SDSS-III: The Baryon Oscillation Spectroscopic Survey (BOSS)

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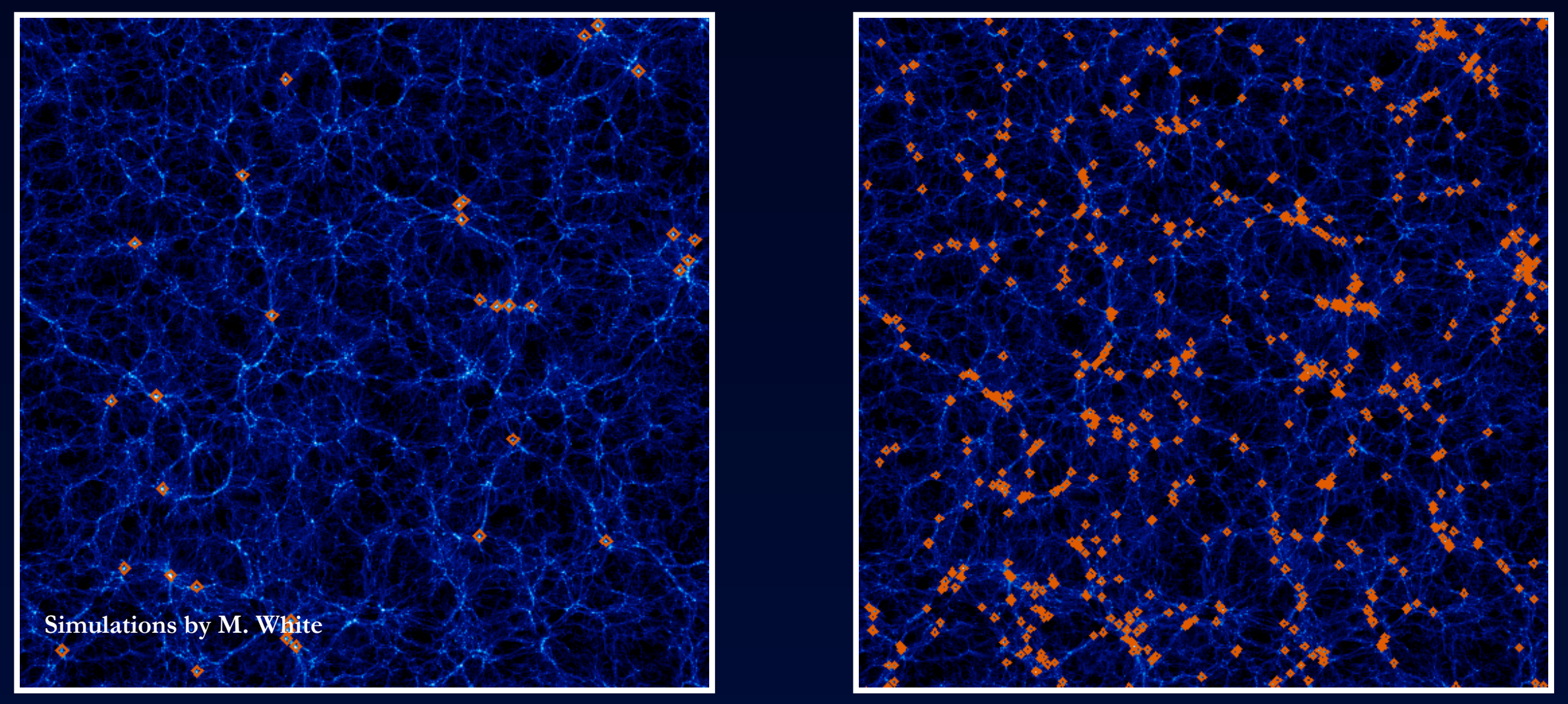
BOSS aims to measure baryon oscillations in the clustering of luminous red galaxies at redshifts < 0.7, as well as make a first detection in the Lyman-alpha forest at a redshift of 2.5. Using baryon oscillations as a standard ruler, BOSS will measure the distance to z = 0.3 and 0.6 to 1%, and to z = 2.5 to 1.5%. These precision distance measures will allow us to improve constraints on the nature of dark energy by a factor of three. In addition, BOSS will be a scientifically rich data set, improving our knowledge on subjects as diverse as the evolution of massive galaxies, the nature of the intergalactic medium, and properties of quasars at high redshift.

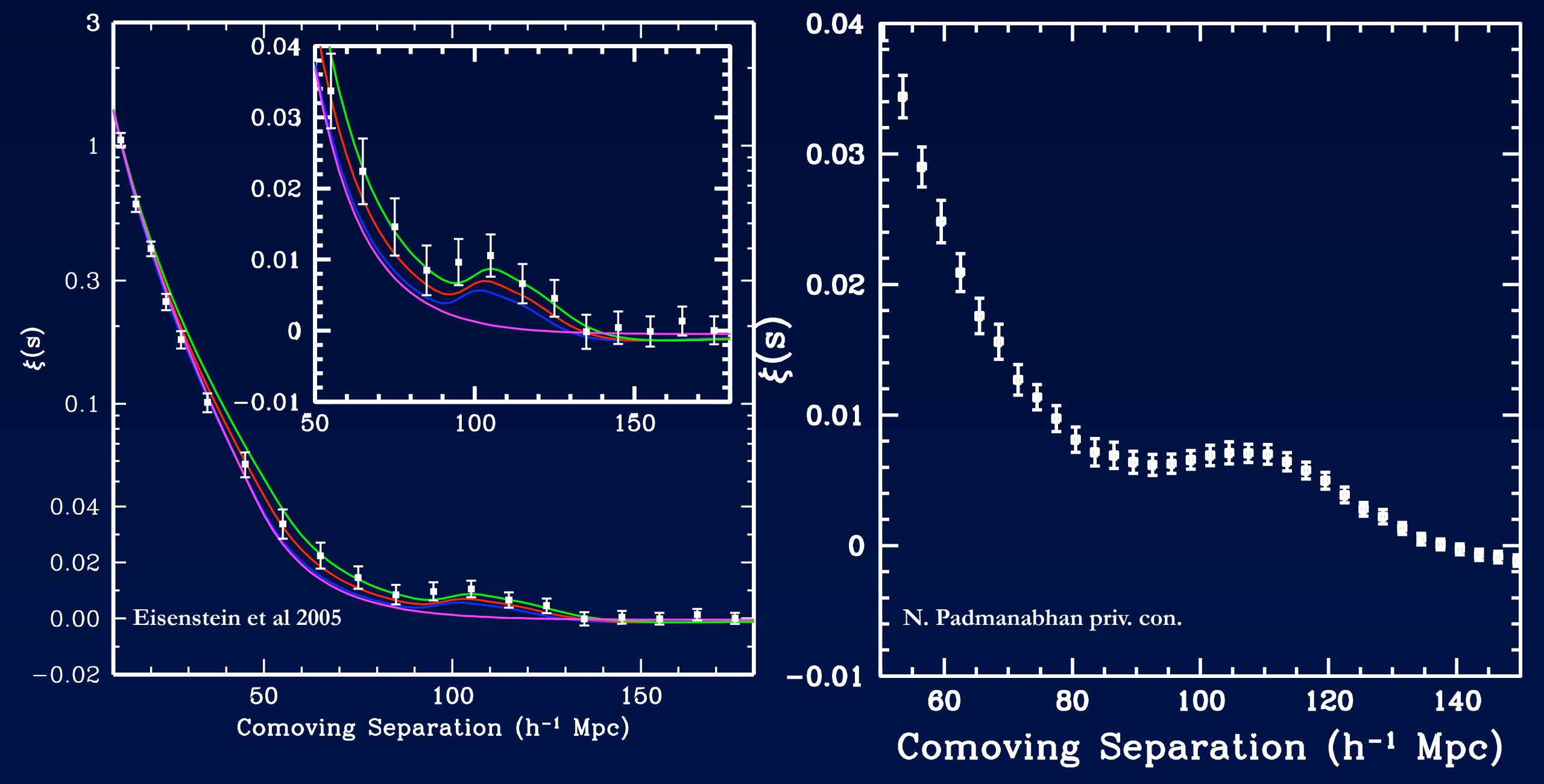
Spectroscopic LRG Survey

1.5 million galaxies, i<20, z<0.7, over 10,000 deg^2

As in SDSS-I, we will use the multi-color SDSS imaging to select the high redshift luminous red galaxies (LRGs). By increasing the targeting depth to i=20, the volume will be increased by 5X and the sampling density by 3X. The higher sampling density also enables a reconstruction of the predicted velocity field, allowing us to ``back out" some of the late-time, nonlinear effects of gravitational collapse.



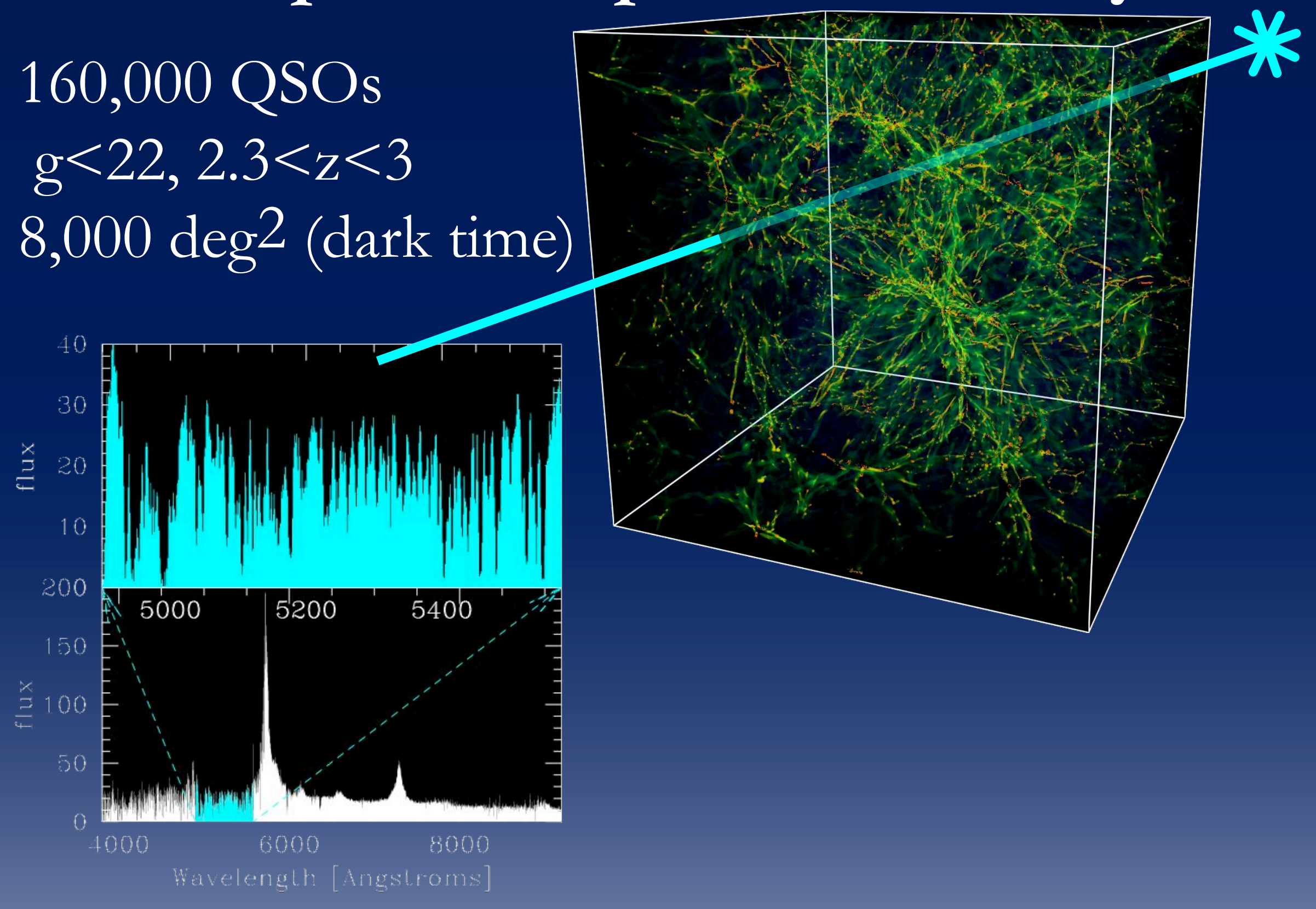
SDSS-II at z= 0.5 BOSS at z= 0.5



Left: The large-scale redshift-space correlation function of the SDSS LRG sample. Models are $\Omega_m h^2 = 0.12$ (green), 0.13 (red), 0.14 (blue), all with $\Omega_b h^2 = 0.024$ and n=0.98 and with a mild non-linear prescription folded in. The magenta line shows a pure CDM model $\Omega_m h^2$ =0.105. Right: Projected correlation function for BOSS LRG.

Spectroscopic QSO Survey

160,000 QSOs
g<22, 2.3<z<3
8,000 deg^2 (dark time)

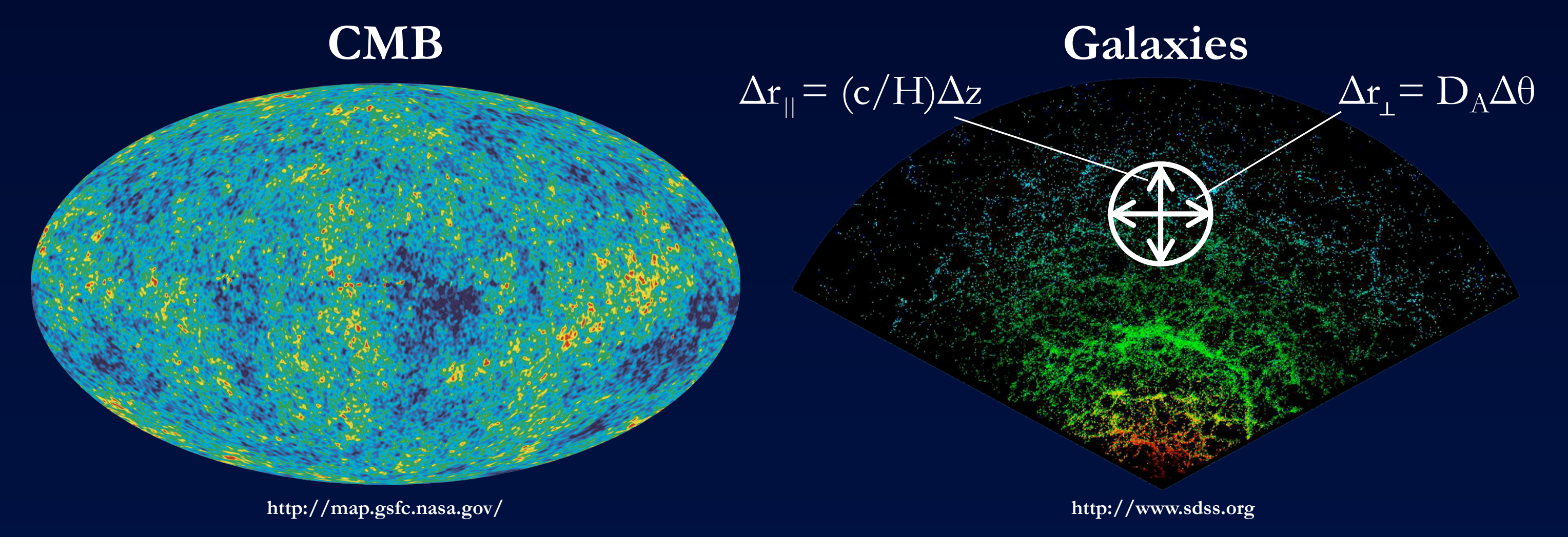


The Ly-alpha forest of QSOs will be used to construct a 3-D density map of the hydrogen gas at 2.2 < z < 3. The Ly-alpha optical depth is closely tied to the underlying dark matter density, so correlations in the flux can be used to measure correlations in the dark matter. Each QSO spectrum gives data on hundreds of points in space, and the dense grid of QSOs allow the reconstruction of the 3-D density field. The measurement is insensitive to QSO continuum errors, which should be uncorrelated across sightlines. The QSO survey will be carried out in parallel with the LRG survey using the same spectroscopic plates and exposures.

Baryon Acoustic Ocillations

The past decade has been one of extraordinary progress in cosmology, with perhaps the most startling discovery being that the expansion of the universe is accelerating. Going beyond the detection of acceleration to informative constraints on its origin require measurements of cosmic expansion with percent-level precision and exquisite control of systematic uncertainties. According to a report from the Dark Energy Task Force (DRTF), baryon acoustic oscillations (BAO) are believed to be the method "least affected by systematic uncertainties, and for which we have the most reliable forecasts of resources required to accomplish a survey of chosen accuracy."

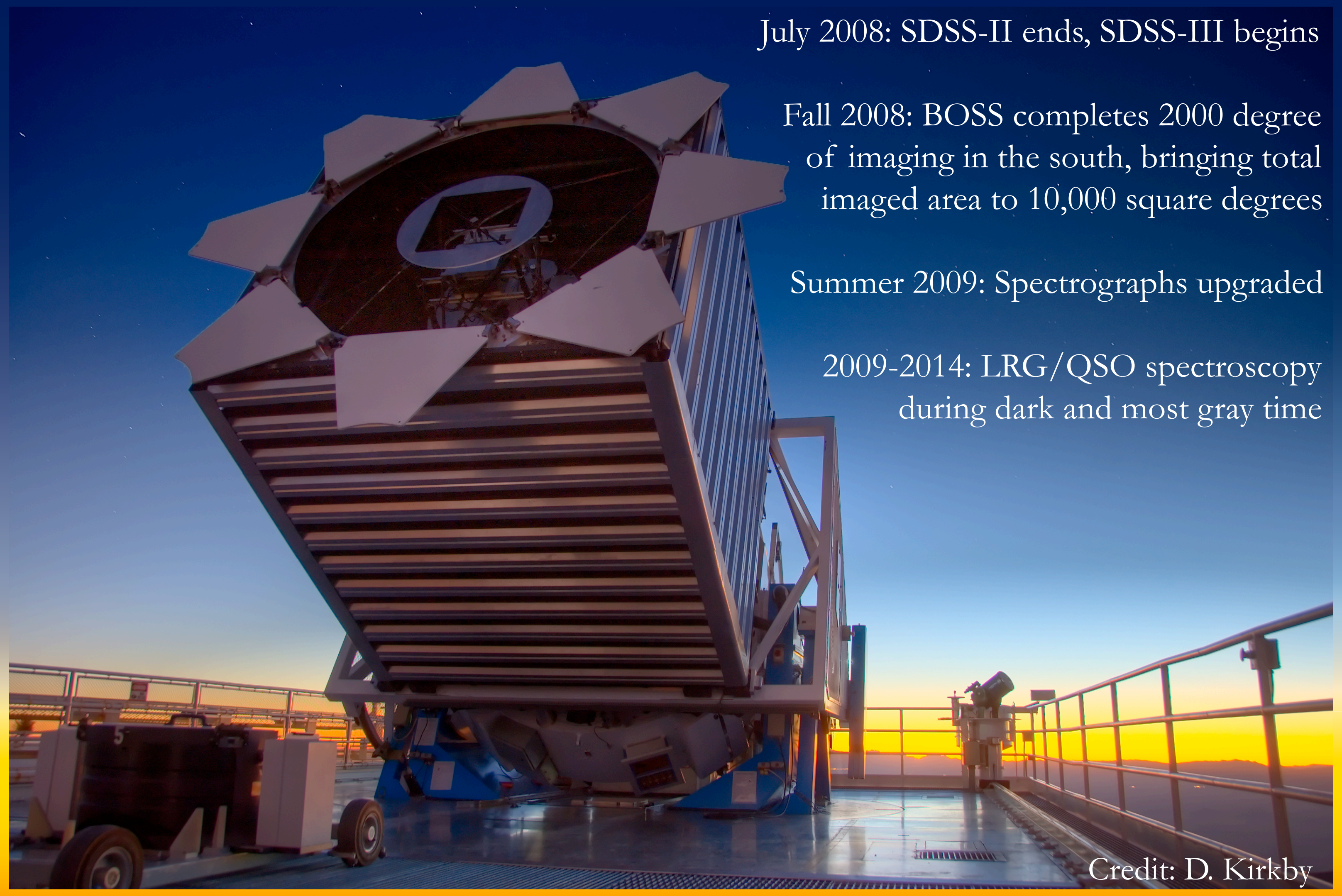
Sound waves that propagate in the opaque early universe imprint a characteristic scale in the clustering of matter, providing a standard ruler whose length can be computed using straightforward physics and parameters that are tightly constrained by cosmic microwave background (CMB) observations. Measuring the angle subtended by this scale determines a distance to that redshift and constrains the expansion rate. The detection of acoustic oscillation scale is one of the signature accomplishments of SDSS.



By measuring the acoustic scale along and across the line of sight one can measure two cosmological distances, the Hubble parameter H(z) and the angular diameter distance $D_A(z)$, at the redshift(s) of the survey. As they are tied to the CMB, the calibration of these measurements in absolute units (e.g. meters or Mpc) is independent of the Hubble constant, in contrast to measurements based on supernovae or other distance indicators calibrated in the local Hubble flow.

Hardware Upgrade and Survey Timeline

	Current (SDSS-II)	**Modified (SDSS-III)**
Number of Fibers	640	1000
Fiber Diameter	180 μm = 3 arcsec	120 μm = 2 arcsec
CCDs	SITe 2K x 2K 24 μm	red: LBNL, blue: e2v : 4K x 4K 15 μm
Grating	blue: 640, red: 440 lines/mm grism	VPH
λ coverage	blue: 3850-6000, red: 5800-9200 Å	blue: 3700-6000, red: 5800-9800 Å
Resolution	1800	blue: 2000, red: 2400



July 2008: SDSS-II ends, SDSS-III begins

Fall 2008: BOSS completes 2000 degree of imaging in the south, bringing total imaged area to 10,000 square degrees

Summer 2009: Spectrographs upgraded

2009-2014: LRG/QSO spectroscopy during dark and most gray time

Credit: D. Kirkby

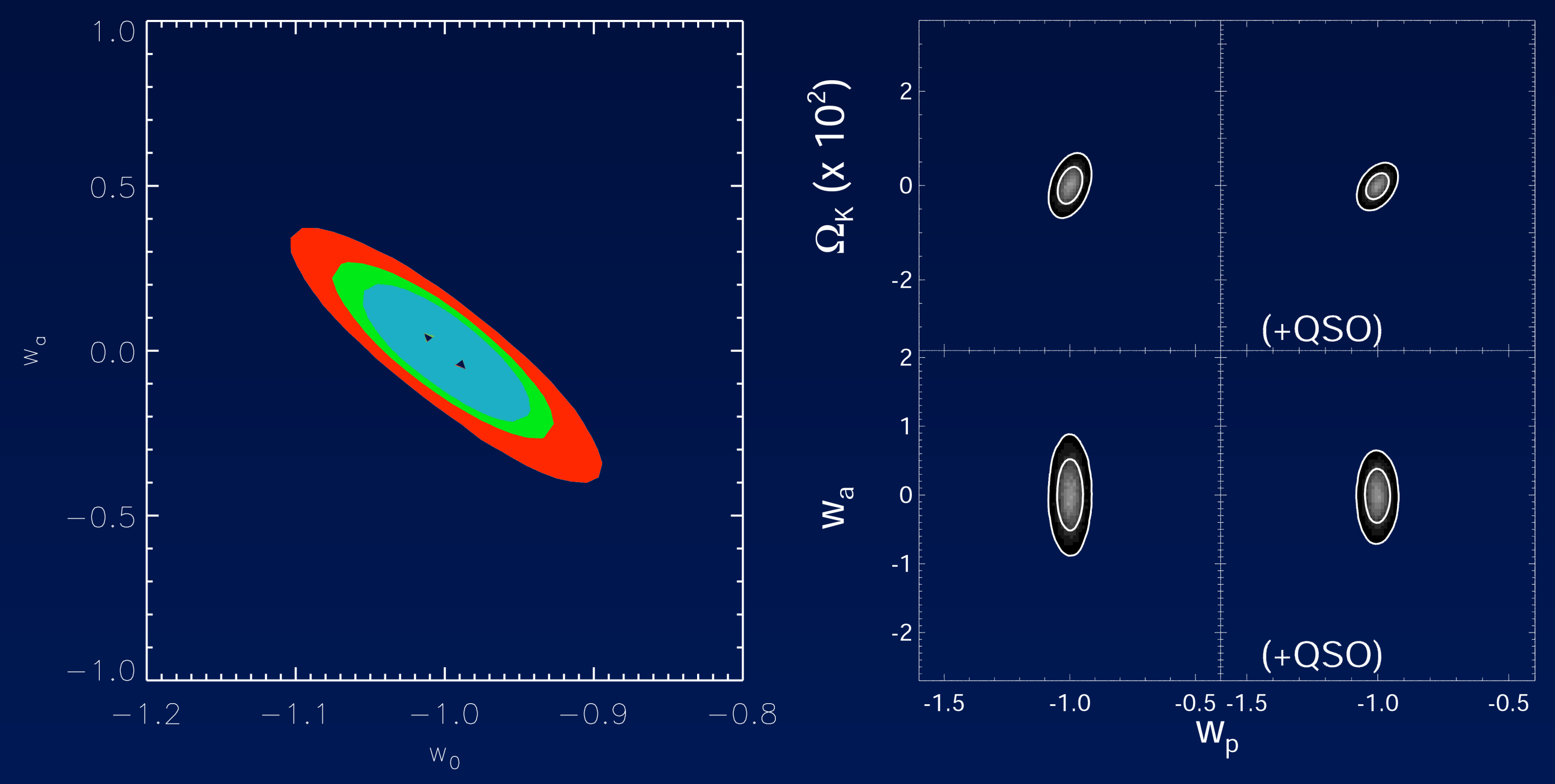
The Apache Point Observatory 2.5-meter Telescope

Dark Energy Constraints

$$\mathrm{FoM} \equiv \frac{1}{\sigma(w_0)\sigma(w_a)}$$

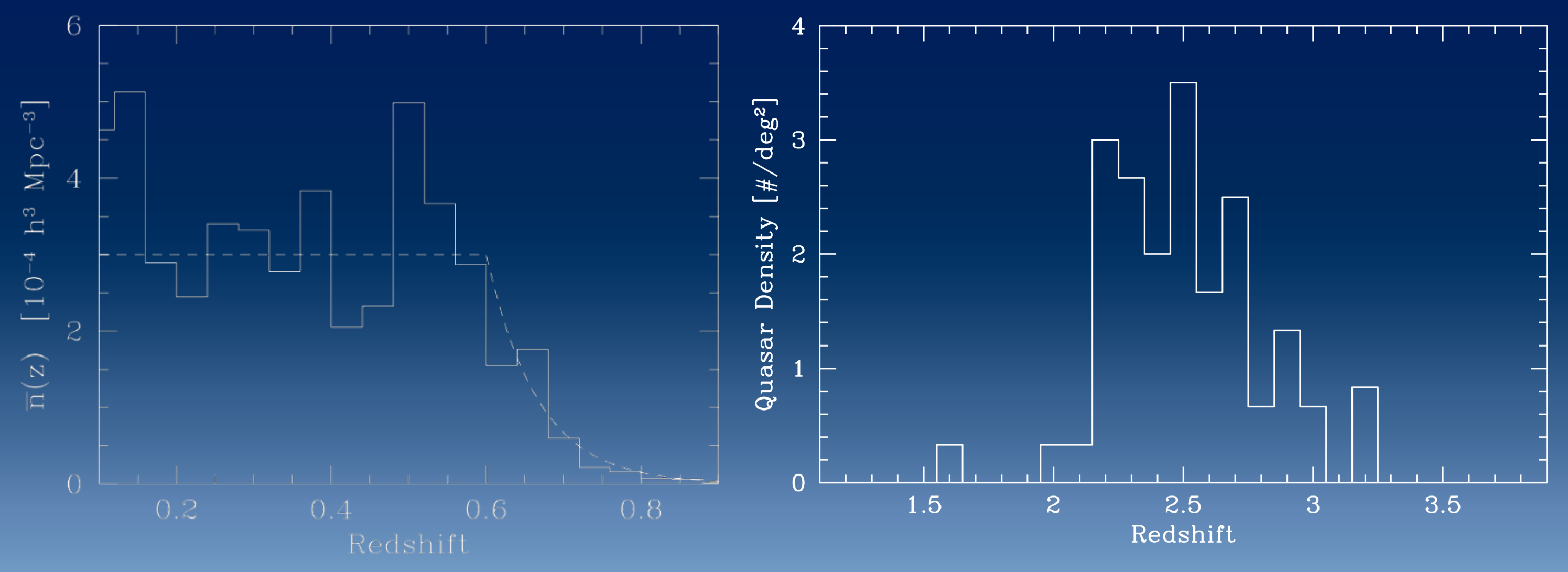
Experiment	$\sigma(h)$	$\sigma(\Omega_K)$	$\sigma(w_0)$	$\sigma(w_p)$	$\sigma(w_a)$	FoM
BOSS LRG	0.008	0.0028	0.089	0.032	0.366	86
BOSS LRG+QSO	0.008	0.0019	0.076	0.029	0.279	**122**
+WL	0.008	0.0017	0.068	0.026	0.227	172
+CL	0.008	0.0018	0.071	0.023	0.244	177
+SN	0.006	0.0019	0.052	0.023	0.220	199
+WL+CL+SN	0.005	0.0016	0046	0.018	0.164	331
WiggleZ	0.012	0.0028	0.099	0.035	0.430	67
HETDEX	0.015	0.0021	0.098	0.034	0.417	70
WFMOS	0.011	0.0017	0.083	0.033	0.323	95
Including Broad-Band Power Information						
BOSS LRG+QSO	0.007	0.0015	0.065	0.016	0.240	257
+WL+CL+SN	0.005	0.0013	0.041	0.014	0.150	479

A comparison of the abilities of current and next generation BAO experiments to constrain the expansion rate and curvature of space and the redshift dependent equation of state of dark energy. All constraints assume the DETF forecasts for "Stage II" experiments, which alone have a FoM of 53, as a prior. Lines 3-6 show the additional gains from adding Stage III weak lensing, cluster, and supernova constraints, using the DETF "optimistic" forecasts. BAO constraints in the first two sections of the table include only the acoustic scale information and are therefore conservative; the final two lines show BOSS forecasts that also incorperate broad-band power information.



Left: 68% marginalized constraints on the DE parameters from BOSS BAO + DETF weak lensing, cluster, SNe Stage II (red), Stage II + Stage III without BOSS (green), BOSS + Stage III (blue). Right: 68% and 95% contours in the Ω_K, w_p, w_a plane, with and without the QSO component.

Target Selection



The redshift distribution of LRGs (left) and QSOs (right) for our baseline target selection. These targets are selected from SDSS imaging over 7.6 deg^2 with spectroscopic redshifts from AGES. http://cmb.as.arizona.edu/~eisenste/AGES/