Of-WN EVOLUTION: SPECTRAL TYPES AND EFFECTIVE TEMPERATURES

E. Myckky Leep
Dept. of Astronomy, University of Washington,
Seattle, W.A. 98195

Because of the growing evidence (Conti 1976, Snow and Morton 1976, Chiosi et al. 1978, de Loore et al. 1977) that some Of stars are evolving into WN stars, we reexamine the classification of WN stars. There are four schemes for classifying WN stars, those of the IAU (1938), Hiltner and Schild (1966), Smith (1968), and Walborn (1974). All of these schemes involve estimating by eye the ratio of the nitrogen line strengths. Walborn's scheme is the most useful because he avoids problems that may arise from the use of helium lines. In other respects Walborn's scheme gives WN classifications similar to those found by Smith.

We have measured equivalent widths of lines of N III λλ4640-4642, N IV λ4058, N V λ4604 for 22 Of stars. These Of stars were then given WN subclasses according to the criteria of Walborn (1974). The equivalent widths of the absorption lines of He I λ4471 and He II λ4541 were measured in three WN transition stars (Conti 1976) HD 93162, HD 93131, HD 92740. (We know that only one of these stars, HD 92740, is a binary and here the absorption lines were determined to come from the WN component of the system (Conti, Niemela, Walborn 1978).) These three WN stars were given Of subclasses using the criteria of Conti and Frost (1977). Figure 1 shows the results. Note the inclusion of the subclass WN9 which Walborn (1977) proposes in connection with WN stars he observed in the Magellanic Clouds. Figure 1 shows that Of stars earlier than O6f all could be given a classical WN spectral type. Yet these stars have effective temperatures between 40000-55000 K (Conti and Frost 1977), much more than the usual 20000 K (Cassinelli and Hartman 1975) associated with late-type WN stars. The three WN stars are in turn classified with the hottest Of stars. From Figure 1 we can conclude that Of stars cannot be clearly separated from WN stars by the available classification criteria. Also, we see that at least some WN stars may have effective temperatures higher than the usual 20000 K. If the early Of stars do give us a true indication of the effective temperature of the WN6-WN8 stars and if WN3-WN5 stars have even higher temperatures (because more highly ionized lines are observed in these stars) the bolometric corrections for WN stars must increase, giving a higher absolute magnitude which would be closer to that observed for Of stars.

P. S. Conti and C. W. H. de Loore (eds.), Mass Loss and Evolution of O-Type Stars, 471–474.

https://doi.org/10.1017/S0074180900013863 Published online by Cambridge University Press

Figure 1.

	03	04	05	05.5	06	06.5	07	07.5	08	08.5	09
WN3											
WN4											
WN5											
WN6	93129A	*93131 *93162									
WN7		190429A	*92740	228766							
WN8		15570 16691 ζPup	14947	152386							
WN9					14442 153919 λCep	148937 150958 602522	29 CMa 108 163758	166734 167971	151804 152408 9 Sge		

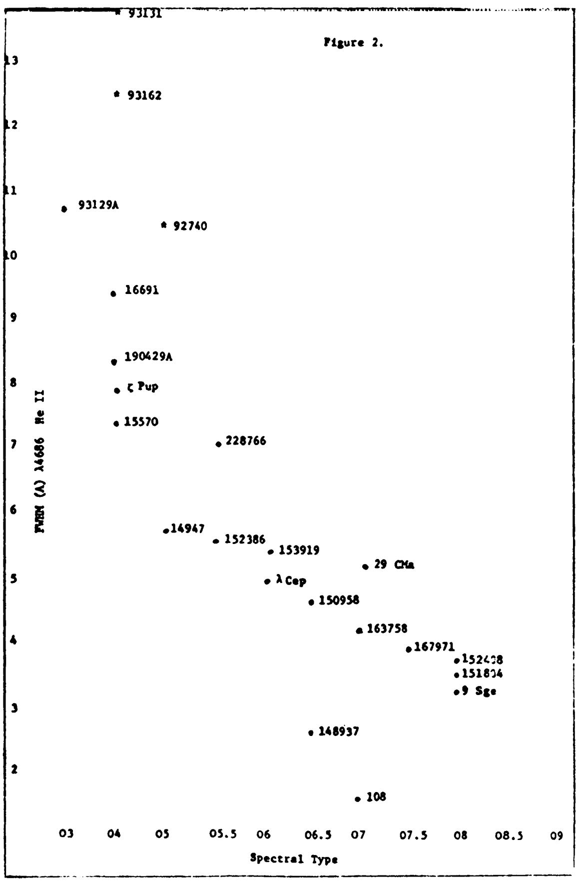

Figure 2. Some stars do not fit the linear relation seen in Figure 2. HDE 228766 and 29CMa are double lined spectroscopic binaries, where the secondary may influence the width of λ4686. For HDE 228766 the spectral type maybe as early as O5f. HD 148937 and HD 108 may also have incorrect spectral types because of P Cygni features in He I λ4471.

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In some stars it is observed that line widths correlate with spectral type. Similar correlations were sought in Of stars, by measuring the full width at half maximum (FWHM) of He II λ4686, which is in emission in all Of stars. In Figure 2 we see the results, which include the three WN stars discussed previously. One can see at once the almost linear relation between spectral type (or effective temperature) and the FWHM of λ4686. Remember that λ4686 can be formed in emission only in stars having envelopes (Mihalas, and Lockwood 1972, Mihalas 1974). Then if the emission of λ4686 is due to the same mechanism in all Of stars, one might expect that the width of λ4686 is an indication of the extent of the envelope. If so, then the hotter Of stars appear to have the more extended envelopes. Further, if the mechanism for emission of λ4686 is the same for Of and WN stars, perhaps some WN stars differ from Of stars primarily in the extent of their envelopes.

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https://doi.org/10.1017/S0074180900013863 Published online by Cambridge University Press

DISCUSSION FOLLOWING LEEP

Underhill: Your observations detail very nicely the spectroscopic likenesses between Of and WN7/8 stars. The next step will be to determine reliable flux effective temperatures for these stars and to see if they are as high as we infer from the electron temperatures which we require to account for the observed visible spectra. To obtain reliable flux effective temperatures for stars of spectral type O8 and earlier we must have absolute spectrophotometry in the range 1800 to 1000 Å. The range from 1800 Å to 4000 Å is also needed, but these fluxes are available for a few of the stars from S2/68 and OAO-2. The necessary observations might be made successfully from the space shuttle. My determination from S2/68 spectra of T_{eff} for ζ Puppis is unreliable in the sense that my answer is constrained by the model atmosphere effective temperature which I adopt, for the estimated part of the integrated flux shortward of 1380 Å drives the solution. However, I am sure from the shape of the spectrum in the range 6000 to 11000 Å that T_{eff} is close to 47000 K. If it is as low as 32000 K as suggested by Code et al. (1976, Ap.J.), the fit is not so good.

Conti: Ms. Leep's temperature scale puts some WN7 stars at values about 45000 K, whereas Willis suggests that some earlier types have effective temperatures near 30000 K. It may be then that the effective temperatures are inverted from the ionization values, in which the earlier types are clearly hotter. The envelope temperature may not be exactly controlled by the effective temperature but by the heat input.

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