PRELIMINARY RESULTS FOR ANOMALOUS SPIN COUPLING TO THE DARK MATTER IN OUR GALAXY

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ABSTRACT

Special, intrinsically compensated masses having ~10^{23} polarized electrons, but with no externally measurable magnetic moment, have been fabricated to probe anomalous spin interactions. Previously, these were used to investigate the existence of weak, hypothetical spin-dependent forces. In the present experiment, two such masses are located on the horizontal beam of a sensitive torsion pendulum, with the spin axes horizontal, perpendicular to the supporting cross-beam, and anti-parallel to each other. Ordinary gravitational interactions at a distance will yield no torque on the pendulum beyond that due to the unavoidable very small mass difference and/or location imbalance of these two masses. Rotation of the Earth provides a scan of the sky for regions of stronger anomalous spin interaction with the masses. An essentially fixed interactive source such as a potential dark matter distribution concentric with the center of our galaxy would provide a torque on the pendulum with a 12 - sidereal hour period. Twenty nine 24-hour runs with the pendulum have been analyzed up to this time. Fitting the observed torques to an appropriate sidereal time function sets a limit of 3.5×10^{-9} cm-s^{-2} for the acceleration of one of these masses towards the center of the galaxy.

1. INTRODUCTION

Phillips[1] and Ni[2] have performed torsion pendulum tests for an anisotropy in the interaction of a laboratory spin mass and the cosmic background, essentially macroscopic versions of the Hughs-Drever anisotropy tests. The present experiment provides a more specific search for anisotropy, towards a hypothetical dark matter distribution centered at the center of our galaxy. This particular motivation follows the suggestion by Stubbs[3] and experiments by the University of Washington group[4] seeking a long range, composition-dependent interaction of ordinary matter falling toward dark matter. This dark matter distribution is inferred from the visibly missing matter needed to account for the observed dynamics of stellar motion about our galaxy's center[5]. Evidence increases for the dark matter to consist of particles outside the Standard Model of particle physics[6], thus making it a likely source for anomalous interactions with local detectors. The experiment presented here combines features of the fifth force and spatial anisotropy searches, using a torsion pendulum to test for a possible long-range anomalous spin interaction with the nonluminous matter.

2. THE SPIN - DARK MATTER EXPERIMENT

Properties of our torsion pendulum, as used for two previous anomalous spin-dependent tests at ranges of a few centimeters, have been outlined in earlier publications[7,8]. The primary experimental feature was the use of special Dy_6-Fe_{23} masses having ~ 10^{23} electrons aligned in intrinsic spin, while the orbital spin cancels their magnetic moment to a high degree at room temperature, thus providing a "macroscopic electron" with huge intrinsic spin but little external magnetic moment. In the present experiment the spin masses are arranged differently from the previous two cases. Now the spin masses are mounted with axes horizontal on the ends of, and perpendicular to, the support rod attached at its center to the fiber. With the mass spins antiparallel to each other this forms a spin couple. A force of the $\sigma \cdot \mathbf{r}$ form between a distant nonpolarized source and this spin couple will create a torque about the fiber, the sense of which depends on the sign of the postulated interaction.

A major difference from the previous two experiments also lies in the fact that in those the pendulum was operated in the dynamic mode, in which the change in its oscillation period with spin direction was the signal of interest, while we now use it in the static mode, seeking patterned angular deflection of the fiber as a signal. The fiber has a torsion constant of 0.9 dyne-cm-rad^{-1}, leading to a period with the present mass arrangement of 649 s.

The pendulum operates at atmospheric pressure, with a natural decay time of 6503 s, resulting in a Q of 63. A magnetic damper at the top of the fiber[7] dissipates the simple pendulum modes but has insignificant effect on the torsional mode. Although moderately low, the damping time still allows the pendulum to execute oscillations driven by noise of several types[9]. To precondition the digitally-sampled signal (at 1000 s intervals), we pass it through a low-pass analog filter with 0.001 Hz cutoff frequency and a roll-off of 48 db per octave above cutoff. These conditions make it relatively easy to avoid aliasing from higher-frequency noise, while not damping any significant components of the postulated dark matter signal. Digital filtering acts subsequently, by appropriate, successive smoothing of the signal with a hanning shape. Figure 1 exhibits a representative, unfiltered signal, along with the (unnormalized) pattern predicted for a $\sigma\cdot\mathbf{r}$ interaction towards the center of our galaxy.

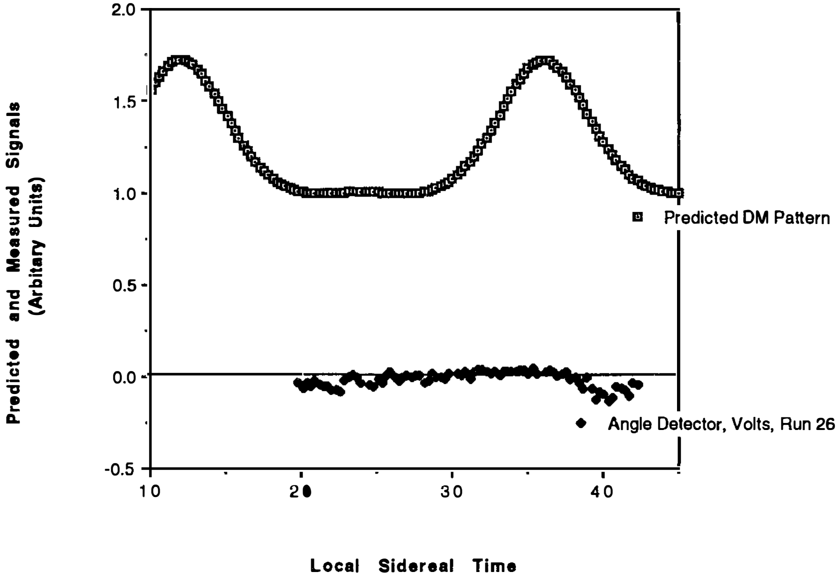

Figure 1. Predicted sidereal pattern for acceleration towards galactic center of the interaction form $\sigma\cdot\mathbf{r}$, along with raw torque pattern for one 24-hour run.

3. EXPERIMENTAL RESULTS

The experimental runs are fit to the sidereal pattern shown in Figure 1. A theoretically predicted axionic $\sigma\cdot\mathbf{r}$ interaction[10] cannot have a long enough range to act in this situation, in view of astrophysical limits on the axion mass[11]. A more likely candidate would be the arion of Anselm[12]. (Many other models of the possible interaction between dark matter and the observable matter in the universe exist. See the preliminary bibliography by Gillies[13] for citations of some of them.) Consequently we calculate the possible amplitude of the *unnormalized* pattern in the presence of experimental noise, at the 1-σ limit, to constitute the individual result of each run, and express it in terms of the acceleration on the spin masses. The present limit for the mean pendulum response in the direction of the galactic center at the 1-σ level is 5.3 x 10^{-4} degree. Taken with the fiber sensitivity and the spin mass locations 3.4 cm from the fiber, this yields an acceleration limit for the masses of 3.5 x 10^{-9} cm-s^{-2} towards the center of our galaxy. The acceleration of gravity to the galactic center is 1.85 x 10^{-8} cm-s^{-2}, so the present $\sigma \cdot \mathbf{r}$ limit is about 0.2 of gravity.

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