
MILD SEVEN
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Rothmans
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Wednesday, April 14, 2010

Monte Carlo Grand Prix

Including Calibration Uncertainties in (X-ray) Parameter Estimation Analyses

Jeremy Drake, Pete Ratzlaff, Vinay Kashyap

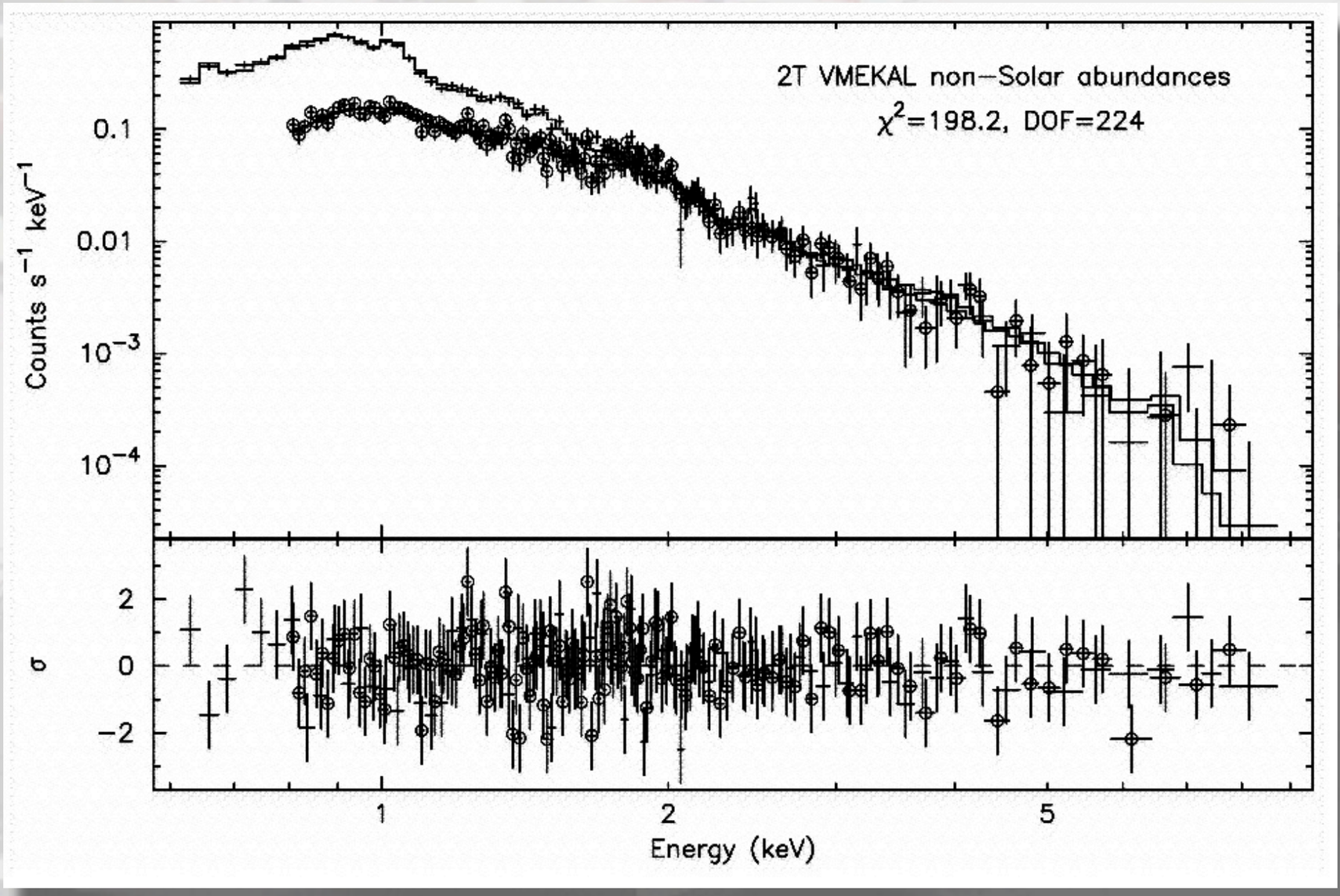
With: Diab Jerius, Catherine Grant, Dick Edgar, Herman Marshall, Alexey Vikhlinin....

"This is an interesting circuit because it has inclines, and not just up, but down as well."

Murray Walker on Monaco GP

Calibration uncertainties...

"There's nothing wrong with the car, except that it's on fire!"



...and why we ignore them

"Do my eyes deceive me, or is Senna's Lotus sounding rough ?"

- Main problem is that uncertainties are **correlated** in very complicated ways
- There are no easy statistical formulae to apply
- You might be able to make up some formalism, but....

E.g. where $\sigma_{i,j}$ represents relative uncertainty between channels i and j

$$\begin{pmatrix} \sigma_{1,1} & \sigma_{2,1} & \cdots & \sigma_{n-1,1} & \sigma_{n,1} \\ \sigma_{1,2} & \sigma_{2,2} & & & \\ \vdots & & \ddots & & \vdots \\ \sigma_{1,n-1} & & & \sigma_{n-1,n-1} & \sigma_{n,n-1} \\ \sigma_{1,n} & & \cdots & \sigma_{n-1,n} & \sigma_{n,n} \end{pmatrix}$$

Statisticians on the correlated uncertainties problem

- "I haven't ever dealt with the problem of correlated uncertainties so I'm afraid can't be much help. Good luck!"

  - Keith Robinson (of Bevington & Robinson)

Monte Carlo Approach

"Tambay's hopes, which were nil before, are absolutely zero now."

* Analytical solutions difficult...
* Moore's law: since initial thoughts and ideas, computer power sufficiently advanced to allow brute-force Monte Carlo methods:
  - Simulate 100's-1000s of response functions that sample nominal response and its uncertainties
  - Repeat parameter estimation and examine distributions of "best-fit" parameters

Method applied to ACIS-S3

"and the car is absolutely unique, except for the one behind it which is identical"

Uncertainties in Photon Path

HRMA: geometry, obscuration, reflectivity, scattering

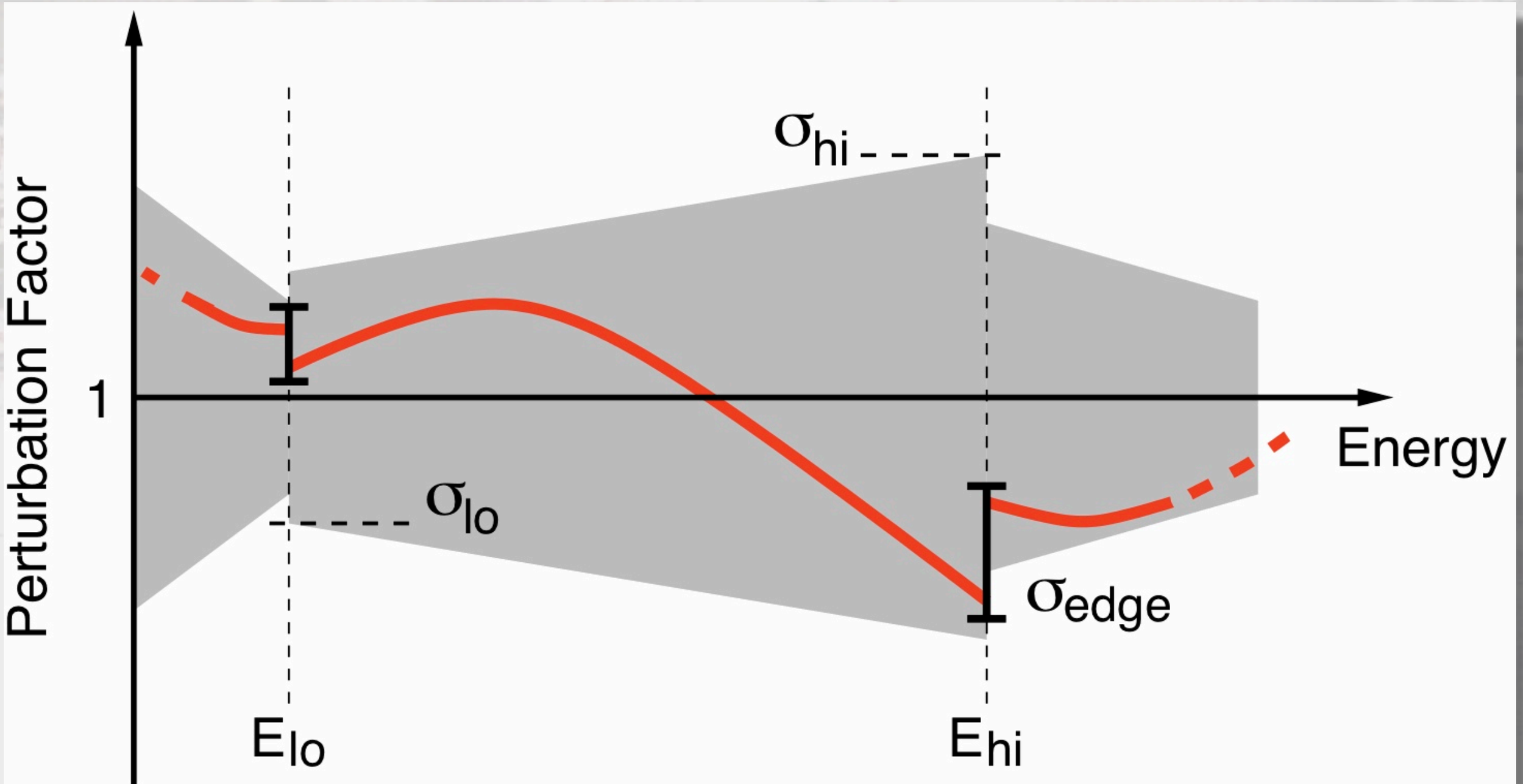
ACIS OBF: transmittance, contamination

ACIS QE: (CTI, dead time, cosmic rays, electronics…)
ACIS RMF: (gain distribution, escape peaks...)

* Use parameterised instrument models where available and vary their parameters
  - HRMA trial models and effects of different C overlayers (18-28Å)
  - ACIS QE, contamination, RMF models
* Derive a "fudge vector" - a perturbation vs E by which to change subassembly responses between edges

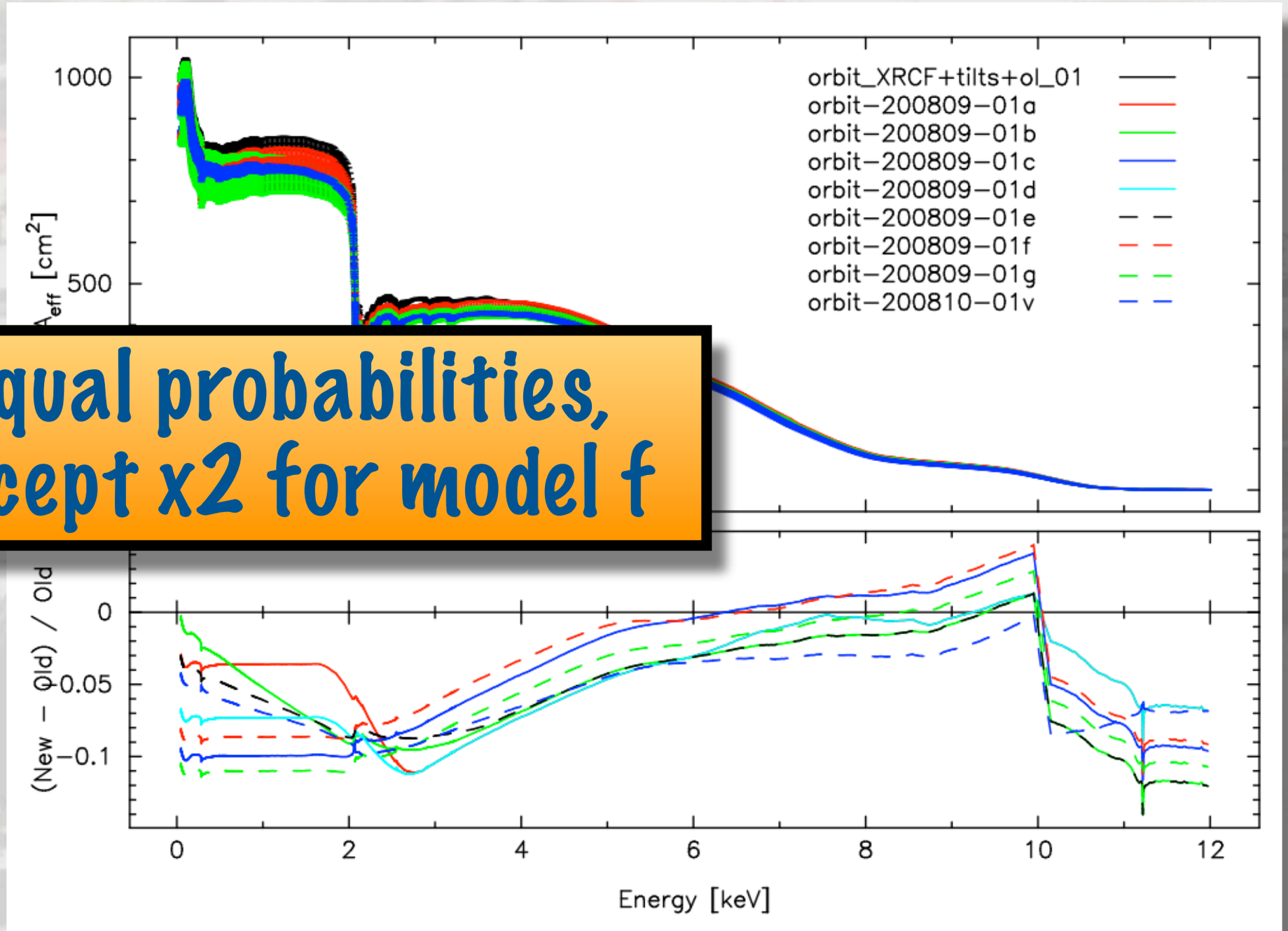
Pertubation function

"And now excuse me while I interrupt myself..."

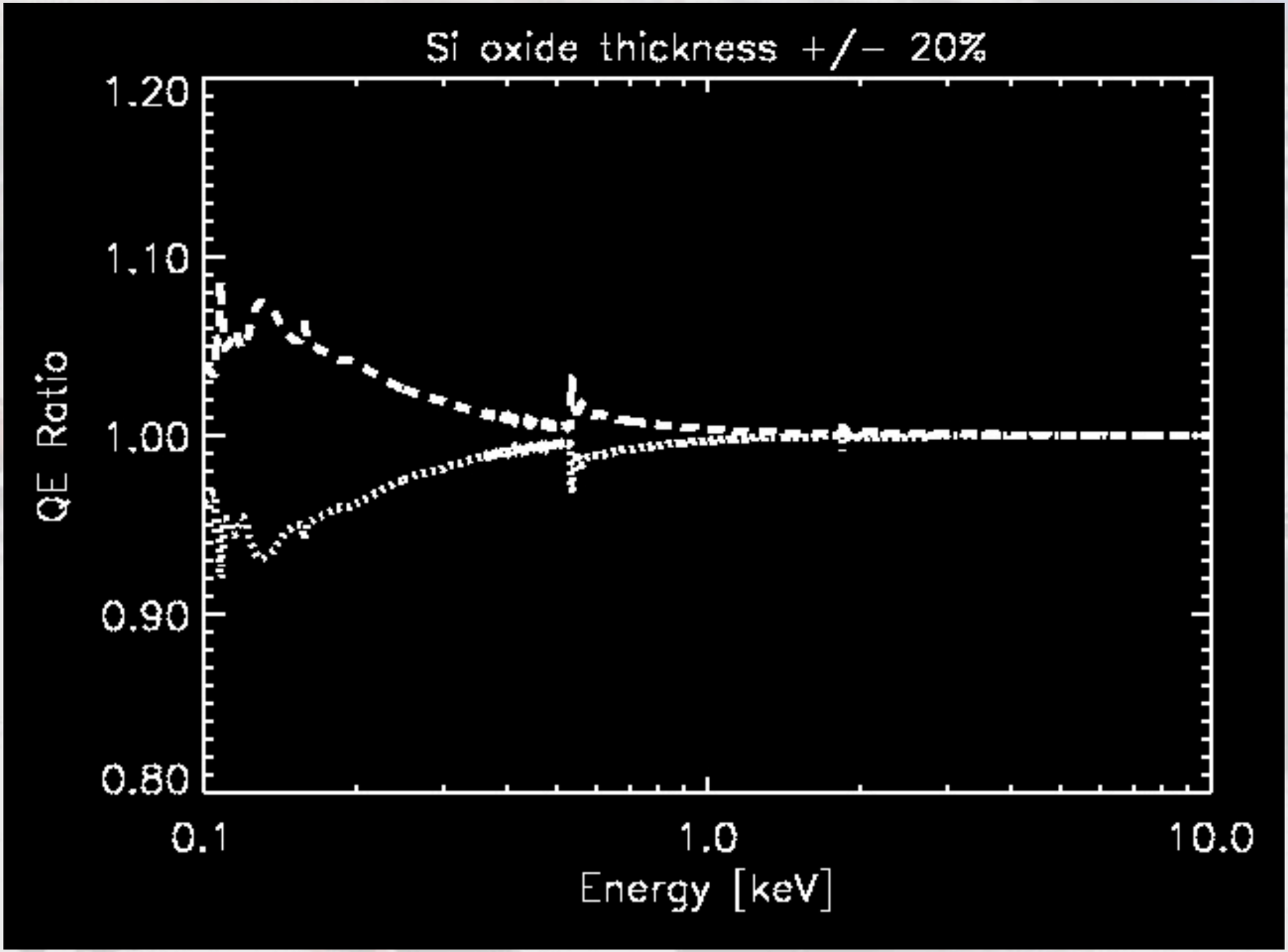


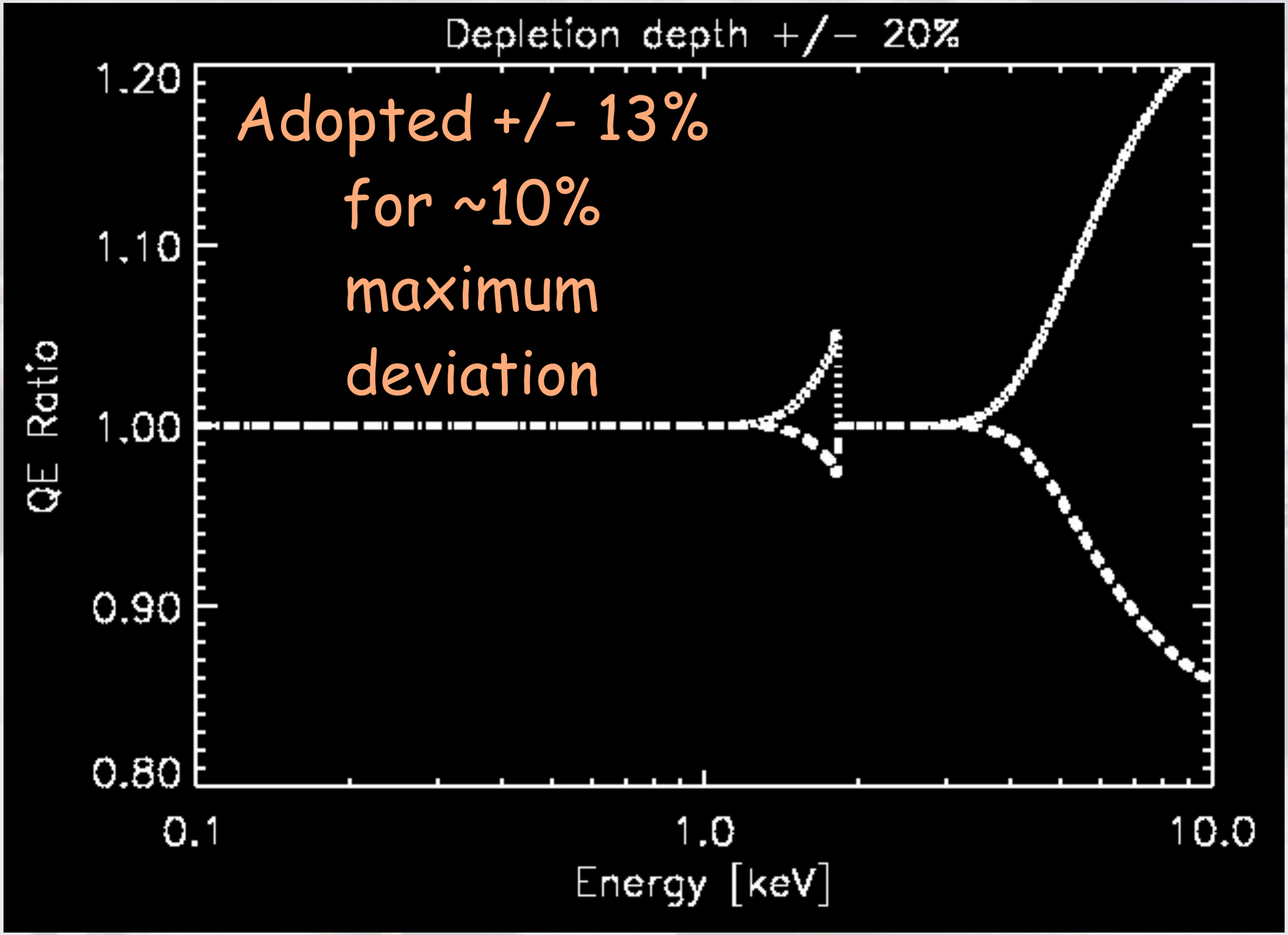
HRMA seed areas

"Senna 1st, Prost 2nd and Berger 3rd, and that makes up the top four!"



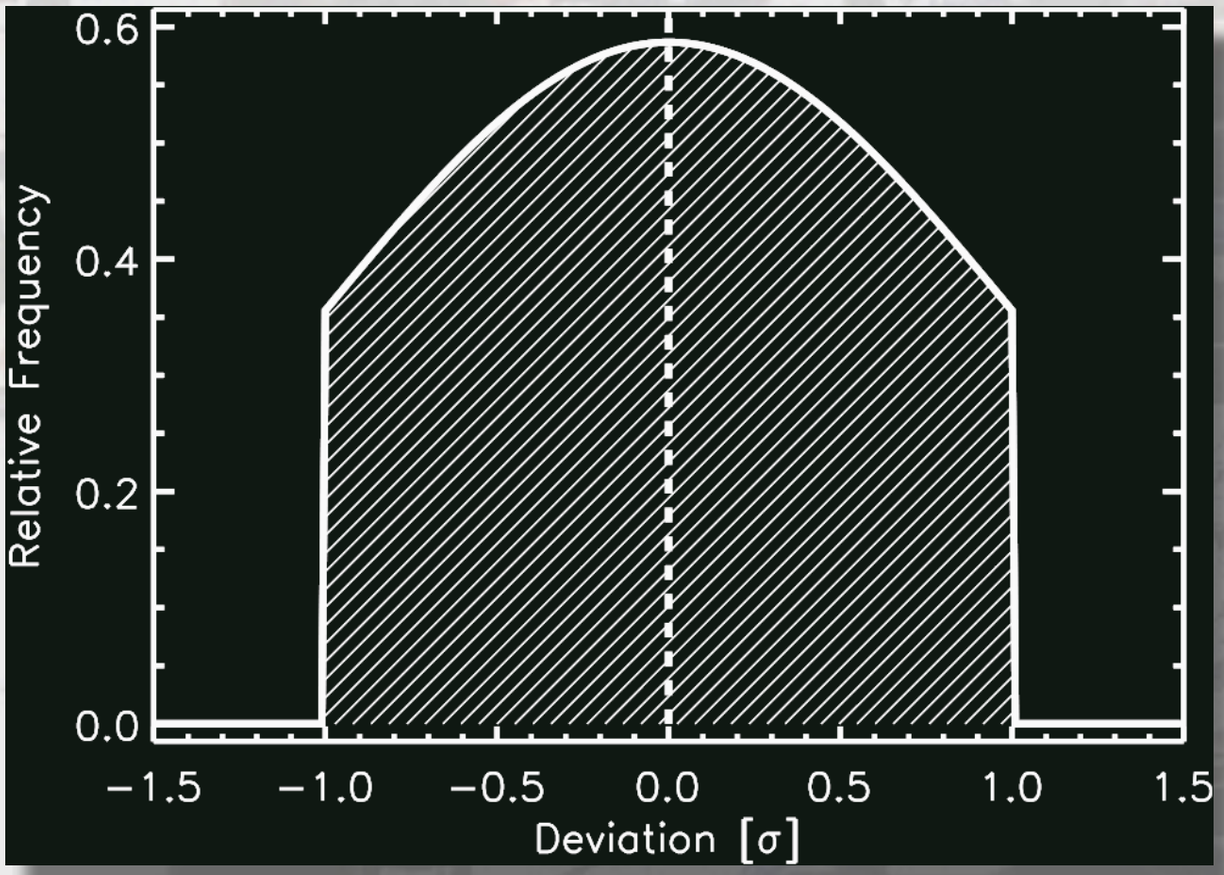
Equal probabilities, except x2 for model f


Si oxide thickness +/- 20%
1.20
1.10
1.00
0.90
0.80
QE Ratio
0.1
1.0
10.0
Energy [keV]


Depletion depth +/- 20%
Adopted +/- 13%
for ~10%
maximum
deviation
QE Ratio
1.20
1.10
1.00
0.90
0.80
0.1
1.0
10.0
Energy [keV]

How are calibration uncertainties distributed?

"He can't decide whether to have his visor half open or half closed."



* Rigorous treatment requires knowledge of how uncertainties are distributed

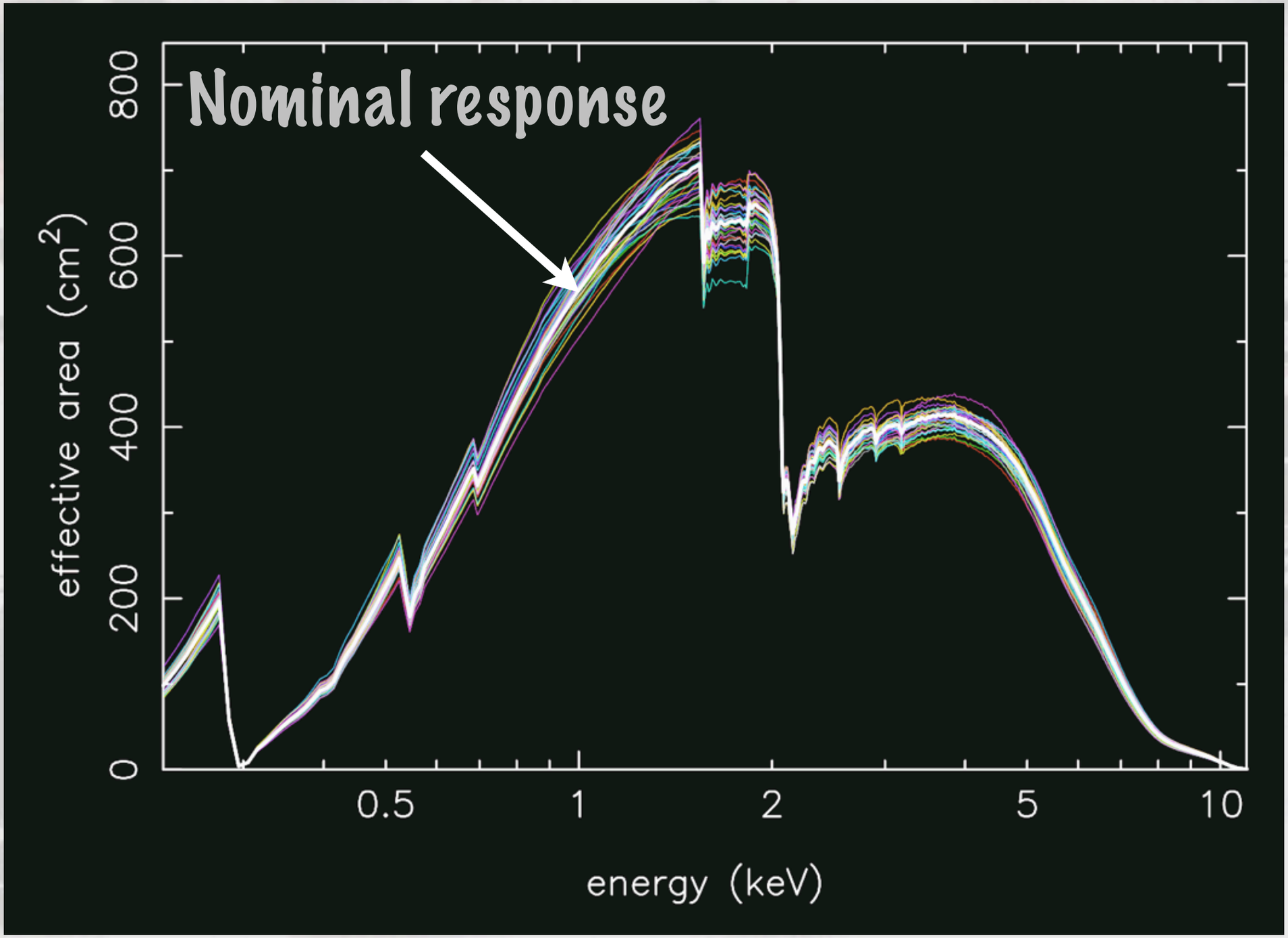
- **Unknown!**

  * Assume a truncated normal distribution -1σ to +1σ

    - Peaked at preferred value
    - Includes gut feeling!

Resulting ACIS-S3 areas

"And the first five places are filled by five different cars."



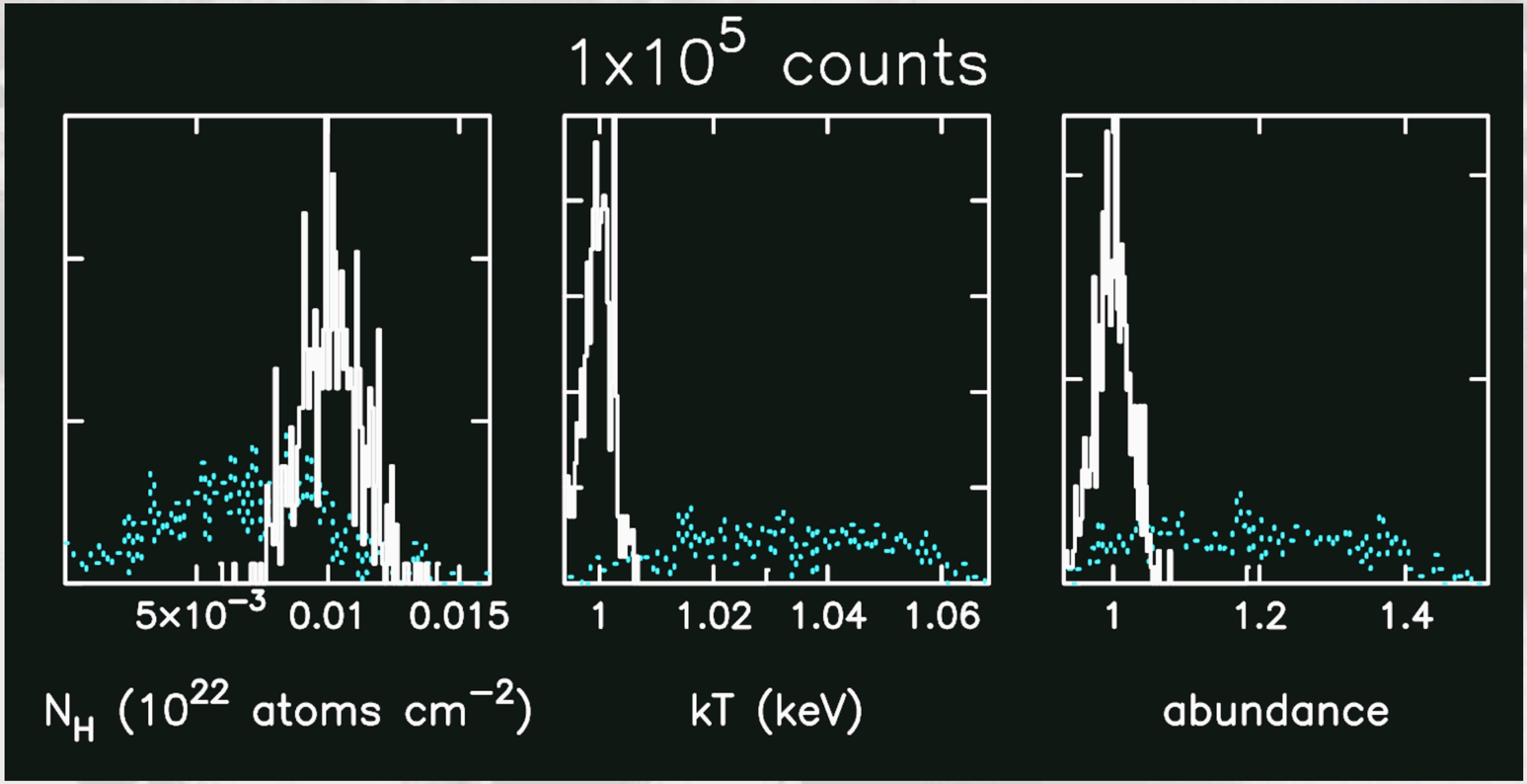
Limiting Accuracy of Chandra

"and there's no damage to the car, except to the car itself."

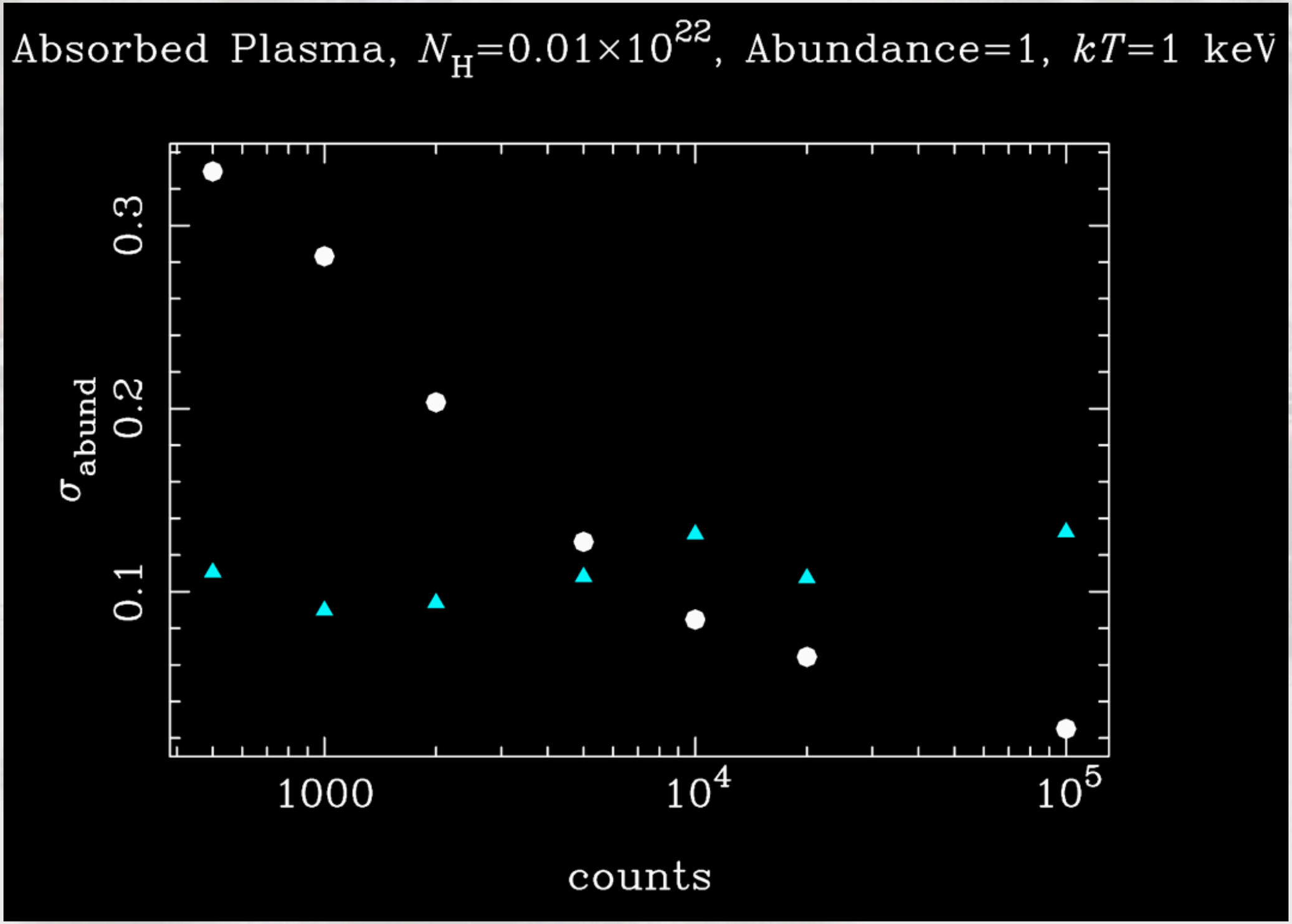
- Simulate spectrum ("fakeit")
- Fit using different effective area realisations a lot of (e.g. 1000) times
  - XSPEC v12.4
  - Models: blackbody, MEKAL, power-law; all with ISM absorption
- Compare with fits to 1000 different "fakeits" using nominal area to probe counting statistics

Poisson vs Calibration

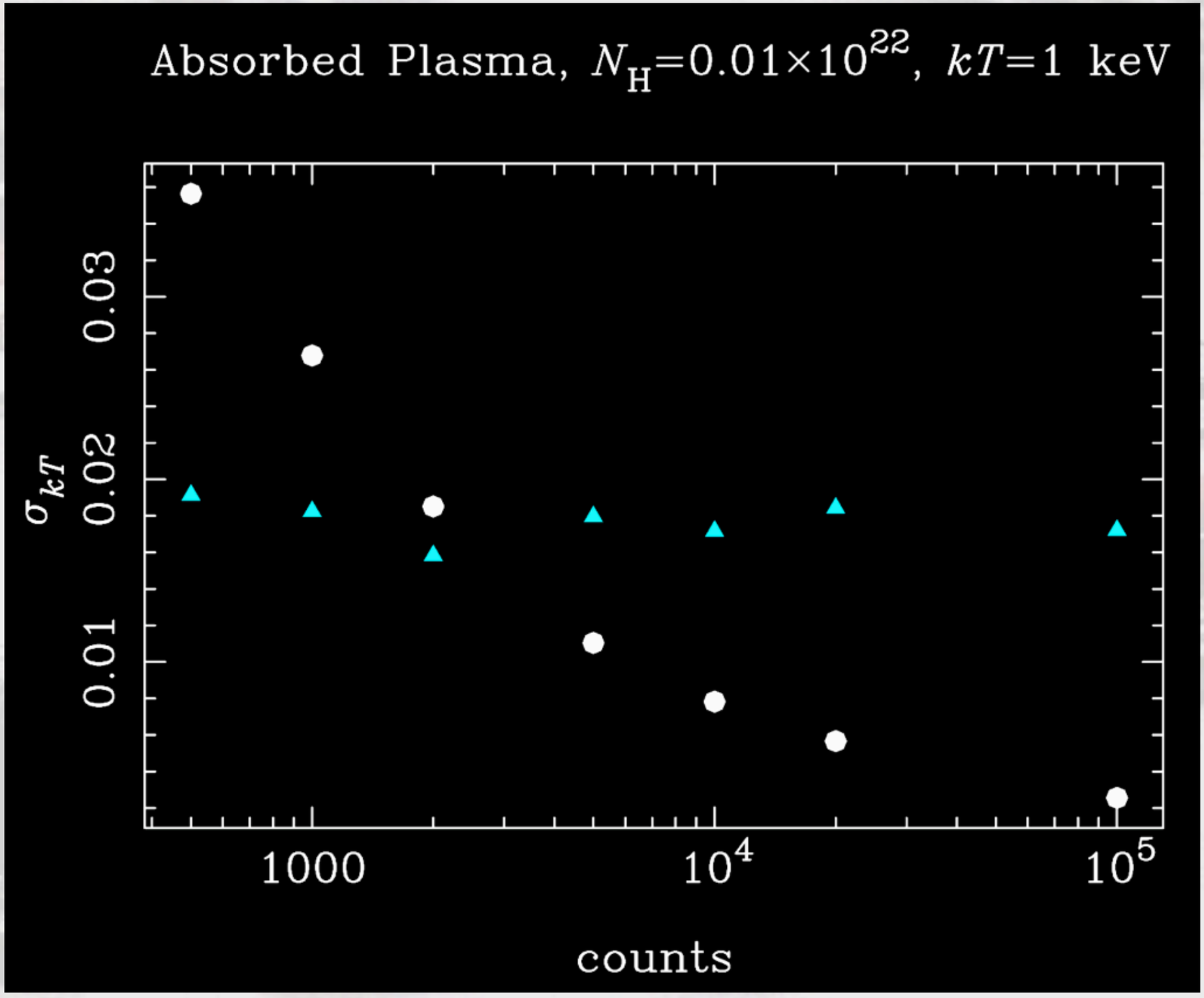
"and the beak of Ayrton Senna's chicken is pulling ahead"



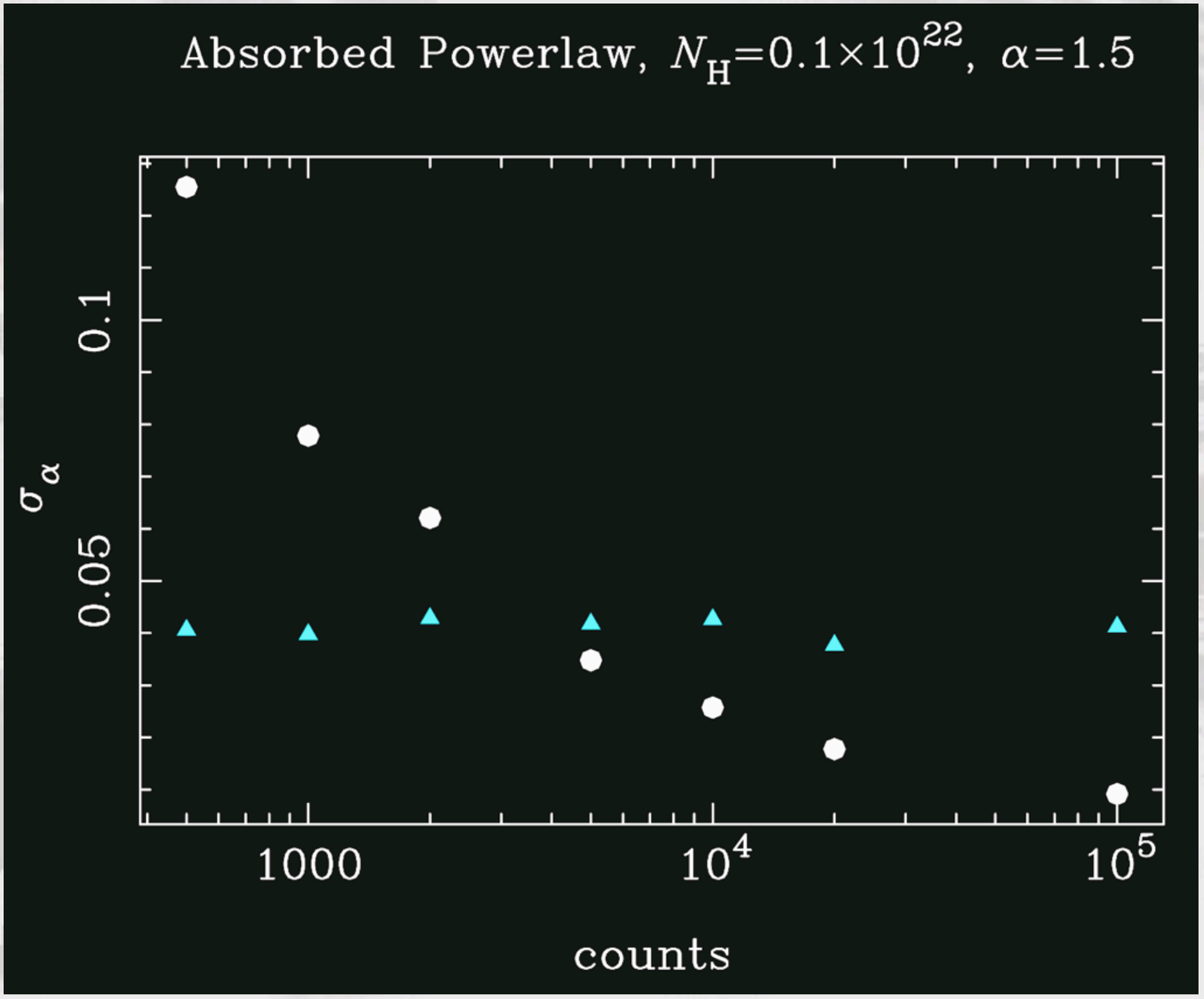
Poisson vs Calibration



Poisson vs Calibration



Poisson vs Calibration



Code release

"and yet again, Damon Hill is modest in defeat"

* Perl β-release now available at

  http://hea-www.harvard.edu/~rpete/mccal

* Ability to perform MC assessment of calibration undertainties on near-on-axis ACIS-S3 observations

  - no RMF's in release yet
  - Feedback, bug fixes etc welcome: jdrake@cfa.harvard.edu

Future

"there is a man with a great Grand Prix future behind him."

- C++ version (possibly --> python) under development
- Addition of other Chandra instruments
- Method completely general: can be done for any mission/instrument
  - eg perturbation function approach can be implemented for XMM-Newton, Suzaku, Swift... "tomorrow"
- Sherpa MCMC method implementing these MC areas now ready.... Vinay

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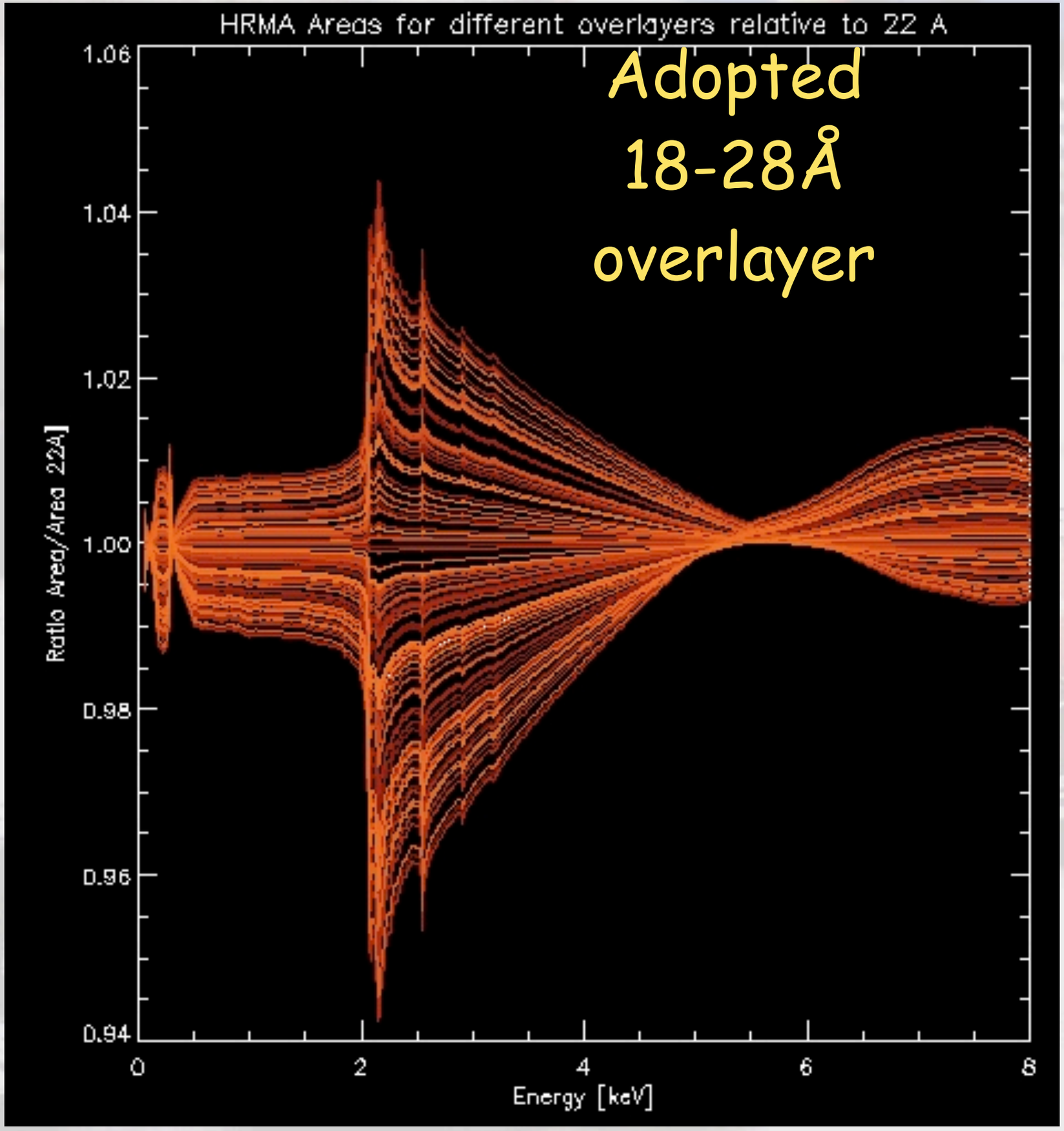
HRMA Areas for different overlayers relative to 22 A
Adopted
18-28Å
overlayer
Ratio Area/Area 22A]
1.06
1.04
1.02
1.00
0.98
0.96
0.94
0
2
4
6
8
Energy [keV]

Pertubation function

"And now excuse me while I interrupt myself..."