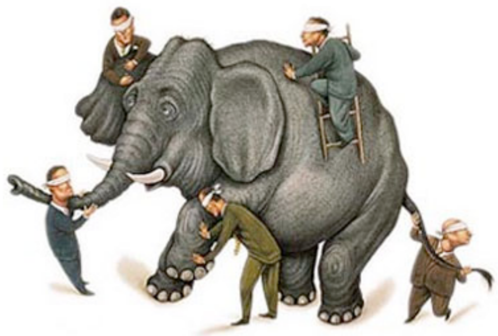
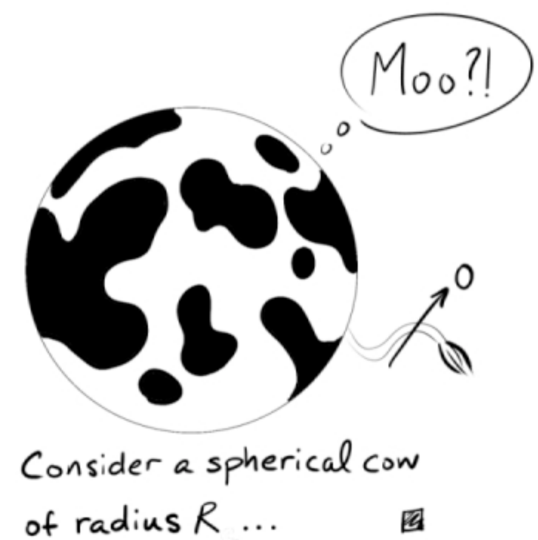


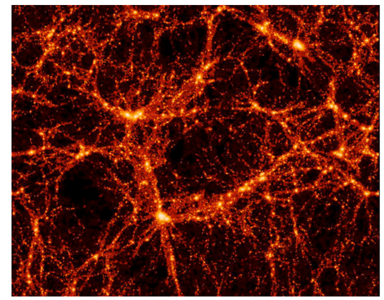
WFIRST Special Session: Survey Complementarity

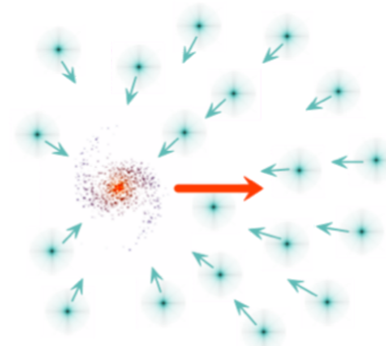
Rachel Bean
Cornell University



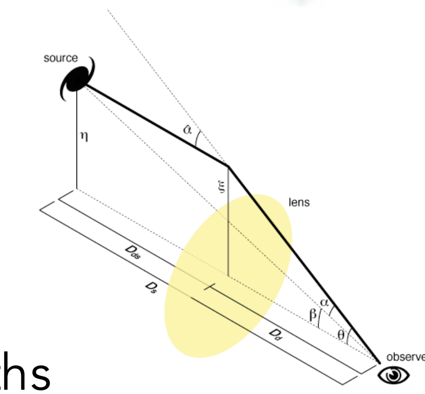
Understanding why the universe is accelerating

- Aim: Connect phenomenological constraints to rich theoretical space with implications across many different environs
- Use distinct cosmological techniques
  1. Standard candles (SN)
  2. Standard rulers (CMB/BAO)
  3. Clustering of non-relativistic tracers
  4. Motion of non-relativistic tracers
  5. Lensing distortion of light

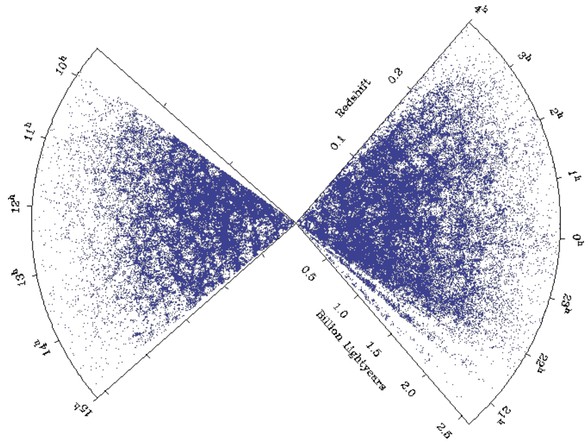


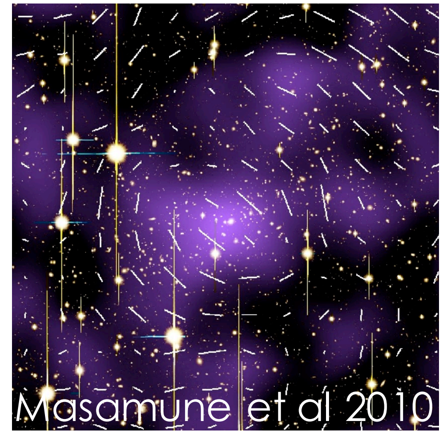


- Cover distinct redshifts and tracers
  - z~0-3
  - LRGs, ELGs, QSOs, Lya, dwarf galaxies, CMB, clusters
- Leverage distinct systematics
  - Different wavelengths
  - Spectroscopic precision vs Photometric speed
  - Overlapping survey areas, different depths and wavelengths



Towards understanding gravity on cosmic scales





$$k^2\Psi = -4\pi G_{\rm matter} a^2 \rho\Delta$$

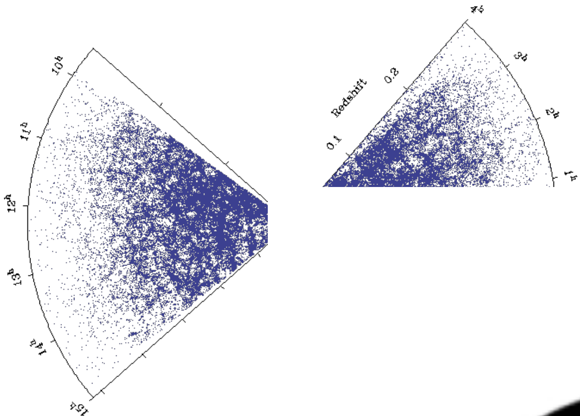
- Non-relativistic: Galaxy positions & motions
  - Sensitive to $\psi \sim G_{mat}$
  - Biased tracer
  - Can be measured at specific z
- $G_{matter} \neq 1$: can be mimicked by additional, dark sector clustering

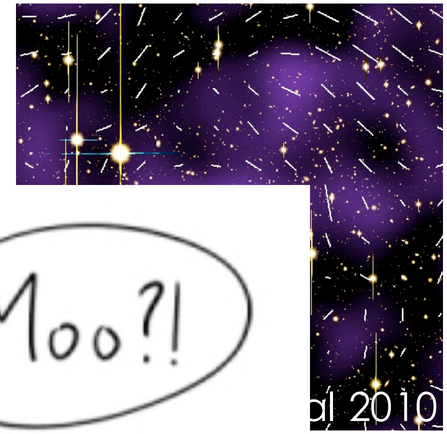
$$k^2(\Psi + \Phi) = -8\pi G_{\rm light} a^2 \rho\Delta\,,$$

- Relativistic: Weak lensing, CMB lensing & ISW
  - Sensitive to $(\phi+\psi)$: G_{light}
  - Direct tracer of potential,
  - Integrated line of sight info
- $G_{light}/G_{matter} \neq 1$: not easily mimicked.
  - potential smoking gun for modified gravity?

Proposal: Contrast both can get at G_{light}/G_{matter} (Zhang et al 2007)

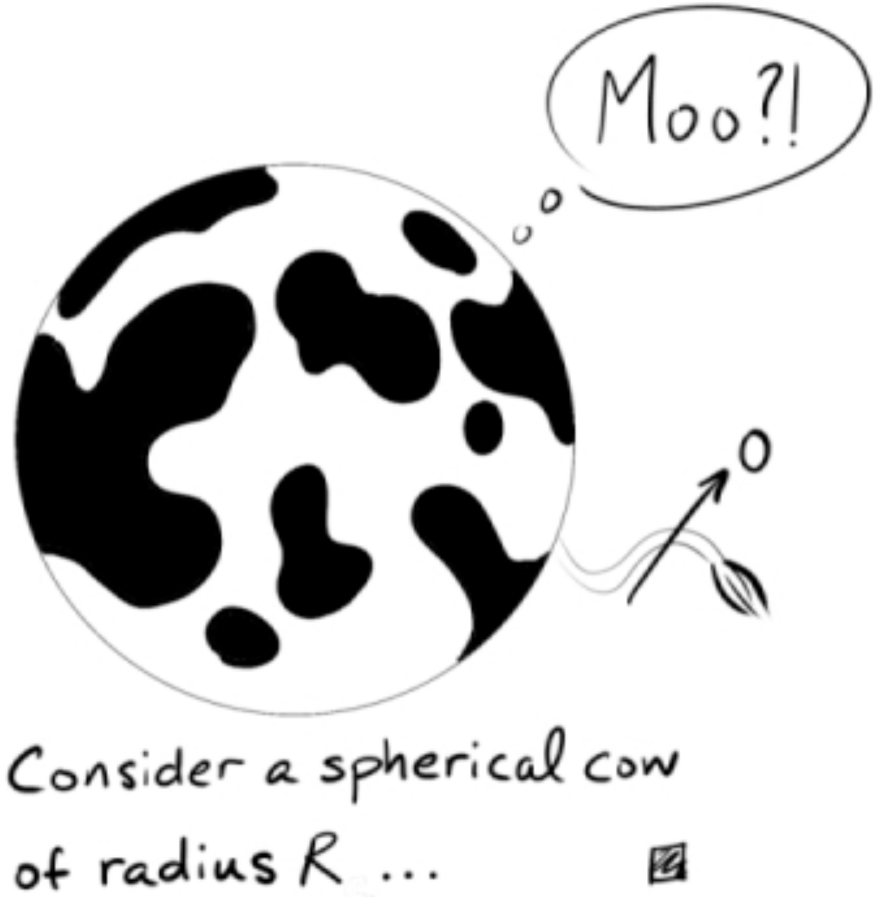
Complementary tracers for testing gravity





l 2010

$k^2\Psi = -4$ … $\pi G_{light} a^2 \rho\Delta$,



- Non-relativistic: (… motions
  - Sensitive to …
  - Biased trace…
  - Can be mea…
- $G_{matter} \neq 1$: can be … additional, dark s…

… nsing, CMB lensing

… $+\psi$): G_{light}

… f potential,

… e of sight info

… easily mimicked.

… king gun for

… ity?

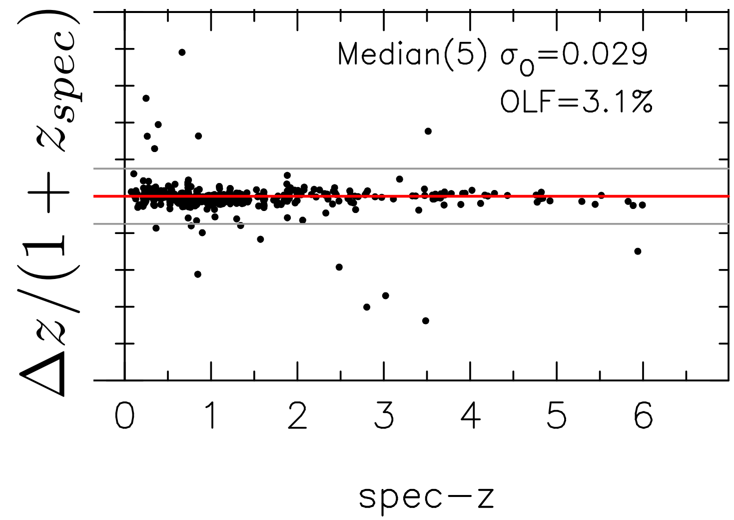
Proposal: Contrast both can get at G_{light}/G_{matter} (Zhang et al 2007)

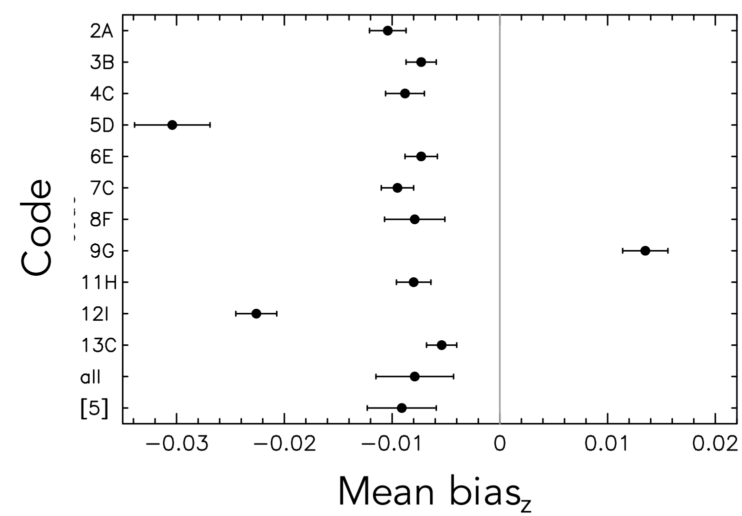
Complications: Photometric redshifts

- Quicker (more galaxies) and concurrent with imaging, but less accurate than spectral z
- Challenge to refine photo-z estimates given disparate and incomplete spectroscopic samples
- Redshift probability distribution dispersed and biased relative to the true spectroscopic z.

$$\sigma_z = rms\left[\frac{\Delta z}{1+z_{spec}}\right]$$

$$bias_z = mean\left[\frac{\Delta z}{1+z_{spec}}\right]$$





Dahlen et al 1308.5353

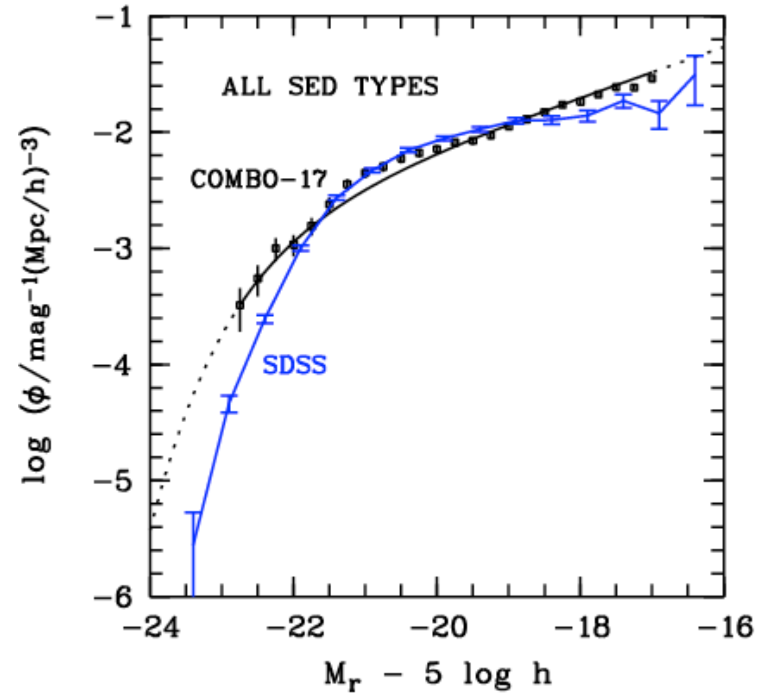
Complications: Lensed galaxies

- Lensing distorts observed volume and magnifies faint galaxies (Moessner & Jain 1997)

$$n^{(i)}(\boldsymbol{\theta}) = n_{\rm m}^{(i)}(\boldsymbol{\theta}) + n_{\rm g}^{(i)}(\boldsymbol{\theta}) + n_{\rm rnd}^{(i)}(\boldsymbol{\theta}) \ ,$$

- Number depends on slope of luminosity function of galaxies in survey sample.

- Galaxy correlations must factor this in



Wolf et al 2003

$$C_{n_i n_j} = C_{g_i g_j} + C_{g_i m_j} + C_{m_i g_j} + C_{m_i m_j}$$

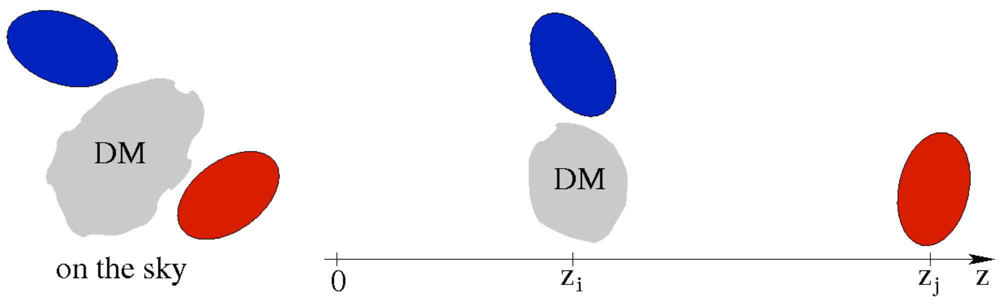
Measured | Unlensed galaxies | Lensed galaxy contributions

Complications: Intrinsic alignments

- Galaxy Intrinsic shapes are aligned in their host halo

$$\epsilon^{(i)}(\boldsymbol{\theta}) = \gamma_{\rm G}^{(i)}(\boldsymbol{\theta}) + \gamma_{\rm I}^{(i)}(\boldsymbol{\theta}) + \epsilon_{\rm rnd}^{(i)}(\boldsymbol{\theta})$$

- Observed shape correlations include both lensed and intrinsic terms



$$C_{\epsilon_i\epsilon_j} = C_{G_iG_j} + C_{G_iI_j} + C_{I_iG_j} + C_{I_iI_j}$$

Measured | Unlensed galaxies | Lensed galaxy contributions

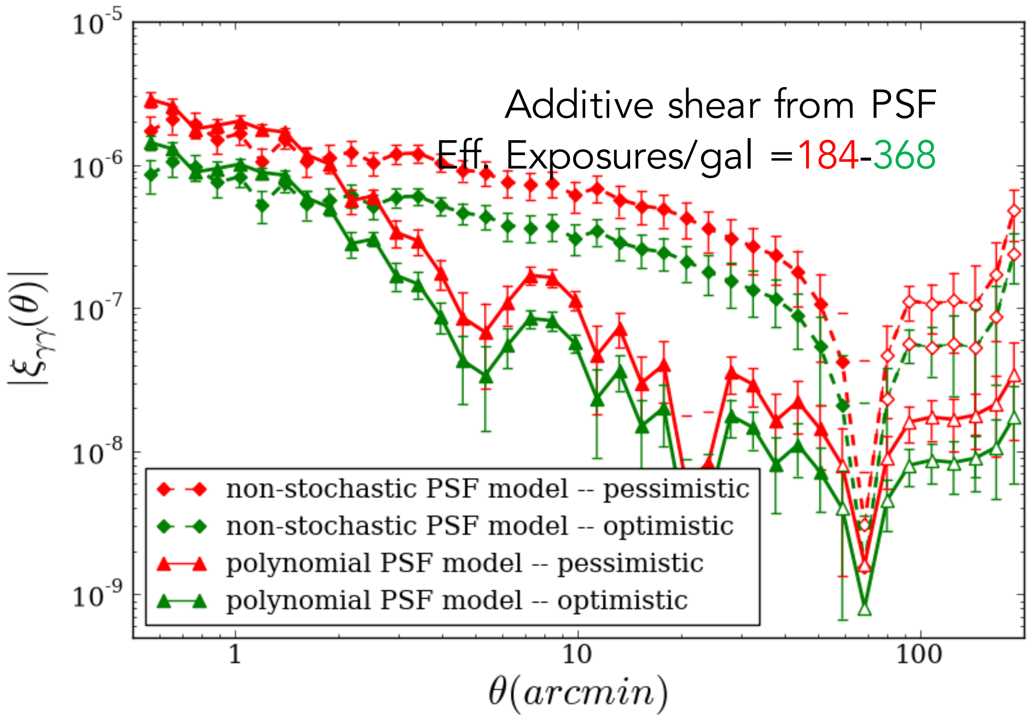
- The amplitude of intrinsic alignments is a function galaxy type, luminosity and redshift – currently leads to factor 4 uncertainty in % z~1 red galaxies

Complications: Shear calibration

- Incomplete correction of the atmospheric and instrumental PSF can induce additive and multiplicative shear errors

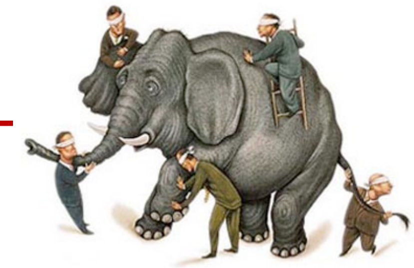
$$\epsilon_i = (1 + m_i)\epsilon_i + a$$

observed — multiplicative bias — additive bias



Chang et al 2012 (1206.1378)

Multi-probe and survey approach



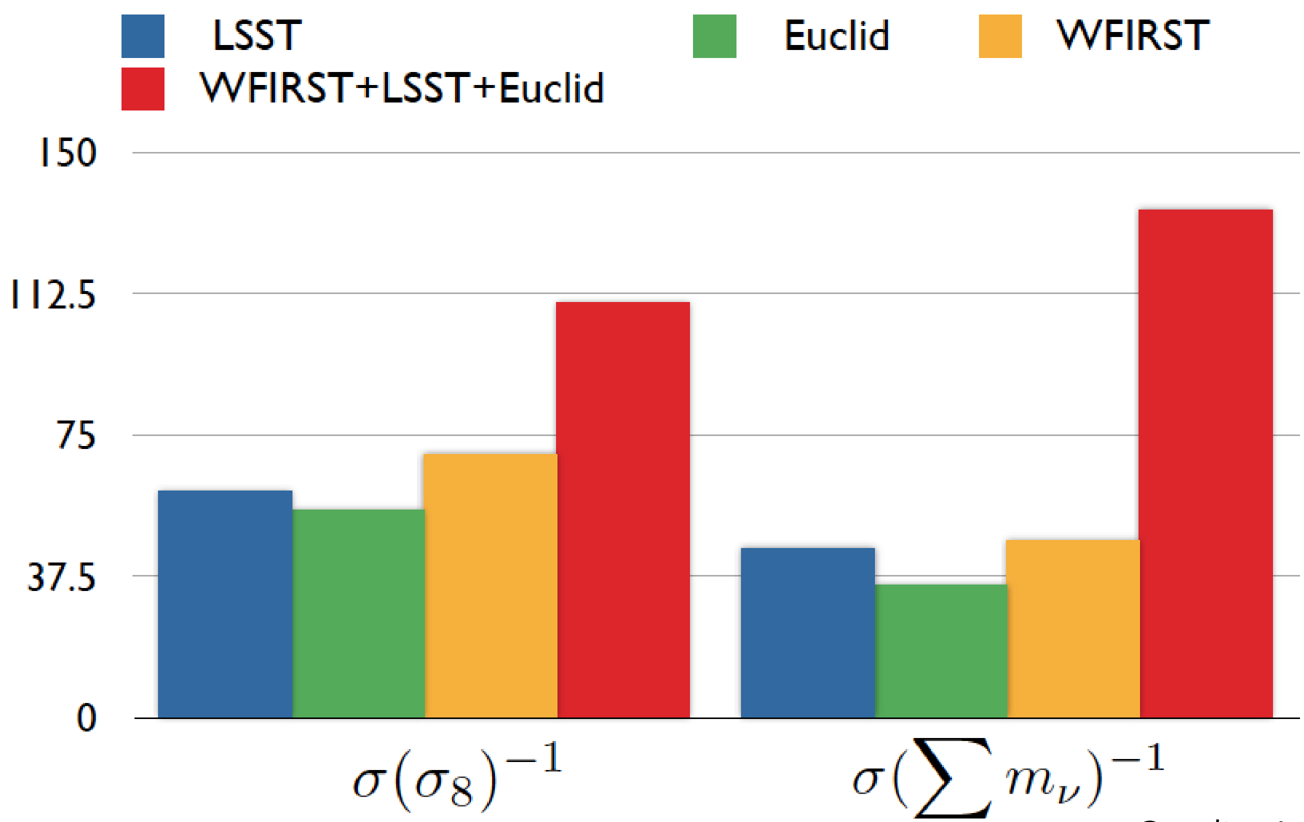
- Upcoming Surveys: Different strengths & systematics

Based on publicly available data

Stage IV	DESI	LSST	Euclid	WFIRST-AFTA
Starts, duration	~2018, 5 yr	2020, 10 yr	2020 Q2, 7 yr	~2023, 5-6 yr
Area (deg^2)	14,000 (N)	20,000 (S)	15,000 (N + S)	2,400 (S)
FoV (deg^2)	7.9	10	0.54	0.281
Diameter (m)	4 (less 1.8+)	6.7	1.3	2.4
Spec. res. $\Delta\lambda/\lambda$	3-4000 (N_{fib}=5000)		250 (slitless)	550-800 (slitless)
Spec. range	360-980 nm		1.1-2 mm	1.35-1.95 mm
BAO/RSD	20-30m LRGs/[OII] ELGs 0.6 < z < 1.7, 1m QSOs/Lya 1.9<z<4		~20-50m Hα ELGs z~0.7-2.1	20m Hα ELGs z = 1–2, 2m [OIII] ELGS z = 2–3
pixel (arcsec)		0.7	0.13	0.12
Imaging/ weak lensing (0<z<2.)		~30 gal/$arcmin^2$ 6 visible bands 320-1080 nm	30-35 gal/$arcmin^2$ Broad visible band 550– 900 nm	68 gal/$arcmin^2$ 3 near-IR bands 927-2000nm
SN1a		10^4-10^5 SN1a/yr z = 0.–0.7 photometric		2700 SN1a z = 0.1–1.7 IFU R=75 spectro.

Where does WFIRST fit in?

- Alone: Strong individual cosmological constraints to z~3.5
  - From deep photometric & multi-z spectroscopic surveys, plus extensive spectroscopic SN survey
- In combination: Important role in systematic mitigation
  - White paper: *"The Whole is Greater than the Sum of the Parts: Optimizing the Joint Science Return from LSST, Euclid and WFIRST"* http://arxiv.org/abs/1501.07897

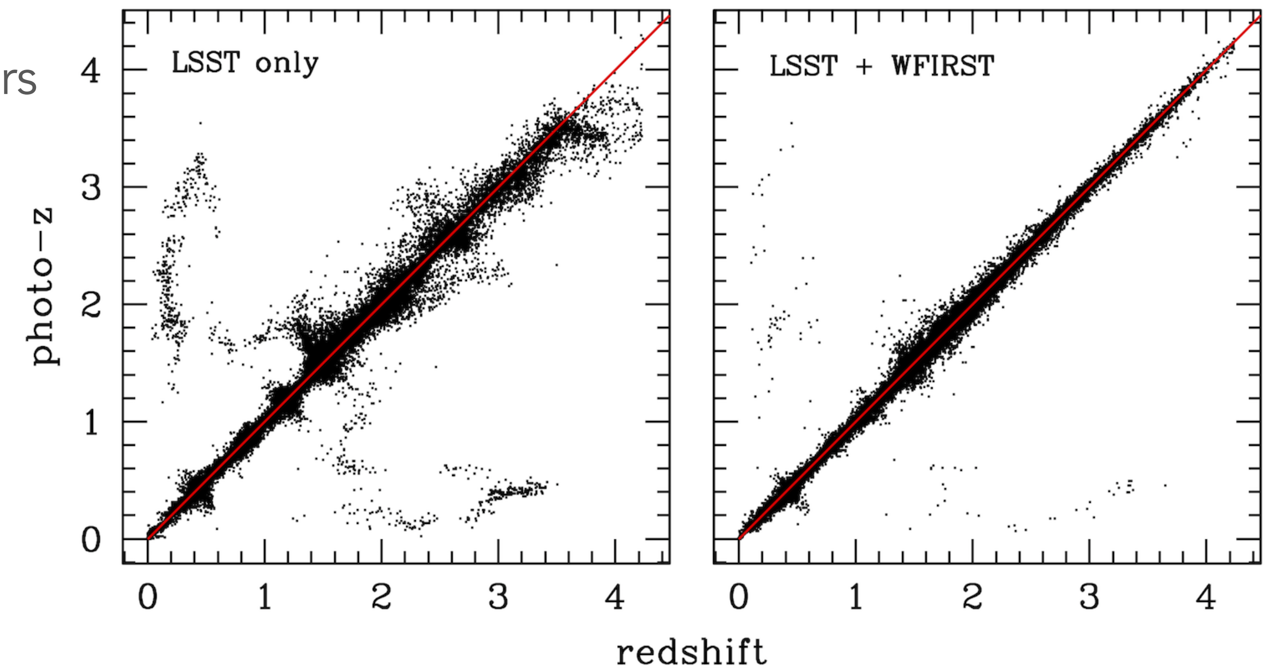


Credit: Jain et al 1501.07897

Where does WFIRST fit in?

- Systematic mitigation from combined photometric, spectroscopic + Stage III CMB convergence data
  - Improved lensing measurements (IA and calibration constraints)
  - Broader redshift range of spectroscopic samples
- Improved photometric redshift calibration: multiple bands WFIRST 4-bands (J,H, F184, Y) and LSST (6-band ugrizy)
  - Halves scatter
  - 33% reduction in outliers

  (excludes calibration and deblending errors)



Credit: Jain et al 1501.07897

Where does WFIRST fit in?

- Improved photometric calibration: WFIRST IFU spectroscopic training sets.
  - Euclid and WFIRST grisms only for limited ranges of z

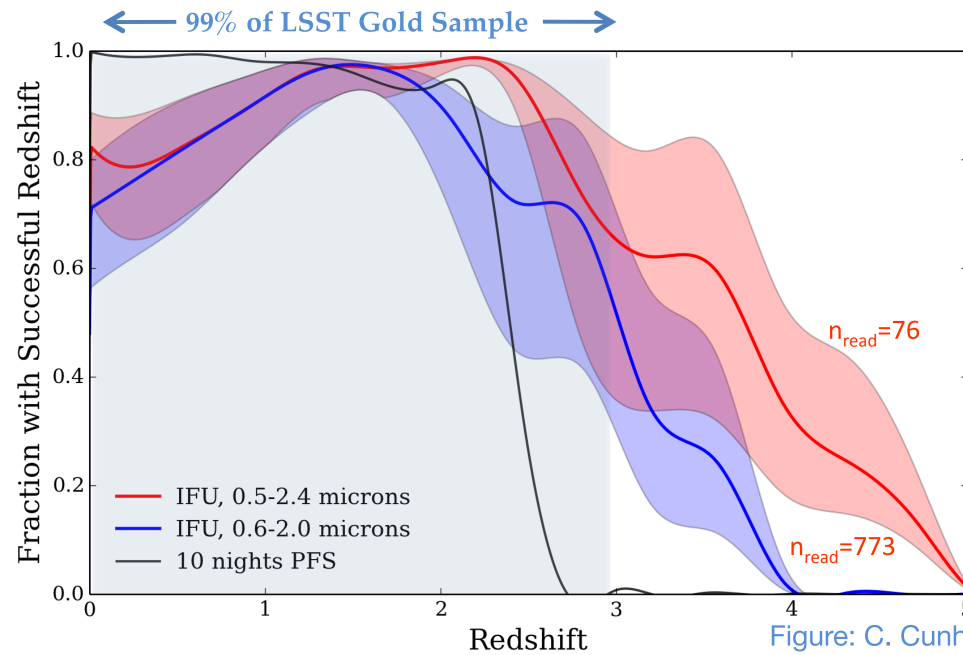


Figure: C. Cunha

- Shear calibration and systematic mitigation:
  - Expect surveys to have different individual shapes (different effective resolutions, wavelength and shear estimation methods).
  - Compare reconstructed shear maps from each survey. WFIRST will not suffer from wide-band chromatic PSF issues Euclid may face.
- Deblending: For the main survey, Euclid will cover broader range of sky and help galaxy and galaxy-star. WFIRST will be helpful for LSST Deep Drilling Fields.

Credit: Jain et al 1501.07897