MEASUREMENT OF HeI λ10830 Å IN THE FLARE STAR, V1005 ORI (= GL 182)

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INTRODUCTION
Investigation of HI line formation in the Sun and late-type stars has given important insight into their chromospheric structures (Athay 1986; Cram & Mullan 1979; Houdebine & Panagi 1990). HeI line formation has been more problematic, however. Higher temperature of formation, along with susceptibility to over-ionisation by coronal EUV-XUV radiation (Zirin 1975) or streaming particles (Jordan 1975), makes HeI a stringent test of our understanding of chromospheric and transition region (TR) physics.

In dMe stars, coronal temperatures and pressures are much higher than in the Sun, so such effects are expected to work under more extreme conditions. Higher EUV-XUV radiation should produce higher over-ionization, while higher TR temperature gradients should enhance particle streaming. On the other hand higher pressures should reduce the latter. We have begun a programme of observation of those lines of HeI accessible from the ground. Here we report the detection of HeI λ10830 Å in the dMe star, V1005 Ori and discuss its implications for TR structure in such objects.

V1005 ORI
V1005 Ori (= GL 182 = Vyss 111) was first reported as a flare star by Shakovskaya (1974). Bopp et al. (1978) suggested it was also a BY Dra (spotted) variable with P ≈ 1.8–2.2 day. Byrne et al. (1984) showed P ≈ 4.56 day and that reports (de la Reza et al. 1981) of extreme chromospheric activity were incorrect, in spite of observing one of the largest optical flares ever recorded on a dMe star. Mathioudakis et al. (1991) measured the quiescent electron density in V1005 Ori’s lower TR using CIII interstellar lines.

OBSERVATIONS
The spectrum reported here was made using the CGS4 spectrograph at UKIRT on 9 November 1992. Spectral resolution was Δλ/λ ≈ 7000. The resulting spectrum, normalised to the local continuum, is shown in Fig. I, along with a similar spectrum of the bright A0V star, BS3314. The absence of terrestrial H2O lines in the latter demonstrates that this was not a problem.

HeI λ10830 Å is strongly in absorption. It was fitted by a multi-component gaussian using the STARLINK (Bromage 1984) software package DIPSO (Howarth & Murray 1987). Nearby atomic lines included in the fit are labelled in Fig. I. The measured HeI λ10830 Å EW was 0.17 Å.
FIGURE I  Spectrum of V1005 Ori near HeIλ10 830Å (lower) along with a spectrum of the A0V star, BS3314 (upper) taken to check for terrestrial H₂O contamination.

FIGURE II  HeIλ10 830Å EW vs TR pressure ($T_{chr} = 8000$K) (upper panel) and vs $T_{chr}$ with $P_{TR}$ fixed ($=0.22\,\text{dyn cm}^{-2}$) (lower panel).

DISCUSSION
A grid of dMe model atmospheres was prepared solving the non-LTE radiative transfer problem for H, He and Si using the program MULTI (Carlsson 1986). The atomic parameters used can be found in Lanzafame (1993a,b). For the He calculations we used accurate collision strengths extrapolated using the method of Lanzafame et al. (1993). The results are summarised in Fig II. The upper panel shows HeIλ10 830Å EW vs TR pressure (at 30 000$^\circ$K), while keeping the upper chromosphere temperature constant. A similarity to Hα EW vs $P_{chr}$ (Cram & Mullan 1979) will be noted, although the details of the formation are different. As $P_{TR}$ is increased absorption EW first increases but eventually the line goes into emission as $P_{TR}$ is increased further. The range of model pressures was chosen to be compatible with observed Hα and SiII fluxes for Gl182. Note that in the limit of low $P_{TR}$ HeIλ10 830Å is still strongly in absorption, which reflects the fact that an appreciable part of the line forms in the upper chromosphere.

The lower panel of Fig. II shows the effect of varying upper chromospheric
conditions, viz. the temperature of the chromospheric plateau while holding $P_{TR}$ constant. Temperatures above $\approx 8400^\circ K$ lead to a dramatic increase in EW of HeI$\lambda 10,830\text{Å}$. An upper chromospheric temperature of $\approx 8450^\circ K$ will reproduce the observed V1005 Ori EW. The calculations made insofar indicate that it is possible to reproduce approximately the observed EW of HeI$\lambda 10,830\text{Å}$ with a model having an electron density $N_e \approx 5 \times 10^{10}\text{cm}^{-3}$ at $40,000^\circ K$, as derived from CIII intersystem line ratios by Mathioudakis et al. (1991).

CONCLUSIONS
Confrontation of NLTE model chromospheres/TR with observations of HeI $\lambda 10,830\text{Å}$ in the dMe star, V1005 Ori, indicate that it is possible to reproduce the observed line with a simple model which is compatible with other observational constraints. This opens the possibility of multi-line modelling and realistic theoretical investigations of the physical conditions of the upper chromosphere/lower TR of dMe stars.

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REFERENCES
Athay, R.G. 1986, Physics of the Sun II, eds. P.A. Sturrock et al. Reidel, 1
Bopp, B.W., Torres, C.A.O., Busko, I.C., & Quast, G.R. 1978, IBVS, No.1443
Howarth, I.D., & Murray, M.J. 1987, STARLINK User Note No.50, Rutherford Appleton Labs
Shakovskaya, N.I. 1974, IBVS, No.897