P CYGNI STARS AS AN INTERMEDIATE STAGE BETWEEN RED SUPERGIANTS AND WOLF-RAYET STARS

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P Cygni's evolutionary status is evaluated using its recently redetermined basic parameters (Lamers et al. 1983) to plot the star on the HRD (Figure 1). The theoretical evolutionary track of a 60 $M_\odot$ star passes through P Cygni's error box twice. From a comparison of the time scales along the two parts of the track it is found to be twenty times more probable to find a star in the He-core burning plus H-shell burning phase evolving to higher T_{eff} than in the thick H-shell burning phase evolving to the RSG region of the HRD.

According to Maeder (1981) such an object should have an atmosphere enriched in N and depleted in C and O. Luud (1967) found some evidence for this but P Cygni does not really resemble a late WN star because a thin layer of unprocessed H efficiently masks the underlying processed atmosphere. However, P Cygni's high mass-loss rate of 2×10^{-5} $M_\odot$ yr^{-1} will soon make it lose its last surface layers after which its WN character should be revealed. Note also that P Cygni's luminosity ($M_{bol} = -9.9$) is in the same range as that of WNL stars ($M_{bol} = -8.0$ to -9.5).

If the 6 GHz radio arc discovered by Wendker (1982) is interpreted as a remnant of the 1600 outburst, the expansion velocity would be 1800 km s^{-1}. This is allright for a B1 supergiant, but a factor 5 too high for P Cygni. However, in the RSG phase typical expansion velocities are 25 km s^{-1} and the most distant parts of the arc must have been ejected 3×10^4 yr ago. This is in good agreement with the evolutionary time scale of 4×10^4 yr from RSG to BSG.

We therefore suggest the following evolutionary scenario for P Cygni: A 60 $M_\odot$ star evolves from the ZAMS to the RSG region. The

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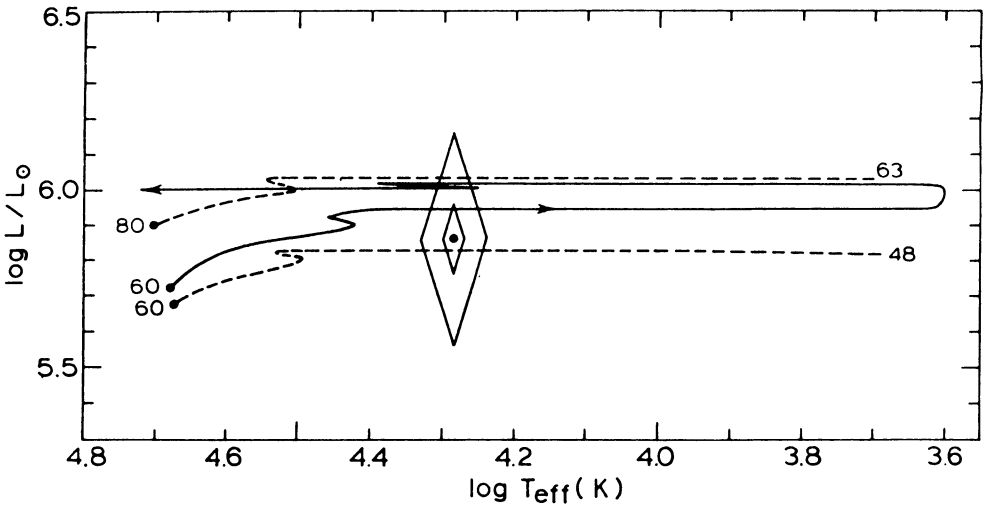

Figure 1. The location of P Cygni in the HR diagram is indicated. The outer error box corresponds to an uncertainty of $\Delta E(B-V) = 0.05$. The inner error box corresponds to $\Delta E(B-V) = 0.00$. The dashed curves are De Loore et al.'s (1978) evolutionary tracks with mass loss (N = 100) for two stars of 60 and 80 $M_\odot$. The full curve is the evolutionary track from Maeder (1981). This last track crosses the error box of P Cygni twice. We argue that P Cygni is in the phase of the second crossing.

RSG loses mass through a dense stellar wind and through sporadic outbursts thereafter. Remnants of this mass loss are now observed as a radio feature and obscured the star sufficiently for it to escape naked-eye detection before 1600 AD. In that year starlight emerged through the dust but inhomogeneities produced the 17th century light variations and red colour. As the dust was blown away by the stellar wind and/or evaporated by the star's UV radiation, the star slowly brightened in the V-band but, due to a much lower degree of re-distribution of UV radiation, only reached $V \approx 5$ against $V \approx 3$ in the period 1600 - 1660. At present P Cygni evolves at constant M_{bol} towards higher T_{eff}. Soon, when all H-rich layers have been blown off, the star will be WNL.

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Note added after the Symposium:

From recent publications (e.g. de Jager, C: "The Brightest Stars", D. Reidel, Dordrecht, 1980; de Jager, C.: Working Group Stars with Extended Atmospheres, Preprint No 30, 1983; Humphreys, R., Astrophys. J. 269, pp. 335-351, 1983) and further discussions at this Symposium it seems as if stars with an initial ZAMS mass of 60 $M_\odot$ are about the most massive ones that can evolve into an RSG. More massive stars encounter an instability zone in the HRD where greatly enhanced mass loss drives the star back to higher T_{eff}. With P Cygni so very near the upper limit for evolution into an RSG these recent ideas might affect certain details of our scenario but leave its essential features intact.

DISCUSSION

Walborn: Roberta Humphreys' diagram shows that P Cygni lies just on the borderline between stars which observationally become red supergiants and those which do not.

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