Sixteenth Marcel Grossmann Meeting

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Dynamics of relativistic electron in non-uniform magnetic field and its applications in astrophysics and quantum computing

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It is known that when charged fermions gyrate in uniform magnetic field, their energy quantizes into discrete levels, called Landau levels. The problem of Landau quantization is typically solved in presence of uniform magnetic fields. Under such condition, the Landau levels are degenerate with overlapping of spin-up fermions in a lower energy level with spin-down fermions in the next higher energy level.

We explore for the first time, quantum properties of fermions, particularly electrons, in **spatially variable magnetic fields in relativistic regime**. We show that the modification of Landau quantization in presence of non-uniform magnetic fields results in **lifting the spin degeneracy**, and such an effect depends on the rapidity of field change. The important consequences of non-uniform magnetic fields leading to lifting the degeneracy of the levels include the splitting of Landau levels of particles with zero angular momentum from those with positive one, which is absent in uniform fields, and the change of equation of state of degenerate Fermi gas.

Landau quantization in non-uniform magnetic fields can have important consequences in different branches of physics, ranging from condensed matter to astrophysics to quantum information. Here we will discuss two of such examples. One is related to **magnetized white dwarfs**, where spatially decaying magnetic fields simultaneously affect the Landau quantization and the Lorentz force. Their combined effect is to change the Chandrasekhar mass-limit –this has far-reaching implications in astrophysics since the Chandrasekhar limit is used to determine the luminosity of the type Ia supernovae, which helps in understanding the size and expansion history of universe. We also show in another example that transition speed of an electron from a state to other increases for spatially growing magnetic fields. This may be very useful in developing **faster processing of quantum information** –which has applications to quantum computing.

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