Evaporation of Jupiter-like planets orbiting extreme horizontal branch stars

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ABSTRACT
We study the evaporation of planets orbiting close to hot (extreme) horizontal branch (EHB) stars. These planets survived the common envelope phase inside the envelope of the red giant star progenitor. We find that Jupiter-like planets orbiting within ~10 R⊙ from an EHB star suffer a non-negligible mass-loss during their ~10^3-yr evolution on the horizontal branch. The evaporated gas is ionized and becomes a source of Balmer lines. Such planets might be detected by the periodic variation of the Doppler shift of the Balmer lines.

Key words: planets and satellites: atmospheres – stars: general – stars: horizontal branch.

1 INTRODUCTION
Horizontal branch (HB) stars are core helium-burning stars that have evolved from main sequence (MS) stars through the red giant branch (RGB). During the RGB phase the star loses a non-negligible amount of mass. The amount of mass lost determines the properties of the descendant HB star, namely, its location on the HR diagram.

HB stars with low-mass envelope have small radii and they are hot. They are called extreme HB (EHB) stars (other names are sdO or sdB or hot subdwarfs; in this work we will use all these terms indistinguishably). To become an EHB star, the RGB progenitor must lose most of its envelope. The reason that some RGB stars lose so much mass was a major unsolved issue in stellar evolution. The debate was whether a single star (e.g. Yi 2008) can account for the formation of hot subdwarfs, or whether binary evolution is behind the hot subdwarf phenomenon (e.g. Han, Podsiałkowski & Lysiański-Grey 2007). Recent studies suggest that the binary interaction is behind the formation of most EHB stars (for a recent paper and more references, see Geier et al. 2010a). However, not all EHB stars have stellar companions. It has been suggested that massive planet companions can also influence RGB stars and cause the formation of EHB stars (Soker 1998; by planet we will refer in this paper also to brown dwarfs). This model was confirmed with the discovery of a substellar object in an orbit close to an sdB star (HD 149382, Geier et al. 2009), as well as a planet orbiting a red HB star that lost some of its envelope (Setiawan et al. 2010). The intense UV radiation from the EHB evaporates the outer layers of a surviving close in planet. In this paper we study this process.

The escape of atoms from a planet has been deduced observationally from the absorption of atomic hydrogen around the planet HD 209458b that orbits an MS star (Vidal-Madjar et al. 2003; Vidal-Madjar & Lecavelier des Etangs 2004). In early studies several groups (e.g. Lammer et al. 2003; Baraffe et al. 2004, 2005) suggested that hot Jupiters orbiting MS stars can be evaporated down to their bare core.

Many detailed calculations have been made on the evaporation of planets in different conditions and circumstances (Dopita & Liebert 1989; Schneider et al. 1998; Soker 1999; Lammer et al. 2003; Baraffe et al. 2006; Erkaev et al. 2007; Garcia Munoz 2007; Schneider et al. 2007; Jackson, Greenberg & Barnes 2008; Lammer et al. 2009; Murray-Clay, Chiang & Murray 2009). Villaver & Livio (2007), for example, calculated the outflowing particle flux by equating the energy input and the energy required for hydrogen to escape. Their treatment is not much different from those of others (e.g. Lammer et al. 2003, 2009; Baraffe et al. 2004; Erkaev et al. 2007; Lecavelier des Etangs 2007; Lecavelier des Etangs, Vidal-Madjar & Desert 2008; Penz, Micela & Lammer 2008a; Sanz-Forcada et al. 2010; Valencia et al. 2010a). Another approach that takes into account the recombination of the evaporated gas is presented by Dopita & Liebert (1989) and McCray & Lin (1994).

Different models predict different mass-loss rates (e.g. Hunten 1982; Sasselov 2003; Vidal-Madjar & Lecavelier des Etangs 2004; Erkaev et al. 2007; Hubbard et al. 2007; Ehrenreich 2008, Ehrenreich et al. 2008; Davis & Wheatley 2009; Lammer et al. 2009; Linsky et al. 2010). Murray-Clay et al. (2009) comprehensively review the basic ‘energy-limited’ model that is based on channelling heating radiation to mass-loss. In the simplest approach most of the ionizing radiation energy goes into work to expel the envelope. This model is similar to the one used by Lecavelier des Etangs (2007), but the assumption of 100 per cent conversion is unrealistic and it overestimates the mass-loss rate. A more realistic approach limits the radiation energy available for mass-loss. In their model Murray-Clay et al. (2009) take a realistic heating efficiency of 10–30 per cent, since not all the absorbed EUV energy is channelled into heating. Other hydrodynamical models by Yelle (2004), Garcia Munoz (2007), Erkaev et al. (2007) and Lammer et al. (2009) take the same approach. Soker (1999; based on Dopita & Liebert
1989), for example, further took into account the recombination of the outflowing gas. This process causes a decrease in the mass-loss rate. We will use the energy–limited process with 10–30 per cent efficiency. For example, by considering the effect of recombination of the outflowing gas. This makes the model generally applicable to high- and low-ionization fluxes for planets around EHB stars.

Levacher des Etangs et al. (2004) and Lecavelier des Etangs (2007) concluded based on their detailed calculations that planets with orbital distances of 0.03–0.04 au from an MS star will be evaporated unless they are significantly heavier than Jupiter. This approach is strengthened by Davis & Wheatley (2009) who examine the EUV from MS stars (F, G and K), and conclude that planets will not exist at small orbital distances. Let us mention some observed cases of planets orbiting MS stars that motivated our study of planets orbiting HB stars, in particular EHB stars. Valencia et al. (2010a,b) raised the question of possibility that the superearth-like planet CoRoT-7b ($M_p = 4.8 \pm 0.8 M_{\oplus}$, $R_p = 1.68 \pm 0.09 R_{\oplus}$, $a_p = 0.017$ au, $e \sim 0$) is the outcome of evaporation of a Uranus-like planet. Baraffe et al. (2004) found that a planet with a mass below a critical mass of $M_{\text{crit}} = 2.7 M_{\text{J}}$ orbiting a solar-type star at an orbital separation of $a_p = 0.023$ au, will be completely evaporated in 5 Gyr unless it has a central rocky core. Jackson et al. (2010) elaborated on the importance of evaporation and calculated two paths. In the first CoRoT-7b has always been a rocky planet, and in the second CoRoT-7b is a remnant of a gas giant. Jackson et al. (2010) took into consideration tides, and concluded that it is possible that CoRoT-7b is a remnant of a gas giant planet. If this finding holds to the cases we study here, it is possible that future observations will reveal many more ‘earth-like planets’ around white dwarfs (WDs) or HB stars, that actually started their life as gas giant planets.

We start by studying the evaporation of planets orbiting EHB stars (Section 2). The gas escaping from the planet will be ionized by the radiation of the HB parent star, and become a source of $H \alpha$ emission. This idea has been raised before as an indirect way to search for planets in Planetary Nebulae and Jupiter-like planets around WDs (Soker 1999; Chu, Dunne & Gruendl 2001). We modify this idea and try to search for planets around EHB stars through their $H \alpha$ emission. In Section 3 we examine the conditions for this emission to be detected. Our short summary is in Section 4.

## 2 EVAPORATION OF A PLANET ORBITING AN HB STAR

### 2.1 Basic evaporation processes

We start by considering heating by EUV radiation, a process that was studied in detail for MS and pre-MS central stars (e.g. Chamberlain & Hunten 1987; Yelle 2004; Tian et al. 2005). At this stage we will not consider the role of the magnetic field of the planet, although it can play some role (e.g. Grießmeier et al. 2004; Lammer et al. 2009). We adopt the simple model presented by Lecavelier des Etangs (2007), which represents the blow-off mechanism (Erkäev et al. 2007), and investigate the implications for a planet orbiting an HB star (this model is similar to the model proposed by Murray-Clay et al. 2009). The potential energy per unit mass in the atmosphere is

$$
\frac{dE_{\text{stami}}}{dm} = \frac{GM_p}{R_p} = \frac{v_{\text{esc}}^2}{2} = -1.8 \times 10^{13} \left( \frac{M_p}{M_J} \right) \left( \frac{R_p}{R_J} \right)^{-1} \text{erg g}^{-1},
$$

(1)

where $M_p$, $R_p$, $M_J$ and $R_J$ are the planet mass, planet radius, Jupiter mass and Jupiter radius, respectively; and $v_{\text{esc}}$ is the escape velocity.

![Figure 1.](image-url) The spectrum (erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$). The red (upper) line represents the flux of the blackbody. The blue line represents the flux of the simulated HD149382.

### from the planet. Even for very hot Jupiter-like planets the magnitude of the potential energy is much larger than the kinetic energy of thermal gas particles, and we follow Lecavelier des Etangs (2007) and ignore the kinetic energy of atoms in the planet atmosphere.

The general expression for mass-loss according to Lecavelier des Etangs (2007) is

$$
m_p = \frac{2n \dot{E}_{\text{EUV}}}{v_{\text{esc}}},
$$

(2)

where $\dot{E}_{\text{EUV}}$ is total EUV power in the range of $100 \leq \lambda \leq 1200$ Å (Lecavelier des Etangs 2007) received by the planet. We took into account the fact that not all the absorbed EUV radiation will be channelled to evaporation by introducing the parameter $\eta \simeq 0.1–0.3$. Although some studies use $\eta = 1$ (e.g. Lammer et al. 2003; Baraffe et al. 2004; Lecavelier des Etangs 2007), more recent studies found the efficiency to be lower; e.g. Penz et al. (2008b) find $\eta < 0.6$ for hydrogen-rich thermosphere, and Lammer et al. (2009) find $\eta \simeq 0.1–0.25$. Most significant in reducing the efficiency is $L_a$ cooling by collisionally excited hydrogen atoms (Murray-Clay et al. 2009).

An appropriate calculated spectrum is required for EHB stars since a blackbody (BB) radiation does not fit the spectrum below 912 Å. In Fig. 1 we compare the spectrum calculated by Geier et al. (2010b) for HD 149382, an sdB star with an effective temperature of $T = 35 500$ K and $\log (g) = 5.75$, where $g$ (cm s$^{-2}$) is the gravity on the stellar surface, with a BB radiation at the same temperature. In the case of a BB radiation we have

$$
\dot{E}_{\text{EUV}} = \pi R_p^2 \frac{R_{\text{EBH}}^2}{\alpha_p^2} \int_{100\angstrom}^{1200\angstrom} \frac{2 \pi \hbar c^2 / \lambda^5}{\exp (\hbar c / \lambda k T) - 1} d\lambda,
$$

(3)

where $h$ is the Planck constant, $c$ is the speed of light and $k$ is the Boltzmann constant.

Soker (1999, where more details are given) calculates the mass ablation rate of the planet by taking the ionization approach, but including the effect of recombination, following McCray & Lin (1994) who calculated the ablation of the ring around SN1987A. Recombination transfers kinetic energy to radiation that escapes, and reduces the ablation rate. The ionization rate is multiplied by the ratio of recombination time to escape time (as long as this ratio
is not larger than 1). The expression derived by Soker (1999) is
\[ \dot{m}_p \simeq N \eta \mu \mu m_0 \left( \frac{\tau}{n} \right) \left( \frac{R_p}{c_s} \right)^{-1}, \]
where \( \tau/n \) is the recombination time, \( n \) is the total number density of the ablated layer, \( R_p/c_s \) is the escape time from the planet, \( c_s \) is the speed of sound, \( N \) is the rate of ionizing photons hitting the planet, \( \eta \simeq 0.1 \) is the ionization efficiency and \( \mu m_0 \) is the mean mass per particle. The ionizing rate is given by \( N = N_c \left( \frac{E_{\text{ion}}}{\mu m_0} \right) \), where \( N_c \) is the number of ionizing photons per unit time emitted by the HB star (Soker 1999). Assuming that the evaporated mass outflows at the speed of sound and towards the half-hemisphere facing the star, the mass-loss rate is
\[ \dot{m}_p \simeq 2n \eta \mu \mu m_0 R_p^2 c_s. \]
We eliminate \( n \) from equations (4) and (5) and obtain
\[ \dot{m}_p \simeq 2n \eta \mu \mu m_0 R_p^2 c_s \left( \frac{\tau N \eta}{8\pi} \right)^{-1}. \]

It must be emphasized that the ionization evaporation rate given by equation (6) was used by Soker (1999) for Uranus-like planets that have very low escape energy (equation 1). For more massive planets the escape energy is comparable to the energy of the ionizing radiation, and cannot be neglected. Therefore, the evaporation rate given by equation (6) becomes inaccurate when it gives value above that given by equation (2). In this paper we deal with massive planets and with brown dwarf orbiting close to HB stars. We consider the ionization evaporation rate as a cautionary step, because it takes into account recombination that reduces the efficiency.

Fig. 2 presents the ablation rate based on Lecavelier des Etangs (2007) as given by equation (2), with the ionization model (Dopita & Liebert 1989; Soker 1999) as given here by equation (6), both as a function of the orbital separation. These are calculated with the appropriate spectrum as was calculated for HD 149382 (Fig. 1). For comparison we show the evaporation rate for a BB spectrum with the same effective temperature and luminosity (black upper line). The ionization model is presented in Fig. 2 only for comparison purposes and it does not apply when the escape velocity exceeds the speed of sound.

The properties of the EHB central star and the planet are taken to be those of the HD 149382 system (Geier et al. 2009; see Fig. 2 caption). The orbital separation of this system is \( a_p = 5–6.1 \, R_\odot \), but in the figure this is an independent variable. On the right-hand axis of Fig. 2 we give the total mass that would be evaporated during a period of \( 6 \times 10^7 \) yr, about the duration of the HB, with the same mass-loss rate given on the left-hand axis. For these parameters we find \( E_{\text{BB}} = 4.4 \times 10^{36} \, \text{erg} \, \text{s}^{-1} \) and \( N \sim 3.8 \times 10^{48} \, \text{s}^{-1} \) and we assume an efficiency of \( \eta \approx 0.1 \), and \( v_o \approx c_s \approx 10 \, \text{km} \, \text{s}^{-1} \), where \( v_o \) is the outflow velocity. For the ablation rate based on ionization (equation 6), we substitute the following numerical values: \( \tau = 3 \times 10^{12} \) s (Osterbrock 1989) and \( \beta = 0.62 \). The expanding gas does not reach the escape velocity. It escapes the planet when it leaves the planet’s Roche lobe. The mass-loss curves in Fig. 2 were calculated for \( \eta = \eta_i = 0.1 \), and therefore represent a lower limit. For the evaporation process to be efficient, the orbital separation cannot be too large, i.e. \( a \lesssim 0.1 \, \text{au} \), depending on the exact planet properties (Davis & Wheatley 2009 and references therein). We here show the results up to an orbital separation of 0.2 au.

We now turn to include recombination in the energy-limited process, as this is the more realistic approach. We do it for the parameters of HD 149382 (represented by the thin blue line in Fig. 2).

2.2 Including recombination of the evaporated gas

When the central source is hot, a large fraction of the radiation is energetic enough to ionize the evaporated gas. The evaporated gas recombines and emits at a longer wavelength radiation that escapes from the planet’s vicinity. Although recombination is not relevant to planets around solar-like stars, its role becomes more important for hot HB stars and central stars of planetary nebulae. To facilitate a simple calculation we make the following simplifying assumptions.

1. Most of the evaporated gas flows towards the radiation source, i.e. the parent star. Namely, the evaporated gas escapes to a solid angle of \( 4\pi\beta \) with \( \beta = 0.5 \).

2. The central star keeps the gas almost fully ionized, such that the rate of recombination equals that of ionization by the radiation of the parent star.

3. The ionizing photons of the parent star that are absorbed by the evaporated gas are removed from the radiation that heat the star.

4. Most of the recombination radiation is by gas close to the planet where density is high. Therefore, a half or less of the radiation of the recombining evaporated gas will be absorbed back by the planet, which in turn will heat it. To put an upper limit on the role of recombination, we assume that all of the radiation emitted by the recombining gas escapes.

5. We assume that the gas outflow velocity is about equal to the speed of sound \( \sim 10 \, \text{km} \, \text{s}^{-1} \) (Gu, Lin & Bodenheimer 2003; Lai, Helling & van den Heuvel 2010; Li et al. 2010; Trammell, Arras & Li 2011 and references therein).
The recombination rate is proportional to density squared, hence to the square of the mass-loss rate. Therefore, the rate at which the evaporated gas removes photons from the parent stellar radiation is \( N_{\text{rec}} = K_2 m_p^2 \), where \( K_2 \) is a constant to be derived below. Instead of equation (2), the new equation now reads

\[
\dot{m}_p = \eta \frac{2}{v_{\text{esc}}^2} (E_{\text{EUV}} - K_2 e_y m_p^2) = \eta m_p \frac{2}{v_{\text{esc}}^2} K_2 e_y, \tag{7}
\]

where \( e_y \approx 20 \) eV is the average energy of the ionizing photons, and in the second equality we defined the zeroth-order evaporation rate (when recombination is neglected and \( \eta = 1 \)) \( \dot{m}_p = 2 E_{\text{EUV}} / v_{\text{esc}}^2 \).

Equation (7) is a quadratic equation that can be solved analytically. By our assumptions, the density of the evaporated gas is

\[
\rho = \frac{\dot{m}_p}{4 \pi \beta v_{\text{esc}}^2}, \tag{8}
\]

where \( v_{\text{esc}} \) is the outflow velocity which is taken as 10 km s\(^{-1}\). The recombination rate per unit volume is \( \dot{N}_{\text{rec}} = \alpha_{\text{rec}} n_e n_p \), where by the assumption of (almost) fully ionized gas can be written as \( \dot{N}_{\text{rec}} = \alpha_{\text{rec}} R_p^2 \), where \( \alpha_{\text{rec}} = 5 \times 10^{24} \) cm\(^3\) g\(^{-2}\) s\(^{-1}\) is appropriately calculated from \( \alpha_{\text{rec}} \) for a fully ionized solar composition in case B recombination (Osterbrock 1989). We neglect processes that become more important due to the high collision rate expected in the very dense outflowing gas near the planet. The total recombination rate is obtained by integrating over the entire volume according to our assumptions:

\[
\dot{N}_{\text{rec}} = \int_{R_p}^{\infty} \alpha_{\text{rec}} R_p^2 4 \pi \beta r^2 \, dr. \tag{9}
\]

Substituting equation (8) and performing the integration gives

\[
\dot{N}_{\text{rec}} = K_2 m_p^2 \frac{\alpha_{\text{rec}}}{4 \pi \beta v_{\text{esc}}^2} \frac{R_p^2}{m_p}. \tag{10}
\]

The last equality gives the value of \( K_2 \) that we substitute into equation (7).

Recombination becomes important when the last term in equation (7) becomes non-negligible. Taking \( m_p \approx \dot{m}_p \), this occurs when

\[
\dot{m}_p \geq 2 \frac{v_{\text{esc}}^2}{K_2 e_y} = \frac{2 \alpha_{\text{rec}}}{\alpha_{\text{rec}} e_y}, \tag{11}
\]

Substituting typical values gives the evaporation rate above which recombination is important:

\[
\dot{m}_p \geq 9 \times 10^{12} \left( \frac{R_p}{0.1 R_\odot} \right)^{-1} \left( \frac{v_{\text{esc}}}{250 \text{ km s}^{-1}} \right)^2 \left( \frac{v_{\text{esc}}}{10 \text{ km s}^{-1}} \right)^2 \left( \frac{e_y}{20 \text{ eV}} \right)^{-1} \text{ g s}^{-1}. \tag{12}
\]

In Fig. 2 the energy-limited process is included with recombination (equation 7) and is depicted by the blue thin line. It can be seen that the recombination becomes important when the evaporation rate is as given in equation (12). In other words, it is important in the entire relevant range of parameters here. The evaporation rate we will use in calculating the H\( \alpha \) emission is the one given by the blue thin line of Fig. 2.

The substellar object (a planet or a BD) mass in HD 149382 is 8–23 M\( _J \) (Geier et al. 2009) at an uncertain orbital separation of \( a_p = 5–61 \) au. From Fig. 2 we learn that the total evaporated mass of this object during the HB phase will be \( \sim 0.1–1 \) M\( _J \). This amount is significant, though it seems that the substellar object in this system will survive the HB phase of its parent star.

3 H\( \alpha \) EMISSION OF THE EVAPORATED MATERIAL

We consider here hot HB stars such that the evaporated gas of close planets is almost fully ionized. The calculation of the H\( \alpha \) luminosity from the evaporated gas is done in the following way (e.g. Bhatt 1985 for destructed comets). We start with the following assumptions, some of which were used in Section 2.

(1) The evaporation is mainly into a solid angle \( 4 \pi \beta \). If it is towards the parent star, \( \beta \approx 0.5 \); when it is spherical, \( \beta = 1 \).

(2) Close to the planet, where most of the recombination occurs, the material flows at the speed of sound.

(3) For typical values we find the medium to be optically thin to H\( \alpha \).

(4) We assume that the evaporated gas is almost completely ionized. Any recombination that occurs is balanced by the incoming photons from the EHB star.

(5) Most of the recombination and the H\( \alpha \) source occur at a relatively high density of \( n \approx 10^{10}–10^{12} \) cm\(^{-3}\). At such densities collision between atoms changes the amount of energy that is channeled to H\( \alpha \). In our simple treatment we neglect the dependence of the recombination coefficient on density. We note that Bhatt (1985) calculates the H\( \alpha \) emission from a destructed comet. He estimates the density to be \( \sim 10^{13} \) cm\(^{-3}\) and neglects the dependence on density. Korista et al. (1997) found that the dependence of the recombination coefficient to H\( \alpha \) on density in these densities is negligible.

The \( \text{H}\alpha \) energy released due to recombination is

\[
L_{\text{H}\alpha} = \int_{R_p}^{\infty} \alpha_{\text{H}} (h \nu_{\text{H}\alpha}) n_e n_p \, dV. \tag{13}
\]

Solving the integral yields

\[
L_{\text{H}\alpha} \sim 2 \times 10^{28} \left( \frac{M}{10^{14} \text{ g s}^{-1}} \right)^2 \left( \frac{\beta}{0.5} \right)^{-1} \left( \frac{R_p}{0.1 R_\odot} \right)^{-1} \left( \frac{v_{\text{esc}}}{10 \text{ km s}^{-1}} \right)^2 \text{ erg s}^{-1}. \tag{14}
\]

The equivalent width of the H\( \alpha \) emission is calculated for the simulated (accurate) spectrum of HD 149382 (Geier et al. 2010b), where \( T_{\text{EHB}} = 33.500 \) K, \( R_{\text{sdB}} = 0.14 R_\odot \), \( \alpha = 0.027 \) au(5.8 R\( _\odot \)). When assuming heating efficiency of \( \eta = 10 \) per cent, \( M = 1.5 \times 10^{14} \) g s\(^{-1}\) therefore, we get \( L_{\text{H}\alpha} = 3.6 \times 10^{25} \) erg s\(^{-1}\) and hence \( \text{EW}_{\alpha} \sim 0.09 \) Å for H\( \alpha \) emission and \( \text{EW}_{\beta} \sim 0.01 \) Å for H\( \beta \) emission. The expected H\( \alpha \) emission is within the capability of existing telescopes, while the expected H\( \beta \) emission seems to be below detection limit. When changing the heating efficiency to \( \eta = 30 \) per cent, the mass-loss becomes \( M = 1.7 \times 10^{14} \) g s\(^{-1}\) and we get \( \text{EW}_{\alpha} \sim 0.1 \) Å for H\( \alpha \) emission and \( \text{EW}_{\beta} \sim 0.014 \) Å for H\( \beta \) emission. Although the EWs are not high in both cases, their periodic variation might ease the detection of the line. At an orbital separation of 5.8 R\( _\odot \) the orbital velocity of the substellar companion is \( \sim 130 \) km s\(^{-1}\). Therefore, during the orbital period the centre of the emission by the evaporated gas might move back and forth over a range of up to \( \sim 5.5 \) and \( \sim 4.0 \) Å, for the H\( \alpha \) and H\( \beta \) emission lines, respectively. We conclude that it might be possible to identify a planet via the H\( \alpha \) emission of its ablated envelope.

4 SUMMARY

We estimated the evaporation mass-loss rate from a planet heated by its parent hot sdB/sdO (EHB) star. The hot star ionizes the
Evaporated gas. We assumed that it is almost fully ionized. We reconciled two known evaporation mechanisms (summarized in Section 1) by including the effect of recombination in the evaporated gas, and using the energy-limited model. We then calculated the expected emission in the lines of Hα (equation 14) and Hβ. As the emission comes from the planet vicinity, the Doppler shift will be of tens of km s$^{-1}$ over the orbital period. The emission with its periodic Doppler shift can be used to directly detect the planet. We note that Bhatt (1985) observed the Hα emission from destructed extrasolar comets.

We found that for the substellar object of the system HD 149382 (Geier et al. 2009) the equivalence widths of the emission of the two lines might be as high as EWα $\approx$ 0.1 Å and EWβ $\approx$ 0.01 Å, respectively, and the Doppler shifts will periodically vary on a range of up to $\sim$5.5 and $\sim$4.0 Å, respectively (depending on the inclination of the system). The detection of the lines is not simple (in particular Hβ/α), as the EHB star itself has absorption in those lines. However, the periodic Doppler variations might help to recognize the emission lines by the evaporated gas from the planet.

The total evaporated mass along the HB evolution can be non-negligible. However, we can assume (despite the big uncertainties) that the planet in HD 149382 will survive the entire HB evolution of the star.

The ramification of our study is that sdB/sdO (EHB) stars should be a prime target for high spectral resolution observation in the Hα (equation 14) and Hβ lines. The observation should look for Doppler variations with an amplitude of tens of km s$^{-1}$, with a period of hours to weeks, which hint at the presence of an evaporating planet. The target stars are sdB/sdO stars in the field (disc of the galaxy), where metallicity is higher. EHB stars in globular clusters are less likely to have surviving substellar objects, and they are typically at large distances. Still, some fraction of EHB stars in globular clusters might have surviving substellar objects around them.

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