X-ray Spectroscopy across the HR-Diagram

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Abstract. X-ray spectra of stellar X-ray sources taken with high, moderate and low spectral resolution are discussed. Only low resolution spectra are available for a sufficiently large number of late-type stars. It is shown that high temperature plasmas (*log* $T > 7$) produce the dominant emission component in the coronae of red dwarfs as well as yellow giants, while the coronae of F stars - usually - have X-ray temperatures similar to those found in the quiet Sun. The need for density diagnostics of stellar coronae is stressed and it is argued that the waveband region between 90 - 140 Å is particularly well suited for this purpose.

1. Introduction

The discovery that X-ray emission from normal stars is an ubiquitous phenomenon found thoughout the HR-diagram is certainly one of the outstanding results of last decade's research in X-ray astronomy (cf., Vaiana *et al.* 1981). X-ray emission, detectable with modest-sized imaging X-ray telescopes, is not restricted to peculiar and more or less exotic types of stars; on the contrary, except for main-sequence A dwarfs and late-type giants and supergiants, it is found in stars of all spectral types and luminosity classes (for recent reviews of the subject see Rosner, Golub and Vaiana (1985), Linsky (1985), Schmitt (1988) and references therein).

While the existence of coronal X-ray sources throughout the HR-diagram has been well established, the spectral properties of the emitted X-ray radiation are only poorly known. The vast majority of the stellar observations was taken with little or no spectral resolution and rather modest signal-to-noise ratio (SNR). Only a relatively small number of coronal sources was observed with modest spectral resolution with the *Einstein Observatory* Solid State Spectrometer (SSS) and the EXOSAT and GINGA proportional counters; spectra with resolving power $\lambda/\Delta\lambda \geq 30$ were obtained for an exceedingly small number of sources with the *Einstein Observatory* Objective Grating Spectrometer (OGS) and Focal Plane Crystal Spectrometer (FPCS) and the EXOSAT transmission grating (TG). While solar soft X-ray spectra are available with resolving powers of $\lambda/\Delta\lambda \sim 10000$ and good SNR, the resolving power of the best FPCS spectra of coronal X-ray sources is of the order ~ 100 and very modest SNR.

FPCS spectra have been published for the RS CVn systems Capella (Vedder and Canizares 1983) and σ *CrB* (Agrawal, Markert and Riegler 1985). Because of the relatively small band passes of individual crystals many band scans must be performed in sequence, and taking a spectrum over a larger energy range is rather time-consuming. Consequently, the available spectra cover only a relatively small

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energy range, typically centered on some interesting lines, in the case of σ CrB, the energy range between 800 - 840 eV and 986 - 1016 eV which contain lines of iron in ionisation stages Fe XVII to Fe XXII. The FPCS spectra of both Capella and σ CrB are consistent with an isothermal plasma emitting at a temperature $log\ T \sim 6.85$.

OGS transmission grating spectra are available for Capella (Mewe *et al.* 1982), EXOSAT transmission grating spectra have been published for Capella and σ CrB as well as the nearby F star Procyon (Schrijver 1985; Mewe *et al.* 1986); in addition grating spectra are available for the hot white dwarf stars HZ 43, Sirius B and Feige 24 (Paerels *et al.* 1986 a,b,c). Grating spectra cover a broader spectral range with a spectral resolution below that of crystal spectrographs; the useful bandpass is determined by the telescope/grating/detector geometry as well as the detector efficiency. While the OGS spectrum of Capella extends out to only $\sim$ 40 AA , the EXOSAT TG spectra extend out to 200 Å (or more), covering in particular the range between 90 - 140 Å which shows extremely strong Fe lines produced in $logT \sim 7$ plasmas as well as the region around 170 Å which contains the strongest spectral line emitted by the quiescent solar corona. The transmission grating spectra typically require two spectral components for a satisfactory fit, or alternatively, a continuous emission measure distribution (Lemen *et al.* 1988).

The Solid State Spectrometer (SSS) had a resolution of about 160 eV in the energy range 0.5 - 4 keV; thus its resolving power increased with increasing energy with photon fluxes however decreasing because of the mirror cutoff and the shape of the incident spectra. Appoximately 20 coronal sources were observed, mostly RS CVn systems such as Capella and σ CrB, Algols and O stars; two M dwarfs (Wolf 630 and AD Leo) and an active G star ($\pi^1 Uma$) were also observed (Holt *et al.* 1979; Swank *et al.* 1981; Swank and Johnson 1983; Cassinelli and Swank 1983; Swank 1984). SSS spectra have lower spectral resolution than grating spectra, but the resolving power is still sufficient to detect the resonance lines of the helium-like ionisation stages of Mg, Si and S if present. The detection of these lines in the SSS spectrum of Capella by Holt *et al.* (1979) led in fact to the first reliable coronal temperature determination and clearly pointed out the need for - a presumably magnetic - confinement of stellar coronae.

Proportional counters provide even less energy resolution than solid state spectrometers ($\Delta E_{keV} \sim 0.4 E_{keV}$), and consequently only very strong, spectrally isolated line features can be detected. The 6.7 keV "iron line", in reality an extremely complex line blend (cf., section 3), has been detected in the RS CVn system UX Ari with both the EXOSAT ME (Pasquini, Schmitt and Pallivicini 1988) and GINGA LAC (Tsuru *et al.* 1988) proportional counters; however, at lower energies proportional counter spectra of coronal sources are essentially featureless and any interpretation relies on the use of theoretical spectral models. Most of the available data on coronal X-ray sources has been taken with proportional counters, i.e., the *Einstein Observatory* IPC which I will discuss in more detail in section 2.

A last method to obtain spectral resolution is the use of filter ratios, a method heavily employed with EXOSAT LE data (cf., Pallavicini *et al.* 1988). Here I shall not discuss filter ratios in any detail except for pointing out that the temperatures obtained from EXOSAT filter ratios are by and large consistent with the conclusions derived from *Einstein* data (see also Schmitt *et al.* 1988).

2. X-ray Spectroscopy throughout the HR-diagram

X-ray astronomers tend to think very positively about the notion of "spectral resolution" and do "spectroscopy" on data with almost any spectral resolution. From the point of view of an optical astronomer most of the X-ray data is color-photometric at best, very similar to UBV photometry at optical wavelengths. Since my task is to discuss the spectral properties of X-ray emission throughout the HR-diagram and since, as pointed out in section 1, the X-ray data with moderate or high spectral resolution are limited to less than a handful of coronal sources, such a spectral characterisation can only be attempted with the presently available low resolution data.

The physical interpretation of such low resolution X-ray data requires many assumptions on the form of the incident spectrum. Here I shall consider only spectra produced by plasma in collisional thermal equlibrium, although in many cases - especially in low SNR situations - other spectral forms can also produce acceptable fits. However, the higher resolution X-ray spectra obtained with the FPCS and the *Einstein* and EXOSAT transmission gratings clearly show emission lines and thus the thermal nature of the emitting plasma. At temperatures below $log\ T \sim 7$ most of the energy loss of such a plasma is carried by a few emission lines, which are however merged into a "pseudocontinuum" due to the low spectral resolution of the proportional counter.

Despite these limitations of proportional counter data Schmitt *et al.* (1989) carried out a survey of coronal temperatures of late-type stars observed with the *Einstein Observatory* IPC; they considered all X-ray sources detected with the IPC either as targets or serendipitously, identified with a bright ($m_V < 6.5$) and/or nearby star ($d < 25\ pc$) of spectral type F, G, K or M, containing more than 200 counts in its X-ray spectrum. Their sample was further subdivided into single stars and binaries as well into the various luminosity classes in order to study any dependence of X-ray temperature on these parameters. In the following I will describe some of the basic results obtained by Schmitt *et al.* (1989) in as much as they are relevant for future observations.

Results: One-component fits

In figure 1 I show - for acceptable one-component fits of single stars - the resulting X-ray temperature as a function of B-V color (open circles denote main sequence stars, filled squares subgiants, and filled circles giants). For M stars with B-V > 1 a large spread in coronal temperature is found, but as shown by Schmitt *et al.* (1989) these data points have low SNR. For stars with 0.2 < B-V < 1 there appears to be a discrepancy between main sequence stars and giants; main sequence stars are characterised by rather low temperatures between $2\ 10^6\ K$ and $5\ 10^6\ K$, quite reminiscent of coronal temperatures typically derived for the quiet Sun. On the other hand, the coronae of giants seem to be fairly hot, with temperatures in excess of 10^7 K, more reminescent of the flaring Sun. However, in most cases flaring is not the cause of the high temperature, rather the high temperature seems to be characteristic of the quiescent emission. Interestingly, this high temperature component does not appear to be accompanied by a corresponding low temperature component, as is the case for stars with B-V > 1. Therefore the coronae of giant stars appear to be quite isothermal (at least in our band pass) with extremely large temperatures, yet the transition from chromoshperic to coronal temperatures must be very abrupt with very little emission measure present at intermediate temperatures.

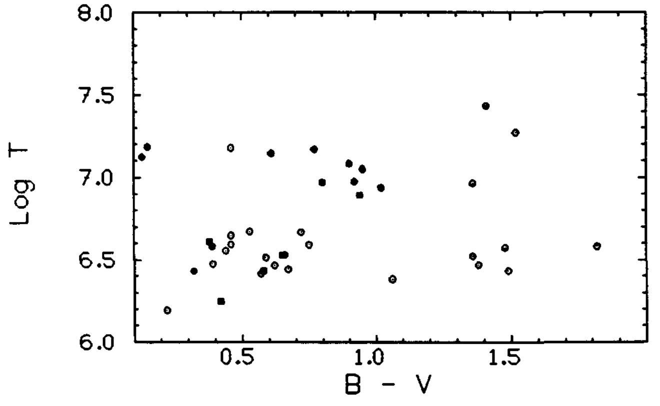

Fig.1: Coronal temperatures as a function of B-V color from single component fits for single stars; circles denote main sequence stars, filled squares subgiants and filled circles giants.

An obvious gap in the X-ray temperature distribution exists between 6.7 < *logT* < 6.9, where absolutely no X-ray temperature measurements were found. From the spectral simulations by Schmitt *et al.* (1989) it is clear that if isothermal coronae with temperatures in the range 6.7 < *log T* < 6.9 did exist, their temperatures could be determined with the IPC; therefore the gap must be due to both the intrinsic differential emission emission distribution of coronal X-ray sources and the spectral response of the IPC.

Results: Two-component fits

In figure 2 I plot - similarly to figure 1 for single stars only - the fitted two temperature components as a function of color for those cases where a one-component description turned out to be statistically unacceptable. From figure 2 it is immediately apparent that a two-component description is required only for main sequence stars redder than B-V ~ 0.5; despite the availability of a few spectra of good SNR single giants never require two temperature components. The temperature components cluster around values of *log T* ~ 7.2 and *log T* ~ 6.4 with some dispersion; in most cases the errors in the temperature determination are so large that the deviations from these "standard" values are not significant. In any event, in many late type stars the appearance of a high temperature component is linked to a low temperature component, with the value of temperature showing little variation for IPC measurements. Schmitt *et al.* (1989) interpret this fact as evidence for the non-isothermality of stellar coronae; however, at the same time, the point out that derived spectral temperature components must not be taken as independent physical entities, but rather as "effective temperatures" in the sense discussed by

Underwood and McKenzie (1977).

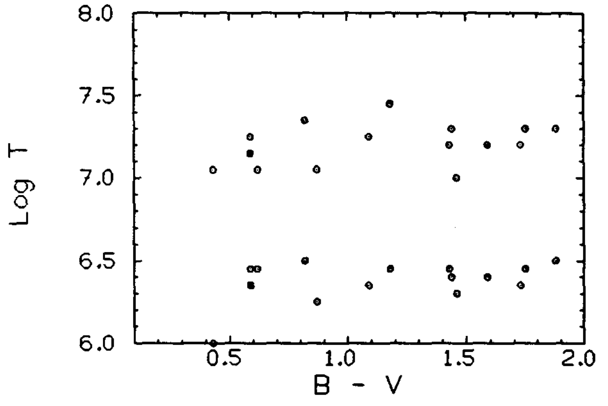

Fig.2: Coronal temperatures as a function of B-V color from two component fits for single stars; circles denote main sequence stars, filled squares subgiants and filled circles giants.

Results: Continuous emission measure distributions

If one accepts the idea that X-ray emission from late-type stars is produced by magnetically confined plasma, the differential emission measure distribution Q(T) is approximately of the form $Q(T) \sim T^{\alpha}$, where the slope of the assumed emission measure distribution is related to the radiative cooling law. Spectral fits to such simply parameterised differential emission measure distribution functions involve three parameters: the power law slope α, the maximum temperature T_{max}, to which the emission measure distribution extends, and a normalisation constant. In figure 3 the results of fits assuming a continuous emission measure distribution are presented for single stars (symbols as in figure 1); the lower and upper panels show the fitted values of T_{max} and α as a function of color; note that the fit results are also displayed even if a one-component description provides an acceptable fit to the spectrum. In figure 3 much larger larger spread of temperatures than in the corresponding figure 1 is apparent. Thus figure 3 demonstrates the fact that the high temperature components found in a two-component fit do not need to reflect the largest possible temperature present in the stellar corona. Obviously, the temperatures resulting from these simple fits are model-dependent; however, they indicate, that the range of coronal temperatures encountered in stars may not be as narrow as a one- or two-component analysis seems to suggest.

Conclusions

Late-type main sequence stars (usually of spectral type K and M) always exhibit a high- and low-temperature component with the emission measure in the high temperature component being substantially larger than that in the low-temperature component. In essentially all cases there is evidence for plasma at temperatures in excess of 10^7 K. Most main sequence stars of earlier type (i.e., spectral type F or G) do not show this high-temperature component and are dominated by plasma at lower temperature; in fact, from the X-ray point of view they appear very much like the Sun in full disk observations outside of strong flares. The observed high-temperature plasmas do not appear to be directly associated with flares, i.e., they are found during periods of "quiescent" emission with no apparent variability present. Yellow giants on the other hand do show a high-temperature component which is not accompanied by low-temperature emission. The lack of this soft component is an intrinsic property of the spectrum; it is not caused by selection effects or absorption of the soft component by the interstellar medium. Two-temperature models do not provide the only possible way of obtaining acceptable fits (especially for M-type stars), rather the X-ray temperatures derived from low-resolution data such as the IPC data should be interpreted as effective temperatures but not necessarily as physical temperatures of the observed plasma.

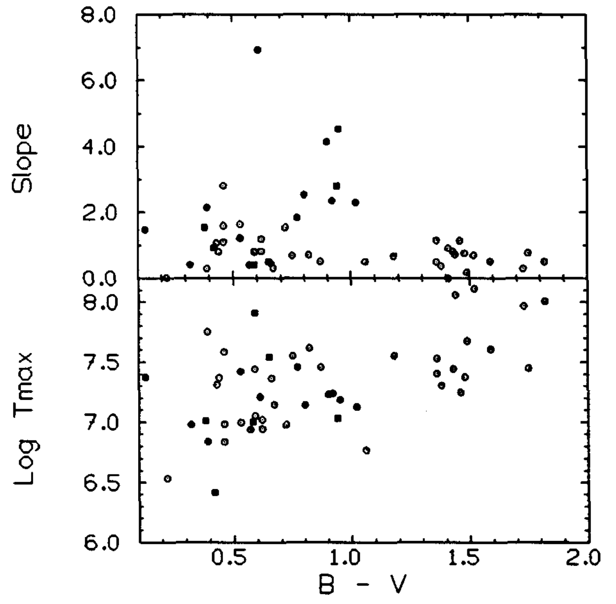

Fig.3: Maximum temperature T_{max} (lower panel) and power law slope α (upper panel) for continuous emission measure distribution fits.

3. Future observations: The case for XUV diagnostics

Why do we need plasma densities ?

Thermal X-ray spectra with their wealth of emission lines obviously call for high spectral resolution observations. For the study of coronal abundances, ionisation equlibria and temperature stratification one needs to identify and measure individual lines, for the study of coronal dynamics and Doppler imaging one even needs to resolve lines and measure their shapes. Instead of discussing the observational requirements for such measurements, I shall single out one specific item which - in my opinion - is of utmost importance for stellar X-ray astronomy, i.e., spectroscopic determination of plasma density.

The need for such density diagnostics is almost self-evident: Emission measure analysis - even when coupled with loop scaling laws - only constrains the product of density and filling factor. As a consequence, large tenuous coronal structures have the same spectral appearance as rather dense and compact structures. Using the solar analogy one would expect the latter to be the paradigm of stellar X-ray emission, while eclipse measurements of RS CVn binaries (Walter, Gibson and

Basri 1983; White *et al.* 1989) seem to indicate the presence of rather hot plasma on length scales comparable to the binary separation rather than a stellar radius, in apparent conflict with the solar analogy.

The same dichotomy between tenuous and compact structures applies to stellar flares. While modelling of many stellar flare events observed with the *Einstein* and EXOSAT satellites indicates relatively small structures with characteristic length scales of a stellar radius or less, some observations, most notably those of Stern, Underwood and Antiochos (1982) on the Hyades star HD27130 and by Tsuru *et al.* (1988) on the RS CVn system UX Ari, seem to indicate extremely large structures if one accepts that the observed decay times of these events have any relationship with the inferred radiative cooling time scales. Again, high resolution spectral diagnostics would provide a direct measurement of density and thus solve the problem.

Density diagnostics: Helium-like lines

The "classic" way to determine densities in a hot plasma is to measure the ratio of intercombination and forbidden lines in the tripletts of helium-like ions (cf., Gabriel and Jordan 1969): in a high density plasma helium-like ions in the $1s2s\ ^3S_1$ state are de-excited collisionally and therefore the forbidden line disappears. By choosing a suitable ion one obtains density diagnostics at a variety of temperatures. However, with increasing atomic number the critical density N_{crit}, i.e., the density at which the $1s2s\ ^3S_1$ state starts to become significantly depopulated by collisions, becomes higher and higher; for example, for Si XIII with a peak formation temperature of ~ 6.6, one finds $log\ N_{crit} \sim 13.6$, a density probably not reached in solar flares and certainly not reached under quiescent conditions. I therefore conclude that density diagnostics with helium-like tripletts in active stars where - as demonstrated by Schmitt *et al.* (1989) - most of the emission measure is located at temperatures of $log\ T \sim 7.0$ or higher, does not appear to be promising unless one postulates significantly higher coronal densities and pressures. While somewhat unlikely this last possibility can of course not be ruled out: active stars may have larger coronal magnetic fields, larger confining pressures and therefore higher densities than the solar corona.

Spectroscopy of Helium-like lines: What spectral resolution ?

In order to exclude any misunderstanding I wish to emphasize that I am **not** argueing that studies of the resonance lines of helium-like tripletts are of no diagnostic use; on the contrary, these lines provide an extremely valuable plasma diagnostics for temperature, abundances and ionisation equilibrium in conjunction with the dielectronic recombination lines (satellite lines) present in such spectra. However, in order to extract the information contained in these lines extremely high resolving power is required as I will demonstrate momentarily. On SMM two crystals tuned to the resonance lines of Ca XIX at 3.18 Å and FeXXV at 1.85 Å were flown; in both cases the resolving power was of the order $\lambda/\Delta\lambda \sim 10000$; examples of these SMM crystal spectra are presented by Bely-Dubau *et al.* (1982) and Lemen *et al.* (1984).

In order to demonstrate the effects of spectral resolution on our capability

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to interpret spectra of helium-like resonance lines I have performed the following numerical experiment. I took a spectrum of "the iron line" as observed with SMM (figure 4, upper panel); the line in fact consists of a blend of many lines of iron ions in ionisation stages Fe XXV - Fe XXII which are discussed and identified by Lemen *et al.* (1984). In the next step the spectral resolution of the SMM spectrum was artificially decreased by replacing a point in the original spectrum by the mean intensity over a broader and broader energy range. The six spectra shown in figure 4 have resolutions of $\sim 0.7\ eV$, the instrumental resolution, in the top panel, $\sim 2.1\ eV$, $\sim 5\ eV$, $\sim 10\ eV$, $\sim 30\ eV$ and $\sim 60\ eV$ in the bottom panel. While in going from 0.7 eV resolution to 2.1 eV resolution little information is lost, the spectral features most important for temperature diagnostics become blended at resolutions of 5 eV, and are only partially resolved at 10 eV, a resolution thought to be feasible for calorimeters. At a resolution of 30 eV most of the satellite lines are gone, and at 60 eV, a resolution that may be within reach of CCD cameras, they are virtually indistinguishable. I therefore conclude that studies of helium-like resoncance lines for high Z atoms require dispersive spectroscopy (unless the spectral resolution of calorimeters can be pushed to the theoretical limits).

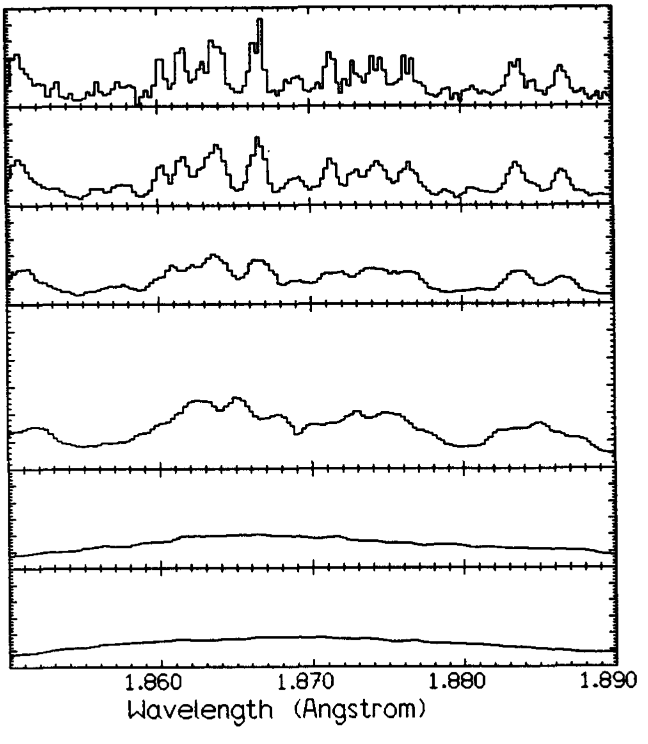

Fig.4: Effects of spectral resolution on 1.85 Å"iron line": top panel spectrum has (instrumental) resolution of $0.7\ eV$, the subsequent spectra have resolutions of $2.1\ eV$, $5\ eV$, $10\ eV$, $30\ eV$, and $60\ eV$ respectively.

Density diagnostics: Lithium-like to fluorine-like iron lines

For density diagnostics in active late-type stars one must observe lines formed at temperatures $logT \sim 7.0$; the only sufficiently abundant element not stripped off all but the K shell electrons is iron. Iron atoms in the ionsiation stages Fe XVIII (fluorine-like iron) to Fe XXIV (lithium-like iron) produce intense emission lines

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the waveband between 90 Å- 140 Å. The ground states of these ions belongs to the electron configuration $1s^2 2s^2 2p^k$ which splits up into a number of states; the energy separation between these states is typically of the order $\sim 10\ eV$. Various excitations from the ground state configuration are possible: for example, excitations into the $1s^2 2s^2 2p^{k-1} 3s$ configuration which require energies of $\sim 1\ keV$ and decay through electric dipole radiation; or excitations into the $1s^2 2s^1 2p^{k+1}$ configuration which require only $\sim 100\ eV$. Transitions from the latter configuration into the ground state configuration are not permitted in LS coupling, however, because of state mixing in high Z atoms, they do have significant transition probabilities.

Thus two types of transitions can occur: allowed transitions requiring high excitation energies and "forbidden" transitions, which can be excited by a much larger fraction of the electrons in the thermal pool. Which type of transition leads to higher photon fluxes cannot be determined a priori; however, an inspection of the line fluxes (in table 1) produced by a plasma in collisonal equilibrium as calculated by Mewe, Gronenschild and van den Oord (1985) shows that the photon fluxes in XUV lines exceed those in the corresponding X-ray lines by factors of 4 - 60; in table 1 I have compiled for the various ionisation stages of iron the peak formation temperature, the wavelengths of the strongest XUV and X-ray line, and the photon flux ratios of these lines in the low density limit.

Ionisation stage	T_{max}	λ_{XUV} Å	λ_{X-ray} Å	XUV/X-ray flux ratio
Fe XVIII	6.7	93.93	14.22	4
Fe XIX	6.8	108.37	13.52	20
Fe XX	6.9	132.85	10.09	19
Fe XXI	7.0	128.73	12.29	10
Fe XXII	7.0	135.78	11.77	20
Fe XXIII	7.1	132.84	11.74	65
Fe XXIV	7.2	192.03	10.64	58

Table 1: Comparison between XUV and X-ray line fluxes

The above transitions can be naturally utilised for density diagnostics. While in a low density plasma only the ground state is populated, the level populations of the ground state configuration must approach the Boltzmann limit as the density increases. Therefore, in a high density plasma lines from excited levels appear which are absent in a low density plasma; this is in contrast to the density diagnostics with helium like ions where one looks for the disappearance of the forbidden line. Since the ground state configuration usually splits up into a larger number of energy levels, one obtains density sensitive line ratios over a whole range of densities, typically starting at $\sim 10^{10}\ cm^{-3}$ up to $\sim 10^{15}\ cm^{-3}$.

Interstellar Absorption

A fundamental problem of XUV observations is of course interstellar absorption. While observations of even the nearest hot stars are difficult or impossible at XUV wavelengths I wish to point out that observations of the majority of cool stars of particular interest are not likely to be significantly affected by interstellar absorption.

For a quantitative discussion I consider an XUV line at wavelength λ and a fictitious X-ray line at 1 keV; unabsorbed, i.e., for $N_H = 0$ both lines are assumed to have a photon flux ratio r_0. Because of the exponential character of interstellar absorption the long wavelength parts of the spectrum are far more affected than the short wavelength parts, and therefore r will decrease with increasing N_H. In table 2 I present those distances out to which $r > 1$, i.e., where the photon flux in the XUV line is at least that of the X-ray line; for the conversion from N_H to distance a mean interstellar density of $n = 0.007\ cm^{-3}$ was assumed (Paresce 1984). While admittedly the assumption of a constant mean interstellar density is quite poor in view of the extreme degree of inhomogeneity of the interstellar medium, table 2 shows nevertheless that even for wavelengths $\lambda \sim 200\AA$ XUV lines produce larger apparent photon fluxes than the corresponding X-ray lines for the vast majority of the most easily observable cool stars. Therefore, for the purposes of observing cool stars, the finiteness of the XUV universe is of no great concern.

r_0	90 Å	110 Å	130 Å	170 Å	200 Å	240 Å
3	210 *pc*	120 *pc*	80 *pc*	40 *pc*	26 *pc*	16 *pc*
10	440 *pc*	260 *pc*	165 *pc*	80 *pc*	54 *pc*	34 *pc*
30	660 *pc*	380 *pc*	240 *pc*	120 *pc*	80 *pc*	50 *pc*
100	890 *pc*	520 *pc*	330 *pc*	160 *pc*	110 *pc*	68 *pc*

Table 2: Effects of absorption on XUV lines

Why not simply do it ?

For reasons unknown to me the wavelength range between 90 - 140 Å has been somewhat neglected observationally. On the Sun, this waveband range is only interesting during flares and the only available spectra (taken in 1969 with the OSO-5 satellite) seem to be those reported by Kastner *et al.* (1974). In the stellar case, the TG spectra of Capella and σ CrB show the wealth of emission lines of highly excited iron in this wavelength band; by analogy we may expect to find similar spectra in all active late-type stars.

Laboratory measurements (Lawson and Peacock 1980) as well as theoretical studies in particular by H. Mason and collaborators have led to a complete listing and understanding of the term schemes and lines for the especially interesting iron lines in the fluorine to lithium isoelectronic sequences (Loulergue *et al.* 1984 for Fe XIX; Bhatia and Mason (1980) for Fe XX; Mason *et al.* 1979 for Fe XXI; Mason and Storey (1980) for Fe XXII; Bhatia and Mason (1981) for Fe XXIII; Hayes (1979) for Fe XXIV). The basic result coming out of this extensive effort is that the wavelength range between 90 - 140 Å is extremely well suited for temperature and density diagnostics of hot gas with temperatures of $\sim 10^7 K$; all the relevant lines and their atomic parameters are sufficiently accurately known. A concern is line blending; however, a spectral resolution of $\sim 0.1\AA$ or a resolving power of $\lambda/\Delta\lambda \sim 1000$ is generally thought to be sufficient to avoid ambiguities due to line blending.

It is clear that the spectroscopic goals, i.e., temperature and density diagnostics, can also be accomplished at higher energies at $\sim 1\ keV$; the observational requirements in terms of resolving power are the same. However, the XUV region appears advantageous for the following reasons: First, the same amount of emission measure will produce fewer X-ray photons than XUV photons; second, the XUV band contains also low temperature lines so that a wide temperature range - which we know to be present in cool stars - can be diagnosed at the same time; and third, a resolving power $\lambda/\Delta\lambda \sim 1000$ can - with currently available technology - only be obtained with crystals at energies of $1keV$. While the proposed AXAF instrumentation (in particular the HETG) will be able to reach $\lambda/\Delta\lambda \sim 1000$, the same resolving power can be obtained at XUV wavelengths with present-day technology, i.e., the ROSAT mirror, a 1000 l/mm transmission grating and a curved micro-channel plate detector. It is therefore hoped that future missions with high resolution Wolter mirrors such as SPEKTROSAT (cf., Predehl 1989) and AXAF will be able to perform the required measurements.

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