SUBDWARFS AND ABSORPTION DUE TO QUASI-MOLECULAR HYDROGEN

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A quasi-molecule of two colliding hydrogen atoms in the unstable $^3\Sigma_u^+$ state goes to the excited $^3\Sigma_g^+$ state, with the absorption of light. The free-bound absorption continuum produced by quasi-$H_2$ was considered as early as 1947 by Wildt and found to be unimportant in late-type stars. Recent work by Erkovich suggested that this source of opacity may in fact be astrophysically important (see e.g. Zwaan). The work of Soloman and of Doyle showed, however, that Erkovich cross-sections have been overestimated by about two orders of magnitude. Hence, the absorption due to quasi-$H_2$ is negligible compared to $H^-$ and $H$ in stars with chemical composition similar to that in the solar photosphere. However, Varsavsky has recently suggested that absorption due to quasi-$H_2$ may not be negligible in subdwarfs, which have rather low metal abundance. We have tried in this note to examine the role of quasi-$H_2$ in metal-deficient stars.

We have assumed that the relative abundance of metals is similar to that in the solar photosphere, with the ratio of metal to hydrogen being one-hundredth that in the Sun, and the ratio of helium to hydrogen, by number, being 0.0625. We have used the absorption cross-sections for quasi-$H_2$ as given by Soloman and have followed Vardy for the continuous opacity due to $H$, $H^-$, $H^-$, $He$ and $He^-$. The relevant range in pressure for a given temperature can be obtained from the work of Swihart and Fischel.
Table I gives the values of \(\theta = 5040 \cdot 39/T\) (where \(T\) is the absolute temperature), electron pressure, \(p_e\), and the corresponding gas pressure, \(P_g\), at which comparisons have been made of the relative importance of quasi-\(H_\alpha\) absorption to other sources of continuous opacity. \((P_g\) and \(p_e\) are in dyn/cm\(^2\).)

Table I

<table>
<thead>
<tr>
<th>(\theta)</th>
<th>(p_e)</th>
<th>(P_g)</th>
<th>(\theta)</th>
<th>(p_e)</th>
<th>(P_g)</th>
</tr>
</thead>
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<tr>
<td>0.4</td>
<td>(10^5)</td>
<td>(7.0 \times 10^6)</td>
<td>1.2</td>
<td>(10^{-1})</td>
<td>(1.5 \times 10^6)</td>
</tr>
<tr>
<td>0.4</td>
<td>(10^6)</td>
<td>(5.1 \times 10^7)</td>
<td>1.2</td>
<td>(10^1)</td>
<td>(9.9 \times 10^7)</td>
</tr>
<tr>
<td>0.8</td>
<td>(10^6)</td>
<td>(7.6 \times 10^8)</td>
<td>1.6</td>
<td>(10^{-2})</td>
<td>(1.3 \times 10^5)</td>
</tr>
<tr>
<td>0.8</td>
<td>(10^8)</td>
<td>(7.6 \times 10^8)</td>
<td>1.6</td>
<td>(10^0)</td>
<td>(4.6 \times 10^7)</td>
</tr>
</tbody>
</table>

Fig. 1 is a plot of \(\log_{10} (\kappa_{\text{quasi-}H_\alpha}/\Sigma\kappa)\) versus \(\lambda\) (wavelength in \(\mu\)) for \(\theta = 0.4\) and 0.8 and Fig. 2 is a similar plot for \(\theta = 1.2\) and 1.6. Here \(\Sigma\kappa\) is the sum of the continuous absorption coefficients due to \(H, H^-, H^-,\) He and \(He^-\). These curves indicate that the importance of quasi-\(H_\alpha\) absorption, compared to other sources of opacity in the ultra-violet region of subdwarfs, increases as one proceeds from high temperatures to low temperatures, reaches a maximum around \(\theta \approx 1.2\), and then its importance decreases. The effect of metal abundance, for a given \((\theta, P_g)\), is rather small at high temperatures, because there most of the electrons are donated by hydrogen and atomic hydrogen is the main source of opacity. In fact, the ratio \(\kappa_{\text{quasi-}H_\alpha}/\kappa_H\), where
\( \kappa_H \) is the absorption coefficient due to atomic hydrogen, is independent of metal abundance. At lower temperatures, where the metals donate most of the electrons, the importance of quasi-\( H_2 \) is greatly enhanced with decrease in metal abundance, as is evident from a comparison of our figures with those of Soloman\(^4\). It is the increasing formation of molecular hydrogen that reduces the relative importance of quasi-\( H_2 \) absorption as one proceeds to values of \( \theta \) beyond \( \theta \approx 1.2 \). Needless to say, the importance of quasi-\( H_2 \) absorption decreases with decrease in hydrogen to metal ratio. Though quasi-\( H_2 \) is important in subdwarfs, it should not be forgotten that, in the ultra-violet region of these stars, Rayleigh scattering is very important in redistributing radiation.

References