The Mass Loss Rates of sdB Stars

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Abstract. According to previous investigations the effect of diffusion in the stellar atmospheres and envelopes of subdwarf B (sdB) stars with luminosities $10 \lesssim L/L_\odot \lesssim 100$ strongly depends on the presence of weak winds with mass loss rates $\dot{M} \lesssim 10^{-12} M_\odot/yr$. These calculations with the mass loss rate as a free parameter have shown that it is hardly possible to reproduce the measured abundances of helium and metals simultaneously. A possible reason is the decoupling of metals, which preferably absorb the photon momentum, from hydrogen and helium in the wind region. In the present paper it will be investigated if “chemically homogeneous” winds, as assumed in previous investigations, with mass loss rates $\dot{M} \leq 10^{-12} M_\odot/yr$ can exist. From an observational point of view the existence of weak winds in sdB stars is unclear. Only in the most luminous ones possible wind signatures have been detected. Therefore it will be investigated if according to the theory of radiatively driven winds the existence of weak winds is plausible. A stellar mass $M_* = 0.5 M_\odot$ is assumed.

The results for effective temperatures $T_{\text{eff}} = 35000, 30000$ and $25000$K, metallicities $0.1 \leq Z/Z_\odot \leq 1$ predict decreasing mass loss rates with increasing surface gravity. Dependent on the luminosity and metallicity the mass loss rates are between about $10^{-11} M_\odot/yr$ and zero. If at all, chemically homogeneous winds can exist for the most luminous sdB stars only. For the other ones selective winds are expected which should lead to additional changes of the surface composition.

In sdB stars, hot white dwarfs and HgMn stars (which are chemically peculiar main sequence stars) the measured metal abundances are tendencially lower than the ones predicted from diffusion calculations which assume an equilibrium between gravitational settling and radiative levitation. Only for helium in almost all cases the measured abundances are larger than the predicted ones, but usually lower, below the solar value. This may be an indication that the abundance anomalies of metals are preferably due to the selective winds, whereas the helium deficiencies are due to gravitational settling, which for still unknown reasons is less effective than expected in an undisturbed stellar atmosphere.

1. Introduction

The abundance anomalies in subdwarf B (sdB) stars, white dwarfs and chemically peculiar main sequence stars are believed to be at least partially due to the effect of diffusion in the stellar atmosphere and envelope. Several attempts have been made to explain the abundances with the effect of gravitational settling which may be counteracted by radiative levitation. As the radiative force on an element decreases with increasing abundance due to saturation effects, the surface composition can be predicted from the equilibrium condition between
the inward gravitational force and the outward radiative force. However, an agreement between predicted and measured abundances requires the absence of disturbing processes like mass loss or convective mixing. This may be the reason why in many cases the agreement is not satisfactory. A comparison between predicted and measured metal abundances for sdB stars (e.g. Bergeron et al. 1988; Ohi et al. 2000; Chayer et al. 2006; Behara & Jeffery these proceedings) and hot white dwarfs (e.g. Schuh et al. 2002, 2005; Good et al. 2005) shows that the measured abundances are tendencially lower than the predicted ones, although a few exceptions exist (e.g. silicon in hot white dwarfs).

According to recent spectral analyses of sdB stars (e.g. Geier et al. 2008a,b; O'Toole & Heber 2006; Edelmann et al. 2006; Blanchette et al. 2006) especially the hotter ones with $T_{\text{eff}} > 30000\text{K}$ in many cases show strong deficiencies of light metals like Al, Mg, O and Si by more than a factor of 100 in comparison to the solar abundances, whereas enrichments of elements heavier than iron by a factor of 100 are not unusual. Qualitatively, these abundance patterns show some similarity to those found in HgMn stars, which are a subgroup of the chemically peculiar main sequence stars reviewed by Smith (1996). The HgMn stars with $10000\text{K} \lesssim T_{\text{eff}} \leq 16000\text{K}$, log $g \approx 4.0$ are characterized by low rotational velocities and weak or non-detectable magnetic fields. Some light metals (e.g. Al, N) tend to be deficient, whereas heavy metals (e.g. Hg, Mn, Pt, Sr, Ga) may be enriched up to several orders of magnitude. Some of the most recent spectral analyses are from Zavala et al. (2007) and Adelman et al. (2006). The measured abundances of iron group elements (Seaton 1996; Jomaron et al. 1999) as well as nitrogen (Roby et al. 1999) tend to be lower than predicted from equilibrium diffusion calculations. Only for mercury abundances larger than predicted have been detected (Proffitt et al. 1999). So in hot white dwarfs, sdB and HgMn stars a common tendency seems to be present, according to which the metal abundances are lower than expected from the equilibrium condition between gravitational settling and radiative levitation. In addition there is a large scatter of abundances from star to star. Even for stars with similar stellar parameters the abundances may be different. This points to some time-dependent process and not to an equilibrium state. In main sequence stars the chemically peculiar phenomenon is restricted to stars with low rotational velocities. In addition the presence of magnetic fields may be of importance, because magnetic fields may change the radiative acceleration or suppress convection (Turcotte 2003). White dwarfs and sdB stars, however, are always more or less chemically peculiar. Up to now no correlation between abundance anomalies and magnetic field strengths has been found (O'Toole et al. 2005). In hot DA white dwarfs no outer convection zones should exist, because hydrogen is preferably ionized and helium is strongly deficient. In sdB stars a thin superficial convection zone with a mass depth of the order $10^{-12}M_*$ may be present only for helium abundances He/H $\geq 0.01$ by number (Groth et al. 1985). So it seems to be unlikely that magnetic fields are of decisive importance for the explanation of the surface compositions.

In hot DAO white dwarfs helium is detectable, but in many cases it is deficient in comparison to the solar value (e.g. Napiwotzki 1999). The same is true for the majority of sdB's (e.g. Edelmann et al. 2003; Lisker et al. 2005) and the helium deficient main sequence stars (e.g. in HgMn stars helium usually is
deficient). In contrast to the metal abundances, however, the abundances of helium are always larger than predicted from equilibrium diffusion calculations (Vennes et al. 1988, Michaud et al. 1989, 1979). These results may be explained with the effect of gravitational settling which, however, somehow must be disturbed. Possible reasons for this disturbance of the equilibrium may be the presence of turbulence (Vauclair et al. 1978) or mass loss. Fontaine & Chayer (1997) and Unglaub & Bues (1998) predicted helium abundances as a function of time in the presence of weak winds. The results have shown that for mass loss rates of the order $10^{-13} M_\odot/\text{yr}$ helium sinks much more slowly than in the case of an undisturbed stellar atmosphere. Within the lifetimes of sdB stars near the extended horizontal branch ($\approx 10^8 \text{yr}$) the helium abundance would gradually decrease from the solar value to $\text{He}/\text{H} \approx 10^{-4}$ by number. This could explain why the helium abundances usually are in this range.

If this scenario with weak winds were the correct explanation for both the helium and the metal abundance anomalies, then it should be possible to find a mass loss rate for which all abundances can be explained simultaneously. The calculations of Unglaub & Bues (2001) for the elements H, He, C, N and O have shown that this is hardly possible. According to these calculations for solar initial composition helium should always be more deficient than the metals. No mass loss rate exists which leads to deficiencies of C and O by more than a factor of 100, whereas helium is deficient by a factor of ten only. This, however, is not an unusual composition in sdB stars (e.g. Heber et al. 2000). Moreover in the presence of winds with mass loss rates of the order $10^{-13} M_\odot/\text{yr}$ which are required to explain the helium abundances, the proposed pulsation mechanism of some sdB stars (Charpinet et al. 1997; Fontaine et al. 2003) would become questionable. As mass loss tends to level out concentration gradients, the reservoir of iron (or other iron group elements) in the stellar envelope needed to explain the pulsations should be destroyed in time scales which are much shorter than the lifetimes of sdB stars. According to Chayer et al. (2004) and Fontaine et al. (2006) for a mass loss rate of $\dot{M} = 6 \times 10^{-15} M_\odot/\text{yr}$ the reservoir would be destroyed on about $10^7 \text{yr}$. For $\dot{M} = 10^{-13} M_\odot/\text{yr}$ the matter in mass depths $\lesssim 10^{-7} M_\star$, where the reservoir is expected, would be blown away within one million years only.

Probably the most crucial assumption in these diffusion calculations with mass loss has been that the winds are “chemically homogeneous”. If $M_I$ is the mass loss rate of an element $I$ and $\zeta_I$ its mass fraction in the photosphere, then this assumption states that $\dot{M}_I = \zeta_I \dot{M}$, where $\dot{M}$ is the total mass loss rate. Such a chemically homogeneous wind prevents (if $\dot{M} > 10^{-11} M_\odot/\text{yr}$) or retards (if $\dot{M} < 10^{-11} M_\odot/\text{yr}$) gravitational settling. However, it does not directly change the surface composition. The opposite case would be a “selective” wind in which the mass loss rates of the individual elements are essentially independent of each other. A selective wind should lead to additional changes of the surface composition, which have not yet been taken into account in the calculations.

In radiatively driven winds of hot stars the photon momentum is absorbed preferably by the metals (see e.g. Abbott 1982; Vink et al. 2001), whereas the contribution of hydrogen and helium is small. Thus the metals are accelerated and move outwards. If the flow of metals is sufficiently large, then due to Coulomb collisions with the metals hydrogen and helium are accelerated as well.
For this purpose, in dense winds a small velocity difference between the metals and hydrogen and helium is sufficient. Then it should be a good approximation that all elements have the same velocity and that the wind is chemically homogeneous. If, however, the flow of metals is small, then it may happen that the coupling of the various constituents due to collisions is not sufficiently effective and that hydrogen and helium are left behind. This scenario may lead to pure metallic winds such as investigated by Babel (1995) for main sequence A stars.

Mass loss has been detected in subdwarf O stars (sdO) which are more luminous than sdB’s (Hamann et al. 1981; Rauch 1993). Up to now there is no observational proof for the existence of winds in sdB stars. From a quantitative analysis of Hα line profiles of 40 sdB stars (Maxted et al. 2001), a comparison of synthetic NLTE Hα line profiles from static model atmospheres with the observations revealed perfect matches for almost all stars. Only in the four most luminous sdB’s anomalous Hα lines with a small emission at the line center have been detected, which possibly are signatures of weak winds (Heber et al. 2003). For the case \( T_{\text{eff}} = 36000 \text{K}, \log g = 5.5 \text{ and } \log L/L_\odot = 1.51 \) from a spectral synthesis of Hα with his wind code Vink (2004) found a similar behaviour of Hα if the existence of a weak wind with \( \dot{M} \approx 10^{-11} M_\odot/\text{yr} \) is assumed.

In Sect. 2 it will be investigated for a stellar mass \( M_* = 0.5 M_\odot \) if winds with mass loss rates \( \dot{M} \lesssim 10^{-12} M_\odot/\text{yr} \) can be chemically homogeneous. The arguments are similar as in the investigations for more luminous stars e.g. from Owocki & Puls (2002), Springmann & Pauldrach (1992) and Krátká et al. (2003). All metals are lumped together into one mean metal which is accelerated due to the absorption of photon momentum. This is some simplification, in Krátká (2006) the individual elements are considered separately. Hydrogen, helium and the free electrons are denoted as “passive plasma” which can only be accelerated due to collisions with the outflowing metals. From the calculations e.g. of Abbott (1982) and Vink et al. (2001) as well as from own calculations as described in Sect. 3 there is no indication that the radiative force on hydrogen and helium is not negligible. The mean radiative acceleration on the metals exceeds the one on hydrogen and helium by at least a factor of 100.

In Sect. 3 the results of mass loss calculations for sdB stars according to the original theory of radiatively driven winds of Castor, Abbott, & Klein (1975, CAK) are presented and are compared with the predictions from the mass loss recipe of Vink & Cassisi (2002). For these wind models, which are obtained from a one component description of the wind, it is again checked if the metals may be coupled to hydrogen and helium. In Sect. 4 the consequences of the results for the surface composition of sdB stars are discussed.

2. Do Chemically Homogeneous Weak Winds Exist?

In the following the hydrogen and helium, for which the radiative acceleration is assumed to be zero, will be denoted as “element” 1, whereas the mean metal is denoted as “element” 2. As in the supersonic region the gradient of the gas pressure can be neglected, the momentum equation for “element” 1 (H+He) can be written as:

\[
\dot{g}_{\text{coll}} = \frac{GM_*}{r^2} + v_1 \frac{dv_1}{dr}
\]  \hspace{1cm} (1)
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$g_{\text{coll}}$ is the collisional acceleration on hydrogen and helium due to Coulomb interactions with the metals and $v_1$ is the mean velocity of hydrogen and helium. The existence of a supersonic wind with increasing velocity in outward direction requires that the acceleration term $v_1 \frac{dv_1}{dr}$ is larger than zero. Thus this equation can only be valid if:

$$g_{\text{coll}} > \frac{GM_*}{r^2}$$

where $G$ is the gravitational constant and $r$ the radius. Hydrogen and helium cannot be accelerated if this condition is violated. As derived by Burgers (1969), $g_{\text{coll}}$ can be written as:

$$g_{\text{coll}} = \frac{\rho_2}{m_1 m_2} \frac{4\pi Z_1^2 Z_2^2 e^4}{kT} (\ln \Lambda) G(x)$$

$m_1$ and $m_2$ are the mean masses of “elements” 1 and 2, $\rho_2$ is the mass density of the mean metal, $k$ the Boltzmann constant, $T$ the temperature and $e$ is the electron charge (cgs system). $Z_1$ is the mean charge of hydrogen and helium, $Z_2$ is the charge of the mean metal. $\ln \Lambda$ is the Coulomb logarithm which according to Burgers (1969) is:

$$\ln \Lambda = -1/2 + \ln \left( \frac{3kTR_D}{Z_1 Z_2 e^2} \right).$$

$R_D$ is the Debye radius:

$$R_D = \left( \frac{kT}{4\pi e^2 (n_1 Z_1^2 + n_2 Z_2^2 + n_e)} \right)^{0.5}$$

where $n_1$ is the number density of hydrogen and helium, $n_2$ and $n_e$ are the number density of the mean metal and the free electrons, respectively.

$G(x)$ in Eq. 3 is the Chandrasekhar function defined as, e.g., in Krtička et al. (2003). It depends on the quantity $x$, which approximately is the velocity difference of the mean metal and the passive plasma in units of the thermal velocity of hydrogen. If $v_2$ is the velocity of the mean metal and $v_1$ the mean velocity of the passive plasma, then the latter can be accelerated only if $v_2 - v_1 > 0$. For small velocity differences, $G(x)$ and thus the collisional acceleration approximately is proportional to $v_2 - v_1$. If, however, the velocity difference is near the thermal velocity of hydrogen, $G(x)$ reaches a maximum value and decreases to larger velocity differences. For the discussion in the present section only this maximum value is important:

$$G_{\text{max}} = 0.214.$$
The mass density $\rho_2$ of the mean metal in Eq. 3 can be substituted from the equation of continuity for the metal:

$$\rho_2 = \frac{\dot{M}_2}{4\pi r^2 v_2}$$

where $\dot{M}_2$ is the mass loss rate of the metals and $v_2$ their mean velocity. With this substitution condition Eq. 2 can be transformed into a condition for $\dot{M}_2$:

$$\dot{M}_2 > \frac{m_1 m_2 k T}{Z_1^2 Z_2^2 e^4 \ln \Lambda G_{\text{max}}} G M_\ast v_2.$$  

This condition depends on the mean velocity of the metals. It is most restrictive in the part of the wind where $v_2$ is maximal. In accelerating winds this maximal velocity is the terminal velocity $v_\infty$. According to theoretical calculations and observations of hot star winds (see e.g. [Lamers & Cassinelli 1999]), radiatively driven winds accelerate to terminal velocities which are at least of the order of the surface escape velocity $v_\text{esc}$. Thus we require that this condition must still be fulfilled for

$$v_2 = v_\text{esc} = \sqrt{\frac{2 G M_\ast}{R_\ast}} = \sqrt{2} \left( G M_\ast g \right)^{\frac{1}{4}}.$$  

Here it has been assumed that the radiative force due to electron scattering is negligible which is justified for subluminous stars. The right equation is obtained from $R_\ast = \sqrt{G M_\ast g^{-1}}$. With this expression for $v_2$ condition (8) can be written as:

$$\dot{M}_2 > \frac{m_1 m_2 k T}{Z_1^2 Z_2^2 e^4 \ln \Lambda G_{\text{max}}} \sqrt{2} \left( G M_\ast g \right)^{\frac{3}{4}} g^{\frac{1}{4}}.$$  

Now we assume a mean mass for hydrogen and helium $m_1 = m_p$ (where $m_p$ is the proton mass) and $m_2 = 15m_p$ for the mean metal. The mean charges are assumed to be $Z_1 = 1$ and $Z_2 = 3$, respectively. According to own calculations $\ln \Lambda$ may vary between about 6.0 at the wind base and 18.0 in the outermost regions. As an upper limit and similar to [Owocki & Puls (2002)] we assume $\ln \Lambda = 20$. With a typical stellar mass for sdB stars $M_\ast = 0.5 M_\odot$ and for $T = T_{\text{eff}}$ it follows:

$$\dot{M}_2 > 1.2 \times 10^{-20} T_{\text{eff}} g^{\frac{1}{4}}.$$  

The mass loss rate $\dot{M}_2$ of the metals is given in $M_\odot/\text{yr}$, $T_{\text{eff}}$ in K and the surface gravity $g$ in cm s$^{-2}$. For typical stellar parameters of sdB stars, e.g. $T_{\text{eff}} = 30000 \text{K}$, $\log g = 5.7$, it follows

$$\dot{M}_2 > 10^{-14} M_\odot/\text{yr}.$$  

This means that the mass loss rate of the metals alone must exceed this value. Otherwise hydrogen and helium will decelerate and cannot be expelled from the star, if not the decoupling occurs at such a large radius at which the velocity is already larger than the local escape velocity.

If the wind is chemically homogeneous, this implies $\dot{M}_2 = \zeta_2 \dot{M}$. If the mass fraction of the metals is of similar order of magnitude as the solar one
(ζ2 ≈ 0.01), then the condition \( \dot{M}_2 \gtrsim 10^{-14}M_\odot/\text{yr} \) implies for the total mass loss rate \( \dot{M} \gtrsim 10^{-12}M_\odot/\text{yr} \). Thus chemically homogeneous winds with lower mass loss rates cannot exist, if the metallicity is not larger than solar. A similar result can be obtained from eq. 22 of Owocki & Puls (2002). In this paper a maximum velocity \( v_{\text{max}} \) is derived up to which the constituents may be coupled. If the wind accelerates at least to the surface escape velocity, then a necessary condition for the existence of a coupled wind is \( v_{\text{max}} > v_{\text{esc}} \).

3. Mass Loss Rates from a One Component Description of the Wind

In this section it will be discussed how large the mass loss rates are in sdB stars according to the theory of radiatively driven winds. These calculations will be described in more detail in a forthcoming paper (Unglaub A&A, submitted). The momentum equation for an isothermal wind is solved without the usual parametrization of the line force multiplier parameters, which becomes questionable in weak winds (Kudritzki 2002). As later improvements of the CAK theory (finite disk correction and changes of ionization in the wind) are neglected, the method of solution is straightforward. The omission of the finite disk correction leads to an overestimate of \( \dot{M} \) by a factor of the order two to three (Lamers & Cassinelli 1999). From these calculations, in which multicomponent effect are neglected, the total mass loss rate \( \dot{M} \) and the velocity law \( v(r) \) are derived. From this solution the acceleration term \( v \frac{dv}{dr} \) is known. With the assumption that metals are trace elements \( (v_1 \approx v) \) it can be checked if metals may be coupled to hydrogen and helium from a criterion similar to the one derived by Owocki & Puls (2002). This criterion requires that hydrogen and helium must accelerate. Thus it will predict decoupling at larger mass loss rates than the less restrictive criterion Eq. 2, which only requires that the passive plasma does not decelerate.

In Fig. 1 the predicted mass loss rates are shown as a function of surface gravity for \( T_{\text{eff}} = 35000, 30000 \) and \( 25000 \text{ K} \) and several metallicities: \( Z/Z_\odot = 1, 1/3 \) and \( 1/10 \). For \( Z/Z_\odot = 1 \) and \( 1/10 \) the results are compared to the ones of Vink & Cassisi (2002), which are represented by dotted lines. It can be seen that especially for \( Z/Z_\odot = 1 \) the agreement is very well in many cases. This, however, is a consequence of the assumptions. As in the present calculations the original version of the CAK theory is used, for the terminal velocity it follows \( v_\infty \approx v_{\text{esc}} \) and the solution of the momentum equation has the form

\[ v(r) = v_\infty \left( 1 - \frac{R_\star}{r} \right)^{0.5}. \]

Vink & Cassisi (2002) assumed a similar velocity law with \( v_\infty \) as a free parameter. Their results shown in Fig. 1 are for \( v_\infty = v_{\text{esc}} \). With this \( v(r) \) they obtain the mass loss rate from the requirement of a global momentum conservation. As the function \( v(r) \) approximately is the same in both calculations, the agreement of the mass loss rates should be expected. Nevertheless it may appear surprising, because Vink & Cassisi’s calculation of the radiative acceleration is clearly more sophisticated than the present one. They took into account about \( 10^5 \) lines of the elements H–Zn with NLTE occupation numbers for the most important
Figure 1. Predicted mass loss rates as a function of surface gravity for $T_{\text{eff}} = 35000, 30000, 25000\text{K}$ and $Z/Z_{\odot} = 1, 1/3, 0.1$ with $M_{\ast} = 0.5M_{\odot}$. Dashed lines indicate decoupling of metals in the corresponding wind model. The upper and lower dotted lines in each figure represent the results of Vink & Cassisi (Vink & Cassisi 2002).
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The predicted mass loss rates shown in Fig. 1 clearly depend on the surface gravity and the metallicity. For $Z/Z_\odot = 1$ coupled winds can exist only if $\log g \lesssim 5.5$. As the criterion for ion decoupling is more restrictive than the one used in Sect. 2, this requires total mass loss rates almost of the order $10^{-11} M_\odot/\text{yr}$. If the metallicity is reduced by a factor of ten, then for the considered effective temperatures at least for $\log g \geq 5.5$ no solution of the momentum equation for a one component plasma exists at all, because the radiative force is not sufficient. This result has been confirmed by calculations of Vink (priv. comm.). For sdB
Figure 2. Lines in the $T_{\text{eff}} - \log g$ diagram above which chemically homogeneous winds may exist for $Z/Z_\odot = 0.1$, $1/3$ and $1$, respectively. Squares and circles represent the sdB stars analyzed by Maxted et al. (2001) and Lisker et al. (2005), respectively. Filled symbols represent the sdB's with peculiar $H\alpha$ line profiles, which may indicate the presence of a weak wind.

stars with $\log g = 5.5$ and $Z/Z_\odot = 1/10$ he could not find any mass loss rate for which a global momentum balance is fulfilled.

4. Discussion

In the $T_{\text{eff}} - \log g$ diagram of Fig. 2 for $25000K \leq T_{\text{eff}} \leq 40000K$ and for various metallicities the lines are shown above which according to the mass loss calculations as described in Sect. 3 chemically homogeneous winds may exist. It can be seen that for the majority of sdB stars this is not possible if the metallicity is solar or subsolar. They are below the line for $Z/Z_\odot = 1$. The sdB stars introduced in the diagram have been analyzed by Maxted et al. (2001) and Lisker et al. (2005). According to the assumptions of the present paper in those ones with peculiar $H\alpha$ line profiles (represented by filled symbols) chemically homogeneous winds may indeed exist if the metal abundances are not too far below the solar value. The predicted mass loss rates agree with the ones from the mass loss recipe of Vink & Cassisi (2002) and are of the order $10^{-10}$ to $10^{-11} M_\odot/yr$. However, as explained in Sect. 3, this agreement does not exclude that the mass loss rates are overestimated. So this result is still questionable.

The existence of winds may depend on the abundance of one element only, which preferably contributes to the radiative acceleration.

From the results it is clear that chemically homogeneous winds with mass loss rates $\dot{M} \leq 10^{-12} M_\odot/yr$ cannot exists. From arguments similar as in the paper of Owocki & Puls (2002), this result can be obtained without the calcula-
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The mass loss rate of the metals alone must be at least of the order $10^{-14} \, M_\odot/\text{yr}$. Otherwise hydrogen and helium cannot be accelerated throughout the wind. This result could be questioned only if a wind solution could be found for which the terminal velocity of the metals is clearly lower than the surface escape velocity. Krtička & Kubát (2000) suggested that the terminal velocity could indeed be lower than $v_{\text{esc}}$ (by a factor of the order two only, however), if the wind switches to a “shallow” solution with an abrupt lowering of the velocity gradient. However, Owocki & Puls (2002) and Krtička & Kubát (2002) argued that these solutions are unstable.

If hydrogen and helium cannot be expelled from the star, then pure metallic winds may exist. As the outflowing metals in the stellar atmosphere not only have to overcome the gravitational force, but in addition the frictional force due to collisions with protons and helium particles, the metal abundances should be lower than predicted from equilibrium diffusion calculations (if concentration gradients are negligible). For these metals, for which the mass loss rate is sufficiently small, measured and predicted abundances should be in agreement. For metals with non-zero mass loss rate this scenario should lead to abundances varying with time as has been discussed by Seaton (1996, 1999) for iron group elements in the envelopes of HgMn stars.

If both hydrogen and helium are in hydrostatic equilibrium, then measured helium abundances should be approximately in agreement with the ones predicted from equilibrium diffusion calculations. The fact that in the various types of helium deficient chemically peculiar stars the measured ones are larger, seems to indicate that gravitational settling in general is less effective than expected in an undisturbed stellar atmosphere. Moreover the existence of two distinct sequences of sdB stars which are characterized by an offset in the helium abundance (Edelmann et al. 2003; Lisker et al. 2005) can hardly be explained with one atmospheric effect alone. It may point to a dependence on the star’s history. Several scenarios of single star and binary evolution of the sdB and the hotter sdO stars are under discussion (Stroeer et al. 2007).

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