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ASTROPHYSICS

HARVARD & SMITHSONIAN

Issues in Measuring Line Shapes

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AtomDB Workshop

Advanced Spectroscopy School

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Outline

- **Motivation: Stellar Coronal Heating Diagnostics**
- **What to do when the “Best Fit” doesn’t**
 - **What to expect from the atomic data**
 - **Examine the important spectral components**
 - **Try things, like the line shape**
- **Conclusions**

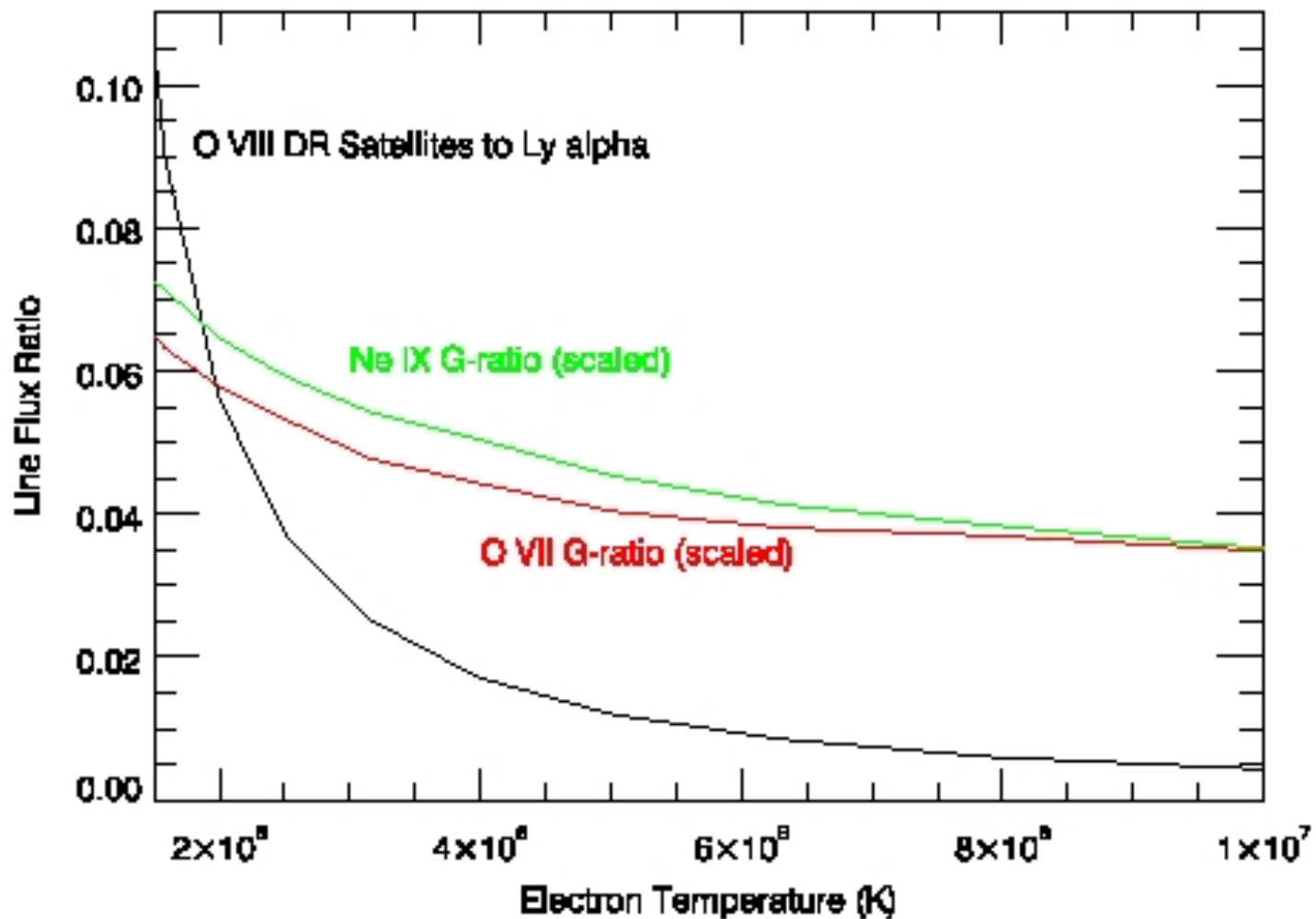
Motivation: Stellar Coronal Heating Diagnostics

- The solar coronal heating problem remains unsolved since the 1930's with the discovery of the **red (Fe X)** and **green (Fe XIV)** optical forbidden lines
- Stellar coronae observed with EUVE and the Chandra and XMM-Newton gratings often show high N_e ($>10^{12}$ cm $^{-3}$) compared with solar active regions ($\sim 10^9$ to 10^{10} cm $^{-3}$).
- Solar impulsive flare models can reproduce the shape of the emission measure distribution (EMD) but not at high N_e (Cargill & Klimchuk 2006).

Motivation: Stellar Coronal Heating Diagnostics

- Impulsive heating or “nanoflare” models intrinsically imply **non-equilibrium ionization**. For a given N_e , cooling (recombination) times are longer than heating (ionization) times, so time-averaged the plasma should appear to be recombining.
- Magnetic wave heating models are steady-state; should be in **collisional ionization equilibrium**.
- Compare T_e determined from a single ionization state to T_e determined from the charge state balance in CIE.

DR satellite diagnostics vs He-like G-ratios

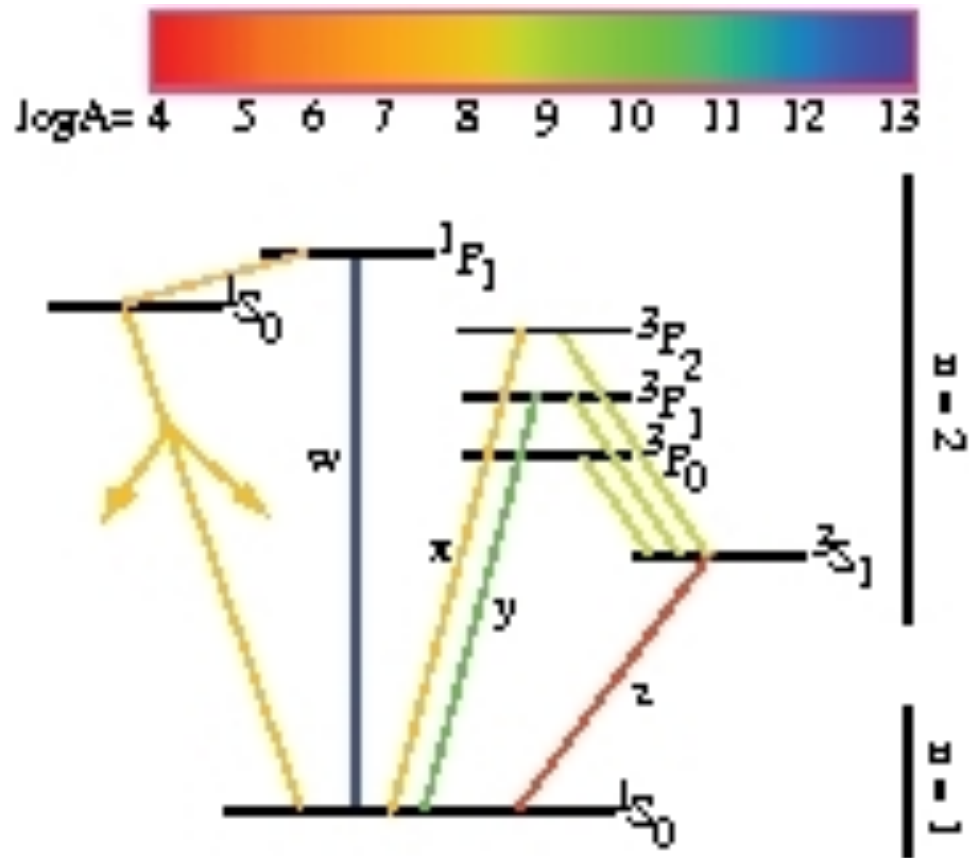


O_VIII	18.967	4	1	2.559e-15	3.162e+06	1.00
O_VII_DRsat	18.969	10112	33	2.073e-18	2.512e+06	0.00
O_VII_DRsat	18.969	10104	37	3.320e-18	2.512e+06	0.00
O_VII_DRsat	18.970	10089	31	1.364e-18	2.512e+06	0.00
Mn_XVI	18.972	3	1	1.644e-18	5.012e+06	0.00
N_VII	18.972	39	1	1.735e-18	2.512e+06	0.00
O_VIII	18.973	3	1	1.282e-15	3.162e+06	0.50
O_VII_DRsat	18.977	10132	38	1.110e-18	2.512e+06	0.00
O_VII_DRsat	18.984	10081	24	1.145e-18	2.512e+06	0.00
O_VII_DRsat	18.987	10071	21	1.257e-18	2.512e+06	0.00
O_VII_DRsat	18.987	10127	41	1.171e-18	2.512e+06	0.00
O_VII_DRsat	18.988	10137	40	8.520e-18	2.512e+06	0.00
O_VII_DRsat	18.990	10136	40	1.267e-18	2.512e+06	0.00
O_VII_DRsat	18.990	10136	39	4.924e-18	2.512e+06	0.00
O_VII_DRsat	18.990	10118	37	3.005e-18	2.512e+06	0.00
O_VII_DRsat	18.992	10135	38	3.031e-18	2.512e+06	0.00
O_VII_DRsat	19.001	10052	18	1.163e-18	2.512e+06	0.00
O_VII_DRsat	19.003	10051	18	1.279e-18	2.512e+06	0.00
O_VII_DRsat	19.005	10076	27	1.524e-18	2.512e+06	0.00
O_VII_DRsat	19.005	10071	23	1.060e-18	2.512e+06	0.00
O_VII_DRsat	19.007	10086	26	1.080e-17	2.512e+06	0.00
O_VII_DRsat	19.007	10067	23	3.757e-18	2.512e+06	0.00
O_VII_DRsat	19.007	10015	12	2.422e-18	2.512e+06	0.00
O_VII_DRsat	19.008	10027	11	1.082e-18	2.512e+06	0.00
O_VII_DRsat	19.010	10085	25	6.673e-18	2.512e+06	0.00
O_VII_DRsat	19.010	10085	26	1.284e-18	2.512e+06	0.00
O_VII_DRsat	19.012	10084	24	4.469e-18	2.512e+06	0.00
O_VII_DRsat	19.012	10084	25	1.240e-18	2.512e+06	0.00
O_VII_DRsat	19.015	10031	11	1.224e-18	2.512e+06	0.00
O_VII_DRsat	19.016	10031	12	4.265e-18	2.512e+06	0.00

From AtomDB:
WebGuide

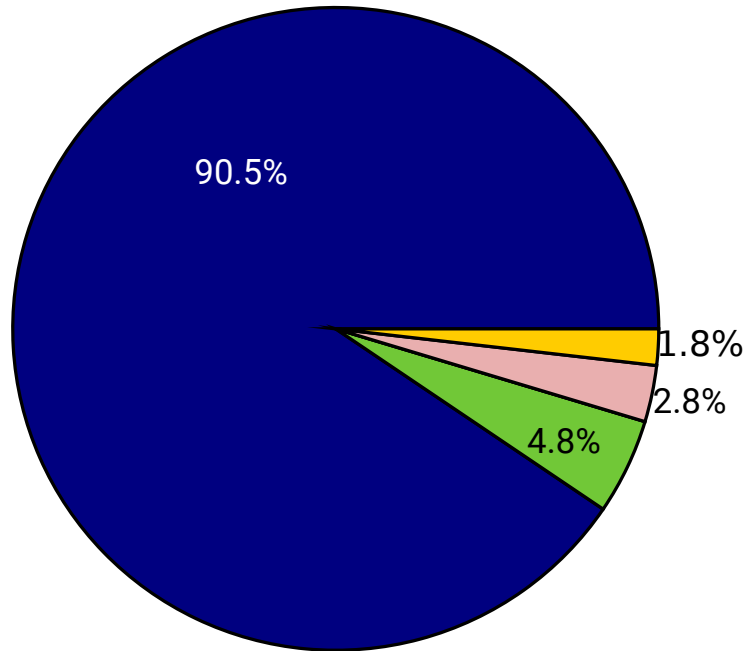
Strongest

Using AtomDB database 3.0.1

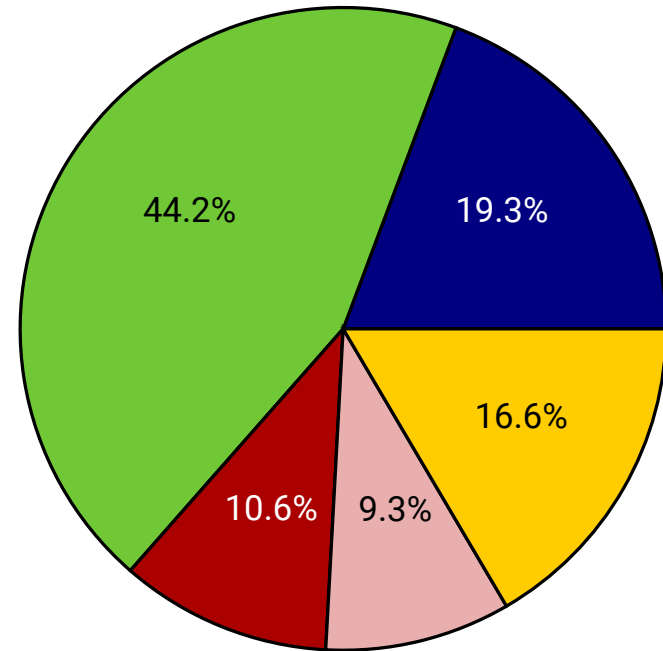


He-like Energy Levels
 T_e Diagnostic Ratios
 (Smith+ 2009)

1s 2p 1P_1 resonance line

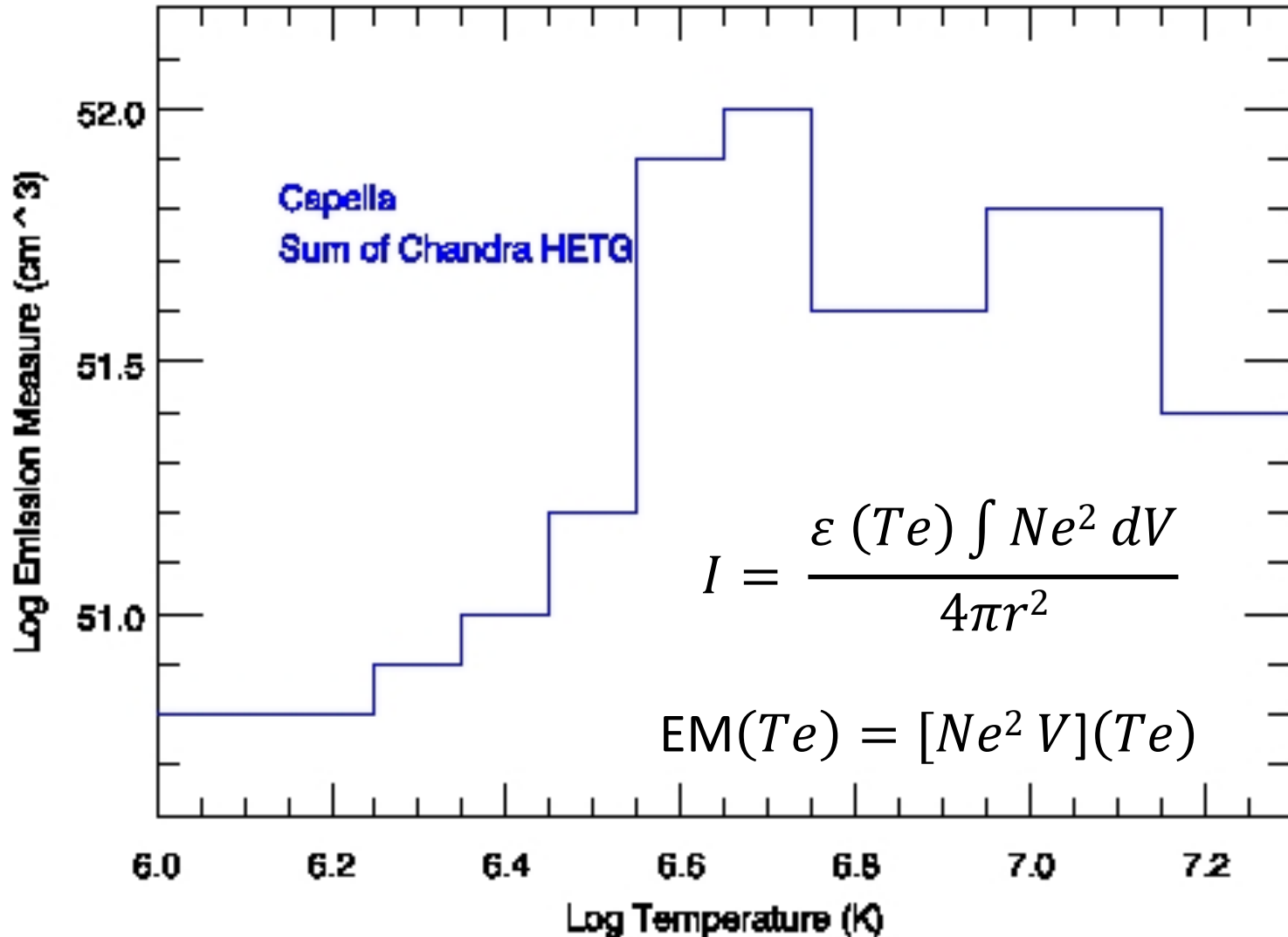


1s 2s 3S_1 forbidden line

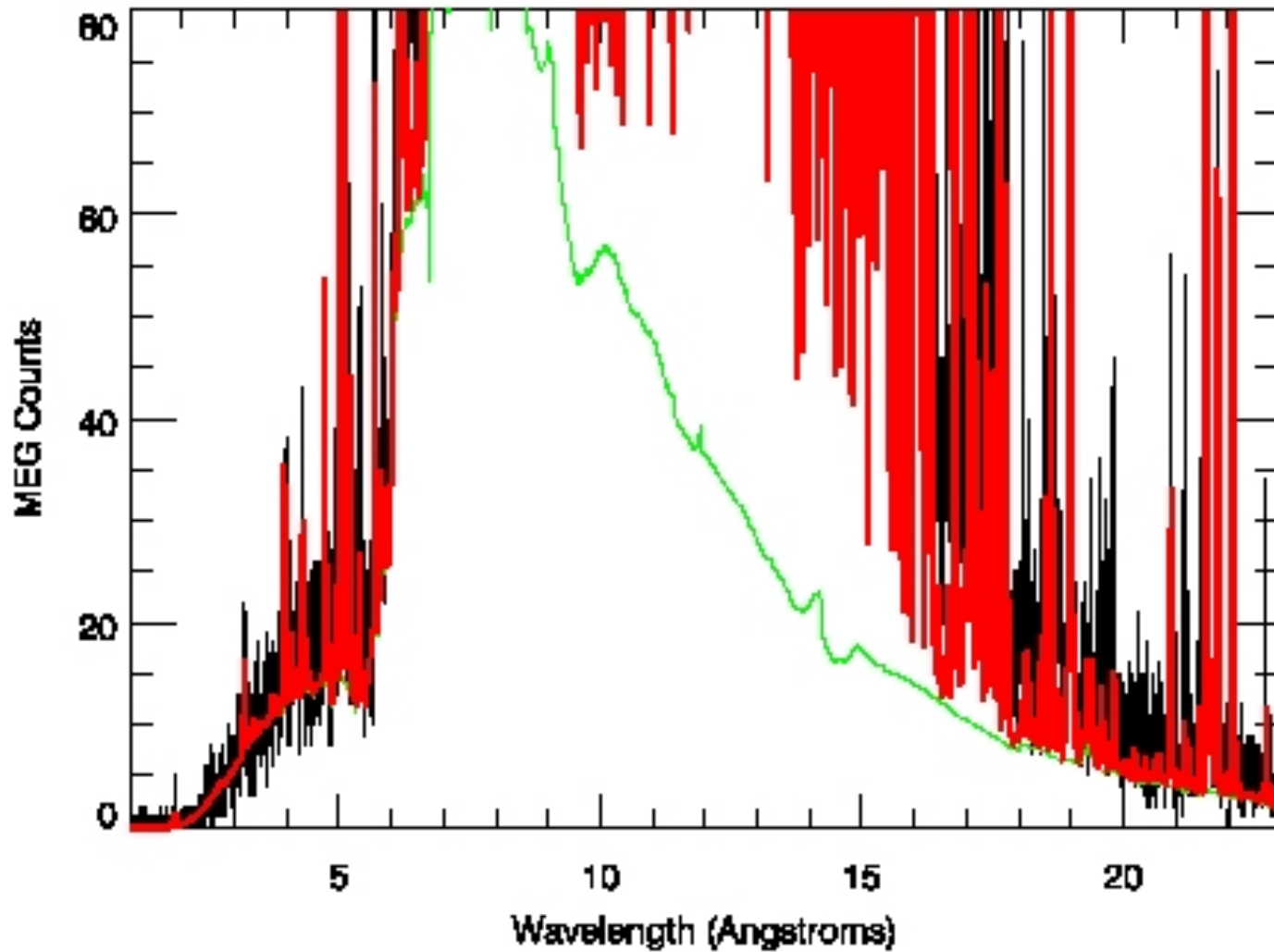


Courtesy Adam Foster

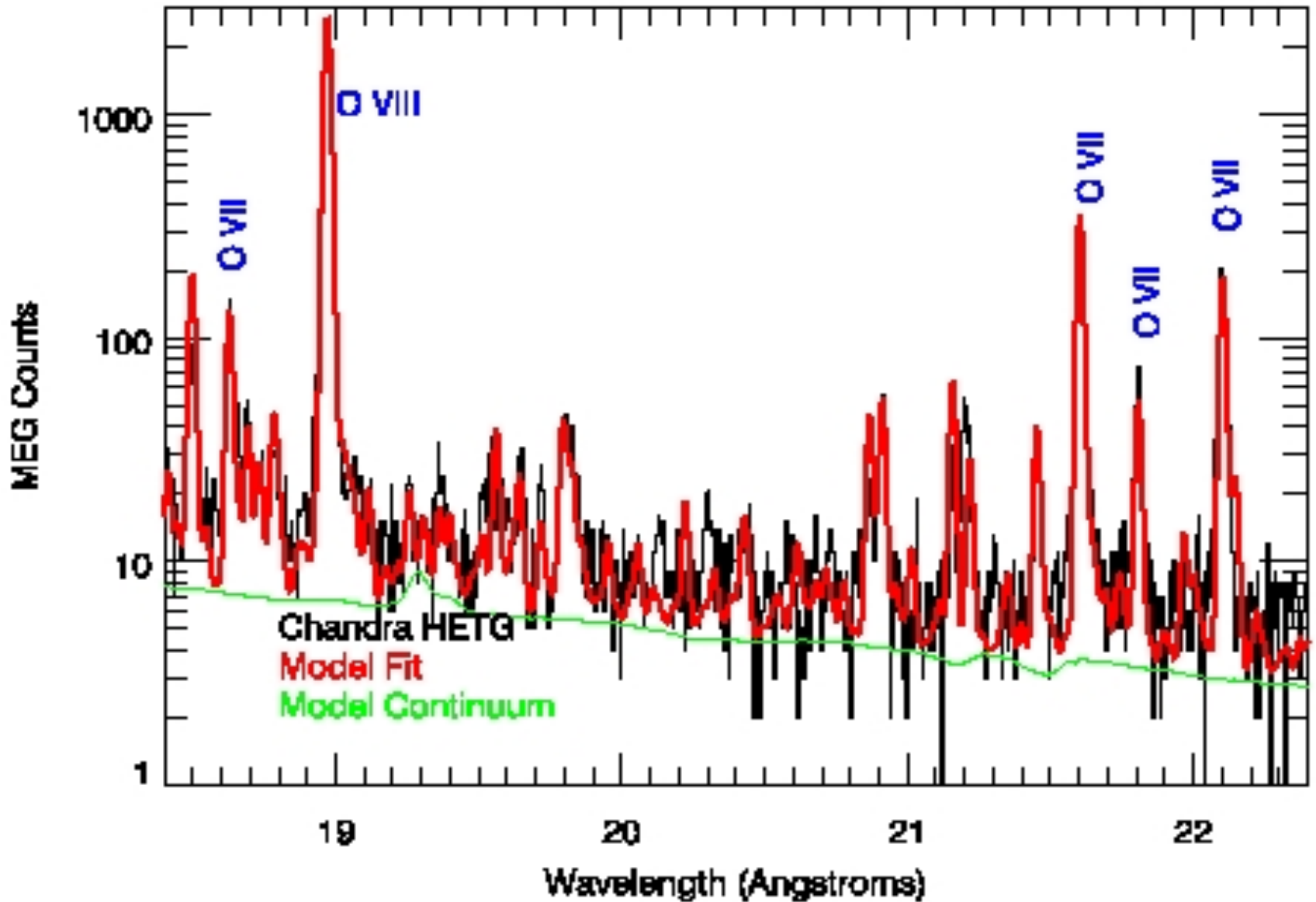
Emission Measure Distribution Model for Capella (542 ksec MEG)



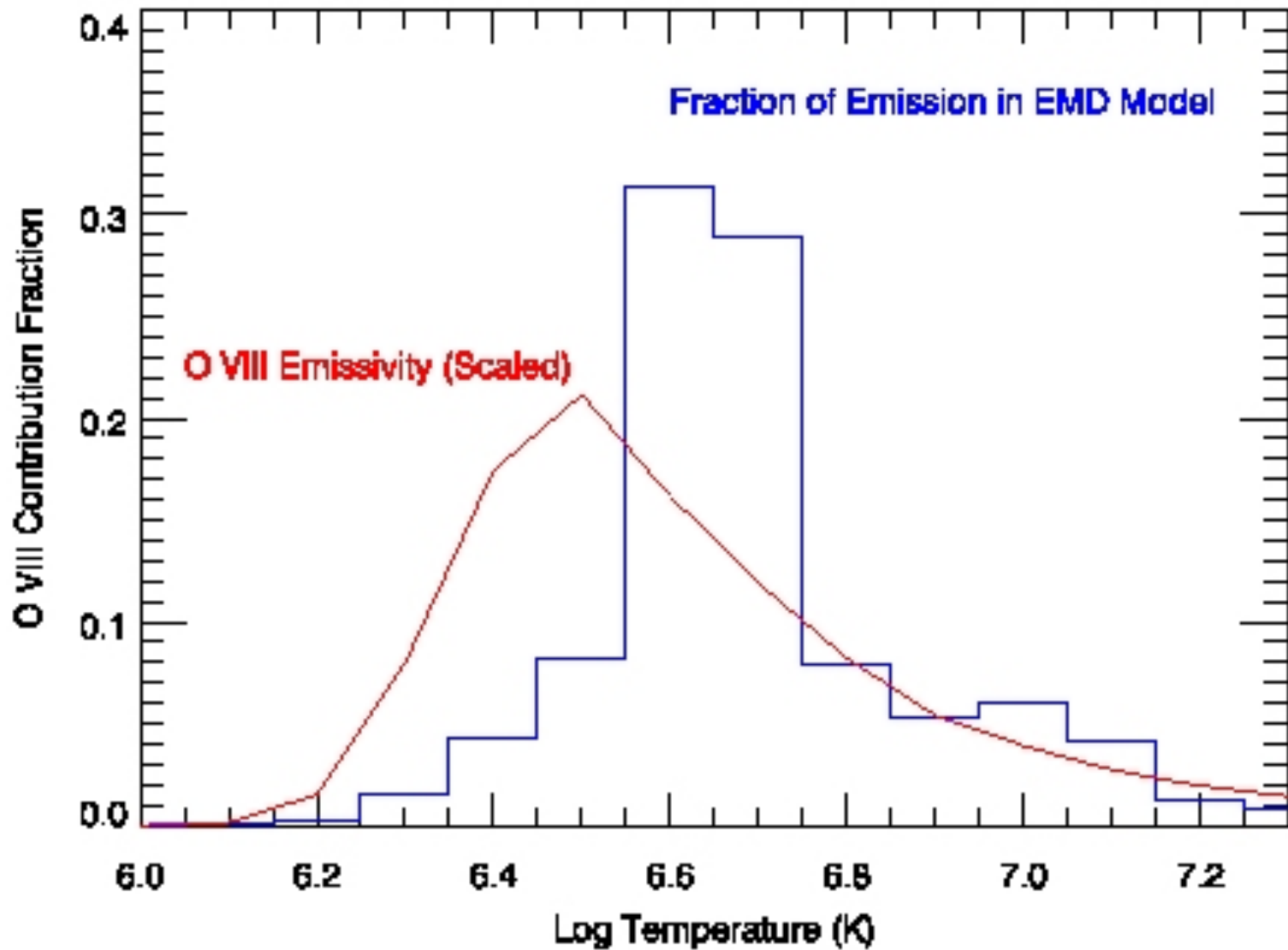
Check the Continuum Fit to “Line-Free” Regions



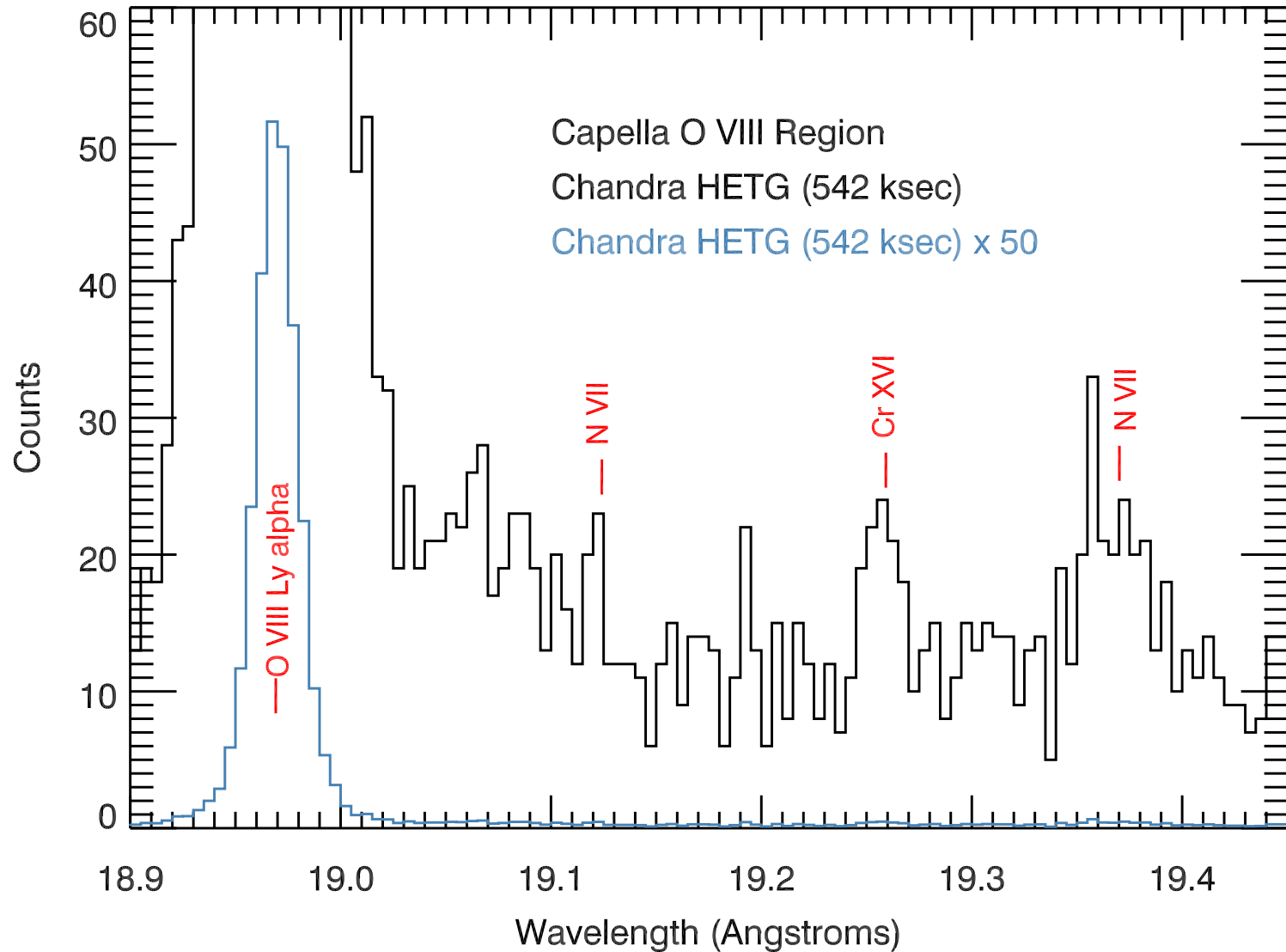
Check the fit to spectral features of interest



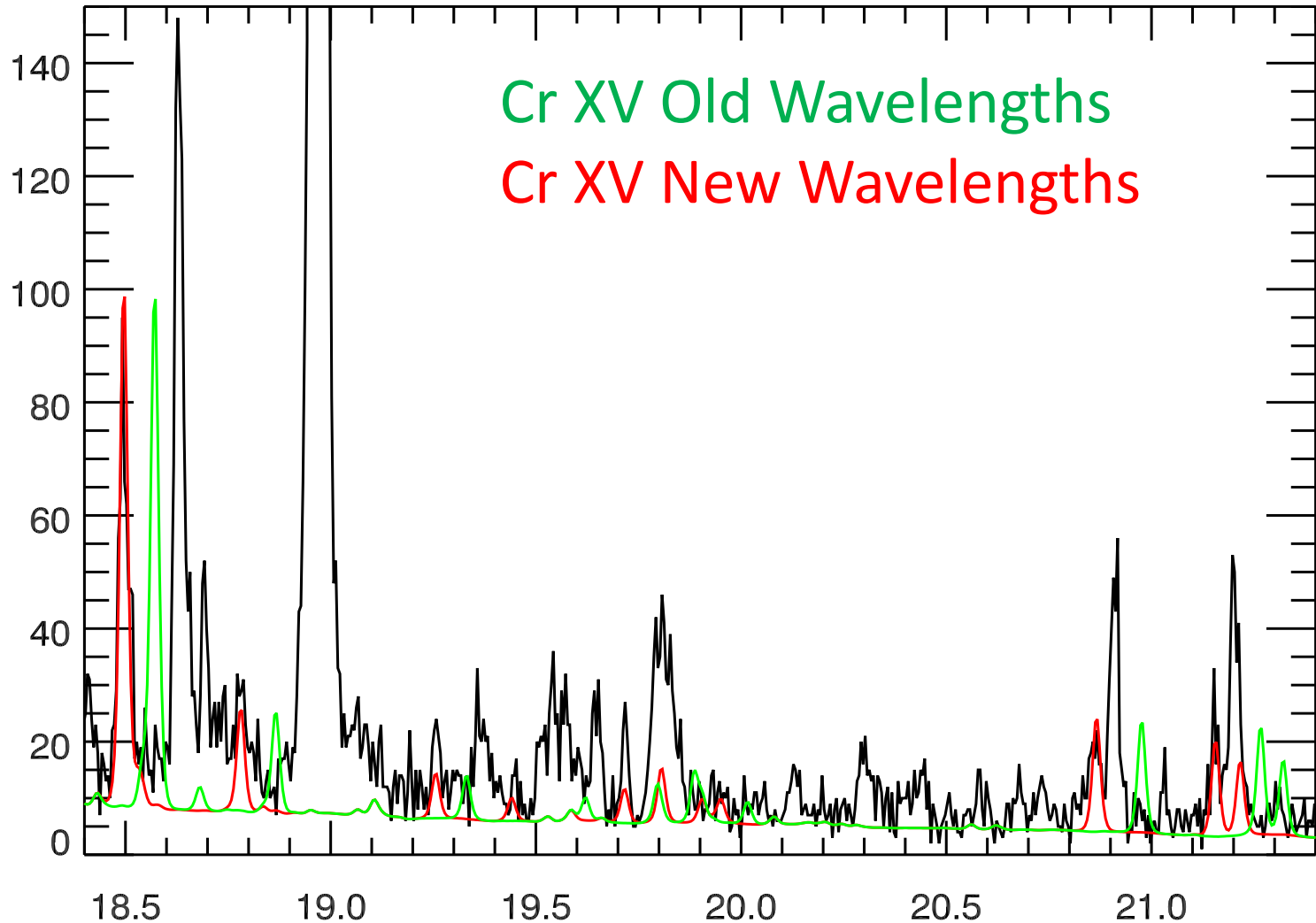
Check how the EM contributes to the line intensities



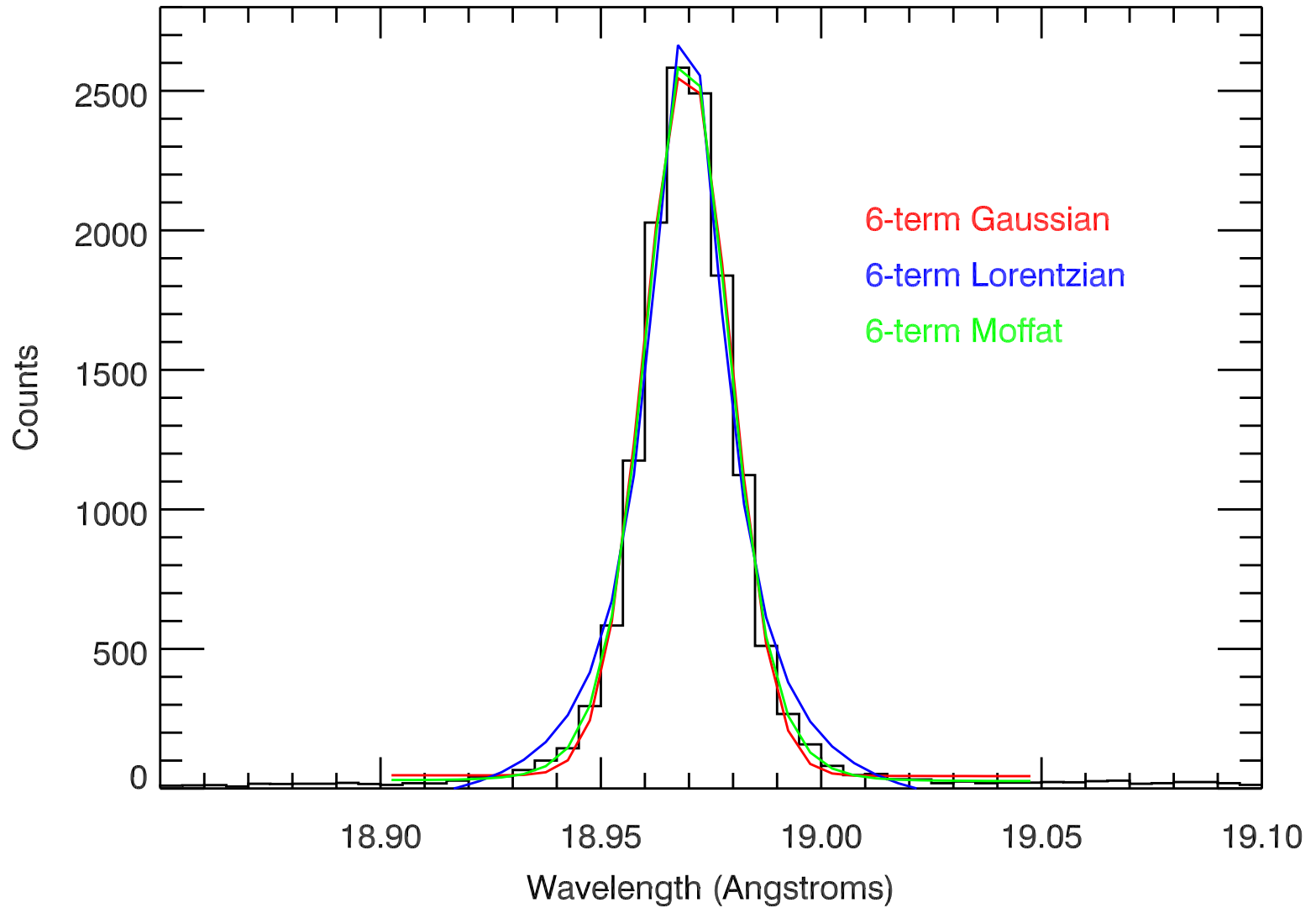
Is the continuum ok? Identify as many lines as possible. Cr XVI??? Chromium?



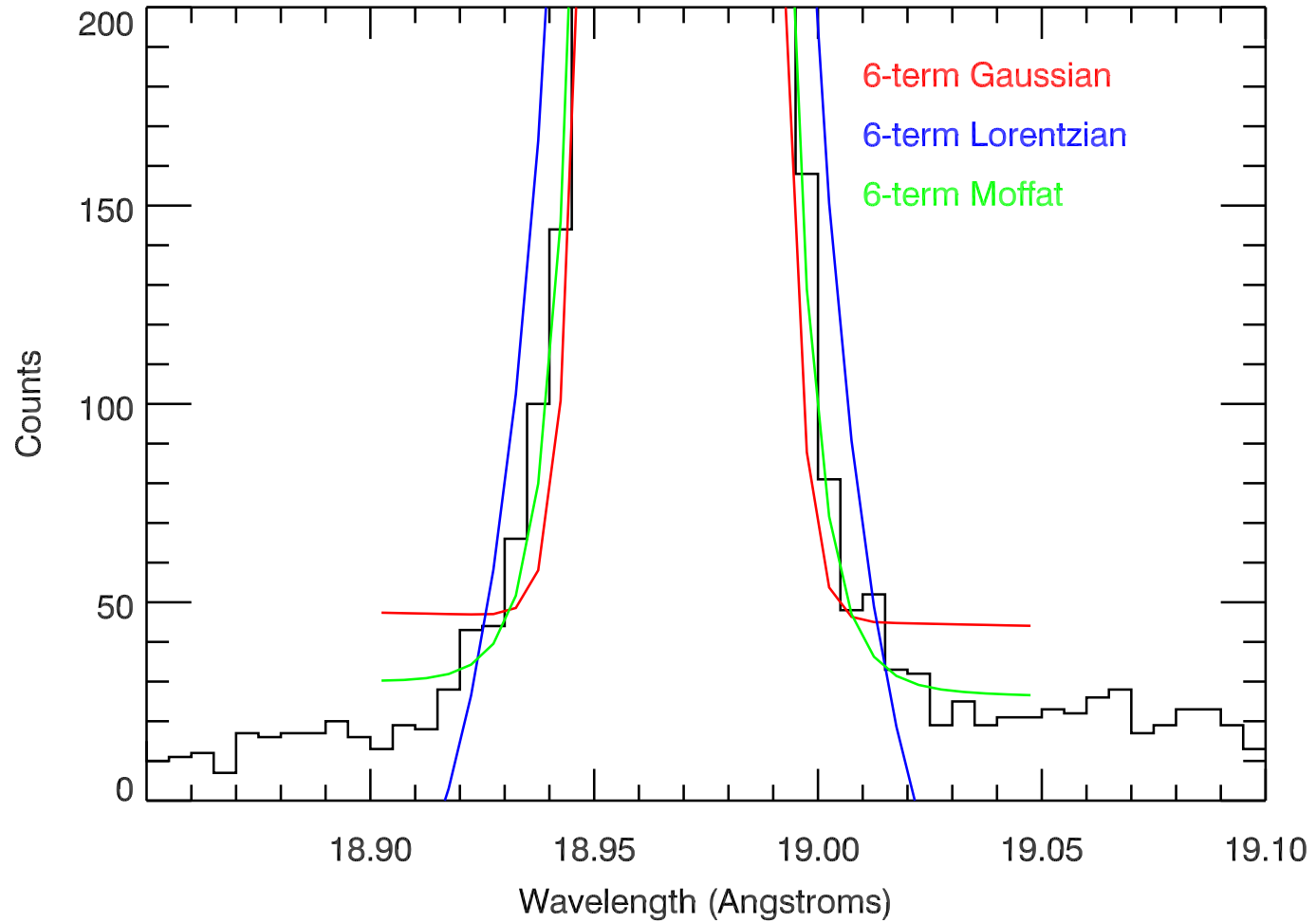
Identify weak lines. Cr XV lines were at the wrong wavelengths, but with corrections they seem right so Cr XVI is probably correct



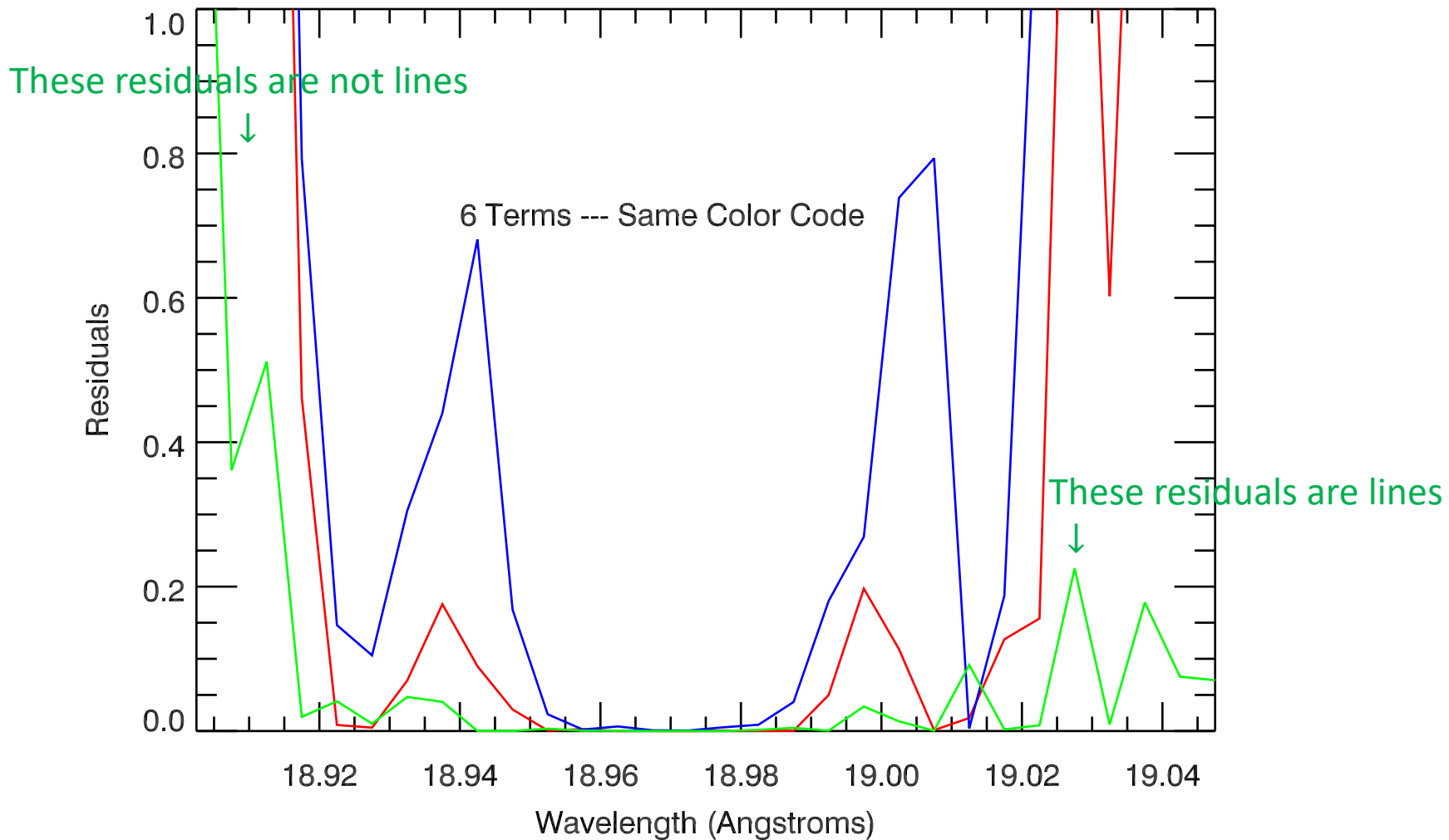
Is the (calibration) Line Spread Function correct?



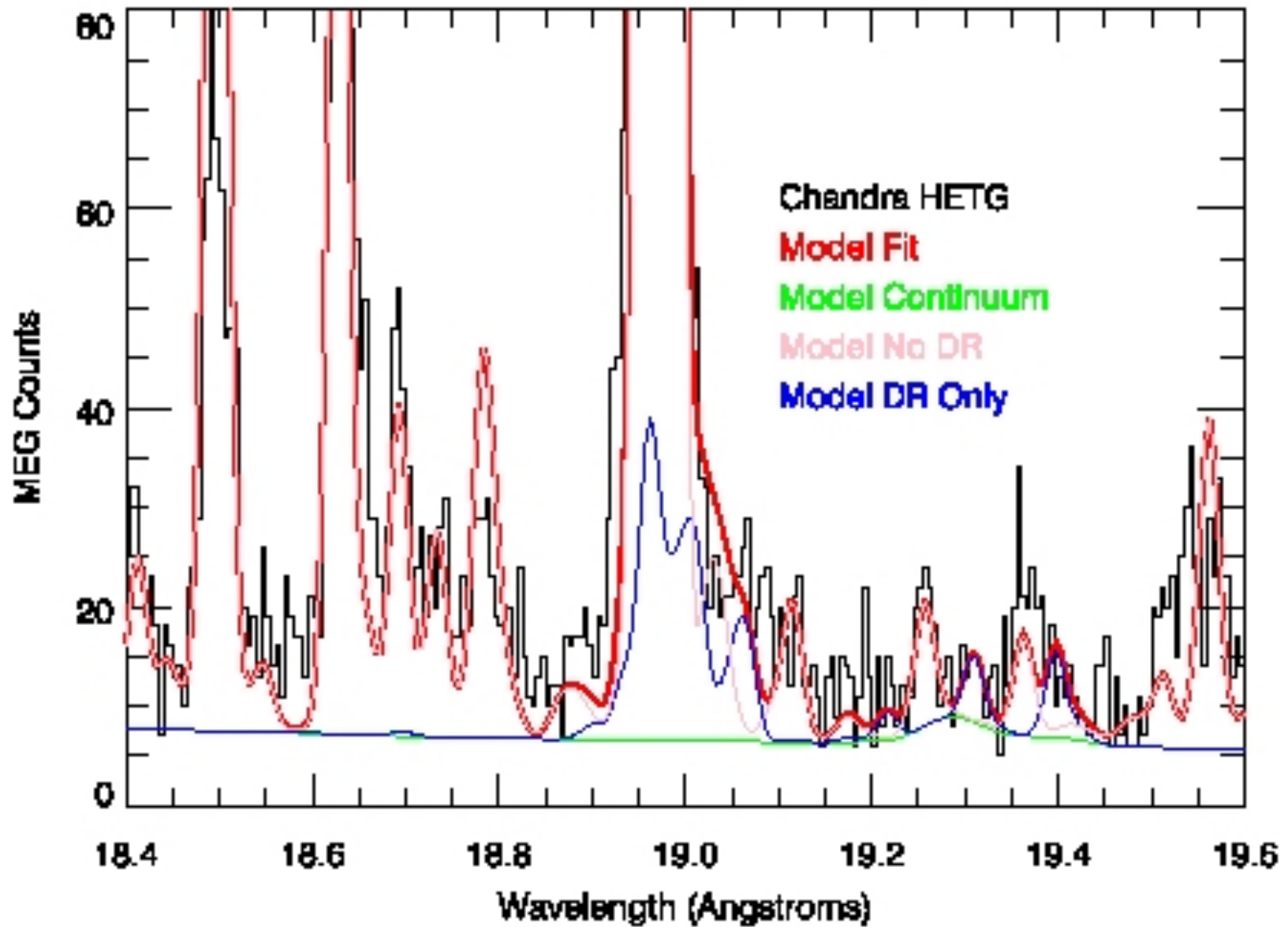
The **6-term Gaussian** fits the calibration LSF but not the wings



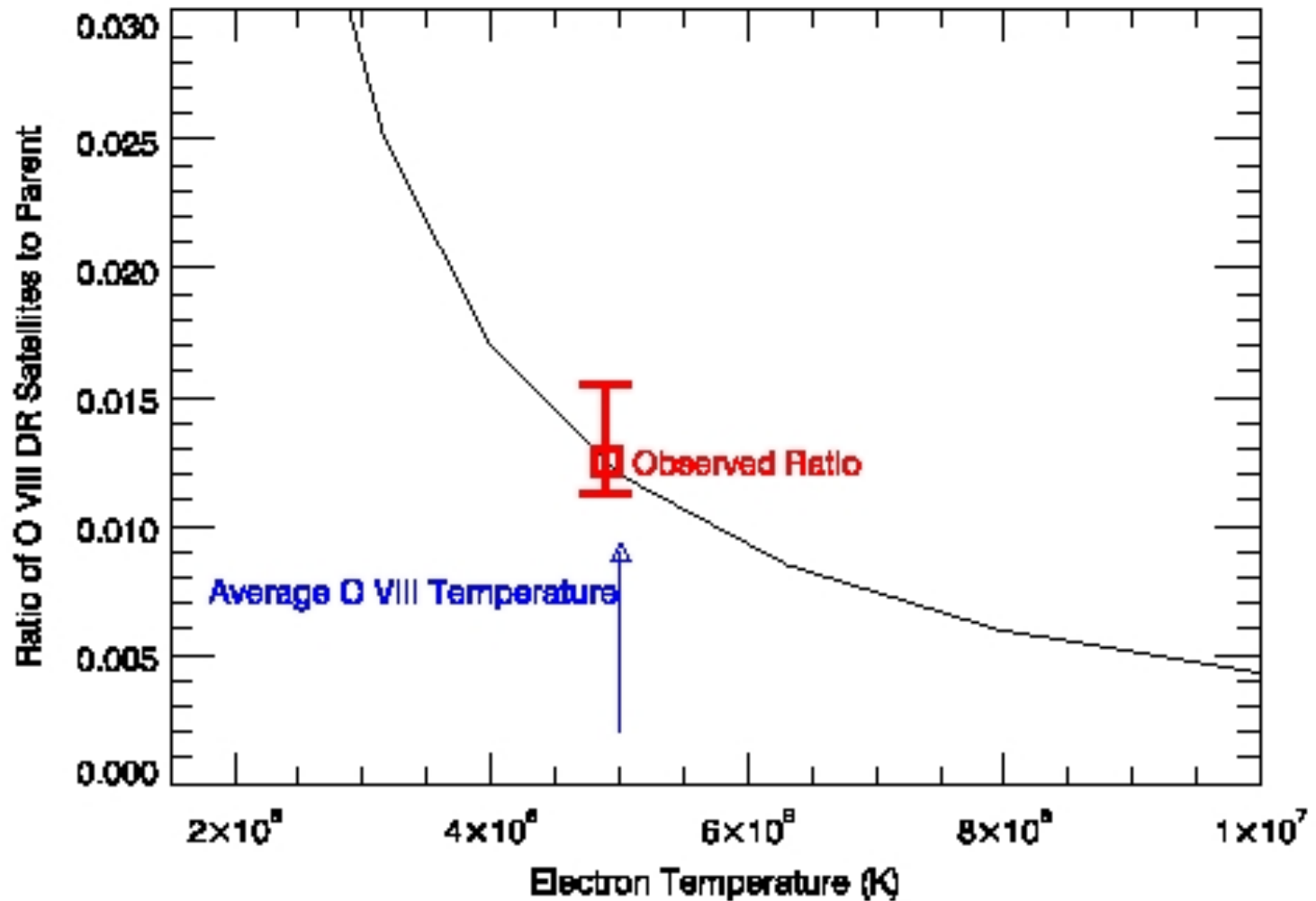
The Moffatt (Voigt) function does a good job



The fit still isn't perfect, but 3 groups of DR satellites are measurable



The fit still isn't perfect, but *preliminary result*:
O VIII DR/Ly α is close to CIE from EMD



➤ Summary

- **Signal-to-Noise Ratio is now good enough**
- **Continuum fit is excellent throughout spectrum**
- **O VII and O VIII strong lines fit well**
- **Calibration LSF probably not good enough; Voigt function is much better, can try asymmetries with Moffatt function**
- **Those pesky unidentified lines and/or lines at the wrong wavelengths confuse the picture still**
- **Is the Capella corona heated by magnetic waves, not the favorite model for the Sun? Stay tuned...**