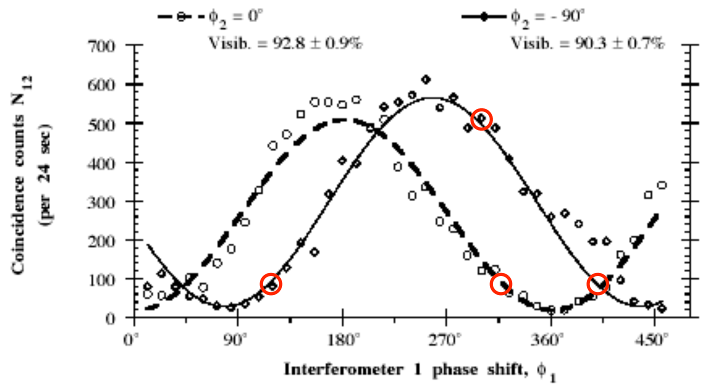
Experimental data violating Bell’s inequality

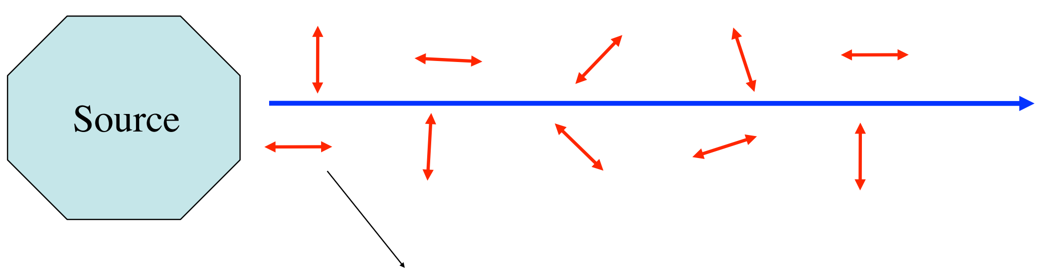


Bell's inequality is violated – in other words, whether or not quantum mechanics is right, this experiment can't be explained by "local hidden variables."
Somehow, we know that the particles don't know what they're doing!

(Have we *proved* that the world really is random??)

Why can’t we imagine that they do?

Can’t we imagine that each time a pair is emitted, it really comes out with 2 definite polarisations?

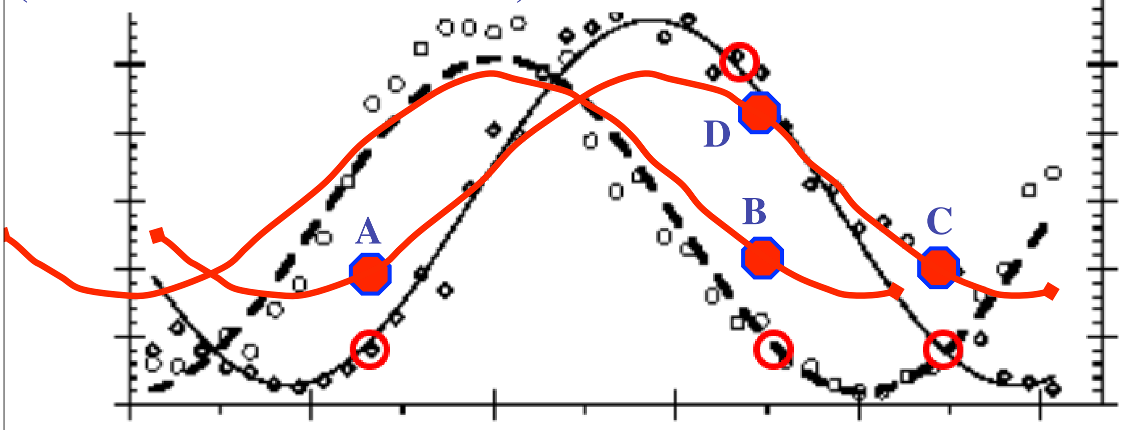


If we measured VH, 1 would be V and 2 would be H.

But **-- if we measured DA, 1 could be either D or A (50/50), and 2 could be either D or A (50/50);**
one half the time, they would be the same (doesn’t happen).

What would we get?

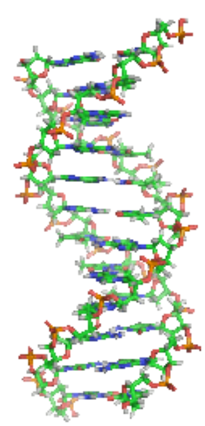
Although it'd be *most likely* to see them for analyzers 90º apart, there would be *no* analyzer setting where you *never* saw them (these curves never fall to zero)



A+B+C > D – exactly as Bell predicted.
And *not* the same as the QM predictions.

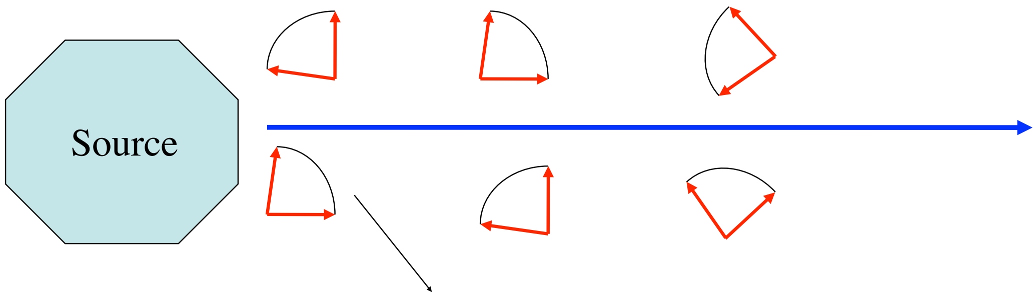
But why assume the "future theory" still has the same rules about polarisation?

The idea of hidden variables is more general –
each particle has some state we don't yet know how to discuss,
but this state determines how it will behave when we measure it.



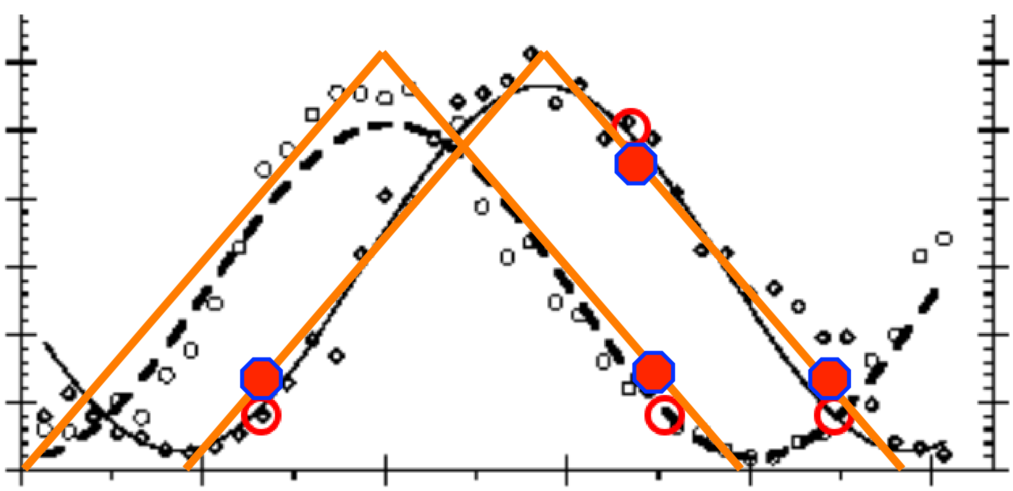
Better model?

Can't we imagine that each time a pair is emitted, one photon "knows" to be transmitted through half the possible settings, and the other only to be transmitted through the other half?



As I tilt my analyzers away from 90 degrees apart, the correlations are no longer perfect... but when I tilt them twice as far, the "errors" are twice as frequent...

What would we get?



(hard to see from the careless picture, but)

A+B+C=D exactly – no violation of Bell's inequalities.

And *not* the same as the QM predictions.

The power of logic (theorems)...

Although a few folks out there don't get it,

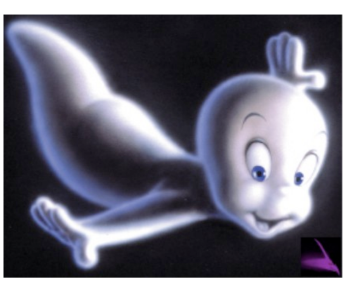
there is *no point* in trying to come up with better & better models like this. Bell has proved that *no* model can agree with LHV's and with quantum mechanics.

Was Einstein right?

"Maybe" and "no."

We can't prove that *all* hidden variables models are wrong; Bohm and de Broglie's model is known to work!

But we *can* show that any *local* hidden variable model obeys Bell's inequalities, and neither QM *nor the real world* does.



Spooky
action
at a distance!

To summarize the reasoning...

QM: Ψ can be used to predict outcomes of measurements
Us: Okay, but what does it really *mean*?

Einstein

The world must be local

Ψ must be incomplete
(there must be more to reality than it)

Bohr *et al.*

No, Ψ is the whole story

Then there must be spooky action at a distance?

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Bell: if the world is local, QM is wrong.
(If QM is right, there is spookiness.)

To summarize the reasoning...

QM: Ψ can be used to predict outcomes of measurements
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Einstein

~~The world must be local~~

↓

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(there must be more to reality than it)

Bohr *et al*.

No, Ψ is the whole story

↓

Then there must be spooky action at a distance?

Bohm de Broglie

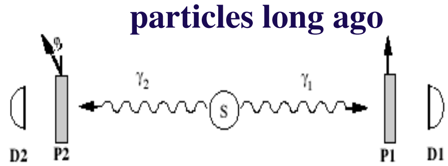
Ψ is incomplete

But no problem with Bell, b/c there is still spooky action.

"FLASH" !?

So, does Bob immediately know what Alice chose to measure?
I.e., can they communicate faster than light?

Source spit out particles long ago



Alice now chooses to measure DA or HV

Bob's particle immediately "collapses" to D,A, H, or V...

But: what does Bob measure?
He can't measure *both* DA and HV;
he must choose...

"FLASH" !?

So, does Bob immediately know what Alice chose to measure?
I.e., can they communicate faster than light?

NO! If she chose "dirtiness," she already knows whether his is clean or dirty – but the answer was random.
If she chose "colour," then she knows whether his is pink or not pink – so its "dirtiness" is undetermined.

In more physics-y terms, if Alice measured H/V
Bob sees V when she gets H and H when she gets V; 50/50.

If she measured D/A,
Bob sees 50/50 when she gets D and 50/50 when she gets A;
--same thing overall!

Bob gets a random answer no matter what... but was the random answer known before he made his measurement?

Two kinds of locality?

Abner Shimony: "peaceful coexistence"
of these seemingly contradictory features

"The universe 'talks to itself' nonlocally (faster than light), but by rules which preclude us from ever talking *to each other* faster than light"

QM violates "outcome independence":
that is, what you observe may depend on the outcome of my measurements, however far away we may be.

But QM *satisfies* "parameter independence":
that is, what you observe does *not* depend on how I turn knobs in my lab (e.g., what measurements I choose to do)

"FLASH" !?

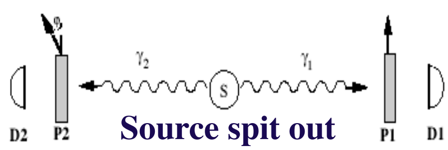
So, does Bob immediately know what Alice chose to measure?

Bob gets a random answer no matter what... but was the random answer known before he made his measurement?

Nick Herbert: if he made 100 copies ("clones") of his photon before measuring, then he could see whether they all have the same dirtiness (because Alice already knew it), or whether each one was random (because Alice measured "colour").

They could communicate faster than light!

Using clones to send instantaneous signals



Source spit out particles long ago

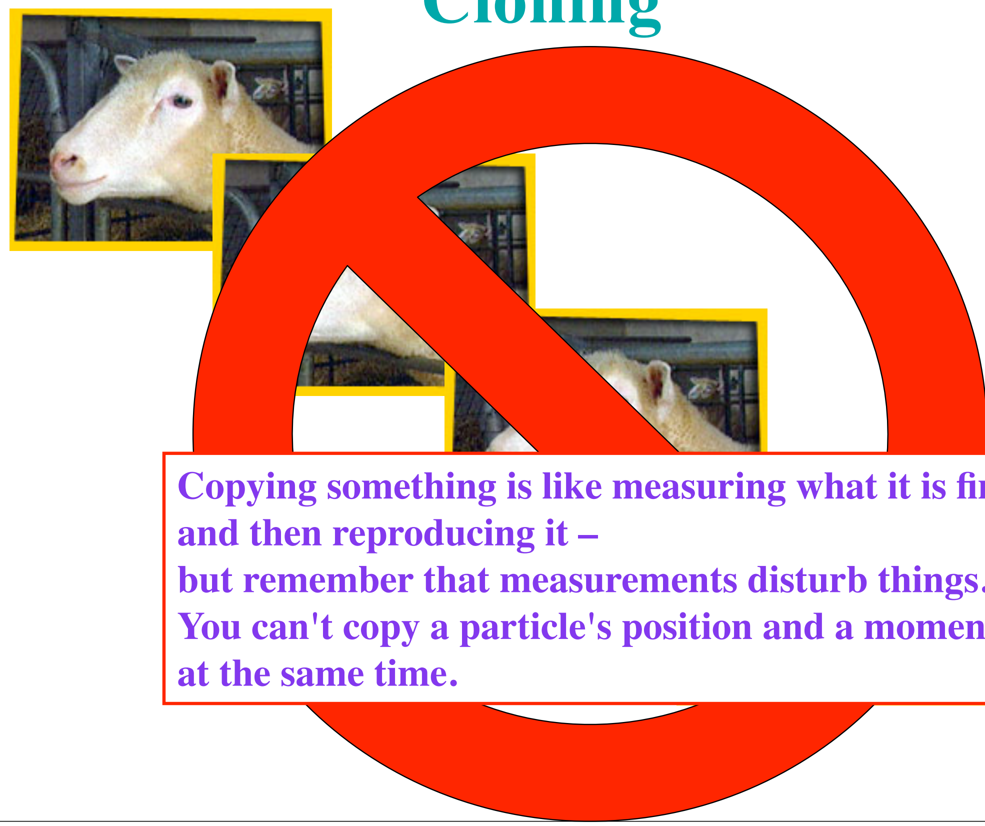
Alice now chooses to measure DA or HV

Bob's particle immediately "collapses" to D,A, H, or V... but he makes 100 copies, and measures HV on all of them...

Alice measures HV -> Bob finds HHHHHHHHHHHHHHH
or VVVVVVVVVVVVVVV

Alice measures DA -> Bob finds HVVHVHHVHHVVVHH
or VVVHVVHHVHVHHVH
or ....
(but *almost* certainly not HHHHHHHHHHH...!)

Cloning



Copying something is like measuring what it is first, and then reproducing it –
but remember that measurements disturb things.
You can't copy a particle's position and a momentum at the same time.

arXiv.org > quant-ph > arXiv:quant-ph/0205076

Search or Article

Quantum Physics

How the no-cloning theorem got its name

Asher Peres

(Submitted on 14 May 2002)

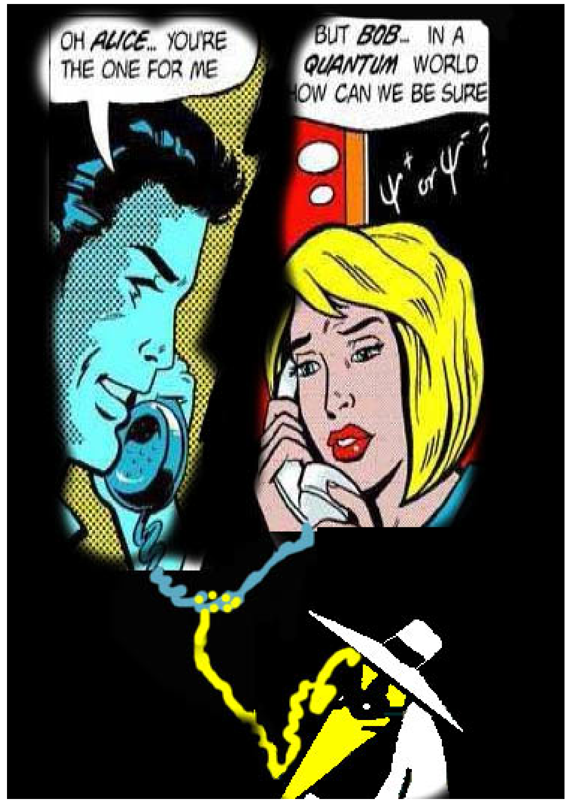
I was the referee who approved the publication of Nick Herbert's FLASH paper, knowing perfectly well that it was wrong. I explain why my decision was the correct one, and I briefly review the progress to which it led.

Comments: proceedings of Quantum Interferometry IV, needs fortschritte.sty
Subjects: **Quantum Physics (quant-ph)**
DOI: 10.1002/prop.200310062
Cite as: **arXiv:quant-ph/0205076**
(or **arXiv:quant-ph/0205076v1** for this version)

Submission history

From: Asher Peres [view email]
[v1] Tue, 14 May 2002 08:18:49 GMT (7kb)

The Problem of Cryptography



Classical Cryptography

The only provably secure way to send secrets:
the "one-time pad." Alice and Bob share a *random* "key", which is AS LONG AS THE ENTIRE MESSAGE.
They never reuse it. (Soviets made this mistake.)

Problem: How to be sure "Eve" didn't get a copy of the key?

Quantum Cryptography

"We don't need to worry about information security or message encryption. Most of our communications are impossible to understand in the first place."