ON THE FORMATION OF CONTINUOUS SPECTRUM AND EMISSION LINE PROFILES OF P CYGNI

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The attempts to interpret the values of the observed radio and infrared fluxes of P Cygni via simple mass outflow models (constant outflow velocity or usual radiative acceleration outflow) lead to a strong discrepancy between the observed and the calculated values.

Barlow and Cohen (1977) found also that constant velocity or usual radiative acceleration outflow models cannot explain the observed continuous spectra. They concluded that a more "extended" acceleration law is needed to fit the observed and the calculated radio and IR fluxes - a law by which the acceleration of matter takes place also at a comparatively large distance from the star.

In our study we analyze such type of expanding envelope models which can explain the shape of line profiles in the spectrum of P Cygni, too. Considering according to Kuan and Kuhi (1975) the hydrogen lines origin in the deceleratively moving part of an envelope and according to Oegerle and Van Blerkom (1976) the neutral helium lines form in the acceleratively moving part of an envelope, we assume that there must exist at least two differently moving regions in the envelope - an initial acceleration zone and a deceleration zone. To get correct values for IR and radio fluxes one must assume that there exists also an acceleratively moving outer zone, which explains very large wings of H_α and H_β lines as well.

We call a model consisting of three differently moving zones ADA-model (accelerating-decelerating-accelerating).

The compilation of the observed spectral energy distribution was carried out using the following data:

Wavelength or frequency	Author
4.995 and 10.68 GHz	Wendker et al. (1973)
3.3 mm	Schwarz and Spender (1977)
2.3 - 19.5 μ	Gehrz et al. (1974)
1.6 μ	Allen (1973)
U, B, V, R, I, J	Johnson et al. (1966)
Celescope: U2, U3	Davis et al. (1973)

P. S. Conti and C. W. H. de Loore (eds.), Mass Loss and Evolution of O-Type Stars, 39–42.

The interstellar absorption corrections are made using $E_{B-V}=0^m.61$ (Woolf et al. 1970) and reddening law by Nandy et al. (1975).

The observed energy distribution corrected for interstellar absorption is given in Fig. 1. There are also presented fluxes for outflow models $v = const$ and $v = v_\infty [1-(1-v_0^2/v_\infty^2) R_0/R]^{1/2}$ (lower lines) which show strong discrepancy between observations and calculations.

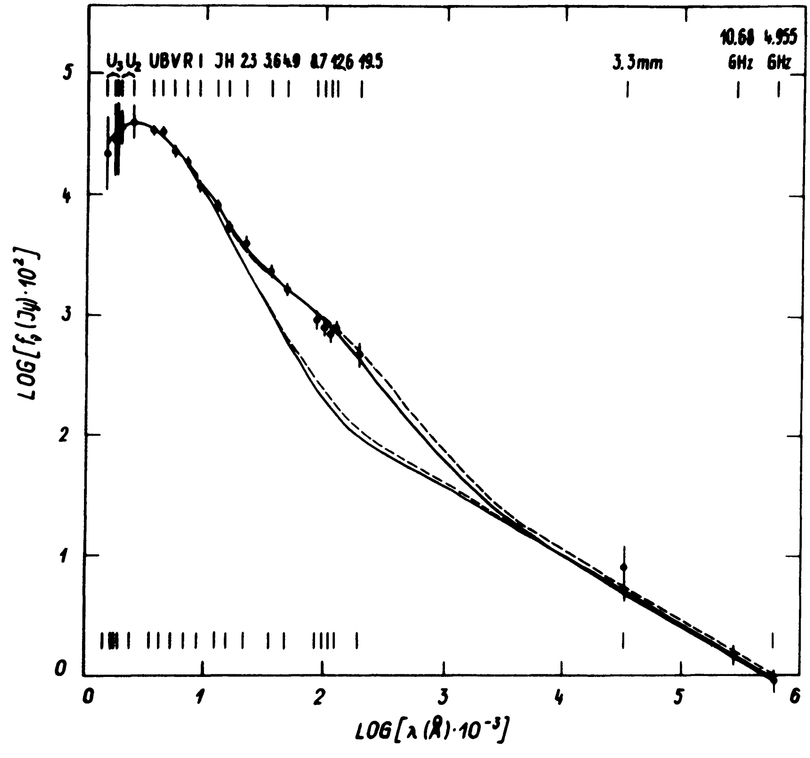

Fig. 1. The energy distribution in the continuous spectrum of P Cyg compared with model fluxes (explanations in text).

In Fig. 1 the upper lines presented fluxes for two ADA-models which well fit the observed ones. The calculations are depending on many parameters and they must be chosen on qualitative considerations of line profile shapes. Actually the good fit of observations can be reached within a large variety of them. We mention that the calculated fluxes are fitted with the observed ones supposing them to be equal at V and 10.68 GHz bands. The mass loss rates for calculated ADA-models are in the range between $6.8 \cdot 10^{-5}$ and $9.3 \cdot 10^{-5}$ $\mathfrak{M}_\odot/yr$ according to $M_V = -8^m.4$ (Hutchings, 1976), this is in agreement with spectroscopic determinations $\sim 9 \cdot 10^{-5}$ $\mathfrak{M}_\odot/yr$ (Luud, 1967), $\sim 2 \cdot 10^{-4}$ $\mathfrak{M}_\odot/yr$ (De Groot, 1969) and $\sim 3.5 \cdot 10^{-4}$ $\mathfrak{M}_\odot/yr$ (Hutchings, 1976).

The reality of ADA-model can be checked by comparison of the observed and the calculated spectral line profiles. Here we present only semiquantitative study of hydrogen lines in which the level populations are estimated from simple outflow model solutions.

In Fig. 2 the comparison of the observed H_α profile and the calculated ones for two ADA-models is given. The observed profile is taken according to Luud et al. (1967).

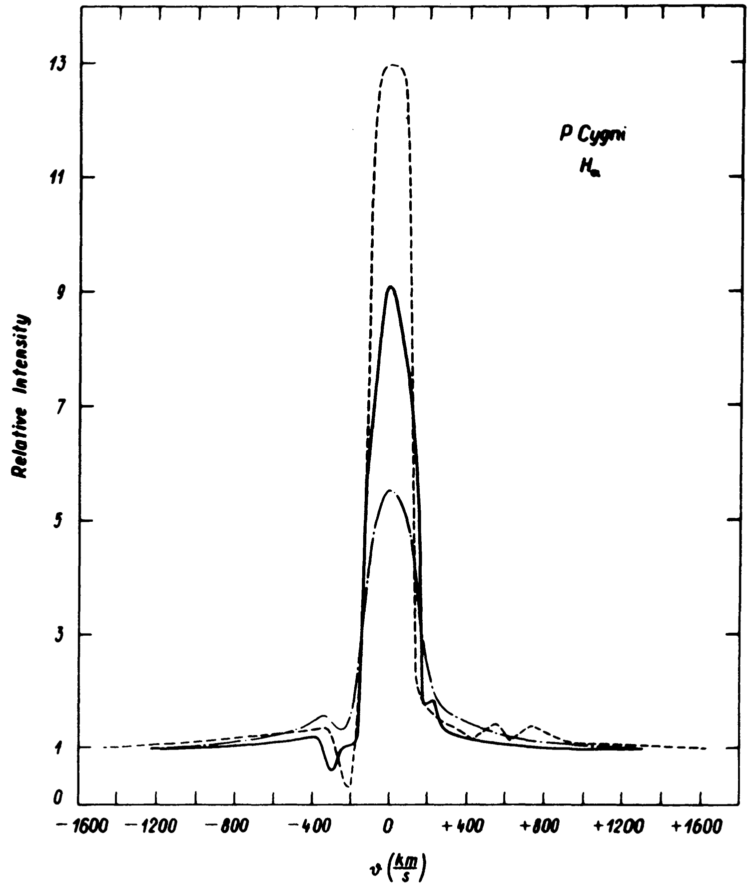

Fig. 2. H_α profile compared with the calculated ones for two ADA-models: — — — the observed, ——— and ——·—— ADA-models.

The qualitative accordance of the calculated and the observed profiles is present, the intensive H_α line has also broad wings and violet absorption. The H_9 line has two absorption components as the observed one.

The origin of ADA structure must be physically founded. Here we briefly discuss a possibility of forming three zones.

In the outer zone the matter is accelerated probably by radiation pressure. Initial acceleration near the core is possibly caused by some kind of mechanical dissipation processes partly assisted by radiation pressure. According to the stellar structure calculations the massive stars are vibrationally unstable that leads to the mass loss (Appenzeller, 1970a, 1970b).

To have the decelerating zone we must check the possibility of the existence of an intermediate zone where gravitation force is high enough to slowdown matter outflow accelerated in the inner part of the envelope. The analysis lead us to the conclusion that if the mass of P Cygni is higher than 60 $\mathfrak{M}_\odot$ that deceleration may be present.

A strongly extended version of our paper will be published after providing complementary calculations.

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DISCUSSION FOLLOWING NUGIS, KOLKA AND LUUD

Snow: The *Copernicus* ultraviolet data on P Cygni show it to be quite unlike other early B supergiants with regard to its wind. The primary anomaly is the low ionization. No trace of N V is seen, for example, while "normal" early B supergiants show this ion, usually with a fully developed P Cygni profile. In the UV data for P Cygni, ions such as Si II and C II show small shifts and possibly weak emission. There are other anomalies about this star, and it properly should be regarded as peculiar, not representative of early B supergiants as a class.

Van Blerkom: I have recently seen a paper from Bernat and Lambert who have observed very broad wings on some P Cygni lines which extend to 1500 km/sec, which they interpret as being due to electron scattering. This might be an alternative explanation.

Luud: I believe the envelope temperature in P Cygni itself is not enough to cause this effect.

https://doi.org/10.1017/S0074180900013218 Published online by Cambridge University Press