CORONAL DIAGNOSTIC SPECTROMETER

SoHO

CDS SOFTWARE NOTE No. 37

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Density and Temperature Diagnostic Line Ratios for CDS Using CHIANTI

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1 Introduction

Spectroscopic diagnostic line ratios in the UV wavelength range have been used extensively to determine the electron density and temperature in the solar atmosphere (cf Dere and Mason, 1981, Gabriel and Mason, 1982, Mason, 1991, Mason and Monsignori Fossi, 1994). The theoretical intensity ratios from individual ion species provide a measurement of electron density which is independent of any assumptions about the volume of the emitting region. This is of particular importance in the transition region and coronal structures. The electron density (which determines the electron pressure) is an essential parameter in the study of energy transfer mechanisms. The Coronal Diagnostic Spectrometer, as its name suggests, will make extensive use of these techniques. Indeed, several prime diagnostic line lists have been provided in the *CDS blue book*.

CHIANTI, developed by Dere, Landi, Mason, Monsignori Fossi and Young aims to provide a straightforward, easy to use package comprising an atomic databank and accompanying IDL routines. Ions from elements which are cosmically abundant have been included. Theoretical line intensity ratios are calculated assuming equilibrium conditions and optically thin spectral line emission. The first release of the CHIANTI package was in July 1996. The atomic data and IDL routines are available by anonymous FTP from http://wwwsolar.nrl.navy.mil/chianti.html. An accompanying publication has been submitted to Astron. Astrophys. Suppl. Ser.

Sadly, during the course of this work, our collaborator and colleague, Brunella Monsignori Fossi died suddenly and prematurely. Her enthusiasm, support and friendship is a great loss not only to us but to the whole of the SOHO community.

2 The atomic data

The best available atomic data have been used and the original sources are documented in each data file. We are particularly grateful to authors for making their atomic data available to us via FTP and E-MAIL. It is anticipated that the atomic data will continue to be updated regularly as new data are calculated or measured in the laboratory. It is intended that these atomic data can be accessed and transfered into users own analysis programs, for more sophisticated applications. Further details can be found in the *CDS Software Note 33*. The energy levels have been obtained from NIST, suplemented by other laboratory or theoretical values. The radiative data have been taken from the published literature. The electron excitation data have been assessed and fitted using an IDL adaptation BURLY of the Burgess and Tully (1992) method OMEUPS. All the atomic data in the CHIANTI database have been visually displayed and assessed for accuracy and any sporadic errors which sometimes creep into published results.

3 The CHIANTI_NE and CHIANTI_TE procedures

The IDL procedure which calculates line intensity ratios as a function of electron density is called CHIANTI_NE. Another IDL procedure to calculate ratios sensitive to electron temperature is called CHIANTI_TE. To run the CHIANTI_NE and CHIANTI_TE procedures, access to the CDS IDL directories and CHIANTI database is needed.

3.1 Selectable parameters

User interactions with the main widget setup the wavelength range and other parameters and are described individually below. On the left hand side are controls for wavelength and electron density or temperature selection and on the right hand side for ion selection.

3.1.1 Wavelength

The wavelength sliders are provided to allow the user to select the wavelength range over which the calculation is performed. The allowable range covers the CDS and SUMER wavelength ranges.

3.1.2 Electron Density/Temperature Range

For CHIANTI_NE, select the electron number density range ($\mathrm{Log}_{10}N_e$) over which the intensity ratios are calculated. Default values are 10^7 to 10^{14} cm^{-3}. The intensity ratios are calculated for the temperature corresponding to the peak ionic abundance T_{max}. For CHIANTI_TE, select the electron temperature ($\mathrm{Log}_{10}T_e$) over which the intensity ratios are calculated. Default values are 10^4 to 10^7 K. The intensity ratios are calculated for an electron number density corresponding to 10^8 cm^{-3}.

3.1.3 Ion

The program can be run for different ions. Select the element and ion stage using the pull-down menus. Only those elements and ions currently available in the CHIANTI database are displayed for selection.

3.2 Controlling the procedure

The action of both CHIANTI_NE and CHIANTI_TE is controlled via the buttons in the central panel of the display. From left to right these are:

QUIT - click on this to exit from the program, all plot windows are also deleted.

CALCULATE LINE INTENSITIES - using the wavelength ranges as defined in the widgets above. For CHIANTI_NE, two plots will apear in the window - on the left the $N_i * A/N_e$ and on the right the intensity ratios (ergs), where N_i is the level population and A is the radiative transition probability (s^{-1}). A list of spectral lines in the given wavelength range for that ion is displayed in the message window. The reference index is in the first column, then the wavelength, intensity and transition. For CHIANTI_TE, only one plot apears, the intensity ratios (ergs) as a function of electron temperature.

HARDCOPY - the menu under this button will allow a variety of hardcopy plots (ratio plots or intensity plots) and the line details (+refs), which gives a record of the input.

SAVE - it is sometimes useful to save the plotted line intensity ratios to study several different ions. The save file can be restored and replotted outside of CHIANTI_NE and CHIANTI_TE using the procedures PLOT_CHIANTI_NE and PLOT_CHIANTI_TE respectively.

PLOT RATIO - prompts for and then plots specific line intensity ratios, using line indices available from the list. The ratios within a particular ion can be stored for later use using the SAVE button. To allow for blended lines in the observed spectra, multiple line indices can be given for the numerator and denominator. The format is fairly flexible but the nominator and denominator specification must be separated by a '/'. Otherwise the line indices can be separated by spaces or commas.

DELETE PLOT WINDOWS - to clear the ratio plots from the screen.

4 References

1. Burgess, A. and Tully, J.A., 1992, *Astron. Astrophys.*, **254**, 436.

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3. Gabriel, A.H. and Mason, H.E., 1982, *Applied Atomic Collision Physics*, **Ch. 12, Solar Physics**, eds. H.S.W. Massey, B. Benderson, E.W. McDaniel, (Publ. Academic Press).

4. Mason, H.E., 1991, *Adv. Sp. Res.*, **11**, (1) 293.

5. Mason, H.E. and Monsignori Fossi, B.C., 1994, *The Astron. Astrophys. Rev.*, **6**, 123.