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On the gravitational quantum states of helium atoms in the gravitational field of a cold neutron star

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A study of gravitational properties of matter and a precision test of Weak Equivalence Principal (WEP) presents a fundamental interest. We have shown the possibility of investigation of quantum gravitational states of matter by the example of helium atom. We examined the capability of the existence of helium quantum states in the gravitational field of a cold neutron star. Observation of such states was done with the help of rotating neutron star's magnetic field. Periodically changing magnetic field induced transitions between gravitational states of helium atom and led to the appearance of gravitational transitions' spectral lines in gigahertz frequency range.

We consider a quite cold old neutron star surrounded by a cloud of cold helium gas. Helium atoms in the gravitational field of the star are localized in long-lived quantum states, similar to the states of neutrons and antihydrogen atoms in the gravitational field of the Earth. Experimental test of the existence of such states for antihydrogen by methods of induction of resonance transitions between quantum levels in temporally oscillating gradient magnetic field is planning. In case of dealing with helium atoms near the neutron star's surface we can use neutron star's own oscillating magnetic field to observe gravitational states of atoms. The main effect that makes these observations difficult is the thermal motion of helium atoms. Helium atoms were chosen because the distance between gravitational levels of helium is larger than the same for hydrogen, that' s why the thermal motion's effects are not so drastic for helium. It will be shown that temperature about 0.4 K will make observation of spectral lines consistent with gravitational transitions possible. Temperature about 0.4 K cannot be achieved if we consider a case of weak anisotropy of cosmic microwave background (TCMB $\sim$ 2.7 K). On the other hand if we manage to register gravitational states' spectral lines, we can speak about the existence of the Universe's areas with sufficiently lower temperatures (T $\ll$ TCMB)

Collaboration

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