XMM-Newton — Chandra Blazar Flux Comparison

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

IACHEC, 12-15 May 2014

Blazar Sample

- Objective: cross calibration of XMM-Newton — Chandra effective areas by comparing instrumental fluxes in various bands.
- Data: sample of Blazars observed simultaneously XMM and Chandra:
  - **PKS 2155-304**, **3C 273**, **H 1426+428**

Blazar Sample

- Objective: cross calibration of XMM-Newton — Chandra effective areas by comparing instrumental fluxes in various bands.
- Data: sample of Blazars observed simultaneously XMM and Chandra:
  - **PKS 2155-304**, **3C 273**, **H 1426+428**
- Featureless spectra over 0.1 – 10.0 keV
- Bright:
  - piled-up in EPIC -> PSF core excision introduces added uncertainty in flux determination
- Highly variable, even within observation timescale:
  - require XMM / Chandra / … coordinated observations
  - simultaneous GTIs across instruments
  - normalise fluxes to compare between observations

Blazar Sample

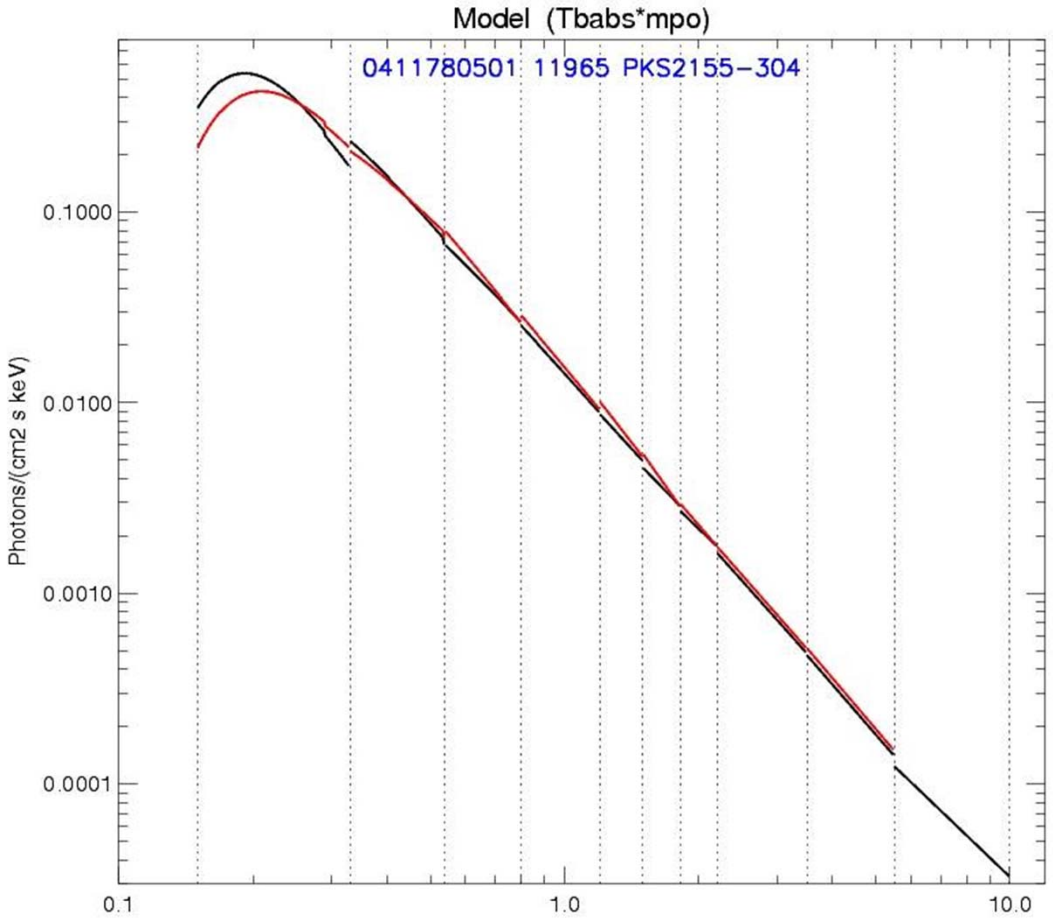
- Objective: cross calibration of XMM-Newton — Chandra effective areas by comparing instrumental fluxes in various bands.
- Data: sample of Blazars observed simultaneously XMM and Chandra:
  - **PKS 2155-304**, **3C 273**, **H 1426+428**
- Featureless spectra over 0.1 – 10.0 keV
- Bright:
  - piled-up in EPIC -> PSF core excision introduces added uncertainty in flux determination
- Highly variable, even within observation timescale:
  - require XMM / Chandra / … coordinated observations
  - simultaneous GTIs across instruments
  - normalise fluxes to compare between observations
- 21 XMM-Newton observations coordinated with Chandra:
  - 36 strictly simultaneous GTIs for flux comparison
- Instruments being compared are:
  - **EPIC**, **RGS**, **ACISS-L/HETG**, **HRCS-LETG**

Data Analysis (I)

- Energy bands:
  - 0.15 – 0.33 keV (Lower EPIC - Lower RGS bound)
  - 0.33 – 0.54 keV (Up to the O-edge)
  - 0.54 – 0.85 keV
  - 0.80 – 1.20 keV O-VII/VIII , Ne-IX/X
  - 1.20 – 1.50 keV
  - 1.50 – 1.82 keV (Up to the Si-edge)
  - 1.82 – 2.20 keV (Up to the Au-edge)
  - 2.20 – 3.50 keV
  - 3.50 – 5.50 keV
  - 5.50 – 10.0 keV

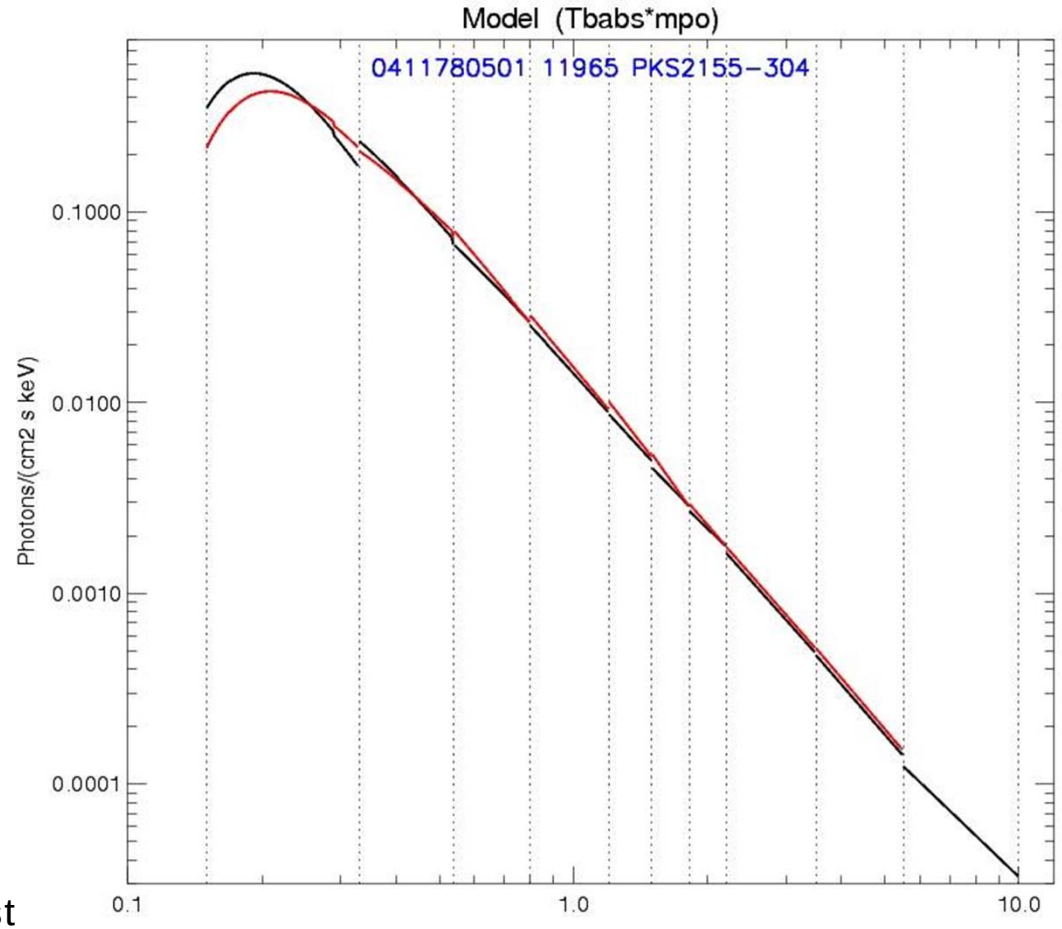
Data Analysis (I)

- Energy bands:
  - 0.15 – 0.33 keV (Lower EPIC - Lower RGS bound)
  - 0.33 – 0.54 keV (Up to the O-edge)
  - 0.54 – 0.85 keV
  - 0.80 – 1.20 keV O-VII/VIII , Ne-IX/X
  - 1.20 – 1.50 keV
  - 1.50 – 1.82 keV (Up to the Si-edge)
  - 1.82 – 2.20 keV (Up to the Au-edge)
  - 2.20 – 3.50 keV
  - 3.50 – 5.50 keV
  - 5.50 – 10.0 keV
- Spectral fitting: model consists of:
  - multiple independent power laws
  - absorption with nH fixed
    - PKS 2155-304: 1.42 x 10^{20} cm^{-2}
    - 3C 273: 1.79 x 10^{20} cm^{-2}
    - H 1426+428: 1.36 x 10^{20} cm^{-2}



Data Analysis (I)

- Energy bands:
  - 0.15 – 0.33 keV (Lower EPIC - Lower RGS bound)
  - 0.33 – 0.54 keV (Up to the O-edge)
  - 0.54 – 0.85 keV
  - 0.80 – 1.20 keV O-VII/VIII , Ne-IX/X
  - 1.20 – 1.50 keV
  - 1.50 – 1.82 keV (Up to the Si-edge)
  - 1.82 – 2.20 keV (Up to the Au-edge)
  - 2.20 – 3.50 keV
  - 3.50 – 5.50 keV
  - 5.50 – 10.0 keV
- Spectral fitting: model consists of:
  - multiple independent power laws
  - absorption with nH fixed
    - PKS 2155-304: 1.42 x 10^{20} cm^{-2}
    - 3C 273: 1.79 x 10^{20} cm^{-2}
    - H 1426+428: 1.36 x 10^{20} cm^{-2}
- Per simultaneous exposure:
  - fit each instrument independently
  - determine band fluxes from resulting best fits.



Data Analysis (II)

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

- Preferably use the same reference across all GTIs and bands. However, no instrument fulfills condition in every case:
  - PN & MOS: Timing Mode exposures not included in analysis;
  - RGS: no data in the lower or higher bands;
  - Chandra instrument configurations vary from exposure to exposure.

Data Analysis (II)

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

- Preferably use the same reference across all GTIs and bands. However, no instrument fulfills condition in every case:
  - PN & MOS: Timing Mode exposures not included in analysis;
  - RGS: no data in the lower or higher bands;
  - Chandra instrument configurations vary from exposure to exposure.

- Use as reference the **PN flux** measured in a particular exposure.

Data Analysis (II)

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

- Preferably use the same reference across all GTIs and bands. However, no instrument fulfills condition in every case:
  - PN & MOS: Timing Mode exposures not included in analysis;
  - RGS: no data in the lower or higher bands;
  - Chandra instrument configurations vary from exposure to exposure.

- Use as reference the **PN flux** measured in a particular exposure.

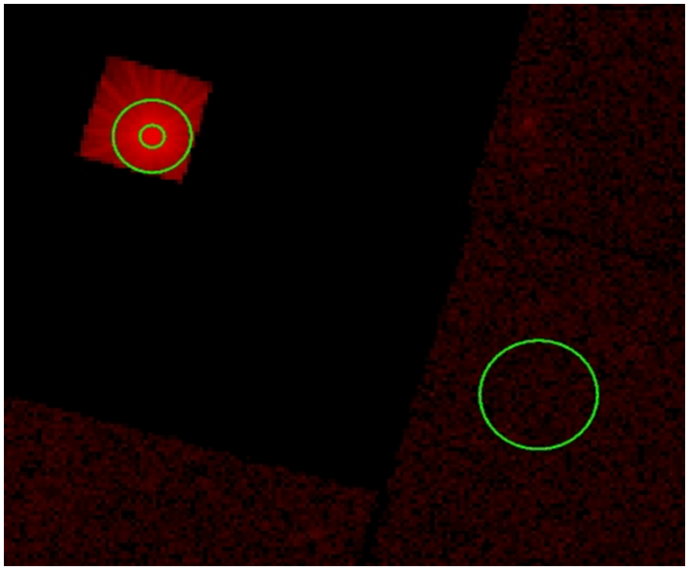
- For 36 simultaneous exposures: a total of 215 spectral fits.

- Data reduction:
  - SAS 13.5 + CCFs as of April 2014
  - CIAO 4.6.1 + CALDB 4.6.1

Data Analysis (III)

Systematic uncertainties:

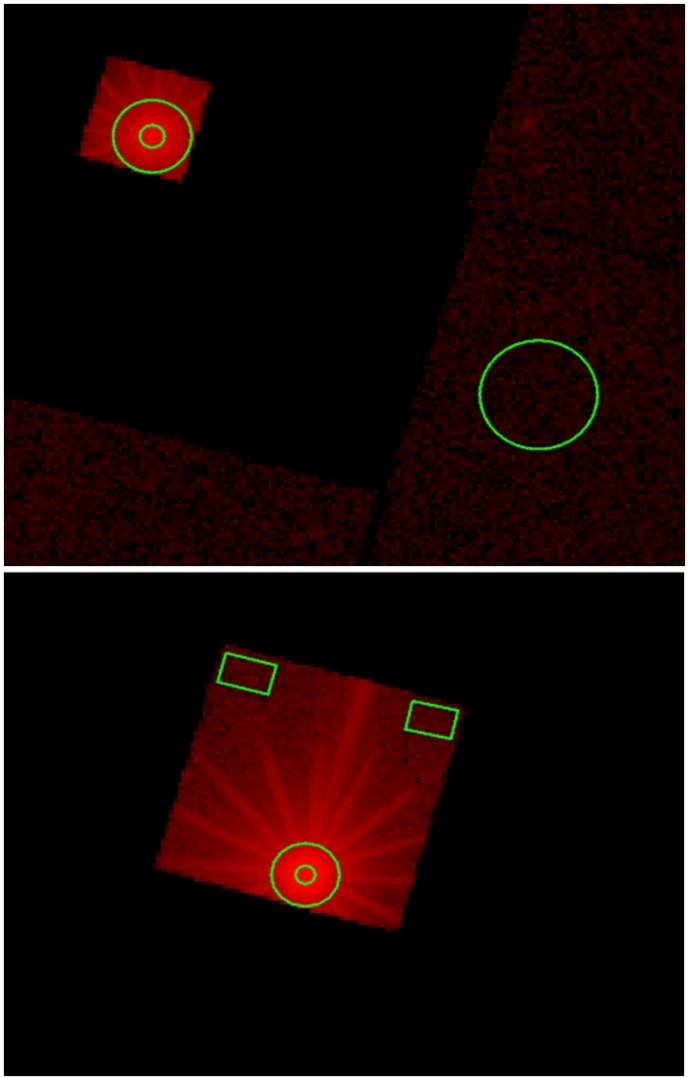
- Pile-up:
  - EPIC requires excision of PSF core: use source extraction annuli.
  - Per observation: for both MOSs use the largest common outer radius within window, and a common inner radius.
  - However, radii vary from observation to observation, and are generally different from the PN radii.
  - Differing annuli may introduce systematic uncertainties due to imperfect EE correction and RMF weighting.



Data Analysis (III)

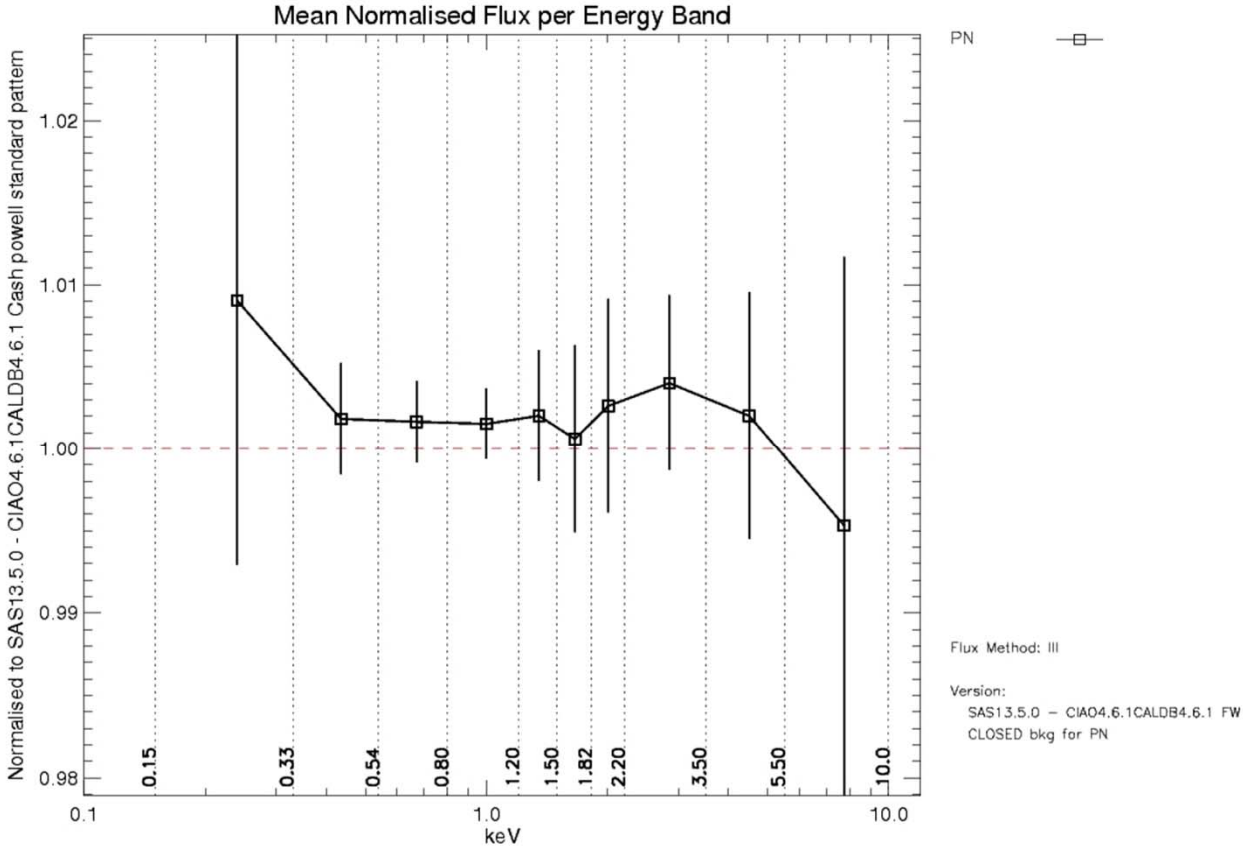
Systematic uncertainties:

- 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.

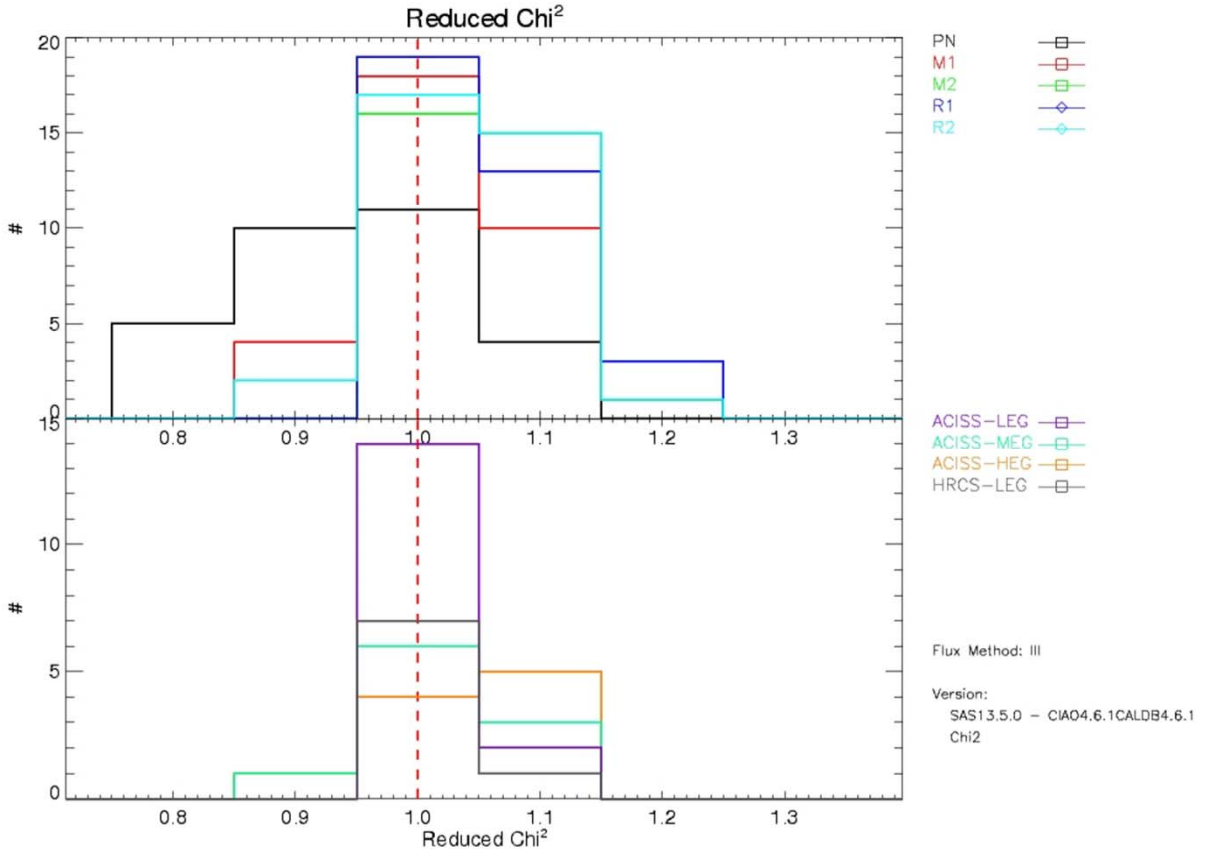


PN Background

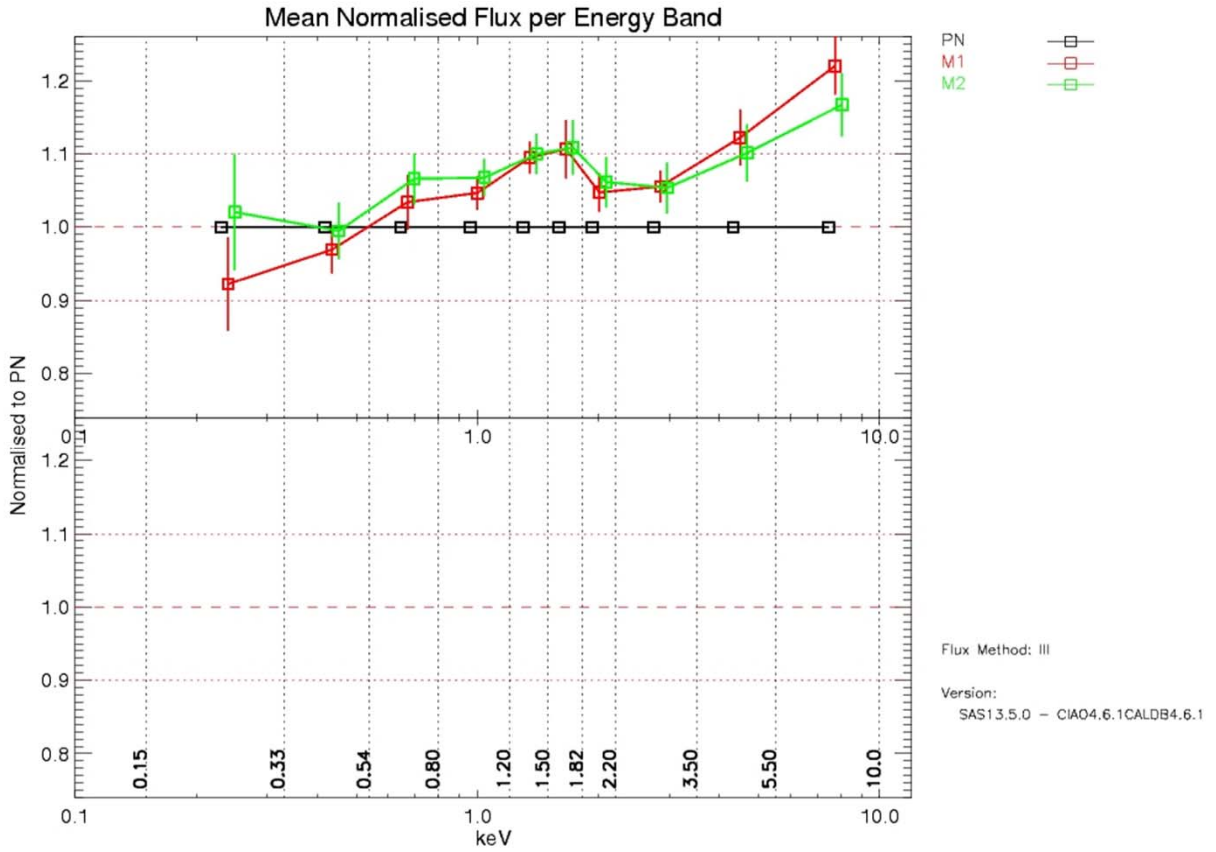
Mean ratio of PN fluxes derived with
CLOSED filter background to those using **observational background**



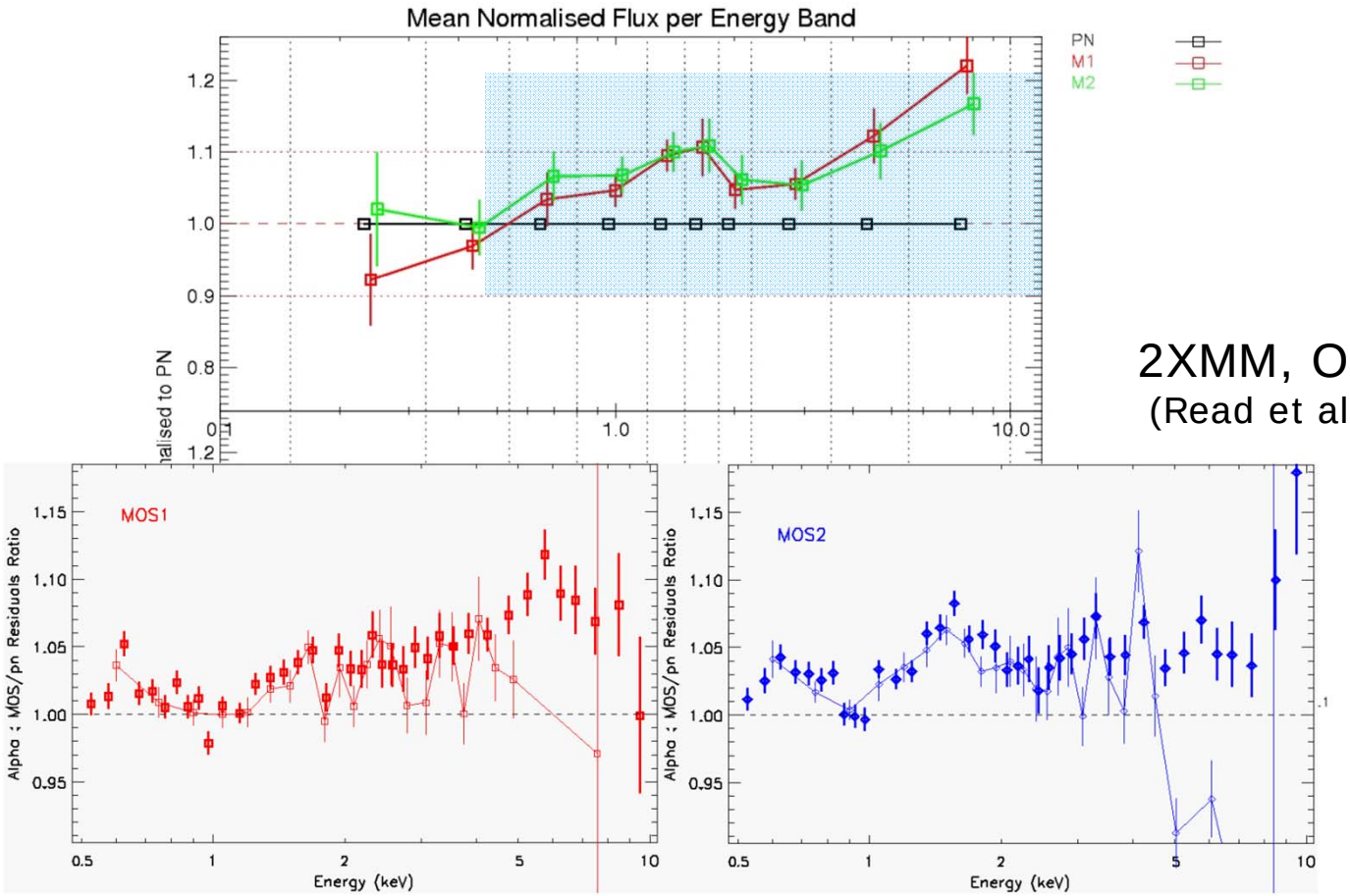
Data Analysis (IV)



Mean Normalised Fluxes

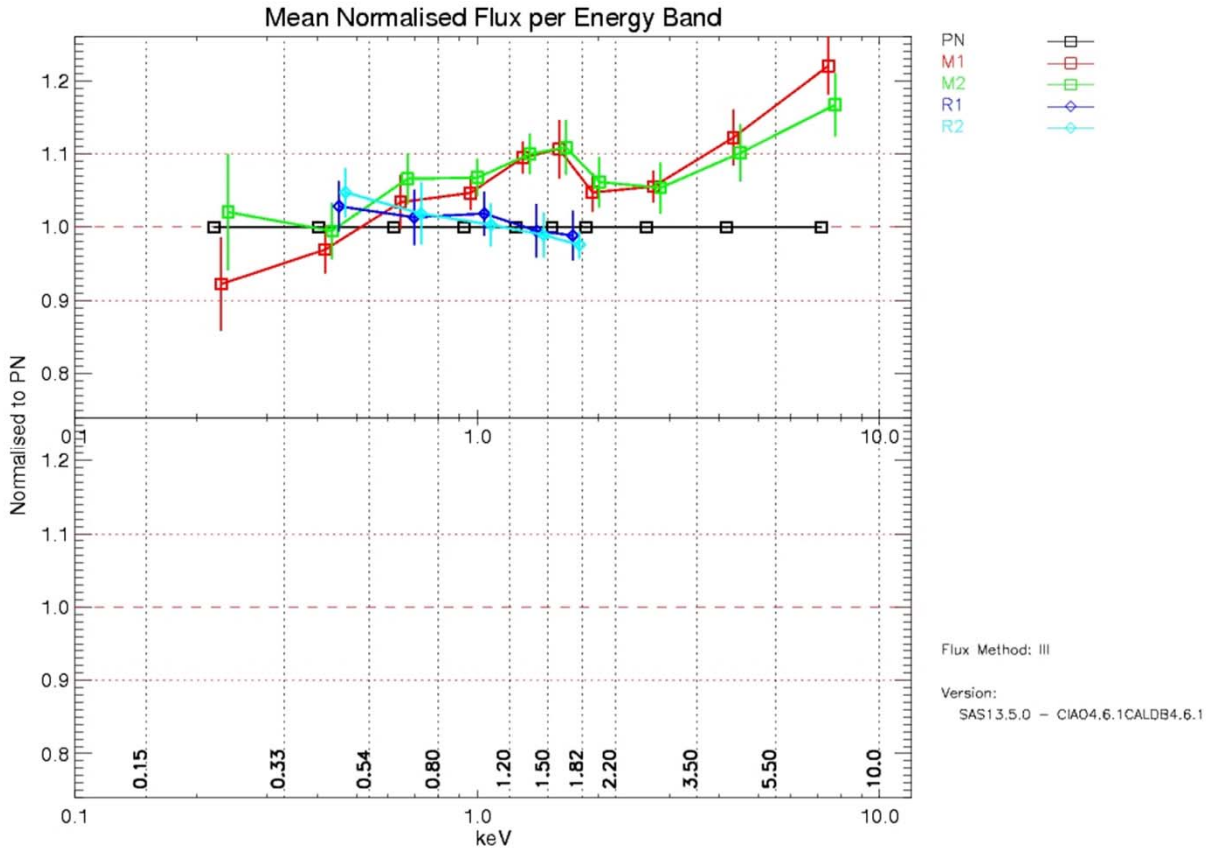


Mean Normalised Fluxes

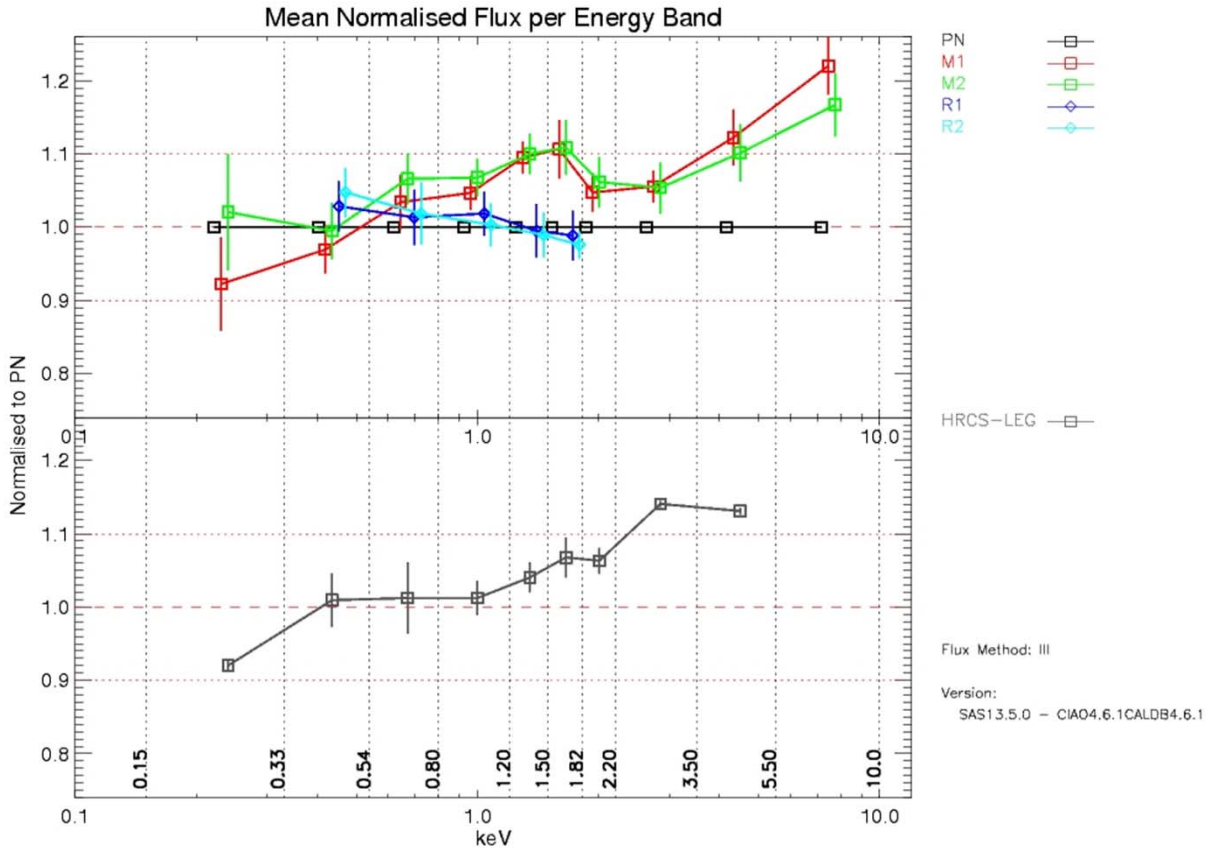


2XMM, On-Axis
(Read et al. 2014)

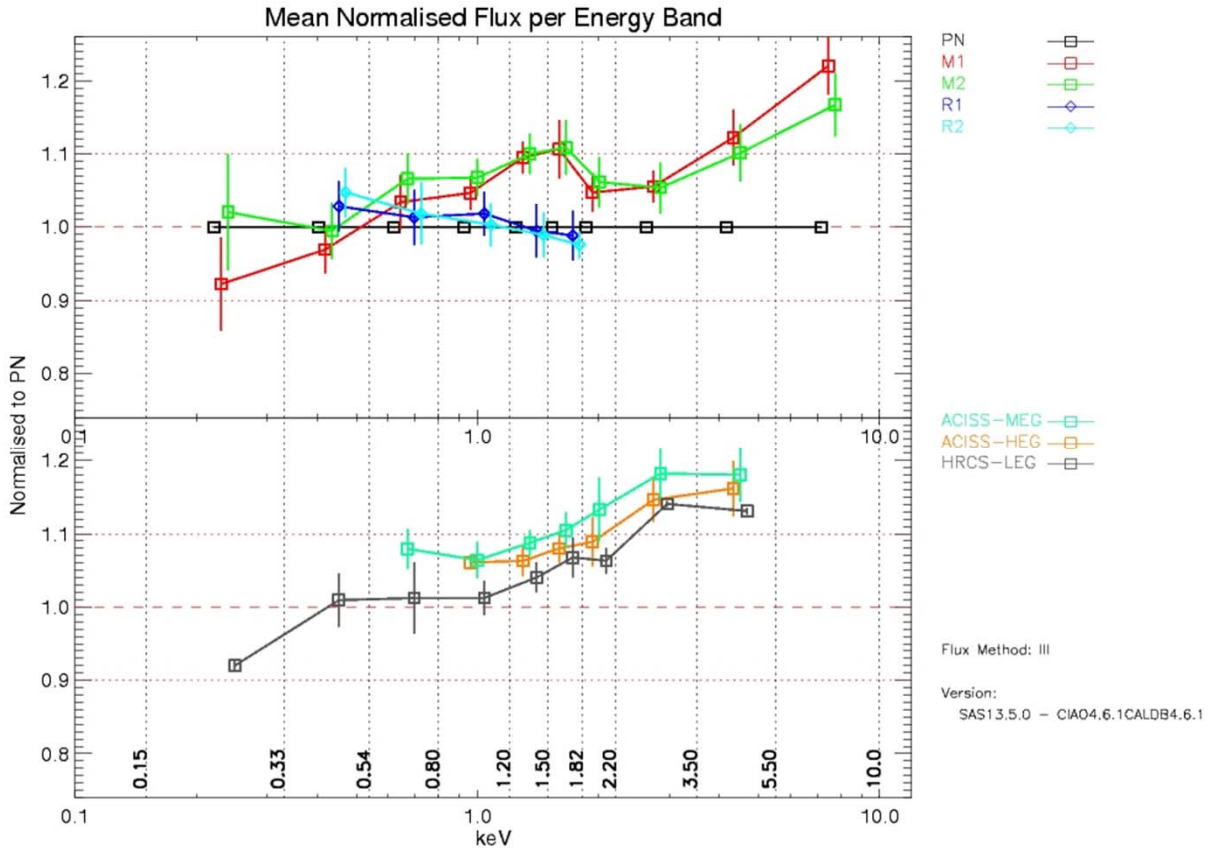
Mean Normalised Fluxes



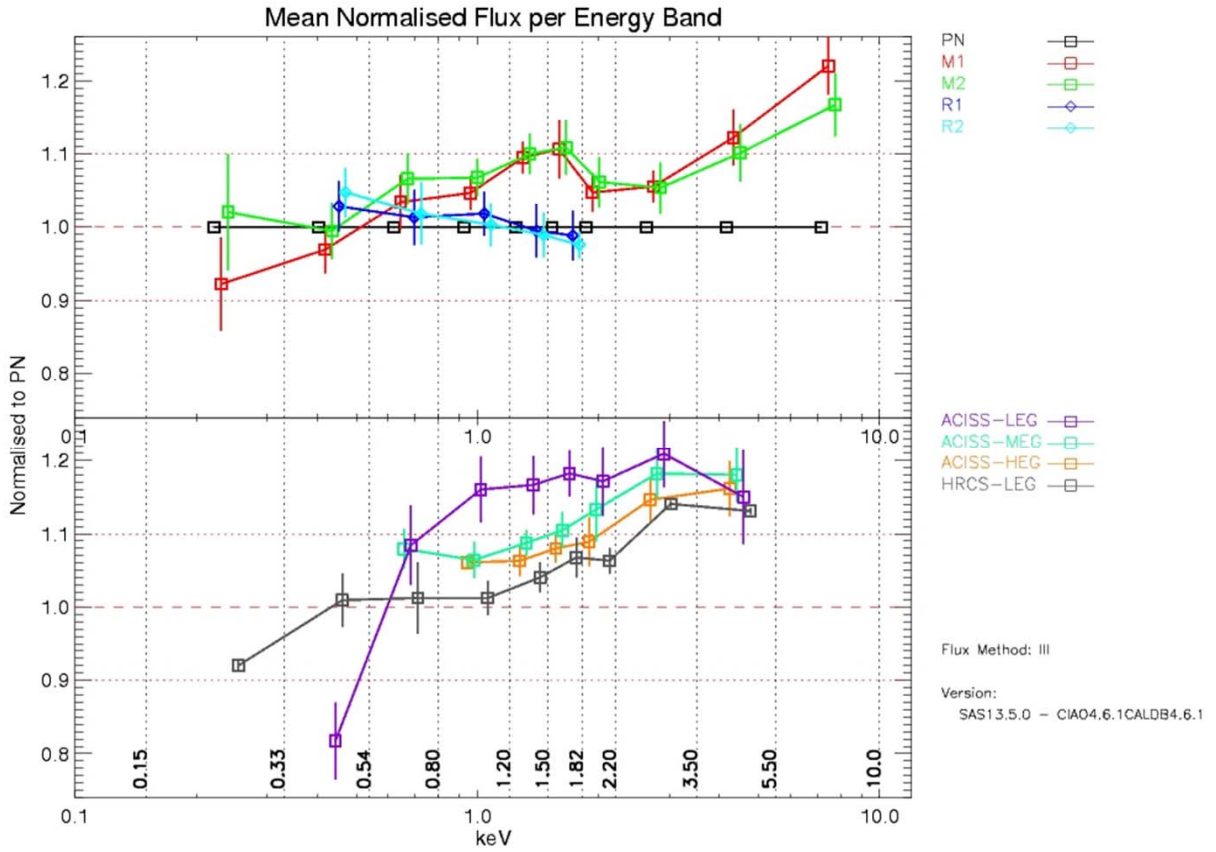
Mean Normalised Fluxes



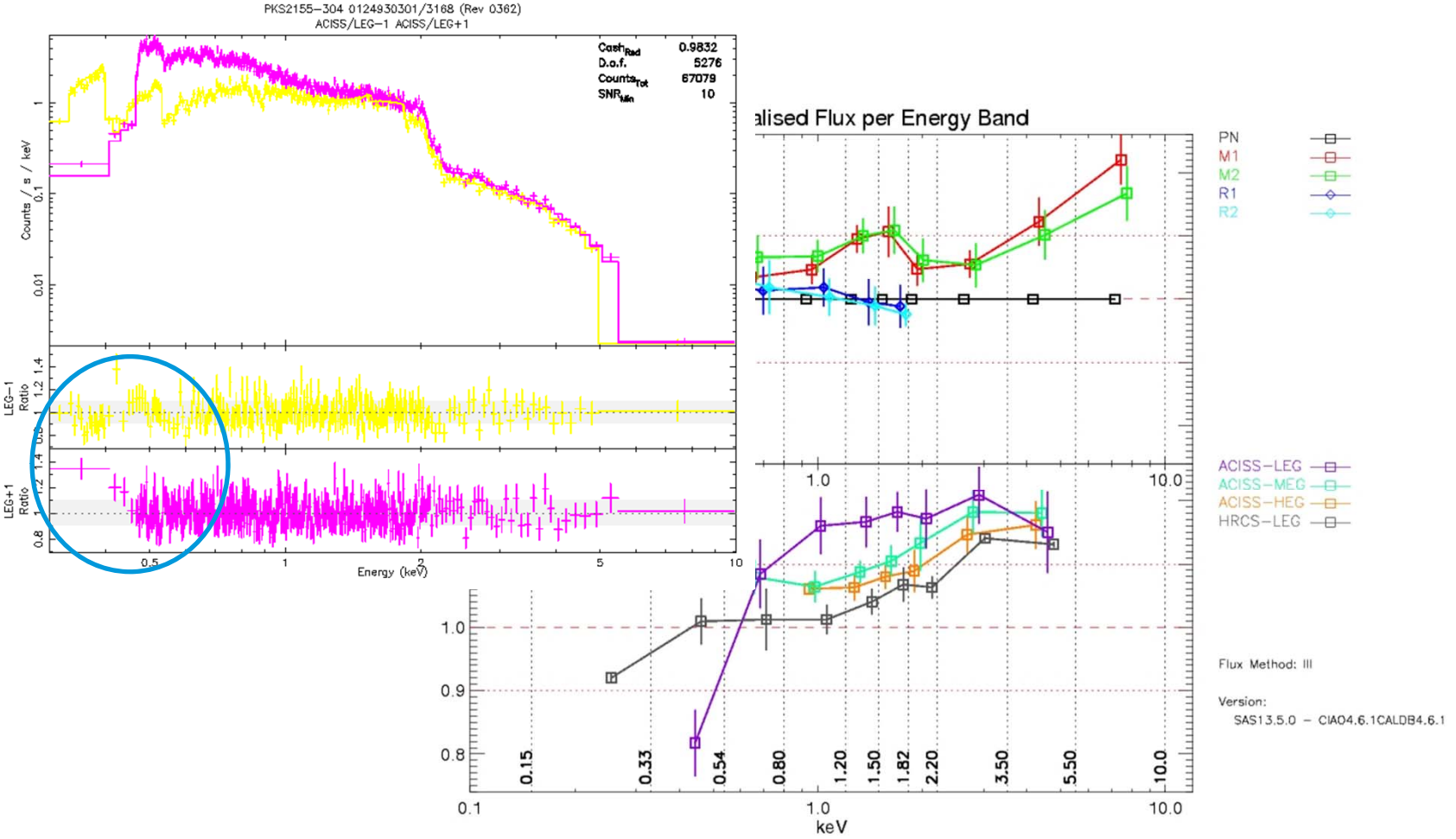
Mean Normalised Fluxes



Mean Normalised Fluxes



Mean Normalised Fluxes



Mean Normalised Fluxes