# HeI emission line formation in symbiotic stars and novae

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## Observational data

The HeI triplet to singlet line ratio $\Lambda = F(\lambda 5876)/F(\lambda 6678)$ in symbiotic stars and novae is often much lower than the planetary nebulae value of $\approx 3.5$, which is also the low density value $\Lambda_0$ predicted by recombination theory.

Fig.1 shows that the dereddened HeI line ratios $\Lambda$ are different for S type and D type symbiotic stars. The spectrophotometric data are mainly from Allen (1984, personal communication) and Blair et al.(1983). The S and D type classification divides the symbiotic stars according to the IR continuum into objects with a stellar continuum or dust emission. Practically all D types have low nebular densities $N_e \lesssim 10^7 \mathrm{cm}^{-3}$ and a rich spectrum of forbidden lines, while in S type objects these lines are suppressed by collisional deexcitation due to the high electron densities $N_e \gtrsim 10^7 \mathrm{cm}^{-3}$. The observed HeI line ratio $\Lambda$ in S type symbiotics, which is systematically too low when compared with the theoretical low density value $\Lambda_0 = 3.5$, can therefore be attributed to the high nebular densities in these objects.

Low HeI line ratios $\Lambda \approx 2$ are also observed in novae. In Fig.2 the line ratio $\Lambda$ is plotted as a function of time for the fast Nova Cyg 1975 (data from Ferland et al.,1986). $\Lambda$ is lowest for the highest nebular densities shortly after outburst.

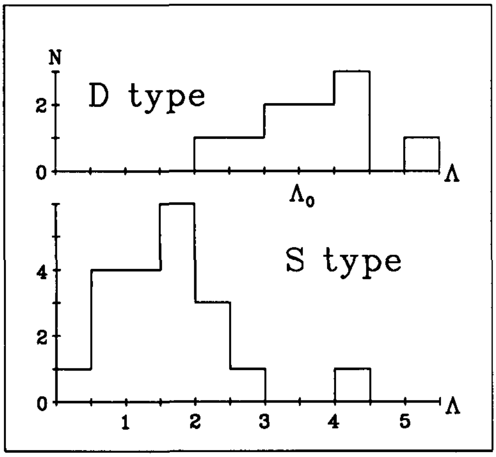


**Fig.1.** Distribution of the HeI line ratio $\Lambda$ in D type and S type symbiotic stars.

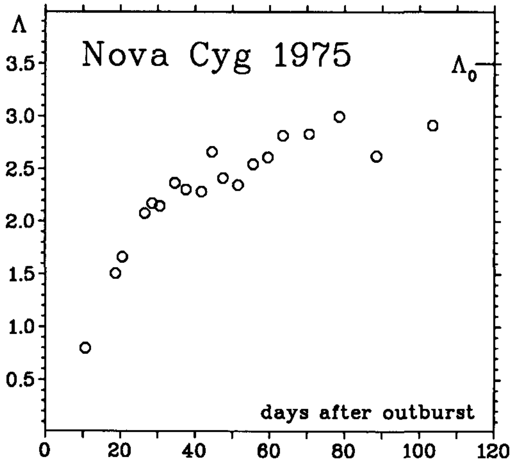


**Fig.2.** Evolution of the HeI line ratio $\Lambda$ in Nova Cyg 1975.

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As the envelope expands and $N_e$ decreases, the line ratio evolves towards the low density value $\Lambda_0$.

These data suggest that the HeI line ratio $\Lambda = F(\lambda5876)/F(\lambda6678)$ in symbiotic stars and novae depends strongly on nebular density.

## Calculations

The line formation in HeI is complicated by the metastability of the levels $2\,^3$S and $2\,^1$S. To investigate in detail the HeI line formation in dense nebulae the coupled rate equations for a 17 level HeI atom have been solved. Fig.3 shows calculated line ratio $\Lambda = F(\lambda5876)/F(\lambda6678)$ as a function of $N_e$ for case B (optical depths $\tau = \infty$ in the HeI Lyman lines $1\,^1\mathrm{S} - n\,^1\mathrm{P}$) and neglecting line transfer effects among the excited levels. According to the line ratios $\Lambda = \Lambda_0$, $\Lambda > \Lambda_0$ and $\Lambda < \Lambda_0$ three density regimes can be distinguished:

(a) Nebulae with low densities $N_e \lesssim 10^3\mathrm{cm}^{-3}$ where no collisions need be considered.

(b) Nebulae with intermediate densities $10^3\mathrm{cm}^{-3} \lesssim N_e \lesssim 10^7\mathrm{cm}^{-3}$, like planetary nebulae, where collisional enhancement of HeI emission lines from $2\,^3$S is important (e.g. Clegg,1987). As collision strengths for spin changing transitions are much smaller than transitions among the same spin, the triplet to singlet line ratio $\Lambda = F(\lambda5876)/F(\lambda6678)$ is enhanced if collisions from $2\,^3$S take place.

(c) Nebulae which have high densities $N_e \gtrsim 10^7\mathrm{cm}^{-3}$ as in S type symbiotic stars and novae. In these objects also collisions from $2\,^1$S must be included. Because the radiative decay for $2\,^1$S is more than 5 orders of magnitude faster than for $2\,^3$S, this effect can be neglected in low and intermediate density nebulae. Collisions from $2\,^1$S enhance mainly the singlet lines and cause the low HeI line ratio $\Lambda = F(\lambda5876)/F(\lambda6678)$ as seen in the observational data presented in the previous section.

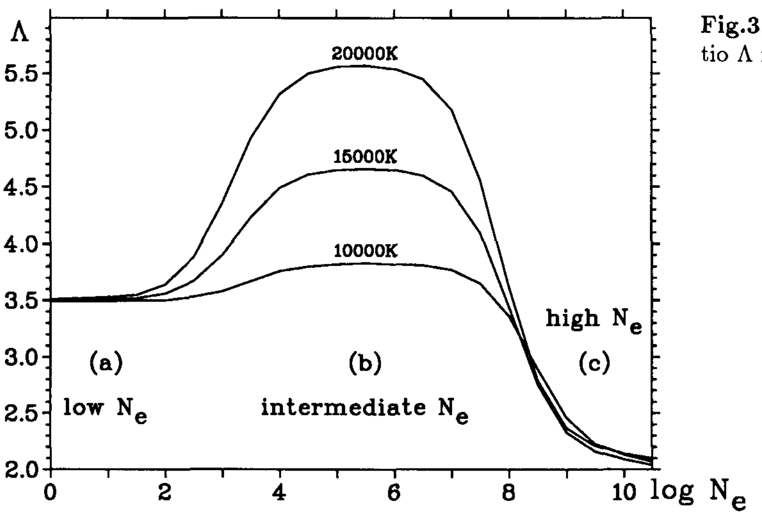


**Fig.3.** Calculated HeI line ratio $\Lambda$ for case B.

If case A ($\tau = 0$) is assumed for HeI Lyman lines, the observed line ratios $\Lambda$ can not be reproduced. The population of the metastable level $2\,^1$S is too low for collisional enhancements, because depopulation via collisional excitations (mainly to $2\,^1$P) and cascades to the ground state are very effective. Observations of symbiotic stars and novae therefore suggest that conditions for the HeI Lyman lines must be close to case B.

## Conclusion

The HeI line ratio $\Lambda = F(\lambda 5876)/F(\lambda 6678)$ can be used for nebular diagnostics. Fig.3 shows that in the intermediate density range $\Lambda$ is a function of the nebular temperature $T_e$. Additionally, nebulae with low or intermediate densities $N_e \lesssim 10^7 \mathrm{cm}^{-3}$ or high densities $N_e \gtrsim 10^7 \mathrm{cm}^{-3}$ can be distinguished according to the observed HeI line ratio $\Lambda \gtrsim \Lambda_0$ or $\Lambda < \Lambda_0$ respectively.

For $He^+$ abundance determination the calculated HeI recombination line emissivities must include collisional contributions. Clegg (1987) gives for several HeI lines the ratio of excitations by collisions to recombinations $C/R$ for intermediate density nebulae. But in high density nebulae $N_e \gtrsim 10^7 \mathrm{cm}^{-3}$ and under case B conditions, the radiative decay rate $2\,^1\mathrm{S}{-}1\,^1\mathrm{S}$ becomes slow with respect to collisional rates and the population of $2\,^3$S and $2\,^1$S rises further. As a result the $C/R$ ratios are much larger in high density nebulae. This can explain very strong HeI lines seen in some symbiotic stars without postulating helium overabundances.

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