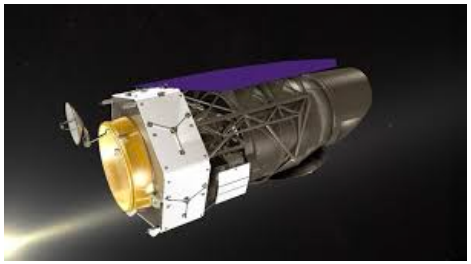

WFIRST High Latitude Survey

and Synergies with Ground-based Surveys

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Yonsei University, Sep. 2018

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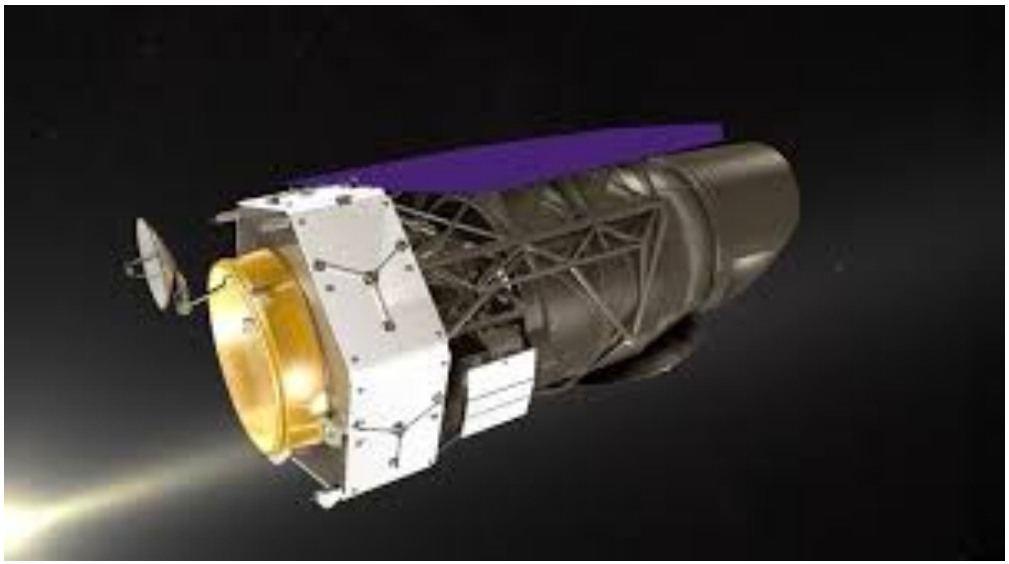
Outline

- **Introduction to WFIRST**
- High latitude survey (imaging + spectroscopy)
- Dark energy science
- Synergies with ground-based surveys

Wide-Field Infrared Survey Telescope

- Wide field of view
- Near-infrared
- 2.4 m mirror
- 2000 squared degrees
- 6 year nominal mission



WFIRST telescope

- Wide-field imager (NIR multi-band photometry)
- 380 resolution grim for galaxy redshift survey (GRS)
- Programs:
  - microlensing survey
  - exoplanet imaging
  - supernova survey
  - guest observer program,
  - high latitude survey (imaging + spectroscopy) for dark energy

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Dark energy

- Cosmic acceleration, non convincing explanation to date
- Superonvae measurements in 1998 confirmed (Lambda = 0.7)
- Testing physics with cosmology:
  - Cosmological constant?
  - New energy component?
  - Deviation from GR? — also changes growth of structures and gravitational potentials

Testing physics with cosmology

- High Latitude Survey (HLS, 1.6 years) + Supernovae survey
- HLS: imaging + spectroscopy
- **Imaging**: weak lensing, galaxy clusters
- **Spectroscopy** (Galaxy Redshift Survey):
  - Baryon acoustic oscillations (BAO)
  - Redshift space distortions (RSD)
- Constrain evolution of dark energy and deviation from general relativity

Testing physics with cosmology

- Current: KiDS, HSC, DES, DESI, etc.
- Upcoming: LSST, Euclid, etc.
- WFIRST designed with excellent control of systematics
- Cross-checks between probes.
- Powerful instrument

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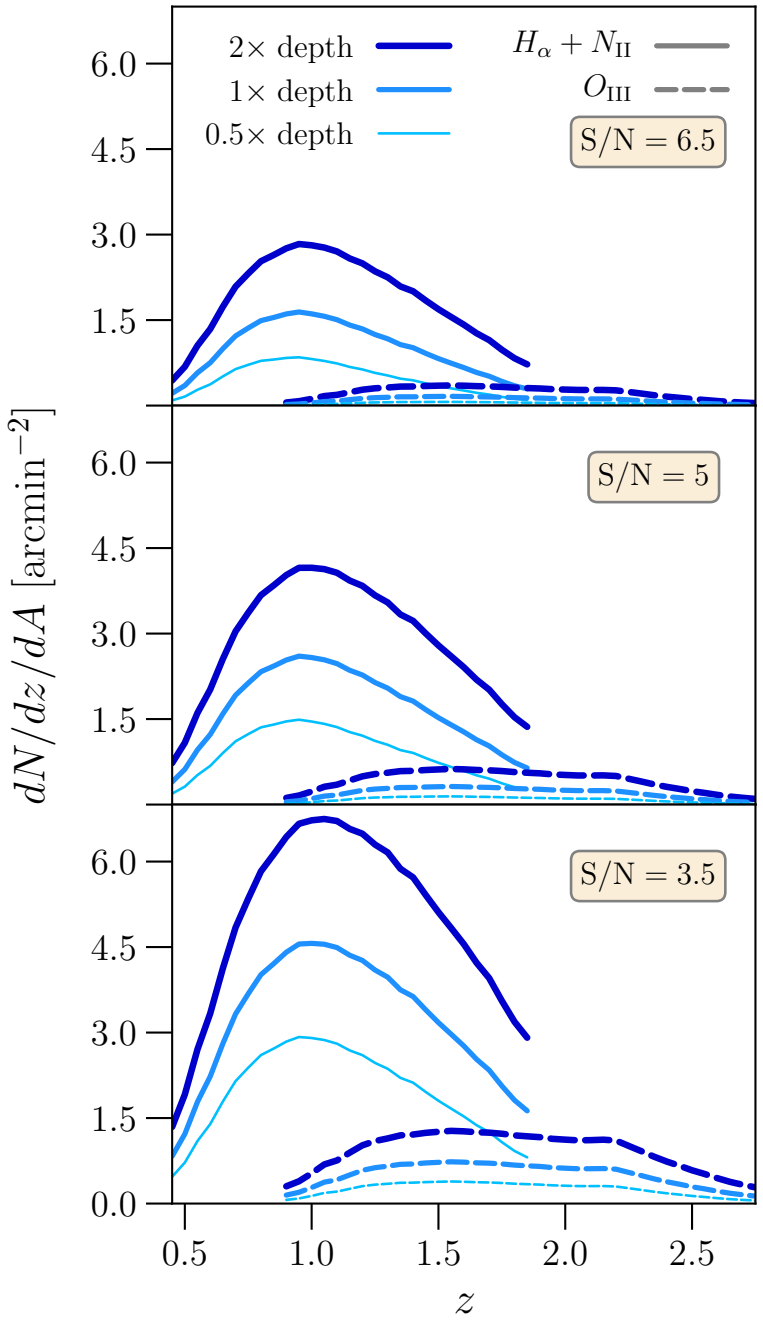
Galaxy distributions: baseline survey + variations

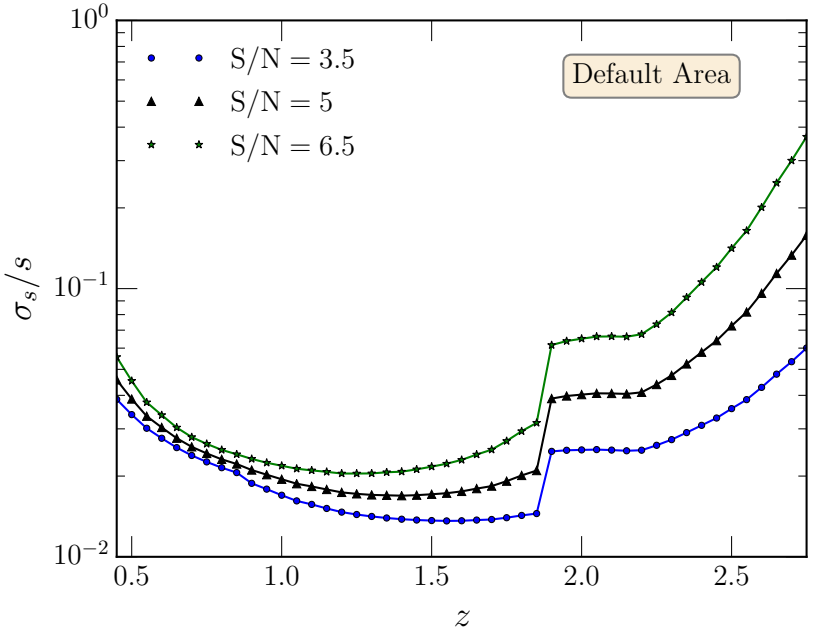
- Baseline survey:
  - Area = 2000 square degrees
  - S/N = 5.
- Varying depth: 2x, 1x, 0.5x (and 0.5x, 1x, 2x area)
- Varying S/N: 6.5, 5, 3.5



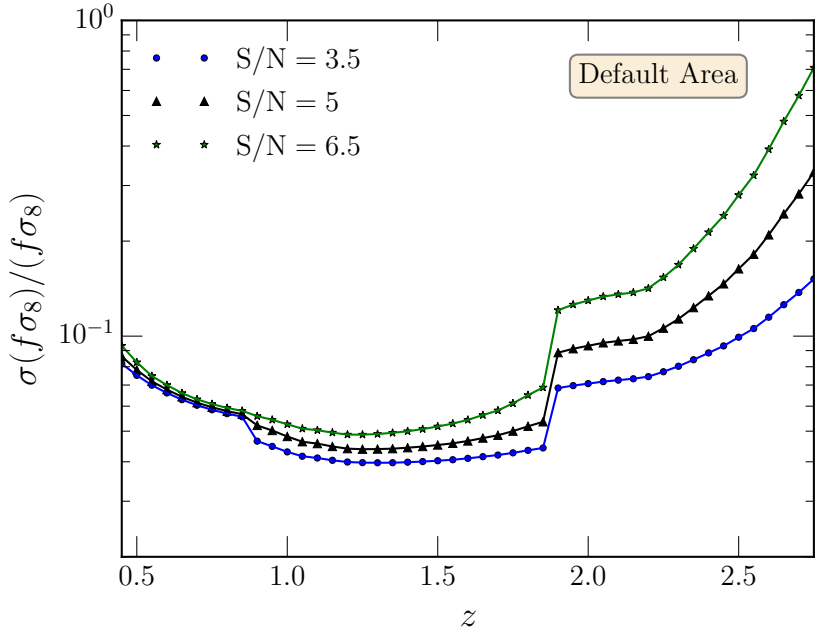
GRS: baseline survey

vary S/N (@ default area)

BAO



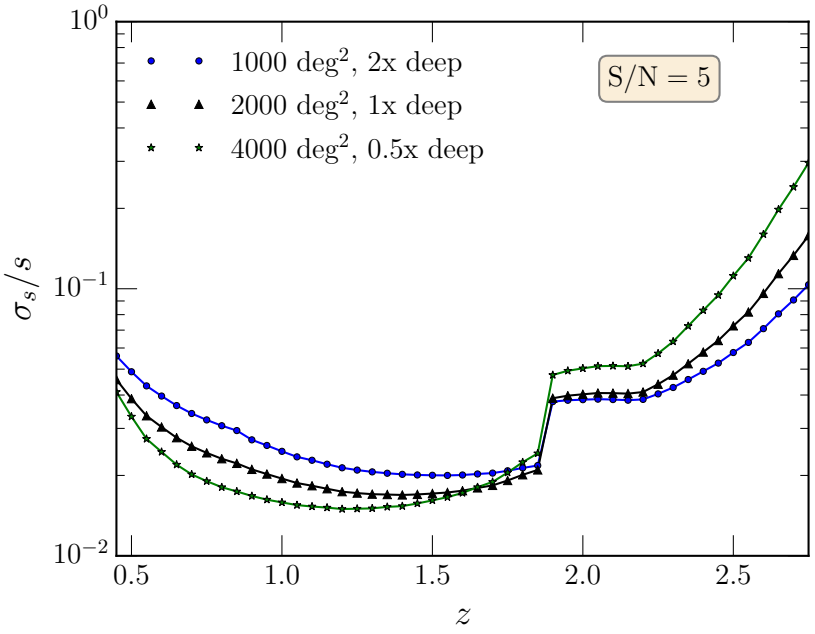
RSD



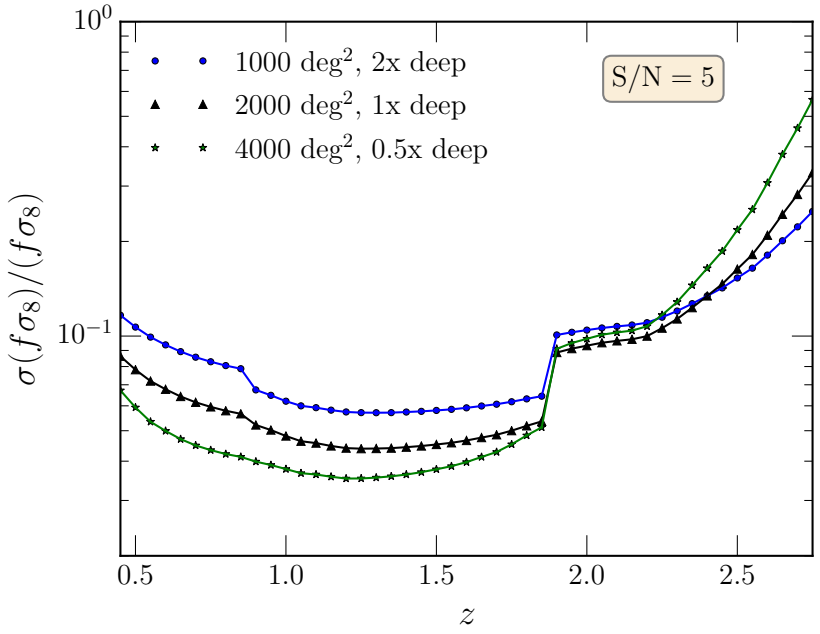
GRS: baseline survey

vary depth (@ S/N=5)

BAO

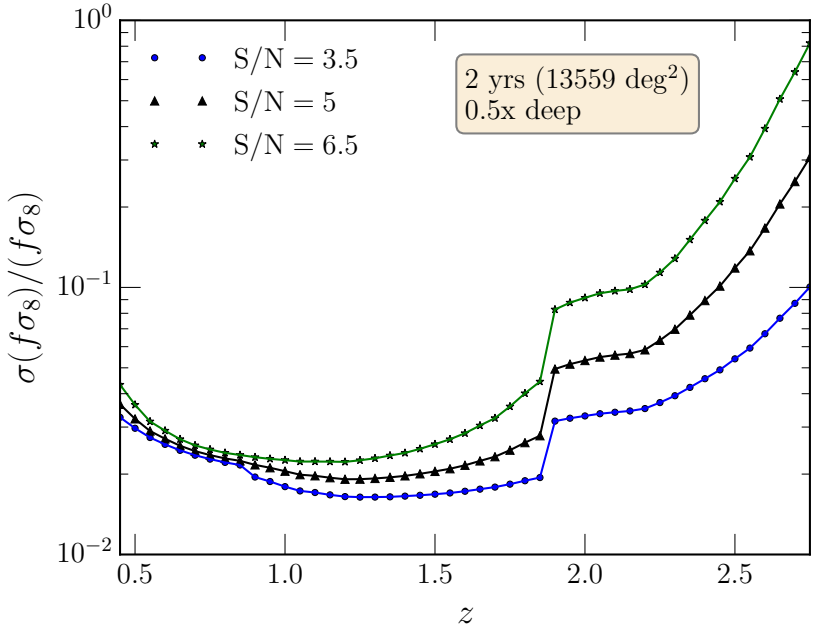


RSD

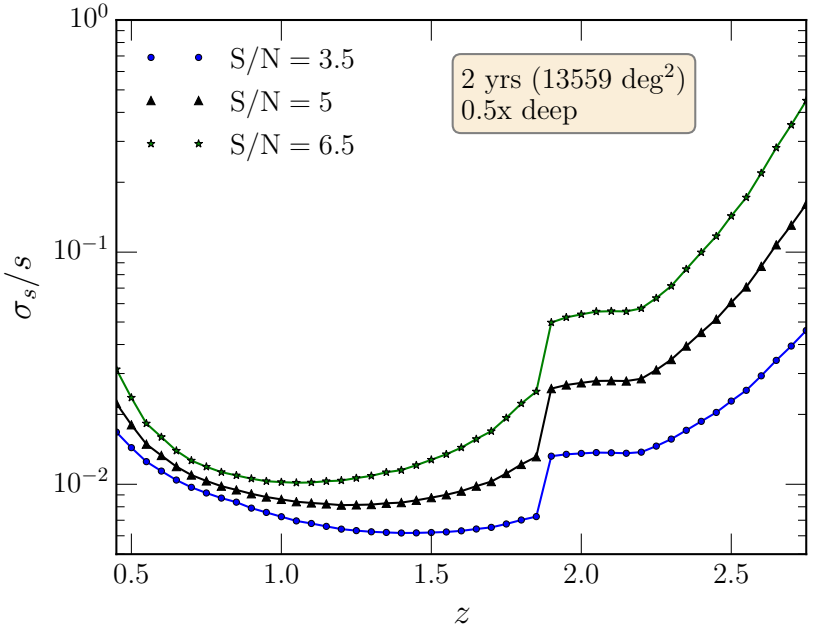


GRS : 2 year survey

RSD



BAO



WFIRST designed to be extendable to up to 10 years.

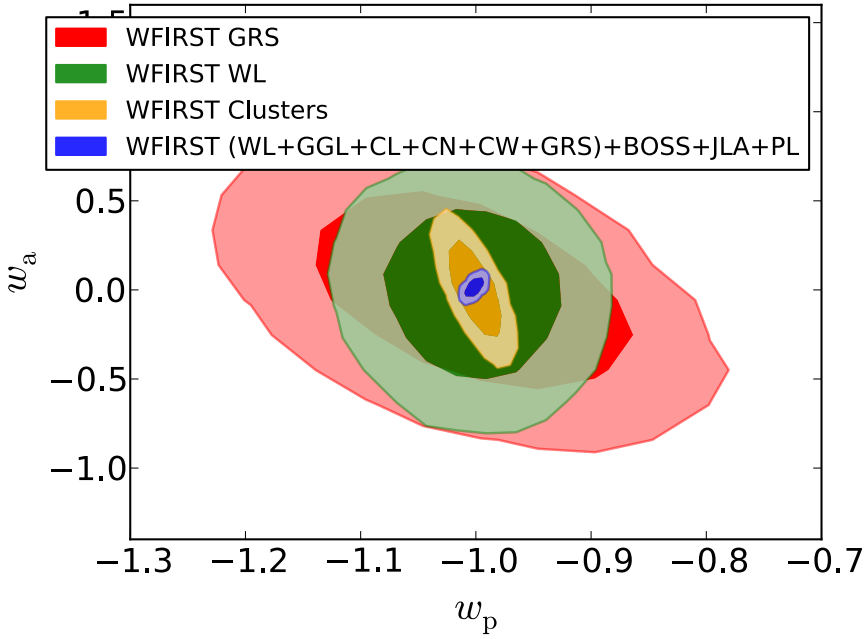
Imaging survey:

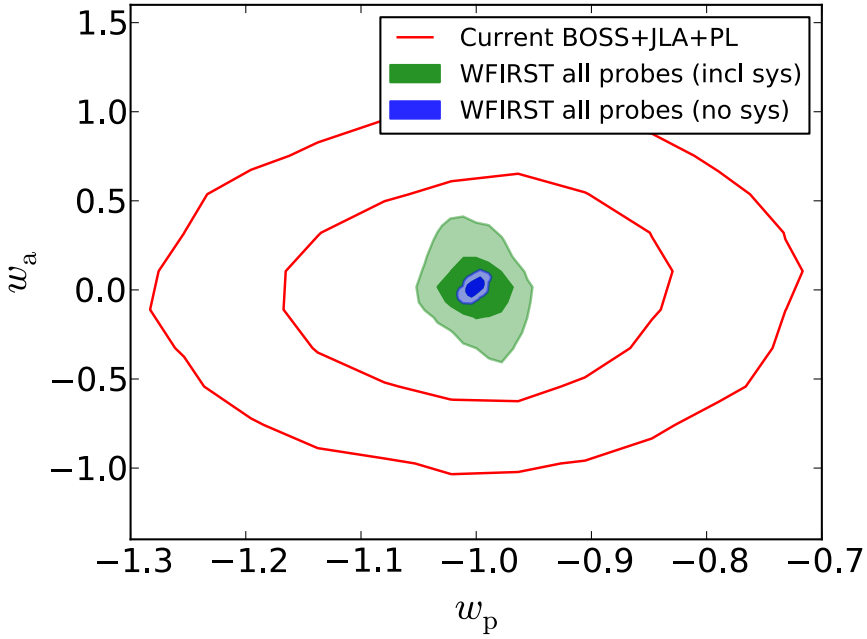
- Lens galaxies: position, z
- Source galaxies: position, z, shape
- Clusters: position, z, optical richness —> mass
- Summary statistics:
    - 3x2pt (lens x lens, lens x source, source x source),
    - cluster number counts (4 z bins, 7 richness bins),
    - cluster x source galaxies

Systematics

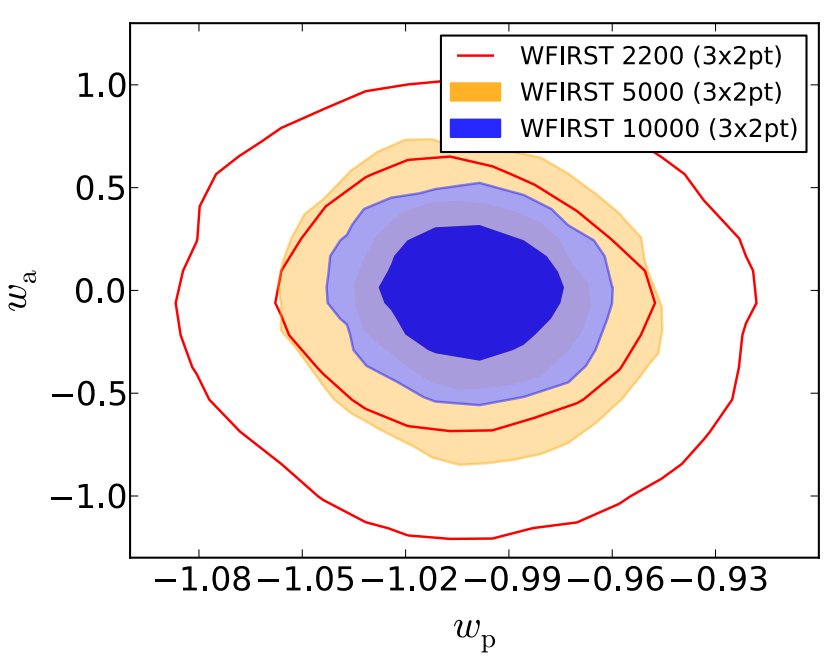
- Photometric redshift uncertainties
- Linear galaxy bias
- Multiplicative shear calibration
- Cluster mass-observable relation
- Intrinsic alignment
- Other: baryonic effects, small scale power spectra; galaxy cluster mis-centering assembly bias

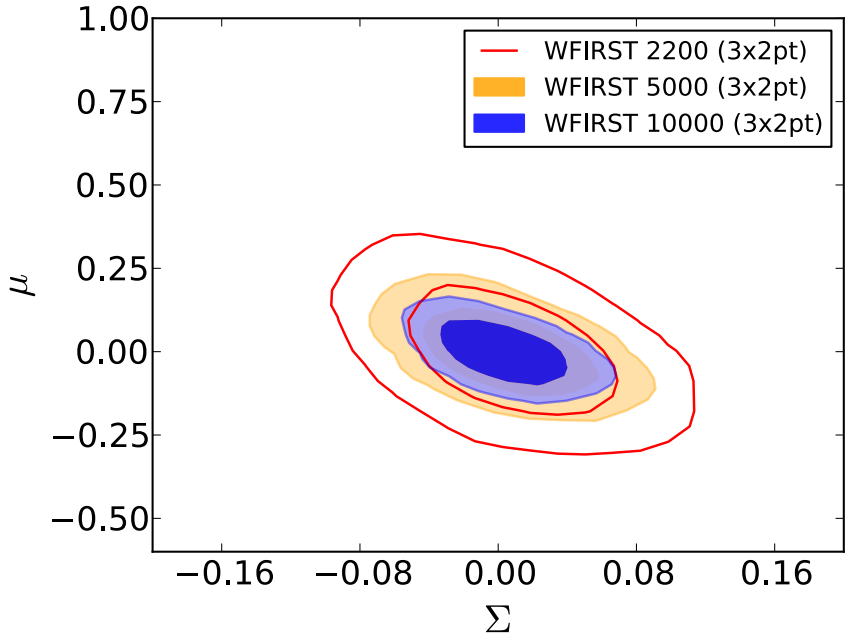
WFIRST HLS (GRS, Weak lensing, Clusters) baseline survey + External (BOSS+JLA+Planck)



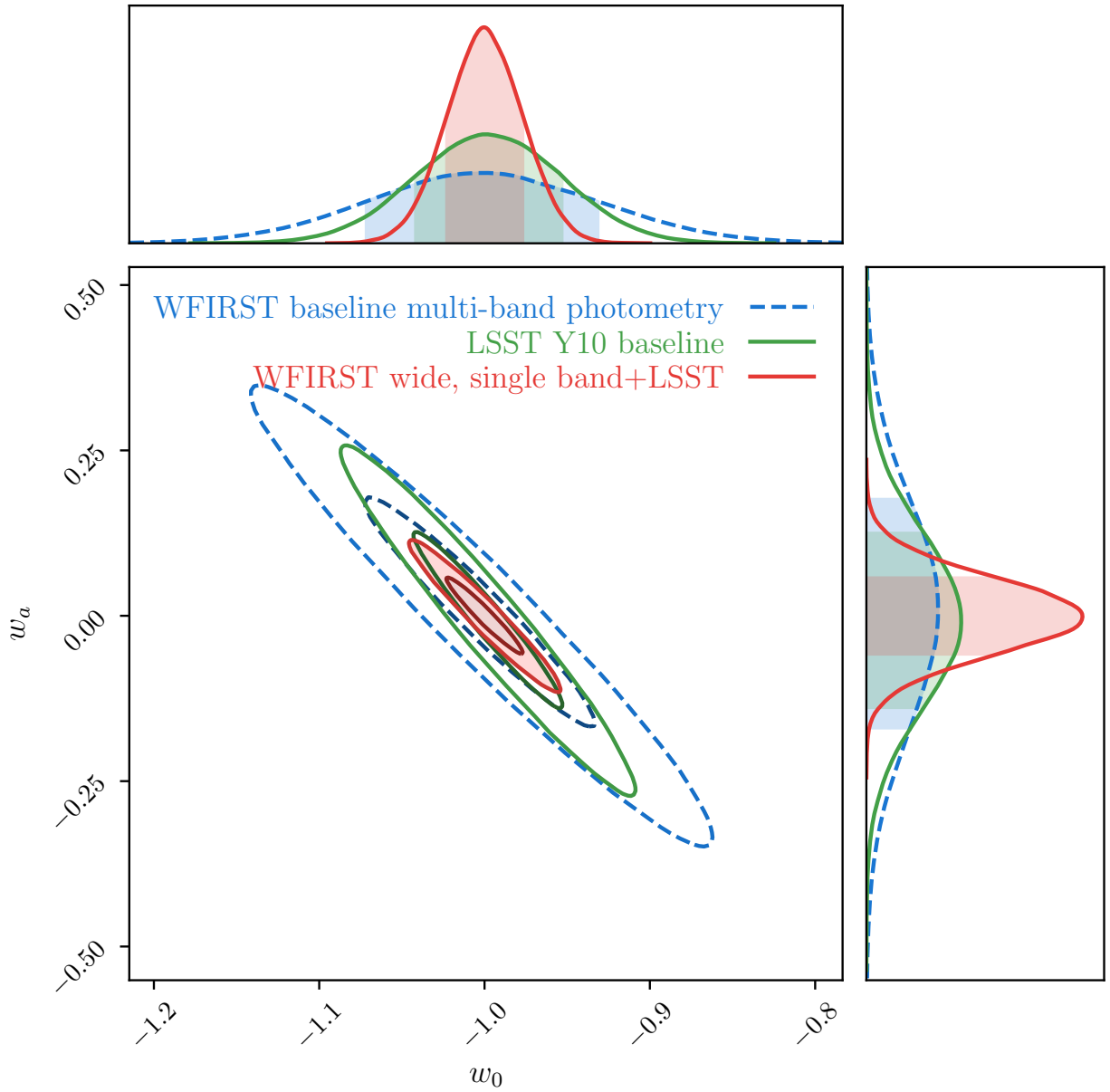


WFIRST HLS: extended surveys





A powerful instrument



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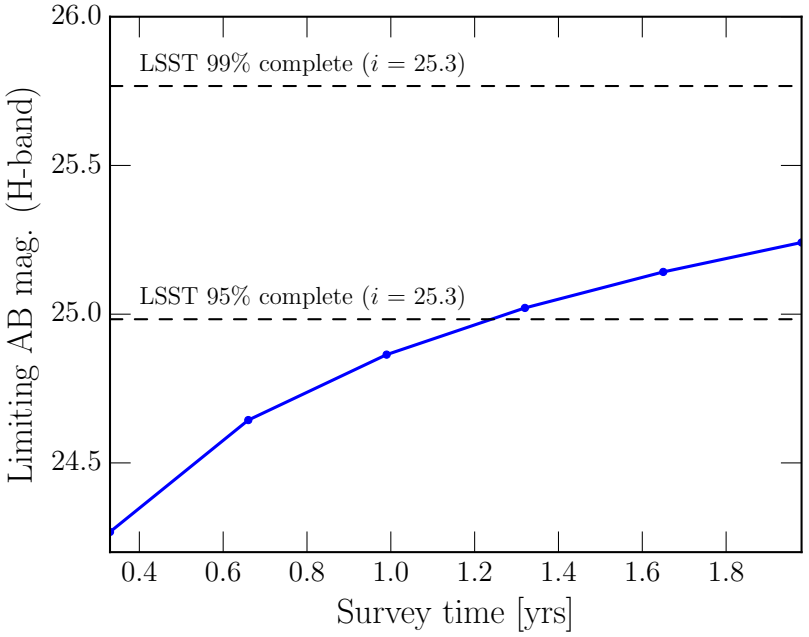
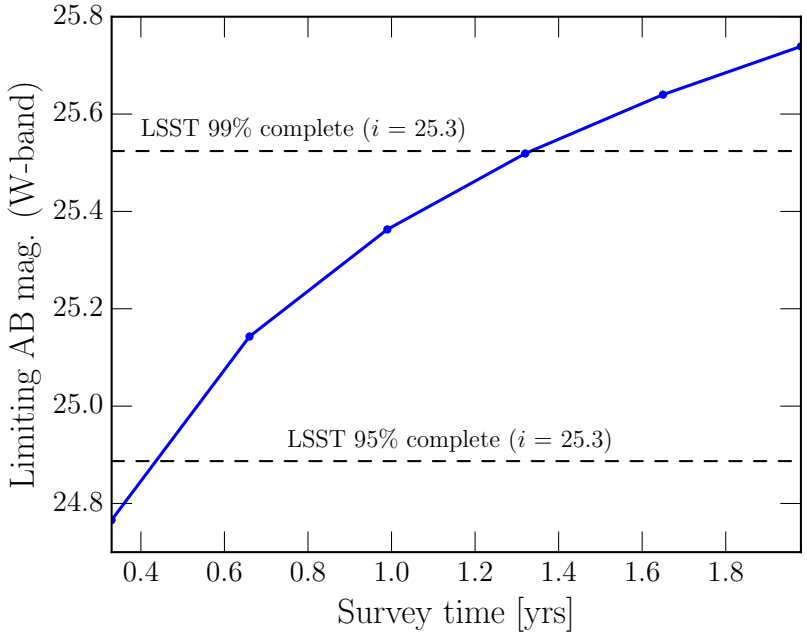
- **Synergies with ground-based surveys**

Synergies with LSST

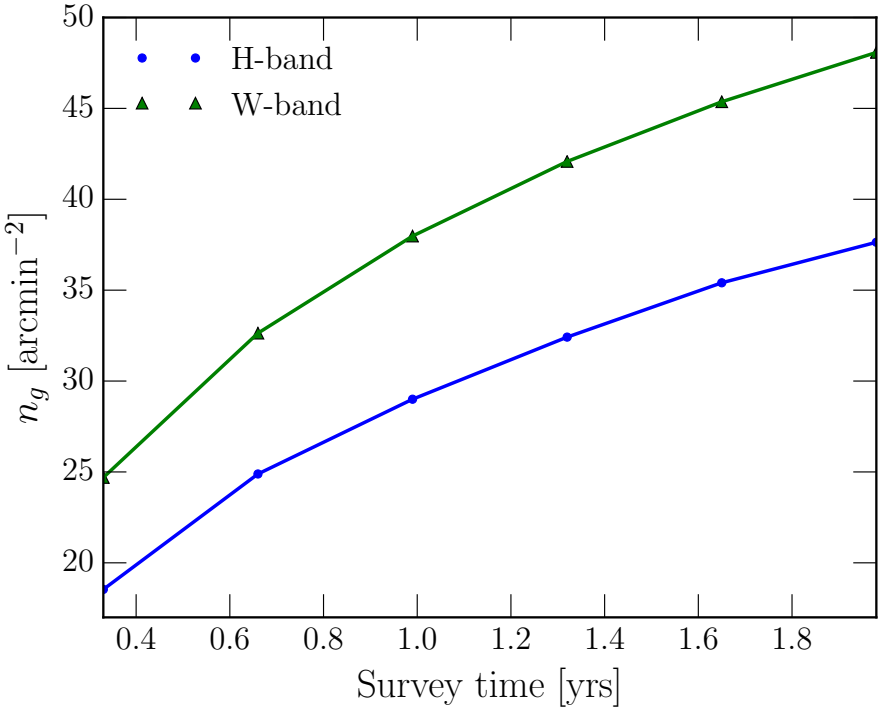
- LSST: 6 optical bands 300 nm to 1000 nm
- WFIRST: 4 NIR bands
- Similar depth, large overlap of detected galaxies (photometric redshift and galaxy shape measurements)
- Spectroscopy from WFIRST

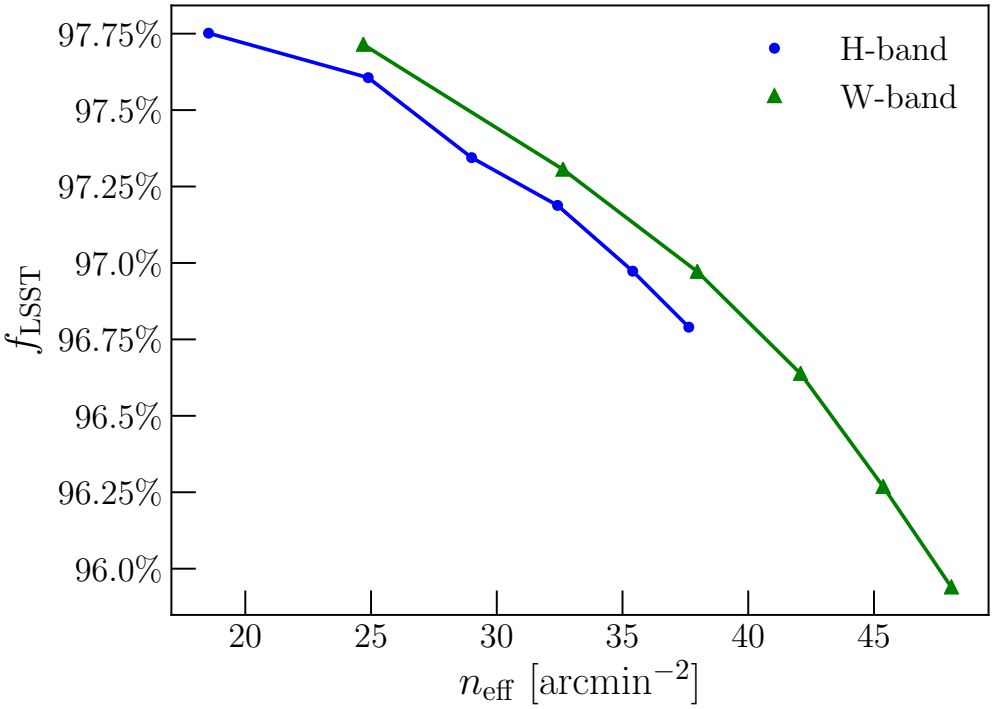
Synergies with LSST

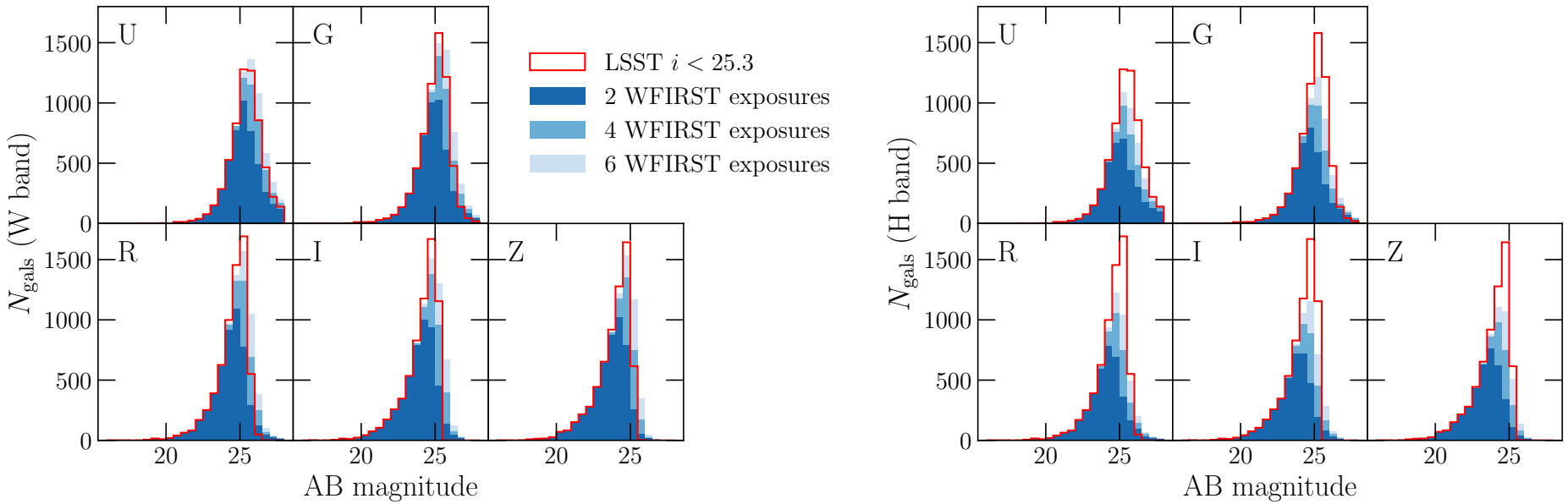




Synergies with LSST






U
G
R
I
Z
LSST $i < 25.3$
2 WFIRST exposures
4 WFIRST exposures
6 WFIRST exposures
$N_{\rm gals}$ (W band)
$N_{\rm gals}$ (H band)
AB magnitude
0
500
1000
1500
20
25

- Backup slides

Clusters

$$N^i(\lambda_\alpha) = \Omega_s \int_{z^i_{\lambda,\min}}^{z^i_{\lambda,\max}} dz \frac{d^2V}{dz d\Omega} \int dM \frac{dn}{dM} \int_{\lambda_{\alpha,\min}}^{\lambda_{\alpha,\max}} d\ln\lambda \, p(\ln\lambda|M,z)$$

$$p(\ln\lambda|M,z) = \frac{1}{\sqrt{2\pi}\sigma_{\ln\lambda|M,z}} \exp\left[-\frac{(\ln\lambda - \langle\ln\lambda\rangle(M))^2}{2\sigma^2_{\ln\lambda|M,z}}\right]$$

$$\sigma_{\ln\lambda|M,z} = \sigma_0 + q_M \ln\left[\frac{M}{M_{\text{pivot}}}\right] + q_z \ln[1+z]$$

$$\langle\ln\lambda\rangle(M) = A + B\ln\left[\frac{M}{M_{\text{pivot}}}\right] + C\ln[1+z]$$

Baseline survey

Parameter	Fid	Prior
	Survey	
Ω_s	2,000 deg^2	fixed
$n_{\rm eff}$	45 gal/arcmin^2	fixed
σ_ϵ	0.26	fixed
	Cosmology	
$\Omega_{\rm m}$	0.3156	flat (0.1, 0.6)
σ_8	0.831	flat (0.6, 0.95)
n_s	0.9645	flat (0.85, 1.06)
w_0	-1.0	flat (-2.0, 0.0)
w_a	0.0	flat (-2.5, 2.5)
$\Omega_{\rm b}$	0.0492	flat (0.04, 0.055)
h_0	0.6727	flat (0.6, 0.76)
	Galaxy bias	
$b_{\rm g}^1$	1.35	flat (0.8, 3.0)
$b_{\rm g}^2$	1.5	flat (0.8, 3.0)
$b_{\rm g}^3$	1.65	flat (0.8, 3.0)
$b_{\rm g}^4$	1.8	flat (0.8, 3.0)
	Lens photo-z (red sequence)	
$\Delta^i_{\rm z,lens}$	0.0	Gauss (0.0, 0.0004)
$\sigma_{\rm z,lens}$	0.01	Gauss (0.01, 0.0006)
	Source photo-z	
$\Delta^i_{\rm z,source}$	0.0	Gauss (0.0, 0.002)
$\sigma_{\rm z,source}$	0.05	Gauss (0.05, 0.003)
	Shear calibration	
m_i	0.0	Gauss (0.0, 0.004)
	Cluster Mass Observable Relation	
A	3.207	
B	0.993	
C	0	See Section 3.4
σ_0	0.456	
q_M	-0.169	
q_z	0.0	