"I'LL BE WORKING ON THE LARGEST AND SMALLEST OBJECTS IN THE UNIVERSE—SUPERCLUSTERS AND NEUTRINOS. I'D LIKE YOU TO HANDLE EVERYTHING IN BETWEEN."

INDAM - 8 June 2013

EUCLID SPACE MISSION

(a few whys and hows)

R. Scaramella (on behalf of Euclid Science Team
and E. Consortium)

**(Euclid Consortium, old timer,
Mission Survey Scientist,
member of the EC Board and EST)**

Lots of figures and material courtesy of: EC&ESA (SciRD, CalWG, ECSURV, ESSWG, VIS, NISP, SWGs, OUs ...)

Red Book released in July 2011 (ESA web pages)

kosmobob@oa-roma.inaf.it

Giga structures-years-pc-samples

Giga €...

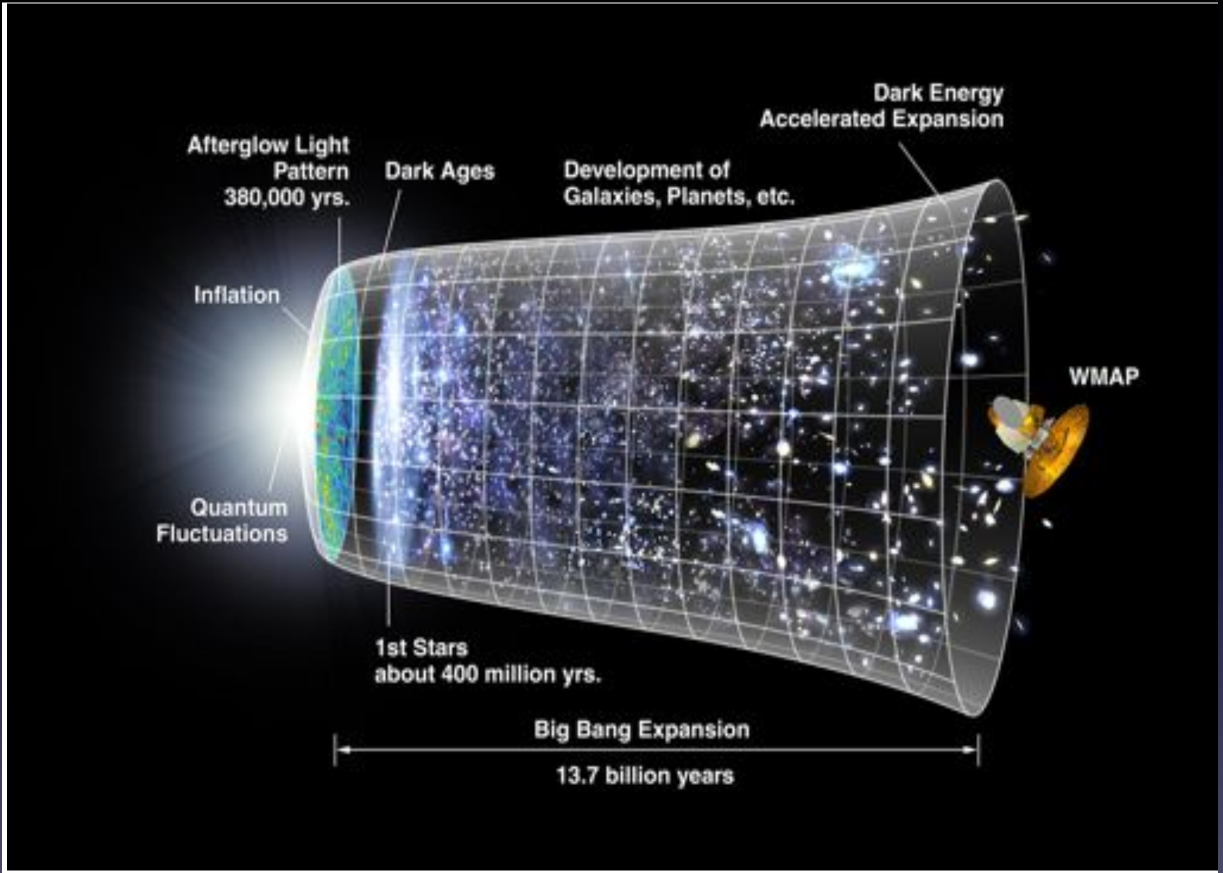


FIGURE 2-5 The cosmic timeline, from inflation to the first stars and galaxies to the current universe. The change in the vertical width represents the change in the rate of the expansion of the universe, from exponential expansion during the epoch of inflation followed by long period of a slowing expansion during which the galaxies and large scale structures formed through the force of gravity, to a recent acceleration of the expansion over the last roughly billion years due to the mysterious dark energy. Credit: NASA Wilkinson Microwave Anisotropy Probe Science Team.

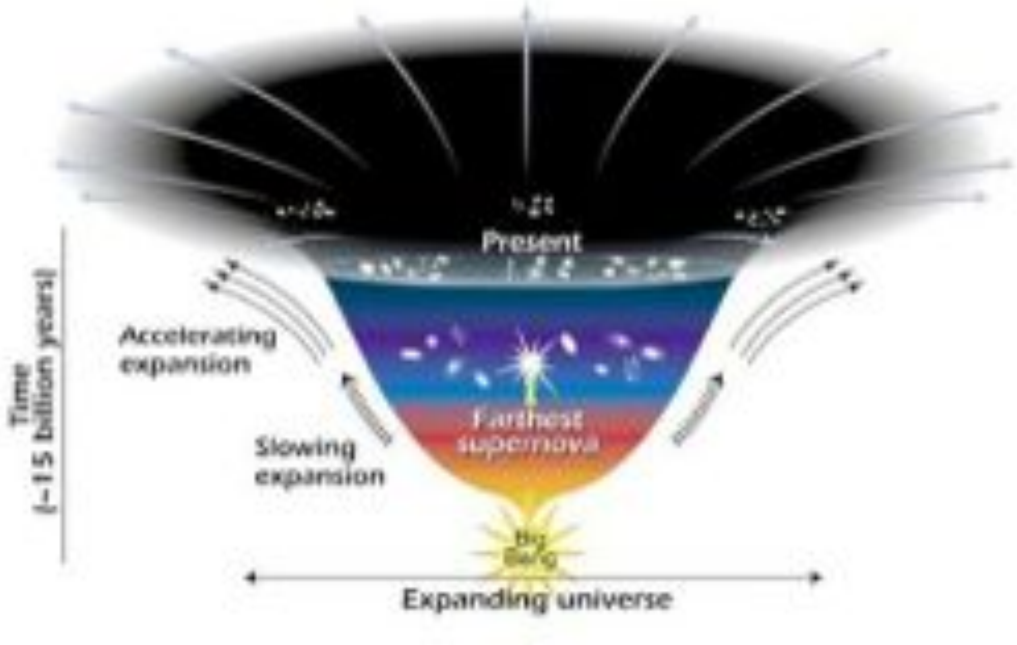
Observed with a **mini** structure: mirror ~1.2 m ∅

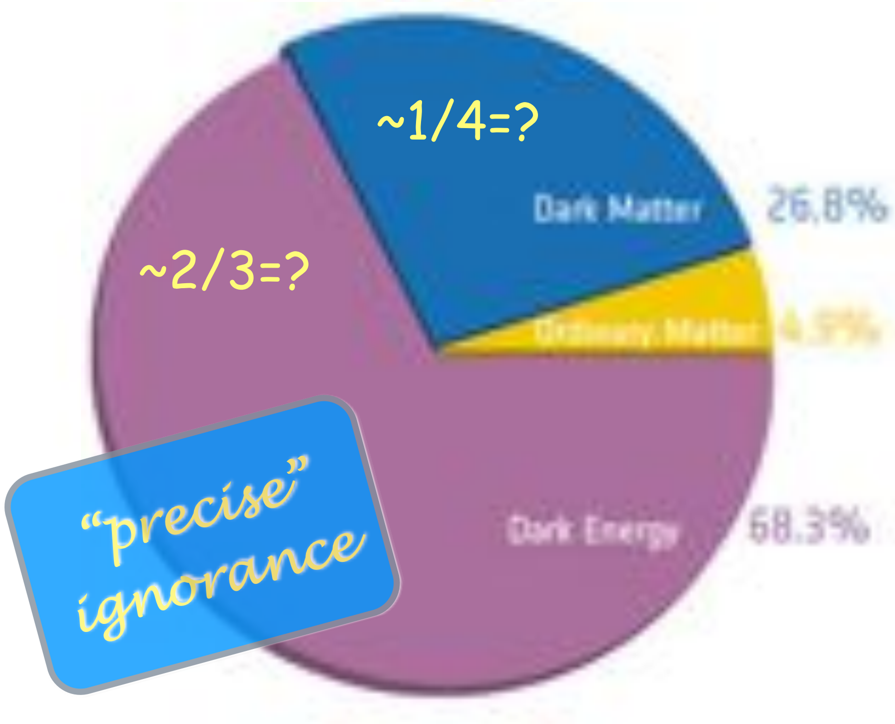
Open Questions in Cosmology

“precise” Cosmology

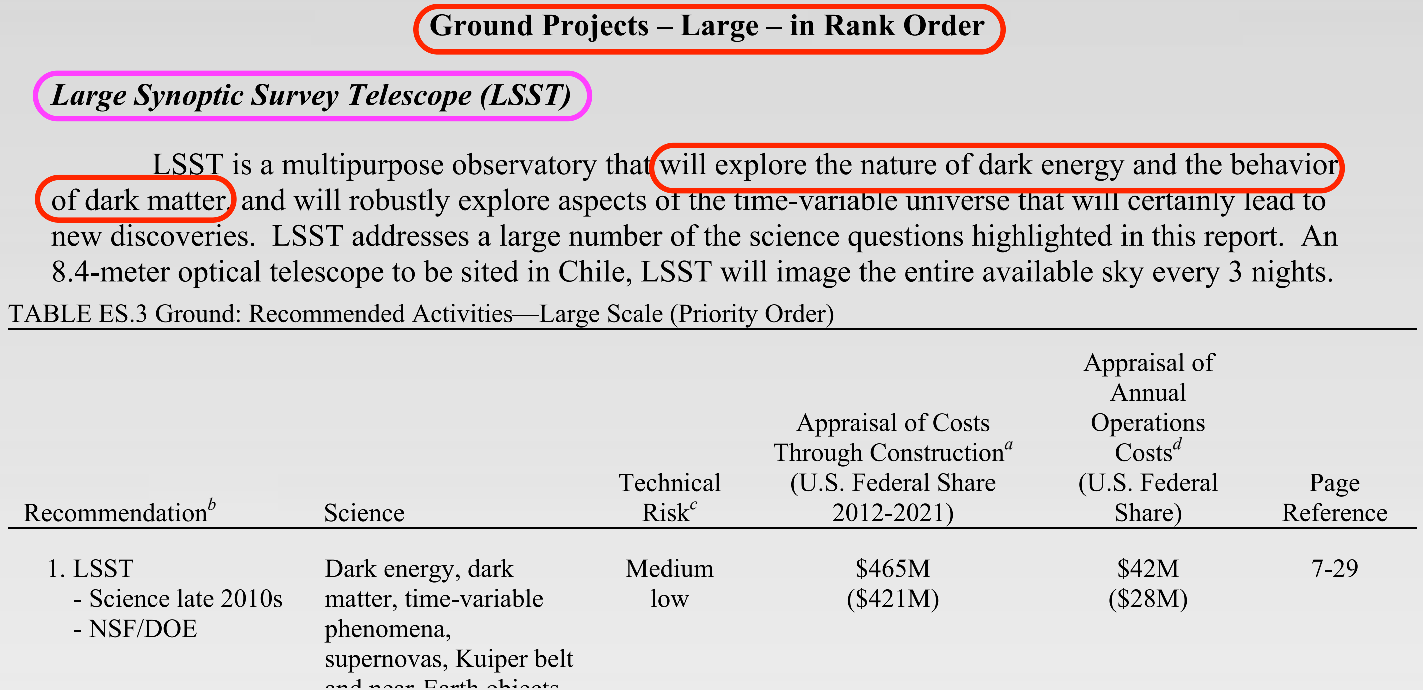
- Nature of the Dark Energy
- Nature of the Dark Matter
- Initial conditions (Inflation Physics)
- Modifications to Gravity
- Formation and Evolution of Galaxies

Large ignorance on ~95% of Universe content !!





New Worlds, New Horizons in Astronomy and Astrophysics (Decadal Survey 2010)



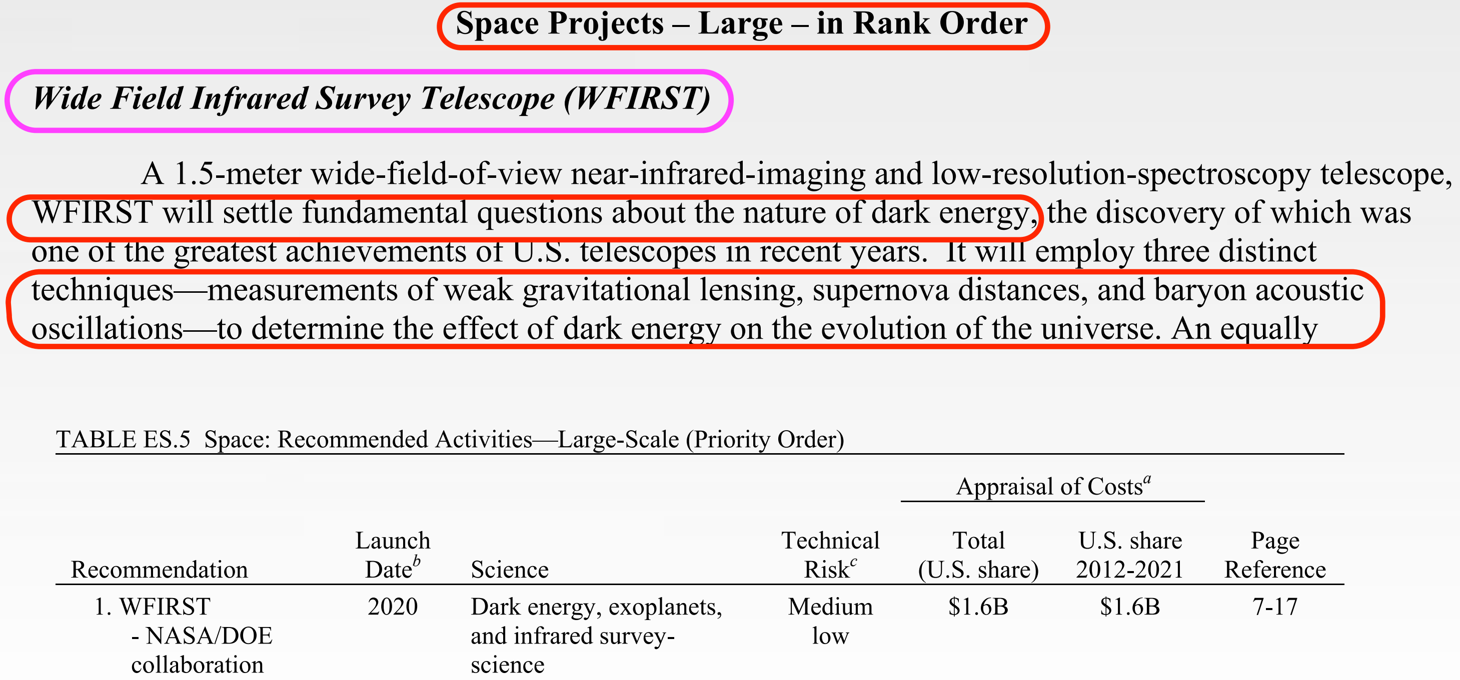
Ground Projects – Large – in Rank Order

Large Synoptic Survey Telescope (LSST)

LSST is a multipurpose observatory that will explore the nature of dark energy and the behavior of dark matter and will robustly explore aspects of the time-variable universe that will certainly lead to new discoveries. LSST addresses a large number of the science questions highlighted in this report. An 8.4-meter optical telescope to be sited in Chile, LSST will image the entire available sky every 3 nights.

TABLE ES.3 Ground: Recommended Activities—Large Scale (Priority Order)

Recommendation[b]	Science	Technical Risk[c]	Appraisal of Costs Through Construction[a] (U.S. Federal Share 2012-2021)	Appraisal of Annual Operations Costs[d] (U.S. Federal Share)	Page Reference
1. LSST - Science late 2010s - NSF/DOE	Dark energy, dark matter, time-variable phenomena, supernovas, Kuiper belt and near-Earth objects	Medium low	\$465M (\$421M)	\$42M (\$28M)	7-29



Space Projects – Large – in Rank Order

Wide Field Infrared Survey Telescope (WFIRST)

A 1.5-meter wide-field-of-view near-infrared-imaging and low-resolution-spectroscopy telescope, WFIRST will settle fundamental questions about the nature of dark energy, the discovery of which was one of the greatest achievements of U.S. telescopes in recent years. It will employ three distinct techniques—measurements of weak gravitational lensing, supernova distances, and baryon acoustic oscillations—to determine the effect of dark energy on the evolution of the universe. An equally

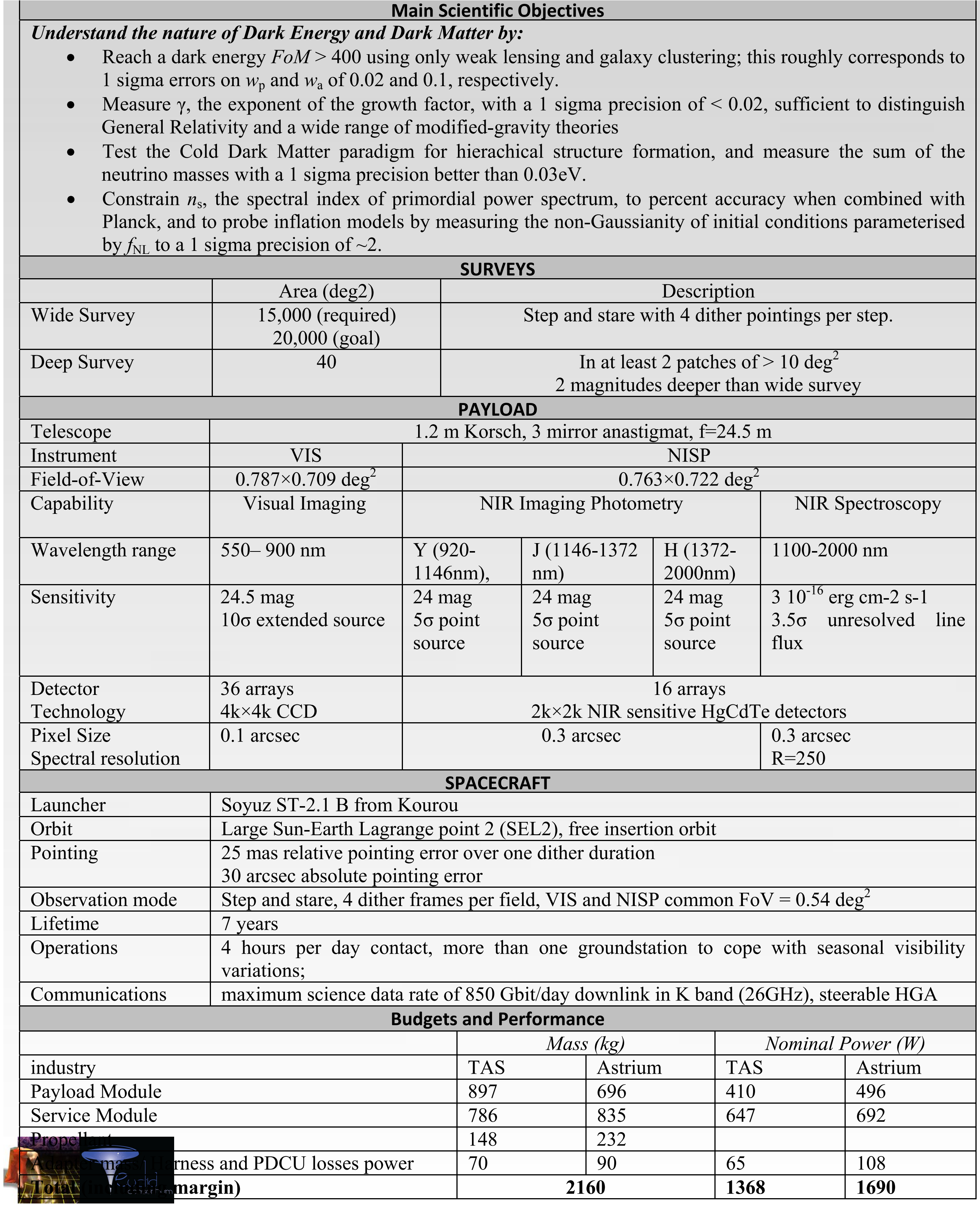
TABLE ES.5 Space: Recommended Activities—Large-Scale (Priority Order)

				Appraisal of Costs[a]		
Recommendation	Launch Date[b]	Science	Technical Risk[c]	Total (U.S. share)	U.S. share 2012-2021	Page Reference
1. WFIRST - NASA/DOE collaboration	2020	Dark energy, exoplanets, and infrared survey-science	Medium low	\$1.6B	\$1.6B	7-17

DE as TOP priority both for Ground and Space also across the Atlantic

EUCLID

1. Why	1. Dark Energy & Dark Matter (Cosmology) ; Legacy
2. How	2. Space imaging (morphology & NIR) + Spectra: Grav. Lensing & BAO
3. When	3. 2020-2025+



Main Scientific Objectives

Understand the nature of Dark Energy and Dark Matter by:

- Reach a dark energy $FoM > 400$ using only weak lensing and galaxy clustering; this roughly corresponds to 1 sigma errors on w_p and w_a of 0.02 and 0.1, respectively.
- Measure γ, the exponent of the growth factor, with a 1 sigma precision of < 0.02, sufficient to distinguish General Relativity and a wide range of modified-gravity theories
- Test the Cold Dark Matter paradigm for hierachical structure formation, and measure the sum of the neutrino masses with a 1 sigma precision better than 0.03eV.
- Constrain n_s, the spectral index of primordial power spectrum, to percent accuracy when combined with Planck, and to probe inflation models by measuring the non-Gaussianity of initial conditions parameterised by f_{NL} to a 1 sigma precision of ~2.

SURVEYS

	Area (deg2)	Description
Wide Survey	15,000 (required) 20,000 (goal)	Step and stare with 4 dither pointings per step.
Deep Survey	40	In at least 2 patches of > 10 deg^2 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 10σ extended source	24 mag 5σ point source	24 mag 5σ point source	24 mag 5σ point source	$3\ 10^{-16}$ erg cm-2 s-1 3.5σ unresolved line flux
Detector Technology	36 arrays 4k×4k CCD	16 arrays 2k×2k NIR sensitive HgCdTe detectors			
Pixel Size Spectral resolution	0.1 arcsec	0.3 arcsec			0.3 arcsec R=250

SPACECRAFT

Launcher	Soyuz ST-2.1 B from Kourou
Orbit	Large Sun-Earth Lagrange point 2 (SEL2), free insertion orbit
Pointing	25 mas relative pointing error over one dither duration 30 arcsec absolute pointing error
Observation mode	Step and stare, 4 dither frames per field, VIS and NISP common FoV = 0.54 deg^2
Lifetime	7 years
Operations	4 hours per day contact, more than one groundstation to cope with seasonal visibility variations;
Communications	maximum science data rate of 850 Gbit/day downlink in K band (26GHz), steerable HGA

Budgets and Performance

	Mass (kg)		*Nominal Power (W)*	
industry	TAS	Astrium	TAS	Astrium
Payload Module	897	696	410	496
Service Module	786	835	647	692
Propellant	148	232		
Adapter mass/ Harness and PDCU losses power	70	90	65	108
Total (including margin)	**2160**		**1368**	**1690**

All data you need to know (Red Book)

- ◆ **Wide Area (>10^4 sq deg)**
- ◆ **Wide Field (FoV > 0.5 sq deg)**
- ◆ **Opt. imaging**
- ◆ **NIR photom**
- ◆ **NIR slitless**

Two instruments:

VIS: optical imager &

NISP: NIR imager + grisms

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

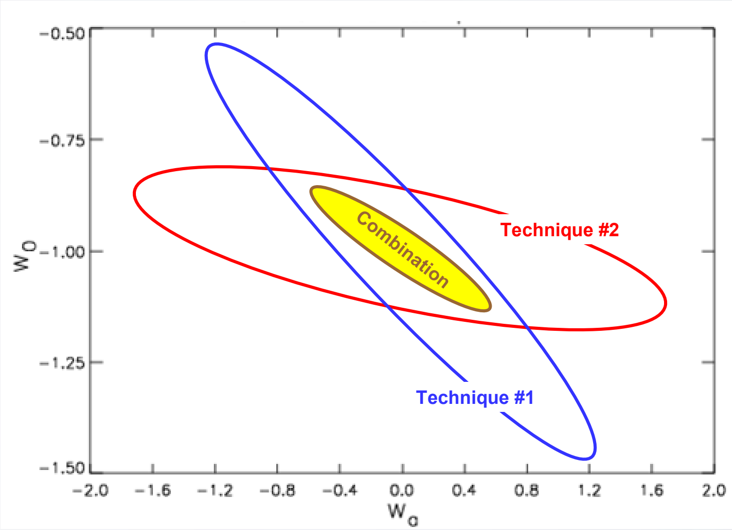
P(k) = power spectrum of δ(**x**,z)

w = p/ϱ, γ=growth index

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

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

Λ: w_0= -1 , w_a =0 , γ~0.55



to get a small uncertainty on power spectrum need:

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

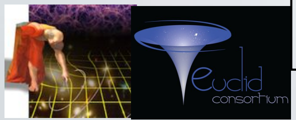
accurate/adequate sampling in number of objects

large volumes to accomodate several Fourier modes

Cosmic Variance ⇔ Volume

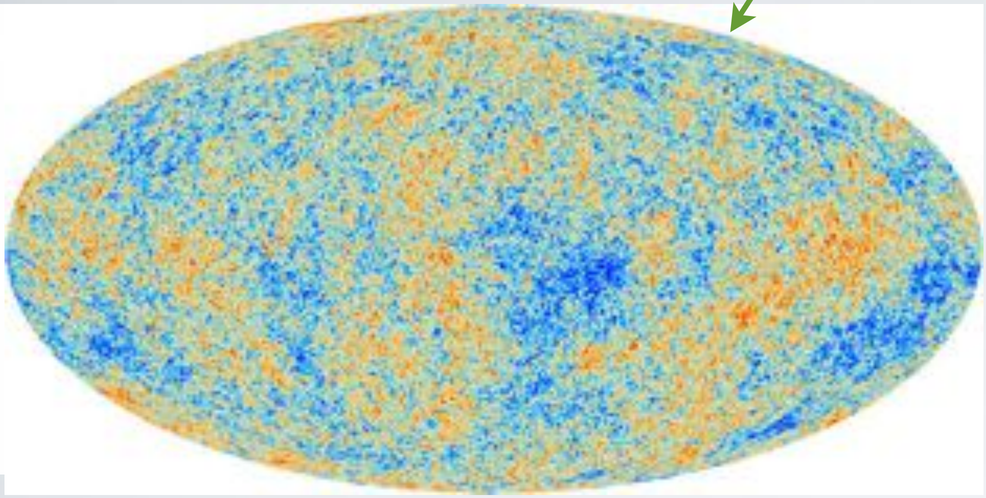
Poisson ⇔ Number of galaxies

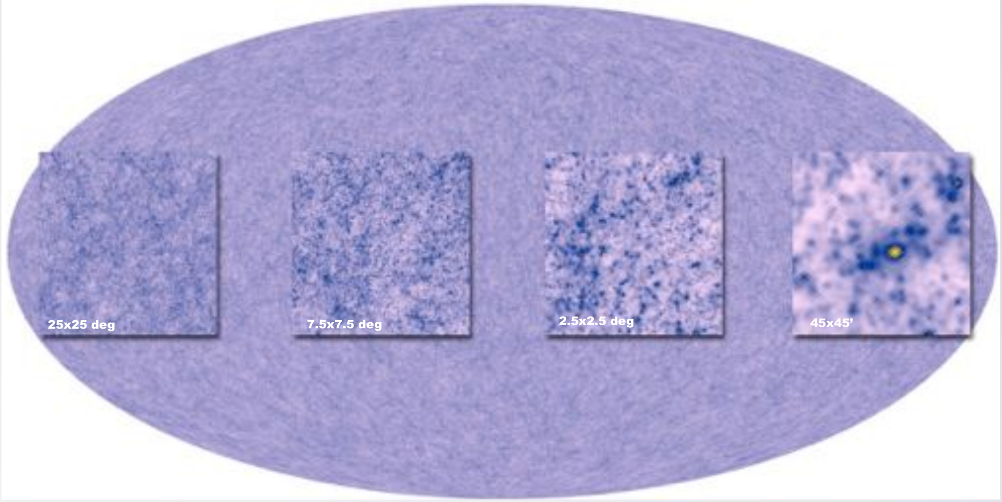
[un]known systematics



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 dynamics to further disentagle

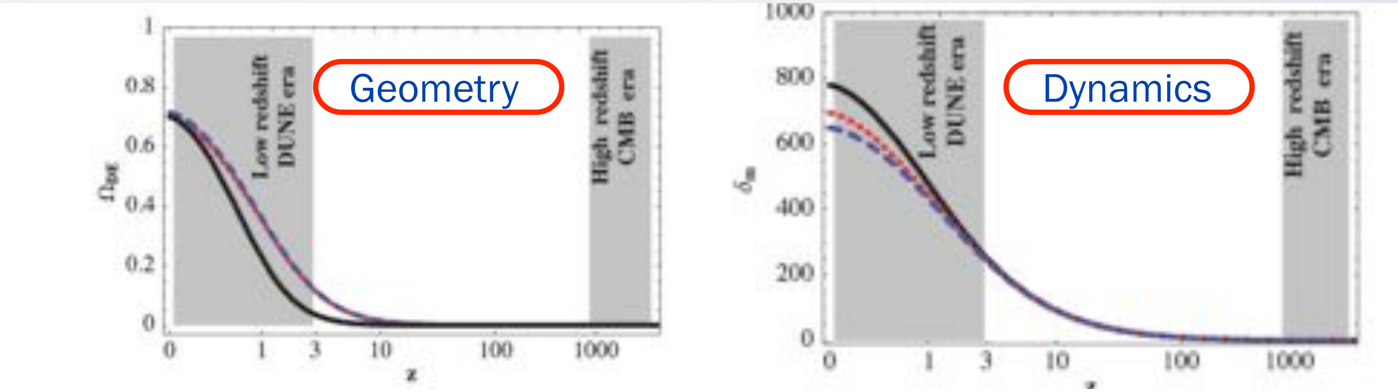


Figure C.1: *Effect of dark energy on the evolution of the Universe.* ***Left:*** *Fraction of the density of the Universe in the form of dark energy as a function of redshift z., for a model with a cosmological constant (w=-1, black solid line), dark energy with a different equation of state (w=-0.7, 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)

Weak limit

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

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

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 $$k^2\Psi = -4\pi G a^2 Q(k,a)\rho_m\delta_m$$
- non-zero anisotropic stress $$\eta(k,a) = \frac{\Phi+\Psi}{\Psi}$$

std matter

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

Std gravity,

new matter

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

New gravity,

std matter

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

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

Modified Gravity at linear level

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

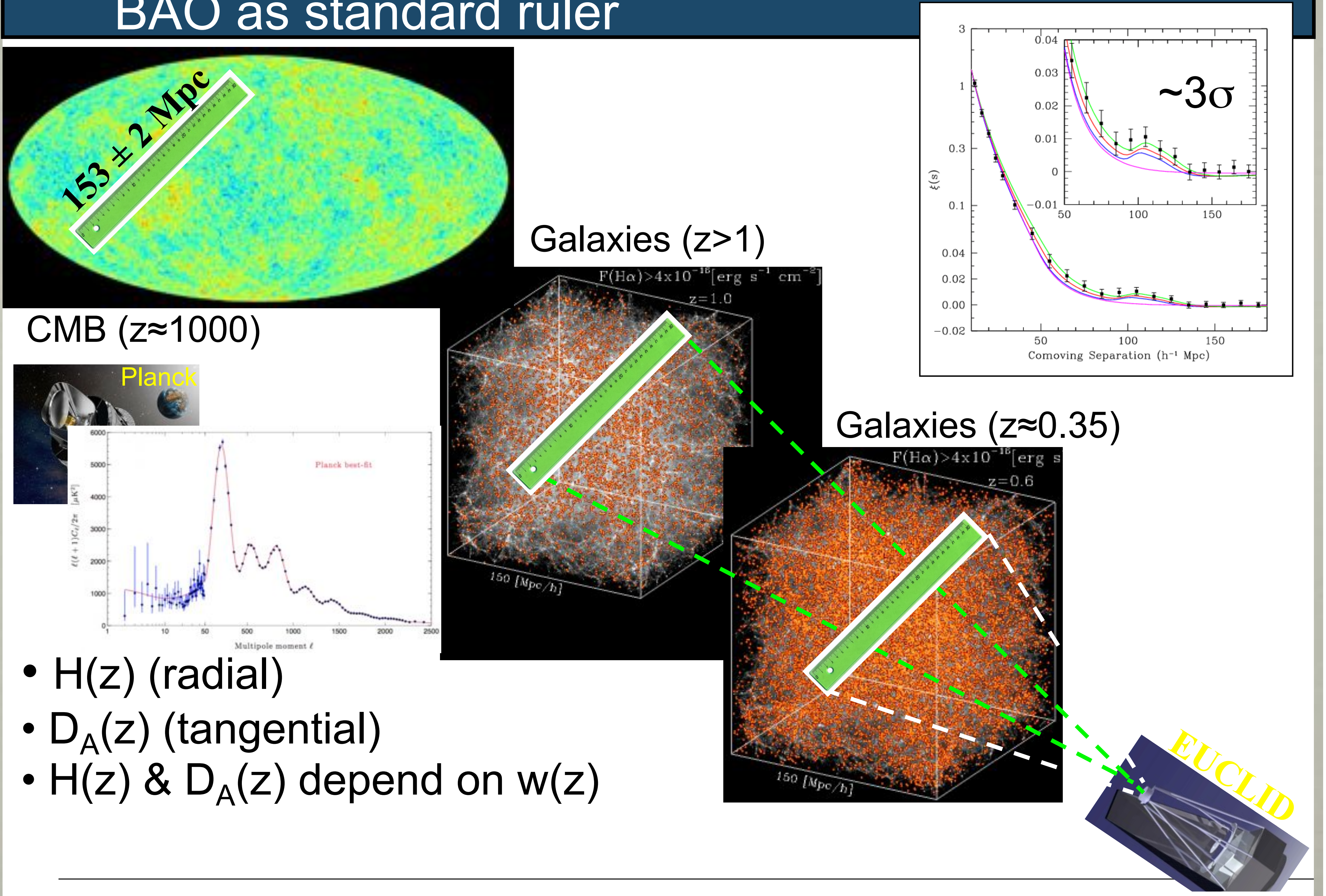
massless particles respond to Φ-Ψ

Need to break degeneracy: *use growth of fluctuations*

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

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

BAO as standard ruler



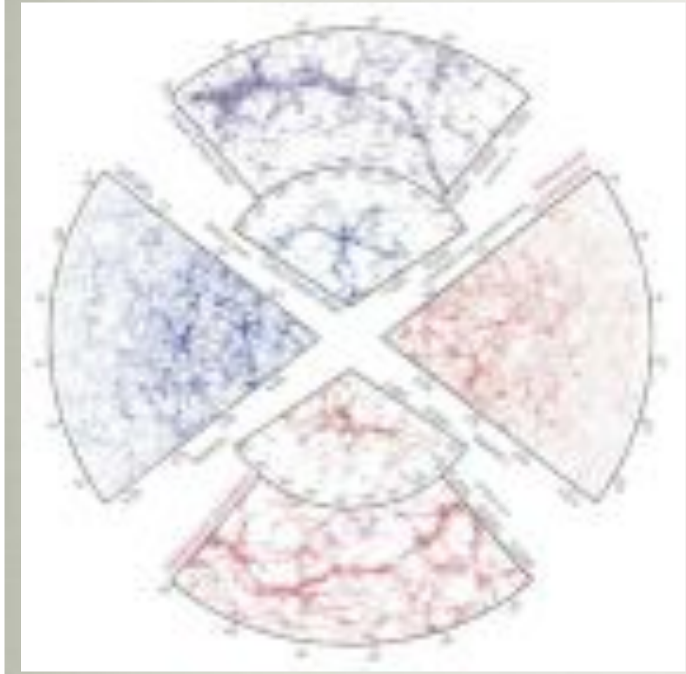
CMB (z≈1000)

Galaxies (z>1)

Galaxies (z≈0.35)

- H(z) (radial)
- $D_A(z)$ (tangential)
- H(z) & $D_A(z)$ depend on w(z)

Expansion and Growth Histories through Galaxy Clustering



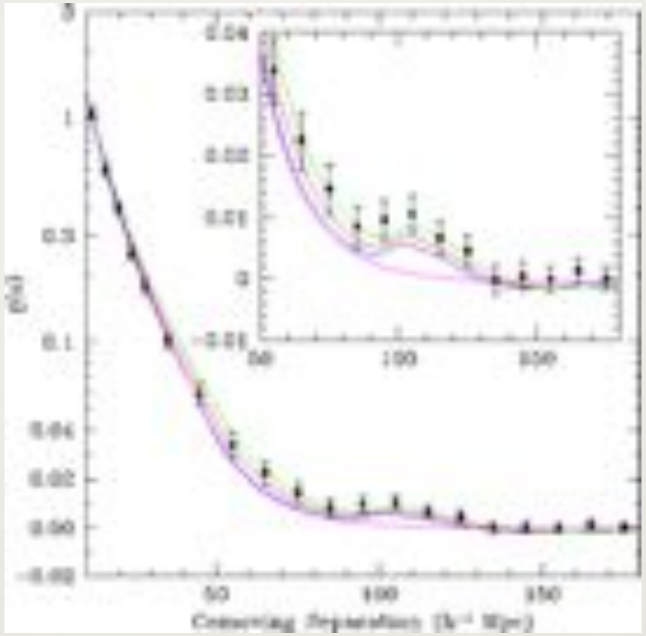
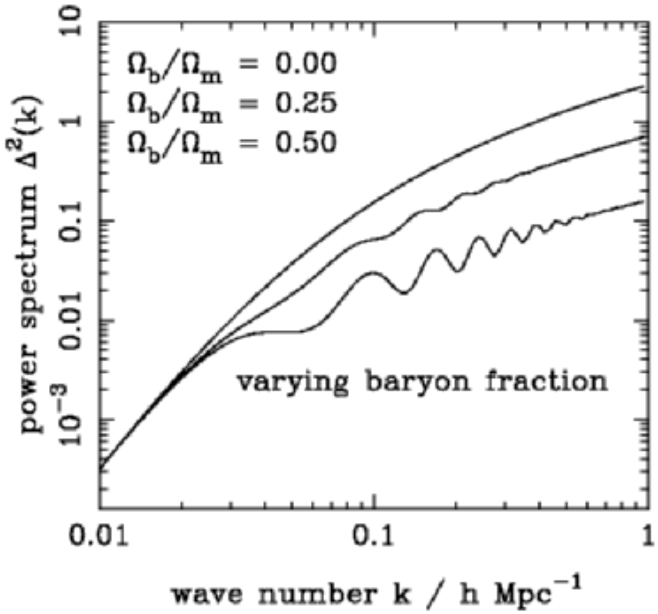
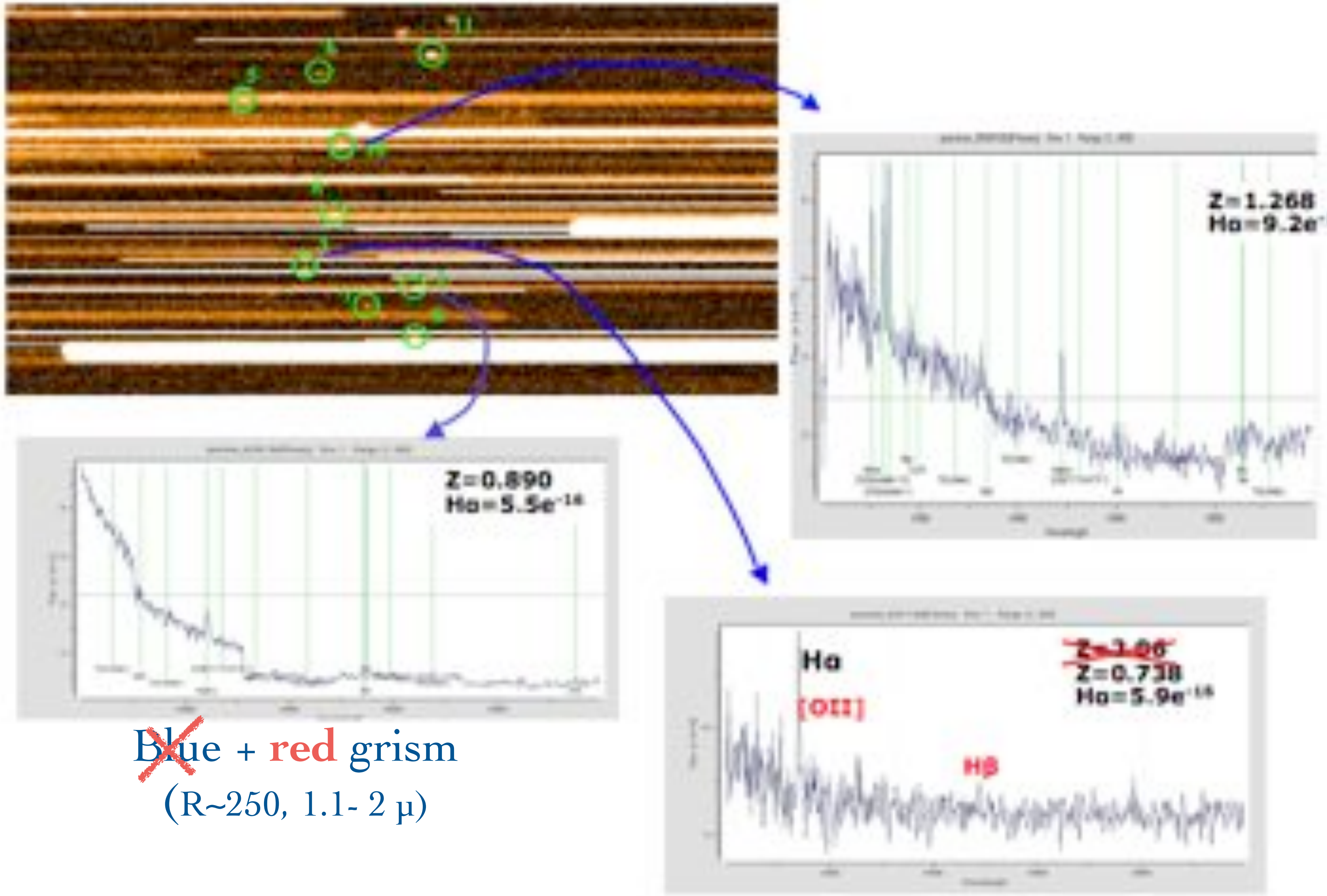


Figure 2.10: a. (Left panel) The galaxy distribution in the largest surveys of the local Universe, compared to simulated distributions from the Millennium Run (Springel et al. 2005); b. (Right panel) The two-point correlation function of SDSS "luminous red galaxies", in which the BAO peak at ~105 h^{-1} Mpc has been clearly detected (Eisenstein et al. 2005).

Clustering reveals features in the power spectrum of density perturbations



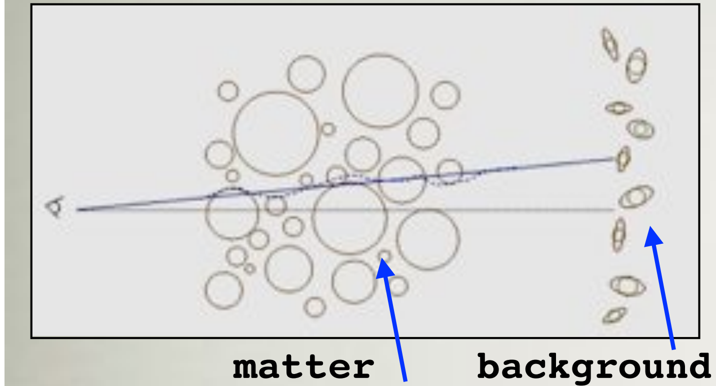
For clustering need spectroscopic redshifts (slitless is not easy)



~~Blue~~ + **red** grism

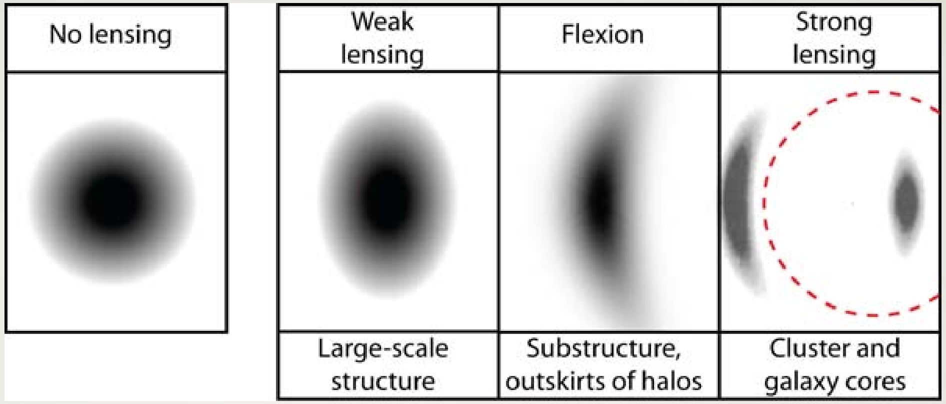
(R~250, 1.1- 2 μ)

Expansion and Growth Histories through Gravitational Lensing



matter (mostly DM)

background galaxies



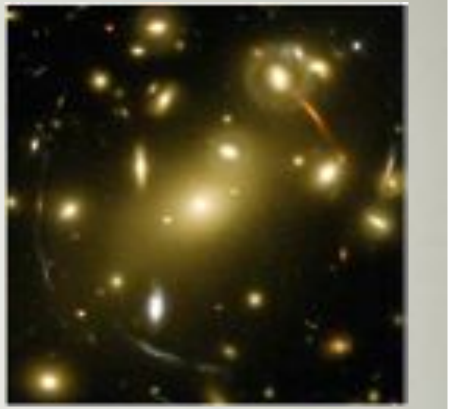


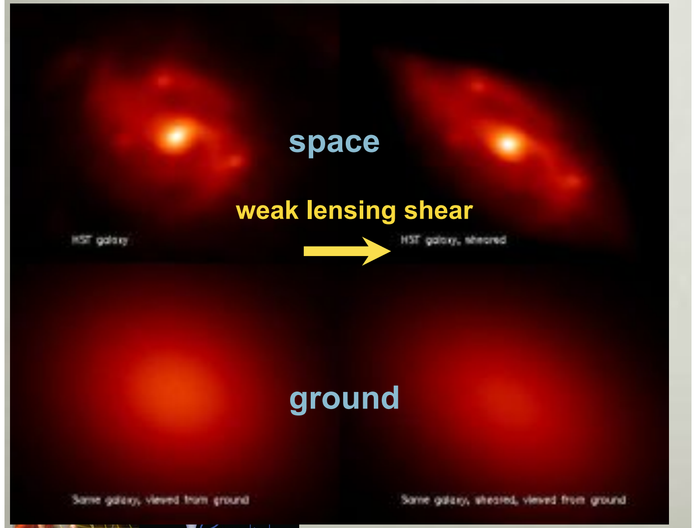
Figure 2.8: a. (Left) Illustrations of the effect of a lensing mass on a circularly symmetric image. Weak lensing elliptically distorts the image, flexion provides an arc-ness and strong lensing creates large arcs

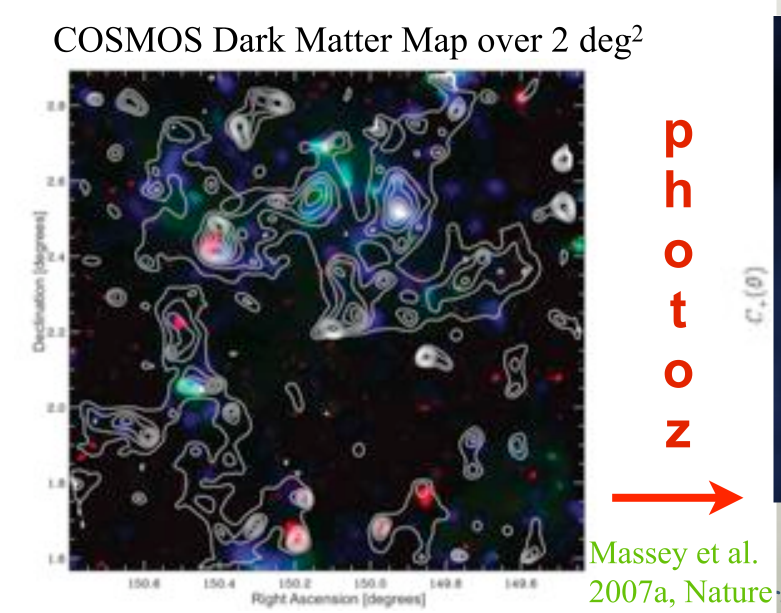
$$\kappa = \frac{3H_0^2\Omega_m}{2c^2}\int_0^{\chi_s} d\chi \frac{D(\chi)D(\chi_s-\chi)}{\chi_s}(1+z)\delta(\chi),$$

observable

distances

density perturbation





photoz

Massey et al. 2007a, Nature

Massey, Rhodes et al. 2007

Ground based lensing is limited by <u>***systematics***</u>

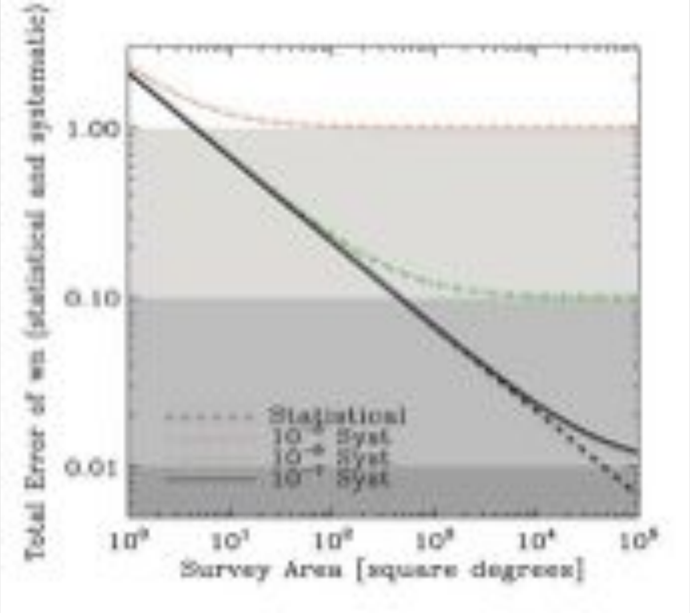


Figure 2.17: Advantages of space based observations in order to reach Euclid's cosmological objectives. The total error on the equation of state decreases statistically as the area of a survey is increased. However systematic effects limit the achievable dark energy constraint. For Euclid to achieve 2% on the dark energy equation of state requires an area of 20,000 square degrees and shape systematic levels with a variance of 10^{-7} (Cf. Amara & Réfrégier 2008). Such a systematic precision can only be achieved with the stability and accuracy of space-based observations.

For photo-z need optical colors from ground based surveys (more systematics)

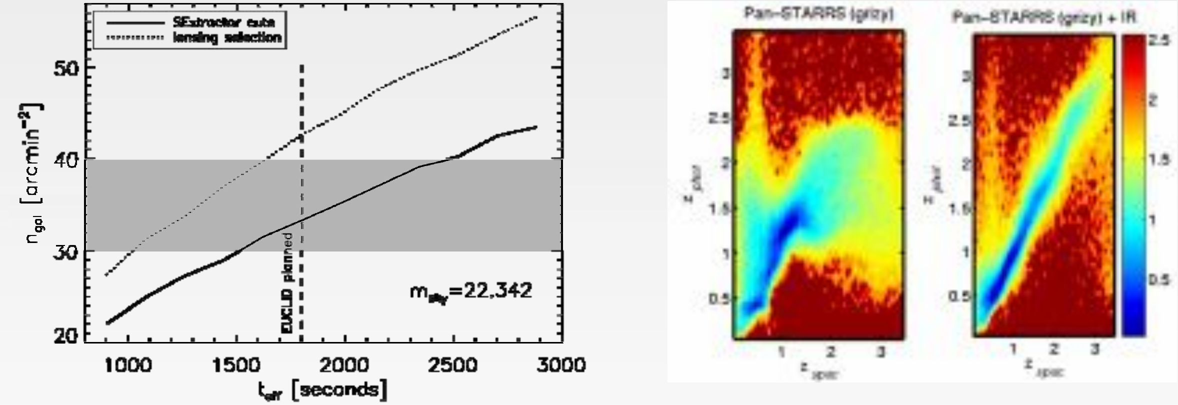


Figure 2.18: a. (Left) The expected number counts of galaxies useful for lensing as a function of exposure time. The solid line is made using a simple cut on SExtractor detection with S/N>10 and FHWM[gal]>1.25FWHM[PSF], the dashed line is from the shape measurement pipelines that sum the lensing weight assigned to each galaxy, with a cut in ellipticity error of 0.1. We see that we are able to reach our requirements of 30-40 gal/amin^2. b. (Right) Shows the redshift measurement for PanSTARRS with and without the Euclid NIR bands (c.f. Abdalla et al 2007). We find that with DES, PanSTARRS-2 and a fortiori PanSTARRS-4 and LSST we will be able to meet out requirements of $\delta z = 0.05(1+z)$.

NIR <u>is mandatory</u> for accurate photoz for $1<z<3$

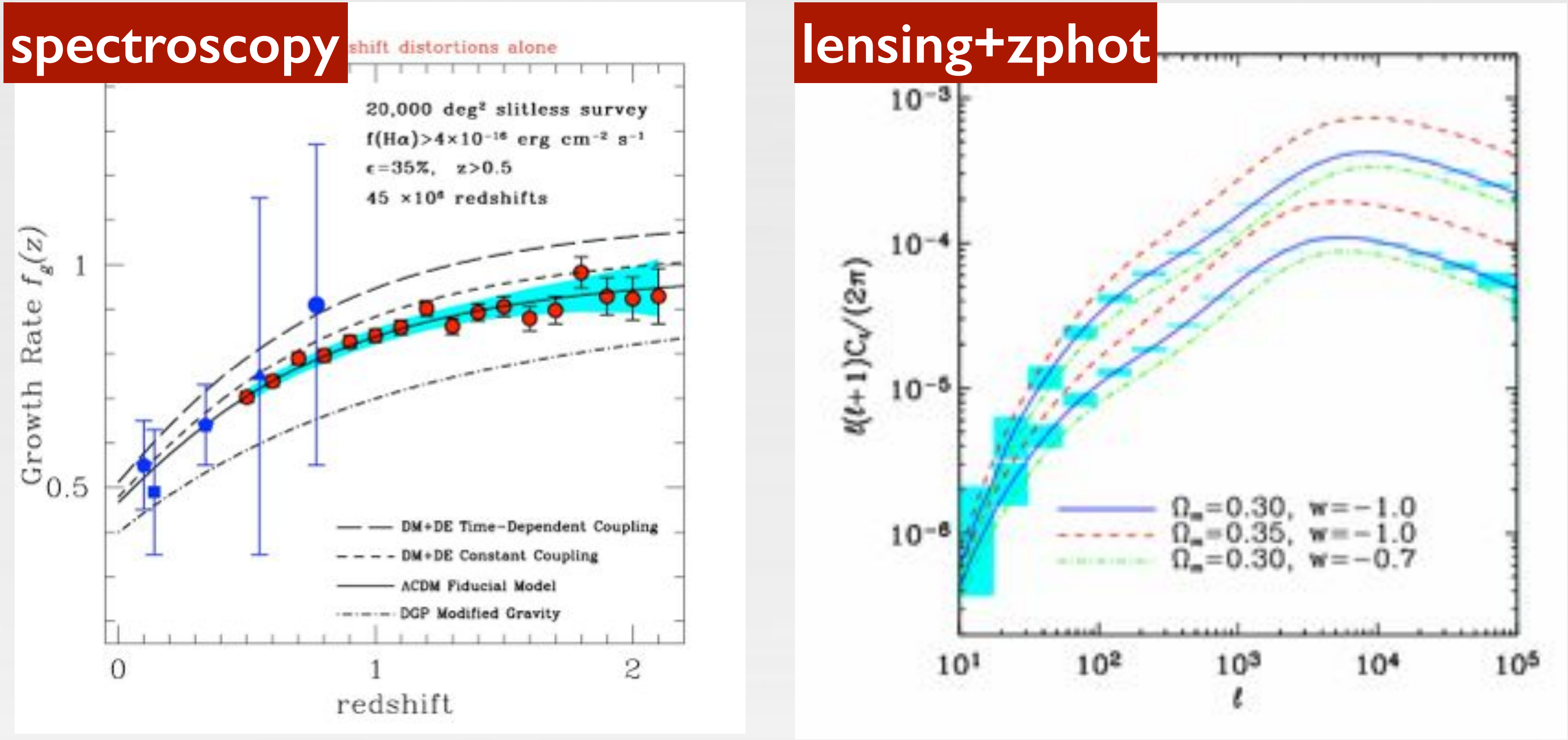


Figure 2.14: a. (left) The growth rate of matter perturbations as a function of redshift. Data points and errors are from a simulation of the spectroscopic redshift survey. The assumed ΛCDM model, coupled dark matter/dark energy modes and DGP are also shown. b. (right): The predicted cosmic shear angular power spectrum at z=0.5 and z=1 for a number of cosmological models

Can discriminate cosmology

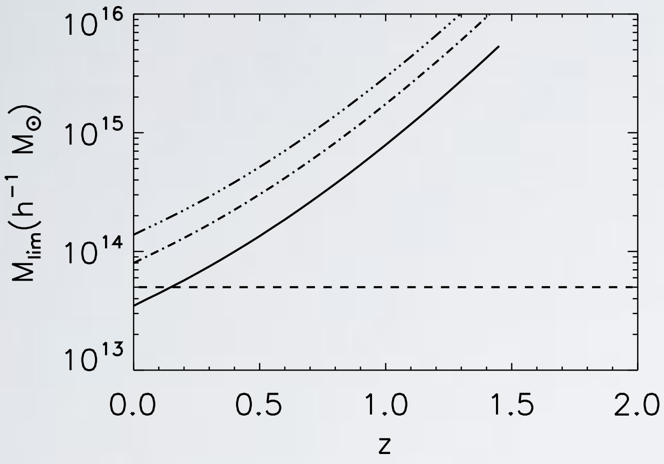
[Dark Energy, Dark matter, non std GR]

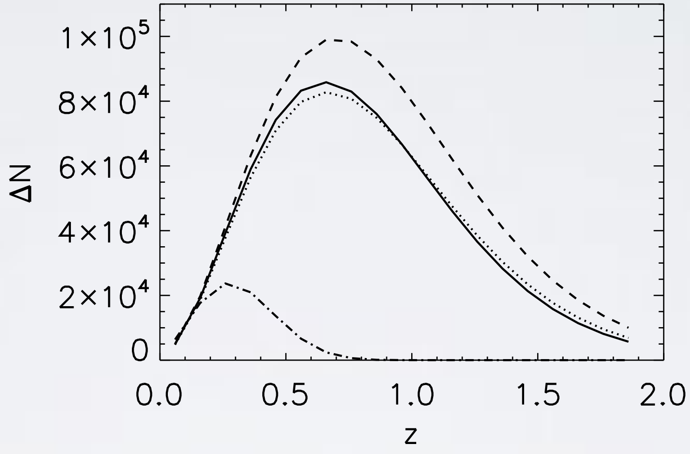
Counts & **Mass** Function *(calibrate!!)*

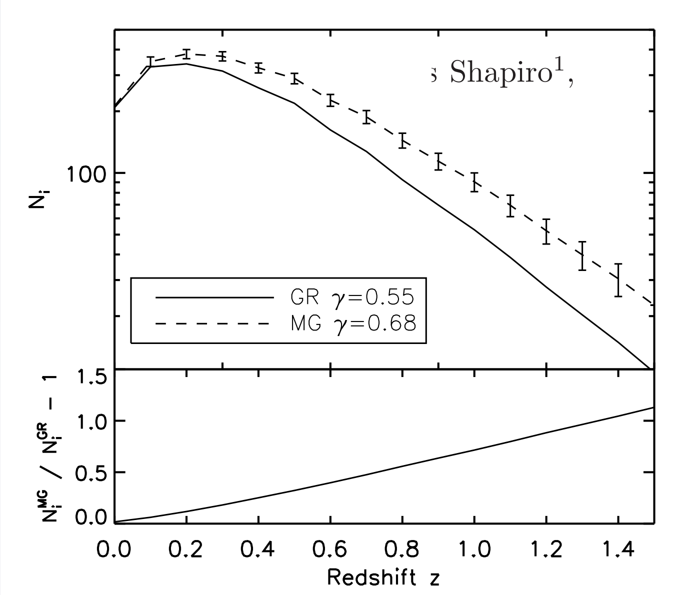
Clusters of galaxies: interesting and powerful

NIR photom (24.5), WL, (vel disp.)

expect N ~ few x 10^5

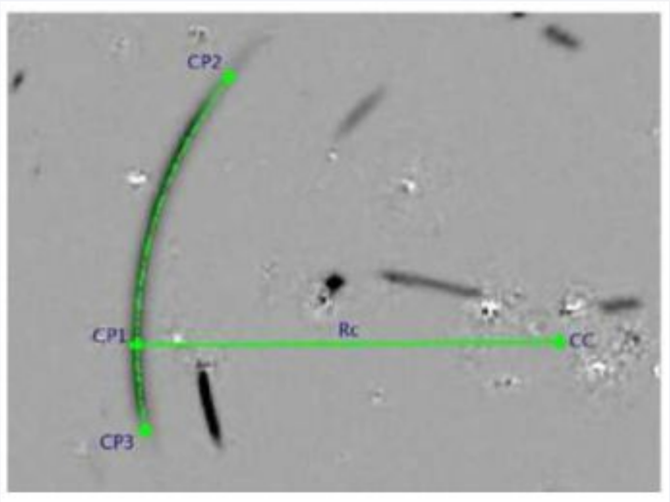






Strong lensing

Mass profile in inner regions; frequency of arcs



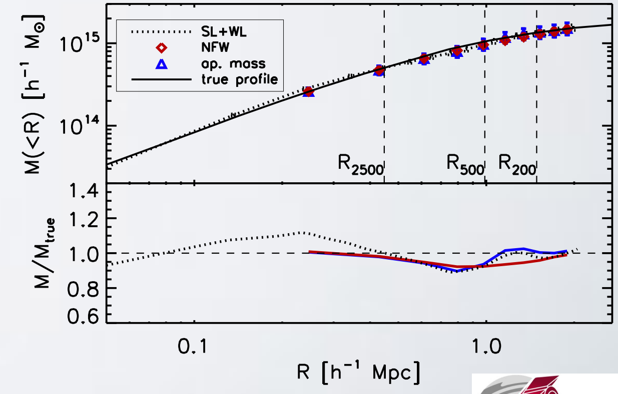
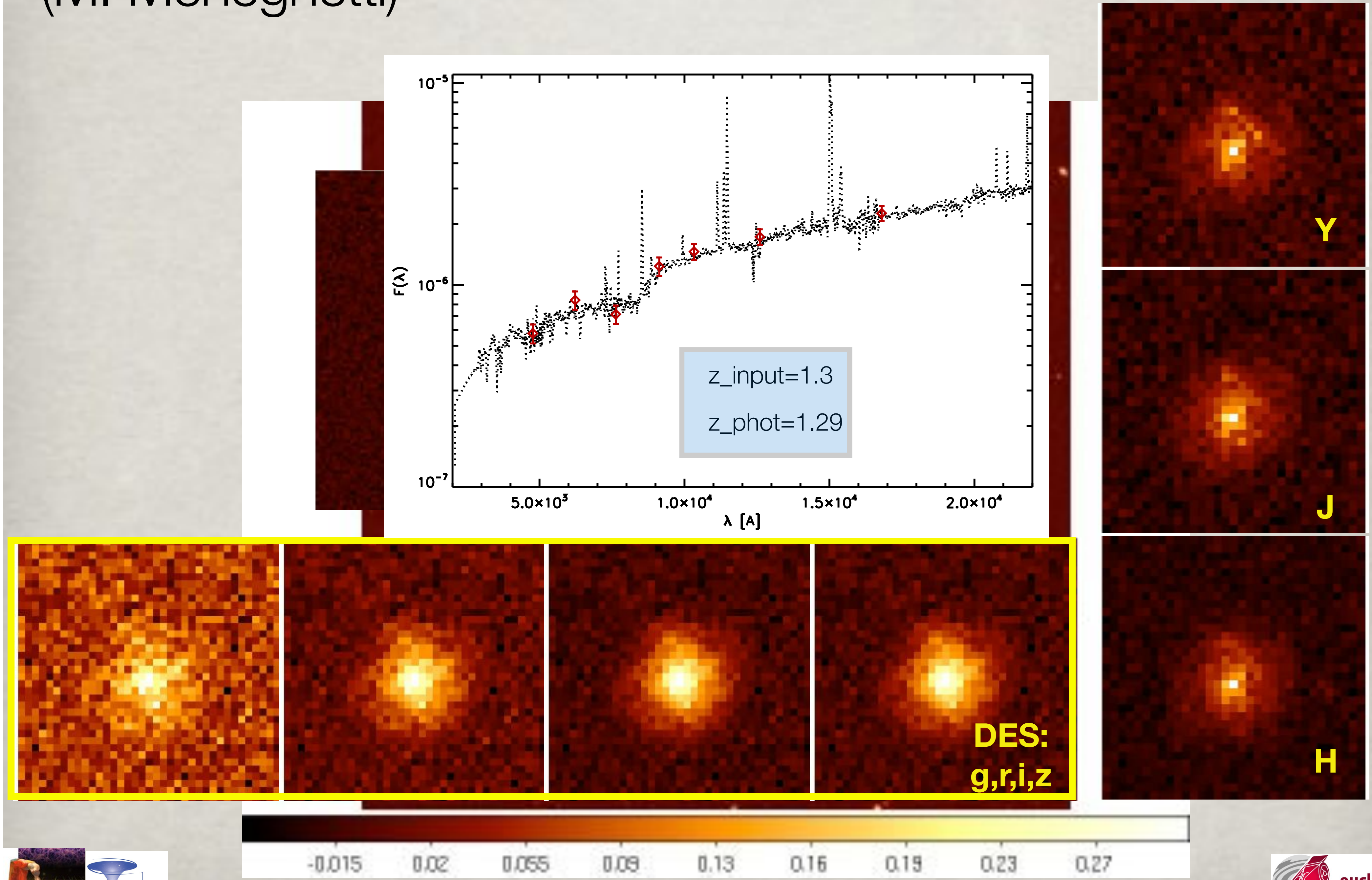


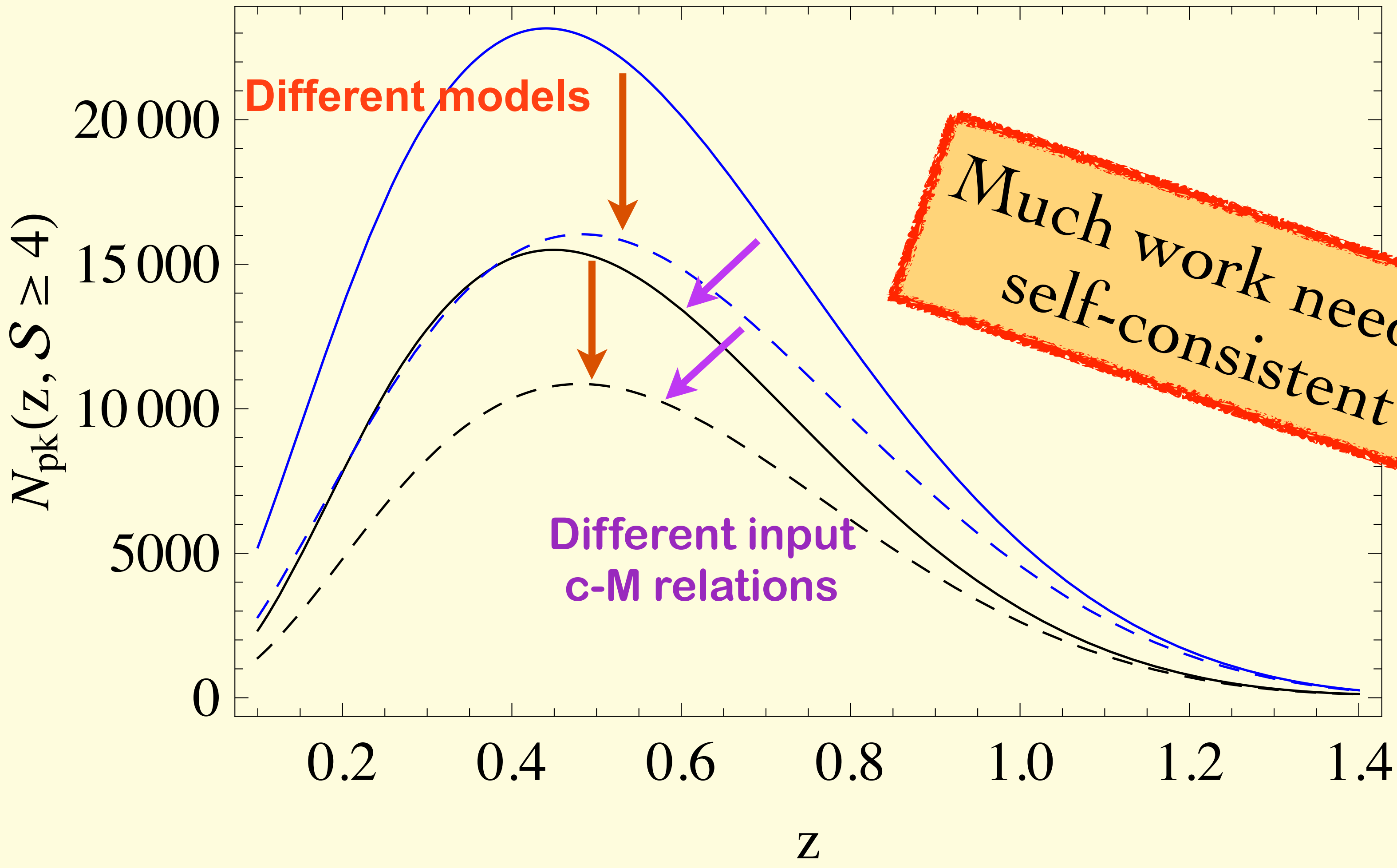
Image simulations: Euclid + ground based data (M. Meneghetti)



An example: cluster abundance in modified gravity

8 *V.F. Cardone et al.* arXiv:1204.3148

Weak lensing peak count as a probe of $f(R)$ theories



Different models

Different input c-M relations

Much work needed to have self-consistent models

Want, NEED! several probes for synergies and Xchecks

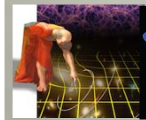
Observational Input	Probe	Description
Weak Lensing Survey	Weak Lensing (WL)	Measure the expansion history and the growth factor of structure
Galaxy Redshift Survey: Analysis of *P(k)*	Baryonic Acoustic Oscillations (BAO)	Measure the expansion history through D_A(z) and H(z) using the "wiggles-only".
	Redshift-Space distortions	Determine the growth *rate* of cosmic structures from the redshift distortions due to peculiar motions
	Galaxy Clustering	Measures the expansion history and the growth factor using all available information in the amplitude and shape of P(k)
Weak Lensing plus Galaxy redshift survey combined with cluster mass surveys	Number density of clusters	Measures a combination of growth factor (from number of clusters) and expansion history (from volume evolution).
Weak lensing survey plus galaxy redshift survey combined with CMB surveys	Integrated Sachs Wolfe effect	Measures the expansion history and the growth

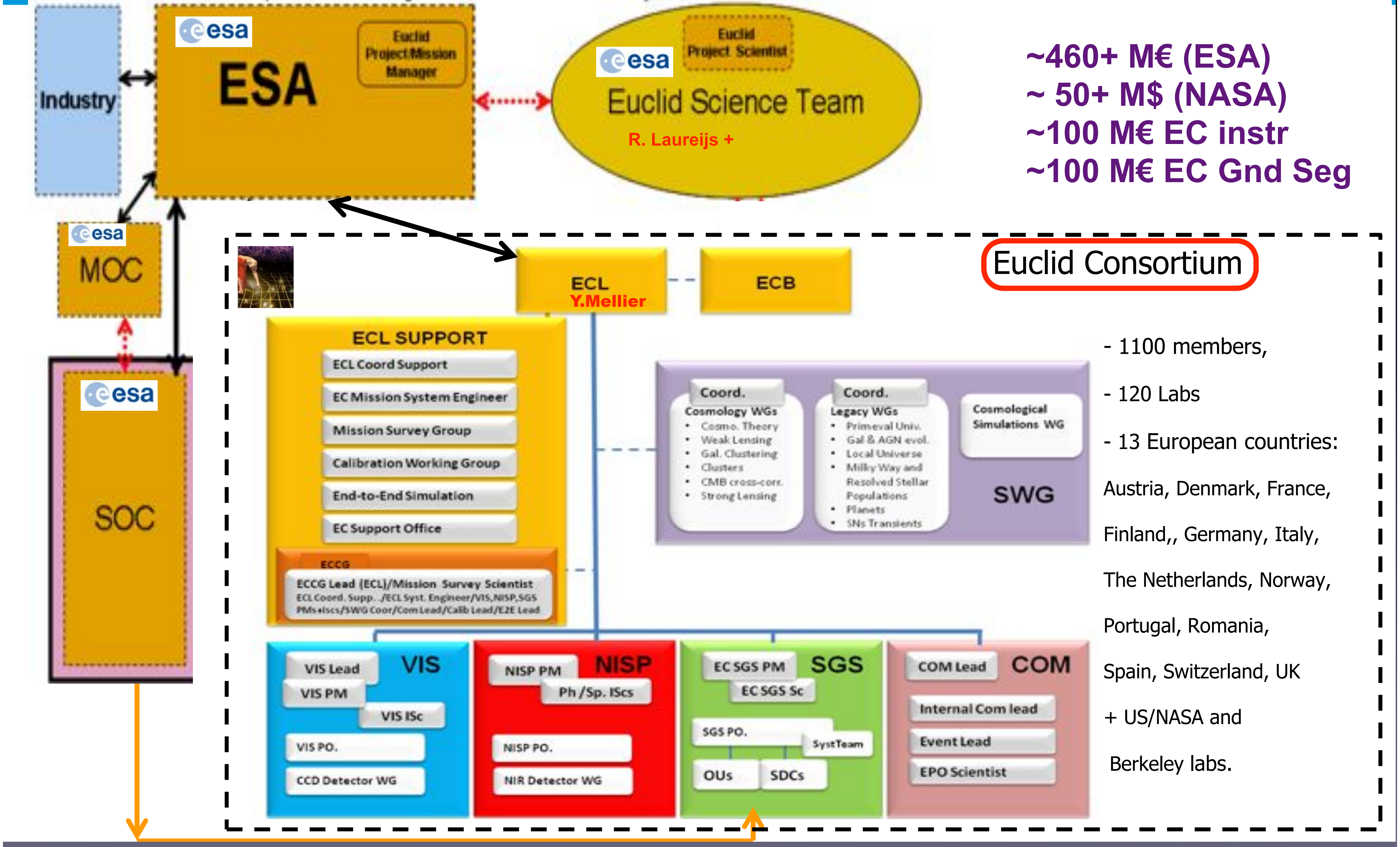
Want to measure expansion factor H(z) - *geometry* -
and growth of density perturbations - *dynamics* -

Legacy

Wide survey: >15,000 sq. deg (visible: 24.5th ABmag 10σ extended; NIR: 24th ABmag 5σ; spectra: $H\alpha$ line flux > 3×10^{-16} erg s^{-1} cm^{-2}, rate ~35%)

Deep Survey: ~40 sq. deg ~ 2 mags deeper (~40 visits)





Industry

ESA

Euclid Project/Mission Manager

Euclid Project Scientist

Euclid Science Team

R. Laureijs +

MOC

SOC

ECL
Y.Mellier

ECB

ECL SUPPORT
- ECL Coord Support
- EC Mission System Engineer
- Mission Survey Group
- Calibration Working Group
- End-to-End Simulation
- EC Support Office

ECCG

ECCG Lead (ECL)/Mission Survey Scientist
ECL Coord. Supp. ../ECL Syst. Engineer/VIS,NISP,SGS PMs+Iscs/SWG Coor/Com Lead/Calib Lead/E2E Lead

Coord.
Cosmology WGs
- Cosmo. Theory
- Weak Lensing
- Gal. Clustering
- Clusters
- CMB cross-corr.
- Strong Lensing

Coord.
Legacy WGs
- Primeval Univ.
- Gal & AGN evol.
- Local Universe
- Milky Way and Resolved Stellar Populations
- Planets
- SNs Transients

Cosmological Simulations WG

SWG

VIS
- VIS Lead
- VIS PM
- VIS ISc
- VIS PO.
- CCD Detector WG

NISP
- NISP PM
- Ph /Sp. ISCs
- NISP PO.
- NIR Detector WG

SGS
- EC SGS PM
- EC SGS Sc
- SGS PO.
- SystTeam
- OUs
- SDCs

COM
- COM Lead
- Internal Com lead
- Event Lead
- EPO Scientist

~460+ M€ (ESA)
~ 50+ M$ (NASA)
~100 M€ EC instr
~100 M€ EC Gnd Seg

Euclid Consortium

- 1100 members,

- 120 Labs

- 13 European countries:

Austria, Denmark, France,

Finland,, Germany, Italy,

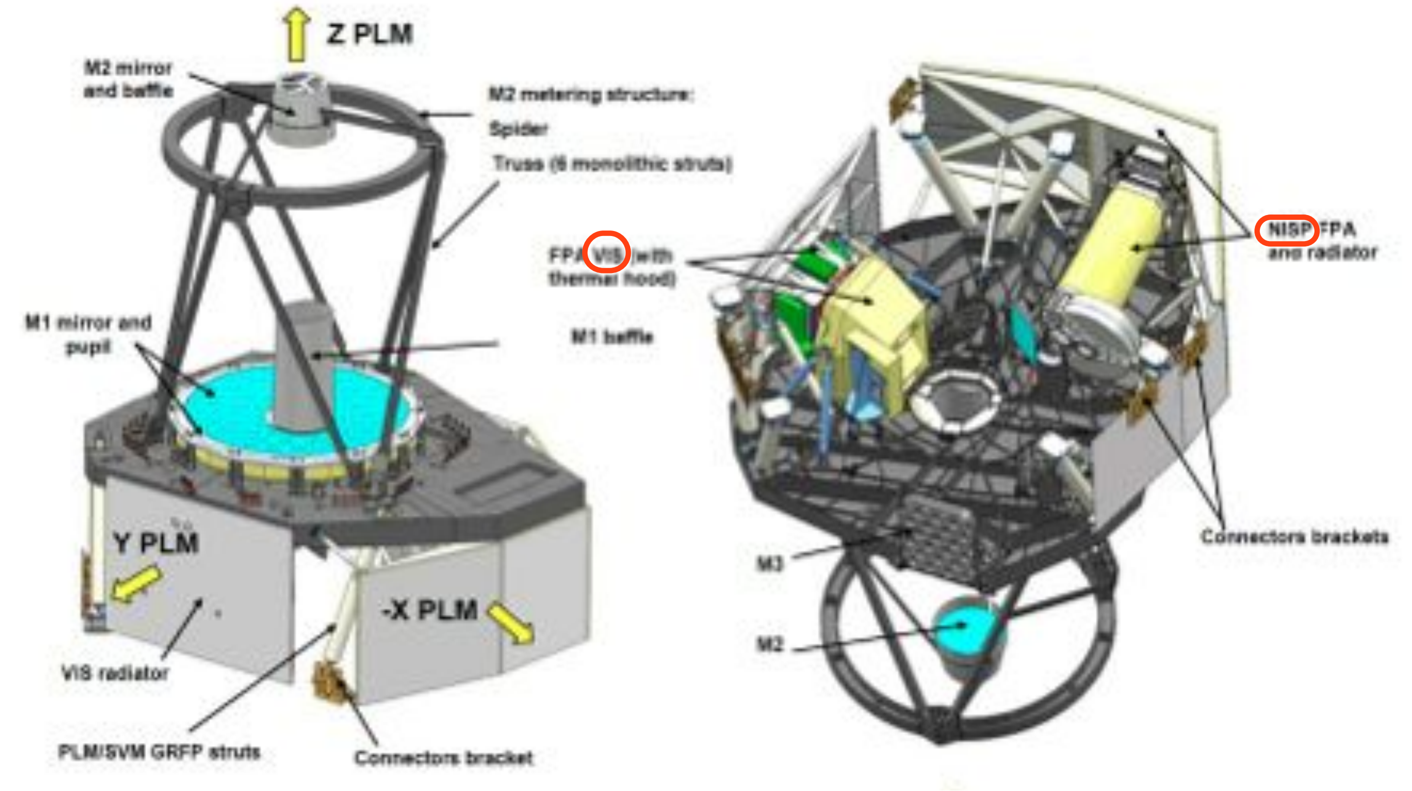
The Netherlands, Norway,

Portugal, Romania,

Spain, Switzerland, UK

+ US/NASA and

Berkeley labs.



Two instruments:

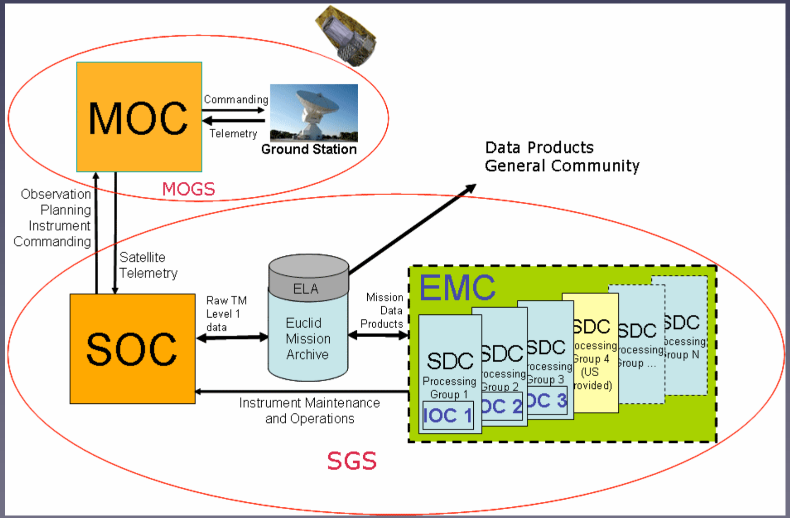
VIS: optical imager

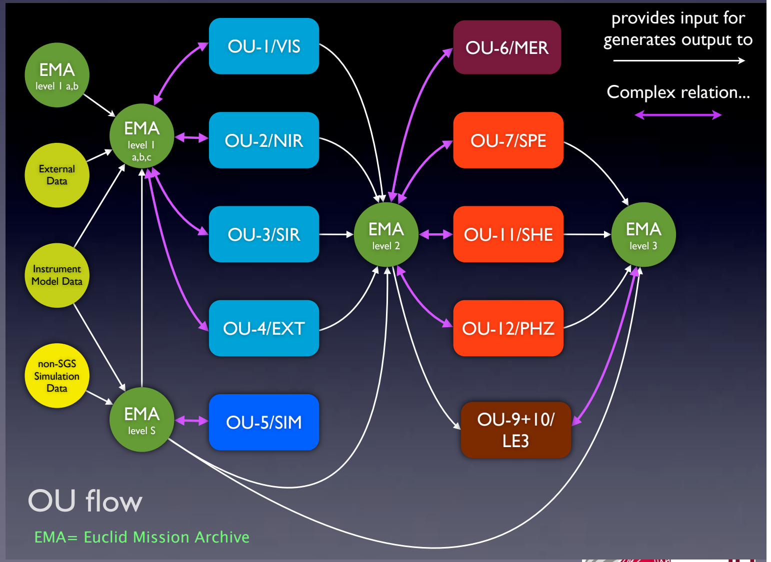
NISP: NIR imager + grisms

Ground Segment

instruments costs ≈ GS costs

A few Petabytes...





The core: ~0.5 sq/degs, VIS & NIR Focal Planes, lots of pixels !!!

The geometrical Field of View is the sky area limited by the contour of the focal plane array of a given instrument (VIS or NISP) projected onto the sky. The contour is defined by the first pixel line or columns of the detectors on the edge of the FPA as indicated on the next figure.

36 (0.1” pix) Visible FPA: 36 VIS CCD

NIR FPA: 16 H2RG **16 (0.3” pix)**

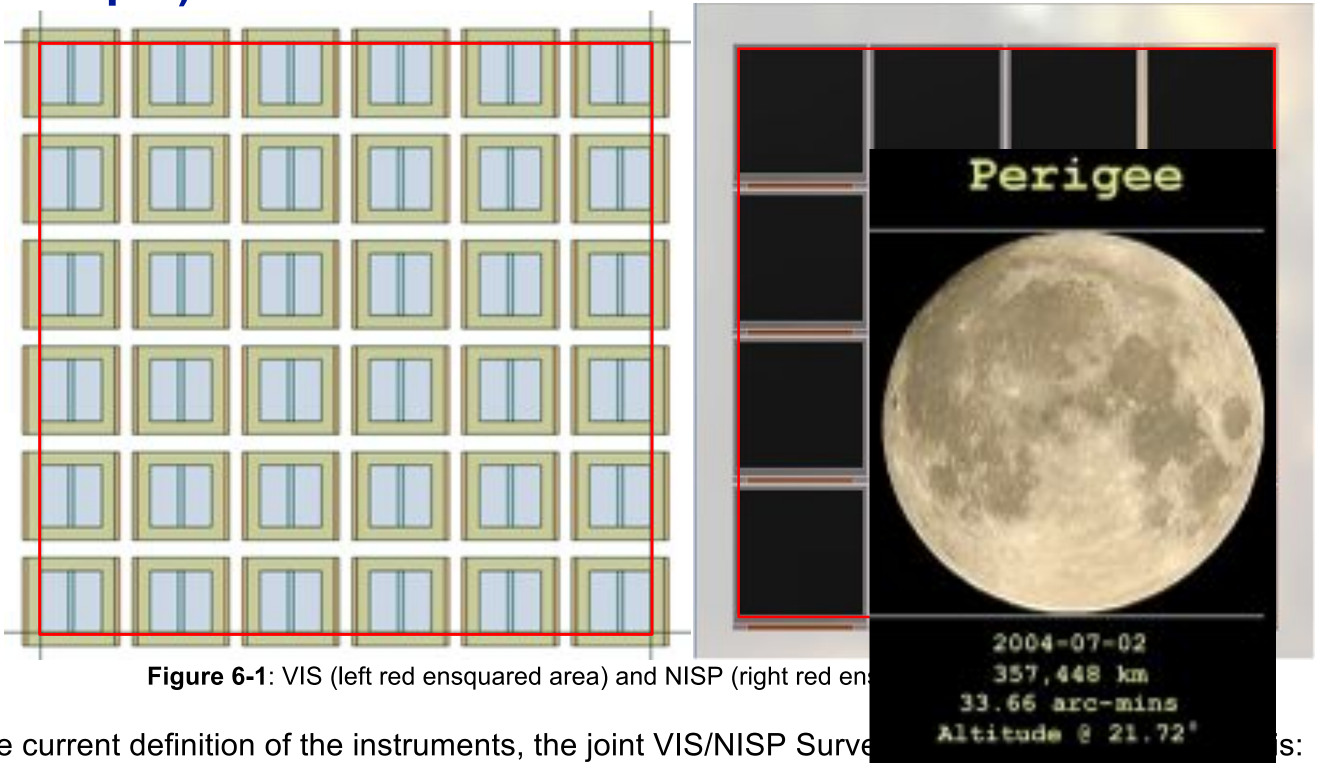


Figure 6-1: VIS (left red ensquared area) and NISP (right red ens

VIS: imaging

NISP: y, J, H photom + slitless

With the current definition of the instruments, the joint VIS/NISP Surve is:

- JOINT_FOV_x= 0.763°
- JOINT_FOV_y= 0.709°

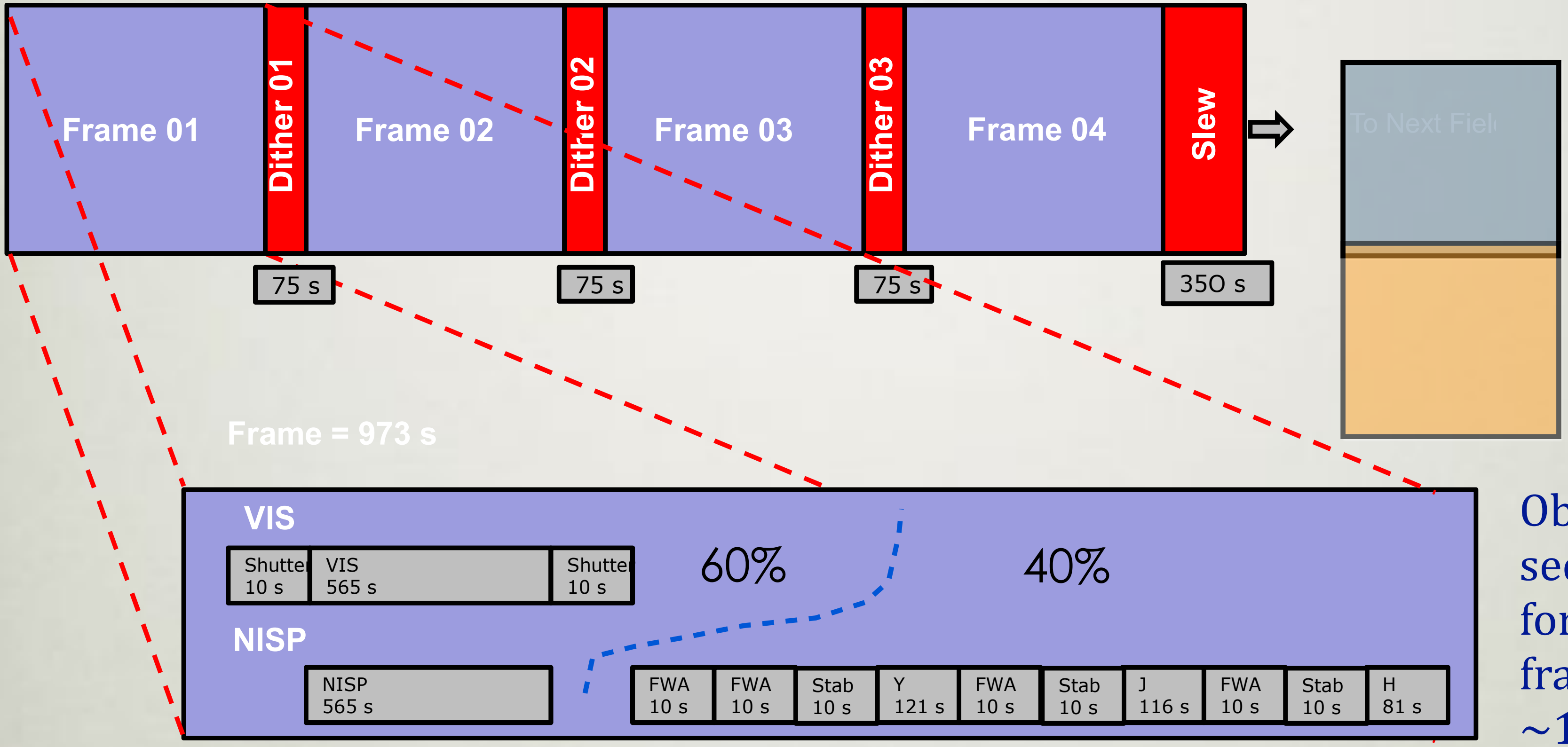
~44’ side

The x and y field orientations are defined in the figure 6-2.

cf Planck: here ~ O(billion) of pixels for field, plan ~ 30,000 fields

4 dithers ~1 full Field -0.5 sq deg- / 1.25 hr (≈10 sq deg/day)

Observing sequence for each field + move to next one ~4500 s



coverage
50% 3 exp
50% 4 exp

Observing sequence for each frame ~1000 s

Figure 5-4: Nominal Field Observation Sequence.

NIR: first spectroscopy contemporarily to VIS, then imaging (filter wheels motion perturbs VIS)

Slitless: Red grism 1.25-1.8μ (Hα: 0.9<z<1.7)

4 exposures: 0, 90, 180 degs, then again once

Slitless: Blue grism 0.92-1.25μ only in the Deep

Strategy

- **Commissioning**
- **First Light**
- **Calibrations**
  - VIS
  - NIP
  - NIS
- **Deep Survey**
  - When
    - Interleaved
    - End of the mission
    - Dedicated time spans during mission
  - How
    - Depth
    - Size
    - Sequences
- **Wide Survey**
  - 🙂 Goal
  - Minimum required
    - Number of galaxies (Poisson)
      - Global [N(M,D,etc)]
        - Effective S
          - Shear
            - Limiting magnitude
            - Useful size
            - Good photoz
          - Spectra
            - Limiting line flux
            - Crowding
            - Halpha detected
    - Spatial sampling: Area/Volume (cosmic variance, char scales)
      - Number of useful dithers, Bright stars etc
- **Additional Surveys**
  - Planet microlensing
    - How long
      - Cadence
      - When
        - End of the mission
        - Dedicated time spans during mission
  - Milky Way
  - Supernovae

Need to fix priorities !!!

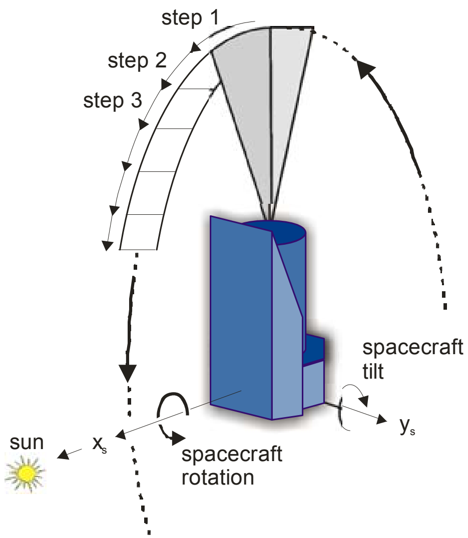
EUCLID Mission

in part OLD

- Launcher: Soyuz ST2-1B from Kourou
- Direct injection into tranfer orbit
  - Transfer time: 30 days
  - Transfer orbit inclination: 5.3 deg
- Launch vehicle capacity:
  - 2160 kg (incl. adapter)
  - 3.86 m diameter fairing
- Launch ≈ 2020
- Mission duration: 6 years

Advanced Studies and Technology Preparation Division

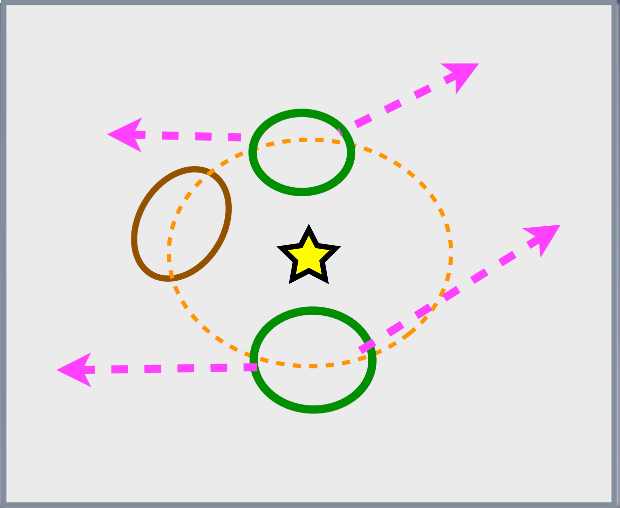
Looks like CMB satellites but with step & stare



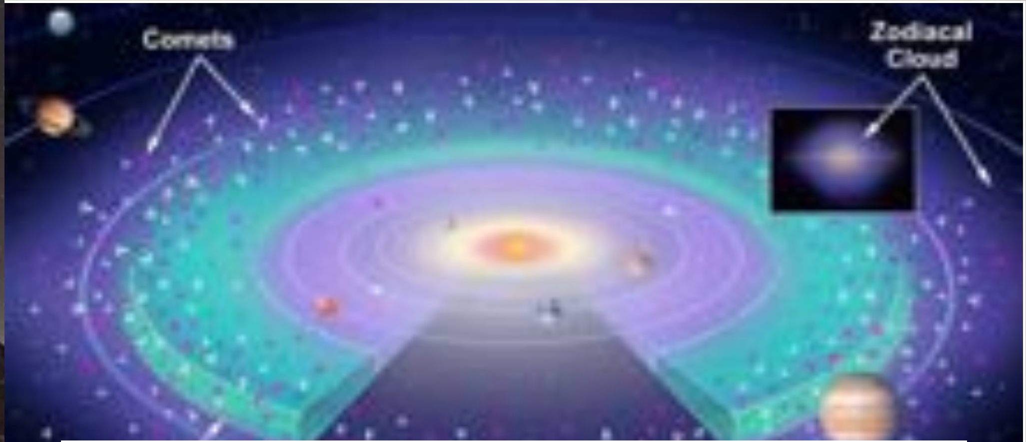
For stability need to always observe orthogonally to the sun

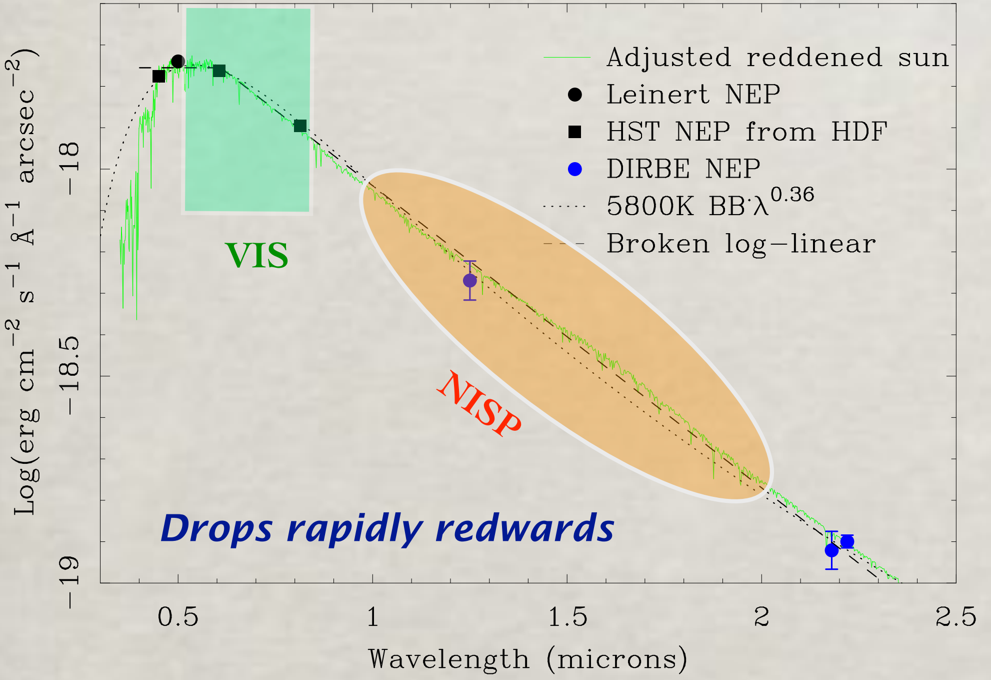
region visibility: twice/yr at ecliptic plane (1deg/day), max at ecliptic poles (always).

spin 2 behaviour as in WL



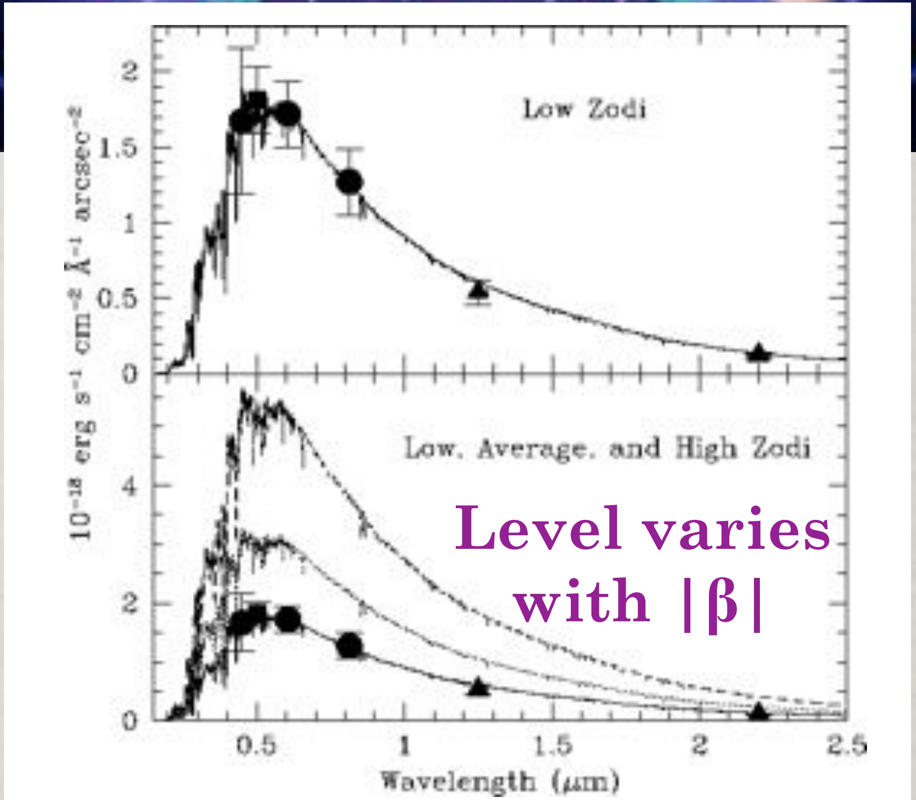
Zodiacal Light





Drops rapidly redwards

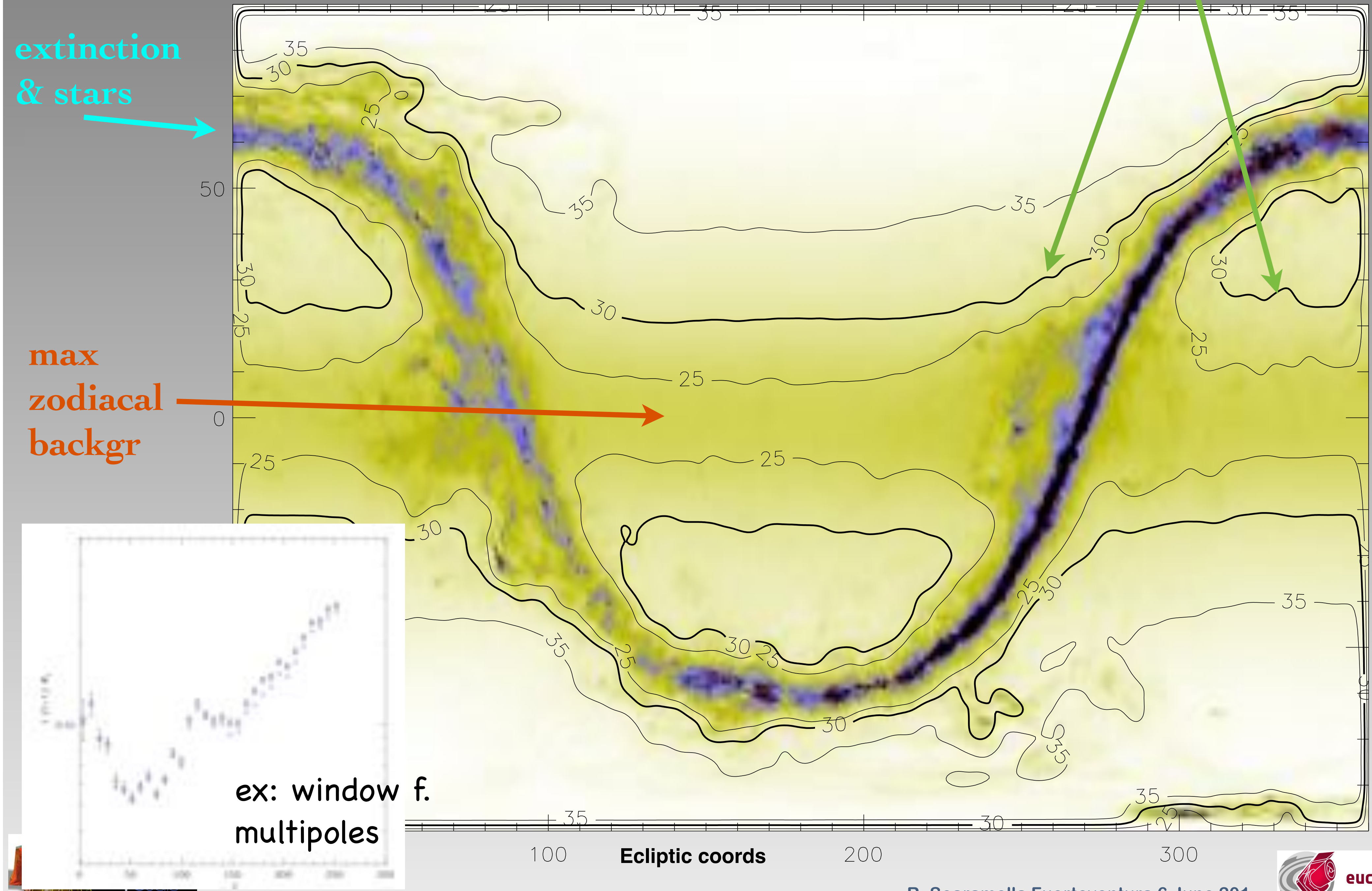
Figure 7: The solar spectrum, adjusted to match the observed zodiacal background (solid green). Simplified characterization - a 5800° K blackbody scaled by $\lambda^{0.36}$ (dotted black). Broken power-law parameterization (dashed black).



Level varies with |β|

Figure 1. Upper panel. The spectrum of the zodiacal background light at the NEP compared to broad-band observations from the ground and HST observations. The circles are data at 0.450, 0.606 and 0.814 μm, respectively from the HDF; the square is Leinert et al. (1998) measure at 0.5 μm, and the triangles are measures from COBE/DIRBE at 1.25 and 2.2 μm. **Lower panel.** The comparison between the intensity of the three adopted normalizations of the zodiacal backgroud light. The lowest normalization is the one relative to the NEP, and it is shown together with the broad-band data points discussed above.

Galaxy density for WL: want the overall average > 30 /sq arc min



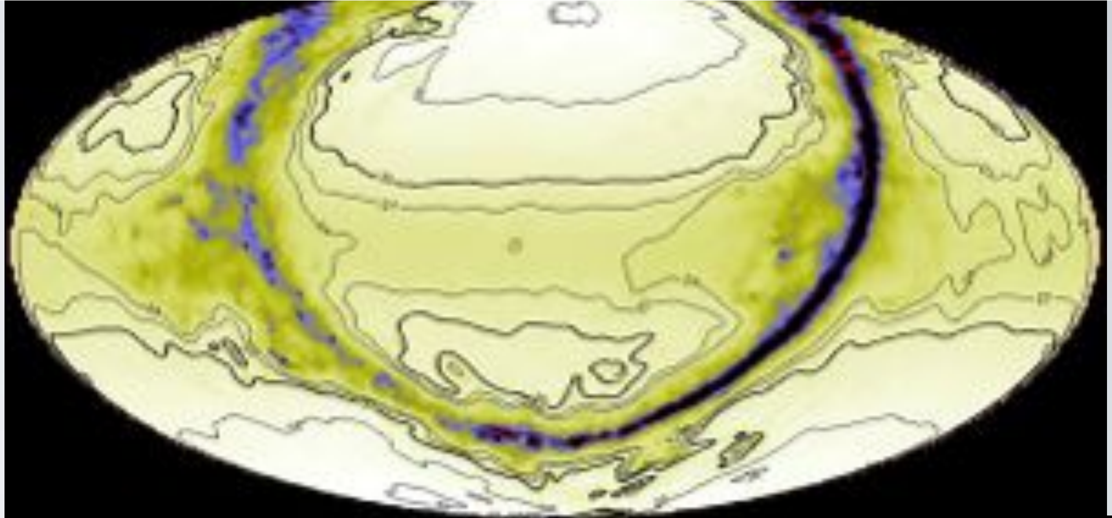
extinction & stars

max zodiacal backgr

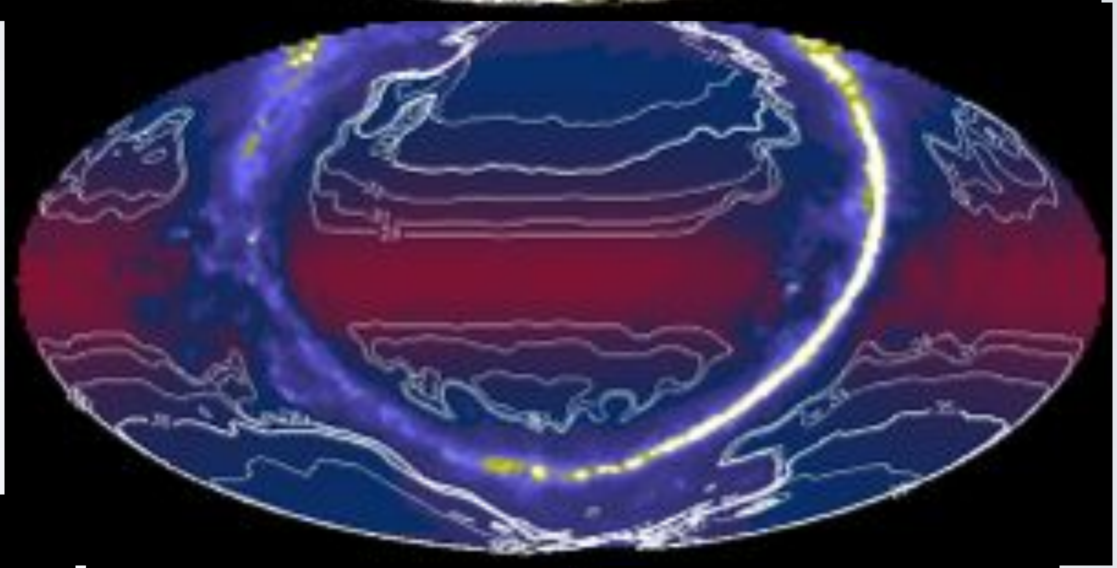
ex: window f. multipoles

Euclid Survey Areas,

(~2012)



$N \sim 1.5\text{-}2\ 10^9$ Weak Lensing sampling



$N \sim 5\text{-}6\ 10^7$ Being revised ditto for Clustering

R.S & J. Amiaux (ESAC tool)

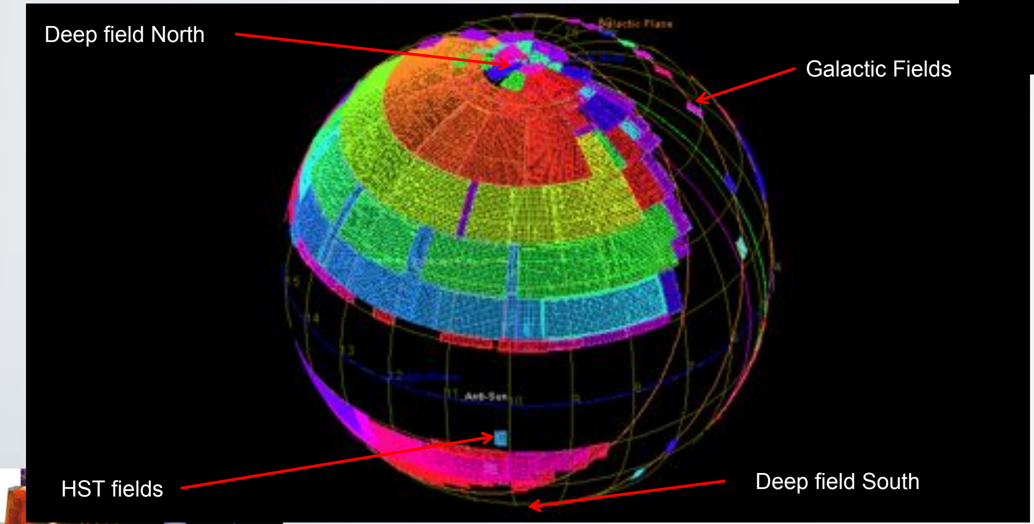


Figure 3.11.4-2: Assumption for locations of main calibrators for building the reference survey and implementation of the fields on the reference survey.

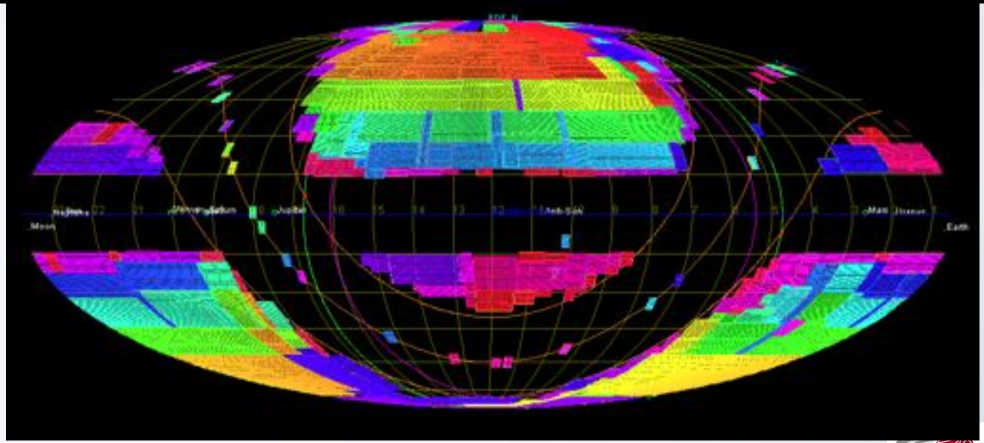
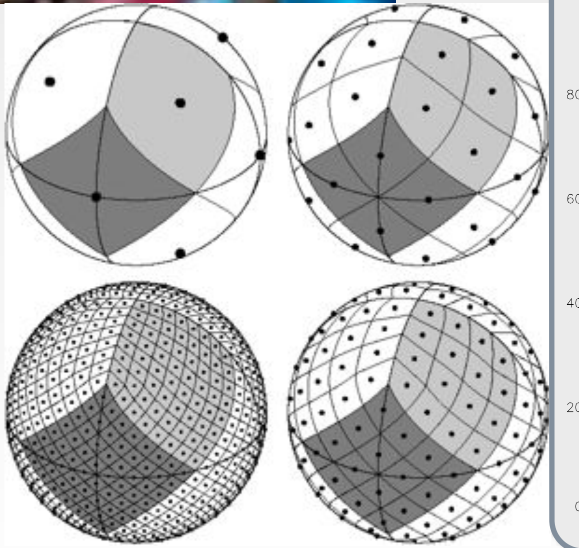


Figure 3.11.4-3: Mollweide representation of the full reference survey (including location of calibration fields).

To tile or not to tile......

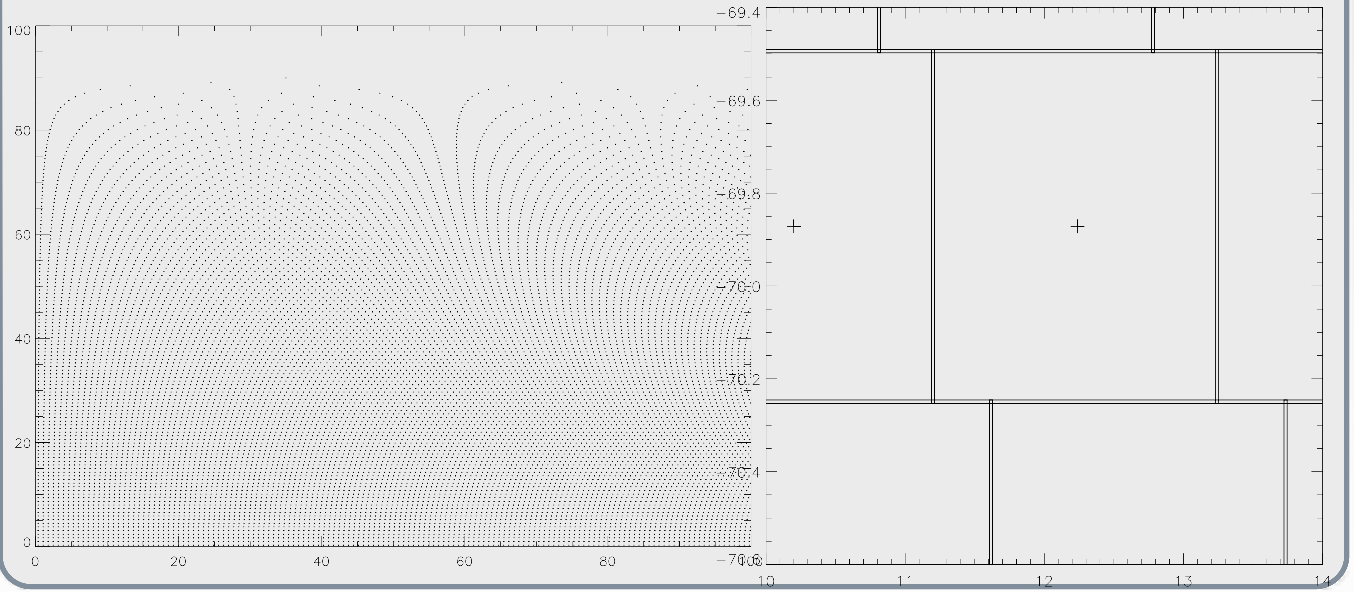
Tiles!!

Pantheon

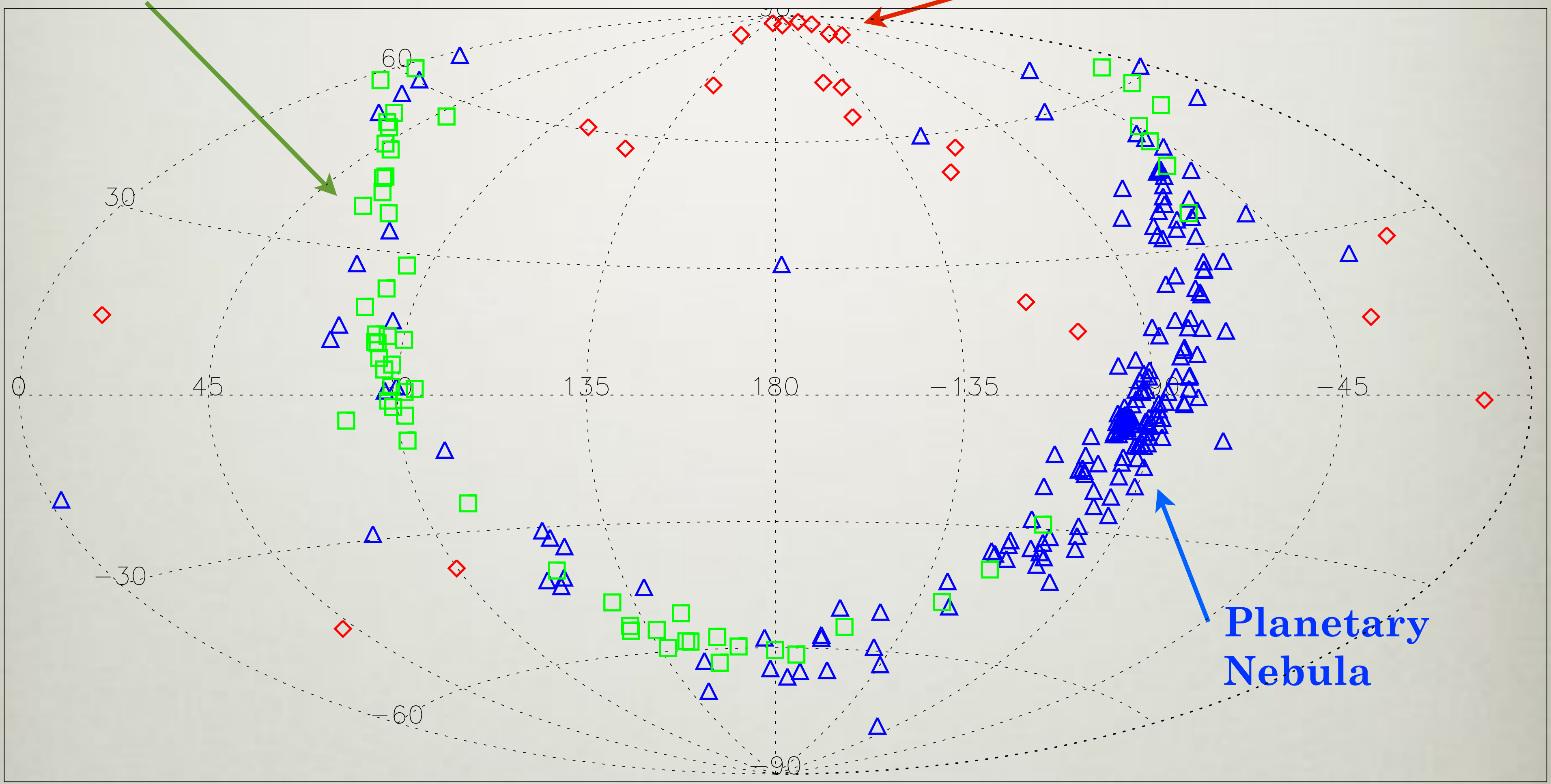


Healpix, (Gorski et al)

Change approach: from satellite relative pointings to a predetermined tiling



For calibrations use specific targets or the Deep Fields



Open Cluster

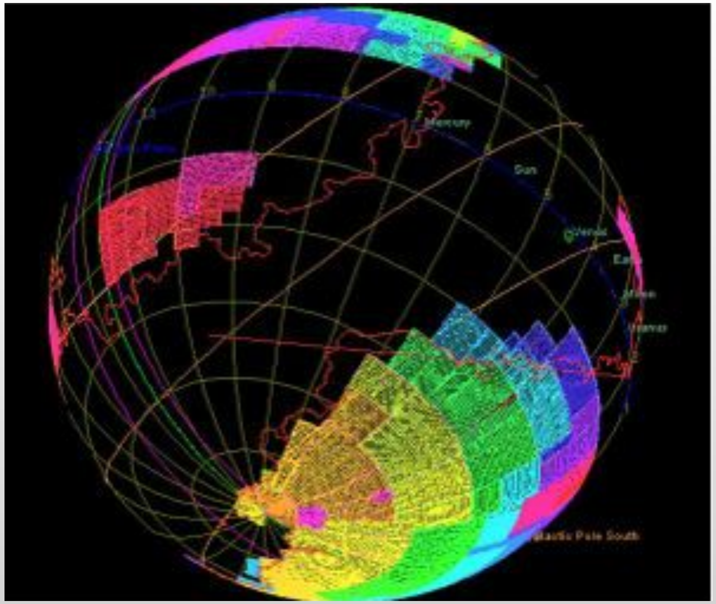
White Dwarf

Planetary Nebula

NISP calibrators above, for WL need dense star regions
(in the galaxy plane)

Then use the ESSPT tool to select by hand at starting times areas which then get populated by the tool [still need to optimise]

I. Tereno, J. Amiaux & ECSURV



Some areas will be moved in optimisation

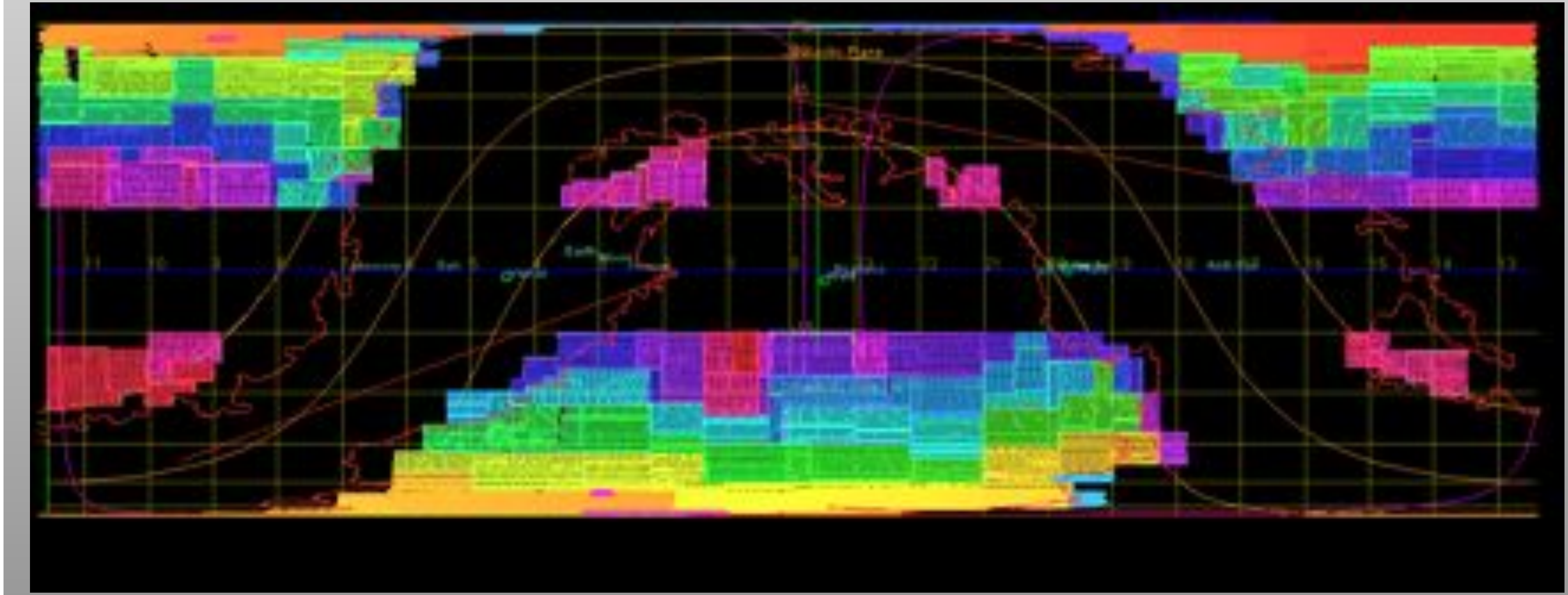
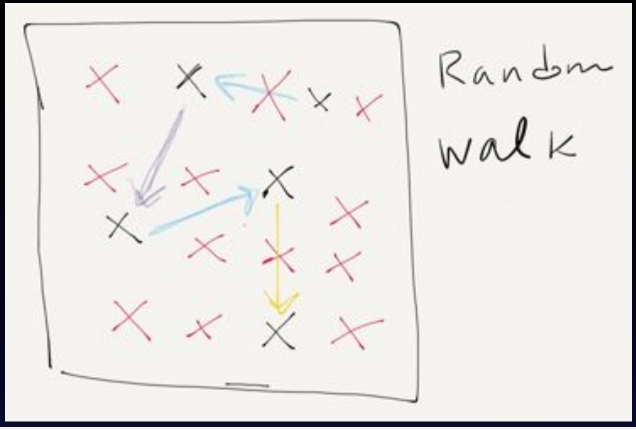
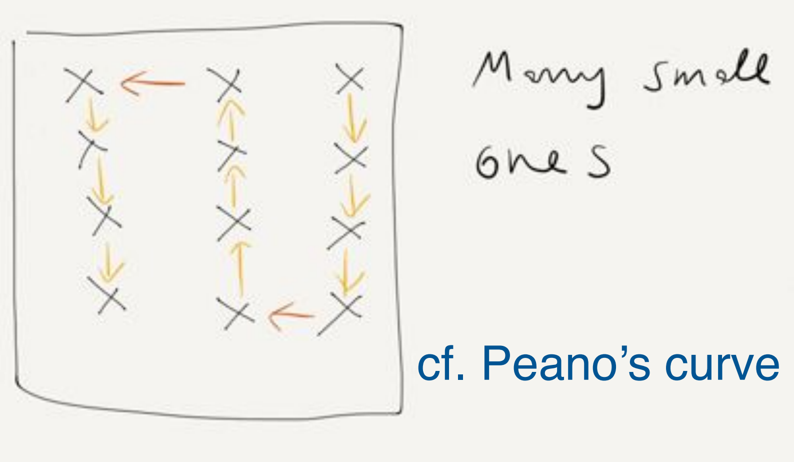


Figure 6-3: Covered area for year 6, Reference case (ecliptic coordinates, cylindrical projection).

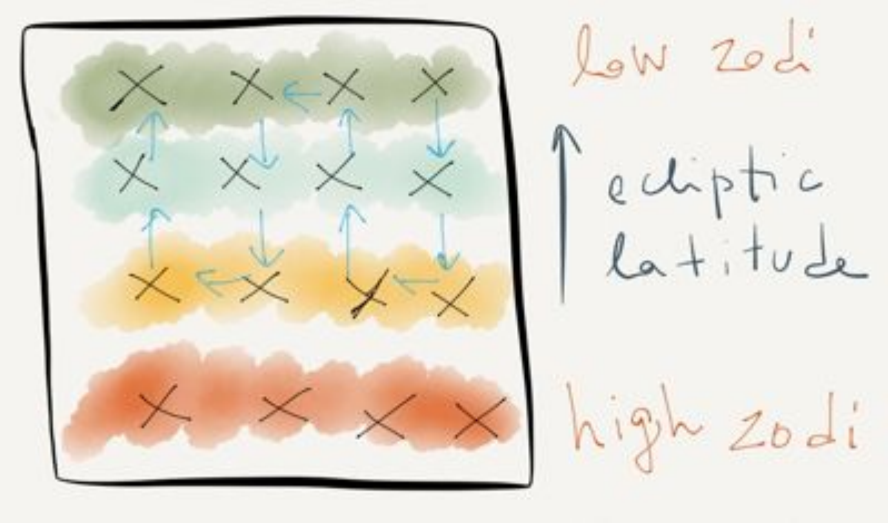
Sequence optimization: minimize moves, background, etc.

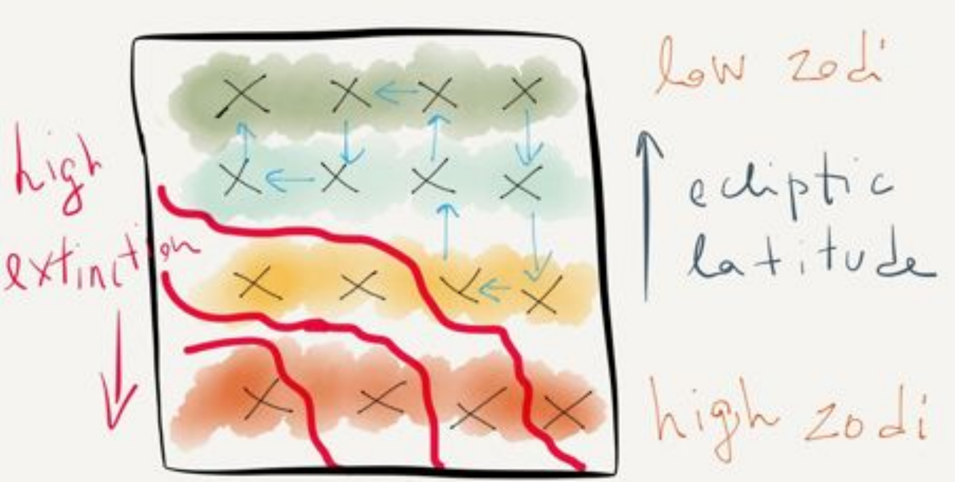
A. Da Silva, S. Carvalho, J. Dinis, D. Oliveira, I. Tereno



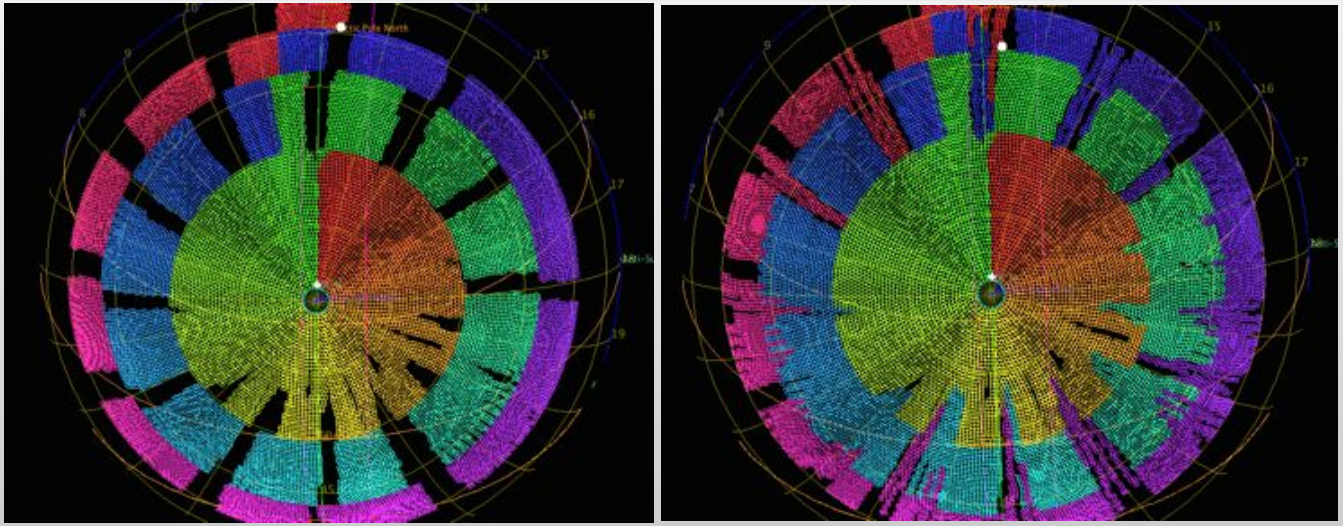


cf. Peano’s curve



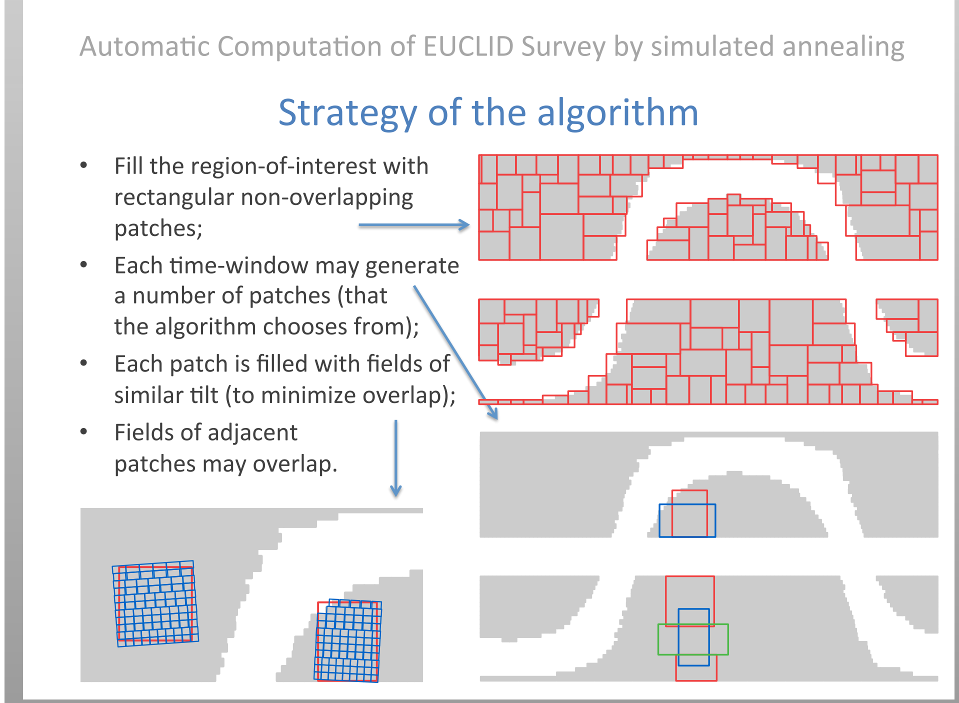


The visual/manual approach must be superseded by optimization algorithms which take into account various quantities and boundaries



S. Carvalho (predefined tiling: minimise overlaps but needs some range in alpha)

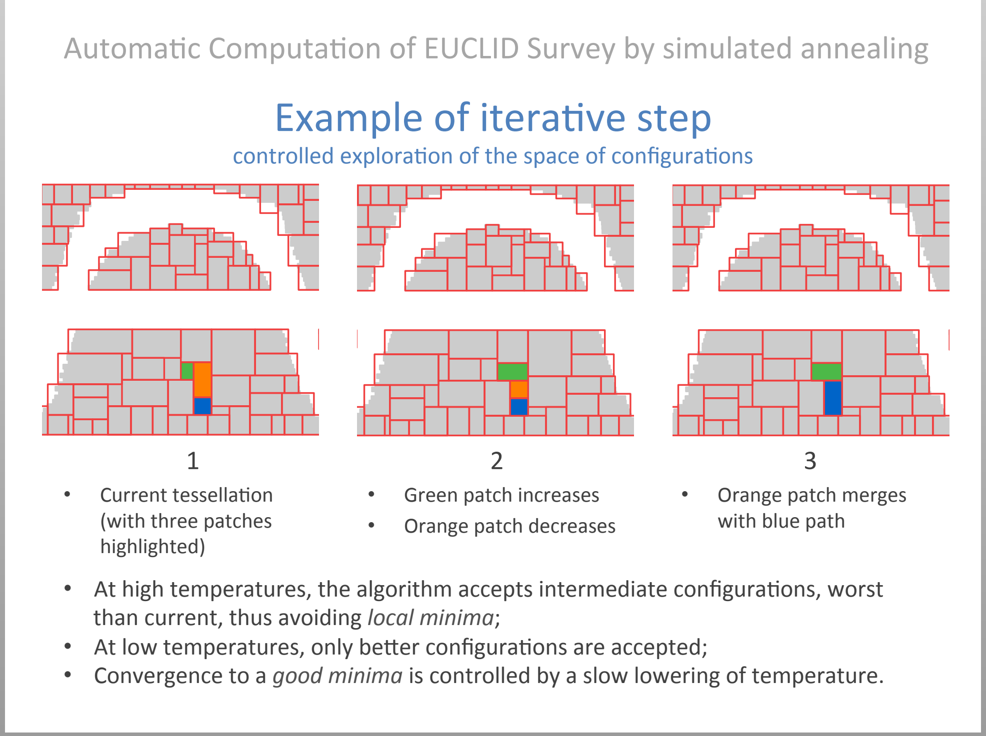
Try to fill regions left empty because of observing calibrations (large slews….)



Automatic Computation of EUCLID Survey by simulated annealing

Strategy of the algorithm

- Fill the region-of-interest with rectangular non-overlapping patches;
- Each time-window may generate a number of patches (that the algorithm chooses from);
- Each patch is filled with fields of similar tilt (to minimize overlap);
- Fields of adjacent patches may overlap.



Automatic Computation of EUCLID Survey by simulated annealing

Example of iterative step

controlled exploration of the space of configurations

1
- Current tessellation (with three patches highlighted)

2
- Green patch increases
- Orange patch decreases

3
- Orange patch merges with blue path

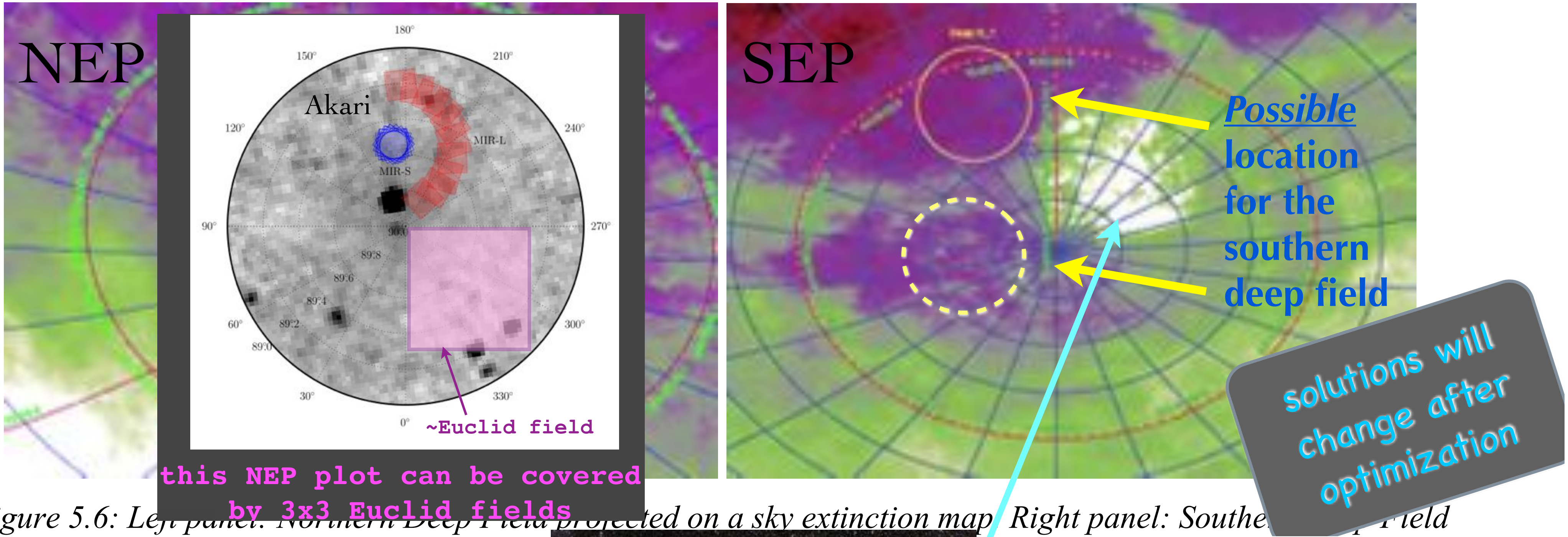
- At high temperatures, the algorithm accepts intermediate configurations, worst than current, thus avoiding *local minima*;
- At low temperatures, only better configurations are accepted;
- Convergence to a *good minima* is controlled by a slow lowering of temperature.

J. Dinis (adaptive tiling: keep same alpha within local rectangle but waste some overlaps at boundaries)

Deep Field(s): calibration reqs (*being updated*) + science

Need high ecliptic latitude for observability (want low extinction too)

main requirements:
2x20 sq deg
2 mags deeper than wide



this NEP plot can be covered by 3x3 Euclid fields

Possible **location for the southern deep field**

solutions will change after optimization

Figure 5.6: Left panel: Northern Deep Field projected on a sky extinction map. Right panel: Southe Field

Part of the SEP is covered by the Large Magellanic cloud … not good for deep xgal field so need to move sideways (shorter visibility)

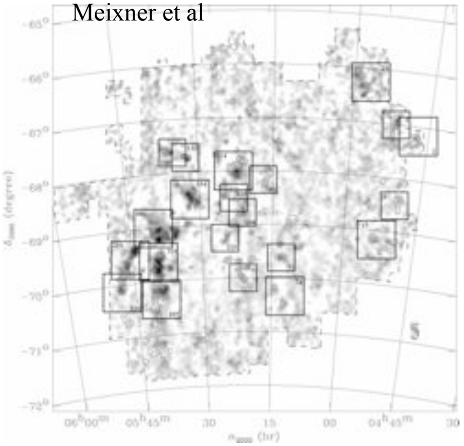
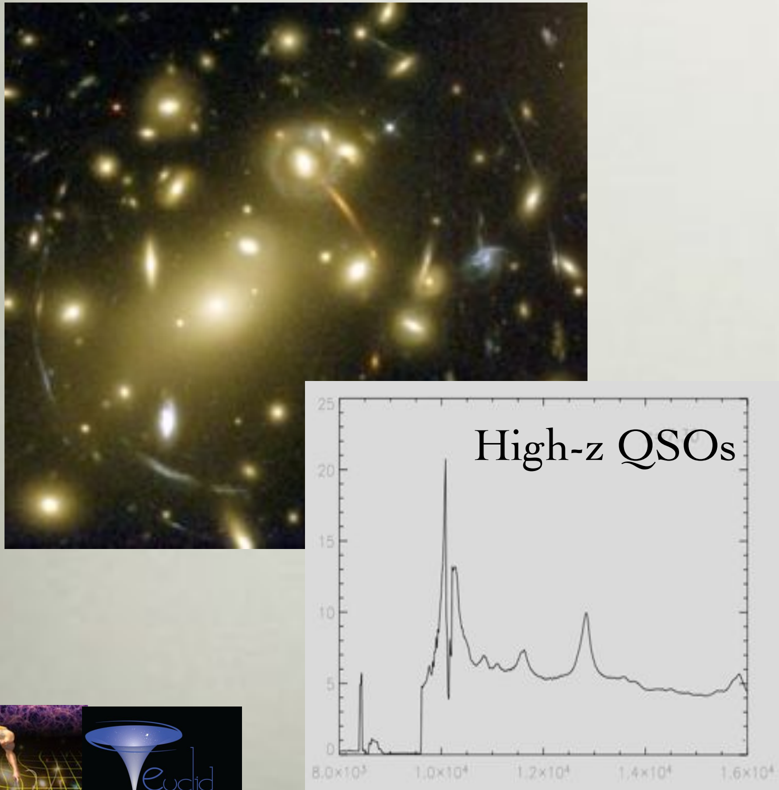


Fig 5: Extinction map of the LMC obtained from star count in the 2-mass catalog overlaid with CO contours. Av ranges from 0 to 5 mag

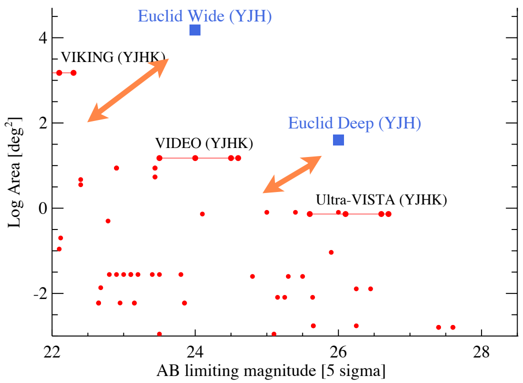
- ***Unique* legacy survey**: 2 billion galaxies imaged in optical/NIR to mag >24 Million NIR galaxy spectra, full extragalactic sky coverage, Galactic sources
- Unique database for **various fields in astronomy**: galaxy evolution, search for high-z objects, clusters, strong lensing, brown dwarfs, exo-planets, etc
- **Synergies with other facilities**: JWST, Planck, Erosita, GAIA, DES, Pan-STARSS, LSST, E-ELT etc (e.g. to do NIR from the ground would take several x 10^3 yr)
- **All data publicly available** through a legacy archive

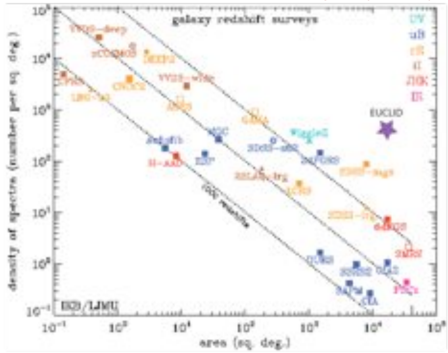
Enormous database to harvest



Euclid in context

	VISTA	SASIR	Euclid
Wide survey	680 years	66 years	5 years
Deep survey	72 years	7 years	“5 years”



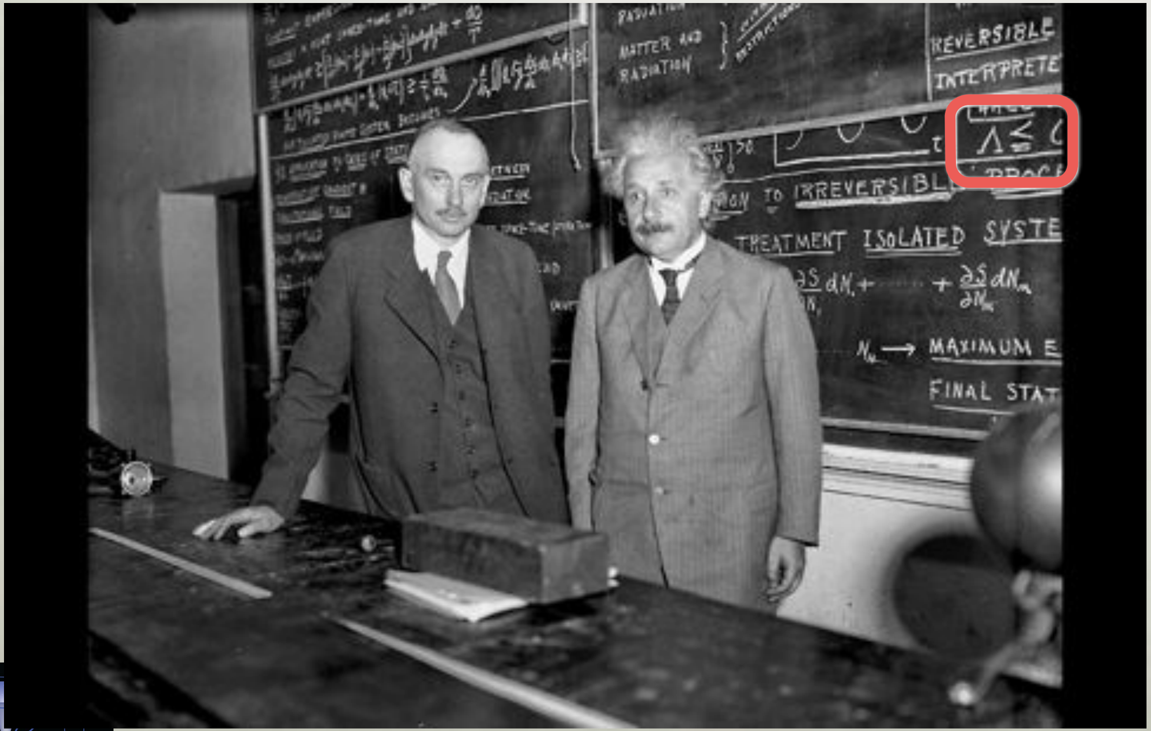


Original by I. Baldry

The ubiquitous symbol.. (hex U+039B)

SAMSUNG

one vowel,
one consonant,
one number



$$R_{\mu\nu} - \frac{1}{2} R\, g_{\mu\nu} + \Lambda\, g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

$\varrho_{vac} = \Lambda/8\pi \quad \sim 10^{-29}\ \mathrm{g/cm^3}$

$t_{pl} = (Gh/2\pi c^5)^{1/2} = 5.4 \times 10^{-44}\,\mathrm{s}$

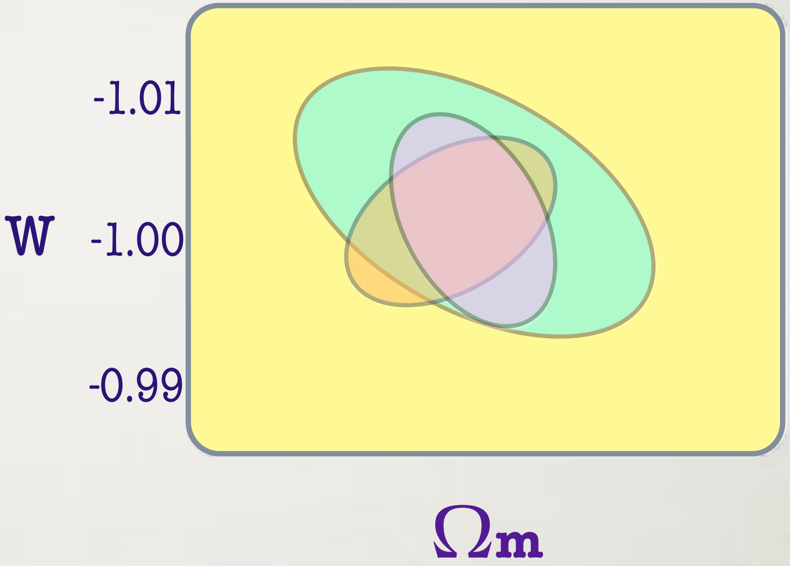
$t_U \sim 8 \times 10^{60}$

$\Lambda \sim t^{-2} \sim 10^{-122}$

Possible outcomes.....

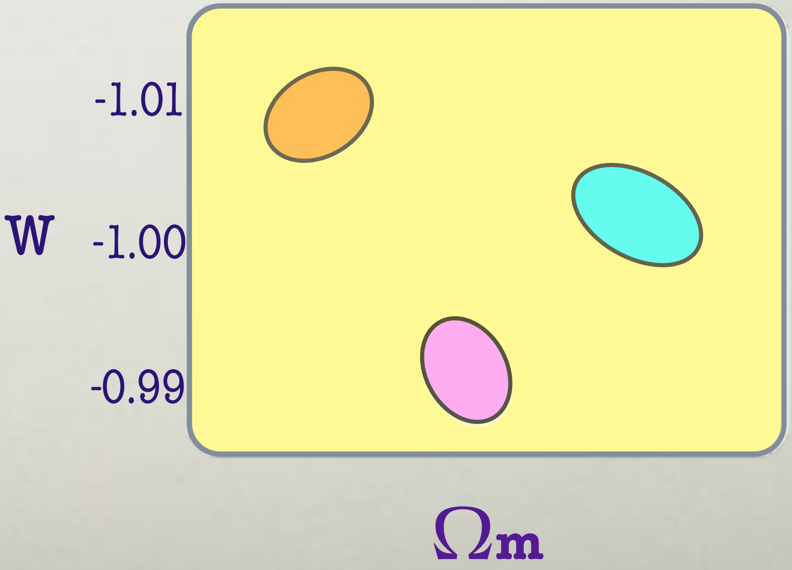
Different probes

Quite useful but
a bit dull....



Λ=const

Much more
interesting!!



?!?!?

An amusing connection with a bunch of visionaries ahead of us….

The Universe must be

RICOSTRUZIONE FUTURISTA DELL'UNIVERSO

LA BALZA

La costruzione materiale del complesso plastico

Balla and Depero
11 March 1915

9/12 well predicted…
notice: no mention
of any constant!

- Abstract 😳
- Dynamical (relative and absolute motion) 😊
- Extremely transparent 😊
- Colorful 😊
- Extremely luminous 😊
- Self sustaining 😊
- Transforming 😊
- Dramatic 😊
- Ephemeral 😳
- Fragrant 😳
- Noisy 😊
- **Exploding** **[!!!!!!]** 😊

An amusing connection with a bunch of visionaries ahead of us….


ITALIAN FUTURISM
1909–1944
RECONSTRUCTING THE UNIVERSE

One hundred years later… from art (vision) to science (numbers)

Euclid Futurism 2020-2030

Measuring the Universe