THE LYMAN-α FOREST AS A COSMOLOGICAL PROBE

MATTEO VIEL

- OBSERVATIONS
  LUQAS: The observational sample
  High-resolution spectra vs. Low resolution

- THEORY
  Hydro-dynamical simulations of the Lyman-α forest
  Full hydro simulations vs. HPM simulations

- RESULTS
  Cosmological parameters – Implications for gravitinos, neutrinos and WDM

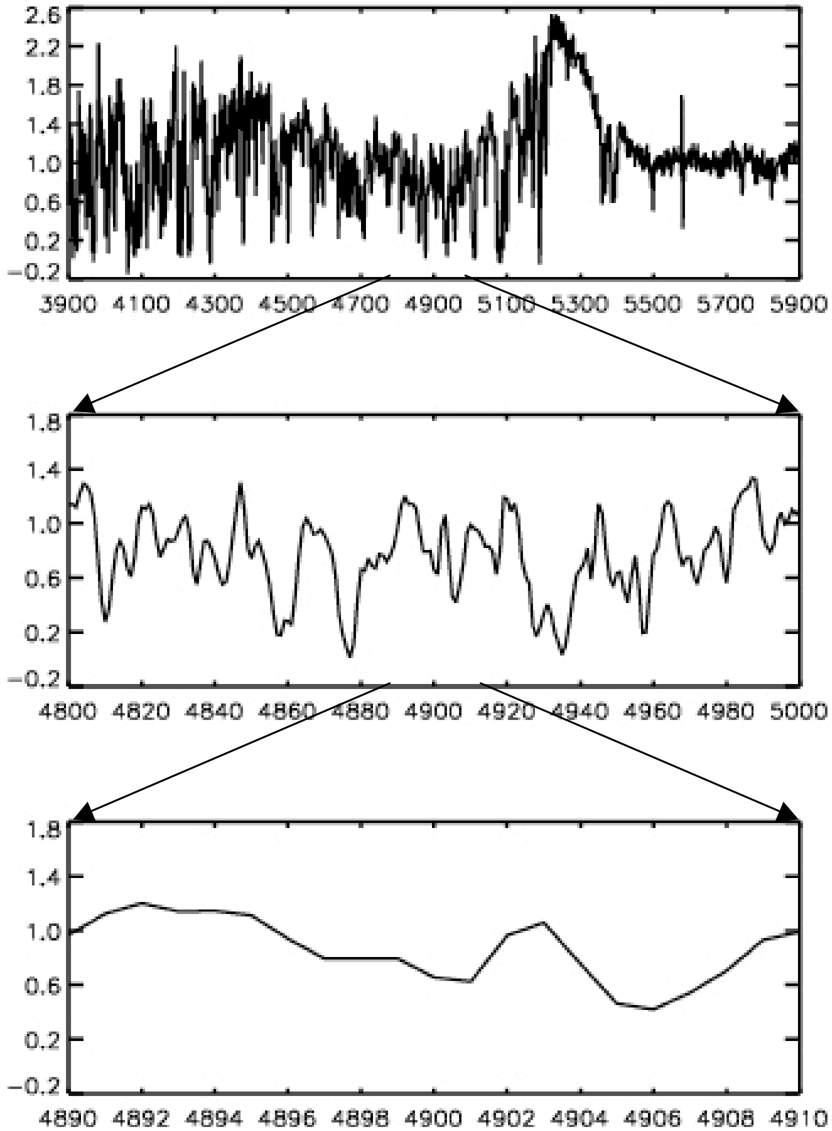
With M. Haehnelt, J. Lesgourgues, S. Matarrese, A. Riotto, V. Springel, J. Weller

'Computational Cosmology' - ICTP, Trieste, 3 June 2005

SDSS vs LUQAS

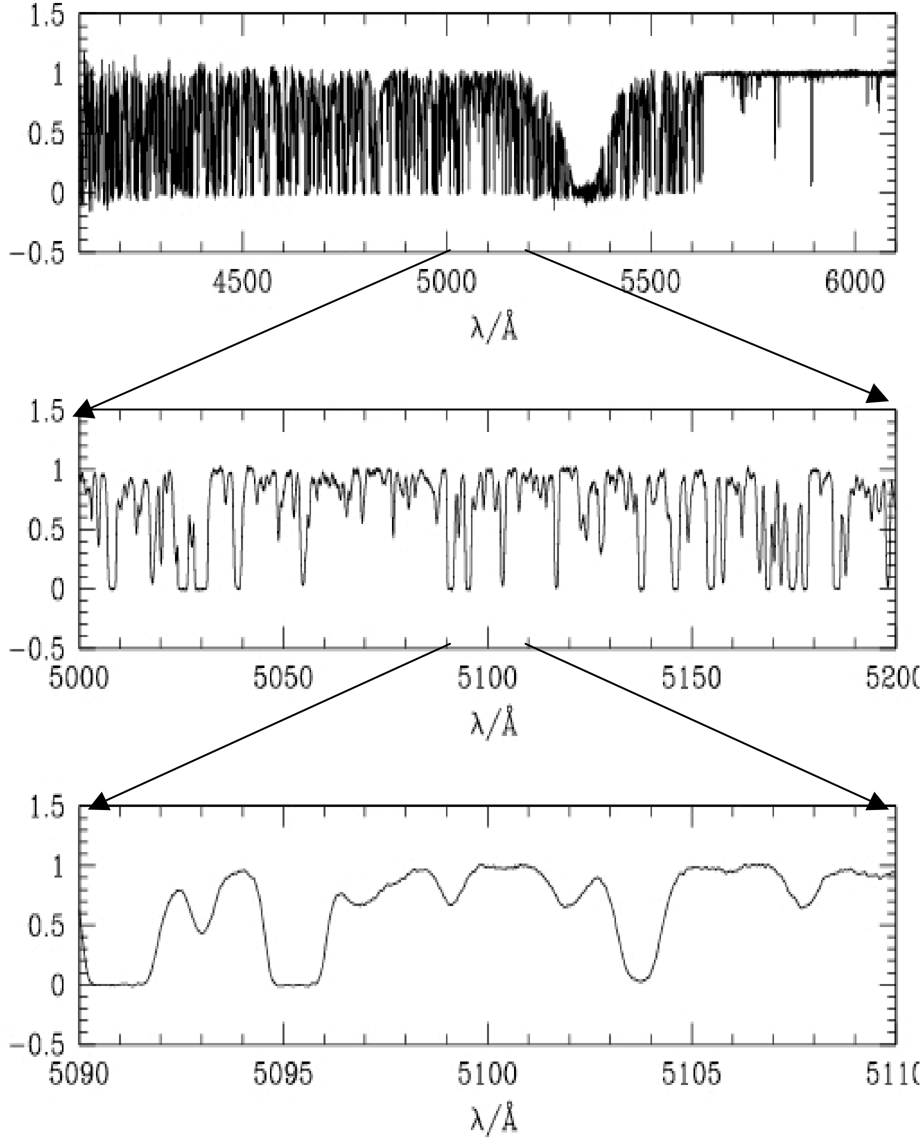
McDonald et al. 2004

SDSS



Kim et al. 2004

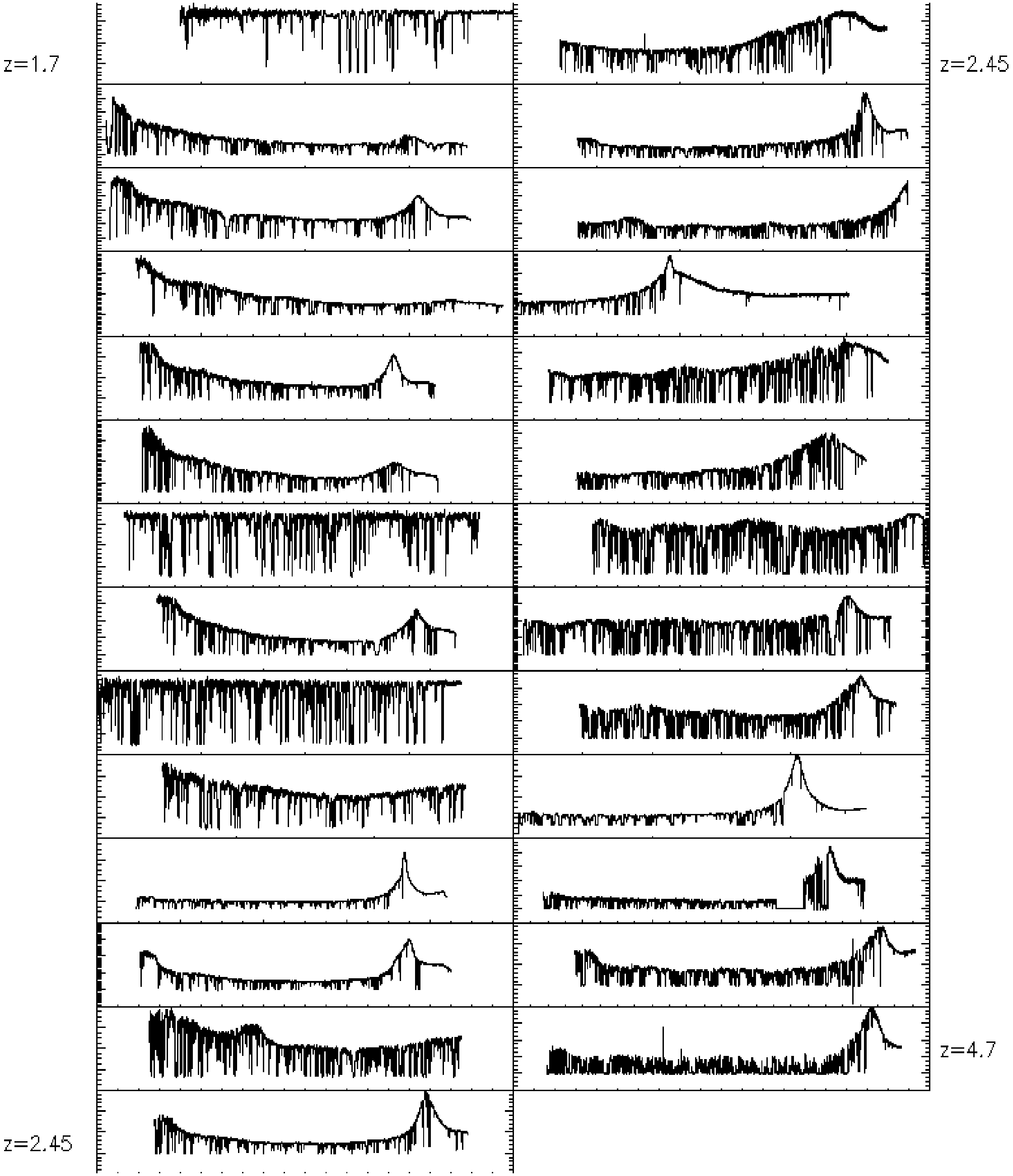
LUQAS



LOW RESOLUTION LOW S/N

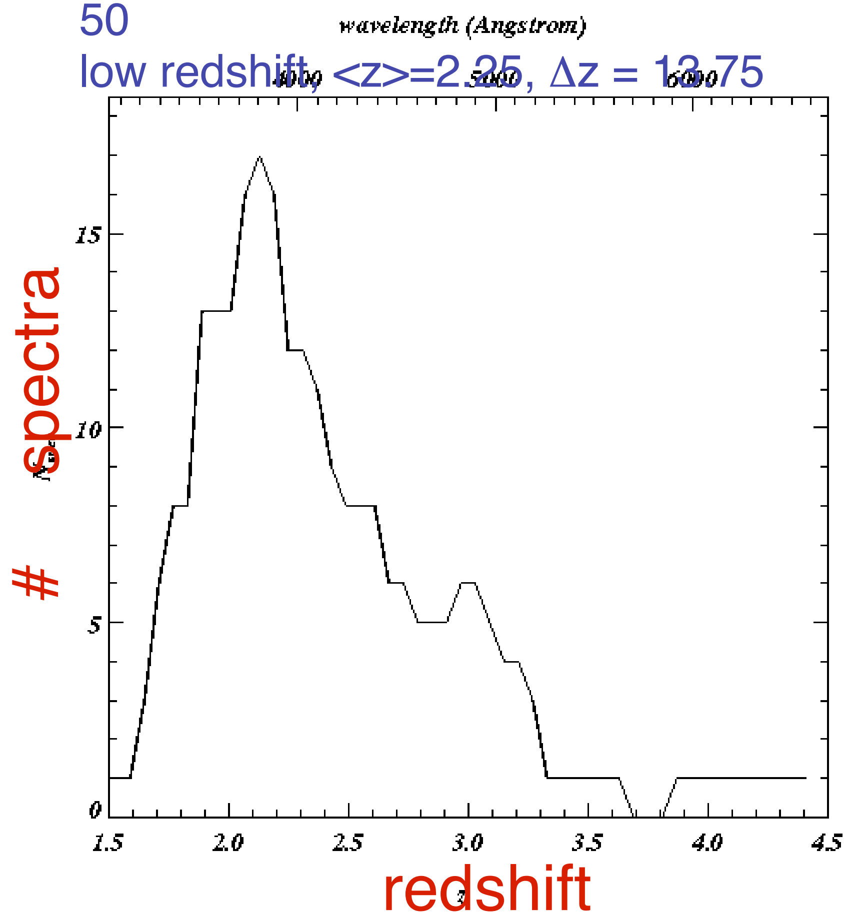
HIGH RESOLUTION HIGH S/N

The LUQAS sample



Large sample Uves Qso Absorption Spectra
(LP-UVES program P.I. J. Bergeron)

high resolution 0.05 Angstrom, high S/N > 50
low redshift, <z>=2.25, Δz = 13.75



Kim, MV, Haehnelt, Carswell, Cristiani, 2004, MNRAS, 347, 355

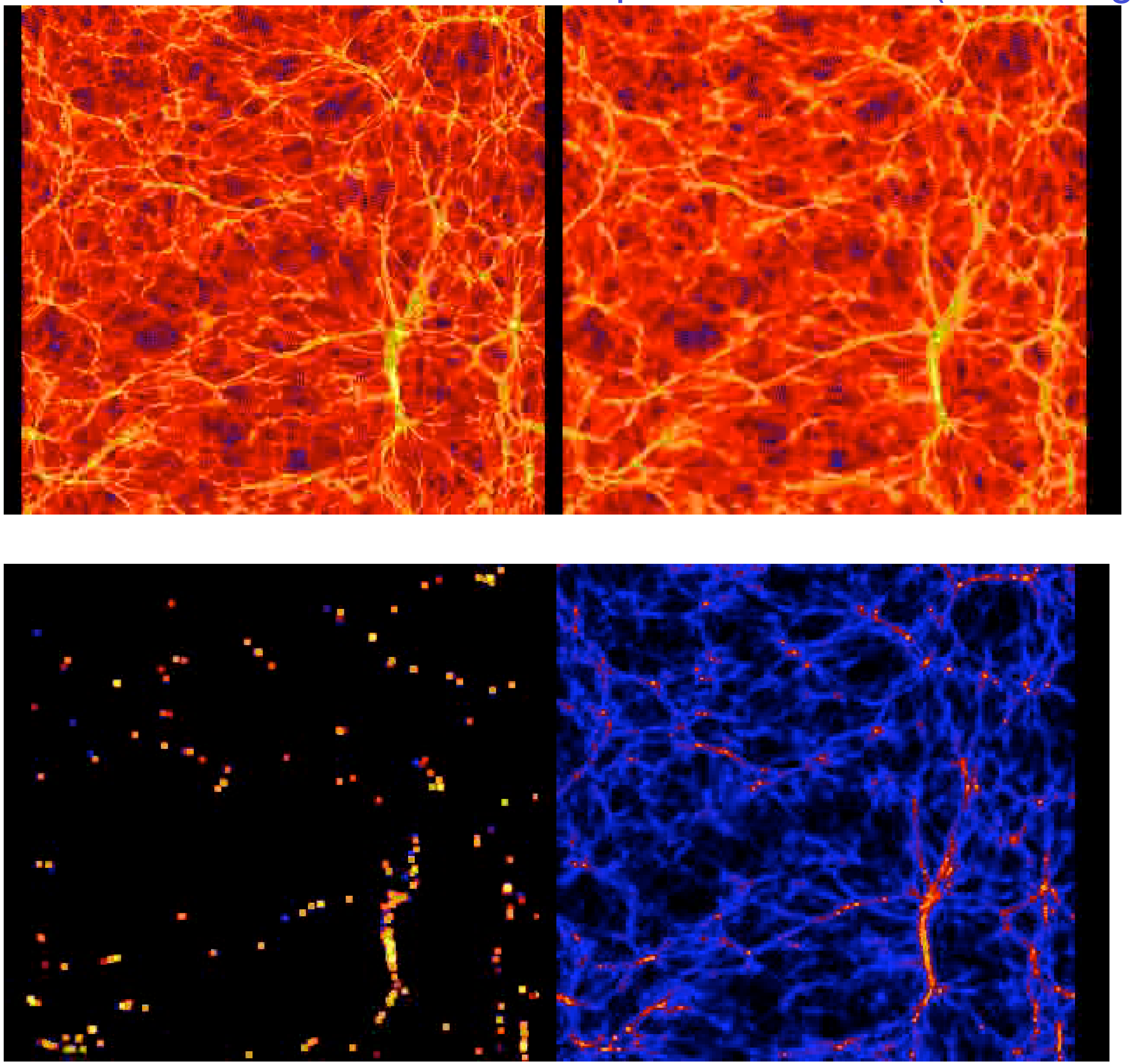
$\Omega_m = 0.26$ $\Omega_\Lambda = 0.74$ $\Omega_b = 0.0463$ $H_0 = 72$ km/sec/Mpc   - 60 Mpc/h 2×400^3 GAS+DM

2.5 com. kpc/h softening length

GADGET –II code   COSMOS computer – DAMTP (Cambridge)

DM

GAS



STARS

NEUTRAL HYDROGEN

Effective bias method (Croft et al.2002)

From full hydro-simulations

$$P_{FLUX}(k) = b^2(k)\ P_{MATTER}(k)$$

Depends on cosmological parameters, mean flux lev
Temperature, non linearities…….

for critical discussion see Gnedin & Hamilton 2002 and Zaldarriaga Scoccimarro Hui 2003

Main drawbacks: it misses dependence on some cosmological parameters
mode coupling is expected
linearity of lyman-α structures

The flux power spectrum seems to be a robust statistics (Galactic winds, DLAs, metals…)
e.g. McDonald et al. (2004)

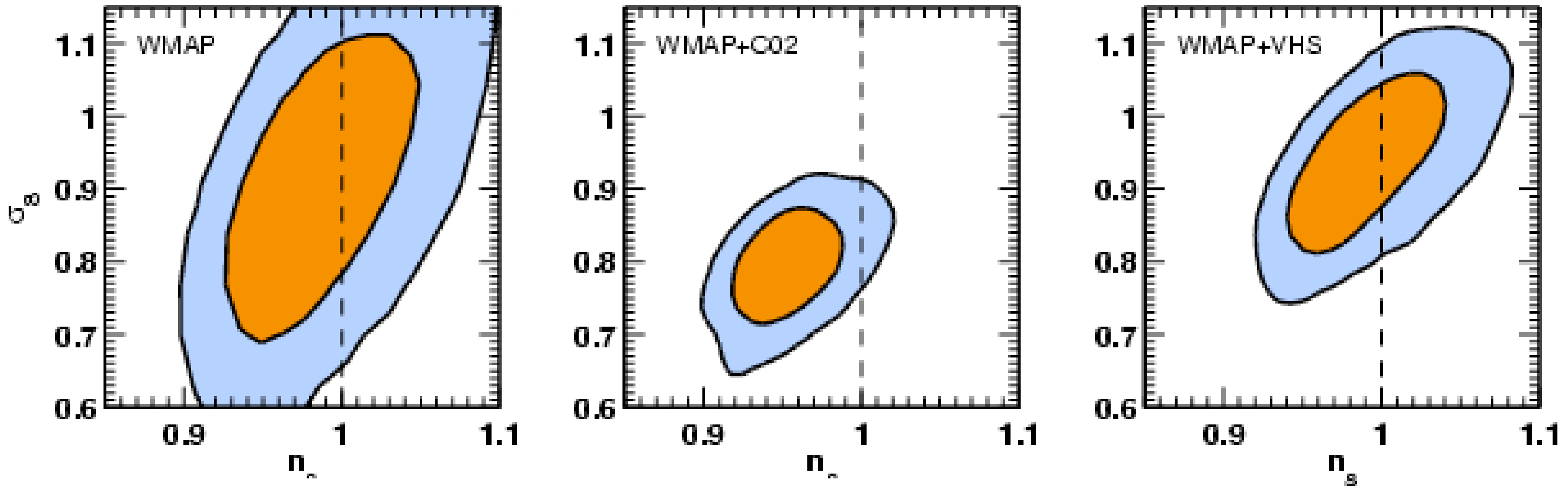
RESULTS

Cosmological implications: combining the forest data with WMAP

MV, Haehnelt, Springel, MNRAS, 2004, 354, 684

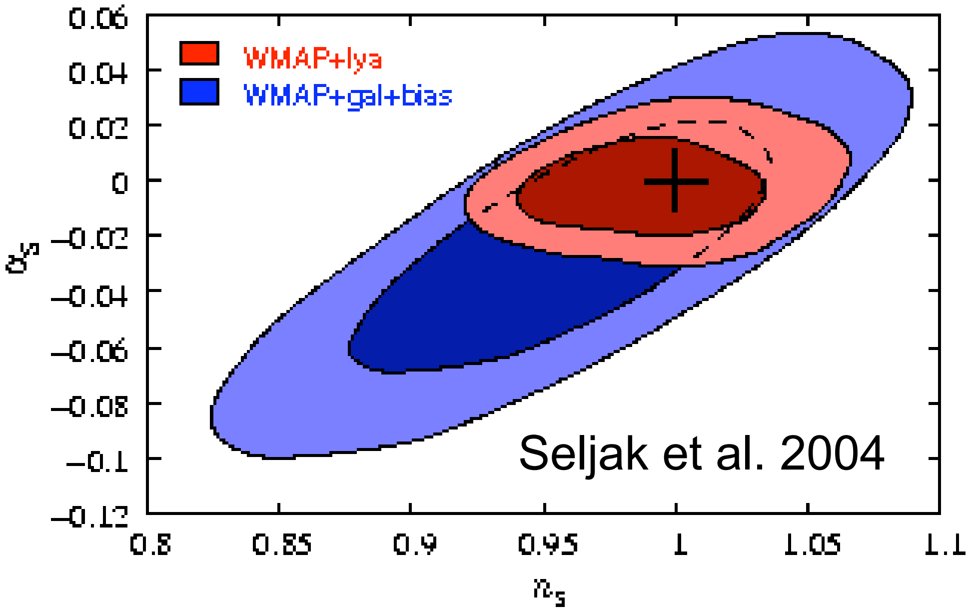
MV, Weller, Haehnelt, MNRAS, 2004, 355, L23

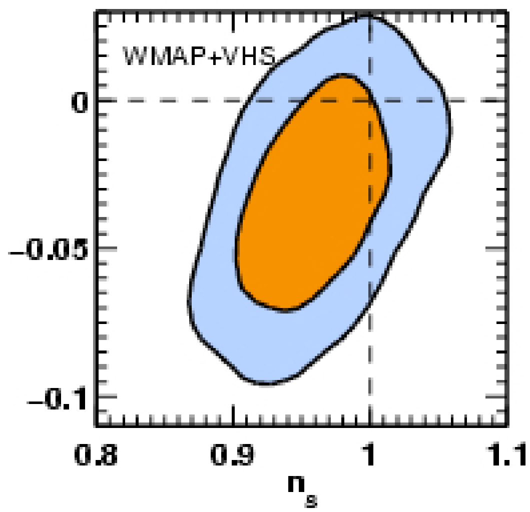
σ_8= 0.93 ± 0.07   n=0.99 ± 0.03



d n_s/ d ln k

n_{run}

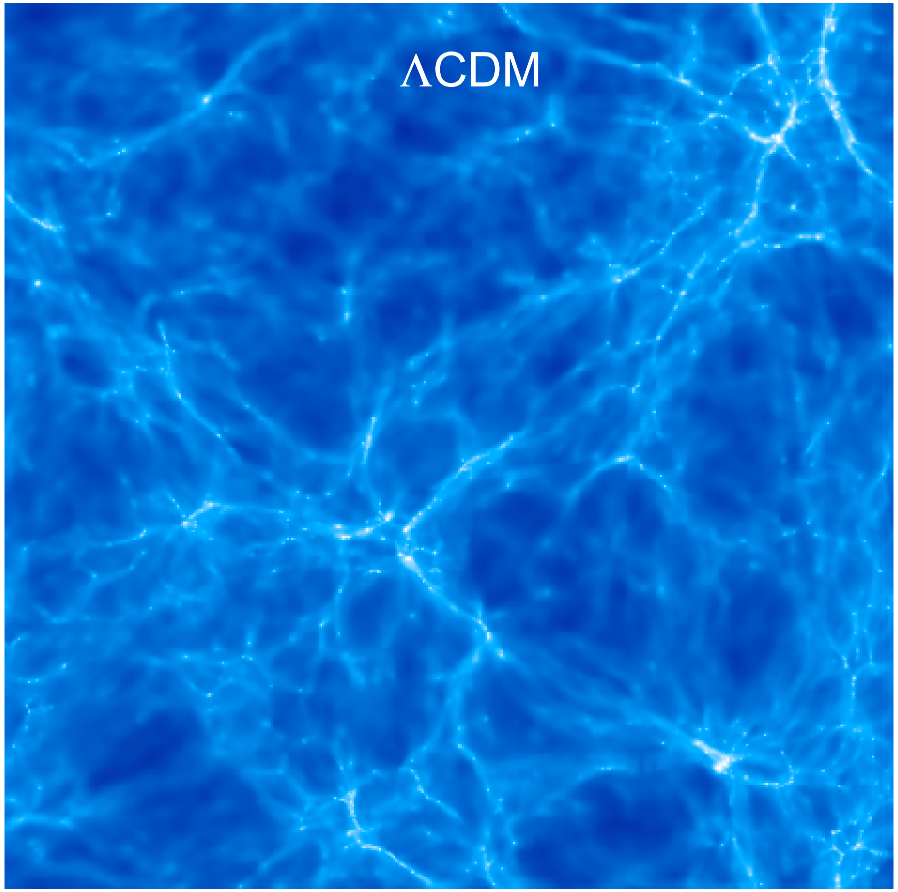


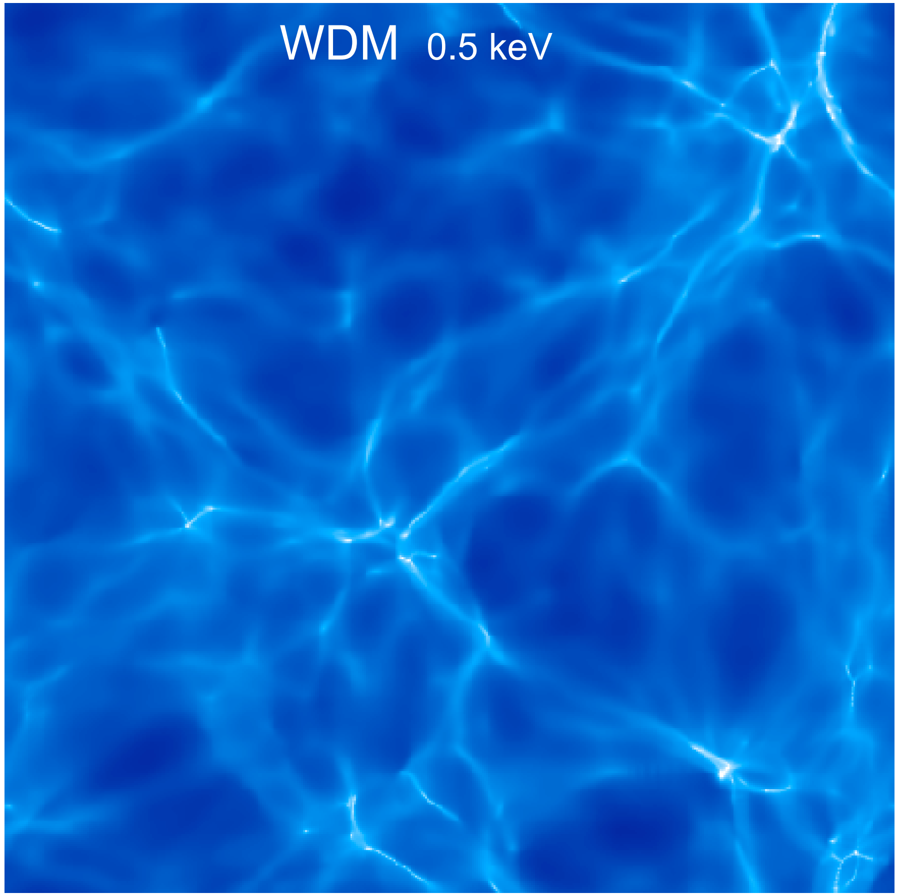


σ_8= 0.90 ± 0.03   n=0.98 ± 0.02 n_{run} = -0.003 ± 0.010

n_{run}=-0.033± 0.025

Cosmological implications: Warm Dark Matter particles-I





30 comoving Mpc/h z=3

In general

$k_{FS} \sim 5\, (T_{\nu}/T_x)\, (m_x/1\text{keV})\ \text{Mpc}^{-1}$

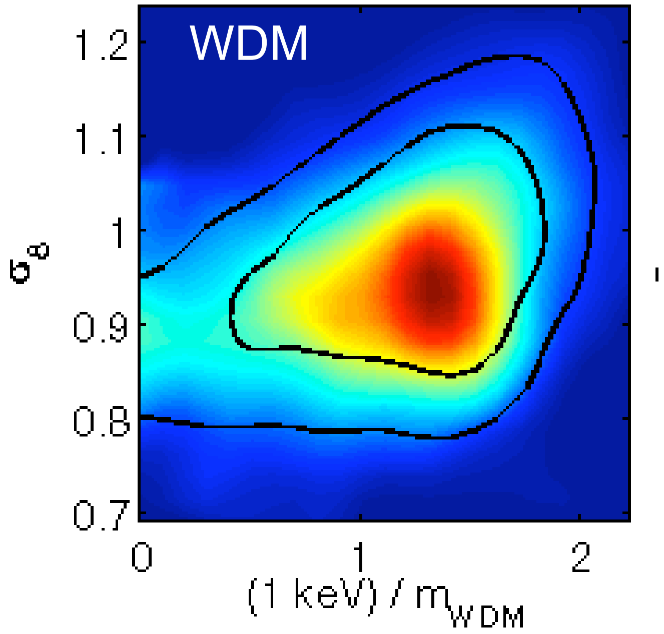
Set by relativistic degrees of freedom at decoupling

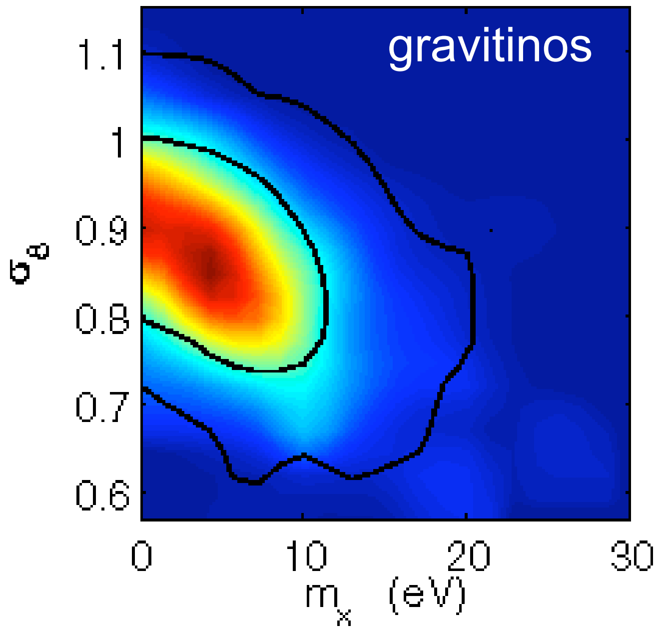
if light gravitinos

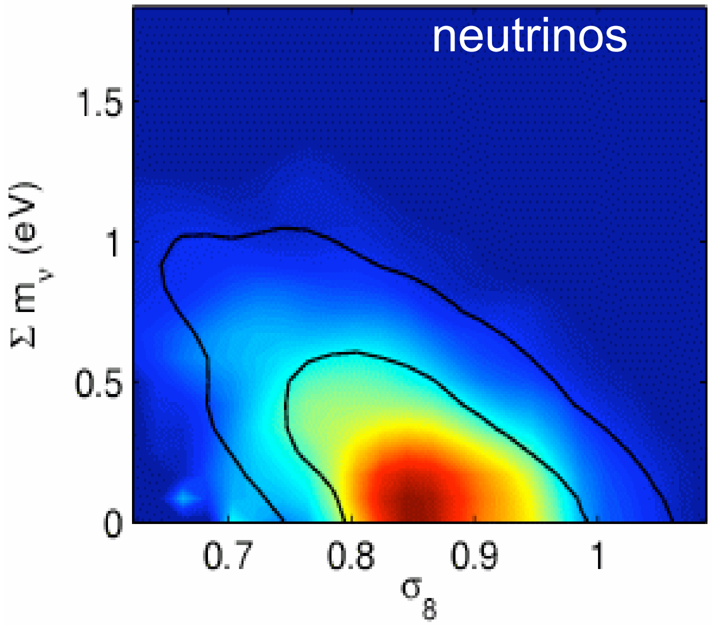
$k_{FS} \sim 1.5\ (m_x/100\text{eV})\ h/\text{Mpc}$

MV, Lesgourgues, Haehnelt, Matarrese, Riotto, PRD, 2005, 71, 063534

Cosmological implications: WDM, gravitinos, neutrinos







m_{WDM} > 550 eV

> 2keV sterile neutrino

m_{grav} < 16 eV

Σm_ν (eV) = 0.33 ± 0.27

WMAP + 2dF + LYα

	ΛWDM	ΛCWDM
$\Omega_x h^2$	0.124 ± 0.015	0.149 ± 0.019
$\Omega_B h^2$	0.024 ± 0.001	0.024 ± 0.001
h	0.72 ± 0.06	0.71 ± 0.06
τ	0.18 ± 0.09	0.17 ± 0.08
σ_8	0.96 ± 0.08	0.86 ± 0.09
n	1.01 ± 0.04	1.00 ± 0.04
α (Mpc/h)	0.06 ± 0.03	—
f_x	—	0.05 ± 0.04

Set limits on the scale of Supersymmetry breaking

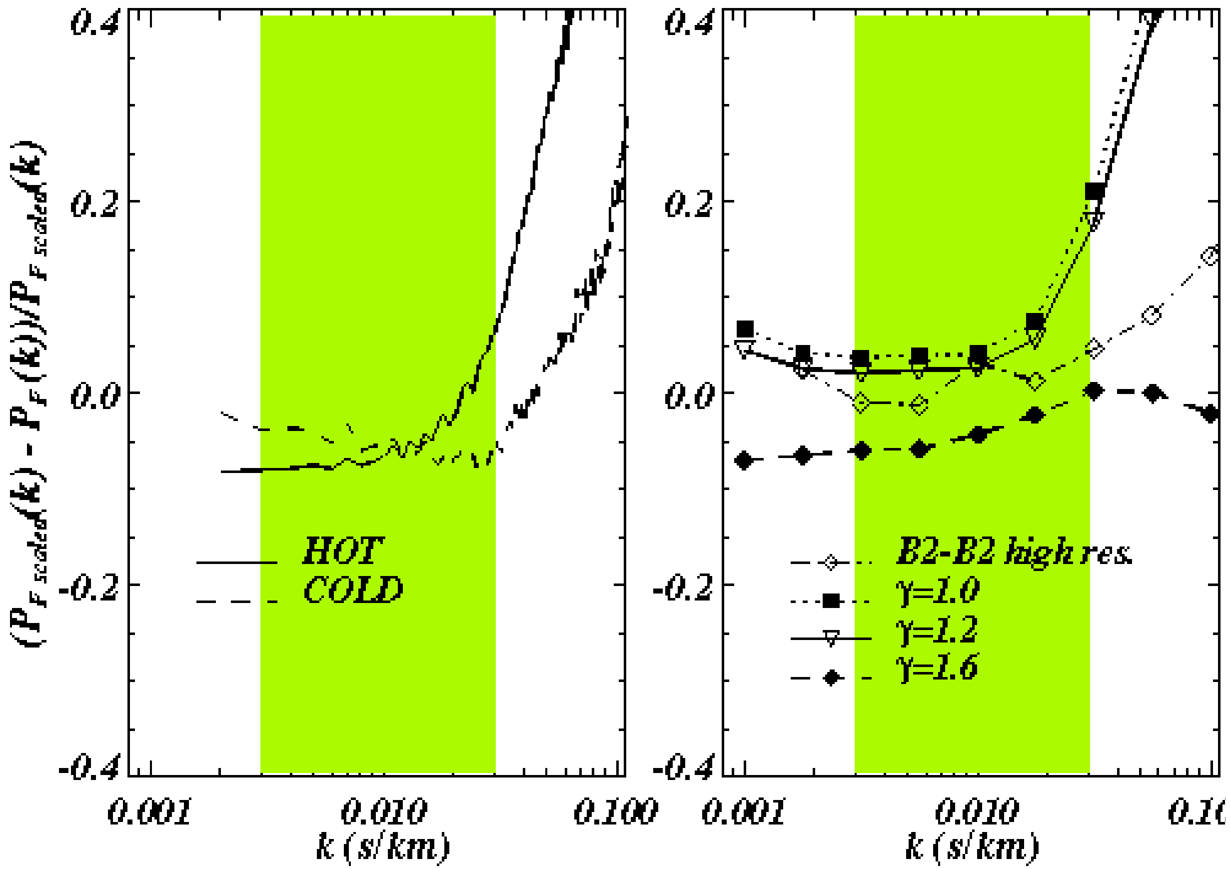
$\Lambda_{susy} < 260$ TeV

SYSTEMATICS

Hydro-simulations: systematics effects

$T = T_0\,(1+\delta)^{\gamma-1}$

Different equation of state | Different γ

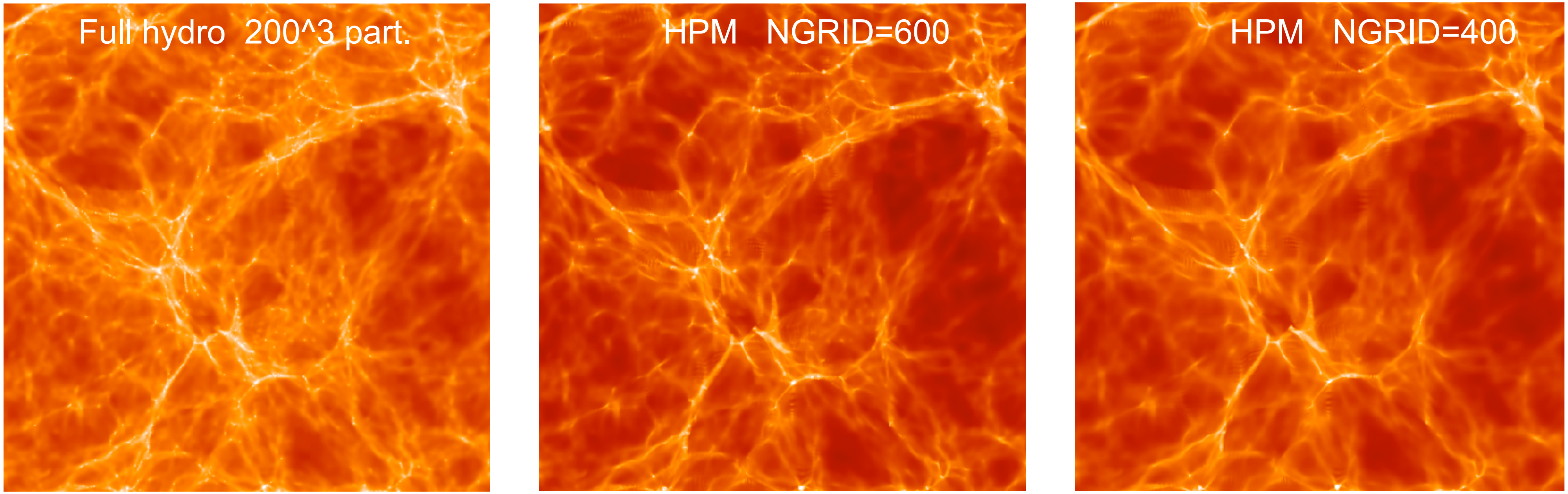


Hydro-simulations: what have we learnt?

Many uncertainties which contribute more or less equally
(statistical error seems not to be an issue!)

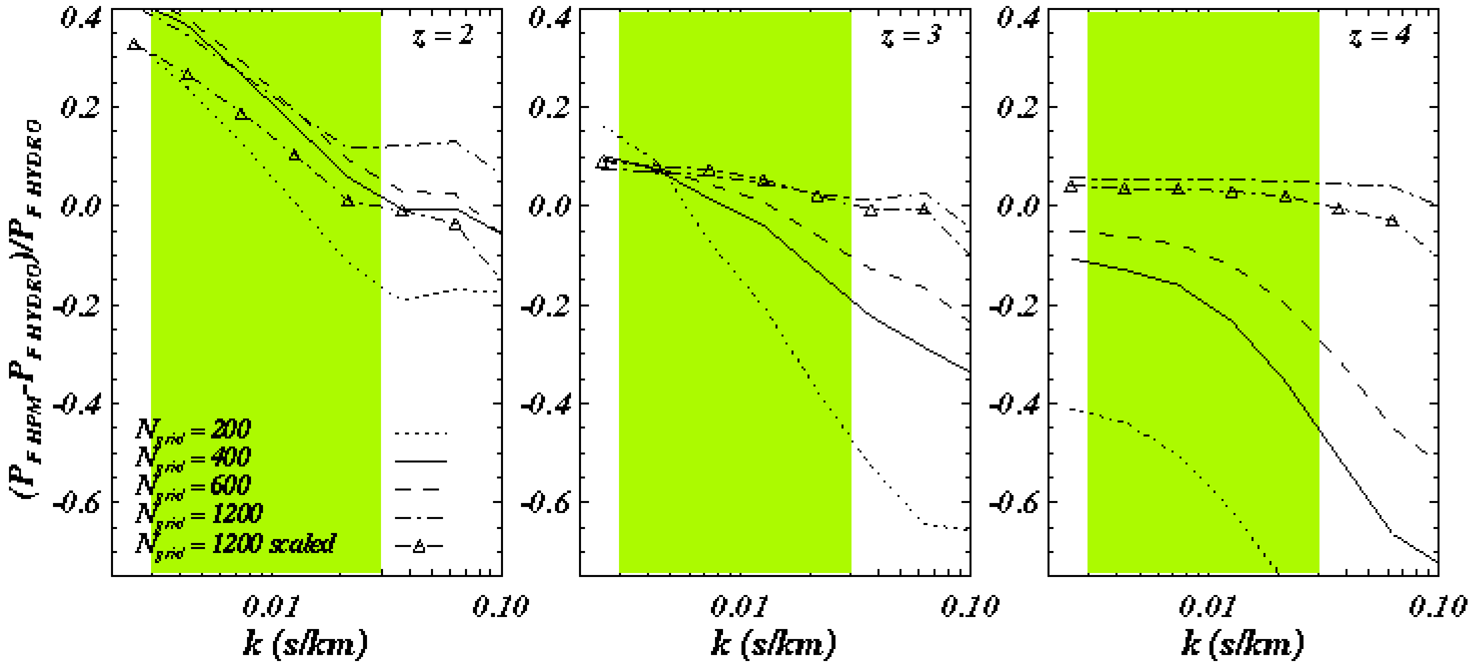
ERRORS	CONTRIBUTION TO FLUCT. AMPL.
Statistical error	4%
Systematic errors	~ 15 %
τ_{eff} (z=2.125)=0.17 ± 0.02	8 %
τ_{eff} (z=2.72) = 0.305 ± 0.030	7 %
γ = 1.3 ± 0.3	4 %
T_0 = 15000 ± 10000 K	3 %
Method	5 %
Numerical simulations	8 %
Further uncertainties	5 %

HPM simulations of the forest

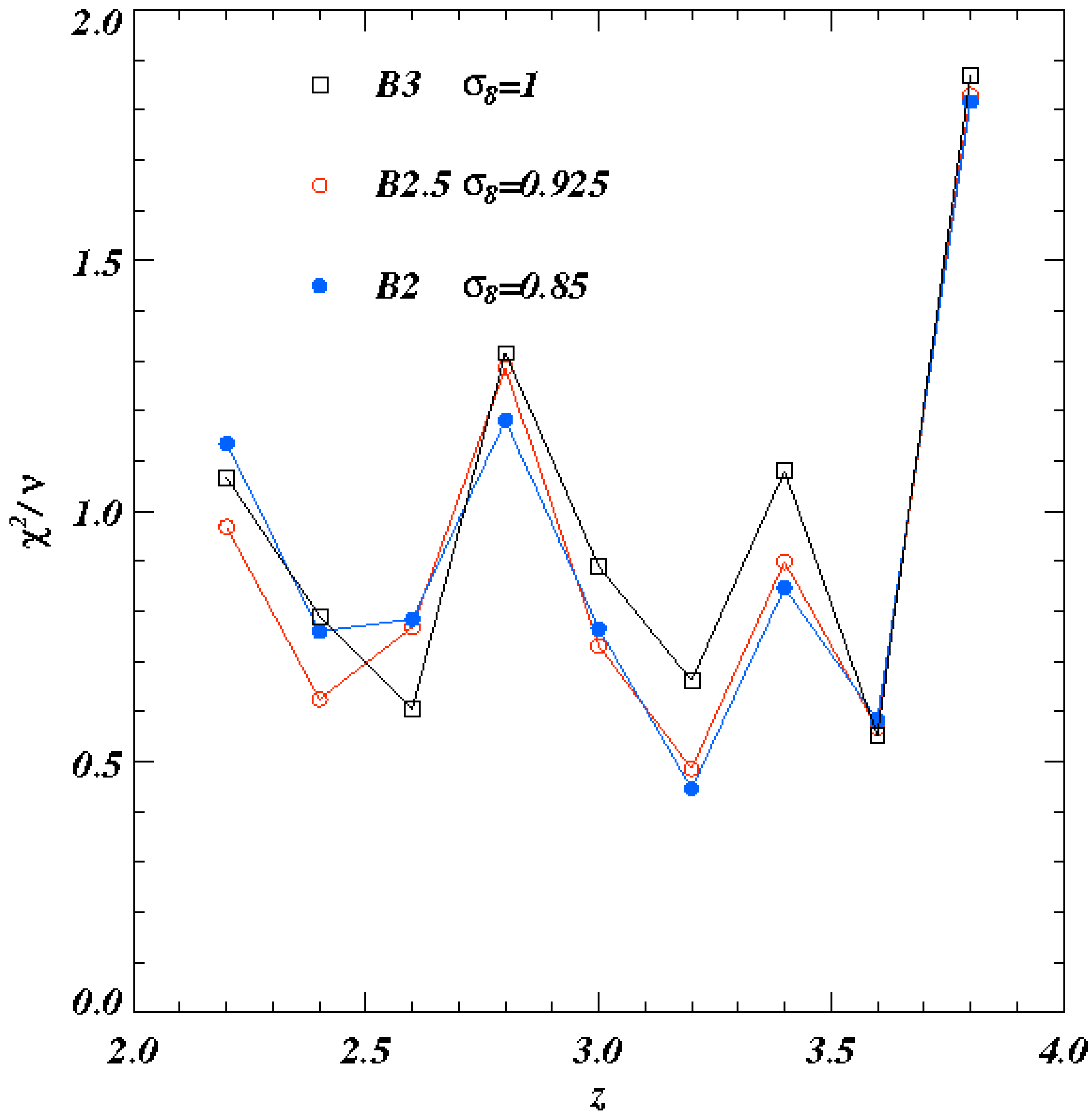


MV, Haehnelt, Springel, astro-ph/0504641

FLUX POWER



Fitting the SDSS flux power spectrum with full hydro simulatio



SUMMARY

1. LUQAS: a unique high resolution view on the Universe at z=2.1

2. Hydro-dynamical simulations of the Lyman-α forest. Systematic Errors? Differences between hydro codes?

3. Cosmological parameters: no fancy things going on
   σ_8 = 0.93 n = 1 no running
   substantial agreement between SDSS and LUQAS but SDSS h
   smaller error bars (factor ~ 2), due to the different
   theoretical modelling and wider range of redshift probed by SD
   Constraints on inflationary models, neutrinos and WDM can be
   obtained