Measuring the Cosmological Distance Scale with Spectroscopic and Photometric Data

Anna Patej

University of Arizona

Based on Patej & Eisenstein (2017) -- 1709.03514

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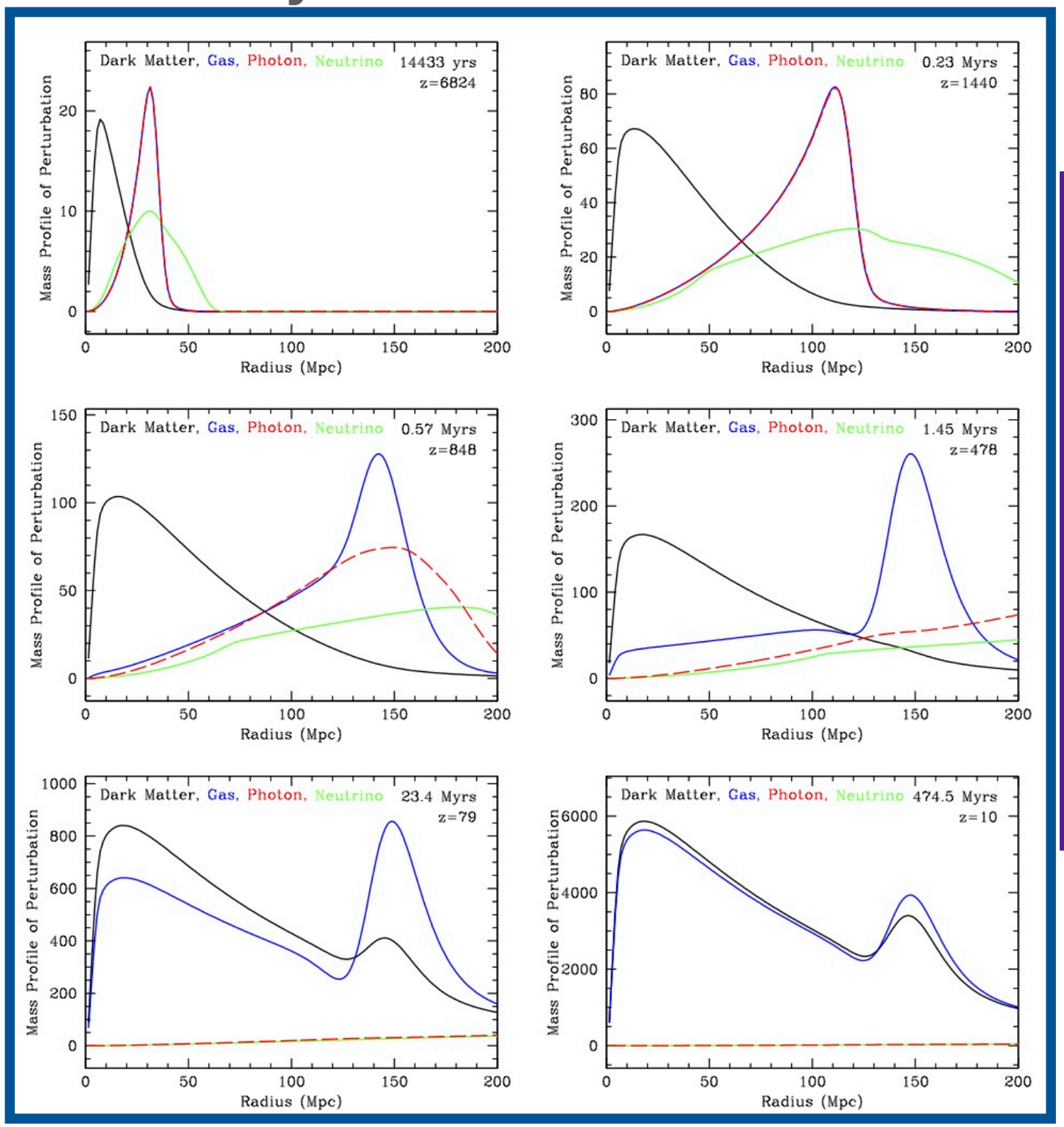
Outline

- Baryon Acoustic Oscillations (BAO) Background
- Measuring BAO in Sparse Spectroscopic Samples
- Future Prospects

Baryon Acoustic Oscillations

- Relic peak in the clustering of galaxies from sound waves in the early universe



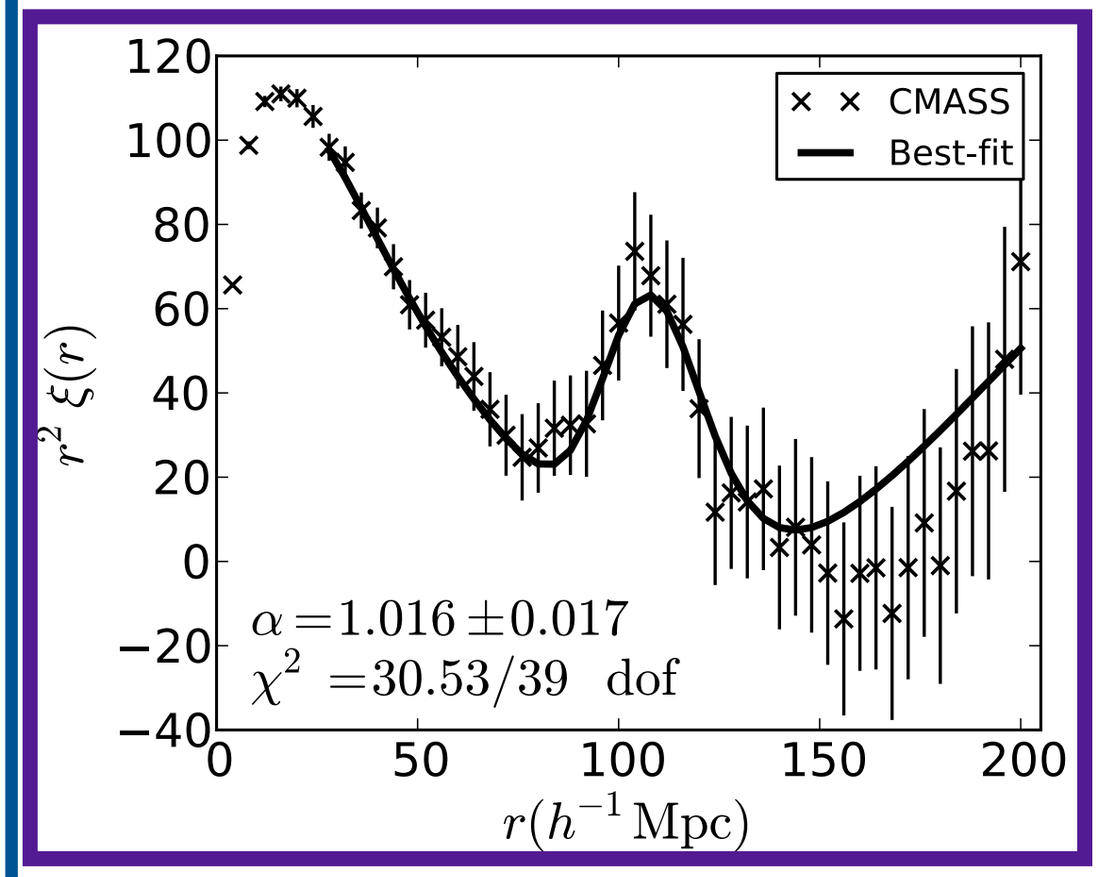


Figure Credits:
Left: Eisenstein et al. (2007)
Above: Anderson et al. (2012)

Baryon Acoustic Oscillations

- BAO: standard ruler in cosmology

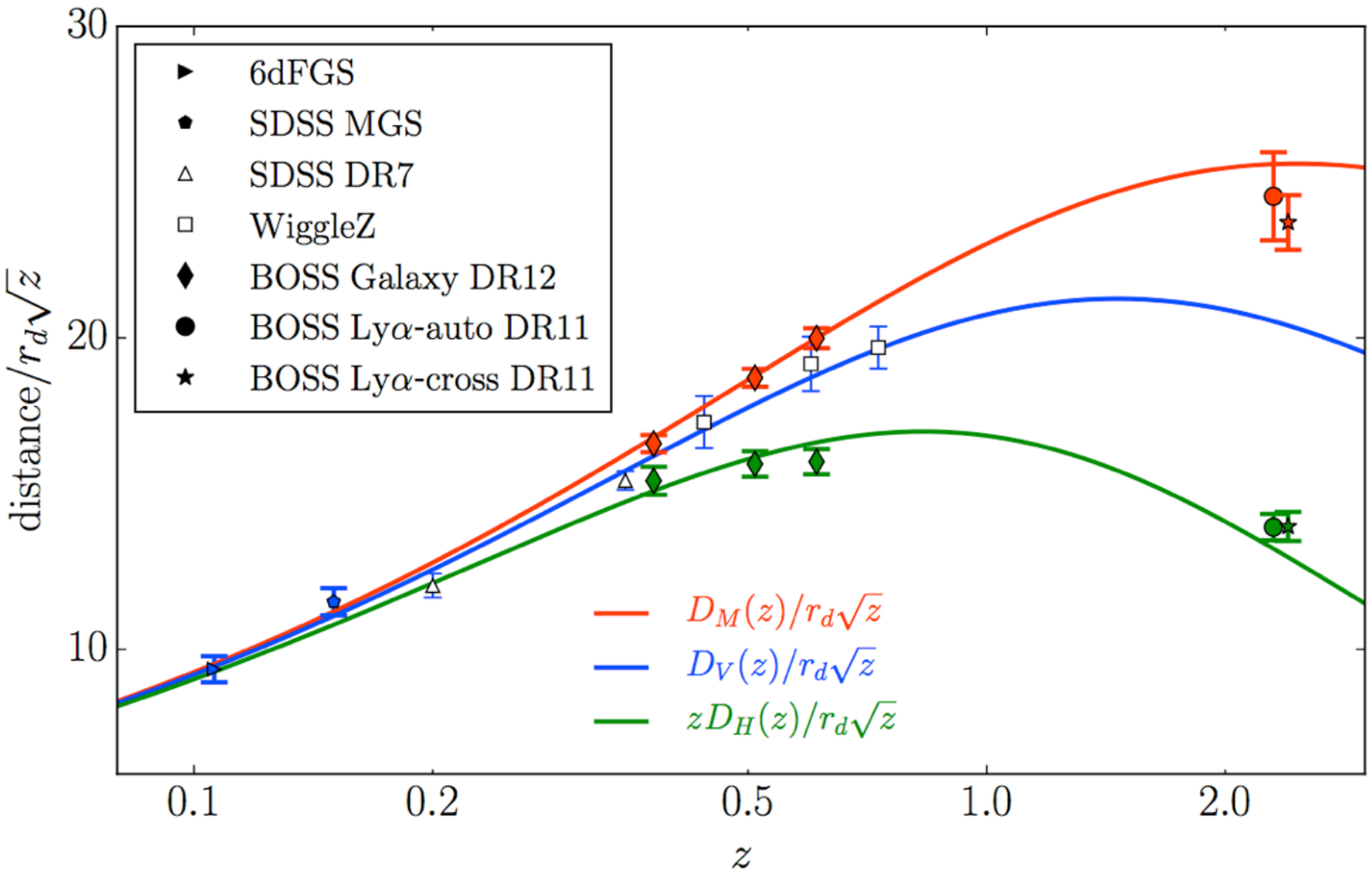
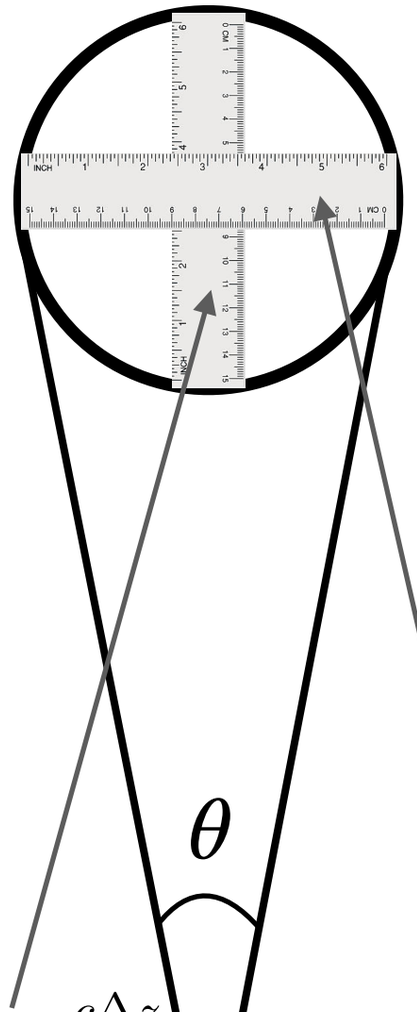
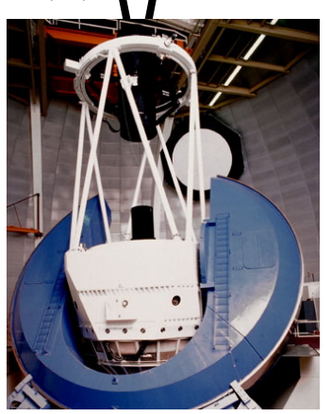


Figure Credit: Alam, et al. (2017)
Photo Credit: NOAO/KPNO

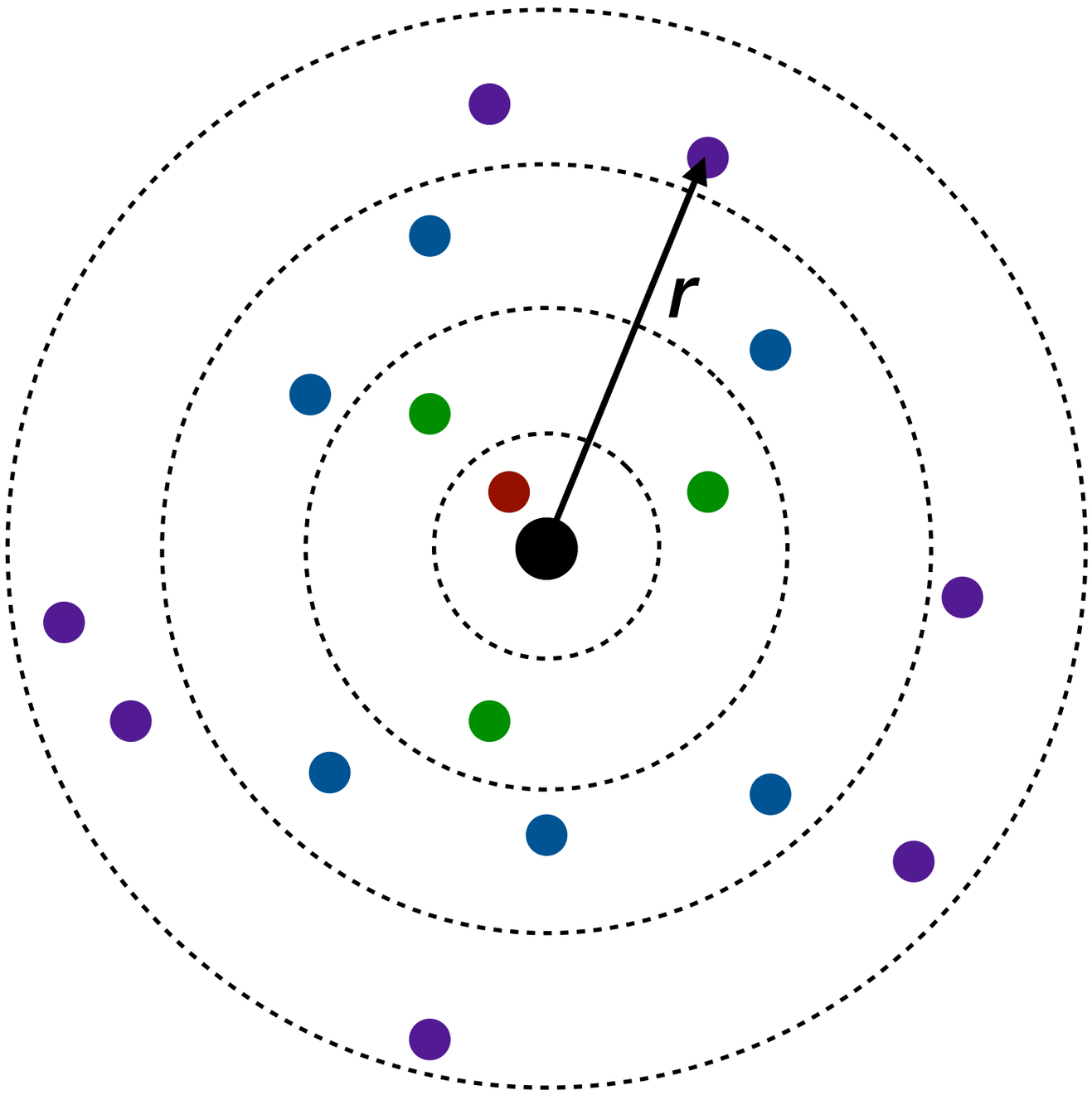


$$L_{||} = D_H(z)\Delta z = \frac{c\Delta z}{H(z)} \qquad L_\perp = \theta D_A(z) = \theta \frac{D_M(z)}{1+z}$$



Measuring BAO

- Correlation function ξ(R) from galaxy pairs



$$\xi(r) = \frac{DD(r)}{RR(r)} - 1$$

Measuring BAO

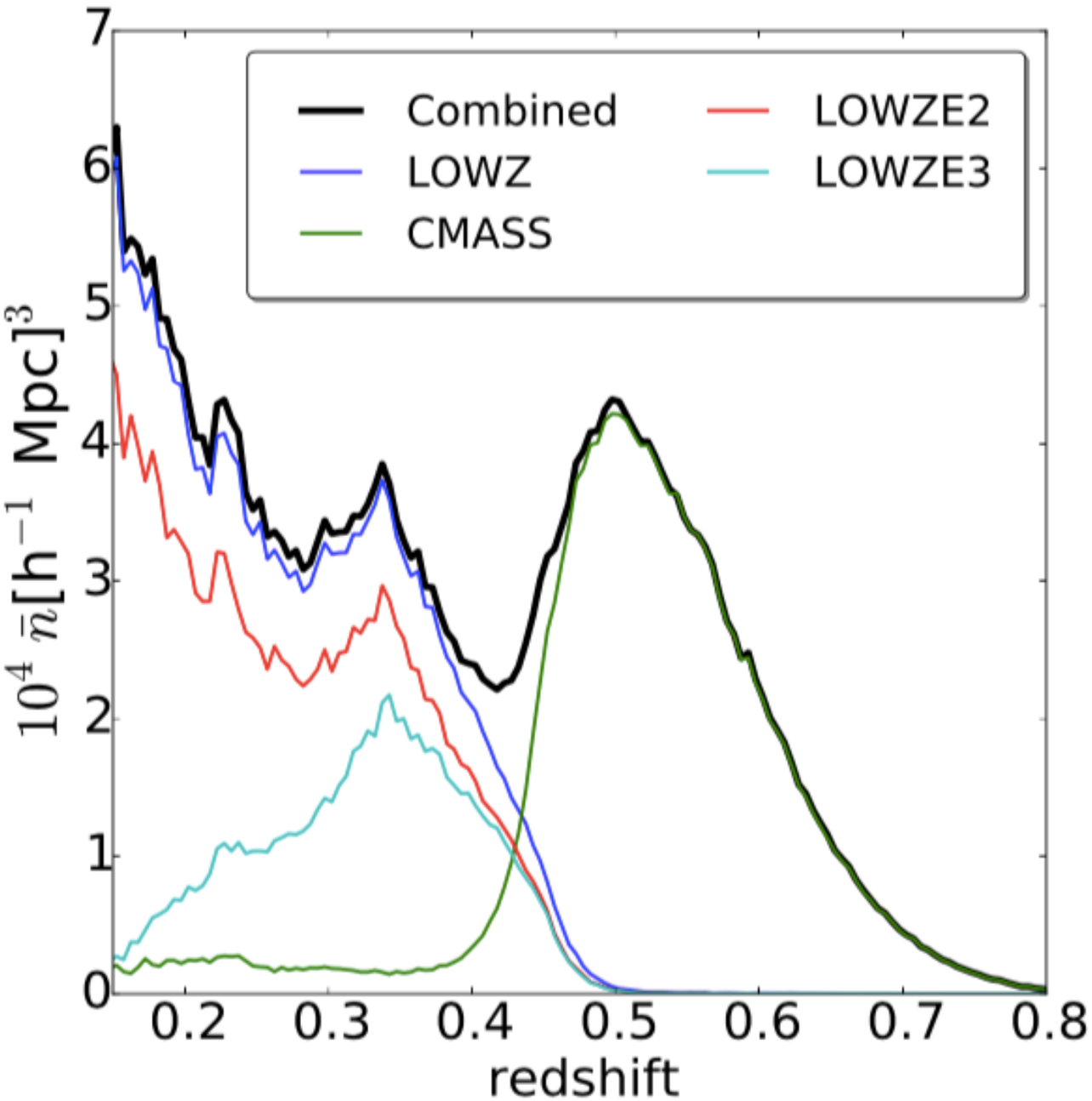


Figure Credit: Alam et al. (2017)

- Require **sufficient density** of spectroscopically observed galaxies
- Can we amplify the signal-to-noise for sparse samples?

BAO with Sparse Samples

- We can get very dense photometric galaxy samples
- Cross-correlating the sparse spectroscopy and dense photometry → a projected correlation function

Data

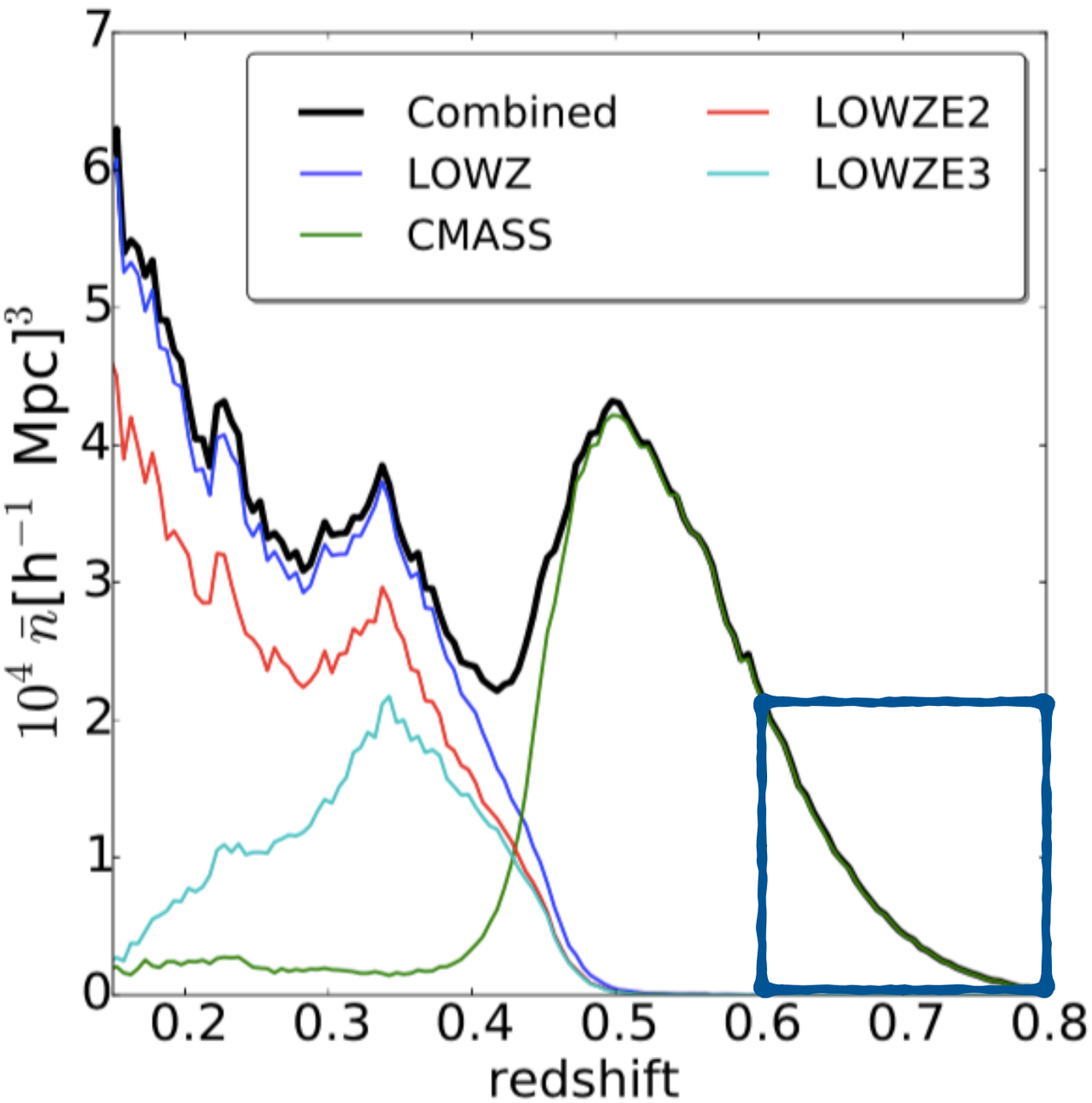


Figure Credit: Alam et al. (2017)

- Fairly sparse spectroscopic sample: the BOSS CMASS z > 0.6 tail

  ~200,000 galaxies

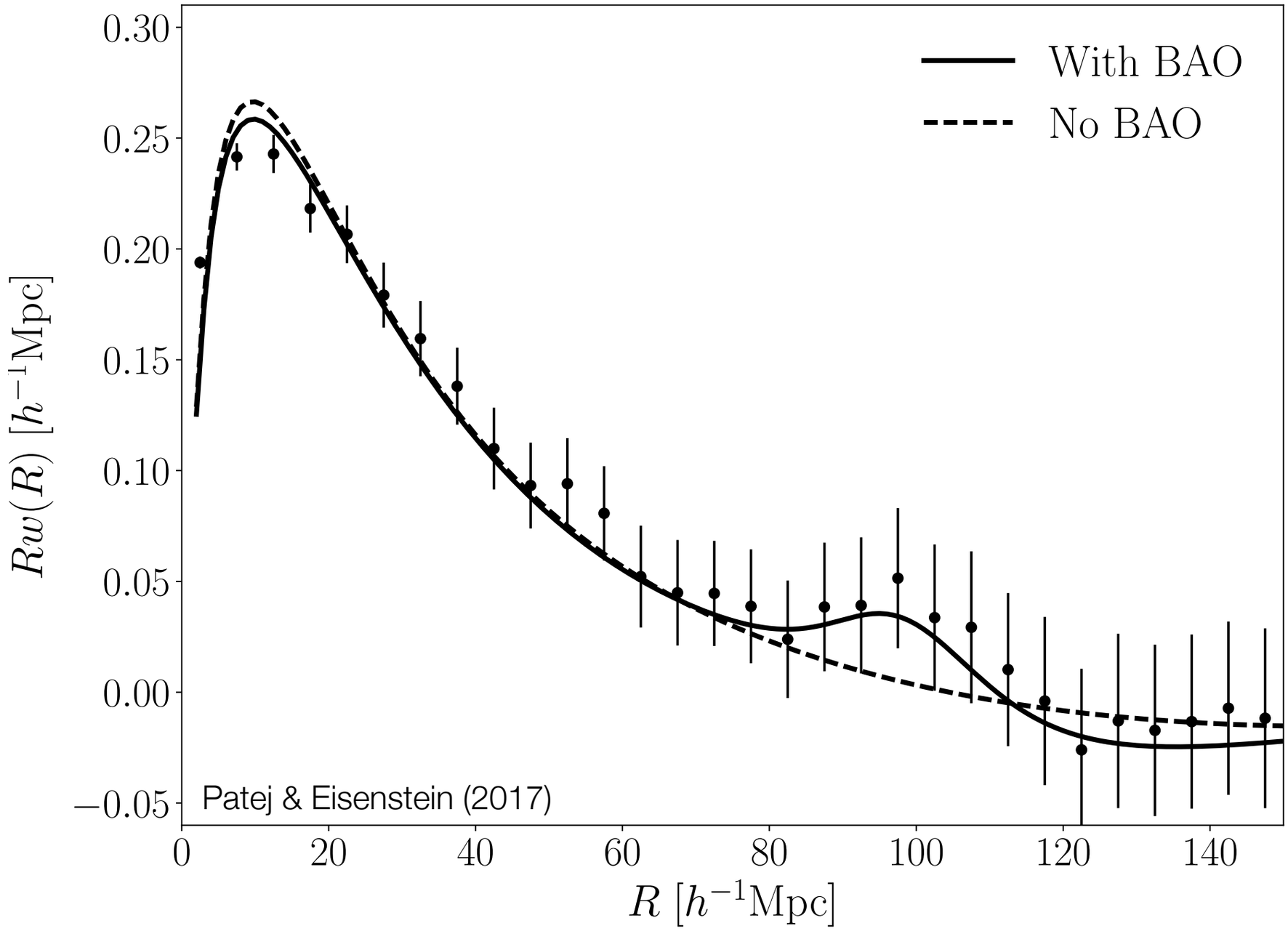
- Dense photometric sample: from SDSS DR9

  ~6.6 million galaxies

  (Law-Smith & Eisenstein 2017)

Results

- We find a ~2.8σ preference for the BAO in the cross-correlation at z = 0.64



Results

- Measured D_M at z = 0.64

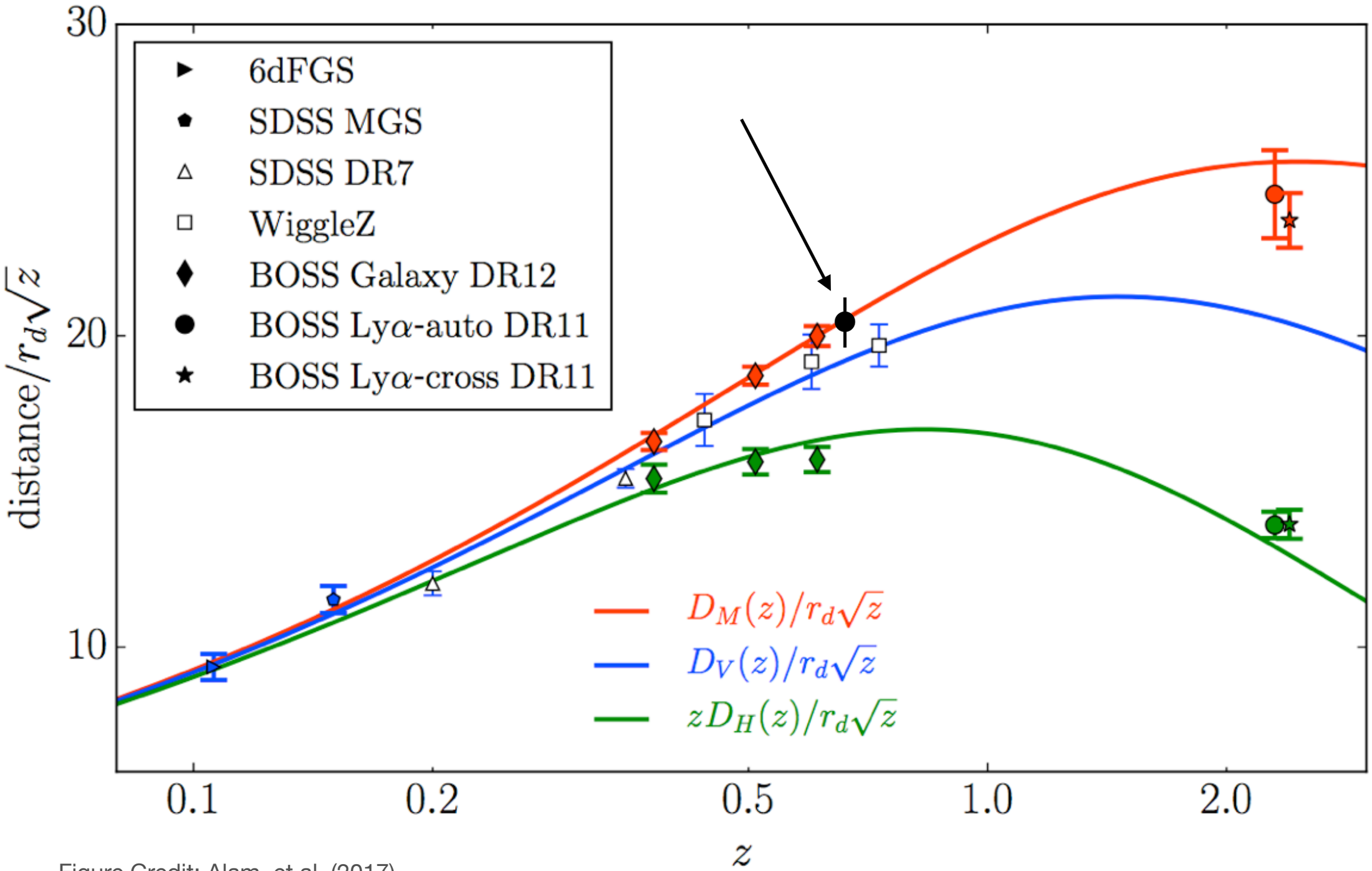


Figure Credit: Alam, et al. (2017)

Future Prospects

- The Dark Energy Spectroscopic Instrument (DESI) and DESI Imaging Surveys (legacysurvey.org):
  - DECam Legacy Survey (DECaLS)
  - Mosaic z-band Legacy Survey (MzLS)
  - Beijing-Arizona Sky Survey (BASS)

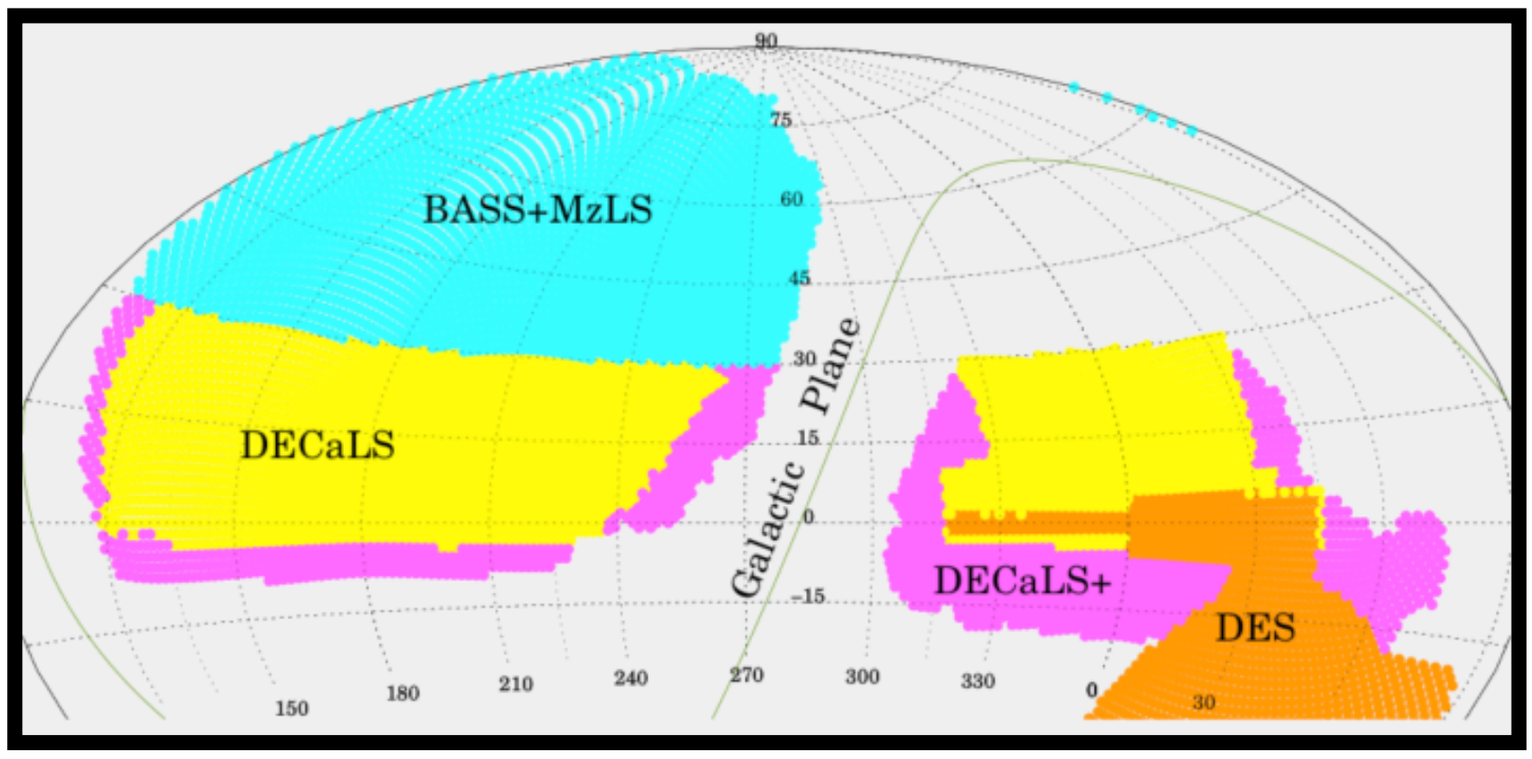


Image courtesy of A. Dey

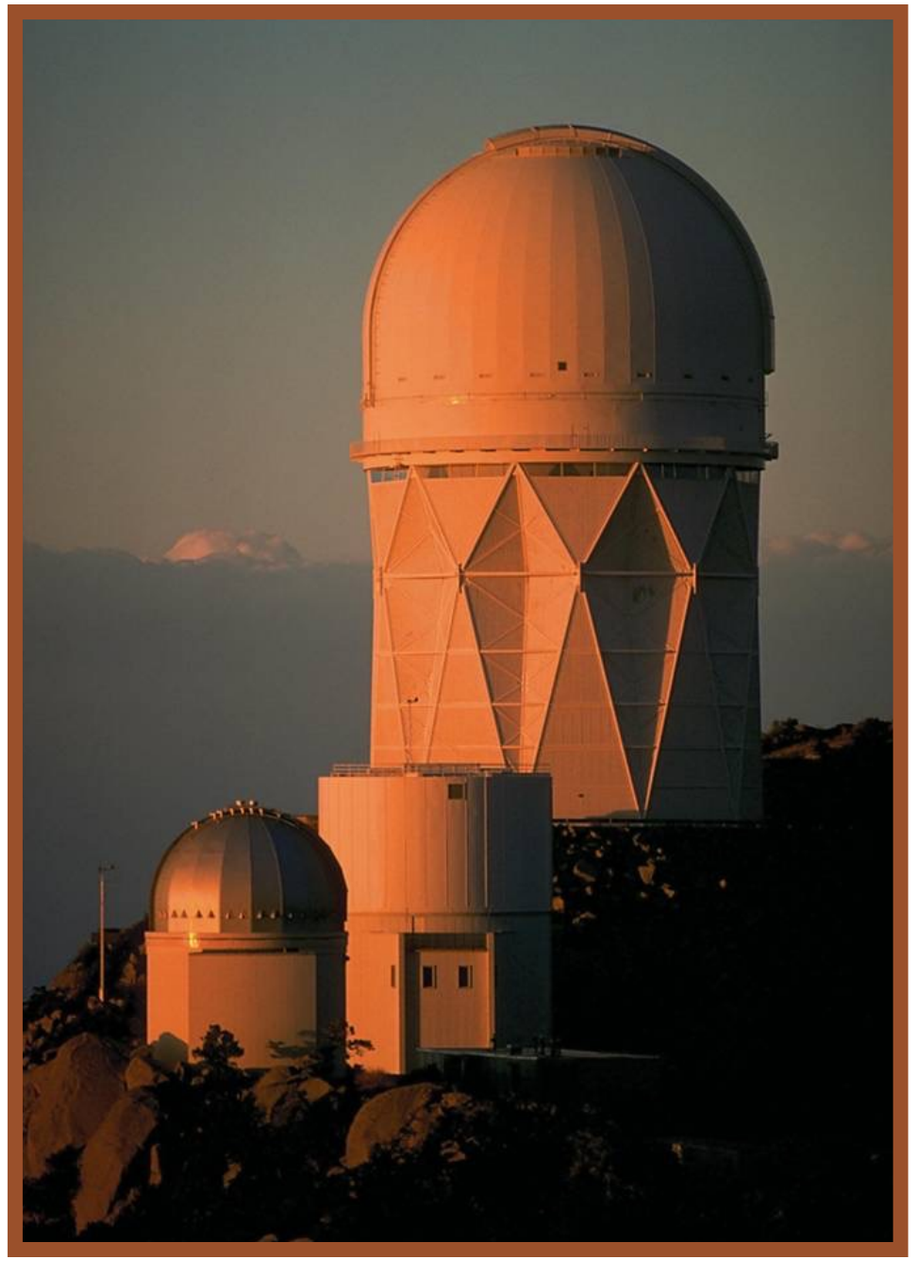


Photo Credit: NOAO/AURA/NSF

Imaging Surveys Photometry

- DESI imaging surveys are providing high quality images in *grz* that are 1-2 mag deeper than SDSS

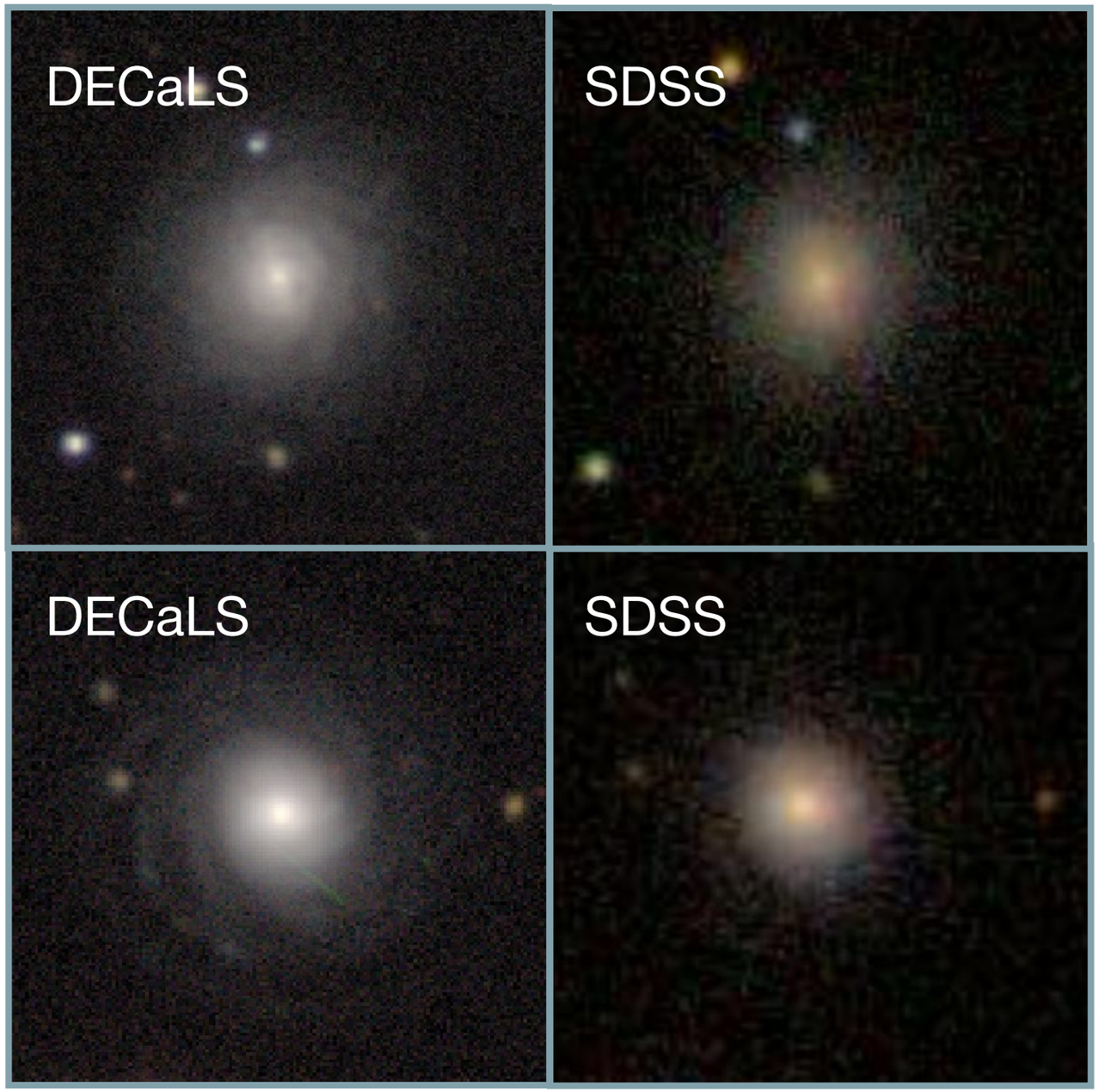


Image credits: Arjun Dey, Kyle Willett, & Galaxy Zoo: DECaLS

Future Prospects

- Possible sparse samples:
  - eBOSS quasars (Zhao et al. 2016)
  - *Euclid* OIII emission line galaxies at *z*~2 (Mehta et al . 2015)

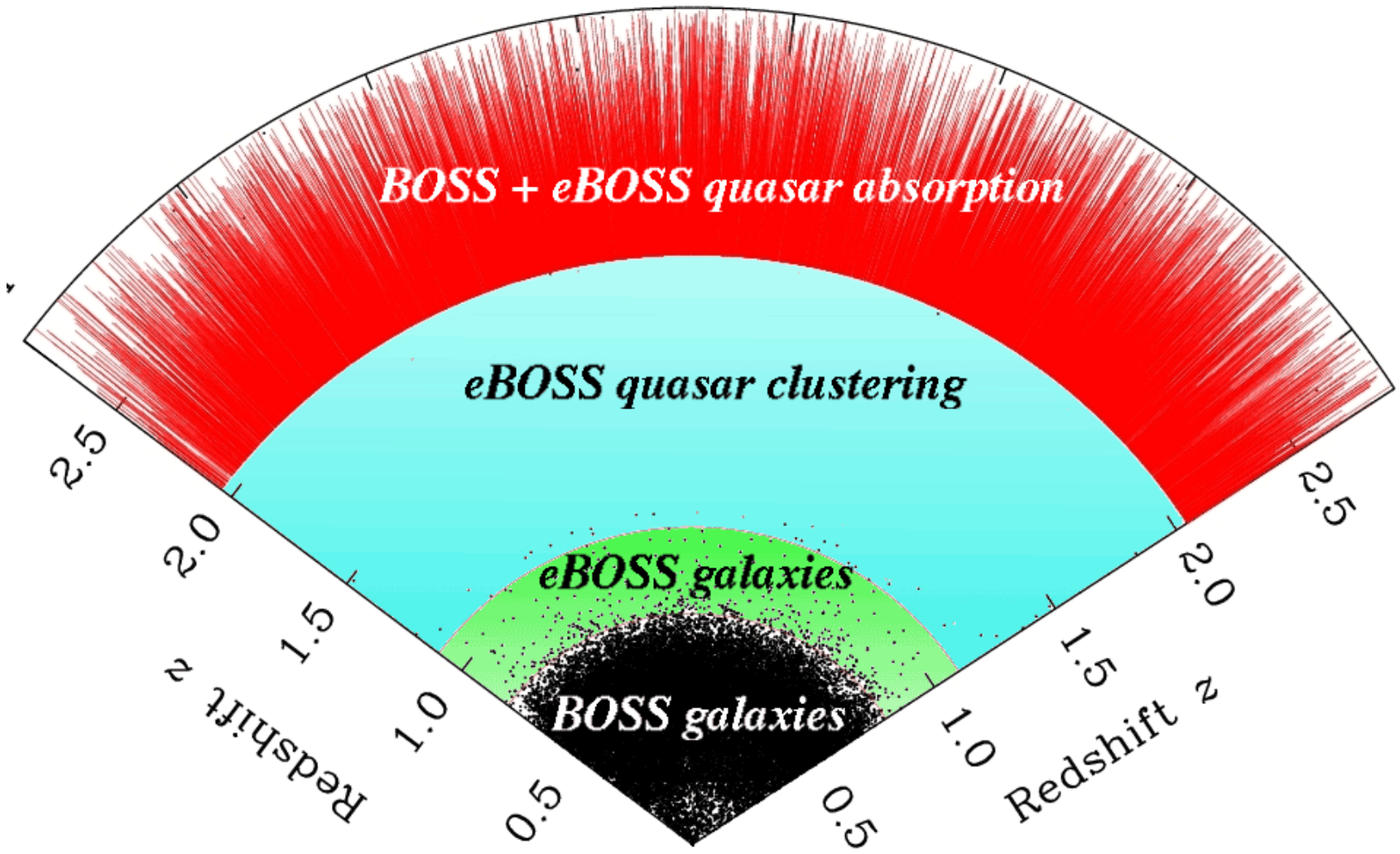


Image Credit: SDSS/eBOSS

Conclusions

- We found a 2.8σ preference for the BAO in the cross-correlation of a fairly sparse spectroscopic sample with a dense photometric sample and measured $D_M(z=0.64)$
- There are several possible future directions with different sparse samples, for example, applying this method to eBOSS quasars with DESI imaging surveys photometry

Thank you!