e^+e^- ANNIHILATION IN STRONG MAGNETIC FIELDS

G. Wunner, H. Herold, and H. Ruder
Institut für Theoretische Physik
Universität Erlangen-Nürnberg
D 8520 Erlangen, FRG

The possible existence of electron-positron plasmas in the magnetosphere of neutron stars gives rise to the question in which way the e^+e^- annihilation process is modified by the strong magnetic fields prevailing there. On the basis of a correct quantum mechanical treatment of the two-body problem in an external magnetic field we have calculated lifetimes of the ground state as well as of excited states of bound e^+e^- pairs (positronium). We find that the 1γ decay remains strictly forbidden, whereas the 2γ process is strongly enhanced with respect to the field-free case.

Starting from the correct quantum mechanical two-body treatment of bound electron-positron pairs (positronium) in strong magnetic fields, it is found that the methods which have proved efficient in determining energy levels, wave functions, and transition probabilities for the H atom (Wunner and Ruder 1980) can be successfully transferred to positronium. For a magnetic field strength of $4.7\ 10^{12}$ G, Figure 1 provides the 10 lowest energy levels of positronium, which we have obtained using the adiabatic approximation. Figure 1 also shows all dipole transitions between the levels drawn with rates greater than $10^8\ s^{-1}$: these are the ones from states with negative z-parity to the energetically strongly lowered ground state. Dipole transitions of states with even z-parity are allowed only to states with odd z-parity, and are reduced on energetic grounds by several orders of magnitude.

As a competitive process, the annihilation of electrons and positrons (Wunner 1979) has to be taken into account. Wunner and Herold (1979) have shown that the one-photon decay of positronium remains strictly forbidden, and have derived the relevant formulae for the two-photon decay in strong magnetic fields. It turns out that states with negative z-parity are stable against 2γ annihilation. The 2γ decay rates of states with even z-parity are given in Figure 1. It is found that the lifetimes of these states, and thus in particular the lifetime of the ground state, are shorter by three orders of magnitude with respect to the field-free case.

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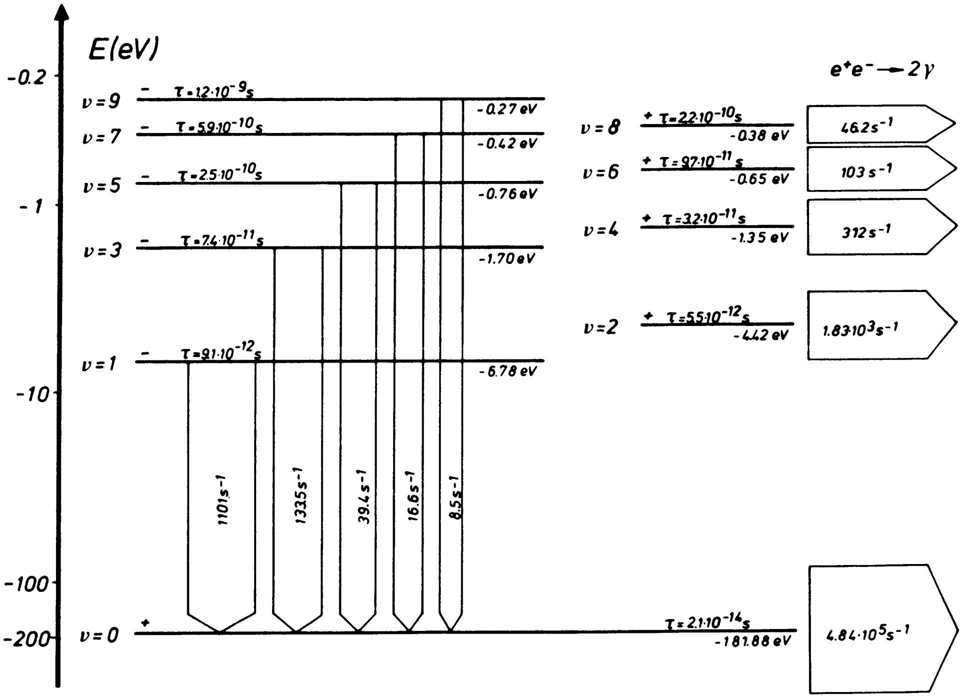

Figure 1. Energy levels, dipole transition probabilities, and 2γ decay rates of positronium for B = 4.70 10^{12} G.
The states have the Landau quantum number n = 0 and z-component of relative angular momentum m = 0, the total linear momentum of e^+e^- is assumed to vanish. The signs + and - refer to the even and odd z-parity of the states, respectively. Only dipole transitions with rates > 10^8 s^{-1} are shown. The numbers in the arrows give the values of the rates in units of 10^8 s^{-1}, the arrow widths are proportional to the logarithms of these numbers. τ denotes the total lifetime of the corresponding positronium state with respect to dipole transitions and 2γ decay. States with even z-parity decay directly into 2γ , while states with odd z-parity first perform dipole transitions, predominantly to the tightly bound ground state, and then decay into 2γ.

REFERENCES

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