TEST

Euclid vs. SKA

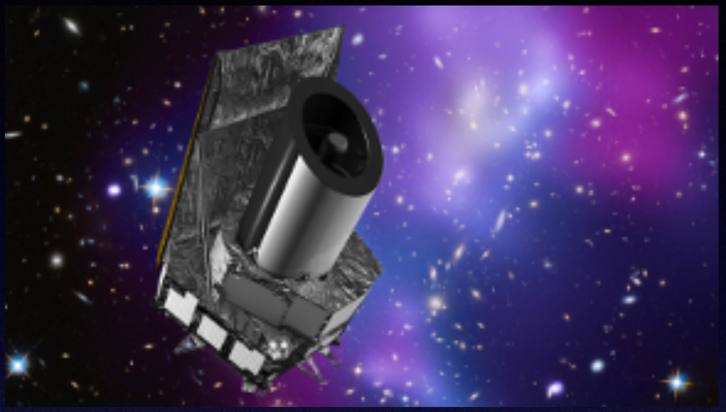
Competition or Synergy?

Both

Lots of material credited to Euclid Consortium, ESA, ECSURV etc

Recall Euclid in a nutshell:

- Visible imaging (PSF ~2 x HST), AB=24.5 @ 10σ
- NIR Photometry (y, J, H), AB=24 @ 10σ
- slitless spectra (Hα z=0.-1.8)
- wide survey 15,000 sq legs
- deep survey 40 sq degs 2 mags deeper
- 6 yr mission
- ~1300 members
- costs up to 1G€ (ESA+NASA+Nat ISpace Ag+Institutes)



Today

- **some reminiscences**
- **Brief, (mostly cosmological) highlights**

some Jurassic memories from previous meetings

R. Scaramella
INAF Osservatorio di Roma

-SKAItaly June 2012-

Old timer...

Interested since long in two fascinating projects:

- Italian involvement in SKA (SKADS, prepSKA, SKA day 2006, etc)

- Italian involvement in Euclid

(since the beginning from the imaging side, currently Mission Survey Scientist;
Euclid material from/thanks the Euclid Consortium)

some Jurassic memories from previous meetings

GIORNATA SKA-LOFAR **2006**

1) GRAZIE DI PARTECIPARE
2) SCOPO INFORMATIVO + STIMOLO
3) RIVOLUZIONE CULTURALE
4) RELAX...

la Repubblica

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L'INCHIESTA

Sospettato di traffico d'~~armi~~ idee

Le frottole di Scaramella consulente

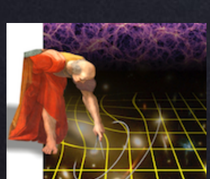
(*Environmental crime protection program*) che egli dice essere «organismo sussidiario dell'organizzazione marittima internazionale dell'Onu». Soprattutto, riceve da Paolo Guzzanti — come egli stesso racconta a verbale il 14 ottobre 2005 alla sezione investigativa del commissariato "Dante" di Napoli — un incarico di «dele-

L'auto viene crivellata di colpi, all'altezza del posto di guida, nel lunotto posteriore. Un proiettile lo ferisce e, ricoverato al "Maresca" di Torre del Greco, il pregiudicato è accusato di tentato omicidio plurimo. Al processo è assolto e si riesce a dimostrare che quel diavolo avrà sulla coscienza tanti peccati, ma non quello di aver voluto uccidere Scaramella. Al contrario, furono le body guard di Scaramella a tentare di elimi-

che ore prima, il furgone ucraino che, settimanalmente, da Leopoli rifornisce gli ambulanti ucraini dei mercati di Teramo, Pescara e Napoli è in panne davanti a una autofficina di Udine. Nella notte il carico viene trasferito su un altro furgone bloccato dalla polizia a Teramo e qui — quale sorpresa — tra le centinaia di colli con indicazioni in cirillico, c'è un unico pacco con caratteri latini e, dentro quel pacco — ohibò — ci sono

Mantovani: SKARAMELLA

frottole: tell tales, balderdash, boloney, guff



some Jurassic memories from previous meetings

STATUS COSE ITALIANE ... **2006**

1) SKA : PARTECIPIAMO AL PROJECT OFFICE, POSIZIONI NEI COMITATI, DIMOSTRATORE BEST NEL PROGETTO EUROPEO SKADS (FP6). POI FP7 ?

2) LOFAR : TENTATIVO DI ENTRARE CON
   A) UPGRADE CROCE DEL NORD <u>UNIBO</u>
   B1) STAZIONE "STD" MEDICINA
   B2) " "STD" IN SARDEGNA

B+ : COLLEGAMENTI IN FIBRA B- : NO € YET

QUALCHE ANALOGIA CON $\{VAR[\text{ASTRONOMO INAF}]\}^{1/2}$ ...

2006

The Soldier Who Wouldn't Quit

On December 17, 1944, the Japanese army sent a twenty-three year old soldier named Hiroo Onoda to the Philippines to join the Sugi Brigade. He was stationed on the small island of Lubang, approximately seventy-five miles southwest of Manila in the Philippines, and his orders were to lead the Lubang Garrison in guerrilla warfare.

As Onoda was departing to begin his mission, his division commander told him, "You are absolutely forbidden to die by your own hand. It may take three years, it may take five, but whatever happens, we'll come back for you. Until then, so long as you have one soldier, you are to continue to lead him. You may have to live on coconuts. If that's the case, live on coconuts! Under no circumstances are you to give up your life voluntarily." It turns out that Onoda was exceptionally good at following orders, and it would be 29 years before he finally laid down his arms and surrendered.

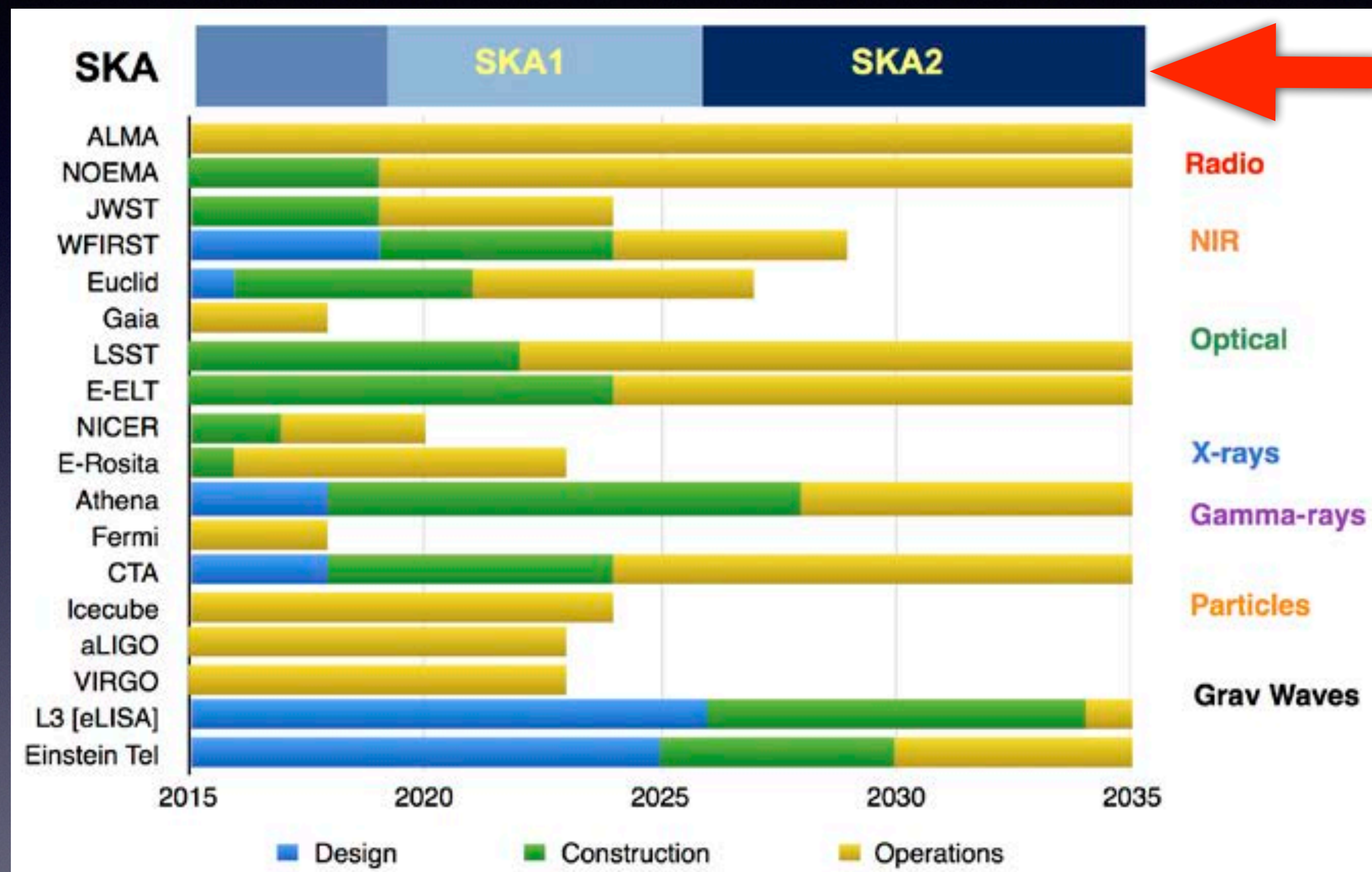
Salvati: "where are the coconuts? At least give some: we haven't seen them!

Luckily we did not have to wait for 30 years!!

Global landscape & nominal timescales (@~2015)

ERTRC report:
Final version – June 2015

Aalto, Susanne	S	
Alberdi, Antxon	ES	
Corbel, Stéphane	F	
Dettmar, Ralf-Jürgen	D	
Fender, Rob	UK	
Gabuzda, Denise	EI	
Grewing, Michael	D	(co-chair)
Hessels, Jason	NL	
Scaramella, Roberto	I	
Wijers, Ralph	NL	(chair)
Zdziarski, Andrzej	PL	



SKA1 vs SKA: All HUGE projects have in common: delays.. delays.. delays.. delays.. delays..

2018

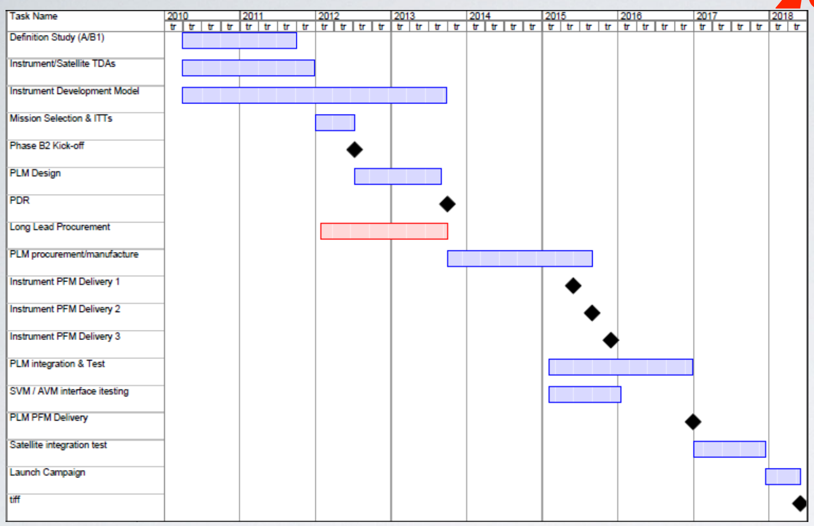


Figure 7.3: Preliminary schedule for PLM

Expected timeschedule

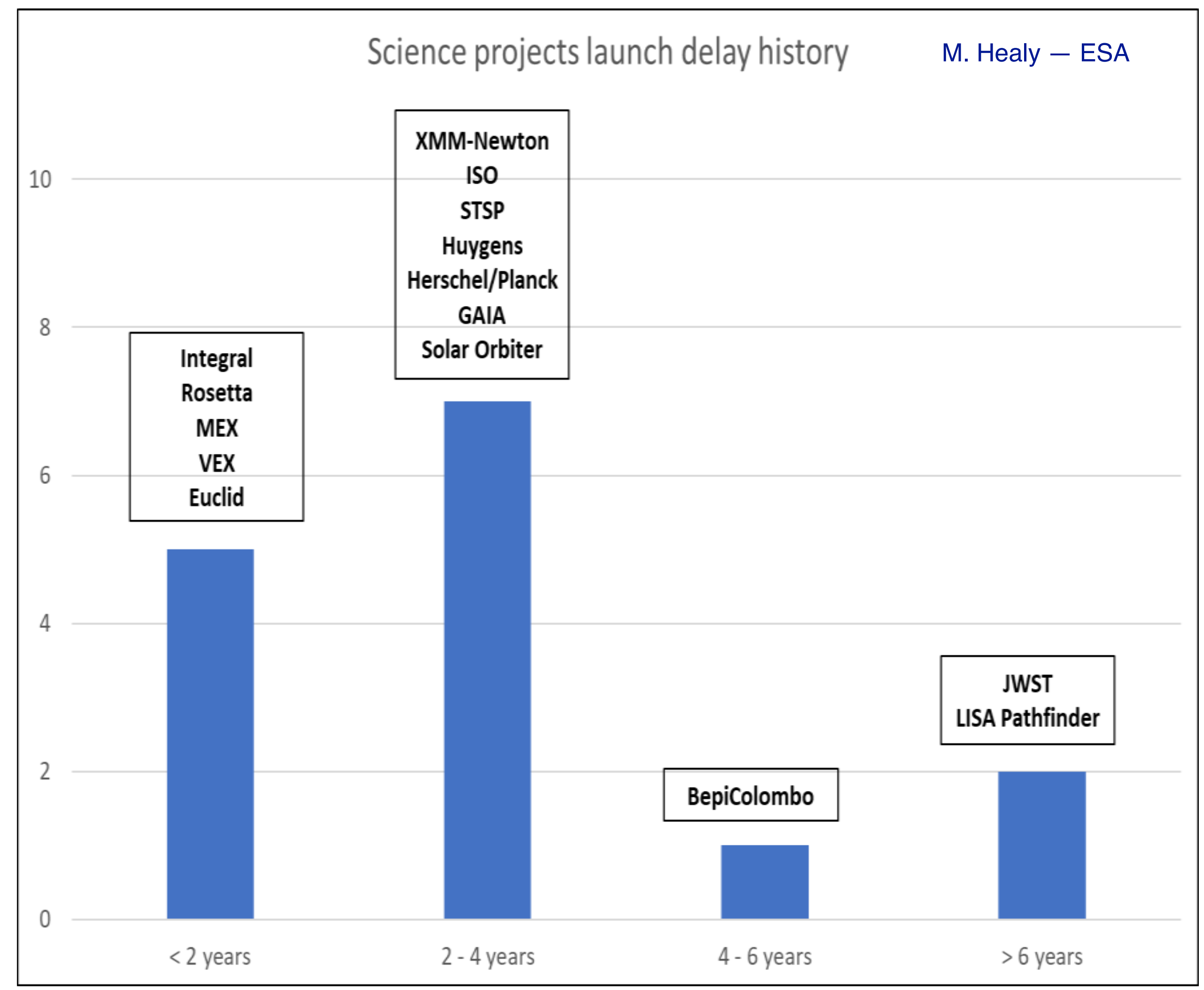
Problems:

- *competition from ground (and space too!)*
- *technical aspects (imaging + spectroscopy)*
- *costs*
- *huge data flow and complex analysis*
- *USA ?*

2009

R. Scaramella SKADS Limelette Nov 2009

Now launch ≥ 2021



Here highlight just a few items, mostly related to Euclid (i.e. no EOR)

Vey recent and comprehensive work (e.g. ask Stefano Camera or Matteo Viel)

Cosmology with Phase 1 of the Square Kilometre Array

Red Book 2018: Technical specifications and performance forecasts

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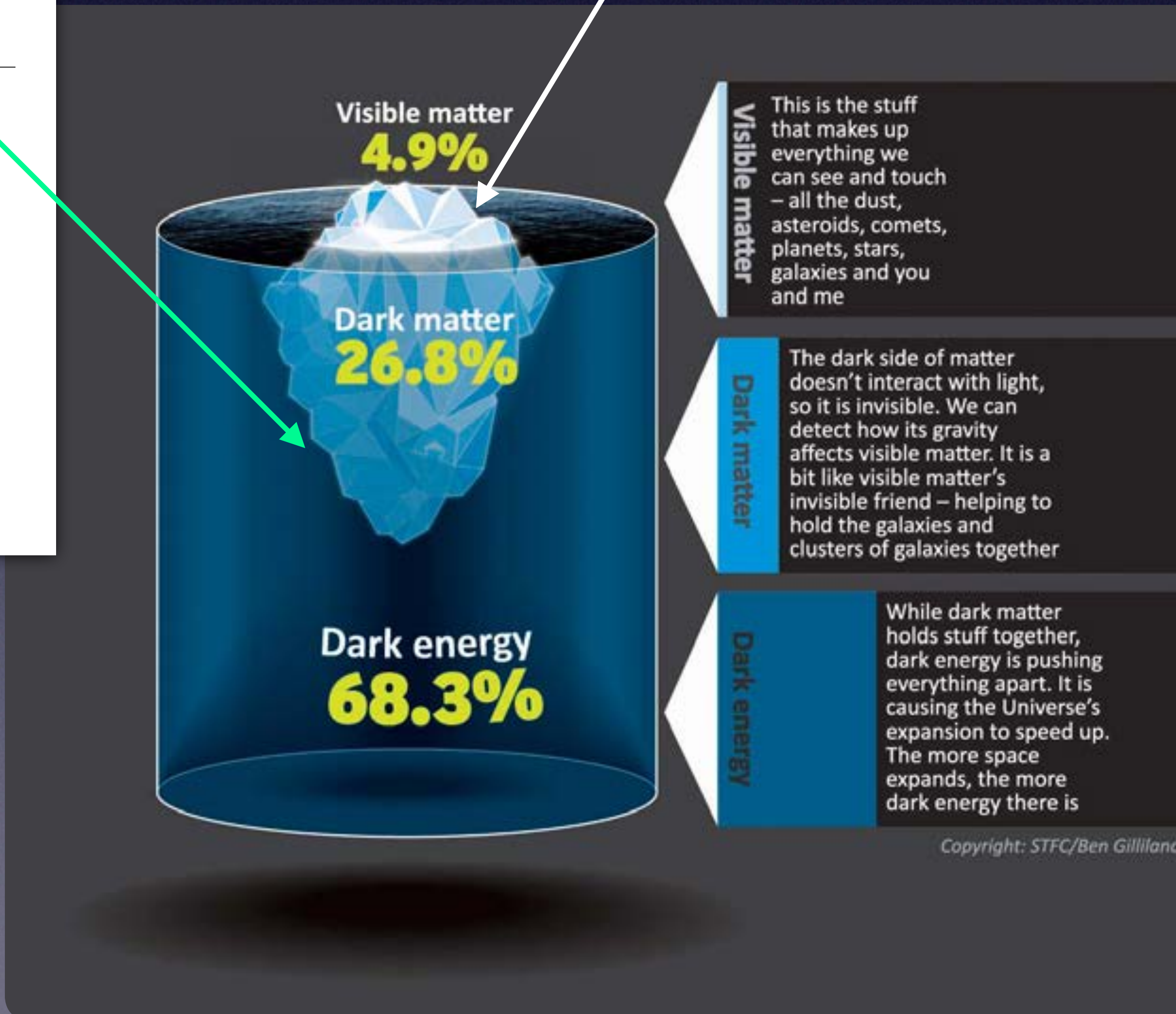
Square Kilometre Array Cosmology Science Working Group: David J. Bacon[1], Richard A. Battye[2,*], Philip Bull[3], Stefano Camera[4,5,6,2], Pedro G. Ferreira[7], Ian Harrison[2,7], David Parkinson[8], Alkistis Pourtsidou[3], Mário G. Santos[9,10,11], Laura Wolz[12,*], Filipe Abdalla[13,14], Yashar Akrami[15,16], David Alonso[7], Sambatra Andrianomena[9,10,17], Mario Ballardini[9], José Luis Bernal[18,19], Daniele Bertacca[20,36], Carlos A.P. Bengaly[9], Anna Bonaldi[21], Camille Bonvin[22], Michael L. Brown[2], Emma Chapman[23], Song Chen[9], Xuelei Chen[24], Steven Cunnington[1], Tamara M. Davis[26], Clive Dickinson[2], José Fonseca[9,36], Keith Grainge[2], Stuart Harper[2], Matt J. Jarvis[7,9], Roy Maartens[1,9], Natasha Maddox[27], Hamsa Padmanabhan[28], Jonathan R. Pritchard[23], Alvise Raccanelli[18], Marzia Rivi[13,29], Sambit Roychowdhury[2], Martin Sahlén[30], Dominik J. Schwarz[31], Thilo M. Siewert[31], Matteo Viel[32], Francisco Villaescusa-Navarro[33], Yidong Xu[24], Daisuke Yamauchi[34], Joe Zuntz[35]

Affiliations listed after references



The relative abundances of the three presumed constituents of mass-energy in our Universe: visible matter, dark matter, and dark energy (Credit: STFC/Ben Gilliland)

ΛCDM model

Many parameters, lots of Physics

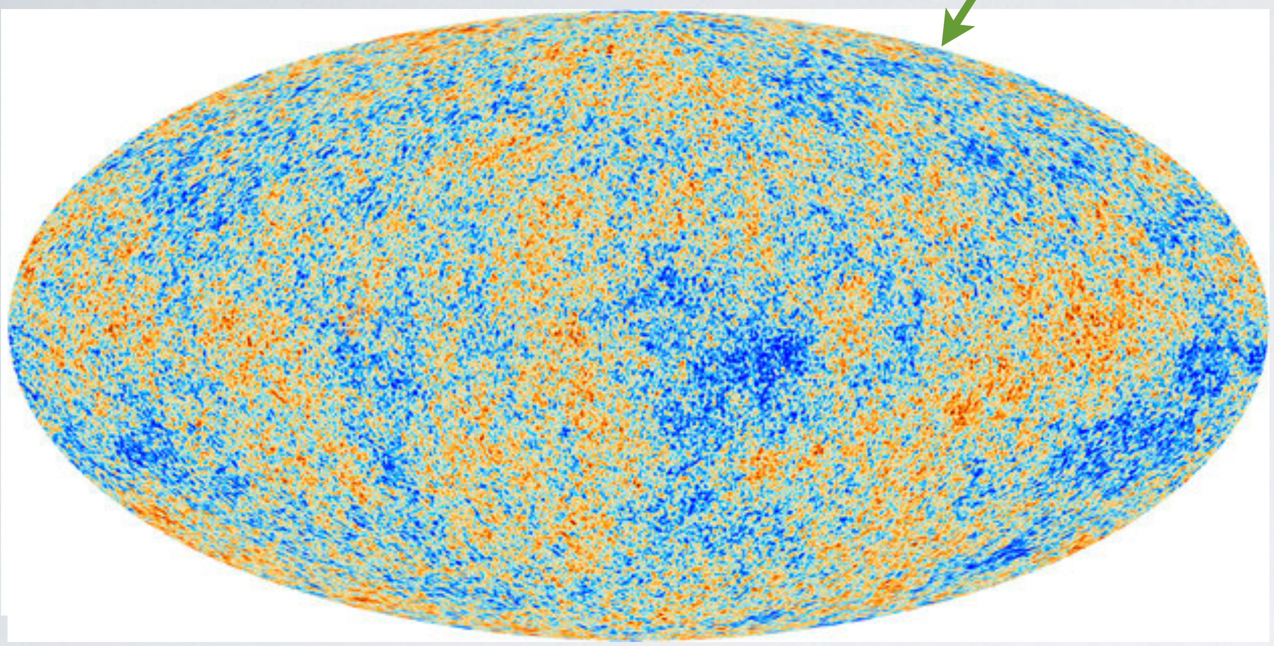
Planck

Planck Collaboration Cosmological parameters[14]

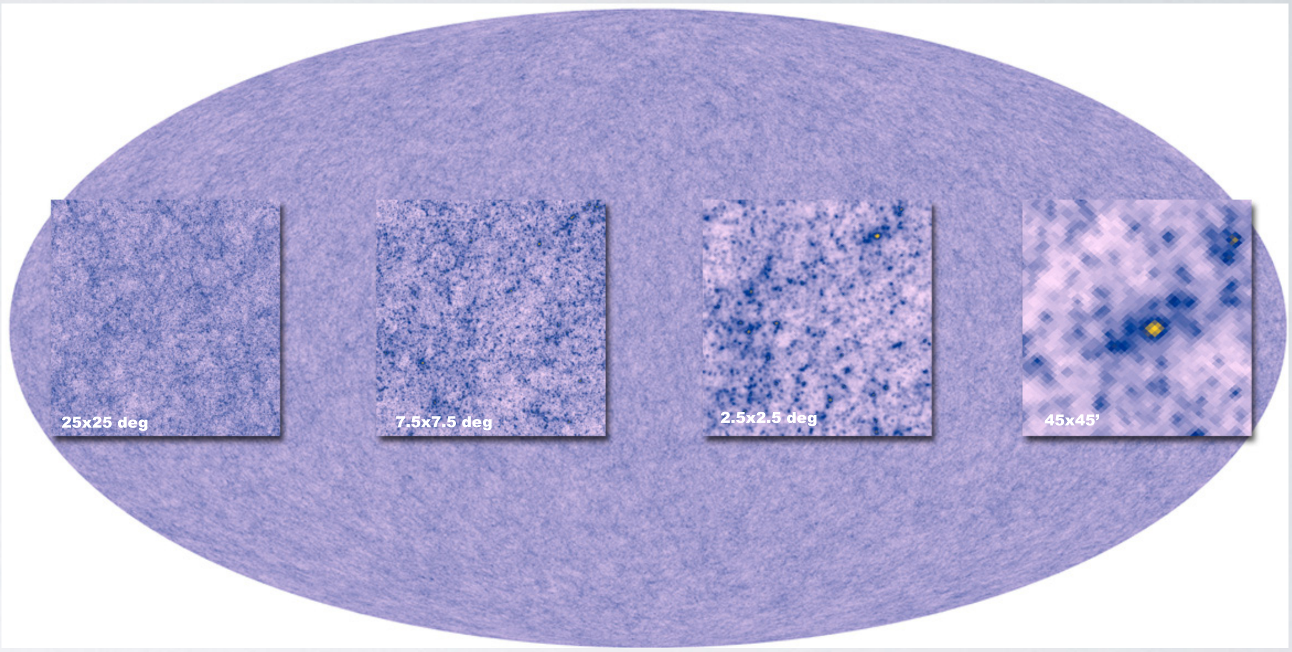
	Description	Symbol	Value
Indepen-dent para-meters	Physical baryon density parameter[a]	$\Omega_b h^2$	0.022 30 ±0.000 14
	Physical dark matter density parameter[a]	$\Omega_c h^2$	0.1188 ±0.0010
	Age of the universe	t_0	13.799 ±0.021 × 10^9 years
	Scalar spectral index	n_s	0.9667 ±0.0040
	Curvature fluctuation amplitude, $k_0 = 0.002\ \mathrm{Mpc}^{-1}$	Δ_R^2	$2.441^{+0.088}_{-0.092} \times 10^{-9}$[17]
	Reionization optical depth	τ	0.066 ±0.012
Fixed para-meters	Total density parameter[b]	Ω_{tot}	1
	Equation of state of dark energy	w	−1
	Sum of three neutrino masses	Σm_ν	0.06 eV/c^2[c][13]:40
	Effective number of relativistic degrees of freedom	N_{eff}	3.046[d][13]:47
	Tensor/scalar ratio	r	0
	Running of spectral index	$d\,n_s / d\ln k$	0
Calcu-lated values	Hubble constant	H_0	67.74 ±0.46 km s^{-1} Mpc^{-1}
	Baryon density parameter[b]	Ω_b	0.0486 ±0.0010[e]
	Dark matter density parameter[b]	Ω_c	0.2589 ±0.0057[f]
	Matter density parameter[b]	Ω_m	0.3089 ±0.0062
	Dark energy density parameter[b]	Ω_Λ	0.6911 ±0.0062
	Critical density	ρ_{crit}	(8.62 ±0.12) × 10^{-27} $\mathrm{kg/m^3}$[g]
	Fluctuation amplitude at $8h^{-1}$ Mpc	σ_8	0.8159 ±0.0086
	Redshift at decoupling	z_*	1 089.90 ±0.23
	Age at decoupling	t_*	377 700 ±3200 years[17]
	Redshift of reionization (with uniform prior)	z_{re}	$8.5^{+1.0}_{-1.1}$[18]

Parameter values listed below are from the Planck Collaboration Cosmological parameters 68% confidence limits for the base ΛCDM model from Planck CMB power spectra, in combination with lensing reconstruction and external data (BAO+JLA+H_0).[13] See also Planck (spacecraft).

Synergy with Planck: Universe @z~1000 vs @z~1-3



R. Teyssier et al.: Full-sky weak-lensing simulation with 70 billion particles



WL sims: <1" pixels

Most of the DE effects happen at z < 3

Need also <u>dynamics</u> to further disentagle

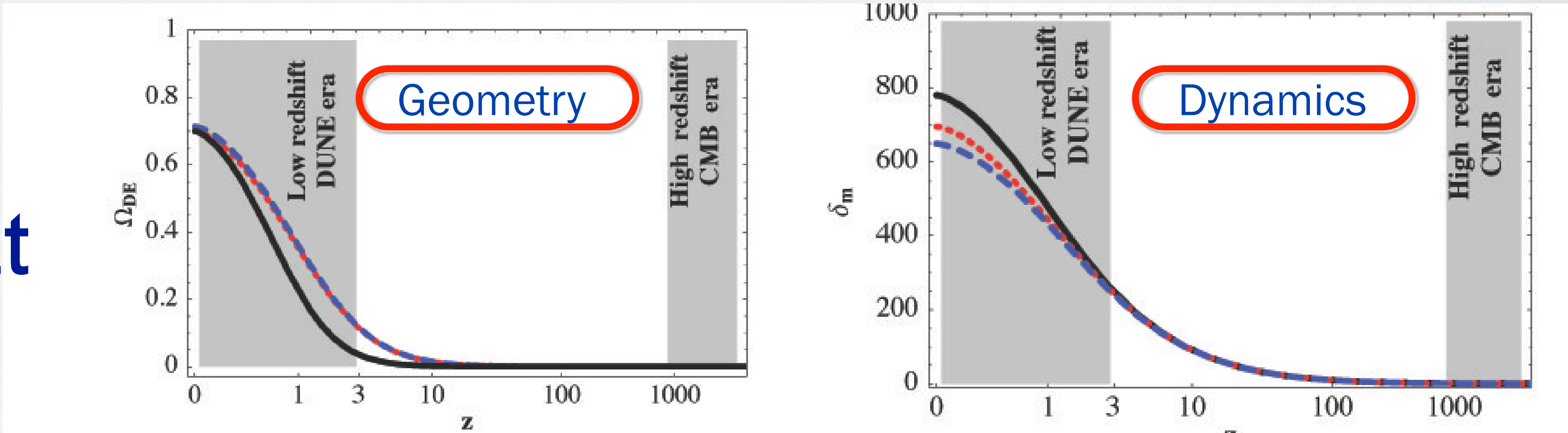


Figure C.1: *Effect of dark energy on the evolution of the Universe.* ***Left:*** *Fraction of the density of the Universe in the form of dark energy as a function of redshift z., for a model with a cosmological constant (w=-1, black solid line), dark energy with a different equation of state (w=-0.7, red dotted line), and a modified gravity model (blue dashed line). In all cases, dark energy becomes dominant in the low redshift Universe era probed by DUNE, while the early Universe is probed by the CMB.* ***Right:*** *Growth factor of cosmic structures for the same three models. Only by measuring the geometry (left panel) and the growth of structure (right panel) at low redshifts can a modification of dark energy be distinguished from that of gravity. Weak lensing measures both effects.*

Does gravity follow standard G.R.? Need experiments with high sensitivity/precision....

(cf. L. Amendola, M. Kuntz, et al Theory SWG, Living reviews)

The most general (linear, scalar) metric at first-order

$$ds^2 = a^2[(1+2\Psi)dt^2 - (1+2\Phi)(dx^2+dy^2+dz^2)]$$

Weak limit

At the linear perturbation level and sub-horizon scales

Full metric reconstruction at first order requires 3 functions

$$H(z) \quad \Phi(k,z) \quad \Psi(k,z)$$

- modified Poisson's equation $\quad k^2\Psi = -4\pi G a^2 Q(k,a)\rho_m\delta_m$
- non-zero anisotropic stress $\quad \eta(k,a) = \dfrac{\Phi+\Psi}{\Psi}$

std matter

$$G_{\mu\nu} = -8\pi G T_{\mu\nu} - Y_{\mu\nu}$$

Std gravity,

new matter

$$Y_{\mu\nu} = X_{\mu\nu} - G_{\mu\nu}$$

New gravity,

std matter

$$X_{\mu\nu} = -8\pi G T_{\mu\nu}$$

$$T^{\nu}_{\mu\,;\nu} = 0.$$

Modified Gravity at linear level

▪ standard gravity	$Q(k,a)=1$ $\eta(k,a)=0$	
▪ scalar-tensor models	$Q(a)=\dfrac{G^*}{FG_{cav,0}}\dfrac{2(F+F'^2)}{2F+3F'^2}$ $\eta(a)=\dfrac{F'^2}{F+F'^2}$	Boisseau et al. 2000 Acquaviva et al. 2004 Schimd et al. 2004 L.A., Kunz &Sapone 2007
▪ f(R)	$Q(a)=\dfrac{G^*}{FG_{cav,0}}\dfrac{1+4m\frac{k^2}{a^2R}}{1+3m\frac{k^2}{a^2R}},\quad \eta(a)=\dfrac{m\frac{k^2}{a^2R}}{1+2m\frac{k^2}{a^2R}}$	Bean et al. 2006 Hu et al. 2006 Tsujikawa 2007
▪ DGP	$Q(a)=1-\dfrac{1}{3\beta};\quad \beta=1+2Hr_c w_{DE}$ $\eta(a)=\dfrac{2}{3\beta-1}$	Lue et al. 2004; Koyama et al. 2006
▪ coupled Gauss-Bonnet	$Q(a)=...$ $\eta(a)=...$	see L. A., C. Charmousis, S. Davis 2006

Galaxies, BAO **COMPLEMENTARITY** **Photons, WL**

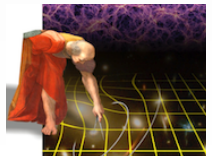
massive particles respond to Ψ

massless particles respond to Φ-Ψ

Need to break degeneracy: *use growth of fluctuations*

$$\delta''+(1+\frac{H'}{H})\delta = \frac{k^2}{a^2}\Psi$$

$$\alpha = \int \nabla_{perp}(\Psi-\Phi)dz$$



Recall a few basics

$$H^2(a) \equiv \left(\frac{\dot{a}}{a}\right)^2 = H_0^2\left[\Omega_m a^{-3} + \Omega_r a^{-4} + \Omega_k a^{-2} + \Omega_X a^{-3(1+w)}\right]$$

Evolution governed by components: H(z) ⇔ Ω_X, w

$$H^2(a) = H_0^2\left[\Omega_R a^{-4} + \Omega_M a^{-3} + \Omega_k a^{-2} + \Omega_{DE}\exp\left\{3\int_a^1 \frac{da'}{a'}[1+w(a')]\right\}\right]$$

Ellipses: uncertainty in parameters via Fisher matrix. An useful *approximation* (curse of dimensionality; also different definitions). Importance of ***Priors***

Usually use Figure of Merit= 1/Area

FoM= 1/(Δw_0 x Δw_a)

$a=(1+z)^{-1}$ expansion factor

δ = density fluctuation

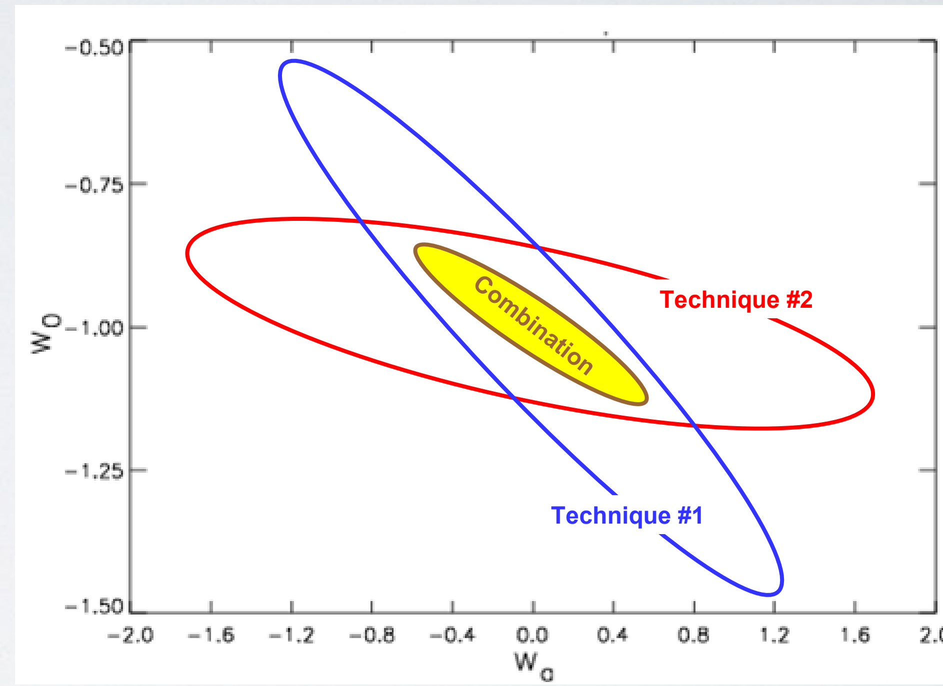
P(k) = power spectrum of $\delta(\mathbf{x},z)$

w = p/ϱ, γ=growth index

$$f_{\rm GR}(z) \equiv \frac{d\ln G_{\rm GR}}{d\ln a} \approx [\Omega_m(z)]^\gamma$$

w(z)=w_0 +w_a (1-a)

Λ: w_0= -1 , w_a =0 , γ~0.55



to get a small uncertainty on power spectrum need:

$$\frac{\sigma}{P} = \sqrt{\frac{2}{n_{\rm modes}}}\left(1+\frac{1}{P\bar{n}}\right)$$

accurate/adequate sampling in number of objects

large volumes to accomodate several Fourier modes

Cosmic Variance ⇔ Volume

Poisson ⇔ Number of galaxies

[un]known systematics

Some among the possible AREAS of interest to you (incomplete list)

- Data contamination pbs
- Photoz
- Removal/model of instrument signatures
- Simulations & replicas
- Measurements (noisy, incomplete)
- Interpretation
  - cosmic rays
  - Point Spread Function
  - redshift, ellipticity (methods & biases)
  - shear fields, power spectra
  - Figure of Merit, Fisher and beyond

Systematics is the new frontier !!

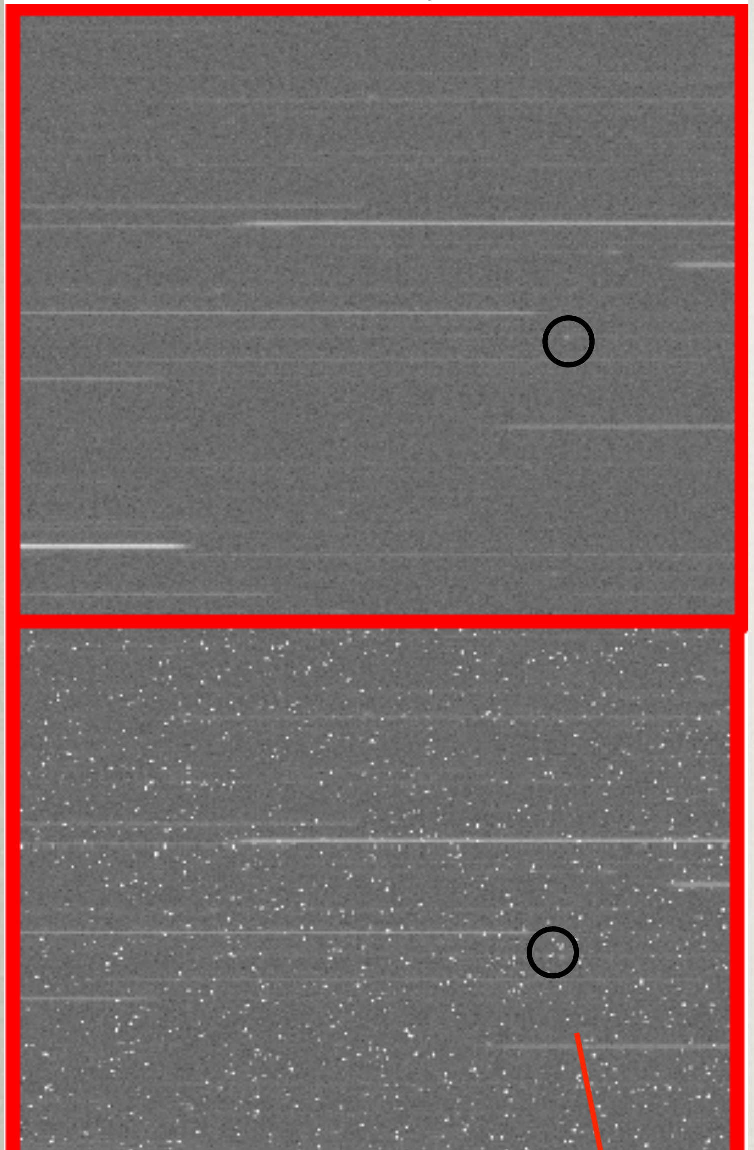
Need different probes and different experiments

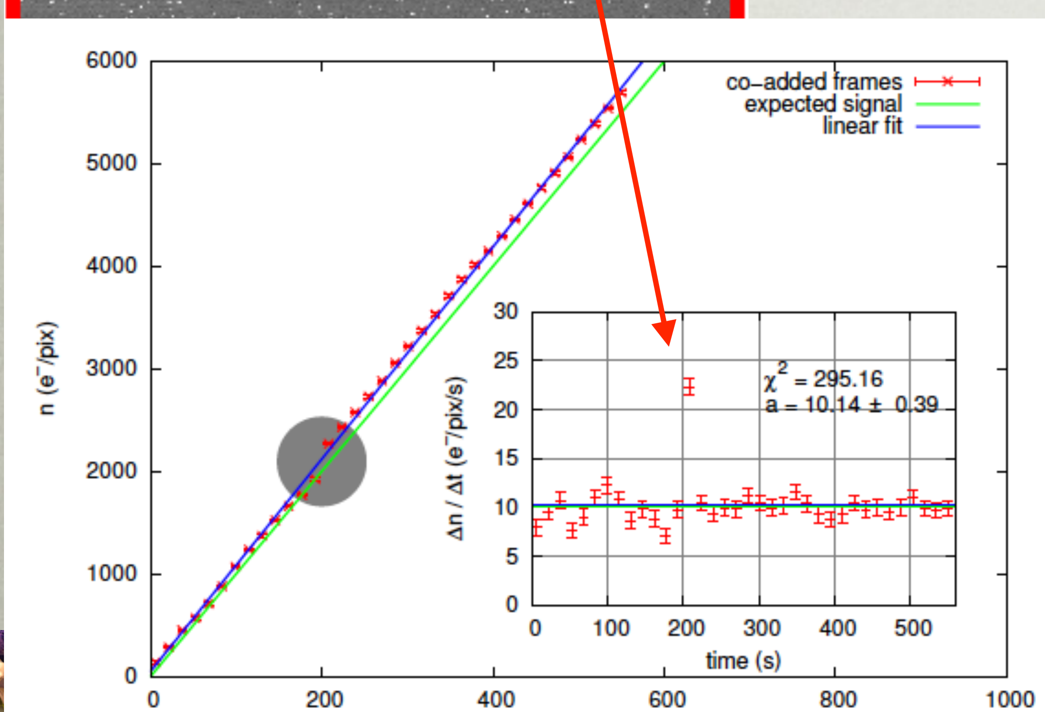
A few examples .... (FOOD FOR THOUGHT)

Cosmic rays

M. Cropper, A. Ealet, K. Jahnke, S. Niemi

NIR array





CCD

CCD woes

R. Massey & VIS team

Moreover: Charge Transfer Inefficiency modifies shapes! need to reconstruct

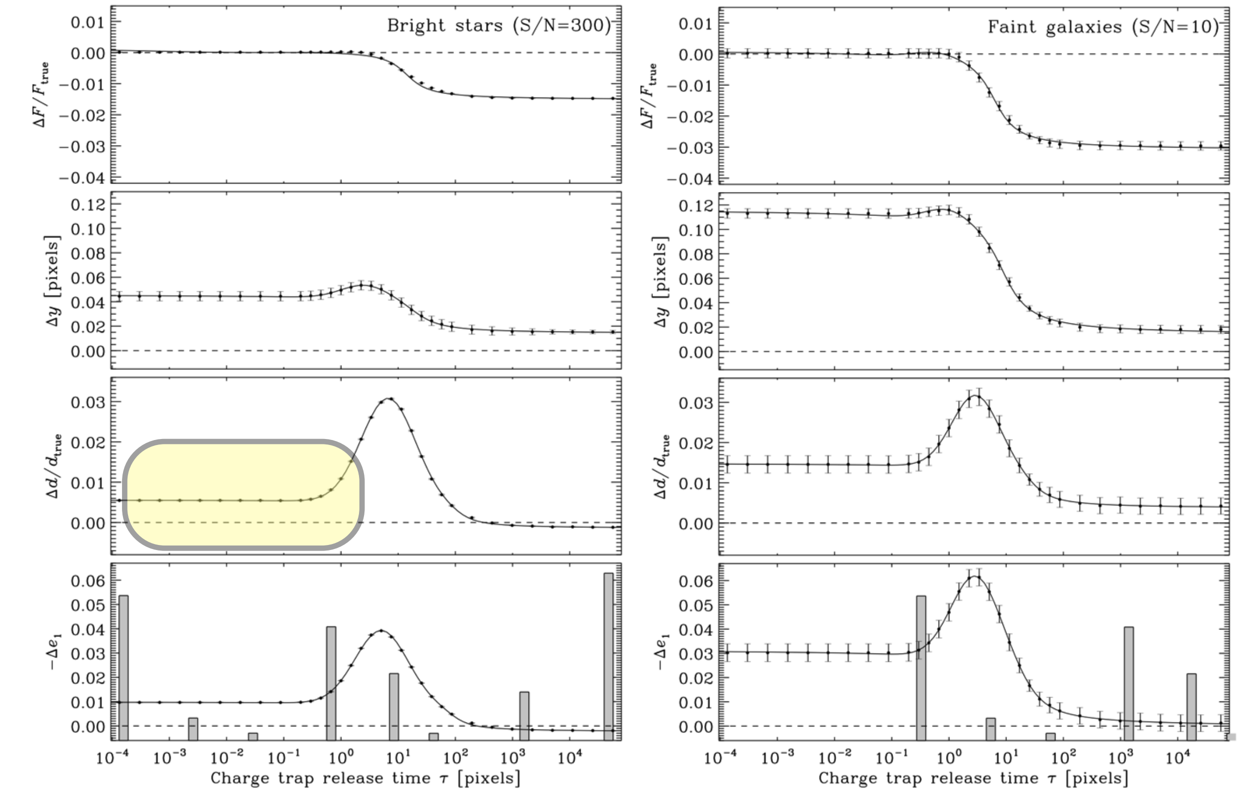
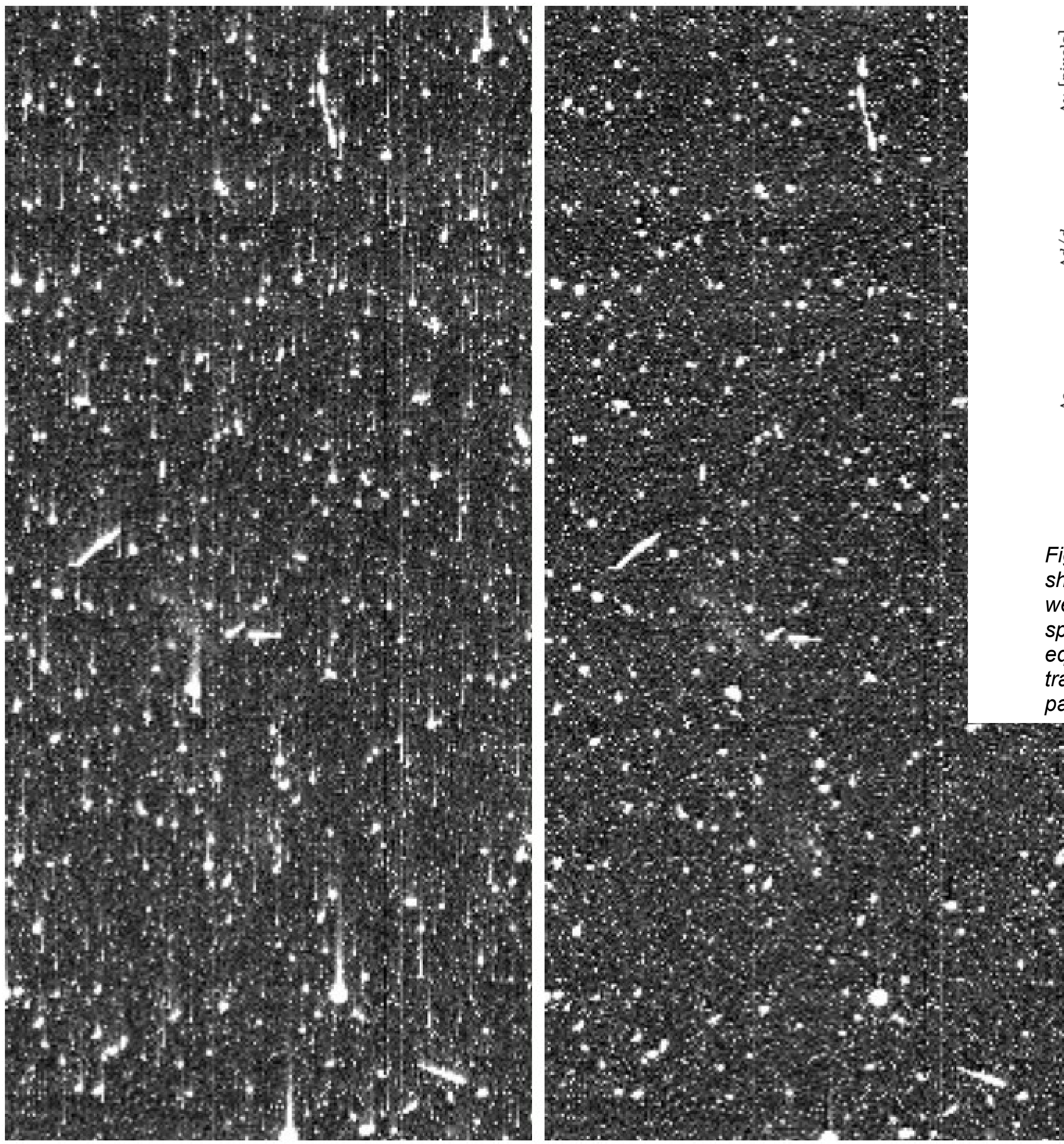


Figure 34 The degradation due to CTI on measurements of flux, astrometry, size and ellipticity. The curves show the response to different trap species of a bright star (left panel) or a faint galaxy (right panels), if there were an (arbitrarily chosen) trap density of 1 trap per pixel. The x axis is the release time of the charge trap species, in multiples of the CCD readout clock speed such that a temporal delay of one clock cycle is equivalent to a spatial displacement of 1 pixel. The histograms in the bottom panels show the population of trap species in CCD204 detectors as a function of their characteristic release time in the same units, for parallel readout (left panel) and serial readout (right panel).

Trails



gure 35 Left: Real image from the Hubble Space Telescope, eight years after launch, showing charge iiling due to CTI. Right: The same image after correction using software like that planned for Euclid. The garithmic colour scale in the images has been chosen to enhance the visibility of the charge trailing. Note at the cosmic ray event trails correctly remain in the right hand image.

For gravitational lensing need to know very well the Point Spread Function (blurring of images):

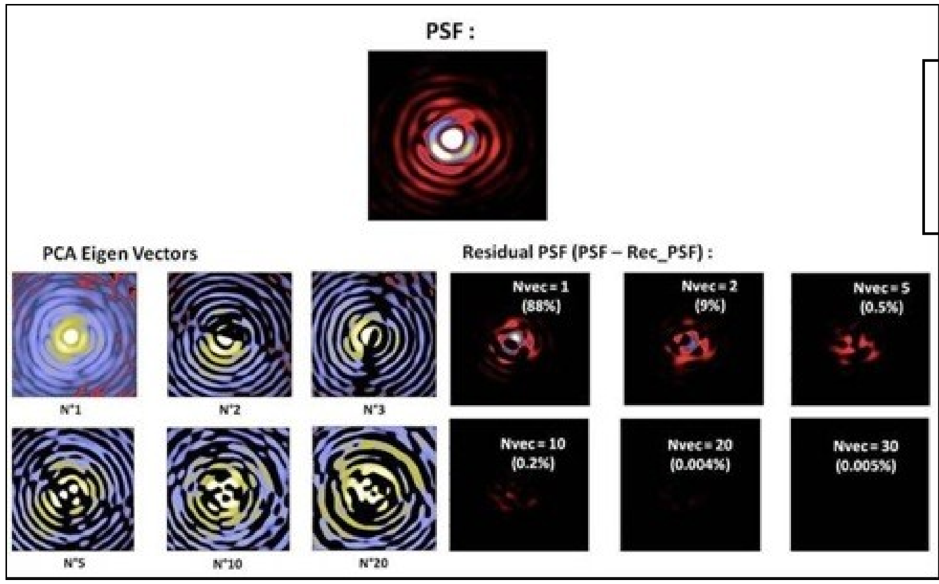


Figure 39: VIS PSF eigenvectors and residuals as a function of number of eigenvectors used in the reconstruction of a given Euclid PSF

L. Miller & VIS team

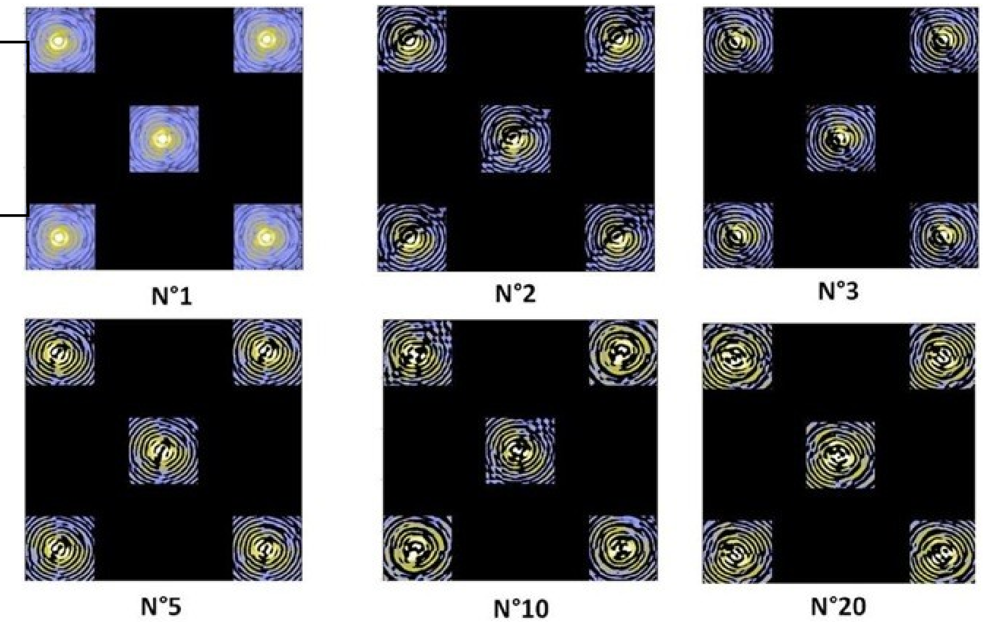


Figure 40: VIS PSF eigenvectors and as a function of number of eigenvectors used in the reconstruction over

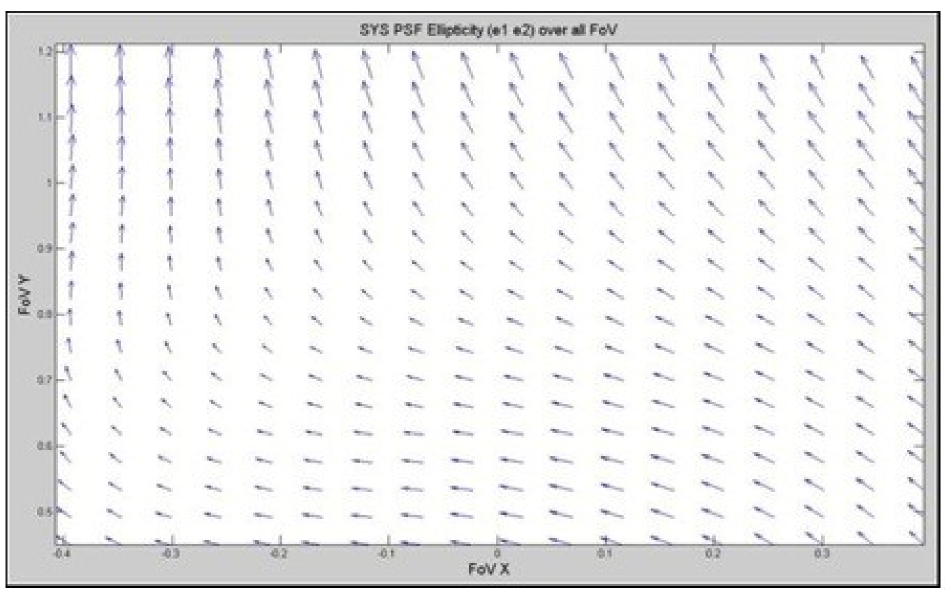
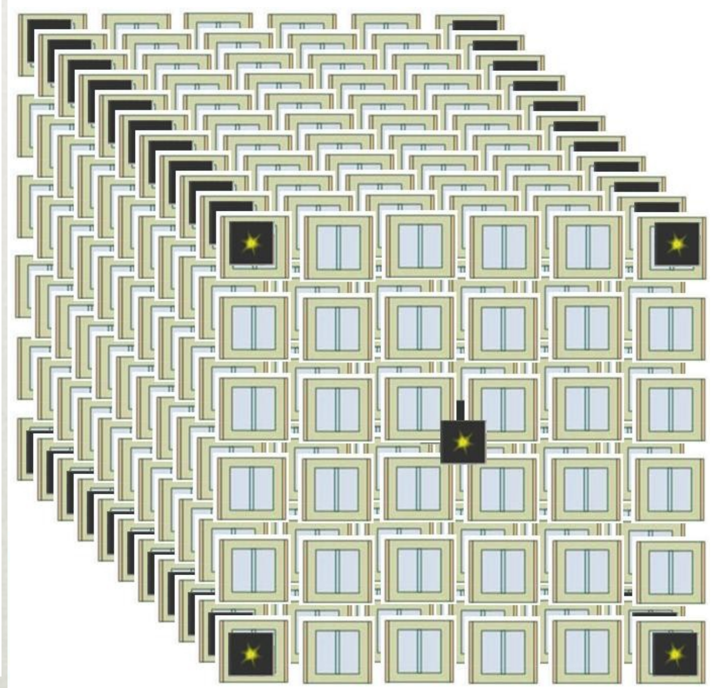
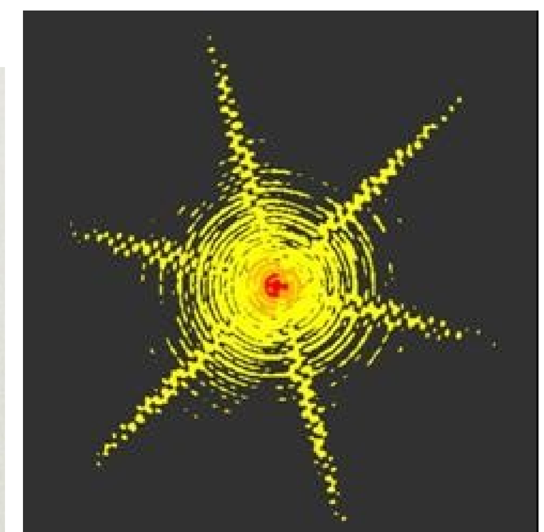
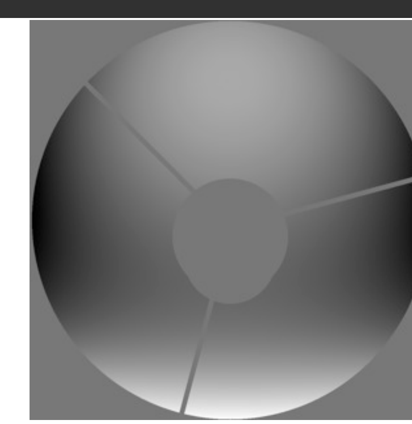


Figure 38: Euclid system VIS PSF ellipticity vector (e1, e2) map over the reference system full FoV





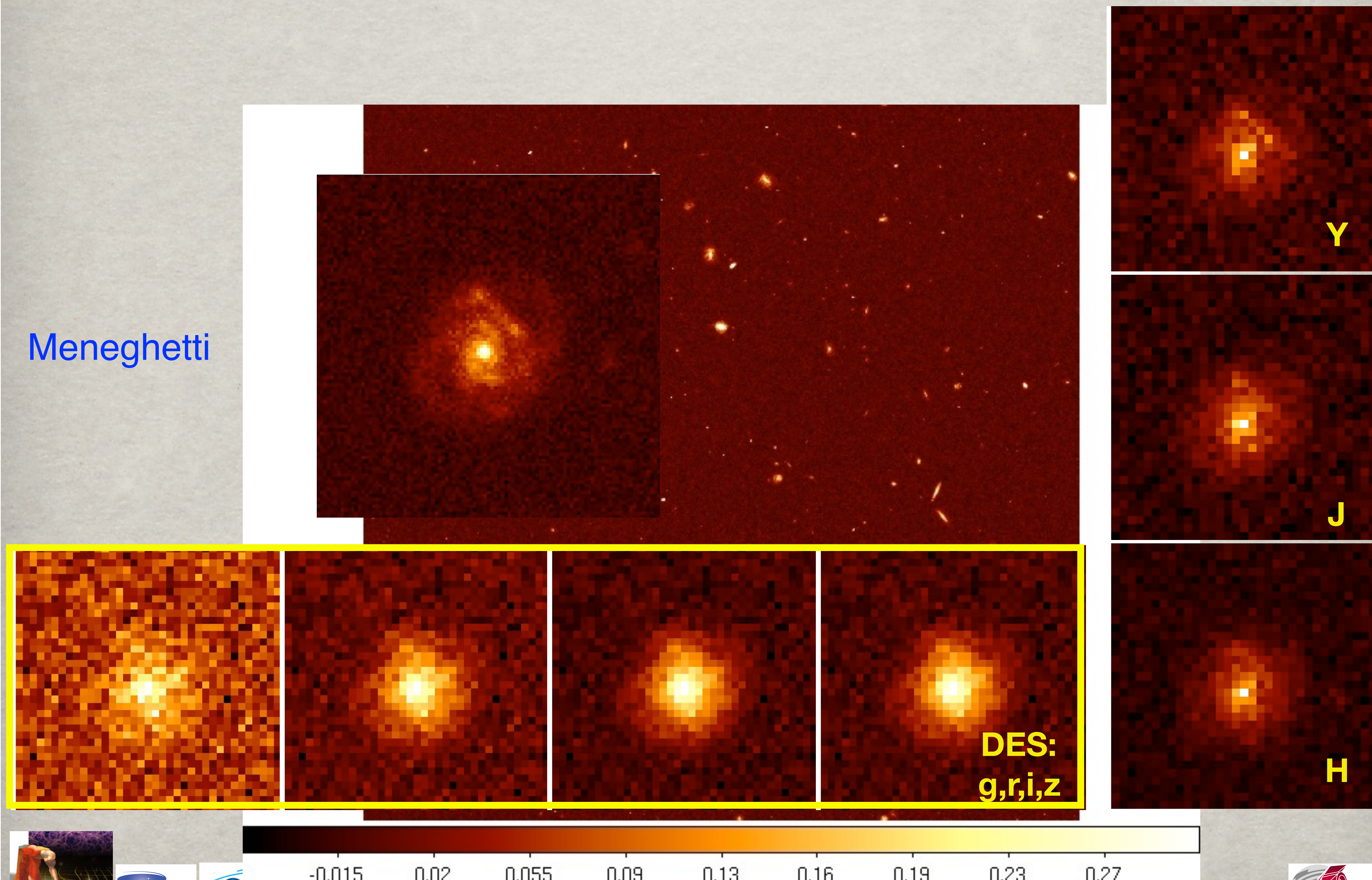


Exit pupil amplitude & phase:
low Zernike-order phase variations

PSF is wavelength (energy) dependent, so is different for blue or red galaxies!!
Also polarisation effects

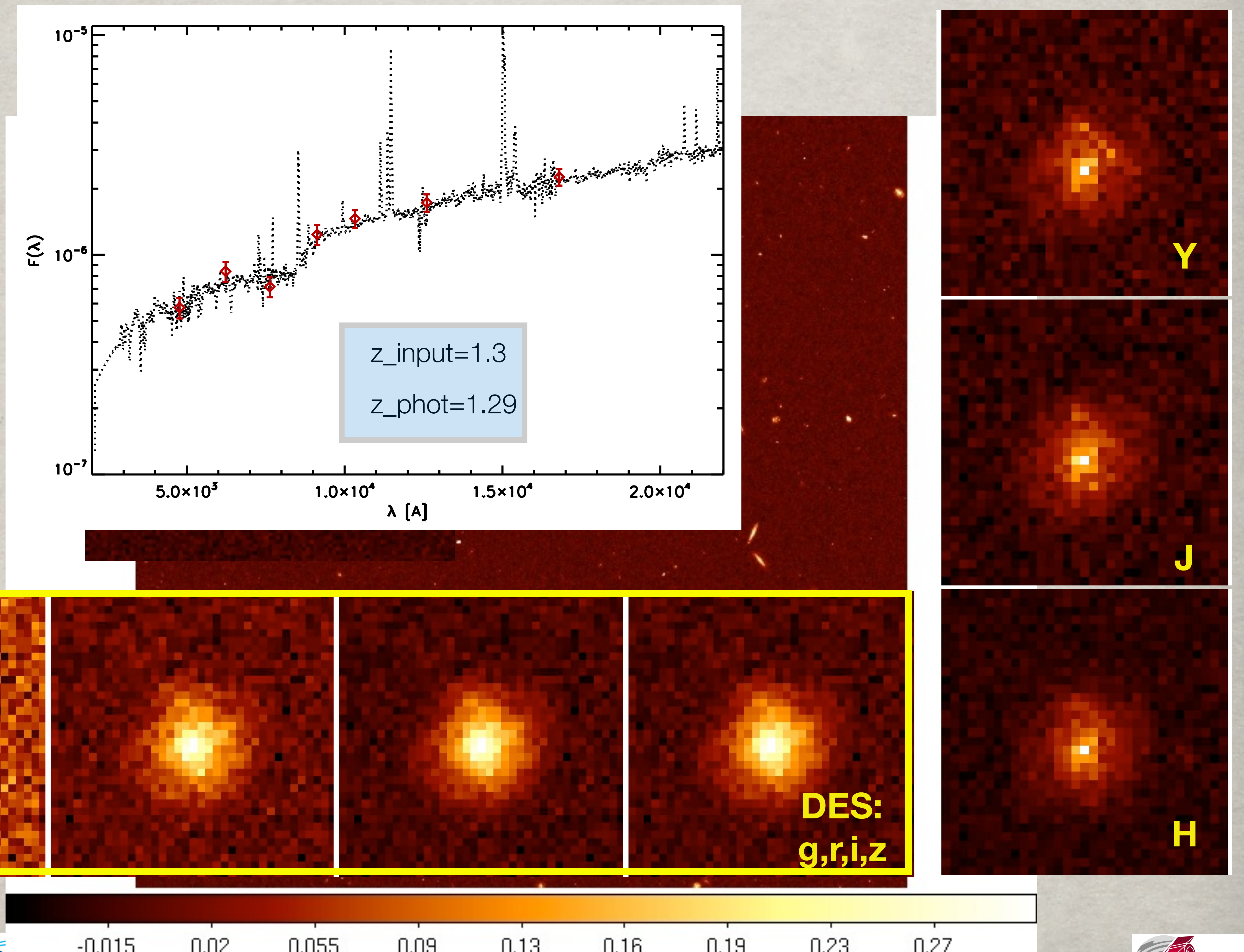
Photoz are crucial, need ground based photometry

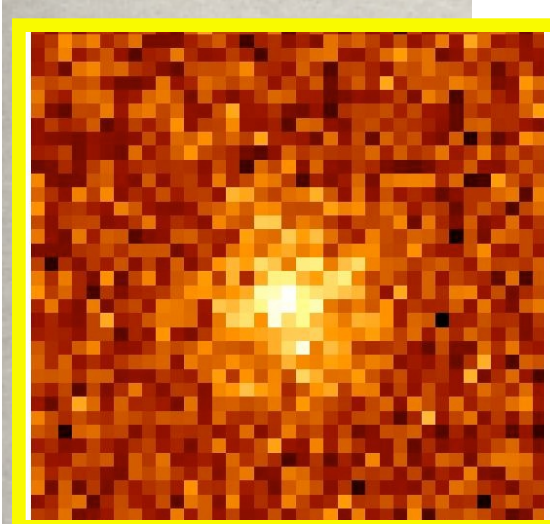
Meneghetti



Photoz are crucial, need ground based photometry

Meneghetti

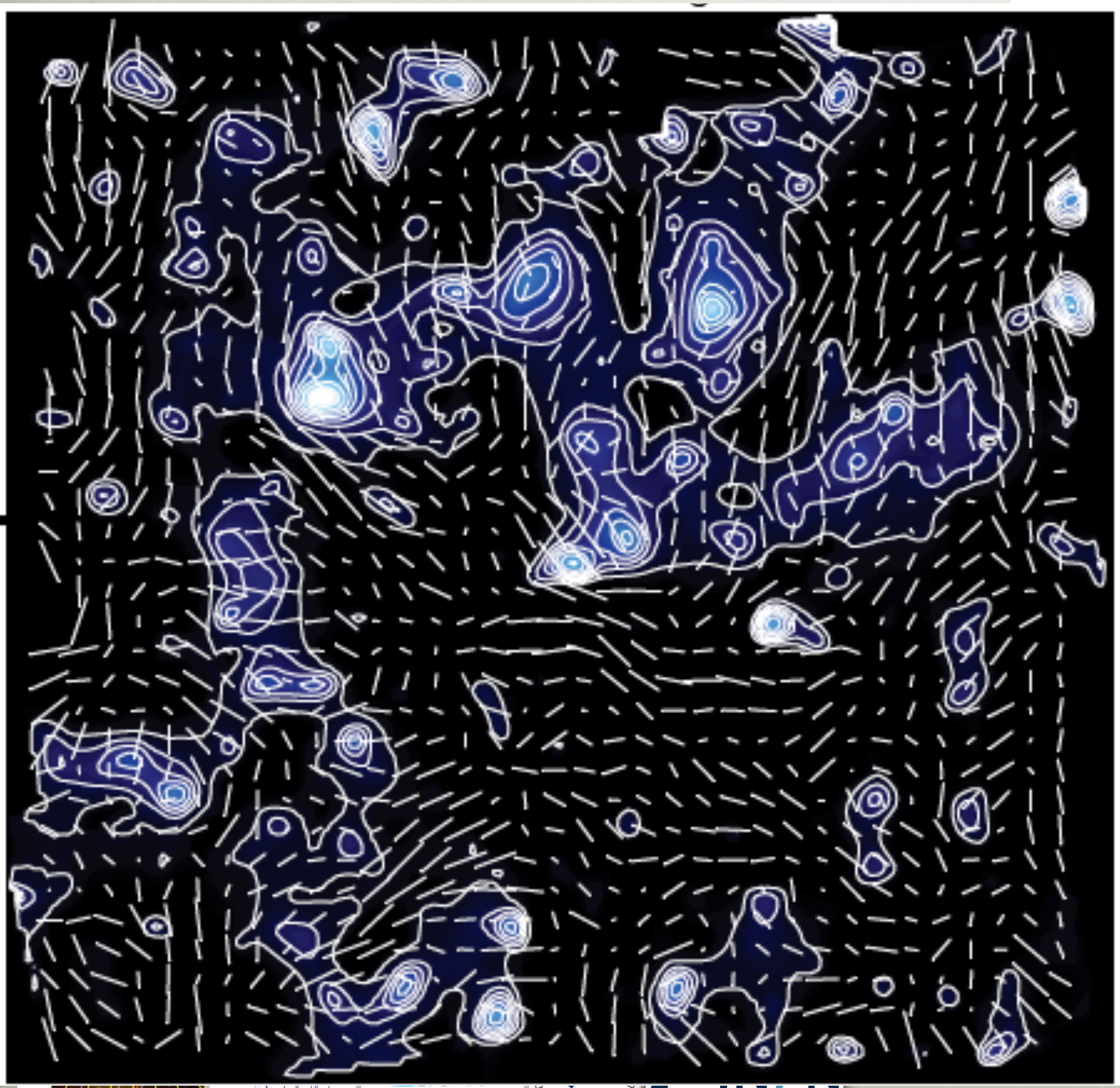




Model systematic effects (holes, boundaries, varying S/N etc)

Weak Lensing
(VIS, WLSWG, OU-SHE)

Shear field



- True two-point correlation function C_{ij} will be affected by additive bias σ^2_{sys} and multiplicative bias M

$$\widehat{C_{ij}} = \left(1+\mathcal{M}^2\right) C_{ij} + \sigma^2_{\rm sys}$$

PSF sizes and ellipticities

$$\mathcal{M} = \sigma[R^2_{\rm PSF}] \left[\frac{1}{R^2_{\rm PSF}} (P^\gamma)^{-1} \left\langle \frac{R^2_{\rm PSF}}{R^2_{\rm gal}} \right\rangle\right] + \sigma[R_{\rm NC}] \left[\frac{1}{R_{\rm obs} - R_{\rm NC}} 2 (P^\gamma)^{-1} \left\langle \frac{R^2_{\rm PSF}}{R^2_{\rm gal}} \right\rangle\right]$$

$$\begin{aligned}\sigma^2_{\rm sys} \quad = \quad & \sigma^2[R^2_{\rm PSF}] \left[\frac{1}{R^4_{\rm PSF}} (P^\gamma)^{-2} \left\langle \frac{R^4_{\rm PSF}}{R^4_{\rm gal}} \right\rangle \langle \varepsilon^2_{\rm PSF} \rangle\right] + \sigma^2[R_{\rm NC}] \left[\frac{1}{(R_{\rm obs} - R_{\rm NC})^2} 4 (P^\gamma)^{-2} \left\langle \frac{R^4_{\rm PSF}}{R^4_{\rm gal}} \right\rangle \langle \varepsilon^2_{\rm PSF} \rangle\right] \\ + \quad & \sigma^2[\varepsilon_{\rm PSF}] \left[2 (P^\gamma)^{-2} \left\langle \frac{R^4_{\rm PSF}}{R^4_{\rm gal}} \right\rangle\right] + \left(\sigma^2[\varepsilon_{\rm NC,1}] + \sigma^2[\varepsilon_{\rm NC,2}]\right) \left[(P^\gamma)^{-2} \left\langle \frac{R^4_{\rm PSF}}{R^4_{\rm gal}} \right\rangle \left\langle \frac{R^4_{\rm obs}}{R^4_{\rm PSF}} \right\rangle\right]\end{aligned}$$

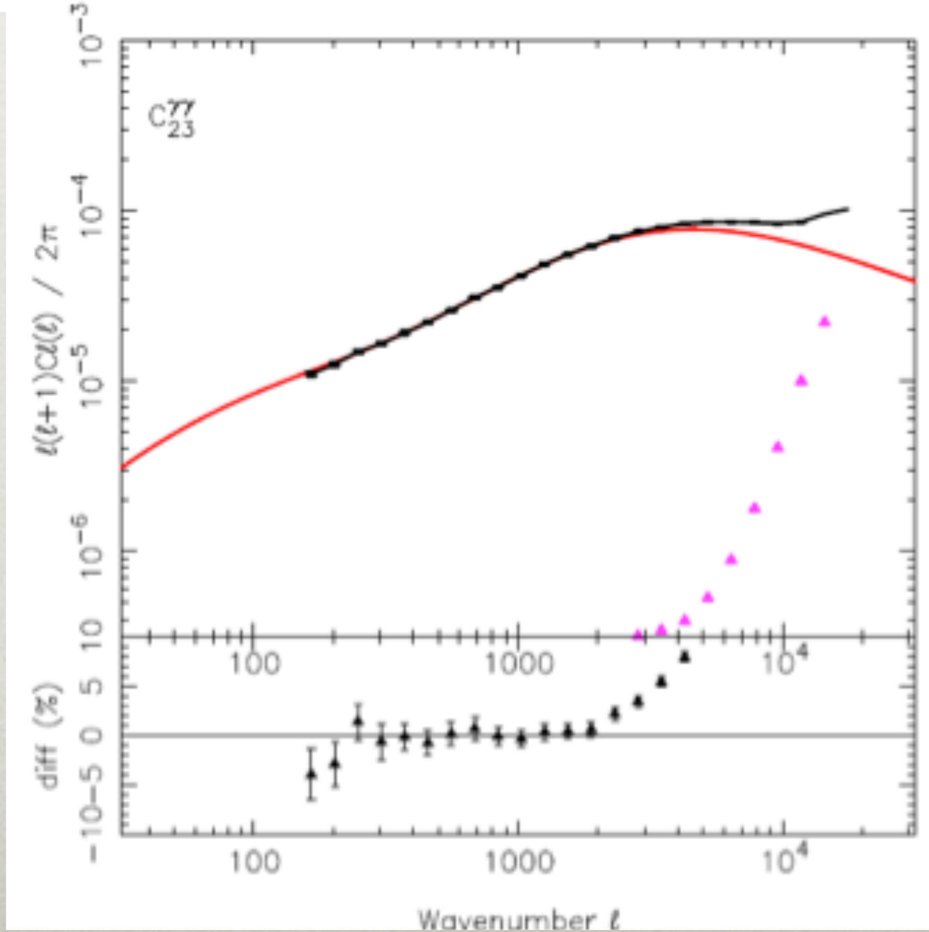
errors in PSF sizes and ellipticities (knowledge)

universe

more simply:

$$\mathcal{M} = \sigma[R^2_{\rm PSF}]\,[m_1] + \sigma[R_{\rm NC}]\,[m_2]$$

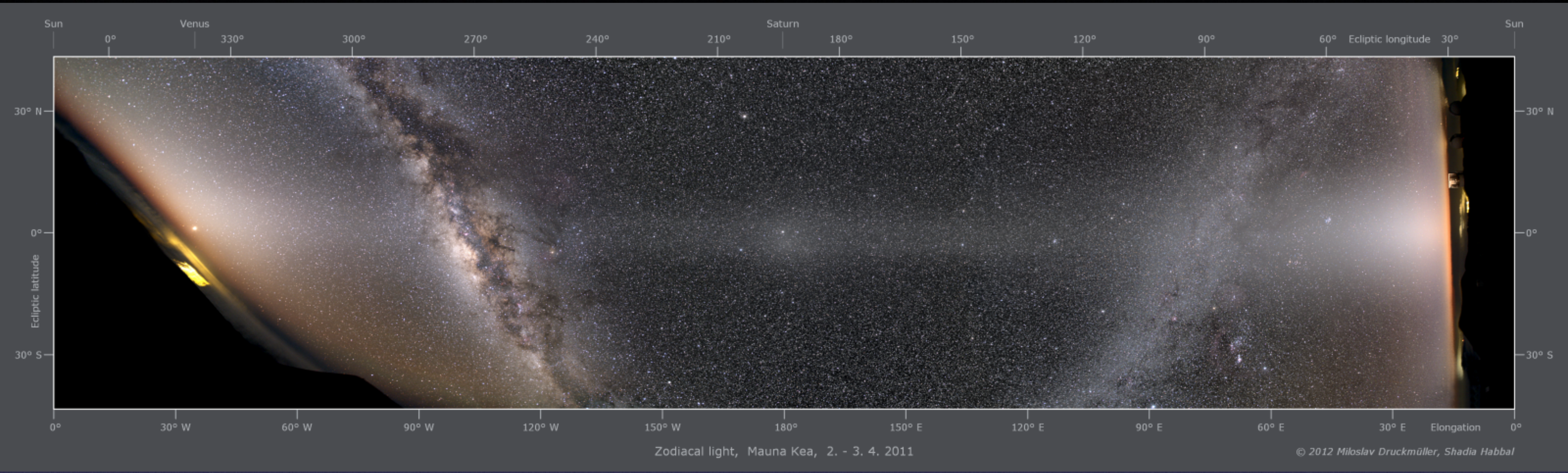
$$\sigma^2_{\rm sys} = \sigma^2[R^2_{\rm PSF}]\,[a_1] + \sigma^2[R_{\rm NC}]\,[a_2] + \sigma^2[\varepsilon_{\rm PSF}]\,[a_3] + \left(\sigma^2[\varepsilon_{\rm NC,1}] + \sigma^2[\varepsilon_{\rm NC,2}]\right)[a_4]$$

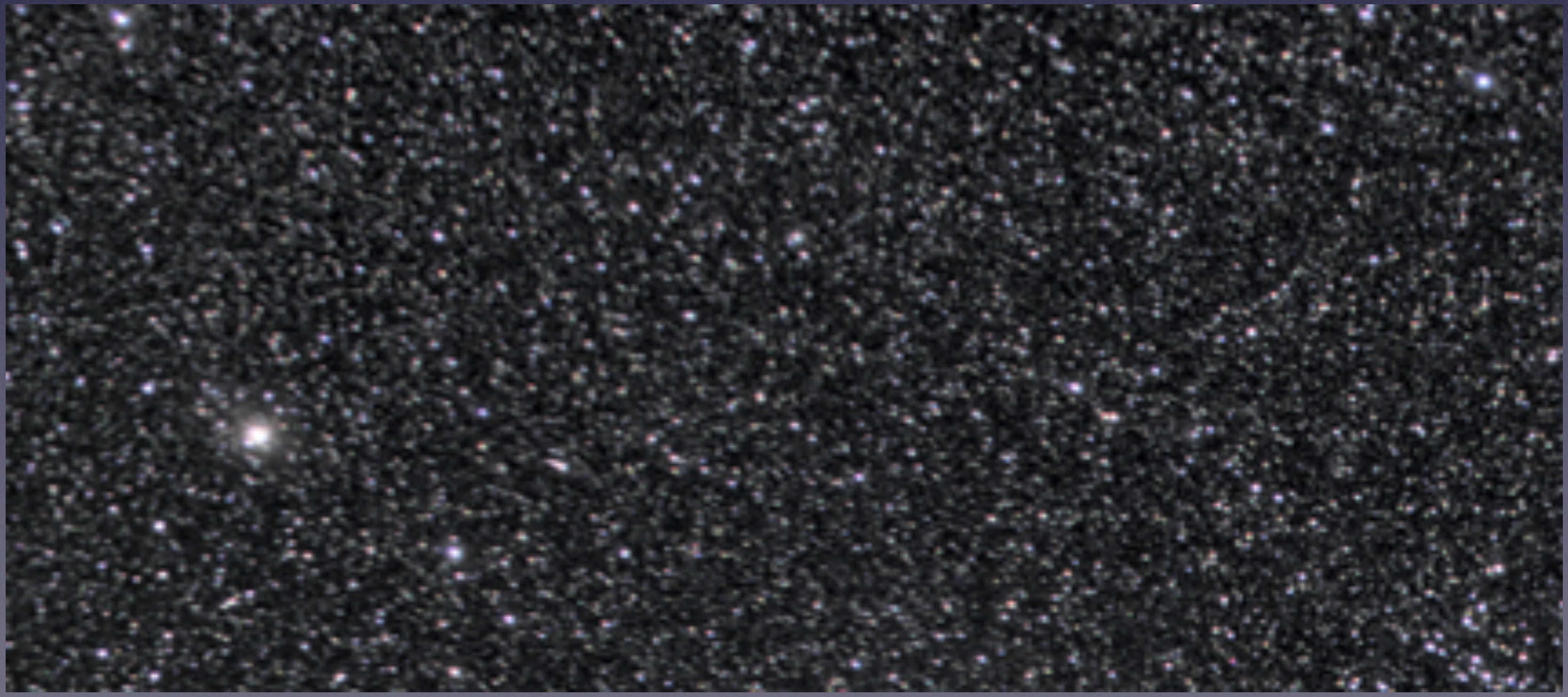


Effects on the angular power spectrum

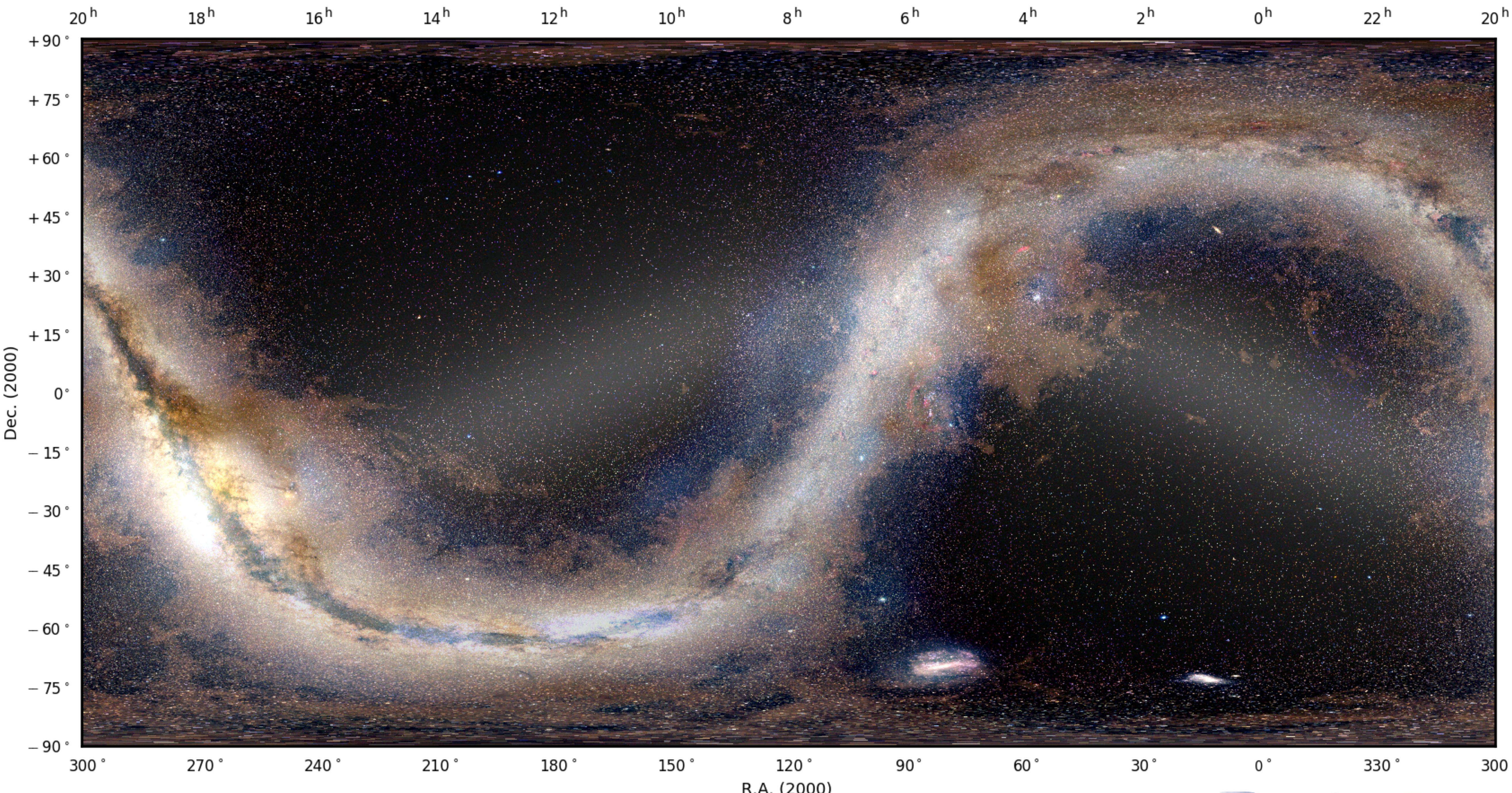
M. Druckmüller, S. Habbal

Zodiacal Light from Mauna kea





J.C. Cuillandre



The entire sky ($4\pi\, sr = 41{,}253\, deg.^2$) in the optical as experienced by Euclid at Lagrangian2

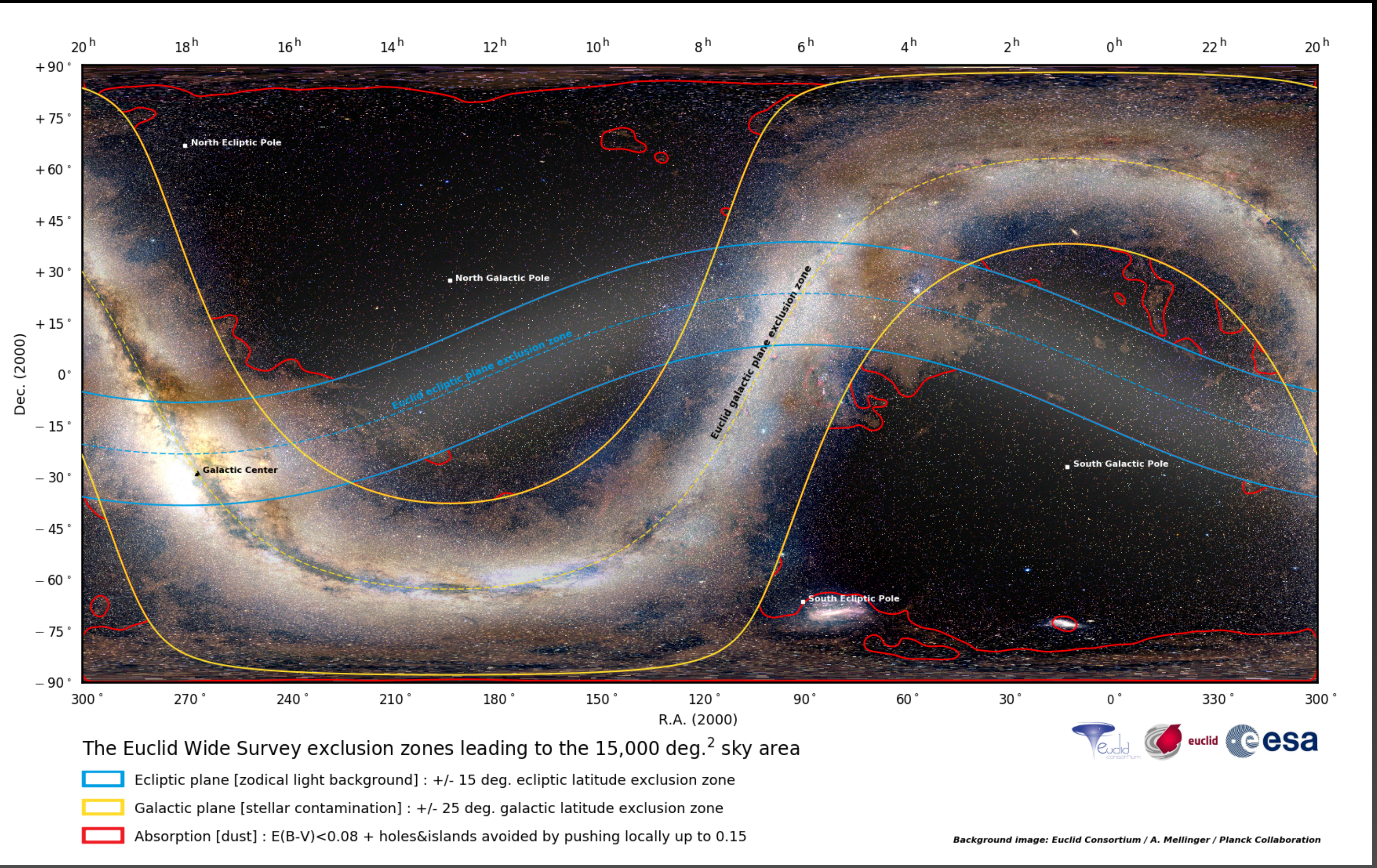
⇒ Representation in equatorial coordinates on an equirectangular projection
⇒ The relative surface brightness of the zodiacal light versus the core galactic plane is respected
⇒ The galactic dust is enhanced up to the Euclid threshold E(B−V)=0.08 for illustration purpose
⇒ The galactic outer stellar disk is enhanced (logarithmic scale)

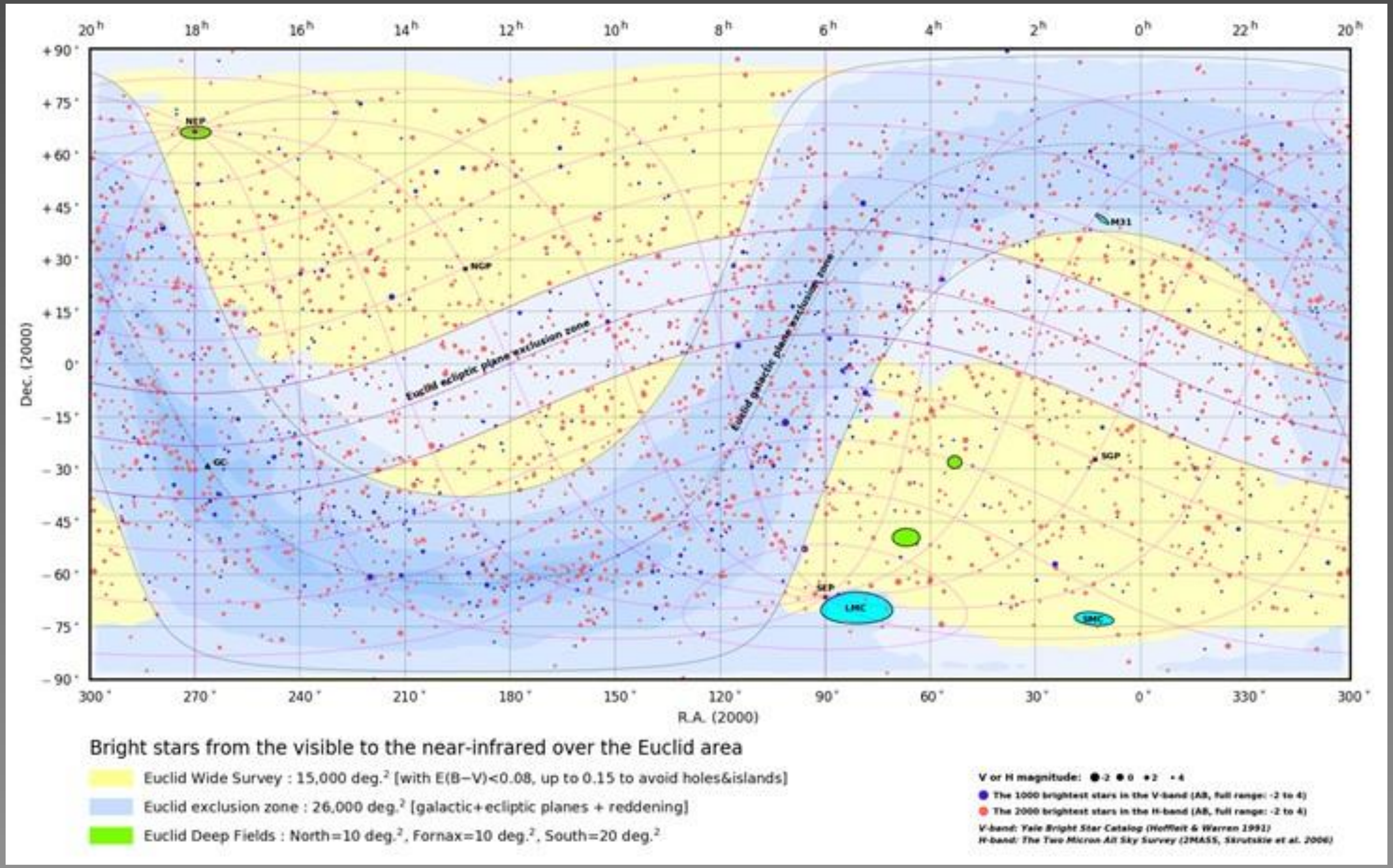
Background image: Euclid Consortium / A. Mellinger / Planck Collaboration

Euclid survey

Plots by J.C. Cuillandre

Galaxy diffuse effects on the sky [dust, MW plane, zodiacal]

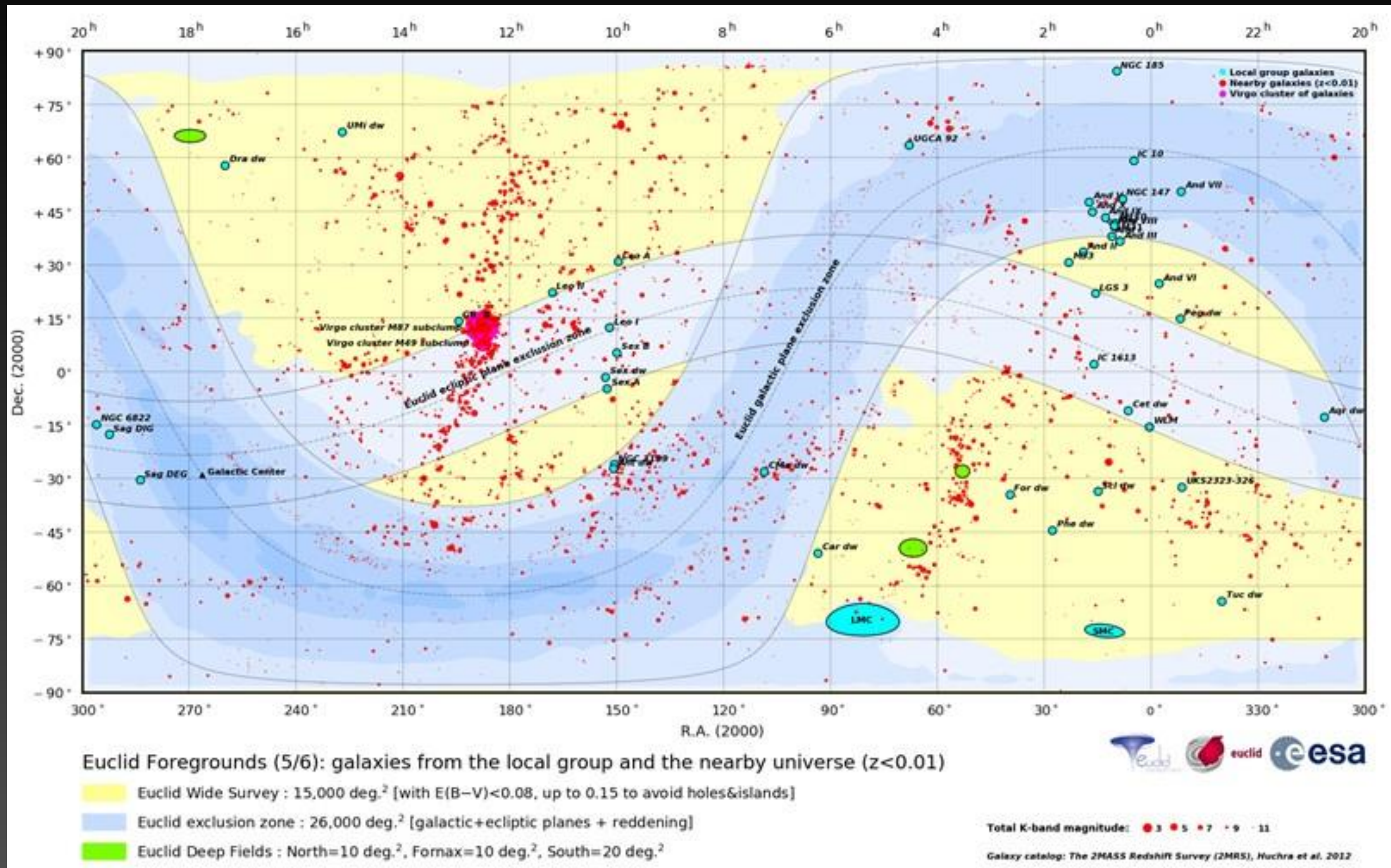




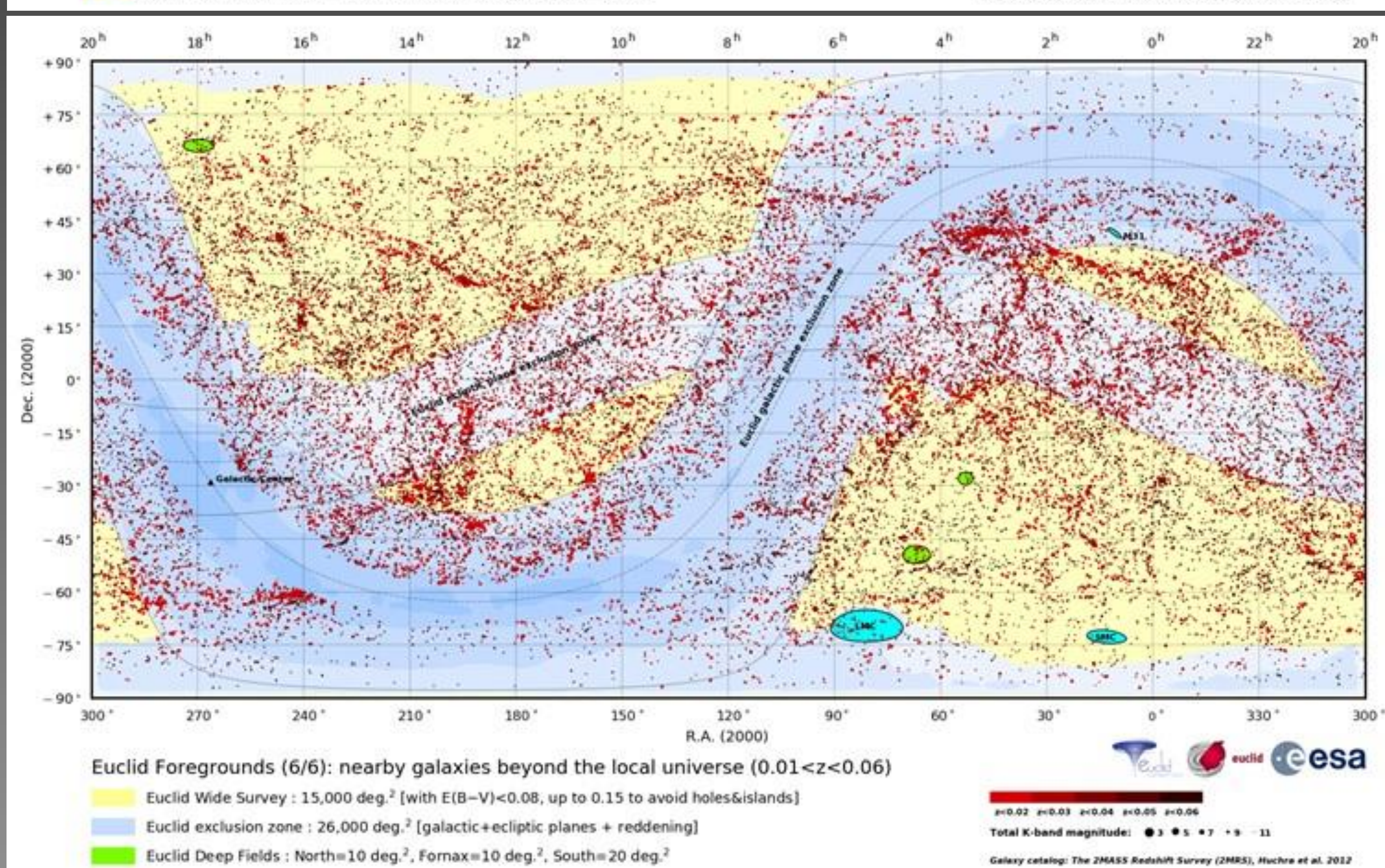
Straylight and very bright stars

Euclid survey

Lots of stuff on the sky

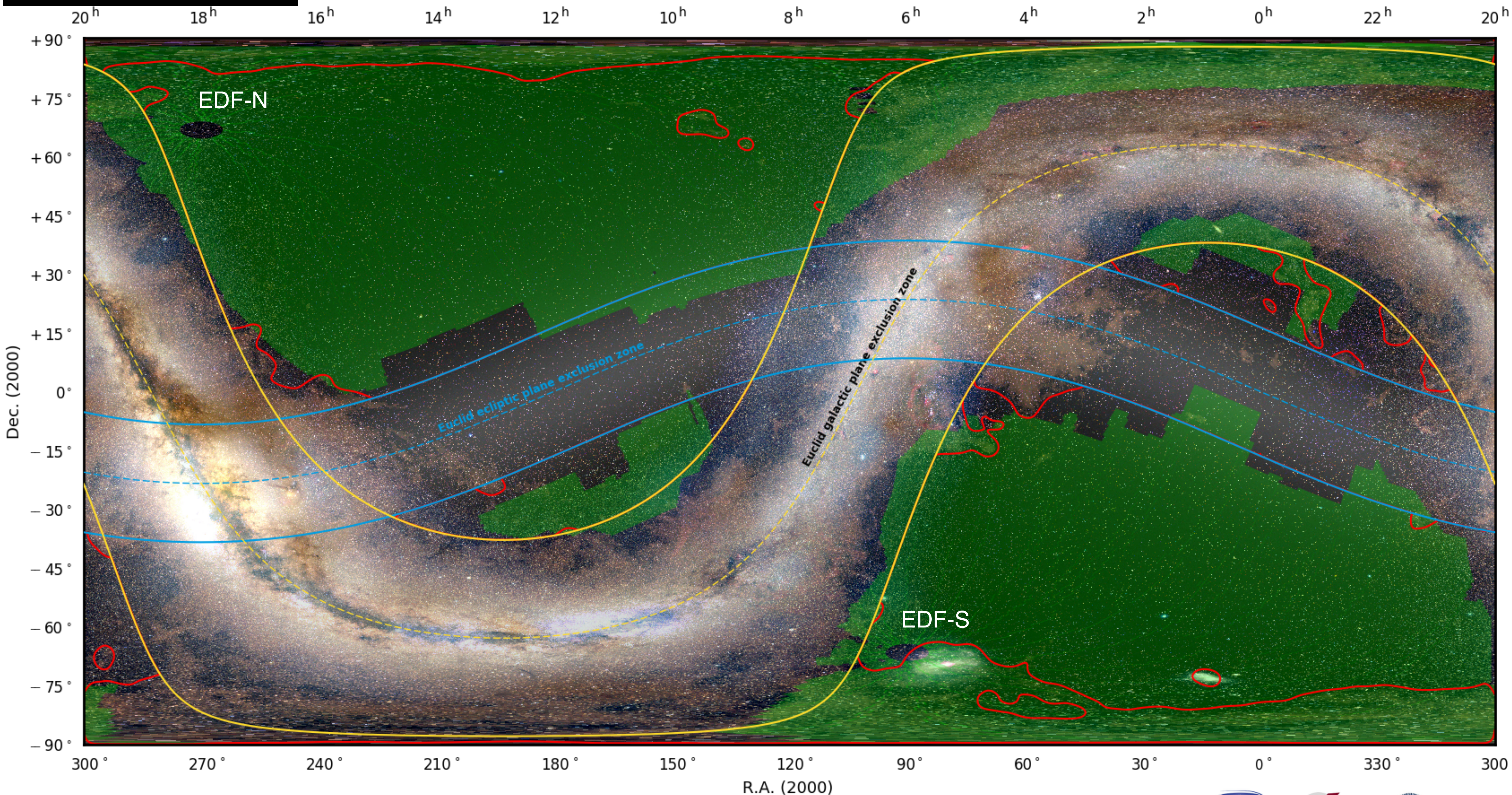


quite local
z<0.01



0.01 < z < 0.06

J.C. Cuillandre



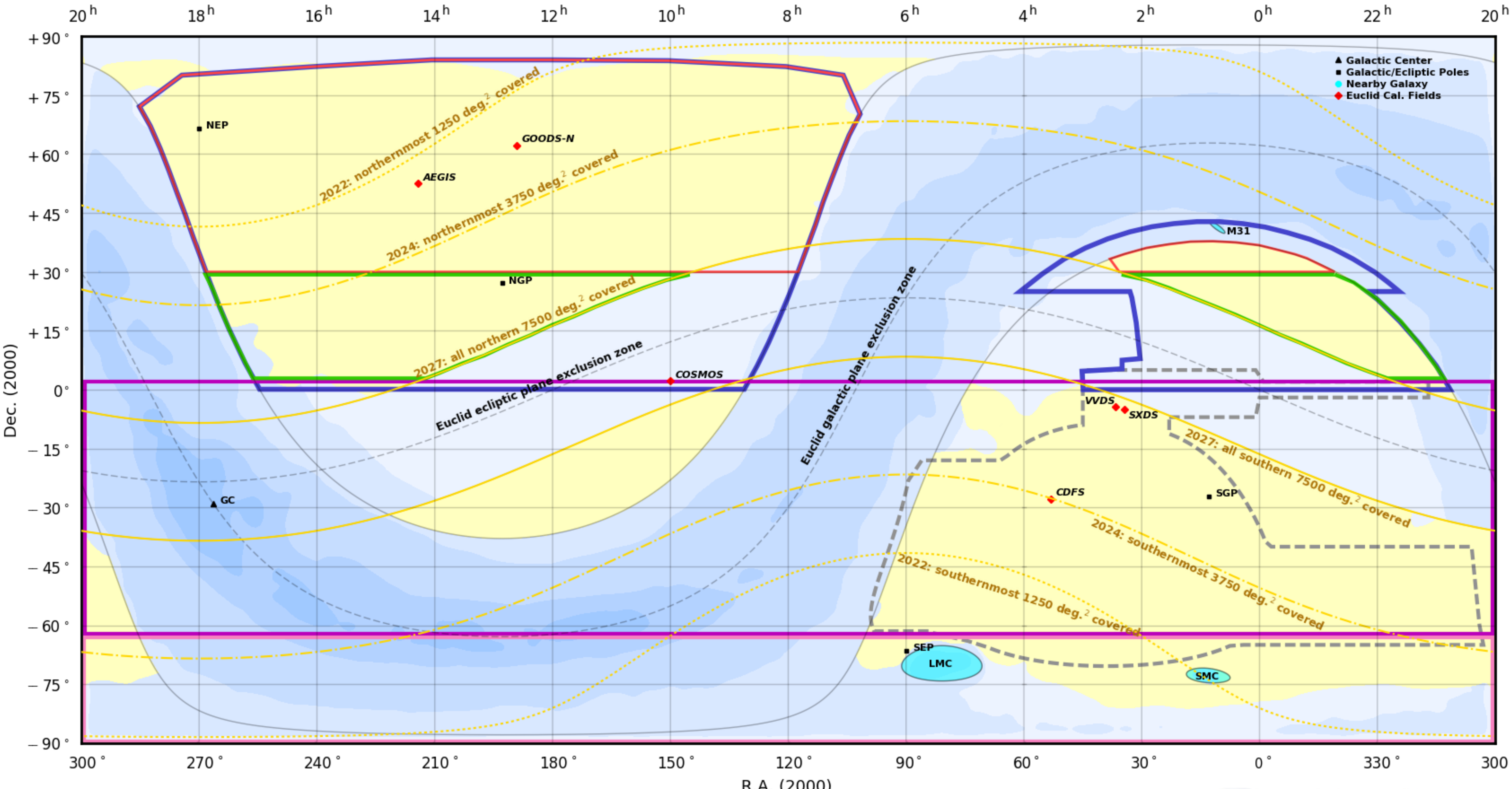
The Euclid Reference Survey (SPV, 2017, green overlay) versus the Red Book limits (ground surveys)

- 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 + holes&islands avoided by pushing locally up to 0.15

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

Survey SPV (weight only for spectra)

J.C. Cuillandre Survey coverage with ground based photometry



Expected ground-based coverage of the Euclid Wide Survey (origin/bands/overlap)

- Euclid Wide Survey : 15,000 deg.² [with E(B−V)<0.08]
- Euclid exclusion zone : 26,000 deg.² [galactic+ecliptic planes]
- ⇒ Ecliptic isolines track the space survey started at the ecliptic poles
- DES−griz : 4,500 deg.²
- CFIS−u : 7,300 deg.²
- CFIS−r + JEDIS−g + PS−iz : 4,800 deg.²
- LSST main survey, ugrizy : 7,000 deg.²
- LSST south extension, ugrizy : 1,000 deg.²
- LSST Euclid extension, griz : 3,000 deg.²

Ongoing negotiations with LSST

survey for SPV2: yearly breakdown

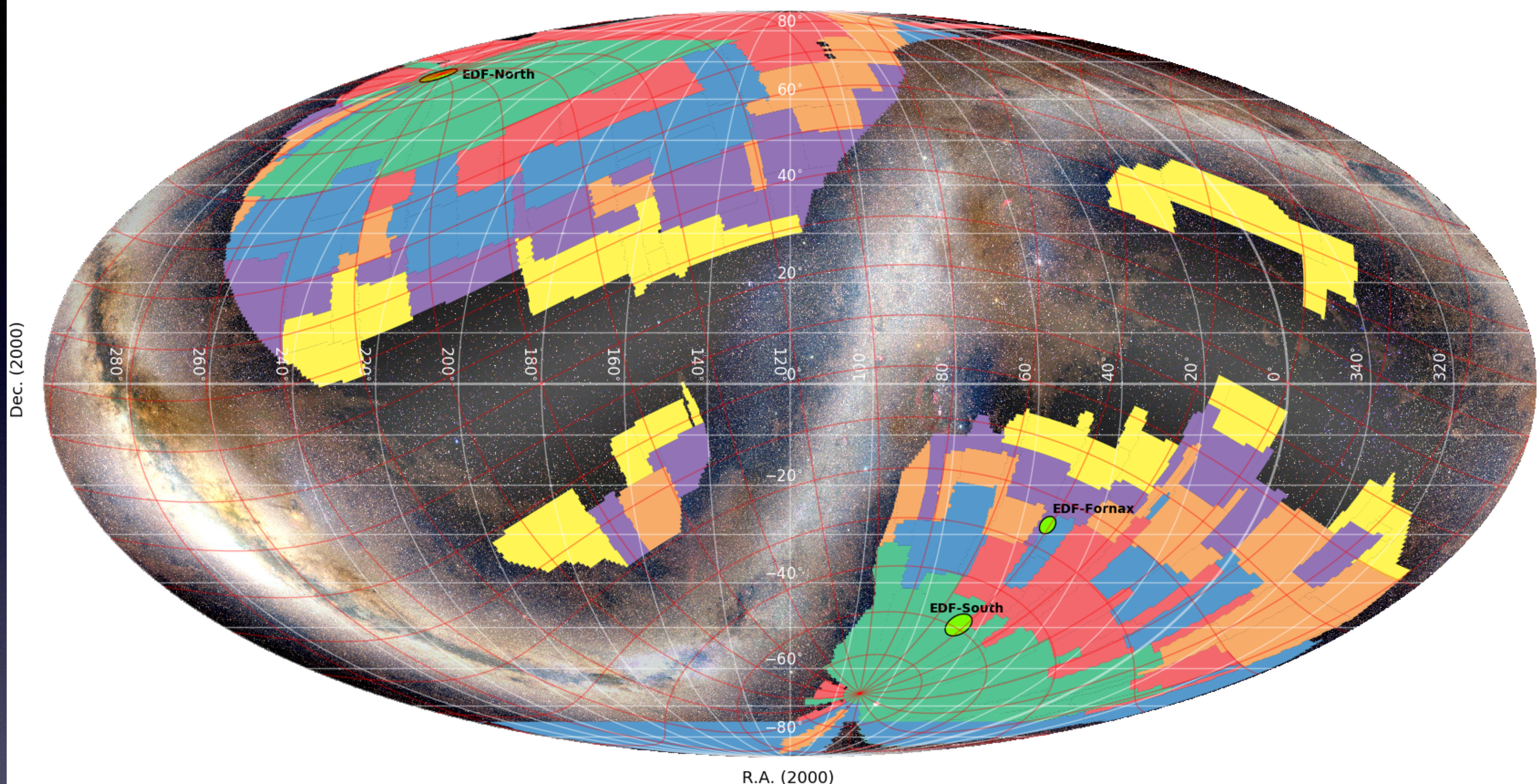


Illustration of a Euclid Wide Survey realization (SPV2, 2017), 15,000 deg.^{2} over 6 years

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

⇒ Representation in equatorial coordinates in a Mollweide projection (ecliptic referential overplotted in red)
⇒ The relative surface brightness of the zodiacal light versus the core galactic plane is respected
⇒ The galactic dust is enhanced up to the Euclid threshold E(B−V)=0.08 for illustration purpose

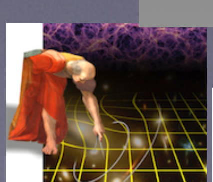
Euclid Wide Survey chronology

Year1 Year2 Year3 Year4 Year5 Year6

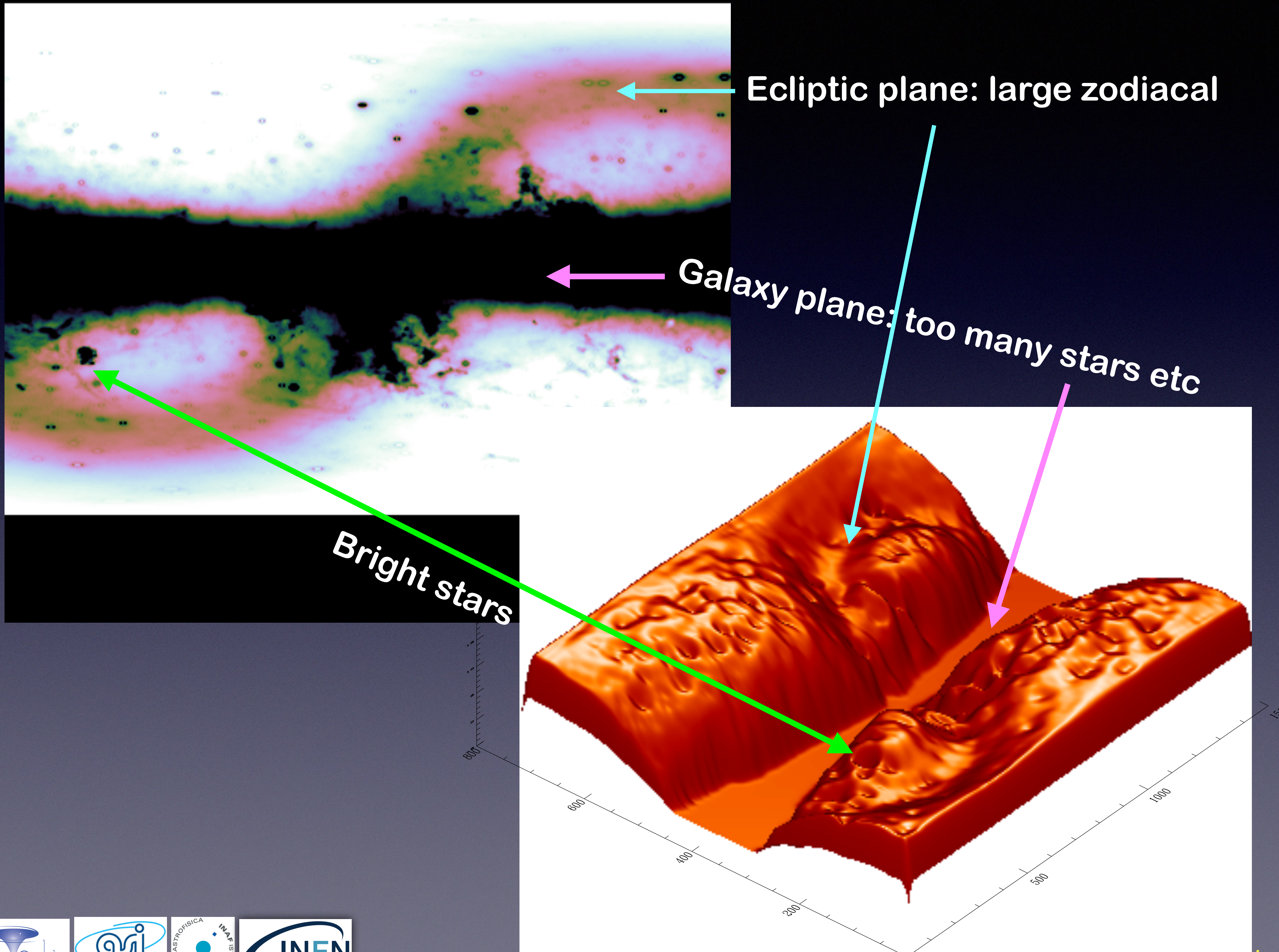
Background image: Euclid Consortium / A. Mellinger / Planck Collaboration

Plot by J.C. Cuillandre

R. Scaramella - EST - 11/16/2018



Spectra on the WIDE: weight map from sims

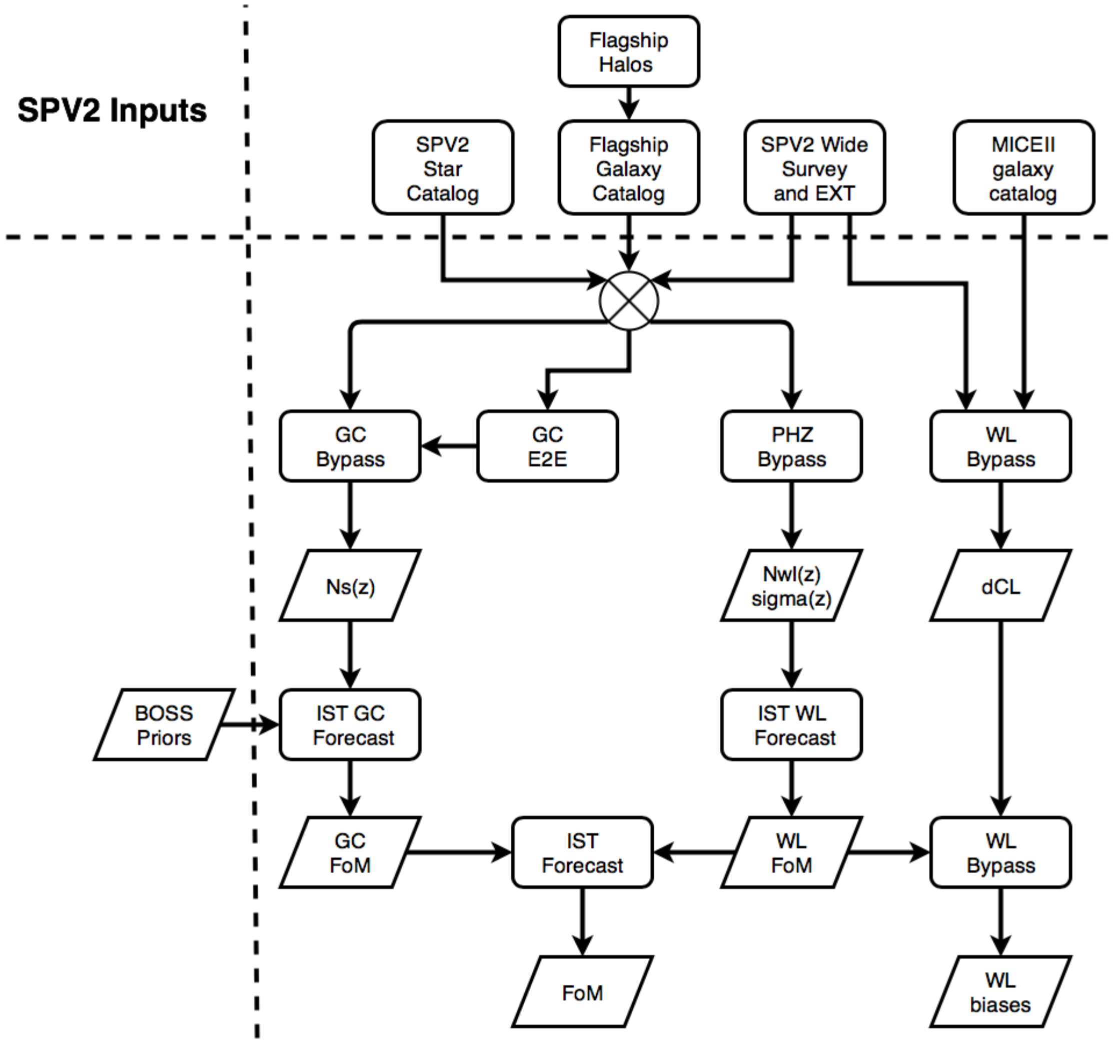


Euclid Science Performance Verification

HUGE effort (H. Aussel & C)

SPV2

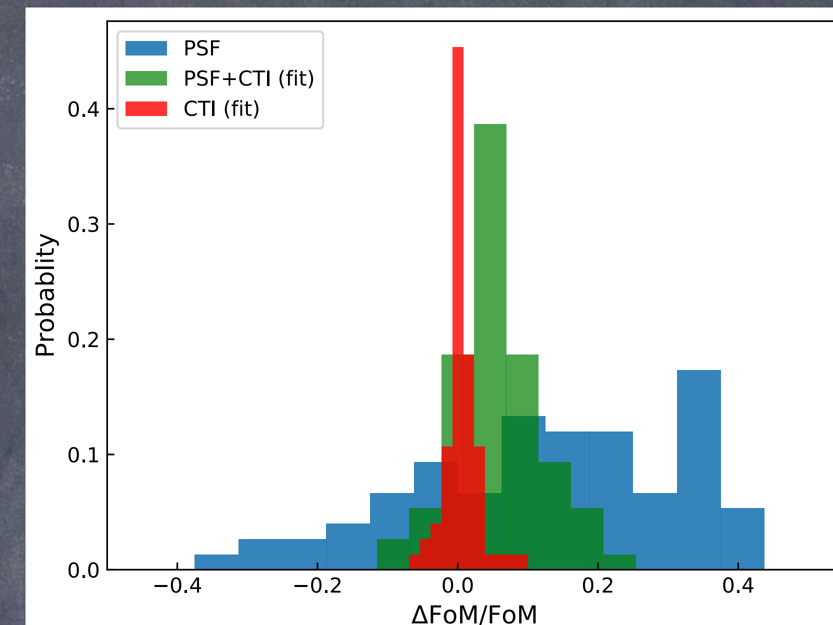
- FoM and accuracy on γ are derived independently on the GCs side and WL side using a Fisher matrix formalism
  - GCs:
    - GCs
    - RSD
  - WL:
    - WL
    - GCp
    - XC
- They are combined assuming independence.
- Biases were also derived on the WL side.



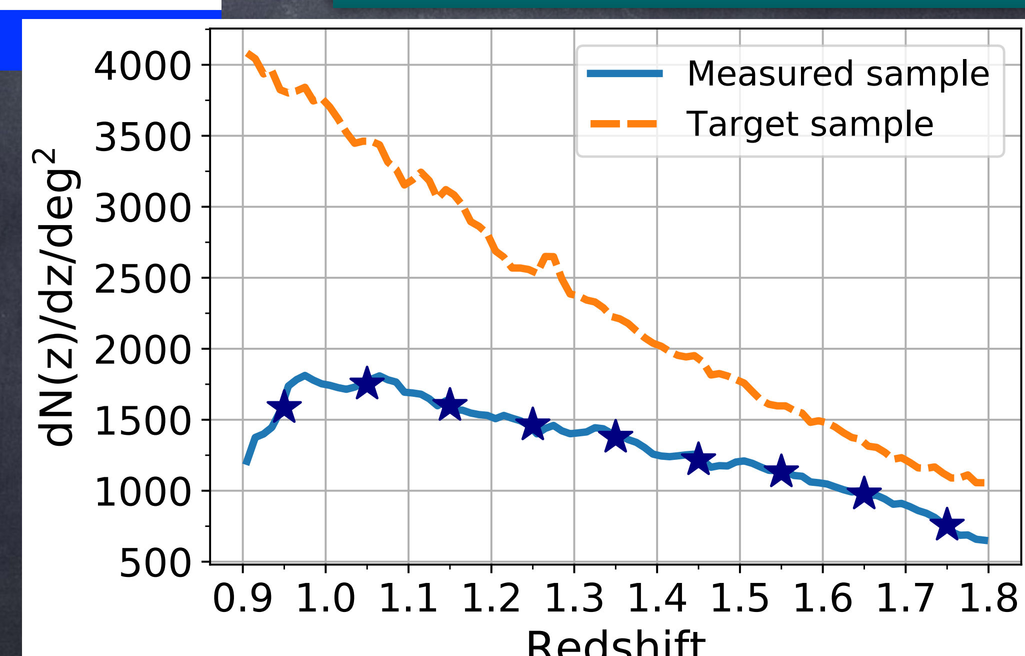
H. Aussel - SPV

MCDR @ ESTEC, Oct 19, 2018

PSF biases



measured redshift biases



Detailed simulations of data & instrument chars starting from large N—Body

euclid

$$w(a) = w_p + w_a(a_p - a) \qquad FoM = \frac{1}{[\det(C_{w_0,w_a})]^{1/2}}$$

$$f(z) = d\ln\delta_m / d\ln a = \Omega_m(z)^\gamma$$

Some Cosmology from wide

—From SPV2—

Euclid FoM at end of the mission: ~ 220 —> 450 (different combinations of probes, assumptions and high k cutoff)

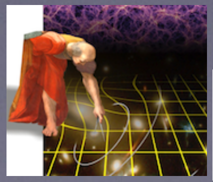
Experiment	$\sigma(\Omega_m)/\Omega_m$,	$\sigma(\sigma_8)/\sigma_8$	$\sigma(w_0)$,	$\sigma(w_a)$	$\sigma(\mu_0)$,	$\sigma(\gamma_0)$	DETF FoM
SKA1-Medium-deep	0.083	0.040	0.52	1.6	0.77	0.63	1.6
SKA1-Medium-deep + *Planck*	0.084	0.040	0.28	0.43	-	-	77
DES	0.056	0.032	0.43	1.4	0.64	0.52	3.5
DES + *Planck*	0.058	0.033	0.22	0.33	-	-	89
SKA1-Medium-deep×DES	0.046	0.024	0.45	1.3	0.59	0.48	3.3
SKA1-Medium-deep×DES + *Planck*	0.046	0.024	0.23	0.36	-	-	106

Planck prior boosts FoM because freezes several parameters.
Here SKA1 CG FoM 1.6—3.3 vs 17—27 for Euclid

Weak lensing experiment	A_{sky} [deg^2]	n [arcmin^{-2}]	z_m	γ	$f_{\text{spec-}z}$	$z_{\text{spec-max}}$	$\sigma_{\text{photo-}z}$	$z_{\text{photo-max}}$	$\sigma_{\text{no-}z}$
SKA1 Medium-Deep	5,000	2.7	1.1	1.25	0.15	0.6	0.05	2.0	0.3
DES	5,000	12	0.6	1.5	0.0	N/A	0.05	2.0	0.3

Euclid 15,000 30

ALSO EUCLID DEEP Survey!
40 sq degs ~26th mag NIR



Intensity mapping quite interesting over a large z range

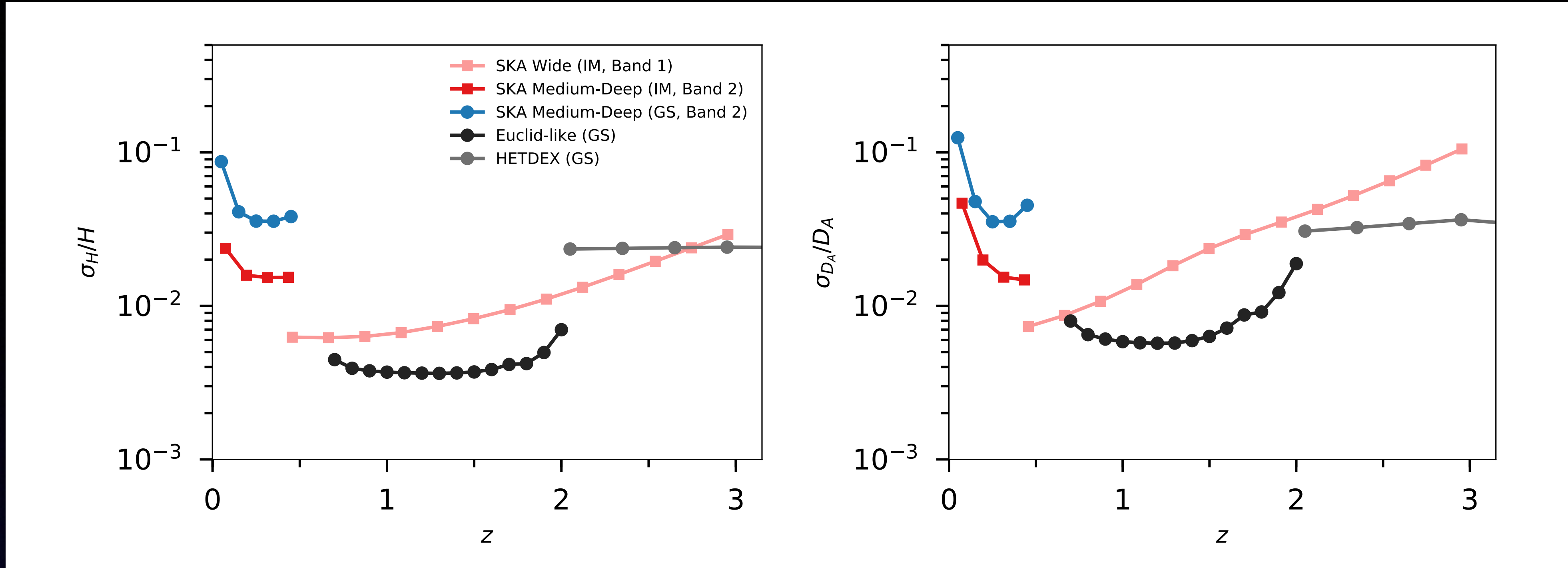
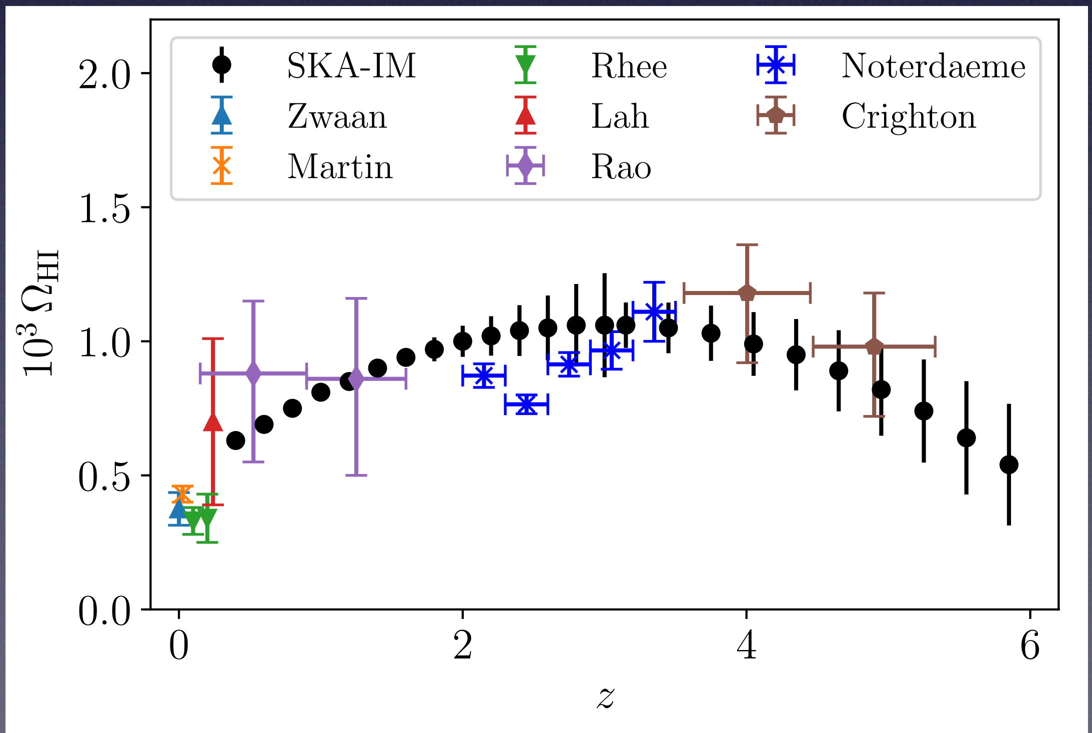


Figure 10. Forecast constraints on the cosmic expansion rate, H, (left panel) and angular diameter distance, $D_A(z)$, (right panel) for several different experiments, following the forecasting methodology described in Bull (2016). The SKA1 *Medium-Deep Band 2 Survey* for HI galaxy redshifts is shown in light blue, HI intensity mapping are shown in red/pink (see Sec. 5 for details), and optical/NIR spectroscopic galaxy surveys are shown in black/grey.

Fate of HI !!



Help to calibrate photoz

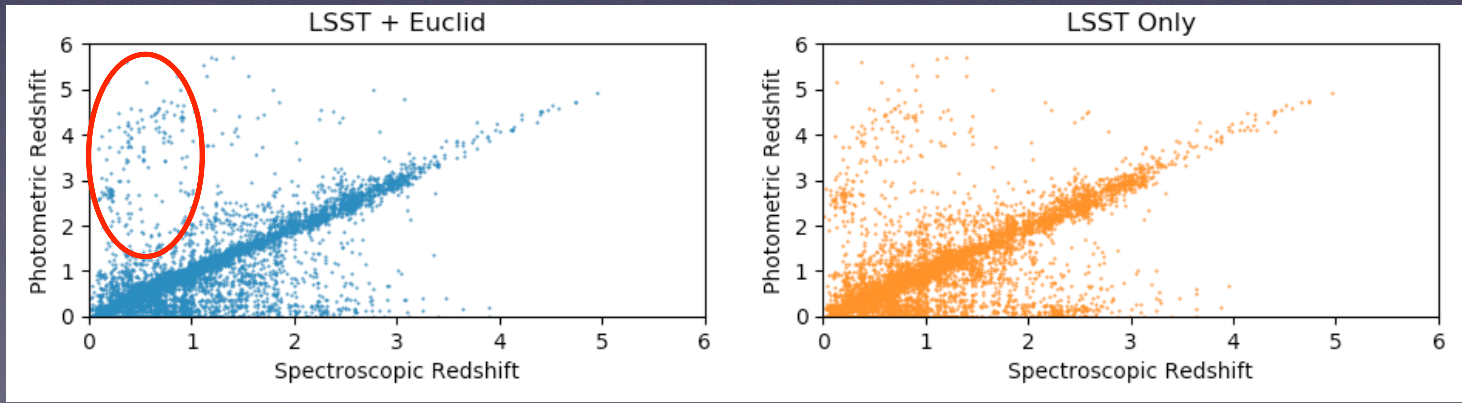


Figure 18. Forecasts for the HI density, $\Omega_{\rm HI}$, using the *Wide Band 1 Survey* and *Deep SKA1-LOW Survey* (black points), and comparison with measurements (see Crighton et al. (2015) and references therein), following the methodology in Pourtsidou et al. (2017). Note that we have used a very conservative non-linear k_{max} cutoff for these results.

HUNTING DOWN HORIZON-SCALE EFFECTS WITH MULTI-WAVELENGTH SURVEYS

José Fonseca,[1*] Stefano Camera,[2] Mário G. Santos[1,3,4], Roy Maartens[1,5]

Multitracer techniques useful and informative

Measuring cosmic velocities with 21 cm intensity mapping and galaxy redshift survey cross-correlation dipoles

Alex Hall[1,*] and Camille Bonvin[2,†]

$$C^{CD}_{AB}(d,d') = \frac{1}{V}\int \frac{k^2 \mathrm{d}k}{2\pi^2} \sum_{\ell,\ell'} i^{\ell'-\ell} w_\ell w_{\ell'} j_\ell(kd) j_\ell(kd') \sum_{L,L'} G^{L'L}_{\ell'\ell} \left[P^{AC}_L(k) P^{DB}_{L'}(k) + (-1)^{\ell'} P^{AD}_L(k) P^{CB}_{L'}(k)\right]$$
$$+ \int \frac{k^2 \mathrm{d}k}{2\pi^2} \sum_{\ell,\ell'} i^{\ell'-\ell} w_\ell w_{\ell'} j_\ell(kd) j_\ell(kd') \sum_{L} \begin{pmatrix} L & \ell & \ell' \\ 0 & 0 & 0 \end{pmatrix}^2 \left[\frac{\delta^K_{AC}}{\bar{n}_A V} P^{DB}_L(k) + \frac{\delta^K_{BD}}{\bar{n}_B V} P^{CA}_L(k)\right.$$
$$\left. + (-1)^{\ell'} \frac{\delta^K_{AD}}{\bar{n}_A V} P^{BC}_L(k) + (-1)^{\ell'} \frac{\delta^K_{BC}}{\bar{n}_B V} P^{DA}_L(k)\right]$$
$$+ \frac{\delta^K_{AC}\delta^K_{BD}}{\bar{n}_A \bar{n}_B V} \frac{\delta^K_{d,d'}}{4\pi d^2 L_p} \sum_\ell \frac{w_\ell^2}{2\ell+1} + \frac{\delta^K_{BC}\delta^K_{AD}}{\bar{n}_A \bar{n}_B V} \frac{\delta^K_{d,d'}}{4\pi d^2 L_p} \sum_\ell (-1)^\ell \frac{w_\ell^2}{2\ell+1}. \quad (17)$$

the estimator noise. The quantity $G^{L'L}_{\ell'\ell}$ arising from the integral of four Legendre polynomials is expressible in terms of Wigner $3j$ symbols as

$$G^{L'L}_{\ell'\ell} \equiv \sum_{L''} (2L''+1) \begin{pmatrix} \ell & \ell' & L'' \\ 0 & 0 & 0 \end{pmatrix}^2 \begin{pmatrix} L & L' & L'' \\ 0 & 0 & 0 \end{pmatrix}^2, \quad (18)$$

Statistics, + statistics, and even more statistics….

What about Physics ?

Summary:

Euclid is nice...
but what about SKA?

Synergies, X-checks & competition on

- ⋆ **BAO**
- ⋆ **LENSING**
- ⋆ **LSS**
- ⋆ **X-IDs**
- ⋆ **morphologies**
- ⋆ **NIR photom.**
- ⋆ **etc.**

Highlight complementarity

Euclid:

- **Dark Matter**
- **Processed Baryons**

SKA:

- **Unprocessed Baryons**

Both have many years to go (and to work on)...

But are among the best experiments !!