Bull. Astron. Soc. India (1999) **xx**,

PINTofALE: Package for the Interactive Analysis of Line Emission

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Abstract. `PINTofALE` was developed to analyze spectroscopic data from coronal sources in the 1-1500Å range. It is based on a modular set of `IDL` tools that interact with an atomic database and with observational data. The tools allow us to easily identify spectral lines, measure fluxes, and carry out more detailed modeling. The package has been extended to handle analysis of high-resolution X-ray spectra that will be obtained with the *Chandra* X-Ray Observatory.

Key words: X-rays, X-ray Spectroscopy, Stellar Coronae, Analysis Methods

1. Introduction

The scientist wishing to analyse EUV and X-ray spectra has a choice of how to proceed: use an existing "black box" compilation of atomic data hard-coded into a program with a fixed functional capability (e.g. the `XSPEC` [Arnaud 1996] and `SPEX` [Kaastra et al. 1996] packages); or gather the atomic data oneself and perform analyses "by hand." While very good in their own right, the former type of packages were developed with statistical fitting of spectral models to low resolution X-ray spectra in mind. For spectra of higher resolution (e.g. EUVE, *Chandra*, and XMM), such approaches are of limited use and can even be misleading owing to incompleteness and errors in the underlying atomic data (e.g. Drake 1996). More discerning analyses involving selective use of well-measured spectral lines and well-known atomic data are generally needed to derive reliable constraints on source emission models. However, measuring line emission/absorption profiles, identifying the lines in complex spectra (e.g., from stellar coronal sources), deblending the contributions from different species, correctly accounting for the temperature and density responses of the various lines, etc. can be a hard task. We have therefore developed an analysis system that is much more flexible for analysing high resolution spectra than existing packages and that offers completely transparent access to atomic data. We describe its structure and briefly describe its status in the following section.

2. Summary

Here we report on an IDL based modular software package for interactive analysis of line emission (PINTofALE) that focuses on the analysis of high-resolution spectra of collision-dominated, optically-thin, thermal bremsstrahlung emission sources, such as stellar coronae. In general, the emission in the wavelength range $[\lambda, \lambda + \Delta\lambda]$ includes contributions from atomic line transitions ($\sim A(Z) \int_{\Delta T_{ul}} \Phi(T; Z, z) G_{ul}(T) N_e^2(T) dV(T)$; where $\Phi(T; Z, z)$ are the ion populations of ionic species Z^{+z}, $G_{ul}(T)$ are the atomic "contribution" functions for the transition $u \to l$, $A(Z)$ are the abundances, and N_e are the electron densities in the emission volume dV), and continuum emission as a result of free-free (Bremsstrahlung), free-bound, and two-photon processes.

None of the existing compilations of atomic line transitions in the EUV and X-ray region such as CHIANTI (Dere et al. 1996), SPEX (Kaastra et al. 1996), and RS (Raymond & Smith 1977) are complete. We therefore re-cast these databases into a uniform format that allows us to pick transparently the appropriate line transitions from any of the supported databases, and to add new atomic data as desired. We also separate out ion populations from the direct atomic contribution function, and are thus able to consider different versions of ion balance calculations (e.g. Arnaud & Rothenflug 1986, Arnaud & Raymond 1992), as well as allow for calculation of line fluxes in the absence of ionization equilibrium. Abundances and emission measure distributions may also be separately defined. We compute continua using the algorithms described by Mewe et al. (1986).

The results of the line identification process are stored centrally in a data structure that is flexible enough to include both observed and predicted line strengths, allow multiple IDs for a blended line, allow identifications with multiple grating orders, etc. These results are then used to perform further analysis, such as determining the Solar coronal Differential Emission Measure (Kashyap & Drake 1998).

This package has been used to analyze solar spectral data (Kashyap & Drake 1998), EUVE data of ξ Boo A (Drake et al. 1999) and other stars (Kashyap et al. 1997). In the future, we plan to include the APEC atomic line database (Brickhouse et al. 1999, in preparation) when it becomes available, and provide support for the "pseudo-continuum" of the vast number of faint lines. We also plan to merge PINTofALE into the *Chandra* Data Analaysis system.

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