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The Arcetri spectral code for thin plasmas

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Abstract. The Arcetri spectral code allows to evaluate the spectrum of the radiation emitted by hot and optically thin plasmas in the spectral range 1 – 2000 Å. The database has been updated including atomic data and radiative and collisional rates to calculate level population and line emissivities for a number of ions of the *minor elements*; a critical compilation of the electron collision excitation for these elements has been performed. The present version of the program includes the CHIANTI database for the most abundant elements, the minor elements data, and Fe III atomic model, radiative and collisional data.

Key words: atomic data – plasmas — solar atmosphere — stellar atmosphere — ultraviolet: general — astronomical data bases: miscellaneous

1. Introduction

More than 25 years ago, M. Landini and B.C. Monsignori Fossi, began to develop a numerical code to evaluate optically thin plasma emissivity, for temperature larger than 10^4 K. The computation was performed in the so called "coronal approximation", where each level population is obtained assuming collisional and radiative coupling with the ground level only. The first result of this work was the theoretical spectrum from 1 to 100 Å both in the lines and in the free-free and free-bound continuum of a few important ions (Landini & Monsignori Fossi 1970). The spectrum was extensively used by the authors to study the solar X-ray emission measured by the SOLRAD satellites equipped with broad band detectors and for predictions of X and EUV emission from coronae of solar type stars. Since then, several upgrades have been performed, including the updating of the ionization balance (Landini & Monsignori Fossi 1991), the extension of the atomic database (Landini & Monsignori Fossi 1990) to include lines from 1 to 2000 Å, the computation of free-bound contribution from minor ions, the inclusion of two-photon continuum and the development of a library of numerical codes for the *differential emission measure* evaluation. The computed spectrum has been extensively applied to the study of the solar corona and to the interpretation of the X and EUV emission of solar type stars, and a version covering the spectral interval from 70 to 700 Å has been used for data reduction of the Extreme Ultraviolet Explorer (EUVE) observations. Most recently a major upgrade of the atomic database has been performed including atomic models, electron collision rates and radiative decays in order to evaluate the detailed population of each level assuming statistical balance among the excitations and decay processes. At first these procedures have been applied to several iron ions (Monsignori Fossi & Landini 1994a and 1994b) and successively extended to the most important ions of several isoelectronic sequences. Most of this work started as a collaboration with the Scientific Team of the Coronal Diagnostic Spectrometer on SOHO (Monsignori Fossi & Landini 1994c); it has now been inserted in the database of the CHIANTI project (Dere et al. 1997) developed by Brunella Monsignori Fossi, so early deceased, with Dr. H.E. Mason and Dr. K.P. Dere.

The aim of this paper is to present the latest version of the Arcetri spectral code and database which now includes the whole database already inserted in the CHIANTI project; moreover the Code allows the evaluation of free-free, free-bound and two-photons continuum (not yet included in CHIANTI) and the line intensity of most of the ions of minor elements, as described in the following sections.

The present update has proved necessary by the increasing need of the theoretical data required for the calculation of more and more accurate synthetic spectra in order to study the spectra observed by rocket and satellite-born spectrographs. This new instrumentation provides very high temporal, spatial and spectral resolution data and represents a great advance for solar and stellar spectroscopy and for the study of spectral emission from a variety of astrophysical objects. The new

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instrumentation which has been already launched, such as EUVE and Yohkoh, and more recently CDS, SUMER, UVCS on SOHO, and SAX, has permitted to greatly extend our knowledge of the physical processes determining the status of solar and stellar atmospheres. A much more detailed investigation of the mechanisms of solar and stellar wind formation and acceleration and of the coronal heating are expected. A large number of lines has been observed in the high resolution spectra provided by the instruments on board of SOHO (Brooks et al. 1998; Feldman et al. 1997; Raymond et al. 1997a) which could be used for temperature and density diagnostics (Landi & Landini 1997; Laming et al. 1997a and 1997b; Seely et al. 1997; Mason et al. 1997), for *differential emission measure* analysis (Landi & Landini 1997), and for element abundances analysis (Young & Mason 1997; Raymond et al. 1997b).

Moreover, future missions are scheduled for launch in the near future (AXAF 1998, XMM around 2000) which also will provide a unique opportunity for studying the X-ray emission from astrophysical sources, for which a large amount of theoretical data is required.

The revised version of the Arcetri Code and the updated database will be released to the scientific community at the website *www.arcetri.astro.it* before the end of spring 1998.

2. The line intensity

The number of photons emitted in a spectral line ($i \to j$) for an optically thin coronal plasma is given by:

$$I_{ij} = \int_V N_j(X^m) A_{ji} \mathrm{d}V \tag{1}$$
$$= \int_V G_{ij}(T, N_\mathrm{e}) N_\mathrm{e}^2 \mathrm{d}V \ \mathrm{ph\ cm^{-3}\ s^{-1}}$$

where

- $G_{ij}(T, N_\mathrm{e})$ is the *contribution function* of the line and depends on the electron temperature (T) mainly through the ion abundance, and on the electron density (N_e), mainly through the level population.

The function $G_{ij}(T, N_\mathrm{e})$ may be expressed as

$$G(T, \lambda_{i,j}) = \frac{N_j(X^m)}{N(X^{+m})} \frac{N(X^m)}{N(X)} \frac{N(X)}{N(H)} \frac{N(H)}{N_\mathrm{e}} \frac{A_{ji}}{N_\mathrm{e}} \tag{2}$$

and

- $\frac{N_j(X^{+m})}{N(X^{+m})}$ is the relative upper level population;
- $\frac{N(X^{+m})}{N(X)}$ is the relative abundance of the ion X^{+m};
- $\frac{N(X)}{N(H)}$ is the abundance of the element X relative to Hydrogen;
- $\frac{N(H)}{N_\mathrm{e}}$ is the hydrogen abundance relative to the electron density (≈ 0.8).

The element abundance and the ionisation balance population of each ion are known from the literature (Allen 1973; Feldman et al. 1992; Meyer 1985; Grevesse & Anders 1992; Waljeski et al. 1994 for the element abundances, Shull & Van Steenberg 1982; Arnaud & Rothenflug 1985; Arnaud & Raymond 1992; Landini & Monsignori Fossi 1991 for the ionisation equilibrium), while the level population must be calculated solving the statistical equilibrium equation including all the important processes involved in level excitation and de-excitation. In low density plasmas the most important populating and de-populating processes are spontaneous radiative decay and excitation and de-excitation from electron-ion collisions, since they are generally faster than ionisations and recombinations. In hot plasmas proton collision rates can also be important in determining the level population.

The statistical equilibrium equations take the form

$$N_j \left(N_\mathrm{e} \Sigma_i C^\mathrm{e}_{j,i} + N_\mathrm{p} \Sigma_i C^\mathrm{p}_{j,i} + \Sigma_{i<j} A_{j,i} \right) = \tag{3}$$
$$\Sigma_i N_i \left(N_\mathrm{e} C^\mathrm{e}_{i,j} + N_\mathrm{p} C^\mathrm{p}_{i,j} \right) + \Sigma_{i>j} N_i A_{i,j}$$

with $C^\mathrm{e}_{j,i}$ and $C^\mathrm{p}_{j,i}$ the electron and proton collisional excitation rates (cm^{3}s^{-1}), $C^\mathrm{e}_{i,j}$ and $C^\mathrm{p}_{i,j}$ the electron and proton collisional de-excitation rates and A_{ji} (s^{-1}) are radiative decay probabilities from level j to level i.

The collisional excitation rate for a Maxwellian electron velocity distribution can be expressed as

$$C^\mathrm{e}_{i,j} = \frac{8.63 \cdot 10^{-6}}{T_\mathrm{e}^{1/2}} \frac{\Upsilon_{i,j}(T_\mathrm{e})}{\omega_i} \exp\left(-\frac{\Delta E_{i,j}}{kT_\mathrm{e}}\right) \tag{4}$$

where ω_i is the statistical weight of level i, k is the Boltzmann constant and $\Upsilon_{i,j}$ is the thermally-averaged collision strength (*effective* collision strength):

$$\Upsilon_{i,j} = \int_0^\infty \Omega_{i,j} \exp\left(-\frac{E}{kT_\mathrm{e}}\right) \mathrm{d}\frac{E}{kT_\mathrm{e}} \tag{5}$$

where $\Omega_{i,j}$ is the collision strength, related to the electron excitation cross section and E is the energy of the scattered electron relative to the final energy state of the ion. In the evaluation of the effective collision strength the scaling laws of Burgess & Tully (1992) have been adopted.

For solving the statistical equilibrium in Eq. (3) it is necessary to have a large dataset which includes an atomic model with experimental energy levels and radiative and collisional transition probabilities for all the possible transitions within the levels of the adopted atomic model. For this reason in the recent past several extensive databases of theoretical data have been developed, such as ADAS (Summers et al. 1996) and CHIANTI (Dere et al. 1997). Both these databases allow the complete solution of the system of equation described above for the most important ions, though both of them neglect, at the moment, the proton collision rates.

The aim of the present update of the Arcetri spectral code is to renew the entire set of theoretical data which composed the old version of the Code, as described in

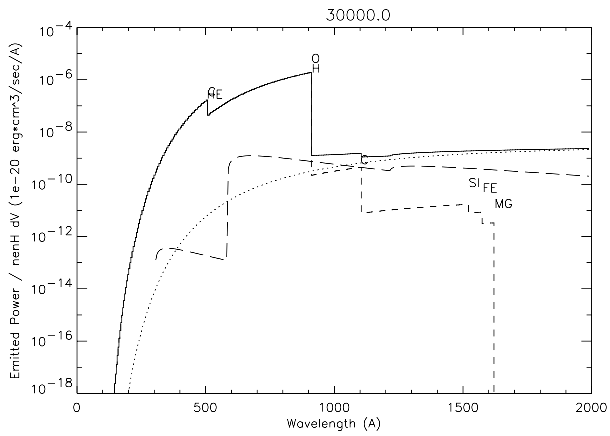

Fig. 1. The continuum emission per unit emission measure for a thin plasma at temperature 3 10^4 K and electron density 1 10^8 cm^{-3} between 1 Å and 2000 Å. Free-free *(dotted line)*, free-bound *(dashed line)* and two-photon continuum *(long-dashed line)* are indicated

Landini & Monsignori Fossi (1990) and Monsignori Fossi & Landini (1996), which included the most important emission lines in the range $1 - 2000$ Å. For the evaluation of their emission the assumption was made that the population of the upper level of the transition j occurs mainly by collisional excitation from the ground level g and the radiative spontaneous decay dominates any other depopulation process. The old version also included a full set of atomic data which allowed the solution of the statistical equilibrium equation for the ions of the Beryllium, Carbon and Nitrogen isoelectronic sequences and for the Iron Ions from Fe IX to Fe XXIV.

In the present update we have included the whole CHIANTI dataset in the Arcetri spectral code, and we have also added some original data:

- Atomic data for the so-called *minor elements* (Na, Al, Cl, P, K, Ti,Cr, Mn, Co and Zn). The ions of these elements may provide several observed lines some of which are weak in most spectra but can prove useful in spectral analysis and DEM studies;
- Fe III atomic model, collisional and radiative dataset.
- The atomic data for the lines in the range $1 - 2000$ Å which are included neither in CHIANTI nor in the minor elements dataset; they have been renewed updating the transition probabilities from the literature.

The program evaluates level population and *contribution functions* for temperature ranging between 10^4 and 10^8 K and any electron density, usually assumed between 10^6 and 10^{15} cm^{-3}. Also continuum emission from free-free, free-bound and two-photon processes is evaluated.

An example of the continuum emission is shown in Fig. 1.

The selection of the data for the minor elements has been carried on using the excellent reviews given in the CHIANTI paper (Dere et al. 1997), Pradhan & Gallagher (1992), Itikawa et al. (1984) and Itikawa (1991) and (1996). The paucity of theoretical calculations in the literature (especially for collisional data) has often severely restricted the range of possible choices. The minor elements dataset have been developed mainly adopting theoretical results calculated using the University College of London distorted wave program (Eissner & Seaton 1972) and the close coupling (CC) R-Matrix package (Burke et al. 1971; Berrington et al. 1978) developed at Queens University of Belfast. Like the CHIANTI data, the minor elements dataset allows to evaluate the statistical equilibrium level population. Nevertheless no collision data are available for the Magnesium-like, Oxygen-like, and nitrogen-like minor elements, so it has been necessary to interpolate the effective collision strengths and the radiative data from the isoelectronic ions which were available in the CHIANTI database. The quality of the interpolation depends heavily on the accuracy of the existing data, and in some cases there are severe limitations to the reliability of the interpolated results.

3. The atomic data for minor elements

3.1. Lithium isoelectronic sequence

The Lithium-like ions atomic structure is simpler than other sequences and there are no metastable levels. This causes the Li-like spectral lines to be density insensitive and very useful for *differential emission measure* studies. The Lithium-like spectrum is dominated by the strong 2s $^2S_{1/2} - 2p\ ^2P_{1/2,3/2}$ doublet, which has been extensively observed and studied in the past two decades in all the spectra of the most abundant elements.

The minor elements $^2S - {}^2P$ doublets have been detected in several observations, both in active region and flare conditions. Na IX has been detected in active and quiet Sun (Vernazza & Reeves 1978; Doyle 1983) and falls in the spectral range covered by both SUMER and CDS spectrograph, where it has been detected in limb and disk spectra (Landi et al. 1998; Feldman et al. 1997). Lines from P XIII to Co XXV have been observed by several authors in active and flaring Sun (Kelly & Palumbo 1973; Sandlin et al. 1976; Widing & Purcell 1976; Dere 1978).

McWhirter (1994) reviewed the existing literature for Lithium-like ions and found that the electron excitation data available seem to be very accurate. Since we are going to include in this database the ions of minor elements heavier than Oxygen, following the suggestions of McWhirter (1994) we adopt the theoretical data calculated by Zhang et al. (1990). The authors provide complete data for all the minor ions. Configurations up to 5d are considered, corresponding to 20 fine structure energy levels. Additional collisional data are also available for the 5f transitions but no radiative transition probabilities have been found in literature so these levels have been omitted. Relativistic distorted wave collision strengths are provided for 6 electron energies, together with the electric dipole oscillator strengths. Some additional oscillator strengths come from Martin et al. (1993). The observed energy levels are taken from the NIST database (Martin et al. 1995). For the heavier ions only the energies of the lowest configurations have been measured so wavelengths for transitions coming from higher levels have been calculated with the theoretical energy levels found in Zhang et al. (1990).

3.2. Beryllium isoelectronic sequence

Beryllium like ions have been studied extensively in literature both for *differential emission measure* determination and for plasma diagnostics, since in their atomic structure some metastable levels are present. The Be-like spectrum is dominated by the strong resonance transition $2s^2\ ^1S_0 - 2s2p\ ^1P_1$ giving rise to some of the most prominent lines in solar and stellar spectra. In the literature some Be-like minor elements lines have been observed (Sandlin et al. 1976; Dere 1978; Vernazza & Reeves 1978; Doyle 1983; Feldman et al. 1987; Thomas & Neupert 1994) in active and flaring Sun. Moreover the Na VIII $2s^2\ ^1S_0 - 2s2p\ ^1P_1$ line at 411.17 Å is observed by the Coronal Diagnostic Spectrometer (CDS) on SOHO (Landi et al. 1998) and several other minor elements lines are detectable by CDS (Brooks et al. 1998). Beryllium-like minor elements lines have been detected also by the Solar UV Measurement of Emitted Radiation (SUMER) on SOHO (Feldman et al. 1997).

Be-like minor elements electron excitation literature is richer than other sequences and has been reviewed by Berrington (1994). It has therefore been possible to insert in the Arcetri spectral code complete data for all the minor ions. Both close coupling R-Matrix and distorted wave calculations are available in literature, and following the suggestions in Berrington (1994) we have adopted the close coupling data when possible, and used distorted wave results only where CC data were unavailable. Maxwellian averaged collision strengths from Keenan et al. (1986) have been adopted for Na VIII, while the values of Keenan (1988) have been used for P XII, Cl XIV and K XVI. Both these works provide analytical fits to the effective collision strengths that allow to calculate their values for a wide range of electron temperature around the maximum abundance temperature of each ion. The relativistic distorted wave collision strengths of Zhang & Sampson (1992) have been taken for the remaining heavier minor elements; they provide relativistic distorted wave collision strengths for all the possible transitions in the adopted atomic model, evaluated for six values of the electron energy. The atomic model includes the $n = 2$ configurations ($2s^2$, 2s2p, $2p^2$) corresponding to 10 fine structure levels. Experimental energy levels have been taken from Edlen (1983). Allowed oscillator strengths are taken from Zhang and Sampson (1992), while forbidden radiative transition probabilities come from Muhlethaler & Nussbaumer (1976) and Bhatia et al. (1986). No radiative transition probability is available for level 2s2p $^3P_0$.

3.3. Boron isoelectronic sequence

The Boron-like spectra have been proved extremely useful for density diagnostic in a variety of plasma conditions and have been studied extensively in literature. Nevertheless their spectra do not present very strong and prominent lines as the Li, Be, Na and Mg-like ions and so in the past lines from the Boron-like minor elements have been observed very seldom (Vernazza & Reeves 1978; Doyle 1983; Thomas & Neupert 1994). Na VII lines fall in the CDS spectral range and have been observed around 350 Å blending Mg V lines (Brooks et al. 1998) and are expected in the range 486−490 Å. Boron-like minor elements lines have been detected by the Solar UV Measurement of Emitted Radiation (SUMER) on SOHO (Feldman et al. 1997).

The Boron-like electron excitation rates have been reviewed by Sampson et al. (1994). It appears that the minor ions have been neglected in the literature and the only complete datasets available are those by Zhang & Sampson (1994a) ($n = 2$ transitions), Zhang & Sampson (1994b) and Sampson et al. (1986) ($n = 2$ to $n = 3$ transitions). Zhang et al. (1994) calculated close coupling LS coupled effective collision strengths for all the $n = 2$ transitions of the most abundant elements as part of the iron project (Hummer et al. 1993). Unfortunately they did not cover the minor elements, and therefore their high quality calculation can only be used for interpolation purposes. An additional problem is that effective collision strengths are reported only between LS coupled levels, while the Arcetri spectral code includes only fine structure data.

In the arcetri spectral code we have included only the $n = 2$ transitions. The configurations $2s^22p$, $2s2p^2$ and $2p^3$ have been considered, corresponding to 15 energy levels whose experimental energies were taken from the NIST database (Martin et al. 1995) and Edlen (1981). Allowed transitions oscillator strengths come from Zhang et al. (1994a), while forbidden and intercombination ones are taken from Flower & Nussbaumer (1975). Zhang et al. (1994a) provide also relativistic distorted wave collision strengths for 6 electron energies for all the possible transitions between the levels included in the atomic model; these collision strengths have been adopted in the Arcetri code.

3.4. Carbon isoelectronic sequence

The atomic structure of Carbon-like ions shows several metastable levels and this produces a rather strong density sensitivity of the emitted lines in a variety of plasma conditions, from quiet Sun (Na VI to Si IX) to active region (Mg VII to S XI) and flares (higher ions). For this reason C-like ions have been widely studied in the past for density diagnostics purposes.

As for the Boron-like ions, the absence of very strong and dominating lines in the C-like spectrum has been an obstacle to the detection of C-like minor ions lines; however a few have been observed by Vernazza & Reeves (1978); Doyle (1983) and Thomas & Neupert (1994). Some lines fall in the CDS spectral range, but their weakness and the blending with stronger lines have been an obstacle to their detection and identification. Carbon-like minor elements lines have been detected by the solar UV measurement of emitted radiation (SUMER) on SOHO (Feldman et al. 1997).

The atomic data available for the Carbon-like ions have been reviewed by Monsignori Fossi & Landini (1994c), although their assessment is limited only to the most abundant ions from O III to Fe XXI. They found that there were differences between distorted wave and close coupling R-matrix results; the discrepancies were mainly due to differences in the target wave functions used in the calculation and to the possibility of taking into account the resonance contributions to the effective collision strengths with the close coupling method. They recommended the use of close coupling results when possible. Nevertheless C-like minor ions collision strengths literature is very poor. Lennon & Burke (1994) calculated close coupling effective collision strengths for transitions between the ground configuration levels, including also the $2s2p^3$ ^5S term for all the ions from N II to S XI. Zhang & Sampson (1996) calculated relativistic distorted wave collision strengths for all the ions with $9 \leq Z \leq 54$ for all the $n = 2$ to $n = 2$ transitions. Therefore, following the recommendation of Monsignori Fossi & Landini (1994c) we adopted the close coupling data from Lennon & Burke (1994) for Na VI and the distorted wave results for all the remaining transitions and ions. We have preferred distorted wave data to close coupling results in the case of Al VIII and P X because Lennon & Burke (1994) provide effective collision strengths only up to 10^5 K, while the temperature of maximum abundance of these two ions is respectively $10^{5.9}$ K and $10^{6.3}$ K. Since we are most interested in the temperature range around the maximum abundance temperature of each ion we felt that Zhang & Sampson results were more reliable for our purposes.

The adopted atomic model includes three configurations ($2s^2 2p^2$, $2s2p^3$ and $2p^4$) corresponding to 20 fine structure levels, whose experimental energies are taken from the NIST database (Martin et al. 1995); additional energy levels come from the compilation of Edlen (1985). Allowed transition oscillator strengths are taken from Zhang & Sampson (1996) and Bhatia et al. (1987a). There are some discrepancies between these data and the results of Fawcett (1987), and differences of $\simeq 20 - 30\%$ have been found in the A values. Ground configuration radiative transition probabilities for the minor ions have been calculated by several authors (Nussbaumer & Rusca 1979; Froese Fischer & Saha 1985; Bhatia et al. 1987a; Bhatia & Kastner 1993a; Bhatia & Doschek 1993a; Bhatia & Doschek 1995a; Galavis et al. 1997). A comparison between these calculations has shown a general good agreement although some more consistent differences arise for transitions $^3P_0 - ^1D_2$ and $^3P_2 - ^1S_0$. In the present work data from Galavis et al. (1997) have been adopted.

All the collisional data are from Zhang & Sampson (1996); they provide relativistic distorted wave collision strengths for all the possible transitions in the adopted atomic model calculated for 6 values of the electron energy. For Na VI, the Lennon & Burke (1994) close coupling effective collision strengths have been adopted. A comparison between these two datasets shows that some differences are found for low temperature values, due probably to the effect of resonances.

3.5. Nitrogen isoelectronic sequence

Nitrogen-like ions show a rather strong density sensitivity for a variety of solar plasma conditions and for this reason have been extensively used for density diagnostic. The *N*-like spectra do not give rise to very strong lines, and for this reason Nitrogen like minor elements lines have seldom been observed. We find some relatively weak lines of the lighter minor elements in the spectra of SERTS (Thomas & Neupert 1994), SUMER (Feldman et al. 1997), while some lines from Cr XVIII have been observed around 15 Å by McKenzie & Landecker (1982), which also point out the importance of chromium as plasma diagnostic for hot plasmas.

The electron-ion collision literature of the nitrogen isoelectronic sequence is rather poor and the same problem is found for the radiative transition probabilities. Kato (1994) has reviewed the existing N-like literature and found that some calculations have been perfomed only for Na V, Ti XVI, Mn XIX and Zn XXIV. The Na V calculation are very old (earlier than 1970) and the Zn XXIV distorted wave calculation by Bhatia et al. (1989) is carried on for only one incident electron energy, giving in this way additional uncertainties in the evaluation of the Maxwellian-averaged collision strength.

For this reason for most of the minor elements it has been necessary to interpolate the existing data for the most abundant elements in order to obtain both the radiative transition probabilities and the effective collision strengths of the œminor elements. The data used for these interpolation come from Bhatia and Mason (1980a) (Mg VI to Ca XIV) and Bhatia & Mason (1980b) (Fe XX). New calculations for Mg VI has been recently performed by Bhatia & Young (1997), who find excellent agreement between their results and Bhatia & Mason (1980a).

Co XXI and Ni XXII collisional data have not been interpolated because of the great uncertainties in the values of the Zn XXIV effective collision strengths. The accuracy of the interpolation results is rather poor, since some irregularities of the effective collision strengths along the isoelectronic sequence are found for several transitions. For this reason further studies on the Nitrogen-like electron-ion collision strengths are required.

The adopted atomic model for N-like minor elements includes two configurations ($2s^22p^3$ and $2s2p^4$) corresponding to 13 fine structure energy levels. The values of the energy levels are taken from Edlen (1984) and NIST (Martin et al. 1995). All radiative and collisional transition probabilities have been interpolated for all the ground transitions and the transitions between the two adopted configurations. Only Ti XVI, Mn XIX and Zn XXIV data have not been interpolated. The distorted wave calculations of Bhatia et al. (1989) have been adopted for Zn XXIV only for the two considered configurations, although data for additional configurations are available. The atomic data for Ti XVI and Mn XIX are taken from the distorted wave calculations of Bhatia et al. (1980) and Bhatia (1982) respectively. These papers report radiative transition probabilities and collision strengths for all the ground configuration and for $2s^22p^3 - 2s2p^4$ transitions; the collision strengths have been calculated for three values of the incident electron energy.

3.6. Oxygen isoelectronic sequence

The Oxygen-like less abundant ions give rise to relatively weak lines on the EUV spectral range and for this reason they have not been observed in the past. Only some lines of the highly ionized Cr XVII have been observed by McKenzie & Landecker (1982). Nevertheless lines for the lighter ions of the sequence are observable by the CDS spectrometer on board on SOHO and some identifications of these lines are suggested by Brooks et al. (1998).

The lack of observed Oxygen-like minor ions lines has caused these ions to be neglected in literature. Lang & Summers (1994) reviewed the existing electron excitation data available; from their compilation it comes out that only Na IV, Al VI and P VIII (calculations earlier than 1970) and the highly ionised Ti XV and Mn XVIII (Bhatia et al. 1980 and Bhatia 1982) have been studied using the distorted wave approximation, while no data is available for the other ions. The Iron Project has partially covered the gaps providing close coupling calculations for collisional induced transitions between the ground levels of all the Oxygen-like ions from F II to Ar XI (Butler & Zeippen 1994). To our knowledge, no collision strengths calculations are available for transitions between the ground and the excited configurations for the minor elements.

The adopted atomic model for Oxygen-like ions includes three configurations ($2s^22p^4$, $2s2p^5$ and $2p^6$) corresponding to 10 fine structure levels. The experimental energy levels of Edlen (1983) are used for calculating the transition wavelengths. The radiative transition probabilities come from different sources. The ground transitions data have been taken from Galavis et al. (1997), while data for the allowed $2s^22p^4 - 2s2p^5$ and $2s2p^5 - 2p^6$ transitions come from Fawcett (1986a). Vilkas et al. (1994) also have calculated electric dipole transition probabilities for the Oxygen-like ions from Ne to Fe, including several minor ions, but their values do not well agree neither with the Fawcett (1986a) data nor with the radiative data of the CHIANTI database for the most abundant elements (Bhatia et al. 1979; Lolergue et al. 1985). Ti XV and Mn XVIII radiative data come from Bhatia et al. (1980) and Bhatia (1982). The Arcetri spectral code adopts the Iron Project collisional data for the ground transitions of the minor elements Na IV, Al VI and P VIII. Collisional data for all the other transitions have been interpolated along the isoelectronic sequence, with the only exception of Ti XV and Mn XVIII whose collision strengths are taken from the distorted wave calculations of Bhatia et al. (1980) and Bhatia (1982). Since data for elements heavier than Fe were not available, it has not been possible to interpolate any data for Co XX, Ni XXI and Zn XXIII which therefore are not included in the Arcetri spectral code.

3.7. Fluorine isoelectronic sequence

The Fluorine-like minor ions give rise to very weak lines and therefore to our knowledge there are no direct observations of their lines in astrophysical plasmas, with the only exception of Cr XVI (Acton 1985; McKenzie & Landecker 1982). F-like minor ions lines are potentially detectable by the CDS spectrometer from Na III to P VII.

Because of their weakness, very few calculations are available in literature providing minor ions electron excitation rates: Bhatia 1994 has reviewed the Fluorine isoelectronic sequence electron excitation data; only very old Coulomb-Born calculations by Blaha (1968, 1969) are mentioned. Moreover no data are available at all for Al IV and Co XIX, and only Ti XIV and Mn XVII have been studied more extensively with the distorted wave approximation (Bhatia et al. 1980; Bhatia 1982); furthermore, only LS coupling results are available from the close coupling calculation of Mohan et al. (1989).

In the present work we have adopted a two configurations atomic model ($2s^22p^5$ and $2s2p^6$), including three fine structure energy levels. The experimental energies are taken from the NIST database (Martin et al. 1995), while all the electron excitation effective collision strengths have been interpolated using the existing data of the most abundant elements included in the CHIANTI database. Ti XIV and Mn XVII data instead come from Bhatia et al. (1980), Bhatia (1982). In order to check the quality of the interpolation method, we have also interpolated collisional data for Ti and Mn, and comparisons have been made between our results and the existing LS coupling literature for these two ions, showing reasonable agreement.

3.8. Sodium isoelectronic sequence

The Sodium-like spectrum is dominated by the two very strong 3s $^2S_{1/2}$ − 3p $^3P_{1/2,3/2}$ lines which give rise to some of the brightest lines observed from visible to UV and EUV spectral ranges. The strength of these features have permitted the observation of all the Na-like minor elements from P V to Zn XX (Burton 1970; Doyle 1983; Vernazza & Reeves 1978; Dere 1978; Thomas & Neupert 1994) in a variety of solar conditions. Several of these lines are included in the CDS and SUMER spectral ranges and have been observed (Feldman et al. 1997). These lines are density insensitive and can be used for *differential emission measure* studies (Landi & Landini 1998).

Sodium-like ions literature is relatively rich, nevertheless the great majority of them deals only with the most abundant ions of the sequence and only few studies cover also the minor ions. In the present work we have adopted the radiative and collisional data coming from Zhang & Sampson (1990). The adopted atomic model includes 11 configurations (3s, 3p, 3d 4s, 4p, 4d, 4f, 5s, 5p, 5d, 5f) corresponding to 19 fine structure energy levels. Allowed radiative and collisional transition probabilities are taken from Zhang & Sampson 1990; they provide relativistic distorted wave collision strengths for 6 values of the incident electron energy. The experimental energies are taken from the NIST database (Martin et al. 1995).

3.9. Magnesium isoelectronic sequence

The Magnesium sequence is dominated by the very strong $3s^2$ $^1S_0$ − 3s3p $^1P_1$ transition giving rise to some of the most prominent lines in EUV and UV spectra. For this reason also the minor elements lines have been observed in astrophysical plasmas (Dere 1978; Vernazza & Reeves 1978; Thomas & Neupert 1994; Feldman et al. 1997; Brooks et al. 1998).

Nevertheless, Mg-like minor elements literature is very poor and data are quite uncertain. Only Cr XIII has been studied by Christensen et al. (1986), which provide distorted wave collision strengths for 3 incident electron energies. To our knowledge there are no other sources for collisional data. A further problem with the Magnesium like ions is the difficulty to reliably interpolate Christensen et al. (1986) data since the collision strengths show irregular behaviour for several transitions. For this reason we have preferred not to calculate minor elements data by interpolation, recommending further work on this subject.

The Cr XIII adopted atomic model is the same as the CHIANTI Mg-like abundant ions: 5 configurations are included corresponding to 16 fine structure energy levels. Radiative transition probabilities and experimental level energies are also taken from Christensen et al. (1986).

3.10. Fe III

Fe III lines have been observed in the past decades in many different astrophysical objects and have been extensively analysed by several authors. In the recent past Ekberg (1993) carried on a very careful analysis of the Fe III spectrum using a laboratory light source, identifying a very large number of lines ($\simeq 3200$), many of which were observed for the first time; moreover the SUMER instrument on board SOHO has recorded many Fe III allowed transitions (Feldman et al. 1997).

All these observations have recently raised the interest into theoretical calculations of the Fe III atomic data and radiative and collisional transition probabilities despite the difficulties caused by the complexity of this ion. Both radiative and collisional transition probabilities have been studied in the Iron Project (Hummer et al. 1993) which represent the most accurate and extensive calculations performed on Fe III. Ab initio calculations of radiative transition probabilities have been performed by Nahar & Pradhan (1996), including electric dipole transitions between the three lowest configurations, and quadrupole and magnetic dipole transitions probabilities among the ground configuration levels. The authors found some differences between their calculation and the semiempirical calculations made in the past (Kurucz & Peytremann 1975; Biemont 1976; Fawcett 1989 and Ekberg 1993). Also Quinet (1996) has calculated radiative transition probabilities between the ground levels; a comparison with the Nahar & Pradhan (1996) results show a reasonable good agreement although sometimes discrepancies larger than 30% are found.

The most recent calculations of collisional data have been performed by Zhang (1996) and Berrington et al. (1991). The former represents a large scale calculation which covers 219 fine structure levels among the three lowest configurations using a non relativistic close coupling approximation. Berrington et al. (1991) data included relativistic effects calculations but studied only some ground configuration transitions. Zhang & Pradhan (1995) show that the relativistic effects should be negligible and that a non relativistic fine structure calculation should be accurate, provided that an extensive eigenfunction basis set is used. For this reason we adopt the Zhang (1996) collisional data in the Arcetri spectral code.

Unfortunately, no radiative transition probabilities are available for $3d^6 - 3d^54s$ transitions and among the $3d^54s$ levels. Thus several metastable levels of the $3d^54s$ configuration have no radiative transition probability available. This would lead to greatly overestimate the population of these levels and to alter the population balance of the ion. For this reason this configuration has not been included in our Fe III model. Since the energies of the $3d^54s$

configuration are close to those of the ground levels, it is possible that in coronal conditions the level populations for the $3d^5 4s$ configuration are high enough to affect the total level population of Fe III, and therefore the omission of this configuration may be a limitation to the present model for Fe III.

The adopted atomic model for Fe III includes the two configurations $3d^6$ and part of the $3d^5 4p$, corresponding to 131 fine structure levels. The experimental energy levels come from Sugar & Corliss (1985) and Ekberg (1993); no value is available for the level $3d^5 4p\ ^5D_3$, and therefore its energy has been interpolated from the available energies of the $3d^5 4p\ ^5D$ multiplet. Radiative data for both forbidden and allowed transition probabilities come from Nahar & Pradhan (1996), while Maxwellian-averaged collision strengths for transitions between all levels of the adopted atomic model come from Zhang (1996), which provides values of the Maxwellian-averaged collision strengths for 20 values of the electron temperature T_e between 10^3 to 10^5 K.

4. Comparison with the old Arcetri spectral code

Most of the lines considered in the old version of the Arcetri spectral code were calculated under the assumption that the population of the upper level of the transition j occurs mainly via excitation from the ground level g and the depopulation of level j occurs through spontaneous radiative decays. We may then express the power emitted per cm^{-3} by the transition $j \rightarrow k$ of the ion X^{+m} following Kato (1976) and Stern et al. (1978) as

$$P_{jk} = \frac{N(X^{+m})}{N(X)}\ \frac{N(X)}{N_H}\ \frac{N_H}{N_e}\ C_{gj}\ E_{jk}\ B_{jk} \qquad (6)$$

where E_{jk} is the energy involved in the transition $j \rightarrow k$ and B_{jk} is the radiative branching ratio. The collisional excitation rate is given by (Kato 1976)

$$C_{gj} = 8.63\ 10^{-6} \exp^{\frac{-E_{gj}}{kT}}\ T^{-\frac{1}{2}}\ \frac{\Omega_{gj}}{\omega_g} \qquad (7)$$

where ω_g is the statistical weight of the ground level and Ω_{gj} is the *collision strength* from the ground level. We are mainly interested in allowed transition and therefore the collision strength may be computed as

$$\Omega_{gj} = \frac{8\pi}{\sqrt{3}}\ \frac{\omega_g}{E_{gj}}\ f_{gj}\ g$$

with E_{gj} in Rydberg. f_{gj} is the *oscillator strength* of the transition and g is the *Gaunt factor*, computed according to Mewe et al. (1985). For the He & Li isoelectronic sequence use is made of the procedure given by Mewe (1972) and Mewe et al. (1981), and for details on transition from metastable levels we refer the reader directly to Landini & Monsignori Fossi (1990).

In the present update of the Arcetri spectral code we have renewed the database of oscillator strengths for the

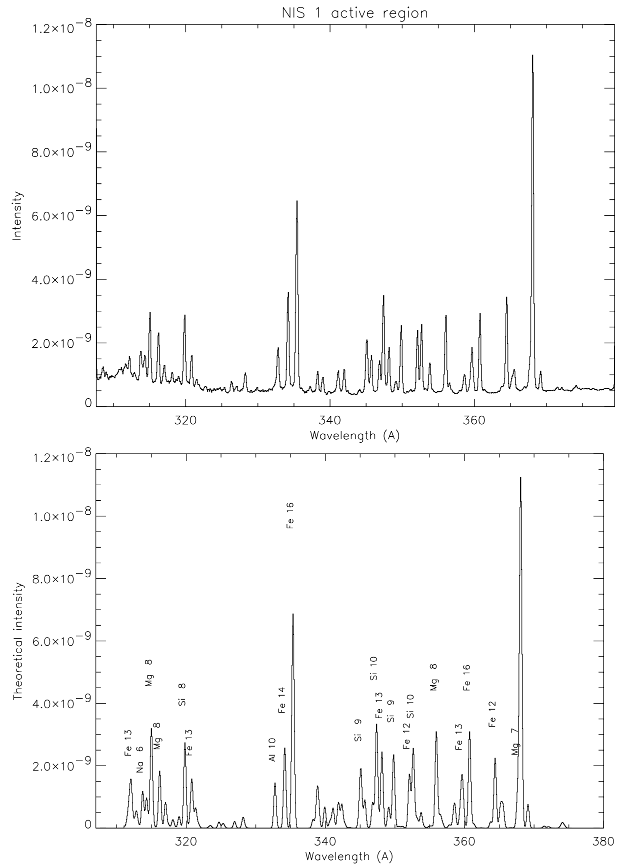

Fig. 2. NIS1 spectrum of a solar active region. The normal incidence spectrograph observation from SOHO of an active region *(top)* is compared with the simulated synthetic spectrum *(bottom)*; use is made of the Arcetri spectral database; the electron density 2 10^9 cm^{-3} is assumed

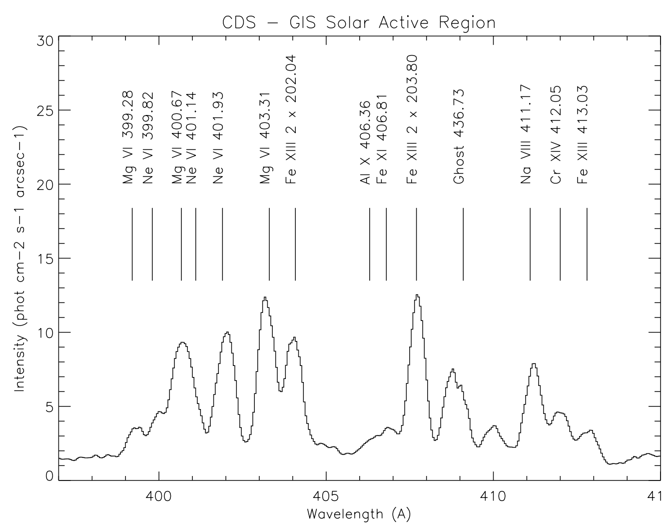

Fig. 3. New lines included in the code. The grazing incidence spectrum of a solar active region from 397 Å to 415 Å. Data from CDS on SOHO. The clearly identified NaVIII 411.17 and CrXIV 412.05 are among the new lines included in the *minor elements* database. The spectrum has been convoluted with a Gaussian in order to remove fixed patterning

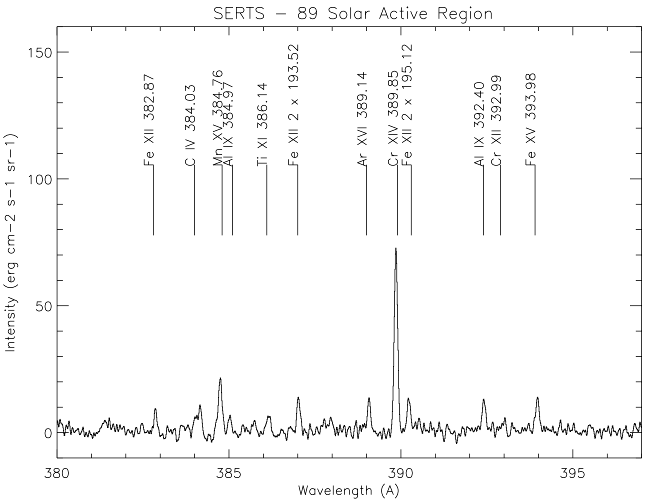

Fig. 4. The SERTS-89 line identification. The section between 380 Å and 397 Å of the spectrum of the SERTS-89 flight (Thomas & Neupert 1994). The lines of Mn XV, Ti XI, and Cr XIV are among the new ones included in the database

ions included in the old version. In the recent past several new calculations of radiative transition probabilities have been carried on in order to match the increasing need for very accurate radiative data. The Opacity Project (Seaton et al. 1992) results has been adopted for most of the transitions included in the new version of the Arcetri spectral code. Oscillator strengths obtained in the Opacity Project are reported in Verner et al. (1996). Since in the Opacity Project calculation relativistic effects are neglected, LS coupling is assumed. Verner et al. (1996) calculated oscillator strengths for each individual line of the LS multiplet assuming the LS coupling rules (Russel 1936). This procedure may introduce some uncertainties in the resulting fine-structure oscillator strengths, nevertheless the values thus obtained are still much more reliable than those included in the old version of the Arcetri code, since the latter were based on much older and less refined calculations. In a few cases very large differences are seen. Other sources for oscillator strengths are Fawcett (1986a) (O-like ions), 1986b (S-like ions) and (1986c) (P-like ions) and Shirai et al. (1987) (Nickel Ions).

New recent calculations of oscillator strengths have also permitted to add to the code a large number of new levels. The new dataset adopted in this version of the Arcetri spectral code allows the calculation of the theoretical emission of a far larger number of lines than the previous version.

In order to understand whether the changes in the atomic data affected the resulting theoretical line intensities we have performed a detailed comparison between the old and the new versions of the Code. A critical discussion is given in the following sections.

The old version of the Arcetri spectral code allowed the full calculation of the level population only for the Iron ions and the most abundant elements of the Beryllium, Carbon and Nitrogen isoelectronic sequences (hereafter *group 1* lines); while the line emission of all the other ions was calculated using the approximation described at the beginning of this section (*group 2*).

4.1. Group 2 transitions

As expected, the comparison between group 2 transitions shows very often marked differences. We have compared lines belonging to the most abundant ions longward of 12 Å.

The differences between singlet lines may be higher than an order of magnitude, and normally it is found that the old version of the Code overestimates the new version's results. It is also interesting to note that the differences between most of the lines are temperature dependent, and sometimes this dependence is very strong (up to a factor of 2). Nevertheless the differences between strong lines such as the Magnesium-like $3s^2\ ^1S - 3s3p\ ^1P$ are very small.

The old version of the Code most often reported transitions between LS coupled terms and therefore these multiplets were summed. The level population calculations of the new Code are carried on considering individual fine structure atomic levels and allows proper consideration of each line of the multiplet. This is a great improvement in most cases since the wavelength differences between each of the lines belonging to the multiplet are often of several Angstroms, much greater of the resolving power of all the modern spectrometers. The differences between the emissivities calculated by the two versions rise very often up to an order of magnitude and are temperature dependent in most cases. Again, the old emissivities are usually greater then the new ones. The differences between very strong lines such as the Lithium-like $2s\ ^2S - 2p\ ^2P$ and Sodium like $3s\ ^2S - 3p\ ^2P$ doublets are much smaller, tipically around 20%.

4.2. Beryllium-like ions

Beryllium-like C III lines show larger differences (up to 40%). This is due to the different adopted data, since the old code uses one electron distorted wave collision strengths (Bhatia & Kastner 1993c) while the present version includes R-Matrix results (Berrington et al. 1985, 1989). In the case of such a light ion the resonances may play a very important role in determining the total collision strength of transitions. O V differences are limited to 20% and are due to changes in the radiative transition probabilities. Similar differences are also found in Fe XXIII, due to the change of collisional transition probabilities for the three lowest configurations, since the old code adopts Bhatia & Mason (1986) three energies distorted wave collision strengths while the CHIANTI database uses the six energies relativistic distorted wave calculations of Zhang & Sampson (1992). More dramatic differences are found for Ne VII, Mg IX and Si XI, where differences rise up even to a factor of 10. The CHIANTI adopted atomic model for these ions includes also $n = 3$ levels, and a metastable level 2p3d $^3F_4$ is found for which no radiative transition probability is available in literature. This causes this level to be strongly populated altering the population of all levels, leading to great differences from the old code atomic model which included only the $n = 2$ levels. Work is in progress to exclude these levels from the statistical equilibrium but further work is recommended for radiative transition probabilities in the Beryllium isoelectronic sequence.

4.3. Carbon-like ions

The differences arising between the Carbon-like ions are mainly due to the fact that for several of them the collisional data between the $2s^22p^2$, $2s2p^3$ and $2p^4$ configurations have been changed. The old version of the Code used for these ions distorted wave collision strengths (Bhatia & Kastner 1993b; Bhatia & Doschek 1993a–c and 1995; Mason et al. 1979), while the CHIANTI database adopted R-Matrix effective collision strengths (Lennon & Burke 1994; Aggarwal 1983, 1984, 1985, 1986 and 1991). The differences between the two spectral codes are significant but not very large. The lighter ions (O III and Ne V) show differences up to 30%, due to the fact that the R-Matrix approximation takes into account more properly the resonance contributions. The higher ions Ca XV and Fe XXI instead show a better agreement, with differences always smaller than 15%. This is as expected since the distorted wave is a valid approximation for highly ionized systems. Differences between the S XI lines rise up to 20%, due to the fact that the old code adopts the one-electron collision strengths of Bhatia et al. (1987b), while the CHIANTI database includes the Mason & Bhatia (1978) three-energies collision strengths, allowing therefore a more precise calculation of the effective collision strengths.

4.4. Nitrogen-like ions

The data for Nitrogen-like ions, Mg VII, Si IX, Ca XVII and Ni XXV have not been changed and therefore we expect identical results. Nevertheless very small differences (smaller than 5% in most cases, always smaller than 10%) are found for several transitions. This is due to the fact the collision strengths and the effective collision strengths of the old code have been scaled according to scaling laws different from those adopted in the CHIANTI database and the new version of the code. Both scaling laws are derived from the work of Burgess and Tully (1992), but there are some differences in considering the high energy limit and the forbidden transitions scaling laws. The fact that there is a very good agreement between calculations performed with the same data but different ways of scaling them is a strong evidence that the use of the scaling laws themselves does not affect significantly the resulting calculated emissivities.

4.5. Iron ions

The old code included data for the Iron ions from Fe IX to Fe XXIII, and a brief description of the Iron database is given in Monsignori Fossi & Landini (1996). This selection of atomic data was very careful and covered all the existing Iron ions literature up to 1994. Nevertheless in the last four years a number of new calculations have been performed for many Iron ions and these have been included in the CHIANTI database and therefore in the new version of the Arcetri code. The data for Fe XVI, XVII, XIX and XX are identical and therefore the differences between the two codes are smaller than 5% and are due to the slight difference between the scaling of the electron collisional data such as for the N-like ions.

CHIANTI Fe IX radiative transition probabilities have been calculated using the program SUPERSTRUCTURE (Eissner et al. 1974) during the development of the CHIANTI database by P.R. Young, adopting 11 configurations ($3s^23p^6$, $3s^23p^53d$, $3s3p^63d$, $3s3p^53d^2$, $3s^23p^43d^2$, $3p^63d^2$, $3p^33d^3$, $3s^23p^54l$ with $l = 0, 1, 2, 3$) and have been used in the present version of the Code. The most important difference between these values and those reported in the old version of the code (from Fawcett & Mason 1991) concerns the strong $3s^23p^6\ ^1S - 3s^23p^53d\ ^1P$ transition observed at 171.07 Å whose oscillator strength which shows a 25% difference between these two calculations. This difference is reflected in the calculated emissivity.

Fe X distorted wave and R-Matrix collision strengths have been calculated by Bhatia & Doschek (1995b) and Pelan & Berrington (1995) and adopted by CHIANTI. The differences between these calculations and the Mason (1975) ones adopted in the old code rise up to factor 2. This is a very important updating since some Fe X are very strong and widely observed in the EUV spectral range.

Bhatia & Doschek (1996) have calculated three energy distorted wave collision strengths for Fe XI whose inclusion in the CHIANTI database causes the new Arcetri code to be different from the old version which adopted the Mason (1975) results. The discrepancies rise up to a factor 2 for some transitions, but for most lines they are smaller than 40%. These differences are temperature dependent.

Fe XII atomic data and transition probabilities of the two Arcetri codes are the same but the new code includes more energy levels whose presence causes great differences between the results. In the new Arcetri code, some Fe XII

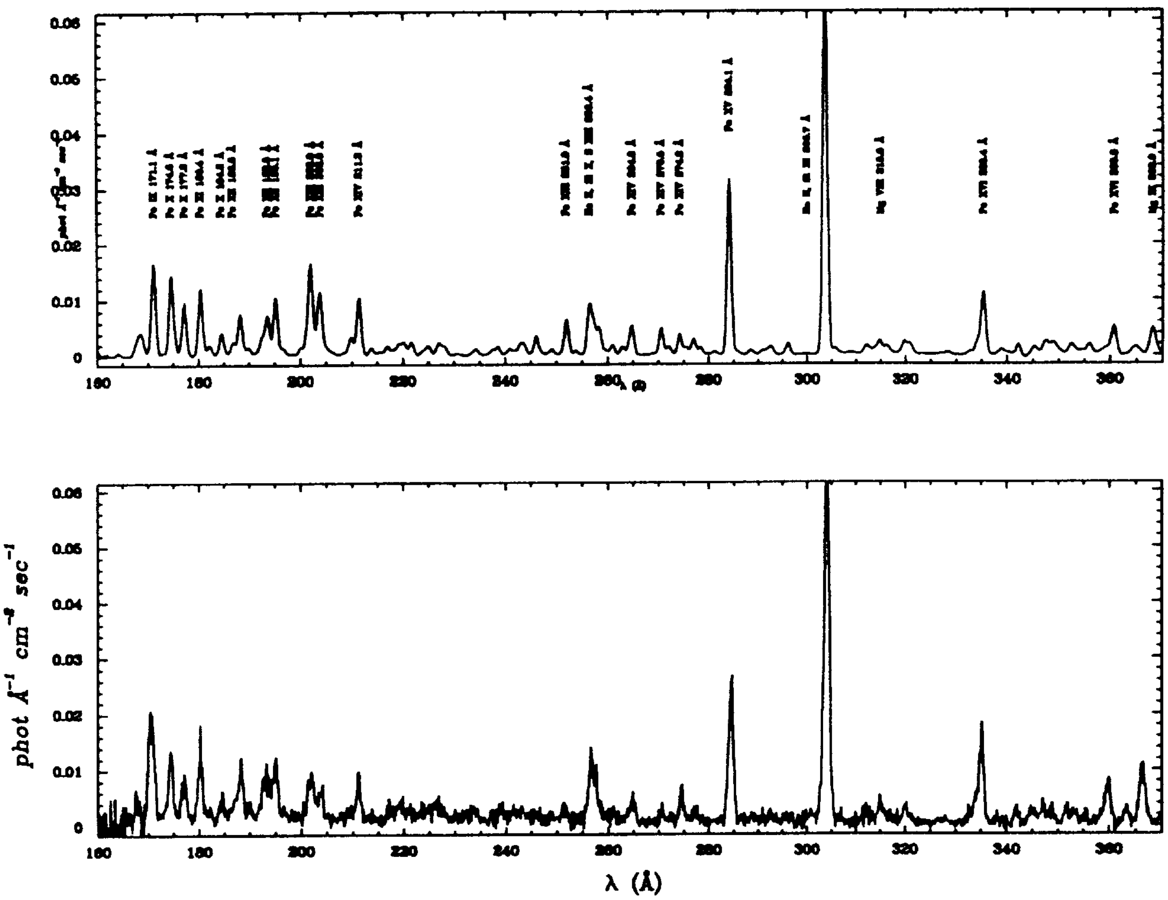

Fig. 5. The EUVE spectrum of α *Centauri*. The medium wavelength section of the *extreme ultraviolet explorer* spectrum of α *Centauri*: the synthetic spectrum *(top)* is compared with the observated one *(bottom)*. Several prominent lines are labeled with their identifications

lines have smaller emissivities than the old ones up to a factor 3.

The Fe XIII collisional transition probabilities are the same in the two versions of the code, but some differences are found in the radiative transition probabilities since the CHIANTI database adopted unpublished SUPERSTRUCTURE calculations obtained with a 24 configuration model. Most importantly, the CHIANTI Fe XIII atomic model includes also the $3s^2 3p3d\ ^3F_4$ metastable level whose population becomes significant at coronal densities and therefore influences the overall Fe XIII level population. This causes the two codes to be different up to 50%.

Storey et al. (1996) calculated R-Matrix effective collision strengths for the Fe XIV ground $^2P_{1/2} - {}^2P_{3/2}$ transition but this is the only difference between the two versions of the code and, as already noted by Dere et al. (1997), this change of data does not alter significantly the results. We find discrepancies between the two datasets smaller than 10%.

Fe XV collisional transition probabilities have been calculated by Bhatia et al. (1996) (three-energies distorted wave collision strengths) and are adopted in CHIANTI. The old code adopted Christensen et al. (1985) results and great differences rise between the two codes. We have found that most transitions have differences up to 50%. It is worth noting that the very strong 284.16 Å transition shows agreement better than 10%.

Changes in Fe XVIII new code dataset have been made both in the radiative and collisional transitions probabilities. CHIANTI adopts A values from Blackford & Hibbert (1994), and relativistic distorted wave collision strengths from Sampson et al. (1991), while the old code takes all data from Cornille et al. (1992). Nevertheless it is found that the differences between the calculated emissivities are limited to less than 20%, consistently with the good agreement found in the two sets of collision strengths.

Fe XXI collisional data have been changed and Aggarwal (1991) data have been adopted in the new code, nevertheless, as noted in Sect. 4.3, agreement better than 15% is found between the two codes.

Fe XXII data have been improved with Zhang et al. (1994) and Zhang & Sampson (1995) calculations, increasing the number of included energy levels (20 in the old code, 125 in the new one). This results in big differences in the output of the two codes.

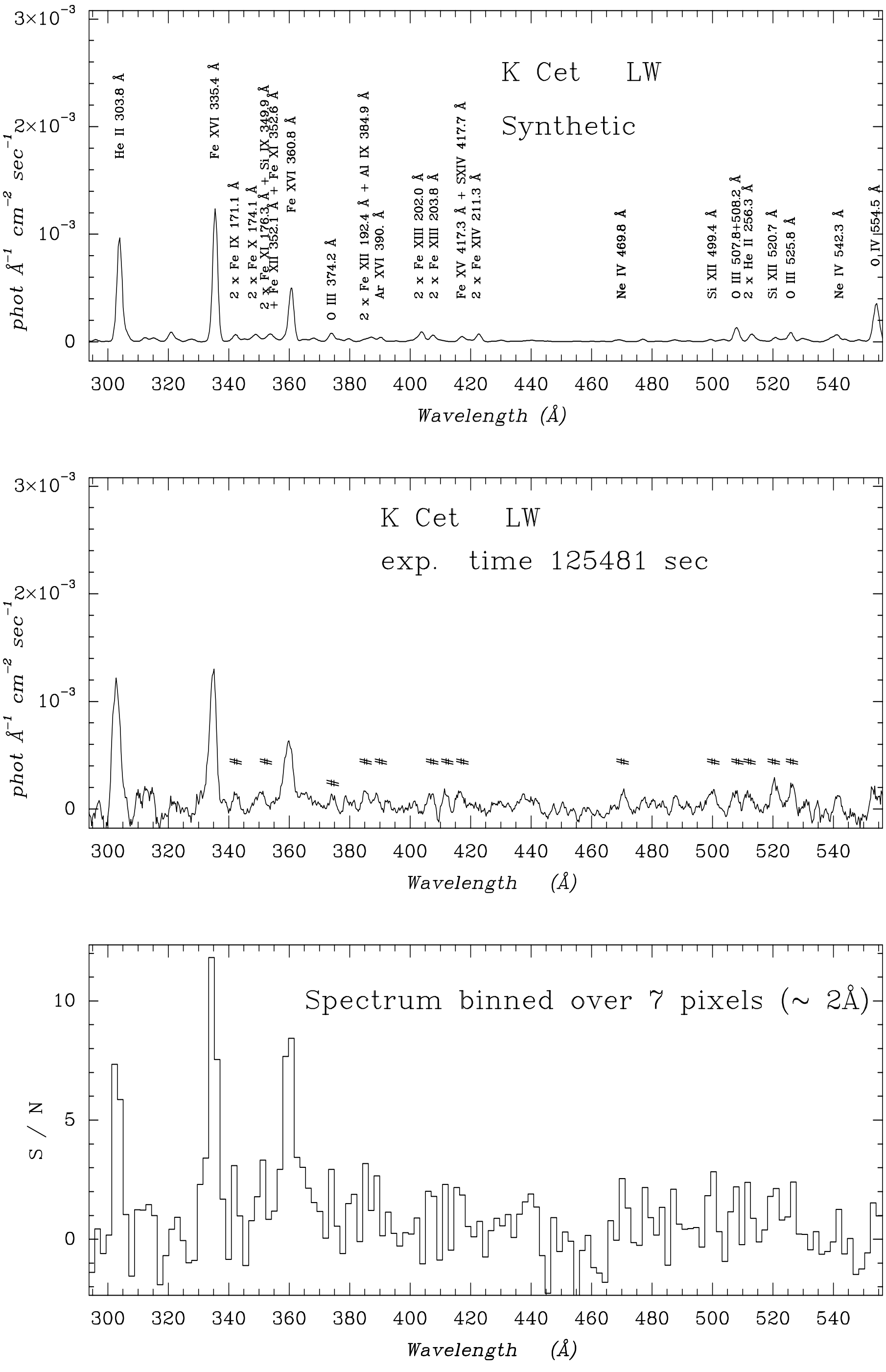

Fig. 6. The EUVE spectrum of *kappa Ceti.* The long wavelength section of the *Extreme Ultraviolet Explorer* spectrum of *kappa Ceti* a solar-type star: the synthetic spectrum *(top)* the observation *(middle)*, the signal-to-noise ratio *(bottom)*. ♯ marks features having signal-to-noise ratio larger than 2 and smallerthan 3

For Fe XXIII, Zhang & Sampson (1992) relativistic distorted wave collision strengths have been adopted by CHIANTI and the new Arcetri code, replacing the older Bhatia & Mason (1986) calculations. Nevertheless differences for Fe XXIII emission lines (including the very strong 132.8 Å line) are limited to less than 30%.

No data were available in the old Arcetri code for Fe II, VII, VIII, XXIV.

Though many important lines do not show appreciable changes, the new Arcetri database represents a great advance for plasma diagnostics and synthetic spectra with the Iron ions, since it adopts more recent data which allow a more precise calculation of level population and line emission.

5. Conclusions

The Arcetri spectral code and database for the evaluation of hot plasmas emissivity has been revised and now includes:

- The whole CHIANTI dataset concerning the atomic models, the electron collision excitation and radiative decay rates for most of the ions of C, N, O, Ne, Mg, Al, Si, S, Ar, Ca, and iron FeII and from FeVII to FeXXIV
- Atomic data for the so-called *minor elements* (Na, P, Cl, K, Ti, Cr, Mn, Co and Zn) and for Al V, VI, VII, VIII not yet included in the CHIANTI database. The ions of these elements may provide several observed lines which can prove useful in spectral analysis and DEM studies, although some of which are weak in most spectra. The *minor elements* Database includes ions belonging to the Li-like, Be-like, B-like, F-like, C-like, N-like, O-like, Na-like, Mg-like isoelectronic sequences. For most sequences, theoretical computation available in the literature has been used; no collision data are available for the Magnesium- , Oxygen- and Nitrogen-like minor elements, so it has been necessary to interpolate the effective collision strengths and the radiative data from the isoelectronic ions which were available in the CHIANTI database.
- Fe III atomic model, collisional and radiative dataset.
- Atomic data for the lines in the range 1 − 2000 Å not included neither in CHIANTI nor in the minor elements dataset; they have been renewed updating the transition probabilities from the literature. Line emission in this case is evaluated assuming collisional population from ground level only.
- Continuum emission including, free-free, free-bound from all the ions in the database, and two-photon continuum from H-like and He-like ions.

The assessment of the atomic data for the *minor elements* is discussed in detail and comparison with results of the old version for the most abundant elements is performed. Most important lines results to have been correctly evaluated also in the old version, but a number of very large differences occurred, due to the use of improved values of the collision excitation rates.

Random comparison have been performed with the Utrecht code (Kaastra et al. 1996) using the line list available at the SRON-SPEX (Spectral X-Ray and UV modeling, analysis and fitting) World Wide Web page at *http://saturn.sron.ruu.nl/general/projects/spex/*

Most results agree within 50% but a number of big differences have been shown and a more detailed comparison will be performed in the future.

The present version of the Arcetri code, is being currently applied to the spectroscopical diagnostic of CDS data from SOHO, Fig. 2 and Fig. 3 to the line identification of SERTS Fig. 4 and to the analysis of EUVE observations of stellar coronae from solar-type stars, Fig. 6 and Fig. 5.

Work is in progress to apply the code to the data analysis of SAX observations of active stars.

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