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X-RAY EMISSION FROM CHEMICALLY PECULIAR STARS

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ABSTRACT

We have searched the *ROSAT* All-Sky Survey (RASS) database at the positions of ∼100 magnetic Bp–Ap stars of the helium-strong, helium-weak, silicon, and strontium-chromium subclasses. We detect X-ray sources at the positions of 10 of these stars; in four cases the X-ray emission presumably arises from an early-type companion with a radiatively driven wind, while we believe that the magnetic chemically peculiar (CP) star is the most likely X-ray source (as opposed to a binary companion) in at least three and at most five of the six remaining cases. The helium-strong stars have X-ray emission levels that are characteristic of the luminous OB stars with massive winds (log $L_x/L_{bol} \sim -7$), whereas the He-weak and Si stars (which generally show no evidence for significant mass loss) have log L_x/L_{bol} values that can reach as high as ~ -6. In contrast, we find no convincing evidence that the cooler SrCrEu-type CP stars are intrinsic X-ray sources. We discuss the X-ray and radio emission properties of our sample of CP stars, and argue that both types of emission may be magnetospheric in origin; however, there is clearly not a simple one-to-one correspondence between them, since many of the magnetic stars that are detected radio sources were not detected as X-ray sources in the present survey.

Subject headings: stars: peculiar — X-rays: stars

1. INTRODUCTION

For some 40 yr, kiloGauss surface magnetic fields have been measured in the Ap and Bp stars, which are collectively known as chemically peculiar or CP stars. Borra, Landstreet, & Mestel (1982) concluded in their review of this phenomenon that longitudinal magnetic fields of more than 0.2 kG are common in Ap stars of the SrCrEu and Si peculiarity classes, the helium-weak (He-W) stars, and the helium-strong (He-S) stars. The latter class has much stronger fields than the other classes. These four classes of magnetic CP stars form a temperature sequence with the SrCrEu stars typically of spectral type A, the He-W and Si stars lying in the range B5–A0, and the He-S stars lying in the range O9–B5. The He-S stars are rapid rotators (100 km s^{-1} $\leq v \sin i \leq$ 200 km s^{-1}) and have effective temperatures in the range 17,000 K $\leq T_{eff} \leq$ 25,000 K (Shore & Brown 1990; Walborn 1983). By comparison, the He-W and cooler stars are often more slowly rotating with $T_{eff} \approx$ 15,000 K (Shore, Brown, & Sonneborn 1987).

The geometries of the magnetic fields in the magnetic CP stars are often inferred to be dipolar, with the magnetic axes usually inclined with respect to the rotation axes (the "oblique rotator" model). As the star rotates, the observed magnetic field is modulated with this period. In some cases, more complex geometries such as decentered dipoles or additional quadrupolar components are required to fit the observed magnetic field variations. Both the He-S and some of the hotter He-W stars show spectroscopic evidence of winds. While radiatively accelerated winds are generally observed in nonmagnetic early B-type stars, the presence of strong dipolar fields is expected to restrict the region of outflow to the magnetic polar regions were the wind emerges in the form of jets. Shore (1987) and Shore & Brown (1990) observed phase-dependent C IV and Si IV line profile variations in both the He-S and He-W stars that indicate the presence of both polar jets and trapped circumstellar plasma in the stellar magnetosphere near the magnetic equator.

Our extensive survey of nonthermal radio emission from magnetic CP stars (Drake et al. 1987; Linsky, Drake, & Bastian 1992; Drake, Linsky, & Bastian 1993) has provided detections of 25 sources at 3.7 cm and/or 6 cm out of 99 observed. In addition to the three He-S stars and two He-W/Si-strong stars initially reported by Drake et al. (1987) as radio stars, the subsequent studies by Linsky et al. (1992) and Drake et al. (1993) discuss detections of 20 new radio-emitting stars with spectral types B5–A0, which have measured kiloGauss magnetic fields and are all confirmed or suspected to have He-W/Si-strong characteristics. We have not yet detected any classical (SrCrEu–type) Ap stars as radio sources among the dozen that we have observed, in agreement with previous unsuccessful searches (e.g., Altenhoff, Pflinderer, & Weiss 1976; Willson, Lang, & Foster 1988).

We find a wide range of radio luminosities for the radio-detected magnetic stars, log L_6 = 14.7–17.9, with the early-B, He-S stars on average 20 times more radio luminous than the late-B He-W stars and 1000 times more luminous than θ Aurigae, the star with both the lowest radio luminosity and effective temperature. Multifrequency observations indicate flat spectra in all cases, and four stars have detected circular

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polarization at one or more frequencies. We interpret our data as due to optically thick gyrosynchrotron emission from a power-law distribution of mildly relativistic electrons. These data support the rotating magnetosphere model of Havnes & Goertz (1984) and André et al. (1988) in which stellar wind plasma expands along the dipolar field lines. In the model for the radio emission described in Linsky et al. (1992), centripetal forces on this plasma disrupt the field lines far from the star in the equatorial plane, forming a current sheet in which field reconnection and electron acceleration to mildly relativistic energies can occur as in the terrestrial magnetotail. These electrons then travel along the magnetic field lines to smaller radii and higher magnetic latitudes where they mirror and emit microwave radiation. This model can qualitatively explain the nonthermal radio emission, and it predicts that these stars should be thermal X-ray sources, although the model does not predict quantitative X-ray fluxes.

Since other classes of rapidly rotating stars with strong magnetic fields (e.g., dMe stars and RS CVn and Algol binary systems) are detected both as unusually strong "coronal" X-ray sources and nonthermal radio continuum sources, there has been speculation for at least 10 yr that the magnetic CP stars should exhibit similar properties. Our discovery that the magnetic CP stars are indeed nonthermal radio sources strongly implies that there must be a reservoir of charged thermal particles from which these high-energy electrons are accelerated. Again arguing from the analogous coronal stars of later spectral type, we would expect that these thermal electrons would have temperatures of 10^6–10^8 K. The only extensive pre-*ROSAT* study of the X-ray emission of CP stars was that of Cash & Snow (1982), who detected four out of nine stars at inferred X-ray luminosities $\sim 10^{28}$–4×10^{30} ergs s^{-1}. Although X-ray emission from unresolved late-type dwarf companions could not be ruled out conclusively, Cash & Snow concluded that the class of Ap stars probably are intrinsic X-ray emitters, unlike normal (single) late-B and A stars, which are generally not. However, only one of the four detected Ap stars reported by Cash & Snow was of a magnetic subclass (ω Oph, a SrCr star), while the other three stars were (nonmagnetic) Hg-Mn stars (and none of them are known radio sources), so that the relationship (if any) between the presence of detectable X-ray emission and of strong magnetic fields remained very uncertain. One additional magnetic CP star HD 20629 (A0 SiSrCr) was detected serendipitously by *EXOSAT*, with an inferred X-ray luminosity of $\sim 10^{31}$ ergs s^{-1} for an assumed distance of 200 pc (Cutispoto, Tagliaferri, & Catalano 1990). Finally, Drake et al. (1987) found only two X-ray sources (HR 1890 ≡ HD 37017, and σ Ori E) among their sample of radio-observed magnetic CP stars, and these were both early-type (B2) He-S stars with log $L_x/L_{\rm bol} = -6.7$, which is typical of hot stars with winds (we note that there is no consensus as to what causes this correlation between X-ray and bolometric luminosities in luminous hot stars). However, few of the intermediate-temperature He-W/Si stars were observed by either *EXOSAT* or *Einstein*, so that severe selection effects are certainly present.

If the standard Lucy & White (1980) model for the production of X-rays in self-shocking stellar winds of OB stars is applicable to the strongly magnetic He-S stars, one could argue that their X-ray emission is purely wind-related while the nonthermal radio emission results from a complex interaction between the outflowing wind material and the strong magnetic fields. In this scenario, the two emissions would not be expected to be simply proportional to each other. However, a new theory of the X-ray emission of hot stars put forward by Usov & Melrose (1992) that is further discussed in § 3 suggests that the X-ray emission may also be the result of magnetic field/stellar wind interaction, and thus might imply a more intimate connection between the nonthermal radio and thermal X-ray emissions of hot stars in general, and He-S stars in particular. Thus, a systematic study of the X-ray emission of magnetic, early-type stars may produce results that have some relevance for the wider subject of the origin of X-ray emission in all OB stars.

We have begun studying the *ROSAT* All-Sky Survey PSPC database to search for X-ray sources at the positions of ~ 100 radio-observed magnetic CP stars, including all of the stars whose radio properties are discussed in Linsky et al. (1992). This sample of CP stars contains mostly He-W/Si stars ($\sim 64\%$), with the remainder being equally divided between He-S stars and SrCrEu–type CP stars. In terms of membership in stellar associations, 25% of our sample are members of the Sco-Cen association at a distance of ~ 160 pc, 25% belong to the Orion OB1 association at a distance of ~ 450 pc, and the remaining 50% are either field stars or belong to other stellar aggregates. This program is an ongoing one with only preliminary results now available, but these results are so encouraging that we feel it worthwhile to present this progress report.

2. OBSERVATIONS

After its successful launch on 1990 June 1, the *ROSAT Observatory* carried out an all-sky X-ray survey (RASS) between 1990 July 30 and 1991 January 25. The satellite, its X-ray telescope, and the focal plane detector used during the all-sky survey, the Position Sensitive Proportional Counter (PSPC), have been described in detail by Trümper et al. (1991) and Pfeffermann et al. (1986). During the all-sky survey, the X-ray telescope scanned the sky along great circles perpendicular to the plane of the ecliptic once per satellite orbit. The scanned longitudes followed the apparent motion of the Sun along the ecliptic, and consequently the full celestial sphere was covered in six months, except for some data losses due to instrumental problems.

The telemetered data stream was processed, aspect-corrected, and accumulated into a sequence of sky images with a size of 2° × 360°. In the currently available REV-0 survey data processing, no attempt has been made to merge data obtained from more than 2 days, in order to take advantage of the increased exposure and hence sensitivity at higher ecliptic latitudes. The so-constructed sky images are then analyzed with a source detection program, which first constructs a smooth background map, assesses the existence of significant excesses over the background, and measures the positions and count rates of these sources; these parameter estimates are calculated from a maximum likelihood technique which in essence compares the hypothesis "background only" with the alternative "background plus point source" (cf. Cruddace, Hasinger, & Schmitt 1988).

Our criterion for source acceptance is that the difference in likelihood of the above two hypotheses exceeds 10, but we now know that this criterion is conservative. The resulting lists of X-rays sources were then cross-checked with our catalog of ~ 100 radio-observed magnetic CP stars. In order to positively identify an X-ray source with a magnetic CP star, we required that the difference between X-ray and optical positions be less than 60″. In addition, the photons for seven of the 10 successful detections were retrieved from the RASS data and reanalyzed

TABLE 1

Radio-Observed Magnetic Bp Stars Detected in the *ROSAT* All-Sky Survey

HD	Star	Spectral Type	Binary Status[a]	PSPC (10^{-2} ct s^{-1})[b]	Existence Likelihood	Comments
12767	ν For	B9.5p Si	Single	3.4 ± 1.0	18.8	
36485	δ Ori C	B2V HeS	Multiple	(132)[c]	2335	Ori OB1 assoc.
37043	ι Ori B	B7IV PGaHeW	Multiple	(190)[c]	3019	Ori OB1 assoc.
37479	σ Ori E	B2Vp HeS	Multiple	(100)[c]	322	Ori OB1 assoc.
64740	HR 3089	B1.5p HeS	Single	3.2 ± 0.9	16.4	
133880	HR 5624	Ap Si	Binary?	3.7 ± 1.5	7.8	Sco-Cen assoc.
144334	HR 5988	B8p HeW	Single	3.7 ± 1.3	8.6	Sco-Cen assoc.
145501	ν Sco CD	B8V?+B9V Si	Multiple	(12.8 ± 2.6)	47.1	Sco-Cen assoc.
146001	HR 6054[d]	B7IV HeW	Binary?	4.5 ± 1.8	14.6	Sco-Cen assoc.
152107	52 Her	A2Vp SrCrEu	Multiple	4.4 ± 0.9	32.0	Close triple system

[a] Single means no known companion within 1′ of target.
[b] Stars whose count rates are enclosed in parentheses are members of visual multiple systems in which the other components are probably the dominant contributors to the observed X-ray emission.
[c] The count rates of these are those obtained from the standard REV-0 processing of the RASS data.
[d] Note that for HR 6054 the rate was derived for the hard band only, since no detection was obtained in the soft band (see text).

using the Extended Scientific Analysis System (EXSAS) developed at MPE. Inspection of all images clearly showed the presence of X-ray sources at the expected positions although the (rederived) likelihood threshold was found to be less than 10 in two cases. The count rates and fluxes quoted in Tables 1 and 2 are those derived with EXSAS, unless otherwise indicated; note that for the case of HR 6054 a detection was obtained only in the hard band of the PSPC, but the resulting energy flux (as quoted in Table 2) has been multiplied by a factor of 2 to make it consistent with the energy fluxes for the other stars which were obtained in the total PSPC band. We emphasise that we consider *all* the detections reported in this paper as real. However, in a future REV-1 reprocessing we hope to be able to lower our threshold for source detection as well as to decrease the distance between optical and X-ray positions for positive identification. Our present threshold for source detection is at an approximate level of ~0.02 PSPC counts per second, equivalent to a flux threshold of 1.2×10^{-13} ergs s^{-1} cm^{-2}, using the conversion factor of 6×10^{-12} ergs s^{-1} cm^{-2} (PSPC counts $s^{-1})^{-1}$ that we have adopted (see § 3). These flux limits translate to limits to detectable X-ray luminosities of log $L_x \sim 29.5$ and 30.5 at the distances of Sco-Cen and Orion OB1, respectively.

With these source acceptance criteria we have found 10 matches between our list of radio-observed magnetic CP stars and the RASS source lists. In Table 1 we list these X-ray detected stars and also indicate their spectral type, binary status, PSPC count rate, their existence likelihood, and additional comments concerning their membership in OB associations and/or the probable presence of source confusion. As is obvious from Table 1, all our sources are well above threshold and are certainly real. We have estimated the probability of any of these sources actually being due to an optically faint extragalactic object within the 1′ error circle using the log $N - \log S$ relationship derived by Gioia et al. (1990) in the *Einstein* Extended Medium-Sensitivity Survey. For a source with an X-ray flux of 3×10^{-13} ergs s^{-1} cm^{-2}, the probability of it being an unrelated extragalactic object is 0.08%. Since the six X-ray sources that can be reliably associated with magnetic CP stars (see below) are all in the range of 2–6 $\times 10^{-13}$ ergs s^{-1} cm^{-2}, it is extremely unlikely that any of them are actually extragalactic.

Four of the 10 sources (σ Ori E, δ Ori C, ι Ori B, and ν Sco CD) are visual binaries containing a CP star secondary separated from the (hotter) primary component by less than 1′. The intrinsic X-ray emission (if any) from the CP star is impossible to estimate, but it is very likely that the primary components are the predominant contributors to the observed X-ray emission. The magnetic He-S star σ Ori E is a member of a trapezium-like visual multiple system and lies 42″ away from the primary, which is itself the close double star, σ Ori AB. The latter system is not known to be magnetic or chemically peculiar, but it is apparently a nonthermal radio source (see Drake 1990). The automatic SASS target software that exam-

TABLE 2

Derived Properties of the X-Ray Detected Magnetic Bp Stars

HD (1)	Star (2)	Spectral Type (3)	*D* (pc) (4)	f_x[a] (5)	log L_x (ergs s^{-1}) (6)	$\log \frac{L_x}{L_{bol}}$ (7)	log L_ν[b] (8)
12767	ν For	B9.5p Si	105	2.0	29.43	−6.39	<15.79
64740	HR 3089	B1.5p HeS	290	1.9	30.29	−7.19	<16.42
133880	HR 5624	Ap Si	160	2.2	29.84	−6.22	17.10
144334	HR 5988	B8p HeW	160	2.2	29.84	−6.41	15.96
146001	HR 6054	B7IV HeW	155	5.4	30.19	−5.86	15.91
152107	52 Her	A2Vp SrCrEu	40	2.6	28.70	−6.11	<14.88

[a] Units: 10^{-13} ergs cm^{-2} s^{-1}.
[b] Units: ergs s^{-1} Hz^{-1}.

ined the all-sky survey data of this field detected two X-ray sources at the location of σ Ori, but the individual fluxes of these sources are rather uncertain. Sigma Ori has been observed by both the *Einstein* IPC and HRI (Drake et al. 1987) and the *ROSAT* HRI (Schmitt et al. 1993), and the inferred X-ray properties of the AB and E components are typical of other luminous OB stars, i.e., $\log L_x/L_{\rm bol} \sim -6.7$: It is thus likely that the X-ray emission of σ Ori E and the similar X-ray detected He-S stars HR 1890 (Drake et al. 1987) and HR 3039 (see below) are unrelated to their magnetic peculiarities.

We do not include any of the abovementioned "confused" multiple systems (whose count rates we have enclosed in parentheses in Table 1) in our subsequent discussion. Of the remaining six stars listed in Table 1, 52 Her is a member of a close multiple system, and HR 5624 and HR 6054 exhibit possible radial-velocity variability that may be indicative of binarity. For the reasons given in the next section, we believe that the magnetic star component is the most plausible candidate as the X-ray emitter in these last two ambiguous cases.

3. DISCUSSION

Of the six X-ray sources which are positionally associated with magnetic CP stars in this sample and that remain after we exclude the four sources (σ Ori, δ Ori, ι Ori, and ν Sco) associated with the multiple systems, three are identified with apparently single stars, one with a CP star that is the primary component of a multiple system, and the remaining two with stars of uncertain duplicity. To estimate X-ray fluxes in the 0.07–2.4 keV band, we have adopted a PSPC conversion factor of 6×10^{-12} ergs s^{-1} cm^{-2} (PSPC counts s^{-1})$^{-1}$, that assumes an X-ray spectrum typically found for active late-type stars, i.e., thermal emission from plasma at temperatures of $\sim 10^7$ K with little intervening absorption. Note that if these sources were instead soft thermal sources with $T_e \sim 10^6$ K, the PSPC conversion factor would be roughly a factor of 2 smaller. In Table 2, we list the following data for our six candidate CP star X-ray sources: in column (1) the HD number, (2) the common name, (3) the spectral type, (4) the adopted distance D, (5) the X-ray flux f_x, (6) the implied X-ray luminosity $\log L_X$, (7) the X-ray efficiency $\log L_x/L_{\rm bol}$, where $L_{\rm bol}$ is the bolometric luminosity, and (8) the monochromatic radio luminosity $\log L_\nu$ at a frequency ν of either 4.8 or 8.4 GHz, using VLA data listed in Linsky et al. (1992) and Drake et al. (1993), expect for HR 3089 for which we quote an upper limit at 8.4 GHz obtained using the Australia Telescope Compact Array (Drake et al. 1993). (Since these stars have fairly flat radio spectra between 1.5 and 15 GHz, to estimate the total radio luminosity $L_{\rm rad}$ one can use $L_{\rm rad} \sim 10^{10} \times L_\nu$). The distances quoted for HR 5624, HR 5988, and HR 6054 are based on their membership in the Sco-Cen association, and should be accurate to $\pm 20\%$, while the distances for the other stars are estimates based on their spectroscopic parallaxes and hence are more uncertain ($\pm 40\%$?). The X-ray efficiencies are distance-independent quantities: their major source of uncertainty (~ 0.3 dex) is the conversion factor from counts per second to X-ray flux, with an additional much smaller uncertainty due to the adopted bolometric correction.

If we exclude the detection of the He-S star HR 3089 (which has $\log L_x/L_{\rm bol} = -7.2$, and thus is probably a stellar-wind–type X-ray source), the remaining five X-ray–detected magnetic stars have X-ray efficiencies between -6.4 and -5.9. Of the SrCrEu stars only 52 Her was detected as an X-ray source with an X-ray luminosity of $\log L_x \sim 28.7$. The object 52 Her is a triple star system and therefore the observed X-ray emission cannot be unambiguously ascribed to the primary star component, but could plausibly be produced by the cooler and less luminous secondary components. Since typical active F to M dwarf stars have $\log L_x \sim 29$ (e.g., Schmitt et al. 1985; Pallavicini, Tagliaferri, & Stella 1990), the present data provide no evidence that SrCrEu magnetic stars are X-ray sources.

Turning now to the remaining four He-W/Si stars (ν For, HR 5624, HR 5988, and HR 6054), we first note that HR 5624 and HR 6054 are possible binary stars, since they are listed in the Yale Bright Star Catalog (Hoffleit & Jaschek 1982) as having definite and suspected radial velocity variability, respectively. Nu For and HR 5988 appear to be bona fide single stars; if they were actually binary stars with as yet undetected companions, these companions would almost certainly be low-mass ($M \ll 1\ M_\odot$) stars. We find that the X-ray luminosities of these four He-W/Si stars range from $\log L_x = 29.5$ to $\log L_x = 30.2$. Only one star (ν For) has an X-ray luminosity significantly lower than 10^{30} ergs s^{-1}, while the other three stars all have X-ray luminosities within 50% of 10^{30} ergs s^{-1}. In addition, their X-ray efficiencies $\log L_x/L_{\rm bol}$ have values in the range of -6.4 to -5.8, which is significantly larger than the typical OB star value of ~ -7. This discrepancy, together with the absence of wind signatures in their spectra, makes us rule out X-ray emission from shocked winds as is observed in the hottest early-type stars as a viable explanation. However, the moderately large values of the X-ray luminosity could possibly be due to hitherto unsuspected highly active, late-type companion stars, given that all but ν For are members of Sco-Cen and thus presumably are very young (10^7 yr old), and that low-mass "naked" or post T Tauri stars in Taurus and other associations of similar or slightly younger ages have X-ray luminosities of this same order (see Walter et al. 1988, for example). The present data on binarity for these four stars suggest that two are single and that two may be binary: we note that sometimes the rotational modulation of the spectral lines of CP stars due to their inhomogeneous distribution of elemental abundances has been incorrectly ascribed to their being spectroscopic binaries, and thus we regard the hypothesis that the X-ray emission is due in all four of these cases to a very active binary companion as less likely than our working hypothesis that it is due to the CP stars. Also, Caillault & Zoonematkermani (1989) have found a dozen B6–A3 stars in the central, youngest parts of Ori OB1 that have $30.5 \leq \log L_x \leq 31.3$ and $-5.7 \leq \log L_x/L_{\rm bol} \leq -4.2$, i.e., are about an order of magnitude more X-ray luminous than the He-W/Si star X-ray sources discussed here. It seems implausible to us that a binary hypothesis can explain all of the anomalous Orion B-star X-ray emitters, and we speculate that this group may be a younger, more active counterpart of our sources. We note that three of the 12 X-ray detected B6 to A3 stars in Orion exhibit spectroscopic peculiarities, and suggest that their spectra should be examined in detail for the presence of chemical peculiarities and large-scale magnetic fields that would indicate that they are magnetic CP stars. We thus will adopt as a working hypothesis that the four He-W/Si star X-ray sources discussed here (and possibly some or all of the 12 B6 to A3 Ori OB1 X-ray sources of Caillault & Zoonematkermani 1989) are members of a new class of intrinsic X-ray sources, which we argue below is magnetospheric in nature.

A recent paper by Usov & Melrose (1992) has proposed an alternate model for the X-ray emission from all hot stars in which, unlike the standard wind-embedded strong shocks model of Lucy & White (1980), the high-temperature emission is interpreted as thermal emission from plasma at $\sim 10^7$ K that is generated near an equatorial current sheet. This current sheet model is somewhat reminiscent of the model proposed by Linsky et al. (1992) to explain the nonthermal *radio* emission of the He-W and He-S magnetic stars. The Usov & Melrose model makes detailed prediction of the dependence of the expected X-ray emission of the stellar and wind properties of hot stars. If we apply it to the He-W stars that we have detected both as nonthermal radio sources and X-ray sources, this model predicts trivial X-ray luminosities (log $L_x \sim 23$) that are 10^7 times smaller than those observed, provided that their mass-loss rates are as low as nonmagnetic stars of the same effective temperature that have radiation-driven stellar winds (i.e., that $\dot{M} \sim 1\text{–}3 \times 10^{-11}\ M_\odot\ \text{yr}^{-1}$). In order to match the observed X-ray luminosities of these stars, the mass-loss rates seem implausibly high: for example, if the winds were assumed to be completely ionized, their monochromatic radio luminosities L_ν due to free-free emission alone should be 6×10^{16} ergs s^{-1} Hz^{-1}, whereas the actual values are $\leq 10^{16}$ ergs s^{-1} Hz^{-1}. Thus, it does not seem that the Usov & Melrose (1992) model is applicable in its present form to the strongly magnetic early-type stars.

The available radio data for all of the X-ray–detected magnetic CP stars are listed in Table 2. For three of these six stars (the He-W/Si stars HR 5624, HR 5988, and HR 6054), we have radio detections at levels of log $L_\nu = 15.9\text{–}17.1$, while for the three others (ν For, HR 3089, and 52 Her) we have only radio upper limits, ranging from log $L_\nu < 14.9$ for 52 Her to log $L_\nu < 16.4$ for HR 3089. Thus, at present, of the four X-ray sources that we have associated with He-W/Si magnetic stars (ν For, HR 5624, HR 5988, and HR 6054), all but ν For have been also detected as radio sources. However, the converse is clearly not true: most of the radio-detected He-W/Si stars were not detected as X-ray sources, and thus, for example, must have log $L_x \leq 29.5$ if at the distance of Sco-Cen. For example, HD 215441 (Babcock's star), the magnetic CP star with the largest known magnetic field of 34 kG (surface field) and also one of the largest measured radio luminosities (log $L_\nu = 17.9$) was *not* detected as an X-ray source, although our upper limit to its X-ray luminosity of log $L_x < 31.7$ is not very stringent due to its relatively large distance of 830 pc. Clearly the present X-ray data need to be considerably augmented both by a complete reanalysis of the all-sky survey data using the REV-1 software and by additional pointed *ROSAT* observations before we can attempt any statistical analysis searching for correlations between the X-ray and radio emission of He-W/Si stars.

Finally, we note that the observed PSPC count rates for all of the X-ray–detected and unconfused CP stars found so far in our RASS program are quite small (~ 0.04 counts s^{-1}), and that the accumulated counts are far too few for meaningful spectral analysis; however, it appears from the limited spectral data available so far that the pulse-height spectra are relatively hard. We have both planned and proposed *ROSAT* pointed observations to obtain relatively long exposures of the strongest X-ray sources in our sample which should provide pulse height data of sufficient signal-to-noise ratio to warrant a detailed spectral analysis.

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