H_α/P_δ Lines of Hydrogen in Cool Luminous Stars

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We have been assembling H_α/P_δ (P for Paschen) line profiles for a wide range of spectral types. The lines are at 6563 and 10049Å. The data have been obtained with the Coude spectrograph of the 1.2-m telescope of the Dominion Astrophysical Observatory (DAO). In this presentation we concentrate on stars of type F, G, K, and M. The advantage of using P_δ to verify models of stellar atmospheres is that departures from LTE are mainly due to the meta-stability of the 2s level. Stars of high luminosity illustrate the differences between LTE and NLTE since collisional effects are reduced as compared with main sequence stars. Profile differences between the P_δ and H_α lines and the synthesized LTE line profiles are shown.

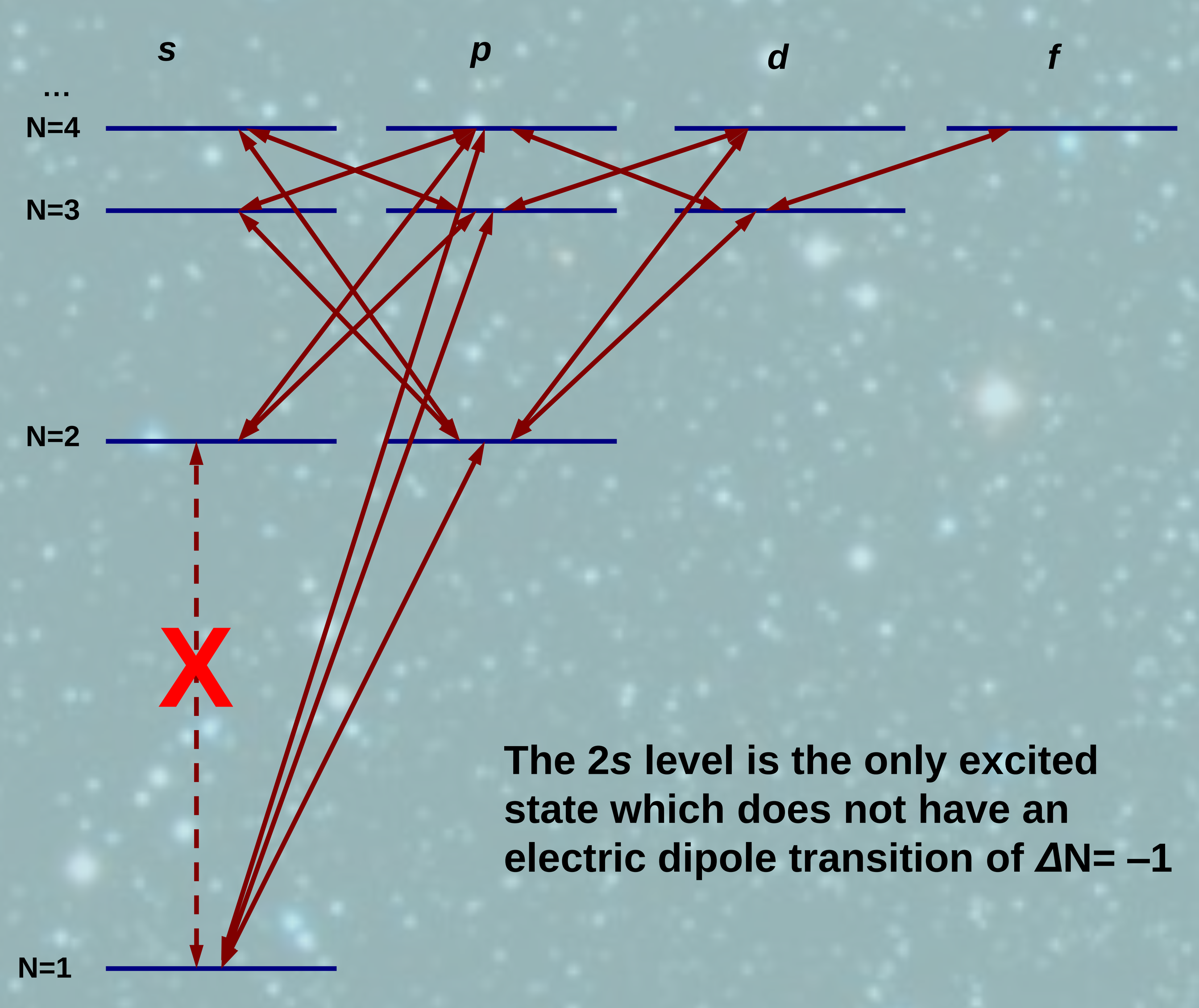
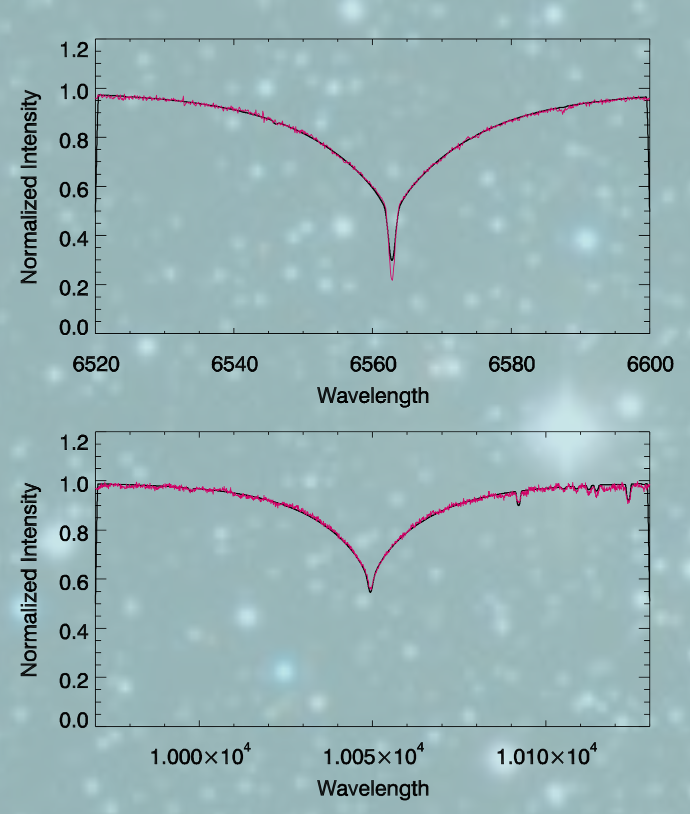


Figure 1: Energy levels of Hydrogen atom

In Hydrogen atoms, the radiative transition between the 1s and 2s levels is forbidden (see Fig. 1). This means that the population of the 2s level should be controlled by radiative and collisional transitions with other excited levels but transitions between the 2s and 1s levels are strongly inhibited. At high densities collisions are effective so that the population ratios among the n>2 levels approach equilibrium but the relative population between n=1 and n=2 deviate from LTE. There is no question as to the presence of non-LTE (NLTE); the only question is one of degree. The Paschen lines which originate from the n=3 level are expected to be closer to LTE than are the Balmer lines.

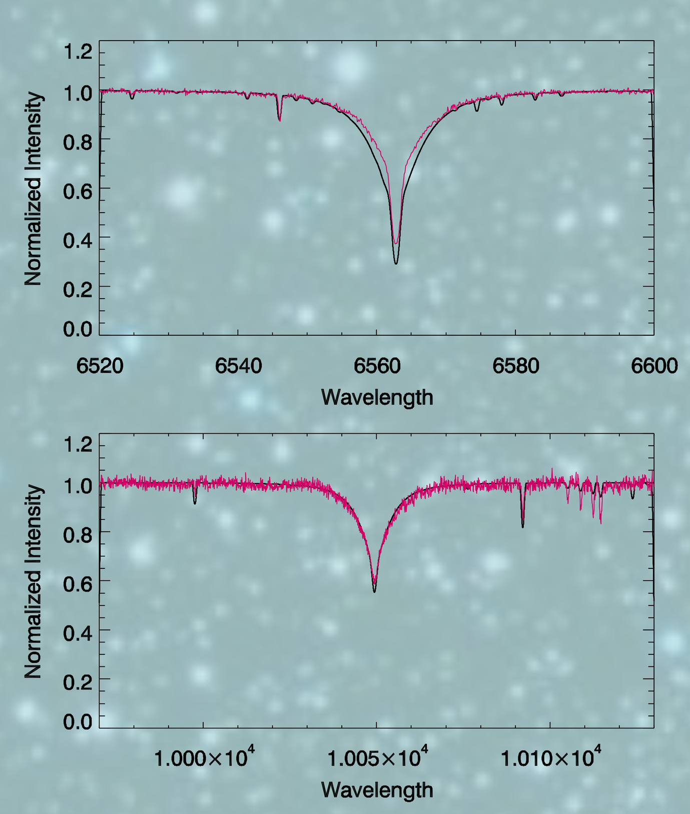
To investigate the importance of these effects, it is helpful to observe the Paschen (and higher) lines and to compare their line profiles with the predictions of atmospheric models. Since the NLTE effects are expected to be more prominent in low density environment, more luminous stars are favored in our observations. We obtained spectra of both the H_α and P_δ regions for a wide range of spectral types, using the Coude spectrograph of the 1.2-m telescope of the Dominion Astrophysical Observatory (DAO). The observed H_α and P_δ profiles (*red lines*) of some stars are shown below as well as the synthesized LTE profiles (*black lines*). These figures clearly show that the NLTE effects are much larger in the H_α profile than in the P_δ profile. Spitzer (1939 ApJ, 90, 494) originally noted that, for *α* Ori (see the last plot below), forming a such strong H_α profile in LTE would require a radiation temperature of 17,000K for Ly-alpha to populate the n=2 level while the effective temperature of the star is only about 3500K.



Vega (A0 V):

T_{eff} = 9540K log *g* = 4.00

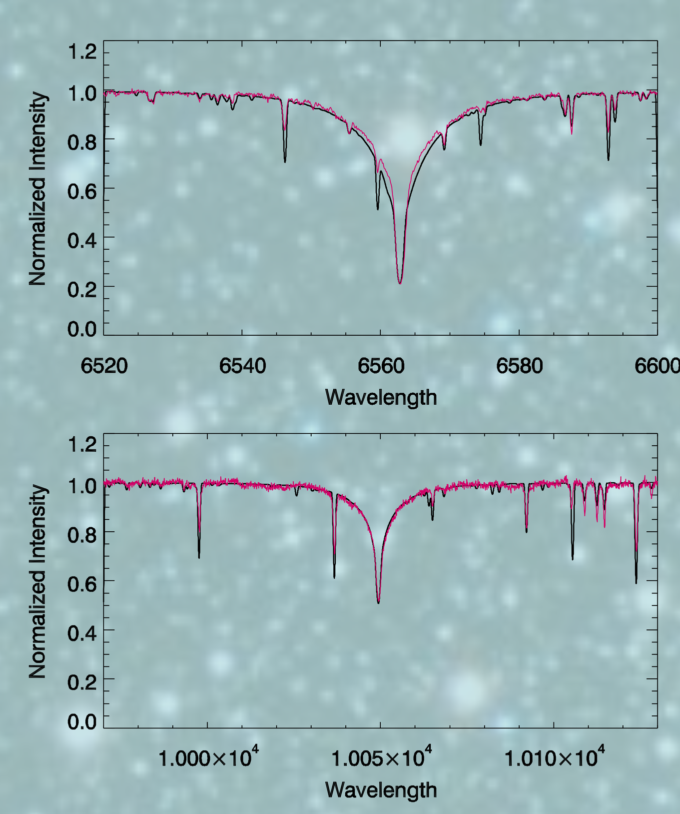
V_t = 1.2 km/s [Fe/H] = – 0.5



13 Mon (A0 Ib):

T_{eff} = 9700K log *g* = 2.00

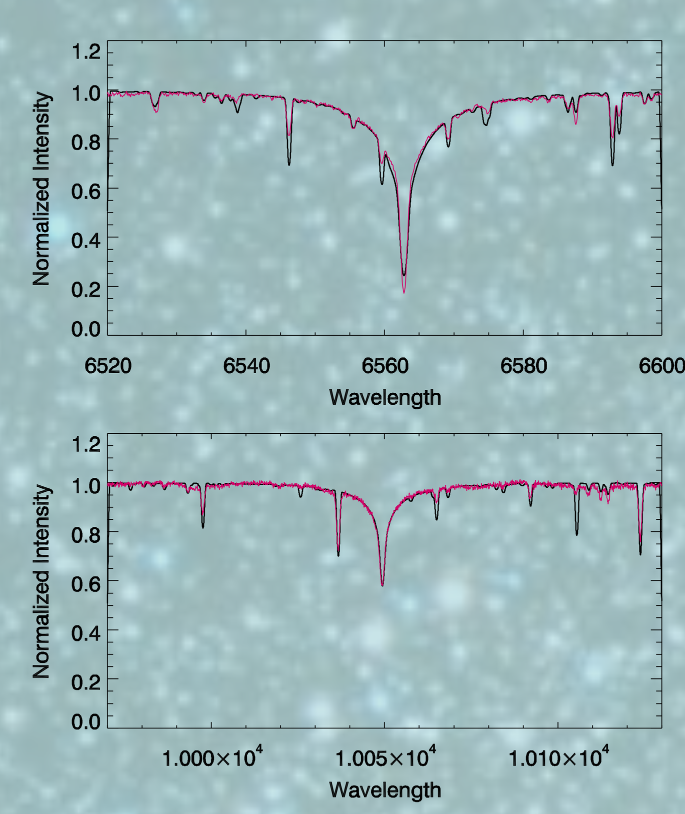
V_t = 4.0 km/s [Fe/H] = – 0.06



HD 182835 (F2 Iab):

T_{eff} = 6750K log *g* = 1.00

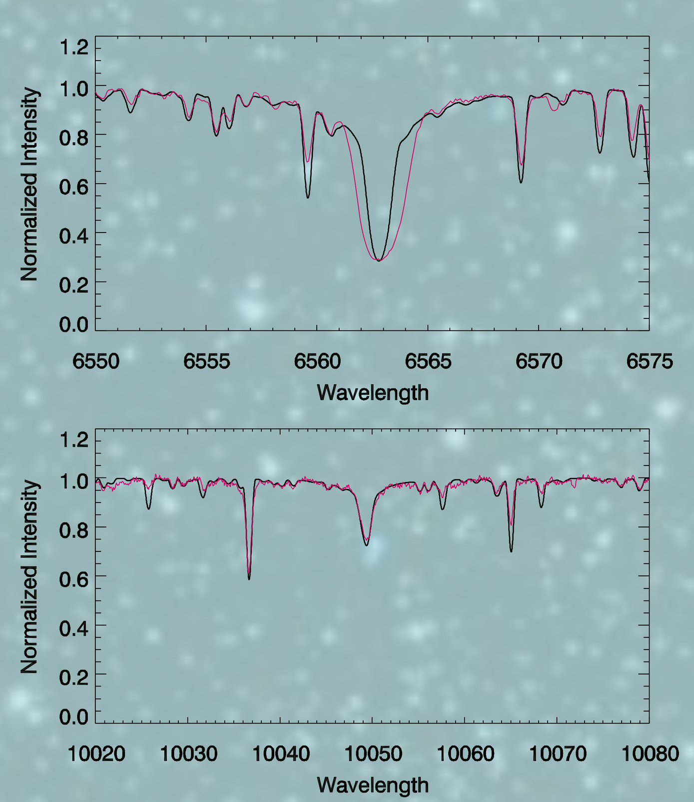
V_t = 5.0 km/s [Fe/H] = 0.0



α Per (F5 Iab):

T_{eff} = 6350K log *g* = 1.90

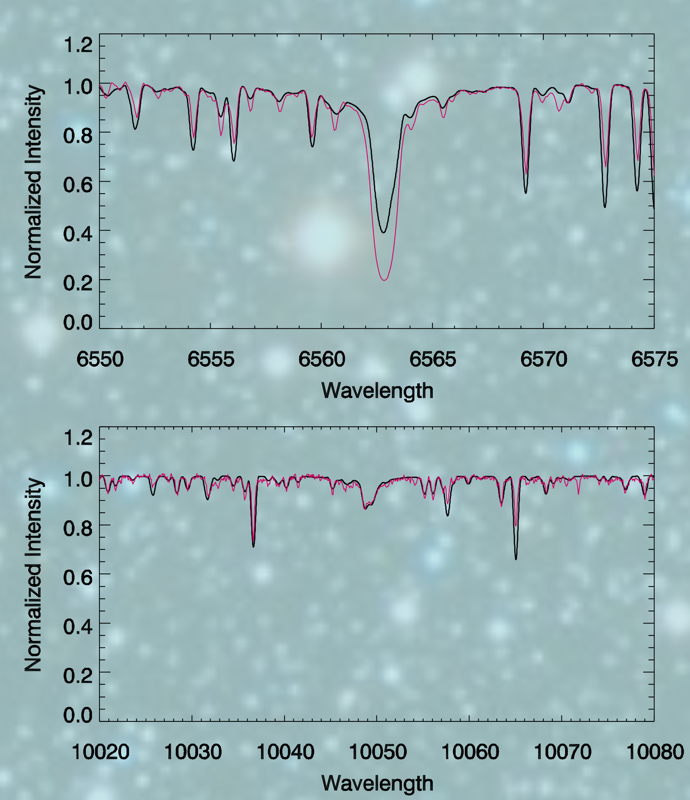
V_t = 5.3 km/s [Fe/H] = 0.0



α Aqr (G2 Ib):

T_{eff} = 5250K log *g* = 1.45

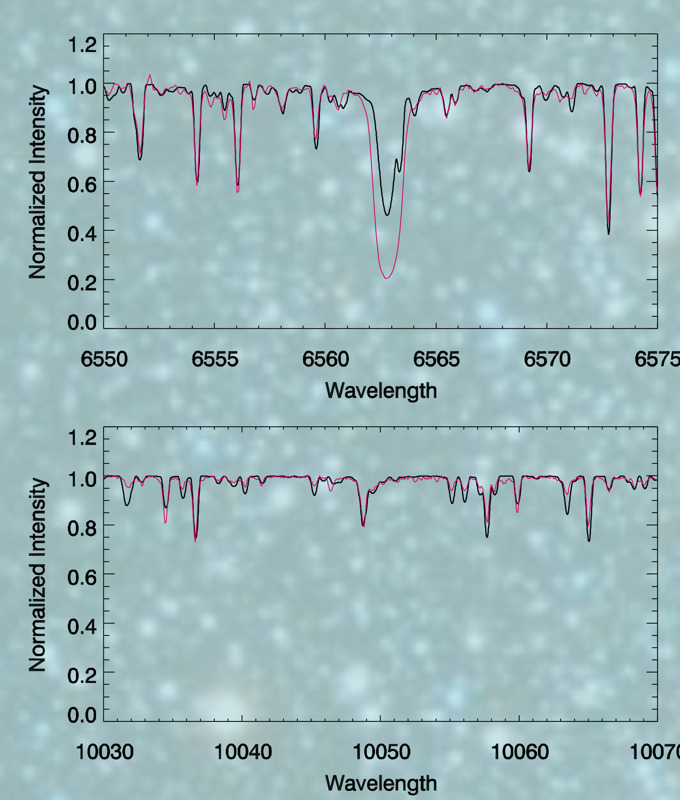
V_t = 3.8 km/s [Fe/H] = 0.0



κ Gem (G8 IIIa):

T_{eff} = 4800K log *g* = 2.90

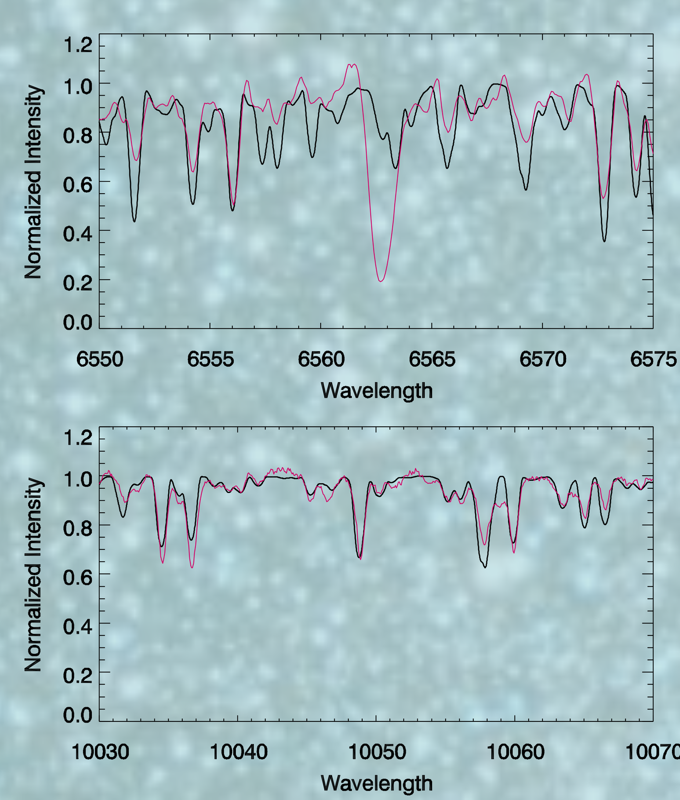
V_t = 3.8 km/s [Fe/H] = 0.0



Arcturus (K1.5 III):

T_{eff} = 4250K log *g* = 1.90

V_t = 1.4 km/s [Fe/H] = – 0.5



Betelgeuse (M2 Iab):

T_{eff} = 3540K log *g* = 0.0

V_t = 2.3 [Fe/H] = 0.0