Using ISIS as an interactive, scriptable AtomDB browser, calculator, & spectral modeler.

"ISIS, the Interactive Spectral Interpretation System, is designed to facilitate the interpretation and analysis of high resolution X-ray spectra. It is being developed as a programmable, interactive tool for studying the physics of X-ray spectrum formation, supporting measurement and *identification of spectral features*, and *interaction with a database of atomic structure parameters and plasma emission models*."

Main web page: **<http://space.mit.edu/cxc/isis>**

Reference: Houck & deNicola (2000)

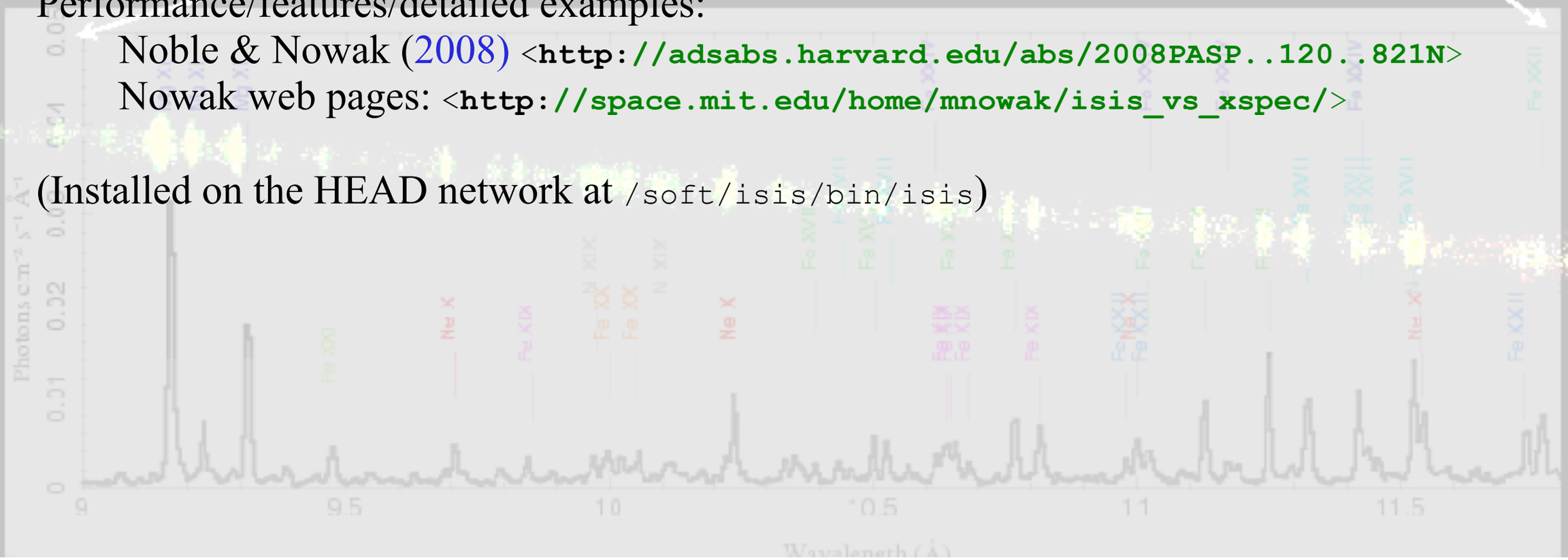
<http://adsabs.harvard.edu/abs/2000ASPC..216..591H>

Performance/features/detailed examples:

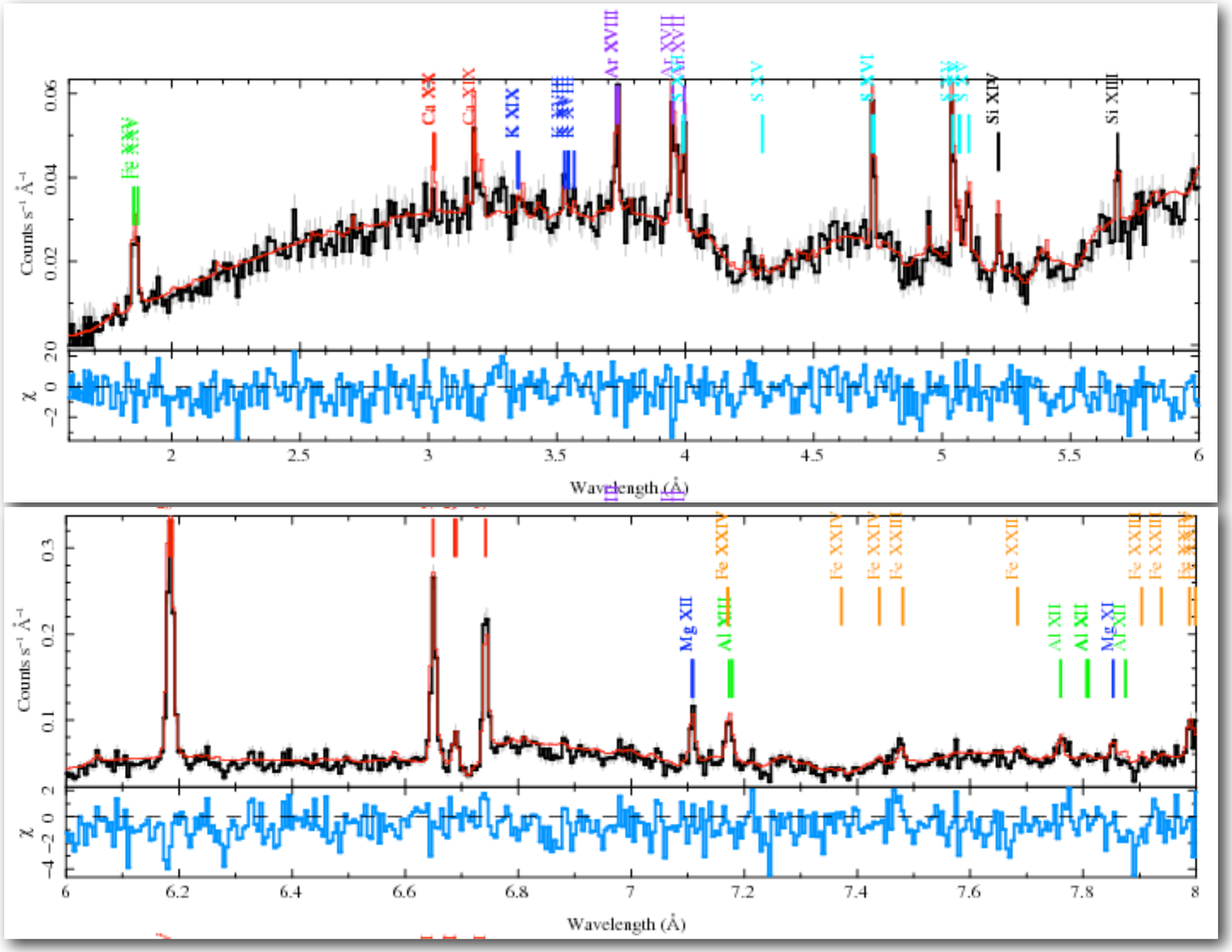
Noble & Nowak (2008) **<http://adsabs.harvard.edu/abs/2008PASP..120..821N>**

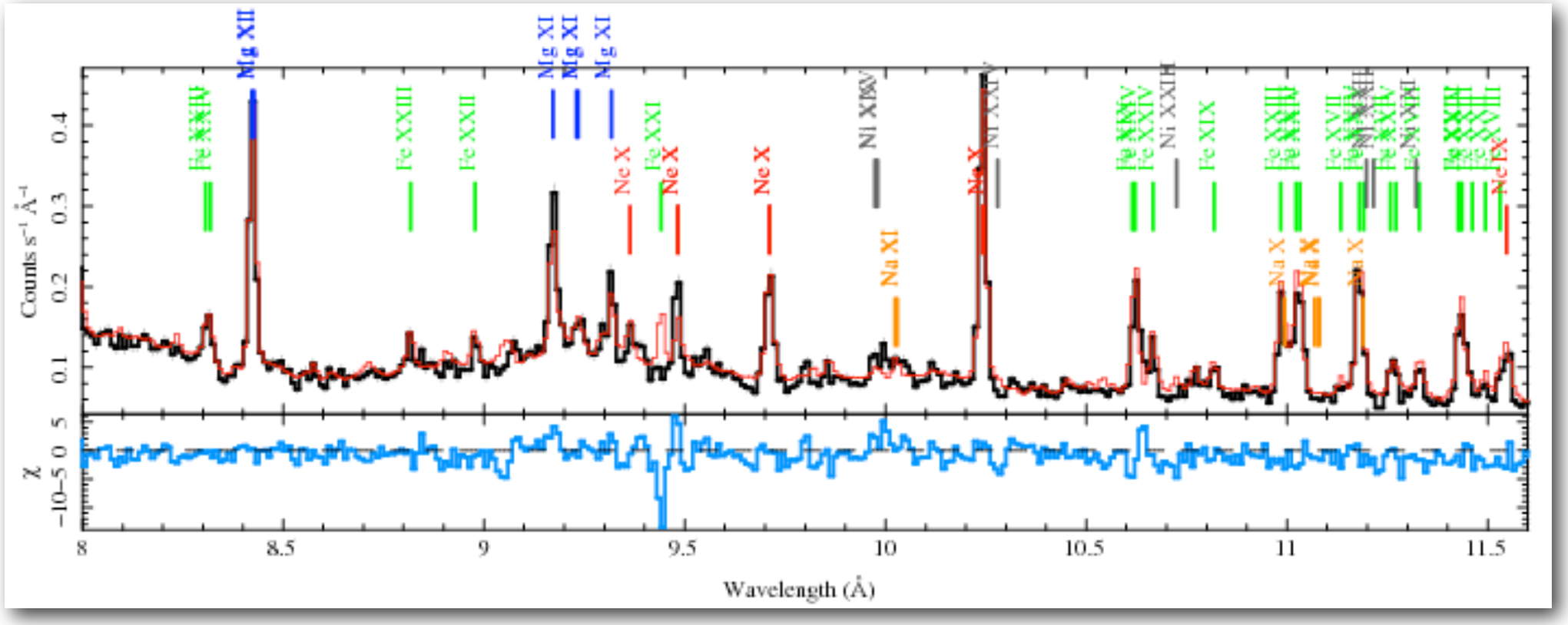
Nowak web pages: **<http://space.mit.edu/home/mnowak/isis_vs_xspec/>**

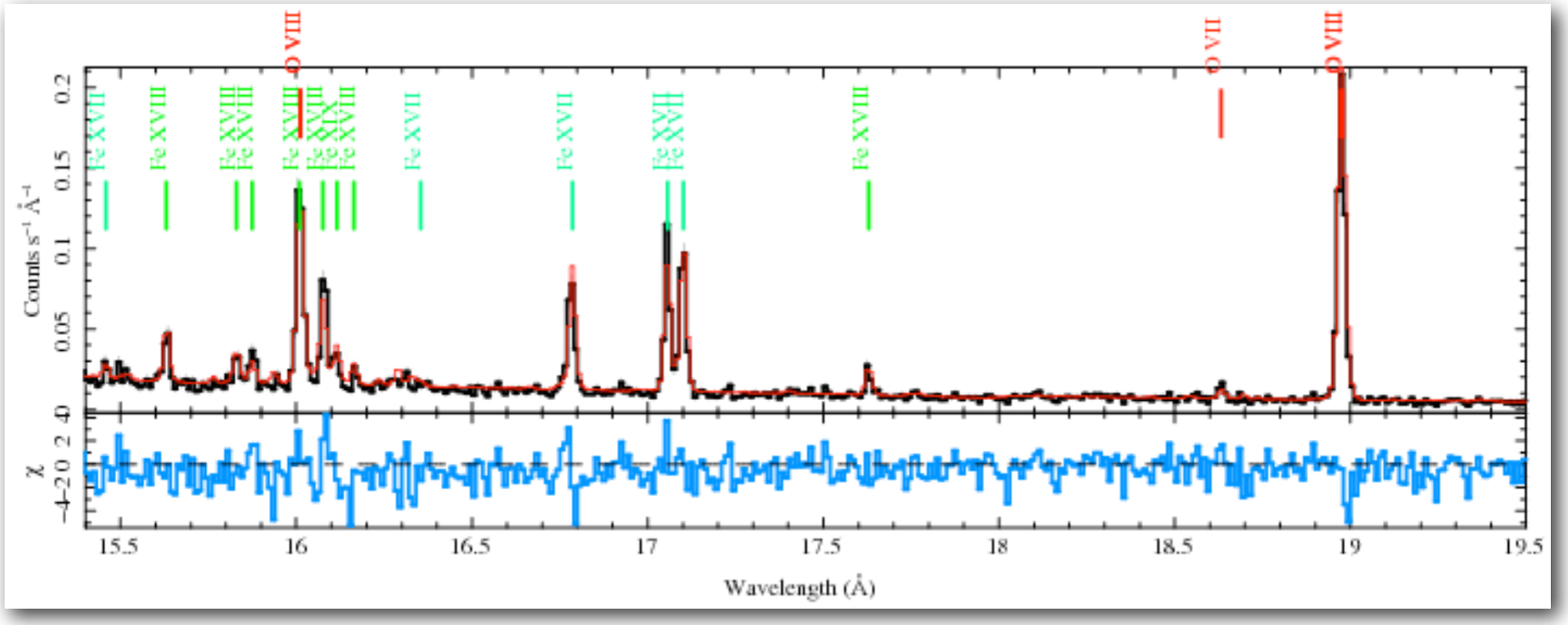
(Installed on the HEAD network at `/soft/isis/bin/isis`)



A counts spectrum, model, and residuals:

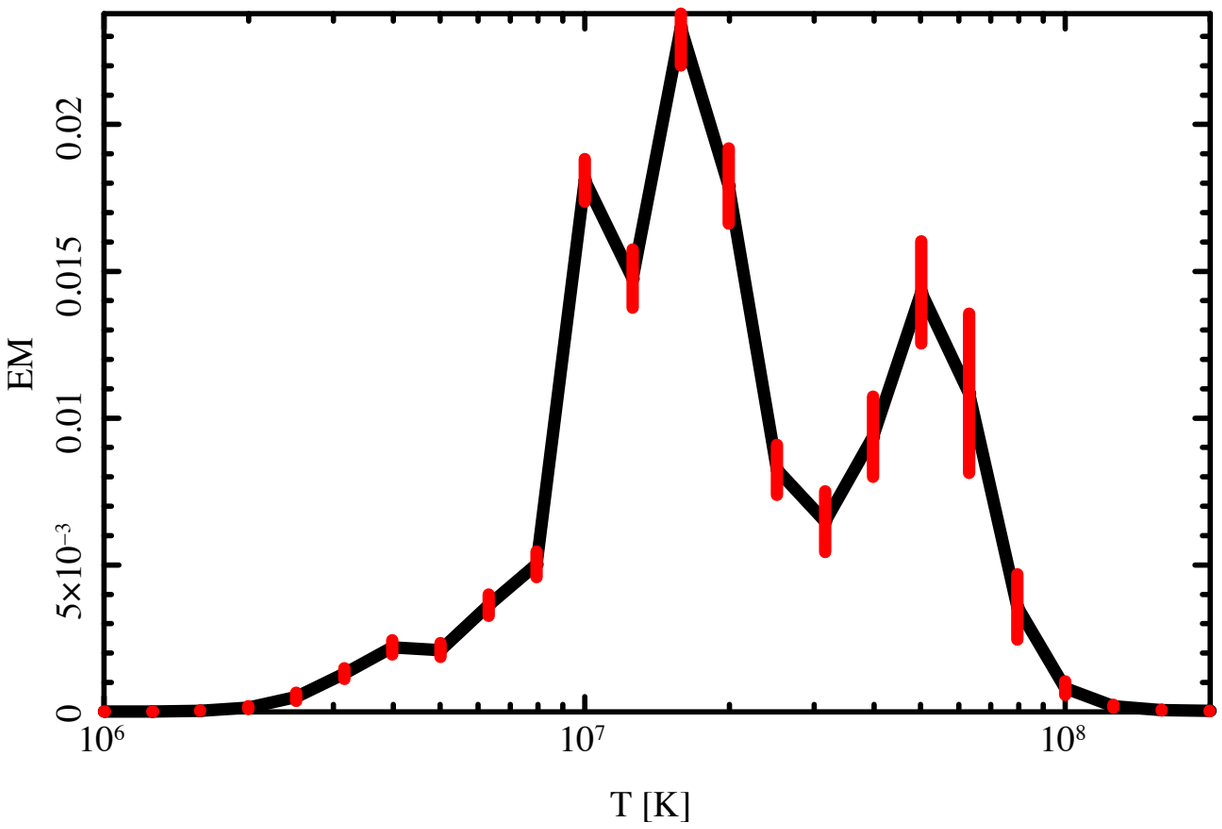



Mg XII
Mg XI
Mg XI
Mg XI
Ne X
Ne X
Ne X
Ni XXVII
Na XI
Ne X
Ni XXVIII
Ni XXVIII
Na X
Na X
Na X
Ne IX
Counts s^{-1} Å^{-1}
χ
Wavelength (Å)

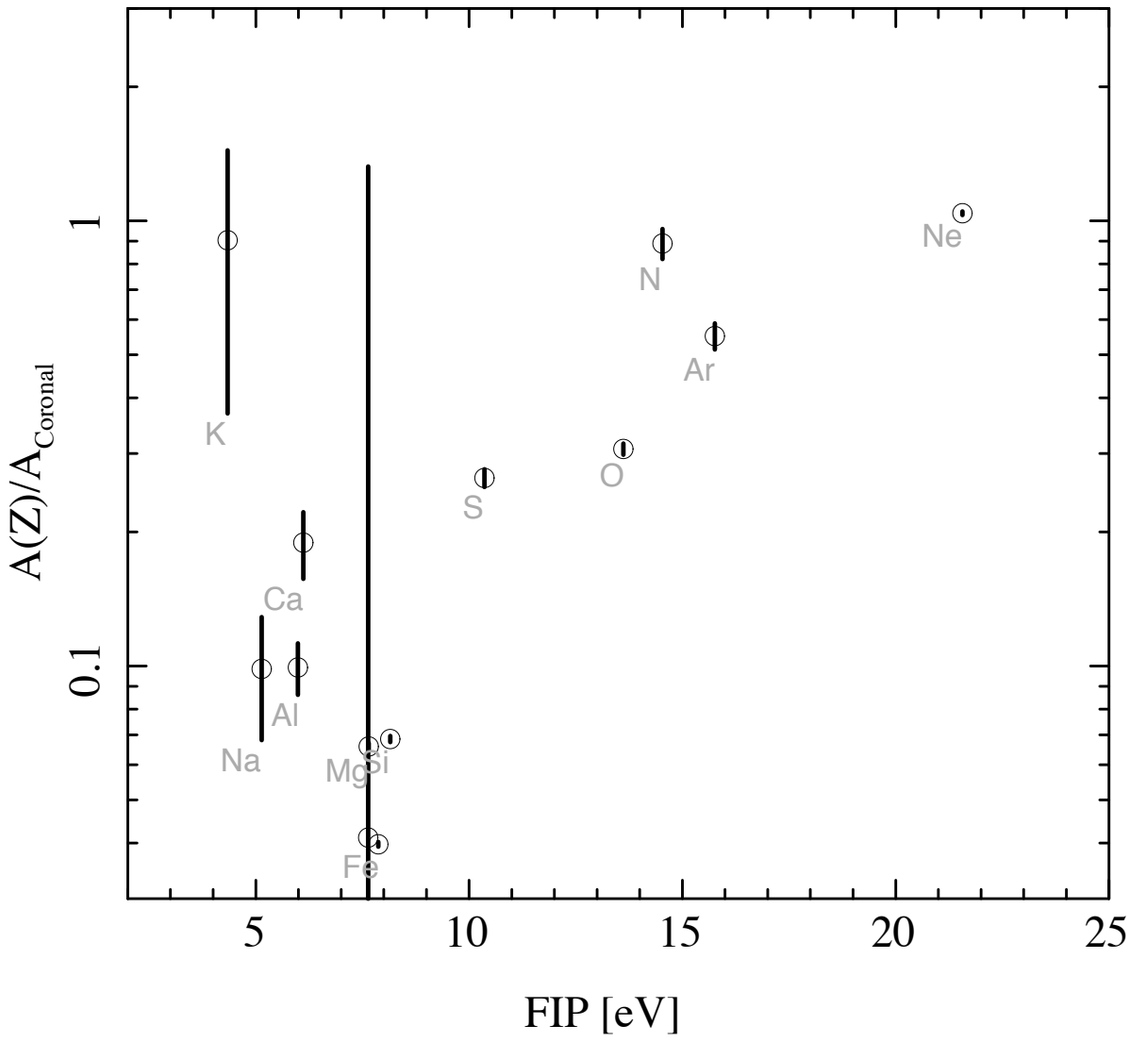

O VIII
O VII
O VIII
Fe XVII
Fe XVIII
Fe XVIII
Fe XVIII
Fe XVII
Fe XVII
Fe XVII
Fe XVII
Fe XVIII
Counts s^{-1} Å^{-1}
χ
Wavelength (Å)

But the model *wasn't* the binned spectrum, it was:

Emission Measure Distribution (EMD)



Relative Abundances



Line-Based Analysis

$$L_{ul}(Z,J) = \int \Lambda_{ul}(T;Z,J)\,(A(Z)[n_e n_H dV/dT])\;dT$$

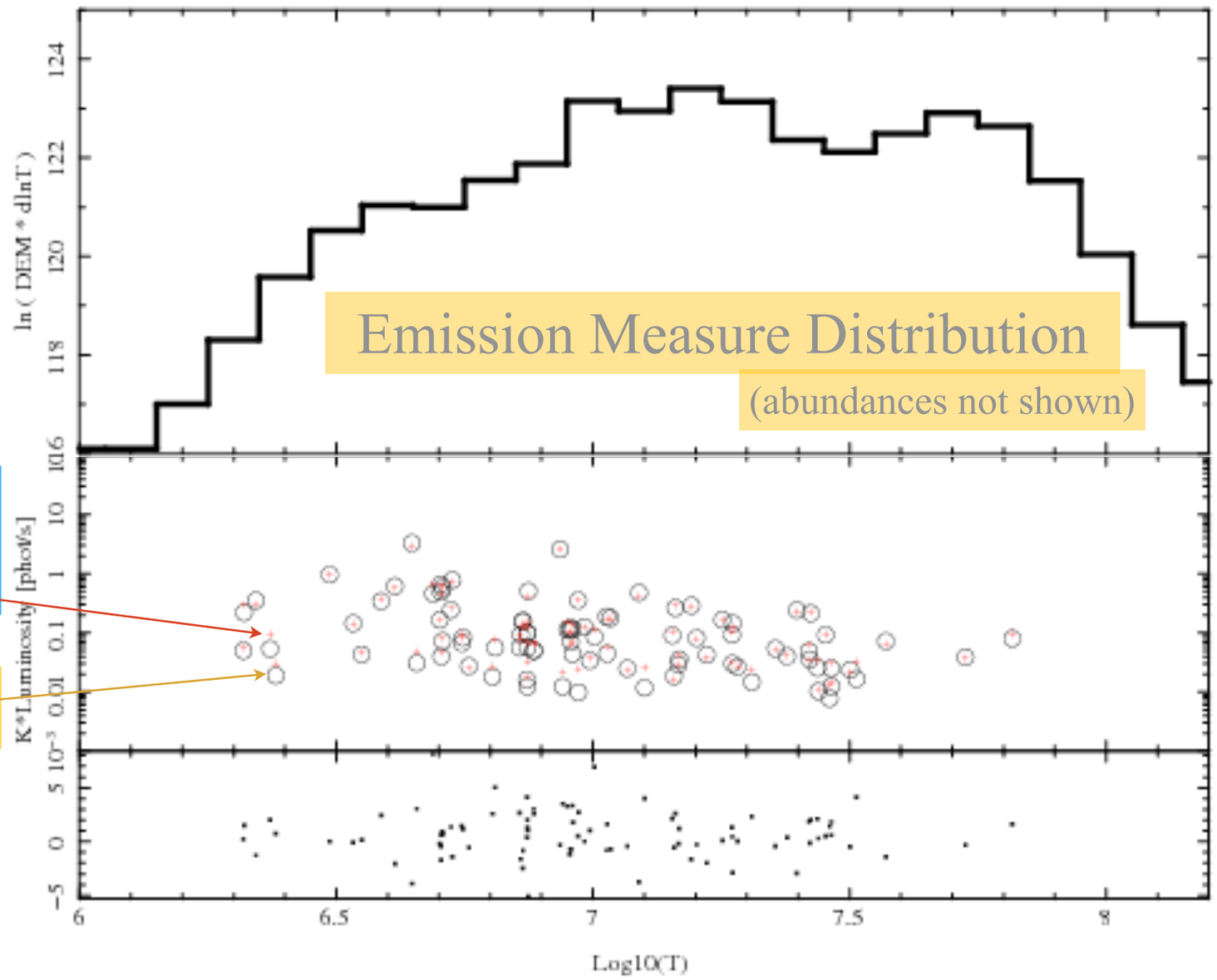
Line Flux | Emissivity | Model

AtomDB provides emissivities for each line.

Each small dot is a line flux measurement (parametric fit)

Each circle is a model line flux

(residuals)



Mis-IDs (large wavelength residuals) and blends (large flux residuals) iteratively removed.

ISIS Database, Spectral Analysis Features

Identify, characterize, evaluate line and continuum models, access atomic data (A-values, wavelengths, energy levels), by element, ion, wavelength, strength.
Some are plasma model independent (database only); others require a plasma model.

Example functions:

`plasma( aped );` Load the database (takes 10-60 sec, depending on your computer);
(it is also possible to have ***multiple*** databases loaded simultaneously)

`em = line_em( ids, temperatures[, densities])`	Retrieve emissivity vs T (and optionally density)
`r = ratio_em( id1, id2, temperatures, densities)`	Compute line ratio vs T (or n_e)
`info = line_info( id )`	Returns data for a single transition

Filters: (how you select line indices):

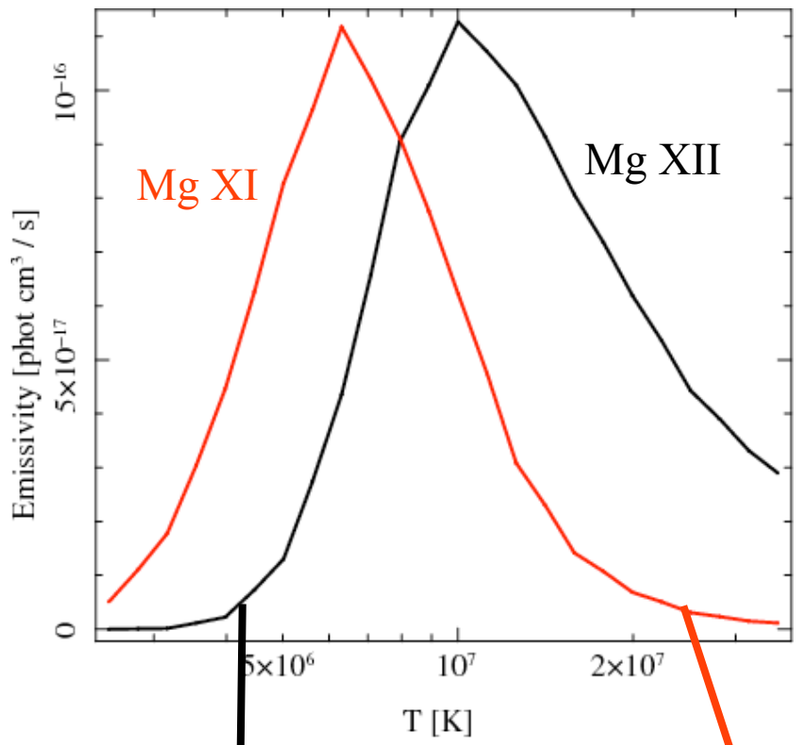
```
indices    = where( flag_array )                    (language intrinsic)

flag_array = el_ion( Z_list, I_list )
flag_array = trans( Z, I, upper_levels, lower_levels )
flag_array = wl( wavelength_lo, wavelength_hi )
indices = brightest( n, line_list )                 (Model dependent)
```

Viewing:	**`page_group( indices )`**	List line information to the screen
	`plot_group( indices )`	Plot line IDs on the current plot

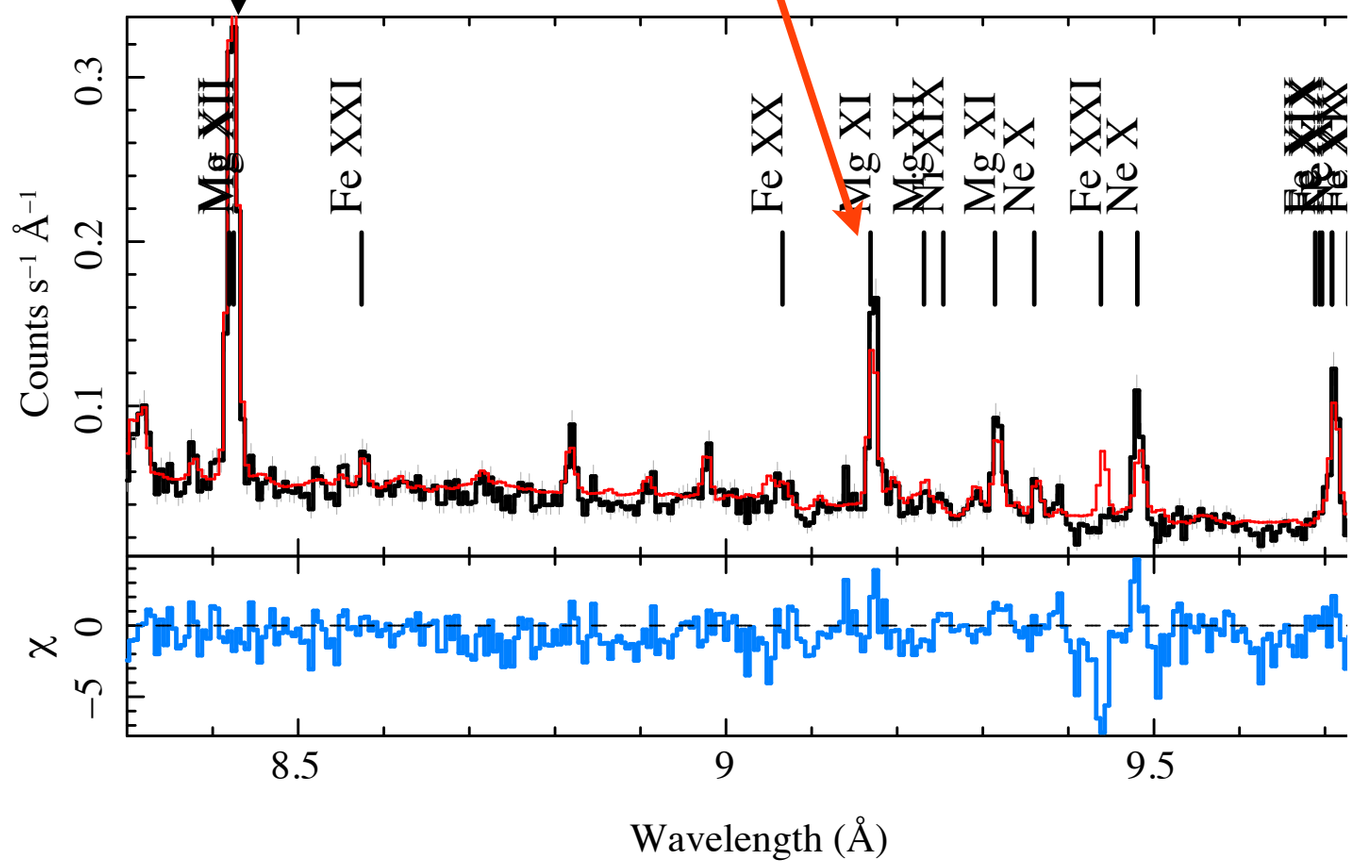
Example of typical use:

```
k = brightest(10,
    where(  (trans(Ne, 9,[2:20],1 )
                  or el_ion(Fe, [18:21]))
                      and wl(13.4, 13.8)));
```

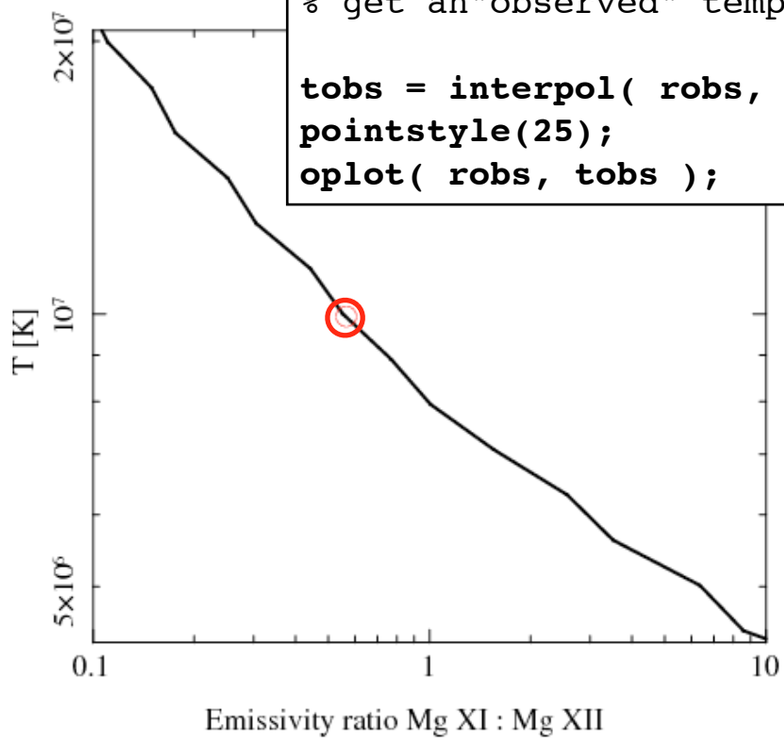
Example: Simple Line-Ratio Temperature Diagnostic




```
% Get AtomDB indices for Mg XI r and Mg XII H-Ly-alpha lines:

k1 = where( trans( Mg, 11, 7, 1 ) ) ;
k2 = where( trans( Mg, 12, [3,4], 1 ) ) ;

t = 10^[ 6.4 : 7.6 : 0.05 ] ;   % Define a temperature grid

% evaluate the emissivities, and the ratio, vs T:

e1 = line_em( k1, t );
e2 = line_em( k2, t );
r12 = ratio_em( k1, k2, t );

% What is model's ratio?
f1 = line_info( k1[0] ).flux;
f2 = line_info( k2[0] ).flux + line_info(k2[1]).flux ;
f1/f2;
0.36    % a little less ("hotter") than isothermal value
```




```
% interpolate the measurement to
% get an"observed" temperature:

tobs = interpol( robs, r12, t );
pointstyle(25);
oplot( robs, tobs );
```



Sleuthing that odd Fe XXI model feature:

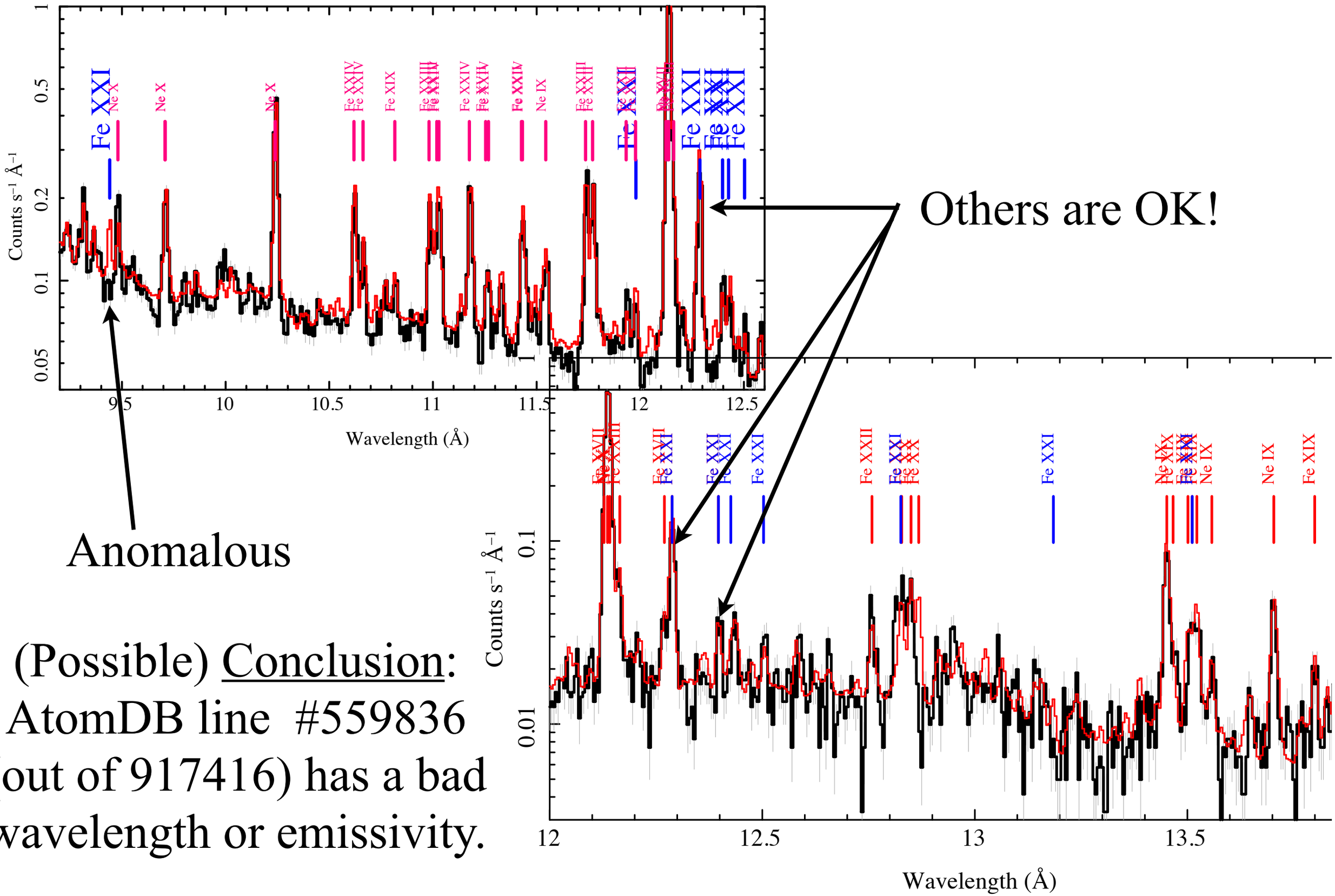
```
isis> page_group( brightest( 20, where( wl( 8.3, 10) ) ));

#  index         ion    lambda     F (ph/cm^2/s)  A(s^-1)  upper lower   label
 588824 *   Fe XXIII     8.3038     1.903e-05   4.330e+12     52     1 2s1 4p1 - 2s2
 603573 *    Fe XXIV     8.3161     1.640e-05   7.030e+12     13     3 4d1 - 2p1
 122049 *     Mg XII     8.4192     1.367e-04   1.298e+13      4     1 2p1 - 1s1
 122047 *     Mg XII     8.4246     6.930e-05   1.295e+13      3     1 2p1 - 1s1
 559932 *     Fe XXI     8.5740     1.111e-05   2.853e+12    460     1 2p{1/2}1 5d{3/2}1 - 2p2
 589134 *   Fe XXIII     8.8149     2.159e-05   5.910e+12     56     5 2s1 4d1 - 2s1 2p1
 588626 *   Fe XXIII     8.9060     8.446e-06   6.970e+11     48     5 2s1 4s1 - 2s1 2p1
 568212 *    Fe XXII     8.9748     2.067e-05   4.790e+12     72     1 4d1 - 2p1
 112737 *      Mg XI     9.1687     7.950e-05   2.000e+13      7     1 1s1 2p1 - 1s2
 112733 *      Mg XI     9.2312     1.158e-05   2.610e+10      5     1 1s1 2p1 - 1s2
  85974 *       Ne X     9.2899     9.158e-06   1.192e+11     39     1 7p1 - 1s1
 121876 *      Mg XI     9.3143     3.994e-05   6.630e+04      2     1 1s1 2s1 - 1s2
  85896 *       Ne X     9.3602     1.439e-05   1.923e+11     28     1 6p1 - 1s1
 559836 *     Fe XXI     9.4381     3.871e-05   5.800e+12    248     1 2p1 4d1 - 2p2
  85852 *       Ne X     9.4807     2.609e-05   3.378e+11     19     1 5p1 - 1s1
  85832 *       Ne X     9.4809     1.278e-05   3.378e+11     18     1 5p1 - 1s1
  85819 *       Ne X     9.7080     5.798e-05   6.746e+11     12     1 4p1 - 1s1
  85806 *       Ne X     9.7085     3.168e-05   1.354e+12     11     1 4p1 - 1s1
 561806 *     Fe XXI     9.8188     9.877e-06   4.904e+12    296     7 2s1 2p{1/2}2 4d{5/2}1 - 2s1 2p3
 420736 *     Fe XIX     9.8552     9.975e-06   3.592e+12    432     1 2p3 5d1 - 2p4
```

This is the one

```
isis> k4 = brightest( 10, where( el_ion(Fe,21) and wl( 8.5, 14.01 ) ) );

isis> page_group( k4 );
#  index         ion    lambda     F (ph/cm^2/s)  A(s^-1)  upper lower   label
 559836 *     Fe XXI     9.4381     3.871e-05   5.800e+12    248     1 2p1 4d1 - 2p2
 559766 *     Fe XXI     11.975     2.489e-05   2.950e+12     58     1 2s1 2p2 3p1 - 2p2
 559742 *     Fe XXI     12.284     3.385e-04   1.910e+13     40     1 2p1 3d1 - 2p2
 560000 *     Fe XXI     12.393     5.919e-05   3.340e+12     40     2 2p1 3d1 - 2p2
 560389 *     Fe XXI     12.422     1.587e-05   1.110e+13     37     2 2p1 3d1 - 2p2
 562623 *     Fe XXI     12.499     2.036e-05   5.510e+12     36     3 2p1 3d1 - 2p2
 561690 *     Fe XXI     12.822     4.162e-05   5.140e+12     83     7 2s1 2p2 3d1 - 2s1 2p3
 560138 *     Fe XXI     13.181     1.946e-05   1.200e+12     22     3 2p1 3s1 - 2p2
 560843 *     Fe XXI     13.507     7.152e-05   1.680e+12     42     7 2s1 2p2 3s1 - 2s1 2p3
 560835 *     Fe XXI     14.008     5.620e-05   3.550e+11     28     7 2p1 3p1 - 2s1 2p3
```

These are the “brightest” Fe XXI lines:

Fe XXI model features, shown in the spectra:



Others are OK!

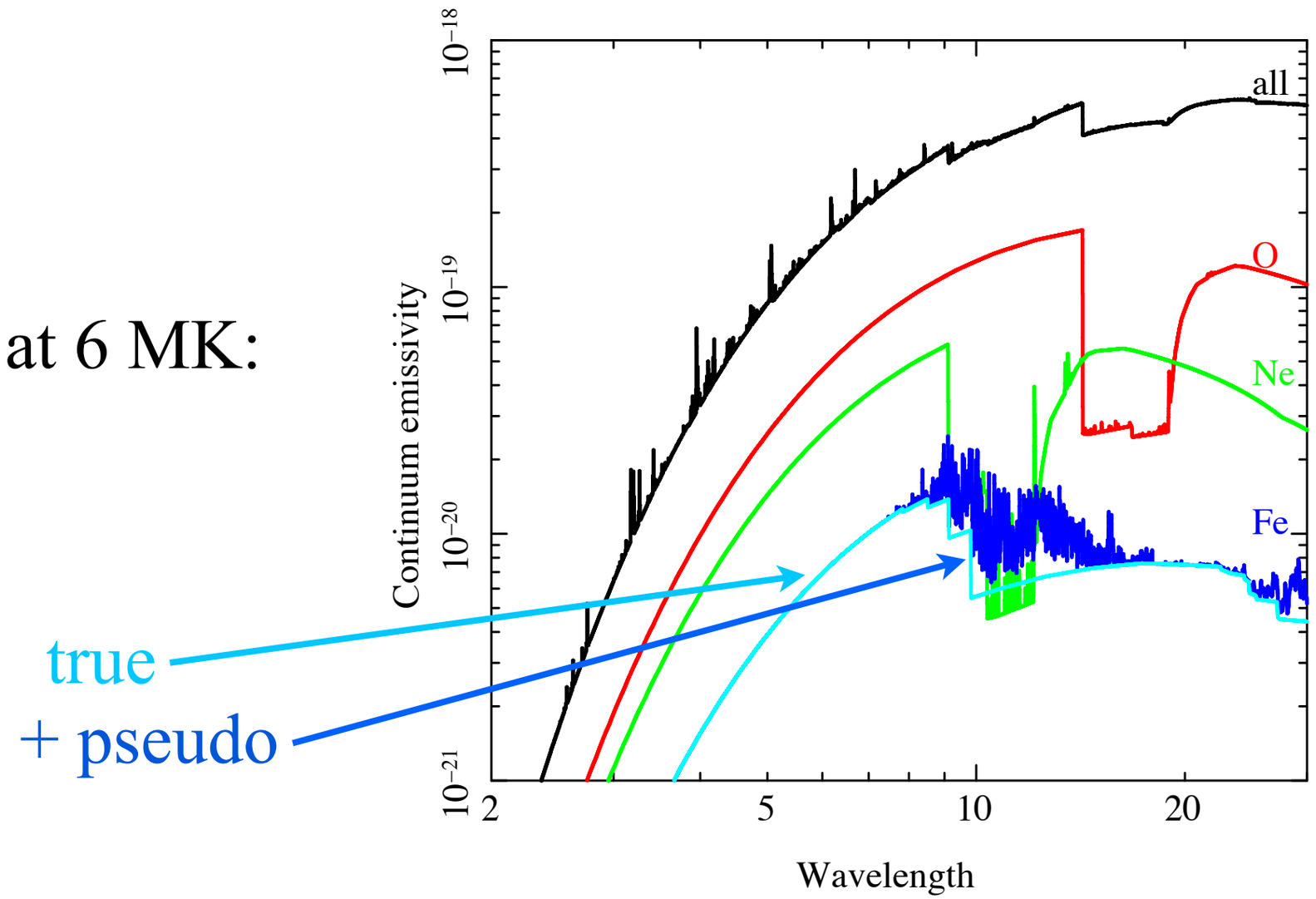
Anomalous

(Possible) Conclusion: AtomDB line #559836 (out of 917416) has a bad wavelength or emissivity.

Miscellaneous Database Functions

```
s = get_contin( wlo, whi, T [, dens][, Z][,Ion] )

frac[] = ion_frac (proton_number, ion, temp[], [ioniz_table_id])
(ion, frac) = ion_bal (proton_number, temp, [ioniz_table_id])
load_alt_ioniz (file)

list_abund
set_abund (name)
a = get_abundances
id = add_abundances (name, abun[], z[])
```

AtomDB continuua at 6 MK:



ISIS Plasma Modeling Functions

```
p = default_plasma_state();
create_aped_fun( model_name, plasma_state [, &hook_fun])
fit_fun( model_expression )
set_par(par, value); v=get_par(par); load_par(file); save_par(file), ...
use_thermal_profile;
f = eval_fun( wlo, whi )    % In model space
eval_counts()               % In counts space, if you have responses loaded/assigned
k = brightest( line_list );
indices = unblended (frac, wl_sep, allowed_type, line-list)
```

An explicit example: make a 3-T model with variable abundances

```
p = default_plasma_state;

p.temperature = 10^[6.2, 6.8, 7.2] ;
p.norm = [0.5,1,0.5] * 1.e-14 * 1.e53 / (4*PI * (PI*1.e18 * 50)^2);
p.elem = [ O, Ne, Fe ];
p.elem_abund = [1, 2.0, 0.5 ];
p.redshift = 50./3.e5 ;
p.vturb = 50.0;

create_aped_fun( "apec3t", p );
fit_fun( "apec3t(1)");
```

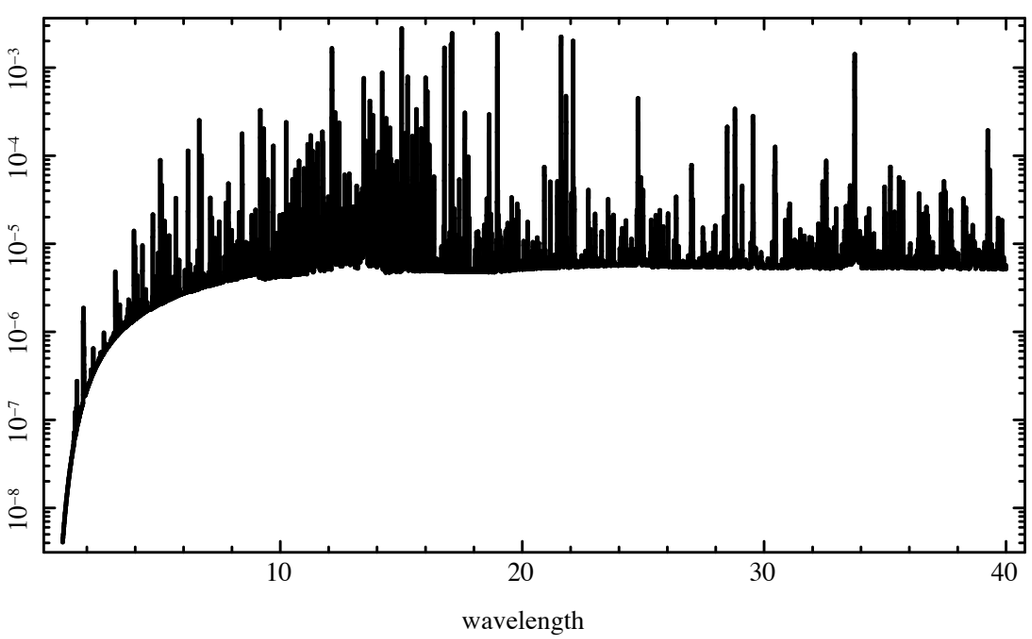
(example continued)

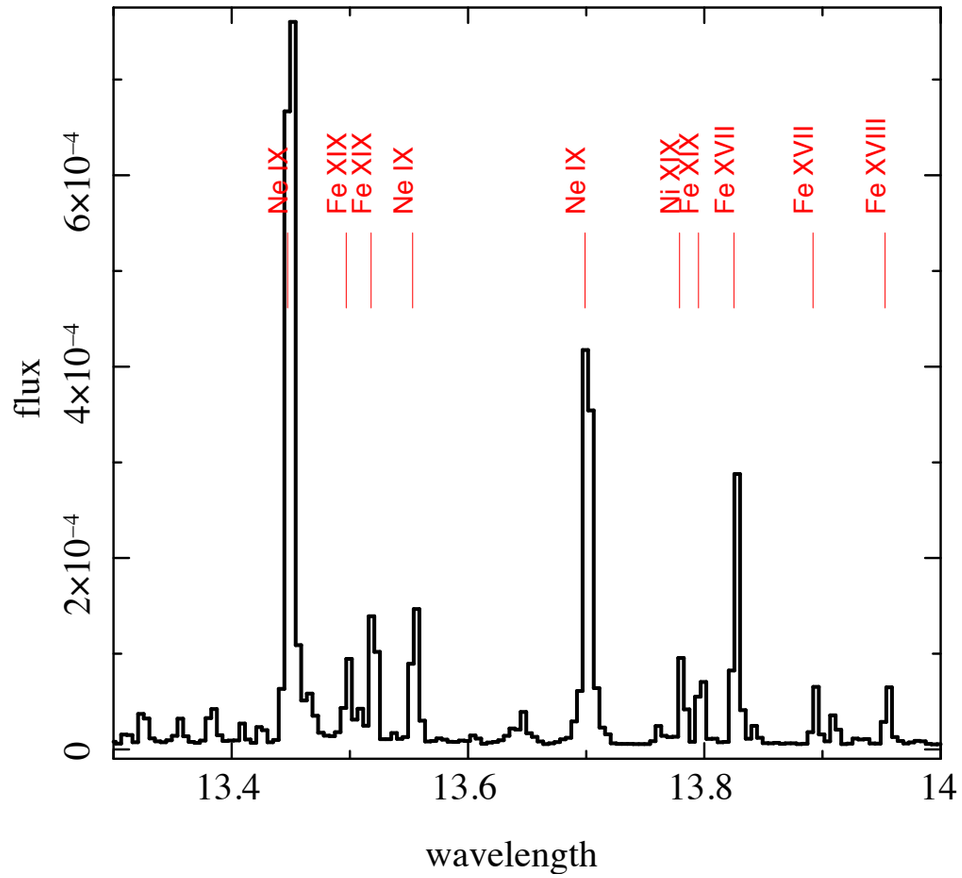
```
list_par;
```

```
apec3t(1)
 idx  param                tie-to  freeze          value          min          max
  1   apec3t(1).norm1           0       1       0.04052847            0            0
  2   apec3t(1).norm2           0       1       0.04052847            0            0
  3   apec3t(1).norm3           0       1       0.04052847            0            0
  4   apec3t(1).temperature1    0       1          1000000            0            0
  5   apec3t(1).temperature2    0       1          6309573            0            0
  6   apec3t(1).temperature3    0       1     1.584893e+07            0            0
  7   apec3t(1).density         0       1                1            0            0
  8   apec3t(1).vturb           0       1               50            0            0
  9   apec3t(1).redshift        0       1     0.0001666667            0            0
 10   apec3t(1).metal_abund     0       1                1            0            0
 11   apec3t(1).abund_O         0       1                1            0            0
 12   apec3t(1).abund_Ne        0       1              1.5            0            0
 13   apec3t(1).abund_Fe        0       1              0.5            0            0
```

```
(w1,w2) = linear_grid( 1.0, 40.0, 8192);   % wavelength grid
use_thermal_profile;       % turn on the thermal+turbulent line profile
f = eval_fun( w1, w2 );    % model flux vs wavelength [phot/cm^2/s/bin]
```

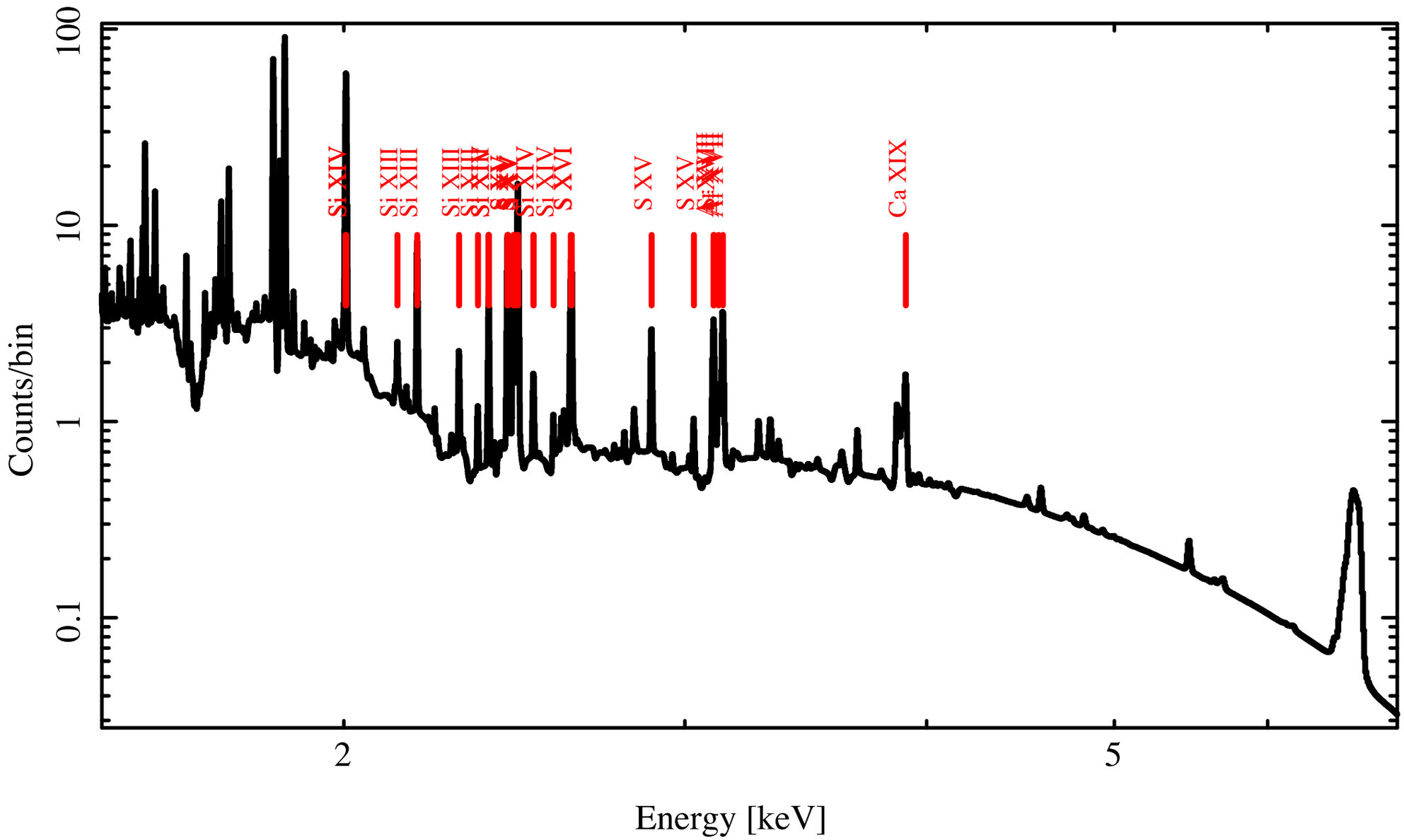
```
ylog; xrange; hplot( w1, w2, f );
ylin;xrange( 13.3, 14); hplot( w1, w2, f );
plot_group( brightest(10, where( wl(13.3, 14))) );
```



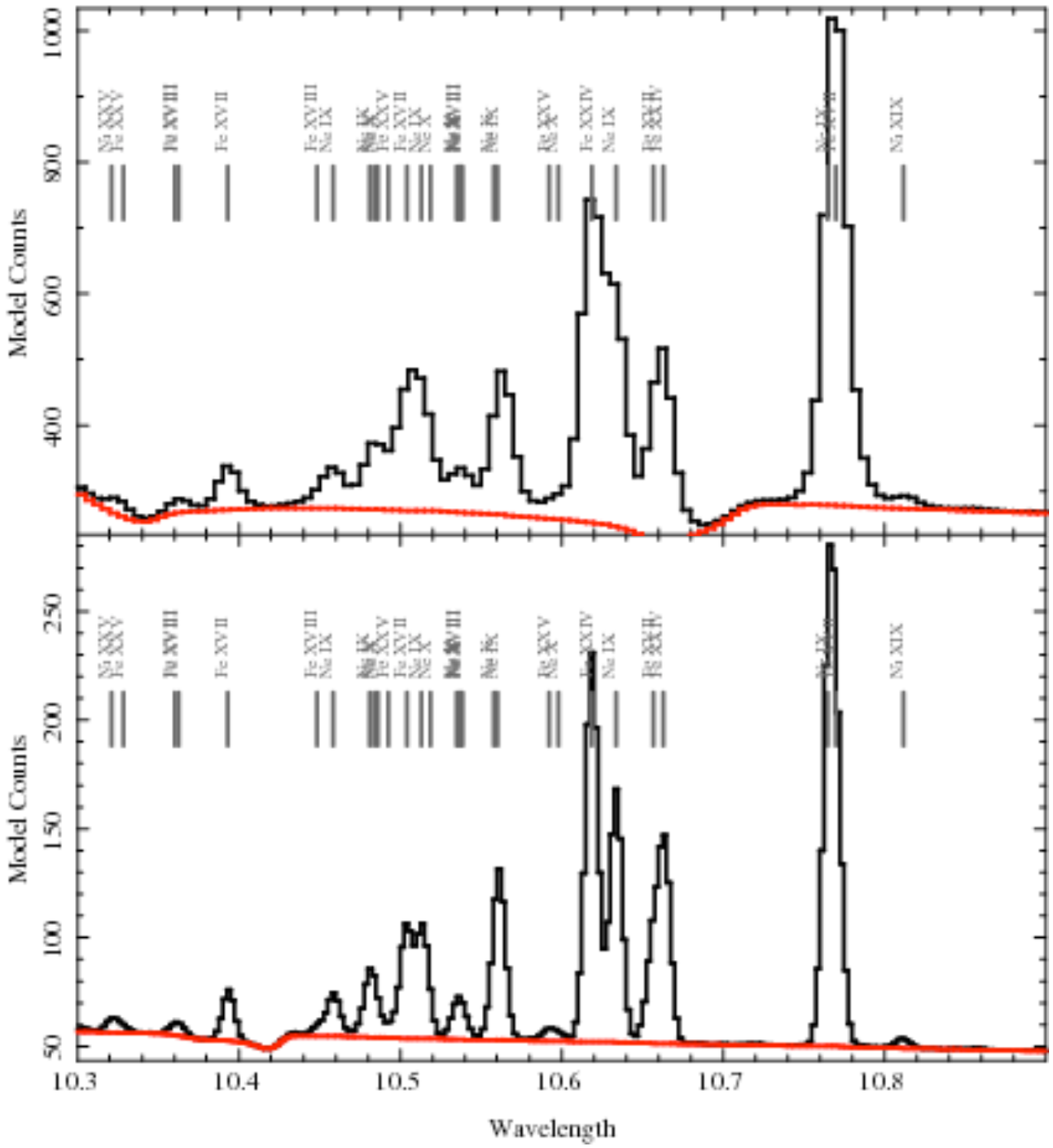


(example continued)

```
eval_counts;   % assuming responses have been loaded and assigned to data

ylog; xlog;
plot_unit( "kev" );   % for the energy-centric
xrange(1.5, 7);
plot_model_counts( 1 );
plot_group( brightest( 30, where( wl(_A(4), _A(2))))  ); % note: w[A]=_A(E); E[keV]=_A(w)
```



Exercise for the reader: use the `create_aped_fun()` "hook" function to evaluate the *continuum model counts*:



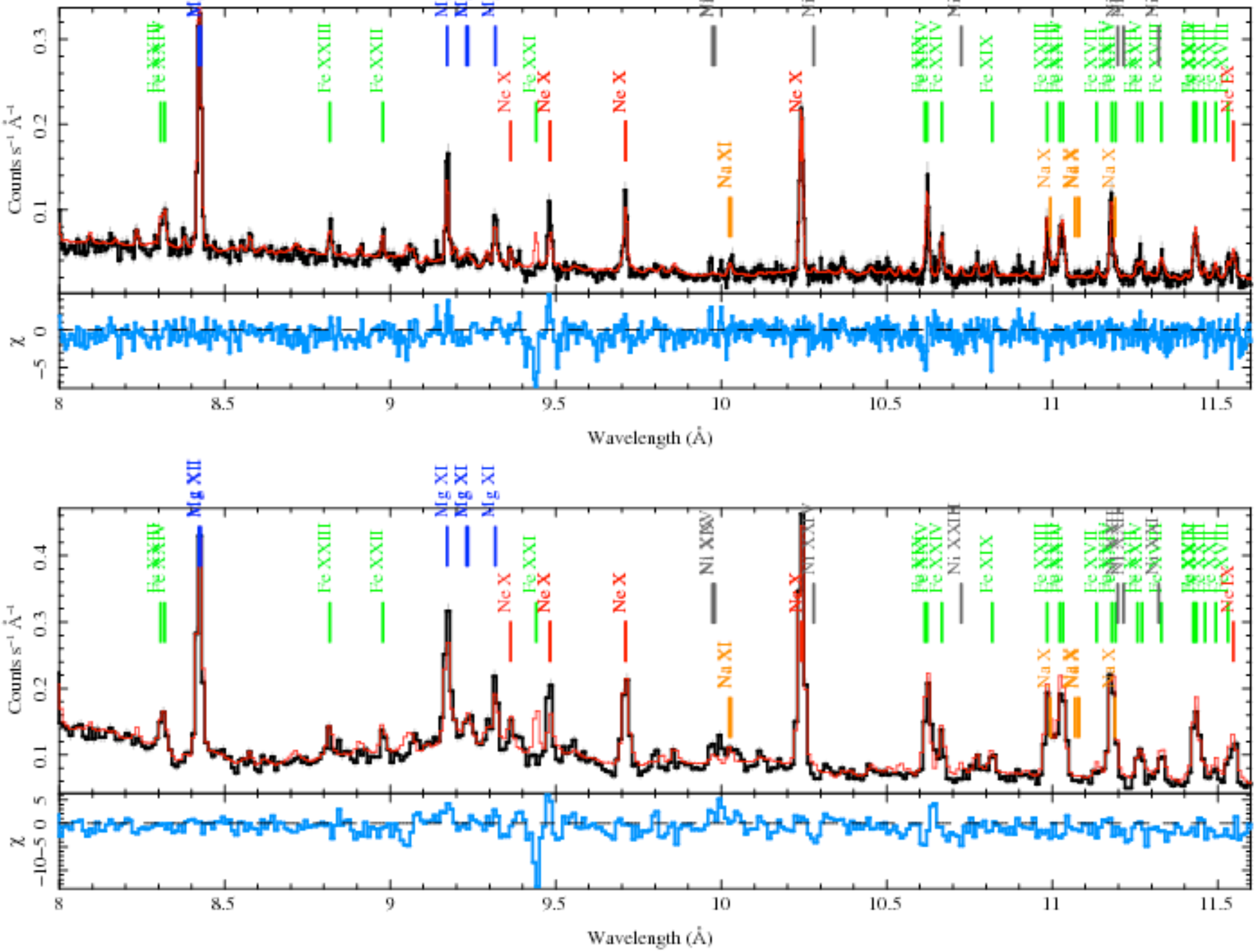
(Note: this can be very useful when fitting line fluxes by providing a model continuum based on an approximate plasma model!)

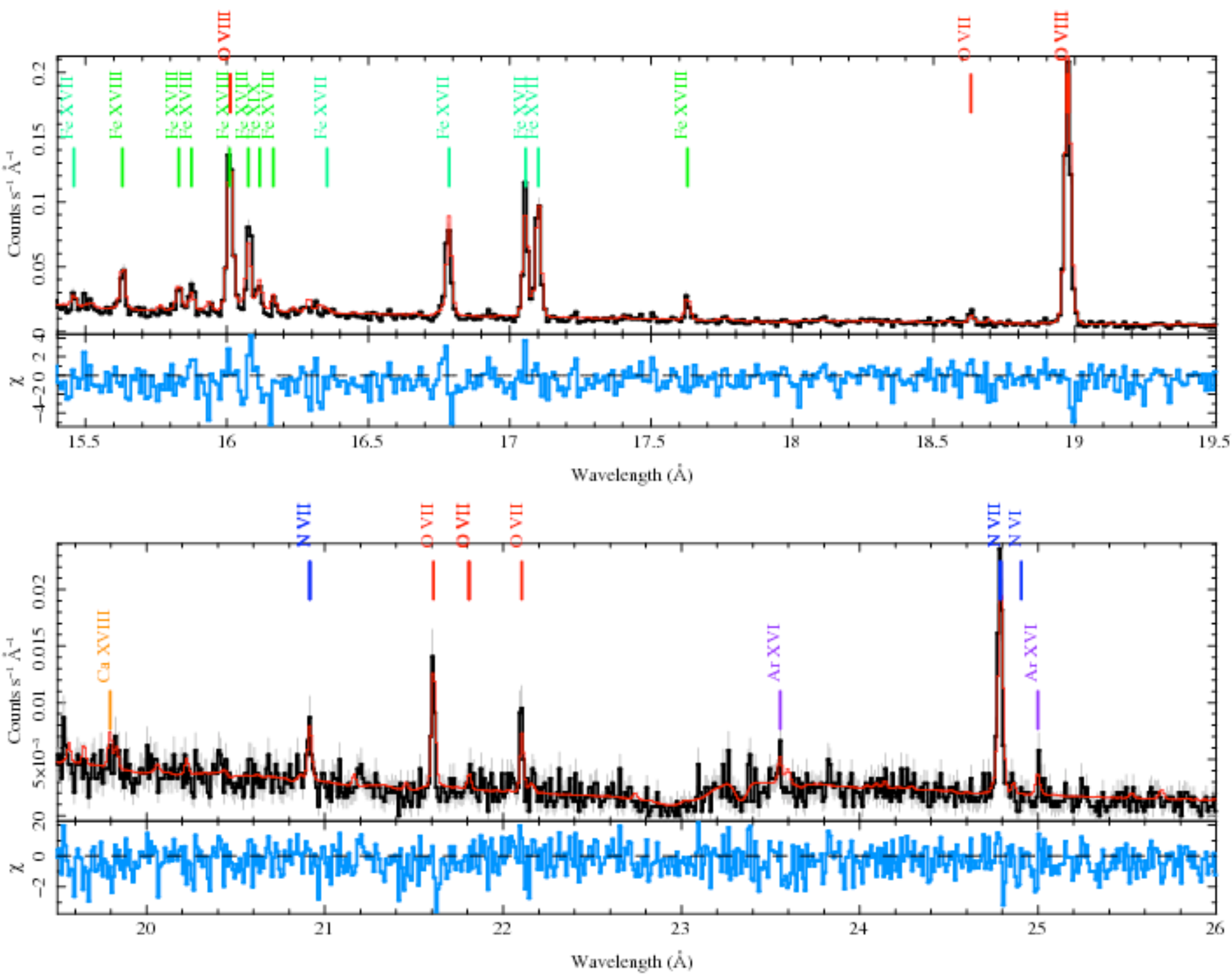
Credit, Where Credit is Due*

```
b = aped_bib(aped, where(trans(Ne,9,[2:20],1)));
s = aped_bib_query_string( b );

s;
http://adsabs.harvard.edu/cgi-bin/nph-bib_query/?bibcode=2006ApJS.. ICFT&bibcode=...

system( "lynx -dump '$s' > /tmp/s.bib"$);     % (I learned this from the on-line help...)

! cat /tmp/s.bib
```

```
Query Results from the ADS Database
Retrieved 6 abstracts, starting with number 1.  Total number selected: 6.

@INPROCEEDINGS{Afoster.Autos.2010,
     year = Afos,
    pages = {2010},
   adsurl = {http://adsabs.harvard.edu/abs/Afoster.Autos.2010},
  adsnote = {Provided by the SAO/NASA Astrophysics Data System}
}

@ARTICLE{2006ApJS..167..334B,
   author = {{Badnell}, N.~R.},
    title = "{Radiative Recombination Data for Modeling Dynamic Finite-Density P
lasmas}",
  journal = {\apjs},
   eprint = {arXiv:astro-ph/0604144},
 keywords = {Atomic Data, Atomic Processes, Plasmas},
     year = 2006,
    month = dec,
   volume = 167,
    pages = {334-342},
      doi = {10.1086/508465},
   adsurl = {http://adsabs.harvard.edu/abs/2006ApJS..167..334B},
  adsnote = {Provided  by the SAO/NASA Astrophysics Data System}
}

@ARTICLE{1988CaJPh..66..586D,
   author = {{Drake}, G.~W.},
    title = "{Theoretical energies for the n = 1 and 2 states of the helium isoe
lectronic sequence up to Z = 100}",
  journal = {Canadian Journal of Physics},
```

* It's not our fault, either.


Counts s⁻¹ Å⁻¹
χ
Wavelength (Å)
Mg XII
Mg XI
Ne X
Ne IX
Na XI
Ni XXV
Ni XXIV
Ni XXIII
Ni XXII
Ni XXI
Fe XXIV
Fe XXIII
Fe XXII
Fe XXI
Fe XX
Fe XIX
Na X


Fe XVII
Fe XVIII
Fe XVIII
Fe XVIII
O VIII
Fe XVII
Fe XVII
Fe XVII
Fe XVII
Fe XVII
Fe XVII
Fe XVII
O VII
O VIII
Counts s⁻¹ Å⁻¹
χ
Wavelength (Å)
N VII
O VIII
O VIII
O VIII
Ca XVIII
Ar XVI
Ar XVI
N VII
N VII
Counts s⁻¹ Å⁻¹
χ
Wavelength (Å)