

**Carnegie Mellon University**  
McWilliams Center for Cosmology

# 2016 Jamboree



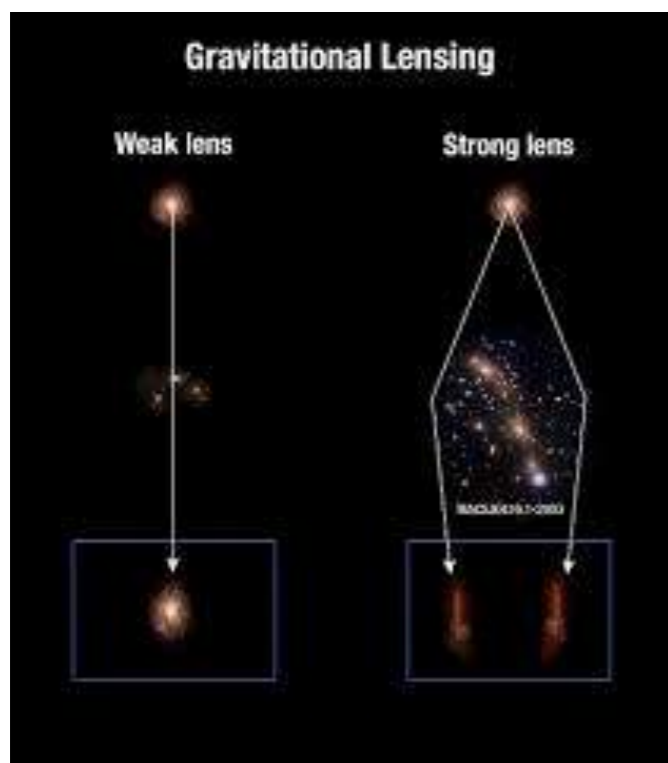
# Rachel Mandelbaum (+Optimus Prime)



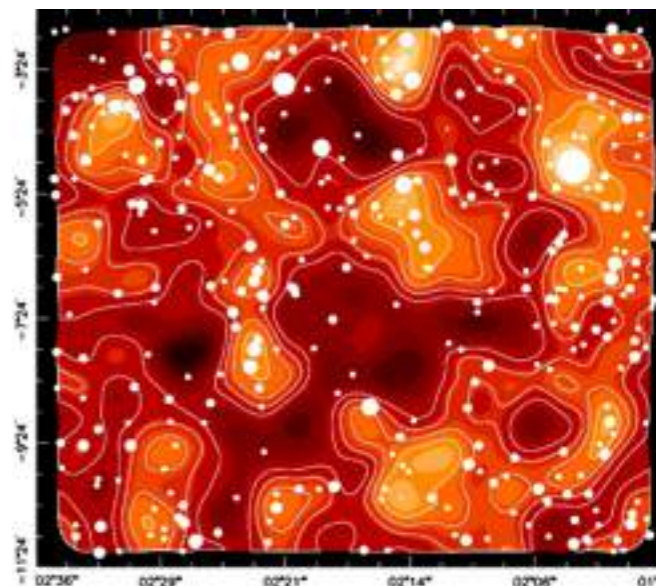
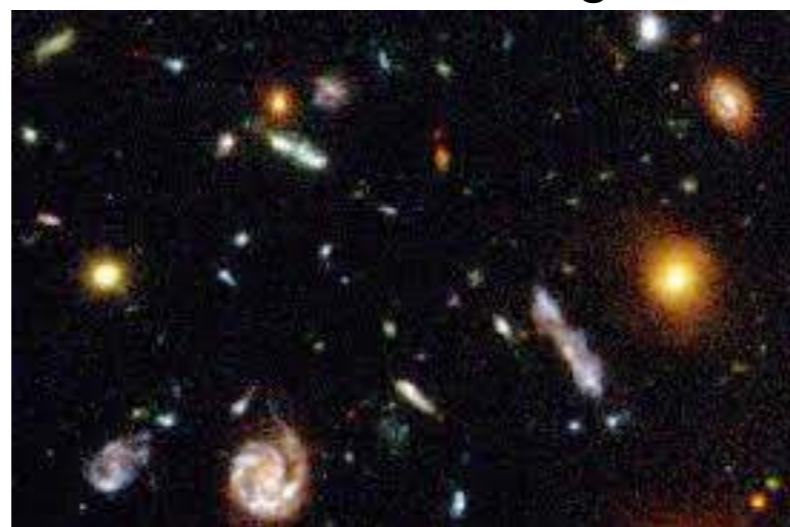
## Observational cosmology:

- how can we make the best use of large datasets? (+stats, ML connection)
- dark energy
- the galaxy-dark matter connection

I measure this:



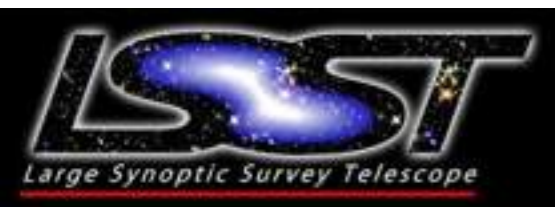
for tens of millions of galaxies to (statistically) map dark matter and answer these questions



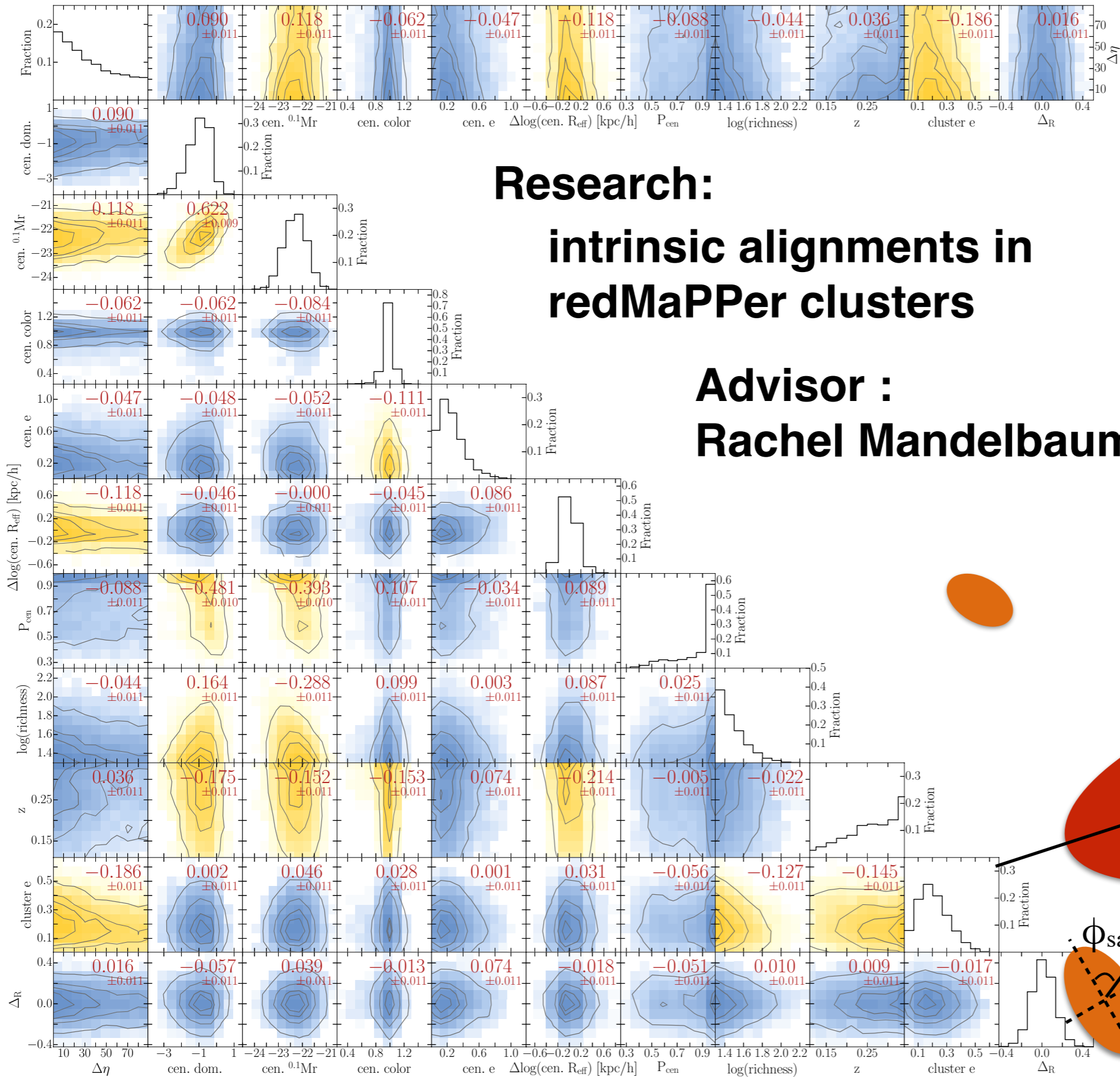
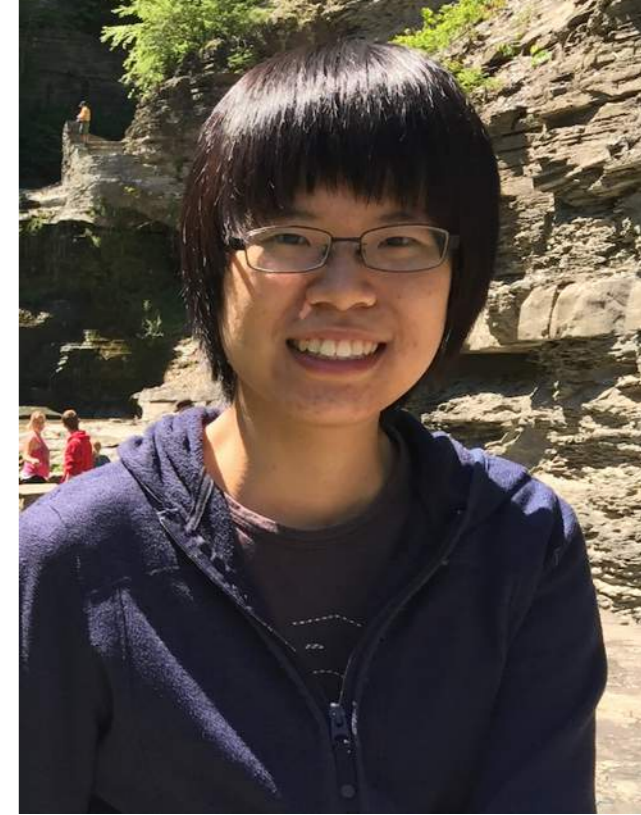
Data I use now:



Future surveys I'm involved in:

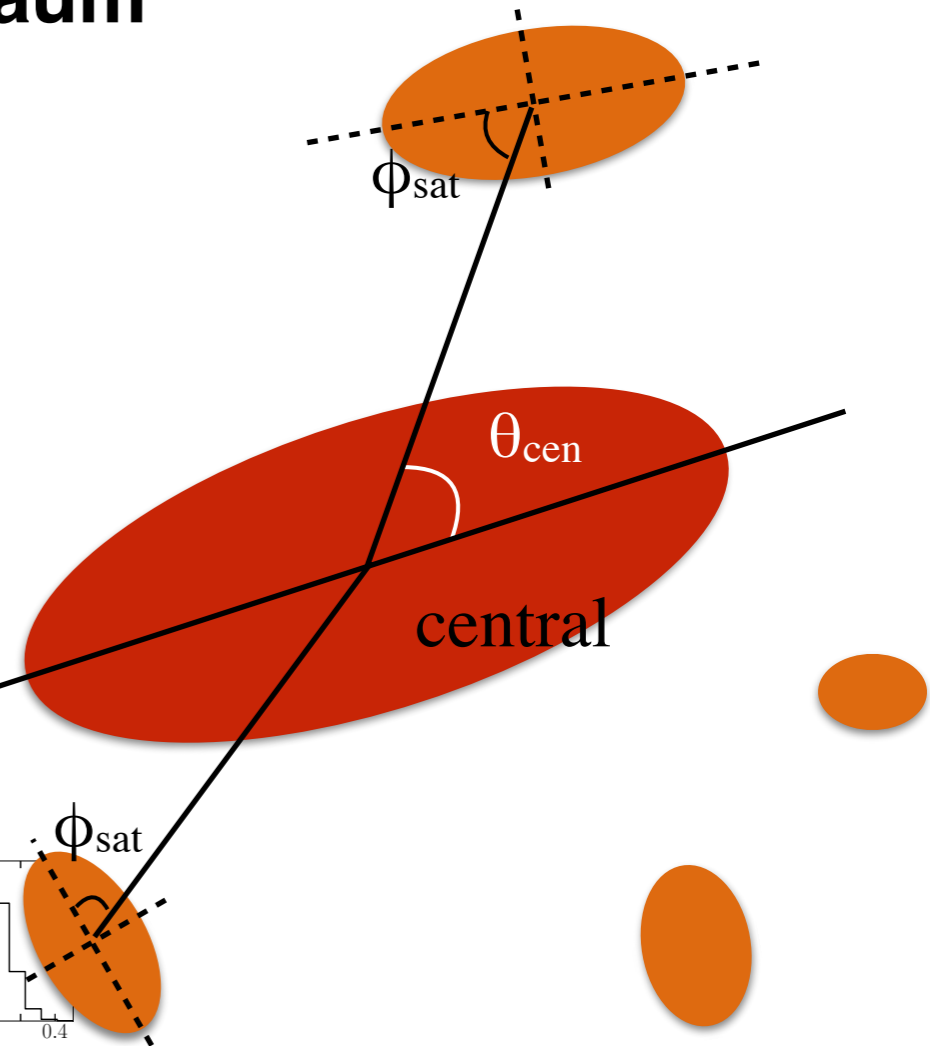


# Hung-Jin Huang



**Research:**  
intrinsic alignments in  
redMaPPer clusters

**Advisor :**  
Rachel Mandelbaum



# Sukhdeep Singh

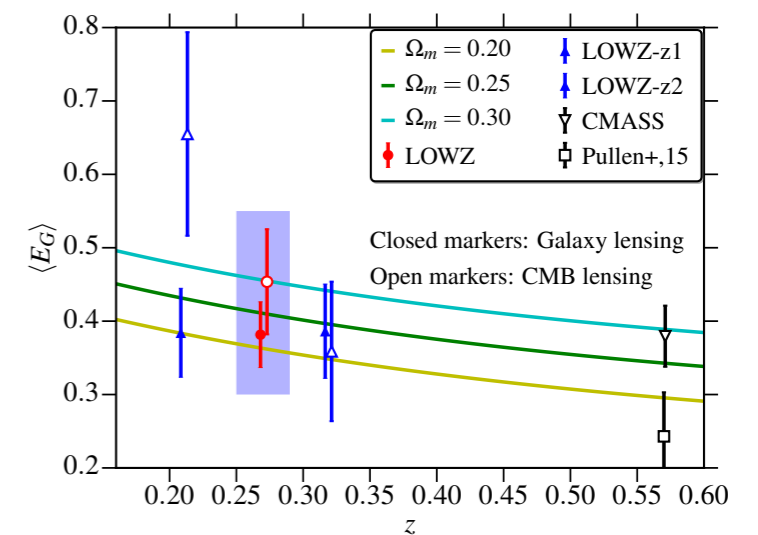
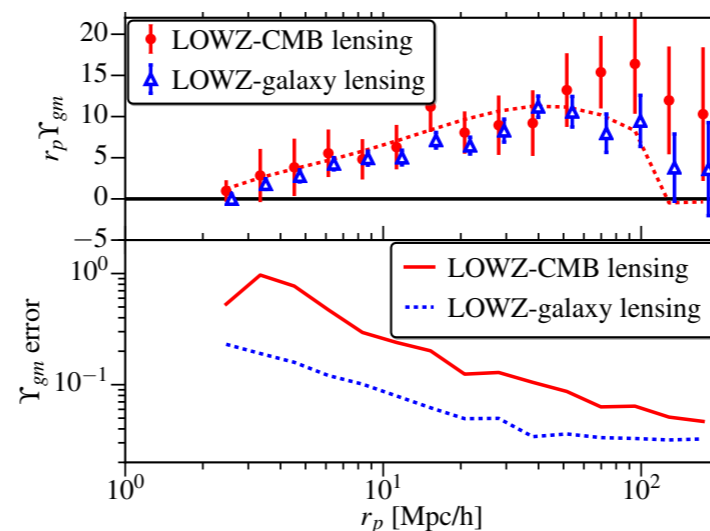
Graduate Student with Prof. Rachel Mandelbaum



## Research

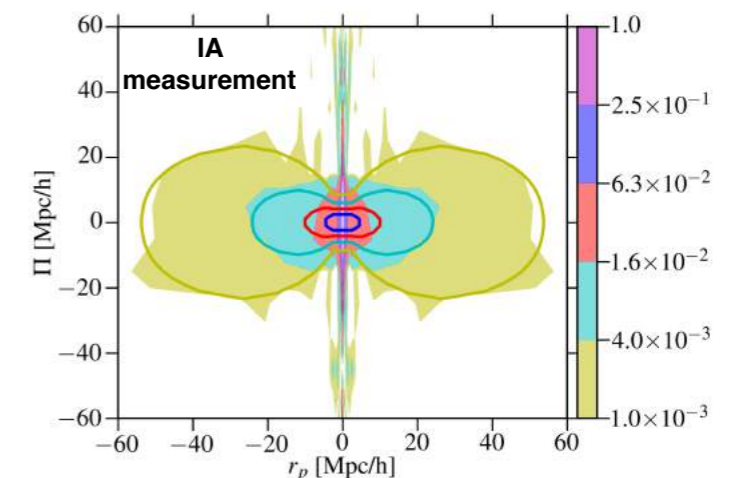
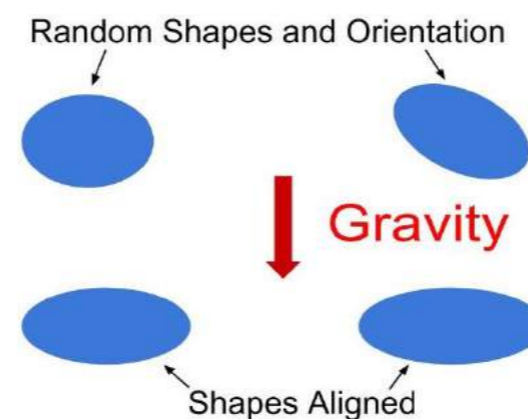
### 1. Weak Lensing Science

- Gravitational Physics
- Nature of Dark Matter, Dark Energy



### 2. Intrinsic Alignments

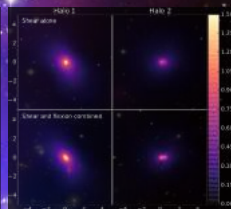
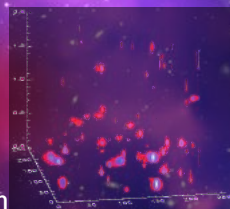
- Galaxy Formation and Evolution
- Weak Lensing Systematics





- Observational cosmology
  - Weak Lensing
- Astrostatistics
  - Sparsity / Machine Learning

Postdoc with Rachel Mandelbaum

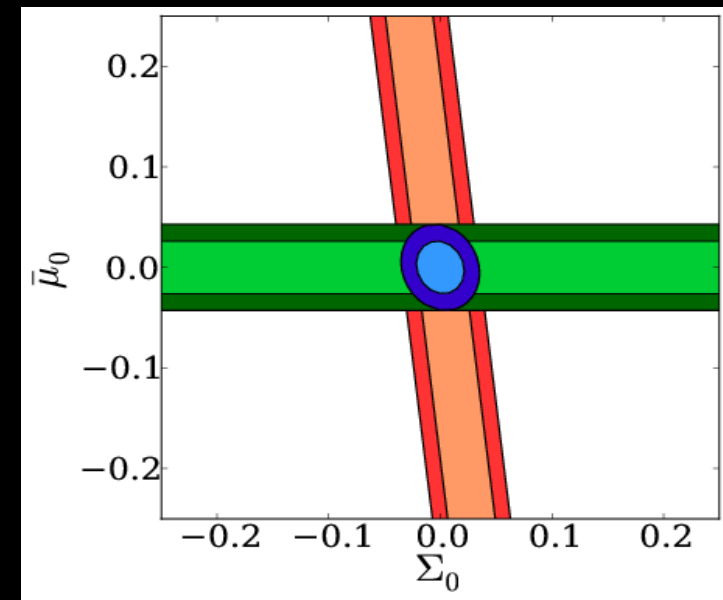
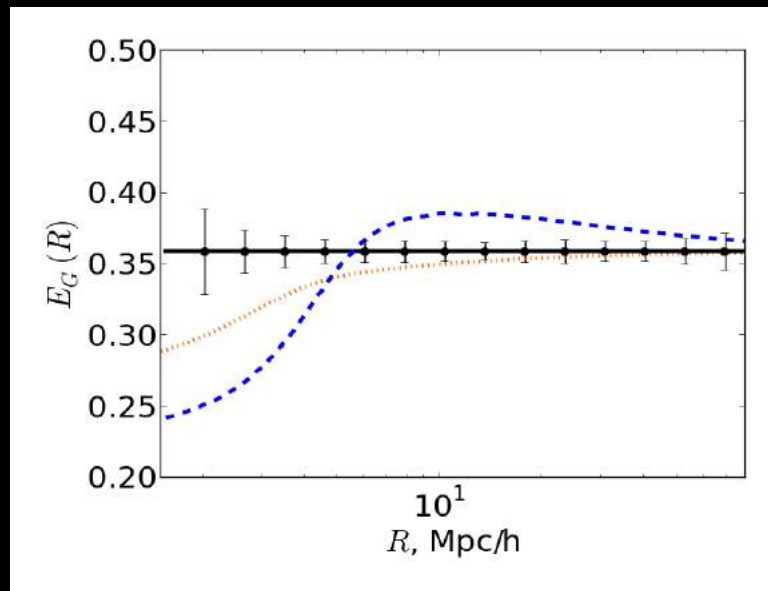


**Carnegie Mellon University**  
McWilliams Center for Cosmology

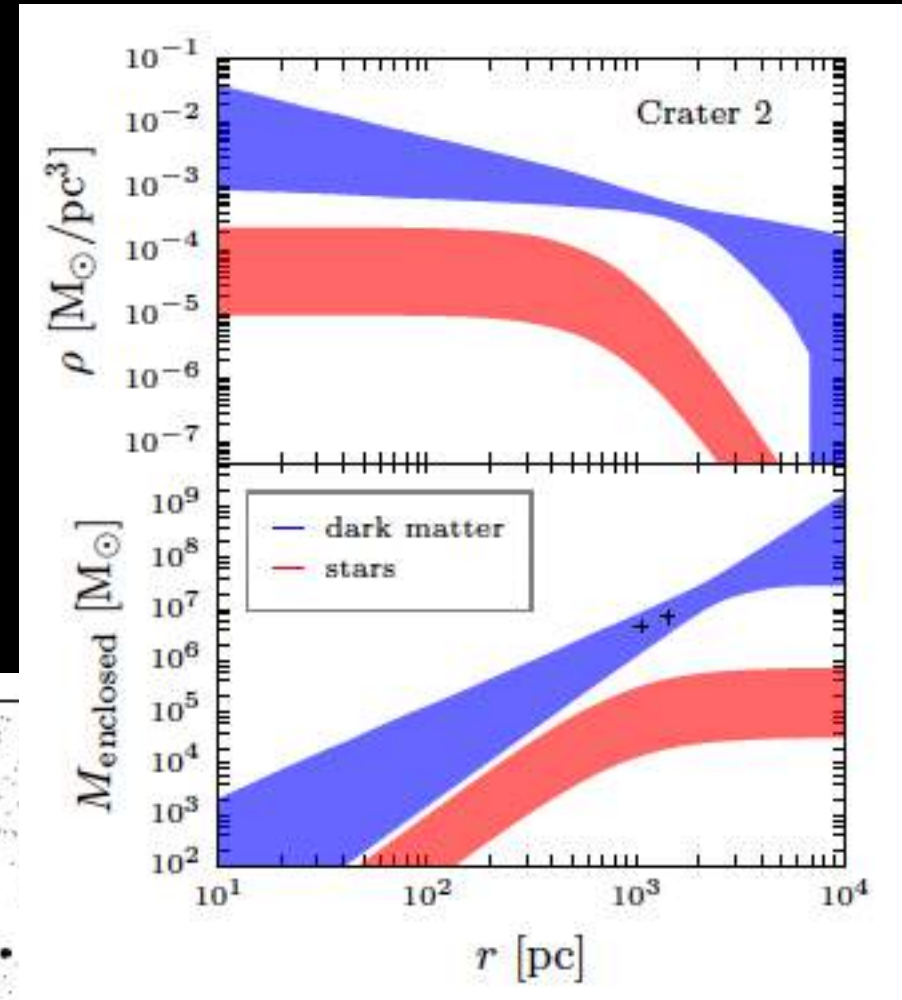
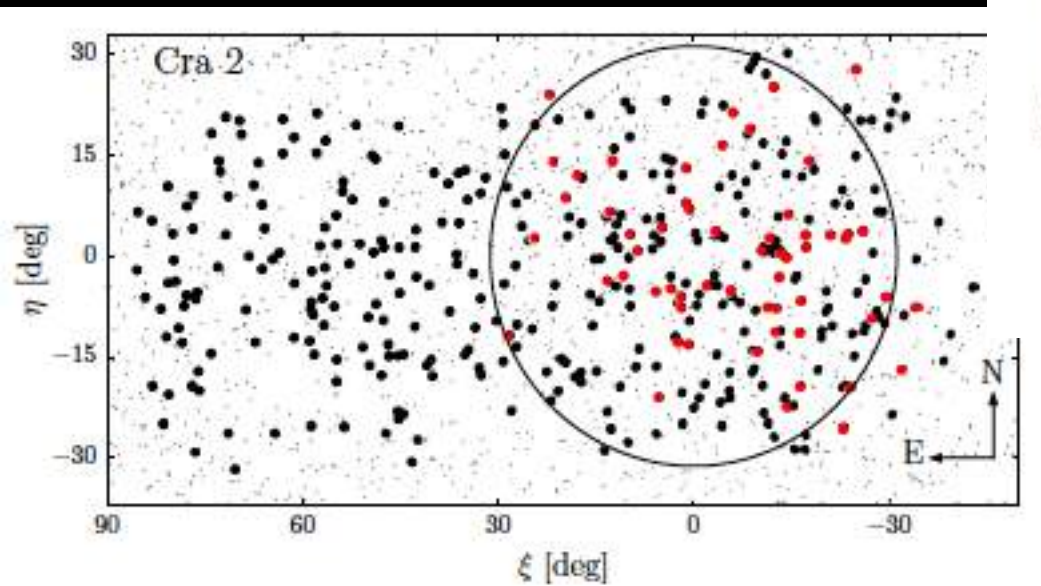
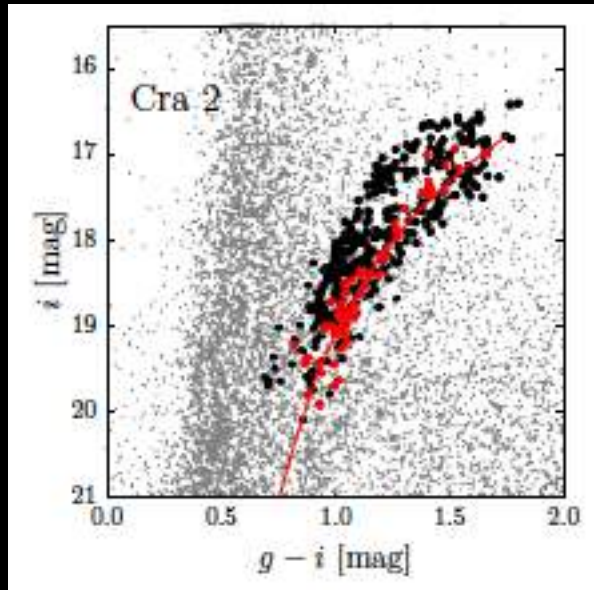
# Danielle Leonard

McWilliams Postdoctoral Fellow

- Weak lensing + other LSS probes of non-standard cosmology, especially alternative theories of gravity
- Degeneracies involving beyond- $\Lambda$ CDM parameters
- Understanding theoretical uncertainties, as related to next-generation surveys



# Matthew G. Walker

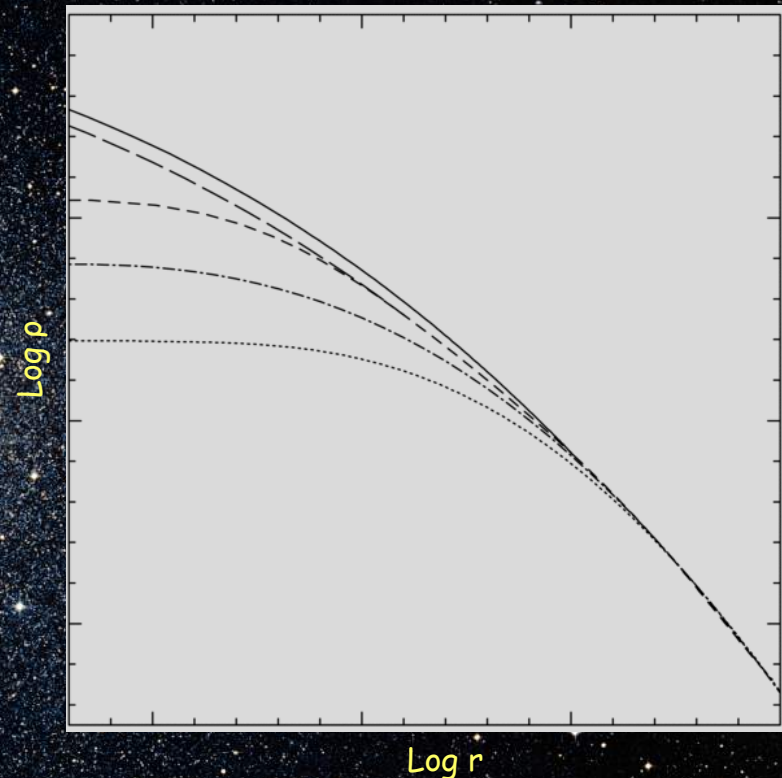


Mao-Sheng Liu (Terrence)  
Advisor: Matthew Walker

---

Study the distribution of dark matter at small scale through sampling-based inference, including:

- Likelihood Approximation
- Approximate Bayesian Computation
- Machine Learning

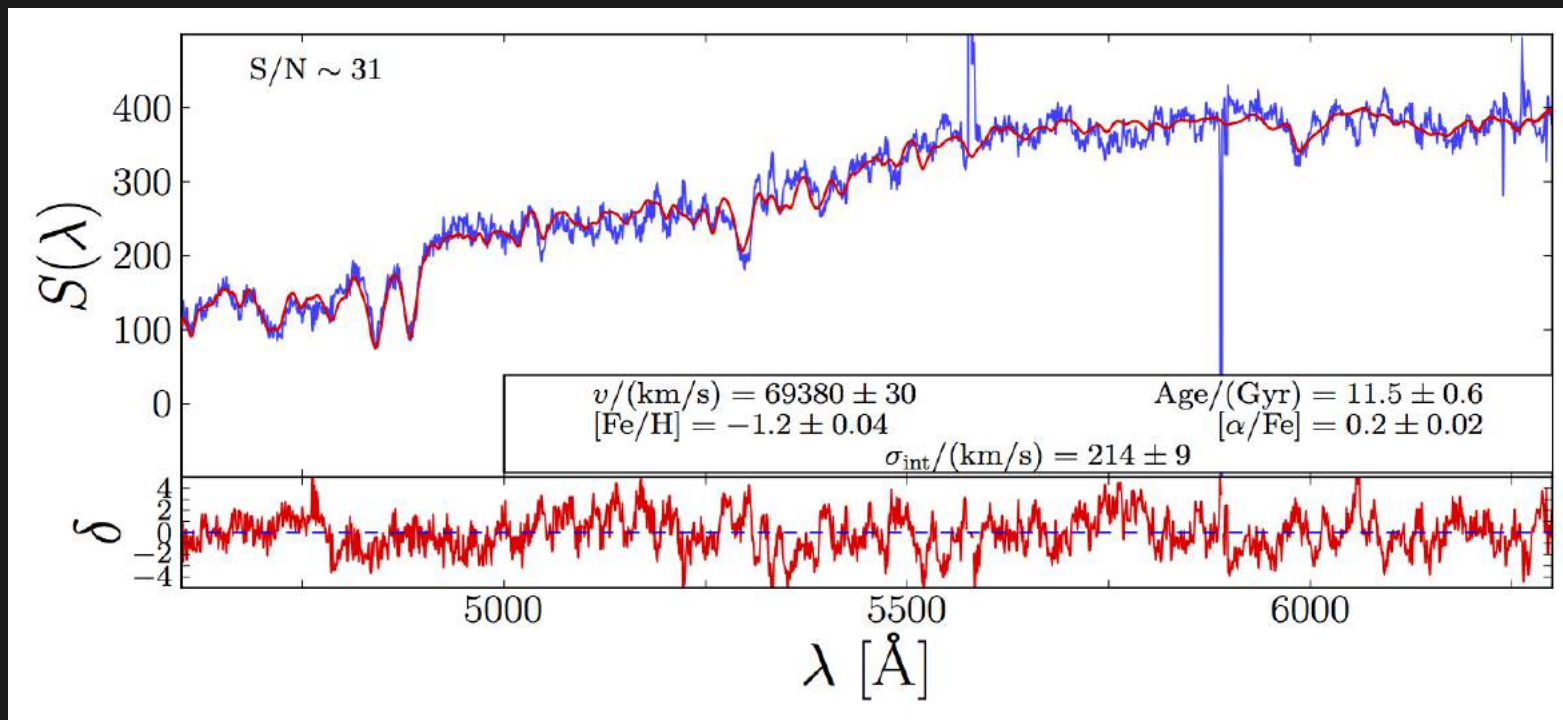




# Evan Tucker - 4<sup>th</sup> Year Grad Student



Working with Matt Walker, we developed a new model for fitting galaxy spectra extracting population properties: age,  $[\text{Fe}/\text{H}]$ ,  $v_{\text{los}}$ , and mass. We are now developing a new mixture model to understand dynamics of galaxy clusters.



# Alex Geringer-Sameth

Postdoctoral researcher

## Astroparticle physics



**observation** = **dark matter particle physics**  $\times$  **astrophysical distribution** + **backgrounds**

gamma-rays

dwarf galaxies

statistical tools

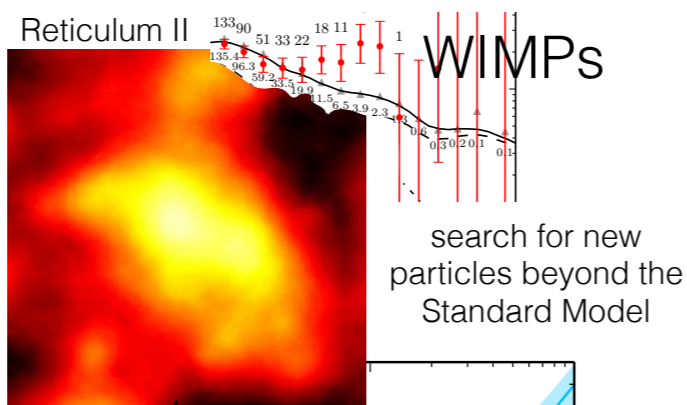
detecting unresolved sources

correlations pulsars, moving objects

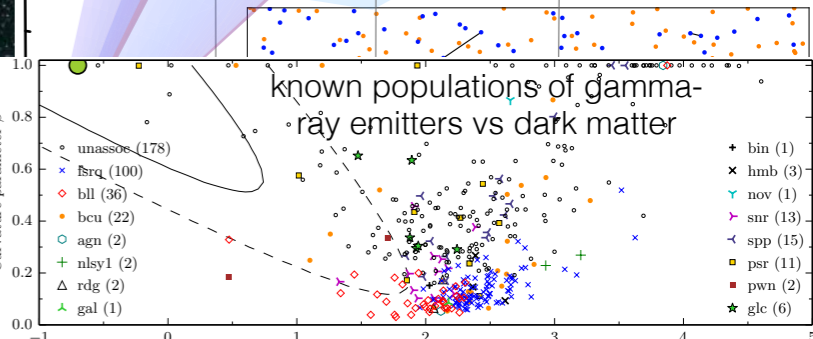
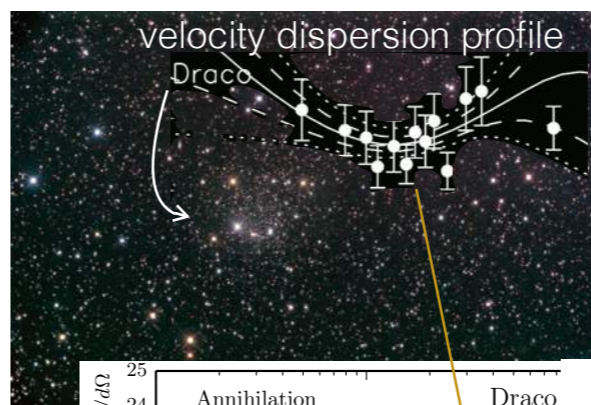


Fermi

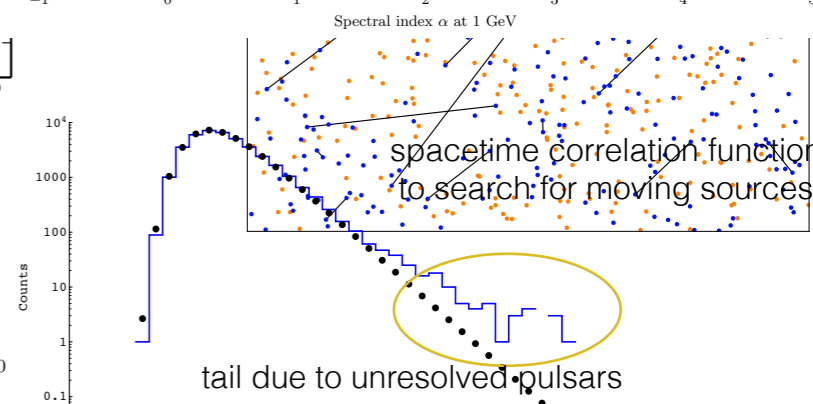
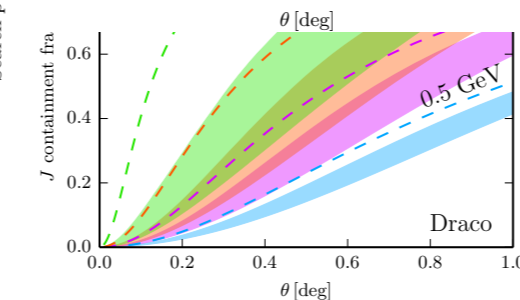
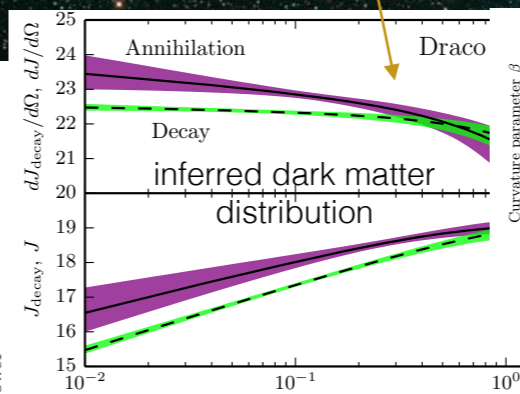
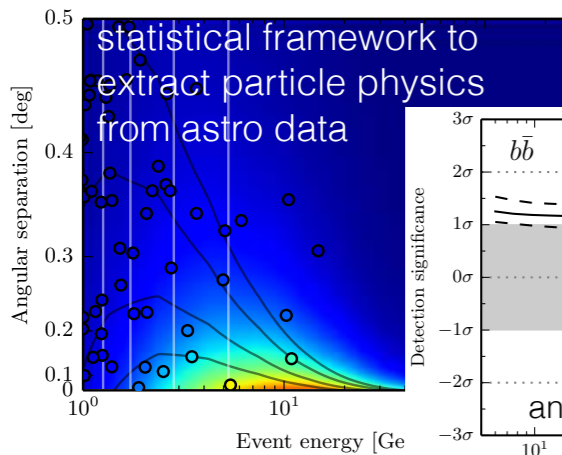
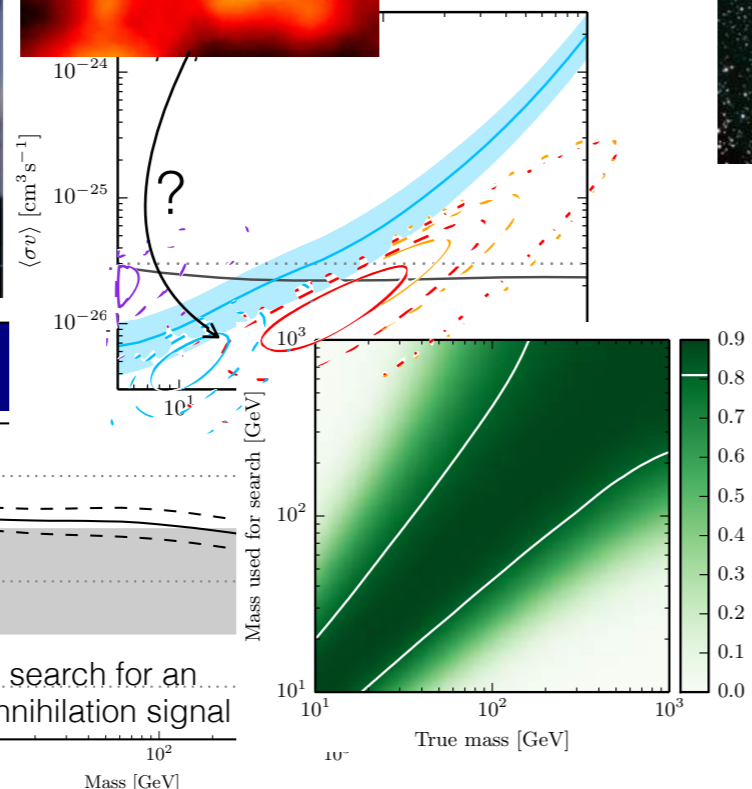
annihilation



stellar kinematics  $\rightarrow$  dark matter distribution



VERITAS



# Tina Kahniashvili

## The McWilliams Center For Cosmology

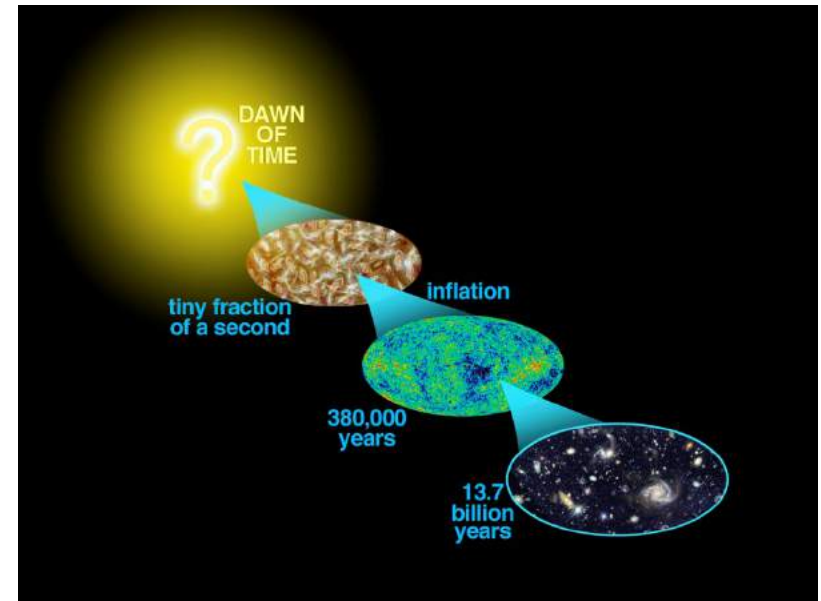


### – Cosmology

- Very Early Universe
  - Fundamental Symmetries Tests
  - Gravitational Waves
  - Cosmic Microwave Background
- Accelerated Expansion
  - Modified Gravity
  - Dark Energy
- Astro-Particle Physics
  - Neutrino Mass Origin

### – Astrophysics

- Cosmic Magnetic Fields
- MHD Turbulence

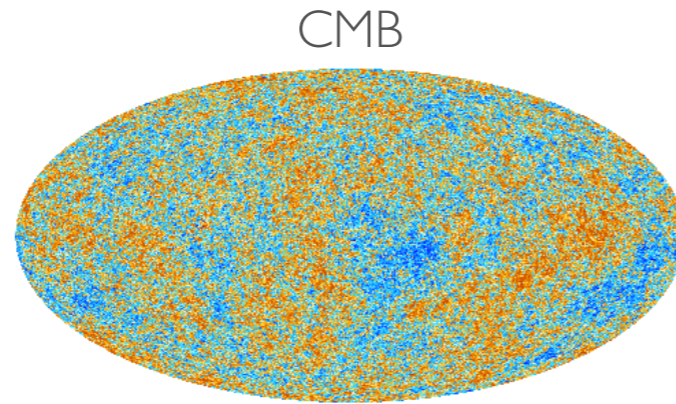


## HyTrac

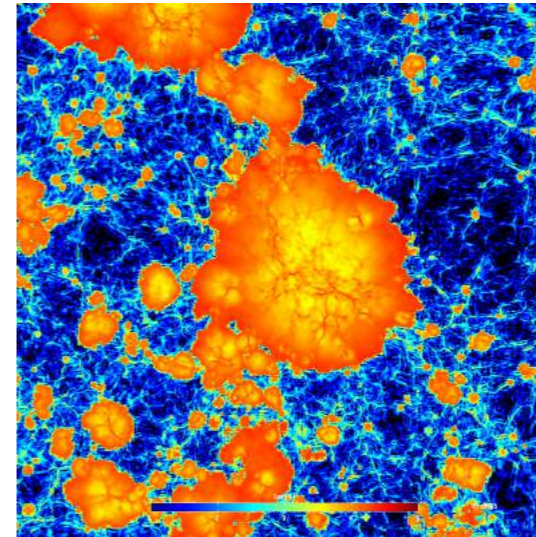
Asst Prof

8307 Wean Hall

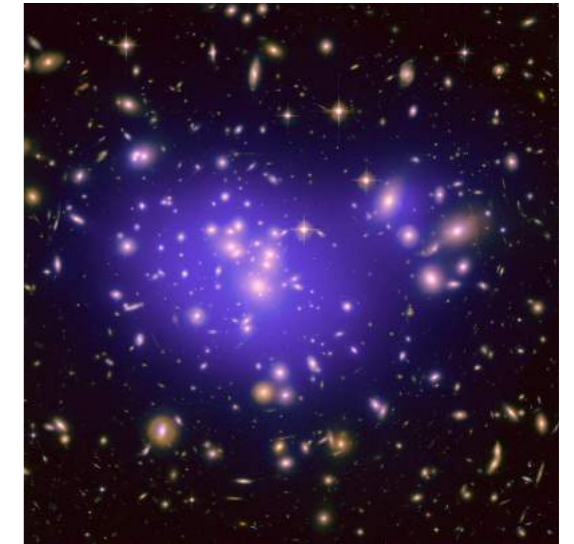
hytrac@cmu.edu



First Stars & Galaxies



Galaxy Clusters



## Group

Minghan Chen, Paul La Plante,  
Michelle Ntampaka, Jeff Patrick,  
Layne Price

## Interests

Structure formation & evolution,  
large-scale structure, dark matter halos,  
galaxies, clusters, cosmic reionization

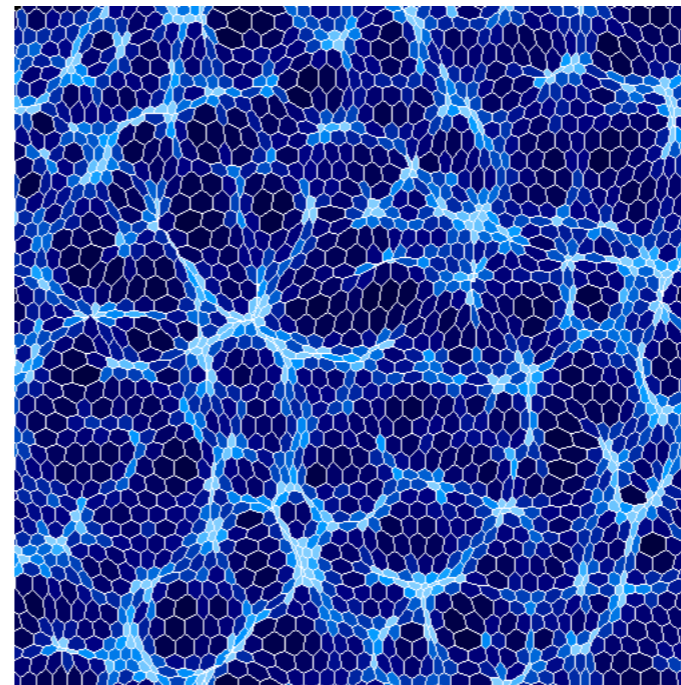
## Tools

Cosmological simulations,  
N-body, hydro, radiative transfer

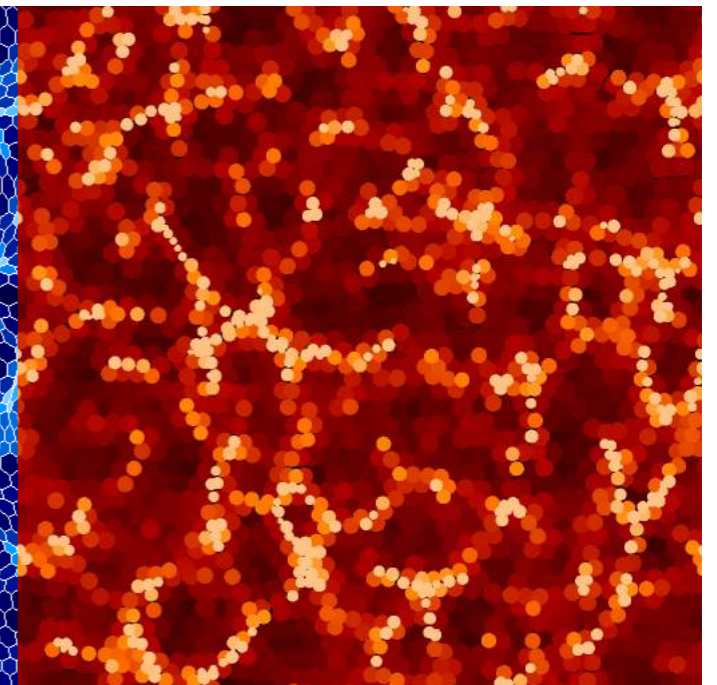
**Ether** (finite-volume particle method)

**Hyper** (fast hydro-particle-mesh)

Meshing



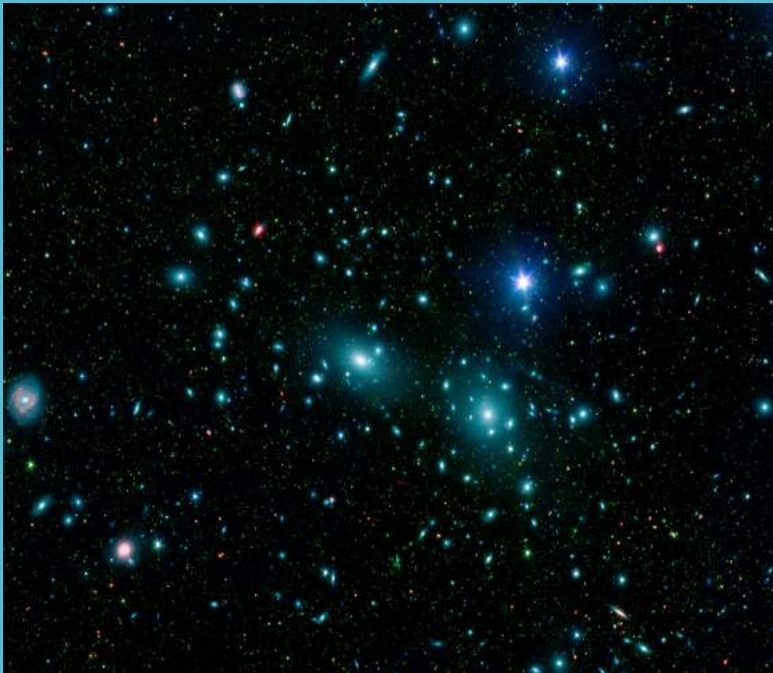
Meshfree



# Michelle Ntampaka

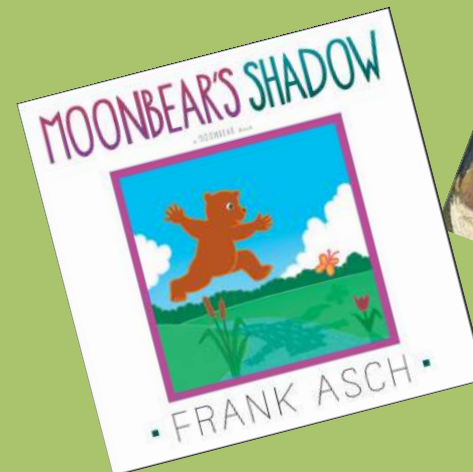
## Research:

- Graduate student working in Hy Trac's group
- Research: Galaxy Cluster Dynamics with ML and Stats



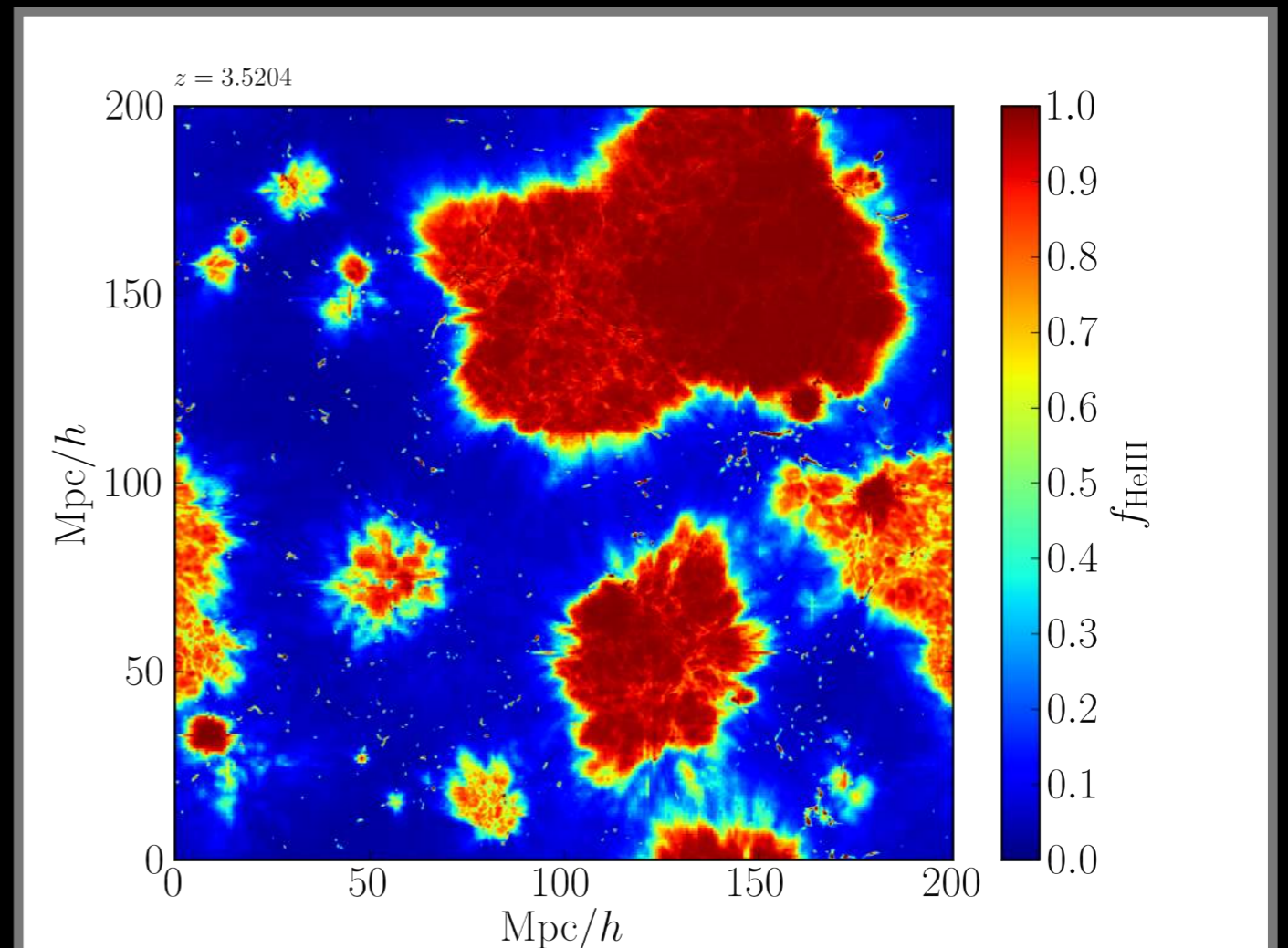
## Outreach:

- Early Childhood Astronomy



# Paul La Plante

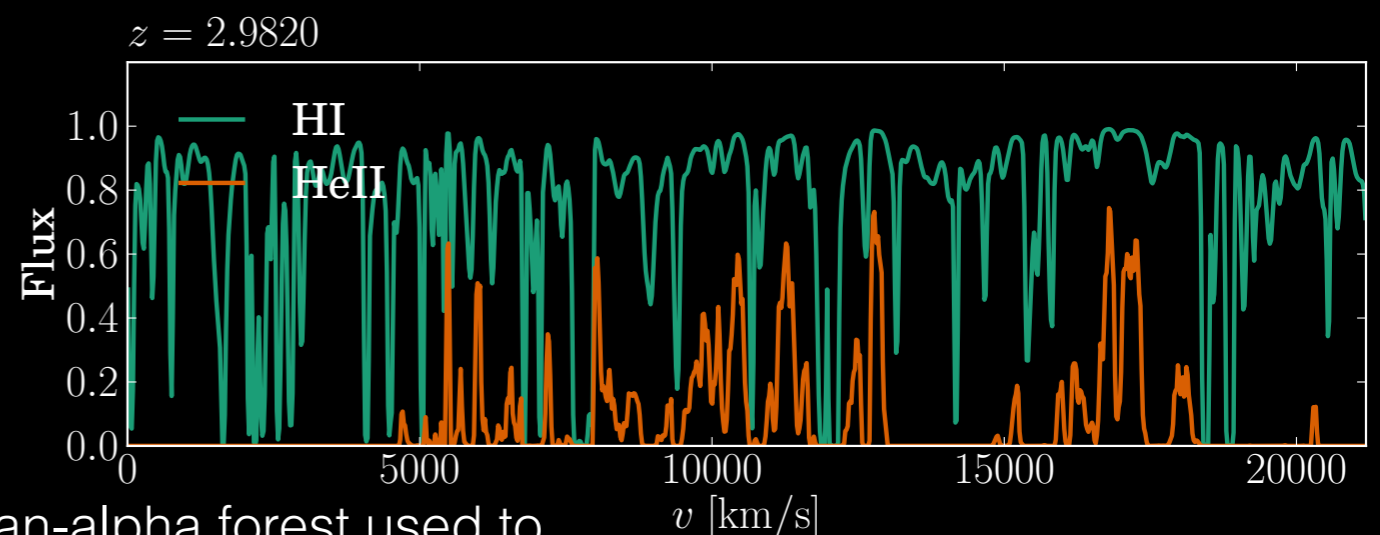
- Graduate student, soon-to-be postdoc
- Works with Prof. Hy Trac
- Simulations of helium reionization
- Quasar properties, IGM thermal history, Lyman-alpha forest
- Efficient, scalable algorithms for cosmological simulations and analysis



Helium reionization in action



Peta-scale computation



Lyman-alpha forest used to measure large-scale structure

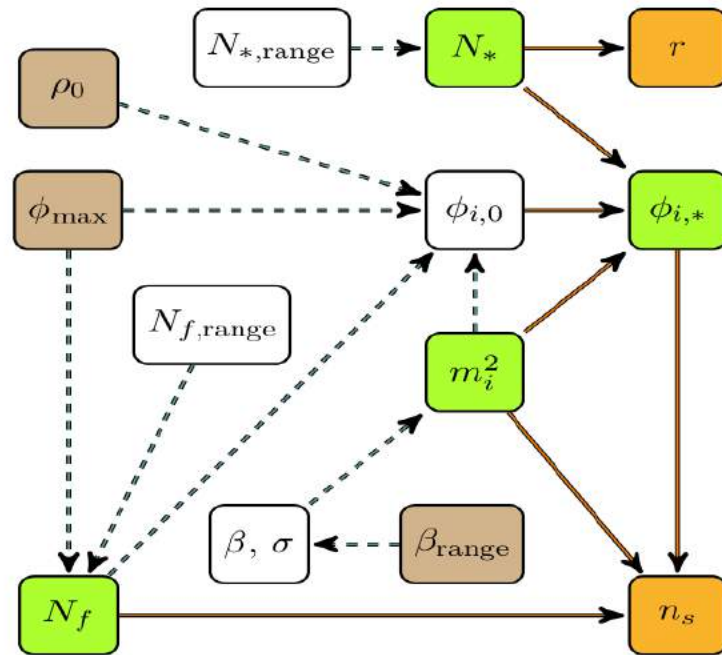
# Diane Turnshek, Special Faculty, Physics, CMU

- Teaches Astronomy and manages classroom demos
- Teacher Advisory Panelist at Carnegie Science Center
- IDA Dark Sky Defender
- Chair of IAU Technical Working Group against light pollution



# Layne Price

Cosmo/Stats/ML



Early universe  
theory

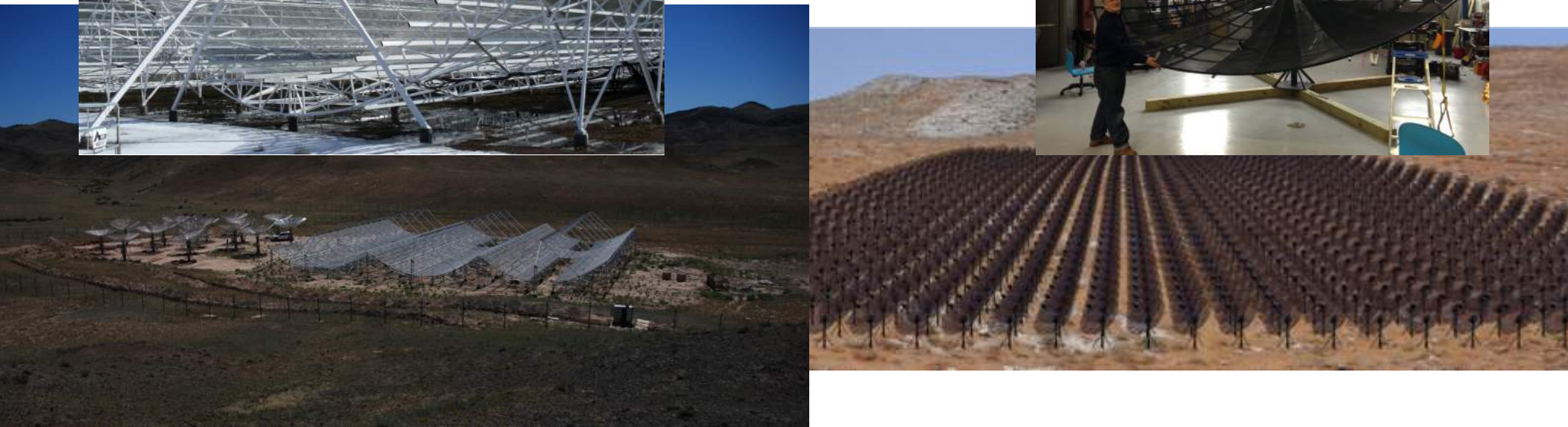
Machine  
learning

Bayesian  
modelling



# Jeff Peterson: Radio Astronomy With 2000-receiver Telescopes

- Building three radically new telescopes in Canada (CHIME), South Africa (HIRAX) and China (Tianlai).
- Primary Goals:
  - Map LSS via 21-cm intensity field—BAO dark energy test
  - Find and localize 10 Fast Radio Burst per day



# Zhonghao Luo (Roy)

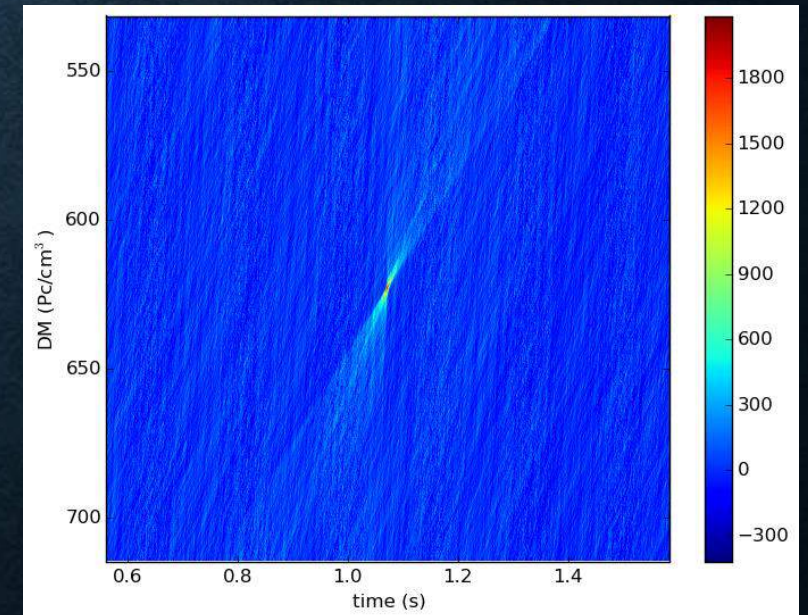
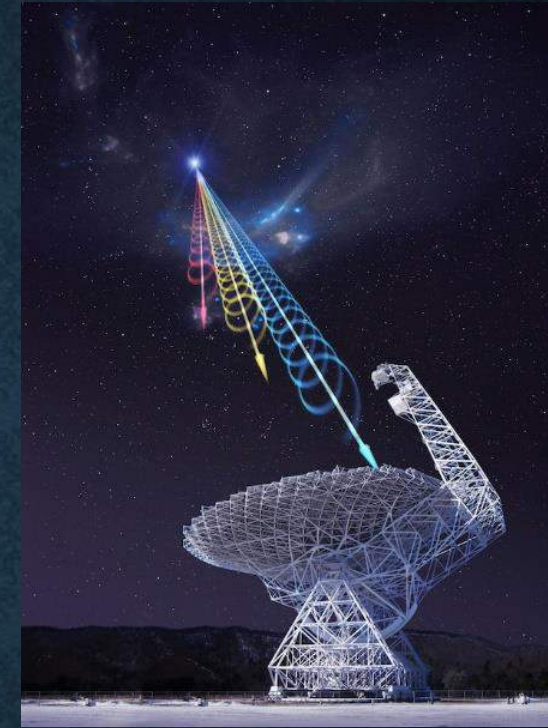


- Advisor: Jeff Peterson
- 4<sup>th</sup> year graduate student
- Lyman Alpha Intensity Mapping using a small aperture telescope with grism spectrometry



# Hsiu-Hsien Lin

- 4<sup>th</sup> year physics graduate student  
Advisor: Jeffrey Peterson
- Search Fast Radio Bursts (FRBs) and Pulsars  
by using Green Bank Telescope and incoming telescopes.
- Discover FRB110523  
Masui, K., Lin, H.-H., Sievers, J., et al. 2015, Nature, 528, 523



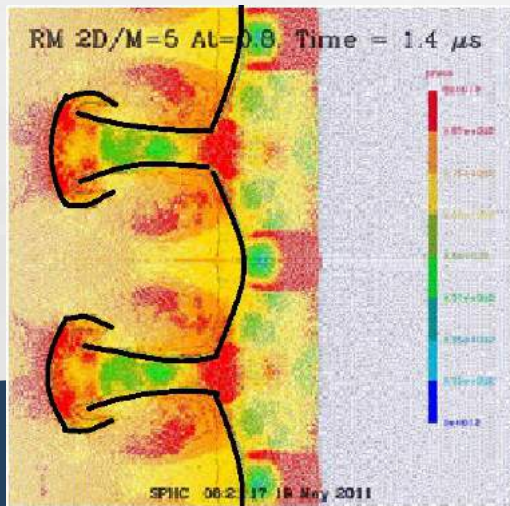
**Name : Aklant Kumar Bhowmick**

**Advisor: Tiziana Di Matteo**

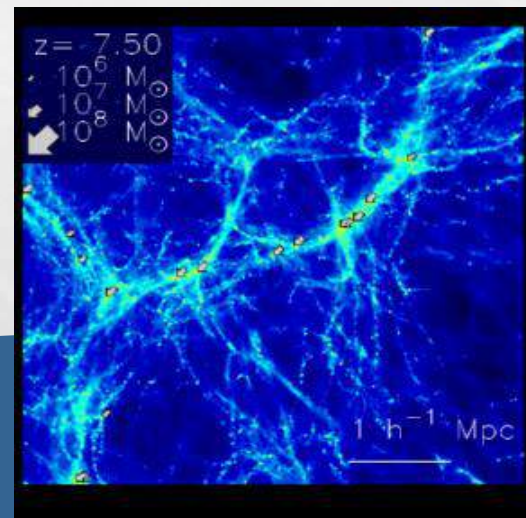
- **Third year graduate student at CMU**
- **Worked in the field of interfacial instabilities**
- **Interested in Smooth Particle Hydrodynamic simulations**



Stanic et al. 2012



<http://web.phys.cmu.edu/~tiziana/D6bh/article/compare2.gif>



# Carolina Núñez

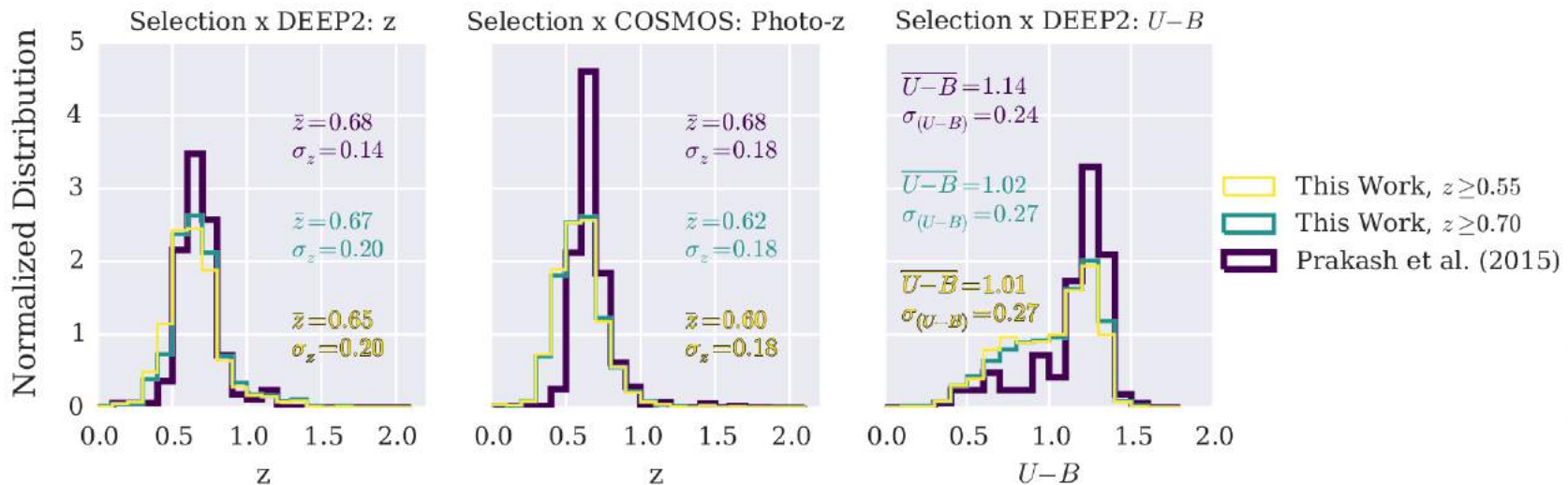


Research Assistant, “Pre-Doc”

Group: Prof. Shirley Ho

Research Topics:

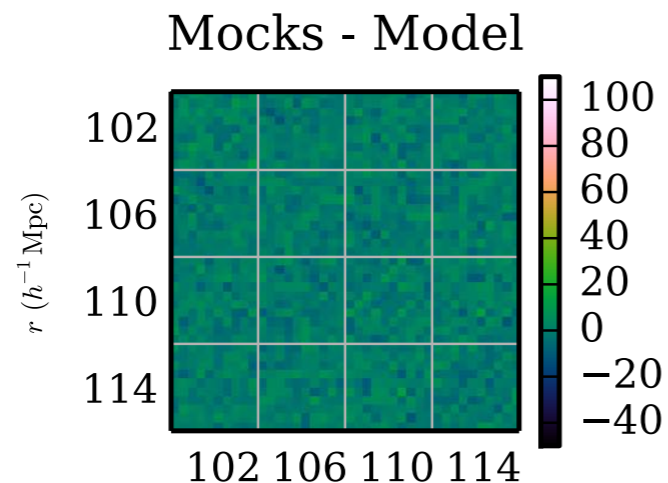
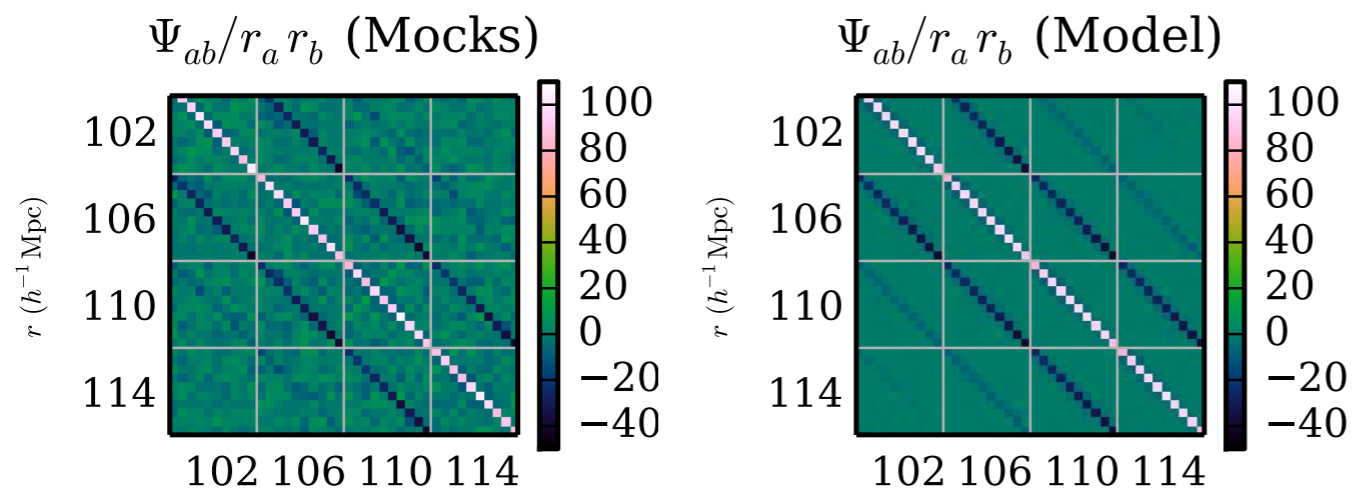
- Photometrically selected massive galaxy catalog
- SZ effect
- Photo-z



# Ross O'Connell

McWilliams Center

LSS, BAO, etc.



**Current interests:**  
Covariance matrix estimation

Tomographic analysis  
(for eBOSS, DESI, etc.)

<https://github.com/rcoconnell/Rascal>

# Elena Giusarma

Postdoctoral Fellow

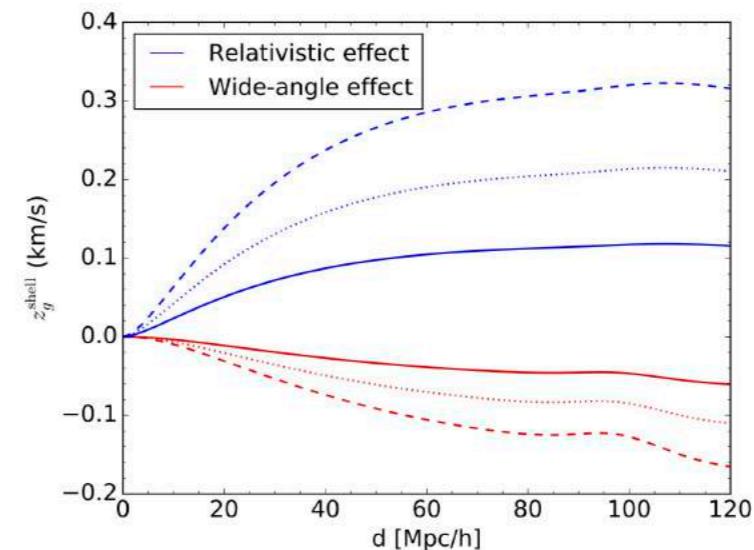
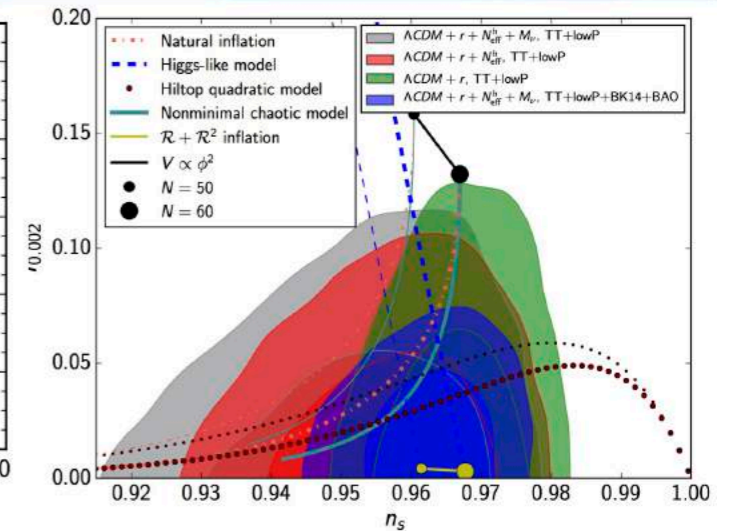
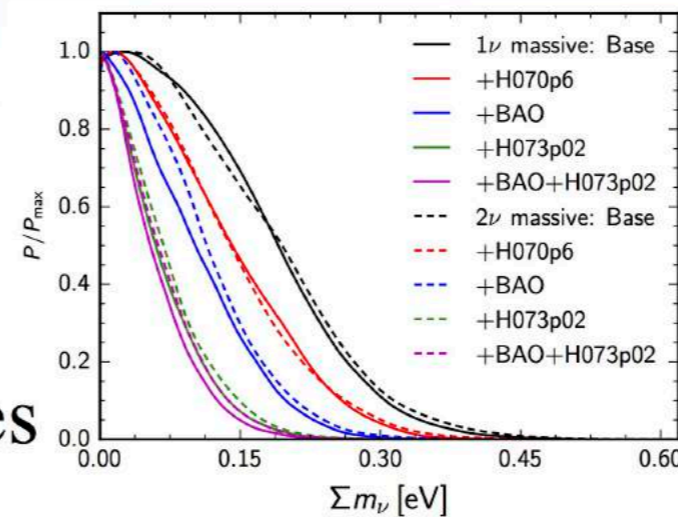


## Research Groups:

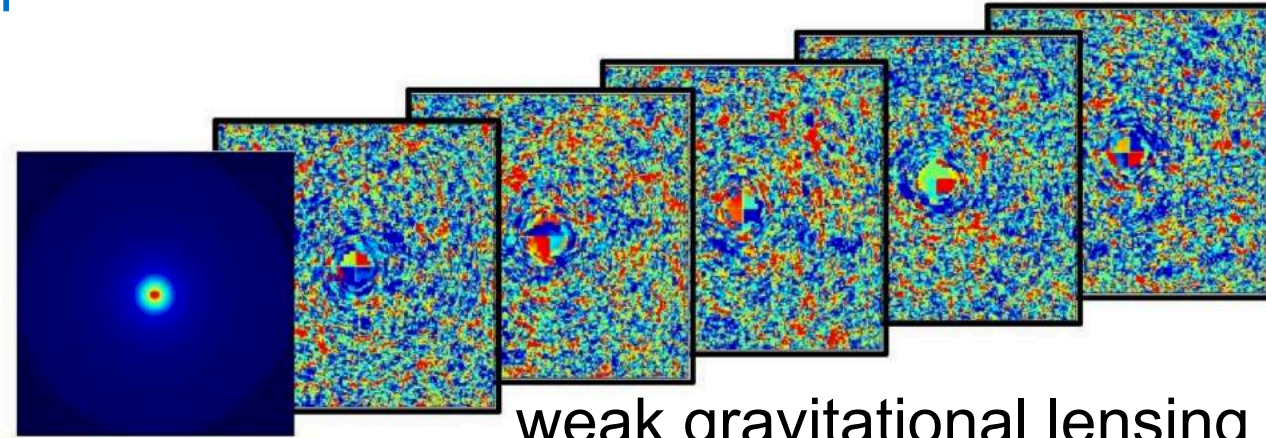
- Prof. Shirley Ho
- Prof. Rupert Croft

## Research Topics:

- Neutrino Cosmology
- Impact of neutrinos properties on inflation
- Modeling scale dependent bias using CMB lensing and galaxy clustering
- Gravitational redshift in galaxy clusters



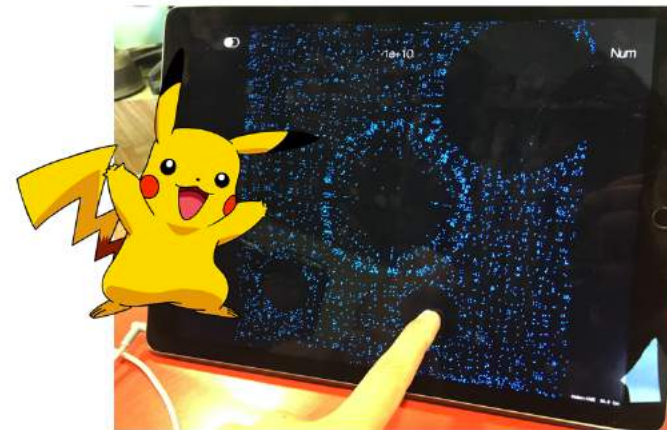
Rupert Croft



weak gravitational lensing of  
the Lyman-alpha forest



relativistic distortions of  
galaxies and large-scale structure



cosmology  
video games

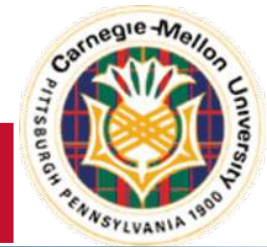




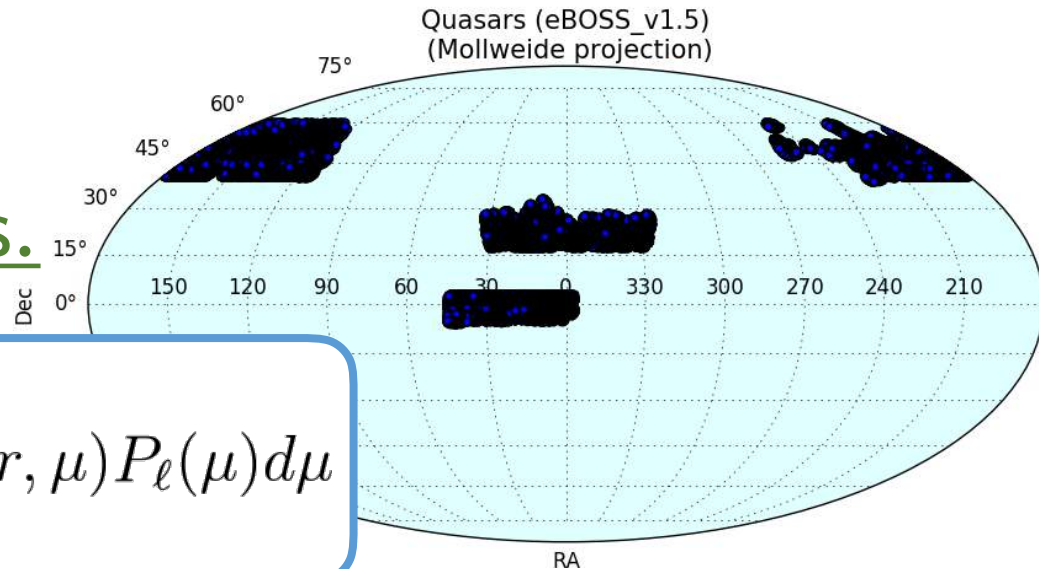
# Fitting Baryon Acoustic Oscillations in Quasars

SIDDHARTH SATPATHY, PROF. SHIRLEY HO, PROF. RUPERT CROFT

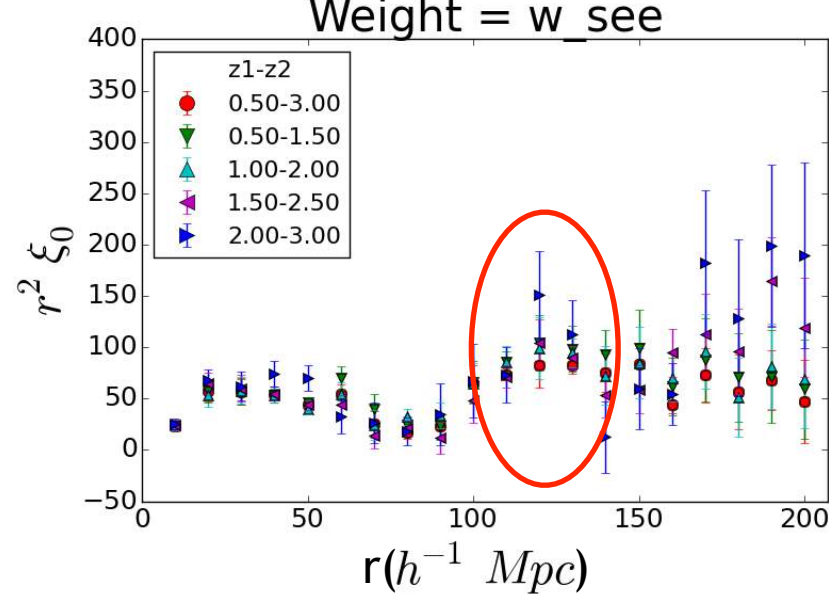
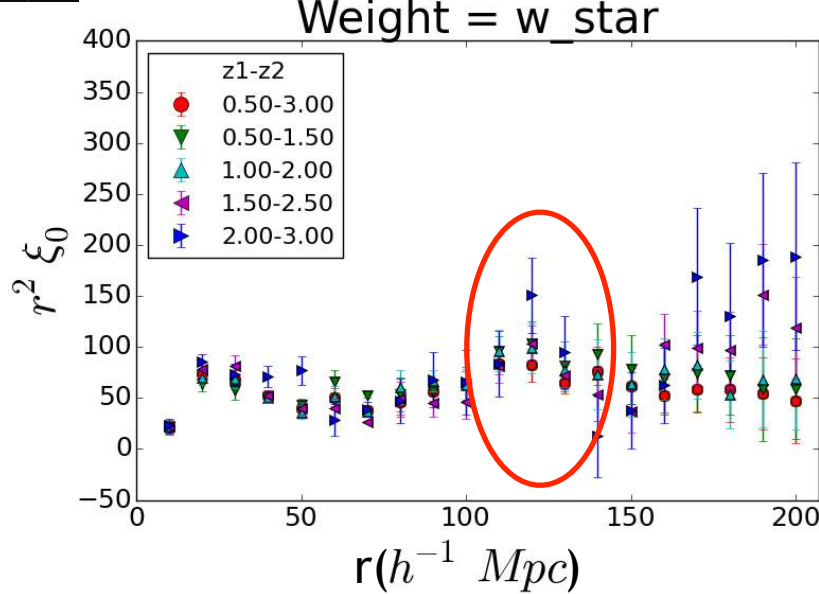
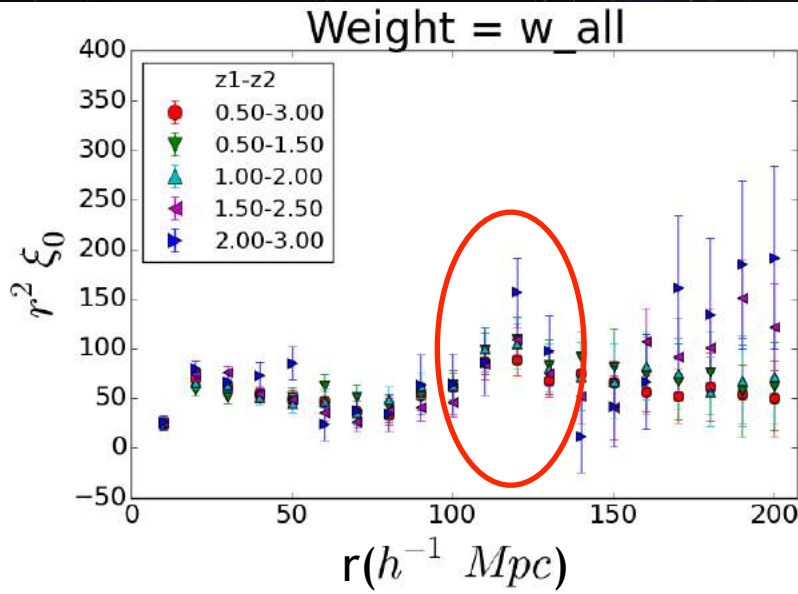
Carnegie Mellon University  
McWilliams Center for Cosmology



Work in progress.



$$\hat{\xi}_\ell(r) = \frac{2\ell + 1}{2} \int_{-\pi/2}^{\pi/2} \xi(r, \mu) P_\ell(\mu) d\mu$$

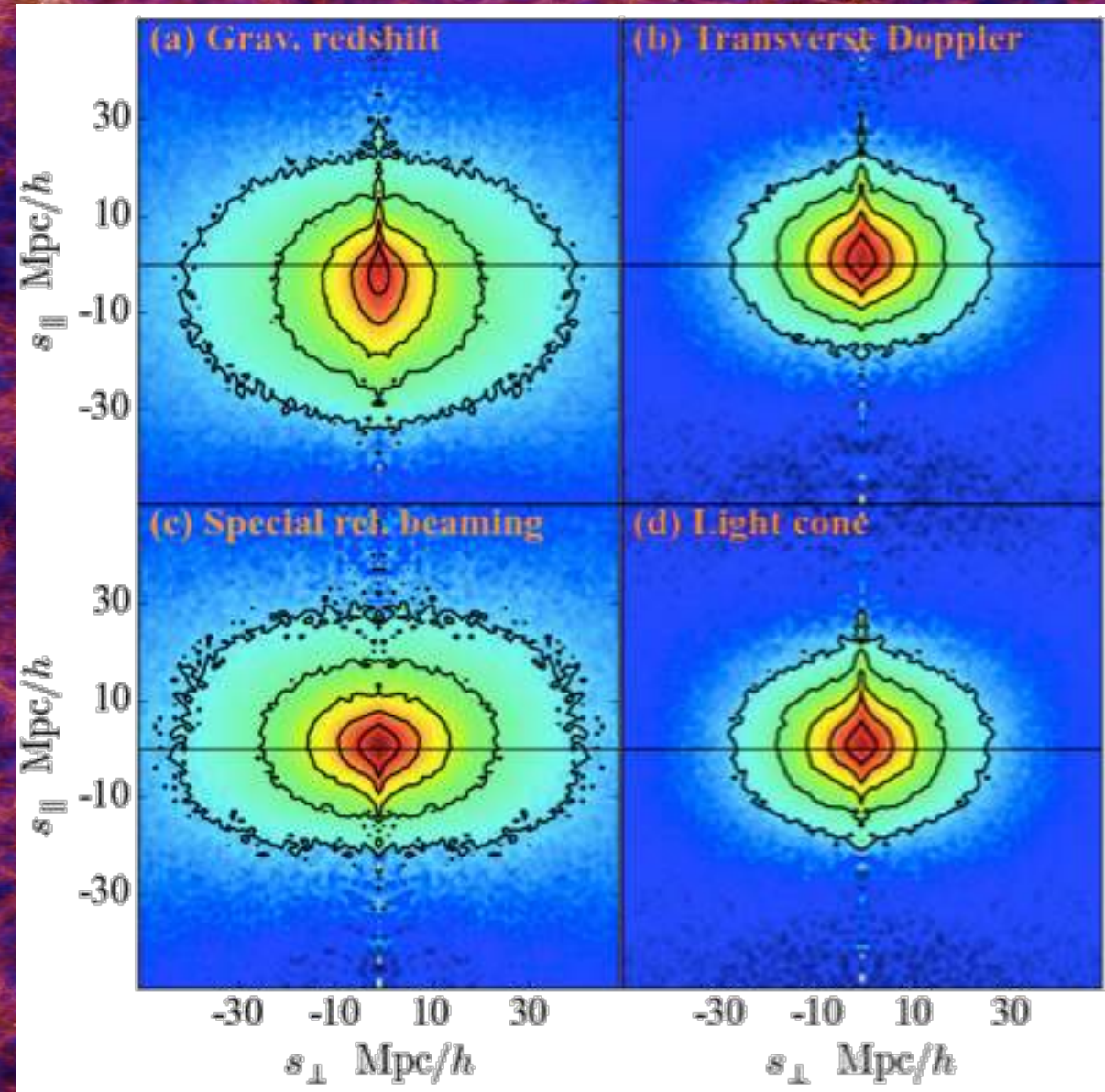
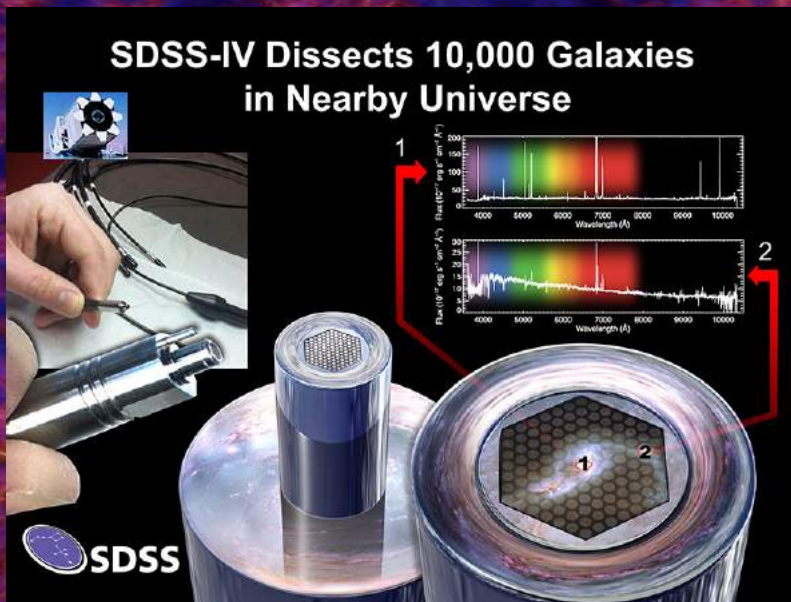


# Gravitational redshifts in galaxy clusters / MaNGA BCGs

\_\_author\_\_ = 'Hongyu Zhu'

\_\_status\_\_ = '4<sup>th</sup> year graduate student'

\_\_advisor\_\_ = 'Prof. Rupert Croft'



**RECENT ASTROPARTICLE THEORY PROJECTS: Leonard Kisslinger and Collaborators:**

1) Review of QCD, Quark-Gluon Plasma, Heavy Quark Hybrids, and Heavy Quark State Production in p-p and A-A Collisions, Leonard S. Kisslinger and Debasish Das, *Int.J.Mod.Phys.A* 31, 1630010 (2016)

This was a review of the Quantum Chromodynamics Cosmological Phase Transitions, the Quark-Gluon Plasma, the production of heavy quark states via p-p collisions and RHIC (Relativistic Heavy Ion Collisions) using the mixed hybrid theory for the  $\Psi(2S)$ ,  $\Upsilon(3S)$  states; and the possible detection of the Quark-Gluon Plasma via heavy quark production using RHIC.

2) Polarized Gravitational Waves from Cosmological Phase Transitions, L.S.K. and Tina Kahniashvili, *Phys.Rev.D* 92, 043006 (2015)

We estimated the degree of circular polarization for the gravitational waves generated during the electroweak and QCD phase transitions (EWPT and QCDPT) from the kinetic and magnetic helicity generated by bubble collisions during those cosmological phase transitions.

3) STERILE NEUTRINOS: neutrinos in addition to the three standard model active neutrinos.

One Sterile Neutrino: Experimental parameters were used to estimate the effect on muon neutrinos converting (oscillating) to electron neutrinos: L.S.K., *Int.J.Theor.Phys.* 54,2141(2015);

Two Sterile Neutrinos: L.S.K., *Int.J.Theor.Phys.* to be published (2016)

Review of Neutrino Oscillations With Sterile and Active Neutrinos: L.S.K., *Int. J. Mod. Phys. A*, Vol 31, 1630037 (2016)

4) Dark Mass Creation During EWPT via Dark Energy Interaction, L.S.K. and S. Casper, *Modern Physics Letters A* Vol 29, 1450055 (2014).

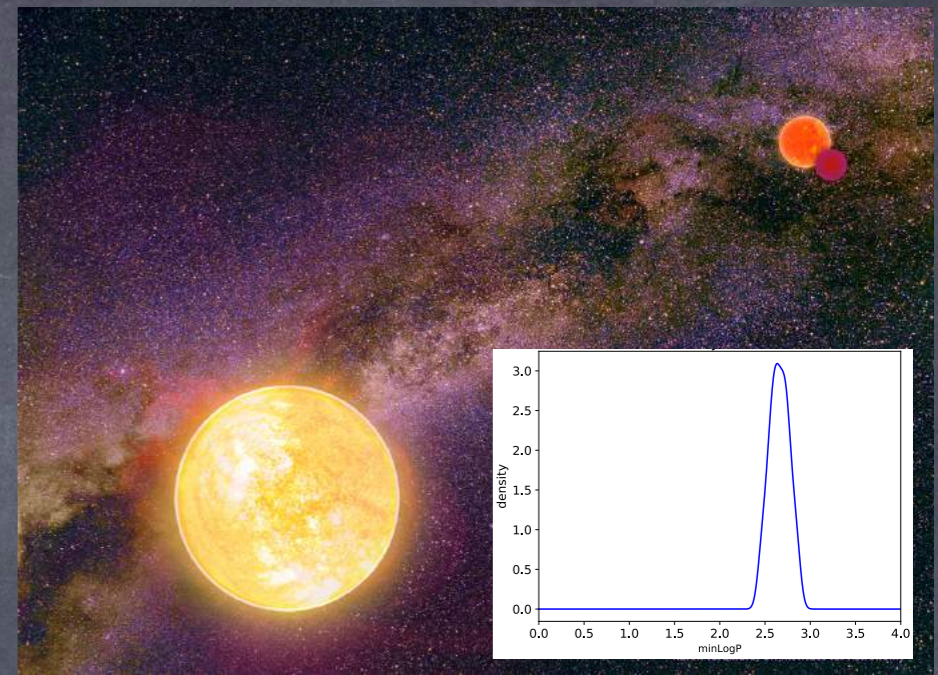
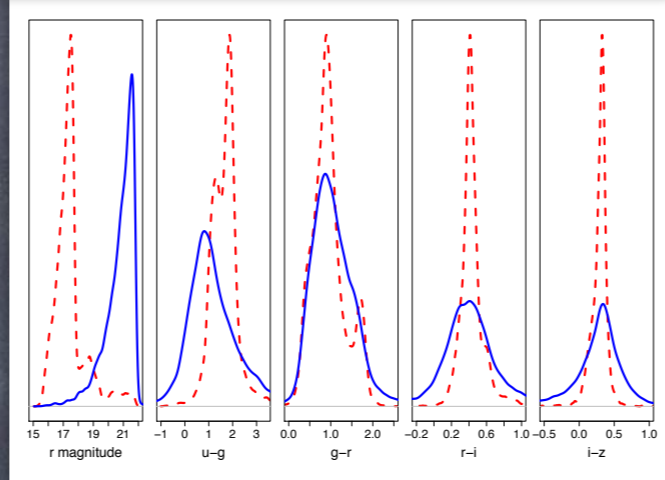
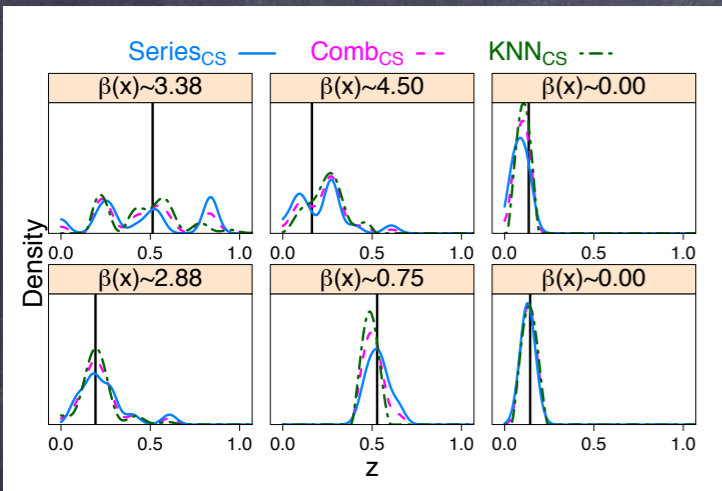
Since all standard particles received their mass during the early universe cosmological Electroweak Phase Transition (EWPT), we added Dark Matter Dark Energy terms with a Dark Energy field interacting with a Dark Matter field, called the Quintessence fields, to the EW Lagrangian previously used to calculate the magnetic field created during the EWPT. From this model we calculated the mass of Dark Matter Particles and estimated the Dark Matter masses to be in the range of a few GeV to 140 GeV, which is consistent with recent experiments.



Department of Statistics

Peter Freeman  
Domain: Astrostatistics

A unified framework for constructing, tuning and assessing photometric redshift density estimates in a selection bias setting

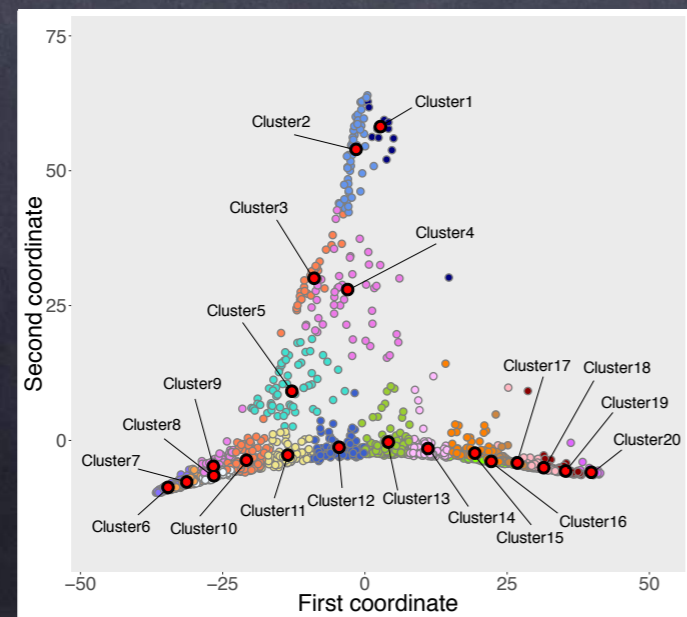
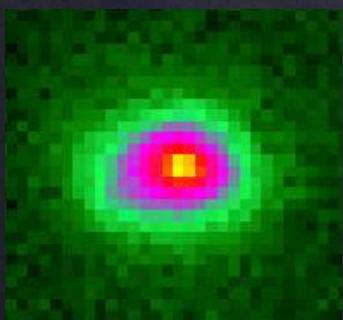
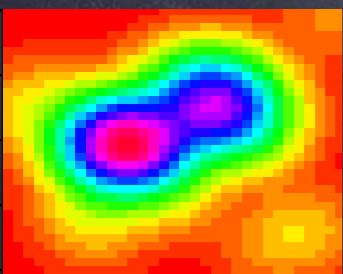


Approximate Bayesian Computation

Conditional Density Estimation + Density Ratio Estimation

samsi 2016-17 Program on Statistical, Mathematical and Computational Methods for Astronomy (ASTRO)

Evolution of Galaxy Morphology  
real

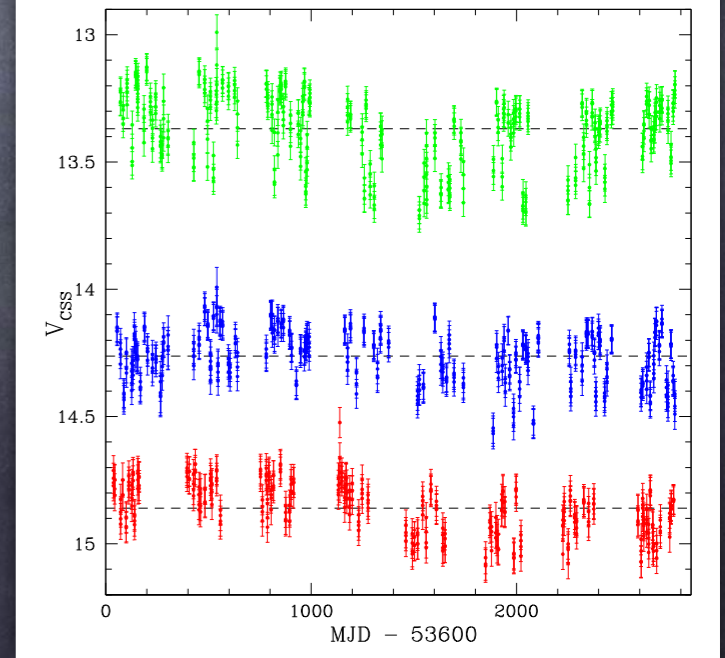
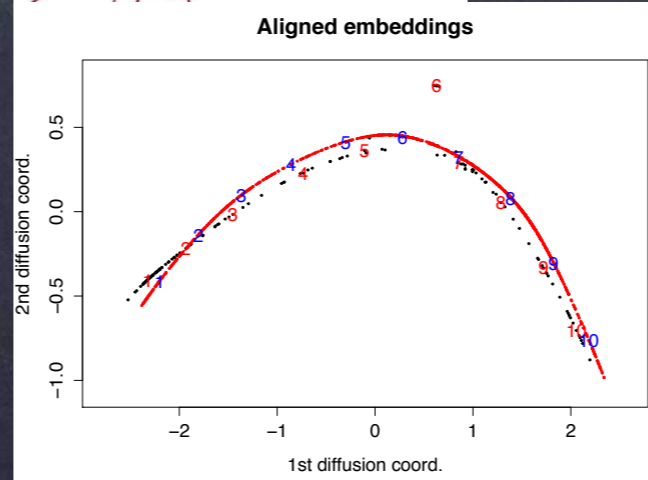


simulated

playing with summary statistics

Hack Week: November 7-11, 2016 - CMU

LSST DESC Data Matching  
Dark Energy Science Collaboration



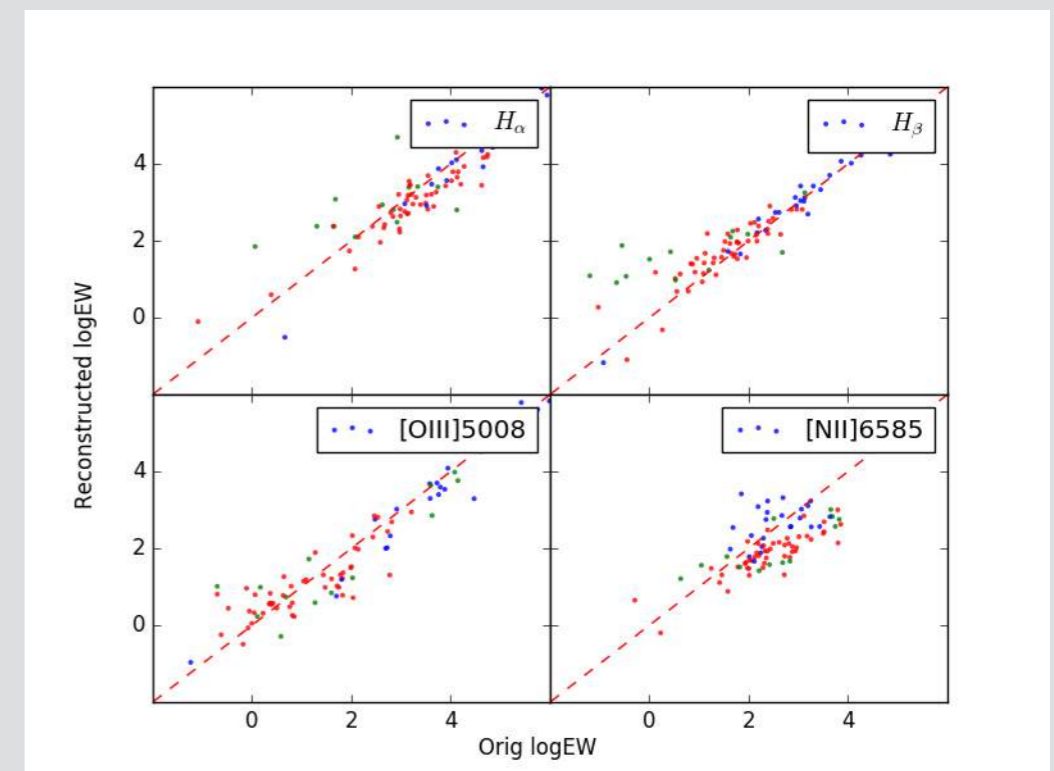
Transient Classification

Etc., Etc.



# Zongge Liu

- About Me: 2nd year PhD in statistics
- Advisor: Chad Schafer
- Interest: applied statistics in astronomy/  
data mining
- Projects:
  - ◆ Astrostats: predicting emission line  
from galaxy continuum
  - ◆ Data mining: Effective recovery and efficient fusion  
for aggregated historical data.
  - ◆ Cosmology: CMB weak lensing



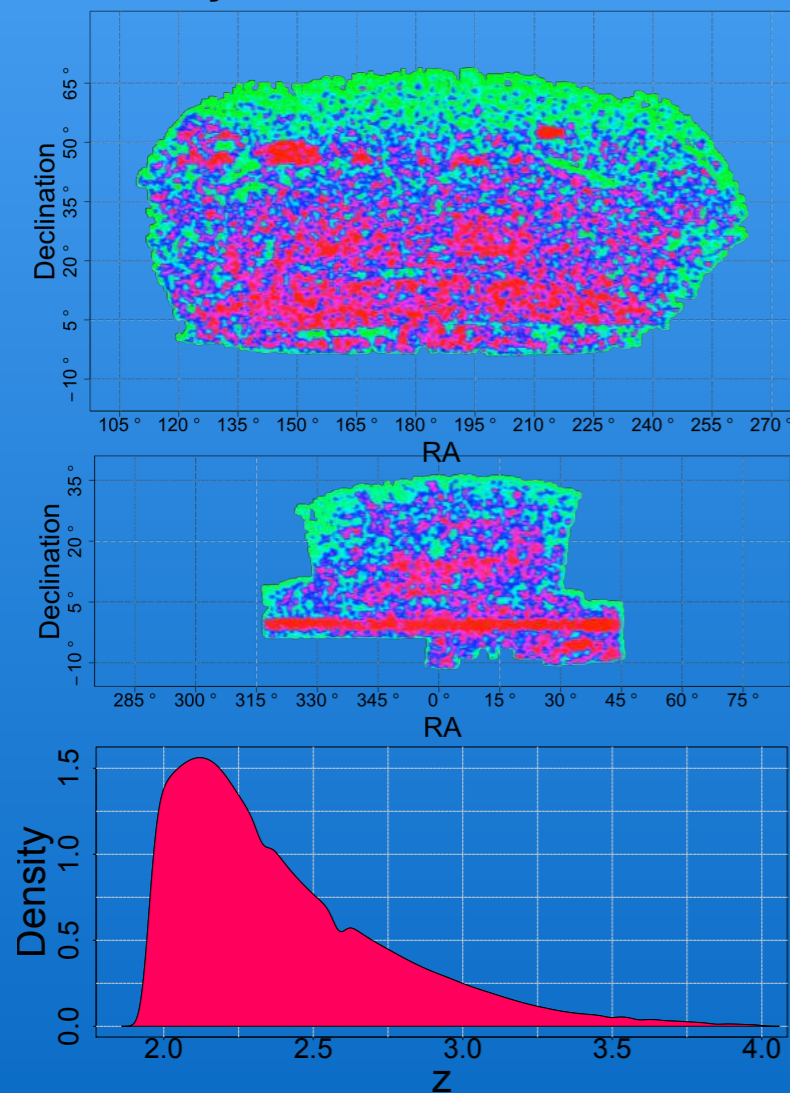
# Exploring the Intergalactic Medium

Collin Eubanks, Jessi Cisewski, Rupert Croft, Doug Nychka, and Larry Wasserman

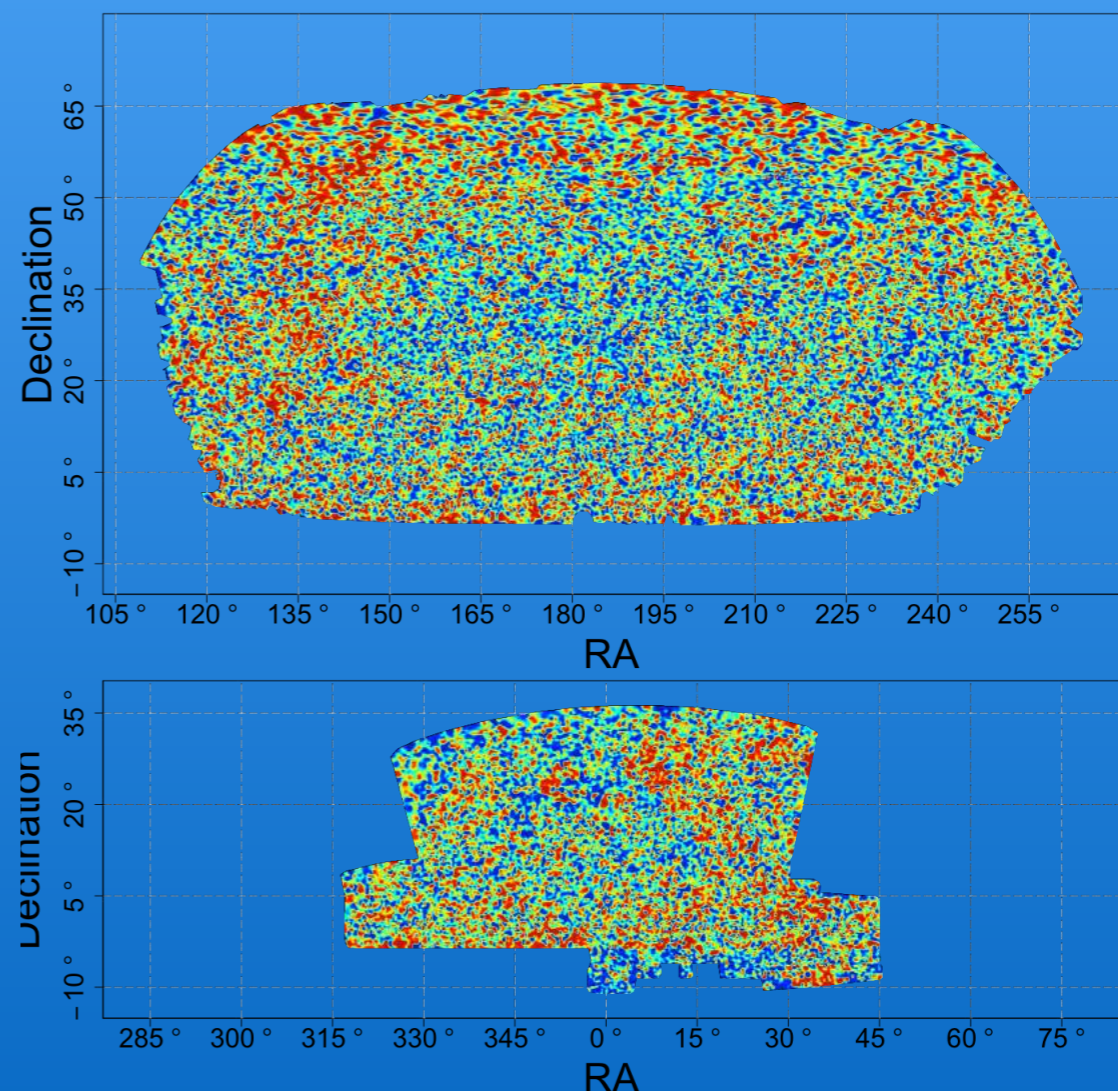
**Goal:** Produce 3D map of  $H_I$  density fluctuations in the IGM from Lyman- $\alpha$  forest in BOSS/eBOSS QSO spectra

**Principle Challenges:** Highly nonuniform sampling, computational costs

Density of BOSS DR12 Observations



Cross-section of Predicted Map  $z \sim 2$

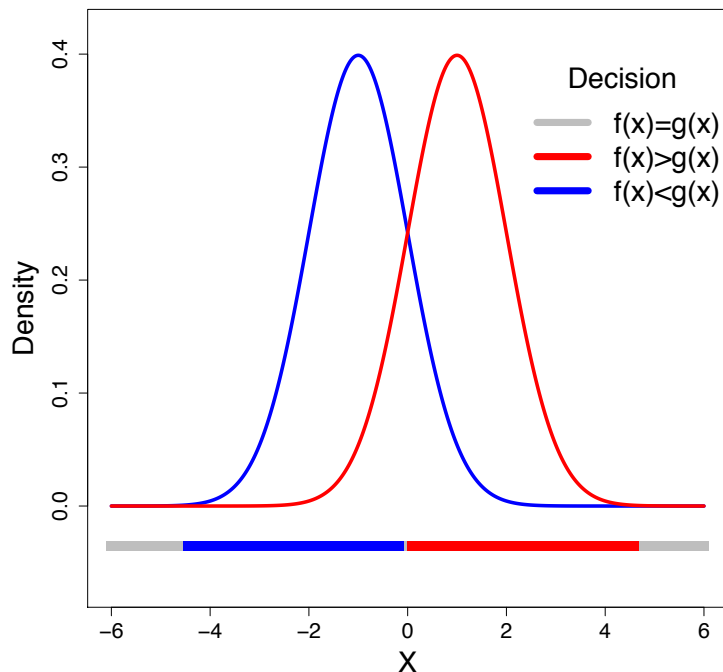


**Future Work:** (Suboptimal) homogeneous map, eBOSS DR13 (and future releases), supercluster catalog, topological analysis, ...

# Interests: Galaxy morphology

- Comparing distributions of galaxy morphologies between two populations (high-mass vs. low-mass, old vs. new and high SFR vs. low SFR)
- Main interest is to know **how** two populations are **locally** different in a multivariate space of morphology statistics such as M, I, D, Gini,  $M_{20}$ , C and A.

Local significant differences (1D toy example)



Binomial Tests for Mass (7-dim feature space)

