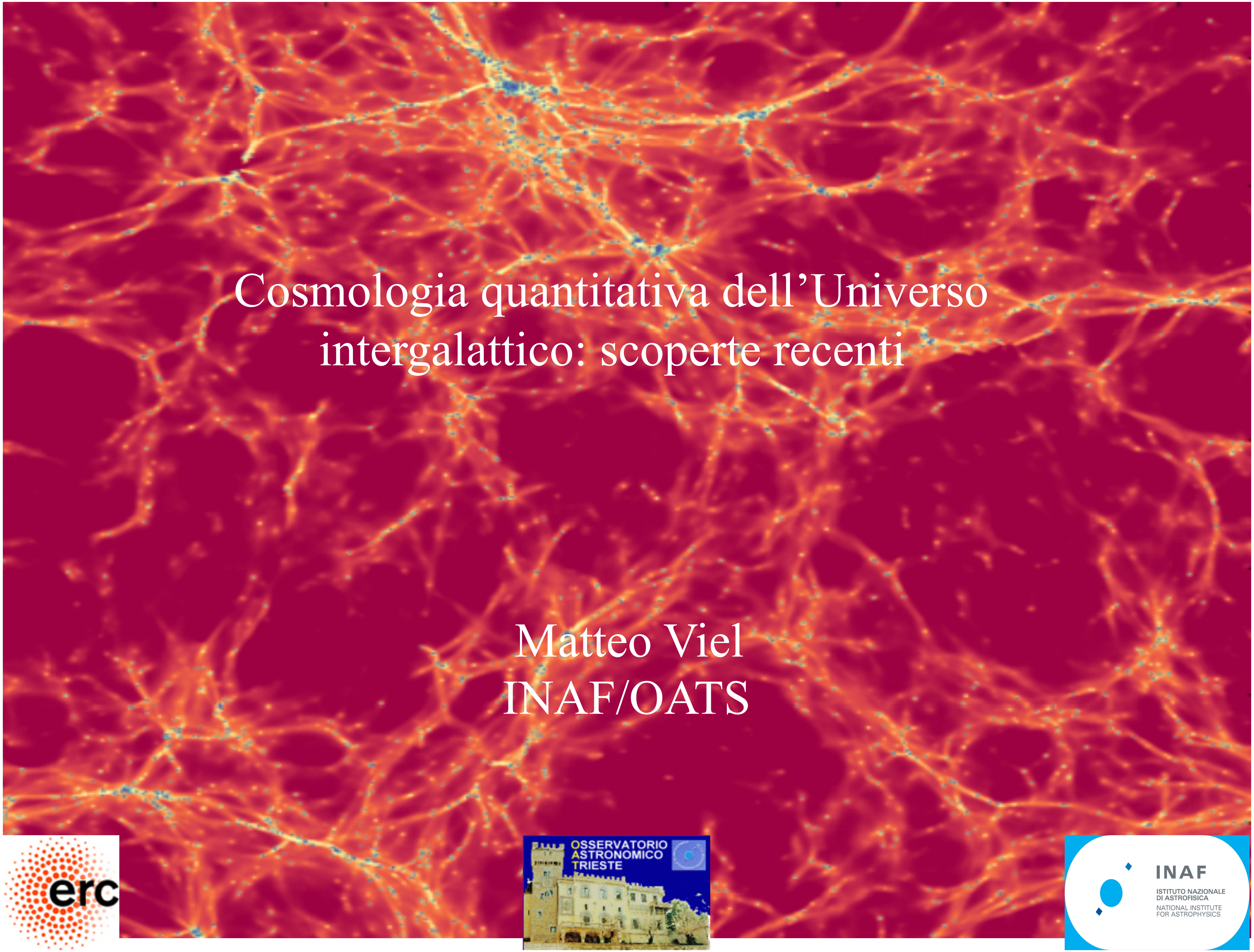
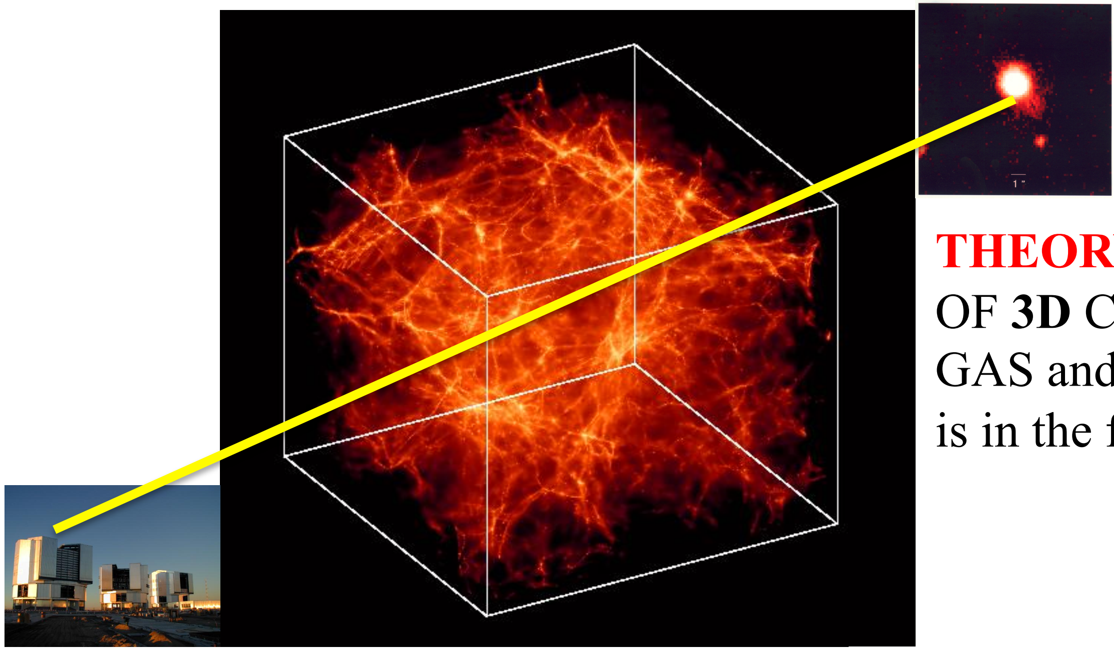


Cosmologia quantitativa dell'Universo intergalattico: scoperte recenti

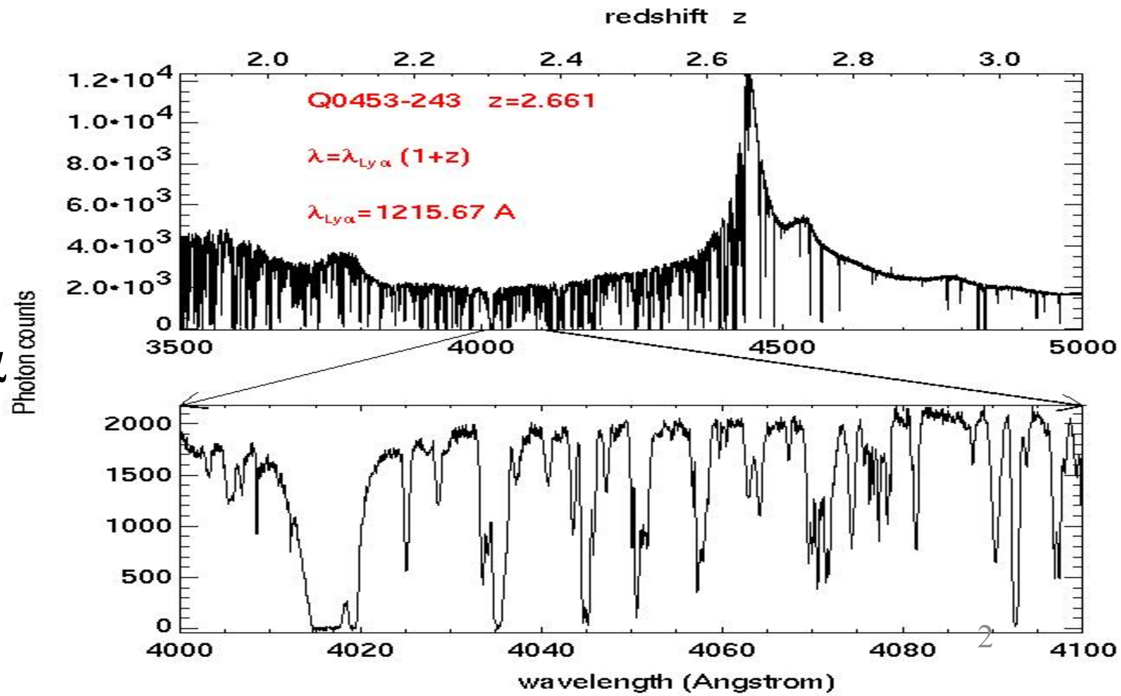
Matteo Viel
INAF/OATS

OSSERVATORIO ASTRONOMICO TRIESTE

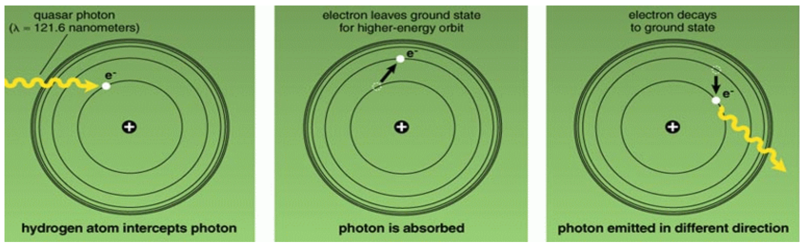
cosmoIGM: scientific background

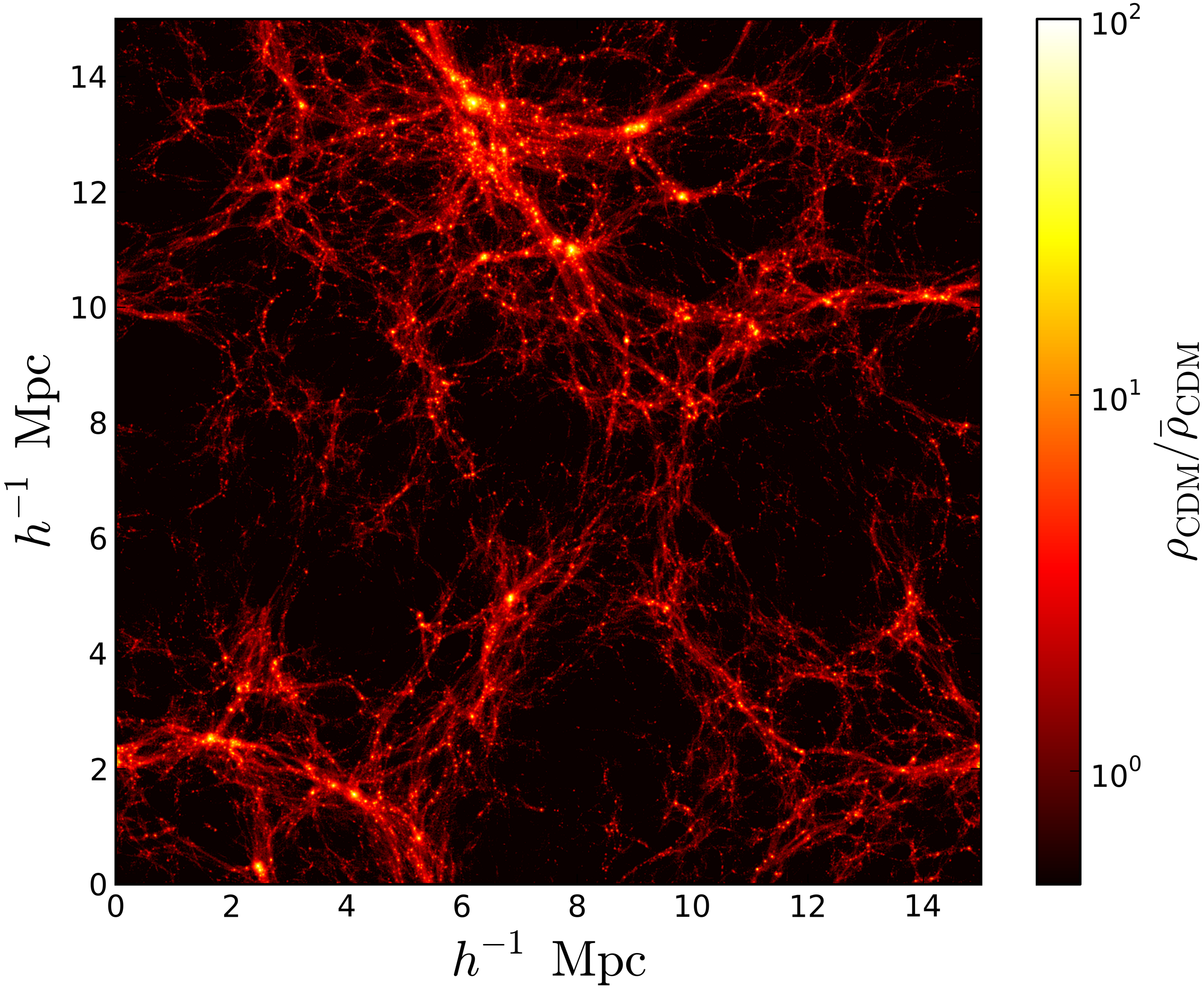


THEORY: NUMERICAL MODELLING OF **3D** COSMIC WEB (DARK MATTER, GAS and GALAXIES): 80% of visible matter is in the form of filaments



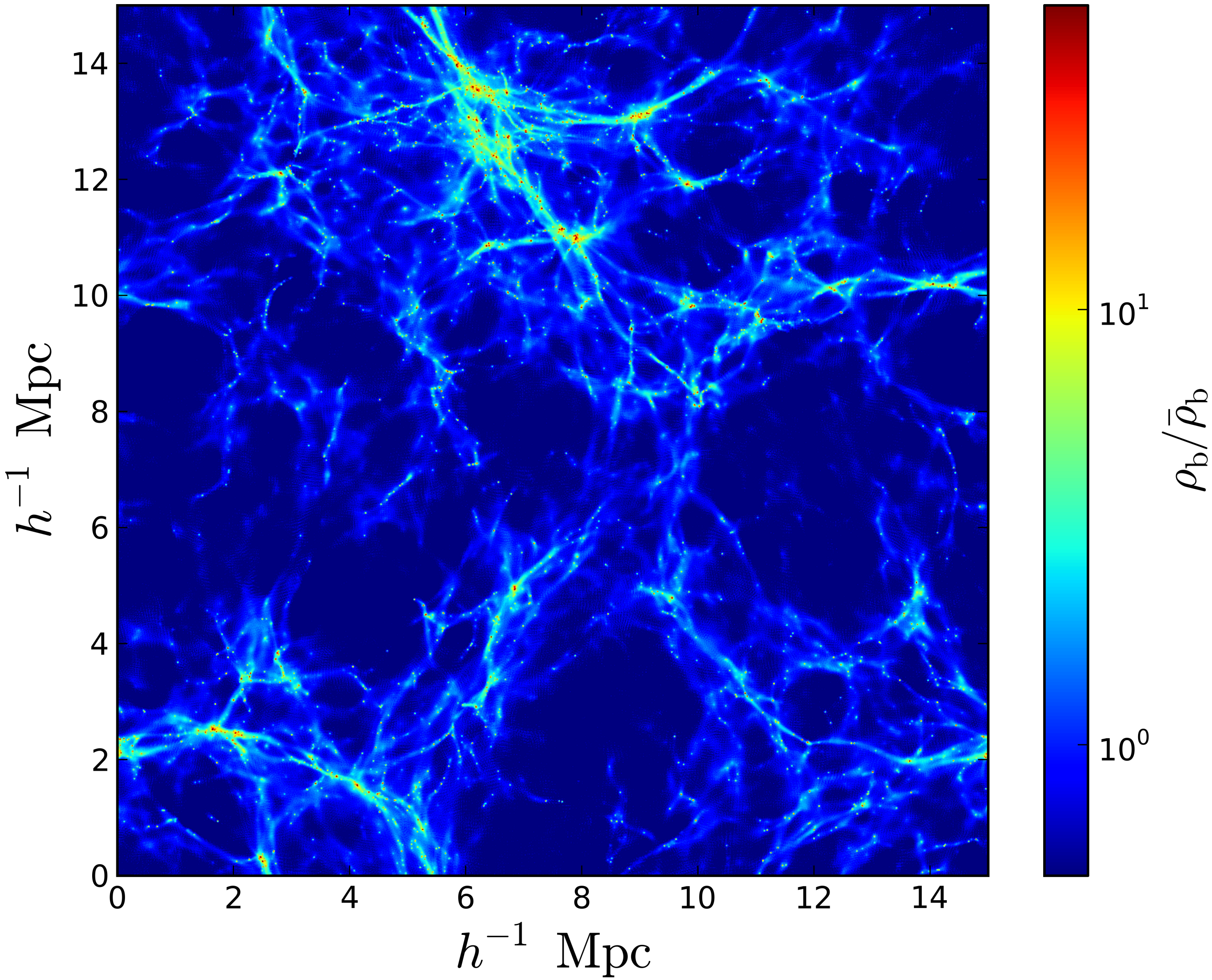
DATA: **1D** TRANSMITTED LYMAN-α FLUX (1s→2p resonant transition)





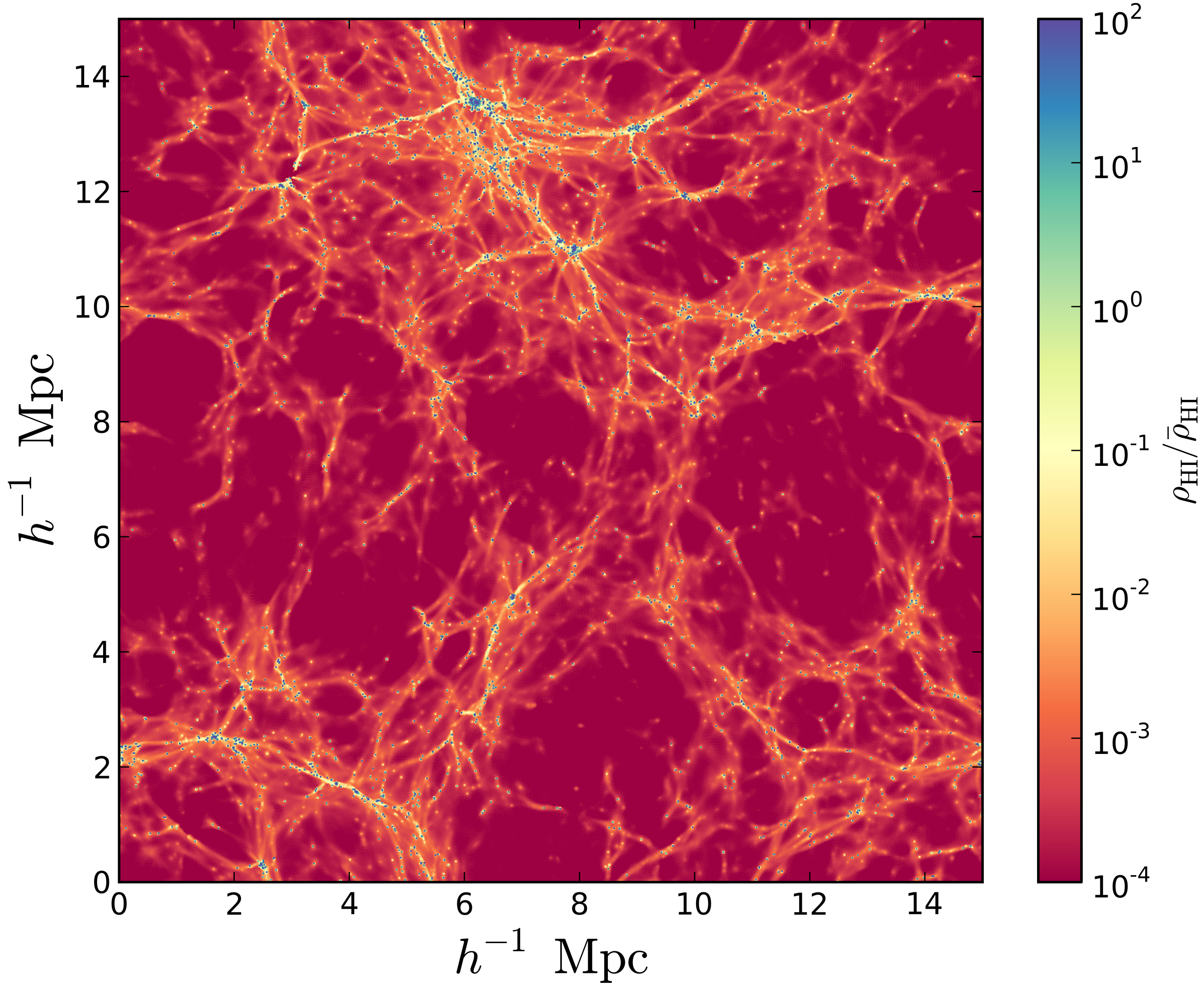
h^{-1} Mpc
h^{-1} Mpc
0
2
4
6
8
10
12
14
10^2
10^1
10^0
$\rho_{\mathrm{CDM}}/\bar{\rho}_{\mathrm{CDM}}$

DARK MATTER



14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
14
h^{-1} Mpc
h^{-1} Mpc
10^1
10^0
$\rho_{\rm b}/\bar{\rho}_{\rm b}$

BARYONS



NEUTRAL HYDROGEN

Tools

Theoretical work: simulation of the Universe in national and international Supercomputing facilities

Nr. 93 in the top 500 supercomputers

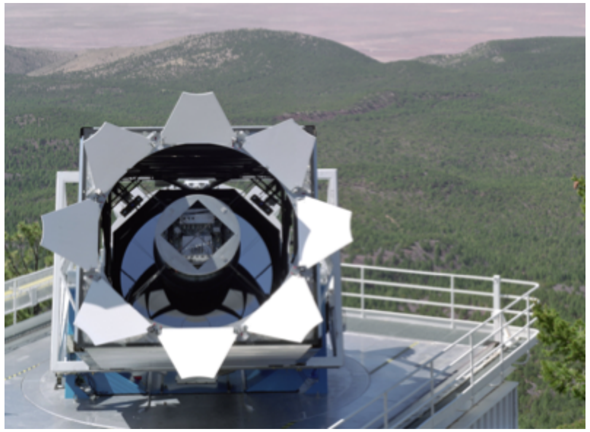
HPCS Darwin @ Cambridge (UK)

Nr. 7 in the top 500 supercomputers

Fermi Blue Gene @ CINECA (Italy)

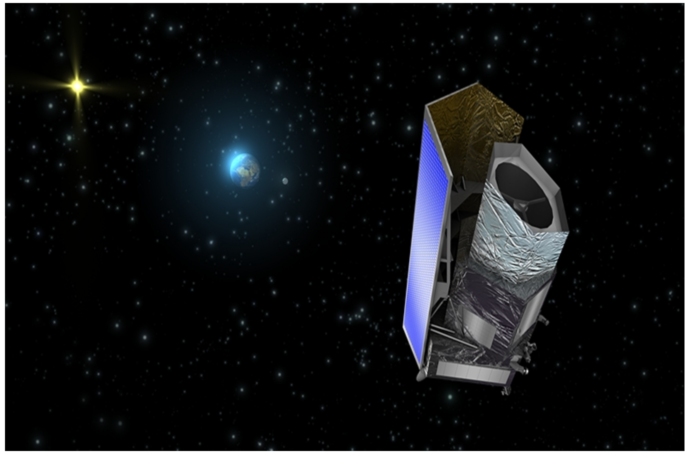
Observations: from international State-of-the-art spectrograph

European Southern Observatory VLT at Paranal (Chile)

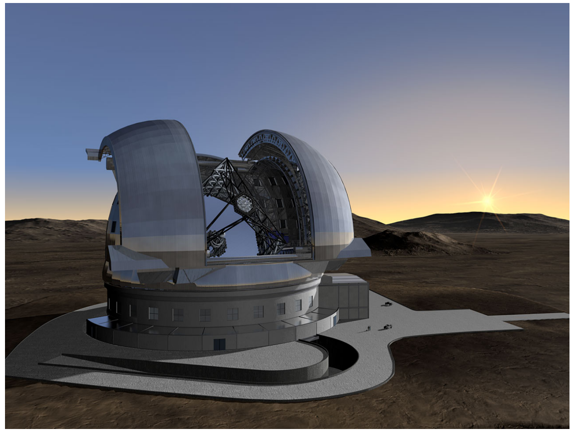


Sloan Digital Sky Survey in New Mexico (USA). US collaboration

Forecast for future instruments



Euclid ESA satellite



E-ELT: European Extremely Large Telescope (39 mt.)

cosmoIGM: interdisciplinary science

COSMOLOGY

IGM as a tracer of the large scale structure of the universe: constraints on its dynamical and geometrical state

cosmoIGM

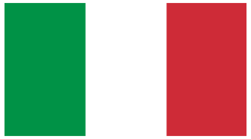
IGM as a probe of fundamental physics: constraints on coldness of cold dark matter and neutrino mass fraction

PARTICLE PHYSICS

Galaxy/IGM interplay: constraints on the physical state of the IGM and galactic feedback mechanisms

GALAXY FORMATION

cosmoIGM: the team

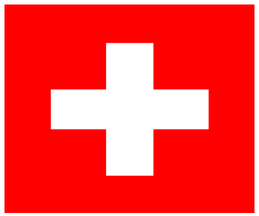
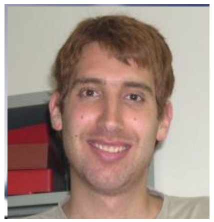



PI: **Matteo Viel**


Dr. Paramita Barai. Nationality: *Indian*.
PhD and 2 Postdoctoral Fellowships in USA Universities.
6 yrs of postdoctoral international experience in Canada/USA.
MAIN TOPIC: Galaxy Formation


Dr. Francisco Villaescusa-Navarro. Nationality: *Spanish*
PhD from Valencia University. 2yrs of international experience
in USA and Italy during his PhD.
MAIN TOPIC: Cosmological neutrinos


Dr. Tae-Sun Kim: Nationality: *South Korean*
Postdoc at ESO, Cambridge, Potsdam, Wisconsin Univ.
MAIN TOPIC: Observations of IGM and galaxy IGM/interplay

Enea Di Dio: Nationality: *Swiss*
PhD Student at Geneve University (Switzerland)
MAIN TOPIC: LSS unveiling the 3D structure of our Universe

SCIENTIFIC HIGHLIGHT

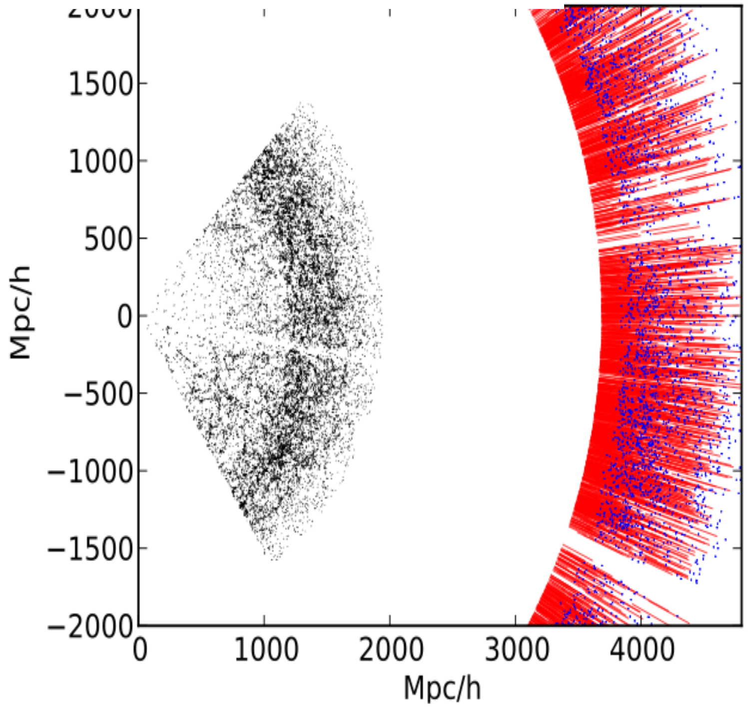
BARYON ACOUSTIC OSCILLATIONS IN LYMAN-α FLUX

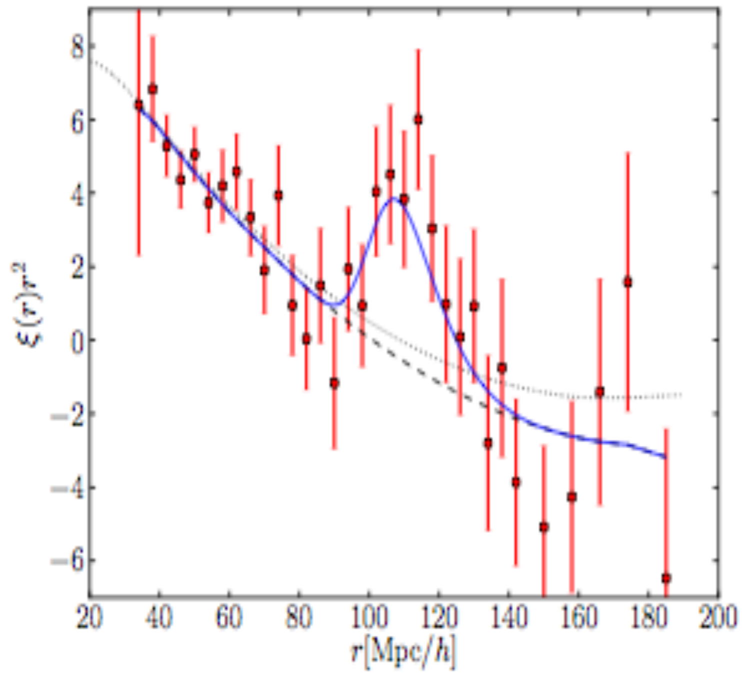
BOSS: Baryonic Acoustic Oscillations Spectroscopic Survey

3D spectroscopy of a Volume 20 $(\mathrm{Gpc}/h)^3$

$$\Delta\theta = \bar{r}_d/[(1+z)D_A(z)]$$
$$\Delta z = r_d/D_H(z)$$

Slosar et al 13 - BOSS Lyman-α coll.



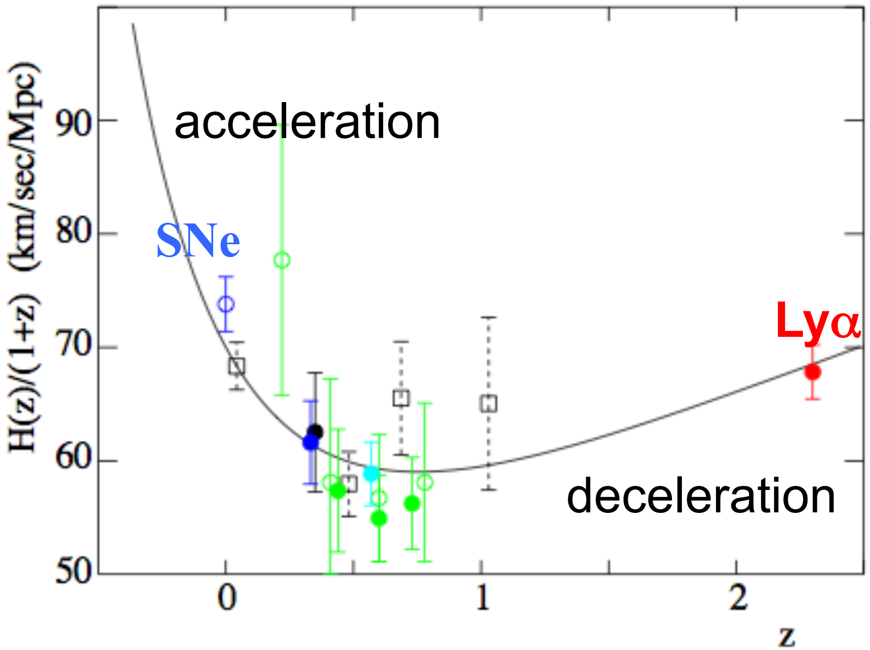


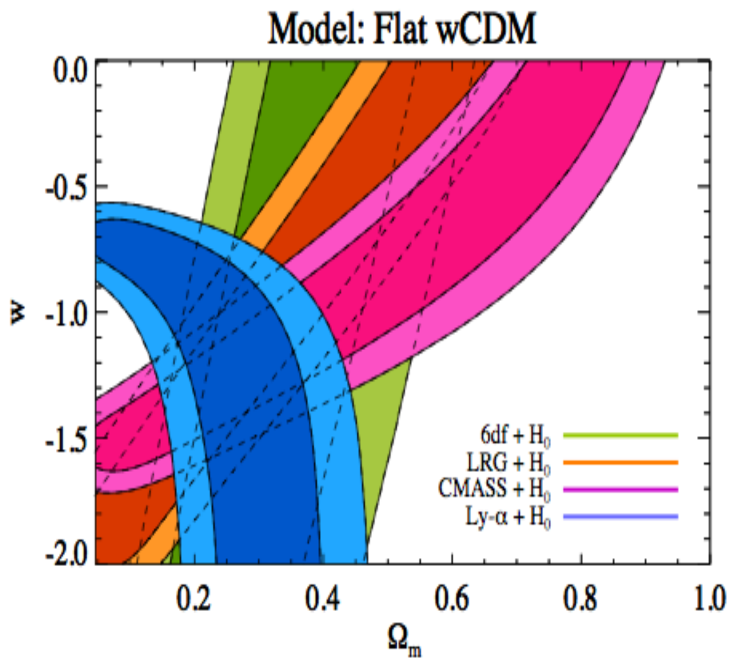
3D correlations in the transverse directions in order to remove continuum fluctuations and recover fluctuations over large scales

BOSS: Baryonic Acoustic Oscillations Spectroscopic Survey

Quantitative Constraints on the geometry of the Universe

Busca et al 13 - BOSS Lyman-α coll.



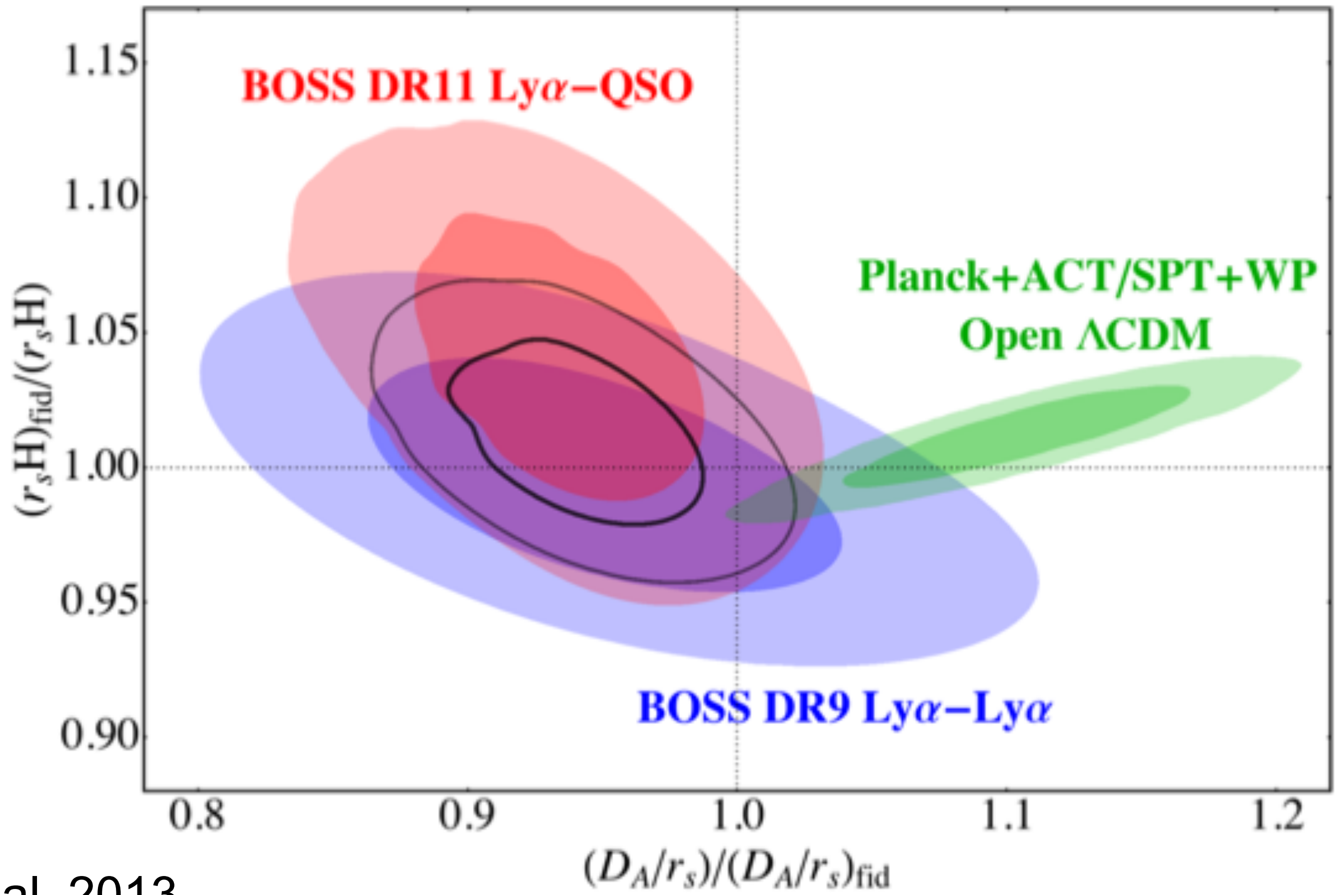


This could be important only for models for which there is a significant departure from ΛCDM at high-z (for example Early Dark Energy cosmologies)

SDSS

3D cross-correlation between Lyman-α flux and quasars

$$P_{qF}(\mathbf{k}) = b_q \left[1 + \beta_q \mu_k^2\right] b_F \left[1 + \beta_F \mu_k^2\right] \; P(k)$$



Font-Ribera et al. 2013

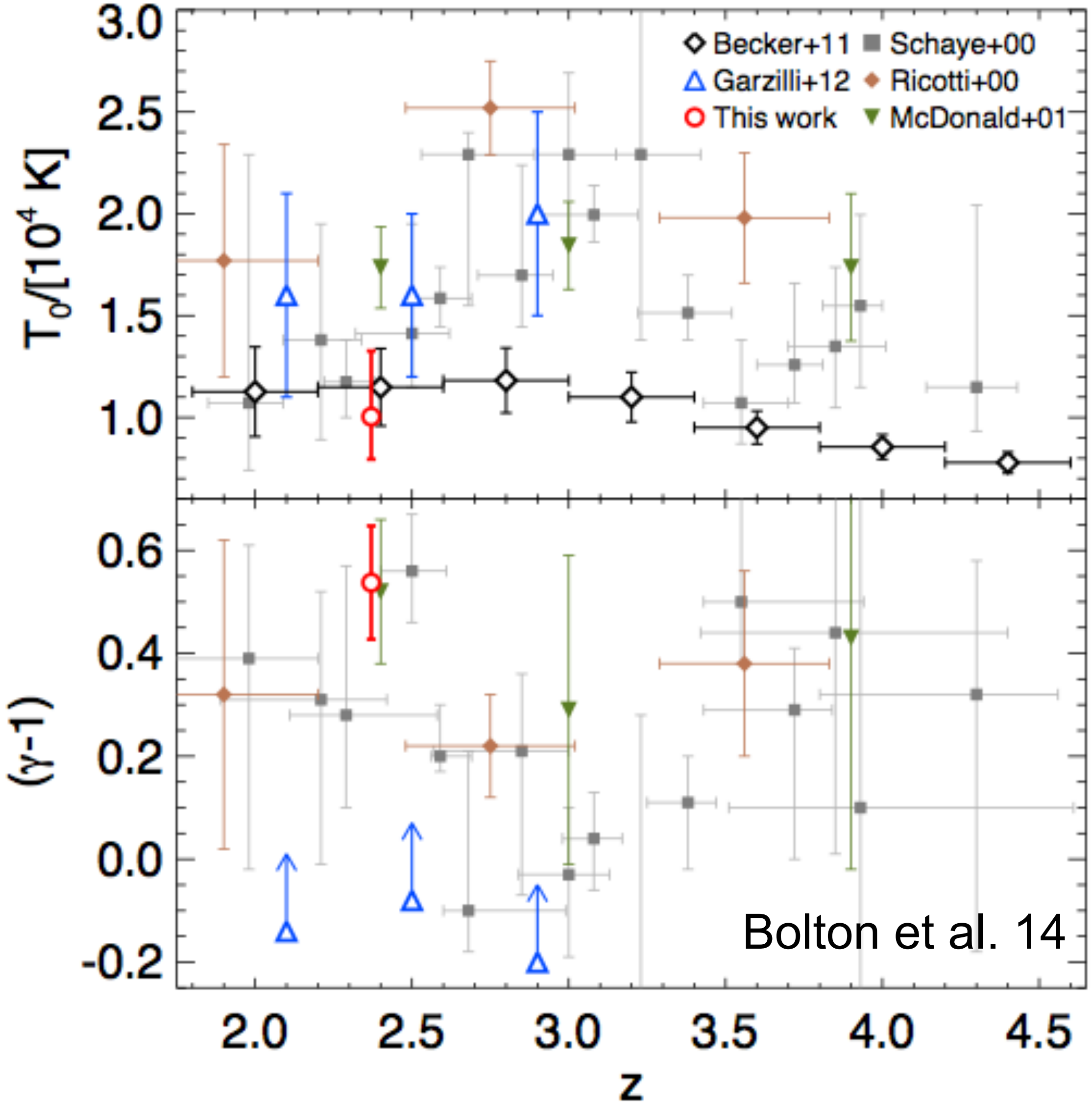
UVES/VLT high resolution spectra

Quantitative Constraints on the IGM thermal state

$$T(z) = T_0 \left[1 + \delta(z)\right]^{\gamma(z)-1}$$

Temperature-density relation is set by equilibrium between cooling and heating processes

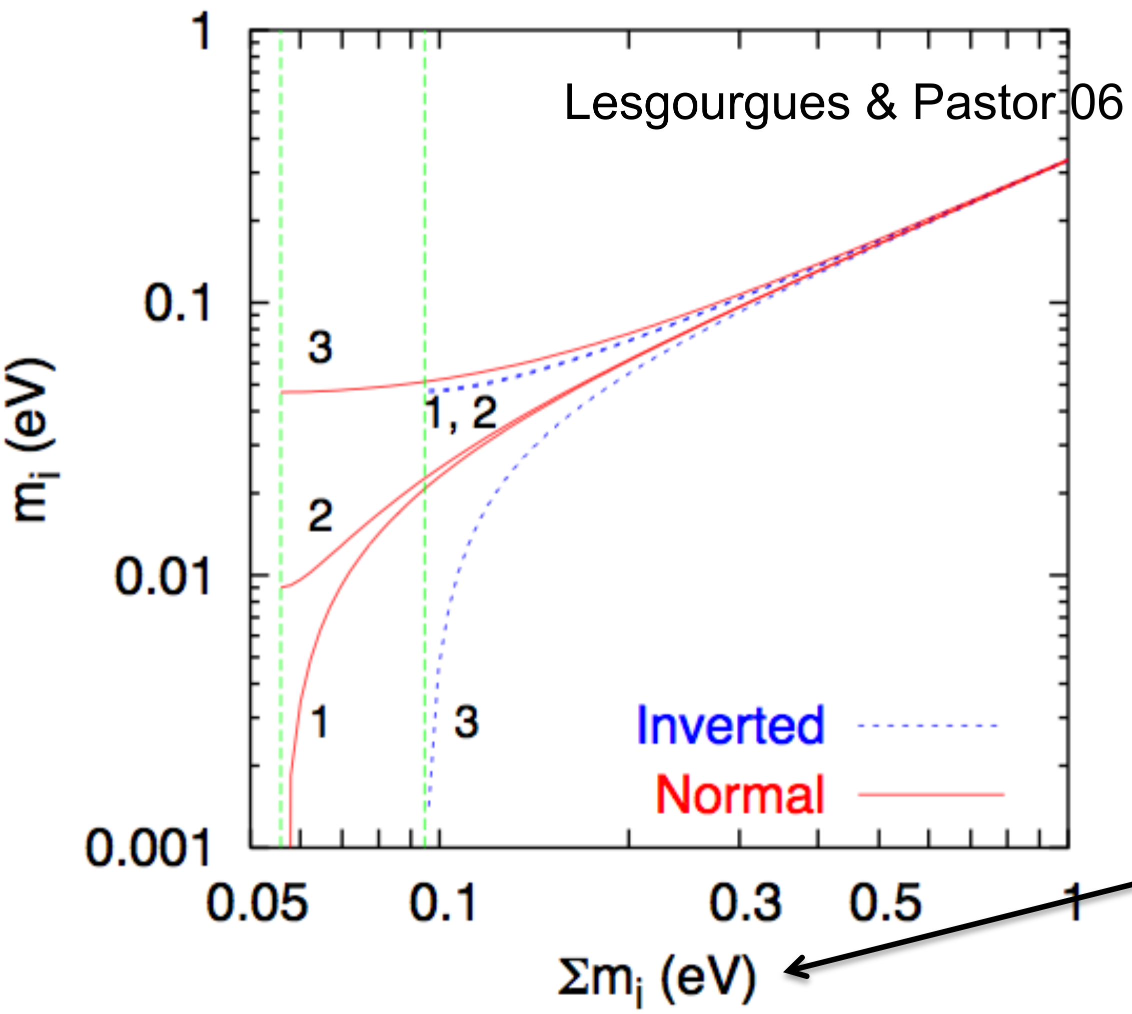
(important nuisance parameter)



SCIENTIFIC HIGHLIGHT

MASSIVE NEUTRINOS IMPACT ON THE UNIVERSE LARGE SCALE STRUCTURE

COSMOLOGICAL NEUTRINOS - I: WHAT TO START FROM

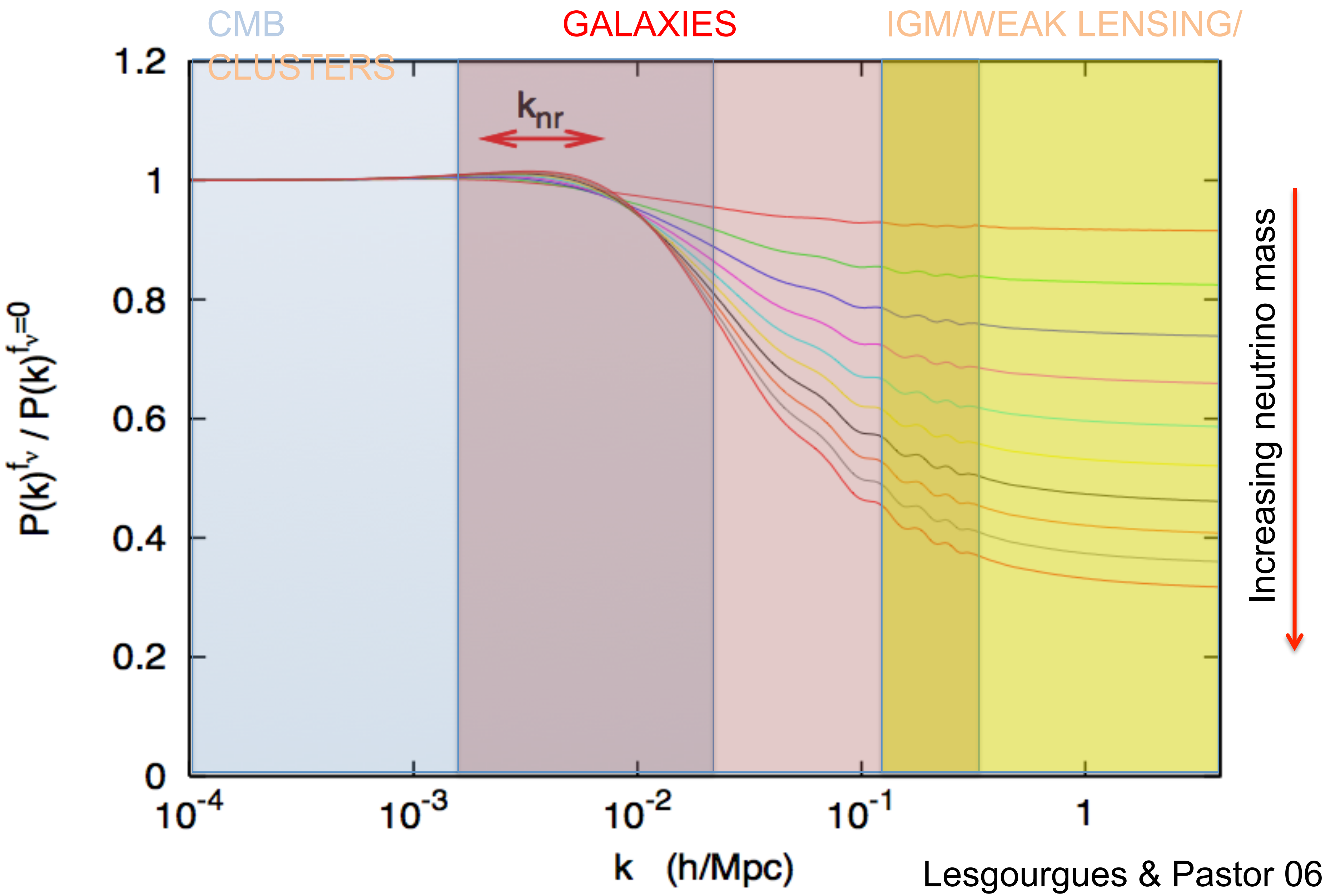


COSMOLOGY

constraints on the sum of the neutrino masses

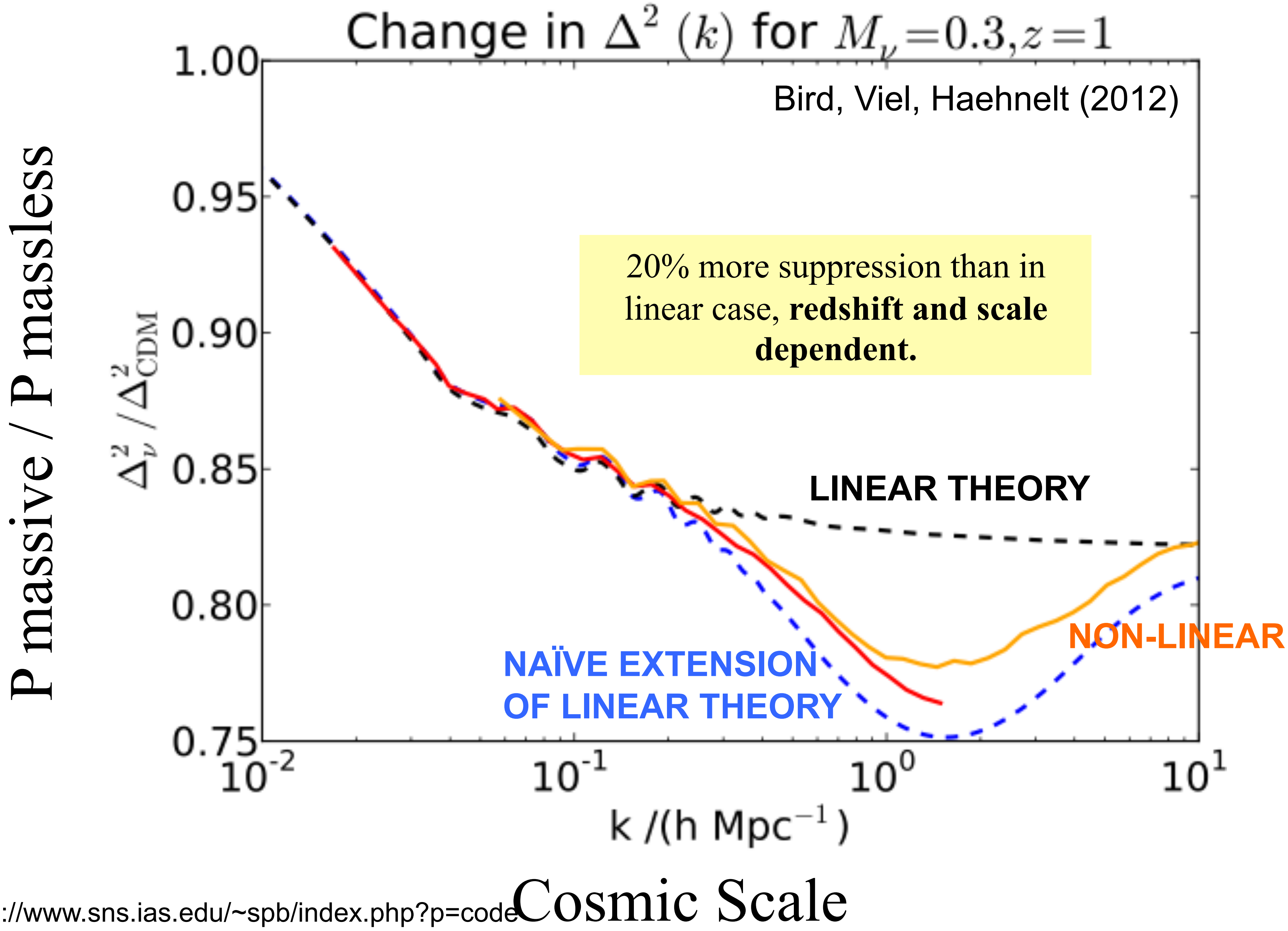
$$0.056\,(0.095)\ \mathrm{eV} \lesssim \sum_i m_i \lesssim 6\ \mathrm{eV}$$

COSMOLOGICAL NEUTRINOS - II: LINEAR MATTER POWER



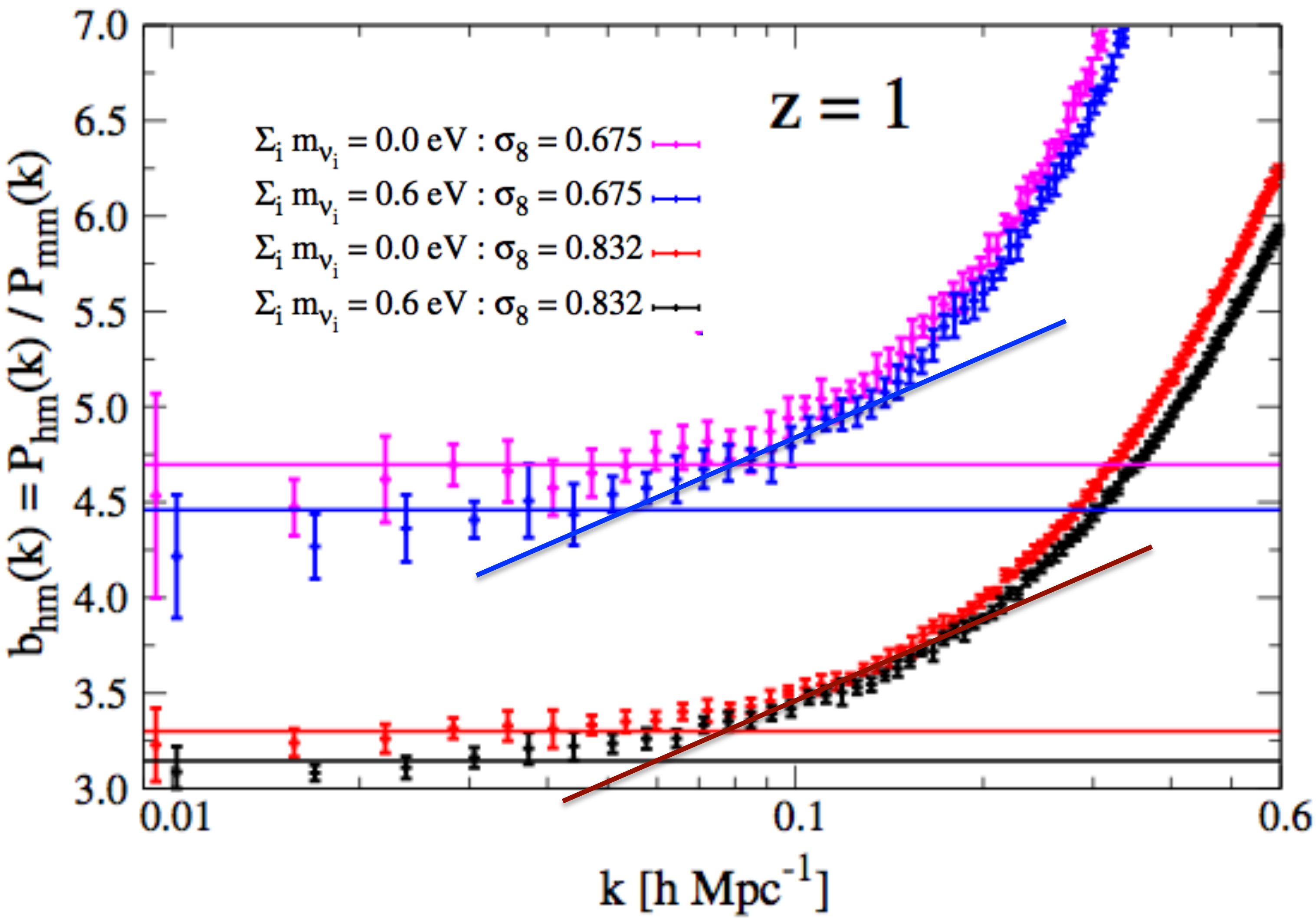
Lesgourgues & Pastor 06

COSMOLOGICAL NEUTRINOS : NON-LINEAR MATTER POWER



http://www.sns.ias.edu/~spb/index.php?p=code

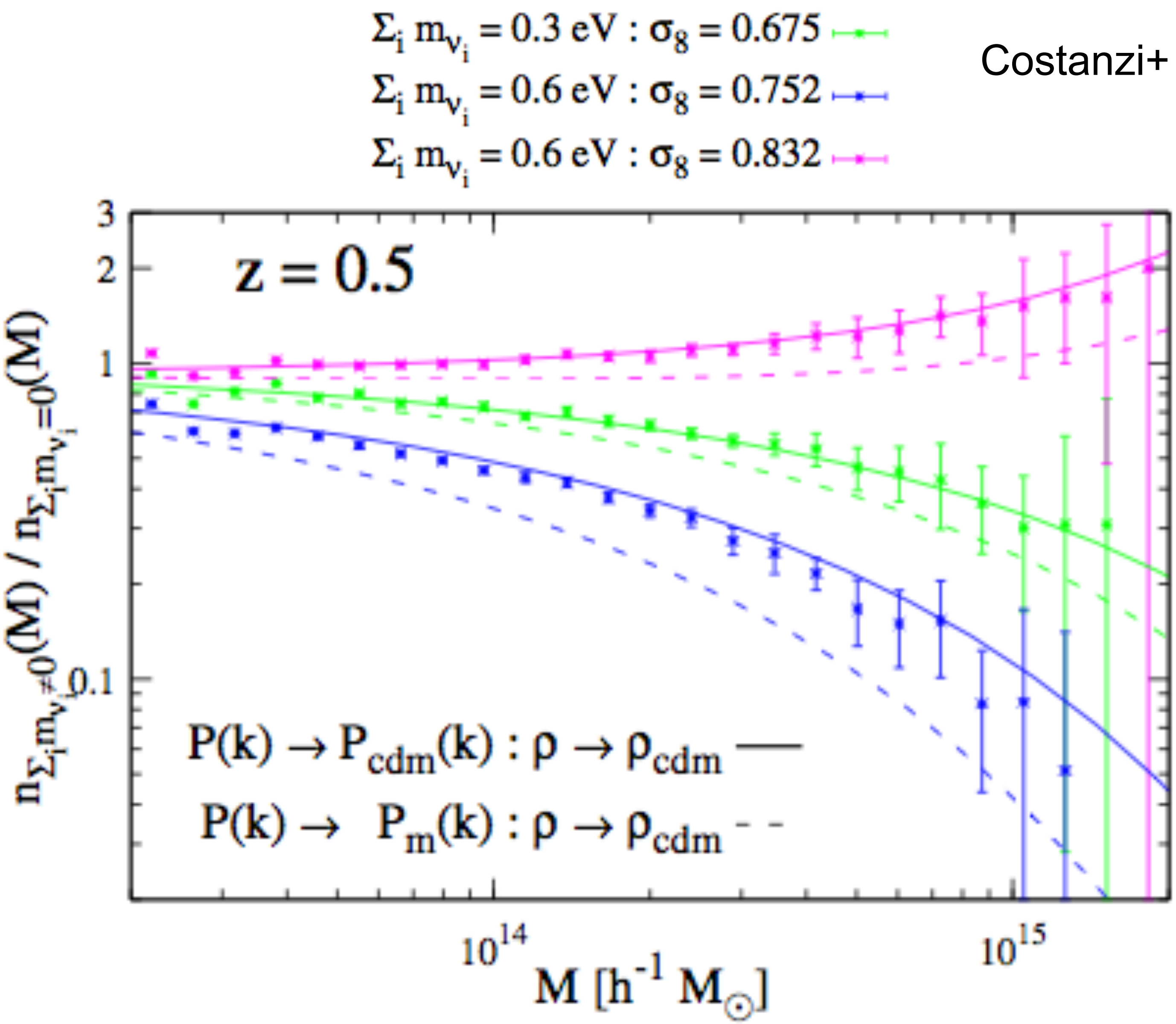
COSMOLOGICAL NEUTRINOS: BIAS BETWEEN MATTER AND HALOES



Villaescusa-Navarro, Marulli, MV+ 14

COSMOLOGICAL NEUTRINOS: MASS FUNCTIONS OF GALAXY CLUSTERS

Costanzi+ 2013, JCAP



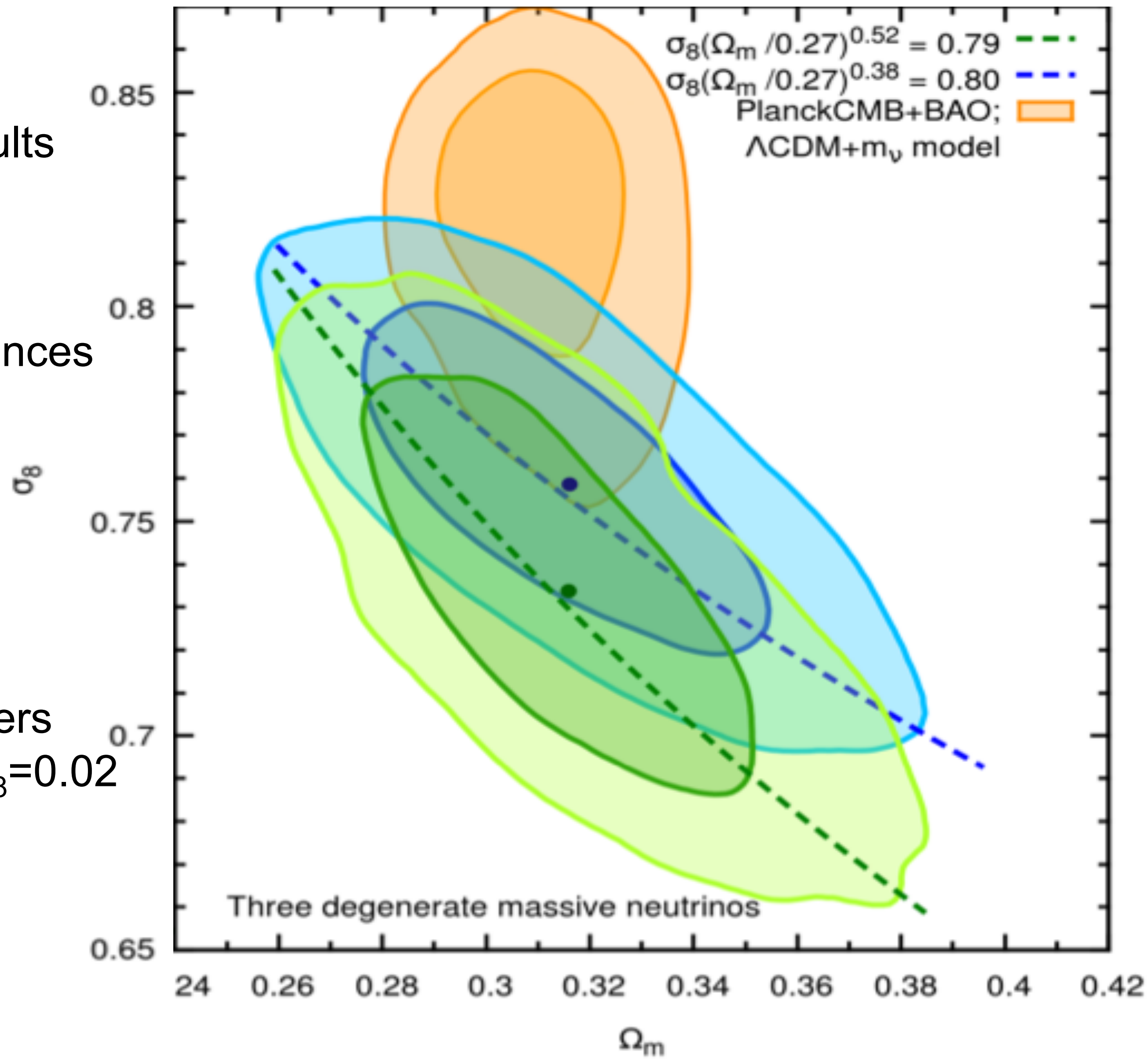
COSMOLOGICAL NEUTRINOS: APPLICATION TO GALAXY CLUSTERS

Costanzi+13, Castorina+14

✓ **P** $_{cdm}$ rather than **P** $_{matter}$ fits better the N-body results

✓ For M_ν = 0.4 eV 30% differences in cluster number counts

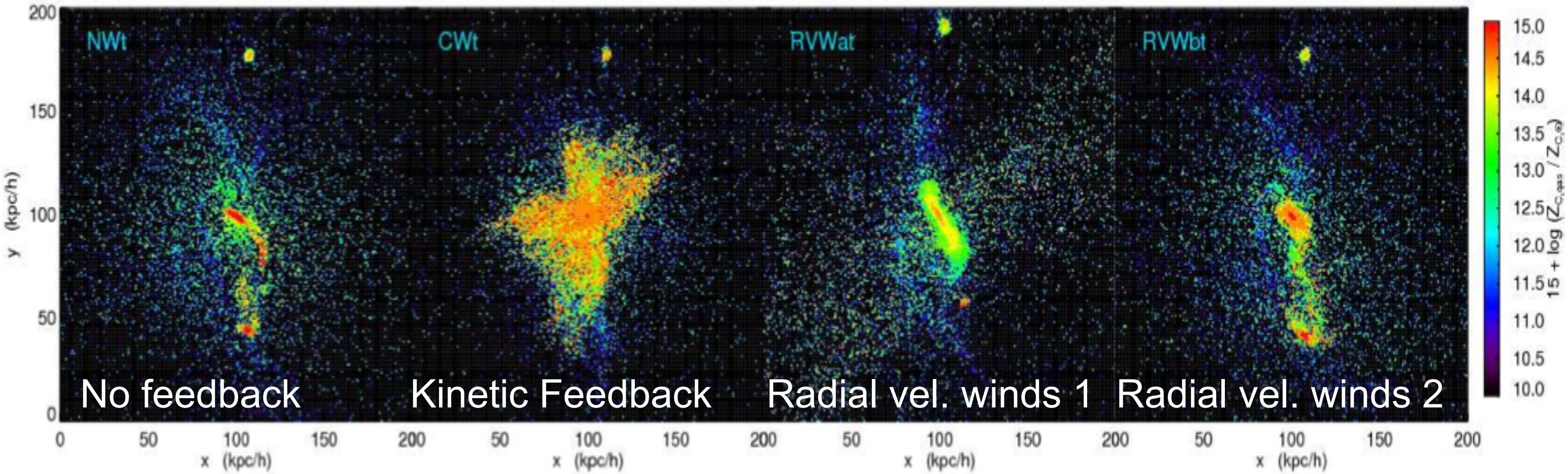
✓ "Tension" between Planck CMB and Planck SZ clusters is further increased by $\Delta\sigma_8$=0.02

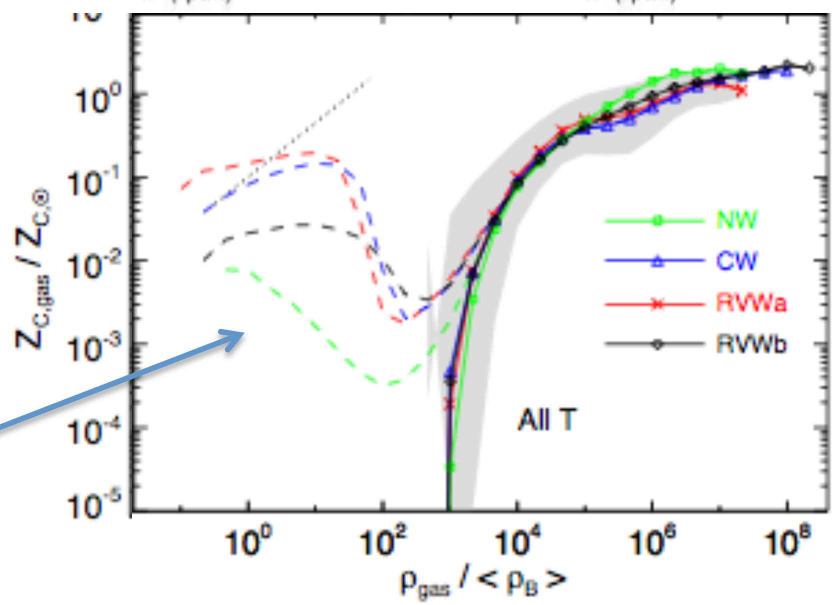


SCIENTIFIC HIGHLIGHT

GALACTIC WINDS AND THE IGM/CGM

Simulated IGM/CGM environments and metal enrichment

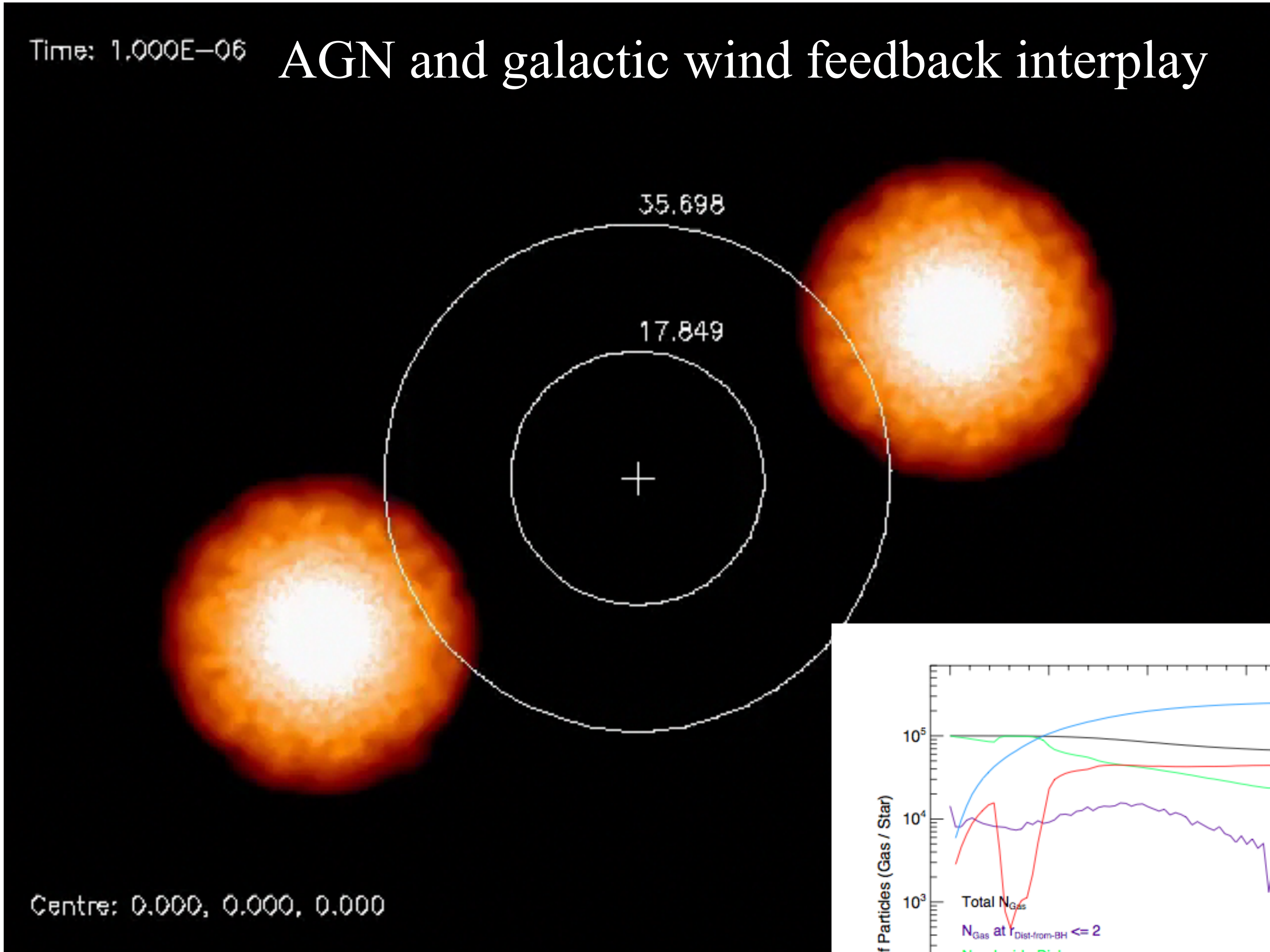


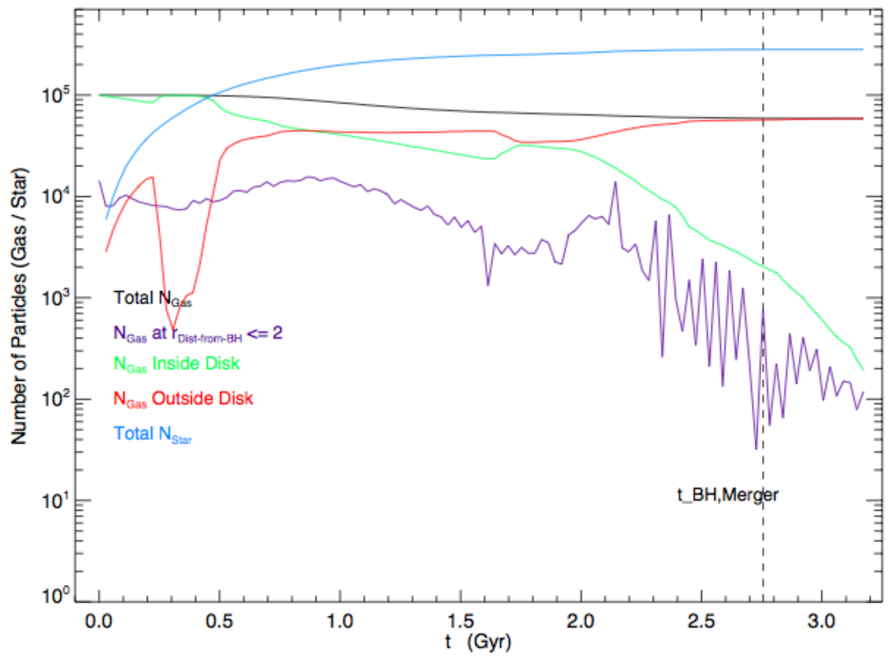


Low density environments close to galaxies could be promising for discriminating between feedback mechanisms (**E-ELT spectrograph**)

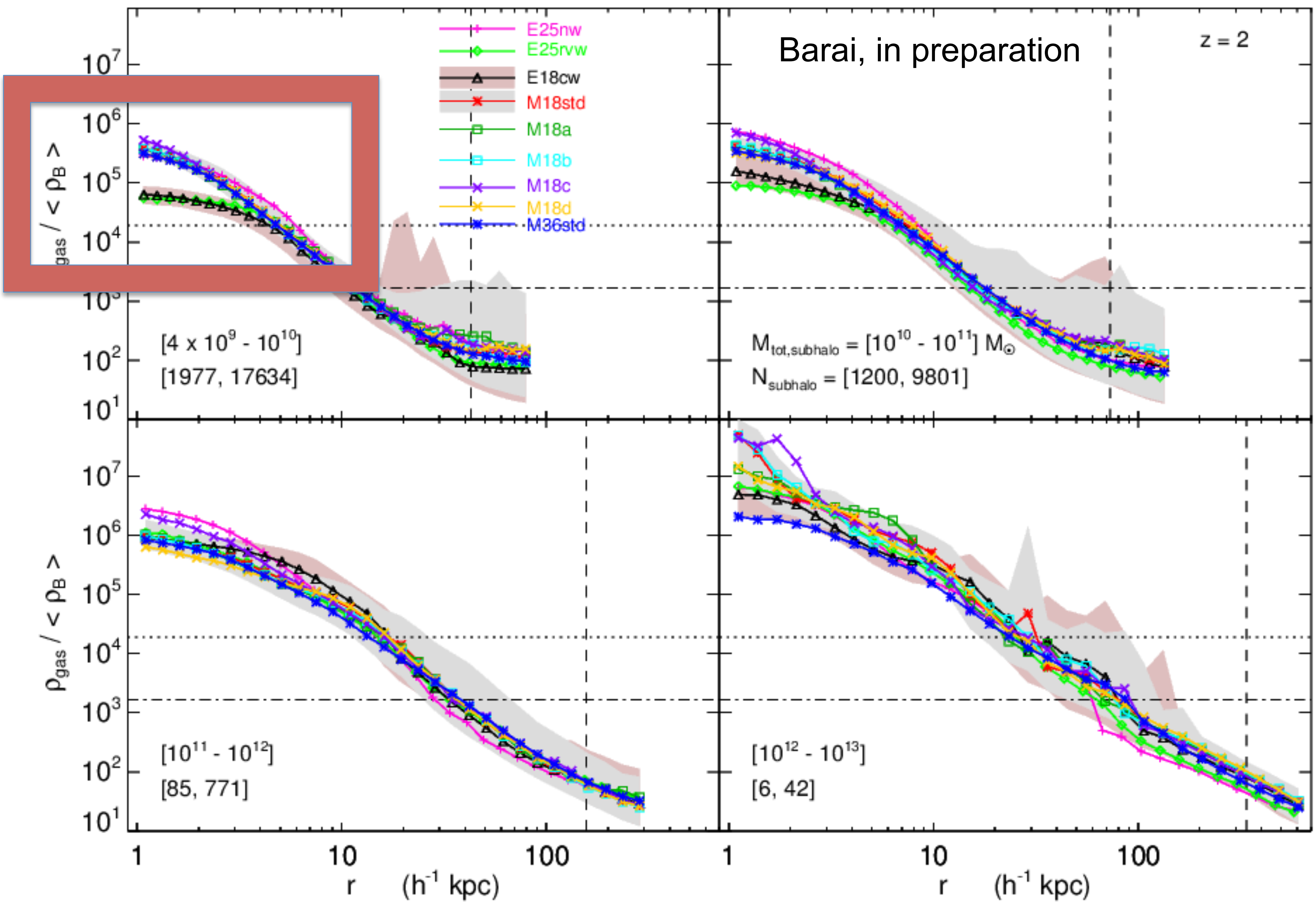
Barai, MV+14

AGN and galactic wind feedback interplay





Barai, MV et al. 2014

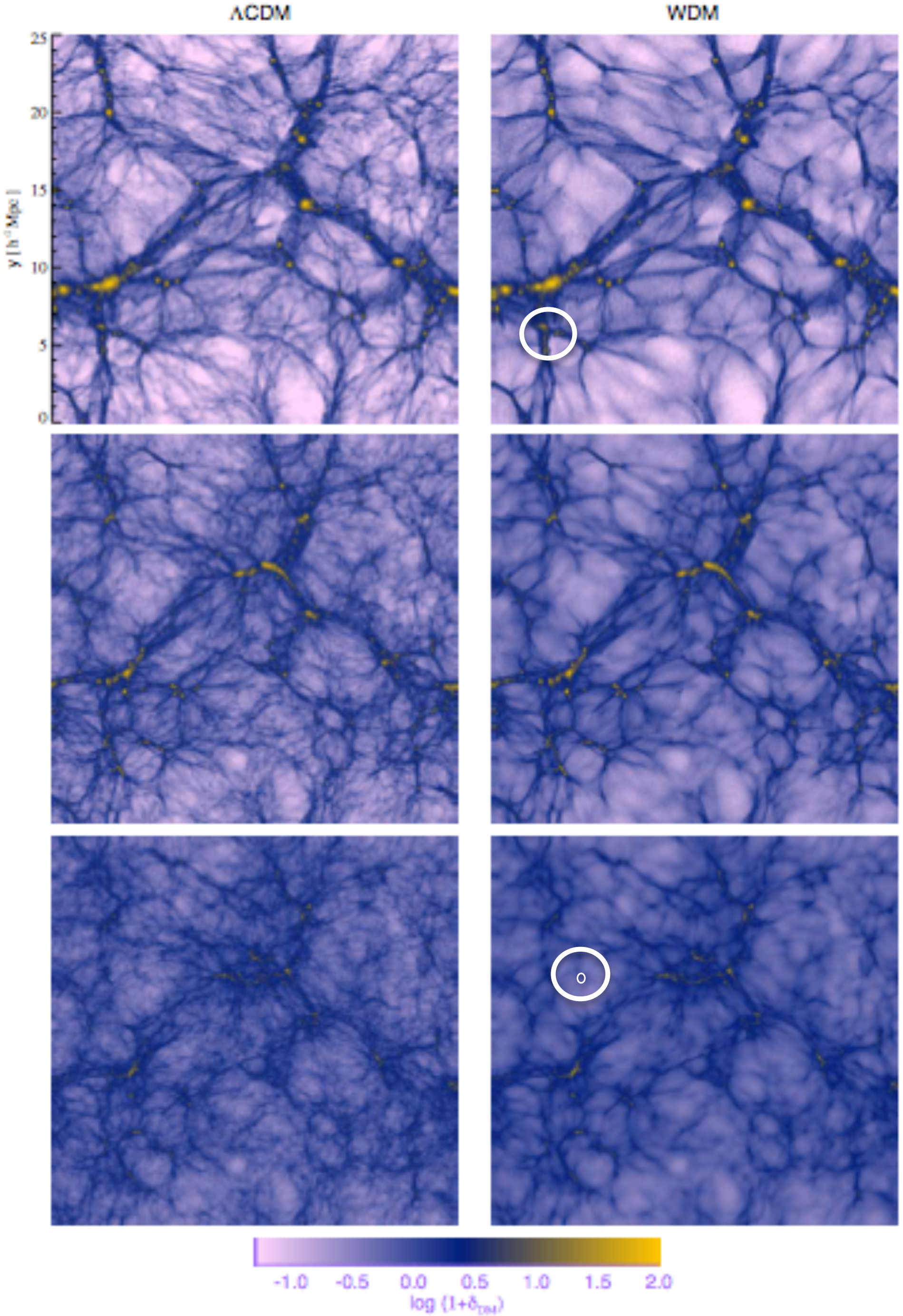


Barai, in preparation
z = 2
E25nw
E25rvw
E18cw
M18std
M18a
M18b
M18c
M18d
M36std
[4 x 10^9 - 10^10]
[1977, 17634]
M_tot,subhalo = [10^10 - 10^11] M_⊙
N_subhalo = [1200, 9801]
[10^11 - 10^12]
[85, 771]
[10^12 - 10^13]
[6, 42]
ρ_gas / < ρ_B >
r (h^-1 kpc)

SCIENTIFIC HIGHLIGHT

THE COLDNESS OF COLD DARK MATTER

THE COSMIC WEB in WDM/LCDM scenarios



z=0

$$\frac{T_x}{T_\nu} = \left(\frac{10.75}{g_*(T_D)}\right)^{1/3} < 1$$

$$k_{\rm FS} = \frac{2\pi}{\lambda_{\rm FS}} \sim 5\,{\rm Mpc}^{-1}\left(\frac{m_x}{1\,{\rm keV}}\right)\left(\frac{T_\nu}{T_x}\right)$$

$$\omega_x = \Omega_x h^2 = \beta\left(\frac{m_x}{94\,{\rm eV}}\right)$$

$$\beta = (T_x/T_\nu)^3$$

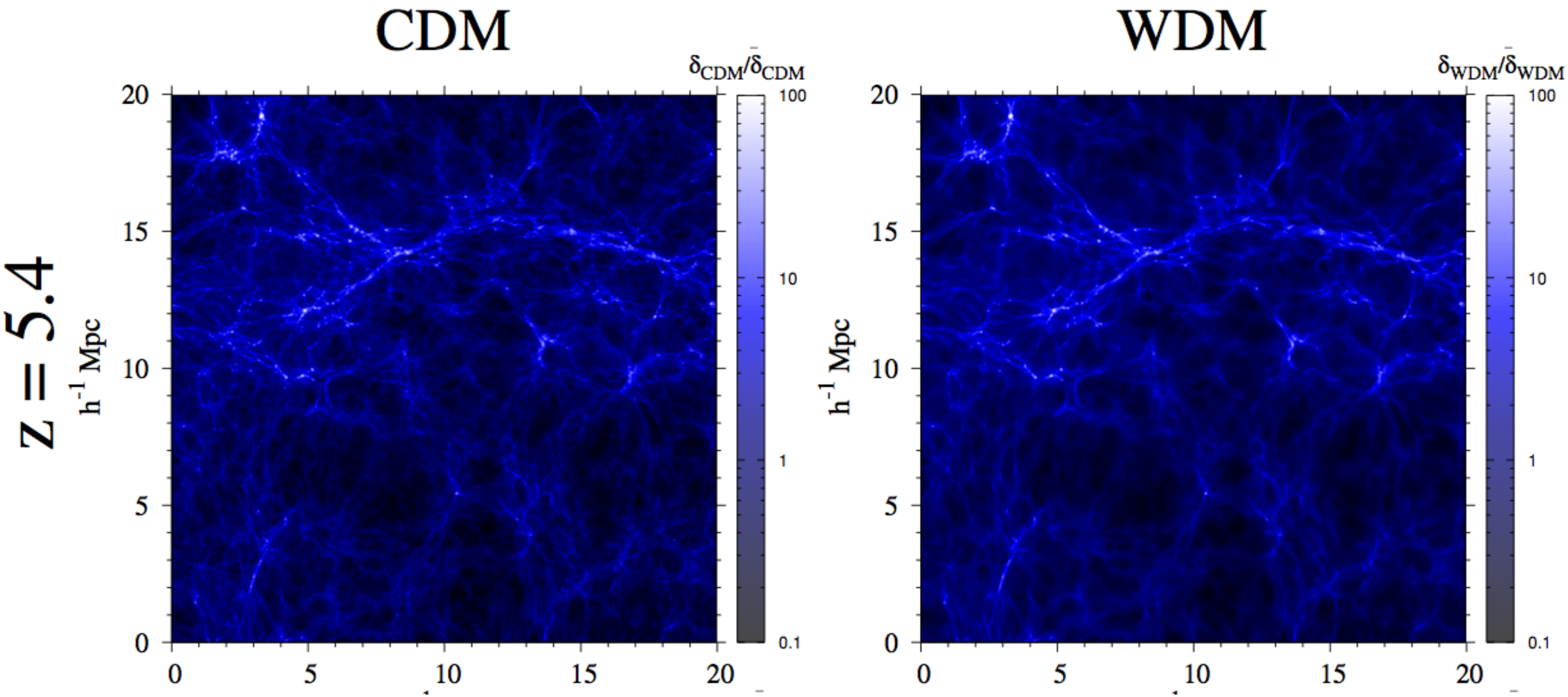
z=2

$$k_{\rm FS} \sim 15.6\frac{h}{\rm Mpc}\left(\frac{m_{\rm WDM}}{1{\rm keV}}\right)^{4/3}\left(\frac{0.12}{\Omega_{DM}h^2}\right)^{1/3}$$

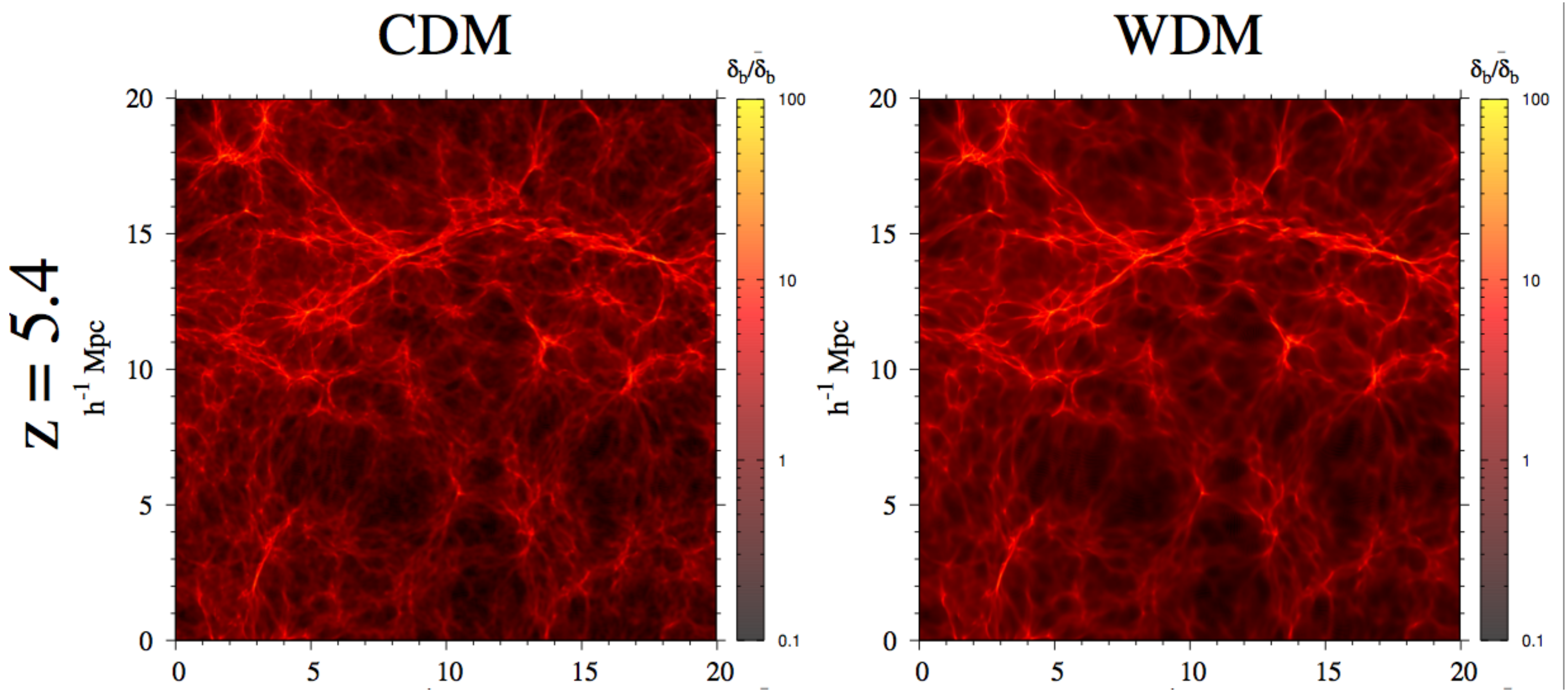
z=5

Viel, Markovic, Baldi & Weller 2013

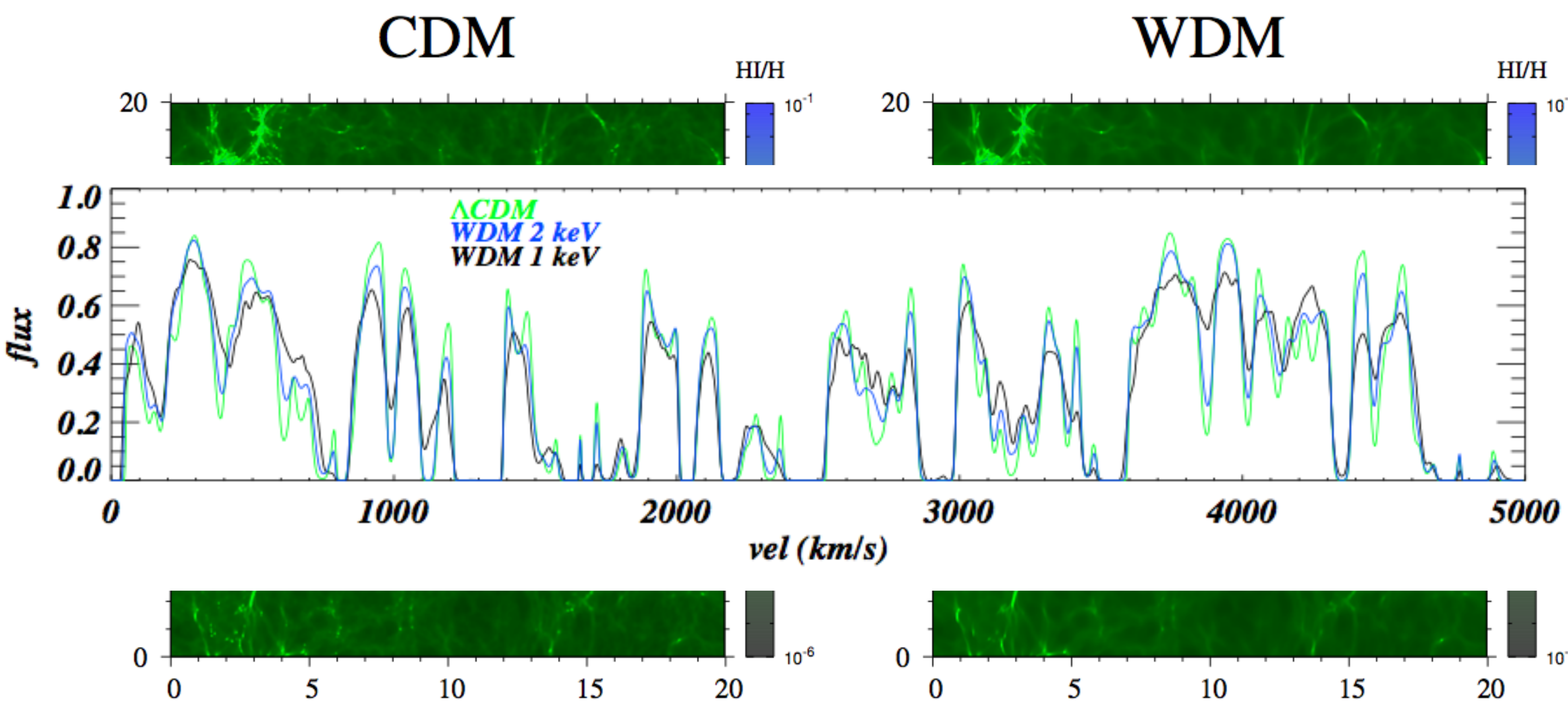
DARK MATTER DISTRIBUTION



GAS DISTRIBUTION

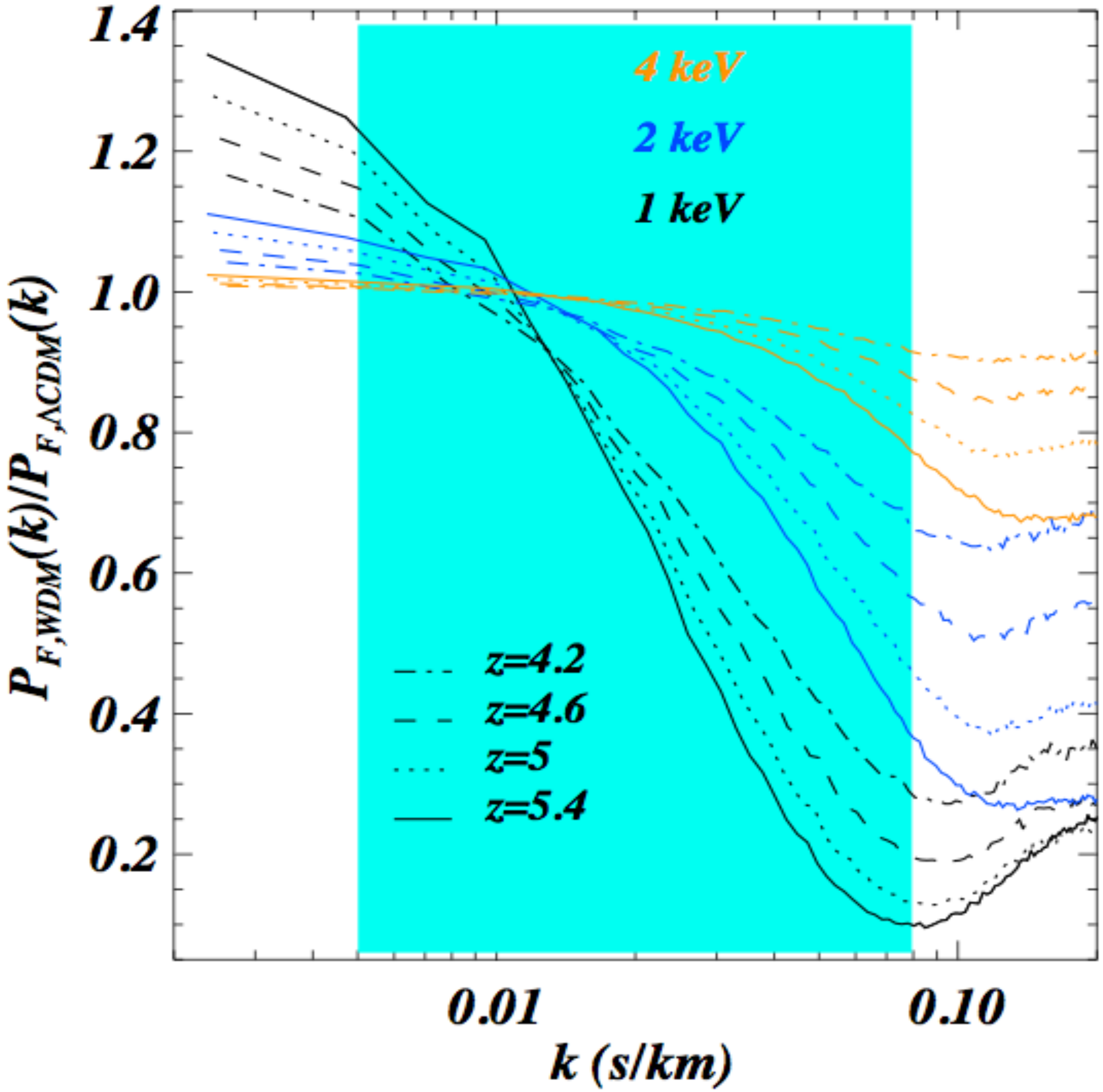


HI DISTRIBUTION

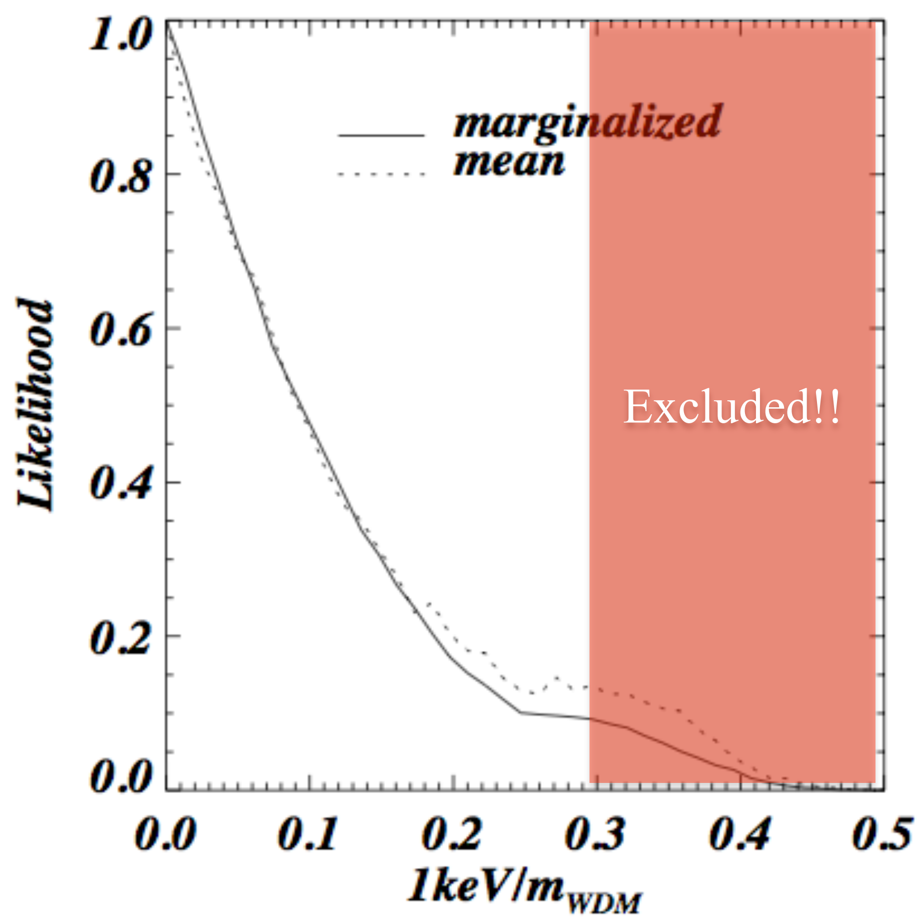


THE HIGH REDSHIFT WDM CUTOFF

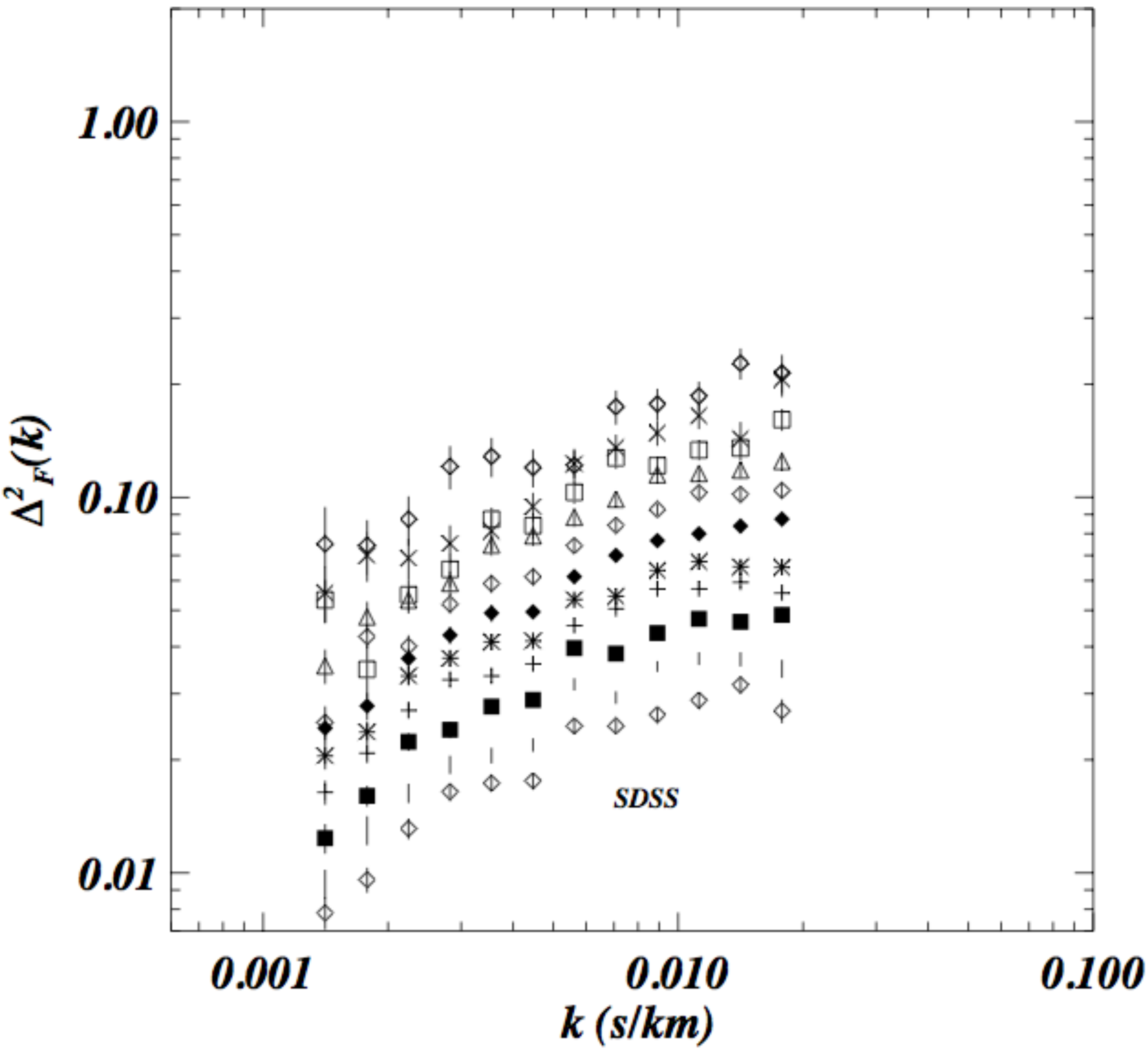
$\delta_F = F/\langle F\rangle - 1$



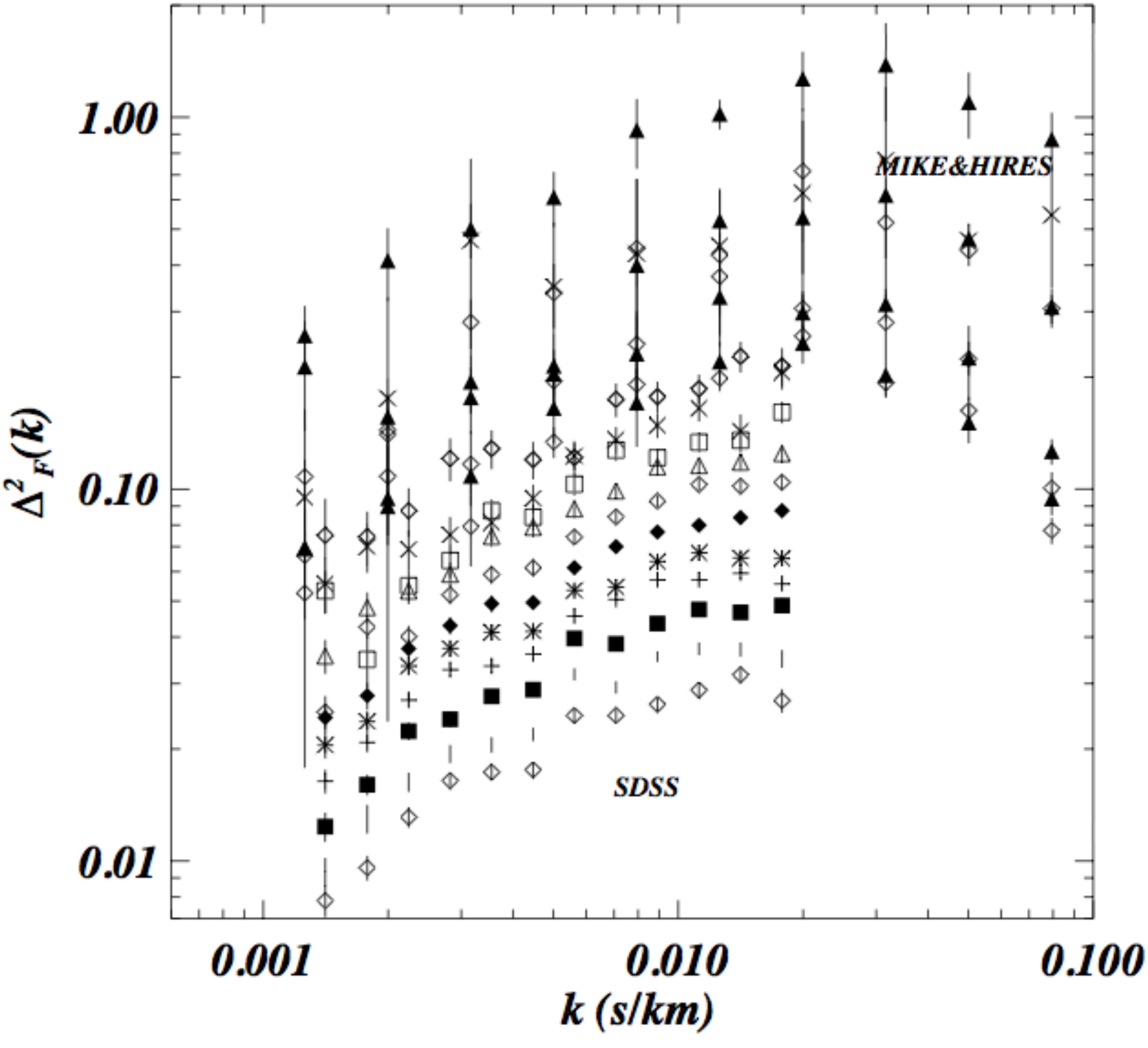
RESULTS FOR WDM MASS



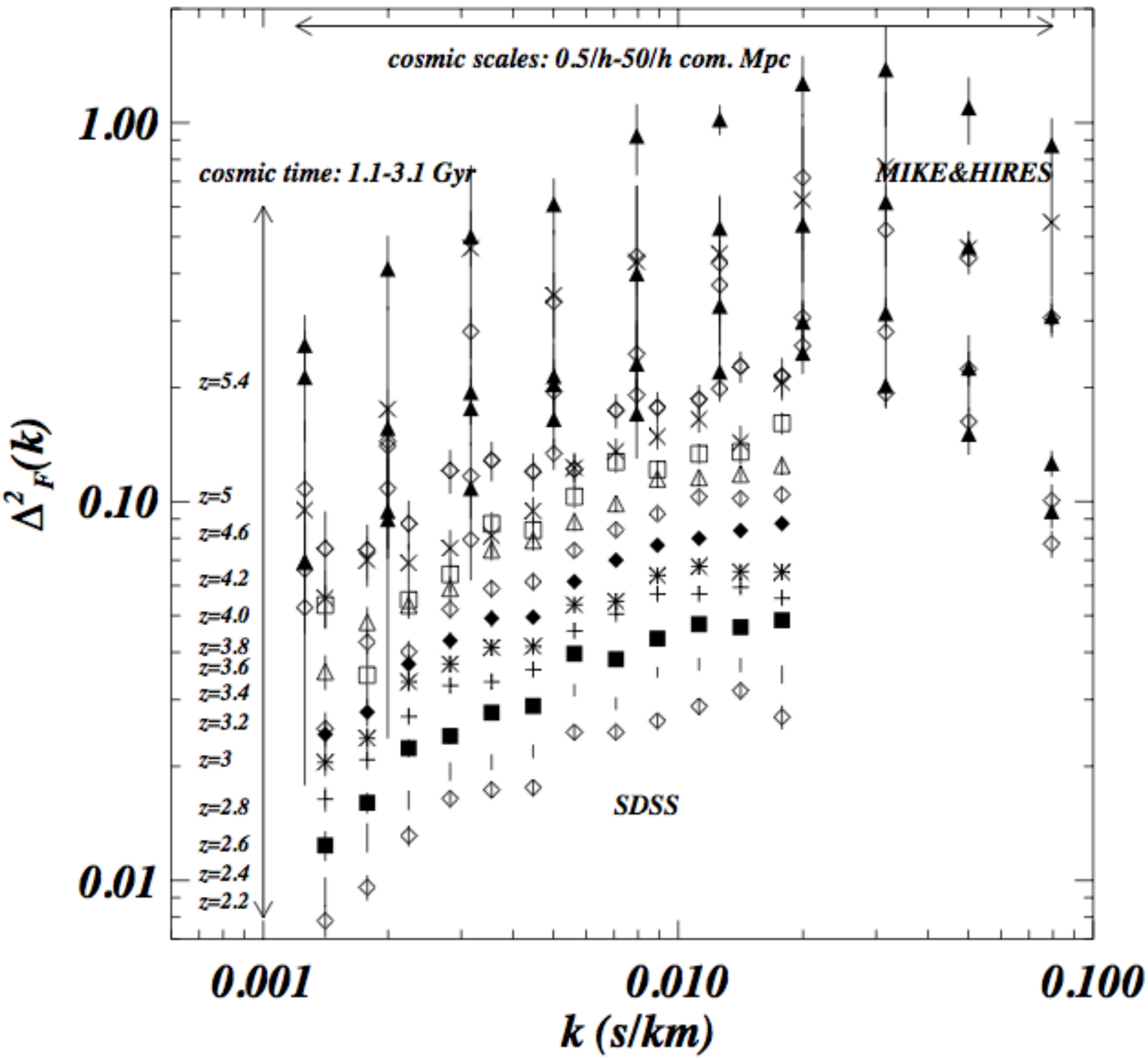
m > 3.3 keV (2σ)

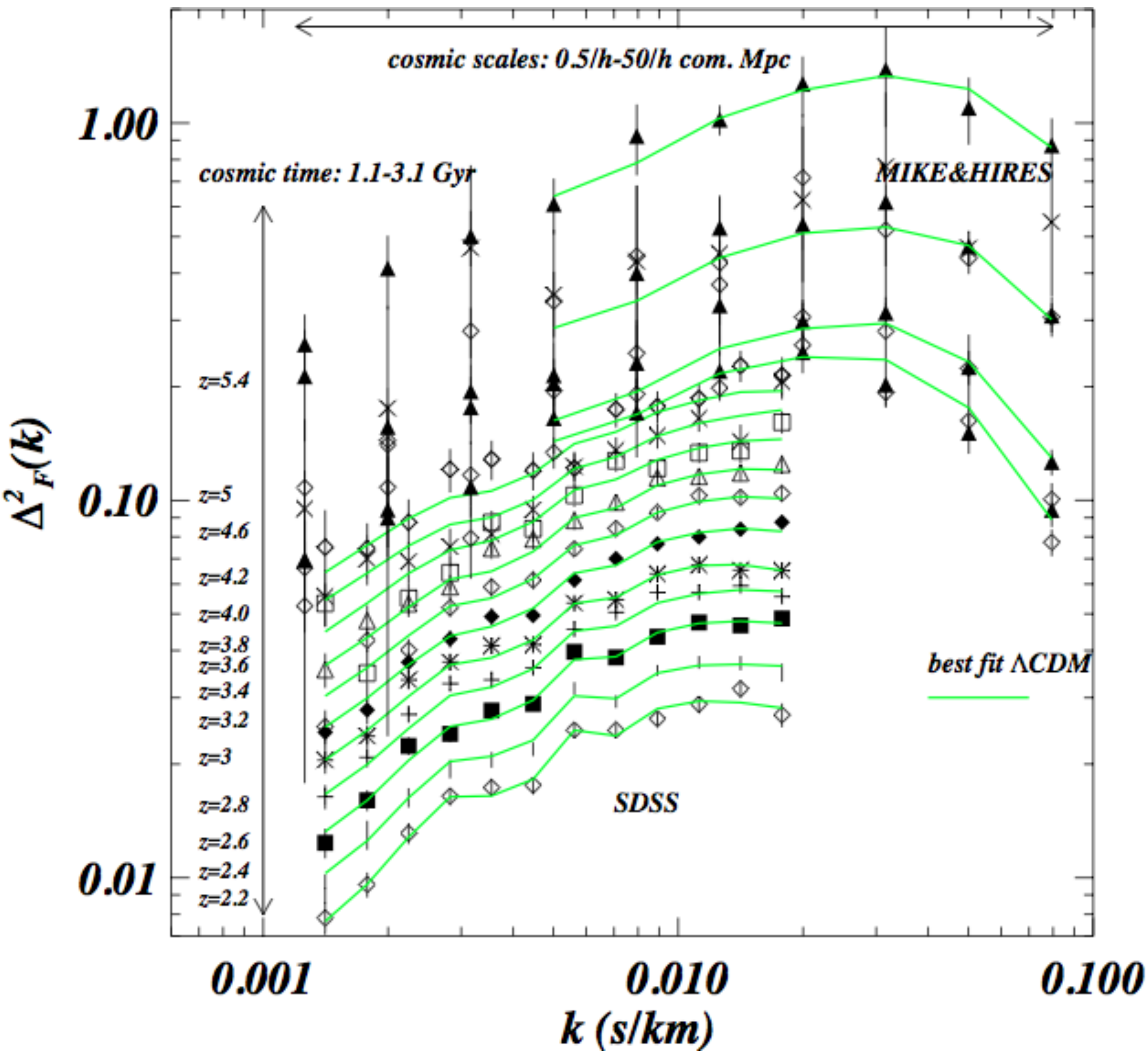


1.00
0.10
0.01
$\Delta^2_F(k)$
SDSS
0.001
0.010
0.100
k (s/km)

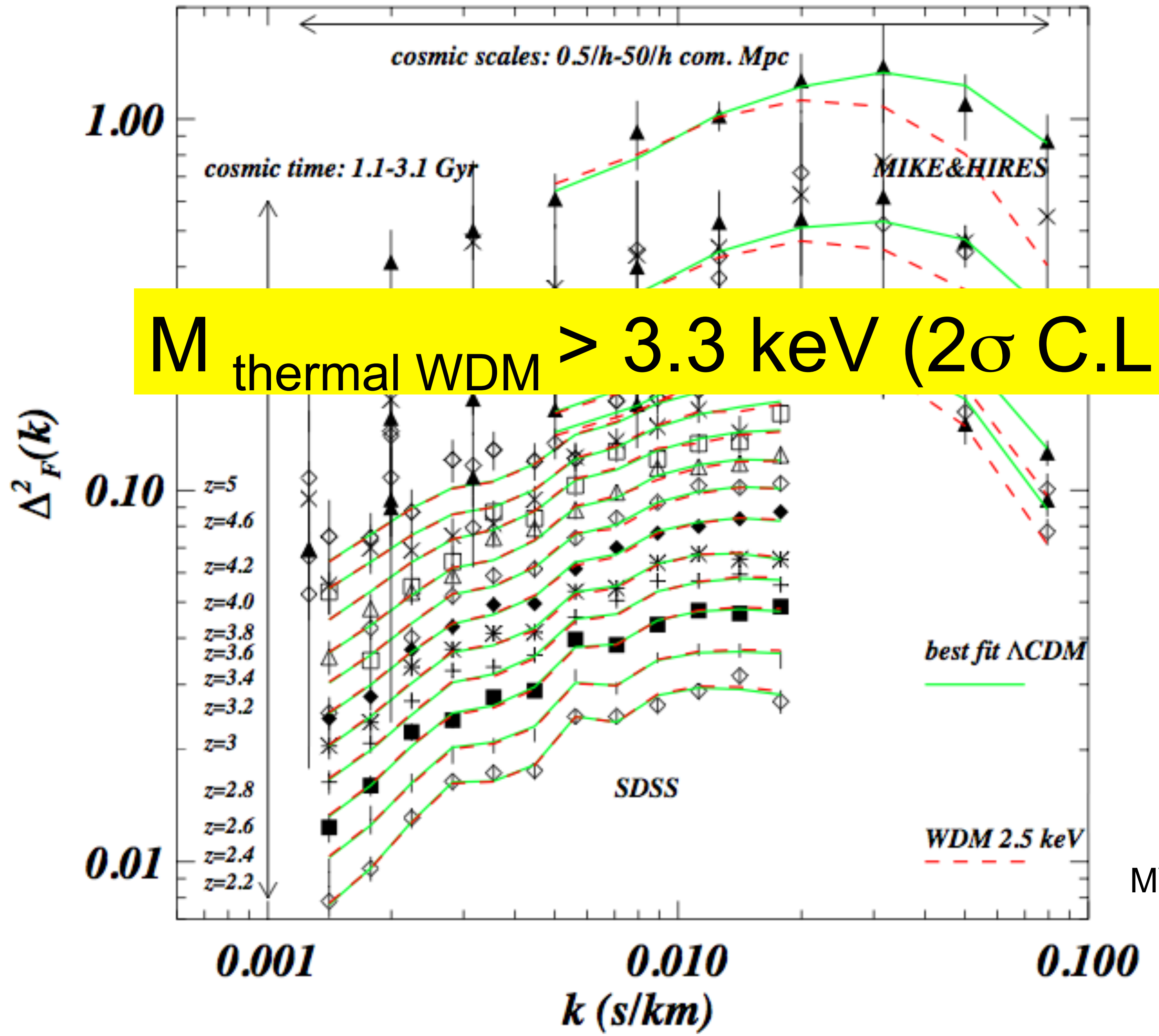


1.00
0.10
0.01
$\Delta^2_F(k)$
MIKE&HIRES
SDSS
0.001
0.010
0.100
k (s/km)


cosmic scales: 0.5/h-50/h com. Mpc
cosmic time: 1.1-3.1 Gyr
MIKE&HIRES
SDSS
z=5.4
z=5
z=4.6
z=4.2
z=4.0
z=3.8
z=3.6
z=3.4
z=3.2
z=3
z=2.8
z=2.6
z=2.4
z=2.2
1.00
0.10
0.01
$\Delta^2_F(k)$
0.001
0.010
0.100
k (s/km)



cosmic scales: 0.5/h-50/h com. Mpc
cosmic time: 1.1-3.1 Gyr
MIKE&HIRES
SDSS
best fit ΛCDM
z=5.4
z=5
z=4.6
z=4.2
z=4.0
z=3.8
z=3.6
z=3.4
z=3.2
z=3
z=2.8
z=2.6
z=2.4
z=2.2
1.00
0.10
0.01
0.001
0.010
0.100
$\Delta^2_F(k)$
k (s/km)



$M_{\text{thermal WDM}} > 3.3$ keV (2σ C.L.)

MV+ 14

SUMMARY

- BAO discovery in the Lyman-α flux at z=2.2 from the BOSS collaboration

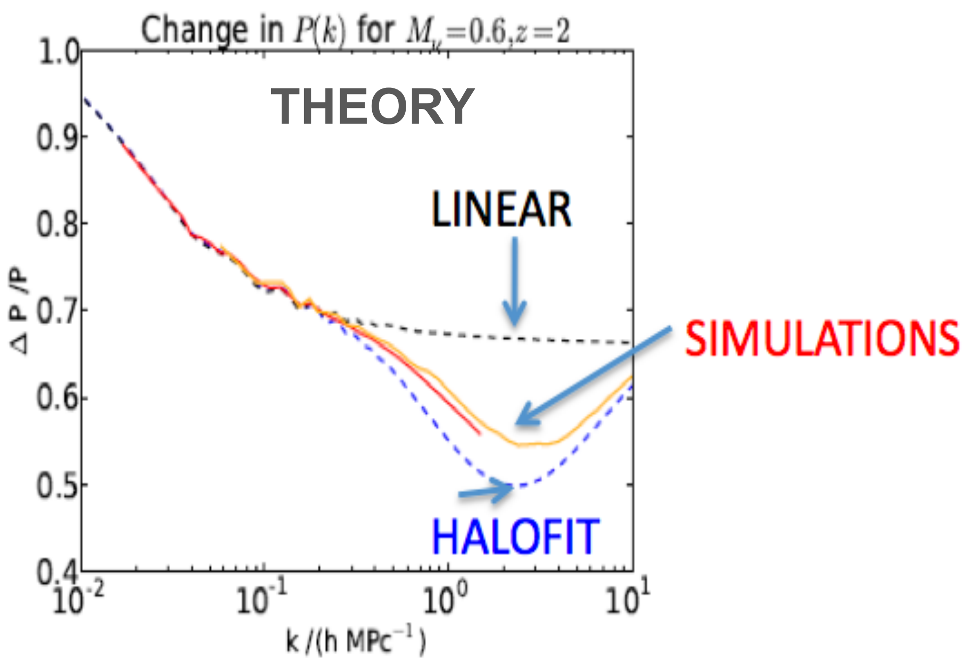
- Characterization of neutrino properties in the Large Scale Structure and around haloes. Constraints from Planck SZ.

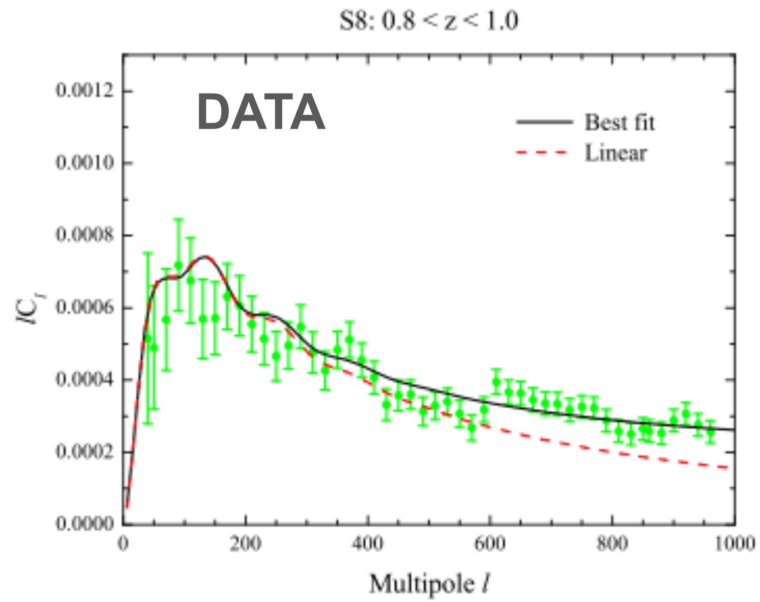
- Characterization of IGM/CGM environment and metallicity distribution in several feedback models

- Constraints on small scale structure of Dark Matter using high-resolution QSO spectra.

- **COMING SOON**: **X-Shooter LP programme** results on WDM and Temperature

Quantitative Constraints on the neutrino masses using CFHTLS and VIPERS data





CONSTRAINTS

95% C.L. $\sum m_\nu$ [eV]	Without HST Prior		With HST Prior	
	$\ell_{max}=630$	$\ell_{max}=960$	$\ell_{max}=630$	$\ell_{max}=960$
WMAP7	1.17		0.50	
WMAP7 + CFHTLS	0.64	0.43	0.41	0.29
WMAP7 + SDSS + CFHTLS	0.47	0.35	0.35	0.28
WMAP7 + SDSS + SN + CFHTLS	–	–	0.33	0.27

Xia, Granett, MV, et al. 2012