Combined Probes
Analysis Strategies for the Precision Cosmology era

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The Power of Combining Probes

- Best constraints obtained by combining cosmological probes
  - independent probes: multiply likelihoods

- Combining probes from same survey requires more advanced strategies
  - clustering, clusters and WL probe same underlying density field, are correlated
  - correlated systematic effects

Betoule et al. 2014
Joint Analysis Ingredients

Science Case
- parameters of interest: which science?
- large data vector: which probes + scales?

Likelihood Function
- number counts: Poisson
- 2PCF: ~ Gaussian (?)
- improvements needed for stage IV

Model Data Vector
- self-consistent modeling of all observables including all cosmology + nuisance parameters

Joint Covariance
- large and complicated, non-(block) diagonal matrix
- use template + regularization

Cosmology Priors

Nuisance Parameters
- systematic effects
- validate

Priors
- parameterize + prioritize!

External Data

$p(\pi | \hat{d}) \propto p(\pi) \int \mathcal{L}(\hat{d} | d(\pi, n), C) p(n) \, dn$
Introducing CosmoLike

- Likelihood analysis library for combined probes analyses
- Observables from three object types, and their cross-correlations
  - galaxies (positions), clusters (positions, N_{200}), sources (shapes)
  - separate n(z) + specific nuisance parameters for each object type
- Consistent modeling across probes
  - including systematic effects
- Computes non-Gaussian (cross-)covariances
- Optimized for high-dimensional likelihood analyses
CosmoLike Data Vector

cosmological parameters

cosmo3d.c

Coyote U. Emulator

distances

transfer function $T(k,z)$
growth factor $D(k,z)$
$P_{\text{lin}}(k,z)$
$P_n(k,z)$

halo.c

collapse density $\delta_c(z)$
peak height $\nu(M,z)$

halo properties
$c(M,z)$ $b(M,z)$ $n(M,z)$

HOD, bias model

scaling relation $M_{\text{obs}}(M)$

$\nu$ (M,z)

nuisance.c

non-linear regime
baryons
cluster finding
galaxy formation
intrinsic alignments
non-Gaussian photo-zs
shear calibration

projection functions

Limber approx.

cosmo2d.c

redshift.c

$z$-distr.
n(z)

photo-z model

clusters.c

$N(M_{\text{obs}};z_i)$

$C^{XY}(l;Z_i,Z_j)$
Joint Analysis Game Plan

Theory

Observations

Simulations

CosmoLike

Blinding

Forecasts to Prioritize Systematics

Single Probe Analyses

Combined Probes Analysis

Stage IV Parameter Constraints

Precision

Consistency

Accuracy
Systematics Work Plan

- Specify probes + scales (data vector)
- Identify + prioritize systematic effects
  - find suitable parameterizations + limits
  - needs to be consistent across probes
- Obtain constraints (priors) on nuisance parameters
  - independent observations
  - other observables from same data set
  - split data set
- Combine theory, simulation & data to improve priors
- Worked example: baryons. See Tim Eifler’s talk for WFIRST WL systematics.
Impact of Baryons on WL

5-bin WFIRST WL tomography
no baryon mitigation
uses OWLS simulations
(Schaye, van Dalen, et al.)
Mitigation of Baryons in WL

- PCA based mitigation strategy (Eifler, EK, et al. 14)
- Reduce FoM degradation by improving priors on range of baryonic scenarios
- measure stacked halo profiles (e.g. SZ, X-ray)
- update parameter range for hydro sims
- feed these into updated marginalization scheme
Joint Analysis Game Plan

- Theory
- Observations
- Simulations

- CosmoLike

- Forecasts to Prioritize Systematics
- Single Probe Analyses
- Combined Probes Analysis

- Precision
- Consistency
- Accuracy

Stage IV Parameter Constraints