COMMENTS

Effect of Earth's Rotation in Neutron Interferometry

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In a neutron interferometer experiment which can successfully demonstrate a quantitative fringe shift due to the different gravitational potential for the neutron in the two legs of the apparatus, an adjunctive consideration must be the nonzero angular velocity of Earth and the lab. As in the classic Michelson-Gale-Pearson experiment done with light, and offset in the fringe pattern is predicted. Such a shift may not be subliminal at present precision levels.

Recently Colella, Overhauser, and Werner[1] have prettily demonstrated that a slow neutron in a two-beam interferometer adapted from the Bonse and Hart type[2] indeed senses a controlled difference in gravitational potential between two legs of the system, the control being effected by manipulating $\hat{n}\cdot\hat{g}$, where $\hat{n}$ is the normal to the plane of the apparatus and $\hat{g}$ is the nadir.

The purpose of this note is to draw attention to the fact that in the course of this kind of experiment the main loop (the parallelogram in the experiment) necessarily presents its normal $\hat{n}$ so as to form generally a nonzero, and likewise controllable, dot product with the angular-velocity vector $\vec{\Omega}_e$ of the Earth-lab-interferometer system. An offset proportional to Ω_e in the fringe pattern for a given orientation should be produced just as in the optical experiment of Michelson, Gale, and Pearson.[3]

The size of this ancillary effect can be compared to the size of the g effect as follows. Colella, Overhauser, and Werner[1] have a relative phase β_g in radians due to gravity of

$$\beta_g/\sin\varphi = 2M^2 gA\lambda\hbar^{-2} \tag{1}$$

where $\hat{n}\cdot\hat{g}$ equals $\cos\varphi$, A is the area of the loop, M is the particle mass, and λ is its deBroglie wavelength. A rudimentary calculation[4] of the additional relative phase β_Ω gives for a nonrelativistic particle

$$\beta_\Omega/\cos\psi = 2MA\Omega_e\hbar^{-1}, \tag{2}$$

to first order in the angular velocity Ω_e. Here $\cos\psi$ is $\hat{n}\cdot\hat{\Omega}_e$.

Numerically the right-hand side of (1) for the recent experiment is almost 60 rad per quadrant, whereas the right-hand side of (2) is about 2.3 rad per quadrant—thus down about $1\frac{1}{2}$ orders of magnitude from the gravitational effect. However at latitude ~45° the observed *difference* in $d\beta_{\text{tot}}/d\varphi$ circa $\varphi=0$ between an Eastward incident beam and a Westward incident beam might possibly show the rotational effect, to the exclusion of any bending effects plus the main gravitational effect.

[1]R. Colella, A. W. Overhauser, and S. A. Werner, Phys. Rev. Lett. 34, 1472 (1975).

[2]U. Bonse and M. Hart, Appl. Phys. Lett. 6, 155 (1965).

[3]A. A. Michelson, Astrophys. J. 61, 137 (1925); A. A. Michelson, H. G. Gale, and F. Pearson, Astrophys. J. 61, 140 (1925).

[4]In neither expression has c been set equal to 1; the speed of light does not enter. The expression (2) is just half the similar Michelson-Gale-Pearson expression of Ref. 3, because the neutron goes only halfway around the loop to suffer interference, in contrast to their setup. Their result, divided by 2, could be stated as relative phase equals $2A\hbar^{-1}(\hbar\omega/c^2)\Omega_e$.