

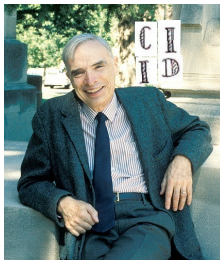
# How might Quantum Physics inform our Faith?

an answer, sort of, with a view of understanding different ways of relating science and faith, and seen from the point of view of an interesting branch of that great crisis in modern physics that is Quantum Mechanics

Dr. Greg Severn

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# This talk reviews ways of relating science and faith, and considers one aspect of quantum mechanics, it's a-causality and lack of LOCAL REALISM, in relation to faith



C I D I  
 CONFLICT INDEPENDENCE DIALOGUE INTEGRATION

ways of relating S&F

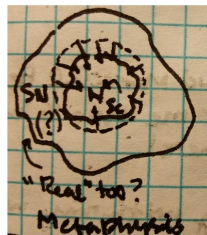
*Involving aspects of QM that could concern us as Christians*

"I, at any rate, am convinced that He [God] does not throw dice."  
 ~Albert Einstein on Quantum Mechanics

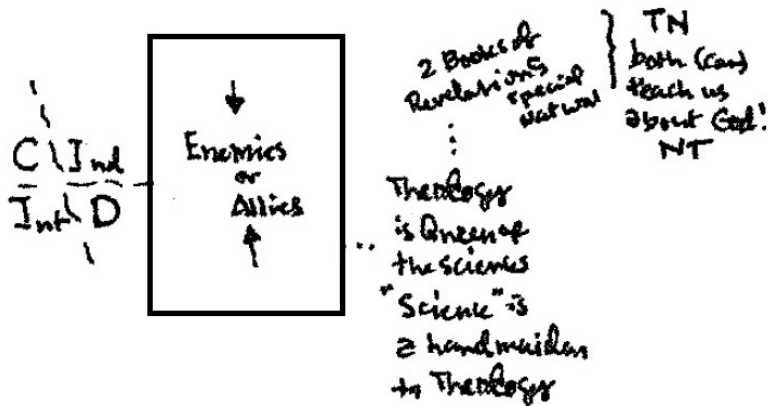
"Einstein, stop telling God what to do."  
 ~Niels Bohr on Einstein's feeling about Quantum Physics

**what does QM say about reality?**

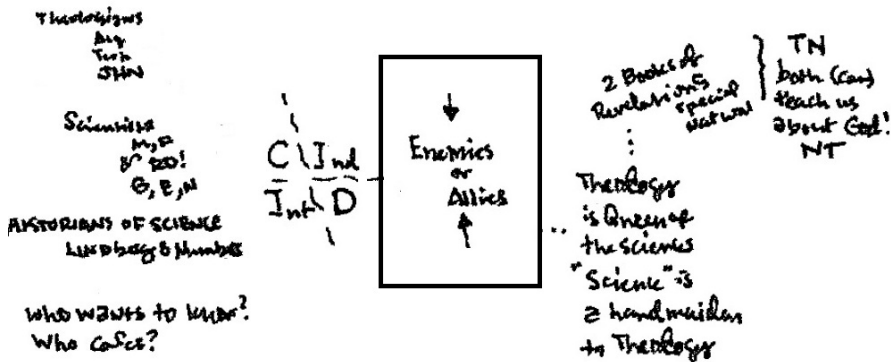
*along with some personal reflections*



# The Main Question fits into a wider context of questions. Different views have held sway at different times in the WEST

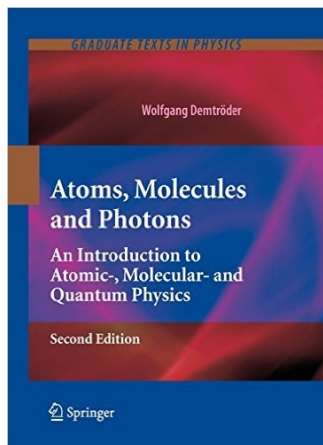


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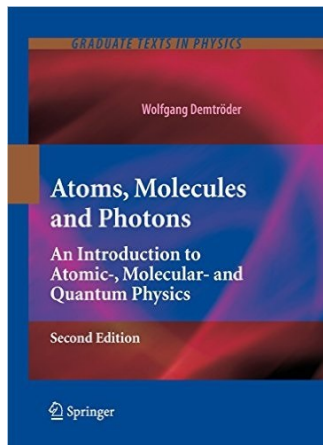
along with the rest of us who wonder whether or not Science is supportive or antithetical, or something in between....

# We will consider what one aspect of QUANTUM WEIRDNESS (ACAUSALITY and lack of LOCAL REALISM) has to do with anything we care about as Christians



- On the face of it, not much

# We will consider what one aspect of QUANTUM WEIRDNESS (ACAUSALITY and lack of LOCAL REALISM) has to do with anything we care about as Christians



- On the face of it, not much
- there is an application having to do with Bell's theorem and EPR experiments...

# Acausality first: quantum mechanics as presented by the founders (Heisenberg, Born, Jordan, Dirac) was abhorrently acausal, issuing in the question of it's COMPLETENESS

Quantum Weirdness 101: non-commuting observables:

$$\hat{P}\hat{Q} - \hat{Q}\hat{P} = \frac{\hbar}{i}$$

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Quantum Weirdness 101: non-commuting observables:

$$\hat{P}\hat{Q} - \hat{Q}\hat{P} = \frac{\hbar}{i}$$

illustrates: the 'uncertainty principle', a-causality, state of the system 'determined' by  $\Psi(x, t)$ , or  $\Psi(p, t)$  (Schrodinger's Wave function), a 'particle's' position and momentum *cannot* simultaneously have sharp values, so there is no trajectory.



# The feeling in physics was this was a largely metaphysical question, not one that admitted of a physical demonstration

*No reasonable definition of **reality** could be expected to permit this.*

— Einstein, Podolsky, and Rosen

*Physics is to be regarded not so much as the study of something *a priori* given, but rather as the development of methods for ordering and surveying human experience.*

— Bohr (*The Unity of Human Knowledge*)

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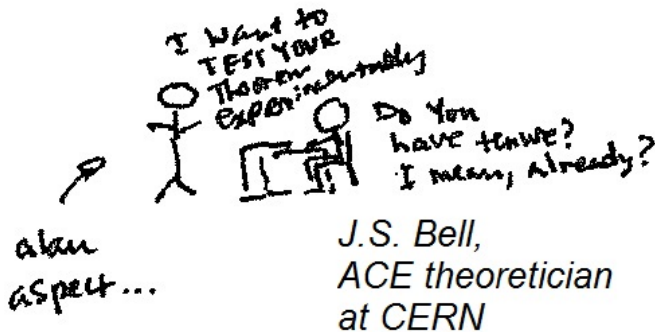
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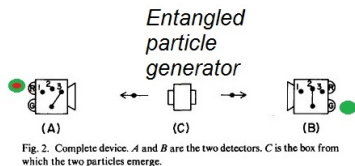
— Bohr (*The Unity of Human Knowledge*)

Einstein and others felt that QM was incomplete, that there were HIDDEN VARIABLES that REALLY EXISTED but weren't described at the level (admittedly successful) of quantum mechanics....

until J.S. Bell, figured out testable consequences of HIDDEN VARIABLES—of course very controversial—a people began to do 'EPR' experiments in the 80's till now!

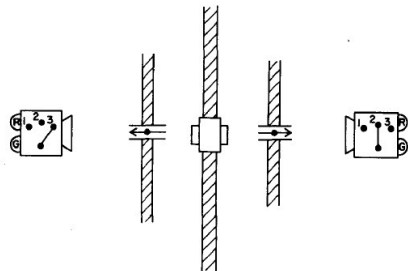


Ok, time for a little quantum mechanics experiment, explained for everyone to understand the deal: local realism doesn't exist. This is Mermin's thought experiment which illustrates Bell's inequality (theorem) and EPR experiments

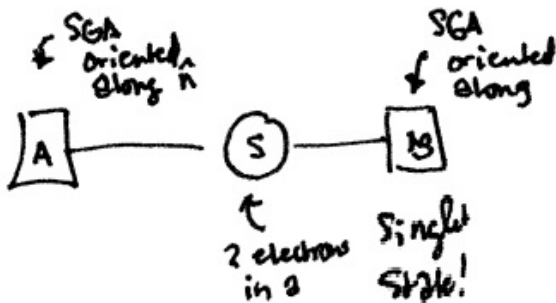


941 *Am. J. Phys.*, Vol. 49, No. 10, October 1981

*Set the switches  
shoot the particles  
lights go off (R-or-G)  
record settings & data, e.g.,  
32 RG*



Ok, time for a little quantum mechanics experiment, explained for everyone to understand the deal: local realism doesn't exist. This is Mermin's thought experiment which illustrates Bell's inequality (theorem) and EPR experiments



# Here's what happens: when the switch settings are the same, detectors always flash the same color

with different detector settings, 1/4 same color, 3/4 different...but otherwise totally random

23GR	12GR	11GG	13GR	23RG	33GG	12RG	21GR
11RR	31RG	22GG	11GG	22GG	11RR	32RG	23RG
31RG	32GR	22RR	31RG	13RG	22GG	22RR	12GG
33RR	22RR	21GR	32RG	11GG	32GR	33GG	21GR
32GG	22GG	11RR	11GG	23GG	12RR	32GR	11GG
32RG	12RG	13RG	33GG	21RG	13GR	31RR	32GR
31GR	13GR	21RG	33RR	13GR	11RR	11GG	13RG
12GG	32GR	33GG	21GR	21GG	33RR	23RG	21GG
13GR	11GG	32GG	31GR	32RG	33RR	13RR	13RG
11GG	31RG	33RR	12RG	21GR	11GG	22GG	33GG
33RR	21GG	21RG	12RG	11GG	12RG	11GG	23GG
11GG	12RR	12RG	31GR	23GR	12GR	33GG	31GG
11RR	22RR	12RG	22GG	23GR	12GR	23RG	21RR
13GR	21RR	33RR	33RR	13RG	23RG	33GG	32RR
13RR	32RG	11RR	11RR	11RR	32RG	12RG	21RG
23RG	23RR	21RG	33RR	13GR	12GR	23RG	21RR
13RR	21GR	12RR	31GR	12RG	13GR	13RG	22RR
21RG	23GR	11RR	12RR	33RR	21RG	13GR	21RR
31GR	23GG	13RG	21RG	11GG	12GR	23GR	13GG
11RR	31RG	11GG	31GR	32GR	32RG	32GR	11GG

Fig. 4. Fragment of a page of a volume from the set of notebooks recording a long series of runs.

*Case (a).* (11, 22, or 33) both detectors always flash the same color: *RR* and *GG* occur with equal frequency; *RG* and *GR* never occur.

*Case (b).* (12, 13, 21, 23, 31, or 32) switches end up with different settings both detectors flash the same color only a quarter of the time different colors three quarters

*CASE (a)? One detector doesn't KNOW the settings of the other!!!  
POSIT HIDDEN VARIABLES (RRR, GGG, RGR, RRG, GGR, GRG, GRR, RGG)*

(NB: Both particles must have the same instruction set)

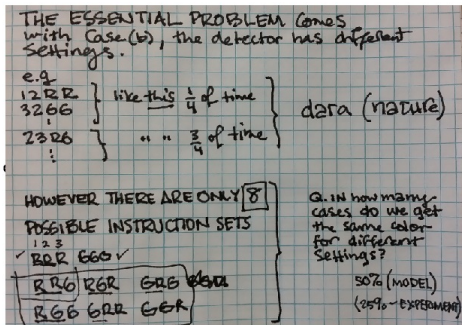
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32GG	22GG	11RR	11GG	23GG	12RR	32GR	11GG
32RG	12RG	13RG	33GG	21RG	13GR	31RR	32GR
31GR	13GR	21RG	33RR	13GR	11RR	11GG	13RG
12GG	32GR	33GG	21GR	21GG	33RR	23RG	21GG
13GR	11GG	32GG	31GR	32RG	33RR	13RR	13RG
11GG	31RG	33RR	12RG	21GR	11GG	22GG	33GG
33RR	21GG	21RG	12RG	11GG	12RG	11GG	23GG
11GG	12RR	12RG	31GR	23GR	12GR	33GG	31GG
11RR	22RR	12RG	22GG	23GR	12GR	23RG	21RR
13GR	21RR	33RR	33RR	13RG	23RG	33GG	32RR
13RR	32RG	11RR	11RR	11RR	32RG	12RG	21RG
23RG	23RR	21RG	33RR	13GR	12GR	23RG	21RR
13RR	21GR	12RR	31GR	12RG	13GR	13RG	22RR
21RG	23GR	11RR	12RR	33RR	21RG	13GR	21RR
31GR	23GG	13RG	21RG	11GG	12GR	23GR	13GG
11RR	31RG	11GG	31GR	32GR	32RG	32GR	11GG

Fig. 4. Fragment of a page of a volume from the set of notebooks recording a long series of runs.



NB: Bell's theorem  $\Rightarrow$  for HIDDEN VARIABLES to exist, certain correlations should satisfy certain inequalities, violated here.

# All experiments to date affirm that both Nature (read: experiment) AND QUANTUM MECHANICS violate Bell's Inequalities in precisely the same way

VOLUME 49, NUMBER 2

PHYSICAL REVIEW LETTERS

12 JULY 1982

## Experimental Realization of Einstein-Podolsky-Rosen-Bohm *Gedankenexperiment*: A New Violation of Bell's Inequalities

Alain Aspect, Philippe Grangier, and Gérard Roger

*Institut d'Optique Théorique et Appliquée, Laboratoire associé au Centre National de la Recherche Scientifique,  
Université Paris-Sud, F-91406 Orsay, France*

(Received 30 December 1981)

The linear-polarization correlation of pairs of photons emitted in a radiative cascade of calcium has been measured. The new experimental scheme, using two-channel polarizers (i.e., optical analogs of Stern-Gerlach filters), is a straightforward transposition of Einstein-Podolsky-Rosen-Bohm *gedankenexperiment*. The present results, in excellent agreement with the quantum mechanical predictions, lead to the greatest violation of generalized Bell's inequalities ever achieved.

PACS numbers: 03.65.Bz, 35.80.+s

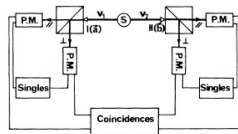


FIG. 2. Experimental setup. Two polarimeters I and II, in orientations  $\hat{a}$  and  $\hat{b}$ , perform true dichotomic measurements of linear polarization on photons  $\nu_1$  and  $\nu_2$ . Each polarimeter is rotatable around the axis of the incident beam. The counting electronics monitors the singles and the coincidences.

NB: the particles either don't come with hidden variables or they can influence each faster than the speed of light... ok, that's disturbing....



Maybe these crazy QUANTUM CO-RELATIONS happen because of SETTING DEPENDENCE owing to the fact that the observer did NOT HAVE FREE WILL in setting up the conditions of the measurements!

Who cares about this: Augustine: I CARE! Why: because if you don't have free will, you aren't responsible for ANYTHING, not in the way CHRISTIAN THEOLOGY SUGGESTS....this affects ones understanding of the point of SALVATION,....

PRL 112, 110405 (2014)

PHYSICAL REVIEW LETTERS

week ending  
21 MARCH 2014

### Testing Bell's Inequality with Cosmic Photons: Closing the Setting-Independence Loophole

Jason Gallicchio,<sup>1,\*</sup> Andrew S. Friedman,<sup>2,†</sup> and David I. Kaiser<sup>2,‡</sup>

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(Received 25 October 2013; published 18 March 2014)

We propose a practical scheme to use photons from causally disconnected cosmic sources to set the detectors in an experimental test of Bell's inequality. In current experiments, with settings determined by quantum random number generators, only a small amount of correlation between detector settings and local hidden variables, established less than a millisecond before each experiment, would suffice to mimic the predictions of quantum mechanics. By setting the detectors using pairs of quasars or patches of the cosmic microwave background, observed violations of Bell's inequality would require any such coordination to have existed for billions of years—an improvement of 20 orders of magnitude.



Maybe these crazy QUANTUM CO-RELATIONS happen because of SETTING DEPENDENCE owing to the fact that the observer did NOT HAVE FREE WILL in setting up the conditions of the measurements!

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ASPNAS

## Violation of local realism with freedom of choice

Thomas Scheidl<sup>a</sup>, Rupert Ursin<sup>a</sup>, Johannes Kofler<sup>a,b,1</sup>, Sven Ramelow<sup>a,b</sup>, Xiao-Song Ma<sup>a,b</sup>, Thomas Herbst<sup>a</sup>, Lothar Ratschbacher<sup>a,2</sup>, Alessandro Fedrizzi<sup>a,2</sup>, Nathan K. Langford<sup>a,4</sup>, Thomas Jennewein<sup>a,1</sup>, and Anton Zeilinger<sup>a,b,1</sup>

<sup>a</sup>Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, 1090 Vienna, Austria; and <sup>b</sup>Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1090 Vienna, Austria

Edited by William D. Phillips, National Institute of Standards and Technology, Gaithersburg, MD, and approved September 15, 2010 (received for review March 4, 2010)

Bell's theorem shows that local realistic theories place strong restrictions on observable correlations between different systems, giving rise to Bell's inequality which can be violated in experiments using entangled quantum states. Bell's theorem is based on the assumptions of realism, locality, and the freedom to choose between measurement settings. In experimental tests, "loopholes" arise which allow observed violations to still be explained by local realistic theories. Violating Bell's inequality while simultaneously closing all such loopholes is one of the most significant still open challenges in fundamental physics today. In this paper, we present

probability zero or one. Mathematically, stochastic hidden variable theories (23, 24) can be seen as mixtures of deterministic theories (25).

In an experiment, the *locality loophole* arises when Alice's measurement result can in principle be causally influenced by a physical (subluminal or luminal) signal from Bob's measurement event or Bob's choice event, and vice versa. The best available way to close this loophole is to space-like separate every measurement event on one side from both the measurement [outcome independence (26)] and setting choice [setting independence (26)] on the other side. Then, special relativistic

CONCLUSION: **Maybe** you have free will

# CONCLUSION: **Maybe** you have free will

what I like about this is that it is a top-down, upper level limiting case...here's how our lack of free will would show up in an actually experiment...less of a long chain of inferences, bottom-up...

# OK, but why are the FED's REALLY interested in these experiments?

that's easy: it's about quantum cryptography, and the possibility of making hacks more or less likely....

PRL **112**, 110405 (2014)

PHYSICAL REVIEW LETTERS

week ending  
21 MARCH 2014

## Testing Bell's Inequality with Cosmic Photons: Closing the Setting-Independence Loophole

Performing a loophole-free Bell test and decisively closing the setting-independence loophole remains an important goal not just in the arena of fundamental physics, but in the burgeoning field of quantum information science [10,11,15]. If hidden variable models of any sort are viable, upcoming quantum encryption schemes could be broken by a sophisticated future eavesdropper that learns to measure the previously “hidden” variables [17].

a little self disclosure: once in the physics library at UCLA it hit me, Maxwell's equation do not have (need) a term like  $\nabla \times \mathbf{G} = \mathbf{E}$ , where  $\mathbf{E}$  is the electric field, and where  $\mathbf{G}$  is God, or the God field, or the God particle....



$$1. \quad \nabla \cdot \mathbf{E} = \frac{\rho_V}{\epsilon}$$

$$2. \quad \nabla \cdot \mathbf{H} = 0$$

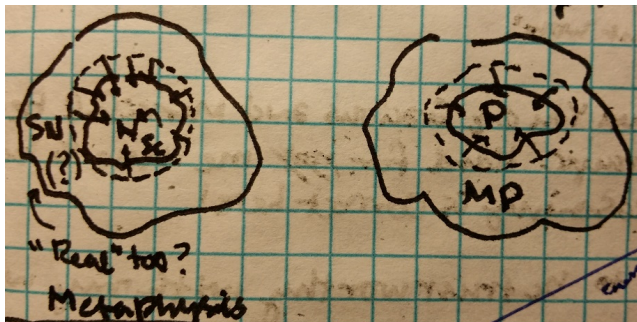
[www.maxwells-equations.com](http://www.maxwells-equations.com)

$$3. \quad \nabla \times \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t}$$

$$4. \quad \nabla \times \mathbf{H} = \epsilon \frac{\partial \mathbf{E}}{\partial t} + \sigma \mathbf{E}$$

# I think there IS a preferred metaphysical perch to stand on when DOING SCIENCE

do people 'live' in this mindset long enough to be 'invested' in it so as to believe it is the ONLY RATIONAL ONE? people do...



Science looks 'in' to NATURE, and as believers, we look 'out' to GOD

# Closing Arguments

- 1 we musn't (pre)judge which science is right because it fits (or doesn't) our theology, because that is a work in progress. Keep Faith and let science do it's thing!
- 2 Be patient to be in a culture, and a time where those who hold FAITH APPEAR TO BE IN A WEAK POSITION. Are we willing to be misunderstood, wavering not, in steady obedience to the gospel, in a world that thinks we are (a bit) crazy? The Apostle Paul predicted this predicament!
- 3 when we 'witness' to unbelievers, strangers, about CHRIST, our credibility rests far more on the obedience to the gospel and to the spirit of Christ of believers they know than to arguments concerning the existence of GOD.



But why do I care? Because the apparent consistency (or lack) between S and F is an open, not closed question, one that MATTERS HUGELY TO ME AS A BELIEVER

NB: I love science, I really do  
and I love God, I really do

I and persons like me authentically, credibly (I.I.D.S.S.M.) exist in this universe, and I am in the fight in this world, and it is a fight, to assert this, and to be a witness for CHRIST in my world