21cm-Galaxy Cross-correlation with Dark Energy Spectroscopic Instrument and Tianlai Cylinder Array

X

Cosmology Group at
Korea Astronomy and Space Science Institute

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Tianlai Collaboration Meeting - Balikun - 9/9/15

Outline

- Cosmology from 3D maps
  - Geometrical and dynamical universe
  - Constraints from SDSS BOSS galaxies

- DESI summary
  - Instrument and design
  - Targets and Survey Strategy

- DESI-TianLai synergy
  - what can we do?

Cosmology from 3D maps

Key observables in spectroscopic galaxy surveys:

(1) Angular diameter distance $\mathbf{D_A}$
- Exploiting BAO as standard rulers which measure the angular diameter distance and expansion rate as a function of redshift.

(2) Radial distance $\mathbf{H^{-1}}$
- Exploiting redshift distortions as intrinsic anisotropy to decompose the radial distance represented by the inverse of Hubble rate as a function of redshift.

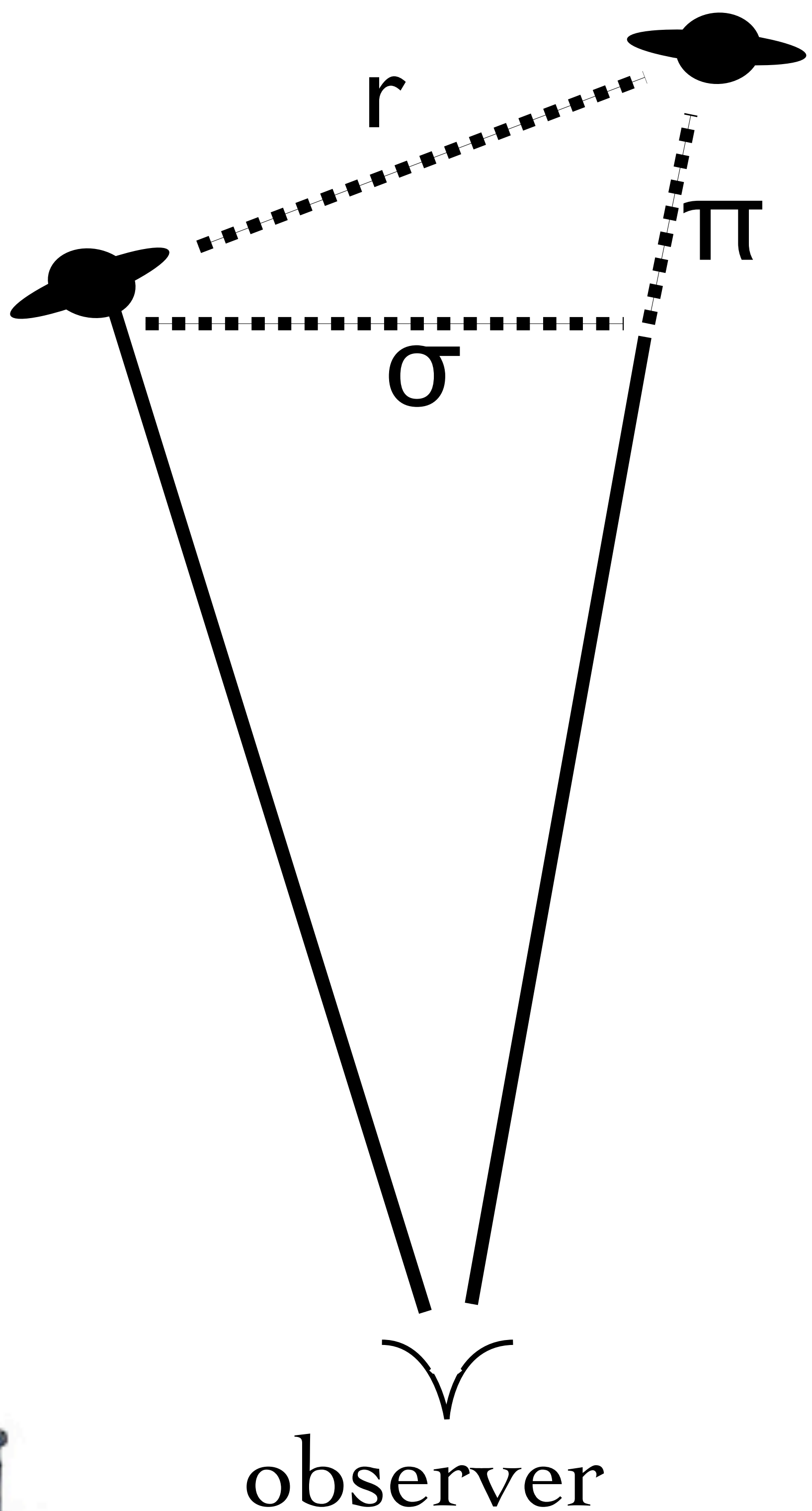
$$H(z) = H_0\sqrt{\Omega_m a^{-3} + (1-\Omega_m)a^{-3(1+w)}},$$

$$D_A(z) = \frac{1}{1+z}r(z) = \frac{1}{1+z}\int_0^z \frac{dz'}{H(z')},$$

(3) Growth Rate, f **(dδ/d ln a)**
- The coherent motion, or flow, of galaxies can be statistically estimated from their effect on the clustering measurements of large redshift surveys, or through the measurement of redshift space distortions.

These are essential to test theoretical models explaining cosmic acceleration; **ΛCDM, Dynamical DE, Einstein's gravity**

Cosmology from 3D maps



Bin galaxy pairs in two distances (π,σ) instead of the single distance between pairs, r.

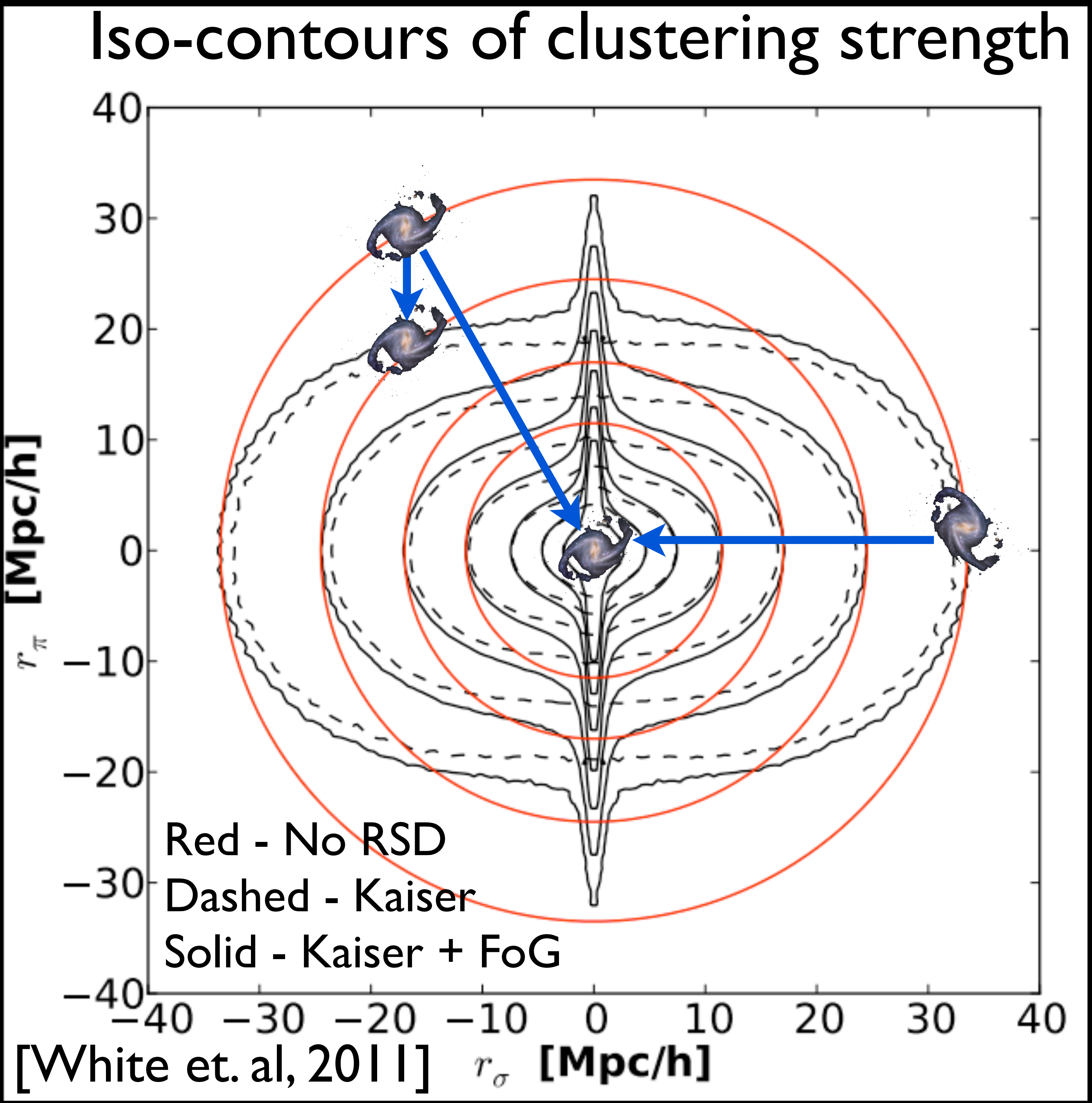
Apart from the binning this is the same as doing the 2PCF.

And if there are no preferred directions then the correlation function will give perfectly circular contours in (π,σ).

$$\xi(r) = \frac{DD - 2DR + RR}{RR}$$

Anisotropic Clustering

Probing the velocity field and growth rate with Redshift-Space distortions

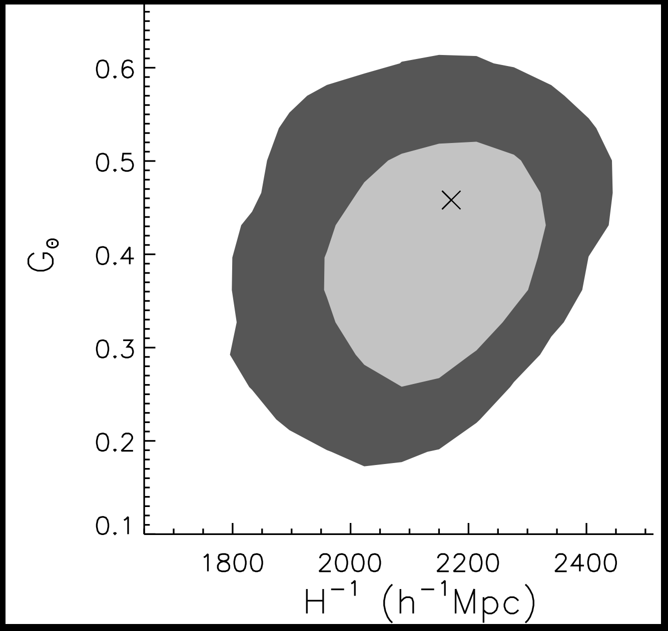


[White et. al, 2011]

- Peculiar velocities of galaxies distort our 3-D view of clustering making it look artificially anisotropic

- However this distortion encodes information about the velocity field of galaxies and the growth rate

- Utilizing the BAO feature and the Alcock-Paczynski effect, this single probe has the potential to probe the geometrical and dynamical universe, and ultimately test gravity!



Linder et. al, 2013
Song et. al, 2014

Cosmology from 3D maps

Theoretically the geometric distortions of the AP effect can be modeled exactly:

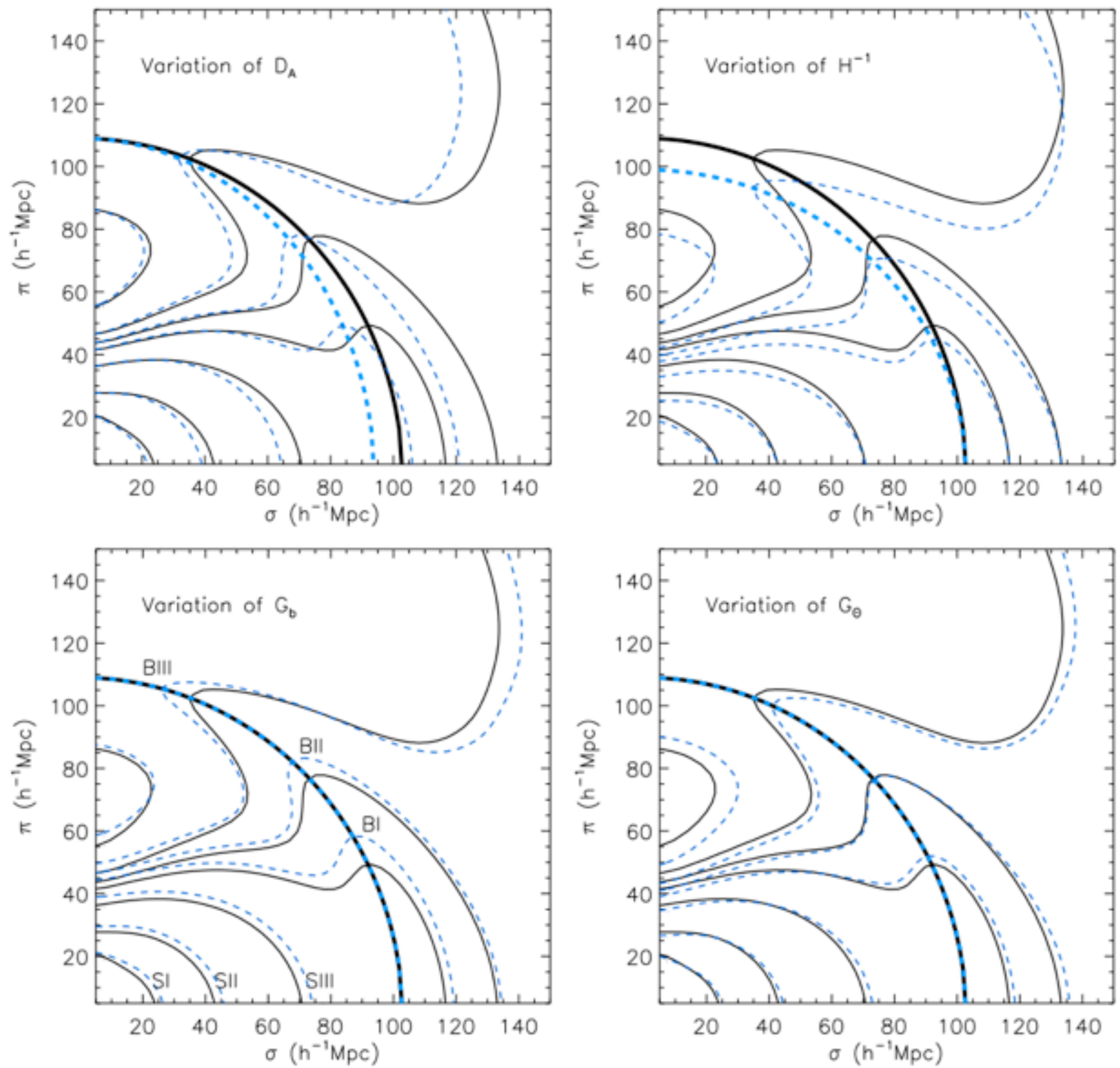
$$\xi^{\rm fid}(r_\sigma, r_\pi) = \xi^{\rm true}(\alpha_\perp r_\sigma, \alpha_\| r_\pi),$$

$$\alpha_\perp = \frac{D_A^{\rm fid}(z_{\rm eff})}{D_A^{\rm true}(z_{\rm eff})}, \qquad \alpha_\| = \frac{H^{\rm true}(z_{\rm eff})}{H^{\rm fid}(z_{\rm eff})},$$

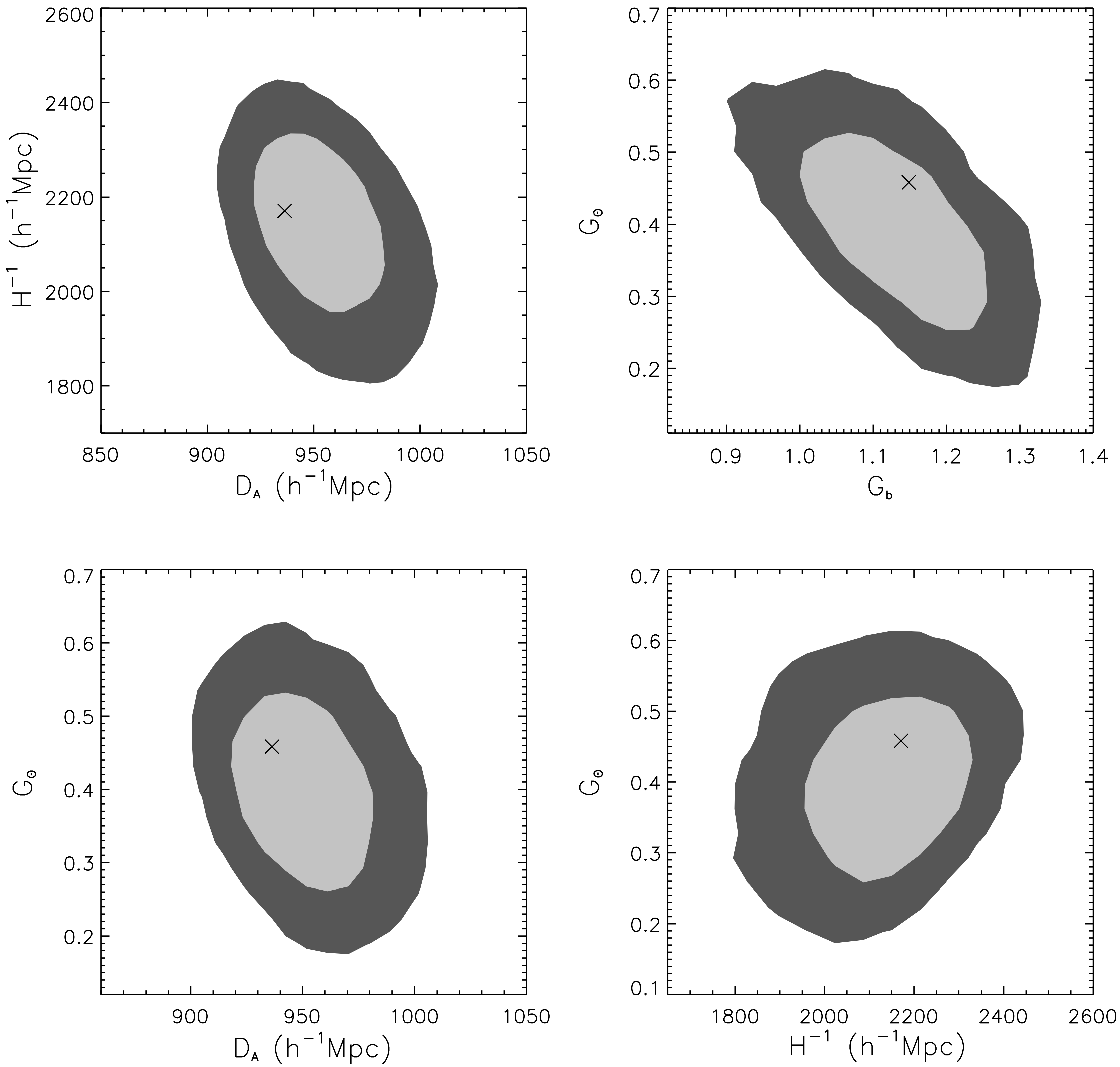
D_A, H vary peak positions off the BAO ring.

Bias and Growth rate G_b, G_θ, shift peak position along BAO ring. But display different behavior on and small and large mu.

These different shifting allows us to separate and constrain the various observables.



Cosmology from 3D maps



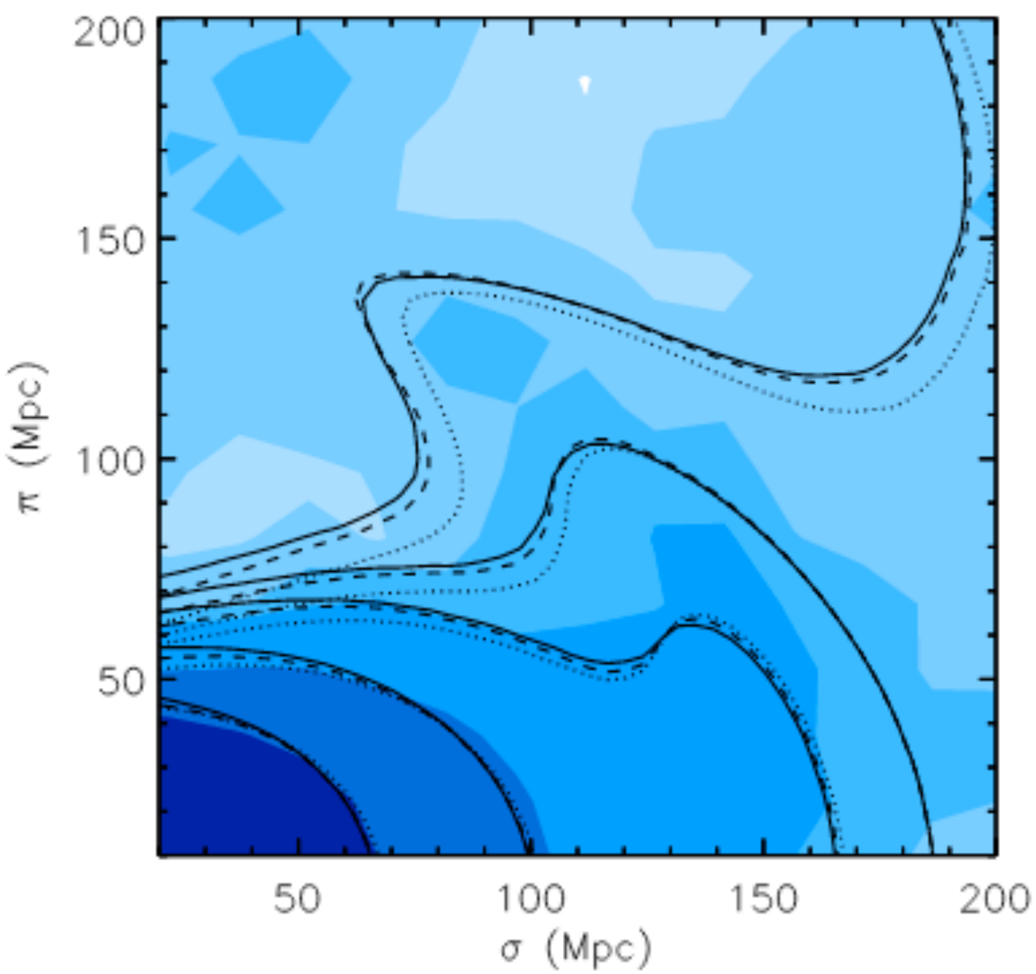
- Constrains from SDSS BOSS DR11

- Using PLANCK prior make model independent measurements of growth rate and geometrical quantities

- No deviation from “GR+LCDM” within observational limits

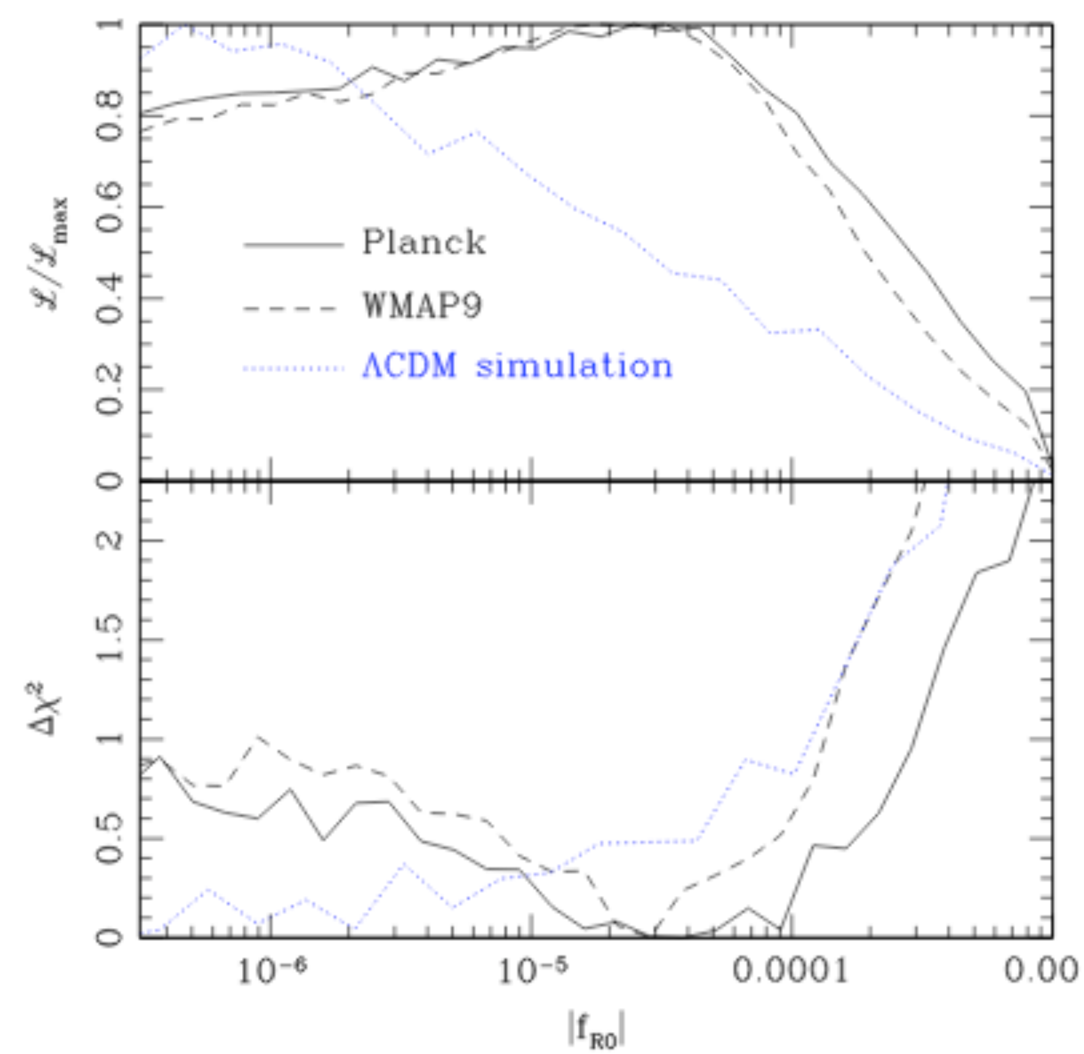
Song, Sabiu, etal (2014)
arXiv:1407.2257

Cosmology from 3D maps



Constraints on f(R) modified gravity from SDSS BOSS

Filled contours - DR11 data
Solid line - LCDM best fit
Dashed - $|f_{R0}|=3.2\times10^{-5}$
Dotted - $|f_{R0}|=3.0\times10^{-4}$



Slight preference for f(R) over pure GR+LCDM, but not significant.

Song, Sabiu, etal (2015)
arXiv:1507.01592

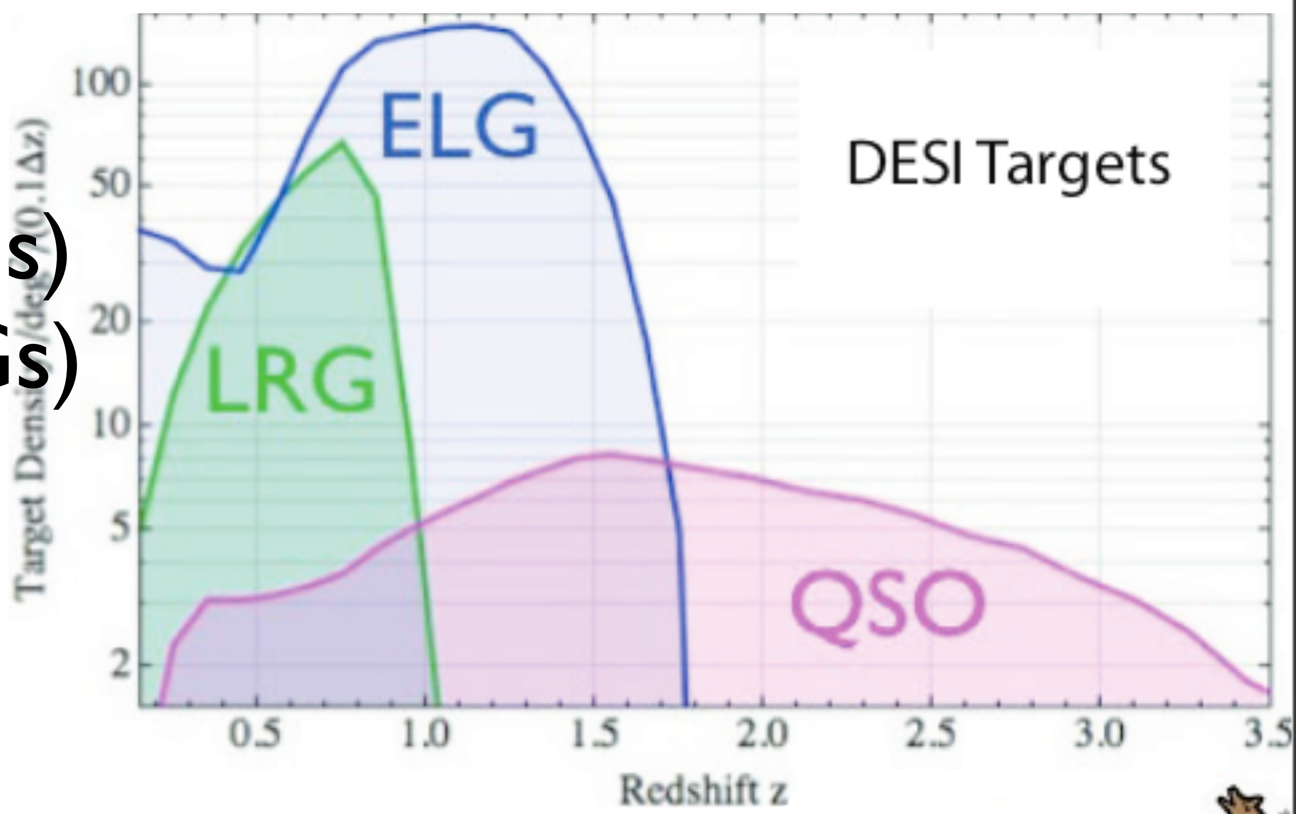
Next Generation Survey

The DESI (the Dark Energy Spectroscopic Instrument) project was formed in 2012 from the merger of the BigBoss and the DESpec wide field multi-object spectrograph concepts.

The DESI collaboration is led by LBNL and has 21 US Universities, 5 DOE labs, 19 foreign institutions, totaling >180 collaborators.

Will produce the measurements of BAO by performing a spectroscopic survey over 14,000 sq. degrees out to redshifts of 3.5

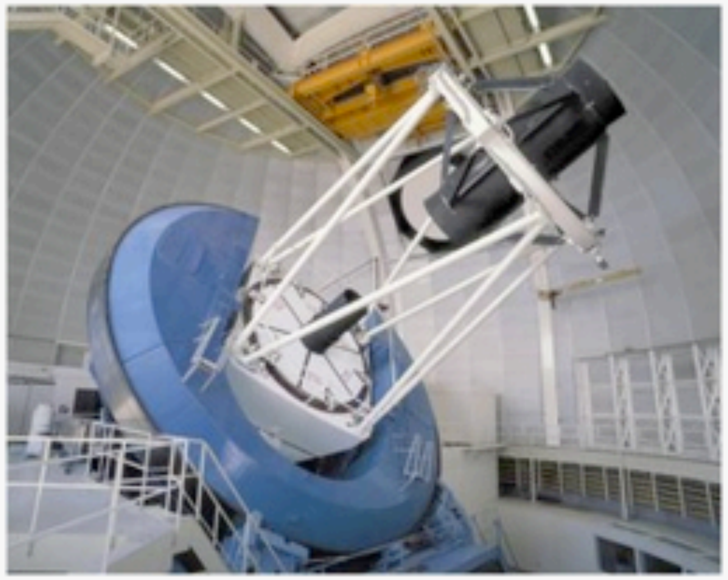
- 4M Luminous Red Galaxies (LRGs)
- 23M Emission Line Galaxies (ELGs)
- 1.4M quasars (QSO)
- 0.6M quasars at z>2.2 for Lyman-alpha-forest



DESI Survey

DESI will be conducted on the Mayall 4-meter telescope at Kitt Peak National Observatory starting in 2018. DESI is supported by the Department of Energy Office of Science to perform this Stage IV dark energy measurement using baryon acoustic oscillations and other techniques that rely on spectroscopic measurements.

Exterior of Kitt Peak Mayall 4-meter telescope (Image: NOAO/AURA/NSF)

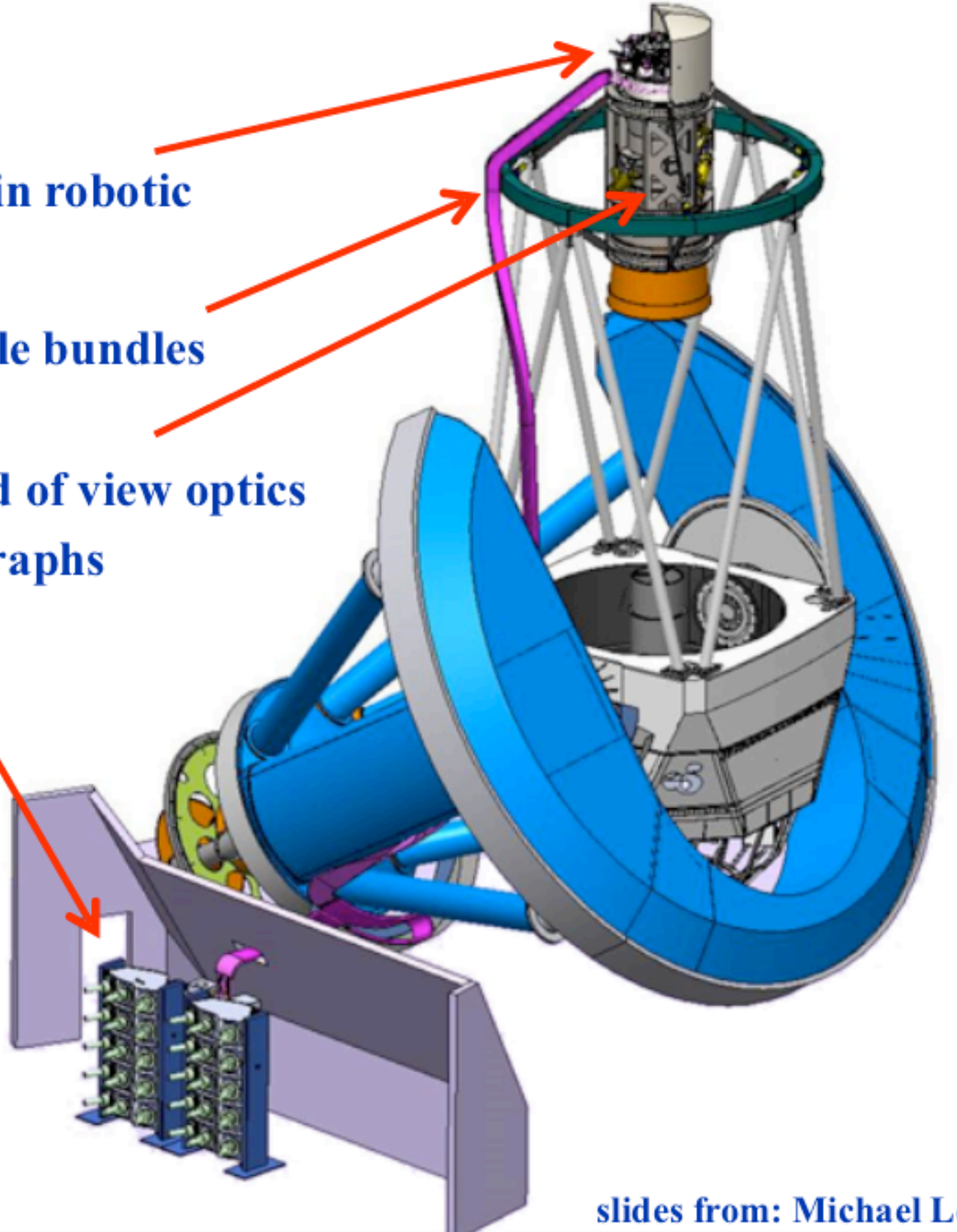


The Kitt Peak National Observatory's Mayall 4-meter telescope (Image: NOAO/AURA/NSF)

A model of the Mayall telescope with a DESI Prime Focus Assembly

DESI

- 5000 fibers in robotic actuators
- 10 fiber cable bundles
- 3.2 deg. field of view optics
- 10 spectrographs



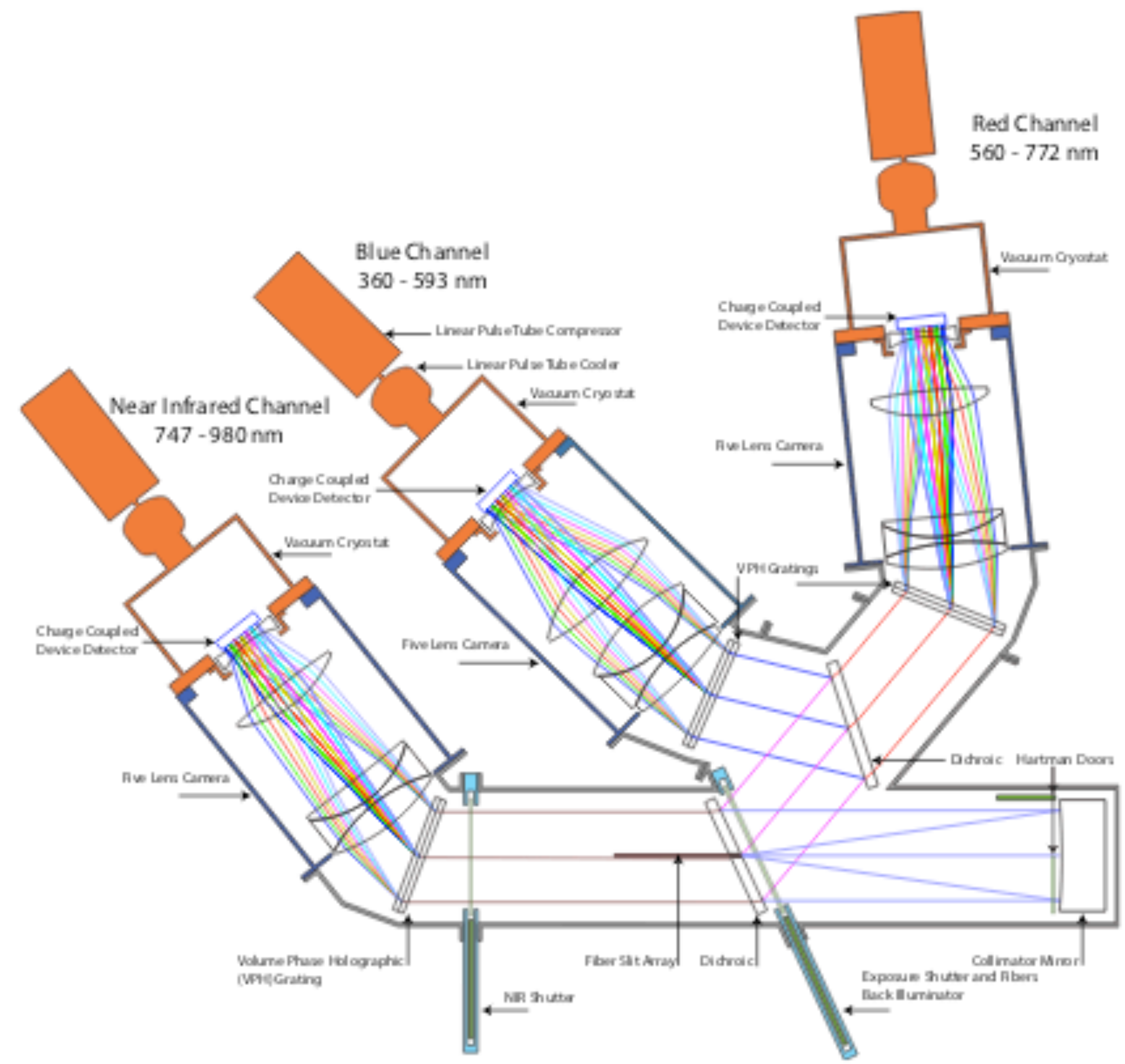
Mayall 4m Telescope
Kitt Peak
Tucson, AZ

Readout
& Control

slides from: Michael Levi (LBNL)

DESI Survey

The spectrograph design was finalized last year. The three arms cover wavelength range from 360 nm to 980 nm with resolution R =l/dl= 2000 - 5500 depending on wavelength, meeting or exceeding the DESI requirements.



The 1st spectrograph fabrication has started and will be complete this year

Each unit serves 500 fibers
One of ten units

DESI Survey

first light in less than 4 years

1. An imaging (targeting) survey over 14,000 deg2

g-band to 24.0 mag

r-band to 23.6 mag

z-band to 23.0 mag

2. A spectroscopic survey over 14,000 deg2

10 million Bright Luminous Galaxies

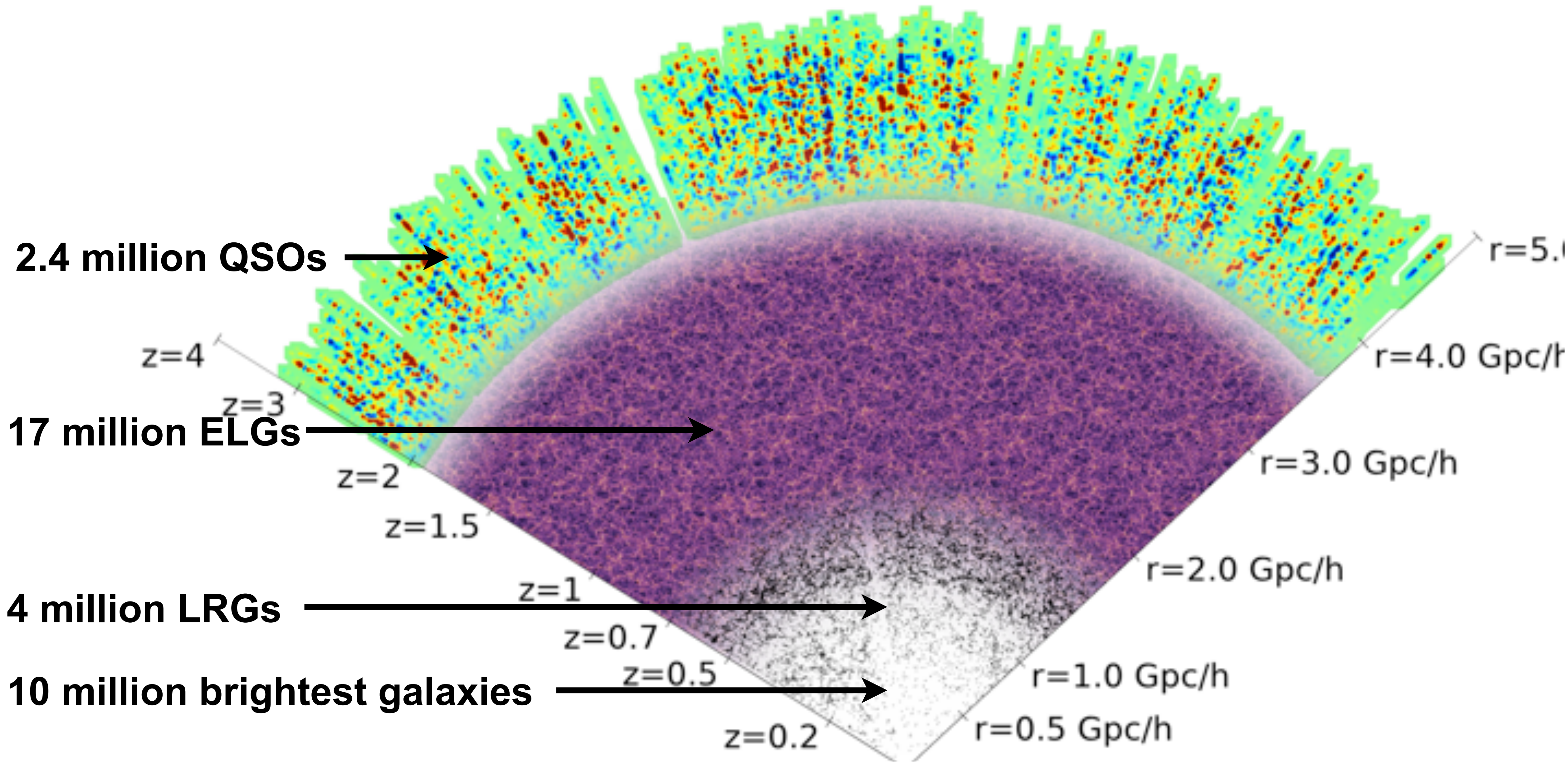
4 million Luminous Red Galaxies
23 million Emission Line Galaxies
1.4 million quasars
0.6 million quasars at z>2.1 for Lyman-alpha-forest

Last year, none of the imaging survey was secure
Today, mostly secured and in progress as public surveys

DESI Survey

The largest spectroscopic survey for dark energy

SDSS ~$2h^{-3}Gpc^3$ ⇨ BOSS ~$6h^{-3}Gpc^3$ ⇨ DESI $50h^{-3}Gpc^3$



Survey Sources

- South:
  - 6200 sq. deg. of SDSS footprint south of dec=+30 and excluding areas covered by DES, plus 500 sq. deg. from DES
  - Allocated 65 nights with Blanco/DECam in 2014B-2017A
  - g, r, z-bands
  - First public data release DR1 on March 18, 2015
- North:
  - Bok Telescope using 90Prime instrument
    - 5500 sq. deg.
    - Survey started
    - g, r-bands
  - Mayall 4m using Mosaic 3 instrument
    - Focal plane upgrade to Mosaic 1.1 instrument (from CTIO)
    - 5500 sq. deg. to start in 2016
    - z-band
- **Combined imaging: g=24.0, r=23.6, z=23.0**

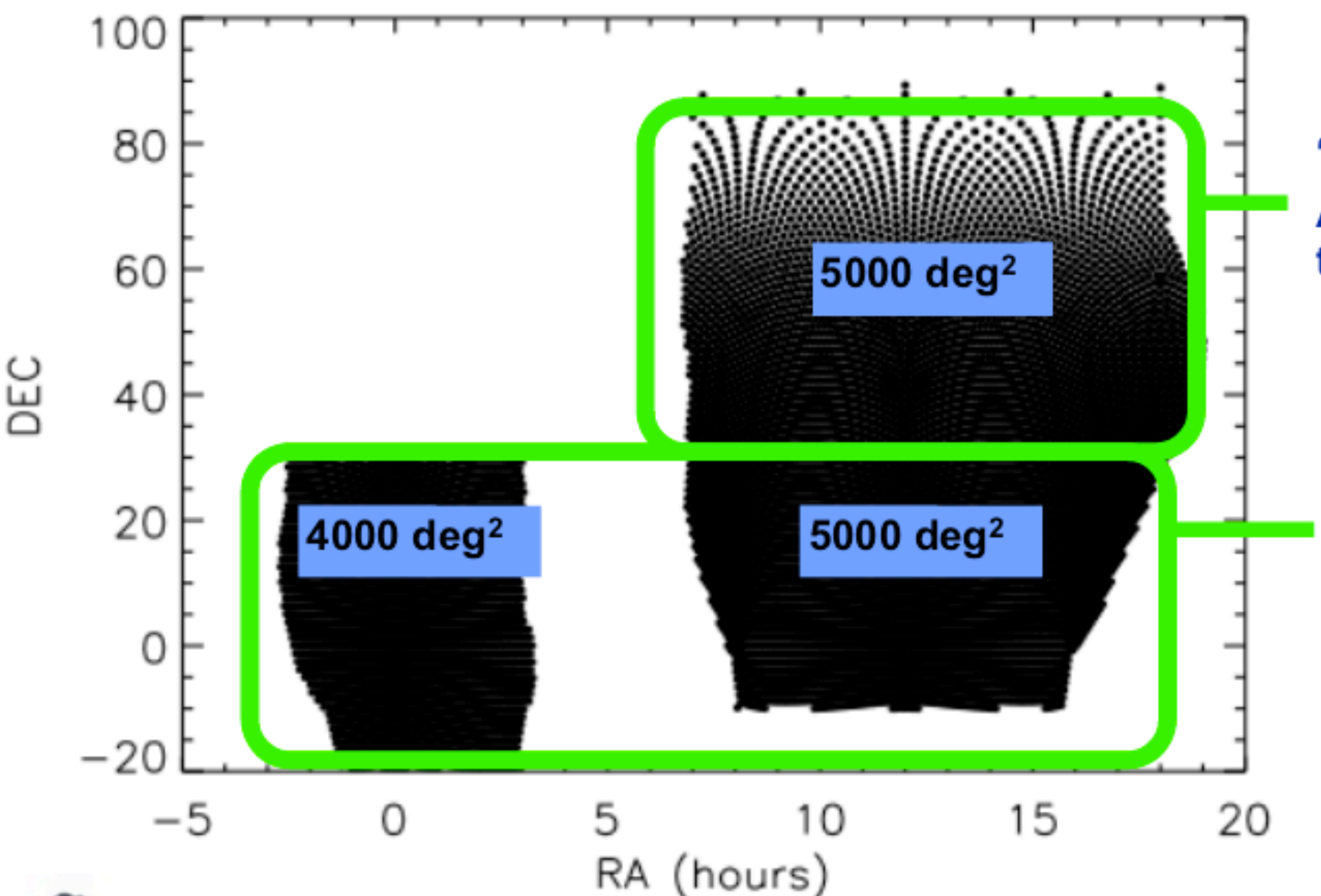
  (compare to SDSS g=22.2, r=22.2, z=20.5)

slides from: Michael Levi (LBNL)

Survey Area

Main survey areas now selected.
Exact survey strategy still to be decided.

Tianlai could drive a change



"North cap":

Accessible from Northern telescopes only

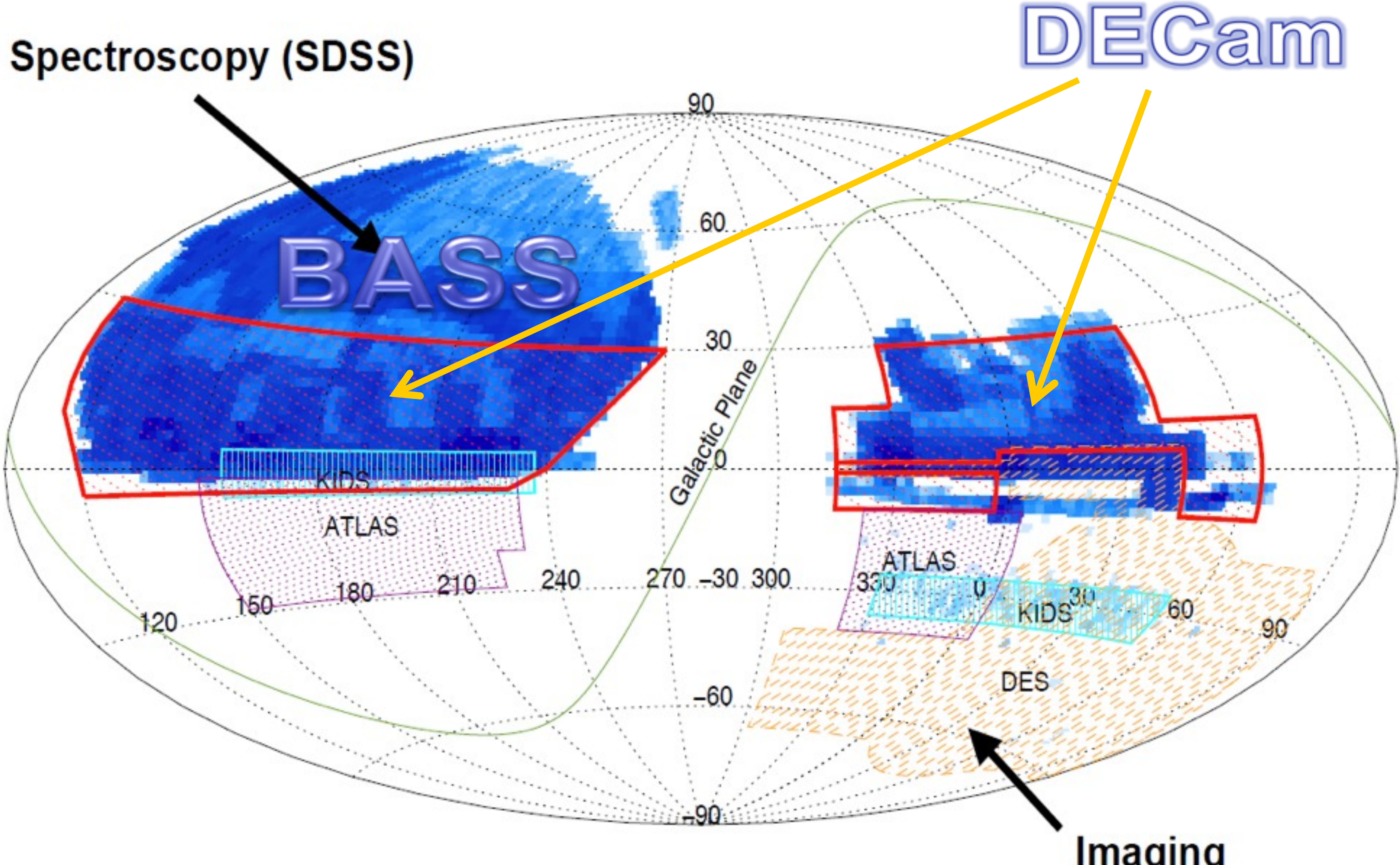
Observing gr bands with Bok
Plan to observe z with upgraded z band on Mayall.

"Equatorial":

Accessible from Northern or Southern telescopes

Observing grz with DECam.
Approved project for 6700 sq. degrees.

Survey Area



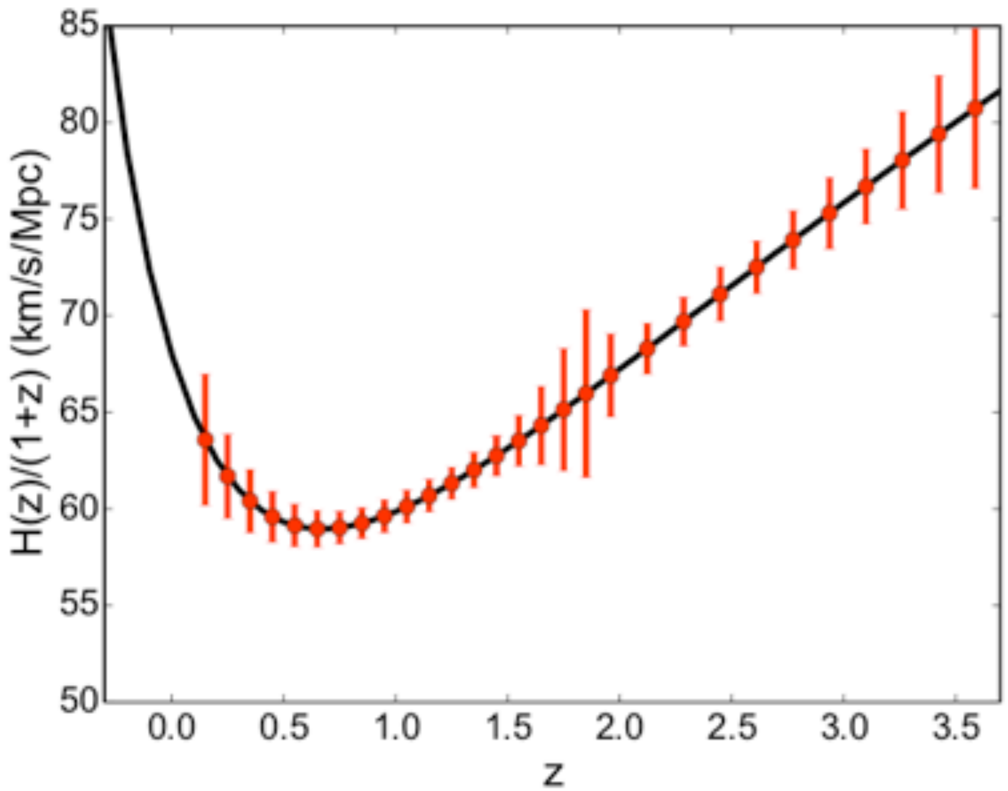
CREDIT: ZHOU Xu

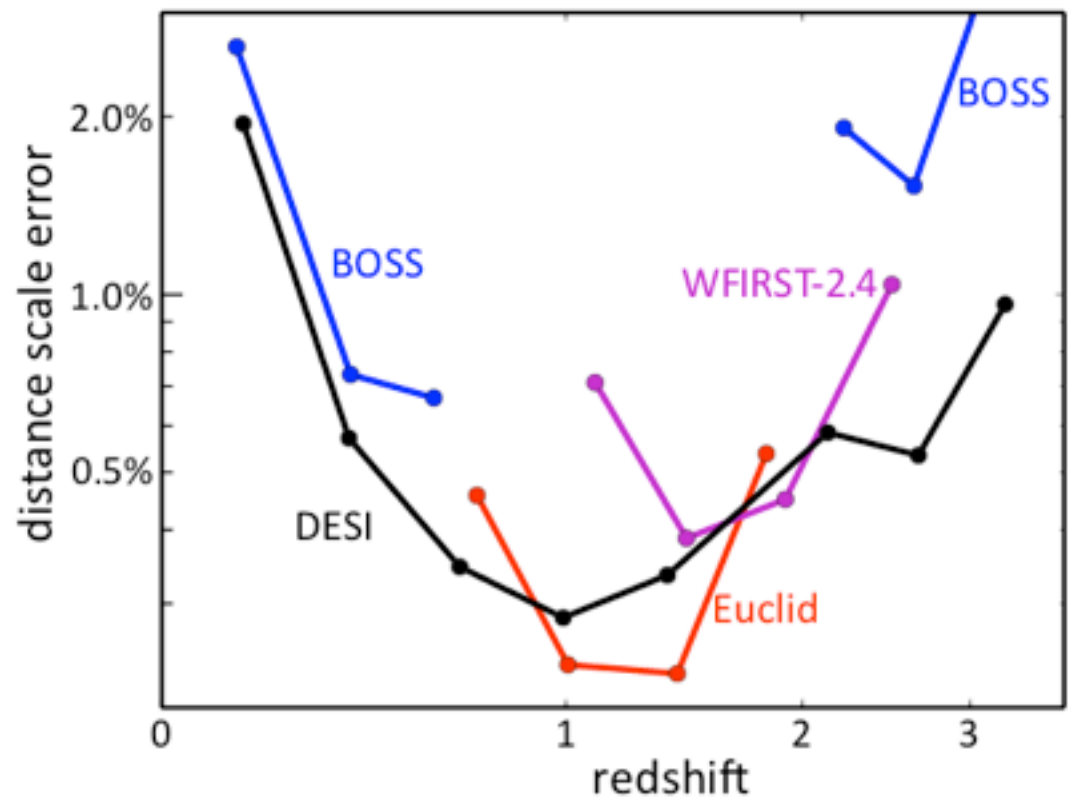
Survey Timeline

DESI Data Assemblies and Milestones

Imaging Surveys	2015--2018	Imaging DA Q3 2018
Prep for SV	2015--2018	December 2018
Science Verification	April--Oct 2019	SV DA March 2020
Season 1	Oct 2019--July 2020	DA1 Jan 2021
Papers on DA1		Nov 2021
Season 2	Aug 2020--Dec 2020	DA2 July 2021
Papers on DA2		April 2022
Season 6 (full data)	-- Dec 2024	DA6 July 2025
Final Cosmology Results		April 2026

DESI Expectation





DESI will produce a world leading survey of the the cosmic distance scale.

Will measure distance scale to better than 0.3% statistical errors.

Systematic uncertainties on H(z) and DA(z) of less than 0.2%

DESI - TianLai synergy

Cross-correlating optical galaxies with 21cm intensity maps

- Galaxy surveys and 21cm radio intensity mapping are very different!

- Depend on very different noise contributions and systematics

- Useful for understanding systematics and foregrounds?

- Once we have key observational parameters (overlap area, array size, integration time...) we can perform Fisher matrix

  - will update in November telecon

Thank you!