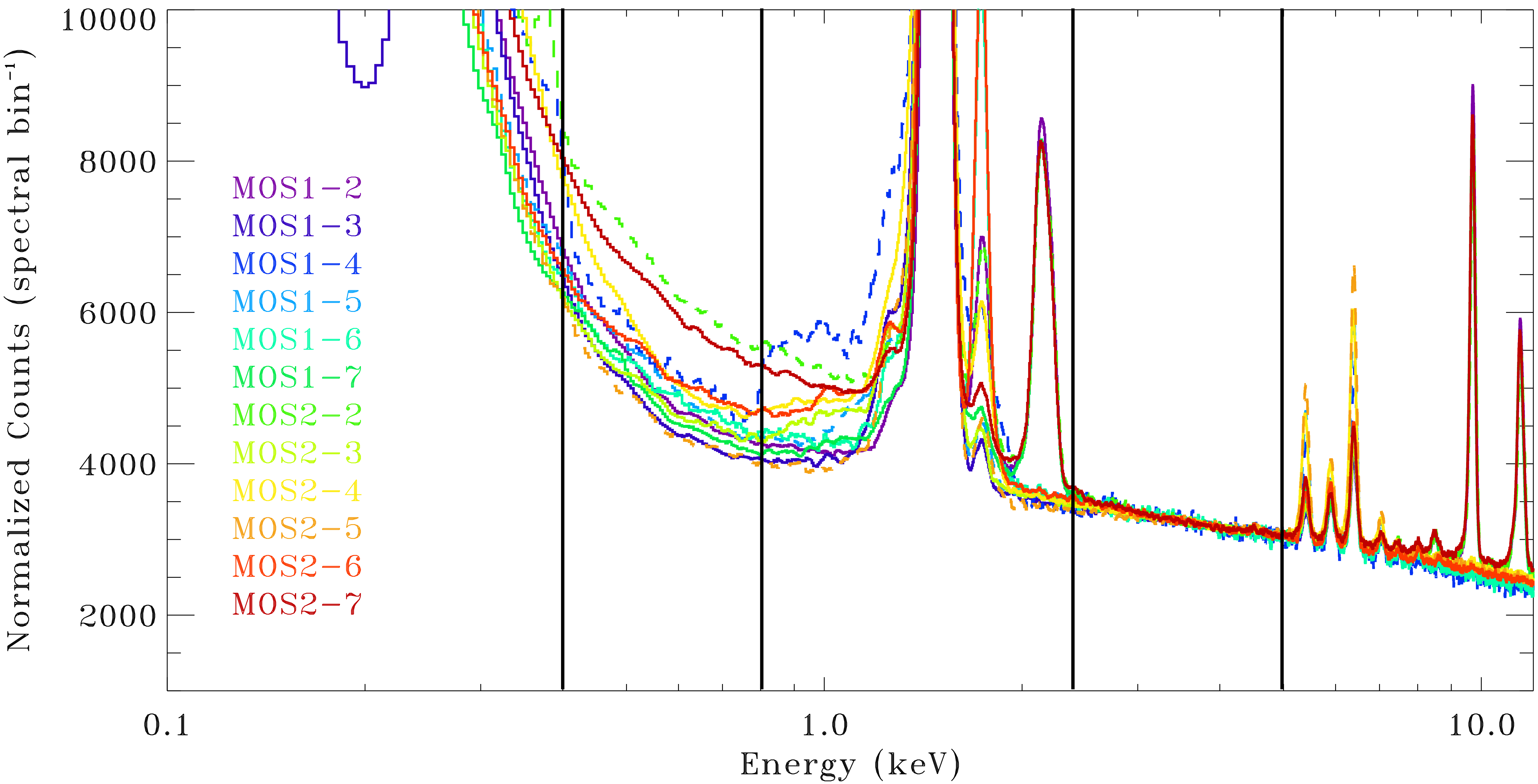
XMM-Newton Quiescent Particle Background

(Primarily a MOS perspective)

K.D. Kuntz & S.L. Snowden

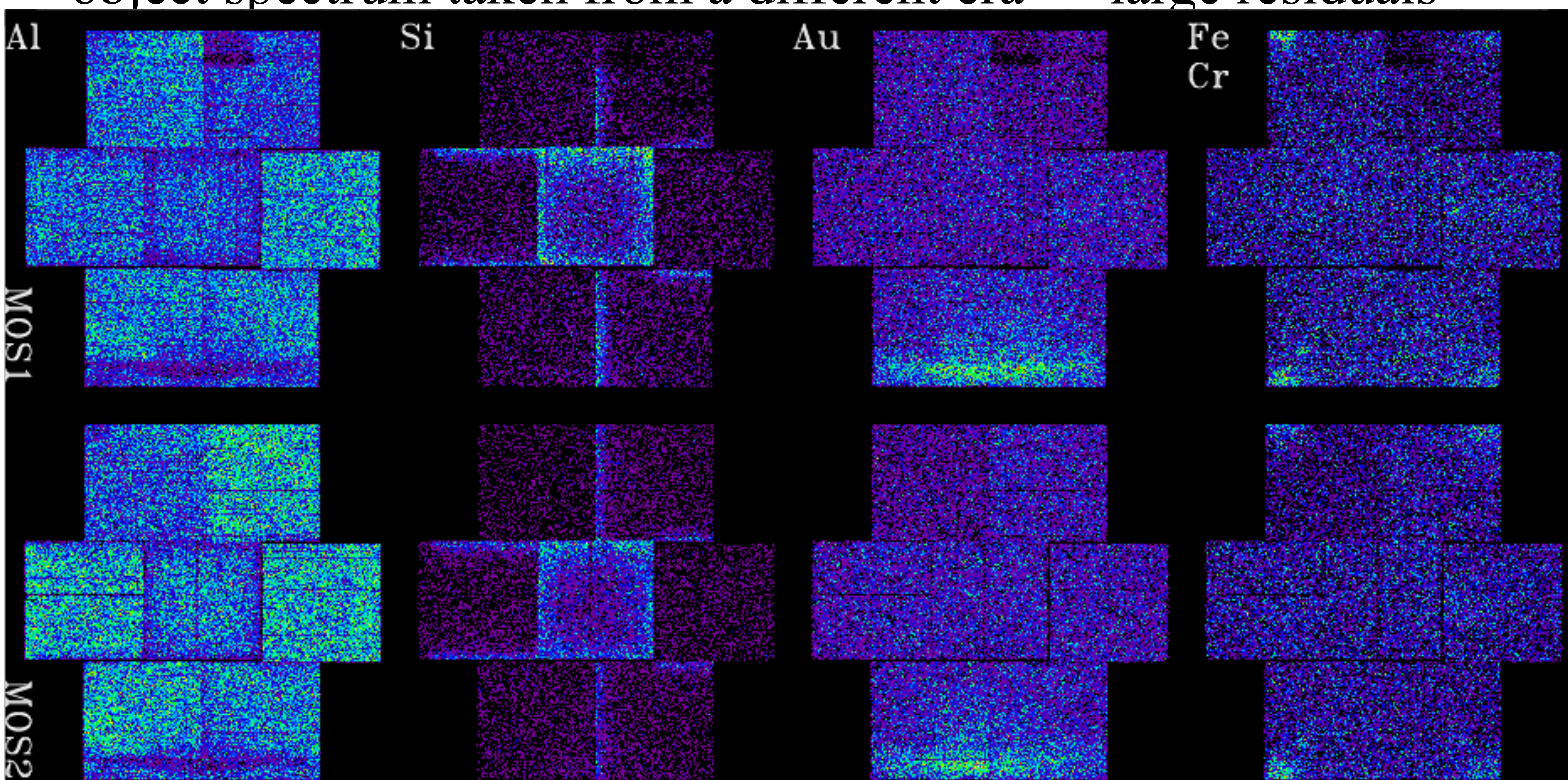
Quiescent Particle Background

- QPB composed of two components - lines & “continuum”
  Both of which vary strongly from chip to chip
  (Even excluding the anomalous states!)



Quiescent Particle Background

- Lines:
  - Strength known to be spatially variable
  - Strength known to depend on s/c location (Tiengo)
  - Shape and recorded energy varies over course of mission
    (Gain shifts, CTI effects, etc.)
    → One can't background spectrum from one era to subtract from an object spectrum taken from a different era → large residuals



Quiescent Particle Background

- Continuum:
  - Spectral shape temporally variable (Kuntz & Snowden 2008)

  - Spectral shape spatially variable (?)

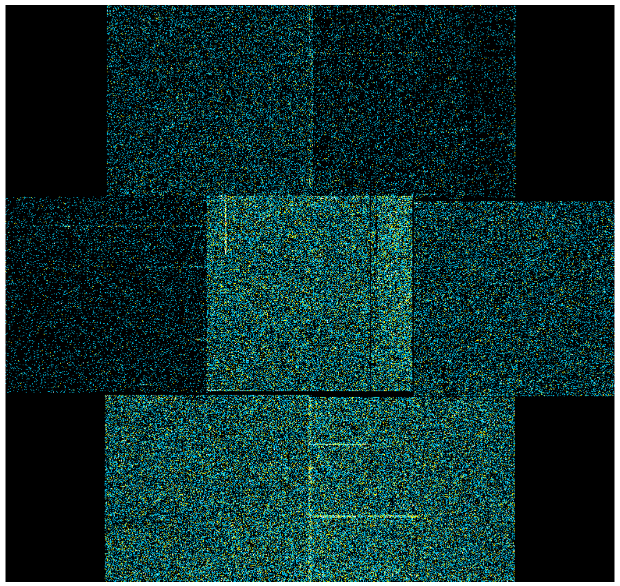
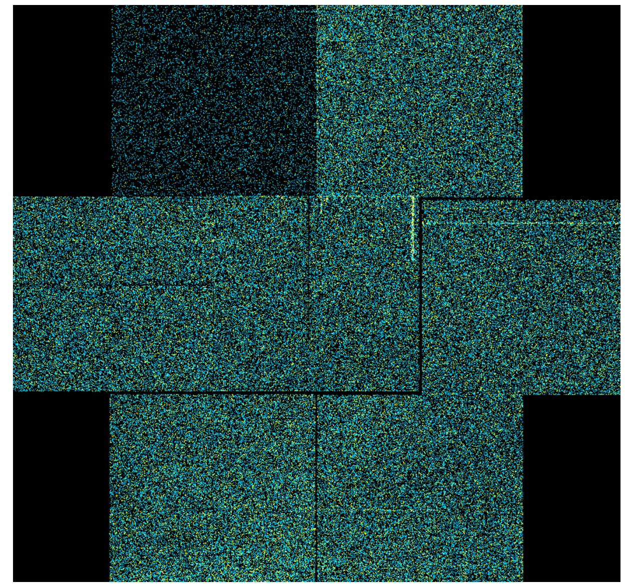
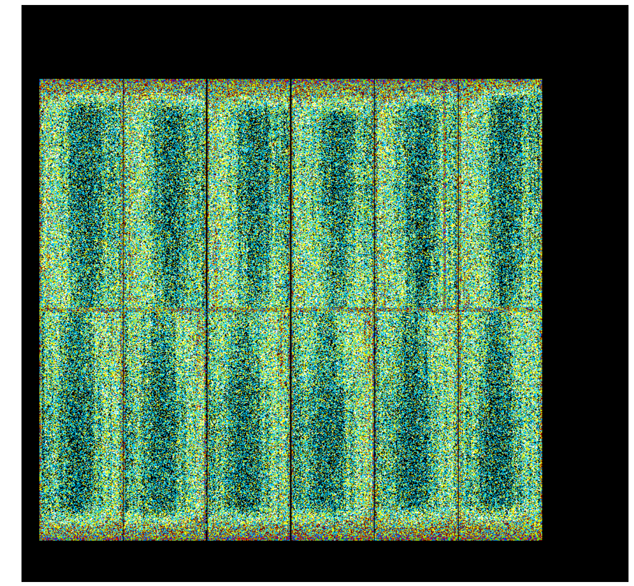
  - Want to characterize spectral shape as function of time and location on the detector.

Quiescent Particle Background

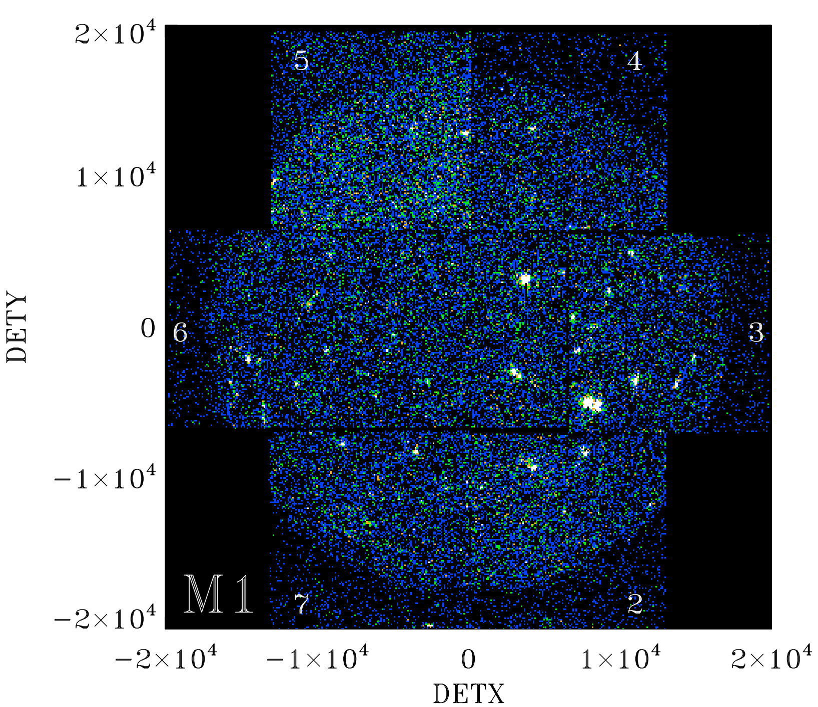
- Continuum:
  - Spectral shape temporally variable (Kuntz & Snowden 2008)
    - Result not wrong - but not entirely correct either
    - In part due to unrecognized anomalous state data
  - Spectral shape spatially variable (?)
    - Difficult to determine as the filter-wheel closed data limited
    - Revisit this issue briefly at the end
    - Of course, Fabio may then tell us I’m wrong!
  - Want to characterize spectral shape as function of time and location on the detector.

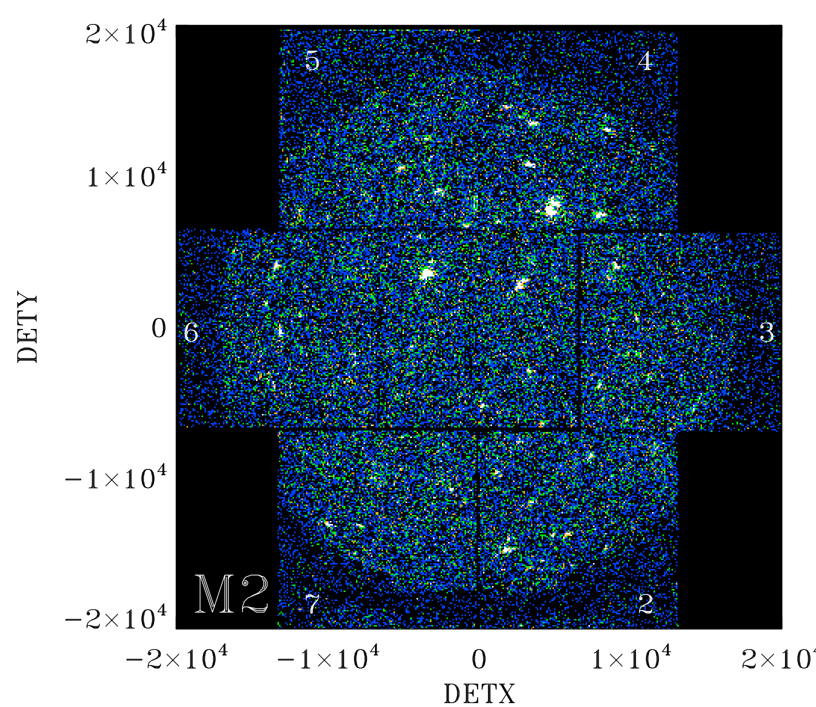
QPB Data

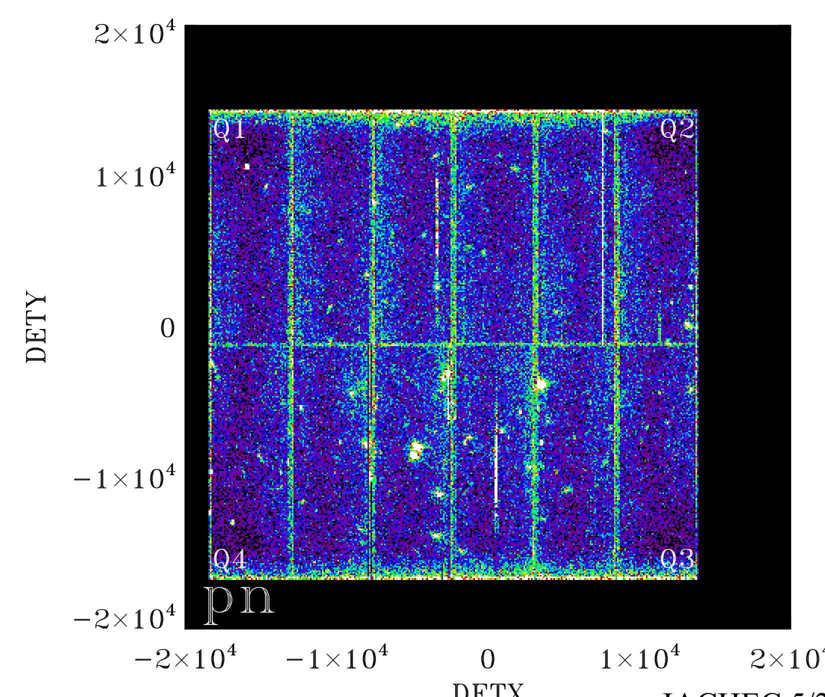
- Filter-Wheel Closed Data → spatial variation

- "Corner" Data → temporal variation
  - From outside the FOV that is shielded from cosmic X-rays and lower energy particles (such as those producing the SPF).
  - Come "free" with (almost) every observation







QPB Data Statistics

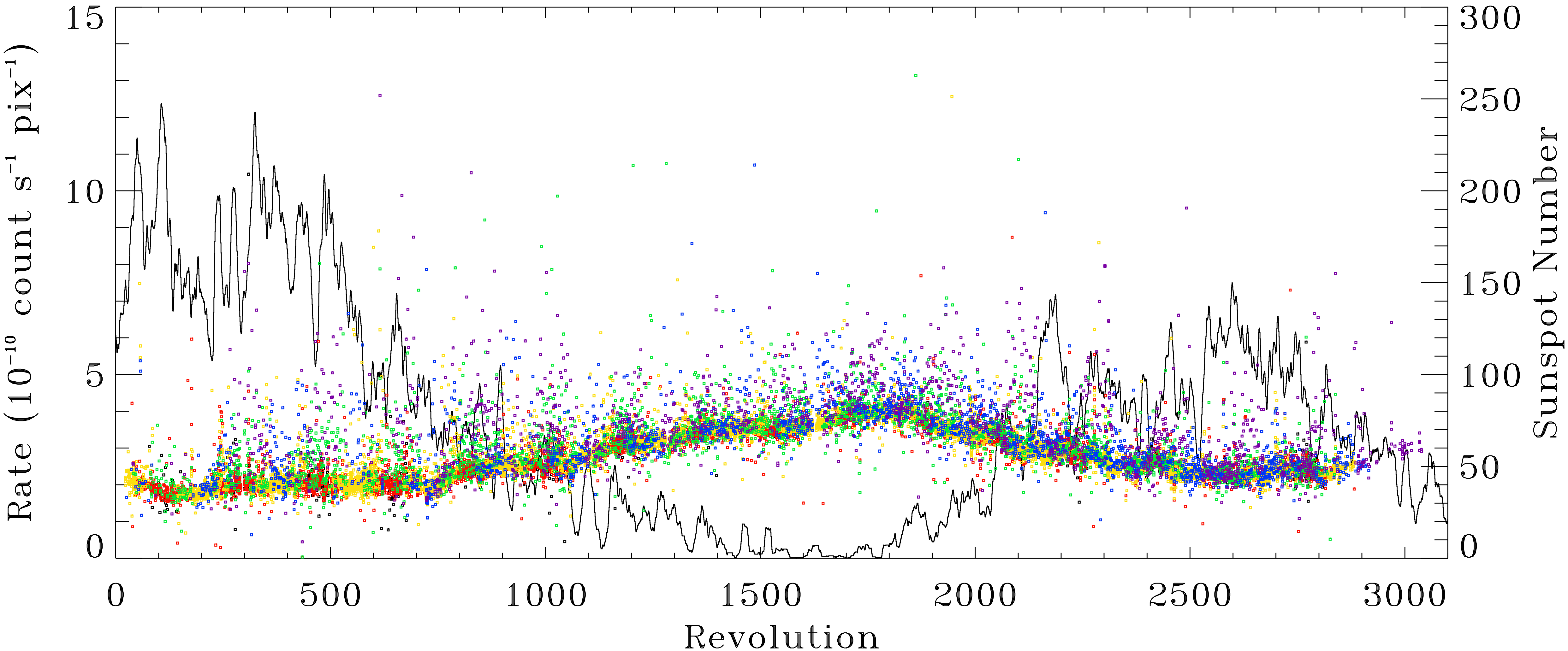
Which data to use to characterize the spectral shape?

	FWC			Corner		
Chip	Exposure	0.35-12. Band	2.5-5.0 Band	Exposure	0.35-12. Band	2.5-5.0 Band
	MS	10^5 Cnt	10^5 Cnt	MS	10^5 Cnt	10^5 Cnt
1-1	1.84	4.33	0.73			
1-2	1.84	4.60	0.80	332.1	152.7	26.9
1-3	1.23	2.64	0.46	247.2	98.8	17.1
1-4	0.57	0.97	0.17	60.7	25.8	4.5
1-4A	0.23	2.94	0.43	271.5	165.0	23.7
1-5	0.89	1.85	0.32	139.4	87.8	15.3
1-5A	0.72	2.57	0.43	192.7	131.6	21.9
1-6	0.63	1.01	0.18	92.1	31.4	5.5
1-7	1.84	4.37	0.77	332.2	161.7	28.6
2-1	1.82	4.18	0.70			
2-2	1.58	3.83	0.64	254.7	115.3	19.5
2-2A	0.14	0.53	0.09	78.3	37.1	5.9
2-3	1.82	4.07	0.70	332.6	131.8	22.4
2-4	1.82	4.08	0.70	333.0	233.7	37.9
2-5	0.69	1.44	0.25	98.1	63.5	11.1
2-5A	0.35	3.23	0.46	234.8	199.8	26.6
2-6	1.82	4.13	0.71	332.5	154.2	26.1
2-7	1.82	4.28	0.73	332.9	166.6	28.1

- The corner data provide a much higher S/N characterization of the QPB background than the filter-wheel closed (FWC) data.

Temporal Variability

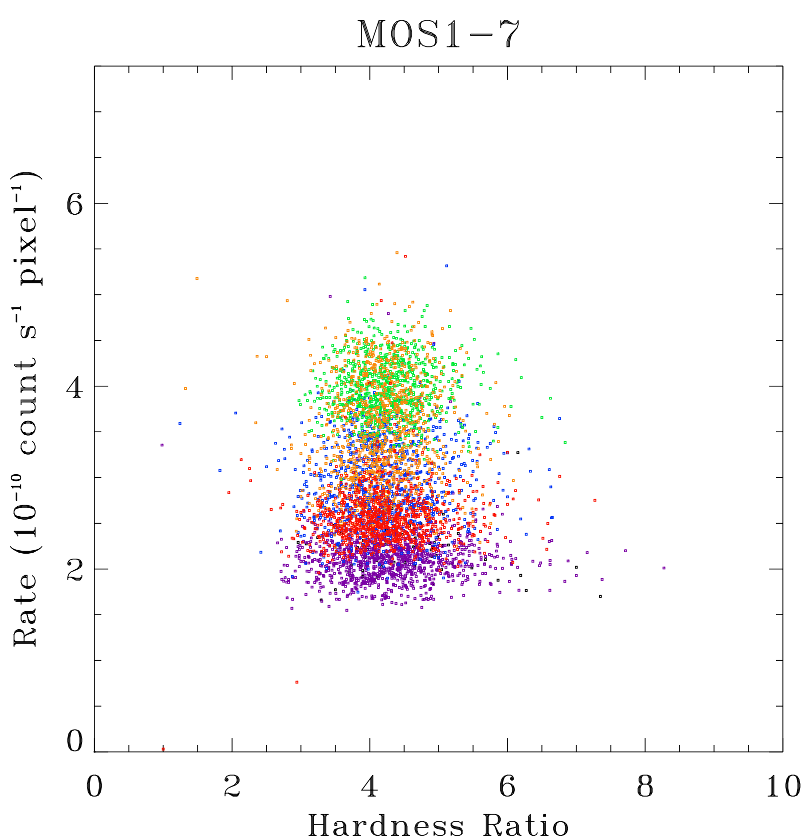
The QPB rate as determined from the corner data has a long term variation due to anti-correlation with the solar activity

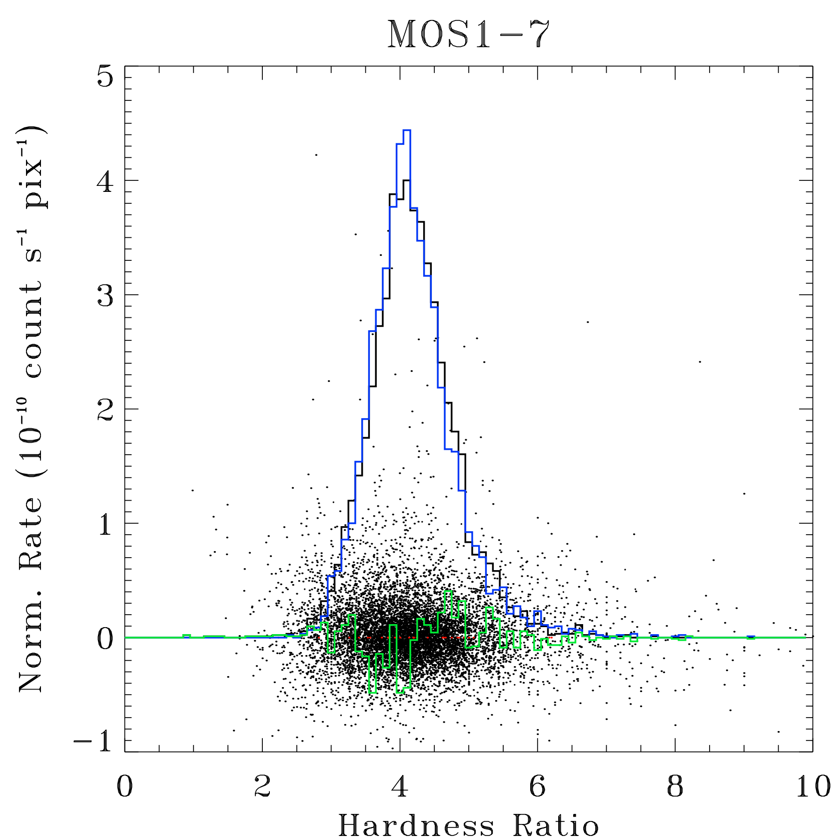


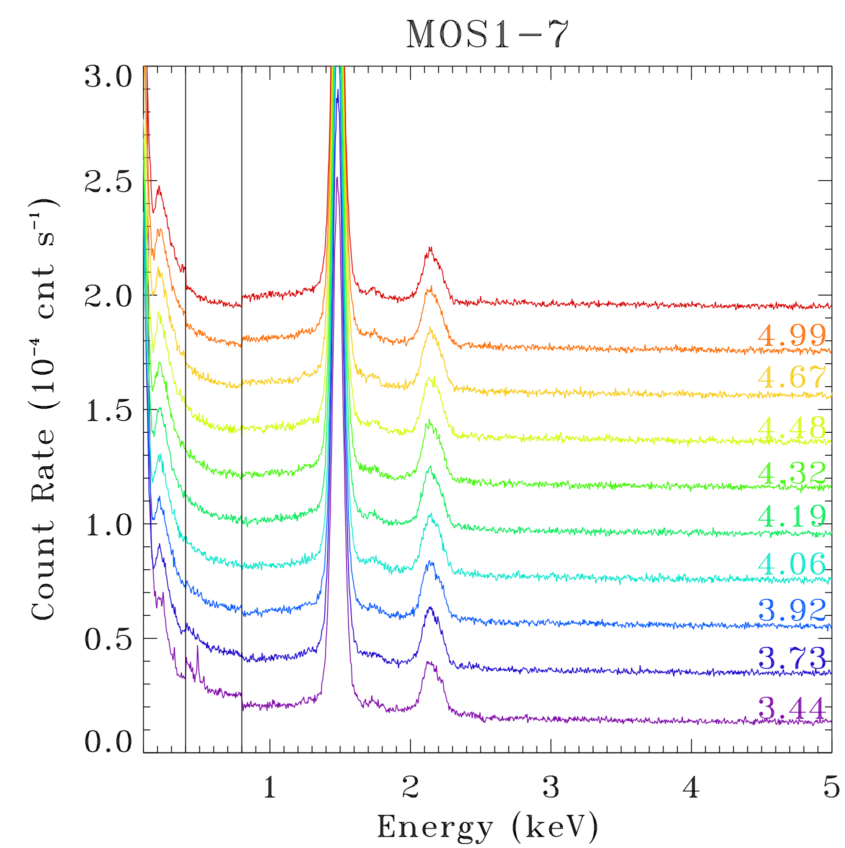
Temporal Variability

Consider the corner data from a well-behaved chip, MOS1-7.

- The hardness ratio (HR) = 2.5-5.0 keV/0.4-0.8 keV does not appear to vary with QPB rate (R)
- However if
  - we assume a constant HR
  - simulate the entire database of corner data for this chip,
  - compare distribution of HR from simulation with measured HR dist.
  - a KS test indicates that they do not have the same distribution!
- True distribution of HR broader than expected







Quiescent Particle Background

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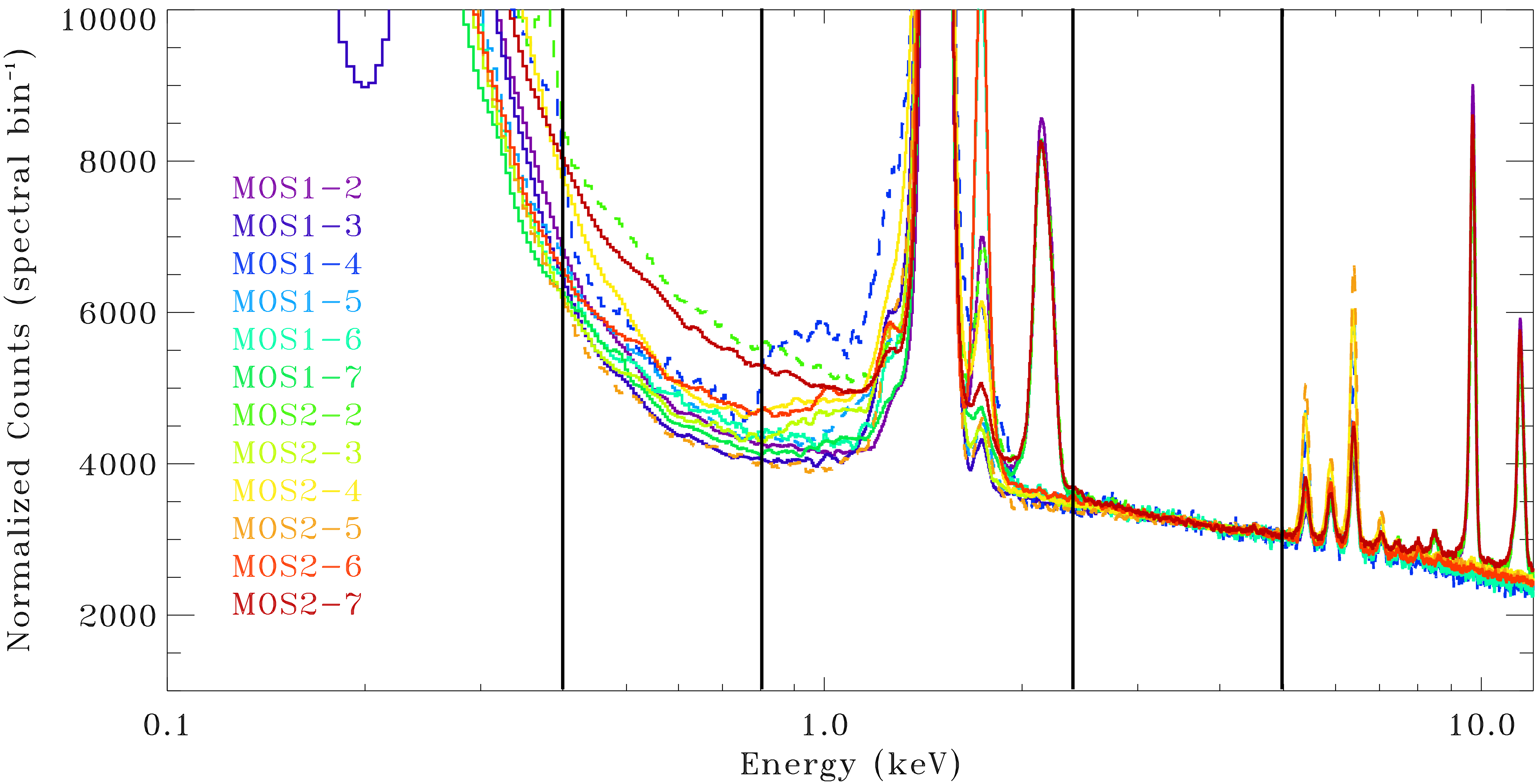

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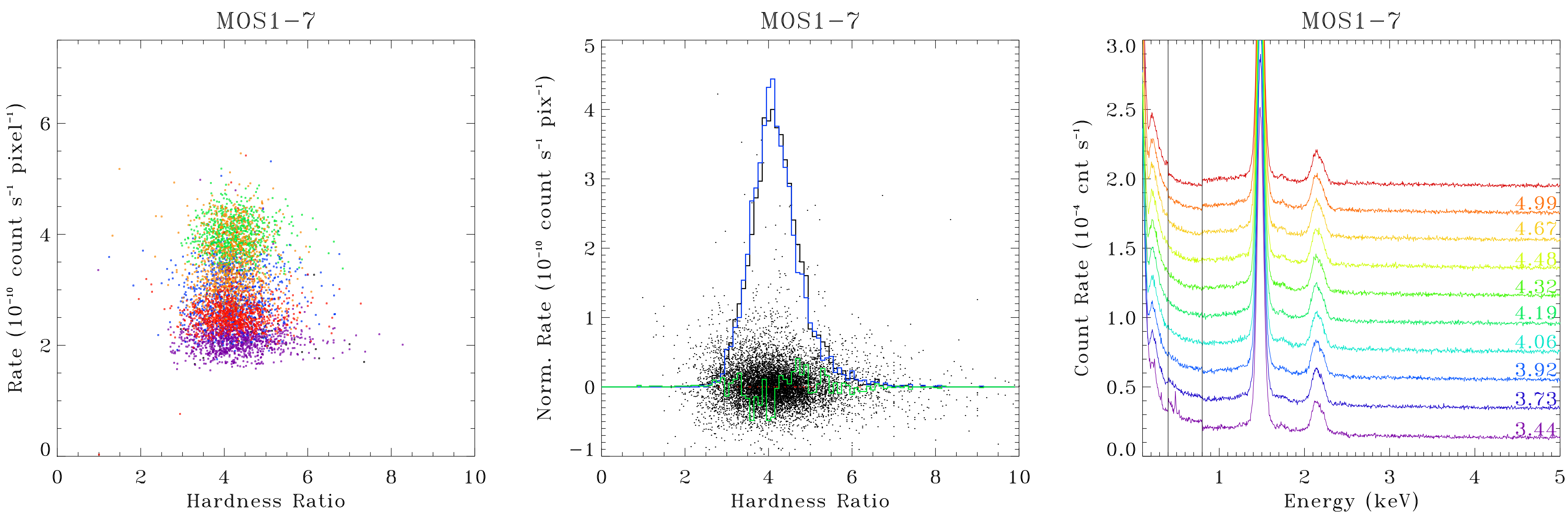
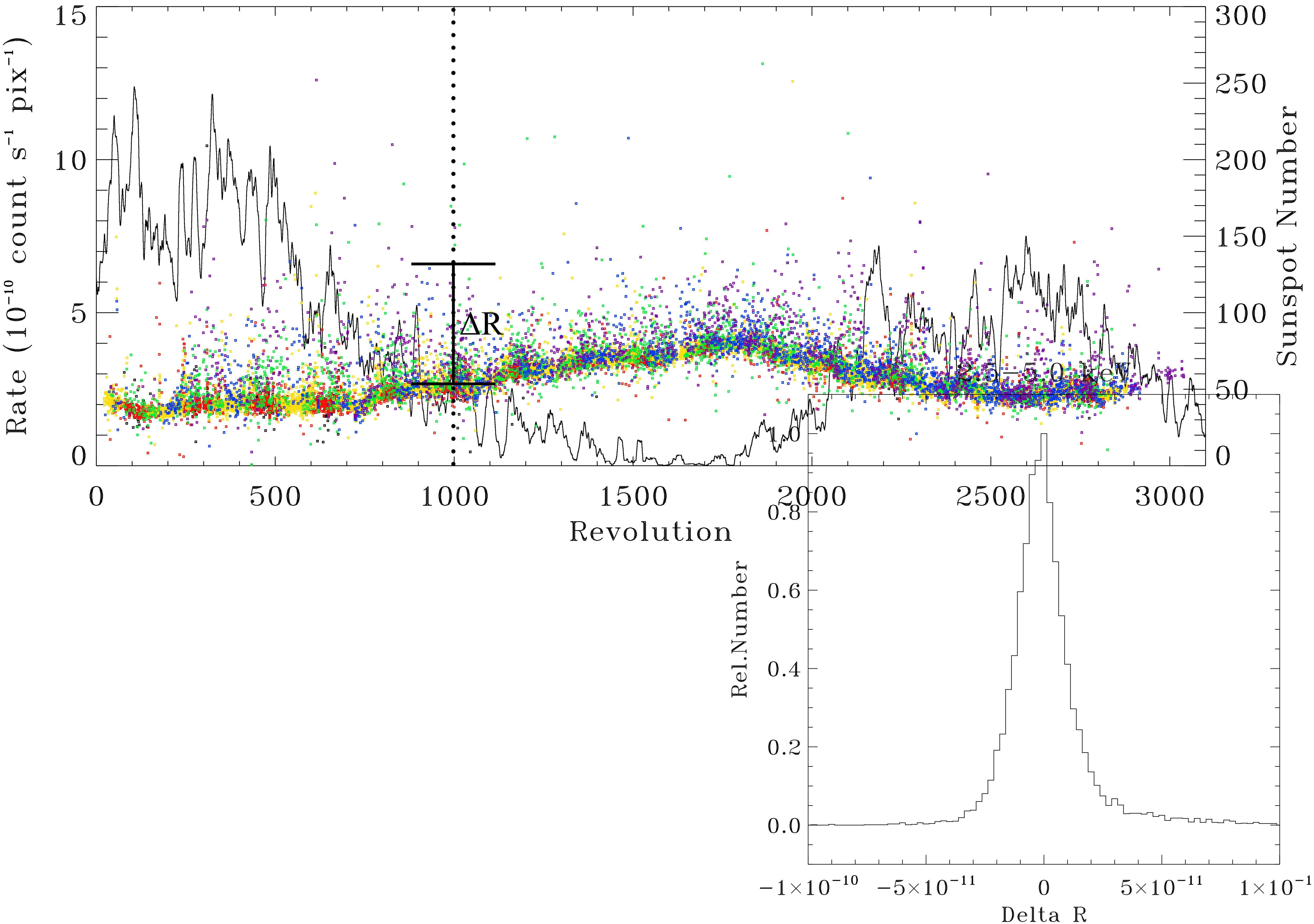


Sources?

- Epoch
  - Due to change in the detectors with age?
  - Partially degenerate with the solar cycle
- QPB Rate (R)
  - QPB rate ↔ change GCR population ↔ particle population spectrum
  - Degenerate with solar cycle
- Normalized QPB Rate ($R-\langle R\rangle=\Delta R$)
  - At any given epoch the distribution of R is asymmetric with high tail
  - (Finally something not degenerate with everything else!)
- Spacecraft Location
  - Known that different near-Earth locations show different particle populations
  - One can't use the physical (X,Y,Z) location of the s/c!
    - Variation in solar wind pressure moves the location of the magnetopause and different particle populations
    - A lesson learned from study of the soft proton problem

ΔR



ΔR
Rate (10^{-10} count s^{-1} pix^{-1})
Sunspot Number
Revolution
2.5–5.0 keV
Rel.Number
Delta R

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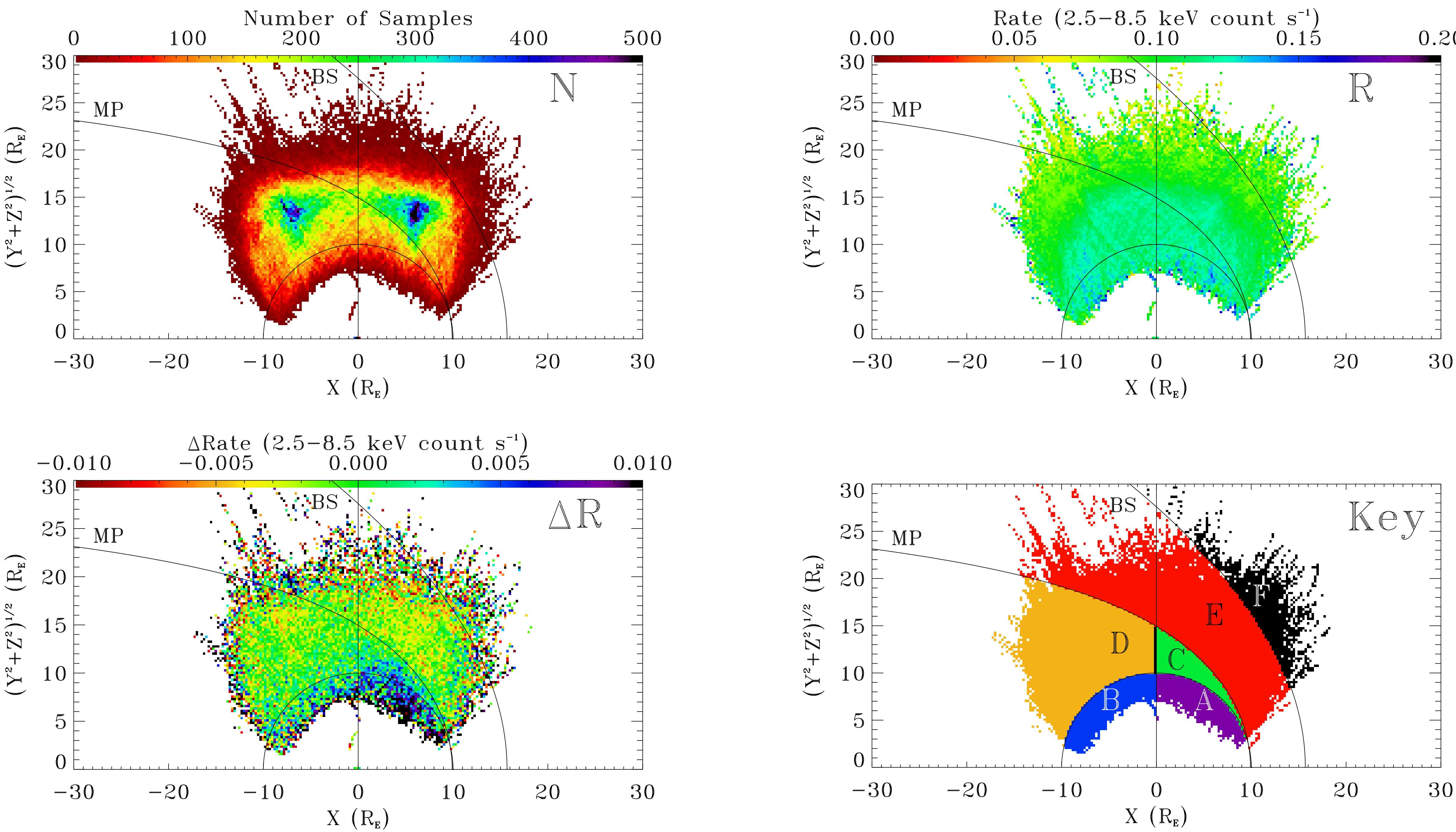
It’s Location

Take all corner data, determine s/c location wrt the magnetopause and bowshock in one minute intervals

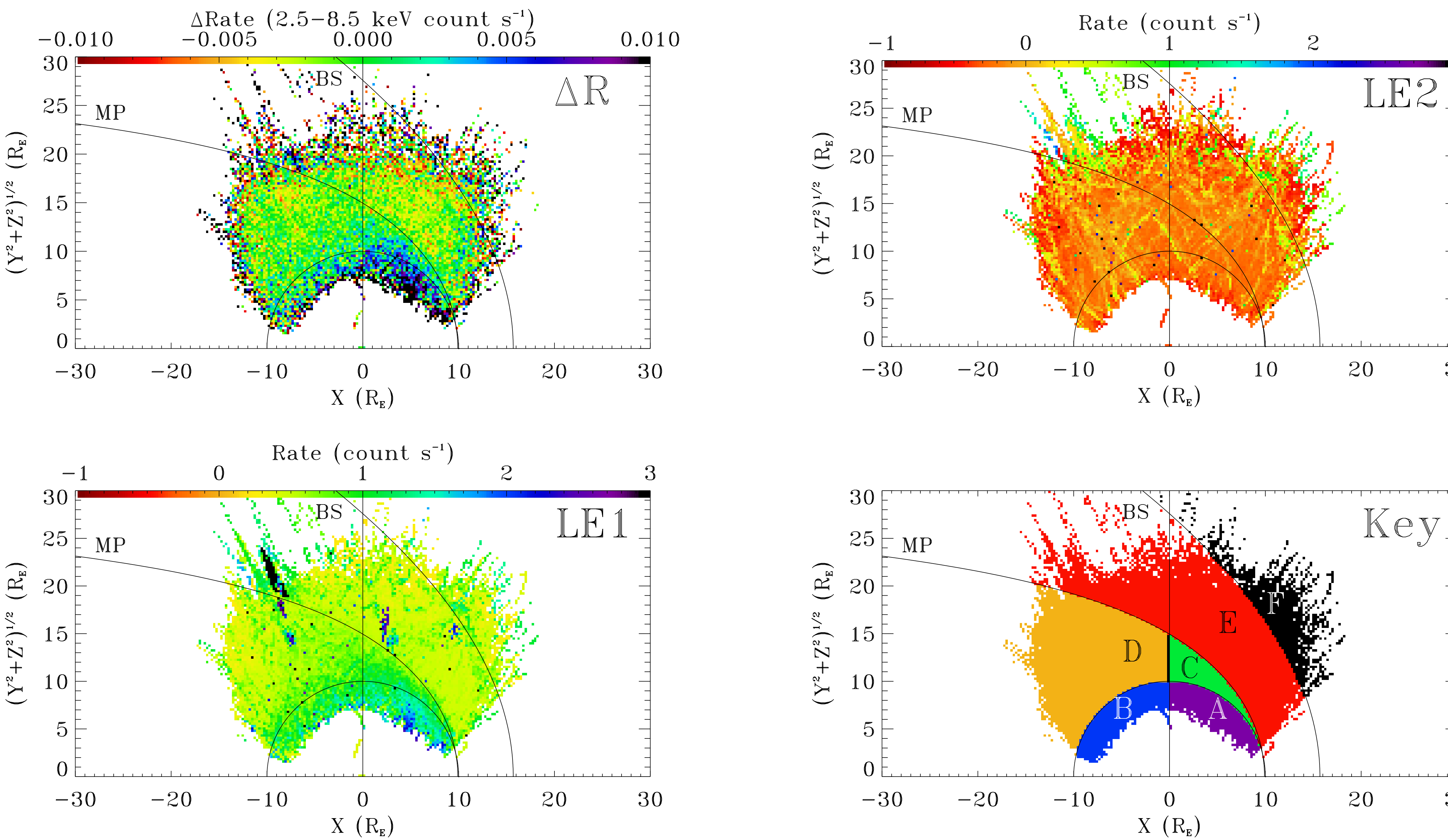
Find that the rate (R) not dependent on location, but ΔR is!

- Particularly high within magnetopause on sunward side of the Earth



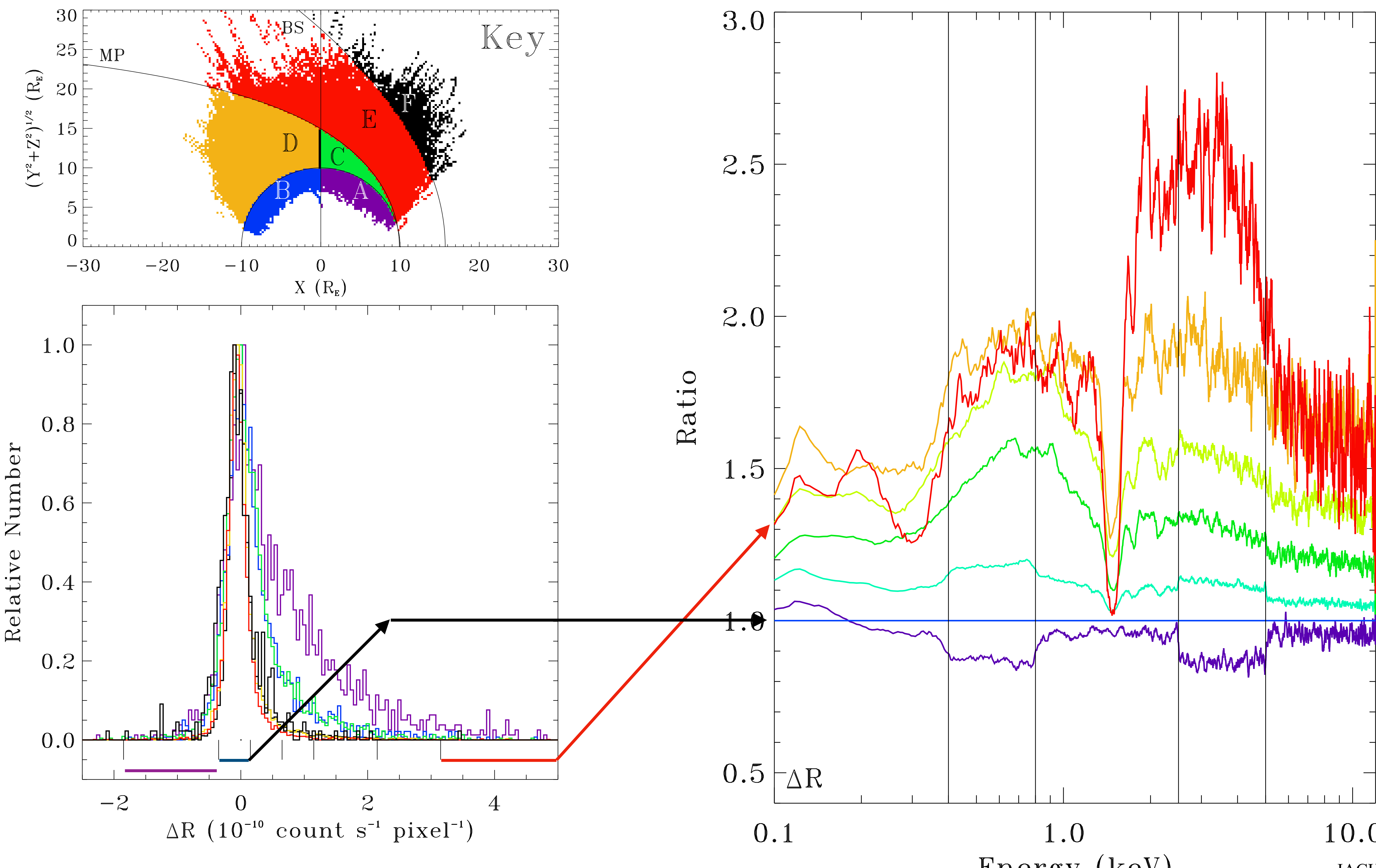
Evidence of the Radiation Monitor

ΔR variation well correlated with the
LE1 channel (160 keV<E_e<1.0 MeV, 1.0 MeV<E_p<1.5 MeV)
but not with the
LE2 channel (1.0 MeV<E_e<1.5 MeV, 1.5 MeV<E_p<4.5 MeV)



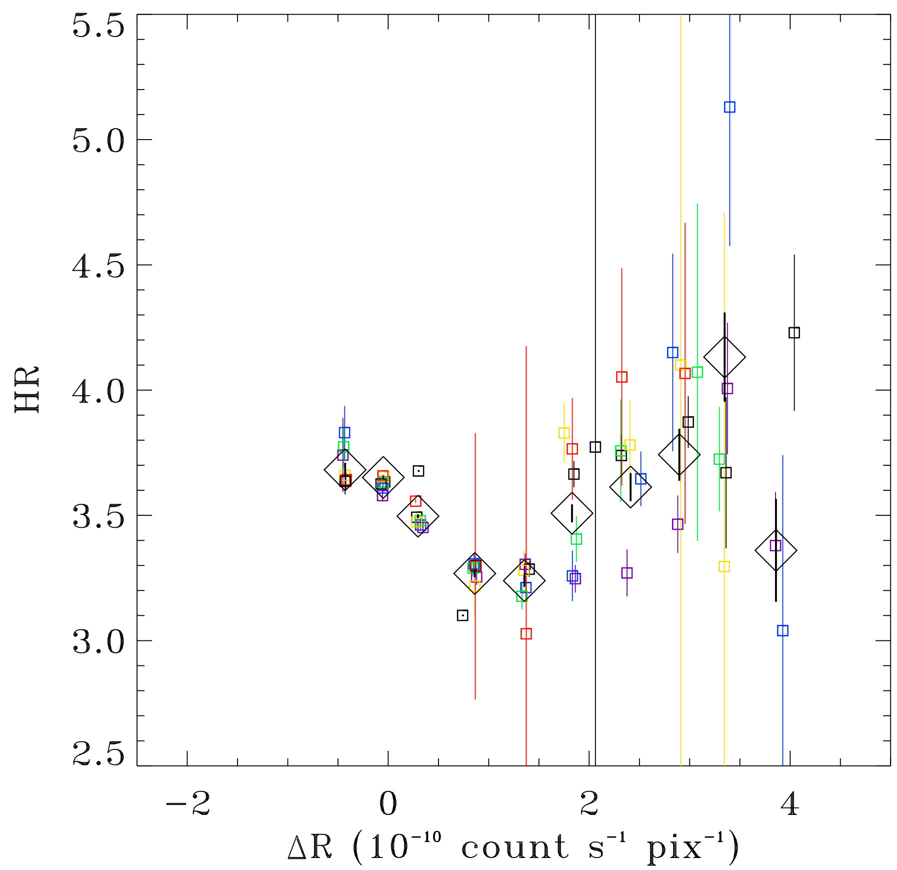
But is ΔR related to changes in HR?

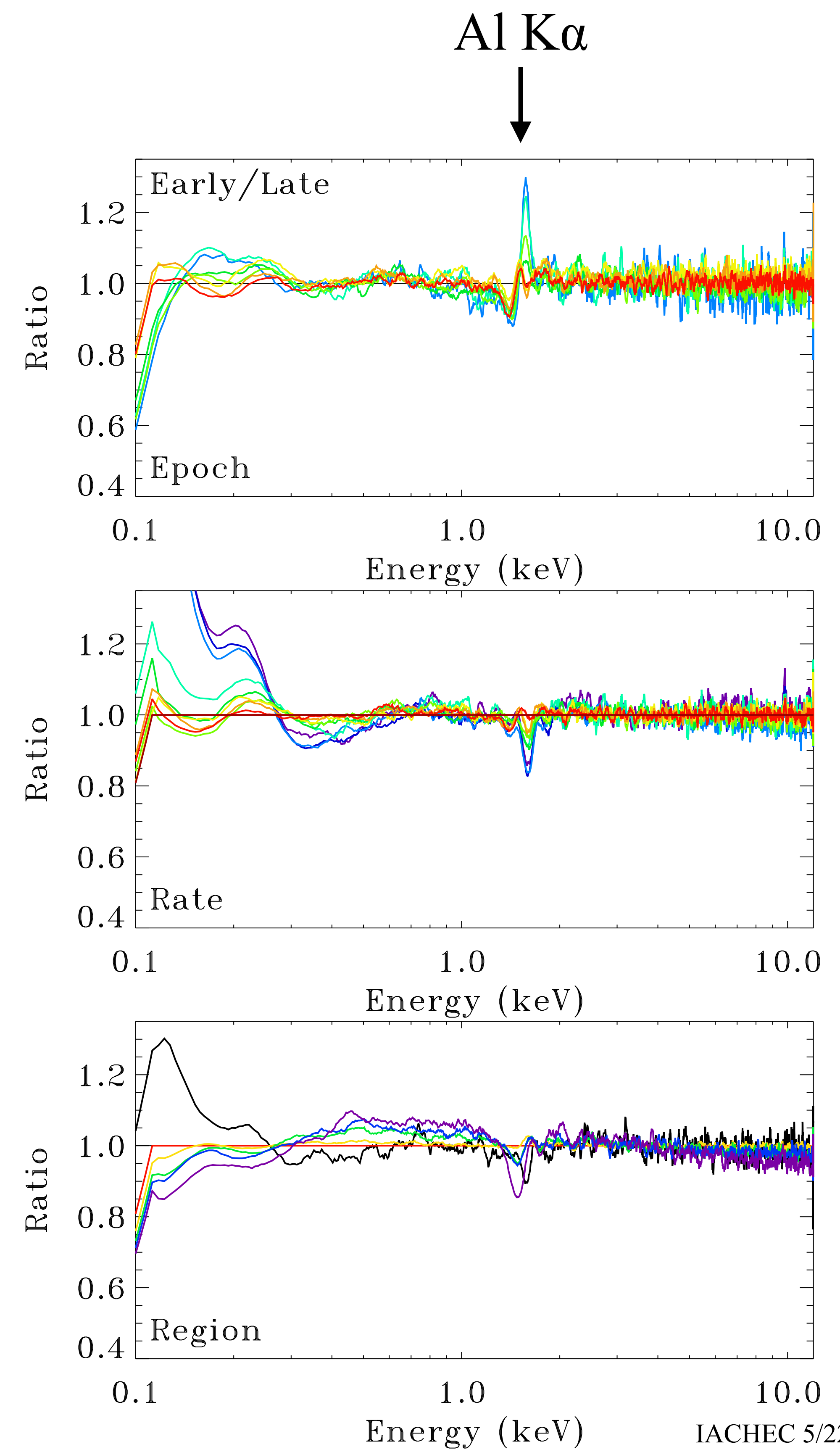
Extract the QPB spectrum from different ranges of ΔR and compare (As spectrum/spectrum ratios)



Is ΔR All There Is?

Spectral shape (and HR) is a function of ΔR
(though not a pretty one!)





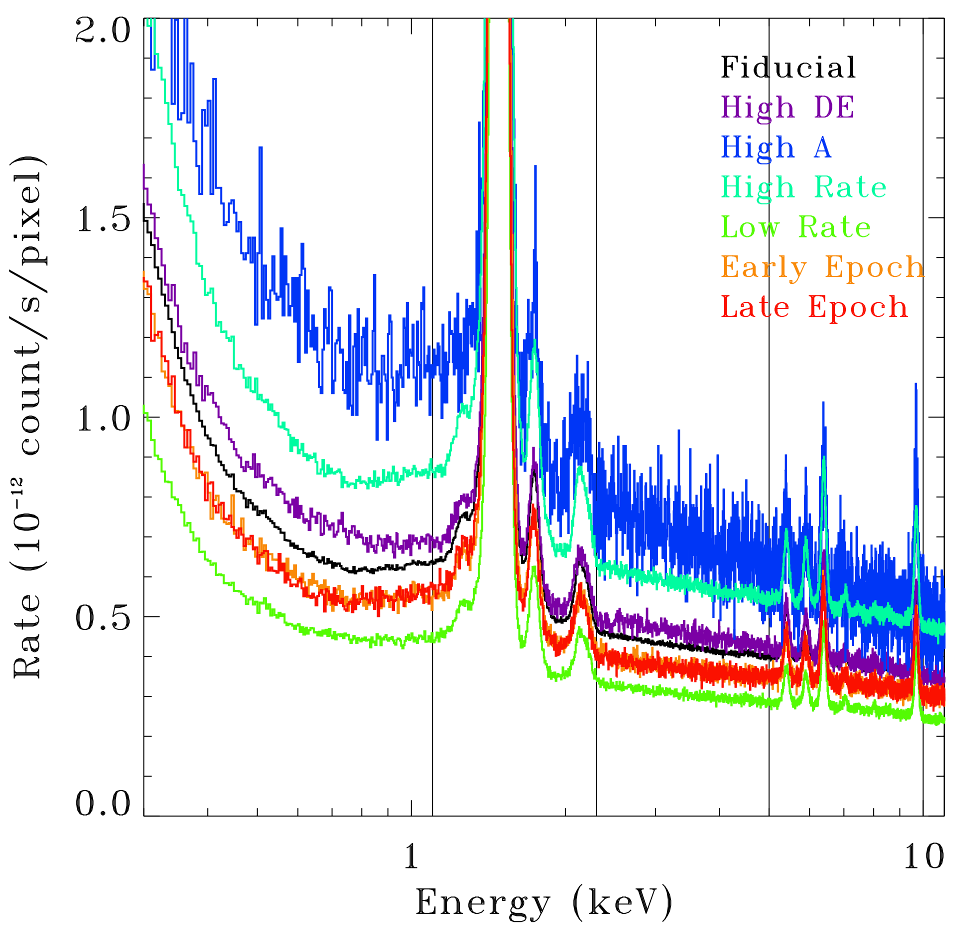
For a constant range of ΔR,
at least for E>0.35 keV,
we don't see significant variation in the spectrum with epoch, rate, or s/c location.

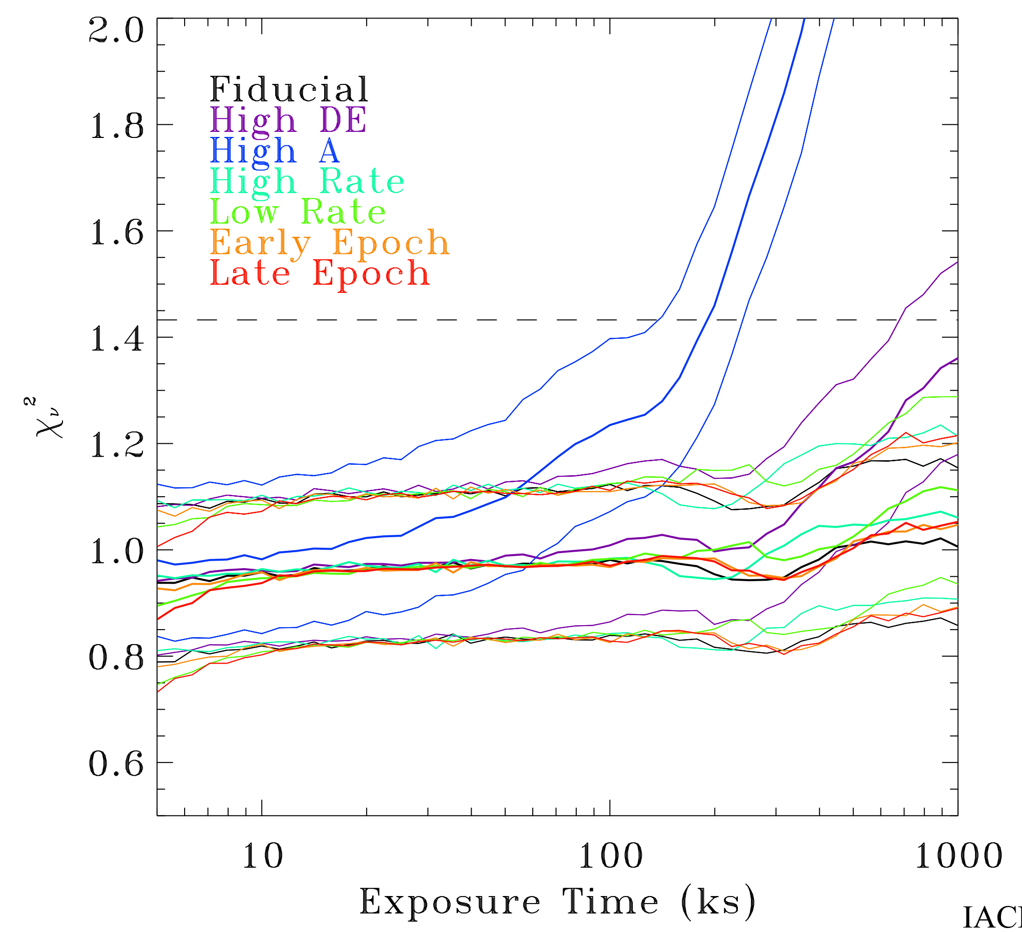
Does the Variation Make A Difference?

Extracted QPB spectra based on a number of different criteria

Name	Selection Criteria[a]	Exposure (Ms)	χ^2_ν	ν
Fiducial	Regions D&E, -0.35< $\Delta R/10^{-10}$ <0.15	217	1.092	863
High DE	Regions D&E, 0.15< $\Delta R/10^{-10}$ <0.65	19.9	1.057	862
High A	Region A, 1.15< $\Delta R/10^{-10}$ <2.15	0.893	1.048	863
High Rate	Regions D&E, -0.35< $\Delta R/10^{-10}$ <0.15, $R/10^{-10}$ < 2.22, Rev<1000	45.5	1.099	861
Low Rate	Regions D&E, -0.35< $\Delta R/10^{-10}$ <0.15, $R/10^{-10}$ > 3.41, 1100<Rev<2200	54.6	1.059	862
Early Epoch	Regions D&E, -0.35< $\Delta R/10^{-10}$ <0.15, 2.04 < $R/10^{-10}$ < 2.52, 750<Rev<1100	15.0	0.972	862
Late Epoch	Regions D&E, -0.35< $\Delta R/10^{-10}$ <0.15, 2.04 < $R/10^{-10}$ < 2.52, 2200<Rev<2550	15.6	1.025	862

Fitted a functional form to a low ΔR fiducial spectrum in 0.35-10. keV.
Simulated each of the extracted spectra for different exposure times, fitted the fiducial functional form, and calculated χ^2 as a function of time.





Does the Variation Make A Difference?

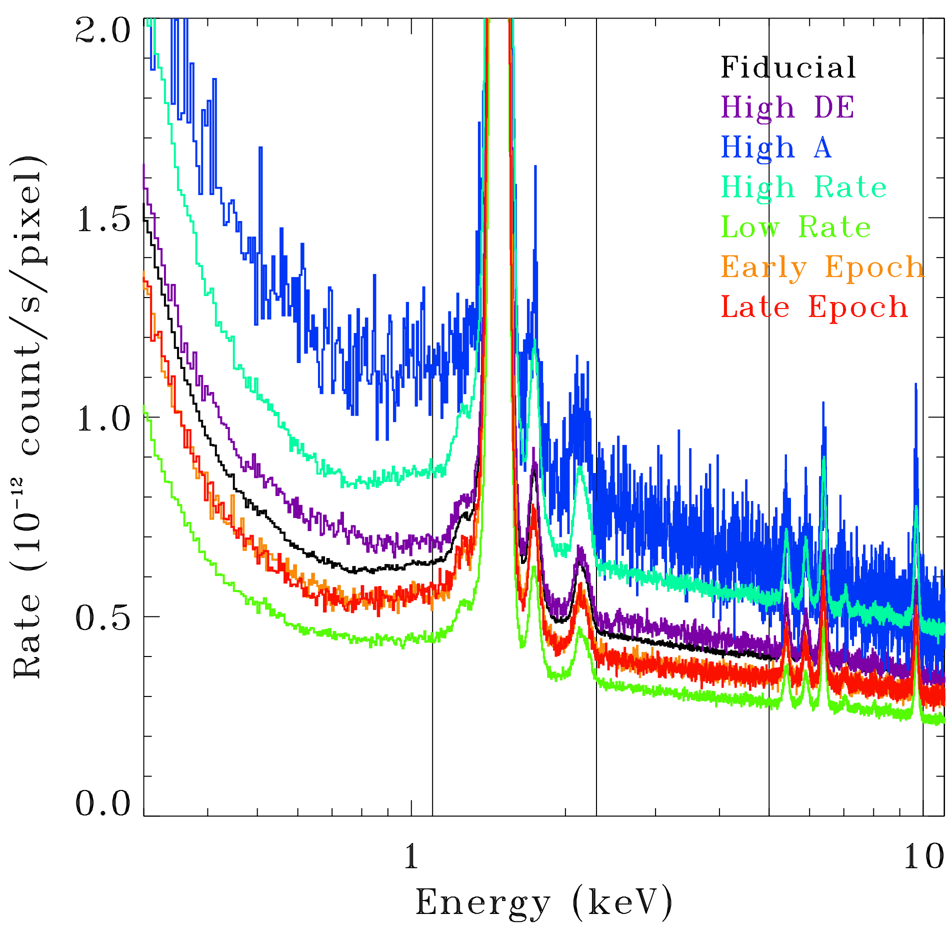
Extracted QPB spectra based on a number of different criteria

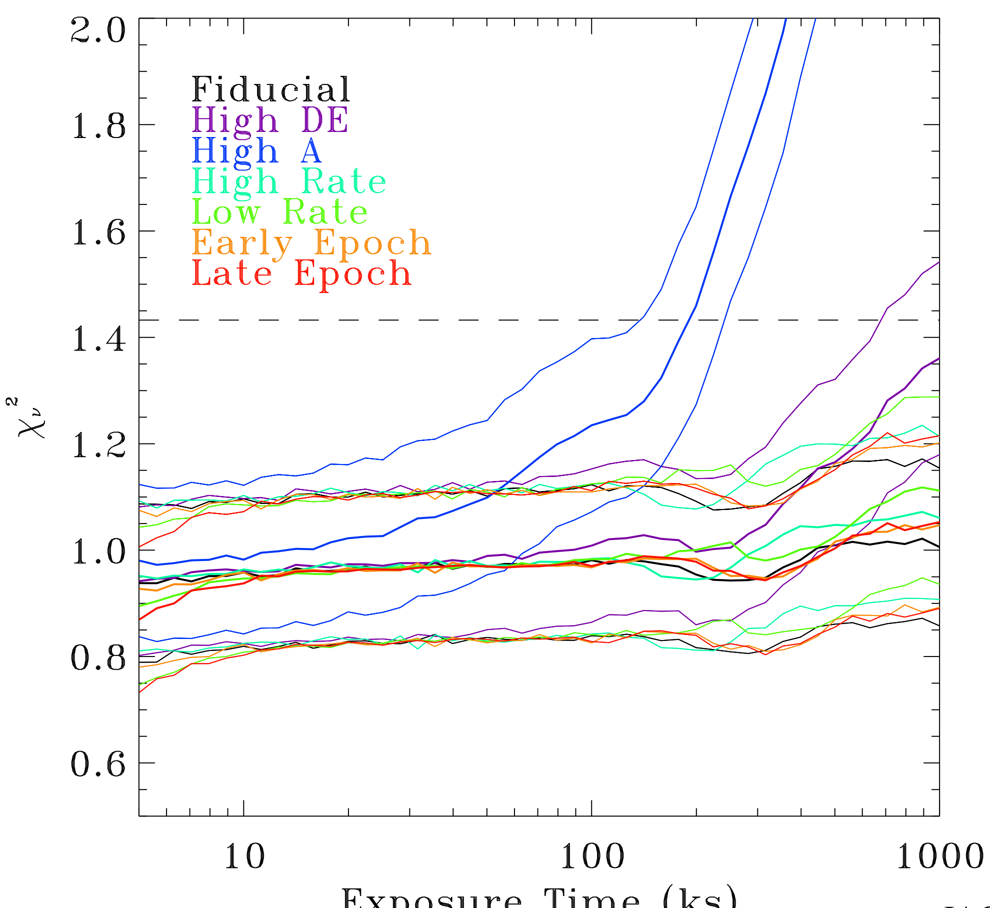
Fitted a functional form to a low ΔR fiducial spectrum in 0.35-10. keV.

Simulated each of the extracted spectra for different exposure times, fitted the fiducial functional form, and calculated χ^2 as a function of time.

With the exception of the most extreme spectrum (High A), at exposure times of 100 ks, the change in χ^2 is negligible.

For most spectra the fiducial QPB spectrum is sufficient!





Spatial Variation

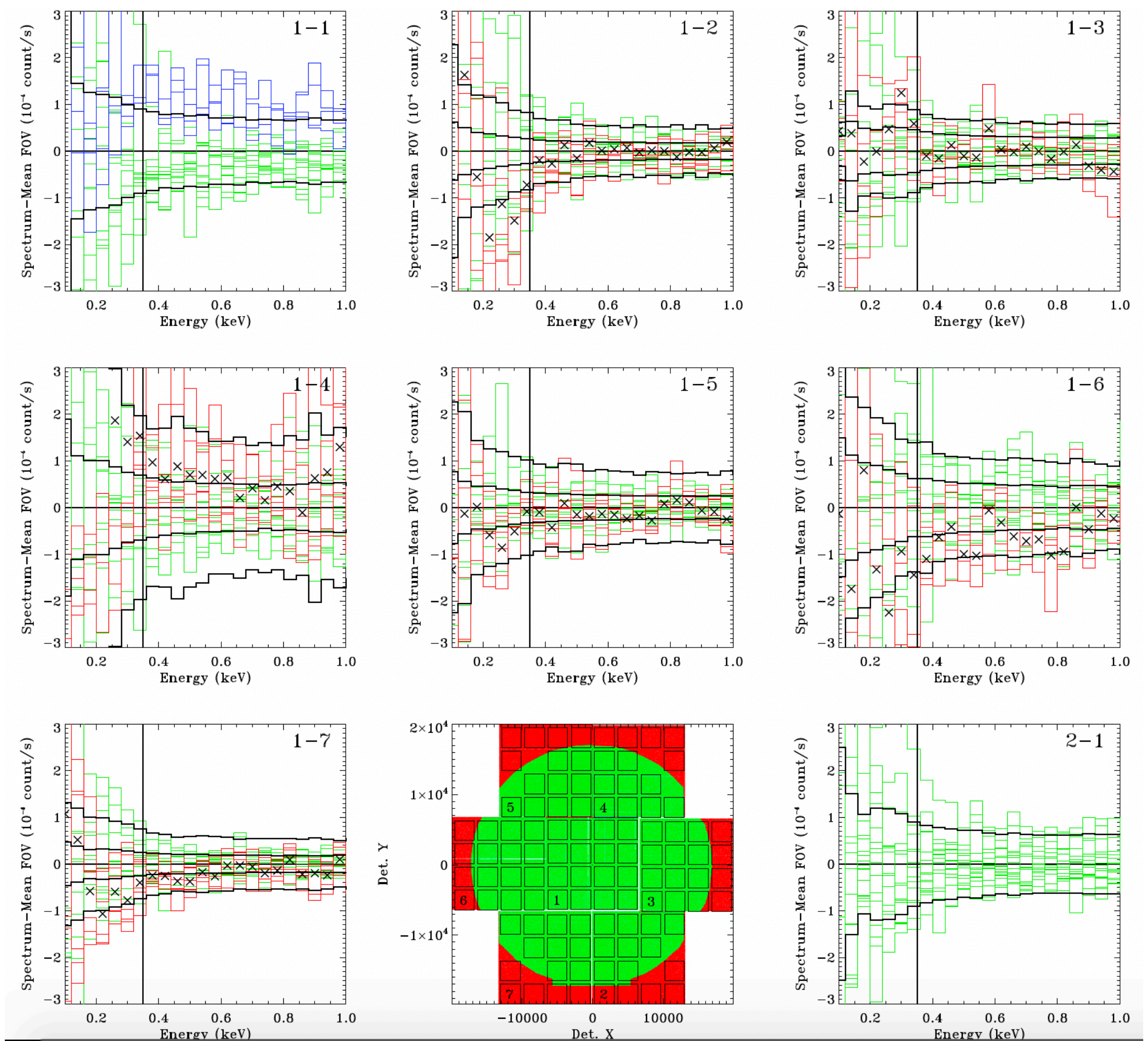
If the corner data is well represented by a single "fiducial" spectral shape

- each chip having it's own fiducial
- each observation having its own offset

How well does the corner represent the QPB spectrum in the FOV?

- For E>0.35 keV
- with the exception of MOS1-1 RAWX>500,

then reasonably well.



Summary

It would appear that the QPB spectrum shape is more temporally stable than previously understood.

For the corner data, *most* observations are characterized by a single fiducial QPB spectrum.

- This is true on a chip-by-chip basis
- Any given observation will have a slightly different normalization

Observations that are not well characterized by the fiducial QPB spectrum

- Have a strong ΔR - determined from contemporary data
- In absence of contemporary data (i.e., brand new observation) one can get a good guess at ΔR from the s/c location and the solar wind pressure.

The corner spectra appear to represent the FOV spectra well; most are within 1σ of mean FOV spectrum.