Pileup Modeling

John E. Davis
MIT/CXC

- Overview of pileup model
- Data Preparation
- Use of the model in Sherpa and Isis
- Examples
- Summary

Examples

Q0836+7104 (Obs 1450)

HETG/ACIS-S

Sept 17, 1999 Claude Canizares

NGC 4579 (Obs 807)

ACIS-S

May 2, 2000 Michael Eracleo

0.8 sec frame time

Nucleus of M81 (Obs 735)

ACIS-S

May 7, 2000 Douglas Swartz

~3' off-axis

"Standard" Model

$$C(h) = (N\tau) \int dE \; R(h,E)\, A(E)\, S(E)$$

N : number of frames

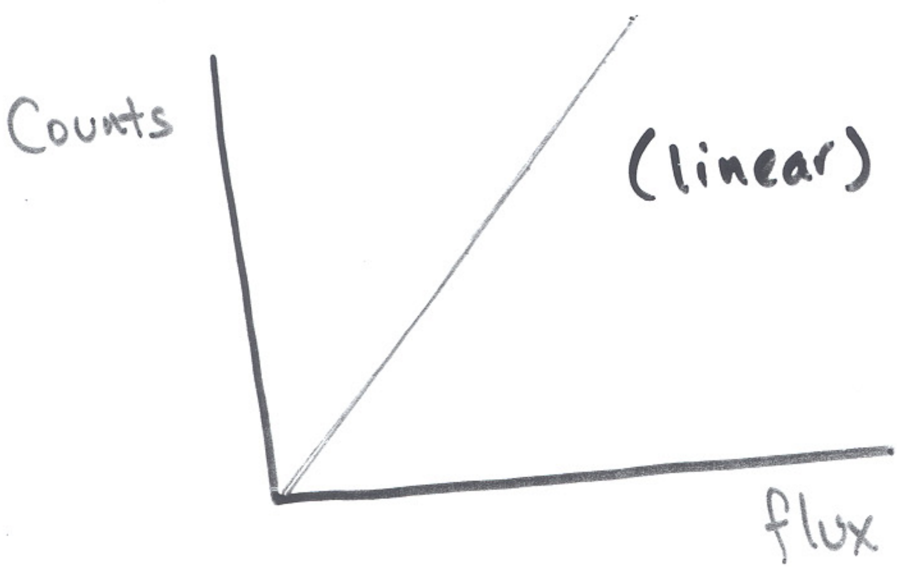
τ : frame time

$R(h,E)$: RMF

$A(E)$: ARF

$S(E)$: spectral model

$C(h)$: PHA spectrum

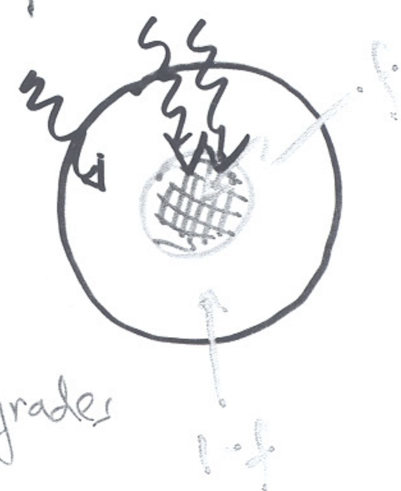


Pileup Model (ApJ 562, 575 2001)

$$C(h) = (N\tau)(1-f)\int dE\, R(h,E)\, A(E)\, s(E)$$

$$+ N n\, e^{-\tau/g_0 \int dE\, A(E)\, f\, s(E)/n}$$

$$\times \sum_{p=1}^{\infty} \alpha^{p-1} \int dE\, R(h,E) \frac{\left[\tau A(E)\, f\, s(E)/n\right]^{*p}}{p!}$$

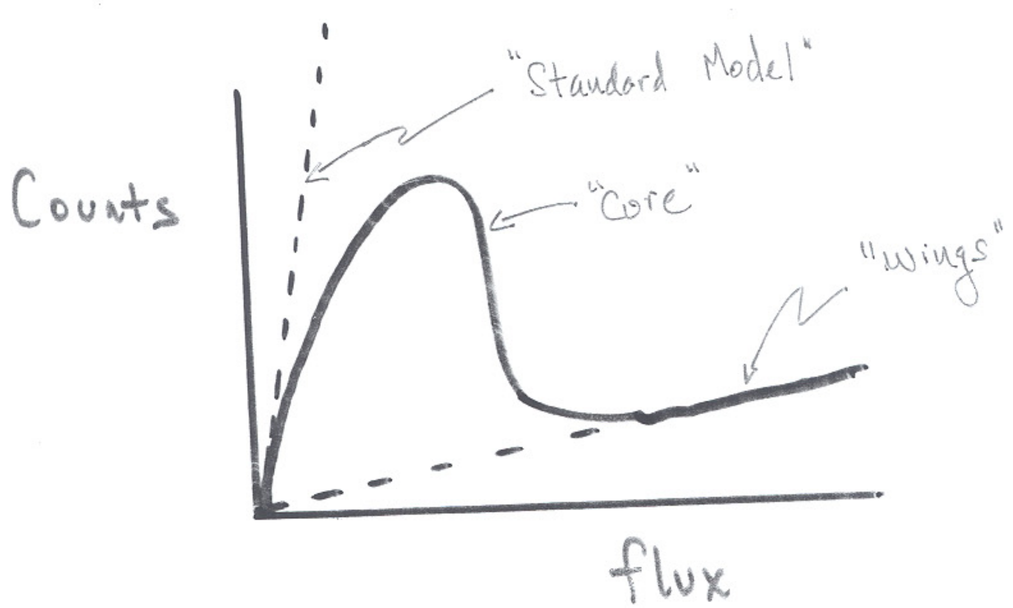


n: number of pileup regions

f: PSF fraction of pileup region

g_0: branching ratio into "good" grades

α: grade migration parameter



Data Preparation

Start with level 1 files!

- Level 2 files have had "afterglow" events removed
- 10-20% of the source events are misidentified as afterglow events!

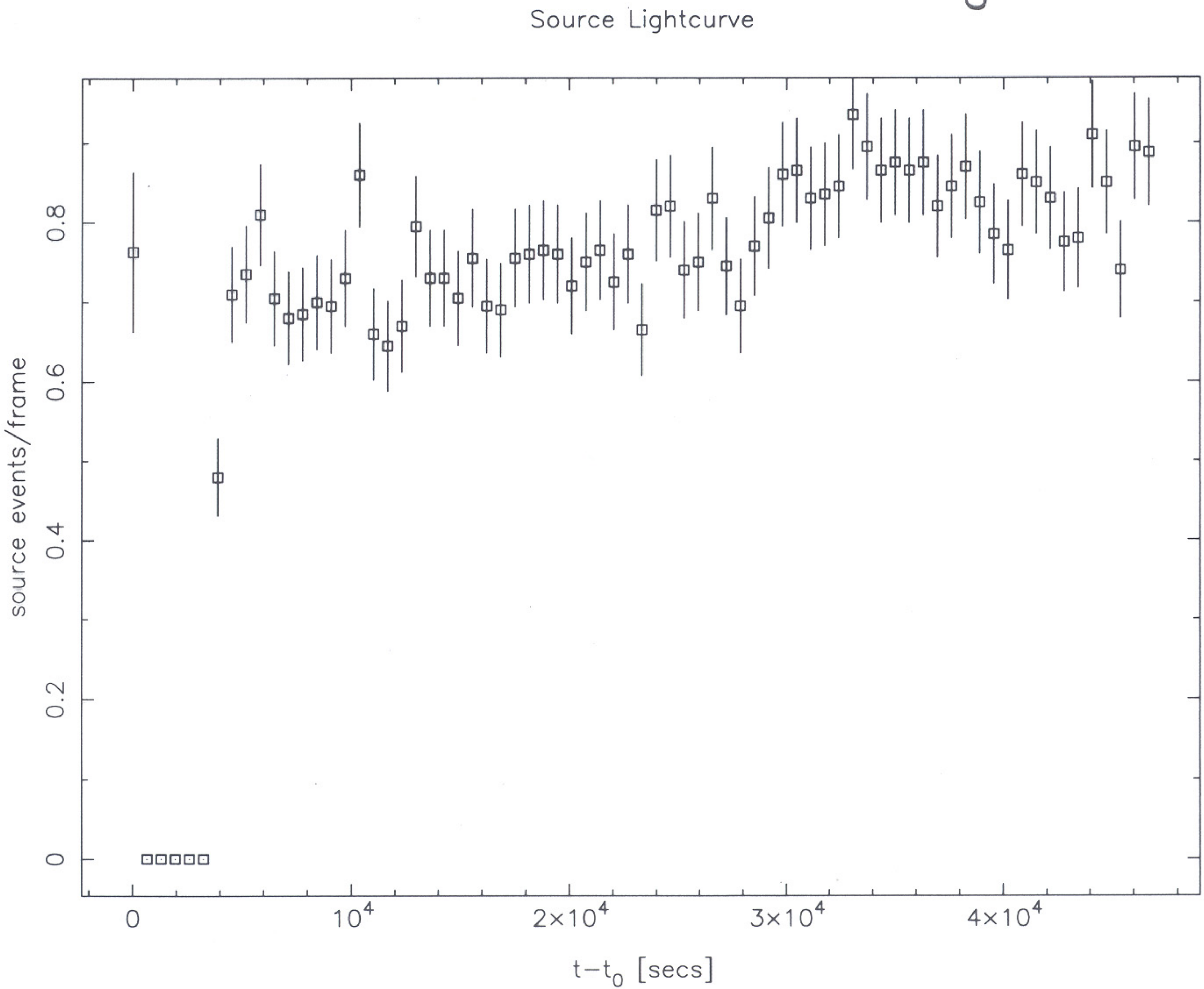
http://cxc.harvard.edu/threads/acisdetectafterglow/

http://www.astro.psu.edu/users/patb/ciao_recipe/ciao2_reci

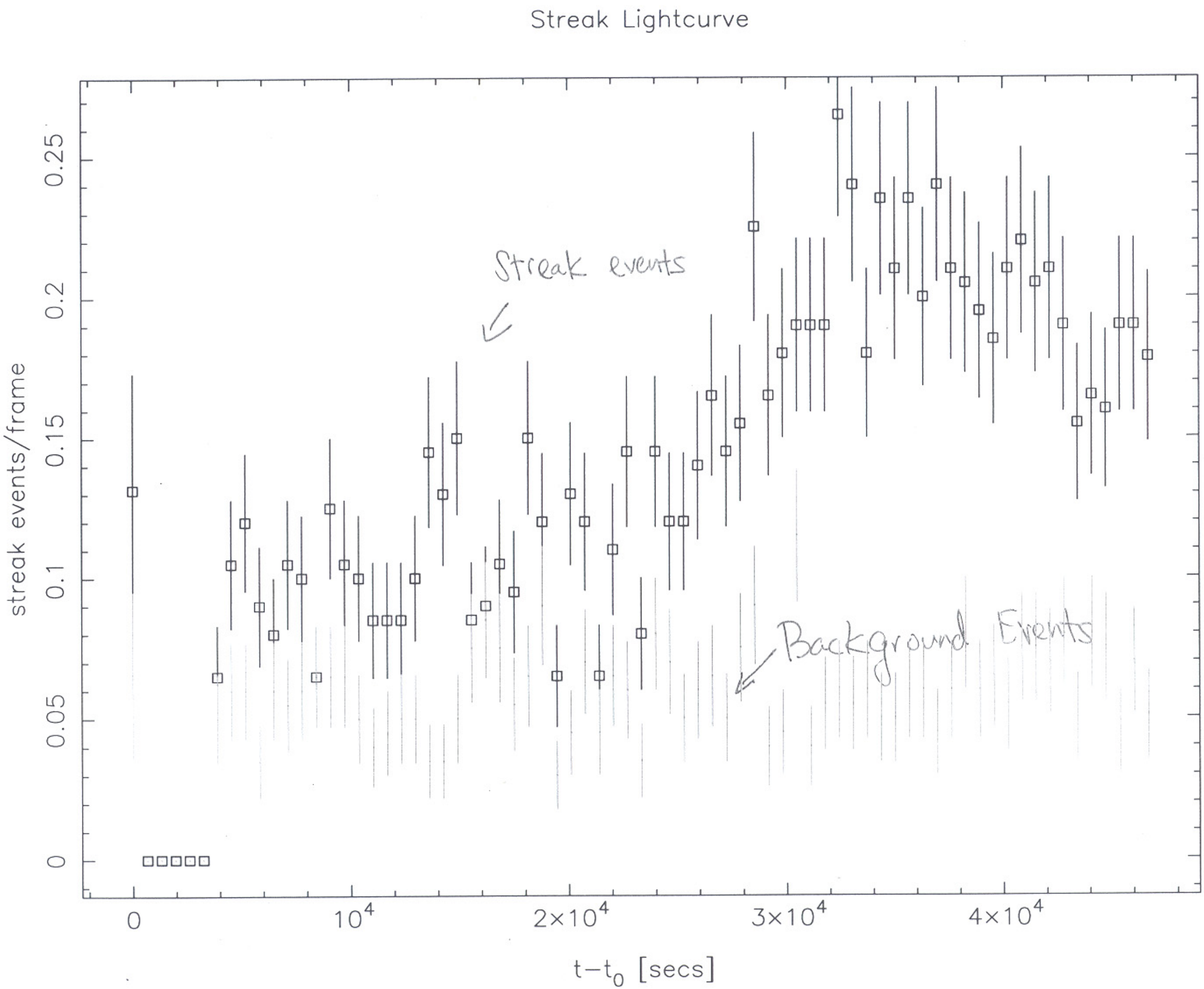
Construct lightcurves using:

- wings of PSF
- ACIS readout streak
- Do not depend upon counts in the core of the PSF for lightcurves!

II Peg (Obs 1451)



II Peg (Obs 1451)



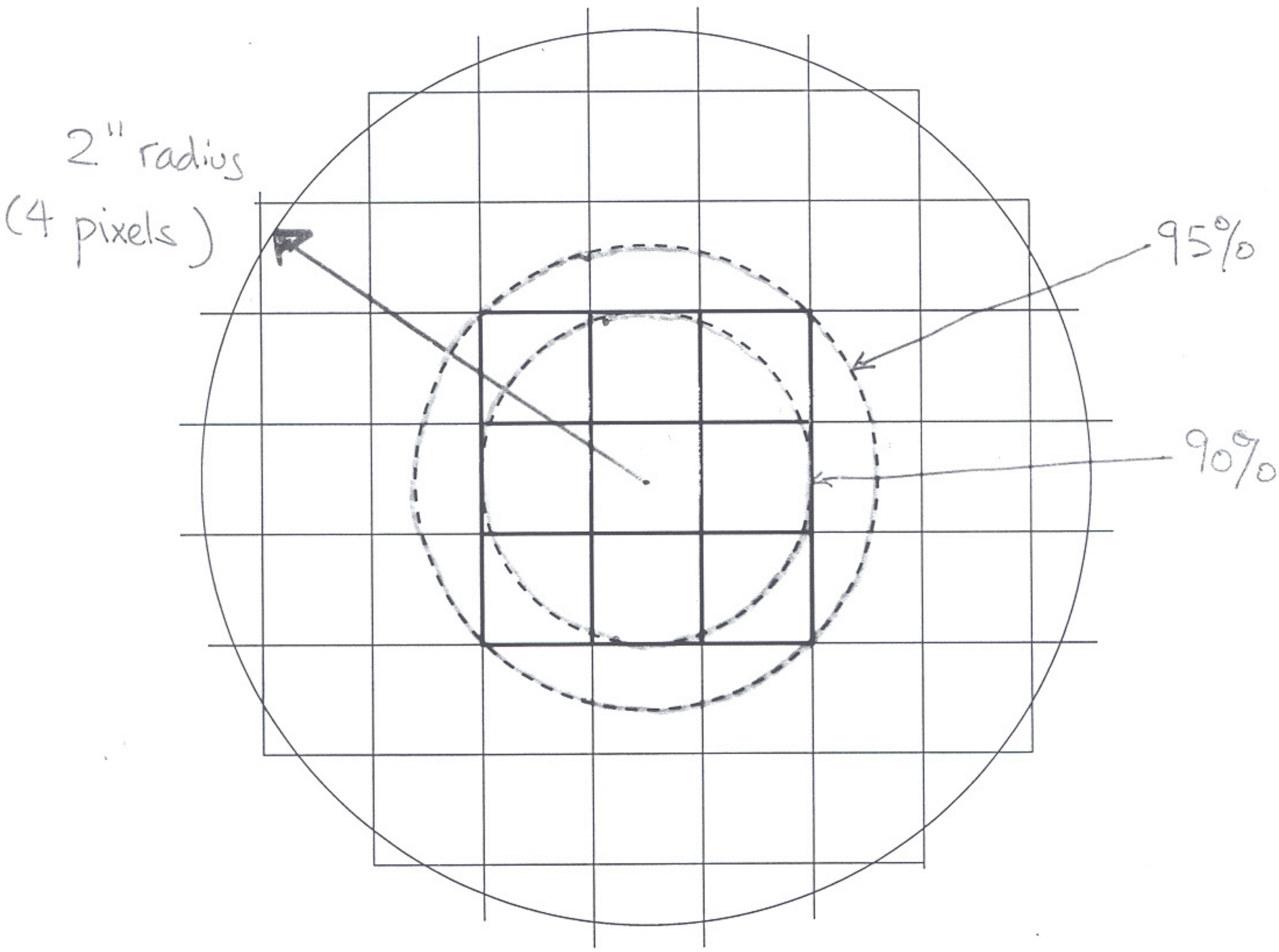
Create ARFs, RMFs, and PHA files

Use <u>mkarf</u> to create an observation specific ARF. Do not use a canned ARF!

Make sure that the value of the EXPOSURE keyword in the ARF is correct.

For an on-axis point source, use a circular extraction region with a 2" radius — no larger!

Recommended Extraction Region for <u>on-axis</u> point source



Spectral Analysis Programs

xspec (http://heasarc.gsfc.nasa.gov/docs/xanadu/xspe

* partial implementation of pileup model
  (full implementation being tested)

sherpa (http://cxc.harvard.edu/ciao)

* ARF must be defined on a uniform grid
* Cannot ignore PHA channels when fitting pileup
* Frametime and fractional exposure must explicitly
  set by user

isis (http://space.mit.edu/CXC/isis/

* Uses Exposure Time from ARF

See also:

http://space.mit.edu/CXC/analysis/PILECOMP/

Sherpa Example

```
DATA 1 pha.fits
INSTRUMENT 1 = RSP[my1]("rmf.fits", "arf.fits")
xswabs[w]
xspowerlaw[p]
source 1 = w*p
PARAMPROMPT OFF
w.nH = 0.1
w.nH.min = 0
w.nH.max = 1
thaw w.nH
p.norm = 0.006
p.norm.min=0
p.norm.max=0.1
p.PhoIndx=1.7
p.PhoIndx.min=0
p.PhoIndx.max=3
thaw p.norm p.PhoIndx
```

Define Model

Set model parameters

```
JDPILEUP[jdp1]
PILEUP 1 = jdp1
jdp1.ftime = 3.2
jdp1.n = 1
jdp1.alpha = 0.5
jdp1.f = 0.95
thaw jdp1.f jdp1.alpha
```

pileup Setup

Isis Example

```
load_dataset ("pha.fits", "rmf.fits", "arf.fits");
fit_fun ("phabs(1)*powerlaw(1)");
set_par ("phabs(1)", 0.1, 0, 0, 1);
set_par ("powerlaw(1)", [0.006, 1.7], [0,0], [0,0], [0.1,3.0]);
```

Define Model / Set parameters

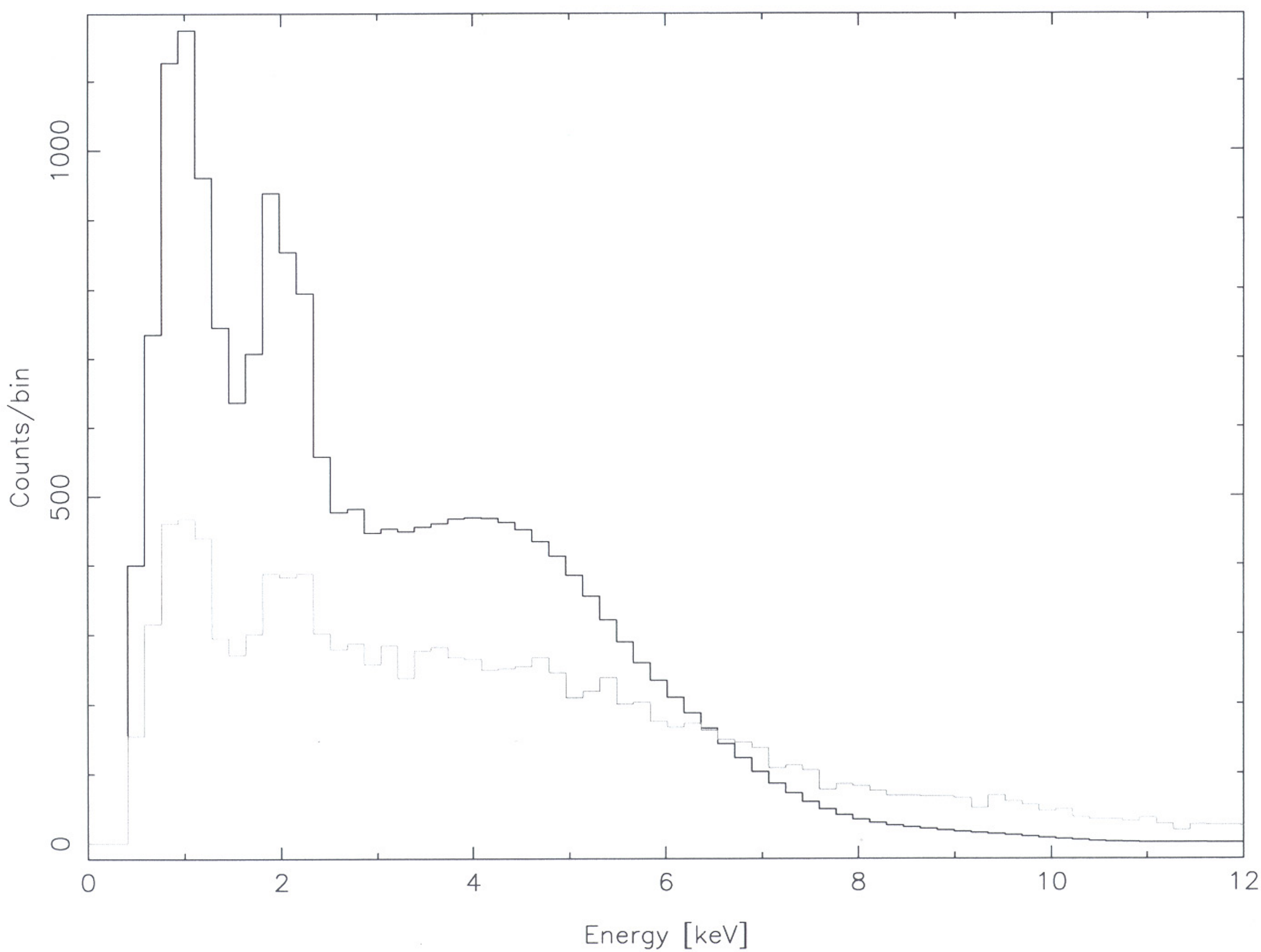
```
set_kernel (1, "pileup");
set_par ("pileup<1>", [1,1,0.5,0.95], [1,1,0,0]);
```

pileup setup

```
group_data (1, 8);
xnotice_en (1, 0.5, 12);
```

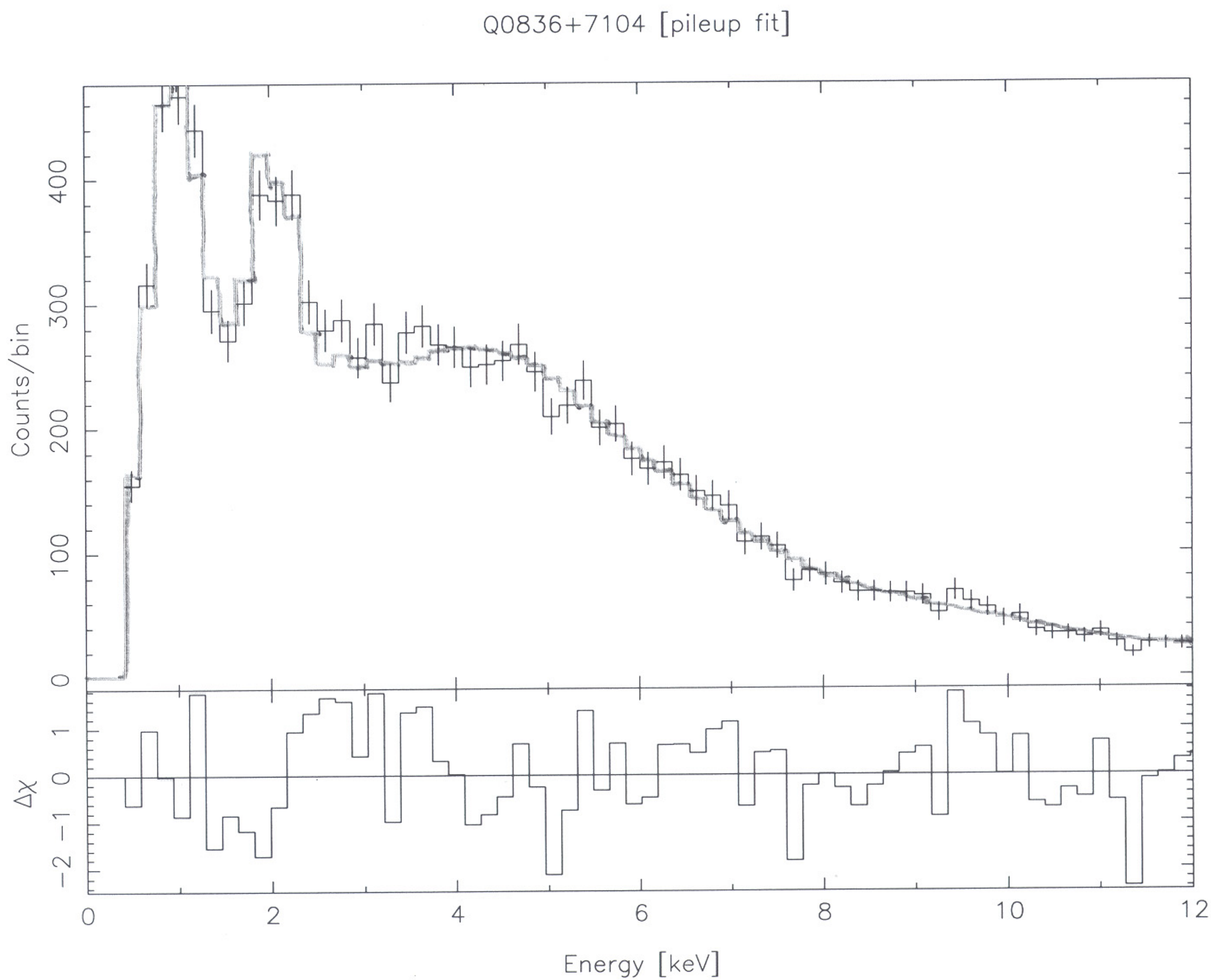
Grouping Data and Setting ignore/notice ranges

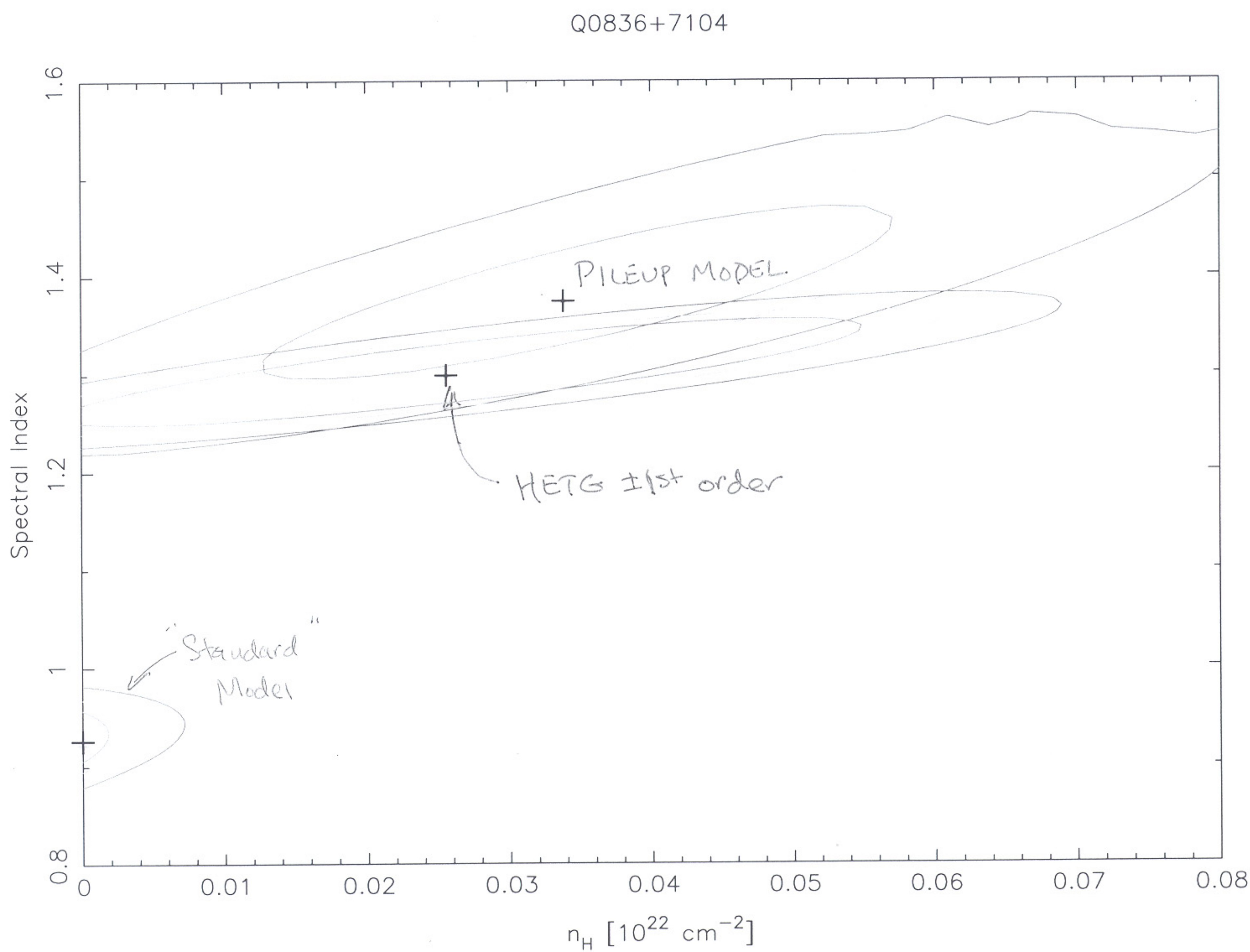
Q0836+7104 predicted –vs– observed



Q0836+7104

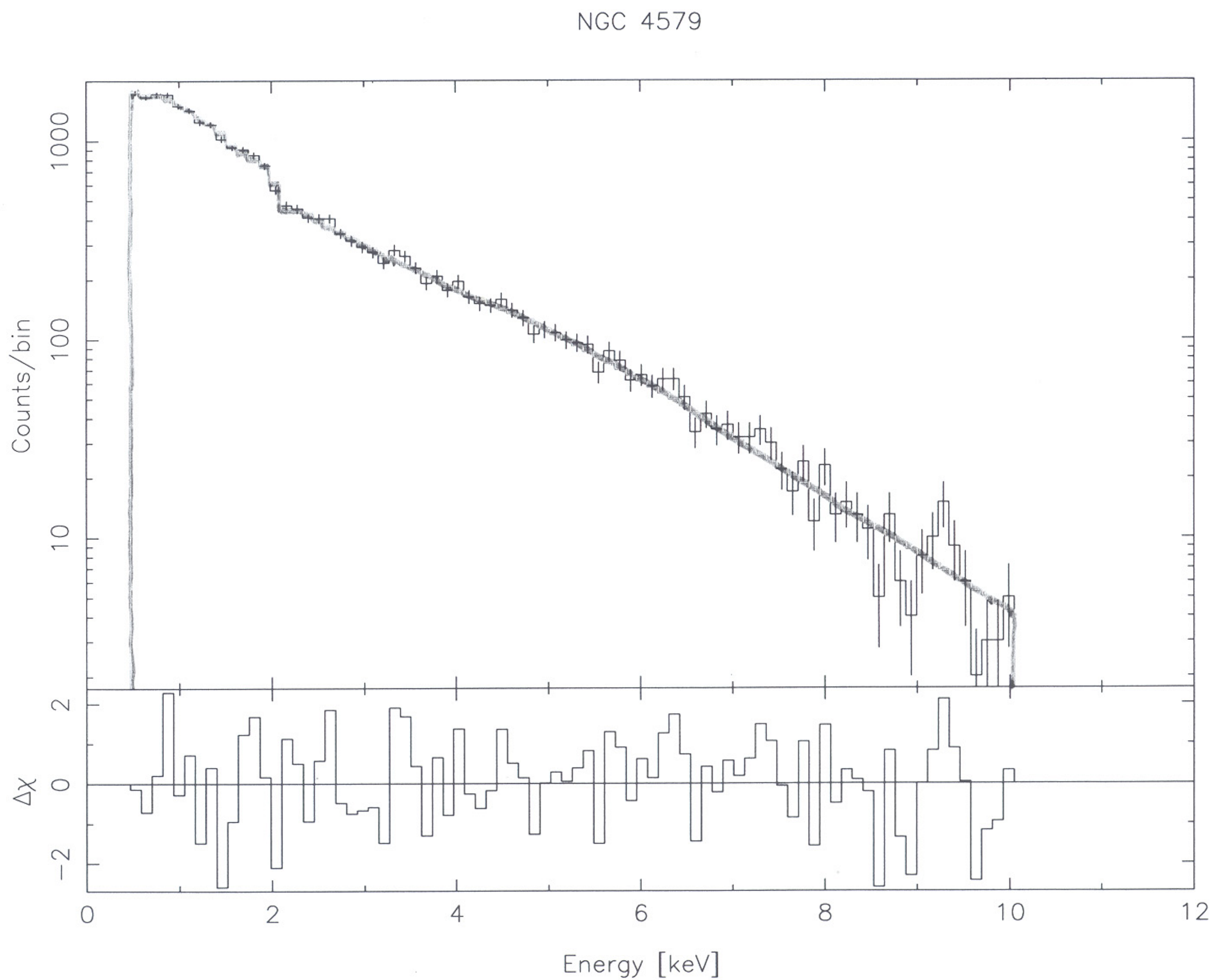
```
isis> fit_counts;

 Parameters[Variable] = 7[5]
 Data bins = 67
 Chi-square = 63.1
 Reduced chi-square = 1.018

isis> list_par;

phabs(1)*powerlaw(1)
 idx  param                  tie-to  freeze         value          min          max
  1  phabs(1).nH                  0       0    0.03381944            0          0.2
  2  powerlaw(1).norm             0       0   0.002399927            0         0.01
  3  powerlaw(1).PhoIndex         0       0      1.374511            0            3
  4  pileup<1>.nregions           0       1             1            1           10
  5  pileup<1>.g0                 0       1             1            0            1
  6  pileup<1>.alpha              0       0     0.8728455         0.35            1
  7  pileup<1>.psffrac            0       0     0.9304663          0.9            1

isis> print_kernel(1);

 1: 0.367879     0.625742
 2: 0.184252     0.273553
 3: 0.061522     0.0797253
 4: 0.0154067    0.0174266
 5: 0.00308658   0.00304732
 6: 0.000515305  0.000444061
 7: 7.37403e-05  5.54651e-05
 8: 9.23323e-06  6.06186e-06
 *** pileup fraction: 0.374258

isis> rplot_counts(1);
```


Q0836+7104 [pileup fit]
Counts/bin
0
100
200
300
400
Δχ
−2
−1
0
1
0
2
4
6
8
10
12
Energy [keV]

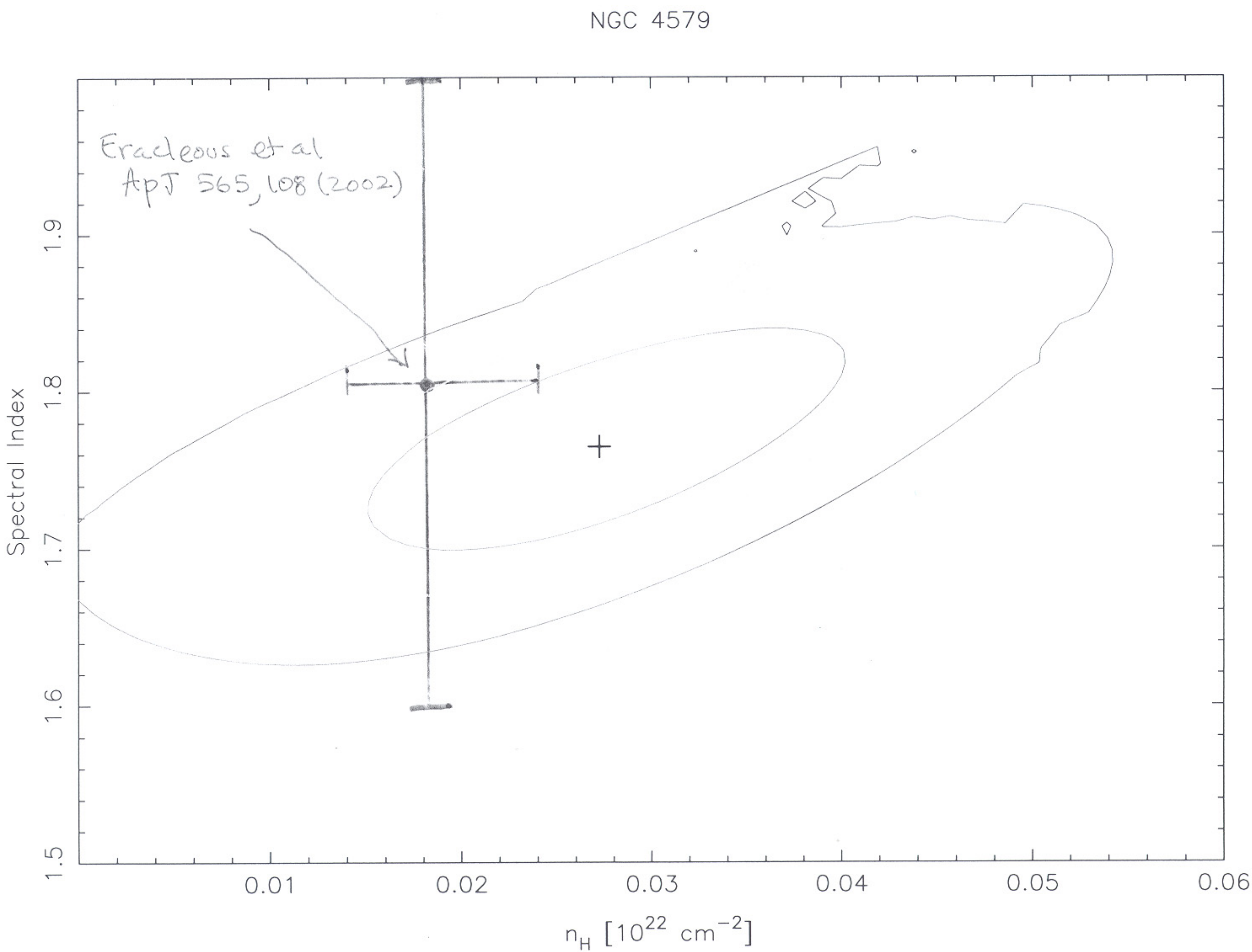

Q0836+7104
Spectral Index
1.6
1.4
1.2
1
0.8
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
n_H [10^{22} cm^{-2}]
PILEUP MODEL
HETG ±1st order
"Standard" Model

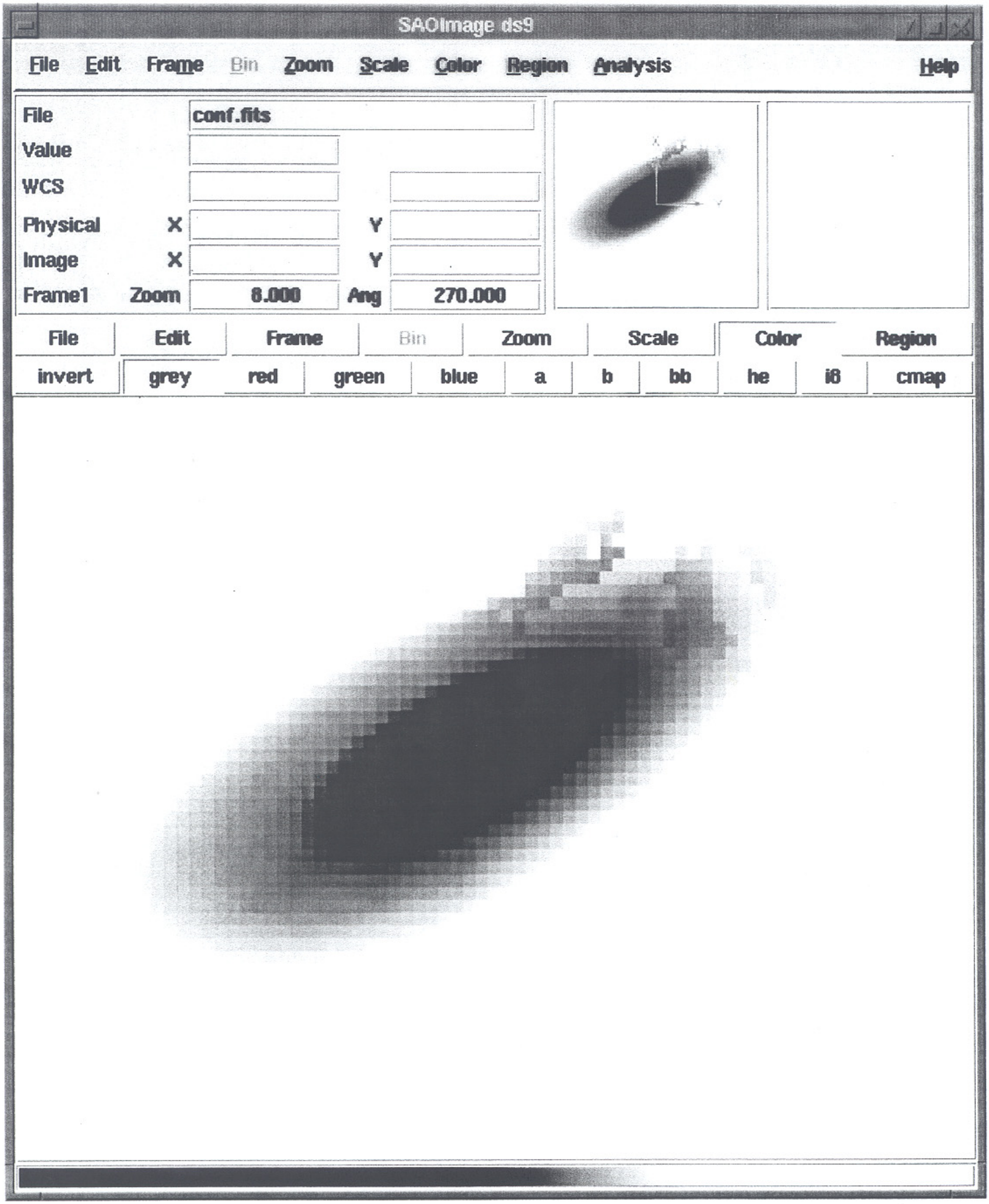
NGC 4579

```
isis> fit_counts;

 Parameters[Variable] = 7[5]
            Data bins = 82
           Chi-square = 103.6
   Reduced chi-square = 1.346

isis> list_par;

phabs(1)*powerlaw(1)
 idx  param                   tie-to  freeze         value         min         max
  1  phabs(1).nH                  0     0        0.02727911          0         0.2
  2  powerlaw(1).norm             0     0       0.001469524          0         0.1
  3  powerlaw(1).PhoIndex         0     0          1.764569          1           3
  4  pileup<1>.nregions           0     1                 1          1          10
  5  pileup<1>.g0                 0     1                 1        0.8           1
  6  pileup<1>.alpha              0     0         0.6937202          0           1
  7  pileup<1>.psffrac            0     0          0.902147        0.8           1

isis> print_kernel(1);

 1: 0.367835     0.688744
 2: 0.186795     0.242635
 3: 0.0632391    0.0569848
 4: 0.0160571    0.0100375
 5: 0.00326167   0.00141443
 6: 0.000552117  0.000166095
 7: 8.01078e-05  1.67181e-05
 8: 1.01701e-05  1.47239e-06
 *** pileup fraction: 0.311256

isis> rplot_counts(1);
```



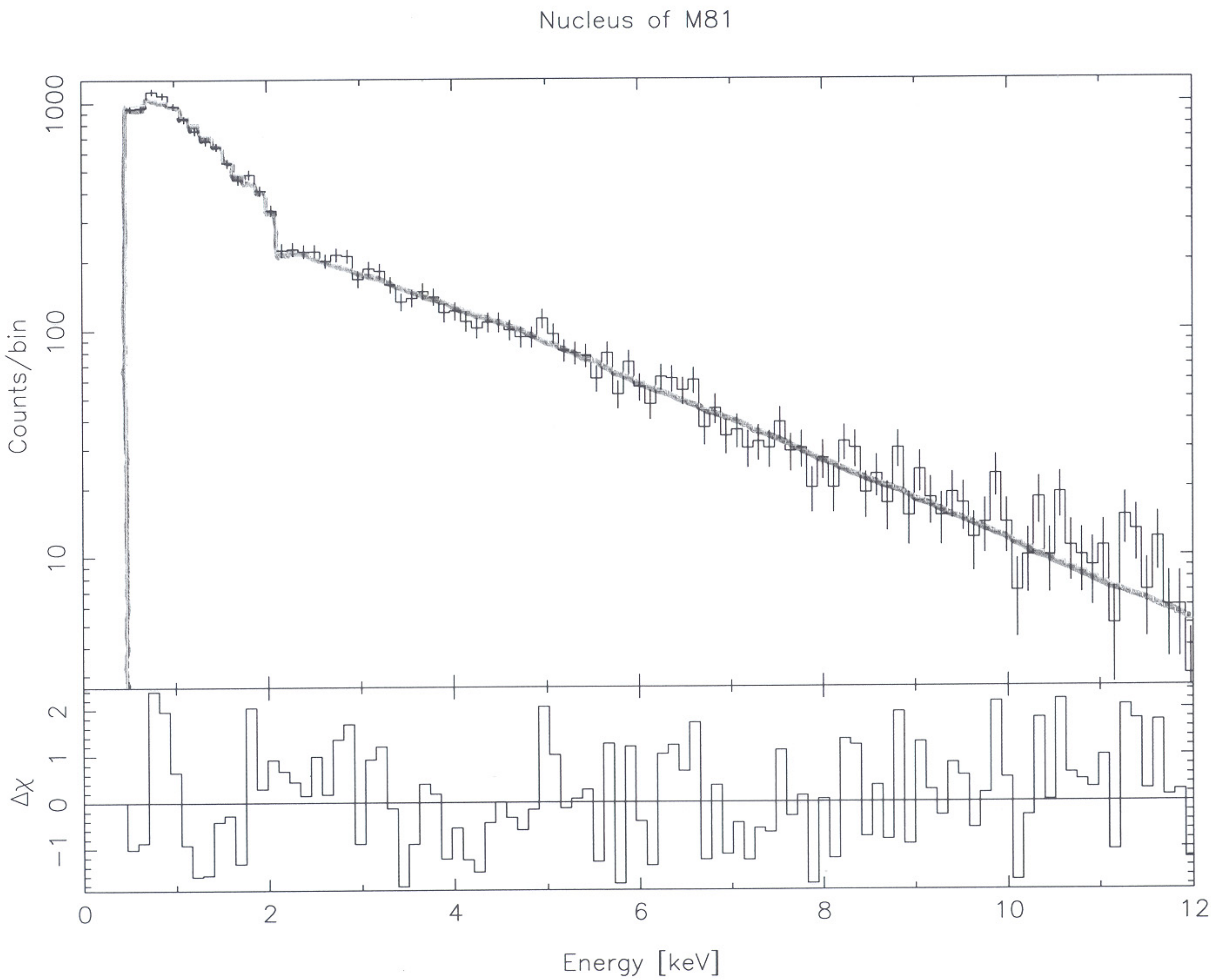
NGC 4579
Counts/bin
1000
100
10
Δχ
2
0
−2
0
2
4
6
8
10
12
Energy [keV]


NGC 4579
Eracleous et al
ApJ 565, 108 (2002)
Spectral Index
1.5
1.6
1.7
1.8
1.9
0.01
0.02
0.03
0.04
0.05
0.06
n_H [10^{22} cm^{-2}]

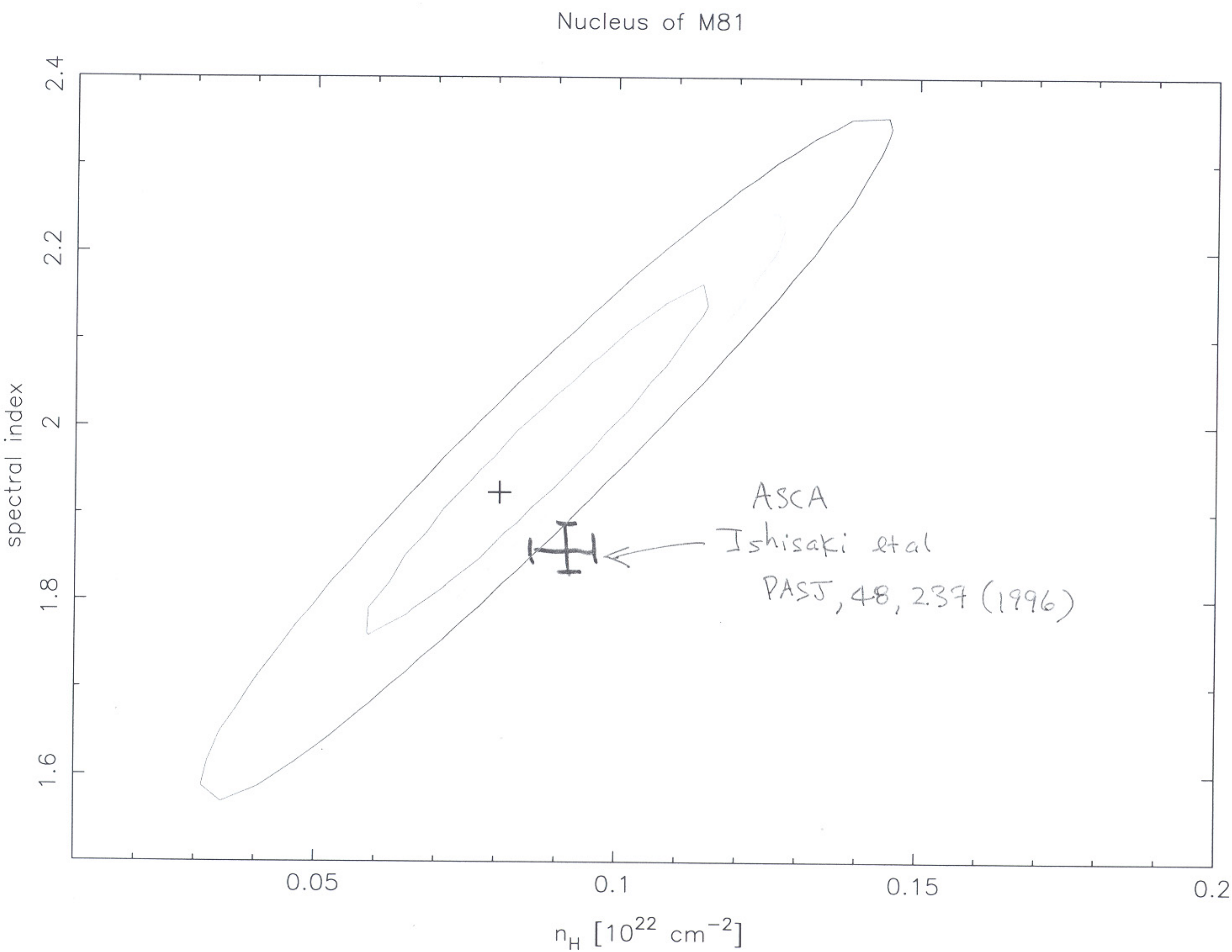

SAOImage ds9
File
Edit
Frame
Bin
Zoom
Scale
Color
Region
Analysis
Help
File
conf.fits
Value
WCS
Physical
X
Y
Image
X
Y
Frame1
Zoom
8.000
Ang
270.000
File
Edit
Frame
Bin
Zoom
Scale
Color
Region
invert
grey
red
green
blue
a
b
bb
he
i8
cmap

Nucleus of M81

```
isis> fit_counts;

 Parameters[Variable] = 7[5]
            Data bins = 99
           Chi-square = 120.8
   Reduced chi-square = 1.285

isis> list_par;

phabs(1)*powerlaw(1)
 idx  param                 tie-to  freeze        value         min        max
  1  phabs(1).nH                0     0       0.08063485          0          1
  2  powerlaw(1).norm           0     0      0.006880267          0        0.1
  3  powerlaw(1).PhoIndex       0     0          1.92351          0          3
  4  pileup<1>.nregions         0     1                3          1         10
  5  pileup<1>.g0               0     1                1          0          1
  6  pileup<1>.alpha            0     0        0.4810092          0          1
  7  pileup<1>.psffrac          0     0        0.9578905          0          1

isis> print_kernel(1);

 1: 0.0241037     0.207965
 2: 0.0652543     0.270813
 3: 0.117772      0.235102
 4: 0.159419      0.153076
 5: 0.172633      0.0797342
 6: 0.155786      0.03461
 7: 0.1205        0.0128769
 8: 0.0815551     0.0041921
 9: 0.0490641     0.0012131
 10: 0.0265656    0.000315941
 11: 0.0130762    7.48036e-05
 12: 0.00590006   1.62349e-05
 13: 0.00245736   1.04828e-05
 *** pileup fraction: 0.792035

isis> rplot_counts(1);
```



Nucleus of M81
Counts/bin
1000
100
10
Δχ
2
1
0
−1
0
2
4
6
8
10
12
Energy [keV]



Nucleus of M81
spectral index
2.4
2.2
2
1.8
1.6
0.05
0.1
0.15
0.2
n_H [10^{22} cm^{-2}]
ASCA
Ishisaki etal
PASJ, 48, 237 (1996)

Summary

- Pileup model seems to work well

- Use level 1 files and **keep** afterglow events

Future:

Still need to investigate:

line dominated spectra

XMM data

Grating pileup correction is being tested http://space.mit.edu/cxc/isis/features.html

Version 1.0.8
[cite]

Main Page
>Features
Examples
Mailing List
Download
Manual

Chandra Science

MIT

ISIS Features

Using ISIS, you can:

- Efficiently generate multi-component spectral models using the APEC spectroscopy database for collisionally ionized plasmas.
- Examine ionization balance tables plus data on individual emission lines and continua.
- Use new ISIS functionality with familiar XSPEC models. **All XSPEC additive and multiplicative models are available, including table models**.
- Analyze data formatted as ASCII files or FITS Type I or Type II PHA files.
- Read arbitrary FITS files and columnar ASCII tables.
- **Rebin your data interactively**, with direct control over how uncertainties are propagated.
- Fit spectral models to your data either directly, or by folding models through the instrument response.
- Generate fake data for Monte-Carlo analysis of model uncertainties and for proposal planning.
- Analyze **piled-up CCD spectra** using the model developed by John Davis (MIT).
- Do **multi-order spectral analysis** (e.g. using the Chandra/LETGS) by assigning multiple instrument responses to a single dataset.
- Fit multiple data sets simultaneously, including an optional instrumental background component.
- Define fit-parameters as arbitrary functions of other fit-parameters (including inequality constraints).
- Compute single-parameter confidence limits
- Generate **confidence contour maps**; save and re-read as FITS images; plot and **overplot contours**.
- Fit **user-defined models** coded in S-Lang or C.
- Apply user-defined fit-statistics coded in S-Lang or C.
- Apply user-defined fit-methods coded in C.
- Apply user-defined RMFs defined in software (rather than as a FITS file)

Future Releases:

Please feel free to submit comments and suggestions for new ISIS features to the ISIS mailing list.

Last updated: Apr 11, 2002
This page is maintained by John C. Houck. To comment on it or the material presented here, send email to houck@space.mit.edu.