

Searching for the hot WHIM

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M. Bonamente, E. Tempel, J. Ahoranta, A. Finoguenov, J. Schaye, N. Wijers, J. Kaastra, E. Tilton...

XMM meeting 2019, Vilspa

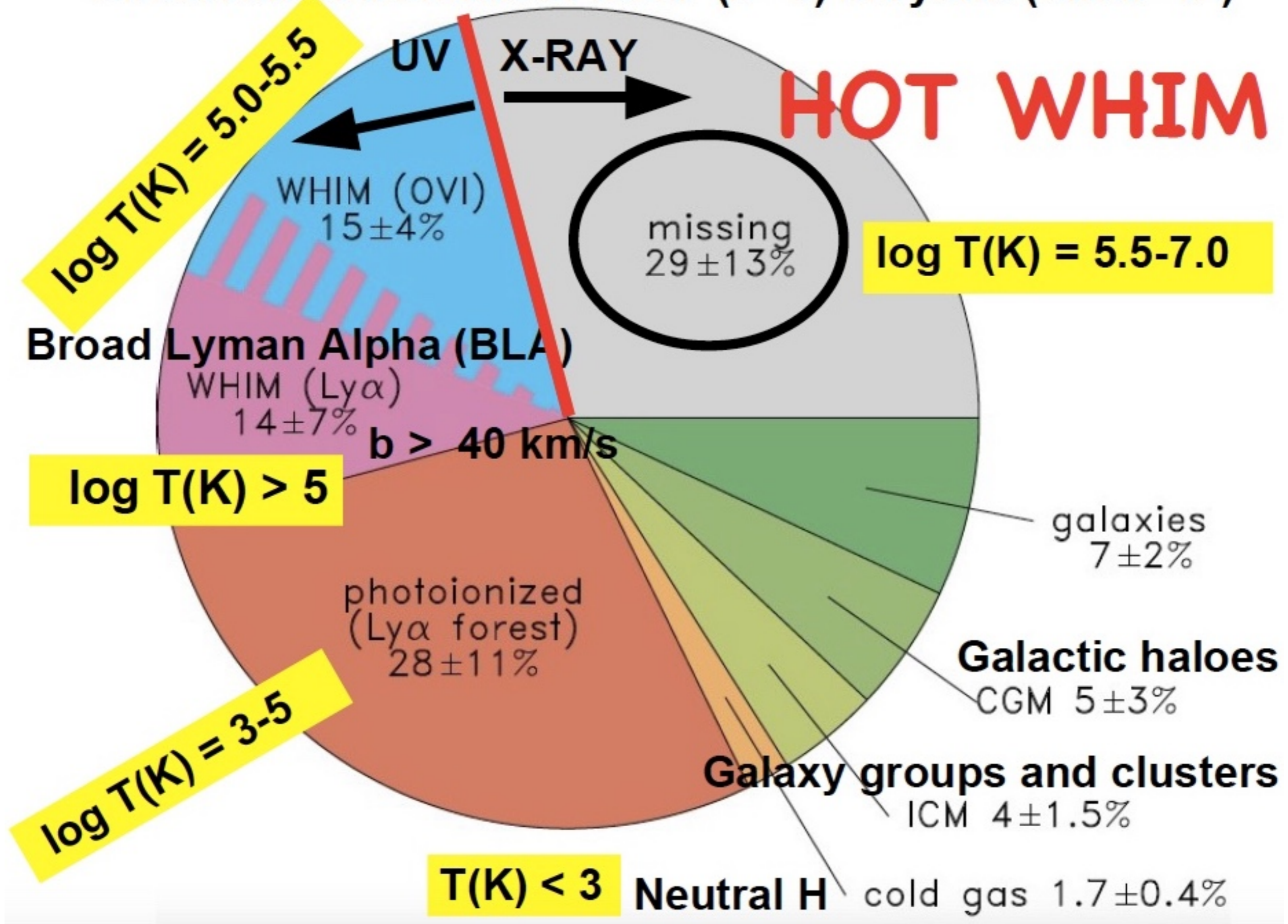
X-ray follow-up of the FUV- detected warm WHIM

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Wijers, J. Kaastra, E. Tilton...

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Observational status of local ($z \approx 0$) baryons (Shull+12)



HOT WHIM

$\log T(K) = 5.5-7.0$

$\log T(K) = 5.0-5.5$

$\log T(K) > 5$

$\log T(K) = 3-5$

$T(K) < 3$

UV X-RAY

WHIM (OVI)
15 ± 4%

missing
29 ± 13%

Broad Lyman Alpha (BLA)
WHIM (Ly α)
14 ± 7%

$b > 40$ km/s

galaxies
7 ± 2%

photoionized
(Ly α forest)
28 ± 11%

Galactic haloes
CGM 5 ± 3%

Galaxy groups and clusters
ICM 4 ± 1.5%

Neutral H cold gas 1.7 ± 0.4%

WHIM X-ray absorption line search



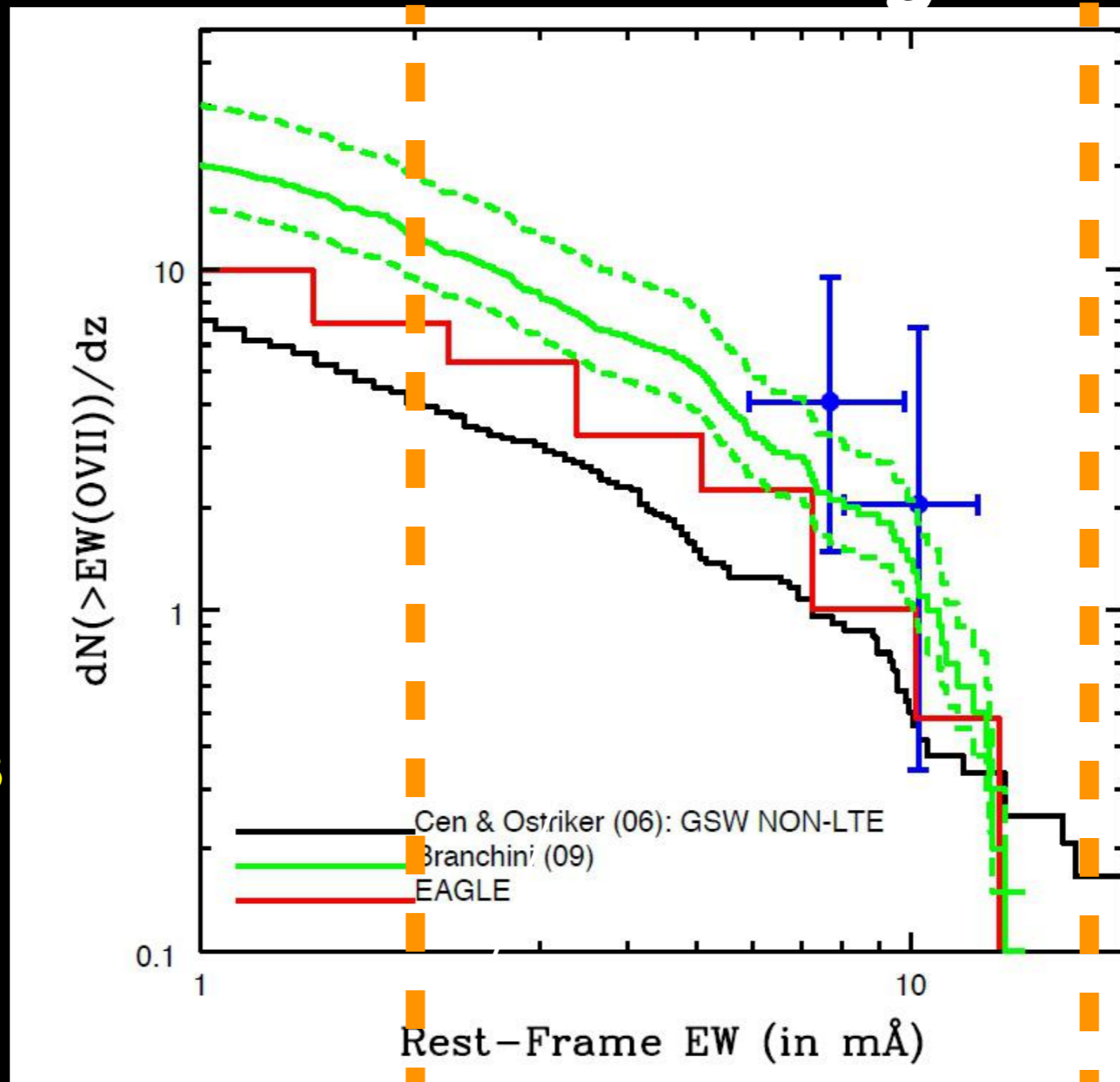
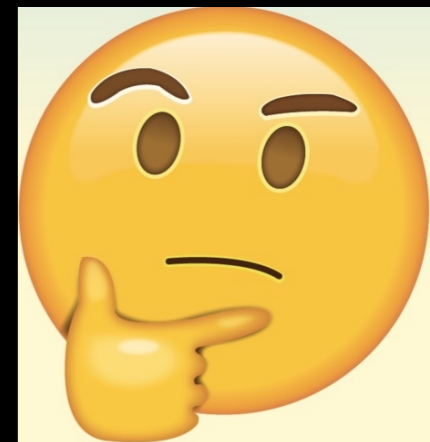
OVII predictions in cosmological simulations

- A few lines expected per unity redshift
- Need $> Ms$ exposure with RGS
- Such exposures are very rare



$\log N(\text{OVII}) = 15$

$\log N(\text{OVII}) = 16$



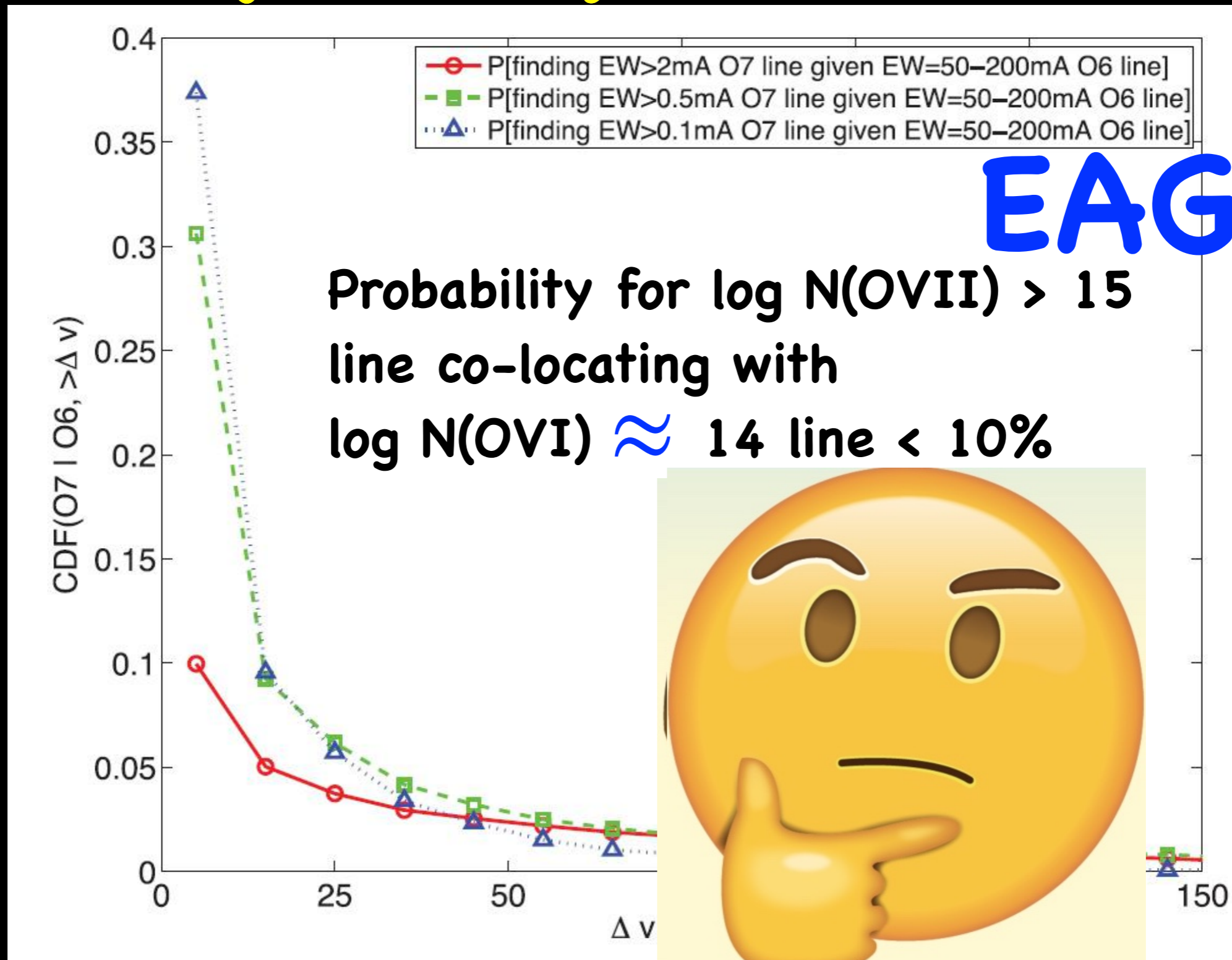
- a few 100 ks exposure with RGS
- These lines are very rare
- Need to probe extremely long path to get one line

- Additional problem: Given a deep data set, where is the WHIM (what redshift?).. blind search is problematic...

- Let's hope the well observable FUV (warm) WHIM is co-located with the hot (X-ray) WHIM

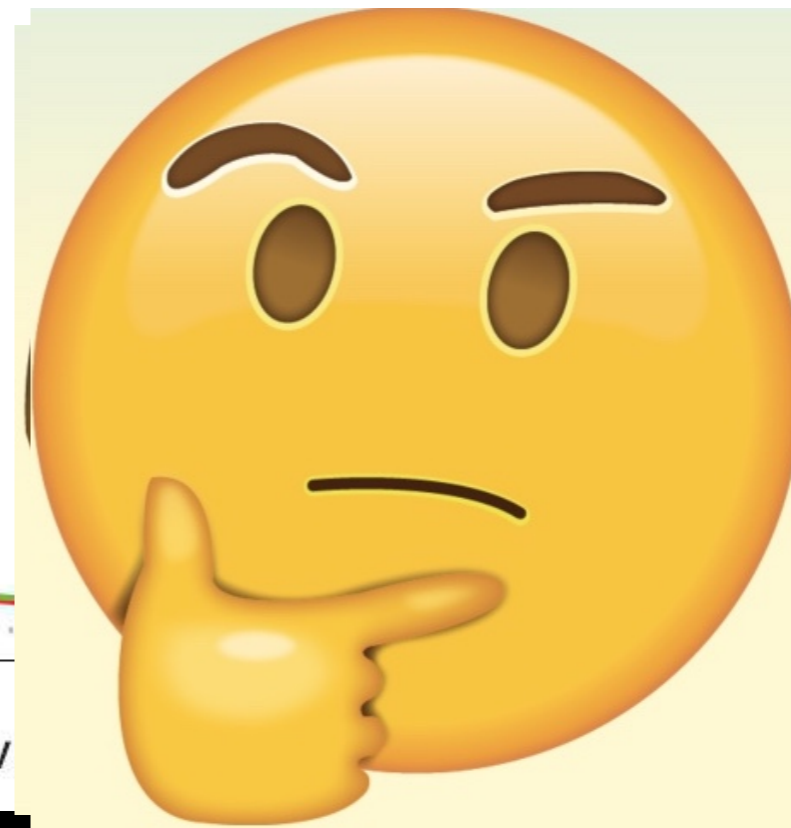


Cen (2012) simulations



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Probability for $\log N(\text{OVII}) > 15$
line co-locating with
 $\log N(\text{OVI}) \approx 14$ line $< 10\%$



- AGN sample:

FUV-detected WHIM (OVI and other metal ions; BLA) with HST/COS and FUSE
Tilton et al., (2012, ApJ, 759, 112) + Danfort et al., (2016, ApJ, 817, 111):
98 blazars and QSOs

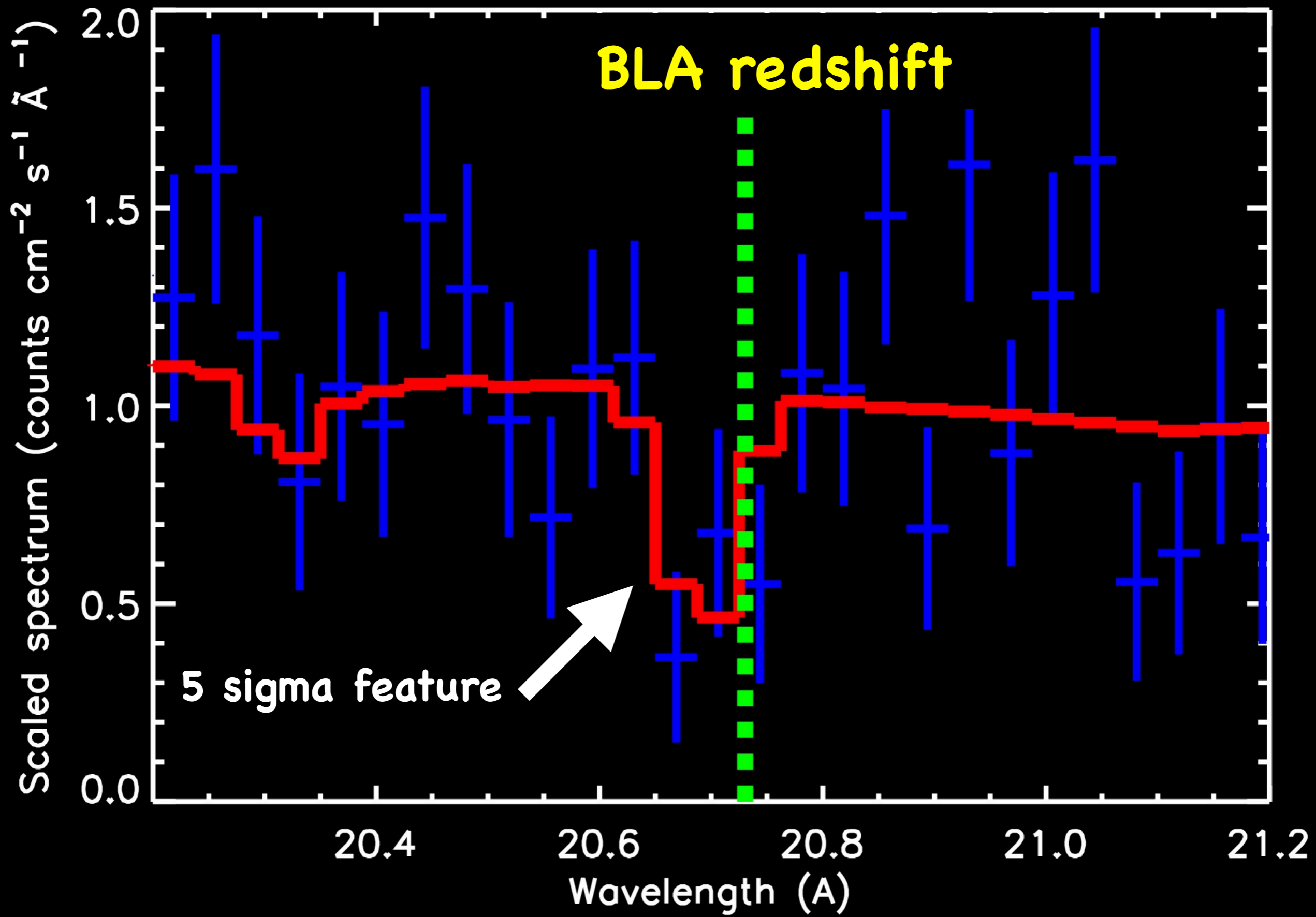
- We browsed the RGS archive for data towards these AGN
- Considering the 1) RGS exposure time, 2) average flux during the observation, and 3) our PKS 2155-304 results (Nevalainen et al., 2019), we use the scaling **1.7 Ms RGS exposure ... log (OVII) = 15**
- 19 AGN covered with RGS to log (OVII) = 15-16 level
- 37 OVI lines covered with deep X-rays
- Assuming the co-location rate from Cen 10%, by maximum 4 OVI-OVII matches expected

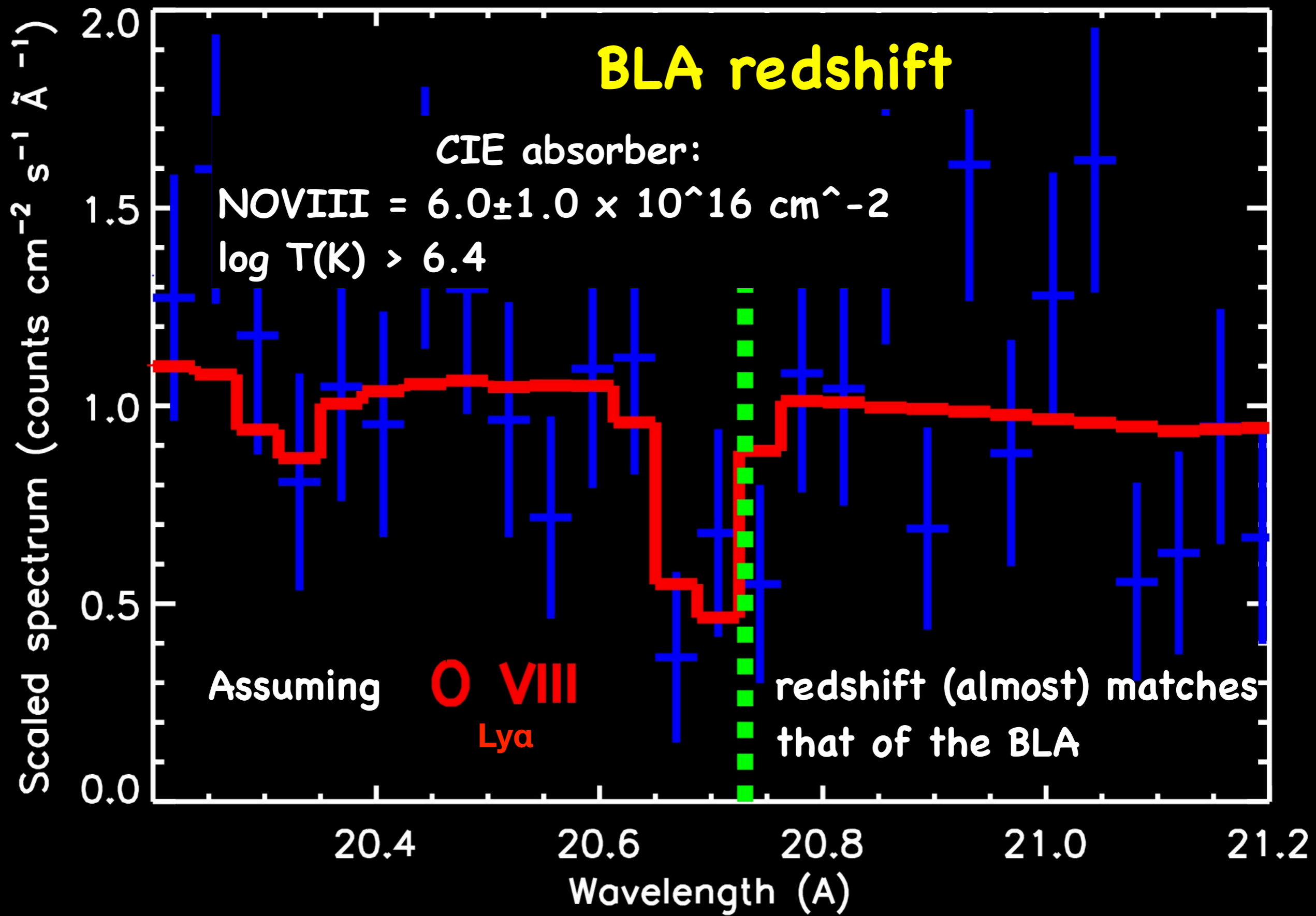
- Assuming the co-location rate from Cen 10%, by maximum 4 OVI-OVII matches expected
- We found none
- Good news: we found 1 **BLA-OVIII** match and 1 **OVI-OVIII** match

**A possible Chandra and Hubble Space
Telescope detection of extragalactic
WHIM towards PG 1116+215**

MNRAS 2016, 457, 4236

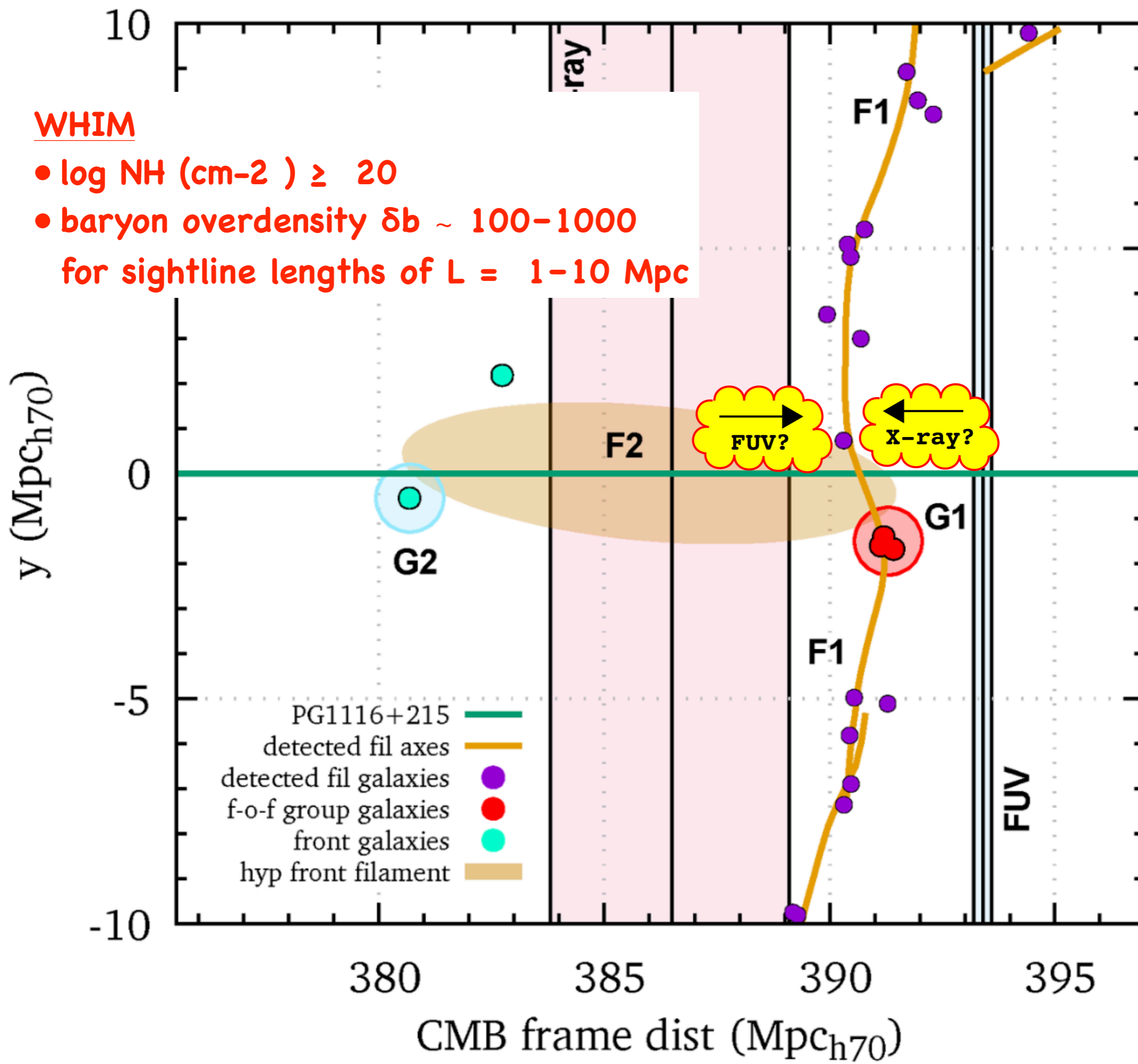
**M. Bonamente, J. Nevalainen, E. Tilton, J. Liivamägi, E. Tempel,
P. Heinämäki and T. Fang**





WHIM

- $\log N_{\text{H}} (\text{cm}^{-2}) \geq 20$
 - baryon overdensity $\delta_b \sim 100-1000$
- for sightline lengths of $L = 1-10 \text{ Mpc}$

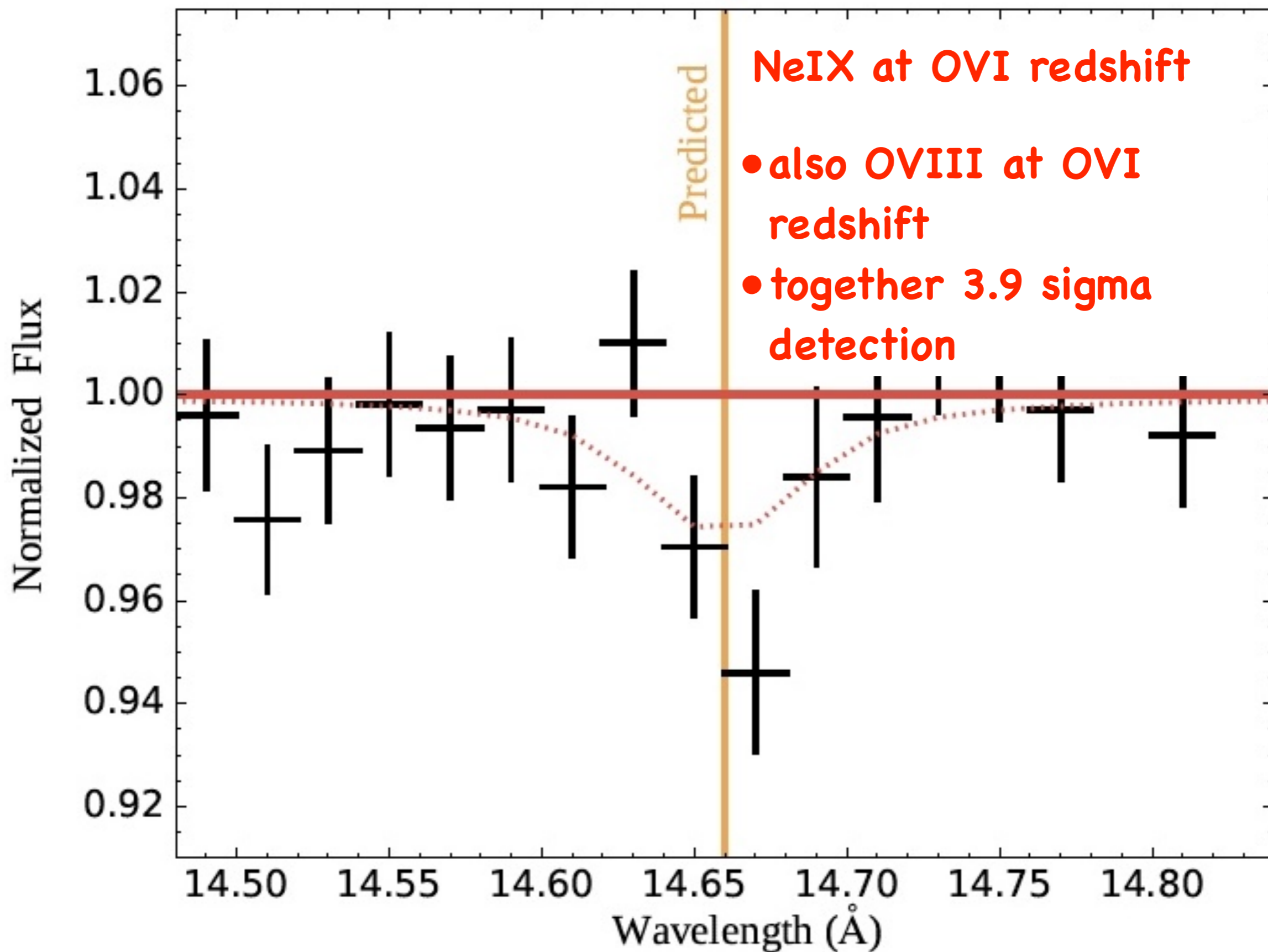


Hot WHIM counterparts of FUV OVI absorbers: The evidence in the line-of-sight towards quasar 3C 273

A&A, submitted

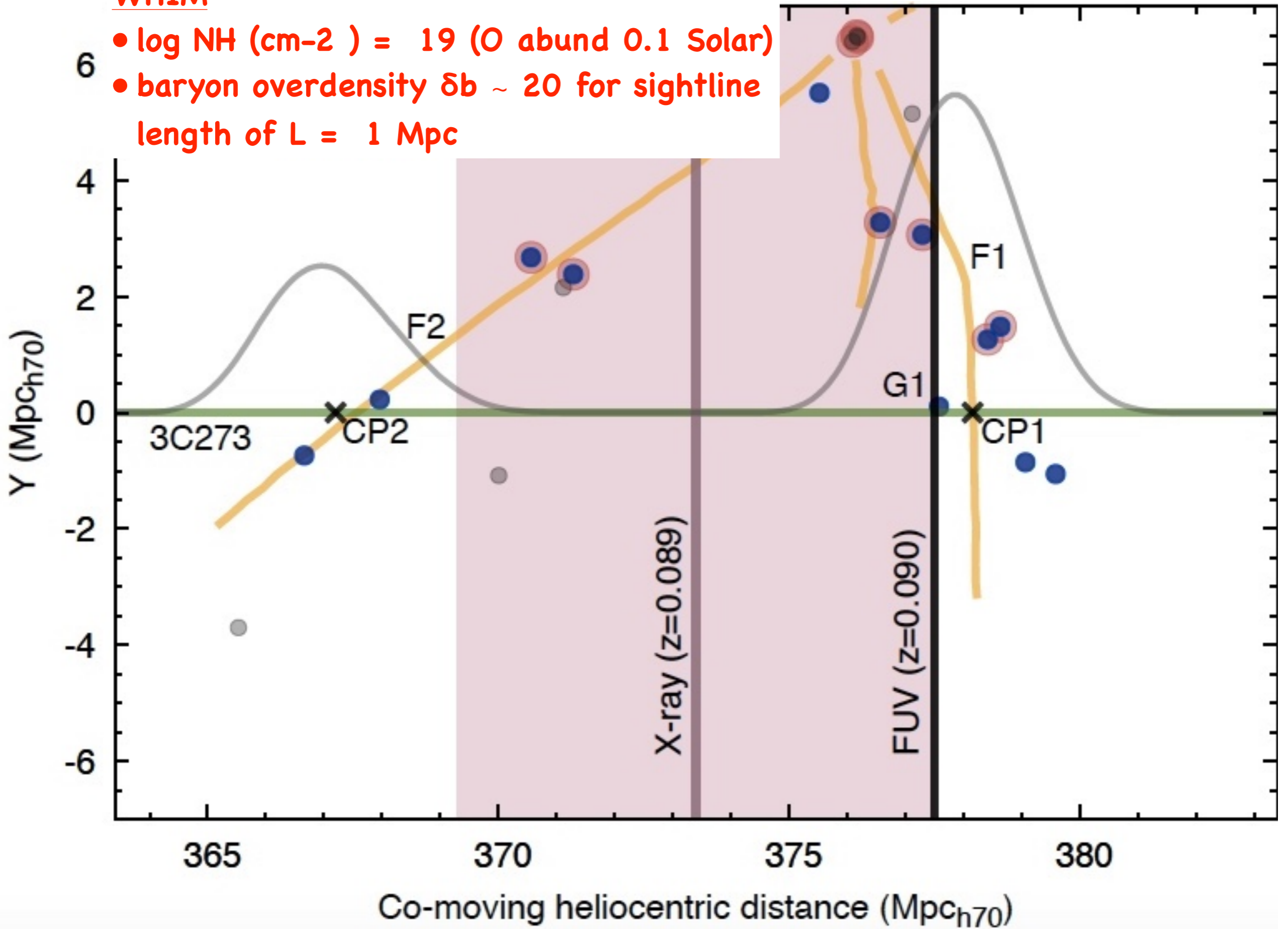
J. Ahoranta, J. Nevalainen, N. Wijers, A. Finoguenov, M. Bonamente,
E. Tempel, E. Tilton, J. Schaye, J. Kaastra and G. Gozaliasl

Fluxed Spectrum: RGS1 & RGS2

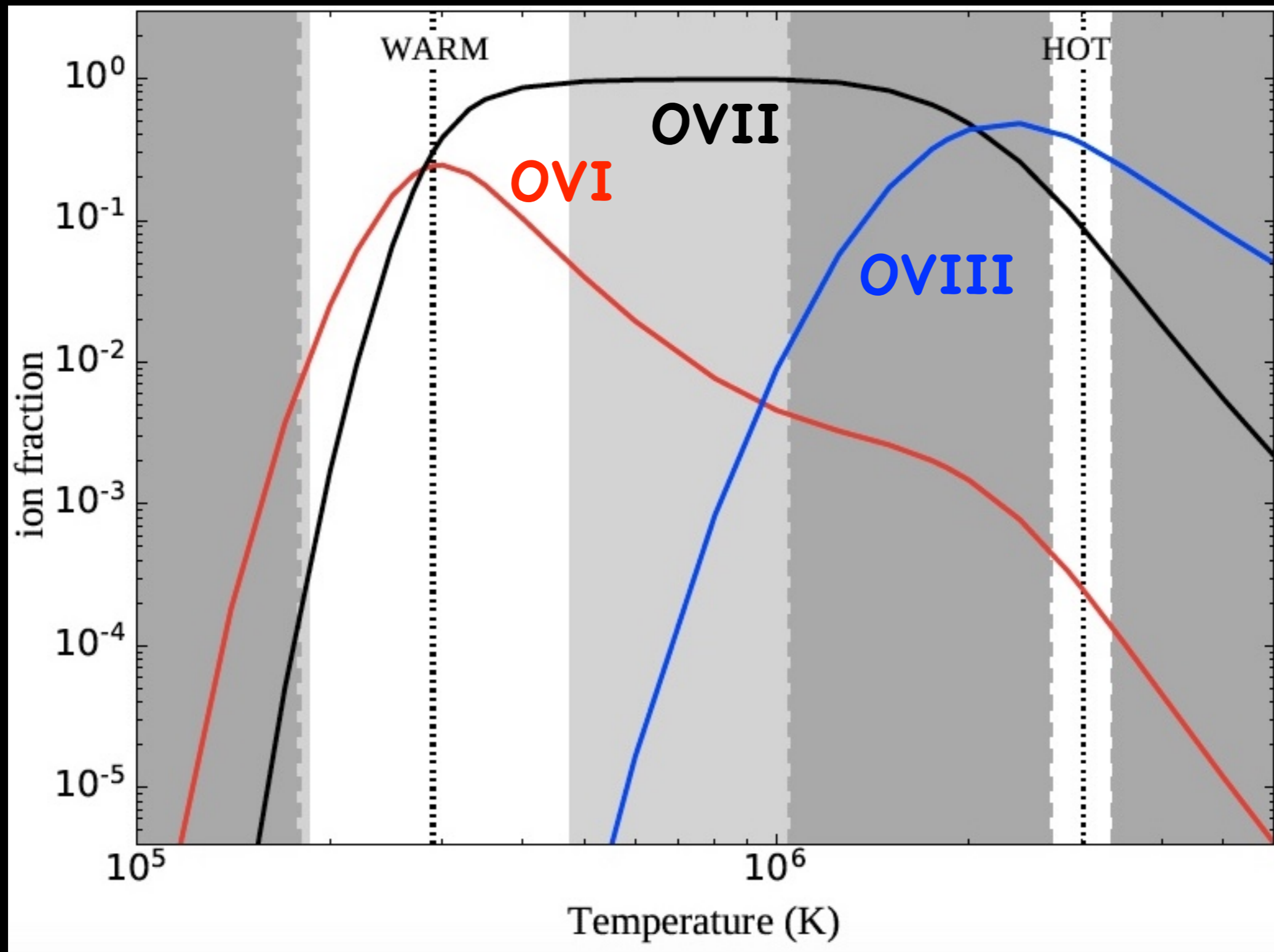


WHIM

- $\log N_{\text{H}} (\text{cm}^{-2}) = 19$ (O abund 0.1 Solar)
- baryon overdensity $\delta_b \sim 20$ for sightline length of $L = 1 \text{ Mpc}$



2T modelling

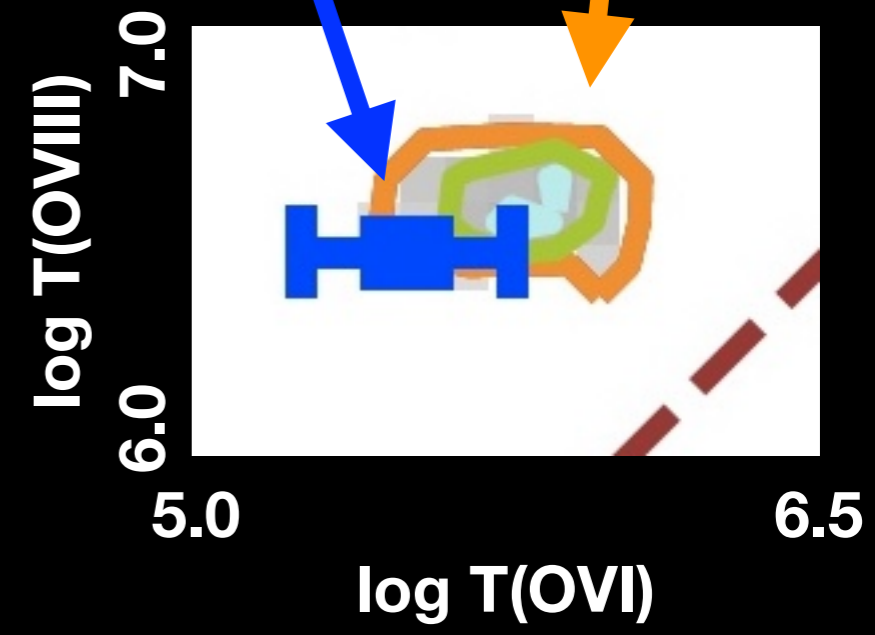
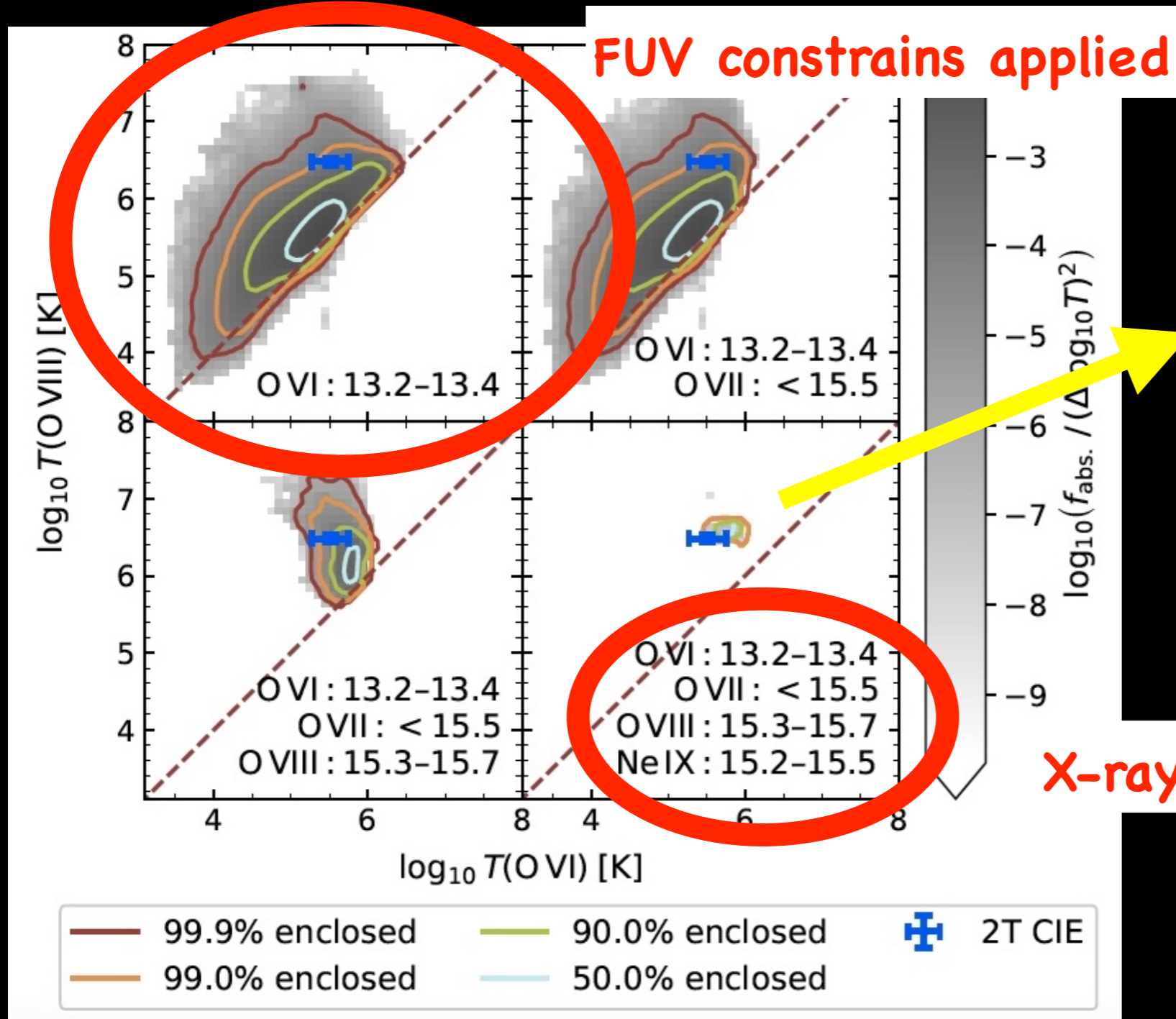


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2T modelling

simulation

Volume divided into boxes of a few Mpc size
 Different (co-located) ions studied in these boxes



X-ray and FUV constrains