The MICE simulations for cosmological surveys: DES, PAU, DESI & Euclid

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on behalf of many collaborators

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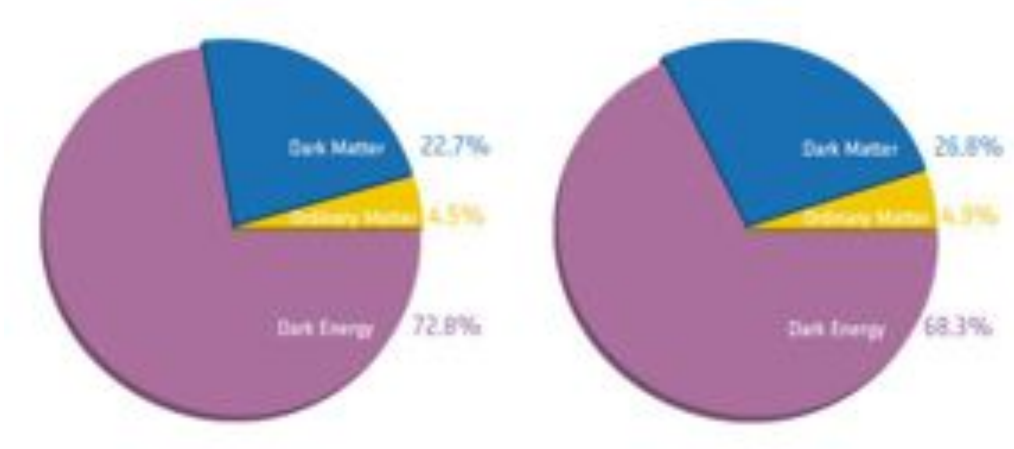
Questions in Cosmology

- What is the physical cause of cosmic acceleration?
  - Dark Energy or modification of General Relativity?
    - If Dark Energy, is it Λ (the vacuum) or something else?
      - What is the DE equation of state parameter *w*?



Before Planck　　　　After Planck

Probing Cosmology

- Cosmology is probed mainly measuring the expansion rate of the universe H(z), the rate growth of structure g(z)

$$H^2(z) = H^2_0 \; [\; \Omega_M (1+z)^{3} + \Omega_R (1+z)^{4} + \Omega_K (1+z)^{2} + \Omega_{DE} (1+z)^{3(1+w)} \;]$$

matter radiation curvature dark energy

g(z) a function of cosmological parameters

Probing Cosmology

- Geometric test: integrals over H(z):

Comoving distance		$r(z) = \int dz/H(z)$
Standard Candles	Supernovae	$D_L(z) = (1+z)\, r(z)$
Standard Rulers	Baryon Oscillations	$D_A(z) = (1+z)^{-1}\, r(z)$
Standard Population	Clusters	$dV/dz d\Omega = r^2(z)/H(z)$

- Growth of Structure test: g(z)

Clusters, Weak lensing, clustering, redshift space distortions

- Matter distribution: P(k,z) and higher orders

Galaxy clustering

Dark Energy Task Force

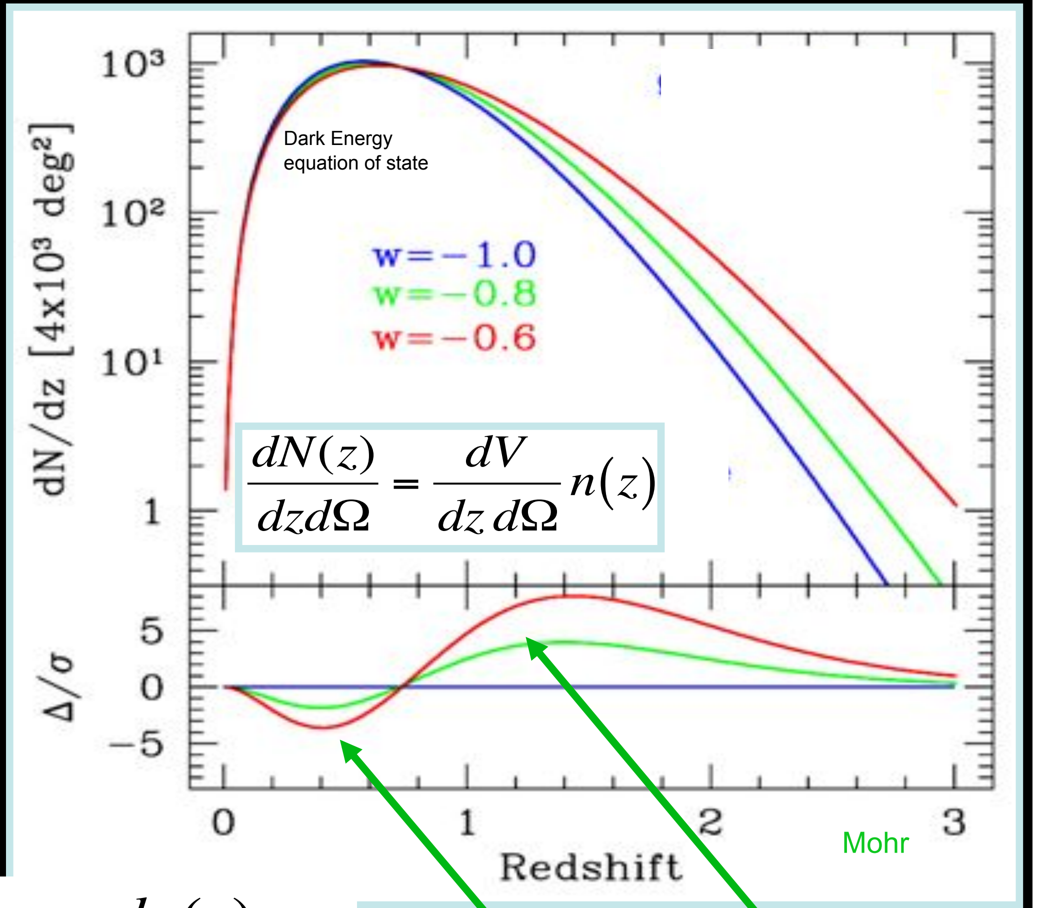
Best observational probes

- Weak lensing (geometrical & growth)
- Baryon acoustic oscillations (geometrical)
- Supernovae (geometrical)
- Clusters of galaxies (growth & geometrical)

I. Clusters

- Elements of the Method:
  - Abundance tracers: measure evolution of density: numbers (growth) / volume (geometry)
  - Clusters are proxies for massive halos whose abundance evolution is sensitive to cosmology
  - Can be detected relatively easy and their z can be estimated (e.g., colours)
  - Observable proxies for cluster mass: optical richness (optical), SZ flux decrement (radio), weak lensing mass (optical), X-ray flux (x-rays)
  - Cluster spatial correlations help calibrate mass estimates

Number of clusters above mass threshold

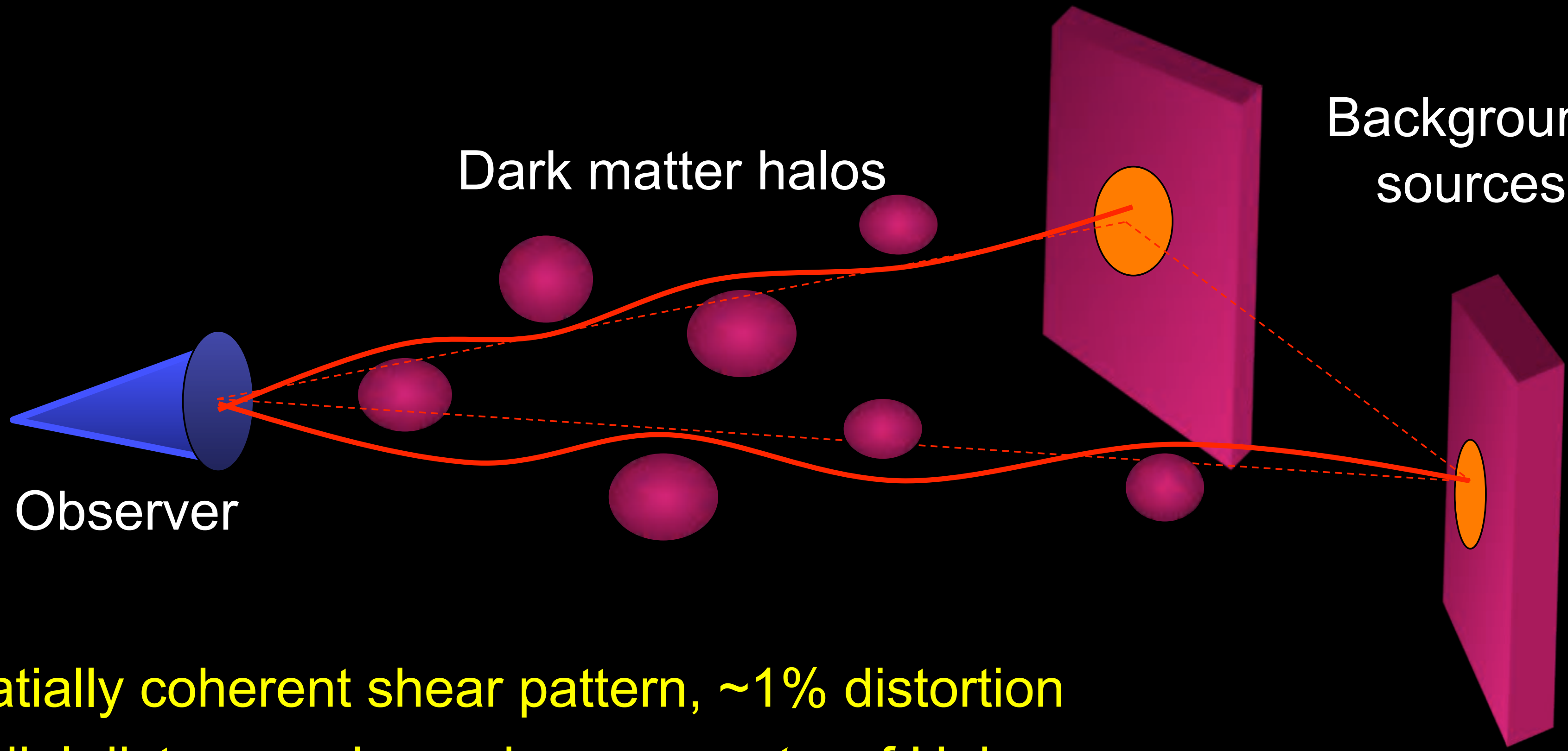


Volume

Growth

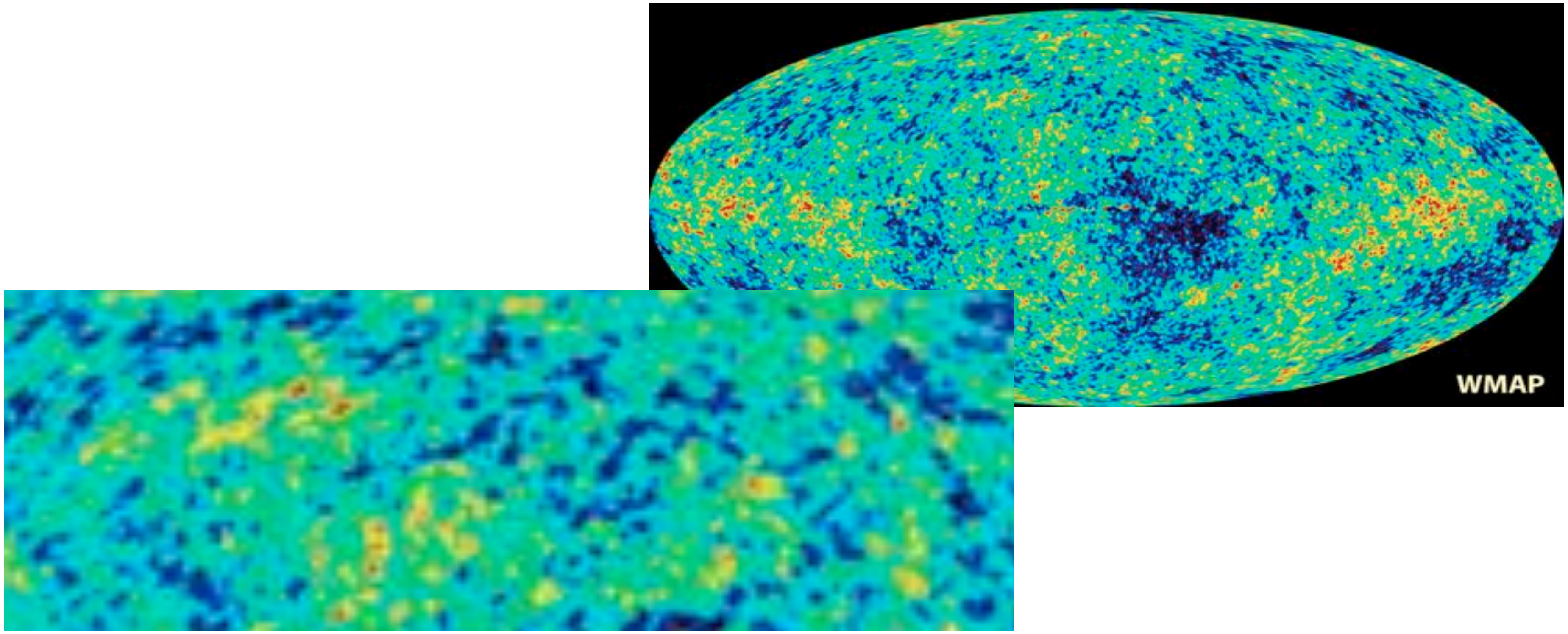
$$\frac{d^2N}{dz d\Omega} = \frac{r^2(z)}{H(z)} \int f(O,z) dO \int p(O \mid M,z) \frac{dn(z)}{dM} dM$$

II. Weak Lensing: Cosmic Shear



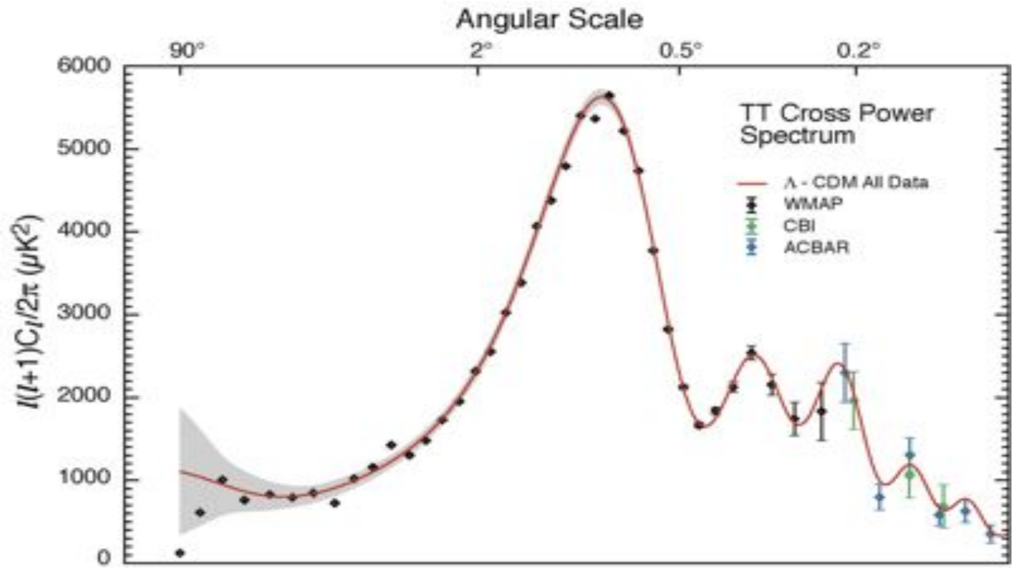
- Spatially coherent shear pattern, ~1% distortion
- Radial distances depend on *geometry* of Universe
- Foreground mass distribution depends on *growth* of structure

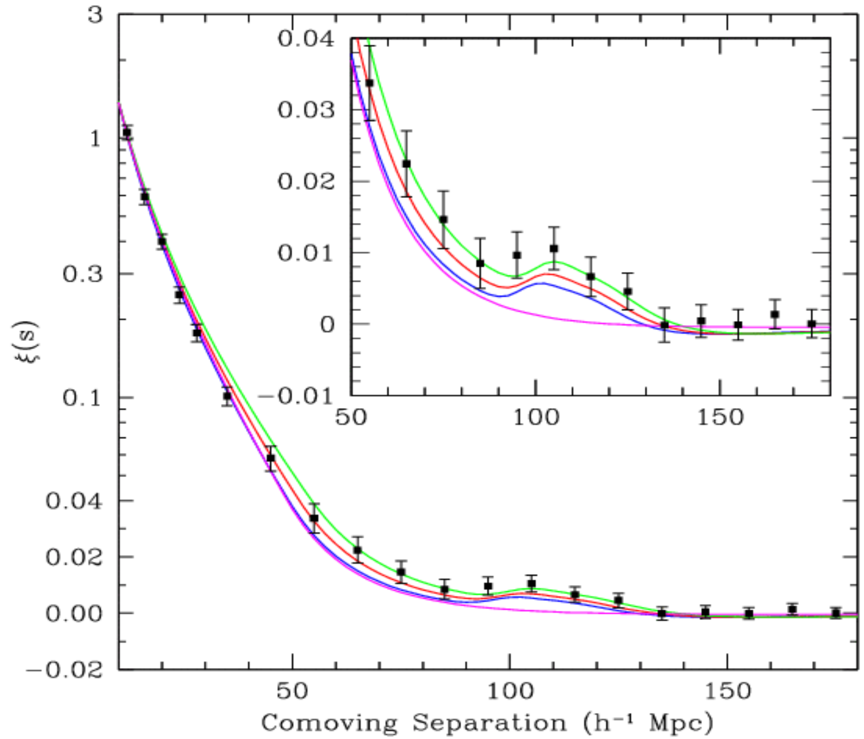
Baryon Acoustic Oscillations (BAO) in the CMB



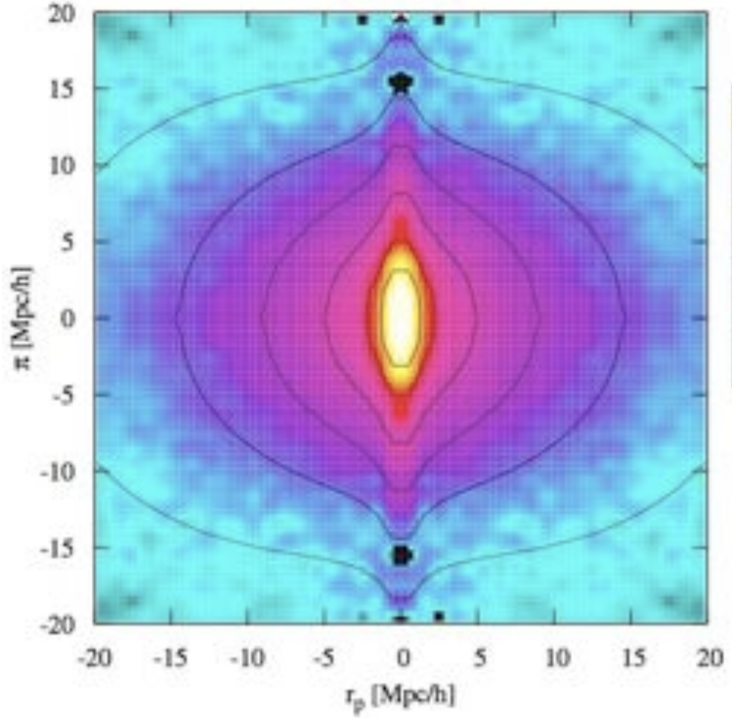
- Characteristic angular scale set by sound horizon at recombination: standard ruler (geometric probe).

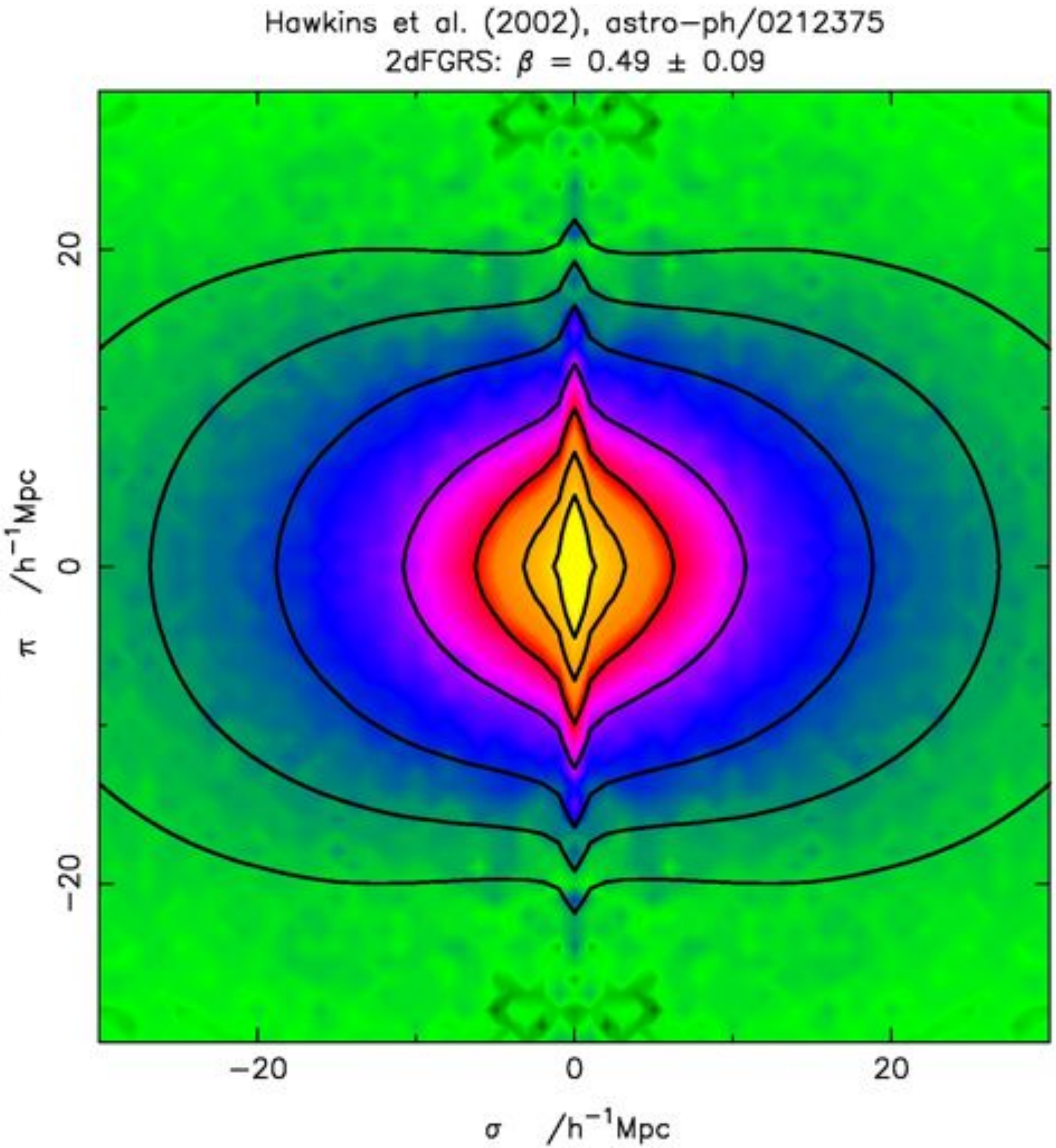
Baryon Acoustic Oscillations: CMB & Galaxies





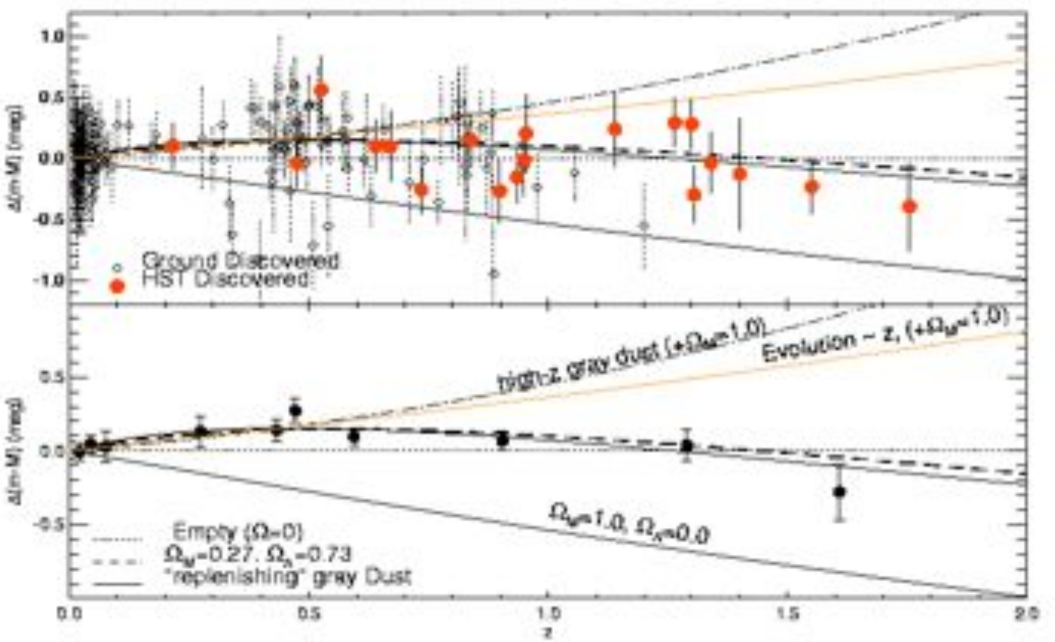
Redshift Space Distortions





Supernovae

- Measure luminosity distance
- Geometric Probe of Dark Energy



Requirements for cosmology survey

- sample large volumes
- sample enough (many) tracers
- measure distances
- measure shapes
- time sampling

Dark Energy Task Force

Survey design optmization: Figure of Merit

- Inverse of the marginalized errors
- Higher FoM => smaller errors
- Fisher matrices approach

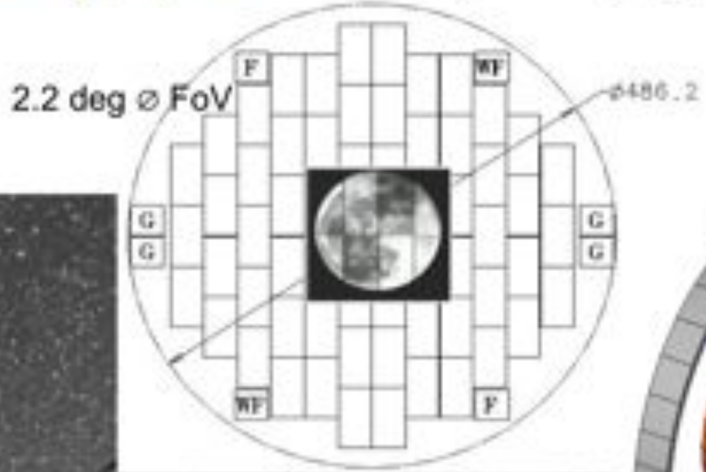
Observational surveys

- Imaging => DES
- Photo-z survey => PAU
- Spectroscopy => DESI
- Space => Euclid

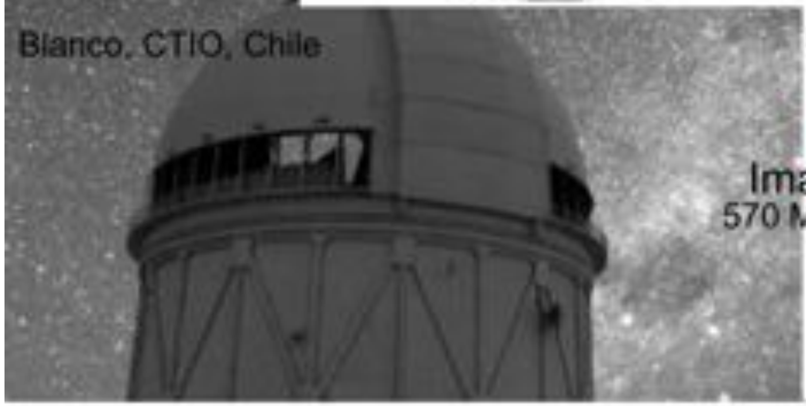
DES: Dark Energy Survey

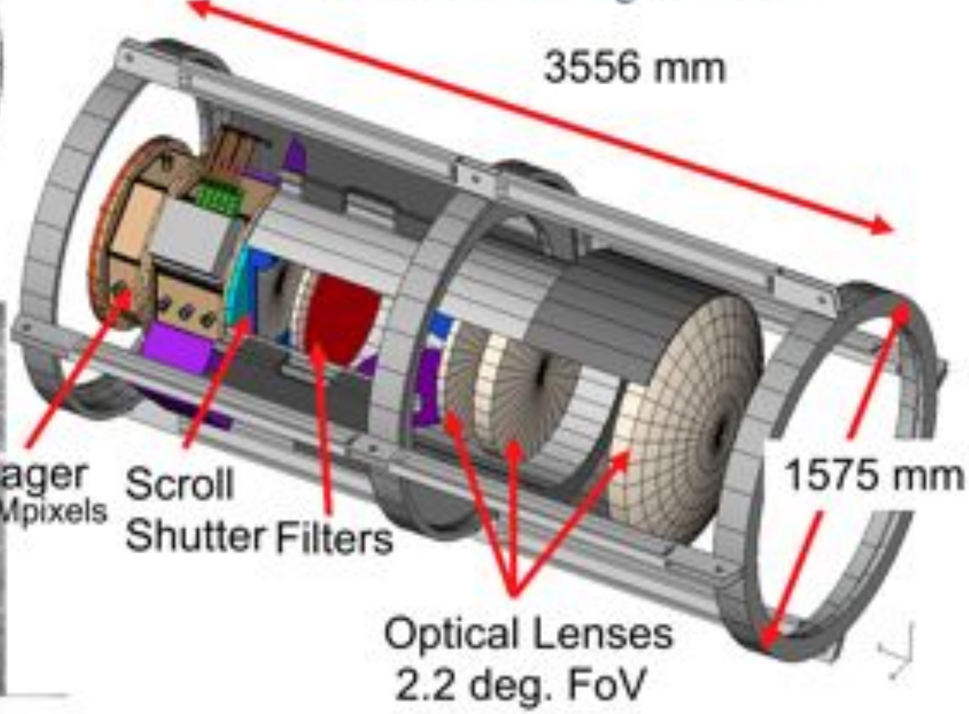
DARK ENERGY SURVEY

- 5000 deg^2 galaxy survey to $i_{AB} < 24$ in grizY. 300M galaxies up to $z < 1.4$. Also 4000 SNe.
- Involves groups in USA (led by FNAL), Spain, UK, Brazil, Germany, Switzerland.



- 525 nights in 5 years
- Started on Aug 31st 2013





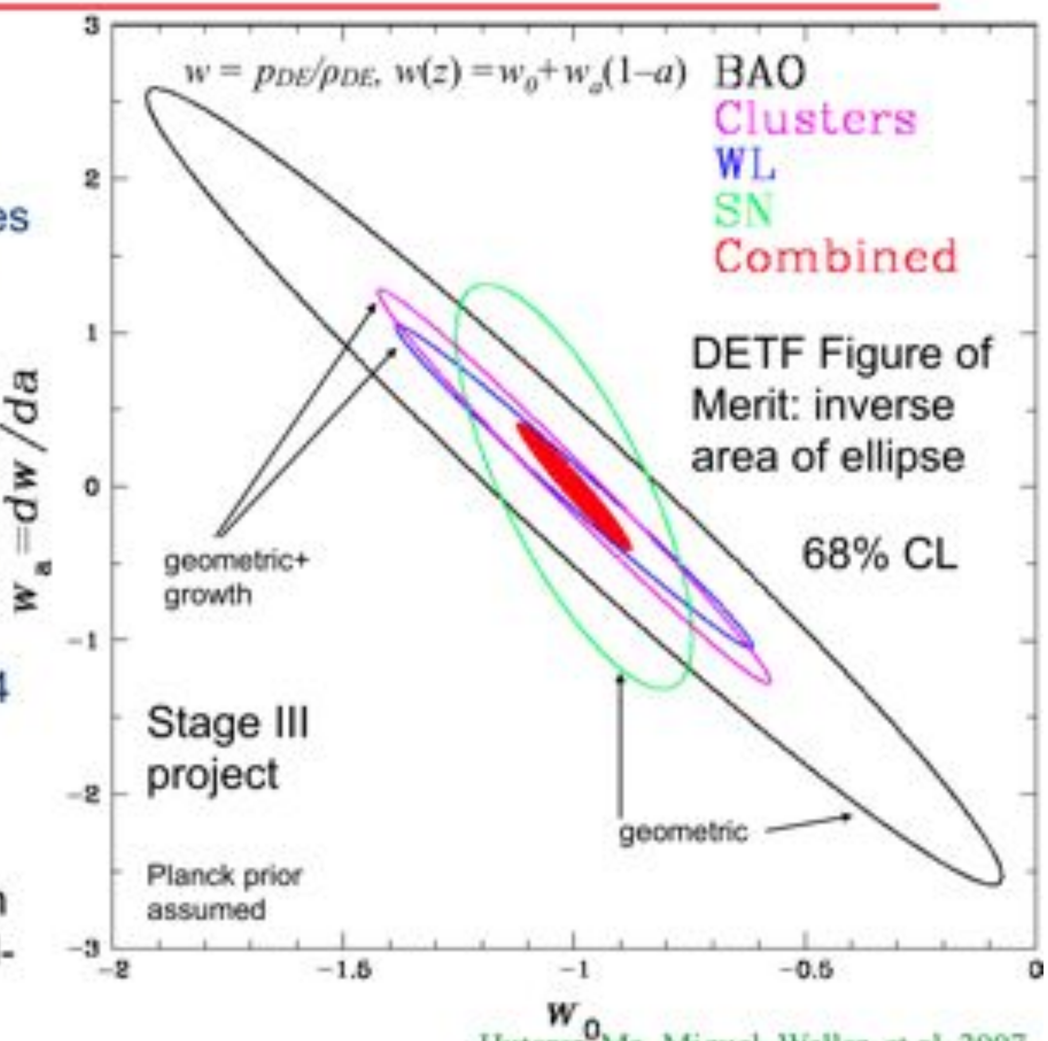
DES Science Program

DARK ENERGY SURVEY

Four Probes of Dark Energy

- Galaxy cluster counting: N(M,z)
    - Measure redshifts and masses
    - ~10,000 clusters to z>1 with $M > 2 \times 10^{14}\ M_{\odot}$
- Weak lensing (shear)
    - >200 million galaxies with shape measurements to z>1
- Large-scale structure (LSS). Includes BAO
    - ~300 million galaxies to z<1.4
- Supernovae
    - ~4000 type-Ia SNe to z>1

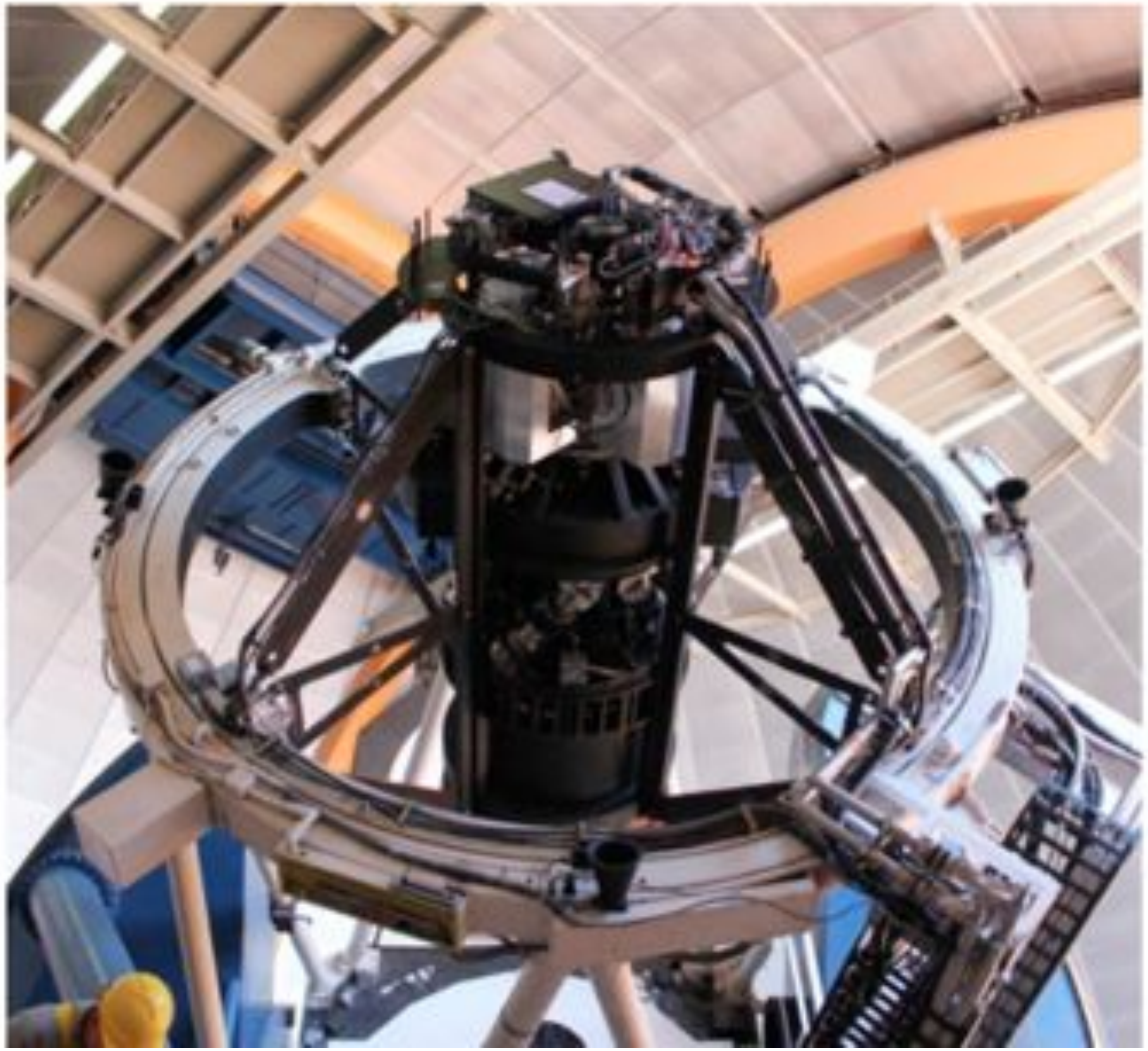
Probes are complementary in both systematic error and cosmological-parameter degeneracies



Huterer, Ma, Miquel, Weller, et al. 2007

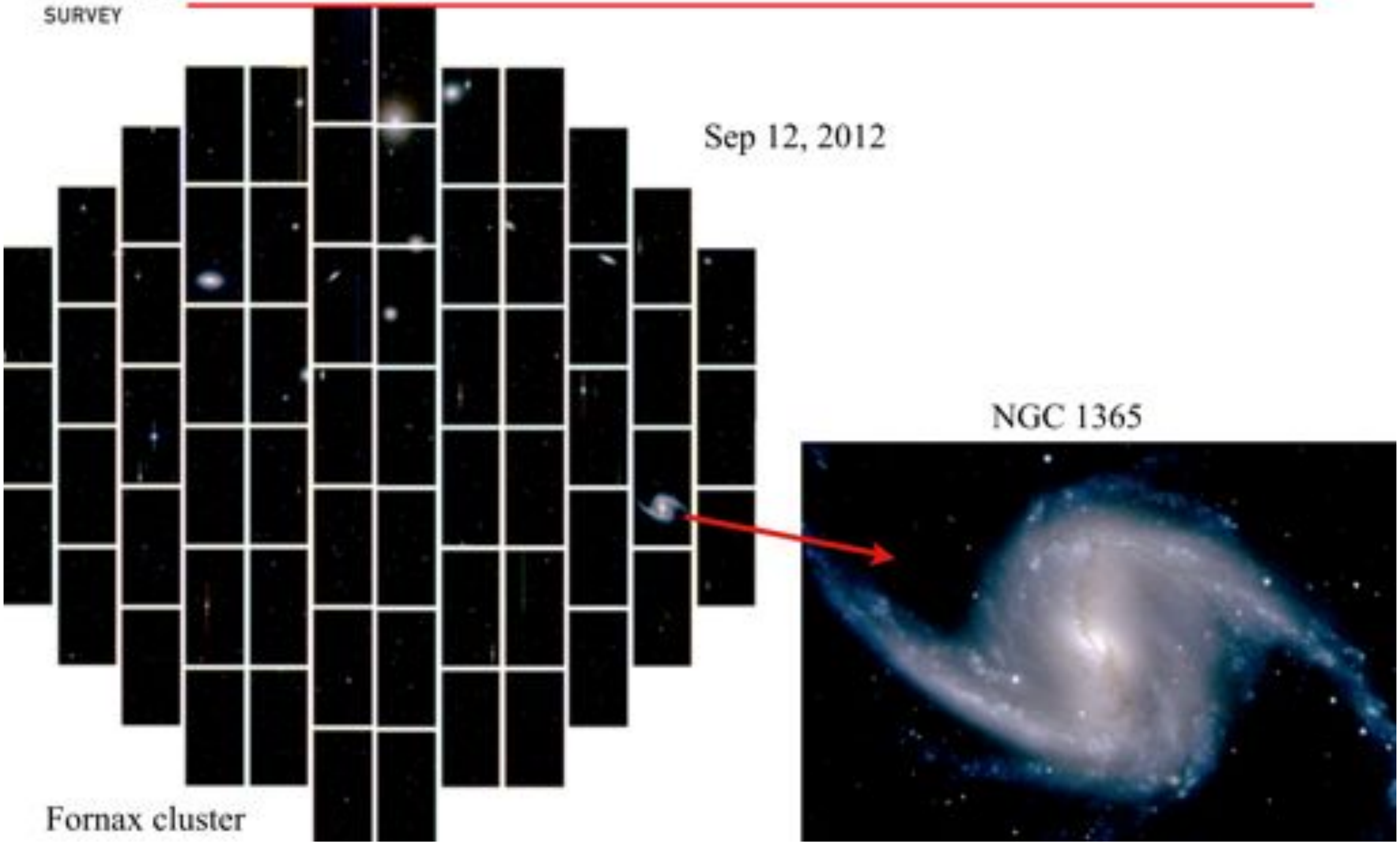
DECam on the Blanco (Sep '12)

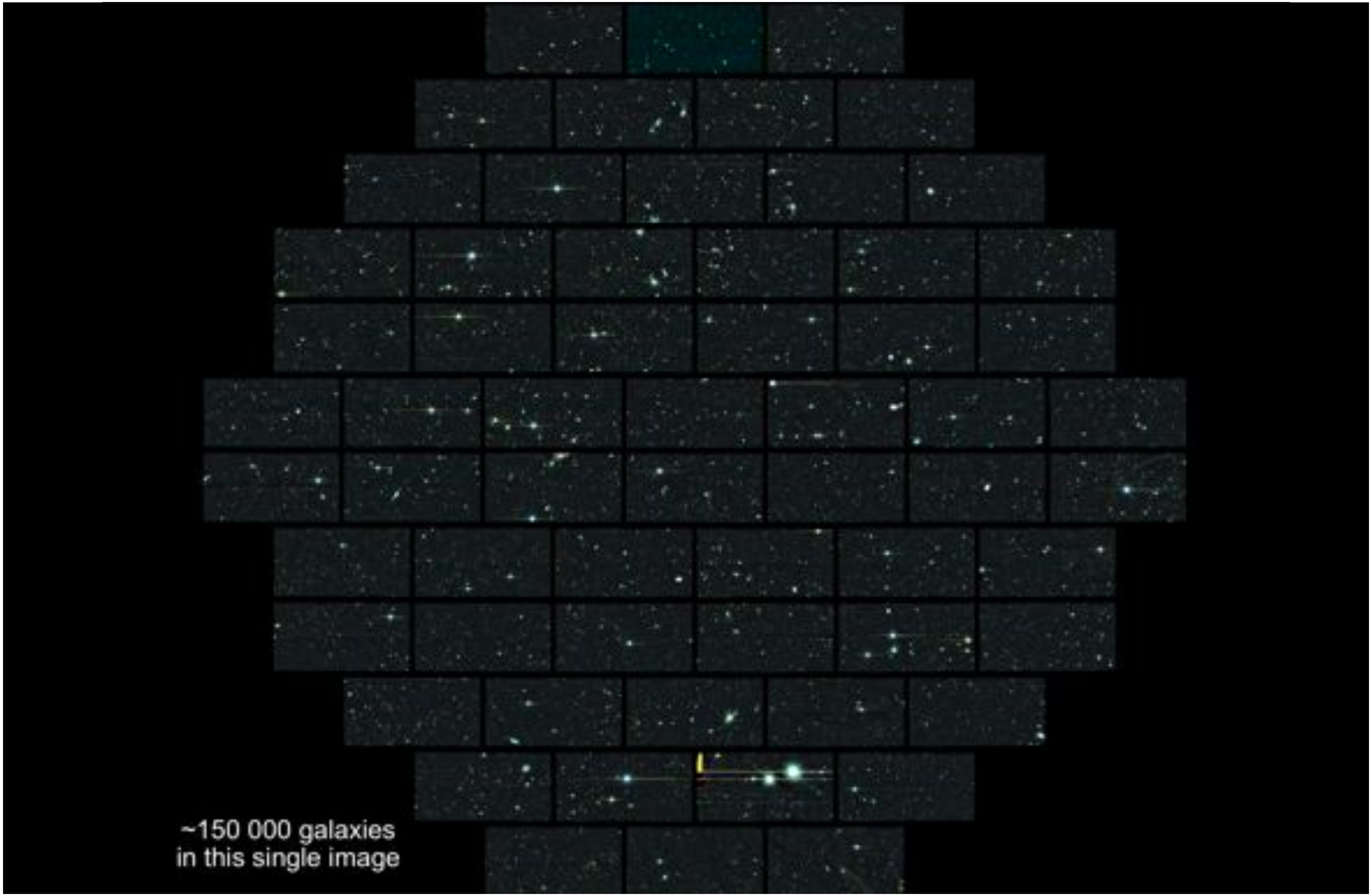
DARK ENERGY SURVEY



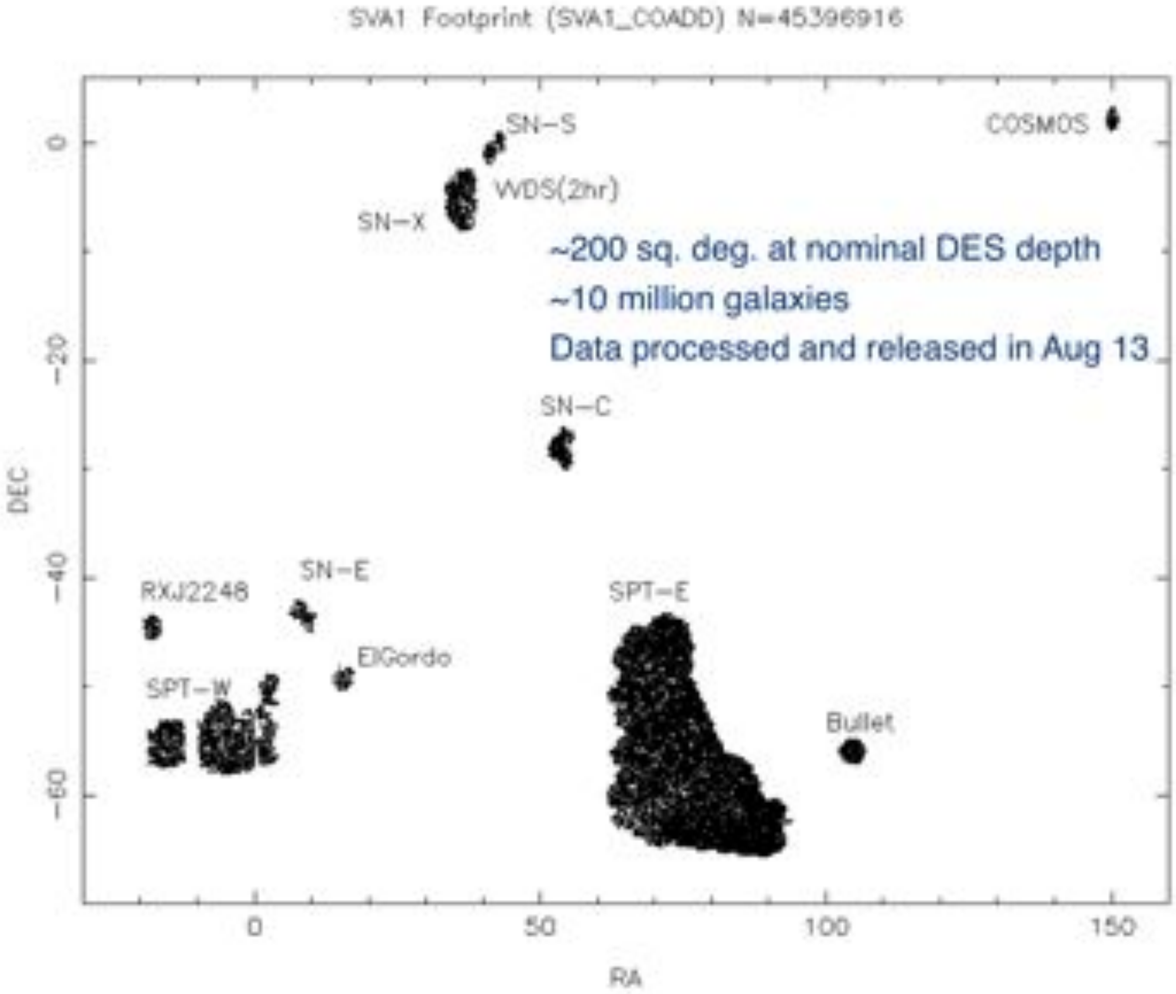
DARK ENERGY SURVEY

First DECam Image




~150 000 galaxies
in this single image

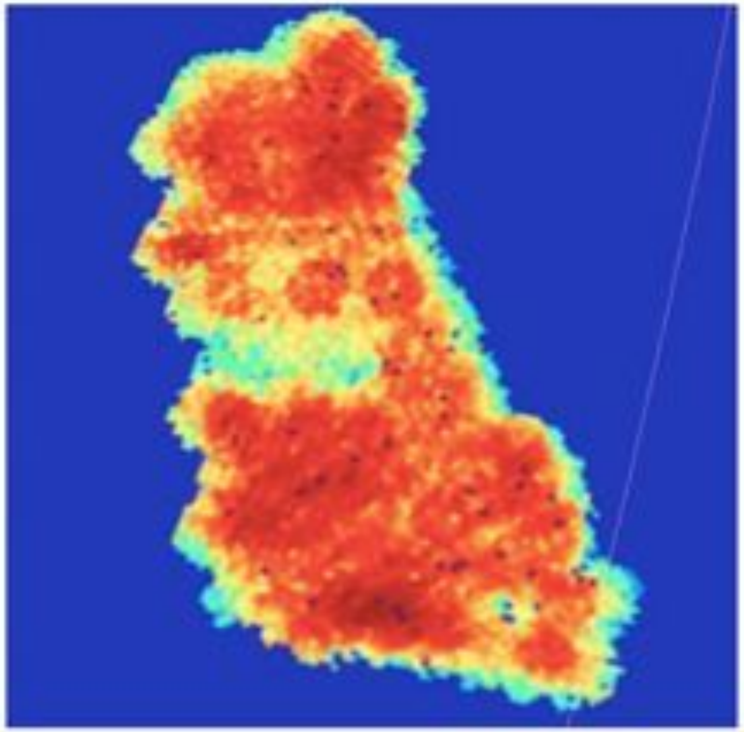
Science Verification (SV): Nov 12 - Feb 13



SV Data Analysis. Pre-requisites

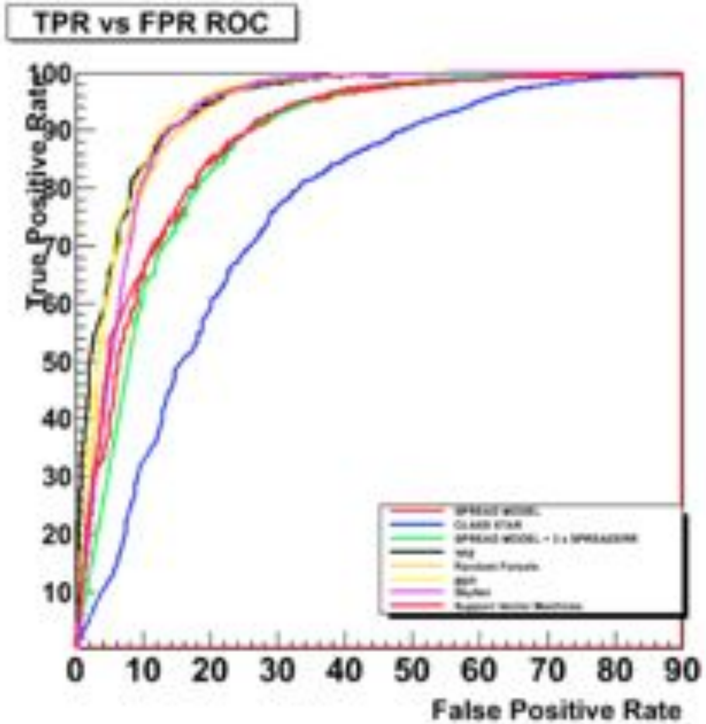
DARK ENERGY SURVEY

Mask: knowledge of the depth of the survey at each point in the footprint



i-band mask for the SPT-E area

Star / galaxy separation: main source of contamination



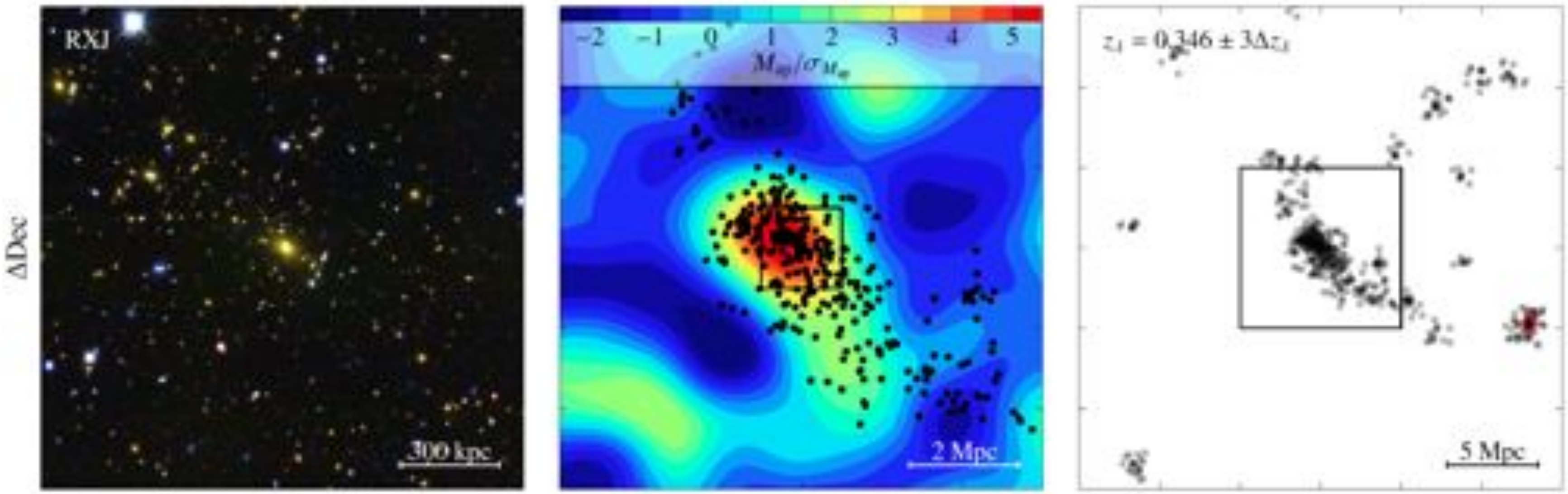
Eff. vs. bgnd. for several methods of s/g sep.

DES/Spain heavily involved in (or leading) these crucial efforts

First DES Paper Out on May 16th

DARK ENERGY SURVEY

P. Melchior et al. **Mass and galaxy distributions of four massive galaxy clusters from Dark Energy Survey Science Verification data**



First DES Paper Out on May 16th

DARK ENERGY SURVEY

P. Melchior et al. **Mass and galaxy distributions of four massive galaxy clusters from Dark Energy Survey Science Verification data**

Table 4. Weak lensing masses M_{200c} in units of $10^{14} M_\odot$ (with a flat prior on c_{200c}), redMaPPer richness λ and redshift estimate z_λ, and their statistical errors (see Section 3.2 and Section 5.1 for details). The literature mass estimates are derived from weak lensing, galaxy dynamics (D) or optical richness (R).

Cluster name	M_{200c}	λ	z_λ	Literature value M_{200c}
RXC J2248.7-4431	$17.6^{+4.5}_{-4.0}$	203 ± 5	0.346 ± 0.004	$22.8^{+6.6}_{-4.7}$ (Gruen et al. 2013b), 20.3 ± 6.7 (Umetsu et al. 2014), 16.6 ± 1.7 (Merten et al. 2014)
1E 0657-56	$14.2^{+10.0}_{-6.1}$	277 ± 6	0.304 ± 0.004	17.5 (Clowe et al. 2004)[1], 12.4 (Barrena et al. 2002, D)
SCSO J233227-535827	$10.0^{+3.7}_{-3.4}$	77 ± 4	0.391 ± 0.008	$11.2^{+3.0}_{-2.7}$ (Gruen et al. 2013a), $4.9 \pm 3.3 \pm 1.4$ (High et al. 2010, R)
Abell 3261	$8.6^{+8.6}_{-3.9}$	71 ± 3	0.216 ± 0.003	—

[1] We converted the measured r_{200c} from Clowe et al. (2004), which lacks an error estimate, to M_{200c} using the critical density in our adopted cosmology.

This paper proves that DES can measure galaxy shapes, even in the Science Verification preliminary data set.

Photometric redshift analysis in the Dark Energy Survey Science Verification data

C. Sánchez[1,*], M. Carrasco Kind[2], H. Lin[3], R. Miquel[1,4], F. Abdalla[5], A. Amara[6], M. Banerji[5], C. Bonnett[1], R. Brunner[2], A. Carnero[7,8], F. J. Castander[9], L. A. N. da Costa[7,8], C. Cunha[10], A. Fausti[8], D. Gerdes[11], N. Greisel[12,13], J. Gschwend[7], W. Hartley[6,14], S. Jouvel[5], O. Lahav[5], M. Lima[15,8], M. A. G. Maia[7,8], P. Martí[1], R. L. C. Ogando[7,8], F. Ostrovski[7,8], P. Pellegrini[7], M. M. Rau[12,13], I. Sadeh[5], S. Seitz[12,13], N. Sevilla[16], A. Sypniewski[11], J. de Vicente[16] + *builders*

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21 May 2014

ABSTRACT

We present results from a study of the photometric redshift performance of the Dark Energy Survey (DES), using the early data from a Science Verification (SV) period of observations in late 2012 and early 2013 that provided science-quality images for almost 200 sq. deg. at the nominal depth of the survey. We assess the photometric redshift performance using about 15000 galaxies with spectroscopic redshifts available from other surveys. These galaxies are used, in different configurations, as a calibration sample, and photo-z's are obtained and studied using most existing photo-z codes. A weighting method in a multi-dimensional color-magnitude space is applied to the spectroscopic sample in order to evaluate the photo-z performance with sets that mimic the full DES photometric sample, which is on average significantly deeper than the calibration sample, due to the limited depth of spectroscopic surveys. Empirical photo-z methods using, for instance, Artificial Neural Networks or Random Forests, yield the best performance in the tests, achieving core photo-z resolutions $\sigma_{68} \sim 0.08$. Moreover, the results from most of the codes, including template fitting methods, comfortably meet the DES requirements on photo-z performance, therefore, providing an excellent precedent for future DES data sets.

Other SV Analyses in the Pipeline

DARK ENERGY SURVEY

Galaxy Clustering and validation against CFHTLS

DES SV Galaxies cross-correlated with CMB lensing

SPT-SZE signature of DES SV RedMaPPer clusters

Joint Optical and Near Infrared Photometry from DES and VHS

Galaxy Populations within SPT Selected Clusters

DES/XCS: X-ray properties of galaxy clusters in DES SV

The Dark Energy Survey SV Shear Catalogue: Pipeline and tests

Calibrated Ultra Fast Image Simulations for the Dark Energy Survey

DES13S2cmm: The first Super-luminous Supernova from DES

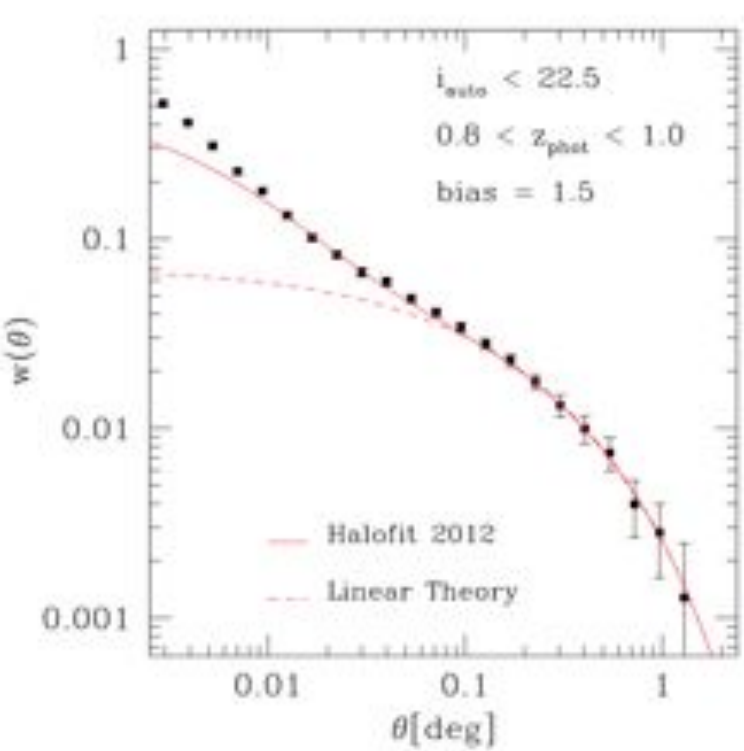
The Dark Energy Survey Supernova Survey: Search Strategy and Algorithm

Wide-Field Mass Mapping with the DES SVA1 data

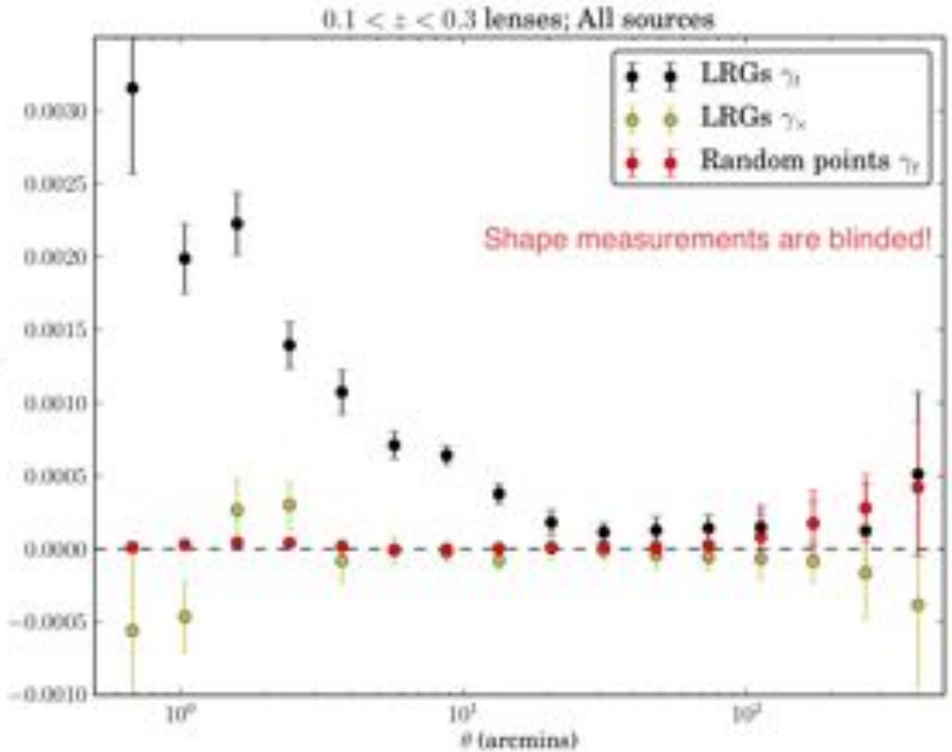
SV Data Analyses

DARK ENERGY SURVEY

LSS: Galaxy-galaxy correlations



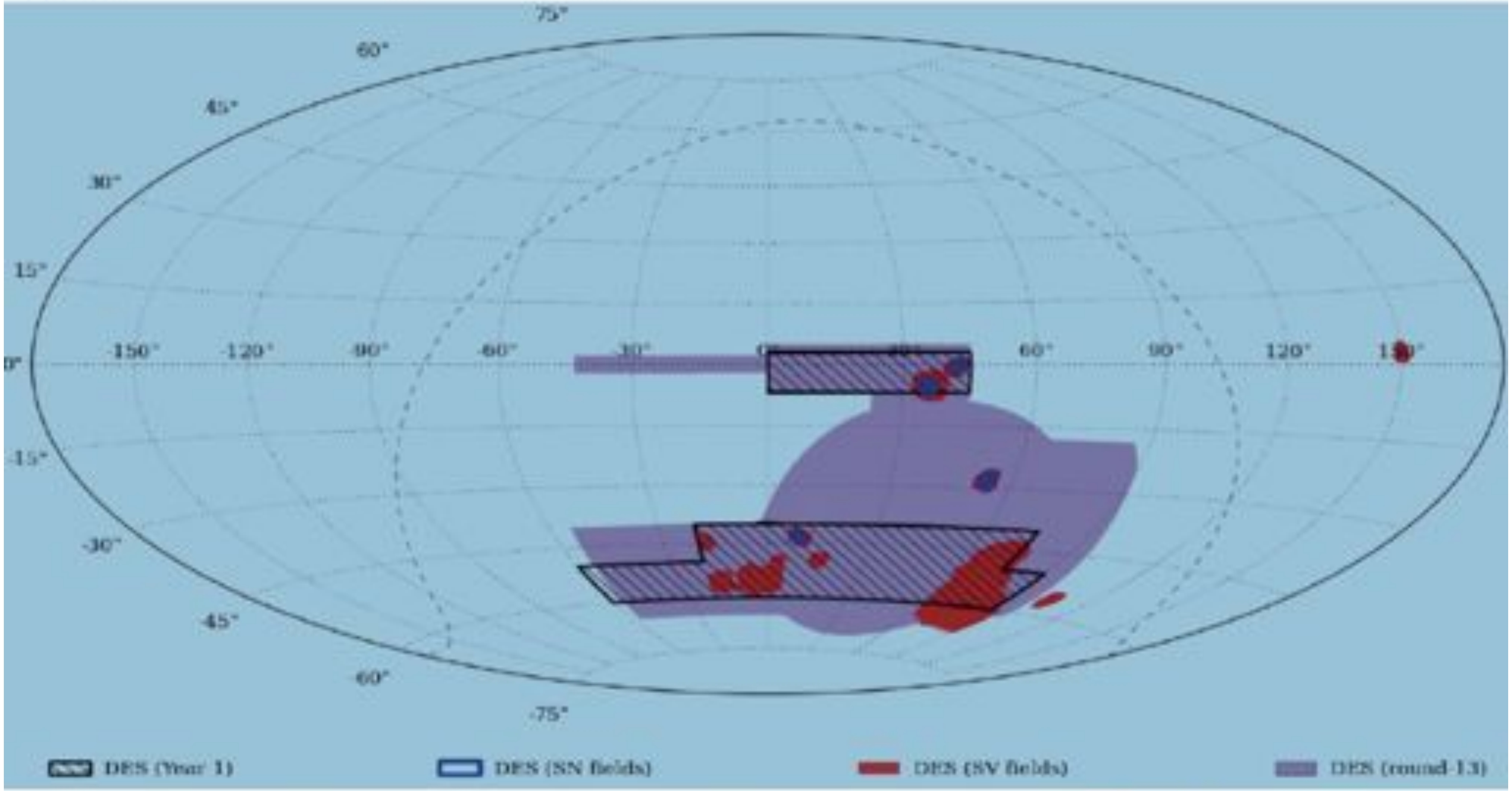
Weak lensing: Galaxy-shear correlations



Analyses on LSS and on WL+LSS combination in DES-SV are led by DES/Spain scientists

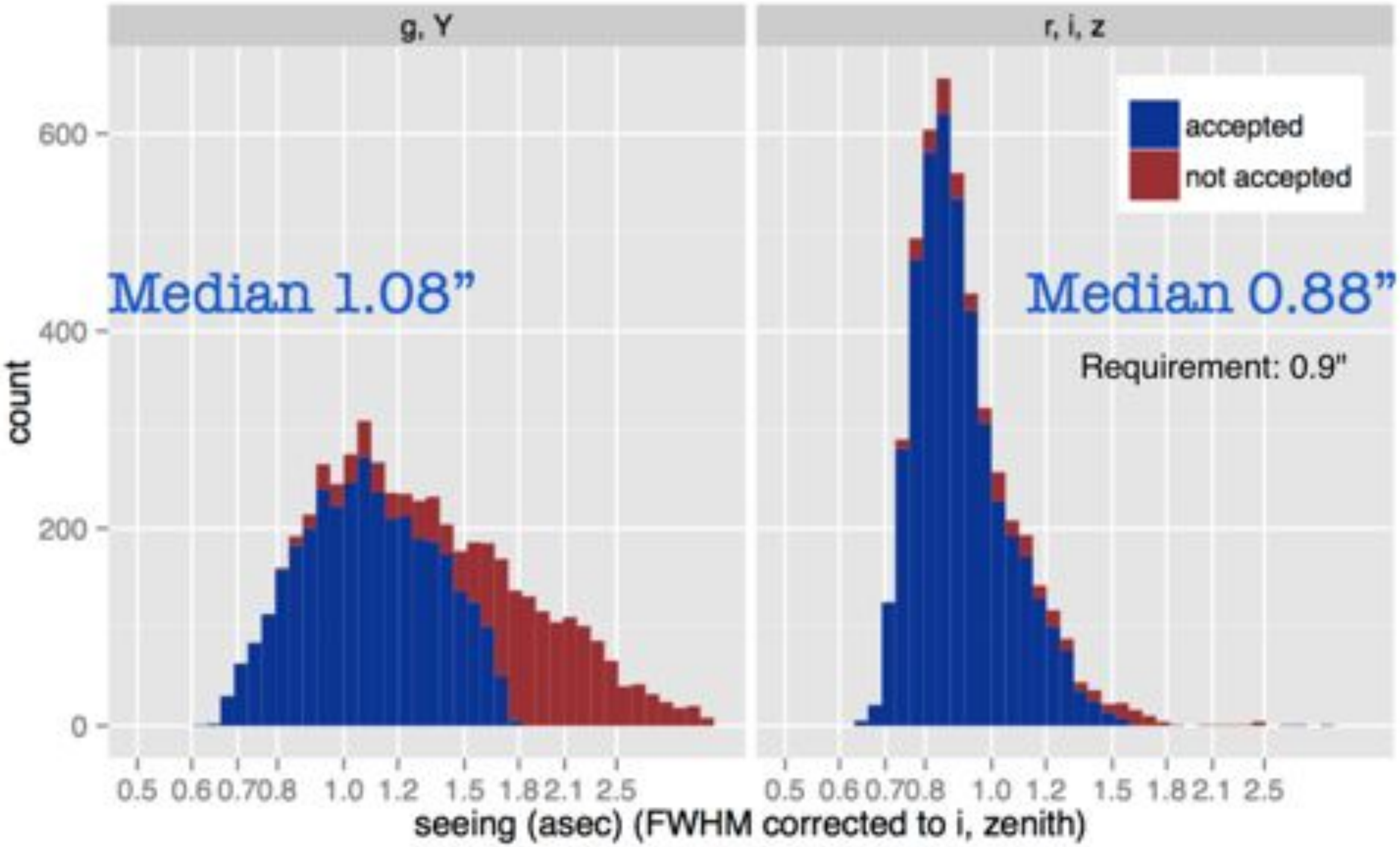
DARK ENERGY SURVEY

Year 1 of 5 (Sep '13 - Feb '14)

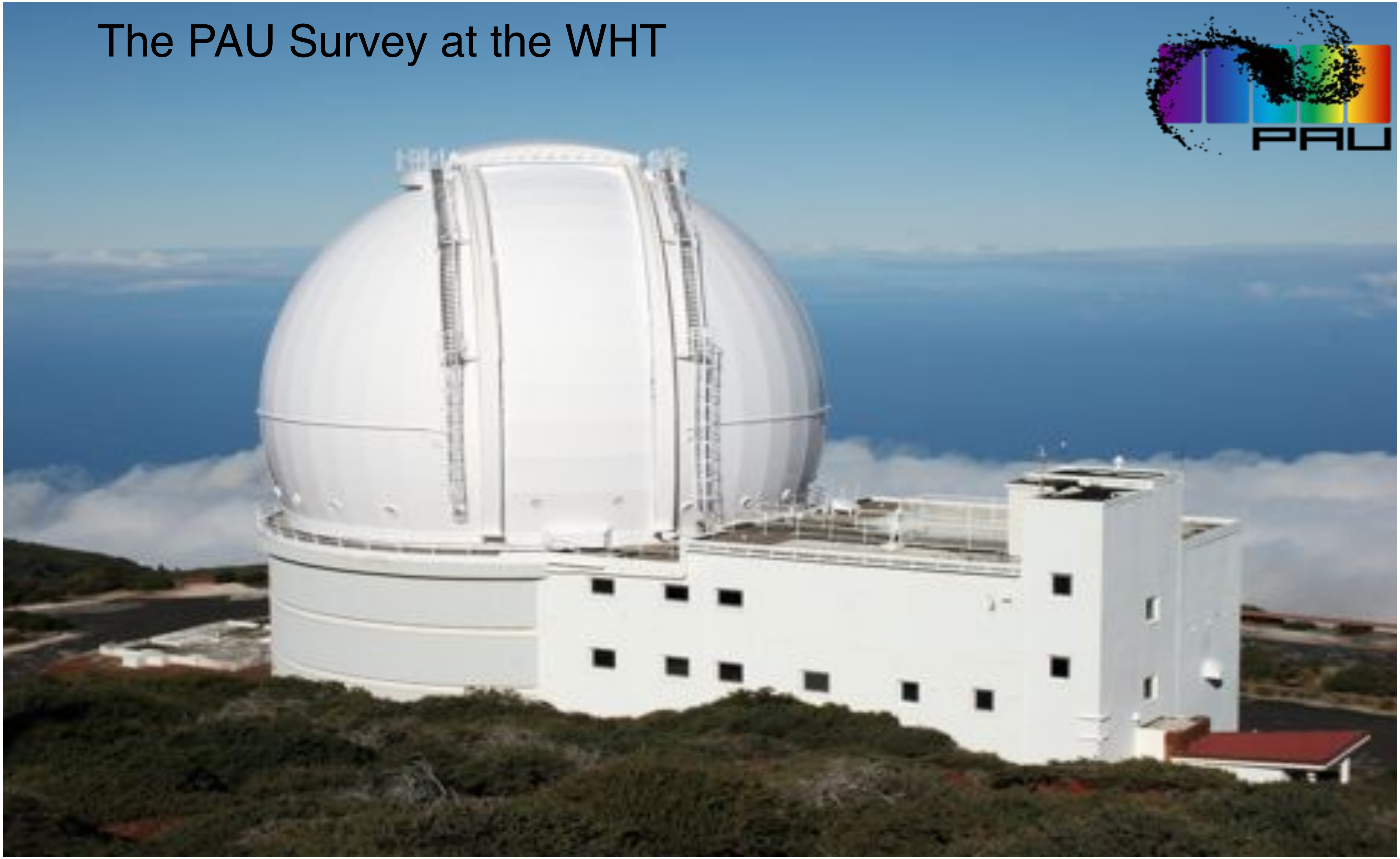


2000+ sq. deg., 4 tilings grizY + SN fields   Data being processed

PSF FWHM for Y1 Data



The PAU Survey at the WHT



Main ideas:

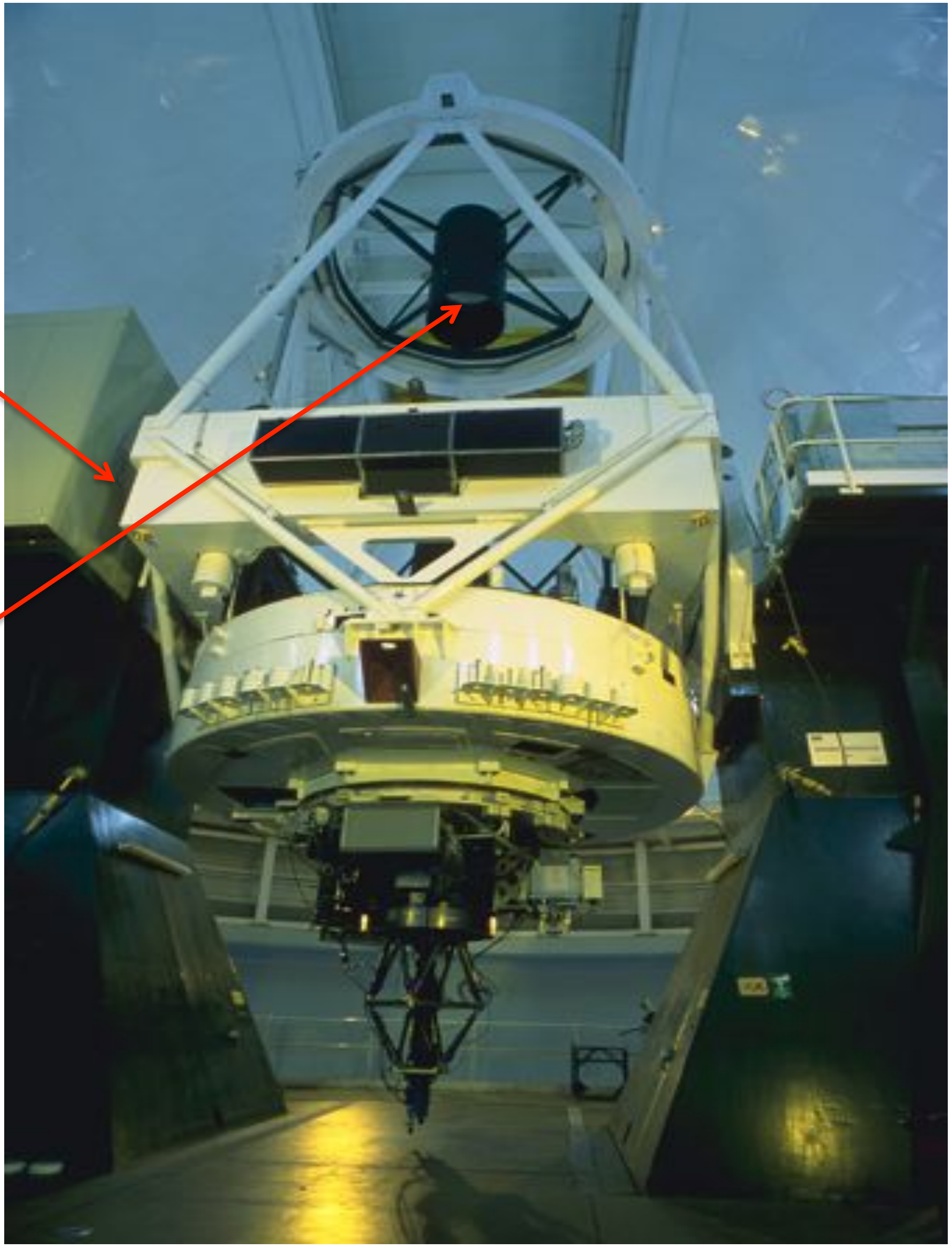
- To prepare for conducting a large photometric red-shift survey.
- Emphasis in measuring Dark Energy probes.
- To build an appropriate instrument with Consolider funds (PAUCam) for an appropriate telescope (several options).

PAUCam at WHT

WHT Telescope

- Diameter: 4.2 m
- Prime focus: 11.73 m
- Focal ratio: f/2.8
- FoV: 1 deg ∅, 40' unvignetted
- Scale: 17.58''/mm ⇔ 0.26''/pixel

PAUCam will be mounted at the prime focus:



Strong limitation in the weight: **max. 235 kg**.

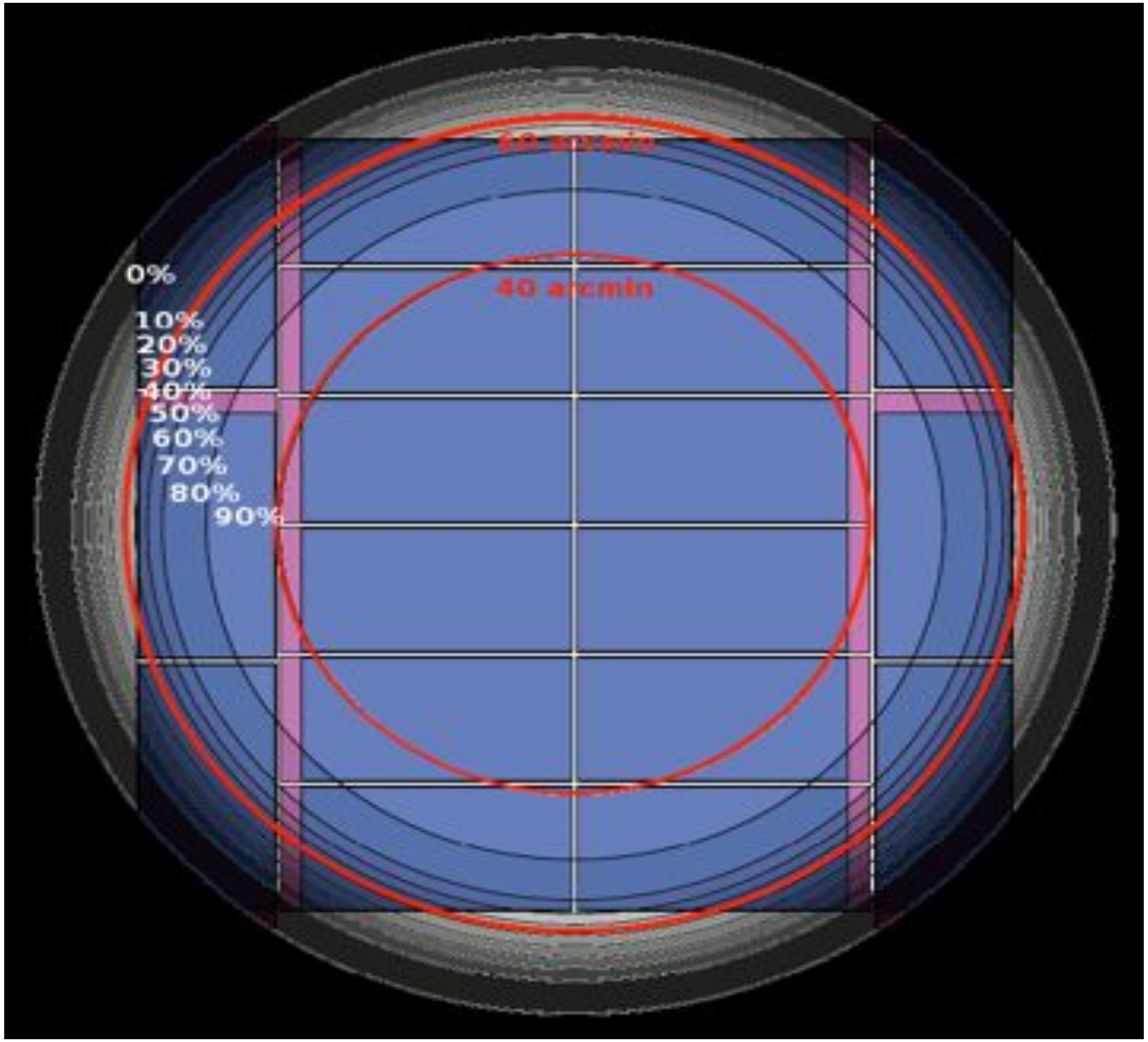
PAUCam focal plane

8 central CCDs with almost 100% exposure for imaging.

Rest of the CCDs:
2 for guiding
8 for additional photons

42 narrow band (10nm) filters covering the range ≈ 430-850 nm
6 BB filters u.g.r.i.z.Y.

Optimization: central CCDs will have 8 NB, others BB



PAU Survey Strategy

- Each central CCDs covers the whole survey area twice.

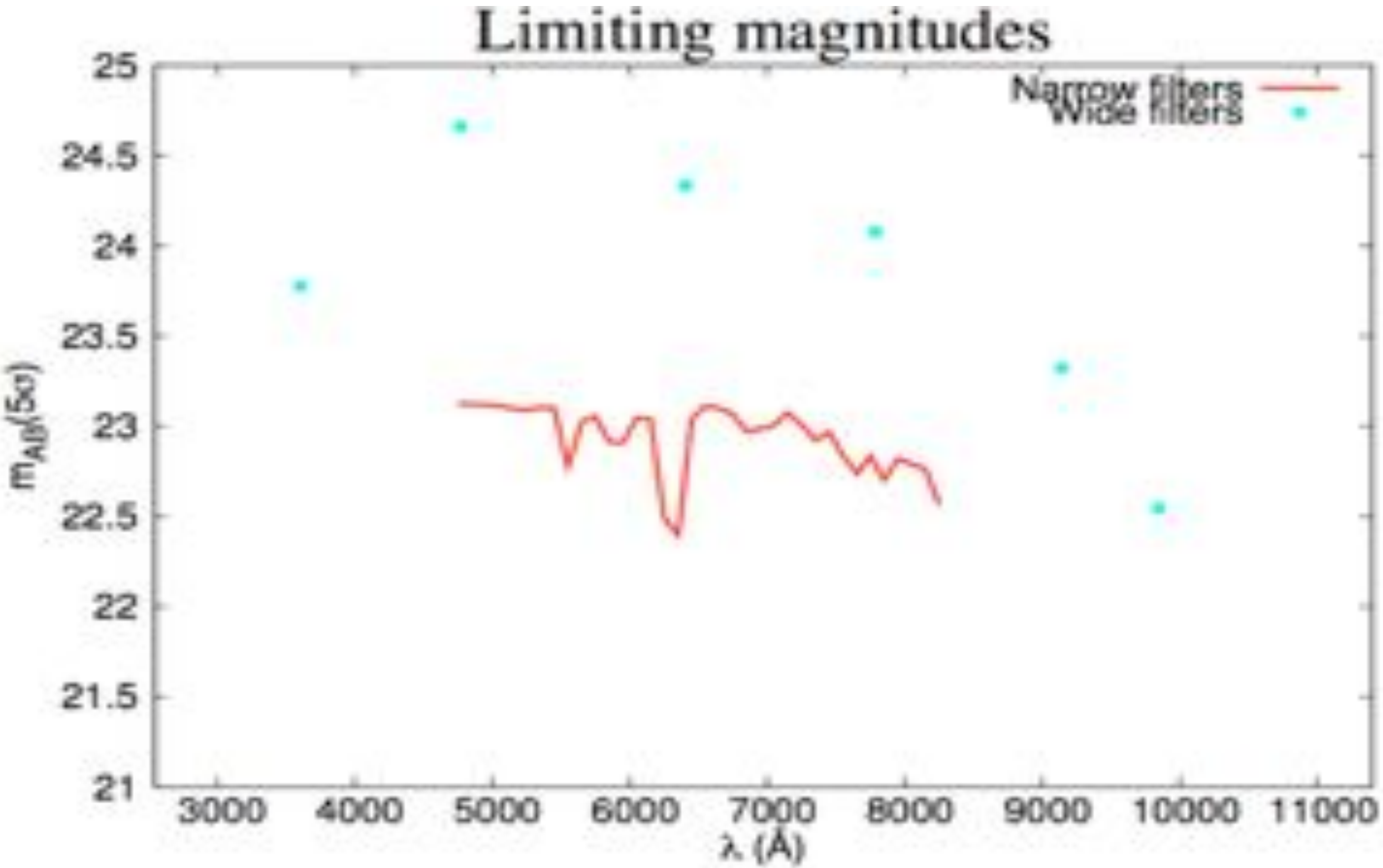
- Broad bands reach ≈1.4 magnitudes deeper than narrow bands.

- Objects detected in the BB, and flux obtained in the NB.

- Exposure times depend on tray: ≈ 100 s. for bluest, ≈250 s. for reddest.

- Surveying capability: sample 2 deg2 / night to $i_{AB} < 22.7$ magnitude in all NBs, and $i_{AB} < 24.1$ in all BBs ➜ 30000 galaxies, 5000 stars, 1000 quasars /night.

PAU Survey Strategy



PAUS (PAU-Survey) Scientific Goals

We expect to obtain ≈ 100 nights during the 4-year period 2014-2018. This implies ≈200 deg^2.

Scientific goals for PAU/WHT will focus on measuring

- Red-shift Space Distortions (RSD)
- Weak Lensing Magnification (MAG),

simultaneously over the same sky area, but by making use of two galaxy samples:

- A bright galaxy sample (B) ($i_{AB} < 22.5$) with high redshift resolution of $\sigma_z = 0.0035\ (1+z)$.
- A faint sample (F) $22.5 < i_{AB} < 24$ with $\sigma_z = 0.05\ (1+z)$.

PAUS (PAU-Survey) Scientific Goals

The scientific case, has been published in
(ref. E. Gaztañaga et al. 2012, MNRAS)

The paper explores several possibilities:

- B
- F
- F + B (different areas)
- F x B (same area) ← substantial improvement.

  B can be seen as a spectroscopic follow-up of a photo-z F sample.

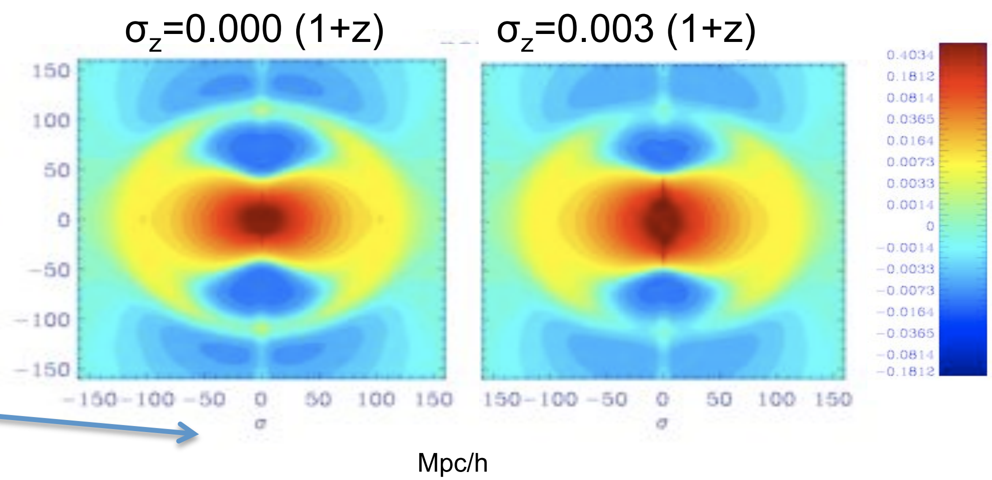
- **Weak-lensing magnification**
  - Lensing changes area of background image ➔ density fluctuations correlated with density fluctuations in the foreground lenses.
  - Very precise photo-z's in foreground lenses allow to perform galaxy-galaxy cross-correlations between well-defined and narrow redshift bins (bin width ≈ 4 times the resolution of the B sample; not critical).

• Red-shift Space Distortions.

- The Hubble relation between redshift and distance in the radial direction is modified by the peculiar velocity of galaxies.

- Large structures give rise to bulk motions which affect the z-r maps. Galaxies behind over-dense regions will appear nearer, while galaxies in front of dense regions will appear farther ➔ squashing of matter distribution in radial direction at large scales.

PAU photo-z resolution particularly well-suited for this measurement over bright sample.



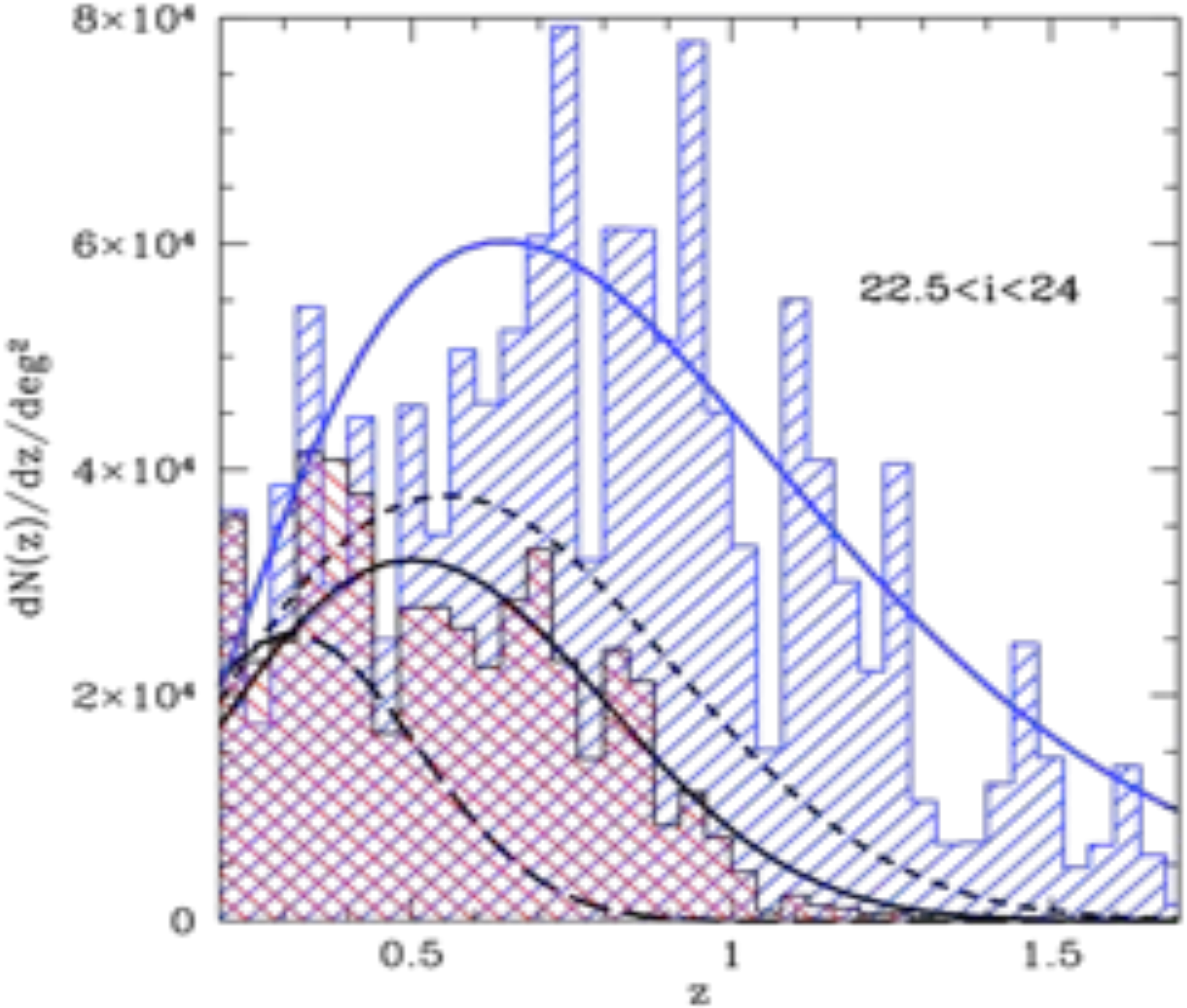
PAUS (PAU-Survey) Scientific Goals

dN(z)/dz /deg^2 for
FAINT (F) and
BRIGHT (B) samples.

6 x 10^6 B galaxies
2 x 10^6 F galaxies
(after 50% efficiency)

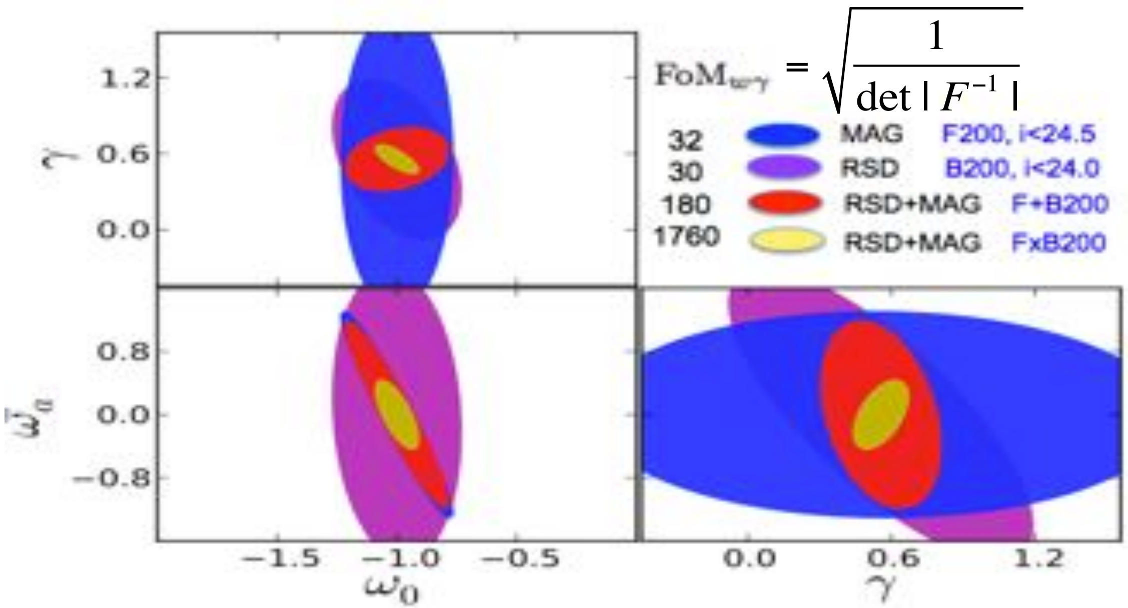
F → for W.L. MAG
and/or shear

B → for RSD



Effects (MAG and RSD) are sensitive to both the equation of state parameter, w = w0 + wa (1-a), and structure growth γ.

The combination of RSD and MAG in the same dataset is very powerful in breaking degeneracies between cosmological parameters
➔A unique advantage of PAU.

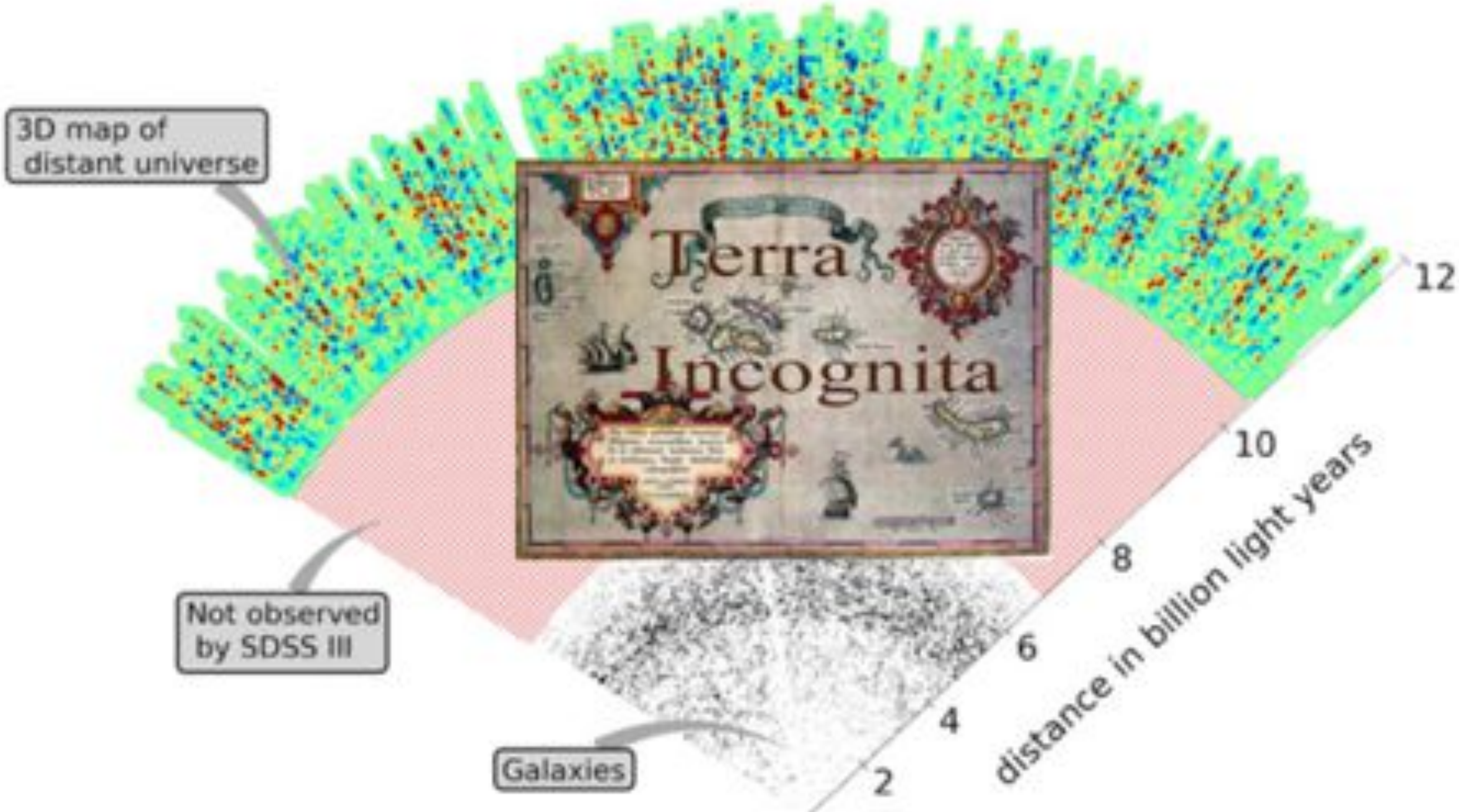


Gaztañaga, Eriksen, Crocce, Castander, Fosalba, Martí, Miquel, Cabré, MNRAS, 422,2904G (2012)


DESI
Borrowed from D. Schlegel

Where are we with SDSS-III/BOSS ?

SDSS-III/BOSS completed on April 1, 2014
1.5 million redshifts spanning ~5 $h^{-3}Gpc^3$

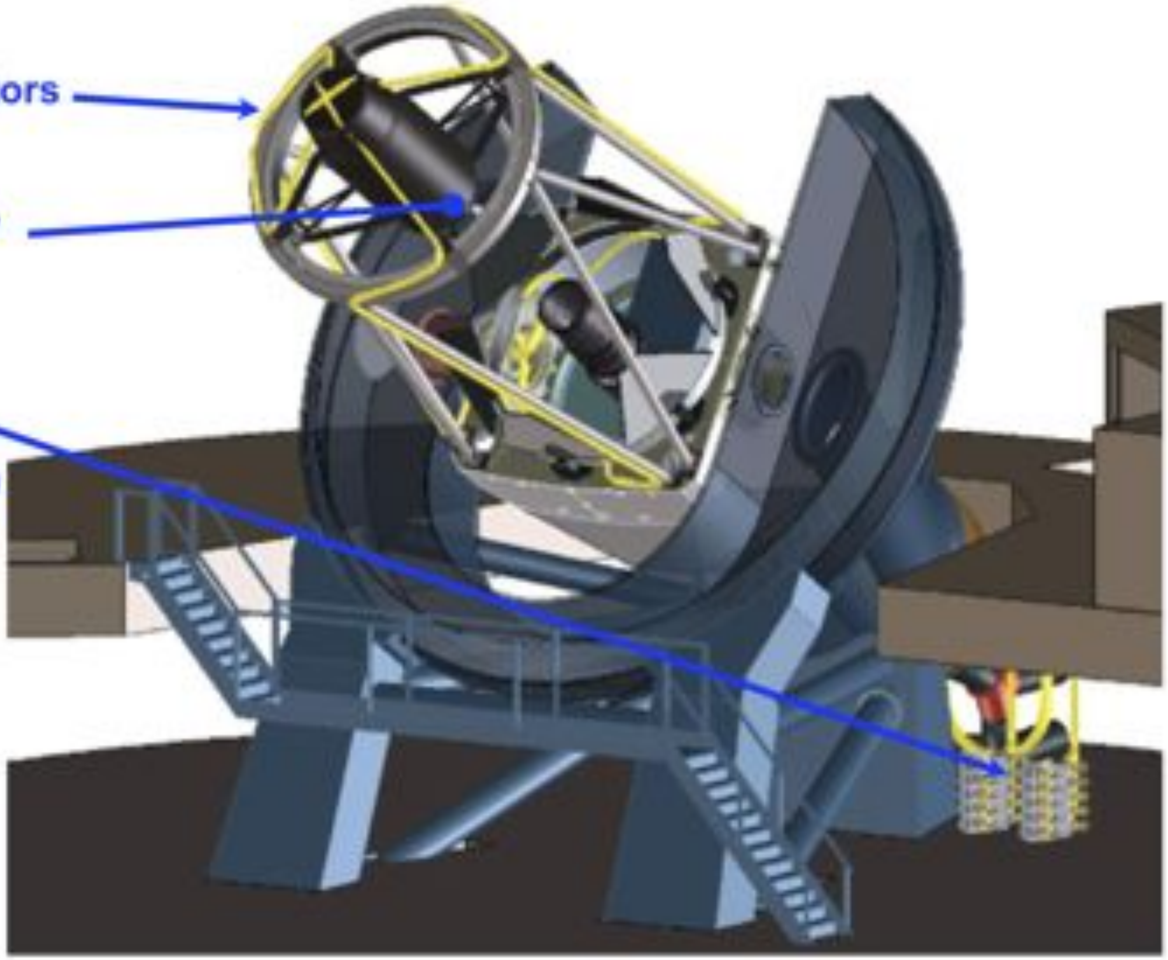


DESI Instrument

5000 fiber actuators

3.2° field-of-view
corrector

Spectrographs
360-980 nm
Resolution 2000-5000



What is the DESI survey?

1. An imaging (targeting) survey over 14,000 deg^2

g-band to 24.0 mag

r-band to 23.6 mag

z-band to 23.0 mag

2. A spectroscopic survey over 14,000 deg^2

4 million Luminous Red Galaxies

23 million Emission Line Galaxies

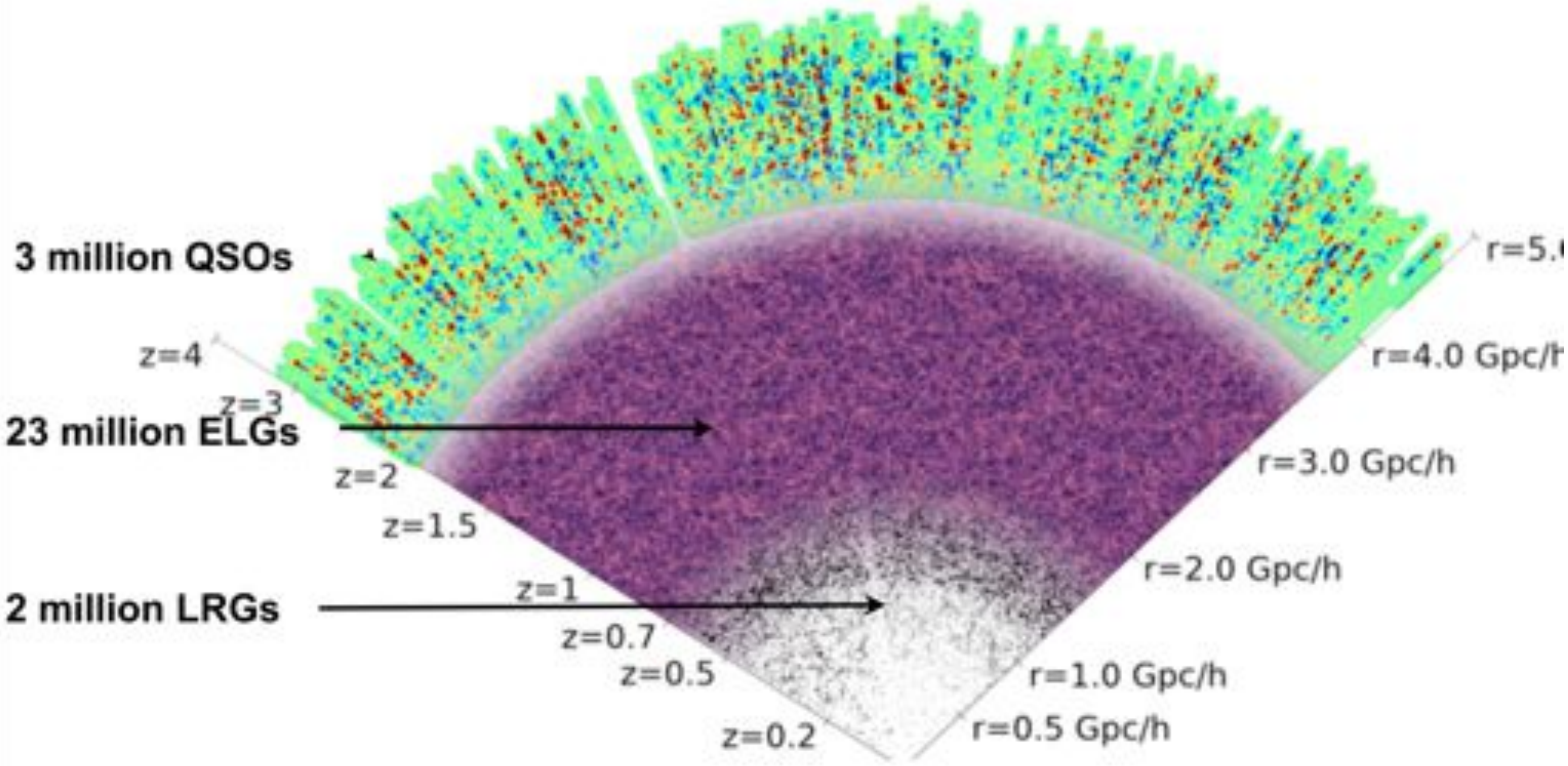
1.4 million quasars

0.6 million quasars at $z>2.2$ for Lyman-alpha-forest

What is the DESI survey?

The largest spectroscopic survey for dark energy

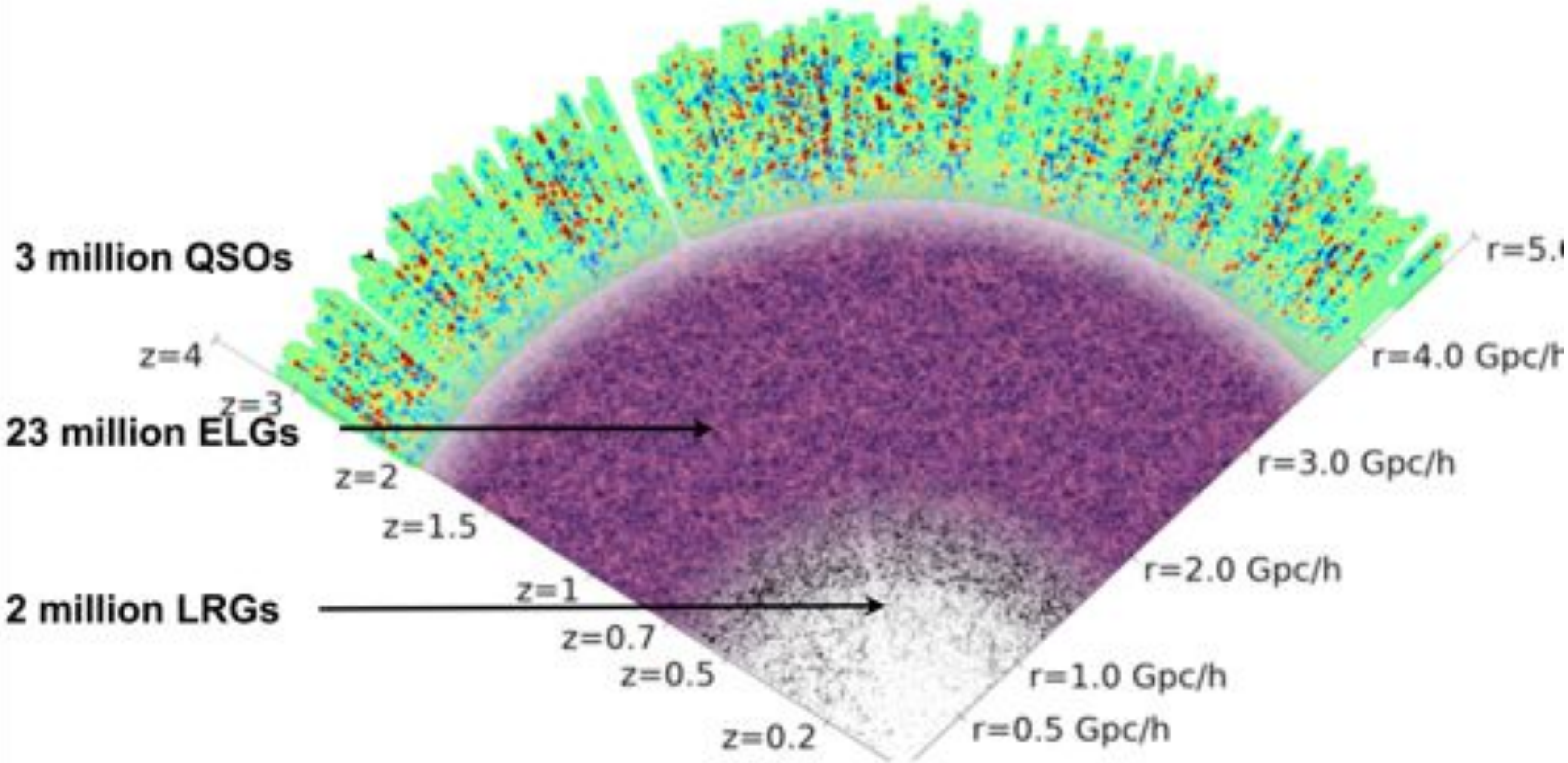
SDSS ~$2h^{-3}Gpc^3$ ⇨ BOSS ~$6h^{-3}Gpc^3$ ⇨ DESI $50h^{-3}Gpc^3$



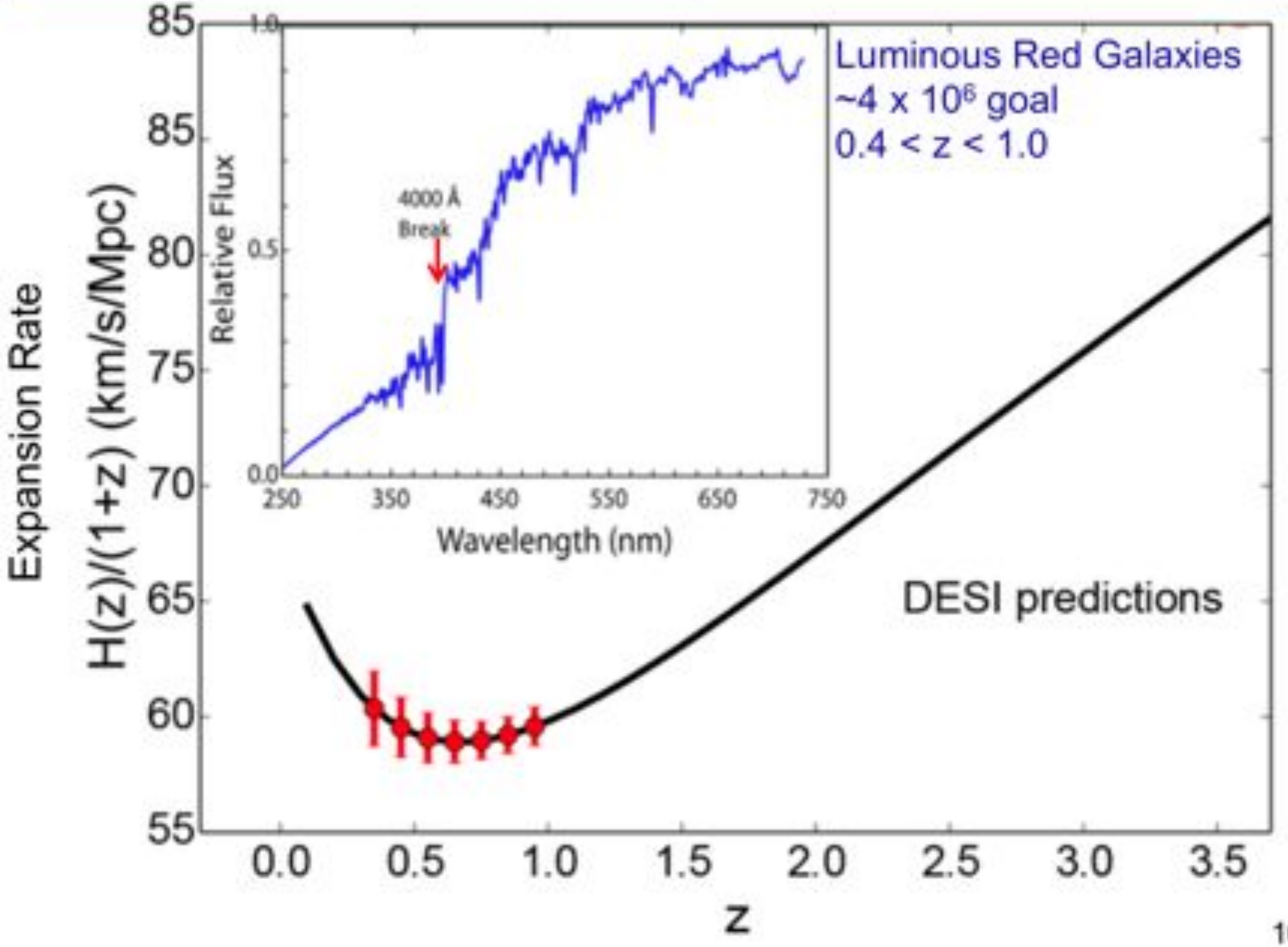
What is the DESI survey?

Four target classes spanning redshifts z=0 → 3.5

Includes all the massive black holes in the Universe (LRGs + QSOs)

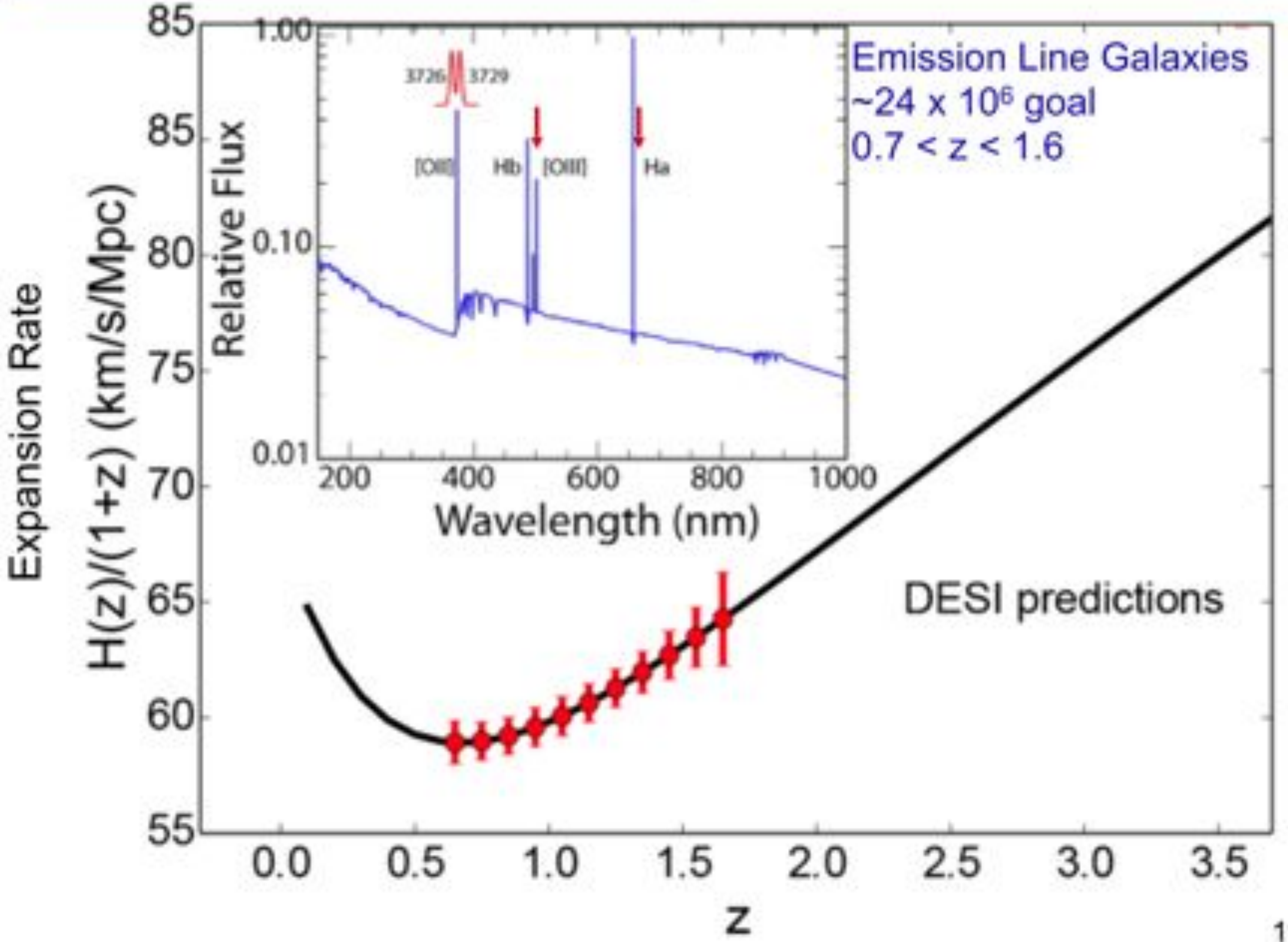


LRG Targets



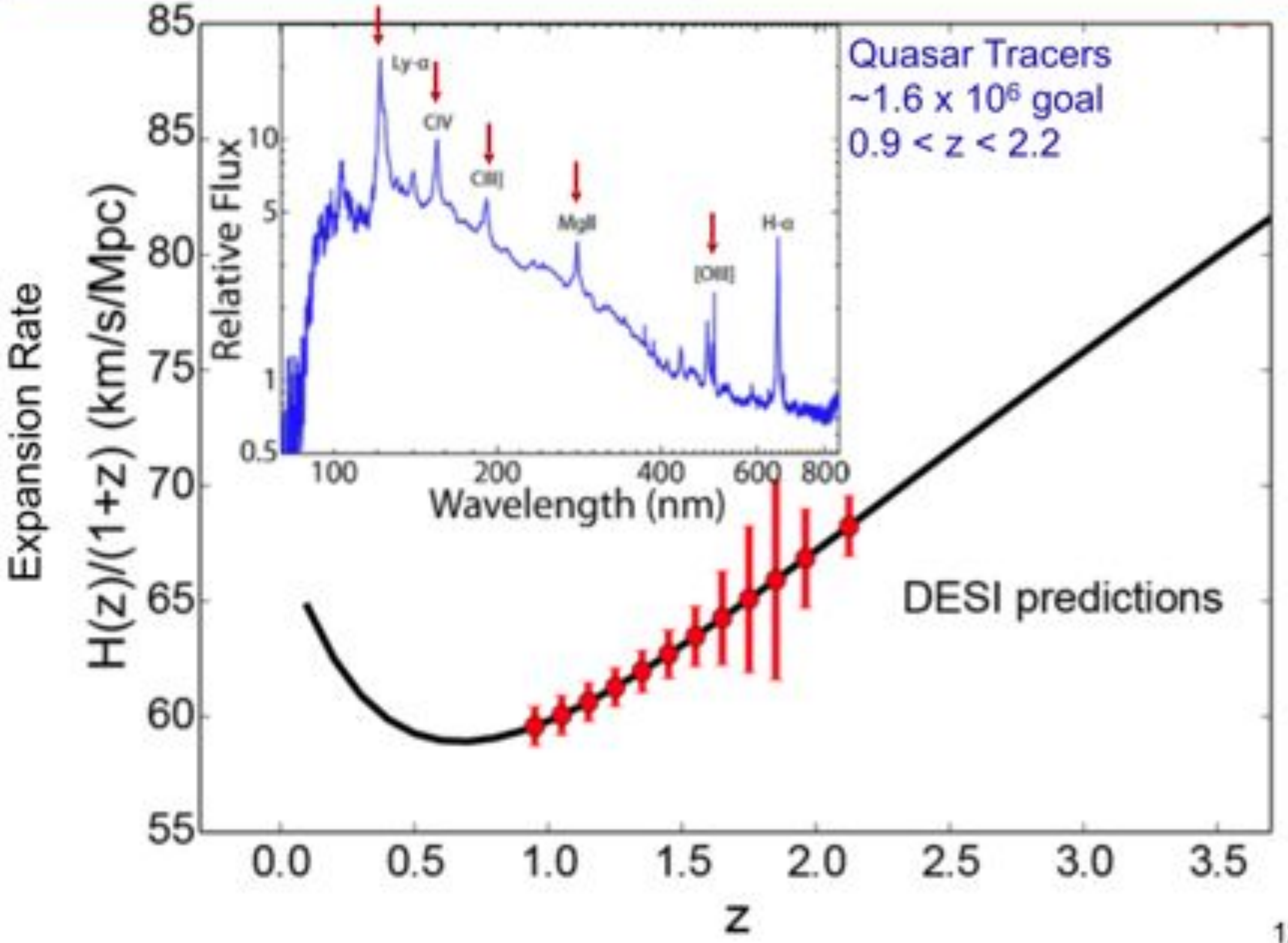
Luminous Red Galaxies
~4 x 10⁶ goal
0.4 < z < 1.0
DESI predictions
Expansion Rate
H(z)/(1+z) (km/s/Mpc)
z
Relative Flux
Wavelength (nm)
4000 Å
Break

ELG Targets



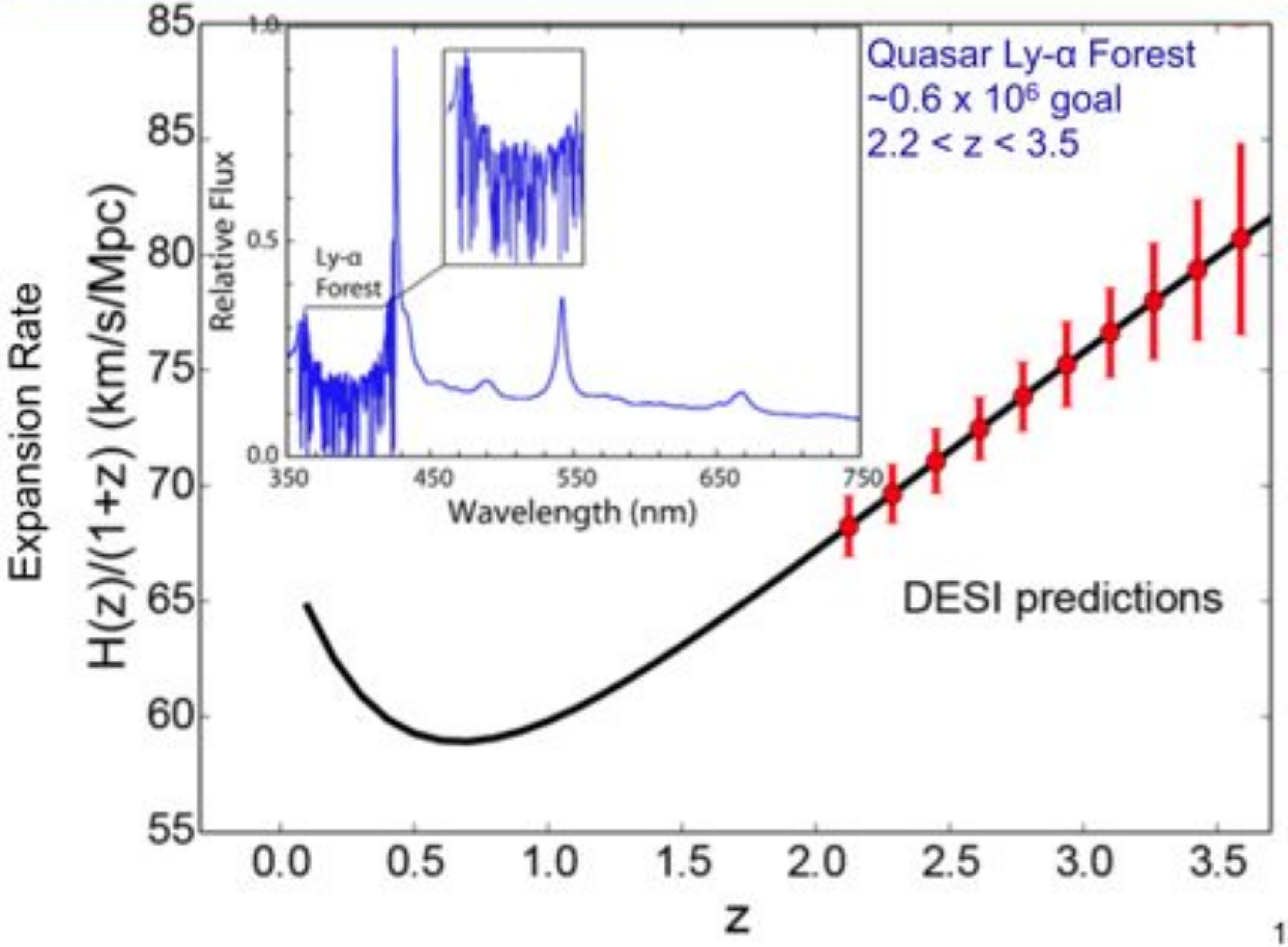
Emission Line Galaxies
~24 x 10⁶ goal
0.7 < z < 1.6
DESI predictions
Expansion Rate
H(z)/(1+z) (km/s/Mpc)
z
Relative Flux
Wavelength (nm)
3726
3729
[OII]
Hb
[OIII]
Ha

QSO Targets

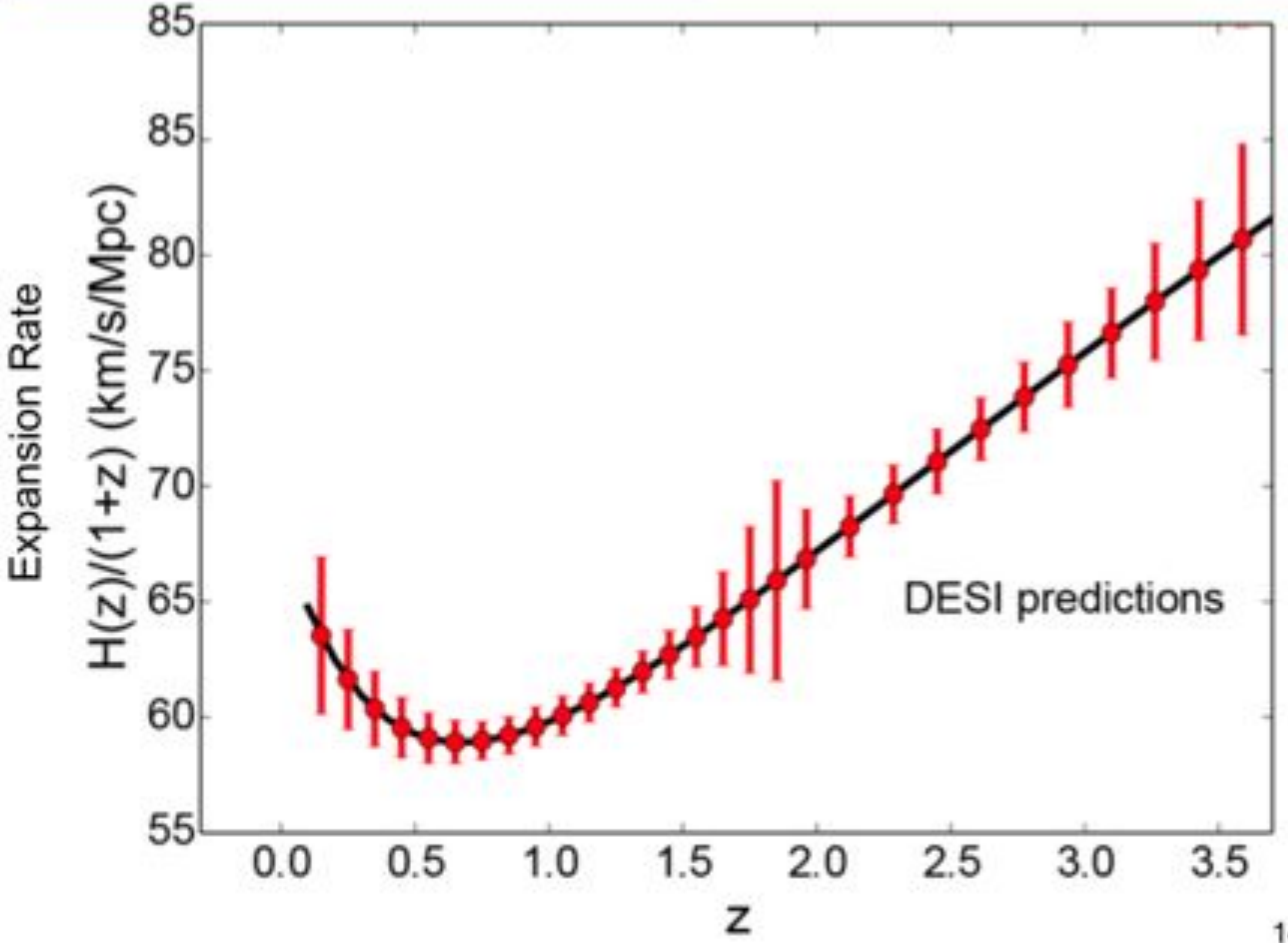


Quasar Tracers
~1.6 x 10^6 goal
0.9 < z < 2.2
Relative Flux
Wavelength (nm)
Ly-α
CIV
CIII]
MgII
[OIII]
H-α
Expansion Rate
H(z)/(1+z) (km/s/Mpc)
DESI predictions
z

Ly-α Forest QSO Targets



DESI on the Hubble Diagram



DESI Key Project goals

Defined in Science Requirements Document (SRD)

- **Distance-redshift relation**
  - Measure distance scale to <0.3% between $0.0 < z < 1.1$
  - Measure distance scale to <0.3% between $1.1 < z < 1.9$
  - Measure the Hubble parameter to < 1% in the bin $1.9 < z < 3.7$

- **Gravitational growth growth**
  - Constrain the growth factor at ~ a few percent level up to $z=1.5$

- **Beyond Dark Energy**
  - Constrain spectral index of primordial perturbations and its running to < 0.4%
  - Measure the neutrino masses to < 0.017 eV

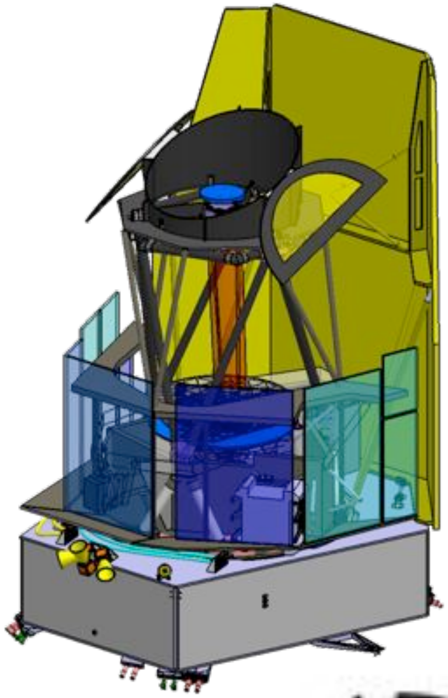

Euclid

Euclid Science Objectives

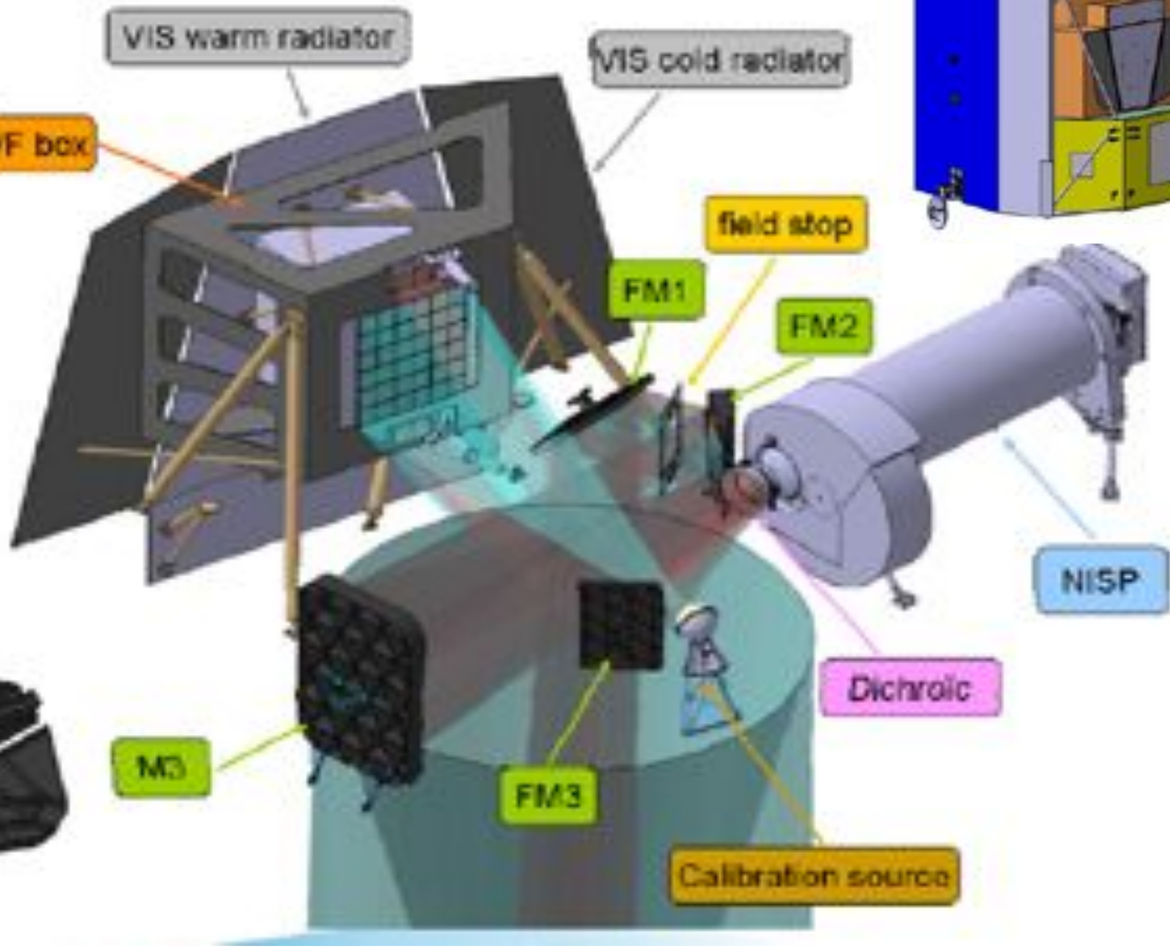
Issue	Euclid's Targets
What is Dark Energy	**Measure the Dark Energy equation of state parameters** w_p and w_a to a precision of 2% and 10%, respectively, using both expansion history and structure growth.
Beyond Einstein's Gravity	**Distinguish General Relativity from modified-gravity theories**, by measuring the galaxy clustering growth factor exponent γ with a precision of 2%.
The nature of dark matter	**Test the Cold Dark Matter paradigm** for structure formation, and measure the sum of the neutrino masses to a precision better than 0.04eV when combined with Planck.
The seeds of cosmic structure	**Improve by a factor of 20 the determination of the initial condition parameters** compared to Planck alone. n (spectral index), σ_8 (power spectrum amplitude), f_{NL} (non-gaussianity)

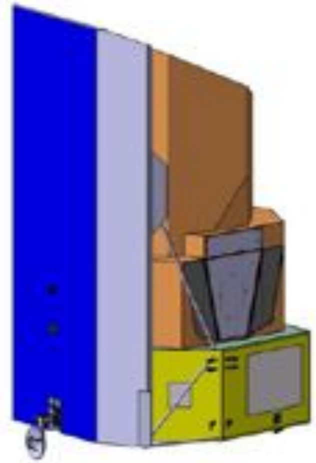
Euclid Payload

EUCLID CONSORTIUM



Brazed baseplate





Euclid

VIS

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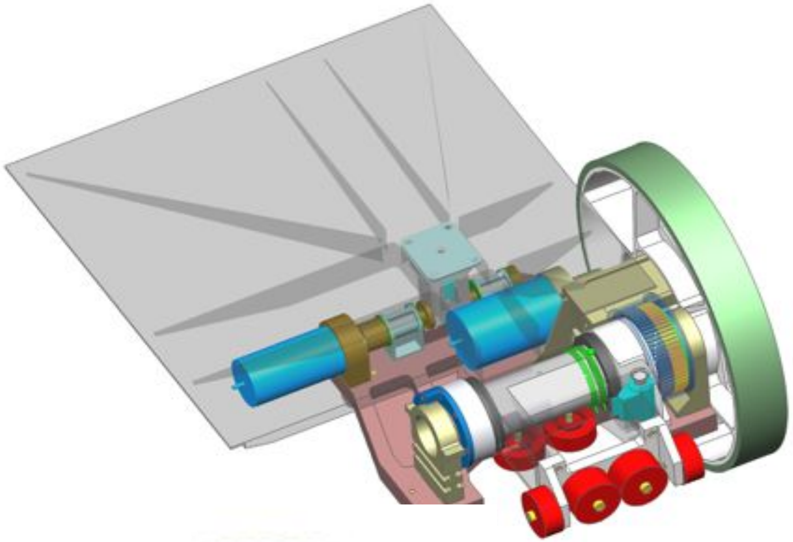
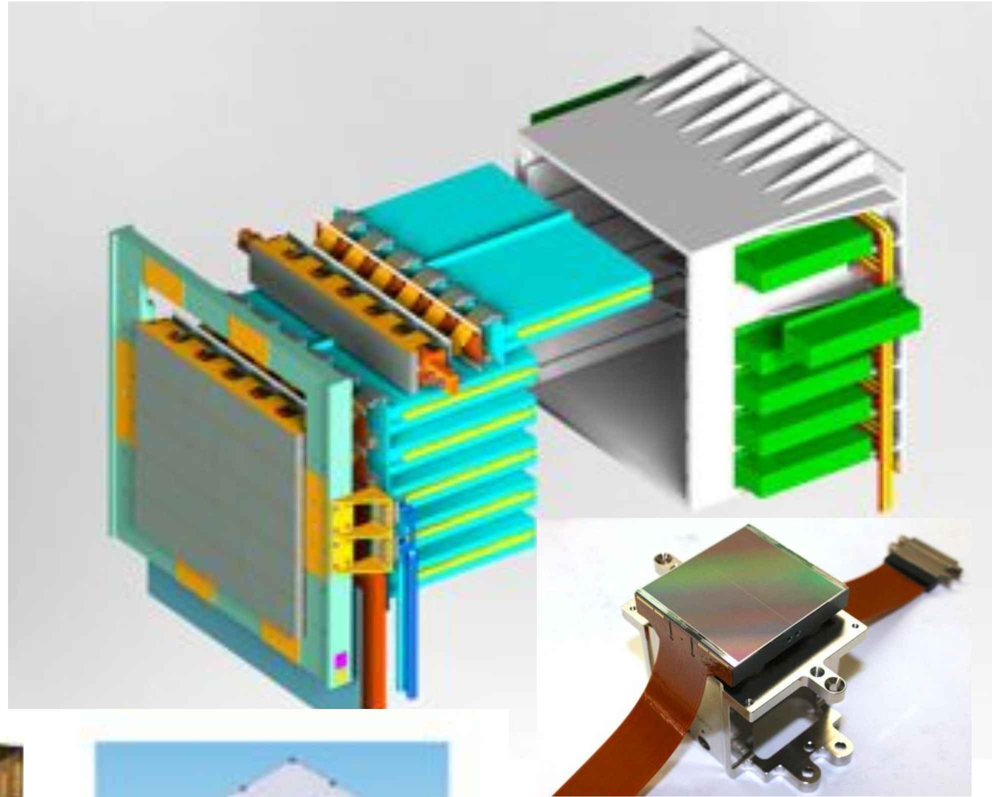
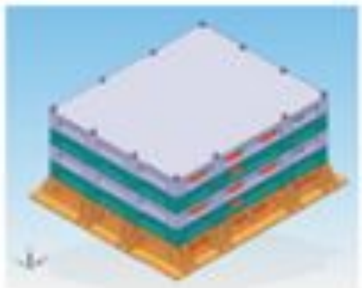
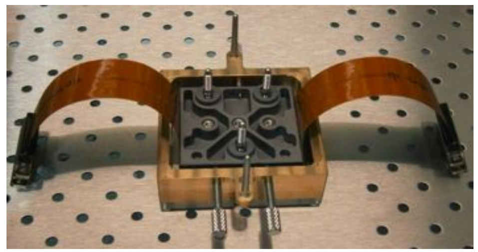
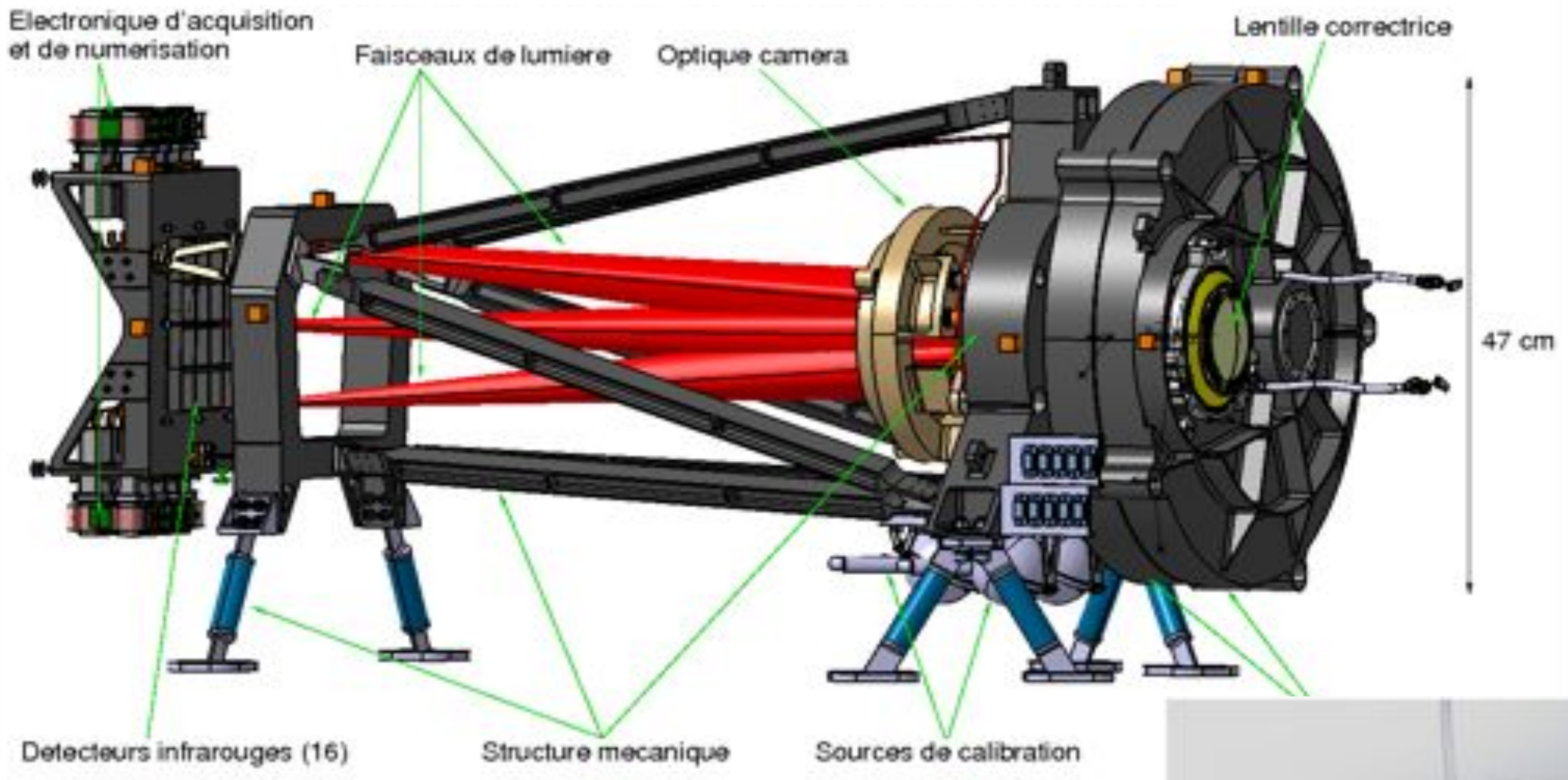








The NISP instrument: Near Infrared Spectrometer and Photometer



Euclid

Euclid Focal planes

EUCLID CONSORTIUM

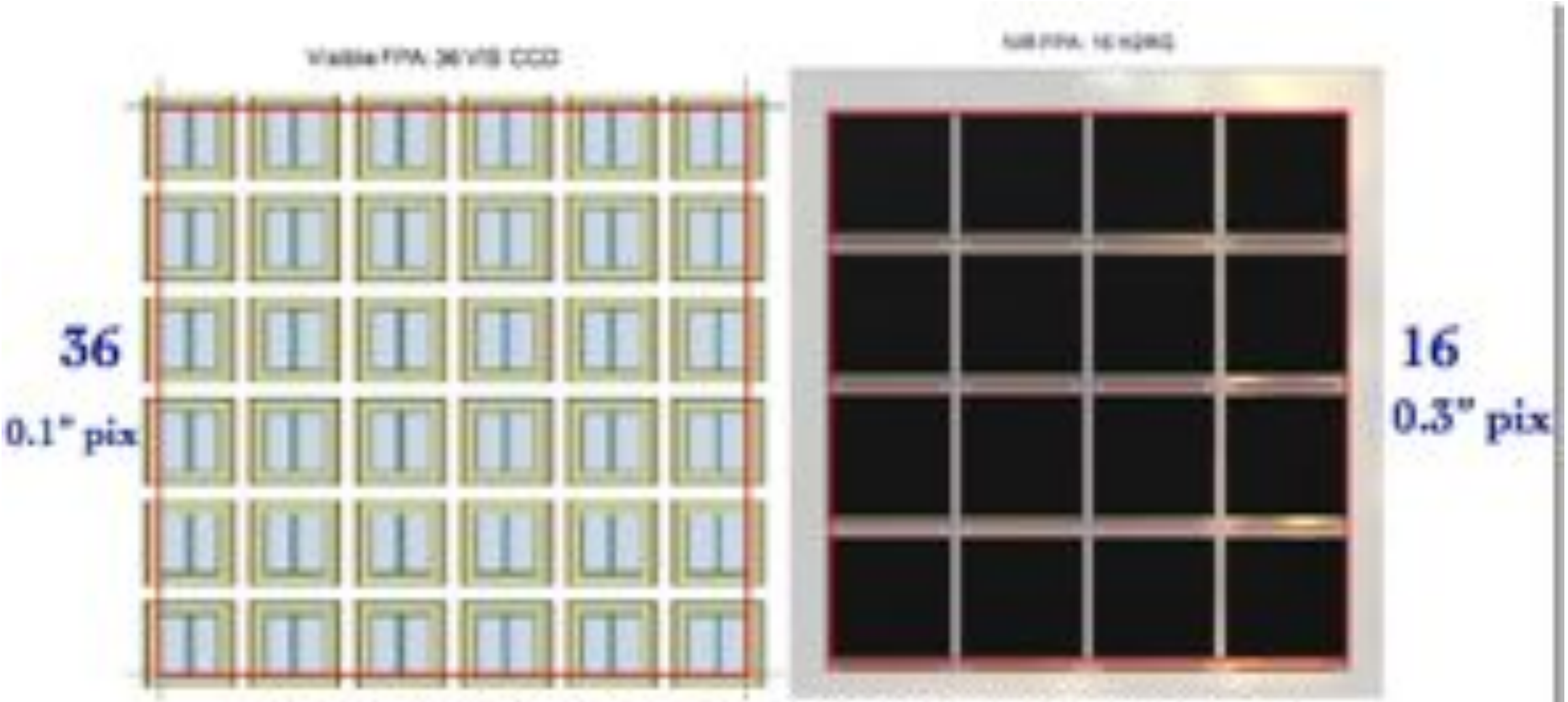


Figure 6-1: VIS (left red ensquared area) and NISP (right red ensquared area) Geometrical FoV.

Euclid Exposure sequence

4 exposures ~1 full field -0.5 sq deg- / 1.25 hr (~ 19/day ≈10 sq deg/day)

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

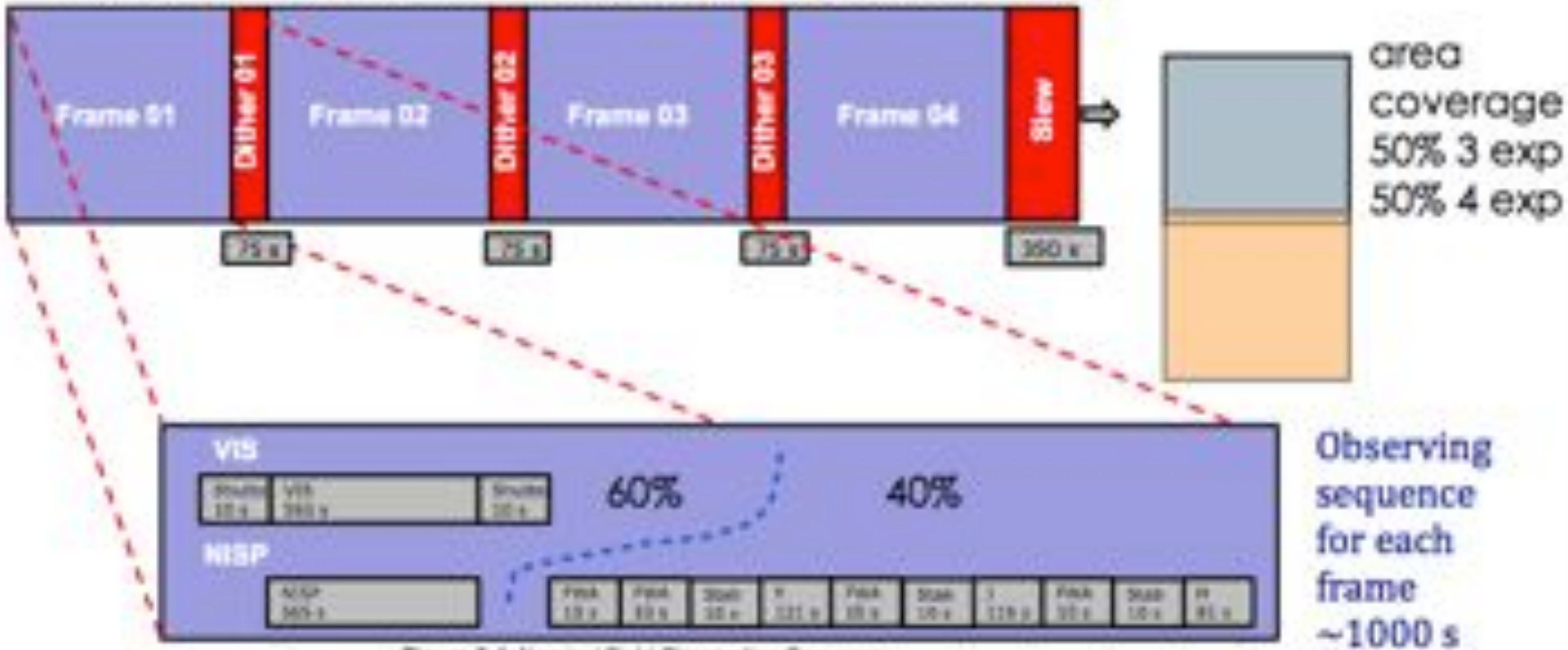


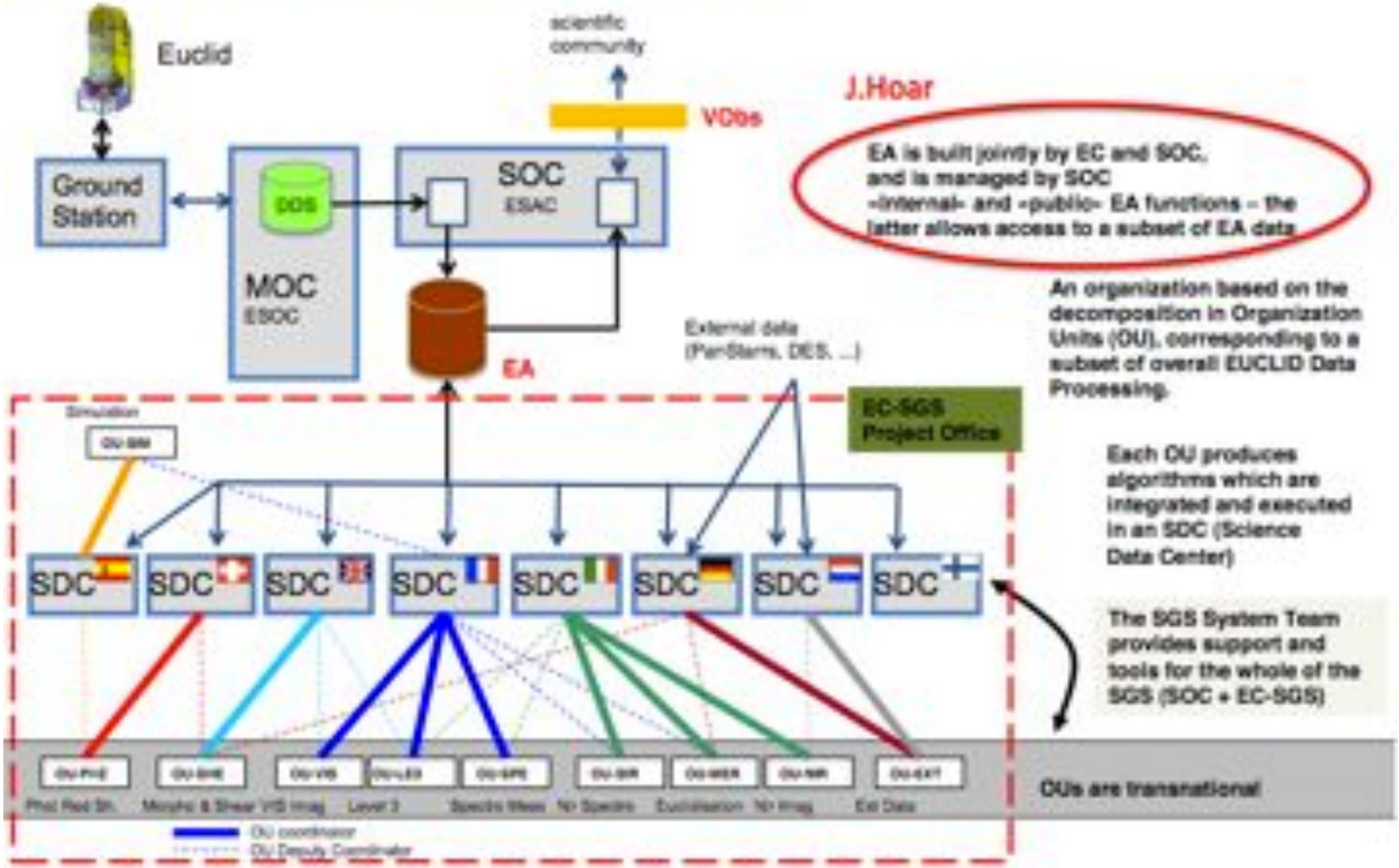
Figure 5-4 Nominal Field Observation Sequence

NIR: first spectroscopy contemporarily to VIS, then imaging (filter/grism wheel motion perturbs VIS)

Slitless: Blue, then Red grism, then again at 90 degs (--> 4 dithers)

Euclid Ground Segment

EUCLID CONSORTIUM



Euclid Mission concept

- Optimize the mission for galaxy clustering and weak lensing, two dark energy complementary probes
- Two instruments: optical imager (VIS) and near-infrared spectrophotometer (NISP)
- Minimum survey area of 15000 deg2 → 6 years nominal mission

Weak Lensing: → VIS imager + NIR photometer

- Shapes and shear of galaxies with a density of >30 galaxies/arcmin^2.
- Very high image quality, high stability
- Minimum Systematics $\sigma_{sys} < 10^{-7}$
- Redshift accuracy dz/z ~ 0.04, down to z~2

Galaxy clustering → NIR slitless spectrometer

- Redshifts for >3500 galaxies/deg^2
- Redshift range $0.7 < z < 2.05$
- Redshift accuracy dz/z < 0.001 in same volume as WL
- Line Flux limit < 3 10^{-16} erg cm^{-2}s^{-1}

Euclid Surveys

Two Survey Strategy

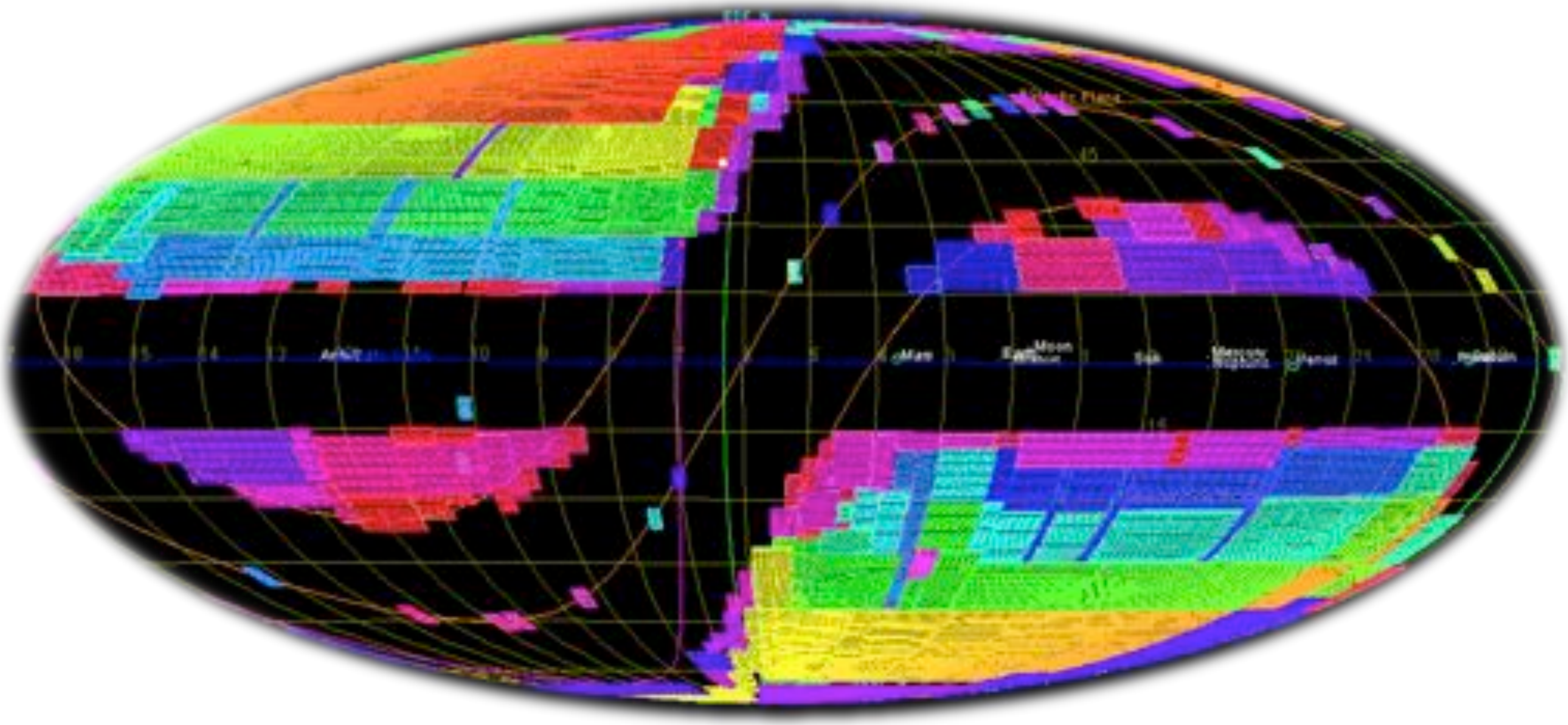
Wide Survey

- Area: 15000 deg^2; goal 20000 deg^2
- Avoid galactic plane, ecliptic plane and high extinction
- Imaging depth: $RIZ_{AB} = 24.5$ at 10σ; NIR $(Y_{AB}, J_{AB}, H_{AB}) = 24.0$ at 5σ
- Spectroscopic depth: $3\ 10^{-16}$ erg cm^{-2} s^{-1}

Deep Survey

- Area: 40 deg^2, in two pointing
- Location TBD, but most likely in ecliptic poles
- Depth: 2 magnitudes deeper than wide survey

Euclid Sky coverage

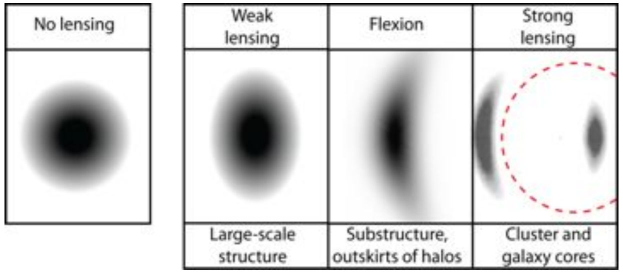


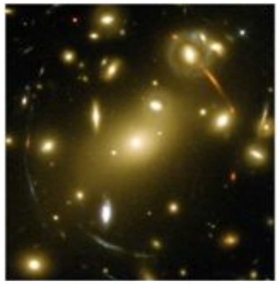
- Ecliptic plane avoided (zodiacal light, |β|<15 deg) and low (|b|<25 deg) galactic latitudes and high extinction regions E(B-V) < 0.08
- Different colours indicate different survey years
- Calibration fields along the galactic plane

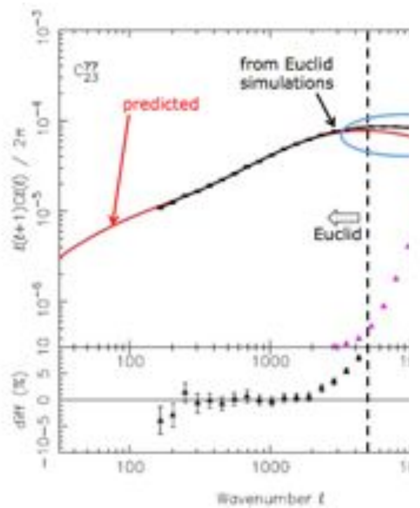
Euclid

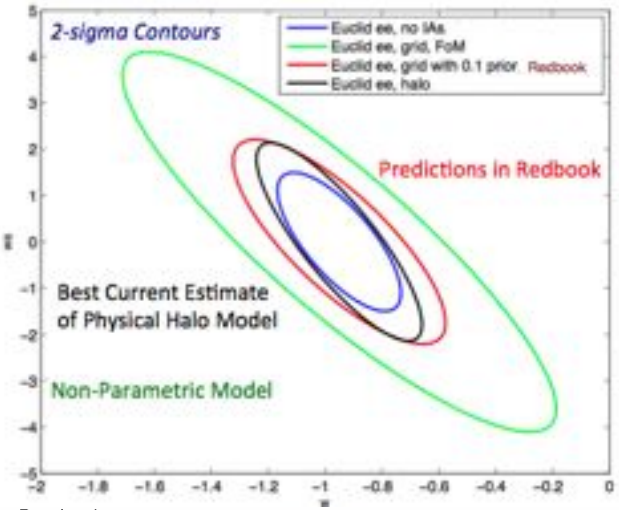
Weak Lensing

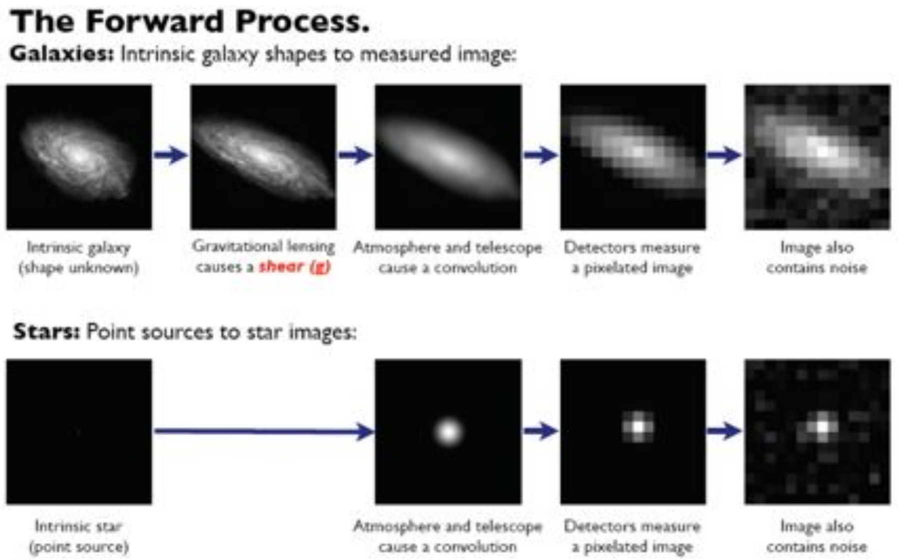
EUCLID CONSORTIUM

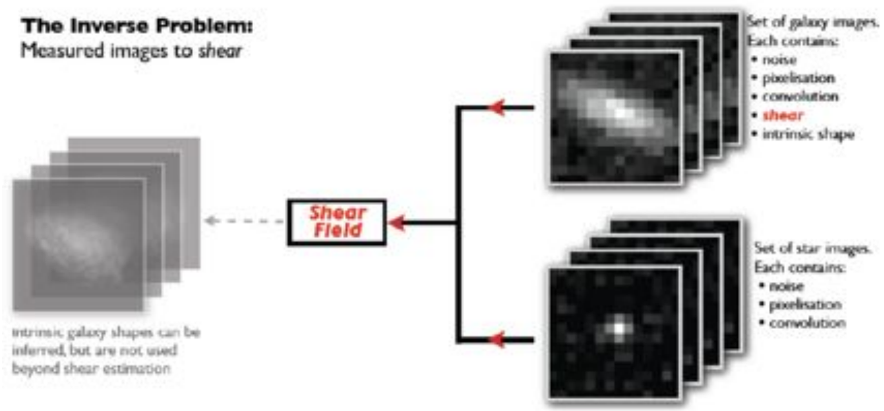


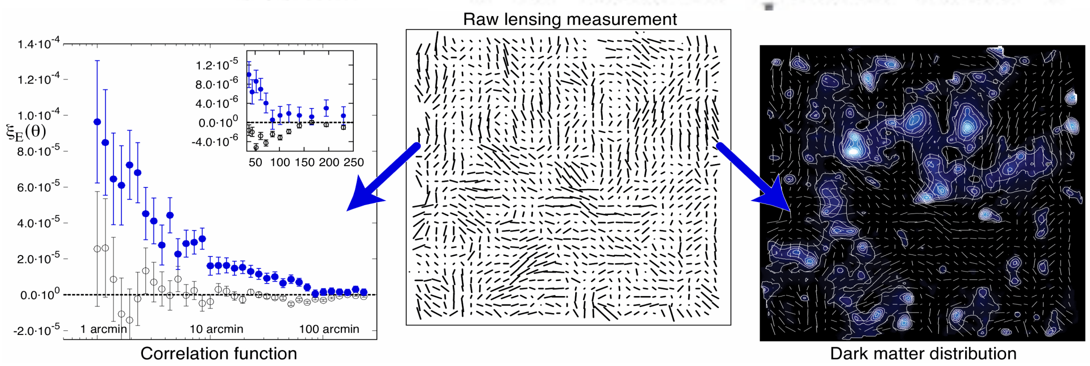






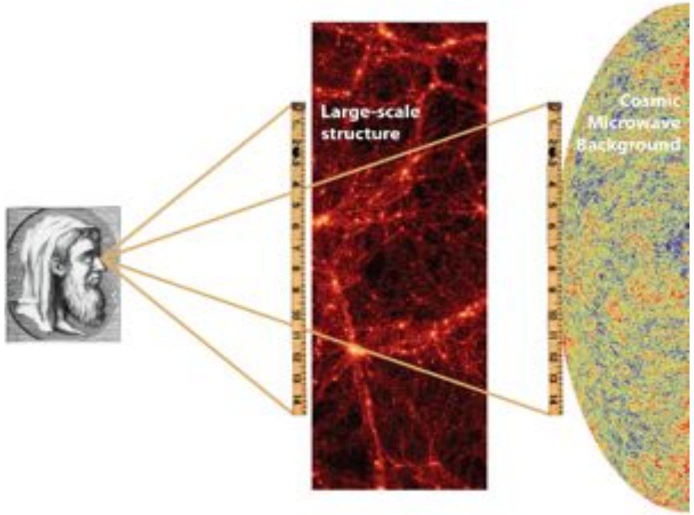


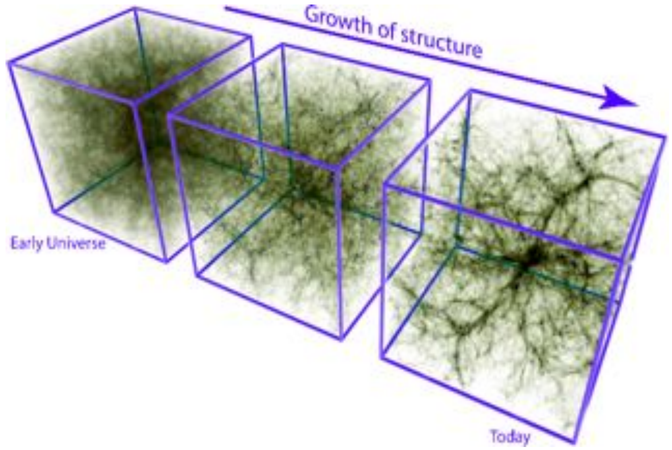


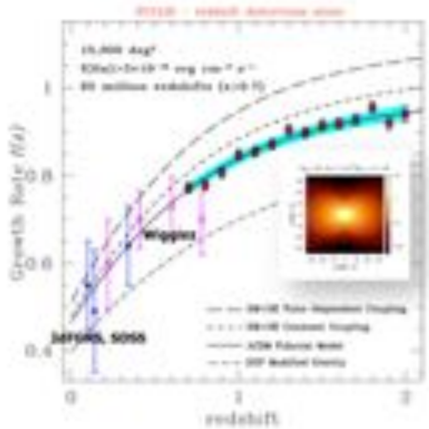


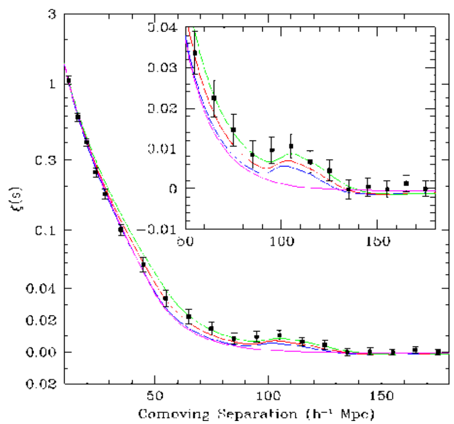
Euclid Galaxy clustering

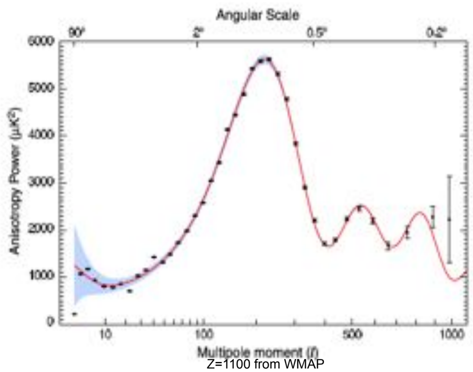
EUCLID CONSORTIUM

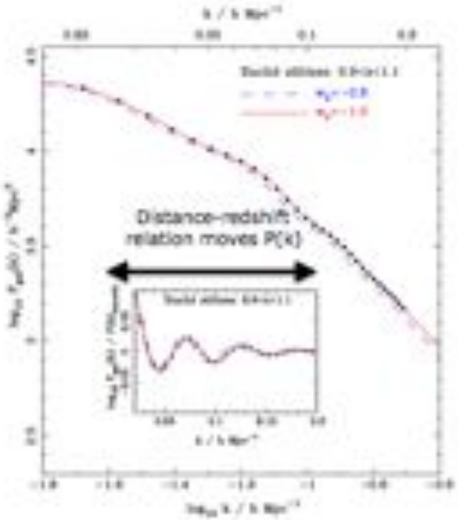


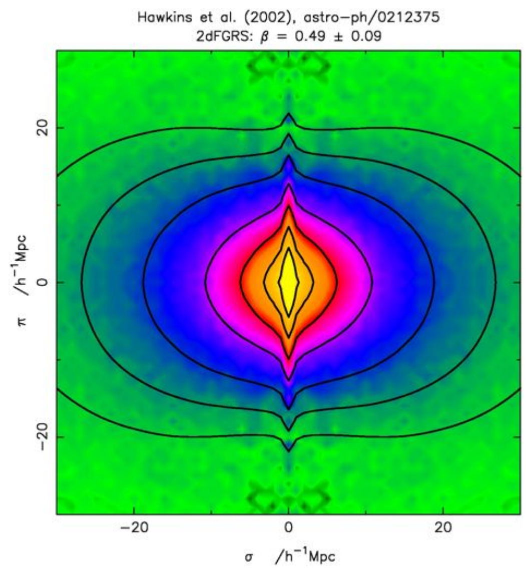










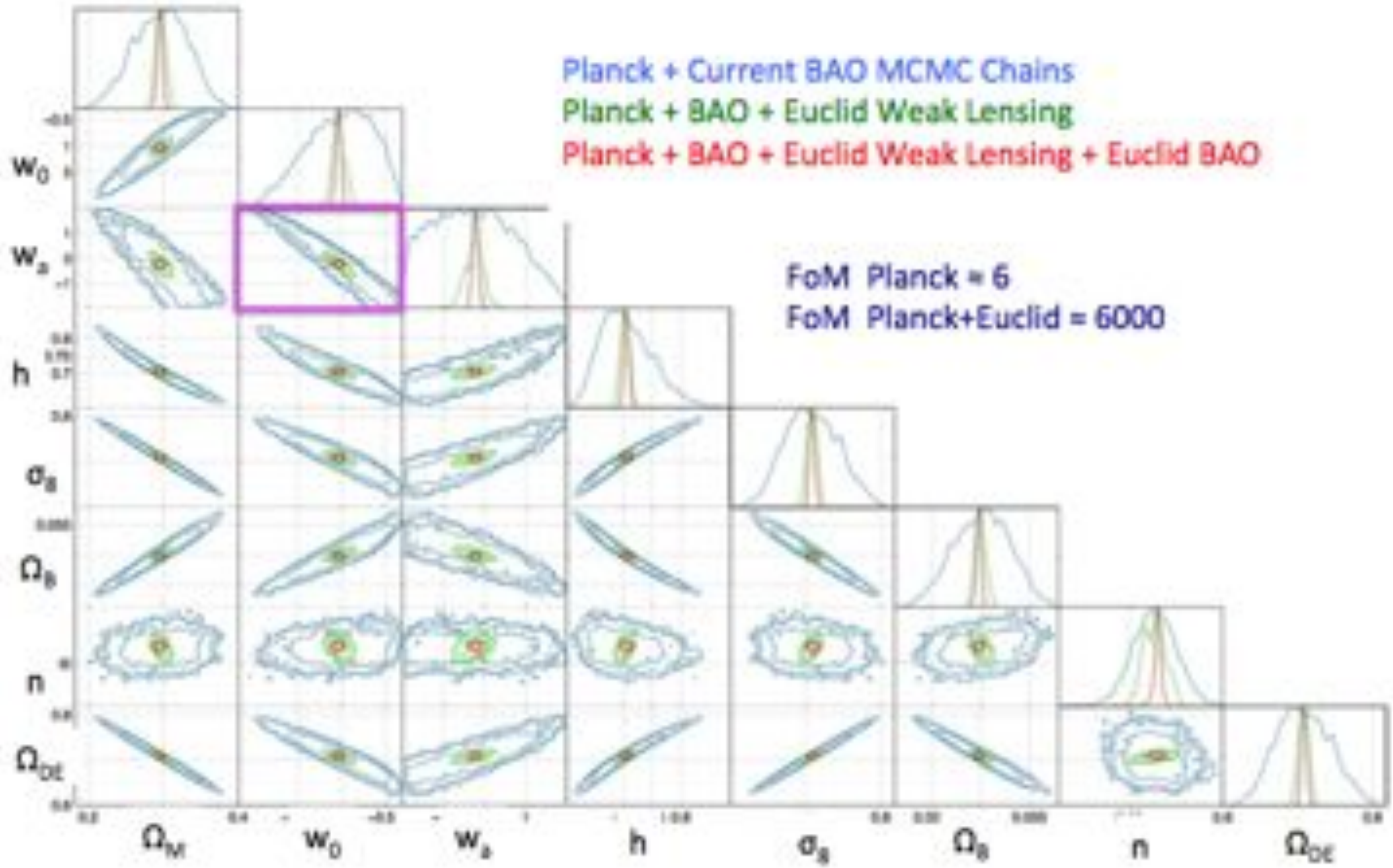


Euclid Science Prediction

Red Book Predictions

	Modified Gravity	Dark Matter	Initial Conditions	Dark Energy		
Parameter	γ	m_ν/eV	f_{NL}	w_p	w_a	FoM
Euclid Primary	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	0.200	0.580	100	0.100	1.500	~10
Improvement Factor	**30**	**30**	**50**	**>10**	**>50**	**>300**

Euclid   Science prediction

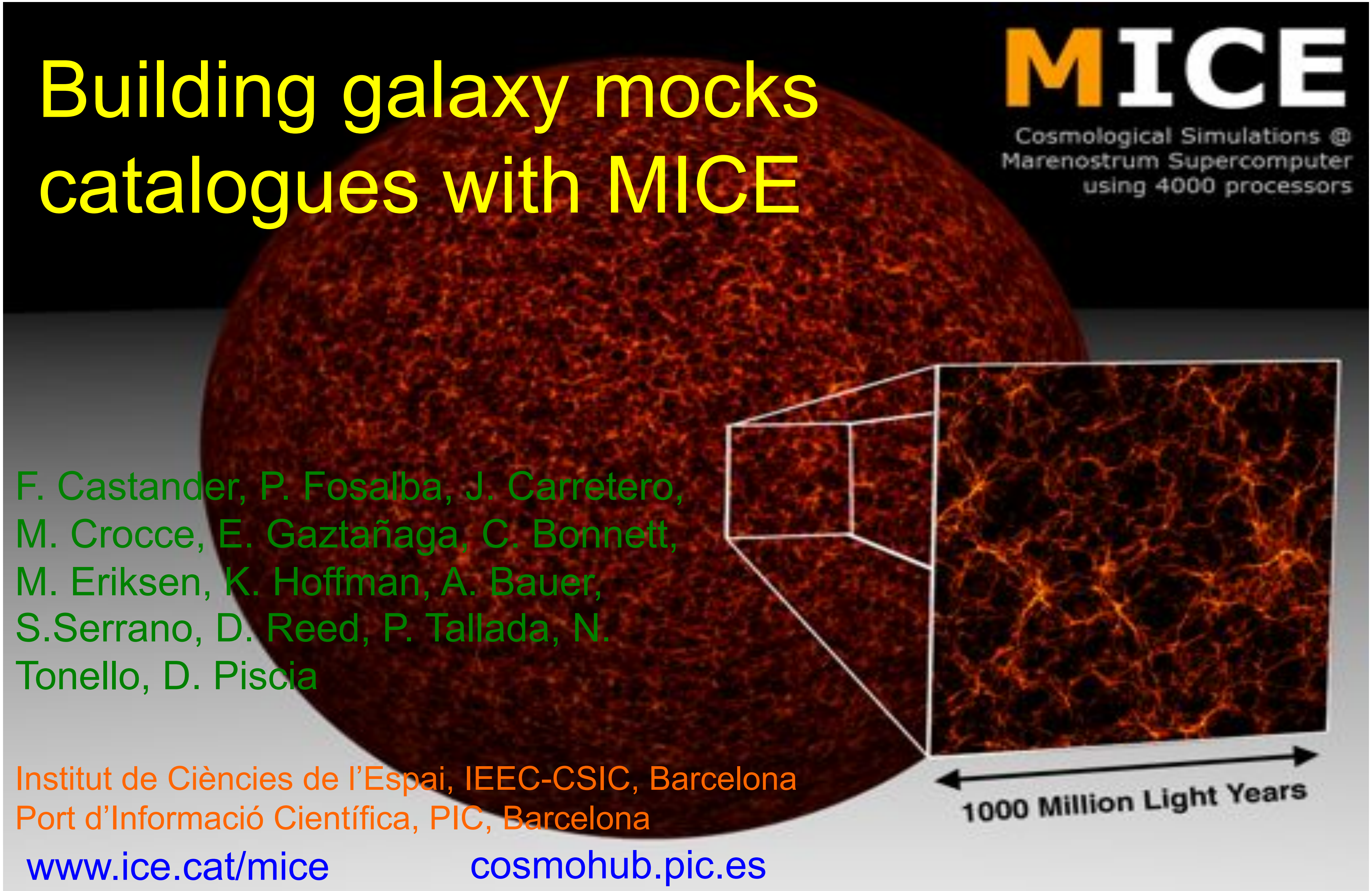


Building galaxy mocks catalogues with MICE

F. Castander, P. Fosalba, J. Carretero, M. Crocce, E. Gaztañaga, C. Bonnett, M. Eriksen, K. Hoffman, A. Bauer, S.Serrano, D. Reed, P. Tallada, N. Tonello, D. Piscia

Institut de Ciències de l’Espai, IEEC-CSIC, Barcelona
Port d’Informació Científica, PIC, Barcelona

www.ice.cat/mice cosmohub.pic.es



MICE

Marenostrum Institut de Ciències de l'Espai Simulations

MICE simulations

www.ice.cat/mice

Cosmological surveys

- Probe large volumes: wide area & z range
- determine tracers (galaxies) positions (redshifts)
- determine the expansion rate and growth of structure

MICE simulations

- Provide mocks for cosmological surveys: DES, PAU, Euclid, DESI
- help plan and optimize surveys
- analyze and exploit cosmological data
- understand errors and covariances

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MICE simulations

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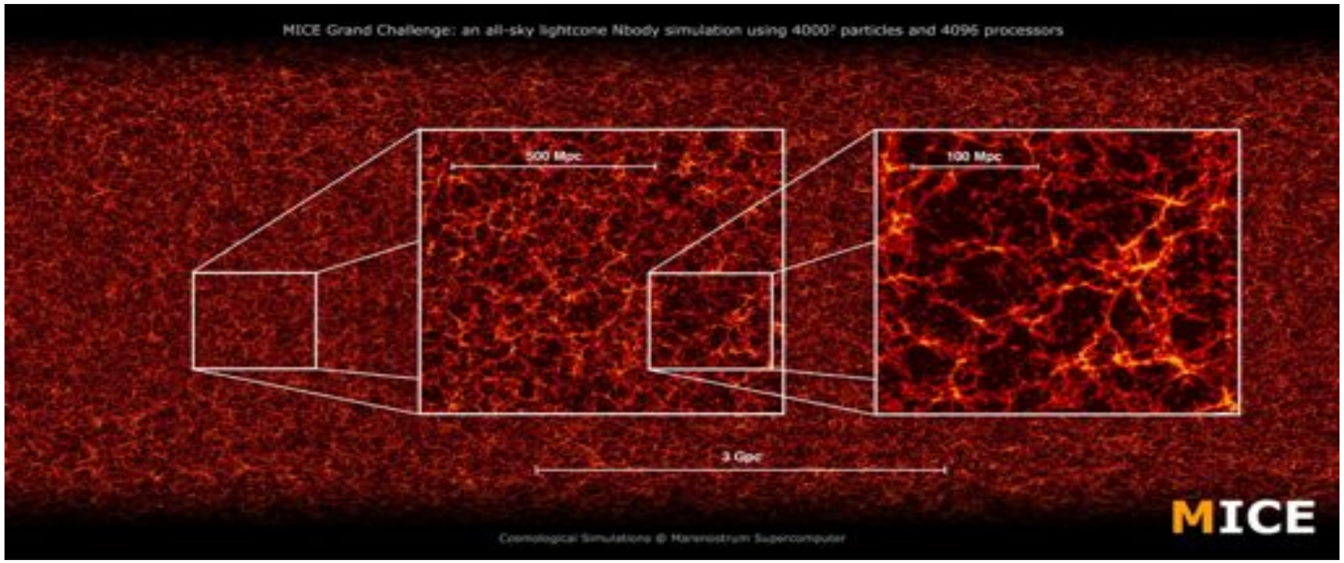
MICE

Simulation process

- Generate large dark matter simulation
- Produce lightcones
- All-sky lensing maps
- generate halo catalogues
- produce galaxy catalogues



Products

- Comoving and lightcone outputs
  - dark matter
  - halo catalogues
  - lensing catalogues
  - galaxy catalogues

Properties

- Clustering
- Lensing
- Galaxy properties

MICE

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de Ciències de l'Espai
Simulations

MICE galaxy catalogue

- Run at BSC Marenostrum
- Uses MICE Grand Challenge simulation: 4096^3 = 70 billion particles, 3 Gpc/h box, mp=3×10^{10} $M_\odot$
- Lightcone without repetition to z=1.4
- FoF halos with b=0.2 (1.2 billion, $n_{part} \geq 10$)
- All-sky lensing maps
- 1 octant (5000 deg^2) filled with HOD+SHAM galaxies
- Apply lensing properties to all galaxies

Box Size (Mpc/h)	Number of Particles	Particle Mass ($\times10^{10}$ Msun/h)	PMGrid size	Initial conditions	Initial redshift	l_{soft} (kpc/h)	MaxSize Timestep
3072	4096^3	2,927	4096^3	ZA	100	50	0,02

MICE GC simulation

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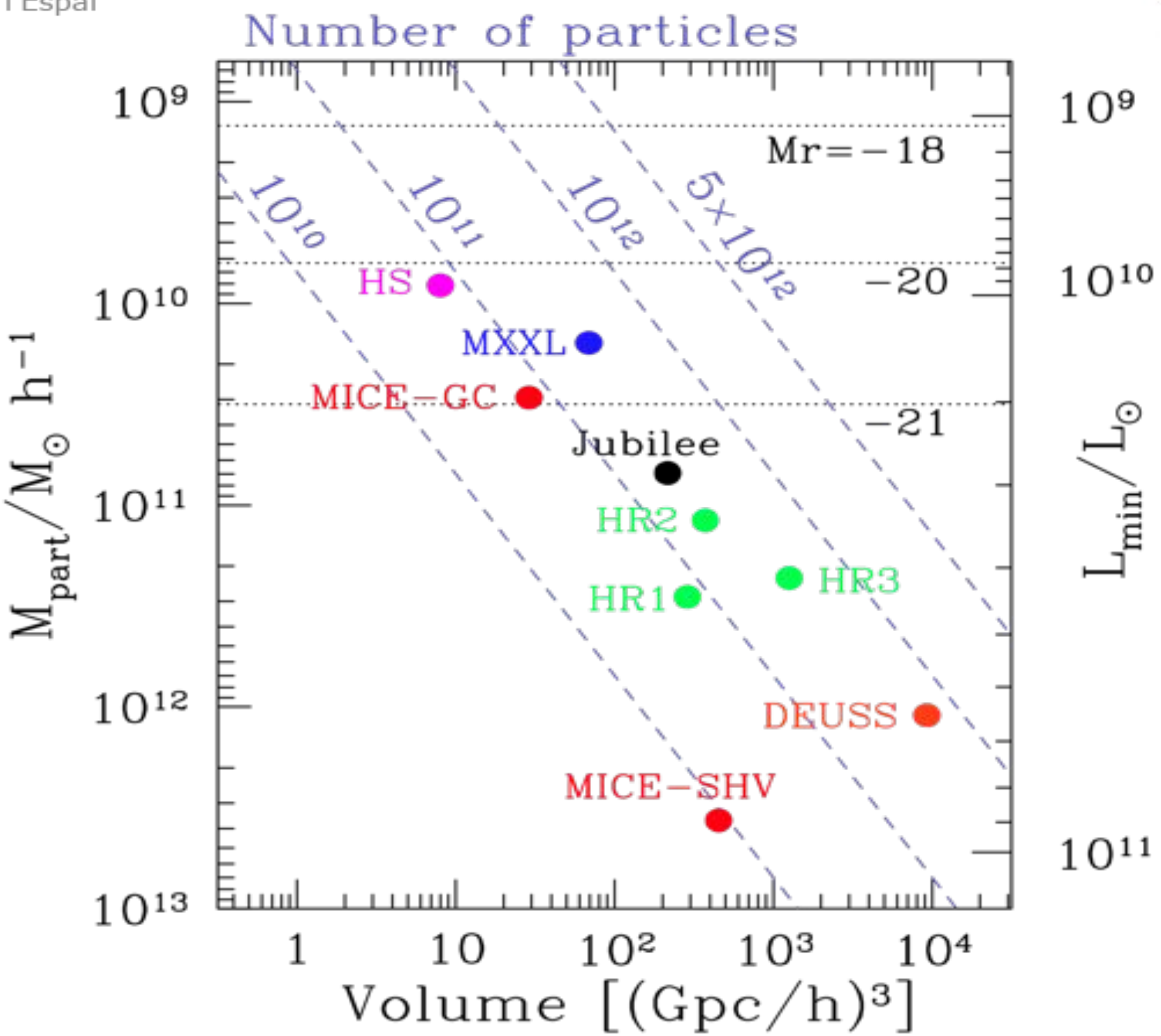

MICE simulations

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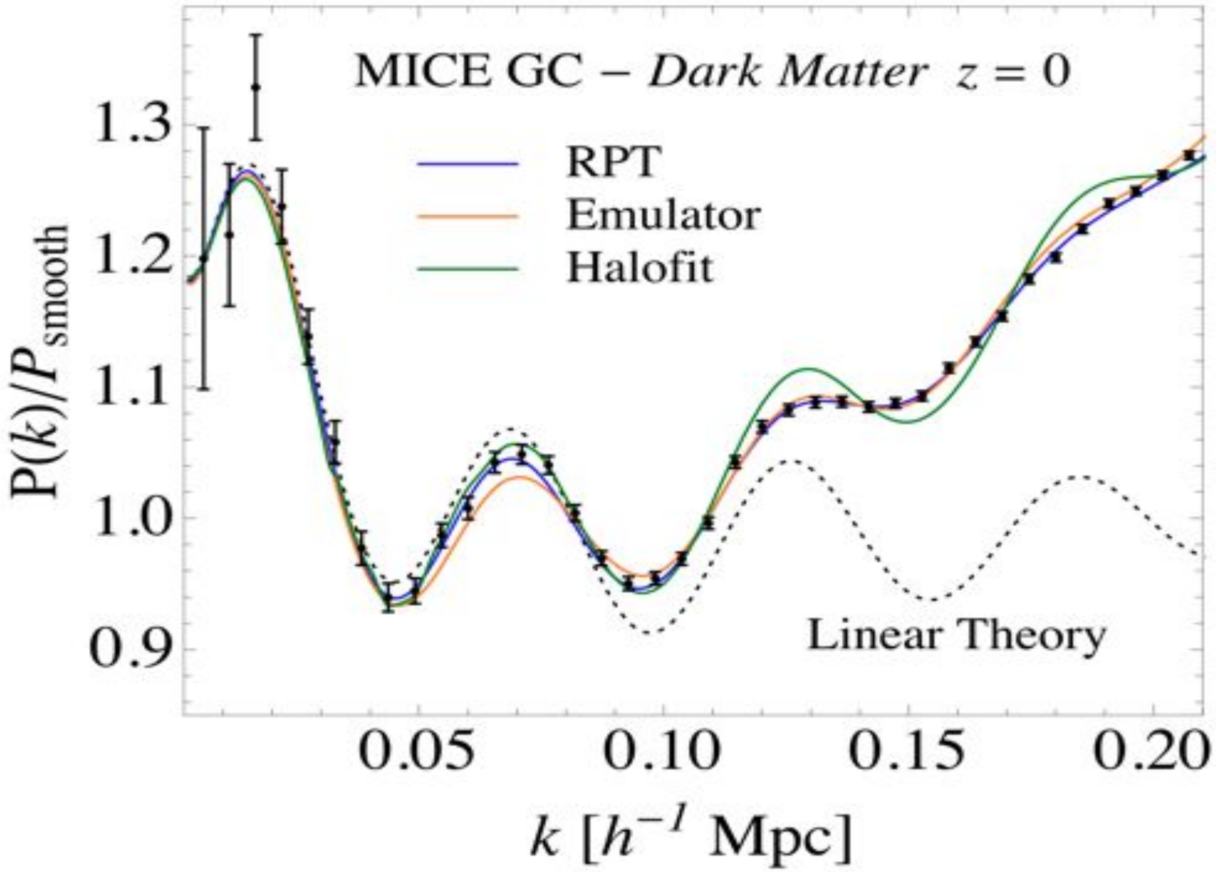
Dark Matter



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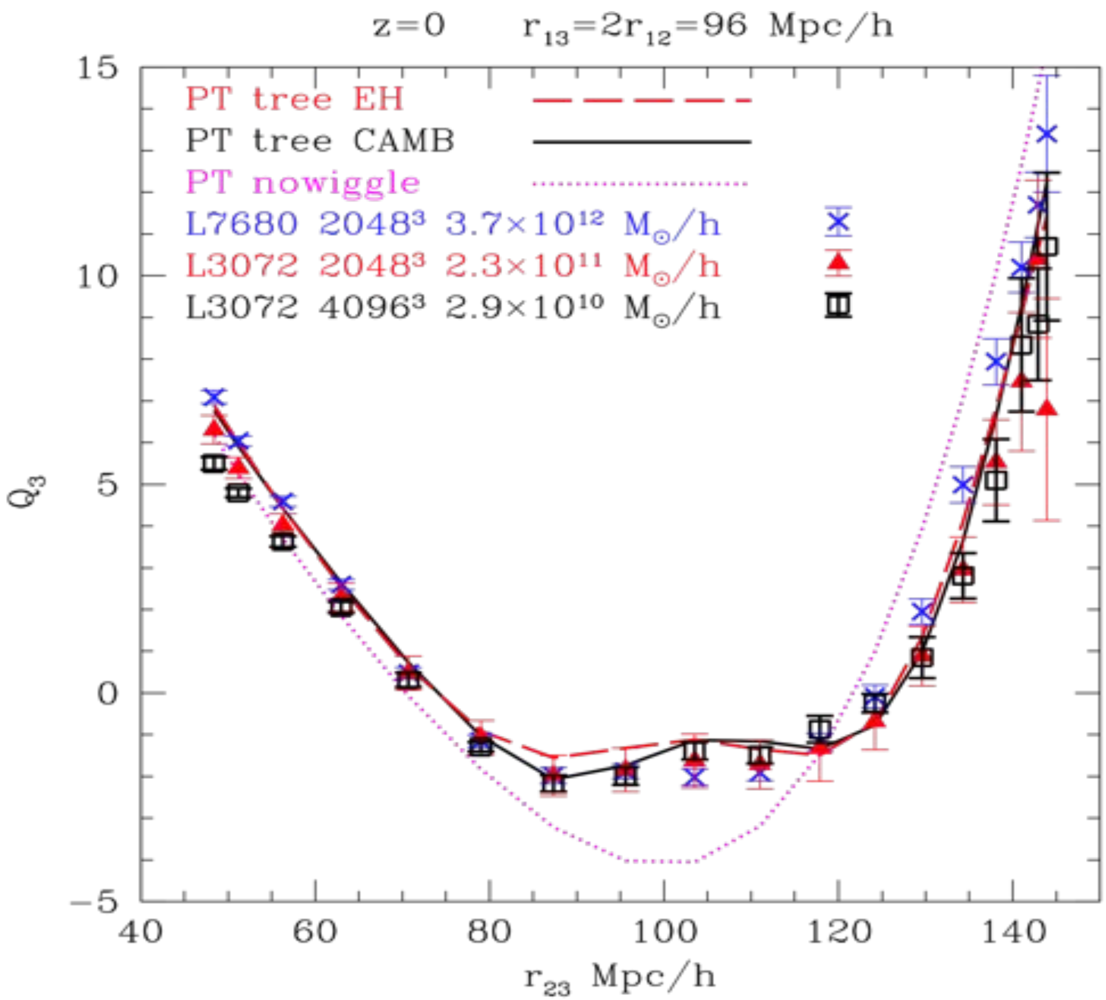
Simulations

MICE simulations

Dark Matter



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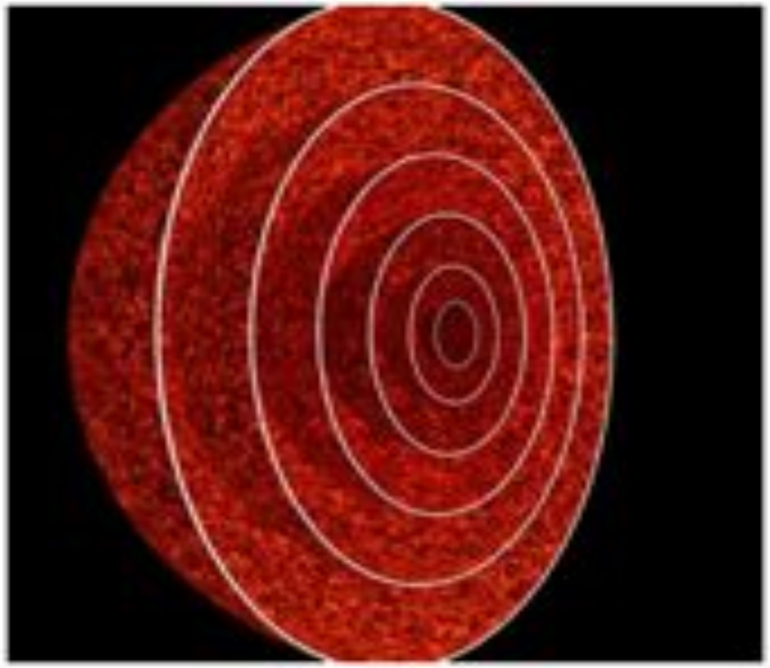
MICE simulations

MICE

All sky lensing maps

" The onion universe: all sky light-cone simulations in spherical shells "
Fosalba et al, MNRAS, **391**, 435 (2008)



- Split data in thin shells
- Interplate into (healpix) pixels
- Combine to produce convergence maps

$$\kappa(\theta) = \frac{3H_0^2\Omega_m}{2c^2} \int dr\ \delta(r,\theta) \frac{(r_s - r)r}{r_s\ a}$$

⇓

$$\kappa(i) = \frac{3H_0^2\Omega_m}{2c^2} \sum_j \delta(i,j) \frac{(r_s - r_j)r_j}{r_s a_j}\ dr_j$$

- From this it is possible to obtain other lensing observables, e.g. shear, magnification, flexion, etc *in the Born approximation*

MICE simulations

MICE
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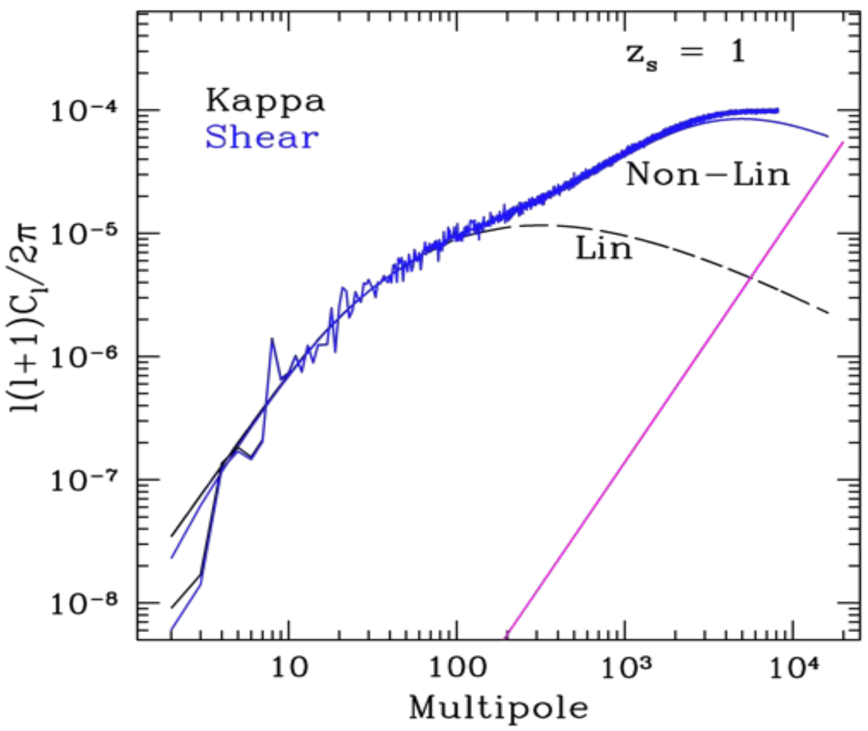
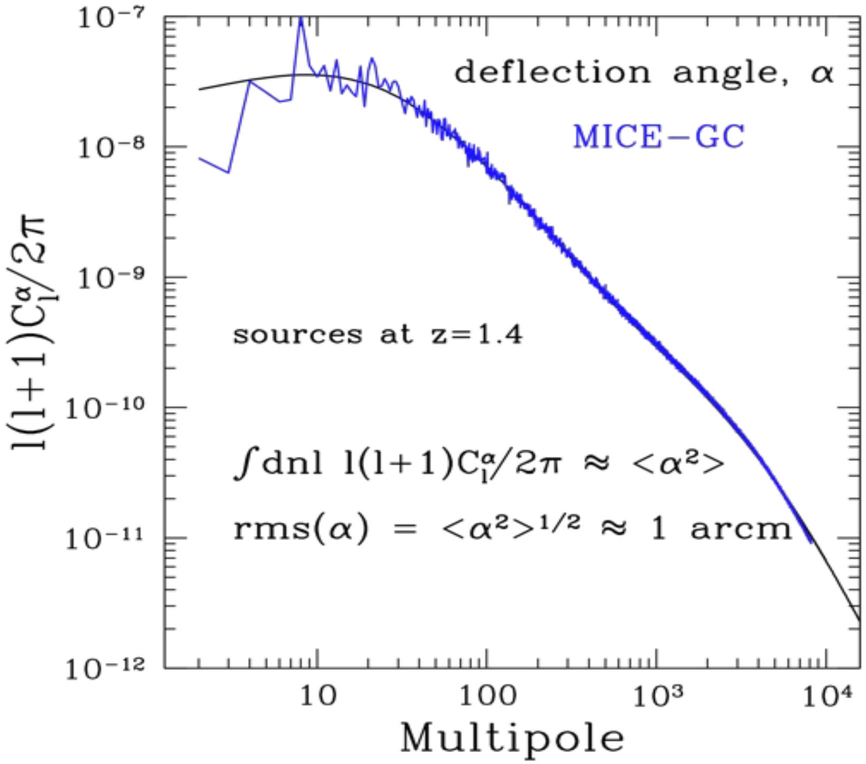
All sky lensing maps

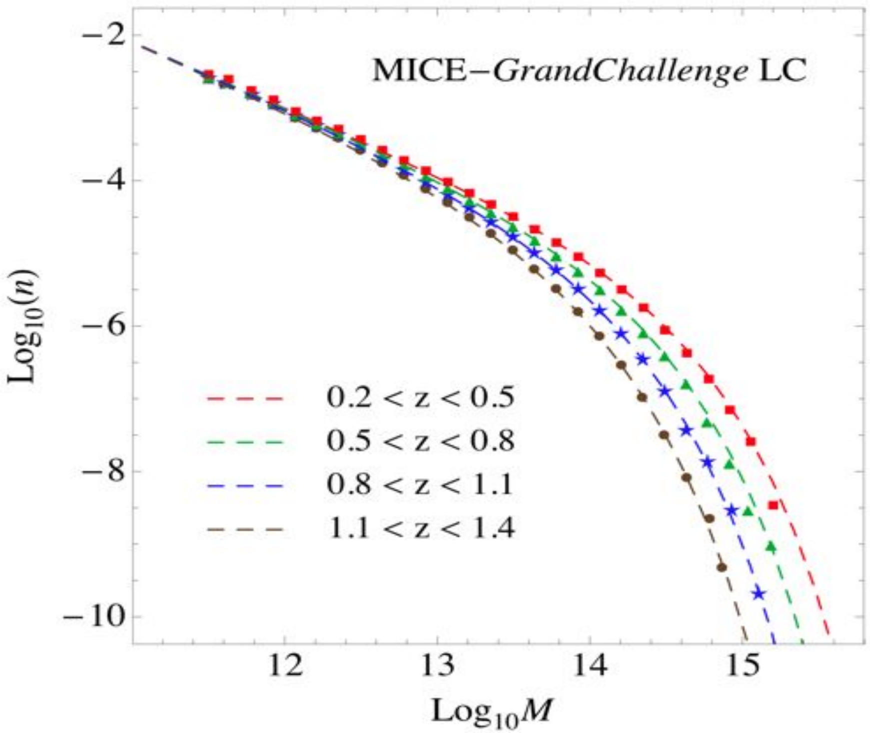


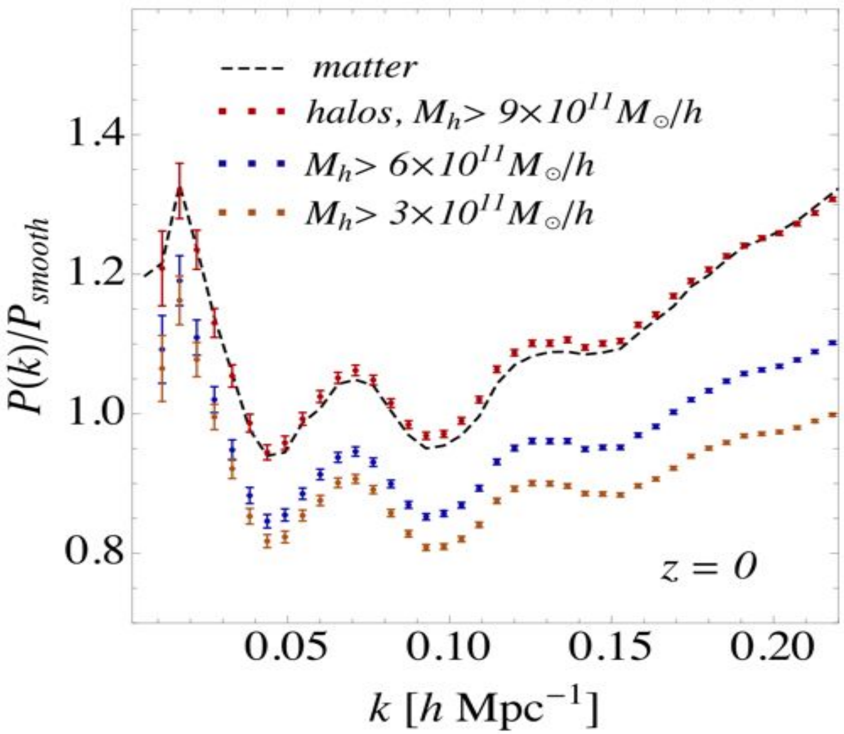


MICE simulations

Halo catalogue

- Select halos with FoF b=0.2; Crocce et al 2010





MICE simulations

MICE
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Simulations

Galaxy Catalogues

- Build mock galaxy catalogues from N-body halos using HOD & SHAM prescriptions
- Generate: positions, luminosities, colours, SEDs and lensing
- Start at z=0 where constraints more stringent
- Constraints
  - luminosity function
  - colour-magnitude diagram
  - clustering as a function of luminosity and colour
- Implement recipes to higher redshifts

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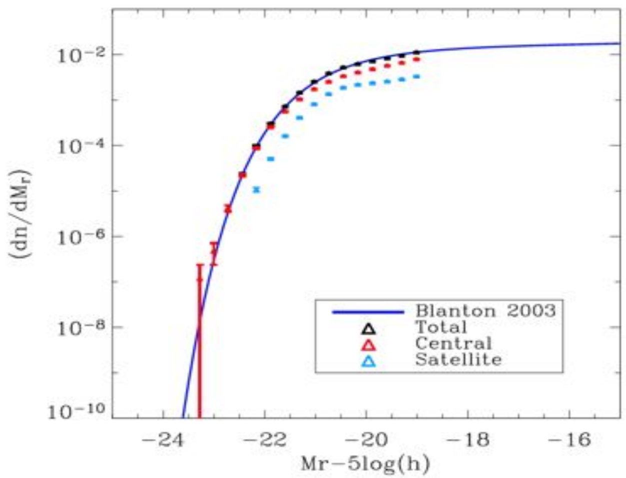
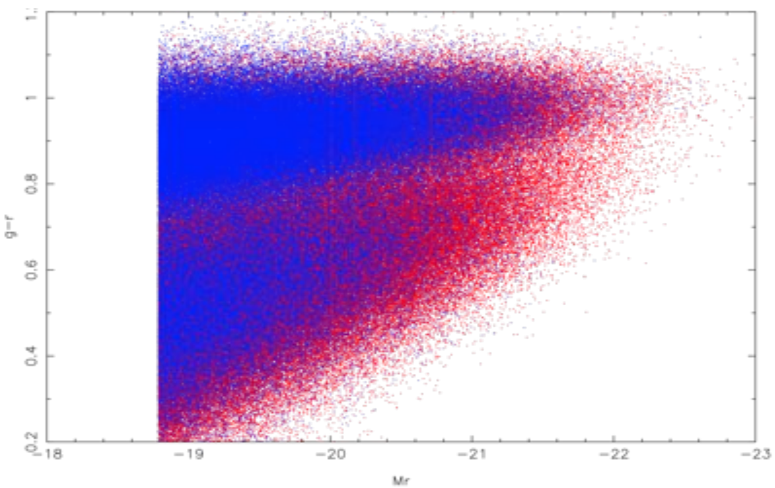
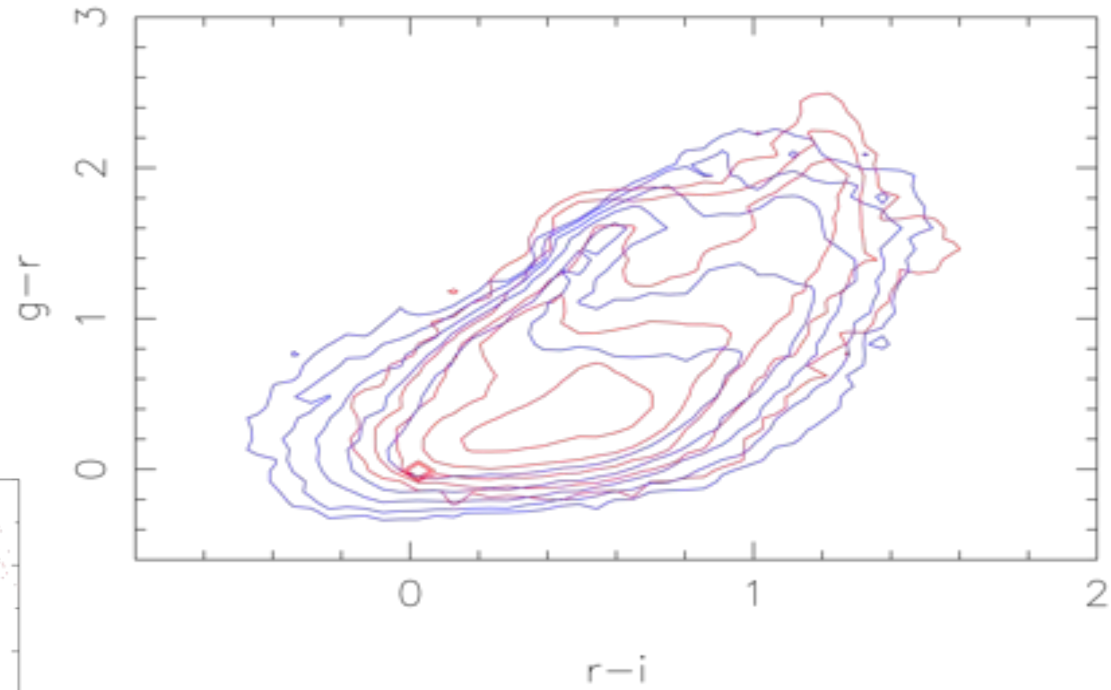
Simulations

MICE simulations

Galaxy catalogue: photometric properties







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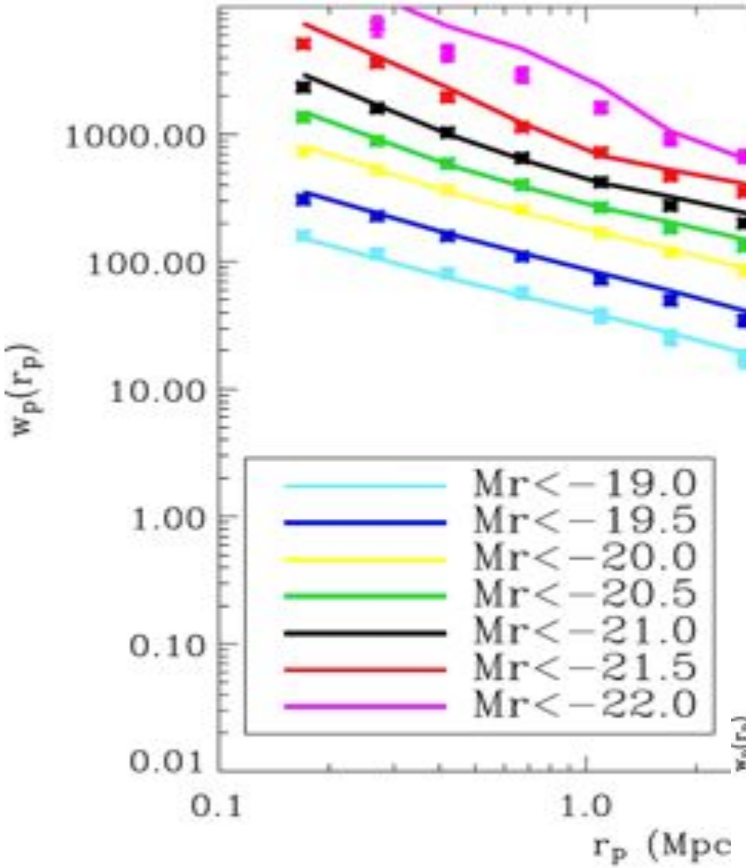
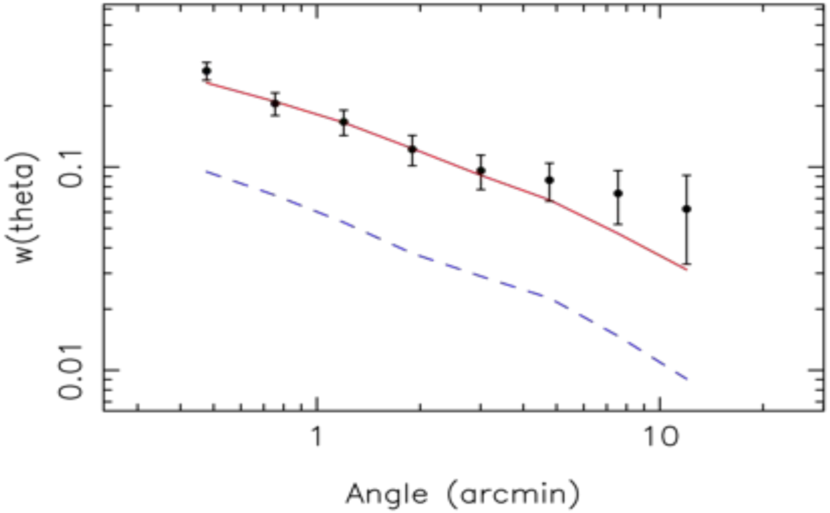
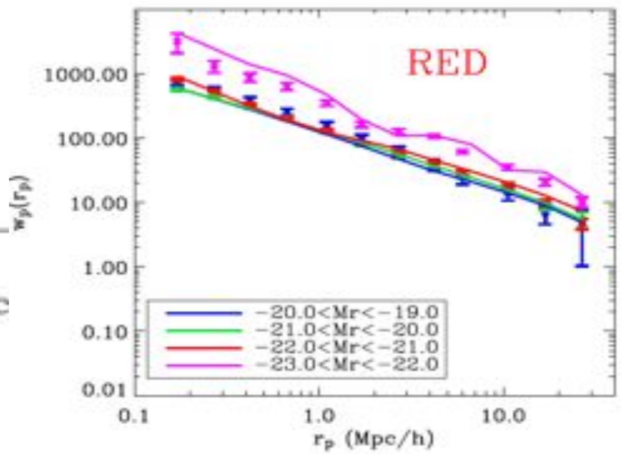
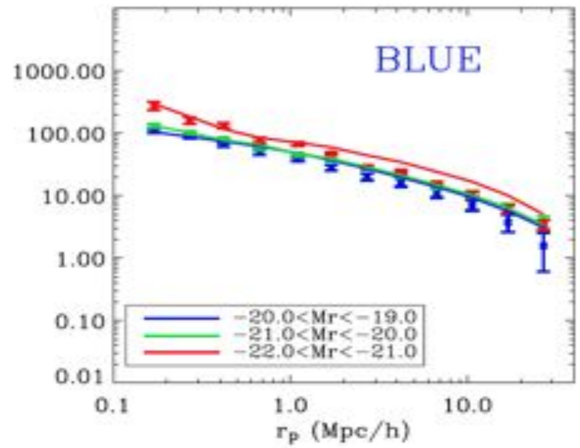
Mock galaxy catalogues

Galaxy Catalogue: clustering









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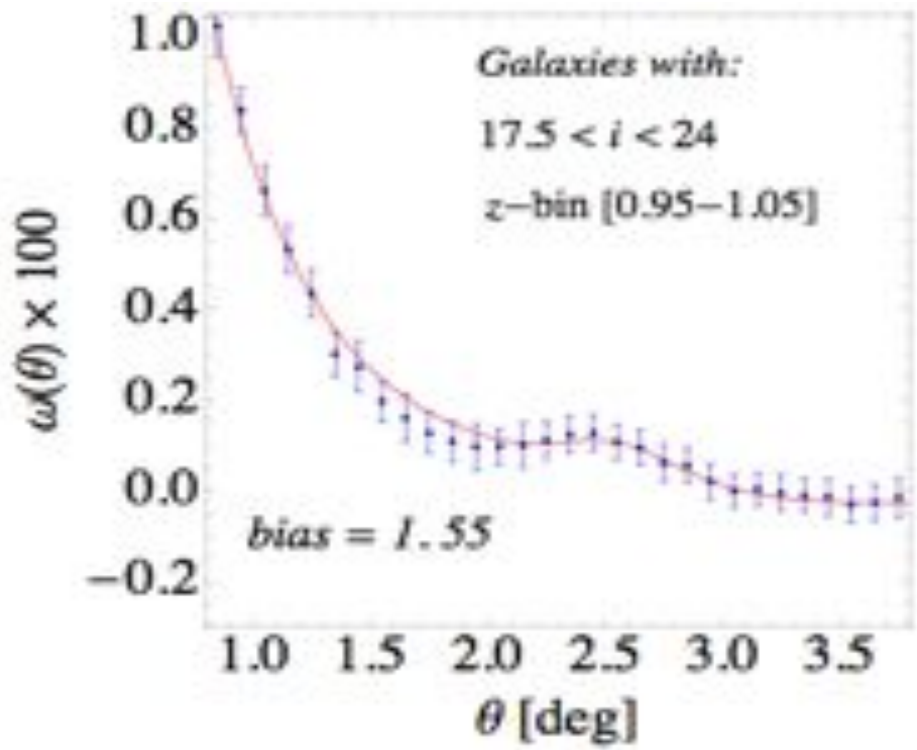
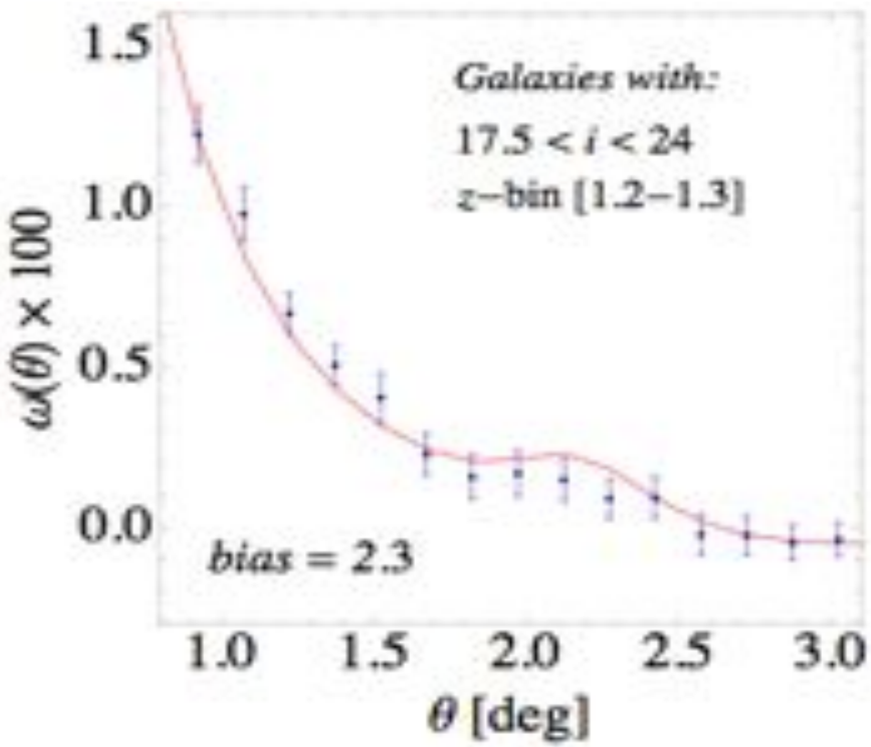
Mock galaxy catalogues

Galaxy catalogues: clustering





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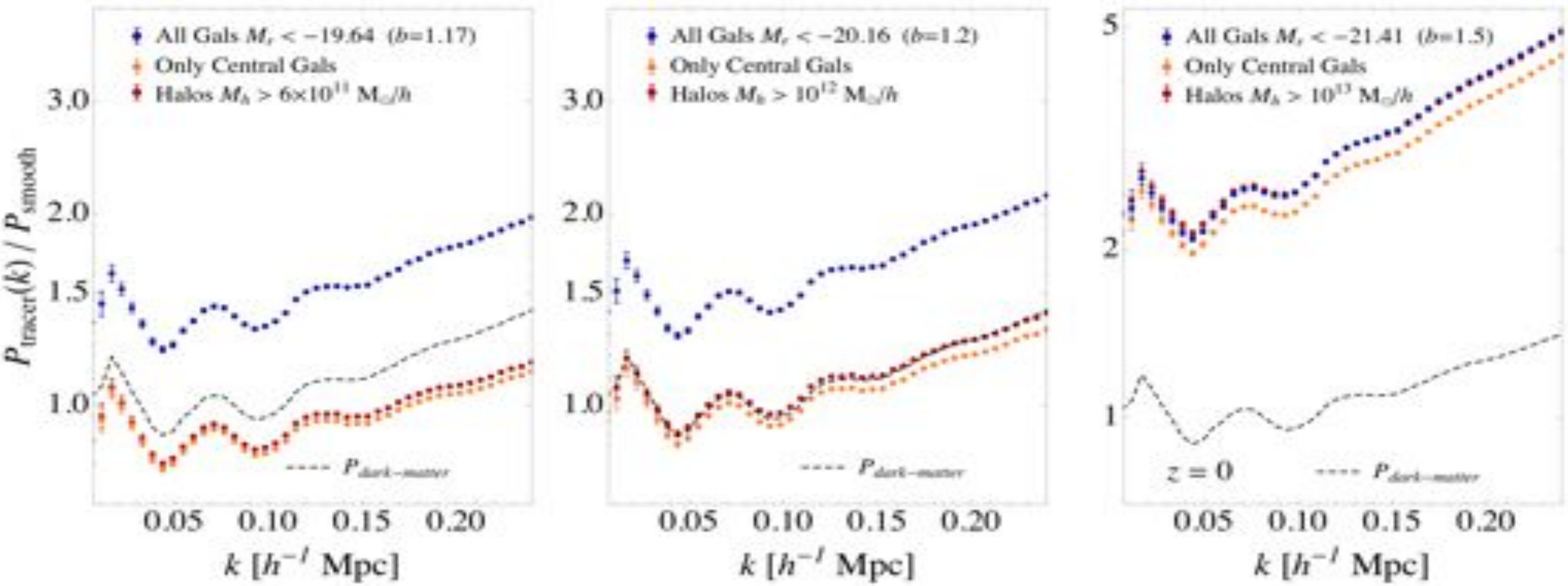
Halo & galaxy catalogue



Mock galaxy catalogues

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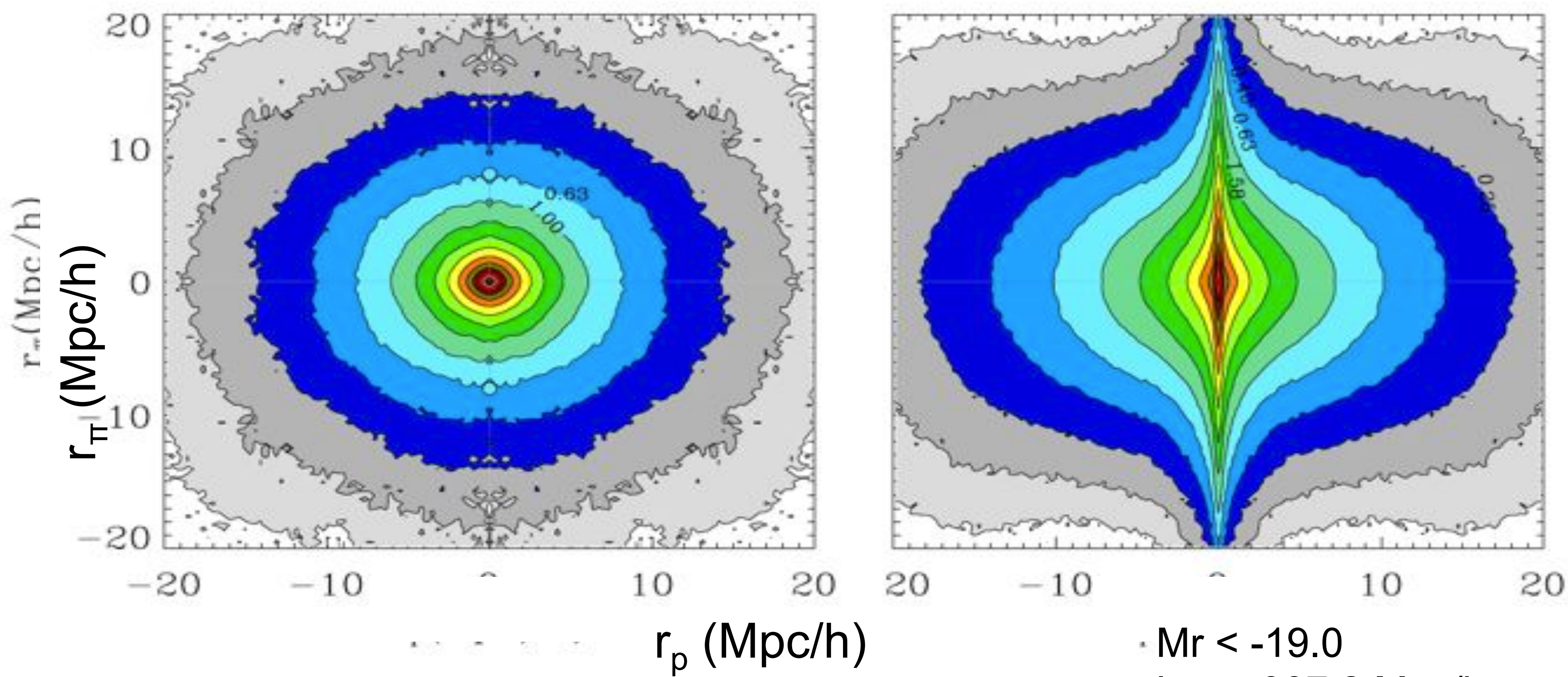
Galaxy Catalogue: Redshift Space Distortions

real space | redshift space



Mr < -19.0
L_{BOX}=307.2 Mpc/h

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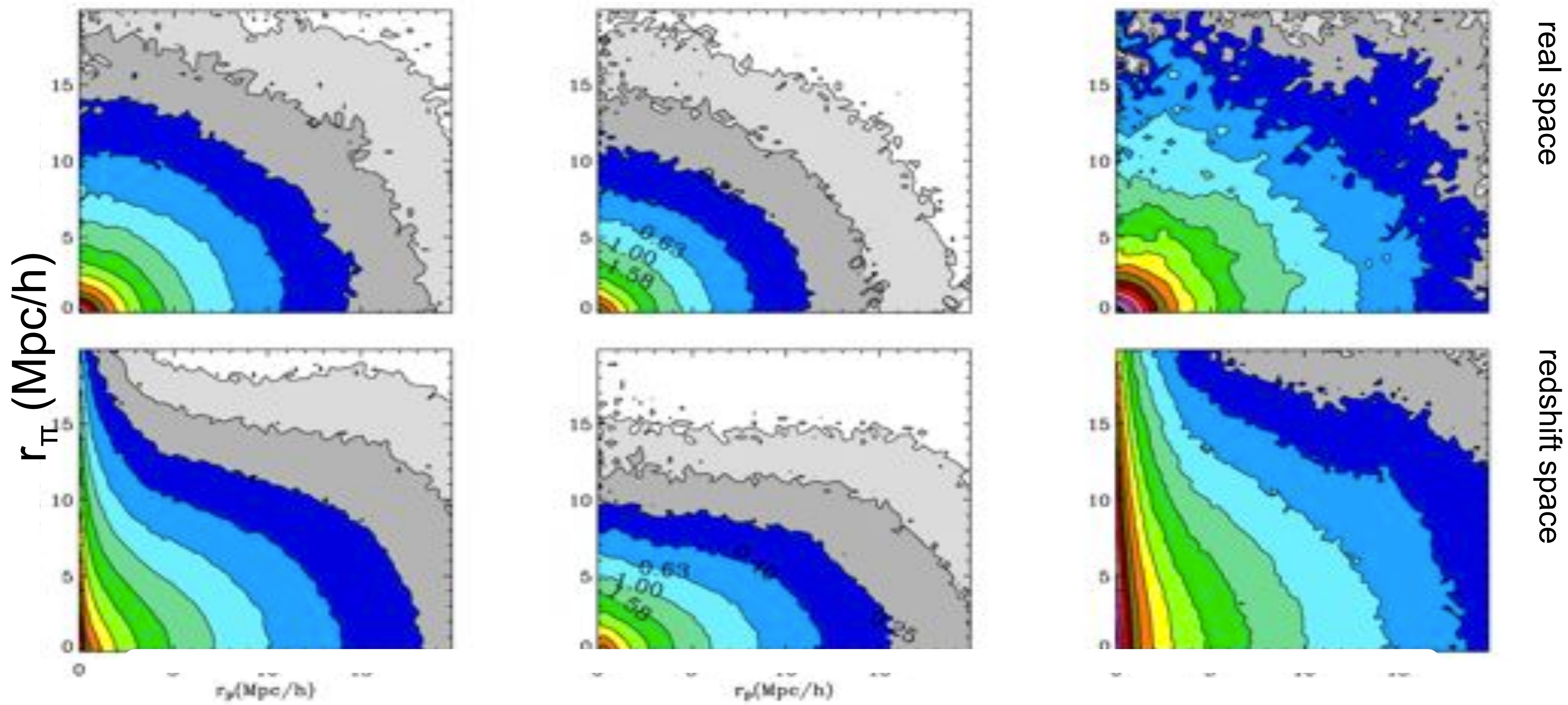
Galaxy Catalogue: Redshift Space Distortions

TOTAL CENTRAL SATELLITE



r_p (Mpc/h)

Mr < -19.0 L_{BOX}=307.2 Mpc/h

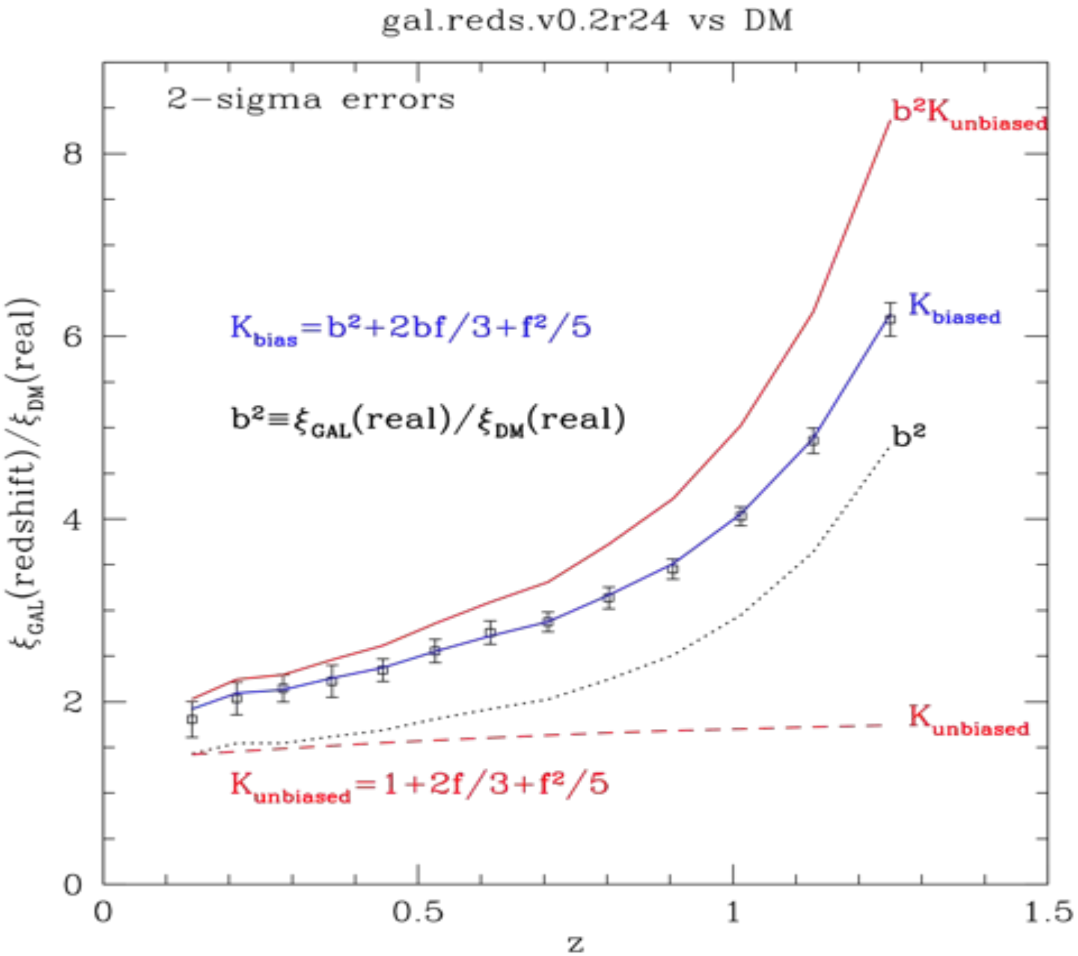
Mock galaxy catalogues

Galaxy Catalogue: Redshift Space Distortions

$$\delta_G(k,\mu) = (b + f\mu^2)\delta_m(k)$$

$$P_{gg}(k,\mu) = <\delta_G^2(k)> = (b + f\mu^2)^2 P(k)$$

$$\xi_{gg} = K(z)\,\xi_{mm}$$
$$K(z) \equiv b(z)^2 + \frac{2}{3}b(z)f(z) + \frac{1}{5}f(z)^2 b(z)^2$$



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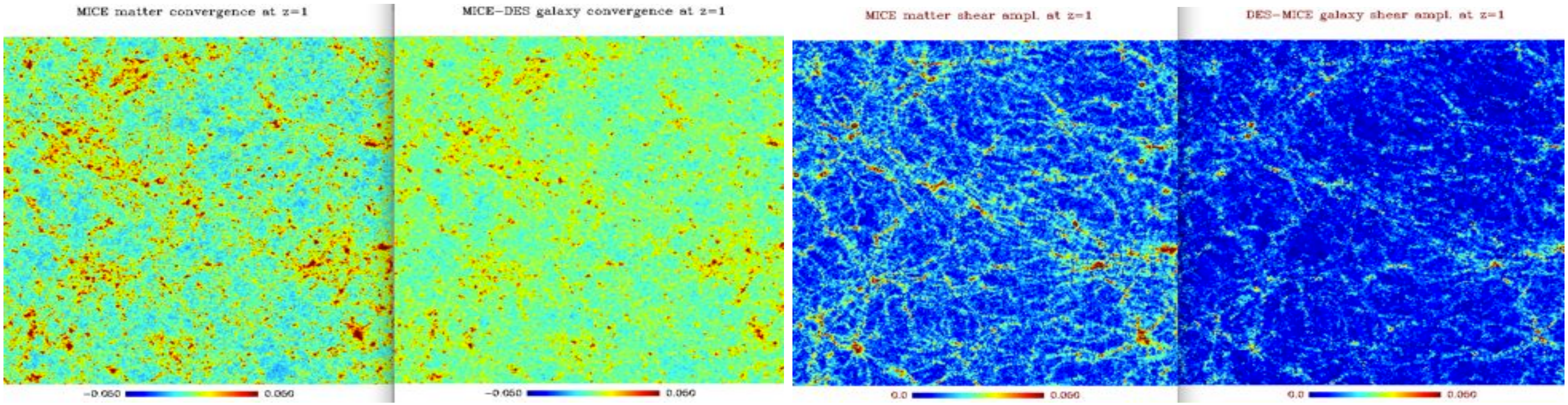
Galaxy catalogue: lensing

- All-sky convergence maps computed in 3D in the LC
- Compute shear in this 3D grid
- Assign convergence and shear to galaxies



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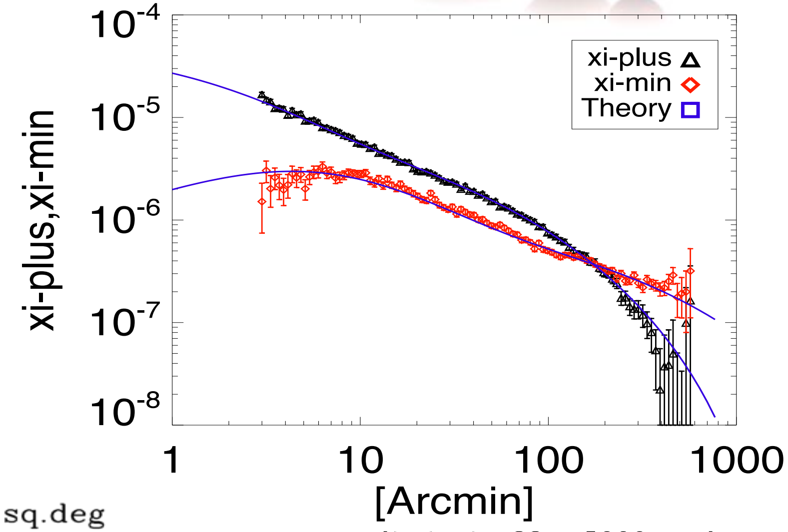
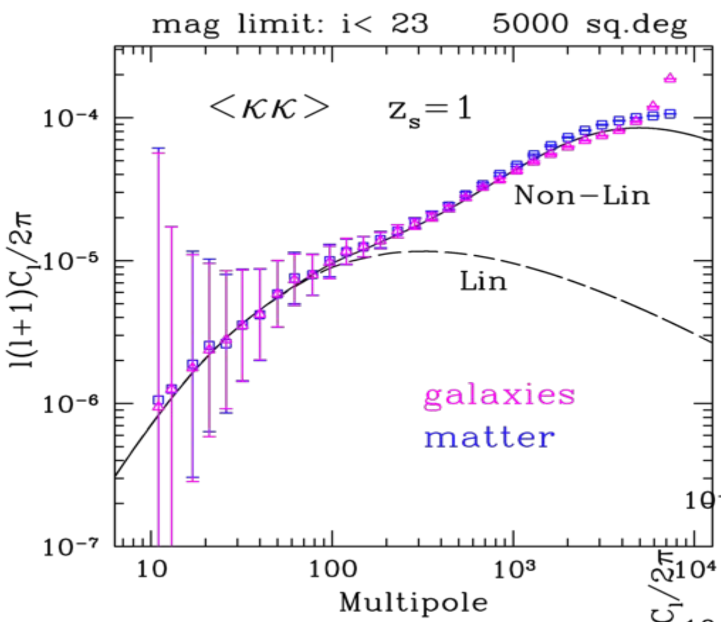
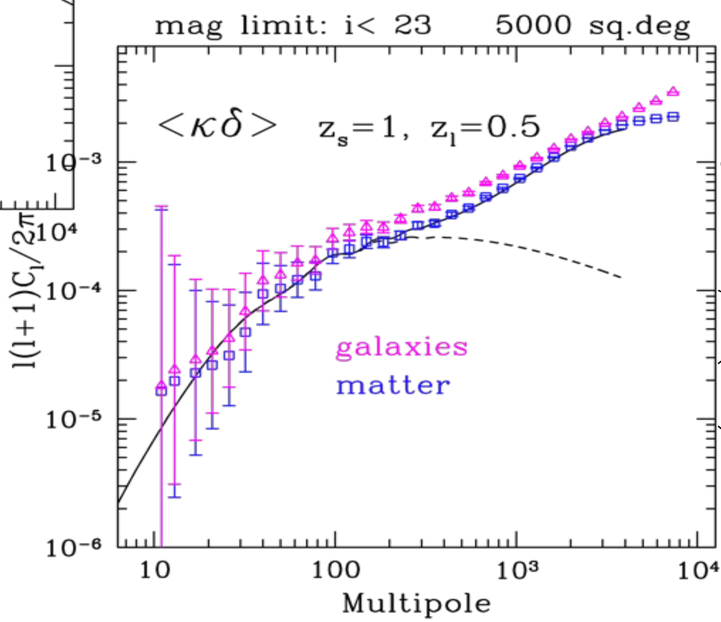
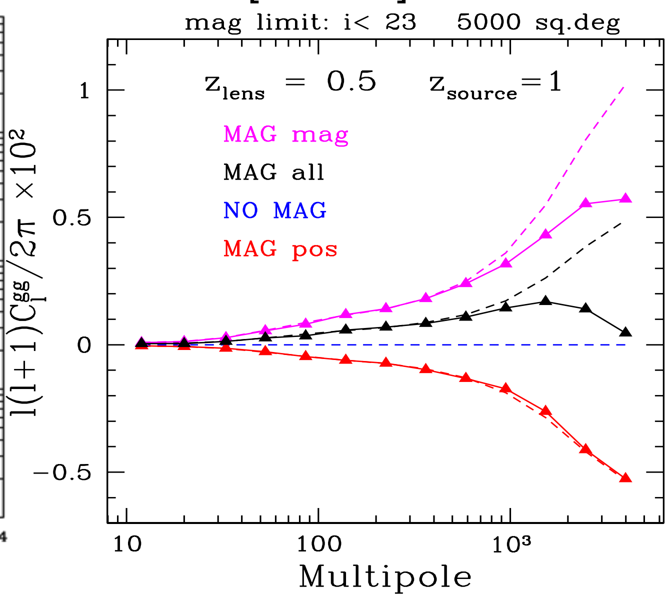
Galaxy catalogue: lensing









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Recent developments

- papers description:
  - Fosalba et al 2013: arXiv: 1312.1707 Dark Matter
  - Crocce et al 2013: arXiv: 1312.2013 Halo & Galaxy Catalogue
  - Fosalba et al 2013: arXiv: 1312.2947 Lensing
  - Carretero et al 2014, submitted galaxy mock method I
  - Castander et al 2014, in prep galaxy mock method II
- improve incompleteness: complete to $i<24$ to $z<1.4$
- increase redshift range: undergoing
- improve SEDs: emission lines added, AGN
- improve lensing resolution: doubled
- improve access portal: cosmohub.pic.es

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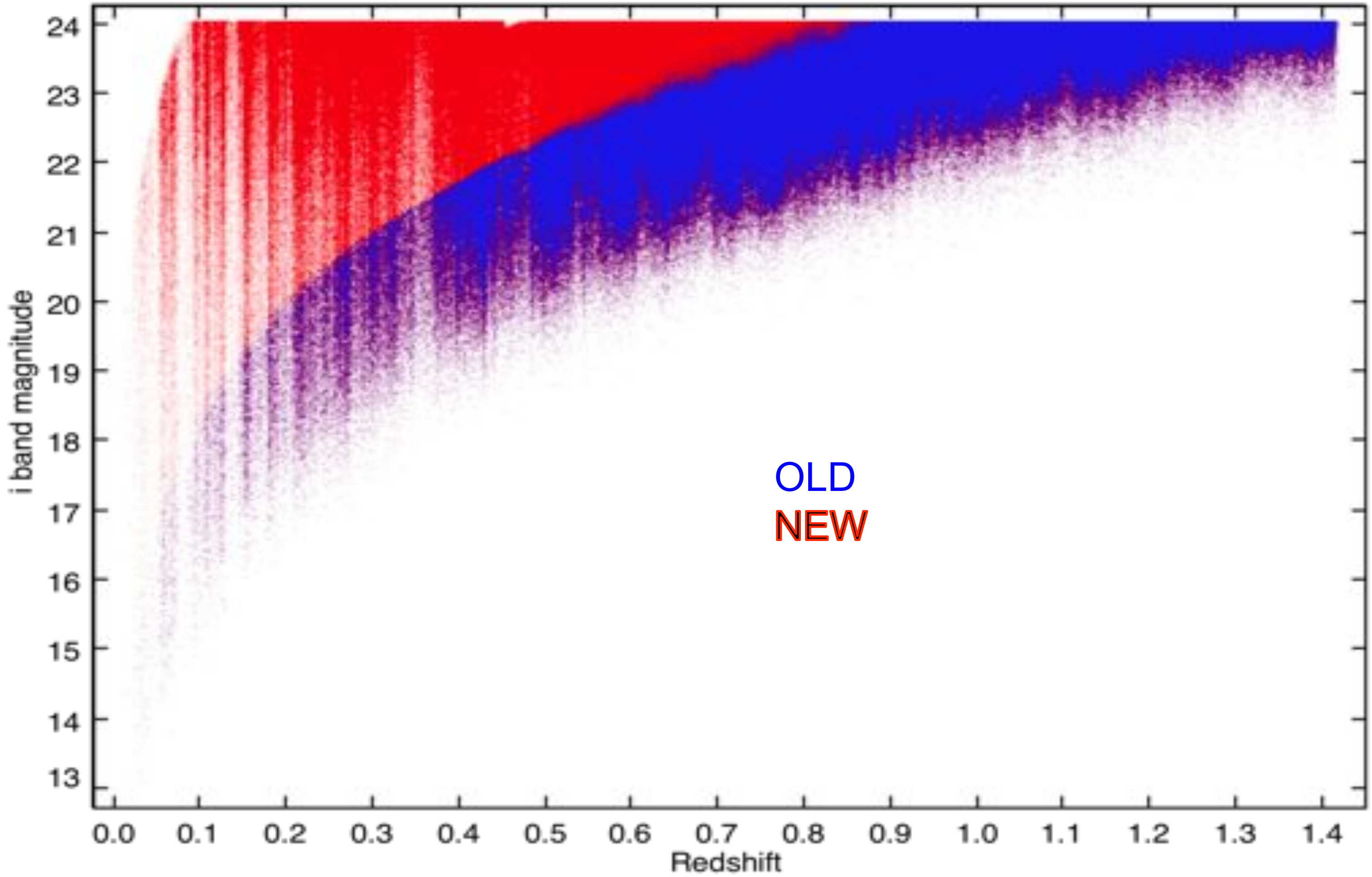
New catalogue



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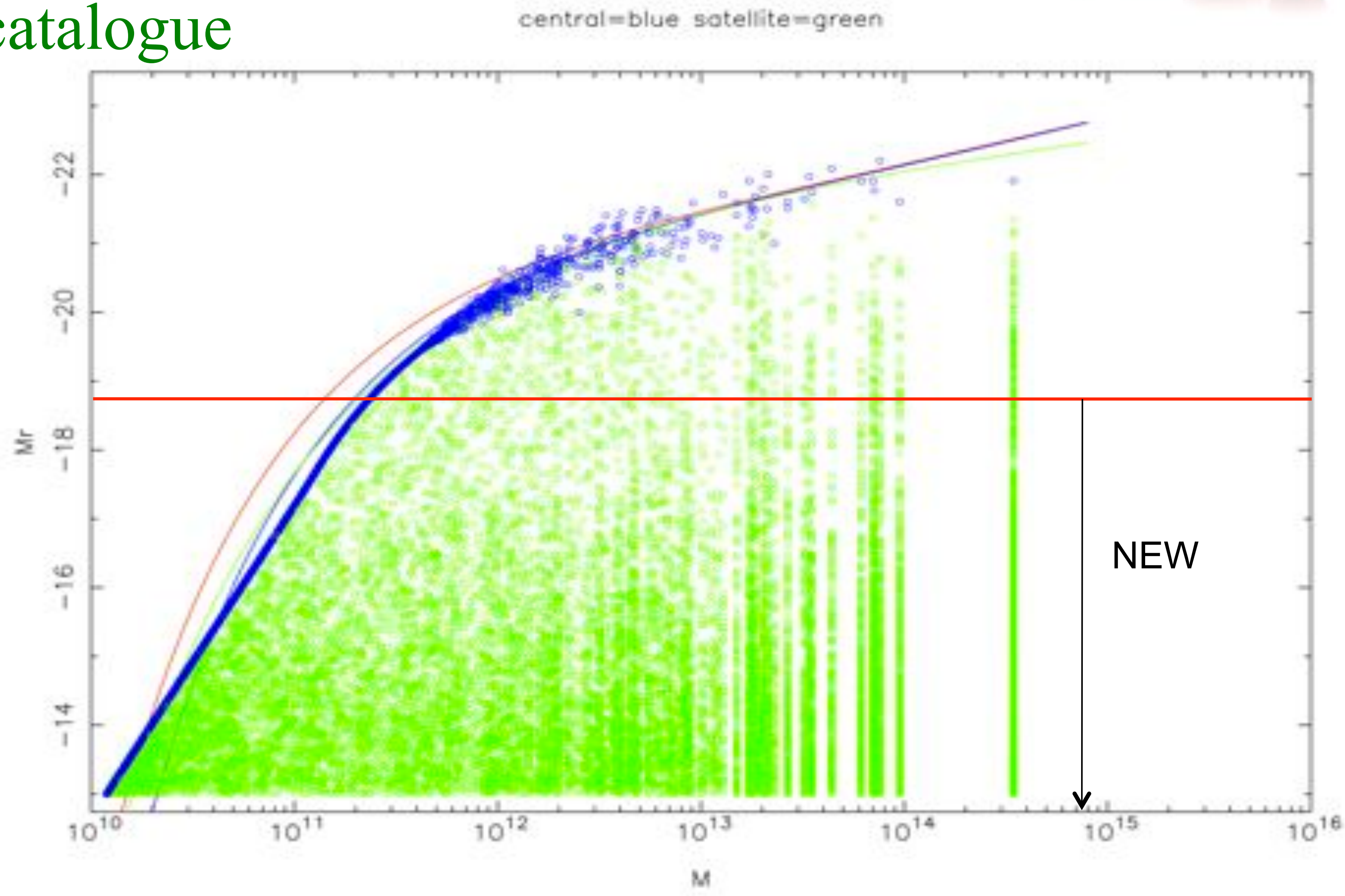

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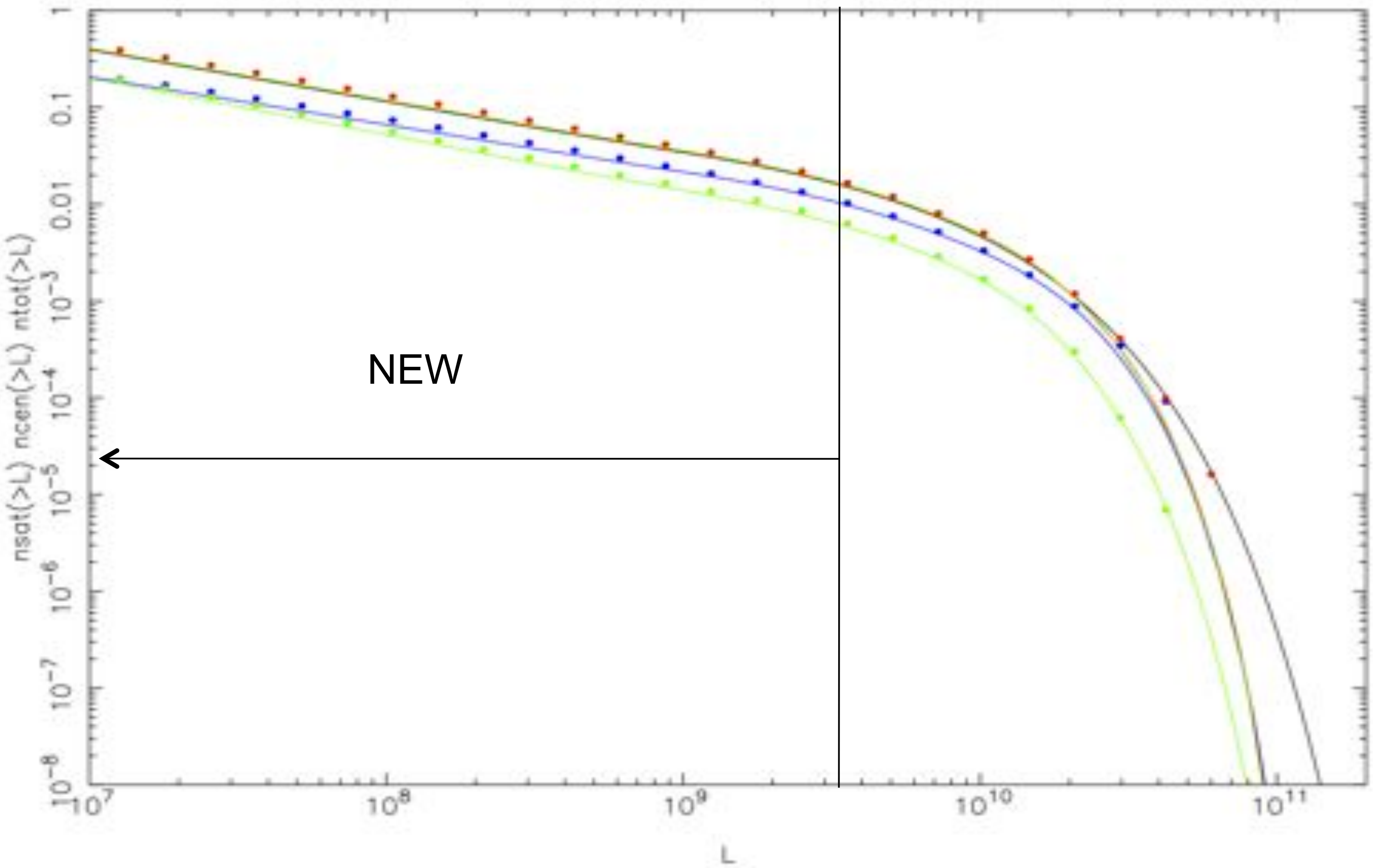

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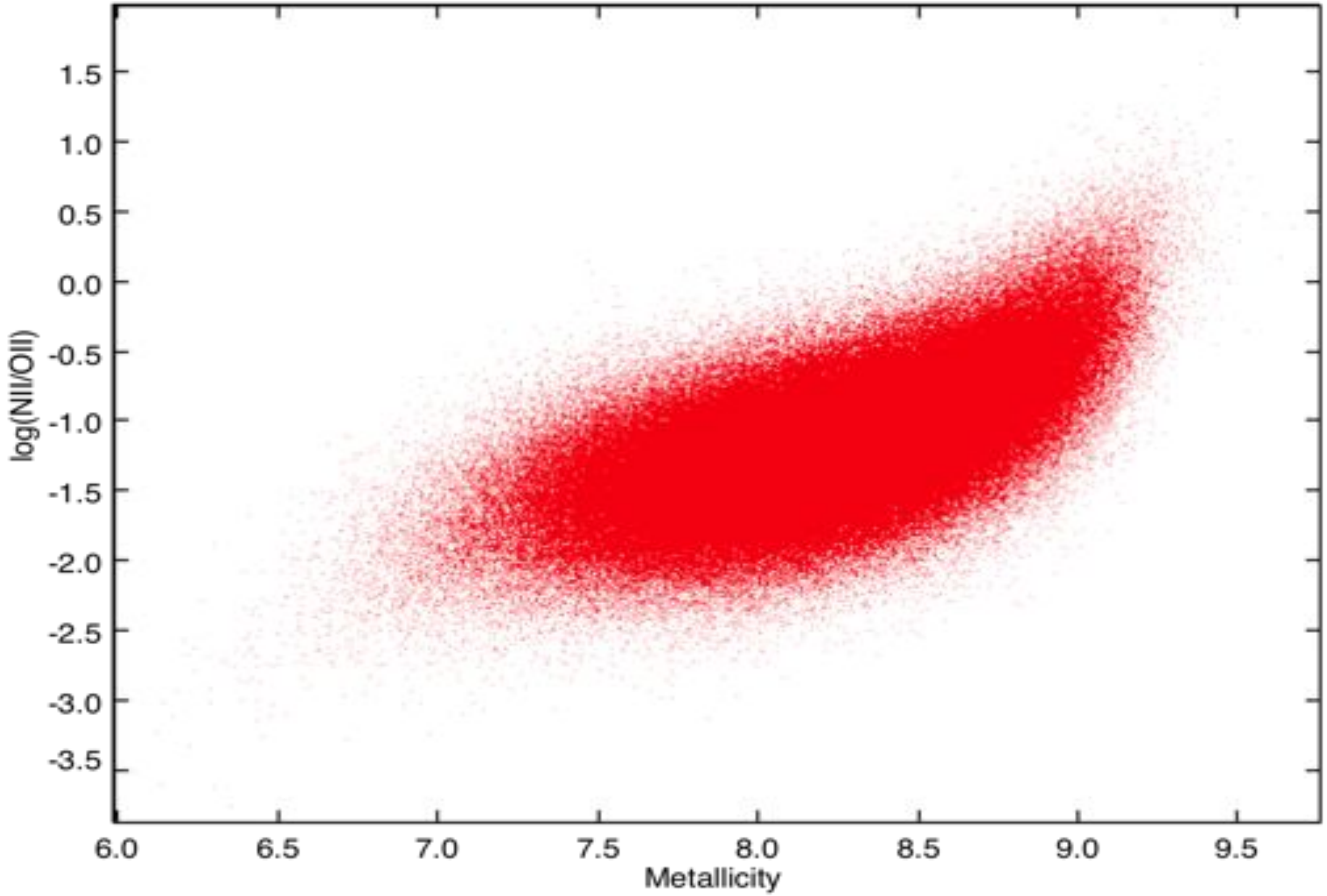

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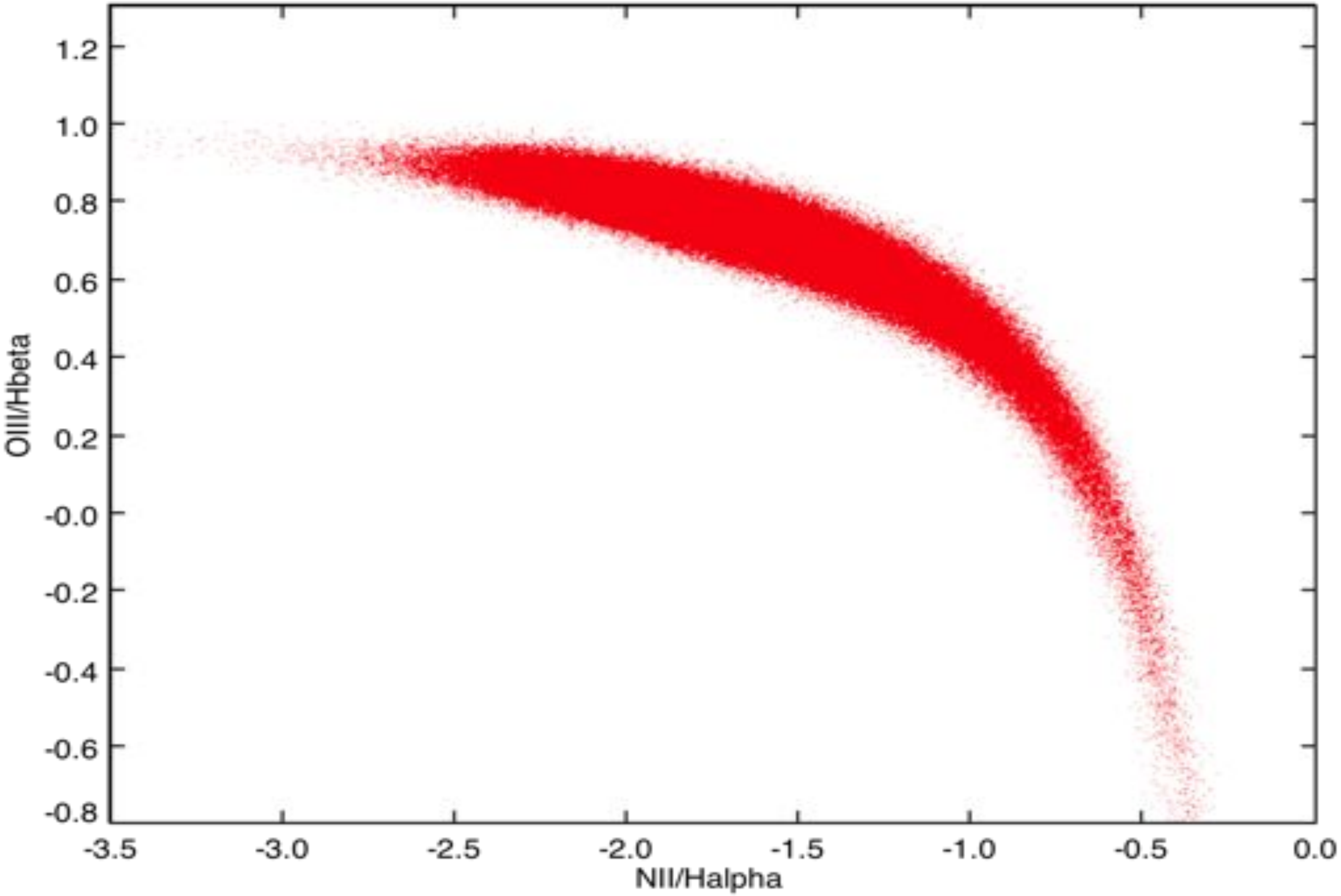

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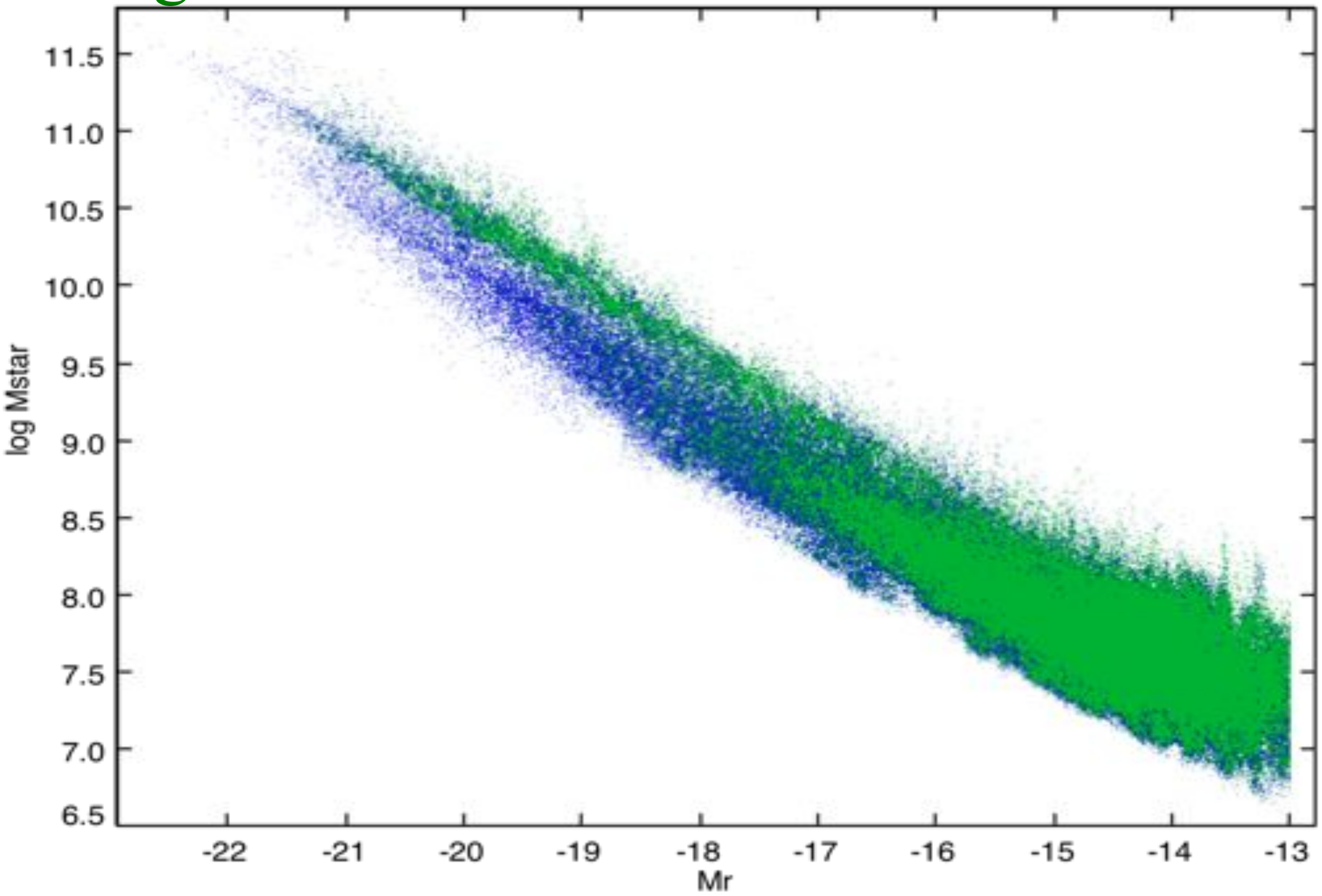

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