Baryon Acoustic Oscillations in the Lyα-forest of BOSS quasars

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SFP Independence day, 2013

Outline

Intro:

- BAO scale: well predicted, well measured, imprinted in the distribution of matter
- It can be observed by measuring the 2pt correlation function
- It be used to measure the expansion of the Universe

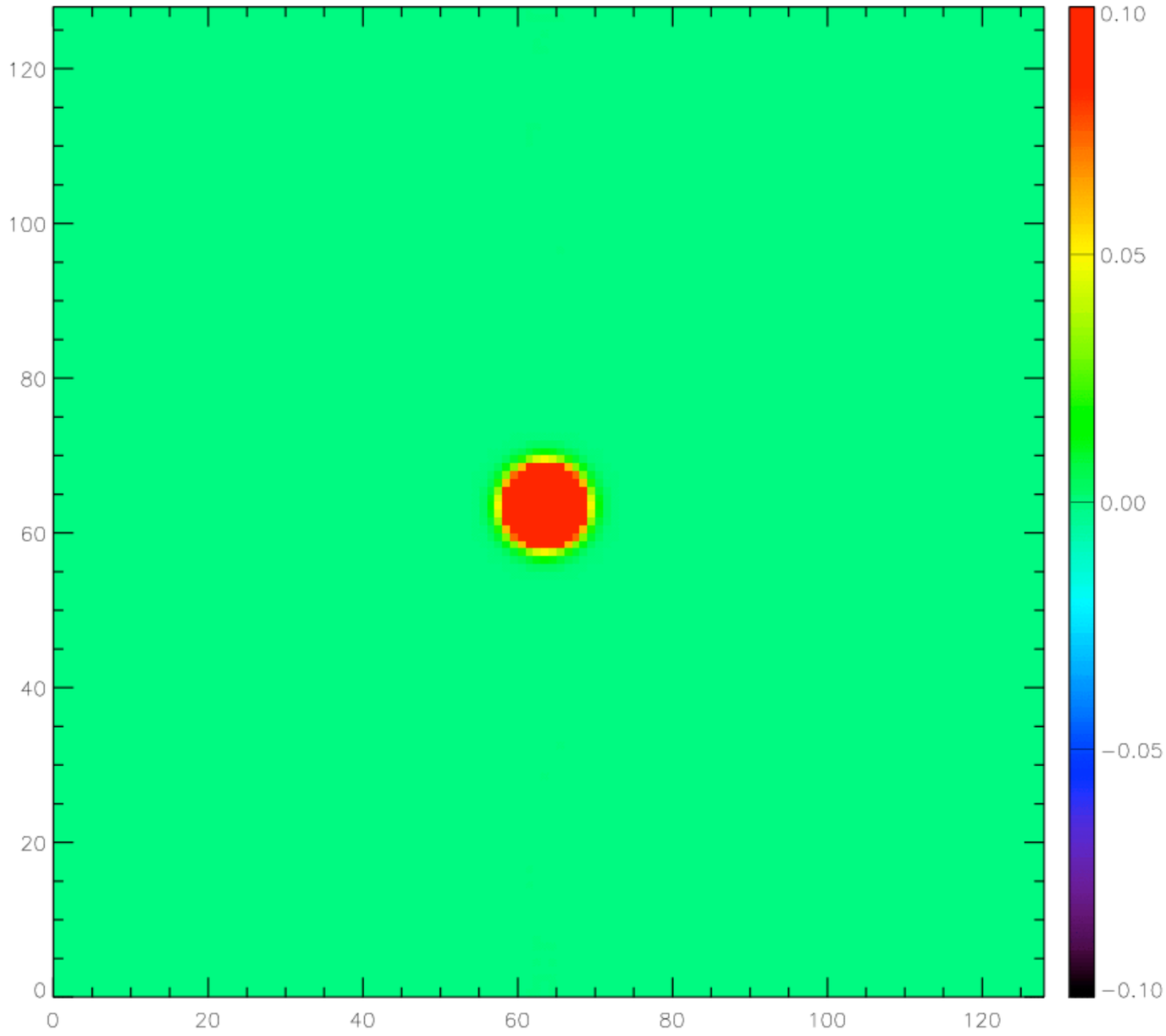
The BOSS measurement:

- Challenges
- How-to
- Results

Conclusions

Baryon oscillations

- young Universe (age < 370.000 yrs)
- hot and ionized (T >> 3000 K)
- capable of supporting pressure waves



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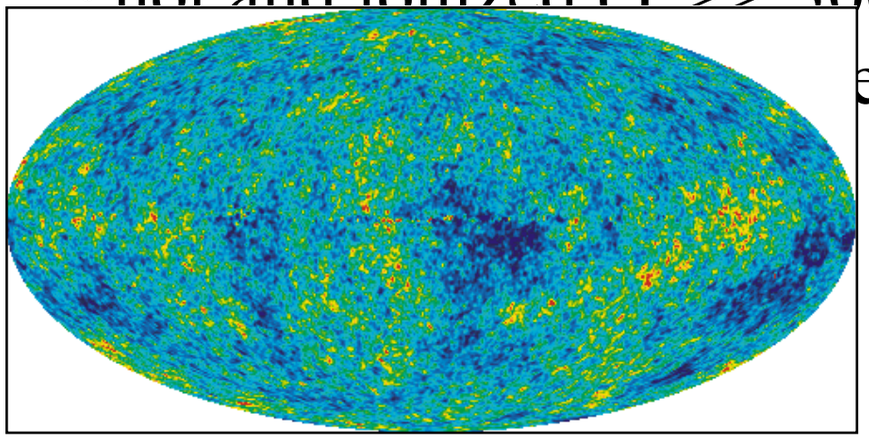
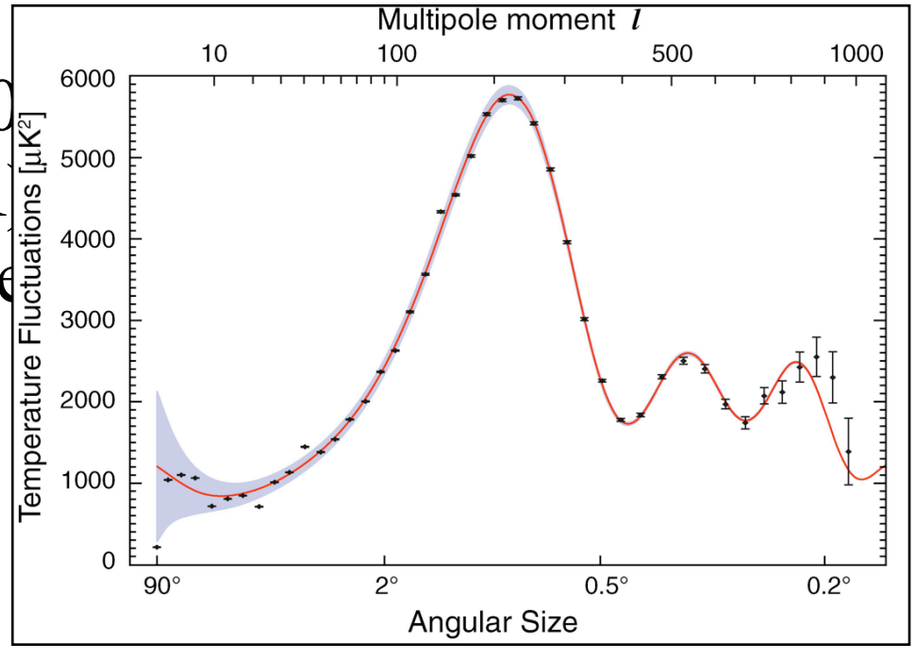
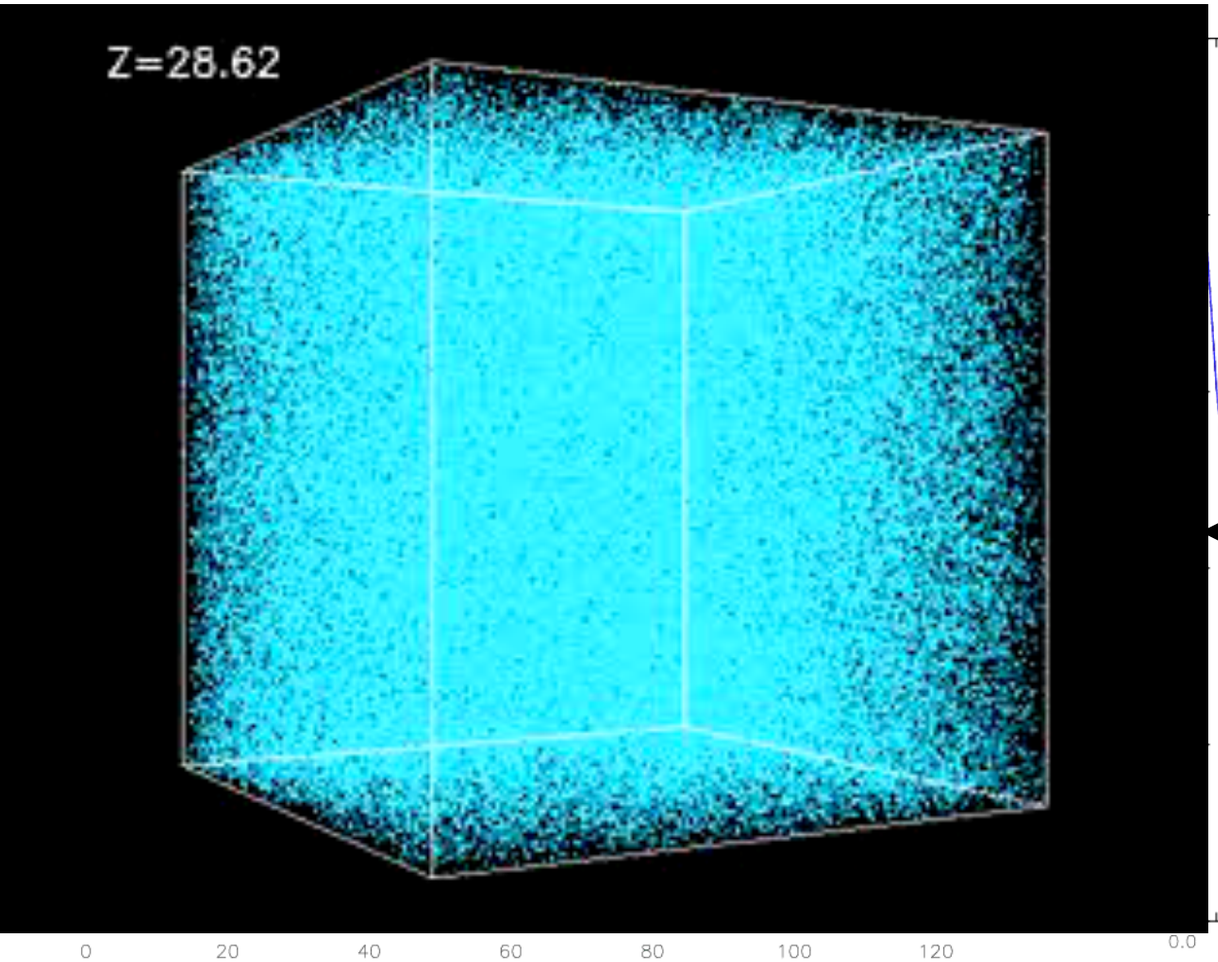


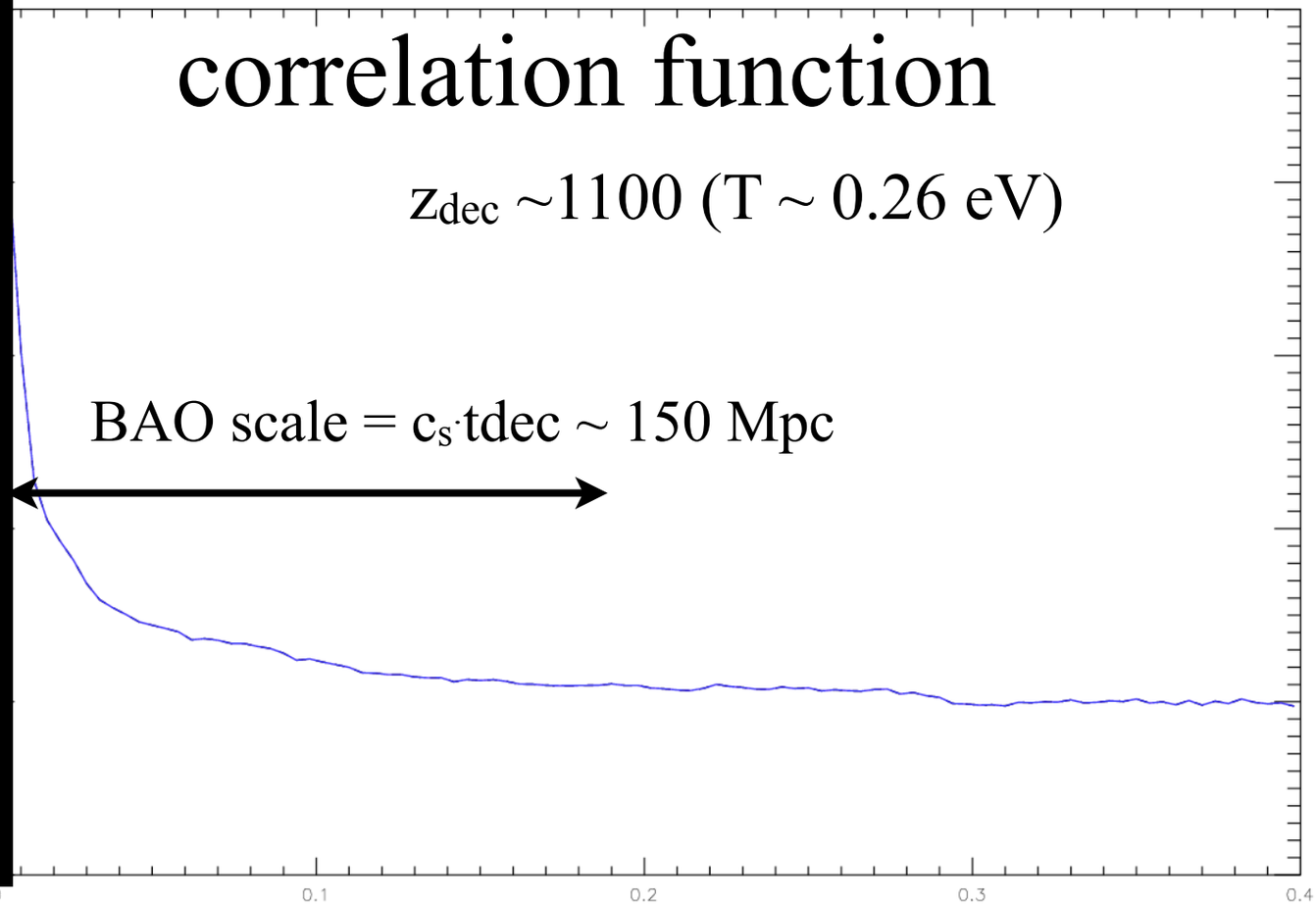




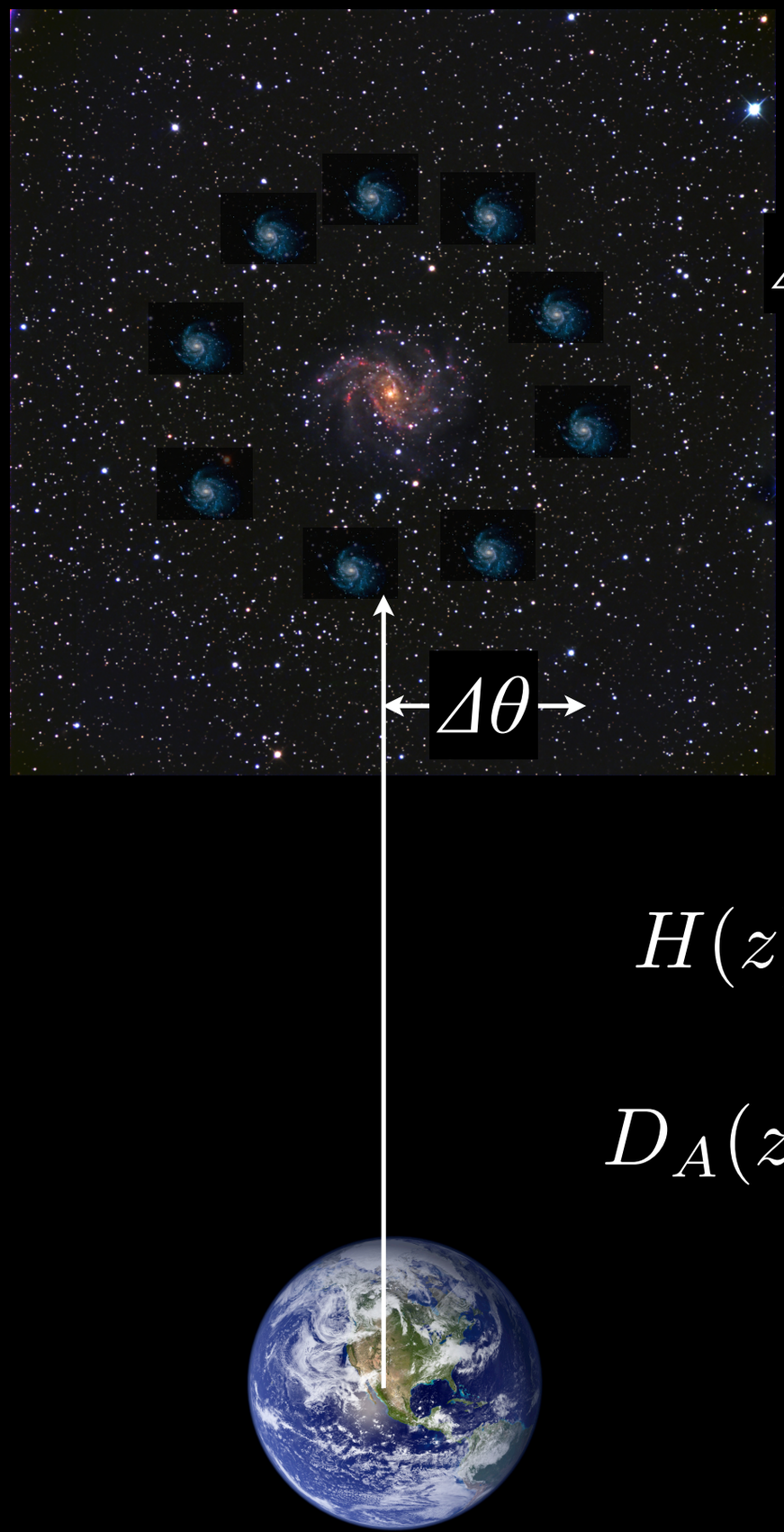
correlation function

z_{dec} ~1100 (T ~ 0.26 eV)

BAO scale = $c_s \cdot t_{dec}$ ~ 150 Mpc



Using the BAO scale...



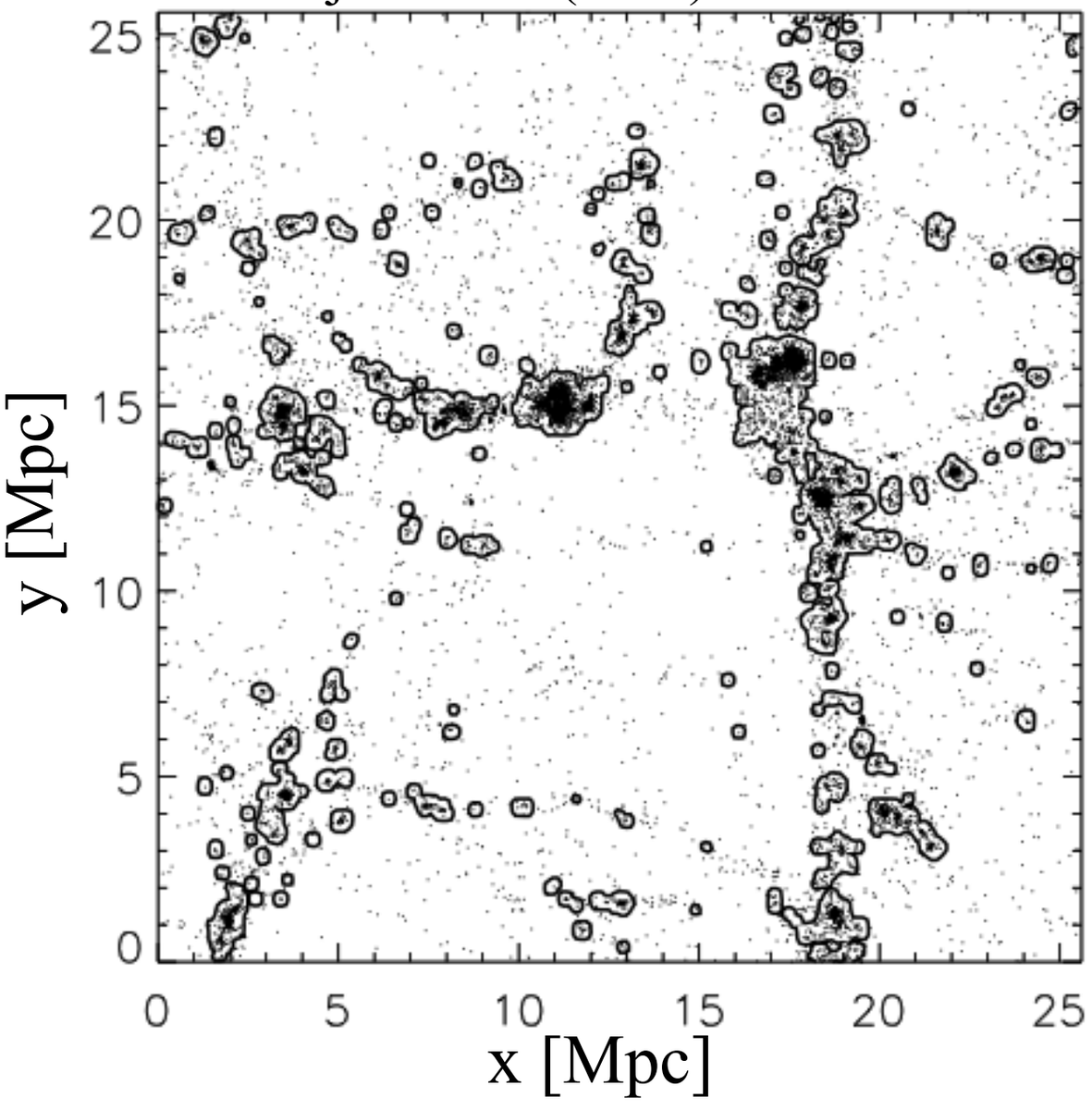
$$H(z) = \frac{c\Delta z}{r_s}$$ hubble rate

$$D_A(z) = \frac{r_s}{\Delta\theta}$$ angular diameter distance

Tracers of matter

Galaxies:

P. Petitjean et al. (1995)



Tracers of matter

Galaxies:

- trace high overdensity regions O(200)
- formation hard to simulate
- linear bias model:

$\delta_{gal} = b\, \delta_{DM}$

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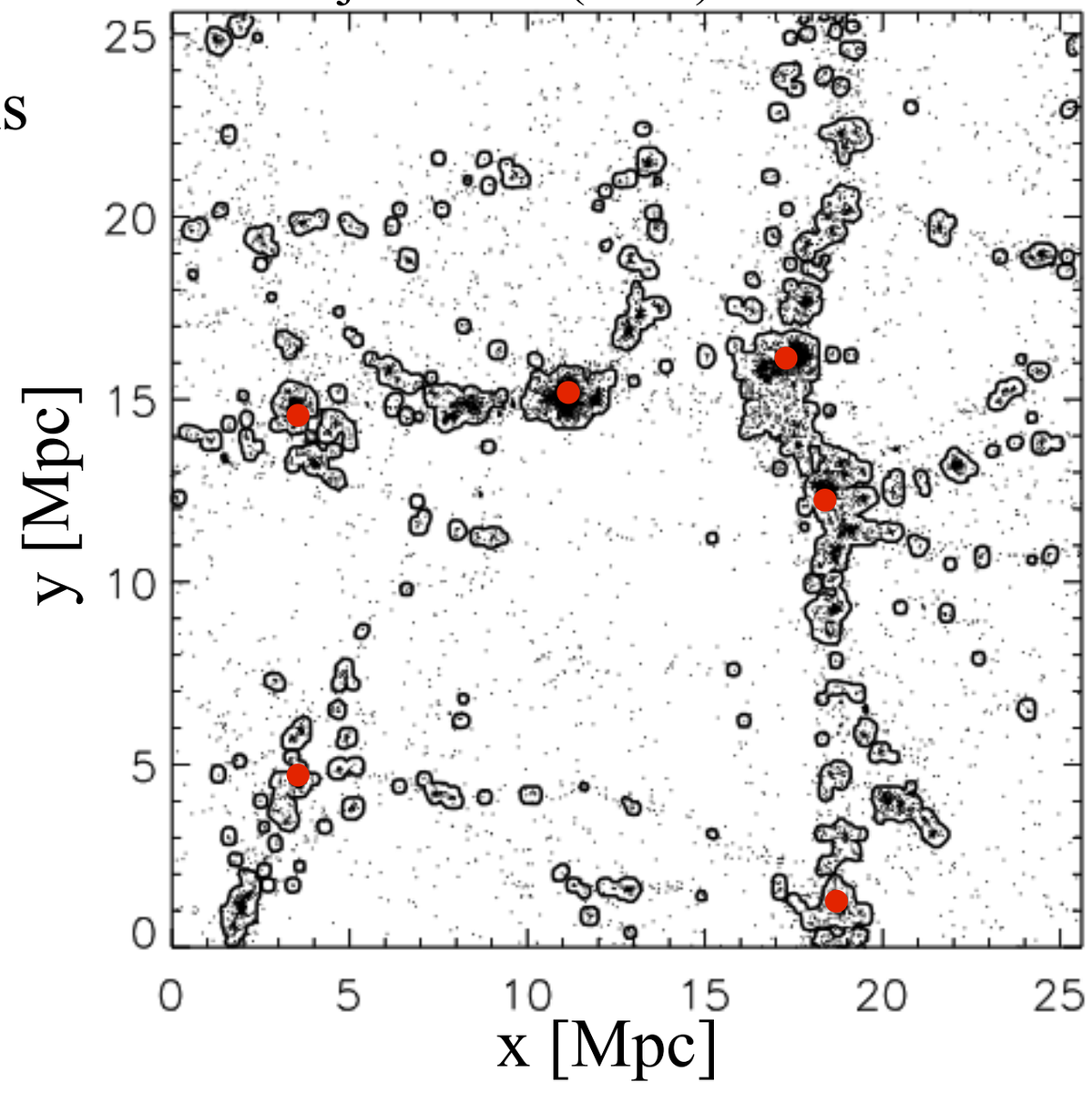


Tracers of matter

Galaxies:

- trace high overdensity regions O(200)
- formation hard to simulate
- linear bias model:
  $\delta_{gal} = b\,\delta_{DM}$, $b \sim O(1)$
- $z \sim$ 0-1

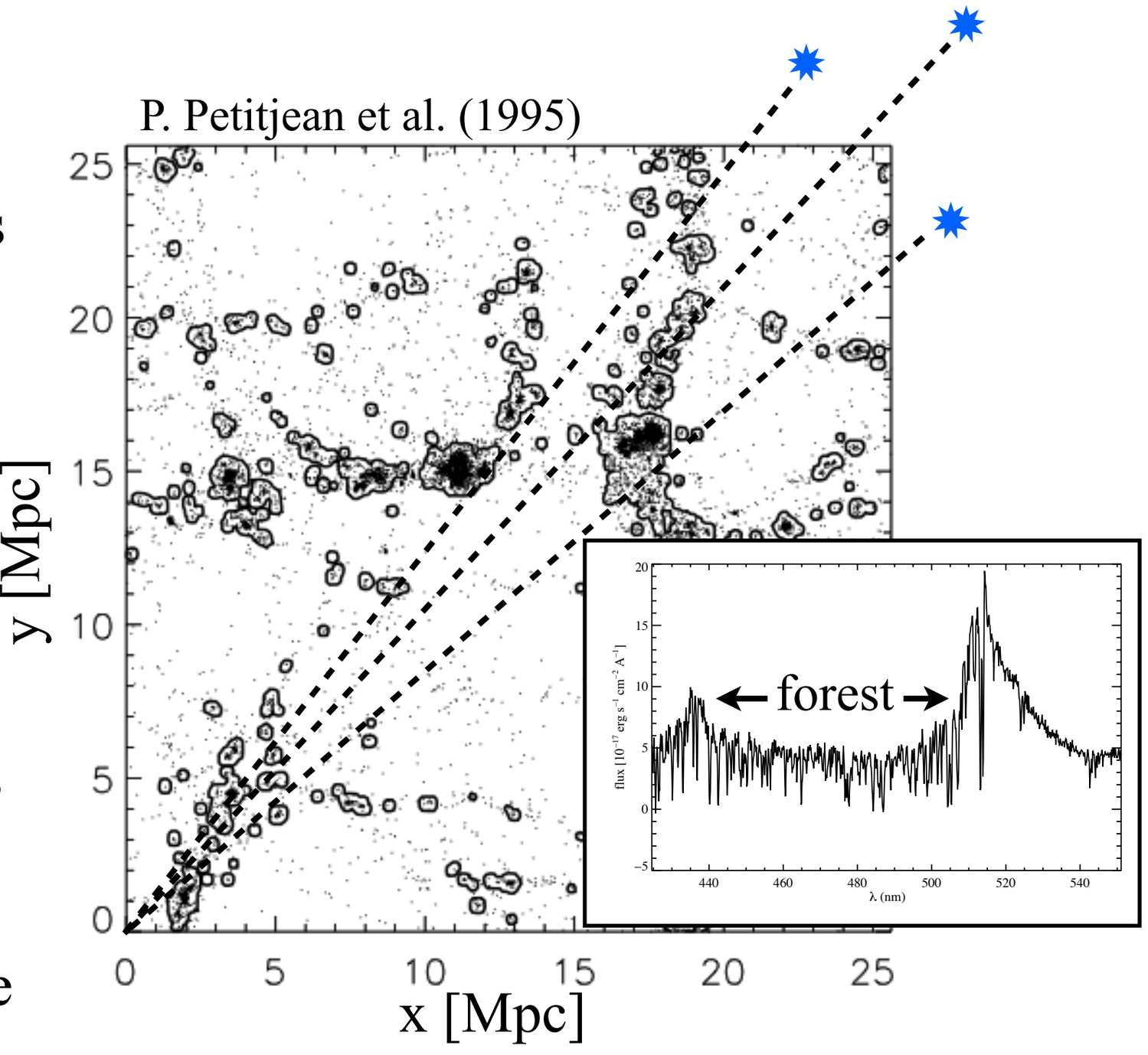
Lyα forest nouveauté 2013 ! :

- trace low overdensity regions
- non-linear tracer:

$$f_\lambda = \exp\left[-\tau(z)\right]$$

- full hydro simulation possible (e.g. McDonald 2003):
- z ~ 2.5

P. Petitjean et al. (1995)



$$P_f(k, \mu_k) = b^2(1 + \beta\mu^2)^2 P_L(k)$$

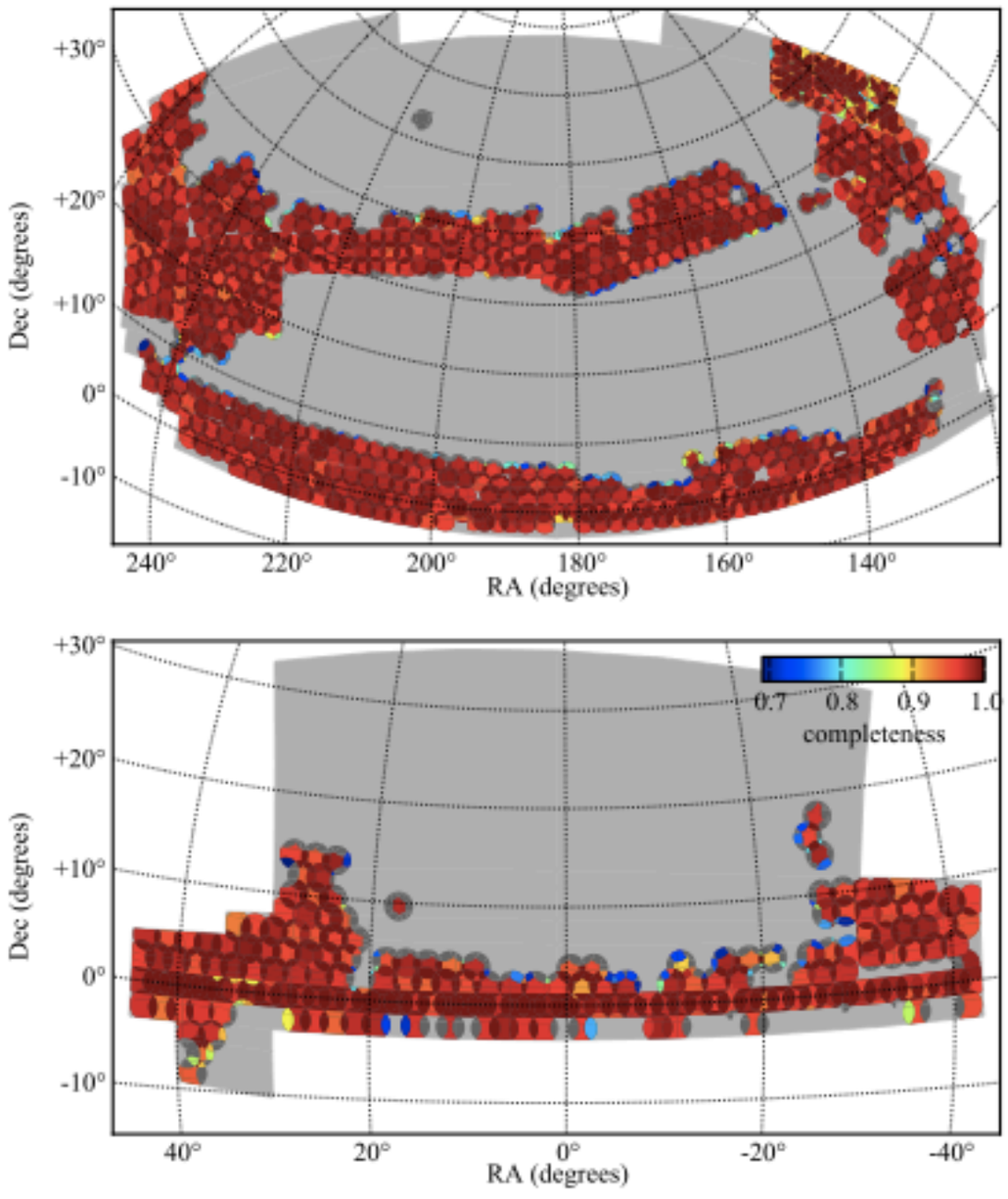
$$b \sim 0.16, \beta \sim 1.05$$

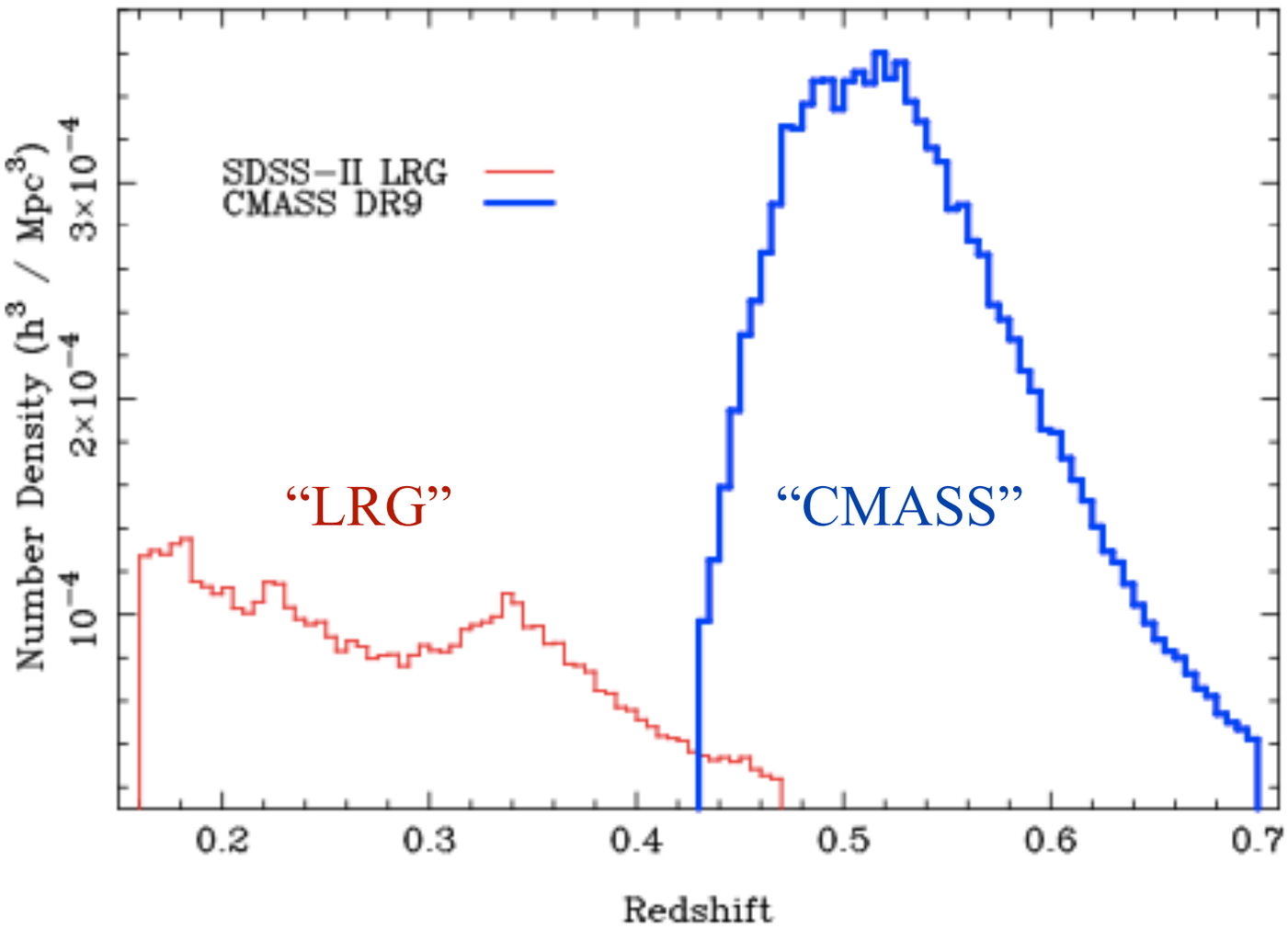
The Baryon Acoustic Oscillations Spectroscopic Survey
BOSS

- one of the four surveys that share the SDSS 2.4m telescope between 2009-2014
- BOSS will observe 1/4 of the sky (10,000 deg^2)
- spectra of 1,600,000 galaxies and 150,000 quasars
- goal: to determine the position of the BAO peak with a precision of 1% at z~0.6 and 1.5% at z~2.3
- best constraints on the equation of state of dark energy until the next generation of experiments

BOSS Galaxies today

~260,000 galaxies (publicly released)





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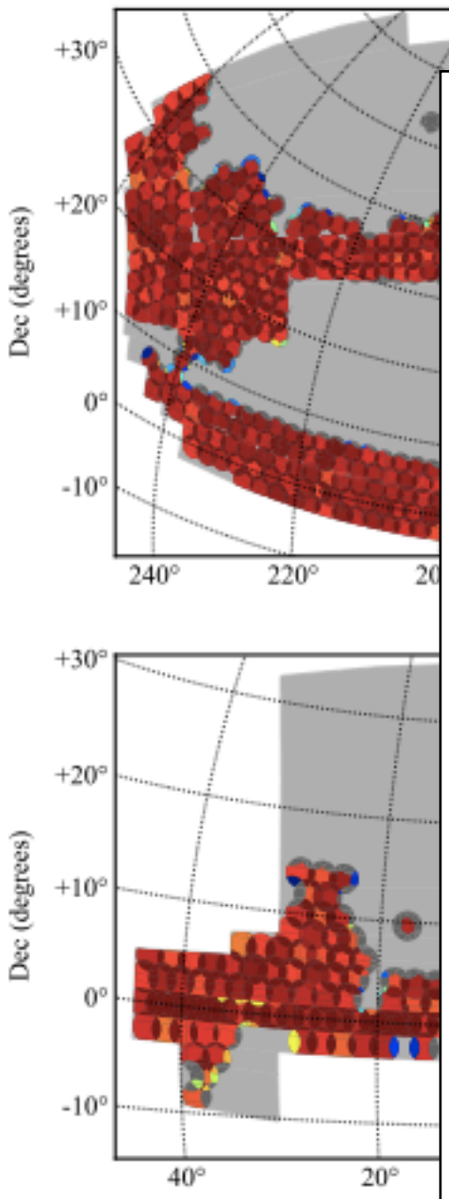
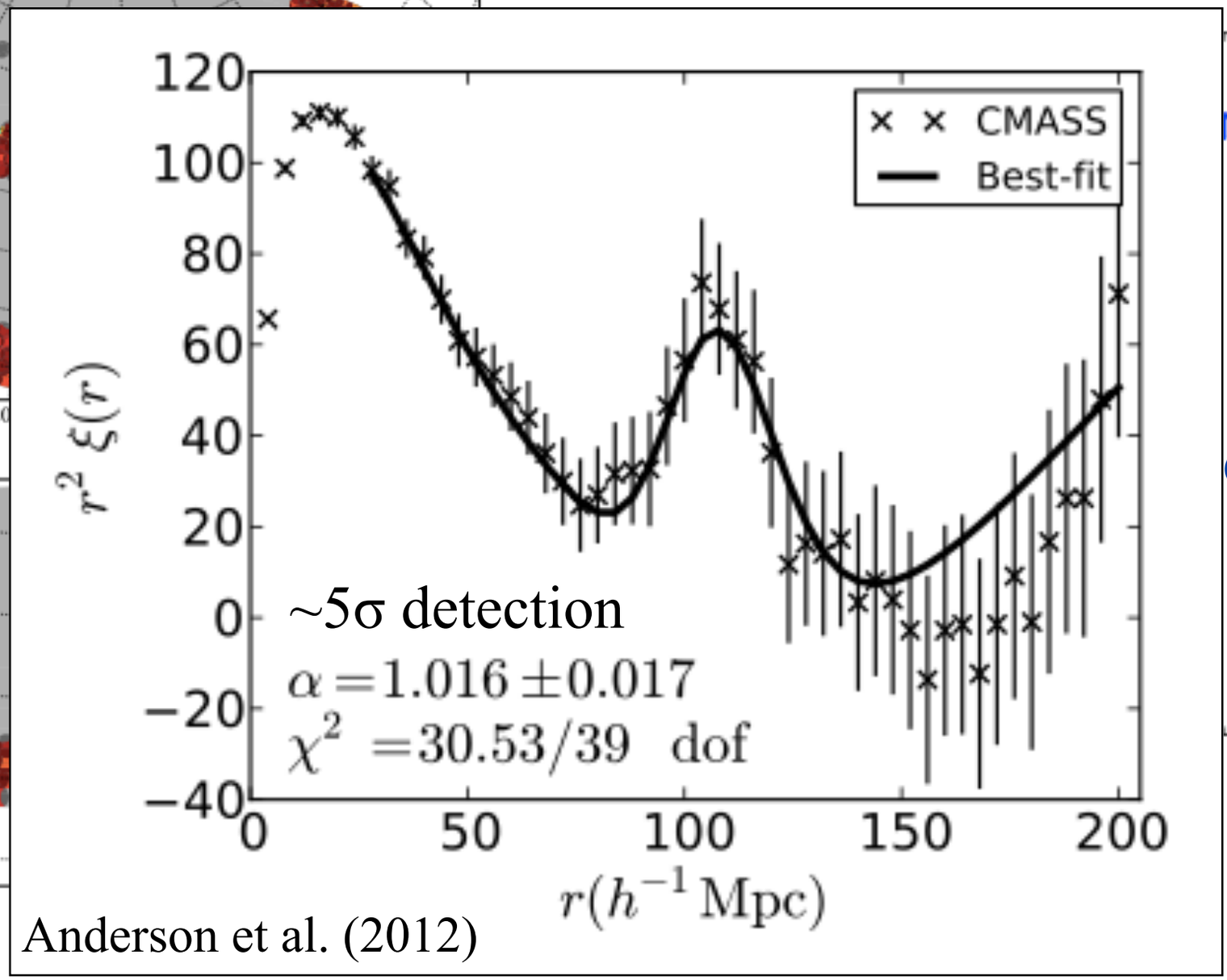
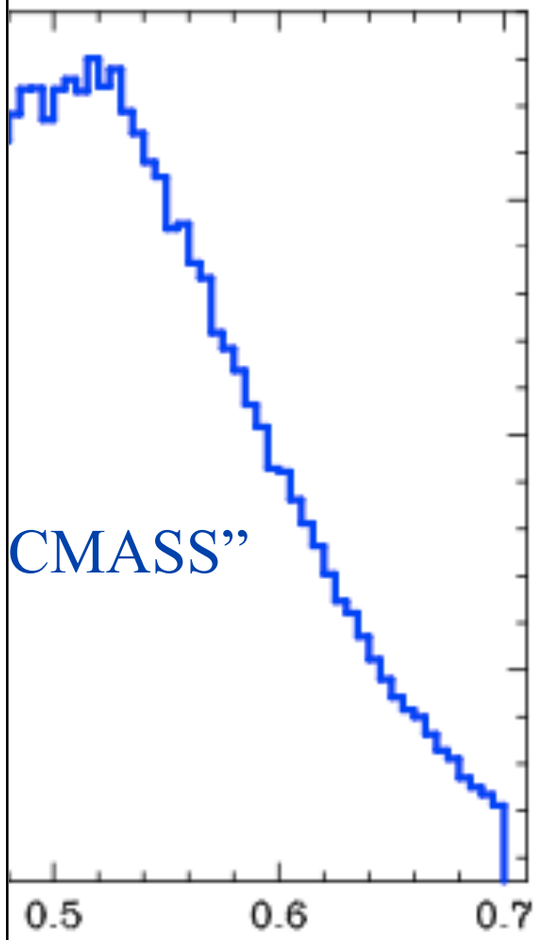




Anderson et al. (2012)



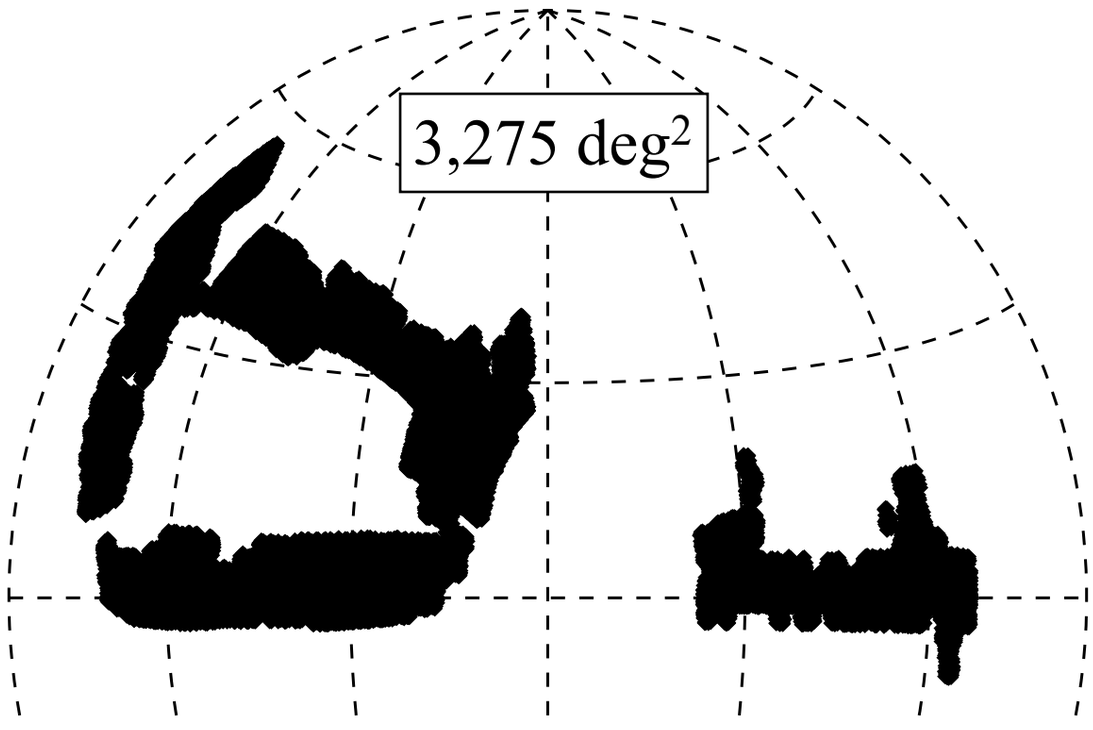
CMASS”

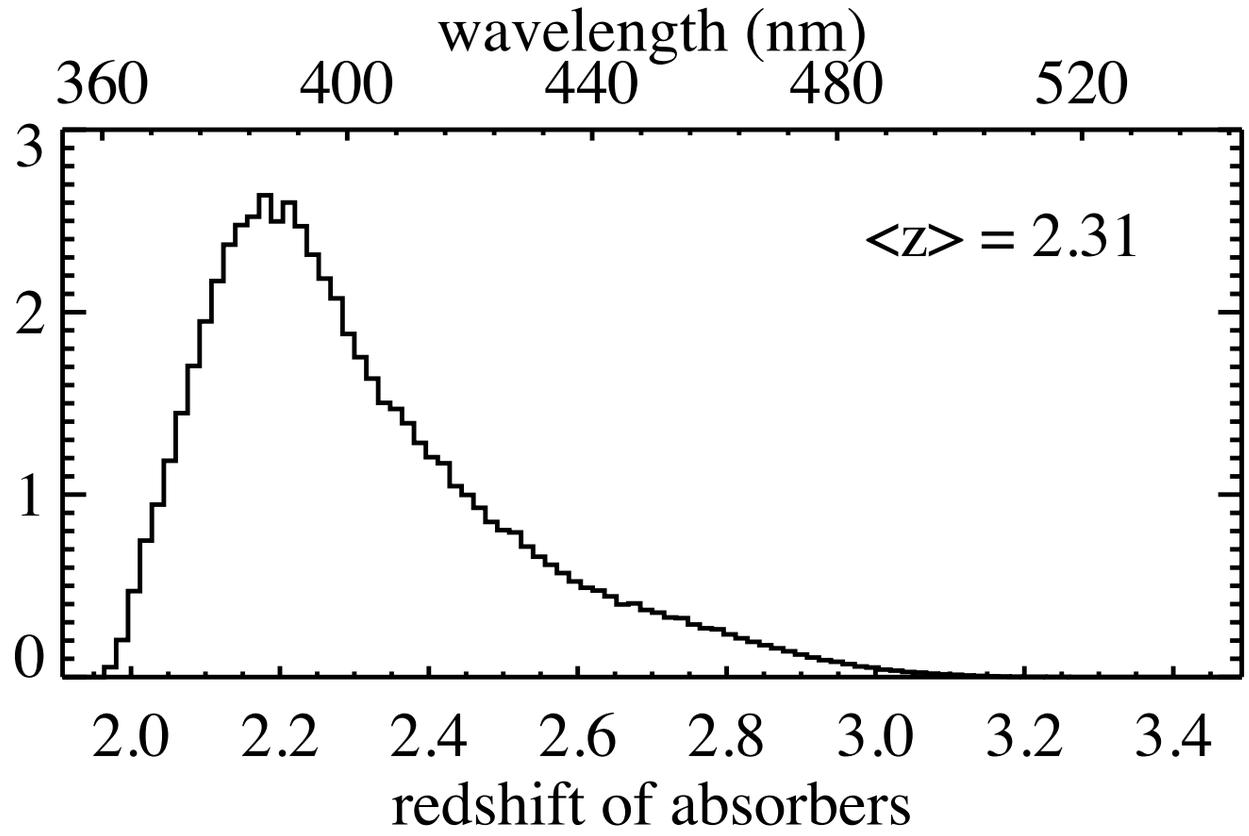
Lyα Measurement

Challenges:

- density of quasars in the sky, need ~ 16/deg^2:
  - QSOs look a lot like stars
  - too many stars in the sky! (compared to QSOs)
  - need high star-rejection and quasar selection efficiency
  - contaminants: metals, UV background fluctuations
- visual scan:
  - all ~200,000 QSO target spectra visually inspected
  - correct redshift classifications
  - tag QSOs with DLAs, BALs

The BOSS-Lyα data sample





- 60,369 quasars of $2.1 \leq z \leq 3.5$
- 48,640 quasars after removal of BAL or DLA
- definition of the data sample done before looking at data
- will measure $\xi(r) \equiv \langle\delta\delta\rangle$, $\delta(z) \equiv \frac{F(z)}{\overline{F}(z)\, C(z)} - 1$

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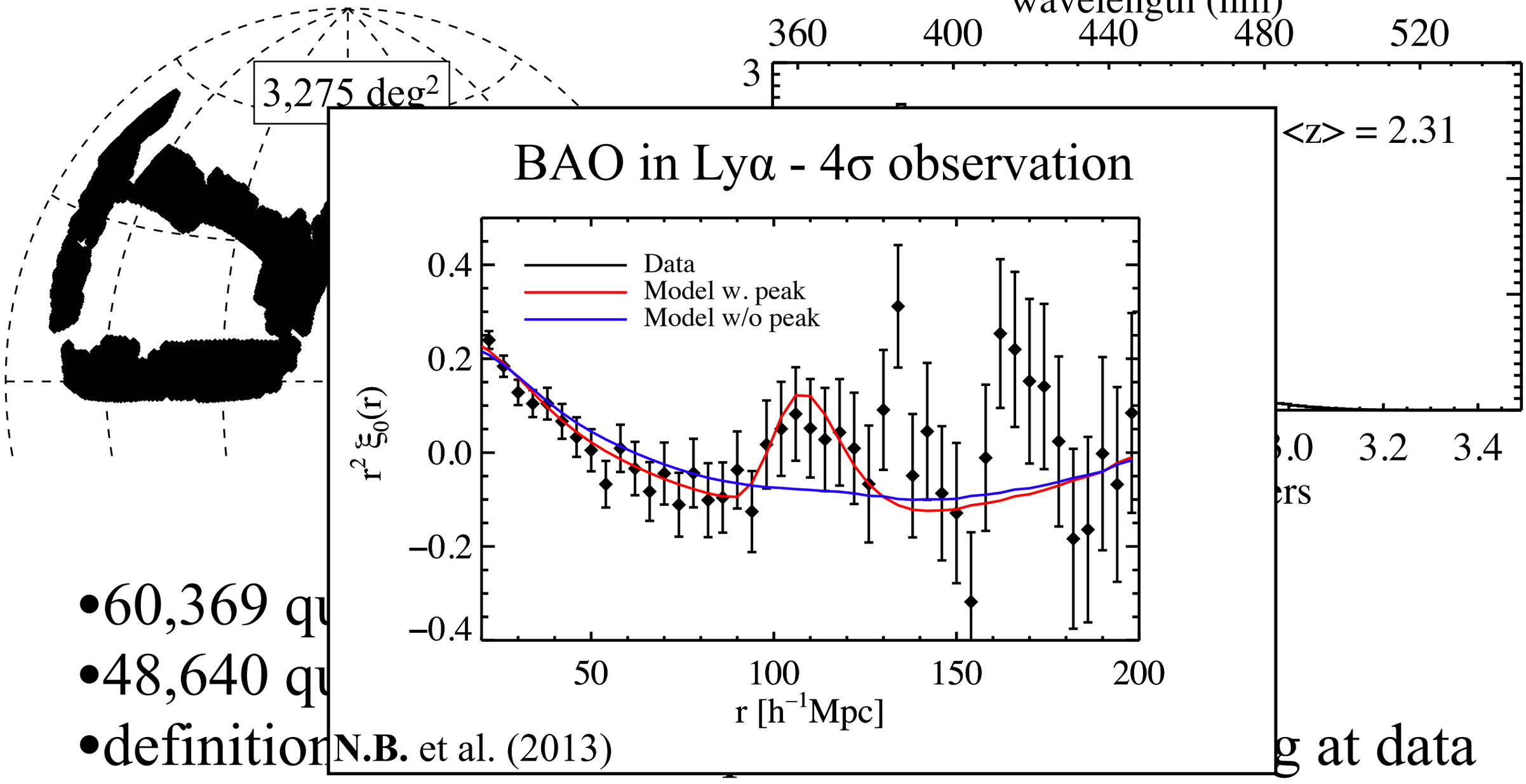

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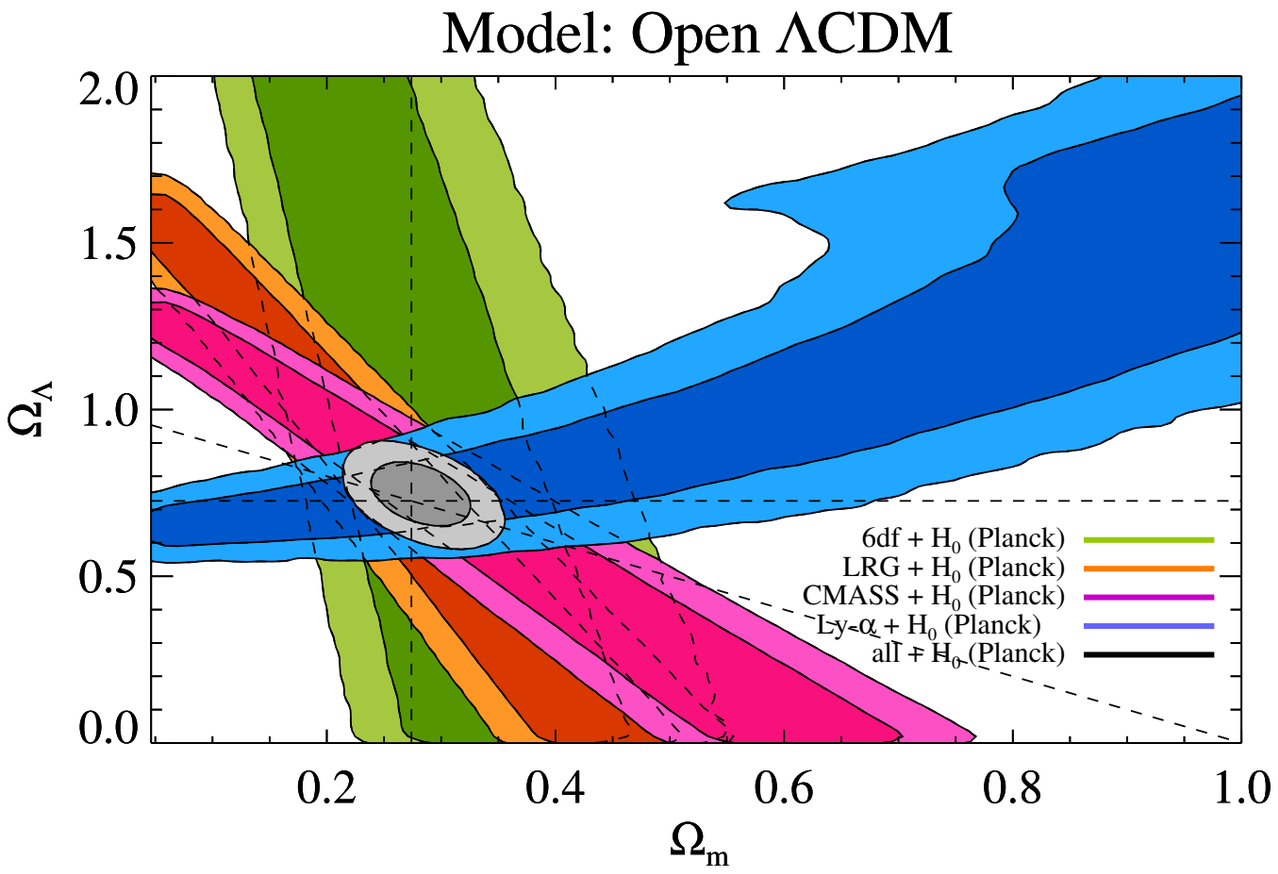
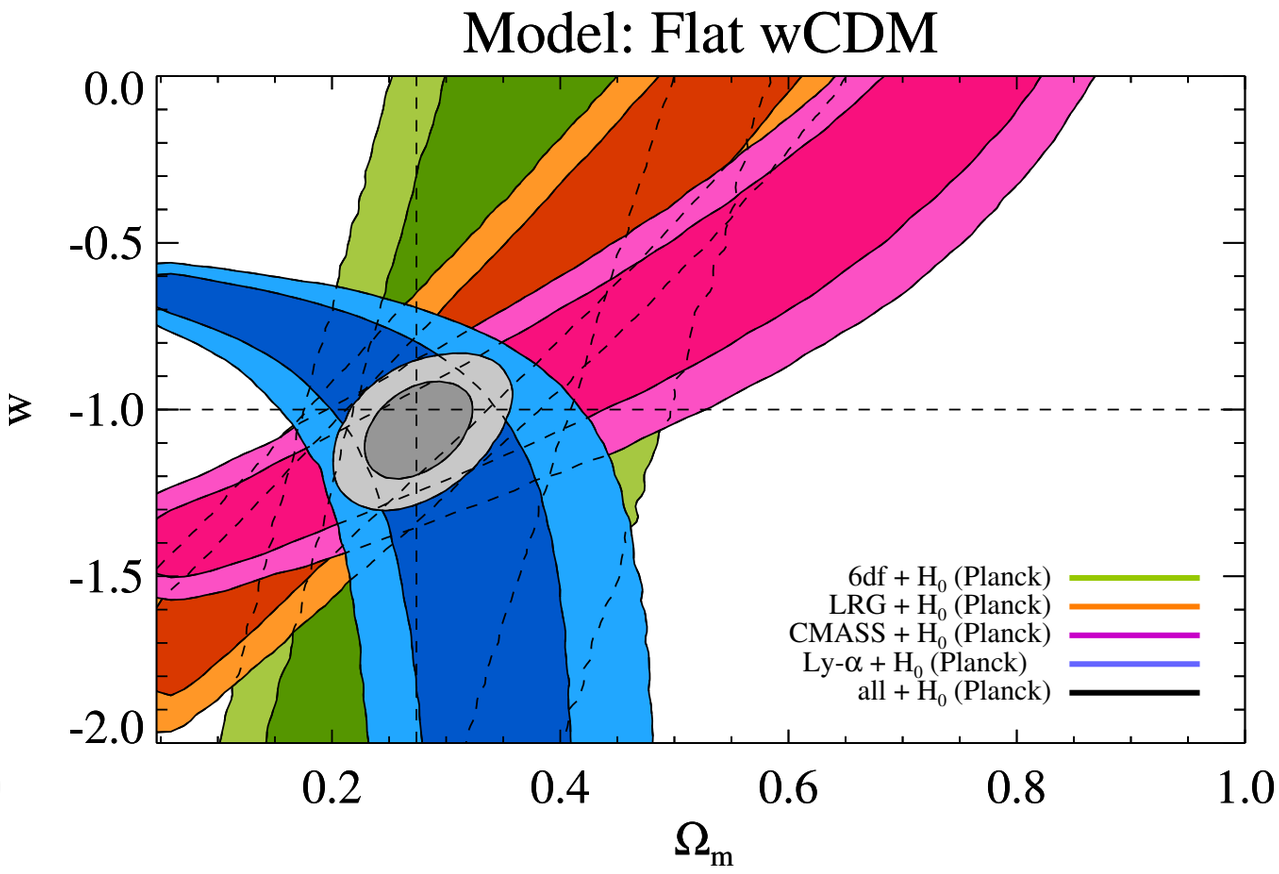
Cosmological Constraints





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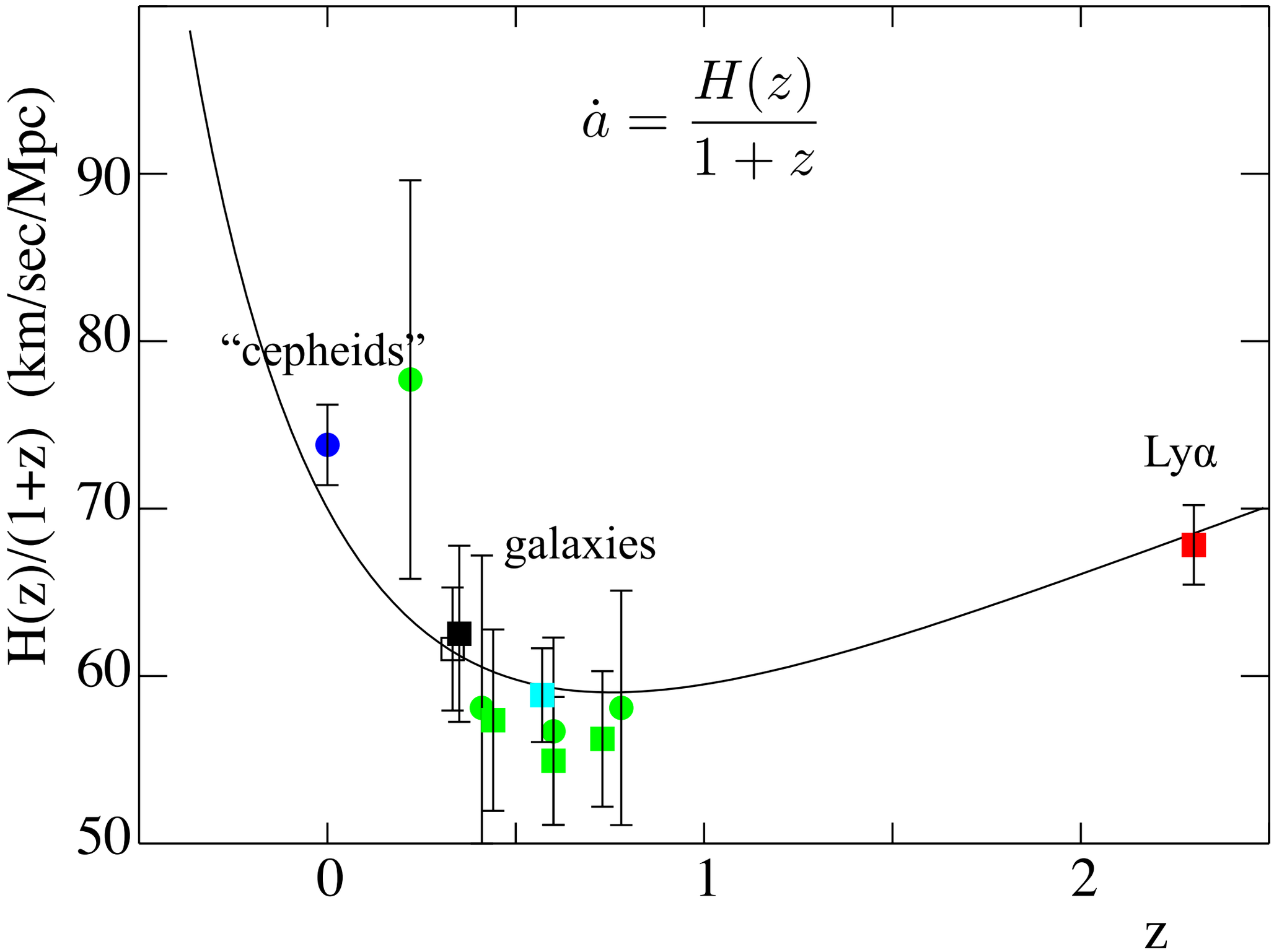

Conclusions

The BAO-Lyα works!

- First observation of the BAO peak at z ~ 2.3
- So far the highest z, deep in the matter domination epoch, able to measure H (with little model dependence)
- Measurement of H at high at z ~2.3 demonstrates the deceleration preceding the expansion
- Lyα data breaks degeneracies in the (Ω_m, Ω_Λ) and (Ω_m,w) plane confirming the concordance ΛCDM paradigm
- Future:
  - in a few months: DR10/DR11 (over 2x the stats)
  - next year: full BOSS (3x this study)