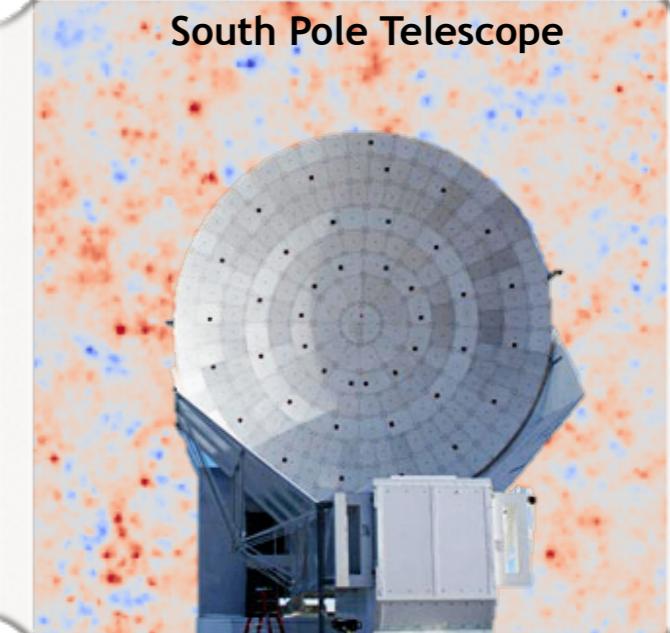
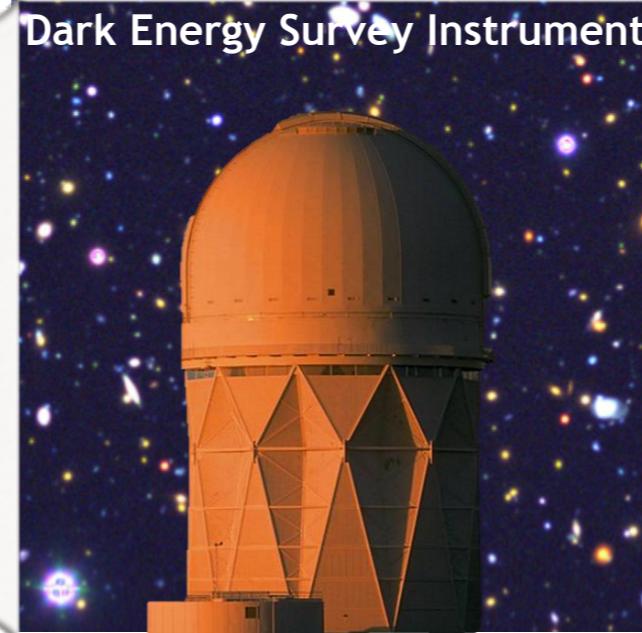
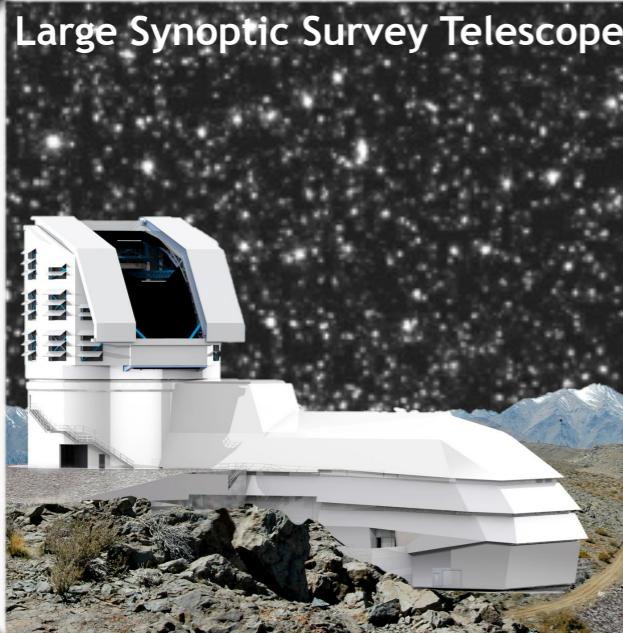


# Advanced Modeling and Simulation for Surveys

Katrin Heitmann  
(for the HACC Team and many collaborators)

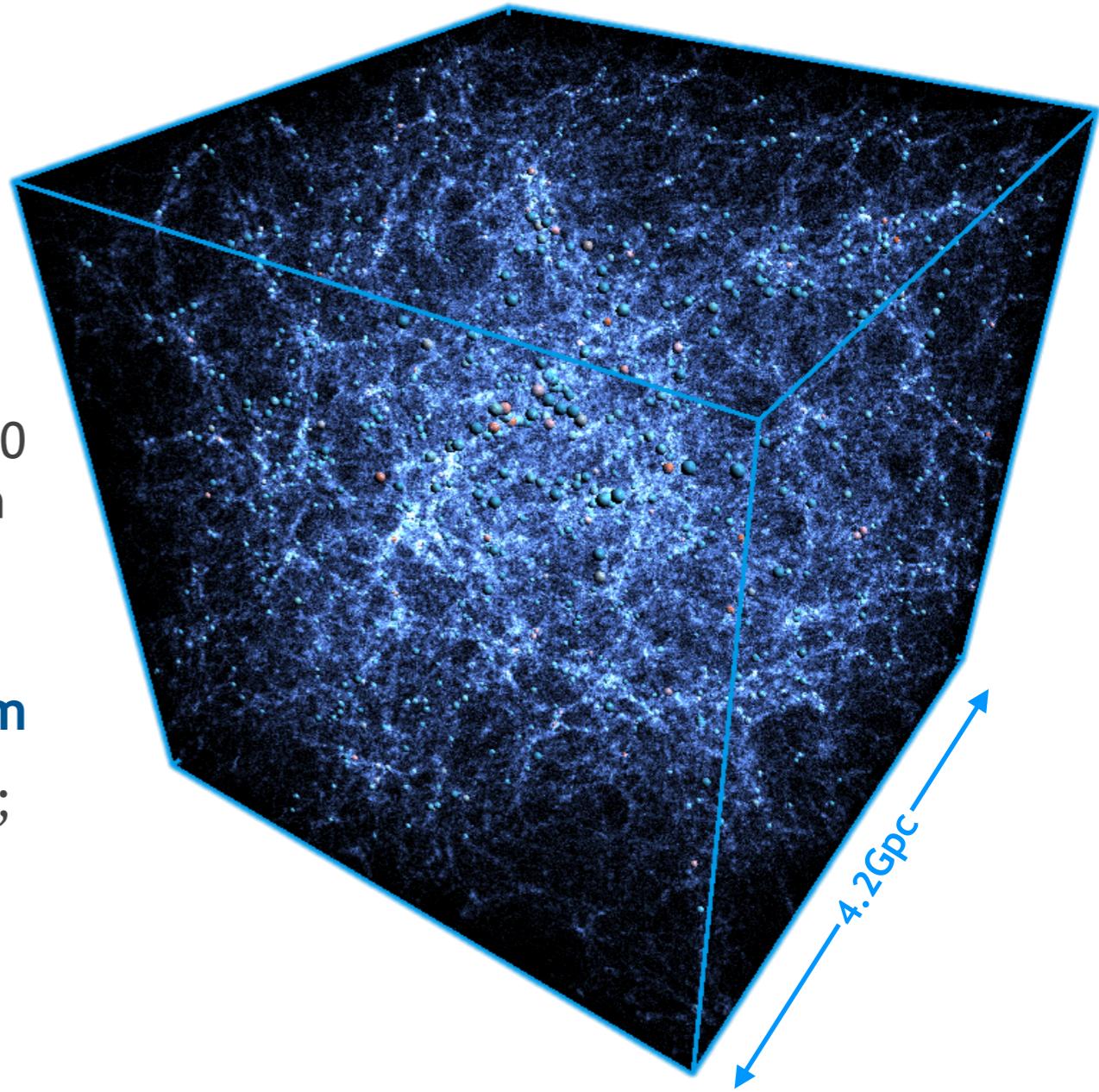
WFIRST-LSST Meeting, September 14, 2016



# HACC Extreme Scale Simulations

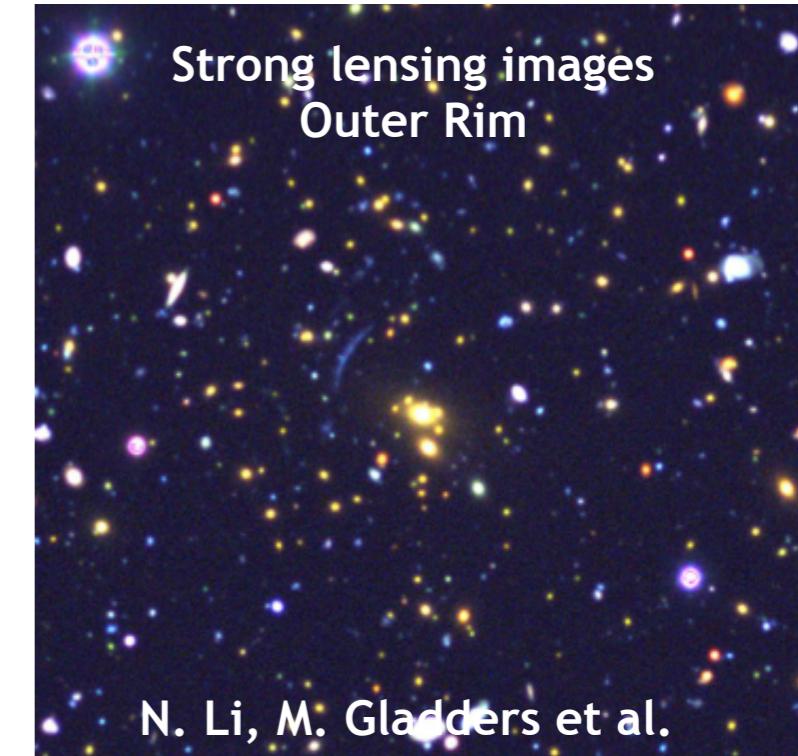
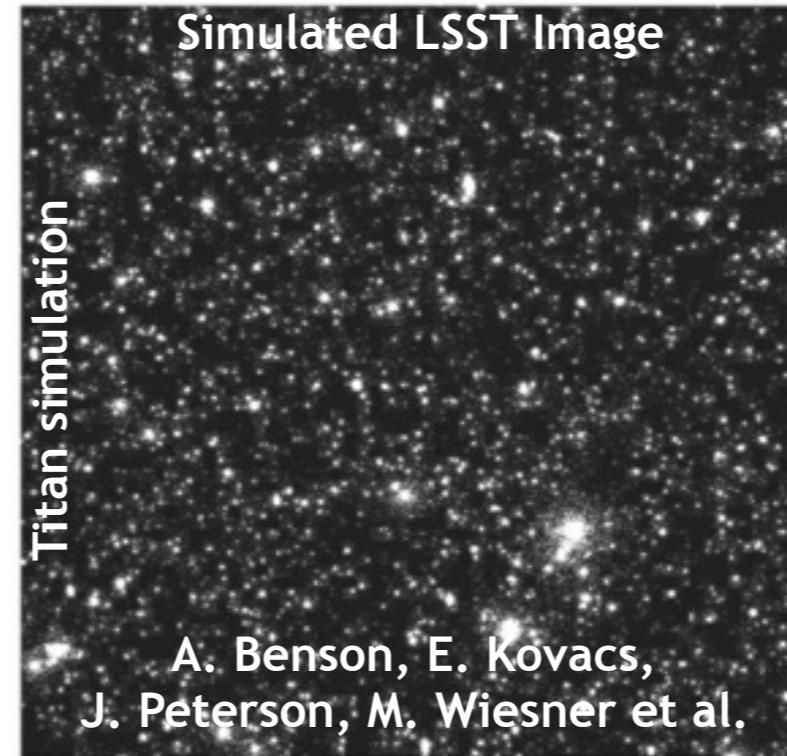
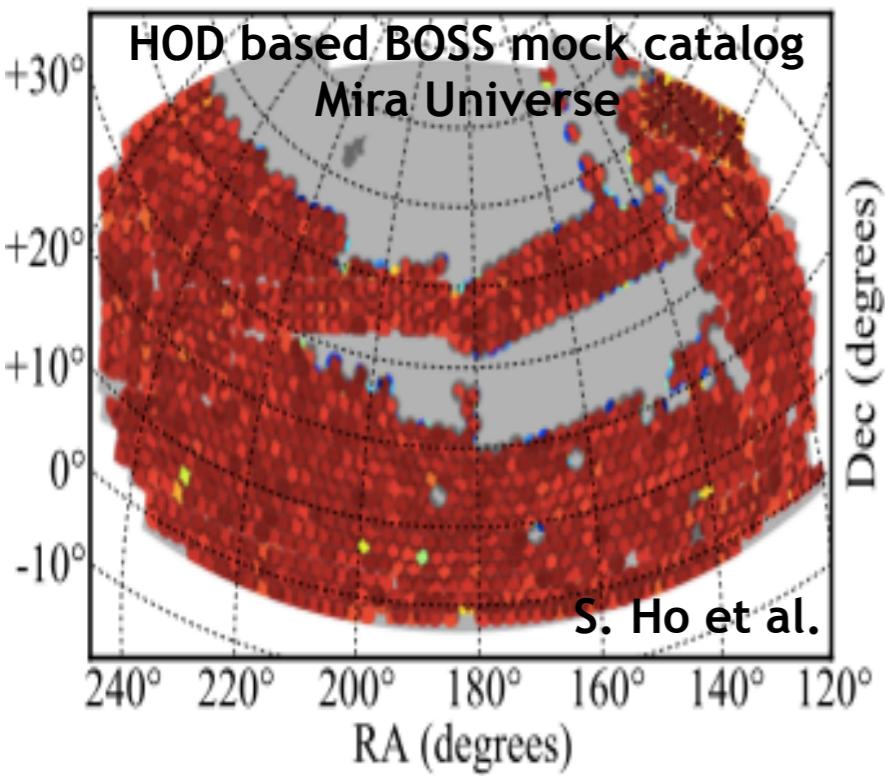
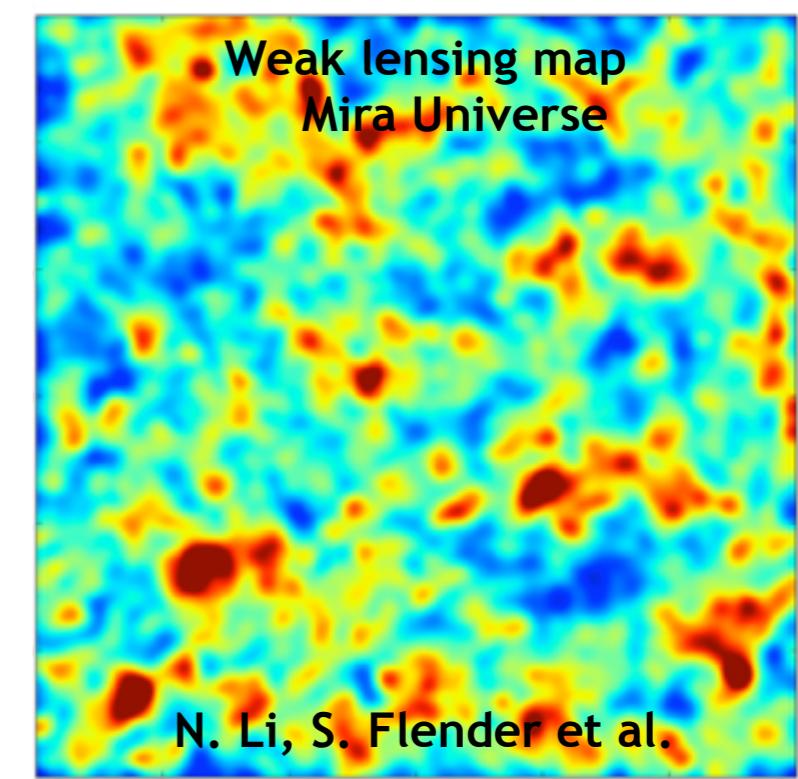
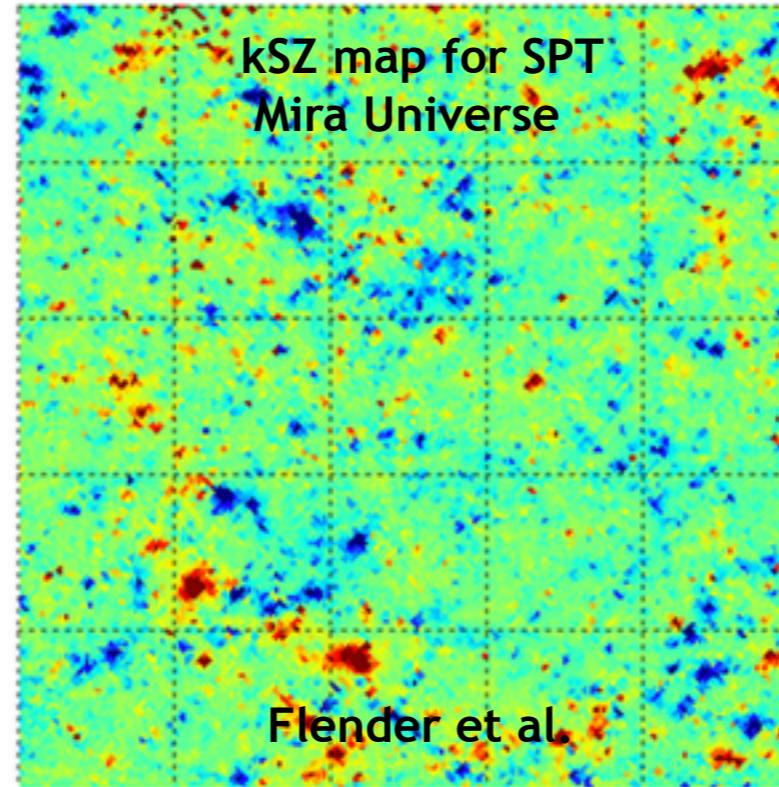
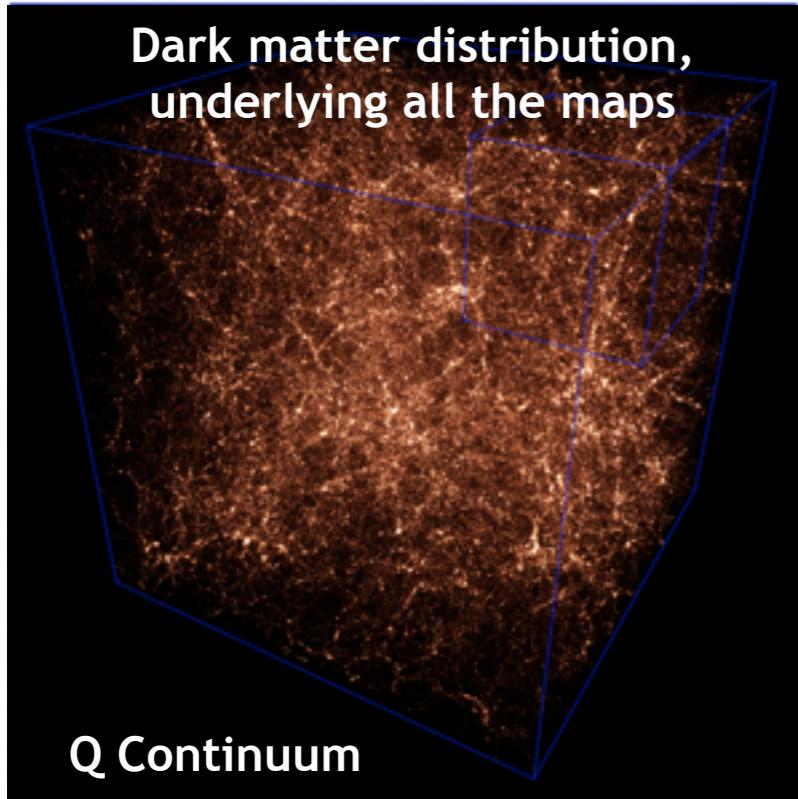
- **HACC: Hardware/Hybrid Accelerated Cosmology Code**
  - ▶ Gravity-only N-body code that runs on any available architecture in the known Universe: X86, GPU systems, BG/Q, KNL, ...
  - ▶ First hydro version undergoing testing
- **The Outer Rim Simulation on BG/Q**
  - ▶ HACC simulation with > 1 trillion particles, 100 snapshots, 4.5PB of data; 4.2Gpc volume with  $2 \times 10^9 M_{\text{sun}}$  mass resolution; **200x larger the Millennium simulation at same resolution**
- **The Q Continuum Simulation on GPU system**
  - ▶ More than 0.5 trillion particles, 2.5PB of data; 1.3Gpc volume,  $10^8 M_{\text{sun}}$  mass resolution; **60x the volume of Bolshoi simulation**
- **The Mira-Titan Universe Suite**
  - ▶ Large suite of different models, each simulation: 2.1 Gpc, 33 billion particles (50 finished, 60 more running/in prep)

*K. Heitmann, et al. ApJS, 2015;  
K. Heitmann et al. ApJ, 2016  
S. Habib et al. New Astronomy 2016*



*Large halos in the Outer Rim simulation,  
volume large enough to hold the DESI survey*

# Virtual Skies for Cosmological Surveys



# Synthetic Skies from the Outer Rim Simulation

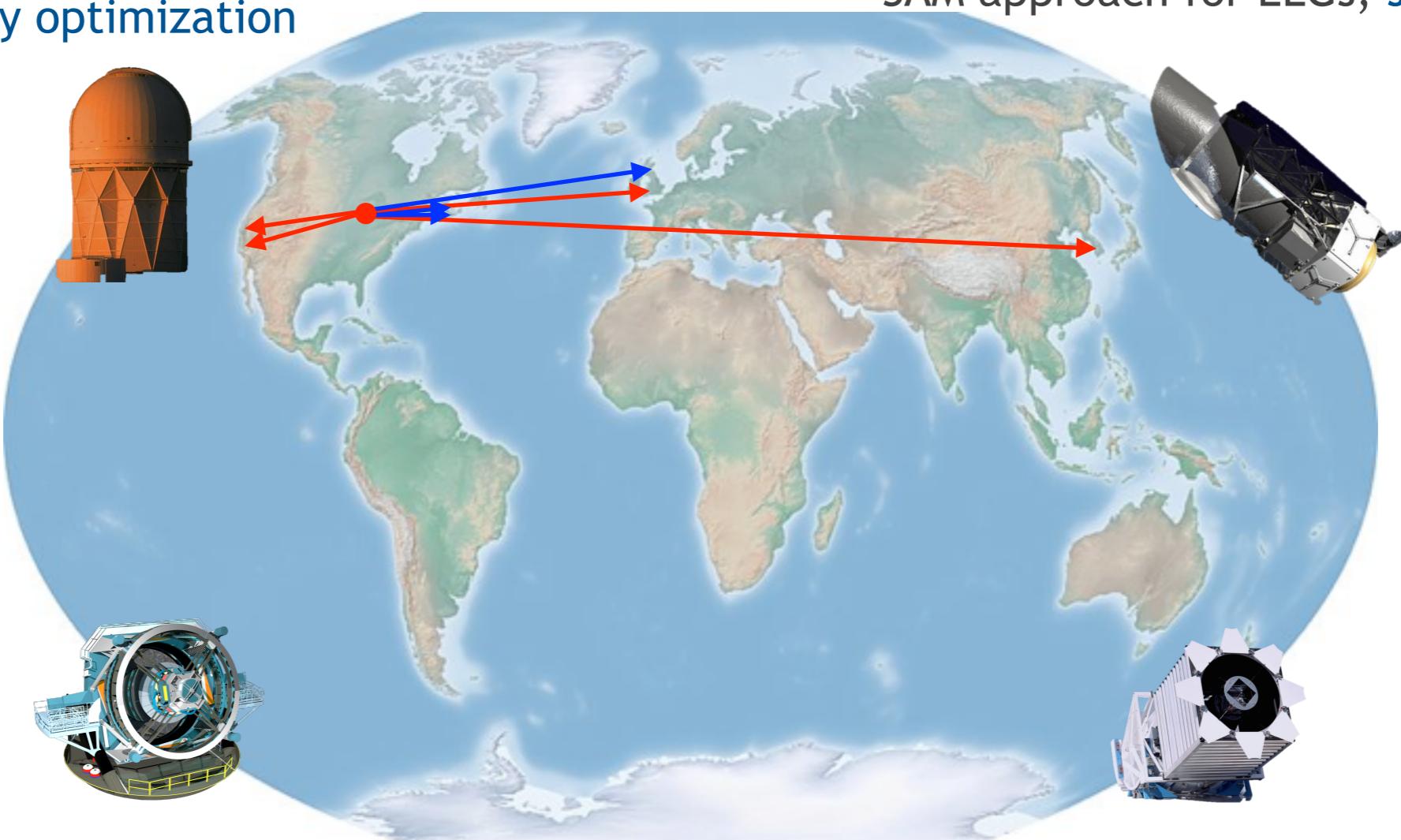
## DESI Mock Catalogs

Collaboration with **UC Berkeley**, Halo-Occupation Distribution (HOD) approach; **fiber assignment, survey optimization**

## WFIRST Mock Catalogs

Collaboration with **IPAC/Carnegie**, SAM approach for ELGs; **survey planning**

Sharing  
the Outer Rim  
simulation



## LSST Mock Catalogs

Semi-analytic Modeling (SAM) approach, collaboration with **Carnegie**; **data challenge, photo-z**

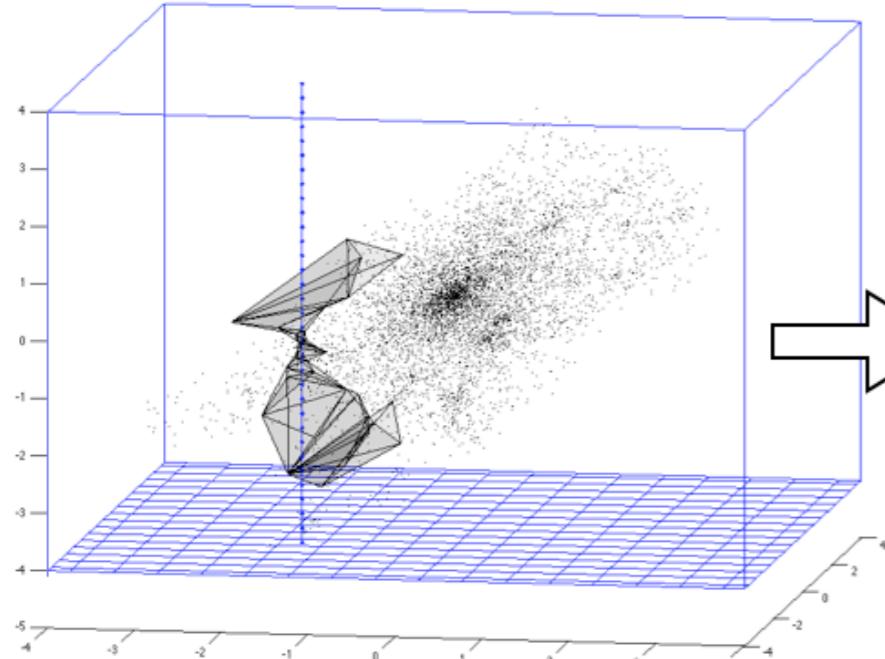
## eBOSS Mock Catalogs

Collaboration with **KIAS** and **Portsmouth**, HOD and subhalo-abundance matching (SHAM) approach; **analysis**

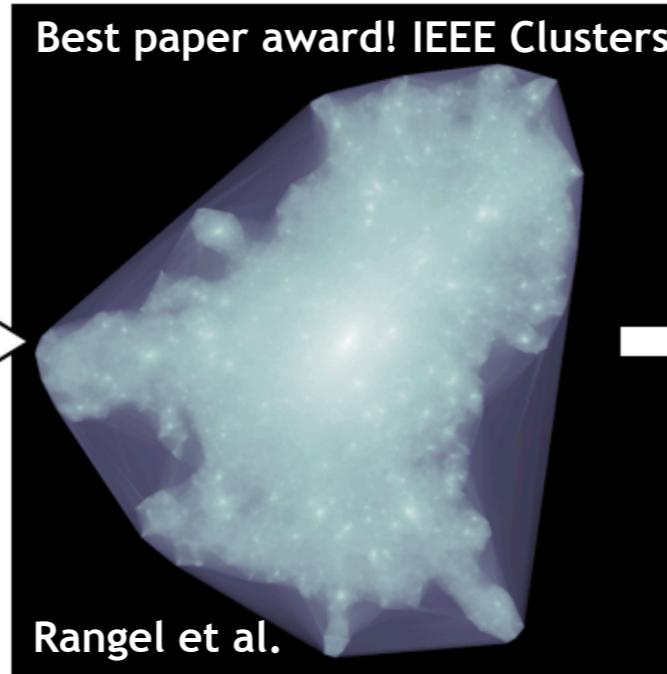


# Outer Rim Simulation: Strong Lensing

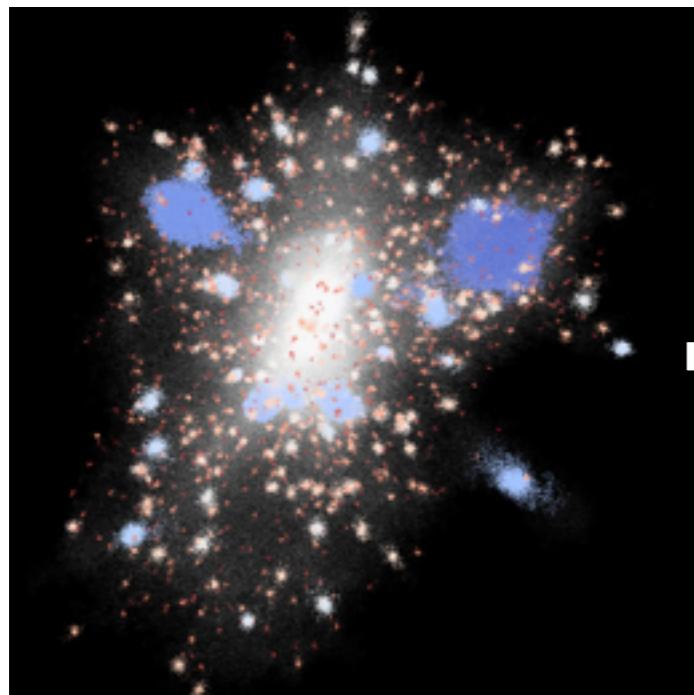
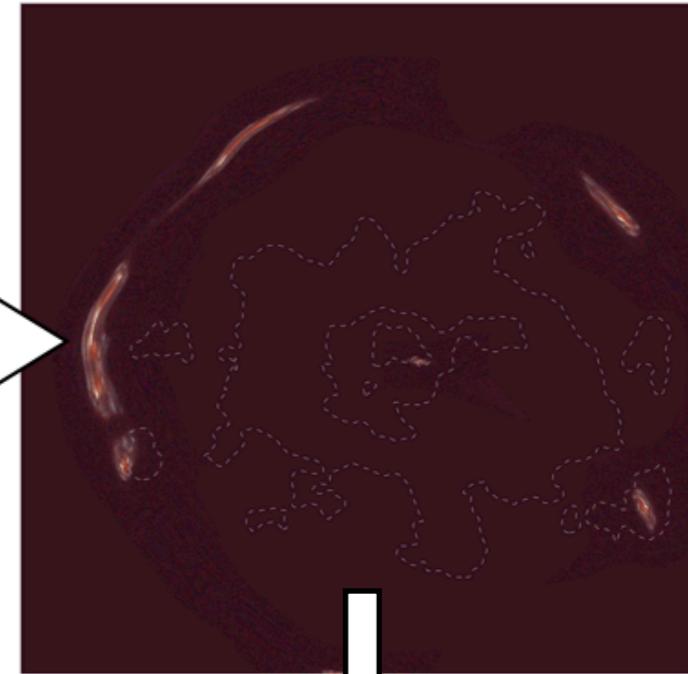
Halo particle data



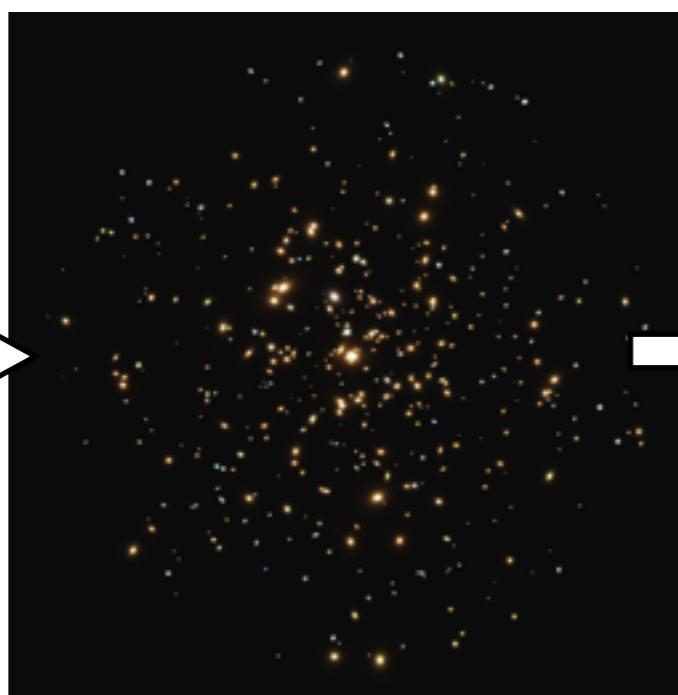
Density



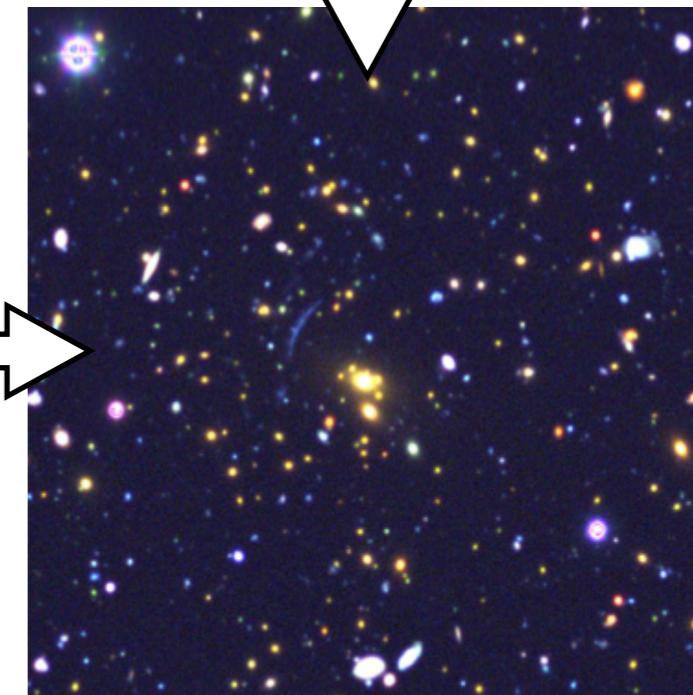
Strong lensing arc



Subhalo particle data,  
now core tracking ...



Cluster galaxies from  
Galsim, optical clusters



Telescope, background  
galaxies, cluster, arc ...



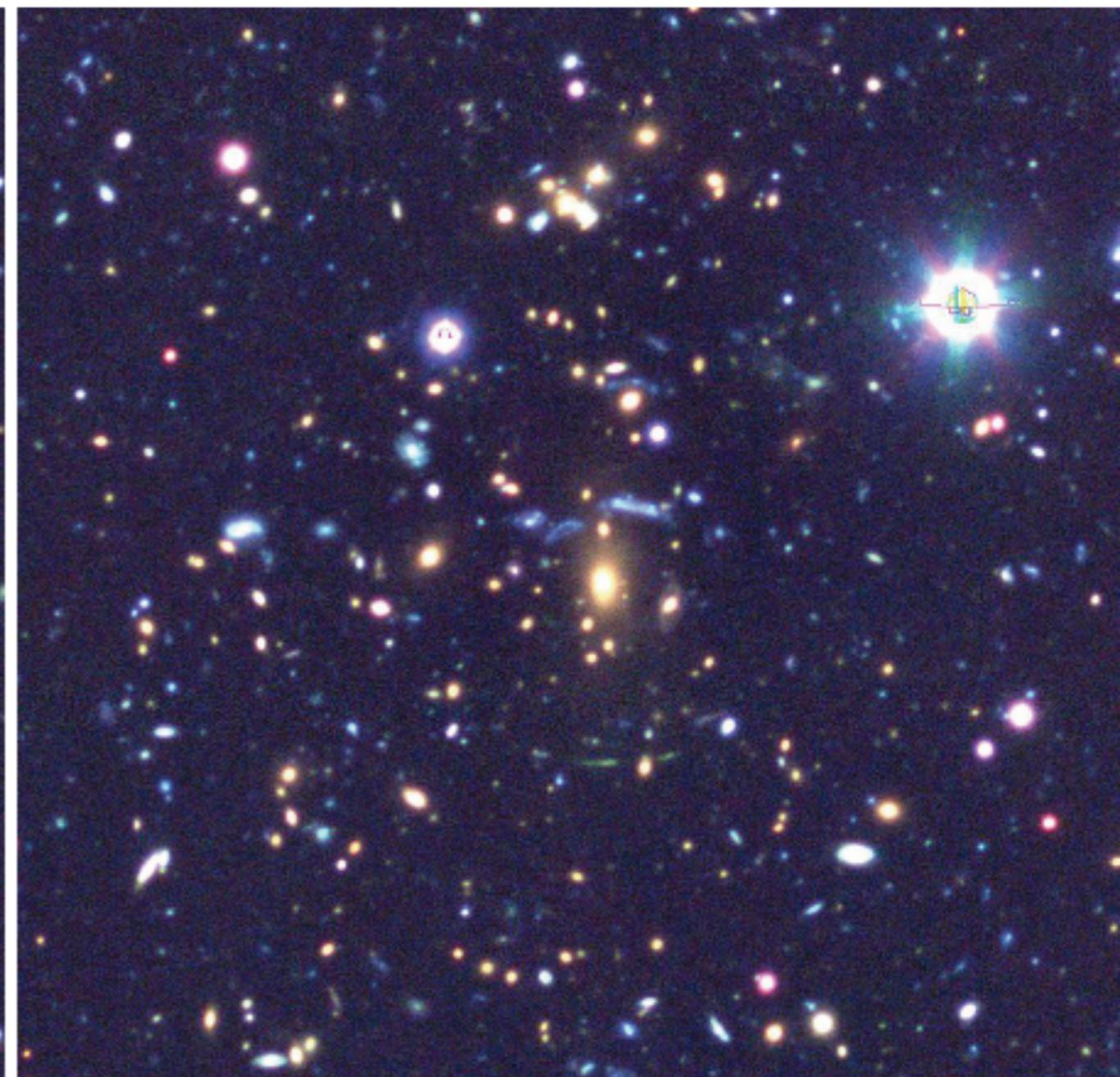
# PICS: Generating Strong Lensing “Observations”

PICS: Pipeline for Images of Cosmological Strong lensing

Simulated



Real

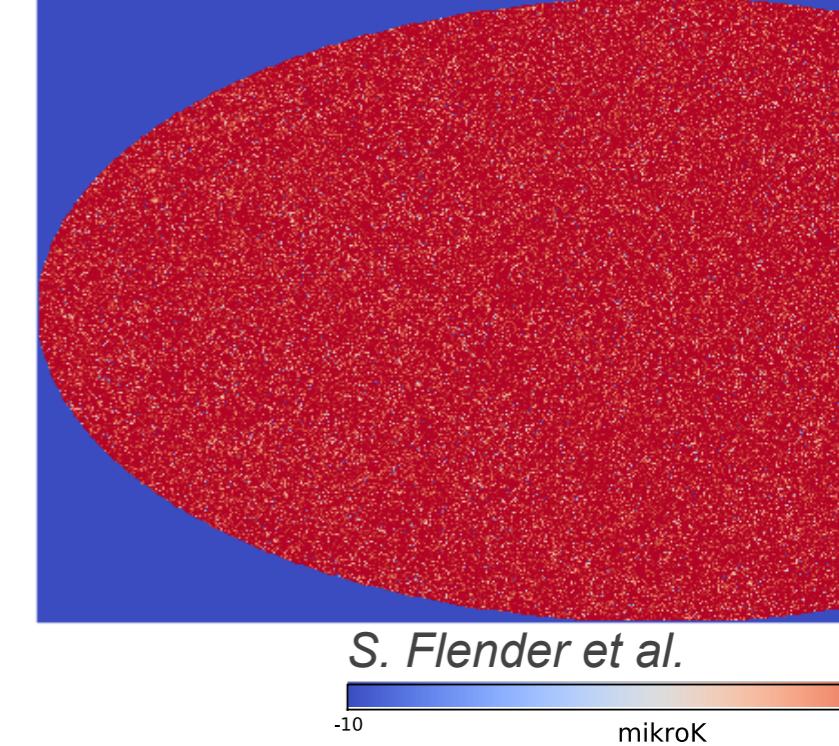
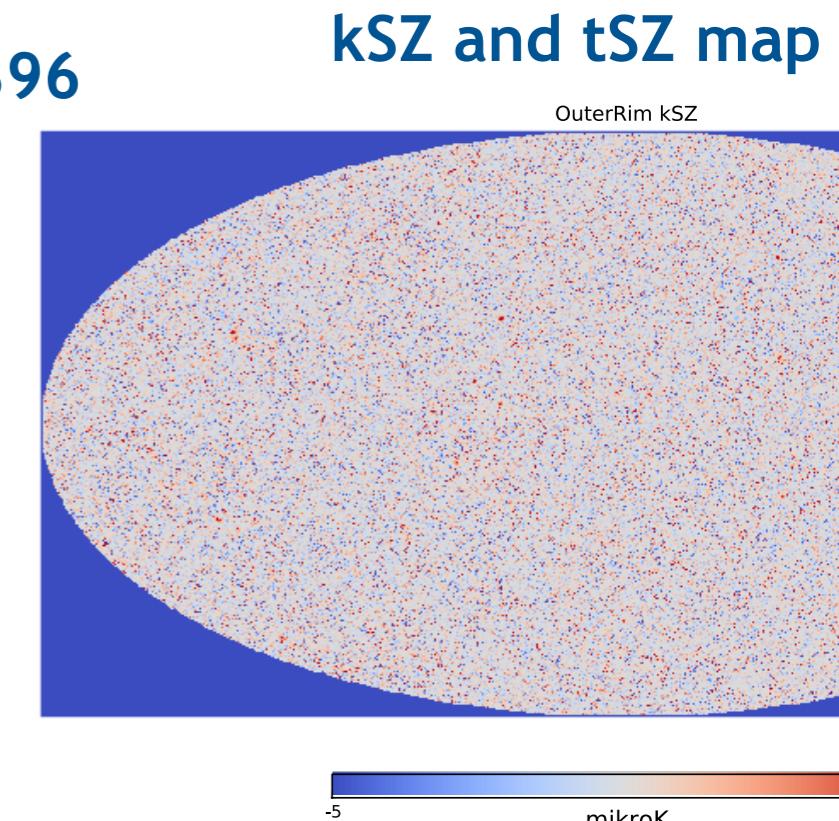
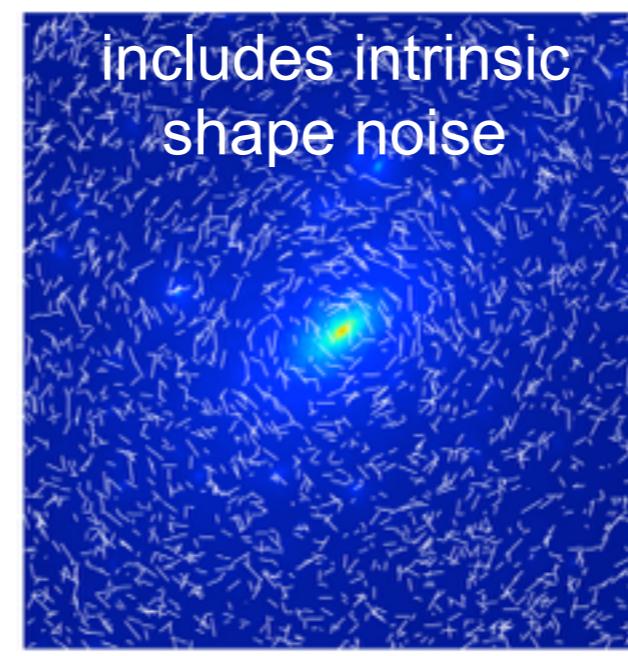
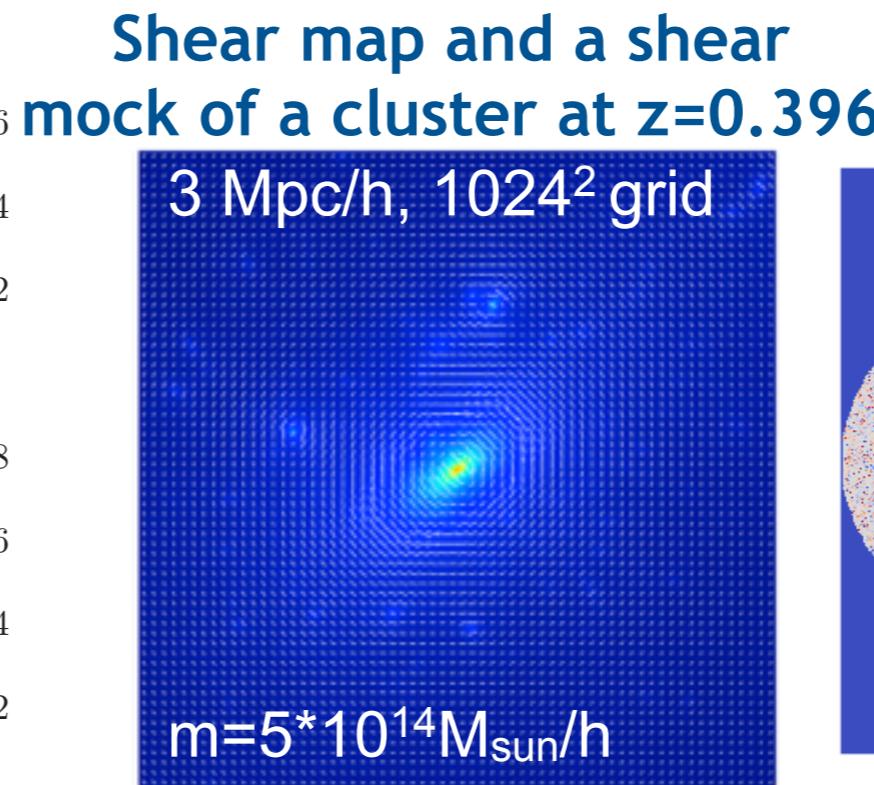
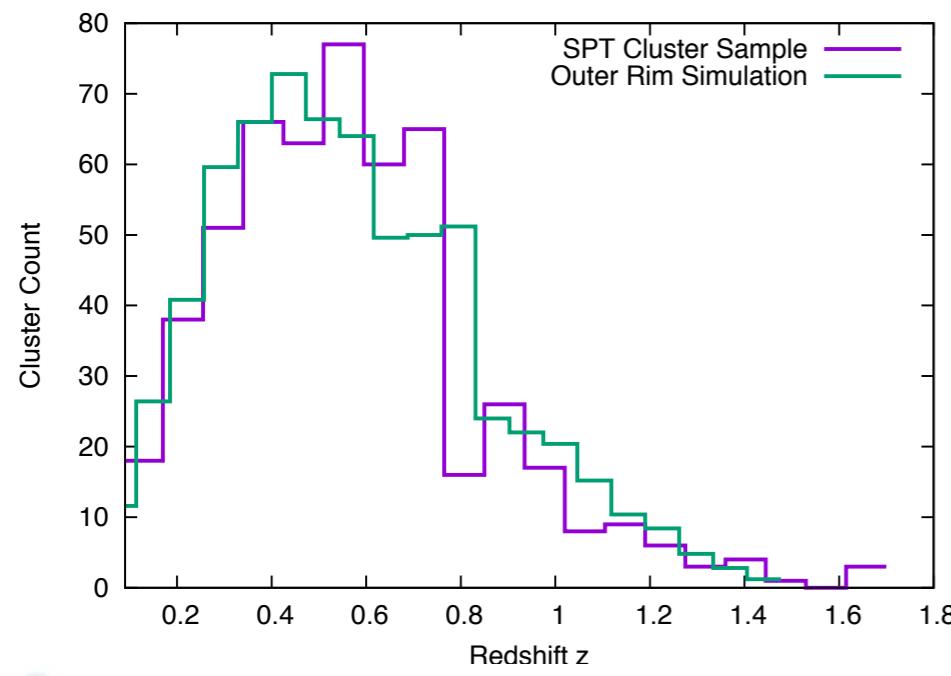
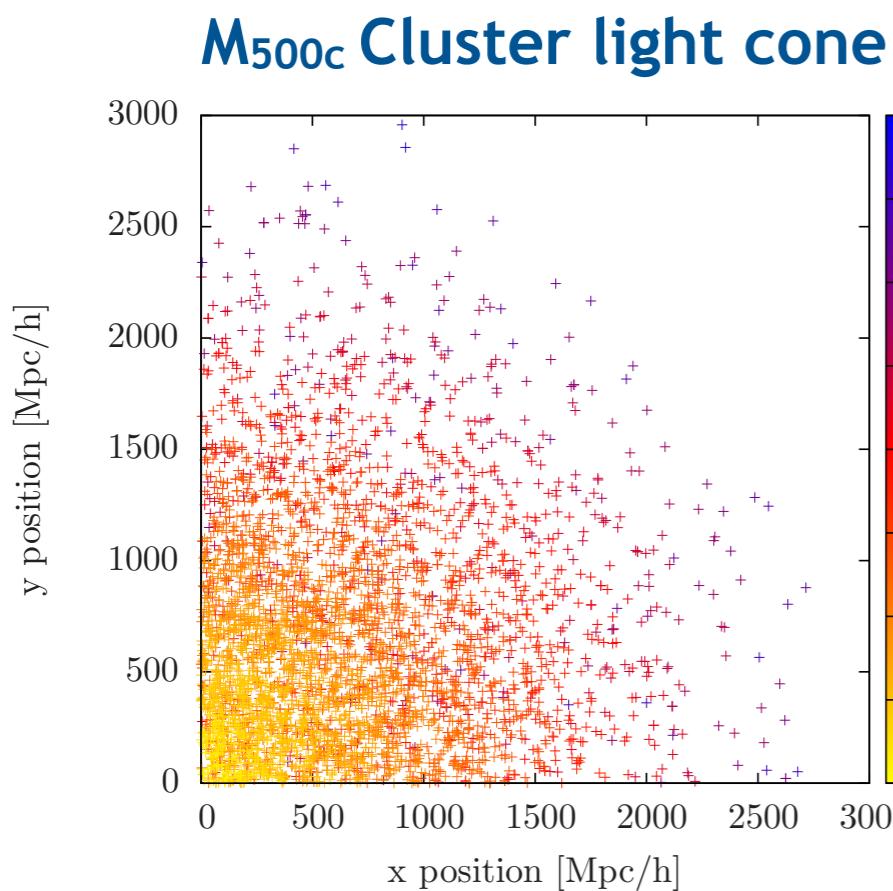


Simulated strong lens image to match SPT cluster observations taken with the MegaCAM camera on Magellan, in collaboration L. Bleem, M. Florian, S. Habib, M. Gladders, N. Li, S. Rangel

N. Li et al., ApJ 2016

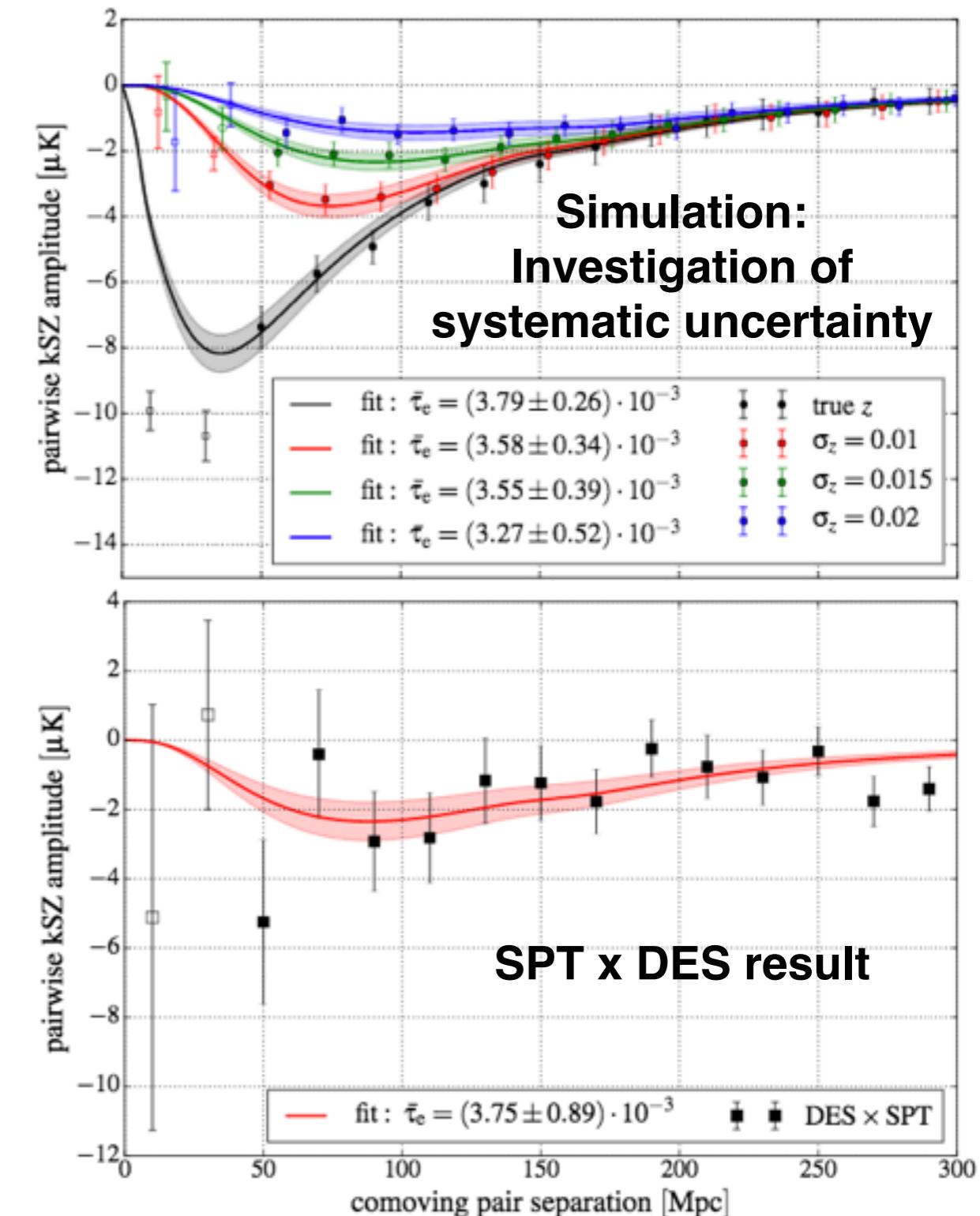


# Synthetic Skies from the Outer Rim Simulation



# Pairwise Kinematic Sunyaev-Zel'dovich Effect

- Example of “end-to-end” project:
  - ▶ Detection of pairwise kSZ at  $4.2\sigma$  using photometric data, DES x SPT
- Interplay between simulations and data
  - ▶ Simulation and modeling work based on large simulation carried out on Mira to investigate signal measurability and systematics
  - ▶ Data analysis of SPT data and cross-correlation work of SPT and DES catalogs
  - ▶ Forecast for future surveys
- Synergy between simulation, CMB, and optical survey work



S. Flender, et al. ApJ, 2016;

B. Soergel, S. Flender, K. Story, L. Bleem, .. S. Habib, K. Heitmann, ..., MNRAS 2016



# Validation of Mock Catalogs for LSST DESC

wp(rp) comparison (2016-06-15\_6)

Log file	contents
Test setup	stdout no stderr
Test compilation	stdout/stderr
Runs completed	sdss_cmucat_mb2 sdss_galacticuscat_mb2 sdss_stanfordcat_liwhite sdss_stanfordcat_mb2 sdss_yalecat_liwhite

---

**sdss\_cmucat\_mb2** ← CMU hydro

Resources used: 1 processor; time: 11 seconds  
Stdout/stderr: contents  
Expectations: validation\_output.txt  
Outputs: catalog\_output.txt  
Plots: wprp.png  
Test output: contents

[Return to top](#)

---

**sdss\_galacticuscat\_mb2** ← Argonne/  
Carnegie  
SAM

Resources used: 1 processor; time: 03:02  
Stdout/stderr: contents  
Expectations: validation\_output.txt  
Outputs: catalog\_output.txt  
Plots: wprp.png  
Test output: contents

[Return to top](#)

---

**sdss\_stanfordcat\_liwhite** ← Stanford  
SHAM

Resources used: 1 processor; time: 37 seconds  
Stdout/stderr: contents  
Expectations: validation\_output.txt  
Outputs: catalog\_output.txt  
Plots: wprp.png  
Test output: contents

[Return to top](#)

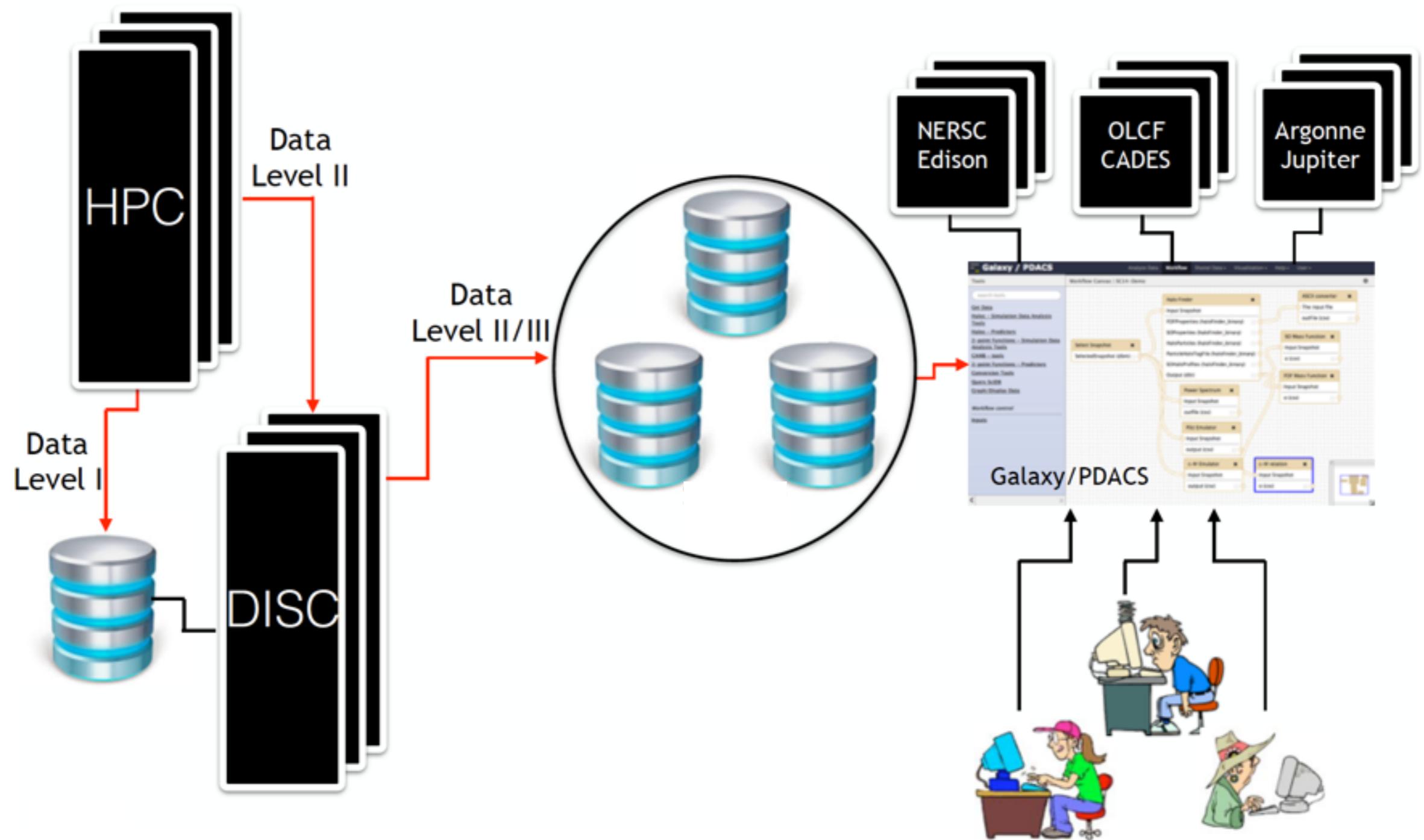
---

**more catalogs from**  
**Yale, Chile, CMU ...**

**sdss\_stanfordcat\_mb2**

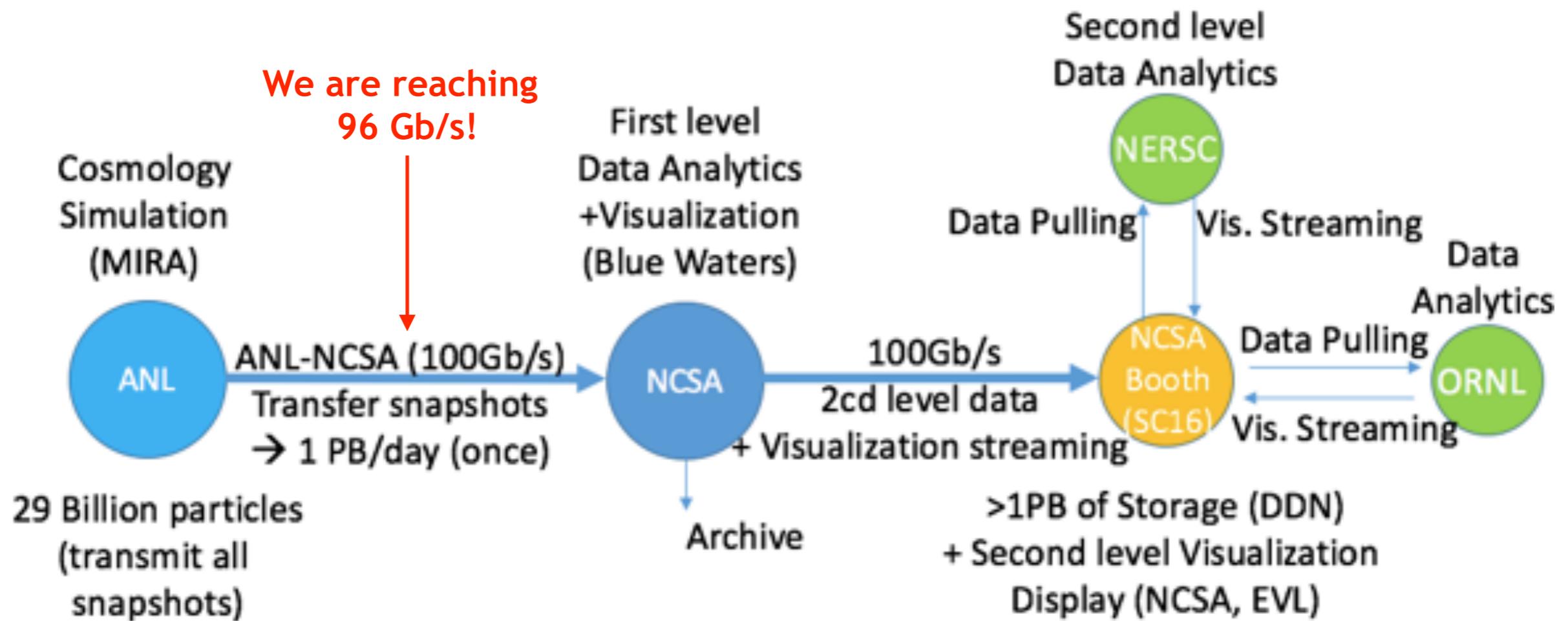
- High-quality, mock catalogs validated against observational data are essential for LSST DESC working groups
- DESC-QA: Automated test of synthetic catalogs against observational data
- Access via NERSC-based web-portal (originally developed by P. Ricker, now supported mainly by T. Uram, ALCF)
- Concept:
  - ▶ Analysis working groups provide crucial observational validation data sets and tests
  - ▶ Simulation working group provides range of catalogs for different analysis tasks
  - ▶ Users can evaluate which catalog is most appropriate for their tasks, inspect tests
- Current status: 9 catalogs, 5 tests

# Cosmic Lab of the Future



# A Realization of the Cosmic Lab of the Future

- Demonstration for SC16 SciNet with the following components:
  - ▶ HPC System: Mira or Theta at Argonne, create and transfer 500 snapshots
  - ▶ DISC System: BlueWaters at NCSA, analyze and store 500 snapshots
  - ▶ Data Center: At SC16 Booth, NERSC, ORNL as data analytics places
  - ▶ PDACS (Portal for Data Analysis of Cosmological Simulation) as analysis engine



# Challenge 1: Data Transfer

May 2016

# ESnet project

# ANL-NCSA aim: 1PB/day! ~100Gbs

