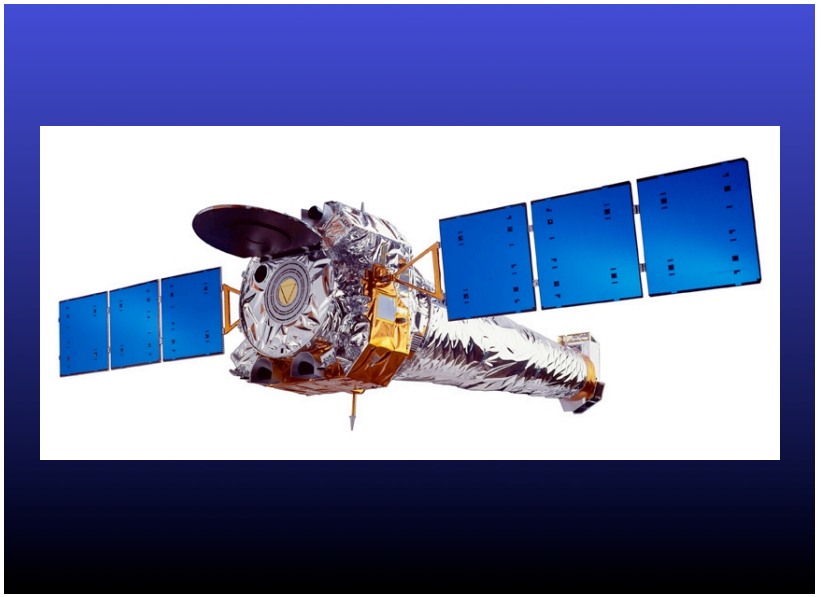


XMM-Newton — Chandra

Blazar Flux Comparison

M.J.S. Smith (ESAC) & H. Marshall (MIT)

6th IACHEC, April 2011

esa

XMM-Newton

Blazar Sample

Objective: Comparison of XMM-Newton — Chandra fluxes in various bands.

For this we're using a sample of Blazars:
PKS 2155-304, **3C 273** and **H 1426+428**

- Relatively simple spectra overall; (absorbed) power laws in narrow bands.
- Flux covers the 0.1 – 10.0 keV band.
- Bright
  - piled in EPIC -> PSF core excision introduces added uncertainty in flux determination
- Variable, even within observation timescale
  - require XMM / Chandra / … coordinated observations
  - simultaneous GTIs across instruments
  - need to use normalised fluxes to compare between observations

16 coordinated XMM-Newton / Chandra observations,
resulting in 31 strictly simultaneous GTIs for flux comparison.

Instruments being compared are: EPIC, RGS, ACISS-L/HETG, HRCS-LETG

Analysis Details (I)

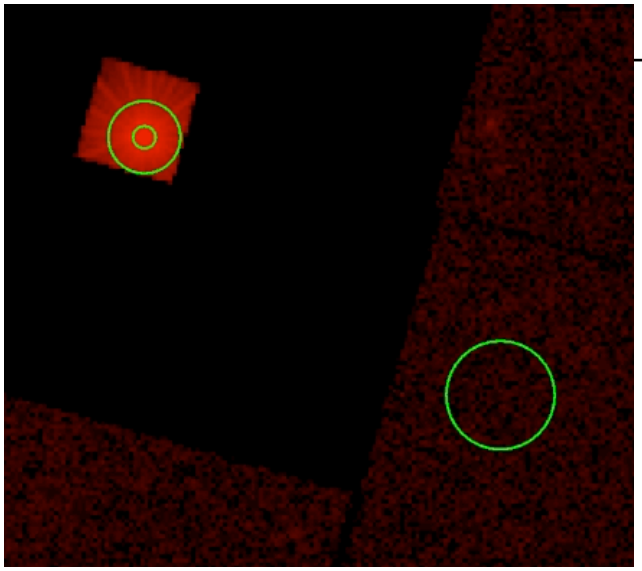
Data reduction:
Use latest publicly available s/w and calibration files:
- SAS 11.0 + CCFs as of March 2011
- CIAO 4.3 + CALDB 4.4.2

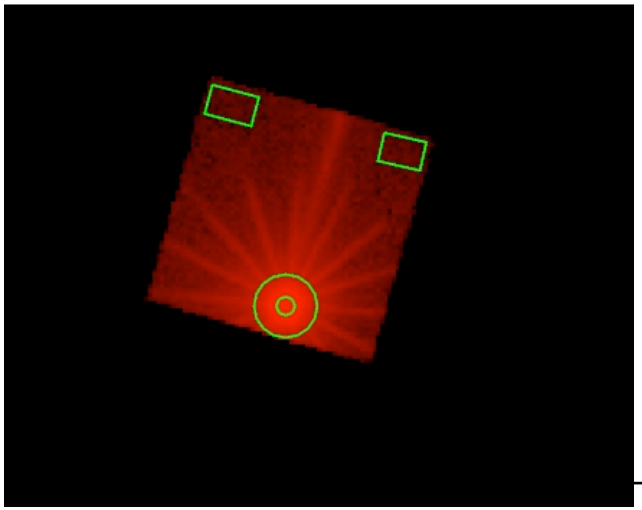
Spectral fitting:
- Per band, fit an absorbed power-law (nH fixed) and determine the model flux
- Fit instruments independently
- Chandra + / - grating orders jointly fit
- Use orders 1 – 10 to create HRC LETG response

> PKS 2155-304: 1.42×10^{20} cm^{-2}
> 3C 273: 1.79×10^{20} cm^{-2}
> H 1426+428: 1.36×10^{20} cm^{-2}

Energy bands are those used originally in the XMM-Newton Cross Cal Archive:
- 0.15 – 0.33 keV (Lower EPIC bound – Lower RGS bound)
- 0.33 – 0.54 keV (Up to the O-edge)
- 0.54 – 0.85 keV (O-VII, O-VIII)
- 0.85 – 1.50 keV (Ne-IX, Ne-X)
- 1.50 – 4.00 keV
- 4.00 – 10.0 keV

Analysis Details (II)





Systematic uncertainties:

Pile-up:
EPIC requires excision of PSF core: use source extraction annuli.

› Per observation: for both MOSs use the largest common outer radius within window, and a common inner radius.
› However, radii vary from observation to observation, and are generally different from the PN radii.

Differing annuli may introduce systematic uncertainties due to imperfect EE correction and RMF weighting.

PN background:
Extracted from regions within the small window: some degree of source contamination.

Fit statistic:
Chi^2 and C-Statistic (Cash) yield different results, up to several percent for flux measurements.

Analysis Details (III)

Normalise fluxes within simultaneous exposures (GTIs) to compare instruments across observations:

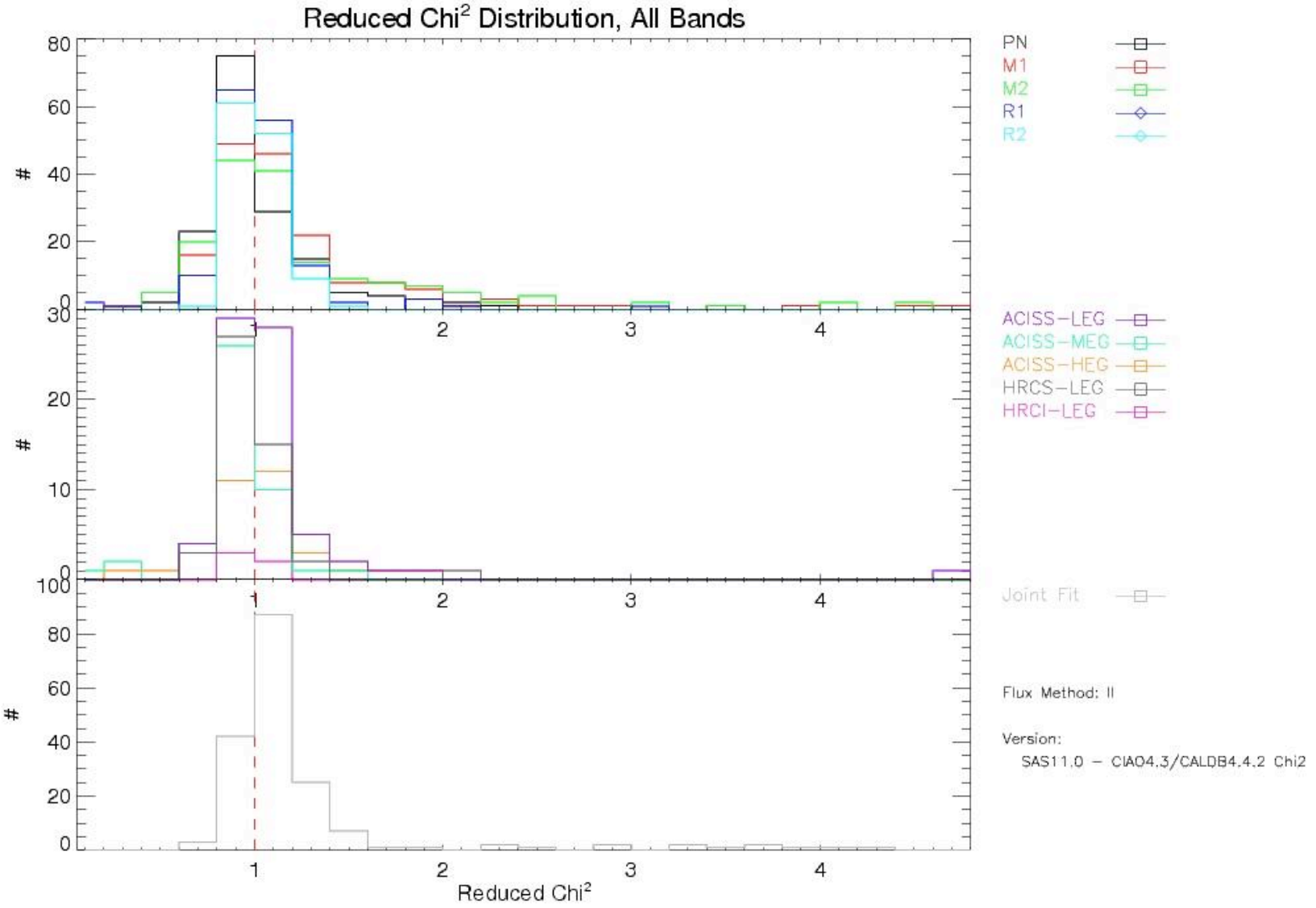
Preferably the same benchmark across all GTIs and bands.

- PN & MOS: when in TI mode no useful data in the lowest energy band
- RGS: no data in the lower or higher bands
- Chandra instrument configurations vary from exposure to exposure

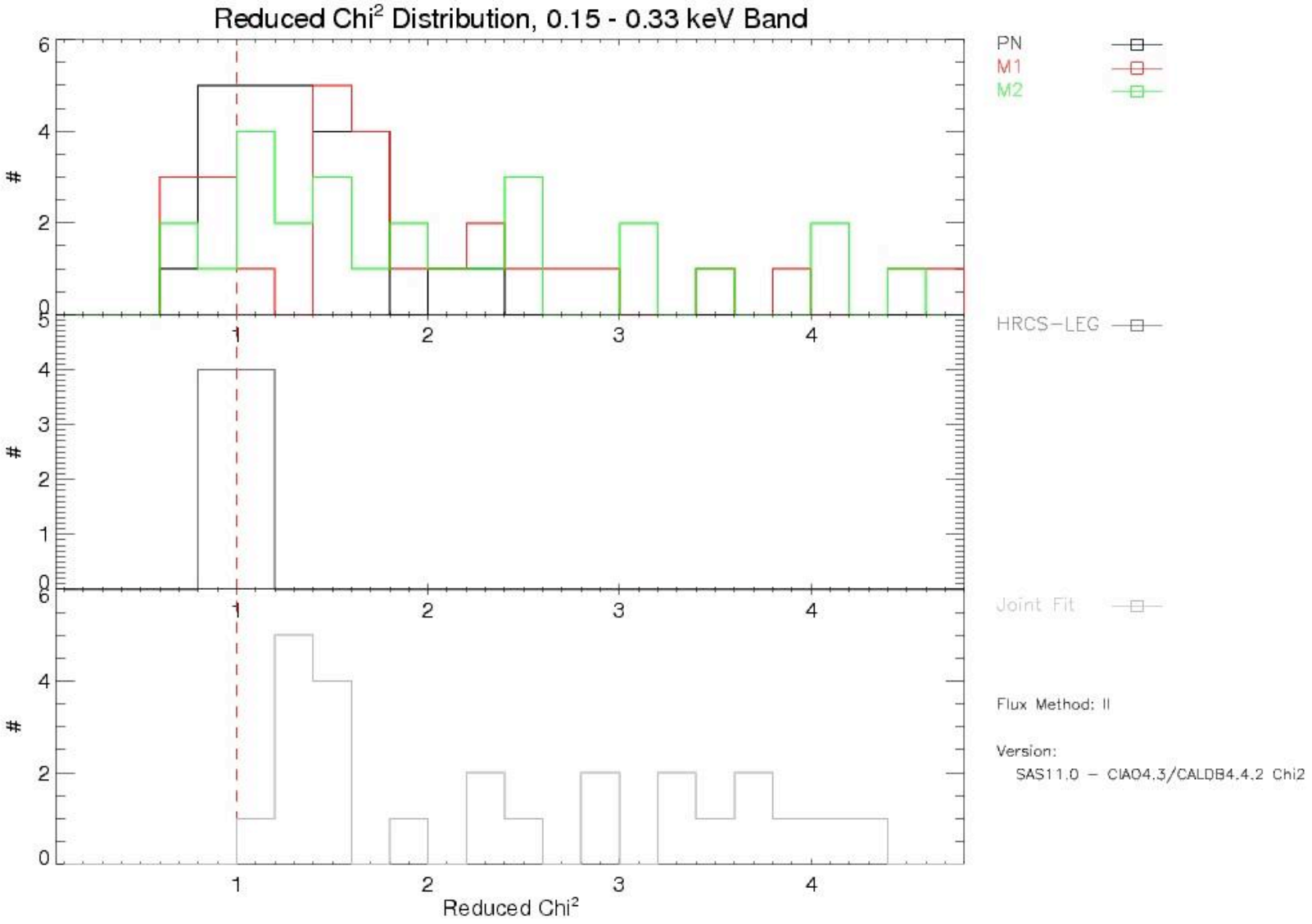
➡ Use as reference the **Joint Fit Flux** of all instruments in use in a particular exposure.

For 31 GTIs and 6 energy bands: a total of > 1200 derived flux values.

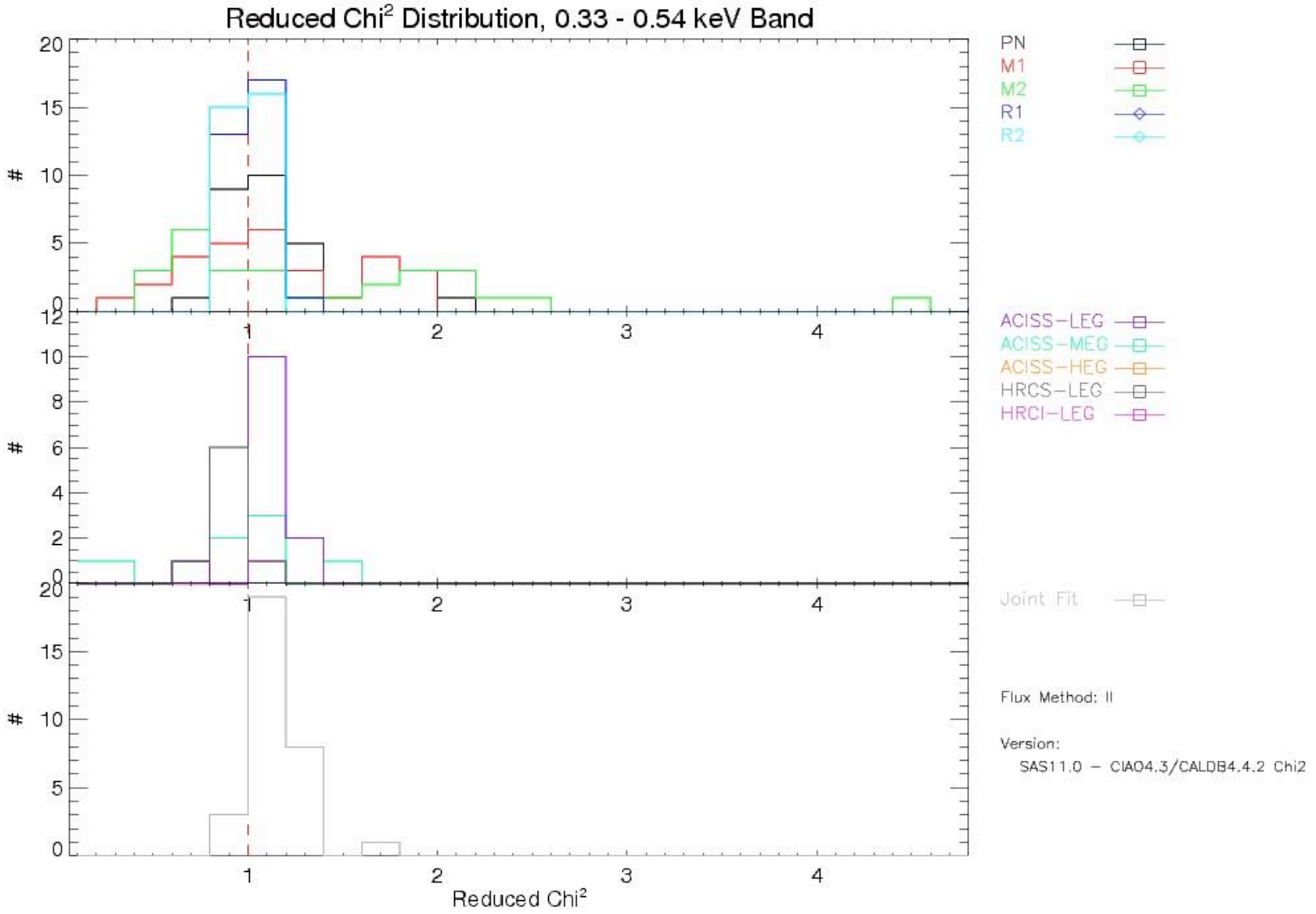
Spectral Fit Quality



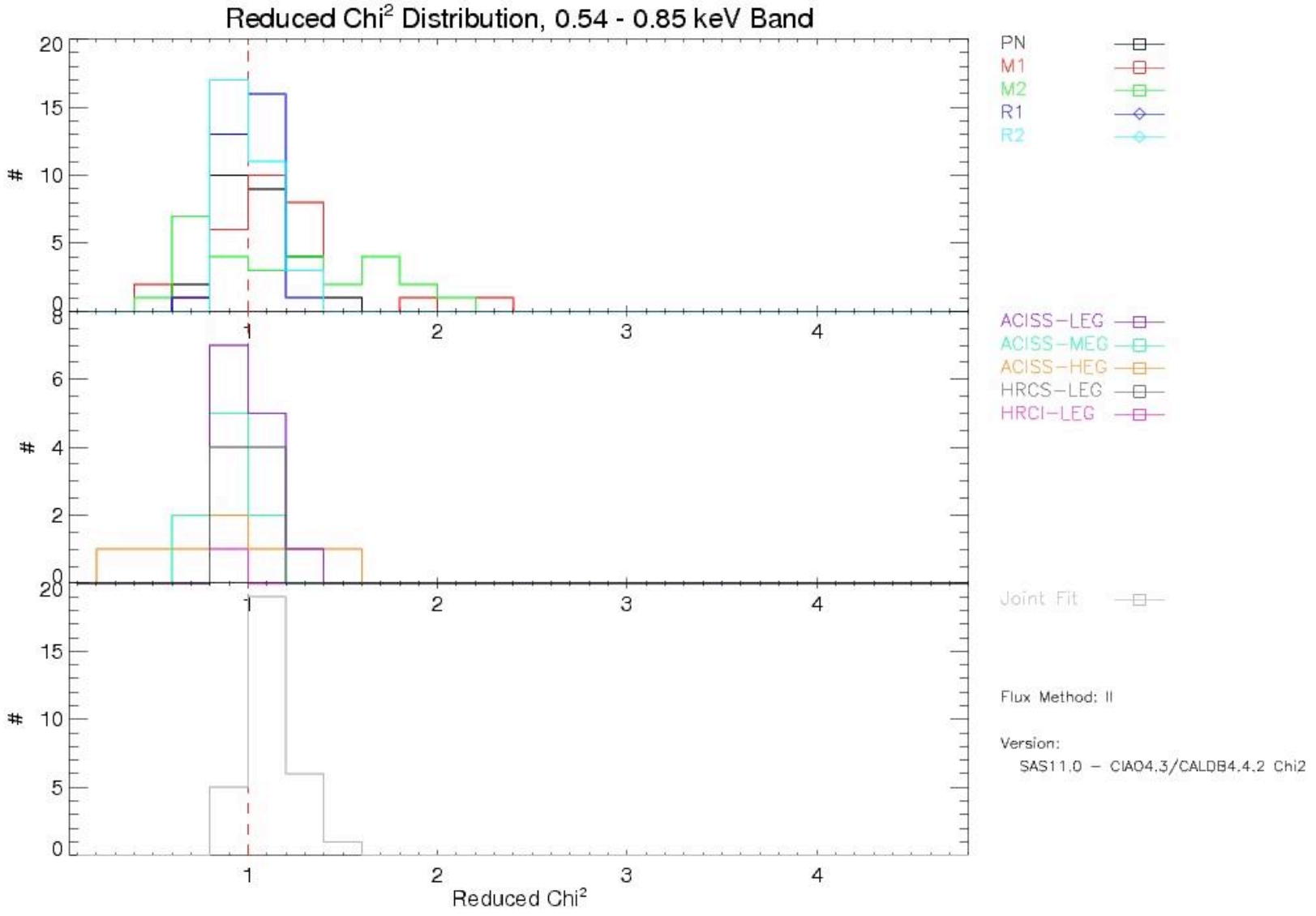
Spectral Fit Quality



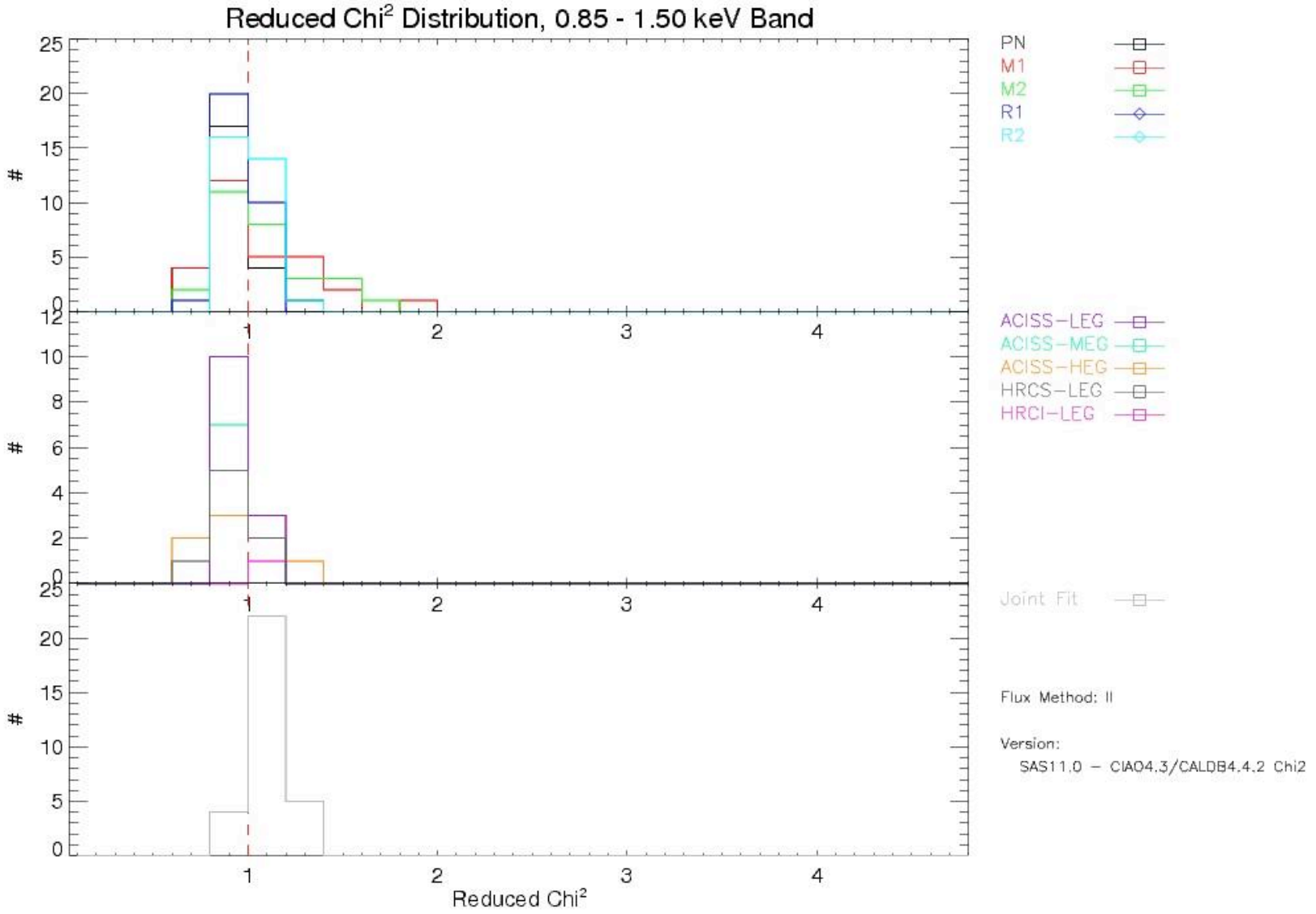
Spectral Fit Quality



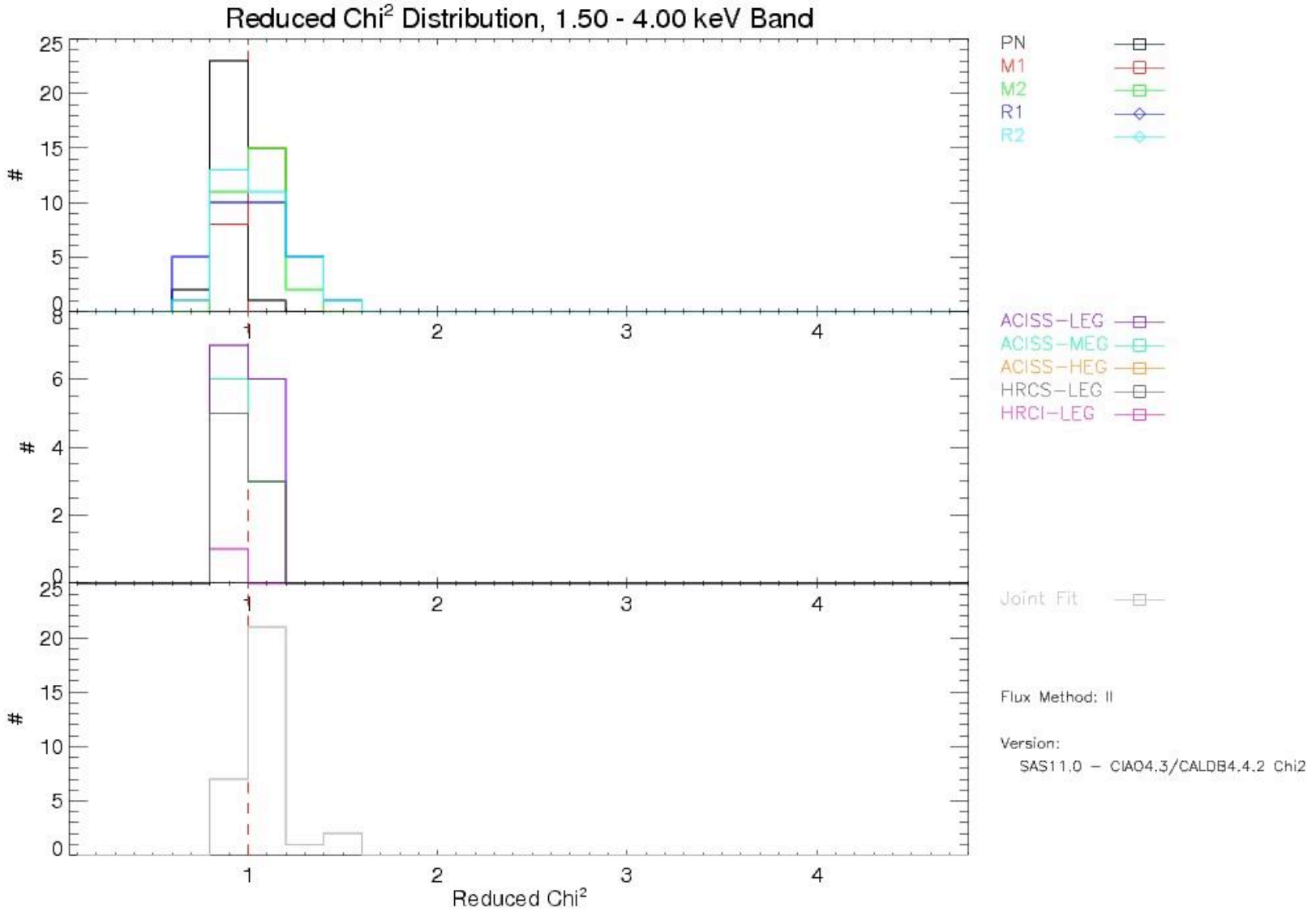
Spectral Fit Quality



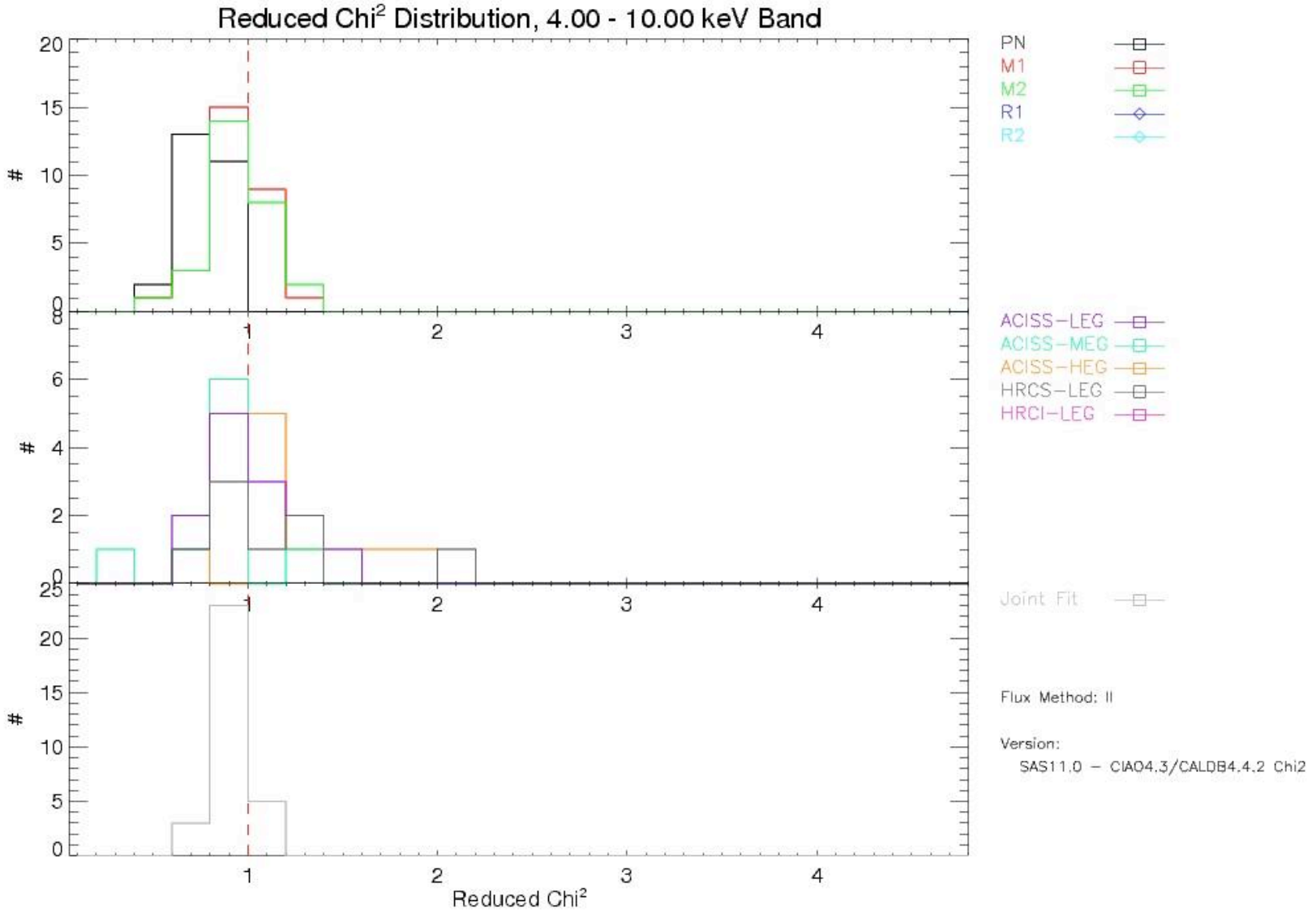
Spectral Fit Quality



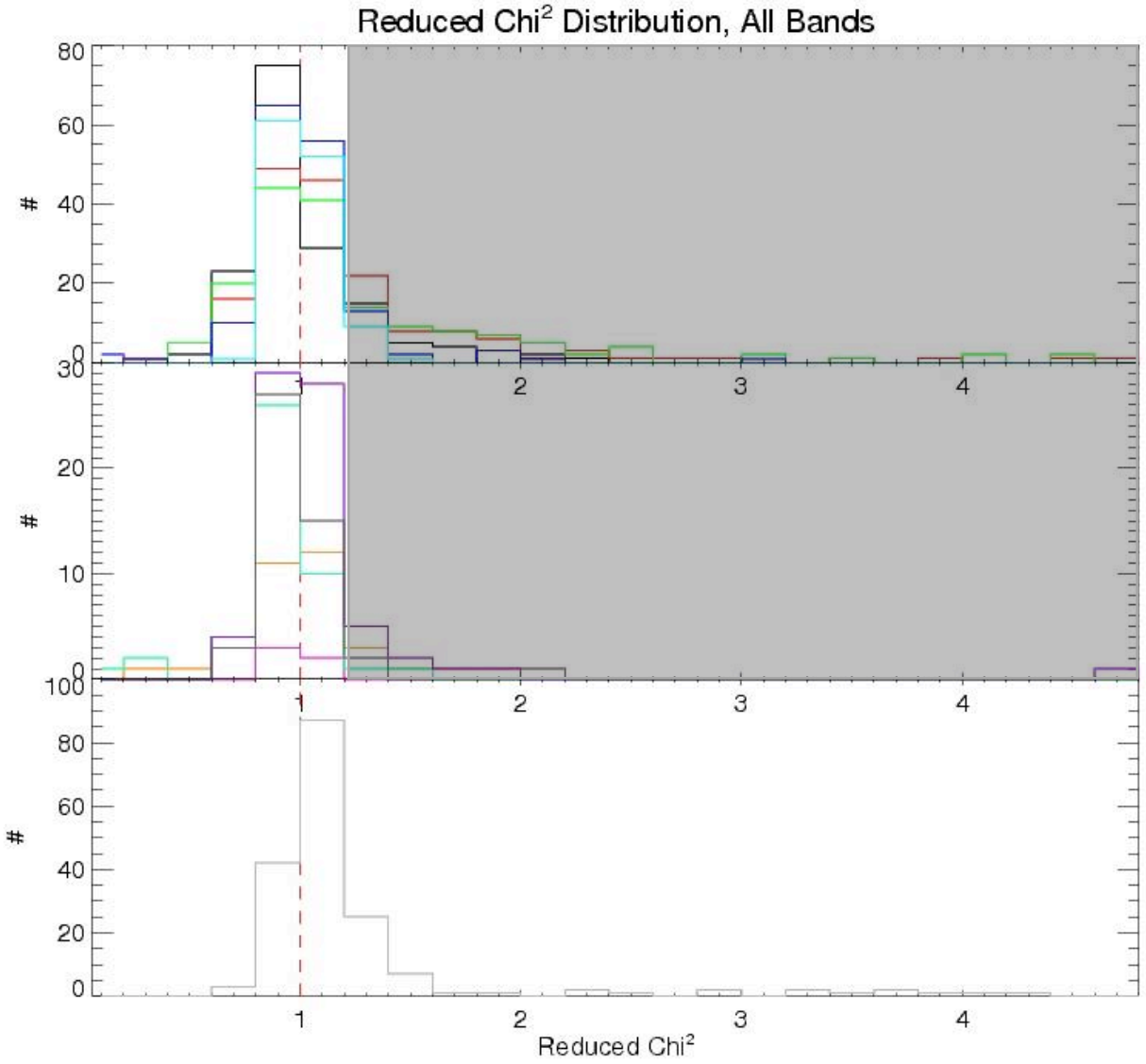
Spectral Fit Quality



Spectral Fit Quality



Spectral Fit Quality



Discard individual instrumental fit results with reduced $\chi^2 > 1.2$

Relax this condition for the joint fit, to allow comparisons to be made.

Discard 0.15 - 0.33 keV band.

Final sample contains > 700 flux measurements

Results

Compare current results:

› SAS 11.0

› CIAO 4.3 + CALDB 4.4.2

"New"

With results presented at the previous IACHEC (April '10):

› SAS 9.0

› CIAO 4.2 + CALDB 4.2.0

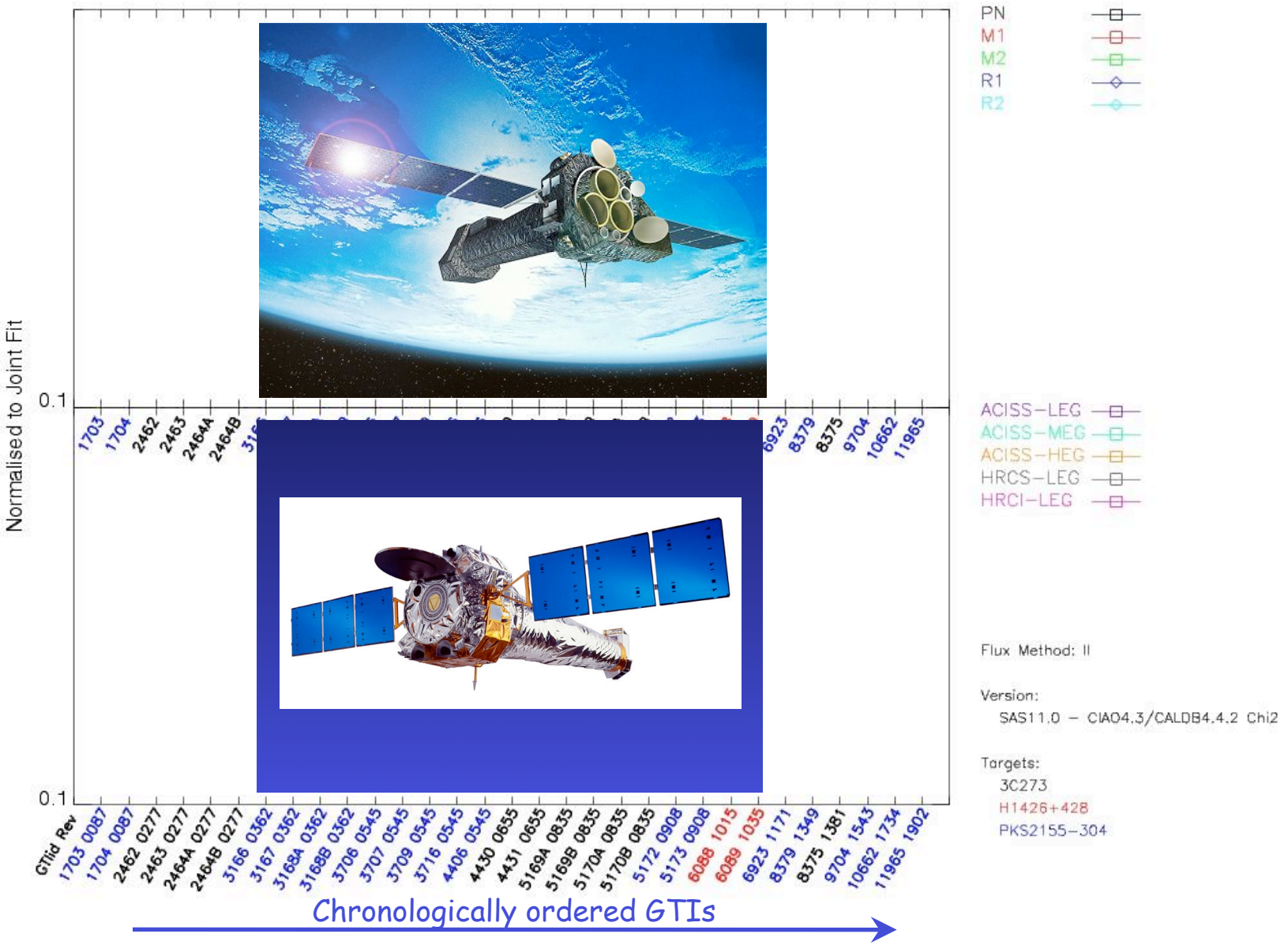
"Old"

Main changes which affect flux comparisons:

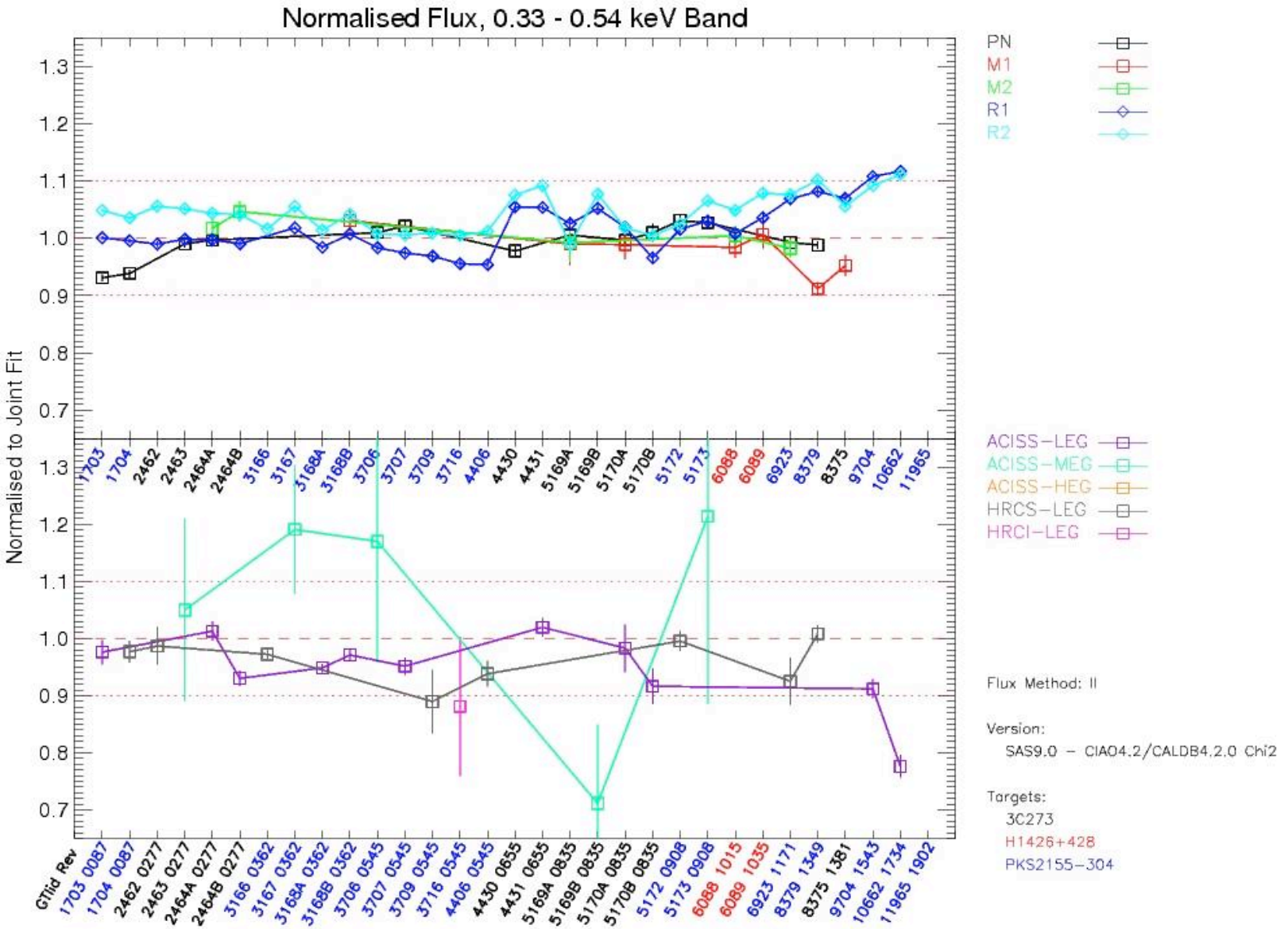
› **Calibration**:
  - › Refinement of PN redistribution
  - › New MOS spatial and time dependent redistribution
  - › RGS effective area with exponential contamination model
  - › New LSF parameters for the ACISS-LETG
  - › Updated LETG grating high order efficiencies (2-7)

› **Data**: an additional PKS2155-304 coordinated observation performed in May 2010

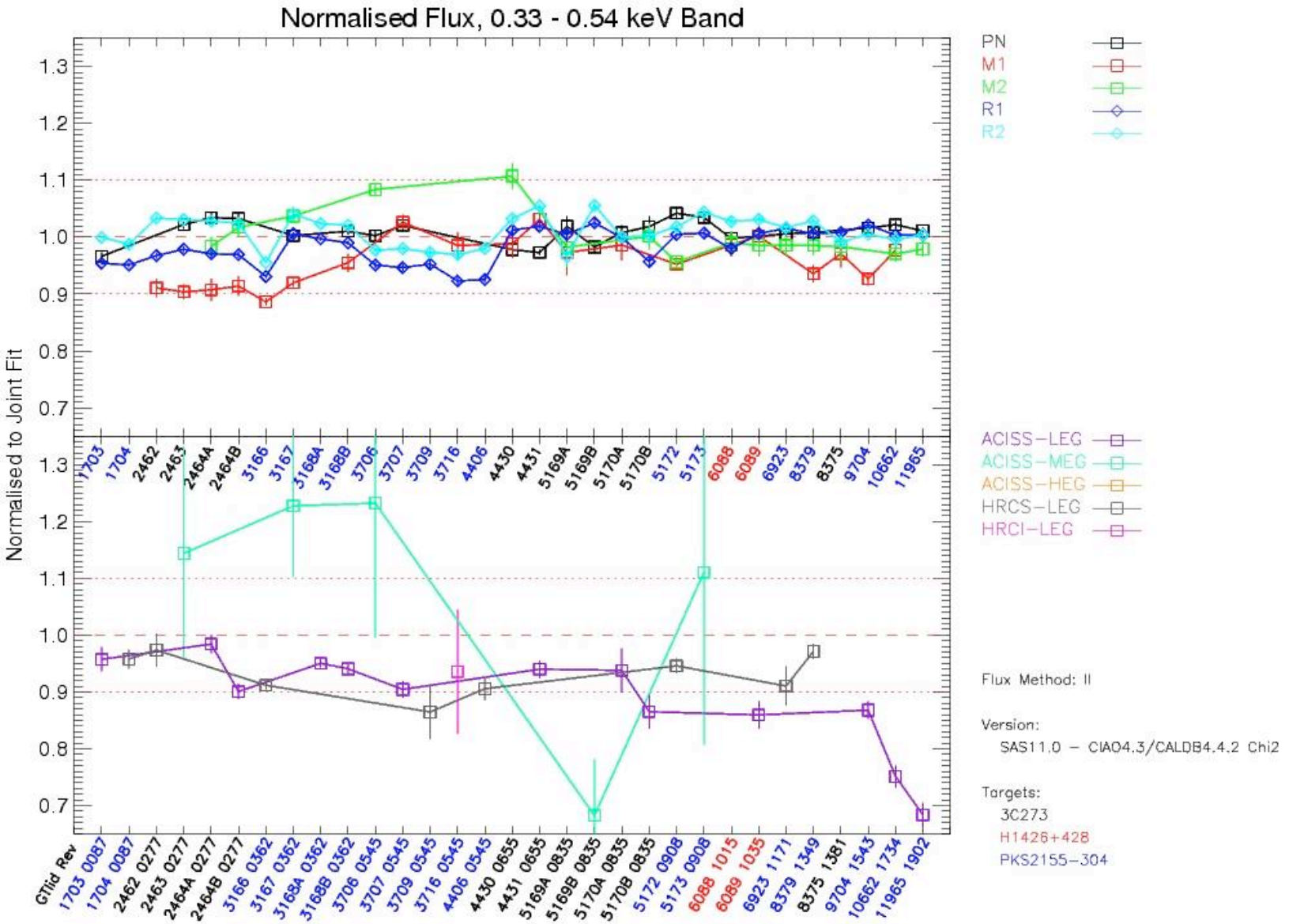
Results


PN
M1
M2
R1
R2
ACISS-LEG
ACISS-MEG
ACISS-HEG
HRCS-LEG
HRCI-LEG
Normalised to Joint Fit
0.1
0.1
1703
1704
2462
2463
2464A
2464B
6923
8379
8375
9704
10662
11965
GTIid Rev
1703 0087
1704 0087
2462 0277
2463 0277
2464A 0277
2464B 0277
3166 0362
3167 0362
3168A 0362
3168B 0362
3706 0545
3707 0545
3709 0545
3716 0545
4406 0545
4430 0655
4431 0655
5169A 0835
5169B 0835
5170A 0835
5170B 0835
5172 0908
5173 0908
6088 1015
6089 1035
6923 1171
8379 1349
8375 1381
9704 1543
10662 1734
11965 1902
Chronologically ordered GTIs
Flux Method: II
Version:
SAS11.0 – CIAO4.3/CALDB4.4.2 Chi2
Targets:
3C273
H1426+428
PKS2155-304

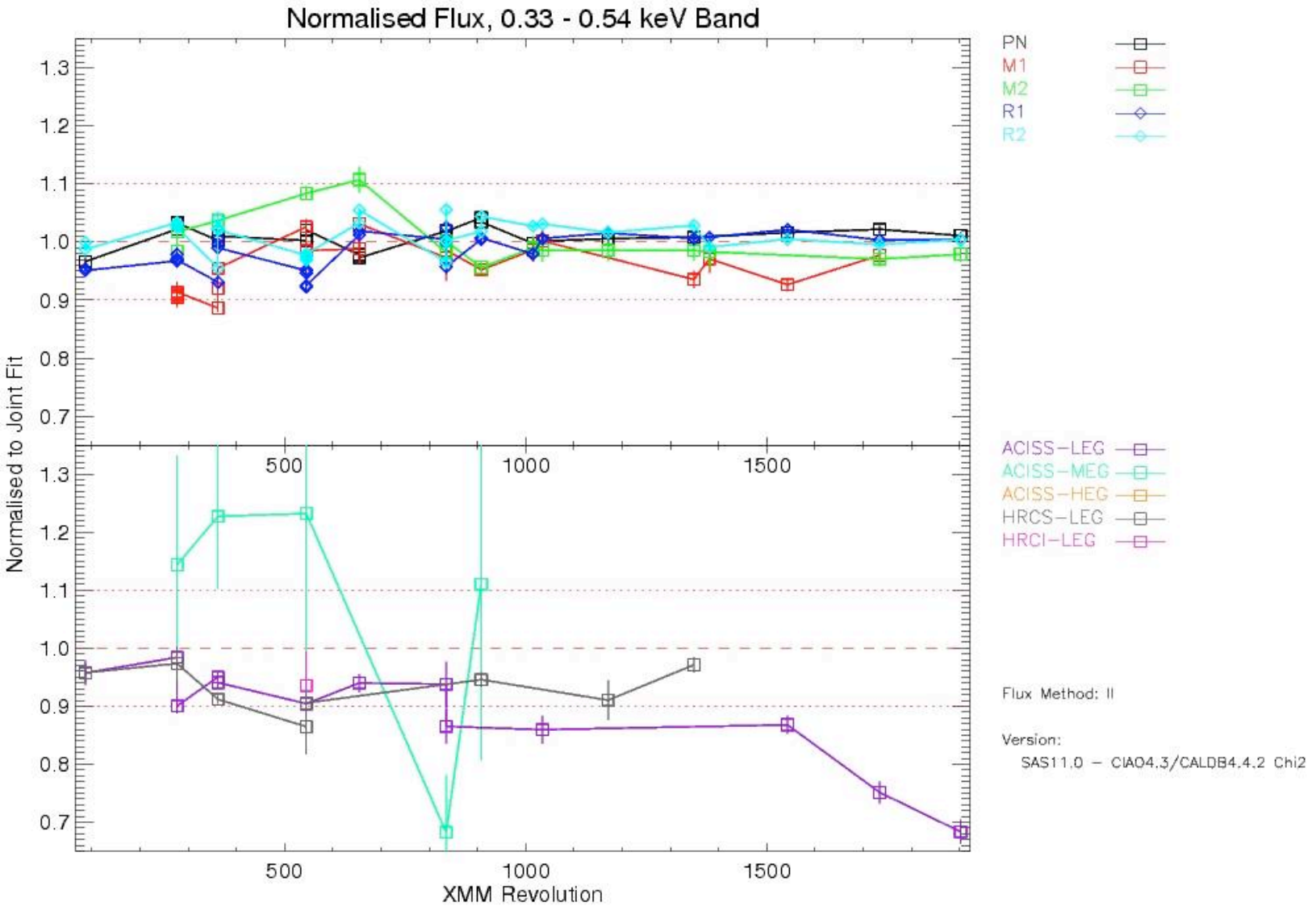
0.33 - 0.54 keV Old



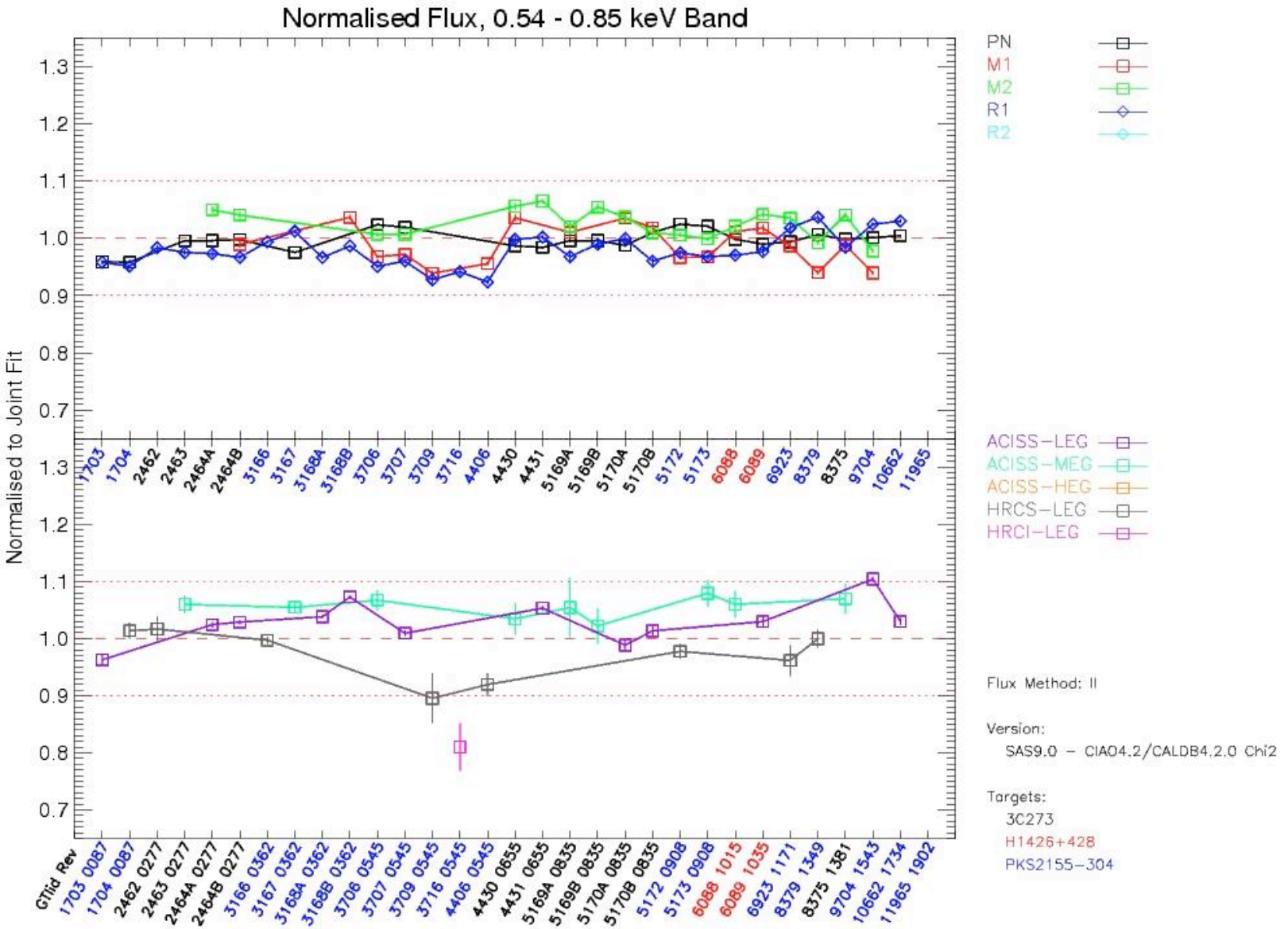
0.33 - 0.54 keV New



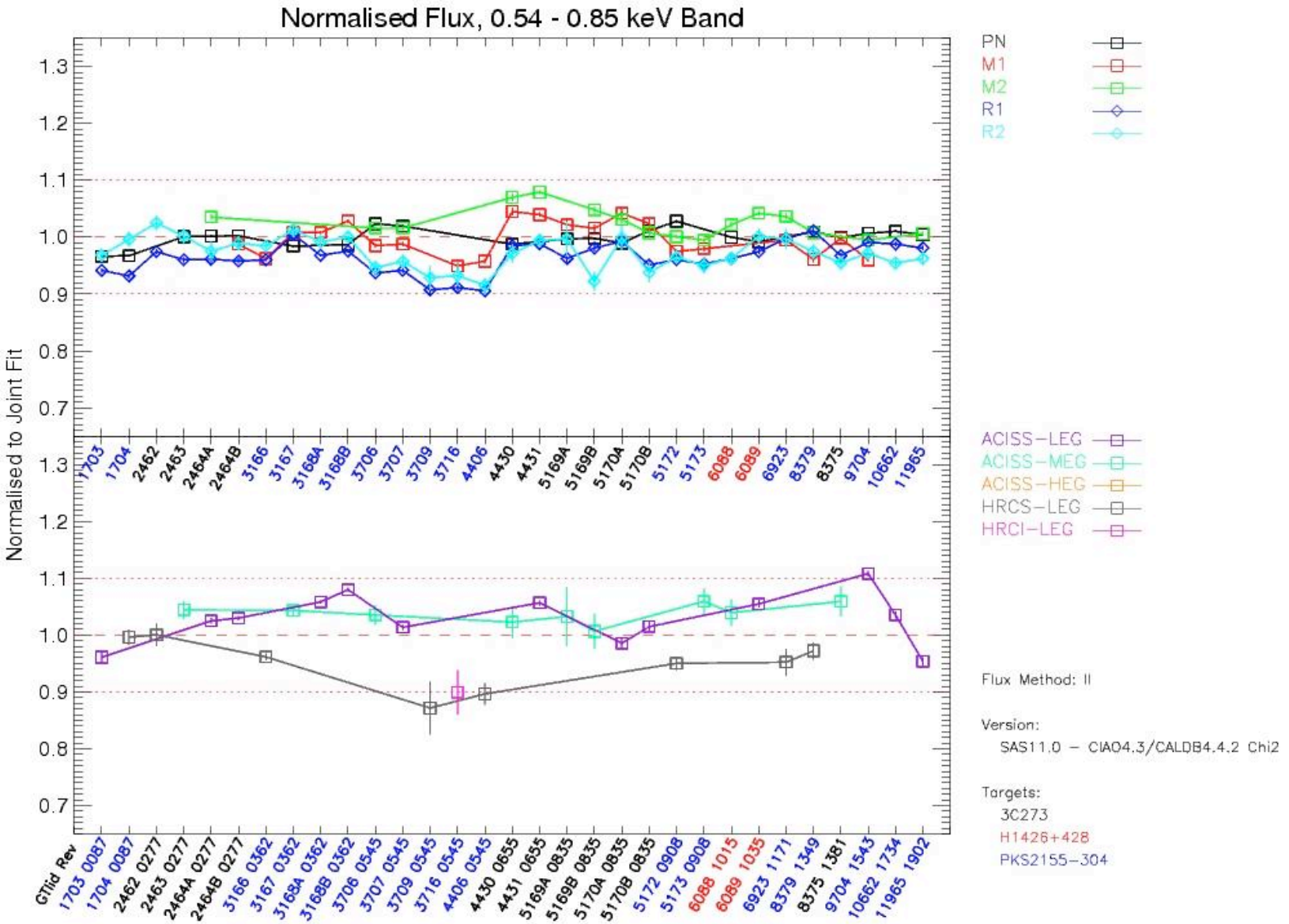
0.33 - 0.54 keV New



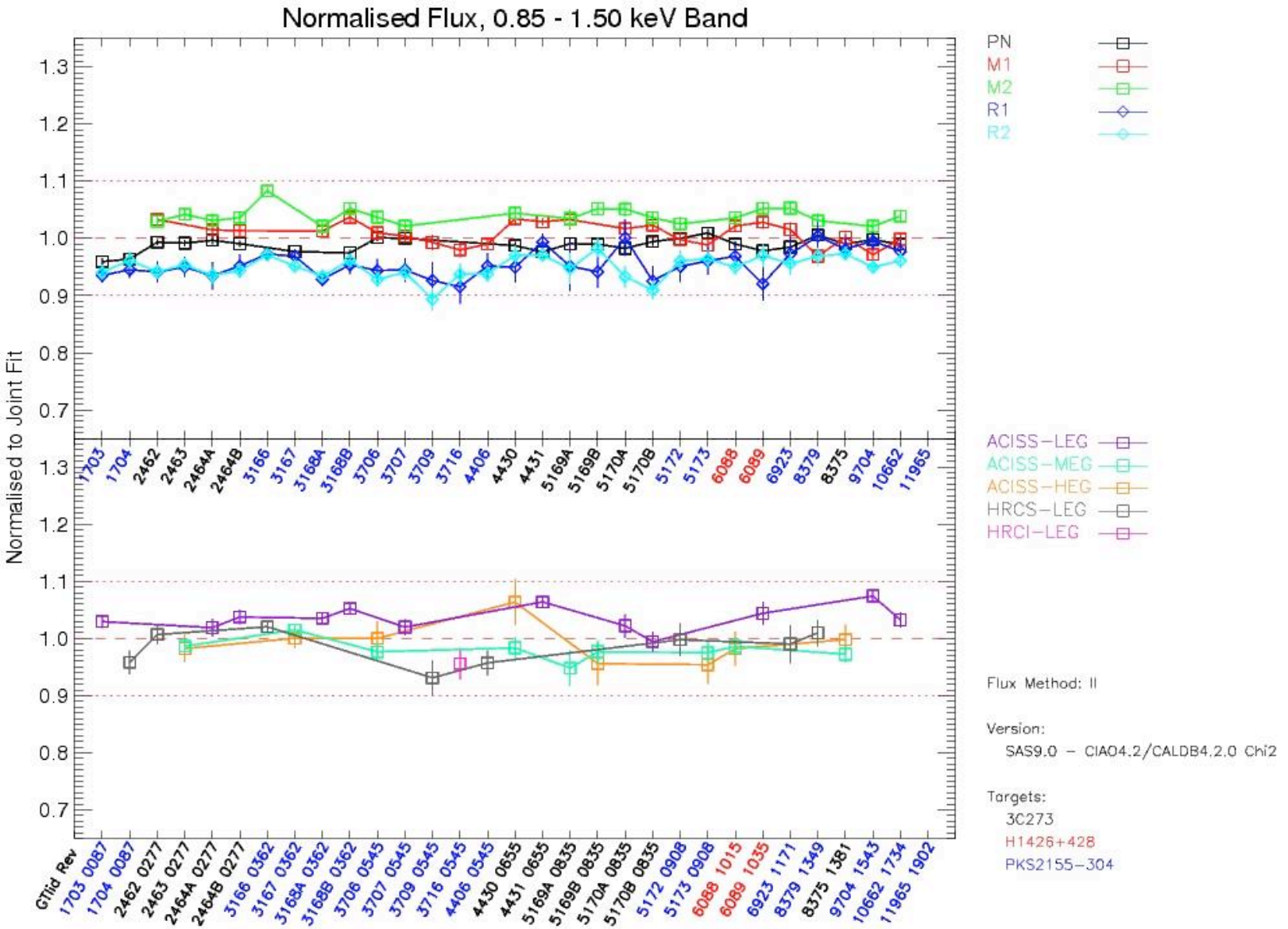
0.54 - 0.85 keV Old



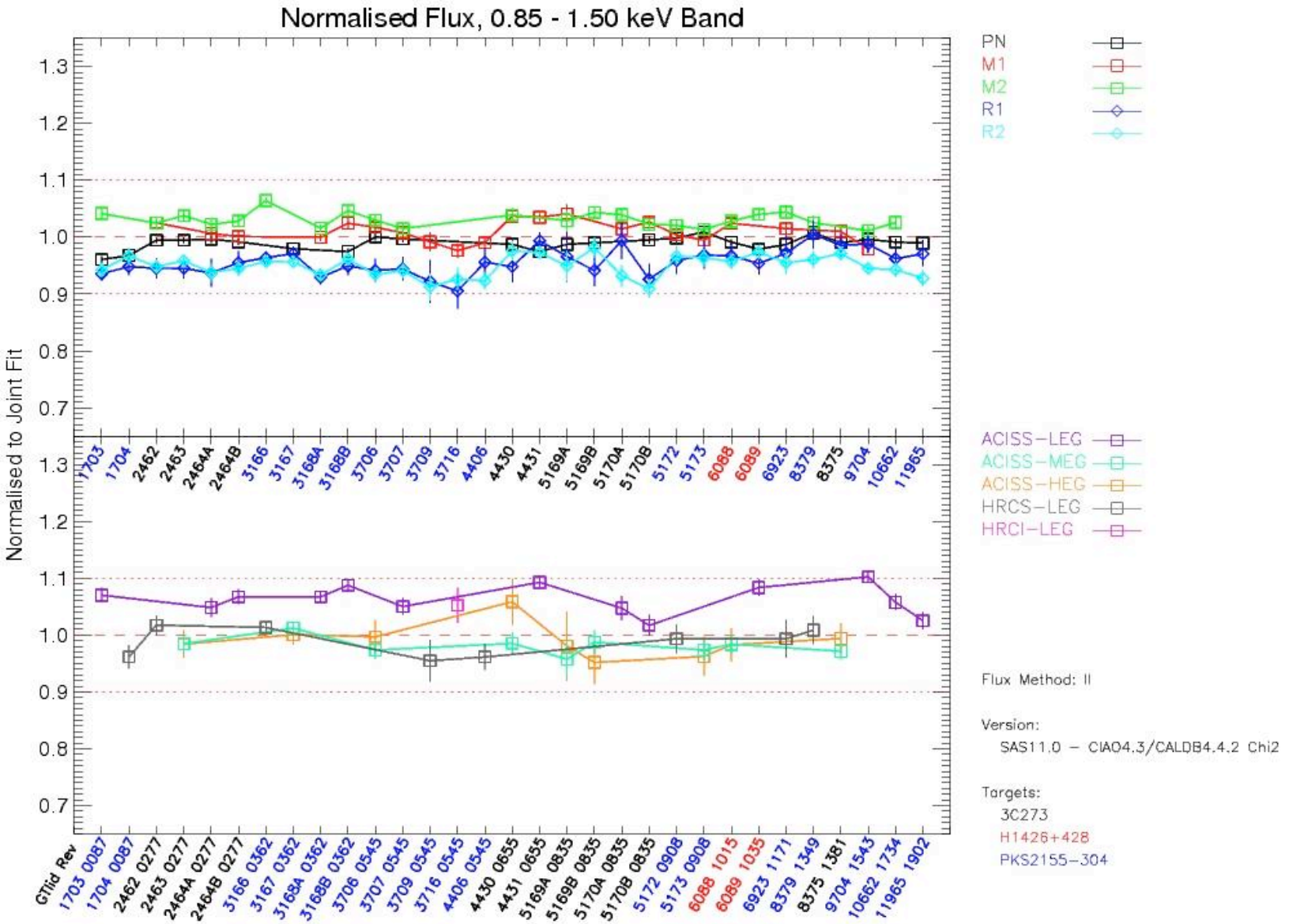
0.54 - 0.85 keV New



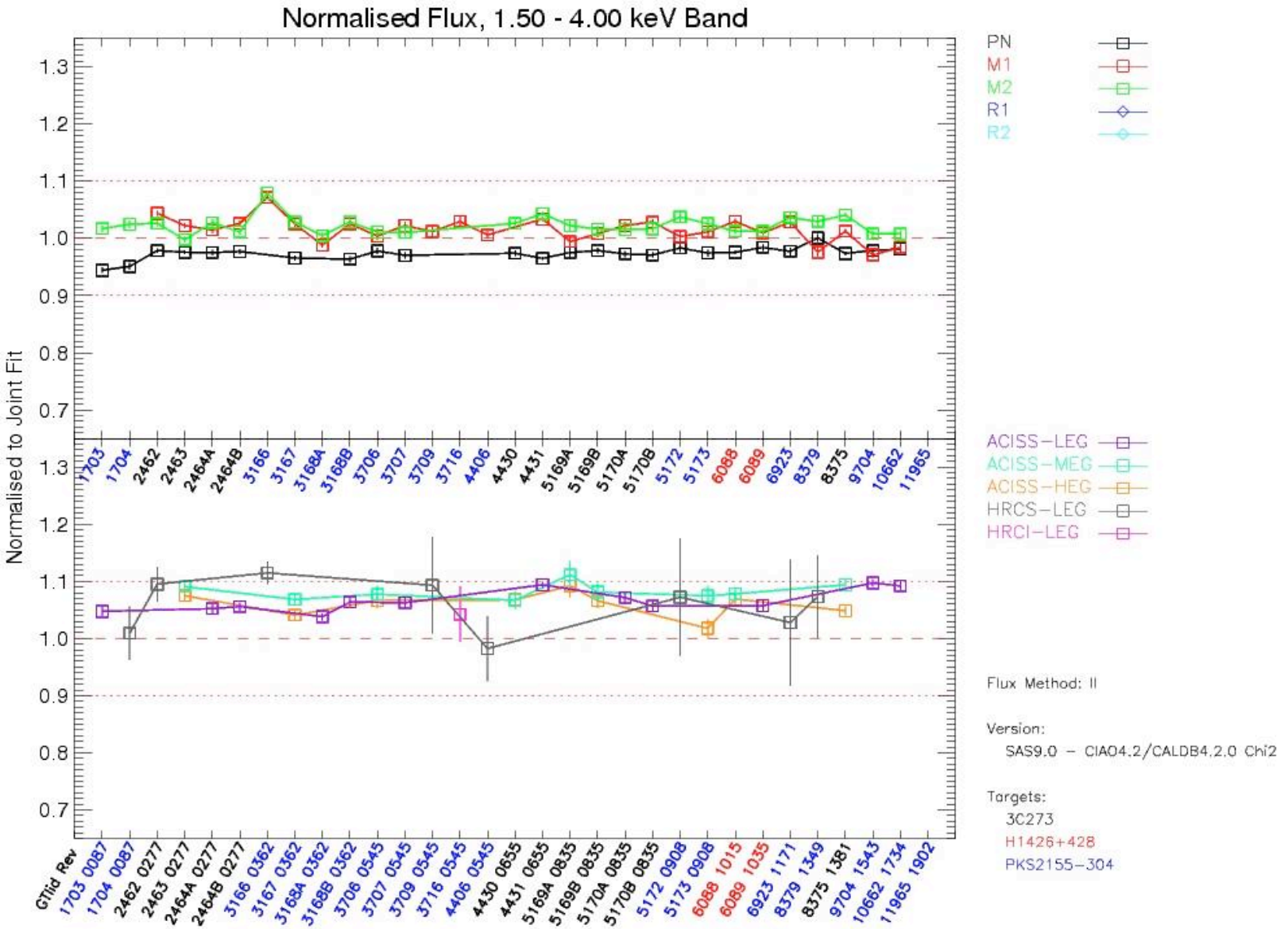
0.85 - 1.50 keV Old



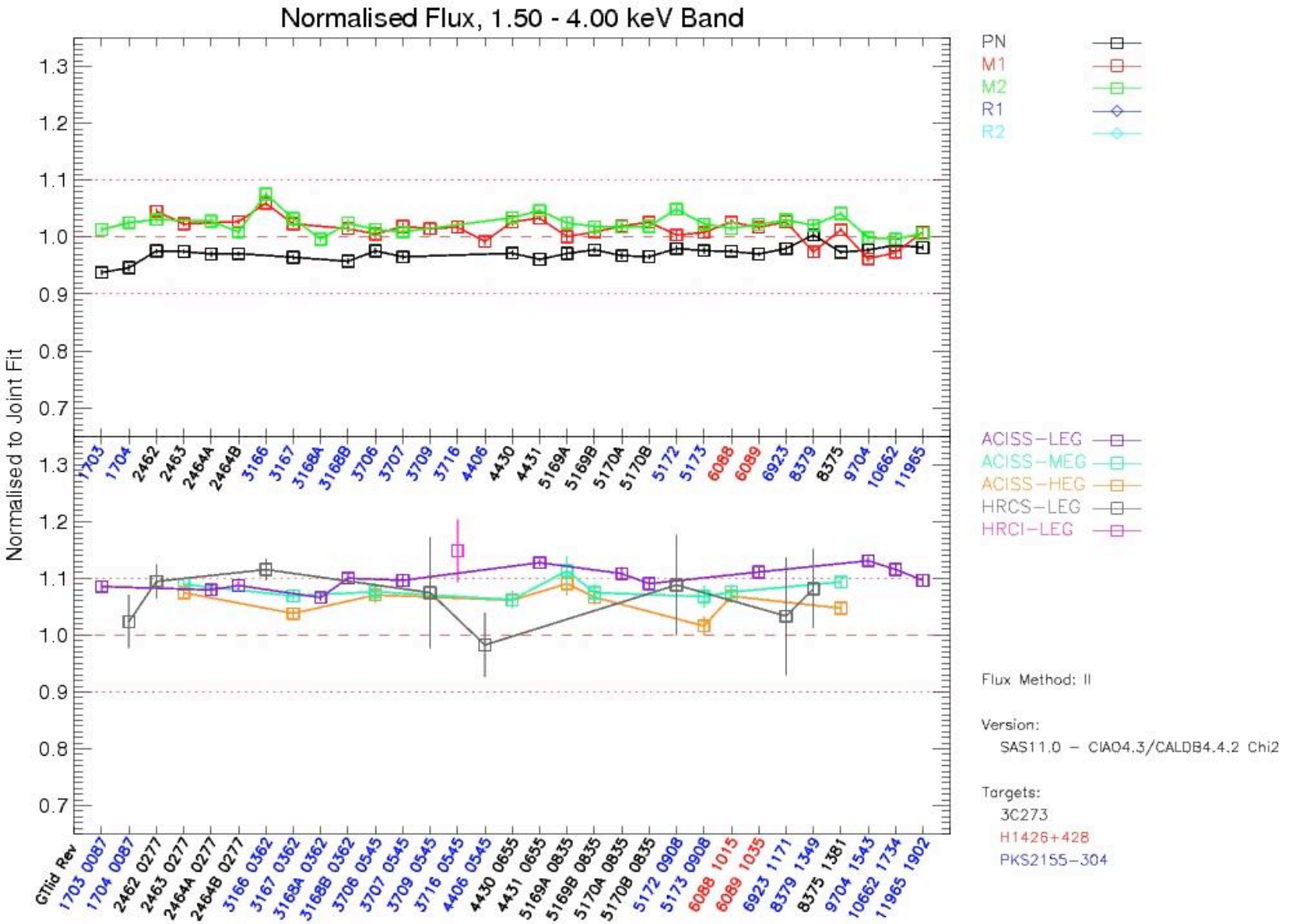
0.85 - 1.50 keV New



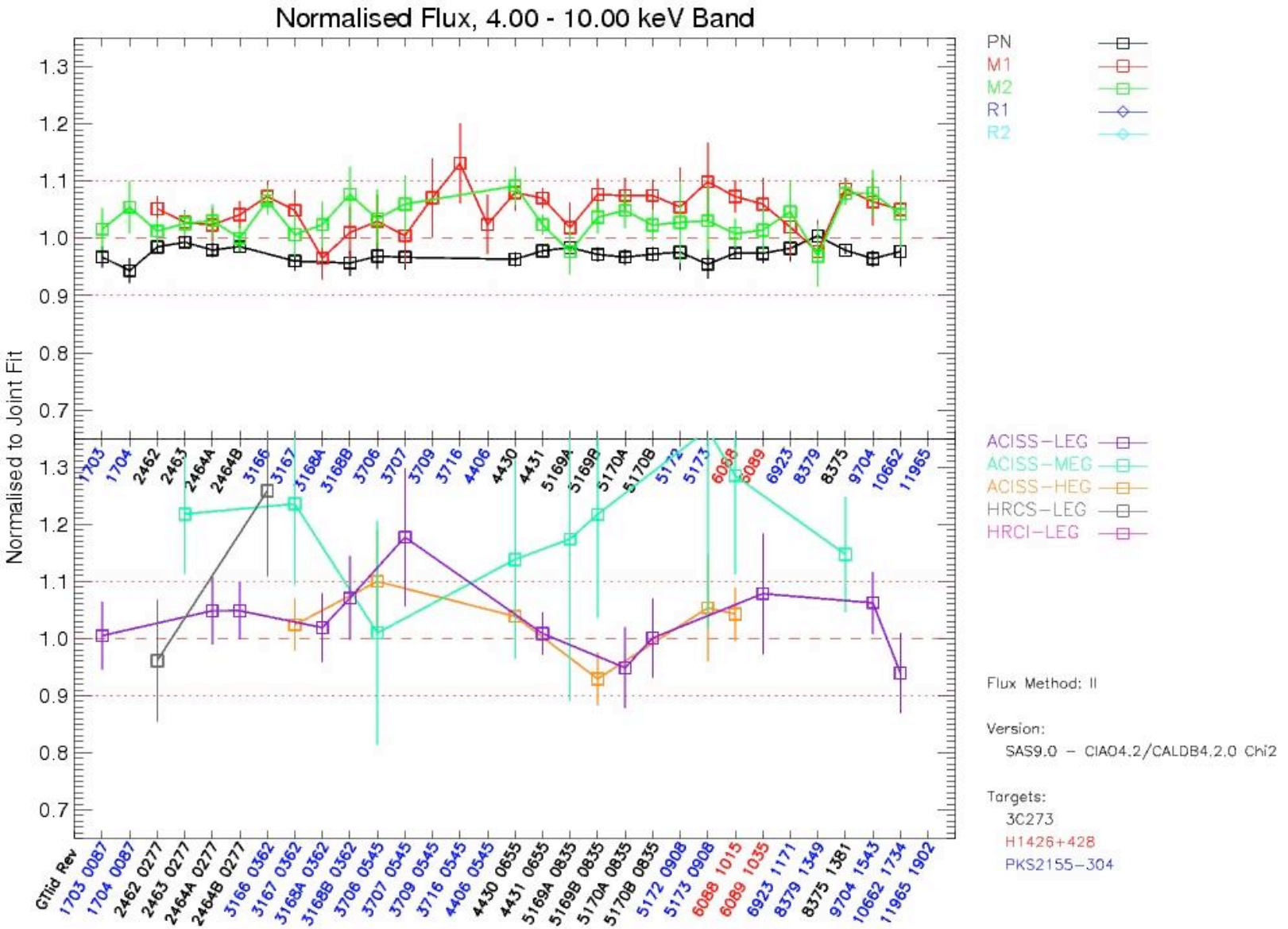
1.50 - 4.00 keV Old



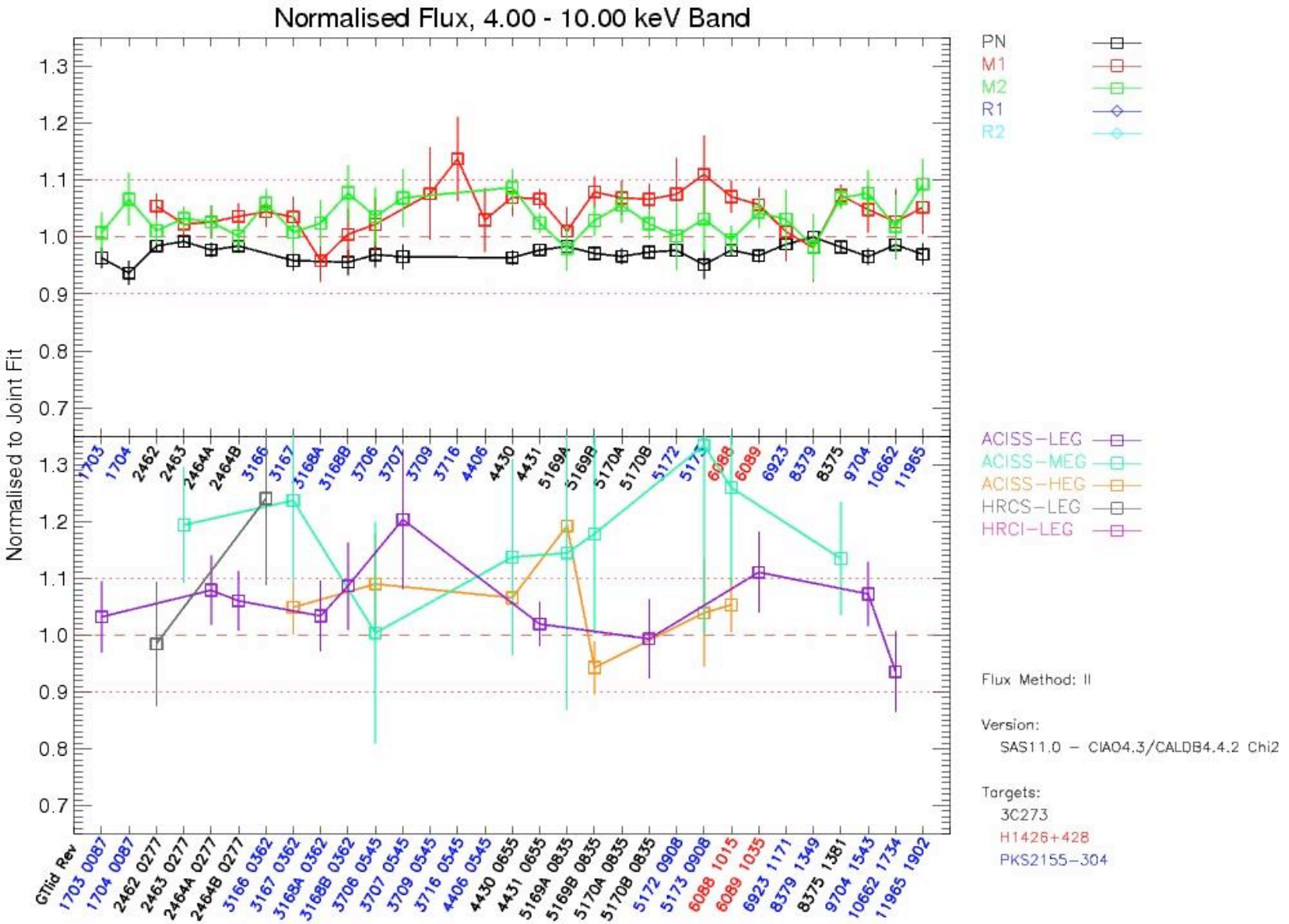
1.50 - 4.00 keV New



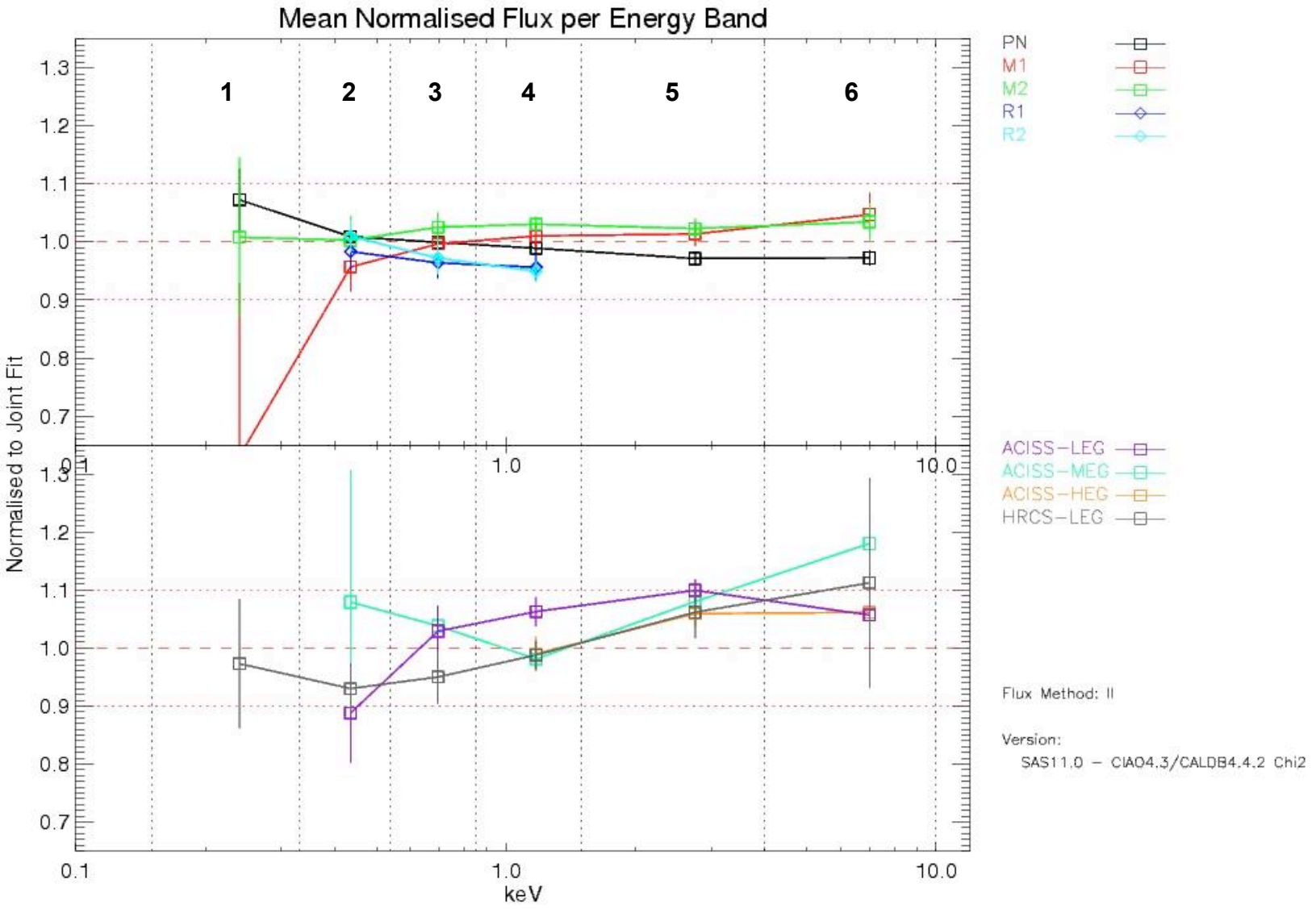
4.00 – 10.0 keV Old



4.00 - 10.0 keV New



Mean Relative Flux



Comparison with Tsujimoto et al. G21.5-0.9 XCal

Table 3. Relative flux among soft-band instruments[a].

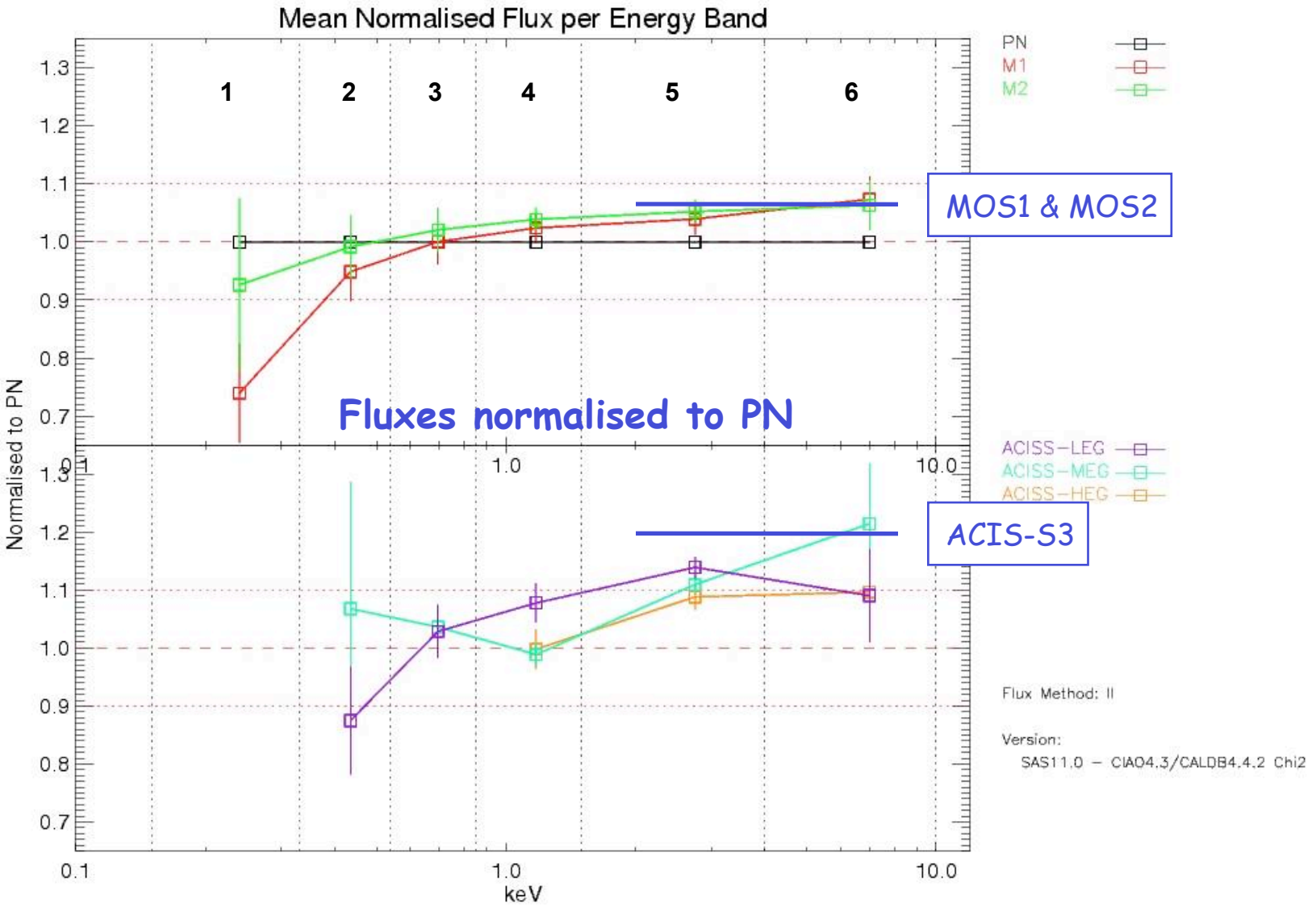
		A							
		ACIS-S3	XIS0	XIS1	XIS3	XRT	MOS1	MOS2	pn
B	ACIS-S3	0.00	**7.49 ± 0.62**	**5.60 ± 0.60**	**6.88 ± 0.62**	**7.75 ± 0.86**	**10.26 ± 0.60**	**12.05 ± 0.61**	**17.76 ± 0.47**
	XIS0	**−7.49 ± 0.62**	0.00	−1.89 ± 0.74	−0.60 ± 0.75	0.27 ± 0.96	**2.78 ± 0.74**	**4.57 ± 0.75**	**10.28 ± 0.64**
	XIS1	**−5.60 ± 0.60**	1.89 ± 0.74	0.00	1.28 ± 0.74	2.15 ± 0.95	**4.66 ± 0.73**	**6.45 ± 0.73**	**12.16 ± 0.62**
	XIS3	**−6.88 ± 0.62**	0.60 ± 0.75	−1.28 ± 0.74	0.00	0.87 ± 0.96	**3.38 ± 0.74**	**5.17 ± 0.74**	**10.88 ± 0.63**
	XRT	**−7.75 ± 0.86**	−0.27 ± 0.96	−2.15 ± 0.95	−0.87 ± 0.96	0.00	2.51 ± 0.95	**4.30 ± 0.96**	**10.01 ± 0.87**
	MOS1	**−10.26 ± 0.60**	**−2.78 ± 0.74**	**−4.66 ± 0.73**	**−3.38 ± 0.74**	−2.51 ± 0.95	0.00	1.79 ± 0.73	**7.50 ± 0.62**
	MOS2	**−12.05 ± 0.61**	**−4.57 ± 0.75**	**−6.45 ± 0.73**	**−5.17 ± 0.74**	**−4.30 ± 0.96**	−1.79 ± 0.73	0.00	**5.71 ± 0.63**
	pn	**−17.76 ± 0.47**	**−10.28 ± 0.64**	**−12.16 ± 0.62**	**−10.88 ± 0.63**	**−10.01 ± 0.87**	**−7.50 ± 0.62**	**−5.71 ± 0.63**	0.00

Notes. [a] The logarithmic flux ratio $100 \times \ln\left(F_X^{(B)}/F_X^{(A)}\right)$ between the soft-band instruments A and B. The flux is measured in the 2.0–8.0 keV band. The range indicates the convolved statistical uncertainty derived as $100 \times \sqrt{\left(\frac{\Delta F_X^{(A)}}{F_X^{(A)}}\right)^2 + \left(\frac{\Delta F_X^{(B)}}{F_X^{(B)}}\right)^2}$. Both the ratio and its deviation are multiplied by 100 to save space. The uncertainties $\Delta F_X^{(A)}$ and $\Delta F_X^{(B)}$ are the mean of the 1σ statistical uncertainties in the upper and lower bound directions (Table 2). The bold face indicates that the difference is larger than 3 times the convolved statistical uncertainty.

M. Tsujimoto et al., A&A 525, A25 (2011)

- Soft band fluxes derived in the 2 – 8 keV band
- Chandra fluxes derived from ACIS-S3 chip
- Calibration files: Aug 2010 CCFs for XMM, CALDB 4.2 for Chandra

Comparison with Tsujimoto et al. G21.5-0.9 XCal



Summary / Conclusions

- Flux comparison method fails in band 0.15 - 0.33 keV, due to bad EPIC fits.

- XMM-Newton:
  - RGS flux time dependence has been corrected
  - PN, MOS2 and RGS consistent within 5% in 0.54 – 0.85 keV band.
  - Diverging trend towards higher energies, with RGS down 5% w.r.t. PN, and MOS up 5-7% w.r.t. PN

- Chandra:
  - ACISS-LETG shows significant flux deficit in the 0.33 - 0.54 band since May 2009
  - Fluxes show a trend: 0-10% deficit w.r.t. joint-fit flux below ~ 1 keV and a 0-10% excess above 1 keV

- Where comparable, blazar results are consistent with Tsujimoto-san G21.5-0.9 results.