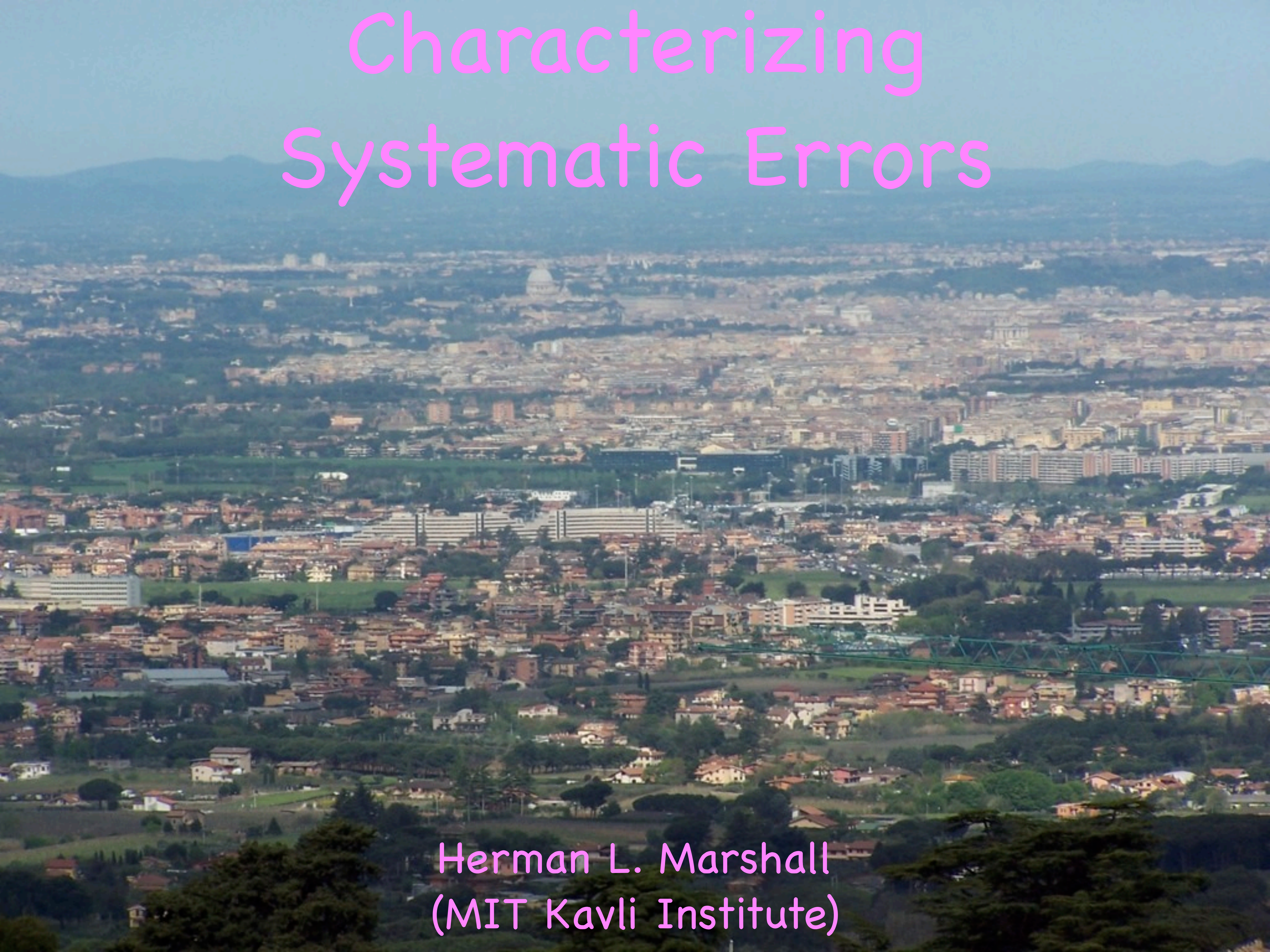
Characterizing Systematic Errors



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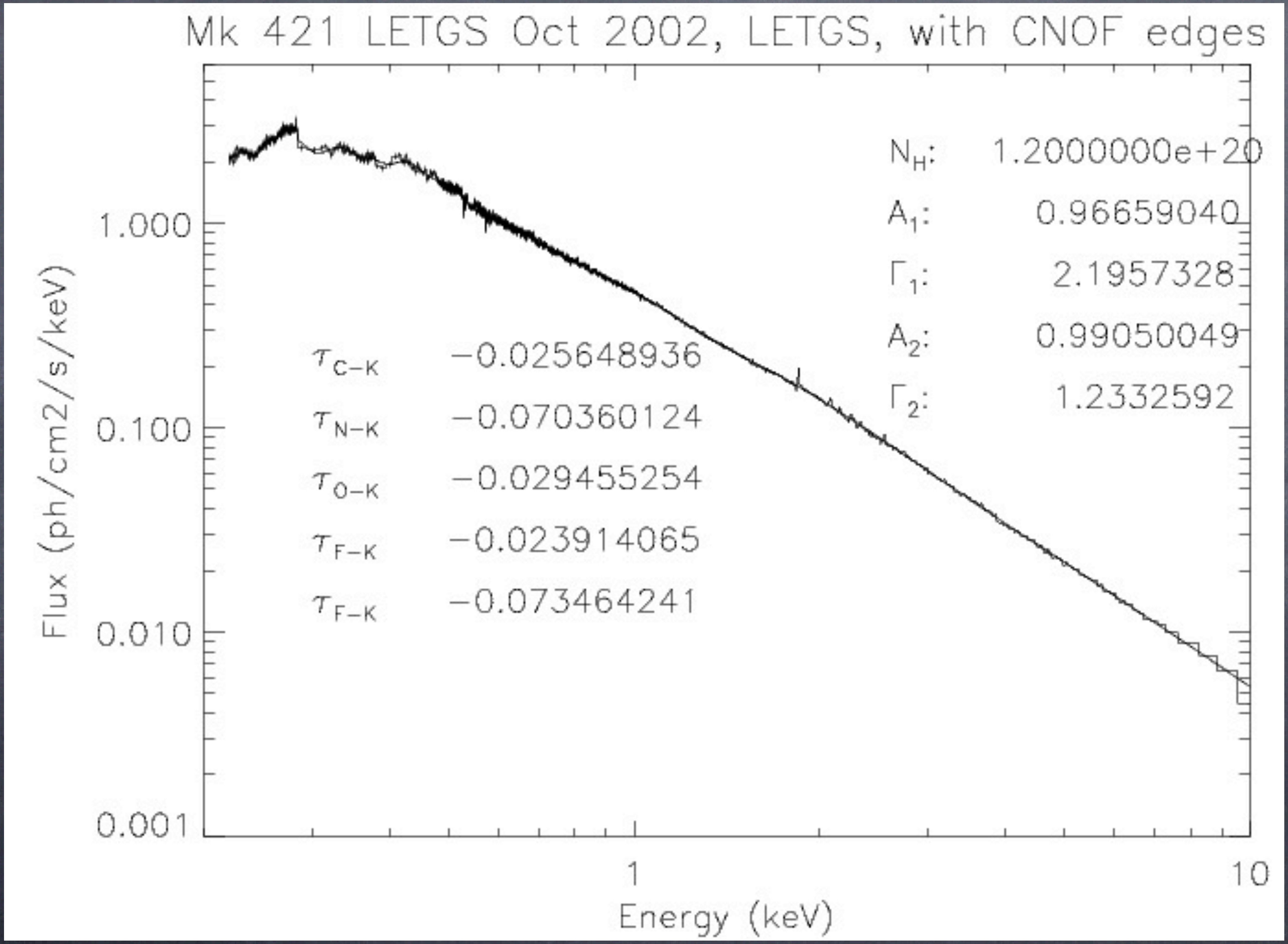
Previous Presentations

- IACHEC1: Goal is to avoid two problems
  - A: claims of new physics due to calibration errors
  - B: features ignored due to presumed systematics
- IACHEC2: Two new tools
  - Multiple adjustment functions (HLM) — bad
  - Vary instrument models (Drake et al.) — good
- IACHEC3: Update
  - Dewey's "science relevance" χ^2/ν adjustment
  - More of Drake's method
- IACHEC4: no update
- IACHEC5: Use of splines for adjustments

Spline Adjustment Method

- Method: spline amplitudes
  - Define correction grid (wavelength, energy, ...)
  - Correction amplitudes defined on grid (init = 0)
  - Adjust A_{eff} by spline through amplitudes
  - Creates a smooth adjustment with arbitrary shape
- Use:
  - Characterizing systematic errors
  - Distribution of examples of systematic errors
  - Informing calibration scientists to fix problems

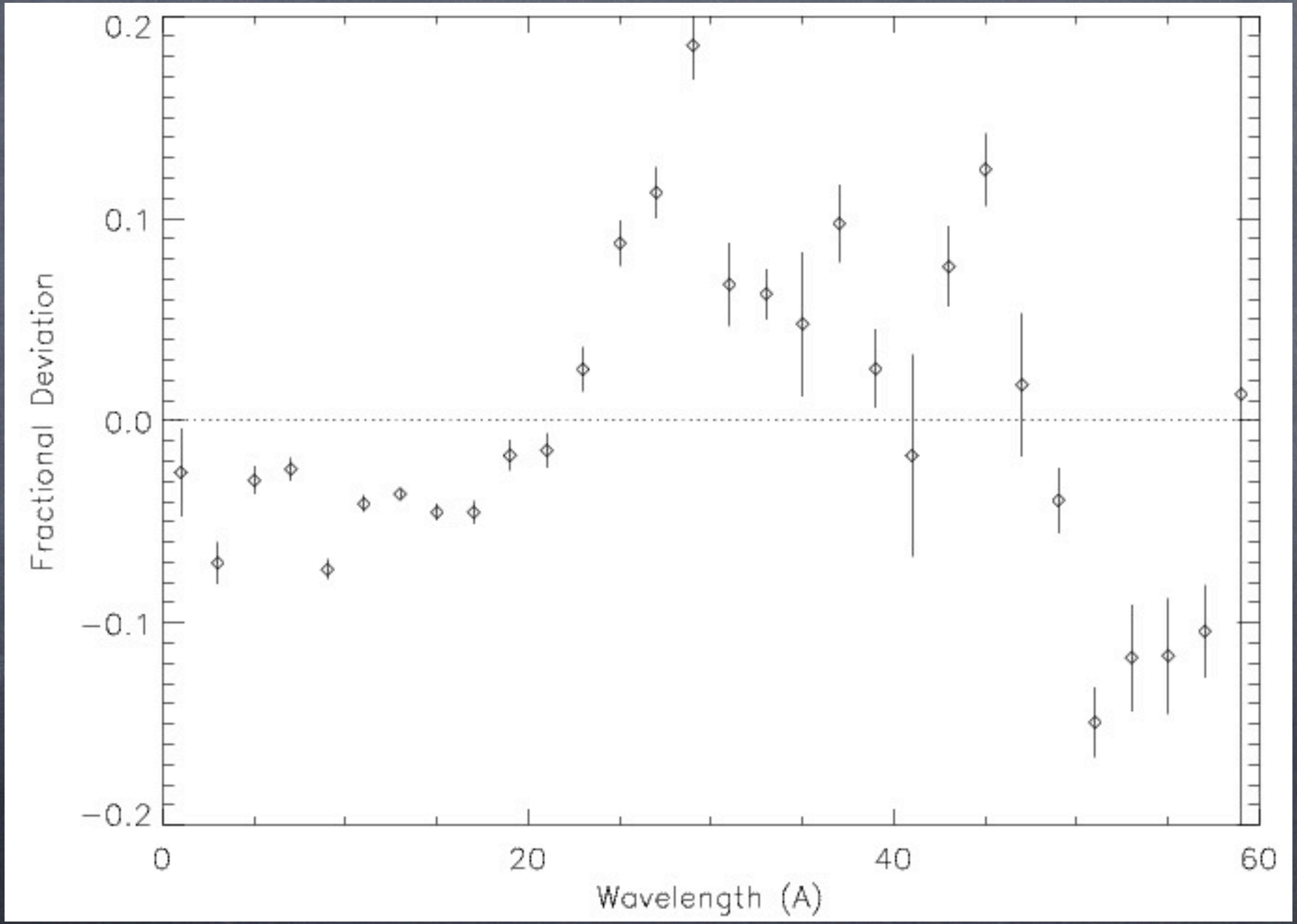
Mk 421 LETGS



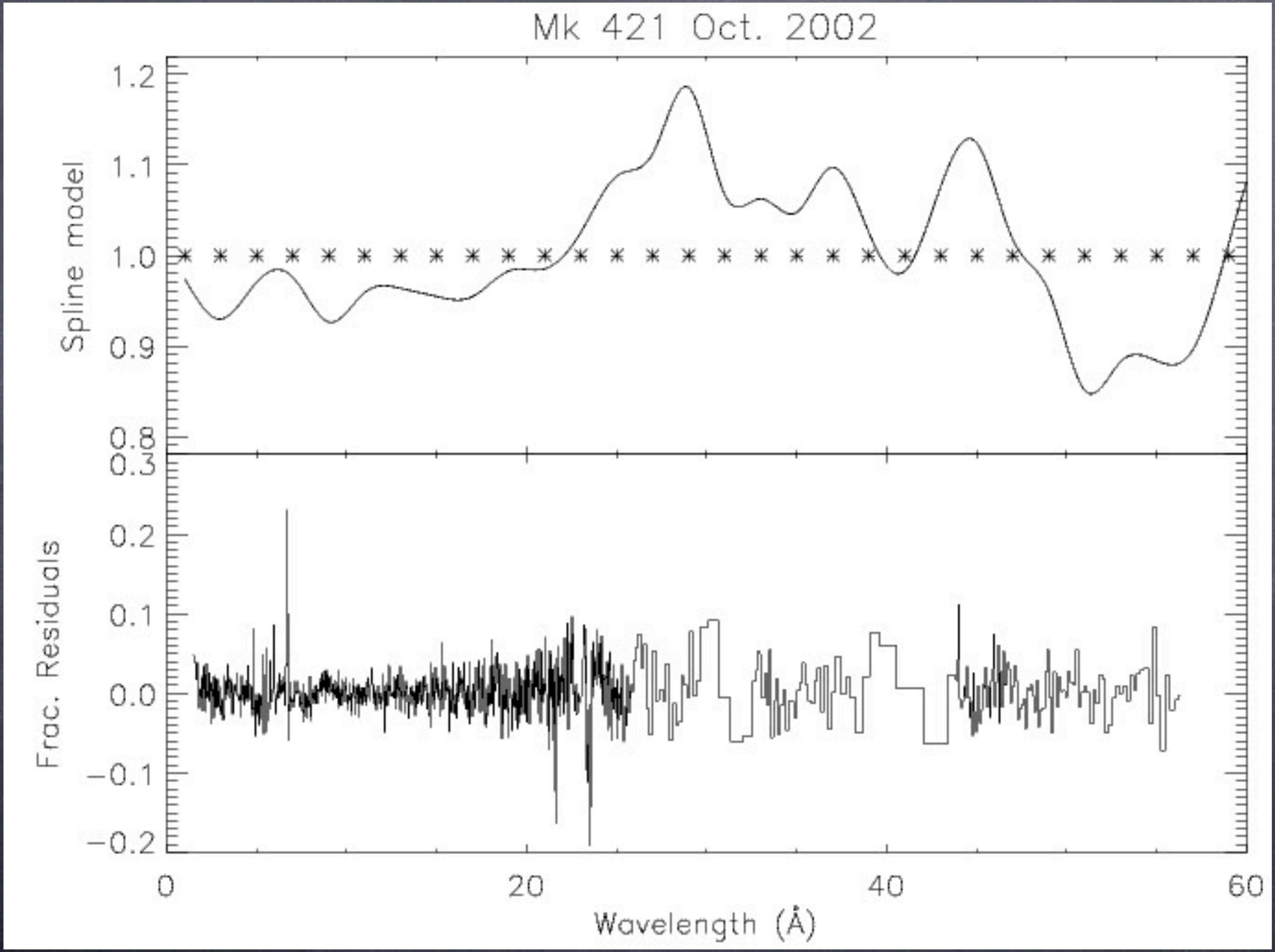
Mk 421 LETGS Oct 2002, LETGS, with CNOF edges
N_H: 1.2000000e+20
A_1: 0.96659040
Γ_1: 2.1957328
A_2: 0.99050049
Γ_2: 1.2332592
τ_C-K −0.025648936
τ_N-K −0.070360124
τ_O-K −0.029455254
τ_F-K −0.023914065
τ_F-K −0.073464241
1.000
0.100
0.010
0.001
Flux (ph/cm2/s/keV)
1
10
Energy (keV)

Normalizations

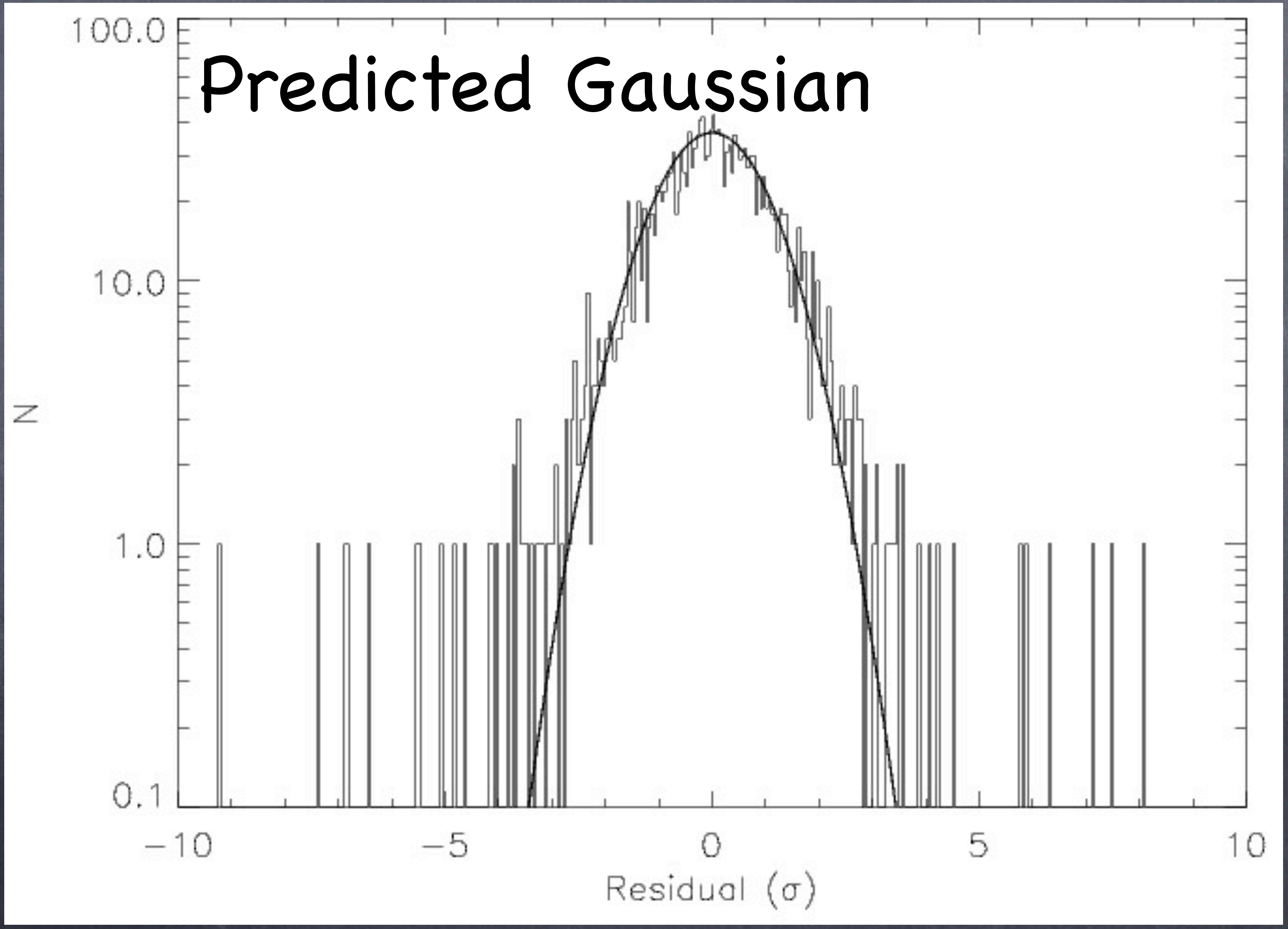
- Spline amplitudes ~ Gaussian norms



Results at a Glance



Are We There Yet?



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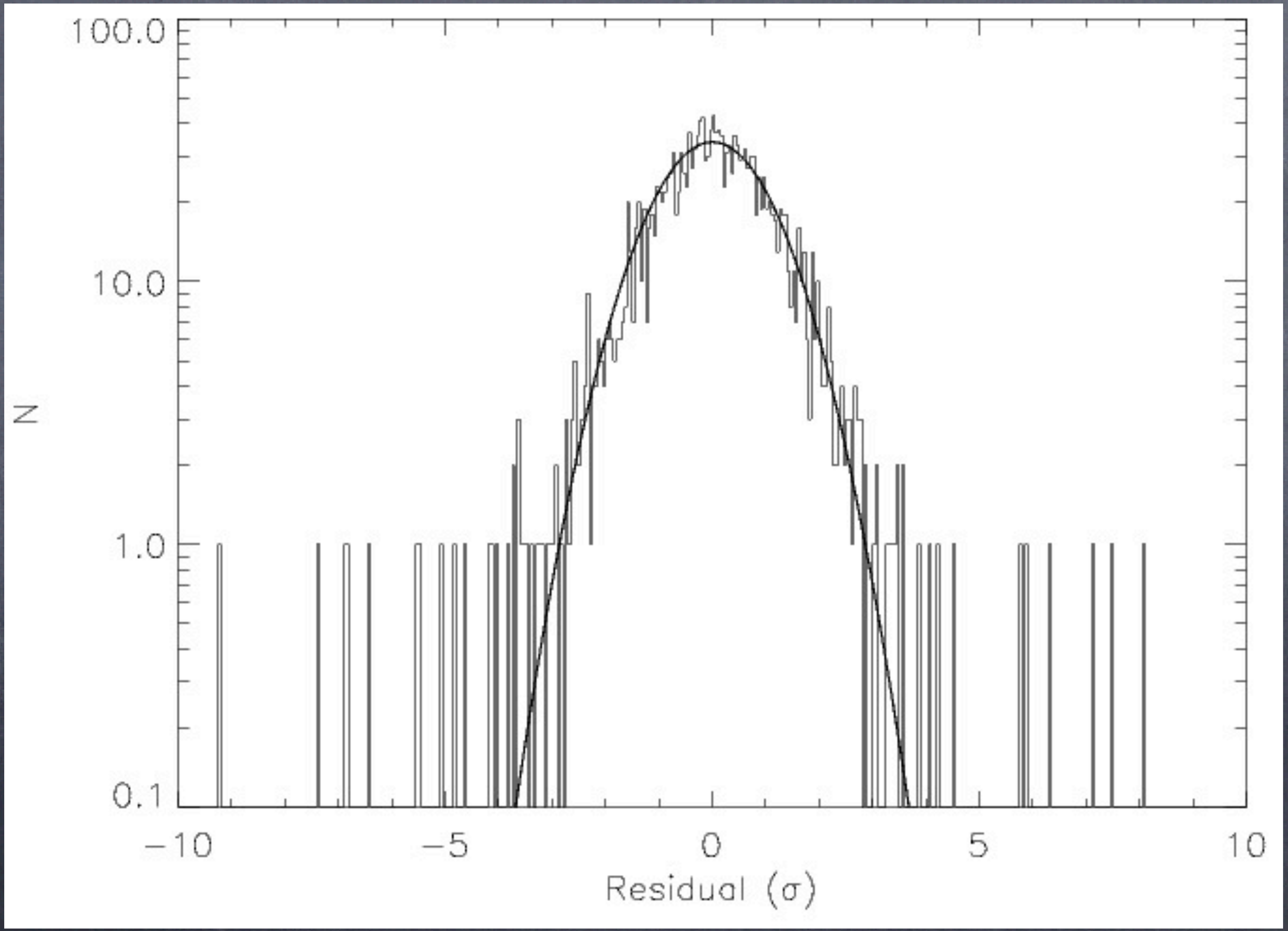
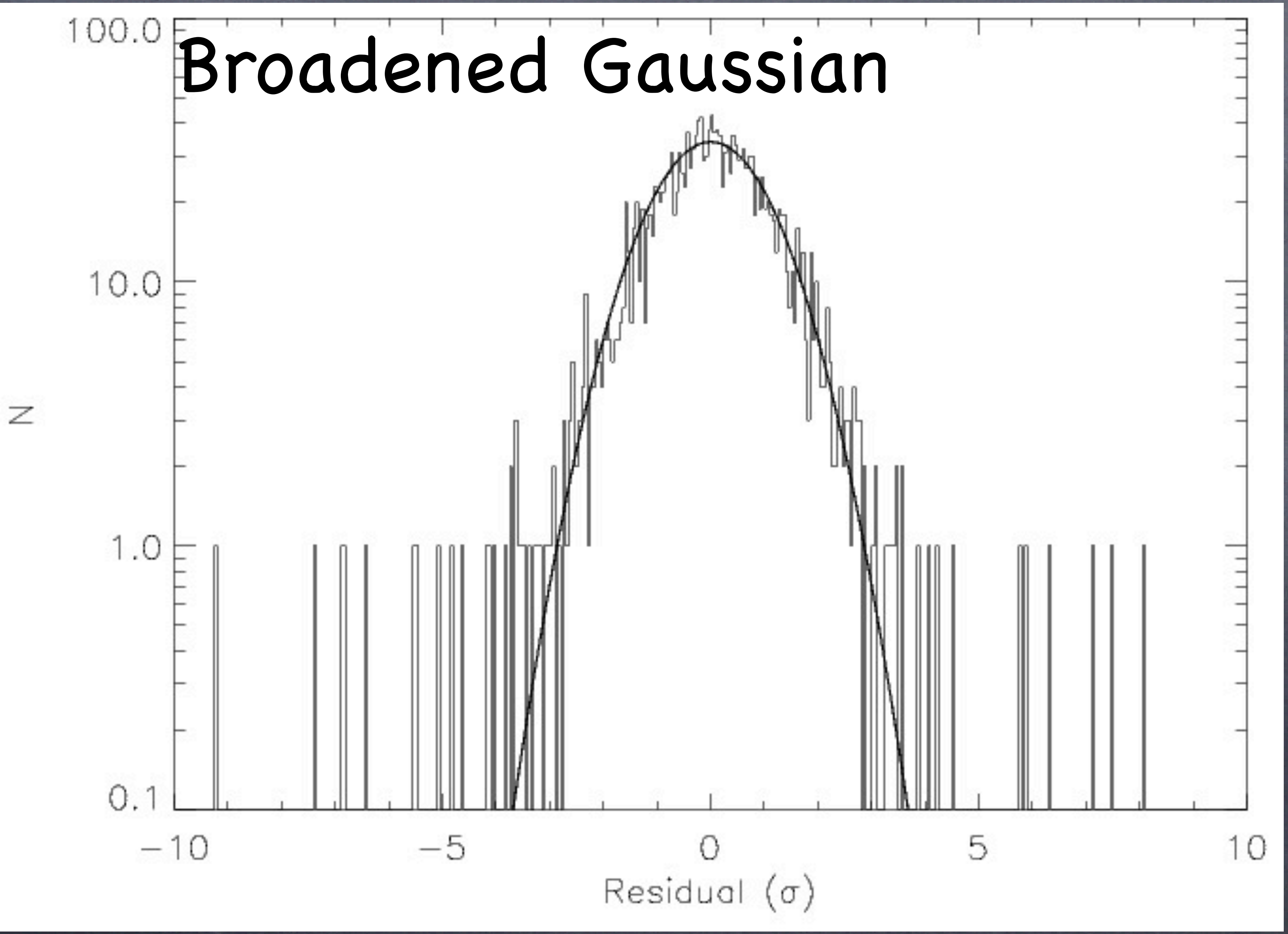
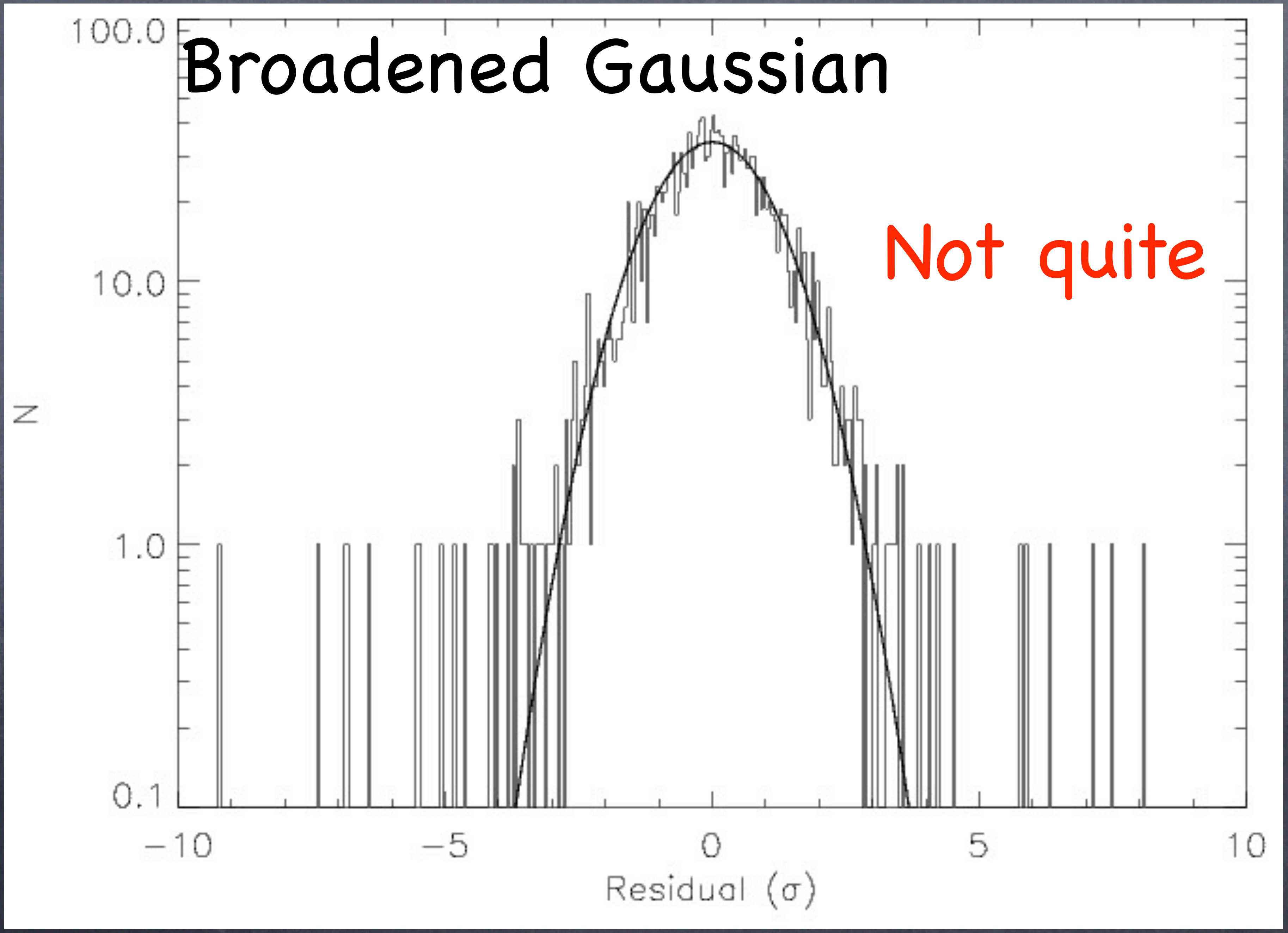


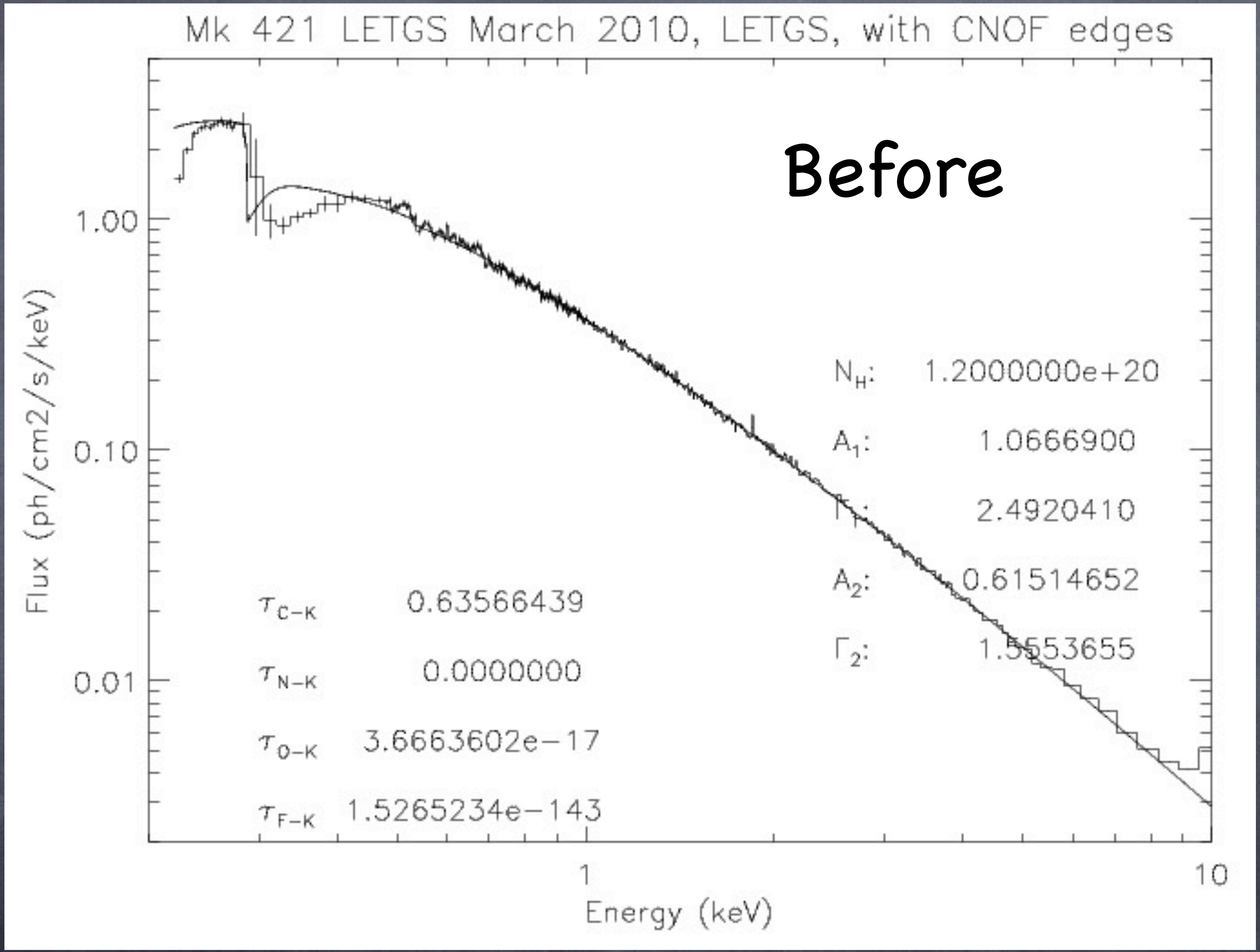
Are We There Yet?



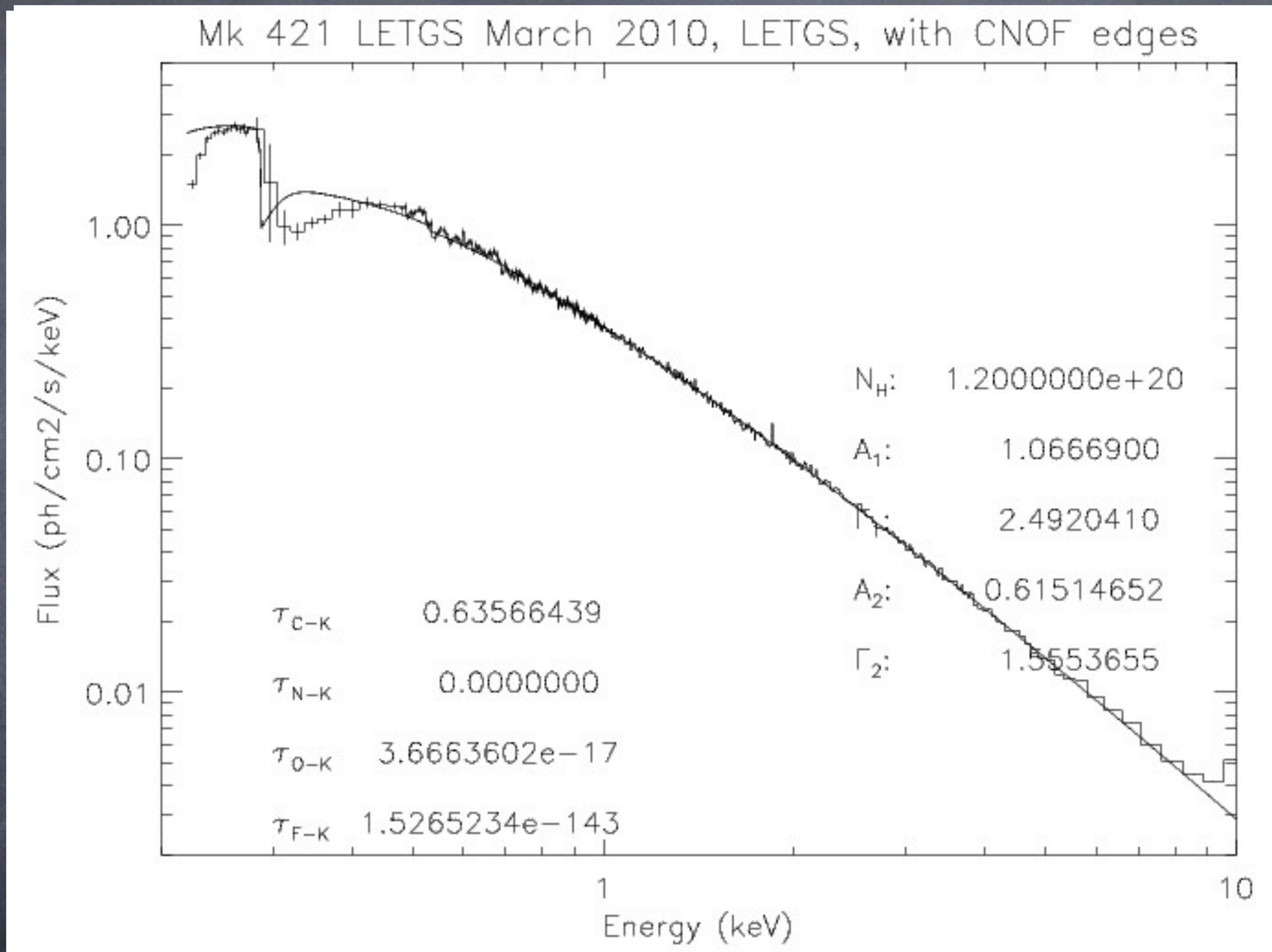
Are We There Yet?



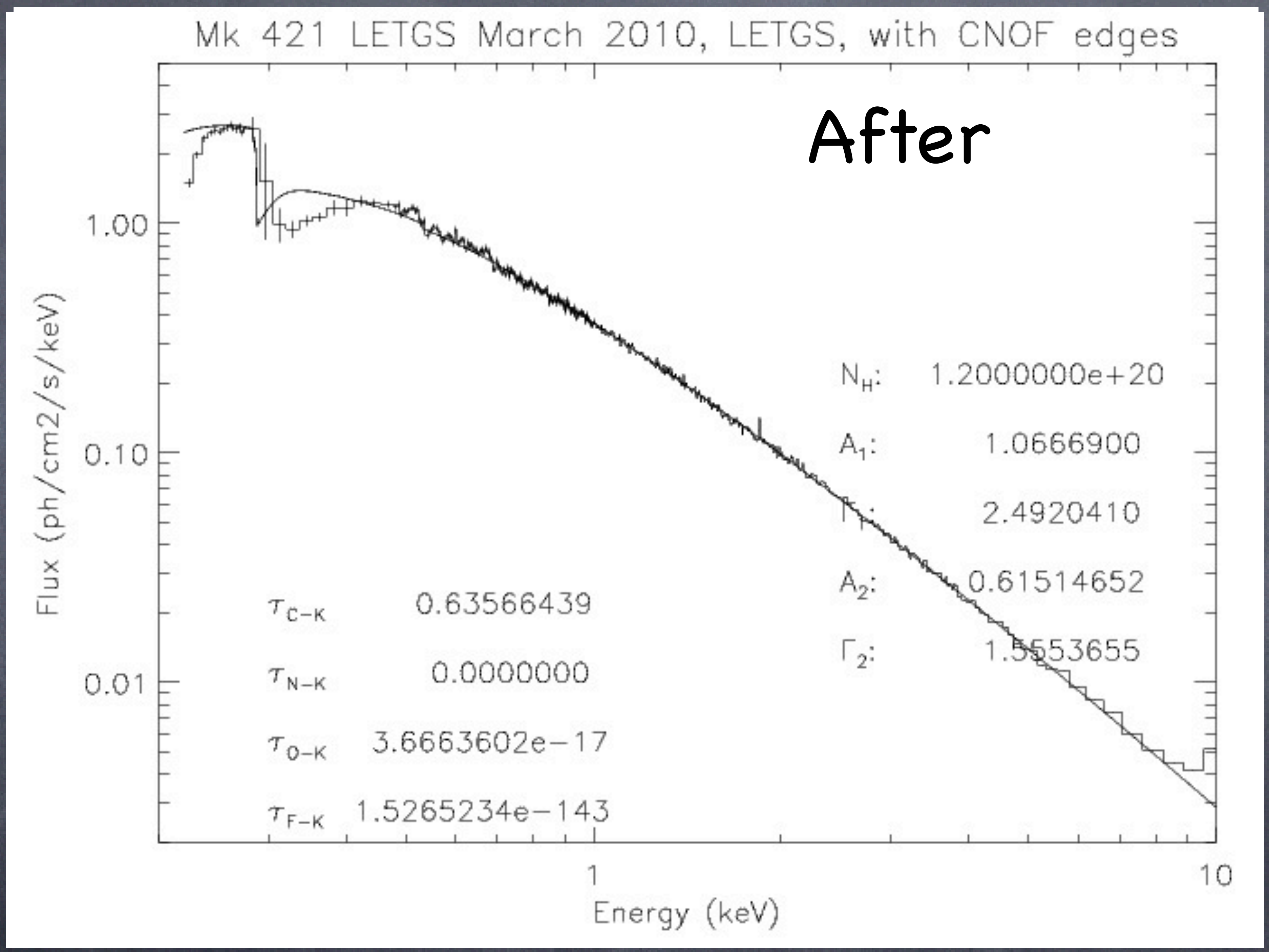
Apply to new data

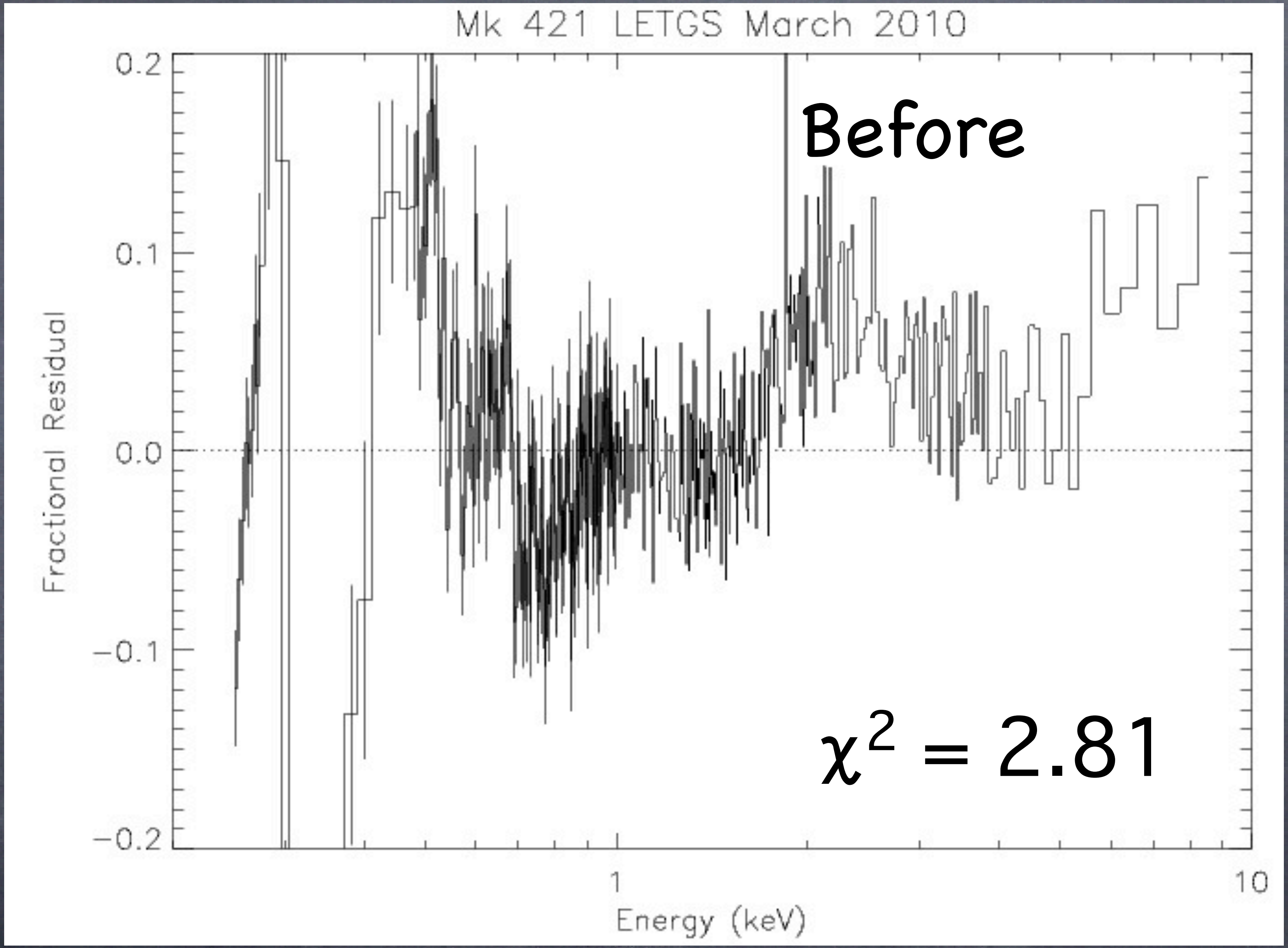


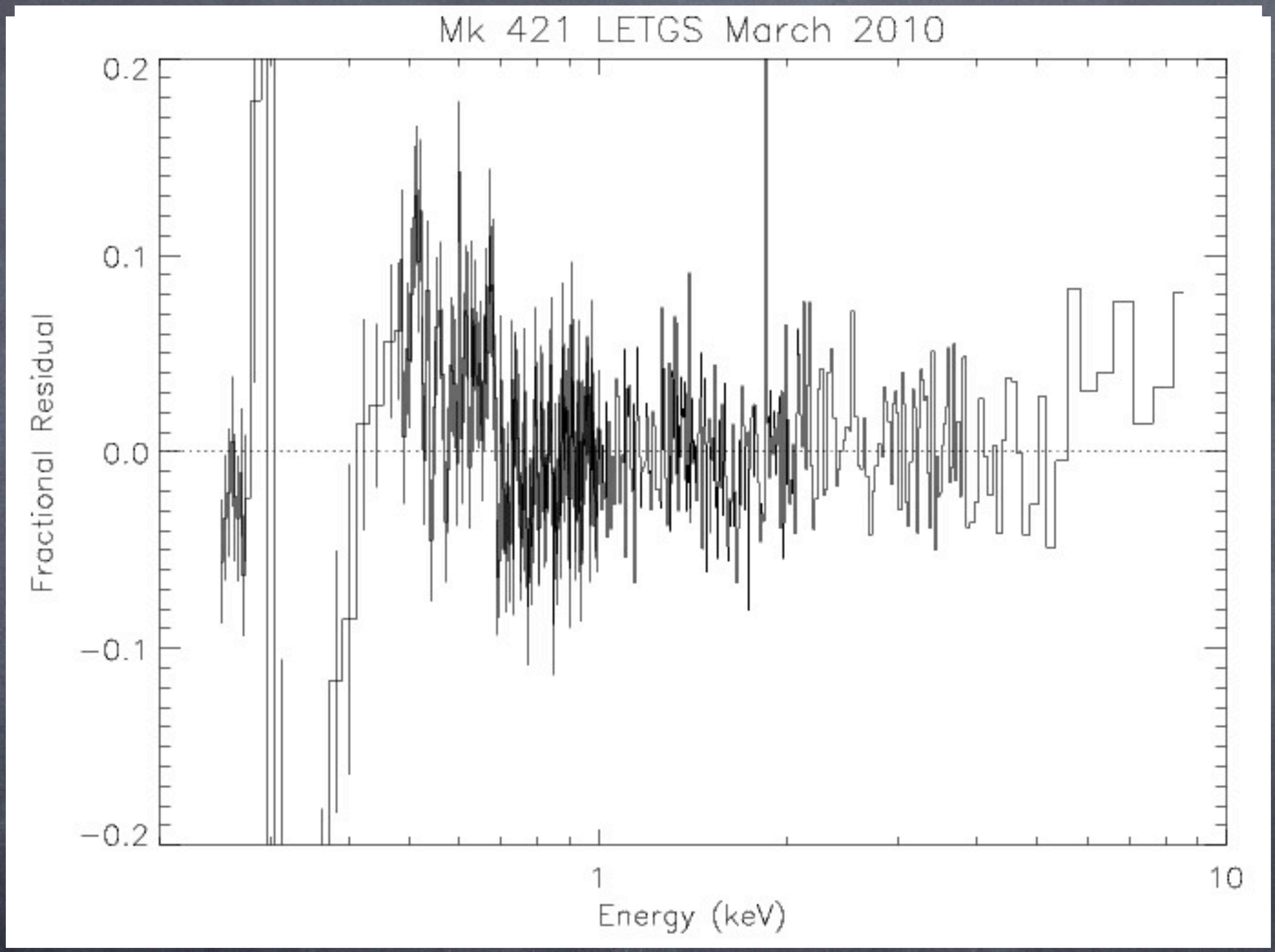
Apply to new data

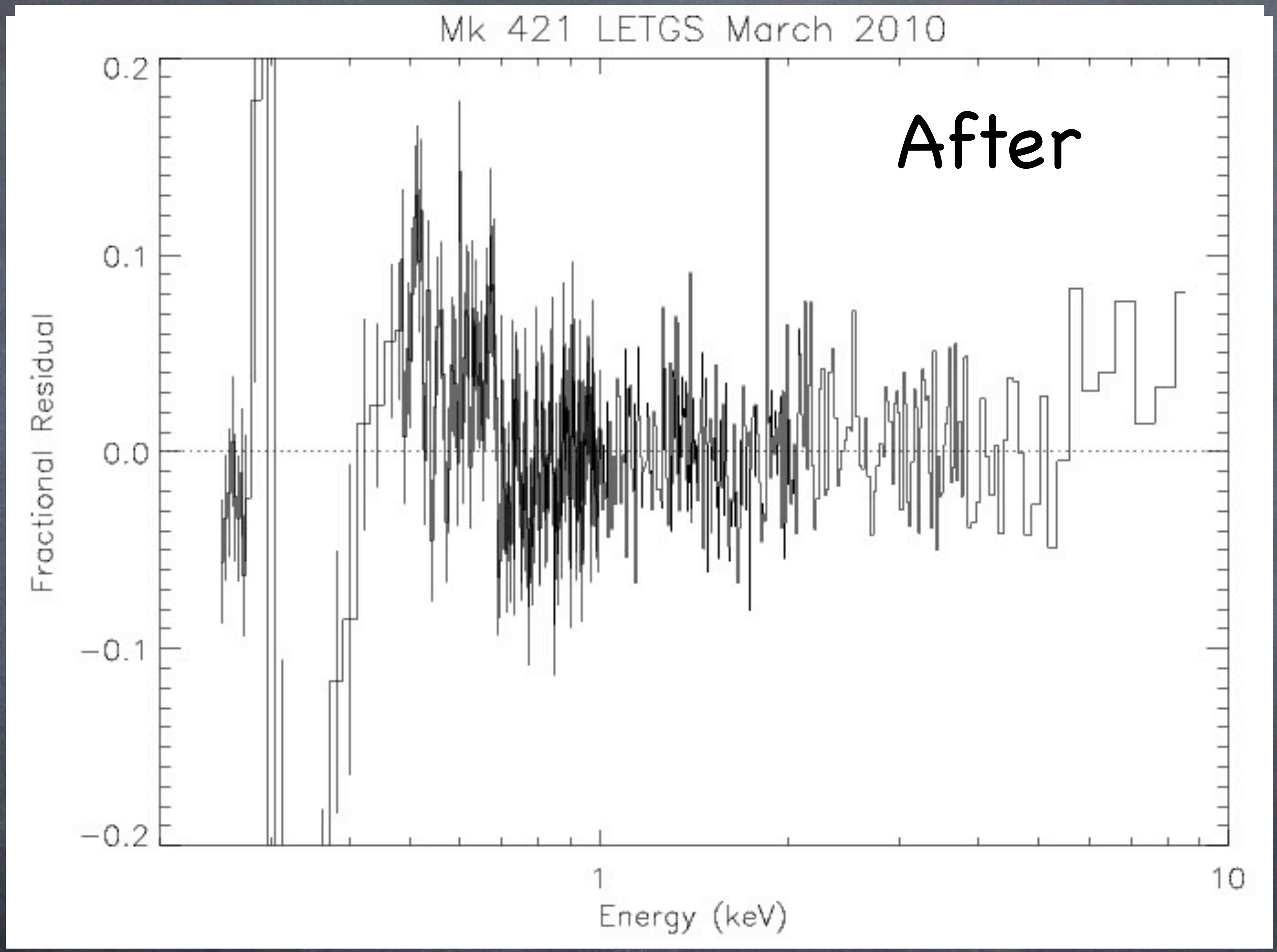


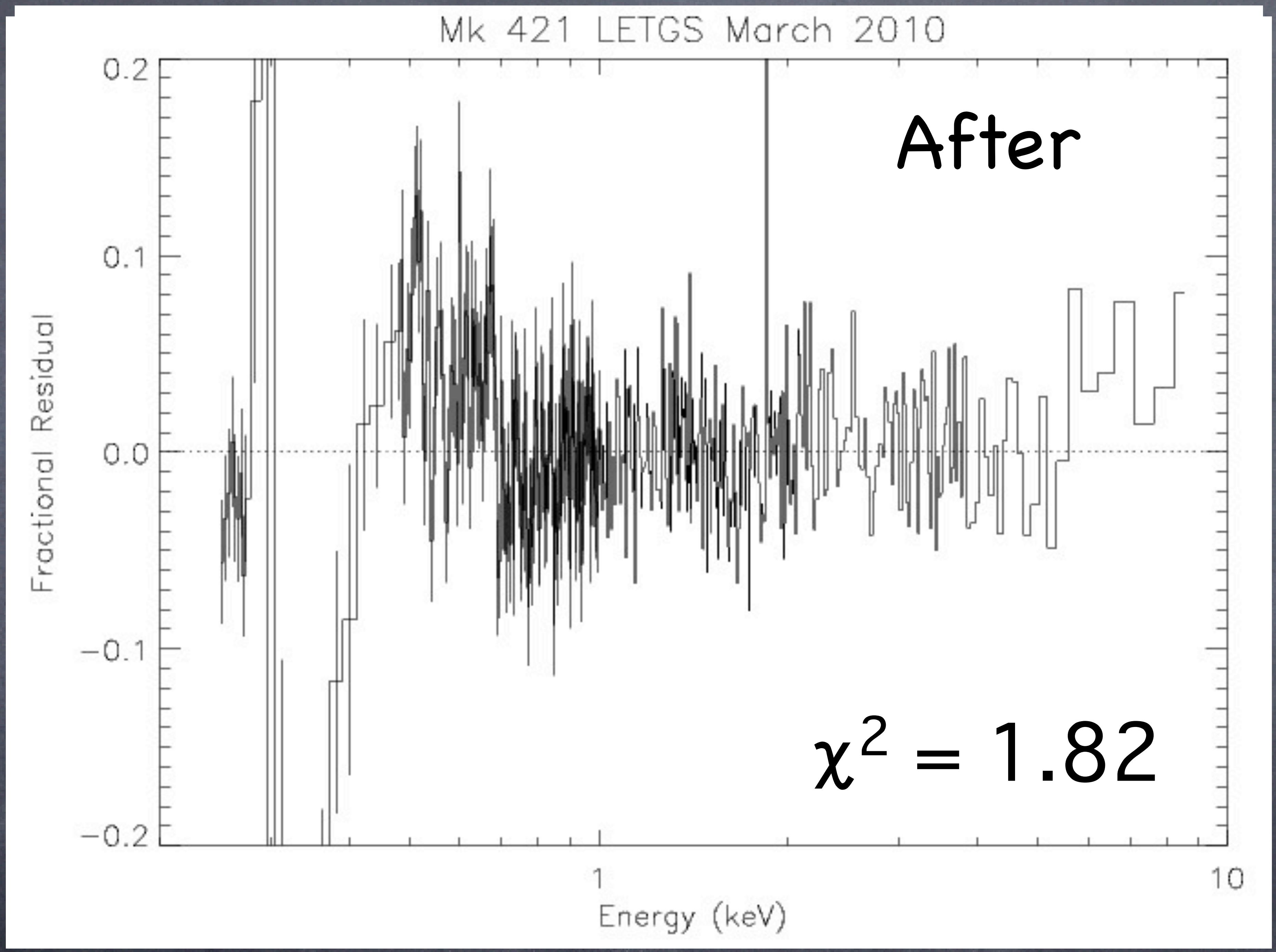
Apply to new data




Mk 421 LETGS March 2010
Before
$\chi^2 = 2.81$
Fractional Residual
0.2
0.1
0.0
−0.1
−0.2
1
10
Energy (keV)


Mk 421 LETGS March 2010
Fractional Residual
0.2
0.1
0.0
−0.1
−0.2
1
10
Energy (keV)


Mk 421 LETGS March 2010
After
Fractional Residual
0.2
0.1
0.0
−0.1
−0.2
1
10
Energy (keV)


Mk 421 LETGS March 2010
After
$\chi^2 = 1.82$
Fractional Residual
Energy (keV)
0.2
0.1
0.0
−0.1
−0.2
1
10

Spline Adjustment Method

- Method: spline amplitudes
  - Define correction grid (wavelength, energy, ...)
  - Correction amplitudes defined on grid (init = 0)
  - Adjust A_{eff} by spline through amplitudes
  - Creates a smooth adjustment with arbitrary shape
- Method succeeds at a “reasonable” level
- A use of method:
  - Make spline EA model for xspec & isis
  - Publish “candidate” adjustment amplitudes
  - Collect users’ fit results
  - Use amplitudes as input to

Fitting Power Laws in Narrow Energy Ranges

- Objective: Coarse characterization of systematic errors
- Method (see M. Smith's presentation):
  - Define narrow energy bands
  - Fit power law to spectrum in each band
  - Compute flux in each band using model
  - Compute confidence interval for each flux
  - Compare fluxes for different instruments
- Claim: flux is robust to error in model
- Concern: RMFs require spectrum outside band

Application to Chandra

- Cross-check results with direct measurement
- Data = {Ci, Ei}, measured in time T
- Effective area = Ai
- Default estimator:

$$F(E_1, E_2) = \sum_{E_i=E_1}^{E_i=E_2} \frac{C_i E_i}{tA_i}$$

Diversion 1

- Consider simple case
  - Source has invariant photon flux n
  - Observe twice with effective area A
  - Exposure times are t1, t2, counts C1, C2
- One estimate of n:

$$n = \frac{n_1/\sigma_1^2 + n_2/\sigma_1^2}{1/\sigma_1^2 + 2/\sigma_1^2}, n_1 = \frac{C_1}{t_1 A}, n_2 = \frac{C_2}{t_2 A}, \sigma_1 = \frac{\sqrt{C_1}}{t_1 A}, \sigma_2 = \frac{\sqrt{C_2}}{t_2 A}$$

- ML estimate of n:

$$n = \frac{C_1 + C_2}{A(t_1 + t_2)}$$

Diversion 2

- Case 2: two observations, different areas

$$n = \frac{C_1+C_2}{A_1 t_1 + A_2 t_2}$$

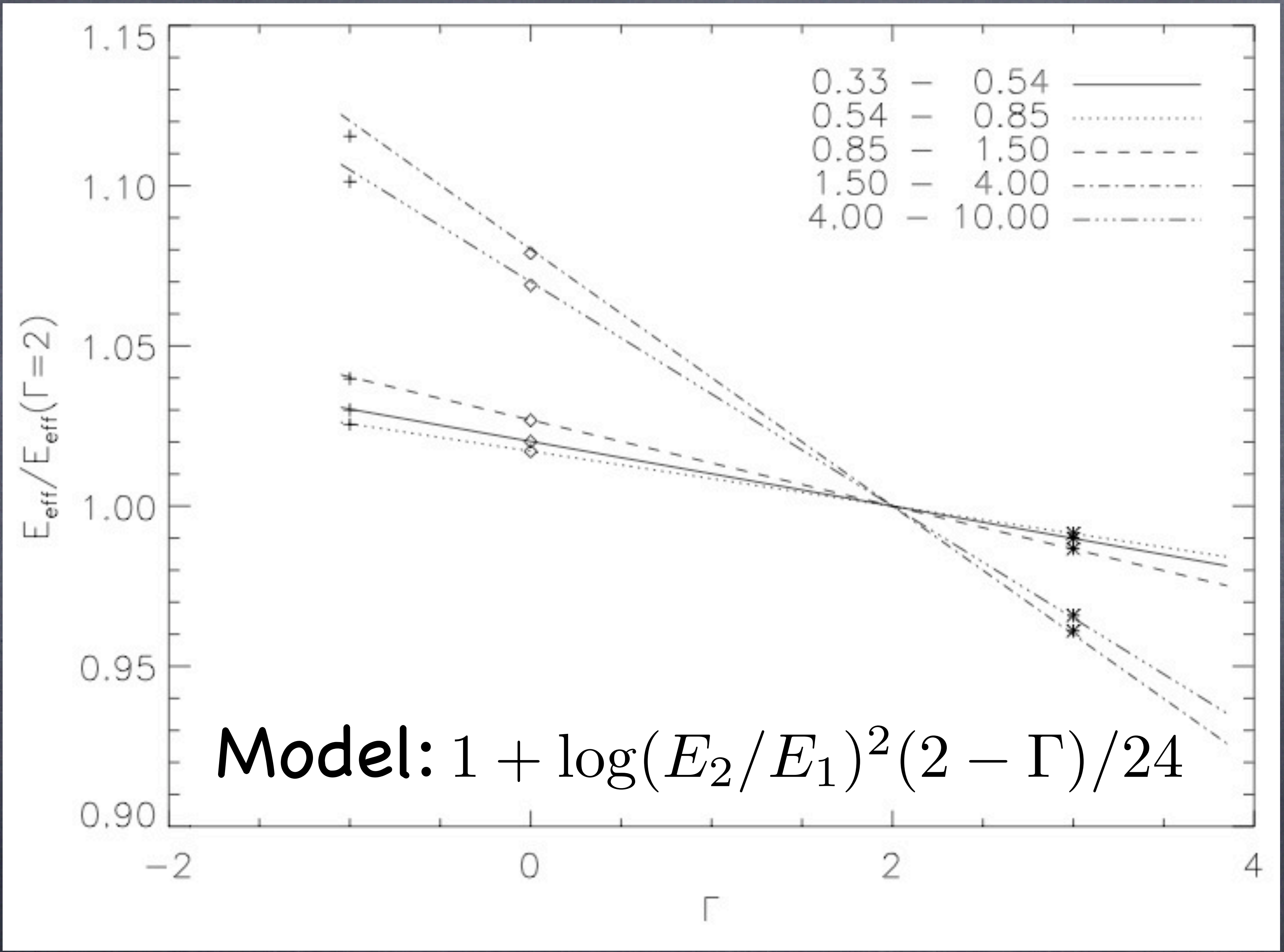
- Case 3: estimate energy flux, F

$$F = \frac{C_1+C_2}{A_1 t_1/E_1 + A_2 t_2/E_2}$$

- Case 4: estimate flux if $n(E) = K\,(E/\hat{E})^{-\Gamma}$

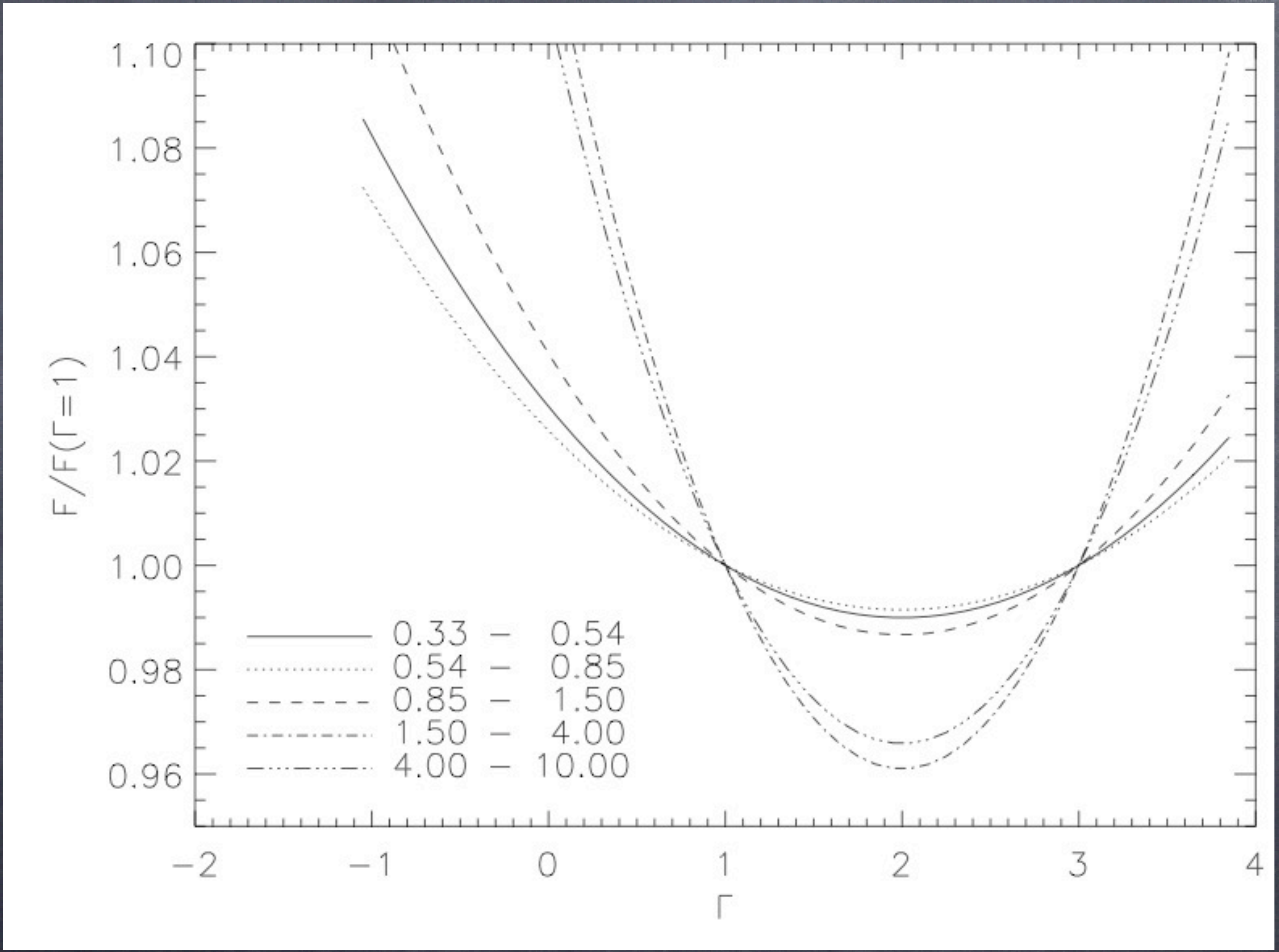
$$F = \frac{\hat{E}(C_1+C_2)}{A_1 t_1 (E_1/\hat{E})^{-\Gamma} + A_2 t_2 (E_2/\hat{E})^{-\Gamma}}$$

Central Energy



Model: $1 + \log(E_2/E_1)^2(2-\Gamma)/24$

Flux Sensitivity



Summary of Bandpass Fitting

- Simple to do, can get "acceptable" fits
- Flux is robust to knowledge of spectral slope
  - --> provides easy measure for cross calibration
- Requires knowledge of spectral slope
  - can estimate from data in band
  - however, slope changes slowly --> use wide band
- Need to include case of wide RMFs