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Exotic atoms at extremely high magnetic fields: the case of Neutron Stars atmosphere

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The presence of exotic states of matter in neutron stars (NS) is currently an open problem in physics: the appearance of muons, kaons, hyperons and other exotic particles is thought to happen in the inner regions of the NS due to energetic considerations and is considered as an effective mechanism to soften the equation of state (EoS) [1, 2].

In the so-called two-families scenario [3, 4], in which NS co-exist with quark stars, NS can be very compact and have a maximum mass of about 1.5−1.6M⊠, while quark stars can have large radii and be even more massive, up to 2.75 M⊠. The increasing softening of the EoS allows to reach very small radii for the star that becomes unstable and converts into a quark star. The process of conversion of a NS into a quark star proceeds in two phases: a first rapid burning followed by a much slower combustion. During this second phase, material can be ablated by neutrinos from the surface of the star. This is particularly interesting, since it opens the possibility of ejecting in the atmosphere not only neutron-rich nuclei, but also more exotic material such as hypernuclei. In this way, the atmosphere of a quark star could be radically different from the atmosphere of a NS. This offers a chance to distinguish between these two types of compact stars, providing a relevant feature that can be tested in observations and thus deserves to be investigated theoretically. In the NS atmosphere and surface traditional atoms from hydrogen to iron exist and their atomic spectra are observed, but also exotic atoms like (p μ−) or (Σ+ e−) could be present and in this talk we propose to investigate this topic. In particular, the spectroscopy of exotic atoms, made in the simplest case by two Fermions like (p μ−) or (Σ+ e−), can be inferred by the results obtained for hydrogen or hydrogen-like atoms in the extremely high magnetic field B of the NS, possibly exceeding 10^9 T. It is expected that, at these remarkably high magnetic fields, atoms are of cylindrical shape and that the traditional level structure observed in terrestrial experiments (gross, fine, hyperfine) is superseded by a much simpler structure (Landau levels) with only two quantum numbers: m that describes the radial excitations and ν that quantizes the motion along B.

The analytical expressions of the wave functions and eigenvalues of these levels have been calculated at present only for hydrogen and in this original work we extend the existing solutions and parametrizations to the exotic atoms (p μ−) or (Σ+ e−), making some predictions on possible transitions that could be detected in the spectra of NS.

References

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