WFIRST/AFTA
NAS Dark Energy Presentation

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Instrument Comparisons

Feature	IDRM	AFTA-WFIRST 2.4
Mirror Diameter	1.3 m	2.4 m
Imager		
Detectors	28 H2RG	18 H4RG
Total Pixels	112 Mpix	288 Mpix
Area on Sky	0.29 sq deg	0.28 sq deg
Plate Scale	0.18”/pix	0.11”/pix
Wavelength	0.6 – 2.0 μ	0.6 – 2.0 (2.4) μ
Spectrometer	Slitless Grism	Grism+Integral Field
Coronograph	No	Yes

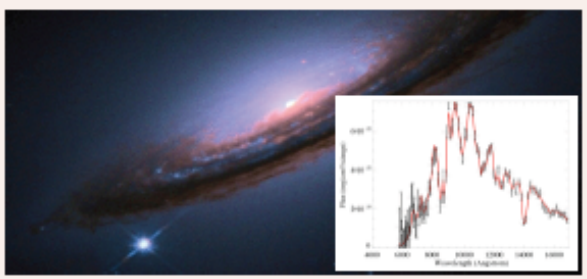
The WFIRST-2.4 Dark Energy Roadmap

Supernova Survey

wide, medium, & deep imaging
+
IFU spectroscopy

2700 type Ia supernovae
z = 0.1–1.7

standard candle distances
z < 1 to 0.20% and z > 1 to 0.34%



High Latitude Survey

spectroscopic: galaxy redshifts

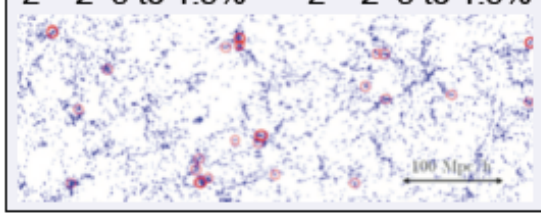
20 million Hα galaxies, z = 1–2
2 million [OIII] galaxies, z = 2–3

imaging: weak lensing shapes

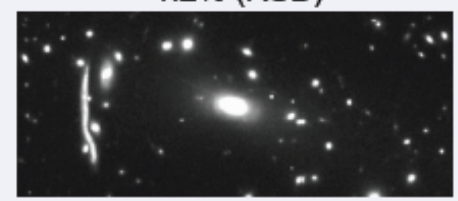
500 million lensed galaxies
40,000 massive clusters

standard ruler

distances	expansion rate
z = 1–2 to 0.4%	z = 1–2 to 0.72%
z = 2–3 to 1.3%	z = 2–3 to 1.8%

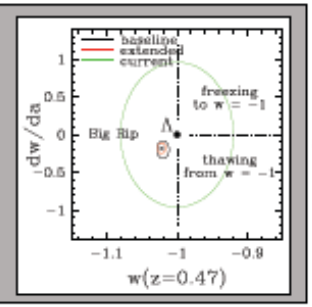


dark matter clustering
z < 1 to 0.16% (WL); 0.14% (CL)
z > 1 to 0.54% (WL); 0.28% (CL)
1.2% (RSD)



history of dark energy
+
deviations from GR

$w(z)$, $\Delta G(z)$, Φ_{REL}/Φ_{NREL}



Dark Energy Changes since Decadal

- Beyond FOM
  - Deviations from GR
  - Desire to measure growth rate and distance as a function of redshift using many techniques
- Experimental improvements
  - Planck, BOSS results consistent with w = -1
  - Euclid selected, defined
  - LSST moving forward with NSF+DOE support
  - DESI with NSF/DOE support
- By 2023, precision measurements at lower redshifts are likely well underway

AFTA-WFIRST Supernova Program

Forecast aggregate precision: 0.20% (z<1), 0.34% (z>1), 0.18% (all z)

Comparison to DRM1 or IDRM

Larger aperture and IFU allow *major* improvements:

- More SNe (2750 vs. 1500)
- More even redshift distribution
- *Lower systematics*: Better photometry and calibration, no K-corrections, spectral diagnostics to compare similar high- and low-z SNe

Observing strategy can be tailored to match statistical and systematic uncertainties in each redshift bin.

Comparison to Euclid

Euclid has no planned SN program

In AFTA-WFIRST, SN makes a large contribution to combined FoM (for fiducial assumptions, it has the highest FoM leverage of any single probe)

Supernova Survey Comparisons

Feature	IDRM	WFIRST2.4
Total no of SNe	1200	2750
Z Range	0.2 – 1.2	0.2 – 1.7
Lightcurves from	Filters	IFU Spectra
Spectroscopy	Slitless Grism	Integral Field Unit
R(2 pixel)	75	75
Peak S/N *	15	47
σ(dist) at best z	0.007-0.010	0.0045
FoM(AFTA)/FoM(IDRM) **	1.0	2.3 – 3.4

* S/N at peak of lightcueve per (synthetic) Filter Band

** Figure of Merit with Planck prior but without Stage III priors. The range in σ(dist) for IDRM and the range in FoM ratio in WFIRST2.4 correspond to the conservative/optimistic error assumptions in the IDRM study.

AFTA-WFIRST Weak Lensing Program

Forecast aggregate precision: 0.16% (z<1), 0.54% (z>1), from cosmic shear

0.14% (z<1), 0.28% (z>1) from cluster-galaxy

Comparison to DRM1

Smaller survey area (2000 deg^2 vs. 3400 deg^2) but higher n_{eff} (68 $arcmin^{-2}$ vs. 40 $arcmin^{-2}$) leads to same number of shape measurements (0.5 billion), similar statistical power

Higher n_{eff} allows detailed dark matter maps, greater gains in extended survey

Obstructed pupil, GEO orbit add complications, but surmountable

Comparison to Euclid

Euclid has lower n_{eff} (20-35 $arcmin^{-2}$) but larger area (14,000 deg^2), with more shape measurements and thus higher statistical precision

AFTA-WFIRST has much tighter control and cross-checks of systematics: 8-9 passes in 3 shape measurement filters (6 auto/cross correlations) vs. 2 passes in a single wide optical filter

AFTA-WFIRST much more likely to achieve statistics-limited accuracy, could confirm (or challenge) accuracy of Euclid and LSST shape measurements

ADD TEXT ON PHOTO-Z

AFTA-WFIRST Galaxy Redshift Survey Program

Forecast aggregate precision: 0.40% in D_A, 0.72% in H, at z=1-2

1.3% in D_A, 1.8% in H, at z=2-3 ([OIII] emitters)

1.2% in $\sigma_m(z)f(z)$ at z=1-2 (from RSD)

Comparison to DRM1

Hα redshift range z = 1-2 instead of z=1.35-2.65

Smaller survey area (2000 deg^2 vs. 3400 deg^2) but much higher galaxy space density (by a factor ~4 at peak redshift)

Similar forecast for aggregate precision

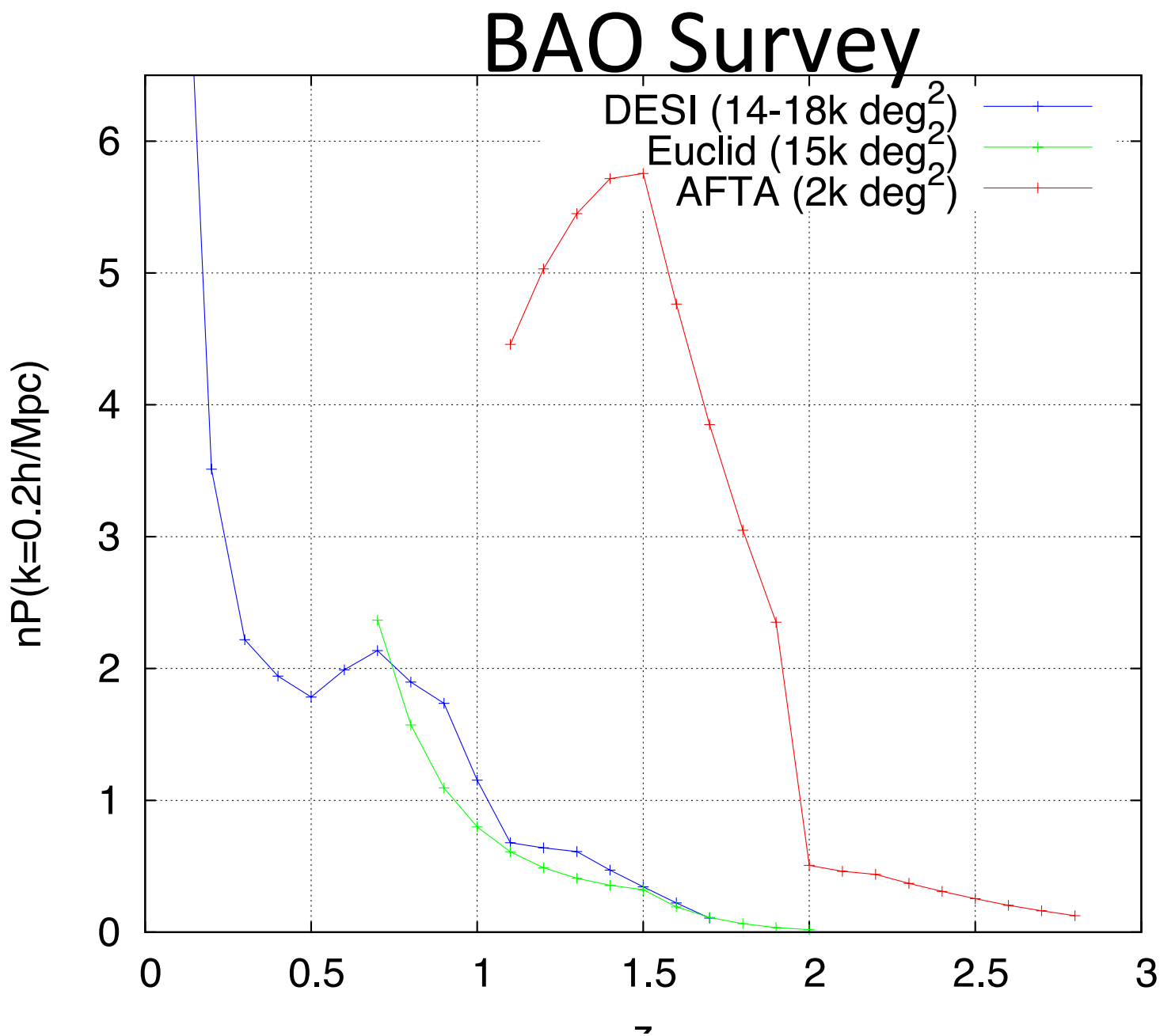
[OIII] emitters provide sparsely sampled tracers for BAO and RSD at z=2-3

Comparison to Euclid

Euclid has larger area but *much* lower space density (factor ~20)

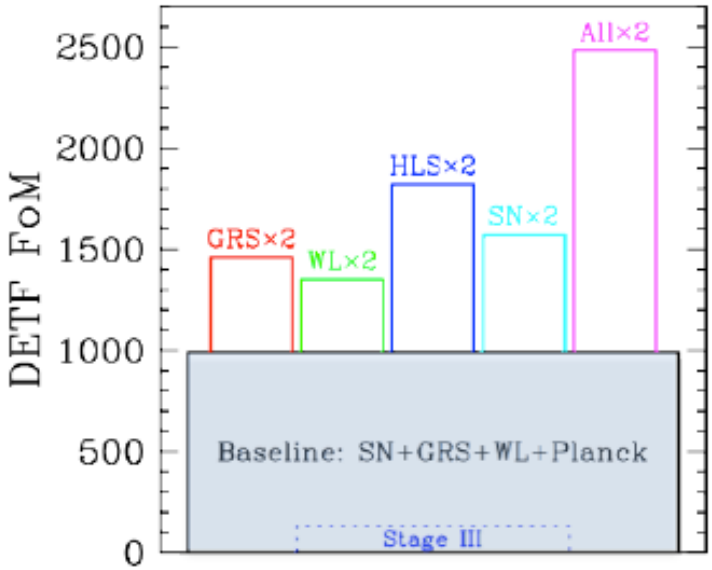
Similar aggregate precision [???] and largely independent BAO/RSD, even in overlapping sky area

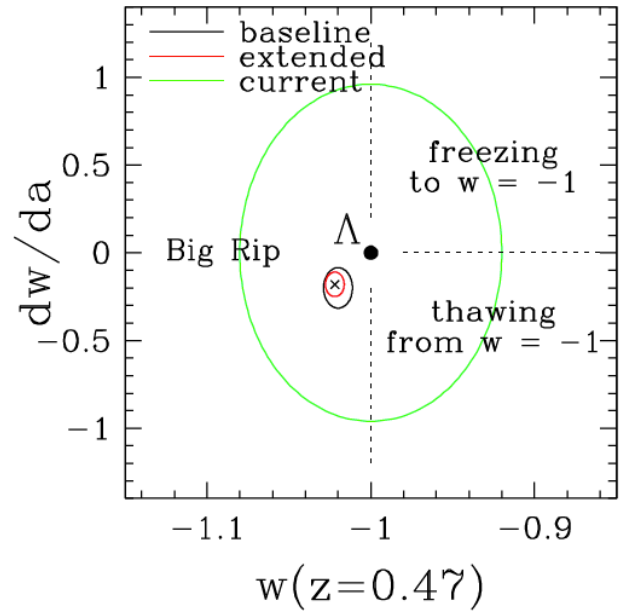
Greater depth of AFTA-WFIRST makes it much more robust to luminosity function uncertainty, allows large potential gains in extended survey.


BAO Survey
DESI (14-18k deg^2)
Euclid (15k deg^2)
AFTA (2k deg^2)
nP(k=0.2h/Mpc)
0
1
2
3
4
5
6
0
0.5
1
1.5
2
2.5
3

DETF-FOM Improvement

	Norm. to IDRM
Supernova	2.3-3.4
BAO	1
Weak lensing	1





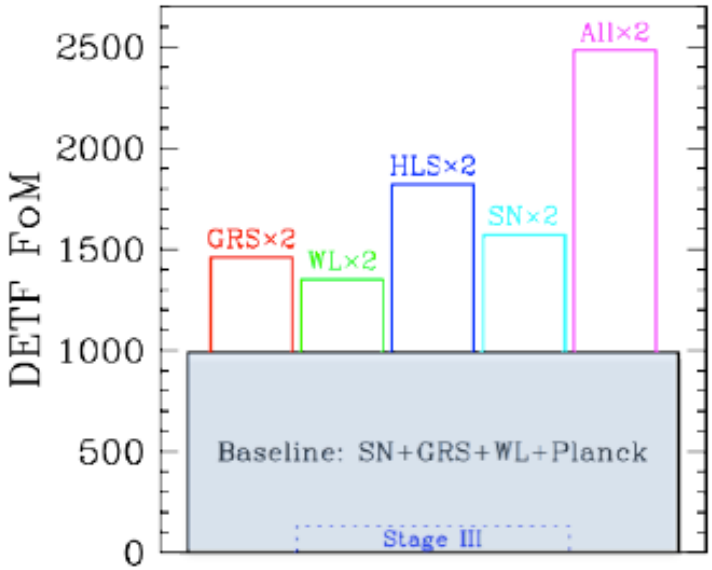
FoM = $[\sigma(w_p) \times \sigma(w_a)]^{-1}$ for baseline case is 7.5× increase over "Stage III" forecast.

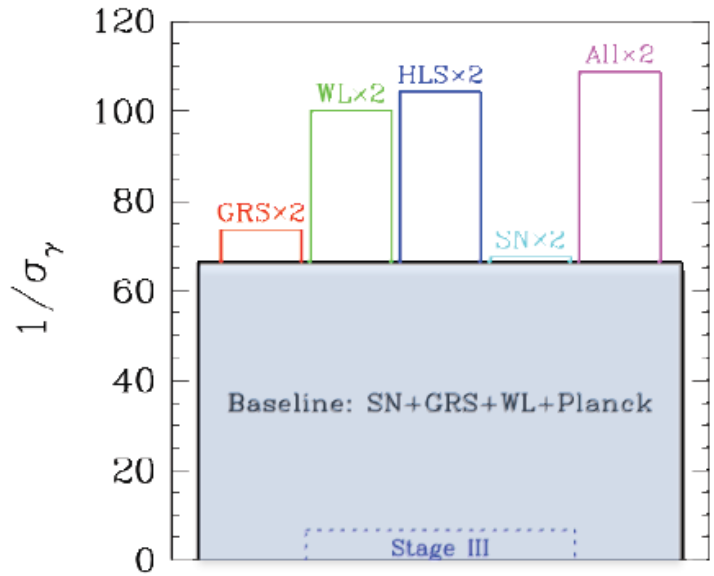
This represents big advance in ability to distinguish physically interesting models.

All elements of program contribute, as one sees by doubling precision of any one of them; such doubling might be achieved by further tightening systematics, increasing survey area in extended mission, better theoretical modeling.

Calculation includes AFTA-WFIRST, Planck, local SN calibrators, BOSS.

Doesn't include cluster-galaxy and galaxy-galaxy lensing; forecasts for these are more uncertain, but likely to improve constraints significantly.





Major advance in testing modified gravity explanations of cosmic acceleration, here parameterized by deviation of growth index γ.

With baseline assumptions, WL dominates these constraints; cluster-galaxy and galaxy-lensing likely to improve them by significant factor.

Comparison of WL and RSD is itself an important test of modified gravity models; affected by different gravitational potentials that are equal in GR.

AFTA-WFIRST RSD also probes higher redshift.