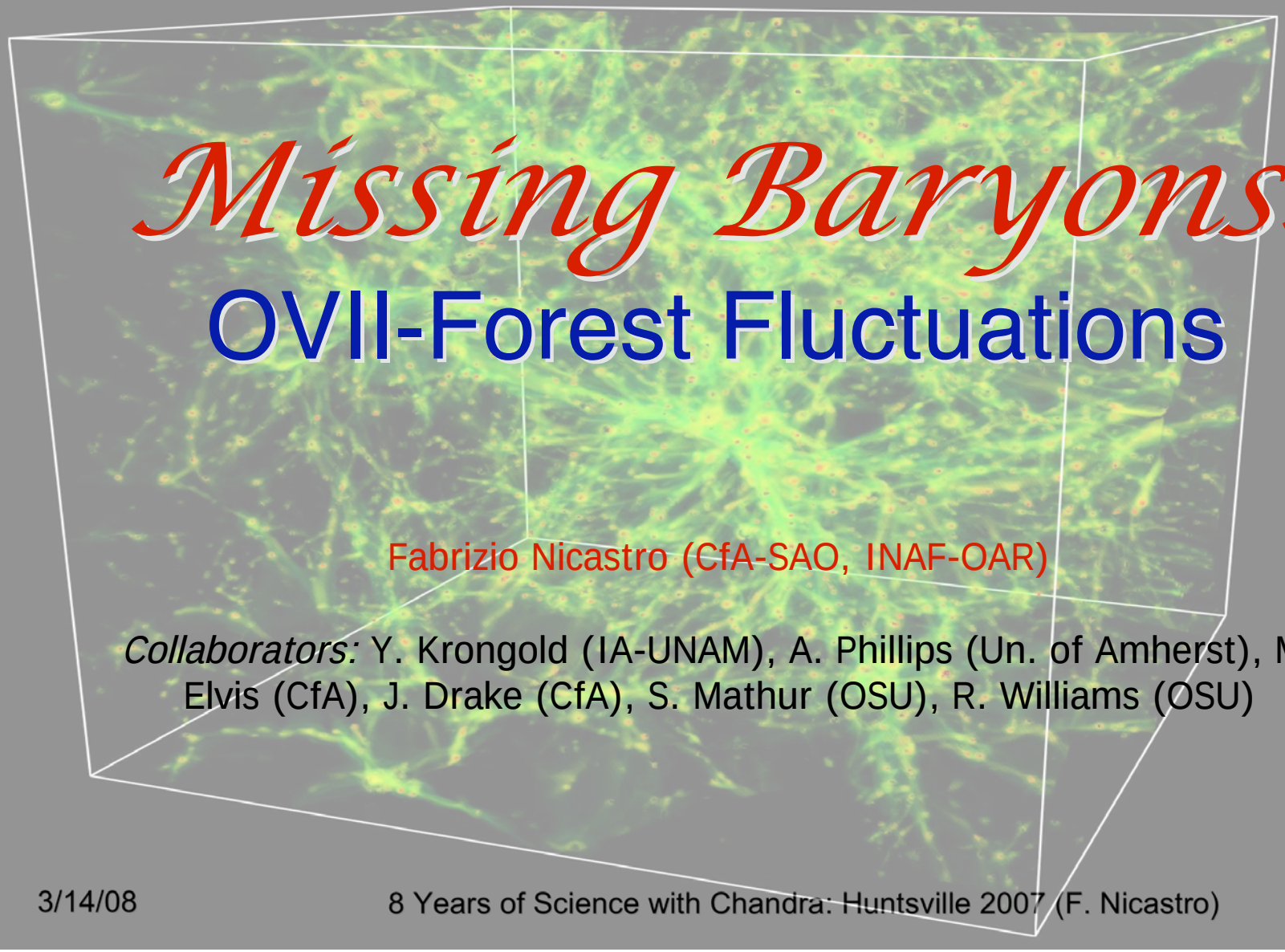
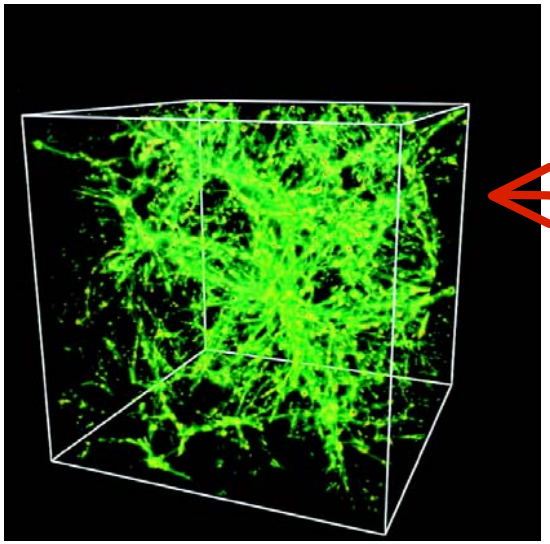


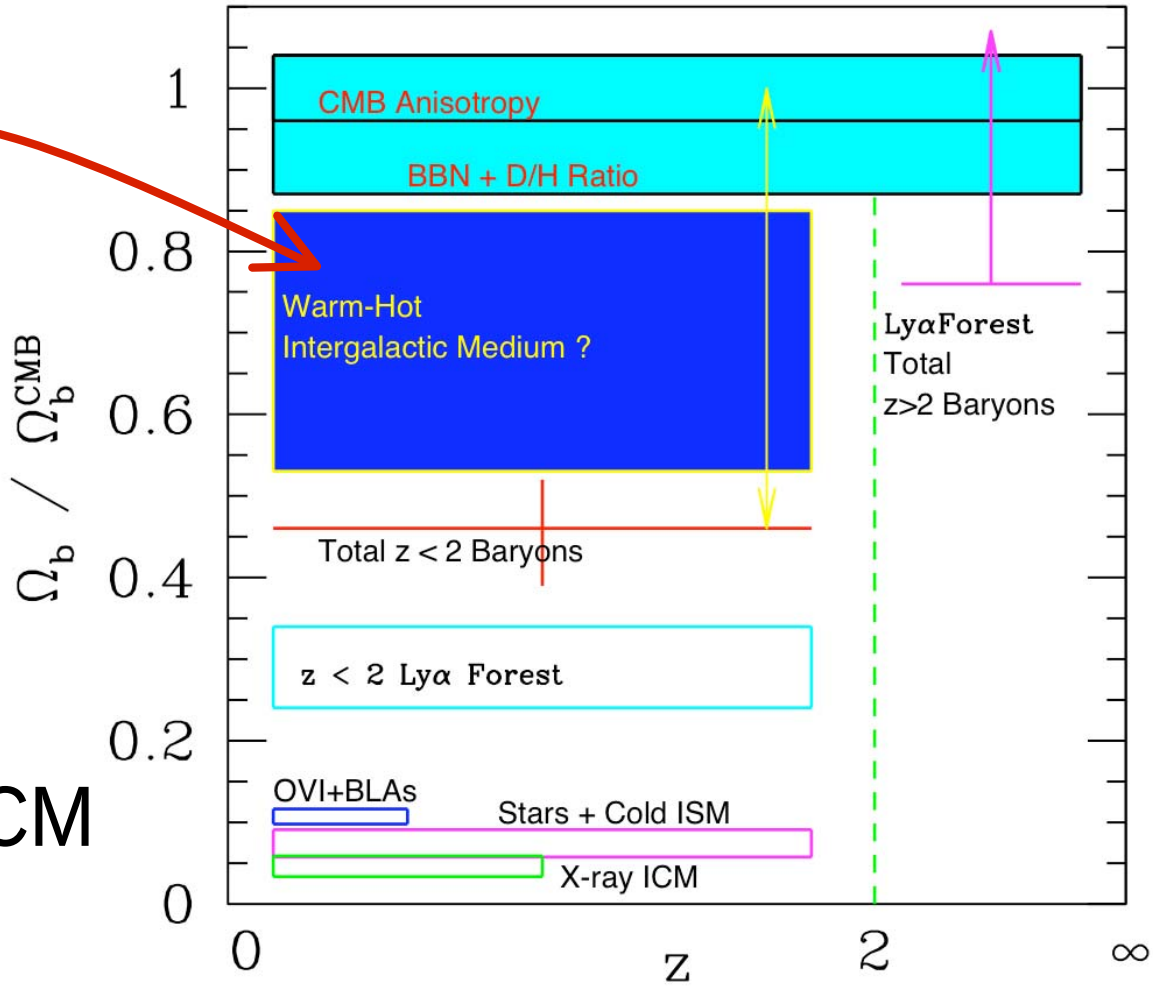
Missing Baryons:
OVII-Forest Fluctuations

Fabrizio Nicastro (CfA-SAO, INAF-OAR)

Collaborators: Y. Krongold (IA-UNAM), A. Phillips (Un. of Amherst), M. Elvis (CfA), J. Drake (CfA), S. Mathur (OSU), R. Williams (OSU)

The Missing Baryons and the WHIM



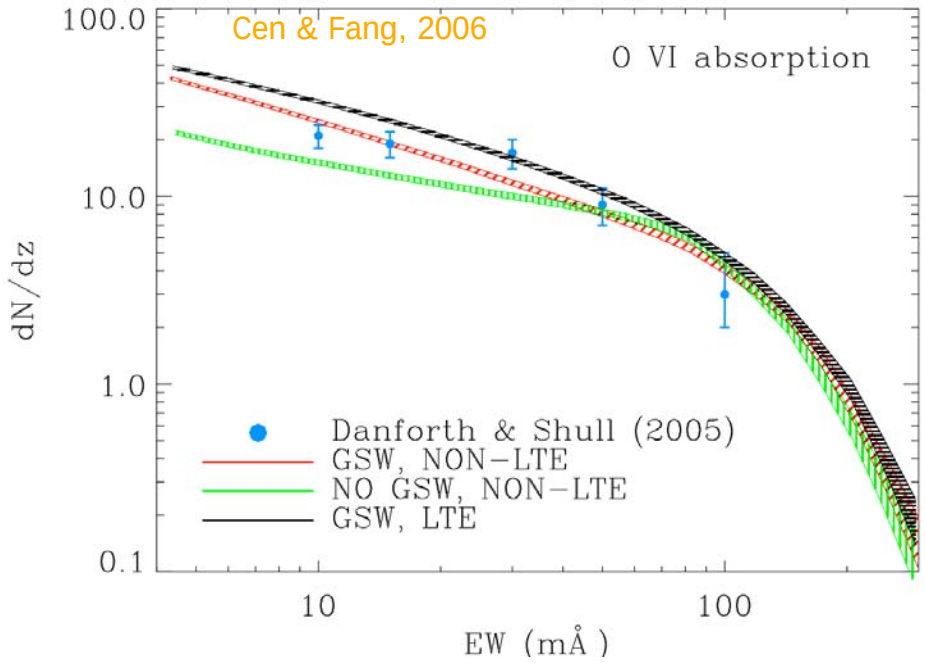


$\Omega_b^{Meas} = \Omega_b^{CMB}$

would validate SCM

The WHIM *is* out there!

But...only 10-20 % of the Missing Mass



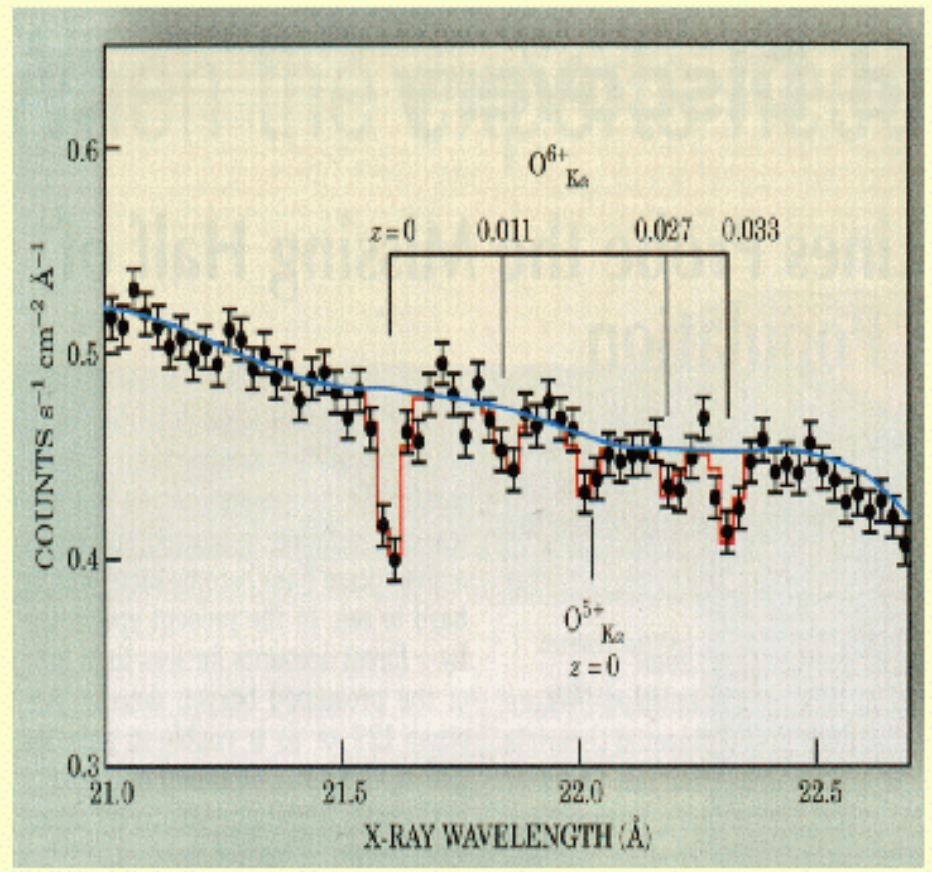
Ω_b(OVI) = 0.22 %, i.e. ~ 10 % Missing Baryons (with $Z_O \sim 0.1\ Z_\odot$)

Also: BLAs (Richter et al., 2006): b_{therm}(HI) > 45 km/s (Cf b(HI) ~ 10-50 km/s in Lyα-Forest)

Ω_b(BLA) = 0.27 %, i.e. ~ 10 % Missing Baryons

The WHIM in X-Rays:
80-90 % of the Missing Mass?

(Nicastro et al., 2005, Nature; Schwartzchild, 2005, Physics Today)



Controversial

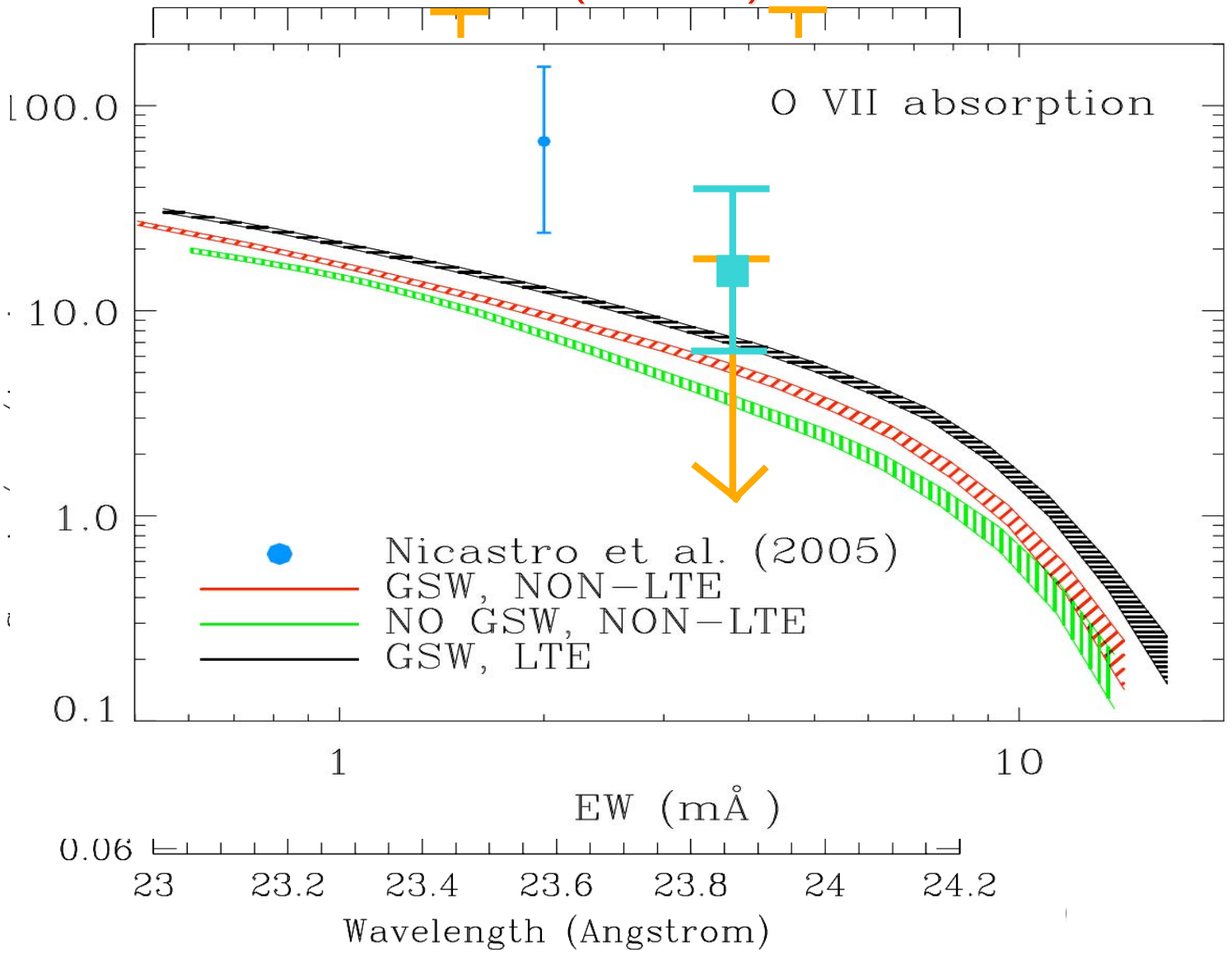
We stand by our Result:

(Nicastro et al., 2008, Science; Nicastro et al., 2007, ApJ)

1. XMM-*Newton* does ***NOT*** rule out *Chandra* detections (Rasmussen et al., 2007)
2. Chances of falsely detecting the two systems are 0.05 % and < 0.01 %, ***NOT*** 40 % and 6 % (Kaastra et al., 2006)

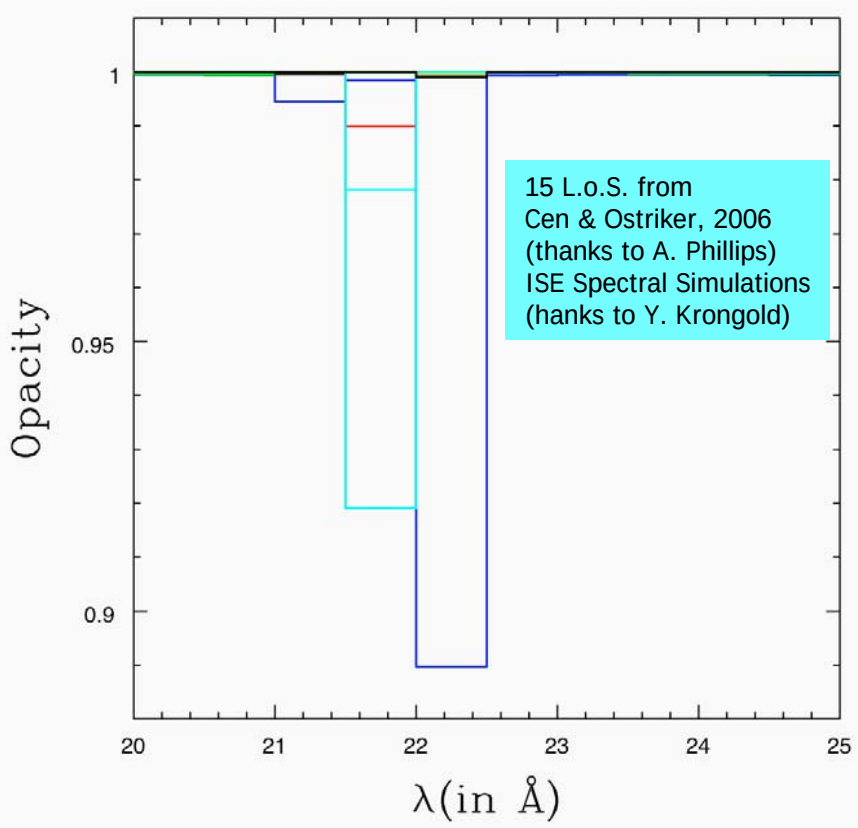
Beyond the Controversy

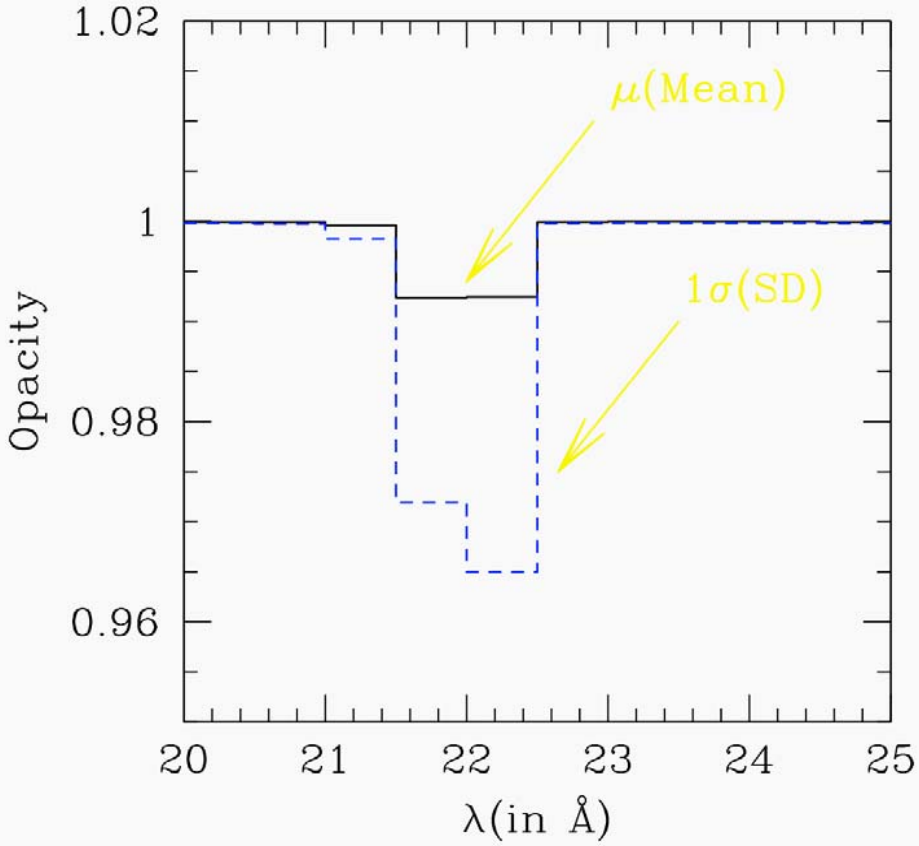
PKS 2155-304 (z=0.116)



OVII-Forest Fluctuations

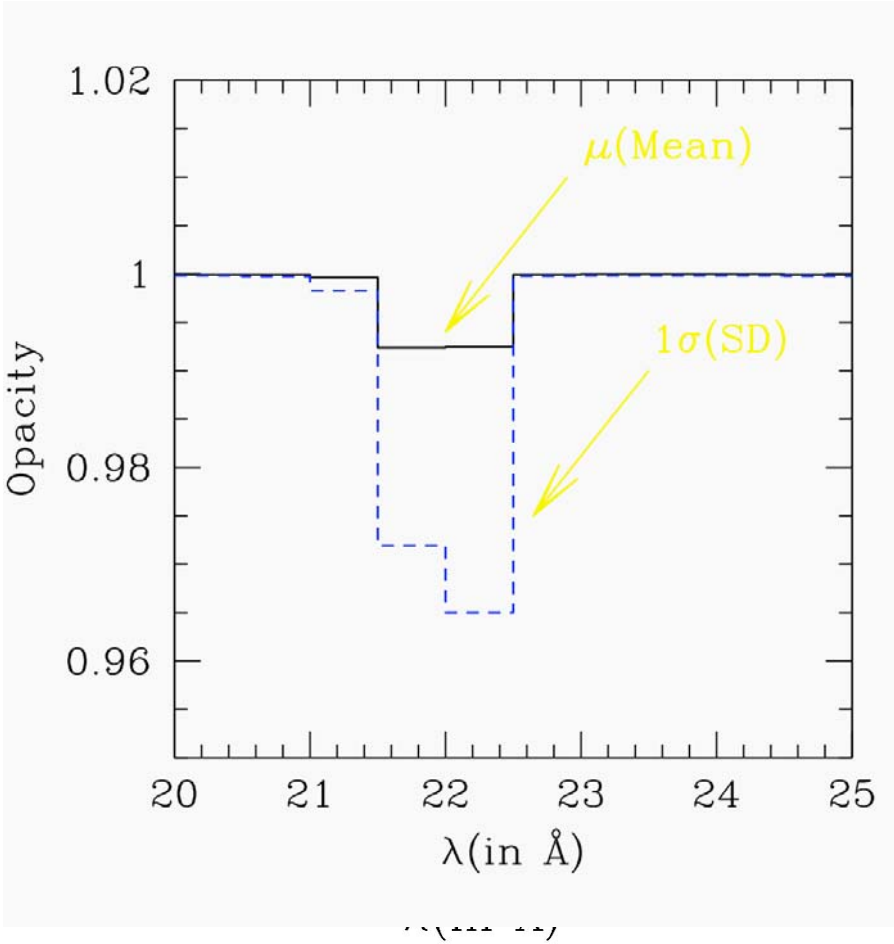
Theoretical Expectations

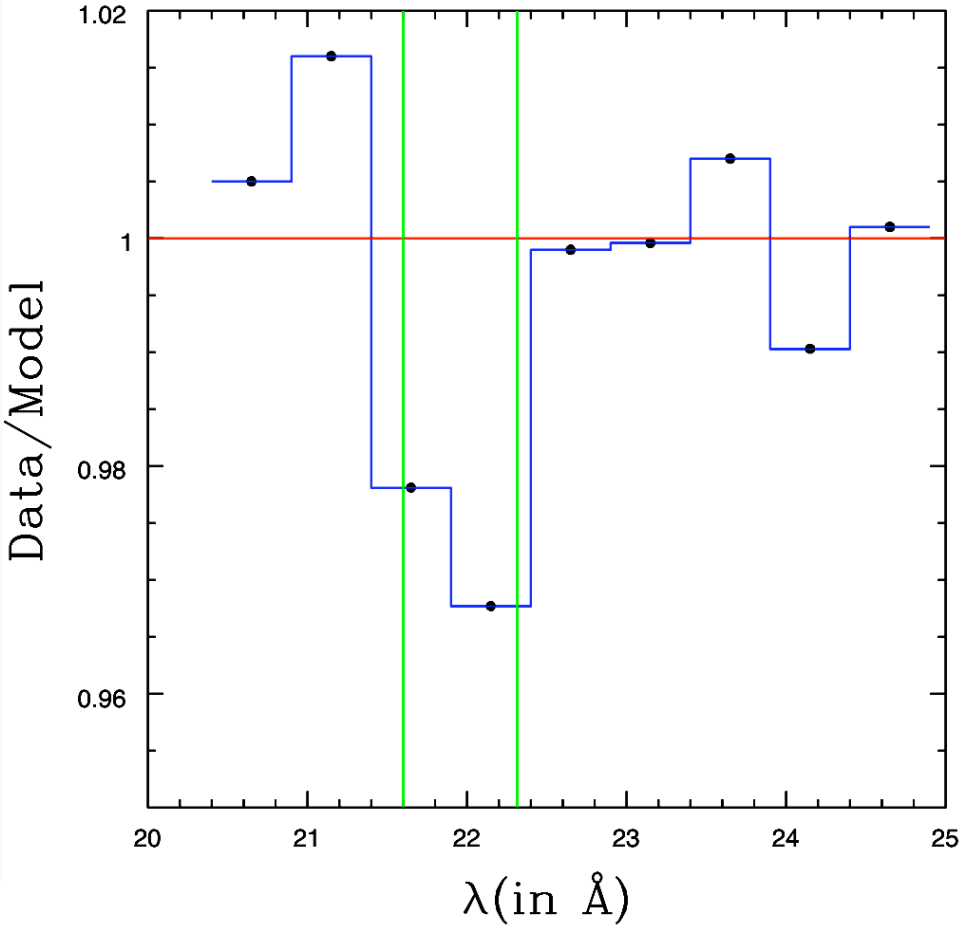




OVII-Forest Fluctuations:

Observations and Comparison with Predictions

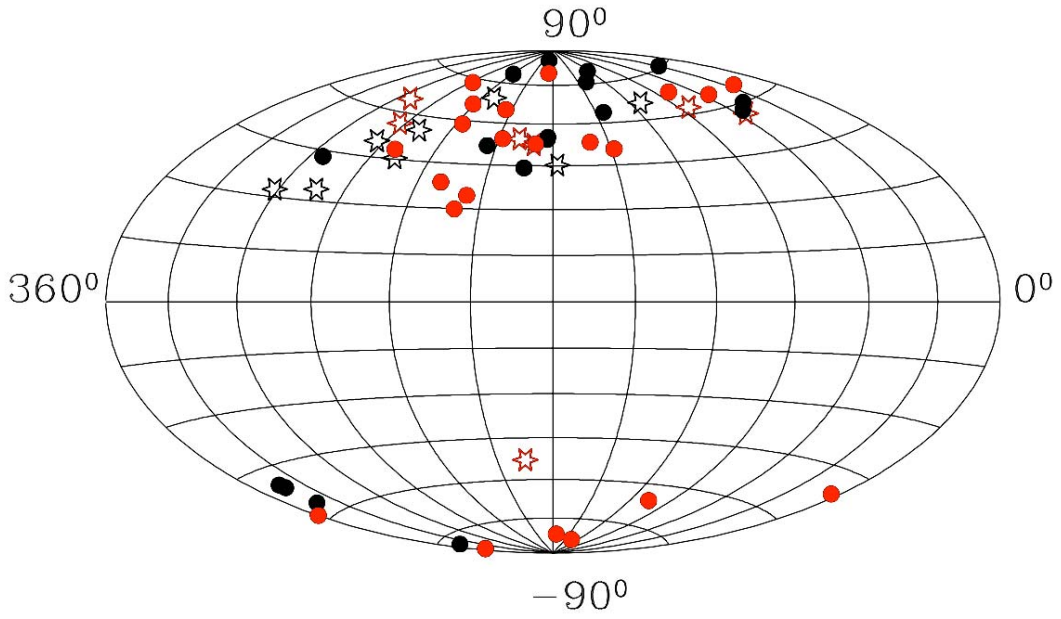




15 with F_S>0.5 mCrab => 100 ks
43 0.2<F_S<0.5 mCrab => 300 Ms
30 Sightlines in 6 Ms
110-220 OVII Systems
[Archival or COS for HI]

ard

< 0.5 mCrab (Filled Circles)
(Empty Stars)



RED = FUV/NUV Spectra (HST/FUSE/Galex)

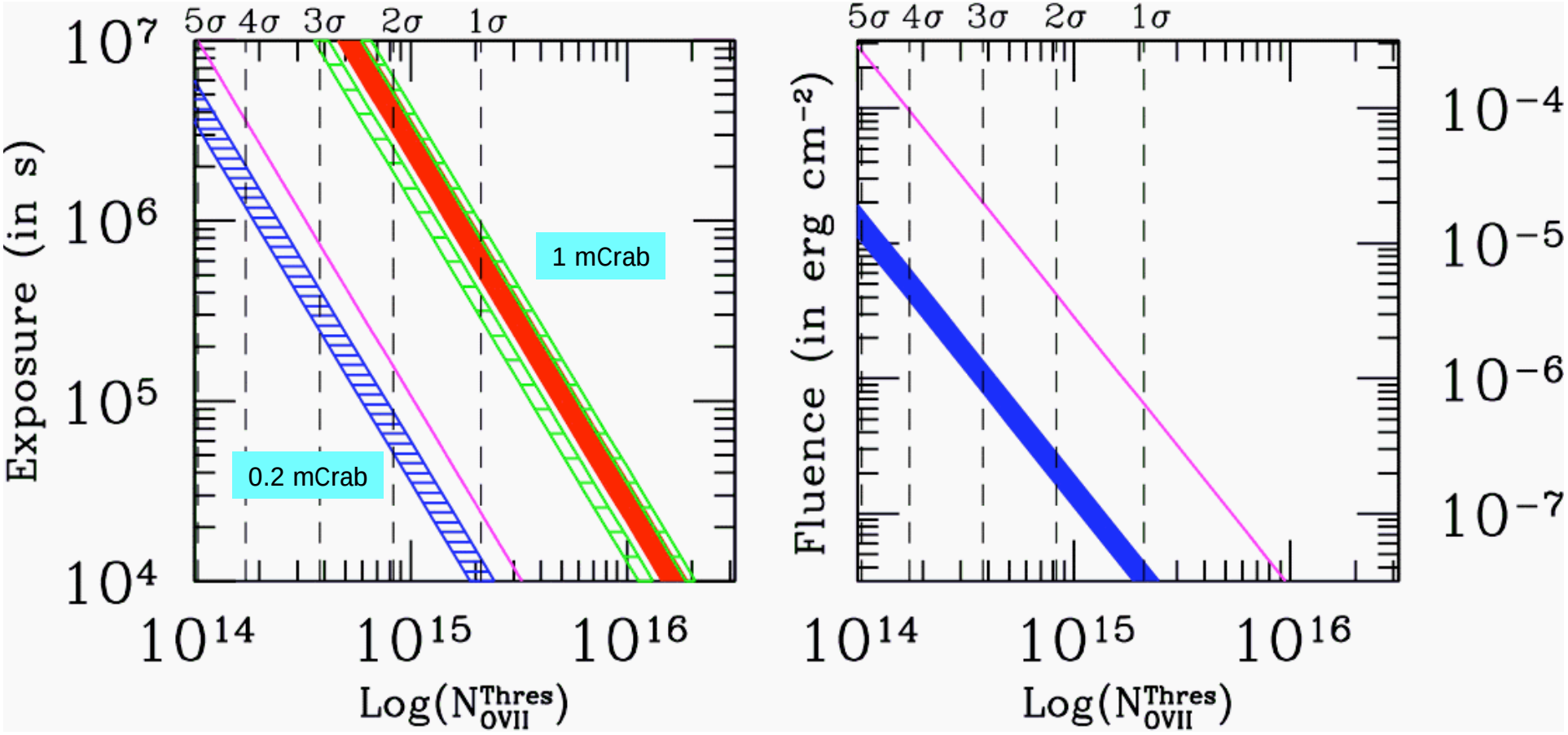
- X-Rays:
  - Only pursuable way with (higher-z, low-N_H^{Gal}, s X-ray spectra) bright
  - On quiescent targets RGS present, because of high
  - LETG is the only instrume

- UV: HST-COS
- X-Rays: Needs larg *Constellation*-X or

The Way Forward (2)

LETG; RGSs; Con-X (grat); XEUS (cal).

Pharos (R=2500, A=600 cm^2)
Edge (R=250; A=800 cm^2)



Conclusions

- WHIM detected in the UV: but < 10 % of Missing Baryons
- In X-Rays > 80 % of Missing Baryons: current evidence not conclusive
- OVII-Forest Fluctuations: theory predicts: 1-3 % (1σ)
- OVII-Forest Fluctuations: Observations show 3 % negative residuals, if LETG effective area has been modeled on these features.
- WHIM detection within reach of Chandra and XMM: only < 0.2 % of Chandra and XMM time dedicated to WHIM studies: ~20x longer exposures can provide firm detection of the Missing Baryons along 2-3 l.o.s.
- Way Forward: Multi-Ms LETG and RGS exposures of "smartly" selected targets ($z>0.3$, $N_H < 1.5 \times 10^{20}$ cm^{-2}, $F_{0.5-2} \sim 1$ mCrab, OVI or BLAs, etc.).
- Future: Constellation-X (or future small/mid-size high-res X-ray spectrometers) can detect ~200 OVII systems in ~ 6 Ms (30 lines of sight)

The Controversy (1)

- N05a,b claim statistical significances of 3.5σ and 4.8σ, i.e. P^{chance}=0.05 % & 0.005 %
- K06 perform MonteCarlo and conclude that: P=40 % and P=6 % of falsely detect the two systems.
- N07 perform new MonteCarlo and confirm P=0.05 % and P < 0.01 % for the two systems (i.e. 3.5σ and > 3.9σ respectively):

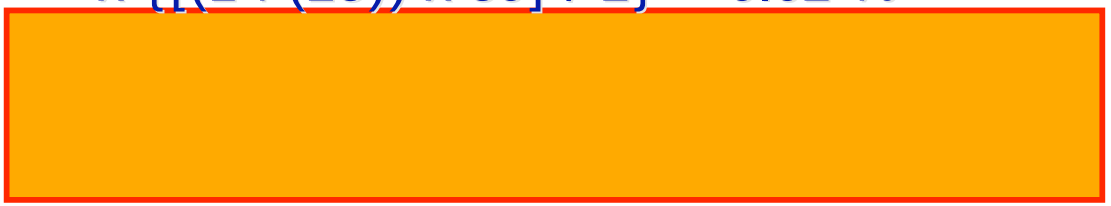
differences due to different assumptions

A Simple Gaussian Argument (z=0.011; 2 lines @ 3.8σ & 2σ)

λ(OVII)=21.602; z(Mkn 421)=0.03 ==> Δλ= λ(OVII)xz(Mkn 421) = 648 mA

Δλ(LETG)=50 mA ==> 13 Ind. Elem.; Over-sampling by 4 ==> 52 bins

$$=> P_{Gauss} \sim \{[(1-P(3.8\sigma)) \times 52] / 2\} \times \{[(1-P(2\sigma)) \times 59] / 2\} = 0.02\ \%$$



The Controversy (2)

Differences are due to different assumptions:

K06 compute:

$$P^{Chance}\left(\sum_{i=1}^{7}(Neg\_Fluct)_i\right)_{z=0-0.03}$$

==> $P^{Chance}(z=0.011)$ = 40 % !!!

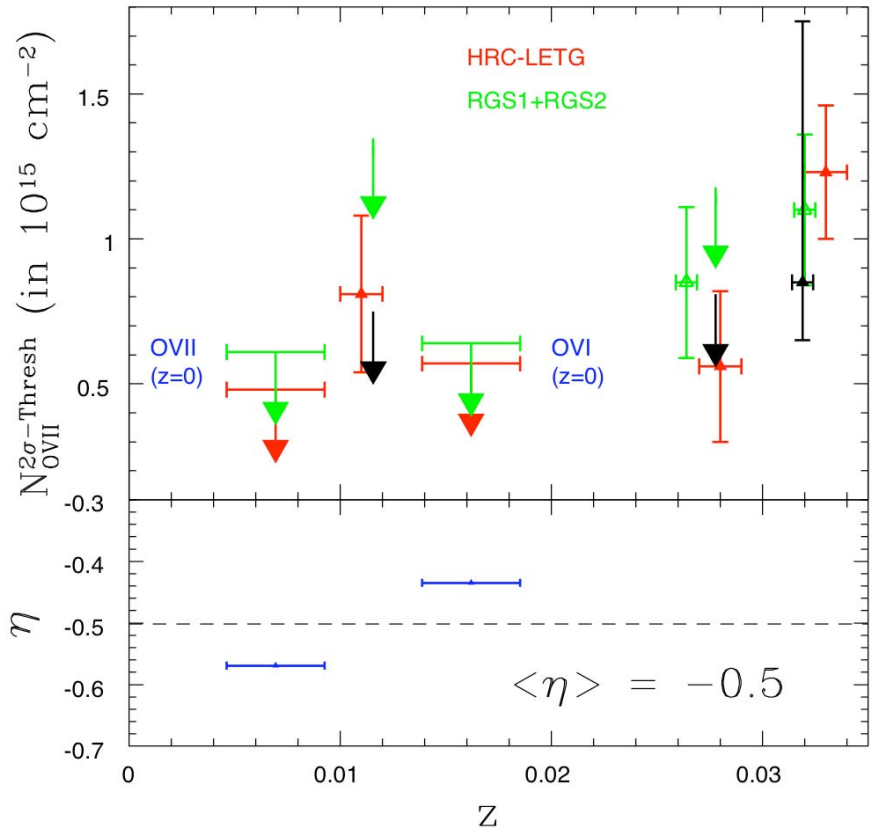
N07 compute:

$$P^{Chance}_{z=0-0.03}(evt_1,\ldots,evt_N) = \prod_{i=1,N} P^{Chance}_{z=0-0.03}(evt_i)$$

==> $P^{Chance}(z=0.011)$ = 0.05 %

The Controversy (2)

Rasmussen+06 claim no evidence, in XMM-RGS, of the absorption lines seen by *Chandra*



$R_{LETG} \sim 2.4 \times R_{RGS}$

XMM does not rule out Chandra Detections