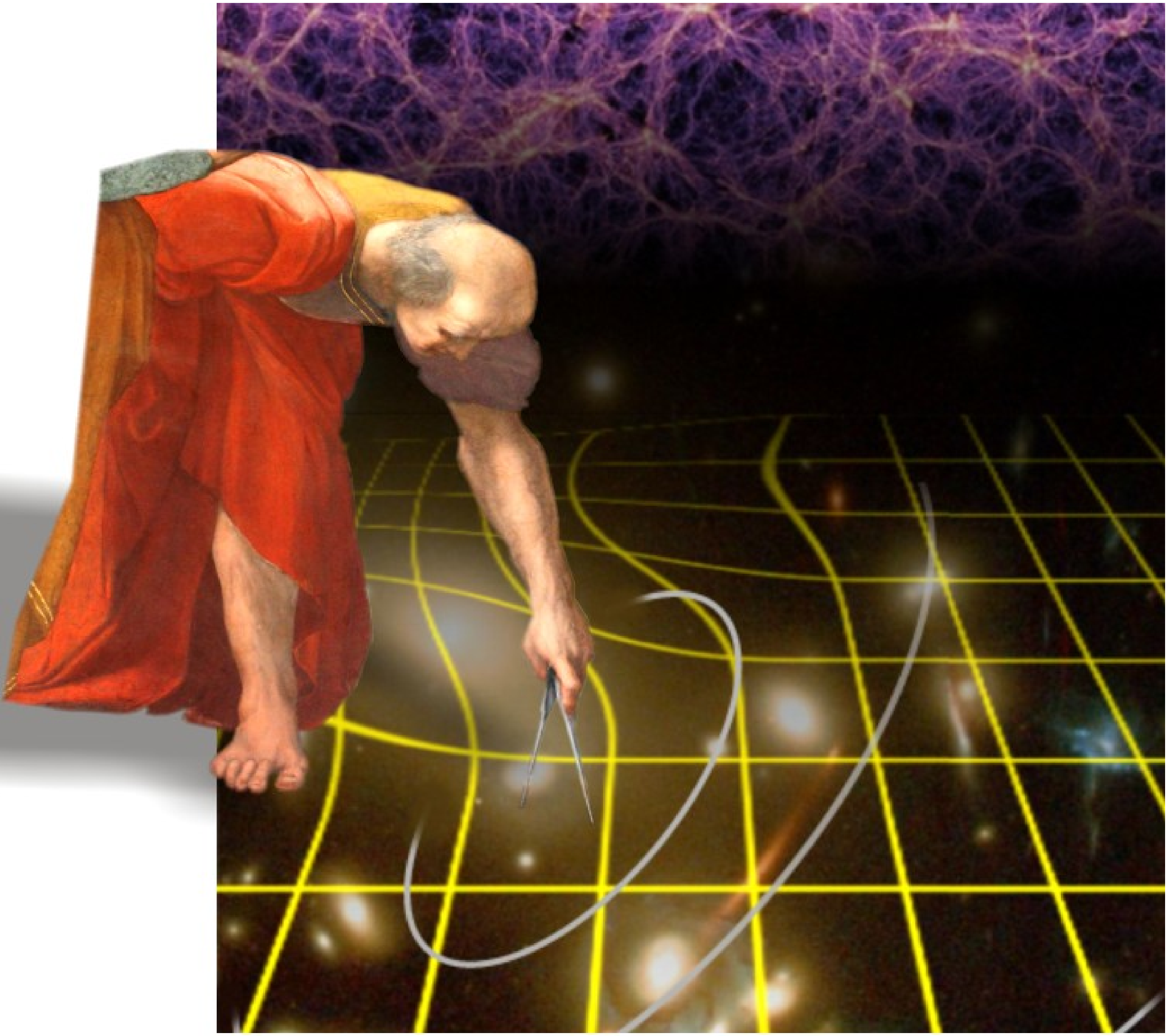


# Euclid

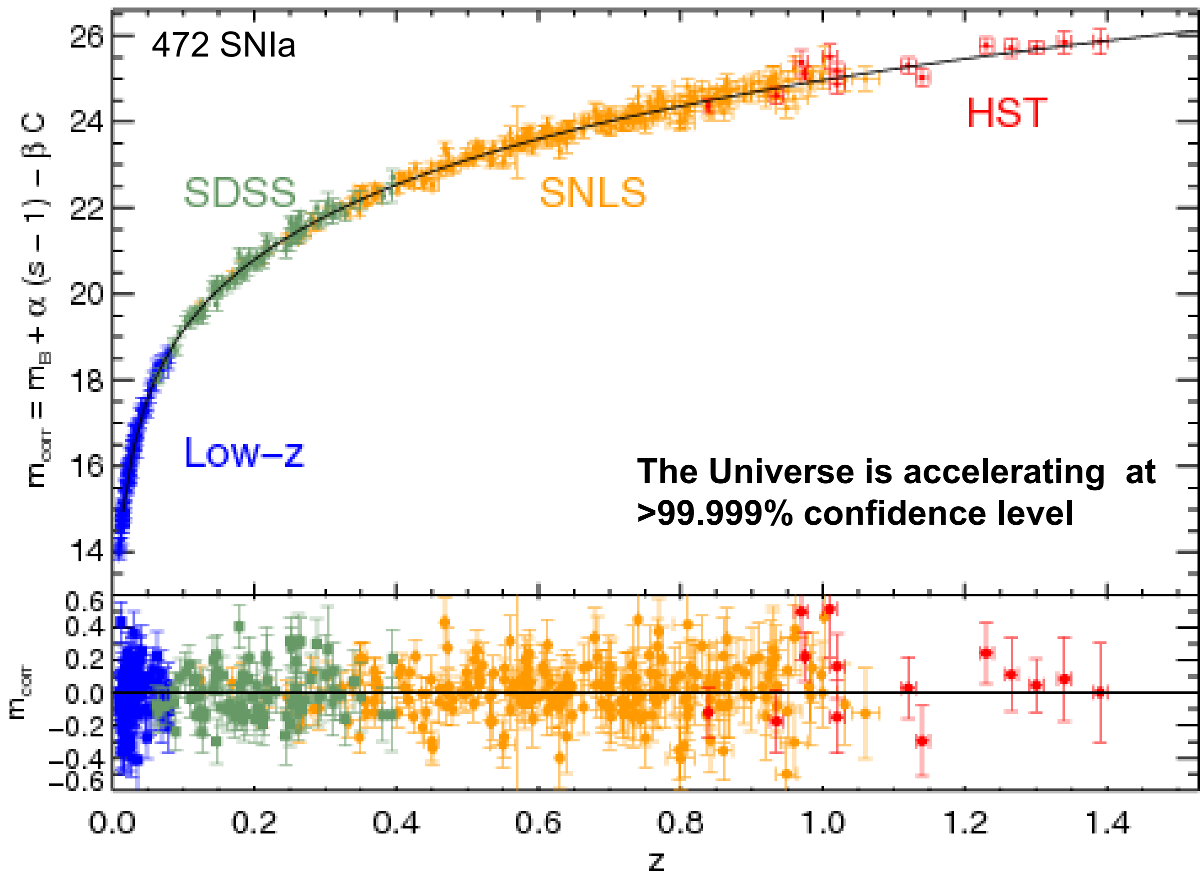
Y. Mellier
On behalf of the Euclid Consortium

http://www.euclid-ec.org

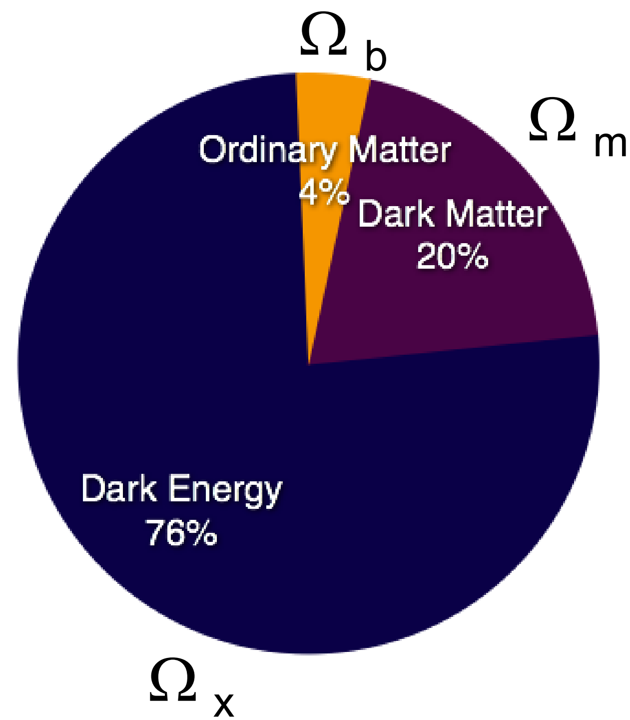
# Scientific objectives

# An accelerating universe dominated by DE





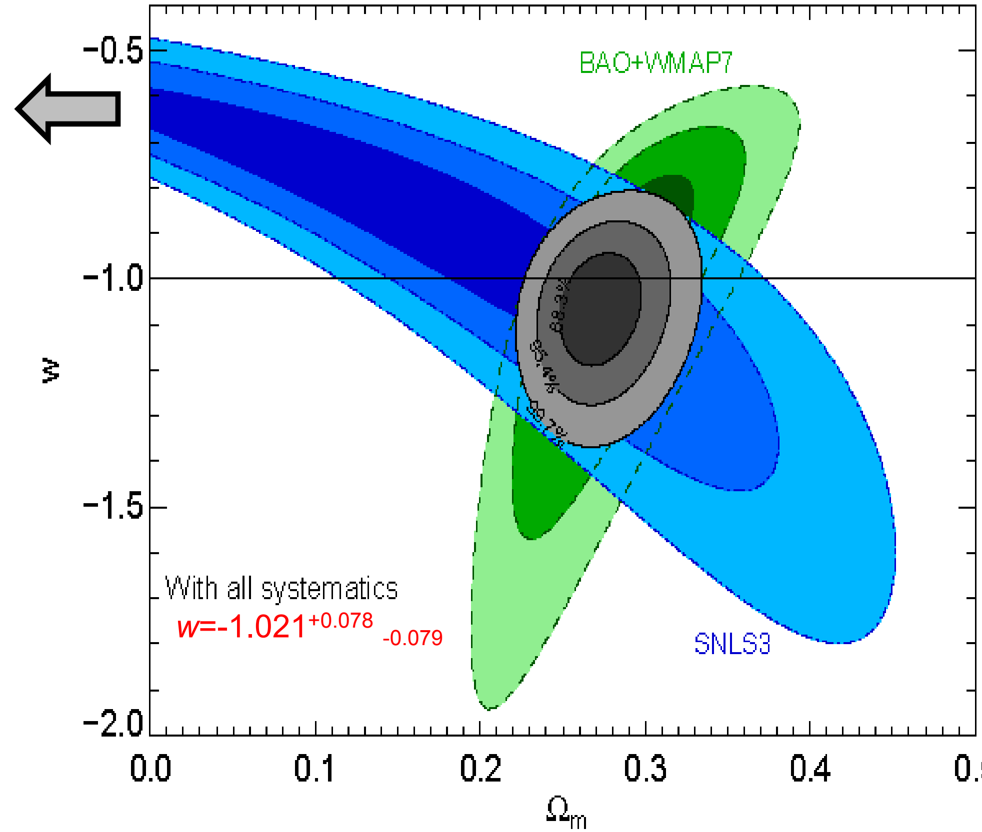

Conley et al 2011



# Is Λ the source of the acceleration?



- If $w_X = P/\rho$ = cte
→ $w_X$ ~ -1. But how close?




- Need high precision data to know if
  - $w_X$ = -1.00 → a «cosmological constant» ?
  - $w_X$ is not constant ? …

  → «dynamical dark energy» or…

  → acceleration not produced by «dark energy» ?

# The ESA Euclid mission: scientific objectives



- Understand the origin of the Universe's accelerating expansion;
- Derive properties/nature of dark energy (DE), test gravity (MG)
- Distinguish DE, MG, DM effects *decisively* by… :
  - using at least 2 independent but complementary probes
  - tracking their observational signatures on the
    - geometry of the Universe:
      - Weak Lensing (WL), Galaxy Clustering (GC),
    - cosmic history of structure formation:
      - WL, Redshift-Space Distortion, Clusters of Galaxies
  - controlling systematic residuals to a very high level of accuracy.

# Distinguishing *decisively*



Parameterising our ignorance:

- DE equation of state: $P/\rho = w$ , and $w(a) = w_p + w_a(a_p - a)$
- Growth rate of structure formation controlled by gravity: $f \sim \Omega^\gamma$ ;

  $\gamma = 0.55$ for general relativity → test GR

# Distinguishing *decisively*

## Parameterising our ignorance:

- DE equation of state: $P/\rho = w$ , and $w(a) = w_p + w_a(a_p - a)$
- Growth rate of structure formation controlled by gravity: $f \sim \Omega^\gamma$ ; $\gamma = 0.55$ GR

## 1. Nature of the apparent acceleration

- Distinguish effects of $\Lambda$ and dynamical dark energy → Measure *w(a)* → slices in redshift
- From Euclid data alone, get $FoM = 1/(\Delta w_a \times \Delta w_p) > 400$:

  → if data consistent with $\Lambda$, and ***FoM* > 400** then :

  → $\Lambda$ favoured with odds of more than 100:1 = a "decisive" statistical evidence.

## 2. Effects of gravity on cosmological scales

- Probe growth of structure → slices in redshift ,
- Separately constrain the metrics potentials ($\Psi$, $\Phi$) as function of both scale and time
- Distinguish effects of GR from MG models with very high confidence level:

  → absolute **1-σ precision of 0.02** on the growth index, $\gamma$, from Euclid data alone.

# Distinguishing *decisively*



Parameterising our ignorance:

- DE equation of state: $P/\rho = w$ , and $w(a) = w_p + w_a(a_p - a)$
- Growth rate of structure formation controlled by gravity: $f \sim \Omega^\gamma$ ; $\gamma = 0.55$ GR

⇩

1. Nature of the apparent acceleration
   - Distinguish effects of $\Lambda$ and dynamical dark energy → Measure *w(a)* → slices in redshift
   - From Euclid data alone, get $FoM=1/(\Delta w_a \times \Delta w_p) > 400$:

     → if data consistent with $\Lambda$, and ***FoM* > 400** then :

     → $\Lambda$ favoured with odds of more than 100:1 = a "decisive" statistical evidence.

2. Effects of gravity on cosmological scales
   - Probe growth of structure → slices in redshift ,
   - Separately constrain the metrics potentials ($\Psi$, $\Phi$) as function of both scale and time
   - Distinguish effects of GR from MG models with very high confidence level:

     → absolute **1-σ precision of 0.02** on the growth index, $\gamma$, from Euclid data alone.

**(1. + 2.) → primary objectives of Euclid → how can Euclid achieve this?**

# WL and GC: optimal primary probes for Euclid



- **Weak Lensing (WL), wide field:**

3-D cosmic shear measurements (tomography) over 0<z<2
→ probes distrib. of matter (D+L), expansion history, growth factor , $\Psi+\Phi$.
→ shapes+distance of galaxies: shear amplitude, and bin the universe into slices. For 0<z<2 photo-z sufficient, but with optical and NIR data.

- **Galaxy Clustering (GC), wide field:**

3-D position measurements over 0<z<2
→ probes clustering history of galaxies induced by gravity, $\Psi$ , $\gamma$, $H(z)$.
→ 3-D distribution of galaxies, but spectroscopic redshifts needed.

# WL and GC: optimal primary probes for Euclid



- **Weak Lensing (WL), wide field:**

3-D cosmic shear measurements (tomography) over $0<z<2$
→ probes distrib. of matter (D+L), expansion history, growth factor , $\Psi+\Phi$.
→ shapes+distance of galaxies: shear amplitude, and bin the universe into slices. For $0<z<2$ photo-z sufficient, but with optical and NIR data.

- **Galaxy Clustering (GC), wide field:**

3-D position measurements over $0<z<2$
→ probes clustering history of galaxies induced by gravity, $\Psi$ , $\gamma$, $H(z)$.
→ 3-D distribution of galaxies, but spectroscopic redshifts needed.

- **GC <u>and</u> WL:**

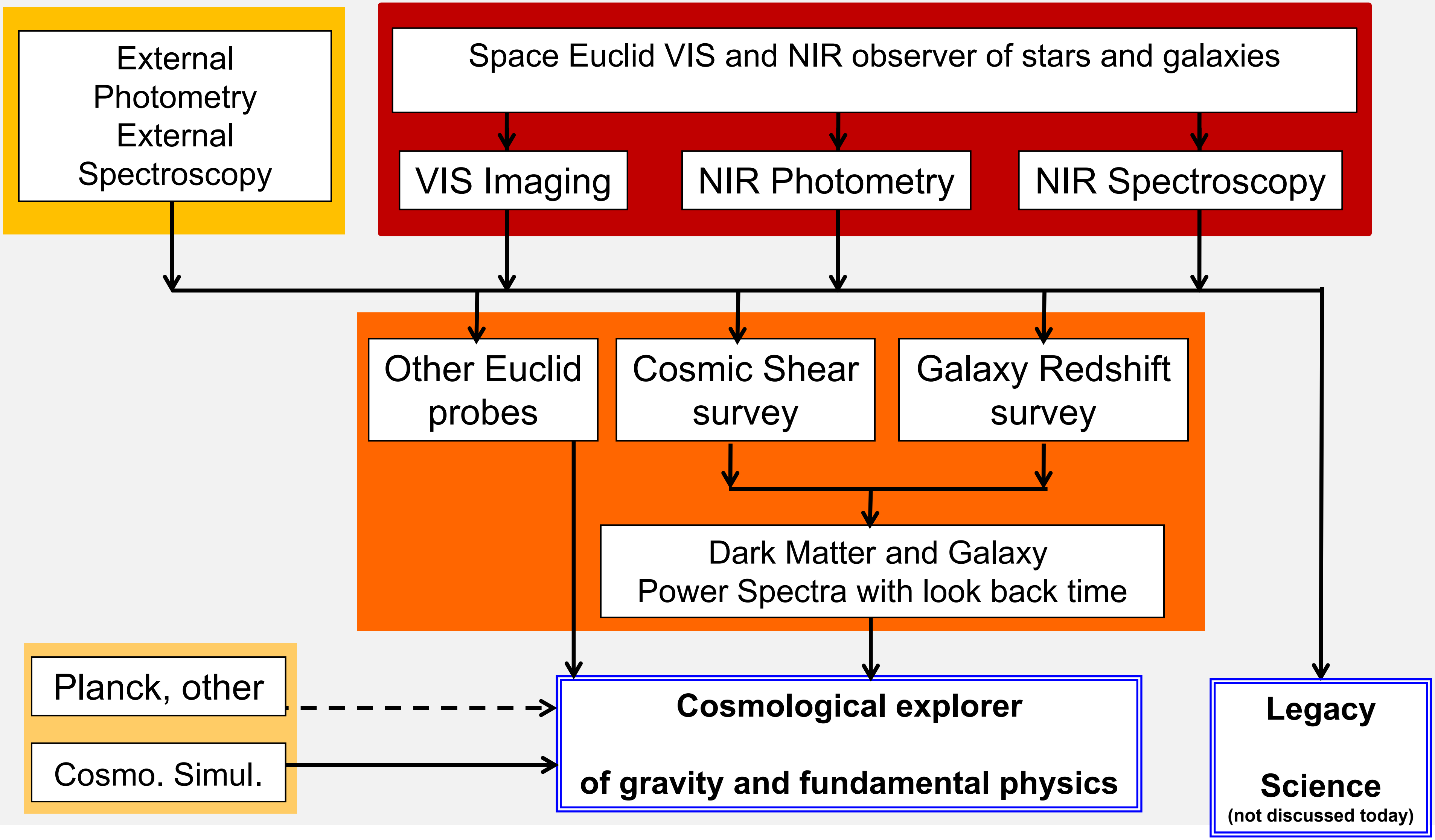
use the same survey (minimise complexity and cost)
use different data, complementary physical effects → different systematics

- **CG and WL are *P*(*k*,z) explorers:**

both probe power spectra → can be used also to probe dark matter (neutrino) and inflation (non-Gaussianity and $f_{NL}$)

# The Euclid Machine





# The Euclid Mission: baseline and options



| SURVEYS In ~5.5 years | | |
|---|---|---|
| | Area (deg2) | Description |
| Wide Survey | **15,000 $deg^2$** | Step and stare with 4 dither pointings per step. |
| Deep Survey | **40 $deg^2$** | In at least 2 patches of > 10 $deg^2$<br>2 magnitudes deeper than wide survey |

| PAYLOAD | | | | | |
|---|---|---|---|---|---|
| Telescope | 1.2 m Korsch, 3 mirror anastigmat, f=24.5 m | | | | |
| Instrument | VIS | NISP | | | |
| Field-of-View | 0.787×0.709 $deg^2$ | 0.763×0.722 $deg^2$ | | | |
| Capability | Visual Imaging | NIR Imaging Photometry | | | NIR Spectroscopy |
| Wavelength range | 550– 900 nm | Y (920-1146nm), | J (1146-1372 nm) | H (1372-2000nm) | 1100-2000 nm |
| Sensitivity | 24.5 mag<br>10σ extended source | 24 mag<br>5σ point source | 24 mag<br>5σ point source | 24 mag<br>5σ point source | $3\ 10^{-16}$ erg cm-2 s-1<br>3.5σ unresolved line flux |
| | **Shapes + Photo-z of *n* = 1.5 x$10^9$ galaxies ?** | | | ***z* of *n*=5x$10^7$ galaxies** | |
| Detector Technology | 36 arrays<br>4k×4k CCD | 16 arrays<br>2k×2k NIR sensitive HgCdTe detectors | | | |
| Pixel Size<br>Spectral resolution | 0.1 arcsec | 0.3 arcsec | | | 0.3 arcsec<br>R=250 |

Possibility to propose other surveys: SN and/or μ-lens surveys, Milky Way ?

Ref: Euclid RB arXiv:1110.3193

# Euclid:optimised for shape measurements

Euclid Consortium

M51

Courtesy J. Brinchmann, Steve Warren

SDSS @ z=0.1 | Euclid @ z=0.1 | Euclid @ z=0.7

- Euclid images of z~1 galaxies: same resolution as SDSS images at z~0.05 and at least 3 magnitudes deeper.
- Space imaging of Euclid will outperform any  other surveys of weak lensing.

# Third Euclid probe: Clusters of galaxies



- Clusters of galaxies: probe of peaks in density distribution
  - number density of high mass, high redshift clusters very sensitive to
    - any primordial non-Gaussianity and
    - deviations from standard DE models

- Euclid data =
  - 60,000 clusters with a S/N>3 between $0.2<z<2$ (obtained for free).
  - more than $10^4$ of these will be at $z>1$.
  - ~ 5000 giant gravitational arcs

→ very accurate masses for the whole sample of clusters (WL)
→ dark matter density profiles on scales >100 kpc
  → direct constraints on numerical simulations.
→ 300000 strong galaxy lensing + 5000 giant arcs
  → test of CDM : probe substructure and small scale density profile.

- Synergy with Planck and eROSITA

# Cluster with Euclid VIS+NIS imaging

Euclid Consortium

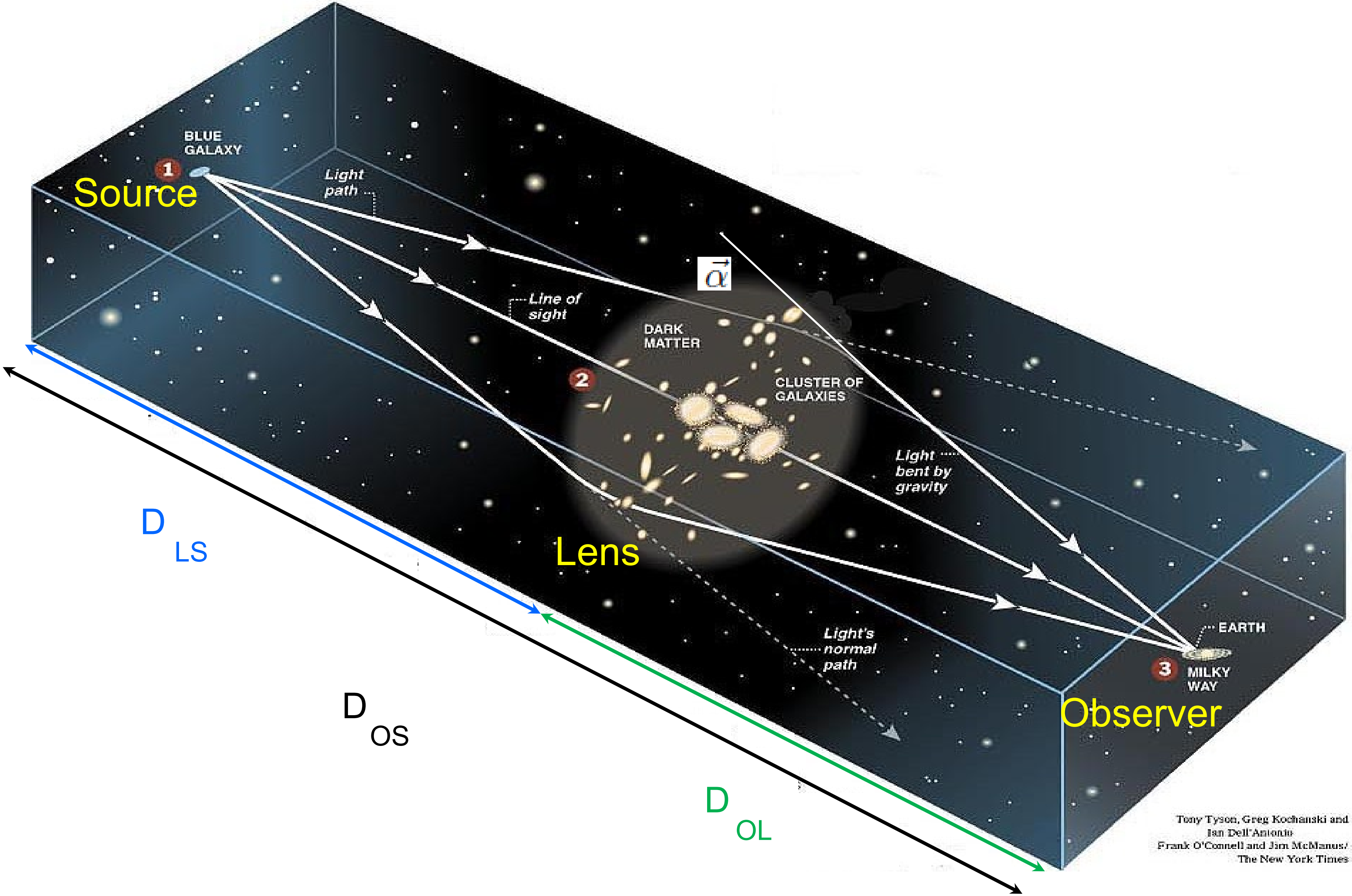
Euclid combined VIS+Y+J+H images of a simulated cluster

Courtesy Massimo Meneghetti

# Weak lensing and Euclid

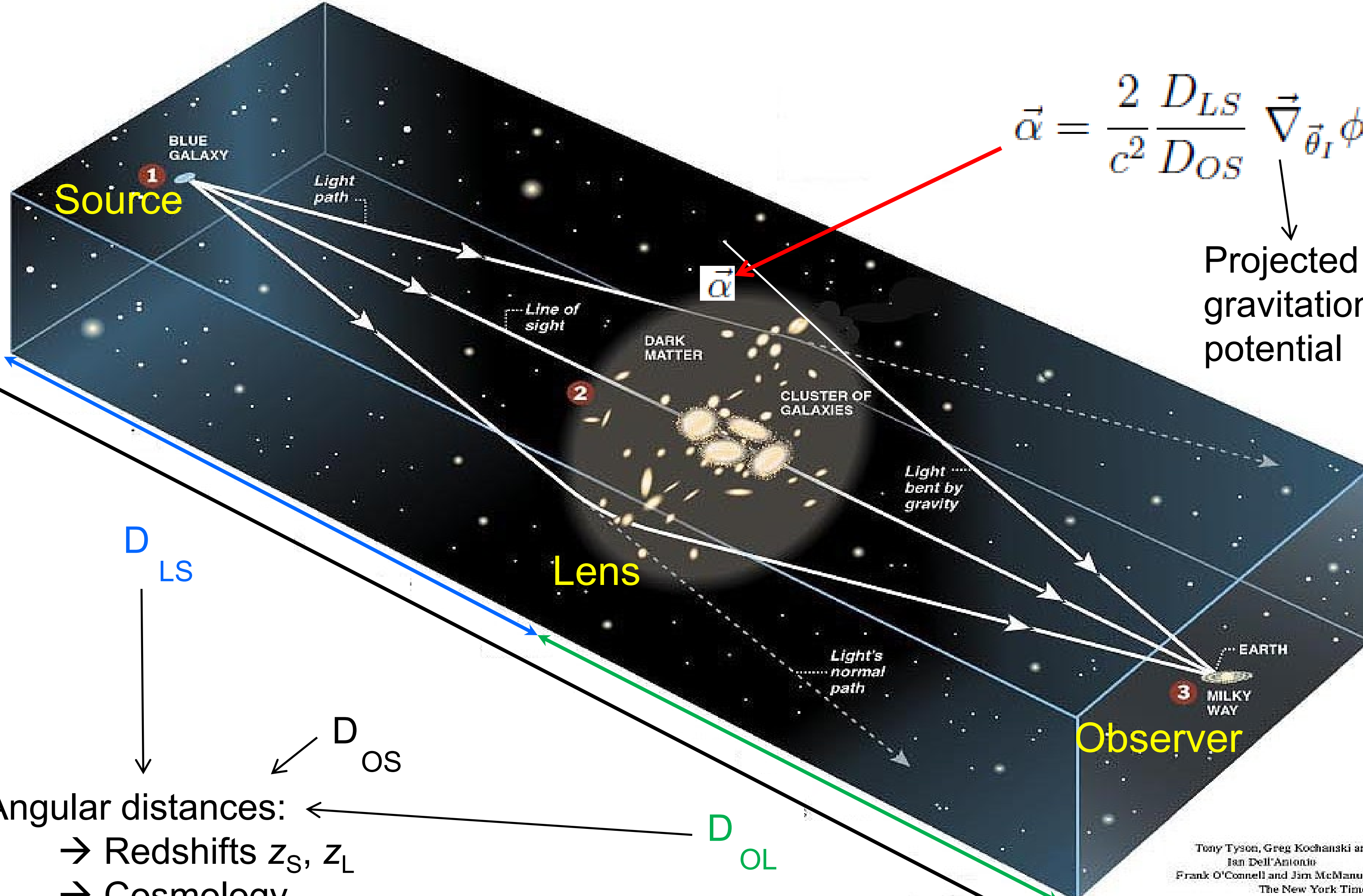
# Gravitational deflection of light





# Gravitational deflection of light






$$\vec{\alpha} = \frac{2}{c^2}\frac{D_{LS}}{D_{OS}}\vec{\nabla}_{\vec{\theta}_I}\phi_N^{2D}$$

Projected gravitational potential

$D_{LS}$

$D_{OS}$

$D_{OL}$

Angular distances:

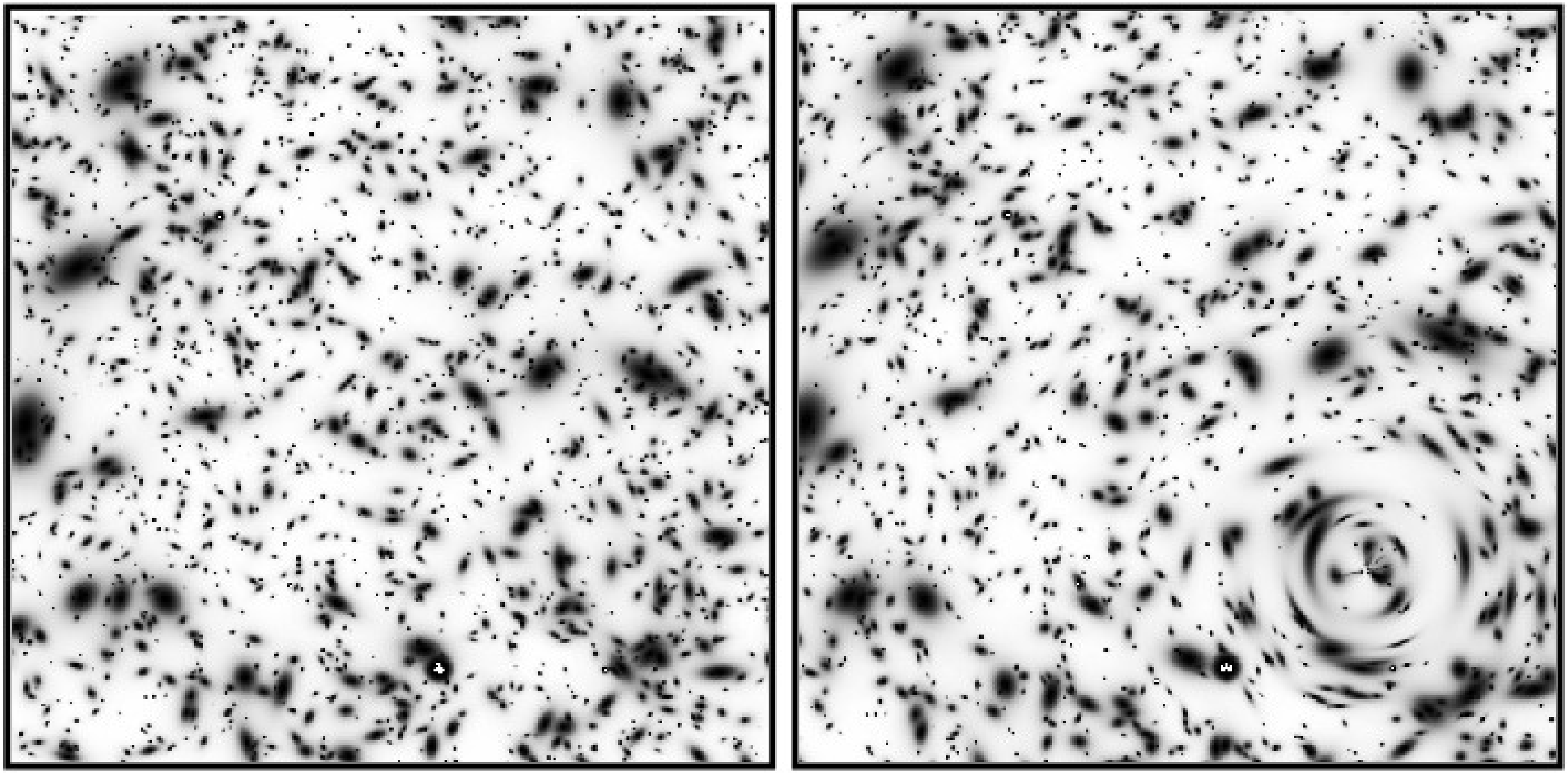
→ Redshifts $z_S$, $z_L$

→ Cosmology

# Gravitational lensing effects on lensed sources



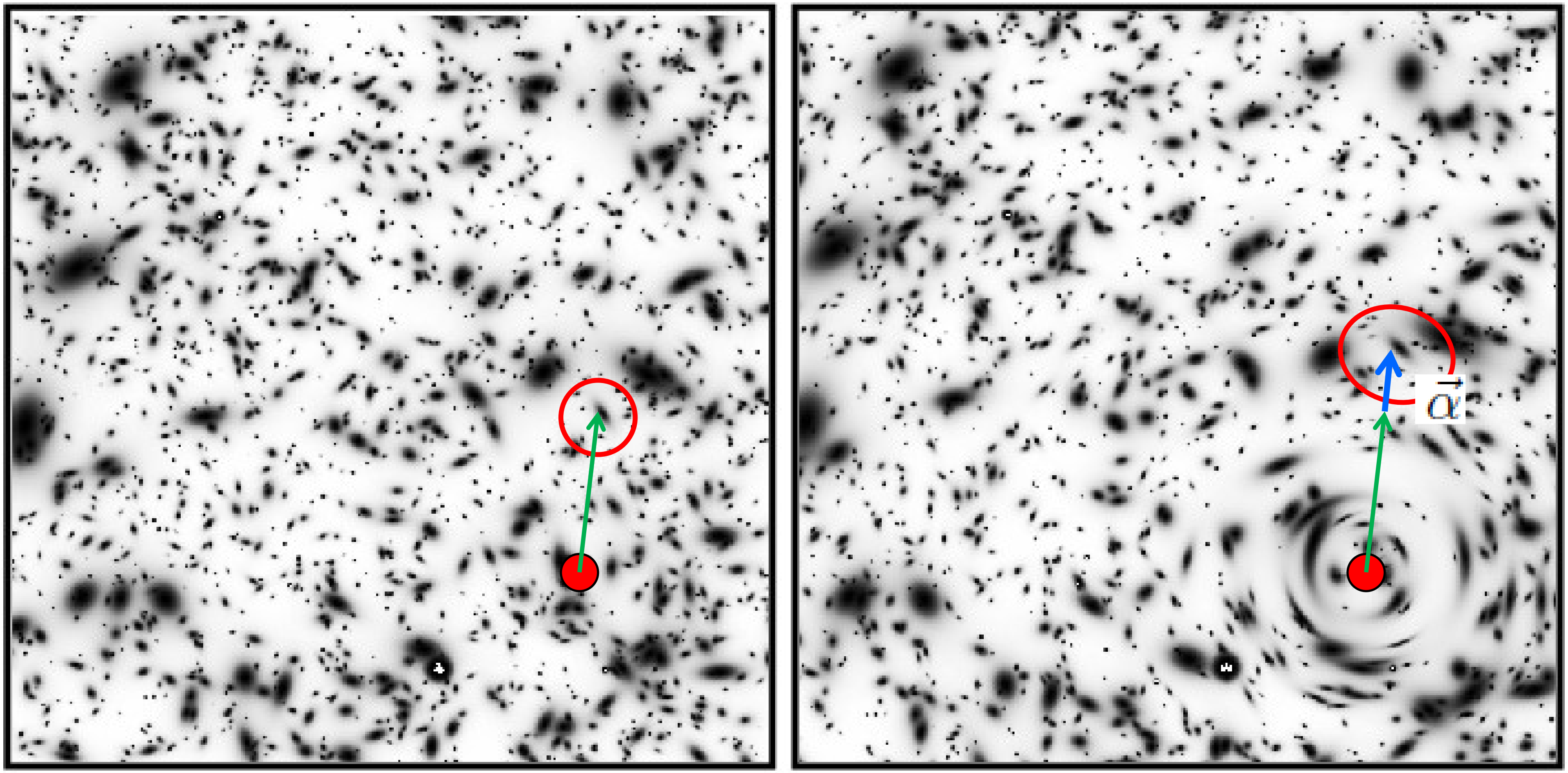
Mellier 1999



# Gravitational lensing effects on lensed sources

- Image multiplication
  - → Image postions, image parity, time delay, flux ratios
- Magnification (size)
- Image distortion (shear)

Mellier 1999

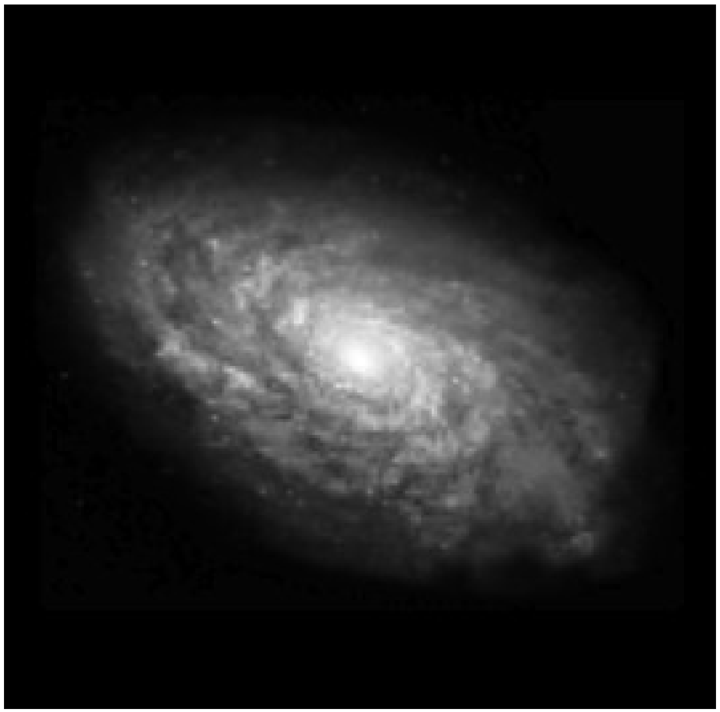


# Weak lensing increases galaxy ellipticity



$$\langle \epsilon \rangle = \langle \epsilon^S \rangle + \langle g \rangle$$
$$\langle \epsilon \rangle \approx \langle g \rangle .$$

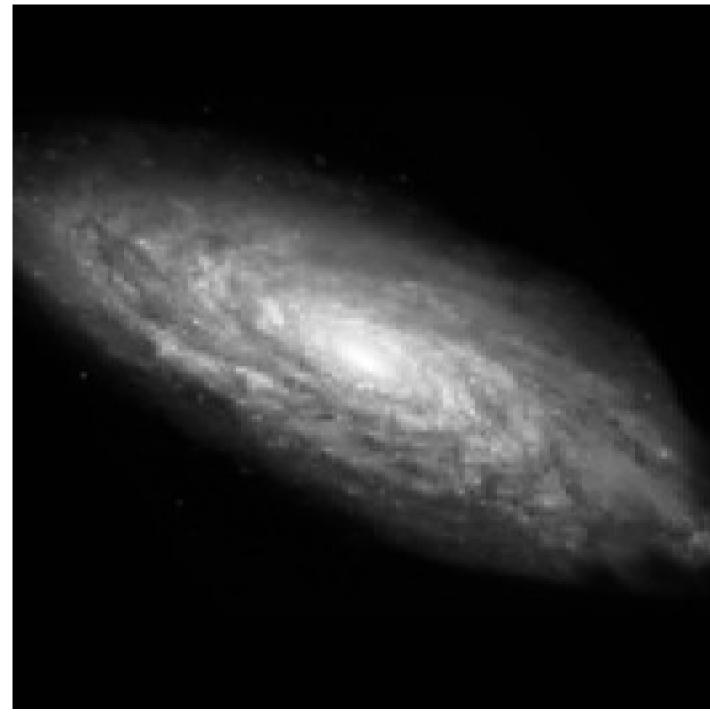
Assuming galaxy orientations are randomly distributed



Dark matter

$g_i$~0.2

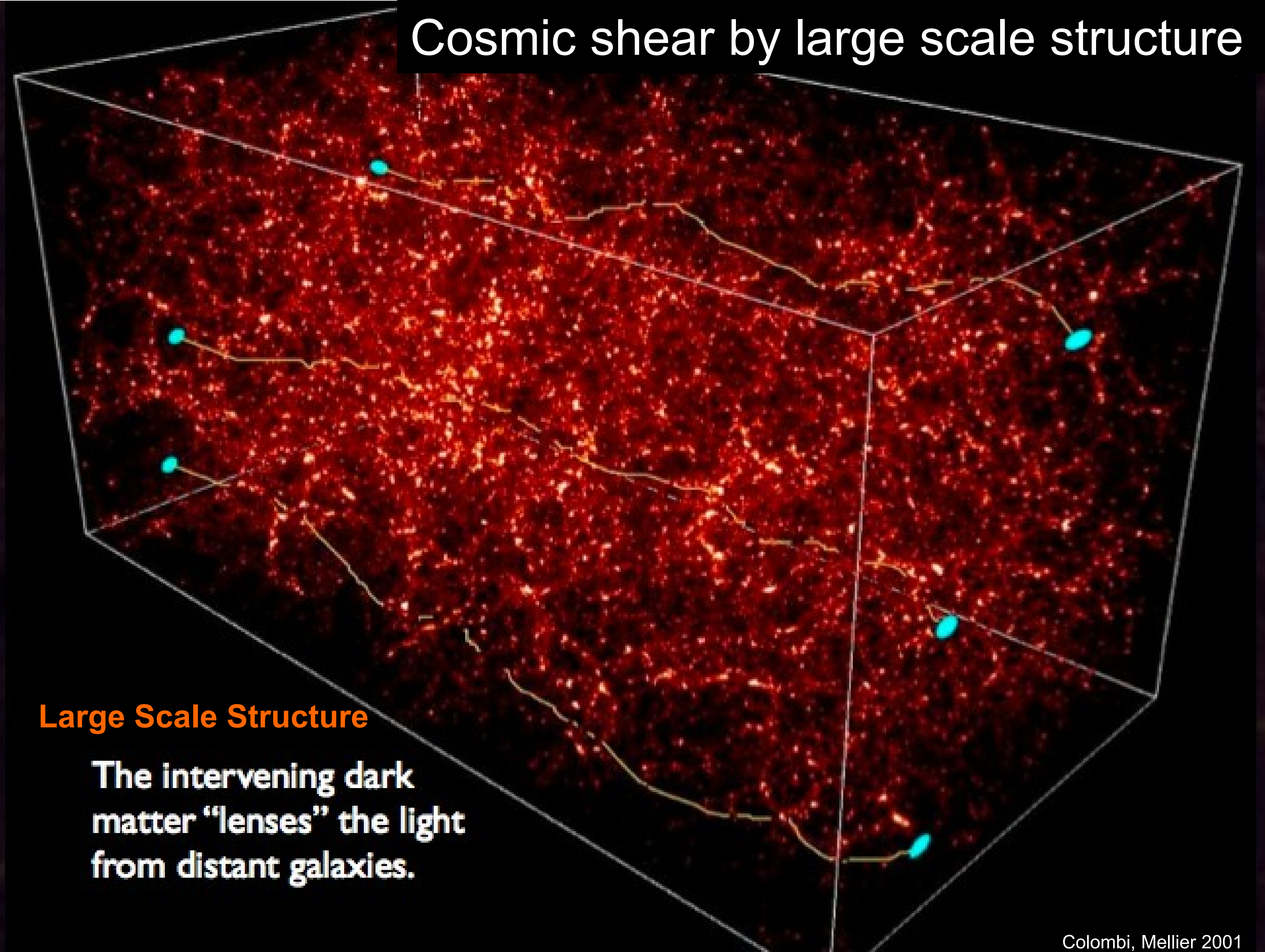
Real data:
$g_i$ ~<0.03



Kitching 2010

$$\begin{pmatrix} x_u \\ y_u \end{pmatrix} = \begin{pmatrix} 1 - g_1 & -g_2 \\ -g_2 & 1 + g_1 \end{pmatrix} \begin{pmatrix} x_l \\ y_l \end{pmatrix}$$

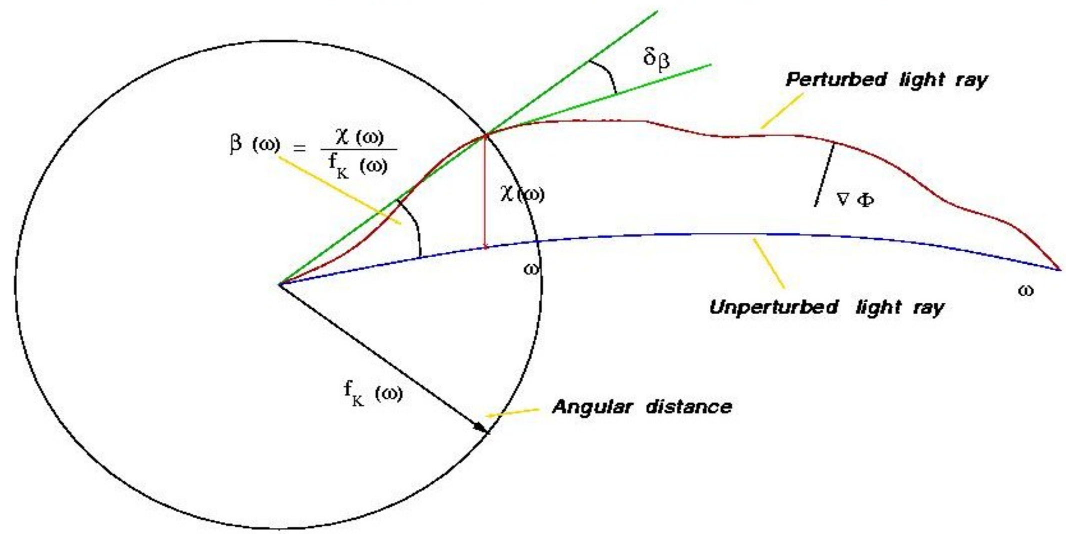
# Cosmic shear by large scale structure




Colombi, Mellier 2001

# Light propagation in the inhomogeneous universe

$$ds^2 = c^2 dt^2 - a^2(t)\,[dw^2 + f_K^{\,2}(w)\, d\omega^2]$$




Deflection angle:

$$\boldsymbol{\alpha} = -\frac{2}{c^2}\int_S^O \nabla_\perp \Phi \, dl \,.$$

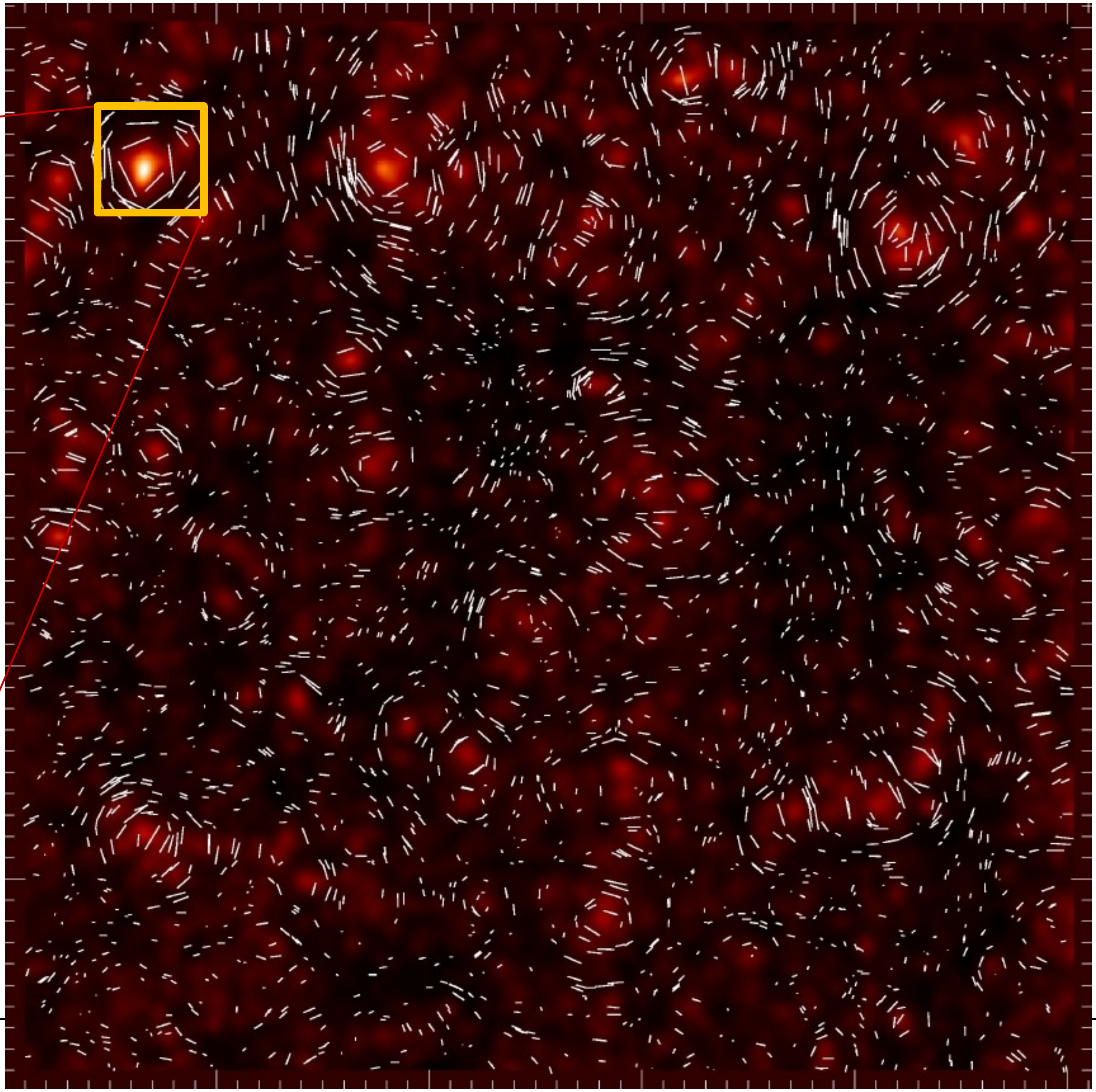
Gravity

Distances/Geometry

Power spectrum,
growth rate of structure

$$\kappa_{eff} = \frac{3H_0^2\Omega_0}{2c^2}\int_0^\omega \frac{f_K(\omega-\omega')\,f_K(\omega')}{f_K(\omega)}\,\frac{\delta\left[f_K(\omega')\,\boldsymbol{\theta};\omega'\right]}{a(\omega')}\,d\omega'$$

- Cosmic shear can « see » $P(k,z)$
- Dark matter and dark energy properties in the universe



# Cosmic shear = the DM power spectrum

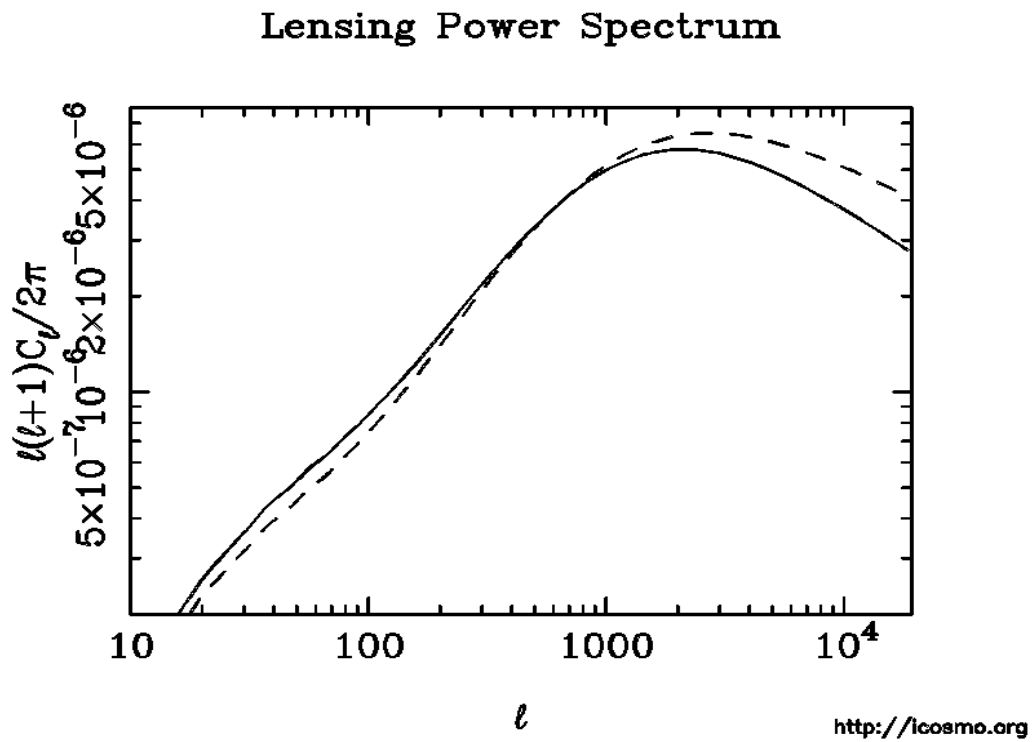


Geometry

Large Scale Structure

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

Light paths integrated
Over source to observer

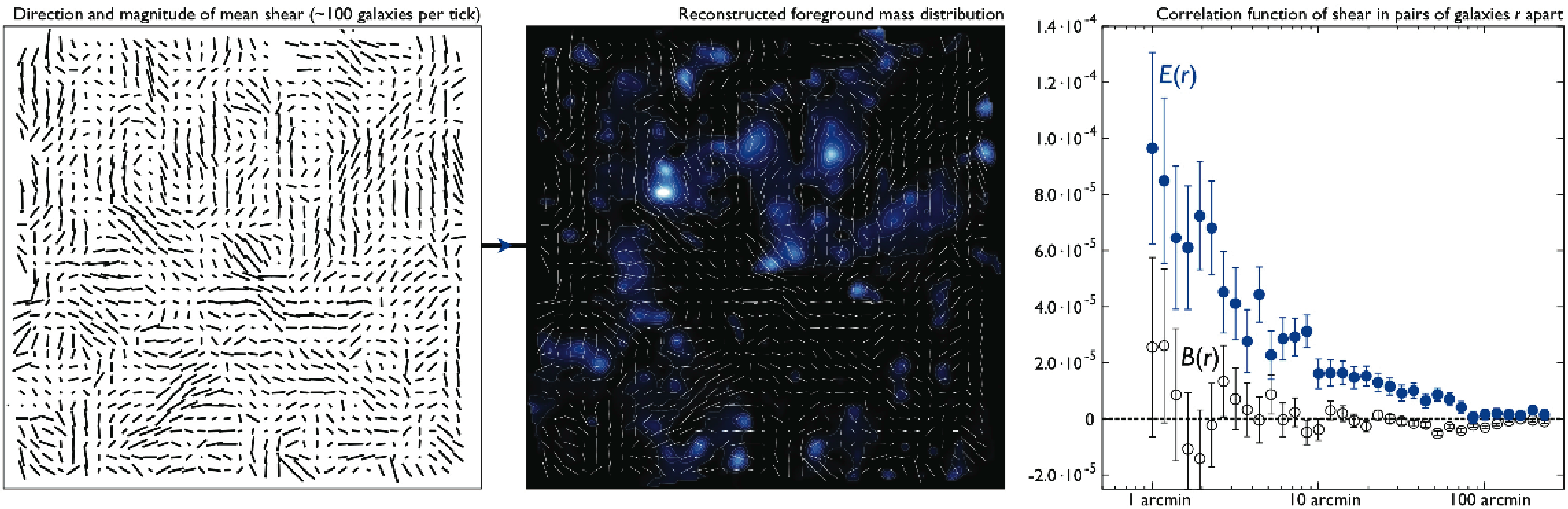



Courtesy Tom Kitching

# Cosmic shear with HST data



Massey et al 2007



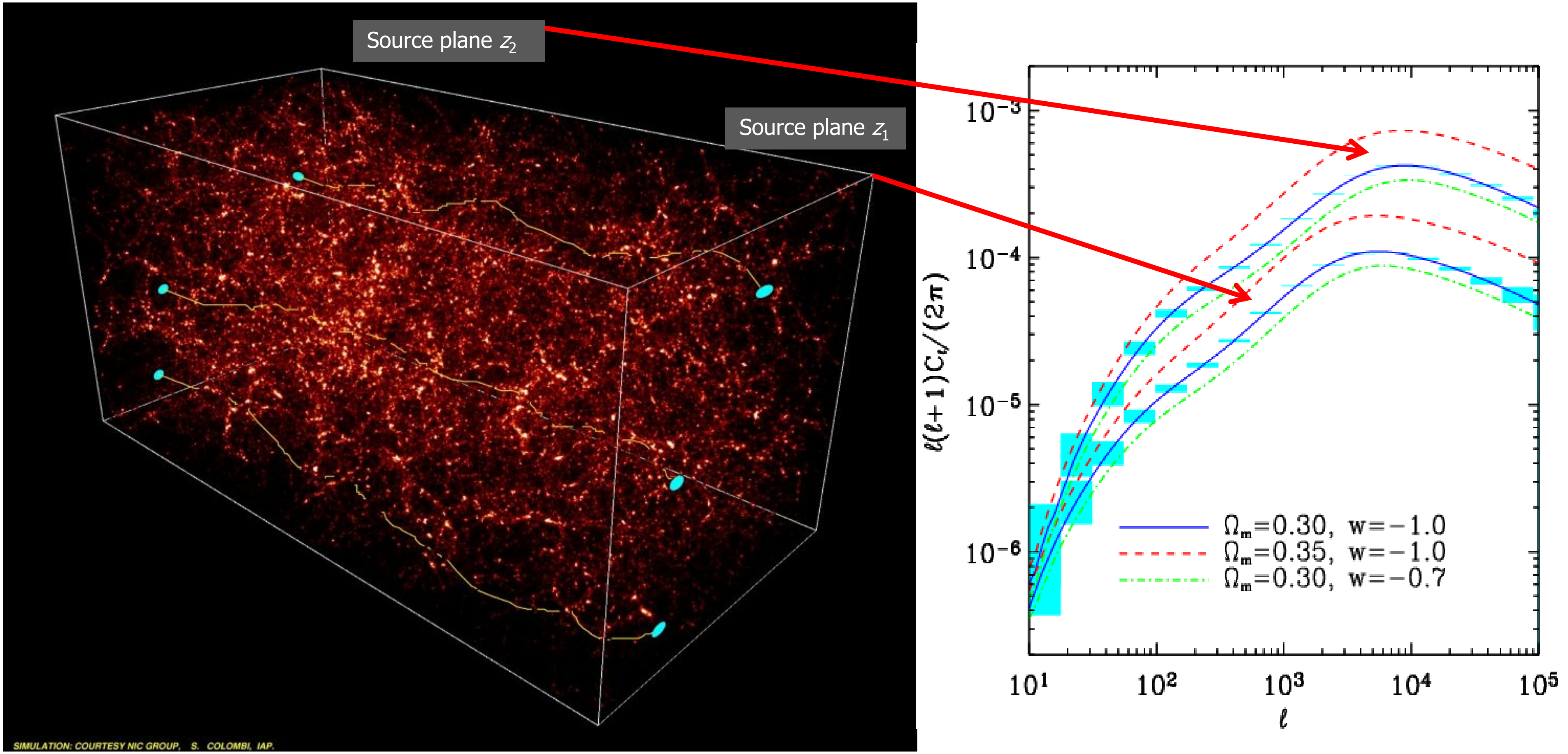

- Shear measured from the ellipticity of galaxies
- Cosmological lensing signal derived from the 2-points shear correlation functions

- But: very weak signal…

# Cosmic shear tomography: $P(k,z,w)$



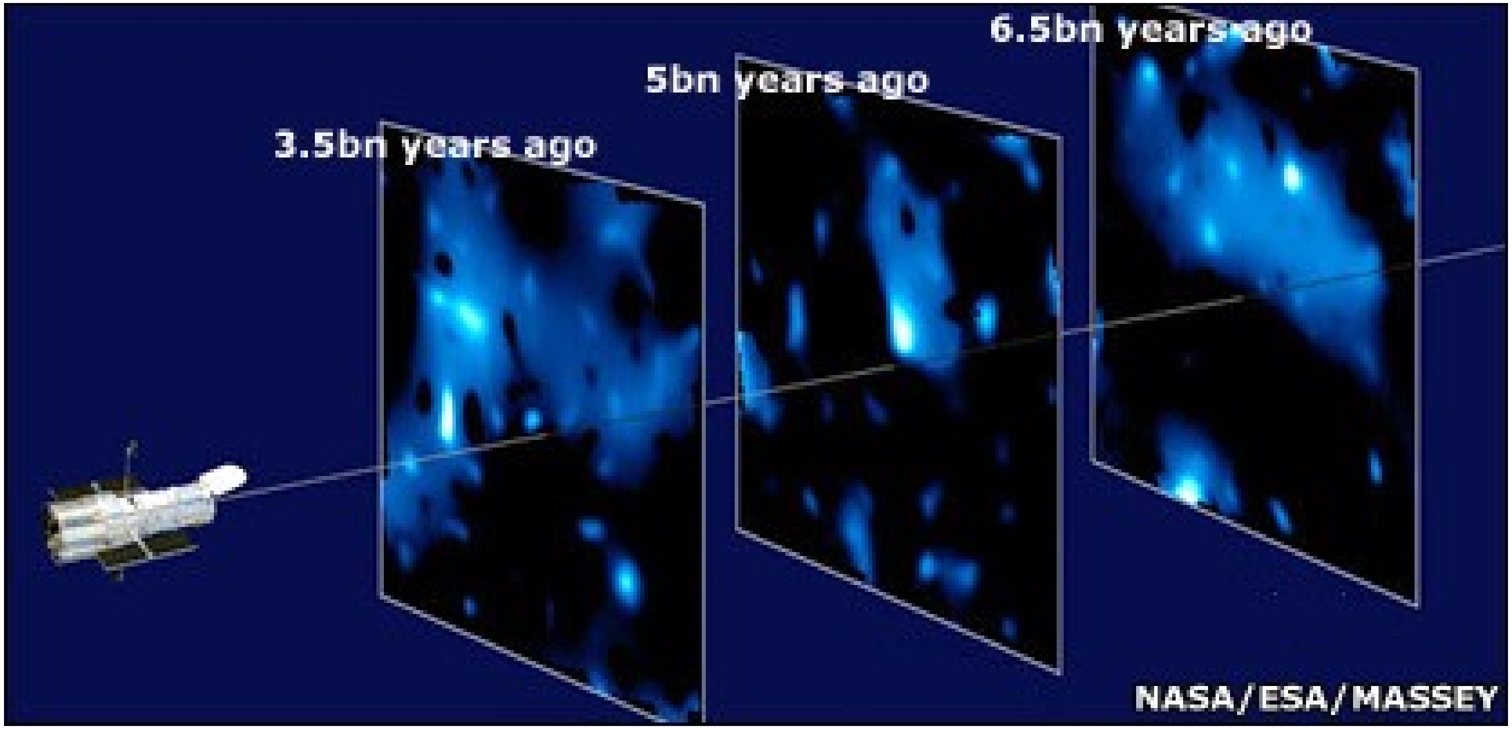
## Probing the evolution of cosmic structures with time




Colombi, Mellier 2001

# Tomography: need redshifts



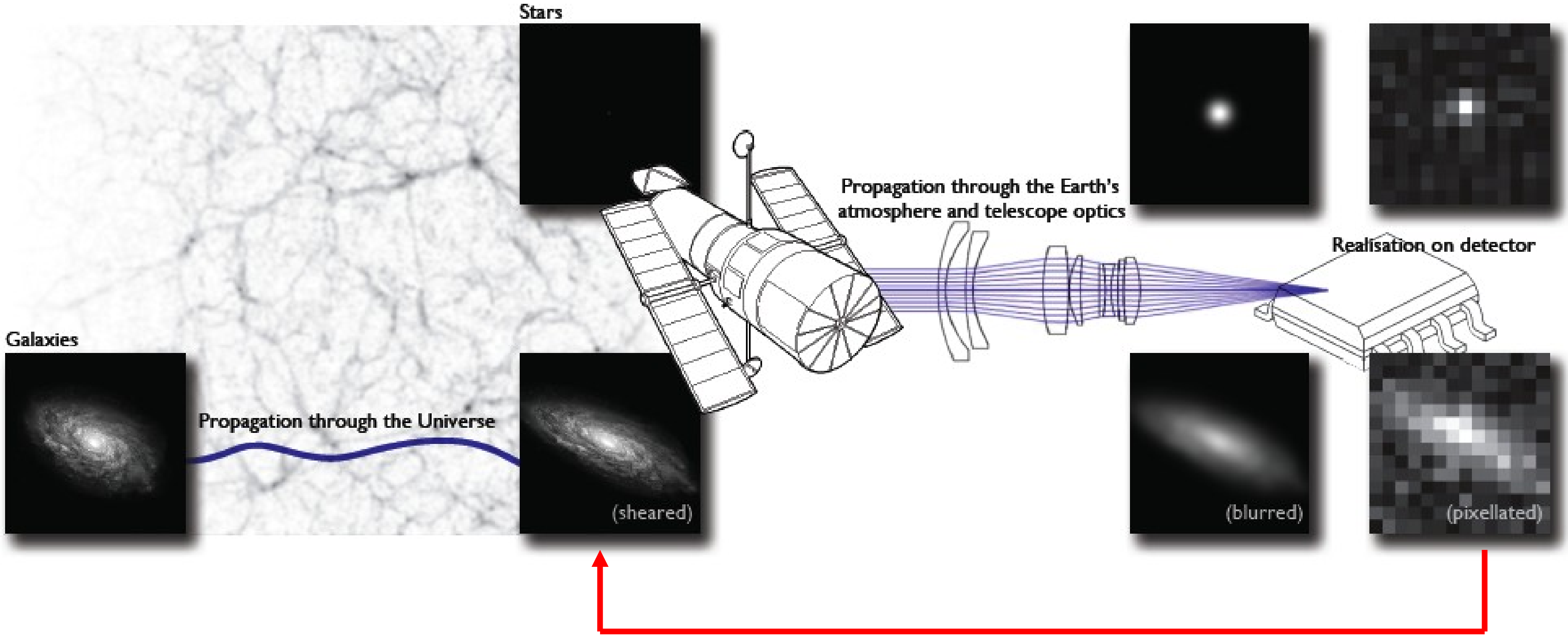



The achieve our science goals we need to measure the matter distribution as a function of redshift: weak lensing tomography requires redshifts for the sources.

# Challenge 1: measuring very weak shear



Figure from Kitching et al. 2012




Need to measure shear to $10^{-3}$

Measuring very weak shear with the same accuracy on 2 billion galaxies, over 15,000 $deg^2$ and with the same instrument during 6 years

# Challenge 2 : importance of redshifts



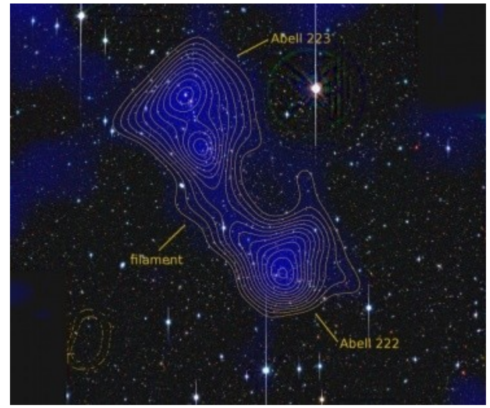
HST/ACS credit NASA/ESA

Galaxy halos

HST/ACS; credit NASA/ESA

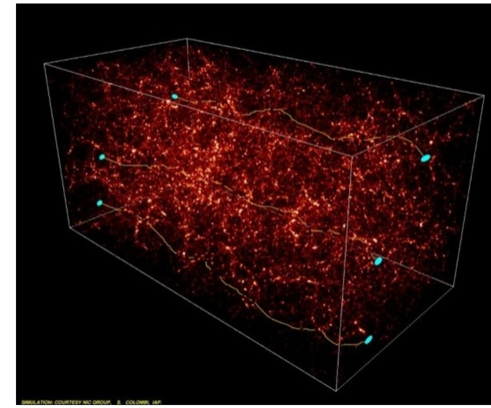
Clusters of galaxies

Dietrich et al 2012




Filaments between clusters

Colombi/Mellier



Cosmic shear

$$\vec{\alpha} = \frac{2}{c^2} \cdot \frac{D_{LS}}{D_{OS}} \; \vec{\nabla}_{\vec{\theta}_I} \phi_N^{2D}$$

Redshifts of sources and lenses are needed

# Importance of redshifts

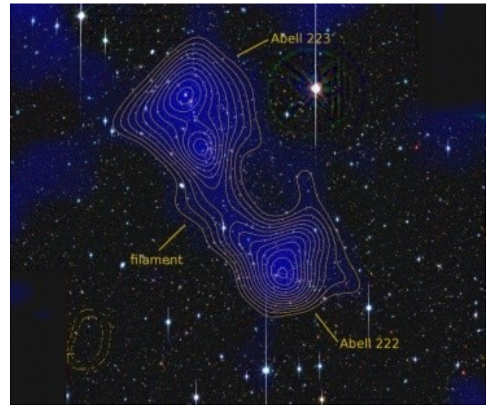
HST/ACS credit NASA/ESA

Galaxy halos

HST/ACS; credit NASA/ESA

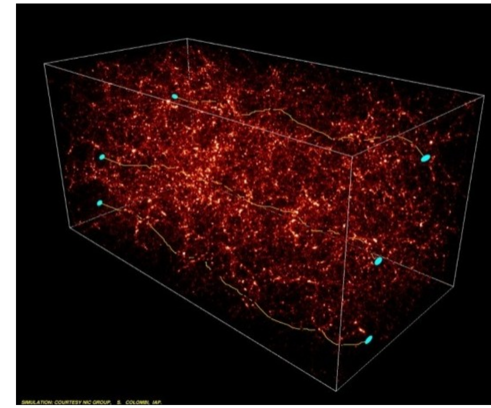
Clusters of galaxies

Dietrich et al 2012




Filaments between clusters

Colombi/Mellier



Cosmic shear

$$\vec{\alpha} = \frac{2}{c^2} \cdot \frac{D_{LS}}{D_{OS}} \vec{\nabla}_{\vec{\theta}_I} \phi_N^{2D}$$

Redshifts of sources and lenses are needed

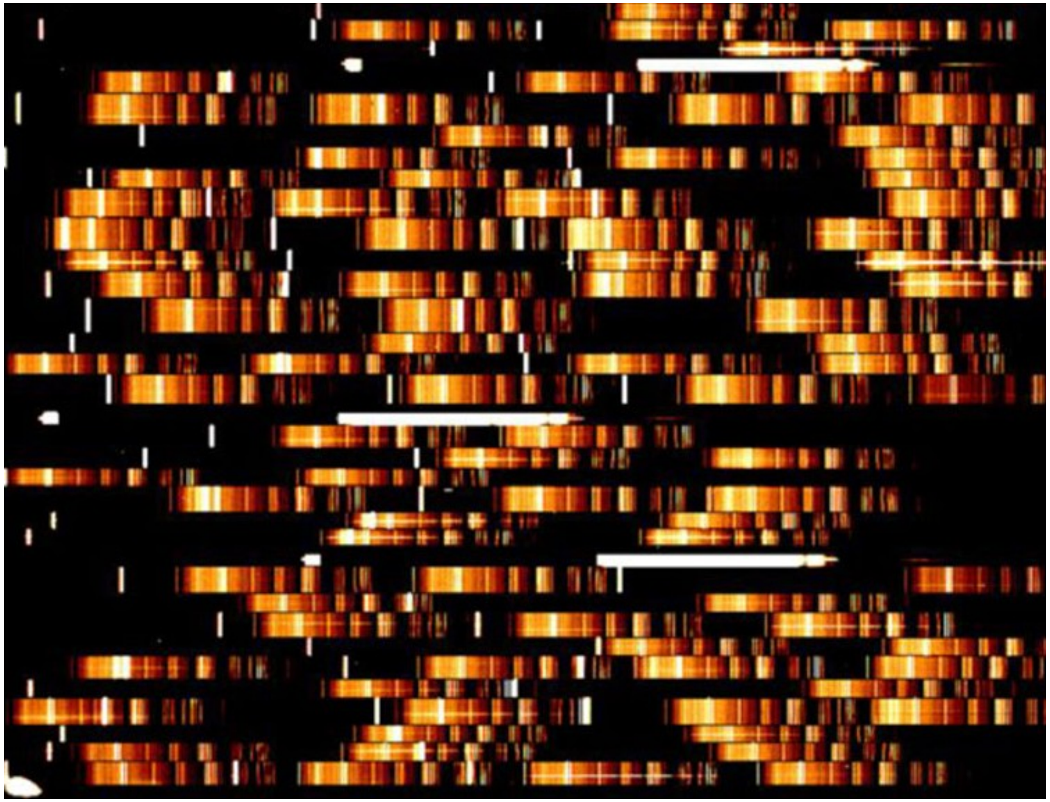
Cosmic shear tomography redshifts are also needed to

- Slice the universe
- Clean contamination by intrinsic alignements of galaxies

# Spectroscopic redshifts: ok for < $10^7$ galaxies



ESO PR, Le Fèvre et al 2006



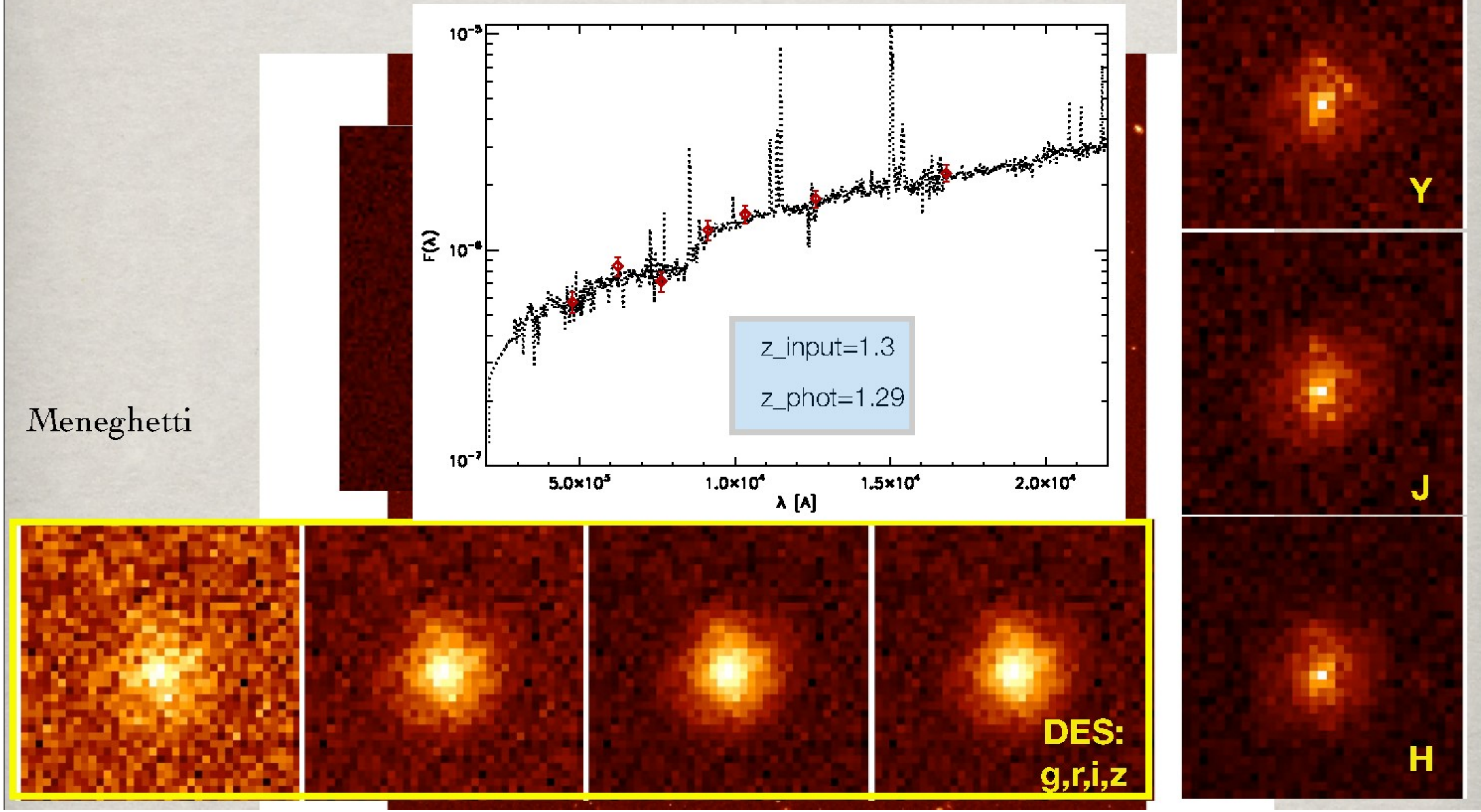
- **CFHTLS : VVDS** with VMOS,
  - 32,000 redshifts to I=22.5 over ~15 $deg^2$, (Garilli et al 2008)
  - 15,000 to I=24 over ~1 $deg^2$ (Le Fèvre et al 2005)
  - 1000 redshifts 23<I<24.75 over 0.15 $deg^2$ (Le Fèvre et al 2012)

- **CFHTLS : VIPERS** with VMOS: ~100,000 redshifts to I=22.5 over 25 $deg^2$ (Guzzo et al 2012)

- **COSMOS : z-Cosmos** with VMOS:
  - ~ 20,000 redshifts to I=22.5 over 1.7 $deg^2$ (Lilly et al 2009)
  - ~10,000 redshiifts B<25.25 color selected, over 0.9 $deg^2$

… but not feasible to get spectroscopic redshifts of 2 billion Euclid galaxies

# Image simulations: Euclid + ground based data

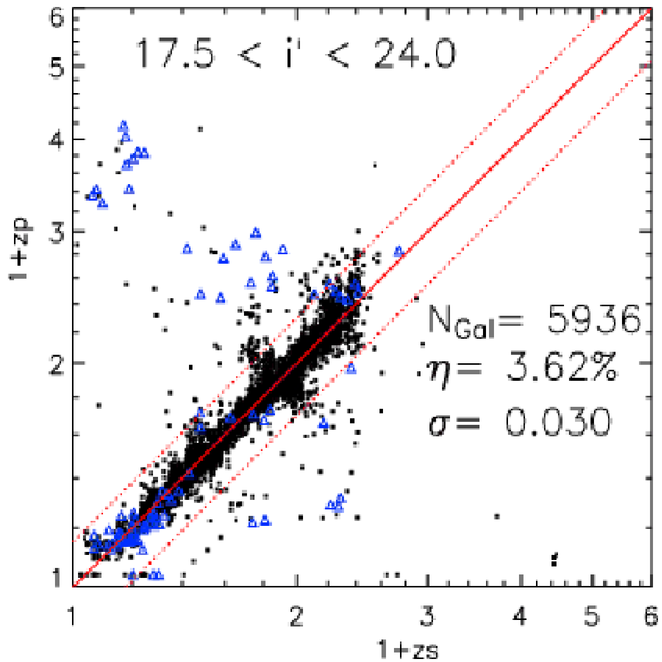



Meneghetti

# Photometric redshifts with Euclid: need VIS+NIR

Euclid Consortium

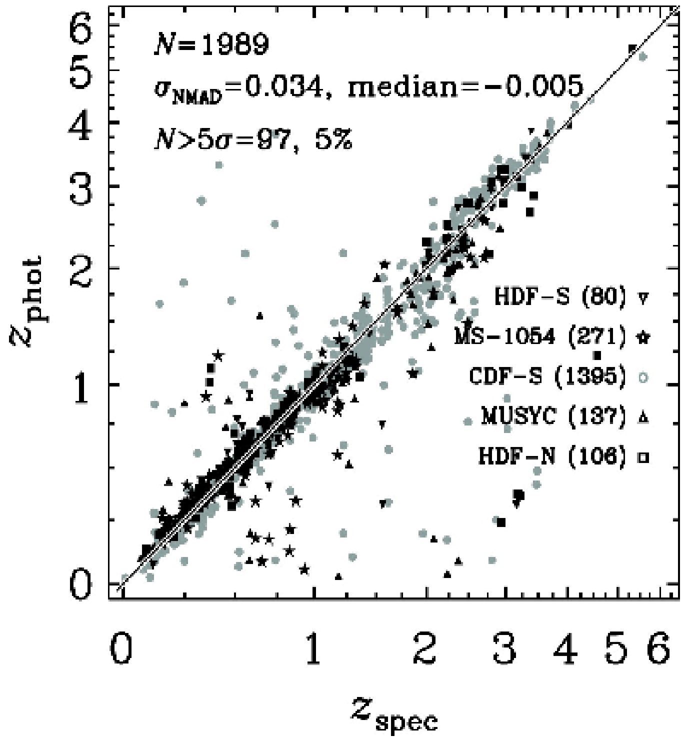
## Photo-z vs. spec-z (deep optical)




Coupon et al. (2009)

Courtesy:H. Hildebrandt

## Photo-z vs. spec-z (deep optical+IR)




Brammer et al. (2008)

Euclid weak lensing will probe the lensed universe between redshift 0.2 and 3…
→ both visible and near infrared photometry are needed for photometric redshift

# Current cosmic shear surveys

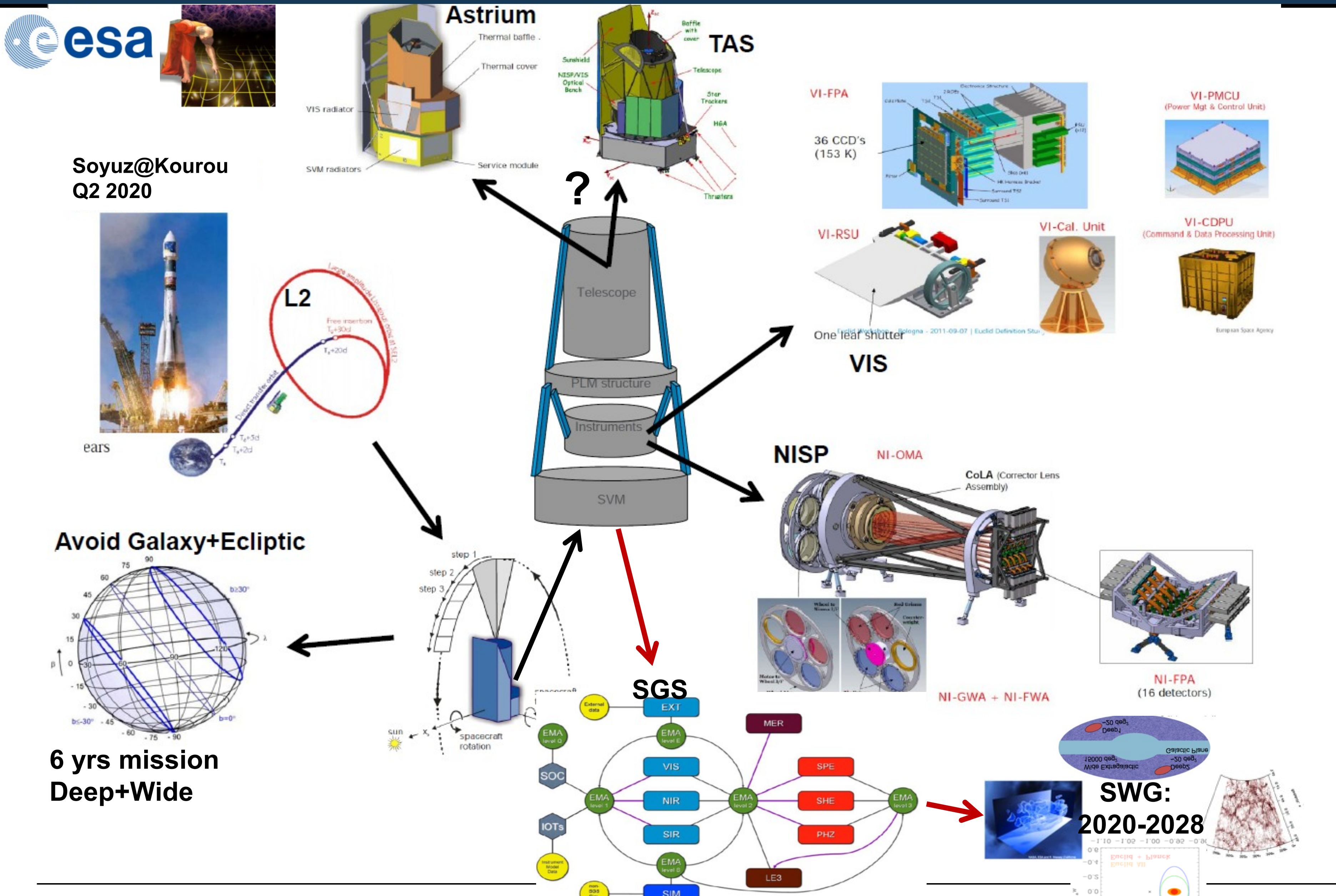


- CFHTLS - CFHTLenS survey 2006-2012
  - CFHTMegacam Ground-based survey
  - 154 square degrees to median z=0.8
  - See Kitching et al. 2012, Kilbinger et al. 2012, Simpson et al. 2012, Benjamin et al. 2012 for cosmological results
- COSMOS/HST 2006-2012: 2 $deg^2$
- Next generation 2012-2017
  - KIDS/VIKING: 1500 $deg^2$ with VST + VISTA
  - Dark energy Survey 5000 $deg^2$
  - HSC with Subaru 2000 $deg^2$

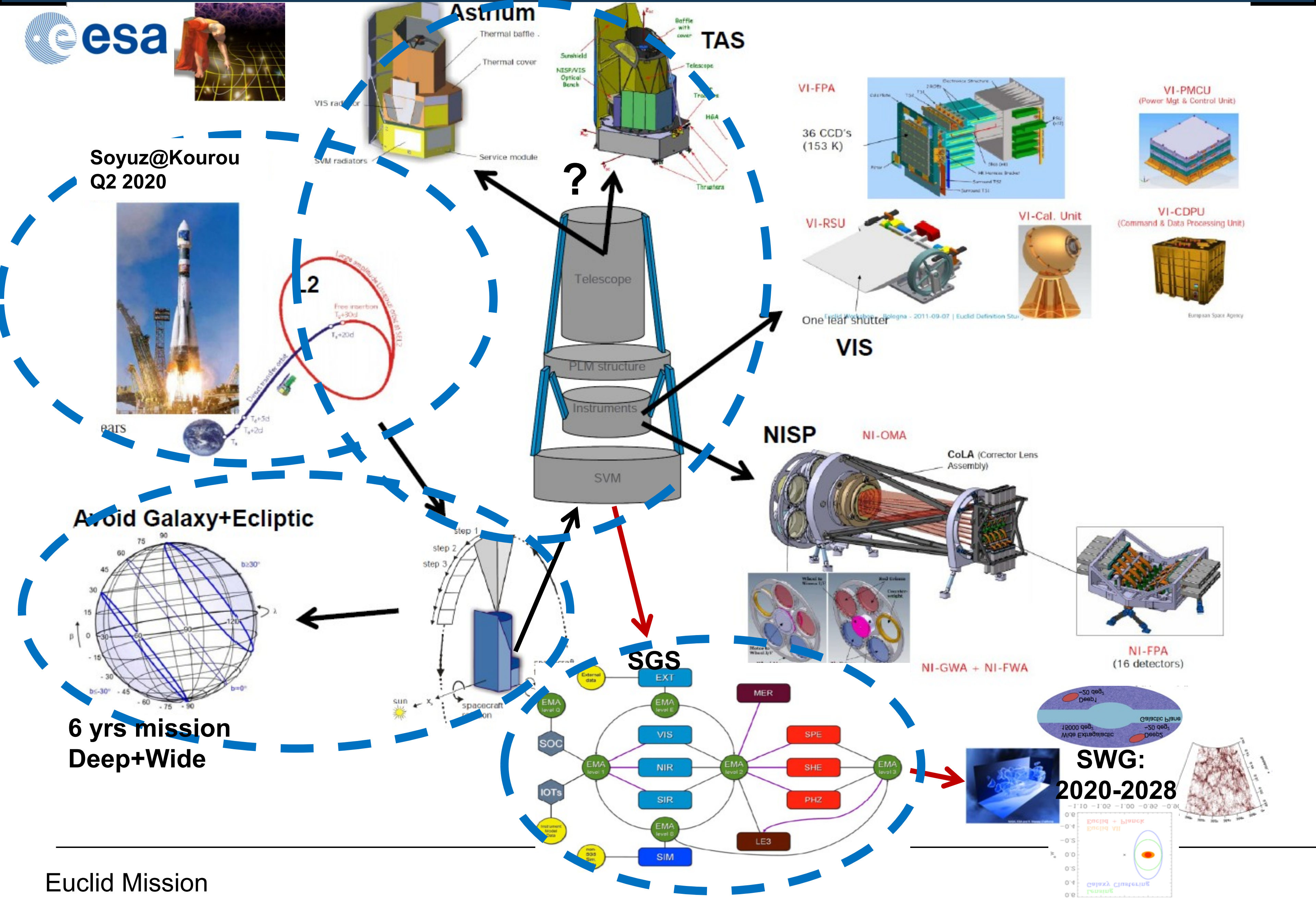
# The Euclid mission

# The Euclid mission



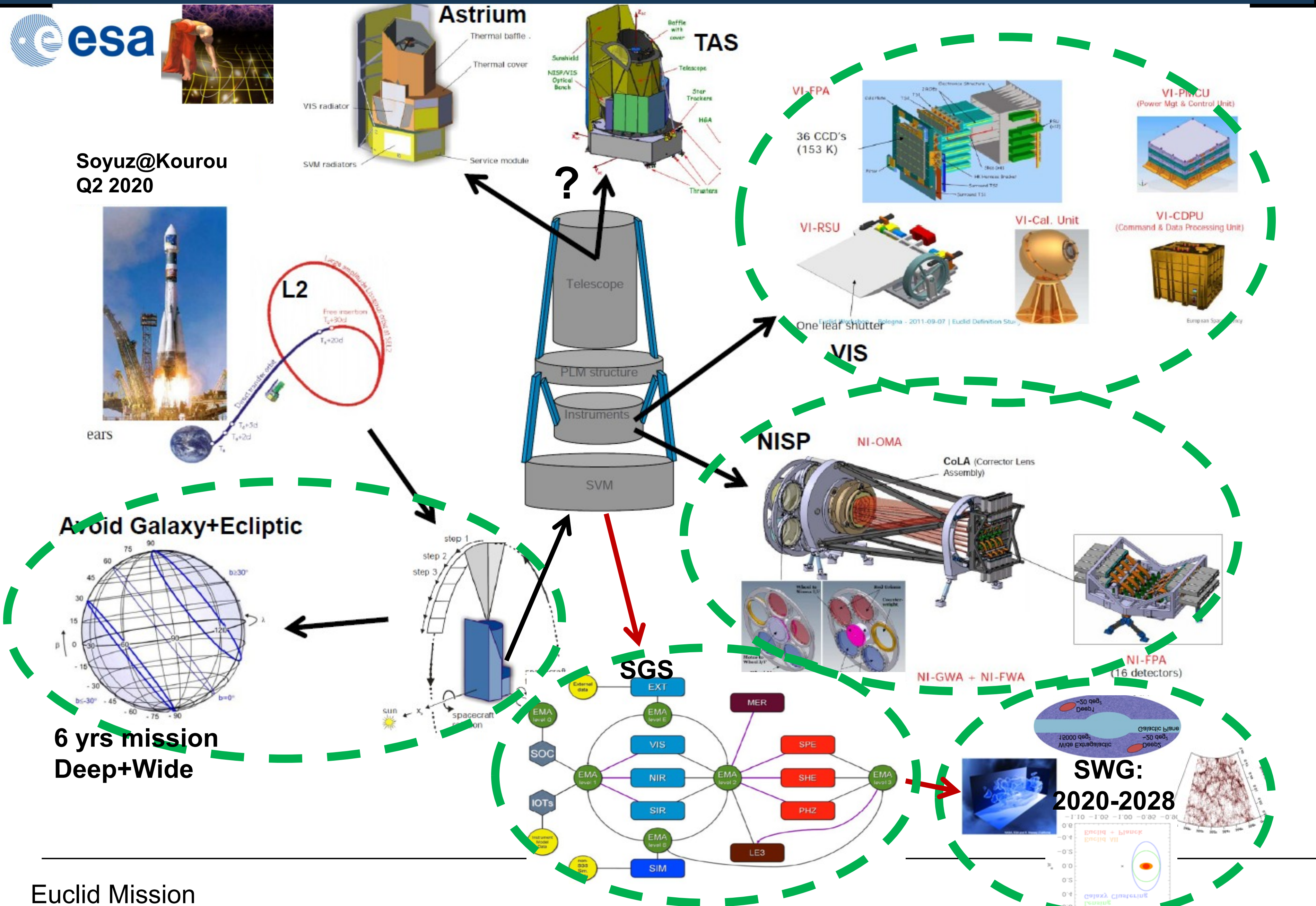


# Contributions of ESA/industry



# Contributions of the Euclid Consortium

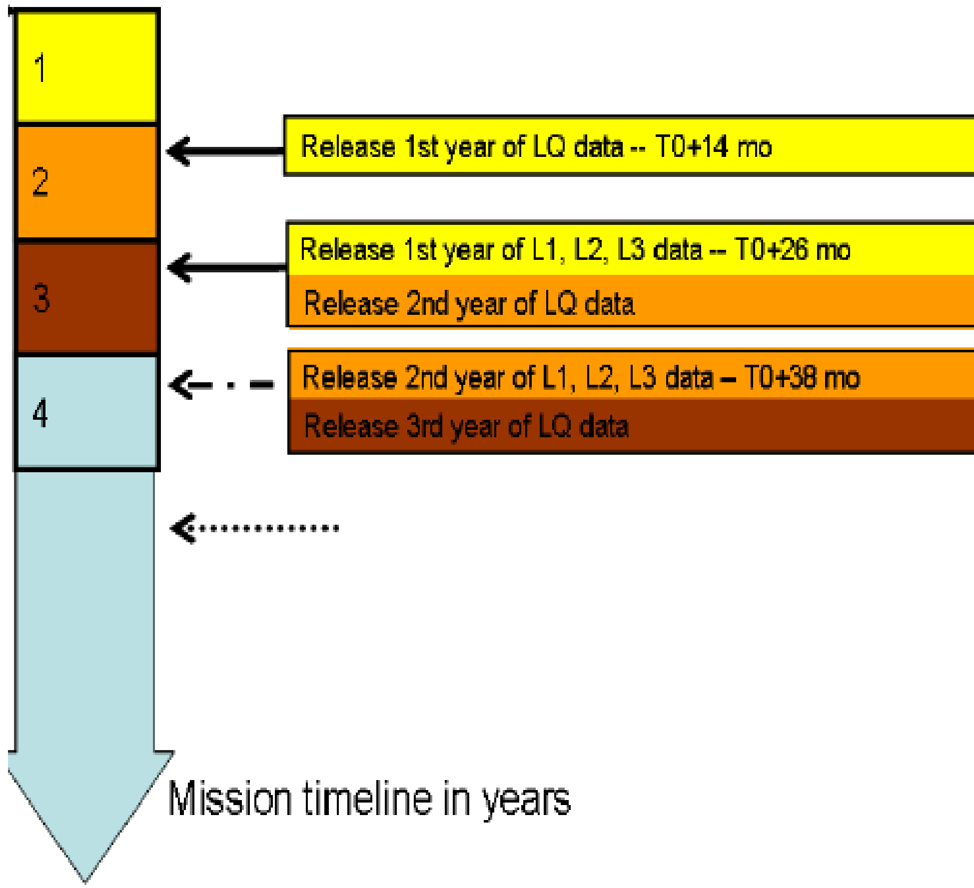




# Data products and releases



- First release Level Q (Quick) data release: 14 months after the start of the survey (TBC)
- 
- First complete data release: 26 months after the start of the survey
- Then yearly releases



# Telescope and instruments

# Main requirements to design the mission

Euclid Consortium

| | Wide survey | Deep survey |
|---|---|---|
| **Survey** | | |
| size | 15000 $deg^2$ | 40 $deg^2$ N/S |
| **VIS imaging** | | |
| Depth | $n_{gal}$ > 30/arcmin$^2$ → $M_{AB}$ =24.5 → <z> ~0.9 | $M_{AB}$ = 26.5 |
| PSF size knowledge | $\sigma[R^2]/R^2<10^{-3}$ | |
| Multiplicative bias in shape | $\sigma[m]<2\times10^{-3}$ | |
| Additive bias in shape | $\sigma[c]<5\times10^{-4}$ | |
| Ellipticity RMS | $\sigma[e]<2\times10^{-4}$ | |
| **NIP photometry** | | |
| Depth | 24 $M_{AB}$ | 26 $M_{AB}$ |
| **NIS spectroscopy** | | |
| Flux limit (erg/cm$^2$/s) | 3 $10^{-16}$ | 5 $10^{-17}$ |
| Completness | > 45 % | >99% |
| Purity | >80% | >99% |
| Confusion | 2 rotations | >12 rotations |

- WL and systematics

$$\gamma^{obs} = (1+m)\times\gamma^{true} + c$$

$$C_l^{true} \approx \left[1+2\langle m\rangle\right]\times C_l^{obs} + \langle c\rangle^2$$

→ $m < 2\times10^{-3}$ : multiplicative bias
$\sigma^2_{sys} \approx \langle c^2\rangle < 10^{-7}$ : additive bias

→ Small PSF
→ Knowledge of the PSF size
→ Knowledge of distortion
→ Stability in time
→ External visible photometry for photo-z accurary: 0.05x(1+z)
(+ Methods to correct distortion)

---

- GC and GC systematics

→ Catastrophic z < 10%
→ <z>/(1+z)<0.002
→ Understand selection→Deep field
  - Completeness
  - Purity

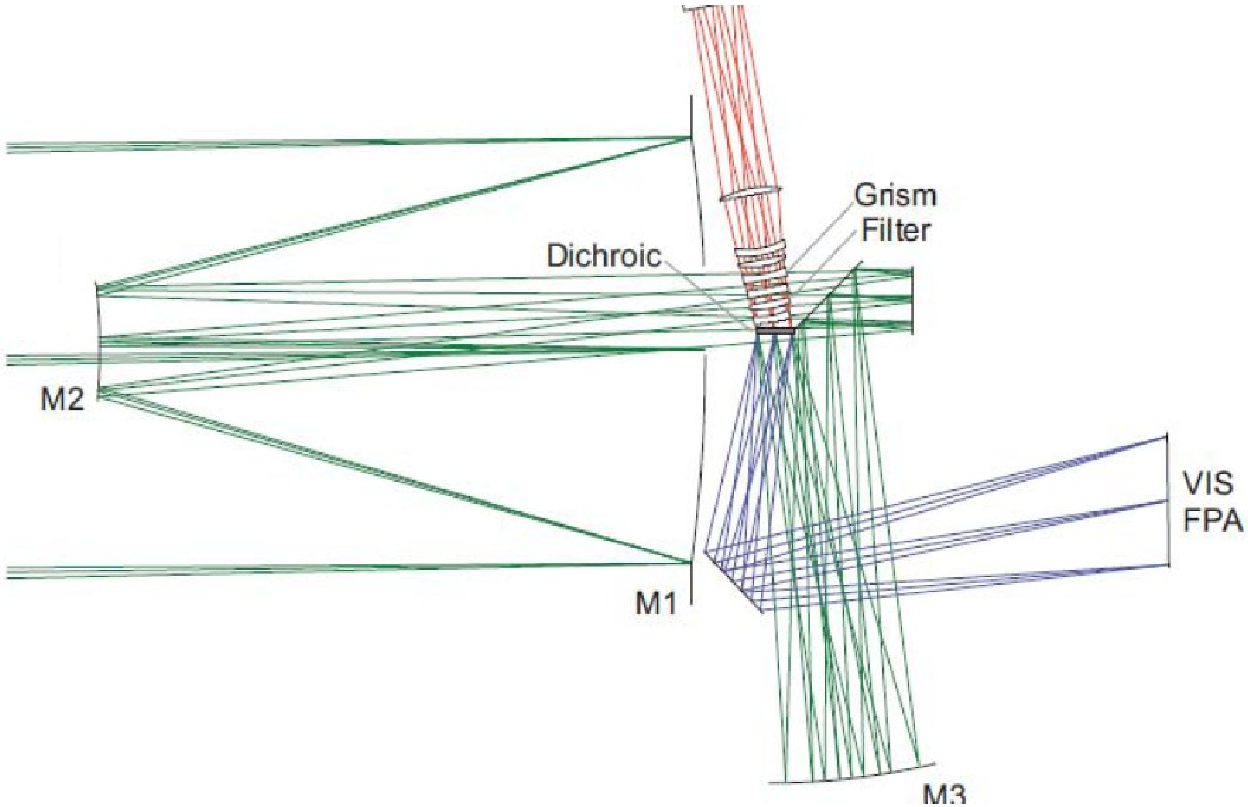
# Current optical design



Telescope:

1.2 m Korsch , 3 mirror anastigmat, with a 0.45 deg. off-axis field , f=24.5m

Optically corrected and unvignetted FoV : 0.79 x1.16 $deg^2$



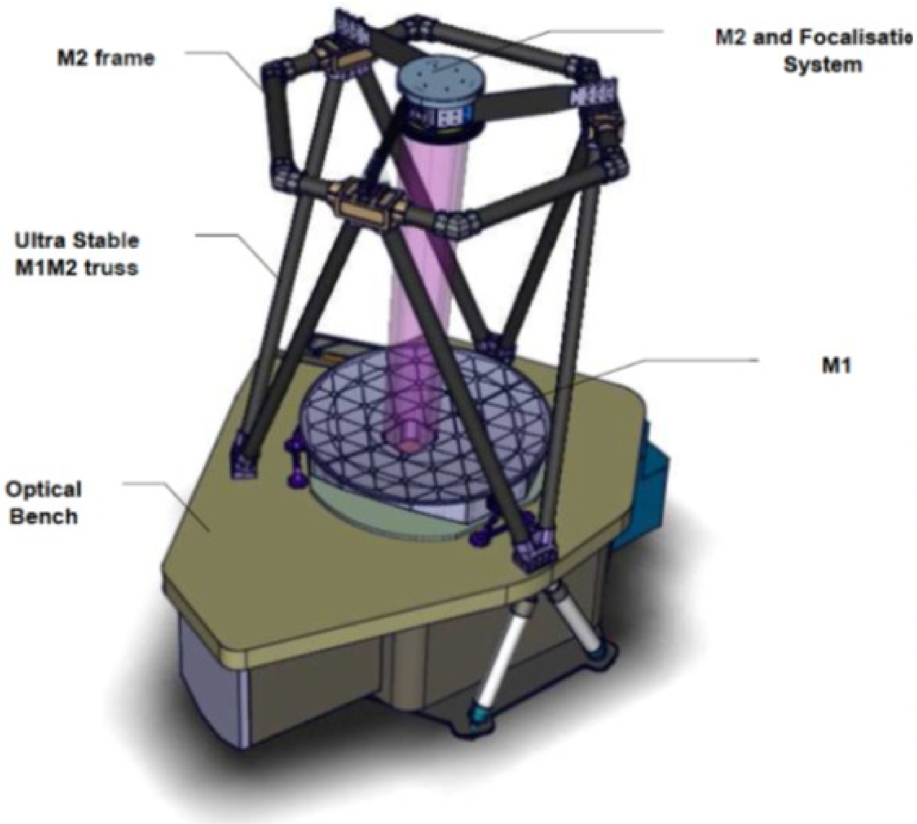

VIS and NISP: share the same FoV (0.54 $deg^2$)

Dichroic beam splitter at exit pupil : Visible and Near Infrared observations in parallel

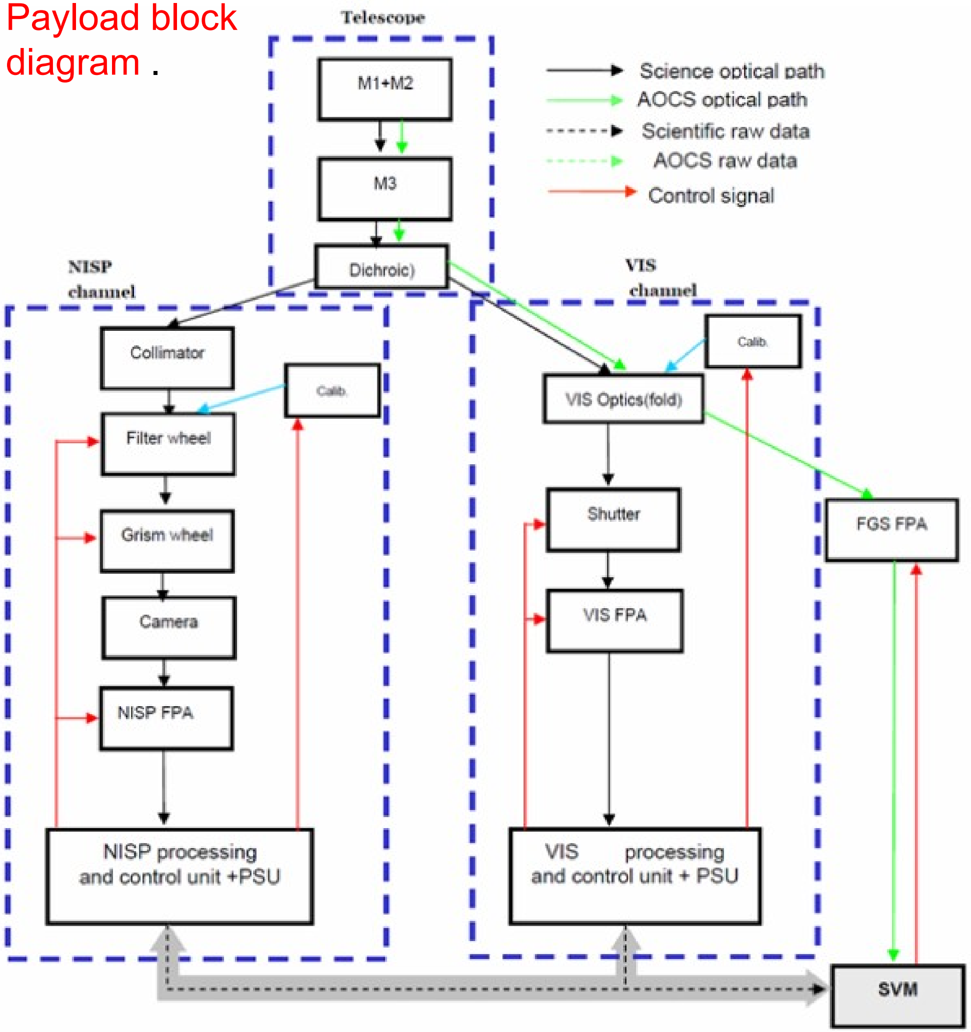
# Telescope and payload module



Typical telescope mechanical architecture




Payload block diagram .




Note: pointing error in spacecraft x,y direction = 25mas over 600 s.

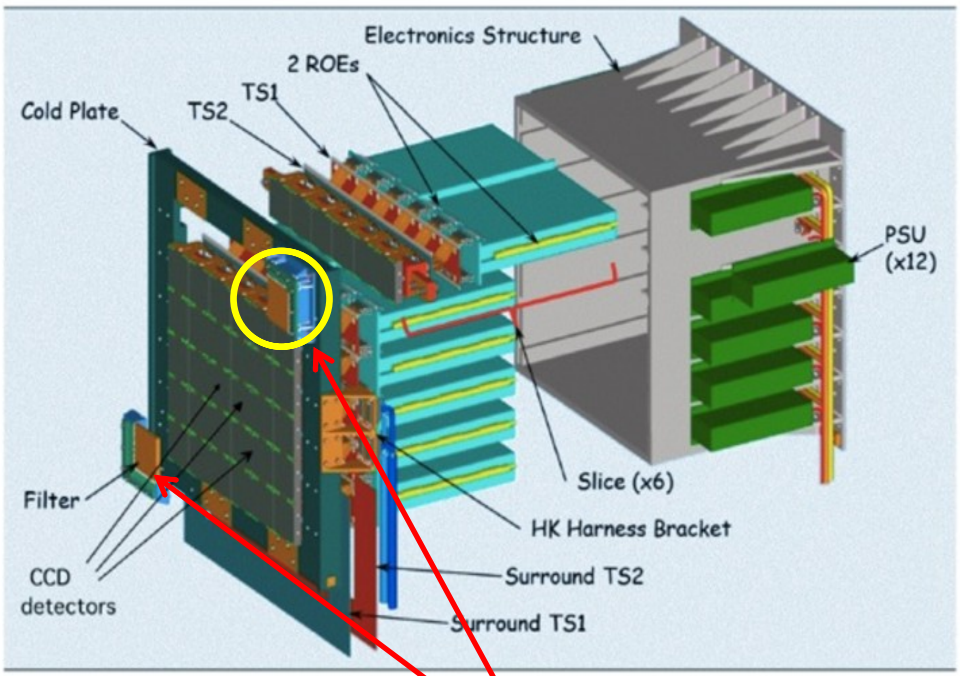
Reference: Laureijs et al 2012. SPIE.

FGS FPA = Fine Guidance Focal Plane Array: mounted on the VIS FPA and part of the Attitude and Control Orbit System (AOCS)

# VIS Instrument



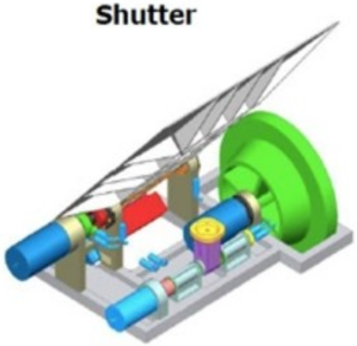
- large area imager – a 'shape measurement machine'
- 36 4kx4k CCDs with 12 micron pixels
- 0.1 arcsec pixels on sky
- bandpass 550-900 nm –
- limiting magnitude for wide survey of magAB = 24.5 for 10σ (extended)
- data volume – 520Gbit/day



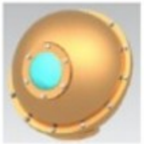

**Focal Plane Assembly**

**Narrow band filters (color gradient)**
**→ Suppressed .**

**Shutter**

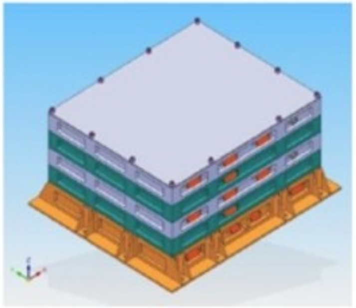


**Cal Unit**



**WARM**

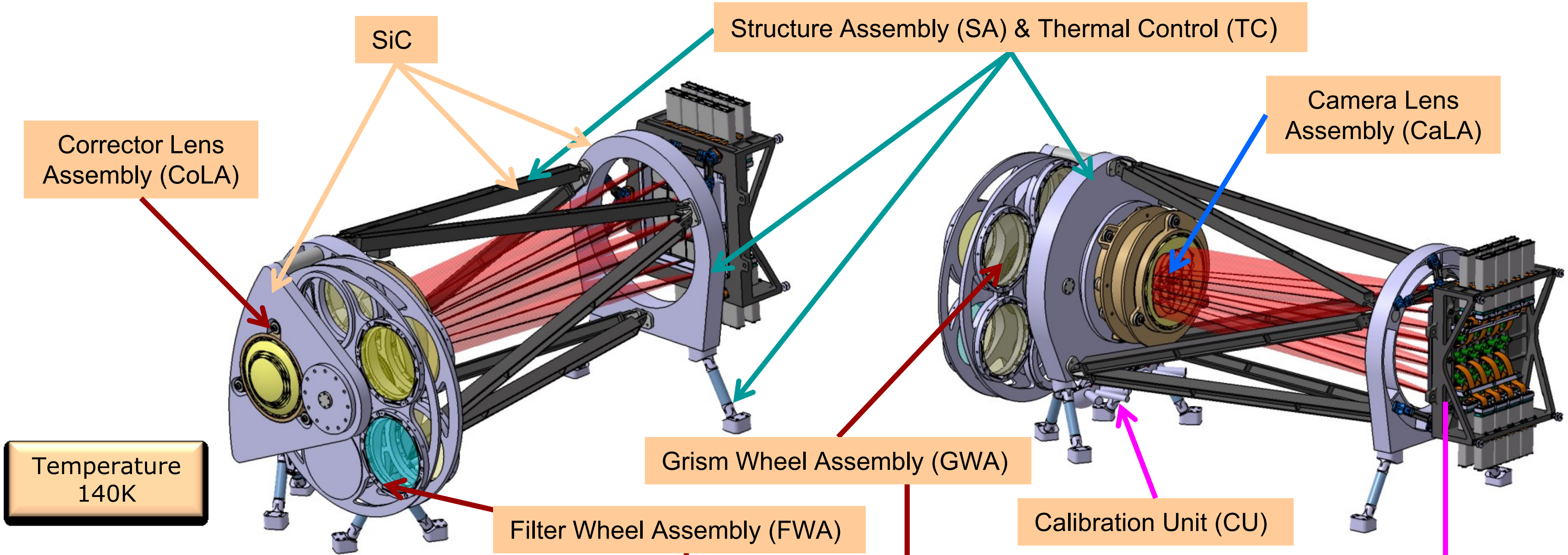
**Power and Mechanisms Control Unit**

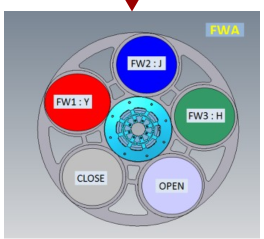


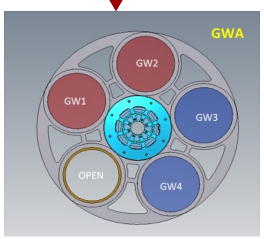
**Command and Data Processing Unit**

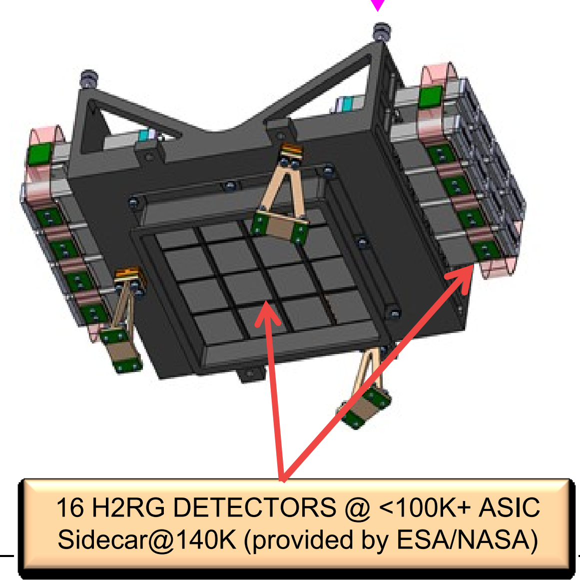
# NISP instrument



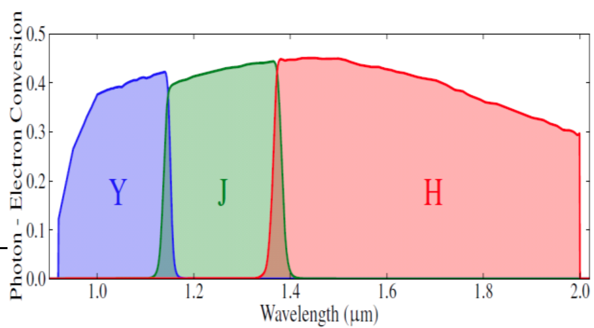


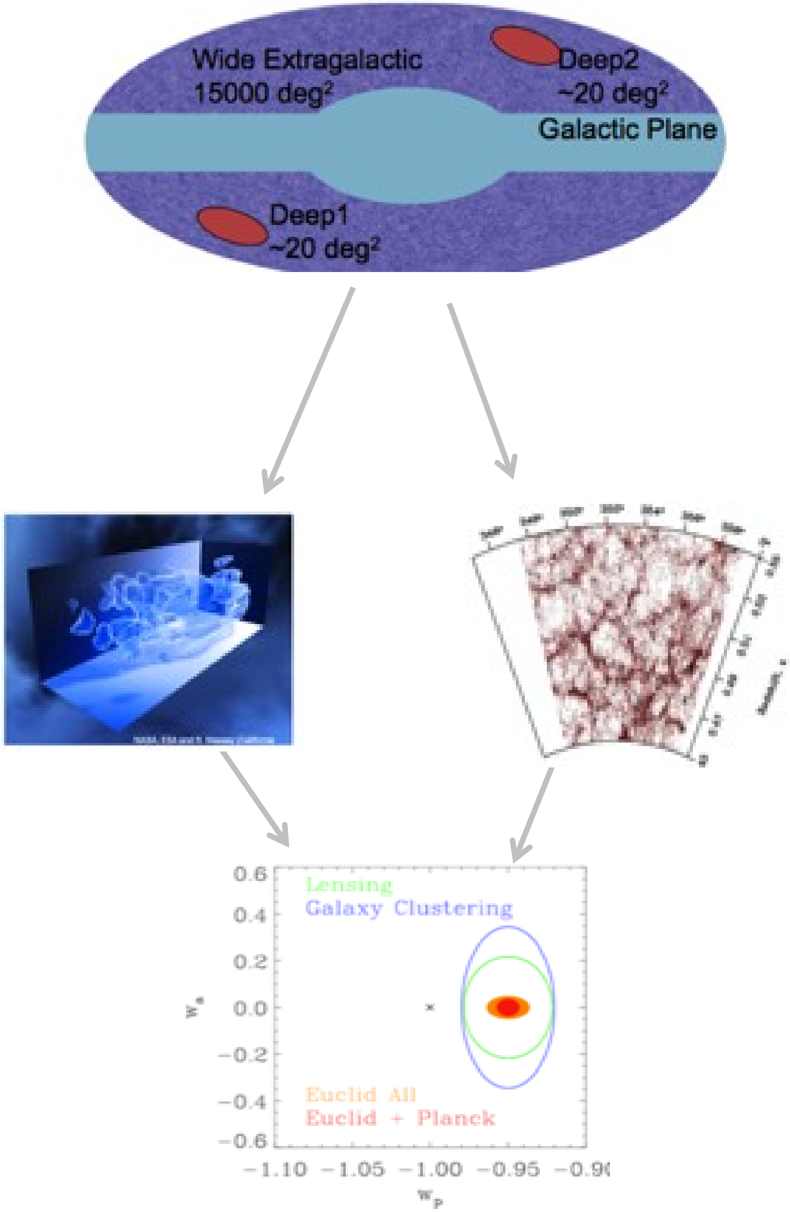




- 16 NIR 2kx2k H2RG detectors
- 0.3 arc/pixel
- 4 Grisms (2 blue, 2 red, rotated by 90 deg.) ;
- 3 NIR filters: Y, J H
- Telemetry= 180 Gbit/day






# Performances:

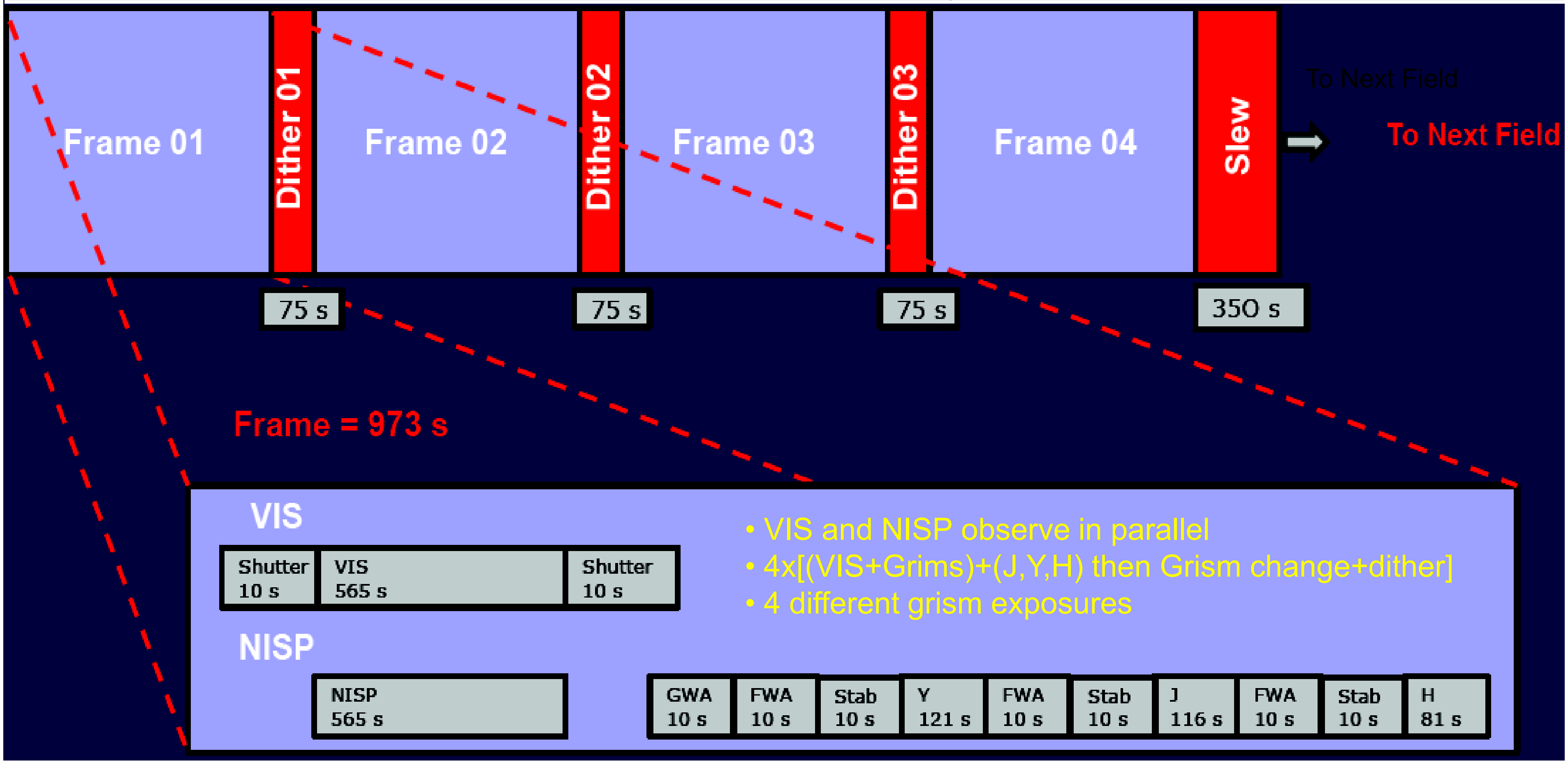
- Survey,
- Images,and observables
- Cosmology

# NISP+VIS field observing sequence



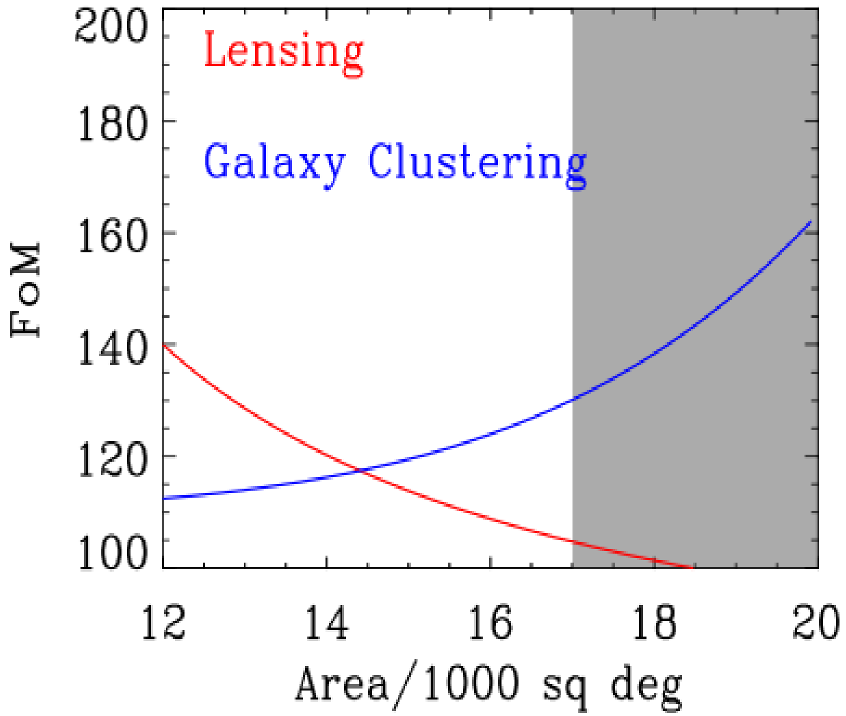
Total Field of View observation time (time between 2 fields observations):

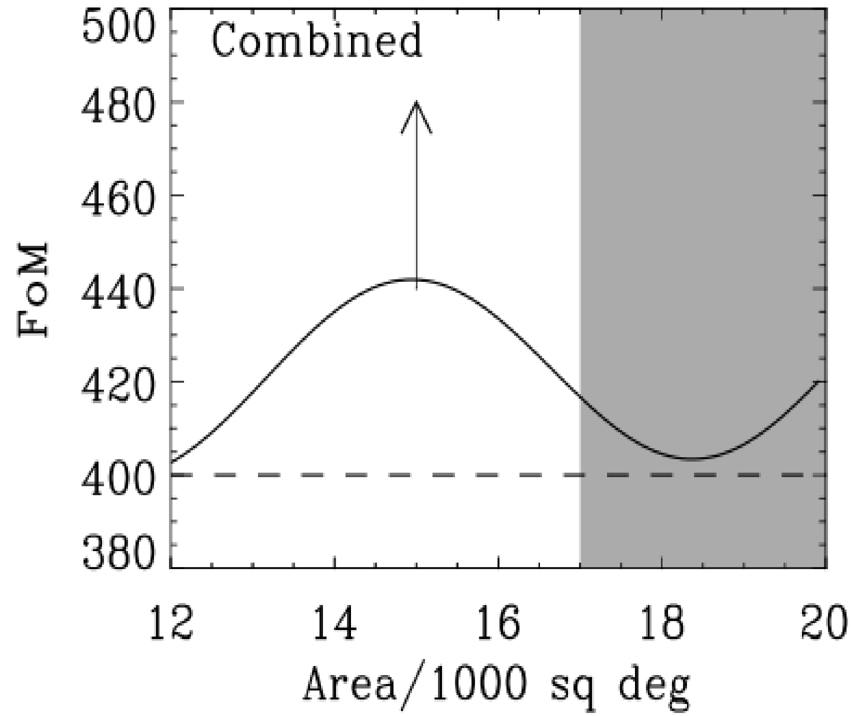
•Reference Case = 4 x 973 s + 3 x 75 s + 350 s = 4467 s → **Reference Field Sequence = 4500 s**



# Optimal sky coverage for a fixed-length survey





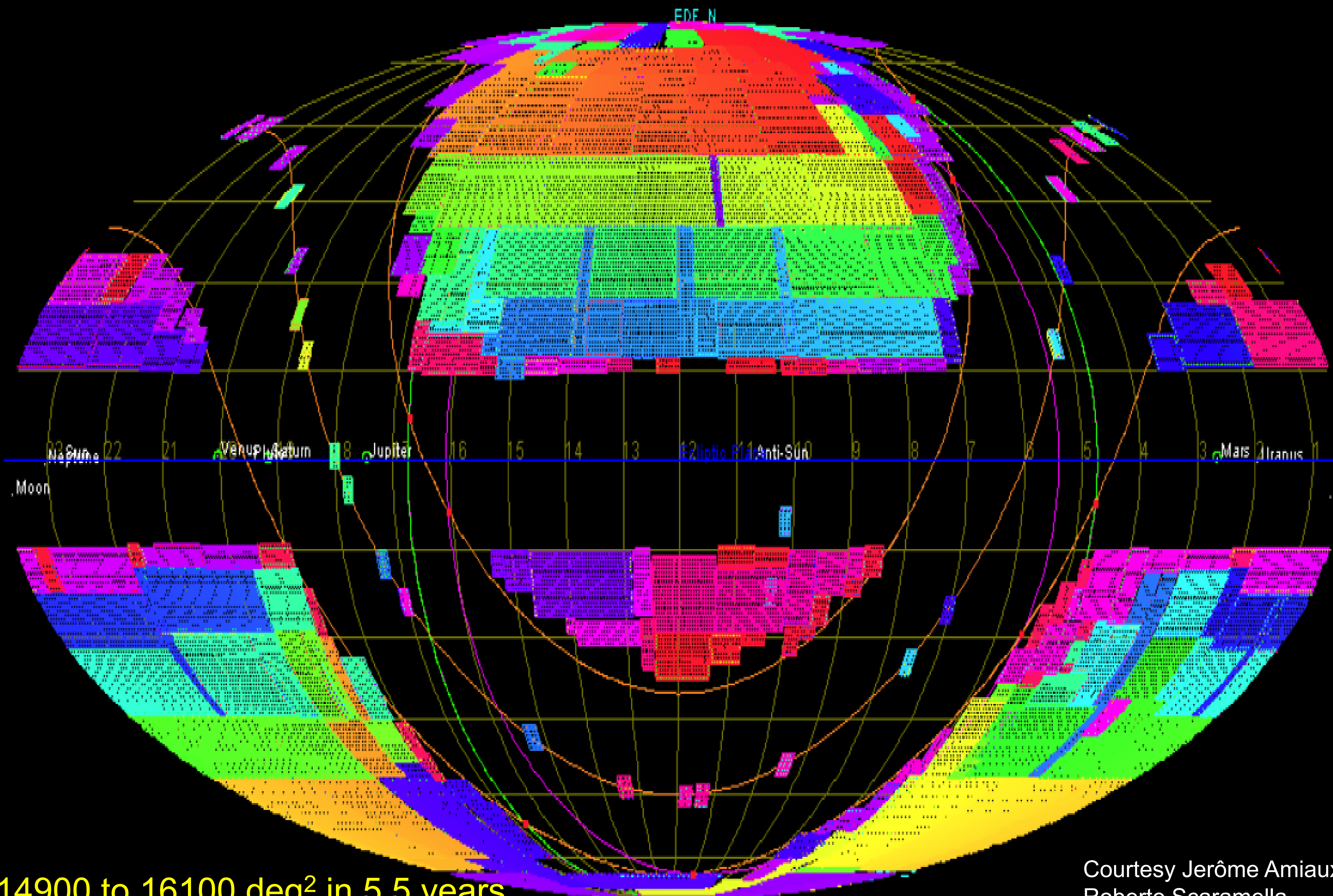




- With 15,000 $deg^2$ for for GC and WL: optimisation for a fixed time survey.
- Allows Euclid  to do WL and GC simultaneously on the same area.

| Req. ID | Parameter | Requirement | Goal |
|---|---|---|---|
| WL.1-1 & GC.1-1 | Survey area | >15,000 $deg^2$ | >20,000 $deg^2$ |
| WL.1-2 | Number density | >30 $arcmin^{-2}$ | >40 $arcmin^{-2}$ |
| WL.1-3 | Mean redshift | >0.8 | |

# Euclid Deep+Wide surveys feasible in 5.5 years

**Euclid Consortium**



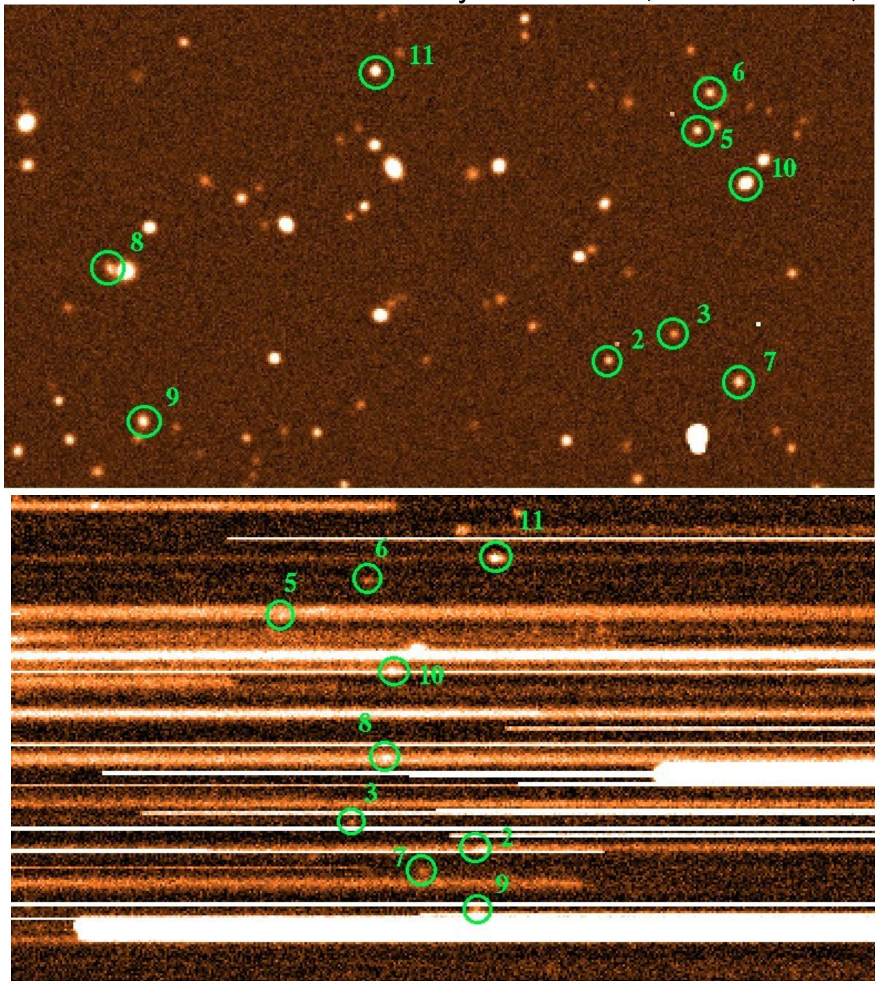

14900 to 16100 $deg^2$ in 5.5 years

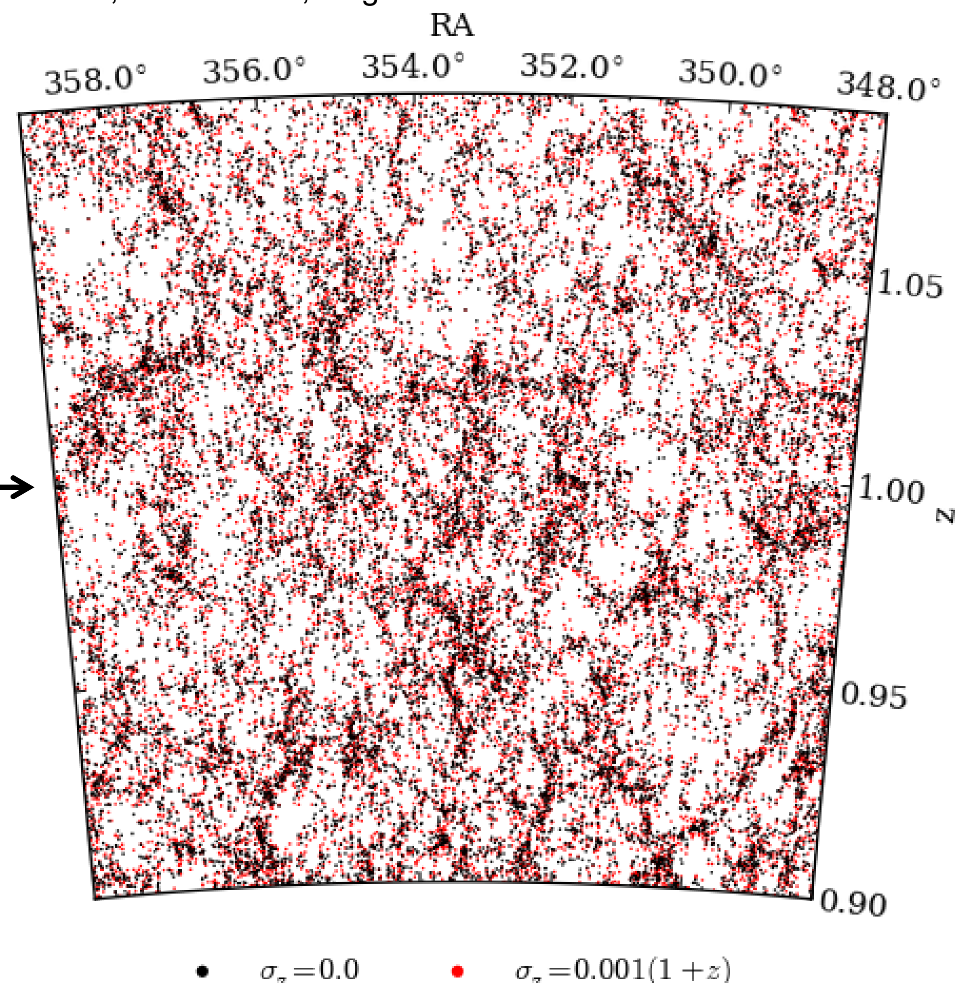
Courtesy Jerôme Amiaux, Roberto Scaramella

# NISP Performance: images/spectra/redshifts

Euclid Consortium

Courtesy Anne Ealet, Knud Jahnke, Bianca Garilli, Will Percival, Luigi Guzzo






- 1 deg2 of the sky simulated and propagated through end-2-end Euclid spectroscopic simulation
- Shows can meet the required n(z), completeness and purity

True vs. measured redshift

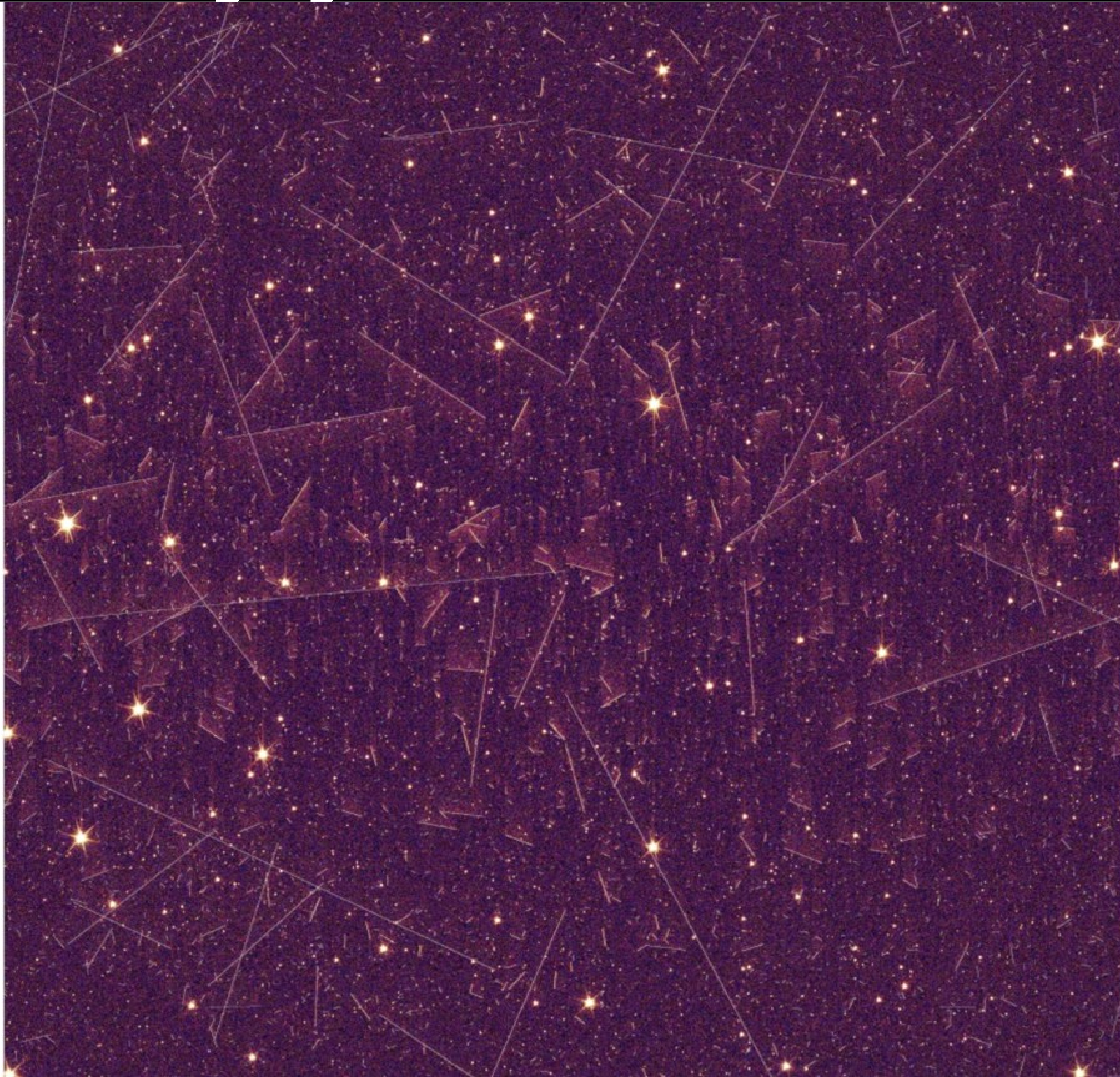
All performances have been verified at image simulation level

# VIS performance:imaging



A 4kx4k view of the Euclid sky

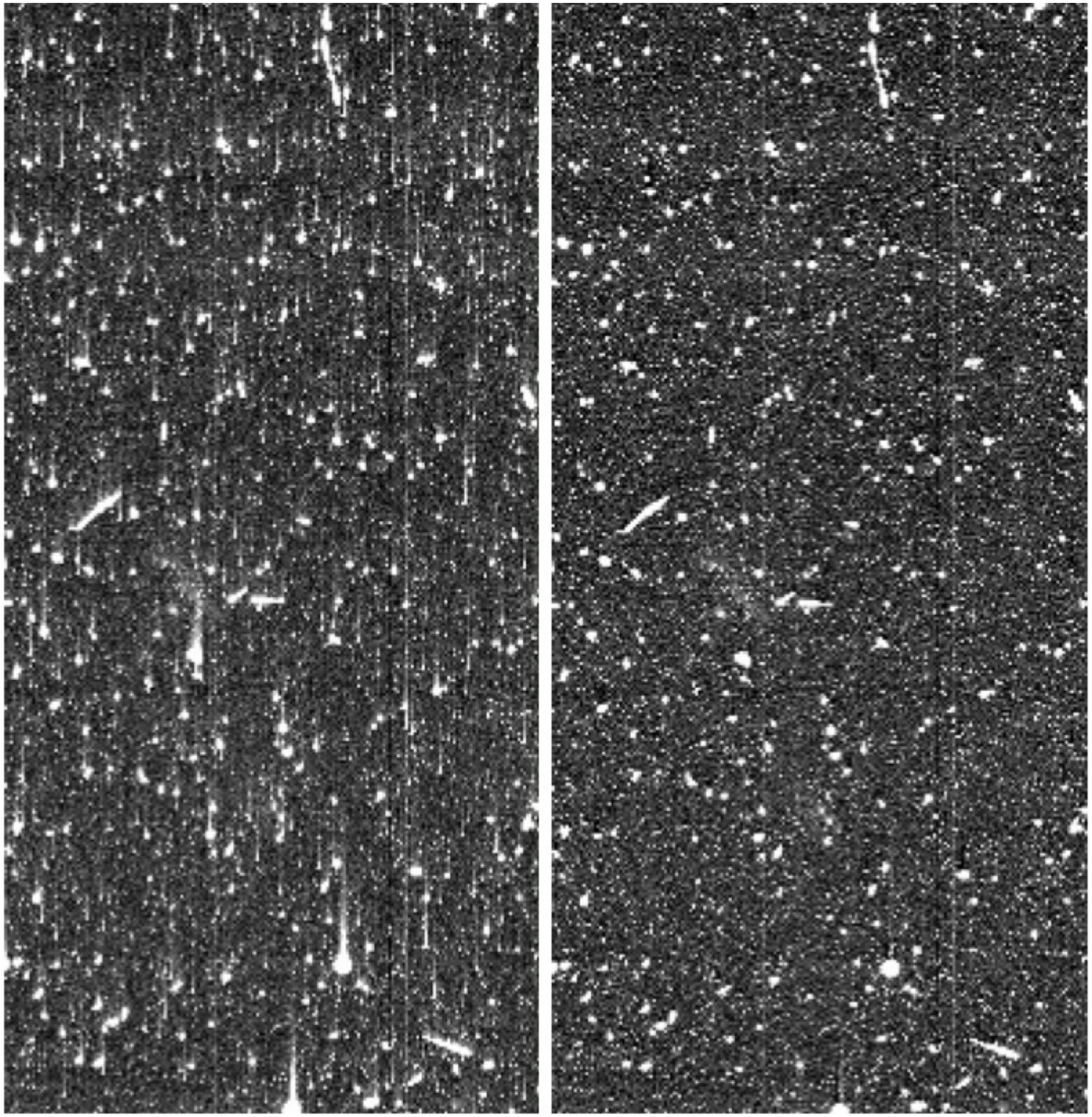
VIS image: cuts made to highlight artefacts



Courtesy Mark Cropper,
Sami M. Niemi

# Charge Transfer Inefficiency





Courtesy
Richard Massey

# Challenge 3: Charge Transfer Inefficiency



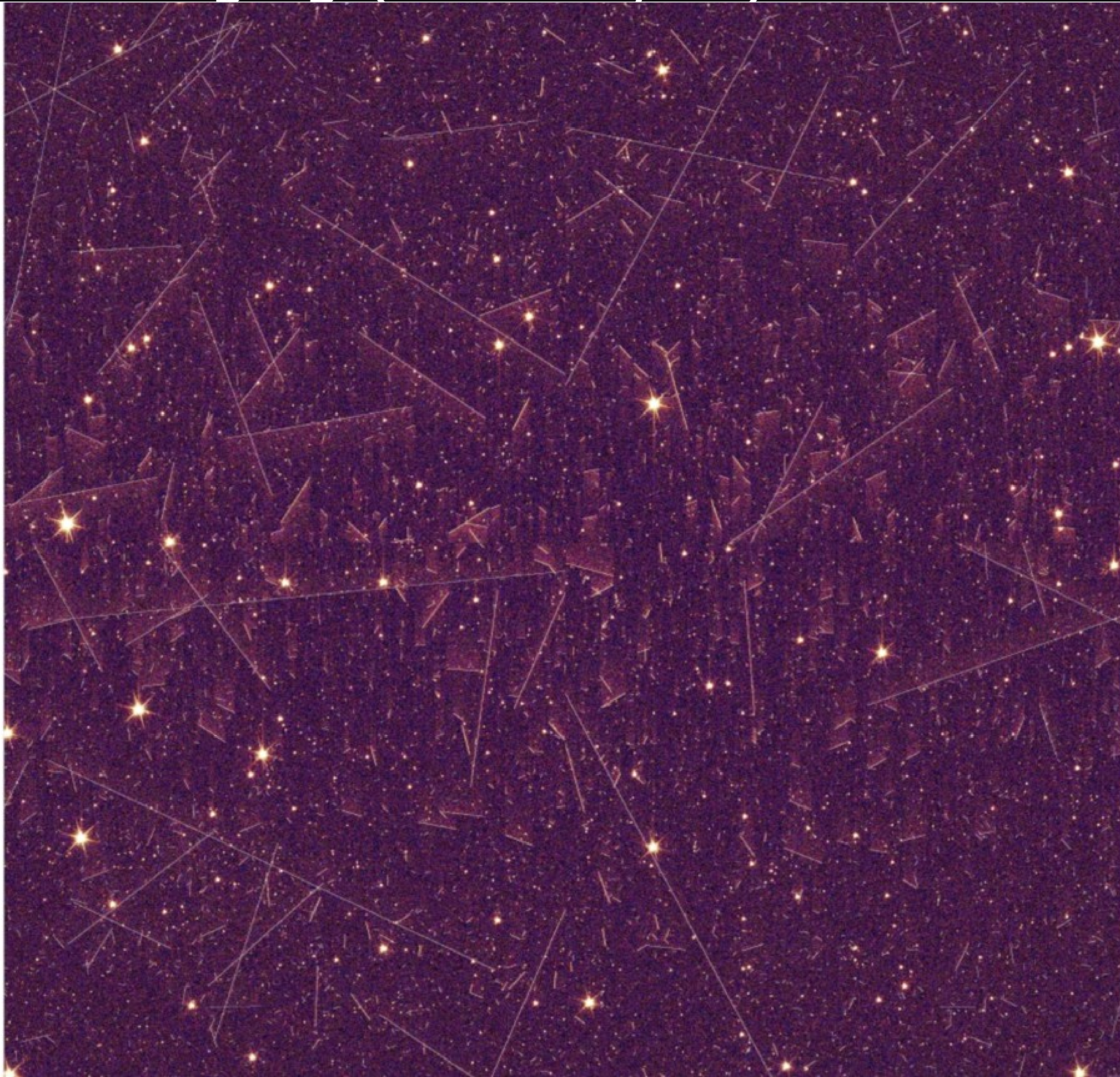
- How well can we undo the charge trailing?
- Improved simulation of the effect (more realistic case)
- Can we further optimize the VIS instrument?
- Can we improve the calibration? (identify traps)
- What is the impact on the cosmology science? (chip scale)

# VIS performance:imaging (EC analysis)



A 4kx4k view of the Euclid sky

VIS image: cuts made to highlight artefacts



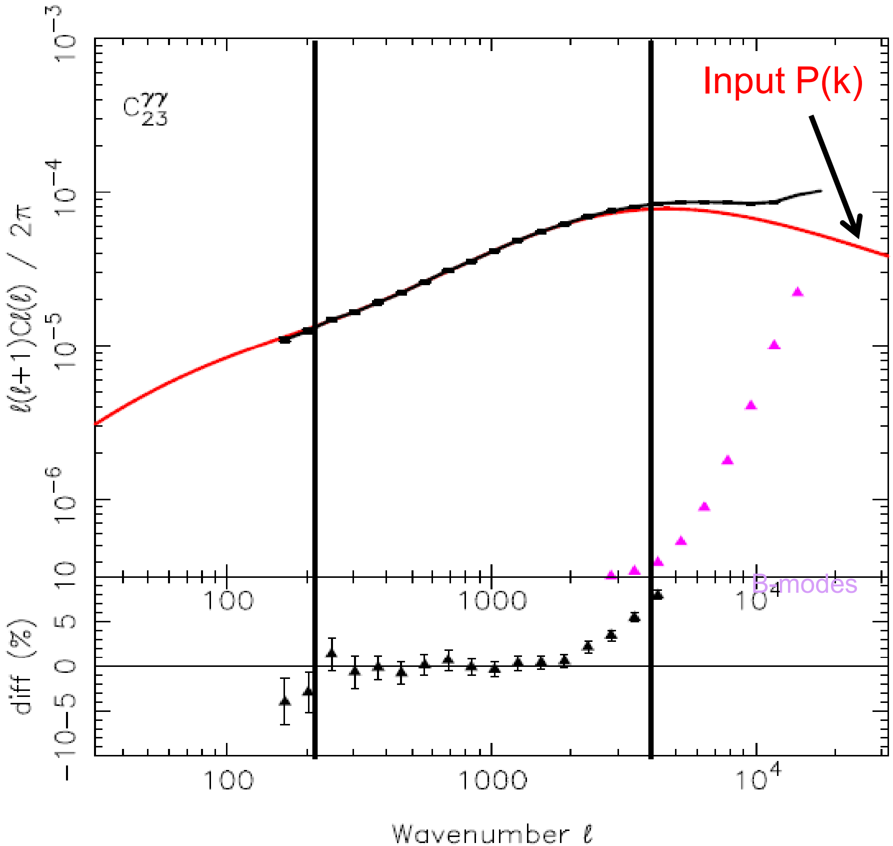
- Charge Transfer Inefficiency (CTI) of CCDs
- Tested in the worse case scenario (End of Life, pixels at extreme distance from the output)

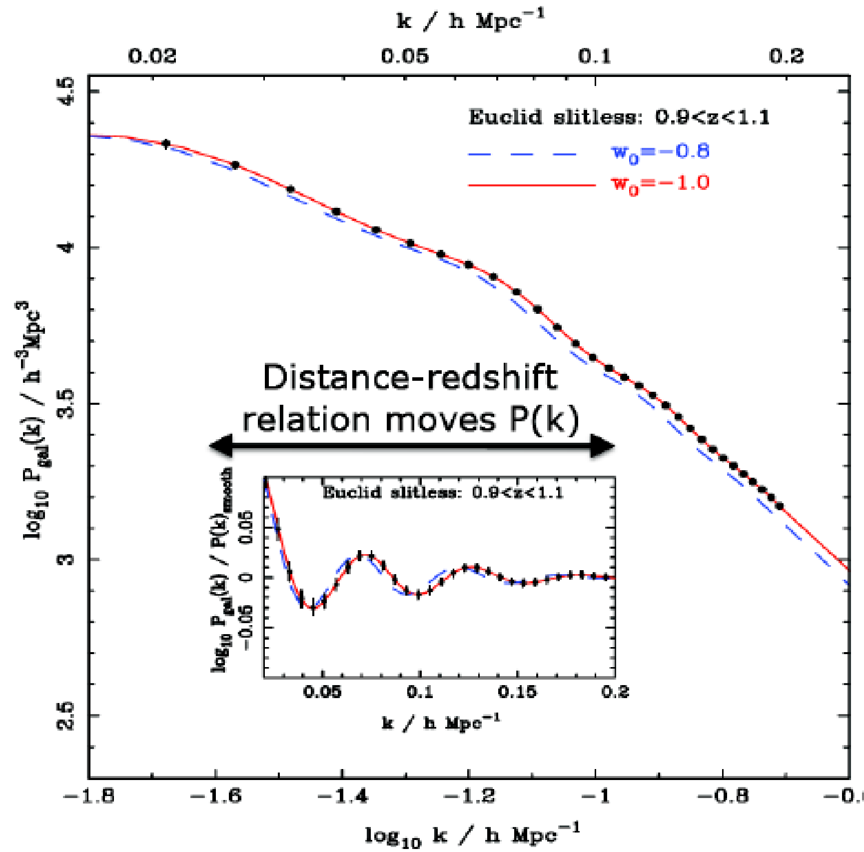
- can be corrected to the required level of accuracy.

- EC analysis: CTI has NO impact on the P(*k*) and the cosmology core program

# Euclid: DM and Galaxy reconstructed P(k)





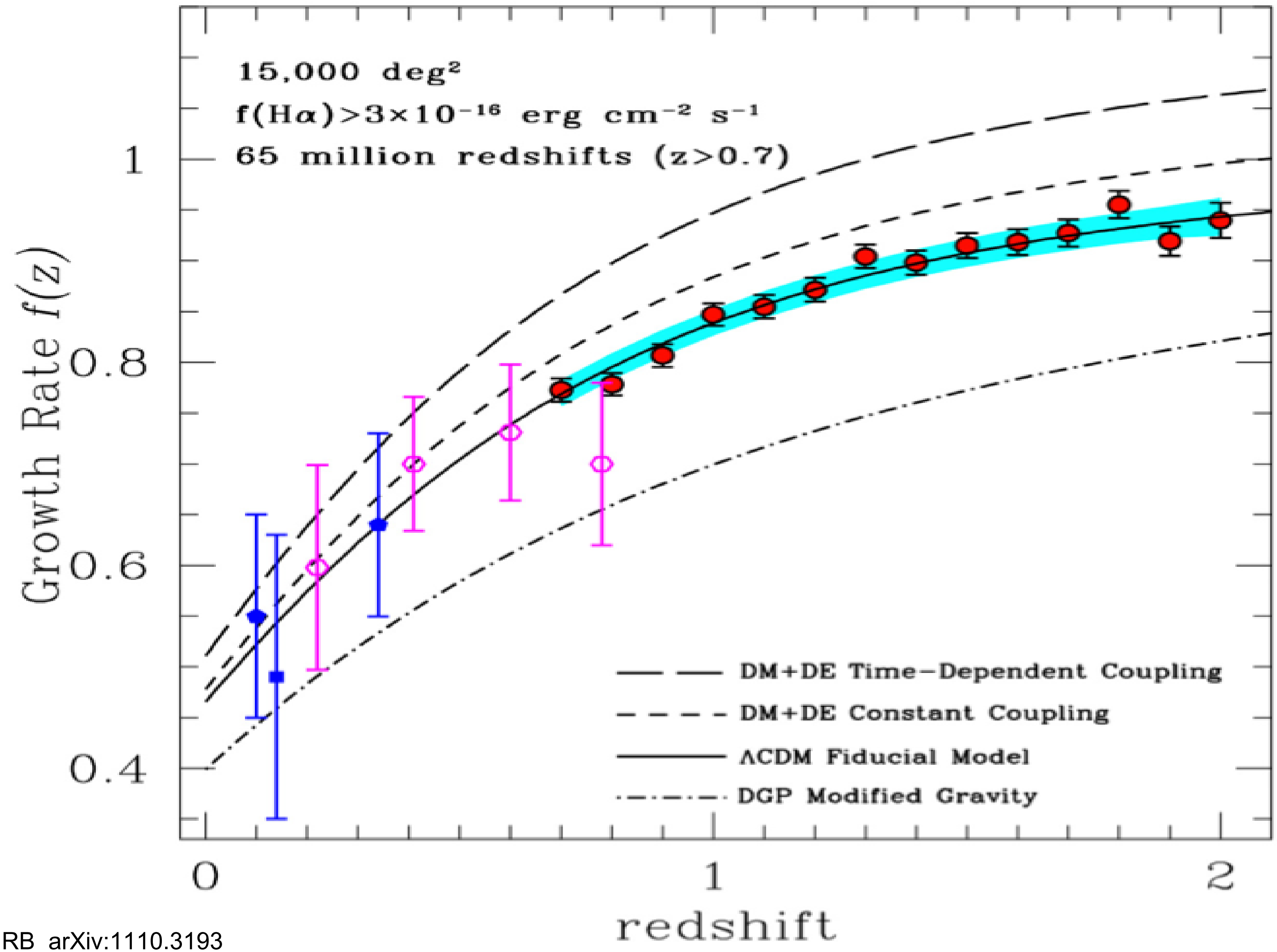

- Tomographic WL shear cross-power spectrum for 0.5 < z < 1.0 and 1.0 < z < 1.5 bins.
- Percentage difference [*expected* – *measured*] power spectrum: recovered to 1% .

- $V_{eff} \approx 19\ h^{-3}\ Gpc^3$ ≈ 75x larger than SDSS
- Redshifts 0<*z*<2
- Percentage difference [*expected* – *measured*] power spectrum: recovered to 1% .

Ref: Euclid RB arXiv:1110.3193

# Euclid – RSD improvements

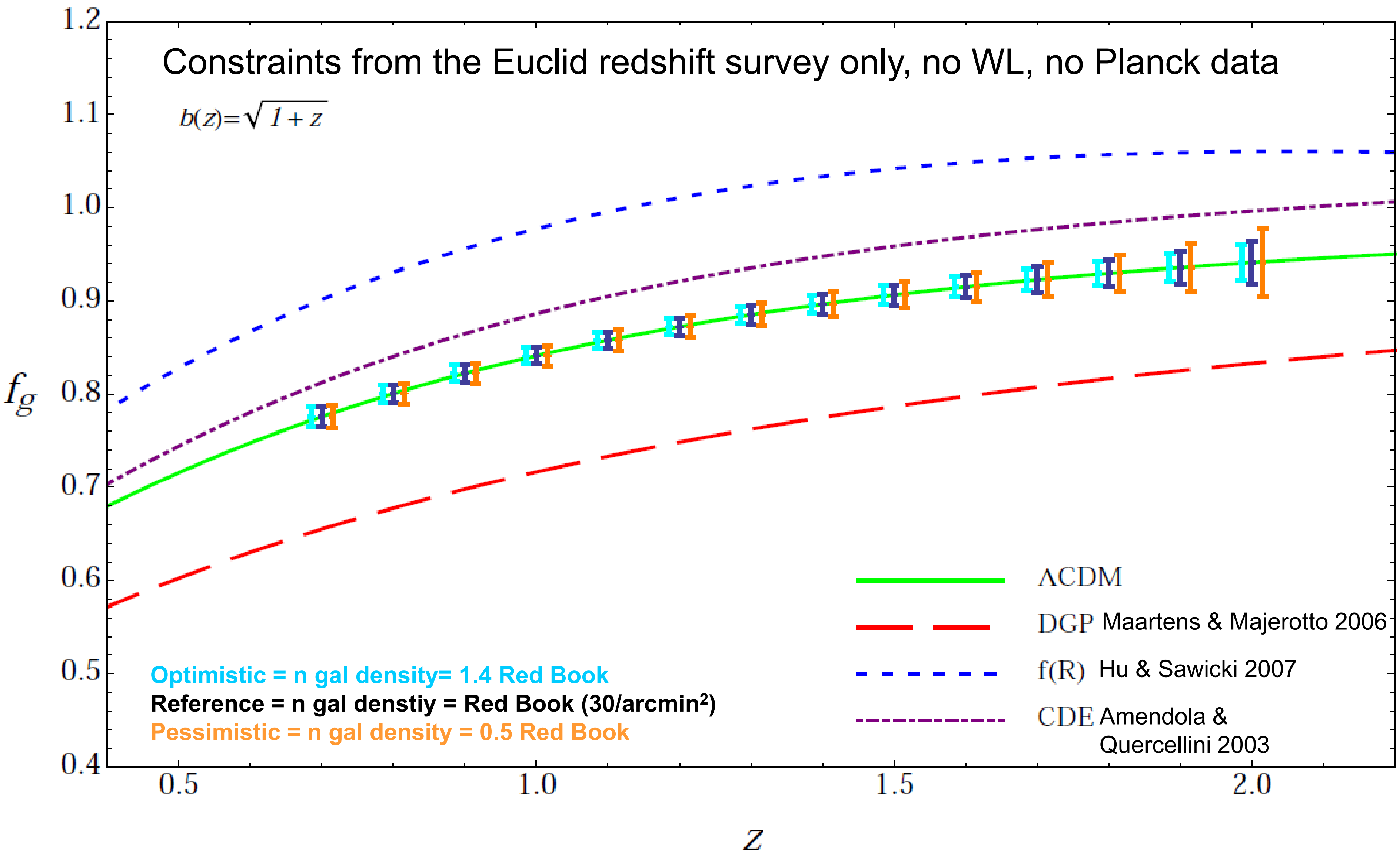





Ref: Euclid RB arXiv:1110.3193

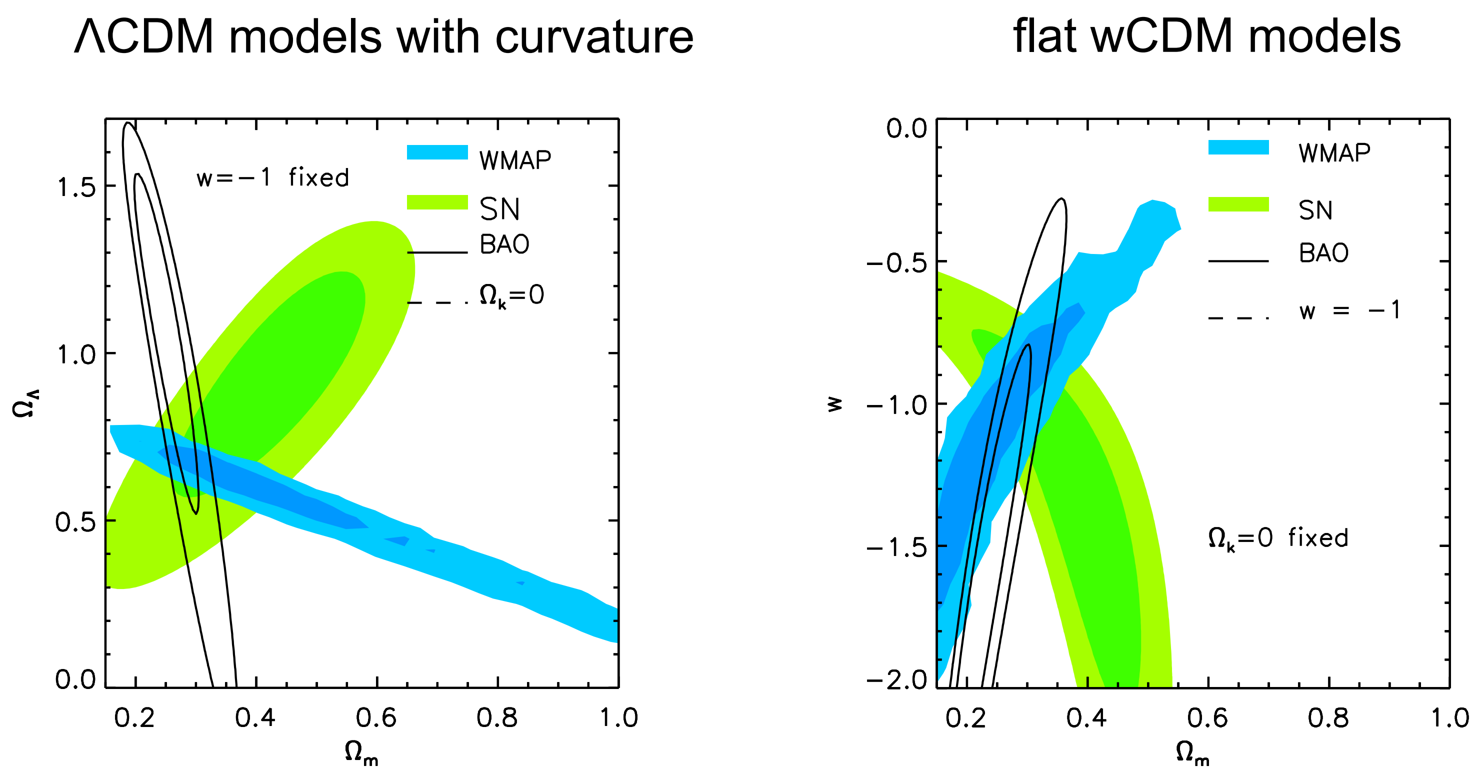
# Biasing and Growth rate from GC data






Amendola et al arXiv:1206.1225

# SDSS-II LRG BAO vs other data



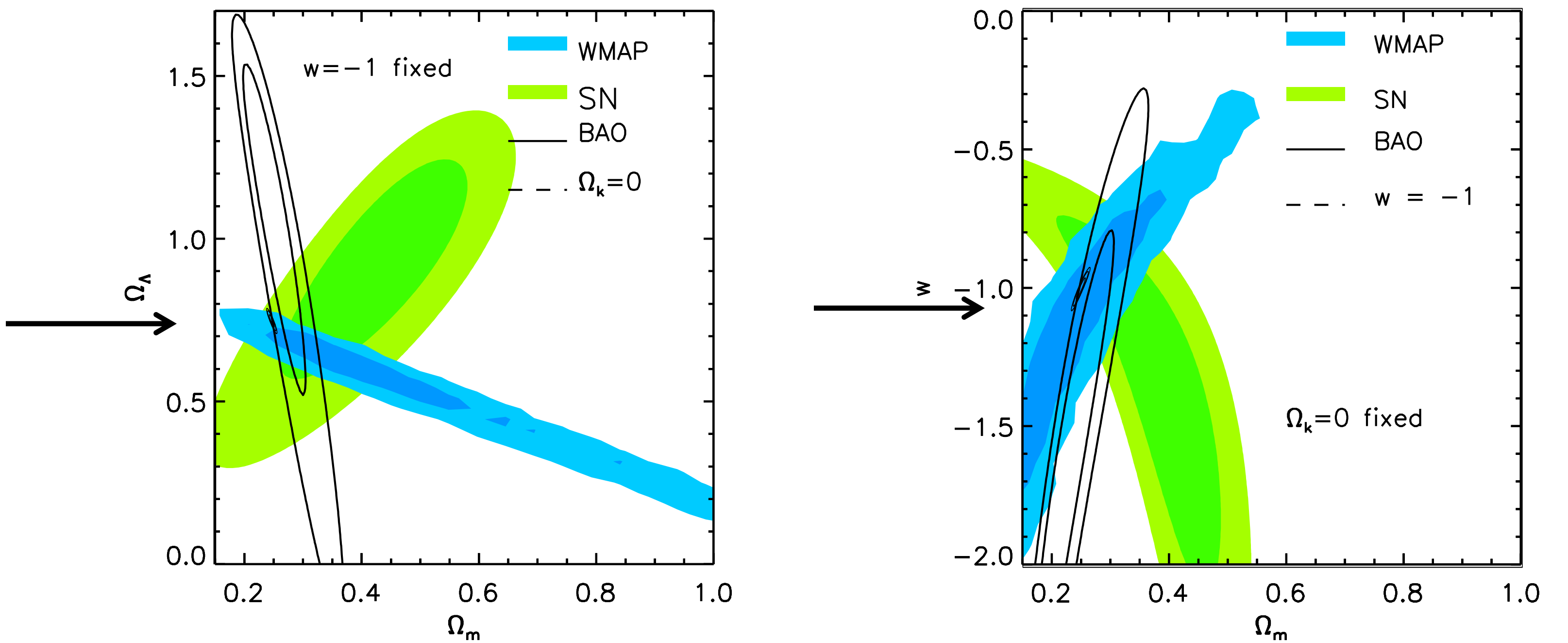

Percival et al. 2009; arXiv:0907.1660

- Union supernovae
- WMAP 5year
- SDSS-II BAO Constraint on $r_s(z_d)/D_V(0.2)$ & $r_s(z_d)/D_V(0.35)$

Courtesy Will Percival

# Euclid BAO predictions

ΛCDM models with curvature | flat wCDM models




Union supernovae

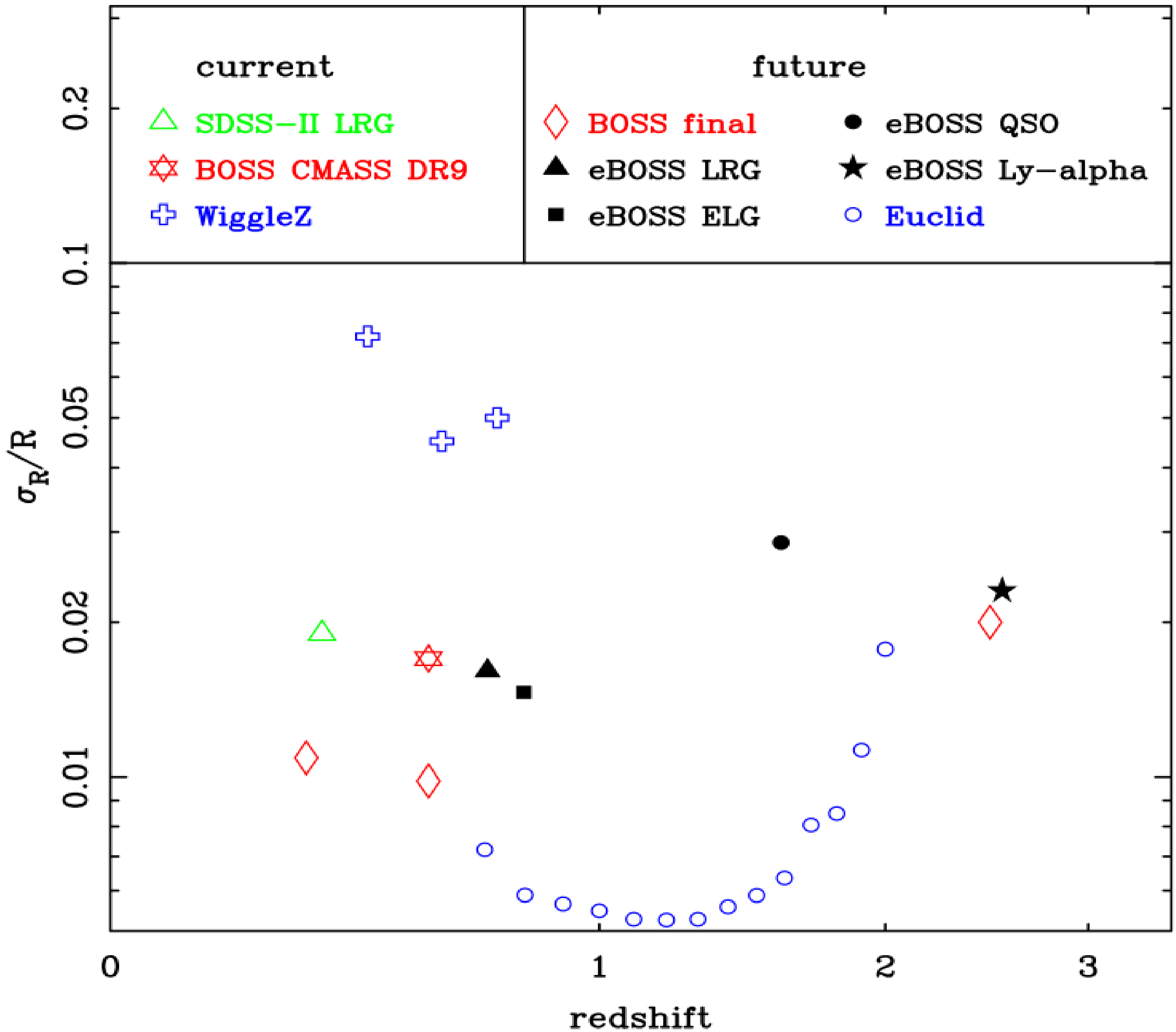
WMAP 5year

SDSS-II BAO Constraint on $r_s(z_d)/D_V(0.2)$ & $r_s(z_d)/D_V(0.35)$

Courtesy Will Percival

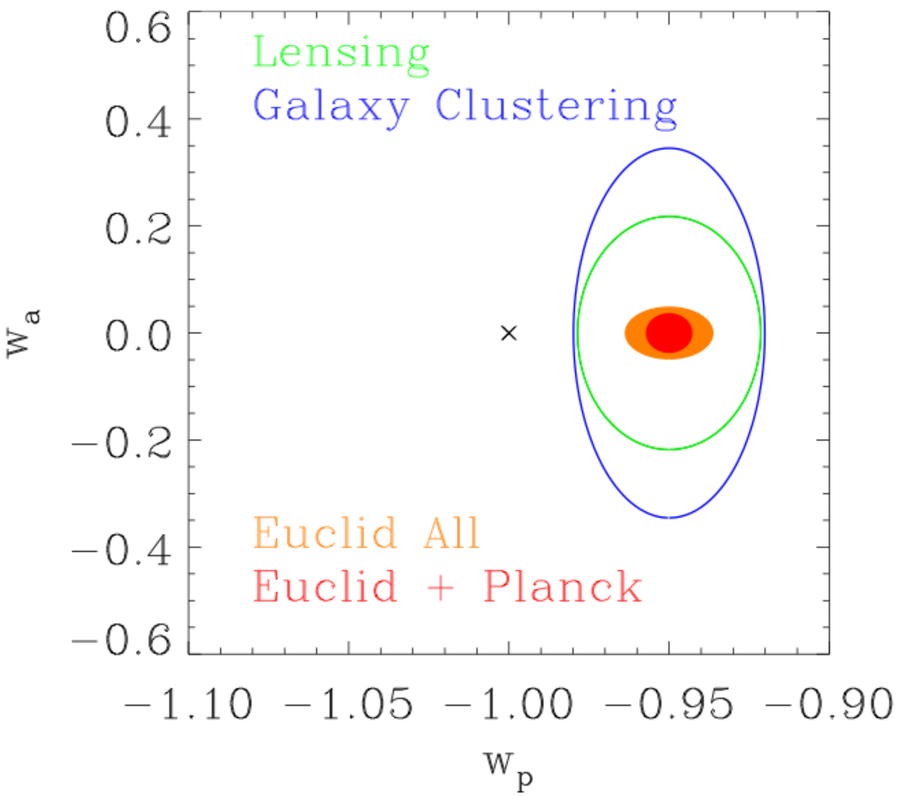
# Euclid – BAO improvements



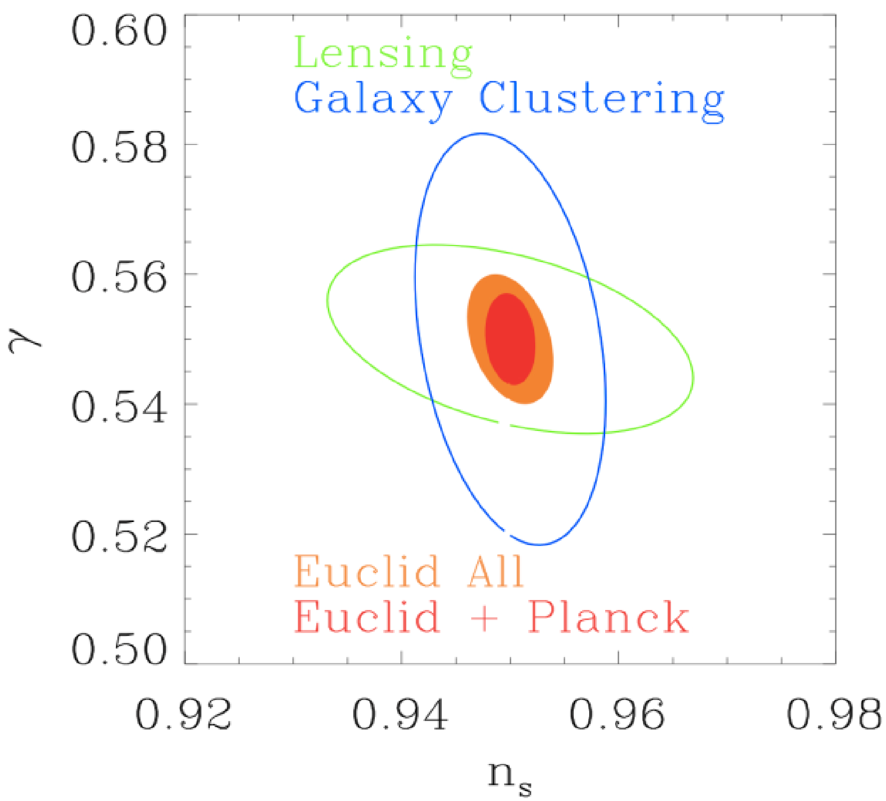


# Euclid WL+GC combined: predicted performances






DE constraints from Euclid: 68% confidence contours in the ($w_p$, $w_a$).




Constraints on the $\gamma$ and $n_s$.
Errors marginalised over all other parameters.

Ref: Euclid RB arXiv:1110.3193

# Predicted FoM of the Euclid mission



| | 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 | 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** |

Ref: Euclid RB arXiv:1110.3193
More detailled forecasts given in Amendola et al arXiv:1206.1225

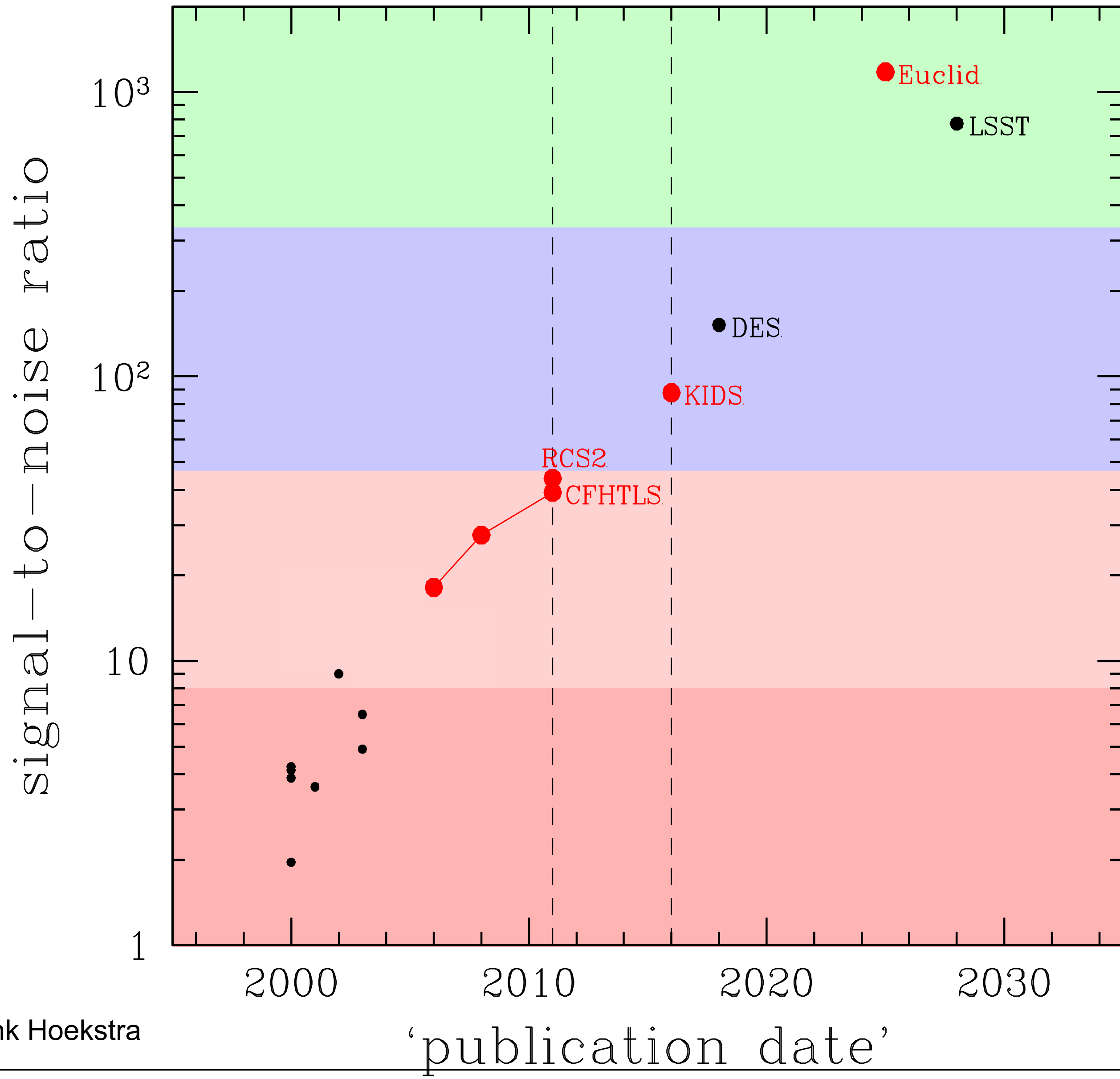
# The challenges



- Shape measurements/systematics
  - Coordination of all teams (UK, FR, NL, DE, CH, US/NASA)
  - Control of both multiplicative and additive biases
  - Manpower for data challenges
  - Plan for selection of methods dev., test, validation, operation, quality control
  - Contamination of PSF/shapes by out-of-band transmission of optics (blue)

# Improving S/N in shape measurements






Courtesy Henk Hoekstra

# The challenges

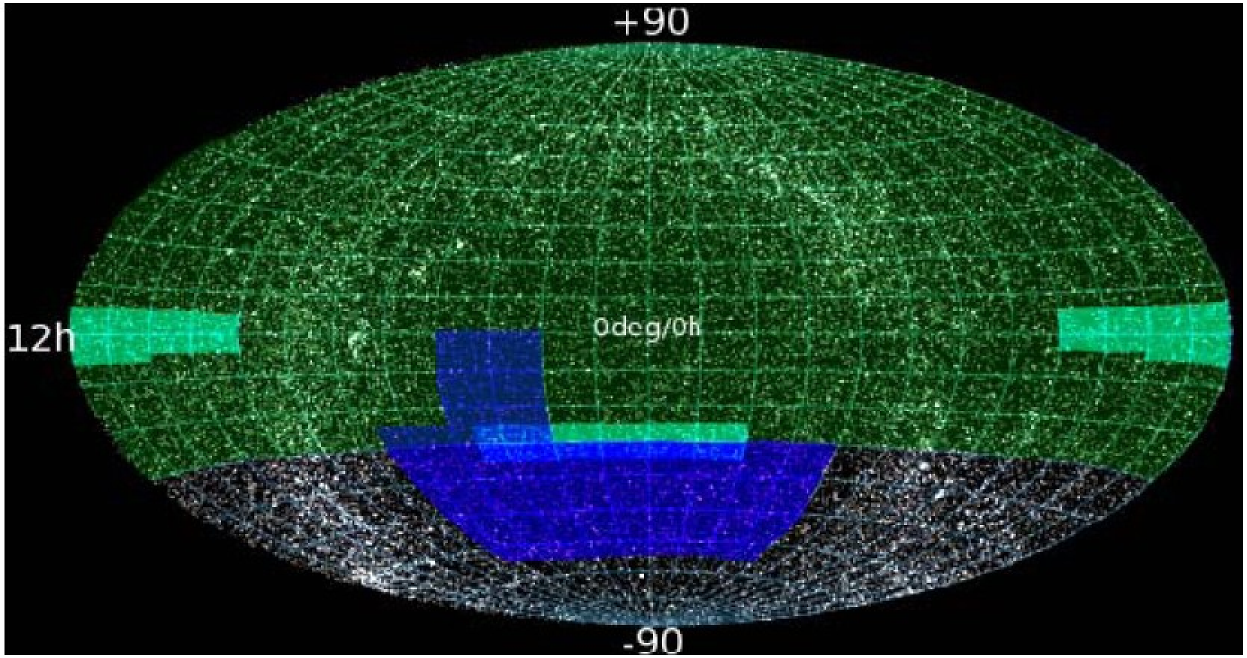


- Shape measurements/systematics
  - Coordination of all teams (UK, FR, NL, DE, CH, US/NASA)
  - Control of both multiplicative and additive biases
  - Manpower for data challenges
  - Plan for selection of methods dev., test, validation, operation, quality control
  - Contamination of PSF/shapes by out-of-band transmission of optics (blue)

- Photo-z:
  - Ground based photometry: enough bands, deep enough, over the whole 15,000 deg$^2$ (i.e. north and south)

# Euclid : Ground surveys






| External survey timelines | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|---|
| KiDS-VIKING | Survey underway | | VIKING completed | KiDS completed, VIKING final release | , KiDS final release | | | |
| Pan-STARRS1 | Survey underway | | Survey completed | | PS1 final release | | | |
| Pan-STARRS2 | | | | Survey start | | | | |
| DES | | Survey start | | 1st data release | | Survey end | Final data release | |
| LSST | | | | | | | | 2020? |
| HSC+WHT | | | | | | | | |

| Survey | Area (sq deg) | U | G | r | i | z | Y | J | H | K |
|---|---|---|---|---|---|---|---|---|---|---|
| KiDS+VIKING | 1500 Eq+SGC | 24,8 | 25,4 | 25,2 | 24,2 | 23,1 | 22,3 | 22.0 | 21,5 | 21,2 |
| Pan-STARRS1 | 15000 NGC+½ SGC | | 23,4 | 23,0 | 22,7 | 22,0 | 20,9 | | | |
| PS2 | 15000 NGC+½ SGC | | 24,8 | 24,4 | 24,1 | 23,4 | 22,3 | | | |
| DES | 5000 ½ SGC | | 25,4 | 24,9 | 24,8 | 24,7 | 22,3 | | | |

# The challenges



- Shape measurements/systematics
  - Coordination of all teams (UK, FR, NL, DE, CH, US/NASA)
  - Control of both multiplicative and additive biases
  - Manpower for data challenges
  - Plan for selection of methods dev., test, validation, operation, quality control
  - Contamination of PSF/shapes by out-of-band transmission of optics (blue)

- Photo-z:
  - Ground based photometry: enough bands, deep enough, over the whole 15,000 deg2 (i.e. north and south)

- Numerical simulations with power spectrum to a 1% accuracy :
  - Resolution
  - Underlying physics: e.g. numerical simulations with baryons
  - Manpower, tools for post-processing
  - Coordinations of all teams (UK, FR, SP, DE, US/NASA): 3 SIM projects
  - Numerical simulation of a large number of DE, GR models: resolution grids of models, which scales are important?

# The challenges

- Cosmic magnification in parallel over super-stable photometric data sets

- High order statistics:
    - Potentials of high order statistics for DE science +
    - Systematics
    - Requirements in data processing and computing resources for cosmological interpretation

- Strong lensing statiscs and DE models

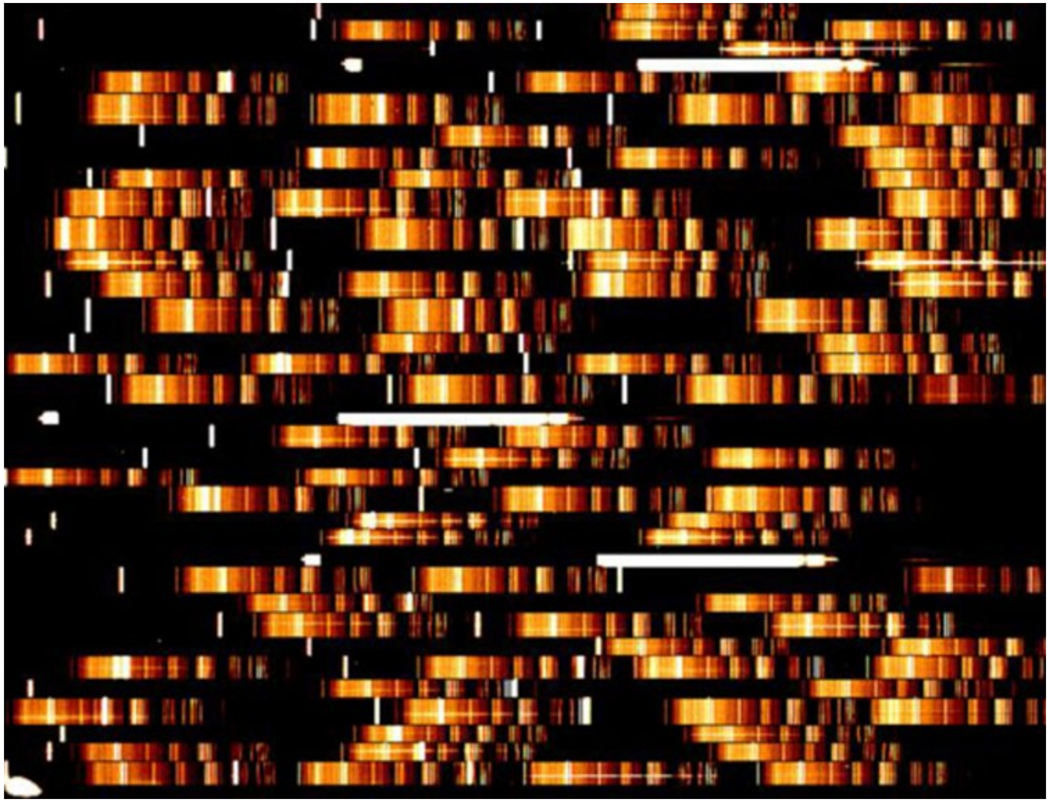
- Spectroscopics surveys to
    - Calibrate deep photo-z and
    - Understand BAO and RSD samples
    - → New wide field MOS instruments?

- Reactivity and diversity of skills of the EC consortium to effects that are still ignored and which may become serious

# Need BIG very-deep spectroscopic samples



ESO PR, Le Fèvre et al 2006



- **CFHTLS : VVDS** with VMOS,
  - 32,000 redshifts to I=22.5 over ~15 deg$^2$, (Garilli et al 2008)
  - 15,000 to I=24 over ~1 deg$^2$ (Le Fèvre et al 2005)
  - 1000 redshifts 23<I<24.75 over 0.15 deg$^2$ (Le Fèvre et al 2012)

- **CFHTLS : VIPERS** with VMOS: ~100,000 redshifts to I=22.5 over 25 deg$^2$ (Guzzo et al 2012)

- **COSMOS : z-Cosmos** with VMOS:
  - ~ 20,000 redshifts to I=22.5 over 1.7 deg$^2$ (Lilly et al 2009)
  - ~10,000 redshiifts B<25.25 color selected, over 0.9 deg$^2$

… How can we get $10^5$ redshifts for I=24.5 + subsamples to I=26??
MOS: PFS@Subaru, 4MOST and/or MOONS at ESO?

# Schedule

- October 4, 2011 : Euclid selected as ESA M2 Cosmic Vision
- Spring 2012 : Completion of the Definition phase (A/B1)

- June 20, 2012 : Adoption for the Implem. Phase (B2/C/D/E1)
- July 2012 : ITT release for Payload Module
- November 2012 : Kick off for the Payload contract
- December 2012 : ITT release for Service Module
- June 2013 : Kick off for the Service Module contract

- Q1 2014 : Instrument PDR
- Q3/Q4 2017 : Flight Model delivery

- Q2 2020 : Launch (L)
- <(L+6 months) : Start Routine Phase
- L+7 yrs : End of Nominal Mission
- L+9 yrs : End of Active Archive Phase

# Summary: Euclid



- ESA has selected the only space mission designed to understand the origin of the accelerating universe;
- Put Europe at the forefront of one of the most fascinating question of physics/cosmology of the next decades;
- Euclid will provide:
  - tight constraints over the broadest range of DE; MG models ever explored,
  - unrivalled legacy value of VIS/NISP images and spectra;
- Extensive simulations have demonstrated it is feasible;
- Entering in implementation phase. Stay tuned until 2020…