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X–ray emission from A0–F6 spectral type stars

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Abstract. We use the ROSAT public data archive to study the X–ray emission of a sample of supposedly single A0–F6 spectral type stars from the Bright Star Catalogue. We detected X–ray emission from 19 A– and 33 F–type stars. However, our results are not sufficient to associate with certainty the X–ray emission to the A–type stars themselves, since the usual argument that it may originate from a binary companion cannot be excluded. A spectral analysis was conducted for 14 sources (3 A and 11 F), finding that for 12 of them a two temperature thermal plasma model is needed to reproduce the observed spectra. The two temperatures are centered at 0.13 and 0.54 keV, respectively. The values found for the higher temperature are lower than that ones of X–ray selected single late–type stars. The X–ray luminosities are in the range $L_X \sim 10^{28}$–10^{30} erg s^{-1}, with a distribution similar to that of active late–type stars. No correlation is found between L_X and B–V color, $V \sin i$ and L_{bol}, while a positive correlation is found between the X–ray luminosity and the hardness ratio.

Key words: X-rays: stars – stars: coronae – stars: chromospheres – stars: activity – stars: binaries: general

1. Introduction

The chromospheric and coronal activity of cool dwarf stars like the Sun is thought to arise from the interaction of stellar magnetic fields with differential rotation and convection. Since significant convection zones make their appearance along the main sequence in late spectral class A, the much debated turn–on of such activity should occur at about the same spectral type, although the precise dependence is not well known. On the other hand significant radiatively driven winds (the instabilities of which are thought to be responsible for the X–ray emission in O– and early B–type stars) are not present beyond spectral type $\sim$ B4. Thus in the B5–A5 spectral range a lack of X–ray emission is theoretically “expected”. In spite of the observational efforts, no conclusive evidence of X–ray emission from B5–A5 type stars has been found; in fact in most of the observed cases the emission is thought to come not from the early type star itself, but from a cooler companion or from a nearby star (Schmitt & Kürster 1993; Gagné & Caillault 1994; Stauffer et al. 1994; Stern et al. 1995). Few interesting cases have been found by Schmitt et al. (1993) and Berghöfer & Schmitt (1994), which detected X-ray emission from both components in some visual binaries formed by a B5–A5 primary star and a cooler companion.

Stringent upper limits have been determined for the X–ray emission of some well studied A–type stars, down to a luminosity of $L_X \sim 3.5 \times 10^{25}$ erg s^{-1} for the prototypical A–type star Vega (Schmitt 1997). This seems to indicate that the coronae surrounding these stars (if may exist at all) must be very different from those surrounding cooler stars. They do not have massive winds, neither have deep enough convective zone for an effective dynamo activity. However, in all the cases reported above, only small samples of late B– early A–type stars were used. Recently, Simon et al. (1995) tried to overcome this problem by using pointed ROSAT PSPC observations to study the X–ray properties of a sample of 74 A–type stars. They detected X–ray emission in 9 late A– and 10 early A–type stars. Of the latter, 5 were confirmed double and 5 were not known to be double but further optical study are necessary in order to determine if they are really single stars.

On the other hand convincing evidence of chromospheric and X–ray emission has been detected in stars as early as spectral type A7 (Schmitt et al. 1985a; Simon & Landsman 1991). Recently Simon & Landsman (1997) reported the detection of chromospheric emission in HST/GHRS spectra of the A4 star τ^3 Eri that seems to be the hottest main sequence star known to have a chromosphere and thus an outer convection zone. Activity indicators in A7–F5 type stars seem to be independent on rotation, while the coronal X–ray emission, as measured relatively to chromospheric emission, is deficient if compared with later–type stars (Pallavicini et al. 1981; Schmitt et al. 1985a; Simon & Landsman 1991). The thin convective zone may not maintain strong enough dynamos to support *solar–like* coronae; rather, it has been suggested that these coronae are heated acoustically (Simon & Landsman 1991; Mullan & Cheng 1994a,b). However, Schrijver (1993a,b) found evidence for a rotation–activity correlation in the C II excess flux for these stars, and also the X–ray activity in early F stars seems to be coupled with the Rossby number (Schmitt et al. 1985a). Finally, using the

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ROSAT All–Sky–Survey, Schmitt (1997) analysed the X–ray emission of all A, F and G stars within 13 pc from the Sun and found that the coronal properties of late A– early F–type are not different from those of later type stars in any respect. These findings support the presence of a magnetic dynamo as early as the A7 spectral type, where convective zones are very shallow.

The ROSAT database provides a powerful instrument for trying to solve some of these problems, in particular to verify the existence of X–ray emission in early A–type stars and to study the characteristics of the X–ray emission in late A– and early F–type stars. Here we present the results obtained for a sample of A0–F6 type stars obtained by cross-correlating the Bright Star Catalogue (Hoffleit & Warren 1991) with the WGA catalogue derived from the ROSAT PSPC public archive (White et al. 1994).

The paper is organized as follows: in Sect. 2 we present the sample of the program stars, the X–ray data and their analysis. The basic results are given in Sect. 3, while in Sect. 4 we discuss our results, compare them to those obtained for samples of similar and cooler stars. In Sect. 5 we present our conclusions.

2. Observations and data analysis

2.1. Program stars

We selected all stars listed in the Bright Star Catalogue (Hoffleit & Warren 1991) with spectral type A0–F6 (0.0 $<$ B–V $<$ 0.5): 1963 A– and 1014 early F–type stars of all luminosity classes. Since the BSC is complete down to a limiting visual magnitude $V = 6.5$, the input sample forms a well defined (optically) flux–limited sample of stars. This sample was cross–correlated against the WGA catalogue of pointed and serendipitous X–ray sources generated from ROSAT PSPC images (see Trümper (1983) and Pfeffermann et al. (1986) for a description of the ROSAT satellite). We accepted all sources whose coordinates were inside the one arcmin region radius of the optical coordinates. Of the 351 A– and 165 F–type stars that could have been observed in our X-ray images, 142 were detected; 66 A– and 76 F–type stars. We tested the probability that one of our optical candidate falls inside the one arcmin error box by chance. We shifted the optical coordinates of our sample of A–F stars by 30 arcmin and then cross-correlated with the WGA catalogue. We found that the probability of mis–identification is very small, of the order of 0.3%. Nevertheless we searched for all the plausible optical counterparts present in the 142 X–ray error boxes and rejected all cases in which the emission could be attributed either to the A0–F6 star or to another optical source on the basis of its X–ray–to–optical flux ratio (e.g. Stocke et al. 1991; Giommi et al. 1991). This search was done using the Space Telescope Guide Star Catalogue (Lasker et al. 1990) and SIMBAD database (we could not use the digitized sky survey plates because these stars are so bright that the plates are totally saturated around these regions). In this step 5 A– and 3 F–type stars were rejected.

Since our purpose is to study the X–ray emission from supposedly *single* A– and early F–type stars, all confirmed or **suspected** binaries or multiple systems not resolved by the PSPC were rejected (42 A– and 40 F–type stars), regardless of the nature of the companion. For instance we rejected HD 61421 (Procyon), although for this nearby astrometric binary, consisting of a slightly evolved F5 IV-V star and a cool white dwarf companion, the observed X–ray emission is attributed to the F–type star (see Schmitt et al. 1985b). In any case the coronal activity of the system is already well studied (see e.g. Lemen et al. 1989, Schmitt et al. 1990a and Schmitt et al. 1996). Another star that we rejected is HD 203280 (Alderamin, A7IV), that is listed as an X-ray source by various authors (e.g. Simon et al. 1995; Schmitt 1985a). However, the SIMBAD database lists a second star at $\sim 15''$ (ADS 14858 CD, V=10.4), thus following our strict criteria we excluded this source. We note that we would reject also the binary systems formed by two early A–type stars (or by an early A– and late–B star). These stars are not expected to be X-ray emitters, so their detection would be of extreme interest (see also Bergöfer et al. 1996). Schmitt et al. (1993) and Berghöfer & Schmitt (1994), using the ROSAT HRI detector to study visual binary systems formed by a B–type star with a cool companion, found that in some cases also the B star was an X–ray source. However, again we would not be able to determine with our data which star would be responsible for the X-ray emission. Moreover of the 42 rejected A–type stars, only one is a visual binary system formed by an early A and a late B–type star separated by 8$''$(A1V + B9V, HD 24071).

The WGA catalogue has not been manually cleaned and/or inspected field by field. By re–analysing interactively all images, one could find some more stars lost by the WGA catalogue. These stars could either be slightly below the WGA detection limit or be in “difficult” fields (crowded or with a very bright source), or lie near the ribs or the border of the detector. Moreover, the latest version of the WGA catalogue has been generated from the PSPC observations available in the public archive at HEASARC in February 1995 for a total of 3007 pointings. The good PSPC observations available at the HEASARC are now 4597. We checked how many sources we are probably loosing in the 1590 PSPC fields missing from the WGA. There are 180 pointings (114 for A– and 66 for F–type stars) in which 36 new A– and 28 new F–type stars could have been detected. If we apply the detection rate that we found for the WGA fields, we should have missed about ~ 7 and ~ 13 stars for the A– and F–type, respectively. If we consider that most of them would be in binary systems, we are really missing very few stars. Thus, the stars that we are presenting here are not ALL the single A– and F–type stars possibly detected in PSPC pointings. But this does not affect our goals, since we are not deriving a X–ray luminosity function. Our aim is a) to look for supposedly single A stars that are X-ray emitters, and b) to study the characteristics of the X–ray emission of single A and F stars. Besides, sources are randomly missed from the WGA and the results should not be biased.

The final sample, here presented, consists of 52 supposedly single stars, **19** A– and **33** early F–type stars, associated with X–ray sources in **74** ROSAT PSPC fields (29 fields for the A–type stars and 45 fields for the early F type stars). The sample contains 30 main–sequence stars, 9 sub–giants, 1 giant,

Table 1. A0–F6 type stars

HD	ST	V	$B–V$	d (pc)	$V \sin i$ ($\mathrm{km\,s^{-1}}$)	$\log L_{bol}$ ($\mathrm{erg\,s^{-1}}$)	Image	Count Rate (10^{-3} cts/s)	HR	$\log L_X$ ($\mathrm{erg\,s^{-1}}$)
16555[1]	A6V	5.30	0.29	44 ± 4	239	34.63	RP700103N00	18.7 ± 3.0	-0.63	28.34
16555	...	...	...	...	...	...	RP300201N00	25.5 ± 1.8	-0.33	28.47
16555	...	...	...	...	...	...	RP701356N00	18.9 ± 1.2	-0.59	28.34
20888[2]	A3V	6.03	0.13	58 ± 2	...	34.56	RP150010N00	26.3 ± 2.8	0.13	28.72
20888	...	...	...	...	...	...	RP200044N00	51.5 ± 4.9	-0.04	29.02
20888	...	...	...	...	...	...	RP600045N00	37.1 ± 2.6	-0.11	28.87
20888	...	...	...	...	...	...	RP600504N00	32.4 ± 2.3	-0.23	28.81
30321	A2V	6.33	0.04	85 ± 8	...	34.78	RP200997N00	13.7 ± 1.9	-0.15	28.77
30478[3]	A8/A9III-IV	5.28	0.20	68 ± 2	177	35.00	RP701021N00	22.7 ± 1.9	-0.32	28.80
38104[4]	A0p	5.46	0.03	148 ± 19	21	35.59	RP900487N00	9.7 ± 1.4	0.40	29.10
39014[5]	A7V	4.34	0.22	44 ± 1	206	35.00	WP141851N00	6.3 ± 1.4	-0.04	27.86
45618[6]	A5V	6.61	0.18	69 ± 3	55	34.46	WP201603N00	9.4 ± 0.7	-0.10	28.43
45638[7]	A9IV	6.59	0.29	61 ± 4	42	34.34	RP900355N00	104.2 ± 7.5	-0.24	29.37
45638	...	...	...	...	...	...	RP900355A01	115.0 ± 10	-0.41	29.41
45638	...	...	...	...	...	...	RP900355A02	90.0 ± 7.0	-0.30	29.30
50241[8]	A7IV	3.24	0.23	30 ± 2	205	35.11	WP200638N00	92.0 ± 3.2	-0.31	28.70
82380	A4V	6.76	0.12	91 ± 7	155	34.69	RP400244N00	29.4 ± 6.3	-0.30	29.16
107966[9]	A3V	5.17	0.08	87 ± 5	54	35.28	WP200307N00	20.7 ± 2.6	0.13	28.97
111893	A7V	6.30	0.17	112 ± 9	215	35.02	WP800393A01	17.4 ± 2.5	-0.20	29.12
116160[10]	A2V	5.69	0.05	65 ± 3	200	34.82	RP300322N00	331.8 ± 10	-0.04	29.92
124953[11]	A9V	5.98	0.28	49	125	34.46	RP150018N00	13.1 ± 1.3	-1.00	28.27
140232[12]	A2m	5.80	0.21	53 ± 2	68	34.61	RP700893N00	106.9 ± 5.1	-0.01	29.25
159312[13]	A0V	6.48	6E-03	104 ± 10	...	34.95	RP200098N00	103.4 ± 14	0.10	29.83
175938[14]	A8V	6.40	0.29	88 ± 4	113	34.81	RP700058N00	40.5 ± 2.3	-0.05	29.27
175938	...	...	...	...	...	...	RP700412N00	42.3 ± 7.2	-0.04	29.29
175938	...	...	...	...	...	...	RP700951N00	48.9 ± 5.6	-0.13	29.36
175938	...	...	...	...	...	...	RP700950N00	57.9 ± 6.3	0.13	29.43
187642[15]	A7IV-V	0.76	0.22	5 ± 0	242	34.57	WP200898N00	194.6 ± 3.8	-0.81	27.46
187753[16]	A1m	6.25	0.10	117 ± 15	10	35.11	WP200898N00	38.01 ± 3.9	0.30	29.49
432	F2III-IV	2.28	0.38	16.7 ± 0.2	70	35.01	WP201520N00	246.7 ± 10	-0.53	28.61
8723	F2V	5.35	0.39	26 ± 1	61	34.14	WP701220N00	265.1 ± 11	-0.19	29.03
13456	F5V	6.00	0.42	50 ± 2	10	34.48	RP800114N00	87.9 ± 3.4	-0.09	29.12
18404	F5IV	5.80	0.42	32 ± 1	28	34.16	WP900138N00	102.0 ± 4.5	-0.27	28.80
20675	F6V	5.94	0.47	46 ± 1	...	34.44	WP200223N00	39.4 ± 6.1	-0.15	28.70
20675	...	...	...	...	...	...	WP200239N00	53.8 ± 7.5	-0.10	28.83
20675	...	...	...	...	...	...	WP200228N00	48.6 ± 13	0.02	28.79
20675	...	...	...	...	...	...	WP200228A01	65.6 ± 15	-0.17	28.92
20675	...	...	...	...	...	...	WP200222A01	49.5 ± 13	-0.40	28.80
20675	...	...	...	...	...	...	WP200222N00	29.3 ± 11	-0.20	28.57
20675	...	...	...	...	...	...	RP201510N00	49.3 ± 1.7	-0.19	28.80
20902	F5Ib	1.79	0.48	181 ± 22	18	37.27	RP201468N00	18.9 ± 1.3	0.70	29.57
24357	F4V	5.97	0.35	41 ± 2	59	34.31	RP200107N00	62.2 ± 2.2	-0.17	28.80
25457	F5V	5.38	0.52	19.2 ± 0.3	23	33.90	WP900140N00	1548 ± 21	-0.09	29.53
28556	F0V	5.40	0.26	46 ± 2	95	34.63	RP200945N00	98.5 ± 5.7	-0.20	29.10
28736	F5V	6.37	0.42	43 ± 2	35	34.19	RP700063N00	103.4 ± 8.8	-0.42	29.06
28736	...	...	...	...	...	...	RP700945N00	102.0 ± 8.2	-0.15	29.05
28736	...	...	...	...	...	...	RP700916N00	90.3 ± 6.2	-0.28	29.0
28736	...	...	...	...	...	...	RP700913N00	94.5 ± 7.8	-0.14	29.02
28736	...	...	...	...	...	...	RP700919N00	86.1 ± 7.7	-0.37	28.98
29169	F5IV	6.01	0.38	44 ± 1	80	34.32	WP200677N00	64.3 ± 16	-0.60	28.87
31362	F0	6.33	0.35	43 ± 2	60	34.19	RP300178M01	62.6 ± 5.0	-0.09	28.84
37495	F5V	5.28	0.49	42 ± 1	31	34.61	WP701094N00	180.7 ± 6.9	-0.12	29.28
38393	F7V	3.60	0.48	9 ± 0.1	11	33.96	WP200643N00	18.9 ± 3.3	-0.90	26.96
40136	F1V	3.71	0.34	15 ± 0.2	...	34.34	RP200907N00	292.4 ± 6.9	-0.34	28.60
45348	F0Ib	-0.62	0.16	96 ± 5	15	37.70	WP200319N00	586 ± 15	0.21	30.51
48737	F5IV	3.35	0.44	18 ± 0.3	70	34.62	RP201487N00	445.8 ± 18	0.08	28.94

Table 1. (continued)

HD	ST	V	$B–V$	d (pc)	$V \sin i$ ($\mathrm{km\,s^{-1}}$)	$\log L_{bol}$ ($\mathrm{erg\,s^{-1}}$)	Image	Count Rate (10^{-3} cts/s)	HR	$\log L_X$ ($\mathrm{erg\,s^{-1}}$)
71243	F5III	4.05	0.41	19 ± 0.2	36	34.43	WP300131N00	271.4 ± 13	-0.16	28.77
87141	F5V	5.71	0.51	47 ± 2	10	34.54	WP700264N00	96.5 ± 7.4	-0.19	29.11
89449	F6IV	4.78	0.45	21 ± 0.4	18	34.22	RP200076N00	164.2 ± 3.1	-0.14	28.64
91480	F1V	5.16	0.35	26 ± 0.4	87	34.25	WP201310N00	93.2 ± 5.4	-0.13	28.58
95310	Am/F0Vs	5.06	0.26	124 ± 10	72	35.60	RP200943N00	23.9 ± 1.7	0.08	29.34
101688	F2IV-V	6.65	0.36	61 ± 3	60	34.431	WP701149N00	72.6 ± 6.1	-0.10	29.21
117361	F0IV	6.42	0.40	78 ± 4	...	34.70	RP800047N00	31.1 ± 3.2	-0.60	29.05
118646	F3V	5.81	0.43	49 ± 2	...	34.54	WP600188N00	91.5 ± 9.3	-0.06	29.12
118646	...	...	...	...	...	...	WP600188A02	108.9 ± 3.1	0.02	29.19
124850	F7V	4.07	0.51	21 ± 0.4	17	34.52	RP200908N00	803.9 ± 17	0.15	29.33
125451	F5IV	5.41	0.39	26 ± 1	42	34.14	WP150053N00	199.1 ± 8.0	-0.26	28.91
125451	...	...	...	...	...	...	RP200543N00	259.4 ± 16	-0.15	29.02
145100	F3V	6.43	0.45	49 ± 2	...	34.31	RP200545N00	18.8 ± 3.6	-0.50	28.43
148048	F5V	4.95	0.39	30 ± 0.4	76	34.46	WP141829N00	144.1 ± 9.0	-0.14	28.89
155203	F3III-IVp	3.32	0.44	22 ± 0.4	150	34.83	RP200132N00	145.5 ± 8.6	-0.69	28.62
157373	F6V	6.36	0.43	40 ± 1	15	34.13	WP701080N00	9.8 ± 1.1	-0.42	27.97
186185	F5V	5.49	0.46	37 ± 3	21	34.41	RP600148N00	166.7 ± 9.0	-0.22	29.14
197373	F6IV	6.02	0.44	33 ± 1	30	34.12	RP600272N00	112.0 ± 3.5	-0.33	28.86

notes: [1] a, b; [2] a, b; [3] a; [4] c; [5] b; [6] a; [7] g; [8] a, g; [9] d; [10] a, g; [11] c, e; [12] g; [13] g; [14] a, b, g, h, i, l, m, n; [15] a, b, g, o, p, q; [16] g; a: Simon et al. 1995; b: Schmitt et al. 1985a; c: Schmitt, Micela et al. 1990; d: Randich et al. 1996; e: Ayres et al. 1991; g: Hünsch et al. 1998b; h: Helfand and Caillault 1982; i: Gioia et al. 1990; l: Stocke et al. 1991; m: Fleming et al. 1995; n: Pan et al. 1997; o: Schmitt 1997; p: Schmitt et al. 1990; q: Golub et al. 1983.

2 super–giants, 6 stars with uncertain spectral type and/or luminosity class and 4 stars without any information about the luminosity class; there are 5 chemically peculiar stars and three δ Scuti stars (HD 124953, HD 432 and HD 89449). In Table 1 we list the 52 stars by their HD number (Column 1). Columns 2, 3, 4 and 5 contain the spectral type, magnitude, B–V color and distance of the stars in parsec. Except for HD 124953, all these data were taken from the HIPPARCOS Output Catalogue (Perryman et al. 1997). For HD 124953 the data are from García et al. (1995). Note that the HIPPARCOS distances often are different from those previously known or derived from spectroscopic parallaxes. This could imply a refinement of the spectroscopic classification (few sub-classes) for various stars. However, given that there is not a systematic effect, this should not have implications on our results as a sample. Column 6 lists the projected rotational velocity from the Bright Star Catalogue and from Uesugi & Fukuda (1982). Column 7 contains the bolometric luminosity calculated following Ayres et al. (1981) and Column 8 lists the ROSAT sequence number of the images. The A–type stars already studied in the literature have been marked with a note after the HD number and the relevant references are reported at the table bottom.

2.2. X–ray observations and data analysis

2.2.1. Count rates

The count rates listed in the WGA catalogue present some limitations for our study due to: (1) the automatic detection technique used, based on an optimized sliding cell algorithm has problems in the case of crowded fields, extended sources, etc.; (2) the count rates are obtained using a constant value of the exposure time (nominal time) across the field, thus the source count rate can be underestimated if the source lies close to the detector ribs or the border; (3) the band used to obtain the count rates corresponds to channels 24–200 or 0.24–2.0 keV, this excludes the band 0.1–0.24 keV, which is extremely important for stellar X–ray sources. Thus the WGA catalogue was used only to identify the sources detected by the PSPC from our optical sample. Each observations was then re–analyzed interactively using the XIMAGE package. Count rates were measured in the energy band 0.1–2.4 keV (PSPC channels 11–235) by processing the event files retrieved from the ROSAT public archive. The effective exposure times were measured from the exposure maps provided by the ROSAT Standard Analysis Software System (SASS). These exposure maps account for the telescope vignetting, the occultation effects due to the support ribs in the detector window and the “wobble” of the spacecraft. These corrections are often important for our X–ray sources because almost all of them have been detected serendipitously, i.e. they were in the field of view of other targets ($\sim 45\%$ of our sources were located near the detector ribs or border). We also compared our results with those obtained from the ROSAT All–Sky Survey (RASS–BSC, Voges et al. 1996; RASS, Hünsch et al. 1998a,b). Of our supposedly single stars, 8 A– and 26 F–type stars are detected also in the RASS. We found good agreement in the count rate values implying that no strong variability is present.

In order to obtain the usual hardness ratio HR=$(H - S)/(H + S)$ (see e.g. Schmitt et al. 1995), we calculated the count rates in the “soft” (*S*: channels 11–41 ≈ 0.1–0.28 keV) and “hard” (*H*: channels 52–201 ≈ 0.5–2.0 keV) PSPC X–ray bands, respectively. A value of HR $\simeq -1$ indicates an extremely soft spectrum, HR $\simeq 0$ indicates an equal number of soft and hard photons and HR $\simeq +1$ an extremely hard one. The results of our data analysis are also tabulated in Table 1, Column 9 lists the PSPC count rate and Column 10 lists the hardness ratio.

2.2.2. Spectral analysis

The PSPC has a moderate spectral capability, with an energy resolution $\Delta E/E \approx 0.42$ at 1 keV and, in principle, it allows to study the temperature of the plasma in the 0.1–2.4 keV energy band. However, as it is typical for serendipitous detections, the majority of our sources lacks the required signal–to–noise ratio to model the spectral energy distribution. Only for few of them, 3 A– and 11 early F–type stars, there are enough counts to perform a detailed spectral analysis. For this analysis we considered only the sources with more than 800 counts. The X–ray pulse height spectra were extracted from the event files using the XSELECT/FTOOLS package and were rebinned to give at least 25 counts per bin. Standard Poissonian statistics should therefore be fairly adequate to compute the errors in the model fitting. The spectral analysis was carried out using the optically thin plasma model “mekal” (see Mewe et al. 1985; Mewe et al. 1986; Kaastra 1992), as implemented in the XSPEC package. The hydrogen column density $N_{\rm H}$ was added in the spectral fit.

3. Results

3.1. Spectral results

For all sources, we compared the best fit values of the $N_{\rm H}$ with those obtained using Paresce’s formula (Paresce 1984). Note that all these stars have d< 50 pc, but one at 65 and one at 96 pc. For 12 out of 14 sources, a two–temperature model (with solar abundances) reproduces observations better than a single temperature model. In 5 of the 12 cases (HD 50241, HD 116160, HD 25457, HD 45348, HD 89449) a further improvement was obtained by introducing the $N_{\rm H}$ as a free parameter. For 4 of them the value of the $N_{\rm H}$ obtained from Paresce’s formula is a factor 2–25 smaller than the lower limit of the $N_{\rm H}$ derived from the best fit (90% confidence range for three parameters of interest: the two temperatures and the $N_{\rm H}$). For the fifth source (HD 45348) the 90% confidence range is consistent with the value obtained from Paresce’s formula (see also Bauer & Bregman 1996). For the remaining two cases nor the second temperature neither the inclusion of the $N_{\rm H}$ does improve the fit: these are HD 13456 (F5V) and HD 18404 (F5IV). In this analysis we used an F–test to check if the improvement of the χ^2 was significant at more than 99.75%.

In order to characterize the X–ray spectra of these sources we used the 2T mekal model with solar abundances for all sources. Due to the low energy resolution of the PSPC and to the relatively low number of photons of our spectra, in Table 2 we report the errors at the 90% confidence level only for the two temperatures. The $N_{\rm H}$ was fixed to Paresce’s value for the 9 sources for which its inclusion did not improve the fit, and to the best–fit value in the remaining 5 cases.

Table 2. Spectral results

HD	kT_1 (keV)	$Norm_1$ ($\times 10^{-4}$)	kT_2 (keV)	$Norm_2$ ($\times 10^{-4}$)	$N_{\rm H}(\times 10^{19})$ (cm^{-2})
50241	$0.09^{+0.02}_{-0.03}$	5.27	$0.57^{+0.13}_{-0.15}$	0.95	20.5
116160	$0.10^{+0.03}_{-0.03}$	7.49	$0.69^{+0.11}_{-0.10}$	5.10	14.6
187642	$0.11^{+0.02}_{-0.03}$	2.85	$0.42^{+0.35}_{-0.19}$	0.48	0.10
13456	$0.17^{+0.0}_{-0.09}$	0.47	$0.47^{+0.43}_{-0.40}$	1.00	1.00
18404	$0.13^{+0.06}_{-0.05}$	0.69	$0.43^{+0.20}_{-0.0}$	1.38	0.64
20675	$0.14^{+0.04}_{-0.05}$	0.35	$0.53^{+0.16}_{-0.15}$	0.57	0.92
24357	$0.18^{+0.71}_{-0.08}$	0.38	$0.56^{+0.33}_{-0.29}$	0.47	0.83
25457	$0.08^{+0.01}_{-0.01}$	64.5	$0.58^{+0.04}_{-0.04}$	27.3	17.1
37495	$0.17^{+0.07}_{-0.08}$	0.90	$0.64^{+0.23}_{-0.19}$	1.50	0.85
40136	$0.10^{+0.04}_{-0.02}$	2.38	$0.34^{+0.09}_{-0.04}$	3.92	0.30
45348	$0.14^{+0.03}_{-0.04}$	7.09	$0.68^{+0.10}_{-0.09}$	10.1	11.2
89449	$0.09^{+0.01}_{-0.02}$	4.94	$0.53^{+0.06}_{-0.08}$	2.09	16.3
124850	$0.17^{+0.05}_{-0.06}$	3.87	$0.66^{+0.09}_{-0.08}$	12.5	0.43
197373	$0.14^{+0.04}_{-0.04}$	0.81	$0.51^{+0.21}_{-0.14}$	0.96	0.67

We note that, a 2T model is required also for the 3 A–type stars in our sample: Altair (HD 187642, A7IV-V), HD 50241 (A7IV) and HD 116160 (A2V). Altair is an unquestionably single star and a known X–ray and chromospheric source (Schmitt et al. 1985a; Simon et al. 1995; Blanco et al. 1980; Landsman & Simon 1991; Simon et al. 1994; Walter et al. 1995; Simon & Landsman 1997). Up to now, the changeover from radiative to convective envelopes is presumed to occur in the close vicinity of its B–V color (see Simon & Landsman 1997). This star has a soft X–ray spectra with the majority of X–ray photons recorded in the lowest energy channels below 0.5 keV and a hardness ratio HR=-0.8. However, unlike previous reported *Einstein* and ROSAT results (Golub et al. 1983; Schmitt et al. 1990a; Freire Ferrero et al. 1995; Simon et al. 1995), we find that the inclusion of a second temperature improves the fit. The first temperature (0.11 keV) is consistent with that obtained in the single temperature fit of the previous works, while the second temperature has a value of 0.42 keV and it contributes to about 20% of the total flux. HD 50241 and HD 116160 are supposedly single A–type stars, although the few data found in the literature do not exclude a cooler binary companion. If HD 50241 is really a single star, this will be a further confirmation that coronal activity can already be present in stars as early as spectral type A7. In case of HD 116160, the spectral type (A2V) and the high X–ray luminosity detected ($\log L_x \sim 30$; see also Simon et al. 1995) could imply that this star has a cool companion. The distributions of T_{low} and T_{high} for the 14 sources are shown in Fig. 1 (solid line), and are discussed in Sect. 4.

The spectra of four F–type star, out of the 11 presented here, are already studied in literature using *Einstein* and/or ROSAT observations (HD 37495, HD 40136, HD 45348 and HD 124850). For HD 124850 our results are well consistent with those obtained by Maggio et al. (1994) analysing the same image. Instead Bauer & Bregman (1996) fit the X–ray spectra of HD 40136, HD 45348 and HD 124850 with a single–

temperature model and free metal abundance. They found a good fit with very low metal abundance values (~ 0.1 of the solar value) and a temperature that is similar to our harder temperature. Finally the X-ray spectra of HD 37495 and HD 45348 obtained with the *Einstein* satellite were fitted using a single temperature model by Schmitt et al. (1990a); the resulting temperature are much harder (~ 1.3 keV) and this is probably due to the harder band of the *Einstein* satellite (0.3–3.5 keV).

In order to give a crude spectral information also for the other sources of the sample (38 objects), in Column 10 of Table 1 we report the hardness ratio (HR) for all sources. An inspection of the HR values shows that they are almost all negative (61 out 74), clustering around the value HR=-0.2. The value of HR immediately gives a rough idea of the coronal temperature distribution for a sample of stars, if the interstellar absorption is unimportant. In our case the majority of stars is closer than 60 pc, thus the absorption should be negligible. Actually, the source with the hardest spectrum (HD 20902, F5Ib with HR=0.7) is also the farthest (d=181 ± 22 pc) and in this case the absorption could be important: Paresce's formula gives a value of $N_H \sim (4 \pm 0.4) \times 10^{19}$ cm^{-2} which is too small to explain the observed HR. However, this formula is not reliable for such a distance and a value of $N_H \sim 5 \times 10^{20}$ cm^{-2} would already be sufficient to absorb all the soft photons.

3.2. X–ray flux and luminosity

To estimate the integrated energy flux, it is necessary to multiply the count rate by a conversion factor (CF). In principle, the CF depends upon the effective area of the instrument as a function of energy, which is known, and the incident X–ray spectrum of the source that, for most of our sources, cannot be determined because there are not enough counts to carry out a spectral analysis. Thus, the conversion from the measured count rate to the energy flux requires some assumptions for the intrinsic source spectrum. On the other hand, as the PSPC is sensitive over a large energy range, we can try to construct an empirical relation between the HR (indicator of the spectral shape in case of small interstellar absorption) and the CF of the stars of our sample for which we performed the spectral analysis. This relation would allow to obtain a CF from the HR value for the other stars of the sample. This attempt was already done for late–type stars samples with a wide range of stellar activity levels and spectral shapes (Fleming et al. 1995; Panarella et al. 1996). However, in our case, we were not able to obtain a relation between HR and CF. This is probably due to the fact that our stars with sufficient counts to conduct spectral analysis (14 stars) have a too small range of HR ($-0.3 <$ HR < 0.2 except for Altair) to be compared with the range between -1 and $+1$ of the late–type star samples. In any case, if we consider all our sample we find that in 51 out of 74 observations the A–F stars have $-0.5 <$ HR < 0 (see Table 1, Column 10). Thus, for our stars the HR has little influence over the CF. Therefore we decided to use a constant value, CF= 5×10^{-12} erg cm^{-2} cts^{-1}, obtained from the mean of the 14 CF of the stars with enough counts for spectral analysis.

We note that all distances, but one, are taken from the HIPPARCOS Output Catalogue (Perryman et al. 1997) which provides extremely precise measurement of the parallax and of the other astrometric parameters (1 milliarcsec level astrometry). Thus, the X–ray luminosity is independent of the measurement of quantities such as spectral type and color index. In Column 11 of Table 1 we list the derived luminosities in erg s^{-1} (in the 0.1–2.4 keV energy band). The X–ray luminosity distribution is shown in Fig. 2, panel a).

4. Discussion

4.1. X–ray temperatures

As in our spectral sample we have only 3 A–type stars, our results are dominated by the early F stars. We find that a thin thermal plasma model with two temperature components agrees with those obtained for late–type stars with *Einstein*, EXOSAT, Ginga, ROSAT and ASCA observatories (e.g. Schmitt et al. 1990a; Dempsey et al. 1993; White 1995; Panarella et al. 1996). In Fig. 1 we show the distributions of the two–temperature components (solid line) for the 14 sources of our sample. From this figure and from Table 2 it emerges that T_{low} is in the range between 0.06 and 0.2 keV, while T_{high} is in the range between 0.3 and 0.7 keV, clustering around values of 0.13 keV and 0.54 keV, respectively. In order to compare our temperatures with those of late–type stars, in the same figure we report the distributions of the two temperatures for a X–ray selected sample of late–type stars (dashed line). The sample consists of EXOSAT serendipitous sources (Giommi et al. 1991, Tagliaferri et al. 1994) for which a spectral analysis like ours was conducted using ROSAT PSPC data (Panarella et al. 1996). Also for this sample a two temperature model was required to represent the spectra of all sources. For this comparison we considered only the supposedly single late–type stars of the sample (15). In this way we compare the temperatures of active supposedly single A–F type stars with those of active supposedly single G–K–M type stars.

The comparison of the temperature distributions shows that, in our case, the second temperature is significantly lower. In fact for late–type stars the second temperature is in the range 0.5–1.2 keV with an average value of $\sim$ 0.9 keV while for A–F type stars the average value is around 0.54 keV. A Kolmogorov–Smirnov test gives a probability of 6.8×10^{-5} that the two high temperature distributions are coming from the same parent distribution.

4.2. X–ray luminosity

In Fig. 2, panel a) we plot the distribution of the derived ROSAT luminosity L_X for our sample. From this figure and from Table 1 (Column 11) it is clear that: (1) the X–ray luminosity distributions of A– and early F–type stars are similar; (2) the X–ray luminosities range from $L_X \sim 10^{28}$ erg s^{-1} up to $L_X \sim 10^{30}$ erg s^{-1}, levels similar to those observed in active late–type stars; (3) X–ray luminosities cluster around the same value of $< \log L_X >= 29.2$ for A– and early F–type stars.

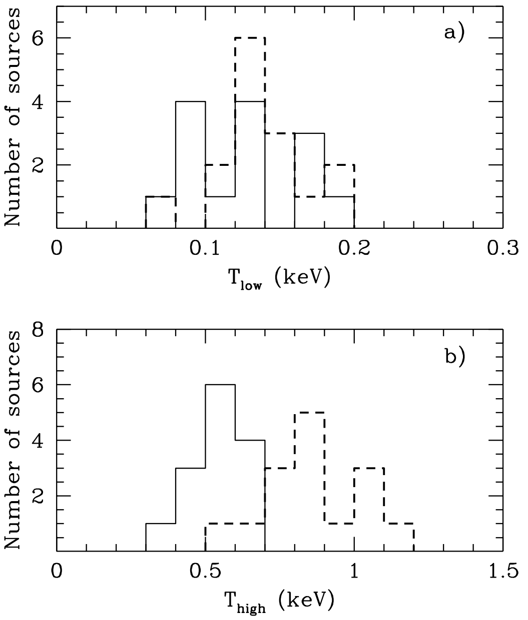

Fig. 1a and b. Distribution of T_{low} (panel **a**) and T_{high} (panel **b**) components for the 14 sources of our sample with enough counts for spectral analysis (solid line). In order to compare our temperatures with those of late–type stars we show also the distribution of the two temperatures for a sample of single late–type stars (dashed line). See discussion in the text.

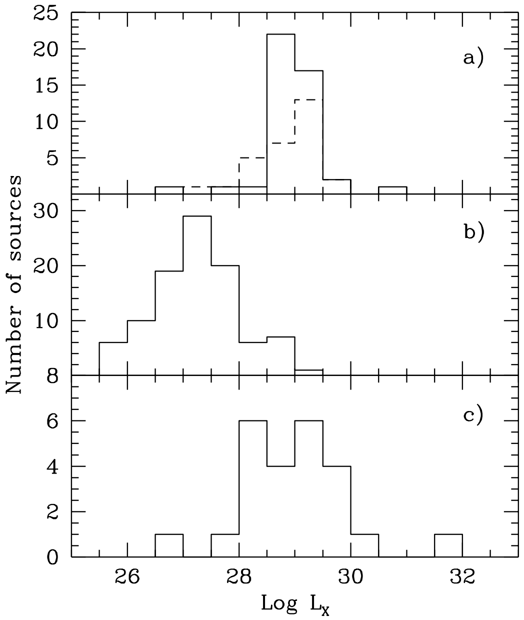

Fig. 2. In panel **a**) we plot the distribution of the derived ROSAT X–ray luminosity for A– (dashed line) and early F–type stars (solid line) of our sample. In order to compare our distribution to that of late–type stars, in panels **b**) and **c**) we show the X–ray luminosity distributions for a sample of "normal" and very active late–type stars, respectively. See the text for a description of the samples and discussion.

In Fig. 2 we compare the X–ray luminosity distribution of our sample to that of two sample of late–type stars. Panel b) shows the X–ray luminosity distribution of all known K and M dwarfs in the immediate solar vicinity with distance less than 7 pc (Schmitt et al. 1995). In this study the X–ray detection rate for K and M dwarfs is 87%. Thus, this sample should be reasonably complete, except possibly for the very faintest stars, and it is not biased toward the intrinsically luminous emitters like the X–ray selected samples of coronal X–ray sources. Inspection of panel b) shows that the luminosity ranges from $L_X \simeq 10^{26}$ erg s^{-1} to $L_X \simeq 10^{29}$ erg s^{-1} clustering in the range $L_X = 1$–3×10^{27} erg s^{-1}. Panel c) shows the luminosity distribution for the sample of the supposedly single late-type stars (G–K–M spectral type stars) studied by Panarella et al. 1996. As this is flux limited X–ray selected sample, it consists of the most active G–K–M stars. Their luminosity is spread in the range $L_X \simeq 10^{28}$–10^{30} erg s^{-1}.

The comparison of panels a), b) and c) shows that our luminosity distribution is similar to that of the X–ray selected sample of late–type stars, but not to that of late–type optically selected stars. We tried to characterize the X–ray emission of our A– and early F–type stars searching for correlations between L_X and the B–V color, $V \sin i$ and the bolometric luminosity, finding none. On the contrary a positive correlation is found between $\log L_X$ and the spectral hardness ratio. A linear regression analysis yields a correlation coefficient $r = 0.6$, the probability of a spurious correlation being less than 10^{-10}. A similar trend was found for samples of late–type stars (see Schmitt et al. 1995; Schmitt 1997; Panarella et al. 1996).

4.3. Comparison with previous observations of A–type stars

The detection of a very stringent upper limit for the X–ray emission of the prototypical A–star Vega ($\log L_X < 25.55$; Schmitt 1997), which is well below our values, raises doubts about the existence of coronae in early A–type stars. In a work similar to our, Simon et al. (1995) used ROSAT PSPC observations to study a sample of 74 A–type stars detecting X–ray emission in 10 early A–type stars. Of these five are known to be binaries, while more optical observations are necessary to determine the physical nature of the remaining five (four of them are also in our sample: HD20888, HD30478, HD45618 and HD116160). In the past X–ray emission was reported for the Ap stars as a class. The main results on these stars can now be summarized as follows. Pre–ROSAT studies of chemically peculiar stars (CP) reported only a small number of X–ray detection of putatively single CP stars (see Cash & Snow 1982; Golub et al. 1983). Drake et al. (1994) searched for X–ray emission in $\sim$ 100 magnetic Bp–Ap stars using the ROSAT All Sky Survey database. They detected X-ray emission for ten of these sources, but only three of them were identified with apparently single stars. Thus, these stars do not seem to be X–ray emitters as a class any more. A wind–fed magnetosphere model has been proposed to explain both the non–thermal radio and the X–ray emission found in some CP stars (Linsky et al. 1992). Cash & Snow (1982), using *Einstein* observations, did not detect single Am stars and suggested that Am stars as a class are not strong coronal emitters (upper limit of about 10^{28} erg s^{-1}). One apparently single Am stars (HD 107168, A8m) was detected by

Randich et al. (1996) using ROSAT PSPC observations. They suggested a cool companion as source of the emission since the star lies slightly above cluster main sequence. We also detected one magnetic Ap star (HD 38104) and two Am stars (HD 140232 and HD 187753). HD 38104 is given as an Ursa Major stream star (Roman 1949). Schmitt et al. (1990b) studied this region using *Einstein* observations, finding for this star only an upper limit $\log L_X < 28.78$ (with a distance d=52 pc). We instead find a value $\log L_X = 29.1$, using the HIPPARCOS distance d=148 pc. With this distance the 3σ upper limit of *Einstein* is fully consistent with our detection. Note that the higher HIPPARCOS distance does not imply that the star is not an Ursa Major stream, which include stars at similar or higher distance (e.g. Roman 1949, Eggen, 1958). The two Am stars were detected also in the ROSAT all-sky survey at a similar flux level by Hünsch et al. (1998b) (see also the RASS – BSC revision 1RXS, Voges et al. 1996). In our sample we have another peculiar star: HD 124953, a variable δ Scuti star (López de Coca et al. 1990; García et al. 1995) with $L_X = 2 \times 10^{28}$ ergs s^{-1}. It belongs to the Ursa Major stream and, as HD 38104, it was not detected by *Einstein* (Schmitt et al. (1990b), with an upper limit $L_X < 4 \times 10^{28}$ erg s^{-1}, a value again consistent with our detection. HD 124953 has been studied also by Ayres et al. (1991), using the same image analysed in our work, they found $L_X = 1 \times 10^{28}$ ergs s^{-1}.

5. Conclusions

We studied the X–ray emission for a sample of A– and early F–type stars which are not known to be double, using the data in the ROSAT PSPC public archive. Starting from a list of 351 A– and 165 F–type stars that could have been detected in our images, X-ray emission was detected in 66 A– and 76 F–type stars. The rejection of all confirmed or suspected binaries gives a final sample of 19 A– and 33 F– supposedly single type stars. As expected, the detection rate is much higher for the F–type stars, given that stars earlier than A7 spectral type are not expected to have strong (if at all present) X-ray emission.

The main conclusions of this paper can be summarized as follows:

1. 19 supposedly single A–type stars are found to coincide with X–ray sources. In many cases we found very little information in literature about these stars. With the only exception of Altair, our results are not sufficient to associate with certainty the X–ray emission to the A–type stars themselves, since the usual argument that it may originate from a binary companion cannot be excluded. Optical and UV studies are needed to establish the physical properties of the early A–type stars detected in X–ray. For this reason we observed in the optical a sub–sample of our A–type stars, monitoring their radial velocities. The reduction of these data is in progress.
2. A two temperature thermal plasma model is a good representation of the spectra of the 11 F– and 3 A–type stars with enough counts to model the spectral energy distribution. The temperatures found for the 3 A– stars are consistent with those of the F–type stars. An interesting case is that of HD 116160, an early spectral type star (A2V), with a high X–ray luminosity. The comparison of the two temperatures found for the stars in our sample with those of a X–ray selected sample of single late–type stars (Panarella et al. 1996) shows that, while T$_{low}$ is similar for the two samples our second temperature component (T$_{high}$) is lower. This result applies mainly to the F-type stars, because our spectral study is dominated by them (11 out of 14).
3. The X–ray luminosity distribution of our sample is similar to that of X–ray selected sample of late–type stars. We find a positive correlation between the X-ray luminosity and the HR, while we do not find significant correlations between X–ray luminosity and other stellar parameters.

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References

Ayres T.R., 1981, ApJ 250, 293
Ayres T.R., Marstad N.C., Linsky J.L., 1981, ApJ 247, 545
Ayres T.R., Fleming, T.A., Schmitt J.H.M.M., 1991, ApJ 376, L45
Bauer F., Bregman J.N., 1996, ApJ 457, 382
Berghöfer T.W., Schmitt J.H.M.M., 1994, A&A 292, L5
Berghöfer T.W., Schmitt J.H.M.M., Cassinelli J.P., 1996, A&AS 118, 481
Blanco C., Catalano S., Marilli E., 1980, ESA SP–157, 63
Cash W., Snow T.P.Jr., 1982, ApJ 263, L59
Dempsey R.C., Linsky J.L., Fleming T.A., Schmitt J.H.M.M., 1993, ApJS 86, 599
Dempsey R.C., Linsky J.L., Fleming T.A., Schmitt J.H.M.M., 1993, ApJ 413, 333
Drake J., Linsky J.L., Schmitt J.H.M.M., Rosso C., 1994, ApJ 420, 387
Eggen O.J., 1958, MNRAS 118, 65
Fleming T.A., Molendi S., Maccacaro T., Wolter A., 1995, ApJS 99, 701
Freire Ferrero R., Gouttebroze P., Catalano S., et al., 1995, ApJ 439, 1020
Gagnè M., Caillault J.P., 1994, ApJ 437, 361
García J.R., Cebral J.R., Scoccimarro E.R., et al., 1995, A&AS 109, 201
Gioia M., Maccacaro T., Schild R.E., et al., 1990, ApJS 72, 567
Giommi P., Angelini L., Jacobs P., Tagliaferri G., 1991, ASP Conf. Ser. 25, 100
Giommi P., Tagliaferri G., Beuermann K., et al., 1991, ApJ 378, 77
Golub L., Harnden F.R.Jr., Maxson C.W., et al., 1983, ApJ 271, 264
Helfand D.J., Caillault J.P., 1982, ApJ 253, 760
Hoffleit D.E., Warren W.H.Jr., 1991, The Bright Star Catalogue. 5th Rev. Ed., Yale Univ. Obs., New Haven
Hünsch M., Schmitt J.H.M.M., Voges W., 1998a, A&AS 127, 251
Hünsch M., Schmitt J.H.M.M., Voges W., 1998b, A&AS 132, 155
Ingham J., 1996, In: The XSELECT User's Guide. version No.1.0
Kaastra J.S., 1992, An X-Ray Spectral Code for Optically Thin Plasmas. (Internal SRON-Leiden Report, updated version 2.0)

Landsman W., Simon T., 1991, ApJ 366, L79
Lasker B.M., Sturch C.R., McLean B.J., et al., 1990, AJ 99, 2019
Lemen J.R., Mewe R., Schrijver C.J., Fludra A., 1989, ApJ 341, 474
Linsky J.L., Drake S.A., Bastian T.S., 1992, ApJ 393, 341
López de Coca P., Rolland A., Rodríguez E., Garrido R., 1990, A&AS 83, 51
Maggio A., Sciortino S., Harnden F.R.Jr., 1994, ApJ 432, 701
Mewe R., Gronenschild E.H.B.M., Van Den Oord G.H.J., 1985, A&AS 62, 197
Mewe R., Lemen J.R., van den Oord G.H.J., 1986, A&AS 65, 511
Mullan D.J., Cheng Q.Q., 1994a, ApJ 420, 392
Mullan D.J., Cheng Q.Q., 1994b, ApJ 435, 435
Pallavicini R., Golub L., Rosner R., et al., 1981, ApJ 248, 279
Pan H.C., Jordan C., Makishima R.A., et al., 1997, MNRAS 285, 735
Panarella A., Tagliaferri G., Pallavicini R., 1996, ASP Conf. Ser. 109, 623
Paresce F., 1984, AJ 89, 1022
Perryman M.A.C., Lindegren L., Kovalevsky J., et al., 1997, A&A 323, L49
Pfeffermann E., Briel U.G., Hippmann H., et al., 1986, Proc. SPIE 733, 519
Randich S., Schmitt J.H.M.M., Prosser C., 1996, A&A 313, 815
Roman N.G., 1949, ApJ 110, 205
Schmitt J.H.M.M., Golub L., Harnden F.R.Jr., et al., 1985a, ApJ 290, 307
Schmitt J.H.M.M., Harnden F.R.Jr., Peres G., Rosner R., Serio S., 1985b, ApJ 288, 751
Schmitt J.H.M.M., Collura A., Sciortino S., et al., 1990a, ApJ 365, 704
Schmitt J.H.M.M., Micela G., Sciortino S., et al., 1990b, ApJ 351, 492
Schmitt J.H.M.M., Kürster M., 1993, Sci 262, 215
Schmitt J.H.M.M., Zinnecker H., Cruddace R., Harnden F.R.Jr., 1993, ApJ 402, L13
Schmitt J.H.M.M., Fleming T.A., Giampapa M.S., 1995, ApJ 450, 392
Schmitt J.H.M.M., Drake J.J., Haisch B.M., Stern R.A., 1996, ApJ 467, 841
Schmitt J.H.M.M., 1997, A&A 318, 215
Schrijver C.J., 1993a, A&A 269, 446
Schrijver C.J., 1993b, A&A 269, 395
Simon T., Landsman W.B., 1991, ApJ 380, 200
Simon T., Landsman W.B., Gilliland R.L., 1994, ApJ 428, 319
Simon T., Drake S.A., Kim P.D., 1995, PASP 107, 1034
Simon T., Landsman W.B., 1997, ApJ 483, 435
Stauffer J.R., Caillault J.P., Gagnè M., Prosser C.F., Hartmann L.W., 1994, ApJS 91, 625
Stern R.A., Schmitt J.H.M.M., Kahabka P.T., 1995, ApJ 448, 683
Stocke J. T., Morris S.L., Gioia I.M., et al., 1991, ApJS 76, 813
Tagliaferri G., Cutispoto G., Pallavicini R., Randich S., Pasquini L., 1994, A&A 285, 272
Trümper J., 1983, Adv. Space Res. Vol. 2, No.4, 241
Uesugi A., Fukuda I., 1982, In: Revised catalogue of stellar rotational velocities. Dept. of Astronomy, Kyoto University, Japan
Voges W., Aschenbach B., Boller T., et al., 1996, IAU Circular 6420, 2
Walter F.M., Matthews L.D., Linsky J.L., 1995, ApJ 447, 353
White N.E., Giommi P., Angelini L., 1994, IAU Circular 6100
White N.E., 1995, Adv. Space Res. 16, 29