MAGNETIC ABSORPTION LINES IN STELLAR SPECTRA *

L. SEMIONOVA  
Departamento de Física, Universidad Nacional,  
Heredia, Costa Rica  
and  
JORGE PÁEZ and J. BONATTI  
Grupo de Astrofísica Teórica, Escuela de Física,  
Universidad de Costa Rica, San Pedro, Costa Rica

Abstract. We analyze the process of absorption which is produced under conditions of strong magnetic fields in the magnetosphere of a compact stellar source. The magnitude of the magnetic field lies in the range $10^{12}-10^{13}$ Gauss, which are common values in modelling pulsars.

Analyzing the first absorption lines ($N = 0$ to $N' \leq 3$) we arrive to the conclusions that the orientation of electron’s spin does not change if it absorbs a photon. It means it maintains its orientation opposite to the external magnetic field after the absorption. For the fundamental line ($N = 0$ to $N' = 1$) the dominant polarization of the photon is $\epsilon^z$. For the next two transition lines ($N = 0$ to $N' = 2$ and $N = 0$ to $N' = 3$), the polarization is $\epsilon^2$. In the case that the absorption lines belong to one of the first three transition lines, then the mean photon energy can be approached with the relation $k = AN'B$ and thus we get an error of 13.6% with respect to values obtained by the theoretical expression. Also we applied our absorption transition probabilities some known pulsar spectra and we determine which transition feature corresponds in their spectra.

1. Introduction

In the magnetosphere of the pulsars one of the important processes, which possibly contribute to the observed spectra, is the one photon absorption process. The Feynman diagram corresponding to this phenomena is presented in Figure 1.

There the double lines indicate the electron’s current when that particle moves in the external uniform magnetic field ($B = Bz$).

In our analysis we suppose that the electron occupies the fundamental Landau level ($N = 0$), because the intensity of magnetic field is sufficient strong to obligate the electron to occupy this level. The electron energy is defined by the expression

$$E_i = \sqrt{m^2 + p_i^2} + \frac{2m^2BN}{B_{cr}},$$

which is characterized by the principal quantum number $N = 0, 1, 2, \ldots$ (we use natural units with $\hbar = c = 1$); and $B_{cr} = (m^2/e) = 4.414 \times 10^{13}$ Gauss, is the critical field.

Each electron Landau state has only two possible orientations with respect to the magnetic field, up ($S = 1$) (spin up), or down ($S = -1$) (spin down). In the fundamental state ($N = 0$) there is only one possible state with spin against the magnetic field, (Harding and Preece, 1987). Thus, when a photon is absorbed, the

* Presented at the 2nd UN/ESA Workshop, held in Bogotá, Colombia, 9–13 November, 1992.
direction of the spin is hold or change in opposite sense. That is why we study only the case below. It means we analyze two cases, i.e., indicated by the following notation, (2,2) and (2,1), where the first number 2 indicates the spin orientation opposite to the magnetic field of the incoming electron and number 1 corresponds to the spin orientation along the direction of the outgoing electron’s field. From now on we use only the spinor of (Sokolov and Ternov, 1968),

\[
U^2(k) = \frac{1}{2\sqrt{2K}K_0} \left\{ \begin{array}{l}
\left( \pm \sqrt{K - k_3} + \sqrt{K + k_3} \right) \sqrt{K_0 \mp k_0} \\
\left( \mp \sqrt{K - k_3} + \sqrt{K + k_3} \right) \sqrt{K_0 \pm k_0} \\
\left( \pm \sqrt{K + k_3} + \sqrt{K - k_3} \right) \sqrt{K_0 \pm k_0} \\
\left( \mp \sqrt{K - k_3} + \sqrt{K + k_3} \right) \sqrt{K_0 \mp k_0}
\end{array} \right.,
\]

where \( K_0 = \sqrt{K^2 - k_3^2}, K = E \) and \( k_3 = p_3 \). Thus, we obtain the formula for the probability of transition for electron from state \( N \) to \( N' \) (\( N' > N \)) for two possible total spin orientations with respect to the external field \( B(2, 2) \) and (2,1):

\[
W^{(2, 2)}_{(2, 1)} = \frac{\alpha}{4} \int_0^\pi \frac{k \sin \theta \, d\theta}{E_i(E_i + k(1 + \cos^2 \theta) + p_{i3} \cos \theta)\sqrt{E_i^2 - p_{i3}^2} \sqrt{E_f^2 - p_{f3}^2}} \times
\]

\[
\times \left\{ (1 + \cos^2 \theta)(E_i E_f - p_{i3} p_{f3} \pm \sqrt{E_i^2 - p_{i3}^2} \sqrt{E_f^2 - p_{f3}^2}) \right\} \times
\]

\[
\times \left[ I_{N-1, N'}^2(z) \left[ \sqrt{E_i^2 - p_{i3}^2} - m \right] \sqrt{E_f^2 - p_{f3}^2} \pm m \right] + I_{N, N'-1}^2(z) \times
\]

\[
\times \left[ \sqrt{E_i^2 - p_{i3}^2} + m \right] \sqrt{E_f^2 - p_{f3}^2} \pm m \right] \mp
\]