SDSS-III and BOSS: The Lyα Forest in 3-D

David Weinberg, Ohio State University SDSS-III Project Scientist

SDSS-I (2000-2005), SDSS-II (2005-2008)

SDSS-III (2008-2014), four surveys on three science themes.

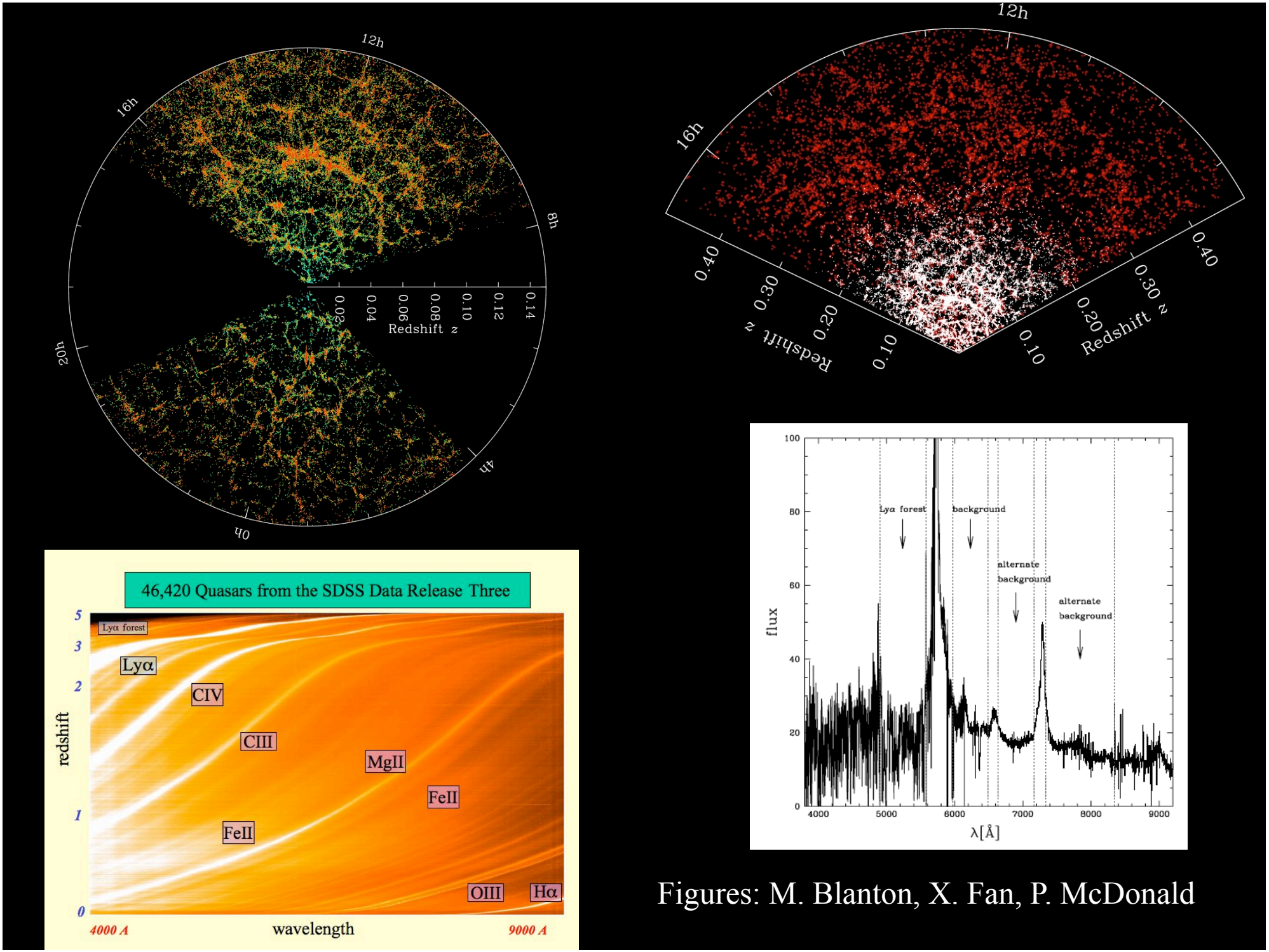
The Baryon Oscillation Spectroscopic Survey: Cosmology and dark energy with baryon acoustic oscillations (BAO). Redshifts of 1.5 million LRGs to z=0.7. Lyα forest spectra of 160,000 QSOs at z~2.5.

SEGUE-2: Galactic structure and evolution. Optical spectra of 120,000 stars in the outer Galaxy, resolution R ≈ 2000.

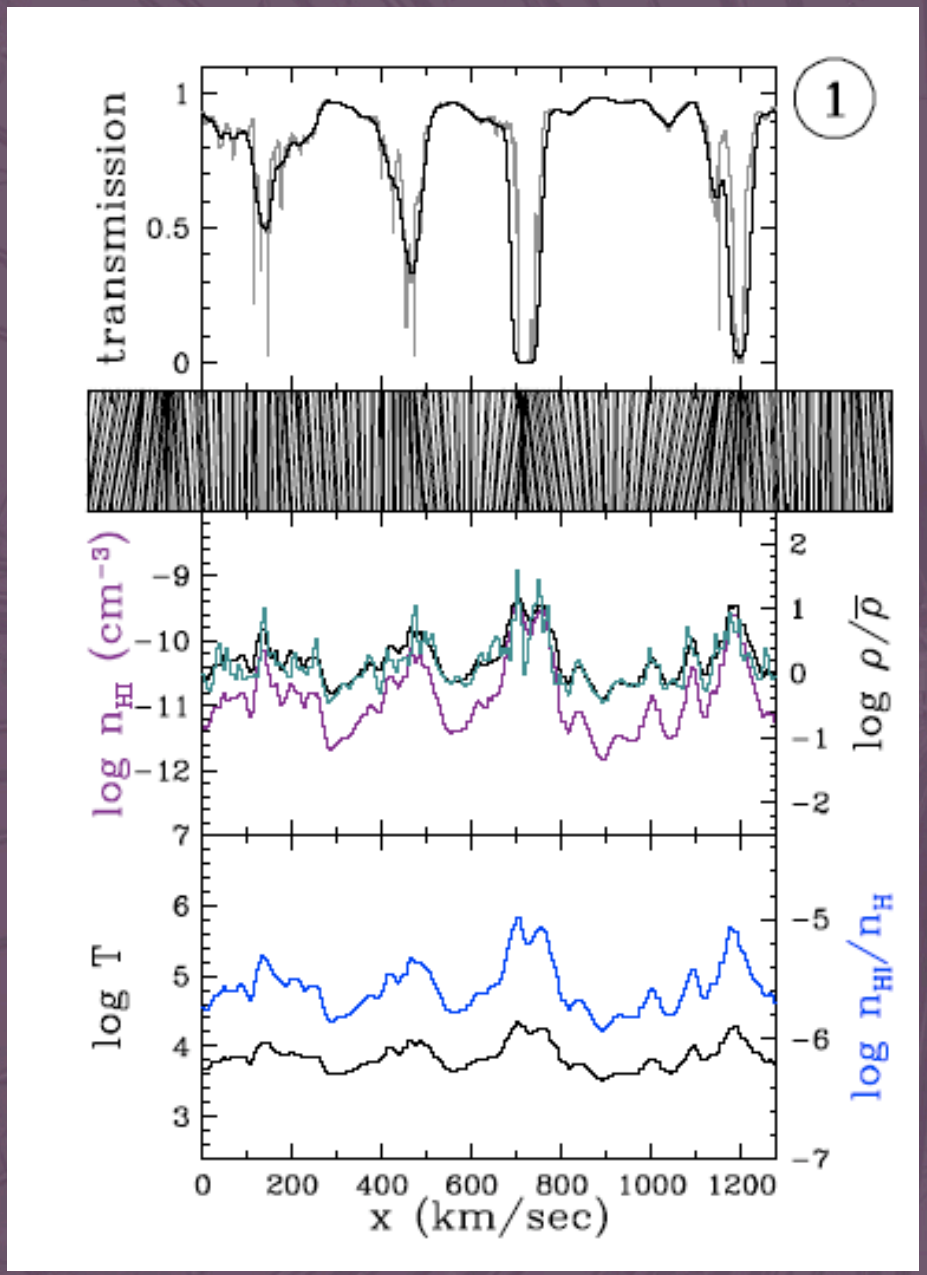
APOGEE: Galactic structure and evolution. H-band spectra of 100,000 stars throughout the Galaxy, resolution R ≈ 25,000.

MARVELS: Extra-solar planets. Radial velocity monitoring of 10,000 stars, ~30 visits over 18 months, 10-20 m s^{-1} precision.

Funding: Sloan Foundation, NSF, DOE, ~25 Participating Institutions.



Figures: M. Blanton, X. Fan, P. McDonald



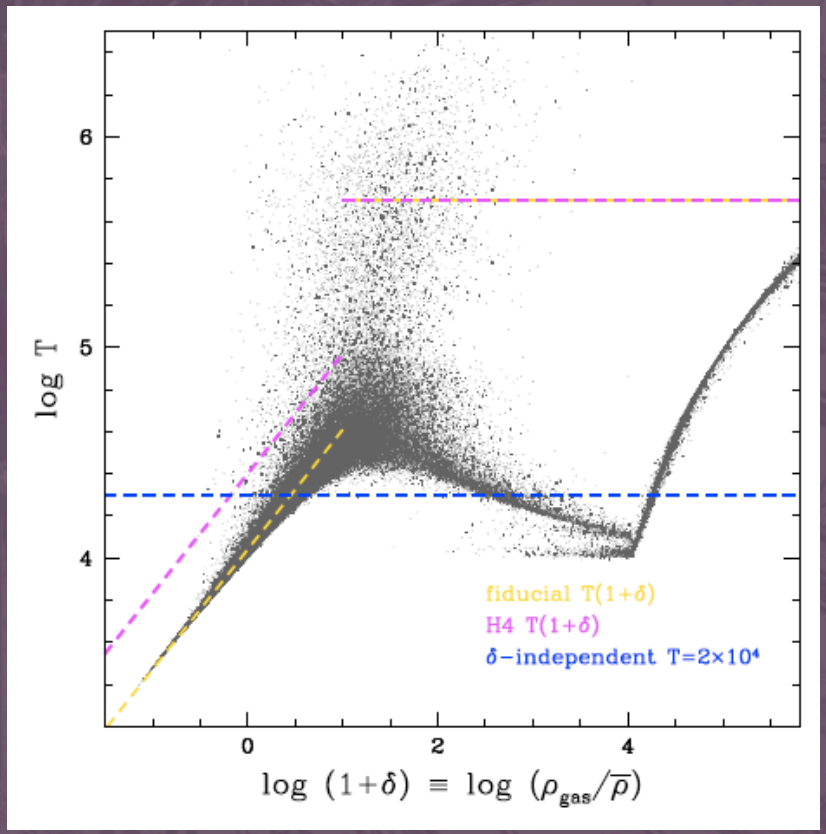
M. Peeples et al, in prep.

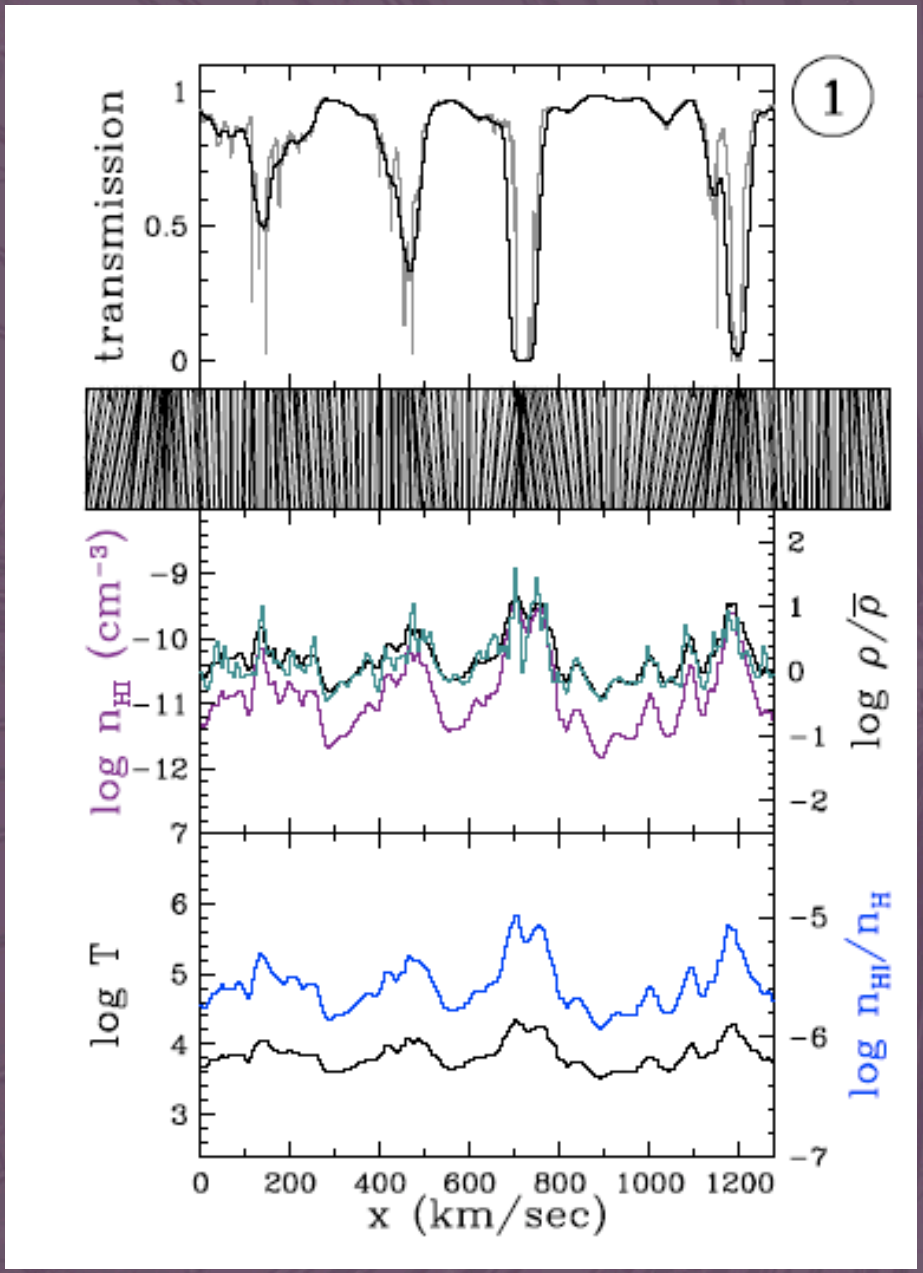
Fluctuating Gunn-Peterson effect:

The Lyα forest arises in a smoothly fluctuating gas distribution. Approximately

$F/F_c = e^{-\tau}$

$\tau \sim n_{HI} \sim n^2 T^{-0.7} = A\,(1+\delta)^{\beta}$





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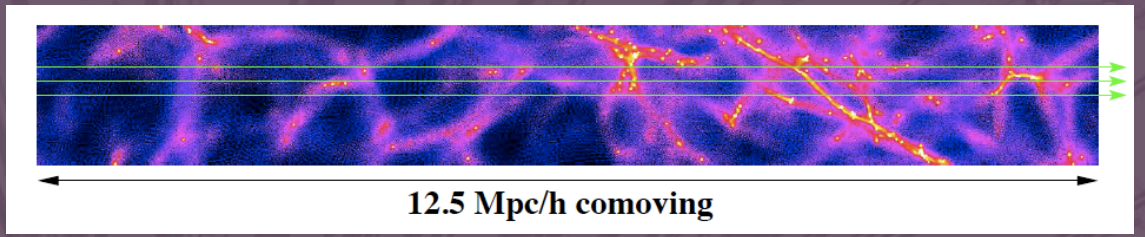
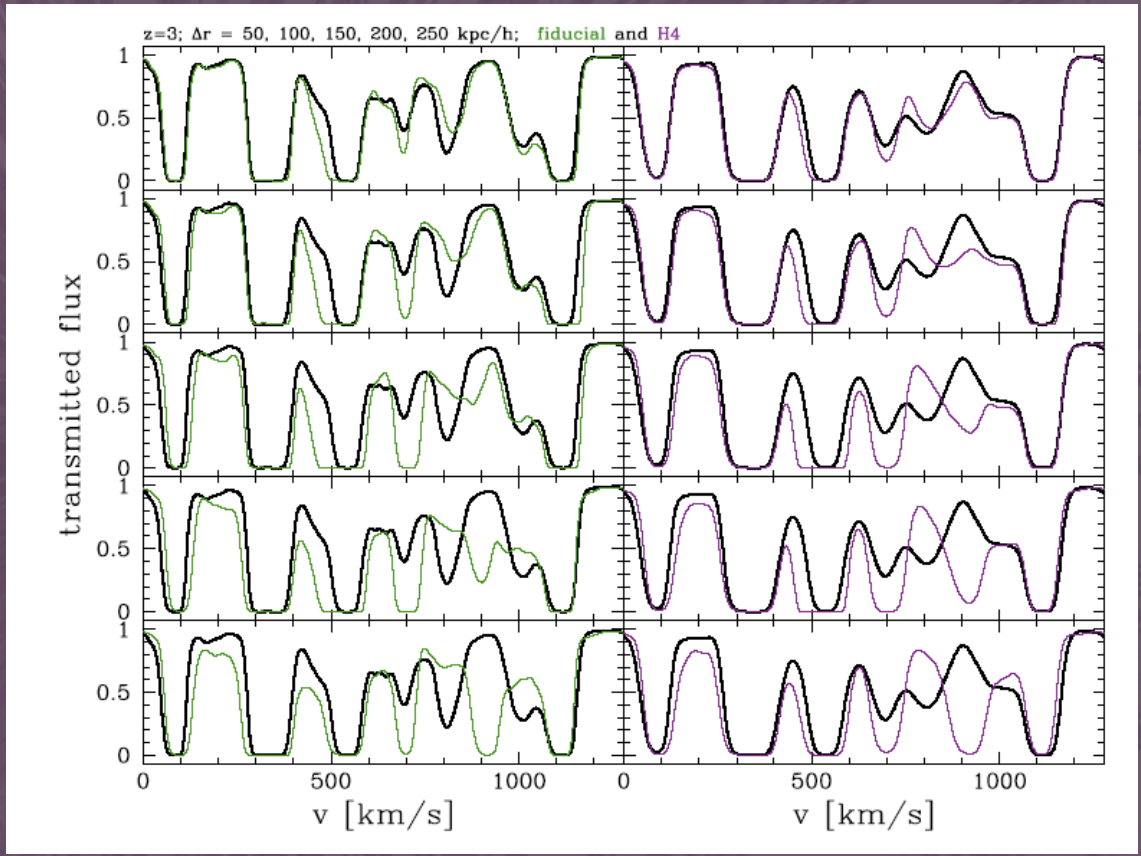
Main Complications:

- Peculiar velocities
- Thermal broadening
- Pressure support of gas
- Shock heating

Lyα forest in 2.5-D

Absorption spectra towards close quasar pairs can probe the pressure-support (Jeans) scale of the diffuse IGM, and maybe cosmological parameters as well.





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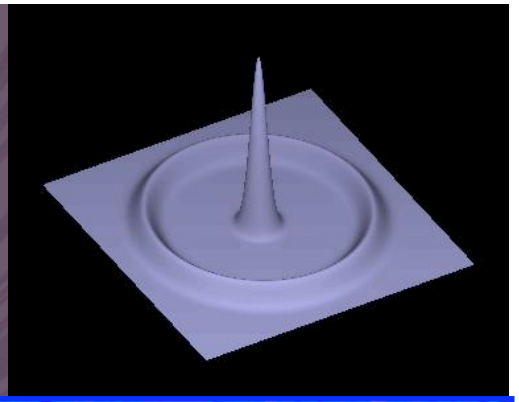
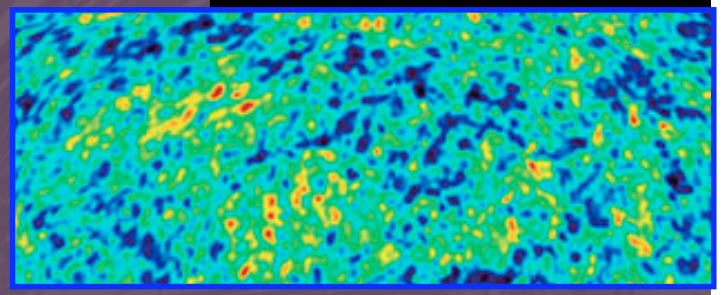
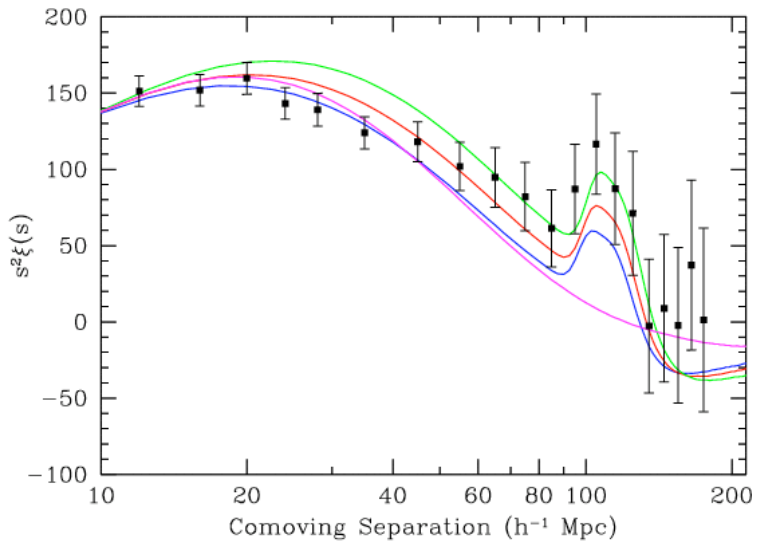
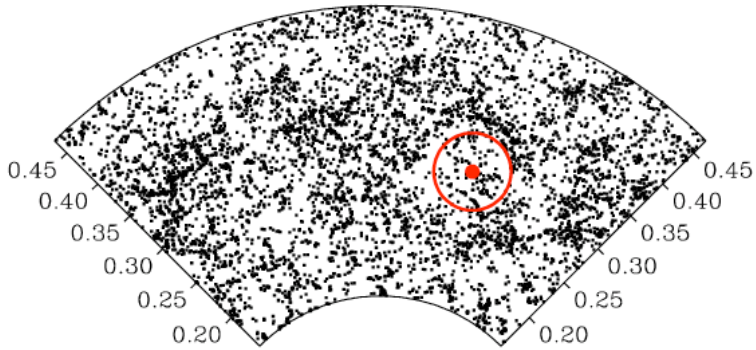
Baryon Acoustic Oscillations

- Sound waves travel in hot early universe. Imprint characteristic scale in the CMB and (more weakly) on the galaxy distribution.
- Detected by SDSS in clustering of luminous red galaxies.
- Physical scale determined by CMB constraints plus straightforward physics.





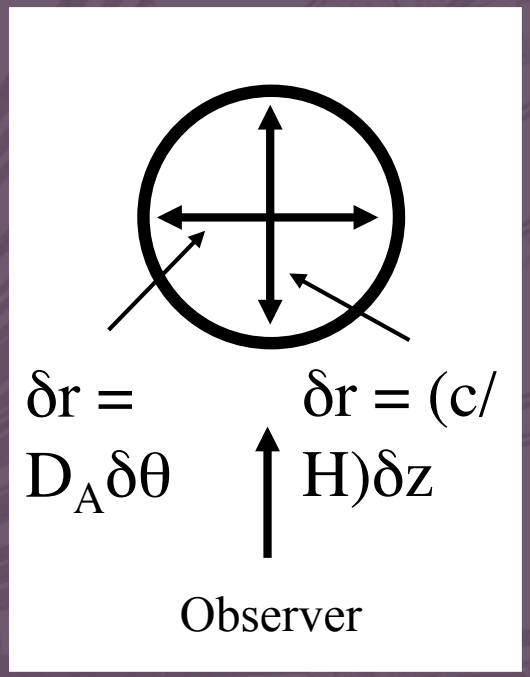


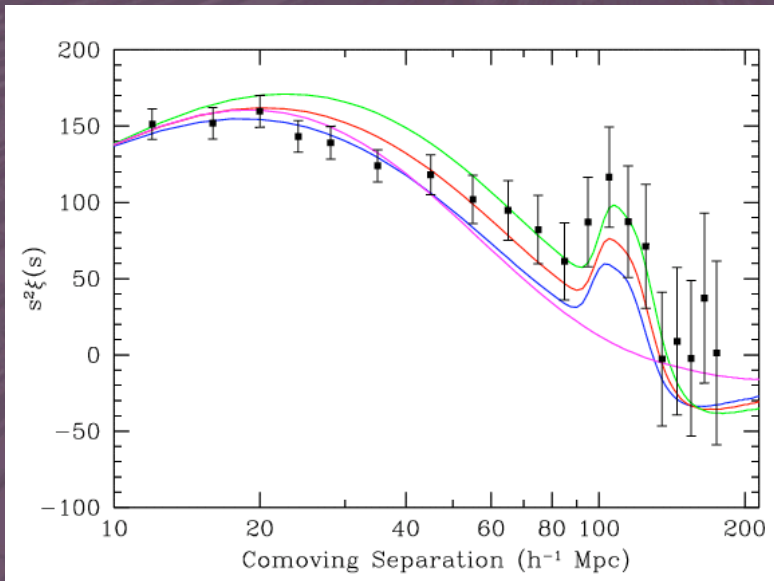


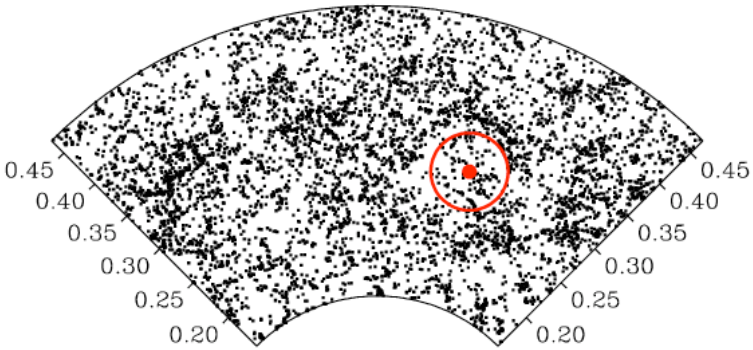
Eisenstein et al. 2005

Baryon Acoustic Oscillations

- Sound waves travel in hot early universe. Imprint characteristic scale in the CMB and (more weakly) on the galaxy distribution.
- Detected by SDSS in clustering of luminous red galaxies.
- Physical scale determined by CMB constraints plus straightforward physics.
- Provides standard ruler 150 Mpc long for measuring $D_A(z)$ and $H(z)$.





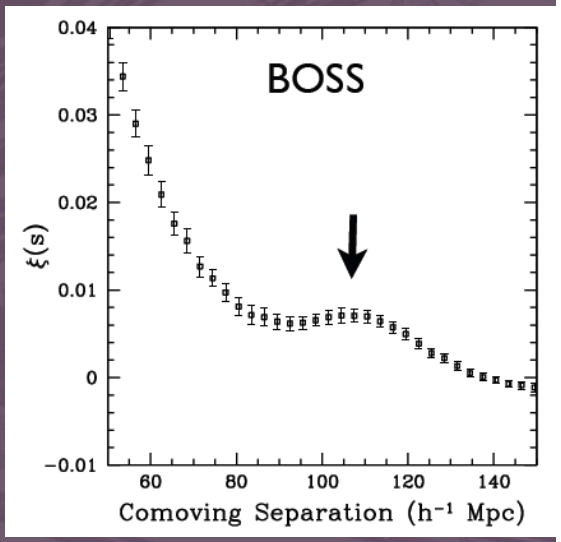


Eisenstein et al. 2005

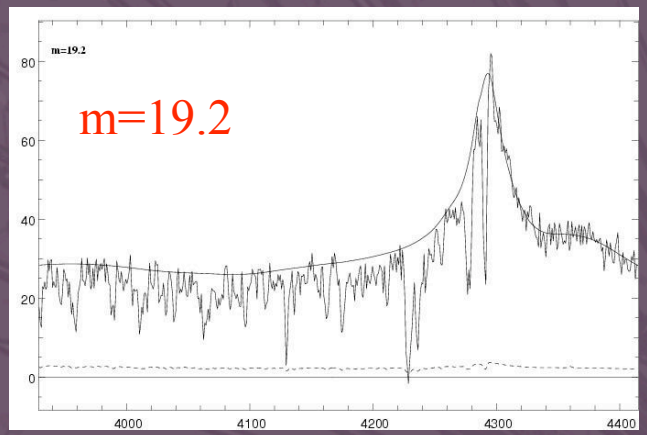
The Baryon Oscillation Spectroscopic Survey

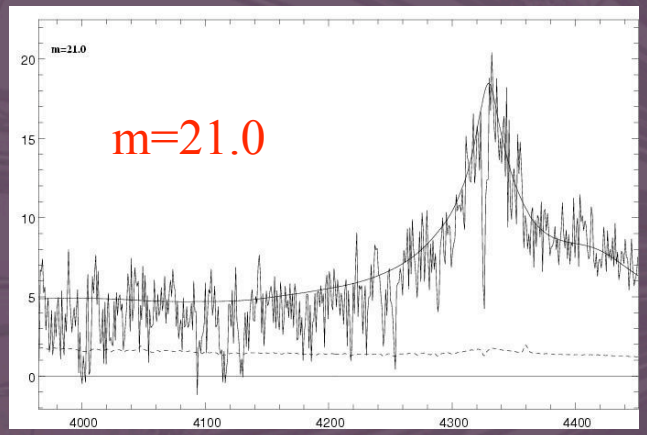
Turn BAO into a precision tool for studying cosmic acceleration.

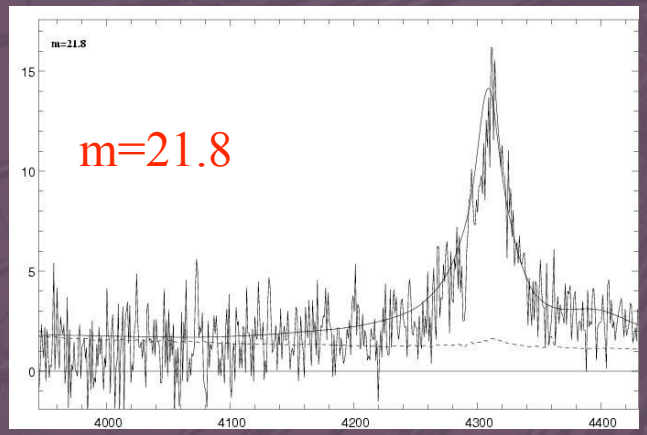
- Redshift survey of 1.5 million LRGs to z=0.7.
- Lyα forest spectra of 160,000 QSOs at redshifts
  - $2.1 < z < 3.0$. Limiting magnitude $g \approx 22$.
  - $\Sigma = 20$ deg^{-2} => 13.4 arc-min separation = 16.4 h^{-1} comoving Mpc at z=2.4.

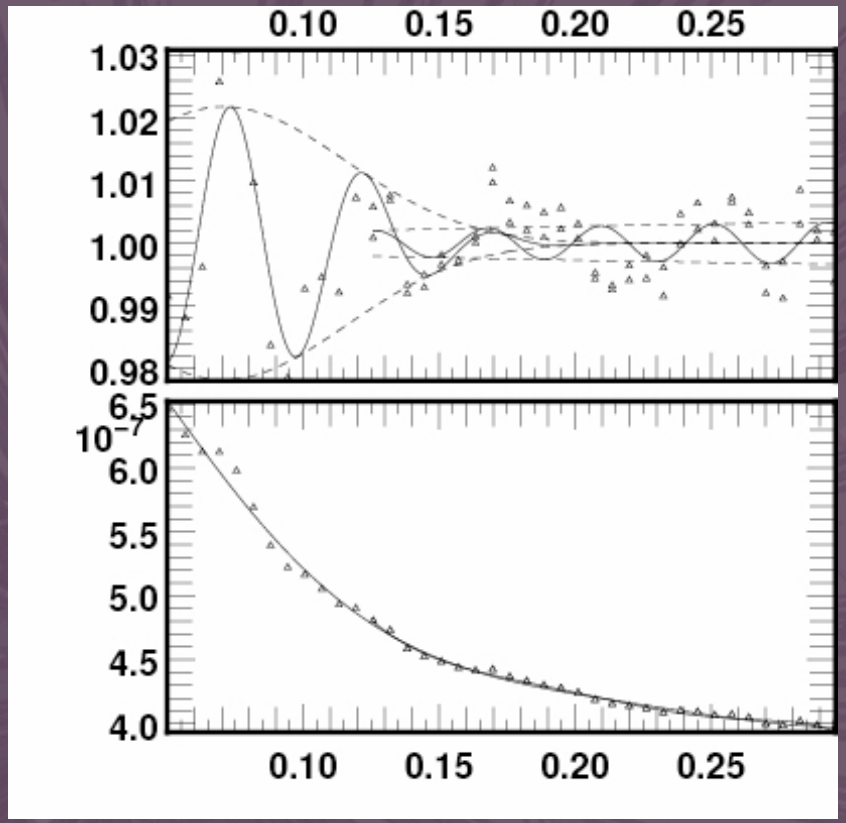


- Forecast D_A precision: 1.0% (LRGs), 1.5% (LyαF)
- Forecast H(z) precision: 1.8% (LRGs), 1.5% (LyαF)
- Uses SDSS spectrographs upgraded with higher throughput optics, more sensitive CCDs, 1000 2-arcsec fibers
- David Schlegel (PI), Martin White (SS), Natalie Roe (IS)









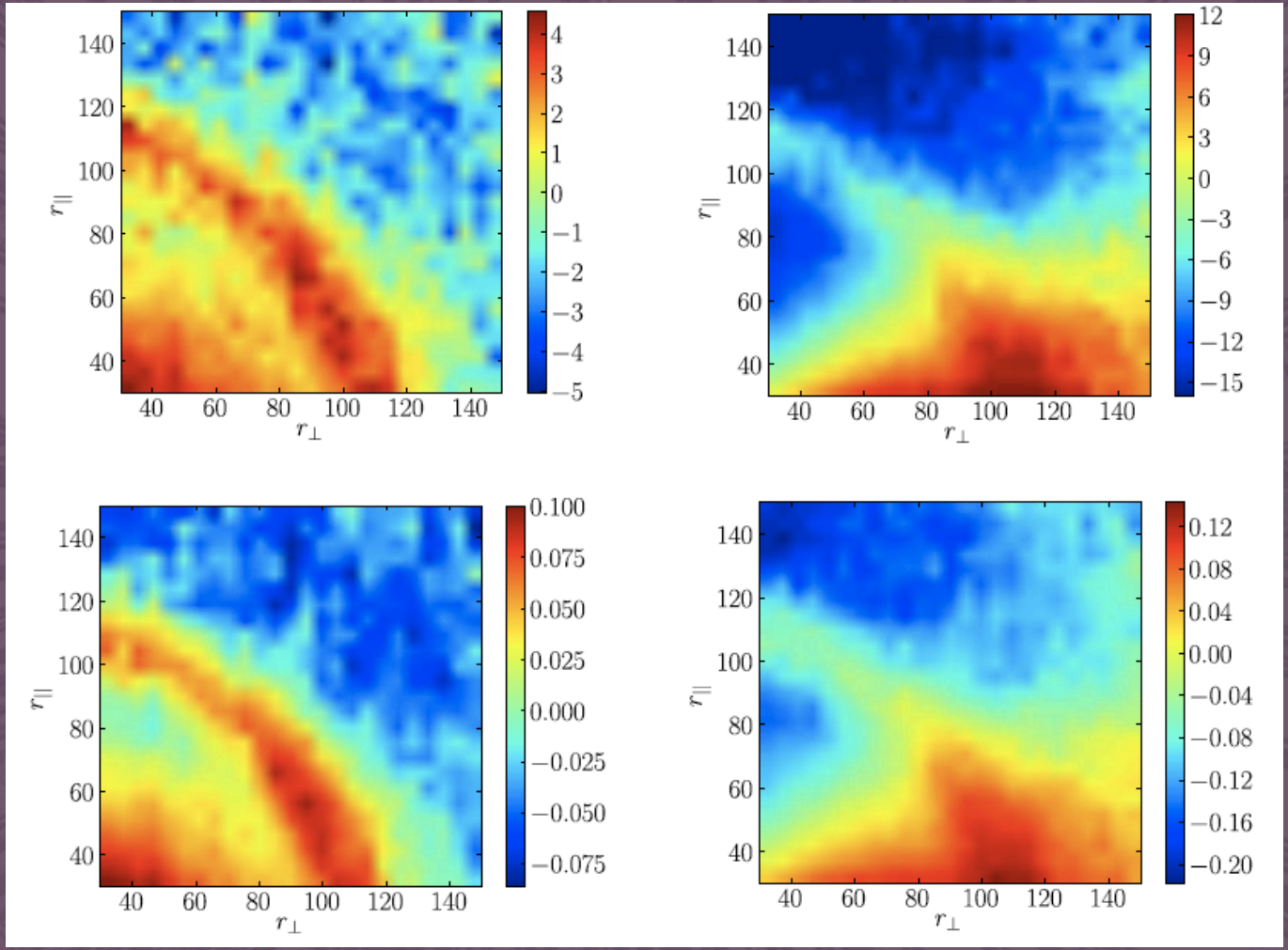
E. Rollinde, J.-M. Le Goff,
C. Pichon, P. Petitjean

Real Space

Redshift Space

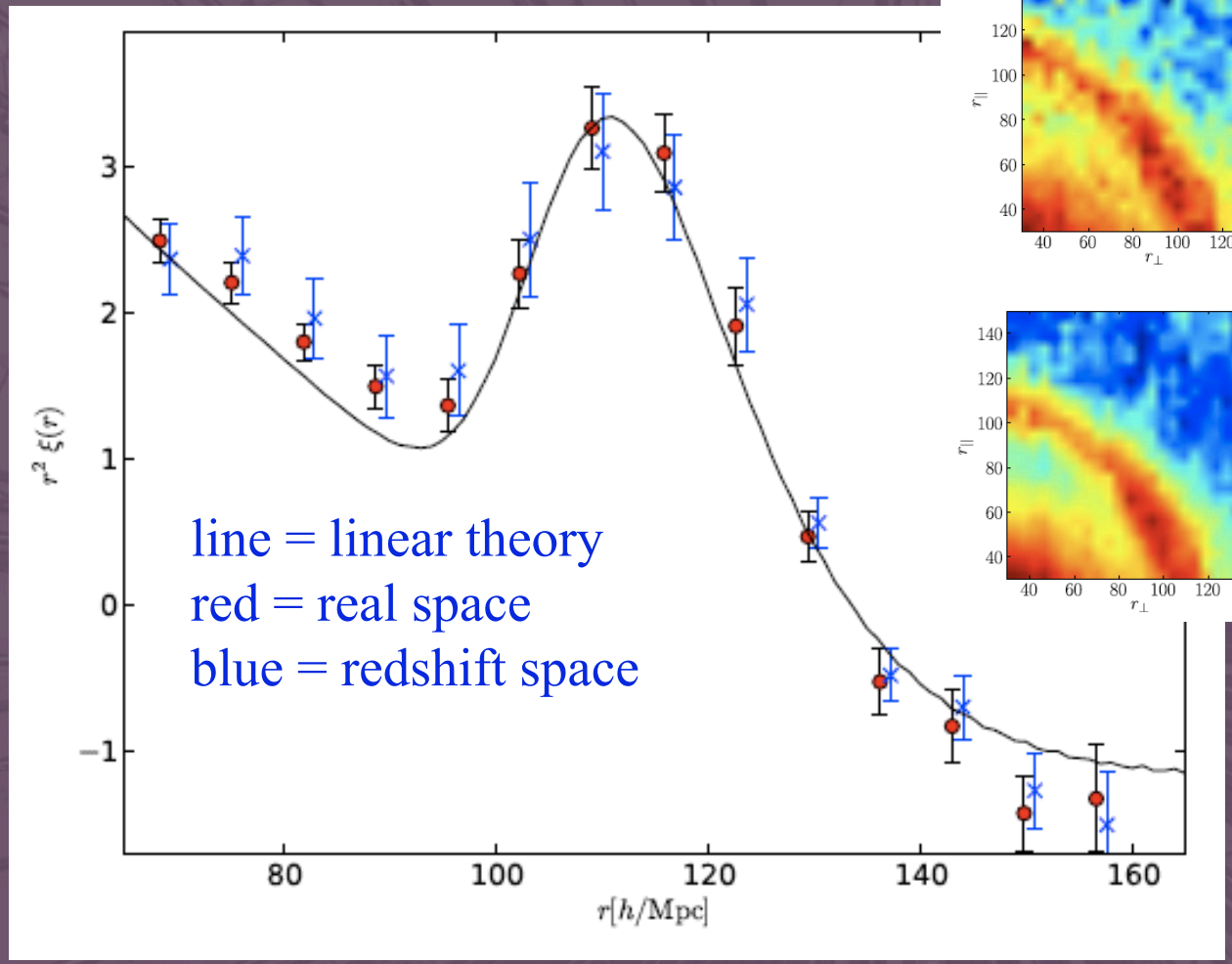
Mass

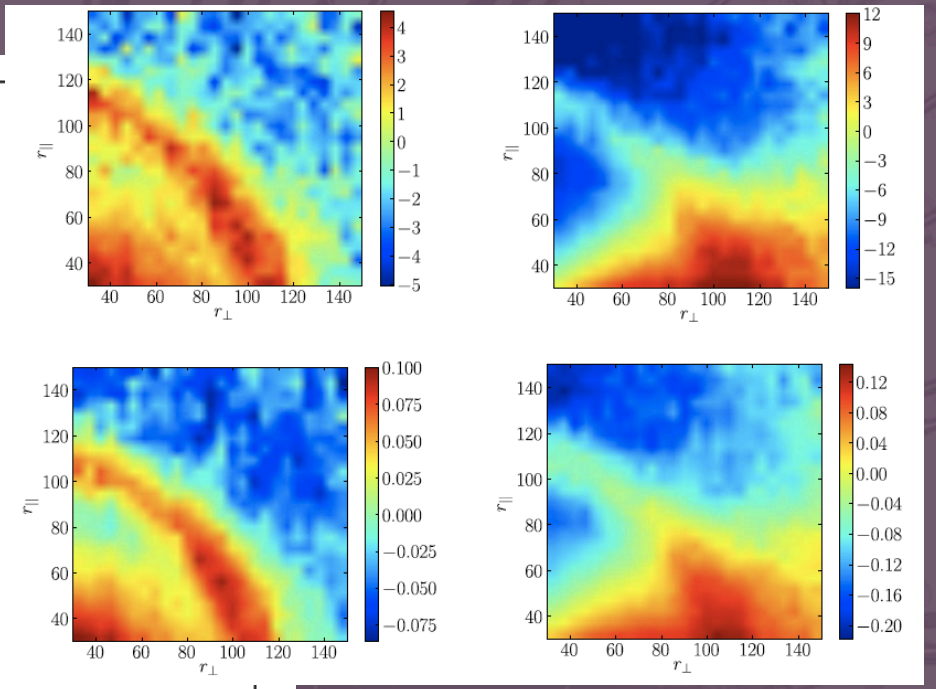
Lyα forest flux



Slosar, Ho, White, Louis 2009, arXiv:0906.2414

180,000 skewers through a 1.5 h^{-1} Gpc box





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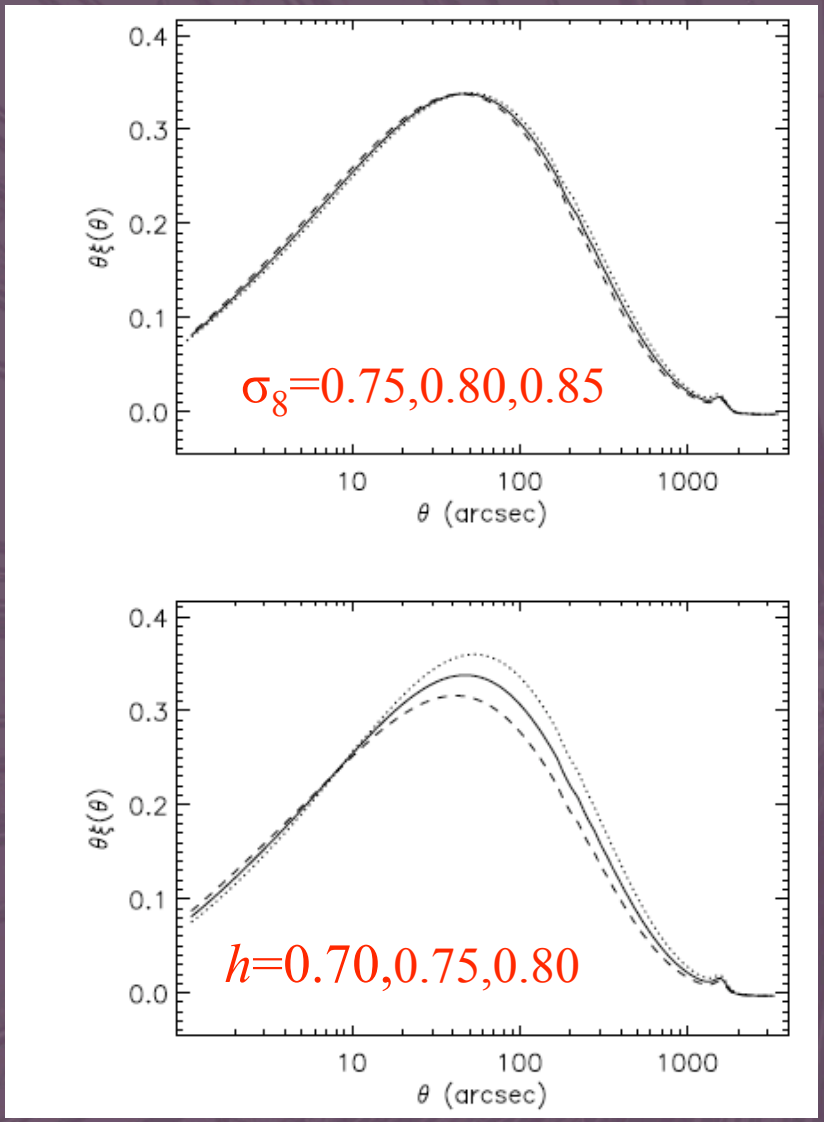

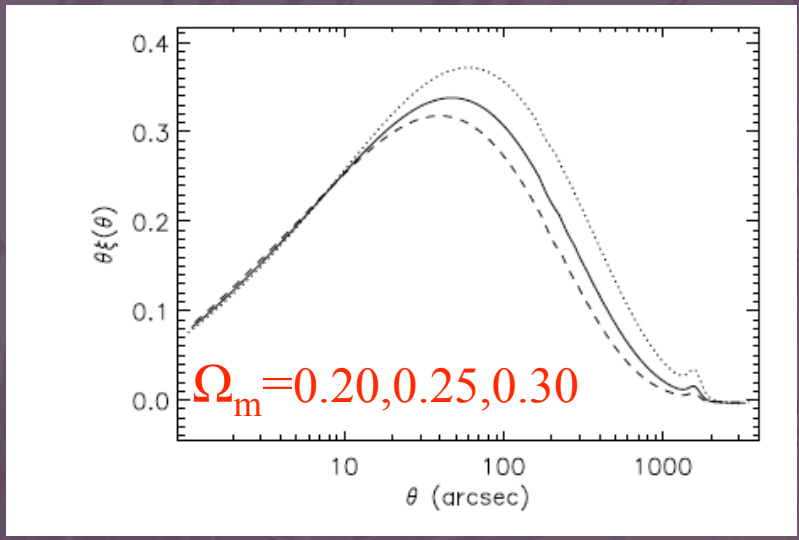

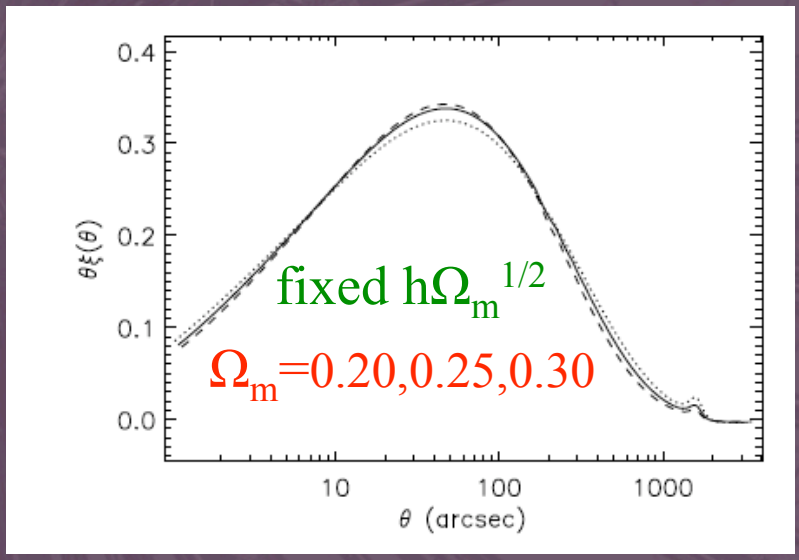

E. Rozo: Sensitivity of intermediate scales to cosmological and IGM parameters, based on log-normal analytic model.

Issues we are investigating:

- How to select 20 high-z QSOs per deg^2 from available data
- QSO continuum determination.
- Metal-line contamination.
- Spatial variations of UV background.
- Shape and spatial variations of IGM equation-of-state.
- Instrument and data pipeline artifacts.
- Optimal extraction of signal from data.

So far, systematics for BAO measurement look small compared to expected statistical errors.

Summary: The Lyα Forest in 3-D

- Close quasar pairs can measure pressure smoothing scale of IGM
- SDSS-III: BAO cosmology, Galactic structure, exoplanets

  One year down, five years to go.
- BOSS: 1.5 million LRGs to z=0.7 ; 160,000 QSOs 2.1 < z < 3.0, typical QSO sightline separation of 15-20 h^{-1} Mpc comoving
- BAO signal clearly present in large volume LyαF simulations
- BOSS makes the LyαF a 3-D phenomenon, many applications