ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Weak Lensing with Euclid

Adam Amara
(on behalf of WLWG)

Outline

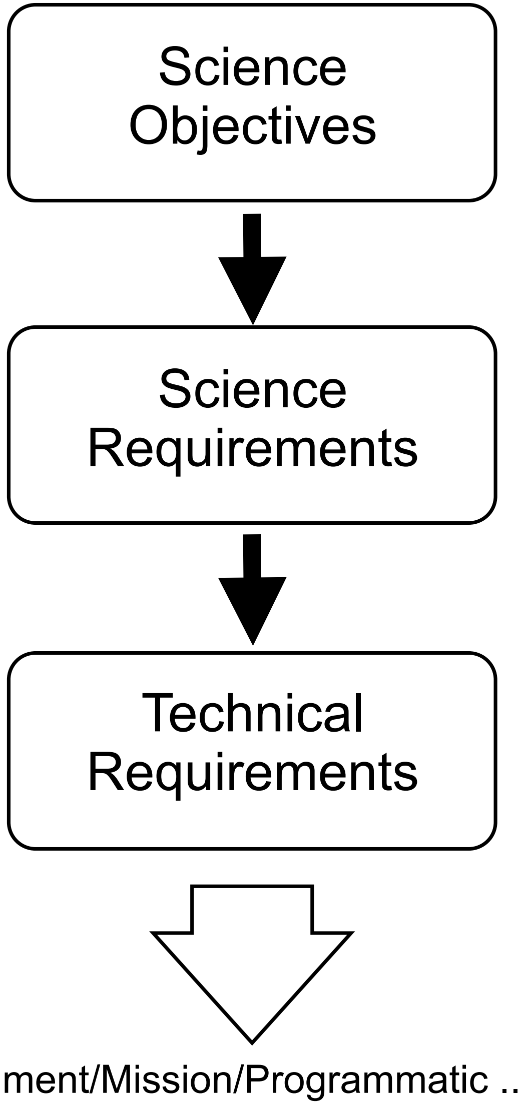
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

1. Weak Lensing Introduction
2. Weak Lensing Science
3. Systematics and Their Treatment

EIC Weak Lensing Working Group

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Adam Amara, (coordinator - ETH Zurich); **Andrew Taylor**, (co-coordinator - U. Edinburgh); Filipe Abdal la, (UCL); Nabila Aghnim, (IAS); Luca Amendola (INAF - OSS.Roma/U. Heidelberg); Vincenzo Antonuccio (INAF - Cantania Astrophys. Obs.); David Bacon (U. Portsmouth); Manda Banerji (UCL/IoA Cambridge); Joel Berge (JPL); Rongmon Bordoloi (ETH Zurich); Julien Carron (ETH Zurich); Frederic Courbin (EPF Lausanne); Eduardo Cypriano (UCL/U. Sao Paulo); Hakon Dahle (U. Oslo); Benjamin Dobke (JPL); Adam Hawken (UCL); Alan Heavens (U. Edinburgh); Benjamin Joachimi (U. Bonn/UCL); David Johnston (Nothwestern U.); Lindsay King (IoA Cambridge); Donnacha Kirk (UCL); Thomas Kitching (U. Edinburgh); Konrad Kuijken (U. Leiden); Ofer Lahav (UCL); Marco Lombardi (U. Milano); Roberto Maoli (U. Roma La Sapienza); Katarina Markovic (UCL/Ludwigs-Maximilians U.); Richard Massey (U. Edinburgh); Massimo Meneghetti (INAF - Oss. Bologna); Stepahne Paulin-Henriksson (CEA Saclay); Mario Radovich (INAF - Oss. Capodimonte); Anais Rassat (CEA Saclay); Justin Read (U. Zurich/U. Leicester); Alexandre Refregier (CEA Saclay); Jason Rhodes (JPL); Anna Romano (U. Roma La Sapienza); Roberto Scaramel la (INAF - Oss. Roma); Michael Schneider (U. Durham); Michael Seiffert (JPL); Fabrizio Sidoli (UCL); Robert Smith (U. Zurich); Jiayu Tang (UCL/IPMU); Romain Teyssier (CEA Saclay/U. Zurich); Shaun Thomas (UCL); Lisa Voigt (UCL)



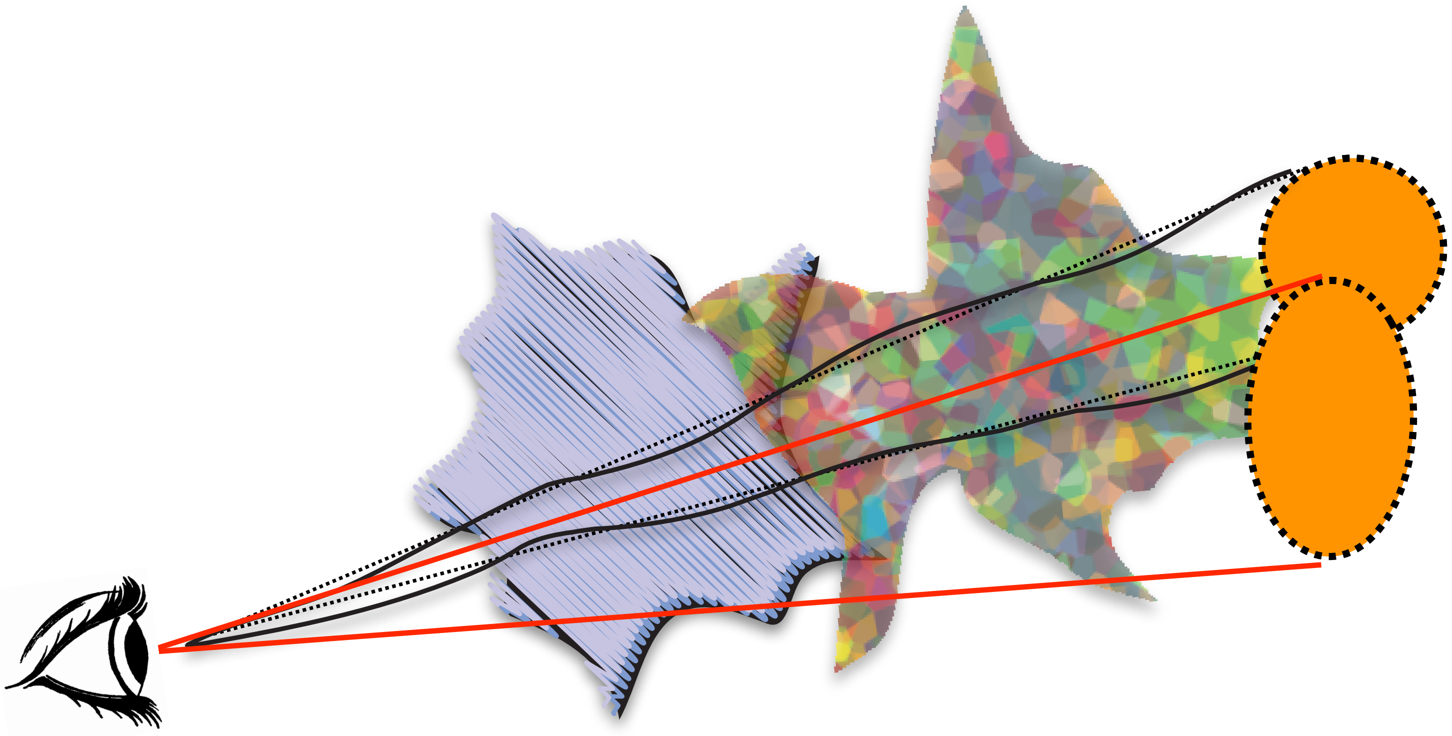
Euclid Primary Science Objectives

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Issue	Our Targets
Dark Energy	Measure the DE equation of state parameters w0 and wa to a precision of 2% and 10%, respectively, using both expansion history and structure growth.
Test of General Relativity	Distinguish General Relativity from the simplest modified-gravity theories, by measuring the growth factor exponent γ with a precision of 2%
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 structures	Improve by a factor of 20 the determination of the initial condition parameters compared to Planck alone.

Weak Lensing

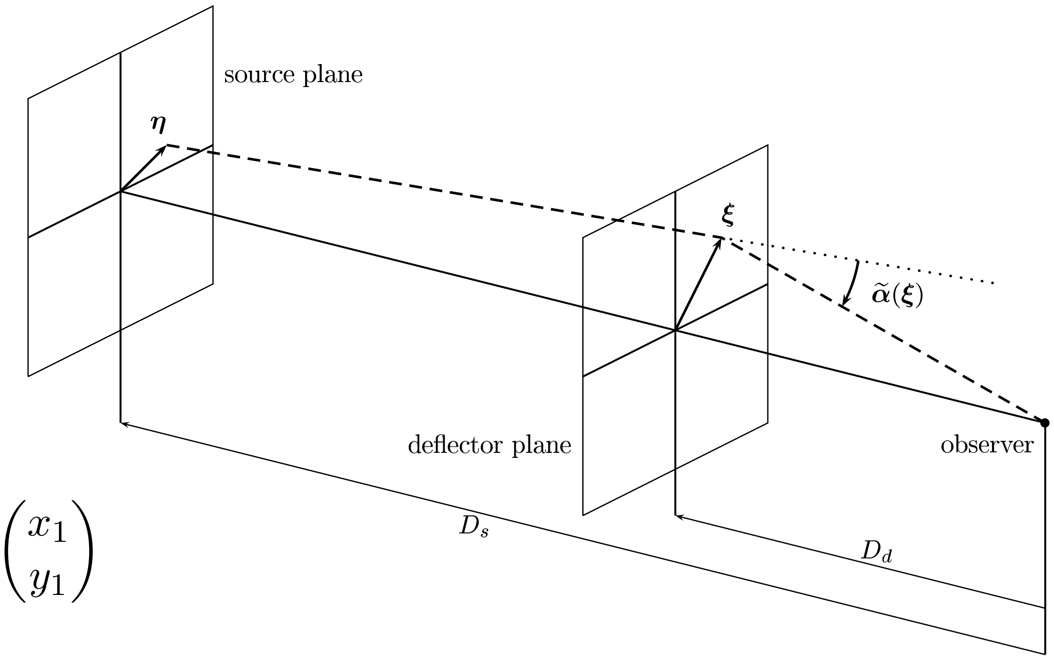
ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



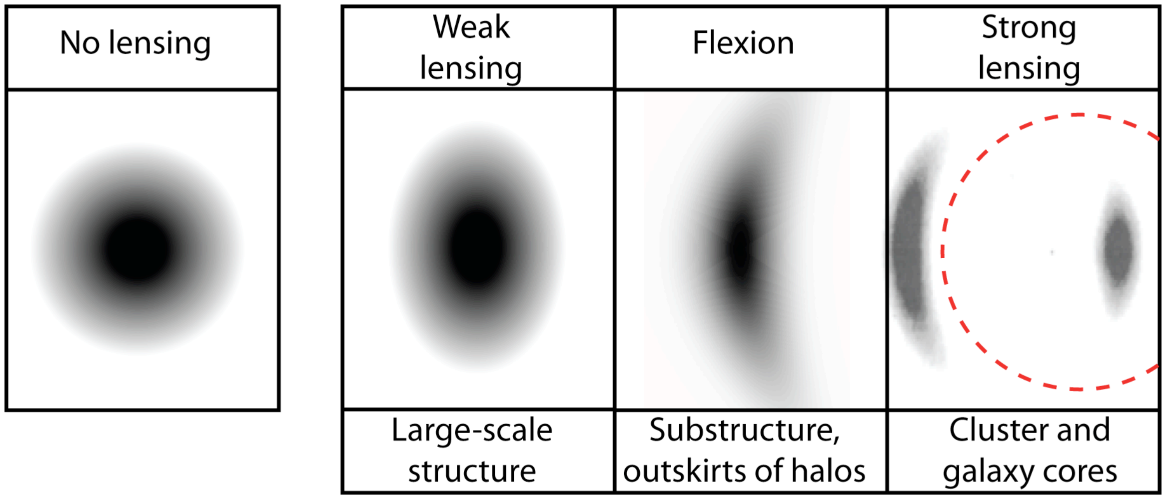
http://icosmo.org

Ray Shooting in Lensing

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

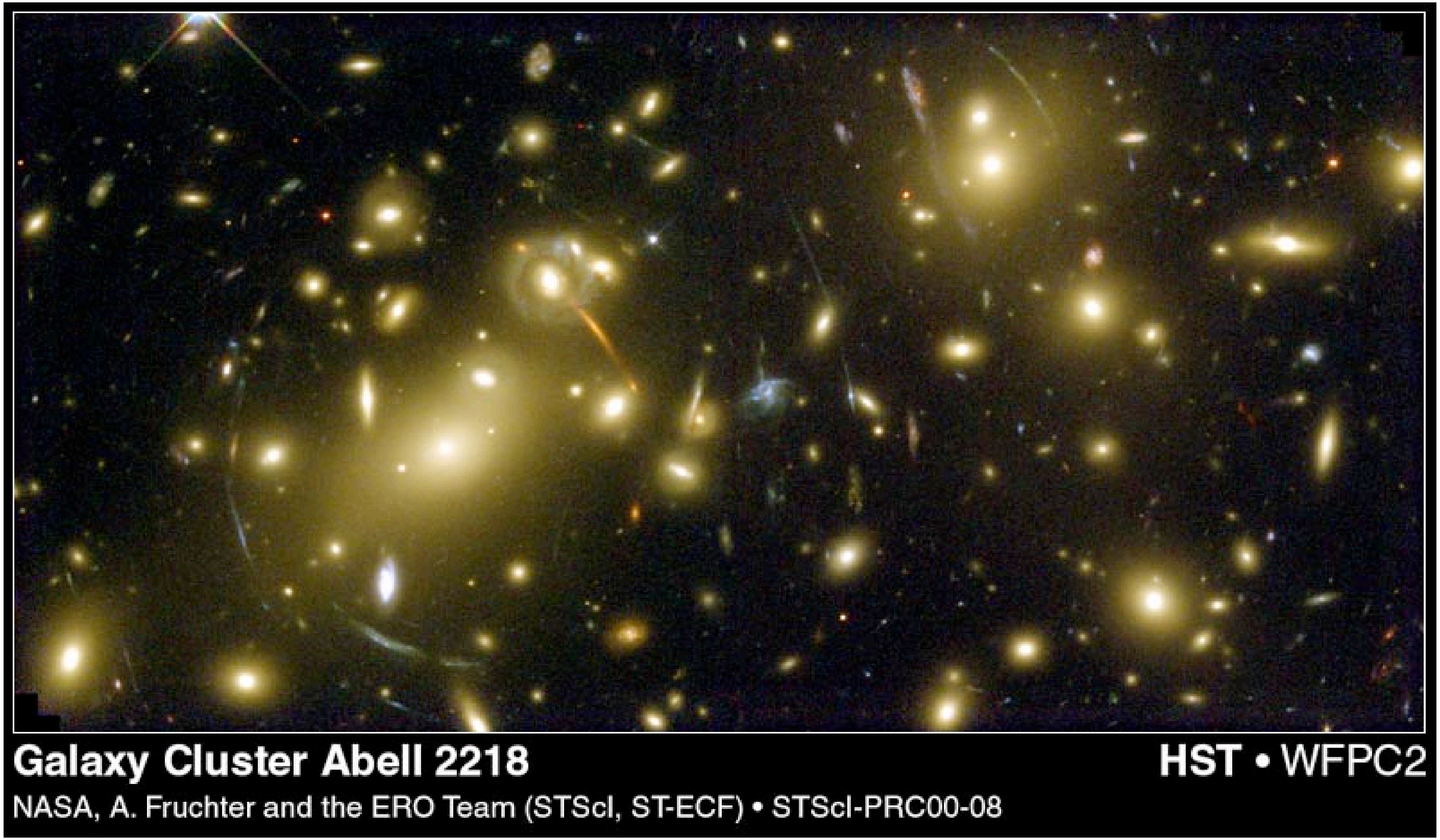


$$\begin{pmatrix} x_2 \\ y_2 \end{pmatrix} = \begin{pmatrix} 1-\gamma_1 & -\gamma_2 \\ -\gamma_2 & 1+\gamma_1 \end{pmatrix} \begin{pmatrix} x_1 \\ y_1 \end{pmatrix}$$



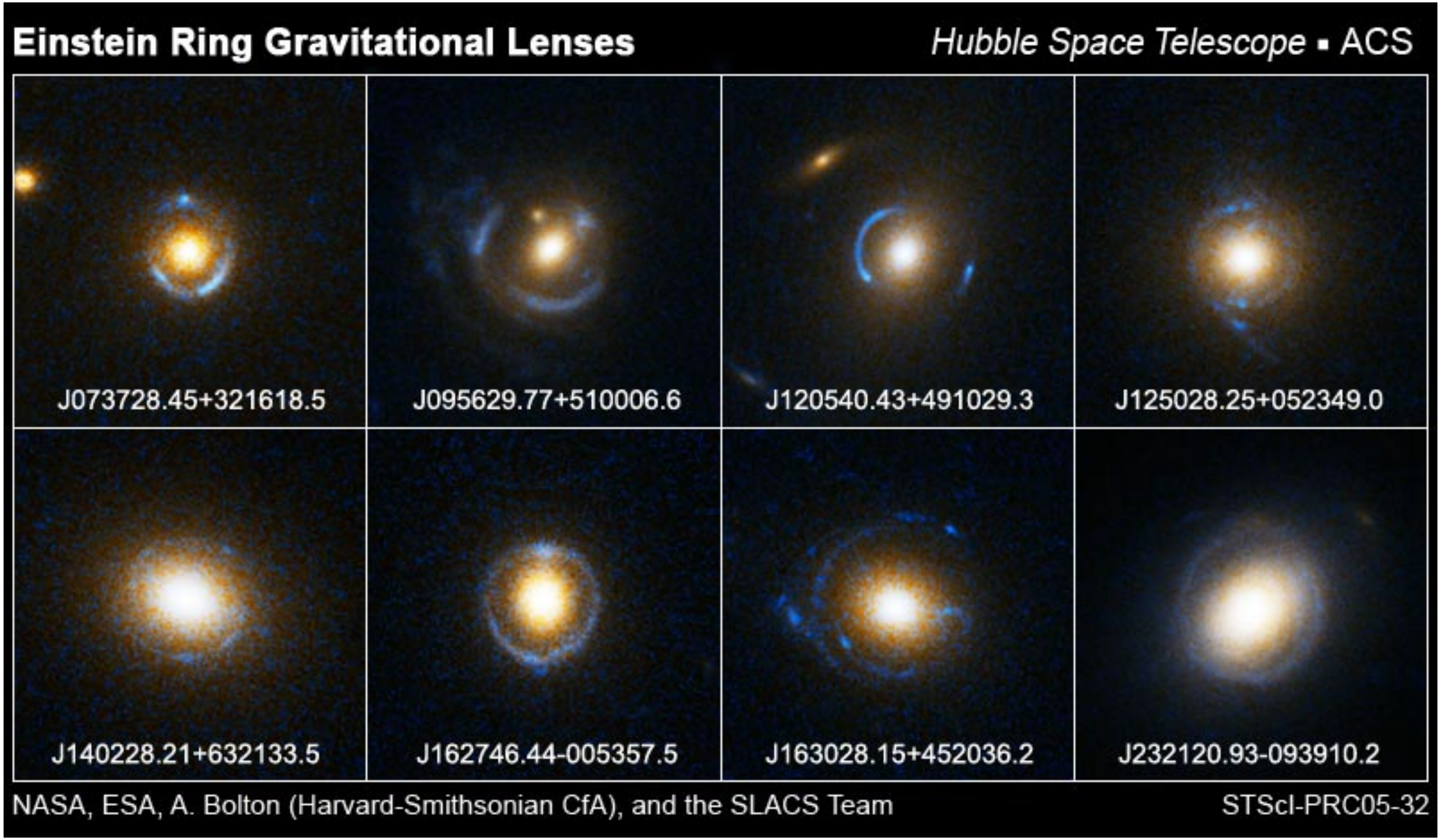
Lensing examples: Giant Arcs

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



Lensing examples: Einstein Rings

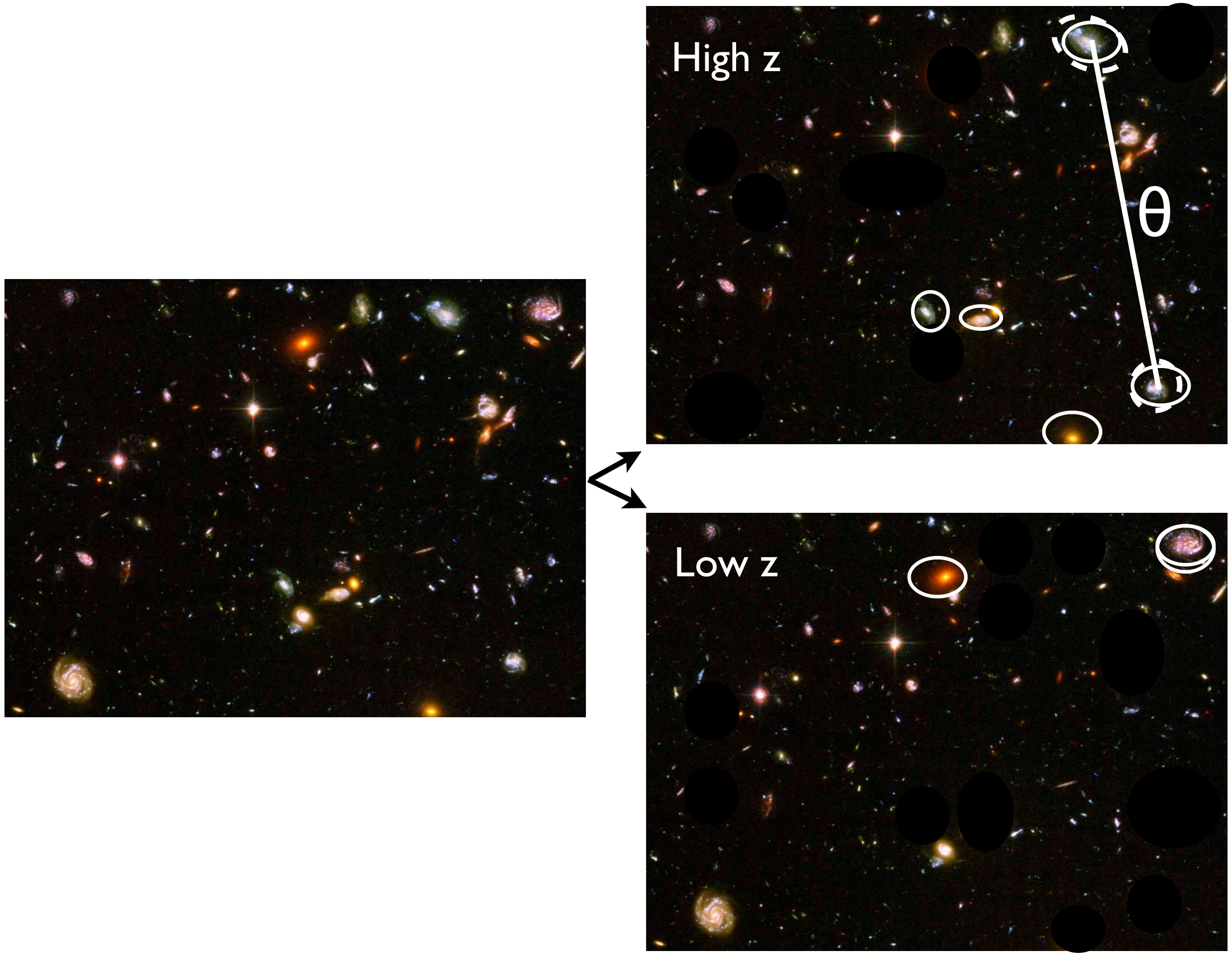
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

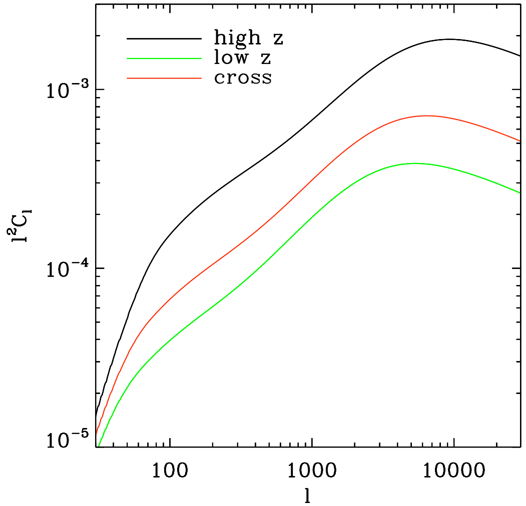


Lensing examples: Cosmic Lensing/Weak Shear

Lensing Tomography

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich





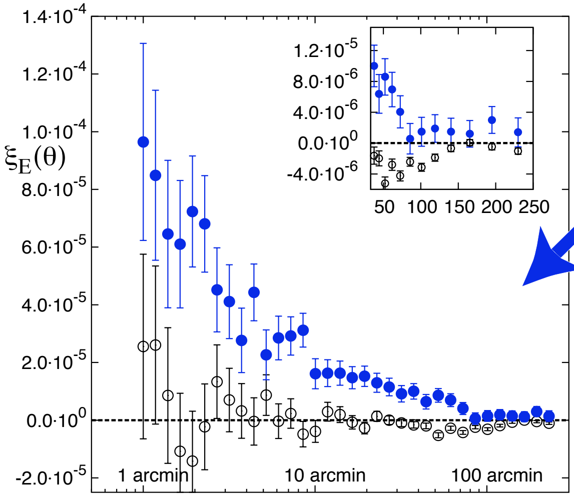
l~1/θ

$$C^{GG}_{\ell(ij)} = \int_0^\infty \frac{q_i(\chi)q_j(\chi)}{\chi^2} P_\delta(k;\chi)d\chi$$

$$q_i(\chi_d) = \frac{3}{2}\Omega_m \frac{H_0^2}{c^2}(1+z_d)\int_0^\infty n_i(\chi_s)\frac{(\chi_s-\chi_d)\chi_d}{\chi_s}d\chi_s$$

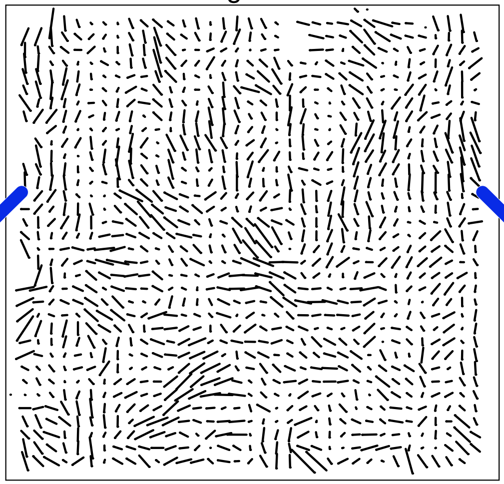
Weak Lensing Correlations and Mass Reconstruction

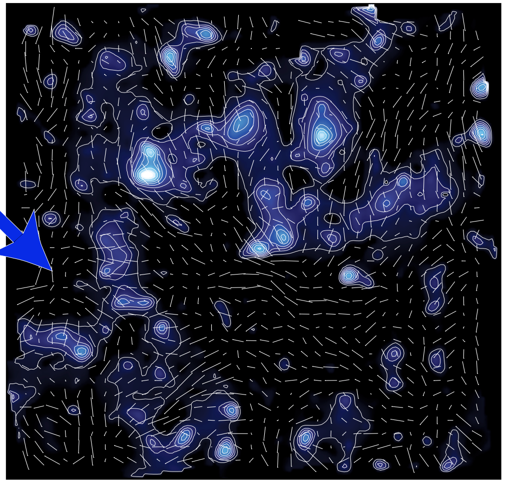
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



Correlation function

Raw lensing measurement





Dark matter distribution

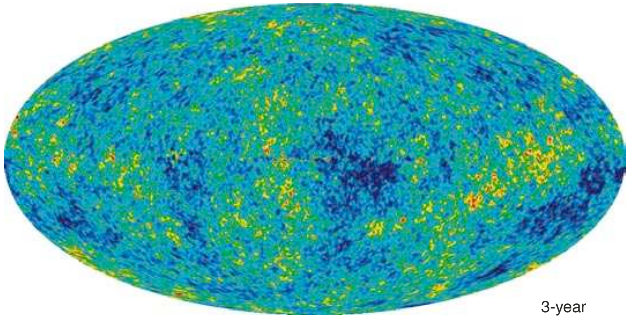
Fu et al 2006

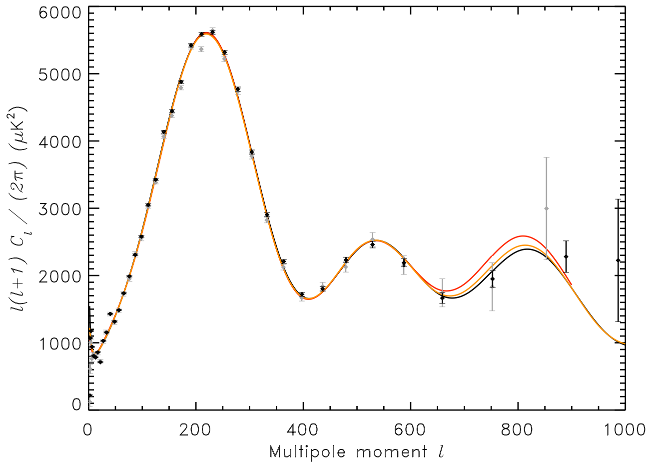
Massey et al 2007

Temperature map

WMAP 3 year data

CMB

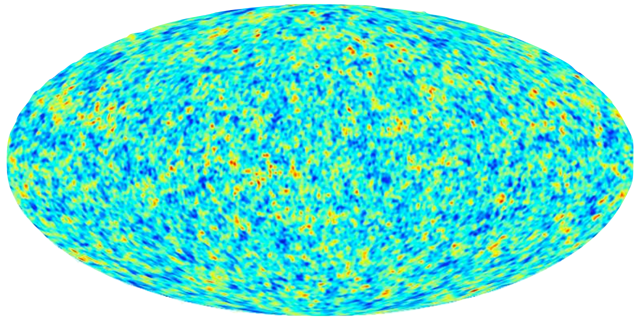


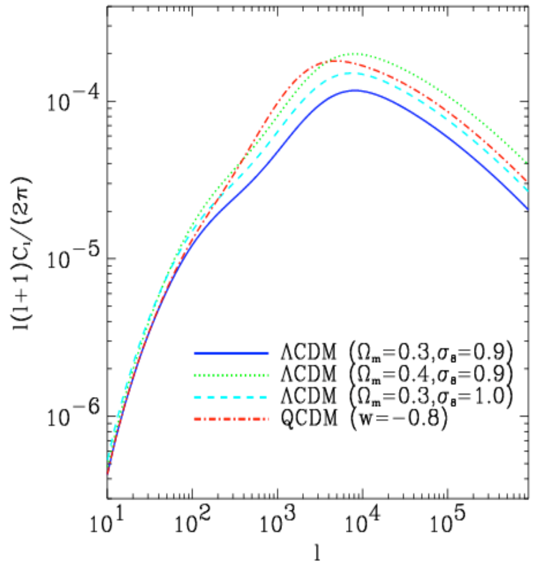


Mass map

Simulated Euclid data
(simulations by Tessyier et al 2008)

Cosmic Shear

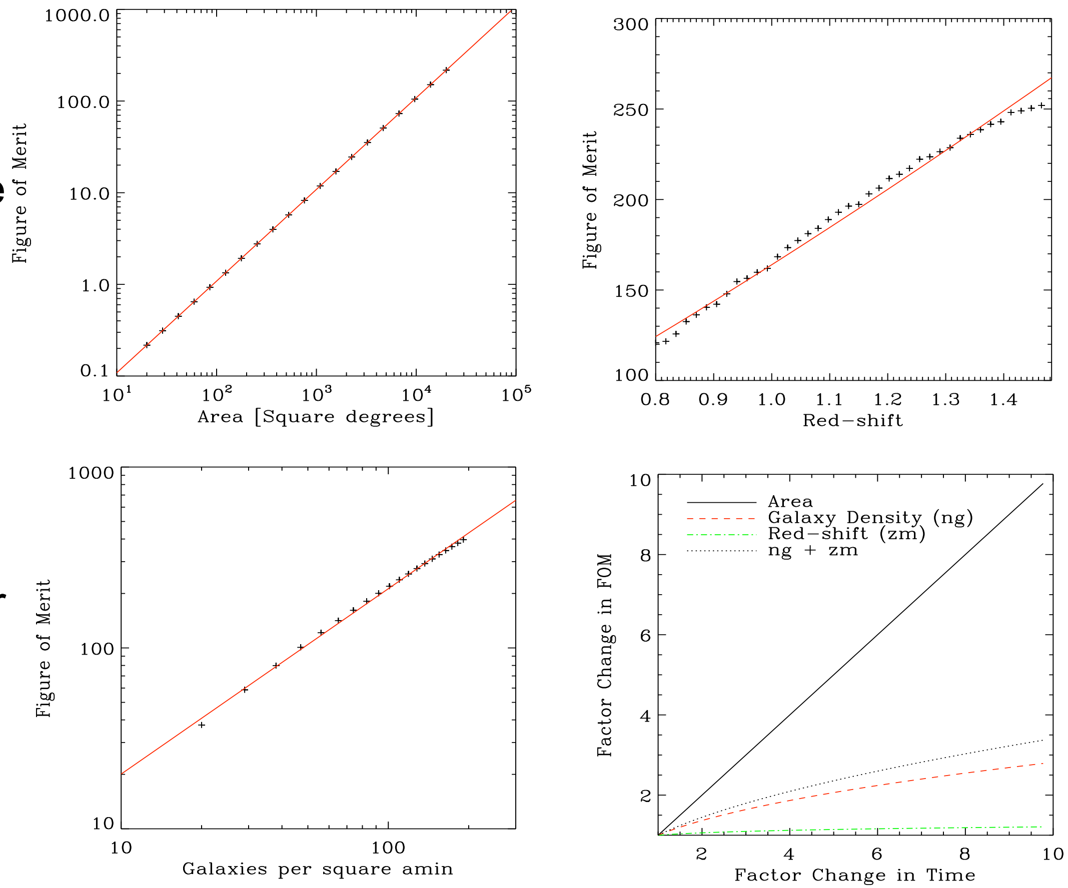




Survey Geometry

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

- Dark Energy Figure of Merit:
  - $FOM=1/(\delta w_n \delta w_a)$
- Wide field imaging survey has three basic properties:
  - Area (A_s)
  - Median redshift (z_m)
  - Number of galaxies (n_g)

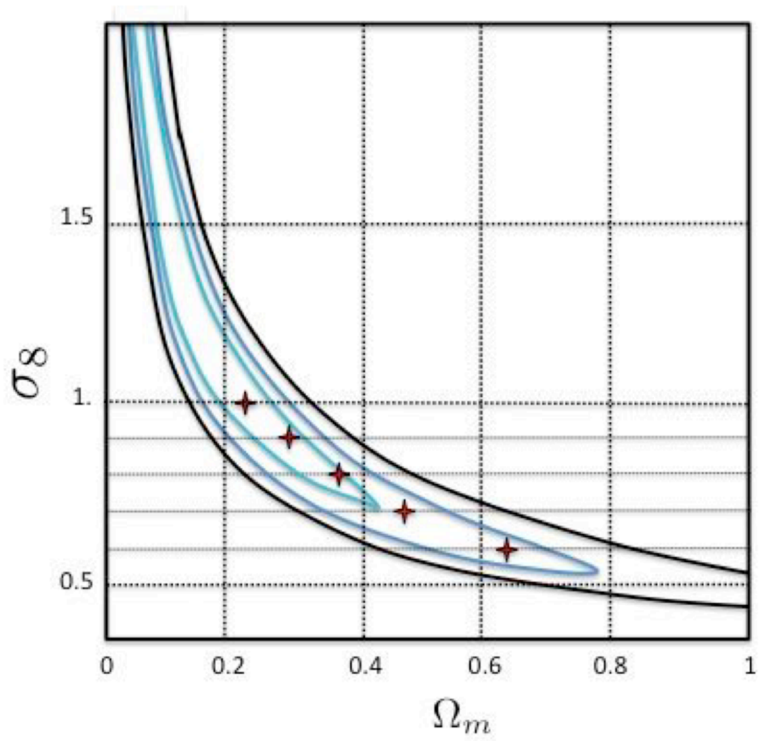


- Choice between wide and deep
- When the median redshift is greater than 0.8 it is always better to go wide
- Constructed a simple scaling relation for survey designers

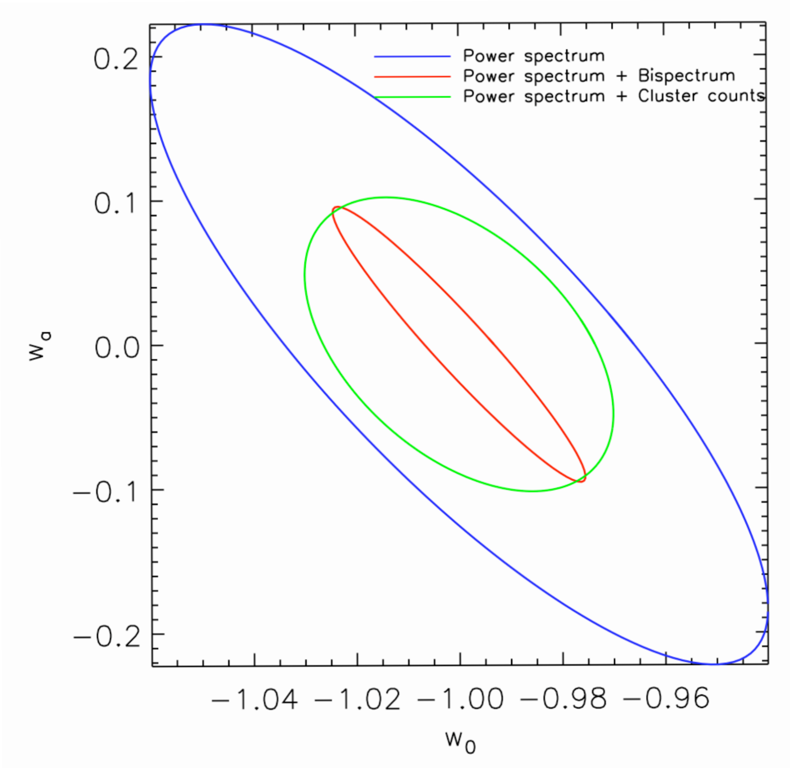
Amara and Refregier (2007)

Weak Lensing Two-Point Correlation Function and More

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



Pires et al 2009

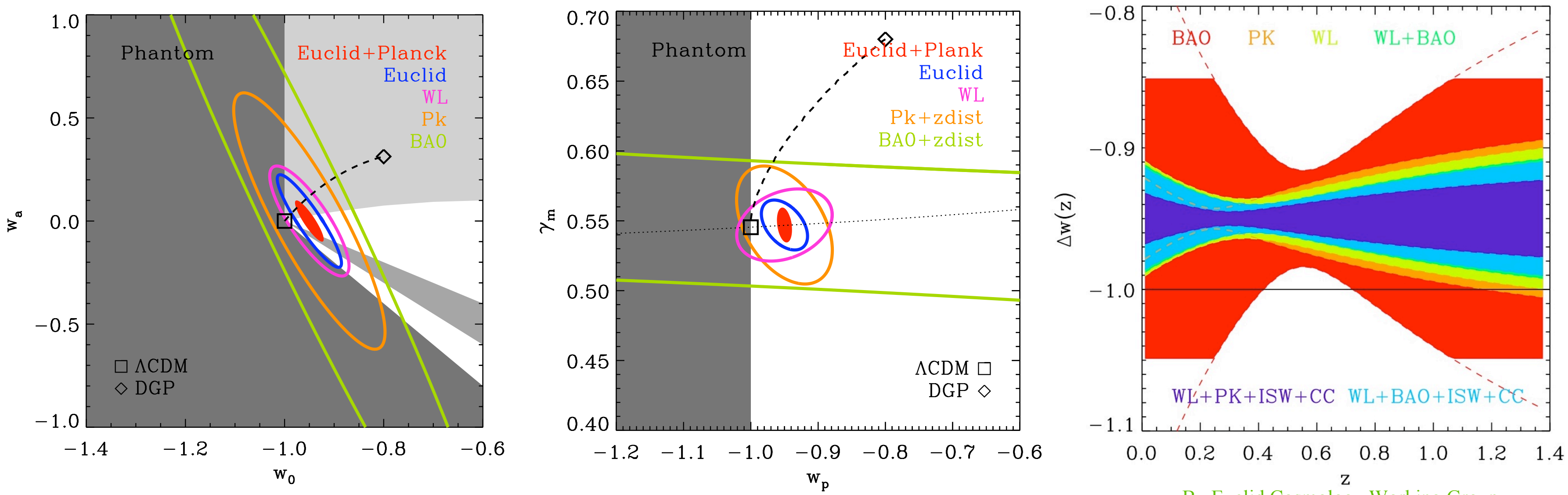


Berge et al 2009

Euclid Parameter Constraints

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

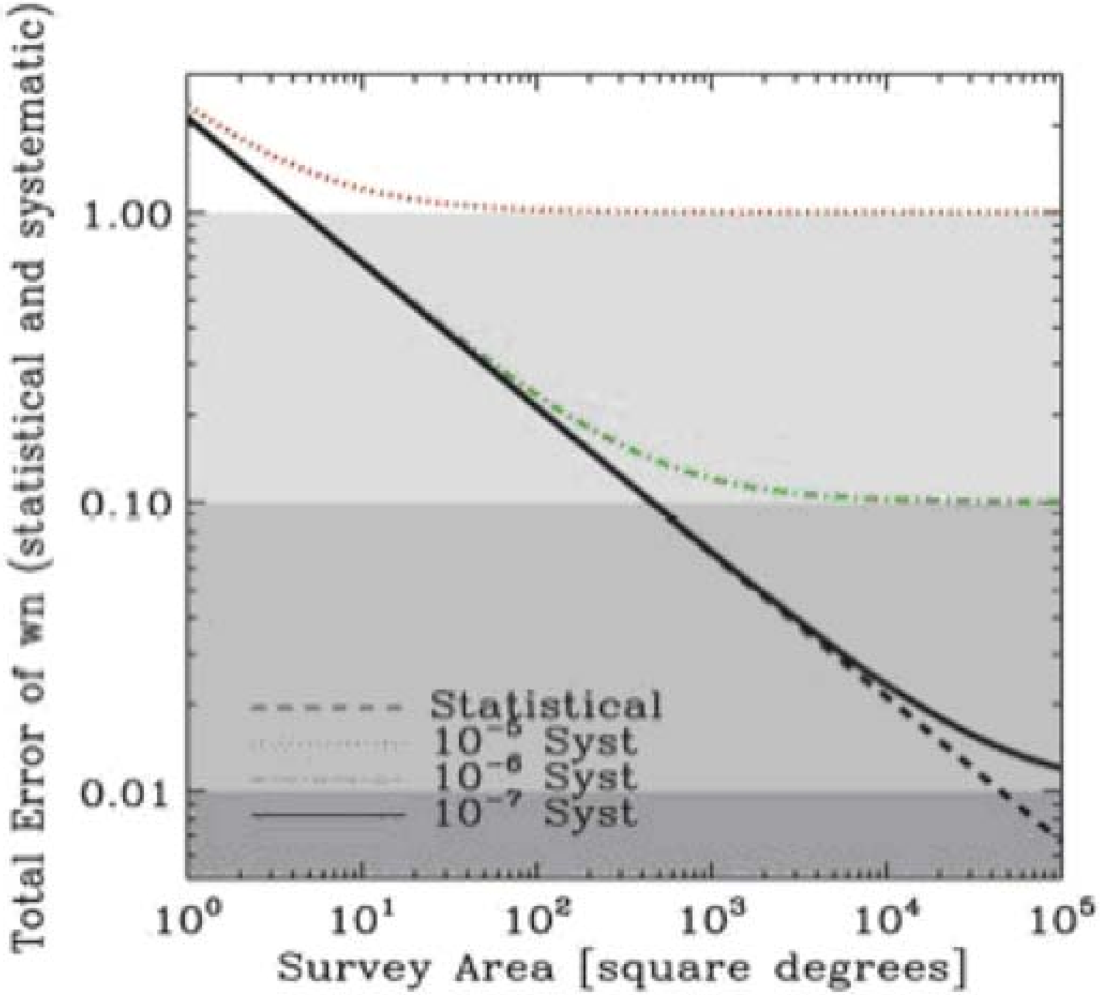
	Dark Energy		Densities			Initial Conditions		Hubble	DE FoM[2]
	Δw_p	Δw_a	$\Delta\Omega_m$	$\Delta\Omega_\Lambda$	$\Delta\Omega_b$	$\Delta\sigma_8$	Δn_s	Δh	
Current +WMAP[3]	0.13	-	0.01	0.015	0.0015	0.026	0.013	0.013	**~10**
Planck	-	-	0.008	-	0.0007	0.05	0.005	0.007	**-**
Euclid Req.	0.018	0.15	0.004	0.012	0.006	0.004	0.007	0.022	**400**
Euclid Goal	0.016	0.13	0.003	0.012	0.005	0.003	0.006	0.020	**500**
Euclid +Planck	0.010	0.066	0.0008	0.003	0.0004	0.0015	0.003	0.002	**1500**
Factor gain on Current	**13**	**> 15**	**13**	**5**	**4**	**17**	**4**	**7**	**150**



By Euclid Cosmology Working Group

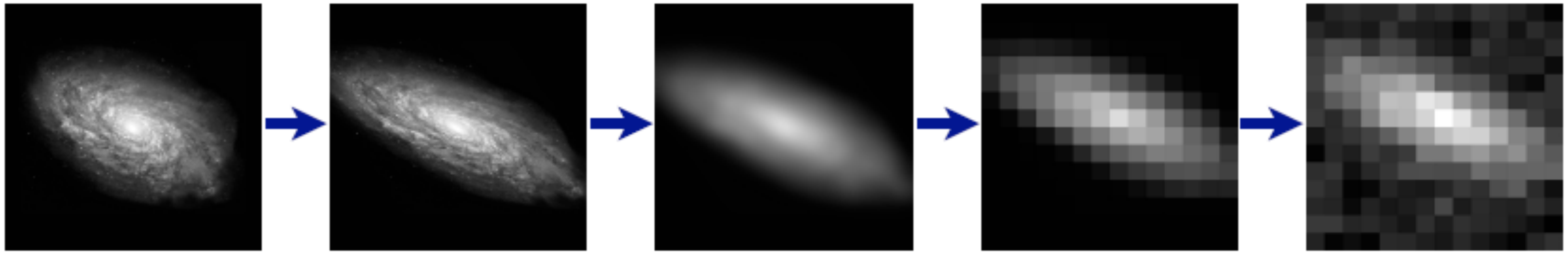
Impact of Systematics

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



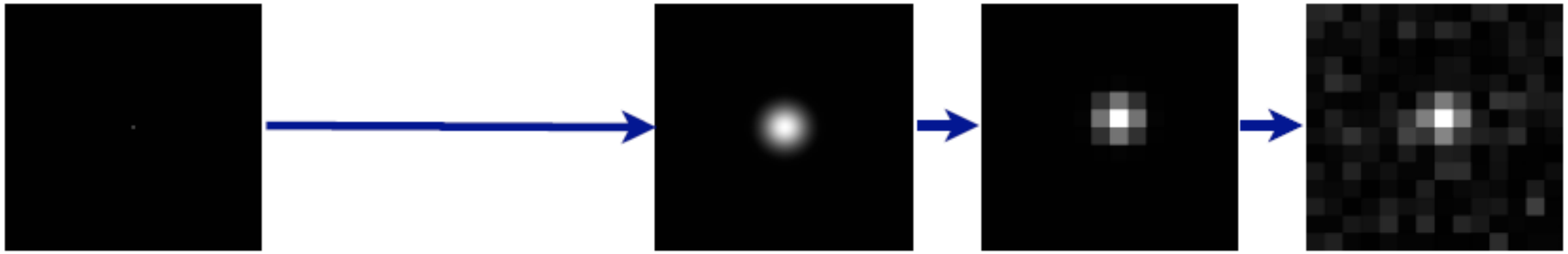
The Forward Process.

Galaxies: Intrinsic galaxy shapes to measured image:



Intrinsic galaxy (shape unknown) | Gravitational lensing causes a ***shear (g)*** | Atmosphere and telescope cause a convolution | Detectors measure a pixelated image | Image also contains noise

Stars: Point sources to star images:

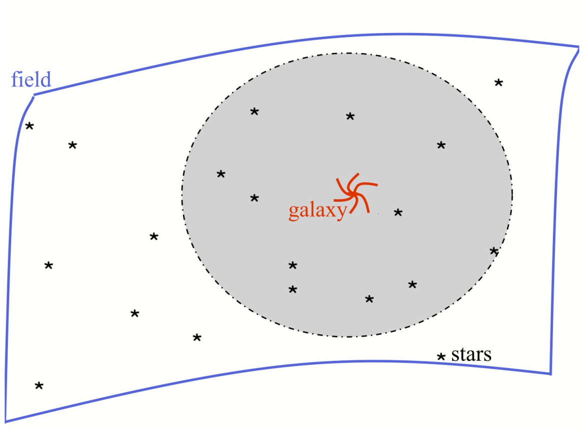


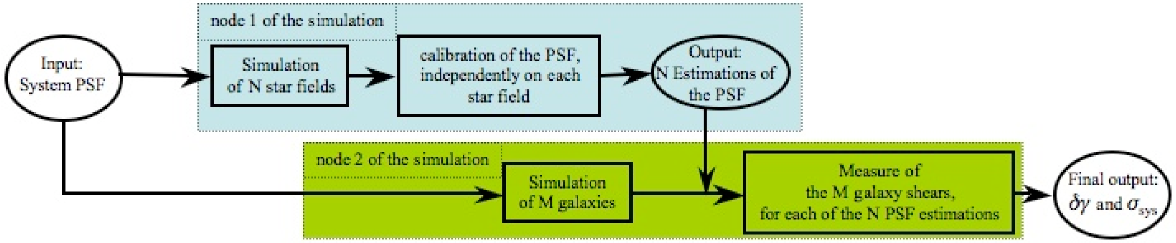
Intrinsic star (point source) | Atmosphere and telescope cause a convolution | Detectors measure a pixelated image | Image also contains noise

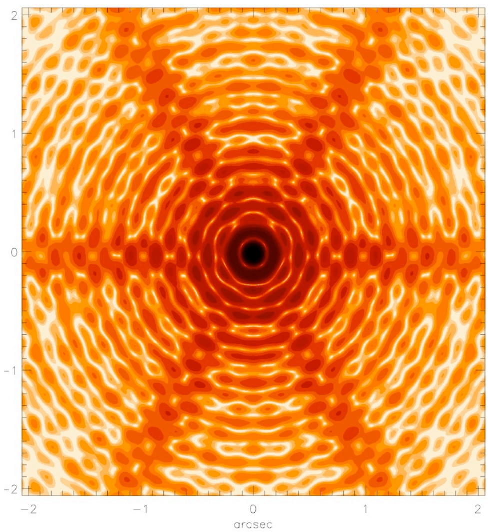
Stable and well behaved PSF

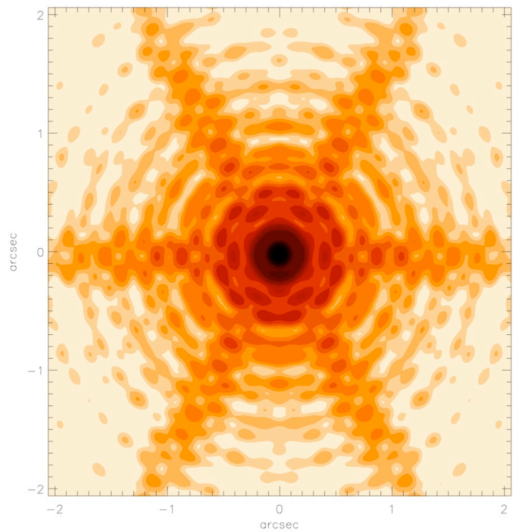
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

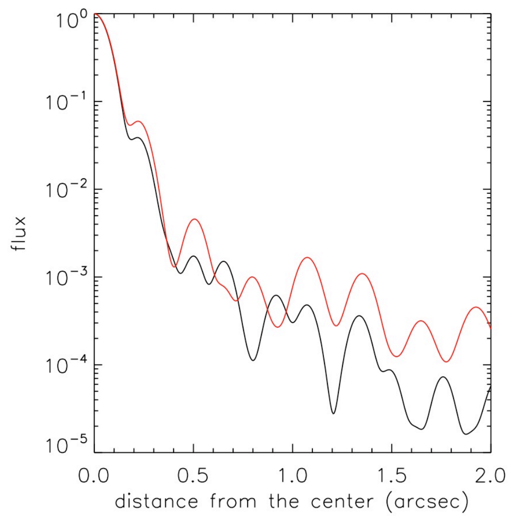
Paulin-Henriksson et al, 2007, 2008







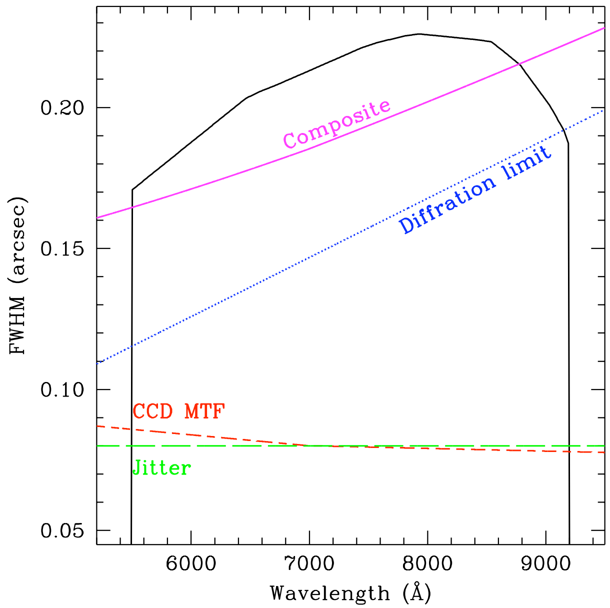


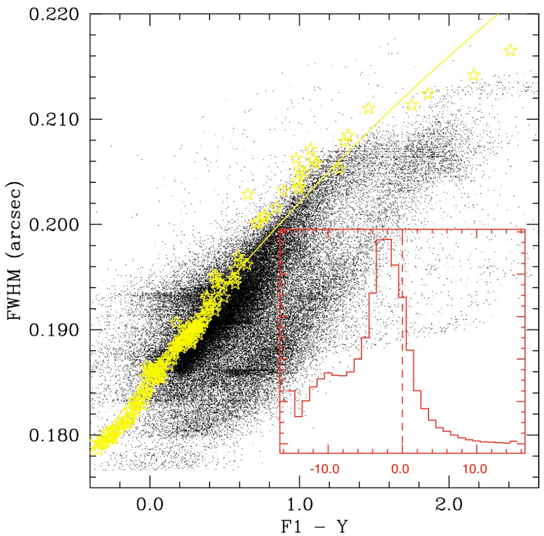


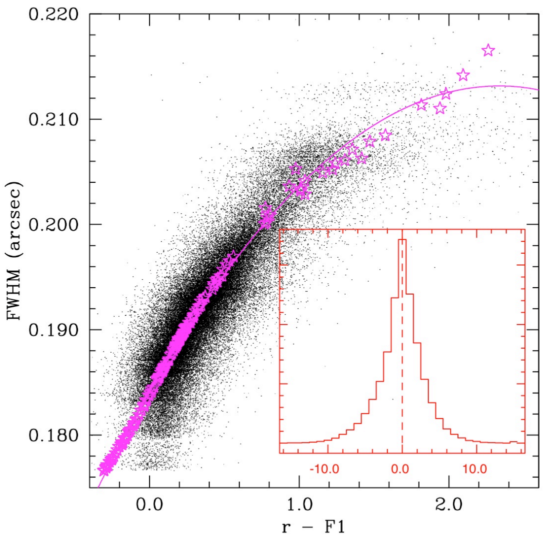
Wavelength dependent PSF

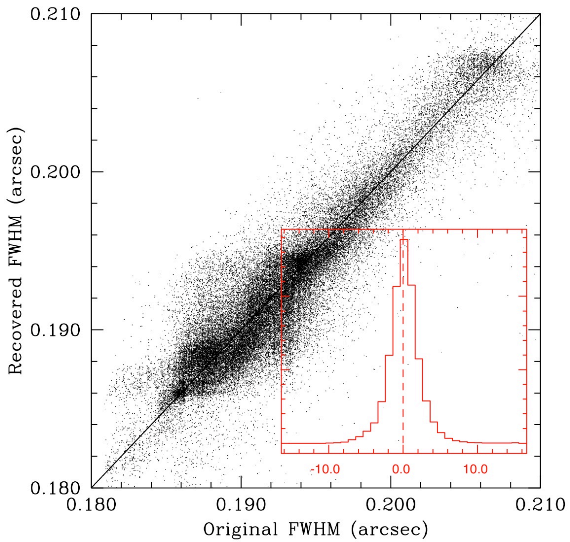
ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

- Measure the PSF as a function of wavelength using stars
- Considered three contributions to the PSF
  - Diffraction limit
  - CCD MTF
  - Jitter
- We can correct the global effect by measuring the SED galaxies using photoz (Cypriano et al in prep)
- Work on Colour gradients is still on going



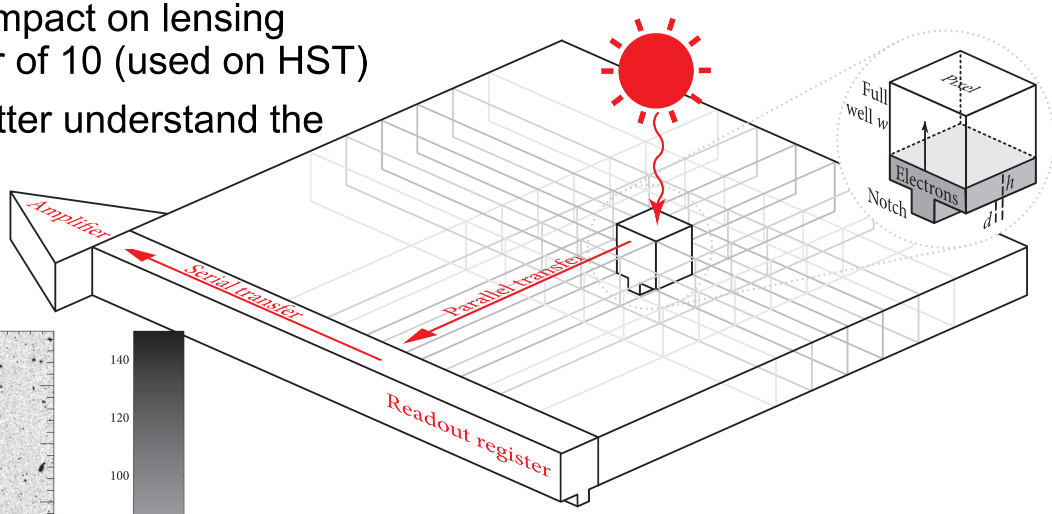


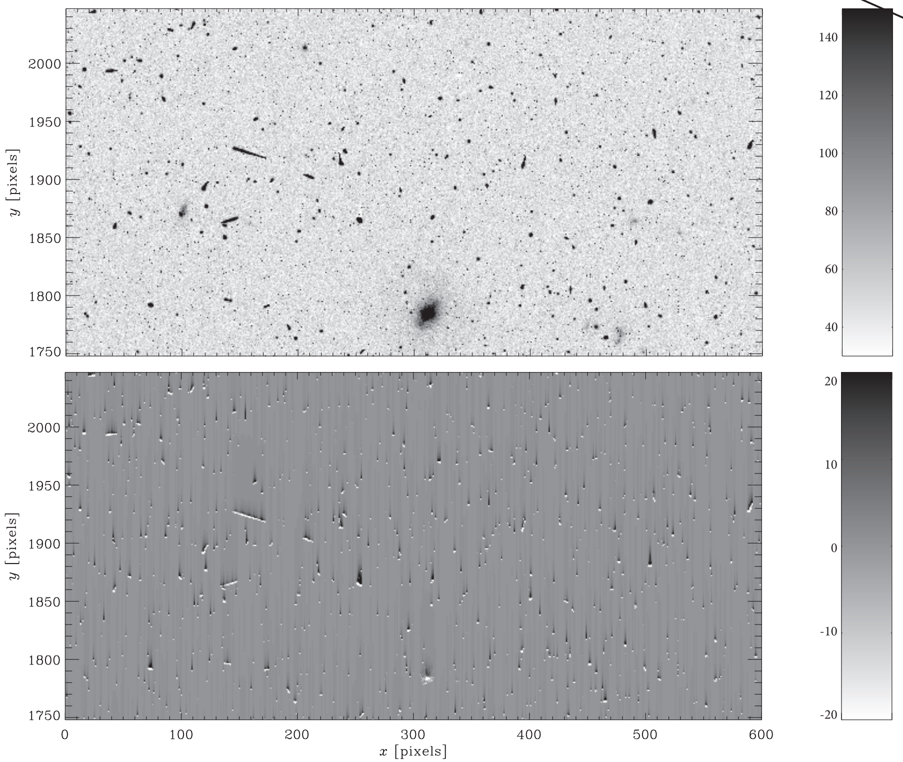




CCD Effects - CTI

- Radiation damage leads to traps in the CCD
- Through modeling of these traps their impact on lensing observables can be reduced by a factor of 10 (used on HST)
- We have initiated hardware tests to better understand the performance of the CCD's





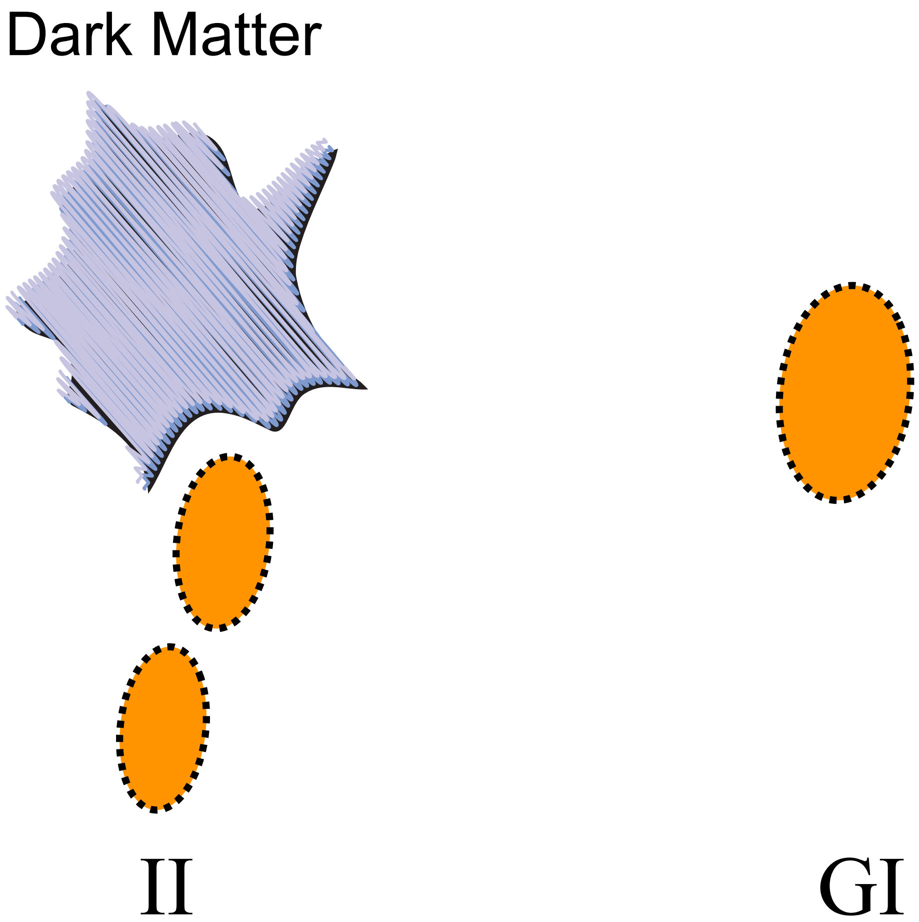
Massey et al 2009

Intrinsic Alignment

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Treatment:

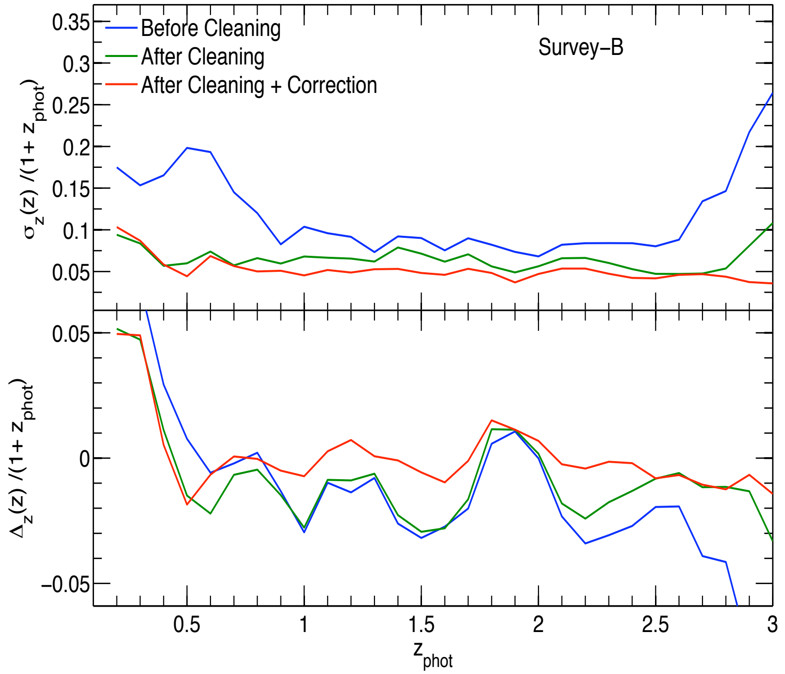
- Nulling
- Modeling
- Simulations

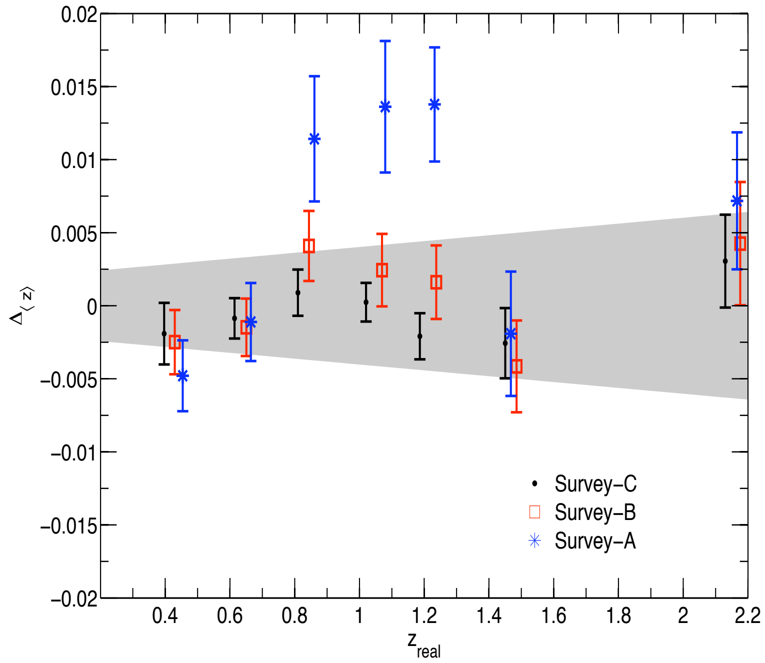


For examples see
Bridle & King 2007,
Joachimi & Schneider 2008
Schneider & Bridle 2009
Joachimi & Bridle 2009 ...

Photo-z

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

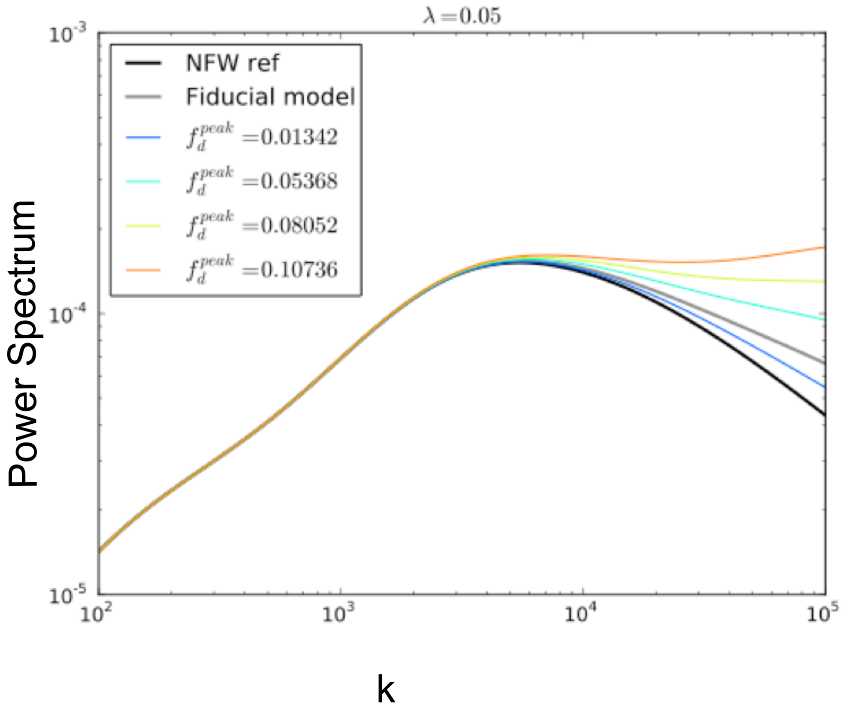




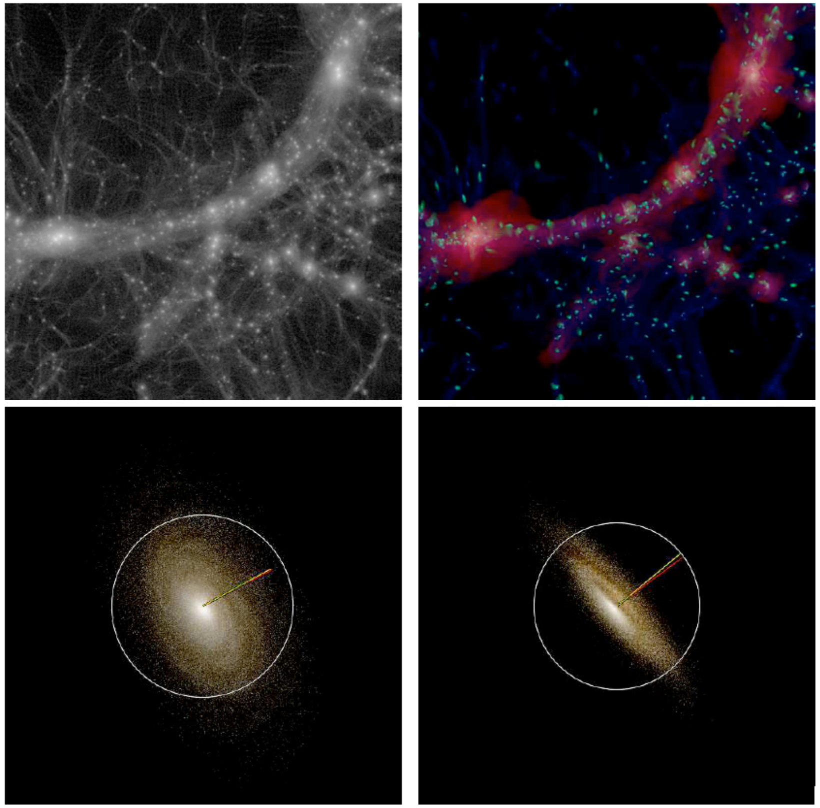
Bordoloi et al 2009

Physics of the Baryons

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



Guilllet et al 2009



Hahn et al 2009

Summary of Top Level Requirements

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Description	Quantity	Requirement
Survey Geometry: Area: Errors on dark energy parameters depend on the area of the survey	A_s	$> 20000\ \mathrm{deg}^2$
Survey Geometry: density of galaxies: And the effective number density of galaxies useful for gravitational lensing (Neff)	$\mathrm{N_{eff}}$	$> 30\ \mathrm{gals/amin}^2$
Survey Geometry: galaxy redshift: Redshift distribution of the lensing galaxies	$\mathrm{z_m}$	> 0.8
Shape Measurement: To reach the above cosmological objectives, systematic effects shall be controlled to a level where they do not dominate over the statistical errors. This is done by controlling the variance of the residual shear systematics.(σ^2_{sys})	σ^2_{sys}	$< 10^{-7}$
Photometric Redshifts statistical: The statistical rms error $\sigma(\overline{z})$ in the photo-zs in the range $0.2 < z < 2.0$	$\sigma(\mathrm{z})/(1+\mathrm{z})$	< 0.05
Photometric Redshifts error in the mean: The mean of the redshift distribution n(z) of each bin must be known to high precision	$\sigma(\overline{\mathrm{z_i}})/(1+\overline{\mathrm{z_i}})$	< 0.002

End