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LSST x S4 LENSing SYNERGIES
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LARGE SYNOPTIC SURVEY TELESCOPE

LSST: The Experiment
- largest planned LSS survey
- map visible sky every 3 nights
- deep, fast, wide survey strategy
- construction started 2015
- commissioning first light 2019
- survey duration 2022-2032

LSST: Science Collaborations
- Solar System
- Starts, Milky Way, Local Volume
- Transients
- Galaxies
- Active Galactic Nuclei
- Informatics and Statistics
- Dark Energy
Prepare for and carry out cosmology analyses with the LSST survey

- 6 cosmology working groups
  Galaxy Clustering, Galaxy Clusters, Strong Lensing, Supernovae, Weak Lensing; Theory & Joint Probes

- 6 technical working groups
  Cosmological Simulations, Survey Simulations, Sensor Anomalies, Photometric Calibration, Photometric Redshift Determinations, Computing Infrastructure
WEAK LENSING WITH $\sim 10^{10}$ GALAXIES

- weak lensing causes coherent distortion of galaxy shapes, "shear"
  related to projected matter distribution, independent of galaxy bias
- sub-percent level effect
  measure shear of S/N $\sim 25$ galaxies
  assume random intrinsic orientation, average over many galaxies

The Forward Process.
Galaxies: Intrinsic galaxy shapes to measured image:
first joint forecast by science collaboration since LSST Science Book (2009) based on much more mature survey & analysis assumptions, understanding of systematics

joint forecasts including cross-correlations (statistical & systematical)

consider two classes of systematics

self-calibrated, e.g. galaxy bias, intrinsic alignments, cluster mass-observable relation

externally calibrated, e.g. photo-zs, shear calibration, photometric calibration
THE NEED FOR MULTIPLE PROBES, AND MULTIPLE SURVEYS

LSST {WL, LSS, cluster, SN, strong lensing}, CMB-S4 are highly complementary in measurements, astrophysics, cosmology

- uncorrelated obs. systematics
- different techniques for derived measurements (e.g. $\kappa$)
- uncorr. astrophysics systematics
- multi-wavelength studies of clusters, galaxies, feedback
- different parameter degeneracies, redshift coverage

- cross-correlate measurements
  - calibrate observational & astrophysical systematics
- do experiments agree?
- joint analysis of consistent measurements
  - maximize containing power

LSST x S4 LENSSING SYNERGIES
Schmittfull & Seljak 2018: cosmic variance cancellation in \( \{ \text{LSST, DESI} \} \) clustering x CMB-S4 lensing \( gg, \kappa_{\text{CMB}} g, \kappa_{\text{CMB}} \kappa_{\text{CMB}} \)
Mishra-Sharma, Dunkley & Alonso 2018: constraints on DE and neutrino mass in $w_a$CDM cosmologies
COSMOLOGY IN THE 2020S

THE NEED FOR MULTIPLE PROBES, AND MULTIPLE SURVEYS

LSSTxS4 analysis, pass 1
the physics detective work begins
LSST x S4 LENSING SYNERGIES: SYSTEMATICS

- LSST *self-calibrates* galaxy bias, IA, baryonic effects, mass-observable relation, ...
- LSST relies on *external calibration* of photo-zs (all probes), shear calibration uncertainty, photometric calibration, ...

Cross-correlations with CMB lensing
- additional S/N + degeneracy breaking improve self-calibration of systematics
- enable external calibration of systematics in joint analysis
  - validate external prior choices
Madhavacheril, Battaglia & Miyatake 2017: improved self-calibration of cluster mass-observable relations of tSZ selected clusters with CMB-S4 and LSST
Valinotto 2012, Das et al. 2013: Calibrate shape measurement uncertainties (shear calibration) through cross-correlation of CMB lensing and galaxy lensing

- Baxter et al. 2016: demonstration on DES-SV x SPT data
- results from DES-Y1 x SPT forthcoming!
- Schaan et al. 2017: LSST x CMB-S4 reaches LSST calibration requirement for high-z galaxies
- alternatively, calibrate $A_L$
PRECISION COSMOLOGY ANALYSIS PARAMETERS

Cosmology Parameters

25% Data Cut Parameters

5% Systematics Parameters

70% observational systematics

Survey specific

Astrophysical systematics

Observable + survey specific
CONCLUSIONS

LSST \{WL, LSS, cluster, SN, strong lensing\}, CMB-S4 are highly complementary in measurements, astrophysics & cosmology

- cross-correlations
  - calibrate observational & astrophysical systematics
  - guide search for previously unknown systematics
- joint analysis of consistent observables
  - maximize containing power

LSSTxCMB-S4 analyses non-trivial $\rightarrow$ cross-collaboration planning & collaboration

Forecasting: LSST DESC Science Requirements Document (v1)

- LSST DESC galaxy sample, analysis choices, systematics parameterizations
- software and data products available
- software + covariance extension to CMB lensing cross-correlations under way
  - how to phrase systematics calibration + search for unknown systematics?