The Universe Under a Magnifying Glass

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Fermi Lab Talk, 10/15/12

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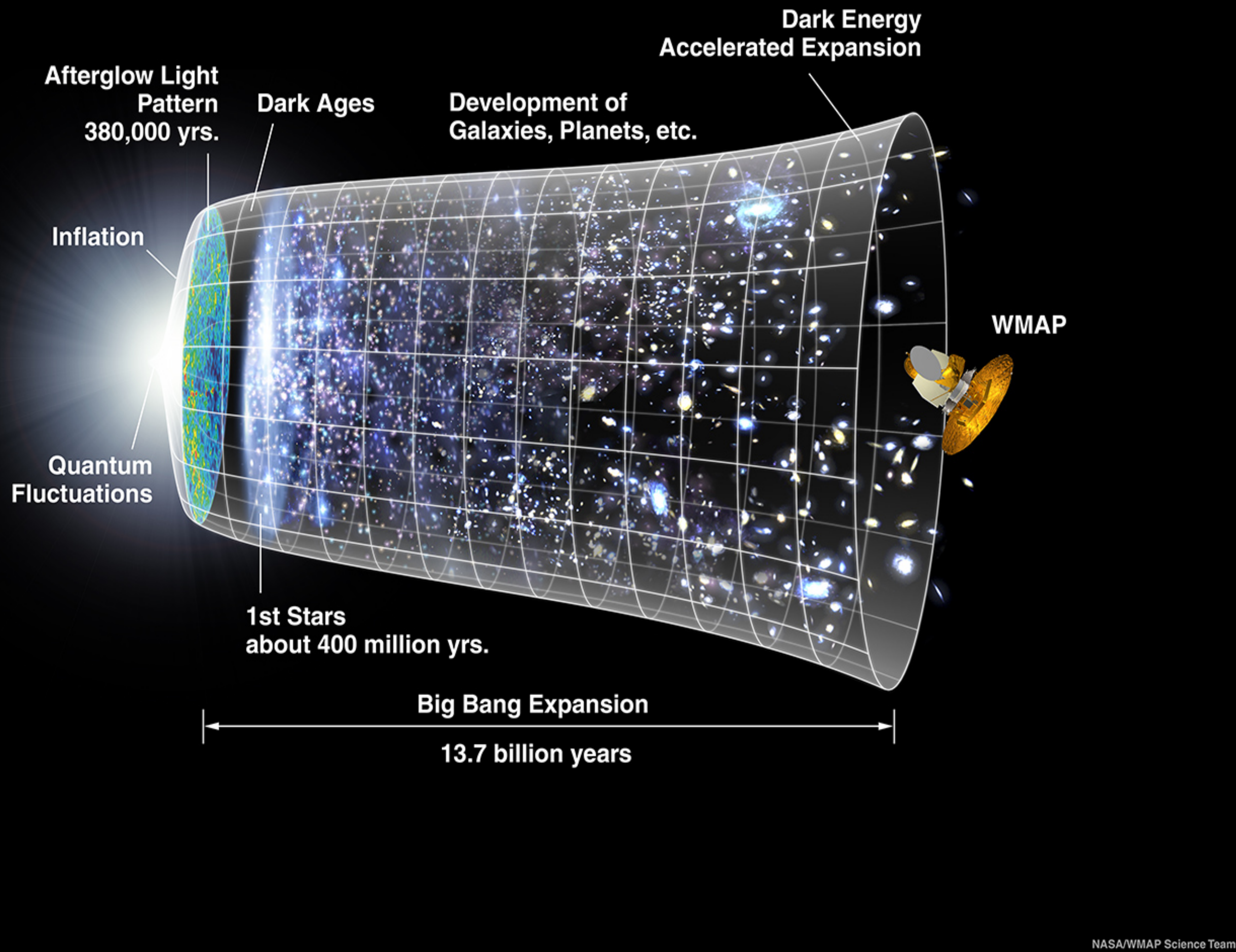
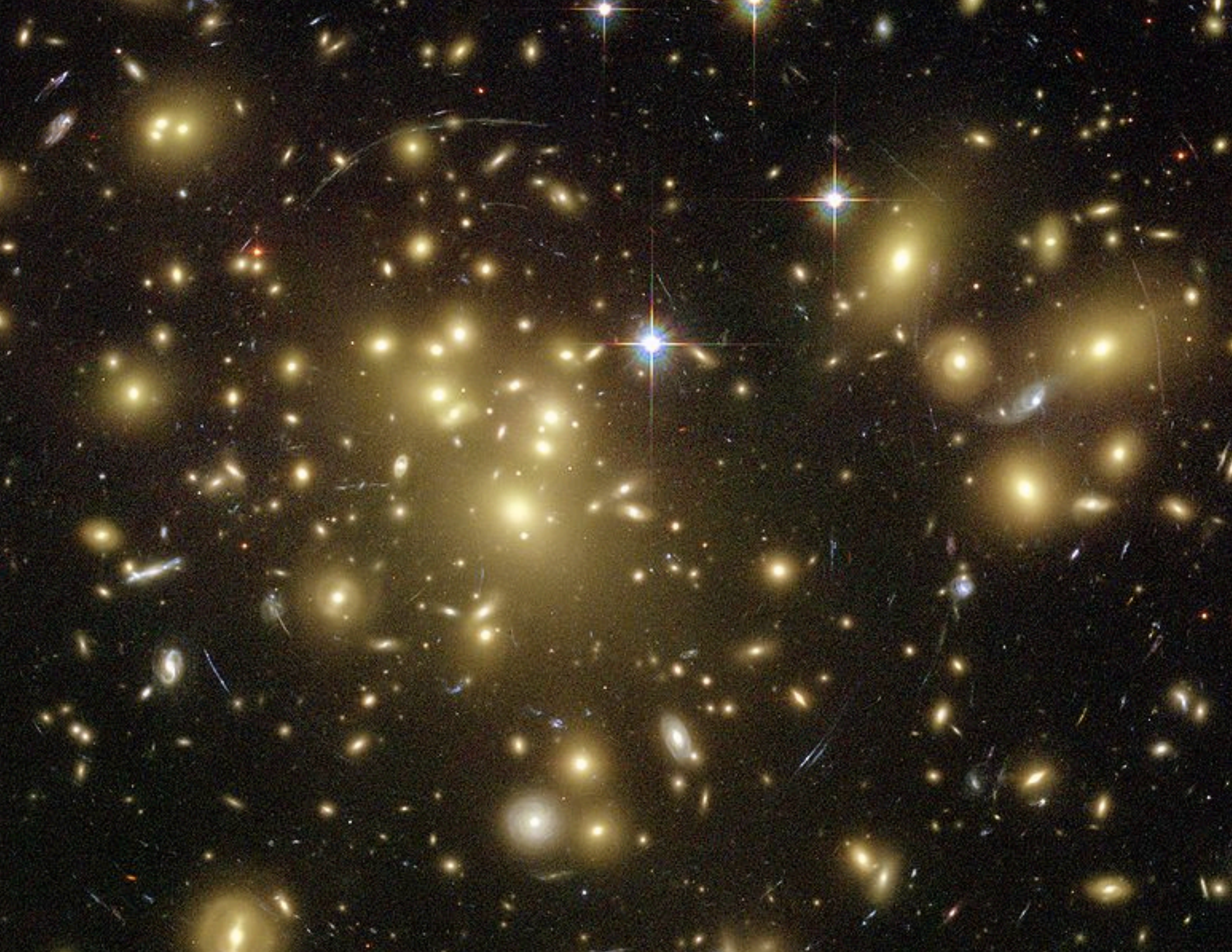
- STScI:
  - Russell Ryan
- Edinburgh:
  - Ami Choi
- The Deep Lens Survey:
  - Ian Dell'Antonio (Brown)
  - David Wittman (UC Davis)
  - Begoña Ascoaso (Barcelona)
  - Jim Bosch (Princeton)
  - Will Dawson (UC Davis)
  - Perry Gee (UC Davis)
  - Jack Hughes (Rutgers)
  - M. James Jee (UC Davis)
  - Vera Margoniner (Sac State)
  - Michael Schneider (UC Davis)
  - Paul Thorman (UC Davis)

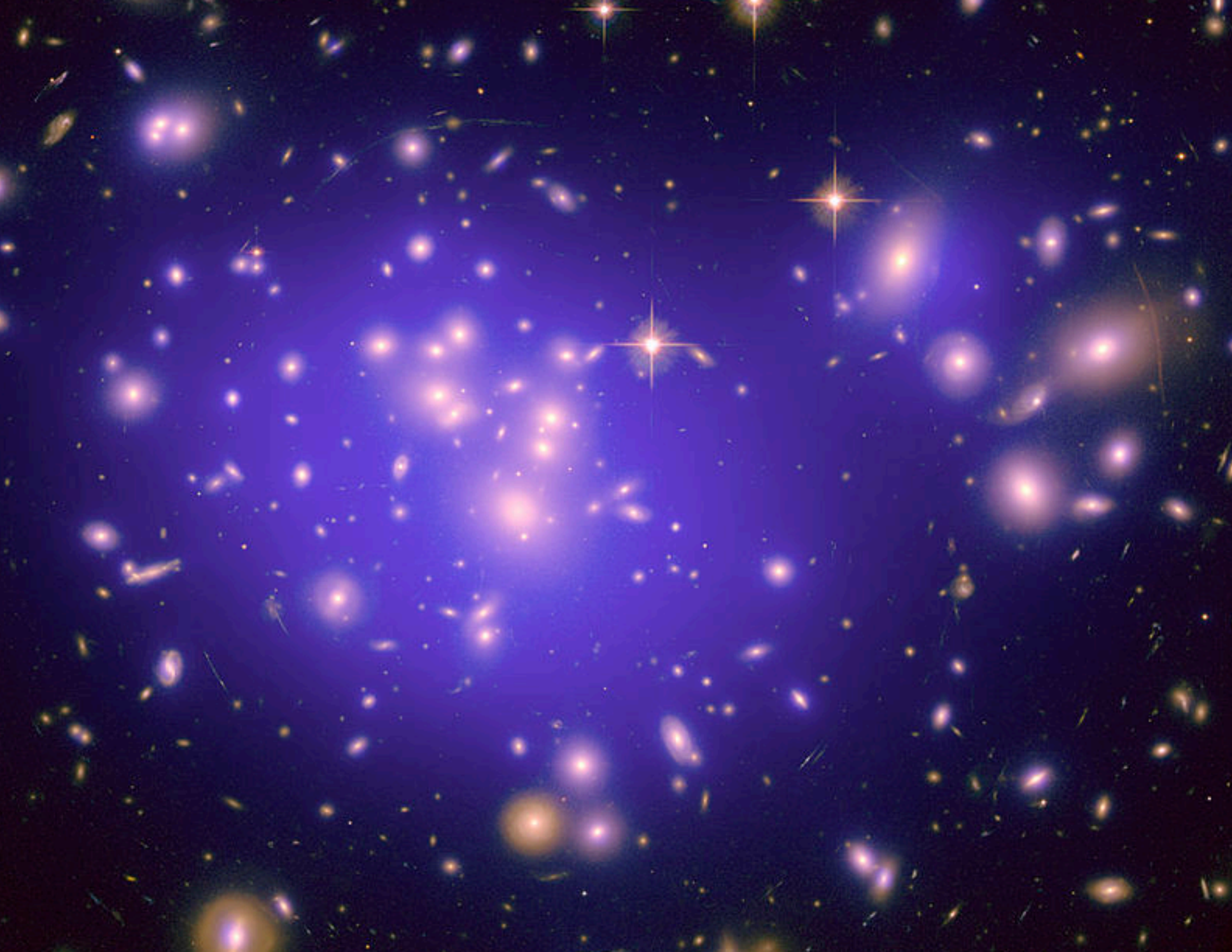
Outline

- Introduction
  - Modern Cosmology in a Nutshell
- Gravitational Lensing
  - Magnification
- The Deep Lens Survey
  - Survey Specifics
  - Data Selection
- Results
  - Lensing Measurements
  - Cosmological Comparison
  - Preliminary Dust Measurements
- Summary/Future Work

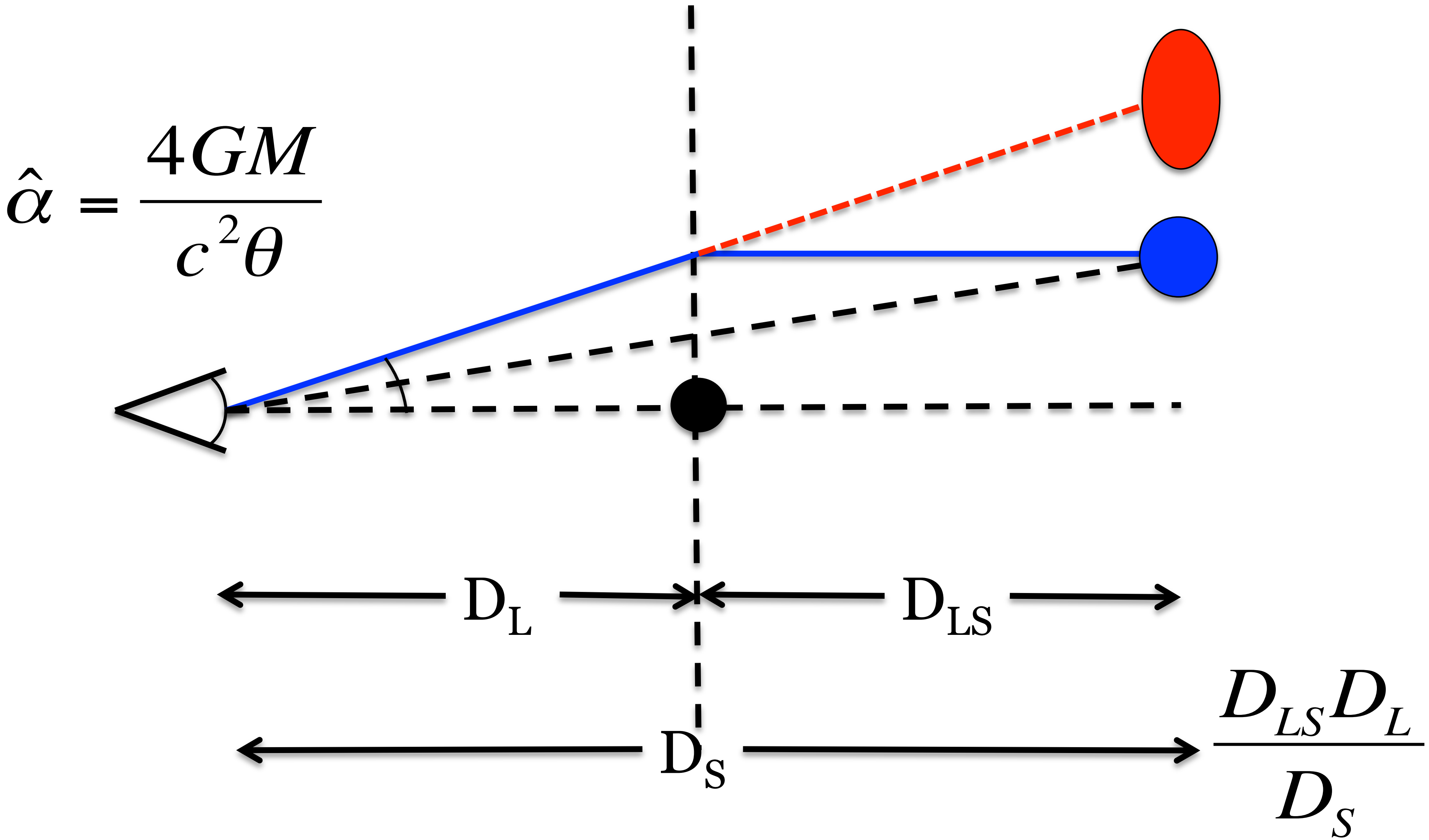
Our Universe



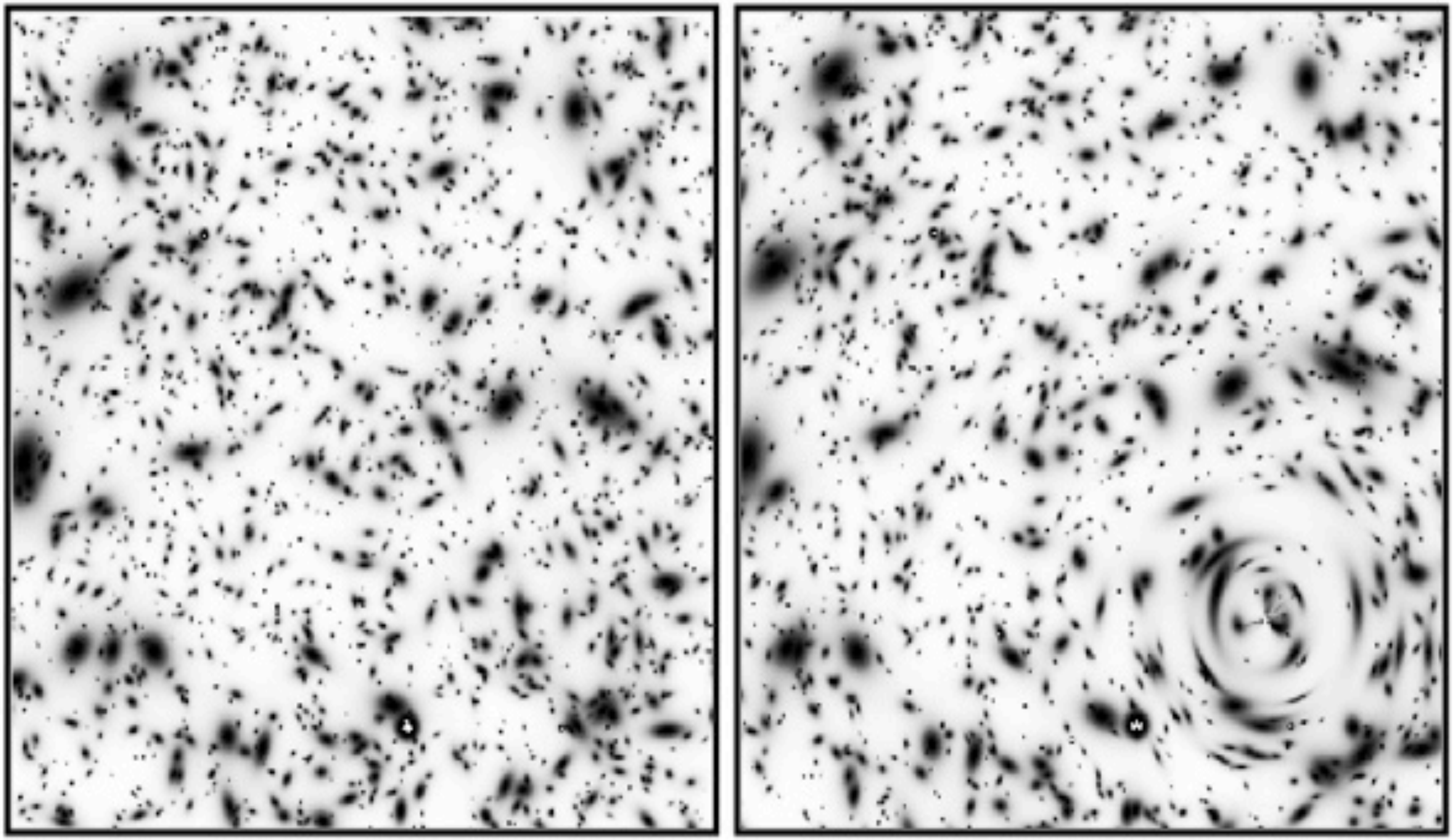




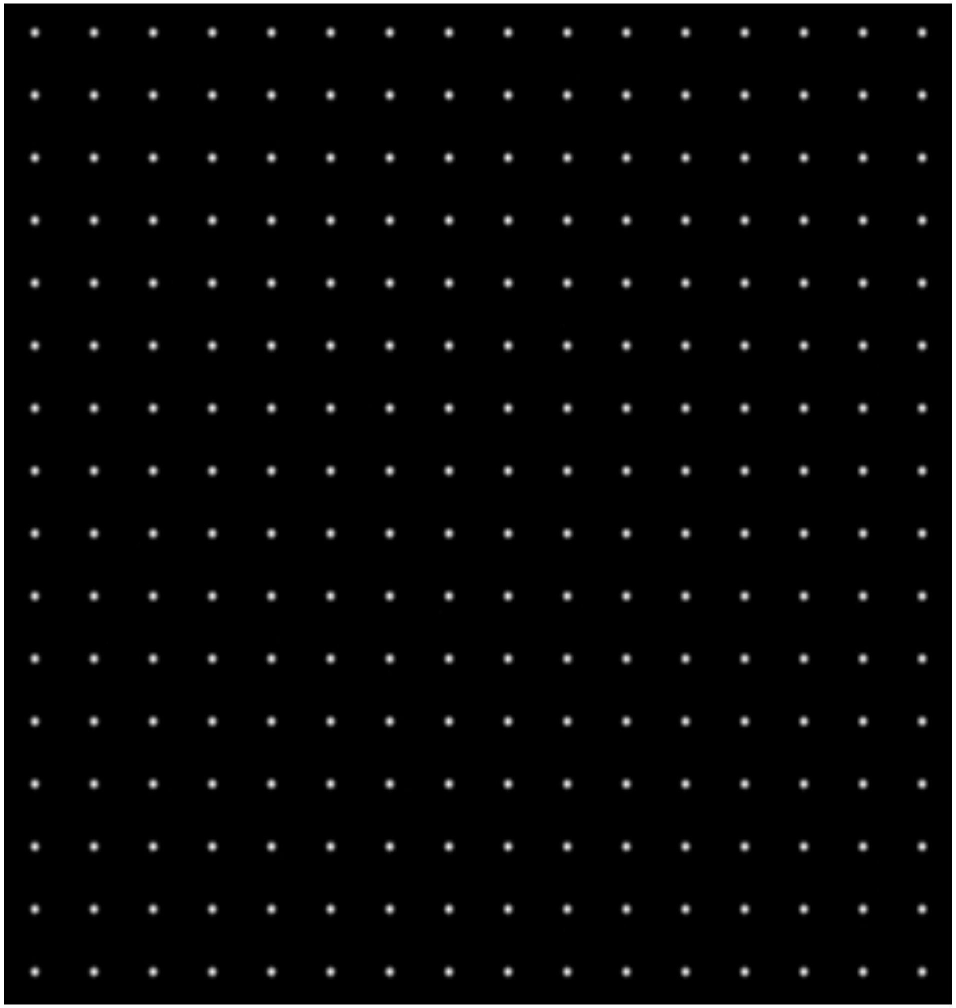
Lensing Geometry

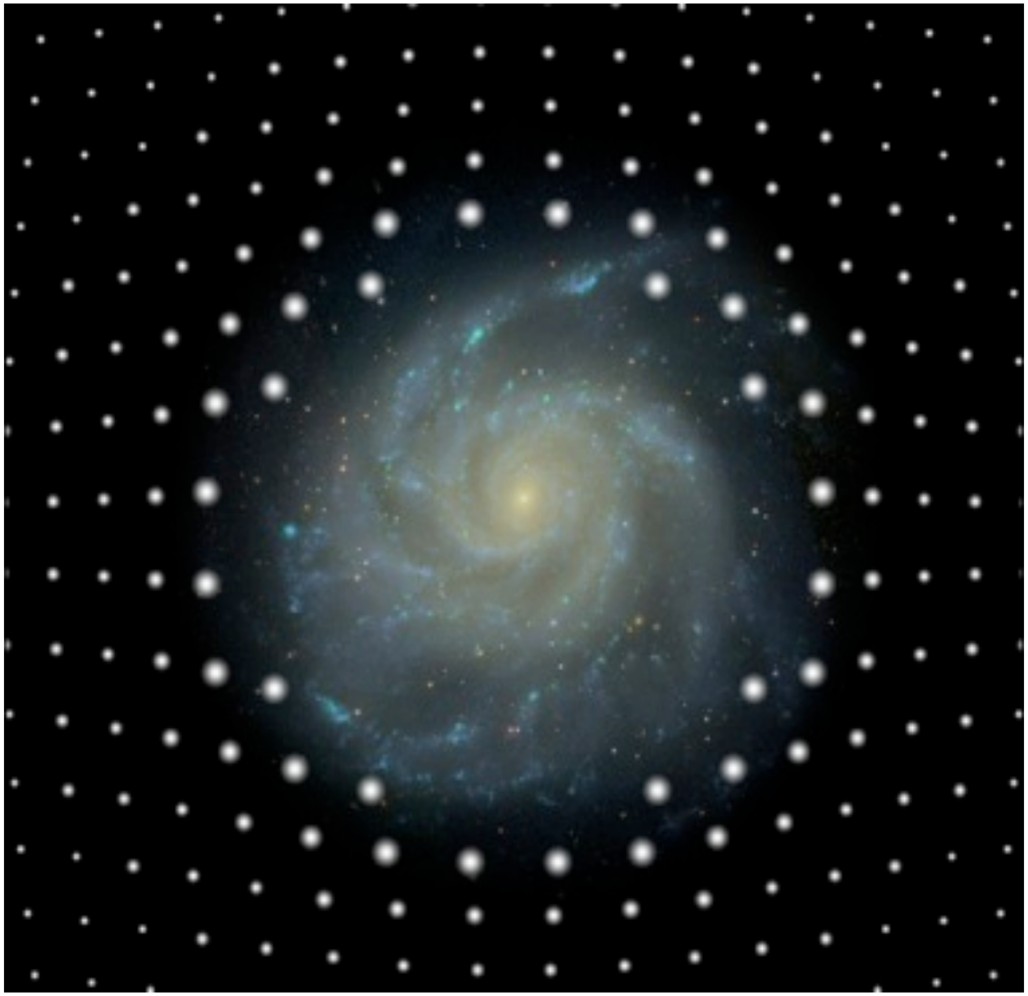


Lensing



Magnification

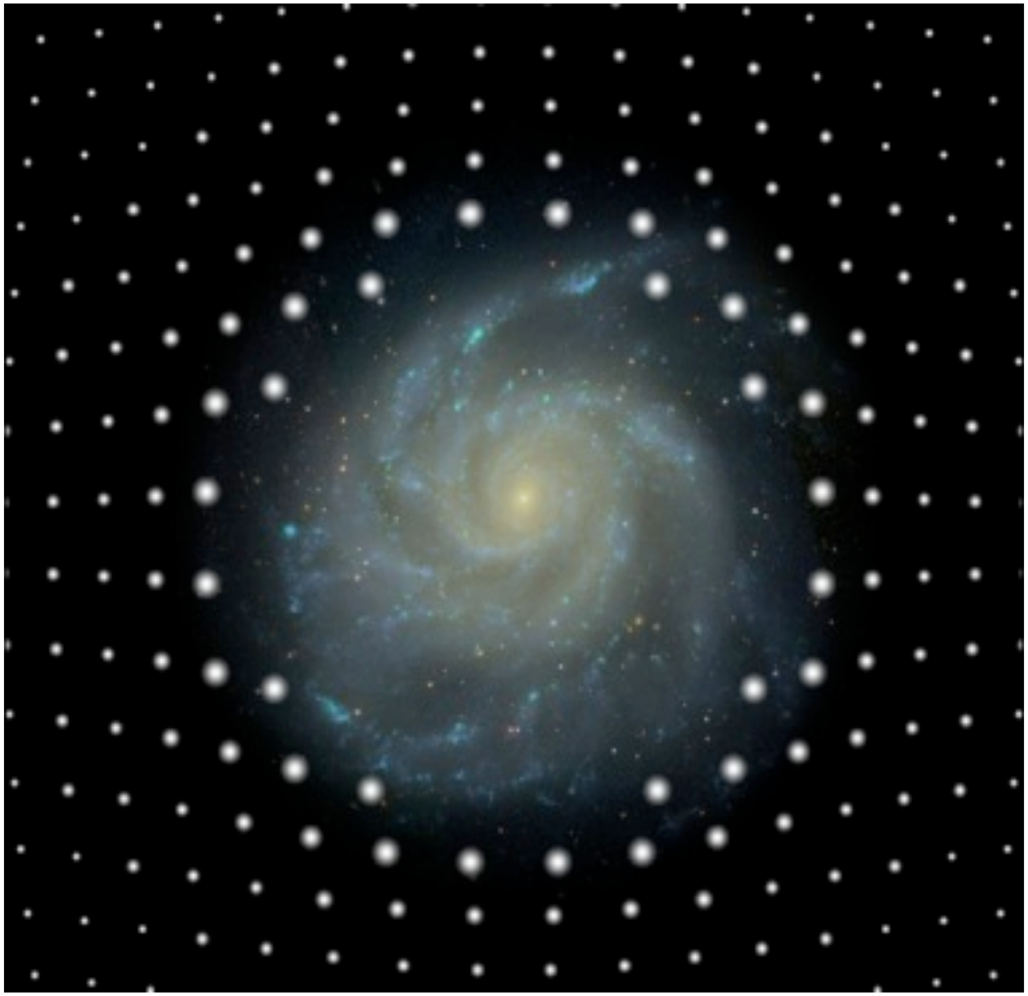




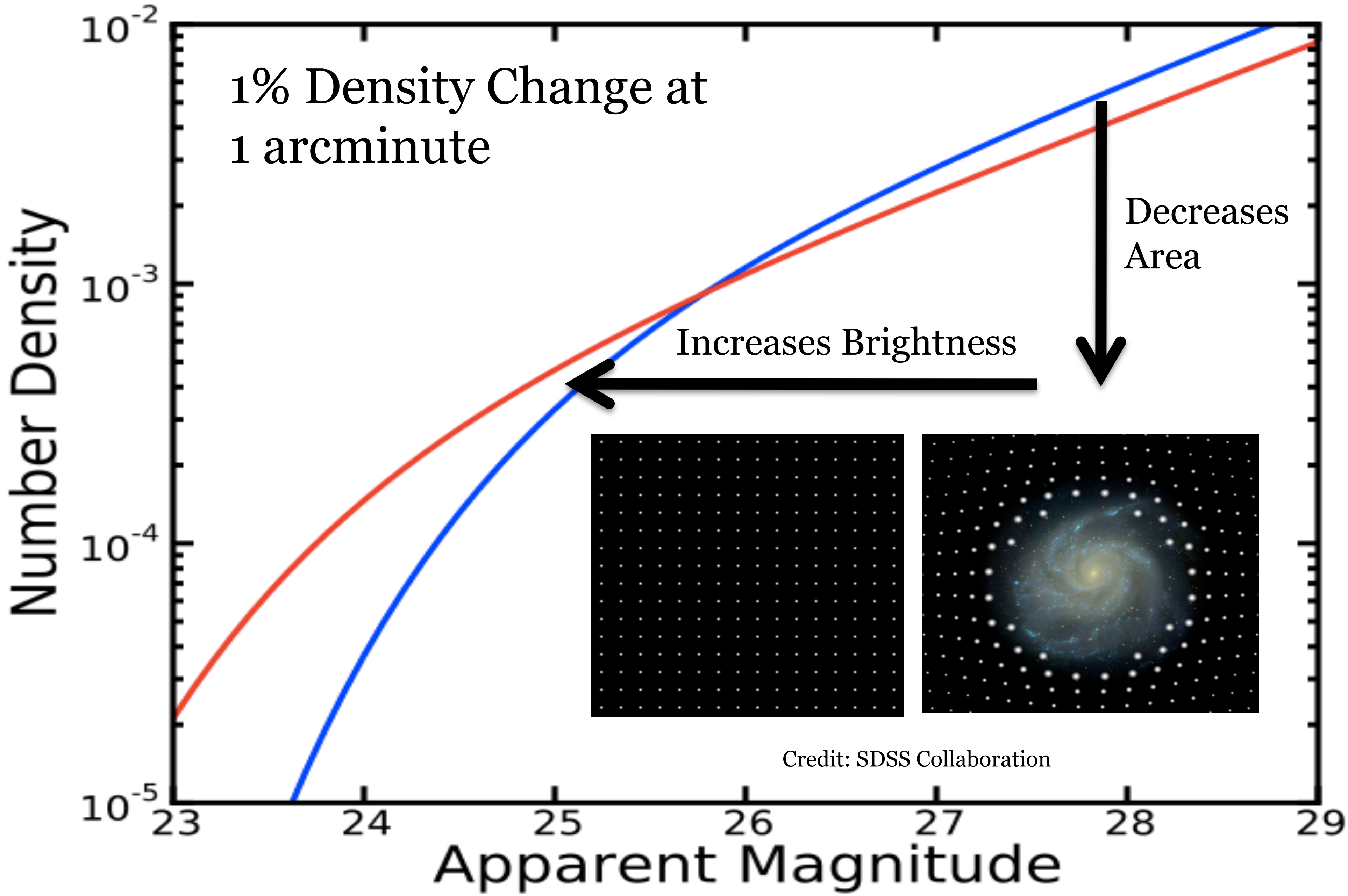
Credit: SDSS Collaboration

Motivating Magnification

- Can be preformed on any survey with sufficiently good photometry.
- No need to measure galaxy shape.
- Complementary mass and cosmological information to shear.
- Measurable at higher redshifts on a given survey than shear.



Measuring Magnification

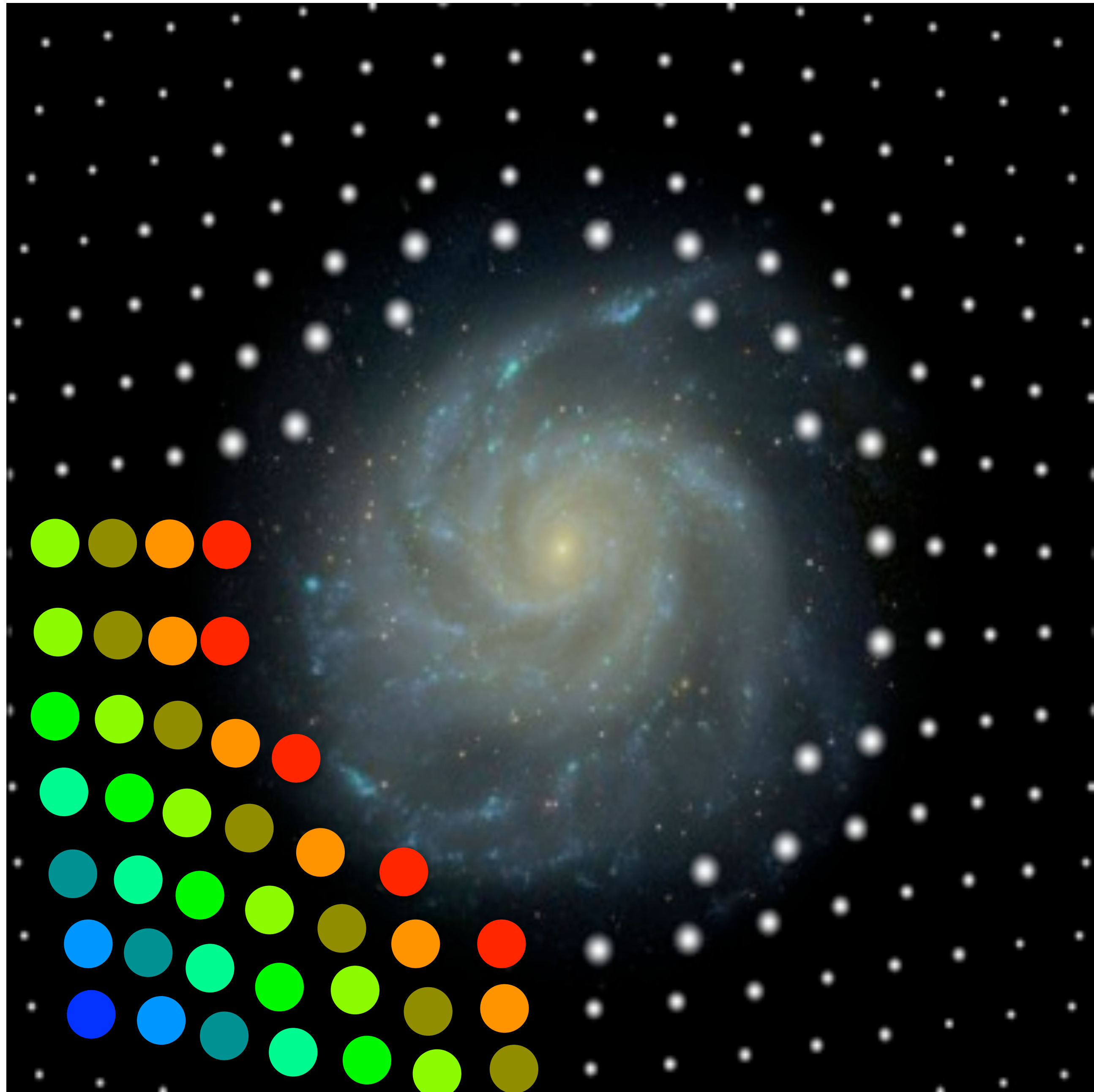


What about Dust?

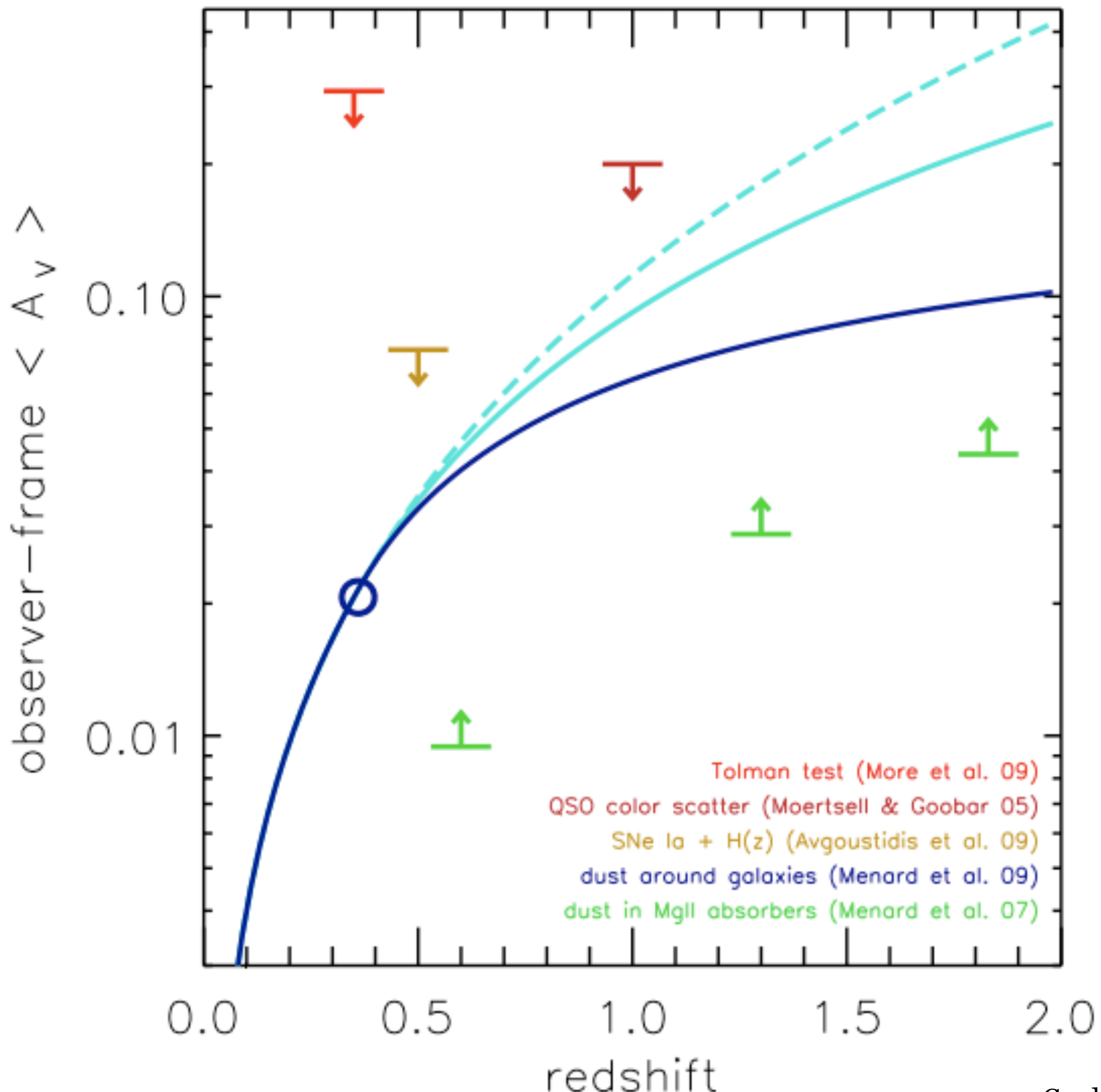
- Lensing is achromatic.
- Trends in color with angle can be interpreted as astrophysical.

$$\langle A - B\rangle(\theta) \propto \cancel{\mu_A - \mu_B} + \tau_A - \tau_B$$

- Can be used to measure the amount of dust in galaxies.

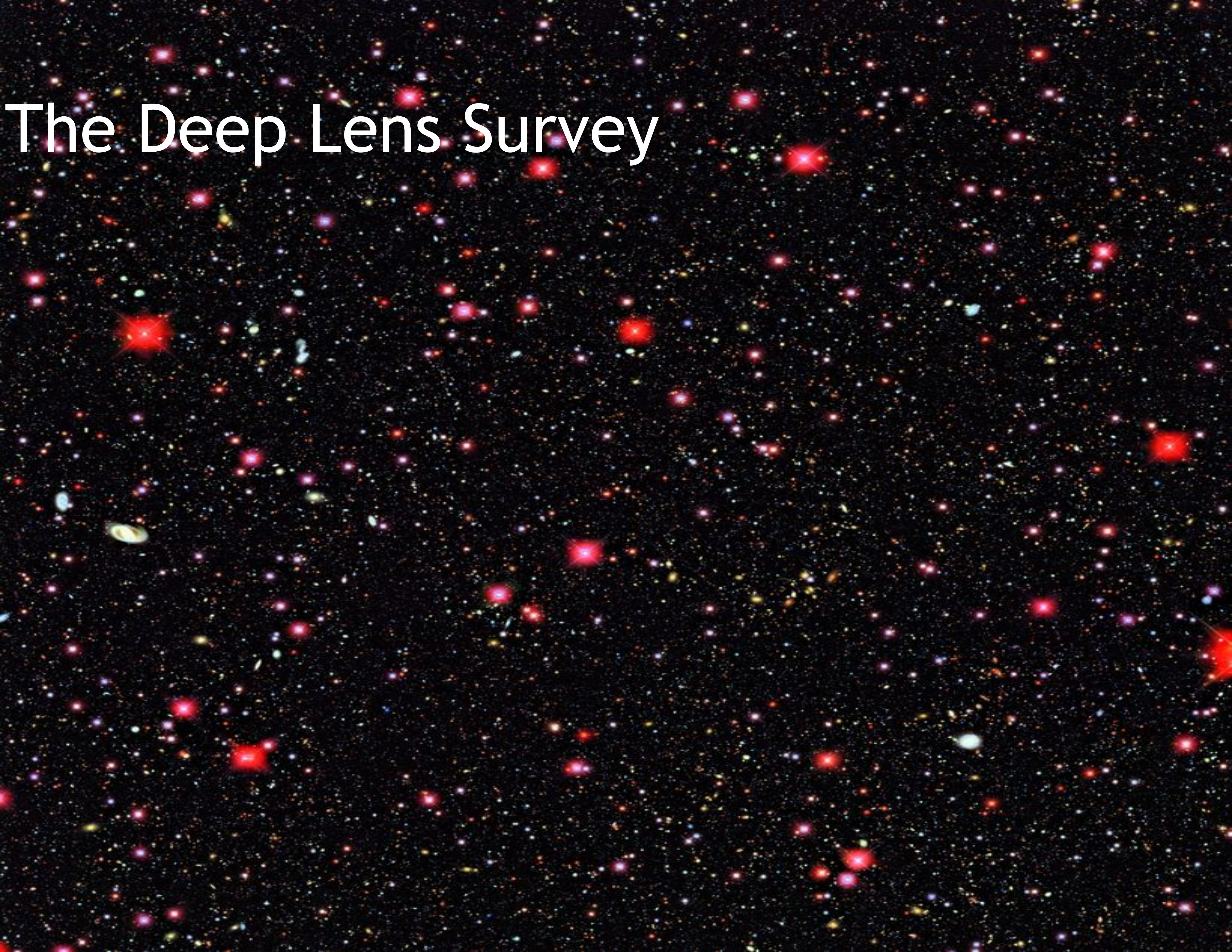


Opacity of the Universe



Credit: Brice Ménard

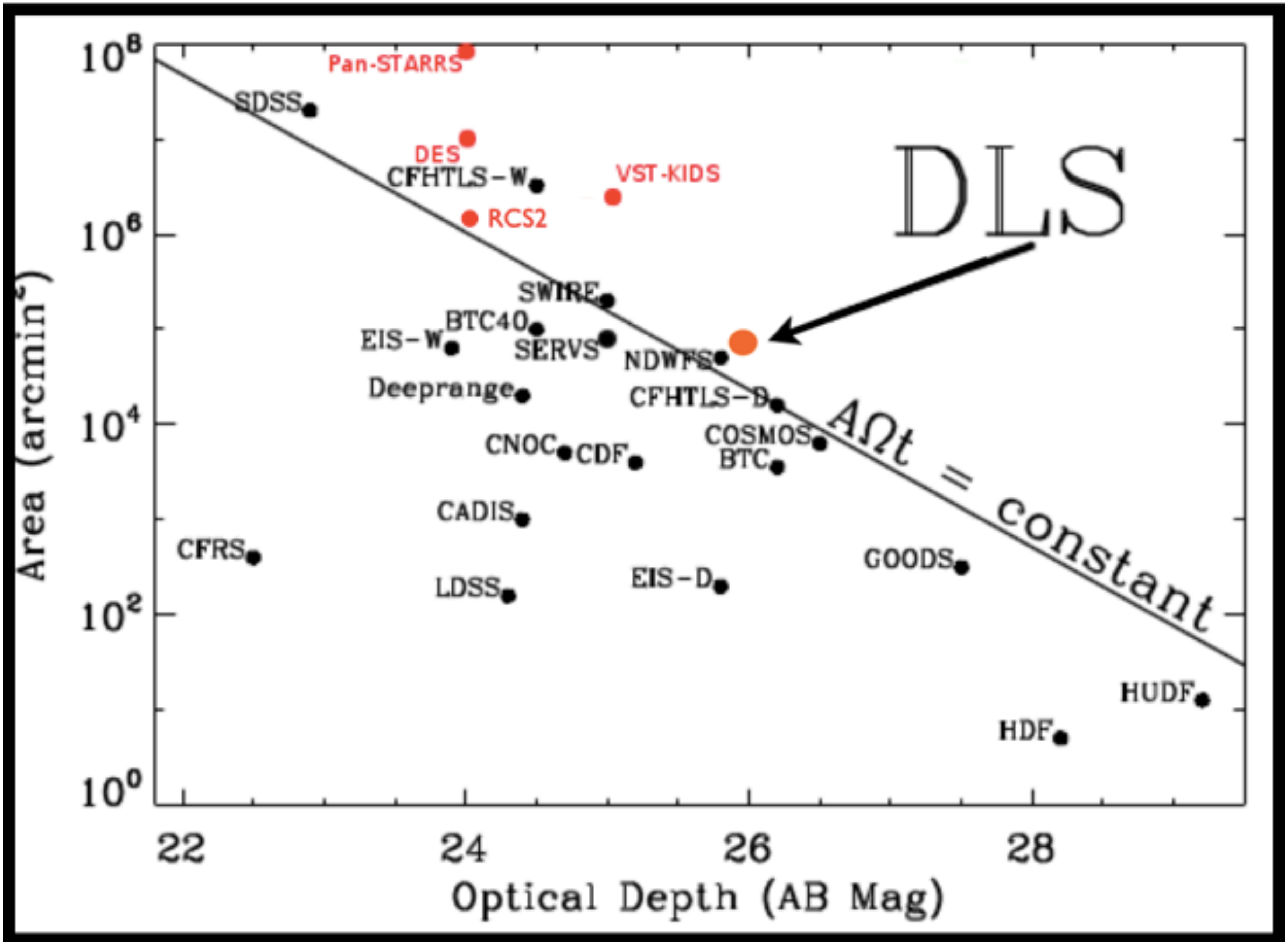
The Deep Lens Survey



The Deep Lens Survey

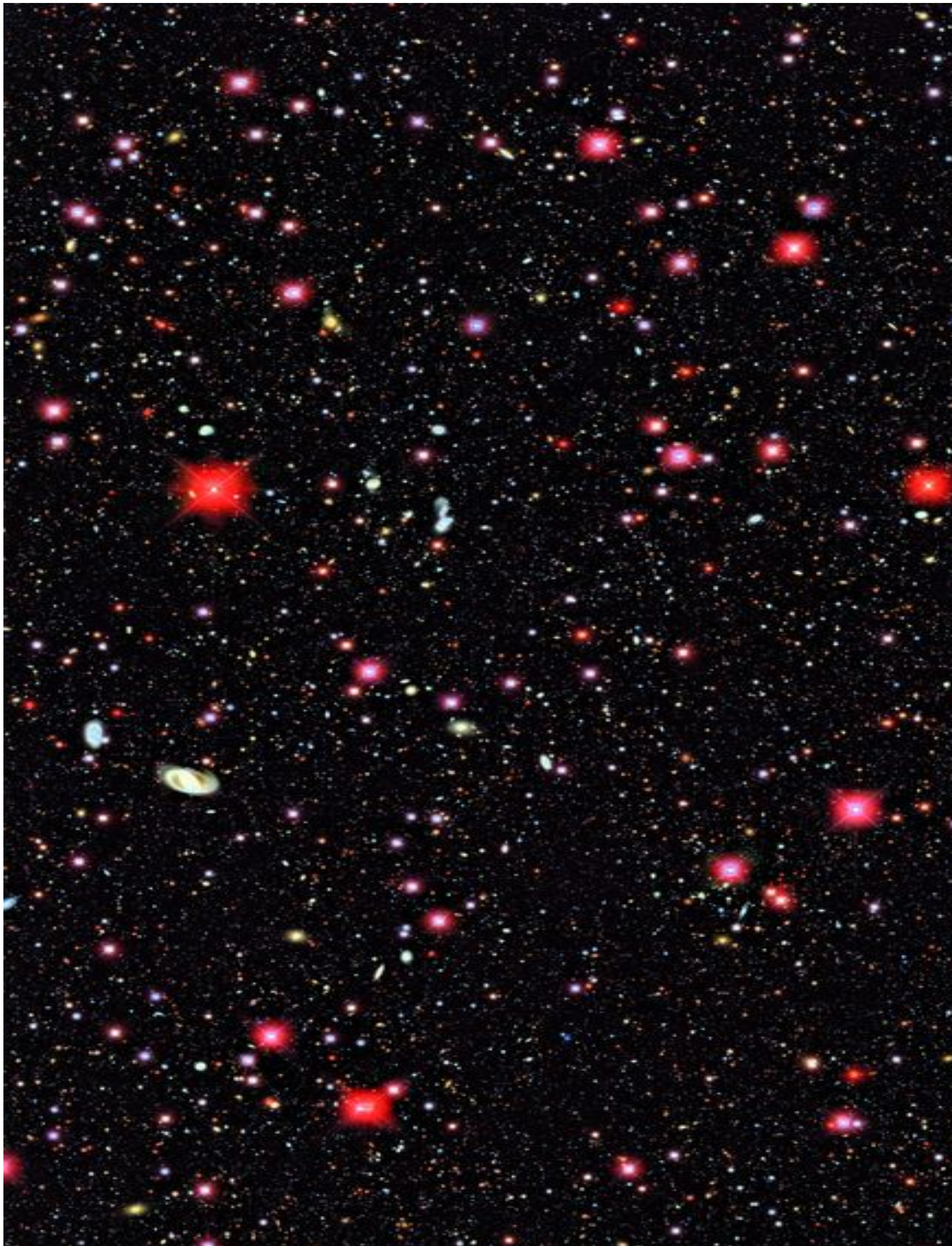
- Observed on the NOAO 4 Meter telescopes from 1999-2005
- 20 square degree area
- B (25.5_{AB}); V (25.5_{AB}); R (26.0_{AB}); z (24.5_{AB})
- R Band Seeing <0.9 arcseconds
- ~5 Million galaxies in the survey
- Precursor for future wide area, deep surveys (DES, LSST, etc.)

Survey Context

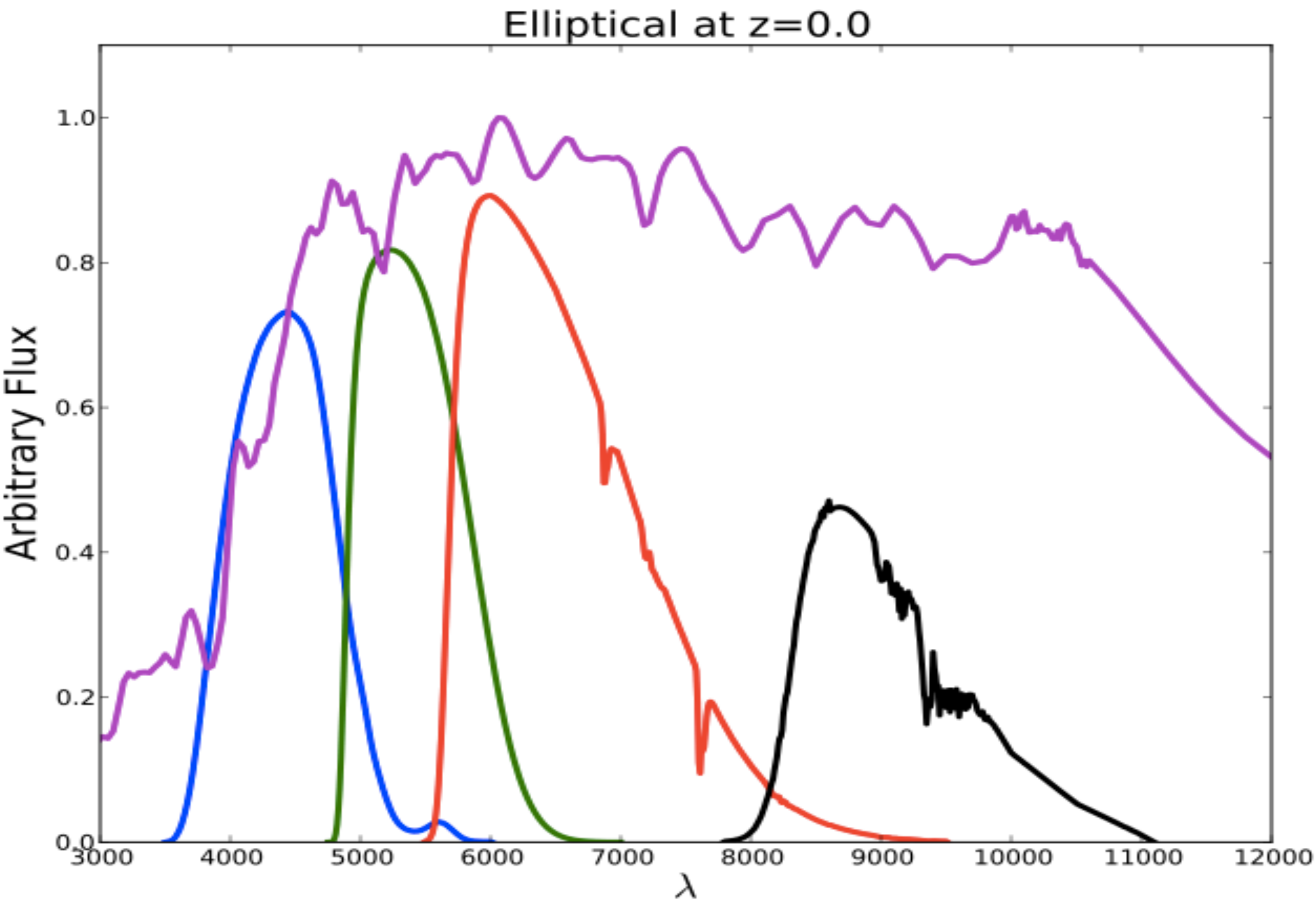


Selecting Galaxies

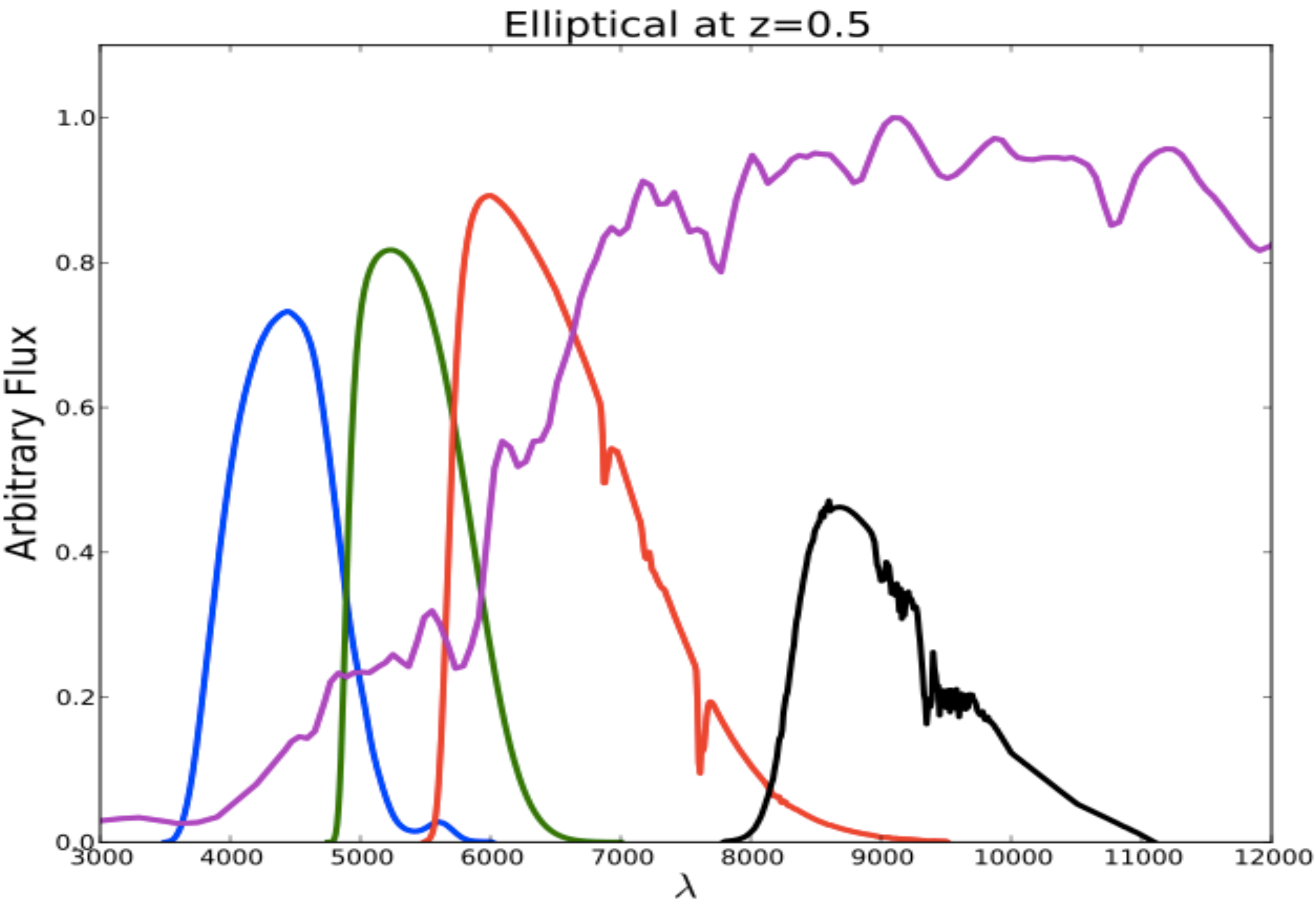
- Need to cleanly select foreground lenses and background sources.
  - Avoid cross contamination between lenses and sources.
  - Also avoid sources(lenses) in front(behind) of lenses(sources).
- Solution: Use information on galaxy redshift as
- Best way to do this: Use spectra of galaxies to identify emission lines.
  - Too expensive to do for large surveys.



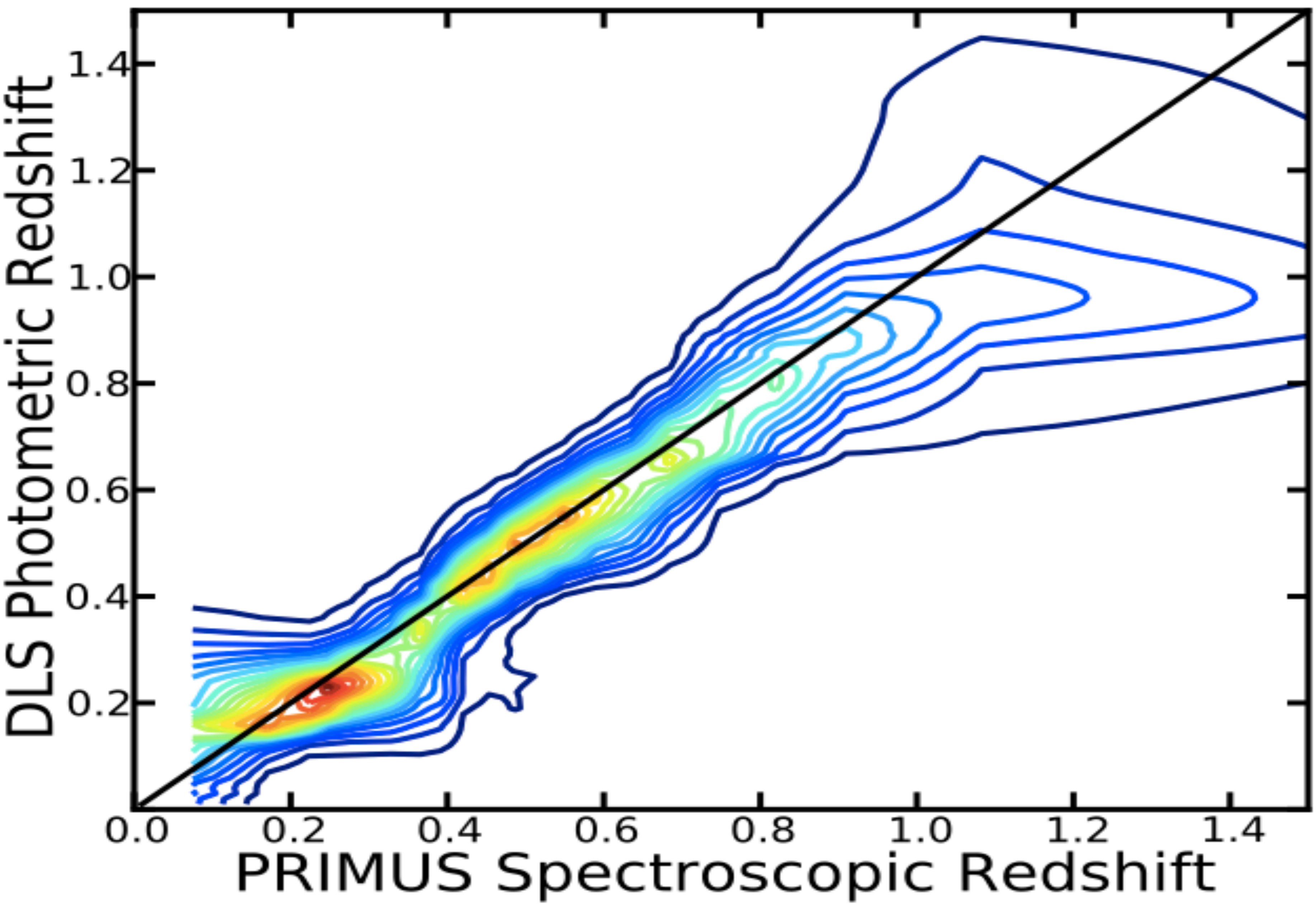
Photometric Redshifts



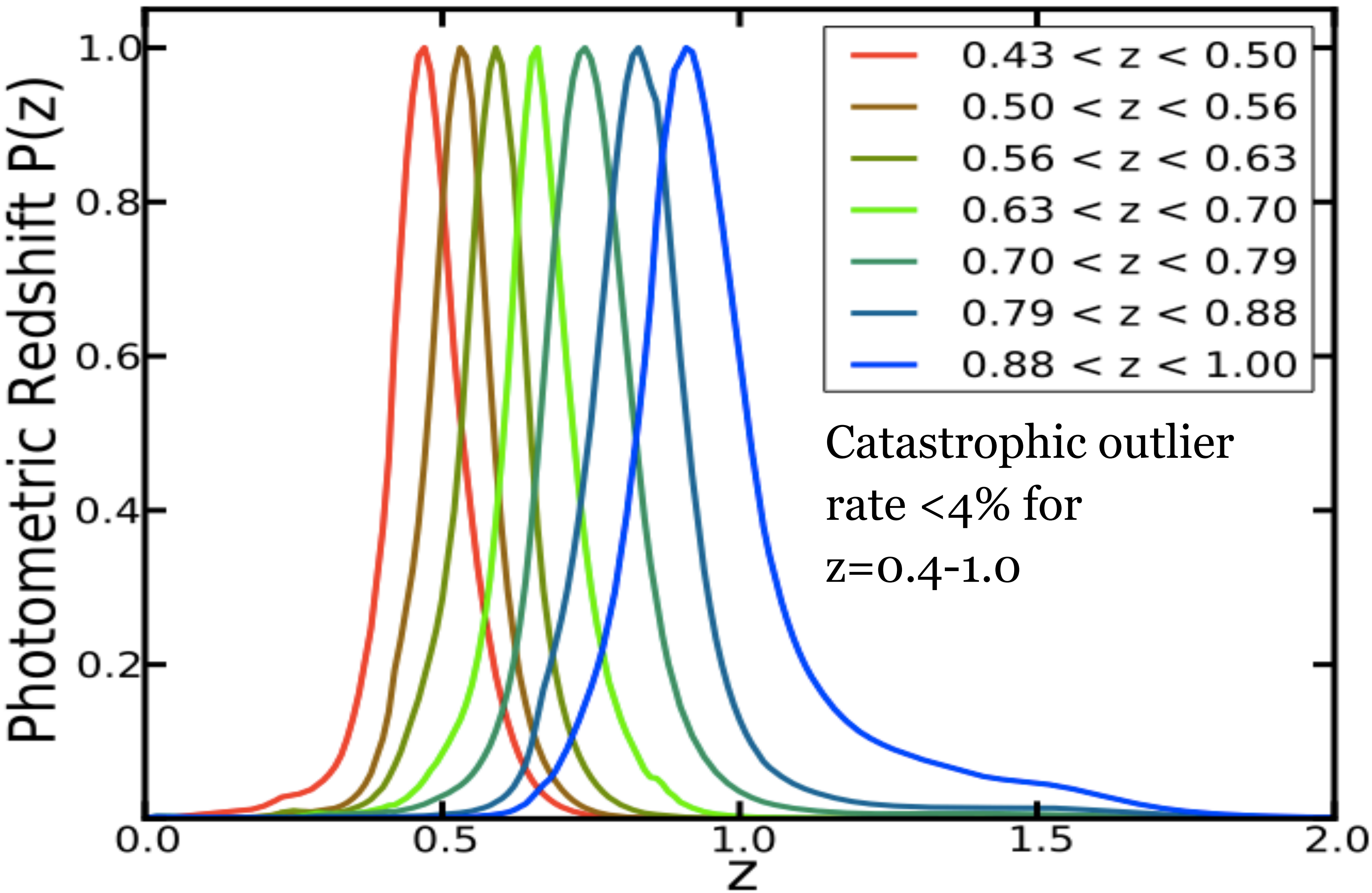
Photometric Redshifts



Spectroscopic Vs Photometric Redshift

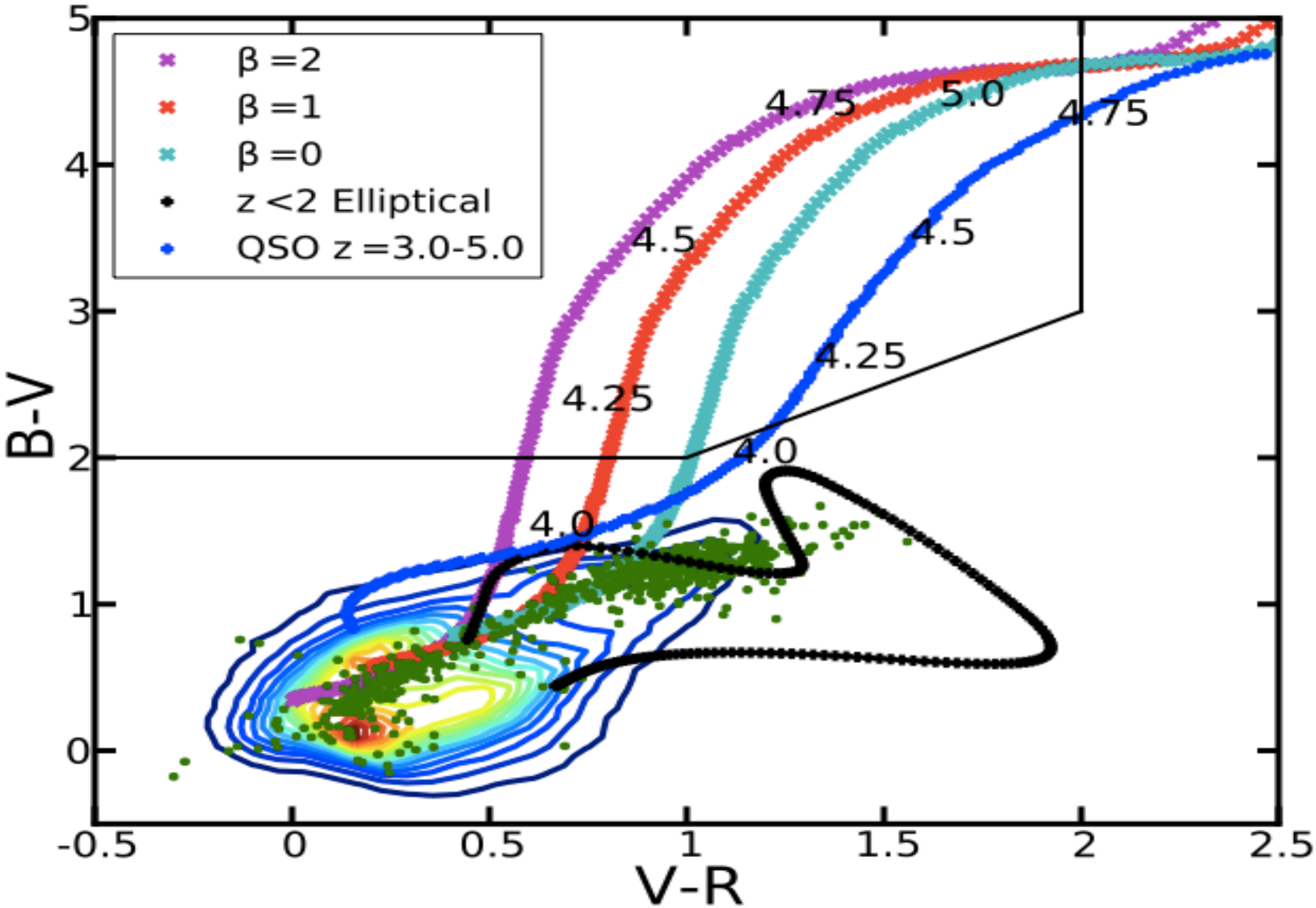


Foreground Lens Redshift Bins



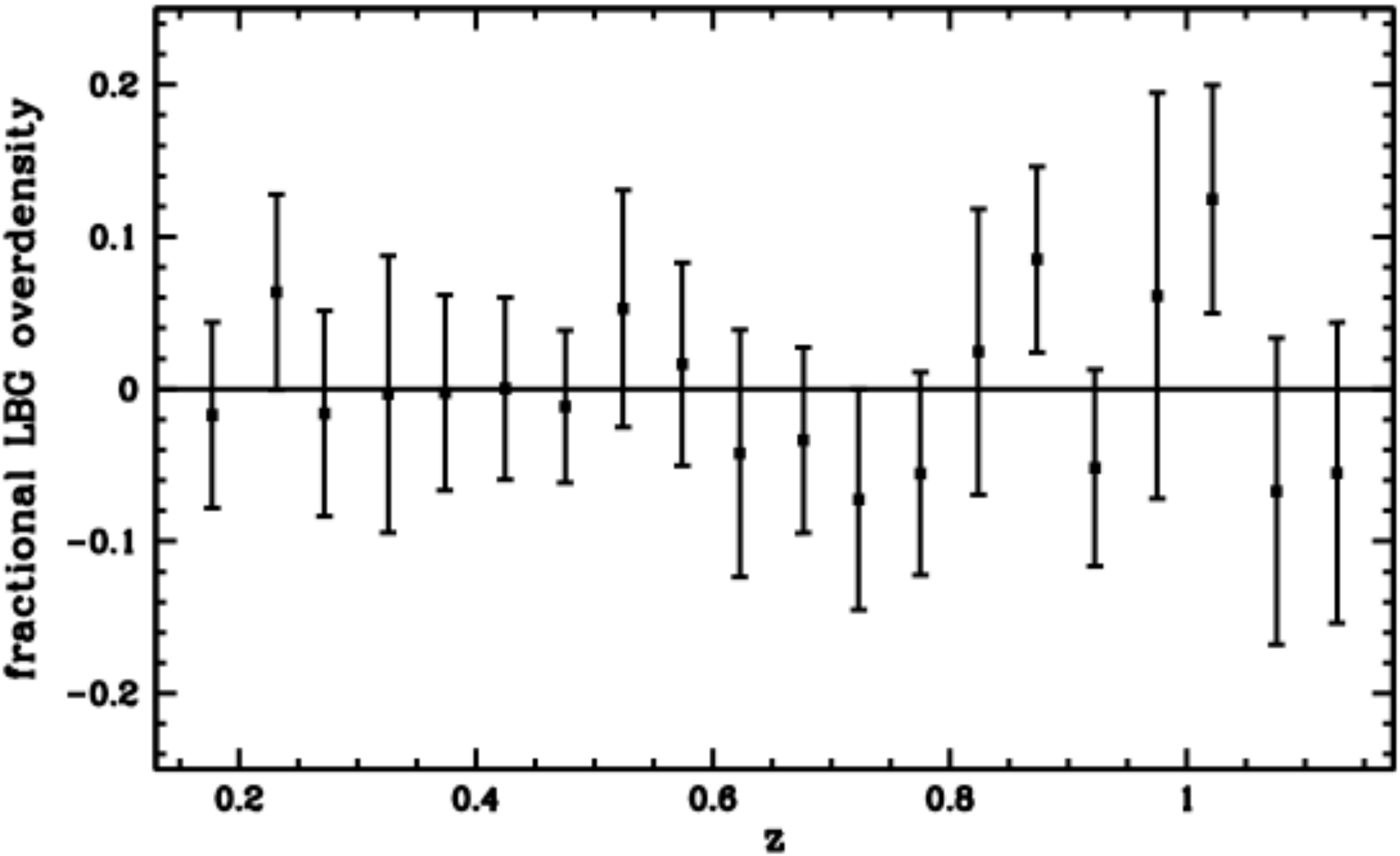
Catastrophic outlier rate <4% for z=0.4-1.0

Background Sources: Lyman Break Galaxies

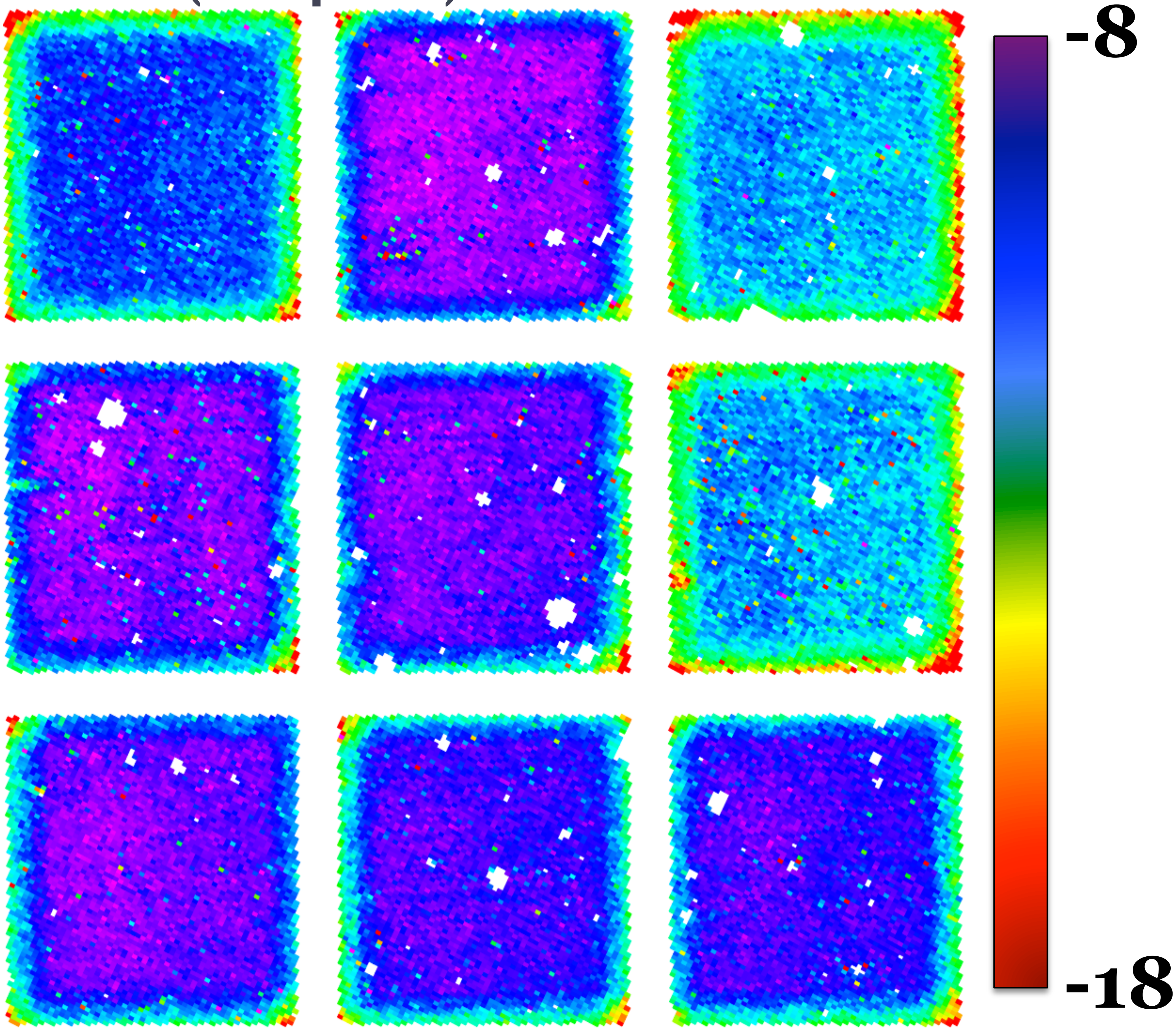


LBG Redshift Recovery

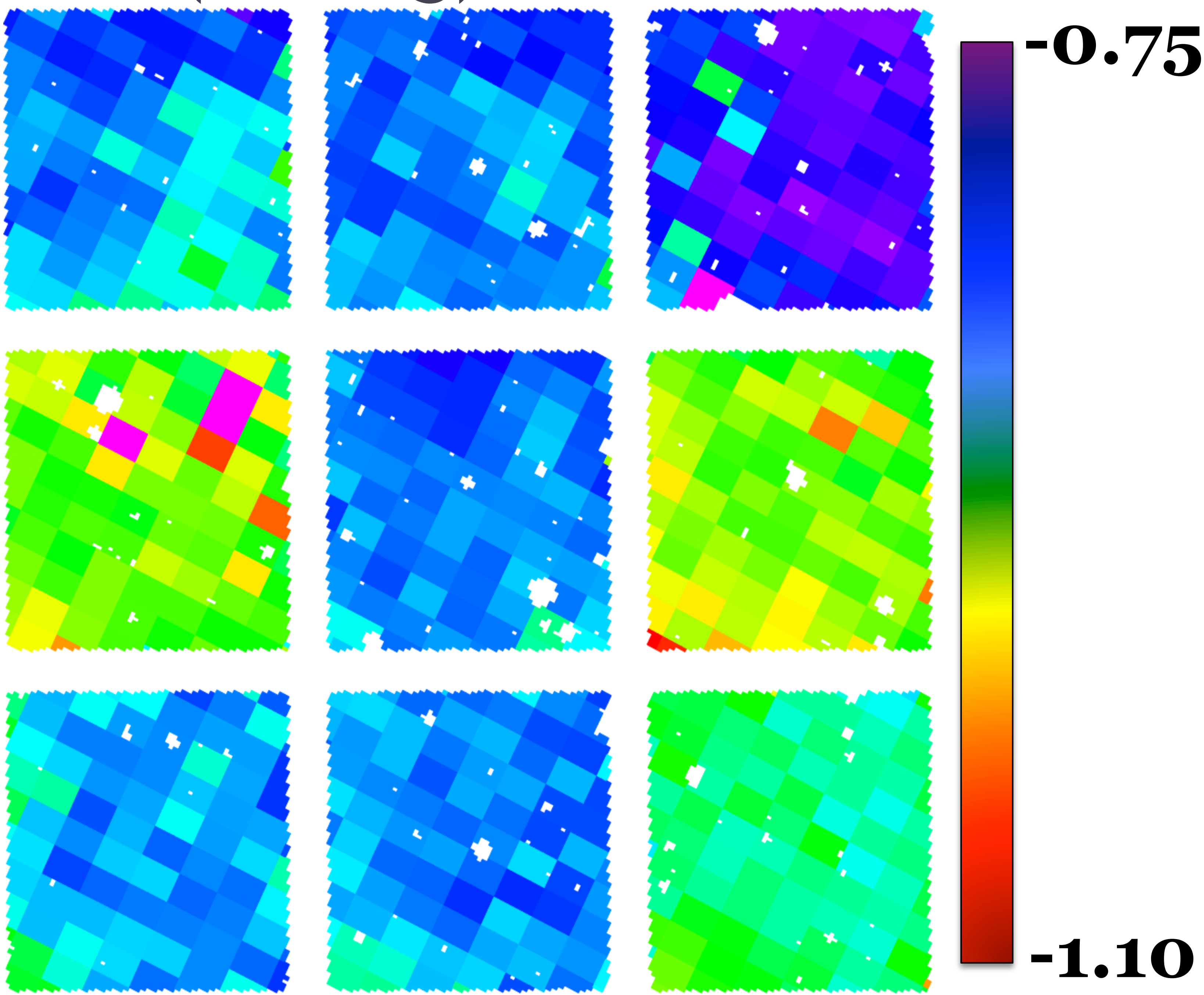
Schmidt et al. in prep.



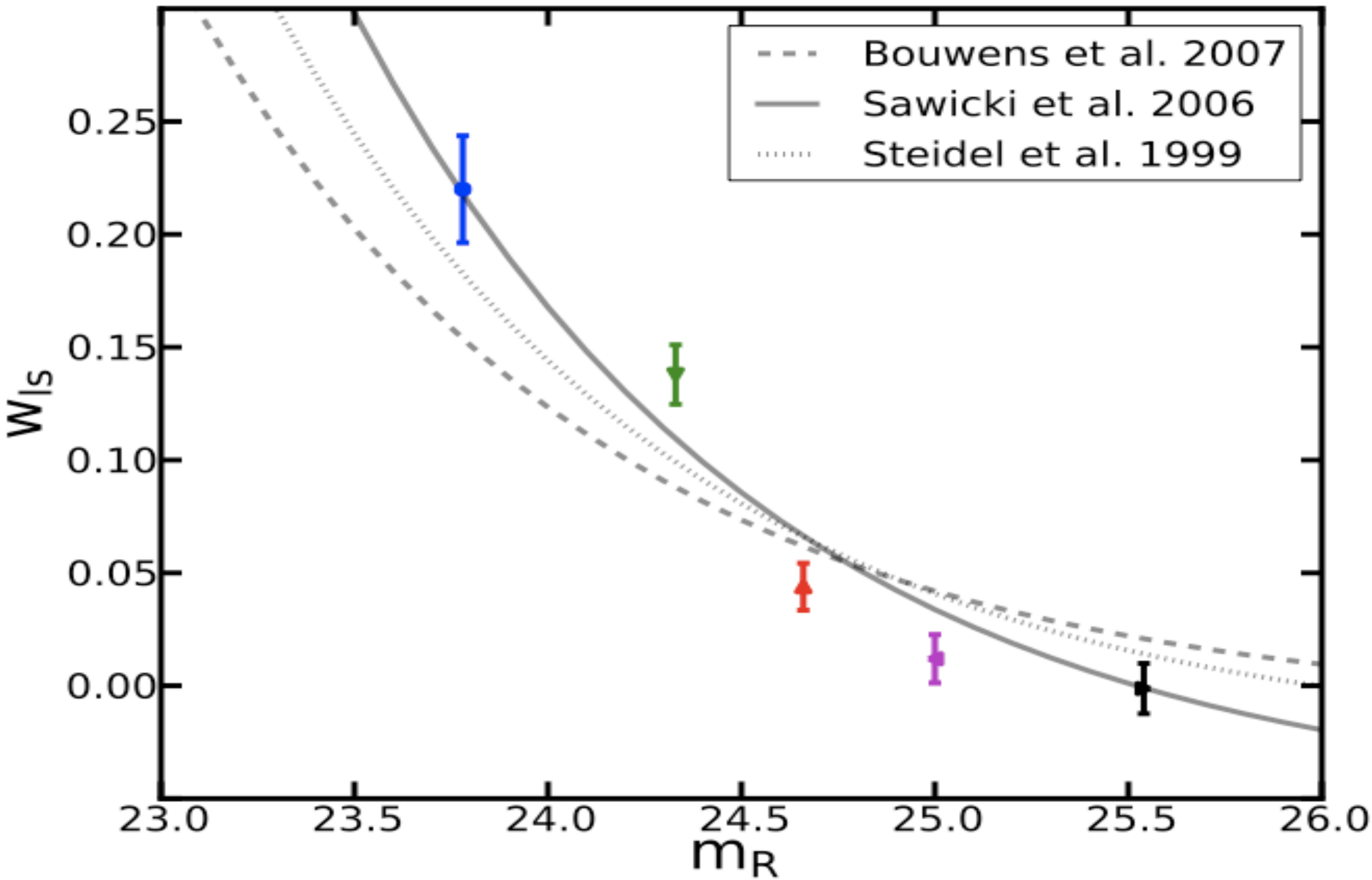
Systematics (Depth)



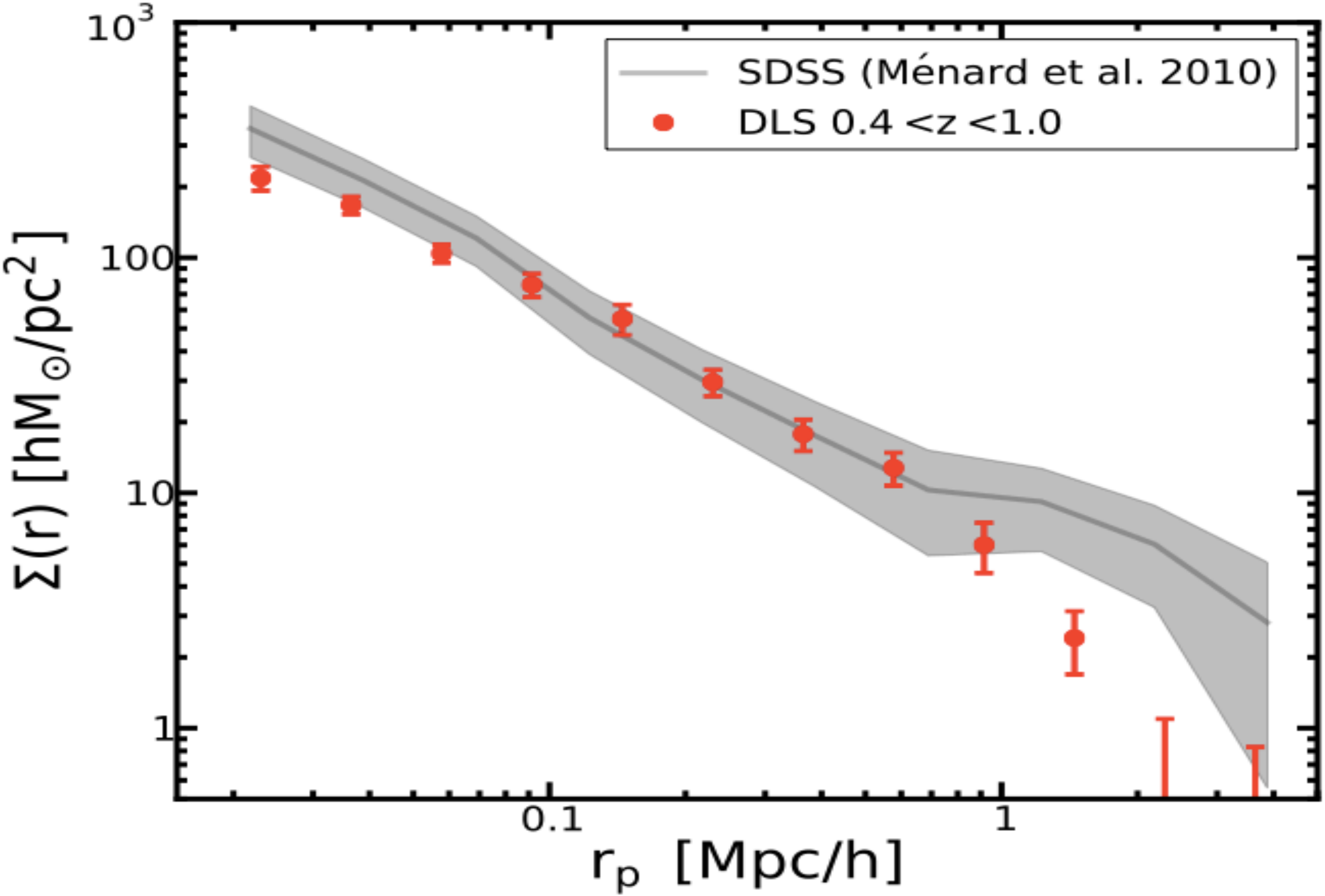
Systematics (Seeing)



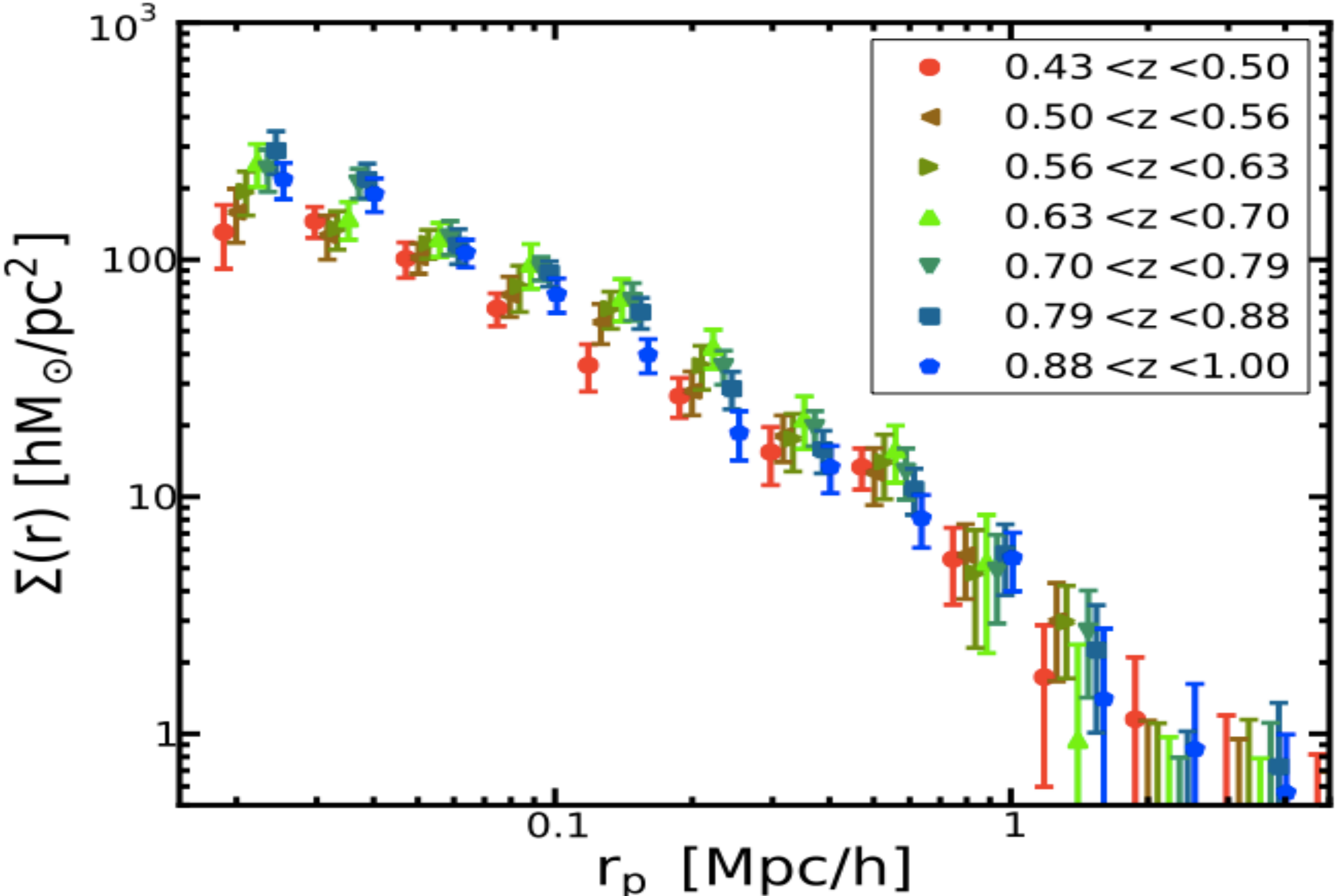
Expected Magnification Signal



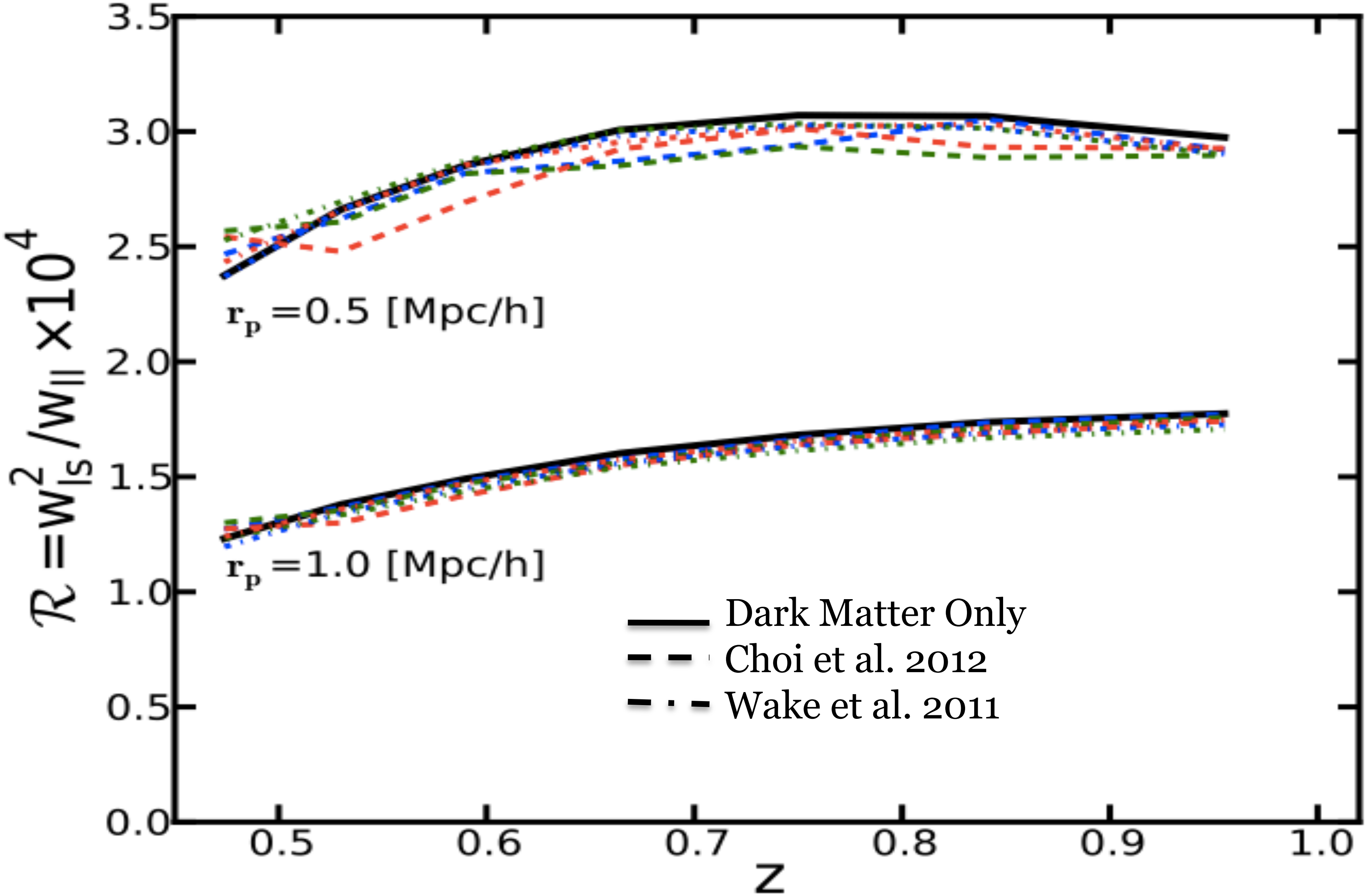
Surface Mass Density (S/N>20)



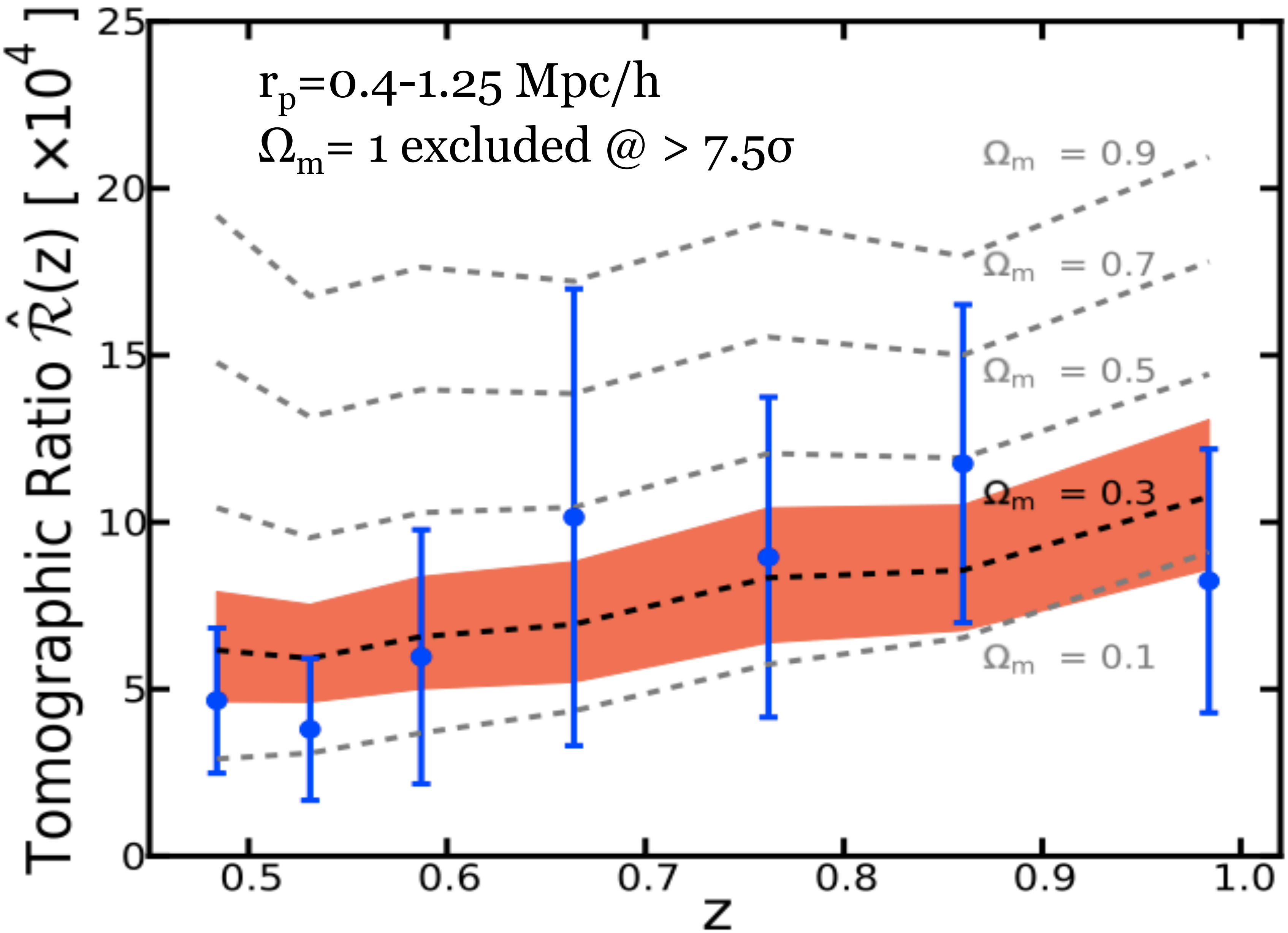
High Significance Tomographic Bins



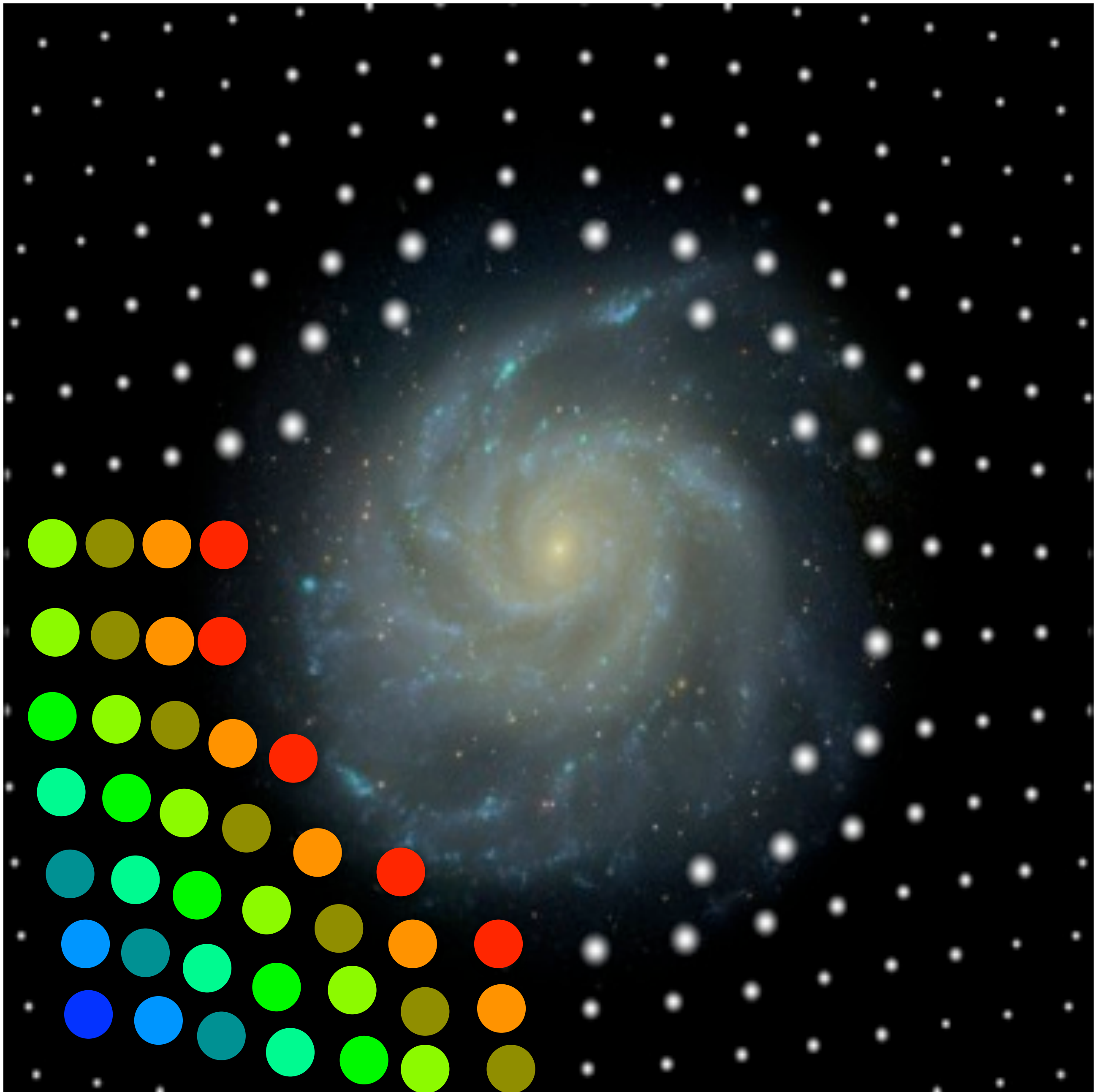
Bias-Free Ratio $w_{ls} \sim b^1$, $w_{ll} \sim b^2$



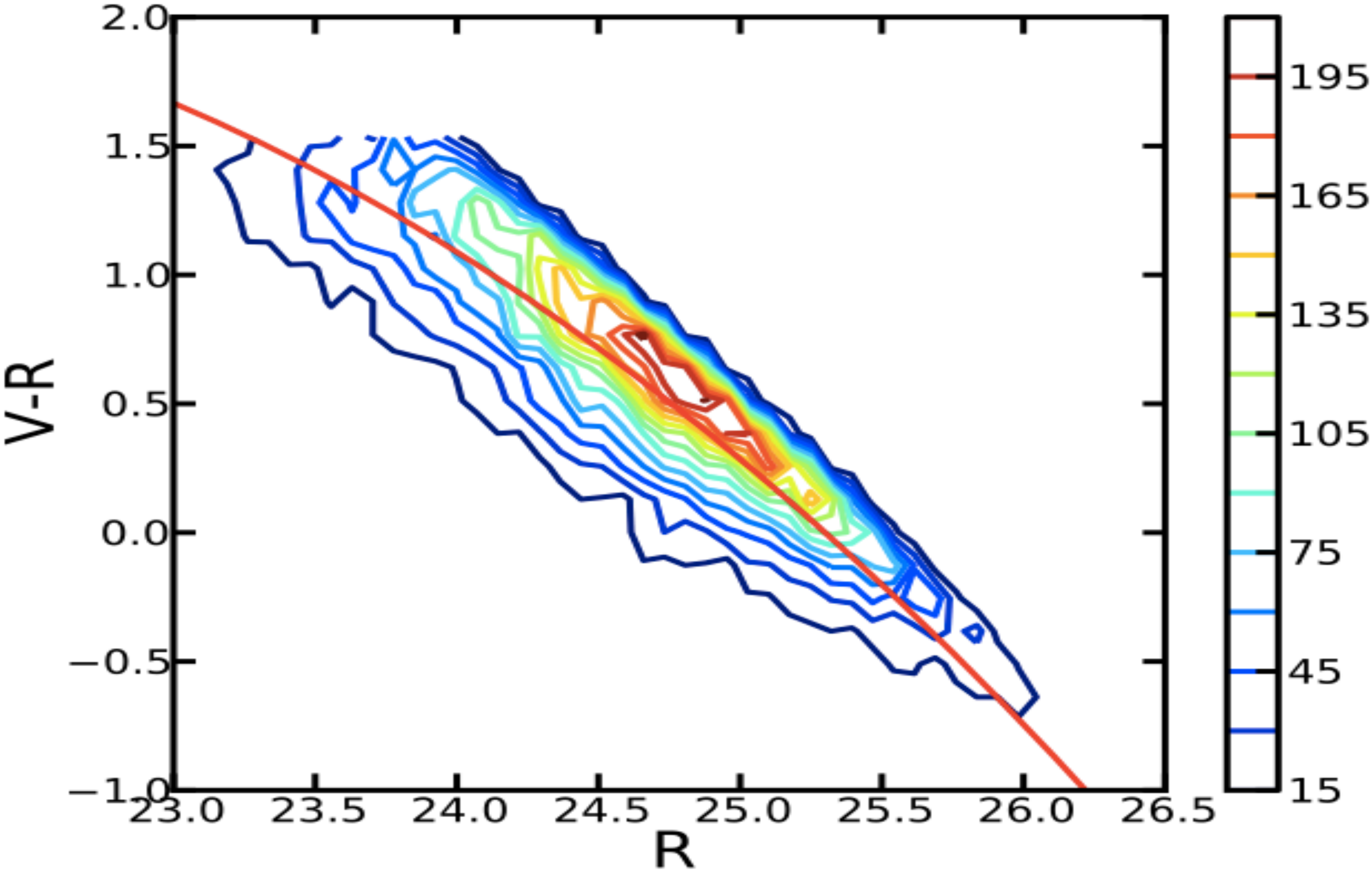
Tomographic Ratio, $\mathcal{R}(z)=w_{ls}^2/w_{ll}$



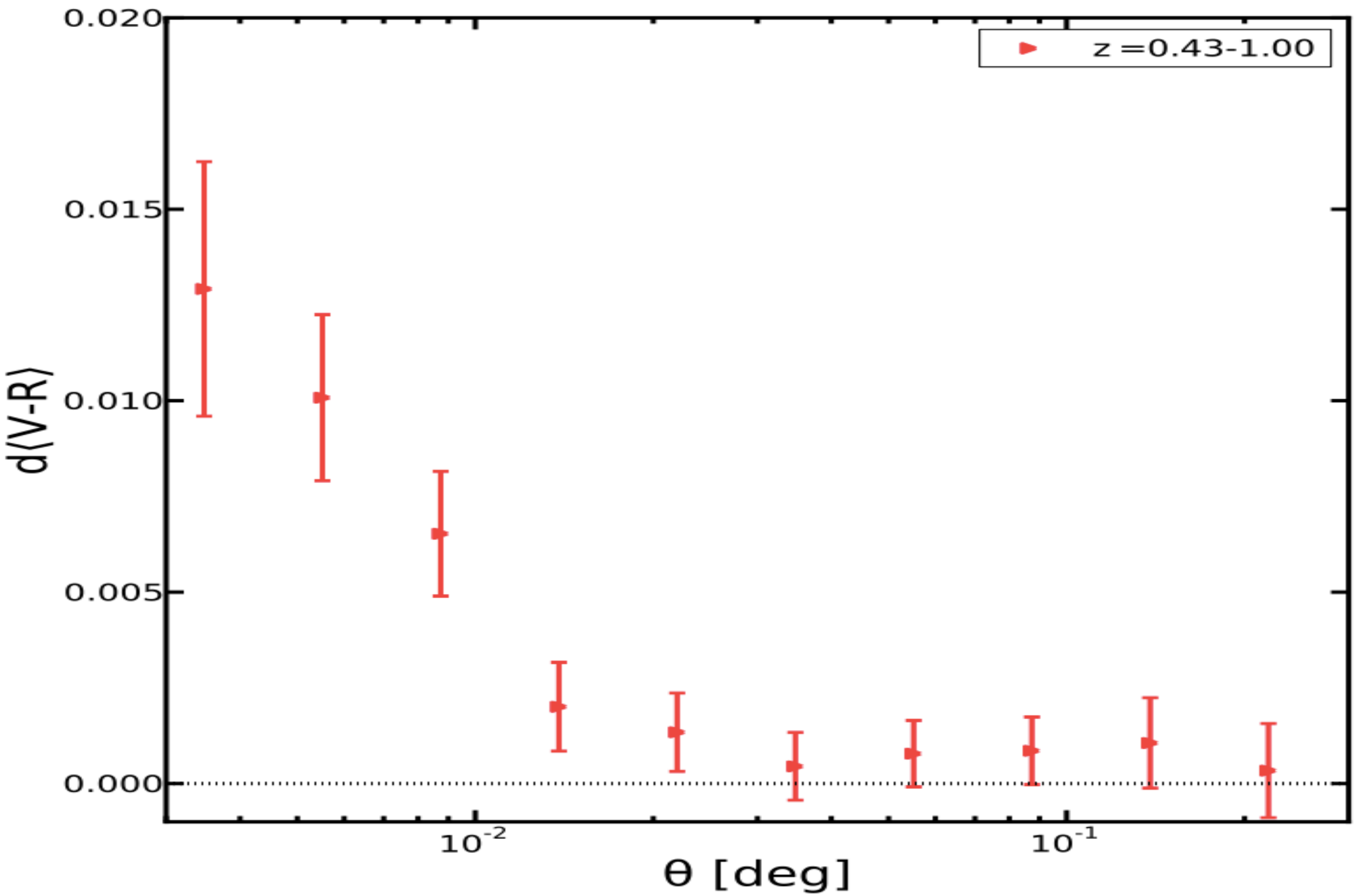
What about Dust?



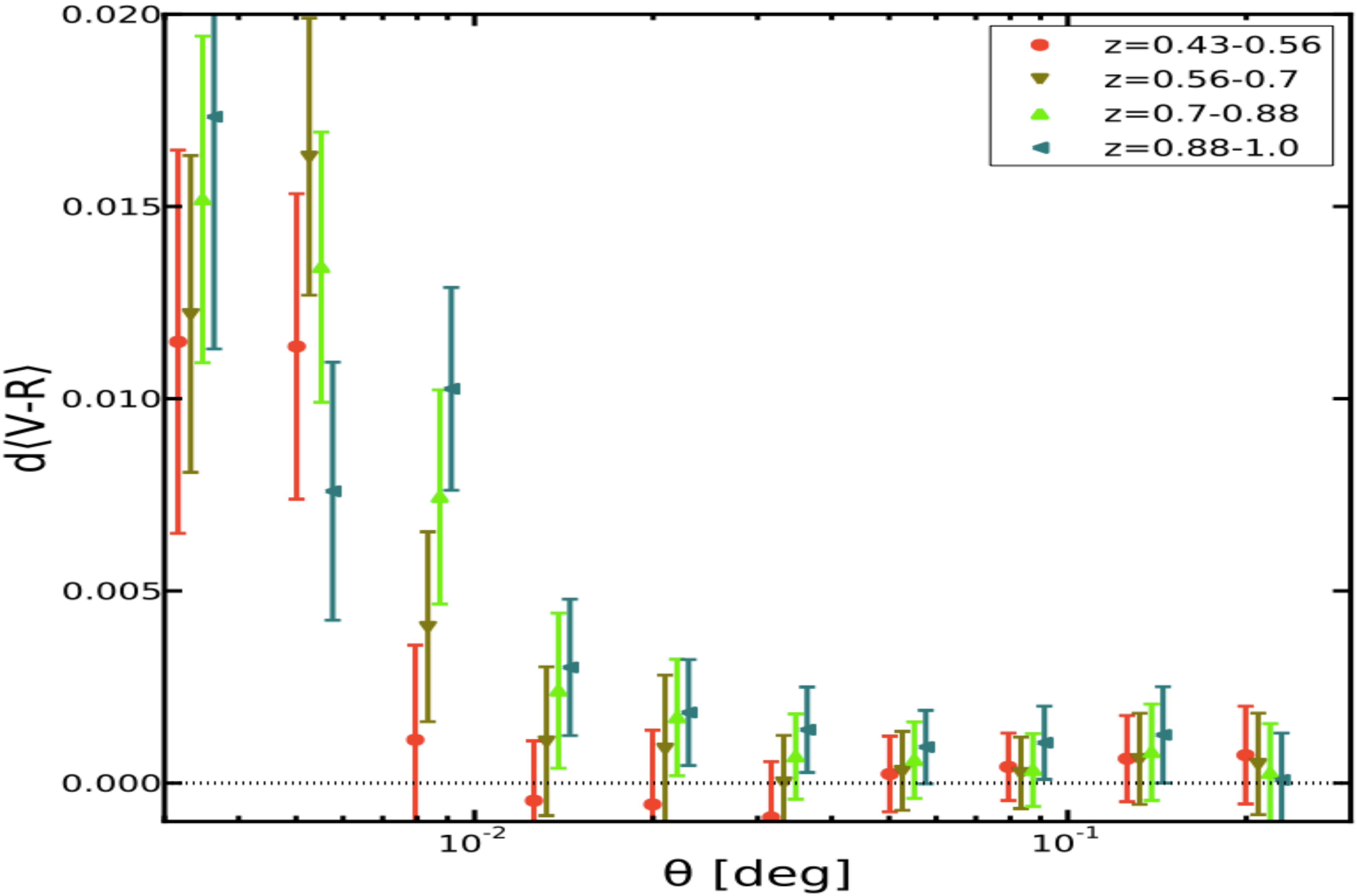
LBG Color Trend



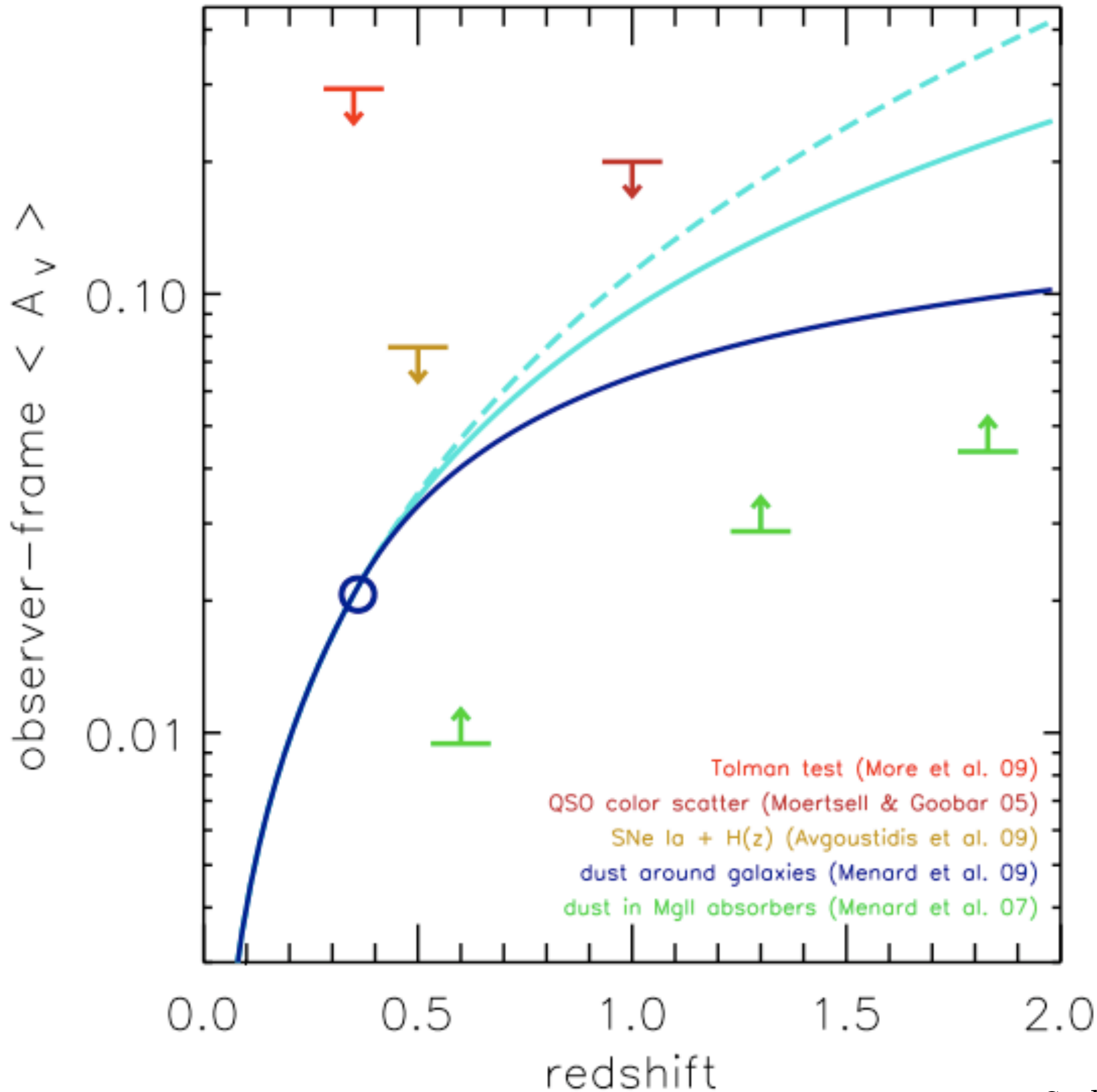
Extragalactic Dust Extinction



Tomographic Dust Extinction



Opacity of the Universe



Credit: Brice Ménard

Summary

Tomography

- Robust detection of magnification, $S/N>20$. No contamination due to physical clustering.
- Tomographic signal consistent with concordance cosmology across 7 redshift bins.
- Tomographic lensing is becoming a reality in current surveys.
- Accepted To MNRAS, arXiv:1204.2830v3

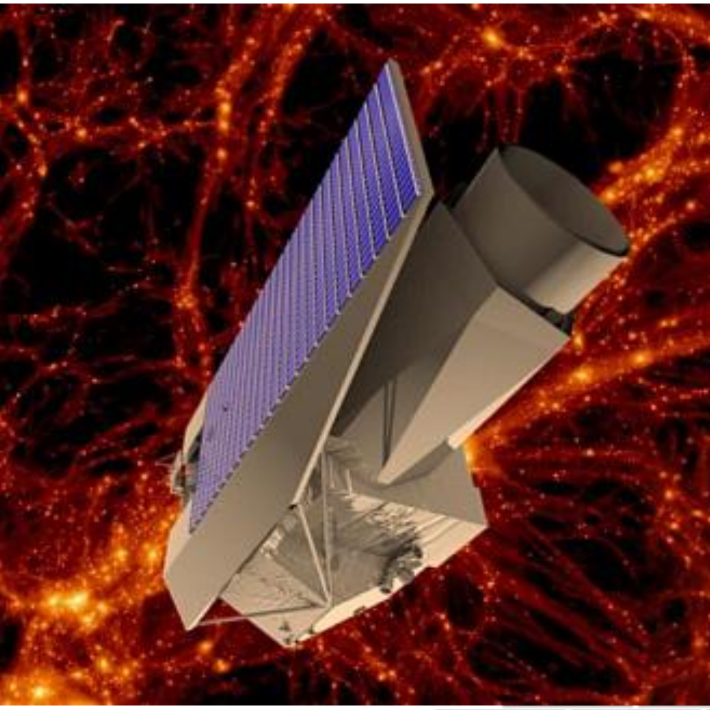
Dust

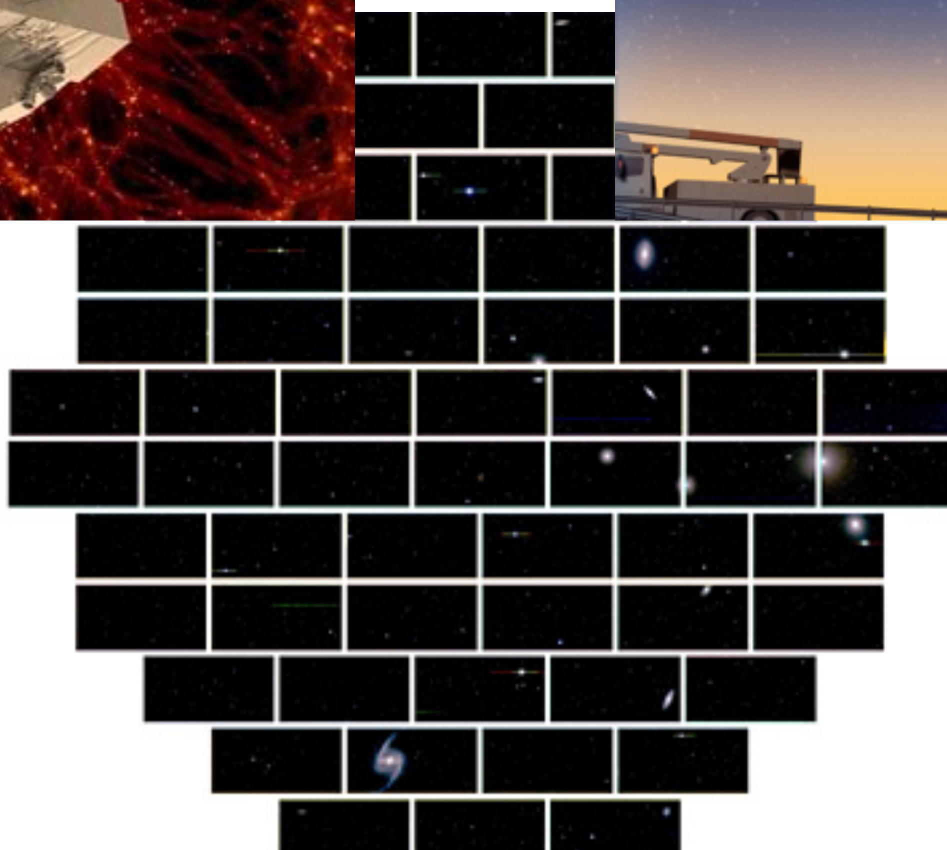
- Preliminary work measuring dust reddening in DLS is promising.
- Work still needs to be done interpreting the results.
    - Measure bias to properly derive cosmological opacity

Future Work

- Use extract galaxy bias and cosmology from the magnification measurement
- Joint magnification/shear lensing measurements
- Model cosmology dependence of covariances for MCMC analysis
  - Part of the CHOMP cosmology suite written by myself and Ryan Scranton
  - Available at: http://code.google.com/p/chomp
- Expand the analysis package STOMP to utilize Google's geometry library S2.
  - Available at: http://code.google.com/p/astro-stomp

Looking Toward The Future





Future surveys will greatly improve over these results and will have a shot at answering what dark energy is.