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An Upper Limit to Coronal X-rays from Single, Magnetic White Dwarfs

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Abstract. Pointed ROSAT PSPC exposures of 9277 and 6992 sec, directed toward the nearby, single, cool, magnetic white dwarfs GR 290 and EG 250 yielded no counts significantly above the expected background rate. The corresponding flux limits (for an assumed source temperature of l keV) are 1.0 and 1.7 × 10^{-14}erg cm^{-2} s^{-1}, within the 0.1–2.5 keV bandpass of the instrument (99% confidence limits). This is more than an order of magnitude below the tentative detection level (for GR 290) and limits (for four other similar stars) obtained from archival Einstein data in 1991. The corresponding limits on coronal electron density are comparable with those implied if cyclotron emission is not responsible for any of the features observed in the optical spectra of magnetic white dwarfs. X-ray data currently provide no evidence for the existence of coronae around these stars. A final long observation (25,000 sec of GD 356) is scheduled for later this year on ROSAT, along with coordinated EUVE observations.

Key words: White dwarfs—stellar coronae—X-ray emission

1. Introduction

Motivated by theoretical considerations (Zheleznyakov & Litvinchuk 1985; Serber 1990) and by the preponderance of magnetic systems among known cataclysmic variable X-ray sources, Arnaud *et al.* (1992, hereafter AZT92) searched in the Einstein IPC data base for X-ray emission from a sample of Five nearby (6–20 pc), strongly magnetic (10–200 MG), relatively cool (6,000-14,000 K) single white dwarfs. The search yielded one apparent detection at better than 99% confidence (GR 290, with L_x = 4.1 × 10^{27} ergs $^{-1}$) and gave upper limits for the other four stars in the range 1.4 –12.5 × 10^{27}erg s^{-1} in the 0.2 –3.5 keV bandpass of the instrument.

In the light of these results, we requested 10,000 sec of the pointed ROSAT PSPC time for each of three stars (GR 290 = G 99-47, GR 329 = GD 356, and EG250 = G 195–19) under Announcement of Opportunity No. 2. Another group requested, and eventually received the data for, GD 356 (Musielak 1992). In March/April, the satellite pointed at the other two stars for us; and the data arrived in late summer.

2. The data and results

Table 1 lists properties of the two stars observed. Data from 9277 and 6992 sec of pointing at the two stars were returned in the form of tapes giving raw counts. vs. time and position in 60 arc minute fields centered at accurately-known right ascension and declination near the positions of the target stars. The raw counts were cleaned to remove data from times of earth occultation, of interference by the South Atlantic Anomaly, and so forth, and entered into an IRAF format. Neither star blazed forth from the center of its field.

Potential sources were sought in two ways. First, positions of previously-known X-ray sources, QSOs, nearby stars, and other interesting objects were extracted from several dozen catalogues, and the pixels in their vicinity were examined. Nothing terribly interesting emerged, though there are possible matches with several faint IRAS sources and HD stars. Second, we extracted the positions of potential sources in our images and compared them with the HST guide star catalog. Possible matches were found for all seven of the sources in the field of EG 250 and all five in the field of GR 290, suggesting that all or most are ordinary stellar coronae. One source in each field has enough counts (≈ 1000) to reveal some spectral information. These ≈ will be reported on separately.

Limits on the numbers of counts and fluxes at the positions of our target white dwarfs were obtained as described in AZT92. Counts within one arc minute of the stellar positions were taken to represent star plus background, and the background count rate was measured from 1.5–4 arc minute annuli around each star. The conversion from counts to fluxes assumed Brehmsstralung emission from pure hydrogen at 1 keV, no significant absorption along the line of sight (because the stars are close and within the local ionized bubble of interstellar medium), and an instrumental energy range of 0.1–2.5keV.The conversion factor is then one count = 6.46×10^{-12} erg cm^{-2}.

Table 1. Stars observed.

Star Alt. Name	RA (1950) Decl. (1950)	Distance, pc Field, MG	Spectral features Effective temp.	Dates observed
G99-47 GR 290	05 53 47 +05 22.0	8.0 25.0	H absorption 5700 K	29 + 31 March
G 195–19 EG 250	09 12 27 +53 38.6	10.3 100.0	Featureless 8000 K	28 April

Table 2. Count, flux, and luminosity limits.

Star	Time[a]	Counts[b]	Rate[c]	Band flux[d]	Total[e] flux	X-ray luminosity[f]	Electron[g] density
EG 250	6992	18.8	2.69	1.74×10^{-14}	2.26×10^{-14}	2.87×10^{26}	7.6×10^{11}
GR 290	9277	14.9	1.61	1.04×10^{-14}	1.35×10^{-14}	1.03×10^{26}	4.6×10^{11}

[a] Total observing time, seconds.
[b] Above background, 99% confidence limit.
[c] Net counts, $s^{-1} \times 10^{-3}$.
[D] erg cm^{-2} s^{-1} in 0.1–2.5 keV bandpass.
[e] erg $cm^{-2} s^{-1}$.
[f] erg s^{-1}.
[g] cm^{-3}.

Setting a formal 99% confidence limit to the number of counts above background was accomplished using a Bayesian method (appropriate to small numbers) that was developed by Laredo (1990) and expanded by AZT92. Table 2 lists limits on count numbers, count rates, fluxes within the instrument bandpass, and total fluxes, again assuming 1 keV Brehmsstralung radiation. The last two columns give upper limits to total X-ray luminosity and the maximum possible electron density for a corona extending out one scale height from a 0.7 $M_{\odot}$, log g = 8.0 (cm s^{-2}) white dwarf (about 200 km).

3. Discussion, conclusions, and the future

Neither of our stars was emitting detectable X-rays in March/April 1992. The limit for GR 290, 1.03 × 10^{26}ergs^{-1}, is very much less than the luminosity reported by AZT, 4.1 × 10^{27}ergs^{-1}, on the basis of archival Einstein data. Thus, either the apparent Einstein detection was a statistical fluke (most likely), or the star varies by more than a factor of 10 in its X-ray luminosity (not impossible, but no independent reason for thinking so). The present limits on coronal electron density for GR 290 and EG 250 (Table 2), 4.6 and 7.6 × 10^{11}cm^{-3} are only slightly larger than the 2× 10^{-11}cm^{-3} limit that comes from requiring that cyclotron emission or absorption makes no detectable contribution to optical spectral features (Zheleznyakov & Litvinchuk 1985).

At least two other magnetic white dwarfs may be better coronal candidates than the stars we observed. GD 229 has a surface field varying over the range 30–300 MG and optical spectral features that defy explanation in terms of the standard picture of Zeeman-displaced components of hydrogen Balmer lines (Greenstein 1992). If these are cyclotron resonances, then the star must have a corona within striking distance of X-ray detectability.

GD 356 displays its Balmer lines in emission, and so must have at least a chromosphere, if not a corona. A short ROSAT guest observation by another group may have seen a marginally significant source at its position (Musielak 1992). The two groups have joined forces to concentrate on this one star and have been awarded 25,000 sec of ROSAT HRI time and 10,000 sec of EUVE (Extreme Ultraviolet Explorer) time to concentrate on it. Because GD 356 is unique in showing Balmer emission line, neither a definitive detection nor a better upper limit will do much to clarify the situation for coronae of single, magnetic white dwarfs in general.

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