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Research Note

New Wolf-Rayet Stars in the Large Magellanic Cloud*

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Summary. The survey of two fields located in the eastern region of the Large Magellanic Cloud (LMC) lead us to detect 13 new Wolf-Rayet stars ($11.9 < m_{pg} \leqq 16.1$). The plates were taken with the 40-cm Objective Prism Astrograph using an interference filter (Breysacher and Azzopardi, 1978). 1975 coordinates, spectral classifications and finding charts are provided. The absolute magnitudes of the WR stars, calculated with an LMC absorption-free distance modulus of 18.5, are discussed in connection with the calibration by Smith (1973).

Key words: Large Magellanic Cloud – 30 Doradus Nebula – Wolf-Rayet stars

I. Introduction

A systematic search for Wolf-Rayet stars with the ESO Objective Prism Astrograph in the Small Magellanic Cloud resulted in the detection of four new WR stars of the WN type (Azzopardi and Breysacher, 1978). During this survey two fields were also observed in the LMC, in the region and to the west of the 30 Doradus nebula. A careful examination of the plates led to the identification of all the WR stars already known (Fehrenbach et al., 1976) plus 13 new WR stars, afterwards confirmed by slit spectroscopy.

II. Observations

The survey was carried out in October 1977 at La Silla, Chile, with the ESO 40-cm Objective Prism Astrograph (Fehrenbach et al., 1964) using an interference filter centered at λ 4650 and having a pass band of 120 Å wide. With this technique, described in detail by Azzopardi and Breysacher (1978), very crowded regions can be studied by reducing the background fog and the length of the spectra and thus the number of overlapping images.

The two partially overlapping fields each having 85′ in diameter were respectively centered on stars HD 38268 (field 1) and HDE 269546 (field 2). IIa-O nitrogen baked plates were used. Four exposures of 20 min, 1, 3, and 6 h for field 1 (30 Dor) and two exposures of 3 and 6 h for field 2 were taken, thus permitting us to reach the continuum of stars up to 16.5 photographic magnitude. With an absorption-free distance modulus of 18.5 for the LMC (Westerlund, 1974), the sub-class WN 4, the least luminous amongst the WR stars [absolute magnitude −3.9 according to Smith's calibration (1973)], is then perfectly detectable. Sub-class WC 5 has possibly escaped our detection due to the technique employed: the width of the λ 4650 emission feature is comparable to the filter pass band in this case.

Spectrograms of the newly discovered WR stars were obtained in January and March 1978 with the Boller and Chivens Cassegrain spectrograph, equipped with a Carnegie image-tube, at the ESO 3.6-m telescope. The dispersion was 114 Å mm^{-1}. The spectra were secured on IIIa-J baked plates and widened to 0.20 mm. Some of them, slightly contaminated by moonlight, were nevertheless good enough to classify the corresponding objects.

III. Results

Table 1 gives the spectral classification and some other data concerning the 13 new WR stars found in the LMC. The first column gives the current number, and the second one the *FD* number according to the numbering system of Fehrenbach et al. (1976), the letters "*a*" or "*b*" meaning an inclusion between two consecutive stars in right ascension of their catalogue. The coordinates given for epoch 1975.0 in column 3 were computed with the method employed by Azzopardi and Vigneau (1975). In column 4, the spectral types were determined according to the classification system proposed by Smith (1968a). The fifth column gives the B photographic magnitudes obtained by measuring, at the micrometer, the image diameters of the stars on astrographic plates taken after removing the prisms of the Objective Prism Astrograph. We used normal and baked IIIa-J plates combined with a Schott GG 385 filter and B photometric sequences established by Martin (1977) (LMC IV) and by us, using selected measurements given by Westerlund (1961) (regions "a", "b4", "d", and 30 Dor). The accuracy is probably of the order of ± 0.1 mag. The sixth column indicates the presence of nebular lines in the spectra and in column 7 are given the *N* emission nebula number of Henize (1956) where the WR star lies. Column 8 provides the identification letter on the finding chart followed by the number of the Hodge and Wright's B charts (1967) to which the WR star belongs. In the last column other identifications of the stars can be found. Identifications with Andrews and Lindsay (1964) numbers are doubtful because of a lack of finding charts. A careful investigation shows that no new WR star belongs to either the catalogue of Hα emission-line stars of Bohannan and Epps (1974) or to the lists of emission-line objects recently published by Fehrenbach et al. (1978). We have only one star in common

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* Based on observations obtained at the European Southern Observatory, La Silla, Chile.

Table 1. New Wolf-Rayet stars in the Large Magellanic Cloud

No.	FD	α (1975.0)	δ	Spectral type	B_{pg}	Nebular lines	HENIZE (1956)	Charts	Star + Identification
1	29 a	$5^h26^m.75$	-68°52!3	WN3 + OB	14.70	yes	N 144	A/44B	Ws 9/32
2	33 a	5 28.46	-69 03.8	WN3	15.35	no		B/" "	
3	35 a	5 30.05	-69 02.1	WN4.5+OB	14.35	"		C/" "	
4	51 a	5 35.87	-69 12.7	WN5-6	13.60	yes	N 157	E/53B	
5	52 a	5 35.90	-69 00.5	WN3	14.80	"		D/" "	AL 351 ?
6	52 b	5 35.91	-68 59.6	WN3-5	15.35	"		D/" "	AL 351 ?
7	53 a	5 35.99	-68 54.5	WN4.5+OB	14.65	"		D/" "	Ws 27/22
8	56 a	5 36.73	-69 10.2	WN3	15.80	"	N 157	E/" "	
9	58 a	5 37.36	-69 08.5	WN4	16.10	"	N 157	E/" "	
10	59 a	5 37.94	-69 10.0	WN4.5+OB	12.10	"	N 157B	E/" "	AL 369
11	63 a	5 38.77	-69 07.6	WN8	14.40	"	N 157A	F/" "	
12	64 a	5 38.82	-69 07.0	WN7-6	13.60	"	N 157A	F/" "	Mk J
13	68 a	5 39.19	-69 30.1	WN9-10 :	11.95	"	N 158C	-/" "	Ws 3/8

+ The following abbreviations are used : AL : Andrews and Lindsay (1964)
Mk : Melnick (1978)
Ws : Westerlund (1961) (Table number/Star number)

Notes to Table 1

No. 1: The presence of an OB companion is inferred from the strength of the continuum relative to the emission features. Westerlund (1961) gives $V=14.82$, $B-V=-0.15$.

No. 2: Spectrogram slightly contaminated by moonlight.

No. 3: A relatively strong continuum and suspected absorption lines suggest the existence of an OB companion but the small widening added to the low resolution of image-tube spectra prevent a more accurate classification. Presence of faint companion, separation about 3″.

No. 4: The star is located in a very crowded region and only an unwidened spectrum was obtained. Two visible companions, separation about 4″.5 and 6″.

No. 5: Spectrogram somewhat underexposed.

No. 6: Moonlight contamination of the spectrogram prevents a more accurate spectral classification.

No. 7: Same remark as for WR No. 3. Westerlund (1961) gives $V=14.66$, $B-V=-0.03$.

No. 9: B magnitude obtained by linear extrapolation of photometric calibration set up photographically at brighter magnitudes; star probably fainter.

No. 10: Same remark as for WR No. 3. Several companions. A careful examination of a five minute exposure IIIa-J astrographic plate shows a diffuse image calling the stellar nature of this object in question.

No. 11: The star is located in the 30 Doradus nebulosity.

No. 12: Only an unwidened spectrum was obtained for this star. Melnick (1978) gives WN 5 for the spectral type. Several companions plus 30 Doradus nebulosity visible.

No. 13: The star Sk −69°249 (Sanduleak, 1969) is not a single object and a close fainter companion shows an emission spectrum similar to that of the WN 8 type with a well-marked P Cygni profile at λ 4471 He I. However, λ 4686 He II is relatively narrow as is also observed in the spectra of stars FD 17 and FD 56 (Fehrenbach et al., 1976). For these two WR stars the types WN 9 or WN 10 have been suggested (Walborn, 1977; Bohannan, 1978). Westerlund (1961) gives $V=12.48$, $B-V=-0.39$.

with Melnick (1978). From his list only the star named "H", sufficiently far out of the central cluster of 30 Doradus, could have been detected, but as it is very close to the known WR star R 134 (Feast et al., 1960) its emission-line cannot be discriminated on our short exposure plate. Notes concerning some individual stars follow Table 1, and Figs. 1 and 2 give the finding charts of the thirteen new Wolf-Rayet stars.

IV. Discussion

Adopting for mean colour index $\overline{B-V}=-0.10$, the detection of these new WR stars ($12.0<V\leqq 16.2$) indicates that the magnitude $V=15$, proposed by Westerlund and Smith (1964) as a real lower limit in luminosity of the LMC WR stars, has probably to be reconsidered.

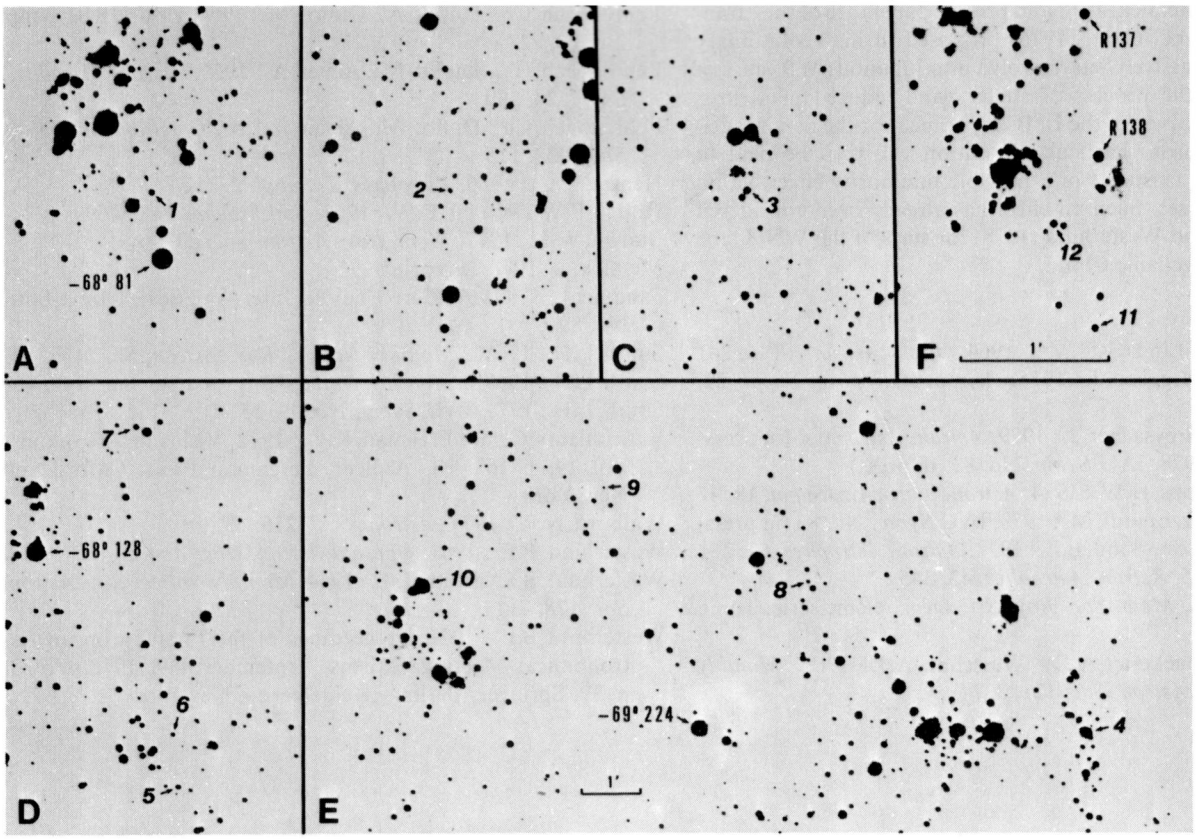
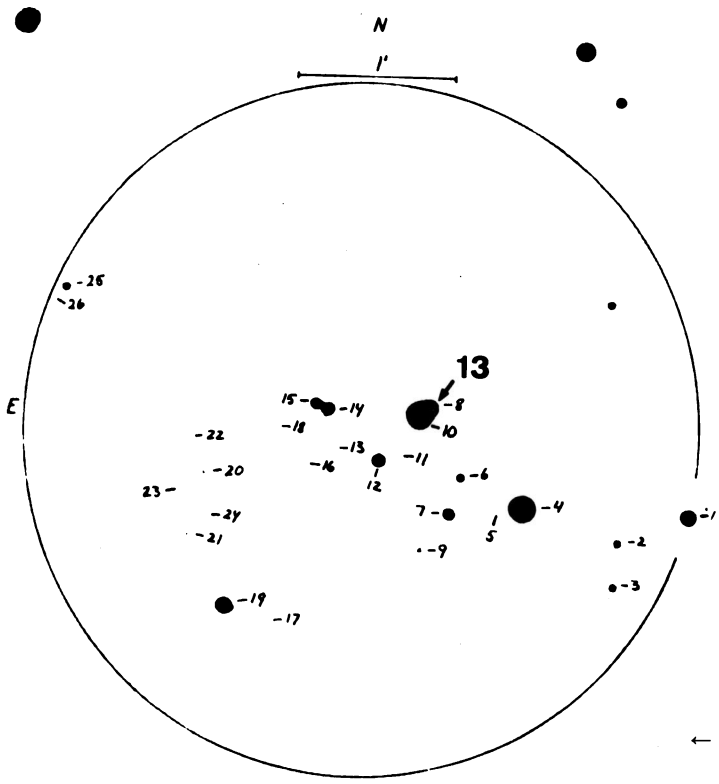


Fig. 1. Finding charts for the WR stars Nos. 1–12 found in the LMC. North is at the top, east is to the left. The scale given on chart "*E*" is the same for panels "*A*", "*B*", "*C*" and "*D*". The stars are identified by their current numbers as given in Table 1 and, when available, Sanduleak (1969) or Radcliffe (1960) numbers are provided to make the localisation of the WR stars in the other more general LMC maps easier



Assuming that the Large Cloud is a system seen nearly "face-on" (de Vaucouleurs and Freeman, 1972) of absorption-free distance modulus 18.5 (Westerlund, 1974) and, according to Brunet (1975), taking for mean colour excess $\bar{E}_{B-V}=0.15$ (stars Nos. 1–3) and $\bar{E}_{B-V}=0.19$ (stars Nos. 4–13) the values found for the absolute visual magnitudes of some WR stars in Table 1 are significantly fainter than the values given by Smith (1968b, 1973) for the corresponding sub-classes. For instance, the M_V absolute magnitude values of the WN 3+WN 4 stars Nos. 8 and 9 are respectively −3.2 and −2.9, i.e. a difference of about one magnitude with Smith's (1973) calibration. A stronger absorption in this region of the LMC is possible but it may well be that these WR stars have in fact lower intrinsic luminosities than the stars of the WN 3 and WN 4 types previously observed in the Large Cloud by Westerlund and Smith (1964). The same remark applies to star No. 11 [$M_V=-4.6$, i.e. 1.6 mag fainter than the value given by Smith (1973) for the WN 8 type] although in this case absorption has to be seriously considered, the star being located in the 30 Doradus nebula.

It is remarkable that in the 30 Doradus complex, a region of recent star formation, quite a number of the observed WR stars

← **Fig. 2.** Finding chart for the WR star No. 13. Reproduction of Westerlund's identification chart (1961) for the stars in NGC 2074

(Smith, 1968b; Melnick, 1978 and present paper) are of the "transition" WN 7 type. Conti (1976) proposed in his evolutionary scenario, that massive O-stars evolve into luminous WR stars of type WN 7 by the process of stellar wind induced mass loss.

A complete survey of the LMC is planned for the next Magellanic Clouds season. Particular attention will then be paid to investigating the existence of a possible luminosity effect within the WR sub-classes. Such an effect has already been considered by Breysacher and Westerlund (1978) for stars of the WN 3 type in the Small Magellanic Cloud.

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Concerning our star No. 13 (Sk-69°249), Dr Sanduleak informed us that he was aware of the fact that there was a close-by star. His classification applied to the brighter star.