GENERAL DISCUSSION

Underhill: We have heard that a few O-type stars have been detected as radio sources, but many more O stars are known to have infrared excesses. We have also heard that a considerable number of late-type stars and some B stars with extended atmospheres are detected in radio wavelengths. I wonder if the relative intensities of infrared and radio emissions are similar for all stars or whether there is a systematic difference that can be related to spectral type. Information on this point should yield information about the structure, temperature and density of the winds around various types of stars. Such data would be a constraint on the theories of stellar einds, a topic which we shall discuss this afternoon. Can anyone comment on what infrared and radio observations of stars tell us about the physics of stellar winds in various parts of the HR diagram and in particular about the winds from O stars?

Kwok: When stellar radio emission is detected a hot star is usually present. The question remains whether the gas is actually ejected from the star. Mass loss from late type giants have velocities of ~10 km/sec compared to ejection velocities of ~1000 km/sec for early giants. Since the radio flux density is proportional to $(m/v)^{4/3}$, there exists a two-order of magnitude difference in favor of detecting a red giant wind. This accounts for the small number of detections of O star winds. As for winds from late-type stars, we have to consider the possibility of the free-free spectrum becoming optically thin before reaching the infrared and the presence of dust. Therefore I do not consider the comparison of the radio/IR intensity ratio between early and late type stars to be particularly useful.

Cassinelli: Free-free opacity varies as λ^2 so as one goes from the visible to infrared wavelengths one is "seeing" to points farther out in the flow. Since the effective radius increases, you get an increasingly large infrared excess.

Conti: I should like to emphasize two points of these data on mass loss rates presented in this session and in the previous two. There is good agreement in the mass loss rate of ζ Pup among the U.V., optical, IR and radio data of $\sim 6\times 10^{-6}$ yr^{-1}. This rate is significant for the evolution of this star and emphasizes the applicability of the consequences of mass loss to be discussed in sessions later on. As we have seen earlier in this Symposium the mass loss rates for WR stars are even larger, typically factors of 10. This is also significant on an evolutionary time scale for these stars.

Underhill: Yes, it's clear that the mass loss rates in WR stars are much larger than in O types. Another point is that Wolf-Rayet stars don't vary in spectral appearance all that much. The initial descriptions by Wolf and Rayet in the mid 1800's are nearly identical with the present spectra. By contrast, Be stars have large spectral variations. The evolutionary state of these two objects is also very different.

P. S. Conti and C. W. H. de Loore (eds.), Mass Loss and Evolution of O-Type Stars, 165–166.

de Loore: I would like to make a remark concerning evolution in connection with what Anne was saying. I think there are two different things. Before nuclear changes in the interior can really affect the atmosphere it takes a large amount of time.

I have a question concerning the WC star 193793 mentioned by Barlow, quoted as WC binary (+O5 star) and a remark that it could possibly be a single star. How strong is the evidence for the fact that it could be single? Peter Conti probably can answer this.

Conti: The evidence is as follows. There are very nice absorption lines (e.g., Balmer lines) observed in the spectrum of HD 193793; Ms. McDonald at Victoria many years ago obtained extensive spectroscopic coverage. The radial velocities have a relatively large range but no period could be found. About 10 years ago I too began to obtain coude plates of this object. I thought all one needed was better resolution. Well, the upshot of a large accumulation of data from that time is that one still finds a variation but no periodicity. It does seem to be two stars since you see O type absorption lines and WC emission lines. You could have the situation where two stars are in the line of sight or else it's an unfavorable inclination. These are the most likely possibilities but cannot be proven for certain. A less likely possibility is that there is just one star. We have some examples of WN stars in which absorption and emission lines are observed in the same object. Dr. Niemela will talk about this in Session 5. It's possible in a WN star to have hydrogen absorption lines since nitrogen enhancement can come about before all the hydrogen is used up. However, this does not seem to be possible in a WC star as Eggleton has emphasized to me (e.g., Dearborn and Eggleton 1977). If WC stars have enhanced carbon, all the hydrogen is probably consumed, and helium also dominates the surface. From the absorption line spectrum of HD 193793 we still have evidence of hydrogen. So my feeling is that it's probably two stars. Hα is in emission, by the way.

Castor: Is there any Pickering absorption?

Conti: Yes.

Underhill: Yes, I have worked on it myself.

Conti: This star does hold the record for outflow velocity in a WR star from Anne's work on the narrow λ 3889 He I. Also, the emission lines are not as strong as in some other WC stars so one infers the O-type companion contributes to the continuum and somewhat drowns out the WC star. But this has not been investigated quantitatively as yet.

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