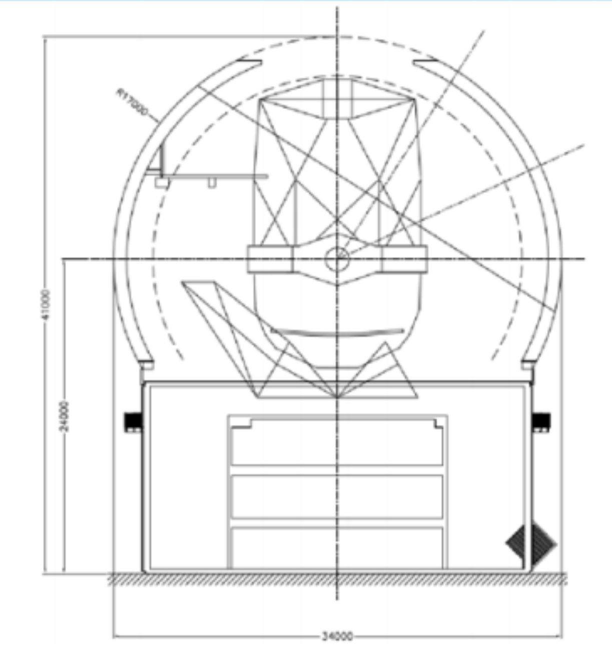
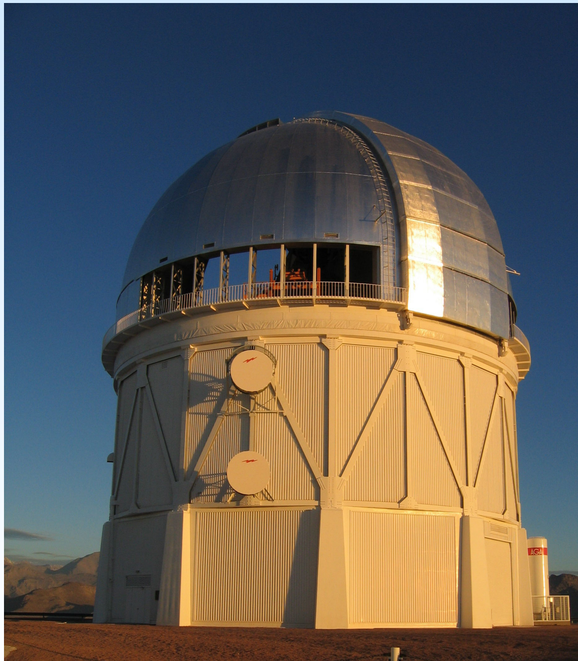
SSSI

Southern Spectroscopic Survey Roadmap: Summary

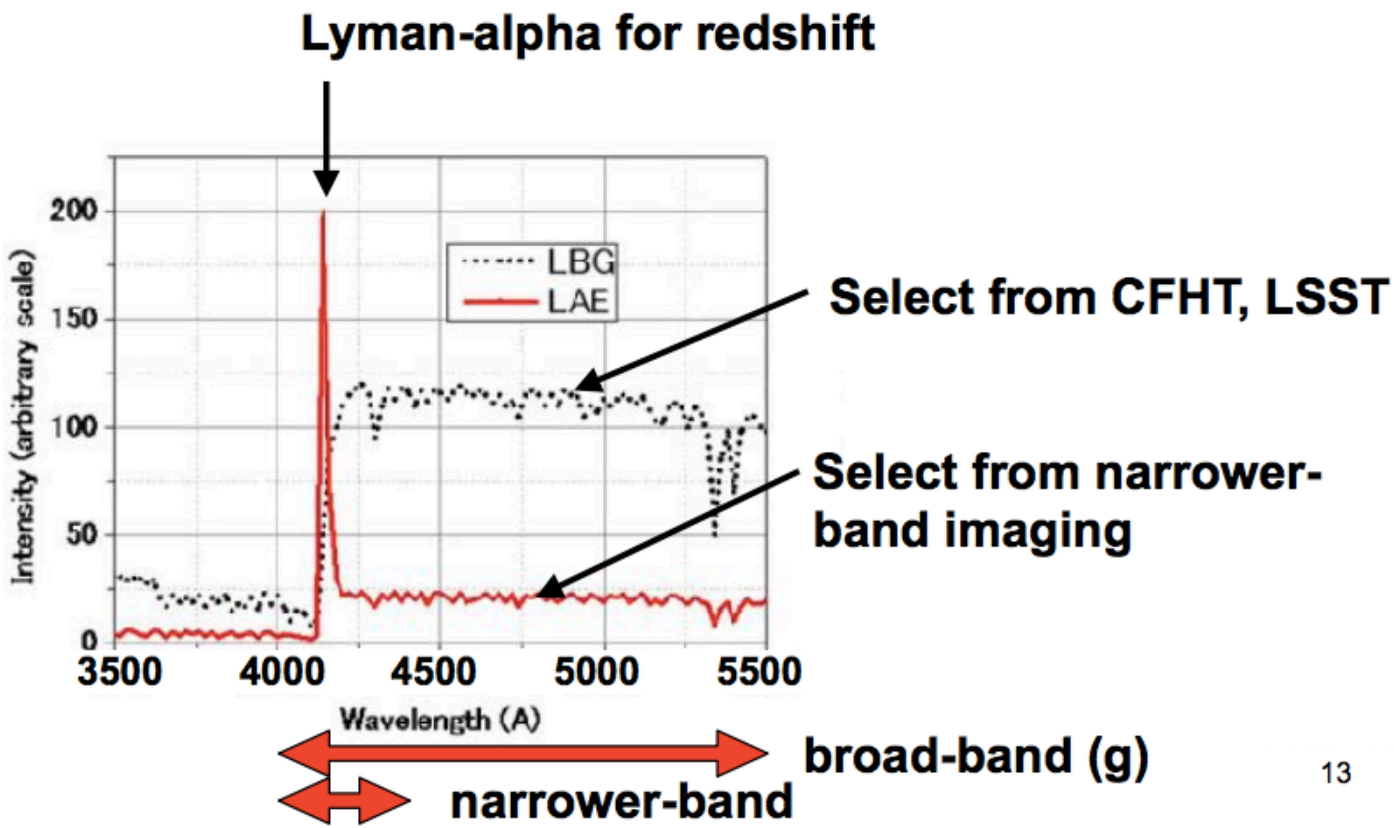
Josh Frieman, Kyle Dawson,
Jeff Newman





Lyman-alpha emission galaxies are the low-hanging fruit at z=2—4

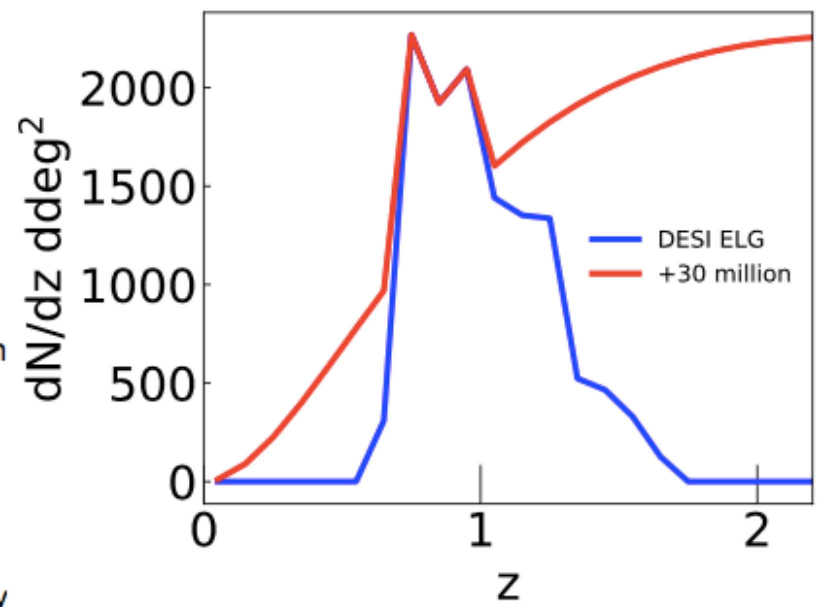
DESI is already the perfect instrument for these galaxies
Broad-band imaging will exist in 2025 to select some
Better would be narrow-band imaging to select all



Schlegel

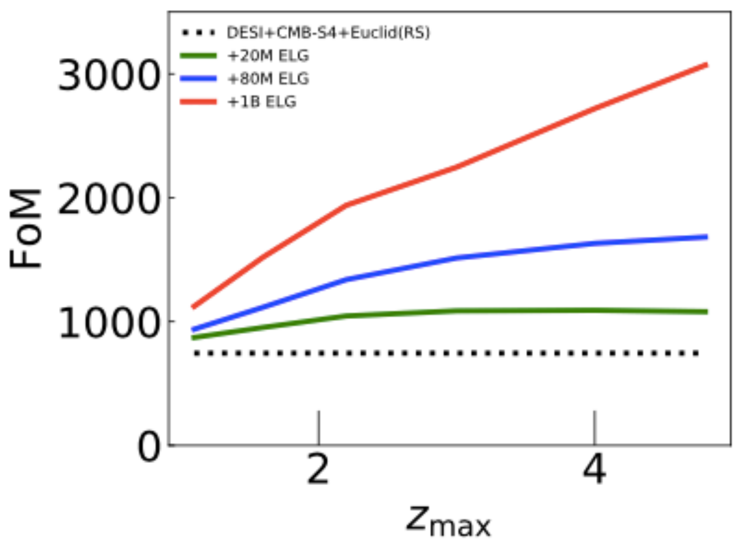
Explore parameter constraints for ~arbitrary additions to DESI

- Fisher matrix calculations including multi-tracers (ELG, LRG, QSO).
- Always assume 14k sq. deg.
- Add some number of galaxies with fixed comoving density, typically over all z<z_max, although in some cases also with z>z_min.
- "ELG" means b(z)D(z)=0.84D(0)
- "LRG" means b(z)D(z)=1.7D(0)
- b(z) capped at bias corresponding to most massive halos for given number density.
- Always include DESI as planned, Planck, CMB-S4, half of Euclid redshift survey (to avoid worrying about overlap).
- Intended more to compare different scenarios than predict absolute results, because based on power spectrum with relatively simple maximum k to account for non-linearity, while real analysis would use some hideously complicated non-linear model and hopefully higher order statistics, or a complex reconstruction process.
- 21 cm can't magically do better in the same volume



McDonald

Dark Energy TF FoM



IG. 7. DETF FoM (marginalized over neutrino mass) for 14000 sq. deg. with uniform comoving density out to z_{max}. Baseline DESI plus CMB-S4 plus Euclid redshift survey only. Improvement factors 1.5, 2.3, 4.1.

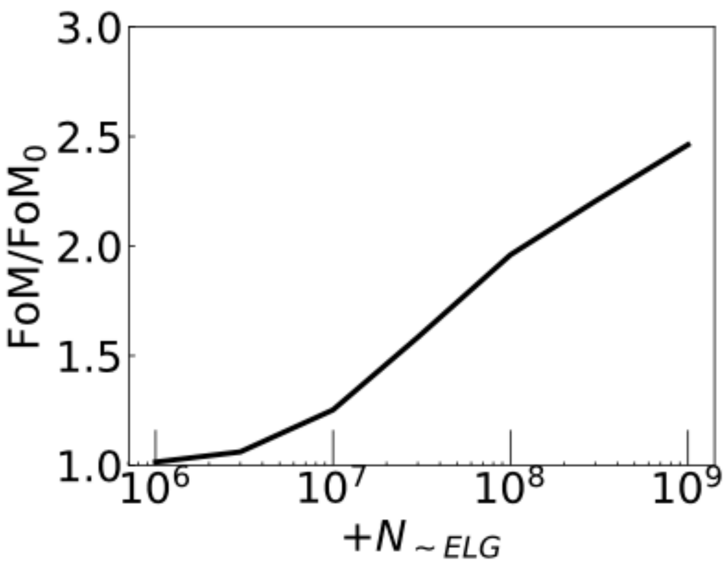


FIG. 9. Dark Energy FoM improvements for 14000 sq. deg. with uniform comoving density added over the range $2 < z <$
Baseline is DESI plus CMB-S4 plus Euclid redshift survey only.

- Proportional to area inside w_0-w_a contours.
- Marginalize over neutrino mass.
- Can get factor of 2 improvement with, e.g., ~100 million galaxies in the range 2<z<3.5 (imagining LAE survey).

McDonald

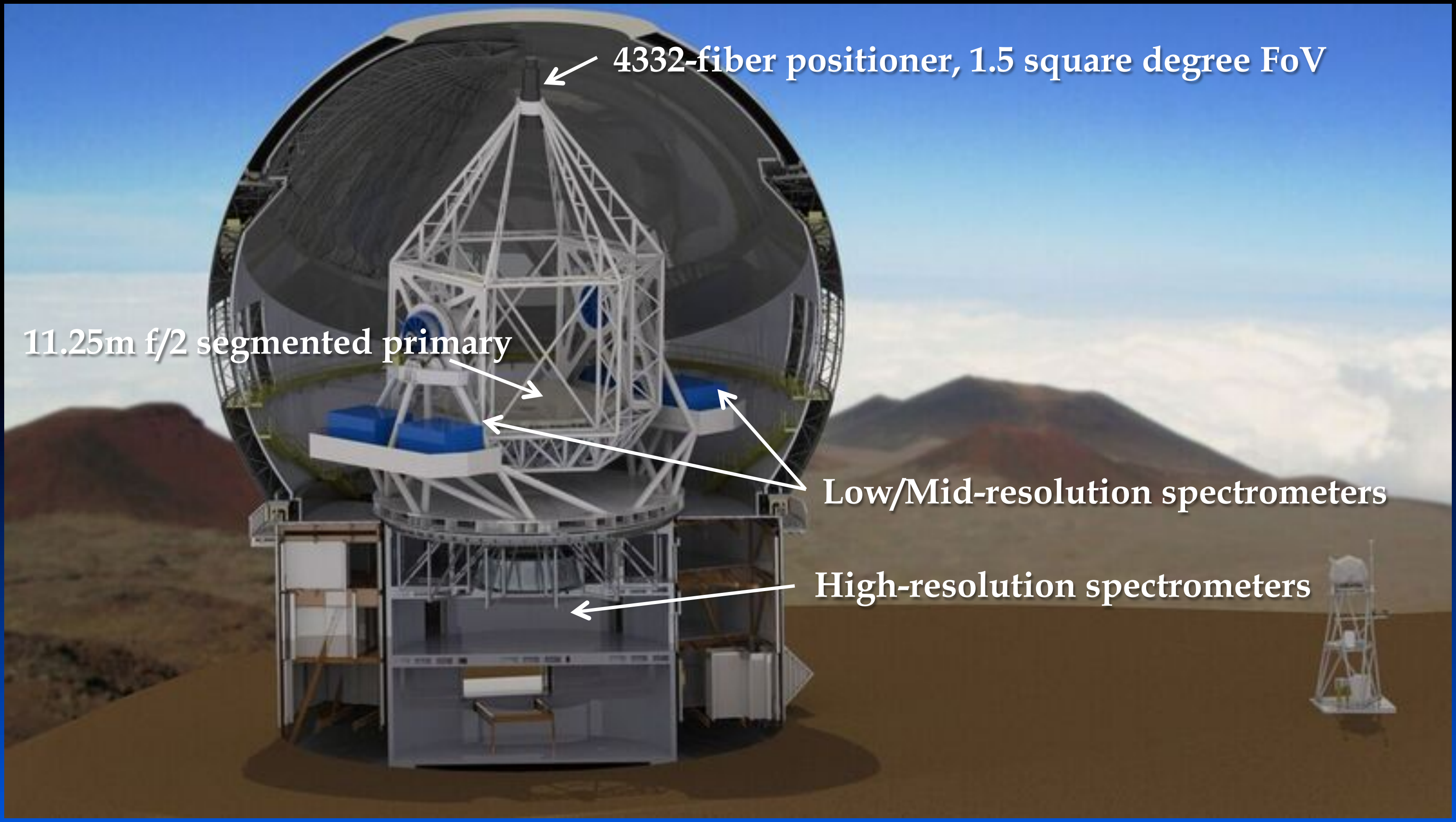
Mode-Counting in the Ly-alpha Forest

- CLAMATO at 2.0<z<2.6 yields effective comoving spatial resolution of 5Mpc/h → **k_{max} ~ 0.7h/Mpc**
- 1deg^2 over 2.0<z<2.6 covers $2 \times 10^6\ h^{-3}$Mpc^3 → 16k modes/deg^2
- 10k deg^2 CLAMATO-like survey over 2<z<3 would yield 200+M modes, going to non-linear (c.f. ~10-15M modes in DESI and LSST)
- ~25M background galaxies at 2.3<z<3.5
  - Cross-correlation/multi-tracer techniques between b~2 galaxies + Lyα forest
  - 2x improvement in curvature measurements c.f. Pat McDonald) from galaxies alone

Lee

Maunakea Spectroscopic Explorer

MSE is the future of CFHT

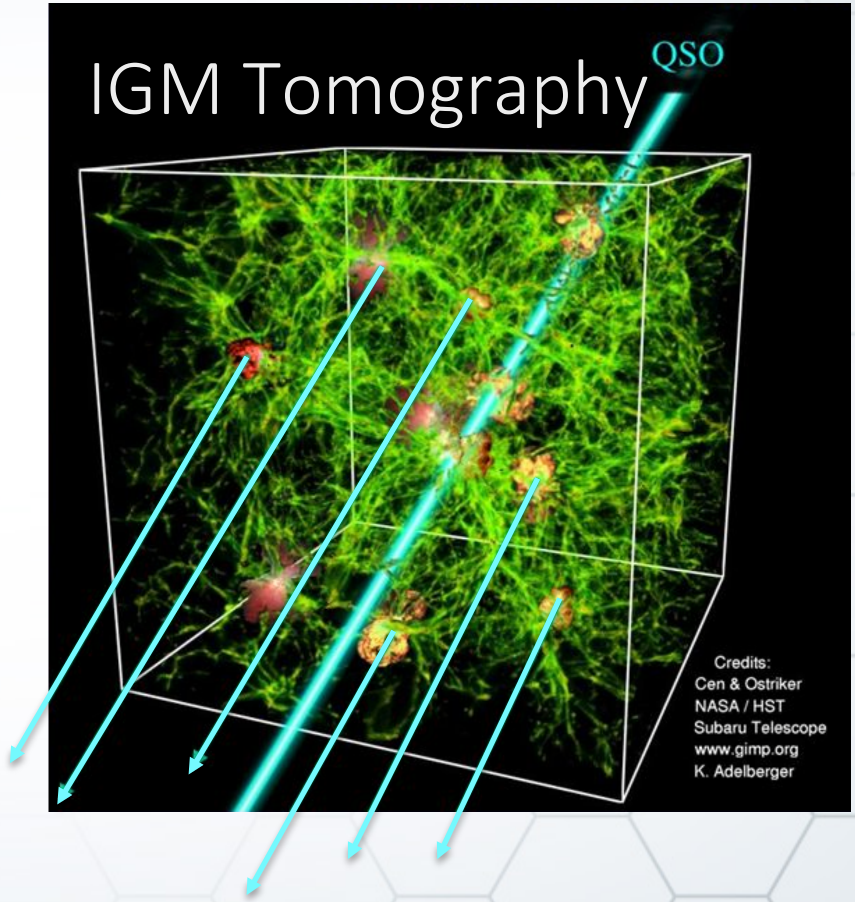


Current MSE Baseline Design

Hall

Top-level WFOS Capabilities

- Primarily multi-object survey instrument
- Also single-object rapid discovery/identification for transient science
- R~5000 spectroscopy from 310 - 1000 nm
- R~1500 mode beneficial if multiplex and S/N improve
- GLAO ready



LSST Photo-z Training

LSST Forecasts

Newman et al. 2015

Product of errors on w and dw/da (i.e., expansion rate at a given time and its rate of change)

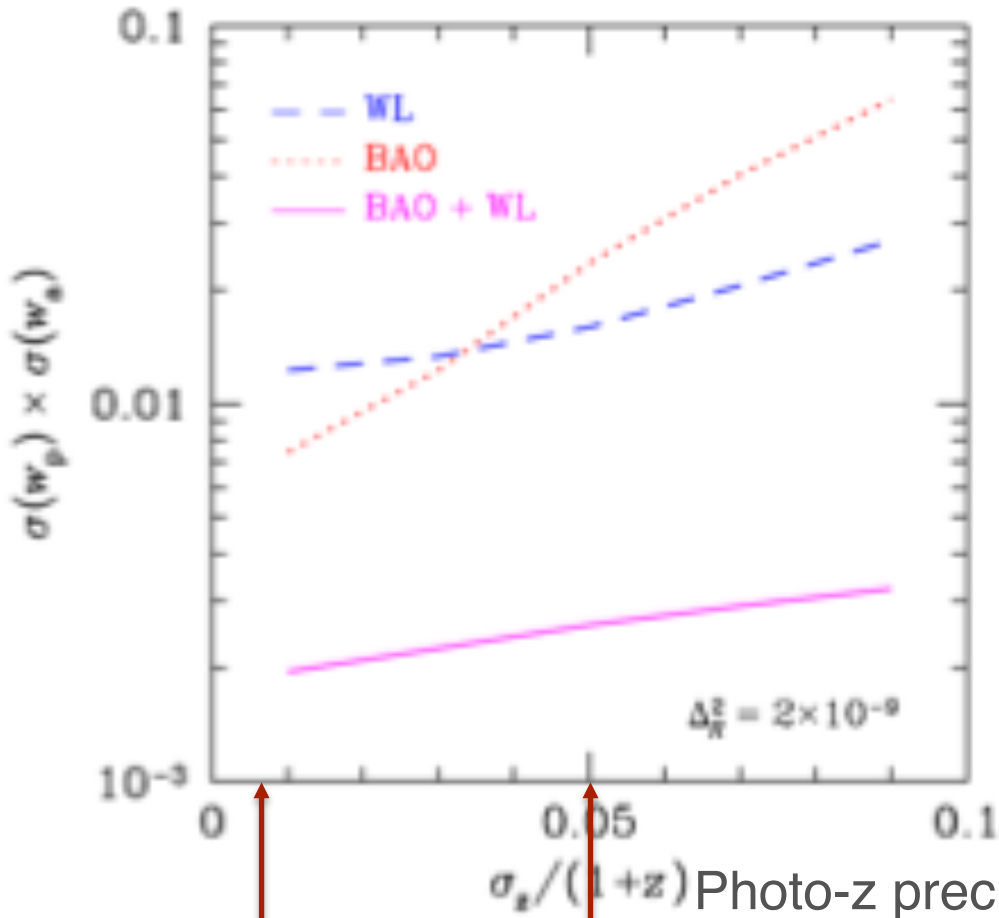


Photo-z precision

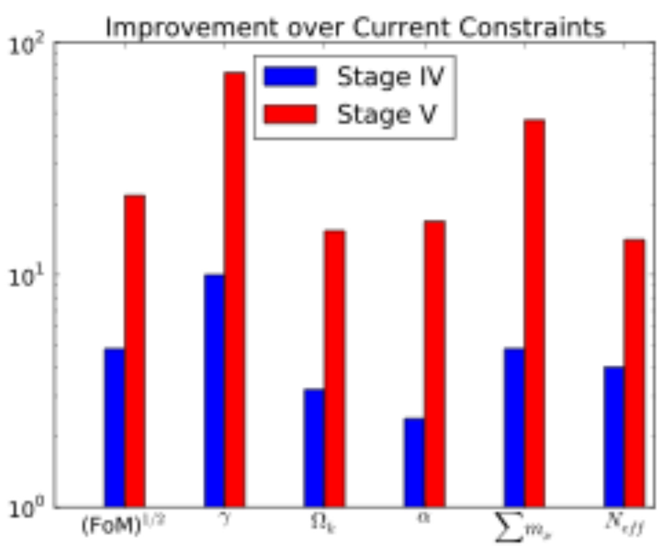
with training

without training

Photo-z training offers 50% gains on billion dollar experiments

Cosmology with a ~billion spectra

- Cosmology parameters from RSD power spectrum
  lots of information left in the sky



5.4 High Resolution Spectroscopy of a Billion Objects

A most ambitious project would be one that obtained high resolution spectra of a large fraction of LSST objects. Such a *Billion Object Apparatus* (BOA) would come close to attaining the parameter improvements depicted in the right panel of Fig. 1 and open up many avenues for new discoveries. Here we outline some

from cosmic visions report
assumes k_{max} = 0.5 h/Mpc

Krause

Cosmological Parameters from SSSI: SSSI Modeling

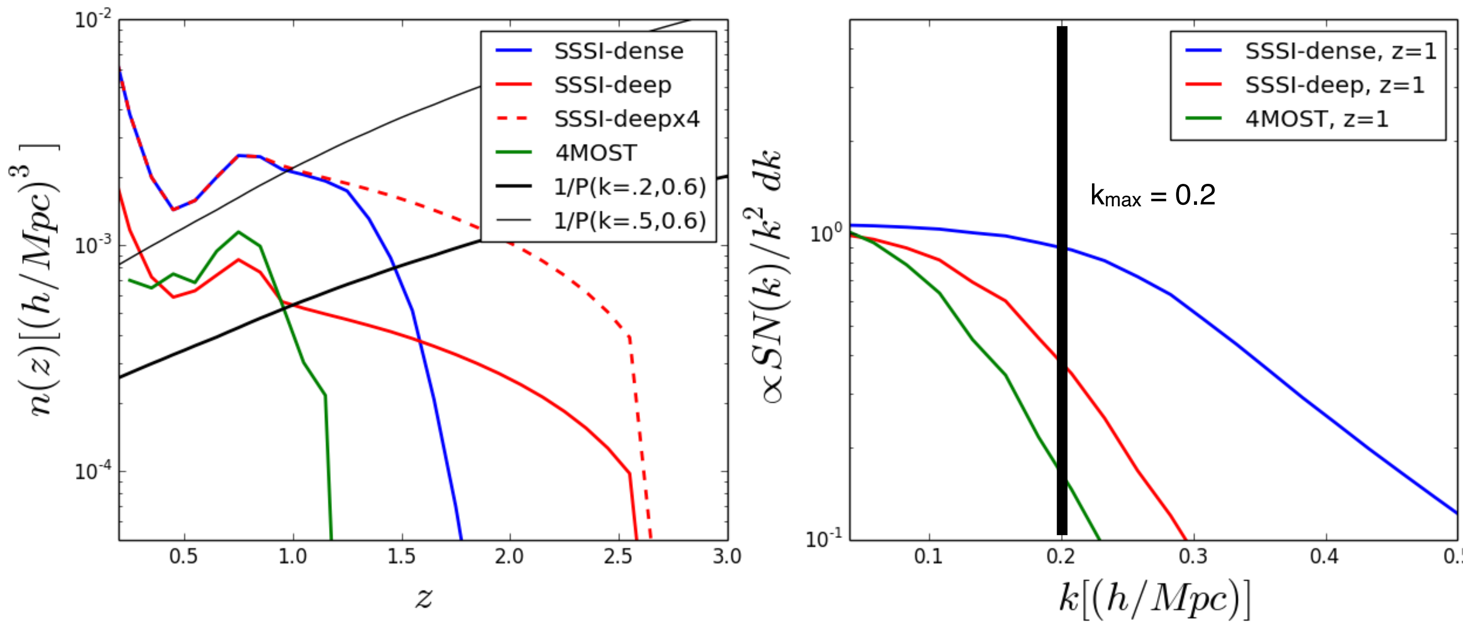
SSSI

- **SSSI Baseline Scenarios**

- SSSI-dense: 4xDESI-like density -> better sampling at large k

- SSSI-deep: DESI-like + high-z sample -> extend redshift baseline

- multi-tracer analysis with ELG, LRG, QSO samples



Krause

Cosmological Parameters from SSSI: Constraints

	Stage IV	+SSSI *dense*, k_{max}=.2	+SSSI *dense*, k_{max}=.5	+SSSI *deep*, k_{max}=.2	+SSSI *deep*, k_{max}=.5	+SSSI *deepx4*, k_{max}=.2	+SSSI *deepx4*, k_{max}=.5
FoM	1089	1486	2430	1425	1972	1697	2860
$\sigma(w_a)$	0.082	0.070	0.050	0.071	0.060	0.062	0.051
$\sigma(\alpha_s)$	0.0028	0.0022	0.0016	0.0022	0.0019	0.0020	0.0013
$\sigma(\mu)$ $\sigma(\Sigma)$	0.019, 0.033	0.014, 0.027	-	0.015, 0.028	-	0.012 0.023	-

- **NB: Lya, CMB-S4, survey cross-correlations not yet included**
- **Stage IV + SSSI includes improved photo-z calibration**

Krause

Cosmology with a ~ billion spectra:Bispectrum

$$B_g(k_1,k_2,k_3) = b_1^3 B_m(k_1,k_2,k_3)$$ **non-lin. gravitational evolution**

$$+b_1^2 b_2 \left[P_m(k_1)P_m(k_2) + (2\,\text{cyclic})\right]$$ **quadratic galaxy biasing**

$$+b_1^3\,(\text{primordial Bispectrum})$$ **inflation**

- High S/N Bispectra may uncover new physics
  - Measuring amplitude of primordial non-Gaussianity templates will distinguish between single/multi-field inflation, constrain slow roll

$\sigma(f_{\rm NL}^{\rm local}) < 1$ <- driven by scale-dep. bias, z< 2.5

$\sigma(f_{\rm NL}^{\rm equal}) \sim \text{a few}$ <- driven by high-z coverage

$\sigma(f_{\rm NL}^{\rm oath}) \sim \text{a few}$

preliminary!

- Anisotropic non-Gaussianity, search for features
- Plenty of room, *and S/N*, for new ideas :)

Krause

Questions overlapping other groups

SSSI

- **Technology questions:**
- **GLAO**
- **Fiber pitch: (how) can we get to very small pitch?**
- **NIR detectors**
- **Theory questions:**
- **how do we exploit cosmological information at small scales?**
- **need to model Ly-alpha forest for forecasts**
- **New windows: e.g., SN hosts, GW standard sirens,…**
- **Will wide-band imaging be sufficient?**
- **e.g., potential advantages of deep spectroscopy & multi-band imaging, e.g., of LSST deep drilling fields**

General Questions/Issues

- **Flesh out complementarity with non-cosmological science & connect with that community: will likely determine scale**
- **Sharpen aperture requirements for science cases**
- **Sharpen location (hemisphere) requirements: how much LSST overlap is needed?**
- **Flesh out roadmap options and carry out trade studies:**
- **Science requirements → Survey design → Facilities**
- **DESI → DESI-II → LSST spectroscopy → Dedicated facility**
- **2019 2024? late 2020's? 2030's**
- **DESI-II: stay north, move south, clone south, or new instrument in south, e.g., with much smaller pitch?**
- **LSST spectroscopy: Magellan? PSF? MSE? GSMT?**

Outline for a (Southern?) Spectroscopic Roadmap: ~10 pages?

I. Introduction
    A. Context in the 2020s and 2030s
    B. XYZ
II. Science drivers for future spectroscopy
    A. Photometric redshift training (J. Newman)
    A. Cosmology from nonlinear modes (Andrew Hearin, Zheng Zheng)
    B. Constraining the galaxy-halo connection
    C. SN hosts (Dan S, Bob K, Alex K), Gravitational wave source hosts (Marcelle, Jim A), dark matter in dwarfs (Keith B), …
    D. IGM (KG)
    E. Voids, higher-order correlations & primordial NG (Elisabeth, Zach)
    F. Connections to astrophysics science cases?
III. Example surveys and forecasts
    A. ABC (Jeff, Kyle, Elisabeth)
    B. XYZ
IV. Potential hardware for these surveys
    A. DESI-2
    B. DESI-South or other 4m wide field spectrograph in south
    C. LASSI
    D. BOA
    E. Options with external projects: Subaru/PFS, MSE, TMT, GMT, …
    F. Technology R&D needs: GLAO (Aaron R), fiber pitch (Tom D), NIR/Ge detectors (Steve H, David S)
    G. Cost estimates (Pat H)
V. An integrated roadmap / Timeline