A simulation of the two hemispheres Bell experiment

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***Abstract*—In [1]Joy Christian proposes an experiment to test Bell's theorem in a purely macroscopic domain. I describe a computer simulation of the experiment, and find that it does not violate Bell's inequalities.**

I. The experiment

In [1] an experiment is proposed involving two hemispherical shells, each with a mass at a random position on the shell. The masses are small in size, but of comparable mass to the shell. Initially the two shells are joined together into a sphere. They are then given an impulse so that they move apart as well as being given equal and opposite angular momenta. They are measured by two detectors A and B, which have directional settings **a** and **b**, each of which is a unit vector. The claim is that in a run of experiments, if the angular momenta of the two hemispheres in the jth run are λ_j and $-\lambda_j$ then the correlation function

$$\mathcal{E}(\mathbf{a},\mathbf{b}) = \frac{1}{N}\sum_{j=1}^{N}\{sign(\lambda_\mathbf{j}\cdot\mathbf{a})\}\{sign(-\lambda_\mathbf{j}\cdot\mathbf{b})\} \qquad (1)$$

will approach $-\mathbf{a}\cdot\mathbf{b}$ as $N \to \infty$, rather than $-1 + \frac{2}{\pi}\cos^{-1}(\mathbf{a}\cdot\mathbf{b})$, which is the maximum correlation allowed by Bell's theorem

II. The simulation

I have written a computer simulation of this experiment, using the Java programming language. The simulation can be seen and run at [2]. The calculations for the rotational dynamics are based on the quaternionic formulation in [3]. Note that the simulation gives the two hemispheres equal and opposite angular momenta, as required by [1], rather than modelling an explosive separation. The simulation has a variable number of trials per run, initially set at 1000, which seems to be a reasonable number to get convergence in Eq.(1) Each run has the detector settings chosen at random at the start. The simulation is set to stop after 1000 runs have been completed, but will start again from the beginning if the 'Restart' button is pressed. Each trial takes about 10 seconds, so to complete a run takes some time. The following graph (Fig.1) shows the result. The green area is that allowed by Bell's theorem, the pink area that forbidden, and the red line the prediction of quantum theory. As can be seen, the simulation obeys Bell's theorem, rather than reproducing the results of quantum theory.

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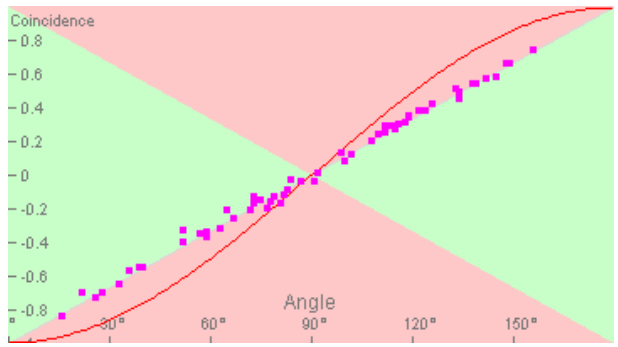
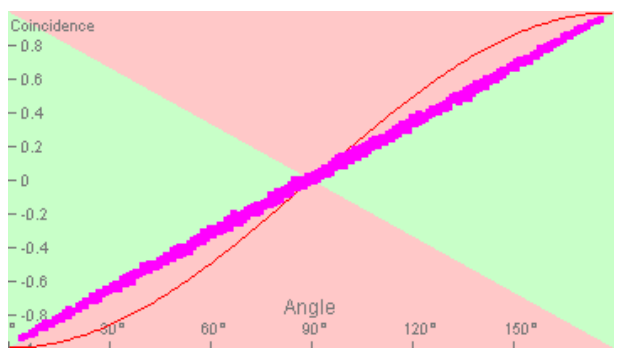
Figure 1: 60 runs of the simulation



While writing this program I realised that it was largely unnecessary. Since angular momentum is conserved, the only role the hemispheres play is to carry fixed quantities to the detectors. With this in mind I made it possible to skip the animation stage, and calculate the correlation directly from the initial angular momenta and detector settings. This allowed many more runs to be performed. The following graph (Fig.2) shows the result of 1000 runs with 5000 trials per run.

Figure 2: 1000 runs without animation



III. Discussion

As has been pointed out in [4], if the measurement is allowed to be a unit vector rather than a single bit, and if the correlation is taken as the dot product, then Bell's inequality can be trivially violated. The detectors just return **a** and $-\mathbf{b}$, ignoring the state of the object being measured, giving the result $-\mathbf{a}\cdot\mathbf{b}$ directly . Christian's geometric algebra approach has the detectors return bivectors $\mu\mathbf{a}$ and $-\mu\mathbf{b}$, where μ is a unit trivector i.e. $\pm I$. The product of these has scalar part $-\mathbf{a}\cdot\mathbf{b}$ and a bivector part $-\mu\cdot(\mathbf{a}\times\mathbf{b})$, which will average to zero if μ takes the values $+I$ and $-I$

equally often. Having the measurement return a bivector is thus essentially the same as having it return a vector. (Note that Christian has objected to the claim that these are equivalent in [5])

In the proposed experiment the result of the measurement was a single bit, as required. The claim was that it would reproduce the violation of Bell's inequality using classical, macroscopic bodies alone. The simulation indicates that it will not. Of course it might be claimed that the physics of rotating bodies differs from what is calculated in this simulation . I don't see how this would help, however, as the rotating hemispheres play no part except to carry the constant angular momenta from the source to the detectors.

References

[1] J. Christian, "Can bell's prescription for physical reality be considered complete?," `arxiv:0806.3078 [quant-ph]`.

[2] S. Lee, "Tachyos.org - 2 hemispheres bell experiment." http://tachyos.org/bell/bell1.html.

[3] M. Arribas, A. Elipe, and M. Palacios, "Quaternions and the rotation of a rigid body," *Celestial Mechanics and Dynamical Astronomy* **96** (2006) 239–251. http://www.unizar.es/galdeano/preprints/2006/preprint15.pdf.

[4] P. Grangier, ""disproof of bell's theorem" : more critics," `arxiv:0707.2223 [quant-ph]`.

[5] J. Christian, "Disproof of bell's theorem: Reply to critics," `arxiv:quant-ph/0703244`.