SPECTRA OF THE WOLF-RAYET STARS IN 30 DORADUS

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The central cluster of the 30 Doradus complex in the Large Magellanic Cloud (LMC) contains at least a dozen Wolf-Rayet (W-R) stars of the nitrogen sequence according to Melnick (1978). In addition to the six stars previously identified by Feast, Thackeray and Wesselinck (1960), Melnick identified an additional six using an Echele spectrograph on the 1.52 m telescope at La Silla. I have obtained high resolution spectra of ten of these stars and would like to discuss the spectral types.

These spectra were obtained on the cassegrain image tube spectrograph attached to the 4 m telescope at Cerro Tololo, mostly during April 1981. These spectrograms were on baked IIIa-J emulsion, with dispersions of 26 Å/mm in the blue and 52 Å/mm in the yellow-red regions. The plate widening was typically 1 mm in the blue and 2 mm in the yellow-red; the use of a moonlight eliminator was crucial to suppress the otherwise very strong emission lines from the nebula. Even so, all spectra show such lines.

The classifications were based upon the L. Smith (1968) system, as developed in the new W-R catalogue (van der Hucht, Conti, Lundstrom and Stenholm 1981). Most of the entries in that catalogue are based upon examination of similarly obtained spectra. Table 1 shows my classifications of these stars — the ordering and nomenclature follow Melnick (1978). Breysacher (1981) has also given classifications of some of these stars.

Prévot-Burnichon, Martin, Prévot, Rebeirot and Rousseau (1981) have recently discussed the binarity and absolute magnitudes of W-R stars in the LMC. They have collected together the best available photometry, together with a careful examination of close companions, to compile M_V for these stars. Their M_V values for the stars of 30 Dor are also included in Table 1.

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Table 1. Wolf-Rayet Stars in 30 Dor

Star	Type	M_V	Remarks
R134	WN6	-6.7	
R135	WN7	-6.3	
R136	WN4.5+abs	-10.2	or Of
R139	Of	-6.6	
R140	WN6+WC	Close VB	Strong C IV
R145	WN6	-7.4	
J	WN6	-6.0	
E	(WN6)	Close VB	
C	WN4.5	-6.4	No abs
H	Of	-6.8	or WN4.5+abs
A	Of	Multiple	or WN4.5+abs
G	(WN+O)	---	

I was unable to obtain additional spectra of Melnick's stars E and G; the former because it is a close visual binary (VB) with the stars not separable on the slit; the latter because it is relatively faint for the amount of observing time I had available. Spectra of stars E have recently been obtained by Phillips (1981) which imply a mixed WN, WC classification.

I need now to spell out a problem of spectral classification: An ambiguity can arise between Of or Wolf-Rayet types in some cases if absorption lines are present. The classifications here, following the W-R catalogue, contain these precepts: If emission is observed at λ4057 N IV and λ4686 He II (with weak or absent N III and N V) the W-R type is WN 4.5. If absorption is seen in the upper Balmer lines (only) then the type would be WN 4.5 "plus abs." One cannot tell from single spectra whether there are one or two stars present; a binary nature will be revealed only with additional spectra and the establishment of periodic velocity variations. However, if the above emission lines are present, and not only the upper Balmer series but also the λ4471 He I and λλ4541, 5411 He II lines are present in absorption, then the object could also be classified as Of. Although the emission line widths appear to be of Wolf-Rayet type, in such stars the He I and He II Pickering series lines are always found in emission. It is not my intent here to argue for or against a particular classification scheme; all I wish to say is that the above is consistent with the W-R catalogue. The difficulty in classification suggests a physical similarity and possible connection among some WN objects and the Of stars (Conti 1976).

Let me now turn to some individual stars:

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R136 has recently been discussed by Cassinelli, Mathis and Savage (1981). They suggest, on the basis of observations over many wavelength regions, that this object is a massive star with a luminosity of $\sim 10^8$ $L_\odot$. I believe their case has merit but do not wish to discuss the details here. I note that the spectrum of R136 is W-R like, having broad emission at λ4057 N IV and λ4686 He II, with weak or absent N III and N V (Walborn 1973). The Balmer series is present in absorption, leading to a mixed classification as indicated. The type might also be considered as Of, except for the emission line widths. My new spectra, interestingly, do not show λ4686 He II emission, which is so prominent on Walborn's plate. The apparent variability of the spectrum of R136 will be discussed elsewhere.

In the spectrum of R140, two components are on the slit. The overall type is WN6, but the strong C IV lines at λ5806 are also observed. It is not clear yet whether or not the spectrum is that of one or two stars; absorption does not appear to be present. The spectrum of R140 could represent a transition WN-C case (Conti 1982), or it could be due to a WN and a WC star, each on the slit. Although Melnick (1978) classified star C as WN+OB, I do not see absorption lines on my spectrogram; the emission lines are weak, but as we have seen in this Symposium (Conti 1982; Leep 1982) this is no guarantee of a binary nature. Stars H and A are tentatively classified as Of since they show the Pickering series lines in absorption; however, the λ4057 N IV and λ4686 He II emission lines are broad, suggesting a W-R type. Star A is also an unresolved multiple system with possibly additional contributers to the spectrum.

Overall, then, 30 Doradus contains five stars of WN type, three of the ambiguous WN/Of class, one undoubted Of star, one WC star, and several other W-R objects in close unresolved groupings. The absolute magnitudes of the apparently single stars are very bright, none being fainter than -6^m. These represent more than one-third of the brightest cluster members (Melnick 1978). As has been noted by Melnick (1982) and others, the presence of so many W-R objects in such a small volume of space is unprecedented. The winds of these stars may, as he suggests, make an important contribution to the overall kinetic energy balance of the 30 Dor giant H II region, although R136 may still dominate (Cassinelli *et al.* 1981).

I think an important result of these observations is that most of these W-R objects do not arise from a binary mass-exchange scenario. I think it rather that some, or perhaps most, of these W-R stars in 30 Dor are still burning H in the core and show emission spectra because of their extensive stellar winds. The apparent nitrogen enhancements could come from mixing processes. The very bright luminosities are not inconsistent with such a concept, and the spectral similarities among many of these objects indicates a close physical connection. One would expect these stars were all born at about the same time, although undoubtedly with somewhat different initial masses,

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stellar angular momenta and possibly other parameters. The spectroscopic distinctions may not represent fundamentally different evolutionary states for most of these stars, but rather different stellar winds. The large fraction of such stars among the brightest 30 Doradus cluster members suggests such anomalous spectra are probably a normal phase in the evolution of very luminous and massive stars. Morphologically similar W-R spectra are also found among the brightest stars in the giant H II regions in M33 (Conti and Massey 1981).

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