Effective Area of the *XMM-Newton* RGS

Andy Pollock

Chandra Calibration Workshop

31 October 2005

Jelle Kaastra, Jan-Willem den Herder, Cor de Vries, Jacco Vink & Jelle de Plaa
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Motivations for an accurate effective area

- Spectral subtleties: soft tails, broad (relativistic) lines
- Ground calibration accuracy ~15-20% due to
  - finite source distance
  - lack of narrow emission lines at long wavelengths
- Apparent discrepancies between RGS and EPIC
- Good calibration pays off in good science

⬆ **effective area at launch**

➡ **assess its stability**

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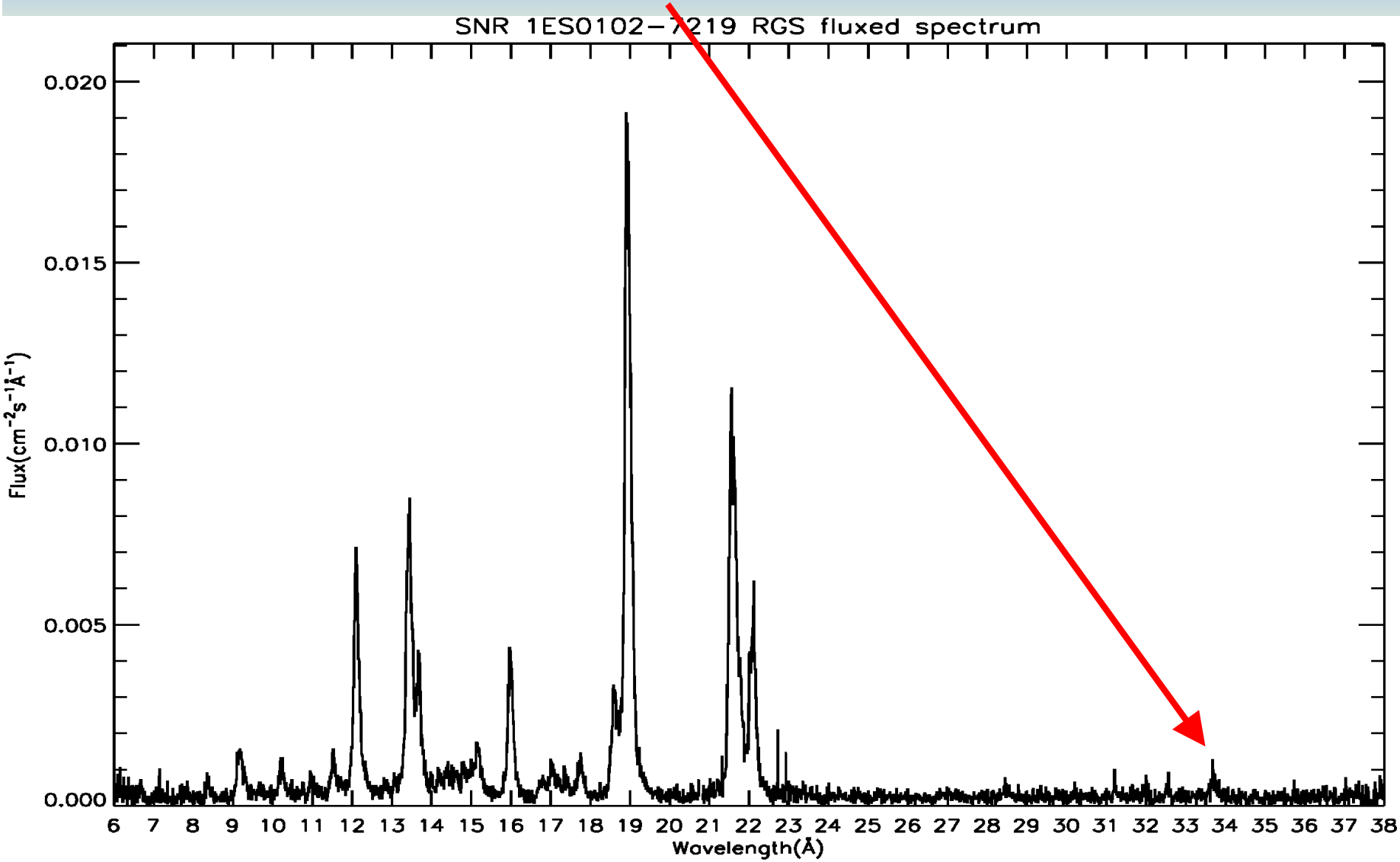
SNR 1ES0102-7219 CVI Lyα



RGS effective area

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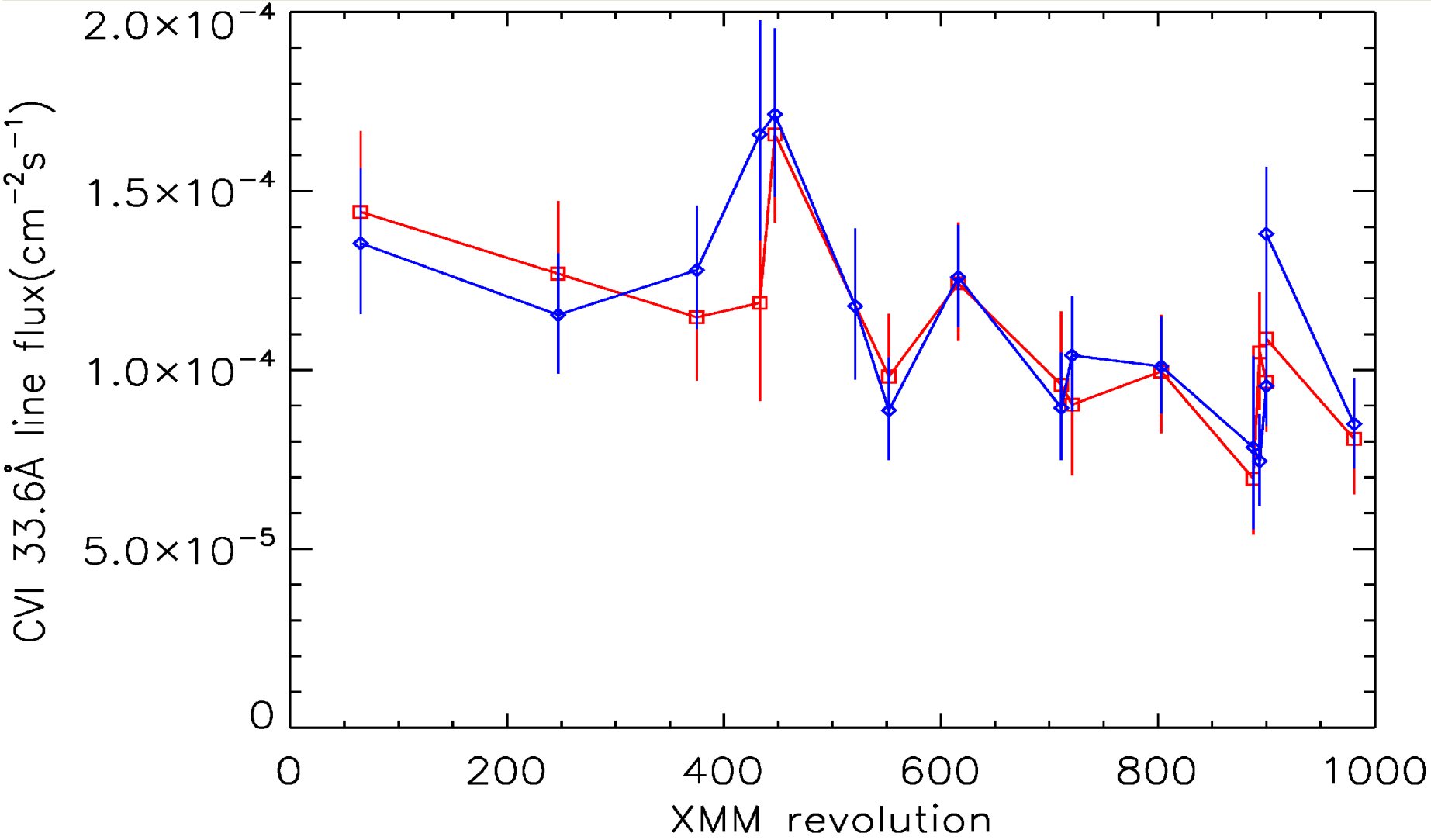

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(No) RGS effective-area stability

- lines in SNRs 1ES0102-7219 and N132D
- RGS/EPIC-pn AGN comparisons
- line ratios in stars like Capella and ζ Puppis
- comparative blazar spectra (see below)

⇒ **RGS effective area at λ > 25 Å has decreased by ~10%**

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RGS effective-area corrections

- empirical approach
- " featureless" blazar spectra show the same shape
- blazars have absorbed power-law spectra **(LETGS ratios $\Rightarrow$ no RGS breaks)**
- calibrate α against the Crab
- N_H (and absorption chemistry) vital

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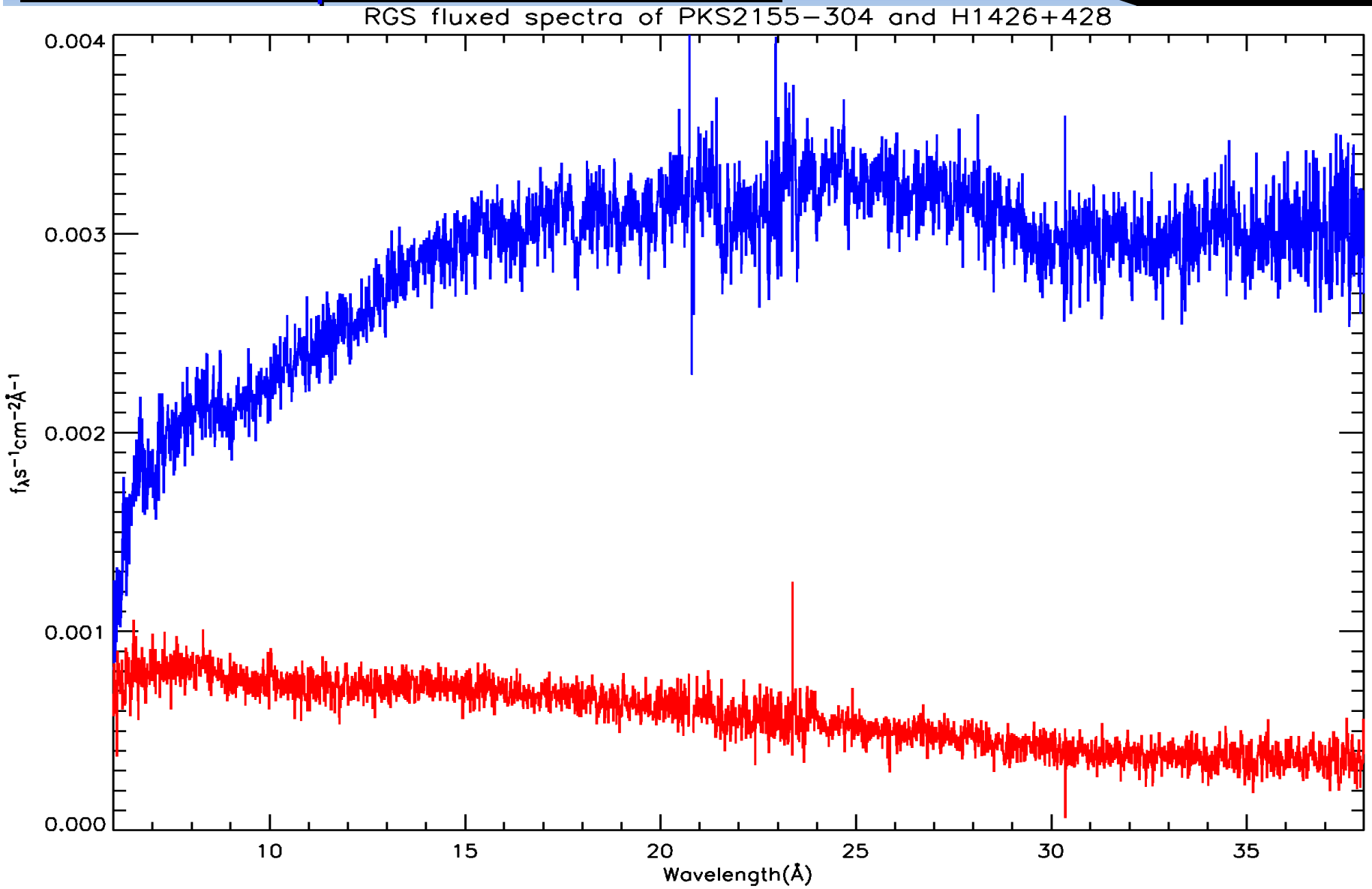
RGS fluxed spectra of two blazars



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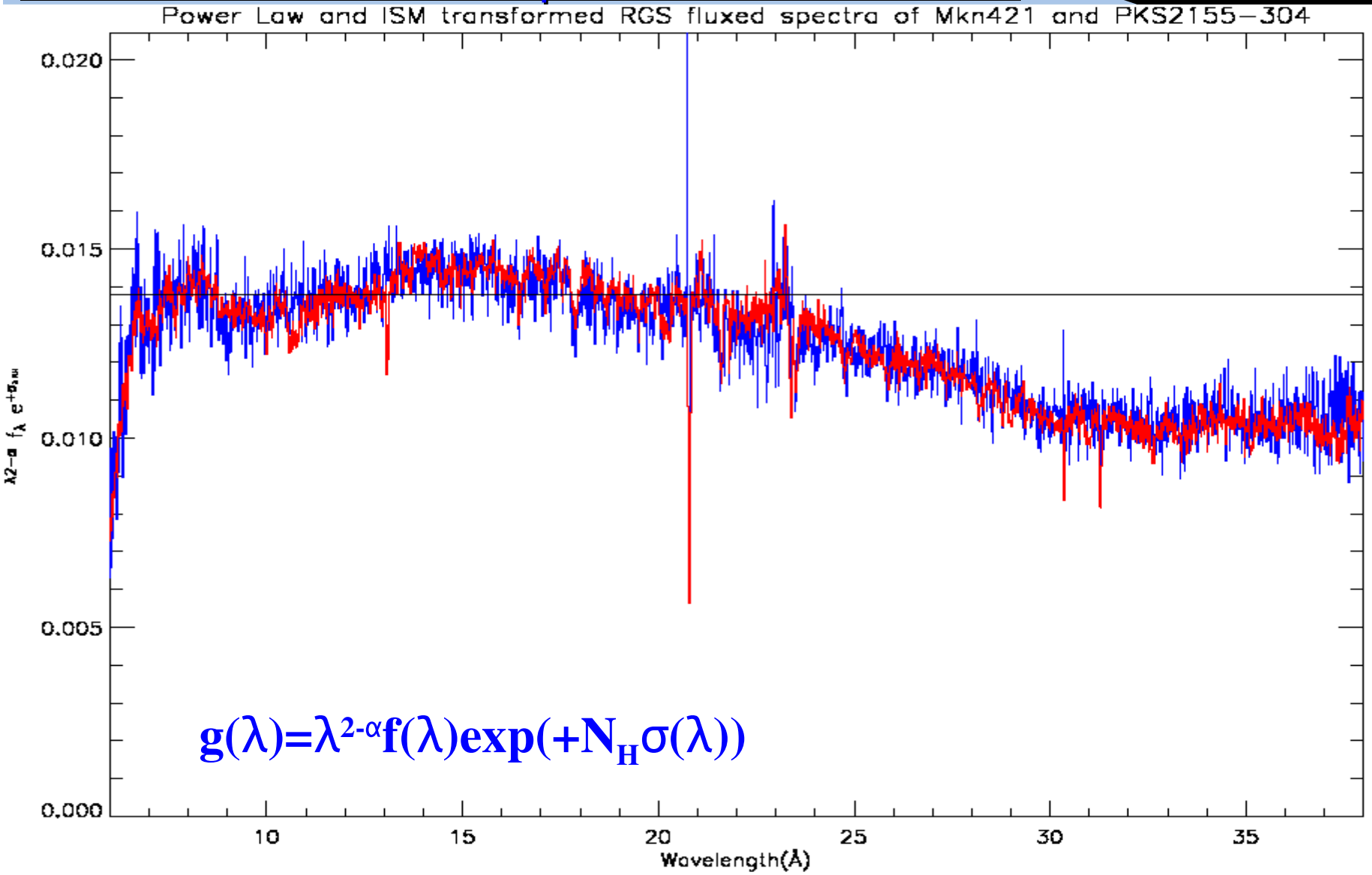
RGS "rectified" fluxed spectra of two blazars



$$g(\lambda)=\lambda^{2-\alpha}f(\lambda)\exp(+N_H\sigma(\lambda))$$

RGS effective area

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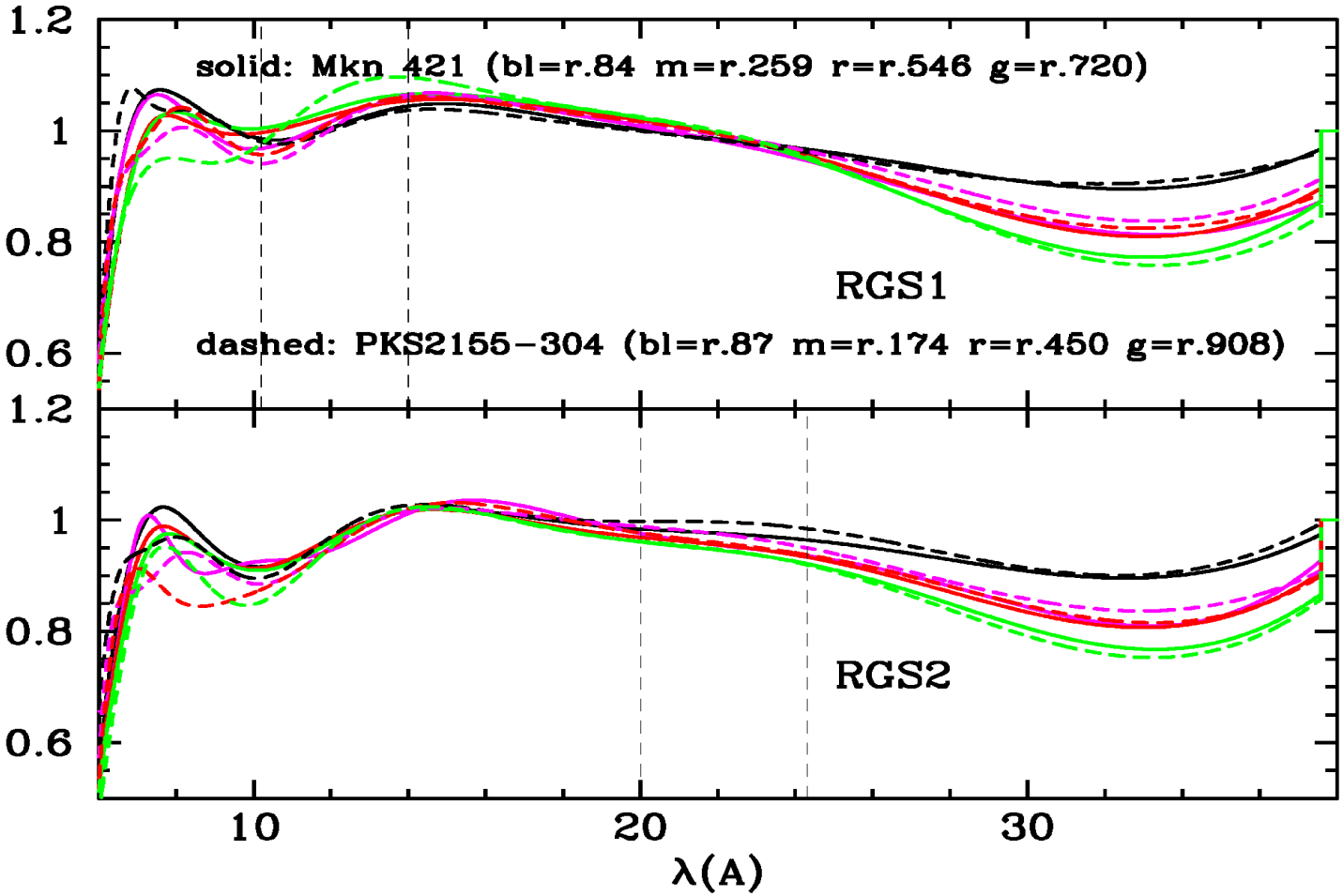
RGS model ARF corrections

- fit blazar spectrum with ISM-absorbed powerlaw 10<λ(Å)<25
- model residuals by sum of Chebyshev polynomials
- repeat throughout the mission



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The Crab's calibration credentials

2. simple continuum ✓
3. known continuum ~✓
4. constant ✓
5. point source ❒ ▶ RGS⊗PSF cross-dispersion losses
6. no dust scattering halo ❒ ▶ RGS⊗PSF cross-dispersion losses

Except for white dwarf or neutron star spectra (which are too soft for the RGS) there is nothing better

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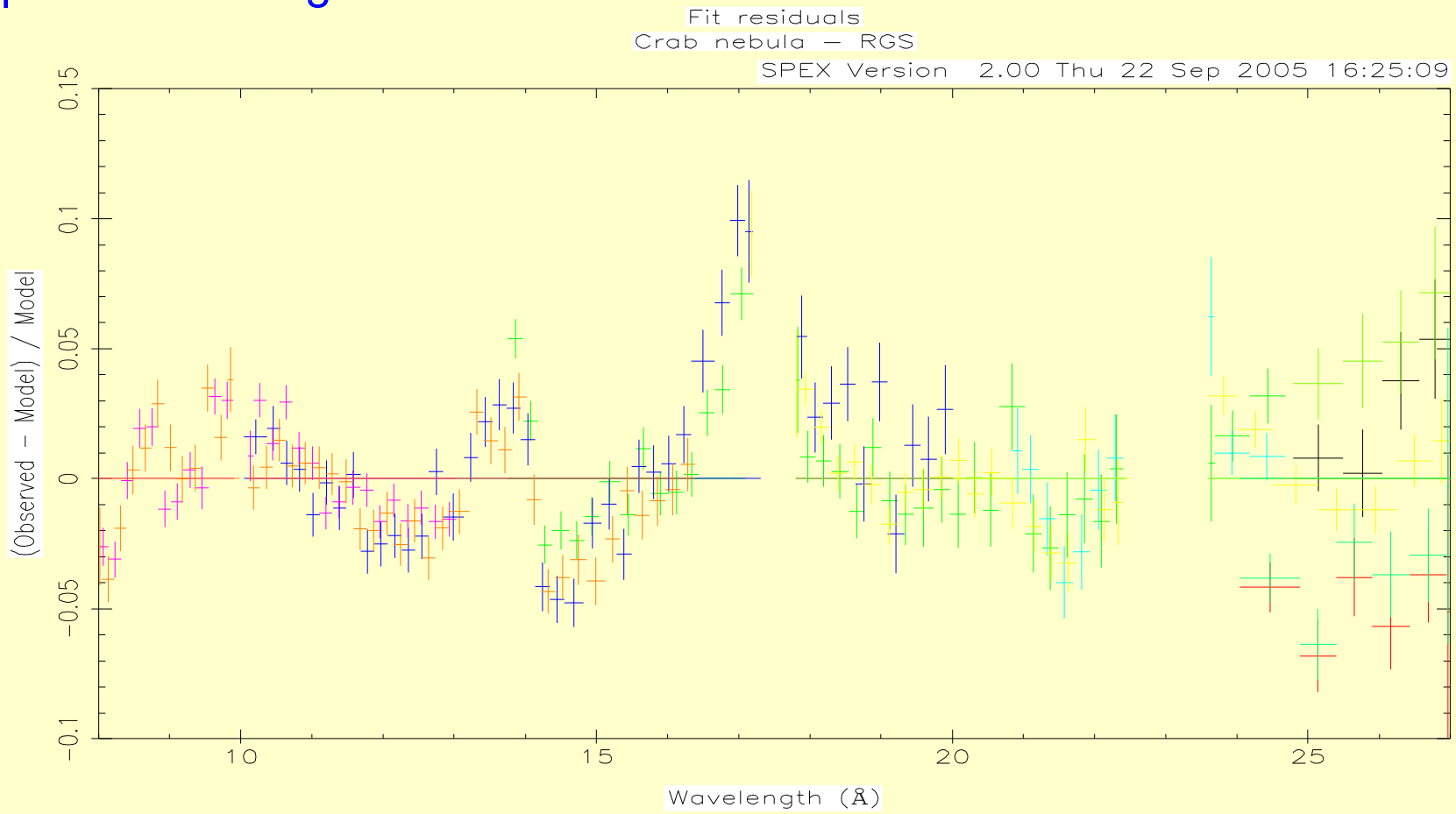
Fit to the RGS Crab spectrum

- Kuiper et al. continuum
- absorption by H, O, Ne & Fe or the Lodders protosolar Z/H
- power-law fudge



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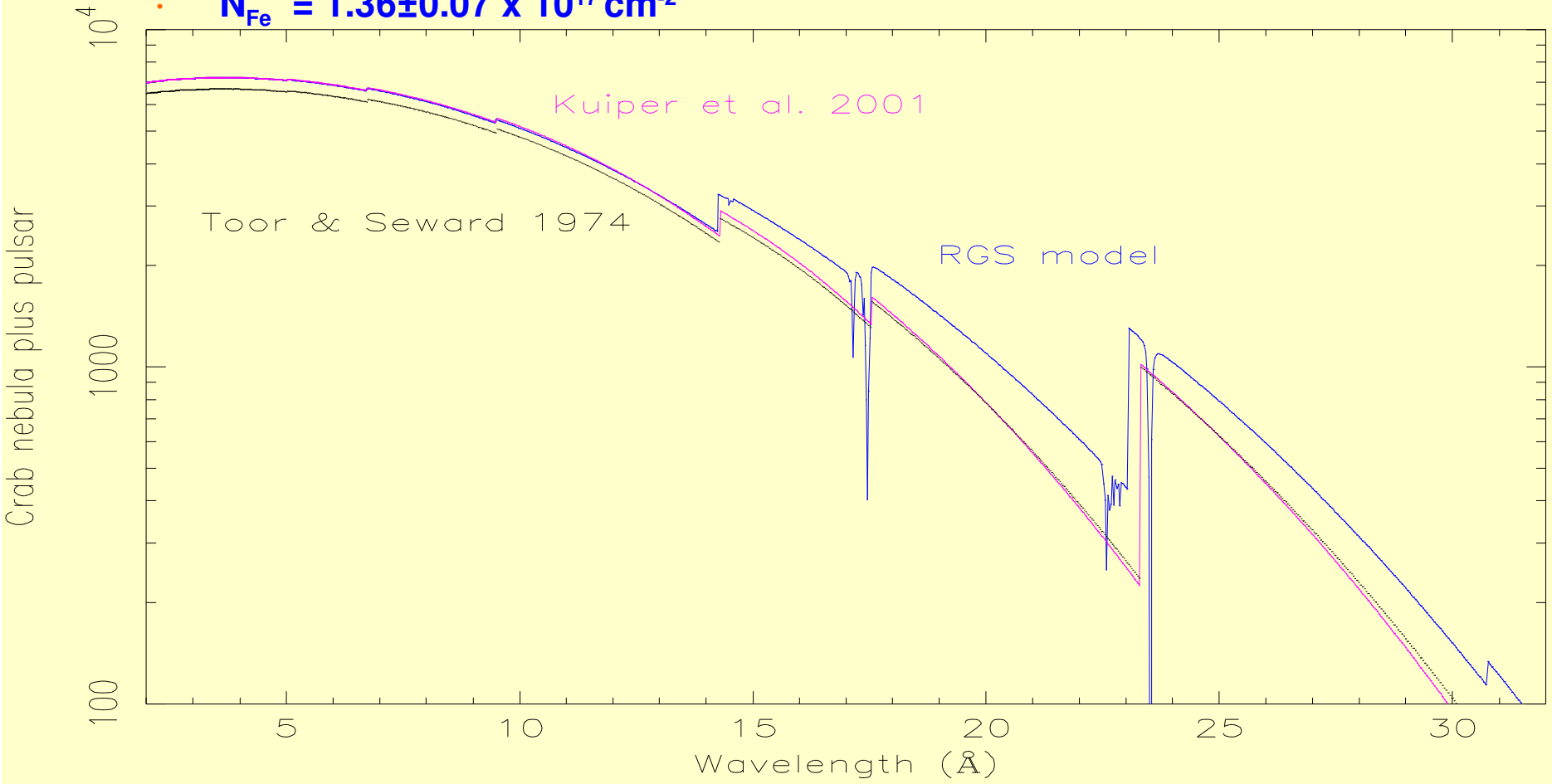
Comparison with other Crab models

- $N_H = 3.30 \pm 0.04 \times 10^{21}\ cm^{-2}$
- $N_O = 2.22 \pm 0.03 \times 10^{18}\ cm^{-2}$
- $N_{Ne} = 8.71 \pm 0.22 \times 10^{17}\ cm^{-2}$
- $N_{Fe} = 1.36 \pm 0.07 \times 10^{17}\ cm^{-2}$

- fudge (1.115)/N $(\lambda/10)^{-0.128}$
- Kuiper et al. Crab normalisation N~1



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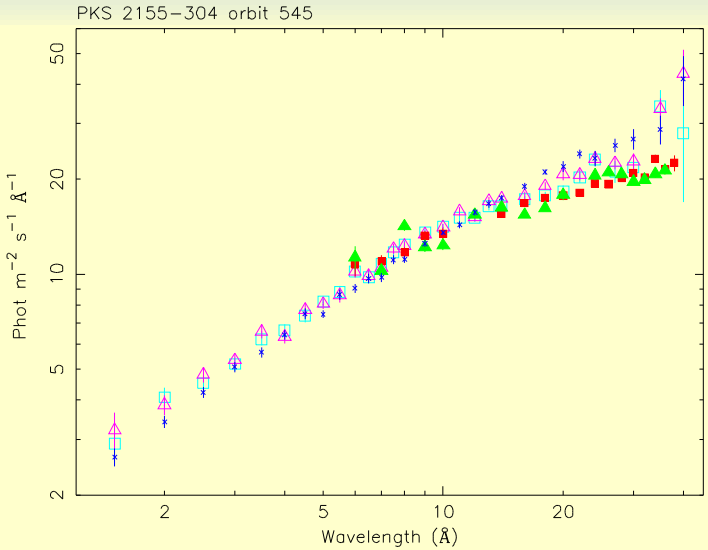
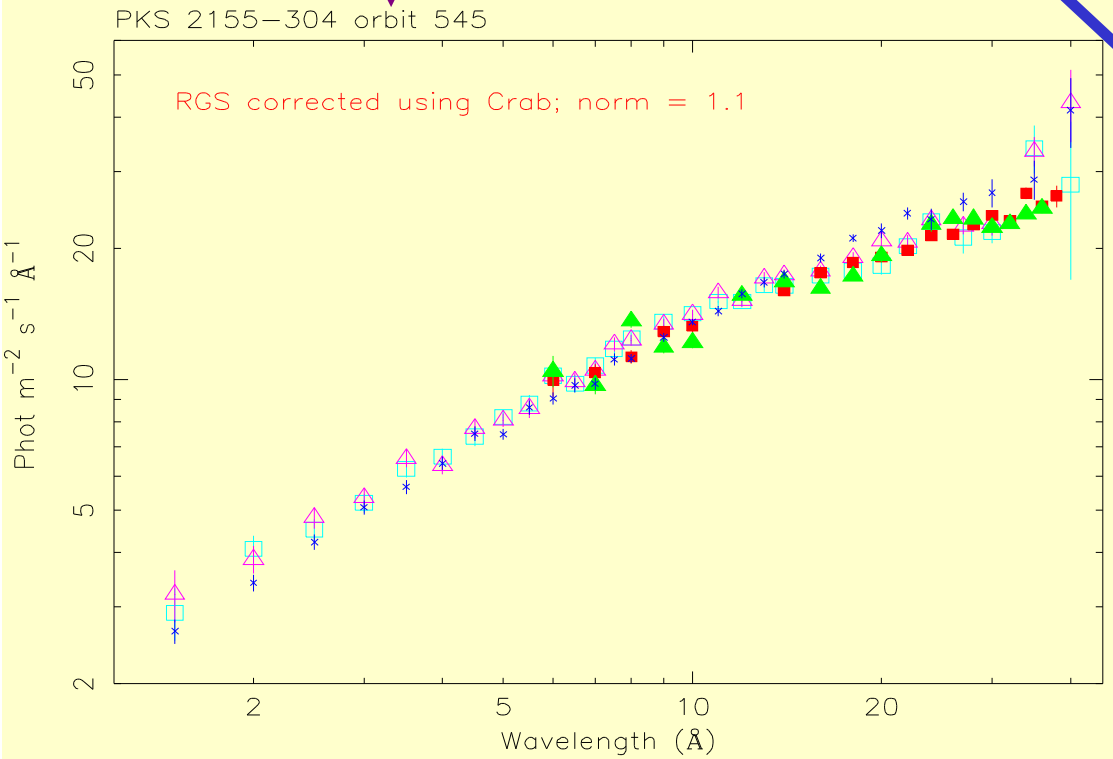
How it works out for PKS2155-304

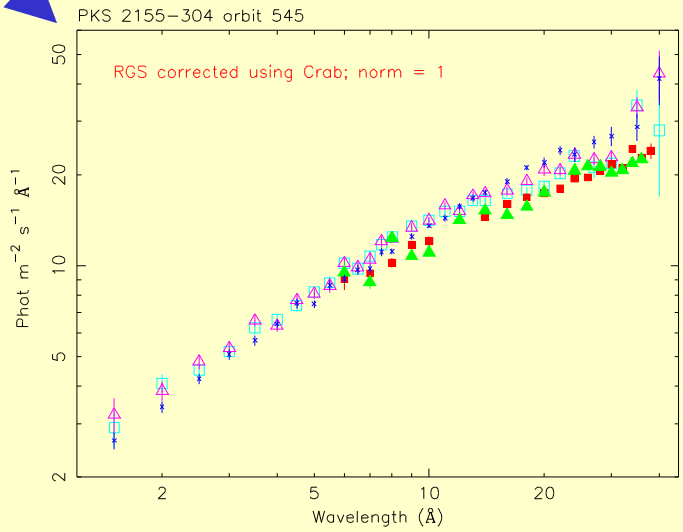
Only Chebychev polynomial

With power law correction

Power law correction + Norm=1.1







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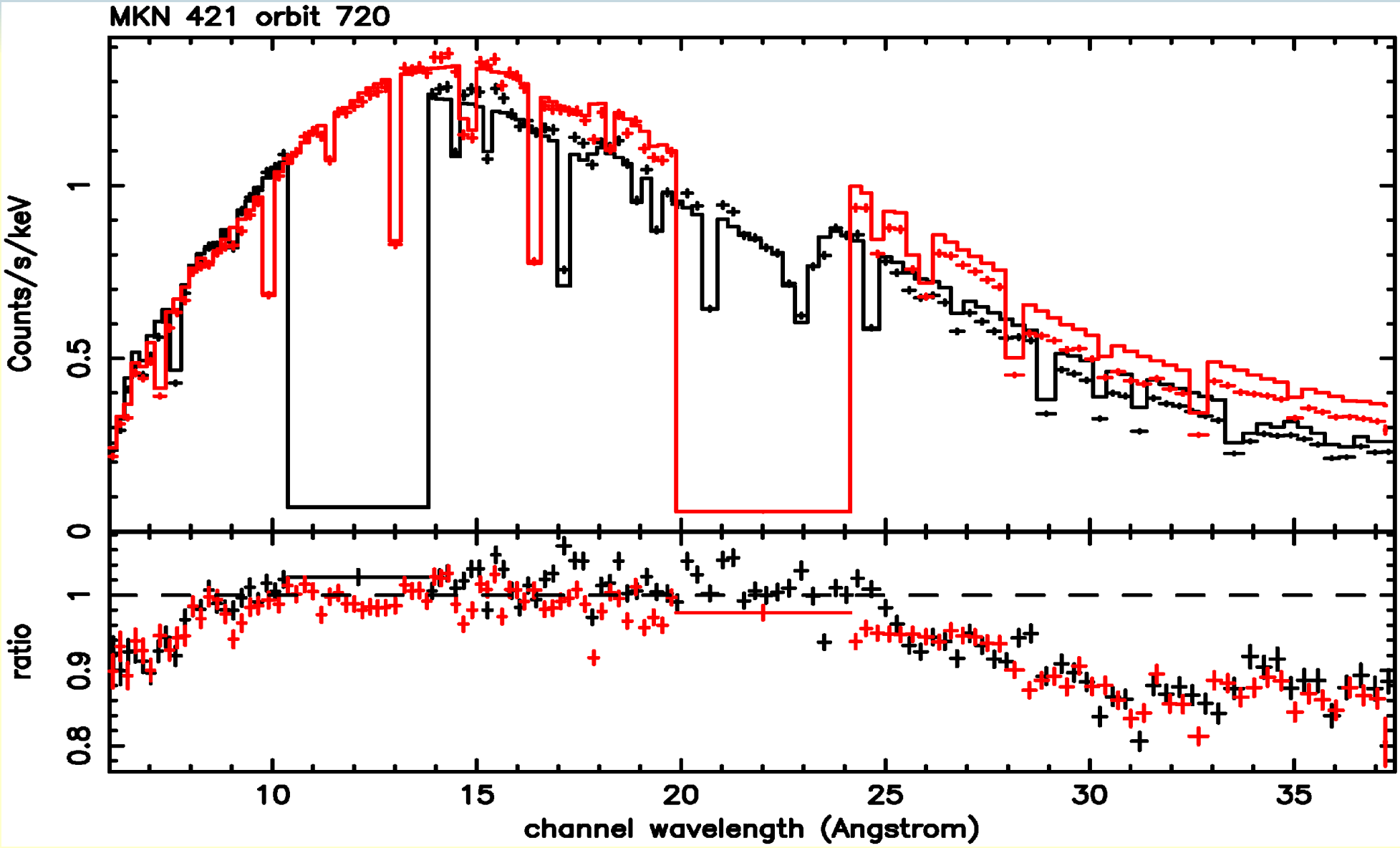
RGS effective area = A(λ,MJD)



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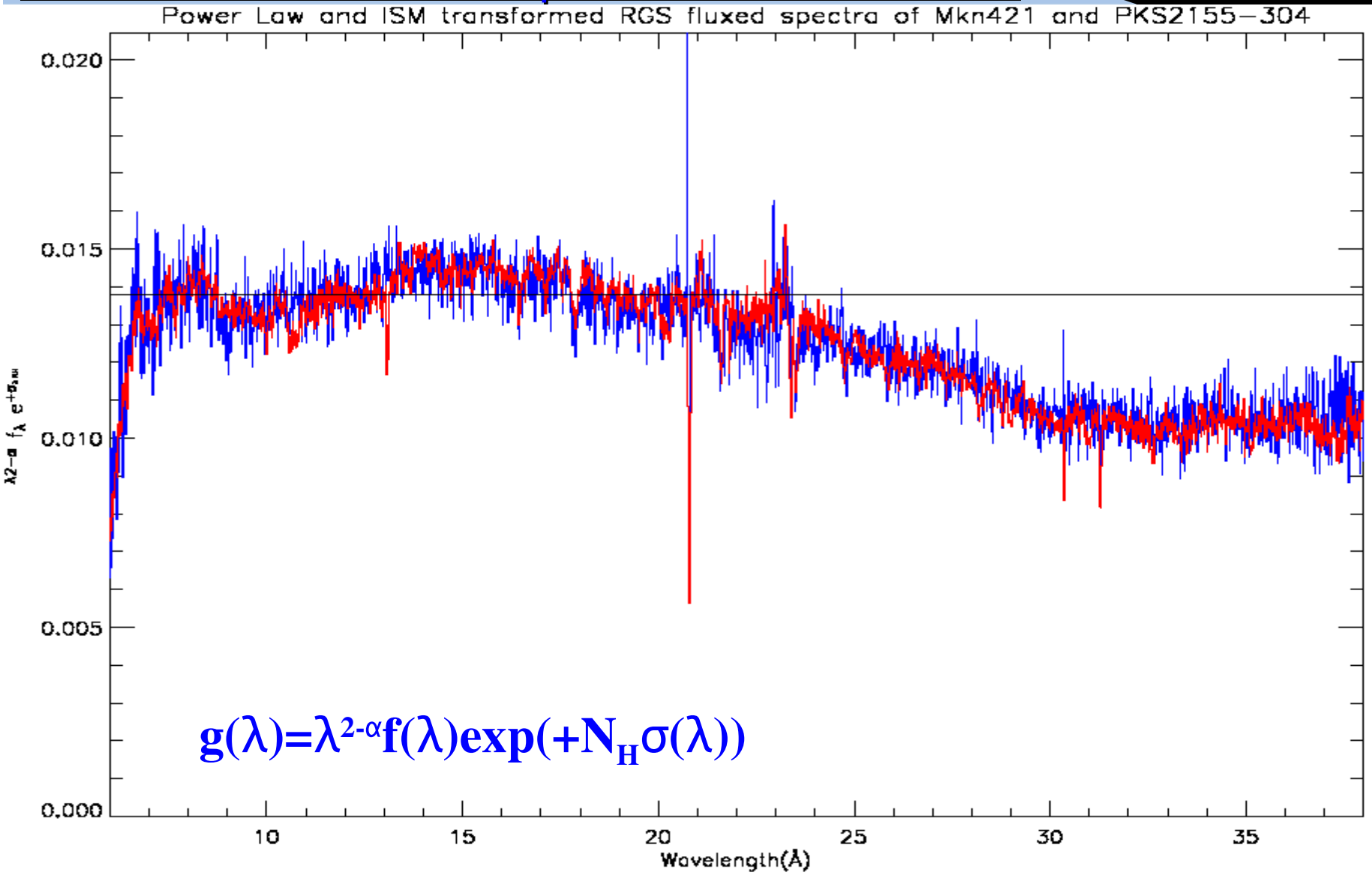

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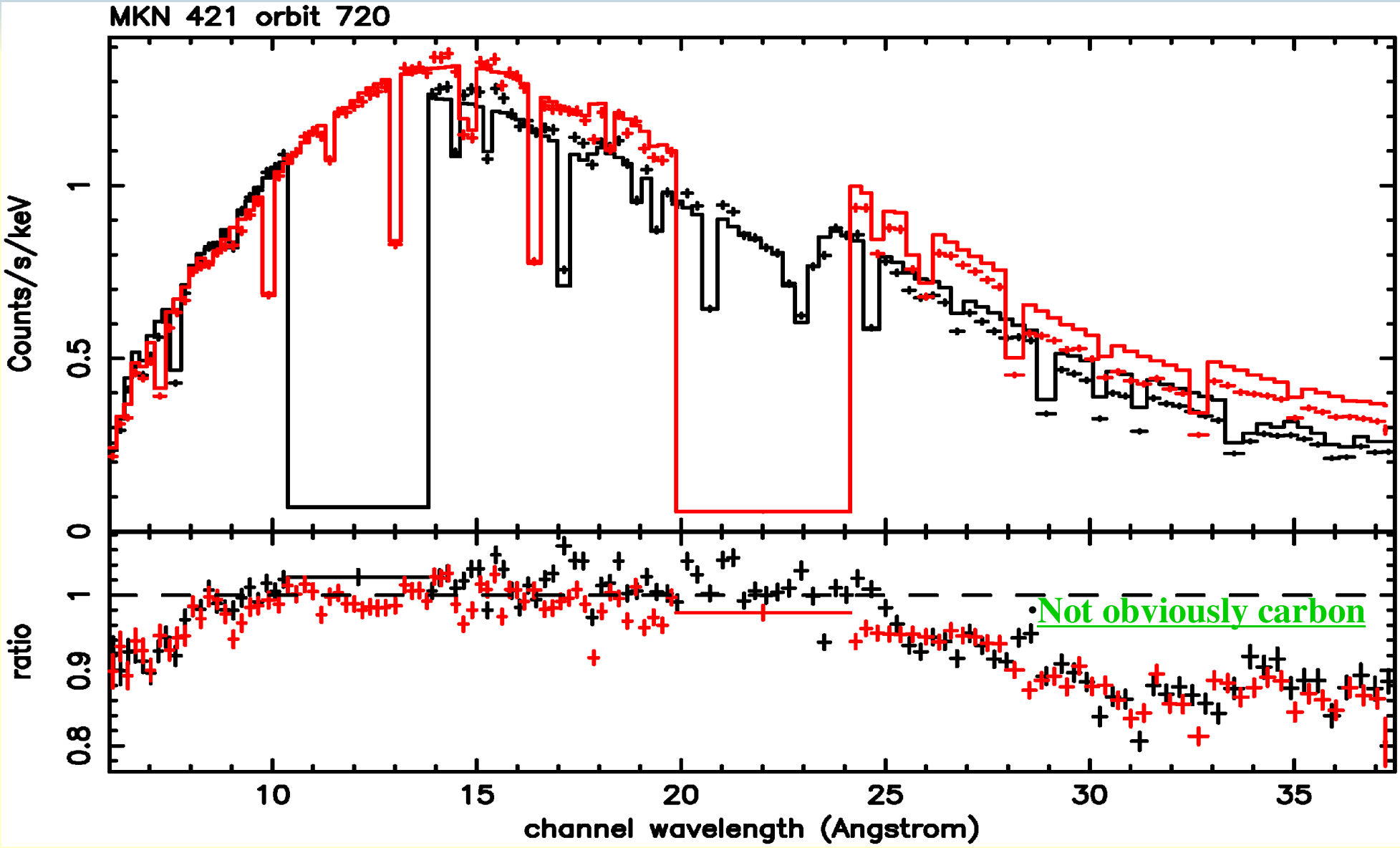

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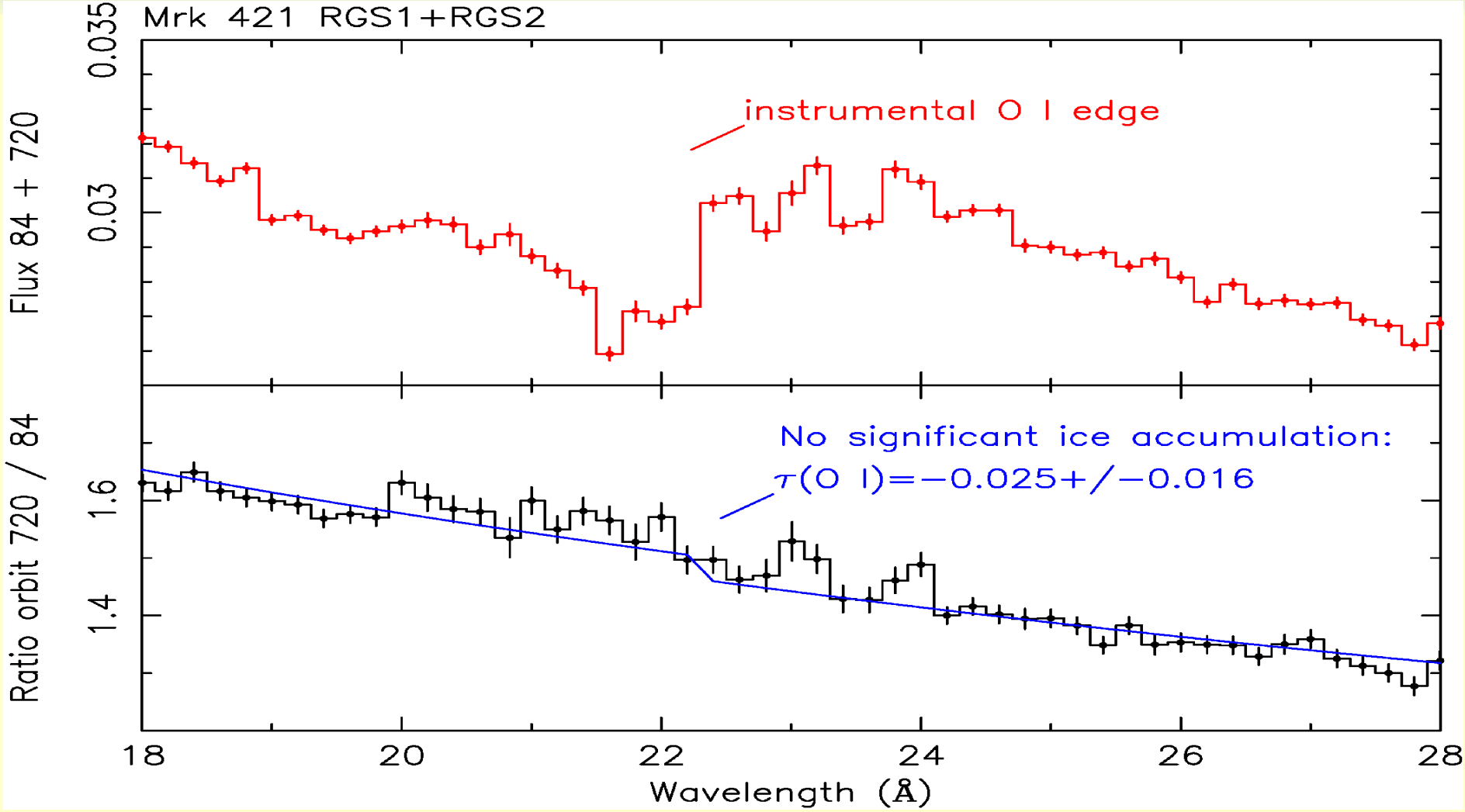
Not oxygen either



Ratio of late and early Mrk 421 spectra ⇒ OI edge τ ≤ 0.04

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Conclusions and prospects

- RGS effective area has decreased by ~10 % at long wavelengths
- causes not understood
- empirical corrections based on spectra of blazars and the Crab
- effective area calibration errors of a few percent are within reach
- testing underway ARF ⇒ CCF ⇒ public early 2006

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