Practicum: Use of the EVE data

First calculation of a dimming DEM?

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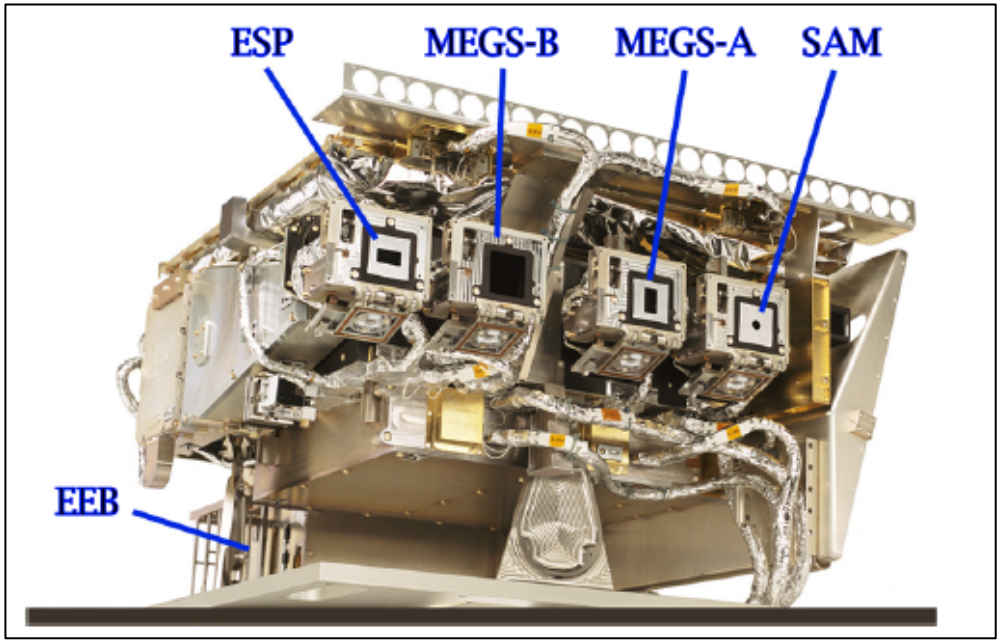
Scope of the Hudson sessions

1) Basic principles, language familiarization
2) Flares as seen in the lower solar atmosphere
3) CMEs and space weather from a flare perspective
4) Practicum: EUV spectroscopy with EVE

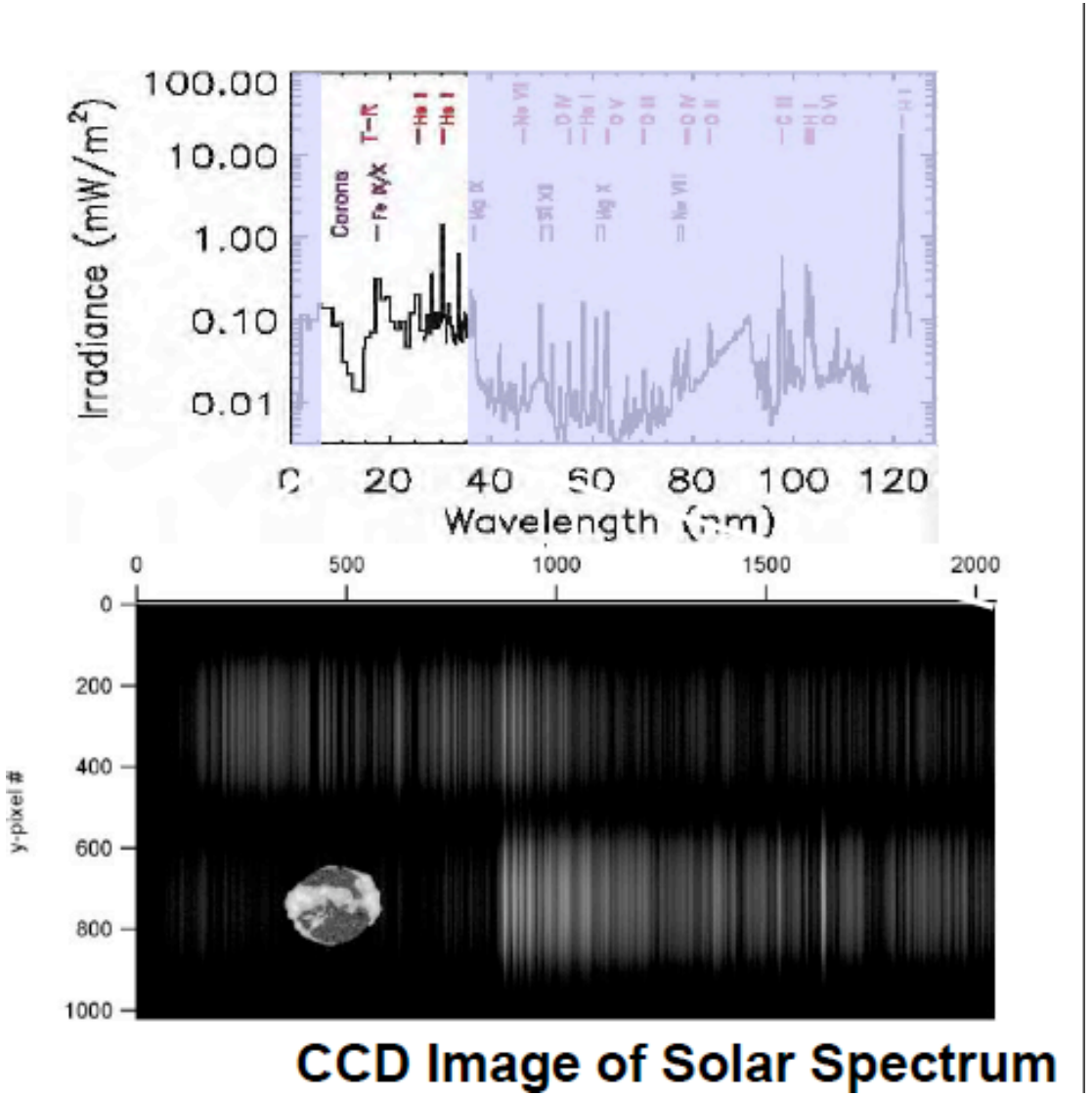
Plan for session

- Some description of the EVE experiment
- Comments on EVE science
- Description of an exciting and novel research problem that this workshop might solve



EVE, first cousin to WALL-E?

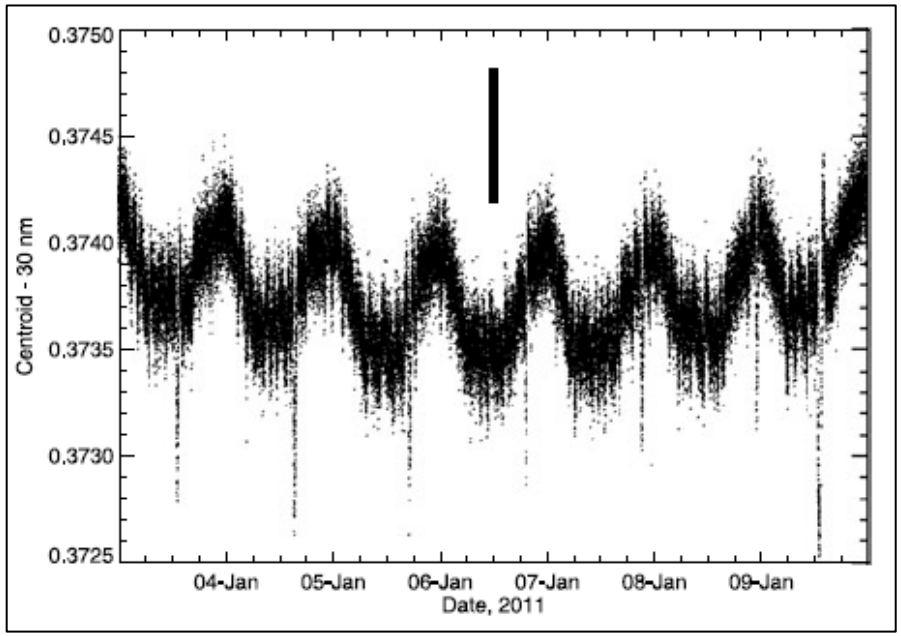
MEGS-A



CCD Image of Solar Spectrum

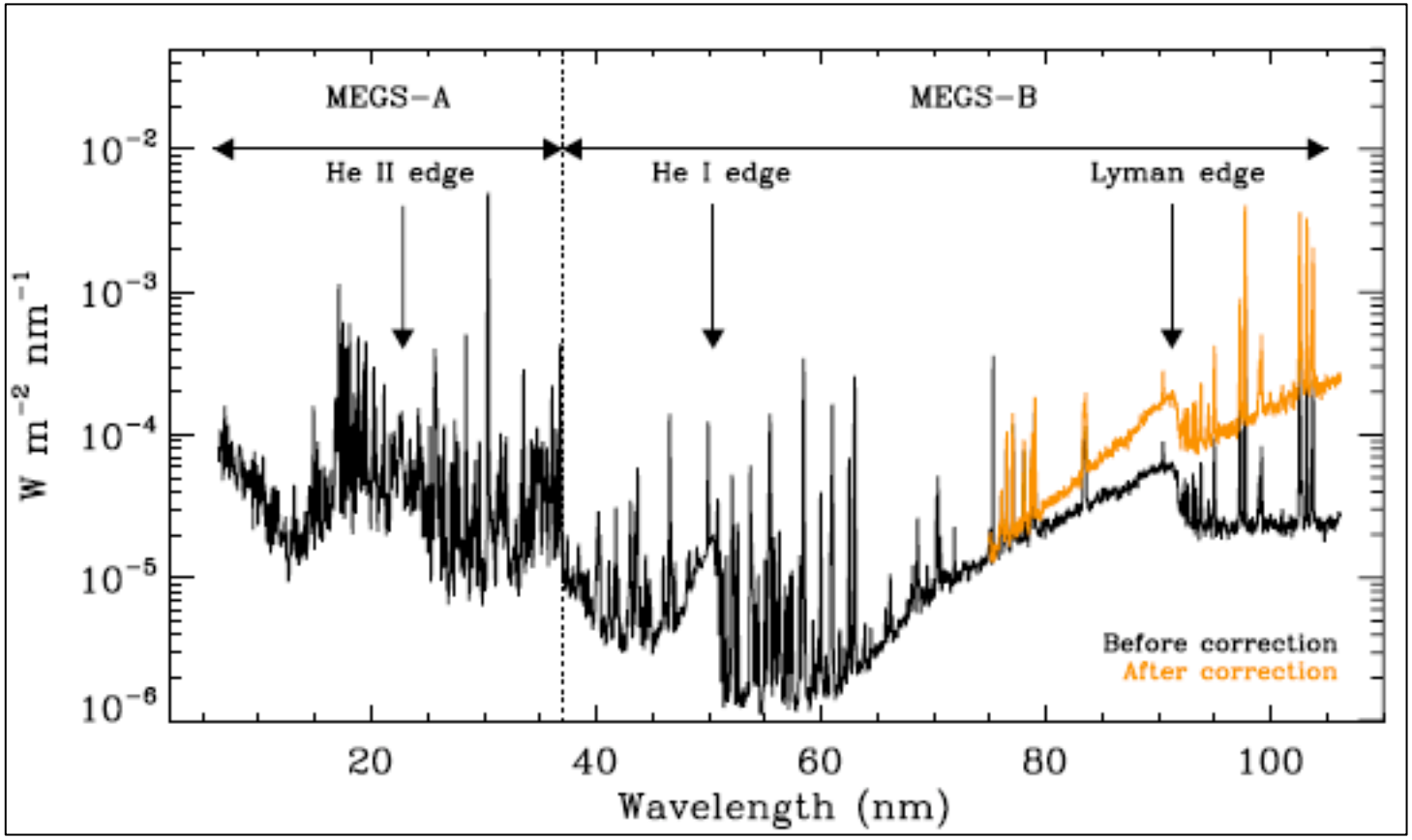
EVE literature

- Woods et al. 2010 (published 2012) basic description of experiment
- Woods et al. 2011: first science results
- Hudson et al. 2011: Doppler sensitivity
- Milligan et al. 2012: Continua in spectra of SOL2011-02-15



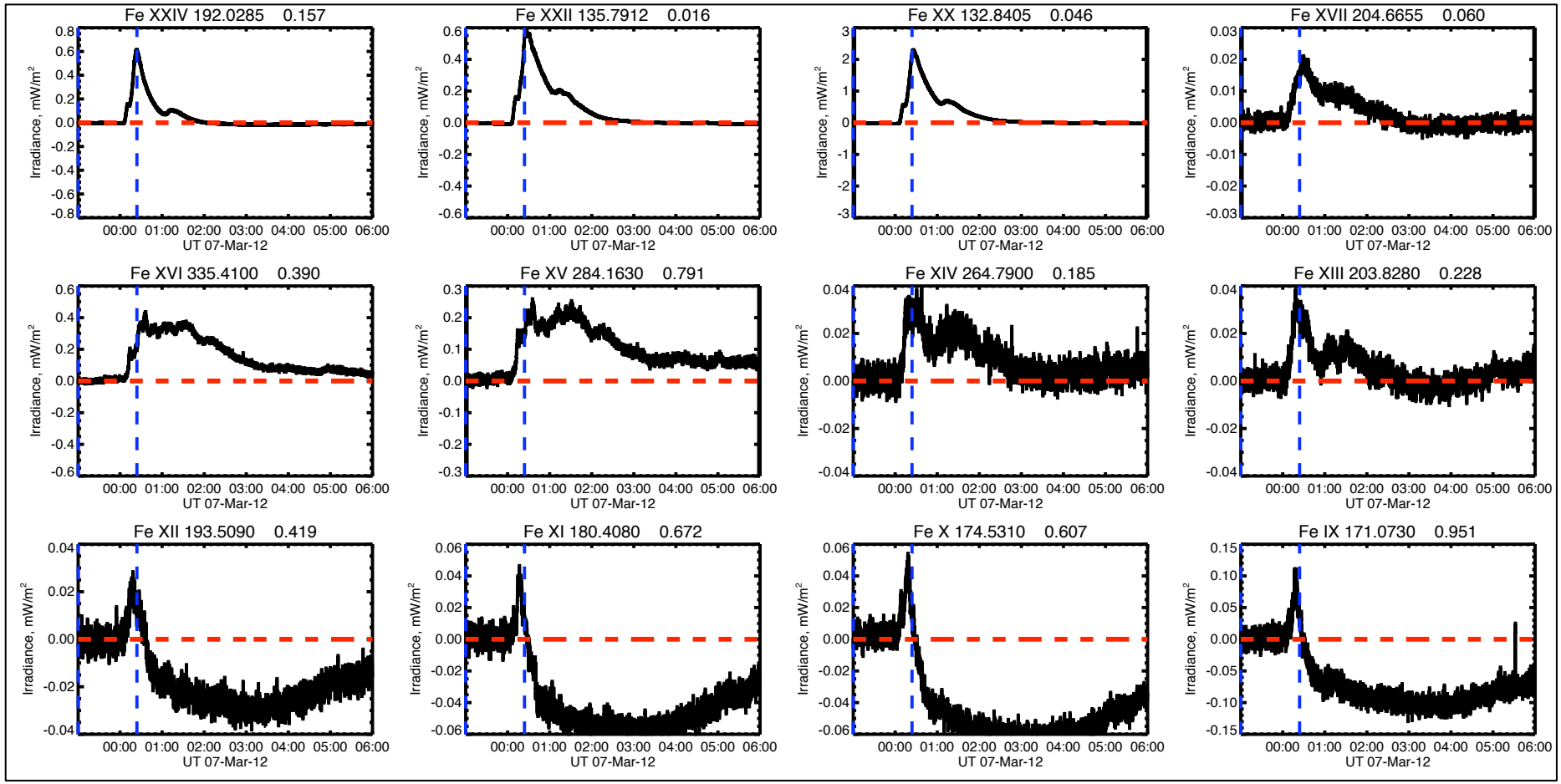
The Doppler sensitivity of EVE: it can see the SDO orbital motion (few km/s) quite easily in the 30.4 nm line of He II. There are also some artifacts

EVE Sun-as-a-Star Spectra



Milligan et al. 2012

“Fe Cascade” for SOL2012-03-07



Fe-cascade plot

```
Fe IX   171.0730
Fe X    174.5310
Fe XI   180.4080
Fe XII  193.5090
Fe XIII 203.8280
Fe XIV  264.7900
Fe XV   284.1630
Fe XVI  335.4100
Fe XVII 204.6655
Fe XX   132.8405
Fe XXII 135.7912
Fe XXIV 192.0285
```

These lines, with full atomic information, are to be found in the CHIANTI database. In SolarSoft, an easy route into this code is

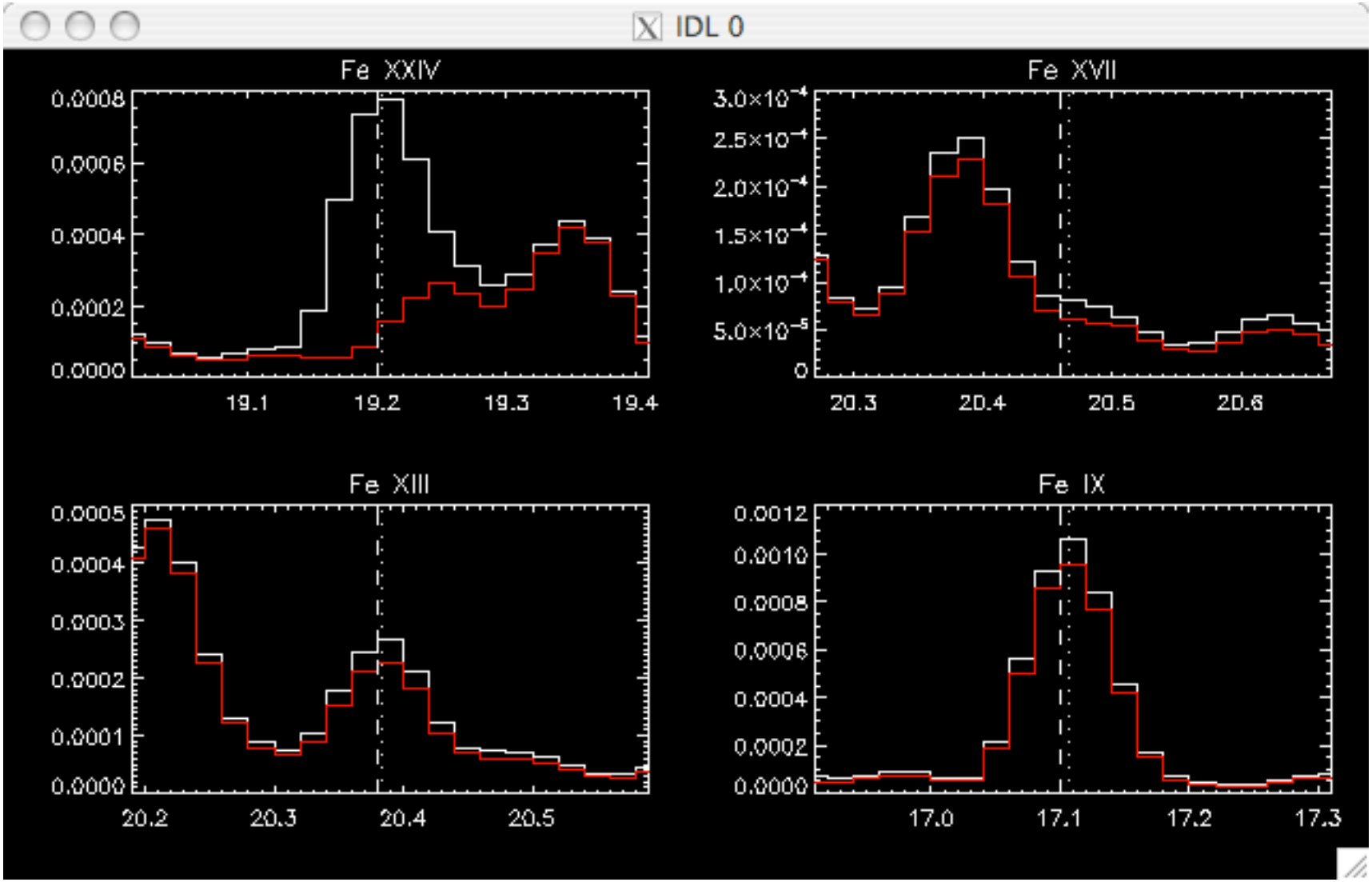
IDL> ch_ss

On the Web, http://www.chianti.rl.ac.uk/

Explanation of Fe cascade

- The plots are the time series of individual Fe lines, one for each of 12 ionization states
- The higher ionization states follow a cooling law (hence “cascade”)
- The lower ionization states (for this flare) show a pronounced “dimming”, which we interpret as mass loss due to CME expulsion
- The lower ionization states also show an impulsive-phase excess

How good is the line set?



- Each plot shows flare maximum, at that line, with background in red

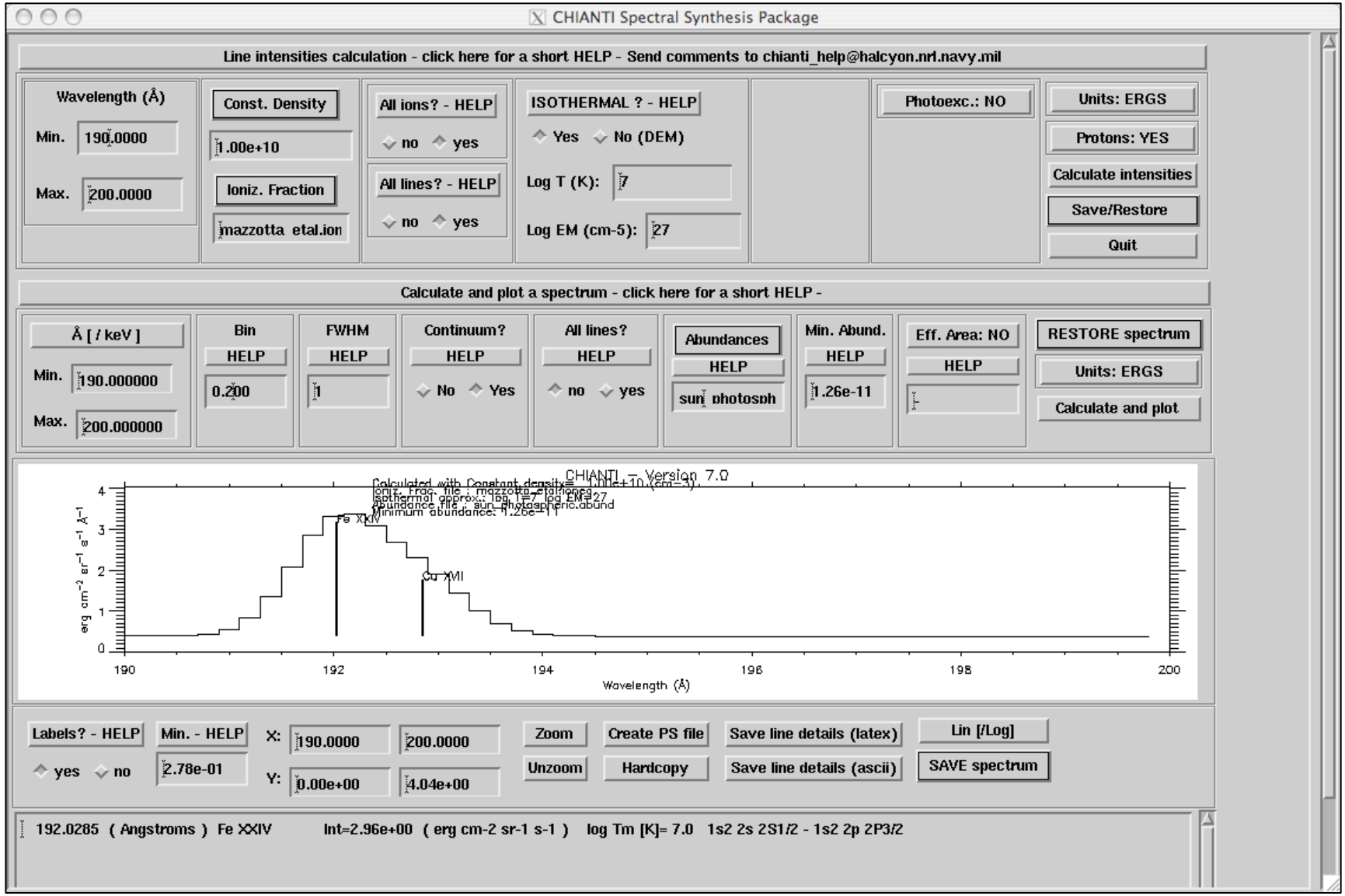
How good is the line set?

- Clearly there's a problem with Fe XVII. The current line is not as bright as CHIANTI claims it should be
- There are serious blends
- Fe_cascade might work better with a different line set
- Are there good enough lines to do a Ca_cascade code as well?

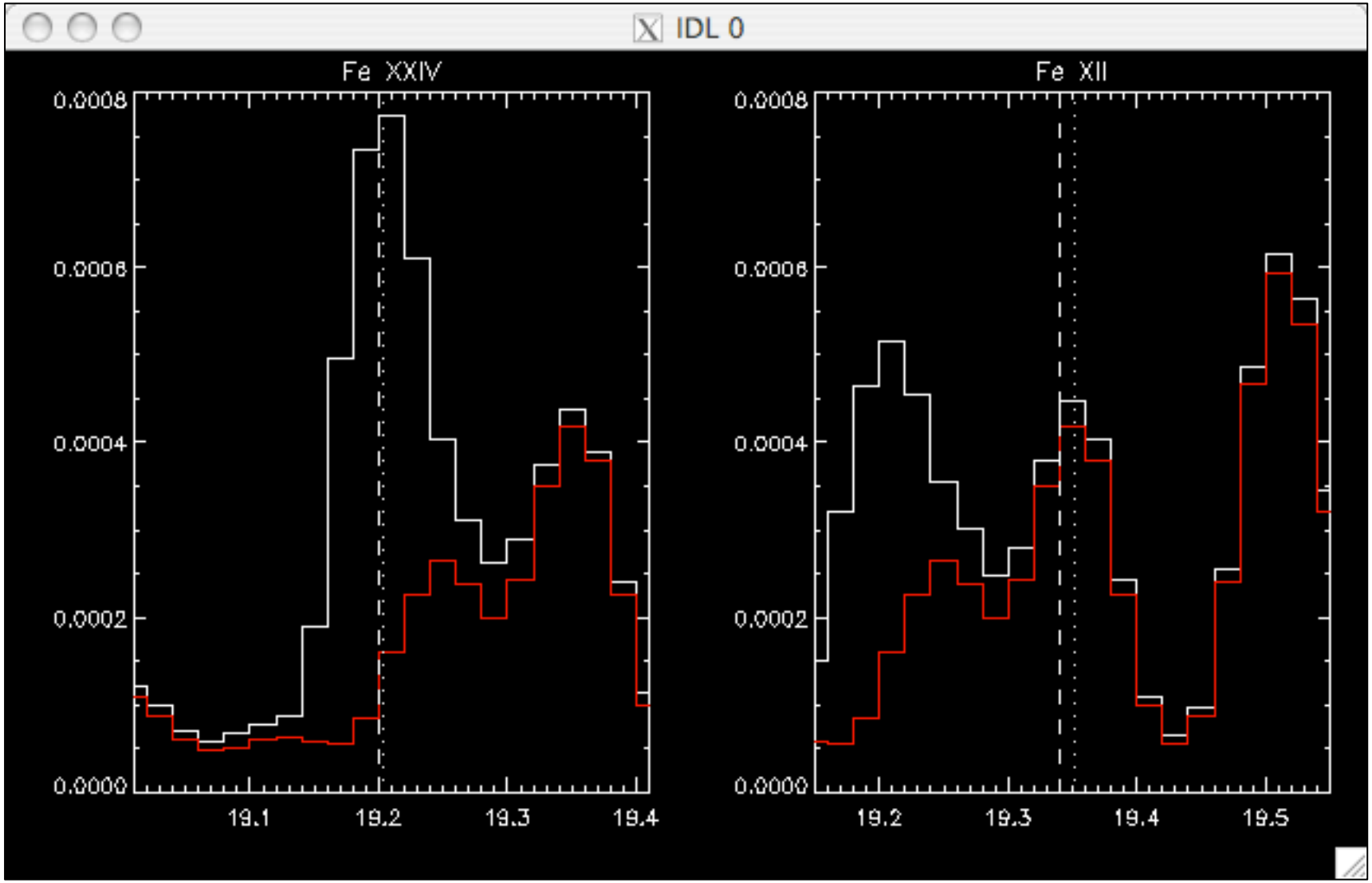
CHIANTI introduction

- This is a standard database for atomic physics, supporting spectroscopy in the EUV
- There is a nice GUI (*ch_ss*, for “CHIANTI spectral synthesis”)
- There are other resources, and full access to IDL code via the CHIANTI package in SolarSoft

The CHIANTI GUI



Oops, another blend in Fe_cascade!

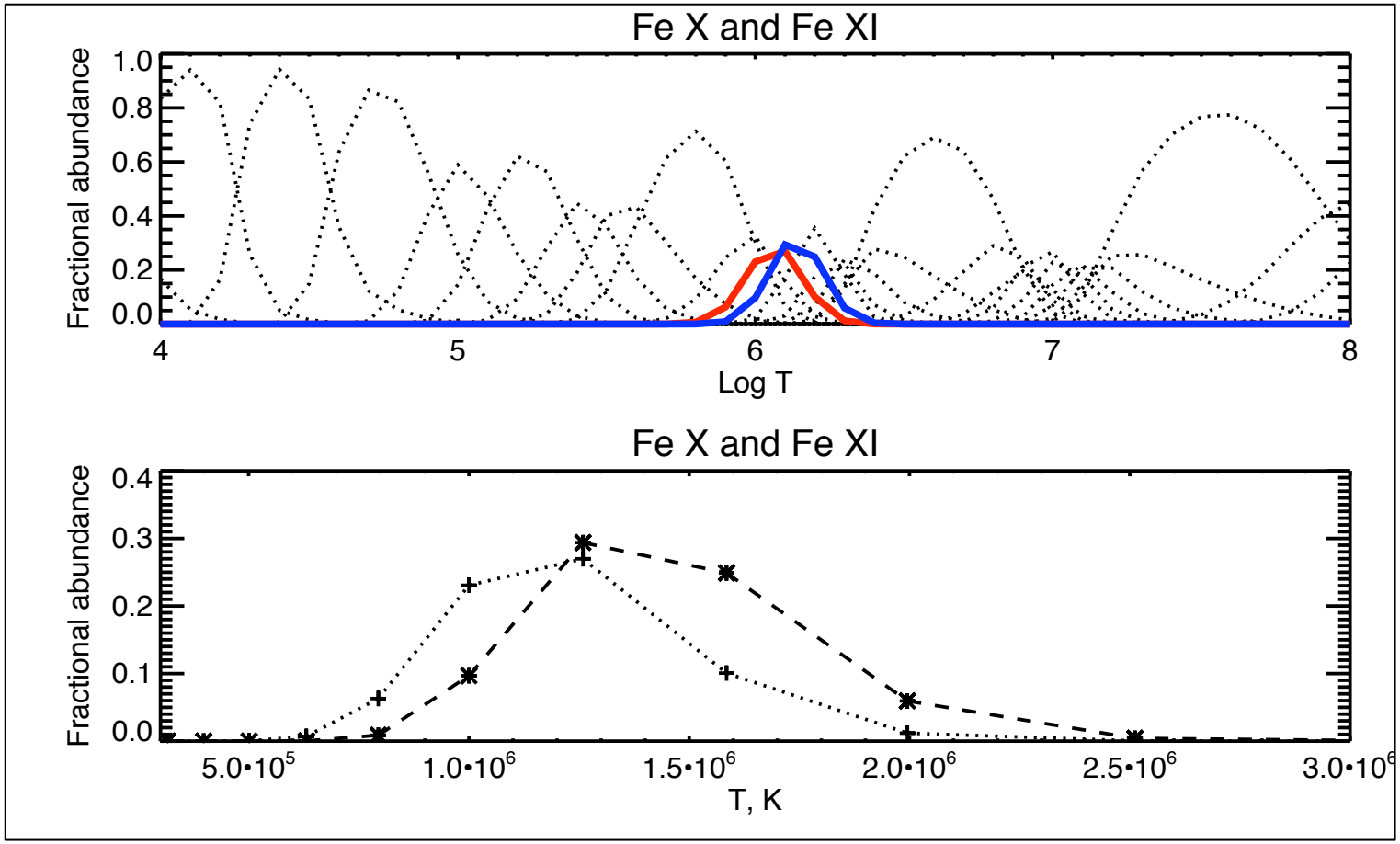


Fe II or Ca XVII?

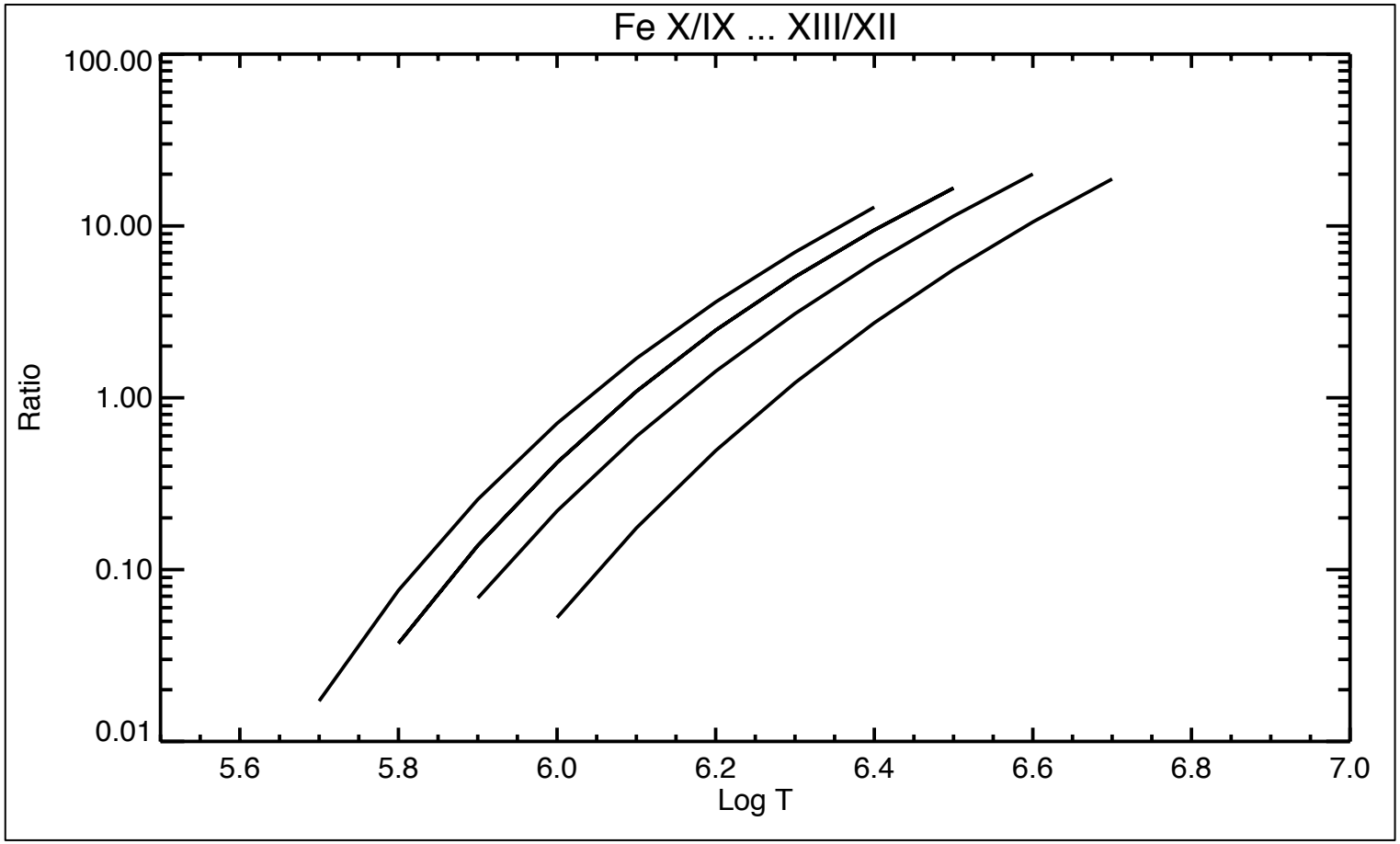
Temperature determination

- EVE observes many individual lines, from many ionic states of several elements
- For a given element, CHIANTI lets us calculate a “transfer function” for a line ratio of two states
- The CHIANTI gives ready access to ionization equilibrium theories

Ionization state of Fe



Temperature determination



Projects with EVE

The EVE data are easily accessible, and give detailed information about the EUV spectra of many flares. In conjunction with CHIANTI, one can study solar flares as one studies stellar flares, ie with no spatial information.

A zeroth-order project would be to examine the existing line set for the 12-panel display, and investigate (a) whether line blends are affecting the signatures of the existing set, or (b) whether other better lines exist. It would be especially good to have ion pairs for other species than Fe; e.g. Ca or O.

Projects I

- Project I: can we compute the differential emission measure (DEM) for the dimming, and thereby estimate the mass of the CME ejection?

  - the DEM to be worked out as a demonstration

- Project II: does the cooling sequence allow one to follow an effective mean temperature during the decay of a flare?

  - the line list can be extended, and each ion pair from a given element (e.g., Fe XXII and Fe XXI) will determine an independent temperature estimate via CHIANTI

Projects II

- Project III: How does the differential emission measure of the impulsive-phase brightening compare with those of the pre-flare emission, or of the dimming?
- Project IV: Can we use AIA images to localize any of the three major sun-as-a-star features of the EVE timeseries (impulsive phase, cooling kernels, dimming)?