

Cross calibration of RGS and MOS using Zeta Puppis

Jenny Carter, University of Leicester



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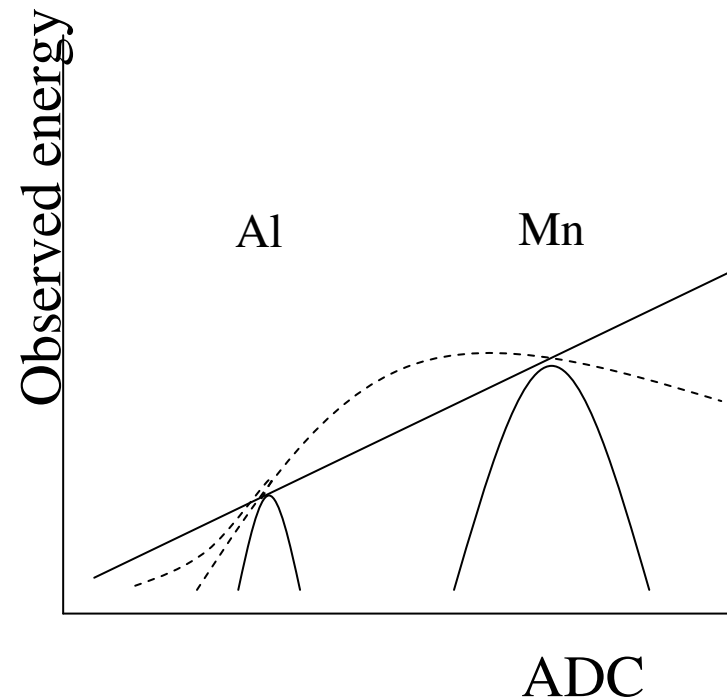
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Aims

- Check low energy - gain relationship, currently linear extrapolation
- Look at cross-calibration between RGS and MOS, checking energy scales and fluxes
- How: use Zeta Puppis, other line rich sources



Observations used

Revn.	Obs. ID.	Exposure (ks)	EPIC Instruments
0091	0095810301	57.35	MOS1
0156	0095810401	40.55	MOS1, 2, pn
0538	0157160501	42.28	MOS1, 2, pn
0542	0157160901	43.65	MOS1, 2, pn
0552	0157161101	38.94	MOS1, 2, pn
0636	0159360101	69.16	MOS1, 2, pn
0795	0159360301	61.29	MOS1, 2, pn
0903	0159360401	63.04	MOS1, 2, pn
0980	0159360501	64.18	MOS1, 2, pn
1071	0159360701	30.06	MOS1, 2, pn
1096	0159360901	53.53	MOS1, 2, pn
1164	0159361101	52.91	MOS1, 2, pn

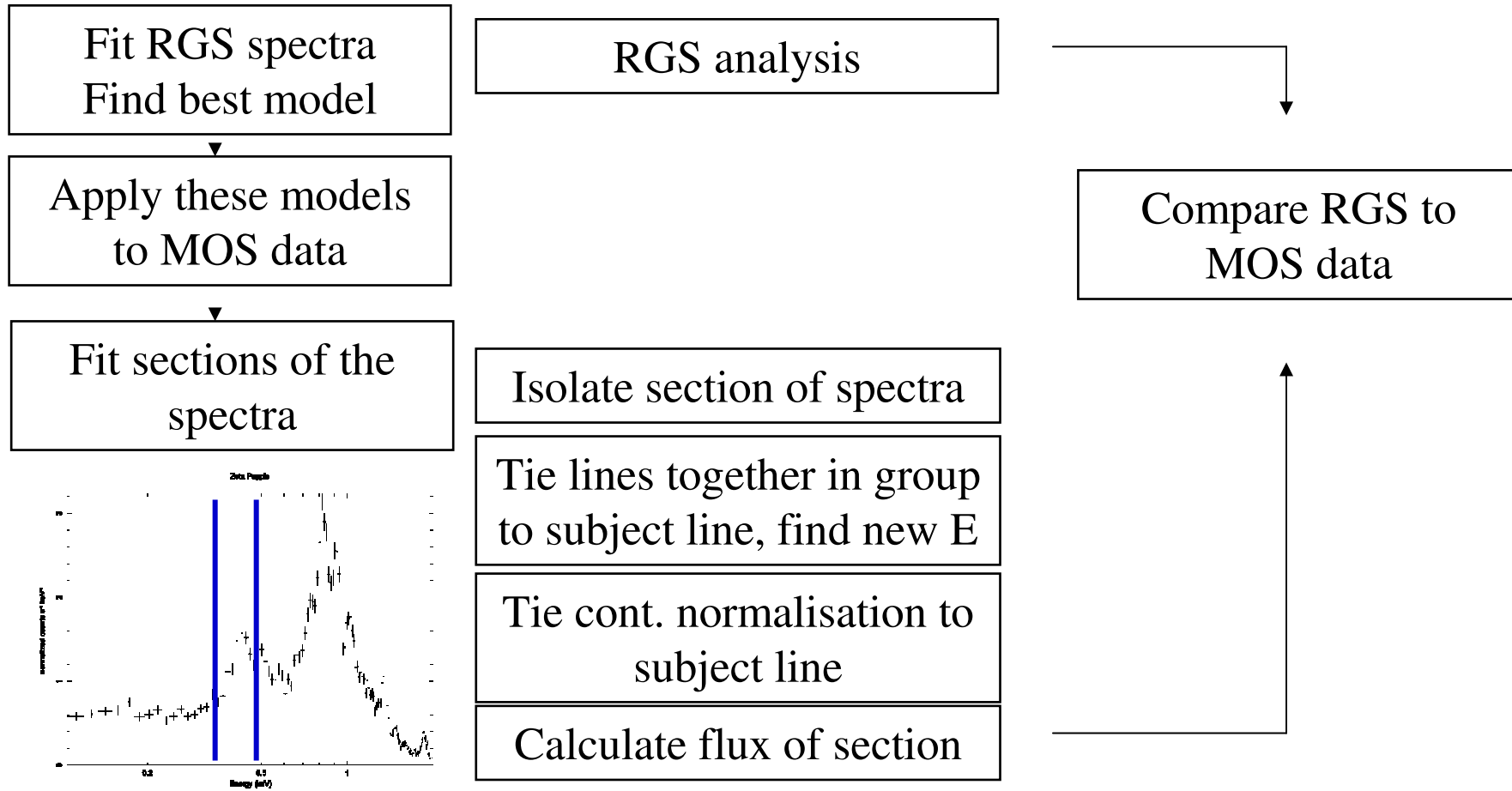


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Analysis process



Analysis - stage 1 for RGS

- Process: rgsproc for each obs. with SAS 7.0.0
- Xspec: apply model
model phabs * (gaussian + gaussian ... (36) + brems)
- fit and find best model for obs.
- save this model for use with MOS



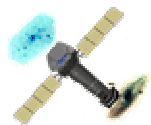
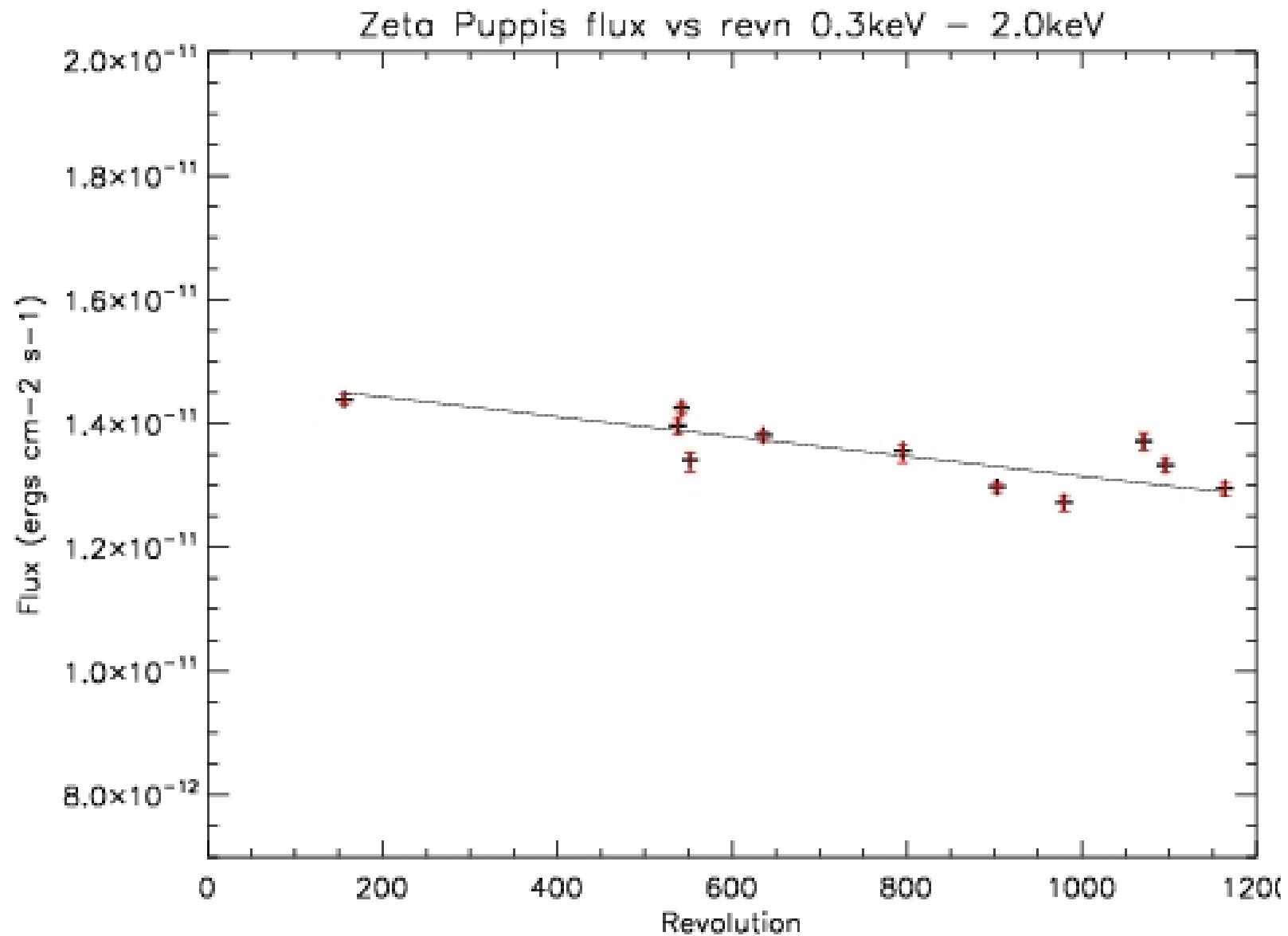
Stage 1 results for RGS

- Flux trends with revn.
 - Combined band 0.3 – 2.0 keV

Fitted using REGRESS regression fit in IDL to get trend over time

Band	Slope	% drop over 1000 revns
0.3 – 2.0 keV	-1.242 -15	8.9
0.3 – 0.8 keV	-7.078 -16	11.2
0.8 – 2.0 keV	-4.879 -16	6.4



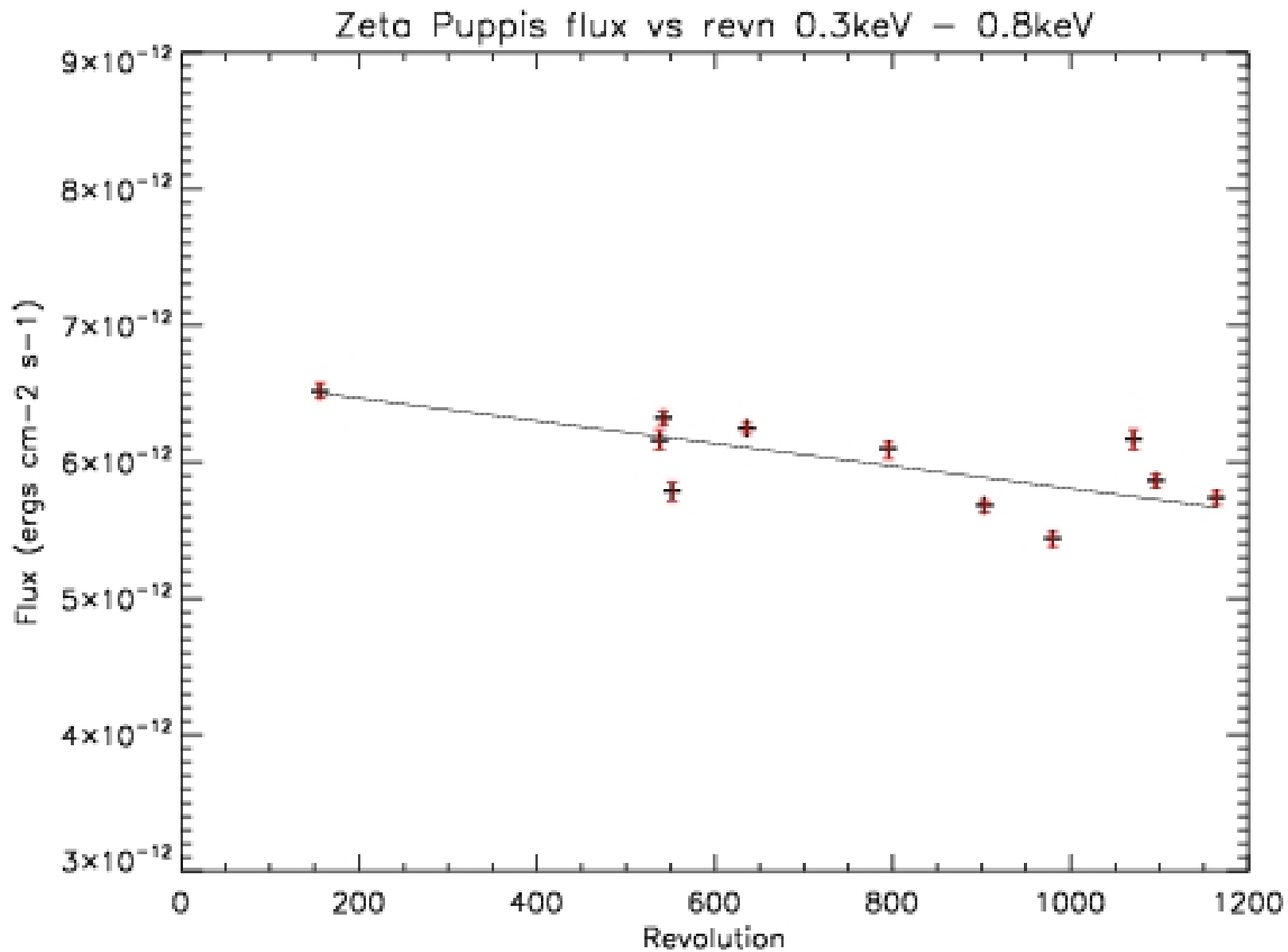


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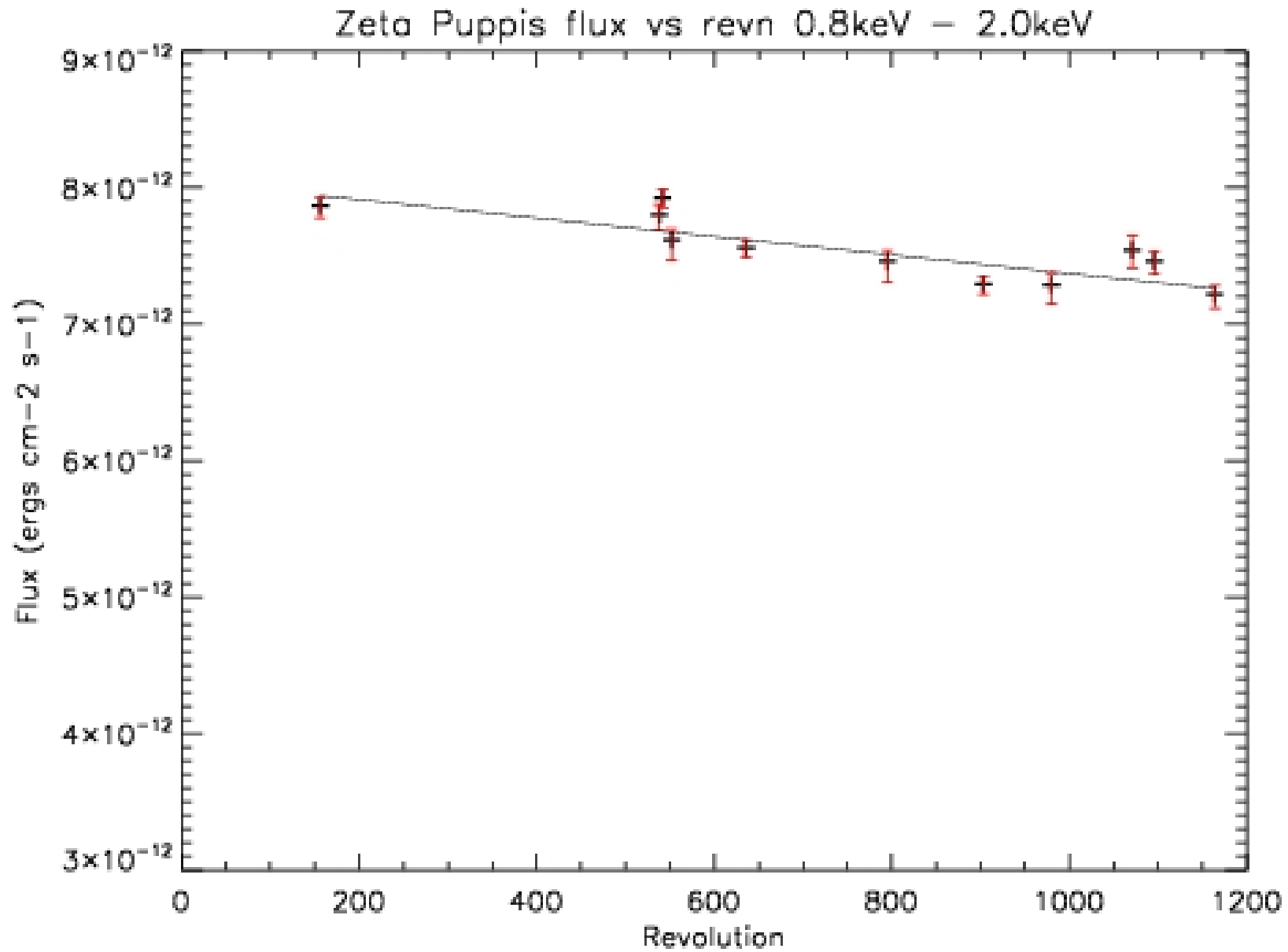


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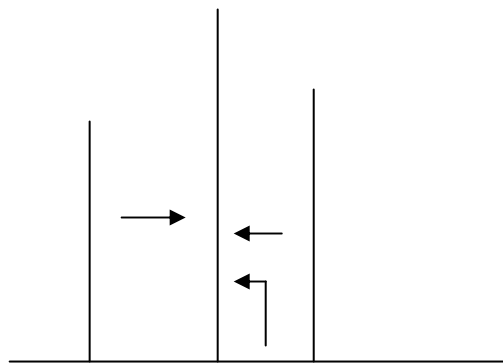
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Analysis – stage 2 for MOS

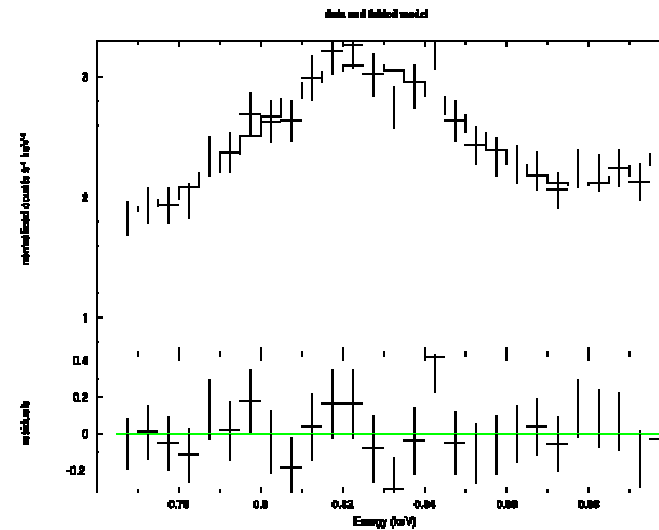
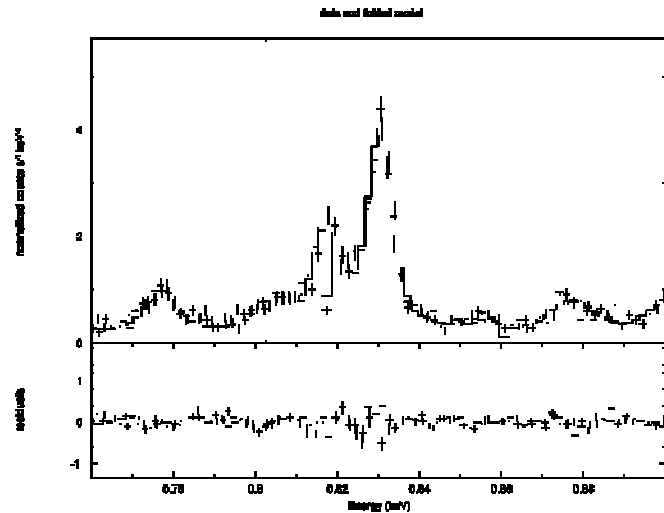
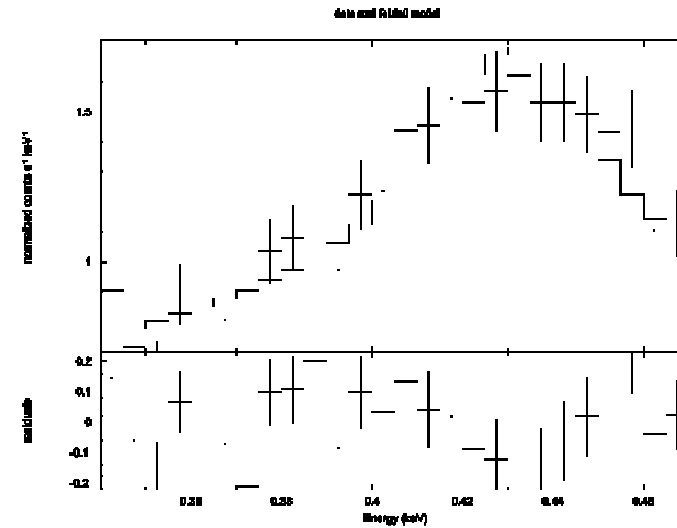
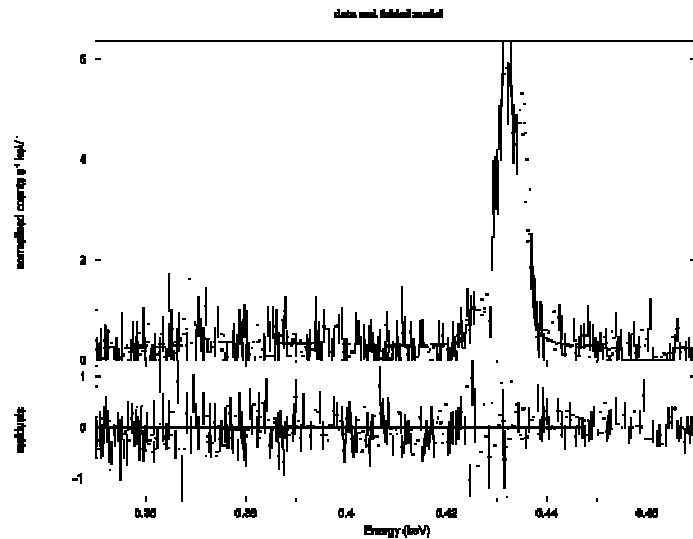
- Apply the best RGS models for each revn. found to MOS data, as produced by Steve with SAS 7.0.0
- Concentrate on certain lines, selected to cover a range of energies



Tie very close lines together and cont. norm

Selection	RGS line (~keV) under study
1	0.432
2	0.801
3	1.023
4	1.856

Fit examples – RGS and MOS



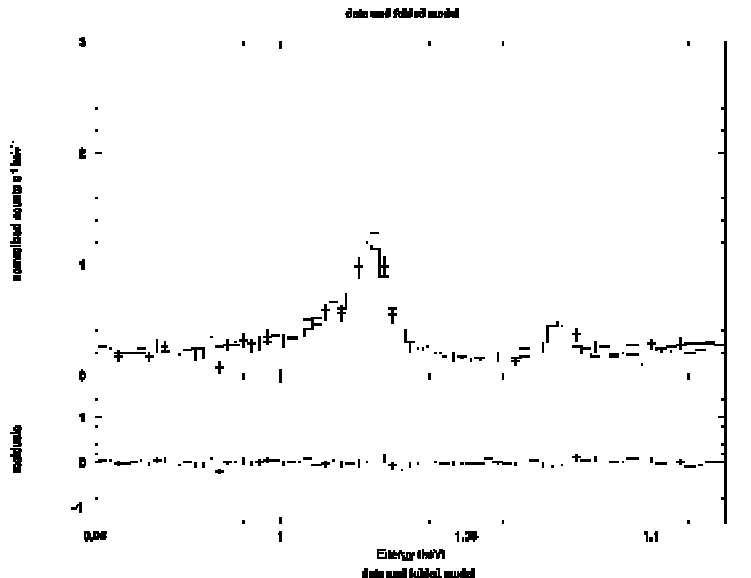
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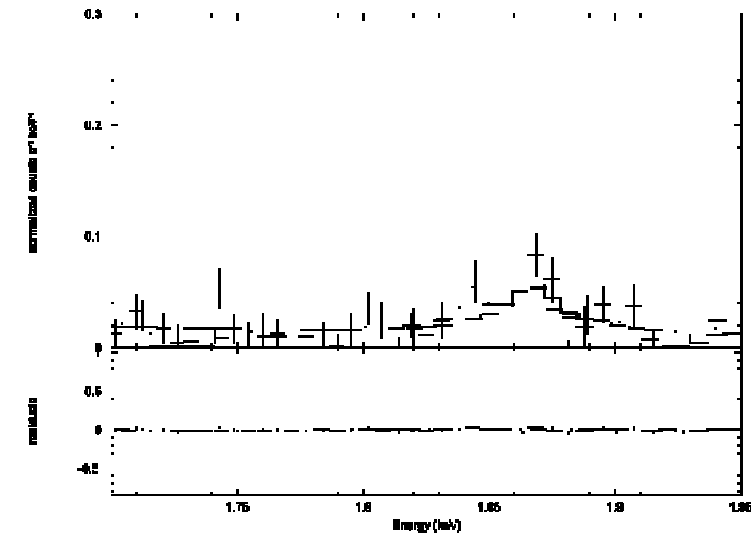
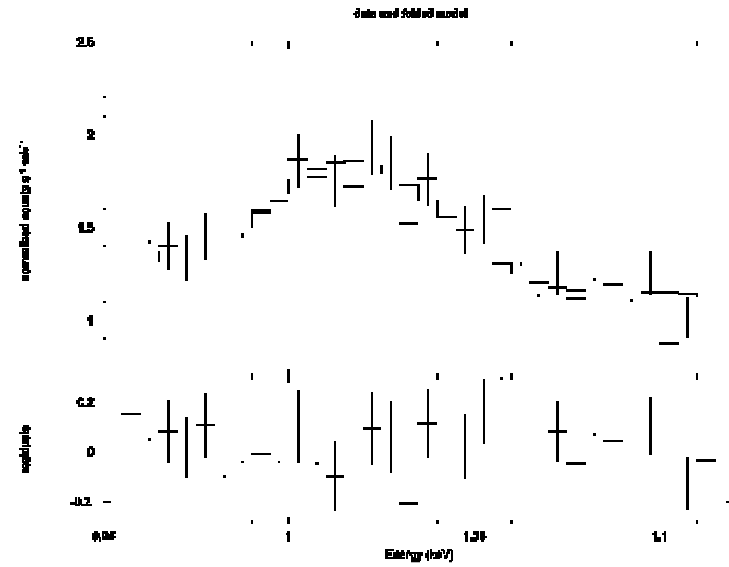


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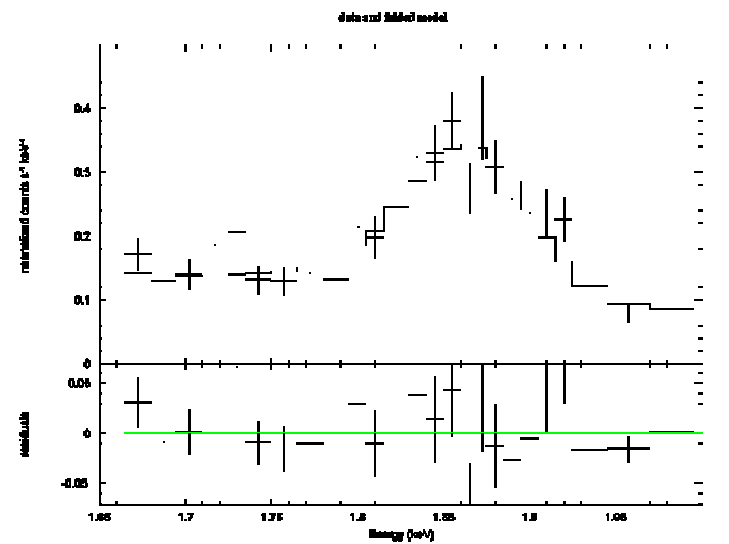
Lines 3 and 4



Line 3



Line 4



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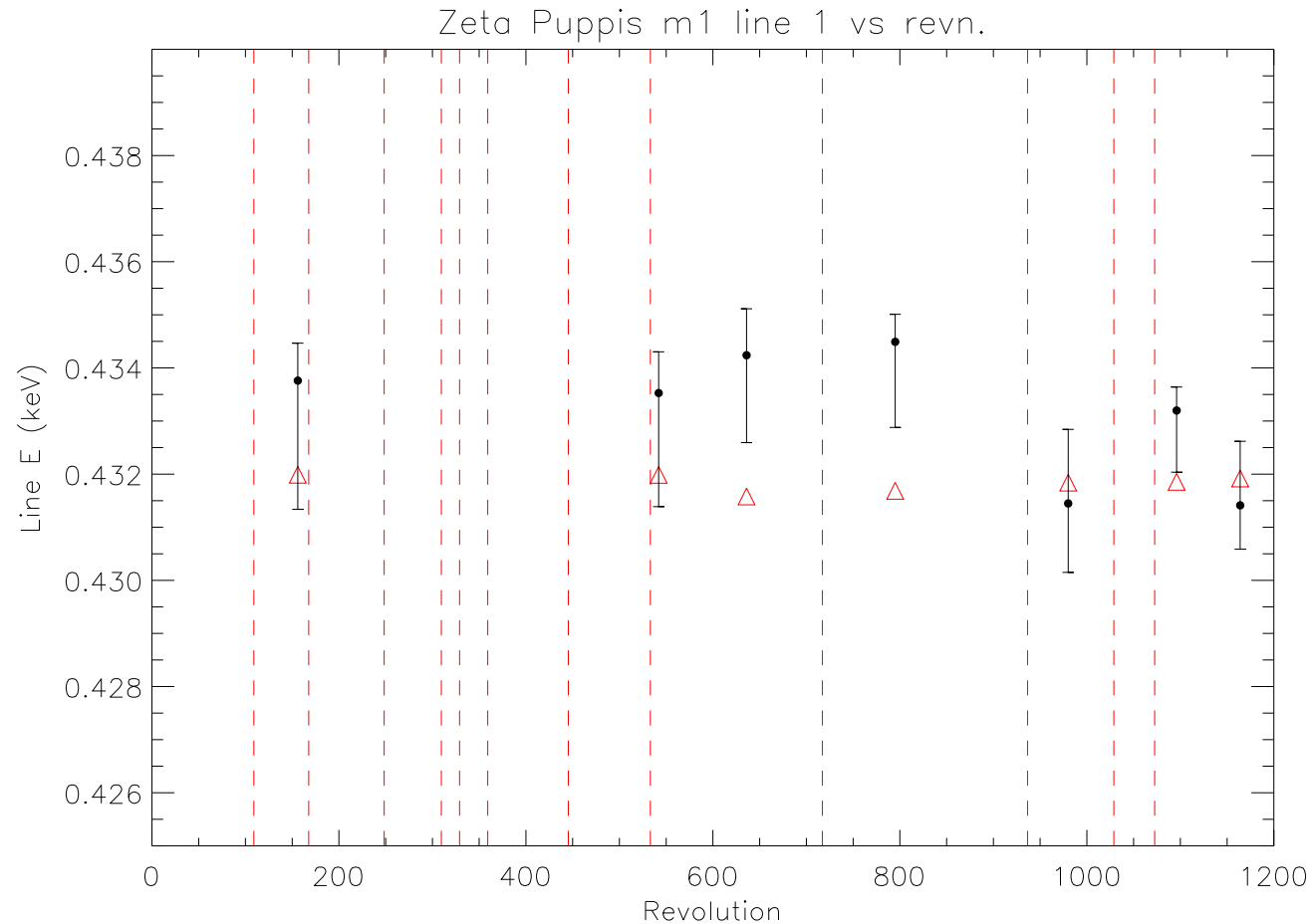
Stage 2 – results for MOS

- Line energy differences between subject line for RGS and MOS
- Flux differences between RGS and MOS over selected energy ranges

Line	RGS average line energy (keV)	MOS1 average line energy (keV)	MOS2 average line energy (keV)
1	0.4318	0.4332	0.4318
2	0.8271	0.8271	0.8271
3	1.0234	1.0276	1.0285
4	1.8614	1.8626	1.8614



Line energy differences – line 1, MOS1



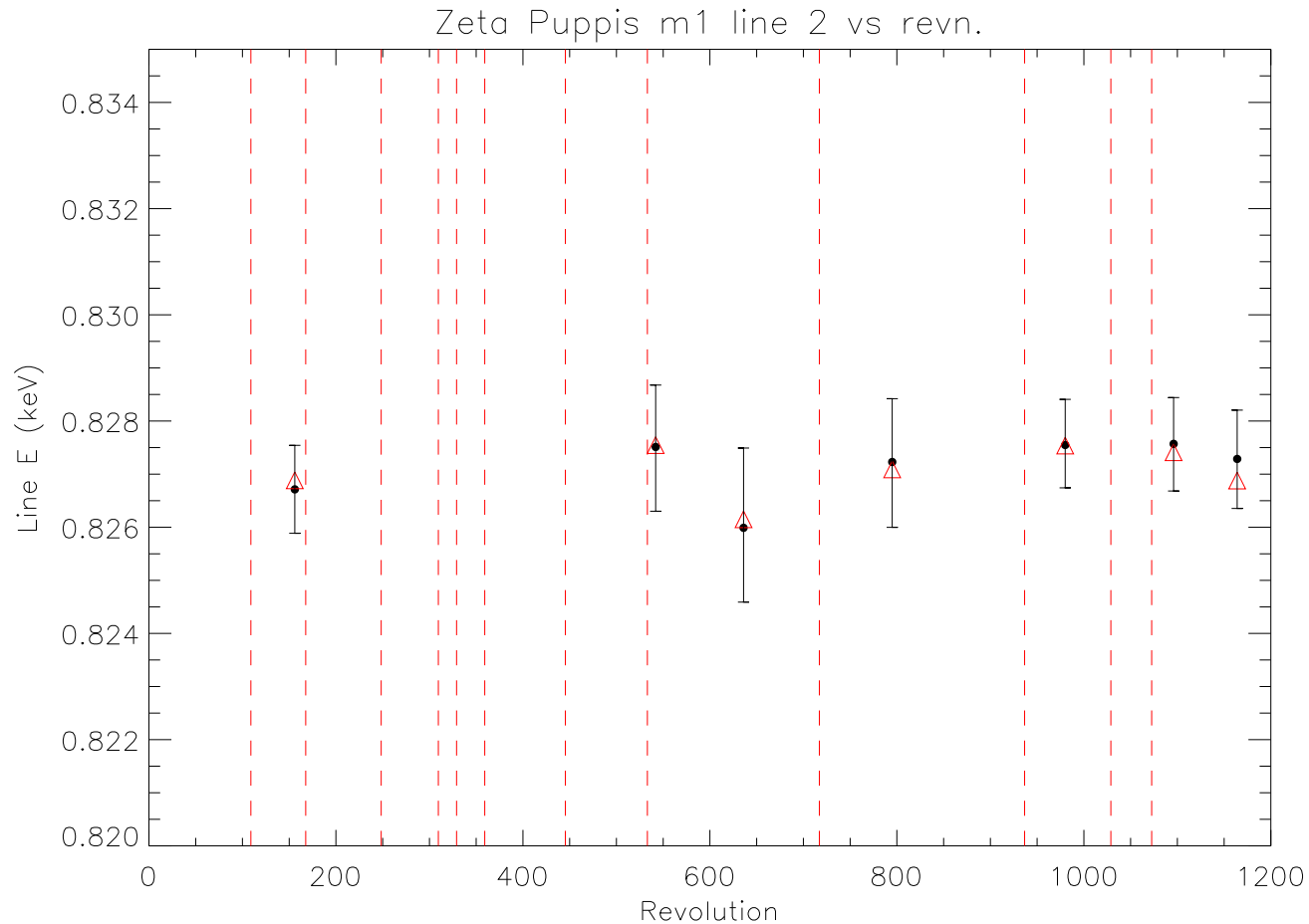
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Line energy differences – line 2, MOS1



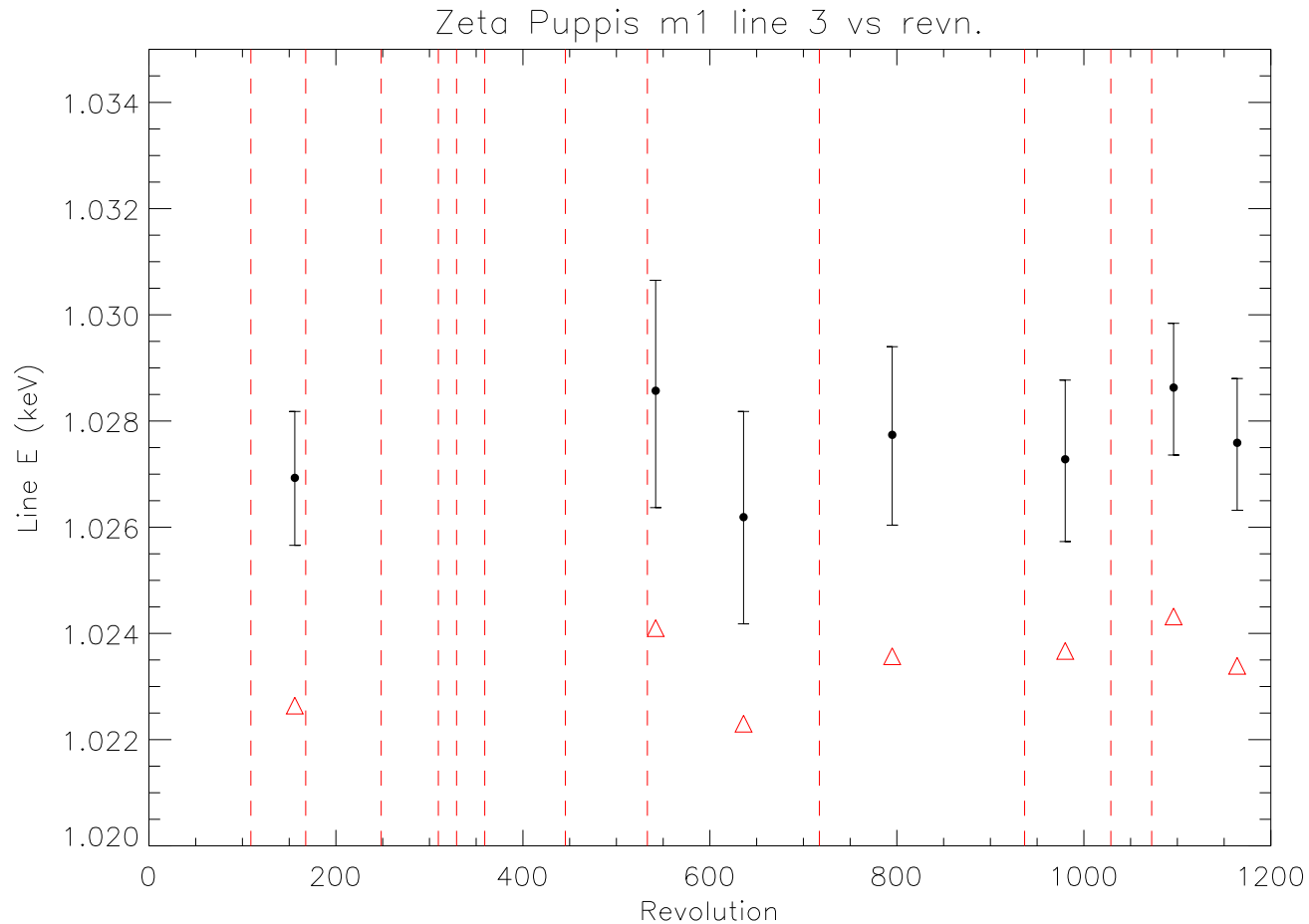
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Line energy differences – line 3, MOS1



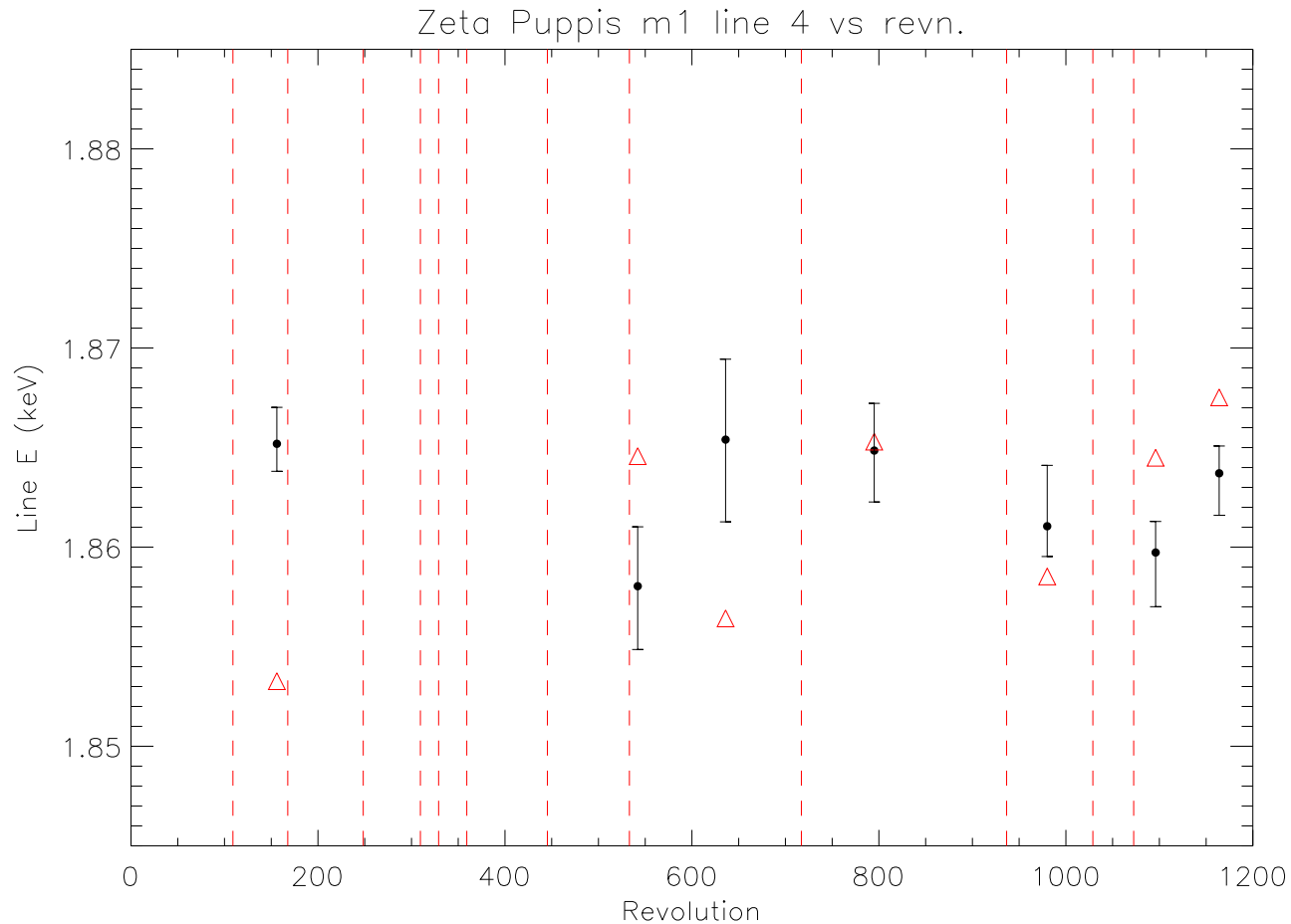
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Line energy differences – line 4, MOS1



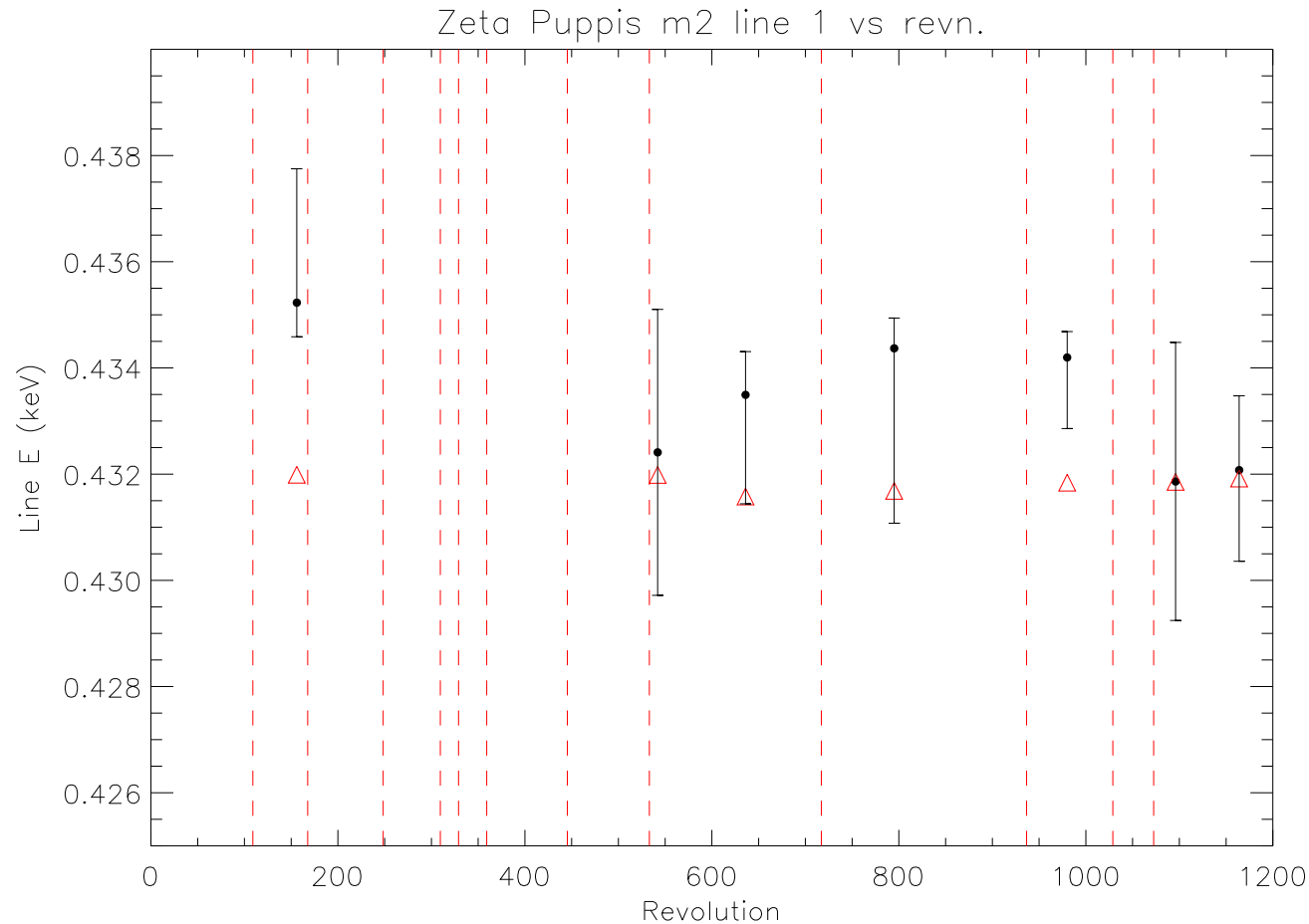
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Line energy differences – line 1, MOS2



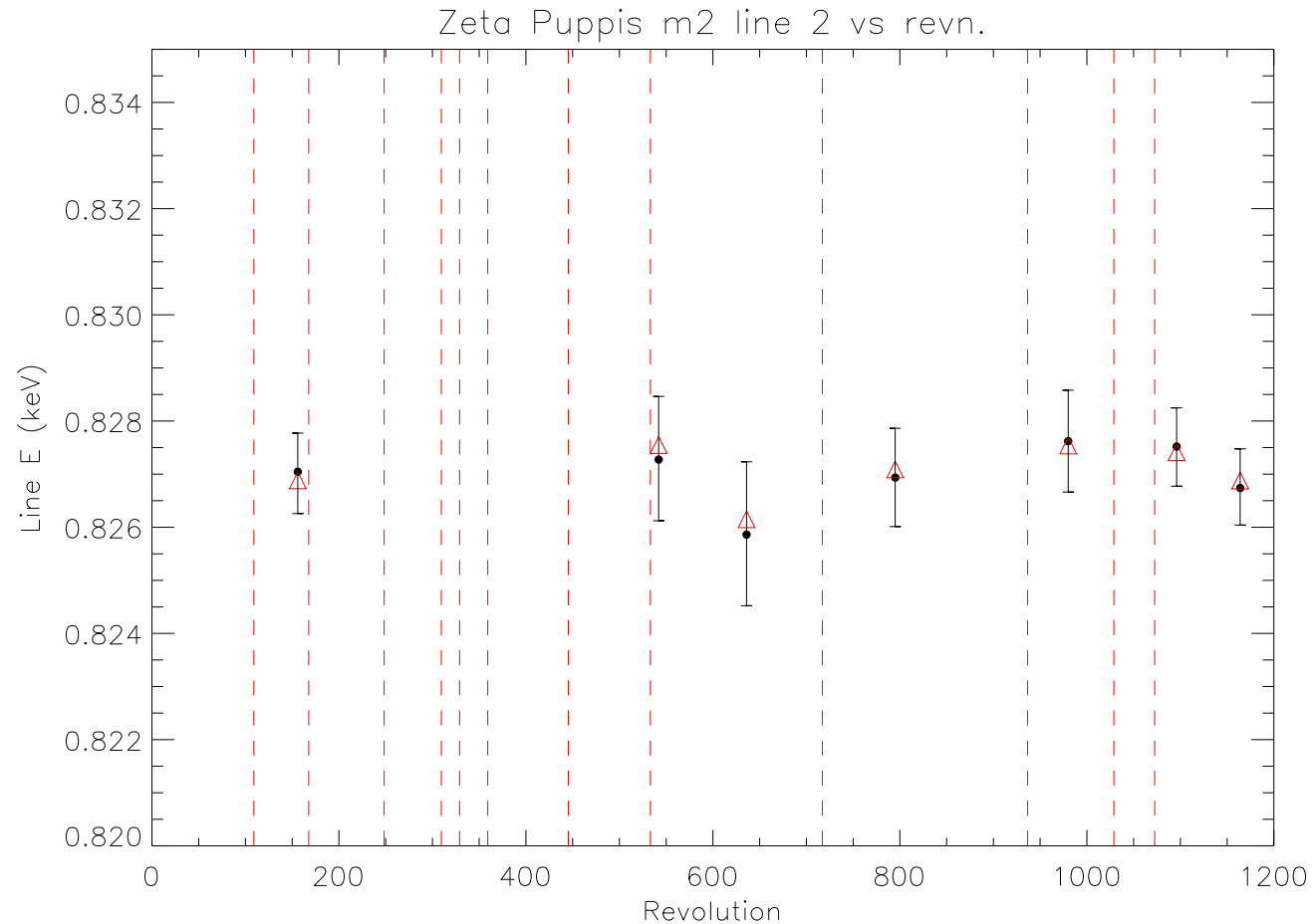
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Line energy differences – line 2, MOS2



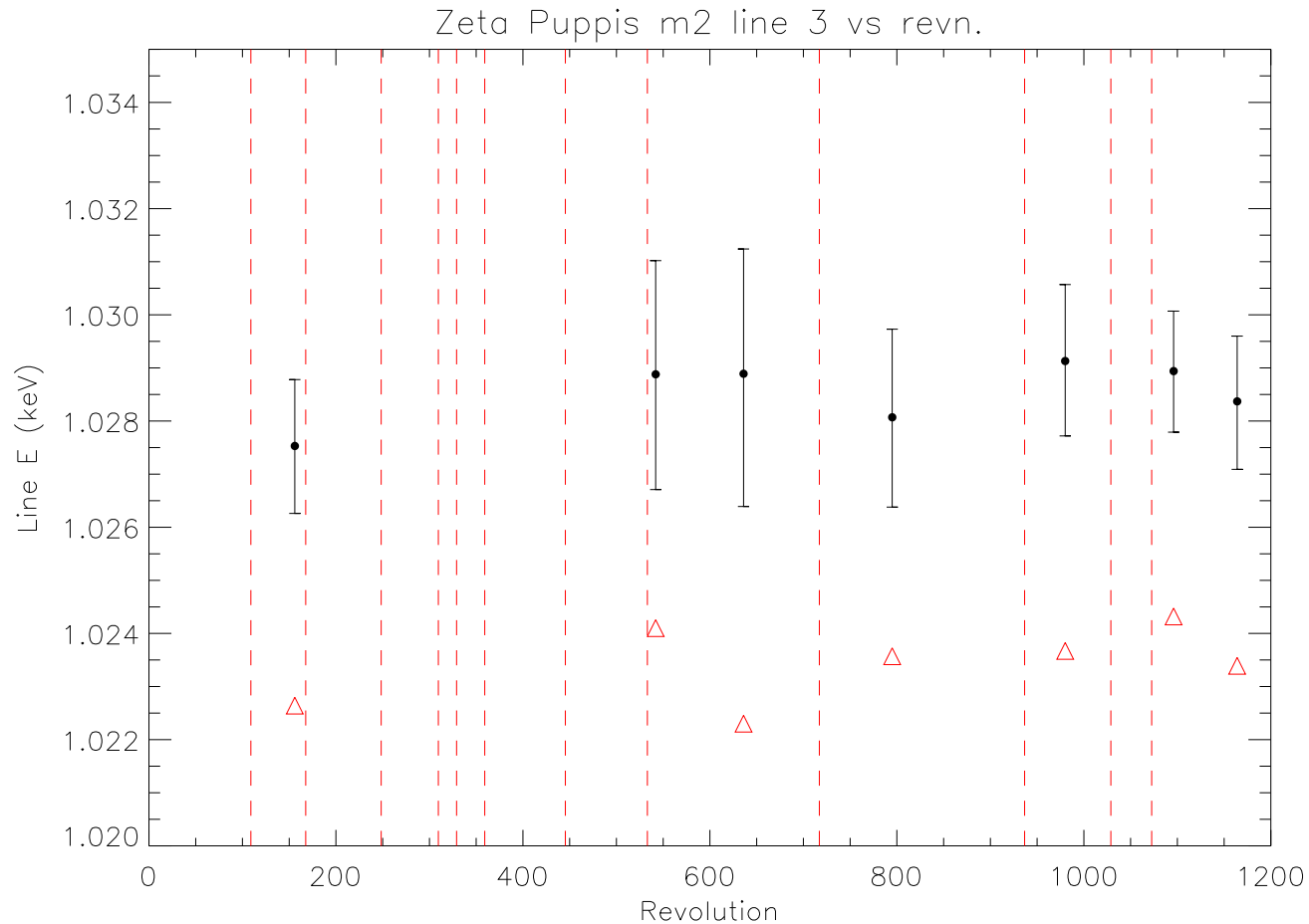
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Line energy differences – line 3, MOS2



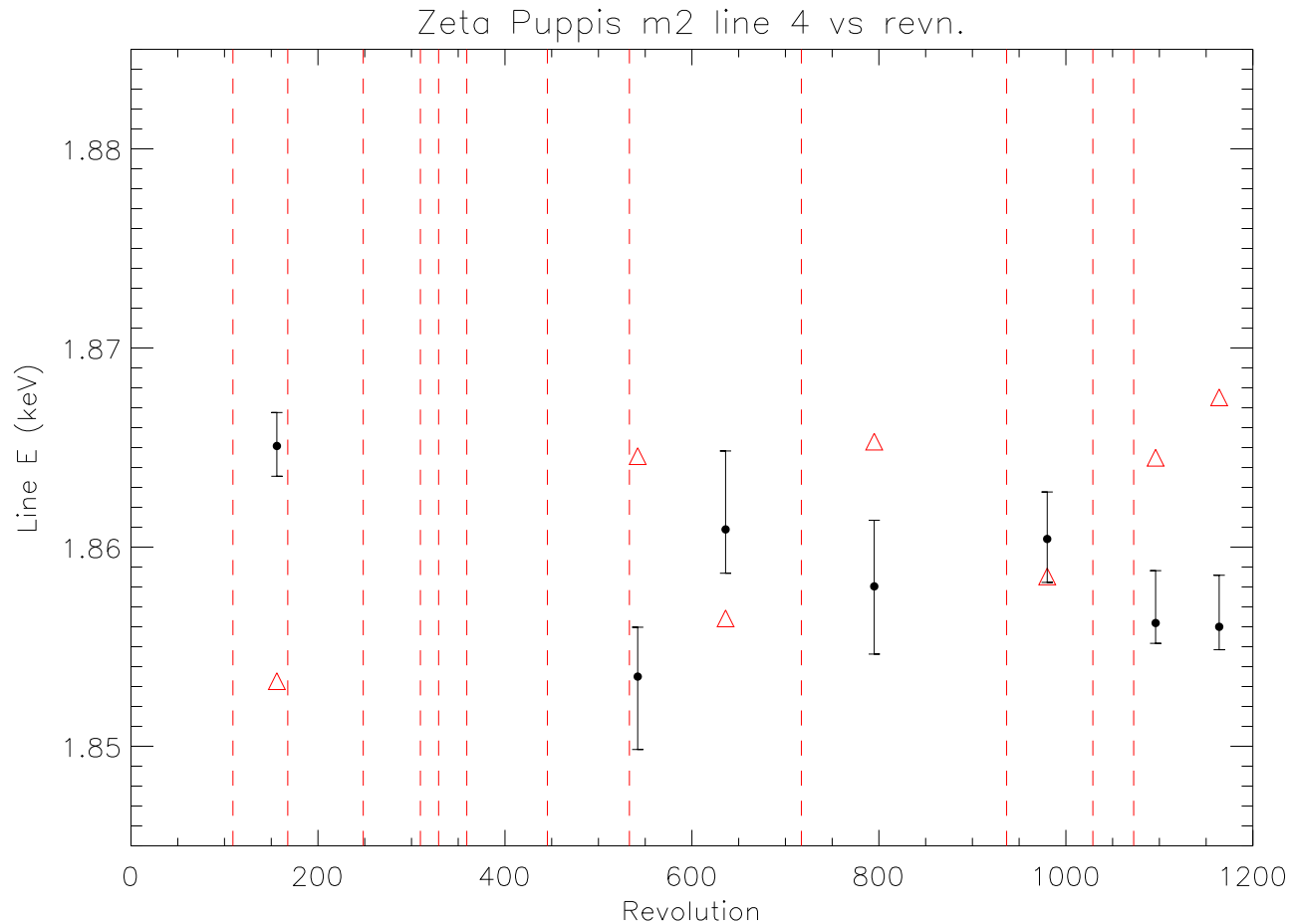
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Line energy differences – line 4, MOS2



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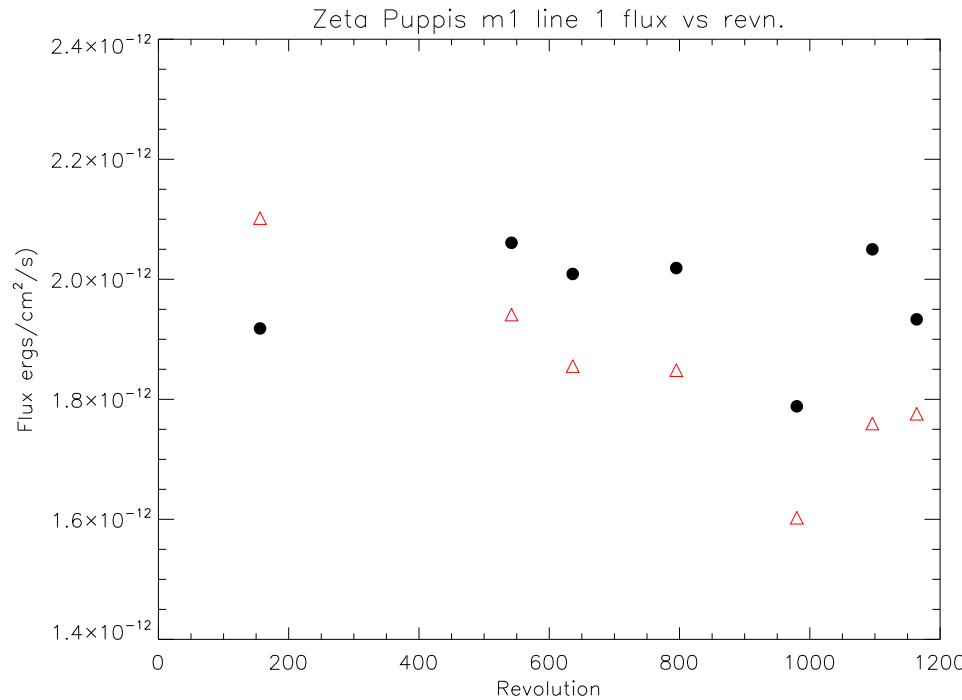
Mean fluxes for RGS and MOS

Although generally downward trend seen

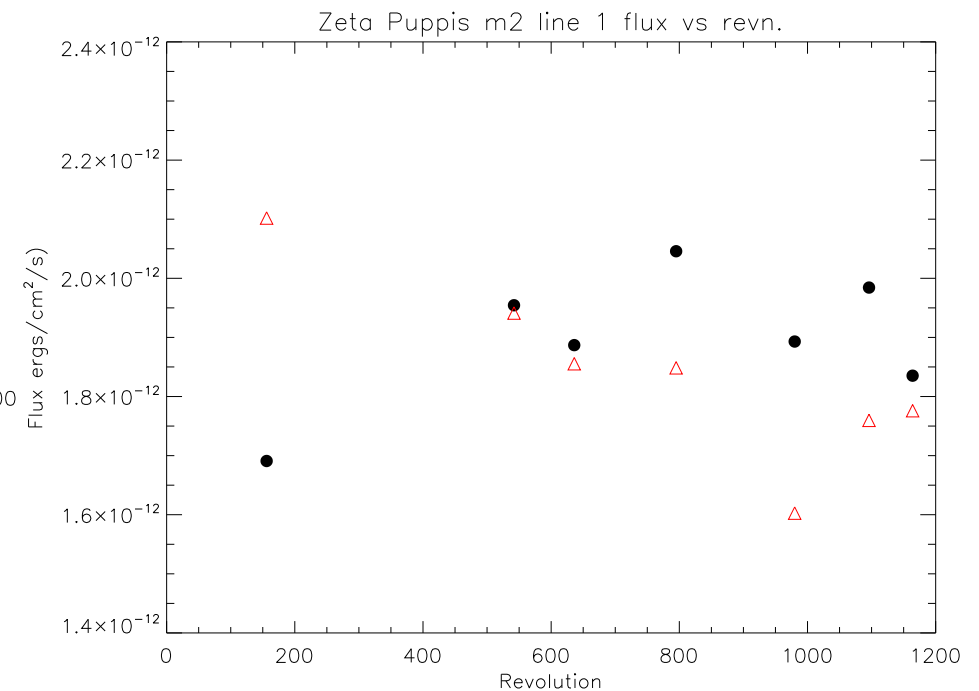
Line and E-range (keV)	RGS average flux (ergs cm ⁻² s ⁻¹)	MOS1 average flux (ergs cm ⁻² s ⁻¹)	MOS2 average flux (ergs cm ⁻² s ⁻¹)
1; 0.34 – 0.47	1.841×10 ⁻¹²	1.968×10 ⁻¹²	1.898×10 ⁻¹²
2; 0.76 – 0.90	2.368×10 ⁻¹²	2.497×10 ⁻¹²	2.693×10 ⁻¹²
3; 0.95 – 1.12	1.460×10 ⁻¹²	1.549×10 ⁻¹²	1.606×10 ⁻¹²
4; 1.65 – 2.00	8.471×10 ⁻¹³	7.321×10 ⁻¹³	7.669×10 ⁻¹³



Flux differences RGS and MOS – line 1



Energy band: 0.34 – 0.47 keV



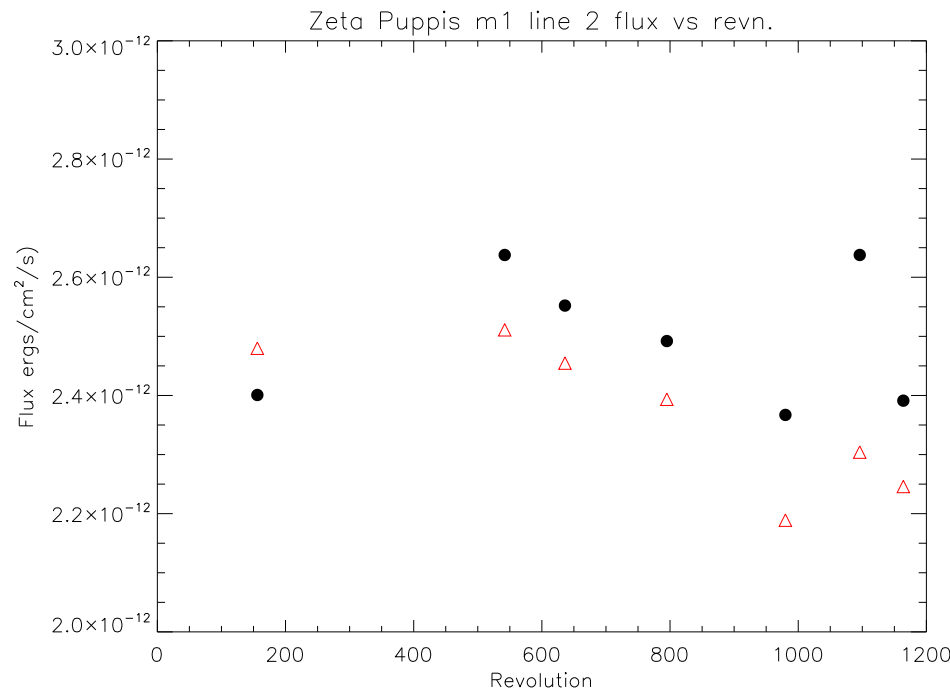
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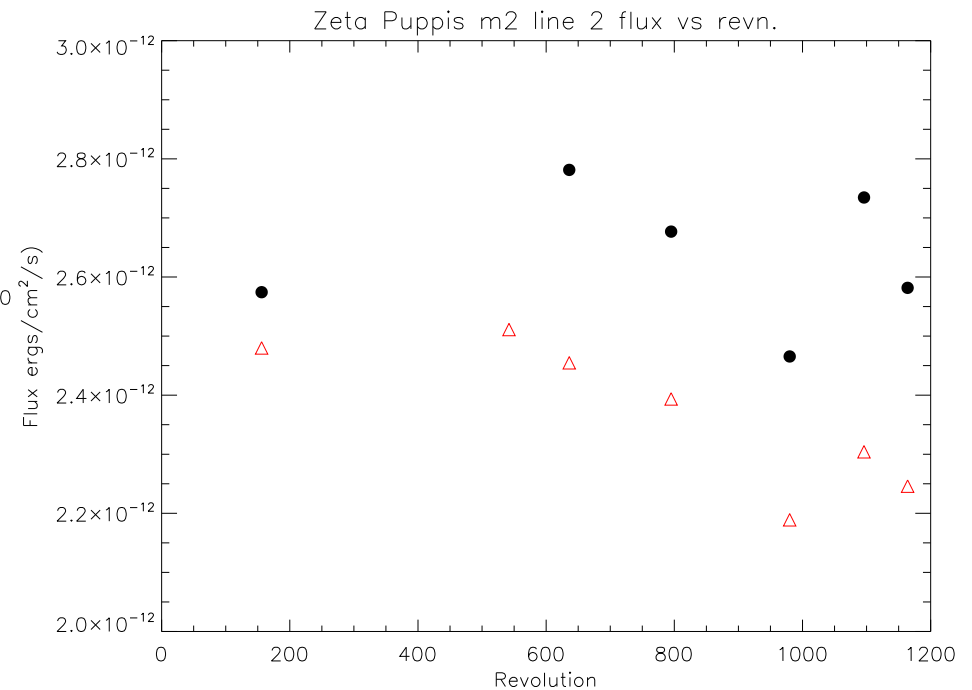


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Flux differences RGS and MOS – line 2



Energy band: 0.76 – 0.90 keV



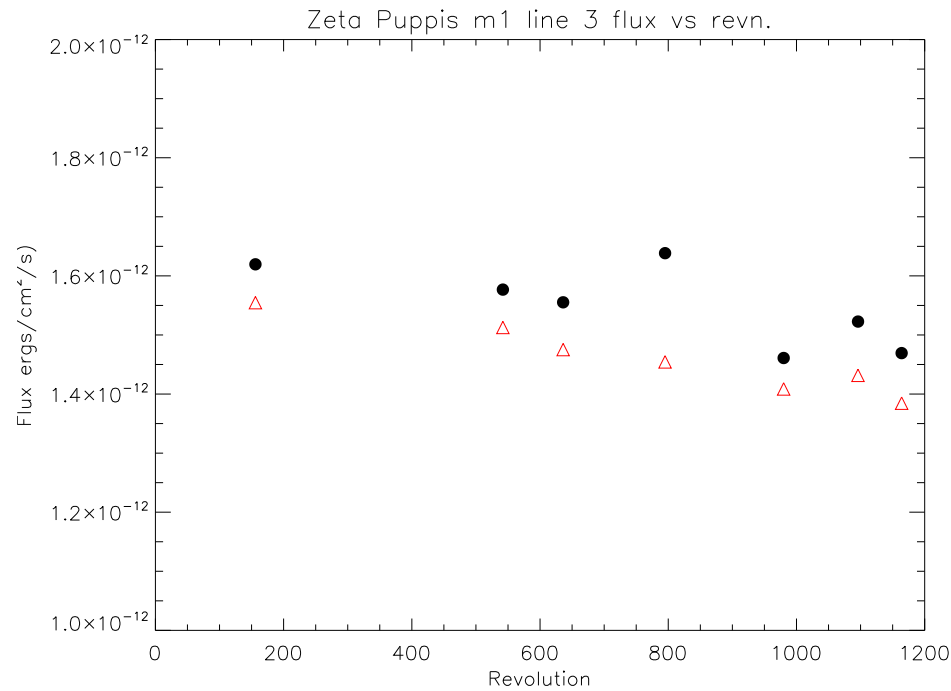
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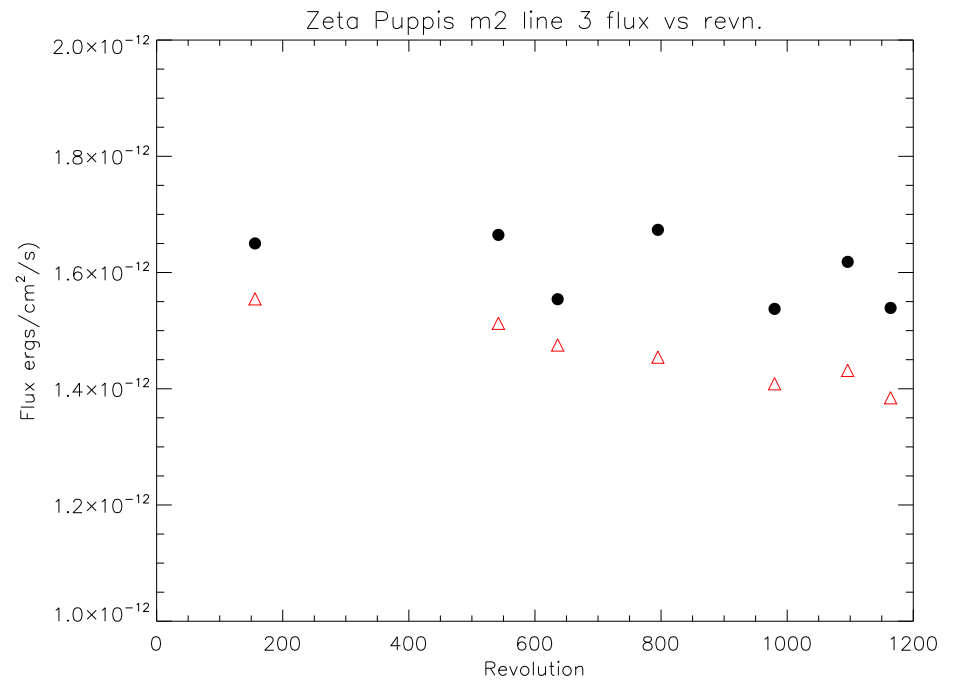


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Flux differences RGS and MOS – line 3



Energy band: 0.95 – 1.12 keV



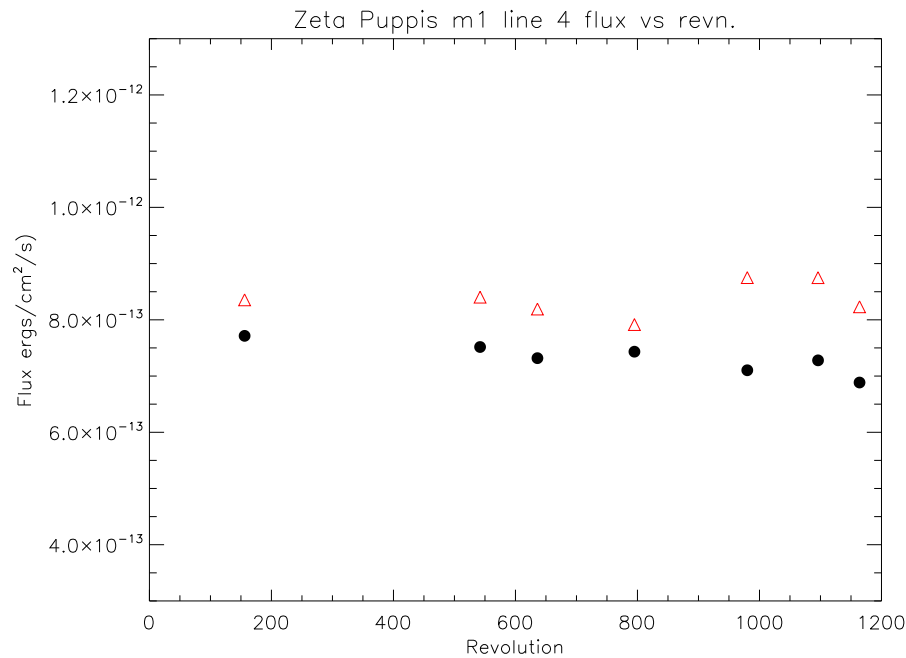
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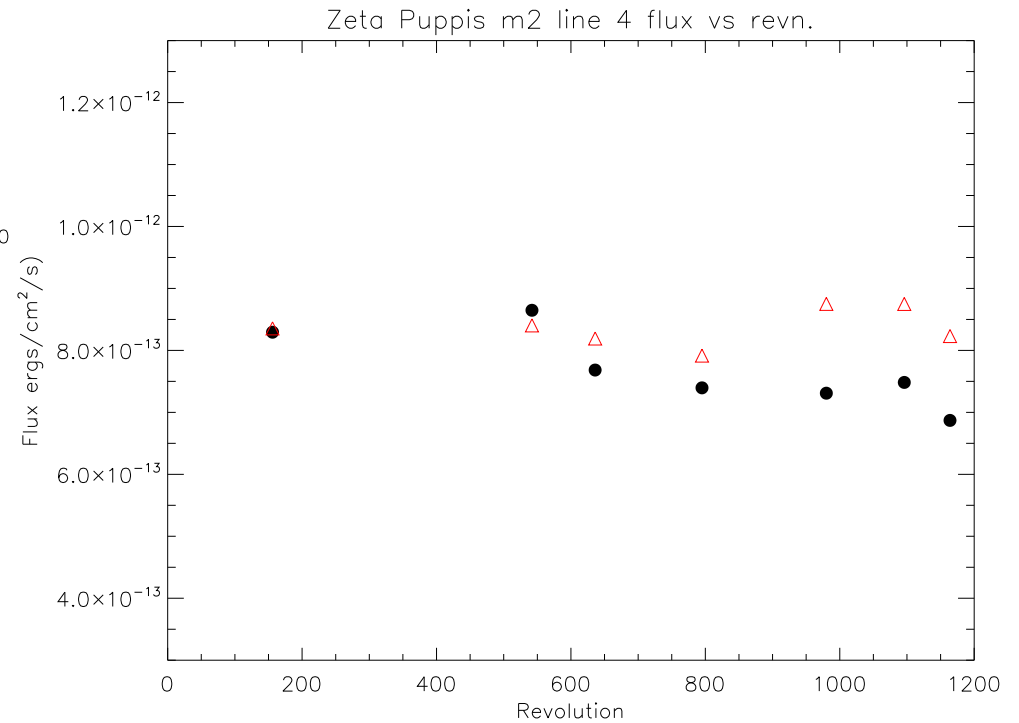


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Flux differences RGS and MOS – line 4



Energy band: 1.65 – 2.0 keV



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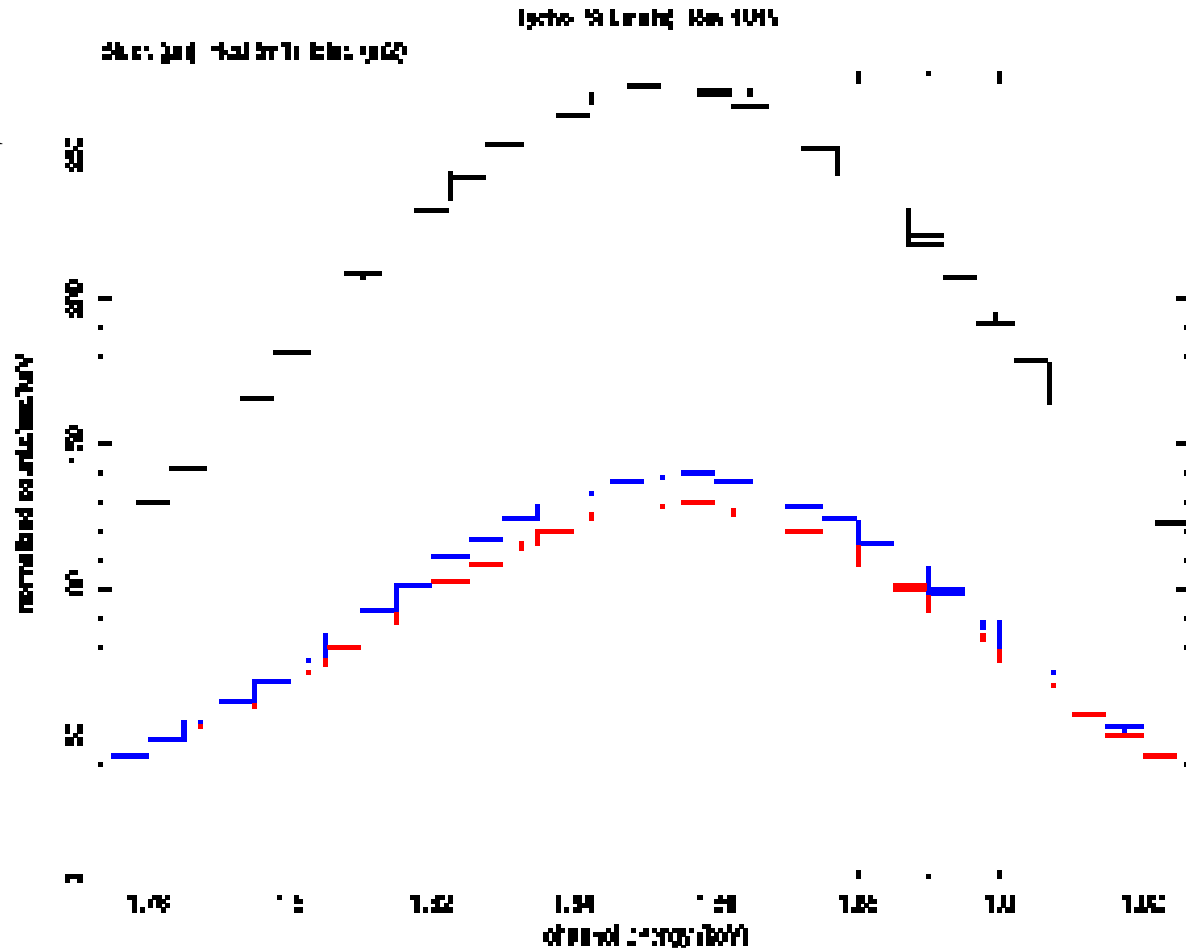


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Tycho

Checking around the silicon line with the pn

pn	1.858 ± 0.001
MOS1	1.859 ± 0.002
MOS2	1.859 ± 0.002



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Conclusions and future plans

- RGS flux decrease over time as shown by long-term blazar comparison, shown by Andy Pollock at the XMM-Newton Users Group
- MOS E-scale in agreement with RGS although systematic offset at ~ 1 keV of about 2-3 eV
- Higher energy line too weak in RGS to use as a calibration for MOS E-scale
- Scatter in flux values for both RGS and MOS, especially at low energies
- Flux of MOS generally above RGS values apart from highest energies
- Would like to look at other sources IES0102, Tycho and Procyon





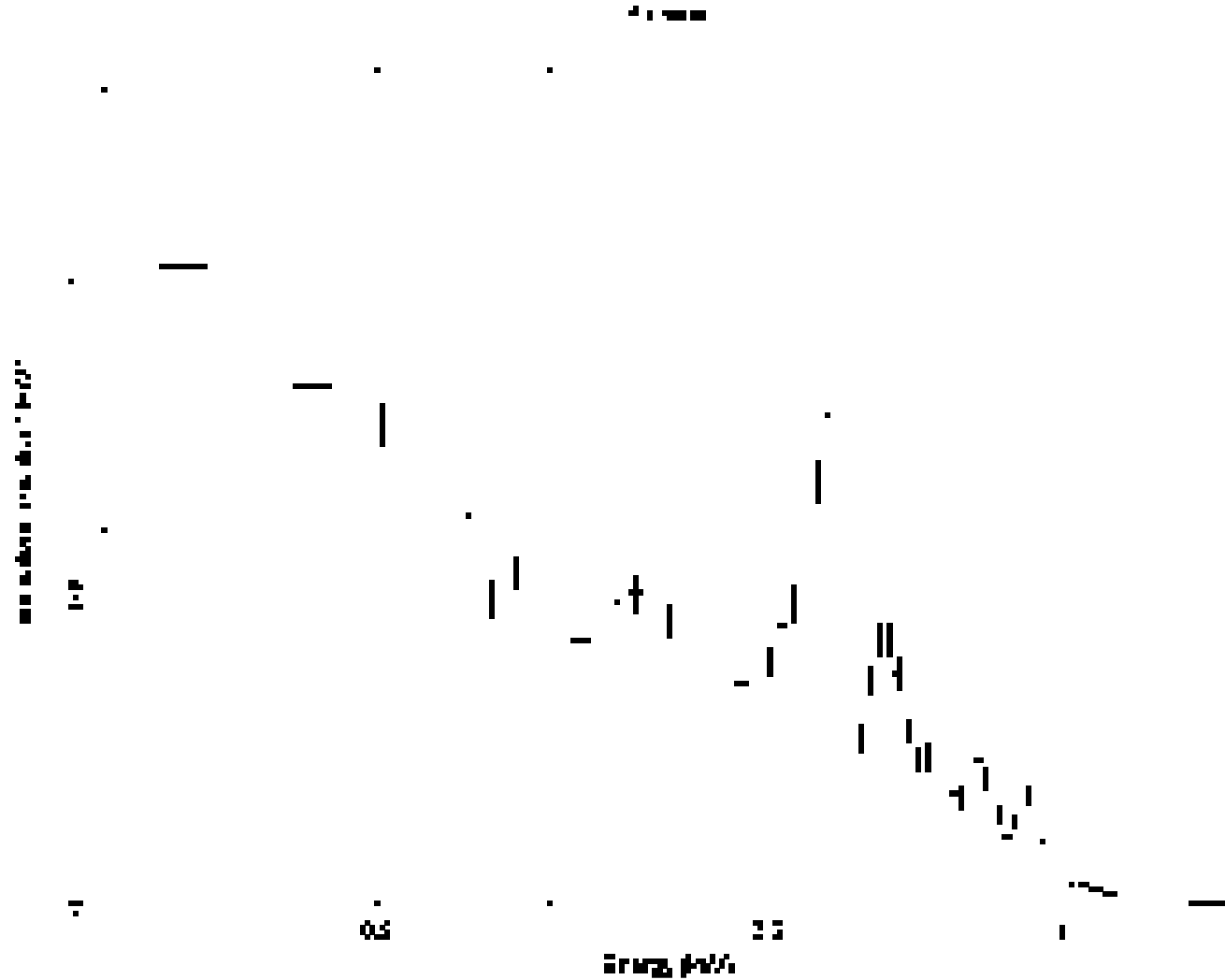
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Procyon



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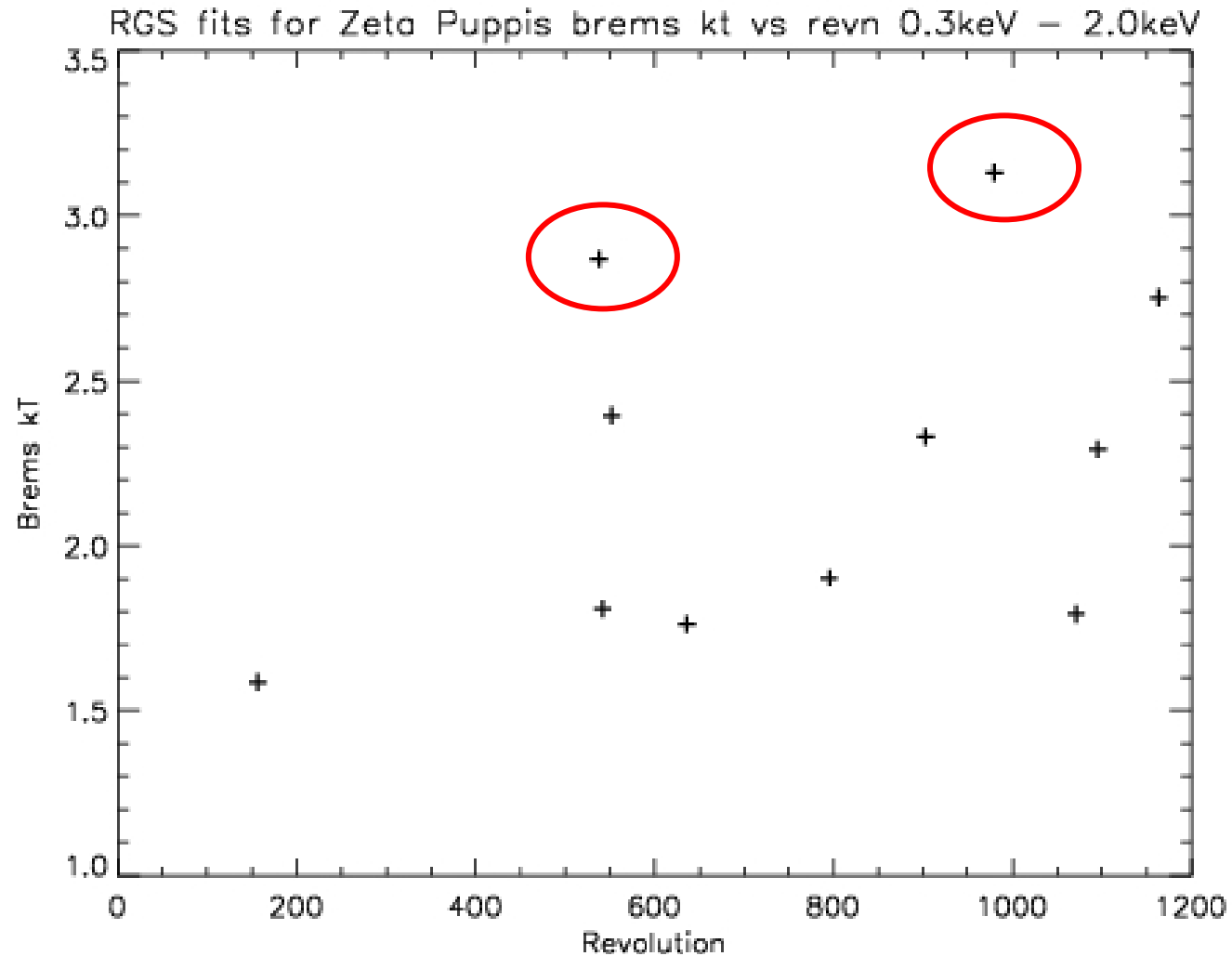
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Brems. temperature with revn.



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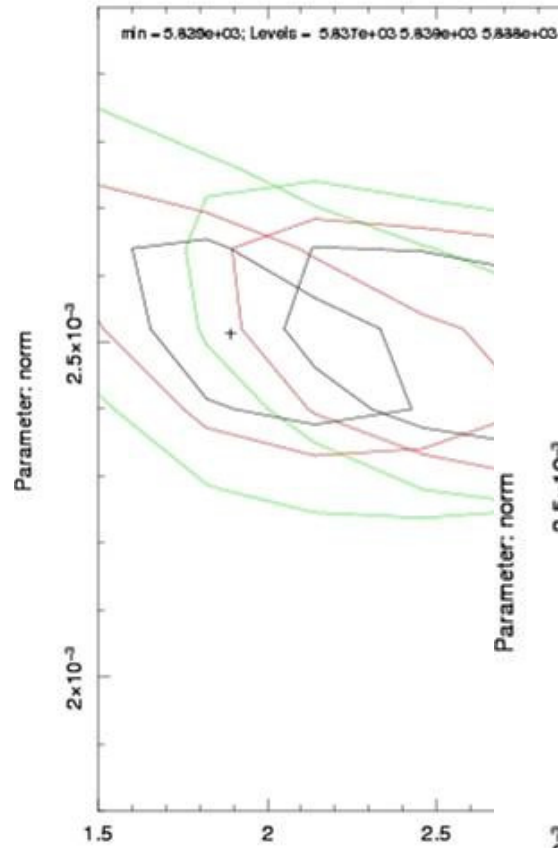
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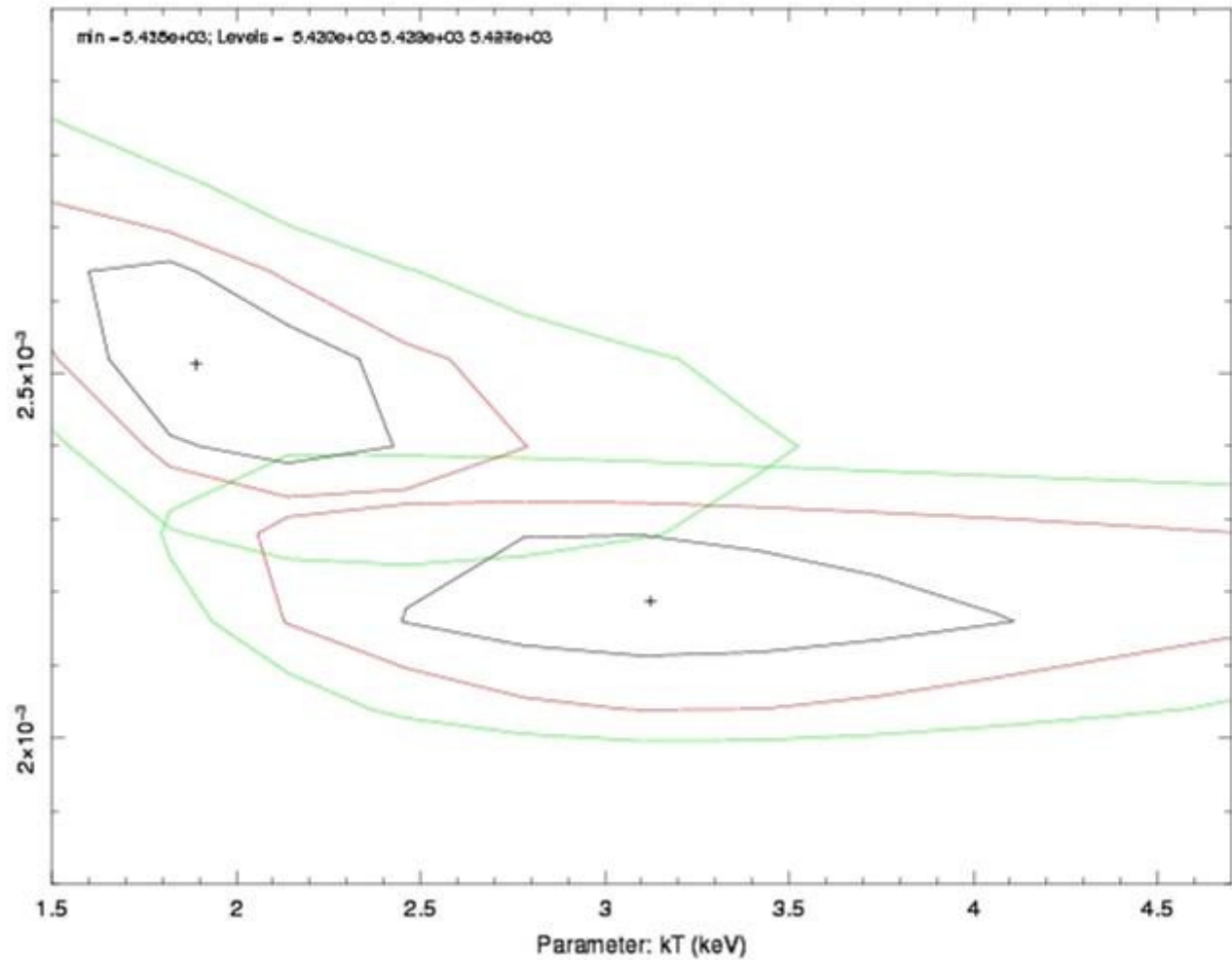
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Brems temperature contours

Confidence contours: C-Statistic



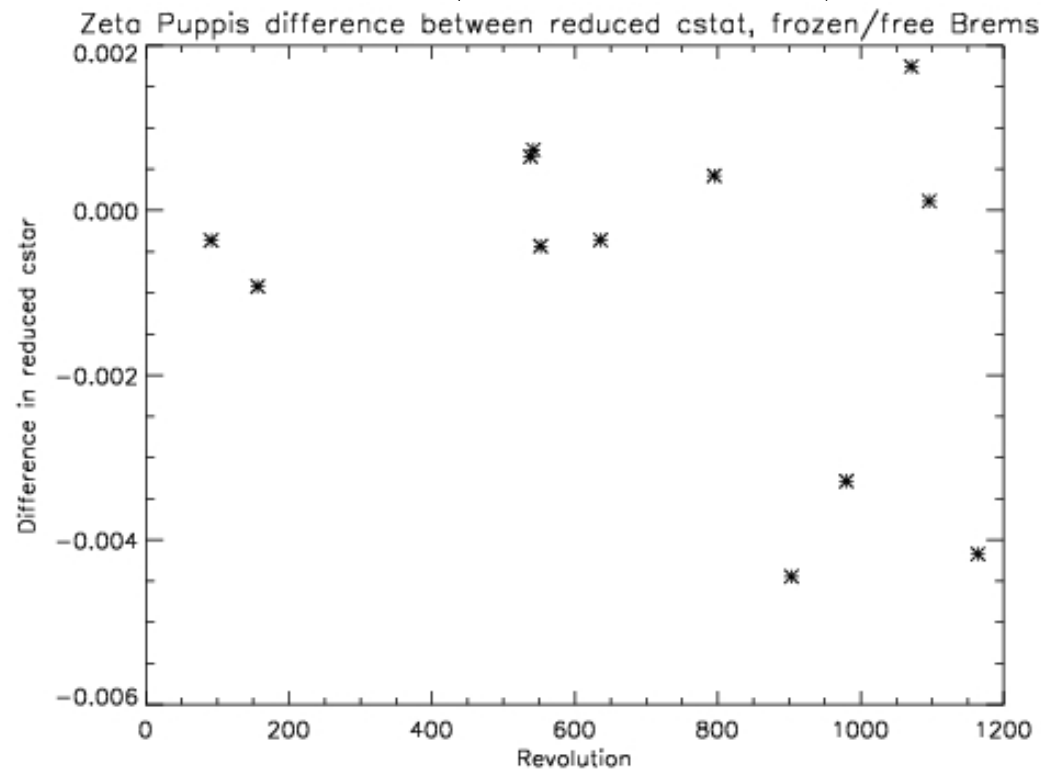
Confidence contours: C-Statistic



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Brems temperature fixed or free

- Fit again, this time keeping the Brems. component fixed and look at c-stat (frozen - red)



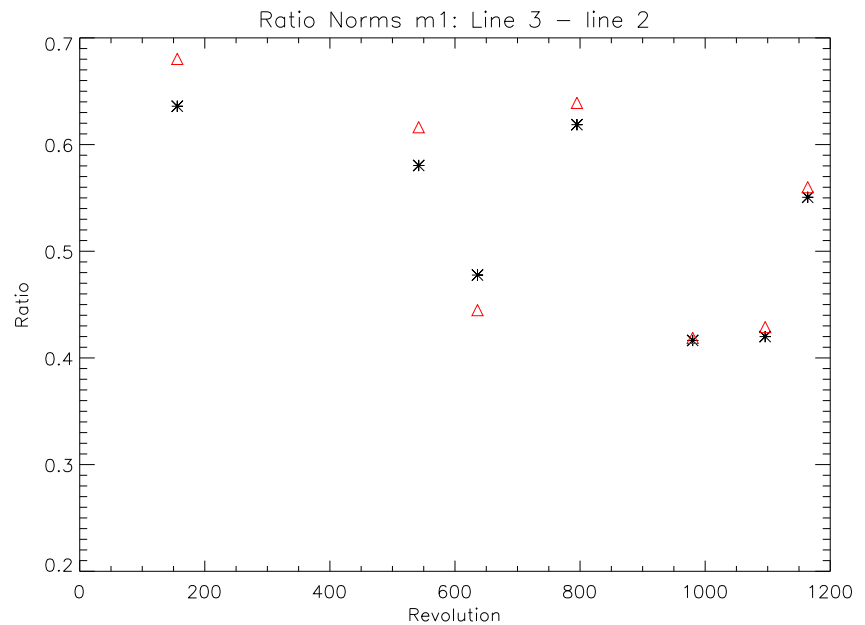
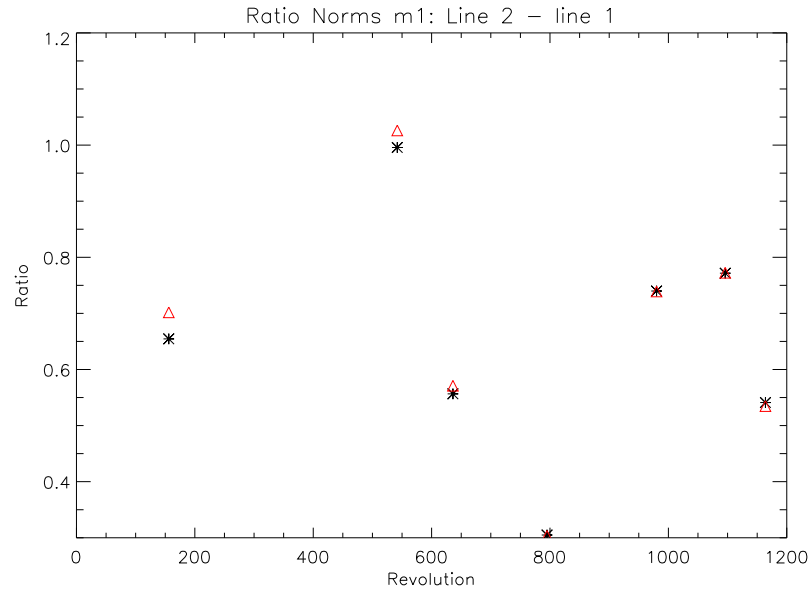
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Normalisation ratios – to line 1 and 2



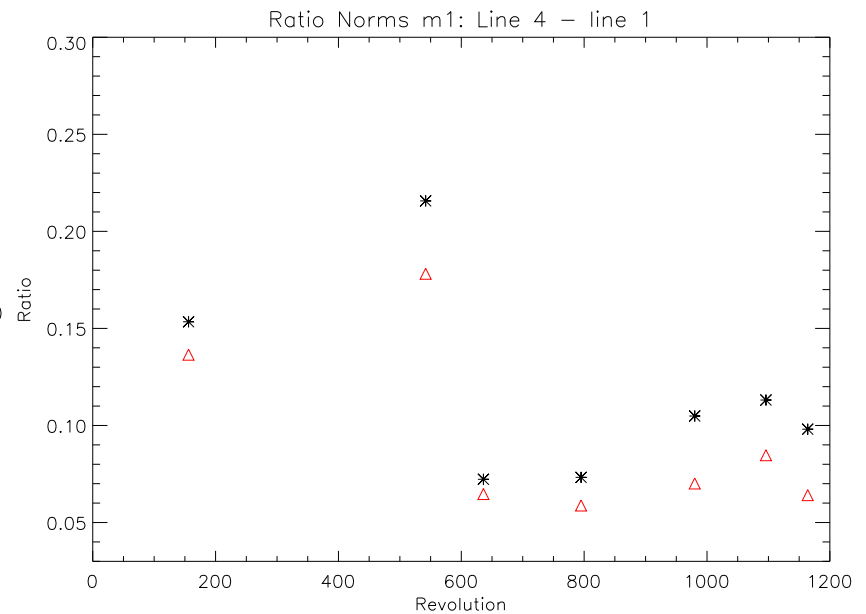
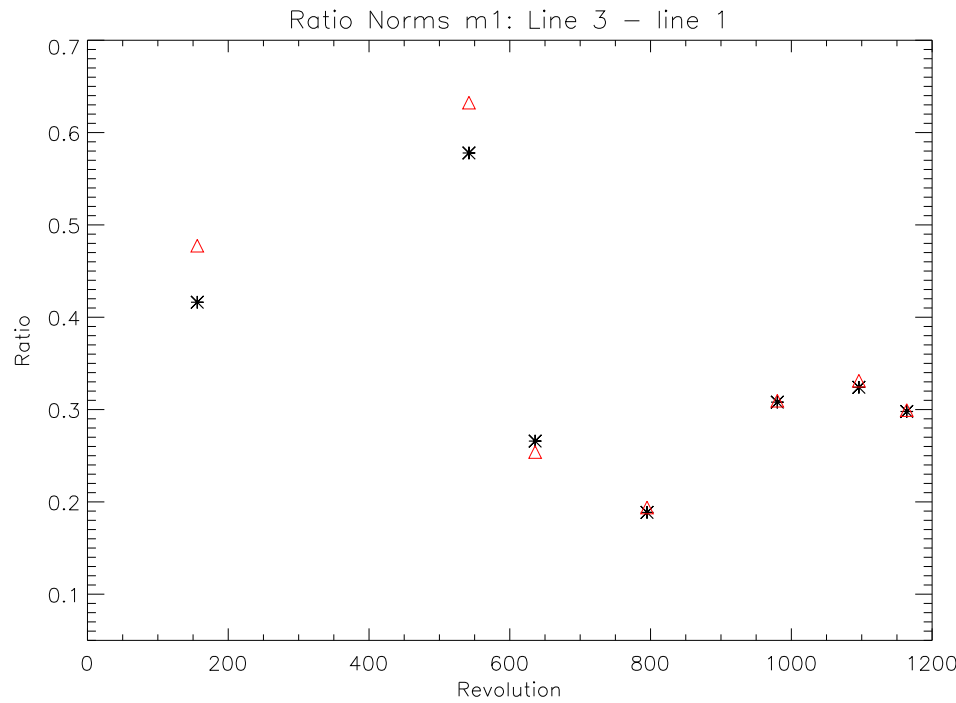
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Normalisation ratios, to line 1

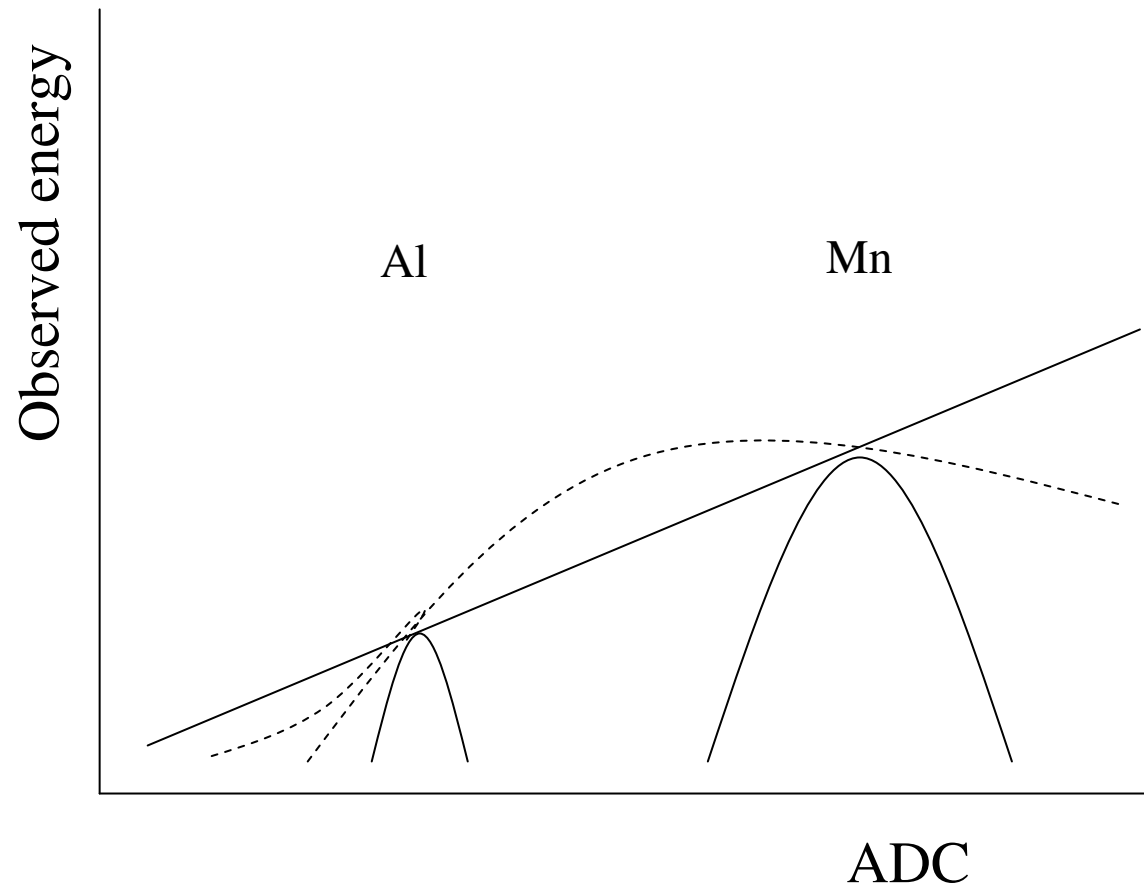


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Analysis – stage 2 - obsolete

- Apply the best models found to MOS data
- Freeze phabs and Brems.
- Concentrate on certain lines, selected to cover a range of energies

Selection	RGS line (~keV)	Range studied (keV)
1	0.432	0.40 – 0.57
2	0.801	0.65 – 0.92
3	1.023	0.92 – 1.25

