A Modern Search for Wolf–Rayet Stars in the Magellanic Clouds. III.
A Third Year of Discoveries

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Abstract

For the past three years we have been conducting a survey for Wolf–Rayet (WR) stars in the Large and Small Magellanic Clouds (LMC, SMC). Our previous work resulted in the discovery of a new type of WR star in the LMC, which we are calling WN3/O3. These stars have the emission-line properties of a WN3 star (strong N V, but no N IV), plus the absorption-line properties of an O3 star (Balmer hydrogen plus Pickering He II, but no He I). Yet, these stars are 15 times fainter than an O3 V star, ruling out the possibility that WN3/O3s are WN3+O3 binaries. Here we report the discovery of two more members of this class, bringing the total number of these objects to 10, 6.5% of the LMC’s total WR population. The optical spectra of nine of these WN3/O3s are virtually indistinguishable from each other, but one of the newly found stars is significantly different, showing a lower excitation emission and absorption spectrum (WN4/O4-ish). In addition, we have newly classified three unusual Of-type stars, including one with a strong C III λ4650 line, and two rapidly rotating “Oef” stars. We also “rediscovered” a low mass X-ray binary, RX J0513.9-6951, and demonstrate its spectral variability. Finally, we discuss the spectra of 10 low priority WR candidates that turned out to not have He II emission. These include both a Be star and a B[e] star.

Key words: galaxies: individual (LMC, SMC) – galaxies: stellar content – Local Group – stars: evolution – stars: Wolf–Rayet

1. Introduction

For many years, our knowledge of the Wolf–Rayet (WR) population of the Magellanic Clouds (MCs) was considered essentially complete: 12 WRs were known in the SMC (Massey et al. 2003) and 134 WRs were known in the LMC (Breysacher et al. 1999). These stars had been found by a combination of general objective prism surveys, directed searches, and accidental discoveries by spectroscopy (see Massey 2013; Massey et al. 2015b). However, over the years, several additional WRs were found in the LMC, culminating in our own discovery of a very strong-lined WO-type (Neugent et al. 2012b), only the second known example of this rare type of WR in the LMC. This discovery prompted us to begin a multi-year survey of both the SMC and LMC in an effort to obtain a complete census of their WR population. In part, this was motivated in terms of finding a more accurate value for the relative number of WC- and WN-type WRs, as this provides a key test of the evolutionary models (see, e.g., Massey & Johnson 1998; Meynet & Maeder 2005; Neugent et al. 2012a). And, such a survey was timely, given our improved knowledge of the populations of other evolved massive stars in the MCs, such as yellow and red supergiants (Neugent et al. 2010, 2012c), and ongoing improvements in massive star models (Ekström et al. 2012; Stanway et al. 2016).

It was entirely possible, of course, that our survey would fail to find much of interest. Instead, in the first year we discovered nine more WRs in the LMC (Massey et al. 2014, hereafter Paper I). More interesting than the numbers, however, were the type of WRs we found: six had spectra that were unlike those of any previously observed. They were also somewhat fainter in absolute visual magnitude ($M_V = -2.5$ to $-3.0$) than the previously known WRs. Their emission-line spectra were dominated by N V $\lambda$4603, 19, $\lambda$4945 and He II $\lambda$4686, and had no trace of N IV $\lambda$4558, implying that they were a WR class of WN3. However, they also showed He II and Balmer absorption spectra with no trace of He I, which are characteristics of an O3 V star. Yet, these stars were 15 times too faint to be WN3+O3 V binaries, as a typical O3 V star has $M_V \sim -5.5$ (Conti 1988; Walborn et al. 2002). Our preliminary modeling demonstrated that we could reproduce both the emission and absorption lines with a single set of physical parameters (Paper I; Neugent et al. 2015), lending further credence to these being single objects. (Our limited number of repeat observations also failed to detect any radial velocity variations.) In our second year of the survey, we detected two more of these stars (Massey et al. 2015a, hereafter Paper II), which we are calling WN3/O3s. In addition, our survey found the third known WO-type star in the LMC and four other WRs (including two WN+O binaries, an O3.5If*/WN5 star, and a WN11), two rare Of?p stars (magnetically braked oblique rotators; see Walborn et al. 2010a), a possible B[e]+WN binary, four Of-type supergiants, and a peculiar emission-line star (the nature of which eludes us), and other, more normal, early-type stars (Papers I and II).

Here we report on the third year of discoveries, which include two additional members of the WN3/O3 class in the LMC, bringing the number of this class to 10, 6.5% of the LMC’s WR population, which now stands at a total of 154

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* This paper includes data gathered with the 1 m Swope and 6.5 m Magellan Telescopes located at Las Campanas Observatory, Chile.

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Here we report on the third year of discoveries, which include two additional members of the WN3/O3 class in the LMC, bringing the number of this class to 10, 6.5% of the LMC’s WR population, which now stands at a total of 154
There were 93 Notes.

Recent candidates that failed to have HeII λ4686 component. We also classify 10 low ranked candidates that failed to have HeII λ4686, including one Be and one B[e] star.

2. Observations and Reductions

The imaging part of our survey is being conducted using the Swope 1 m telescope on Las Campanas. Complete details are given in Papers I and II; here we summarize our observing and reduction procedures. The current e2v camera provides a 29/8 (EW) × 29/7(NS) field of view with 4110 × 4096 15 μm pixels, each subtending 0.435. Our exposure times were 300 s through each of three interference filters, a WC filter centered on C III λ4650, the strongest optical line in WC- and WO-type WRs, a WN filter centered on He II λ4686, the strongest optical line in WN-type WRs, and a continuum filter (CT), centered at 4750 Å. All three filters have a 50 Å bandpass (full width at half maximum, FWHM). We were initially assigned 10 nights on the Swope (UT) 2015 November 15–24. However, since some of that time was lost due to clouds, Carnegie was kind enough to assign us 5 additional nights, December 25–29, which had been unscheduled. The typical image quality on both of the runs ranged from 1′.3 to 1′.9. There were 93 fields observed (or reobserved in the LMC, and 21 fields in the SMC in total during this third year of our survey. There was about a 1′ overlap between adjacent fields, so the total new coverage is 19.9 deg² in the LMC, and 4.5 deg² in the SMC.

For calibration purposes, 10 bias frames were taken daily. When conditions were clear, 3–5 sky flats were obtained in bright twilight through each filter, dithering the telescope between exposures in order to allow us to filter out any stars when we combined frames. Since these twilight exposures were short (a few seconds), it was necessary to correct each of the exposures for the iris pattern of the camera shutter. The details of this procedure are given in Paper II. Since the CCD is read out through four amplifiers, each quadrant is treated separately in the preliminary reductions. Overscan and bias structure (which is practically non-existent) were removed. After these additive corrections were made, the counts in each quadrant were corrected for slight nonlinearities in the CCD amplifiers, as discussed in Paper II. Each quadrant was flat-fielded, and then the four sections were recombined. Accurate

### Table 1

| ID  | α2000 | δ2000 | V  | B − V | CT | WN–CT | He II λ4686 | Mr  | Sp. Type | Comment |
|-----|-------|-------|----|------|----|-------|------------|-----|----------|---------|
| LMCe078-3 | 05 41 17.50 | −69 06 56.2 | 17.03 | +0.03 | 17.2 | −0.27 | 12.0 | 1.2 | 16 | −2.2e | WN3/O3 |
| LMCe055-1 | 04 56 48.72 | −69 36 40.3 | 16.15 | −0.10 | 16.4 | −0.17 | 8.4 | 0.8 | 17 | −2.8 | WN4/O4 |

Notes.

a Designation from the current survey. We have denoted the e2v fields with a small “c” to distinguish them from our numbering system from Paper I, i.e., LMCe159 is distinct from LMC159. We plan to impose less idiosyncratic designations once our survey is complete.

b Photometry from Zaritsky et al. (2004).

c We assume an apparent distance modulus of 18.9 for the LMC, corresponding to a distance of 50 kpc (van den Bergh 2000) and an average extinction of AV = 0.40 (Massey et al. 1995; van den Bergh 2000).

d “EW” is the equivalent width, measured in Å.

e Assumes an extra 0.3 mag of extinction at V given its B − V color.

Figure 1. Comparison of the spectra of our two newly found WN3/O3 stars with the prototype of this class, LMC170-2 (Paper I). LMC078-3 is very similar, but LMC055-1 shows lower emission excitation (N IV λ4058, which is missing in the other two) and N V λ3400, 19 has a P Cygni profile. The comparison of the absorption lines is better seen in Figure 2.

(0.5) coordinates were obtained through the use of the “astrometry.net” software (Lang et al. 2010).

The frames were then analyzed by first running aperture photometry on each image to identify stars that were significantly brighter in one of the two emission-line filters than in the continuum image. In addition, image subtraction was performed with the High Order Transform of Point-spread function ANd Template Subtraction (HOTPANTS) software described by Becker et al. (2004). The resultant WC–CT and WN–CT images were examined by eye to identify the WR candidates. The combination of the two techniques has proven to be very effective, as shown in Papers I and II.

This procedure was carried out under some time pressure, as we had a single night (UT 2016 January 11) allocated on the Baade 6.5 m Magellan telescope for follow-up spectroscopy. Despite the short time between the December imaging and January spectroscopy time, we had successfully reduced and
analyzed most of the fields, with 15 WR candidates at various significance levels.

The spectroscopic observations took place with the Magellan Echellette Spectrograph (MagE) mounted on a folded port of the Baade. The instrument is described in detail by Marshall et al. (2008). MagE provides complete coverage from the atmospheric cutoff (∼3200 Å) to ∼1 μm. We used MagE with a 1″ slit, which then yielded a resolving power \( R \) of 4100. The night was clear, and the seeing was 0″6–0″7. As we described in Paper II (and in more detail in Massey & Hanson 2013), the pixel-to-pixel sensitivity variations are quite small, and we have found that we can achieve better results by not flat-fielding the data in the blue. The data from this night were flat-fielded in the red, primarily to remove fringing. After extraction, wavelength calibration, and fluxing, the individual orders were combined. Our typical signal-to-noise ratio (S/N) in the blue classification region was 100–150 per spectral resolution element.

Figure 2. Expansion of the blue region of the spectra shown in Figure 1. Here we see how similar the absorption spectrum is in LMCe078-3 compared to that of LMC170-2, while LMCe055-1 shows weak He I λ4471 absorption.

Our initial spectrum of LMCe058-1 was intriguing but quite noisy, and we were fortunate to be able to squeeze in additional MagE observations of the source on three additional nights throughout the following months, as described below. Analysis of a few remaining fields that were not fully analyzed previous to our January night revealed one other high-significance WR candidate (LMCe113-1), which was observed with MagE on UT 29 March 2016 at the beginning of the night.

3. Discoveries

Our spectroscopy identified six stars among our candidates that have He II λ4686 emission. Ten other candidates proved to be (mainly) B-type stars, not of immediate interest to us, but
Table 2
Other Emission-lined Stars

| ID* | \( \alpha_{2000} \) | \( \delta_{2000} \) | \( V^b \) | \( \beta - V^b \) | CT | WN-CT | He II \( \lambda 4686 \) | \( M_V^e \) | Sp. Type | Comment |
|-----|------------------|---------------|--------|----------------|-----|--------|----------------|----------|--------|---------|
| LMCe078-1 | 05 37 29.63 | −69 14 52.0 | 13.49 | −0.02 | 13.8 | −0.07 | 3.3 | 0.2 | 15 | −5.4 | O6 Iic | O5.5 Iaf in Evans et al. (2015) |
| LMCe078-2 | 05 37 27.84 | −69 23 52.9 | 13.38 | −0.16 | 13.3 | −0.06 | 3.2 | −0.2 | ... | −5.5 | O5 nfp |
| LMCe113-1 | 04 49 28.01 | −67 42 39.8 | 13.18 | −0.23 | 13.2 | −0.09 | 4.4 | −0.9 | ... | −5.7 | O7.5 nfp |
| LMCe058-1 | 05 13 50.80 | −69 51 47.6 | 16.71 | −0.05 | 17.1 | −0.35 | 15.3 | 0.7 | 14d | −2.2 | LMXB RX |

Notes.

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b Photometry from Zaritsky et al. (2004).

c We assume an apparent distance modulus of 18.9 for the LMC, corresponding to a distance of 50 kpc (van den Bergh 2000) and an average extinction of \( A_V = 0.40 \) (Massey et al. 1995, 2007).

d “EW” is the equivalent width, measured in Å.

e The He II \( \lambda 4686 \) line consists of a broad component (WN star?) and a narrow component (disk?). The values given in the table are for the broad component. The narrow component has a log(−EW) of 0.8 and a FWHM of 2.8 Å. The total log(−EW) of the line is 1.0.

Figure 3. Light curve of LMCe-055-1 (OGLE LMC-ECL-3548). The I-band photometry is from OGLE (Graczyk et al. 2011), and has been phased with their period of 2.159074 days.

discussed further below. This success rate is similar to our second year (Paper II). We discuss our “winners” and “losers” below.

3.1. Newly Found Wolf-Rayet Stars

Our most exciting discovery was identifying two new members of the class of WRs that we are calling WN3/O3s (Papers I and II). Other members of this class show the strong N V \( \lambda 4603 \), 19 doublet, N V \( \lambda 4945 \), and He II \( \lambda 4686 \) emission lines that are characteristic of a WN3 star, and a He II and Balmer line absorption spectrum that is typical of an O3 star. A composite spectrum can be immediately ruled out, as these stars have \( M_V = −2.3 \) to −3.0, 15 times fainter than an O3 V would be by itself (\( M_V ≈ −5.5 \); Conti 1988) and even slightly fainter than a normal WN3 star would be by itself (\( M_V ≈ −3.8 \); Hainich et al. 2014).

We list the properties of these two WN3/O3 stars in Table 1 and illustrate their spectra in Figures 1 and 2. One thing we have been strongly struck by is how similar all the previous members of this group have been; their spectra are nearly indistinguishable (see, e.g., Figure 7 in Paper I and Figure 3 in Paper II). LMCe078-3 is now the ninth example, with a spectrum nearly identical to one of the prototypes of this class, LMC170-2, also illustrated here in Figures 1 and 2.

However, the spectrum of our newly discovered tenth member of the WN3/O3 class, LMCe055-1, is substantially different. Both the emission and the absorption are indicative of a lower excitation temperature. The spectrum shows N IV \( \lambda 4058 \) emission, which is missing from the other members of this group. Furthermore, weak He I \( \lambda 4471 \) is visible in absorption. The N V \( \lambda 4603 \), 19 doublet lines have P Cygni profiles, with a strong absorption component to the blue side of the emission. We would more properly call this star a WN4/O4 rather than an WN3/O3!

Further complicating the picture is the fact that this star was identified as an eclipsing binary by OGLE with a 2.159074 day period (Graczyk et al. 2011). Might this star simply be a normal WN4+O4 V binary? We can rule this out immediately using the same argument as for “normal” WN3/O3 stars. As shown in Table 1, LMCe055-1 has an absolute visual magnitude of only \( M_V = −2.8 \), while an O4 V star is expected to have \( M_V ≈ −5.5 \) (Conti 1988). Furthermore, the OGLE light curve itself is inconsistent with the presence of a massive companion. As shown in Figure 3, there is no sign of the ellipsoidal variations that are seen in massive binaries with similarly short periods, such as DH Cep (Lines et al. 1986).\(^5\) We are continuing to investigate this star, including the use of a radial velocity study.

\(^5\) We are indebted to our colleague Dr. Laura Penny for commenting on the OGLE light curve and pointing out the implications of the comparison with DH Cep.
3.2. Other Emission Line Stars

3.2.1. Of-type Stars

Our survey is sufficiently sensitive that we detect many Of-type stars. Although such stars are significantly brighter than our WN3/O3s, the equivalent widths (EWs) of their HeII λ4686 emission are sufficiently weak to make these among the hardest stars for us to detect (see, e.g., Figure 9 in Paper II). Here we discuss the discovery of three of these stars, as listed in Table 2.

The spectrum of LMCe078-1 is shown in Figure 4. We classify the star as O6 Ifc, where the “c” is required given the strong presence of CIII λ4650 emission (Walborn et al. 2010a) in addition to the strong N III λ4634, 42 and HeII λ4686 lines that result in the luminosity “If” classification. Subsequent to our spectroscopy, but prior to this publication, Evans et al. (2015) also classified this star (their star #271) as an O5.5 Iaf, in substantial agreement with our classification here, although the presence of the CIII emission went unnoticed. (The line is only marginally visible in the online version of their spectrum, due to their lower S/N.)

Another Of-type star, LMCe-078-2, is shown in Figure 5. It too is unusual: HeII λ4686 emission shows a central reversal (absorption), and the absorption lines are extremely broad, with $v \sin i \sim 385$ km s$^{-1}$. These are the classic characteristics of “Oef” stars (Conti & Leep 1974), also known as “Onfp” stars.
Based upon the relative He II and He I absorption line strengths, we classify the star as O5 nfp. Given the weakness of the emission, it is rather remarkable that we detected this star in the first place. Fortunately, the N III λ4634, 42 emission doublet is within the bandpass of the WC filter, so this star was considered of high significance, as it was brighter in both of the emission-line filters relative to the continuum. In addition, Onfp stars are known to have variable He II strengths, and it is possible that we detected this star when the line was stronger. We note that this star may show signs of C III λ4650 as well, but the broadness of the lines precludes a definitive assessment.

Our third Of-type star, LMCe113-1, is yet another Onfp star, which we classify as O7.5 nfp. As shown in Figure 6, He II λ4686 has a central reversal. The emission here is quite weak, and we are again surprised (but pleased) we detected it. Without the N III λ4634, 42 emission we probably would not have. The absorption lines are quite broad, with $v \sin i \sim 300$ km s$^{-1}$. The star is identified in the Sanduleak (1970) catalog as Sk−67°3 according to Brian Skiff’s online spectral catalog and was classified as B0.5 in Rousseau et al. (1978) based on low resolution objective prism plates.

Figure 6. Spectrum of the O7.5 nfp star LMCe113-1. Note the reversal (absorption) in the He II λ4686 line, characteristic of the "nfp" designation.
One of the more interesting spectra we have encountered is that of LMCe058-1, shown in Figure 7. The star is known to be a super-soft X-ray source, RX J0513.9-6951, and its optical spectrum has been previously described by Cowley et al. (1993). The star is variable both in the X-ray region (Leavitt 1908; Cowley et al. 1993; Alcock et al. 2003), with a Harvard Variable designation, HV 5682. Cowley et al. (1993) describe the spectrum as being typical of that of a low-mass X-ray binary (LMXB) with narrow emission components of the He II and the Balmer lines, along with N III and C III and O VI (see also Pakull et al. 1993). The He II λ4686 profile clearly has two components, a narrow component and a broad component. Cowley et al. (1993) attributes the broad component to the high velocities of the inner part of the accretion disk. Cowley et al. (1993) and Pakull et al. (1993) both note that the optical spectrum is similar to that of Cal 83, the prototype of the LMXBs (Crampton et al. 1987).

We reobserved this star, as we were intrigued by the description of a broad He II λ4686 emission component. Might this be a previously unrecognized Wolf–Rayet star with a disk? Alas, the early descriptions are an accurate match to our optical spectrum. Although He II λ4686 has a broad component, there are no other WR signatures present. Qualitatively, the optical spectrum is similar to that described over twenty years ago (compare Figure 2 in Cowley et al. 1993 to our MagE spectrum in Figure 7). We obtained four spectra of this star throughout a four month period and found dramatic changes in the emission line EW. For instance, the EW of He II ranged from −5 to −25 Å. (Cowley et al. 1993 reported an EW of −16 Å.) Is this variability due to changes in the emission line fluxes or due to the change in the continuum level affecting the EWs? To answer this, we turned to the fluxed versions of our spectra. As shown in Figure 8, it is clear that although the continuum flux varies, the emission line fluxes vary even more; the two appear to be correlated, in that the emission lines are their strongest (both in terms of EWs and fluxes) when the star is brightest.

### Table 3

| ID     | $\alpha_{2000}$ | $\delta_{2000}$ | V | B − V | M$_V$ | Sp. Type | Comment                        |
|--------|----------------|----------------|---|-------|-------|----------|-------------------------------|
| LMCe033-1 | 0:45:28.28     | −73:56:36.6    | 14.98 | −0.14 | −4.1  | B0.5 III | [M2002] SMC 5611; B2 (II), Evans et al. (2004) |
| LMCe055-1 | 0:29:46.91      | −73:08:40.6    | 15.65 | −0.06 | 3.5   | B1-B1.5 IIIe | Weak Si III, no Mg II; Balmer emission |
| LMCe005-1 | 5:31:31.76      | −71:56:10.1    | 16.27 | −0.07 | 2.6   | B2-V     | Si III and Mg II |
| LMCe029-1 | 4:50:47.05      | −70:37:58.7    | 15.37 | −0.10 | 3.6   | B5 III   | [M2002] LMC 8808          |
| LMCe027-1 | 4:59:01.99      | −70:48:53.0    | 15.73 | −0.03 | 3.5   | B0.5 V[e] | [M2002] LMC 41535; Balmer and Fe II (?) emission |
| LMCe050-2 | 5:46:05.71      | −69:59:57.2    | 16.65 | +0.20 | 2.3   | A0 V:    | No He I                        |
| LMC1c17-1 | 5:06:13.53      | −67:49:11.3    | 15.96 | +0.09 | −2.9  | B2 V     | Si III and Mg II |
| LMC1c17-2 | 5:05:43.53      | −69:53:53.0    | 16.85 | −0.05 | −2.0  | B2 V     | Si III and Mg II |
| LMC1c141-1 | 4:51:19.42      | −66:52:18.9    | 16.90 | +0.03 | −2.0  | B8 III   | Mg II stronger than He I      |
| LMC1c155-1 | 5:03:37.35      | −66:33:19.5    | 16.42 | −0.18 | −2.5  | B2 V-III | Weak Mg II and Si III       |

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* Photometry from Zaritsky et al. (2002) for SMC members and Zaritsky et al. (2004) for LMC members.  
* For the SMC, we assume an apparent distance modulus of 19.1, corresponding to a distance of 59 kpc (van den Bergh 2000), and an average extinction of $A_V = 0.30$ (Massey et al. 1995, 2007). For the LMC, we assume an apparent distance modulus of 18.9, corresponding to a distance of 50 kpc (van den Bergh 2000), and an average extinction of $A_V = 0.40$ (Massey et al. 1995, 2007).

### 3.2.2. RX J0513.9-6951 Revisited

In assigning observing priorities, we ranked our candidates on a 1–4 scale, with 1 being the most potentially interesting. All of the emission-lined stars discussed above had been classified as a 1 or a 2. All of our remaining candidates that were observed were ranked as either a 3 or a 4, and none of them proved to have He II λ4686 emission. These priority 3 to 4 candidates were invariably B-type stars (including both a Be and a B[e] star), plus one A0 I. Given the large number of stars on our frames and our desire to be thorough, a few low-significance candidates without emission are expected just on statistical grounds. Although these stars are not of immediate interest to us, we list their properties in Table 3. These stars were classified using the relative strengths of Si IV λ4089, Si III λ4553, and Si II λ4128. For stars later than B2, Mg II λ4481 and He I λ4471 are secondary indicators (for more details, see Massey et al. 2016). In this, we made reference to the Walborn & Fitzpatrick (1990) atlas. A difficulty, particularly for the SMC B stars, is that the metal lines are almost undetectable, and thus our classifications are particularly uncertain even at our S/N. We confess to being influenced by our knowledge of the absolute visual magnitudes in assigning the luminosity classes.

### 3.3. Non-emission-line Stars

In assigning observing priorities, we ranked our candidates on a 1–4 scale, with 1 being the most potentially interesting. All of the emission-lined stars discussed above had been classified as a 1 or a 2. All of our remaining candidates that were observed were ranked as either a 3 or a 4, and none of them proved to have He II λ4686 emission. These priority 3 to 4 candidates were invariably B-type stars (including both a Be and a B[e] star), plus one A0 I. Given the large number of stars on our frames and our desire to be thorough, a few low-significance candidates without emission are expected just on statistical grounds. Although these stars are not of immediate interest to us, we list their properties in Table 3. These stars were classified using the relative strengths of Si IV λ4089, Si III λ4553, and Si II λ4128. For stars later than B2, Mg II λ4481 and He I λ4471 are secondary indicators (for more details, see Massey et al. 2016). In this, we made reference to the Walborn & Fitzpatrick (1990) atlas. A difficulty, particularly for the SMC B stars, is that the metal lines are almost undetectable, and thus our classifications are particularly uncertain even at our S/N. We confess to being influenced by our knowledge of the absolute visual magnitudes in assigning the luminosity classes.

### 4. Summary and Future Work

We report here the detection and spectroscopic observations of 16 WR candidates from our late 2015 to early 2016 observing season, the third year of our survey. All six of the higher ranked candidates proved to have He II λ4686 emission. Of these six, two are members of the WN3/03 class, bringing the total number of this class to ten. All 10 are in the LMC and they make up >6% of the LMC’s WR known population, which is now 154 in total. The spectral features of nine of these WN3/03 are remarkably homogeneous, but one of the newly found members here is not like the others, showing a lower excitation emission spectrum (specifically, N IV λ4058), P Cygni profiles for the N V λ4503, 19 emission, and weak He I absorption. Spectral modeling of all of these stars is in progress, with preliminary results reported by Neugent et al. (2015).
In addition, we have found three unusual Of-type stars, one of which is a member of the rare “Ifc” luminosity class, showing relatively strong CIII at $\lambda4650$, while two others are rapidly rotating “Ofn” type stars (now often designated as “nfp”). We also present modern spectra of the LMXB RX J0513.9-6951, and note that qualitatively they look very similar to the discovery spectra of Cowley et al. (1993) and Pakull et al. (1993). Our repeated observations demonstrate that there are significant changes in the emission-line intensities, unsurprising given the star’s large photometric variations.

Ten of the candidates showed B-type or early A-type spectra; these were all lower ranked candidates, and were observed for completeness. One turned out to be a previously unrecognized Be star, and another is a newly found B[e] star.

We are now prepared to begin the fourth year of our survey with 26% of the SMC and 12% of the LMC left to observe. We do not know what our final year of discoveries will bring us, but if past performance is any indication of future results, we are sure to find something interesting!

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Facilities: Magellan: Baade (MagE spectrograph), Swope (e2v imaging CCD).

References

Alcock, C., Allsman, R., Alves, D., et al. 2003, γCat, 2247, 0
Becker, A. C., Wittman, D. M., Boeshaar, P. C., et al. 2004, ApJ, 611, 418
Breysacher, J., Azzopardi, M., & Testor, G. 1999, A&AS, 137, 117
Baade, D., Conti, P. S., Divan, L., et al. 1988, in O Stars and Wolf-Rayet Stars, ed. P. S. Conti & A. B. Underhill (NASA SP-497; Washington, DC: NASA) Conti, P. S., & Leep, E. M. 1974, ApJ, 193, 113
Cowley, A. P., Schmidt, P. C., Hutchings, J. B., Crampton, D., & McGrath, T. K. 1993, ApJL, 418, L63
Crampion, D., Cowley, A. P., Hutchings, J. B., et al. 1987, ApJ, 321, 745
Ekström, S., Georgy, C., Eggenberger, P., et al. 2012, A&A, 537, A146
Evans, C. J., Howarth, I. D., Irwin, M. J., Burnley, A. W., & Harries, T. J. 2004, MNRAS, 353, 601
Evans, C. J., van Loon, J. T., Hainich, R., & Bailey, M. 2015, A&A, 584, A58
Graczyk, D., Sozyszyni, I., Polski, R., et al. 2011, A&A, 61, 103
Hainich, R., Rühlting, U., Todt, H., et al. 2014, A&A, 565, A27
Lang, D., Hogg, D. W., Mierle, K., Blanton, M., & Roweis, S. 2010, AJ, 139, 1782
Leavitt, H. S. 1908, AnHar, 60, 87
Lines, H. C., Lines, R. D., Guinan, E. F., & Robinson, C. R. 1986, IBVS, 2912, 1
Marshall, J. L., Burles, S., Thompson, I. B., et al. 2008, Proc. SPIE, 7014, 701454
Massey, P. 2013, NewAR, 57, 14
Massey, P., & Hanson, M. M. 2013, in Planets, Stars and Stellar Systems, Vol. 2, Astronomical Techniques, Software and Data, ed. T. D. Oswalt & H. E. Bond (Dordrecht: Springer), 35
Massey, P., & Johnson, O. 1998, ApJ, 505, 793
Massey, P., Lang, C. C., Dégioia-Eastwood, K., & Garmany, C. D. 1995, ApJ, 438, 188
Massey, P., Neugent, K., & Smart, B. 2016, AJ, 152, 62
Massey, P., Neugent, K. F., & Morrell, N. 2015a, ApJ, 807, 81 (Paper II)
Massey, P., Neugent, K. F., Morrell, N., & Hillier, D. J. 2014, ApJ, 788, 83 (Paper I)
Massey, P., Neugent, K. F., & Morrell, N. I. 2015b, in Wolf-Rayet Stars: Proc. of an Int. Workshop, ed. W.-R. Hamann, A. Sander, & H. Todt (Potsdam: Helge Todt. Universitätswesel Potsdam), 35
Massey, P., Olsen, K. A. G., Hodge, P. W., et al. 2007, AJ, 133, 2393
Massey, P., Olsen, K. A. G., & Parker, J. W. 2003, PASP, 115, 1265
Meynet, G., & Maeder, A. 2005, A&A, 429, 581
Nazaré, Y., Walborn, N. R., Morrell, N., Wade, G. A., & Szymański, M. K. 2015, A&A, 577, A107
Neugent, K. F., Massey, P., & Georgy, C. 2012a, ApJ, 759, 11
Neugent, K. F., Massey, P., Hillier, D. J., & Morrell, N. I. 2015, in Wolf-Rayet Stars: Proc. of an Int. Workshop, ed. W.-R. Hamann, A. Sander, & H. Todt (Potsdam: Helge Todt. Universitätswesel Potsdam), 101
Neugent, K. F., Massey, P., & Morrell, N. 2012b, AJ, 144, 162
Neugent, K. F., Massey, P., Skiff, B., et al. 2010, ApJ, 719, 1784
Neugent, K. F., Massey, P., Skiff, B., & Meynet, G. 2012c, ApJ, 749, 177
Packull, M. W., Motch, C., Bianchi, L., et al. 1993, A&A, 278, L39
Rousseau, J., Martin, N., Prévot, L., et al. 1978, A&AS, 31, 243
Sanduleak, N. 1970, CoTol, 89, 1
Sota, A., Maíz Apellániz, J., Walborn, N. R., et al. 2011, ApJS, 193, 24
Stanway, E. R., Eldridge, J. J., & Becker, G. D. 2016, MNRAS, 456, 485
van den Bergh, S. 2000, The Galaxies of the Local Group (Cambridge: Cambridge Univ. Press)
Walborn, N. R. 1973, AJ, 78, 1067
Walborn, N. R., & Fitzpatrick, E. L. 1990, PASP, 102, 379
Walborn, N. R., Howarth, I. D., Evans, C. J., et al. 2010b, AJ, 139, 1283
Walborn, N. R., Howarth, I. D., Lennon, D. J., et al. 2002, AJ, 123, 2754
Walborn, N. R., Sota, A., Maíz Apellániz, J., et al. 2010a, ApJL, 711, L143
Zaritsky, D., Harris, J., Thompson, I. B., & Grebel, E. K. 2004, AJ, 128, 1606
Zaritsky, D., Harris, J., Thompson, I. B., Grebel, E. K., & Massey, P. 2002, AJ, 123, 855