# Spectrum of the Positronium Atom

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The experimental observation of Zitterbewegung [R. Gerritsma, G. Kirchmair, F. Zaehringer, E. Solano, R. Blatt. And C. Roos, Nature **463**, 68 (2010)] is incompatible with Dirac's hole interpretation of the negative-energy states, namely that the occupation of negative-energy states by positive-energy electrons is forbidden such that Zitterbewegung motion, due to the interference of positive-energy and negative-energy states, cannot be a real physical effect. This paradox must be resolved since hole theory explains countless annihilation and pair-creation experimental results. To this end a two-body Dirac theory of Positronium (Ps) is studied using the Hartree model, in which the electron and positron are each described by a Dirac equation whose positron-electron Coulomb potential is approximated by its quantum mean (self-consistent field) with respect to the positron in the Dirac equation for the electron and with respect to the electron in the Dirac equation of the positron. The equations are solved using one-parameter variational trial wave functions. The model gives 80% of the Ps ground-state energy. However a hitherto unreported state of approximate binding energy of $2mc^2$ is found, such that annihilation and pair-creation can be understood in two-body Dirac theory simply as ordinary two-photon emission and absorption transitions between the nominal ground state and the negative-energy state. Binding in the negative-energy state is supported by the spin-orbit interaction, which is attractive in the negative-energy region for $\kappa = -1$ states and has a scaling with the variational parameter comparable to that of the kinetic energy which otherwise would be dominant in this region of the spectrum.