AN X-RAY SURVEY OF WOLF-RAYET STARS IN THE MAGELLANIC CLOUDS. II.
THE ROSAT PSPC AND HRI DATA SETS

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ABSTRACT

Wolf-Rayet (WR) stars in the Magellanic Clouds (MCs) are ideal for studying the production of X-ray emission by their strong fast stellar winds. We have started a systematic survey for X-ray emission from WR stars in the MCs using archival Chandra, ROSAT, and XMM-Newton observations. In Paper I, we reported the detection of X-ray emission from 29 WR stars using Chandra ACIS observations of 70 WR stars in the MCs. In this paper, we report the search and analysis of archival ROSAT PSPC and HRI observations of WR stars. While useful ROSAT observations are available for 117 WR stars in the MCs, X-ray emission is detected from only seven of them. The detection rate of X-ray emission from MCs WR stars in the ROSAT survey is much smaller than in the Chandra ACIS survey, illustrating the necessity of high angular resolution and sensitivity. LMC-WR 101–102 and 116 were detected by both ROSAT and Chandra, but no large long-term variations are evident.

Subject headings: Magellanic Clouds — stars: Wolf-Rayet — surveys — X-rays: stars

1. INTRODUCTION

Wolf-Rayet (WR) stars are characterized by their broad emission lines, indicating copious fast stellar winds. Spectral analyses of WR stars show typical wind terminal velocities of 1000–3000 km s⁻¹ (Prinja et al. 1990) and mass-loss rates of a few times 10⁻⁵ M☉ yr⁻¹ (de Jager et al. 1988). Such powerful stellar winds are expected to generate a variety of X-ray sources. Within the WR wind itself, instability shocks produce regions with high temperatures and densities for X-ray emission (Lucy & White 1980; Gayley & Owocki 1995). Upon leaving the WR star, the wind may encounter a massive companion’s wind, and the colliding winds produce compressed hot gas that emits X-rays. Finally, as the WR wind impinges on the ambient medium, a wind-blown bubble may form, and the shocked WR wind in the bubble interior may emit in X-rays (Weaver et al. 1977; García-Segura et al. 1996b, 1996a). Therefore, X-ray observations of WR stars provide an opportunity to probe the opacity of the stellar wind, study the orbital configuration of an WR+OB binary system, and examine the stellar mechanical energy injection into the interstellar medium.

Previous Einstein and RöntgenSatellit (ROSAT) X-ray surveys of Galactic WR stars have shown that WR stars in binary systems have higher L_X/L_bol than single WR stars or O stars and that single WR stars of the nitrogen sequence (WN) are generally brighter than WR stars of the carbon sequence (WC) stars, although no simple L_X/L_ bol relationship appears to exist among single WN stars (Pollock 1987; Pollock et al. 1995; Wesselowski 1996). While these results reveal the potential of scientific yields from X-ray observations of WR stars, the Galactic sample is plagued by heavy obscuration in the Galactic plane that renders a large fraction of WR stars undetectable. The nearby Large and Small Magellanic Clouds (LMC and SMC) are ideal locations to expand the X-ray observations of WR stars, since the foreground and internal extinctions in these galaxies are small. Furthermore, their lower metallicities allow us to probe abundance effects on the stellar winds, and their known distances allow us to determine L_X with greater certainty.

In the first paper of this series (Guerrero & Chu 2008, hereafter Paper I), we have used the current archive of the Chandra X-ray Observatory to search for X-ray emission from WR stars in the Magellanic Clouds (MCs). This survey included useful Advanced CCD Imaging Spectrometer (ACIS) observations for 70 of the 146 known WR stars in the MCs and resulted in credible detection of X-ray emission from 29 of these WR stars and possibly another four WR stars. Many of the WR stars in the MCs that have not been observed by Chandra have ROSAT X-ray observations available in the archive. In this paper, we have used the entire ROSAT archive of pointed observations to search for and analyze X-ray sources associated with WR stars in the MCs in order to complement our Chandra ACIS X-ray survey for WR stars in the MCs and to investigate long-term X-ray variability. In an upcoming paper (J. Carter et al. 2008, in preparation, hereafter Paper III), the results from the ROSAT and Chandra surveys of WR stars in the MCs will be complemented by an XMM-Newton survey. All three archival studies will be analyzed together in conjunction with a systematic spectroscopic search for binaries for all WR stars in the MCs (Bartzkas et al. 2001; Foellmi et al. 2003a, 2003b; O. Schnurr et al. 2008, in preparation) to determine accurately the origin of X-ray emission from WR stars.

2. ROSAT OBSERVATIONS OF WOLF-RAYET STARS IN THE MAGELLANIC CLOUDS

ROSAT had two types of X-ray detectors onboard: the Position Sensitive Proportional Counter (PSPC) and the High-Resolution Imager (HRI). The PSPC has an on-axis angular resolution of ~30″ and a spectral resolution of ~45% at 1 keV; it is sensitive in the energy range of 0.1–2.4 keV and has a field of view of ~2°. The HRI has a higher angular resolution, ~5″, but does not provide spectral resolution over the operational energy range of 0.1–2.0 keV; its field of view is ~38″. During the ROSAT mission from 1990 to 1999, numerous pointed observations of targets in the MCs were made, and the large field of view serendipitously included many WR stars. These observations can be retrieved from the ROSAT archive3 maintained by the High Energy Astrophysics

3 ROSAT archival data can be obtained from the anonymous ftp site ftp://legacy.gsfc.nasa.gov or downloaded from the Web site http://heasarc.gsfc.nasa.gov/W3Browse.
| WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) |
|--------|---------|---------|-------------------|----------------|--------|---------|---------|-------------------|----------------|--------|---------|---------|-------------------|----------------|
| LMC-WR 3 | Brey 3 | rp900320 | 31.3 | 23 | LMC-WR 31 | Brey 25 | rp400154 | 6.5 | 2 | LMC-WR 54 | Brey 4a | rp180251 | 20.2 | 23 |
| LMC-WR 5 | Brey 4 | rp500258 | 13.8 | 34 | LMC-WR 32 | Brey 26 | rp400263 | 24.1 | 24 | LMC-WR 55 | Sk –69 175 | rp180251 | 20.2 | 23 |
| LMC-WR 6 | Brey 5 | rp500263 | 12.7 | 22 | LMC-WR 33 | Sk –68 73 | rp400154 | 6.5 | 5 | LMC-WR 5 | Sk/C0 68 | rp600577 | 9.0 | 25 |
| LMC-WR 9 | Brey 7 | rp600093 | 6.5 | 5 | LMC-WR 34 | Sk/C0 69 | rp180179 | 15.9 | 23 | LMC-WR 6 | Sk/C0 66 | rp50037 | 6.8 | 19 |
| LMC-WR 10 | Brey 9 | rp600093 | 6.5 | 5 | LMC-WR 35 | Sk/C0 67 | rp500140 | 40.0 | 23 | LMC-WR 7 | Sk/C0 65 | rp500258 | 13.8 | 32 |
| LMC-WR 11 | Brey 10 | rp500258 | 13.8 | 18 | LMC-WR 36 | Sk –69 | rp600577 | 9.0 | 21 | LMC-WR 8 | Sk/C0 67 | rp180251 | 20.2 | 24 |
| LMC-WR 12 | Brey 10a | rp500258 | 12.7 | 32 | LMC-WR 37 | Sk –68 73 | rp180179 | 15.9 | 23 | LMC-WR 9 | Sk/C0 68 | rp500093 | 8.7 | 9 |
| LMC-WR 13 | Sk –66 40 | rp500093 | 6.5 | 5 | LMC-WR 38 | Sk/C0 68 | rp600099 | 8.8 | 7 | LMC-WR 10 | Sk/C0 69 | rp180251 | 20.2 | 24 |
| LMC-WR 14 | Brey 11 | rp500258 | 13.8 | 19 | LMC-WR 39 | Sk/C0 68 | rp500138 | 31.6 | 15 | LMC-WR 11 | Sk/C0 66 | rp500258 | 13.8 | 19 |
| LMC-WR 15 | Brey 12 | rp500060 | 3.9 | 33 | LMC-WR 40 | Sk/C0 67 | rp500263 | 24.1 | 33 | LMC-WR 12 | Sk/C0 67 | rp500263 | 24.1 | 33 |
| LMC-WR 16 | Brey 13 | rp600093 | 6.5 | 5 | LMC-WR 41 | Sk/C0 68 | rp500140 | 40.0 | 23 | LMC-WR 13 | Sk/C0 67 | rp500263 | 24.1 | 33 |
| LMC-WR 19 | Brey 16 | rp300129 | 4.0 | 18 | LMC-WR 42 | Sk/C0 68 | rp500061 | 3.8 | 11 | LMC-WR 14 | Sk/C0 67 | rp500061 | 3.8 | 11 |
| LMC-WR 20 | Brey 16a | rp300129 | 4.0 | 18 | LMC-WR 43 | Sk/C0 68 | rp500161 | 1.9 | 32 | LMC-WR 15 | Sk/C0 67 | rp500161 | 1.9 | 32 |
| LMC-WR 21 | Brey 17 | rp500052 | 12.4 | 2 | LMC-WR 44 | Sk/C0 68 | rp180033 | 3.8 | 11 | LMC-WR 16 | Sk/C0 67 | rp180033 | 3.8 | 11 |
| LMC-WR 22 | Brey 18 | rp180033 | 3.8 | 11 | LMC-WR 45 | Sk/C0 68 | rp141507 | 1.3 | 33 | LMC-WR 17 | Sk/C0 67 | rp180033 | 3.8 | 11 |
| LMC-WR 23 | ... | rp500052 | 12.4 | 4 | LMC-WR 46 | Sk/C0 68 | rp141508 | 1.3 | 33 | LMC-WR 18 | Sk/C0 67 | rp180033 | 3.8 | 11 |
| LMC-WR 24 | Brey 19 | rp900398 | 12.4 | 20 | LMC-WR 47 | Sk/C0 68 | rp141518 | 1.3 | 33 | LMC-WR 19 | Sk/C0 67 | rp180033 | 3.8 | 11 |
| LMC-WR 25 | Brey 19a | rp500061 | 3.8 | 11 | LMC-WR 48 | Sk/C0 68 | rp141519 | 1.3 | 33 | LMC-WR 20 | Sk/C0 67 | rp180033 | 3.8 | 11 |
| LMC-WR 26 | Brey 20 | rp500061 | 3.8 | 11 | LMC-WR 49 | Sk/C0 68 | rp141520 | 1.3 | 33 | LMC-WR 21 | Sk/C0 67 | rp180033 | 3.8 | 11 |
| LMC-WR 27 | Brey 21 | rp500061 | 3.8 | 11 | LMC-WR 50 | Sk/C0 68 | rp141521 | 1.3 | 33 | LMC-WR 22 | Sk/C0 67 | rp180033 | 3.8 | 11 |
| LMC-WR 28 | Brey 22 | rp141507 | 1.3 | 29 | LMC-WR 51 | Sk/C0 67 | rp141530 | 1.1 | 30 | LMC-WR 23 | Sk/C0 67 | rp180033 | 3.8 | 11 |
| LMC-WR 29 | Brey 23 | rp500053 | 8.3 | 0 | LMC-WR 52 | Sk/C0 67 | rp141531 | 1.1 | 30 | LMC-WR 24 | Sk/C0 67 | rp180033 | 3.8 | 11 |

**TABLE 1**

**ROSAT PSPC Observations of Wolf-Rayet Stars in the Magellanic Clouds**

- **WR No.** refers to the identification number of each Wolf-Rayet star.
- **WR Name** indicates the name assigned to each star.
- **Obs. ID** is the identification code for the observation.
- **$t_{\text{exp}}$ (ks)** denotes the exposure time in thousands of seconds.
- **Offset (arcmin)** is the angular offset from the target location.

This table lists detailed observations of Wolf-Rayet stars in the Magellanic Clouds, providing essential data for astrophysical studies.
| WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) |
|--------|---------|--------|------------------|---------------|--------|---------|--------|------------------|---------------|--------|---------|--------|------------------|---------------|
| LMC-WR 30.............. Brey 24 | rp500053 | 8.3 | 21 | | | | | | | | | | | |
| LMC-WR 62.............. Brey 51 | rp400246 | 14.5 | 13 | | | | | | | | | | | |
| LMC-WR 63.............. Brey 52 | rp900533 | 1.6 | 29 | | | | | | | | | | | |
| LMC-WR 64.............. Brey 53 | rp110167 | 2.3 | 22 | LMC-WR 69.............. TSWR 4 | rp110167 | 2.3 | 24 | | | | | | | |
| LMC-WR 76.............. Brey 64 | rp180251 | 20.2 | 4 | | | | | | | | | | |
| LMC-WR 77.............. Brey 65 | rp110168 | 1.8 | 11 | | | | | | | | | | |
| WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) |
|-------|---------|---------|-----------------|----------------|
| rp110167 | Brey 58 | 2.3 | 24 | LMC-WR 75 | Brey 59 |
| rp110173 | 2.0 | 32 | LMC-WR 90 | Brey 74 |
| rp110174 | 2.9 | 26 | | |
| rp600100 | 22.7 | 8 | | |
| LMC-WR 68 | Brey 58 | | | |
| rp110168 | 1.8 | 28 | | |
| rp110173 | 2.0 | 29 | | |
| rp110179 | 2.2 | 21 | | |
| rp180251 | 20.2 | 12 | | |
| rp500100 | 26.6 | 12 | | |
| rp500140 | 40.0 | 15 | | |
| rp500300 | 9.4 | 15 | | |
| rp600100 | 22.7 | 14 | | |
| LMC-WR 83 | HD 269858 | | | |
| rp110168 | 1.8 | 24 | | |
| rp110173 | 2.0 | 30 | | |
| rp110179 | 2.2 | 20 | | |
| rp180251 | 20.2 | 12 | | |
| rp500100 | 26.6 | 12 | | |
| rp500140 | 40.0 | 12 | | |
| rp500303 | 9.4 | 12 | | |
| rp600100 | 22.7 | 11 | | |
| LMC-WR 85 | Brey 67 | | | |
| rp110168 | 1.8 | 9 | | |
| rp110179 | 2.2 | 27 | | |
| rp180251 | 20.2 | 8 | | |
| rp500100 | 26.6 | 8 | | |
| rp500140 | 40.0 | 8 | | |
| rp500303 | 9.4 | 8 | | |
| rp600100 | 22.7 | 8 | | |
| LMC-WR 86 | Brey 69 | | | |
| rp110168 | 1.8 | 5 | | |
| rp110179 | 2.2 | 29 | | |
| rp180251 | 20.2 | 12 | | |
| rp500100 | 26.6 | 12 | | |
| rp500140 | 40.0 | 7 | | |
| rp500303 | 9.4 | 12 | | |
| rp600100 | 22.7 | 11 | | |
| LMC-WR 87 | Brey 70 | | | |
| rp110168 | 1.8 | 19 | | |
| rp110173 | 2.0 | 35 | | |
| rp110179 | 2.2 | 19 | | |
| rp180251 | 20.2 | 11 | | |
| rp500100 | 26.6 | 11 | | |
| rp500140 | 40.0 | 11 | | |
| LMC-WR 88 | Brey 70a | | | |
| rp110168 | 1.8 | 7 | | |
| rp110179 | 2.2 | 27 | | |
| rp180251 | 20.2 | 13 | | |

**TABLE 1—Continued**
| WR No.     | WR Name     | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No.     | WR Name     | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No.     | WR Name     | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) |
|------------|-------------|---------|------------------------|-----------------|------------|-------------|---------|------------------------|-----------------|------------|-------------|---------|------------------------|-----------------|
| rp500100   | LMC-WR 95   |         | 26.6                   | 13              | rp500303   |             | 9.4     | 20                     |                 | LMC-WR 104  | Brey 76     |         | 1.8                     | 9                |
| rp50131    |             |         | 16.0                   | 5               | rp600100   |             | 22.7     | 12                     |                 | LMC-WR 89   | Brey 71     |         | 2.2                     | 26               |
| rp500140   |             |         | 40.0                   | 13              | rp500100   |             | 26.6     | 19                     |                 | LMC-WR 105  | Brey 77     |         | 2.2                     | 19               |
| rp500303   |             |         | 9.4                    | 13              | rp600100   |             | 22.7     | 19                     |                 | LMC-WR 106,108,110... R 136a |         | 2.2                     | 26               |
| rp600100   |             |         | 22.7                   | 12              | rp500100   |             | 22.7     | 19                     |                 | LMC-WR 111   | R 136b      |         | 2.2                     | 26               |
| rp500140   |             |         | 40.0                   | 13              | rp500131   |             | 16.0     | 1                      |                 | LMC-WR 112   | R 136c      |         | 2.2                     | 19               |
| rp500303   |             |         | 9.4                    | 20              | LMC-WR 118 | Brey 89    |         | 1.8                     | 9                | LMC-WR 119   | Brey 90     |         | 1.8                     | 27               |
| rp600100   |             |         | 22.7                   | 19              | LMC-WR 120 | Brey 91    |         | 1.8                     | 9                | LMC-WR 121   | Brey 90a    |         | 1.8                     | 10               |
| rp500140   |             |         | 40.0                   | 19              | LMC-WR 122 | Brey 92    |         | 1.8                     | 11               | LMC-WR 123   | Brey 97     |         | 1.8                     | 18               |
| WR No.   | WR Name  | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No.   | WR Name  | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No.   | WR Name  | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) |
|---------|----------|---------|------------------------|-----------------|---------|----------|---------|------------------------|-----------------|---------|----------|---------|------------------------|-----------------|
| rp500303 | 11.1 | 9.4 | 19 | | rp110179 | 2.2 | 29 | | | rp300335 | 11.3 | 29 |
| rp600100 | 22.7 | 19 | | | rp600100 | 22.7 | 19 | | | rp600100 | 22.7 | 19 | | |
| rp110168 | 1.8 | 9 | | | rp500100 | 26.6 | 24 | | | rp1500044 | 5.3 | 23 |
| rp110179 | 2.2 | 27 | | | rp500131 | 16.0 | 5 | | | rp400052 | 8.8 | 22 |
| rp180251 | 20.2 | 20 | | | rp500140 | 40.0 | 24 | | | rp400133 | 1.8 | 22 |
| rp500100 | 26.6 | 20 | | | rp500100 | 26.6 | 20 | | | LMC-WR 130 | Sk – 69 297 | | | |
| rp500131 | 16.0 | 1 | | | rp500131 | 16.0 | 5 | | | rp600100 | 22.7 | 23 | | |
| rp500140 | 40.0 | 20 | | | rp500140 | 40.0 | 24 | | | LMC-WR 131 | Brey 98 | | | |
| rp500303 | 9.4 | 20 | | | rp500100 | 26.6 | 39 | | | LMC-WR 132 | Brey 99 | | | |
| rp500303 | 9.4 | 20 | | | rp600100 | 22.7 | 19 | | | LMC-WR 133 | Sk – 67 266 | | | |
| LMC-WR 117 | Brey 88 | | | | rp500179 | 15.9 | 39 | | | SMC-WR 1 | AV 2a | | | |
| LMC-WR 117 | Brey 88 | | | | rp600140 | 40.0 | 39 | | | SMC-WR 10 | HD 6043 | | | |
| SMC-WR 2 | AV 39a | | | | rp600196 | 23.5 | 13 | | | SMC-WR 11 | HD 6043 | | | |
| rp500249 | 19.2 | 9 | | | rp600196 | 23.5 | 13 | | | SMC-WR 12 | HD 6043 | | | |
| rp500251 | 2.1 | 15 | | | rp600196 | 23.5 | 13 | | | SMC-WR 13 | HD 6043 | | | |
| rp600196 | 23.5 | 10 | | | rp600196 | 23.5 | 13 | | | SMC-WR 14 | HD 6043 | | | |
| rp600445 | 17.6 | 40 | | | rp600195 | 26.1 | 9 | | | SMC-WR 15 | HD 6043 | | | |
| rp600454 | 18.0 | 33 | | | rp500182 | 4.9 | 6 | | | SMC-WR 16 | HD 6043 | | | |
| SMC-WR 3 | AV 60a | | | | rp500142 | 4.9 | 3 | | | SMC-WR 17 | HD 6043 | | | |
| rp500249 | 19.2 | 17 | | | rp500250 | 20.8 | 6 | | | SMC-WR 18 | HD 6043 | | | |
| rp500196 | 23.5 | 9 | | | rp500195 | 23.0 | 33 | | | SMC-WR 19 | HD 6043 | | | |
| rp600454 | 18.0 | 34 | | | rp600196 | 23.5 | 33 | | | SMC-WR 20 | HD 6043 | | | |
| SMC-WR 4 | Sk 41 | | | | rp500249 | 19.2 | 23 | | | SMC-WR 21 | HD 6043 | | | |
| WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) |
|--------|---------|--------|------------------------|----------------|--------|---------|--------|------------------------|----------------|--------|---------|--------|------------------------|----------------|
| LMC-WR 3 .......... Brey 3 rh400654 2.6 7 | LMC-WR 38 ............ Brey 31 rh400353 7.9 13 | rh400125 4.9 11 |
| LMC-WR 9 .......... Brey 7 rh900321 32.2 10 | LMC-WR 39 ............ Brey 32 rh400356 3.1 17 | rh400658 5.9 11 |
| LMC-WR 10 .......... Brey 9 rh900321 32.2 0 | LMC-WR 40 ............ Brey 33 rh400356 3.1 17 | rh500470 28.7 17 |
| LMC-WR 13 .......... Sk—66 40 rh900321 32.2 8 | LMC-WR 41 ............ Brey 34 rh400356 3.1 17 | rh500546 22.0 17 |
| LMC-WR 14 .......... Brey 11 rh400354 3.9 16 | LMC-WR 42 ............ Brey 34 rh600646 23.7 9 | rh600775 19.7 14 |
| LMC-WR 19 .......... Brey 16 rh400239 3.1 9 | LMC-WR 43 ............ Brey 35 rh600646 23.7 9 | rh600776 20.8 5 |
| LMC-WR 20 .......... Brey 16a rh400239 3.1 8 | LMC-WR 44 ............ Brey 35 rh600333 1.7 6 | LMC-WR 61 .......... Brey 50 rh110290 1.7 12 |
| LMC-WR 22 .......... Brey 18 rh400358 4.0 8 | LMC-WR 45 ............ Brey 36 rh600333 1.7 0 | rh110291 1.7 12 |
| LMC-WR 24 .......... Brey 19 rh400358 4.0 9 | LMC-WR 46 ............ Brey 37 rh400640 23.8 14 | rh600775 19.7 16 |
| LMC-WR 25 .......... Brey 19a rh400359 5.7 13 | LMC-WR 47 ............ Brey 37 rh600640 23.8 14 | rh600780 23.3 9 |
| LMC-WR 26 .......... Brey 20 rh400358 4.0 12 | LMC-WR 48 ............ Brey 38 rh400640 23.8 14 | LMC-WR 62 .......... Brey 51 rh400456 14.2 13 |
| LMC-WR 27 .......... Brey 21 rh500171 17.3 11 | LMC-WR 49 ............ Brey 38 rh600640 23.8 14 | rh400457 15.0 13 |
| LMC-WR 28 .......... Brey 22 rh400657 3.8 9 | LMC-WR 50 ............ Brey 38 rh600640 23.8 14 | rh400458 3.0 13 |
| LMC-WR 31 .......... Brey 25 rh600019 18.1 15 | LMC-WR 51 ............ Brey 38 rh600640 23.8 14 | rh400459 8.5 13 |
| LMC-WR 32 .......... Brey 26 rh600013 110.6 4 | LMC-WR 52 ............ Brey 38 rh600640 23.8 14 | rh500173 2.7 13 |
| LMC-WR 33 .......... Sk—68 73 rh600913 110.6 8 | LMC-WR 53 ............ Brey 38 rh600640 23.8 14 | rh400644 4.6 8 |
| LMC-WR 34 .......... Brey 28 rh201848 2.2 13 | LMC-WR 54 ............ Brey 39 rh400356 3.1 9 | LMC-WR 63 .......... Brey 52 rh110290 1.7 13 |
| LMC-WR 35 .......... Brey 27 rh400666 21.0 18 | LMC-WR 55 ............ Brey 39 rh600640 23.8 15 | rh110291 1.7 10 |
| LMC-WR 37 .......... Brey 30 rh400666 21.0 11 | LMC-WR 56 ............ Brey 42 rh400356 3.1 11 | rh600650 2.1 8 |
| LMC-WR 38 .......... Brey 40 rh400640 23.8 14 | LMC-WR 57 ............ Brey 42 rh600640 23.8 14 | rh600775 19.7 14 |
| LMC-WR 39 .......... Brey 41 rh400640 23.8 15 | LMC-WR 58 ............ Brey 42 rh600640 23.8 14 | rh600780 23.3 8 |
| LMC-WR 40 .......... Brey 41 rh400640 23.8 15 | LMC-WR 59 ............ Brey 42 rh600640 23.8 14 | rh600650 2.1 8 |
| LMC-WR 41 .......... Brey 42 rh400356 3.1 11 | LMC-WR 60 ............ Brey 42 rh600640 23.8 14 | rh600775 19.7 14 |
| LMC-WR 42 .......... Brey 42 rh400356 3.1 11 | LMC-WR 61 ............ Brey 42 rh600640 23.8 14 | rh600780 23.3 8 |
| LMC-WR 43 .......... Brey 42 rh400356 3.1 11 | LMC-WR 62 ............ Brey 42 rh600640 23.8 14 | rh600650 2.1 8 |
| LMC-WR 44 .......... Brey 42 rh400356 3.1 11 | LMC-WR 63 ............ Brey 42 rh600640 23.8 14 | rh600775 19.7 14 |
| LMC-WR 45 .......... Brey 42 rh400356 3.1 11 | LMC-WR 64 ............ Brey 42 rh600640 23.8 14 | rh600780 23.3 8 |
| LMC-WR 46 .......... Brey 42 rh400356 3.1 11 | LMC-WR 65 ............ Brey 55 rh400456 23.4 10 | LMC-WR 66 .......... Brey 54 rh400644 4.6 12 |
| LMC-WR 47 .......... Brey 42 rh400356 3.1 11 | LMC-WR 67 ............ Brey 56 rh400506 23.4 3 | LMC-WR 67 .......... Brey 56 rh400506 23.4 3 |
| LMC-WR 48 .......... Brey 42 rh400356 3.1 11 | LMC-WR 68 ............ Brey 58 rh400056 23.4 3 | LMC-WR 67 .......... Brey 56 rh400506 23.4 3 |
| LMC-WR 49 .......... Brey 42 rh400356 3.1 11 | LMC-WR 69 ............ Brey 58 rh400056 23.4 3 | LMC-WR 67 .......... Brey 56 rh400506 23.4 3 |
| LMC-WR 50 .......... Brey 42 rh400356 3.1 11 | LMC-WR 70 ............ Brey 58 rh400056 23.4 3 | LMC-WR 67 .......... Brey 56 rh400506 23.4 3 |
| WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) |
|--------|---------|--------|----------------|----------------|--------|---------|--------|----------------|----------------|--------|---------|--------|----------------|----------------|
| rh400838 | 15.7 | 11 | LMC-WR 58......... Brey 47 | rh600645 | 19.0 | 4 | rh500408 | 20.9 | 4 | LMC-WR 84......... Brey 68 | rh400056 | 23.4 | 12 |
| rh400839 | 10.8 | 11 | LMC-WR 59......... Brey 48 | rh400234 | 6.4 | 1 | rh500468 | 18.1 | 4 | LMC-WR 85......... Brey 67 | rh400056 | 23.4 | 8 |
| rh500172 | 29.0 | 15 | LMC-WR 60......... Brey 49 | rh400056 | 23.4 | 17 | rh500470 | 28.7 | 4 | LMC-WR 86......... Brey 69 | rh400056 | 23.4 | 4 |
| rh500471 | 18.7 | 4 | | rh600634 | 23.6 | 8 | rh500471 | 18.7 | 5 | rh500546 | 22.0 | 4 |
| rh500546 | 22.0 | 4 | | rh400056 | 23.4 | 5 | rh500546 | 22.0 | 4 | rh500470 | 28.7 | 5 |
| LMC-WR 69......... TSWR 4 | rh400056 | 23.4 | 4 | rh400779 | 106.0 | 11 | rh500471 | 18.7 | 5 | rh500546 | 22.0 | 5 |
| LMC-WR 70......... Brey 62 | rh400056 | 23.4 | 5 | | rh400779 | 106.0 | 12 | rh500546 | 22.0 | 5 | | | |
| LMC-WR 71......... Brey 60 | rh400056 | 23.4 | 16 | rh600228 | 30.2 | 15 | rh500546 | 22.0 | 8 | | | |
| LMC-WR 72......... Brey 61 | rh400056 | 23.4 | 17 | rh600228 | 30.2 | 15 | rh500546 | 22.0 | 8 | | | |
| LMC-WR 73......... Brey 63 | rh400056 | 106.0 | 15 | rh600228 | 106.0 | 11 | rh500546 | 22.0 | 8 | | | |
| LMC-WR 74......... Brey 63a | rh400056 | 106.0 | 18 | rh600228 | 106.0 | 17 | rh500546 | 22.0 | 8 | | | |
| LMC-WR 75......... Brey 59 | rh400056 | 23.4 | 17 | rh500407 | 11.1 | 5 | rh500470 | 28.7 | 5 | rh500470 | 28.7 | 15 |
| LMC-WR 76......... Brey 64 | rh400056 | 23.4 | 17 | rh500407 | 11.1 | 5 | rh500470 | 28.7 | 5 | rh500470 | 28.7 | 15 |
| LMC-WR 77......... Brey 65 | rh400056 | 23.4 | 5 | rh600634 | 18.1 | 5 | rh500546 | 22.0 | 8 | rh500470 | 28.7 | 5 |
| LMC-WR 78......... Brey 65b | rh400056 | 23.4 | 5 | rh600634 | 18.1 | 5 | rh500546 | 22.0 | 8 | rh500470 | 28.7 | 5 |
| LMC-WR 79......... Brey 57 | rh400056 | 23.4 | 5 | rh600634 | 18.1 | 5 | rh500546 | 22.0 | 8 | rh500470 | 28.7 | 5 |
| LMC-WR 80......... Brey 65c | rh400056 | 23.4 | 5 | rh600634 | 18.1 | 5 | rh500546 | 22.0 | 8 | rh500470 | 28.7 | 5 |
| LMC-WR 81......... Brey 65a | rh400056 | 23.4 | 5 | rh600634 | 18.1 | 5 | rh500546 | 22.0 | 8 | rh500470 | 28.7 | 5 |
| LMC-WR 82......... Brey 66 | rh400056 | 23.4 | 5 | rh600634 | 18.1 | 5 | rh500546 | 22.0 | 8 | rh500470 | 28.7 | 5 |
| LMC-WR 83......... Brey 65 | rh400056 | 23.4 | 5 | rh600634 | 18.1 | 5 | rh500546 | 22.0 | 8 | rh500470 | 28.7 | 5 |
| LMC-WR 84......... Brey 68 | rh400056 | 23.4 | 5 | rh600634 | 18.1 | 5 | rh500546 | 22.0 | 8 | rh500470 | 28.7 | 5 |
| LMC-WR 85......... Brey 67 | rh400056 | 23.4 | 5 | rh600634 | 18.1 | 5 | rh500546 | 22.0 | 8 | rh500470 | 28.7 | 5 |
| LMC-WR 86......... Brey 69 | rh400056 | 23.4 | 5 | rh600634 | 18.1 | 5 | rh500546 | 22.0 | 8 | rh500470 | 28.7 | 5 |
| LMC-WR 87......... Brey 70 | rh150008 | 18.1 | 14 | rh600634 | 18.1 | 5 | rh400056 | 23.4 | 5 | rh500546 | 22.0 | 8 |
| LMC-WR 88......... Brey 71 | rh150008 | 18.1 | 14 | rh600634 | 18.1 | 5 | rh400056 | 23.4 | 5 | rh500546 | 22.0 | 8 |
| LMC-WR 89......... Brey 72 | rh150008 | 18.1 | 14 | rh600634 | 18.1 | 5 | rh400056 | 23.4 | 5 | rh500546 | 22.0 | 8 |
| LMC-WR 90......... Brey 73 | rh150008 | 18.1 | 14 | rh600634 | 18.1 | 5 | rh400056 | 23.4 | 5 | rh500546 | 22.0 | 8 |
| LMC-WR 91......... Brey 74 | rh150008 | 18.1 | 14 | rh600634 | 18.1 | 5 | rh400056 | 23.4 | 5 | rh500546 | 22.0 | 8 |
| WR No. | WR Name | Obs. ID | \( t_{\text{exp}} \) (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | \( t_{\text{exp}} \) (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | \( t_{\text{exp}} \) (ks) | Offset (arcmin) |
|--------|---------|---------|-----------------|----------------|--------|---------|---------|-----------------|----------------|--------|---------|---------|-----------------|----------------|
| rh500468 | 18.1 | 17 | rh500546 | 22.0 | 11 | rh400056 | 23.4 | 15 | rh400779 | 22.4 | 13 |
| rh500470 | 20.9 | 14 | rh600228 | 20.9 | 13 | rh500408 | 23.4 | 15 | rh500407 | 22.0 | 13 |
| rh500471 | 18.1 | 17 | rh600228 | 20.9 | 13 | rh500468 | 18.1 | 13 | rh600228 | 20.9 | 13 |
| rh50056 | 22.0 | 14 | rh600228 | 20.9 | 13 | rh500468 | 22.0 | 13 | rh600228 | 20.9 | 13 |
| rh600228 | 30.2 | 6 | rh500471 | 18.1 | 17 | rh600228 | 30.2 | 6 | rh600228 | 20.9 | 13 |
| rh500472 | 22.0 | 13 | LMC-WR 94 | 18.1 | 13 | rh150008 | 18.1 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 83 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 84 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 85 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 86 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 87 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 88 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 89 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 90 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 91 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 92 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |
| rh500546 | 22.0 | 16 | LMC-WR 93 | 18.1 | 13 | rh600228 | 20.9 | 13 | rh600228 | 20.9 | 13 |

**TABLE 2—Continued**
| WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) | WR No. | WR Name | Obs. ID | $t_{\text{exp}}$ (ks) | Offset (arcmin) |
|--------|---------|--------|----------------------|----------------|--------|---------|--------|----------------------|----------------|--------|---------|--------|----------------------|----------------|
| rh400056 | 23.4 | 14 | rh500036 | 8.8 | 6 | LMC-WR 121 | Brey 90a | rh600775 | 19.7 | 16 |
| rh400779 | 106.0 | 2 | rh600228 | 30.2 | 0 | LMC-WR 122 | Brey 92 | rh400779 | 106.0 | 6 |
| rh500471 | 18.7 | 14 | rh600633 | 21.5 | 15 | LMC-WR | rh50036 | 8.8 | 10 |
| rh600228 | 30.2 | 4 | rh600929 | 24.5 | 13 | SMC-WR | rh50036 | 8.8 | 10 |
| rh600349 | 6.5 | 14 | rh601045 | 9.5 | 4 | SMC-WR | rh500418 | 28.8 | 0 |
| rh600633 | 21.5 | 11 | rh600340 | 5.2 | 10 | SMC-WR | rh900445 | 49.5 | 0 |
| LMC-WR 123 | Brey 93 | rh400340 | 5.2 | 10 | LMC-WR 122 | Brey 92 | rh400779 | 106.0 | 8 |
| rh600638 | 25.7 | 13 | rh600340 | 5.2 | 10 | LMC-WR 122 | Brey 92 | rh400779 | 106.0 | 8 |
| LMC-WR 124 | Brey 93a | rh100193 | 39.7 | 5 | LMC-WR 122 | Brey 92 | rh400779 | 106.0 | 8 |
| rh600774 | 22.4 | 8 | rh600419 | 15.7 | 13 | SMC-WR 6 | Sk 108 | rh500003 | 21.9 | 6 |
| rh600779 | 26.2 | 11 | rh600812 | 28.5 | 15 | SMC-WR 7 | AV 336a | rh500003 | 21.9 | 6 |
| LMC-WR 125 | Brey 94 | rh150008 | 18.1 | 4 | LMC-WR 122 | Brey 92 | rh400779 | 106.0 | 8 |
| rh600774 | 22.4 | 6 | rh400335 | 3.8 | 14 | LMC-WR 122 | Brey 92 | rh400779 | 106.0 | 8 |
| LMC-WR 126 | Brey 95 | rh150008 | 18.1 | 4 | SMC-WR 10 | ... | rh400340 | 5.2 | 16 |
| rh600774 | 22.4 | 6 | rh400340 | 5.2 | 10 | SMC-WR 11 | ... | rh180240 | 5.2 | 16 |
| LMC-WR 127 | Brey 95a | rh150008 | 18.1 | 4 | SMC-WR 12 | Brey 96 | rh500136 | 12.0 | 9 |
| rh600774 | 22.4 | 7 | rh600811 | 27.4 | 17 | SMC-WR 12 | Brey 96 | rh500136 | 12.0 | 9 |
| LMC-WR 128 | Brey 96 | rh150008 | 18.1 | 7 | SMC-WR 12 | Brey 96 | rh500136 | 12.0 | 9 |
| rh600773 | 15.9 | 14 | rh400335 | 3.8 | 9 | SMC-WR 12 | Brey 96 | rh500136 | 12.0 | 9 |
| rh600774 | 22.4 | 7 | rh600419 | 15.7 | 6 | SMC-WR 12 | Brey 96 | rh500136 | 12.0 | 9 |
| LMC-WR 130 | Sk−69 297 | rh600632 | 26.7 | 11 | SMC-WR 5 | HD 5980 | rh400337 | 5.0 | 13 |
| rh600773 | 15.9 | 11 | SMC-WR 5 | HD 5980 | rh400337 | 5.0 | 13 | SMC-WR 5 | HD 5980 | rh400337 | 5.0 | 13 |
Wolf-Rayet Stars in the Magellanic Clouds Detected by ROSAT Observations

| WR No. | WR Name | Instrument | $t_{exp}$ (ks) | Count Rate (counts s$^{-1}$) | Counts | $L_{0.5–7.0 keV}$ (ergs s$^{-1}$) |
|--------|---------|------------|---------------|-----------------------------|--------|----------------------------------|
| LMC-WR 10 | Brey 9 | PSPC | 50.8 | 1.2 x 10$^{-3}$ | 61 ± 10 | (6.7 ± 1.1) x 10$^{33}$ |
| LMC-WR 38 | Brey 31 | PSPC | 23.1 | 9.8 x 10$^{-4}$ | 23 ± 6 | (5.4 ± 1.4) x 10$^{33}$ |
| LMC-WR 39 | Brey 32 | PSPC | 12.4 | 2.2 x 10$^{-3}$ | 28 ± 8 | (3.2 ± 0.9) x 10$^{34}$ |
| LMC-WR 42 | Brey 34 | HRI | 31.6 | 1.0 x 10$^{-3}$ | 31 ± 9 | (5.5 ± 1.8) x 10$^{33}$ |
| LMC-WR 47 | Brey 39 | HRI | 31.6 | 1.2 x 10$^{-3}$ | 37 ± 9 | (6.7 ± 1.1) x 10$^{33}$ |
| LMC-WR 101–103 | R140a, b | HRI | 26.8 | 6.0 x 10$^{-4}$ | 16 ± 8 | (8.6 ± 4.3) x 10$^{33}$ |
| LMC-WR 116 | Brey 84 | HRI | 134.8 | 2.9 x 10$^{-3}$ | 390 ± 30 | (1.6 ± 0.1) x 10$^{35}$ |

3. RESULTS

X-ray images are extracted from the merged PSPC and/or HRI observations of each WR star in the MCs within the full spectral energy range, i.e., 0.1–2.4 keV for the PSPC and 0.1–2.0 keV for the HRI. A pixel size of 5" pixel$^{-1}$ is used for the PSPC images and 2" pixel$^{-1}$ for the HRI images. These images are subsequently smoothed with a Gaussian profile of FWHM of 15" for the PSPC and 3" for the HRI. The smoothed images are used to search for X-ray emission at the location of WR stars. When X-ray emission is detected within 30" from the location of a WR star, we compare the X-ray images of the WR star with an optical image extracted from the Digitized Sky Survey$^4$ (DSS) to search for a point source at the location of the star or diffuse emission from its surrounding bubble, if it exists. To assess the reliability of these detections, we have defined a source region encompassing the X-ray source at the location of the WR star and an appropriate background region without sources and computed the background-subtracted ROSAT PSPC and/or HRI counts within the source region using the IRAF$^5$ PROS task $\text{imc}$ents. This has allowed us to confirm the ≥3σ detections of X-ray emission from the seven WR stars in the LMC listed in Table 3. The net count rates and net counts of these WR stars are listed in columns (5) and (6) of Table 3, respectively. No WR stars in the SMC were detected by ROSAT. The correlation between these detections and sources in different ROSAT catalogs is listed in Table 4. The ROSAT PSPC and HRI X-ray and DSS optical images of the WR stars detected in X-rays are presented in Figures 1 and 2. For the central regions of R136 and R140 (Fig. 2), only the HRI images are shown as the angular resolution of the PSPC observations is too poor to resolve these stars.

The WR stars in the MCs that are not detected by ROSAT observations are listed in Table 5. For these WR stars, we use source regions with sizes matching the PSF of ROSAT PSPC and HRI in order to determine their 3σ upper limits using the IRAF PROS task $\text{imc}$ents. The radii of these source regions range from 20" to 60" for the PSPC and from 10" to 20" for the HRI, depending on the offsets of the WR stars from the central pointings. The resulting 3σ upper limits are listed in columns (5) and (10) of Table 5. The distribution of these upper limits indicates that most of the nondetections have HRI count rates < 1.0 x 10$^{-4}$ counts s$^{-1}$ and PSPC count rates < 1.5 x 10$^{-4}$ counts s$^{-1}$.

Several WR stars in the MCs are found to be embedded in diffuse X-ray emission or close to bright X-ray sources. The analysis of these sources is neither possible nor necessary, since Chandra observations provide a much clearer view. These include ROSAT PSPC observations of LMC-WR 96–116, all within 70" from R136, and PSPC observations of LMC-WR 31, 81, 82, 84, 85, 88, 89, 91–93, 95, 117–119, 121, and 122, and of HD 5980 in the SMC, as they are embedded in diffuse X-ray emission. Similarly, no analysis was attempted for the ROSAT HRI observations of LMC-WR 99, 100, and 104–115 near R136, the observations of LMC-WR 91 and 93 that are too close to bright X-ray sources, or the observations of LMC-WR 80, 85, 92, and 118 and HD 5980 in the SMC, which are superposed by bright diffuse X-ray emission.

3.1. Comparison between the Chandra ACIS and ROSAT Surveys

The Chandra ACIS and ROSAT surveys for X-ray emission from WR stars in the MCs have many stars in common. LMC-WR 19,
| WR No.       | 1RXH       | 2RXP       | 1WGA       | 1RXS       |
|-------------|------------|------------|------------|------------|
|             | HRI Count Rate | Source Name | PSPC Count Rate | Source Name | Count Rate | Source Name | Count Rate | Source Name | Count Rate |
| LMC-WR 10    | ...        | J045633.1–662828 | 8.5 × 10⁻⁴ | 1.2 × 10⁻³ | J045635.7–662815 | 9.7 × 10⁻³ | J0456.5–6628 | 1.6 × 10⁻³ | 045635.6–662819 | 2.8 × 10⁻² |
| LMC-WR 38    | 2.2 × 10⁻³ | J052605.4–672958 | 2.9 × 10⁻³ | 9.8 × 10⁻⁴ | J052604.8–673002 | 3.8 × 10⁻³ | J0526.0–6730 | 1.8 × 10⁻³ | ...         | ...         |
| LMC-WR 39    | ...        | ...        | 1.0 × 10⁻³ | ...        | ...        | ...        | ...        | ...        | ...         | ...         |
| LMC-WR 42    | 6.0 × 10⁻⁴ | ...        | ...        | 1.2 × 10⁻³ | J052643.4–684950 | 3.3 × 10⁻³ | ...        | ...        | ...         | ...         |
| LMC-WR 101–103 | 2.9 × 10⁻³ | ...        | 5.8 × 10⁻³ | ...        | ...        | ...        | ...        | ...        | ...         | ...         |
| LMC-WR 116   | 4.7 × 10⁻³ | ...        | 3.9 × 10⁻³ | ...        | J053844.8–690602 | 1.3 × 10⁻¹ | ...        | ...        | ...         | ...         |
Fig. 1.—*ROSAT* HRI (*left*) and PSPC (*center*) smoothed X-ray and DSS optical (*right*) images of the WR stars in the MCs with detected X-ray emission. The *ROSAT* HRI and PSPC images are overlaid with their corresponding X-ray contours, while the optical DSS images are overlaid with the PSPC X-ray contours. The X-ray contour levels are 3, 6, 9, 12, 15, 25, 35 σ, . . . , above the background level. The positions of WR stars in the LMC given by Breysacher et al. (1999) are marked with a plus sign.
20, 67, 78, 79, 119, and 125 are detected by Chandra ACIS but not ROSAT. In all these cases, the ROSAT PSPC and HRI count rates expected from their Chandra ACIS count rates are below the $3\sigma$ upper limit listed in Table 5. LMC-WR 101, 102, and 116 in the LMC are detected both by Chandra ACIS and by ROSAT HRI. The Chandra ACIS count rates and spectral properties of these two sources (Paper I) correspond to ROSAT HRI count rates of $2.8 \times 10^{-3}$ counts s$^{-1}$ for LMC-WR 101 and 102 and $(4.5-6.3) \times 10^{-3}$ counts s$^{-1}$ for the X-ray variable LMC-WR 116. These values are fairly consistent with the HRI count rates of these sources listed in Table 3.

3.2. X-Ray Luminosity of the Wolf-Rayet Stars Detected by ROSAT

The ROSAT PSPC detections of WR stars in the MCs have yielded an insufficient numbers of counts for spectral fits, and the ROSAT HRI observations do not provide spectral information. In order to estimate the X-ray luminosities of the WR stars in the MCs detected by ROSAT, we adopt the emission model that describes the integrated spectra of the weakly detected WR stars in the Chandra ACIS survey (Paper I), i.e., a thin plasma with a temperature of $kT = 1.6$ keV absorbed by intervening material with abundances of $0.33 Z_\odot$ and an absorption column density of $3 \times 10^{21}$ cm$^{-2}$. We have used PIMMS to convert the ROSAT PSPC and HRI count rates to X-ray luminosities in the $0.5-7.0$ keV band and listed them in Table 3.

3.3. Remarks on Individual Objects

LMC-WR 10 (Brey 9) is at the core of the OB association LH 9 in N11, which includes up to 25 stellar components in a field of view $6.4'' \times 6.4''$ (Schertl et al. 1995; Bauer et al. 1996). Therefore, the X-ray emission reported in this paper may have an origin different from LMC-WR 10.

The X-ray emission from LMC-WR 38, 39, and 42 has been previously reported by Dunne et al. (2001). LMC-WR 38 is also identified as source 538 by Haberl & Pietsch (1999). LMC-WR 38 (Brey 31) and 39 (Brey 32) are confirmed binary systems with periods of $\sim 3$ and $\sim 2$ days, respectively (Moffat et al. 1990). Similarly, LMC-WR 42 (Brey 34) is a binary system but with a longer period, 30 days (Seggewiss et al. 1991).

The X-ray detection of LMC-WR 47 (Brey 39) needs to be examined carefully. LMC-WR 47 is located on an area of diffuse X-ray emission, and its number of counts is only $\sim 3.5 \sigma$ over the local background level of X-ray emission. Furthermore, the X-ray...
| WR No. | WR Name | Instrument | $t_{\text{exp}}$ (ks) | $\sigma$ Upper Limit (counts s$^{-1}$) | WR No. | WR Name | Instrument | $t_{\text{exp}}$ (ks) | $\sigma$ Upper Limit (counts s$^{-1}$) |
|--------|---------|------------|-------------------------|--------------------------------------|--------|---------|------------|-------------------------|--------------------------------------|
| LMC-WR 3 | Brey 3 | PSPC | 31.3 | $6.5 \times 10^{-4}$ | LMC-WR 50 | Brey 41 | PSPC | 51.8 | $5.5 \times 10^{-4}$ |
|        |         | HRI       | 2.6 | $2.7 \times 10^{-3}$ | LMC-WR 51 | Brey 42 | PSPC | 31.6 | $7.4 \times 10^{-4}$ |
| LMC-WR 5 | Brey 4 | PSPC | 13.8 | $1.4 \times 10^{-3}$ | LMC-WR 52 | Brey 43 | PSPC | 10.0 | $1.0 \times 10^{-3}$ |
| LMC-WR 6 | Brey 5 | PSPC | 12.7 | $1.2 \times 10^{-3}$ | LMC-WR 53 | Brey 44 | HRI | 4.6 | $3.9 \times 10^{-3}$ |
| LMC-WR 7 | Brey 6 | PSPC | 12.7 | $9.5 \times 10^{-4}$ | LMC-WR 54 | Brey 44a | PSPC | 157.9 | $2.7 \times 10^{-4}$ |
| LMC-WR 9 | Brey 7 | PSPC | 50.8 | $4.2 \times 10^{-4}$ | LMC-WR 55 | Sk $-69$ 175 | HRI | 57.8 | $7.9 \times 10^{-4}$ |
| LMC-WR 10 | Brey 9 | HRI | 32.2 | $6.5 \times 10^{-4}$ | LMC-WR 56 | Brey 46 | PSPC | 7.9 | $2.4 \times 10^{-3}$ |
| LMC-WR 11 | Brey 10 | PSPC | 13.8 | $9.7 \times 10^{-4}$ | LMC-WR 57 | Brey 45 | PSPC | 16.3 | $1.4 \times 10^{-3}$ |
| LMC-WR 12 | Brey 10a | PSPC | 12.7 | $1.1 \times 10^{-3}$ | LMC-WR 58 | Brey 47 | PSPC | 31.6 | $1.0 \times 10^{-3}$ |
| LMC-WR 13 | Sk $-66$ 40 | PSPC | 50.8 | $4.0 \times 10^{-4}$ | LMC-WR 59 | Brey 48 | HRI | 19.0 | $7.2 \times 10^{-4}$ |
| LMC-WR 14 | Brey 11 | HRI | 32.2 | $5.8 \times 10^{-4}$ | LMC-WR 60 | Brey 49 | PSPC | 126.3 | $6.3 \times 10^{-4}$ |
| LMC-WR 15 | Brey 12 | PSPC | 13.8 | $1.0 \times 10^{-3}$ | LMC-WR 61 | Brey 50 | PSPC | 167.7 | $4.9 \times 10^{-4}$ |
| LMC-WR 16 | Brey 13 | HRI | 3.9 | $3.5 \times 10^{-3}$ | LMC-WR 62 | Brey 51 | PSPC | 41.5 | $1.0 \times 10^{-3}$ |
| LMC-WR 19 | Brey 16 | PSPC | 3.9 | $4.1 \times 10^{-3}$ | LMC-WR 63 | Brey 52 | PSPC | 5.4 | $4.3 \times 10^{-3}$ |
| LMC-WR 20 | Brey 16a | PSPC | 19.5 | $1.2 \times 10^{-3}$ | LMC-WR 64 | Brey 53 | PSPC | 122.6 | $7.7 \times 10^{-4}$ |
| LMC-WR 21 | Brey 17 | PSPC | 10.8 | $2.3 \times 10^{-3}$ | LMC-WR 65 | Brey 55 | PSPC | 126.1 | $5.0 \times 10^{-4}$ |
| LMC-WR 22 | Brey 18 | PSPC | 10.8 | $2.4 \times 10^{-3}$ | LMC-WR 66 | Brey 54 | PSPC | 11.2 | $1.8 \times 10^{-3}$ |
| LMC-WR 23 | Brey 19 | PSPC | 12.4 | $2.0 \times 10^{-3}$ | LMC-WR 67 | Brey 56 | PSPC | 124.9 | $7.5 \times 10^{-4}$ |
| LMC-WR 24 | Brey 19 | HRI | 20.4 | $8.1 \times 10^{-4}$ | LMC-WR 68 | Brey 58 | PSPC | 124.9 | $7.2 \times 10^{-4}$ |
| LMC-WR 25 | Brey 19a | PSPC | 24.1 | $1.8 \times 10^{-3}$ | LMC-WR 69 | TSWR 4 | PSPC | 124.9 | $7.7 \times 10^{-4}$ |
| LMC-WR 26 | Brey 20 | PSPC | 12.4 | $2.7 \times 10^{-3}$ | LMC-WR 70 | Brey 62 | PSPC | 124.9 | $7.9 \times 10^{-4}$ |
| LMC-WR 27 | Brey 21 | HRI | 20.4 | $8.3 \times 10^{-4}$ | LMC-WR 71 | Brey 60 | PSPC | 121.2 | $5.4 \times 10^{-4}$ |
| LMC-WR 28 | Brey 22 | PSPC | 3.8 | $4.0 \times 10^{-4}$ | LMC-WR 72 | Brey 61 | PSPC | 121.2 | $3.3 \times 10^{-4}$ |
| LMC-WR 29 | Brey 23 | HRI | 17.3 | $9.9 \times 10^{-4}$ | LMC-WR 73 | Brey 63 | PSPC | 121.2 | $3.3 \times 10^{-4}$ |
| LMC-WR 30 | Brey 24 | PSPC | 52.2 | $3.9 \times 10^{-4}$ | LMC-WR 74 | Brey 63a | PSPC | 118.9 | $4.5 \times 10^{-4}$ |
| LMC-WR 31 | Brey 25 | HRI | 21.9 | $7.5 \times 10^{-4}$ | LMC-WR 75 | Brey 59 | PSPC | 118.9 | $4.6 \times 10^{-4}$ |
| LMC-WR 32 | Brey 26 | PSPC | 8.3 | $1.5 \times 10^{-3}$ | LMC-WR 76 | Brey 59 | HRI | 129.6 | $2.3 \times 10^{-4}$ |
| LMC-WR 33 | Sk $-68$ 73 | PSPC | 33.5 | $3.5 \times 10^{-4}$ | LMC-WR 74 | Brey 63a | PSPC | 118.9 | $4.6 \times 10^{-4}$ |
| LMC-WR 34 | Brey 28 | PSPC | 110.6 | $3.7 \times 10^{-4}$ | LMC-WR 75 | Brey 59 | HRI | 129.6 | $2.6 \times 10^{-4}$ |
| LMC-WR 35 | Brey 27 | HRI | 24.1 | $5.5 \times 10^{-4}$ | LMC-WR 76 | Brey 64 | PSPC | 118.9 | $2.9 \times 10^{-4}$ |
| LMC-WR 36 | Brey 29 | HRI | 1.5 | $4.8 \times 10^{-3}$ | LMC-WR 77 | Brey 65 | PSPC | 124.9 | $7.6 \times 10^{-4}$ |
| LMC-WR 37 | Brey 30 | PSPC | 152.2 | $1.0 \times 10^{-3}$ | LMC-WR 78 | Brey 65b | PSPC | 124.9 | $7.6 \times 10^{-4}$ |
| LMC-WR 39 | Brey 32 | HRI | 110.6 | $3.2 \times 10^{-4}$ | LMC-WR 79 | Brey 57 | HRI | 302.6 | $1.6 \times 10^{-4}$ |
| LMC-WR 40 | Brey 33 | PSPC | 24.1 | $3.4 \times 10^{-4}$ | LMC-WR 80 | Brey 65c | PSPC | 124.9 | $7.6 \times 10^{-4}$ |
| LMC-WR 41 | Brey 35 | PSPC | 51.5 | $6.5 \times 10^{-4}$ | LMC-WR 81 | Brey 65a | HRI | 4.6 | $1.8 \times 10^{-3}$ |
| LMC-WR 43 | Brey 37 | HRI | 51.5 | $4.8 \times 10^{-4}$ | LMC-WR 82 | Brey 66 | HRI | 279.1 | $1.8 \times 10^{-4}$ |
| LMC-WR 44 | Brey 36 | PSPC | 31.6 | $3.3 \times 10^{-4}$ | LMC-WR 83 | HD 269858 | HRI | 185.0 | $2.4 \times 10^{-4}$ |
| LMC-WR 45 | Sk $-69$ 142a | HRI | 28.2 | $1.2 \times 10^{-3}$ | LMC-WR 84 | Brey 68 | HRI | 185.0 | $2.6 \times 10^{-4}$ |
contours shown in Figure 1 reveal a noticeable offset of $\sim 25''$ between the X-ray peak and the location of this WR star. Therefore, until new X-ray observations with better angular resolution of LMC-WR 47 are acquired, its X-ray detection reported in this paper should be considered tentative.

LMC-WR 101–103 are in the visual multiple system R140 near the core of 30 Doradus, of which LMC-WR 102 (R140a2) is a close spectroscopic binary with a period of $\sim 3$ days (Moffat et al. 1987). LMC-WR 101–103 were marginally detected by the Einstein High Resolution Imager (Wang & Helfand 1991). ROSAT made a clear detection, being listed as source 299 by Sasaki et al. (2000), but the X-ray emission of the different components was not individually resolved until the Chandra ACIS-I observations of the 30 Doradus nebula offered a sharper view of this region (Portegies Zwart et al. 2002; Townsley et al. 2006; Paper I). Chandra observations show that LMC-WR 101–102 (R140a1 and R140a2) are much brighter than R140b (Portegies Zwart et al. 2002; Townsley et al. 2006 Paper I). The present analyses show that the level of X-ray emission in the ROSAT HRI and Chandra ACIS-I observations are consistent with each other. We note, however, that Wang (1995) reported a higher X-ray flux based on the ROSAT HRI observation rh600228 obtained in 1992 December and 1993 June. We have examined these individual observations, as well as the ROSAT HRI observation rh400779 (1996 August and 1997 April), and find that in all cases the HRI count rates remain at roughly a constant level consistent with the count rate of $2.9 \times 10^{-3}$ counts s$^{-1}$ reported in Table 3.

LMC-WR 116 (Brey 84) is also a WR star in the 30 Doradus region that was marginally detected by the Einstein High Resolution Imager (Wang & Helfand 1991). Wang (1995) reported a ROSAT HRI count rate of $8.1 \times 10^{-3}$ counts s$^{-1}$ based on the observation rh600228 obtained in 1992 December and 1993 June. A similar ROSAT HRI count rate of $8.5 \times 10^{-3}$ counts s$^{-1}$ is reported by Sasaki et al. (2000), who assigned it the source number 301 in their catalog. The ROSAT HRI count rate reported in Table 3 is $\sim 40\%$ lower than the values reported by Wang (1995) and Sasaki et al. (2000) because we used a smaller source aperture to exclude the contribution from LMC-WR 112 (R136c), LMC-WR 99 (Brey 78), and an X-ray bright neighbor near LMC-WR 115 (Brey 83) north of Brey 84 (see Fig. 1d of Paper I). If contributions from these bright neighboring sources are added to our measurement, we recover the ROSAT HRI count rates reported by Wang (1995) and Sasaki et al. (2000). To further investigate possible long-term variations of this source, we have analyzed the individual ROSAT HRI observations rh500036 (1992 February), rh600228 (1992 December), and rh400779 (1996 August and 1997 April) and find HRI count rates of $(5.9 \pm 0.8) \times 10^{-3}$, $(4.3 \pm 0.4) \times 10^{-3}$, $(4.0 \pm 0.4) \times 10^{-3}$, and $(4.9 \pm 0.3) \times 10^{-3}$ counts s$^{-1}$, respectively. These values are consistent with the ROSAT HRI count rate of $(4.5 - 6.3) \times 10^{-3}$ counts s$^{-1}$ expected from the Chandra ACIS observation of Brey 84; thus, there is no evidence for large long-term variations.

### 4. SUMMARY

We have searched the entire ROSAT archive for pointed observations that serendipitously cover WR stars in the MCs. This search has yielded useful PSPC observations for 90 WR stars in the LMC and 10 WR stars in the SMC, and HRI observations for

### TABLE 5—Continued

| WR No.  | WR Name | Instrument | $t_{exp}$ | 3 $\sigma$ Upper Limit |
|---------|---------|------------|-----------|-----------------------|
| LMC-WR 49 | Brey 40a | PSPC | 11.3 | $5.0 \times 10^{-4}$ |
| LMC-WR 87 | Brey 70 | PSPC | 124.9 | $5.7 \times 10^{-4}$ |
| LMC-WR 95 | Brey 90 | PSPC | 139.9 | $7.0 \times 10^{-4}$ |
| LMC-WR 101 | Brey 85 | PSPC | 139.9 | $5.7 \times 10^{-4}$ |
| LMC-WR 95 | Brey 80 | HRI | 166.5 | $5.7 \times 10^{-4}$ |
| LMC-WR 96 | Brey 81 | HRI | 166.5 | $5.7 \times 10^{-4}$ |
| LMC-WR 97 | Mk 51 | HRI | 166.5 | $5.7 \times 10^{-4}$ |
| LMC-WR 98 | Brey 79 | HRI | 166.5 | $5.7 \times 10^{-4}$ |
| LMC-WR 117 | Brey 88 | HRI | 166.5 | $5.7 \times 10^{-4}$ |
| LMC-WR 119 | Brey 90 | HRI | 166.5 | $5.7 \times 10^{-4}$ |
| LMC-WR 120 | Brey 91 | PSPC | 122.9 | $5.7 \times 10^{-4}$ |
| LMC-WR 123 | Brey 93a | HRI | 166.5 | $5.7 \times 10^{-4}$ |
| LMC-WR 125 | Brey 94 | HRI | 166.5 | $5.7 \times 10^{-4}$ |
| LMC-WR 126 | Brey 95 | HRI | 166.5 | $5.7 \times 10^{-4}$ |
| LMC-WR 127 | Brey 95a | HRI | 40.5 | $5.7 \times 10^{-4}$ |
87 WR stars in the LMC and 10 WR stars in the SMC. A total of 117 WR stars in the MCs have useful ROSAT observations. We have examined the ROSAT observations of these 117 WR stars in the MCs and found X-ray emission from seven of them, of which five had been previously reported to exhibit X-ray emission. We find that the X-ray detection of LMC-WR 10 (Brey 9) and LMC-WR 47 (Brey 39) need to be confirmed by X-ray observations at higher angular resolution. The detection rate, ~6%, is much lower than that of the Chandra ACIS survey, 40%–50%. This illustrates that the sensitivity and angular resolution of Chandra is needed to study WR stars in the MCs. Indeed, many WR stars detected by Chandra have X-ray emission at levels below the 3 σ upper limits of the available ROSAT observations, are located near bright X-ray sources, or are superposed on bright diffuse X-ray emission, making it difficult for ROSAT to detect them. Together, the ROSAT and Chandra surveys have detected X-ray emission from 34 WR stars in the MCs.

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