Creating a Galaxy Cluster Simulation to Constrain Cosmology

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5/8/25

Cosmic Structure

- Vast majority of matter is dark matter, invisible to telescopes
- Visible matter cannot form galaxies without help
- Galaxies form at clumps in the dark matter called halos
- How can we connect galaxies to dark matter?

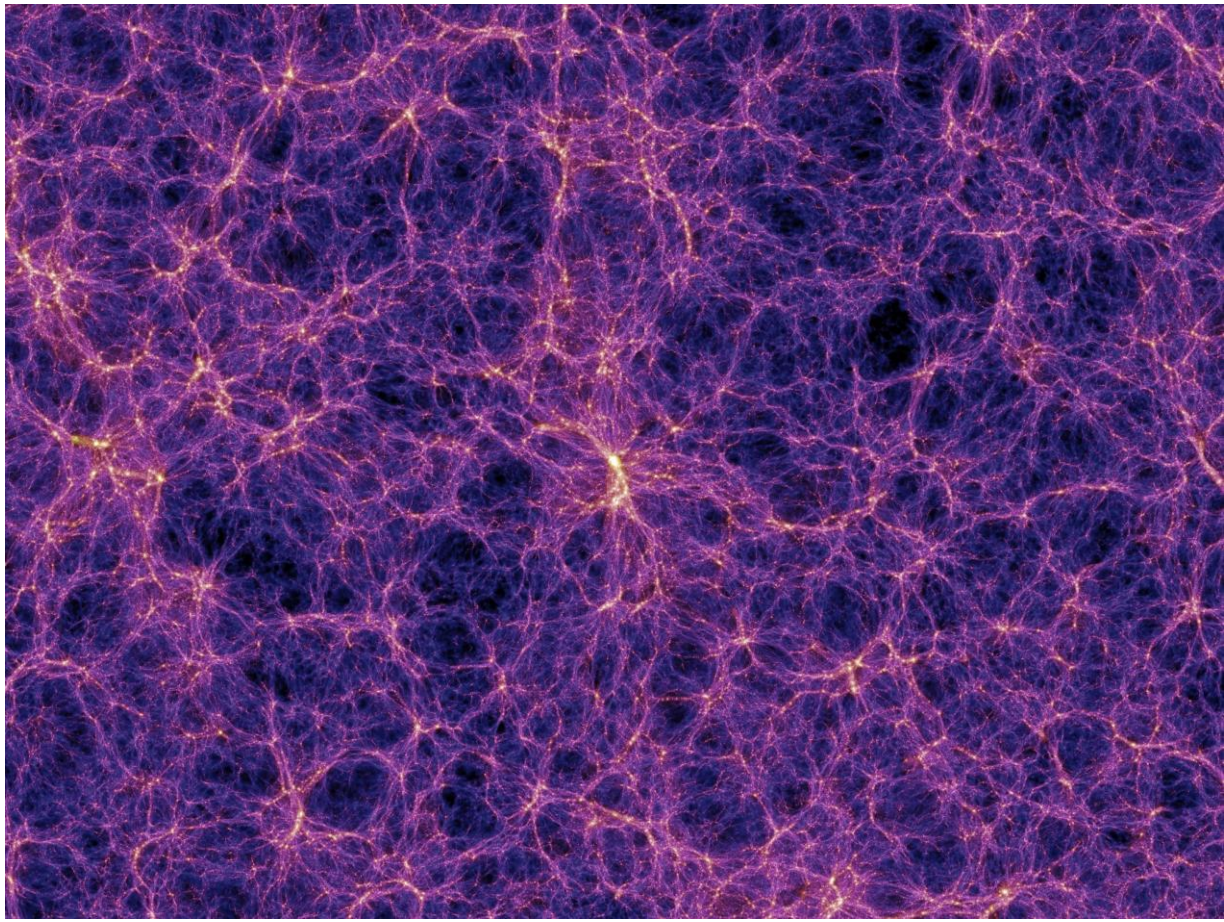


Image Credit: Springel et al. (2005)

Simulation Based Inference

- Use simulations to create a fake universe
- Control all aspects of fake universe to imitate real data
- Infer information by comparing using a galaxy cluster finder

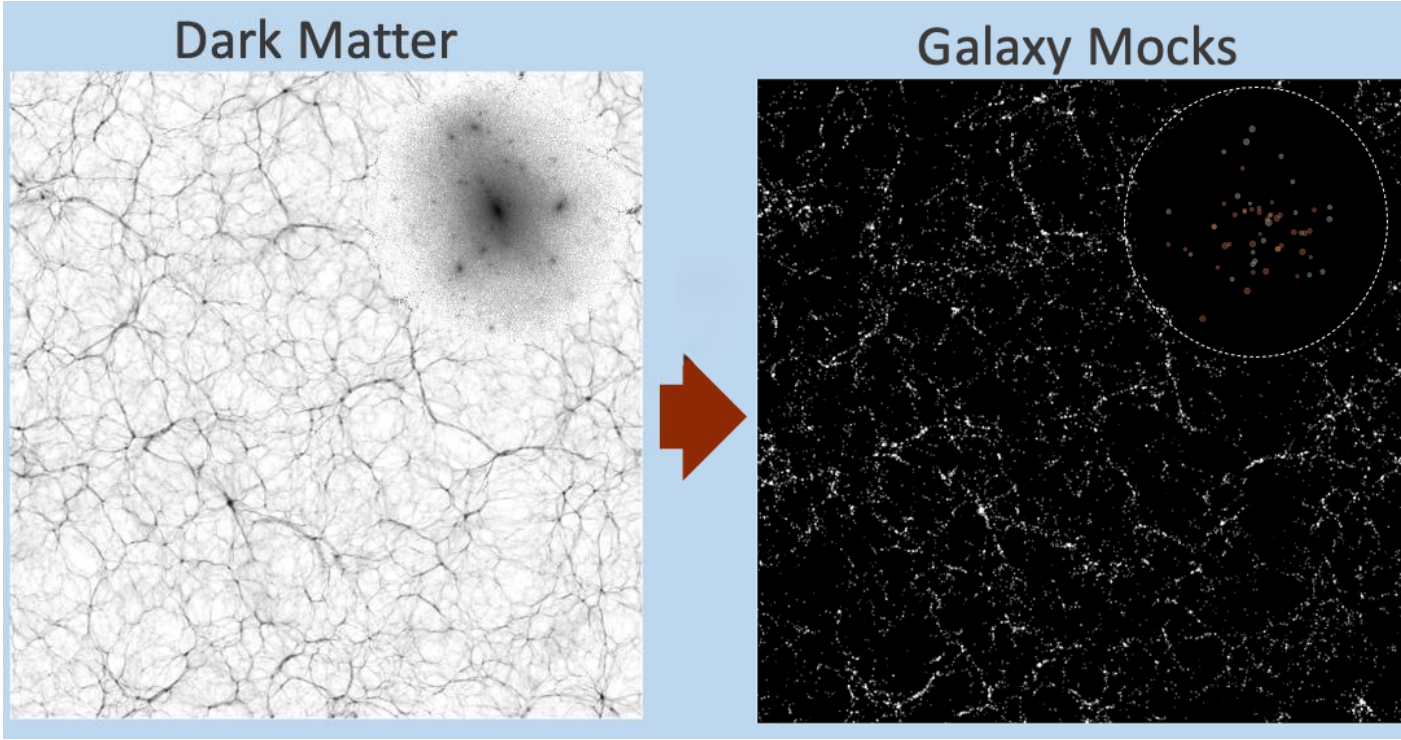


Image Credit: To et al. (2023)

Transforming Dark Matter into Galaxies

- Given a dark matter halo
  - Choose number of galaxies
  - Give each galaxy the data a galaxy survey would have
- Know all properties and parameters of simulation

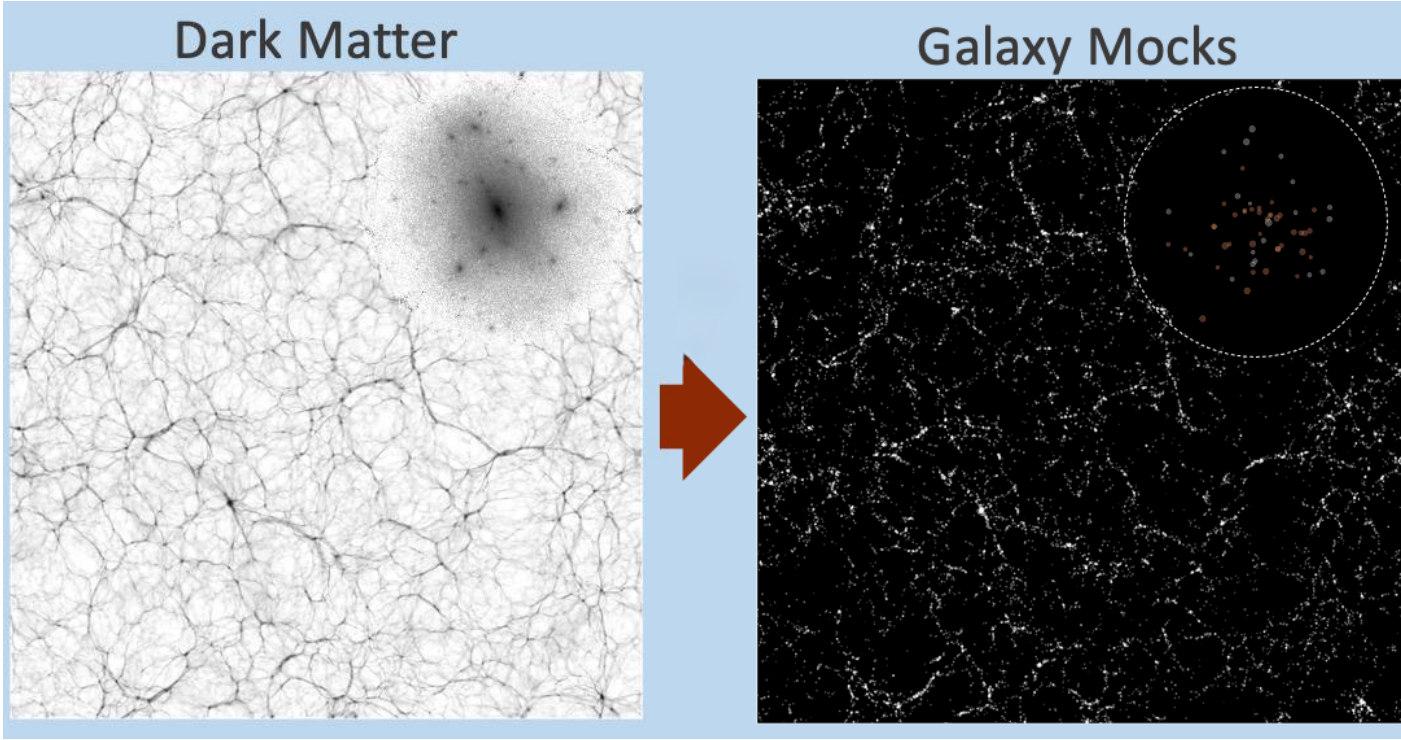


Image Credit: To et al. (2023)

Goals for My Simulation

- Highly accurate to real-world data and conditions
- Able to quickly generate many simulations
  - Allows wide parameter range for inference
- Build for specific galaxy cluster finder – redMaPPer
  - Improve function and accuracy of cluster finder
- Build to work with Dr. Salcedo's pipeline of simulation-based inference

Determining Number of Galaxies

- Centrals, the brightest and most massive galaxies
  - Luminosity linked to mass of halo
- Satellite galaxies orbiting the central

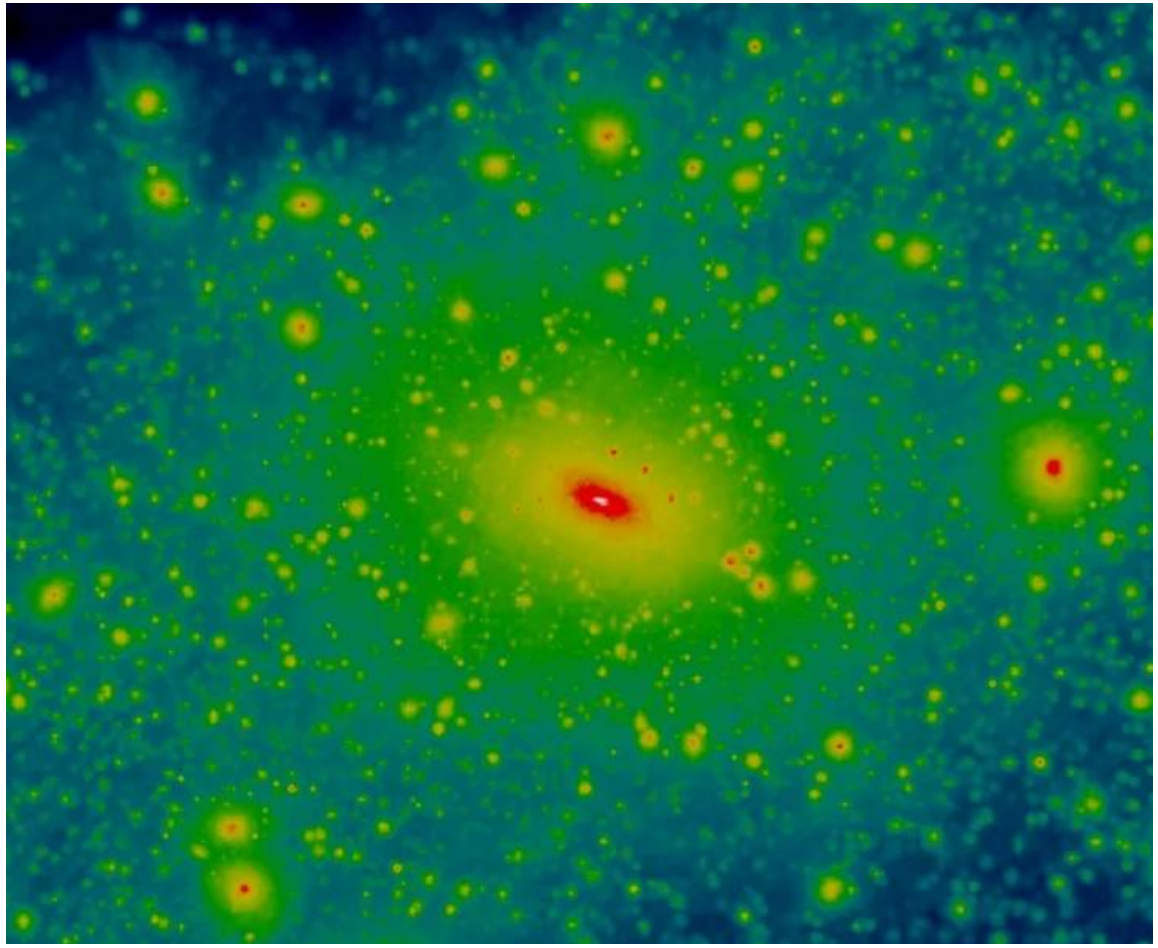
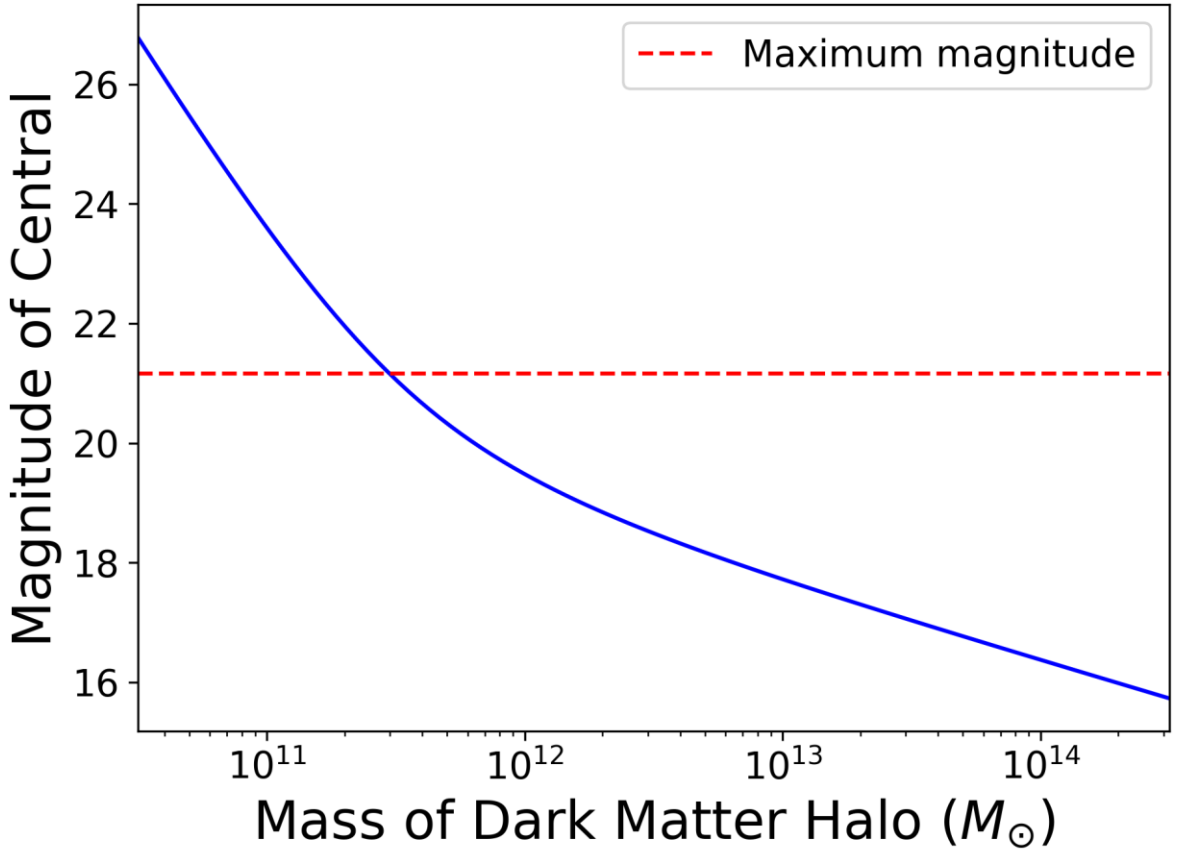


Image Credit: Garrison-Kimmel et al. (2014)

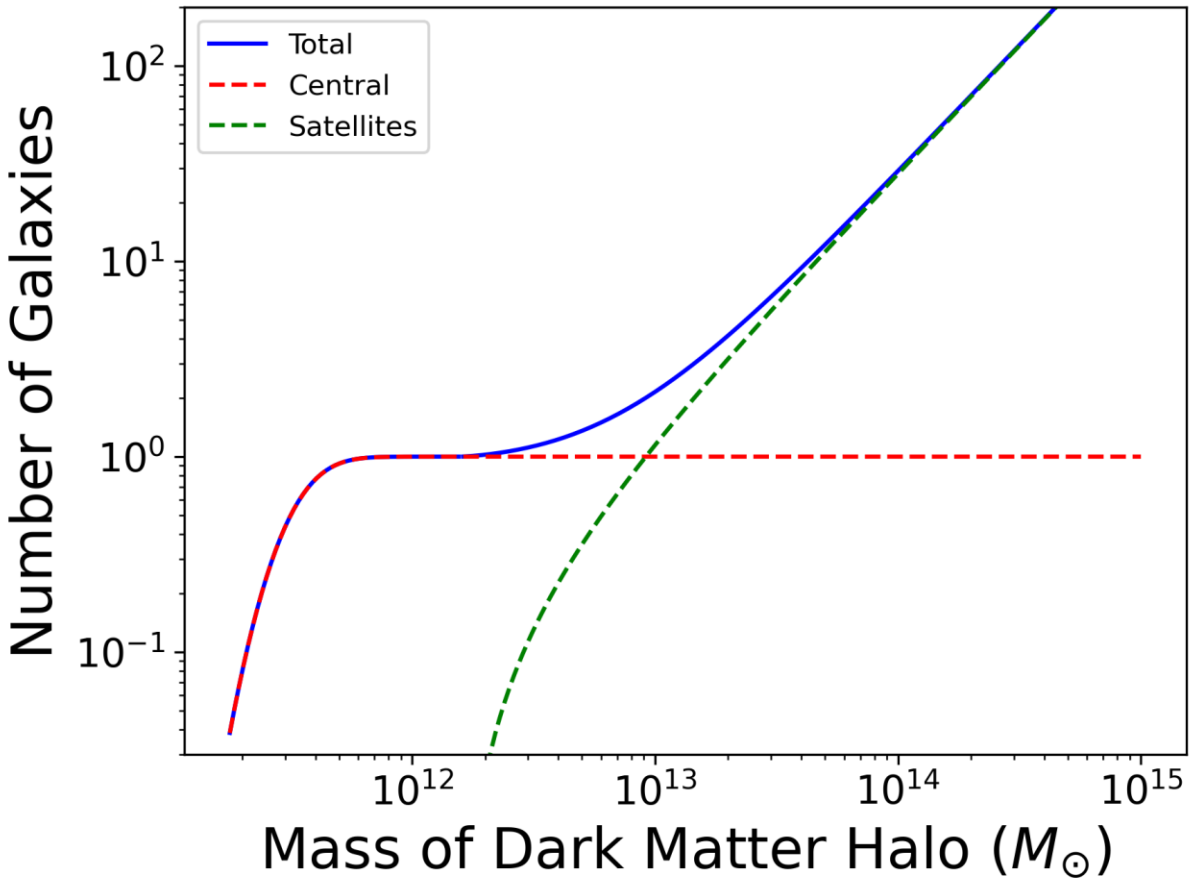
Determining Number of Centrals

- Give every halo a central
- Determine magnitude of central from the mass of the host halo
- RedMaPPer maximum magnitude is used to remove dim centrals



Determining Number of Satellites

- Based on mass of the dark matter halo
- Magnitude cut in centrals causes shape of red line
- Satellites are a simple power law with a cutoff



Determining Galaxy Properties

- redMaPPer needs brightness in each DES band

- Assign each galaxy
  - z-band magnitude
  - i-z, r-i, g-r colors

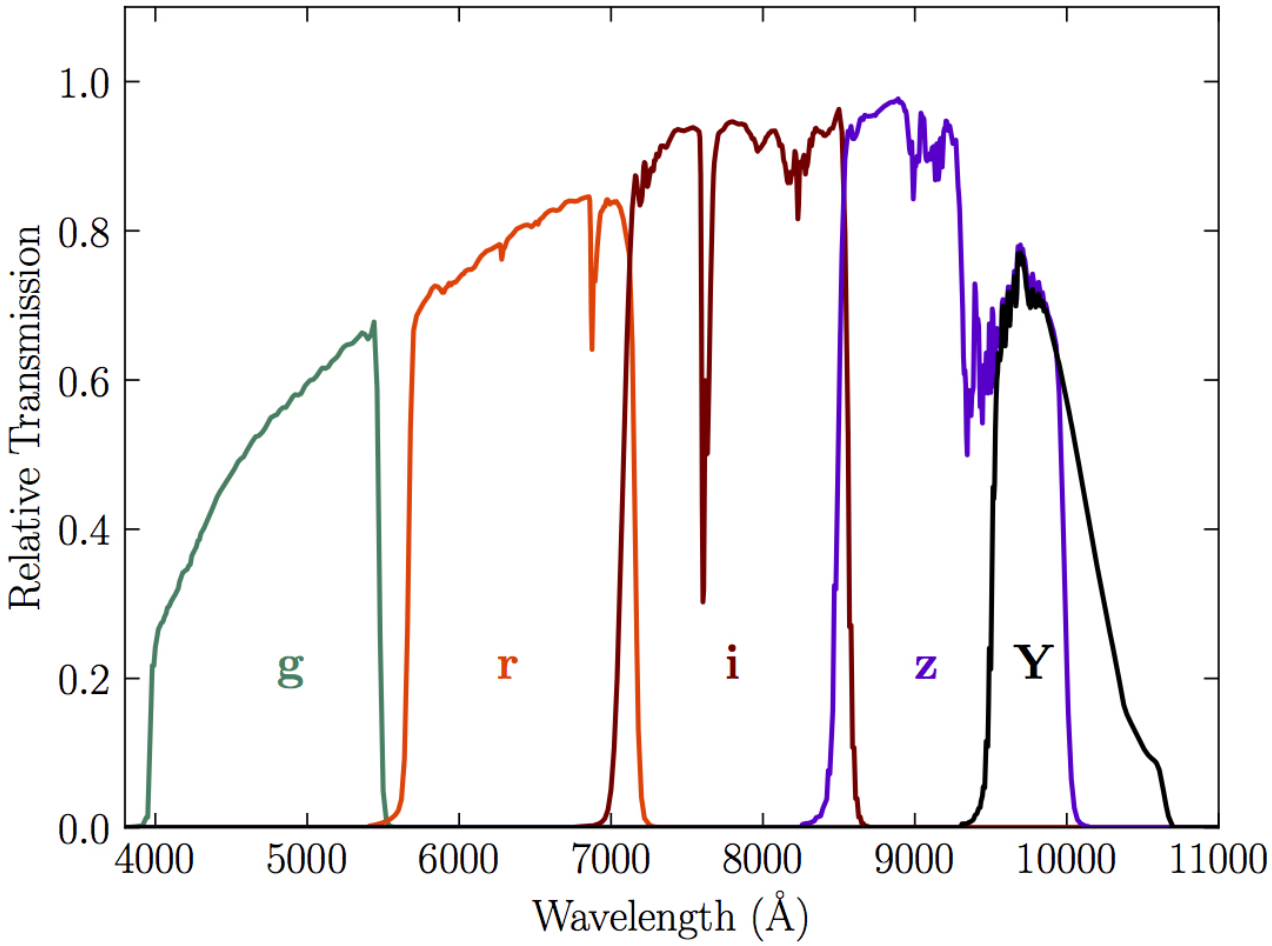
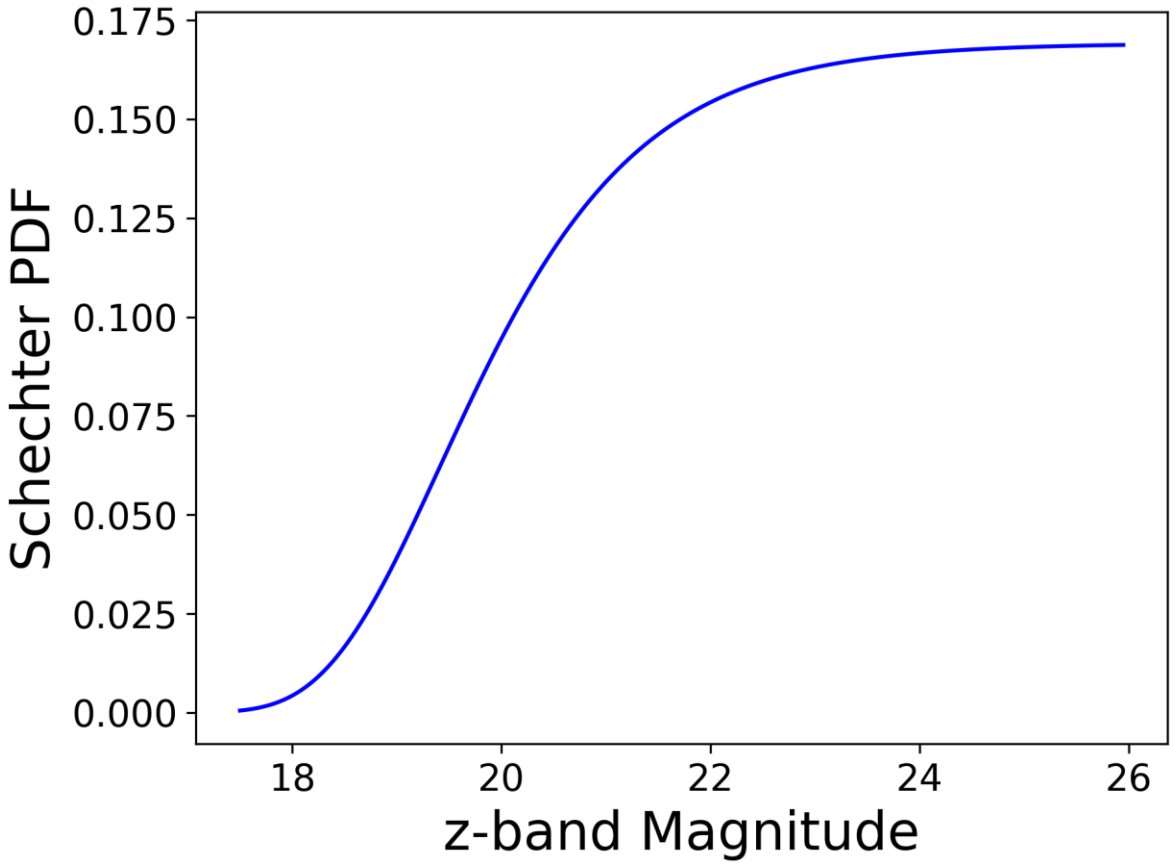


Image Credit: NOIRLab DECam

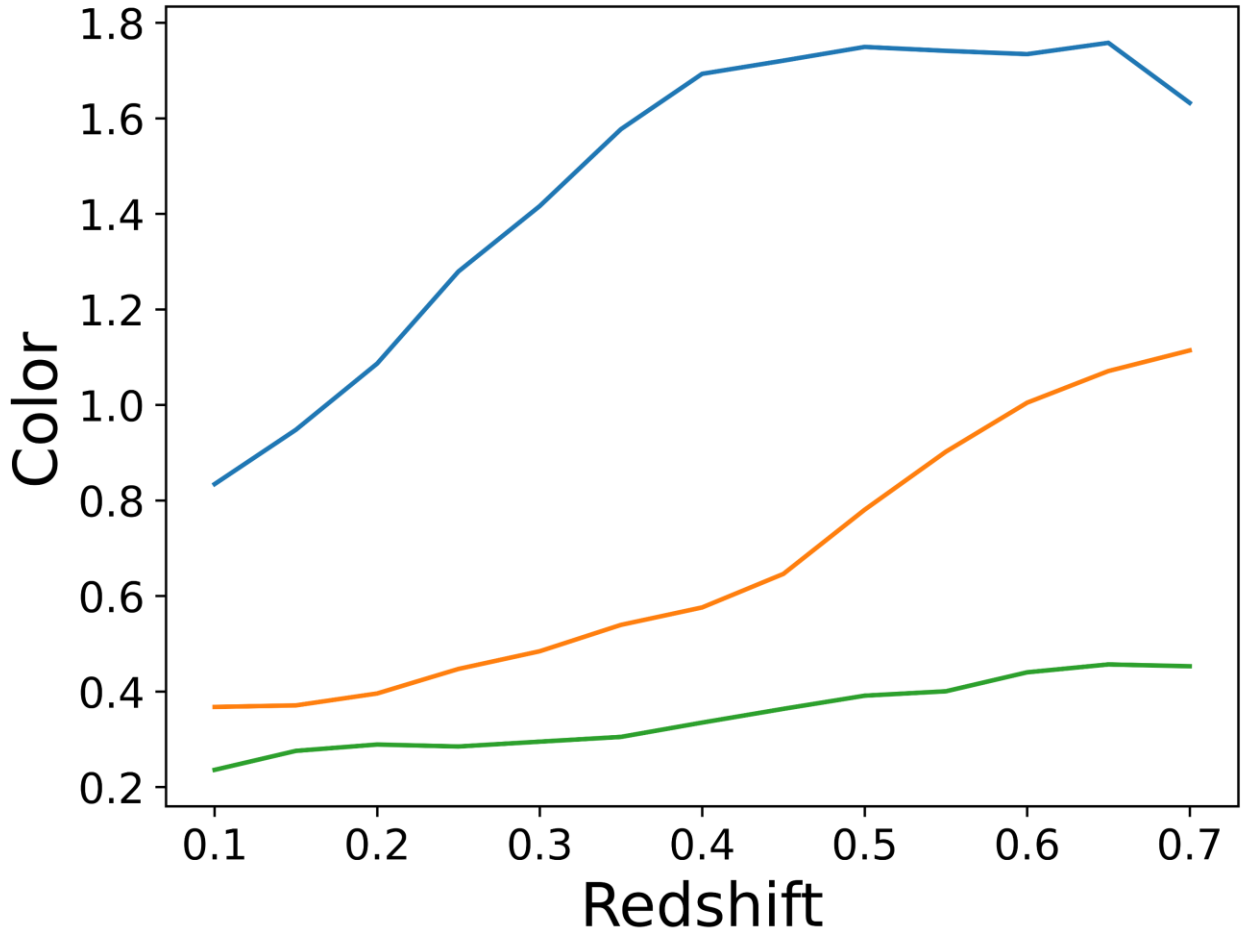
Determining z-band Magnitude

- Centrals – already assigned from halo mass to luminosity relation
- Satellites – random draws from Schechter luminosity function



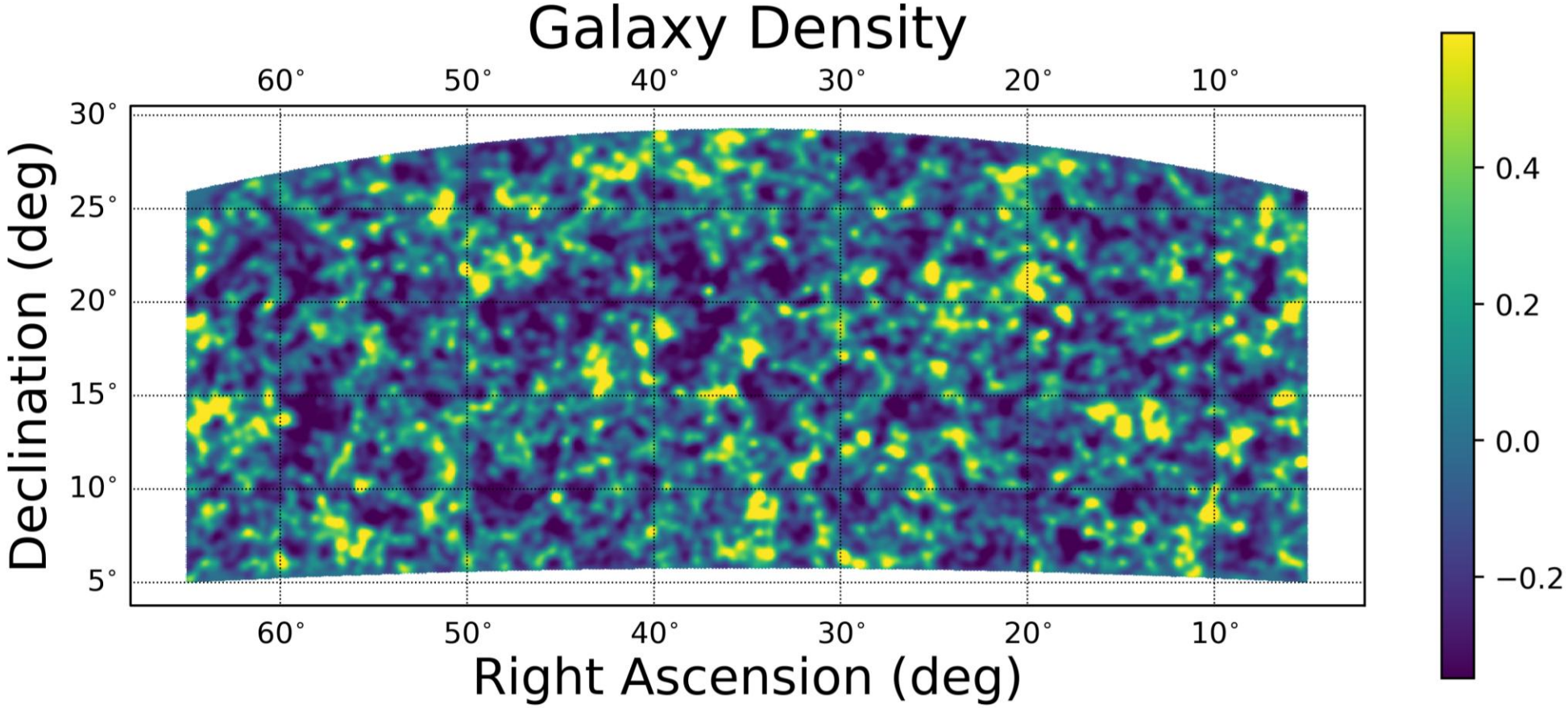
Determining Color of Galaxies

- Color is difference in the brightness of different bands
- Important property for cluster finding with redMaPPer



My Galaxy Simulation

- Fast - creating a catalog of galaxies takes ~10 minutes, not hours
- Accurate - includes photometric error from survey depth



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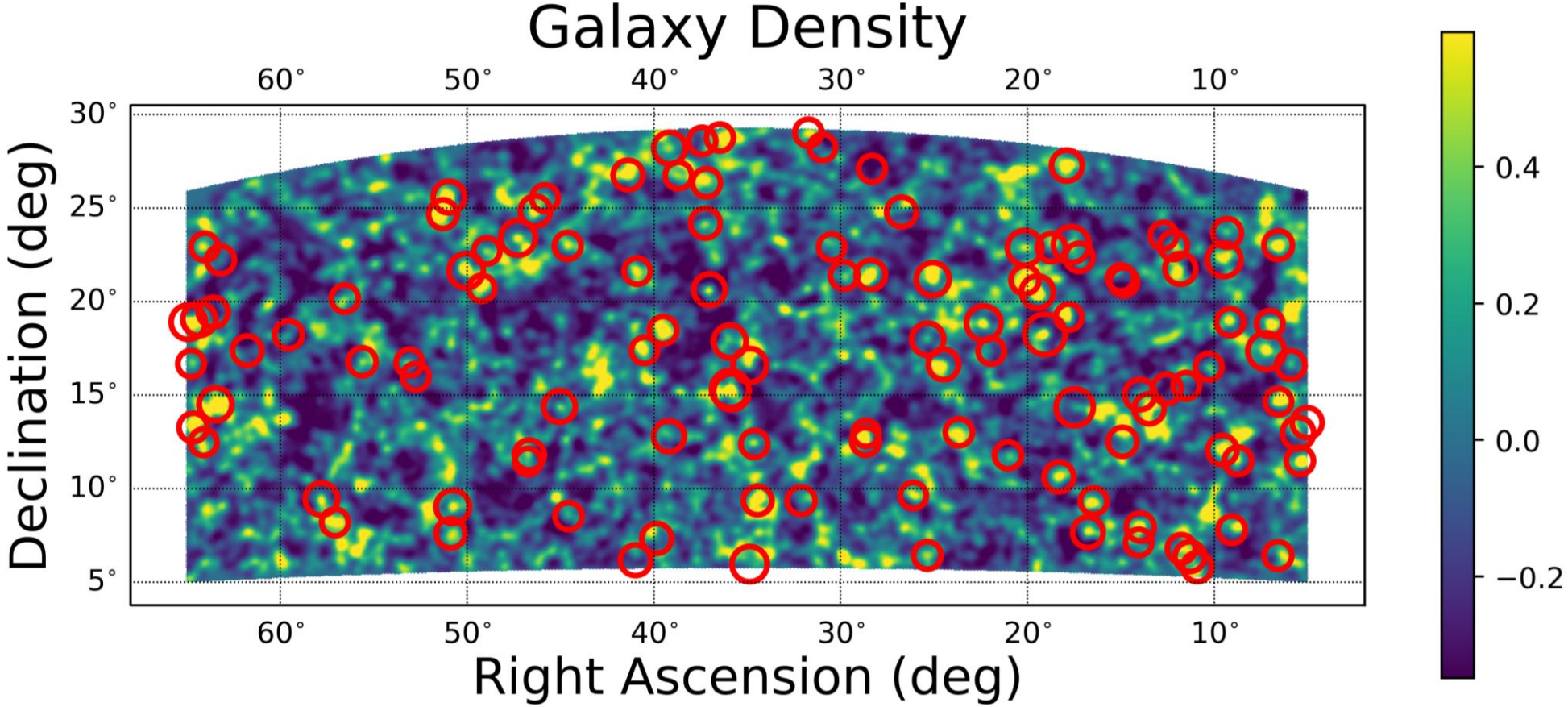
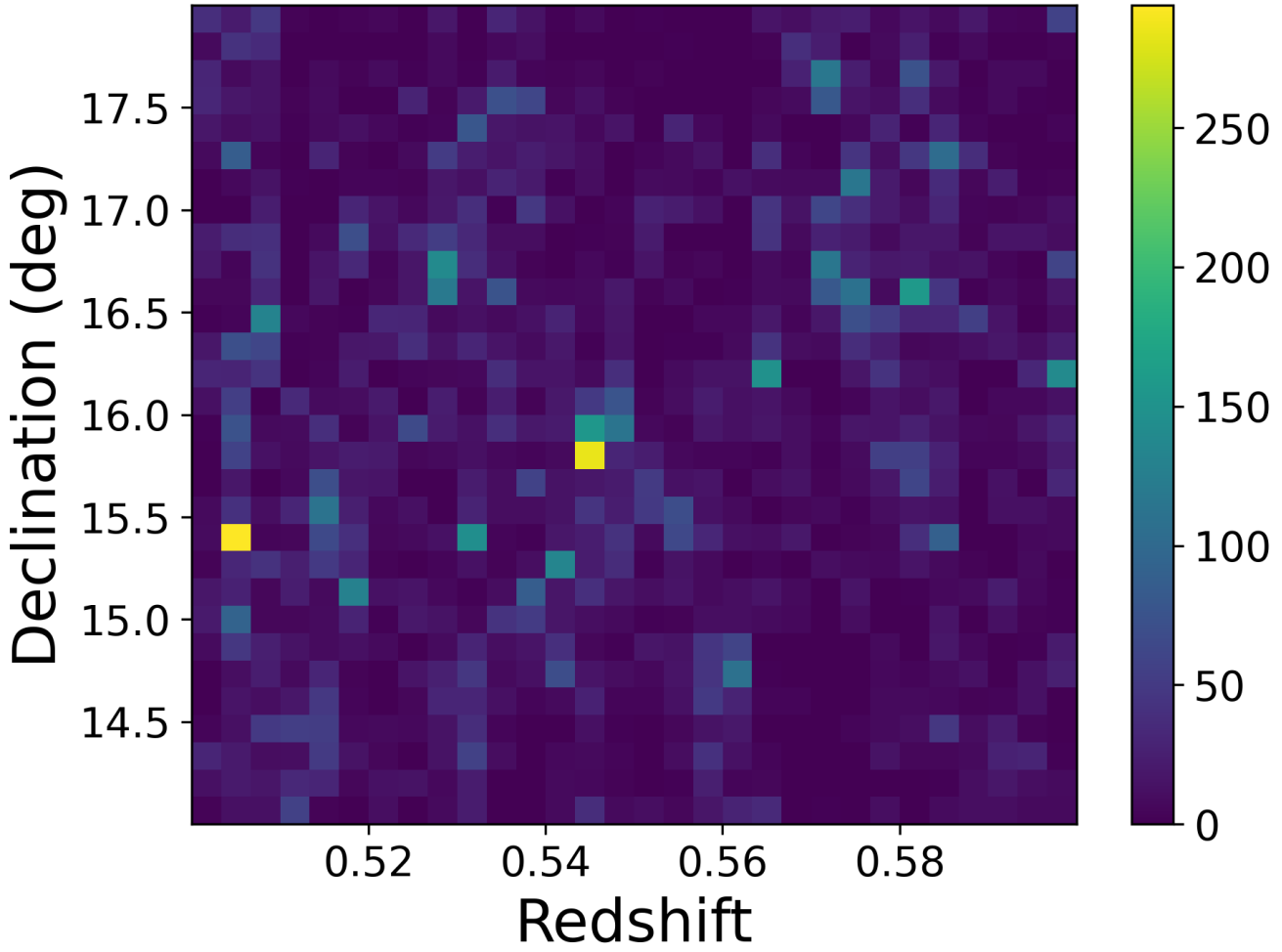


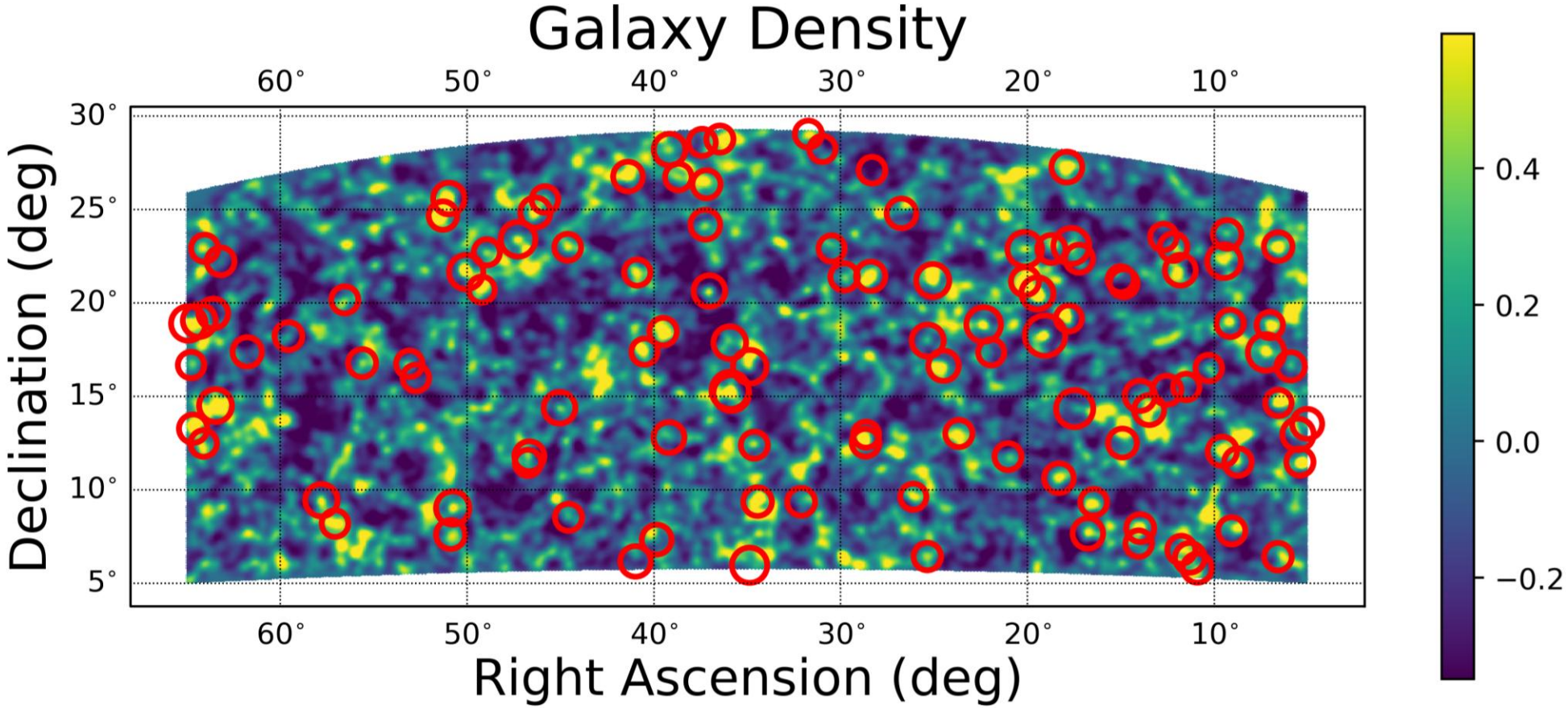
Investigating Cluster Finding

- Close clusters in RA, Dec may be separate in redshift
- High density areas may be below size minimum imposed



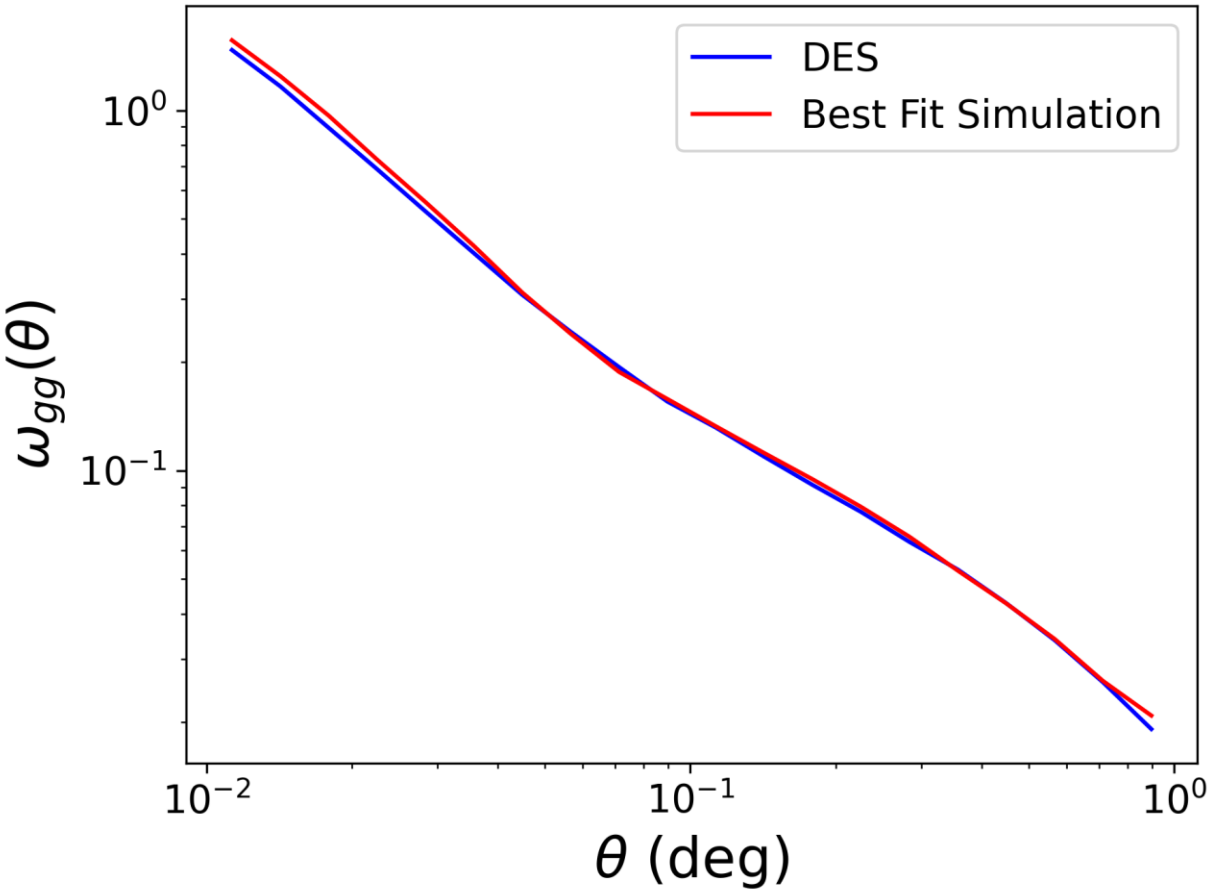
Next Steps

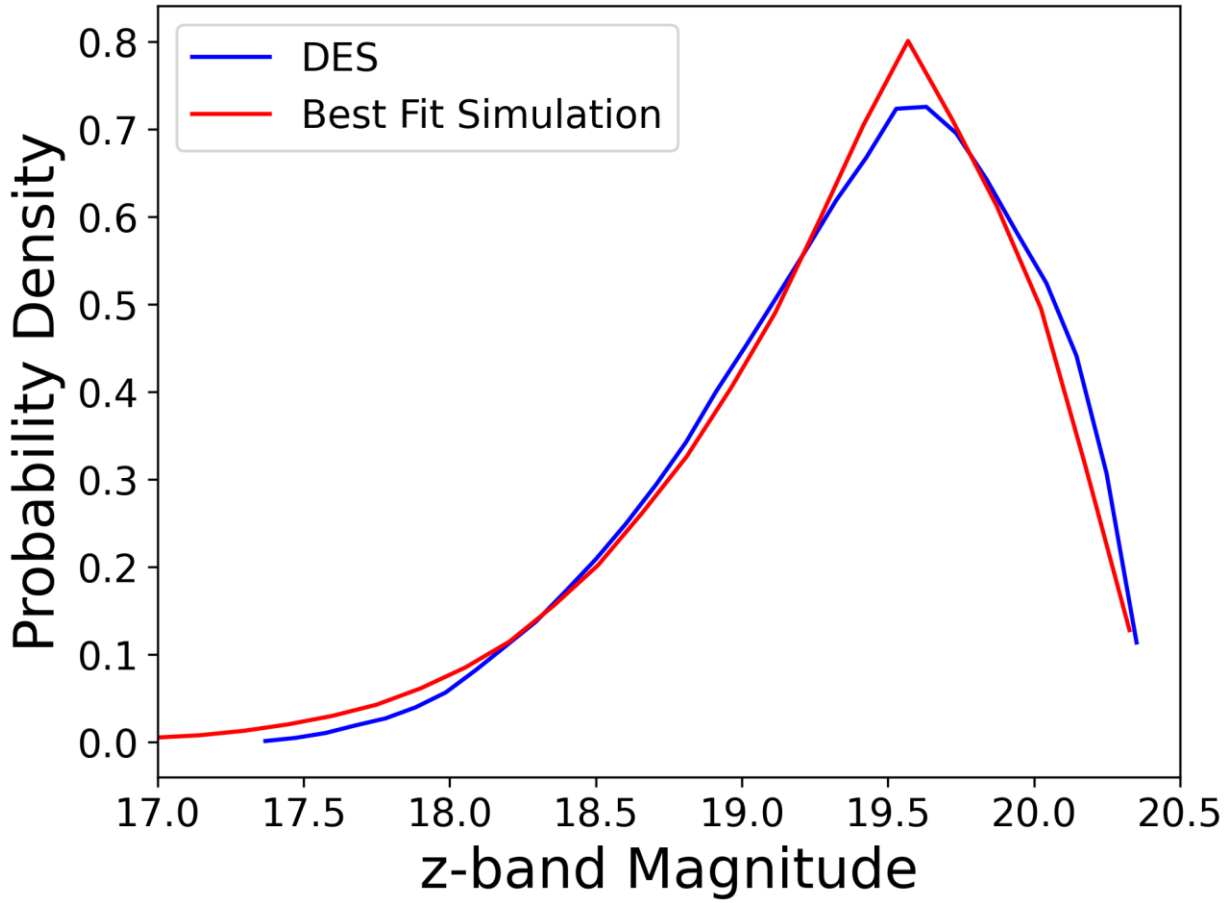
- Confirm accuracy and ability to match DES
- Use Dr. Salcedo's method to measure cosmology



Matching DES

- Fit two parameters of my simulation using least-squares to DES





Thank You

- Acknowledgements
  - Dr. Eduardo Rozo
  - Dr. Andres Salcedo
  - University of Arizona Department of Physics
  - John Engel

- For questions:
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