Grating Threads

Threads need to be "turn key" - very detailed explanations without assuming *any* prior knowledge.

Proposal threads: encourage new users. These must include "starting the software" and end with "fill in the RPS fields".

Analysis threads: help existing users, based on tricky situations we've encountered, or which we've become aware of through the help-desk.

New proposal planning threads:

- He-triplet simulation and fitting
- LETG/HRC-S multi-order + background modeling and fitting.

New analysis thread:

- LETG/HRC-S crowded field: using `tgextract2` on 2 close sources.

He-triplet simulation and fitting:

Simulate the High Energy Transmission Grating Spectrum of a Coronally Active Star and Measure Line Fluxes and Ratios.

Thread Overview

This thread simulates an observation with the High Energy Transmission Grating Spectrometer (HETGS) of a stellar coronal plasma, then measures lines in the region of the astrophysically interesting Ne IX triplet at 13 A. The simulations are based on the Chandra/HETGS observations of the coronally active binary system, UX Ari (obsid 605). The Ne IX triplet lines are density sensitive in a regime important for coronal plasmas, with a critical density of log(n_e) ~ 11.

The thread shows how to determine single-parameter confidence limits in the flux and also computes count-rates and signal-to-noise ratios for the features. The density sensitive ratio of the forbidden to intercombination line fluxes is evaluated, along with its uncertainty.

This thread is written as an ISIS script, using Cycle 10 responses & APED.

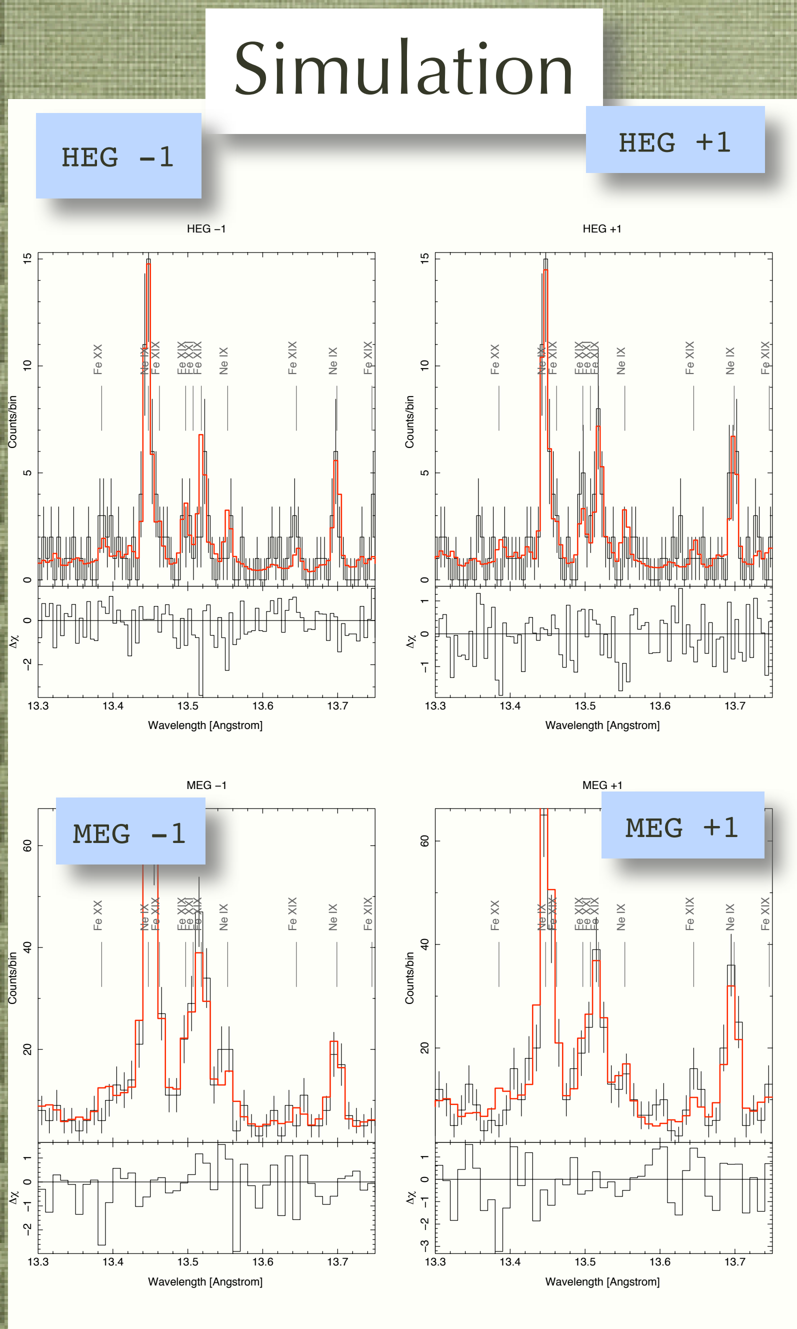
He-triplet simulation and fitting (continued)

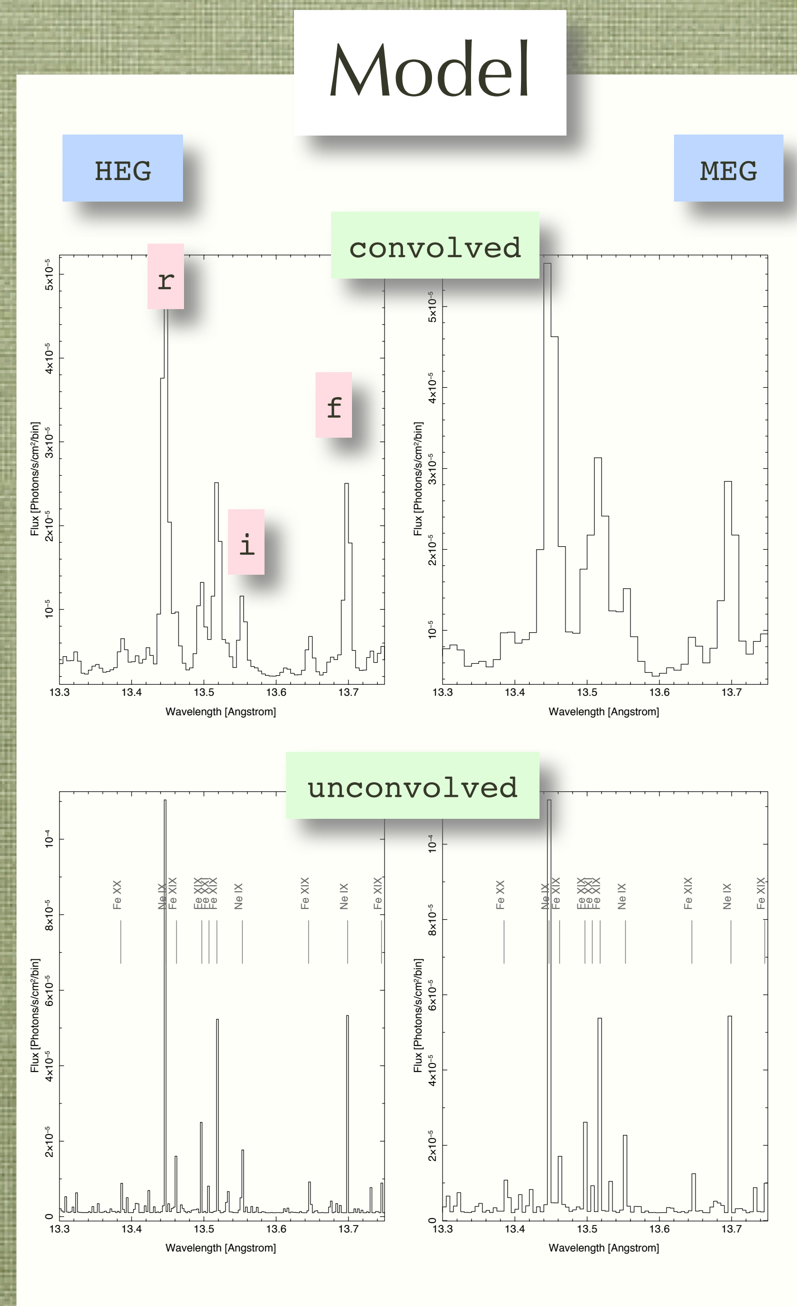
Thread contents:

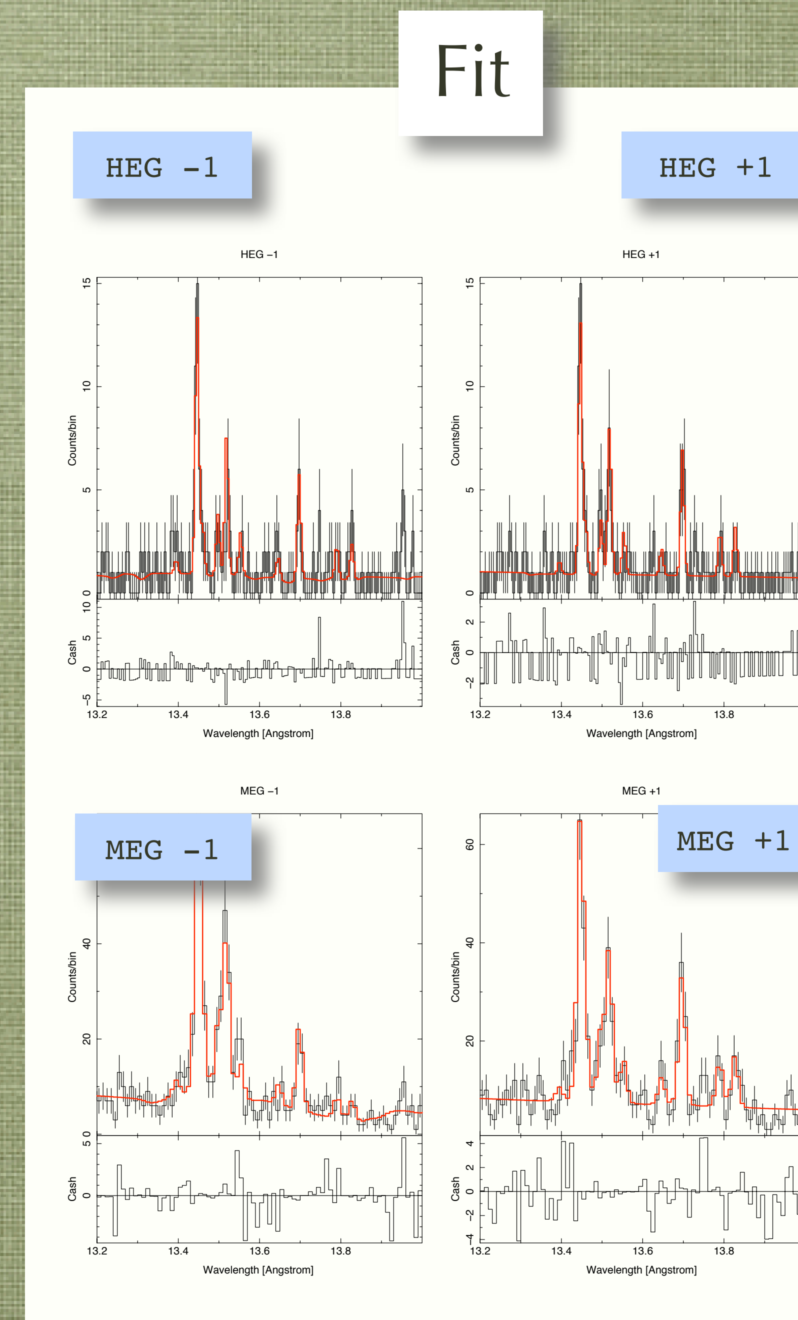
- Preliminary considerations (software setup, required data)
- Running the script
- Load responses, set the exposure, assign responses
- Define a source model and set its parameters; adjust normalization for desired flux
- Simulate the counts and inspect
- Fit features with sum of Gaussians and polynomial continuum
- Determine confidences and signal-to-noise ratios
- Compute the density sensitive *f/i* ratio for Ne IX
- Compute zero order and background rates for RPS forms
- Complete Target Form
- Description of output files
- Further resources

He-triplet simulation and fitting (continued)

Graphical Output







He-triplet simulation and fitting (continued)

Tabular output

Model lines, for defining the multi-Gaussian model and constraining the fit parameters

# index	ion	lambda	F (ph/cm^2/s)	A(s^-1)	upper	low
78070 *	Fe XX	13.385	1.049e-05	8.013e+12	111	
3948 *	Ne IX	13.447	1.478e-04	8.867e+12	7	
38603 *	Fe XIX	13.462	1.797e-05	1.414e+13	74	
38915 *	Fe XIX	13.497	3.154e-05	1.292e+13	71	
129758 *	Fe XXI	13.507	9.535e-06	1.605e+12	42	
39128 *	Fe XIX	13.518	6.952e-05	1.868e+13	68	
3946 *	Ne IX	13.553	2.104e-05	6.500e+09	5	
39124 *	Fe XIX	13.645	1.114e-05	2.432e+12	57	
3944 *	Ne IX	13.699	7.162e-05	1.087e+04	2	
39135 *	Fe XIX	13.746	1.084e-05	6.859e+12	76	

Counts and rates for feasibility and proposal forms

```
HEG:         0.237 cts/s
MEG:         0.586 cts/s
Total:       0.824 cts/s

 wavefit     wave flux [phot/cm^2/s] (68%)           [ergs/cm^2/s]  S/N
  13.395   13.385 7.32e-06 (3.66e-06,1.16e-05)      1.09e-14     1.9
  13.447   13.447 1.36e-04 (1.23e-04,1.47e-04)      2.01e-13    11.5
  13.460   13.462 2.66e-05 (1.94e-05,3.69e-05)      3.93e-14     3.0
  13.498   13.497 3.39e-05 (2.80e-05,4.04e-05)      4.99e-14     5.5
  13.519   13.518 7.87e-05 (7.14e-05,8.67e-05)      1.16e-13    10.3
  13.553   13.553 2.30e-05 (1.79e-05,2.84e-05)      3.37e-14     4.4
  13.646   13.645 1.50e-05 (1.03e-05,2.01e-05)      2.18e-14     3.0
  13.698   13.699 7.17e-05 (6.40e-05,7.99e-05)      1.04e-13     9.0
  13.790   13.795 2.76e-05 (2.18e-05,3.41e-05)      3.97e-14     4.5
  13.827   13.825 2.98e-05 (2.35e-05,3.67e-05)      4.29e-14     4.5
 contin/A 8.78e-04 (8.47e-04,9.08e-04)     1.30e-12

  wave    HEG cts/s   MEG cts/s
  13.395  4.28e-05 1.84e-04
  13.447  7.74e-04 3.36e-03
  13.460  1.50e-04 6.56e-04
  13.498  1.77e-04 8.25e-04
  13.519  4.40e-04 1.87e-03
  13.553  1.30e-04 5.03e-04
  13.646  7.34e-05 3.04e-04
  13.698  3.53e-04 1.32e-03
  13.790  1.26e-04 4.36e-04
  13.827  1.33e-04 4.42e-04

HEG, MEG contin cts/s/A
4.61e-03  1.88e-02

 Ne IX f/i = 3.12 ( 0.80 )

ZO rate =    0.755 [cts/s]
piled ZO rate =    0.172 [cts/s]

Background rate =    47.00 [cts/s]
```

LETG/HRC-S Simulation and Fitting

LETGS Orders: Modeling and Assessment of Higher Spectral Orders in LETG/HRC-S Spectra.

Thread Overview

This thread uses observations made with the Low Energy Transmission Grating Spectrometer (LETGS) to show how to assess and model higher spectral order contributions. We do this for two cases, Markarian 421, a strong continuum source, and Capella, an emission-line dominated source. We also show how to manipulate the background contribution.

After working with the observed data, we then adjust model parameters to create a simulated dataset for a fainter source such as may be done for proposal planning purposes. We fit models to the fake data to determine parameter values and confidence limits which may be of interest for scientific justification. We also derive some values which are useful for feasibility and for entry on the proposal target summary forms.

LETGS data are tricky to simulate due to multiple overlapping orders and significant background. Neither back-of-the-envelope calculations nor PIMMS is sufficient. This thread is also written as an ISIS script.

LETG/HRC-S Simulation and Fitting (continued)

Thread contents:

Multi-Order Analysis of a Continuum Dominated Spectrum:

- Preliminary considerations (software, data)
- Running this script
- Load the data, responses, and background, and assign them.
- Define a model and fit it.
- Evaluate the fractional contribution of first order, excluding background.
- Simulate and fit data for proposal planning
- Compute rates for proposal forms

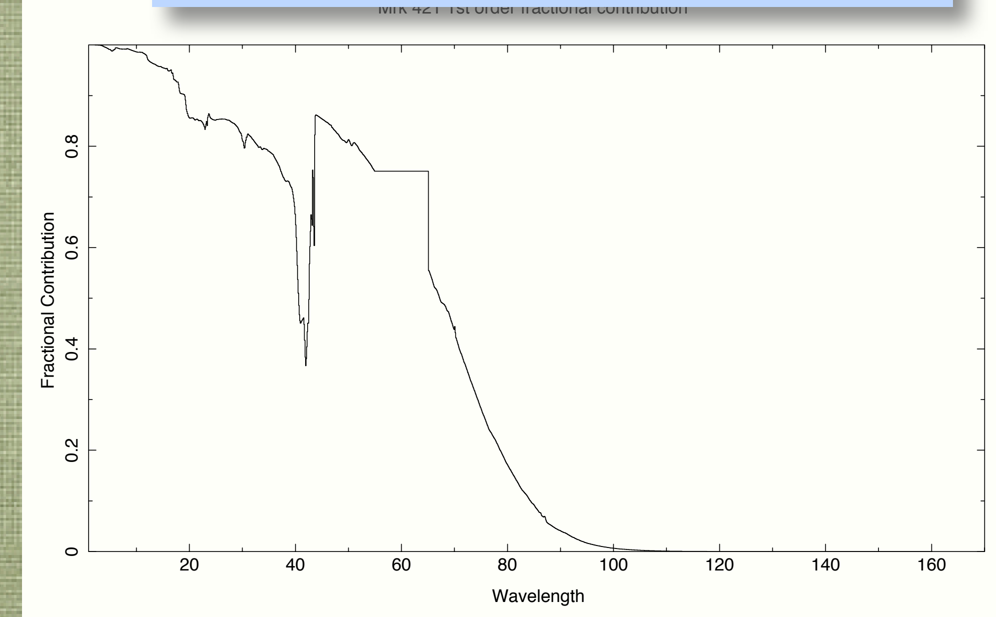
Multi-Order Analysis of an Emission Line Spectrum:

- Define a model
- Fit the spectrum
- Evaluate the fractional contribution of first order.
- Contamination assessment, order-by-order view:
- Simulate and fit for new model parameters and exposure
- Compute rates for proposal forms

LETG/HRC-S Simulation and Fitting (continued)

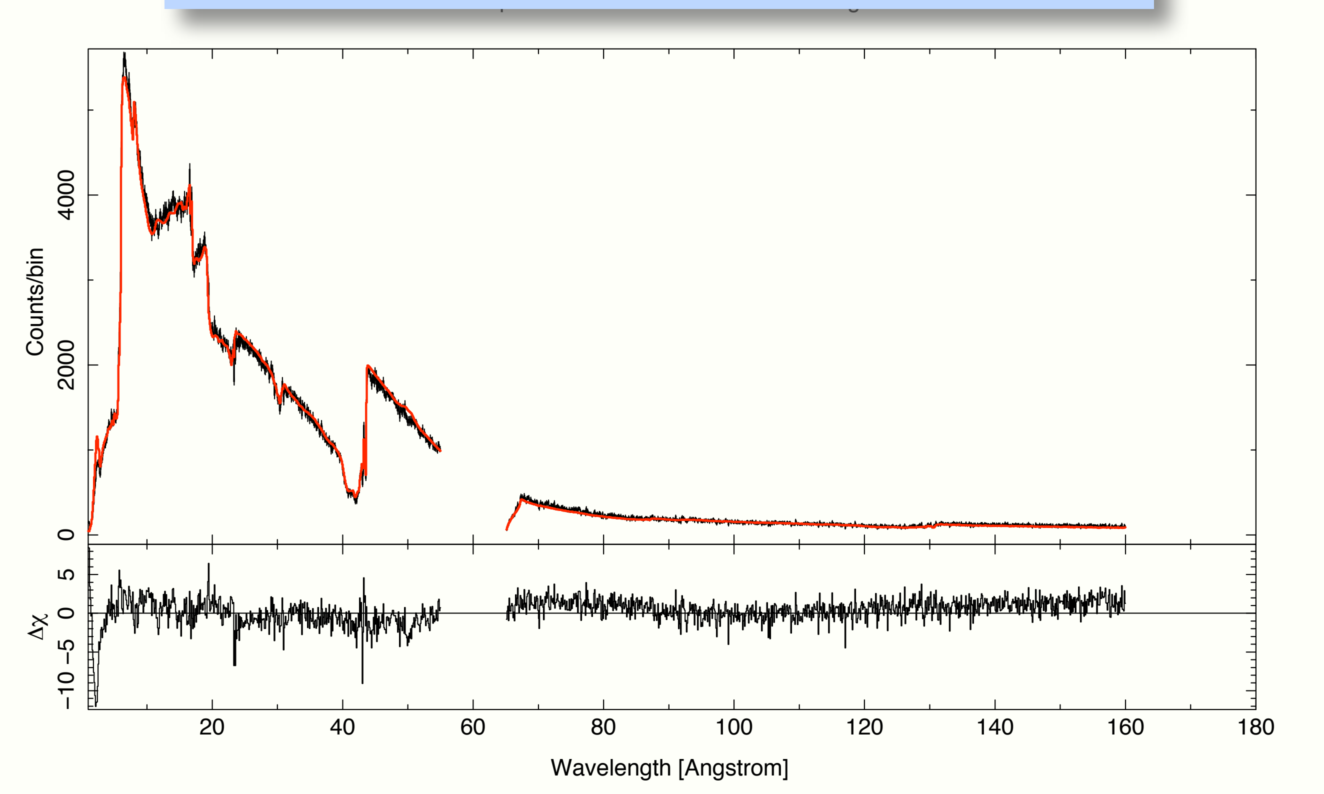
Multi-Order Analysis of a Continuum Dominated Spectrum:

First order's fractional contribution

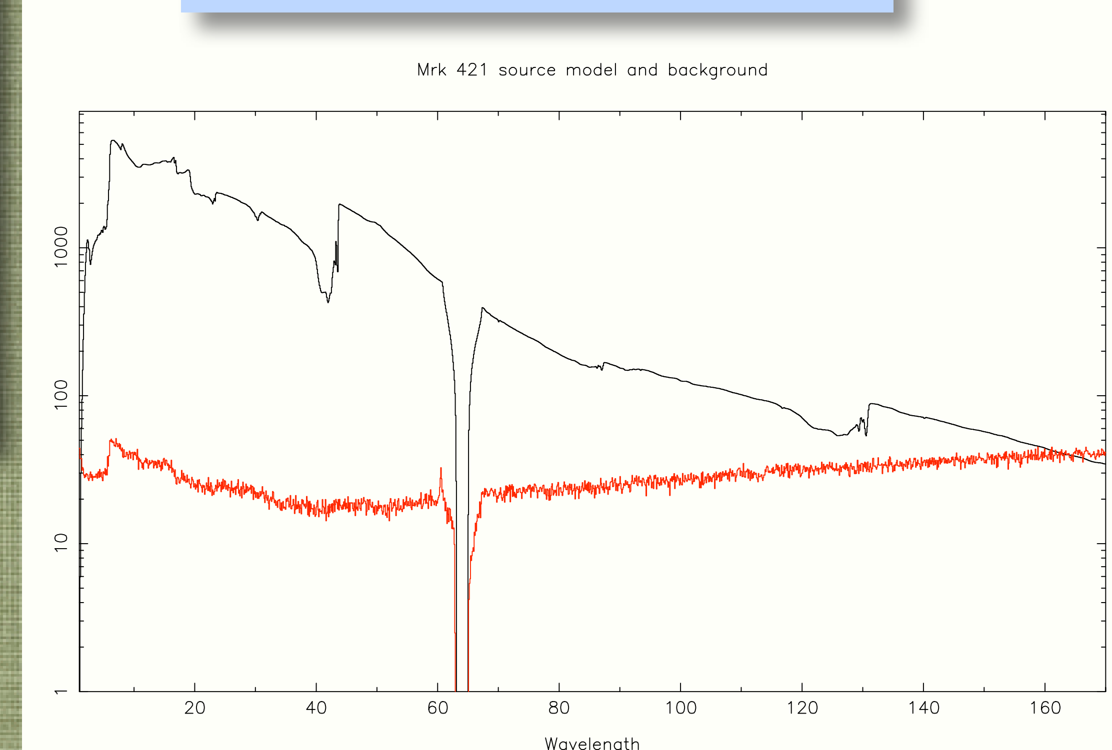


Graphical Output

Absorbed powerlaw fit using 8 orders.



Background contribution



LETG/HRC-S Simulation and Fitting (continued)

Multi-Order Analysis of a Continuum Dominated Spectrum:

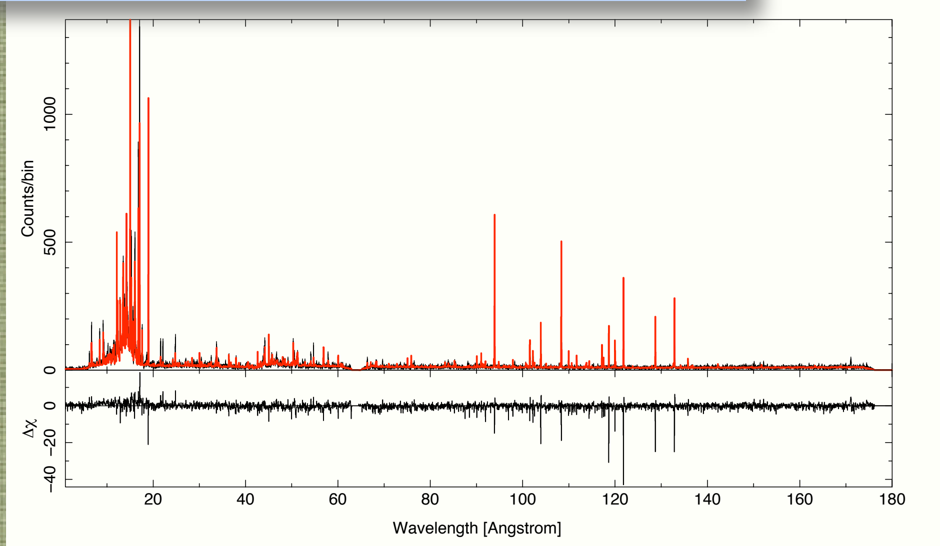
Text Output - for fit to simulated data with a reduced flux value:

```
wabs(1)*Powerlaw(1)
 idx  param           tie-to  freeze        value         min          max
  1  wabs(1).nH            0      0      0.1174182        0.01            2  10^22
  2  Powerlaw(1).norm    0      0     0.01849913       0.001            1
  3  Powerlaw(1).alpha   0      0      -2.106785          -3            0

wabs(1).nH = 0.117  (0.110, 0.125)(90%)
Powerlaw(1).norm = 1.85e-02  (1.80e-02, 1.90e-02)(90%)
Powerlaw(1).alpha = -2.11  (-2.15, -2.06)(90%)

Source dispersed count-rate = 7.307e-01 cps

Approximate zero-order count-rate ~ 3.65e-01 cps
Approximate full-field count-rate ~ 60 cps

Field rate ~ 6.157e+01 cps
Ratio of zo to dispersed rates = 0.64
```

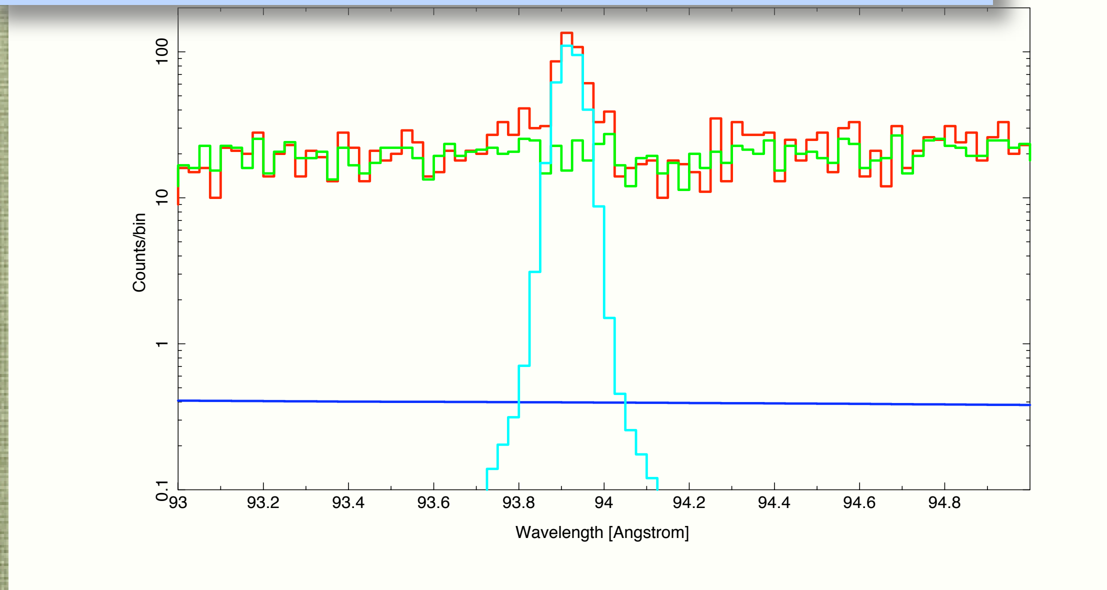
LETG/HRC-S Simulation and Fitting (continued)

Multi-Order Analysis of an Emission Line Spectrum: Graphical Output

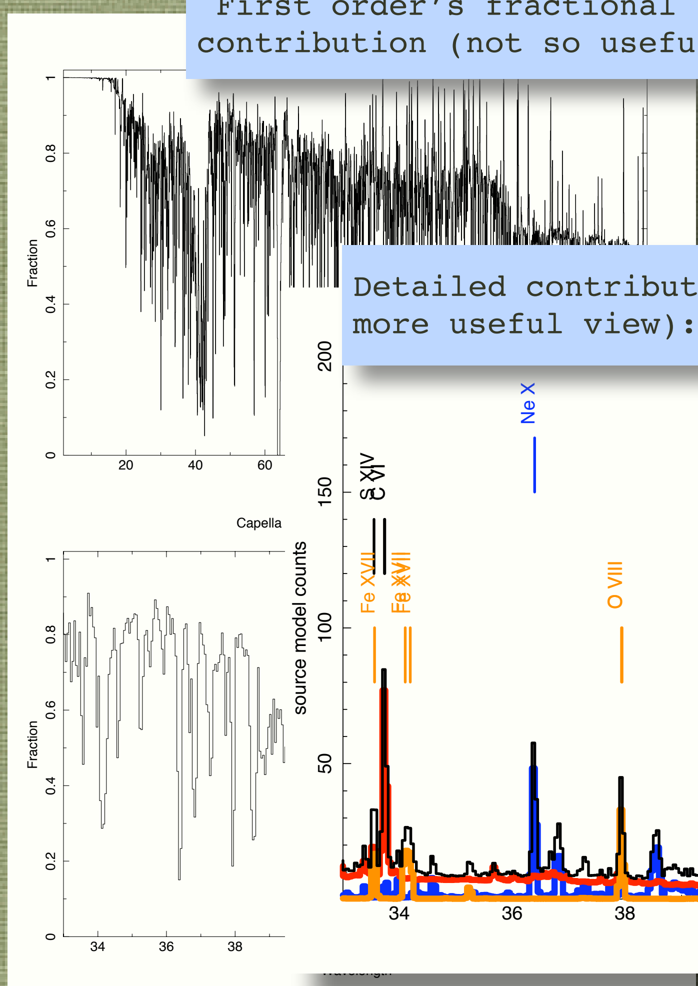
Simulated isothermal spectrum and a (poor) global fit.



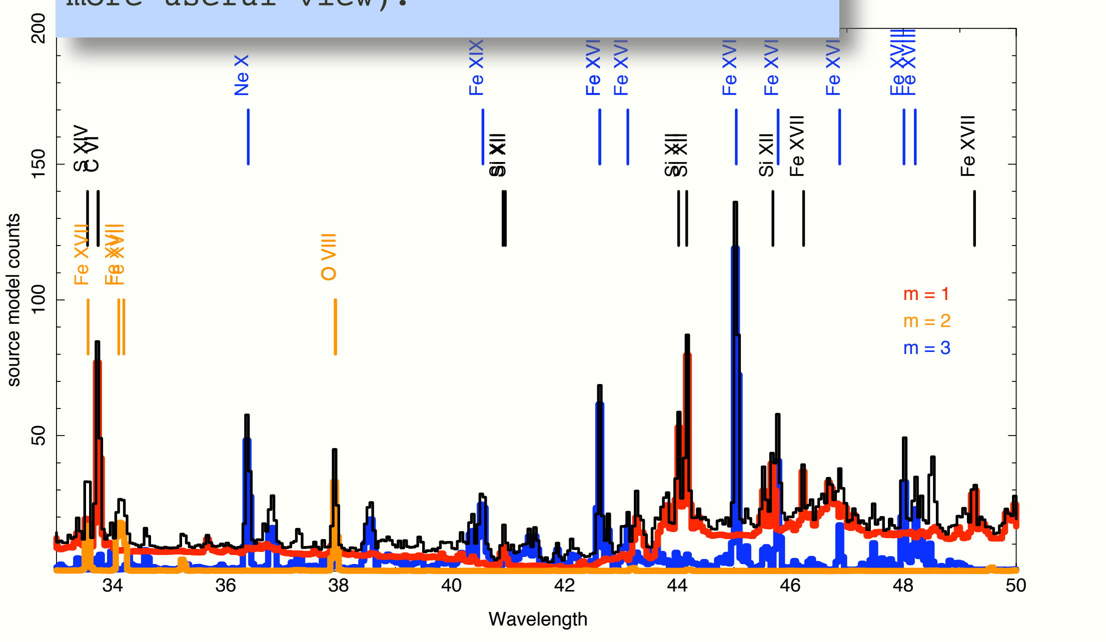
Parametric (gaussian+polynomial) fit to a line.



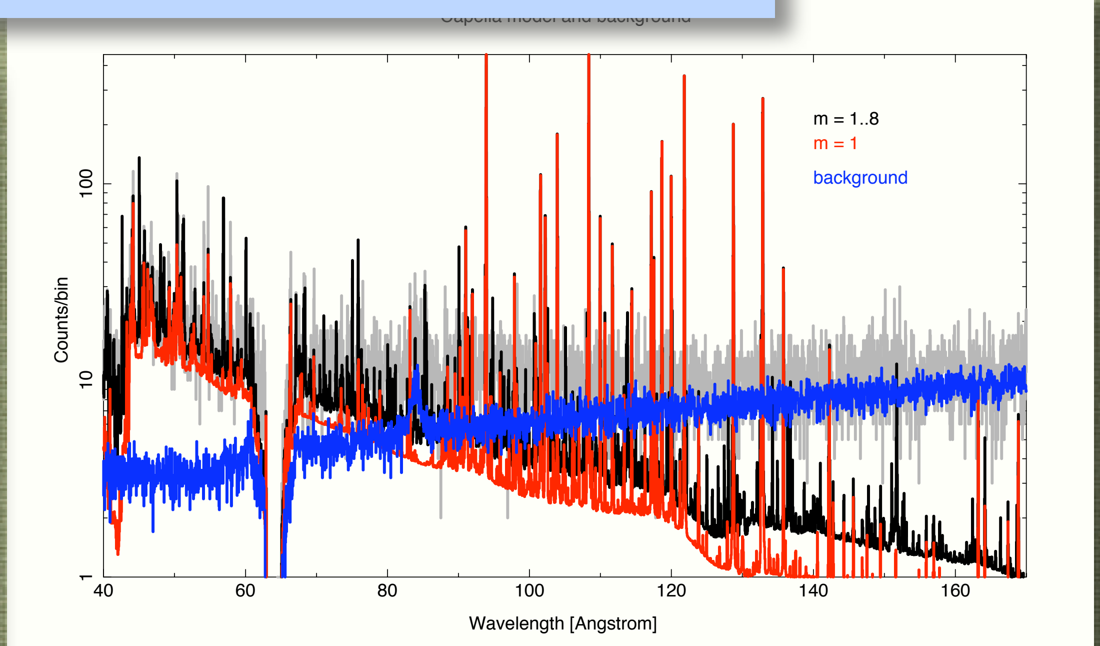
First order's fractional contribution (not so useful here)



Detailed contribution for 3 orders (a more useful view):



Order & Background assessment



LETG/HRC-S Simulation and Fitting (continued)

Multi-Order Analysis of an Emission Line Spectrum:

Text Output - for fit to an emission line:

```
gauss(1) + poly(1)
 idx  param         tie-to  freeze          value         min          max
  1  gauss(1).area      0      0      0.0004288858       1e-08         0.01  photons/s/cm^2
  2  gauss(1).center    0      0          93.92177        93.7           94  A
  3  gauss(1).sigma     0      0        0.01331952       1e-08          0.1  A
  4  poly(1).a0         0      0      2.169621e-05       1e-08          0.1
  5  poly(1).a1         0      1                 0           0            0
  6  poly(1).a2         0      1                 0           0            0

gauss(1).area = 4.443e-04  (3.749e-04, 4.802e-04)(90%)
gauss(1).center = 93.9218  (93.9178, 93.9262)(90%)
gauss(1).sigma = 1.322e-02  (2.000e-03, 2.098e-02)(90%)
poly(1).a0 = 4.338e-05  (2.170e-05, 6.170e-05)(90%)

Line rate = 3.611e-03 [cps]
Background rate = 6.142e-04 [cps]
Source count rate, positive and negative orders = 1.549e+00
Zero order rate ~ 7.745e-01

Field rate ~ 5.647e+01 cps
Ratio of zo to dispersed rates = 0.39
```

Analysis Thread

Using `tgextract2` on an LETG/HRC-S double source

Thread overview:

This thread demonstrates the use of `tgextract2` to apply customized background regions to an LETG/HRC-S observation of a field with two close, bright sources. With LETGS, it is important to include backgrounds in the analysis since the HRC-S instrumental background is significant. For the observation in this demonstration, ObsID 29 (α Cen), each source falls into one of the default background regions for the other. The sources themselves are far enough apart that their spectra can be extracted cleanly.

`Tgextract2` is an alternative to `tgextract`, the CIAO program which filters and bins spectra. `Tgextract2` provides support for variable shaped background regions which do not need to have a constant width ratio with the source region. `Tgextract2` computes a vector "backscale" - the scaling factor which relates the background count rate at any wavelength to the source extraction region width at that wavelength. `Tgextract2` also sums the background extractions from each side of the spectrum, whereas `tgextract` write two counts arrays, one from the "_UP" and one from the "_DOWN" sides of the spectrum.

Using tgextract2 (continued)

Thread contents:

1. Visualize the field in grating angular dispersion coordinates;
2. Overlay the default source and background regions;
3. Adjust the region and inspect it;
4. Write the new region to a FITS region file;
5. **Execute `tgextract2` to produce new spectral ("pha2") files;**
6. **Use `dmcopy` to split the source and background counts into separate "Type I PHA" files (single spectra, column oriented).**
7. Demonstrate use of the source and background spectra in analysis.

Thread methods:

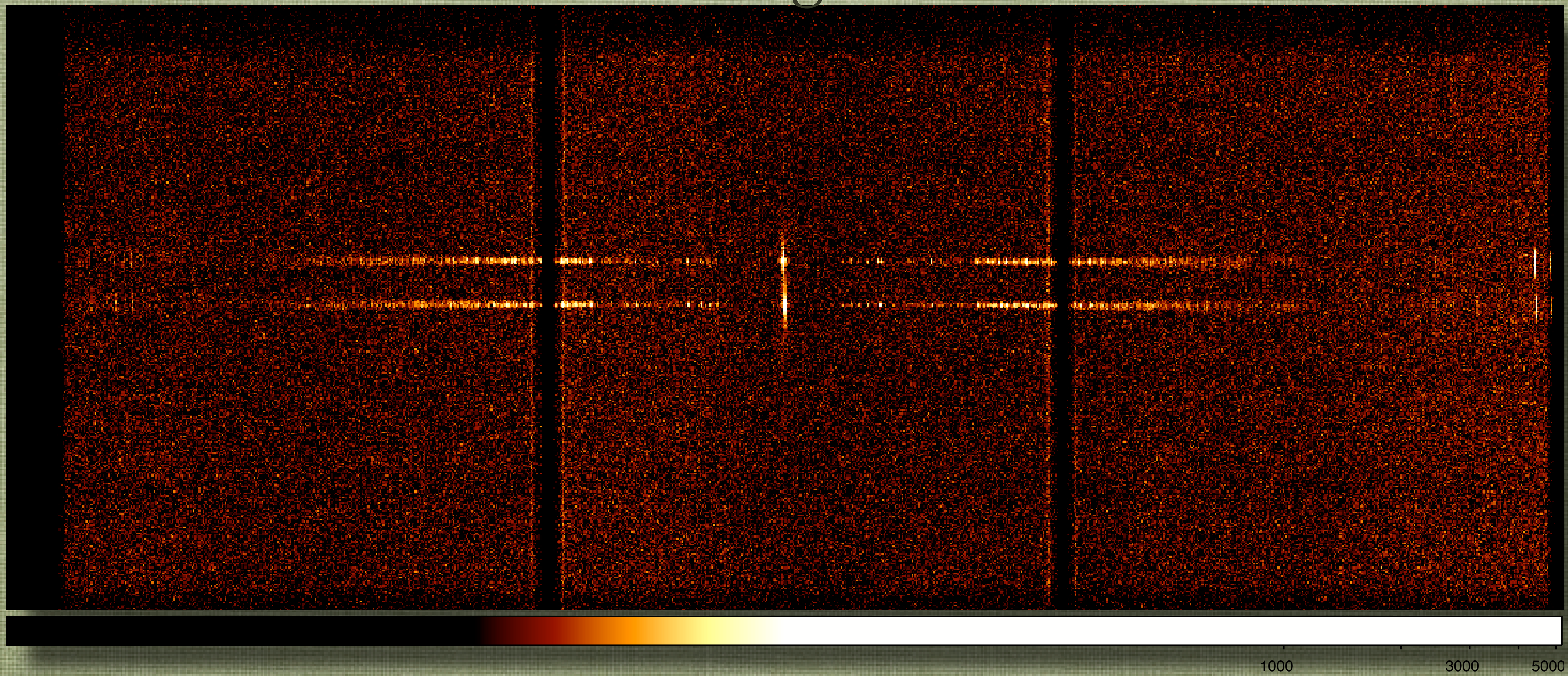
Steps 5 and 6 are the substance of the example. These produce the files that can be used in X-ray spectral analysis systems, such as ISIS, Sherpa, or XSPEC. They are standard CIAO tool operations.

There are many ways to handle the other steps. Here we will work in S-Lang using the `ds9/xpa` module to control `ds9`, use the `cfitsio` module for reading and writing FITS region tables, and we will use ISIS as a platform, since it includes the `cfitsio` module by default, and since it can also be used to validate the products with spectral analysis.

The `ds9` steps can be done manually using the `ds9` menus. Comments in the script indicate which menu and item to choose.

Using tgextract2 (continued)

The LETG/HRC-S image of the α Cen field.

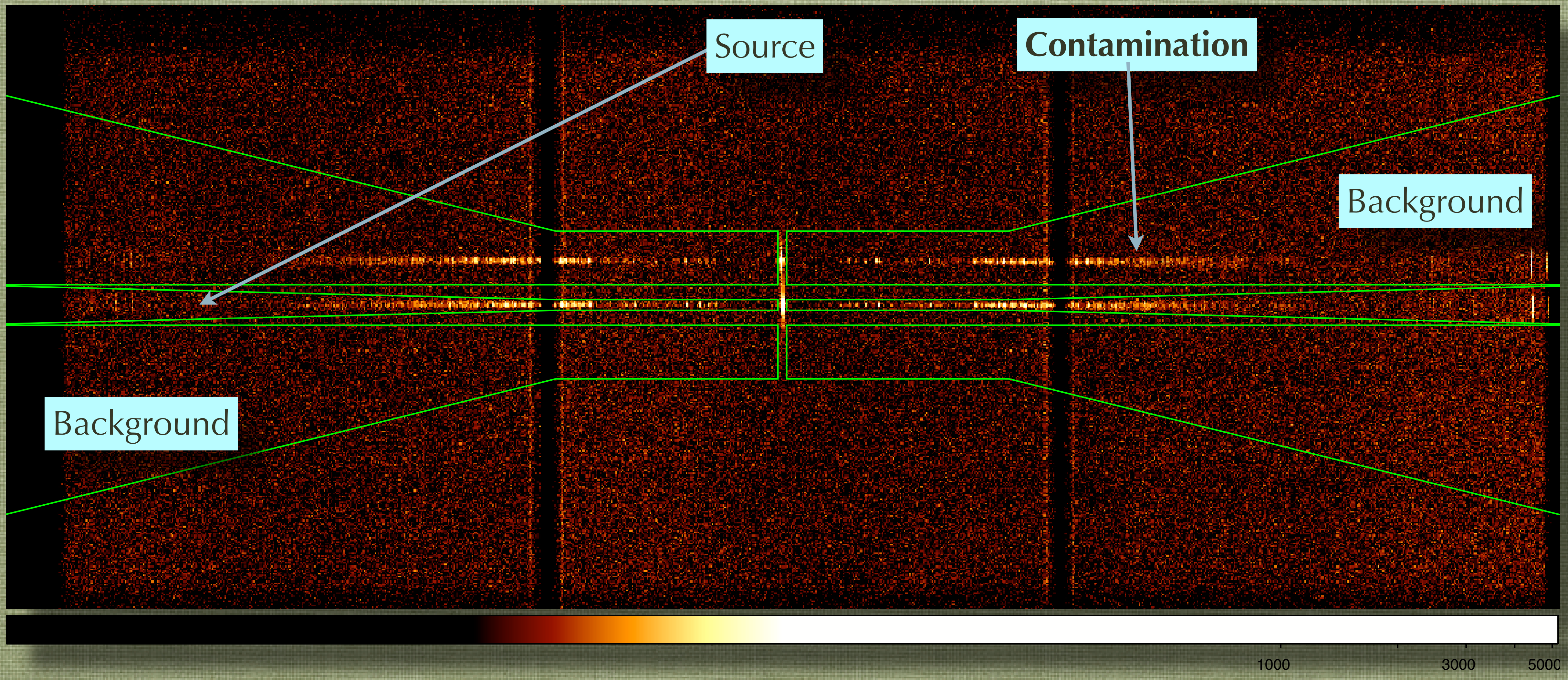



```
ds1 = ds9_new(); % Start a new ds9 session.

% Set the height and width, scale, colormap, and intensity table:
ds1.send("height 400");    % ds9 menu:  Frame -> Set Display Size
ds1.send("width 1024");    % ds9 menu:  Frame -> Set Display Size
ds1.send( "scale log" ) ; % ds9 menu:  Scale -> Log
ds1.send( "cmap bb" ) ;    % ds9 menu:  Color -> BB
ds1.send( "cmap value 5 0.4");  % ds9 menu: Color -> Colormap Parameters

% Load the data, then set the binning parameters:

ds1.send( "file hrcf00029N005_evt2.fits.gz");  % ds9 menu: File -> Open
ds1.send("bin cols tg_r tg_d");            % ds9 menu: Bin -> Binning Parameters
ds1.send("bin factor 0.002 0.00015");      % ds9 menu: Bin -> Binning Parameters
ds1.send("bin about 0.0 0.0");             % ds9 menu: Bin -> Binning Parameters
```

An aside: this is how to make the image above in `ds9` *without touching a mouse.*

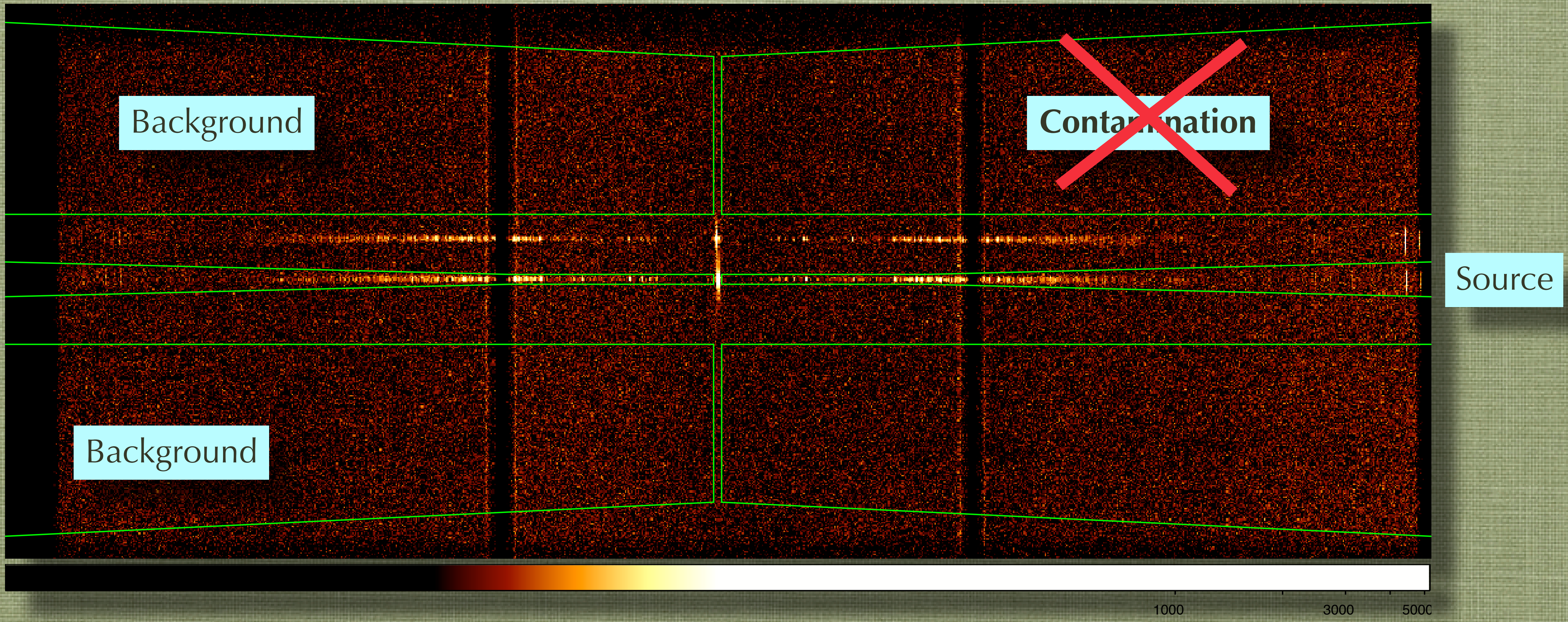
Using tgextract2 (continued)

The problem: for the default regions, the upper source falls in the lower source's background region.



Using tgextract2 (continued)

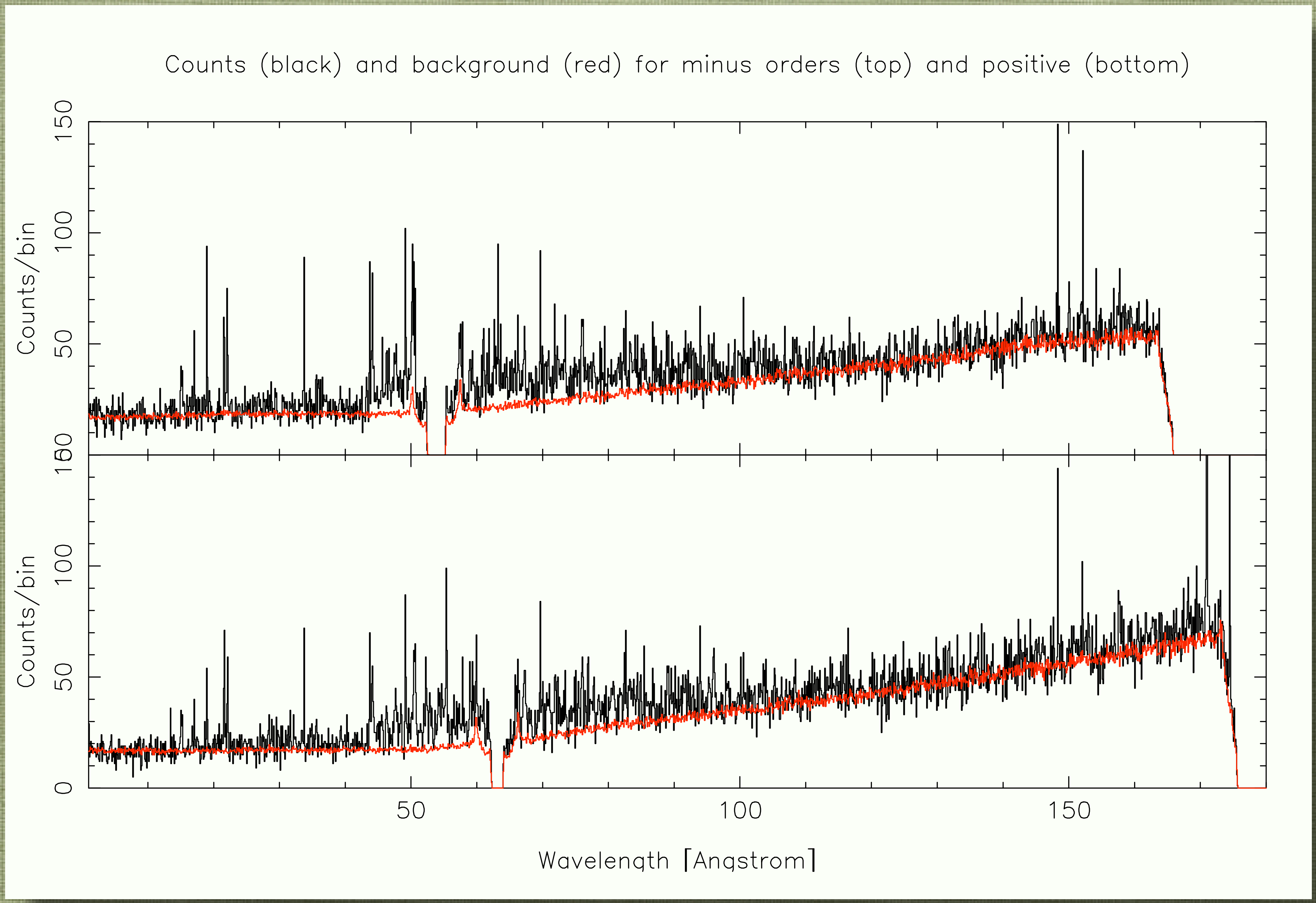
The solution: modify the background regions. Write to a FITS region file, then run `tgextract2`.



Note: regions need not have uniform widths or a constant ratio of source to background widths with wavelength; `tgextract2` will compute a variable backscale.

Using tgextract2 (continued)

The result: correct source and background spectra.



Future Proposal Threads

Proposal Planning - **Absorption lines in AGN**, observed with HETG & LETG/ACIS-S

- Absorption lines are different than emission - the latter can go to infinity the former only to 0.
- Statistical issues of significance at a known location, vs. blind searches need to be discussed in this thread.
- AGNs are potentially faint sources, so this would be an appropriate thread for discussion of, e.g., fitting gratings spectra using Cash statistics.

New Analysis Utility

He-like Line Emissivity Modifier: ISIS/APED density dependent emissivities

The He-like triplet lines which occur in the X-ray band from 5-42A are powerful diagnostics of density or photoexcitation. The APED (Astrophysical Plasma Emission Database), however, only contains emissivities for low density. To use triplet lines as a density diagnostic, one method is to fit the line strengths and from the ratio of the forbidden to intercombination line fluxes (*f/i*), then look up the implied density from external sources. To provide better support for more direct fitting and modeling, we have

- made very general modifications to ISIS to provide APED-emissivity modifiers;
- constructed a database of emissivity modifier coefficients (by fitting APEC output) which parameterize the density dependence;
- written an ISIS model to implement the modifier via the coefficients table.

Further details can be found at:
http://space.mit.edu/cxc/analysis/hemodifier/index.html