ANOMALOUS SPIN COUPLING TO DARK MATTER?

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Two years of the experimental search for an anomalous spin coupling to the hypothetical dark matter halo of our galaxy were reported last year [1]. This experiment used a torsion pendulum with two special masses each having ~10^{23} aligned intrinsic electron spins, but unmeasurable magnetic interactions, arranged to be a "spin quadrupole." Such a device can in principle interact only anomalously with matter. The instrument seeks a preferential astronomical direction for a long-range spin interaction, such as might occur with a nonbaryonic dark matter halo, or with dark baryonic matter coupled anomalously. As the Earth rotates, the pendulum response direction sweeps out the sky, with a sidereal-time patterned observational component along the vector toward the galactic center. Recently, a set totalling 53 ten-day runs was completed. The resulting mean of these observations implies an acceleration of each spin mass by $(-3.3 \pm 1.2) \times 10^{-10}$ cm/s^2 toward the galactic center. Additional studies aimed at evaluating potential artifactual sources of the signal are discussed. Most recently the plane of the spin quadrupole was inverted, which should reverse the sign of any real signal. At this writing it is too early in this new series to see a signal of any significance above the noise.

1. INTRODUCTION

Motivations and limitations for this study [1] seeking a spin coupling to a dark matter cloud of our galaxy were discussed previously, as were means for filtering some types of artifactual signals. The possibility of such couplings of this torsion pendulum as a quadrupole rest on polarized electrons in each of the individual masses interacting with a "spin-mass, or dipole-monopole coupling" [2].

The present report carries the run series [1] to its conclusion after a total of 720 sidereal days of running. It takes up further studies seeking to rule out potential artifactual sources of an observed signal at the 2.7 σ level for this first run series, and a discussion of a second experimental series recently started.

THE EXPERIMENT

The torsion pendulum position is sampled each 1000 s in UTC time. A run totals 10 sidereal days of such data, in two sets of five contiguous days each, the sets separated in starting time by ~ 183 sidereal days. Each set includes 5 full rotations of the Earth, so a quadrupole coupling to a matter cloud centered at our galaxy center would have 10 full 12-hour patterns of interaction during each five-day data set. Sidereal filtering consists of comparing the siderally synchronized sum of the two five day runs (the "signal run") with their difference, in which a real signal would be cancelled. In the half-year time difference, UTC time lags sidereal time by 12 hours, and the signal run removes or reduces effects of a number of common artifactual sources.

ANALYSIS OF RESULTS FROM SERIES I

Because of unavoidable interferences, only 530 of the total (630 + 183) sidereal days provided useful data, in the form of 53 runs. The sequence of accumulating averaged signals, of accumulating standard deviations of these signals, and of their ratio extends but does not change trends in the incomplete series of 42 such runs in [1]. The final average of the 53 signal runs corresponds to an acceleration of each mass by $(-3.3 \pm 1.2) \times 10^{-10}$ cm/s^2 toward the galactic center (the error is statistical only, at the 1σ level). This mean signal is 1/60 of the gravitational acceleration. The comparative (difference) data yields $(-1.5 \pm 1.2) \times 10^{-10}$ cm/s^2 for its final signal.

Raw data obtained for the pendulum position are corrected for temperature variations based on empirical studies of our system [3]. The corrected data are fit to a predicted pattern to yield an experimentally scaled value related directly to an accleration of the pendulum masses towards a given direction. The mean single-run signal-to-noise ratio is about $(4 \pm 2)\%$. Such a small ratio might for example, allow small effects to cause a general bias in the trends of the data.

The 1000 second data sampling time limits the resolution of FFT spectra used to assess the sidereal filtering leakage, and other potential artifacts. Figure 1 shows that the signal spectrum has a significantly stronger 12 hour peak than the difference spectrum, and little response at 11.6 microherz (24 hours). It has a general low frequency background averaging 13% of the 12 hour peak. The difference spectrum background is 60% higher.

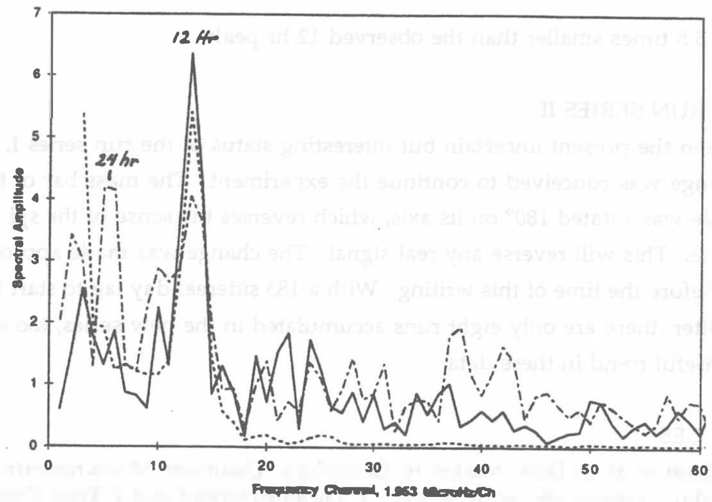

Figure 1. Comparison of the sum spectrum (——) of the averaged series data, the difference spectrum (– . – . –), and a predicted signal pattern (- - - - -) from the $\sigma \cdot \mathbf{r}$ interaction with a spherical dark matter cloud [4].

To test whether the data and pattern distributions themselves might allow an overall bias in our method of analysis, we generated and similarly analyzed 60 random number data sets, each having the same standard deviations from the mean as our raw data. The results are, for the summed data set: $(+0.93 \pm 3.2) \times 10^{-10}$, and for the difference set: $(-0.028 \pm 3.6) \times 10^{-10}$. They rule out such a data-based bias.

Our scaling method permitted some suspicion of possible statistical bias. Therefore we performed a different analysis, in which a standard correlation matrix was constructed between the predicted pattern and each of the two data sets. Such fits distribute the leverage of the data fitting differently from the linear fitting. Results from this anaysis are for the signal data: $(-3.1 \pm 1.4) \times 10^{-10}$ cm/s^2, and for the difference data: $(2.2 \pm 1.4) \times 10^{-10}$ cm/s^2.

Within the quadrupole a mass imbalance (measured to <0.5%) or lever-arm imbalance (known to <2%) would be antisymmetric and lead to a 24-hour gravitational signal pattern, which could not mimic a true signal. In Figure 1, we see a 24 hour peak in the difference data spectrum, which can not contain a signal anyway, but not on the signal data spectrum. Any possible 24 hour background peak is at least 3.5 times smaller than the observed 12 hr peak.

SECOND RUN SERIES II

Given the present uncertain but interesting status of the run series I, a simple major change was conceived to continue the experiment. The mass bar of the quadrupole was rotated 180° on its axis, which reverses the sense of the spin quadrupole. This will reverse any real signal. The change was made approximately 260 days before the time of this writing. With a 183 sidereal day lag to start the sidereal filter, there are only eight runs accumulated in the new series, too early to expect a useful trend in these data.

REFERENCES

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RESUME:

L'an dernier, nous avons présenté les résultants de deux années de mesures d'une expérience qui cherche un couplage de spin avec l'hypothétique halo de matière invisible de notre galaxie. Nous avons utilisé un pendule de torsion avec des masses contenant ~ 10^{23} spins électroniques intrinsèques alignés, mais sans interaction magnétique mesurable, et qui forme un "quadripôle de spin". Comme il n'existe pas de monopôle magnétique, cet appareil ne peut en principe interagir que de manière anormale avec de la matière. L'instrument permet de chercher s'il existe une direction privilégiée pour une interaction de spin à grande distance, comme celle qui pourrait être due à un halo de matière invisible non baryonique ou à un couplage anormal avec de la matière baryonique. Grâce à la rotation de la Terre, la direction dans laquelle le pendule est sensible parcourt le ciel et l'angle qu'elle fait avec la direction du centre galactique a une variation périodique. En utilisant au total 53 ensembles de points, dont chacun représente 10 jours de donneés, la moyenne de ces observations implique une accélération de chaque masse de (-3.3 ± 1.2) cm/s^2 dans la direction du centre galactique. Nous présentons aussi les résultats d'études complémentaires pour évaluer d'autres sources possibles pour expliquer ce signal. Récemment nous avons inversé le plan du quadripôle de spin, ce qui devrait changer le signe du signal détecté. Au moment où nous écrivons ces lignes, la durée de cette série ne permet pas encore d'obtenir un rapport signal à bruit suffisant.