Simulation and Modeling Challenges

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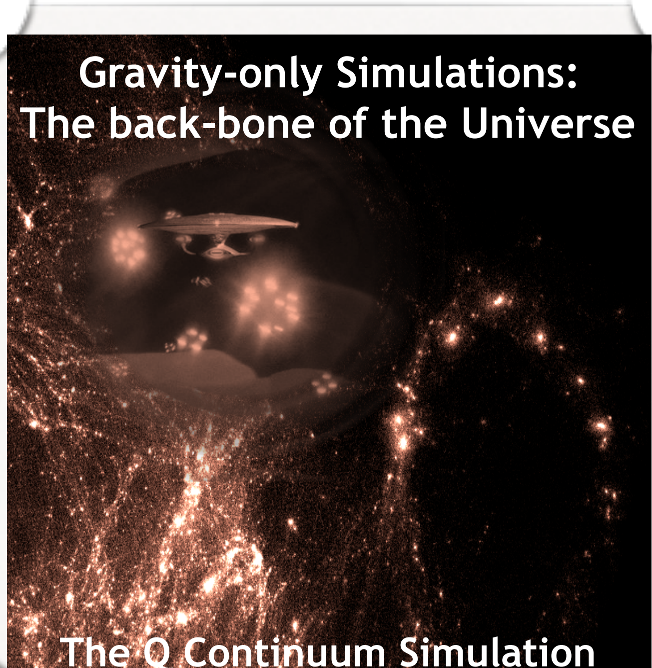
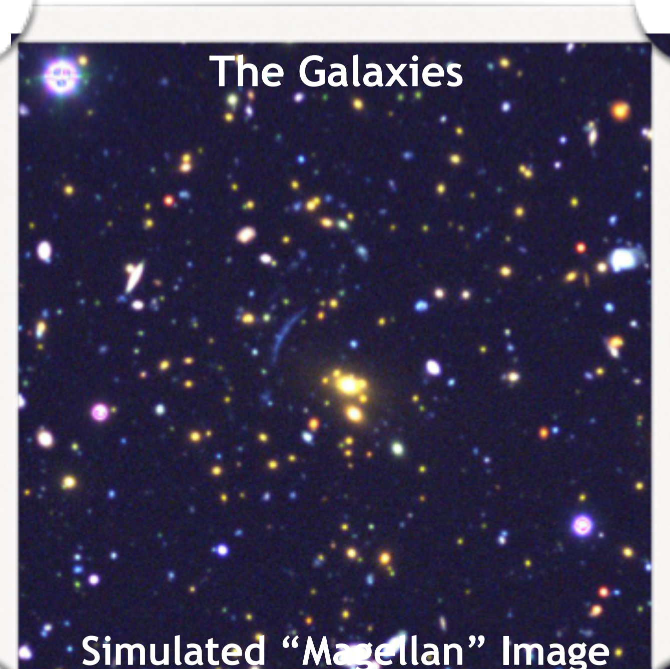
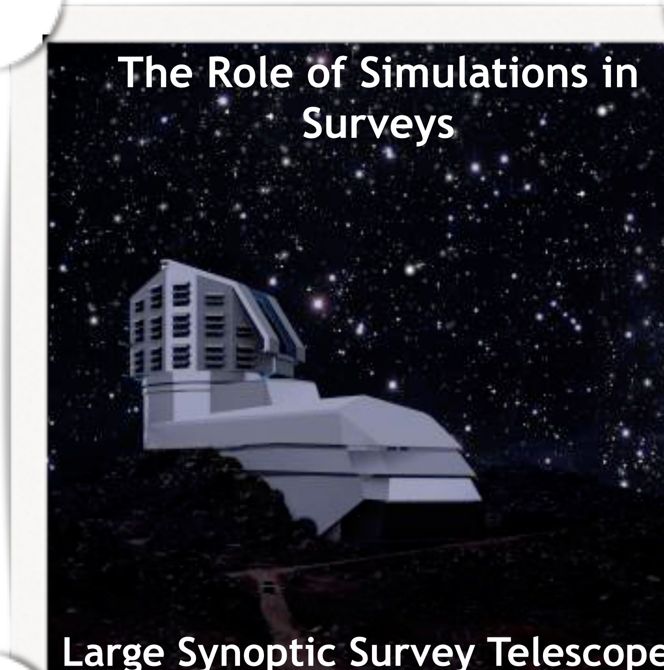
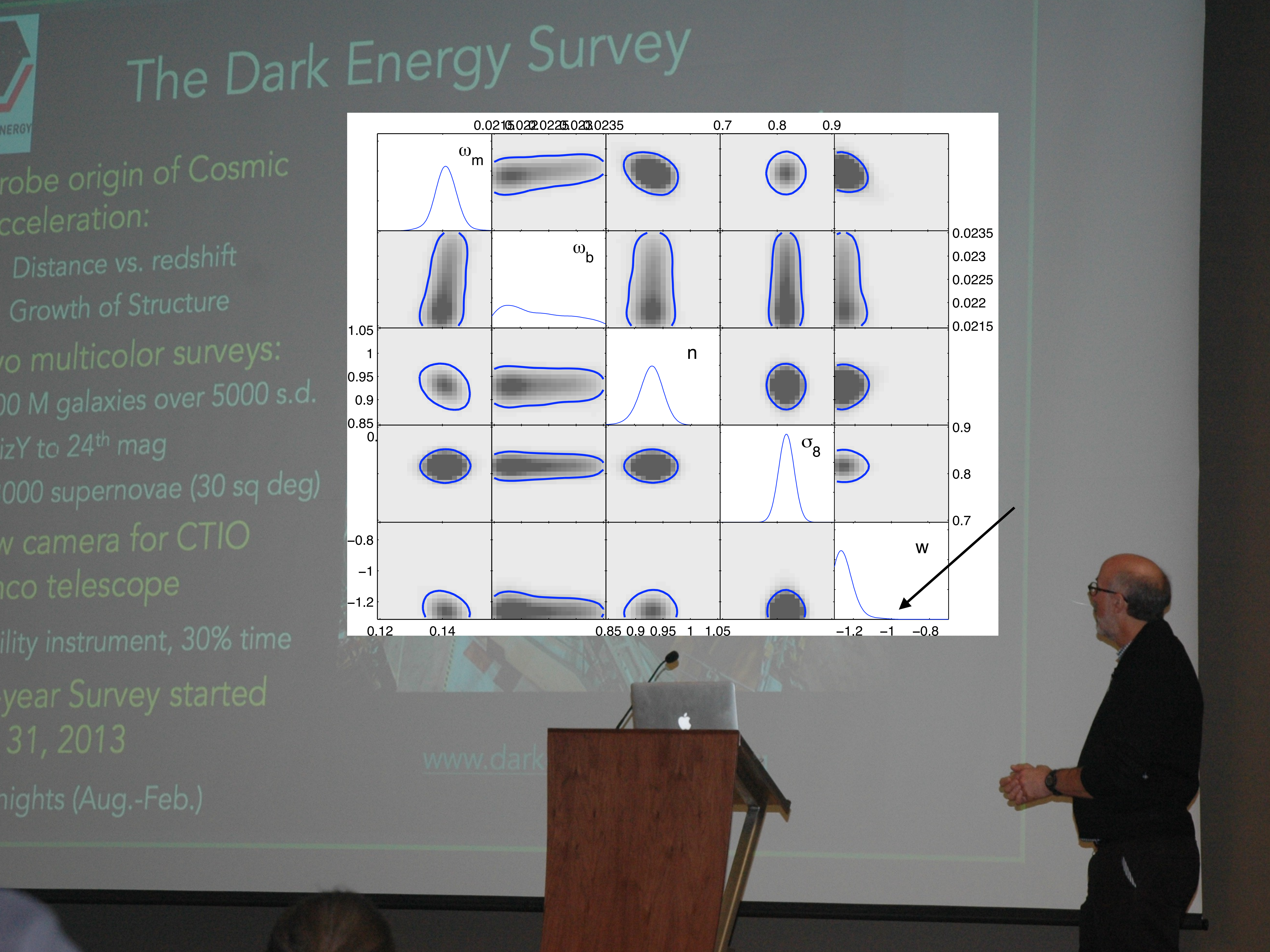
Cosmic Visions Midwest Meeting, November 10, 2015









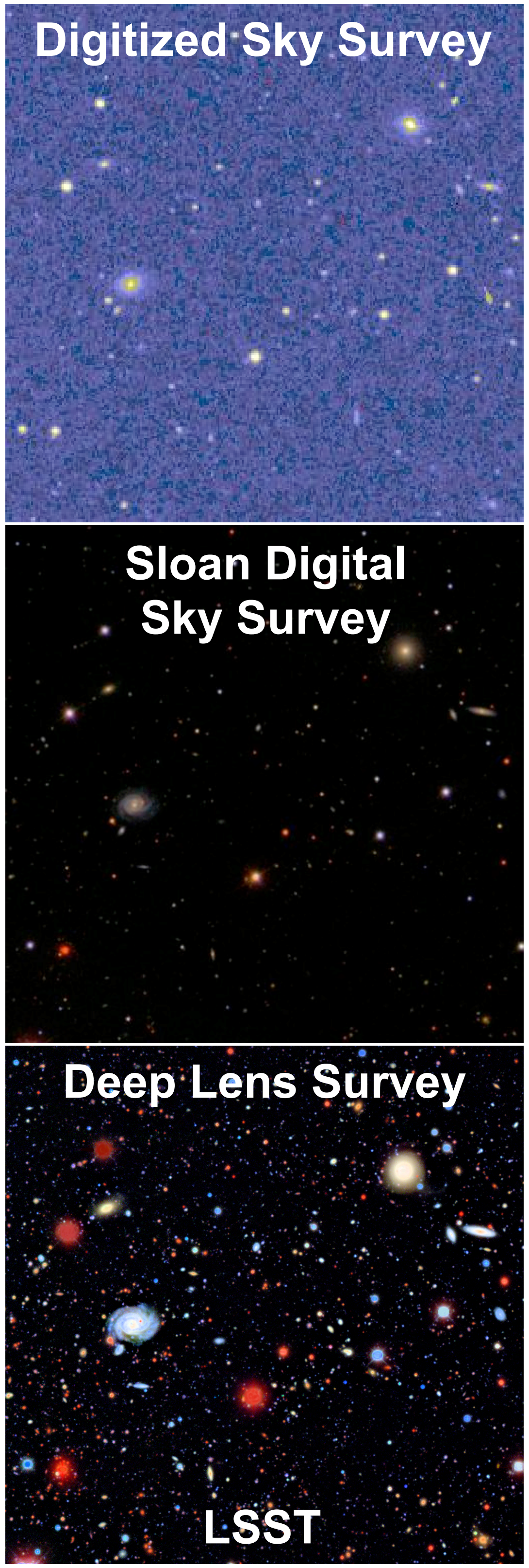
The Dark Energy Survey
robe origin of Cosmic
cceleration:
Distance vs. redshift
Growth of Structure
o multicolor surveys:
00 M galaxies over 5000 s.d.
izY to 24th mag
000 supernovae (30 sq deg)
w camera for CTIO
nco telescope
ility instrument, 30% time
year Survey started
31, 2013
nights (Aug.-Feb.)
ωm
ωb
n
σ8
w
0.7 0.8 0.9
0.0235 0.023 0.0225 0.022 0.0215
1.05 1 0.95 0.9 0.85
0.9 0.8 0.7
−0.8 −1 −1.2
0.12 0.14
0.85 0.9 0.95 1 1.05
−1.2 −1 −0.8

Roles of Simulations in Survey Science

Past

Present

Future

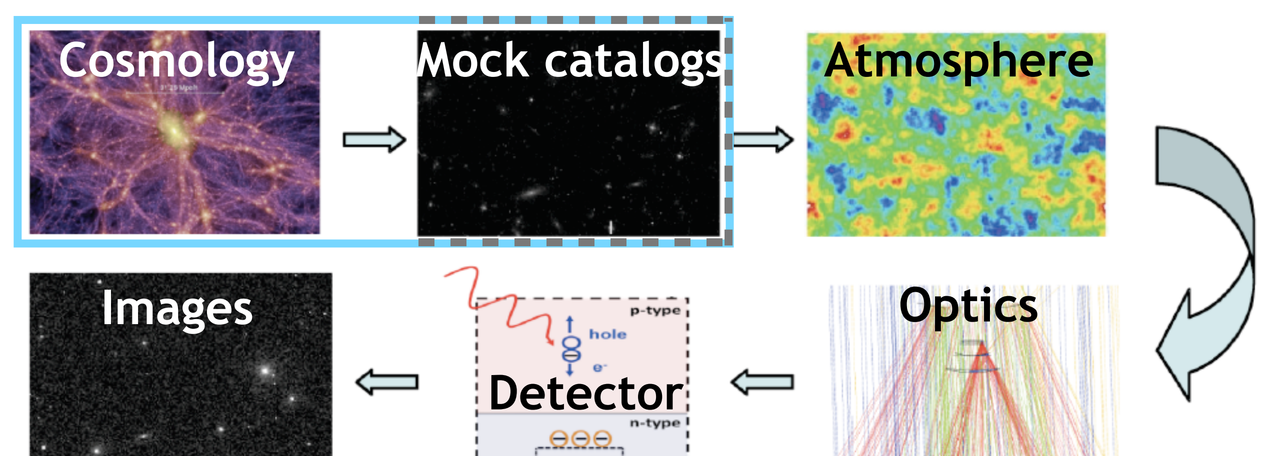


(1) Solving the Inverse Problem

- Exploring fundamental physics
- Fast, very accurate predictions tools (emulators) for physics and observables of interest
- Astrophysical "systematics"
- Predictions for covariances

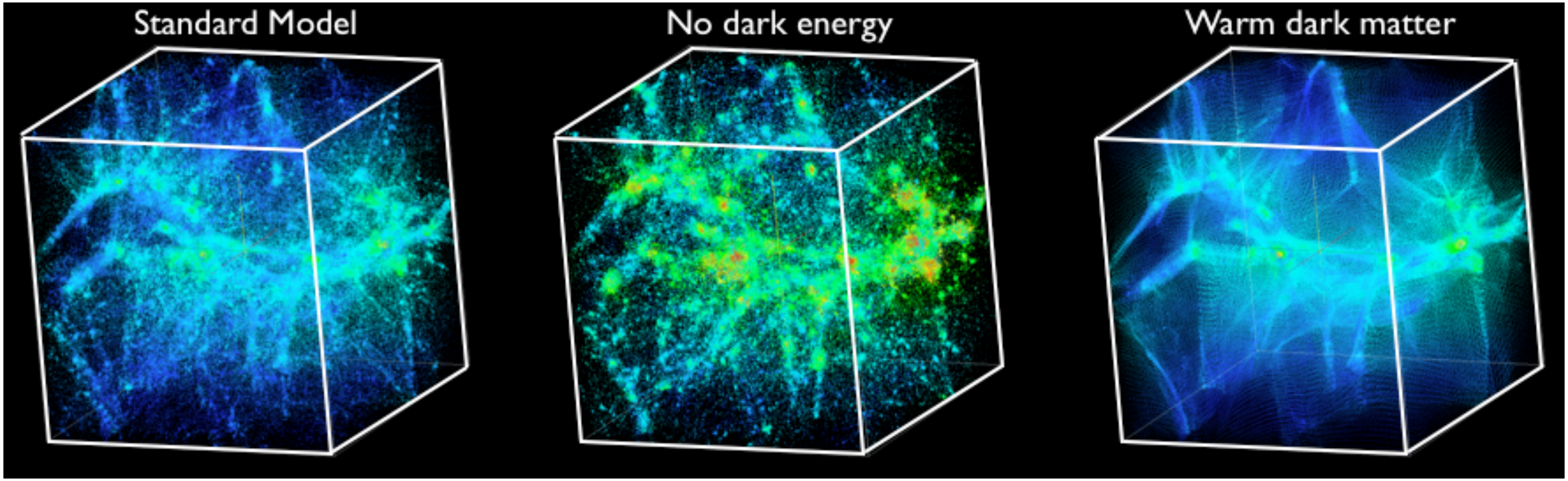
(2) Cosmology simulations and the survey

- End-to-end simulations
- Control of systematics



from the LSST Science Book

Exploring Fundamental Physics

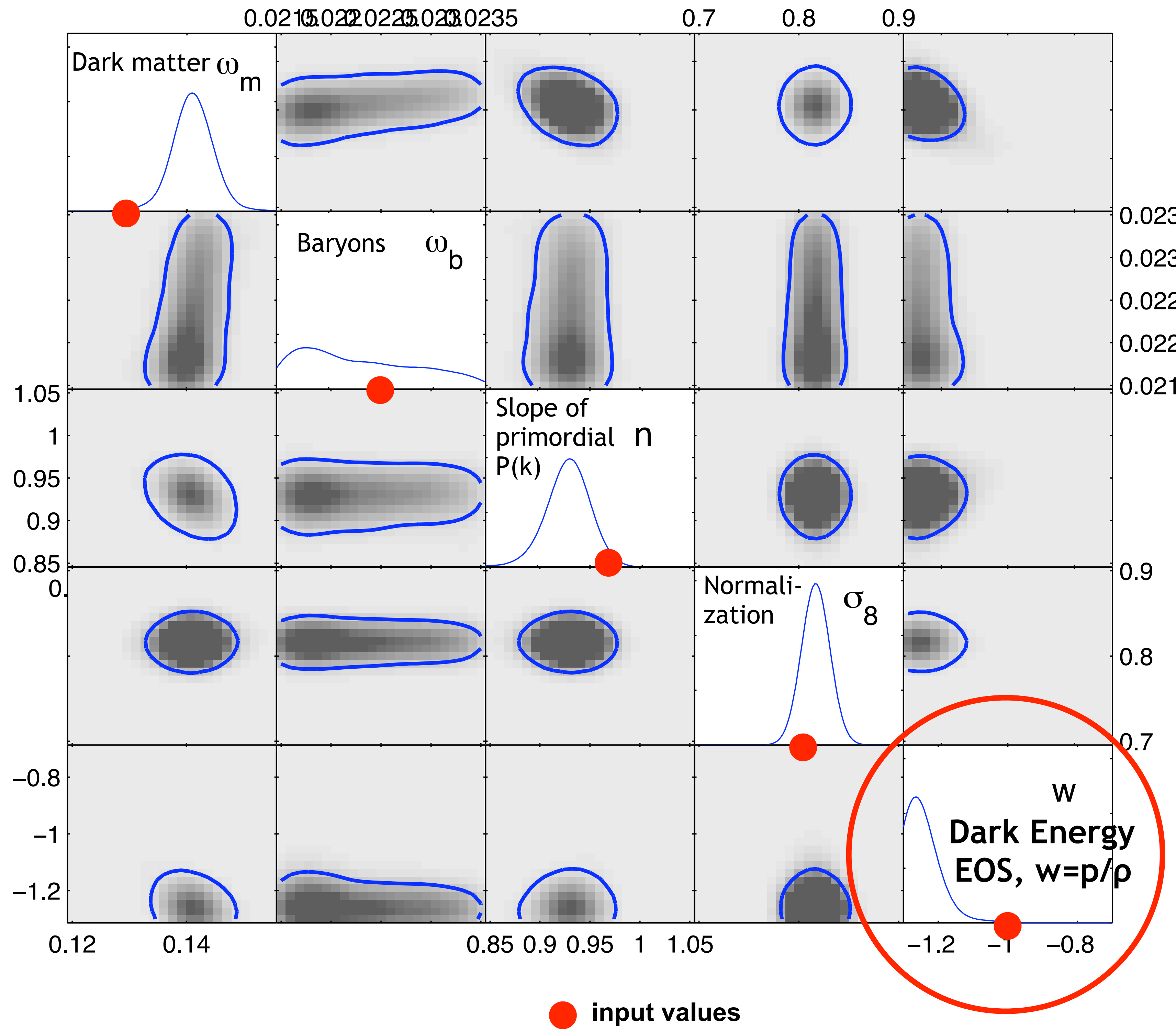


- **Exploration of different dark energy (DE) models and modified gravity (MG)**
  - Dynamical DE: w0-wa parametrization easy to implement, but neglects perturbations
  - MG: How to explore model space, costly simulations, nonlinear scales essential
- **Exploration of dark matter and neutrinos in the Universe**
  - Neutrino simulations are challenging, approximate methods have been developed, but are they accurate at 1% over the k- and z-range needed?
  - Self-interacting dark matter has been explored, push to smaller scales?

Accurate Prediction Tools

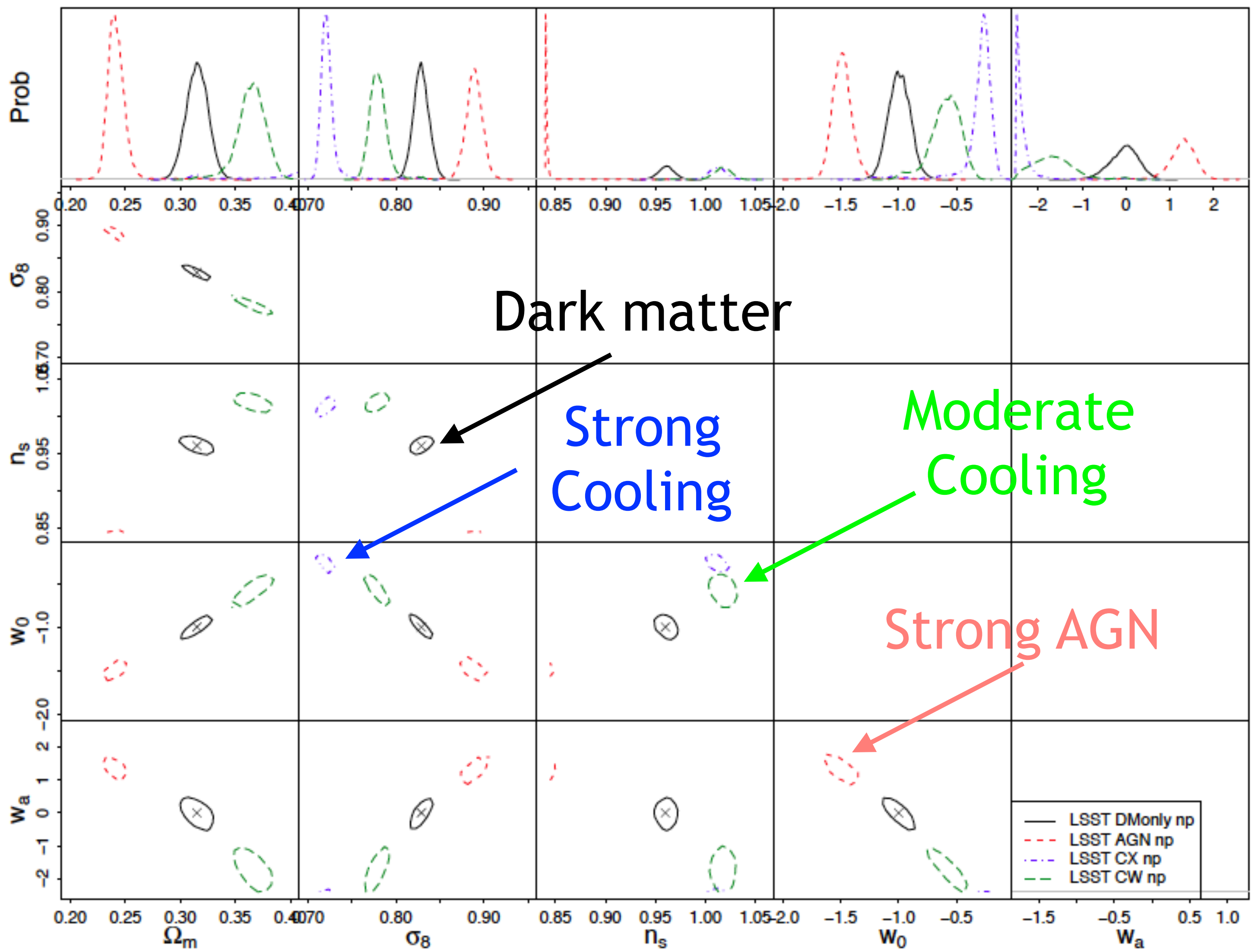
- Generate mock data from high-resolution simulation (out to k~1 h/Mpc), focus on P(k) for this example
- Use Halofit for analysis (5-10% inaccurate on quasi-linear to nonlinear scales)
- Parameters are up to 20% wrong! (We checked that with more accurate predictions the answer is correct)
- Over-simplified, but:
- We need predictions at the 1% level accuracy for diverse observables ("LSSFast"), including a range of cosmological parameters and astrophysical effects have to be under control

Heitmann et al. 2014

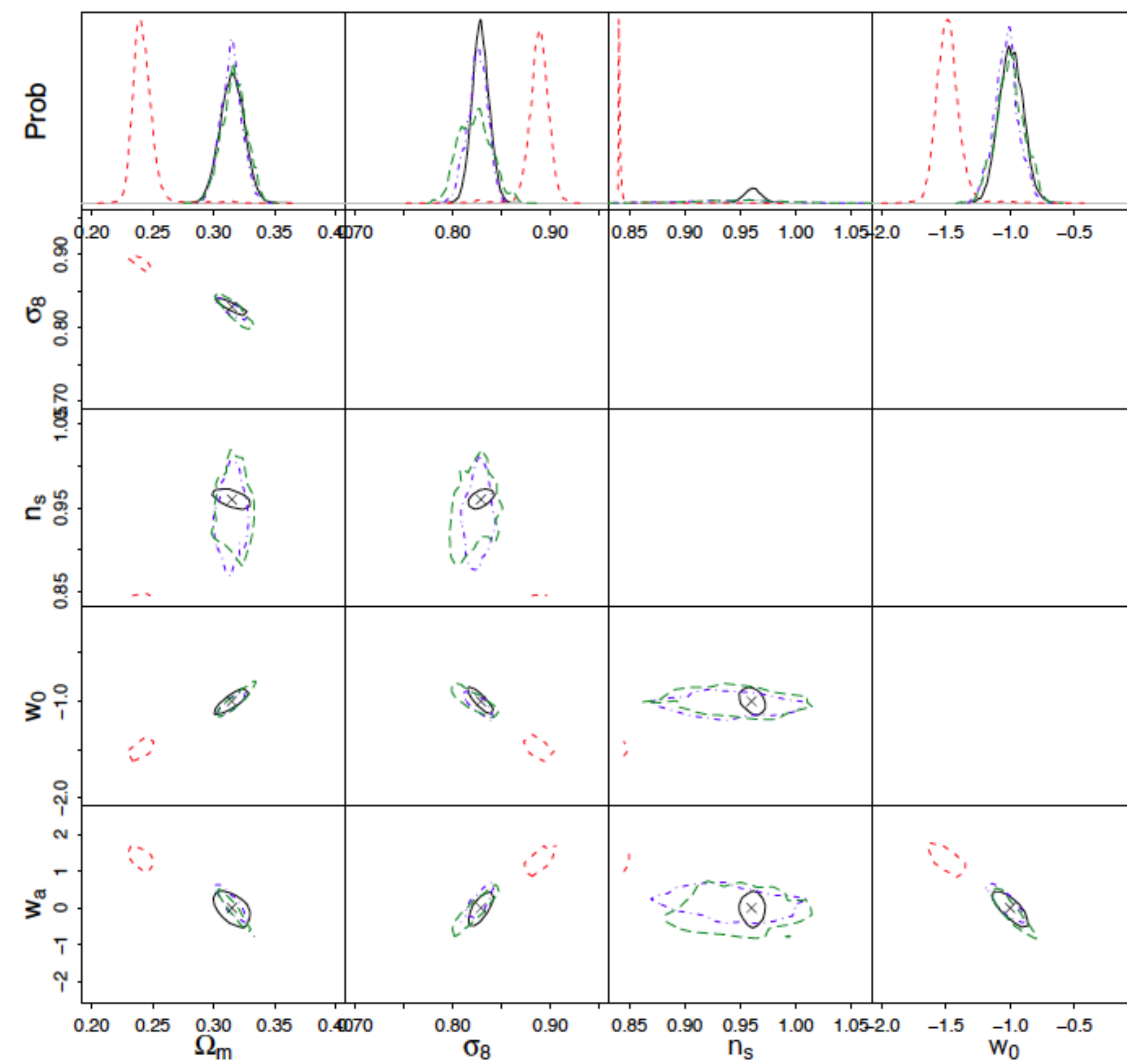


Astrophysical Effects

- Astrophysical effects (baryons, bias, intrinsic alignments etc.) can mimic new physics
- More severe on small scales, but those are the scales we hope to get more information
- Need to be able to model/bracket these effects (e.g. Eifler et al.), or disregard some of the information available (e.g. Krause et al. 2015, Simpson et al. 2015)



LSST/Euclid constraints, baryonic effects unaccounted

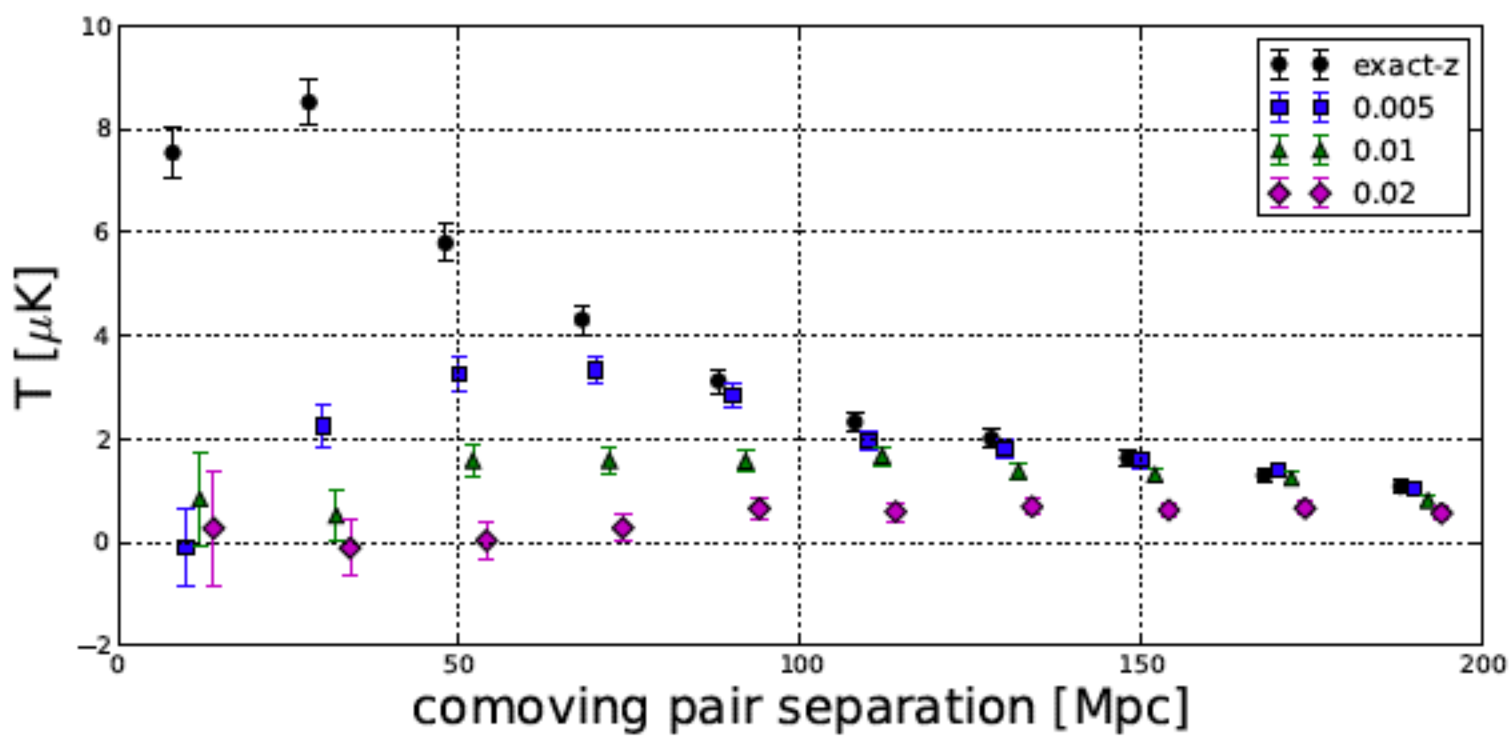


Mitigation via PCA marginalization

Eifler et al. 2015

Control/Tests of Systematics, Pipelines, and Analysis Tools

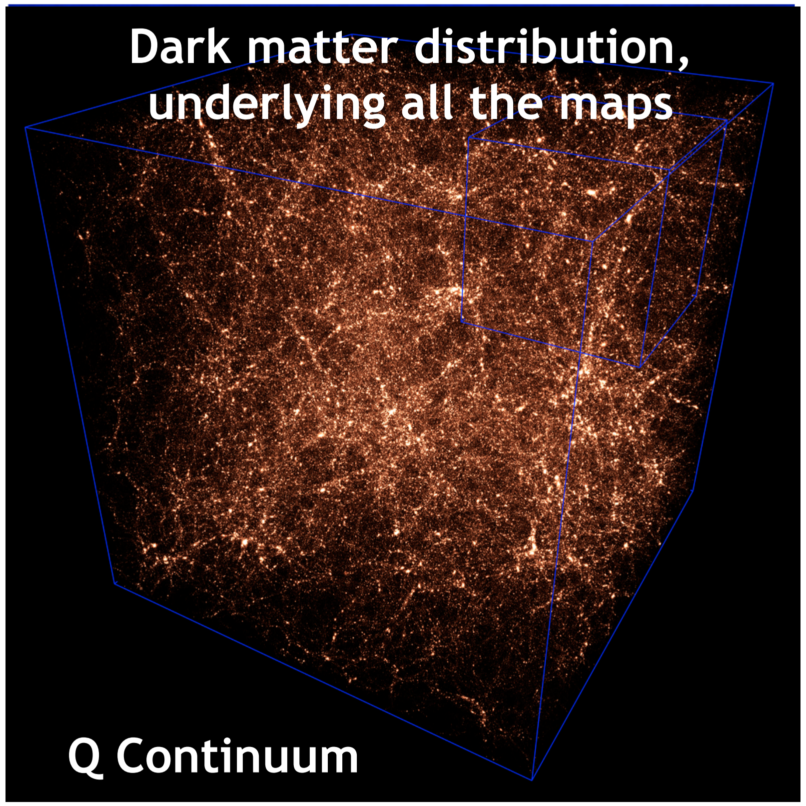
- Simulations and simulated maps are essential to test analysis strategies and pipelines
- Modeling and maybe mitigation of systematics in the data that are not of physical origin but rather due to limitations in our data (e.g. photo-z errors, mis-centering, cosmic variance, etc.)
- Challenge: Synthetic maps have to be as close to reality as possible and cover large area
  - Very high mass resolution required for LSST/DESI
  - Modeling of galaxies not an easy task (HAM, SAM, SHAM, …)
  - Validation very important but difficult (data curation, data availability etc.)

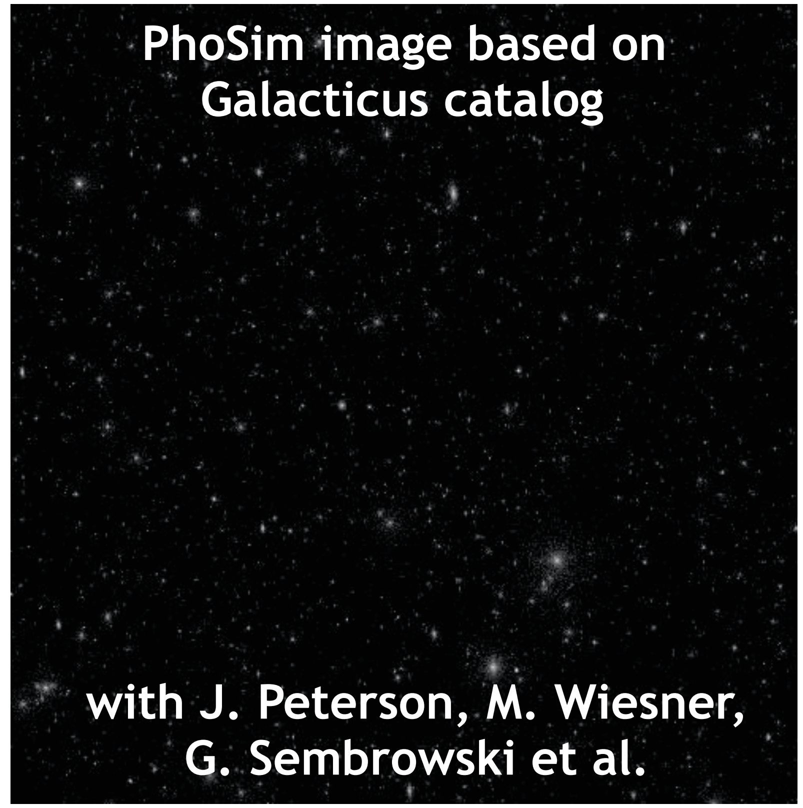


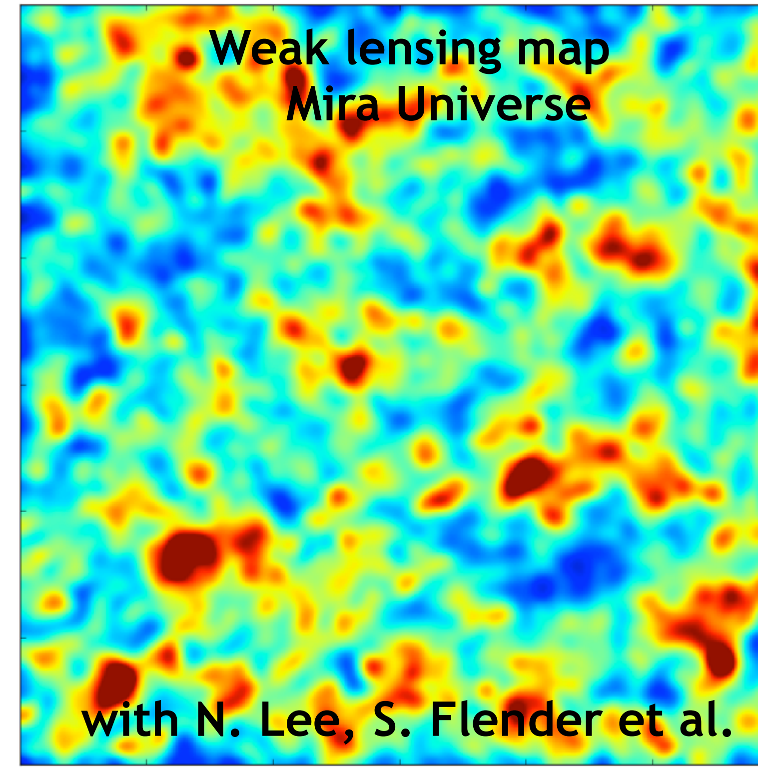
Pairwise kSZ signal for different errors in redshift estimates

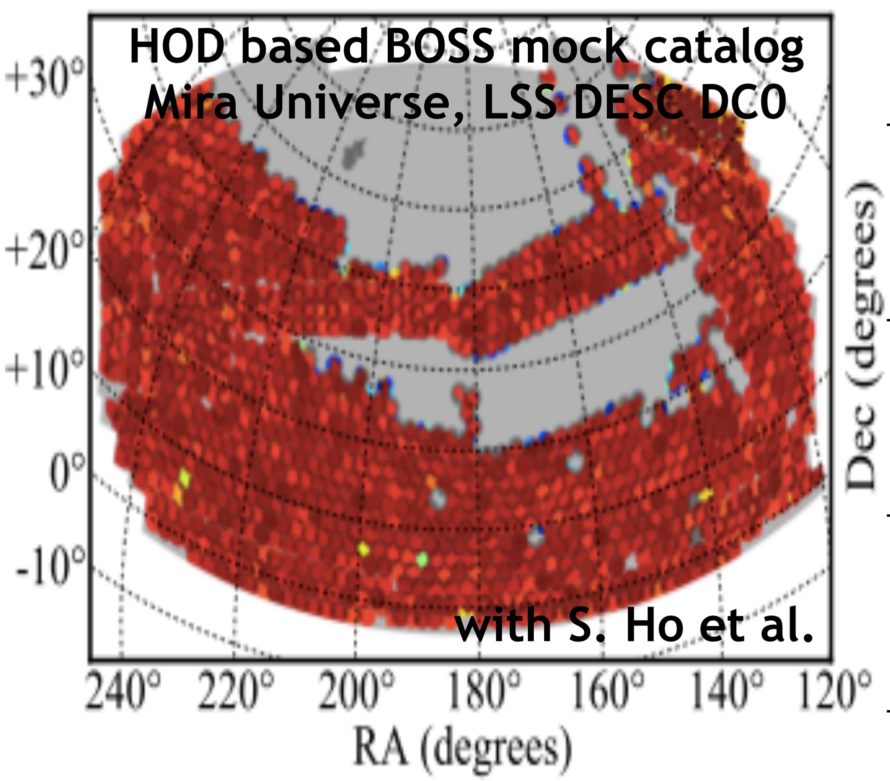
Flender et al. 2015

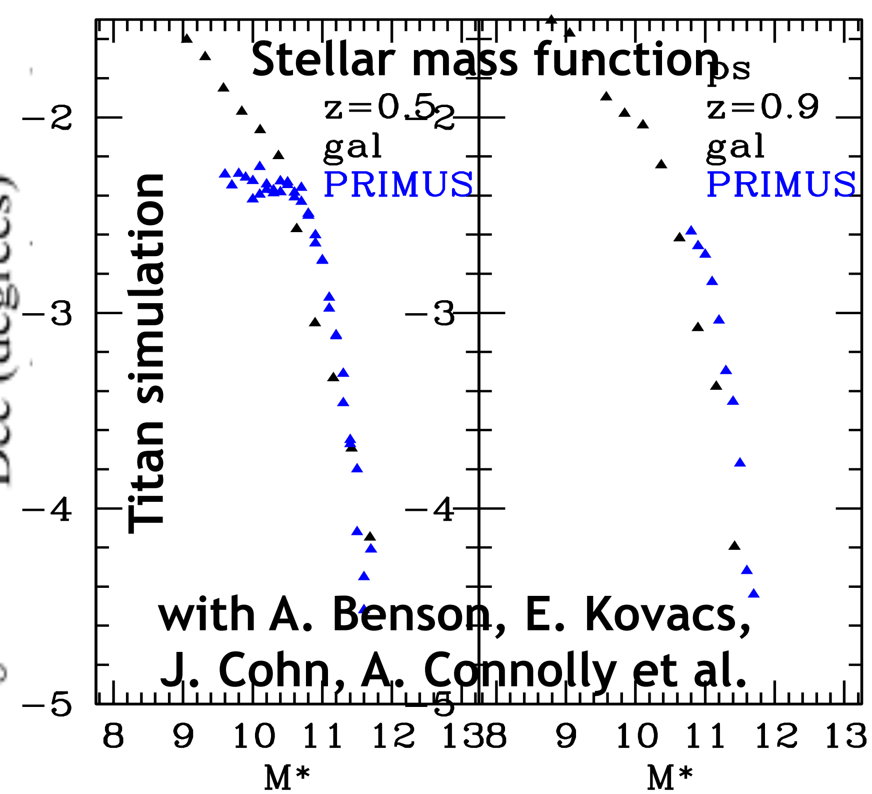
Examples for Synthetic Sky Maps

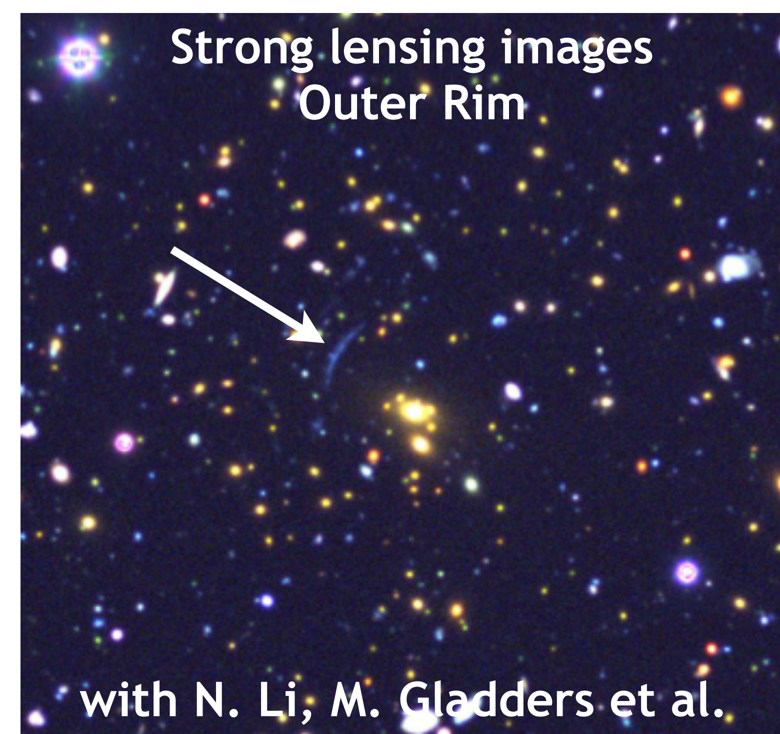












Summary of Challenges for LSST, DESI, and Beyond

- If we see “new physics”, how do we convince ourselves that we are not looking at systematics?
- Simulations and modeling play an important role for survey science
- Understanding/modeling of astrophysical effects and systematics (for each probe we can list several … clusters: mass calibration; weak lensing: baryonic physics, IAs; strong lensing: baryonic physics; etc.)
- Testing of pipelines and analysis tools
- Predictions for new physics, exploration of new probes
- Data challenges rely on simulations
- Upcoming surveys require very high mass resolution, gravity-only as well as hydro simulations, different cosmologies, large ensembles for covariances …
- We need concerted effort for modeling and simulating surveys in a similar way as high-energy physics experiments