Ground observations for Euclid

… with special focus on CFIS

Euclid - CSS-OS ISSI meeting, Bern
December 2018

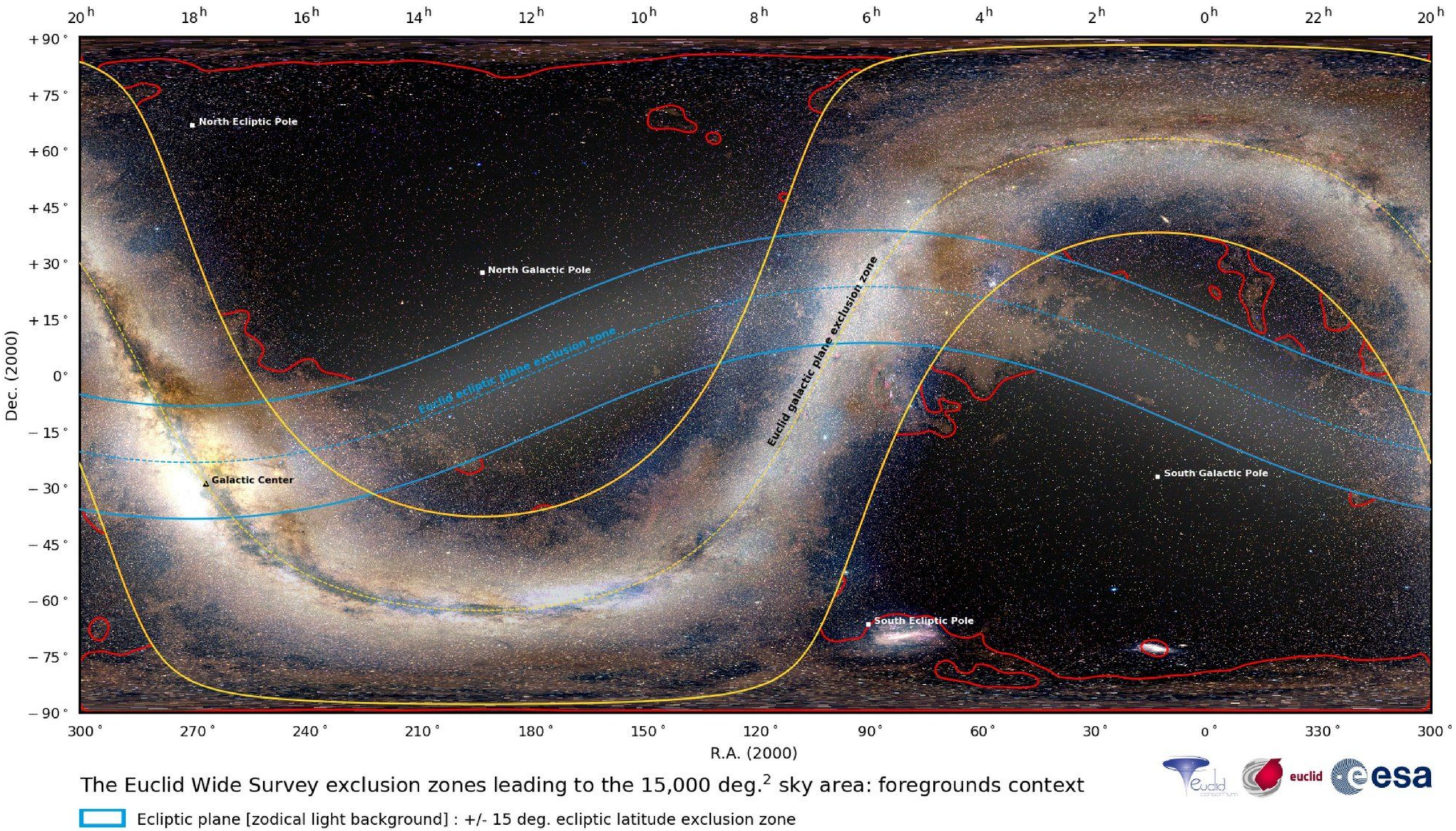
Martin Kilbinger, CEA Saclay, France

Ground observations for Euclid

Presenting work from:

Jean-Charles Cuillandre (CEA)
Euclid Consortium Complementary Observations Group
(EC GOC) and Survey Group

The Euclid Wide Survey



The Euclid Wide Survey exclusion zones leading to the 15,000 deg.^{2} sky area: foregrounds context

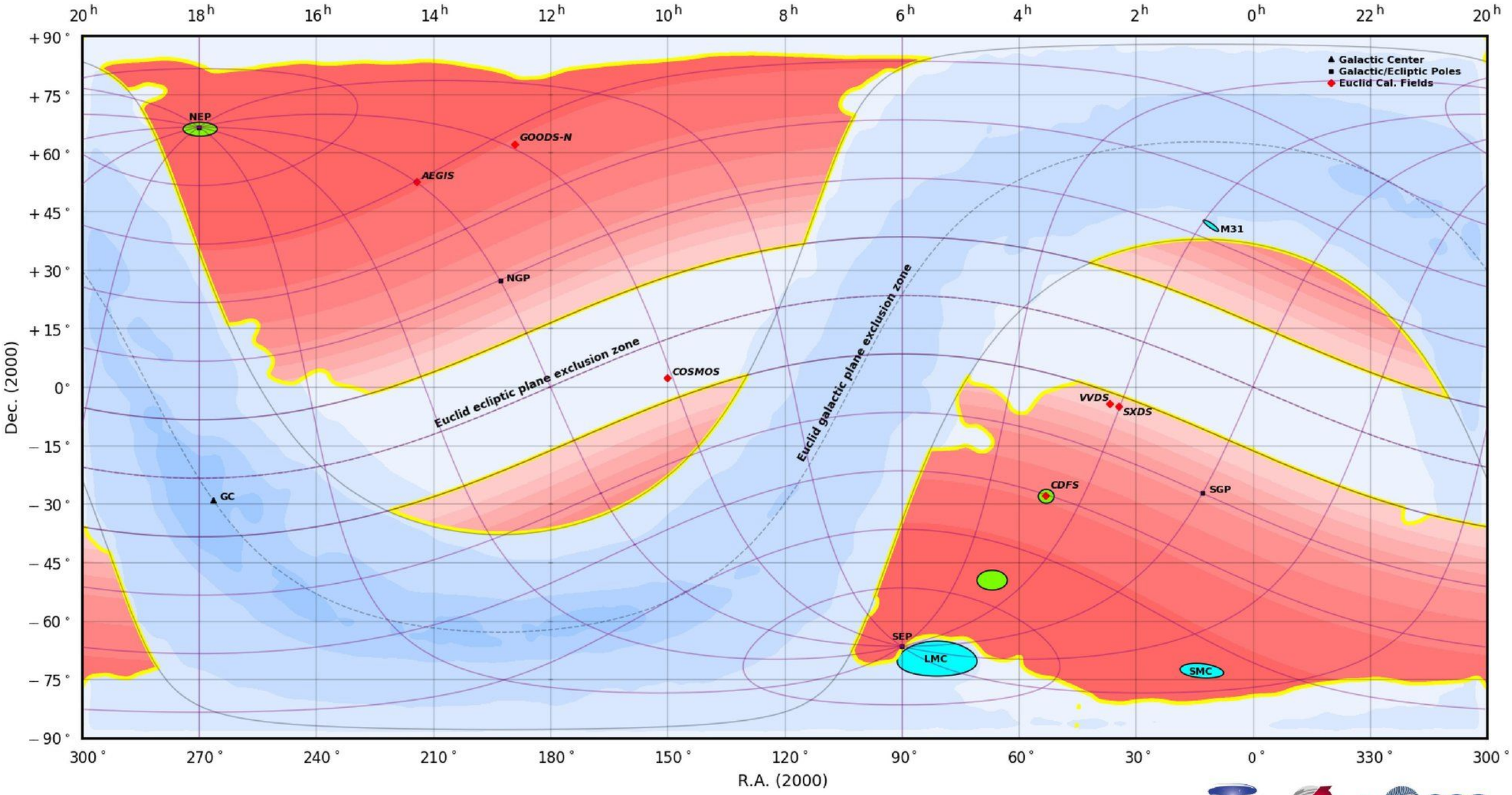
Ecliptic plane [zodical light background] : +/- 15 deg. ecliptic latitude exclusion zone

Galactic plane [stellar contamination] : +/- 25 deg. galactic latitude exclusion zone

Absorption [dust] : E(B-V)<0.08

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

The Euclid Wide Survey



Euclid Foregrounds (1/6): zodiacal light background level from Lagrangian2

Euclid Wide Survey : 15,000 deg.^{2} [with E(B−V)<0.08, up to 0.15 to avoid holes&islands]

Euclid exclusion zone : 26,000 deg.^{2} [galactic+ecliptic planes + reddening]

Euclid Deep Fields : North=10 deg.^{2}, Fornax=10 deg.^{2}, South=20 deg.^{2}

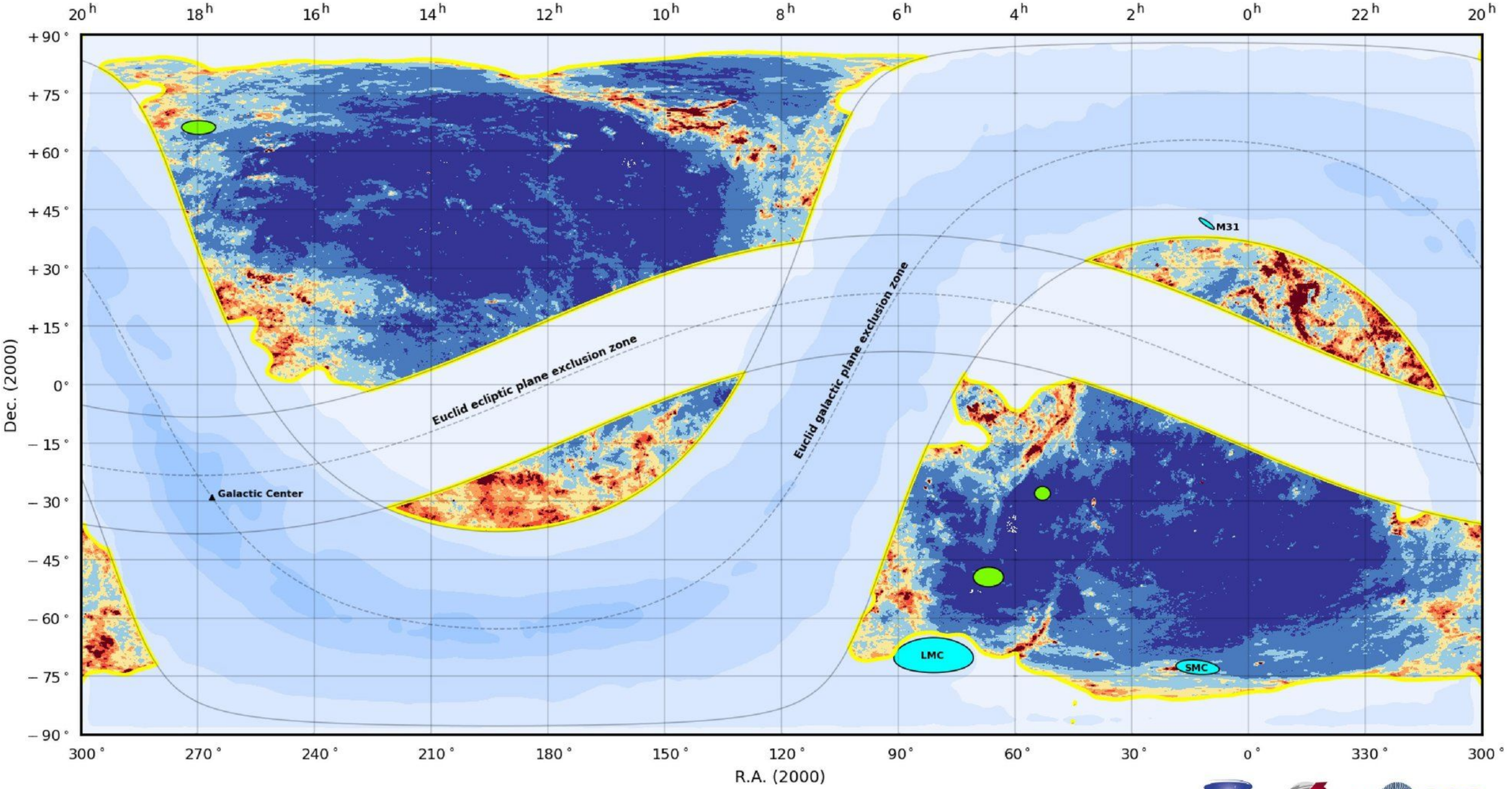
Zodiacal light level in the VIS band (MJy/sr & mag./arcsec^2)

0.11 — 0.27

22.7 — 21.8

The ecliptic referential is overplotted in light purple

The Euclid Wide Survey



Euclid Foregrounds (2/6): reddening and galactic light reflection from interstellar cirrus

Euclid Wide Survey : 15,000 deg.^{2} [with E(B−V)<0.08, up to 0.15 to avoid holes&islands]

Euclid exclusion zone : 26,000 deg.^{2} [galactic+ecliptic planes + reddening]

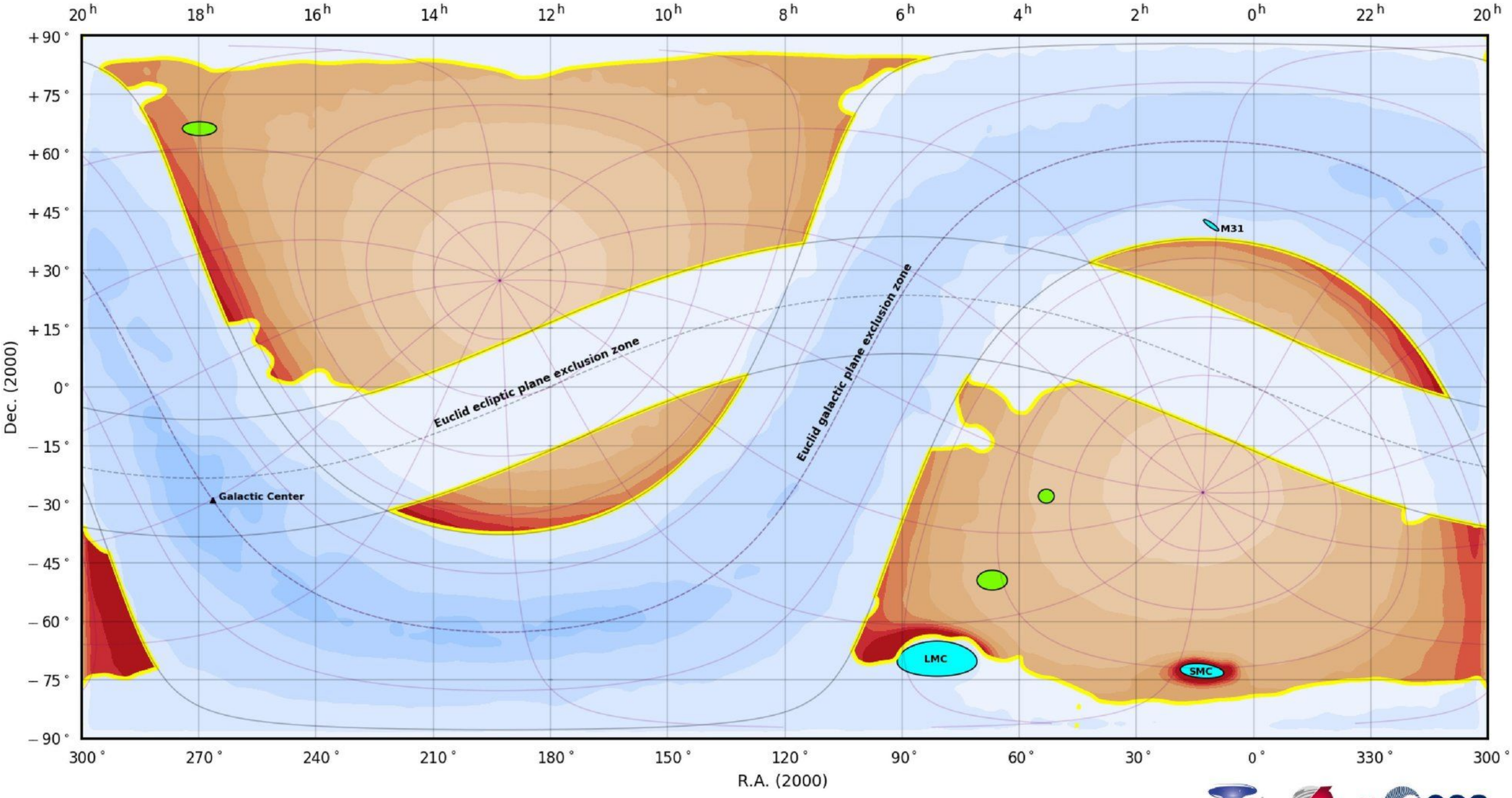
Euclid Deep Fields : North=10 deg.^{2}, Fornax=10 deg.^{2}, South=20 deg.^{2}

E(B−V) and cirrus surface brightness (mag./arcsec^2)

0.01 ~28 — 0.15 ~26

Dust map: ESA / Planck Collaboration

The Euclid Wide Survey



Euclid Foregrounds (3/6): cumulated stellar brightness from the Galaxy

Euclid Wide Survey : 15,000 deg.^{2} [with E(B−V)<0.08, up to 0.15 to avoid holes&islands]

Euclid exclusion zone : 26,000 deg.^{2} [galactic+ecliptic planes + reddening]

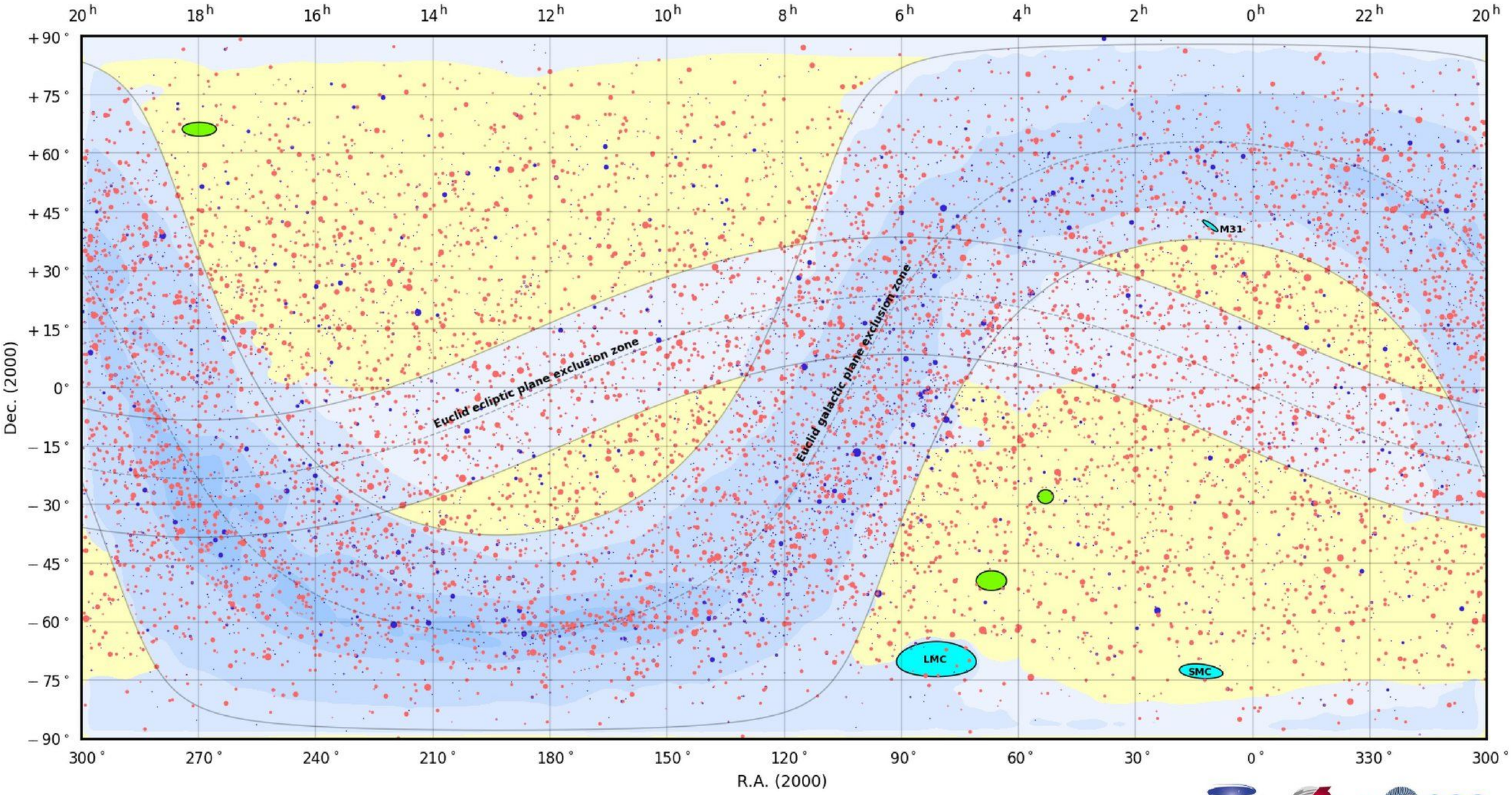
Euclid Deep Fields : North=10 deg.^{2}, Fornax=10 deg.^{2}, South=20 deg.^{2}

Stellar density per square degree [*Gaia G_{RP} = 20th magnitude*]

10,000 — 20,000 — 50,000

The galactic referential is overplotted in light purple
Stellar density dataset: ESA/Gaia/DPAC

The Euclid Wide Survey



Euclid Foregrounds (4/6): bright stars from the visible to the near-infrared

Euclid Wide Survey : 15,000 deg.^{2} [with E(B−V)<0.08, up to 0.15 to avoid holes&islands]

Euclid exclusion zone : 26,000 deg.^{2} [galactic+ecliptic planes + reddening]

Euclid Deep Fields : North=10 deg.^{2}, Fornax=10 deg.^{2}, South=20 deg.^{2}

V or H magnitude (AB): -2 0 2 4 6

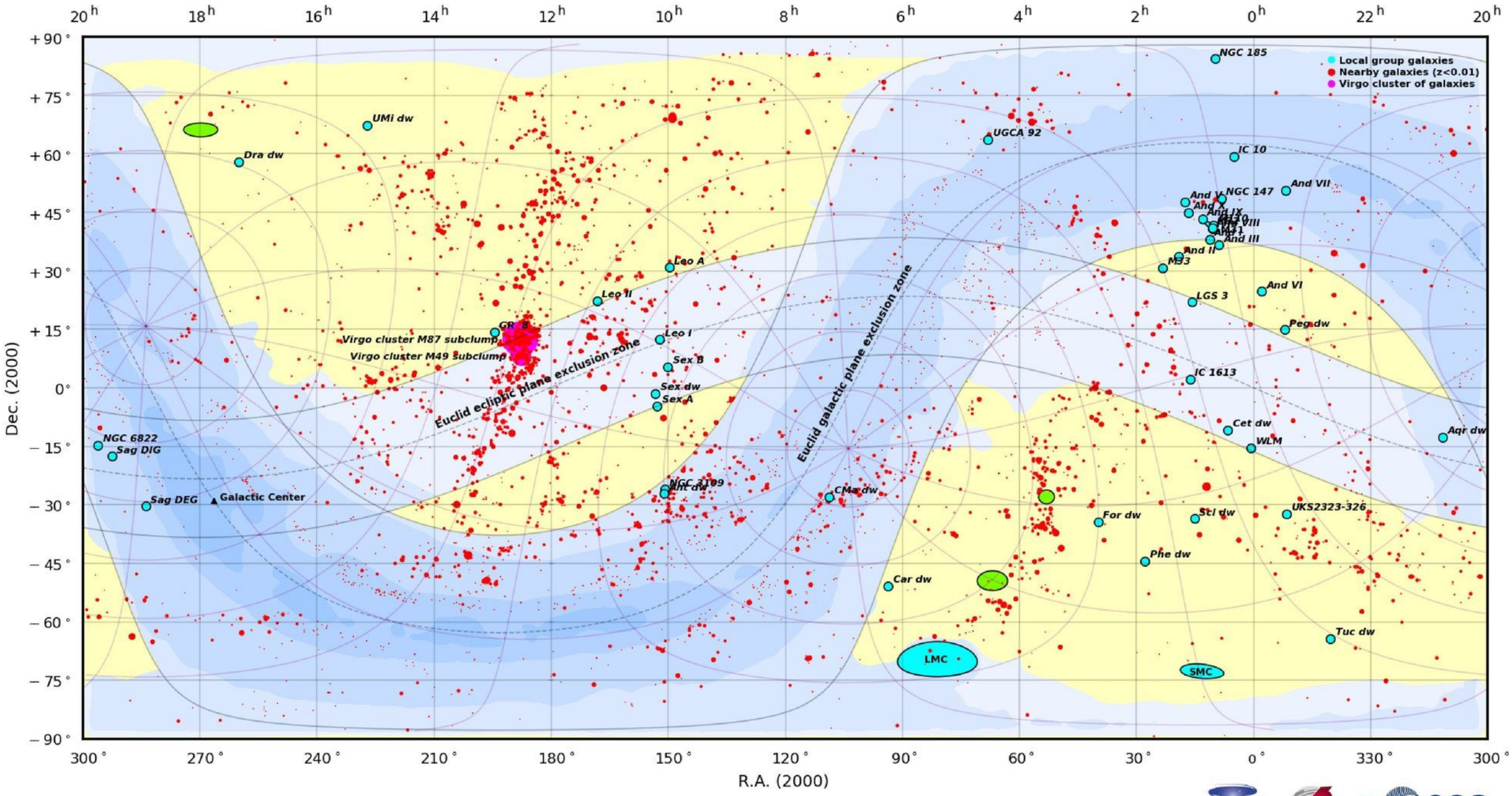
All 8357 brightest stars in the sky up to V-band = 6.9

All 8265 brightest stars in the sky up to H-band = 6.9

V-band: Yale Bright Star Catalog (Hoffleit & Warren 1991)

H-band: The Two Micron All Sky Survey (2MASS, Skrutskie et al. 2006)

The Euclid Wide Survev



Euclid Foregrounds (5/6): galaxies from the local group and the nearby universe (z<0.01)

Euclid Wide Survey : 15,000 deg.^{2} [with E(B−V)<0.08, up to 0.15 to avoid holes&islands]

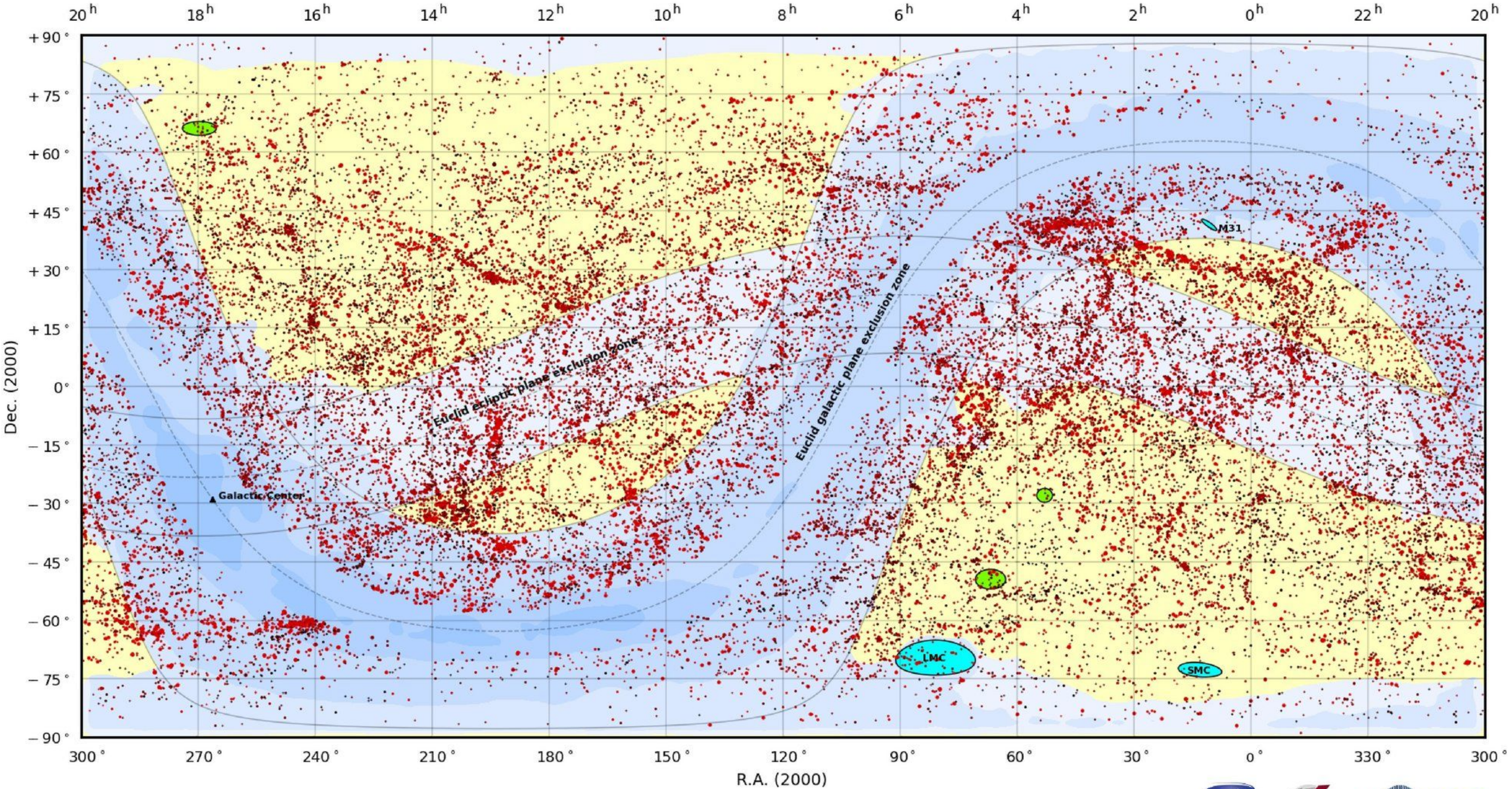
Euclid exclusion zone : 26,000 deg.^{2} [galactic+ecliptic planes + reddening]

Euclid Deep Fields : North=10 deg.^{2}, Fornax=10 deg.^{2}, South=20 deg.^{2}

Total K-band magnitude: 3 5 7 9 11

The supergalactic referential is overplotted in light purple
Galaxy catalog: The 2MASS Redshift Survey (2MRS), Huchra et al. 2012

The Euclid Wide Survey



Euclid Foregrounds (6/6): nearby galaxies beyond the local universe (0.01<z<0.06)

Euclid Wide Survey : 15,000 deg.^{2} [with E(B−V)<0.08, up to 0.15 to avoid holes&islands]

Euclid exclusion zone : 26,000 deg.^{2} [galactic+ecliptic planes + reddening]

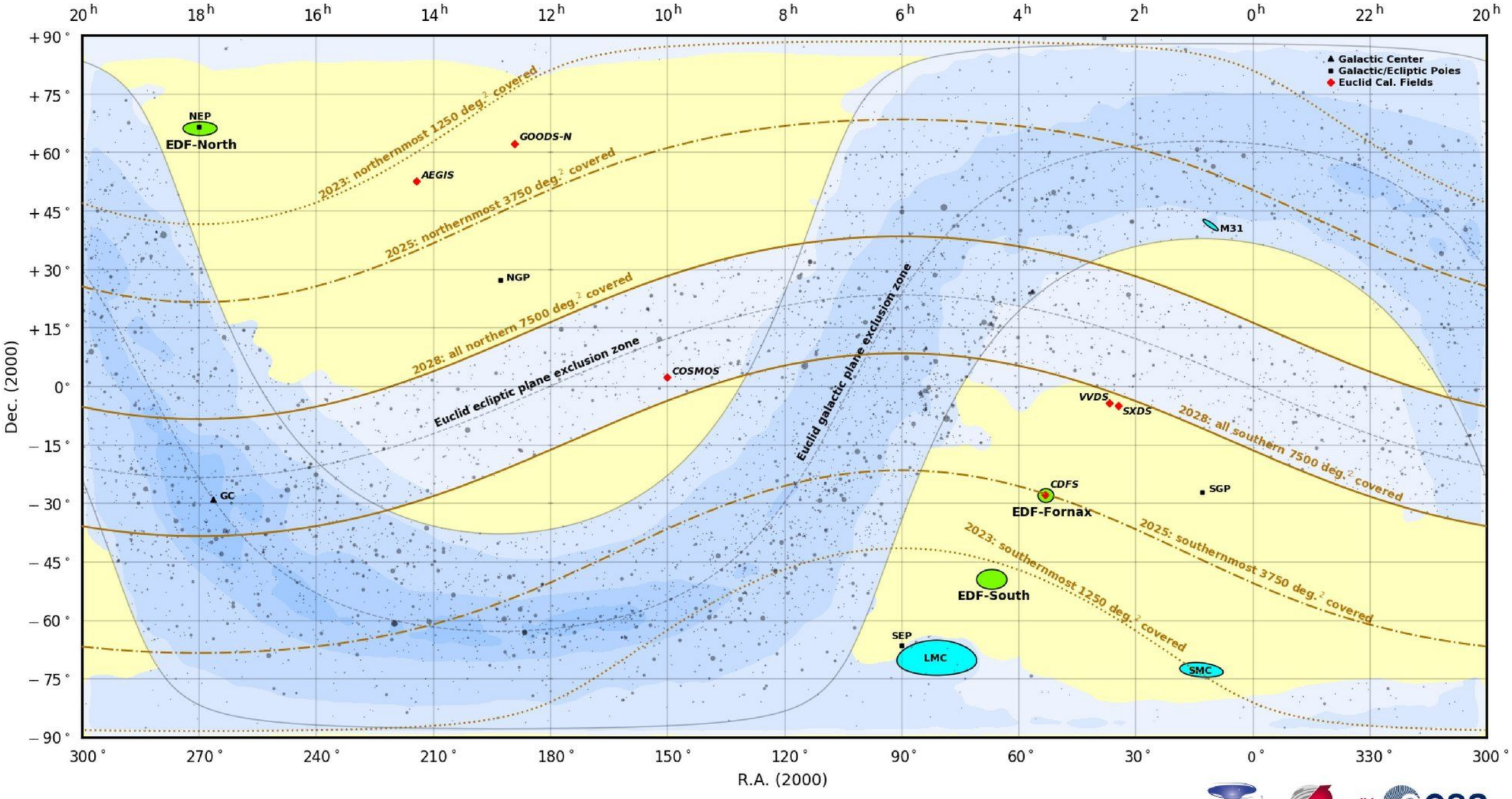
Euclid Deep Fields : North=10 deg.^{2}, Fornax=10 deg.^{2}, South=20 deg.^{2}

z<0.02 z<0.03 z<0.04 z<0.05 z<0.06

Total K-band magnitude: 3 5 7 9 11

Galaxy catalog: The 2MASS Redshift Survey (2MRS), Huchra et al. 2012

The Euclid Wide Survey



The Euclid Wide Survey (Red Book limits) & the Euclid Deep Fields

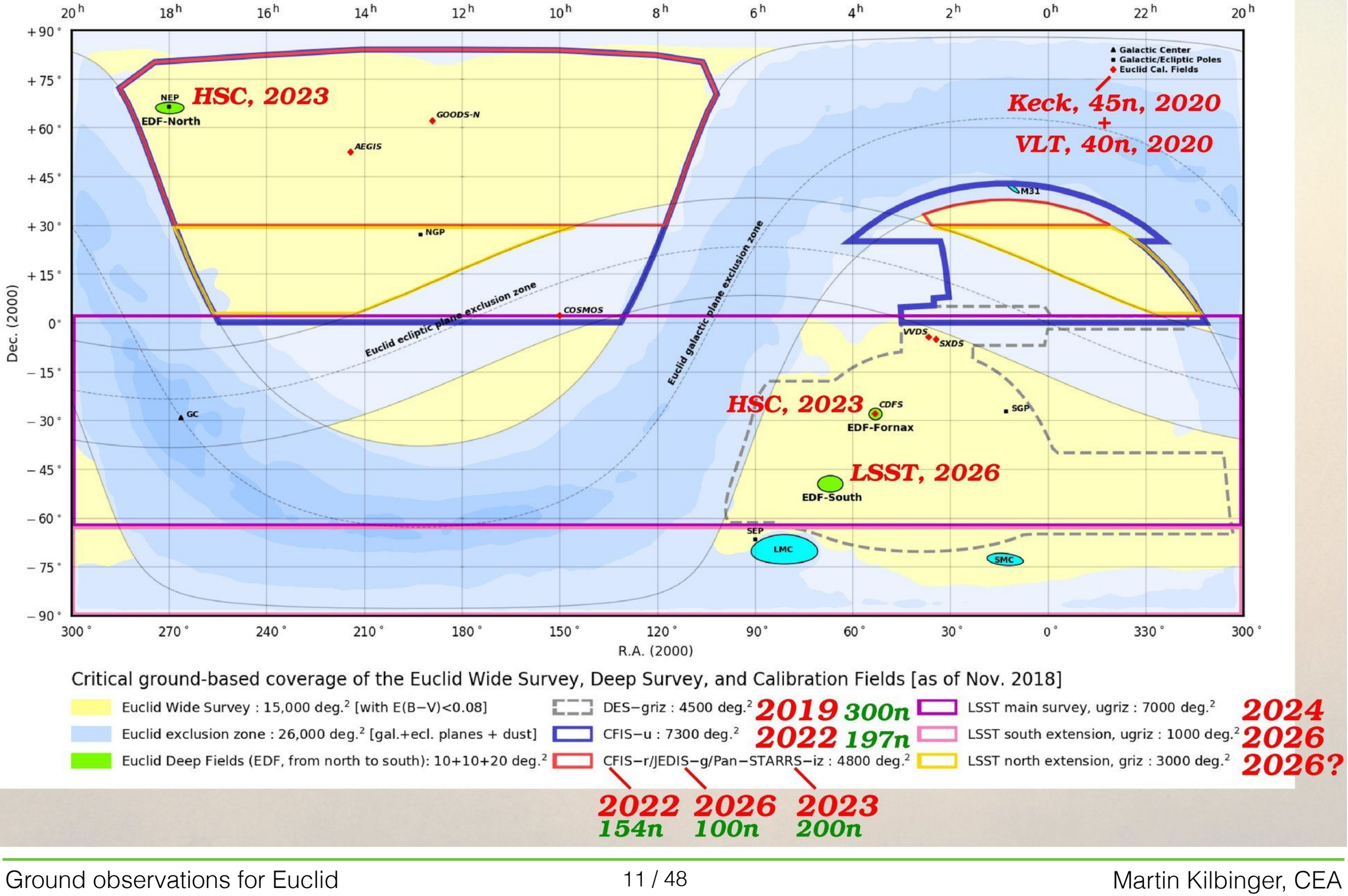
Euclid Wide Survey : 15,000 deg.^{2} [with E(B−V)<0.08, up to 0.15 to avoid holes&islands]

Euclid Deep Fields (EDF, from north to south): 10+10+20 deg.^{2}

Euclid exclusion zone : 26,000 deg.^{2} [galactic+ecliptic planes + reddening]

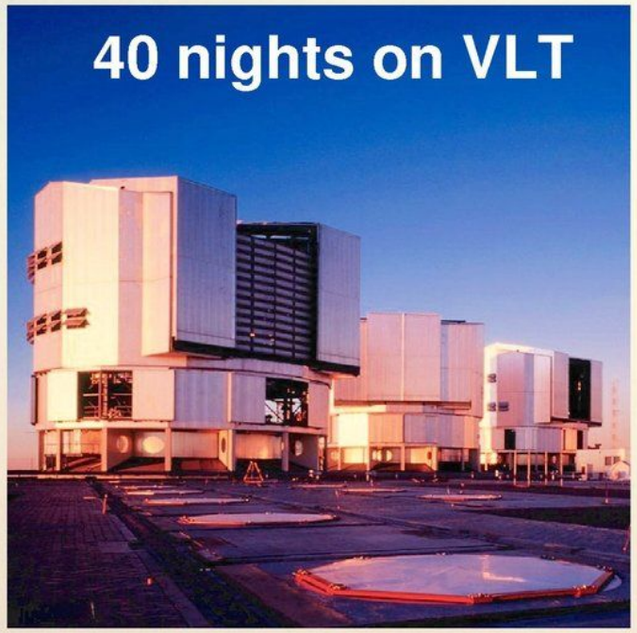
⇒ Ecliptic isolines track the Wide space survey started at the ecliptic poles

Euclid Complementary Observations

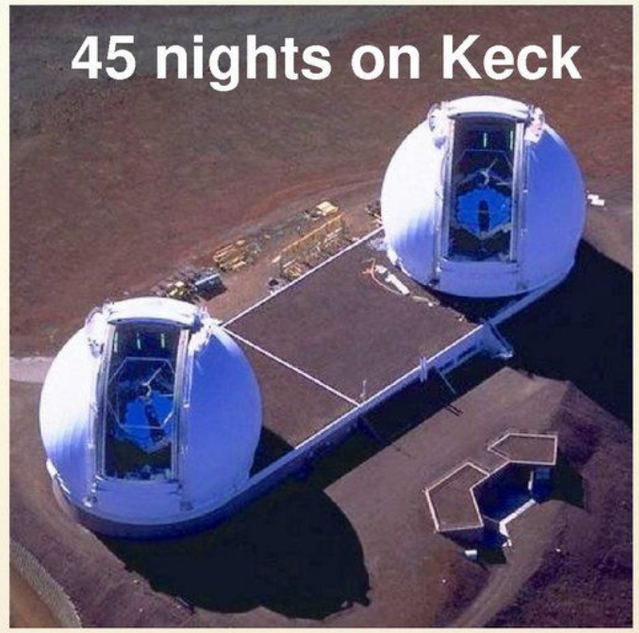


Euclid Complementary Observations: Spectroscopy

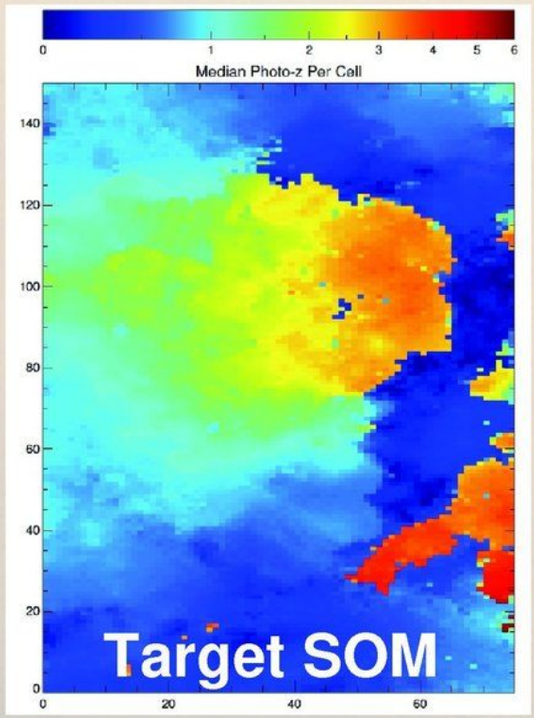
Spectroscopy for photo–z calibration on the Euclid calibration fields + EDF–N

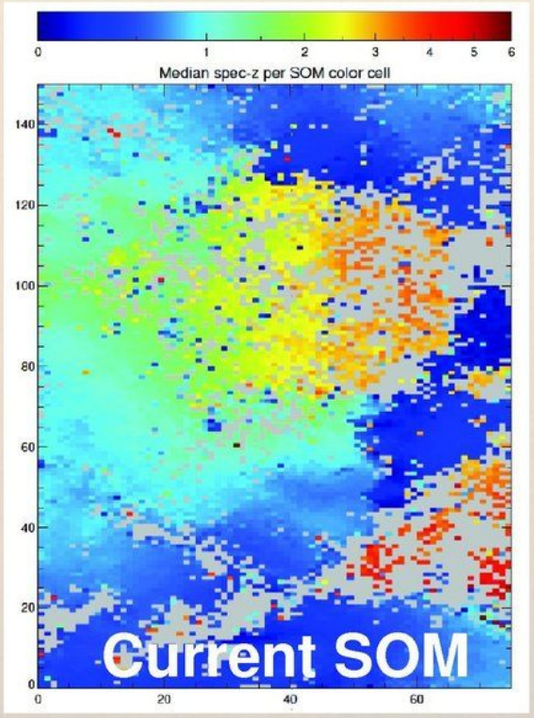


COMPLEMENTARY
Photo–z calibration



Unbiased deep field spectroscopy for direct photometric redshifts calibration





85% coverage
Thousands of spectra

Present and upcoming wide–field imagers relevant to Euclid

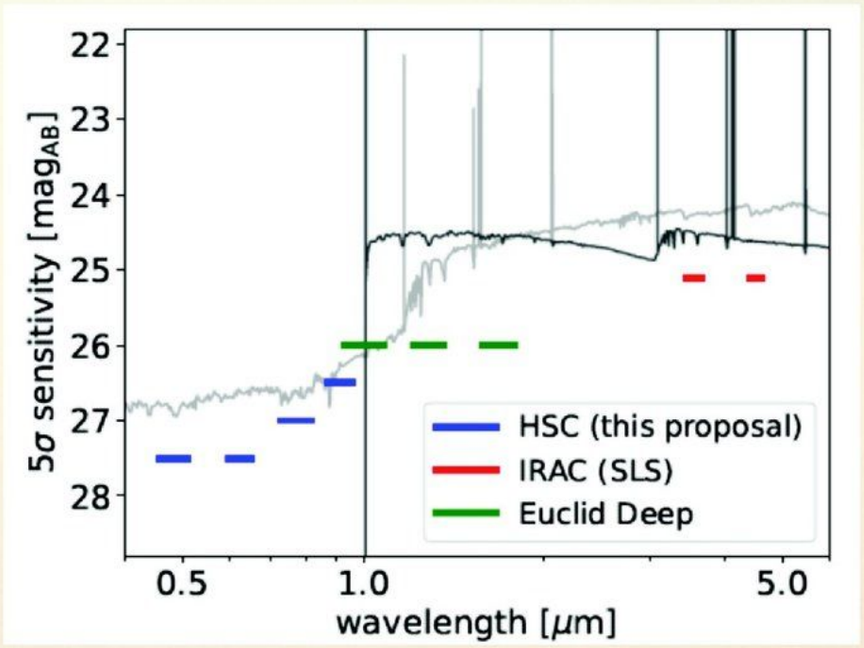
Facility	Year	Aper.	FOV	IQ	CCD class	Type	Hemisphere
LSST	2022	6.6m	9.6 sq.deg.	0.8"	Deep depletion	Surveyor	South
Subaru	2013	8.2m	1.8 sq.deg.	0.6"	Fully depleted	Observatory	North
Blanco	2013	4.0m	3.0 sq.deg.	1.0"	Fully depleted	Observatory	South
JST	2020	2.5m	4.8 sq.deg.	0.7"	Deep depletion	Surveyor	North
PS1+PS2	2018	2x1.5m	7.0 sq.deg.	1.0"	Fully depleted	Surveyor	North
CFHT	2003	3.6m	1.0 sq.deg.	0.6"	EPI	Observatory	North

Etendue

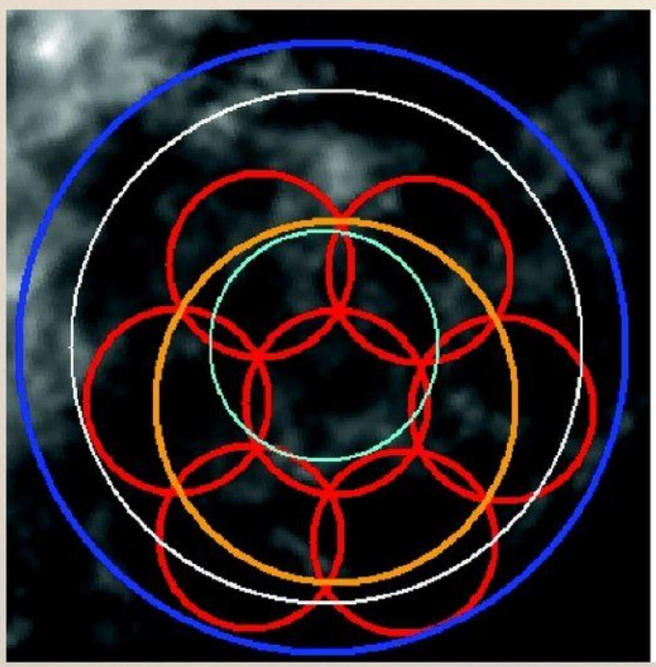
Euclid Complementary Observations: Hawai'i 2-0

Deep photometry for photo–z calibration on the Euclid deep fields EDF–N + EDF–F

COMPLEMENTARY
Photo–z calibration



30 IfA nights on Subaru–HSC (2018–21) Wide depths + ~2 mag. [g,r,i,z,y]



EDF–N

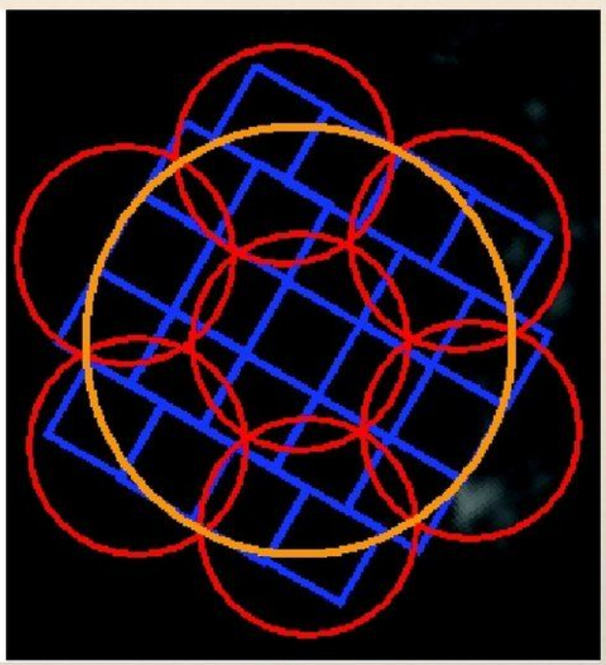
Euclid CVZ (NEP) and Nominal Pointings (Fornax)

Deep Spitzer Data

H20 Hyper-Suprime-Cam Data

Proposed Self-Calibration Field

Proposed De-Contamination Field (White)



EDF–F

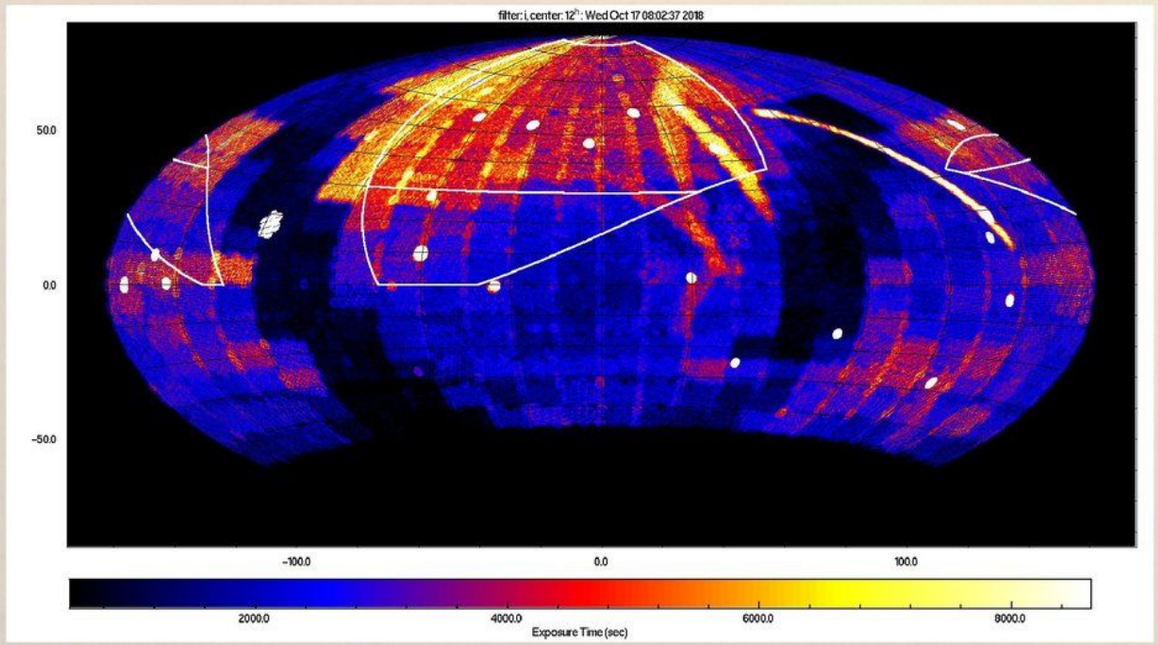
Pan-STARRS: *i* and *z* bands

Expectation over 5 years:

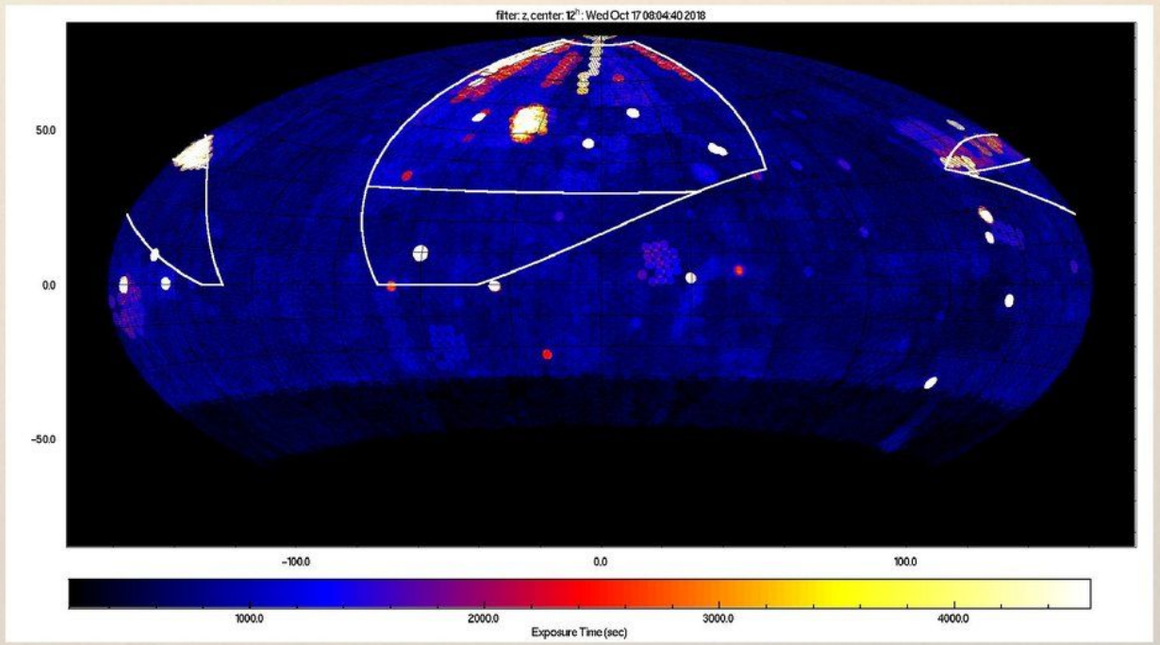
12,500s in both i & z over the 5000 square degrees in the northernmost Euclid sky

(MOU ready but not signed yet)

Both telescopes are now operational (2018)

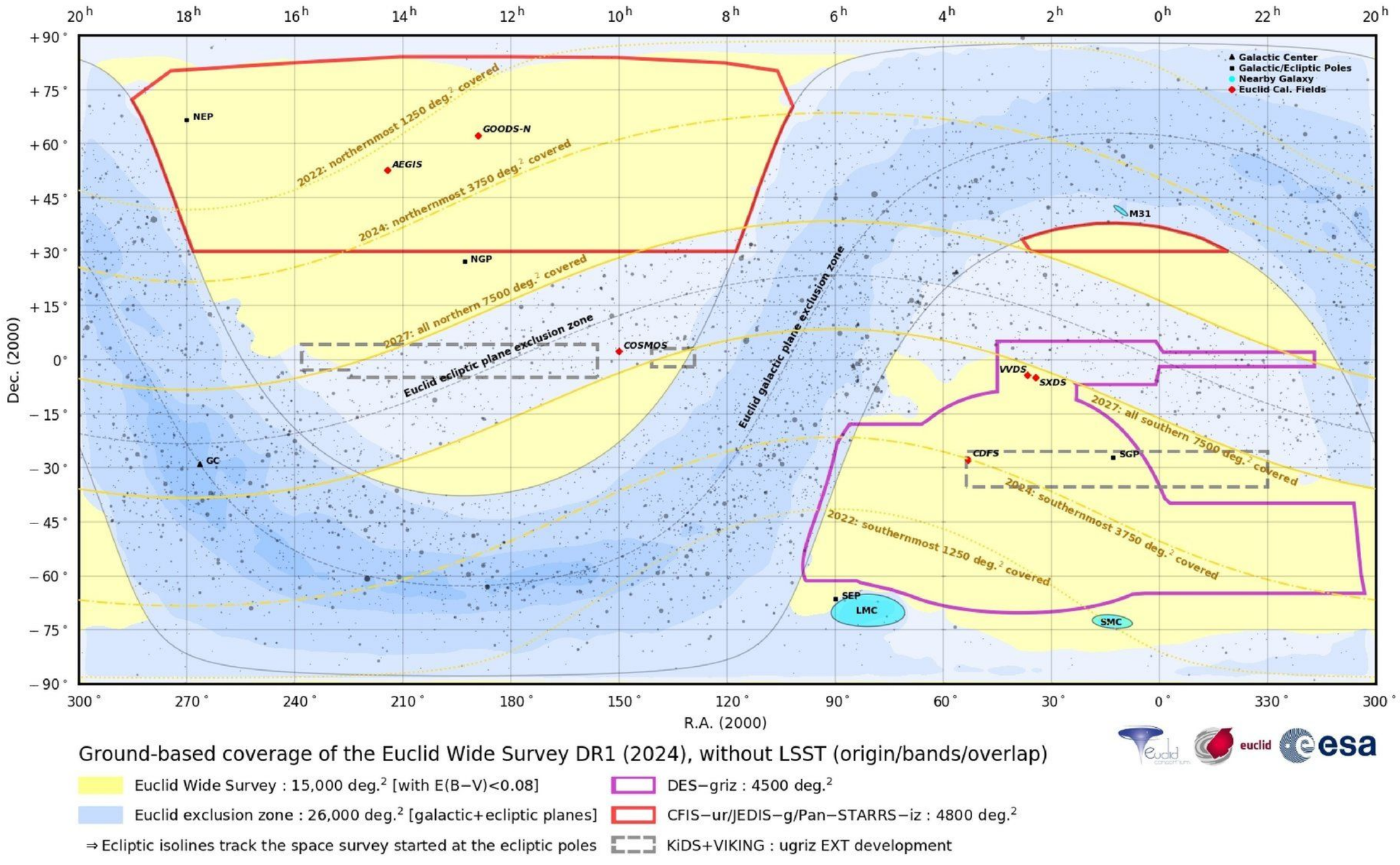


i–band depth grows with NEO search



Euclid z–band in bright time & twilights

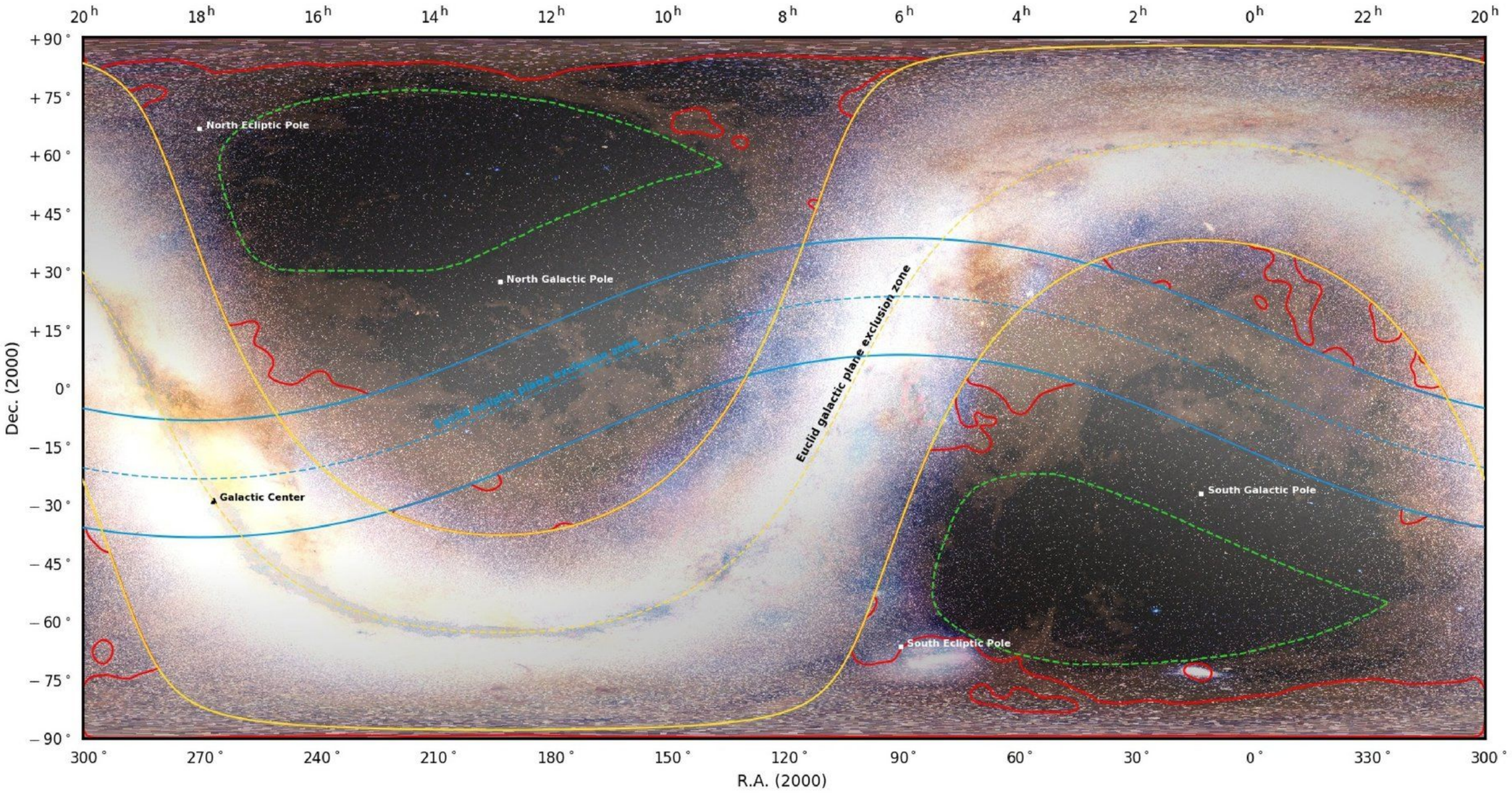
Euclid DR-1: 2,500 deg²



Best option (by **2023**): 1,250 deg2 in the North (CFIS + JEDIS + Pan-STARRS),

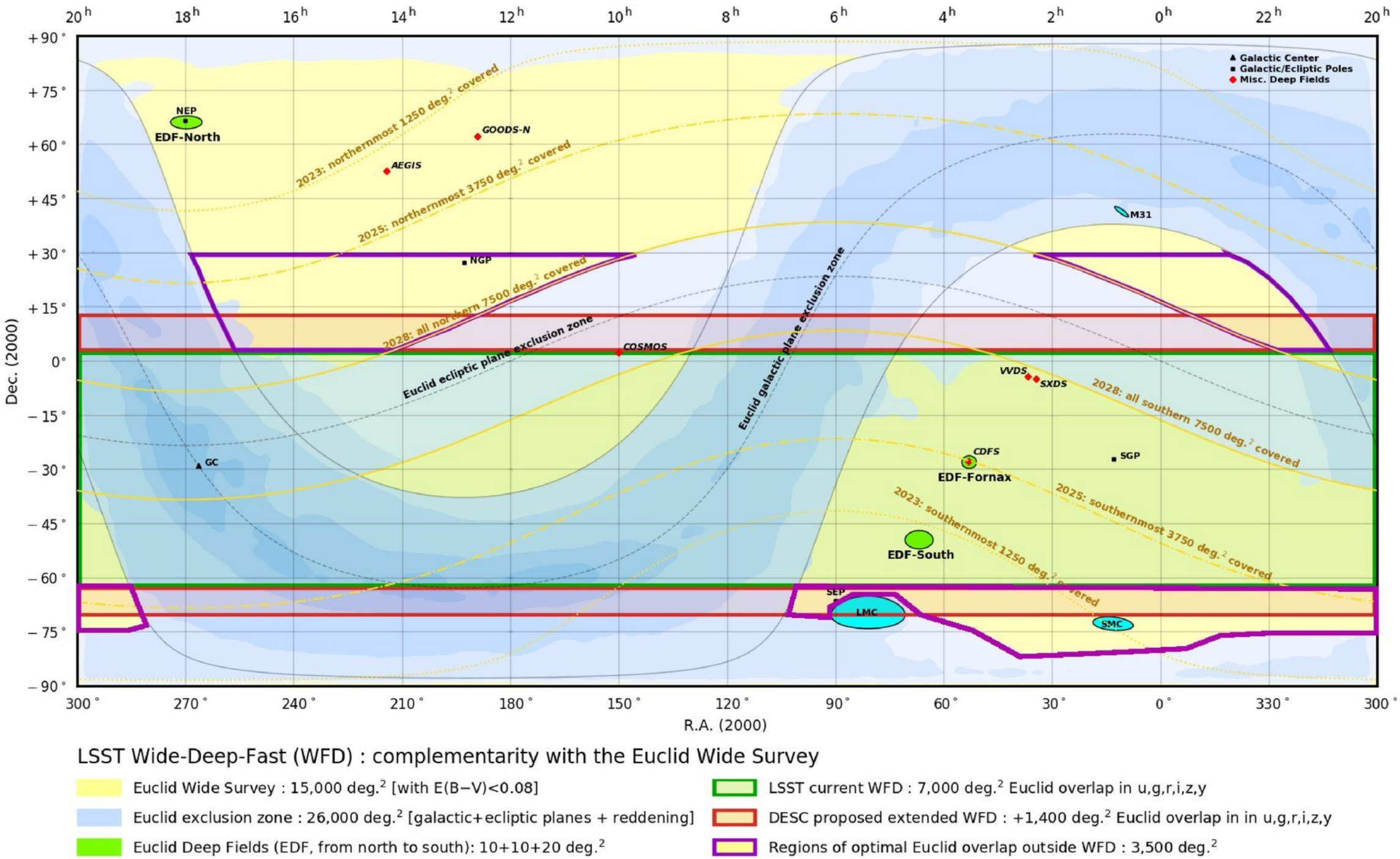
1,250 deg2 in the South (DES)

Euclid DR-1: 2,500 deg²



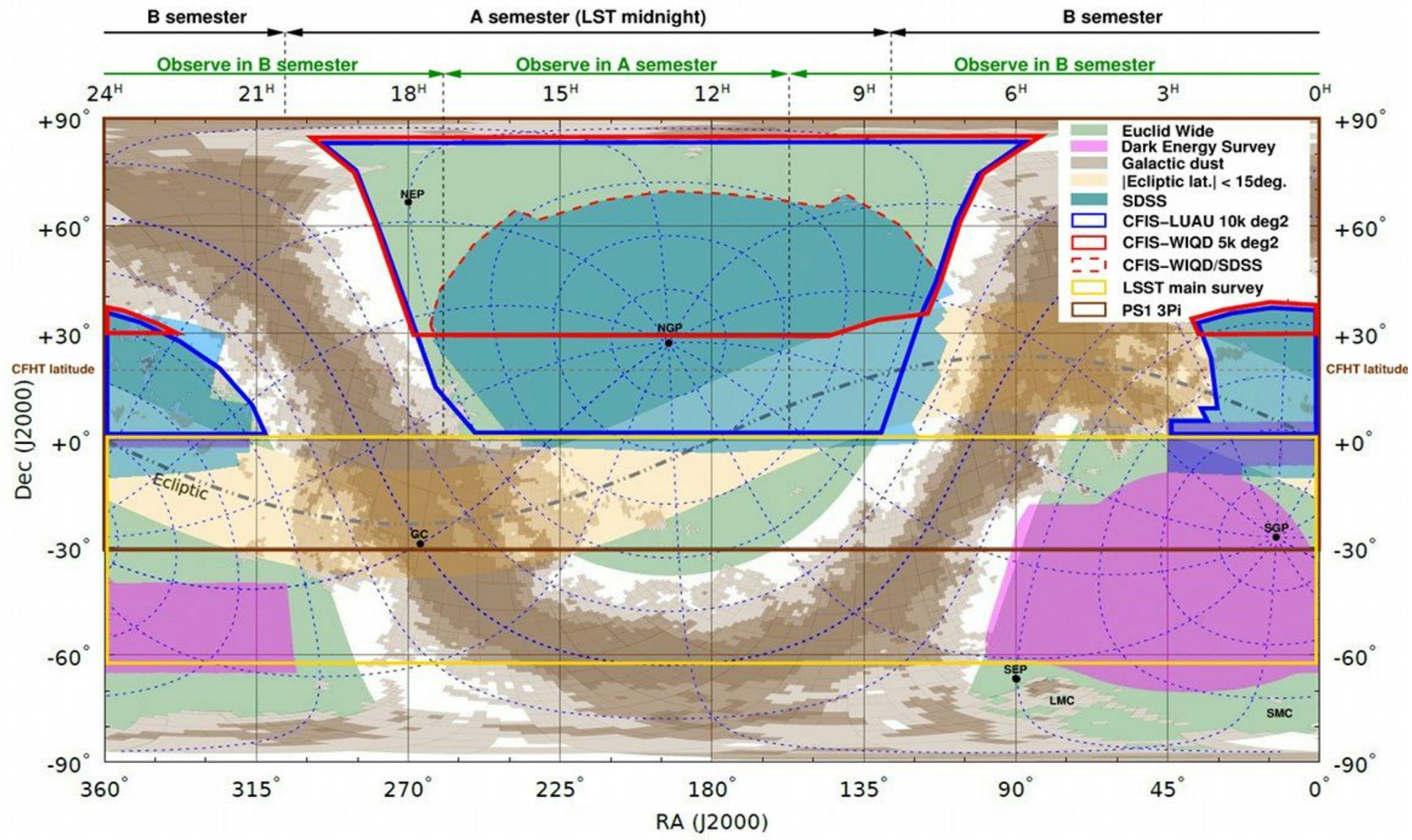
Best option (by **2023**): Covers lowest regions of galactic dust absorption and zodiacal light

Euclid DR-2/3: 7,500/15,000 deg²



LSST will replace DES in the South. Unclear coverage for $0 < \delta < 30°$.

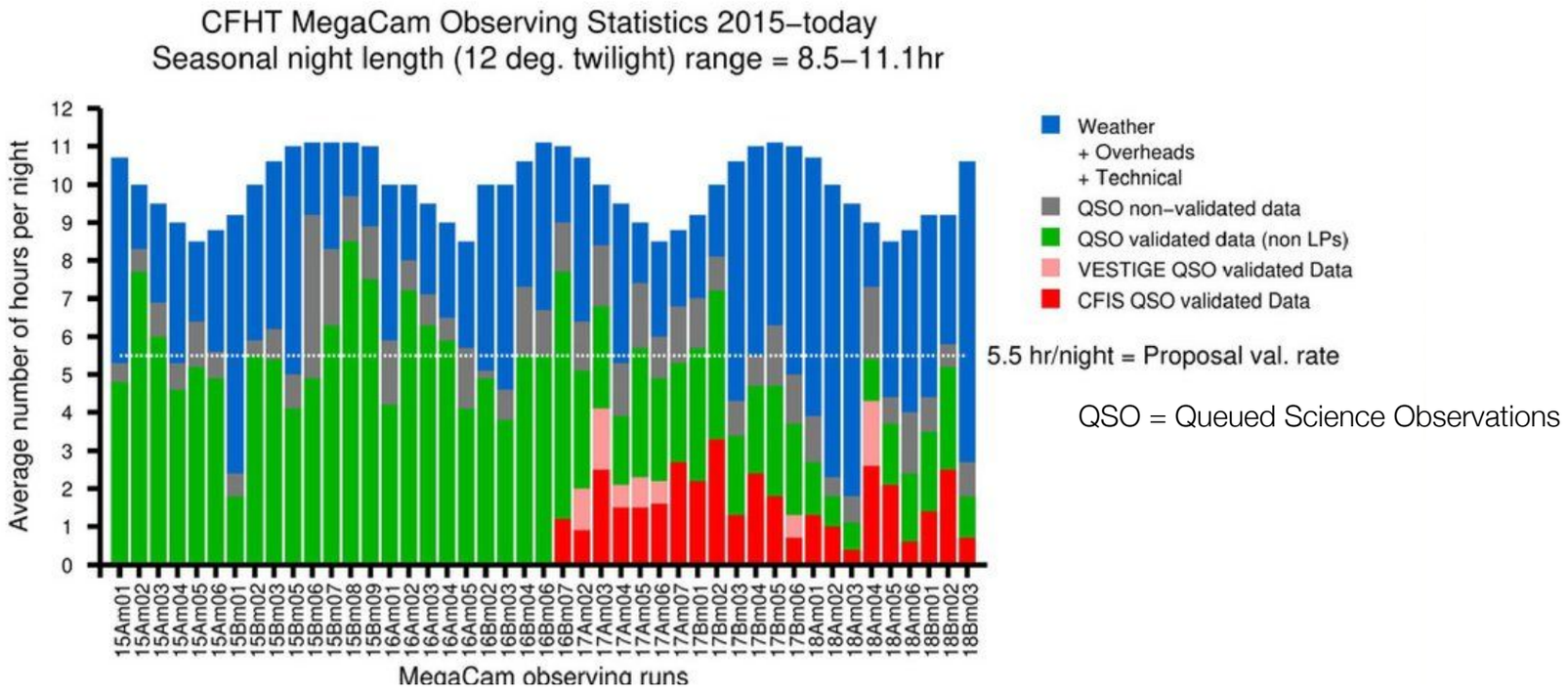
CFIS: Canada-France Imaging Survey



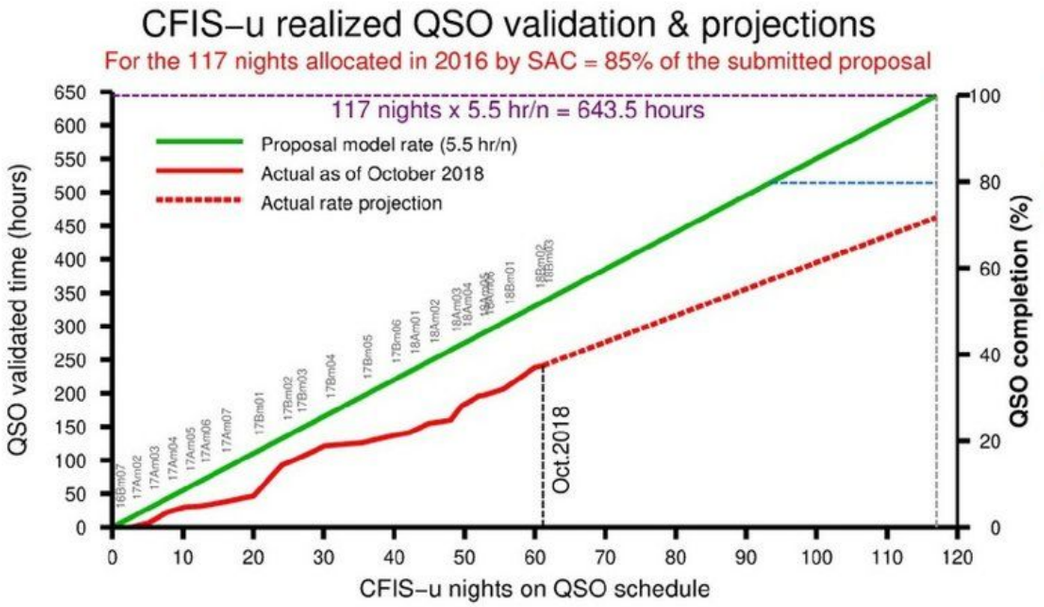
CANADA-FRANCE IMAGING SURVEY

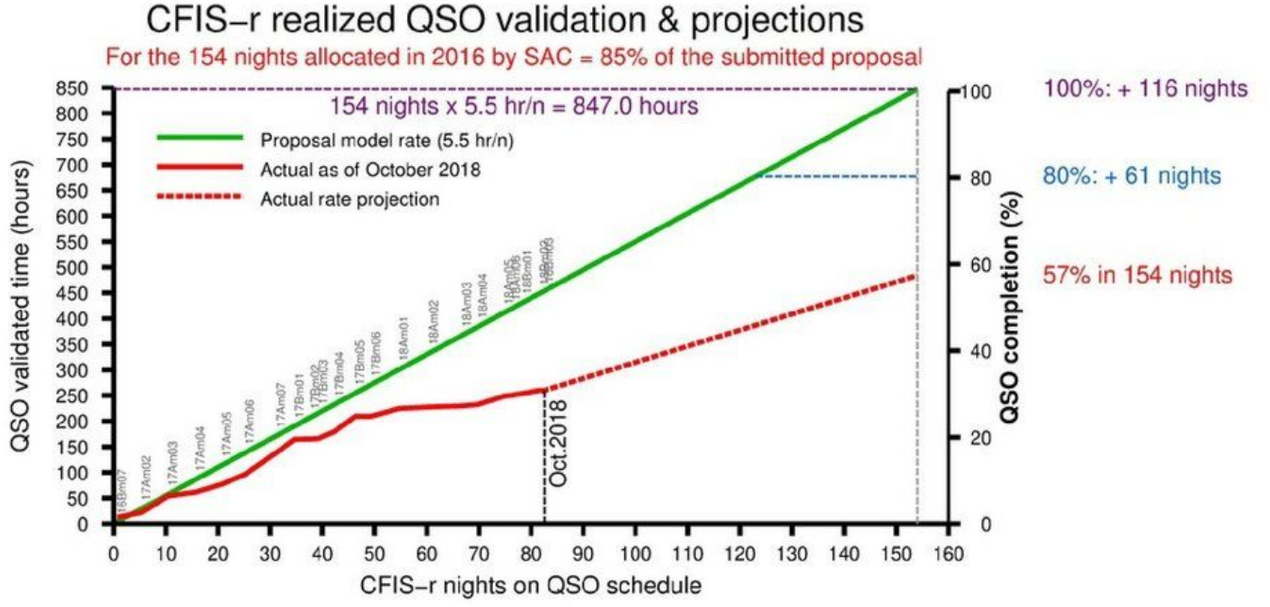
MegaCAM/CFHT, 2017 - 2019, u=24.5, r=24.1 (10s extended obj).

CFIS: Worst weather on Mauna Kea in 30 years



QSO = Queued Science Observations

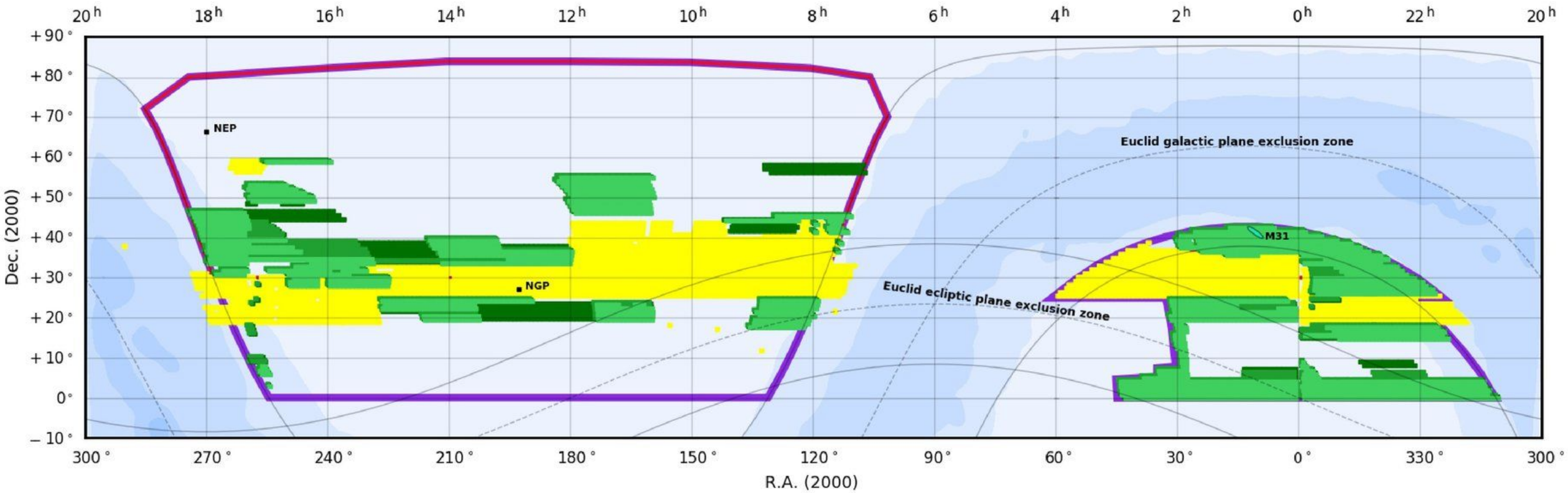




- CFIS not reaching initial goal set in 2016.
- New (2018) proposal was rejected, but: CFHT new policy for Large Projects.

CFIS *u*-band survey progress

November 2018

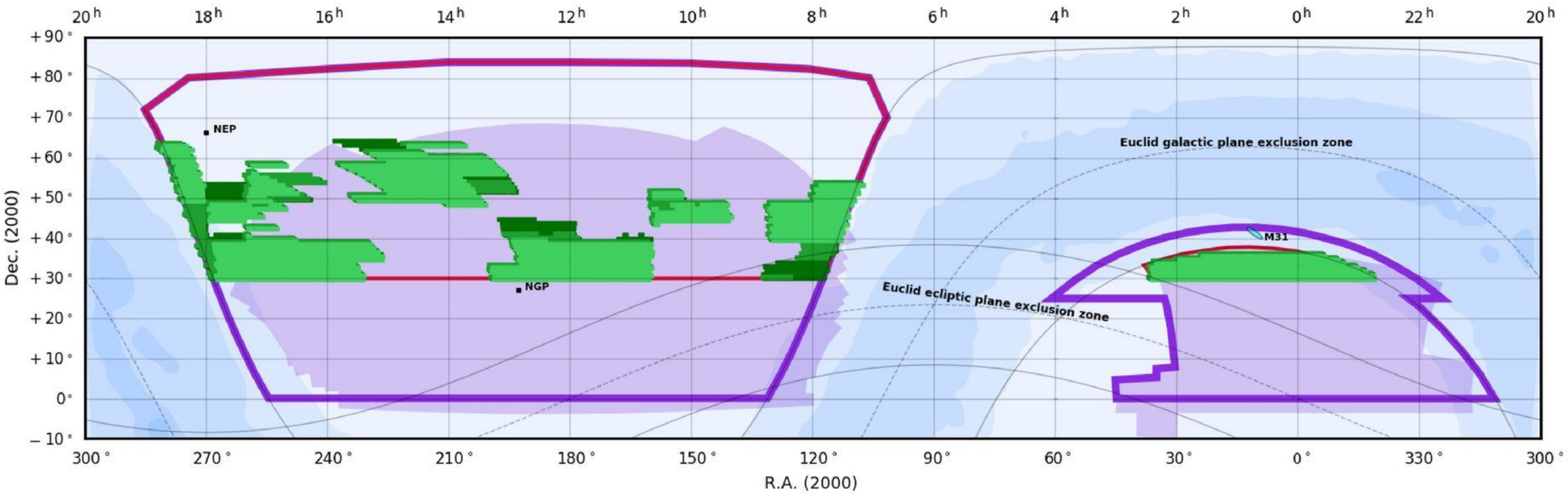


CFIS-u sky coverage completed as of November 2018

- Galactic plane
- CFIS−u : 10,000 deg.^{2} with priority to DEC>25 deg.
- CFIS−r + Pan−STARRS−iz + JEDIS−g: 4,800 deg.^{2} [Euclid North]
- Luau full depth with 3 exposures: 2608 deg.^{2} (2015−2016)
- CFIS−u covered with 1 exposure (1st pass): ~ 2679 deg.^{2}
- CFIS−u covered with 2 exposures (2nd pass): ~ 2293 deg.^{2}
- CFIS−u covered with 3 exposures (full depth): ~ 1969 deg.^{2}

CFIS *r*-band survey progress

November 2018

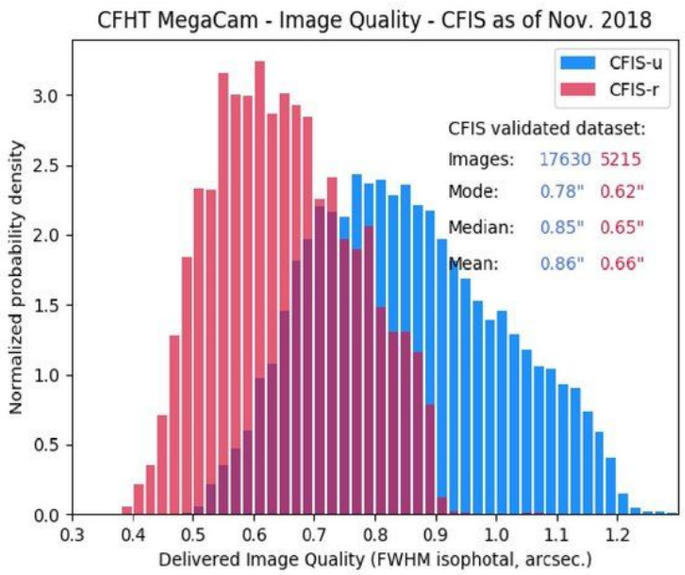


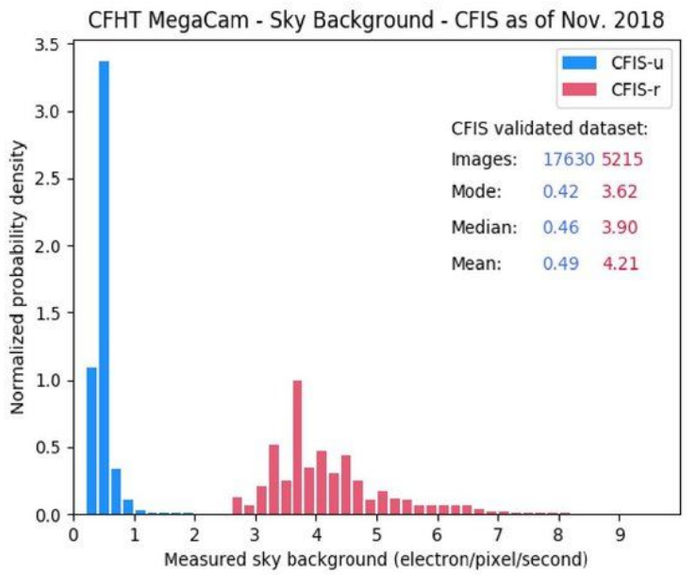
CFIS-r sky coverage completed as of November 2018

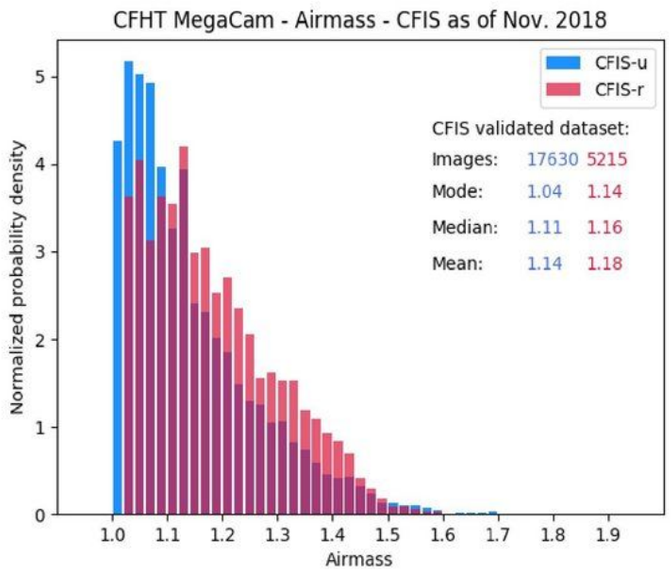
- Galactic plane
- BOSS
- CFIS−u : 10,000 deg.^{2} with priority to DEC>25 deg.
- CFIS−r + Pan−STARRS−iz + JEDIS−g: 4,800 deg.^{2} [Euclid North]

- CFIS−r covered with 1 exposure (1st pass): ~1846 deg.^{2}
- CFIS−r covered with 2 exposures (2nd pass): ~1654 deg.^{2}
- CFIS−r covered with 3 exposures (full depth): ~1501 deg.^{2}

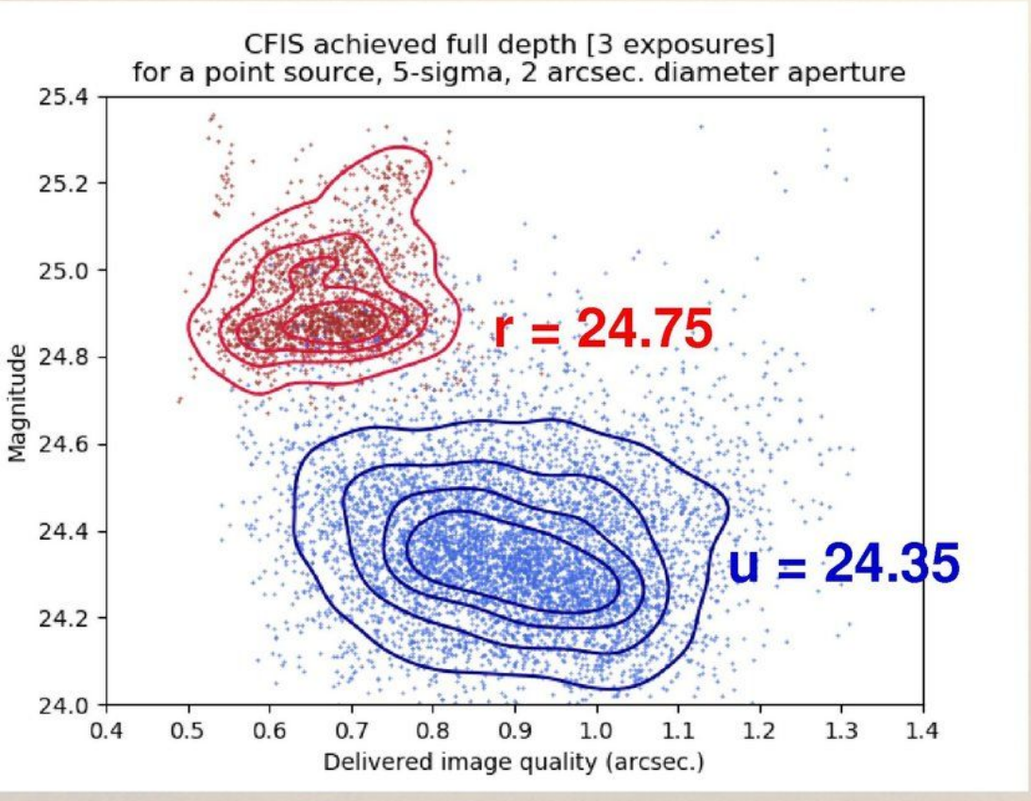
CFIS data quality



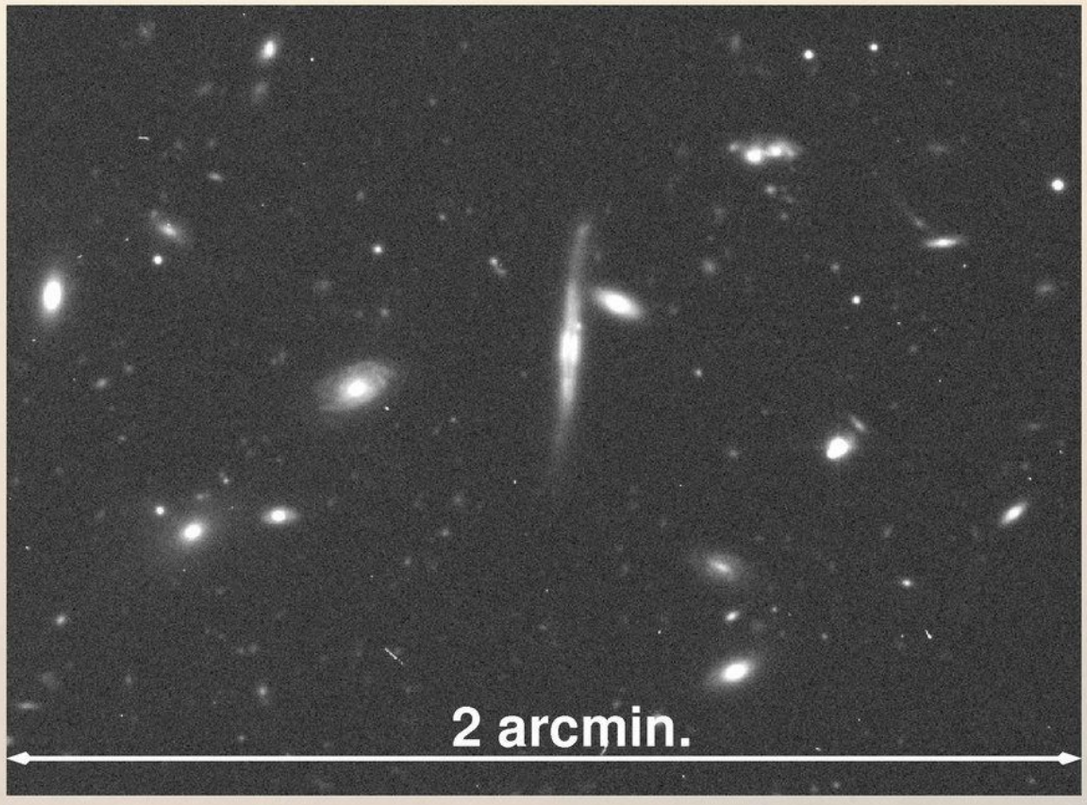




- **A high quality dataset**

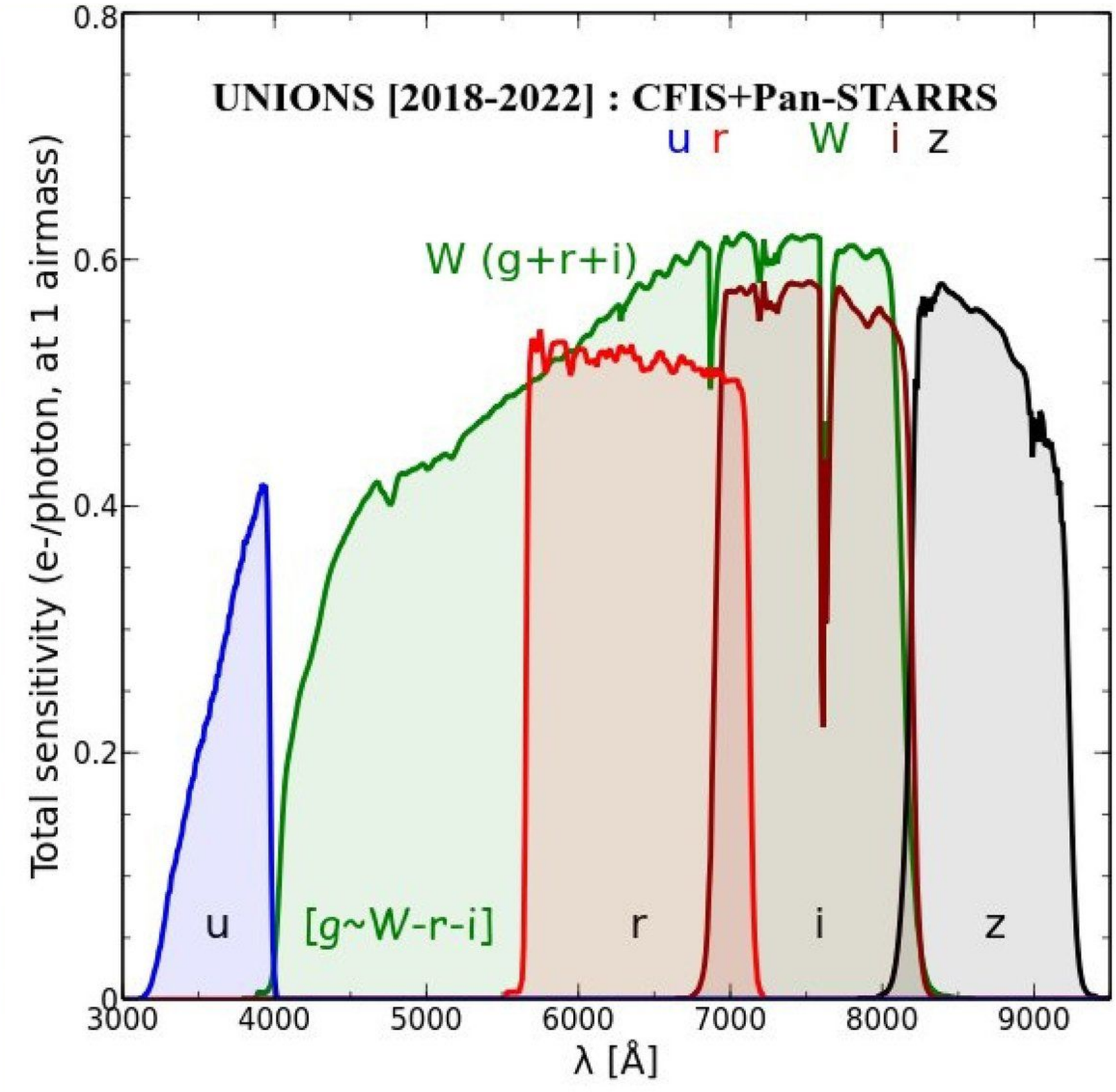


- **Planned depths achieved (MegaPipe stacks)**



- **Crop of a single frame (r–band, 0.51")**

UNIONS filter set



CosmoStat WL group

CEA

Martin Kilbinger - **WL data analysis, cross-correlations**
Sam Farrens - **PSF, pipeline architecture, blends**
Axel Guinot - **CFIS data analysis, redshift estimation**
Morgan Schmitz - **PSF**
Arnau Pujol (left for Barcelona) - **shear calibration, cross-correlations**
Austin Peel - **mass mapping, peak counts**
Florent Sureau - **pipeline architecture, shape measurement**
Jean-Luc Starck - **mass mapping, PSF**
Sandrine Pires - **mass mapping**
Jérôme Bobin - **machine learning, redshift estimation**
Jean-Charles Cuillandre - **Data analysis**

External collaborators

EPFL (CH)

Marc Gentile
Frédéric Courbin

IAP WL group

Raphaël Gavazzi
Henry McCracken
Emmanuel Bertin

Waterloo

Mike Hudson (**CFIS WL lead**)
Isaac Spitzer

LenS team (DE/CA/UK)

Ludo van Waerbeke (UBC)
Hendrik Hildebrandt (Bonn)
Thomas Erben (Bonn)
Catherine Heymans (Edinburgh)

CFIS overlap with spectroscopic surveys

Survey	Period	n_{gal} [deg^2]	Galaxies	Redshift	A_{joint}
BOSS	DR12 released in 2016	147	LOWZ, CMASS	0.15 < z < 0.7	2,800
eBOSS	2014 - 2018	50	LRG, ELG	0.6 < z < 1	3,000
DESI-2y	2019 - 2021	~285	LRG low-z	0.4 < z < 1	4,000
		~700	BGS	0.04 < z < 0.4	4,000

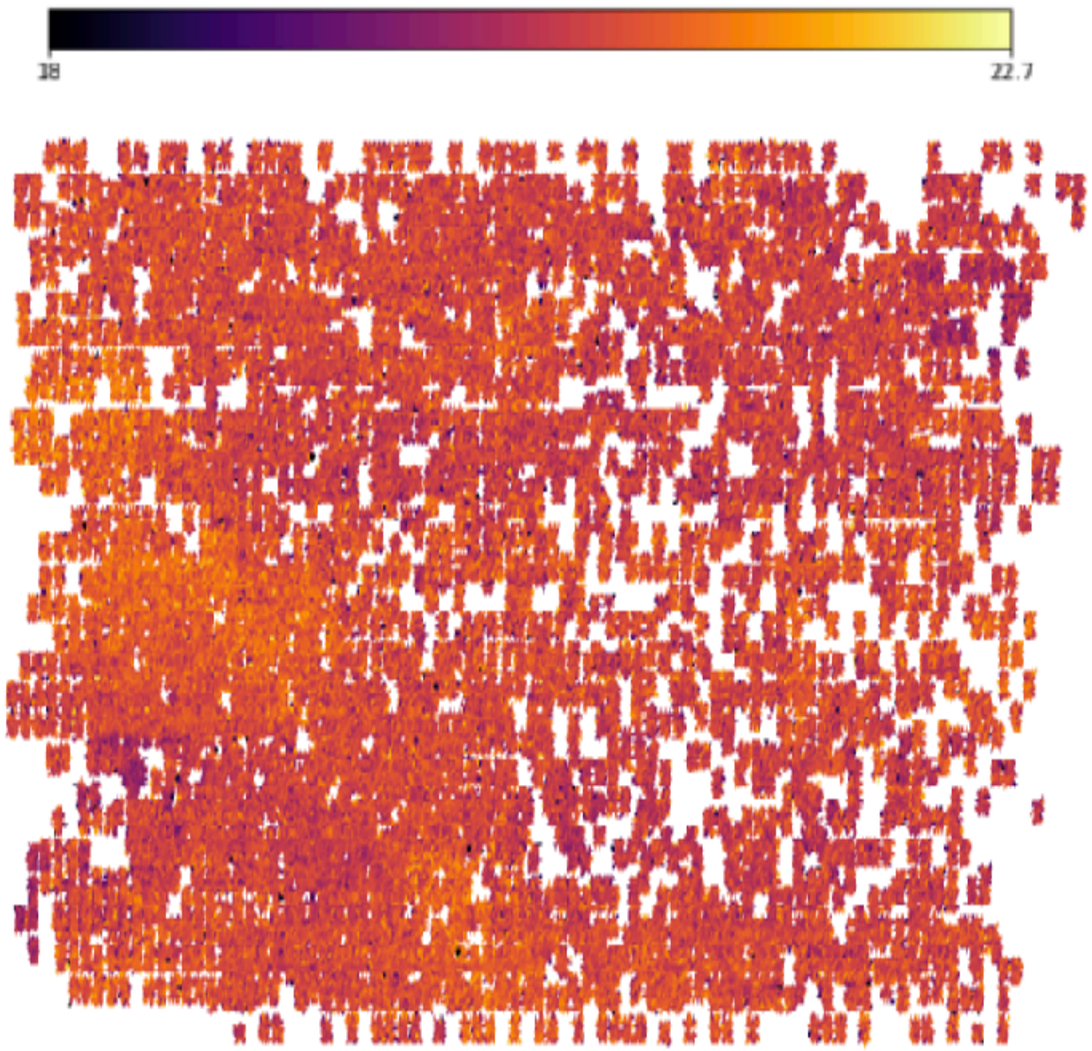
CFIS: First weak-lensing results

Axel Guinot

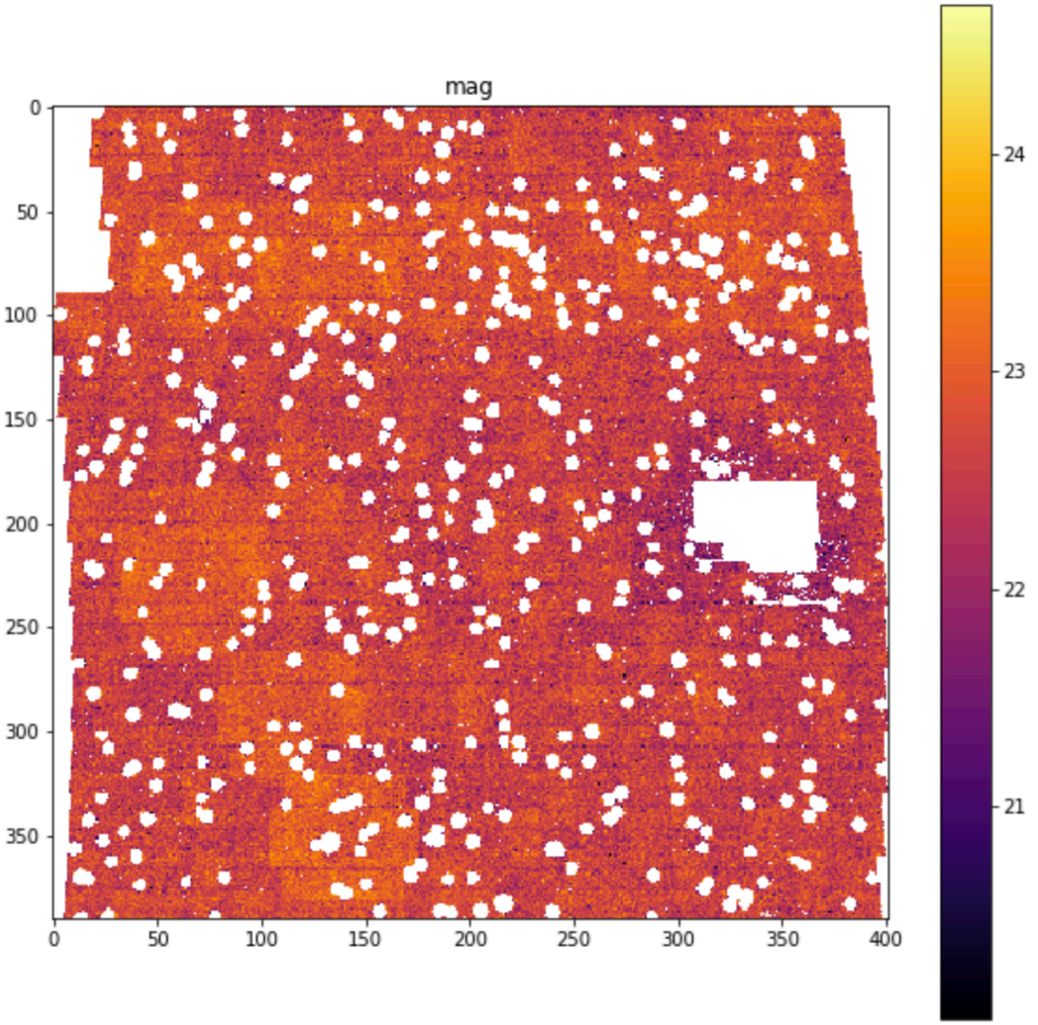
Arnau Pujol

CFHTLS-W3 field

Single exposures (CEA)



Stacks (LenS)

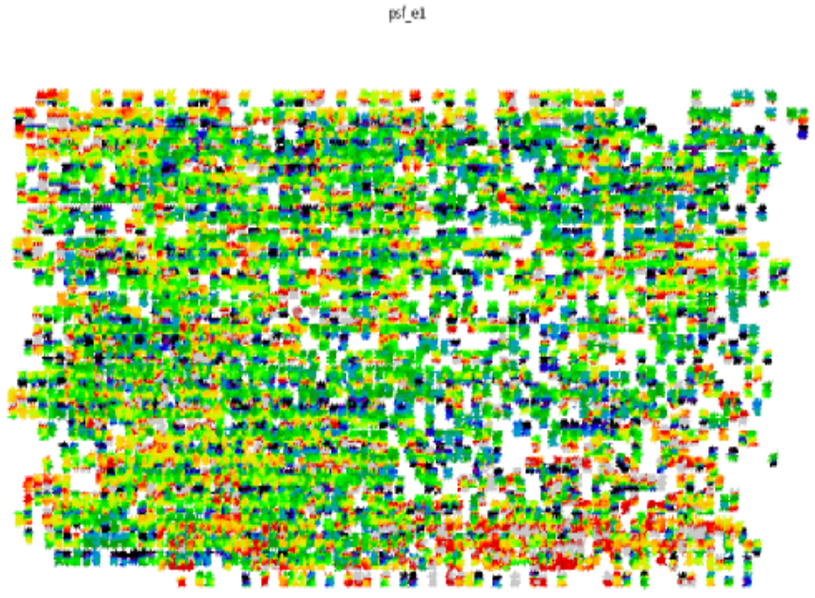


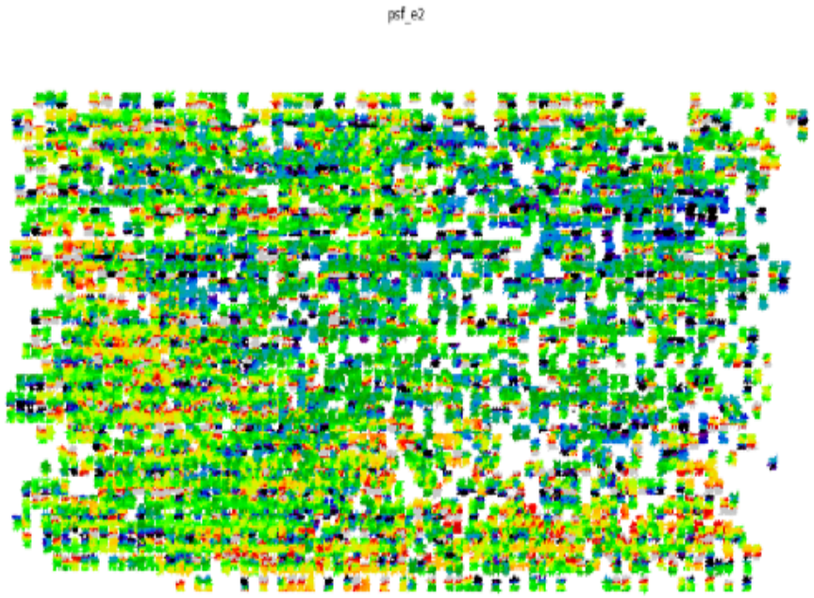
CFIS: First weak-lensing results

Axel Guinot

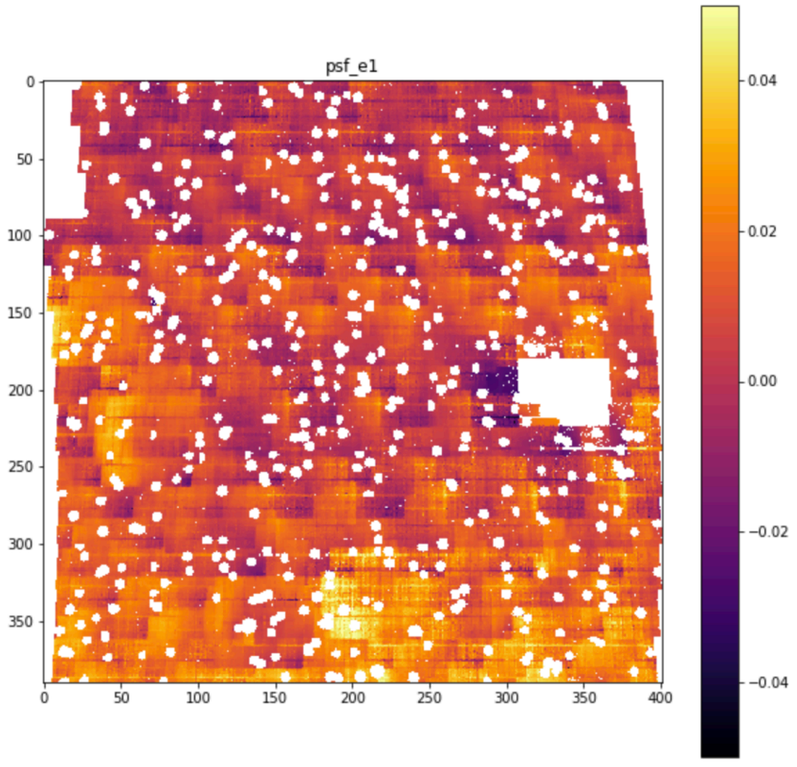
Arnau Pujol

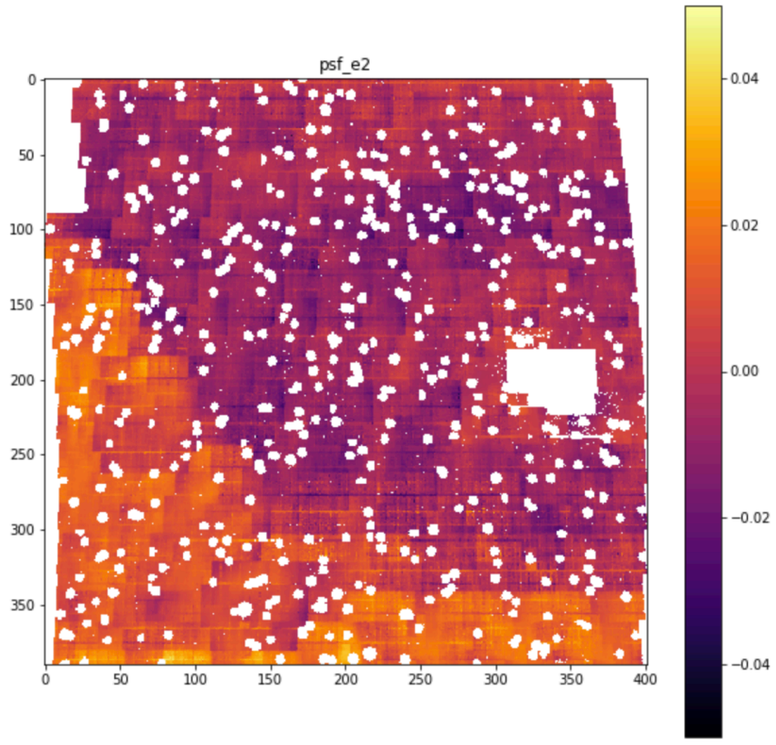
Single exposures (CEA)





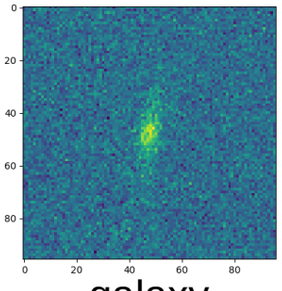
Stacks (LenS)



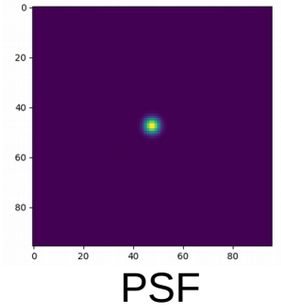


CFIS: Shear calibration, preliminary results

Axel Guinot



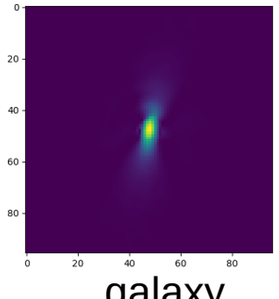
galaxy



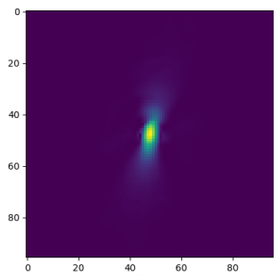
PSF

Deconvolution with a sparsity/law-rank based software

(Ref : Farrens S. et al. 2017, A&A, 601, A66)

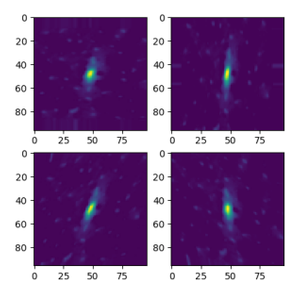


galaxy deconvolved

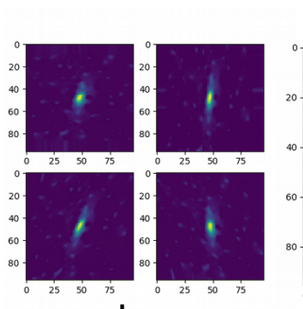


galaxy deconvolved

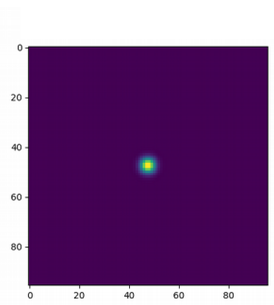
Application of an artifitial shear with spline-interpolation



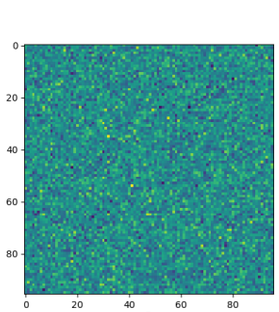
galaxy sheared



galaxy sheared

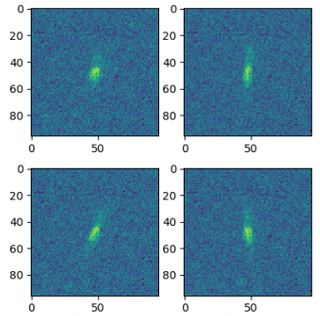


PSF



noise map

Convolution and addition of simulated noise



Images for the calibration

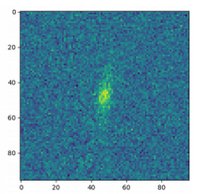
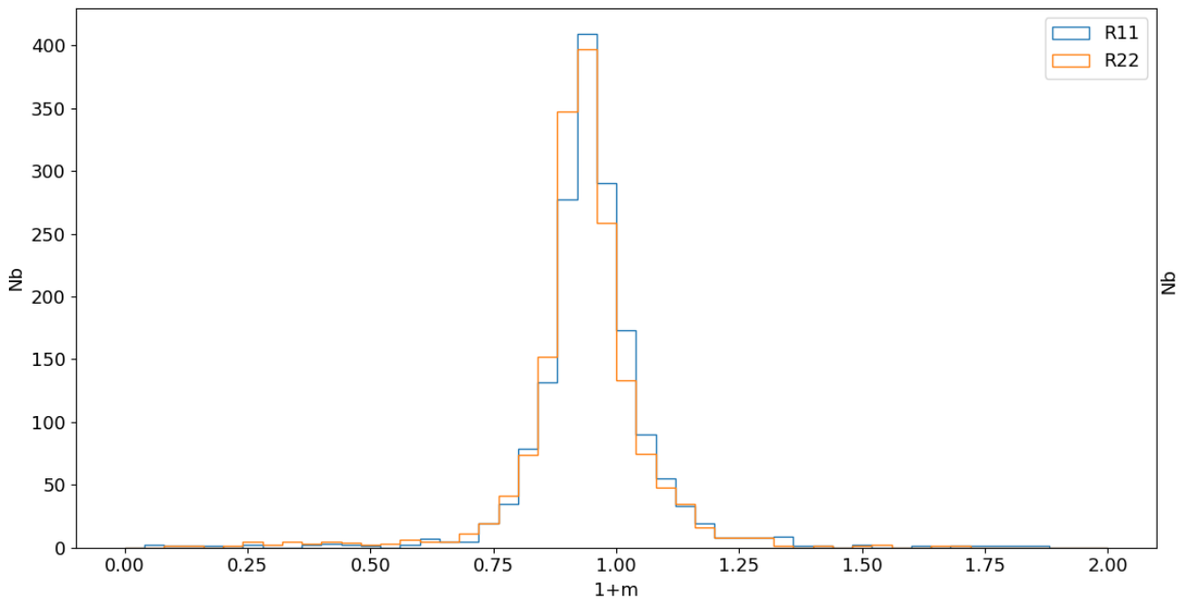


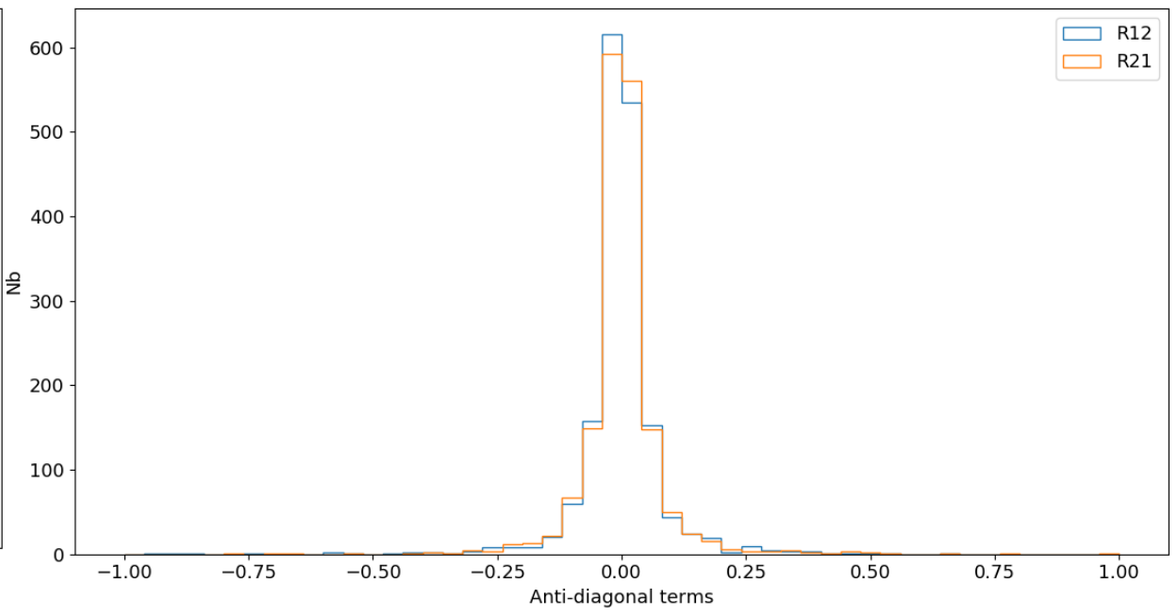
Image for the measurement

CFIS: Shear calibration, preliminary results

Axel Guinot

- Preliminary tests on CFIS (~1700 galaxies) : $e^{\mathrm{obs}} = e^{\mathrm{int}} + R\,\gamma$





$[R_{11},R_{22}] = 1+m = 0.94 \pm 0.001$

$[R_{12},R_{21}] = -0.0013 \pm 0.0006$

- Results on simulation (1000 galaxies)

$[R_{11},R_{22}] = 1+m = 0.94 \pm 0.007$ ~1% error compared to true value.

$[R_{12},R_{21}] = -0.009 \pm 0.006$

- Also tested on CFHTLenS (500 galaxies on one field) :

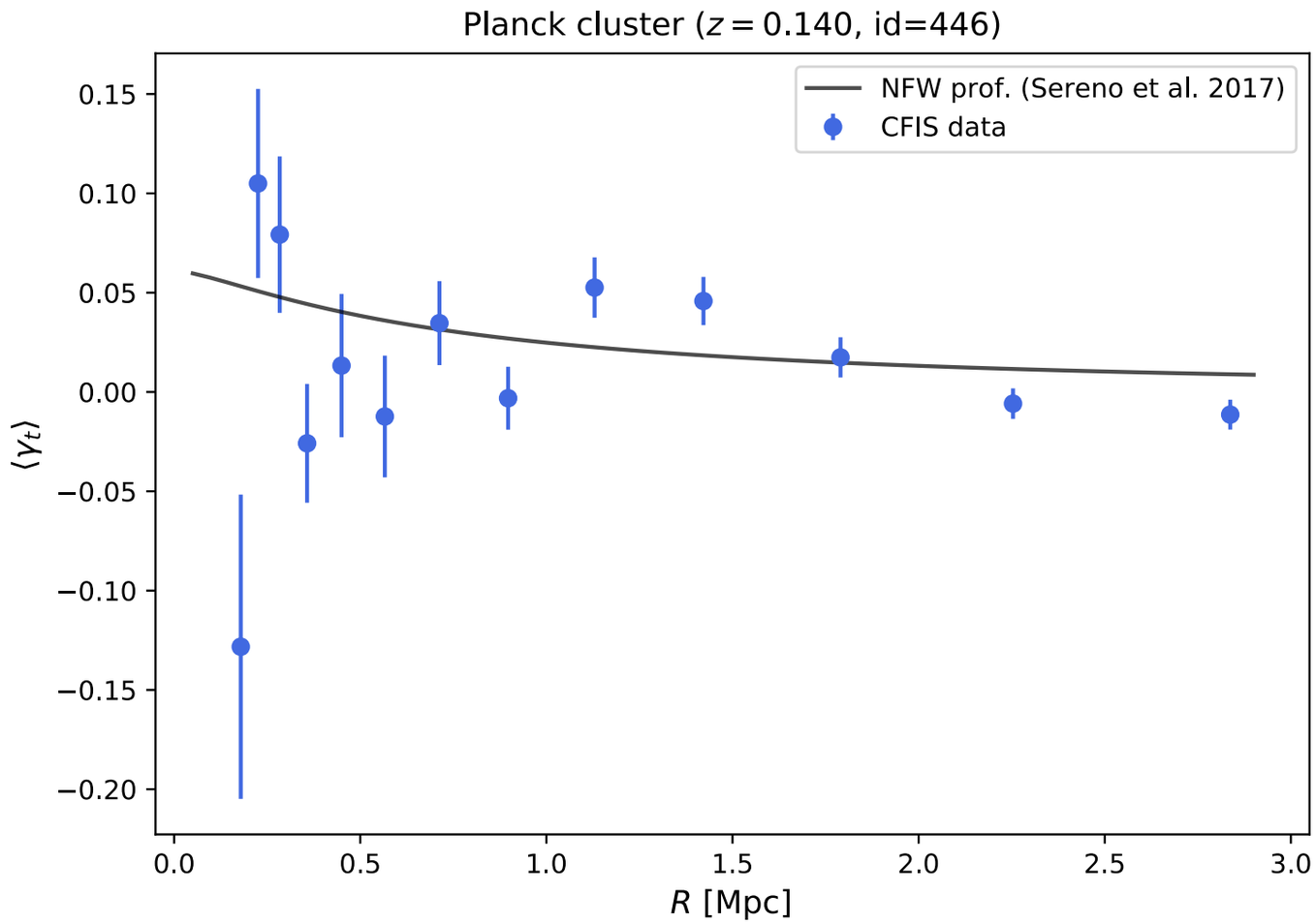
$[R_{11},R_{22}] = 1+m = 0.92 \pm 0.002$ 1% error compared to the reference (mean bias for the all survey).

$[R_{12},R_{21}] = -0.0017 \pm 0.0007$

CFIS: First weak-lensing results

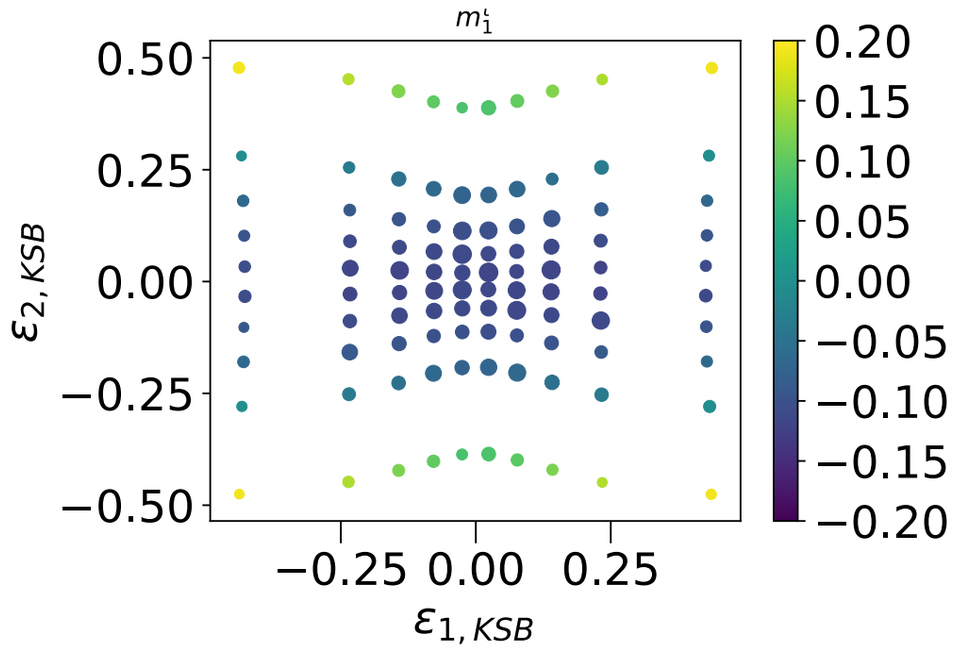
Axel Guinot

Austin Peel



CFIS: Work in progress

- Test and comparison of the two WL pipelines (CEA & LenS)
- CFIS image simulations (Isaac Spitzer), shear calibration tests, validation of metacalibration
- Machine learning calibration (Arnau Pujol)
- Higher-order terms in shear-ellipticity relation, spatially varying shear bias
  (Axel Guinot, Olivier Kauffmann, Arnau Pujol)



$$e = \frac{e^I + g}{1 + g^* e^I} = e^I + g - g^*(e^I)^2 + O(g^2)$$

$$\vec{e} = \vec{e}^I + \begin{pmatrix} 1 - (e_1^I)^2 + (e_2^I)^2 & -2e_1^I e_2^I \\ -2e_1^I e_2^I & 1 + (e_1^I)^2 - (e_2^I)^2 \end{pmatrix} \vec{g} = \vec{e}^I + A(\vec{e}^I)\vec{g}$$

$$\vec{e}^{obs} = R(\vec{P})A(\vec{e}^I)\vec{g} + \vec{a}(\vec{P}) + f(\vec{e}^I)$$

$$\frac{\partial e_\alpha^{obs}}{\partial g_\beta} = \left[R(\vec{P})A(\vec{e}^I)\right]_{\alpha\beta} = \widetilde{R}(\vec{P}, \vec{e}^I)_{\alpha\beta}$$

WL surveys in comparison

	KiDS(+VIKING)	HSC	DES	UNIONS
Mirror [m]	2.6	**8.2**	4.0	3.6
Focus	**Cassegrain**	Prime	Prime	Prime
FOV [deg²]	1.0	1.8	**3.0**	1.0
Area [deg²]	1350	1400	**5000**	**4800**
Filters	***u****gri*(+*ZY****JHKs***)	*grizy*	*griz(y)*	***u****(g)wriz*
Seeing [arcsec]	**0.68**	**0.58**	0.94	**0.65**
Source density [gal/arcmin²]	~8	**~22**	~5-7	~10?
Depth	***r*~24**	*i*~24.5	***r*~23-24**	***r* >~ *24***
WL Team	>30	>30	**>130**	15-20

Table adapted from Hendrik Hildebrandt