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The Red Edge of GW Virginis stars

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We derive the theoretical red edge of the pulsating GW Vir stars by using full evolutionary calculations that involve mass loss and diffusion. The specific mass loss law used in the evolutionary computations determines the red edge's position. By combining this specific property with the observed location of the red edge in the effective surface temperature gravity domain, we obtain interesting constraints on possible mass loss laws for PG 1159 stars.

We used an improved version of the evolutionary code based on a finite element method to model the effects of diffusion and mass loss on the red edge's position.

Here are the mass loss laws used in the present calculation: $\mathrm{WM1} = 1.14 \times 10^{-11} L^{0.93}$ is a fit to the mass loss rates measured in five PG 1159 type stars, three of which are also GW Vir stars; $\mathrm{WM2} = 1.82 \times 10^{-13} L^{1.36}$ is a fit to the five previous stars plus nine nuclei of planetary nebulae of similar luminosity; for $\mathrm{WM3} = 1.29 \times 10^{-15} L^{1.86}$ we chose the theoretical model used for typical post-AGB calculations; finally, $\mathrm{WM4} = 1.00 \times 10^{-17} L^{2.38}$ is an empirical law derived in such a way that the theoretical red edge falls directly on the empirical red edge observed for the GW Vir class.

The effects of the mass loss over the position of the red edge is pictured in Fig. **??**. We have calculated the evolution of three different models having masses of 0.5, 0.55 and 0.6 $M_\odot$. These models were all allowed to evolve under the effects of the WM1, WM2, WM3, and WM4 wind models. We then used our nonadiabatic pulsation code to probe the stability of the models along each track. The red edges obtained in the figure are simply fits along the three tracks calculated with the different mass loss laws WM2, WM3 and WM4. The position of the WM1 red edge, around $T_{\rm eff} = 30\,000$ K, is not shown here as it is off scale. As is well known, no PG 1159 stars exists at this low temperature. This temperature is clearly too cool and that particular mass loss law must be abandoned. The same conclusion could be drawn for WM2, but we prefer to set conservatively this law as a maximum value for the magnitude of the mass loss in GW Vir stars, $\dot{M} < \mathrm{WM2}$.

By construction, and as indicated above, we have devised the WM4 model in order to match fairly closely the empirical red edge as defined by the position of the coolest known GW Vir star, PG 0122+200 at 80 000 K. However, it should be noted that the predicted surface composition according to the WM4 model at that effective temperature is highly deficient in carbon and oxygen as compared to the real atmospheric chemical composition of PG 0122+200 ($X(\mathrm{He}) = 0.43$, $X(\mathrm{C}) = 0.39$, and $X(\mathrm{O}) = 0.17$). Hence, it would appear that the WM4 model underestimates the true average mass loss in the GW Vir stars. On the other end, the empirical red edge could also be actually somewhat cooler than the effective temperature of PG 0122+200. In any case, we can use the WM4 model to set a minimum value for the mass loss in GW Vir stars, $\dot{M} > \mathrm{WM4}$.

On the other hand, the WM3 wind model, still permits relatively high abundances of carbon and oxygen close to the empirical red edge. Also, the red edge produced by this wind model is not far, in the $\log g - T_{\rm eff}$ diagram, from the coolest known GW Vir stars. This model with $\dot{M} = \mathrm{WM3}$, is therefore more likely to be representative of the actual red edge of GW Vir stars.

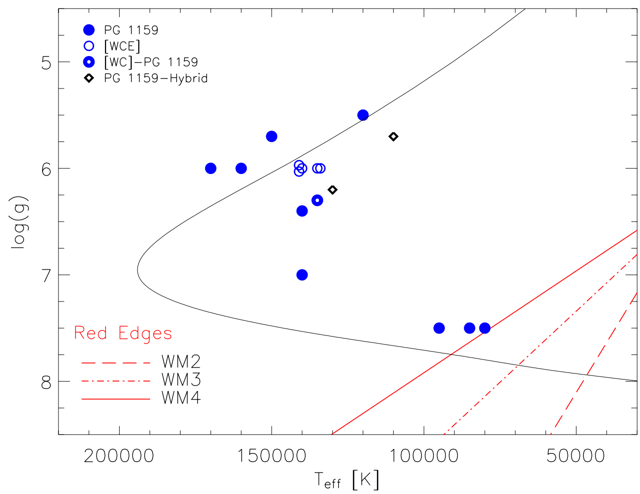

Figure 1: Positions of the known GW Vir stars in the $\log g - T_{\rm eff}$ diagram. The four spectroscopic types and sub-types of GW Vir are shown along with a representative 0.604 $M_\odot$ track from F. Herwig (personal communication) and with the calculated red edges for WM2, WM3 and WM4.

Some more LOC announcements to come!