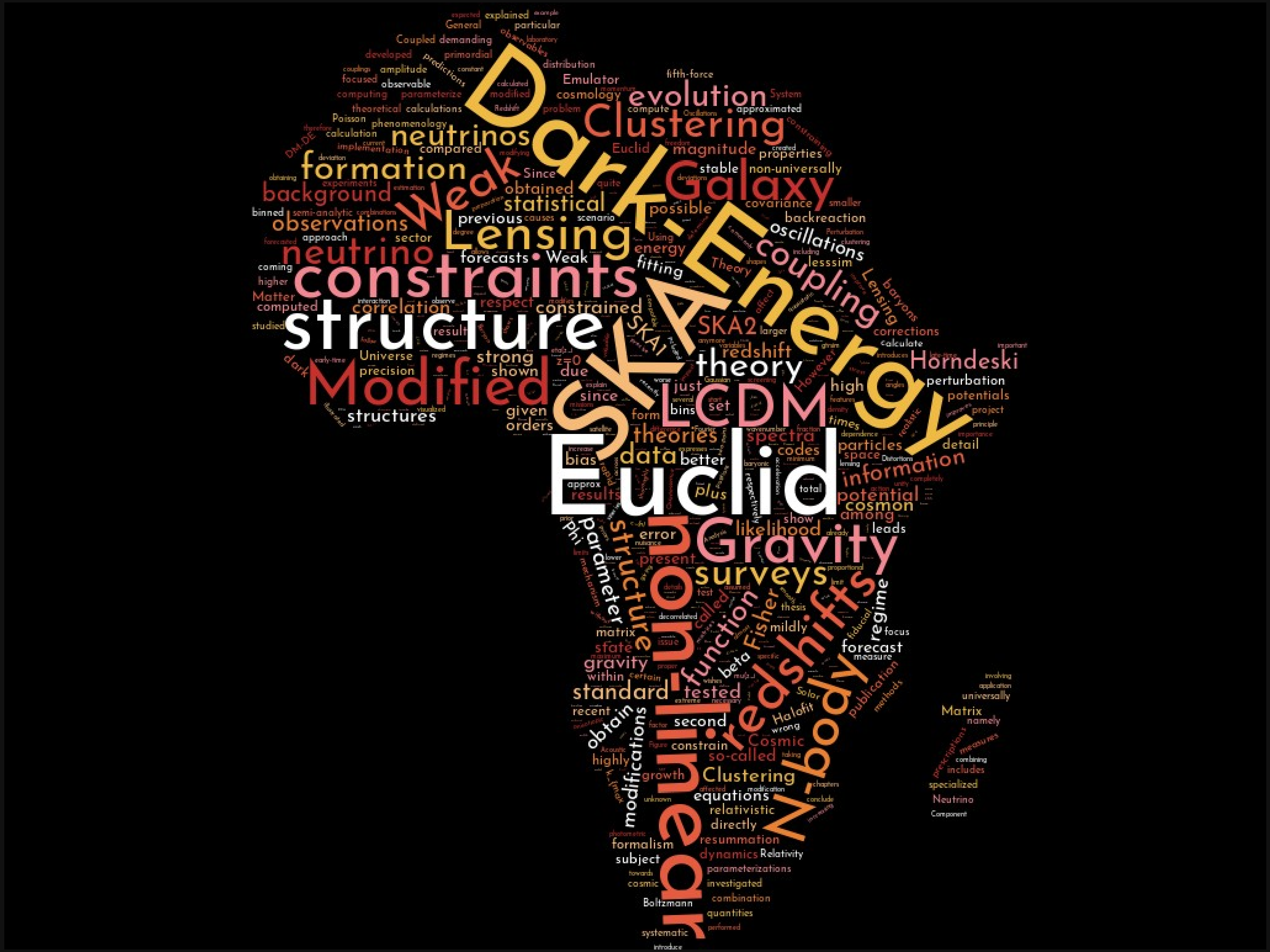


10 sq.deg. on EDF−F

Cosmology with Euclid and SKA

Santiago Casas
CEA Paris-Saclay

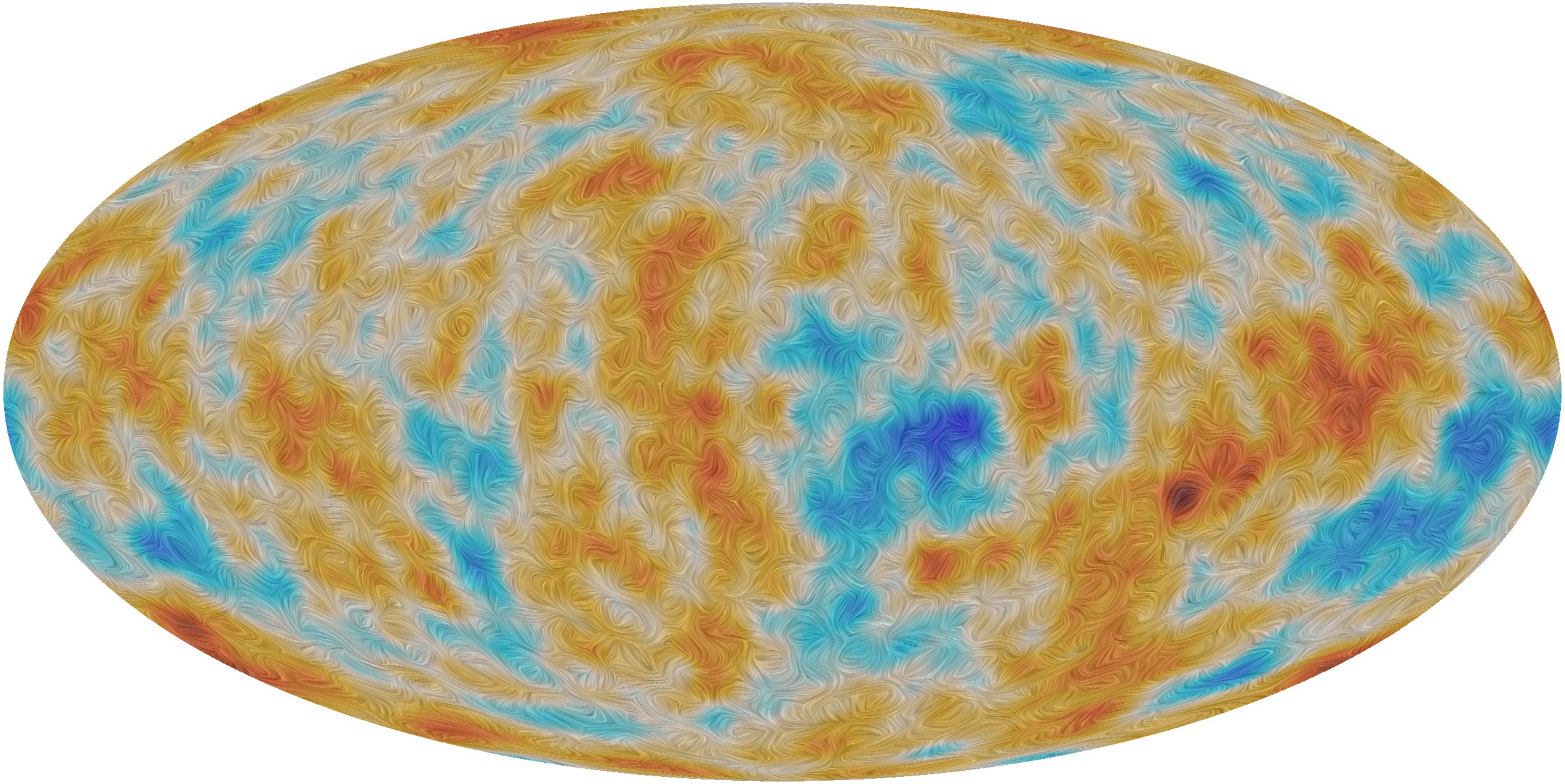
CosmoStat



CosmoStat

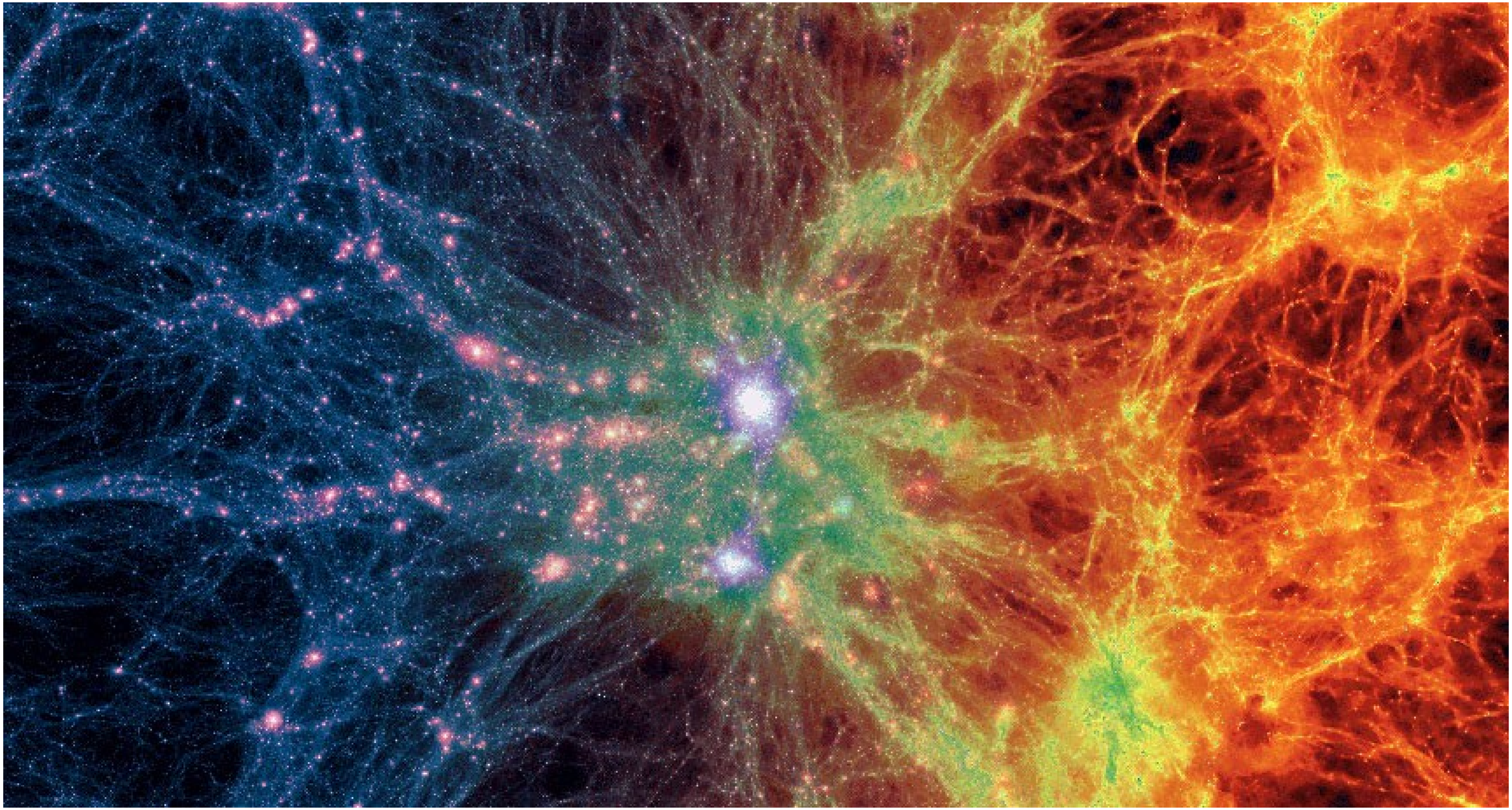
Working with: Valeria Pettorino, Martin Kilbinger and Jean-Luc Starck

Cosmic Microwave Background



Planck 2015 CMB+polarization. https://www.cosmos.esa.int/web/planck/picture-gallery

Large Scale Structure



Illustris Simulation: www.nature.com/articles/nature13316

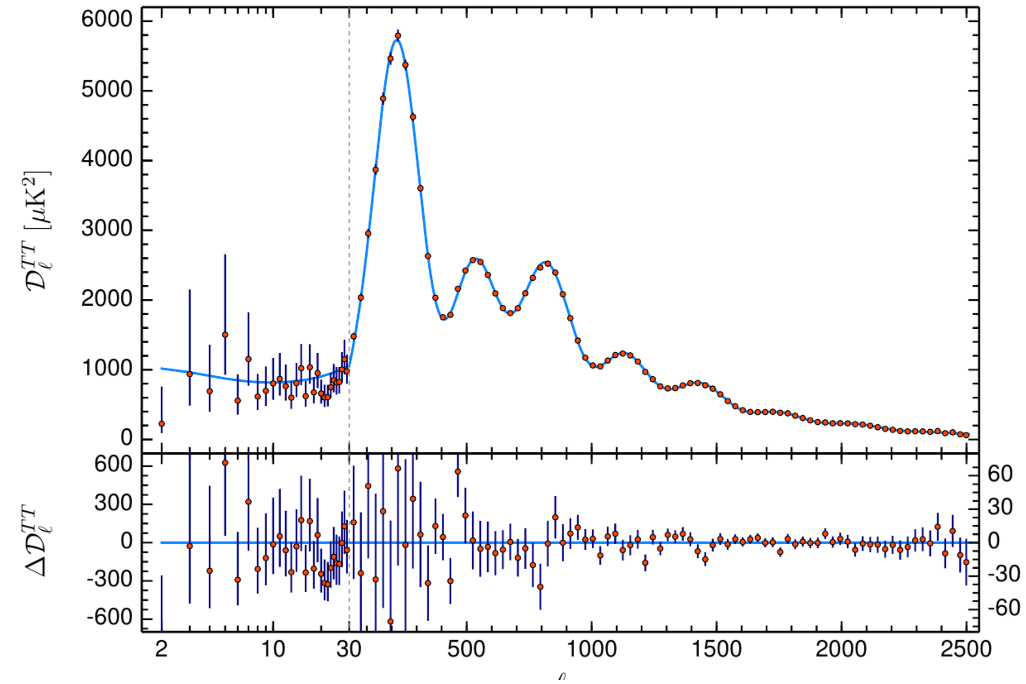
The standard ΛCDM Model

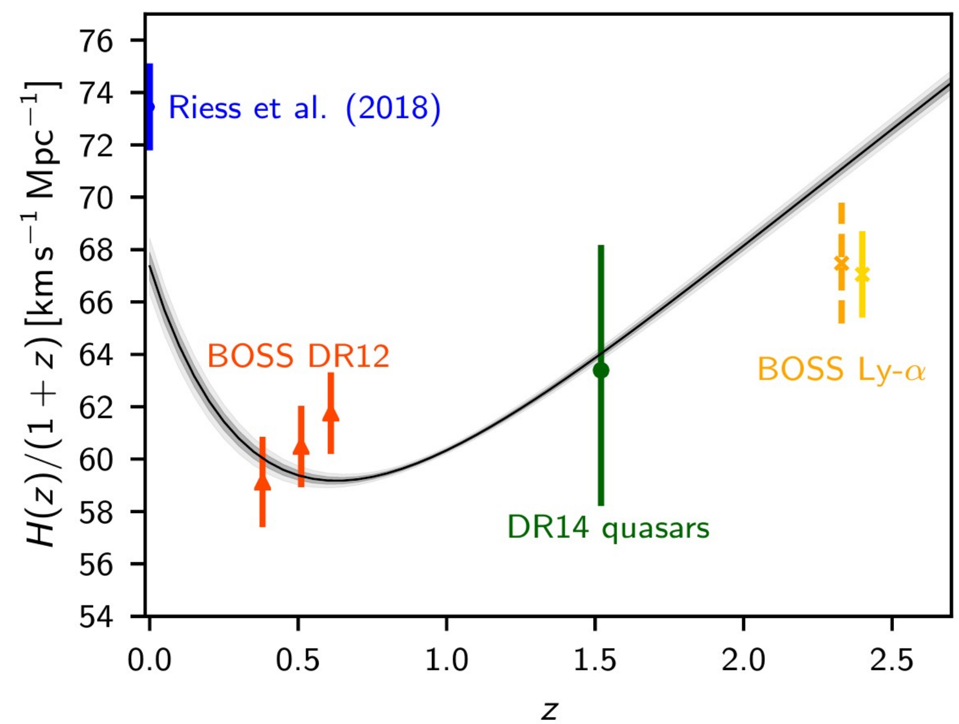
- ΛCDM is still best fit to observations.
- Impressive agreement with data.
- CMB + BAO + WL agree well.

- However some questions remain:

- Cosmological constant problem.
- H0 from local measurements.
- σ8: amplitude of matter fluctuations.

- Growth of structure, still unconstrained.





Planck 2018 results: arxiv:1807.06209

Modified Gravity

GR (LCDM) →

$$S = \frac{1}{16\pi G}\int dx^4 \sqrt{-g}\,(R - 2\Lambda + \mathcal{L}_m)$$

Variety of models:

f(R)

K-essence

$$\mathcal{S} = \int d^4x\,\sqrt{-g}\left[\frac{1}{2}F(\varphi, R) - \frac{1}{2}K(\varphi)g^{\mu\nu}\partial_\mu\varphi\partial_\nu\varphi - U(\varphi)\right]$$
$$- \int d^4x\,\sqrt{-g}\mathcal{L}^i_m(g_{\mu\nu}, \Psi^i_m \zeta^i(\varphi)) \quad ,$$

Quintessence

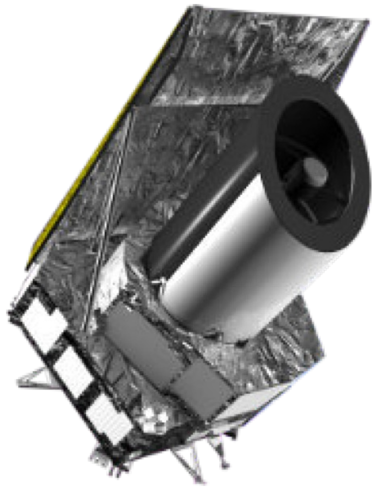
Equivalence principle

DM-DE coupling, Neutrino coupling

GW170817 + EM counterpart: ruled out several sectors

Euclid space satellite & SKA telescope

- All-sky surveys 15.000-20.000 square degrees.
- ~10^7 galaxy redshifts , ~10^9 galaxy positions and shapes.
- Euclid: photometric and spectroscopic Galaxy Clustering, photometric Weak Lensing.
- SKA: spectrosopic and continuum Galaxy Clustering, HI intensity mapping, radio Weak Lensing.

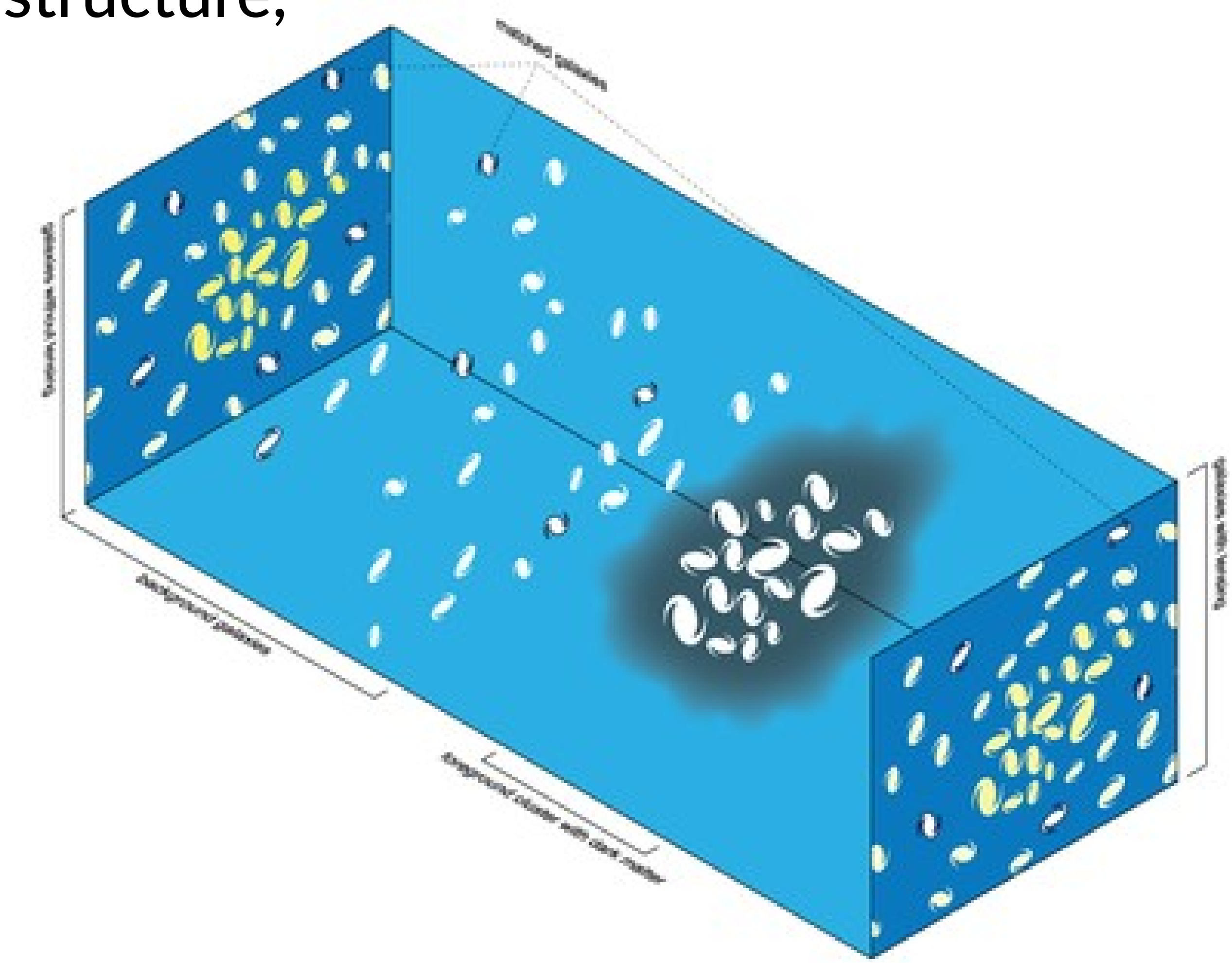


Images: Euclid France Communication, www.skatelescope.org

Weak Lensing

- Deflection of light depends on growth of structure, expansion of the Universe, and specific theory of gravity.

- Measuring the cosmic shear correlation function is a powerful tool for cosmology.



Cosmic Shear

Expansion

Modified Gravity

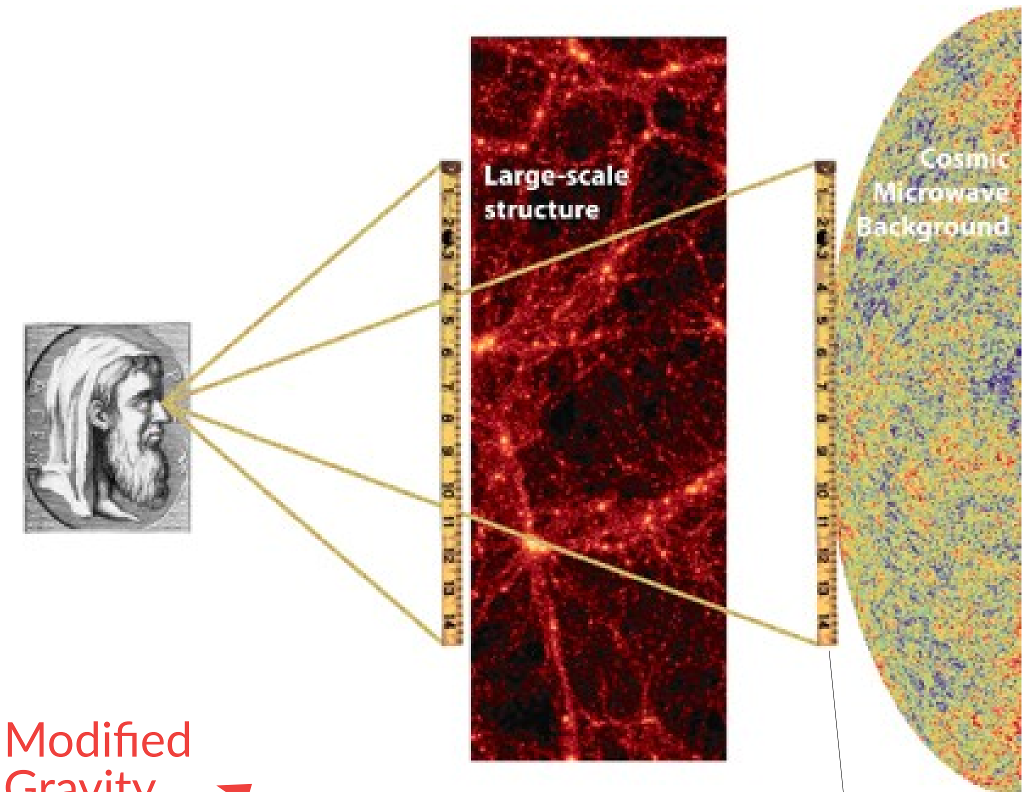
Growth of Structure

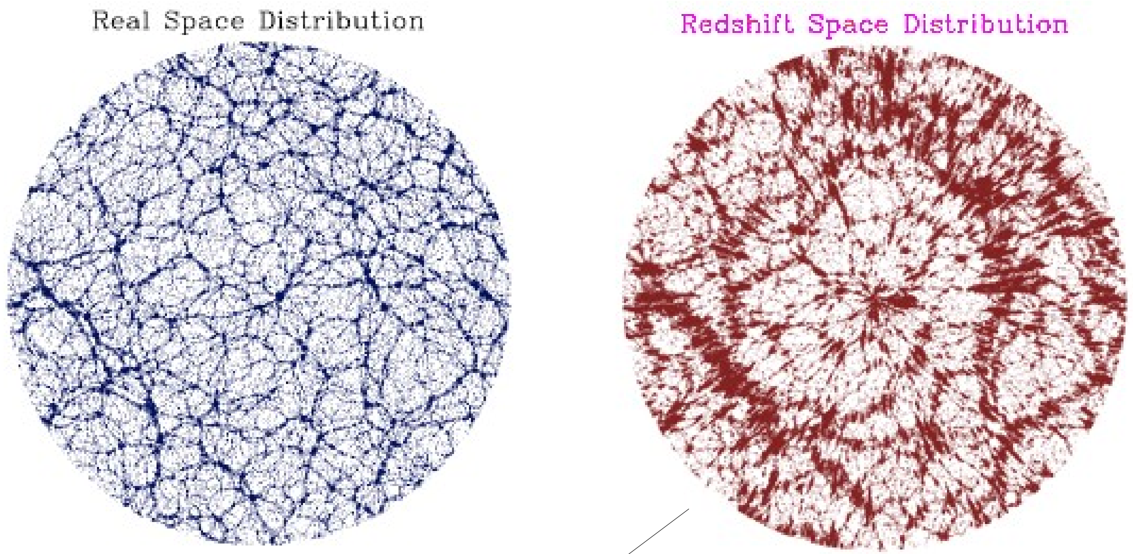
$$C_{ij}(\ell) = \frac{9}{4}\int_0^\infty \mathrm{d}z\, \frac{W_i(z)W_j(z)H^3(z)\Omega_m^2(z)}{(1+z)^4}\Sigma^2(\ell/r(z),z)\, P_m(\ell/r(z))$$

Image credit en.wikipedia.org/wiki/Weak_gravitational_lensing

Baryon Acoustic Oscillations and Redshift Space Distortions

- Scale at recombination is also observed in large scale structure.
- Galaxy velocities, nonlinear growth → distortions in redshift space.





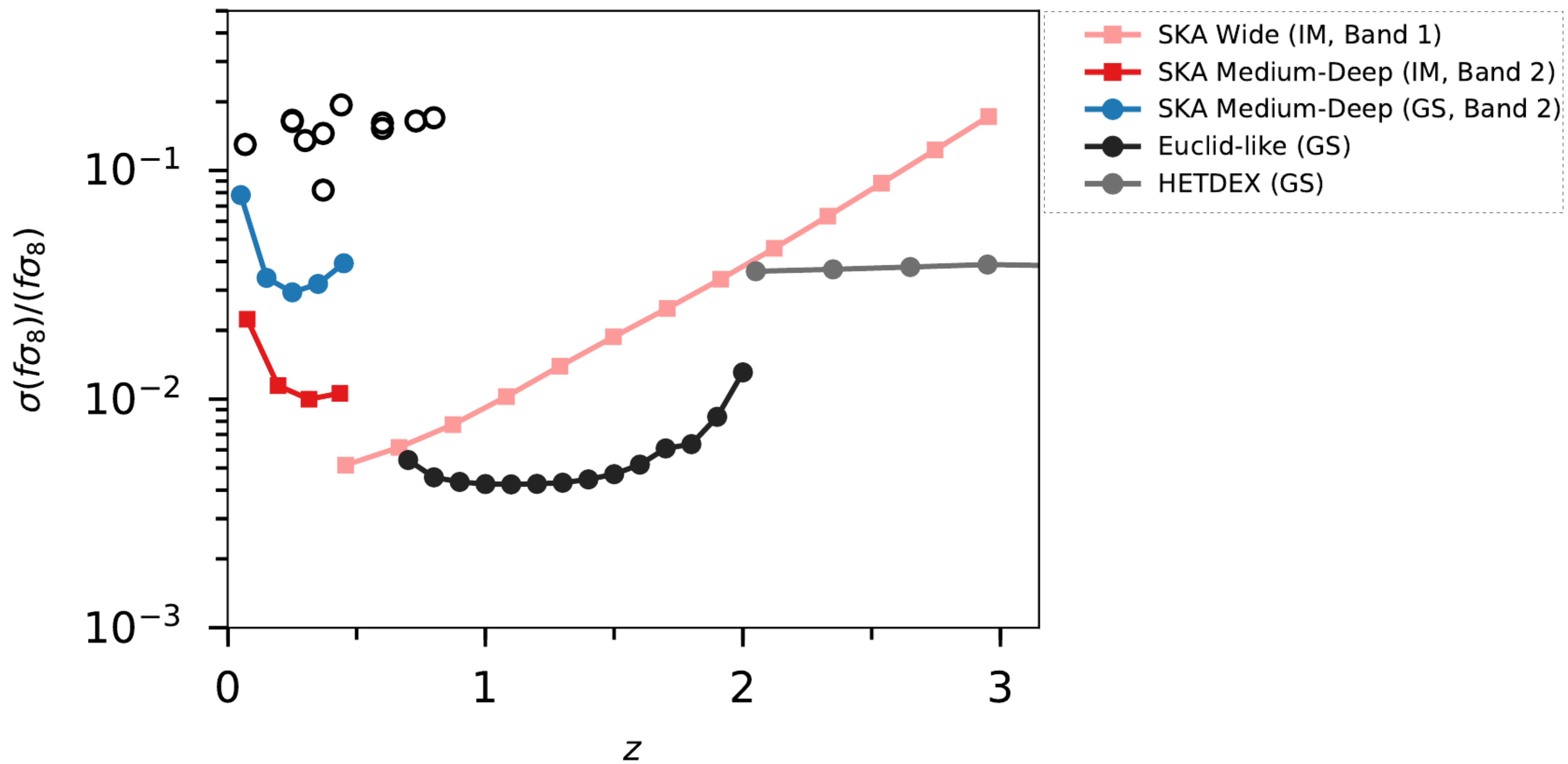
Modified Gravity

$$\ddot{\delta} + 2H\dot{\delta} = \frac{3H_0^2\Omega}{2a^3}\mu_{\mathrm{MG}}\delta$$

$$P_{\mathrm{obs}}(k_{\mathrm{ref}}, \mu_{\mathrm{ref}}; z) = \frac{D_{\mathrm{A,\,ref}}(z)H(z)}{D_{\mathrm{A}}(z)H_{\mathrm{ref}}(z)}\left(b\sigma_8(z) + f\sigma_8(z)\mu^2\right)^2 \frac{P_{\mathrm{m}}(k;z)}{\sigma_8^2(z)} e^{-k^2\mu^2\sigma_{\mathrm{r}}^2(z)} + P_{\mathrm{s}}(z)$$

SKA1 vs. Euclid

- SKA1 at lower z, Euclid at higher z.
- SKA1 provides independent points → breaking degeneracies in systematics.
- Cross-correlations.



- Constraints on geometry and growth
  → project onto constraints on Dark Energy.

Figure : SKA1 Redbook: https://arxiv.org/abs/1811.02743

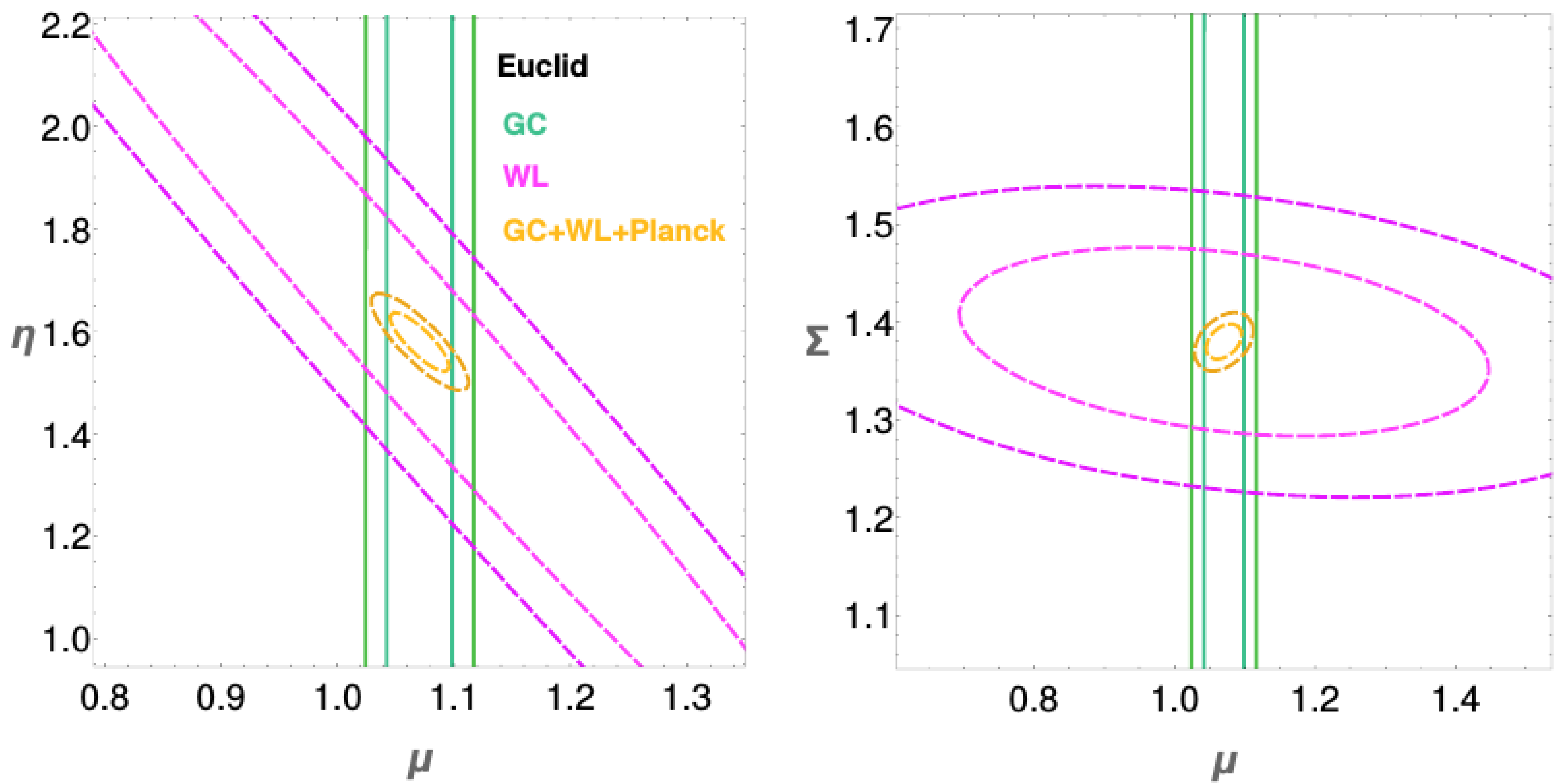
Combination of GC and WL

- Galaxy clustering sensitive to “fifth forces” μ.

$$k^2\Psi = -\mu(a,k)4\pi G a^2 \rho\delta$$

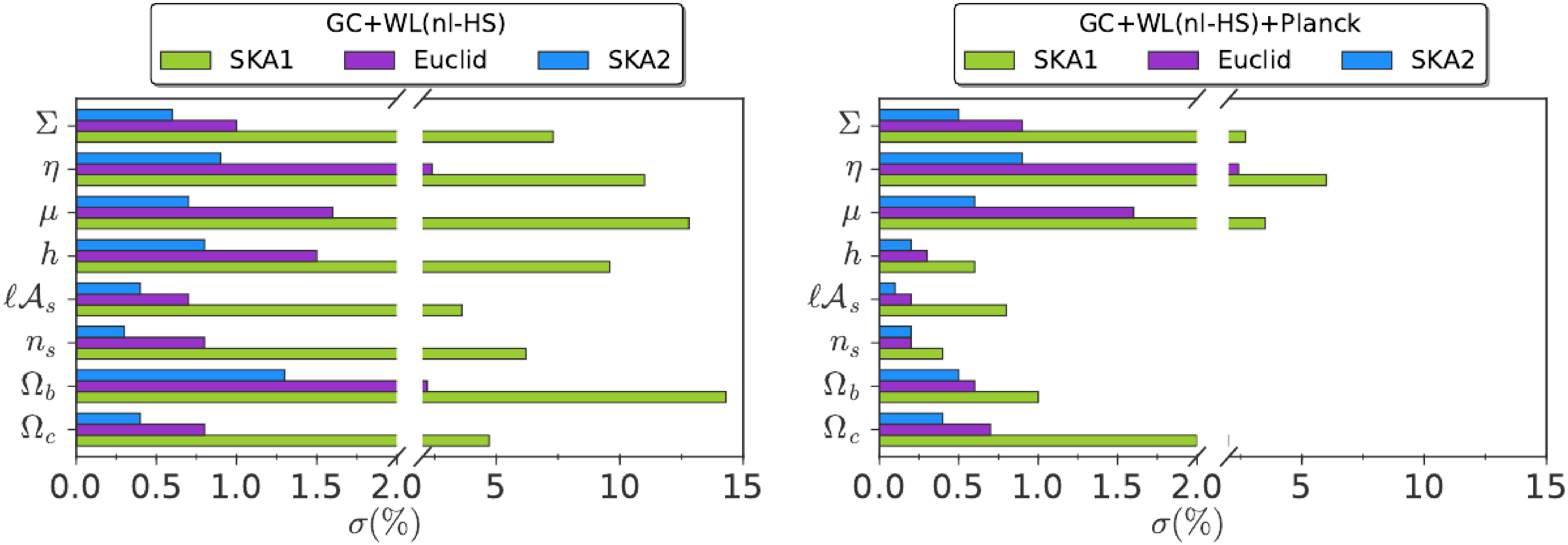
- Weak lensing measures “light deflection” Σ.

$$k^2\left[\Phi + \Psi\right] = -\Sigma(a,k)4\pi G a^2 \rho\delta$$



Forecasts for Modified Gravity

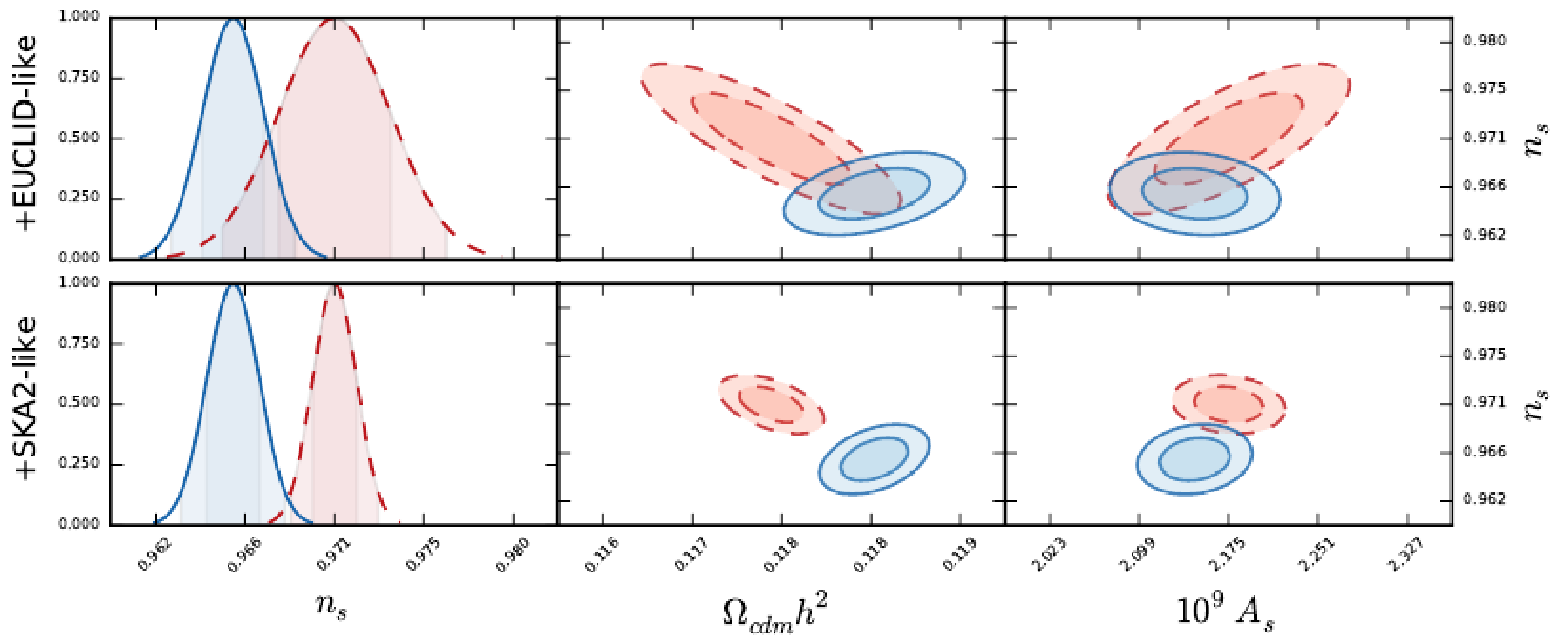
- SKA1 forecasts to be updated with new Redbook specifications.
- Impact of cross-correlations on Modified Gravity needs to be studied.
- SKA1 will deliver complementary constraints to DES and DESI.
- SKA2 as planned would be more powerful than Euclid.



S. Casas, M. Martinelli, V .Pettorino, M. Kunz; arXiv: 1703.01271, Phys.Dark Univ. 18 73-104.

Forecasts for Inflation-Dark Energy

- Some models predict connections between late and early Universe.
- SKA2 constraints primordial Universe parameters, better than Euclid and CMB measurements alone.
- To be tested for SKA1, using combination of Intensity Mapping and 21cm line.



Conclusions

- ΛCDM still passing multiple tests.
- Euclid+SKA will be powerful probes of the expansion of the Universe, lensing and clustering of galaxies.
- Gain information on the gravitational potentials, DE evolution and GR at very large scales.
- Many challenges ahead in terms of analysis and theory.

Thanks!