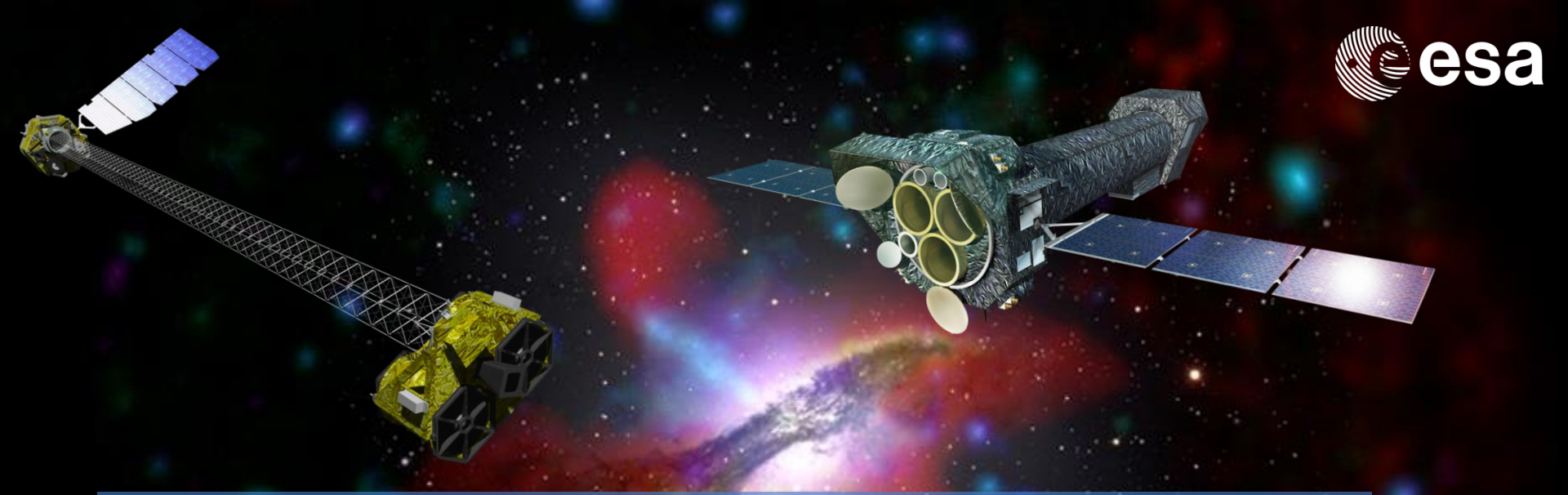


XMM-Newton EPIC-pn vs. *NuSTAR*

Gabriele Matzeu (Quasar SR for ESA)

20th April 2026

F. Füerst, E. Kuulker, M. Smith for the EPIC-pn IDT and SOC USG

ESA UNCLASSIFIED - For Official Use

Coordinated XMM-NuSTAR & NuSTAR sample

GOAL 1 (✅): Data Reduction & Sample Construction
Reduce and analyse a large sample of 70 coordinated *XMM-Newton–NuSTAR* observations (primarily Galactic sources) using a semi-automated pipeline (EPIC-pn in timing mode; NuSTAR FPMA/FPMB).

GOAL 2 (✅): Cross-Calibration Assessment
Perform detailed spectral cross-comparisons to quantify and characterize discrepancies between EPIC-pn (timing mode) and NuSTAR FPMA/FPMB.

GOAL 3 (✅): Correlation Analysis & Systematics
Investigate correlations between spectral residuals and observational/instrumental parameters to identify potential sources of systematic disagreement.

GOAL 4 (⏳ Ongoing): Calibration Refinement
Develop and test strategies to mitigate discrepancies and improve cross-calibration consistency between instruments.

Cross-calibration diagnostics performed since 2024

i. Model the FPM continuum with a simple constant*power-law and load the EPIC-pn.

ii. Apply a SPLINE to the continuum model on *NuSTAR* and cross-check with EPIC-pn.

iii. Check and correct for pileup and remove inner column/s.

iv. Cross-check the spectral behaviour by testing either variable **test1**: cross-cal const. and **test 2** power-law Γ

v. Make H-S/H+S vs (1-const) and H-S/H+S vs ΔΓ

vi. Adopt the SAS `task` **`evenergyshift`**.

vii. Cross-check the spectral behaviour by varying simultaneously the constant factor and Γ.

viii. Make an updated H-S/H+S vs (1-const) and H-S/H+S vs ΔΓ.

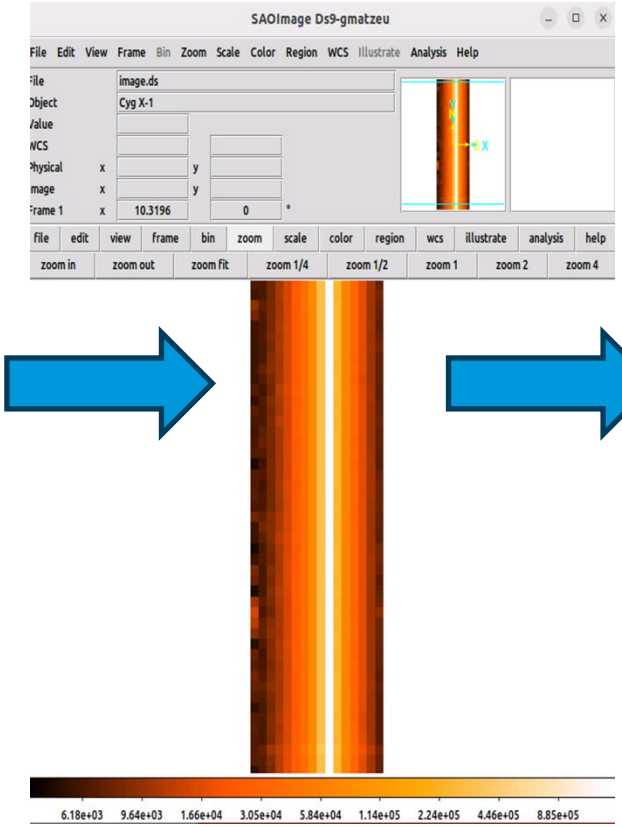
ix. Model EPIC-pn and FPMA (I could have chosen FPMB) independently by applying a SPLINE to both spectra

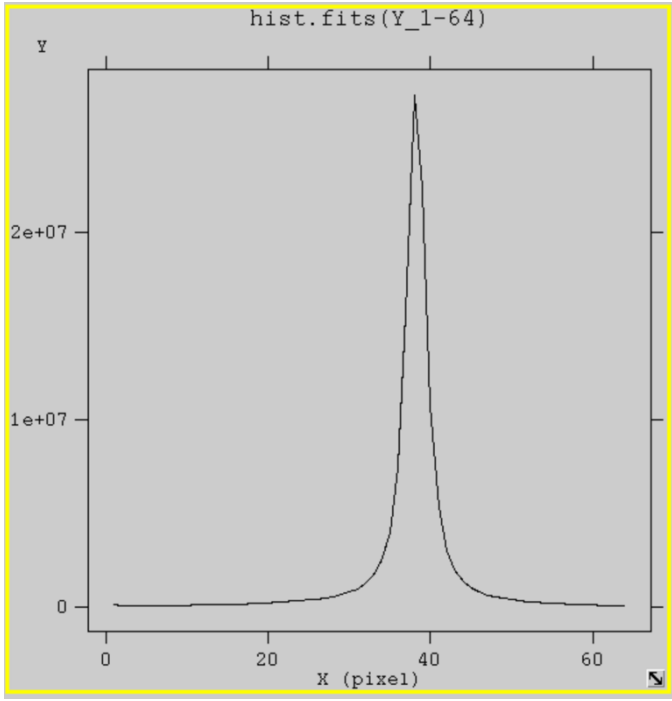
x. Calculate the FLUX RATIO 3-10 keV and plot it against the H-S/H+S.

Reduction and analysis approach

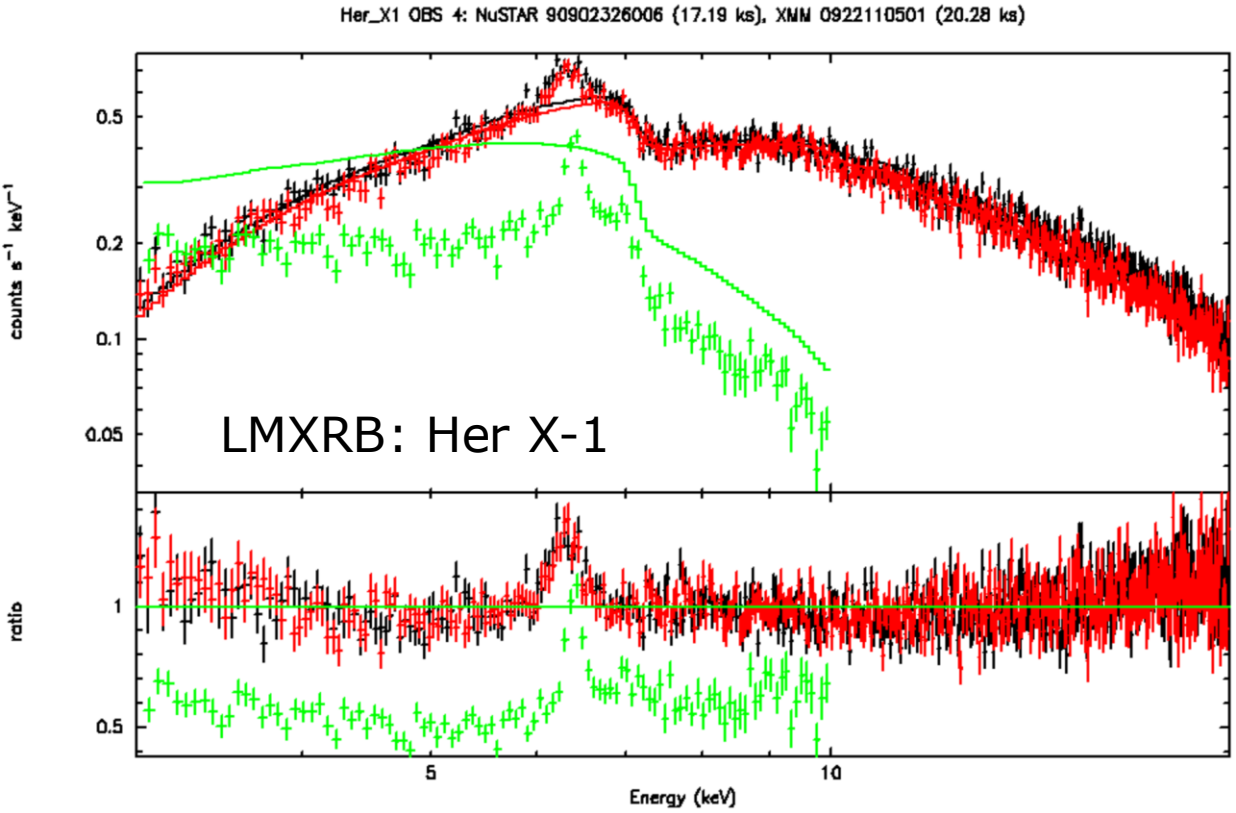
XMM-Newton
EPIC-pn
Timing mode
RAWX =1-64
Using 3-10 keV

In the Timing mode, spatial information is maintained only in one dimension, along the column (RAWX) axis.





Example from (i-ii):



Find best-fit continuum model to *NuSTAR* data only
(in this case: constant*pow)

(*XMM* EPIC-pn not fitted)

EPIC-pn photo-index wrt *NuSTAR*: harder

(*XMM* EPIC-pn not fitted)

```
arfgen applyabsfluxcorr=
```

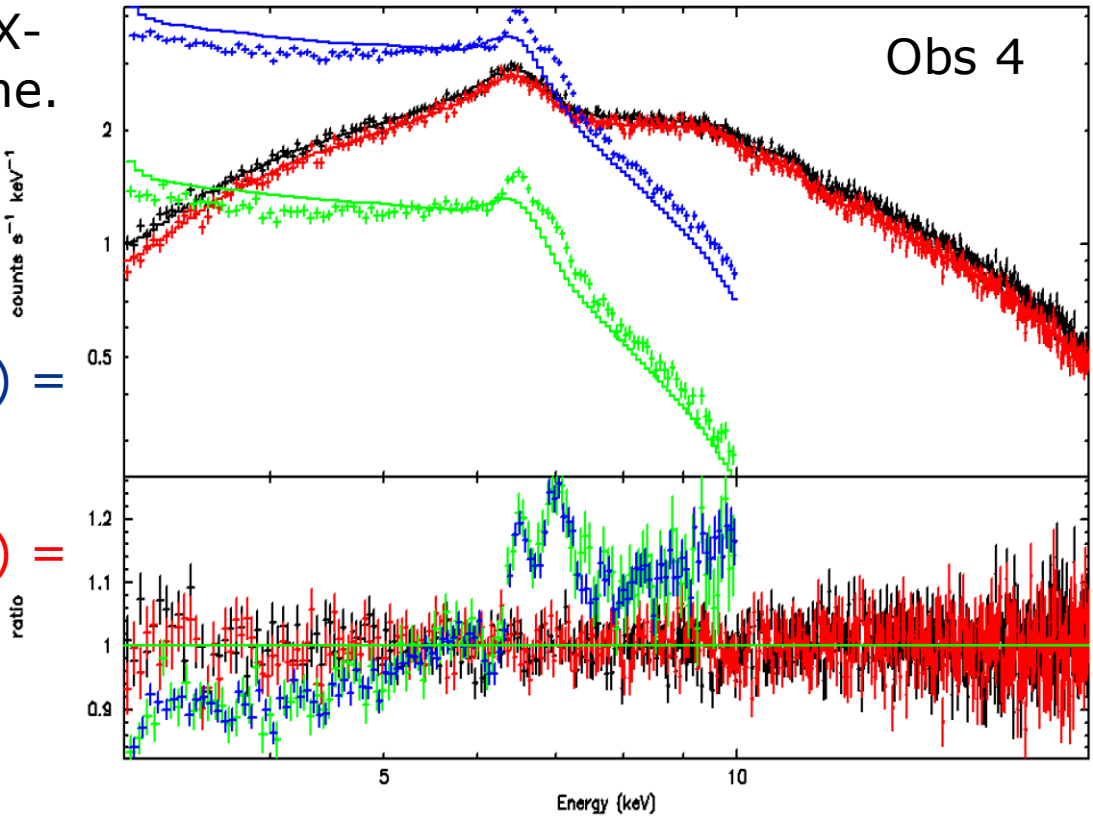
TEST 1 example (iii-iv) – EPIC-pn VARIABLE CONSTANT

Her X-1; An accreting low mass X-ray binary with a strong Fe Kα line.

Fe Ka centroid energy lines is shifted by ~10 eV

Δconst = 1 – constant (EPIC-pn) = 0.38 - 10by4

Δconst = 1 – constant (EPIC-pn) = 0.40 – 10by0



TEST 2 example (iii-iv) – EPIC-pn VARIABLE Γ

Her X-1; An accreting low mass X-ray binary with a strong Fe Kα line.

Fe Ka centroid energy lines is shifted by ~10 eV

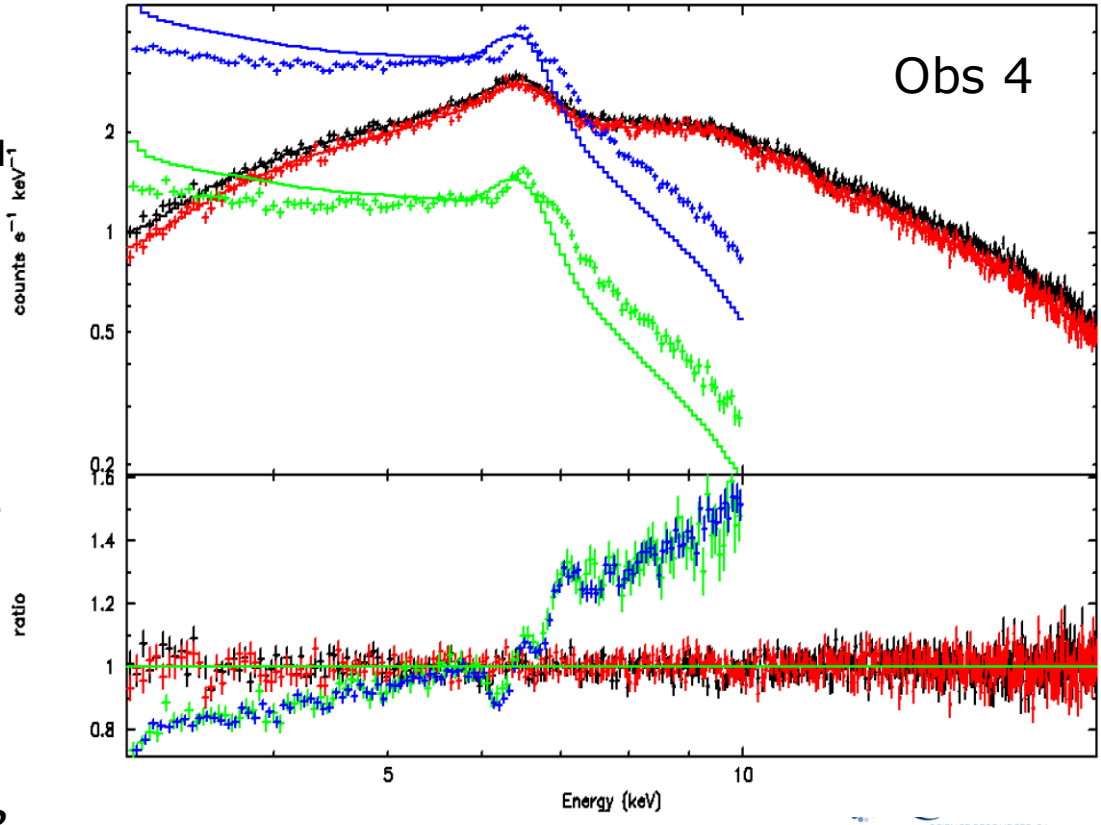
$\Delta\Gamma$ = Γ (FPMA) - Γ (pn) = -0.32

10by2

$\Delta\Gamma$ = Γ (FPMA) - Γ (pn) = -0.33

10by0

The majority of EPIC-pn slopes are softer w.r.t. *NuSTAR FPMA/B*



ESA UNCLASSIFIED - For Official Use

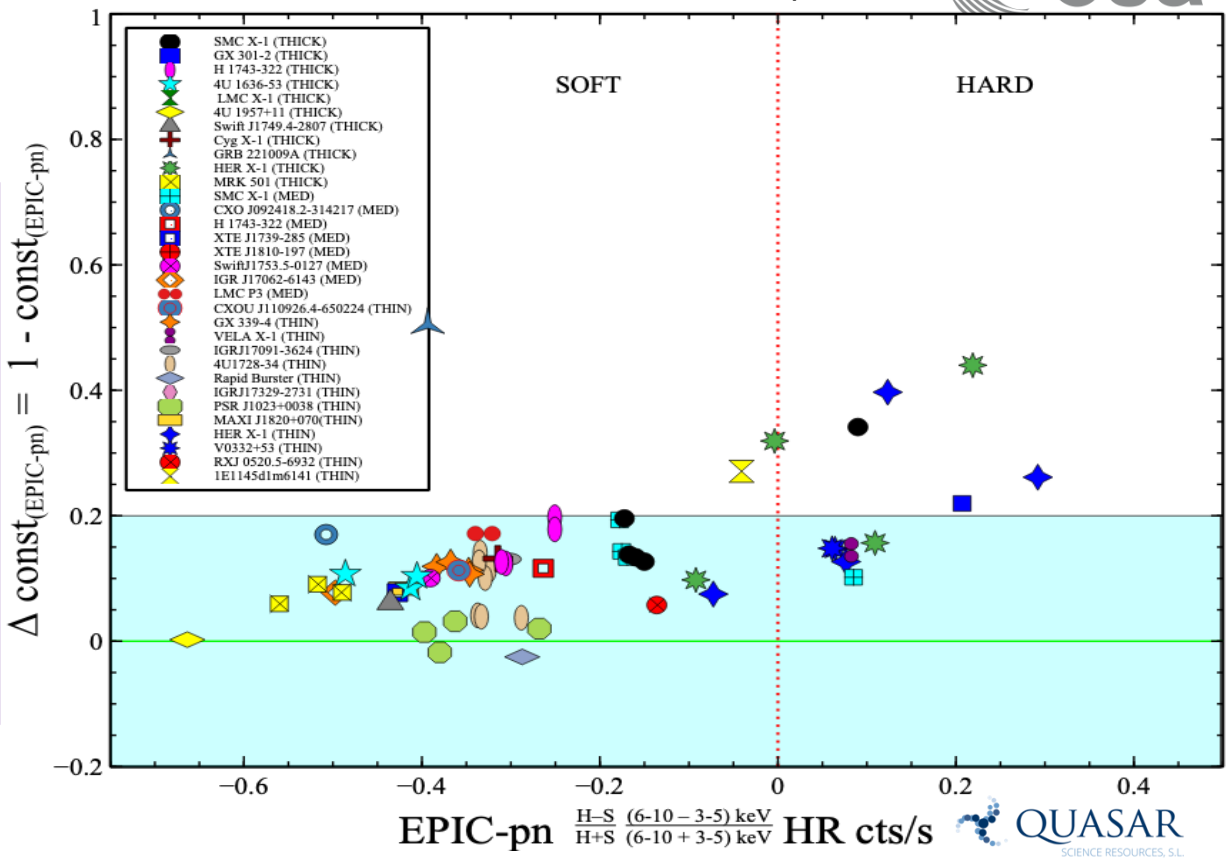
Results 1a (v)

(H–S)/(H+S) HR cts/s vs (1 – constant$_{pn}$)

High S/N so 1-3% error

We use 10by0 spectra

There is some scatter above (1-const.) = 0.2



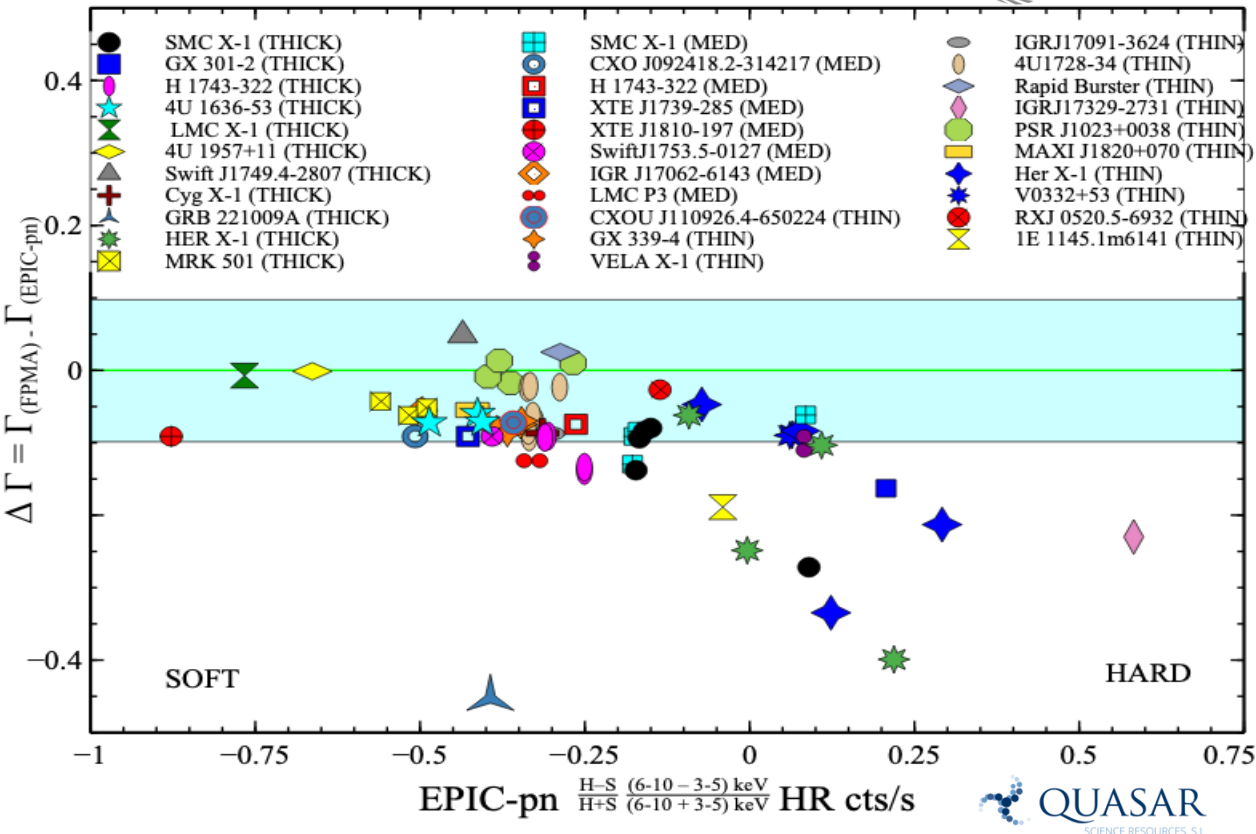
Results 1b (v)

(H–S)/(H+S) HR cts/s vs ΔΓ

High S/N so 1-3% error

There is some scatter above ΔΓ = ±0.1

Hard pn spectra tend do disagree most with FPMA



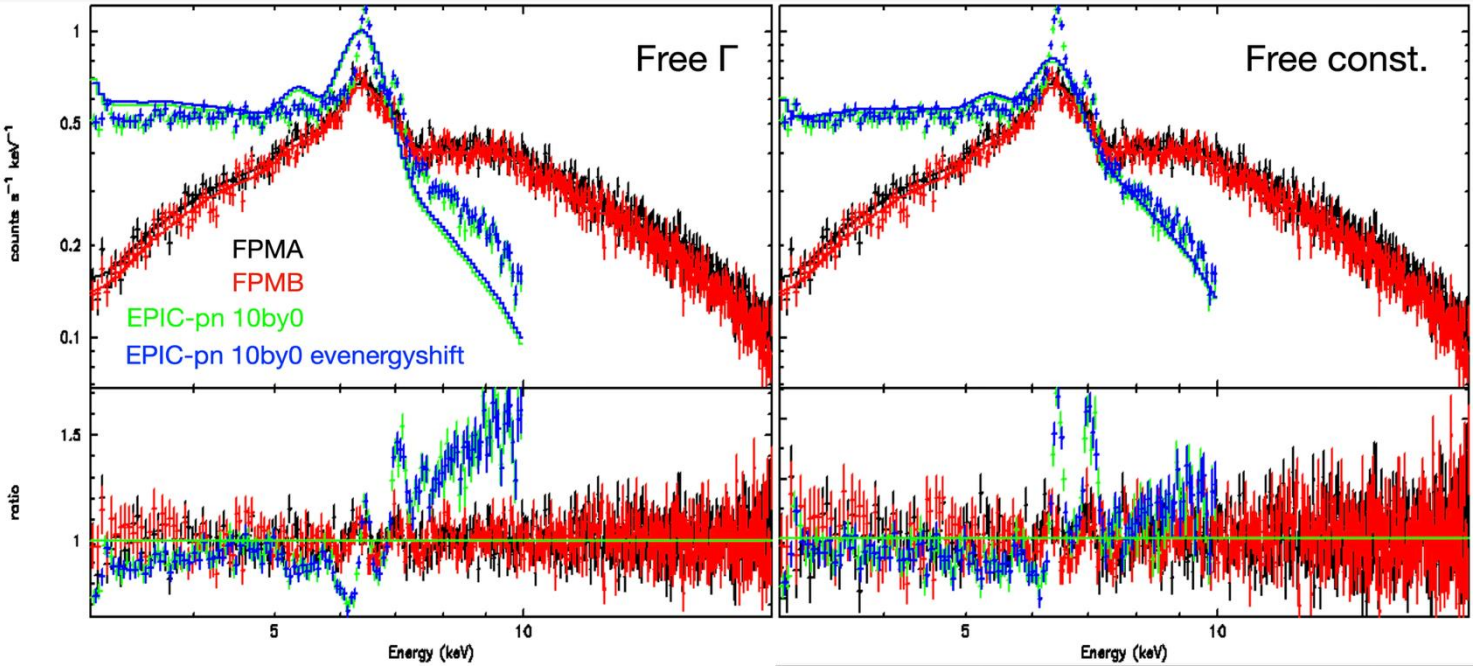
Results (vi)

Adopt the SAS `task` **evenergyshift**

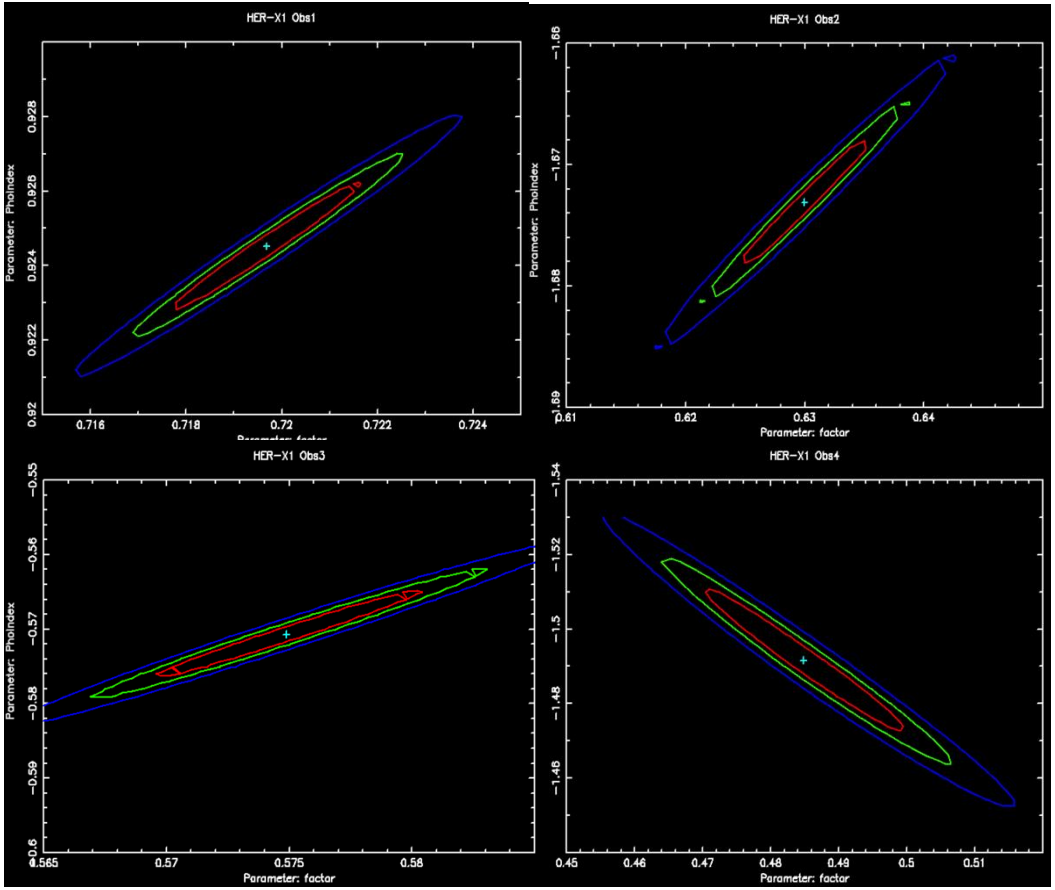
Her X1 Obs. 4 – 0922110501

I used **two** absorption edges: Si Ka at 1.84 keV and Au-M at 2.2 keV

By adopting a **third** absorption edge Au-L edge at 11.9 keV no differences were detected from using two

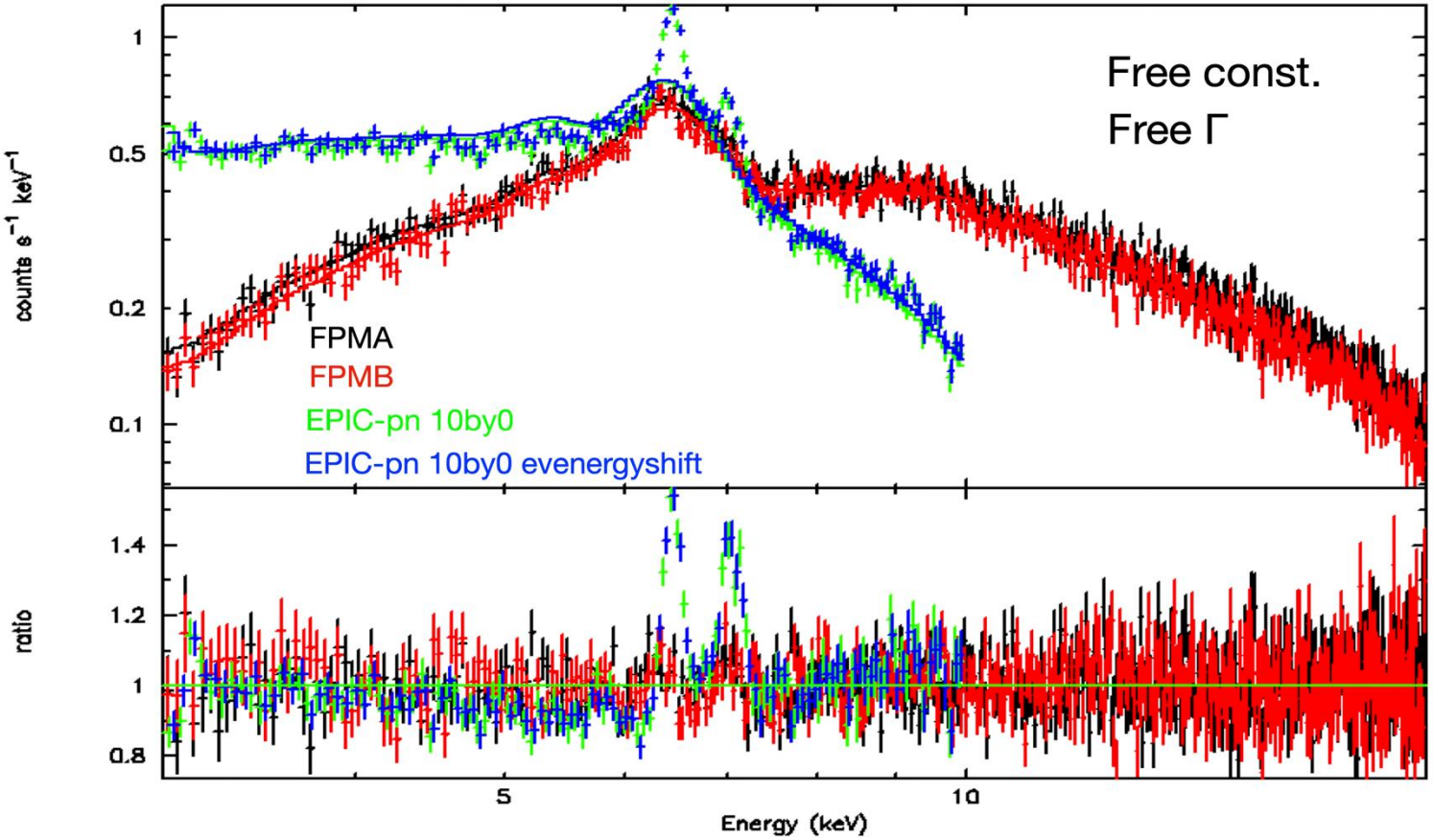


Results (vii) constant vs Γ contours

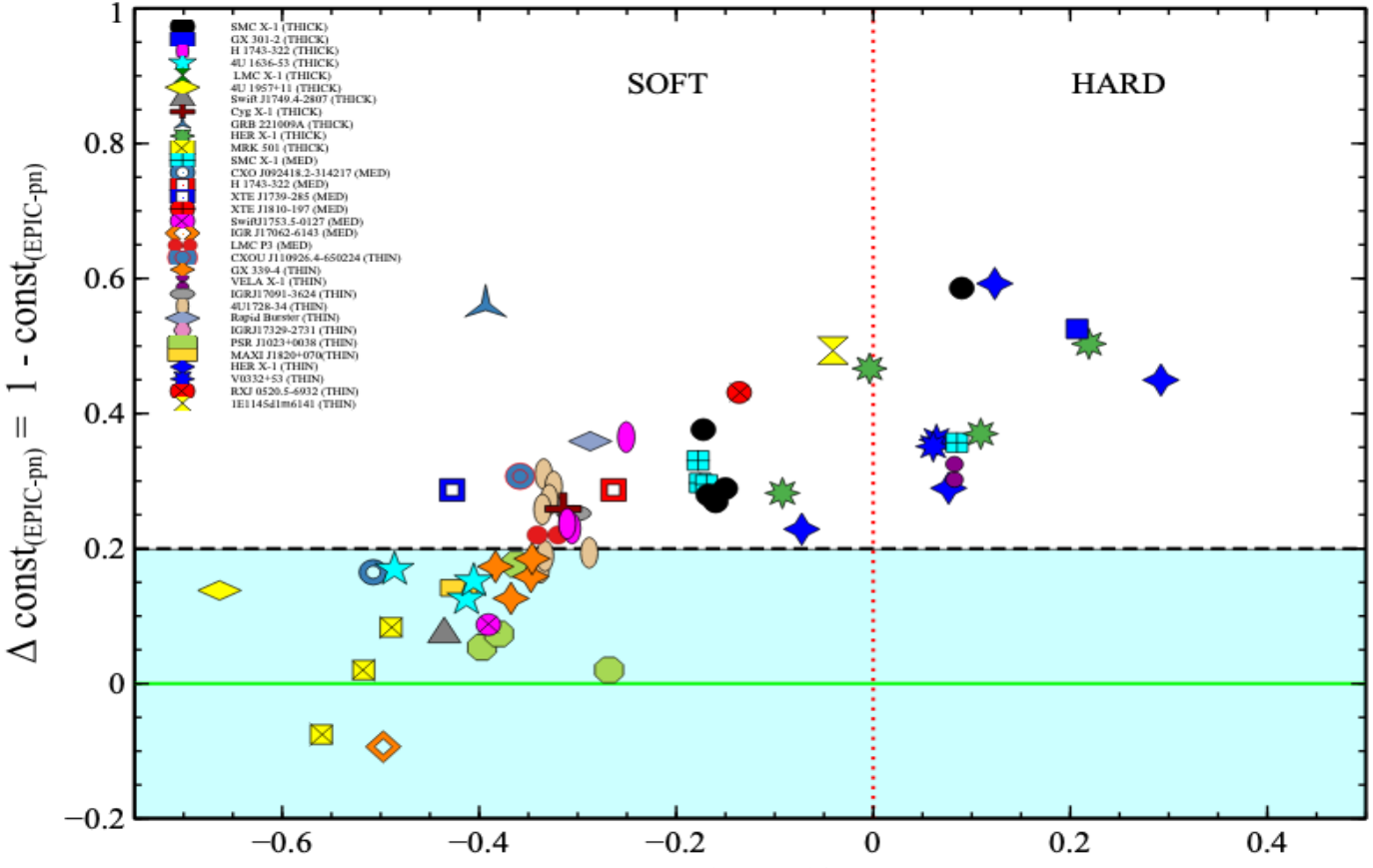


Not significant degenacies are found between constant factor and Γ for Her X-1 (THICK FILTER) and the rest of the sample.

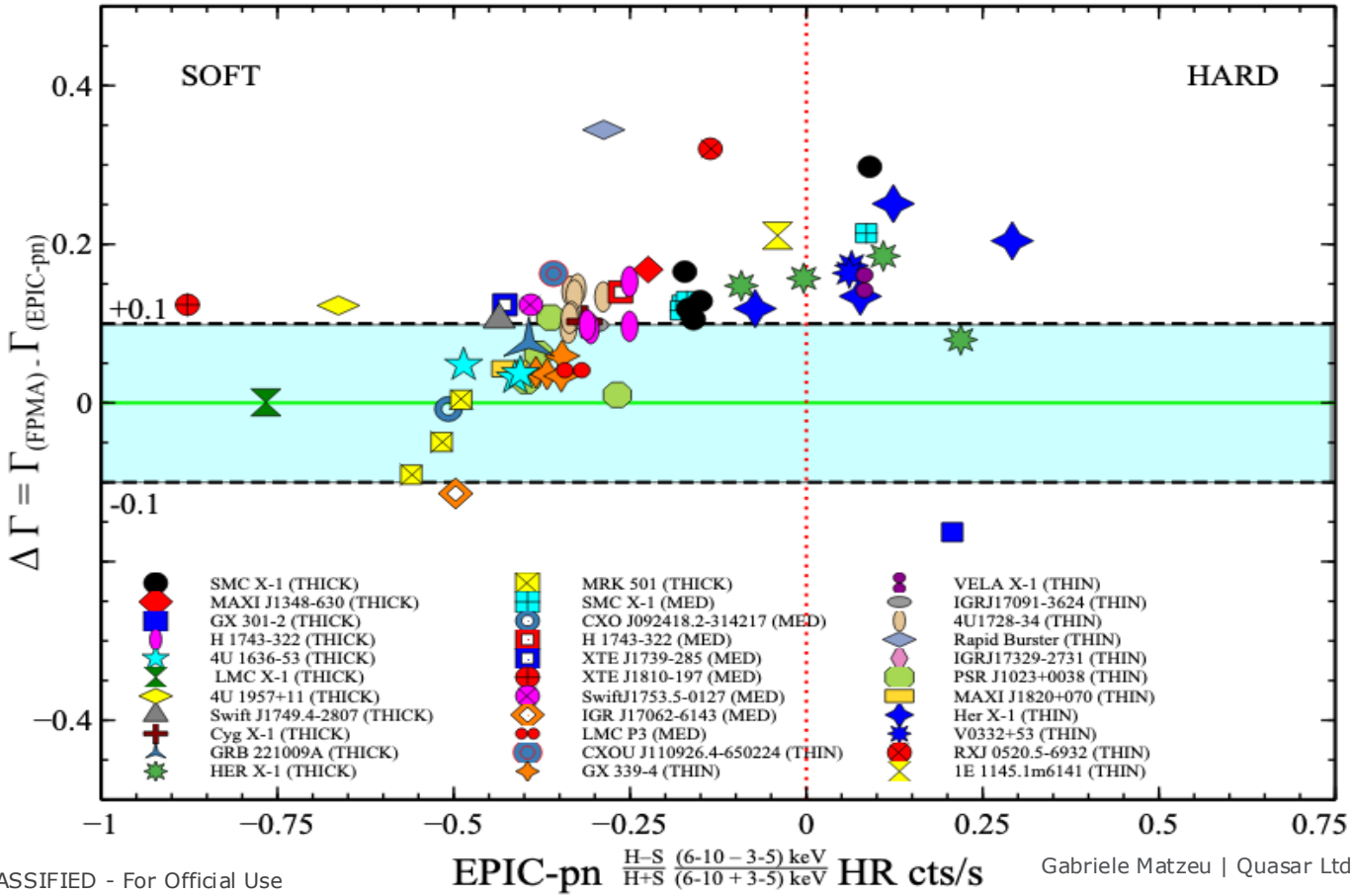
Results (vii) Test 3: variable constant and Γ



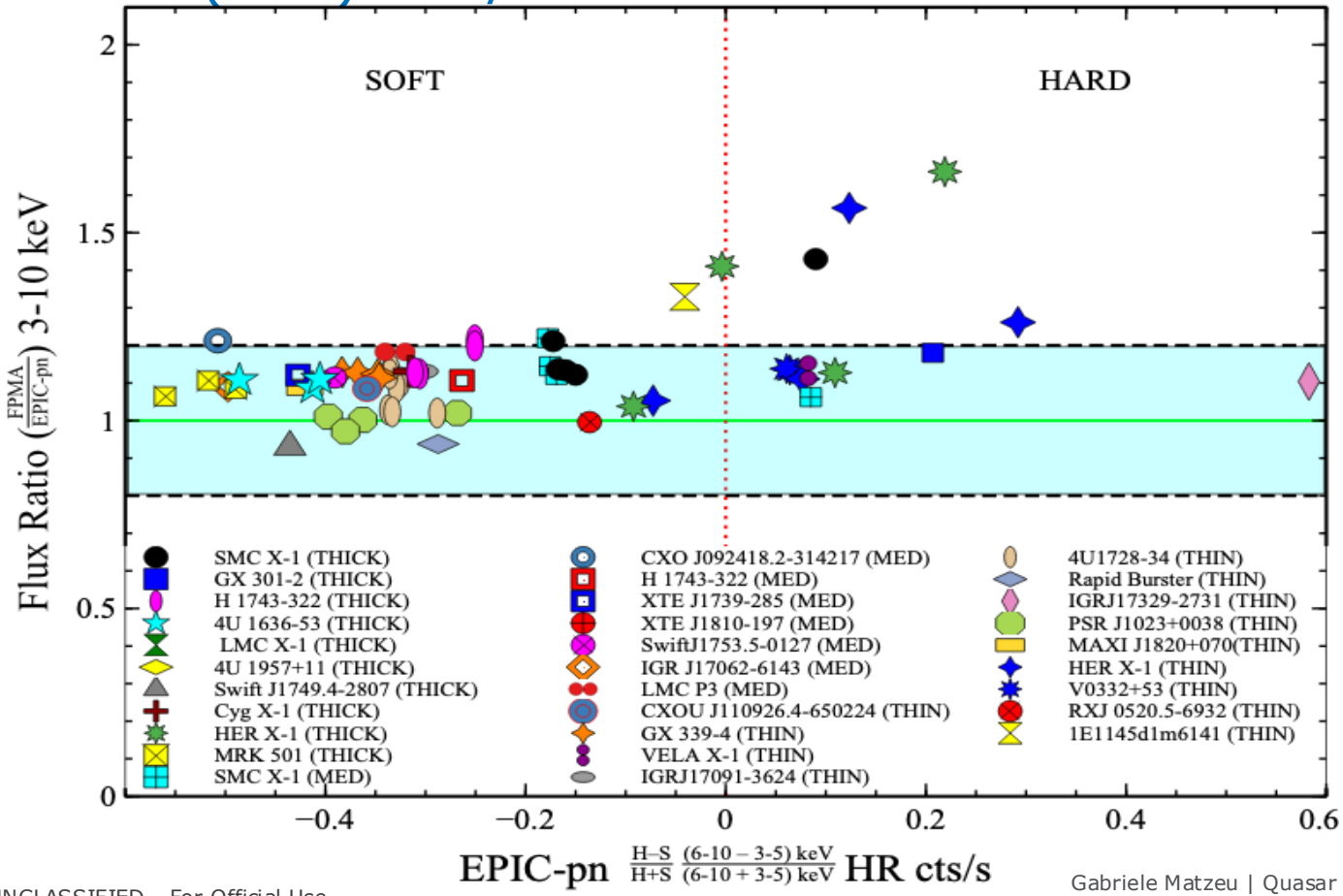
Results 1a (viii) Test 3: free constant and Γ



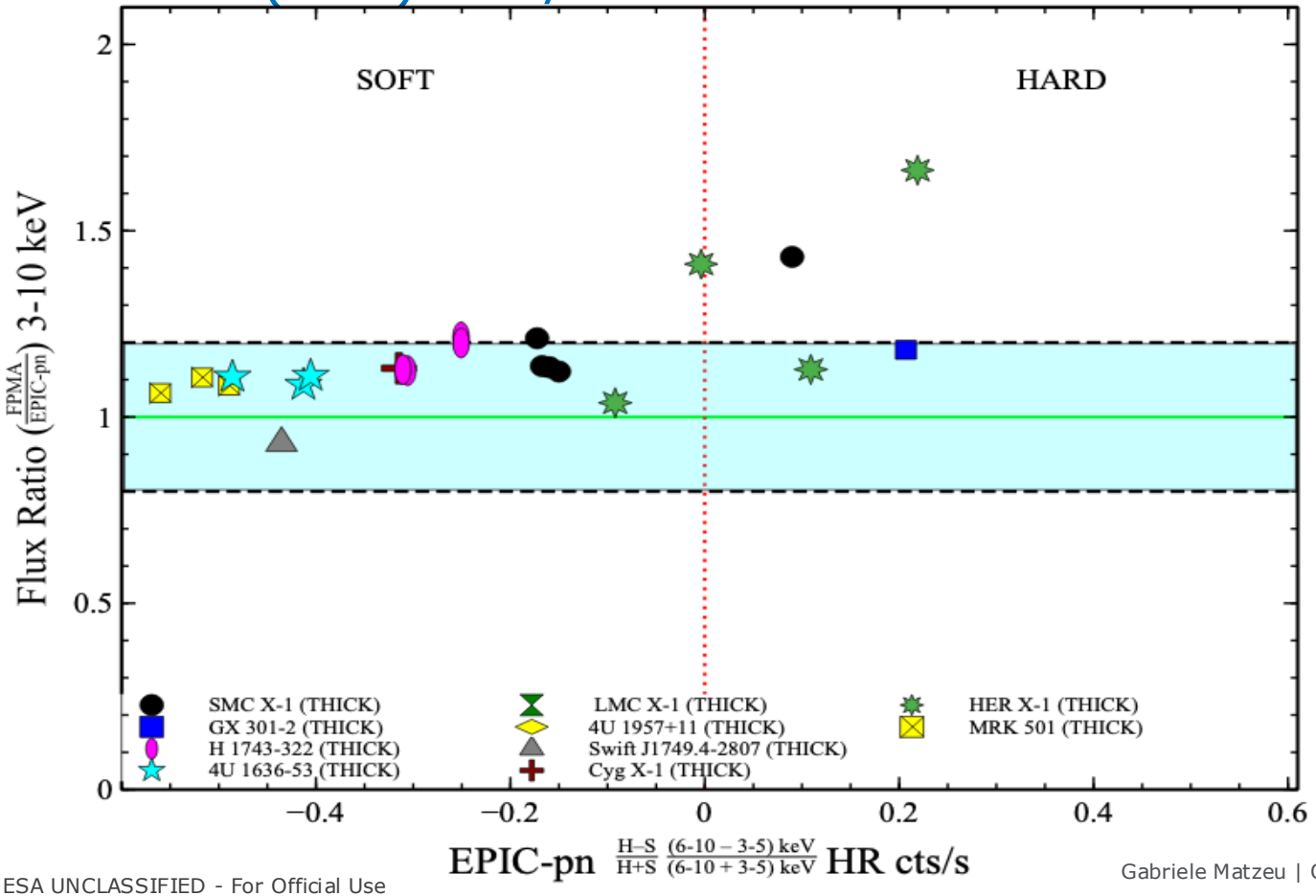
Results 1b (viii) Test 3: free constant and Γ



Results (ix-x) H-S/H+S vs 3-10 keV Flux Ratio



Results (ix-x) H-S/H+S vs 3-10 keV Flux Ratio



THICK FILTER ONLY

Current status and outlook

Flux difference of ~20% obvious in most of the sources with some outliers

Slope difference of ±0.1 for most of the all targets with some pronounced outliers

From our correlations we find that observation with harder Γ are more likely to deviate from the above thresholds.

Causes: scattering halos?; intrinsic absorption?; …

We are now working to find solutions.

Suggestions are WELCOME

w.r.t. *NuSTAR*
XMM flux typically lower by ~ 20%
XMM spectrum softer (ΔΓ ~ 0.1)

XMM-Newton Calibration Note is currently being written.
Work is ongoing to create automated pipeline, add more sources.