Transition temperature (10^5 K) Galactic gas discovered with high resolution X-ray spectroscopy in PKS 2155-304 sight line

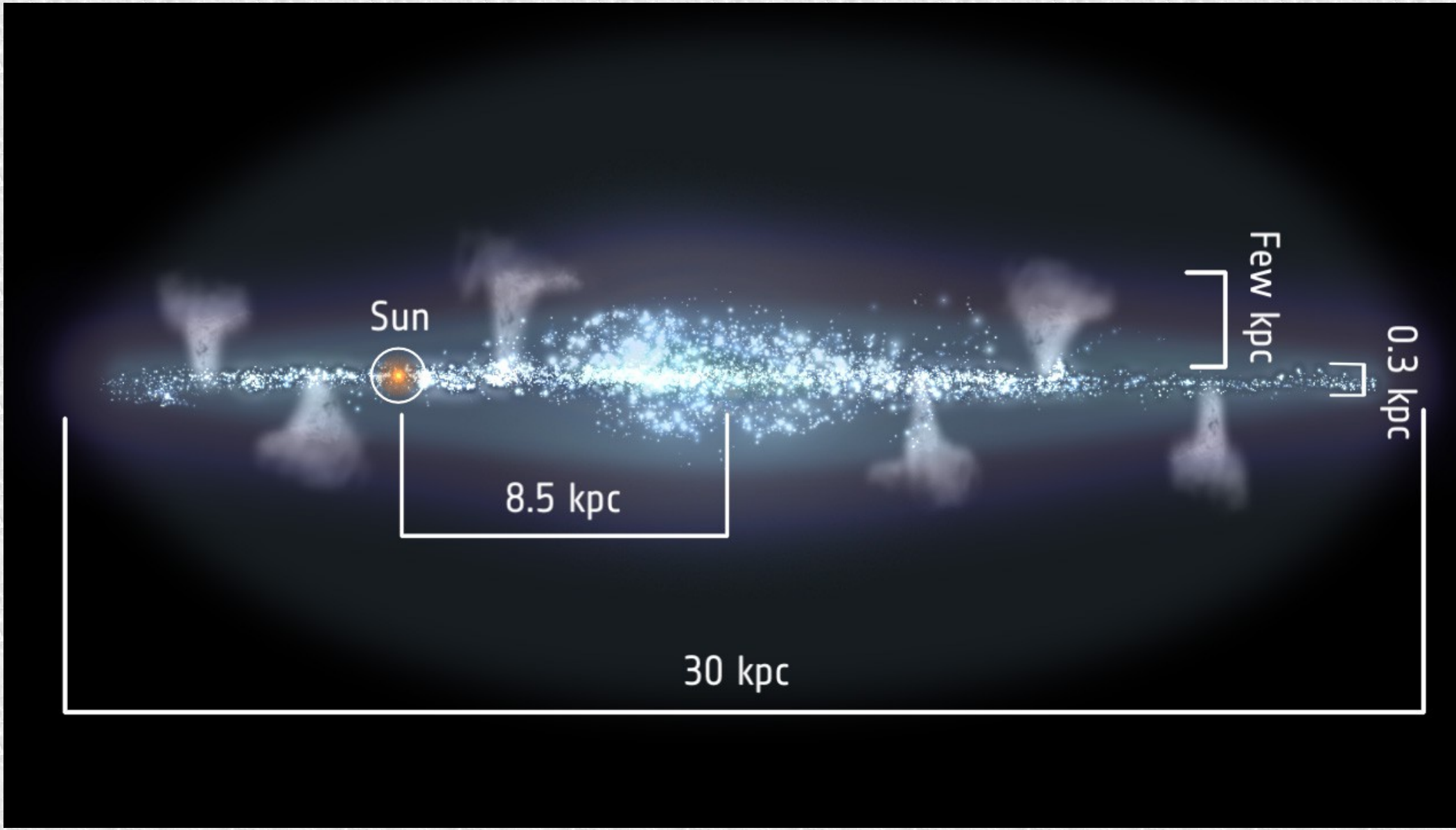
J. Nevalainen, B. Wakker, J. Kaastra, M. Bonamente, S. Snowden, F. Paerels and C. de Vries,

2017, A&A accepted, arXiv:1705.08497

X-ray Universe 2017, Rome

1) Galactic fountain model

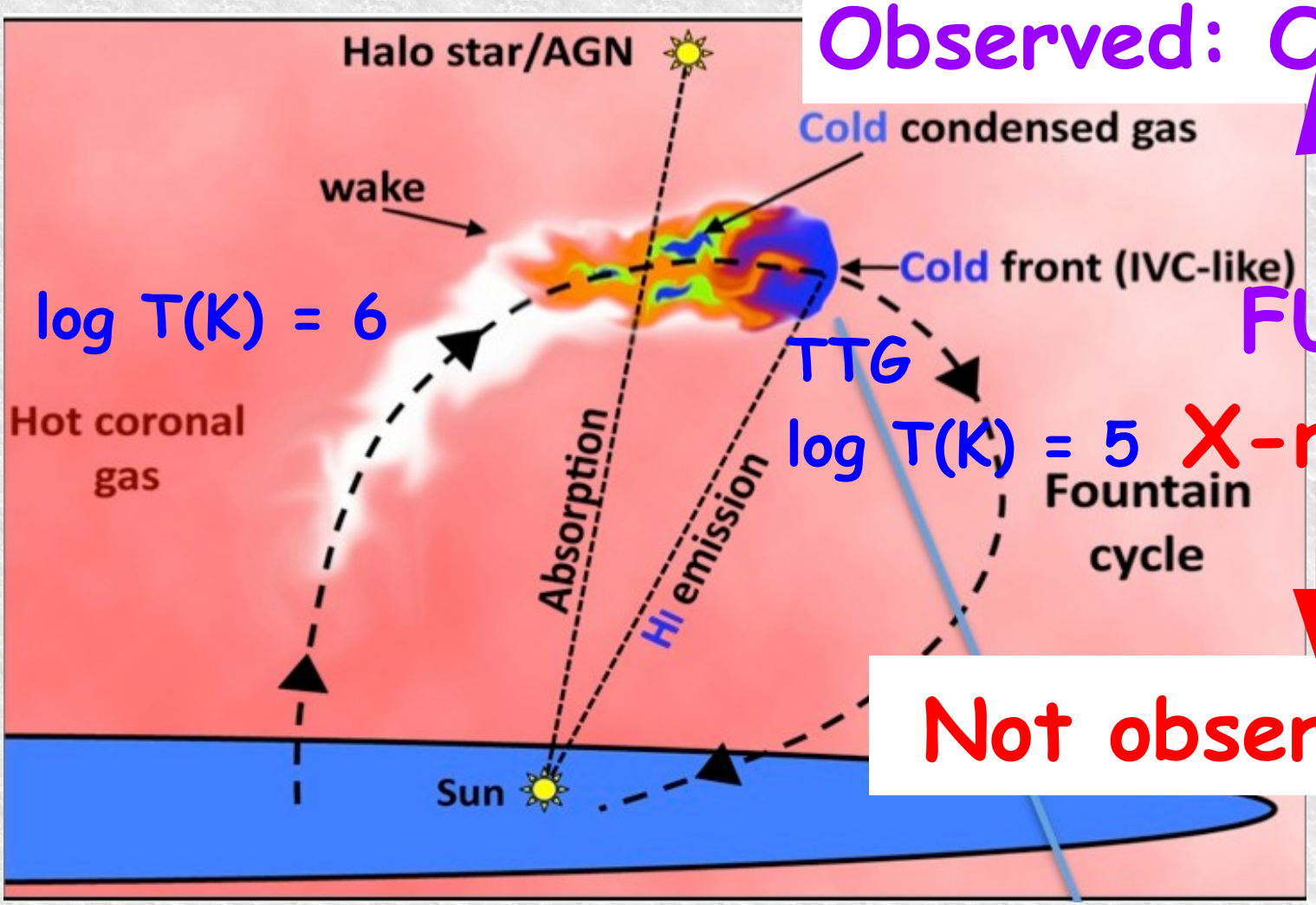
Supernovae in the Galactic Plane shoot hot 10^6 K metal enriched gas a few kpc away from the GP



Gas cools and falls closer to the GP

➔Transition Temperature Gas TTG

(name from Savage & Wakker 2009)



Observed: OVI

X-rays

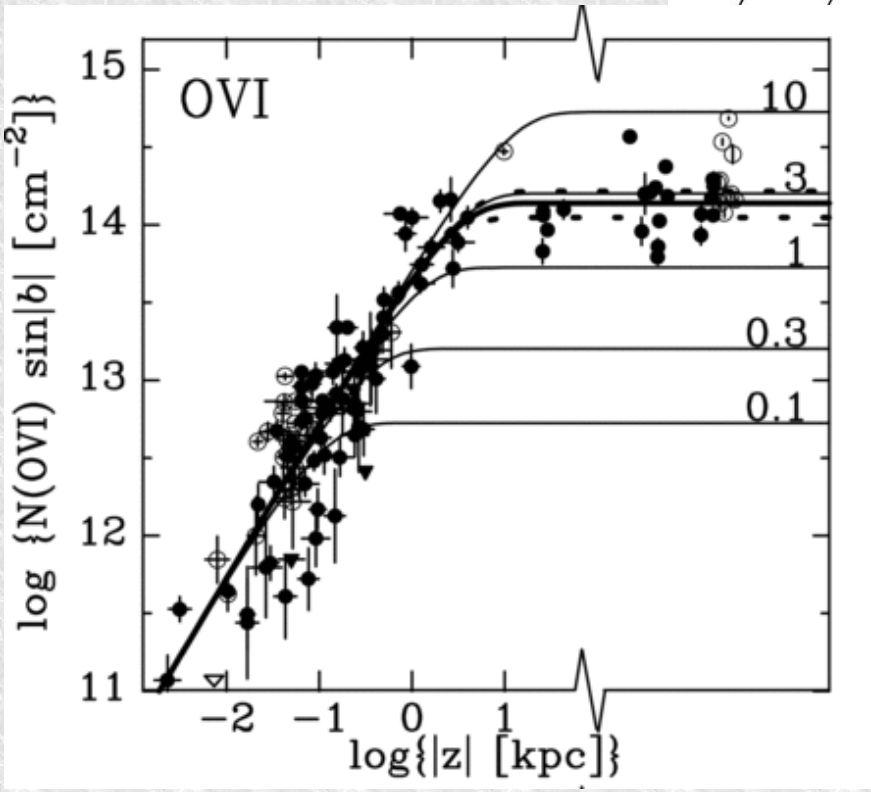
FUV

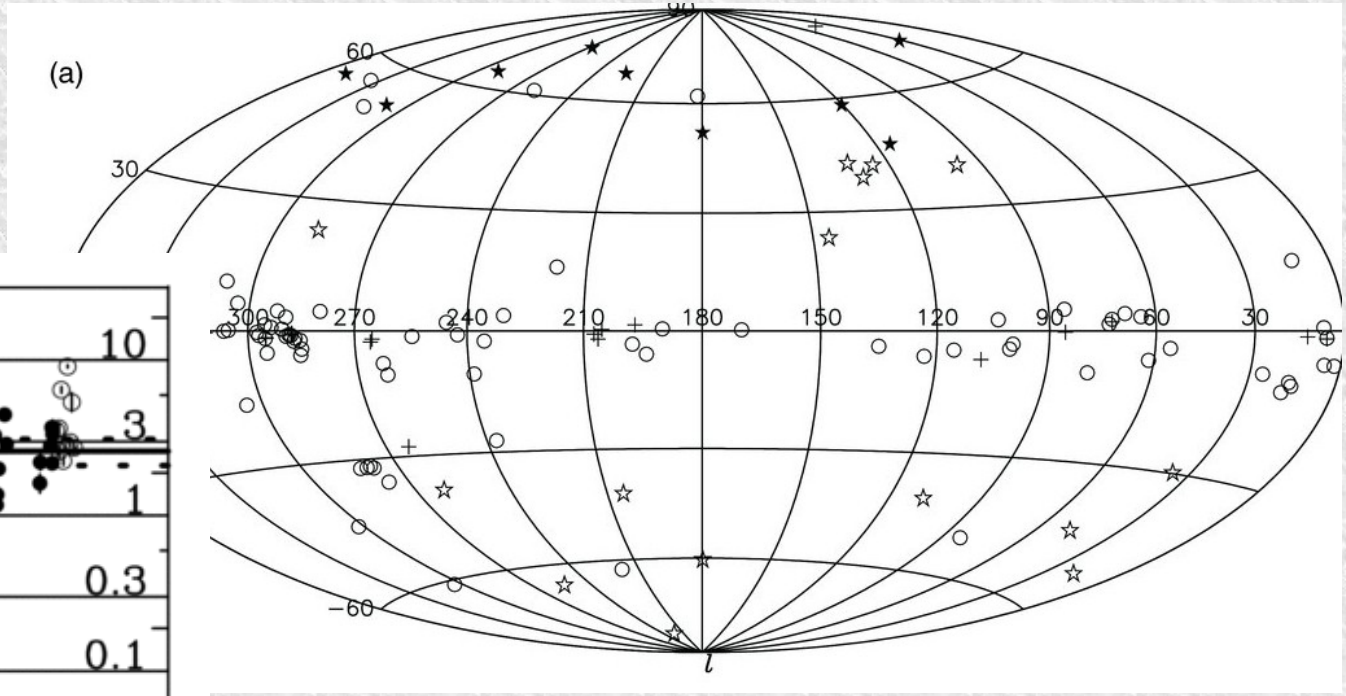
X-rays

Not observed

TTG observed via FUV absorption of blazars

Savage et al., 2009, ApJ, 702, 1472





OVI scale height ~3 kpc

2) PKS analysis

PKS in X-rays

- PKS is a bright blazar ☞
- commonly used calibration source for XMM and Chandra
- We obtained 3 Ms of data with RGS1, RGS2, LETG/HRC and LETG/ACIS-S grating spectrometers
- Statistical errors a few %
- We analysed spectra with SPEX (Kaastra+96)

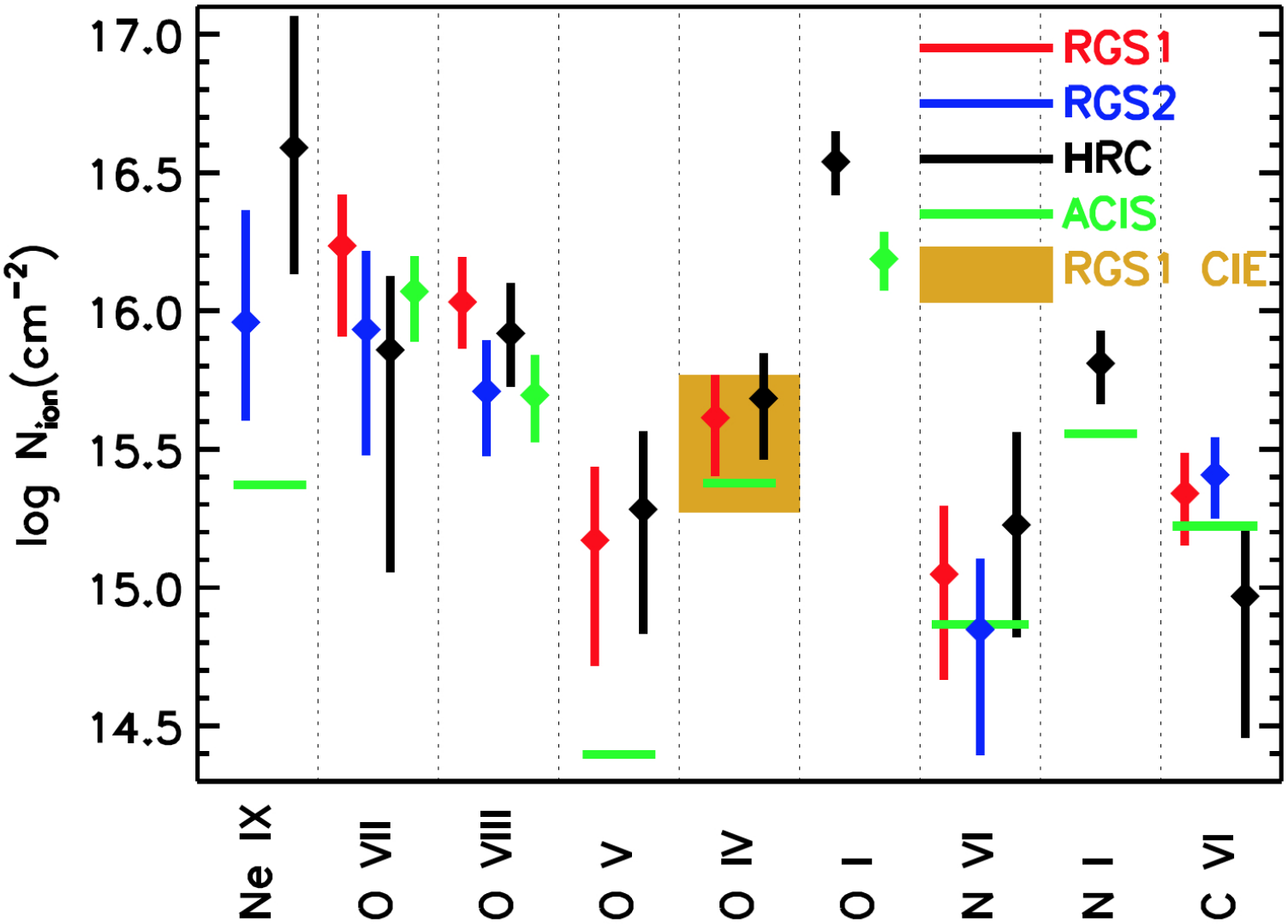
Selection criteria

We very conservatively accepted only lines which

- are detected at $\geq 2\ \sigma$ level with all relevant instruments (by 2 instruments, i.e. at 99.75% CL by minimum)
- have wavelength consistent with one of SPEX database lines at z = 0 (Verner+96 + numerous additions, see the SPEX manual)
- don't have wavelengths coinciding at any problematic channels (bad columns, CCD gap, O edge, instrumental lines)

- We detected 10 Galactic lines

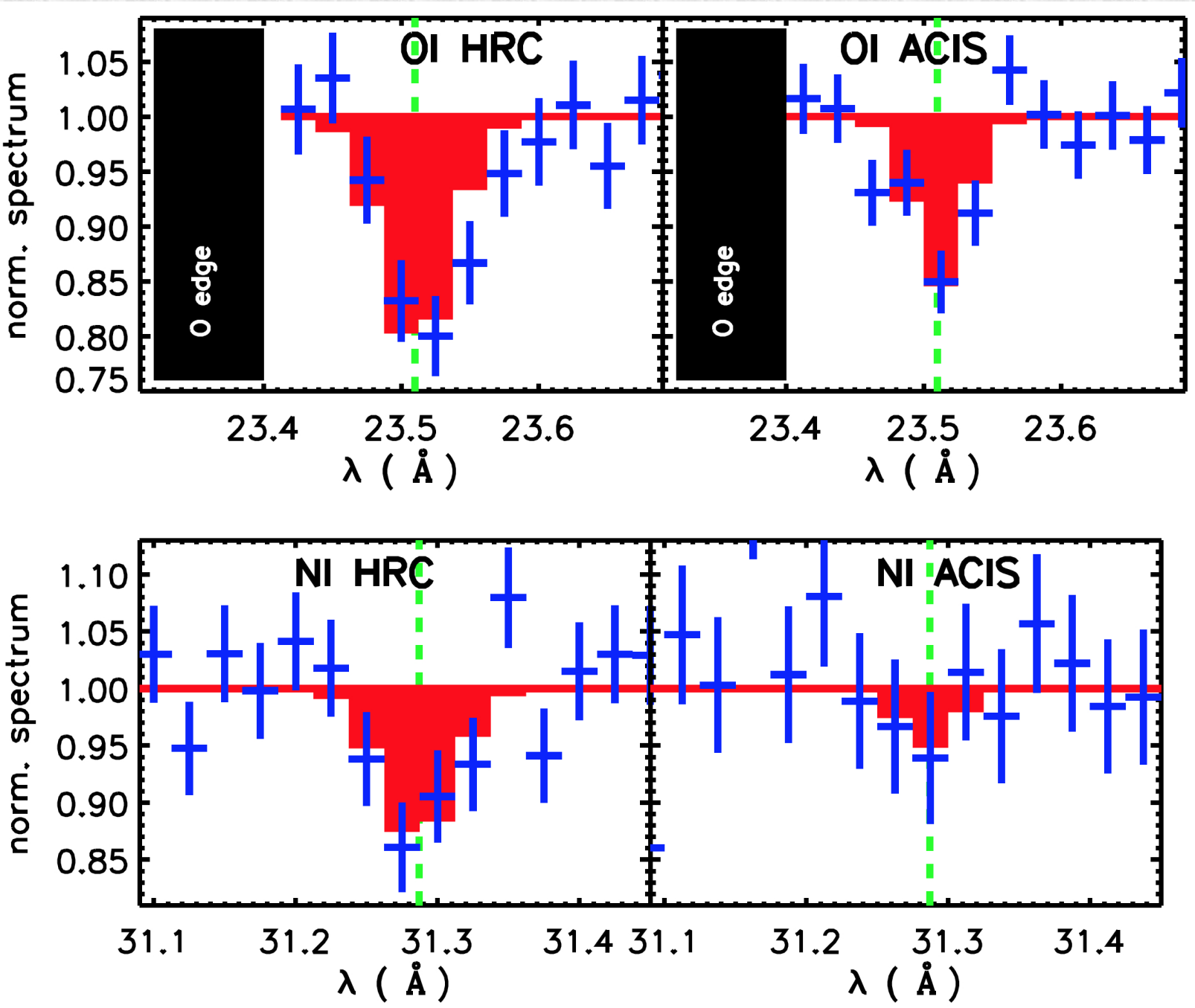
Column densities directly from EW ("slab" model of SPEX, no assumptions about linear part of CoG)



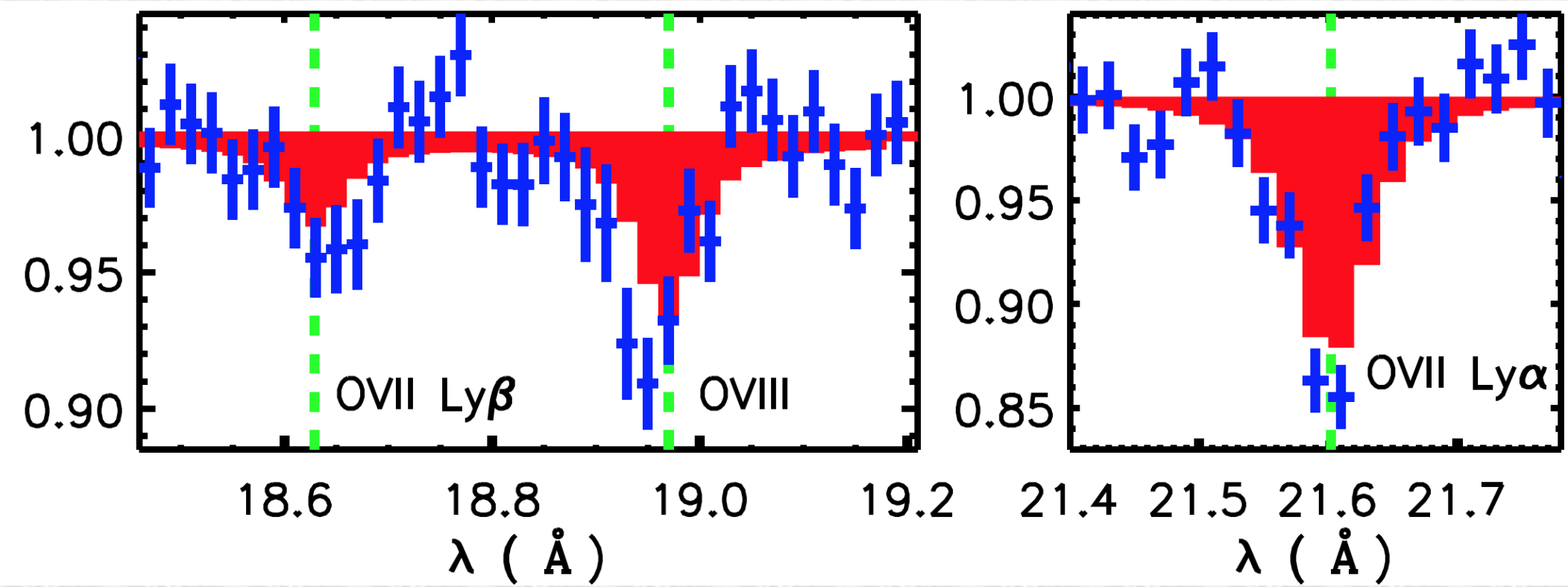
Instruments mostly agree

ACIS has a low bias (perhaps due to under-sampling of the PSF...)

The neutral disk



The hot 10^6 K corona



Transition temperature gas discovered via OIV triplet and OV

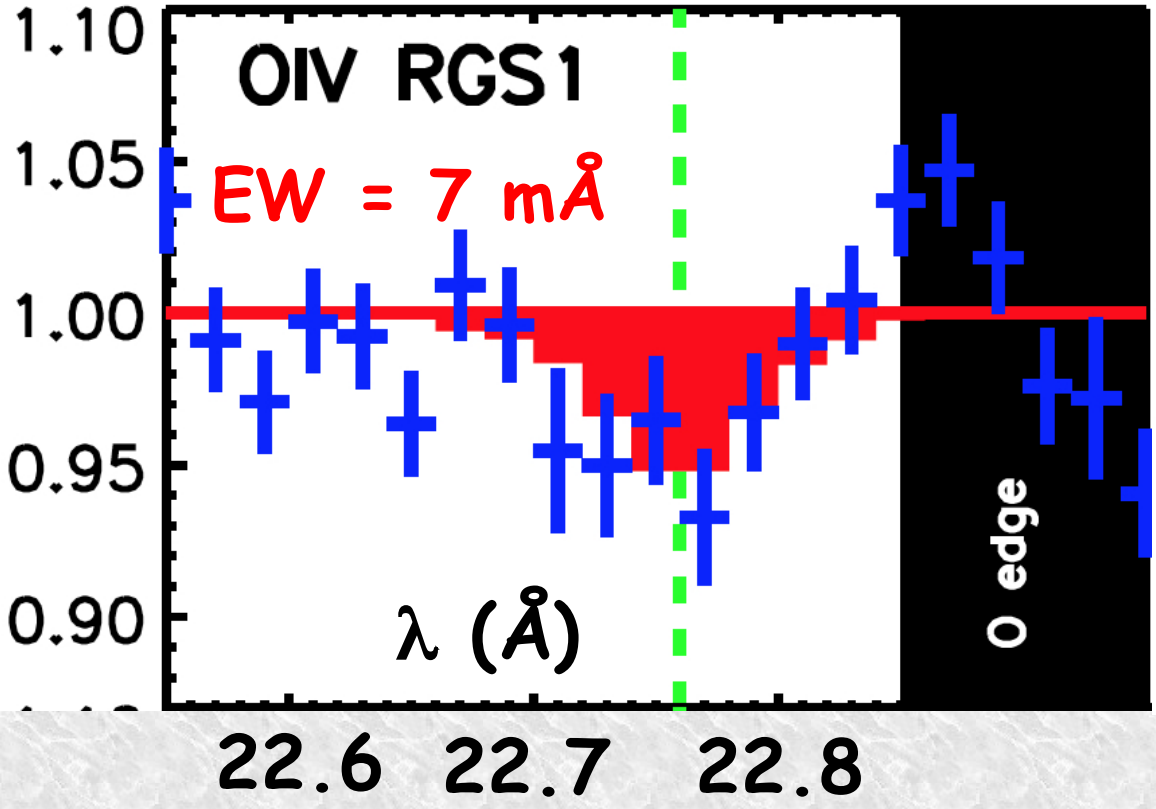
1s-2p ^{2}S: λ = 22.571 Å

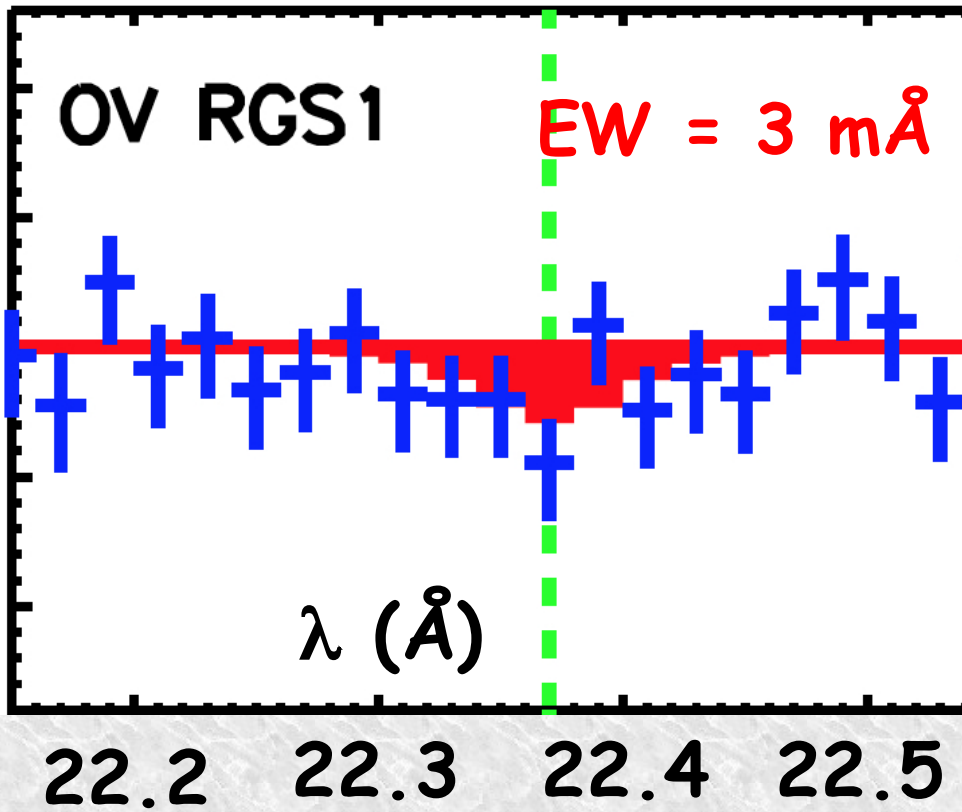
1s-2p ^{2}P: λ = 22.741 Å

1s-2p ^{2}D: λ = 22.777 Å

- Gu+05, ApJ, 627, 1066
- HULLAC calculations, Behar, private communication

1s-2p: λ = 22.370 Å





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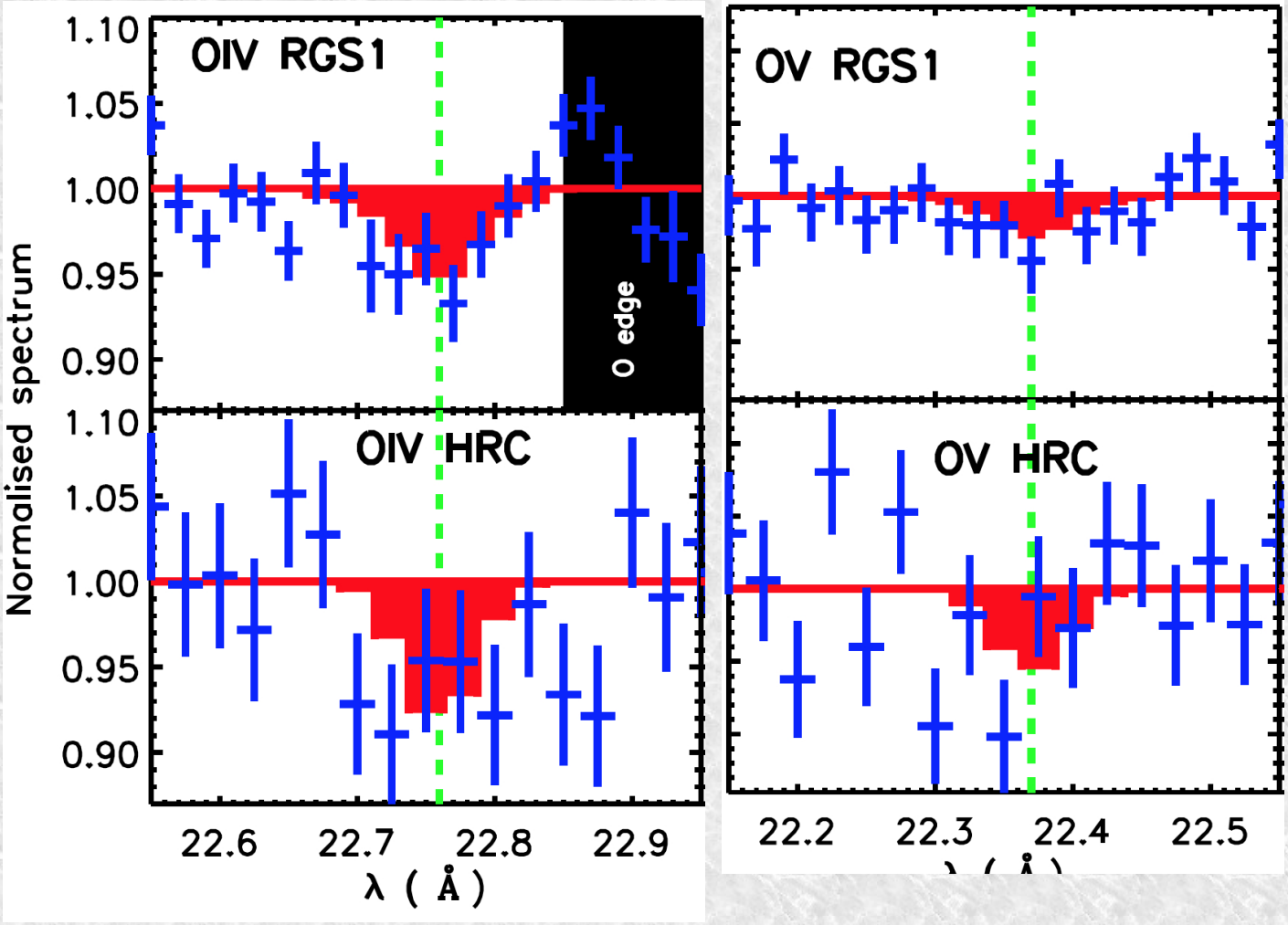


Including 2% systematics, the detection significances are

OVI RGS1: 2.5σ

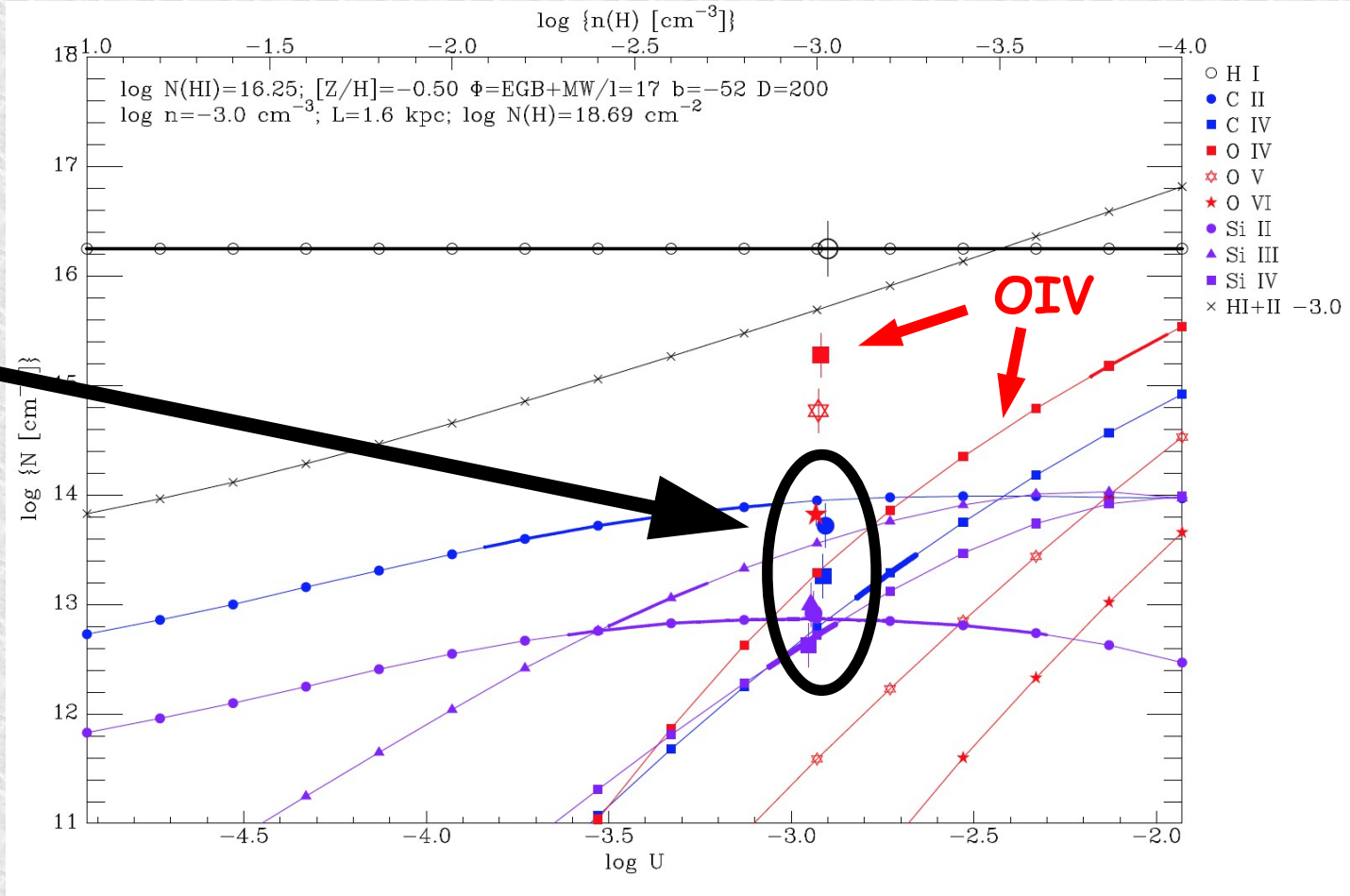
OVI HRC: 2.6σ

OV RGS1: 2.0σ

OV HRC: 1.6σ

Photo-ionisation?

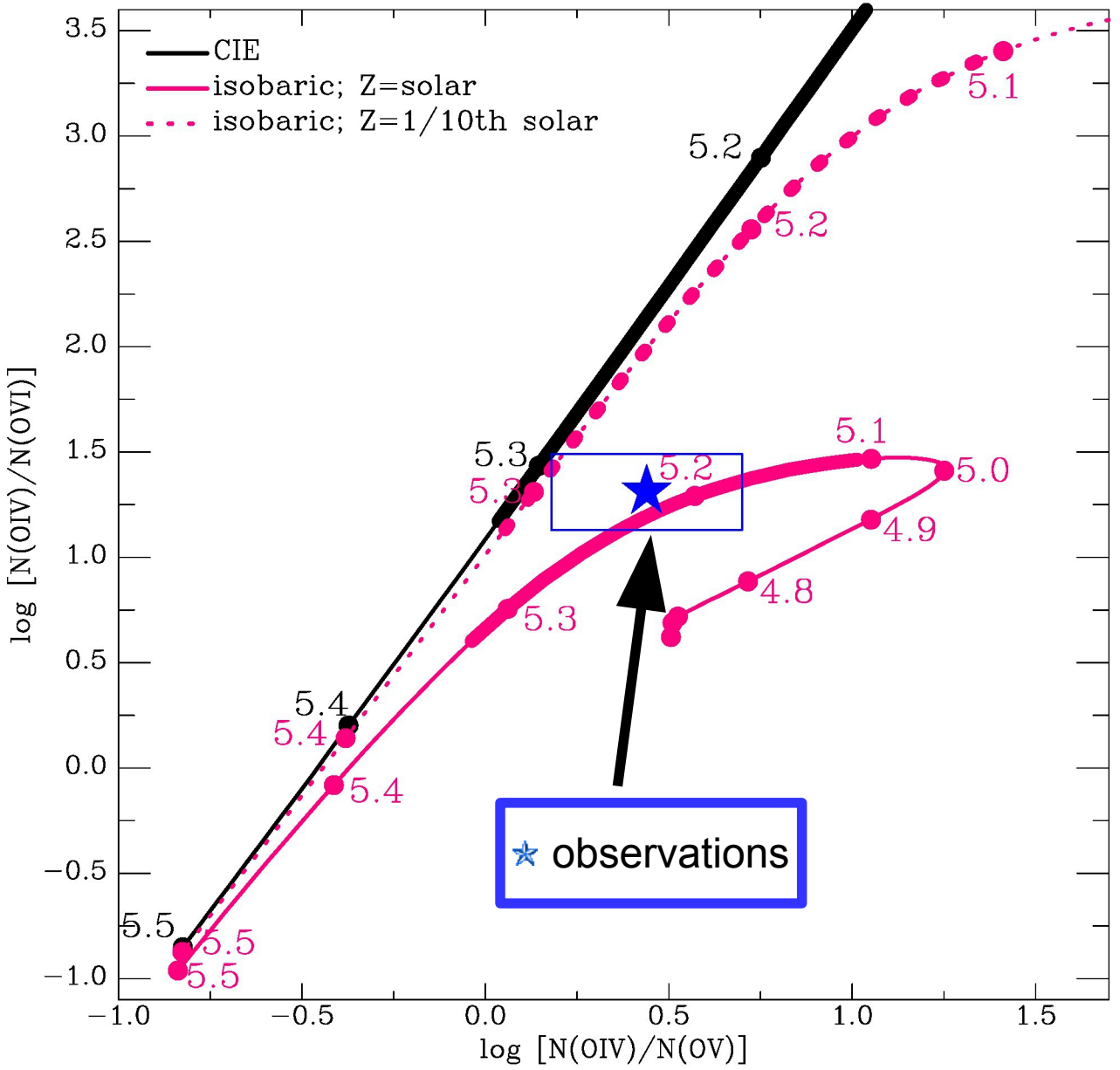
- We checked with CLOUDY, whether the photo-ionisation may affect the OIV and OV column densities
- CII, CIV, SII, SIII, SIV: log U ≈ -3, path length 1.6 kpc
- But OIV and OV underpredicted by a factor of 100-1000: we found no solution where FUV obs + X-ray OVI and OV explained



☞ Photo-ionisation not important for OIV and OV X-ray lines

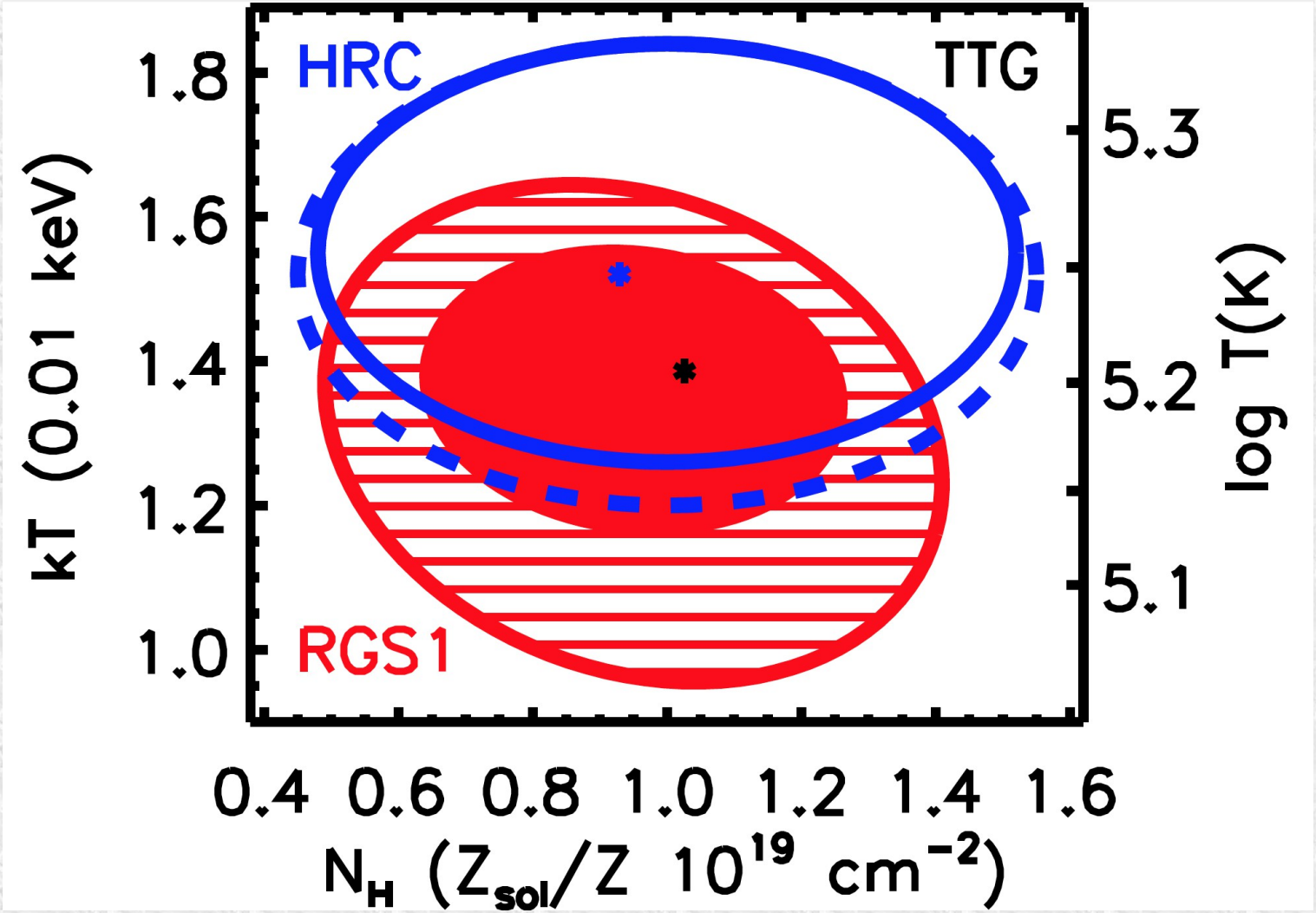
Cooling phase

- Gnat & Stenberg (2007) non-equilibrium models
- OIV, OV (X-rays) and OVI (FUV) columns
  - ☞ Isobaric Z = solar model with log T = 5.2 agrees best with the columns
  - ☞ agreement with Galactic Fountain models
- Log T differs from CIE value only by 0.05, OK to use CIE



CIE modelling: T-NH of TTG

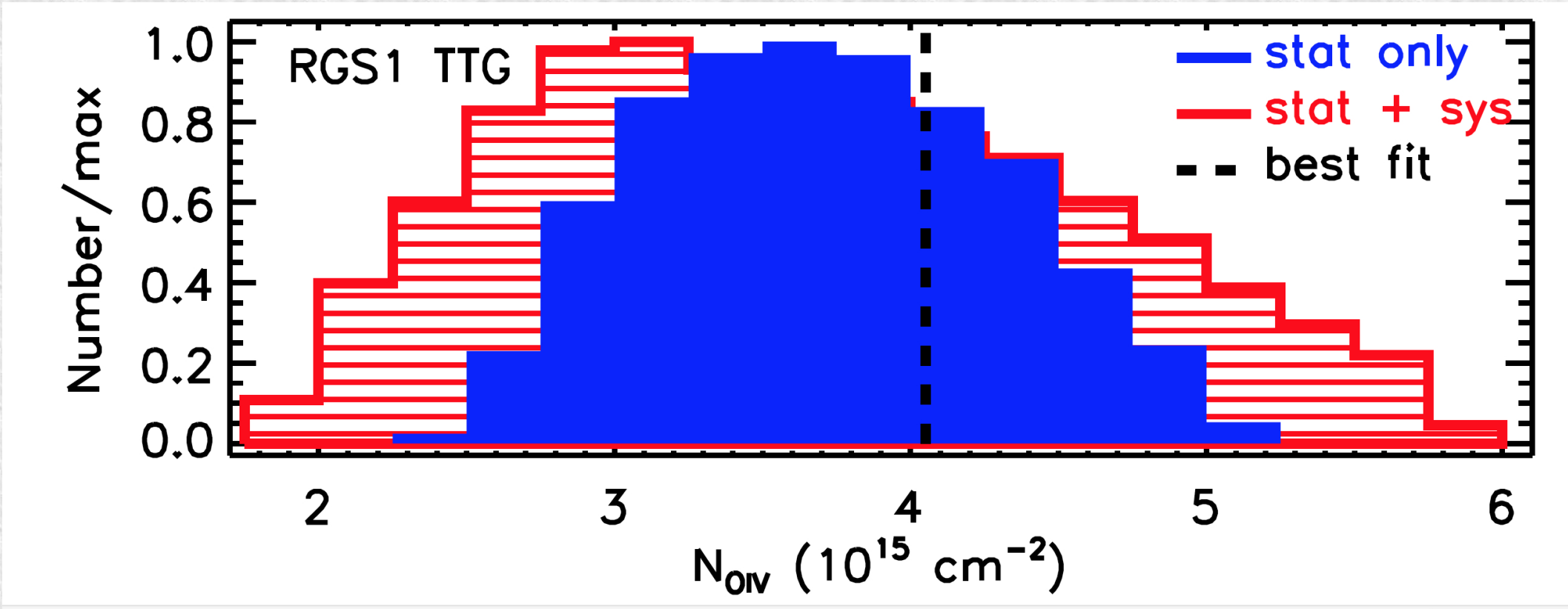
$NH = 1.0 \mp 0.5 \times 10^{19} Z_{\odot} / Z_{TTG}\ cm^{-2}$



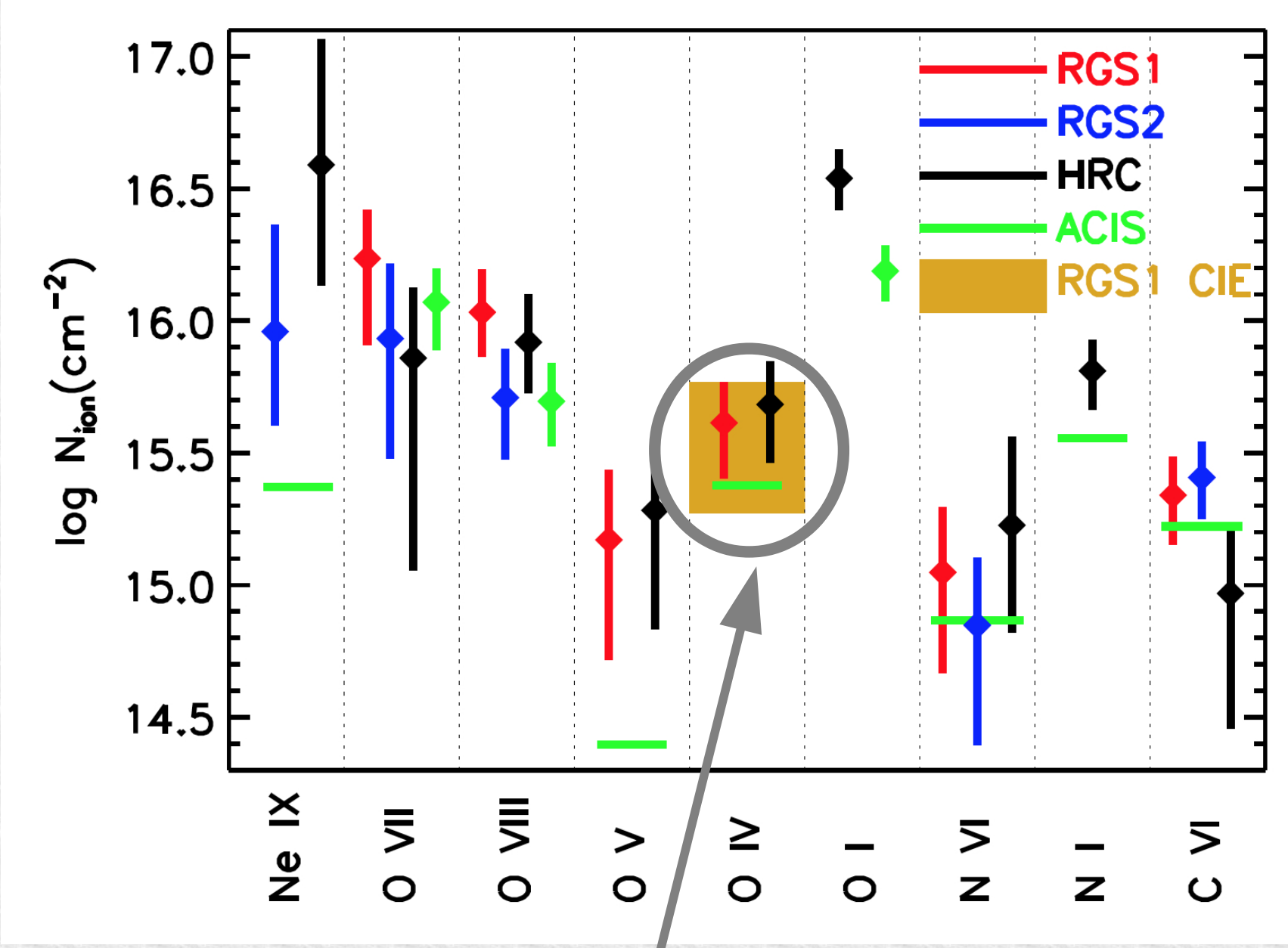
log T(K) = 5.2 ∓ 0.1

RGS1 and LETG/HRC yield consis-tent values

CIE: N(OIV) distribution



$N(OIV) = 3.6 \mp 2.0 \times 10^{15}\ cm^{-2}$



- CIE yields N(OIV) consistent with direct measurement from EW

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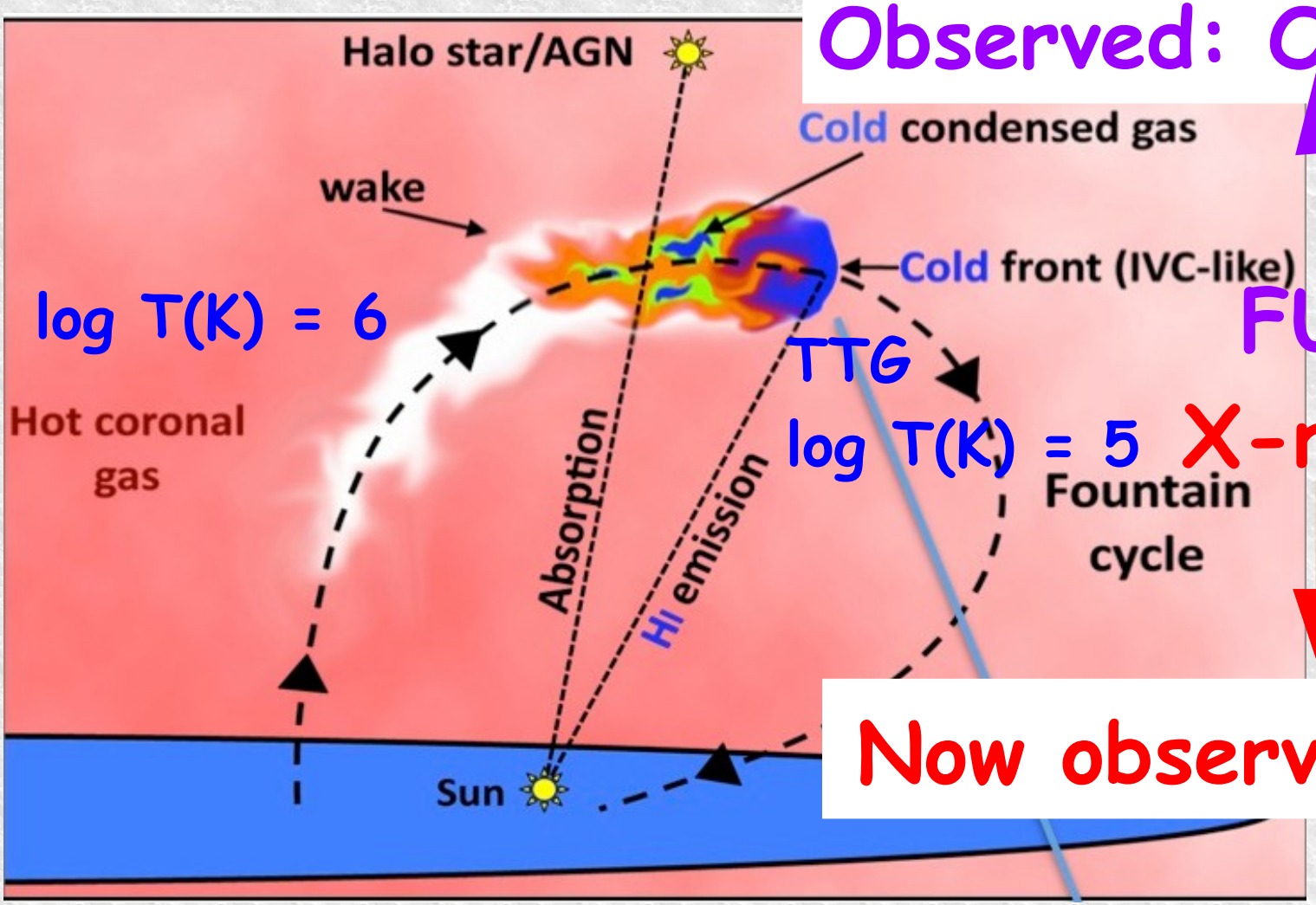

Observed: OVI

X-rays

FUV

X-rays

Now observed!

Conclusions

- We discovered Galactic transition temperature gas TTG via OIV and OV absorption, consistently with RGS1 and HRC (at 99.75% CL)
- No significant photo-ionisation
- TTG in isobaric cooling phase
- CIE: log T (K) = 5.2∓0.1, log N(OIV,OIV) ≈ 15.5 , log N_H ≈ 19 (for Solar abundances)
- Temperature and cooling phase consistent with Galactic Fountain models