Application of CHIANTI to Solar-B

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Abstract. CHIANTI (http://wwwsolar.nrl.navy.mil/chianti.html) has been developed to support the interpretation of solar and astrophysical spectroscopic measurements. The most recent release, version 5.0 (Landi et al. 2005) presents an improvement over previous versions by including new large scale datasets for Fe ions from Fe XVII to Fe XXIV for X-ray emission and improved atomic data for EUV line emission. We will demonstrate how this can be applied to the analysis of XRT and EIS data, in particular. For example, new excitation rates for Fe XII have resolved a long standing problem in the use of Fe XII line ratios as accurate density diagnostics. Current work involves improvements to ionization and recombination rates which will also be useful in the interpretation of Solar-B data.

1. CHIANTI and Solar-B

The CHIANTI atomic database for astrophysical spectroscopy is freely available at:


On this web page, users can subscribe to the email list to be notified of any changes to CHIANTI. It offers an email link to the CHIANTI team to ask for help. CHIANTI is also included as a package within SolarSoft.

The first version of CHIANTI was described by Dere et al. (1997). Since that time, CHIANTI has been continually updated and improved. The version 5 (Landi et al. 2006) is the most recent. One of the major improvements provided by version 5 is the inclusion of excitation rate to n=4 and n=5 levels of Fe XVII-XXIII (Landi & Gu 2006). These excitation rates enable CHIANTI to provide
a more complete reproduction of the solar spectrum at X-ray wavelengths, as shown in Figure 1. This figure shows observed spectra from SMM at the top. Below are shown the spectrum predicted by CHIANTI versions 4 and 5. It can be seen that version 5 includes essentially all of the lines that are observed between 10.6 and 12.5 Å.

CHIANTI will be used to determine the instrumental response of the Solar-B coronal instruments XRT and EIS to solar radiation. For example, Phillips, Chifor & Landi (2005) (and see also Del Zanna & Mason (2003)) used CHIANTI to calculate the response of the TRACE 171 and 195Å bands. Figure 2a shows the various contributions to the response of the TRACE 195Å band as a function of temperature. It is compared to a previous calculation by Handy et al. (1999) which used a previous version of CHIANTI, which, for example, did not include the most recent data for Fe VIII which only became available recently (Griffin, Pindzola & Badnell 2000). The expected signals for EIS have recently been calculated by Del Zanna & Mason (2005b).

A general part of the CHIANTI update process is to include any new and improved atomic data that becomes available in the literature. For version 5, we were able to include new excitation rates for Fe XII (Storey et al. 2005). Lines of Fe XII are the strongest lines in the EIS short wavelength band. Certain ratios of these lines provide a valuable density diagnostic of coronal plasmas. However, for years, the densities derived from Fe XII line ratios did not agree
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with densities derived from other line ratios formed at a similar temperatures. This discrepancy has been resolved with the latest Fe XII excitation rates (Del Zanna & Mason 2005a). Plots of the old (version 4) and new (version 5) ratios of Fe XII as a function of electron density are shown in Figure 2b. The change in the predicted ratio moves the density determinations from the Fe XII lines into agreement with other line ratio measurements.

CHIANTI can also provide important parameters to help interpret the Solar-B measurements through modeling coronal plasmas. For example, the total radiative loss rate is a necessary component of any modeling effort that includes energy balance. The calculations of the radiative loss rate with CHIANTI version 5 are shown in Figure 3. This figure also shows the significant difference between plasmas with photospheric abundances and those with coronal abundances. Further, for modeling the time-dependent ionization state of coronal plasma, it is easy to extract the radiative loss rate for any and all single ions so that these do not have to be calculated at each step.

2. Ionization and Recombination Rates for CHIANTI

The rapid evolution of coronal structures suggests that the ionization state of the plasma may not be the steady state that has been the basis for essentially all previous analyses of solar X-ray and EUV measurements. In order to explore this question with the CHIANTI database, it is necessary to include ionization and recombination rates as a function of both temperature and density. Because of high-lying metastable levels that become more populated with increasing density, the net ionization rate for a given ion can be a function of electron density, e.g. Vernazza & Raymond (1979). The recombination rate of a given ion is also dependent on the population of its various levels (Badnell et al. 2003). The basis for most ionization equilibrium calculations in the past have assumed that only the ionization rate from the ground level and recombination into the ground level were important.

For CHIANTI, many recombination rates as a function of level population, calculated by Badnell and colleagues, are becoming available and will be incorporated into CHIANTI.
For ionization rates, many new measurements have become available since the most recent analyses by Arnaud & Rothenflug (1985) and Arnaud & Raymond (1992). Also, the Flexible Atomic Code (FAC, Gu (2002)) is now available. This is a distorted wave code and can calculate direct ionization (DI) rates and excitation-autoionization (EA) rates. An example is shown in Figure 3b. Recent measurements of the ionization cross-section for Ni XVI by Cherkani-Hassani, Kouilid & DeFrance (2001) are plotted together with the total of the DI and EA cross-sections calculated with FAC. It is our intention to develop a new set of ionization rates for all stages of all ions from hydrogen through zinc. This is a long term project and will not be complete before the launch of Solar-B.

Figure 3. Left (a) Radiative loss rates calculated for photospheric and coronal abundances. Right (b) Ionization cross section for Ni XVI

References
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