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A SURVEY OF LOCAL GROUP GALAXIES CURRENTLY FORMING STARS. III. A SEARCH FOR LUMINOUS BLUE VARIABLES AND OTHER Hα EMISSION-LINE STARS[1]

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ABSTRACT

We describe a search for Hα emission-line stars in M31, M33, and seven dwarfs in or near the Local Group (IC 10, NGC 6822, WLM, Sextans B, Sextans A, Pegasus, and the Phoenix dwarf) using interference filter imaging with the KPNO and CTIO 4 m telescopes and Mosaic cameras. The survey is aimed primarily at identifying new luminous blue variables (LBVs) from their spectroscopic similarity to known LBVs, avoiding the bias toward photometric variability, which may require centuries to manifest itself if LBVs go through long quiescent periods. Follow-up spectroscopy with WIYN confirms that our survey detected a wealth of stars whose spectra are similar to the known LBVs. We "classify" the spectra of known LBVs and compare these to the spectra of the new LBV candidates. We demonstrate spectacular spectral variability for several of the new LBV candidates, such as AM2, previously classified as a Wolf-Rayet star (WR), which now shows Fe I, Fe II, and Balmer emission lines but neither the N III $\lambda\lambda$4634, 4642 nor the He II λ4686 emission it did in 1982. Profound spectral changes are also noted for other suspected and known LBVs. Several of the LBV candidates also show >0.5 mag changes in V over the past 10–20 years. The number of known or suspected LBVs is now 24 in M31, 37 in M33, 1 in NGC 6822, and 3 in IC 10. We estimate that the total number of LBVs in M31 and M33 may be several hundred, in contrast to the eight known historically through large-scale photometric variability. This has significant implications for the timescale of the LBV phase. We also identify a few new WRs and peculiar emission-line objects.

Key words: catalogs — galaxies: stellar content — stars: early-type — supergiants — surveys

Online material: machine-readable tables

1. INTRODUCTION

The nearby galaxies of the Local Group serve as our astrophysical laboratories for understanding the effect that metallicity has on the evolution of massive stars. For instance, the relative number of red supergiants (RSGs) and Wolf-Rayet stars (WRs) is known to vary by 2 orders of magnitude with just a 0.8 dex change in oxygen abundance (Massey 2003 and references therein), in keeping with the general predictions of massive-star evolutionary theory (Maeder et al. 1980). Although such studies are made more difficult by the stars' faintness and crowding, they have the advantages over Galactic studies that the distances of these systems are relatively well known (usually to a few percent; see van den Bergh 2000), and that in general the correction for interstellar extinction is low and relatively uniform within these galaxies.

In previous papers of this series, we presented *UBVRI* catalogs for the two Local Group spiral galaxies M31 and M33 (Massey et al. 2006, hereafter Paper I) and for the seven dwarf irregular galaxies IC 10, NGC 6822, WLM, Sextans B, Sextans A, Pegasus, and Phoenix (Massey et al. 2007, hereafter Paper II). This paper now discusses the analysis of narrowband (50 Å FWHM) images centered on Hα, [S II] $\lambda\lambda$6717, 6731, and [O III] λ5007. The data are used to identify Hα emission-line stars in these nine galaxies, in particular stars which are spectroscopically similar to luminous blue variables (LBVs).

LBVs are a rare class of luminous stars which undergo episodic mass loss and represent a transitional phase between the most massive O stars and the WR stage. The archetype LBVs in the Milky Way are the stars η Carinae and P Cygni. Observations of nebulae around these stars reveal very high ejecta masses, of order 10 $M_{\odot}$, and evidence of multiple ejections on the timescales of order 10^3 yr. (For two recent provocative reviews, see Smith & Owocki [2006] and Smith [2007].) Massey (2003) has argued that if η Car or P Cyg were located in M31 or M33 we would not know of them today, since their spectacular photometric outbursts were hundreds of years ago. Indeed, Hubble & Sandage (1953) identified only five such stars in all of M31 and M33 looking for photometric variability on archival plates dating back 40 yr. (Subsequent work brought this number to eight; see Parker 1997.) In the absence of large photometric variability (which might take 1000 years to manifest itself), better statistics concerning the number of LBVs

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TABLE 1
MOSAIC OBSERVATIONS

FIELD	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	OBS.	Hα[a] Date	Hα[a] DIQ (arcsec)	[S II][a] Date	[S II][a] DIQ (arcsec)	[O III][a] Date	[O III][a] DIQ (arcsec)
M31-F1	00 47 02.4	+42 18 02	KPNO	2001 Sep 17	1.3	2001 Sep 17	1.1	2001 Sep 17	1.2
M31-F2	00 46 06.5	+42 03 28	KPNO	2000 Oct 5	0.9	2000 Oct 5	1.0	2000 Oct 5	1.1
M31-F3	00 45 10.6	+41 48 54	KPNO	2001 Sep 17	1.4	2001 Sep 17	1.5	2001 Sep 17	1.5
M31-F4	00 44 14.7	+41 34 20	KPNO	2001 Sep 17	1.2	2001 Sep 17	1.2	2001 Sep 17	1.3
M31-F5	00 43 18.8	+41 19 46	KPNO	2002 Sep 12	1.0	2002 Sep 12	1.3	2002 Sep 12	1.2
M31-F6	00 42 22.9	+41 05 12	KPNO	2002 Sep 12	0.9	2002 Sep 12	0.9	2002 Sep 12	1.1
M31-F7	00 41 27.0	+40 50 38	KPNO	2002 Sep 9	0.9	2002 Sep 9	0.8	2002 Sep 9	0.9
M31-F8	00 40 31.1	+40 36 04	KPNO	2001 Sep 19	1.3	2001 Sep 19	1.1	2001 Sep 19	1.1
M31-F9	00 39 35.2	+40 21 30	KPNO	2001 Sep 20	1.2	2001 Sep 20	1.0	2001 Sep 20	1.0
M31-F10	00 38 39.3	+40 06 56	KPNO	2001 Sep 21	1.1	2001 Sep 21	1.3	2001 Sep 12	1.2
M33-North	01 34 00.1	+30 55 37	KPNO	2001 Sep 18	0.9	2001 Sep 18	0.9	2001 Sep 18	1.0
M33-Center	01 33 50.9	+30 39 37	KPNO	2000 Oct 5	1.0	2000 Oct 5	1.1	2000 Oct 5	1.1
M33-South	01 33 11.3	+30 22 10	KPNO	2001 Sep 18	0.9	2001 Sep 20	1.1	2001 Sep 21	1.1
IC 10[b]................	00 20 24.5	+59 17 30	KPNO	2001 Sep 22	0.9	2001 Sep 22	0.9	2001 Sep 22	1.0
NGC 6822..........	19 44 56.1	−14 48 05	CTIO	2000 Sep 2	0.9	2000 Sep 2	1.0	2000 Sep 2[c]	1.0
WLM.................	00 01 57.9	−15 27 51	CTIO	2000 Sep 2	0.9	2000 Sep 2	0.9	2000 Sep 2	1.0
Sextans B[b]..........	10 00 00.1	+05 19 56	KPNO	2001 Feb 27	1.2	2001 Feb 27	1.5	2001 Feb 27	1.4
Sextans A[b]	10 11 00.8	−04 41 34	KPNO	2001 Feb 27	1.3	2001 Feb 27	1.1	2001 Feb 27	1.2
Pegasus[b]	23 28 36.2	+14 44 35	KPNO	2000 Oct 5	1.4	2000 Oct 5	1.4	2000 Oct 5	1.5
Phoenix	01 51 06.3	−44 26 41	CTIO	2000 Sep 2	0.8	2000 Sep 2	0.9	2000 Sep 2	1.0

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.
[a] Series of five dithered 300 s exposures, unless otherwise noted.
[b] Field was offset 540″ south and 270″ west in order to center on chip imt2 (Jacoby 2000).
[c] Series of five dithered 360 s exposures.

(and hence their lifetimes) might be gathered by finding stars which are spectroscopically indistinguishable from the known LBVs. In the recent past, such "LBV candidates" have been identified in nearby galaxies by spectroscopic surveys of UV-bright objects (Massey et al. 1996), He-emission objects (Corral & Herrero 2003), or Hα-emission stars (Neese et al. 1991; Corral 1996; King et al. 1998), or by just blundering across them spectroscopically (Massey et al. 2000; Massey 2006) in spectroscopic surveys of bright blue stars.

While we are mainly searching for LBVs, our selection has the potential to uncover many other types of interesting Hα emission-line stars, such as the brightest Of-type stars, WRs, and Be and B[e] stars. We expect that if there exists an equivalent to SS 433 (a "miniquasar" with a pair of jets ejecting material at 0.26 times the speed of light; see Margon 1984) in the Local Group, our survey is likely to pick it out, as such an object would also have strong Hα emission with colors similar to LBVs and other early-type stars.

In § 2 we describe our observations and how we did our photometry. The basis of selecting Hα emission-line stars is given in § 3, along with the resulting catalogs. Spectroscopy of the initial sample for M31, M33, NGC 6822, and IC 10 is given in § 4. We discuss our results in § 5.

2. DATA AND PHOTOMETRY

The narrowband observations were made with the Mosaic cameras mounted at the prime foci of the KPNO and CTIO 4 m telescopes. The instruments and basic reduction procedures are given in detail in Paper I. Here we note that each camera consists of a 2×4 array of 2048×4096 SITe CCDs. The field of view (FOV) is $36' \times 36'$, and the plate scale of the final reduced images is 0.27″ pixel^{-1}. Exposures were obtained through 50 Å wide filters centered on Hα, [S II] λλ6717, 6731, and [O III] λ5007. A typical sequence consisted of five exposures of 300 s each with the telescope offset slightly between adjacent exposures in order to compensate for the small gaps between adjacent CCDs. The journal of observations is given in Table 1, along with the delivered image quality (DIQ) measured on each frame. Conditions were generally good, but not necessarily photometric.

For the seven dwarfs in our sample we restricted our analysis to the regions centered on the galaxy, as the FOV is much larger than the size of the galaxies. The coordinate ranges can be found in the captions of Figures 14–20 of Paper II, except that there is a misprint for the coordinates used for Sextans A (Fig. 18 of Paper II), where the correct range is $\alpha_{J2000.0} = 10^h10^m48^s$ to $10^h11^m15^s$ and $\delta_{J2000.0} = -4°45'$ to $-4°39'$, an area of 0.011 deg^2. We also extended the analysis region of NGC 6822 by 2′ to the south of the region listed in Paper II, as we found that it was too conservative; the range we used was $\alpha_{J2000.0} = 19^h44^m34^s$ to $19^h45^m22^s$ and $\delta_{J2000.0} = -14°58'$ to $-14°40'$, an area of 0.058 deg^2.

For the *UBVRI* photometry in Papers I and II we found that we needed to treat each CCD as a separate detector due to the slight differences in color terms. However, this effect is negligible for the narrowband imaging discussed here, and so we did the photometry of these images on the average of the registered ("stacked") images. Our photometry relied on the broadband source lists given in Papers I and II. We began with the 0.1″ coordinates given in those catalogs and performed aperture photometry at those positions on the Hα, [S II], and [O III] stacked images. We chose a 5 pixel (1.35″) radius measuring aperture as a reasonable compromise between seeing and crowding. Sky was determined from the modal value within an annulus extending from 10 to 20 pixels from each object. Only objects that had positive fluxes in all three apertures were retained. For the galaxies consisting of multiple overlapping fields (M31 and M33) the results were averaged for stars in common.

TABLE 2
ADOPTED CALIBRATION

Observatory	Continuum Source			Emission-Line Source		
	Hα	[S II]	[O III]	Hα	[S II]	[O III]
KPNO	2.14×10^{-18}	2.21×10^{-18}	6.41×10^{-18}	1.79×10^{-16}	1.84×10^{-16}	3.92×10^{-16}
CTIO	2.18×10^{-18}	2.02×10^{-18}	5.11×10^{-18}	1.80×10^{-16}	1.71×10^{-16}	2.75×10^{-16}

NOTE.—These numbers are the equivalent of 1 count s^{-1} in units of ergs s^{-1} cm^{-2} $Å^{-1}$ for a point source measured with a 15 pixel radius aperture.

In order to convert counts into approximate flux, we used observations of spectrophotometric standard stars. Our goal was to achieve an absolute calibration good to 5%–10%. Although this is fairly crude, it provides a sufficiently accurate measurement of the absolute measures of the fluxes, while our selection criteria (described below) rely principally on the relative measures between different filters, not the absolute fluxes. For the standard stars, we performed aperture photometry using a 15 pixel radius aperture, with a sky annulus extending from 20 to 25 pixels. We corrected for air mass (both with the standards and program photometry) using the "standard" KPNO and CTIO coefficients. The KPNO data were collected over four observing runs (2000 October, 2001 February, 2001 September, and 2002 September), but the zero points were found to be quite similar (to within 0.05 mag), and a single average was adopted. The differences between the northern and southern calibrations are also small, as shown in Table 2, and we adopted an average value for each filter. In general, the standards were observed on a single chip (im2), but tests conducted one night by moving a spectrophotometric standard between the eight chips confirmed that the flat-fielding was sufficiently good to keep chip-to-chip differences in the zero point to less than 1%. We determined a mean aperture correction (from the 15 pixels used for the standards to the 5 pixels used on our program frames) of −0.15 mag, with a scatter of 0.06 mag, and applied the −0.15 mag correction to all of our Hα magnitudes.

We refer to our fluxes in terms of "AB" magnitudes (Oke 1974), with the reminder that this is defined in terms of the flux f_ν (cgs) as simply $-2.5 \log f_\nu - 48.60$. Since our Hα images are publicly available,[11] we also give in Table 2 the conversion from counts s^{-1} to f_λ (cgs), as these may be useful to others wishing to use our images. Note that while this calibration allows us to determine the fluxes of continuum sources, purely emission-line objects (such as H II regions and planetary nebulae [PNe]) will have their lines "diluted" by the bandpass of our filter. We determined a correction factor by following Jacoby et al. (1987), where we determined the effective bandpass using the filter response curves simulated in an f/3 beam, similar to the situation at prime focus at each of the 4 m telescopes. We then divided by the normalized transmission of the filter at the wavelength of the line. These are also provided in Table 2 for the benefit of others. Although our sources are continuum and emission, the emission is a minor component of the flux.

We give in Table 3 the photometric errors as a function of magnitude for our three narrowband filters. These errors reflect only the *internal* errors (i.e., photon statistics and read noise) and not the external (calibration) errors, but since we rely on photometric indices to select our objects, it is the internal errors which matter. We see that our errors were negligible from <0.02 to roughly 20 mag.

3. ANALYSIS: SEPARATING THE WHEAT FROM THE CHAFF

Determining what criteria to apply to select Hα emission-line stars while rejecting H II regions and PNe required careful consideration and experimentation. We constructed a number of photometric indices using our Hα, [S II], and [O III] magnitudes in combination with the broadband values from Papers I and II. We determined what was effective by examining the distribution of known interesting objects in M31 and M33 (LBVs, LBV candidates, and WRs from Tables 8 and 9 of Paper I) to the general stellar populations of these two galaxies. We illustrate our selection criteria in Figures 1–9 and summarize them in Table 4.

First, we imposed a flux limit. This was necessary in order to not include objects whose photometry was so poor that they appeared to be emission-line objects when they were not, and it also included the practical consideration that we wanted stars that were bright enough to be observable on 6.5 m telescopes. We used the

[11] See http://archive.noao.edu/nsa/ and ftp://ftp.lowell.edu/pub/massey/lgsurvey/datarelease/.

TABLE 3
PHOTOMETRIC ERRORS

Mag	Hα, [S II]									O III								
	M31	M33	IC 10	N6822	WLM	Sex B	Sex A	Pegasus	Phoenix	M31	M33	IC 10	N6822	WLM	Sex B	Sex A	Pegasus	Phoenix
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	...	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	...	...
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.01
19	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
20	0.04	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02
21	0.08	0.06	0.05	0.06	0.05	0.04	0.04	0.06	0.03	0.05	0.05	0.04	0.06	0.06	0.04	0.04	0.07	0.05
22	0.12	0.11	0.12	0.12	0.10	0.10	0.09	0.14	0.07	0.10	0.10	0.10	0.12	0.12	0.08	0.07	0.13	0.10

NOTE.—Median error (mag) for stars within 0.5 mag of the stated value, i.e., 14.5–15.5 for the first row.

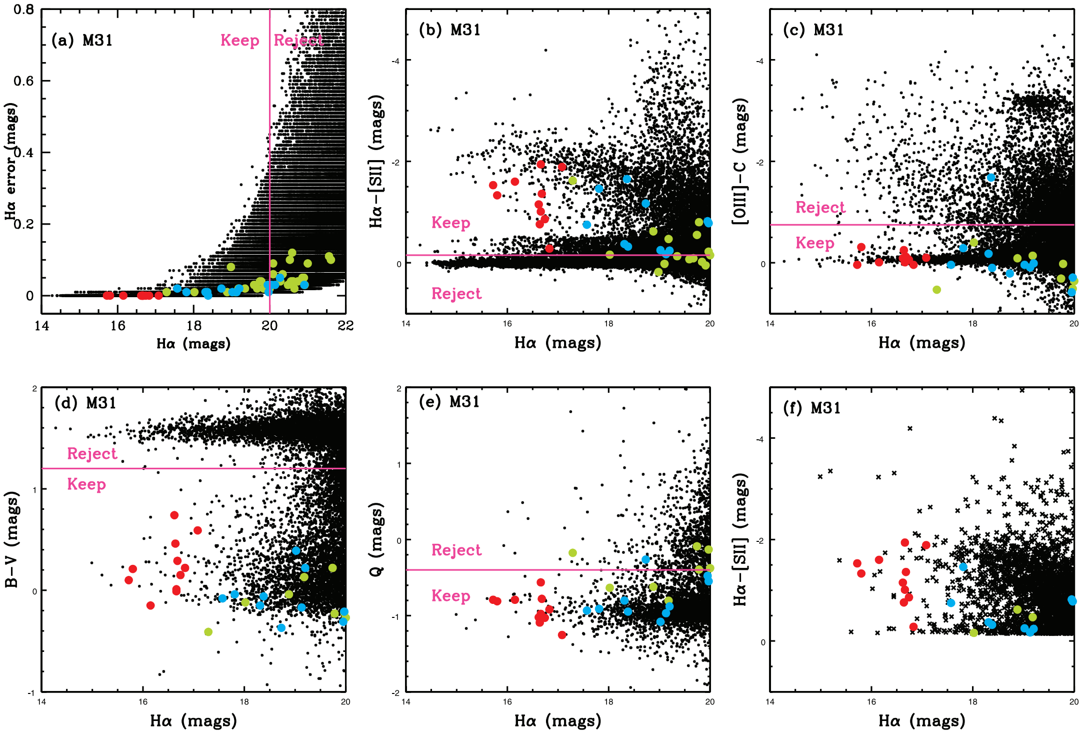


FIG. 1.—Selection criteria for Hα emission-line stars applied to M31. Red circles denote the previously known LBVs and LBV candidates, while blue and green circles denote WRs of WN- and WC-type, respectively. (*a*) We demonstrate that the errors in the Hα fluxes begin to increase past a (spectrophotometric) magnitude of $\sim$20. Imposing 20 mag as a cutoff keeps all of the LBVs but only the brightest of the WRs. (*b*) Rejecting the stars that show little or no Hα emission is done by eliminating stars with Hα $-$ [S II] ≥ -0.15. (*c*) We attempt to eliminate H II regions and PNe by requiring little [O III] emission, i.e., [O III] $- C \geq -0.75$. (*d*) Our sample is still dominated by red foreground stars, which we eliminate by $B - V < 1.2$. (*e*) Finally, in order to keep stars which are only intrinsically quite blue, we impose a cutoff $Q \leq -0.4$, where $Q = (U - B) - 0.72(B - V)$, the Johnson reddening-free index. (*f*) Our final sample contains 2334 stars.

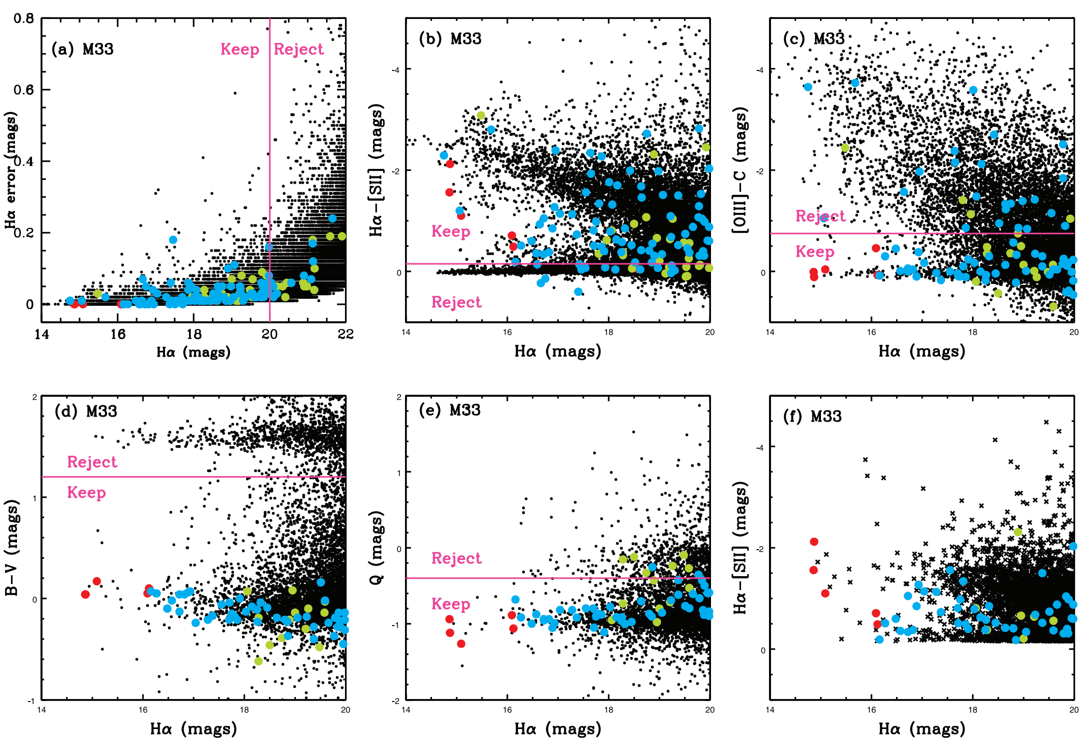


FIG. 2.—Selection criteria for Hα emission-line stars applied to M33. Same as Fig. 1, except (*f*) our final sample contains 3707 stars.

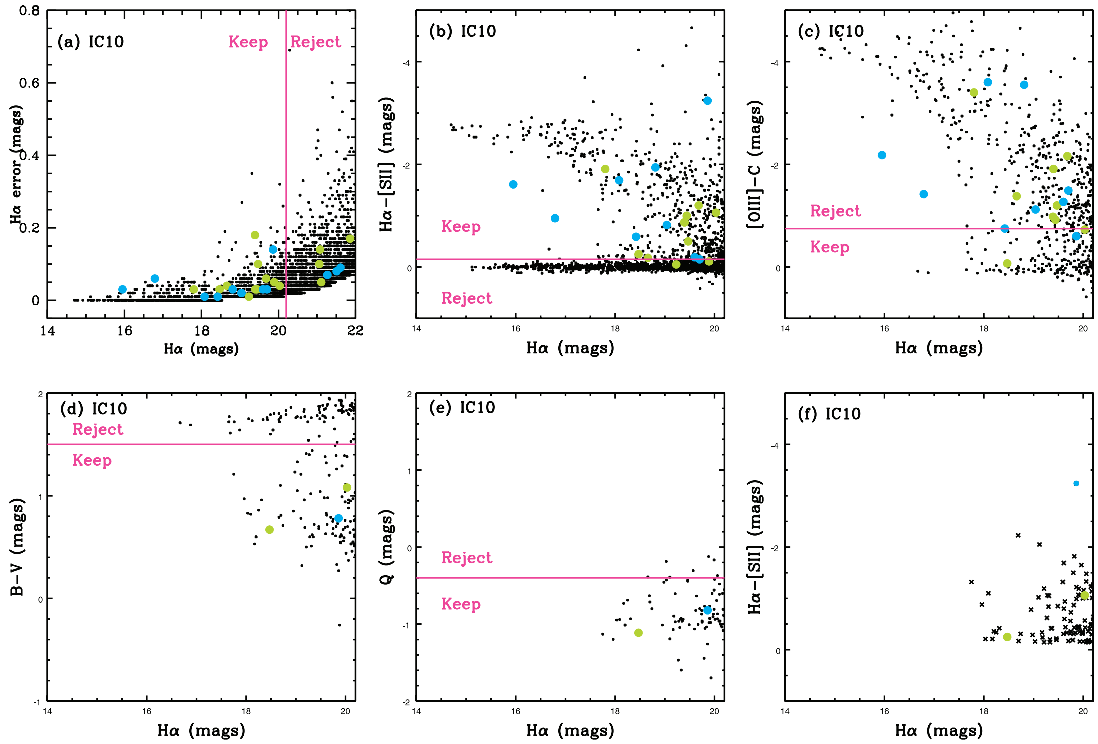


FIG. 3.—Selection criteria for Hα emission-line stars applied to IC 10. Same as Fig. 1, except that there are no previously known LBVs, and (*f*) our final sample contains 81 stars.

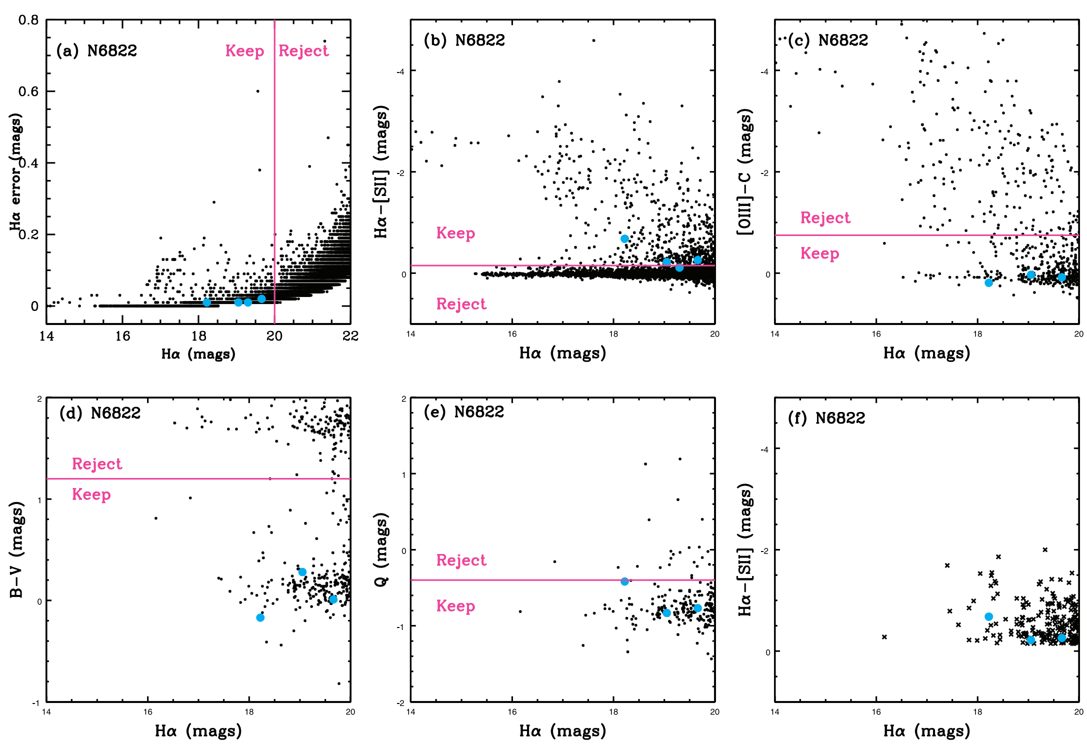


FIG. 4.—Selection criteria for Hα emission-line stars applied to NGC 6822. Same as Fig. 1, except that there are no previously known LBVs or WCs, and (*f*) our final sample contains 163 stars.

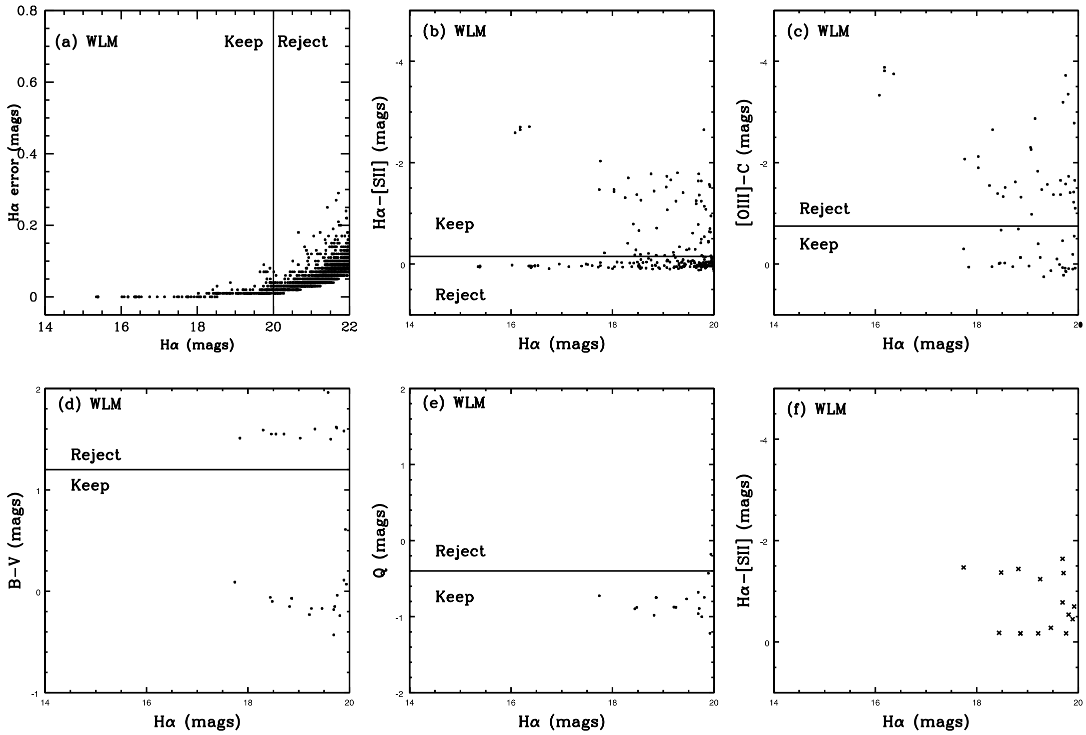


FIG. 5.—Selection criteria for Hα emission-line stars applied to WLM. Same as Fig. 1, except that there are no previously known Hα emission-line stars, and (*f*) our final sample contains 15 stars.

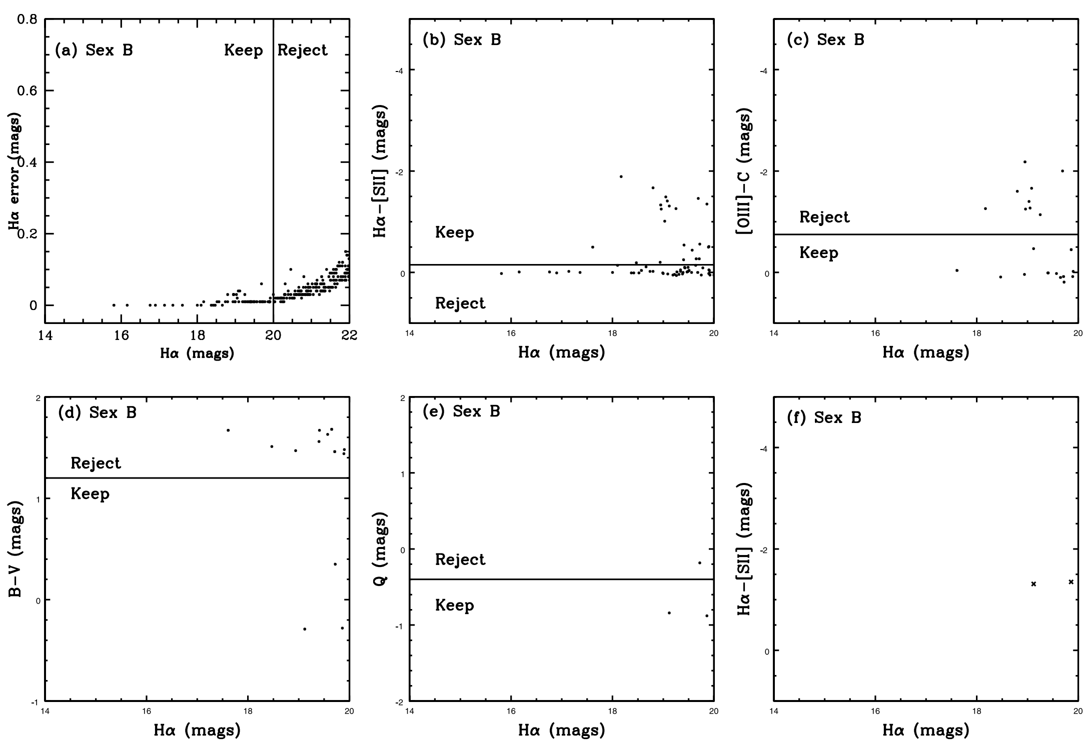


FIG. 6.—Selection criteria for Hα emission-line stars applied to Sextans B. Same as Fig. 1, except that there are no previously known Hα emission-line stars, and (*f*) our final sample contains two stars.

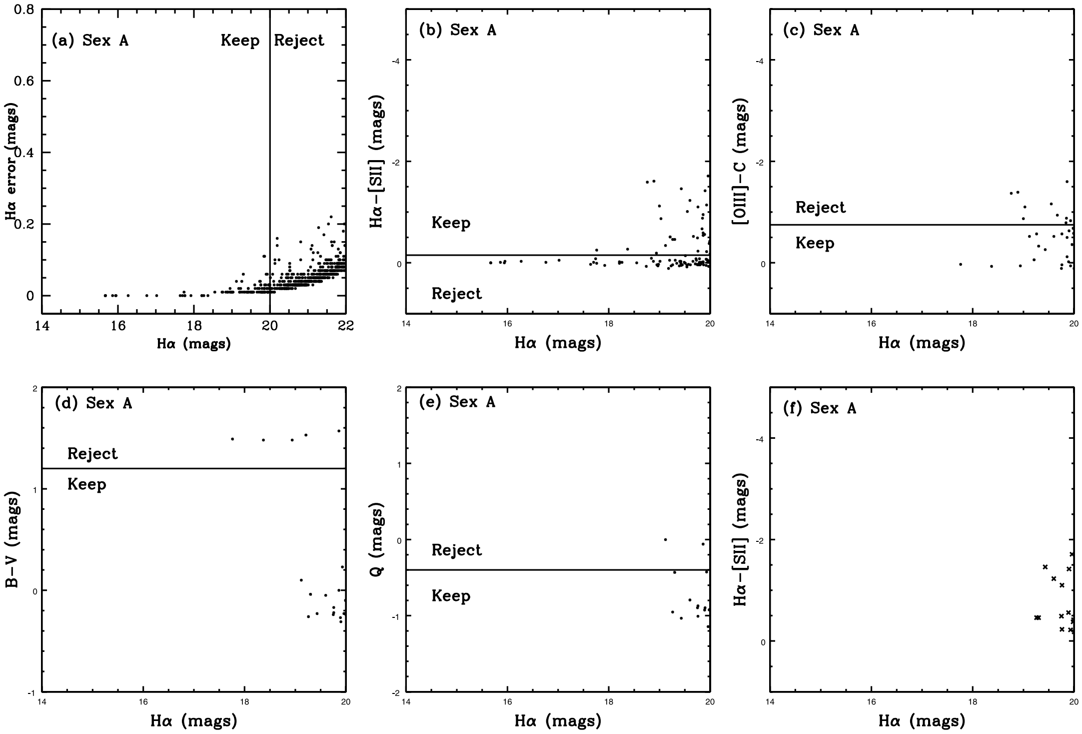


FIG. 7.—Selection criteria for Hα emission-line stars applied to Sextans A. Same as Fig. 1, except that there are no previously known Hα emission-line stars, and (*f*) our final sample contains eight stars.

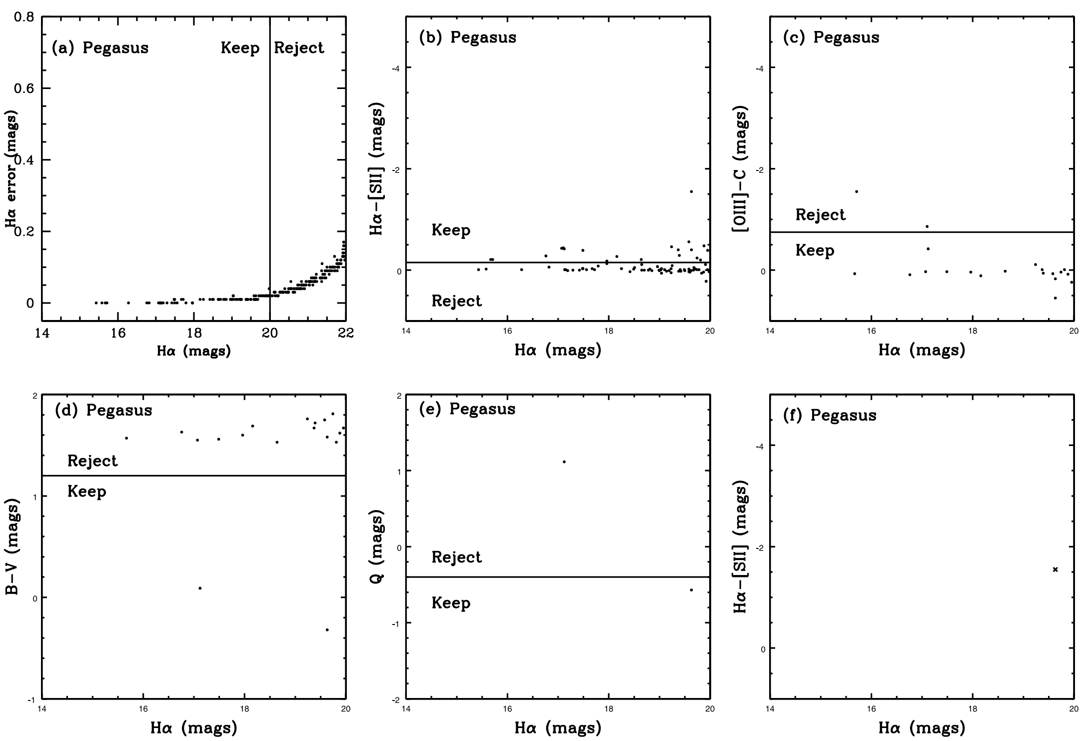


FIG. 8.—Selection criteria for Hα emission-line stars applied to Pegasus. Same as Fig. 1, except that there are no previously known Hα emission-line stars, and (*f*) our final sample contains one star.

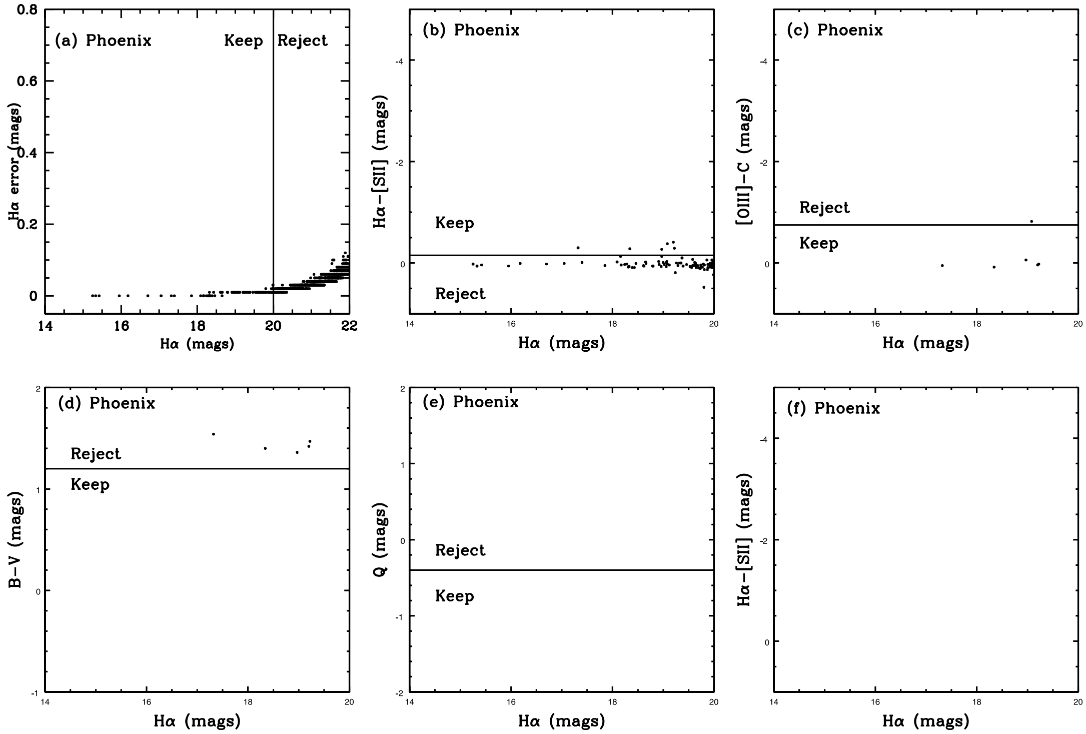


FIG. 9.—Selection criteria for Hα emission-line stars applied to Phoenix. Same as Fig. 1, except that there are no previously known Hα emission-line stars, and (*f*) our final sample contains no stars.

TABLE 4
SELECTION CRITERIA

Index	Used
Hα	≤20.0[a]
Hα − [S II]	≤−0.15
[O III] − C	≥−0.75
$B - V$	≤1.2[b]
Q	≤0.4[c]

[a] For IC 10, ≤20.2.
[b] For IC 10, ≤1.5.
[c] For IC 10, stars without $U - B$ were also retained.

TABLE 6
PHOTOMETRIC SHIFTS APPLIED

Galaxy	Hα − [S II]	[O III] − C
M31	−0.10	−0.32
M33	−0.06	−0.29
IC 10	−0.17	−0.10
NGC 6822	−0.20	+0.07
WLM	−0.16	+0.00
Sextans B	+0.34	−0.51
Sextans A	−0.17	−0.37
Pegasus	−0.02	−0.33
Phoenix	−0.09	−0.05

TABLE 5
ADOPTED DISTANCES AND REDDENINGS

Galaxy	$(m-M)_0$[a]	$E(B-V)$[b]	$(m-M)_{\mathrm{H}\alpha}$[c]	$M_{\mathrm{H}\alpha} = -6$
M31	24.4	0.13	24.7	18.7
M33	24.5	0.12	24.8	18.8
IC 10	24.1	0.81	26.2	20.2
NGC 6822	23.5	0.25	24.1	18.1
WLM	24.8	0.07	25.0	19.0
Sextans B	25.6	0.09	25.8	19.8
Sextans A	25.8	0.05	25.9	19.9
Pegasus	24.4	0.15	24.8	18.8
Phoenix	23.0	0.15	23.4	17.4

[a] True distance moduli are from van den Bergh (2000).
[b] Typical color excess of a blue star from Paper II.
[c] Apparent distance moduli at Hα follow from $(m-M)_0 + 2.54E(B-V)$.

TABLE 7
NUMBER OF POTENTIAL Hα EMISSION-LINE OBJECTS WITH $M_{\mathrm{H}\alpha} \leq -6$

Galaxy	M_V[a]	$\log \dot{M}$[b]	Number	Number with Spectra
M31	−21.2	−1.3	498	59
M33	−18.9	−1.0	1068	136
IC 10	−16.3	−1.3	96	7
NGC 6822	−16.0	−2.0	9	2
WLM	−14.4	−2.8	6	0
Sextans B	−14.3	−3.0	1	0
Sextans A	−14.2	−2.2	9	0
Pegasus	−12.3	−4.4	0	0
Phoenix	−9.8	...	0	0

[a] Absolute visual magnitude from van den Bergh (2000) and references therein.
[b] Star formation rate in terms of $M_\odot$ yr^{-1} integrated over the entire galaxy, from Table 1 of Paper II and references therein.

TABLE 8

Hα Emission-Line Stars in M31

LGGS	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	Hα	Hα − [S II]	[O III] − C	V	$B-V$	$U-B$	Q	Spectral Type	Cross-ID	Ref.
J004140.32+411730.9	00 41 40.32	+41 17 30.9	18.02	−0.87	−0.06	19.10	0.33	−0.80	−1.04	...	...	...
J004140.46+411714.1	00 41 40.46	+41 17 14.1	19.88	−0.23	0.04	19.92	0.28	−0.77	−0.97	...	...	...
J004142.91+411822.1	00 41 42.91	+41 18 22.1	19.90	−0.43	−0.20	20.27	0.13	−0.75	−0.84	...	...	...
J004142.96+412043.9	00 41 42.96	+41 20 43.9	19.81	−0.35	−0.56	20.20	−0.03	−0.97	−0.95	...	...	...
J004143.00+412042.7	00 41 43.00	+41 20 42.7	19.56	−0.25	−0.33	19.70	−0.04	−0.99	−0.96	...	...	...
J004143.13+411551.9	00 41 43.13	+41 15 51.9	19.03	−0.35	0.10	18.95	0.01	−0.97	−0.98	...	...	...
J004143.44+411555.3	00 41 43.44	+41 15 55.3	19.66	−1.81	−0.16	22.50	0.24	−0.87	−1.04	...	...	...
J004143.54+411820.1	00 41 43.54	+41 18 20.1	19.53	−0.35	−0.36	19.98	0.08	−0.89	−0.95	...	...	...
J004143.56+411815.8	00 41 43.56	+41 18 15.8	18.91	−0.78	−0.27	20.16	0.86	−0.33	−0.95	...	...	...
J004143.71+411826.3	00 41 43.71	+41 18 26.3	20.00	−1.07	0.08	21.20	0.08	−0.78	−0.84	...	...	...

Notes.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. Table 8 is published in its entirety in the electronic edition of the *Astronomical Journal*. A portion is shown here for guidance regarding its form and content.

References.—For spectral types and cross-IDs: (1) Paper I; (2) this paper; (3) Massey et al. 1995; (4) Bianchi et al. 1994; (5) Hubble & Sandage 1953; (6) Massey & Johnson 1998 and references therein.

TABLE 9

Hα Emission-Line Stars in M33

LGGS	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	Hα	Hα − [S II]	[O III] − C	V	$B-V$	$U-B$	Q	Spectral Type	Cross-ID	Ref.
J013225.51+302652.3	01 32 25.51	+30 26 52.3	18.94	−1.10	−0.66	20.60	−0.01	−0.94	−0.93	...	...	...
J013226.94+302538.1	01 32 26.94	+30 25 38.1	18.90	−1.22	−0.46	20.68	0.04	−0.55	−0.58	...	...	...
J013226.99+302413.2	01 32 26.99	+30 24 13.2	18.56	−1.21	−0.15	20.41	−0.02	−1.14	−1.13	...	...	...
J013227.89+302542.8	01 32 27.89	+30 25 42.8	20.00	−1.05	−0.05	21.23	0.02	−0.90	−0.91	...	...	...
J013228.78+303044.8	01 32 28.78	+30 30 44.8	19.80	−0.21	−0.12	19.73	−0.16	−1.09	−0.97	...	...	...
J013229.01+303453.7	01 32 29.01	+30 34 53.7	19.47	−0.23	0.02	19.83	−0.05	−1.14	−1.10	...	...	...
J013229.03+302819.6	01 32 29.03	+30 28 19.6	18.48	−0.76	0.10	19.00	0.04	−0.77	−0.80	...	...	...
J013229.24+303445.3	01 32 29.24	+30 34 45.3	19.18	−0.41	−0.14	19.56	−0.03	−1.03	−1.01	...	...	...
J013229.35+303445.4	01 32 29.35	+30 34 45.4	19.90	−0.29	−0.44	20.42	−0.14	−0.83	−0.73	...	...	...
J013229.57+303412.8	01 32 29.57	+30 34 12.8	18.81	−0.16	−0.08	18.87	−0.09	−0.81	−0.75	...	...	...

Notes.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. Table 9 is published in its entirety in the electronic edition of the *Astronomical Journal*. A portion is shown here for guidance regarding its form and content.

References.—For spectral types and cross-IDs: (1) Paper I; (2) this paper; (3) Massey et al. 1996; (4) Massey et al. 1995; (5) Monteverde et al. 1996; (6) Hubble & Sandage 1953; (7) Massey & Johnson 1998 and references therein; (8) Corral 1996; (9) Viotti et al. 2007 and references therein.

TABLE 10

Hα Emission-Line Stars in IC 10

LGGS	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	Hα	Hα − [S II]	[O III] − C	V	$B-V$	$U-B$	Q	Spectral Type	Cross-ID	Ref.
J002003.24+591343.7	00 20 03.24	+59 13 43.7	19.84	−0.33	0.00	20.69	0.73	−0.51	−1.04	...	...	...
J002024.68+591648.3	00 20 24.68	+59 16 48.3	20.00	−0.16	−0.04	20.75	1.11	0.38	−0.42	...	...	...
J002027.96+591659.4	00 20 27.96	+59 16 59.4	19.61	−0.80	−0.74	21.80	1.32	100.00	99.99	...	...	...
J002030.95+591702.3	00 20 30.95	+59 17 02.3	18.95	−0.78	−0.13	20.21	0.85	−0.40	−1.01	...	...	...
J002026.65+591714.4	00 20 26.65	+59 17 14.4	19.93	−0.35	−0.01	22.06	0.99	100.00	99.99	...	...	...
J002028.07+591714.3	00 20 28.07	+59 17 14.3	19.86	−3.24	−0.60	21.54	0.78	−0.26	−0.82	WN7-8	RSMV2	1
J002020.20+591724.1	00 20 20.20	+59 17 24.1	19.99	−0.35	−0.50	21.72	0.94	100.00	99.99	...	...	...
J002030.85+591728.4	00 20 30.85	+59 17 28.4	20.06	−1.48	0.58	21.76	0.88	100.00	99.99	...	...	...
J002011.89+591737.6	00 20 11.89	+59 17 37.6	19.49	−0.85	0.05	20.88	1.04	−0.26	−1.01	...	...	...
J002024.66+591744.6	00 20 24.66	+59 17 44.6	19.81	−0.87	−0.50	22.06	0.70	−0.55	−1.05	...	...	...

Notes.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. An entry of "99.99" denotes no measurement. Table 10 is published in its entirety in the electronic edition of the *Astronomical Journal*. A portion is shown here for guidance regarding its form and content.

References.—For spectral types and cross-IDs: (1) Crowther et al. 2003; (2) this paper; (3) Massey & Armandroff 1995.

TABLE 11
Hα Emission-Line Stars in NGC 6822

LGGS	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	Hα	Hα − [S II]	[O III] − C	V	$B-V$	$U-B$	Q	Spectral Type	Cross-ID	Ref.
J194434.02−144229.0......	19 44 34.02	−14 42 29.0	19.93	−0.50	−0.47	20.04	0.09	−0.74	−0.80	...	...	...
J194434.10−144224.5......	19 44 34.10	−14 42 24.5	18.91	−0.33	−0.10	19.37	0.04	−0.82	−0.85	...	...	...
J194434.17−144229.8......	19 44 34.17	−14 42 29.8	18.55	−0.63	−0.69	19.13	0.01	−0.78	−0.79	...	...	...
J194434.24−144149.0......	19 44 34.24	−14 41 49.0	19.93	−0.57	0.17	20.54	0.20	−0.72	−0.86	...	...	...
J194434.39−144227.5......	19 44 34.39	−14 42 27.5	18.38	−0.16	0.02	18.50	0.18	−0.85	−0.98	...	...	...
J194435.78−144620.0......	19 44 35.78	−14 46 20.0	19.97	−0.48	0.14	20.37	0.18	−0.68	−0.81	...	...	...
J194436.37−144820.8......	19 44 36.37	−14 48 20.8	19.87	−0.44	0.11	20.38	0.24	−0.70	−0.87	...	...	...
J194437.40−145044.0......	19 44 37.40	−14 50 44.0	19.70	−0.31	−0.21	19.98	0.16	−0.43	−0.55	...	...	...
J194437.97−145106.2......	19 44 37.97	−14 51 06.2	19.66	−0.26	0.08	19.83	0.01	−0.76	−0.77	WN	N6822-WR4	1
J194438.39−145147.0......	19 44 38.39	−14 51 47.0	19.70	−0.68	−0.31	20.36	0.04	−0.75	−0.78	...	...	...

Notes.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds. Table 11 is published in its entirety in the electronic edition of the *Astronomical Journal*. A portion is shown here for guidance regarding its form and content.
References.—For spectral types and cross-IDs: (1) Massey & Johnson 1998 (note that for the WR stars, the CDS lists these as [AM85] N); (2) this paper; (3) Westerlund et al. 1983.

TABLE 12
Hα Emission-Line Stars in WLM

LGGS	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	Hα	Hα − [S II]	[O III] − C	V	$B-V$	$U-B$	Q	Spectral Type	Cross-ID	Ref.
J000153.57−152732.6............	00 01 53.57	−15 27 32.6	19.81	−0.54	0.09	20.29	−0.24	−0.92	−0.75	...	...	...
J000154.96−152831.4............	00 01 54.96	−15 28 31.4	19.69	−1.64	0.07	22.24	−0.43	−1.27	−0.96	...	...	...
J000155.24−152718.7............	00 01 55.24	−15 27 18.7	19.76	−0.17	0.15	19.78	−0.04	−1.03	−1.00	...	...	...
J000155.90−152839.3............	00 01 55.90	−15 28 39.3	19.21	−0.17	−0.40	20.09	−0.23	−1.04	−0.87	...	...	...
J000156.08−152837.5............	00 01 56.08	−15 28 37.5	18.48	−1.37	−0.67	20.77	−0.10	−0.95	−0.88	...	...	...
J000156.16−152841.9............	00 01 56.16	−15 28 41.9	18.86	−0.17	−0.13	18.92	−0.07	−0.80	−0.75	...	...	...
J000156.16−152841.9............	00 01 56.16	−15 28 41.9	18.86	−0.17	−0.13	18.92	−0.07	−0.80	−0.75	...	...	...
J000156.53−152703.2............	00 01 56.53	−15 27 03.2	18.44	−0.18	−0.01	18.50	−0.06	−0.94	−0.90	...	...	...
J000156.75−152636.6............	00 01 56.75	−15 26 36.6	19.89	−0.45	0.10	20.27	0.11	−0.35	−0.43	A3 II	B8	1
J000157.14−152700.9............	00 01 57.14	−15 27 00.9	19.92	−0.70	−0.55	21.52	0.61	−0.78	−1.22	...	...	...
J000157.20−152648.2............	00 01 57.20	−15 26 48.2	18.82	−1.44	−0.69	21.25	−0.15	−1.09	−0.98	...	...	...
J000159.58−152728.9............	00 01 59.58	−15 27 28.9	19.25	−1.24	−0.13	21.19	−0.17	−1.00	−0.88	...	...	...
J000159.62−153016.0............	00 01 59.62	−15 30 16.0	19.71	−1.36	0.22	21.43	−0.15	−1.00	−0.89	...	...	...
J000200.42−152935.7............	00 02 00.42	−15 29 35.7	19.69	−0.78	−0.46	21.07	−0.18	−0.81	−0.68	...	...	...
J000201.95−152744.8............	00 02 01.95	−15 27 44.8	19.46	−0.28	0.13	19.47	−0.17	−0.89	−0.77	...	...	...
J000202.33−152743.2............	00 02 02.33	−15 27 43.2	17.74	−1.47	−0.30	19.46	0.09	−0.66	−0.72	...	...	...

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.
References.—For spectral types and cross-IDs: (1) Bresolin et al. 2006.

TABLE 13
Hα Emission-Line Stars in Sextans B

LGGS	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	Hα	Hα − [S II]	[O III] − C	V	$B-V$	$U-B$	Q
J100002.93+052022.8.......................	10 00 02.93	+05 20 22.8	19.12	−1.31	−0.47	19.86	−0.29	−1.05	−0.84
J100005.54+051802.5.......................	10 00 05.54	+05 18 02.5	19.86	−1.35	−0.45	21.68	−0.28	−1.08	−0.88

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

TABLE 14

Hα Emission-Line Stars in Sextans A

LGGS	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	Hα	Hα − [S II]	[O III] − C	V	$B-V$	$U-B$	Q
J101053.60−044117.8	10 10 53.60	−04 41 17.8	19.60	−1.23	−0.52	20.97	−0.05	−0.83	−0.79
J101053.67−044118.4	10 10 53.67	−04 41 18.4	19.76	−1.10	−0.57	21.07	−0.17	−1.13	−1.01
J101053.90−044111.0	10 10 53.90	−04 41 11.0	19.99	−0.42	−0.58	20.32	−0.10	−0.99	−0.92
J101053.94−044110.1	10 10 53.94	−04 41 10.1	19.98	−0.38	−0.68	20.53	−0.23	−1.09	−0.92
J101054.08−044111.5	10 10 54.08	−04 41 11.5	19.76	−0.23	0.04	19.49	−0.22	−1.03	−0.87
J101100.56−043930.9	10 11 00.56	−04 39 30.9	19.93	−0.22	0.06	19.87	0.23	−0.26	−0.43
J101105.07−044214.6	10 11 05.07	−04 42 14.6	20.00	−0.18	0.11	19.74	−0.24	−1.10	−0.93
J101105.17−044236.0	10 11 05.17	−04 42 36.0	19.30	−0.46	−0.33	19.36	−0.04	−0.46	−0.43
J101105.30−044210.1	10 11 05.30	−04 42 10.1	19.89	−0.56	−0.02	19.98	−0.27	−1.12	−0.93
J101105.38−044240.1	10 11 05.38	−04 42 40.1	19.26	−0.46	−0.57	19.46	−0.26	−1.14	−0.95
J101105.69−044213.6	10 11 05.69	−04 42 13.6	19.75	−0.49	0.11	19.70	−0.24	−1.07	−0.90
J101106.56−044217.1	10 11 06.56	−04 42 17.1	19.90	−1.42	−0.63	21.29	−0.31	−1.12	−0.90
J101107.34−044231.7	10 11 07.34	−04 42 31.7	19.43	−1.46	−0.26	20.57	−0.23	−1.20	−1.03
J101109.27−044053.3	10 11 09.27	−04 40 53.3	19.96	−1.71	−0.36	21.80	−0.23	−1.31	−1.14

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

TABLE 15

Hα Emission-Line Stars in Pegasus

LGGS	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	Hα	Hα − [S II]	[O III] − C	V	$B-V$	$U-B$	Q
J232834.97+144356.9	23 28 34.97	+14 43 56.9	19.63	−1.55	0.55	22.44	−0.32	−0.80	−0.57

Note.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

TABLE 16

Spectroscopic Exposures

			Exposures (s)	
Field	$\alpha_{J2000.0}$	$\delta_{J2000.0}$	Blue	Red
M31-NE	00 43.8	+41 33	6 × 1800	3 × 1800
M31-SW	00 41.2	+40 44	4 × 1800, 1000	. . .
M33-N	01 33.7	+30 44	3 × 1800, 3 × 1600	4 × 1800
M33-S	01 33.7	+30 34	5 × 1800, 1600	4 × 1800
IC 10	00 20.2	+59 18	. . .	3 × 1200
NGC 6822	19 44.7	−14 53	4 × 1800, 1200	3 × 1600

Note.—Units of right ascension are hours and minutes, and units of declination are degrees and arcminutes.

TABLE 17

New Spectroscopic Identifications

LGGS	Spectra	Figure
IC 10		
J002012.13+591848.0	Hot LBV candidate	16
J002016.48+591906.9	Hot LBV candidate?	17
J002020.35+591837.6	Hot LBV candidate	16
M31		
J003910.85+403622.4	H II?	...
J003944.71+402056.2	H II	...
J004030.28+404233.1	H II/B1.5[a]	...
J004032.37+403859.8	H II/B[a]	...
J004033.80+405717.2	H II/B0.2[a]	...
J004043.10+410846.0	Hot LBV candidate	12
J004052.19+403116.6	No emission; star/B8[a]	...
J004057.03+405238.6	Broad-line peculiar	31
J004058.04+410327.9	H II/B8[a]	...
J004109.26+404906.0	H II	...
J004129.74+405100.8	H II	...
J004130.37+410500.9	WNL	28
J004220.31+405123.2	H II	...
J004229.87+410551.8	Hot LBV candidate	13
J004242.33+413922.7	P Cyg LBV candidate	24
J004253.42+412700.5	Star in H II region	...
J004259.31+410629.1	H II	...
J004303.21+410433.8	H II	...
J004313.27+410257.4	No emission; star	
J004322.50+413940.9	Hot LBV candidate	13
J004334.50+410951.7	Ofpe/WN9	26
J004339.28+411019.4	H II?	...
J004350.50+414611.4	Cool LBV candidate	19
J004410.90+413203.2	Star in H II region	...
J004411.36+413257.2	Hot LBV candidate (k315a)	14
J004415.00+420156.2	Hot LBV candidate	12
J004416.28+412106.6	H II	...
J004417.10+411928.0	Hot LBV candidate (k350)	12
J004425.18+413452.2	Cool LBV candidate (k411)	19
J004433.58+415248.0	H II	...
J004434.65+412503.6	B3 I/B1:[b] in H II	30
J004438.55+412511.1	H II	...
J004442.07+412732.3	H II	...
J004442.28+415823.1	Hot LBV candidate	12
J004443.57+412616.5	Star in H II	...
J004444.52+412804.0	P Cyg LBV candidate	24
J004500.90+413100.7	WC in H II	28
J004507.65+413740.8	Cool LBV candidate	19
J004511.60+413716.8	H II	...
J004522.58+415034.8	Hot LBV candidate	12
J004526.62+415006.3	Hot LBV candidate	12
J004545.94+415030.5	AVe (foreground)	...
M33		
J013235.25+303017.6	Hot LBV candidate	14
J013241.30+302231.2	H II	...
J013242.26+302114.1	Hot LBV candidate	14
J013245.00+303456.7	H II	...
J013248.26+303950.4	Hot LBV candidate	14
J013259.74+303854.8	H II?	...
J013300.86+303504.9	B1 I in H II/B1.5 Ia[b]	30
J013301.24+303051.3	H II	...
J013303.09+303101.8	H II	...
J013307.50+304258.5	WN (UIT041 = M33WR19)	29
J013311.26+304515.3	H II	...
J013311.45+302951.3	H II	...
J013315.21+305318.5	H II	...

TABLE 17—*Continued*

LGGS	Spectra	Figure
M33		
J013316.50+303212.1	Late A I/early F I	30
J013317.22+303201.6	H II	...
J013324.62+302328.4	Hot LBV candidate	12
J013327.03+303841.6	H II	...
J013329.88+303147.3	H II/O+neb[a]	...
J013332.64+304127.2	Hot LBV candidate[c]	15
J013333.22+303343.4	Hot LBV candidate	12
J013334.06+304744.3	H II plus He II λ4686?	...
J013334.27+304136.7	WNL in H II	28
J013334.29+303400.1	H II	...
J013334.39+303208.4	H II	...
J013335.32+303931.0	H II	...
J013337.56+303202.3	H II	...
J013339.08+302010.7	Star in H II	...
J013339.42+303124.8	B3 I/B1 Ia[b]	30
J013339.42+303810.8	H II	...
J013339.52+304540.5	P Cyg LBV candidate[d]	24
J013341.28+302237.2	P Cyg LBV candidate[e] (101-A)	24
J013342.03+304733.6	Star in H II	...
J013342.52+303258.6	H II	...
J013343.19+303906.4	H II	...
J013343.50+303911.5	H II	...
J013344.52+304432.3	H II/OB+neb[a]	...
J013344.56+303201.3	H II	...
J013344.79+304432.4	H II/OB+neb[a]	...
J013344.85+303600.4	H II	...
J013345.25+303626.6	H II/B[a]	...
J013347.33+303306.8	H II	...
J013349.28+305250.2	H II	...
J013349.72+303730.6	H II	...
J013349.94+302928.8	H II	...
J013350.21+303347.6	H II	...
J013351.46+304057.0	P Cyg LBV candidate	24
J013352.19+303636.6	H II	...
J013352.39+303920.9	H II/OB+neb	...
J013355.51+304526.8	H II	...
J013355.87+304528.4	WNL in H II	
J013357.73+301714.2	Cool LBV candidate	19
J013359.01+303353.9	B8 I in H II	30
J013359.11+303437.2	Star in H II	...
J013359.40+302311.0	H II/A0 Ia[a]	...
J013401.44+303630.8	H II	...
J013401.68+303720.0	H II	...
J013406.72+304154.5	Of/early O[b]	28
J013407.32+304732.4	H II	...
J013408.21+303405.2	H II	...
J013410.93+303437.6	Hot LBV candidate	12
J013414.21+303343.3	H II	...
J013415.43+303707.4	H II	...
J013416.07+303642.1	P Cyg LBV candidate (H108)	24
J013416.35+303712.3	H II/WN7[a]	...
J013416.44+303120.8	Cool LBV candidate	22
J013422.91+304411.0	Cool LBV candidate	19
J013424.78+303306.6	Cool LBV candidate	19
J013426.11+303424.7	Hot LBV candidate	14
J013429.64+303732.1	Cool LBV candidate	22
J013430.29+304039.8	Star in H II	...
J013432.76+304717.2	Ofpe/WN9	27
J013433.10+304659.0	H II	...
J013435.15+304705.1	H II	...
J013438.76+304358.8	H II/Late O[a]	...
J013439.73+304406.6	Late A I/early F I	30
J013442.14+303216.0	Hot LBV candidate?	17
J013459.47+303701.9	Hot LBV candidate	12

TABLE 17—*Continued*

LGGS	Spectra	Figure
M33		
J013500.30+304150.9	Hot LBV candidate	12
J013509.73+304157.3	Ofpe/WN9 (Romano's Star)	26, 27
NGC 6822		
J194452.97−144305.1	H II	. . .
J194503.77−145619.1	Hot LBV candidate?	17

[a] In a few cases where our fiber spectroscopy revealed only the spectra of an H II region, previous long-slit spectra had permitted a spectral type to be determined for the underlying star. We include these here and retain the originals in Tables 8–11.
[b] Previous spectral type is shown, but we adopt the new one (given first) here.
[c] Previously called WN by Massey & Conti (1983); see text.
[d] Previously called B0.5 Ia+WNE by Massey et al. (1996); see text.
[e] Previously called B1 Ia (101-A) by Monteverde et al. (1996); see text.

magnitude in the Hα image itself as a general measure of the brightness of the object (continuum plus emission). Based on the numbers in Table 3, we decided to impose a cutoff at an Hα magnitude of 20. In Table 5 we list our adopted distance moduli and reddenings (from Table 1 of Paper II and references therein), along with the apparent distance modulus at Hα, using a correction for interstellar reddening of $A_{\mathrm{H}\alpha} = 2.54E(B-V)$ (Cardelli et al. 1989). We see that 20 mag corresponds to an absolute magnitude (at Hα) of roughly -5 in M31 and M33. For the galaxy with the largest apparent distance modulus, IC 10, it corresponds roughly to -6. Although our source catalogs are based on how good our photometry is (i.e., flux-limited to a certain apparent magnitude), we still wanted to compare the number of objects to the same absolute magnitude, and so we have adjusted the flux limit for IC 10 slightly to reach $M_{\mathrm{H}\alpha} = -6$ (i.e., Table 4). We show the effects of this cut on the full sample in panel *a* of Figures 1–9.

Second, for a measure of the actual Hα emission, we chose to use [S II] as our continuum filter, as we found that this provided cleaner separation in the various diagnostic two-color plots than did, say, broadband *R*. (King et al. [1998] also used Hα − [S II] in their search for LBVs in M31.) Based on our examination of the known LBVs in M31 and M33 we chose Hα − [S II] ≤ -0.15 to select emission-line stars from the general stellar population[12] (see Table 6). We illustrate the effect of this selection in panel *b* of Figures 1–9.

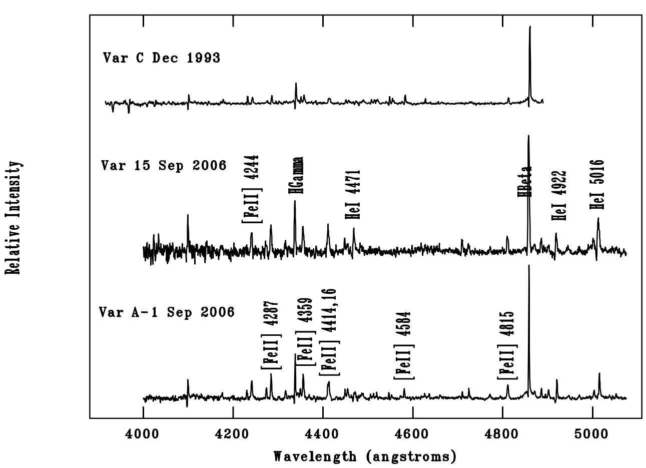


FIG. 10.—Spectra of known "hot" LBVs with [Fe II] emission. We show spectra of Var C (M33), Var 15 (M31), and Var A-1 (M31) in their "quiescent" state, where the spectra are dominated by emission of the Balmer lines, He I, and forbidden Fe II. We have identified only the strongest lines; the wavelengths of the other emission features correspond to [Fe II] lines listed by Kenyon & Gallagher (1985) for AE And (their Table 3).

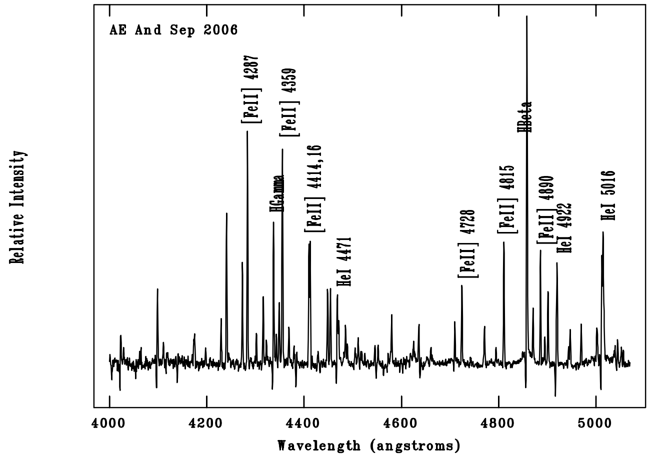


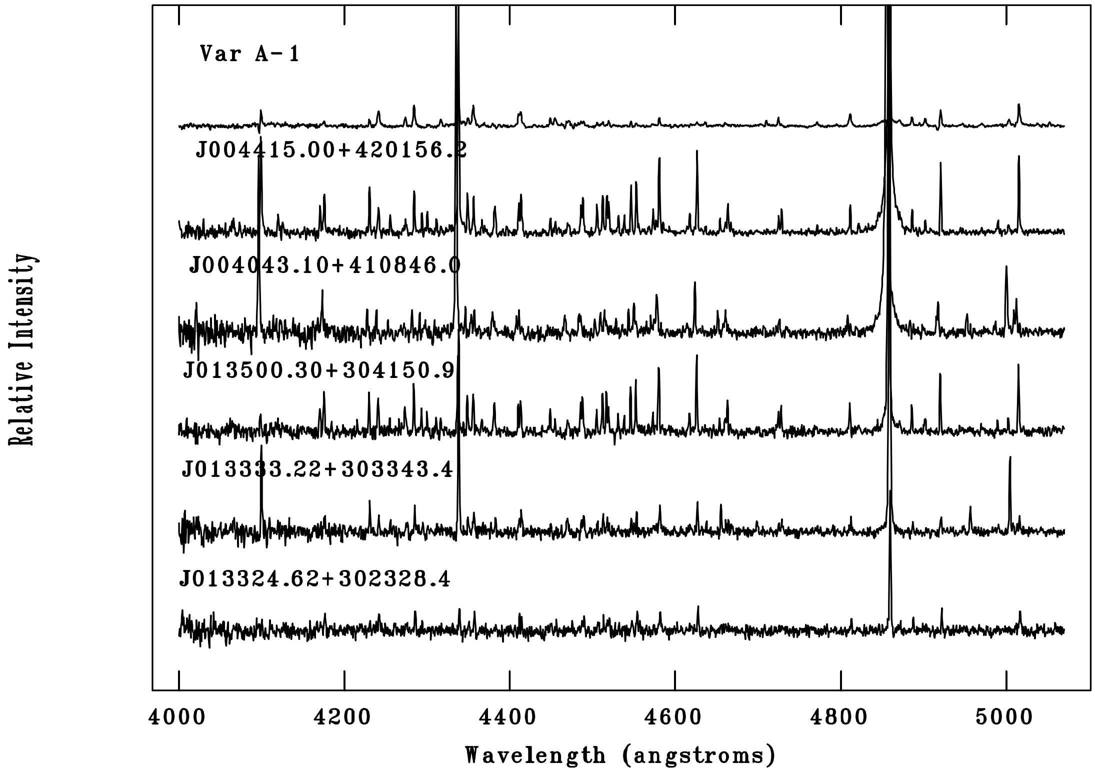
FIG. 11.—Spectrum of AE And in 2006 September. In the 1983 spectrum shown by Kenyon & Gallagher (1985) many of the [Fe II] lines were significantly stronger than that of Hβ. In our rather noisy spectrum we see only Hβ emission, as a P Cygni line superposed on broad emission.

Third, we constructed an index that would measure the amount of [O III] emission. For this, we found that a continuum comprised of the average of *V* and *B* worked well; i.e., [O III] − *C*, where $C = (V+B)/2$. This was necessary in order to eliminate compact H II regions and PNe. Our examination of the locations of the known LBVs indicated that some showed emission in the [O III] bandpass; this is likely due to emission in the He I λ5016 line. Therefore, we adopted a fairly conservative criterion of keeping only objects with [O III] − $C > -0.75$. However, even this will eliminate legitimate Hα emission-line stars which happen to excite small H II regions. The most extreme example of this problem is in IC 10, where the [O III] − *C* cut resulted in eliminating the vast majority of WRs (Fig. 3). In most cases, however, we expect that this cut eliminated unwanted gaseous emission regions (panel *c* of Figs. 1–9).

After applying all of these criteria, we were surprised to find that some of the remaining objects were actually very red stars. We attribute this to a molecular absorption band located at 6715 Å. (Mostly, these are foreground red dwarfs, although a few might be bona fide RSGs in these galaxies.) This absorption band falls within the [S II] filter and creates the appearance of Hα emission. To eliminate these unwanted objects a color criteria was imposed using $B-V < 1.2$ for all galaxies (panel *d* of Figs. 1–9), save one. In IC 10, the colors were shifted a fair amount due to reddening. From careful examination of color plots for IC 10, we determined that a value of 1.5 would be equivalent to the $B-V$ criteria. (Based purely on the reddening we would have picked a much higher cutoff, about 1.9, but we infer from our plots that the vast majority of the stars are nearer foreground stars, and that just a small increase in our cutoff was sufficient.)

In addition, we decided to use the reddening-free color index $Q = U - B - 0.72(B-V)$ to keep only the intrinsically bluest stars, using $Q \leq -0.4$ (panel *e* of Figs. 1–9; O-type stars typically have $Q < -0.9$, while -0.4 corresponds to a B5 dwarf or

[12] For all of our indices, we applied small shifts (of order a few tenths of a magnitude) in order for the general population of stars to have a zero value. This was partially an artifact that the emission-line indices, such as Hα − [S II], were constructing without separate aperture corrections. We list these shifts in Table 6.



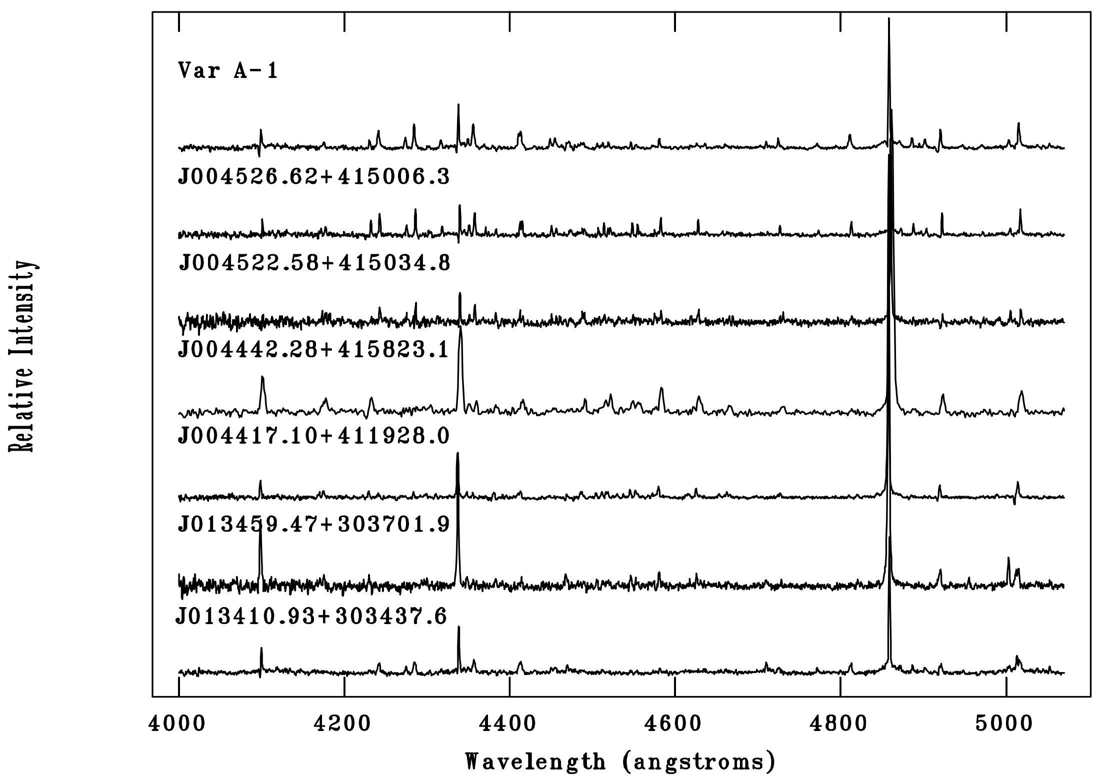


FIG. 12.—Spectra of newly found M31 and M33 hot LBV candidates compared to Var A-1. In the top panel we show the stars whose spectra have strong [Fe II], while in the bottom panel we show stars which have relatively weak [Fe II] and Fe II lines. For line identifications see Fig. 10. All the spectra were obtained in 2006 September, except for that of J004442.28+415823.1, which was obtained by N. Caldwell in 2006 November. The star J004417.10+411928.0 was previously identified as an LBV candidate (k350) by King et al. (1998).

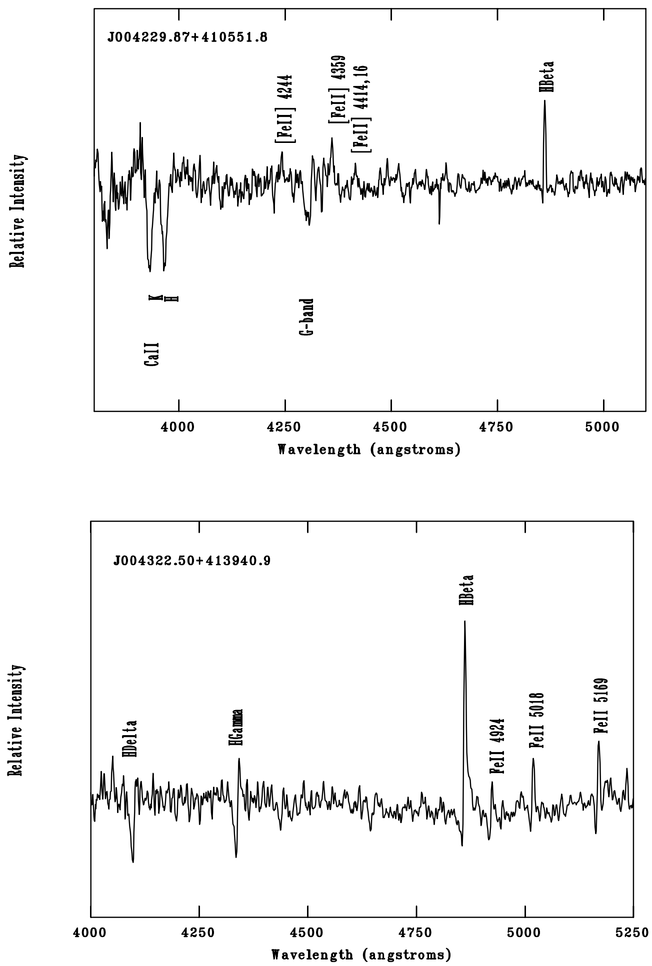


Fig. 13.—Two peculiar hot LBV candidates. The spectrum of the M31 star J004229.87+410551.8 (*top*) shows [Fe II] and Balmer emission, but also an absorption spectrum characteristic of a mid-F star or later. The spectrum may be composite. The spectrum of the M31 star J004322.50+413940.9 (*bottom*) shows P Cygni emission in the lower Balmer lines plus several lines of Fe II. The spectra were obtained by N. Caldwell in 2006 November.

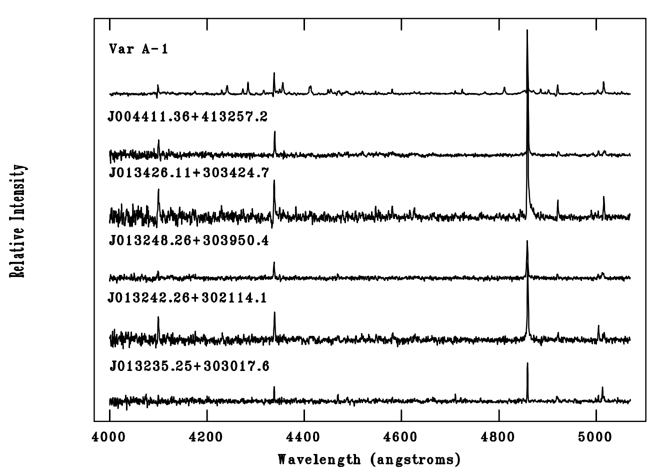


Fig. 14.—Spectra of newly found additional hot LBV candidates compared to Var A-1. These stars show Balmer and some He I emission, but any [Fe II] emission is incipient at best. The M31 star (J004411.36+413257.2) was previously identified by King et al. (1998) as an LBV candidate (k315a) based on its spectrum.

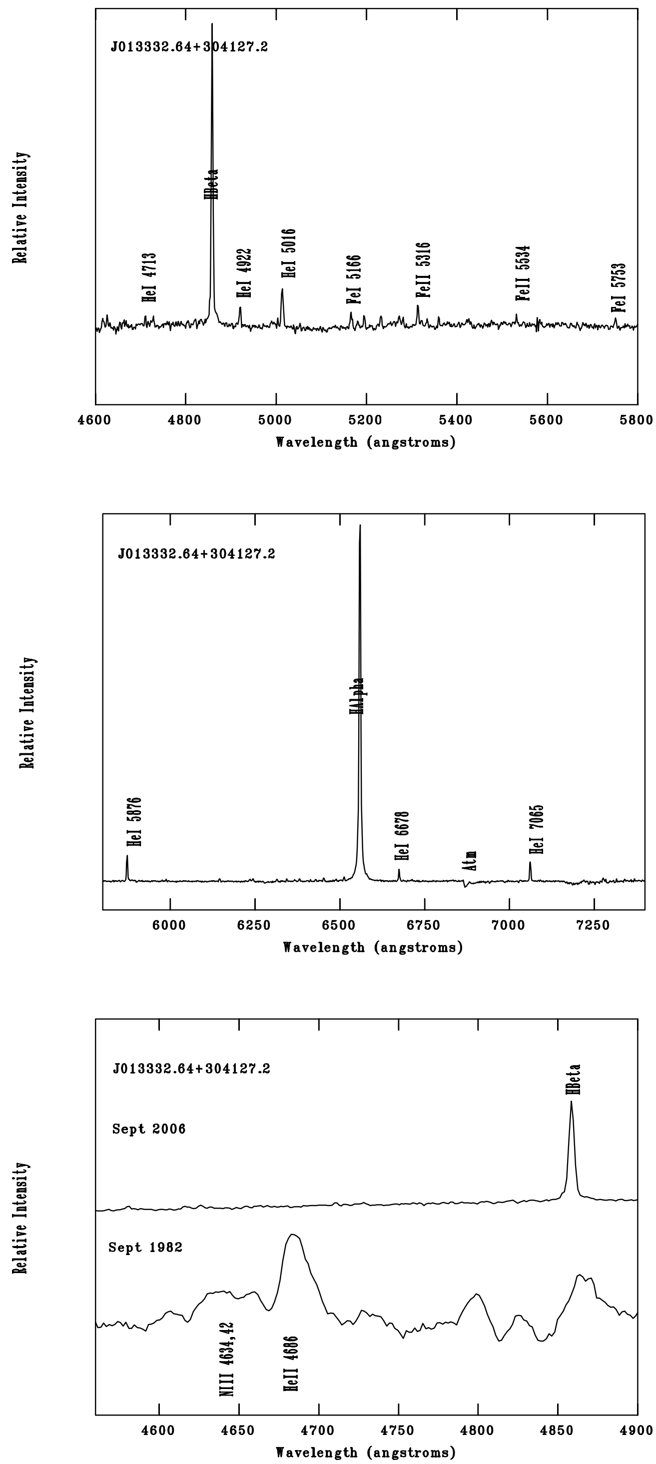


Fig. 15.—Spectra of the M33 star J013332.64+304127.2 (AM2 from Armandroff & Massey [1985], also known to SIMBAD as [MC83] 28), formerly a WN star and now an LBV candidate. *Top and middle*: Currently this star shows Balmer and He I emission, and numerous metal lines of Fe I and Fe II. *Bottom*: In 1982, however, its spectrum was that of a WN-type WR.

giant or an A0 supergiant; see Table 3 of Massey [1998]). Not all of our stars had *U*-band photometry, and the result of this cut meant that any star without good *U*-band photometry would be eliminated. This was judged to be a particular problem for IC 10, and so we decided to include stars without *U* but which met the other criteria.

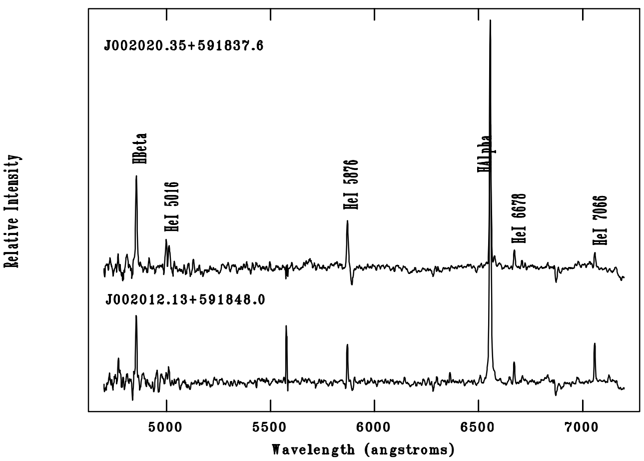


Fig. 16.—Spectra of two hot LBV candidates in IC 10. The stars show He I and Balmer emission. Note that the absorption feature to the red of He I $\lambda5876$ is due to a Na D interstellar line.

We show our final selections in panel *f* of Figures 1–9 and list the total number of candidates found in Table 7. The Hα candidates themselves are listed in Tables 8–15. (No objects were found in the Phoenix dwarf.) We have included the relevant broadband photometry from Papers I and II, along with spectral types, both those that were previously known (from Papers I and II and references therein) and those which are newly determined here (§ 4).

We include stars in these tables as faint as an AB magnitude of 20.0 in Hα (20.2 in the case of IC 10). For M31 we find 2334 potential Hα emission-line stars. In our complete catalog of M31 there are 32,802 sources this bright or brighter in Hα, so the fraction is about 7%. In M33 we find 3707 potential Hα emission-line stars, while the catalog contains 18,867 stars this bright or brighter, about 20%: a much larger fraction.

The full lists in Tables 8–15 are based on a given apparent magnitude in Hα. A more meaningful comparison is to use the absolute luminosity. In Table 5 we list the apparent Hα magnitude corresponding to $M_{\mathrm{H}\alpha} = -6$. If we count only stars that bright or brighter, then we arrive at the number of Hα sources listed in Table 7. We include in that table the absolute visual magnitude of each galaxy, along with the current star formation rate. There is clearly a much better correlation with star formation rate than with M_V; for instance, we find about twice as many sources in M33 as in M31, although the latter is 8 times more luminous. The current star formation rate in M33 (integrated over the galaxy) is twice as large as in M31. It is interesting that the number of sources we detect in IC 10 is much lower than the current star formation rate would indicate. However, our $[\mathrm{O\ III}] - C$ cut eliminated most of the WRs, and we believe that therefore our potential list is spuriously low for that galaxy. The results for NGC 6822 are harder to explain, as only nine objects were found, while we might expect 85–90 by scaling from M31 or M33. Perhaps in the dwarfs we are seeing the effects of low metallicity: that lower mass-loss rates result in disproportionately fewer Hα emission stars. The paucity of potential Hα emission-line stars in NGC 6822 *is* consistent with its scant number (four) of WRs, compared to, say, M33, where deep surveys of about half of the galaxy have confirmed roughly 160 WRs (Massey & Johnson 1998). We also include in Table 7 the number of stars with $M_{\mathrm{H}\alpha} \leq -6$ for which we know the spectral types, either from previous work or from the present study. We can see that despite the efforts reported in the next section, we have only just begun to investigate the interesting emission-line stars in these nearby galaxies.

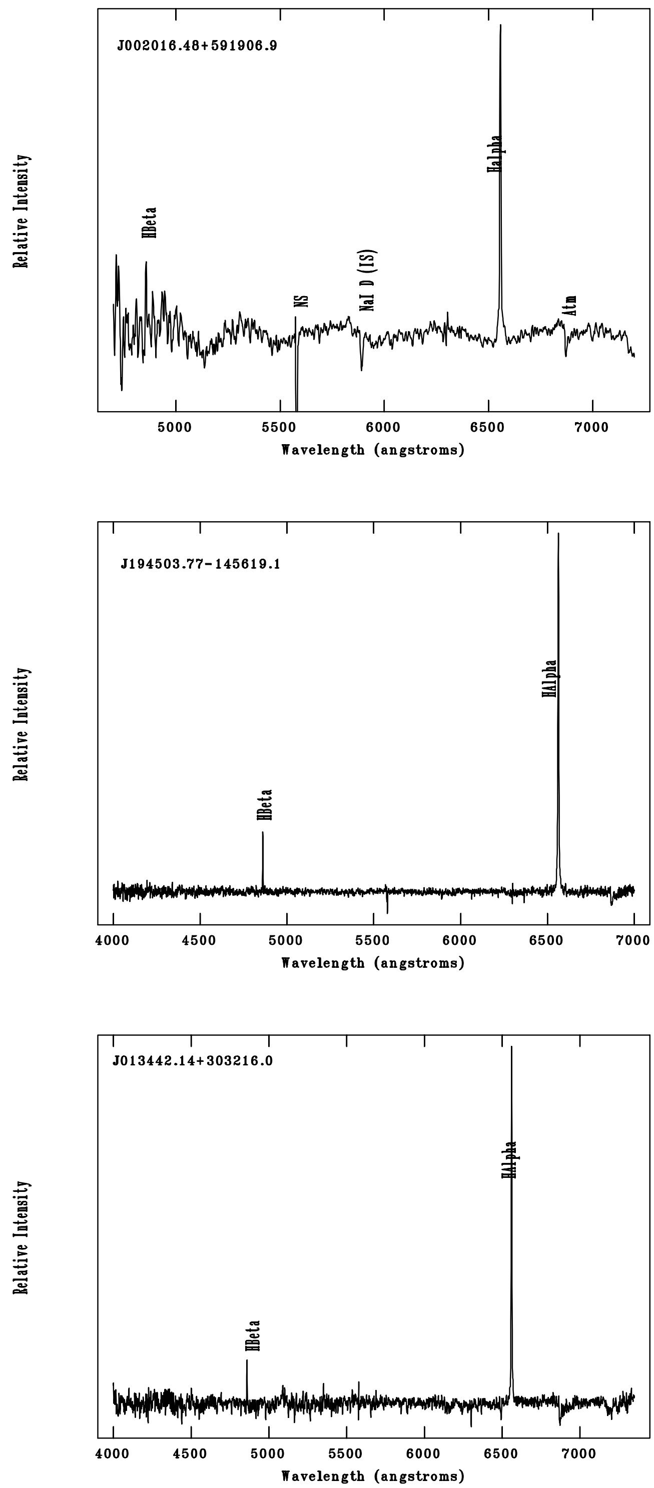


Fig. 17.—Spectra of three questionable LBV candidates. These stars show Hα and Hβ emission but none of the forbidden lines we would expect of an H II region. Incomplete night-sky (NS), Na I D interstellar (IS), and the atmospheric B band (Atm) are the only other features visible in the IC 10 spectrum at top.

4. A SPECTROSCOPIC RECONNAISSANCE IN M31, M33, IC 10, AND NGC 6822

The stars listed in Tables 8–15 are *potentially* interesting objects, likely—but not certain—to have Hα emission. Although our detection criteria were chosen to be fairly conservative (by necessity, so as not to include too many non-emission-line objects), the inherent uncertainties of such photometry in crowded

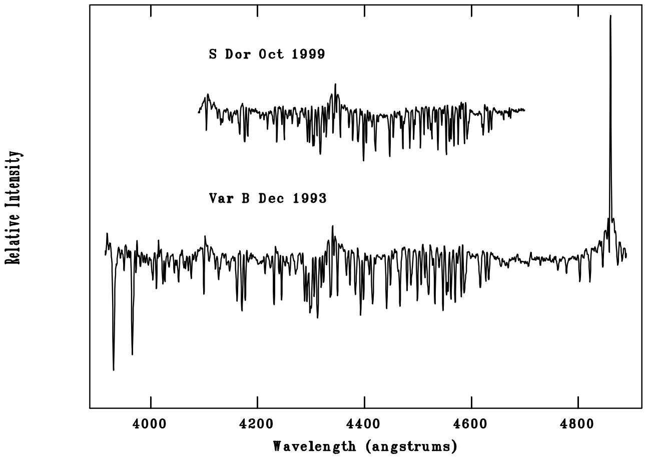


Fig. 18.—Spectra of LBVs in their cool state. We show the spectrum of the M33 LBV Var B obtained in 1993 December (during its 1992–1993 outburst) compared to a spectrum of the LMC LBV S Dor obtained in 1999 October. The absorption-line spectra resemble that of an extreme late-type F-type supergiant, with numerous metal absorption lines. This figure is based on Fig. 1 of Massey (2000).

fields necessitates spectroscopy to see what it is we actually have.

We observed on four nights (2006 September 19–22) with the Hydra fiber positioner at the WIYN 3.5 m telescope. On the first two nights we used the blue fiber cable (consisting of ~100 fibers of 3.1″ diameter) with a 790 line mm^{-1} grating (KPC-18C) used in second order with a BG-39 blocking filter. The spectral coverage was 3970–5030 Å, with a spectral resolution of 1.5 Å; the setup was identical to that described in Paper I. The first night was clear, with good conditions (seeing ≈1″), while there were intermittent clouds on the second. On the third and fourth nights we used the red fiber cable (~100 fibers of 2.0″ diameter) with a 600 line mm^{-1} grating (60010.1) in first order with a GG-420 blocking filter. The spectral coverage was 4550–7400 Å, with a spectral resolution of 3.4 Å. Conditions were marginal on the first red night (2006 September 21) and we were only able to observe for the first hour or so of the night due to humidity; conditions were again good for September 22. For both setups we used the Bench Spectrograph Camera with the T2KA CCD, a 2048 × 2048 device with 24 μm pixels and excellent cosmetics.

The FOV of Hydra is 1°, and we assigned fibers to two overlapping fields in M31, two overlapping fields in M33, and one field each in NGC 6822 and IC 10. Each field was observed for 2.3–3.0 hr in the blue and 1.0–2.0 hr in the red, as summarized in Table 16. The IC 10 field was not observed in the blue, and the second M31 field was not observed in the red, due to the variable conditions.

In addition to our Hydra spectra, we also obtained a new high signal-to-noise ratio (S/N) spectrum with the 6.5 m MMT of two of our P Cygni–like LBV candidates: the stars J004341.84+411112.0, previously described by Massey (2006), and J013416.07+303642.1, newly described here. We used the Blue Channel spectrograph on 2006 October 28 with the 832 line mm^{-1} grating in second order ($CuSO_4$ blocking filter) with a 1.25″ slit, for a resolution of 1.1 Å, and covering 4075–5020 Å. These spectra were obtained principally for the purposes of modeling, but we use them here for illustration.

Finally, we include here three spectra contributed by N. Caldwell, who contacted us during the course of our writing of this paper with questions about several M31 objects that he thought resembled LBVs. Three of these turned out to be on our list of M31 potential Hα sources (Table 8): J004229.87+410551.8, J004322.50+413940.9, and J004442.28+415823.1. These had not been observed at WIYN, and he kindly suggested we include their spectra here. He obtained these spectra on the MMT 6.5 m with the Hectospect fiber positioner on 2006 November 15 using the 270 line mm^{-1} grating, which provided wavelength coverage from 3650 to 9200 Å and a resolution of roughly 5 Å.

Nearly every object had Hα emission, as shown by the red spectra. Many of our objects (60%) were simply stars in low-excitation H II regions (usually with minimal [O III] λ5007), but in general our selection criteria worked very well, and our spectroscopy revealed a wealth of interesting objects. We list the results of spectroscopy in Table 17 and discuss the newly discovered objects below.

4.1. *New LBV Candidates*

The vast majority of our discoveries were stars whose spectra are extremely similar to those of known LBVs. Of course, these stars cover a significant range in spectral properties, and, in addition, some of these stars are known to have drastic changes in their spectra. We illustrate some current and past spectra in Figures 10-23, where we draw primarily from the eight previously known LBVs in M31 and M33.

4.1.1. *Hot LBV Candidates*

Generally, during the visual minimum ("quiescent") phase, the optical spectra of high-luminosity LBVs are marked by strong emission in the lower hydrogen lines (Hα, Hβ, and Hγ), plus emission of singly ionized metals, primarily [Fe II] (Massey 2000 and references therein). We consider the prototype of this spectrum to be the current spectral state of Var C, one of the original Hubble & Sandage (1953) variables, although many other LBVs in M31 and M33 share this spectral characteristic, such as A-1 and Var 15, as shown in Figure 10. A 1983 spectrum of AE And shown in Kenyon & Gallagher (1985) is very similar, and we used this star's line list to identify lines shown in Figure 10.[13] S Doradus itself, the star whose name is used to refer to the class of objects now known as LBVs, has shown similar spectra (see Fig. 2 of Wolf & Kaufer 1997). It should be noted that at our dispersion, these spectra are sometimes indistinguishable from those of the high-luminosity B[e] stars, which Conti (1997a) has argued are not LBVs. The emission in B[e] stars is believed to originate in a disk, as demonstrated by the study of R136 (in the LMC) by Zickgraf et al. (1985). In contrast, the emission in the quiescent LBVs shows P Cygni profiles at high dispersion (cf. Kenyon & Gallagher 1985). Here we call stars that resemble Var C, AE And, and Var A-1 "hot LBV candidates," but we note that more detailed studies might reclassify some of them as B[e]. In the nomenclature of Bohannan (1989) such stars would be called "A extr." Massey et al. (1996) discovered four such stars in M33 by observing the brightest UV sources, and King et al. (1998) discovered five similar objects in M31 based on observing Hα-bright sources. It is unsurprising that many more remained to be discovered.

We begin by showing the spectra of 10 similarly hot LBV candidates, five in M31 and five in M33, compared to that of Var A-1 in Figure 12. We include in this figure one previously identified LBV candidate, J004417.10+411928.0 (k350 in the study of King et al. 1998). For ease of displaying these spectra we have

[13] Our 2006 September spectrum of this star shows some changes in the intervening 23 yr, with the Balmer lines and He I lines now showing P Cygni profiles, which were missing in the 1983 spectrum. We show our spectrum in Fig. 11 for comparison to Fig. 4 in Kenyon & Gallagher (1985).

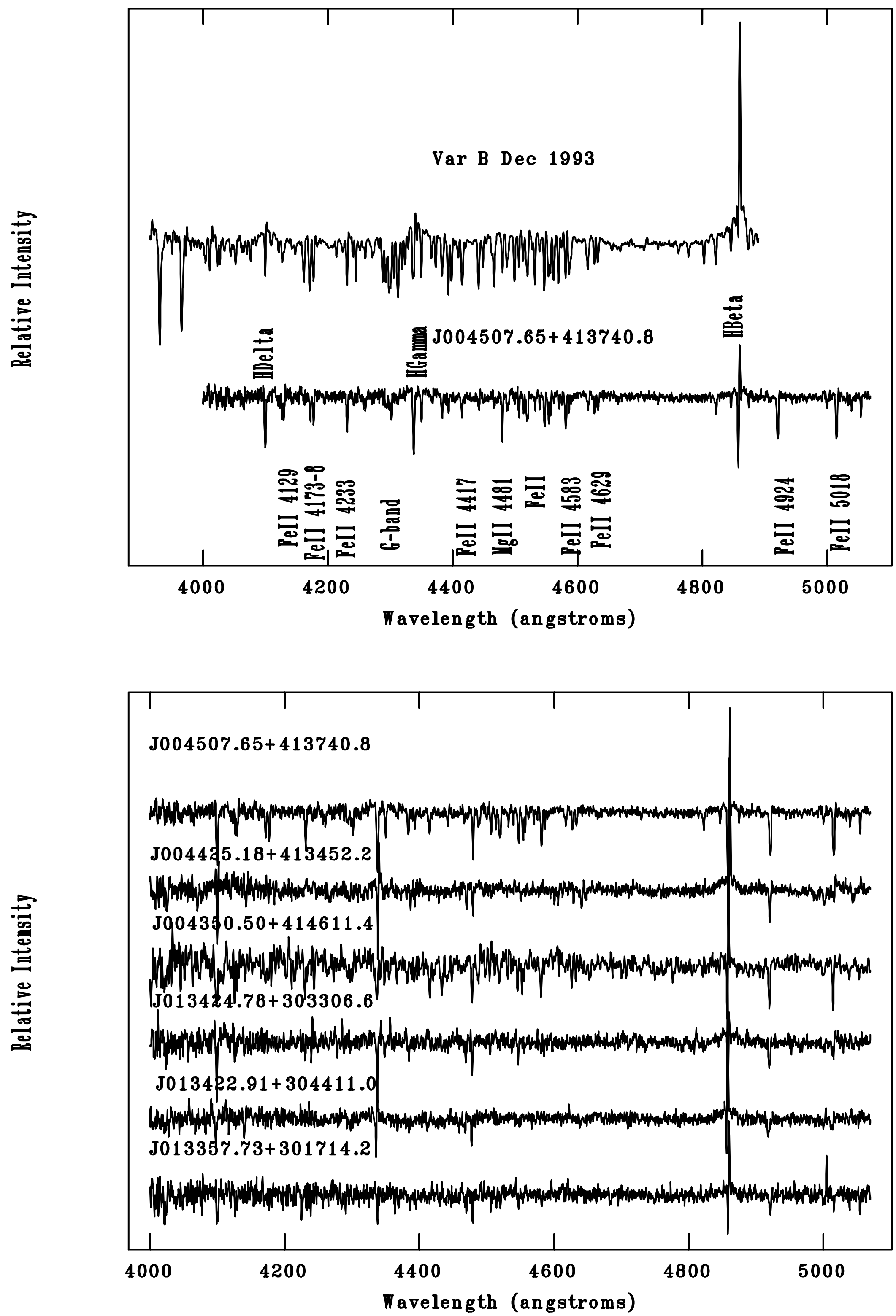


FIG. 19.—Blue absorption spectra of newly found LBVs in their cool state. In the top panel we compare the spectrum of the M33 LBV Var B during outburst to that of the M31 star J004507.65+413740.8. We have identified some of the prominent lines in J004507.65+413740.8 using the very useful line list given by Coluzzi (1993). In the bottom panel we show the spectra of J004507.65+413740.8 compared to those of the other five newly found "cool" LBV candidates in M31 and M33, with the spectra scaled to emphasize the absorption components. The star J004425.18+413452.2 was previously described as an LBV candidate (k411) by King et al. (1998). See also Fig. 20.

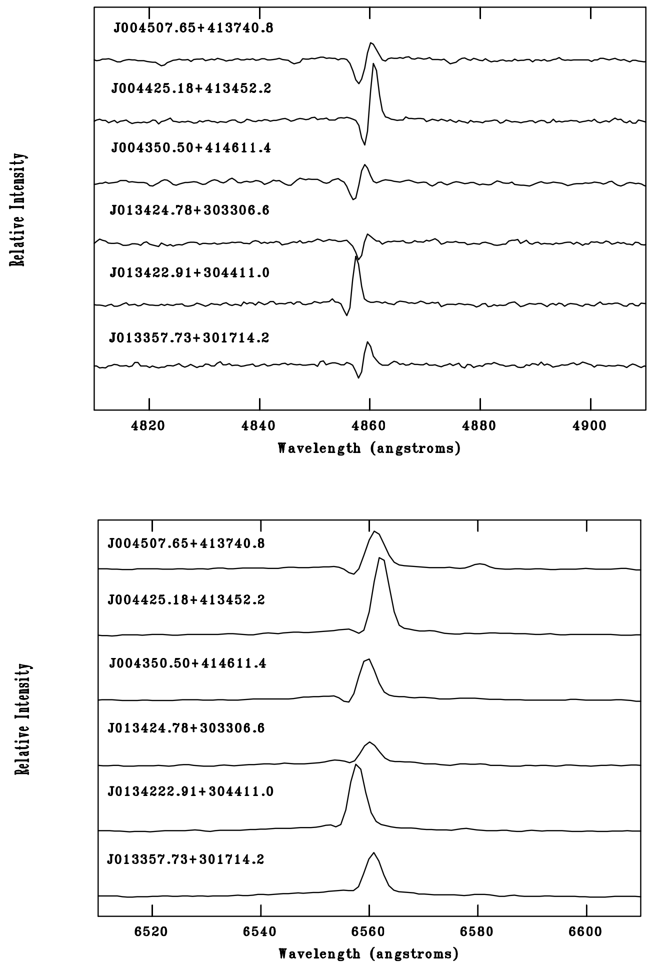


FIG. 20.—Emission spectra of newly found LBVs in their cool state. Here we show the Hβ profiles (*top*) and Hα profiles (*bottom*) of our cool LBV candidates. See also Fig. 19.

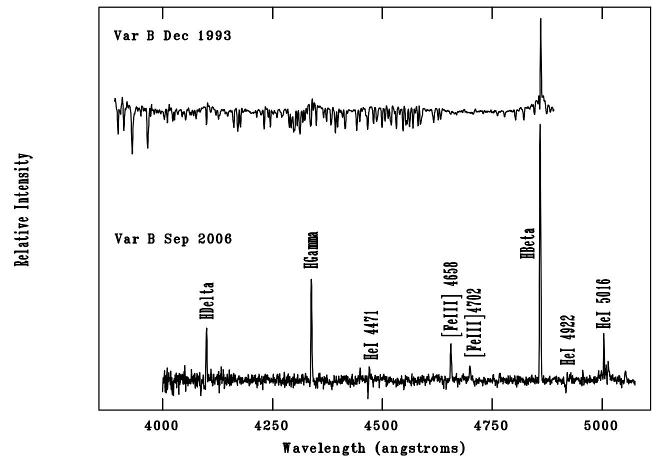


FIG. 21.—Changes in the spectra of the M33 LBV Var B. We show the spectrum of Var B obtained in 1993 December (during its 1992–1993 outburst) compared to that obtained in 2006 September.

(roughly) divided them into stars whose [Fe II] and Fe II lines are stronger than those in Var A-1 (Fig. 12, *top*) and those with weaker lines (Fig. 12, *bottom*).

Two additional such stars were found in M31 by N. Caldwell: J004229.87+410551.8 and J004322.50+413940.9. Both spectra are somewhat peculiar (Fig. 13). The spectrum of J004229.87+410551.8 may be a composite. Although the Balmer lines are in emission and [Fe II] is present, the strength of the H and K Ca II lines and the presence of the G band would indicate a much cooler absorption spectrum than we see in the other hot stars. The spectrum of the other star, J004322.50+413940.9, looks at first blush to be that of a P Cygni–type LBV, with strong P Cygni profiles in the lower Balmer lines (Hα, Hβ, and Hγ). However, closer inspection reveals P Cygni lines in (permitted) Fe II, notably λ4924, λ5018, and λ5169.[14] The spectrum of Var C shown by Kenyon & Gallagher (1985) also showed strong P Cygni profiles in many of the permitted Fe II lines and is also lacking in He I. However, J004322.50+413940.9 is somewhat peculiar compared to the Kenyon & Gallagher (1985) Var C exposure, as the many other strong Fe II emission lines in the blue are not evident. Possibly this is due to the lower resolution and modest S/N of the spectrum. There is also an absorption line near 4643 Å that we were unable to identify unambiguously. Both of these stars show significant photometric variability over the timescale of a decade, as shown below.

There are another five stars (one in M31 and four in M33) for which we have blue spectra similar to those of the hot LBV candidates. All have Hβ and Hγ in emission, and all also show He I λ4922 and λ5016 in emission. However, any [Fe II] or Fe II emission is so weak as to be considered either incipient or uncertain. We show their spectra in Figure 14, where we have again included the spectrum of Var A-1 for comparison. One of these stars, J004411.36+413257.2, was previously described as an LBV candidate by King et al. (1998), where it was listed as k315a.

We have only a red spectrum of the M33 star J013332.64+304127.2 (Fig. 15, *top and middle*), but it too reveals Balmer emission plus [Fe II] and Fe II emission. This star would simply serve as another example of a hot LBV candidate were it not for the fact that it is M33WR41 (AM2), whose spectrum was called WNL by Massey & Johnson (1998), based on an observation made in 1982 September and shown in Figure 2*b* of Massey & Conti (1983), where it is identified as number 28. We have checked the cross-identification carefully, and there appears to be nothing amiss. The star J013332.64+304127.2 is certainly the star labeled 2 in Armandroff & Massey (1985), where it showed up in on-band, off-band imaging in He II λ4686. Furthermore, it was independently identified as being bright in He II λ4686 in the *HST* imaging of Drissen et al. (1993), where they identified it as NGC 595-WR6. In Figure 15 we compare the two. Although the 1982 spectrum is quite noisy, there is no question that it is of a WN-type WR. The resolution of the 1982 data (taken with the Intensified Image Dissector Scanner on the KPNO 4 m) is 6 Å, and it is possible that the star was actually an Ofpe/WN9, with the P Cygni absorption components washed out by the relatively low resolution. Unfortunately, it was not in the sample of M33 WRs recently reobserved by Abbott et al. (2004). The star HDE 269858 (Radcliffe 127) is (or rather, was) an Ofpe/WN9 star that underwent an LBV-like outburst in 1980 (Stahl et al. 1983). We believe that J013332.64+304127.2 (AM2) is another such example.

The spectra of two stars in IC 10 are very similar, although they do not have the S/N needed to reveal weak emission (Fig. 16). One of these stars, J002020.35+591837.6, is located just 1.6″ from RSMV8 (J002020.56+591837.3), classified as WN10 by Crowther et al. (2003). Their classification is equivalent to the Ofpe/WN9

[14] Given the dispersion of the Hectospect spectra, we could not be certain of the line identifications. We considered the possibility that the first two lines were He I λ4922 and λ5016. However, the absence of any other He I lines in the spectra ruled this out.

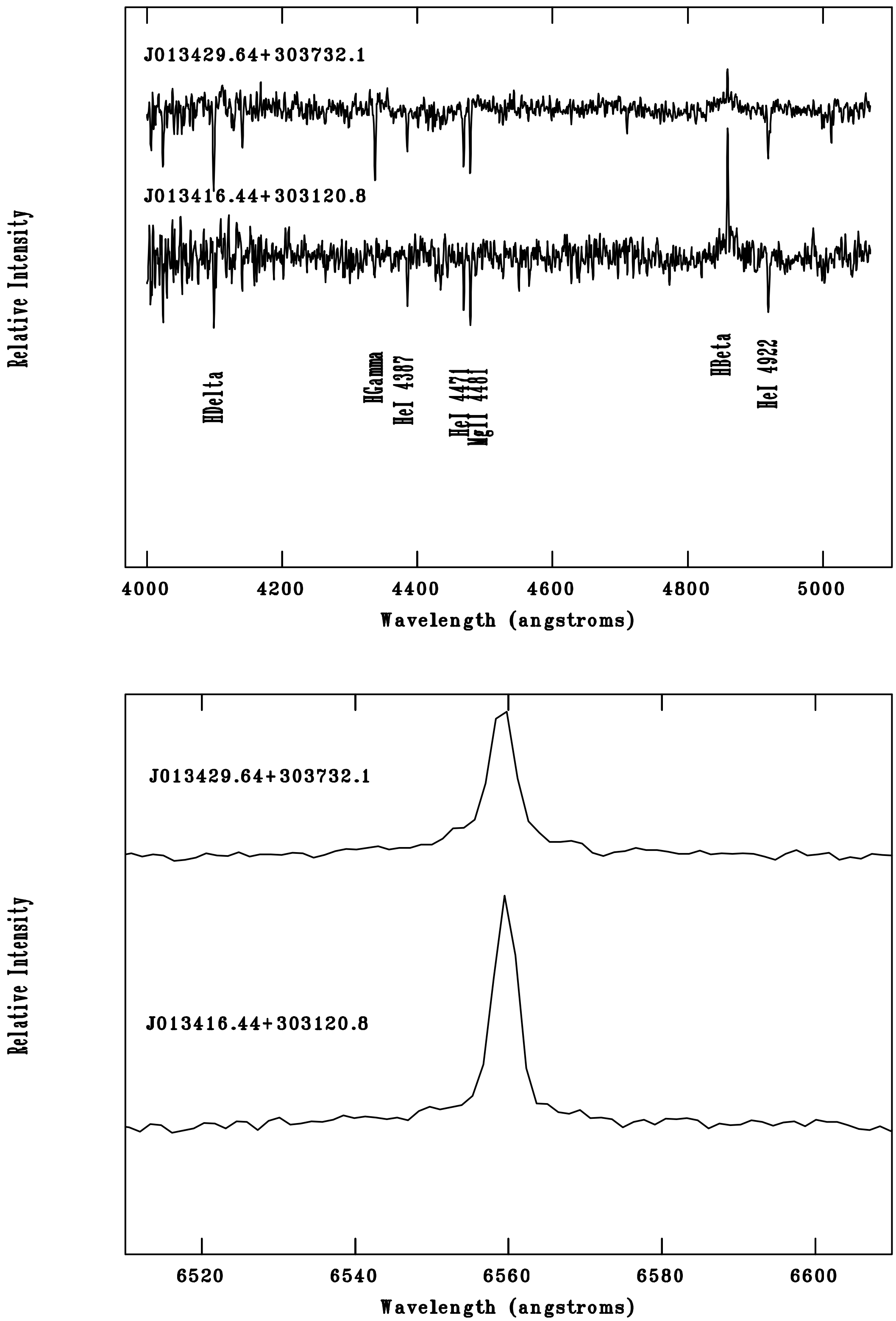


FIG. 22.—Two possible additional cool LBV candidates. These stars show B8 I absorption spectra, with Hβ and Hα emission. Both the Hβ and Hα profiles show a very broad component with a narrow component superposed.

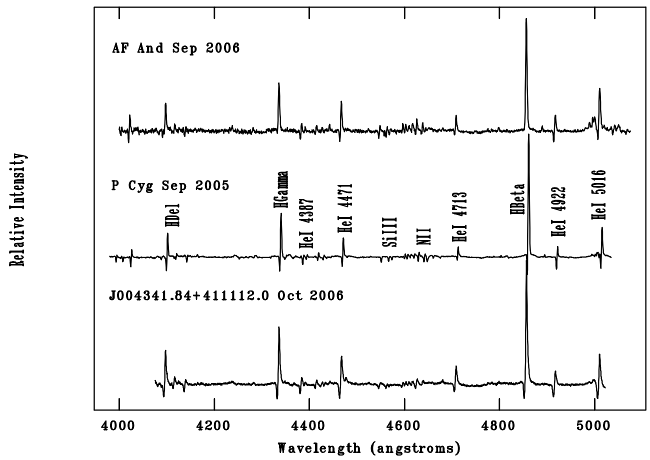


Fig. 23.—Spectra of P Cygni LBVs. The upper spectrum is of AF And, an LBV in M31. The middle spectrum is of P Cyg itself. The bottom spectrum is of the star J00341.84+411112.0, an LBV candidate in M31 (Massey 2006). Prominent lines are labeled.

designation. We do not think, however, that our spectrum of J002020.35+591837.6 has been contaminated by this object, as we used the 2″ diameter red fibers for the observation, and RSMV8 is at least a magnitude fainter than J002020.35+591837.6.

A third IC 10 star and the only NGC 6822 star to prove of interest are even less certain examples; J002016.48+591906.9 (IC 10) and J194503.77−145619.1 (NGC 6822) show only Balmer emission. The star J013442.14+303216.0 (M33) is very similar. We show their spectra in Figure 17. It is a stretch to call these LBV candidates based on these spectra, so we include a "?" in their classification. Higher S/N data are clearly warranted, as they *may* reveal [Fe ii] emission. We note, however, that J002016.48+591906.9 (IC 10) showed photometric variability at the 0.7 mag level in a 10 yr period (see below), bolstering its case.

4.1.2. *Cool LBV Candidates*

At outburst (visual maximum), the spectra of LBVs are often said to resemble that of an extreme F-type supergiant, with the absorption arising in a "pseudophotosphere" (see, e.g., Humphreys & Davidson 1994). The spectra of all five of the original Hubble-Sandage variables (Var 2, Var A, Var B, Var C, all of which are in M33; and Var 19 in M31) were in this state when observed by Hubble & Sandage (1953).[15] We use Var B during its 1992–1993 outburst (Szeifert et al. 1996) as the archetype (Fig. 18). We would estimate the spectral type of this photosphere to be late-F or even early-G type. The figure shows that S Dor exhibited a very similar spectrum in 1999 October, although the star was clearly *not* undergoing a (photometric) outburst at the time (Massey 2000). This, we believe, underscores how complex and poorly understood the LBV phenomenon really is, and why additional examples of LBVs can only help improve our understanding of the LBV phenomenon. We refer to LBVs showing such spectra as being in their "cool state" rather than in outburst.

We did not observe any star that was quite as extreme as Var B during its outburst. However, there are six stars that show underlying absorption spectra which are not that late, more like B8 to early-F, along with very strong emission at Hα and P Cygni profiles at Hβ. We compare the spectrum of one of these, J004507.65+413740.8, to that of the outburst spectrum of Var B in Figure 19 (*top*). Clearly, J004507.65+413740.8 is of earlier type (compare, e.g., the strength of the G band). We estimate the absorption spectral type as F2 Ia. We show all six spectra in Figure 19 (*bottom*), where we have scaled the figure to emphasize the absorption spectra. Note that the two lines to the red of Hβ are clearly Fe ii $\lambda\lambda$4924, 5018, and not the He i $\lambda\lambda$4922, 5016 lines visible in the spectra of the hotter stars discussed above. This is evident not only from the wavelengths but also from the lack of other, usually stronger, He i lines, such as λ4471. The emission profiles of Hβ and Hα can be found in Figure 20. This shows that all six have strong P Cygni profiles in the Balmer lines.

It is interesting to note that our 2006 September observation of Var B shows a fairly boringly weak emission-line spectrum with the Balmer lines in emission, slight P Cygni emission in the He i lines, and a few doubly ionized forbidden Fe lines, i.e., [Fe iii] $\lambda\lambda$4658, 4702. We compare this to the 1993 December spectrum in Figure 21. It is hard to believe we are looking at the same star! Less dramatic spectral changes for Var B on the timescale of months were discussed and illustrated by Szeifert et al. (1996).

We do have spectra of two other M33 stars which may be "cool" LBV candidates: J013416.44+303120.8 and J013429.64+303732.1. Both of these show an absorption spectrum typical of a B8 I star. However, Hβ shows a very narrow emission component superposed on a very broad component. We show the blue spectra in Figure 22 (*top*). We also show the Hα profiles in Figure 22 (*bottom*). Such a broad profile could be indicative of a rapidly rotating disk, but it could also be indicative of a more optically thick wind, reminiscent of WRs. The narrow emission component could be nebular, although the region around the Hα profile seems to suggest otherwise, as there is no sign of the [N ii] $\lambda\lambda$6548, 6584 lines nor is there [O iii] λ5007 emission characteristic of a nebula. The broad components extend to $\pm$600–1000 km s^{-1}.

4.1.3. *P Cygni LBV Candidates*

Of course, not all LBV spectra fall into these two extremes. The most notable exception is the Galactic star P Cygni. This star contains no Fe ii or [Fe ii] features, but instead the He i and Balmer lines show characteristic line profiles that bear the name of this famous star: there is a blueshifted absorption component, with a strong emission component extending redward from the line center. A good S/N spectrum also reveals lines of N ii, indicative of enriched material at the stellar surface. We show the spectra of P Cygni, AF And, and J004341.84+411112.0 in Figure 23. Although the latter has not shown the same sort of spectacular photometric outbursts that characterize LBVs, its spectrum is uniquely similar to that of P Cygni itself, and like P Cygni it may be surrounded by nebulosity indicative of a past eruption—about two millennia ago in the case of J004341.84+411112.0 (Massey 2006). The spectrum of J004341.84+411112.0 shown here is new, was acquired with the MMT 6.5 m on 2006 October 28, and will be discussed elsewhere; here we just note that the N ii features only hinted at in the lower S/N spectra shown by Massey (2006) are quite obvious in these higher S/N data.

We identify six similar stars here and compare their spectra to that of P Cygni in Figure 24. Although all six show strong P Cygni components in the Balmer lines, and some in the He i lines (i.e., J004242.33+413922.7, J013351.46+304057.0, and J013416.07+303642.1), none show the startlingly close resemblance to P Cygni itself that J004341.84+411112.0 (Fig. 23) does. Still, the same three that show He i P Cygni also show evidence of the N ii emission bands indicative of enriched material at the surface. In the case of J013416.07+303642.1 we show our MMT spectrum of the star, as our Hydra spectrum has significant nebular contamination.

[15] Note that Var A is now considered to be an LBV candidate by some; see Humphreys & Davidson (1994) and Parker (1997).

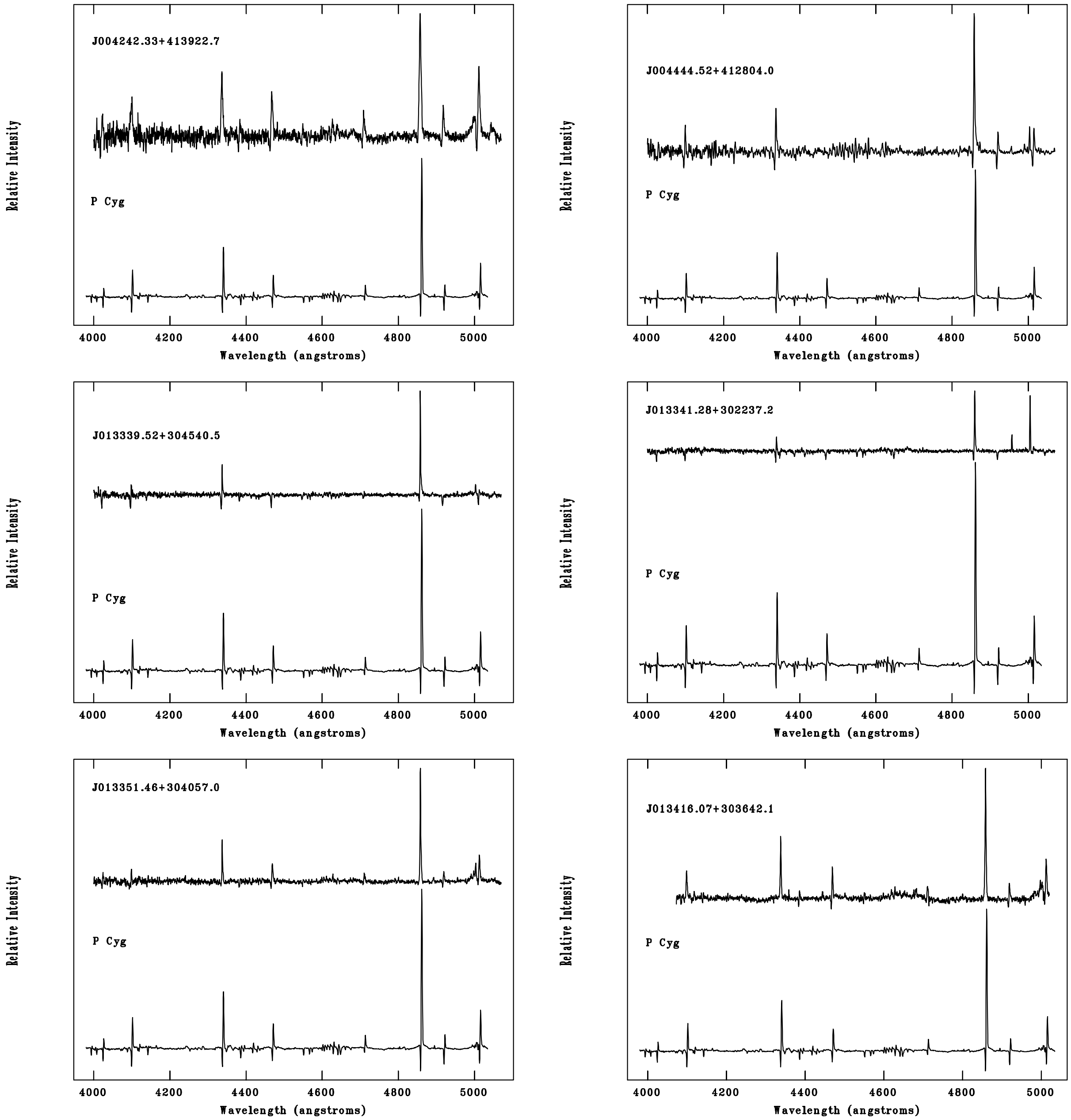


Fig. 24.—Spectra of P Cygni–type LBV candidates in M31 and M33. We compare the blue spectra of six more LBV candidates to that of P Cygni. For line identifications, see Fig. 23. The star J013416.07+303642.1 was also described as an LBV candidate by Corral (1996), who called it H108.

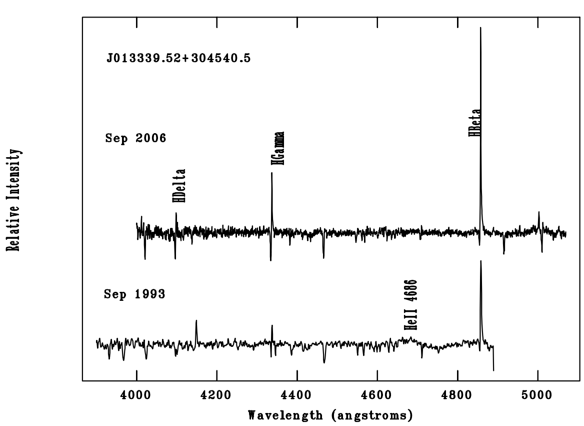


Fig. 25.—Spectrum of the M33 star J013339.52+304540.5 in 1993 and 2006. Emission in the Balmer lines has strengthened, and the broad He II λ4686 feature in the 1993 spectrum has disappeared.

One of these P Cygni–like stars, J013339.52+304540.5, had previously been classified as B0.5 I+WNE (Massey et al. 1996, where it was called UIT154; the star is listed in Massey & Johnson [1998] as M33WR57). Its spectrum was also described by Crowther et al. (1997), where it was referred to by its Humphreys & Sandage (1980) designation, B517. We compare the 1993 spectrum with that from 2006 in Figure 25. The broad He II λ4686 feature has clearly disappeared, while the Balmer emission has gotten stronger. (In 1993 Hδ was primarily absorption, while in 2006 it showed strong P Cygni emission.) Nevertheless, the P Cygni lines were quite evident in the 1993 spectrum, and the classification of this star as B0.5 I+WNE appears, in retrospect, to have been overly simplistic. Crowther et al. (1997) described it as WN11h based on a 1995 optical spectrum; the star showed only weak He II λ4686 at that time. Finally, we note that another of these P Cygni–like LBV candidates, J013341.28+302237.2, had previously been called a B1 Ia by Monteverde et al. (1996), who refer to the star by its designation

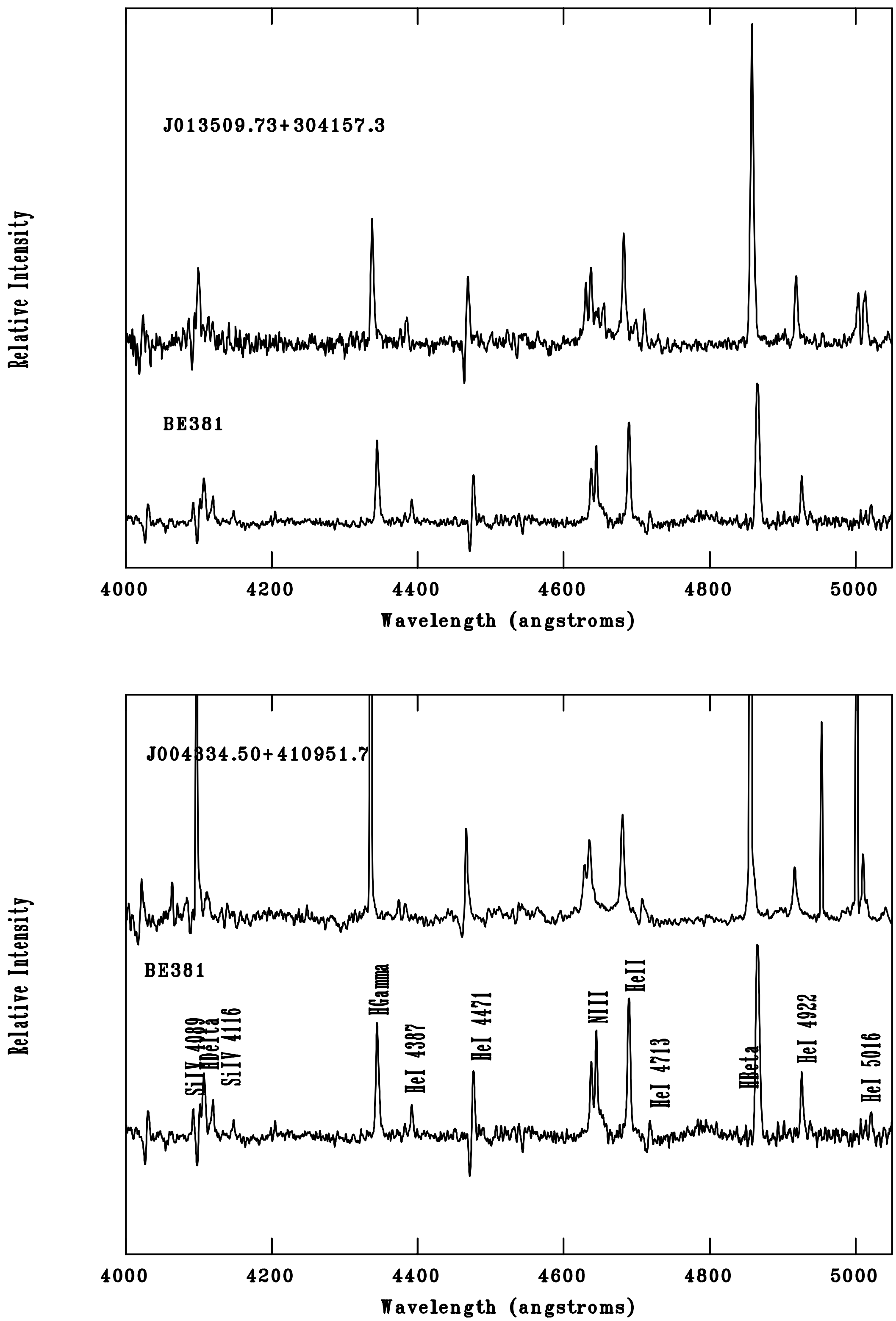


FIG. 26.—Spectrum of two newly discovered Ofpe/WN9 stars in M33 (*top*) and M31 (*bottom*). For each star, we compare the spectra to the LMC star BE 381, one of the original Ofpe/WN9 stars (Bohannan & Walborn 1989). The star J013509.73+30417.3 is also known as Romano's Star, an LBV candidate recently found independently to be in an Ofpe/WN9 state by Viotti et al. (2007).

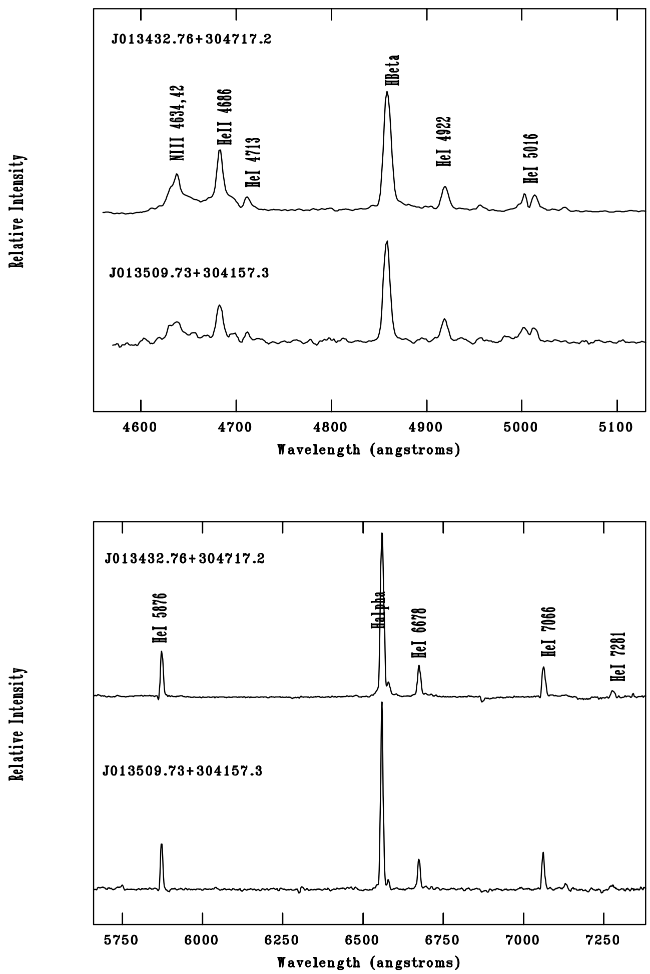


FIG. 27.—Red spectrum of an additional Ofpe/WN9 star in M33. Here we compare the spectrum of J013432.76+304717.2 to that of J013509.73+304157.3. The blue spectrum of the latter is shown in Fig. 26.

in Humphreys & Sandage (1980), 110-A. Its spectrum is shown in Monteverde et al.'s (1996) Figures 1 and 2. Although Hα is in emission, there is no sign of P Cygni emission at Hγ, although it may be partially filled in by emission. Thus, the spectrum has clearly changed, as Hγ has roughly equal absorption and emission components in our spectrum (Fig. 23) of this star. Monteverde et al. (1996) did not include Hβ.

4.1.4. *Ofpe/WN9 LBV Candidates*

Further complicating the LBV issue, R127, AG Car, and HDE 269582 are three examples of stars whose spectra at minimum light are Ofpe/WN9 stars (Walborn 1977; Bohannan & Walborn 1989; Humphreys & Davidson 1994 and references therein; see also Smith et al. 1995). Therefore, we have chosen to discuss newly found "slash stars" with the other LBV candidates rather than with WRs. We also find below that the Ofpe/WN9 stars tend to be photometrically variable.

We show the blue spectra of J013509.73+304157.3 (M33) and J004334.50+410951.7 (M31) in Figure 26, where we use the LMC star BE 381 as a reference. BE 381 was one of the stars that originally defined the class (see Bohannan & Walborn 1989), and its spectrum was kindly made available by B. Bohannan. The M33 star J013509.73+304157.3, also known as Romano's Star, is known to be photometrically variable by more than a magnitude (Romano 1978) and is usually included in lists of LBV candidates

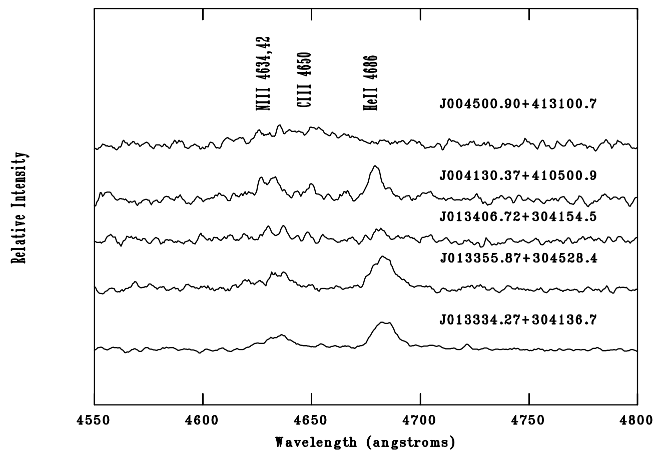


FIG. 28.—Spectra of other newly found WR stars in M31 and M33. We classify all of these as WNL except for J004500.90+413100.7, which is a WC.

(see, e.g., Parker 1997). Its spectrum was recently discovered independently to have changed to that of Ofpe/WN9 (Viotti et al. 2007). The Ofpe/WN9 nature of the M31 star J004334.50+410951.7 is newly discovered here.

A third star, J013432.76+304717.2, located in M33, we also call Ofpe/WN9. We have only a "red" spectrum (>4550 Å) of this star. The spectrum is shown in Figure 27, where we compare it to that of J013509.73+304157.3. They are clearly quite similar.

With the addition of these newly found Ofpe/WN9 stars, the number of such stars known in M31 is now two, and in M33 it is eight. Such stars are quite rare.

4.2. *Wolf-Rayet and Of Stars*

We expected to find few WRs: we saw in § 3 that our selection criteria eliminated the vast majority of known WRs, primarily at the stage of eliminating H II regions via the [O III] $-$ *C* restriction. This is simply because most WRs are found in H II regions. The exceptions tended to be the previously known Ofpe/WN9 stars, which generally were retained in our Hα catalogs. Nevertheless, we found three new WRs in M31 and three or four new WRs in M33 (one of which may simply be an Of star) and identified a classification problem with a previously identified WR.

Of the other stars with WR-like emission lines, one is a WC-type, three are WN-type, and one is likely to be an Of star rather than a WN. We show their spectra in Figure 28. For the WRs, the low S/N of the data, plus the presence of nebular emission, precludes a more precise classification than WNL (based on the strength of N III λ4634, 4642 for the WNs) and WC.

The M33 star J013406.72+304154.5 by far has the weakest emission of any of these. That star had been classified by Massey et al. (1996) as an early-O star, which we would indeed expect to have the N III λ4634, 4642 and He II λ4686 emission that characterizes Of stars. We measure its equivalent width to be -1.4 Å. This is significantly weaker than the -10 Å usually taken as the cutoff between WNs and Ofs, and so we call it an Of star. We note with some amusement that this star is located just 5$''$ to the north of the much brighter LBV candidate J013406.63+304147.8.

The M33 star J013334.27+304136.7 is very close (1.7$''$) to another known WNL star, J013334.31+304138.3 (M33WR49 = AM6).

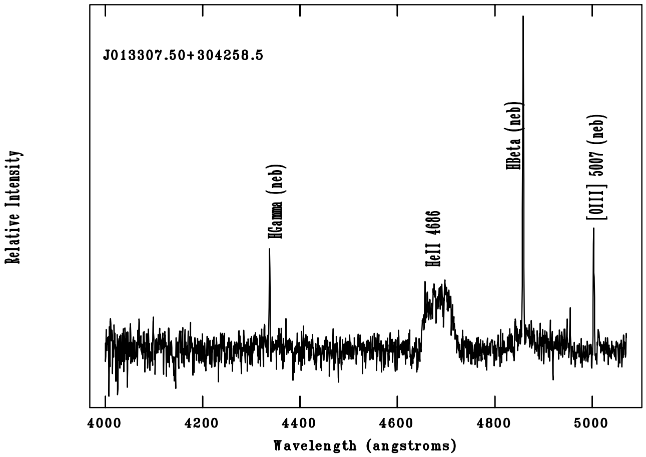


FIG. 29.—Spectrum of the M33 star J013307.50+304258.5. This is a previously recognized WR star, but one which was not properly classified until now.

It is possible that the light from the latter contaminated our spectrum of the former, although the region around He II λ4686 looks identical on both our blue exposure, taken with a 3.1″ diameter fiber, and our red exposure, taken with a 2.0″ diameter fiber. It is also conceivable that the cross-identification of M33WR49 with J013334.31+304138.3 is wrong, and that the correct identification should have been with J013334.27+304136.7. Future observations will have to resolve that issue. The WNL star J013355.87+304528.4 (M33) is 7.4″ from J013355.60+304534.9 (M33WR107 = MJ B17), another WN star, but this separation is large enough that there is likely to be no confusion.

4.2.1. *J013307.50+304258.5 = M33WR19*

The star J013307.50+304258.5 was classified by Massey et al. (1996) as WNE+B, where it was designated UIT041. The star was recognized as being blue by Humphreys & Sandage (1980), where it is called "B52." Massey & Johnson (1998) repeat the WNE+B spectral type and rechristen it as M33WR19. It is quite bright, with a continuum magnitude of $\sim$17.2.

Our blue spectrum of this star reveals a very flat-topped He II λ4686 and no absorption lines present. We rechecked the spectra used by Massey et al. (1996) and found that the spectra of UIT041 and UIT177 were interchanged in their Figure 6. The classification WNE+B really belongs to UIT177 (M33WR75 in Massey & Johnson [1998], or J013343.34+303534.1), which was also called "WN4.5+O6-9" on the basis of a better spectrum. The real classification of UIT041 (=J013307.50+304258.5 = B52 = M33WR19) was never made.

The spectrum we show in Figure 29 shows a very broad He II λ4686 feature. The width (60 Å) would suggest it is an early-type WN, but the equivalent width of about -20 Å is quite weak for a WNE; see Figure 5 in Armandroff & Massey (1991). The star is 1.5″ to the west of a bright late-type star (J013307.60+304259.0) which compromised our red spectrum of the object.

4.3. *Supergiants in* H II *Regions*

There are six stars which we observed whose presence in the Hα list is due to their lying in an H II region (as evidenced by [O III] $\lambda\lambda$4959, 5007, [N II] $\lambda\lambda$6548, 6584, and [S II] $\lambda\lambda$6717, 6731 emission) but whose blue spectra reveal them to be interesting supergiants in their own right. We show their spectra in Figure 30. In the top panel are two late-A or early-F type supergiants. Such stars are very rare. In the bottom two panels we show the spectra of four B supergiants, ranging from B1 I to B8 I: J013300.86+303504.9 (B1 I), J013339.42+303124.8 (B3 I), J004434.65+412503.6 (B3 I), and J013359.01+303353.9 (B8 I). We have identified the strongest lines, using Coluzzi (1993)[16] and Walborn & Fitzpatrick (1990). Three of the stars had been

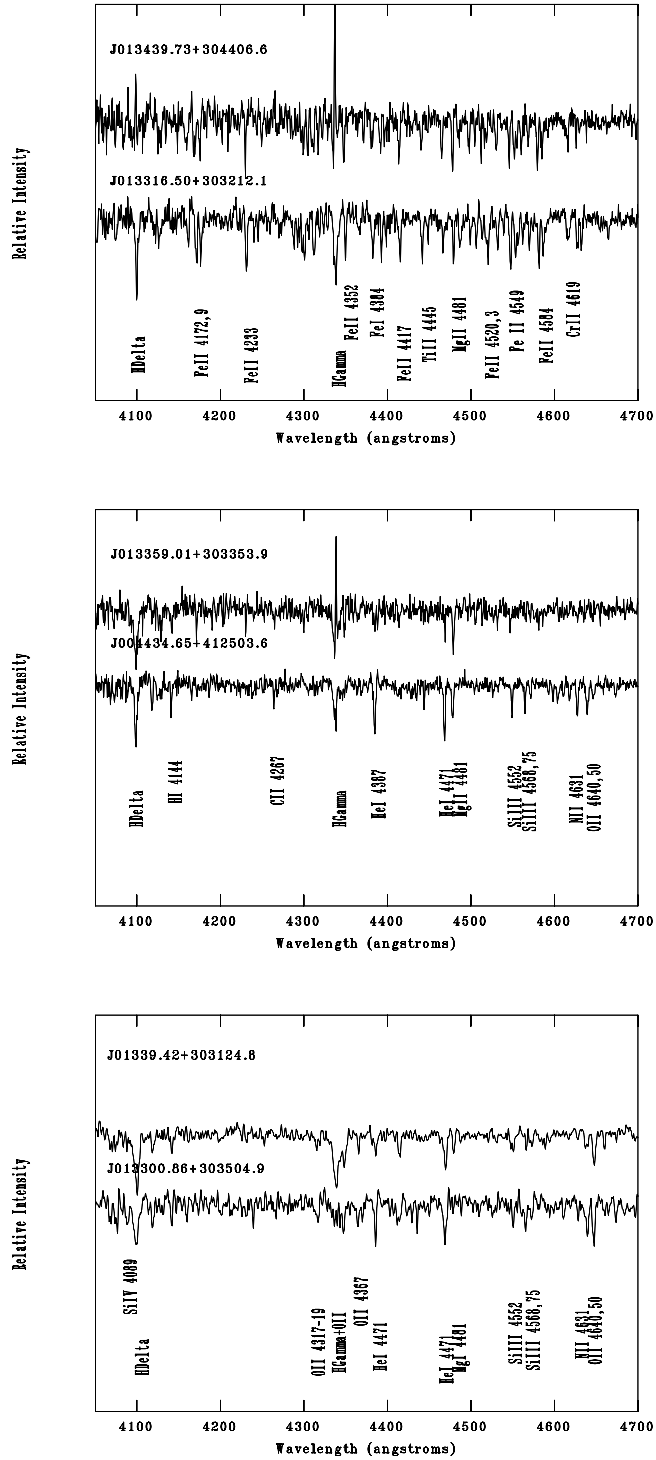


FIG. 30.—Spectra of supergiants found in H II regions in M31 and M33. In the top panel we show the spectra of two A/F supergiants. We estimate the spectral types to be late A or early F. In the middle panel we show the spectra of two B-type supergiants. The spectral types are B3 I (J004434.65+412503.6) and B8 I (J013359.01+303353.9). In the bottom panel we show the spectra of two more B-type supergiants. The spectral types are B3 I (J013339.42+303124.8) and B1 I (J013300.86+303504.8).

[16] Available at http://cdsweb.u-strasbg.fr/htbin/Cat?VI/71.

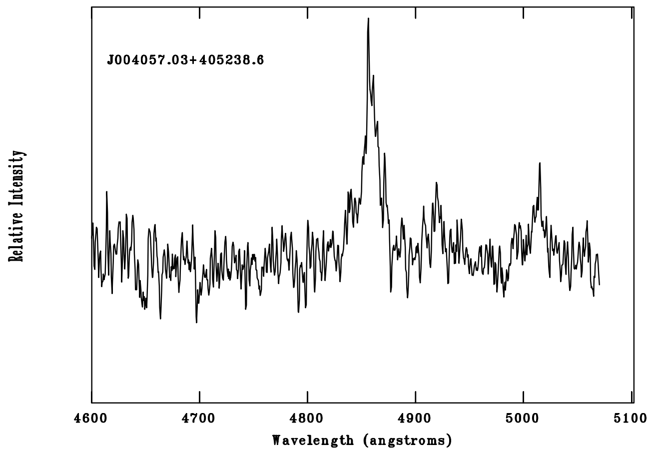


FIG. 31.—Spectrum of an unusual emission-line source in M31.

previously classified. The star J004434.65+412503.6 was classified as B1: from spectra obtained in Paper I; our spectrum here is superior, and we adopt the B3 I type. The star J013300.86+303504.9 was called B1.5 Ia+ by Massey et al. (1995), in essential agreement with the B1 I type assigned here, which we prefer. The star J013339.42+303124.8 was called B1 Ia by Massey et al. (1995), but our current spectra shows it is somewhat later, and we adopt the B3 I type here.

4.4. *A Very Broad-line* Hα *Emission Object*

As in any such survey, there are a few truly peculiar objects which are not easily categorized. Our most interesting such object is J004057.03+405238.6, shown in Figure 31. We see very broad emission at Hβ (as well as at Hγ and Hδ, not shown). Are the two broad emission lines redward of Hβ He I $\lambda\lambda$4922, 5016, or could they be Fe II $\lambda\lambda$4924, 5018? We lack a red spectrum of the star, and the rest of the blue is too noisy to permit identification of weak lines. The FWHM of the Hβ profile is 20.5 Å, or nearly 1270 km s^{-1}. Such broad lines might be seen in WR stars, but there is no He II λ4686. The heliocentric radial velocity based on Hβ is -225 km s^{-1}. However, at its location at $X/R = -0.973$ (in the notation of Rubin & Ford 1970) we would expect a radial velocity of -530 km s^{-1}, significantly more negative. The object might be part of M31's halo population and not partake of the disk's rotation. Alternatively, the object might be variable in radial velocity. The broadness of the lines is a bit reminiscent of those of SS 433 (Margon 1984), although without showing the characteristic three components. Still, one is reminded of one of the early spectra of SS 433, caught when all three components had similar velocities (Margon et al. 1979). The object is coincident with long-period variable 15043 with a 330 day period (Mould et al. 2004) but does not appear to be an X-ray source. A similar object in M33 *may* be described by Neese et al. (1991). Whatever the object is, it is not one of the familiar emission-line objects (LBVs and WRs) that we have so far discussed.

5. DISCUSSION

Clearly, our survey has been very effective in identifying interesting objects. Our spectroscopy has identified 12 new LBV candidates in M31 (excluding the three previously suggested by King et al. [1998] that we reobserved here) and 18 new LBV candidates in M33. This brings the number of known or suspected LBVs to 24 in M31 and 37 in M33.[17] In addition, our spectroscopy identified three possible LBVs in IC 10 and one in NGC 6822; none had previously been reported in either galaxy. We give the full list of known and candidate LBVs in Table 18.

To what extent are we certain that these newly found objects are truly LBVs? In some cases, spectral and photometric variability may require decades—if not centuries, or even millennia—to manifest itself. Still, it is worth recalling that in this paper we found evidence of spectral variability for several of the LBV candidates. In some cases this spectral variability is spectacular, as we found for the (former) WR star AM2, whose spectrum now lacks either He II or N III.

We can also ask to what extent we know that these stars vary photometrically. Answering that is somewhat more difficult than is sometimes assumed, as many of the past photometric surveys, particularly the photographic ones, have large magnitude-dependent errors associated with them when compared to modern CCD data (see discussion in Paper I). For IC 10, we used some 1992 August CCD images obtained on the 4 m telescope by P. M. and G. H. J. and performed differential photometry of the LBV candidates relative to nearby stars, which we calibrated using the IC 10 LGGS photometry from Paper II. These data were previously unpublished and were obtained as part of testing T2KB, a (then) brand-new 2048×2048 device with 24 μm pixels. The seeing was quite poor, about 2.0″, which is why the data were not previously used. However, they do suffice to check for variability of two of the IC 10 LBV candidates; the third was too crowded. For M31 we compare the LGGS 2000–2001 *V*-band photometry of Paper I with the CCD photometry of Magnier et al. (1992), obtained from images taken in 1990. For M33 we use the photographic photometry of Ivanov et al. (1993). Some of the plates used in that study were obtained at the CFHT in the early 1980s; the rest were from plates obtained from the Rozhen 2 m telescope at an unspecified time. In Paper I we showed that the Magnier et al. (1992) data agreed well, on average, with the LGGS data. On the other hand, we found that there were problems with the Ivanov et al. (1993) photometry. For stars fainter than $V = 19$, the Ivanov et al. (1993) values were too bright compared to the LGGS data, with only fair agreement for stars brighter than $V = 19$.

We list the photometry and ΔV (in the sense of LGGS minus other) in Table 18. We see that the known LBVs show (absolute) differences of 0.6–1.5 mag, with some exceptions (Magnier et al. [1992] did not include photometry of AE And, and Var B shows only a -0.19 mag difference). In general, the (absolute) differences in the photometry of the LBV candidates is smaller, but perhaps this just means that these stars are not variable *at present*: after all, the archetypical P Cyg has shown little photometric variability over many decades of monitoring; see Israelian & de Groot (1999). Nevertheless, *some* of the LBV candidates listed in Table 18 show quite significant variations, of 0.6–1.3 mag. This includes some of the spectroscopically questionable LBV candidates, such as the IC 10 star J002016.48+591906.9.

We also checked to see which stars appear in the list of variables discovered by the DIRECT project, using a merged list of stars kindly prepared by A. Bonanos and based on the nine

[17] Parker (1997) lists 4 known and 5 candidate LBVs in M31, plus 4 known and 12 candidate LBVs in M33. However, among the latter group, he lists two of the stars twice, under separate names, not recognizing that Corral's (1996) S193 is the same star as Massey et al.'s (1996) UIT 301, and that Corral's (1996) S95 is the same star as Massey et al.'s (1996) UIT 212. The fact that Corral (1996) and Massey et al. (1996) were published at about the same time meant that these works did not cross-reference each other, resulting in some subsequent confusion.

TABLE 18

Spectroscopic Luminous Blue Variables in IC 10, M31, M33, and NGC 6822

LGGS	Type	Cross-ID[a]	Ref.	V LGGS	V Older[b]	ΔV	Other Var.[c]
			IC 10				
J002012.13+591848.0..........	Hot LBV candidate	...	1	19.37	19.48	−0.11	...
J002016.48+591906.9..........	Hot LBV candidate?	...	1	19.19	19.84	−0.65	...
J002020.35+591837.6..........	Hot LBV candidate	...	1	19.10	...	...	...
			M31				
J004043.10+410846.0..........	Hot LBV candidate	...	1	18.62	...	...	...
J004051.59+403303.0..........	P Cyg LBV candidate	...	2	16.99	...	...	...
J004056.49+410308.7..........	Ofpe/WN9	OB69-WR2	3	18.09	18.13	−0.04	...
J004229.87+410551.8..........	Hot LBV candidate	...	1	18.78	17.51	1.27	...
J004242.33+413922.7..........	P Cyg LBV candidate	...	1	18.56	...	...	...
J004302.52+414912.4..........	LBV	AE And	4	17.43	...	...	Spect. var., DIRECT IX D31J04302.5+414912.3
J004320.97+414039.6..........	LBV candidate	k114a	5	19.22	19.12	0.10	...
J004322.50+413940.9..........	Hot LBV candidate	...	1	20.35	...	...	...
J004333.09+411210.4..........	Hot LBV	AF And	4	17.33	16.44	0.88	...
J004334.50+410951.7..........	Ofpe/WN9	...	1	18.14	18.17	−0.04	...
J004341.84+411112.0..........	P Cyg LBV candidate	...	6	17.55	17.53	0.02	...
J004350.50+414611.4..........	Cool LBV candidate	...	1	17.70	17.54	0.16	...
J004411.36+413257.2..........	Hot LBV candidate	k315a	1, 5	18.07	18.02	0.05	DIRECT IX D31J04411.4+413257.2[d]
J004415.00+420156.2..........	Hot LBV candidate	...	1	18.29	...	...	...
J004417.10+411928.0..........	Hot LBV candidate	k350	1, 5	17.11	17.20	−0.09	...
J004419.43+412247.0..........	LBV	Var 15	4	18.45	16.97	1.48	...
J004425.18+413452.2..........	Cool LBV candidate	k411	1, 5	17.48	17.50	−0.03	DIRECT IX D31J04425.2+413452.1
J004442.28+415823.1..........	Hot LBV candidate	...	1	19.68	...	...	...
J004444.52+412804.0..........	P Cyg LBV candidate	...	1	18.07	...	...	DIRECT IV V13833 D31C
J004450.54+413037.7..........	LBV	Var A-1	7, 8	17.14	16.50	0.64	DIRECT IX D31J04450.6+413037.7
J004507.65+413740.8..........	Cool LBV candidate	...	1	16.15	16.34	−0.19	...
J004522.58+415034.8..........	Hot LBV candidate	...	1	18.47	18.52	−0.05	...
J004526.62+415006.3..........	Hot LBV candidate	...	1	17.16	16.31	0.84	...
J004621.08+421308.2..........	LBV candidate	k895	5	18.16	17.84	0.32	...
			M33				
J013235.25+303017.6..........	Hot LBV candidate	...	1	18.01	...	...	Hartman 250024
J013237.72+304005.6..........	Ofpe/WN9	M33WR2, MCA 1B, UIT003, H235	9, 10, 11	17.63	17.50	0.13	...
J013242.26+302114.1..........	Hot LBV candidate	...	1	17.44	18.30	−0.86	...
J013245.41+303858.3..........	Ofpe/WN9	M33WR5, UIT008	10	17.61	17.40	0.21	Hartman 250427
J013248.26+303950.4..........	Hot LBV candidate	...	1	17.25	...	...	...
J013300.02+303332.4..........	Hot LBV candidate	UIT026	10	18.32	18.00	0.32	Hartman 251233
J013309.14+304954.5..........	Ofpe/WN9	M33WR22, UIT045	10	17.91	17.81	0.10	Hartman 150200
J013324.62+302328.4..........	Hot LBV candidate	...	1	19.58	...	...	...
J013327.26+303909.1..........	Ofpe/WN9	M33WR39, MJ C7	12	17.95	...	...	Hartman 242552, Wise 31347
J013332.64+304127.2..........	Hot LBV candidate	M33WR41, AM2	1	18.99	19.20	−0.21	Spect. var.
J013333.22+303343.4..........	Hot LBV candidate	...	1	19.40	...	...	DIRECT VIII D33J013333.2+303344.5[e]
J013335.14+303600.4..........	LBV	Var C	4	16.43	15.20	1.23	Wise 31284

TABLE 18—*Continued*

LGGS	Type	Cross-ID[a]	Ref.	V LGGS	V Older[b]	ΔV	Other Var.[c]
			M33				
J013339.52+304540.5	P Cyg LBV candidate	B517, S193	1, 11, 13	17.50	17.68	−0.18	Spec. var.
J013340.60+304137.1	Hot LBV candidate	S204	11	18.31	18.20	0.11	...
J013341.28+302237.2	P Cyg LBV candidate	...	1	16.28	16.10	0.18	...
J013349.23+303809.1	LBV	Var B	1, 4	16.21	16.40	−0.19	Spec. var.
J013350.12+304126.6	Hot LBV candidate	UIT212, S95	10, 11	16.82	16.60	0.22	...
J013350.92+303936.9	Hot LBV candidate	UIT218	10	14.17	...	...	...
J013351.46+304057.0	P Cyg LBV candidate	...	1	17.73	17.80	−0.07	...
J013353.60+303851.6	Ofpe/WN9	M33WR103, MJ X15	12	18.09	18.50	−0.41	Hartman 23654
J013355.96+304530.6	Cool LBV candidate	UIT247, B324	10	14.86	15.20	−0.34	Wise 10327
J013357.73+301714.2	Cool LBV candidate	...	1	17.39	...	...	...
J013406.63+304147.8	Hot LBV candidate	UIT301	10	16.08	16.30	−0.22	...
J013410.93+303437.6	Hot LBV candidate	...	1	16.03	16.48	−0.45	Wise 21206
J013416.07+303642.1	P Cyg LBV candidate	H108	1, 11	17.95	18.10	−0.15	DIRECT VIII D33J013416.1+303641.8, Hartman 221349
J013416.10+303344.9	LBV candidate	UIT341, B526	10	17.12	16.70	0.42	...
J013416.44+303120.8	Cool LBV candidate	...	1	17.10	17.00	0.10	Wise 22199
J013418.74+303411.8	Ofpe/WN9	M33WR132, UIT349	10	19.58	19.20	0.38	...
J013422.91+304411.0	Cool LBV candidate	...	1	17.22	17.08	0.14	...
J013424.78+303306.6	Cool LBV candidate	...	1	16.84	...	...	...
J013426.11+303424.7	Hot LBV candidate	...	1	18.97	18.85	0.12	Hartman 222305
J013429.64+303732.1	Cool LBV candidate	...	1	17.10	17.42	−0.32	...
J013432.76+304717.2	Ofpe/WN9	...	1	19.09	18.90	0.19	...
J013442.14+303216.0	Hot LBV candidate?	...	1	17.34	...	...	...
J013459.47+303701.9	Hot LBV candidate	...	1	18.37	17.94	0.43	Hartman 210675
J013500.30+304150.9	Hot LBV candidate	...	1	19.30	...	...	...
J013509.73+304157.3	Ofpe/WN9	Romano's Star	1, 14	18.04	...	...	Hartman 110031
			NGC 6822				
J194503.77−145619.1	Hot LBV candidate?	...	1	18.24	...	...	Mennickent Field 2/Star 411

[a] Cross-IDs: MCA nnn designations are from Massey et al. (1987) and are listed in CDS; UITnnn designations are from Massey et al. (1996); M33WRnnn designations are from Massey & Johnson (1998) and known to CDS as [MJ98] WR nnn; Bnnn designations are blue stars from Humphreys & Sandage (1980); Hnn and Snnn designations are from Corral (1996) and known to CDS with the prefix [S92b]; knnn designations are from King et al. (1998); MJ designations are from Massey & Johnson (1998); AM nn designations are from Armandroff & Massey (1985) and known to CDS as [AM85] M33 nn; OB69-WR2 is from Massey et al. (1986).

[b] "Older" sources for the photometry are Magnier et al. (1992) for M31 and Ivanov et al. (1993) for M33.

[c] Other variability. We note whether the star is shown in this paper to be a spectral variable or cite references which claim that the star is photometrically variable. The latter includes the DIRECT series of papers (see text), Hartman et al. (2006), and Mennickent et al. (2006).

[d] Listed as a Cepheid with a period of 11.0987 days.

[e] Listed as a Cepheid with period of 9.985 days.

References.—(1) This paper; (2) Paper I; (3) Massey 1998; (4) Hubble & Sandage 1953; (5) King et al. 1998; (6) Massey 2006; (7) Rosino & Bianchini 1973; (8) Keynon & Gallagher 1985; (9) Willis et al. 1992; (10) Massey et al. 1996; (11) Corral 1996; (12) Massey & Johnson 1998; (13) Crowther et al. 1997; (14) Viotti et al. 2007 and references therein.

separate lists published by Kaluzny et al. (1998, DIRECT I; 1999, DIRECT IV), Stanek et al. (1998, DIRECT II; 1999, DIRECT III), Mochejska et al. (1999, DIRECT V; 2001a, DIRECT VII; 2001b, DIRECT VIII), Macri et al. (2001, DIRECT VI), and Bonanos et al. (2003, DIRECT IX). Their fields do not cover all of M31 and M33, so the lack of designation of a variable is not particularly telling, but several of these stars are listed. Two of them are identified as Cepheids from their light curves, which is not consistent with the spectra we show here. For M33 we also checked two additional resources: the updated version of the Hartman et al. (2006) variable list[18] and the Wise Observatory M33 variability study (Shporer & Mazeh 2006).[19] We are indebted to K. Stanek for calling both of these to our attention. These lists reveal several additional variables, the majority of which turned out to be the Ofpe/WN9 stars. Such long-term monitoring programs as the DIRECT project, Hartman et al. (2006), and the Wise Observatory project are quite valuable, and their continuation into the future is quite useful.

Our NGC 6822 LBV candidate is slightly too south to be included in the photometry of Bianchi et al. (2001). However, the star was found to be a low-amplitude, nonperiodic variable in the *I* band by Mennickent et al. (2006).

Only about 40% of the sources we observed spectroscopically proved to be interesting. It is not clear how the percentage will be affected going to fainter limits. Of the noninteresting objects, most proved to be H II regions, with a small smattering of stars without emission, principally in the two dwarf galaxies.

With our additional knowledge, could we further refine our selection criteria? In Figure 32 we compare our selection criteria to the "winners" (LBVs, LBV candidates, and Ofpe/WN9 stars) and "losers" (H II regions and the occasional star with no emission). We see that there is no adjustment we could have made in our selection criteria that would have favored the winners over the losers. Still, our approach has been one-dimensional, and it is possible that with the new data one could devise more effective selection criteria by a multidimensional approach.

It is worth noting that we cut off the selection of objects for spectroscopic observation at about $B = 19.5$; fainter than this, we expected to obtain no useful spectroscopic data with the WIYN telescope and Hydra. We obtained spectra of 42 stars in M31 and 79 in M33 (Table 17), but the complete catalogs (Tables 8 and 9) contain 307 and 820 stars, respectively, brighter than this limit. Thus, our spectroscopy, even at this magnitude limit, was only about 10% complete. We can therefore expect *many* more LBV candidates and other interesting objects to be found, with potentially profound effects on the statistics of LBVs in nearby galaxies. We expect that the actual number of LBVs, rather than being four each in M31 and M33 (as the generally recognized LBVs number), is probably more on the order of several hundred. This clearly has implications for the duration of the LBV phase.

Throughout this paper we have taken the conservative approach of referring to stars with spectroscopic similarities to known LBVs as LBV "candidates." In attempting to define an LBV at the 1996 Kona meeting, Bohannan (1997) argued that, "A star should not be considered an LBV because its current spectroscopic character is similar to that of a known LBV. Remember what is said about ducks: it may look like a duck, walk like a duck, but it is not a duck until it quacks." In this case, the "quacking" involves photometric variability, or possibly an outburst. In his redefinition of an LBV at the same meeting, Conti (1997b) concurred, arguing that an outburst is needed to "promote" a candidate to an LBV. Here we would make two points. First, many of the stars in this sample in fact do have demonstrated photometric variability, and at a level comparable to the known LBVs, at least over a 20 yr time span. We leave it to others to decide whether this variability is sufficient to promote any of these stars from candidate status to true LBVs. But, our more important point is that we would argue that the requirement of variability may be misguided. Major outbursts may occur only on timescales of centuries or millennia, and so we would argue that the lack of variability should not preclude a star from being considered an LBV. Perhaps instead spectral resemblance to known LBVs should be considered a sufficient criterion, as what other objects have such spectra? In a raft of ducks, at any one time, some will be quacking and some will not. Momentary silence does not transform a duck into a goose, nor would it confuse most bird spotters.

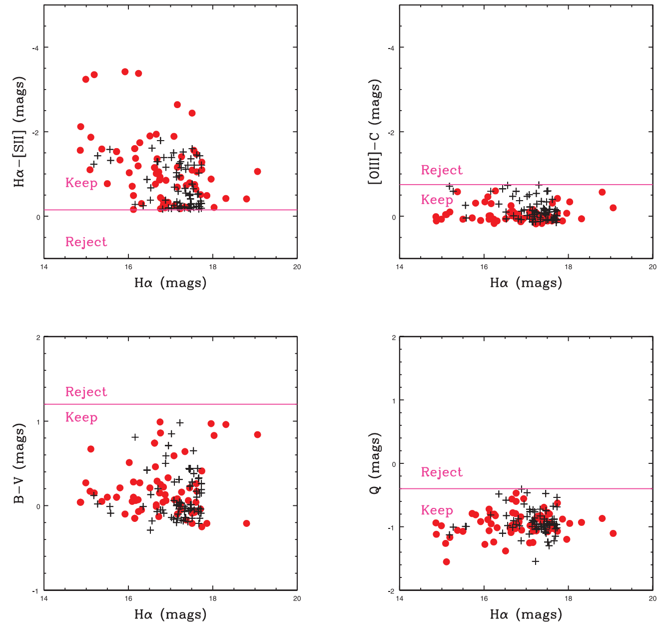


Fig. 32.—Selection criteria for Hα emission-line stars compared to "winners" (*red dots*) and "losers" (*black crosses*). The winners include the previously known and newly found LBVs, LBV candidates, and Ofpe/WN9 stars. The losers include H II regions and stars with no emission.

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[18] See http://www.astro.livjm.ac.uk/~dfb/M33/.
[19] See http://wise-obs.tau.ac.il/~shporer/m33/.

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