Notes on Tajmar et al "Experimental Detection of the Gravitational London Moment"

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First I want to congratulate the authors for pioneering this theoretical avenue and assembling a difficult experiment. Seeing apparently positive results must be most gratifying.

The comments below are primarily in regard to the experimental apparatus, setup and procedure. They are designed to gain a better understanding of exactly how the experiment was carried out as well as to provide suggestions for improvements.

1) You claim that a non-Newtonian gravitational field (the claimed Gravitomagnetic London Moment, GLM) is generated along the tangential/azimuthal plane by the accelerated motion of a spinning superconductor (SC) according to rot g (eq 5). Perhaps it is more clearly explained in another paper how the GLM "field" differs from a Newtonian-like divergent gravitational field that falls off as inverse square with distance. The implication is that the GLM is non-divergent and may actually not be a "field" in the classical sense at all. On pg 13, you state that the above-ring sensor measured "…90% of the in-ring sensor [as] expected from a field …similar to electromagnetism." The point here is whether the Applied MEMS variable capacitance accelerometers respond as expected to this type of "field".
2) Further confusion as to the geometric nature of the GLM arises from the statement on pg 5 that it should "point" in the opposite direction to that of the applied tangential acceleration, due to the negative sign in Eq 5. How is this characteristic "…similar to electromagnetism."?
3) It should be noted that the buffering and amplifying package of the Applied MEMS sensor is mounted on top of the actual MEMS accelerometer so is also subject to possible spurious signals that could influence the accelerometer itself. This is confirmed for AC magnetic field as described on pg 9. What was the frequency of this AC driving current through the test coil? Was it equivalent to the top rotational speed of the drive shaft?
4) What were the fluxgate magnetometers used for if the accelerometers are claimed to be insensitive to magnetic fields?
5) Spinning a 150 mm dia. ring of YBCO, especially if it is sintered, at 6500 rpm will force it to fly apart. Fig. 1 appears to show the SC ring in a support ring of some sort. What is the material of this support ring?
6) The support ring in previous point prevents the SC from full contact with either the liquid Helium (LHe) or the cold He vapours and is necessarily in strong thermal and mechanical contact with the drive shaft. Is there any high thermal reluctance material between the SC and the support ring to allow the SC to reach the expected cryogenic temperatures?
7) Did the support ring need to be dynamically balanced by machining off small amounts of its material? This might cause severe turbulence in the LHe or He vapours.

8) How did you ensure that the accelerometers and their associated electronics were insensitive to the normal but periodic induced SC London magnetic moment of a slightly-unbalanced SC rotor?
9) The LHe storage dewar shown in Fig 2 appears to contain about 60 liters. From Fig 2 and the scale (?) drawing of Fig. 1, it appears that the experimental cryostat could contain much more than 60 liters if it was filled to the height of the spinning SC. Also the LHe transfer line shown seems awfully small for filling the cryostat in any reasonable time. Did you pre-cool with LN2 and ensure that no LN2 or water ice condensed onto the rotor? You must have had plenty of LHe available to fill that size cryostat!
10) A more thermally efficient design would be to put the test apparatus (stainless steel Faraday cage vacuum chamber and SC rotor) at least down in the middle of the cryostat instead of at the top. That would have necessitated a longer drive shaft and better mechanical anti-vibration supports for the Faraday cage. Was this ever considered?
11) What is the wall thickness of the stainless steel Faraday cage and what vacuum was capable of being contained? How did you ascertain that this level of vacuum was sufficient to completely thermally isolate the sensors from variations in Faraday cage wall temperature? Although it is shown attached to what appear to be thermal baffles in Fig 1, its bottom surfaces will be extremely hot relative to the LHe below it. Any LHe within several cm will be vigorously boiling. In fact you state on pg 9 that you had to lower the height of the LHe to 20 cm from the SC rotor to quell the violent evolution of He gas. This boiling is in addition to the rotation of the SC rotor which serves to de-stratify the He vapours so that warmer gases evaporate more LHe from the liquid surface. I would argue that not only pressure but also temperature variations on the Faraday cage could cause spurious signals depending on the speed of the Kapton heating foils control system. These temperature spikes could have been transmitted to the sensors via minute thermal or pressure pulses in the "vacuum" in the cage in addition to actual mechanical vibrations. You only state that the problem was reduced but not eliminated.
12) Our experiments have shown that even with optimum thermal isolation from the outside world, no stable temperatures below about 15-20K can be maintained in a SC which is spinning rapidly in turbulent vapours 20 cm from the LHe surface. It is not clear on pg 7 exactly how the diode temperature sensor was mounted except to say on pg 13 "…temperature measurement is done on the bottom of the SC.". Was this actually fixed to the SC itself and rotated up to 6500 rpm and didn't fly off or severely unbalance the rotor? Or was it mounted on the bottom of the SC support ring (thus "seeing" a colder temperature that at the SC itself? I suppose that the LTN "miniature collector ring" is a high-speed slip ring. How were the leads to the diode fed from the slip ring "…on top of the axis…" down to the diode itself – taped to the outside of the drive shaft, inside a hollow drive shaft? How were the magnetic fields generated by these high-speed rotating wires isolated from the accelerometers?
13) Were any independent verifications of the actual temperature of the spinning SC done apart from using the diode – eg testing for Meissner effect at ~ 85K for spinning or stationary YBCO sample in actual cryostat? Was the spinning diode itself calibrated in a known temperature gas? As noted above, the support ring, rotor assembly and drive shaft must be quite massive to maintain reasonable rotation at 6500 rpm. This is a

tremendous thermal load for the helium vapours to overcome. In addition, the SC sees a relatively hot surface just above it – the Faraday chamber.

14) Why is it necessary to seal the cryostat (pg 6) when explosive pressures will be generated by evaporating He gas?
15) The text gives the impression that the SC rotor, drive shaft and motor are all mechanically connected to the cryostat which is mounted in a weighted sand-filled box. It would be useful to have a diagram of how the Faraday cage sensor chamber is mechanically isolated from the cryostat. Fig 1 appears to show them all as a unit.
16) How well shielded and mechanically isolated were the signal cables? Any ground loop or crosstalk problems?
17) I presume that there is a lower bearing supporting the SC rotor from beneath. This will be at cryogenic temperatures. What is the bearing material (which eventually degraded)? Were all tests done with the degraded bearing(s) (pg 8)? How was the differential thermal contraction of these bearing radial supports accounted for to ensure that the SC rotation had minimal run-out (eccentricity)?
18) Why did the noisy bearing produce a mere offset rather than a periodic spurious signal? Can you explain in more detail how this was accounted for "…by always performing 2 slope measurements…with alternating sense of rotation."
19) Why were the test signals subtracted from the reference signal before being fed to the nanovoltmeters? What tests were done to ensure that this subtraction circuit was not a cause of artifact?
20) The coil "around the SC" mentioned on pg 5 was apparently used to test the effect of trapped fields. Yet on pg 9 this coil is only used to test the "…influence of a strong magnetic field on the accelerometers…" Where are the test results concerning trapped fields? If this coil could be used to kill the Meissner effect during run-up, and the GLM signal was instantly killed, this would be also an additional verification that the signal was due to some property of the SC.
21) How was this coil positioned with respect to the SC rotor? Was it rotating as well? Was it also cooled in He vapours. How were its leads thermally isolated? Was it left in place during all the runs?
22) I would suggest that there are more magnetic influences than simply the drive motor. A complete inventory should be done. For example, is the drive shaft made of magnetic material?
23) Under what conditions are the numbers in Table 1 taken – rotation (at what rpm?) with dummy material instead of SC at room temperature; no rotation at some cryogenic temperature; rotation of dummy material at some cryogenic temperature; no rotation but magnetic field coil on; niobium vs YBCO rotating at some cryogenic temperature; or what?
24) It would be very useful to see an expansion of at least one of the accelerometer peaks shown in Fig 4 and 5 to examine more closely their detailed time structure. How do their rise and fall times etc correspond to the acceleration slope of the SC rotor; is their shape reasonable from the theory?
25) In Fig. 5, why does the Niobium GML signal first peak appear at the beginning of the acceleration (and maybe not coincidentally the greatest slope of the warming pulse) but at the end of the Lead acceleration?

26) In Fig 5, it appears that the “Reference Tangential” signal for Lead is definitely more “active” during the acceleration with one pronounced peak just after 250 s. Is this not significant also?
27) How are the peak labels (eg 277 ug, 273 ug) calculated from their corresponding signals in Fig 5?
28) On pg 11 you state that the sensor signals needed to be “damped” by a factor of 5 to reduce mechanical vibration noise. Was this damping using an active or passive damping network or was the damping done in software? Were any other signal processing options tried to reduce noise?
29) It appears that the major negative peaks for Niobium in Fig. 5 actually appear just before passing through Tc and just after for Lead. Is it the uncertainty in the temperature measurement that allows you to claim that the peaks coincide with passage through Tc?