Multi-temperature plasma and the spectroscopic-like temperature bias with the Athena-XIFU

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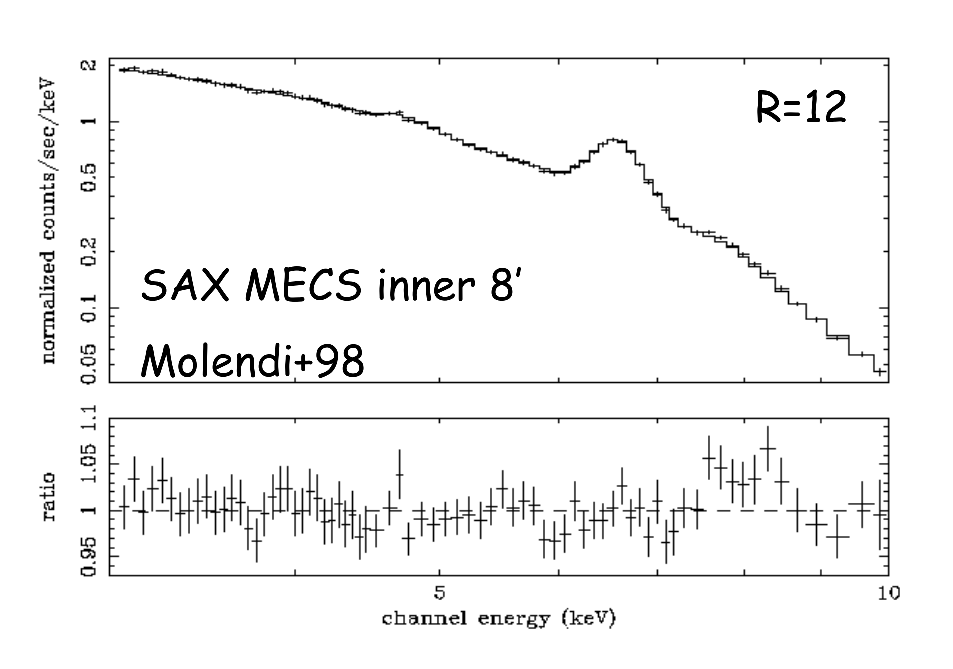
WHY DO WE CARE ?

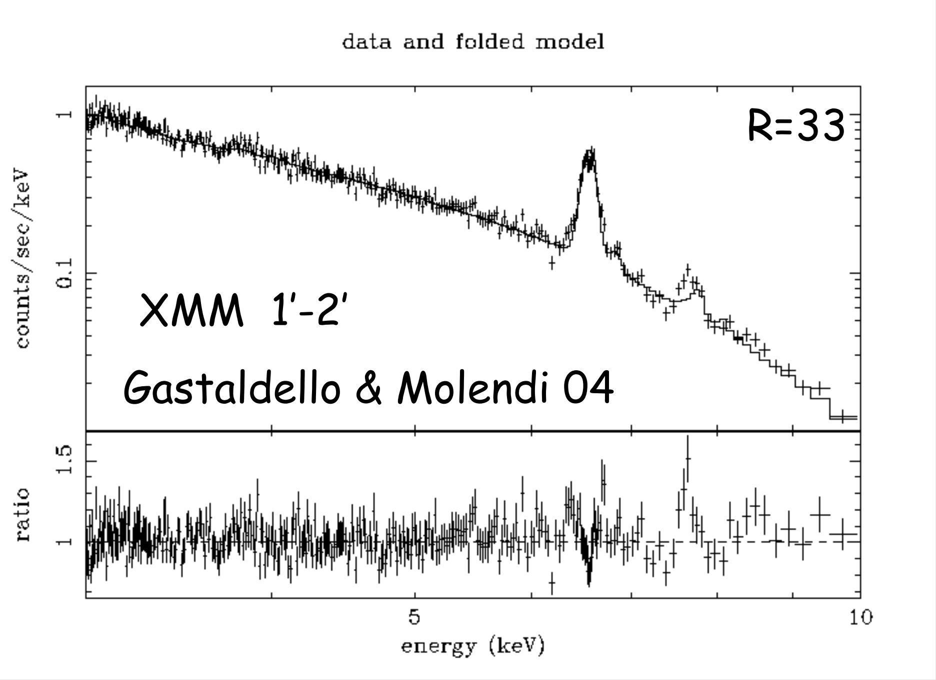
- STRONG TEMPERATURE GRADIENTS ARE PRESENT IN THE ICM SUCH AS IN COLD FRONT OR SHOCK FRONTS

- DIFFERENT TEMPERATURE COMPONENTS MIGHT BE COSPATIAL AS IN COOL CORES

- FOR DETERMINING MASSES THROUGH THE HYDROSTATIC EQUILIBRIUM YOU ASSUME A SINGLE TEMPERATURE PLASMA

INCREASING SPECTRAL RESOLUTION





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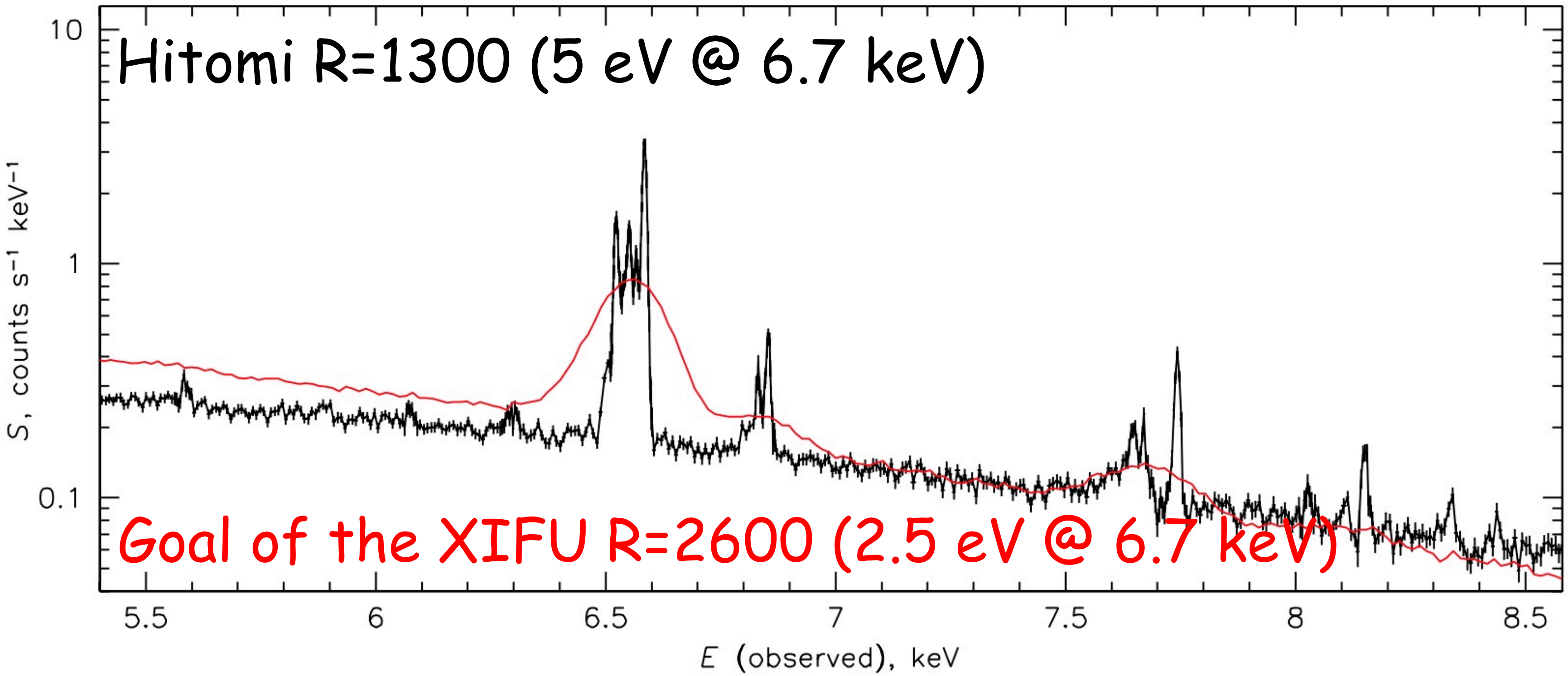

Extended Data Figure 1 | SXS spectrum of the full field overlaid with a CCD spectrum of the same region. The CCD is the Suzaku X-ray imaging spectrometer (XIS) (red line); the difference in the continuum slope is due to differences in the effective areas of the instruments.

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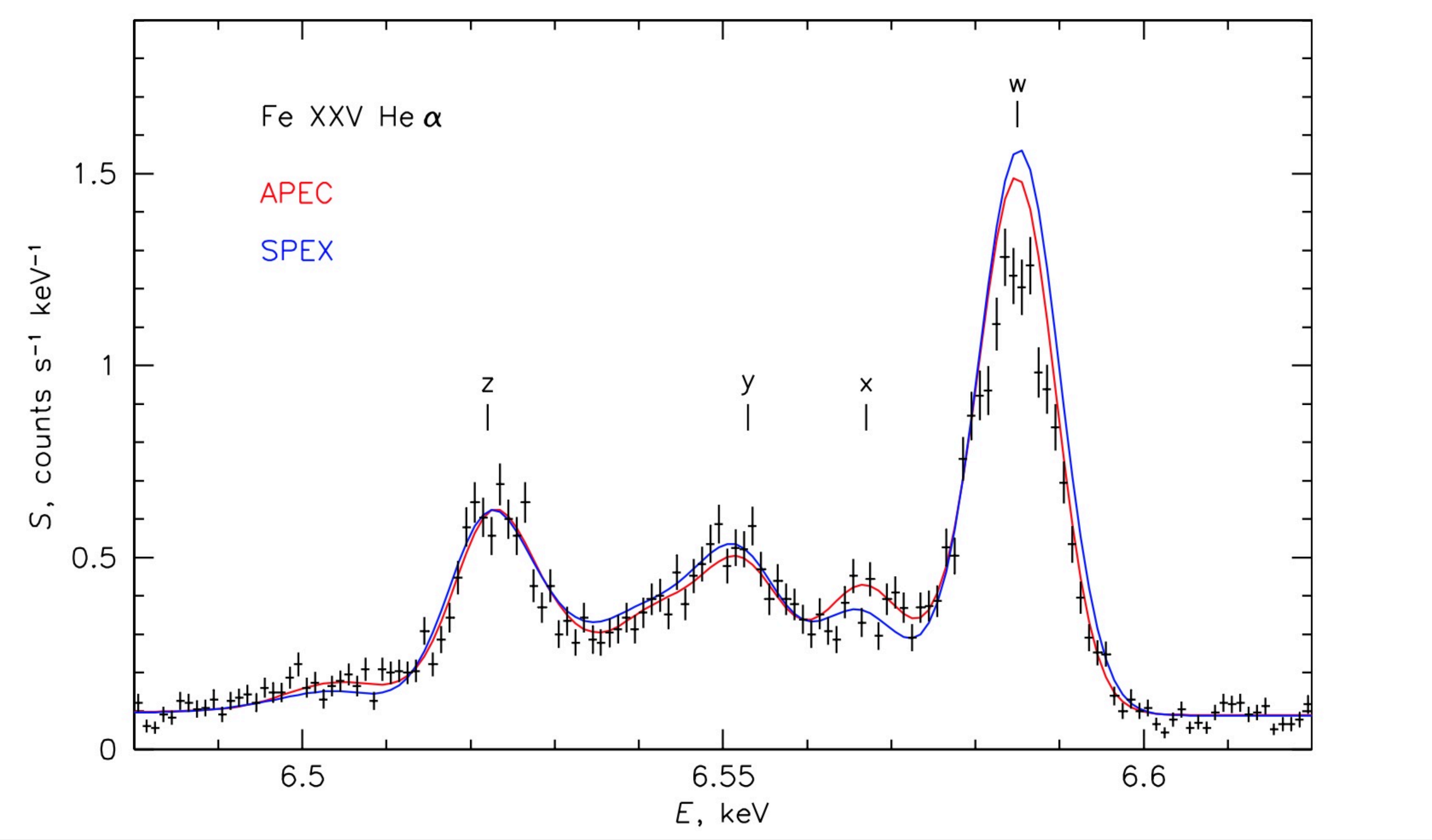
INCREASING SPECTRAL RESOLUTION



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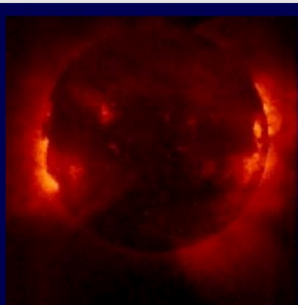


The Sun as seen in X-rays (from the Yohkoh satellite)

Discovery of spectral lines resulting from transitions from the n=2 level in He-like ions in the solar spectrum:

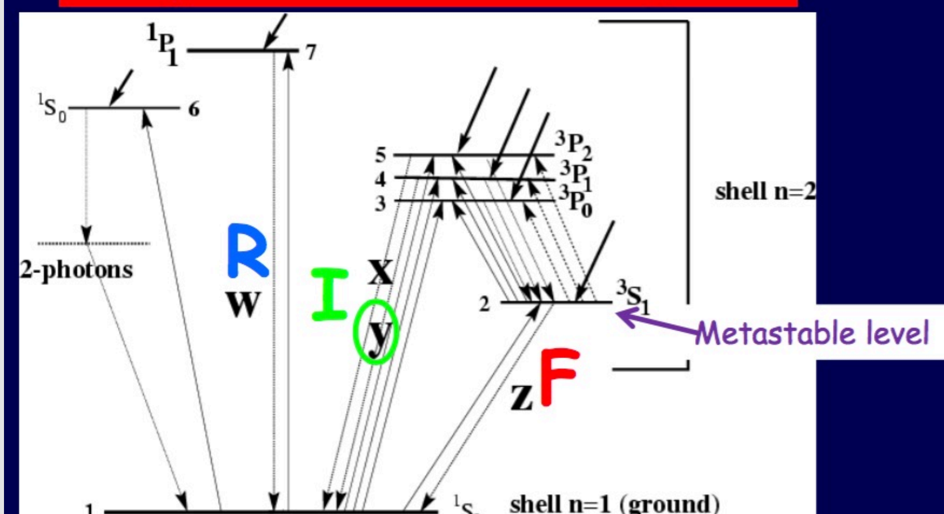
triplet/quadruplet

R (or w) : Resonance line (allowed)
$1s2p\ ^1P_1 \rightarrow 1s2\ ^1S_0$
electronic dipole transition

I (or x+y): Intercombination line
$1s^2\ ^1S_0 - 1s2p\ ^3P_1$ (y)
$1s^2\ ^1S_0 - 1s2p\ ^3P_2$ (x)

F (or z) : Forbidden line
$1s^2\ ^1S_0 - 1s2s\ ^3S_1$
relativistic magnetic dipole transition (A_{ji} very low)

Simplified Grotrian diagram



Porquet & Dubau (2000)

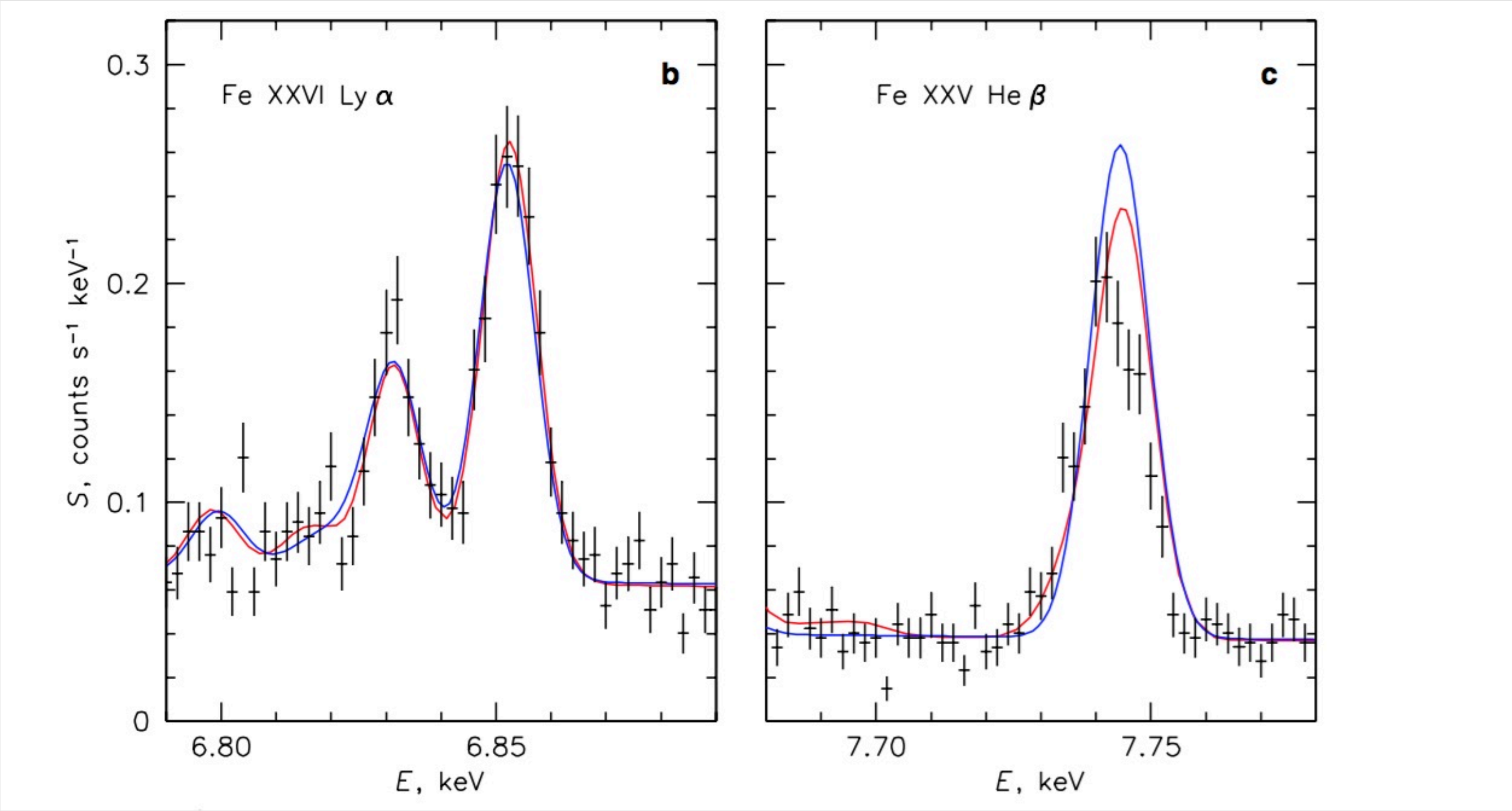
Gabriel & Jordan (1969):
⇨ plasma diagnostics:

Density: $\Re(n_e) = F / I$

Temperature: $G(T_e) = (F + I) / R$

From D. Porquet presentation

INCREASING SPECTRAL RESOLUTION



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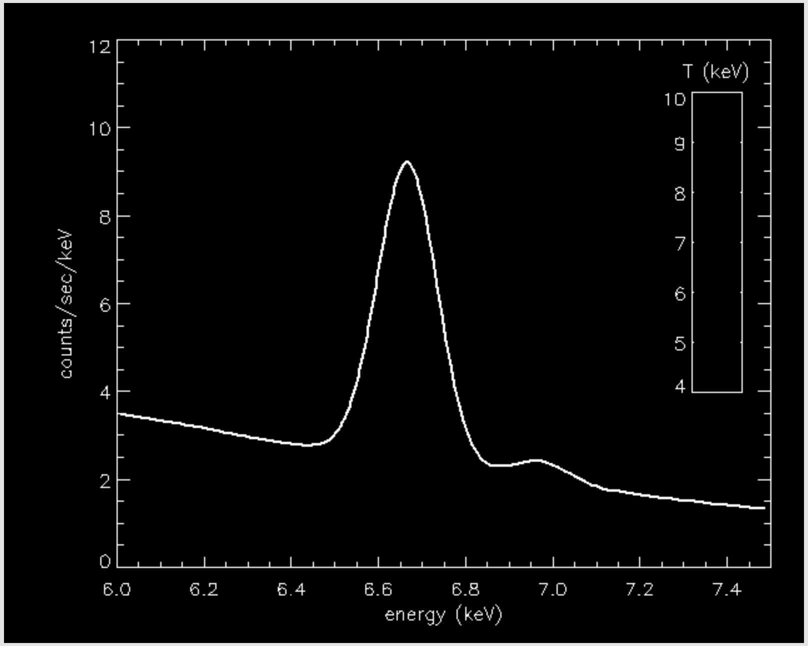
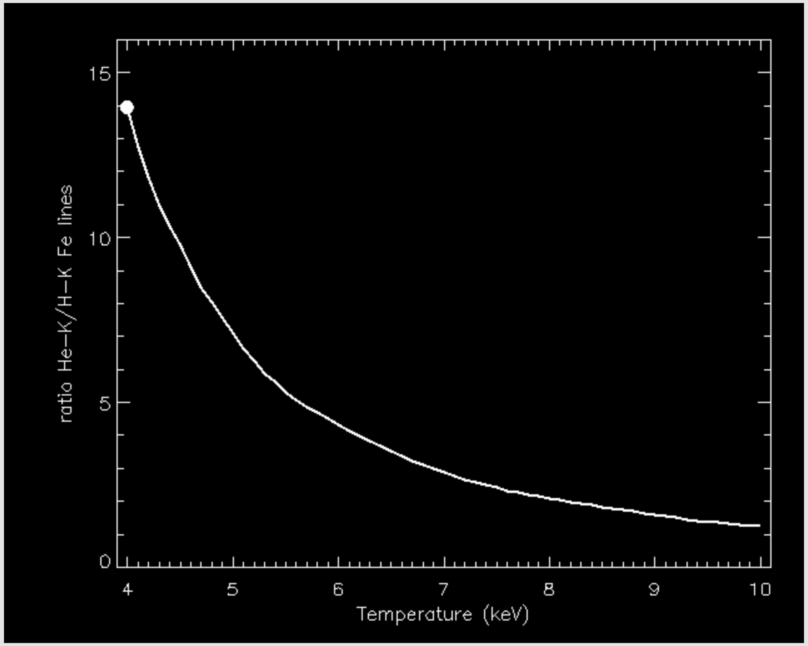
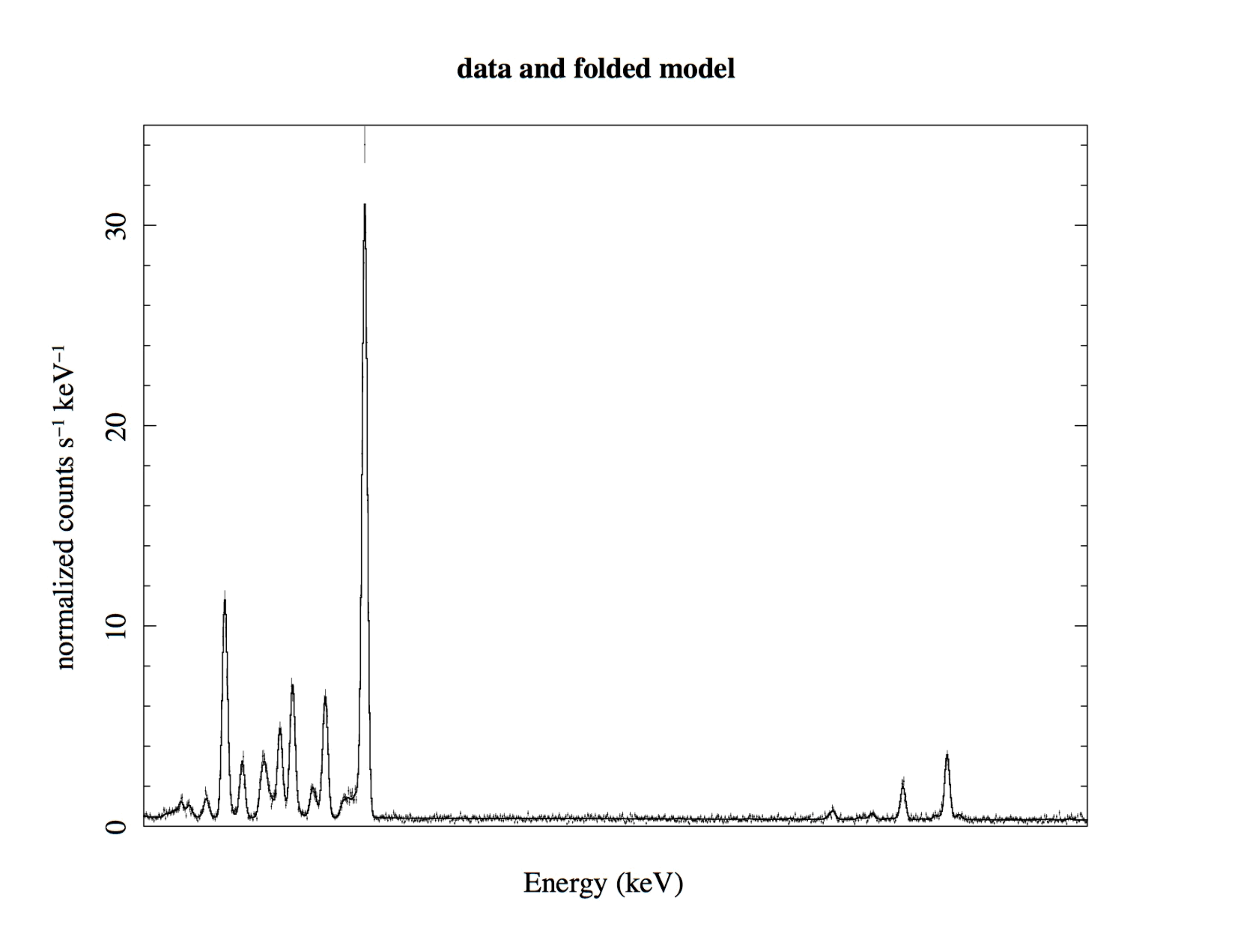
IRON LINE TERMOMETER





This movie shows the changing behavior of the ratio of He- and H-like complex of lines as a function of temperature with the XMM pn

IRON LINE TERMOMETER



This movie shows the same energy band as a function of the temperature as the previous movie but with the X-IFU instrument.

CCD SPECTROSCOPIC-LIKE TEMPERATURE BIAS

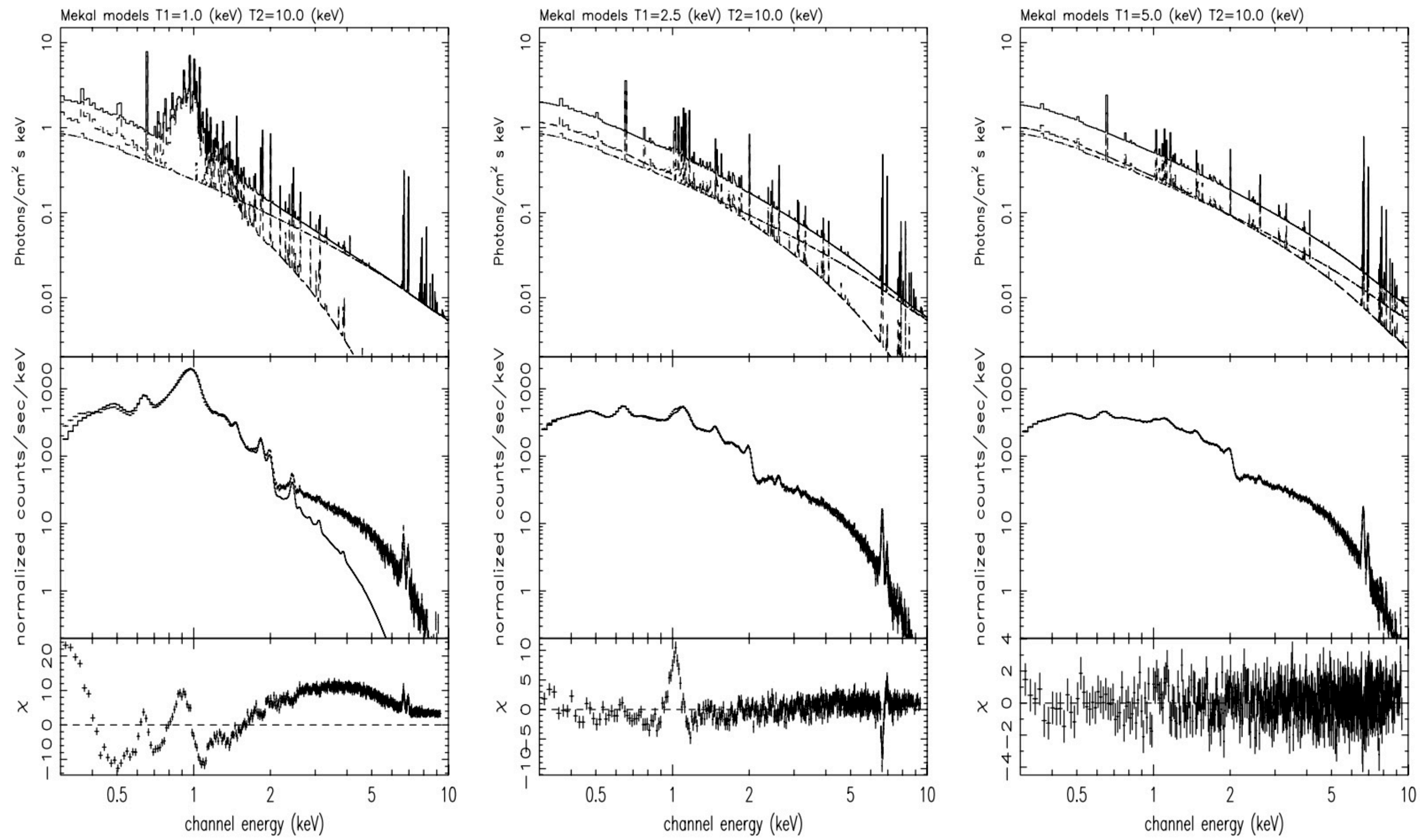


Figure 3. As Fig. 1, but for metallicity $Z = 1$.

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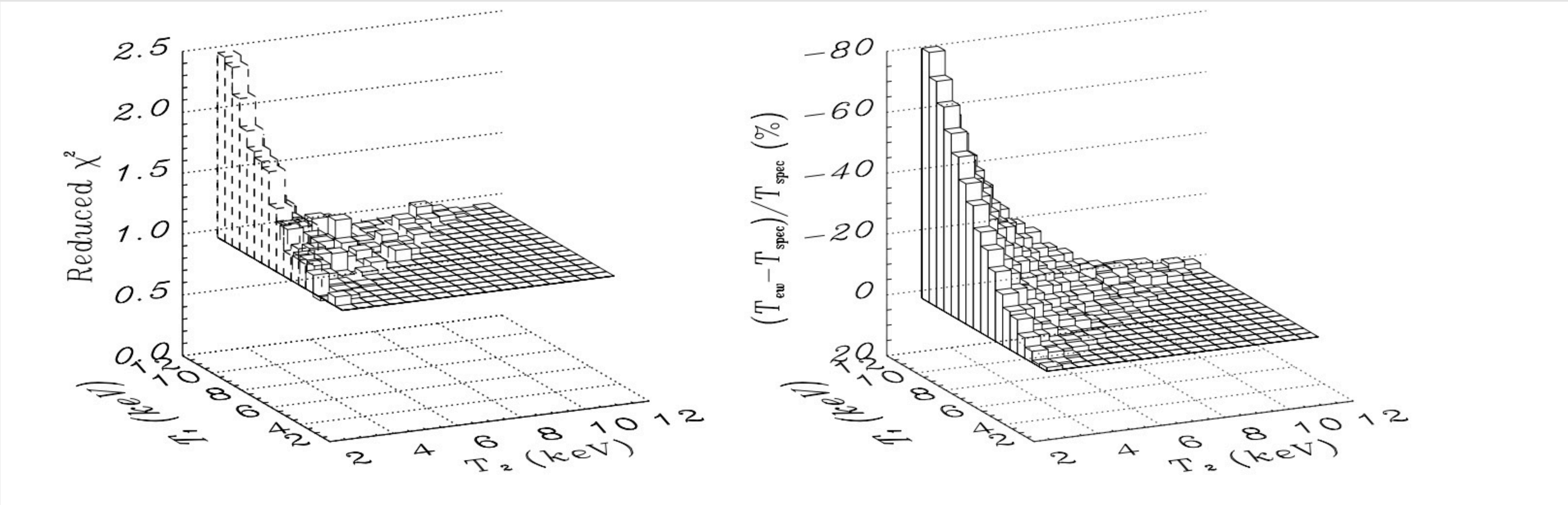
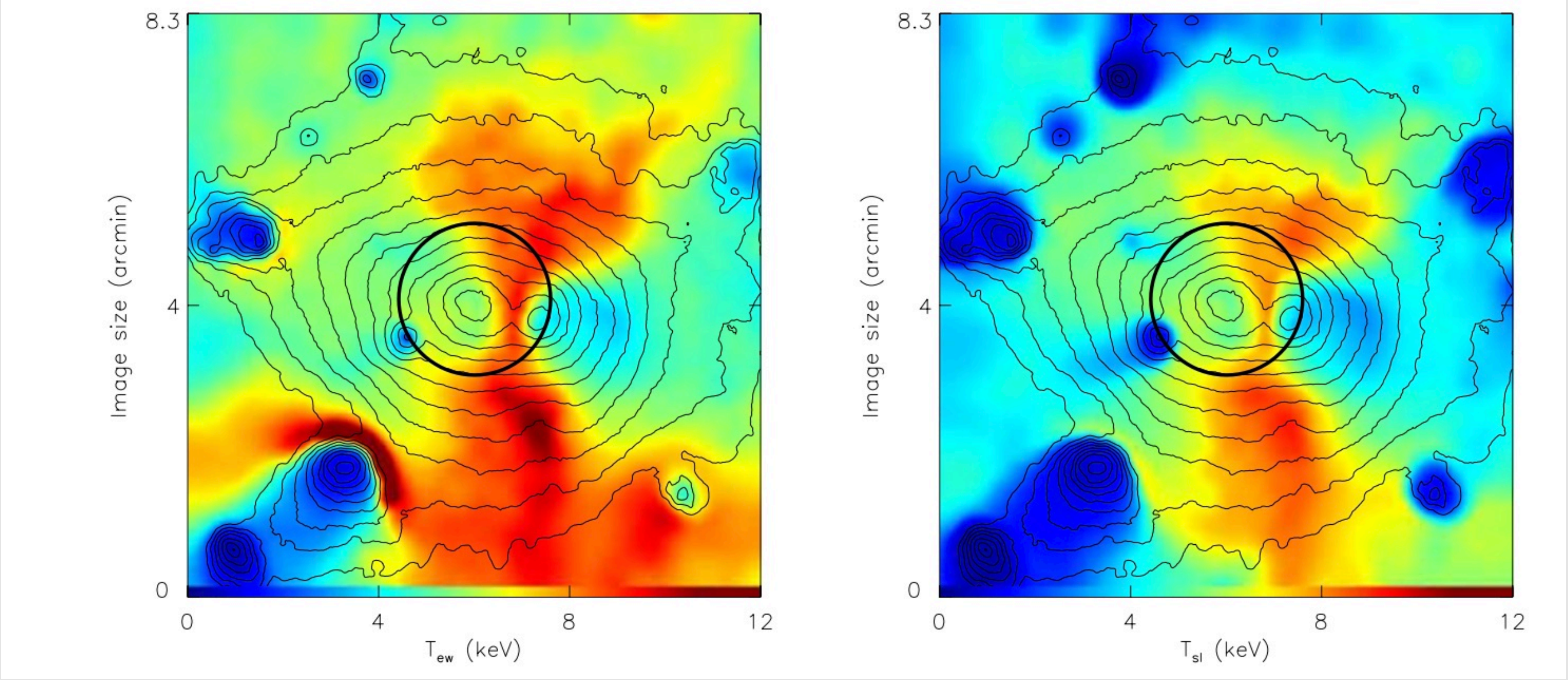
CCD SPECTROSCOPIC-LIKE TEMPERATURE BIAS



All source spectra with lower temperature component > 3 keV are statistically indistinguishable from a single T model

Mazzotta+04

CCD SPECTROSCOPIC-LIKE TEMPERATURE BIAS



Denser and cooler regions are weighted more by our combination of telescopes+CCDs

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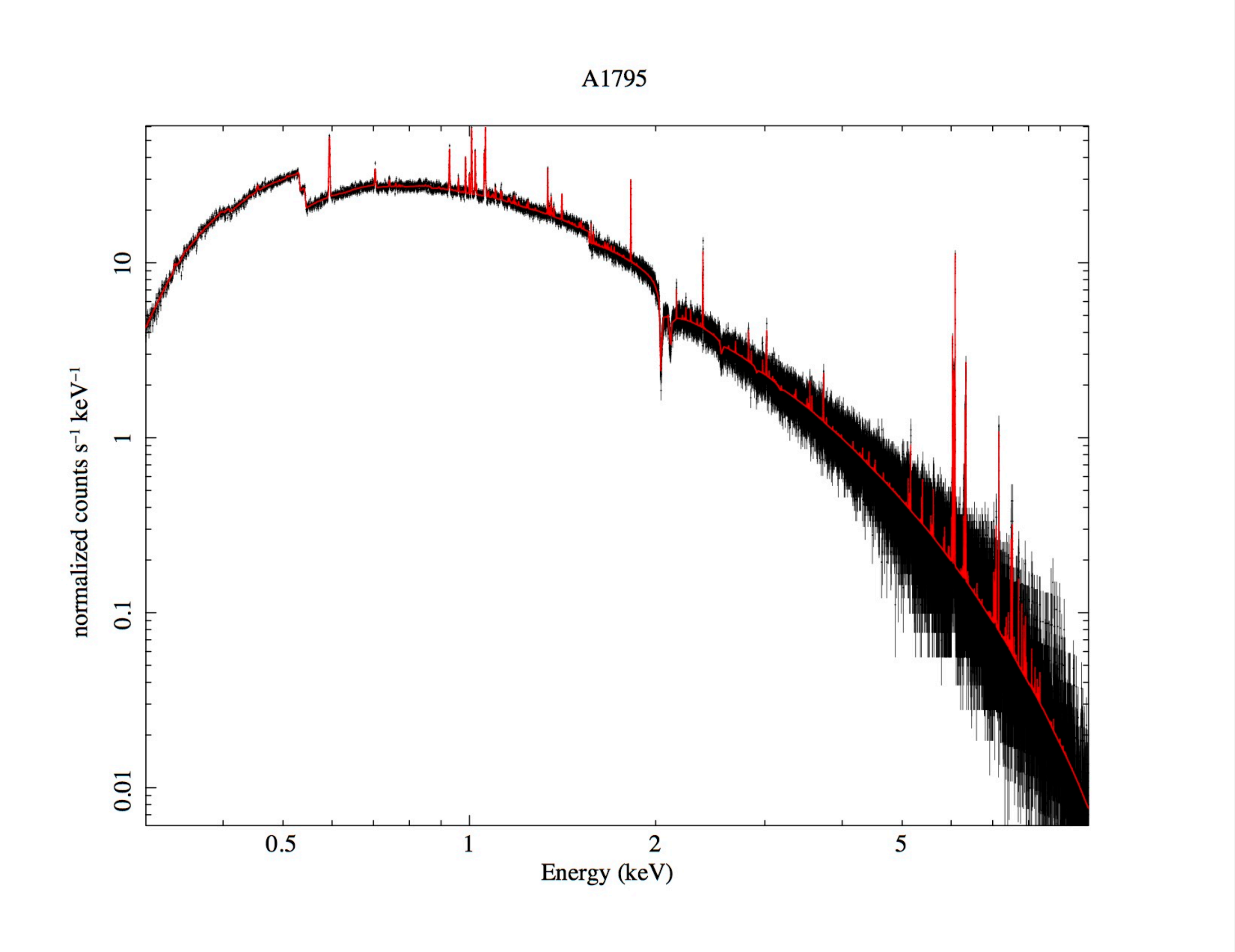
HOW WILL IT LOOK WITH X-IFU ?



Inner 0.5' of A1795, 100ks -> 4M counts in the 0.3-10 keV band

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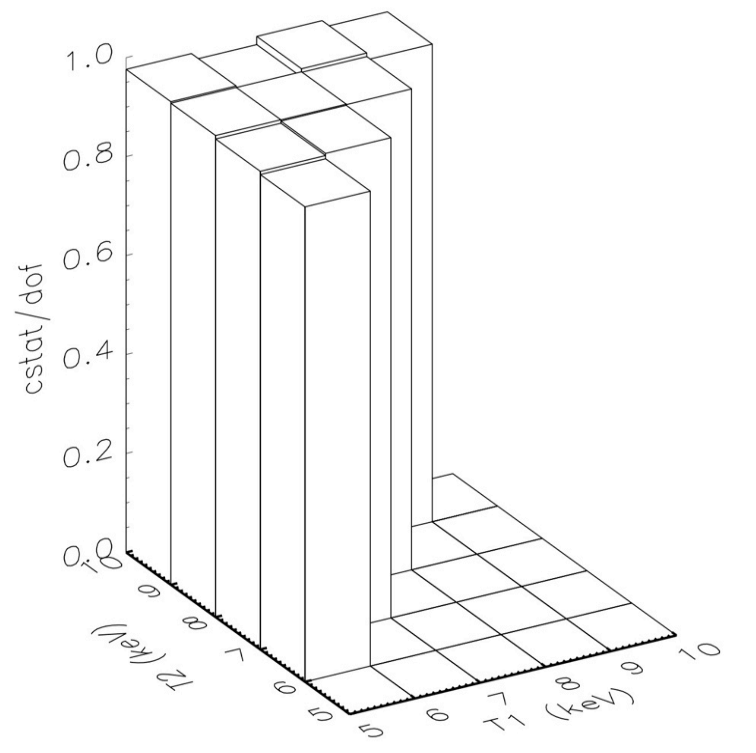

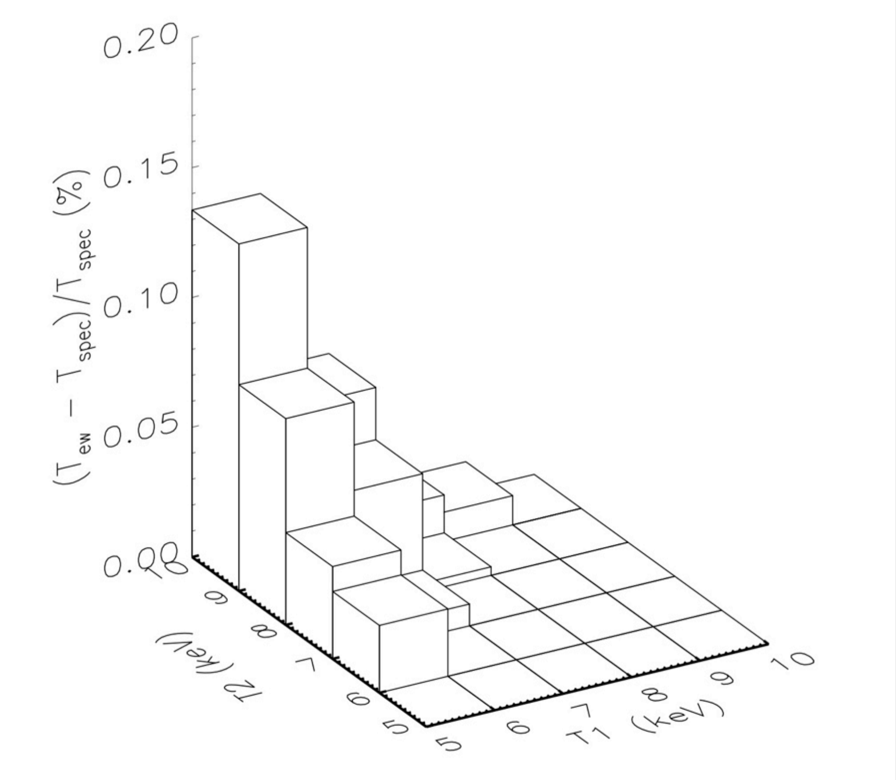

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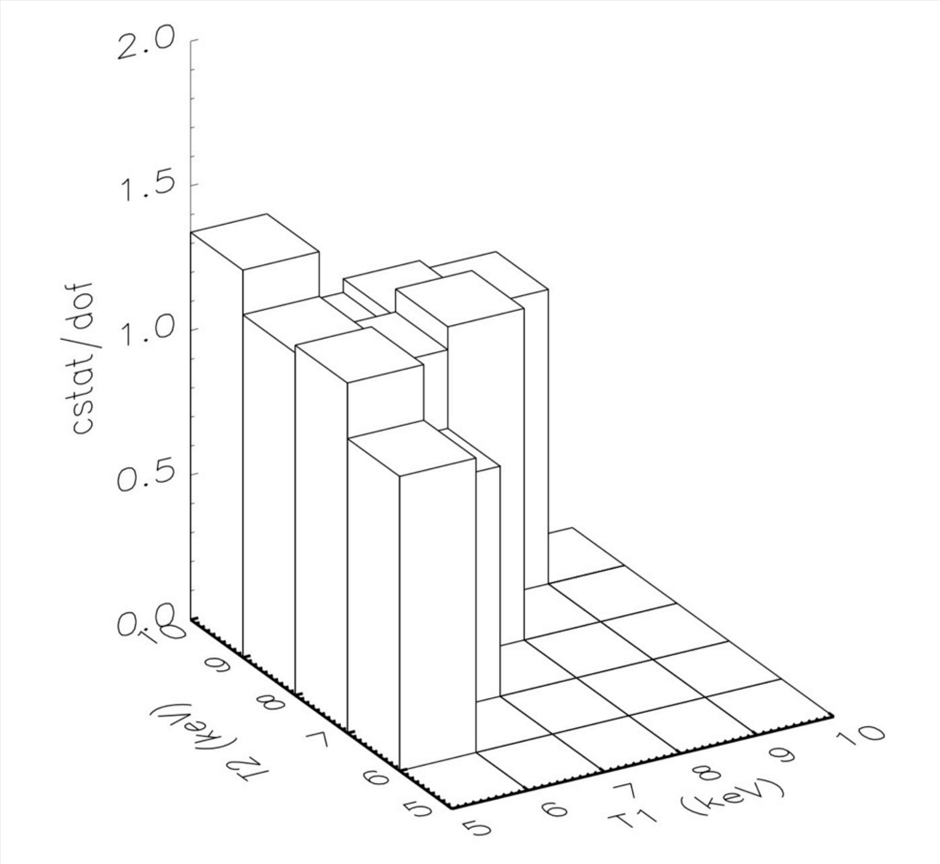
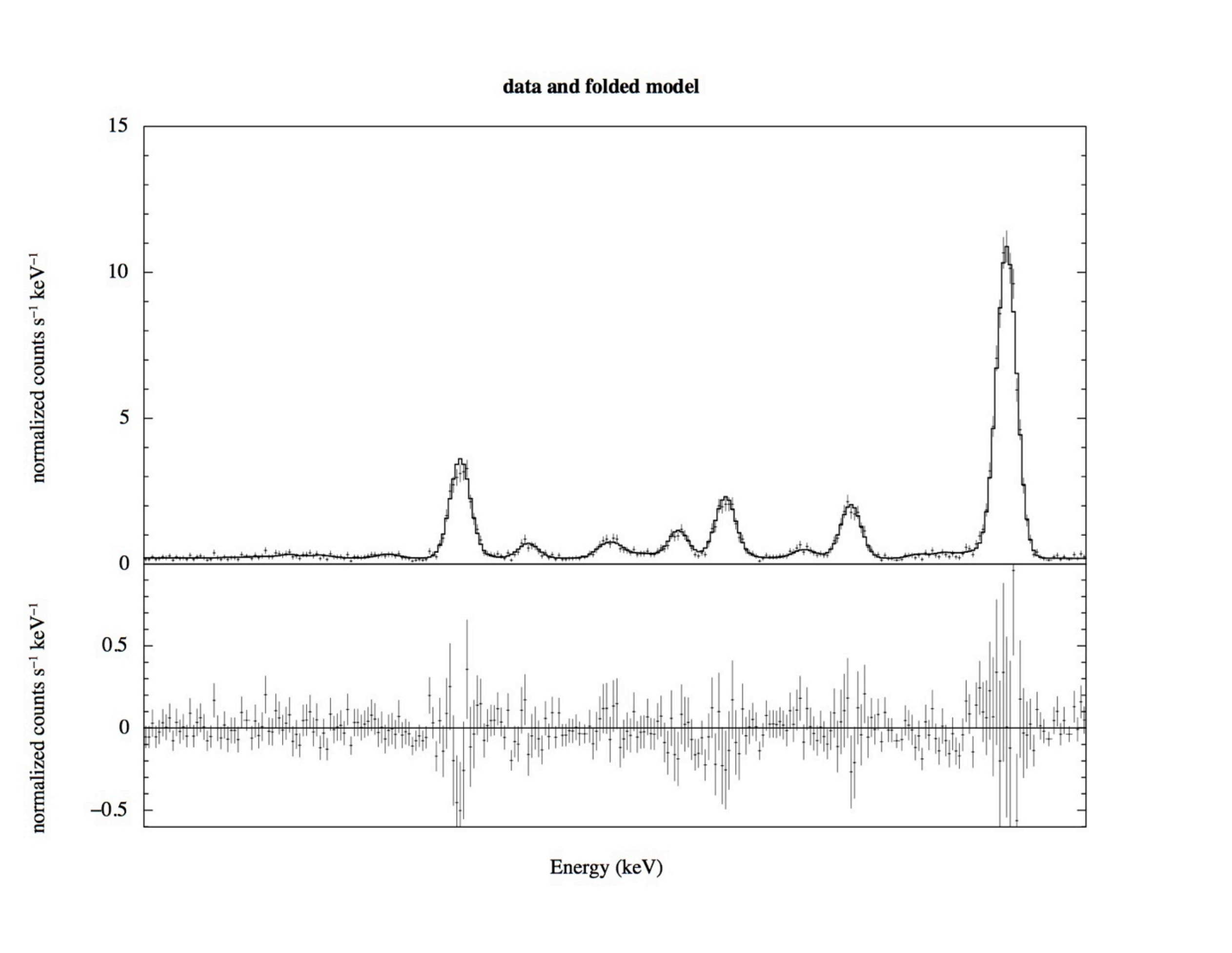


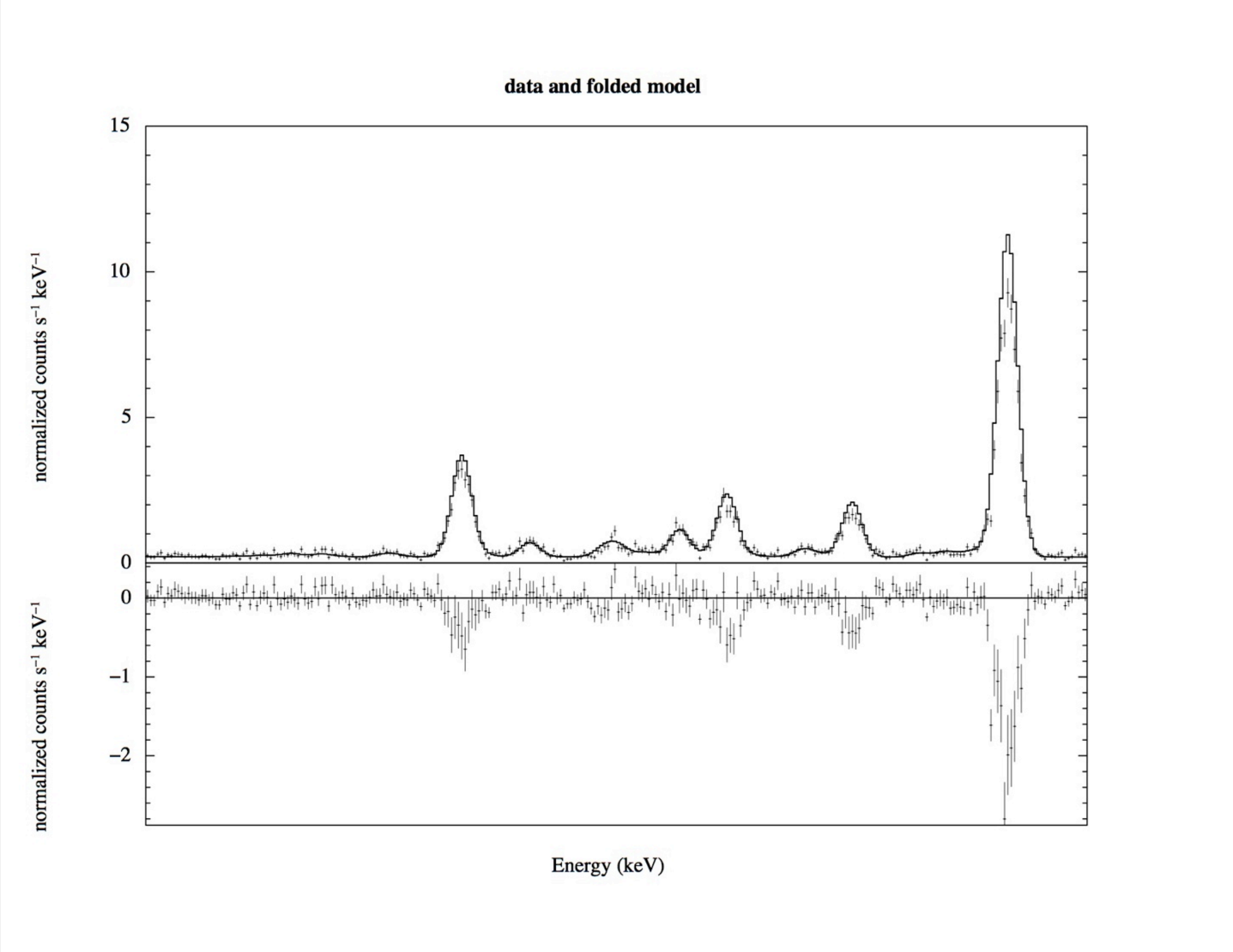
Repeat in the very narrow energy band (100 eV) with the Fe XXV He-like complex

HOW WILL IT LOOK WITH X-IFU ?



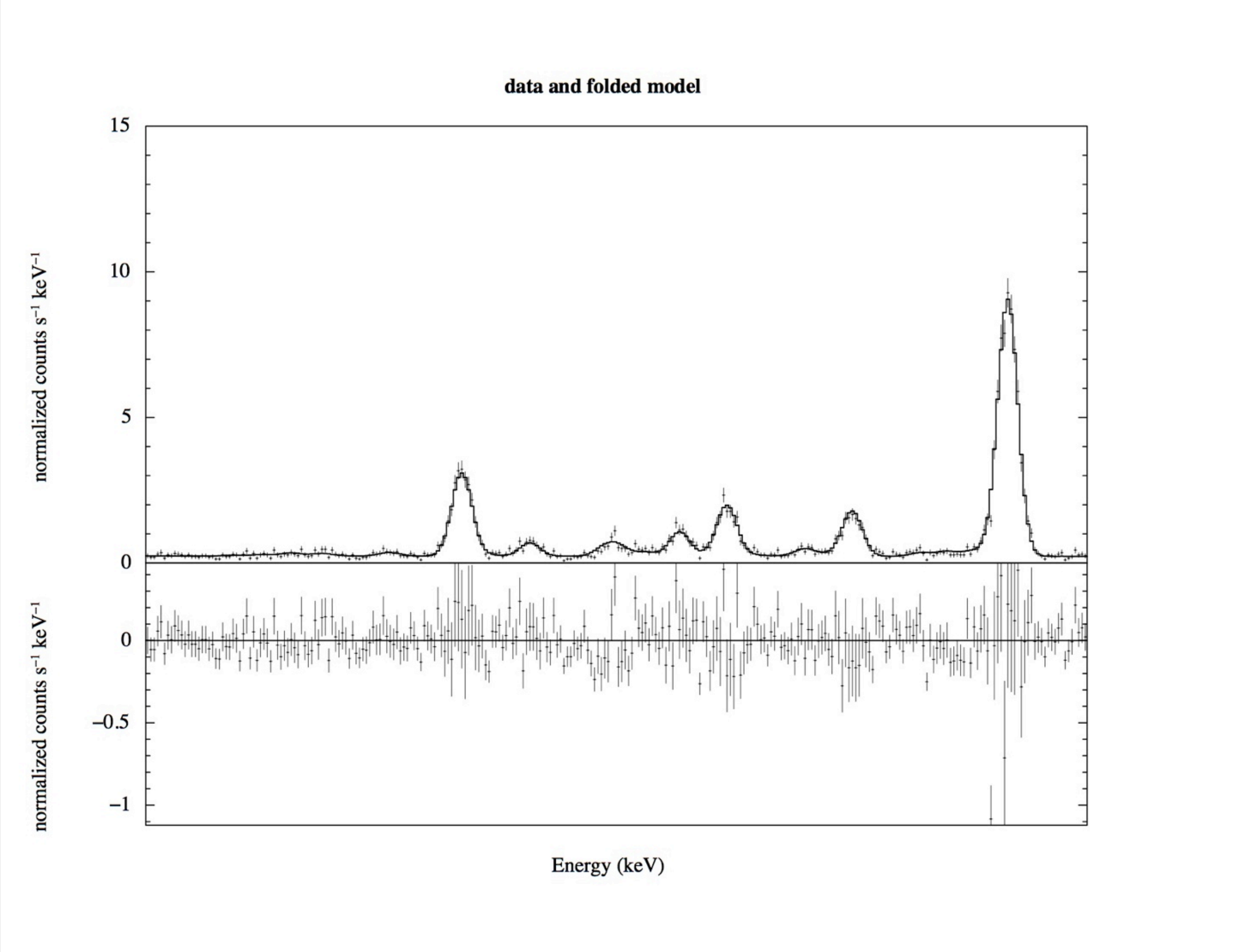
A 2T simulated model with T1=6 keV and T2=7 keV. Already 7k counts just in this narrow energy band. Cstat/dof= 218/274

HOW WILL IT LOOK WITH X-IFU ?



A 2T simulated model with T1=5 keV and T2=10 keV. Cstat/dof=456/274.
Best fit T=6.64 keV

AGAIN POSSIBLE BIASES …



FIT just in the narrow range: Cstat/dof=277/274. Best fit T=6.16 keV and Z=0.2 solar (simulated 0.3). Reminiscent of the Fe bias (Buote 00)

WHAT DO WE FIT AND HOW DO WE FIT ?

LOCAL VS GLOBAL FITS: using ratios of lines may miss details with respect to a self-consistent fit of the full spectrum (Hitomi coll.+17, the atomic code paper)

For Perseus a true multi-phase structure in which different temperature components are co-spatial can not be ruled out, projection effects are a natural explanation for deviations from a single temperature

Even in single or two temperature parameters, the best-fit parameters are sensitive to the effective area calibration

(Hitomi coll.+17, the T paper)

WHAT DO WE FIT AND HOW DO WE FIT ?

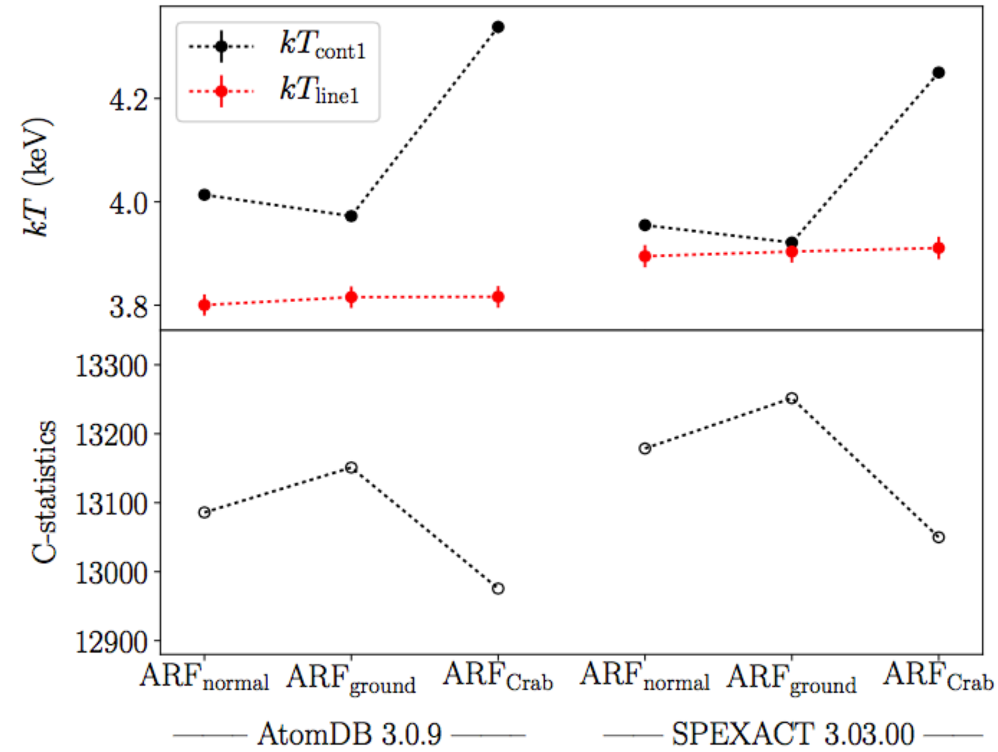


Fig. 7: Comparison of the best-fit temperatures and C-statistics among different ARFs and atomic databases for the modified 1CIE model.

CONCLUSIONS

- SPECTROSCOPIC-LIKE BIAS TEMPERATURE PRESENT, BUT DEVIATIONS FROM A SINGLE TEMPERATURE EASIER TO DETECT THAN CCD

- CHALLENGE IN THE ANALYSIS, COMPLEX MIX OF MODELING, CALIBRATION, COMPLEXITY OF THE SOURCE, ATOMIC CODES