5April2007
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Analyzing MEG spectrum of zeta Pup using Maurice's Jan. 2007 version of windproof in xspec v.12

In this document, I look only at 15.014 A, and do not employ porosity, line scattering, etc. We're just fitting the standard Owocki-Cohen smooth wind profile model.

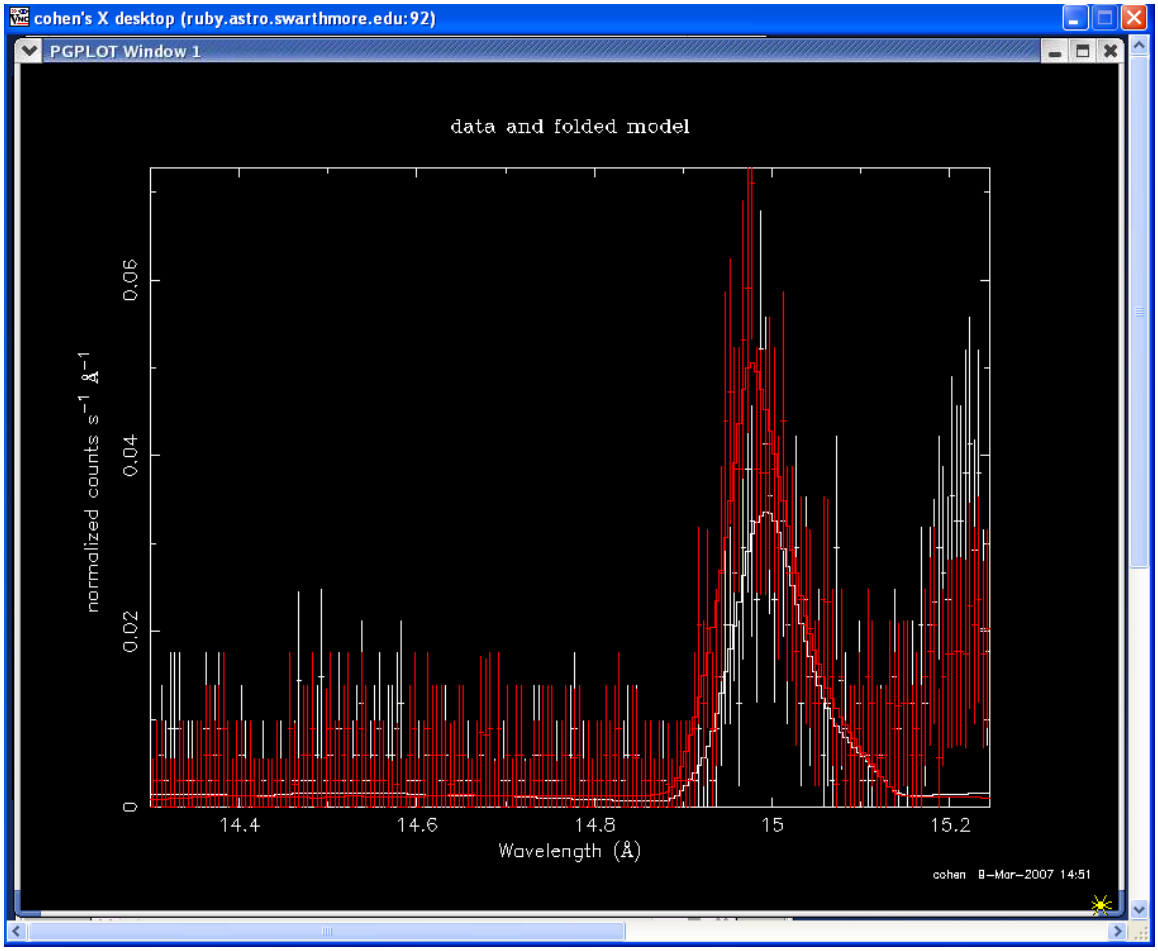
I wanted to investigate a couple of different effects (fit parameter sensitivities to various things aside from the model free parameters), and establish a fitting procedure which we can then systematically apply to all lines in the spectrum.

Here we look just at MEG +/- 1. I fit the two orders simultaneously but not coadded. The plots I show do have the data coadded (and the models too), but that's done after the fitting.

First, establish the continuum level.

I did this first on a pretty broad region of the spectrum, on the blue side of this line. The red side (in other O star spectra too) has unresolved weak line emission between the red wing (and as we'll see, maybe even overlapping the red wing) and the blue side of the 15.26 line. I don't think the true continuum can be reliably determined in this range.

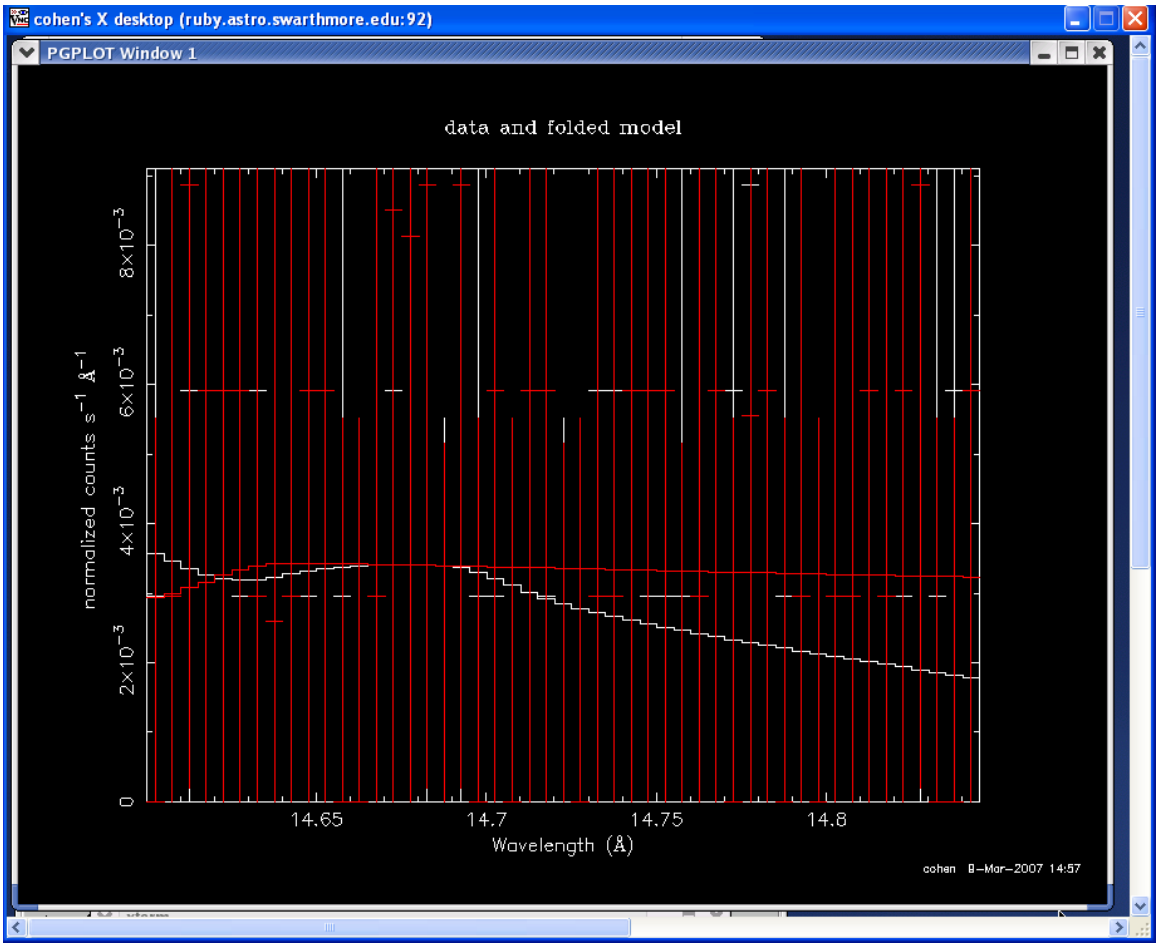
The plot below – a snapshot screen capture from XSPEC – shows the line plus the region where I first tried fitting the continuum, plus some of the red side continuum; the superimposed model is unimportant for our purposes (but clearly includes a model of the line itself). Just want to display the data.



Now I fit the continuum only on 14.60:14.85:

```
========================================================================
Model powerlaw<1> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   powerlaw   PhoIndex          2.00000      frozen
   2    1   powerlaw   norm              4.08633E-03  +/-  5.80675E-04
```

XSPEC12>goodness 100
45.00% of realizations are < best fit statistic 111.75



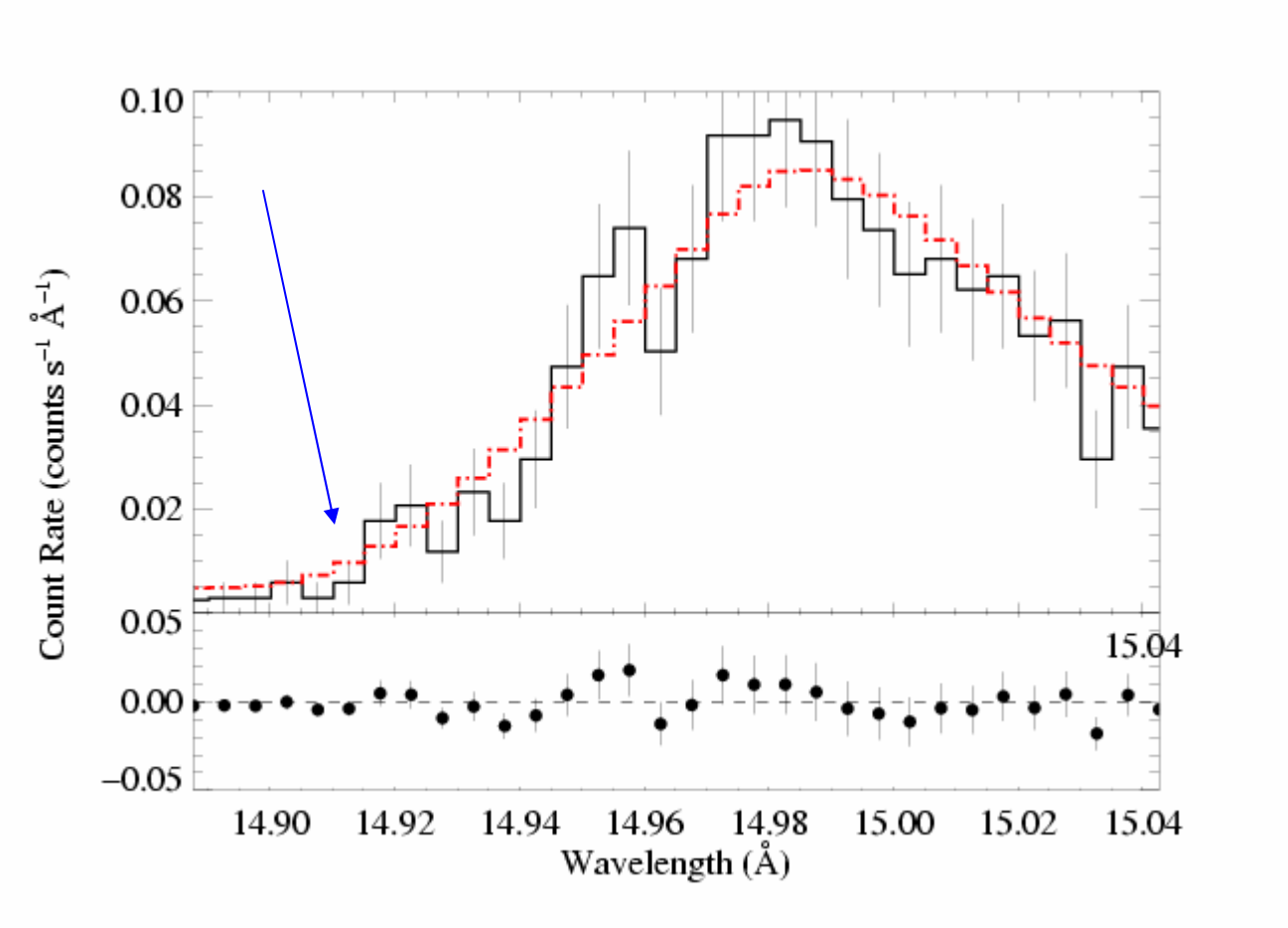
The above figure is the best-fit powerlaw model. The continuum fit is formally good; the best-fit normalization is **4.086e-3**

Delta(C) = 1.0 range:

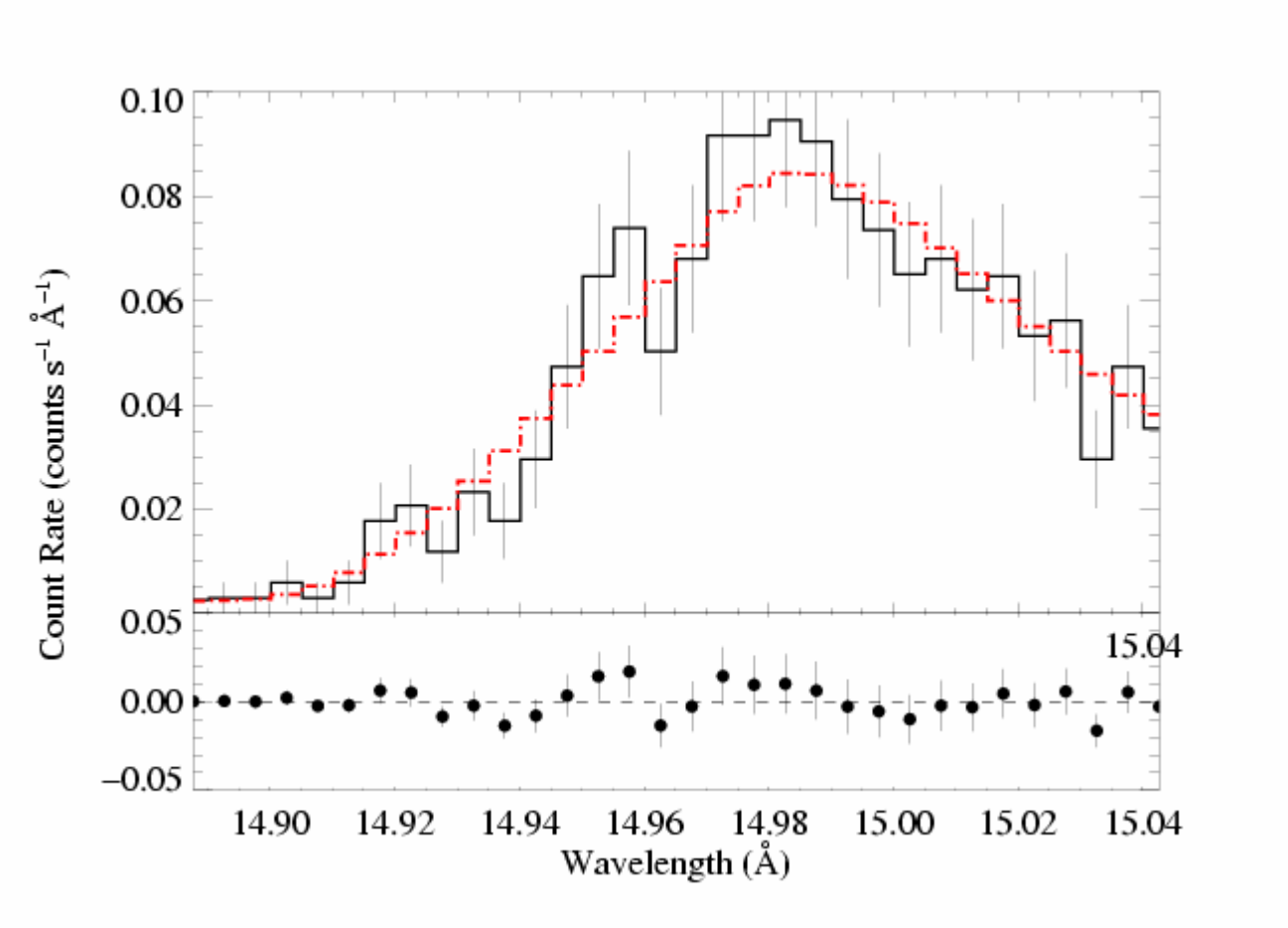
3.68e-3 : 4.51e-3

I tried a couple of different fits, with different wavelength ranges and different values of the terminal velocity. The fit statistics were OK, but the models looked like they systematically deviated from the data.

Here's a typical example. Note especially how the model lies above nearly all the data on the blue wing:



When I let the continuum level be a free parameter of the fit (again, though, only fitting over the spectral range that includes the line), I get a better looking fit:



…with a significantly lower continuum level: **1.85518E-03**

Certainly looks better… Do we want to reevaluate our independent fit of the continuum?

Back to fitting the continuum with a powerlaw:

First, **14.80-14.90**:

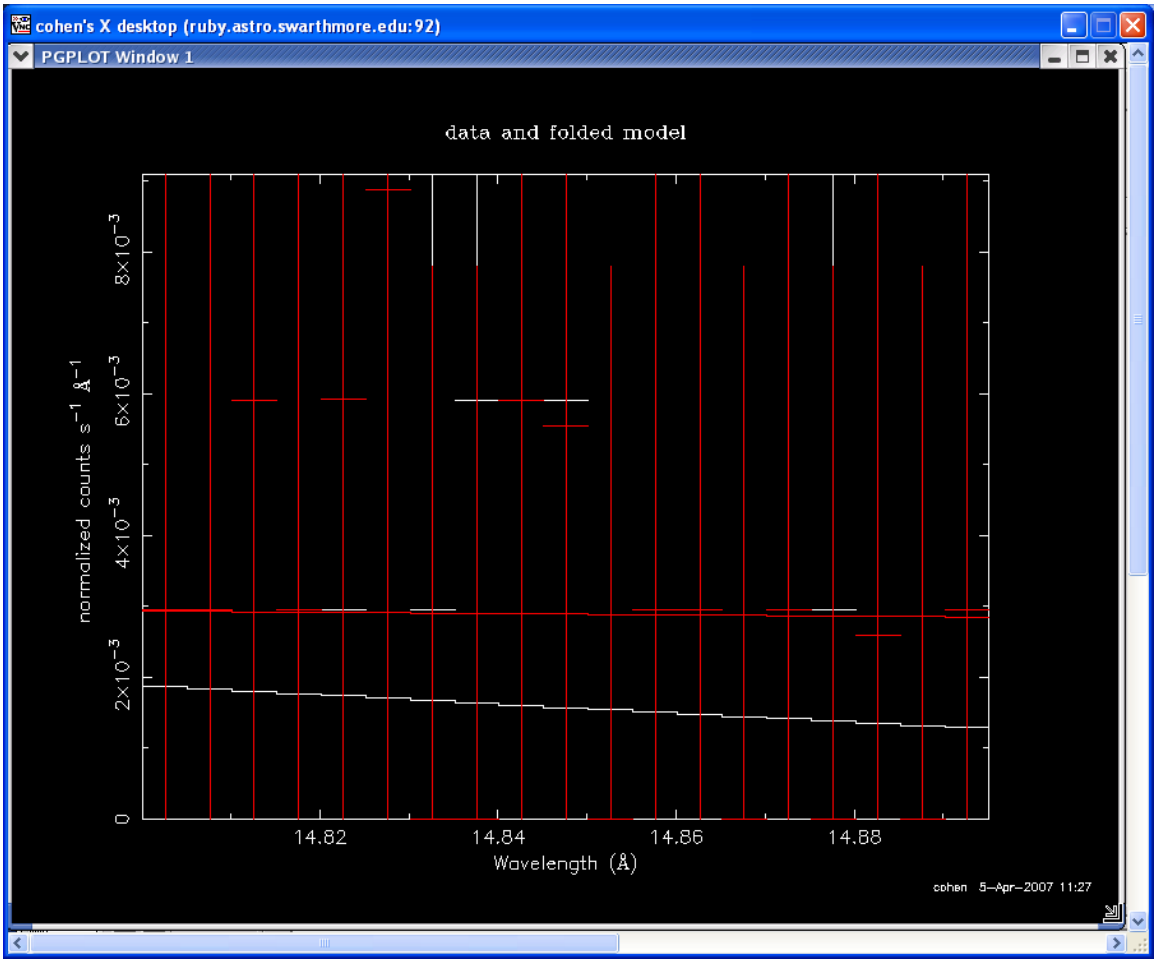
```
========================================================================
Model powerlaw<1> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   powerlaw   PhoIndex          2.00000      frozen
   2    1   powerlaw   norm             3.66151E-03  +/-  1.00383E-03
------------------------------------------------------------------------
```

C-statistic = 38.18 using 38 PHA bins and 37 degrees of freedom.

Warning: Cstat statistic is only valid for Poisson data.

XSPEC12>plot
XSPEC12>goodness 100 nosim

32.00% of realizations are < best fit statistic 38.18



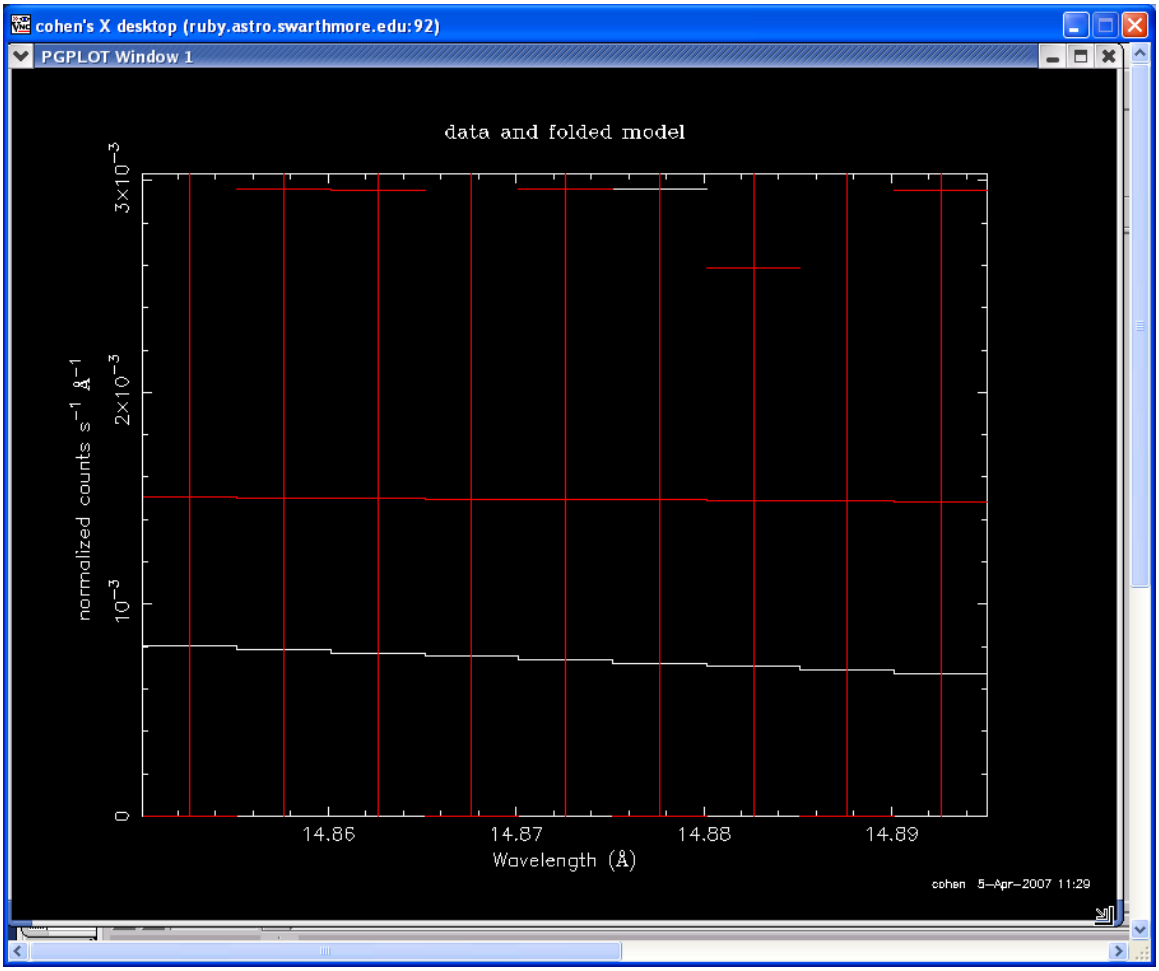
Next, on just **14.85:14.90**

```
========================================================================
Model powerlaw<1> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   powerlaw   PhoIndex            2.00000      frozen
   2    1   powerlaw   norm               1.90864E-03  +/-  1.24649E-03
------------------------------------------------------------------------
```

C-statistic = 12.00 using 18 PHA bins and 17 degrees of freedom.

Warning: Cstat statistic is only valid for Poisson data.

XSPEC12>plot
XSPEC12>goodness 100 nosim
5.00% of realizations are < best fit statistic 12.00



OK, this is almost exactly the same value we got for the simultaneous line+continuum fit; and it seems to exclude any and all weak lines.

It may seem a little ad hoc, but we have to keep our eyes open, as it's easy to include portions of the spectrum in the "continuum" fit that include weak, unidentified lines.

It seems to me that if the independently derived continuum level overpredicts the part of the continuum adjacent to a line, then something's wrong. It is (essentially) only possible to overestimate the continuum level when fitting an ostensibly line-free portion of the continuum; it is nearly impossible to significantly underestimate the continuum level.

So, I think this reevaluation of the continuum level is the right thing to do.

Now, let's go back to fitting the line over a broader range of wavelengths, say 14.90:15.10, with the continuum fixed at this low level - **1.90864E-03**

Fixing the continuum level at 1.909e-3 (with index=2); we can now fit the windproof model to the Fe XVII 15.014 profile.

The two effects we want to investigate are

(a) The assumed terminal velocity – we'll test 2200 km/s and 2485 km/s (two commonly referenced values from the literature).
(b) The wavelength range over which we fit the line. For this line, this might be an issue because of possible contamination on the red wing. We'll test 14.90:15.10 and 14.90:15.06. Even the broader range excises a bit of the red wing, but what looks like an extra emission bump is included in the broader range and excluded in the narrower range.

So, below, I present four fits:

1. vinf=2485 fit on 14.90:15.10
2. vinf=2200 fit on 14.90:15.10
3. vinf=2485 fit on 14.90:15.06
4. vinf=2200 fit on 14.90:15.06

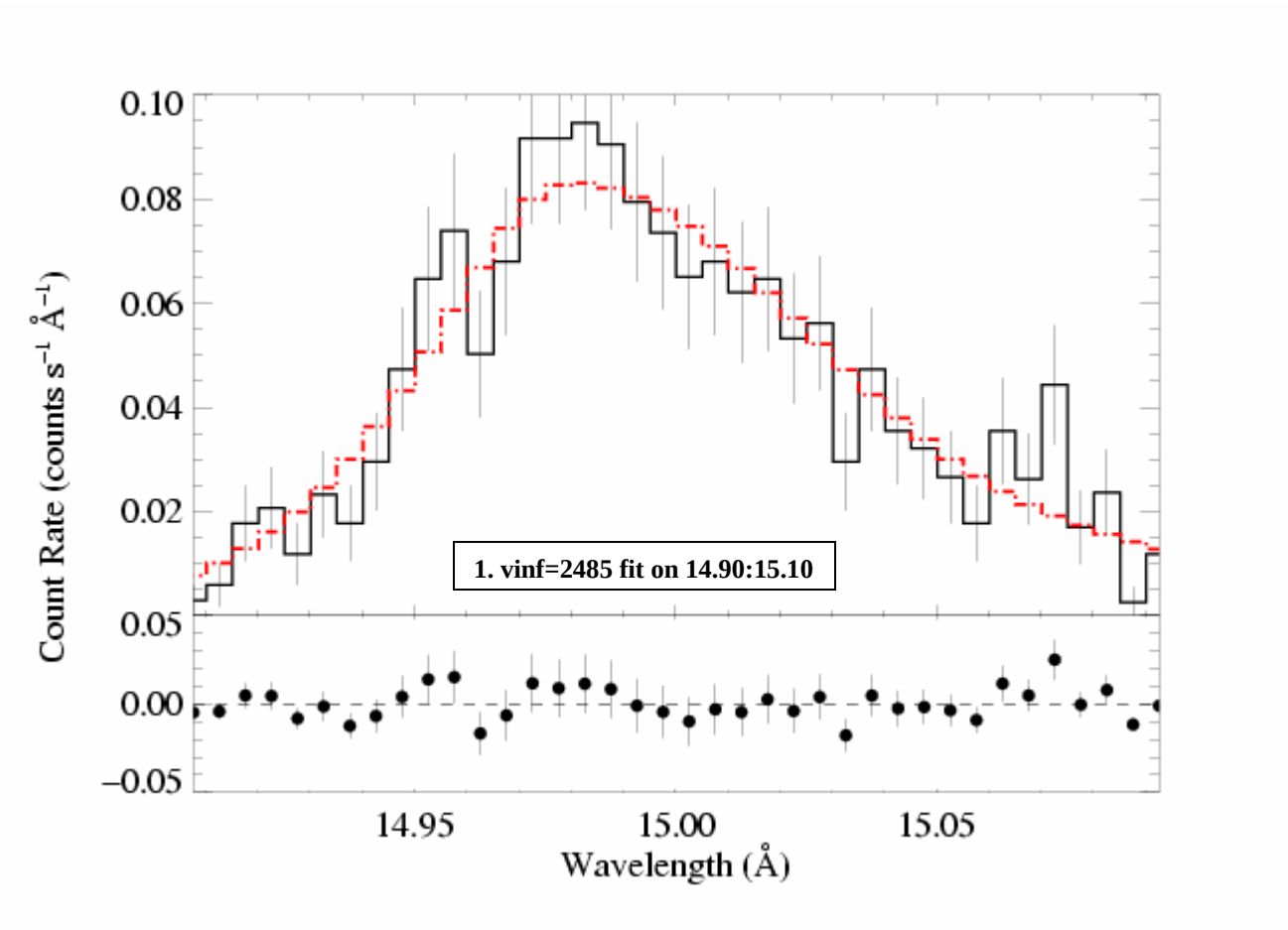
note that the powerlaw continuum level is frozen identically for all four fits.

1. vinf=2485 fit on 14.90:15.10

```
========================================================================
Model windprof<1> + powerlaw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1  windprof   q              0.276047     +/-  0.231172
   2    1  windprof   taustar          1.40756     +/-  0.276013
   3    1  windprof   u0             0.631757     +/-  5.19428E-02
   4    1  windprof   h              0.0          frozen
   5    1  windprof   tau0star         0.0          frozen
   6    1  windprof   beta           1.00000      frozen
   7    1  windprof   betaSob          0.0          frozen
   8    1  windprof   numerica         0            frozen
   9    1  windprof   anisotro         0            frozen
  10    1  windprof   rosselan         0            frozen
  11    1  windprof   expansio         0            frozen
  12    1  windprof   thick            0            frozen
  13    1  windprof   waveleng   "A"      15.0140      frozen
  14    1  windprof   shift      "mA"     0.0          frozen
  15    1  windprof   velocity   (scale)  2485.00
  16    1  windprof   verbose          0            frozen
  17    1  windprof   norm           5.15823E-04  +/-  4.51885E-05
  18    2  powerlaw   PhoIndex         2.00000      frozen
  19    2  powerlaw   norm           1.90000E-03  frozen
------------------------------------------------------------------------

 C-statistic =          76.29 using 78 PHA bins and 74 degrees of freedom.
```

XSPEC12>goodness 1000 nosim
31.30% of realizations are < best fit statistic 76.29



2. vinf=2200 fit on 14.90:15.10

```
========================================================================
Model windprof<1> + powerlaw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   windprof   q              0.102343     +/-  0.169240
   2    1   windprof   taustar        2.11219      +/-  0.442785
   3    1   windprof   u0             0.634940     +/-  8.69144E-02
   4    1   windprof   h              0.0          frozen
   5    1   windprof   tau0star       0.0          frozen
   6    1   windprof   beta           1.00000      frozen
   7    1   windprof   betaSob        0.0          frozen
   8    1   windprof   numerica       0            frozen
   9    1   windprof   anisotro       0            frozen
  10    1   windprof   rosselan       0            frozen
  11    1   windprof   expansio       0            frozen
  12    1   windprof   thick          0            frozen
  13    1   windprof   waveleng   "A"     15.0140      frozen
  14    1   windprof   shift      "mA"    0.0          frozen
  15    1   windprof   velocity   (scale) 2200.00
  16    1   windprof   verbose        0            frozen
  17    1   windprof   norm           5.18591E-04  +/-  4.38937E-05
  18    2   powerlaw   PhoIndex       2.00000      frozen
  19    2   powerlaw   norm           1.90000E-03  frozen
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 C-statistic =          74.79 using 78 PHA bins and 74 degrees of freedom.
```
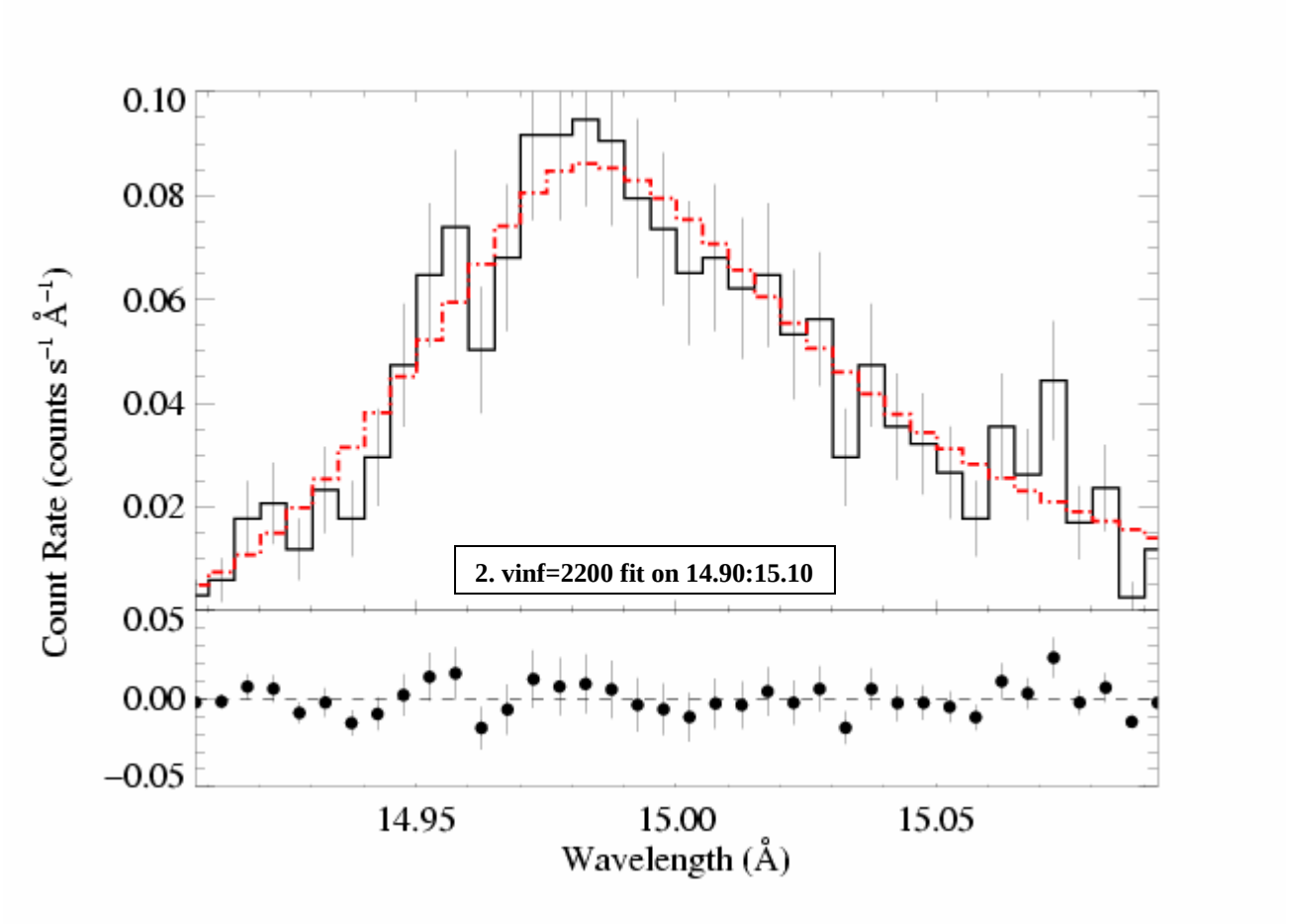

Lower C value by about 1.4

XSPEC12>goodness 100 nosim
29.00% of realizations are < best fit statistic 74.79


0.10
0.08
0.06
0.04
0.02
0.05
0.00
−0.05
Count Rate (counts s^{-1} Å^{-1})
2. vinf=2200 fit on 14.90:15.10
14.95
15.00
15.05
Wavelength (Å)

Now, let’s repeat these two fits, but eliminating the bump on the red wing

Higher terminal velocity (2485) first:

3. vinf=2485 fit on 14.90:15.06

```
========================================================================
Model windprof<1> + powerlaw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   windprof   q              0.586390     +/-  0.346974
   2    1   windprof   taustar         1.58780     +/-  0.284225
   3    1   windprof   u0             0.625070     +/-  5.10832E-02
   4    1   windprof   h              0.0          frozen
   5    1   windprof   tau0star       0.0          frozen
   6    1   windprof   beta           1.00000      frozen
   7    1   windprof   betaSob        0.0          frozen
   8    1   windprof   numerica       0            frozen
   9    1   windprof   anisotro       0            frozen
  10    1   windprof   rosselan       0            frozen
  11    1   windprof   expansio       0            frozen
  12    1   windprof   thick          0            frozen
  13    1   windprof   waveleng   "A"     15.0140      frozen
  14    1   windprof   shift      "mA"    0.0          frozen
  15    1   windprof   velocity   (scale) 2485.00
  16    1   windprof   verbose        0            frozen
  17    1   windprof   norm           4.93146E-04  +/-  4.81336E-05
  18    2   powerlaw   PhoIndex       2.00000      frozen
  19    2   powerlaw   norm           1.90000E-03  frozen
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 C-statistic =          44.12 using 62 PHA bins and 58 degrees of freedom.

XSPEC12>goodness 100 nosim
4.00% of realizations are < best fit statistic 44.12
```

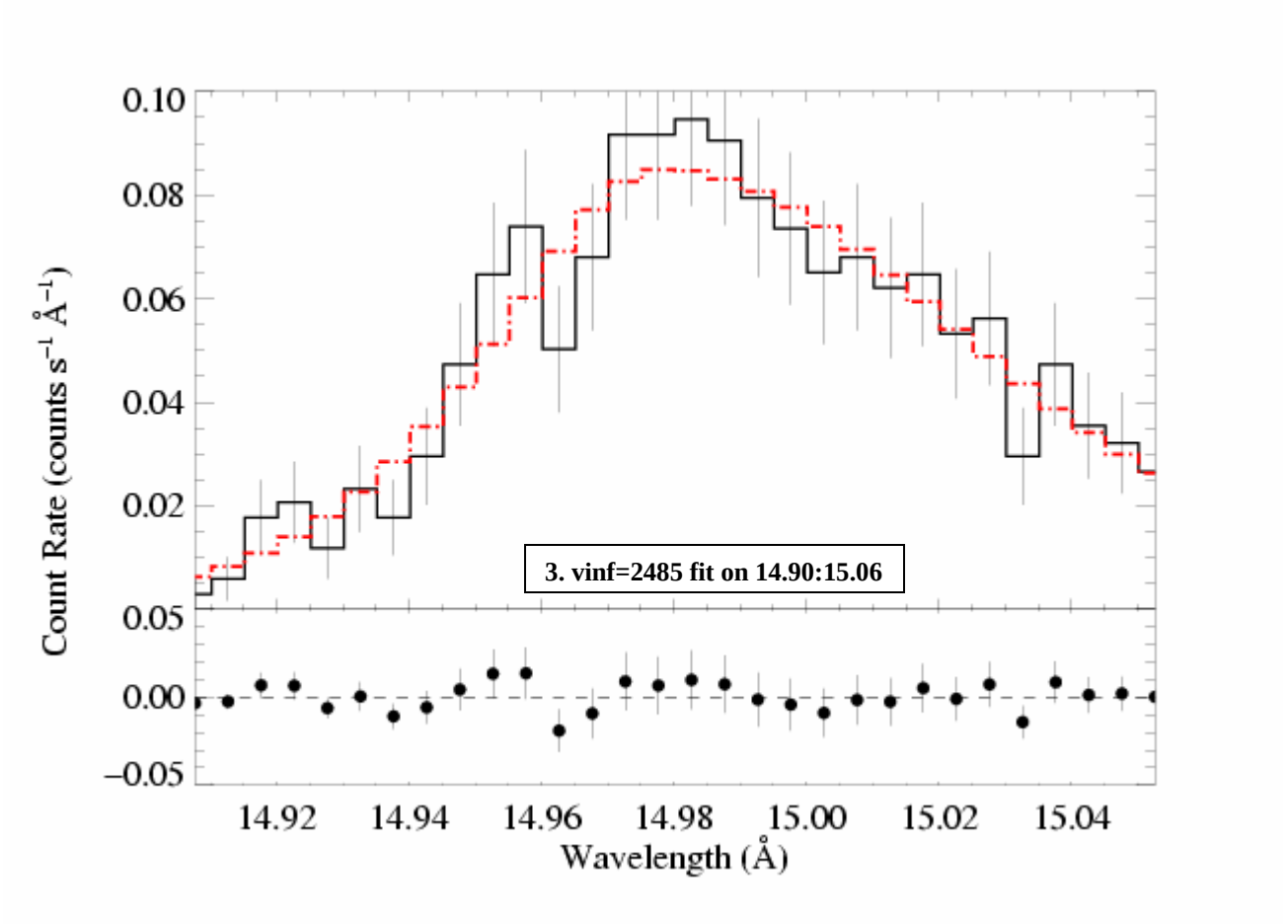
0.10
0.08
0.06
0.04
0.02
0.05
0.00
−0.05
Count Rate (counts s^{-1} Å^{-1})
3. vinf=2485 fit on 14.90:15.06
14.92
14.94
14.96
14.98
15.00
15.02
15.04
Wavelength (Å)

4. vinf=2200 fit on 14.90:15.06

```
========================================================================
Model windprof<1> + powerlaw<2> Source No.: 1   Active/On
Model Model Component  Parameter  Unit     Value
 par  comp
   1    1   windprof   q              0.242630     +/-  0.241888
   2    1   windprof   taustar         2.25991     +/-  0.453241
   3    1   windprof   u0             0.632599     +/-  8.73260E-02
   4    1   windprof   h              0.0          frozen
   5    1   windprof   tau0star       0.0          frozen
   6    1   windprof   beta           1.00000      frozen
   7    1   windprof   betaSob        0.0          frozen
   8    1   windprof   numerica       0            frozen
   9    1   windprof   anisotro       0            frozen
  10    1   windprof   rosselan       0            frozen
  11    1   windprof   expansio       0            frozen
  12    1   windprof   thick          0            frozen
  13    1   windprof   waveleng   "A"     15.0140      frozen
  14    1   windprof   shift      "mA"    0.0          frozen
  15    1   windprof   velocity   (scale)  2200.00
  16    1   windprof   verbose        0            frozen
  17    1   windprof   norm           5.06210E-04  +/-  4.77395E-05
  18    2   powerlaw   PhoIndex       2.00000      frozen
  19    2   powerlaw   norm           1.90000E-03  frozen
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 C-statistic =          44.91 using 62 PHA bins and 58 degrees of freedom.
```
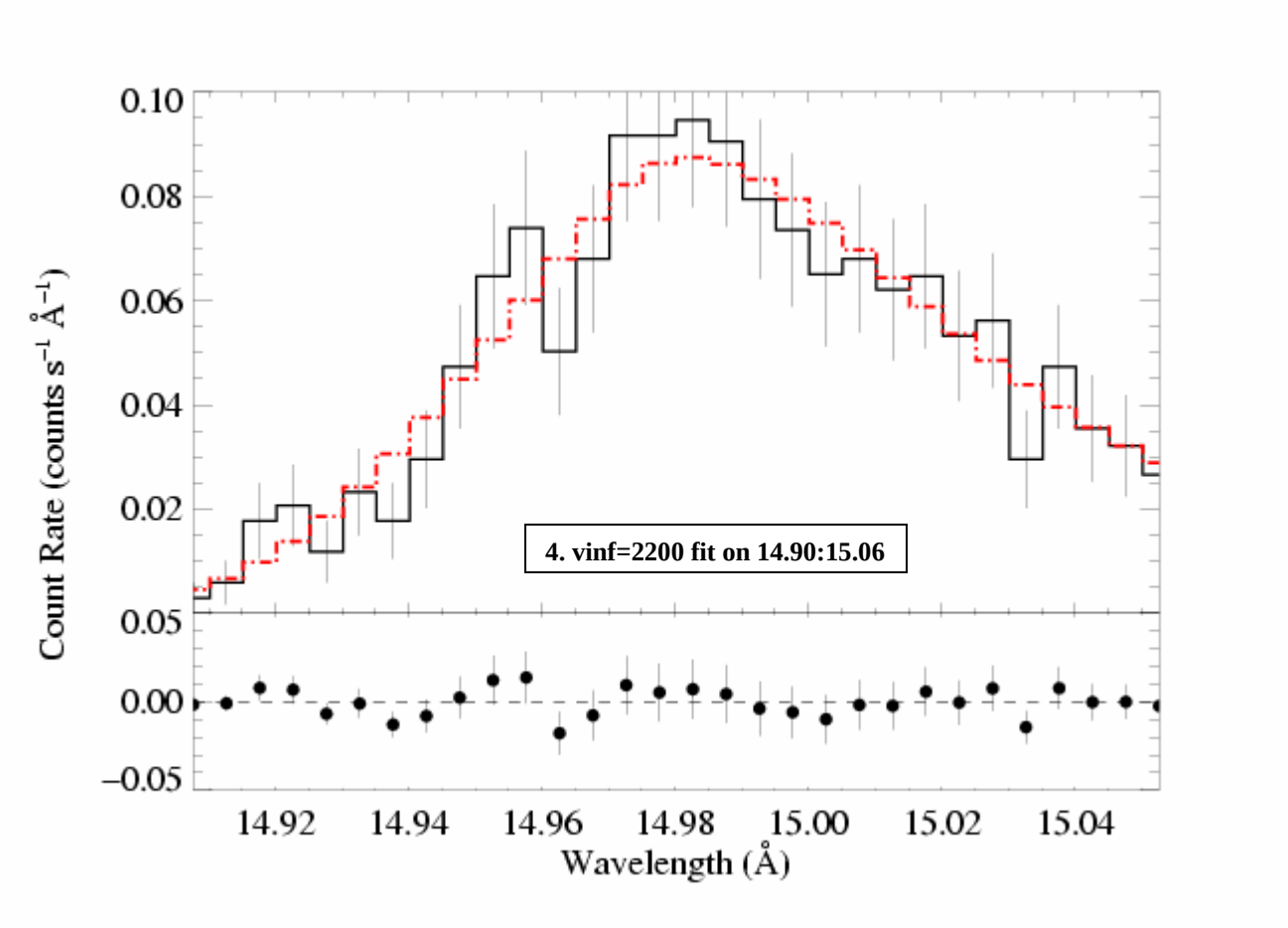

Note that C is only slightly better (Delta-C < 1.0) compared to the previous fit, with the higher terminal velocity

```
XSPEC12>goodness 100 nosim
2.00% of realizations are < best fit statistic 44.91
```



Let's summarize these fitting results:

v_inf	lam range	q	tau_star	u_max	norm (/10-4)	C	MC%
2485	14.90:15.10	0.28	1.41	0.63	5.16	76.29	31%
2200	14.90:15.10	0.1	2.11	0.63	5.19	74.79	29%
2485	14.90:15.06	0.59	1.59	0.63	4.93	44.12	4%
2200	14.90:15.06	0.24	2.26	0.63	5.06	44.91	2%

Main conclusions:

- neither wind velocity value is strongly preferred statistically (though, for the wider wavelength range, the small velocity is preferred at the ~1 sigma level);
- the fit parameters don't change significantly when the red wing is excluded;
- u_max is especially robust;
- taustar gets significantly (50%) bigger when we use the smaller terminal velocity.