14	Mon., 12/1 Tues. 12/2 Wed., 12/3 Fri., 12/5	**12.1-.2** EPR Paradox and Bell's Theorem; Scholosauer – 8 Bell's **12.3-.5** Cats, Clones, and Zeno; Scholosauer – 7 Measurement Schloshauer Ch.3 – Interpretations, Ch. 12 Switching	**Daily 14.M** **Weekly 14** **Daily 14.W** **Daily 14.F**
15	Mon., 12/8	**Review for Final** (comprehensive with emphasis on 5,6,8,12)	

Daily: Kyle Jacob Spencer Gigja Anton Jessica Sean Antwain Jonathan Casey Jeremy Mark Connor Brad

Equipment

- Griffith's text
- Elegance & Enigma
- Bohm's pilot wave analog - https://www.youtube.com/watch?v=nmC0ygr08tE
- "A Snapshot of Foundational Attitudes Toward Quantum Mechanics" – Maximilian Schlosshauer et. al.

Check dailies

Announcements

Daily 14.M Monday 12/1 Griffiths **12.1-.2,** Scholosauer **8** EPR and Bell's Theorem

1. *Starting Weekly*: Griffiths 12.1
2. *Conceptual* : Summarize Scholosauer's 17 participant's main points about Bell's Theorem. What do you find most or least compelling?

"Could we also go over "locality" and the "local hidden variable theory"? I'm not fully understanding on what makes certain results compatible and incompatible." Jeremy,

I am confused about this too. Jonathan

I think we could use a little bit of defining the specifics of local hidden variable theory. Kyle B

More detail on the local variable theories, as well as causal and ethereal descriptions would be welcome. Bradley W

"I agree, I was also confused about this" Jessica

"Are the nonlocal influences synonymous with the the "etherial" influences?" Mark T

"What does it mean for a hidden variable to be local? Could we go over the interpretation of Bell's inequality [12.12]?" Spencer

I am also still confused about what it means for a variable to be local. Does it just mean non relativistic? Gigja

I had kind of assumed local to mean "specific to one instance" and therefore not be a general rule or set of values that could be used for all experiments. Bradley W

12. Afterward

12.1 EPR paradox

Einstein, Podolsky, and Rosen's Position: Realists

Einstein was famously adverse to the notion that nature was fundamentally probabilistic. As with statistical mechanics, he believed quantum mechanics was probabilistic simply because we were ignorant of / ignoring some underlying details that may be *impractical* to keep track of, but existed and determined experiments' outcomes none the less. We'd call him a "realist" – he believed that physical systems 'really' simultaneously had properties physical that we've called 'incompatible' with the states they've been prepared in or had *other* properties which determined them. For example, that a particle for which the momentum was known, and thus described by a momentum state, actually *did* have a well-defined position. Or, that an electron that was measured to have spin along the z-axis really also had a definite component along the x axis.

Einstein, Podolsky, and Rosen's (and Bohm's) Experiment: Entangled Particles

Einstein, Podolsky, and Rosen dreamt up a thought experiment that they thought demonstrated this. The conclusion they *wanted* was that Measurement may collapse our *knowledge* of a system's measurable property to a given value, but the system always had a definite value (we just didn't know what it was), and thus Quantum Mechanics' probabilistic description is an incomplete one. The conclusion it *lead to* was something altogether different.

In Bohm's simplification, the experiment goes something like this:
A neutral, spinless pion decays into an electron and an anti-electron / positron.

$$\pi^o \rightarrow e^- + e^+$$

Since the pion was spinless, the electron and positron must, together, be described by the singlet state. In terms of any axis (though we often call it *z*):

$$\left|0,0\right\rangle = \tfrac{1}{\sqrt{2}}\left(\uparrow_-\downarrow_+ + \uparrow_+\downarrow_-\right)$$

That state does not assign a particular value to either particle, just to the system. Of course, while the expectation value, i.e., average value for the electron or for the positron may be 0, if you should *measure* one of the particles' (say, the electron's) spin components along any given axis you'll either get $S_a^e = \pm\tfrac{\hbar}{2}$. Then, conservation of angular momentum dictates that the projection of the *other* particle's (say, the positron's) spin along that same axis must be the opposite: $S_a^p = \mp\tfrac{\hbar}{2}$, *without your having to measure it.*

That's the crucial point: by making a measurement on one member of an entangled system of particles, you can *instantly* predict with certainty what you'll measure for the other member.

Einstein, Podolsky, and Rosen's (and Bohm's) Conclusion: Realism

E,P, & R argued that, in the absence of any faster-than-light signaling, it would be unfathomable that the measurement you made at one location would influence the measurement you'll make at the other location, so it must be that the other particle had its given spin all along, even though quantum mechanics couldn't predict it.

Problem 12.1 Entangled States. Griffiths asks you to demonstrate that there's no way to write an entangled state, such as that of the electron and proton in the singlet state, as the simple product of the separate particle's individual, independent 'actual' states. (In contrast, you *can* write a hydrogen electrons' wavefunction as a simple product of radial and angular dependences separately, so they are truly independent and you can think of the electron as having definite radial and angular states.)

12.2 Bell's Theorem / Inequality for hidden-variables theories

Bell's inequality relates entangled pairs' spins projected/measured along different axes. If we assume that there information that's absent from or 'hidden' from the quantum mechanical model, he could set a condition on how they can be related. We could then check whether the condition was compatible with the quantum mechanical theory (which it isn't) and whether experiment agreed with the quantum mechanical theory or with his hidden-variables condition.

Bell observed that if the Quantum Mechanical description is 'incomplete', that means that nature has more information than we do, i.e., there are "hidden variables" that, if we only knew them, we would be able to predict the outcomes of the experiments.

> ***Brownian Motion Analog***: An analog is Brownian Motion (the random wandering of a speck of dust). When a microscopically-observable speck of dust jitters left and then right, it's because lots of too-small-to-see particles are bumping into it all the time; if we knew all of *their* positions and momenta just before a jitter, we'd be able to predict the jitter.

In the abstract, call these additional pieces of information λ. Then the outcome of a spin measurement would be a function of this variable. For example, if you wanted to know the electron's spin projection along some axis *a*, that would be determined by the function

$$S_a^e = S^e(\hat{a},\lambda) = \pm\tfrac{\hbar}{2}.$$

> **Notes:** To keep this a little more tangible and relatable to things we've already done in this course, I'm going to use less general / abstract notation than Griffiths' does. I'm using the 'hat' notation to mark unit vectors (rather than operators).

In the EPR experiment, one piece of information that we *do* have is that, whatever you measure for the electron along a given axis, you must measure the opposite for the positron (for conservation of angular momentum); that is,

$$S^p(\hat{a},\lambda) = S_a^p = \mp\tfrac{\hbar}{2} = -S_a^e = -S^e(\hat{a},\lambda) \qquad (1)$$

So the function for the positron is just negative that for the electron.

Product of electron and positron spin measurements along the *same* axis

Another fairly trivial relation that will prove useful is that, since they're opposite, the product

$S^p(\hat{a},\lambda)S^e(\hat{a},\lambda) = S_a^p S_a^e = -\left(\tfrac{\hbar}{2}\right)^2$ or, using equation 1,

$$-S^p(\hat{a},\lambda)S^p(\hat{a},\lambda) = S_a^p S_a^P = -\left(\tfrac{\hbar}{2}\right)^2 \qquad (2)$$

Product of electron and positron spin measurements along *different* axes

Now, that's a guarantee if you look along the *same* axis, but what if you measure the spin along *different* axes for the electron and the proton? Say, you measure the spin along axis *a* for one and *b* for the other particle. You know how averages go:

$$\left\langle S_a^p S_b^e \right\rangle = S^p(\hat{a},\lambda_1)S^e\left(\hat{b},\lambda_1\right) + S^p(\hat{a},\lambda_2)S^e\left(\hat{b},\lambda_2\right) + S^p(\hat{a},\lambda_3)S^e\left(\hat{b},\lambda_3\right) + \ldots = \sum_i S^p(\hat{a},\lambda_i)S^e\left(\hat{b},\lambda_i\right)$$

In the case that λ is a continuous variable or space of variables (rather than just taking on discrete values), this sum would be better expressed as an integral

$$\left\langle S_a^p S_b^e \right\rangle = \int \rho(\lambda) S^p(\hat{a},\lambda) S^e\left(\hat{b},\lambda\right) d\lambda \qquad (3)$$

Where $\rho(\lambda)$ is the probability density of this variable (look back at chapter 1 if this seems hazy). Of course, as for all probability densities, sum the probabilities of each value and you better get 1.

$$1 = \int \rho(\lambda) d\lambda \qquad (4)$$

Substituting equation (1) into equation (3) we can express in terms of the one function,

$$\left\langle S_a^p S_b^e \right\rangle = -\int \rho(\lambda) S^p(\hat{a},\lambda) S^p\left(\hat{b},\lambda\right) d\lambda$$

Similarly, if we were to measure the positron's spin along the *a* axis and the electron's along the *c* axis, we'd have

$$\left\langle S_a^p S_c^e \right\rangle = -\int \rho(\lambda) S^p(\hat{a},\lambda) S^p(\hat{c},\lambda) d\lambda$$

So, for kicks, what's the difference between these two products?

$$\left\langle S_a^p S_b^e \right\rangle - \left\langle S_a^p S_c^e \right\rangle = -\int \rho(\lambda) S^p(\hat{a},\lambda)\left(S^p\left(\hat{b},\lambda\right) - S^p(\hat{c},\lambda)\right) d\lambda$$

Or, using equation (2), we can 'factor out' $S^p\left(\hat{b},\lambda\right)$ too $S^p\left(\hat{b},\lambda\right)S^p\left(\hat{b},\lambda\right) = \left(\tfrac{\hbar}{2}\right)^2$

$$\left\langle S_a^p S_b^e \right\rangle - \left\langle S_a^p S_c^e \right\rangle = -\int \rho(\lambda) S^p(\hat{a},\lambda) S^p\left(\hat{b},\lambda\right)\left(1 - \left(\tfrac{2}{\hbar}\right)^2 S^p\left(\hat{b},\lambda\right) S^p(\hat{c},\lambda)\right) d\lambda$$

Now, for a given value of l, $S^p(a,\lambda)S^p(b,\lambda) = \pm\left(\tfrac{\hbar}{2}\right)^2$, so we can set some bounds on the difference if we consider the most / least this product can be:

$$\left|\left\langle S_a^p S_b^e \right\rangle - \left\langle S_a^p S_c^e \right\rangle\right| \le \int \rho(\lambda)\left(\tfrac{\hbar}{2}\right)^2\left(1 - \left(\tfrac{2}{\hbar}\right)^2 S^p\left(\hat{b},\lambda\right) S^p(\hat{c},\lambda)\right) d\lambda = \left(\tfrac{\hbar}{2}\right)^2 \int \rho(\lambda) d\lambda - \int \rho(\lambda) S^p(b,\lambda) S^p(c,\lambda) d\lambda$$

$$\boxed{\left|\left\langle S_a^p S_b^e \right\rangle - \left\langle S_a^p S_c^e \right\rangle\right| \le \left(\tfrac{\hbar}{2}\right)^2 + \left\langle S_b^p S_c^e \right\rangle}$$

Quantum Mechanics' Prediction

So, is this compatible with what Quantum Mechanics predicts? Say you measure the positron's spin along the *a* axis (say, the z axis); you have

$P_{+a}^{p} = \tfrac{1}{2}$ chance of measuring $S_{+a}^{p} = +\tfrac{\hbar}{2}$

and

$P_{-a}^{p} = \tfrac{1}{2}$ chance of measuring $S_{-a}^{p} = -\tfrac{\hbar}{2}$

In the latter case, without bothering to actually do it, you know from the EPR argument that the electron's alignment relative to axis *a would* be $S_{a}^{e} = \tfrac{\hbar}{2}$. Now, you might recall from Moore's text that if you were to run a beam of electrons through a Stern-Gerlach machine aligned with axis *a*, call it the Z axis, and then run that beam through a machine aligned with some axis *b* at angle $\theta_{b\text{-}a}$ relative to axis *a*, the probability of measuring

$S_{+b}^{e} = +\tfrac{\hbar}{2}$ for the electron's alignment is $P_{+b}^{e} = \cos^2\left(\tfrac{\theta_{b-a}}{2}\right)$

Similarly, the probability of measuring

$S_{-b}^{e} = -\tfrac{\hbar}{2}$ for the electron's alignment is $P_{-b}^{e} = \sin^2\left(\tfrac{\theta_{b-a}}{2}\right)$.

So, *given* that the positron was measured to be aligned along the +*a* axis, the average product spin measurements would be

$$\left\langle S_a^p S_b^e \right\rangle = S_{-a}^{p} \cdot \left(P_{+b}^{e} S_{+b}^{e} + P_{-b}^{e} S_{-b}^{e}\right) = -\tfrac{\hbar}{2} \cdot \left(\tfrac{\hbar}{2}\cos^2\left(\tfrac{\theta_{b-a}}{2}\right) - \tfrac{\hbar}{2}\sin^2\left(\tfrac{\theta_{b-a}}{2}\right)\right) = -\left(\tfrac{\hbar}{2}\right)^2 \cos\left(\theta_{b-a}\right) = -\left(\tfrac{\hbar}{2}\right)^2 \hat{a}\cdot\hat{b}$$

Now, if you were instead to measure the positron to have the opposite alignment, the signs for each term would be flipped, and you'd get the same *product*, so we have the average product.

Similarly, if you were to measure the positron's alignment along axis *a* and the electron's along axis *c*, or similarly if you were to measure the positron's alignment along *b* and the electron's along *c*.

0

So,

$$\left|\left\langle S_a^p S_b^e \right\rangle - \left\langle S_a^p S_c^e \right\rangle\right| = \left|\left(-\left(\tfrac{\hbar}{2}\right)^2 \hat{a}\cdot\hat{b}\right) - \left(-\left(\tfrac{\hbar}{2}\right)^2 \hat{a}\cdot\hat{c}\right|\right. = \left(\tfrac{\hbar}{2}\right)^2 \left|\hat{a}\cdot\left(\hat{b}-\hat{c}\right)\right|$$

Quantum vs. Bell's

So, on the one hand we have Bell's inequality which must hold for a hidden-variable's theory:

$$\left|\left\langle S_a^p S_b^e \right\rangle - \left\langle S_a^p S_c^e \right\rangle\right| \le \left(\tfrac{\hbar}{2}\right)^2 + \left\langle S_b^p S_c^e \right\rangle$$

On the other hand, we have Quantum Mechanic's predictions that

$\left\langle S_a^p S_b^e \right\rangle = -\left(\tfrac{\hbar}{2}\right)^2 \hat{a}\cdot\hat{b}$, $\left\langle S_a^p S_c^e \right\rangle = -\left(\tfrac{\hbar}{2}\right)^2 \hat{a}\cdot\hat{c}$, and $\left\langle S_b^p S_c^e \right\rangle = -\left(\tfrac{\hbar}{2}\right)^2 \hat{b}\cdot\hat{c}$

So, how does Quantum Mechanics predict the left and right-hand sides of Bell's inequality should be related?

$$\left|\left\langle S_a^p S_b^e \right\rangle - \left\langle S_a^p S_c^e \right\rangle\right| \,?\, \left(\tfrac{\hbar}{2}\right)^2 + \left\langle S_b^p S_c^e \right\rangle$$

$$\left|\left(-\left(\tfrac{\hbar}{2}\right)^2 \hat{a}\cdot\hat{b}\right)-\left(-\left(\tfrac{\hbar}{2}\right)^2 \hat{a}\cdot\hat{c}\right)\right| ? \left(\left(\tfrac{\hbar}{2}\right)^2-\left(\tfrac{\hbar}{2}\right)^2\hat{b}\cdot\hat{c}\right)$$
$$\left(\tfrac{\hbar}{2}\right)^2\left|\hat{a}\cdot\hat{b}-\hat{a}\cdot\hat{c}\right| ? \left(\tfrac{\hbar}{2}\right)^2\left(1-\hat{b}\cdot\hat{c}\right)$$
$$\left|\hat{a}\cdot\hat{b}-\hat{a}\cdot\hat{c}\right| ? \left(1-\hat{b}\cdot\hat{c}\right)$$

Specific Case

For example, if $\hat{a}=\hat{z}$, $\hat{b}=\hat{x}$, and $\hat{c}$ is 45° up from x toward z. Then the inequality would claim

$$\tfrac{1}{\sqrt{2}} \le \left(1-\tfrac{1}{\sqrt{2}}\right)=\tfrac{\sqrt{2}-1}{\sqrt{2}}$$
$$2 \le \sqrt{2}$$

Wrong!

And experiment backs up quantum mechanics – not Bell's inequality. So, the predictions of quantum mechanics and the experimental results violate Bell's inequality and are therefore incompatible with the assumptions upon which it is based.

"Why is equation 12.4 'incompatible with any local hidden variable theory'?" Casey P,

Implications: non-locality

As Griffiths points out, though EPR was designed to argue we must have realism, the conclusion is that we can't have locality, or rather, that locality is more limited than first thought.

Non-local Realism?

Realism *can* be preserved if it's non-local. For example, what if, at any given moment, both the electron and the positron both really do have a set spin orientation, but they're continuously varying *in such a way* that they remain complementary.

Non-local / instantaneous Collapse

In any event, the measurement locks one and thus both members of the pair into having well-defined values *instantaneously!* That is, in some reference frames, it would appear that the positron's spin was measured before the electron's and in other frames it would appear that the electron's was measured before the positron's.

Now, that doesn't sound so bad, but generally 'instantaneous' communication of information over a distance is physically unrealistic. For example, if it were a bullet getting shot from a gun to a victim, instantaneous flight would mean in some frames the victim falls dead *before* the bullet is fired. That is clearly unrealistic!

So, what's the essential difference between these two scenarios? The bullet carries energy and momentum and the outcome is the result of a choice – something we can point to and call a 'cause.' However, in the case of measuring the spins, none of these is true: the experimenter doesn't get choose what state the positron and electron will be in and no energy or momentum get transmitted by it. Also, measuring the positron's spin doesn't actually change the electron's behavior – *we* go from not knowing to knowing what the measurement will yield, but we can't say whether it was going to yield that measurement anyway.

Griffiths says that the measurement of the positron's spin "influences" the measurement of the electron's spin – I'd say that's too strong a verb; I'd say it "predicts" the measurement of the electron's spin.

"The book seems to go from talking about measuring photons, to the projector shadow, to killing your infant grandfather. Honestly, I have no idea what it is talking about. Also, what does "incompatible" mean in this context?" Anton

Question 8: Bell's Inequalities

What do the experimentally-observed violations of Bell's inequalities tell us about nature?

Guido Bacciagaluppi

Distant correlations of entangled systems can't be understood in terms of local models.

- Since Bohm's Pilot Wave theory is the only fleshed-out non-local, hidden-variables theory that's been developed, he spends some time on it.
- Anything else provides no mechanistic / conceptual way of understanding how the collapse of the wavefunction for one member of the pair leads to the instantaneous collapse for the other.
    - Hellwig & Kraus have something like wavefunction collapse radiating from the two measurement locations at the speed of light, but there's still no explanation for why the two measurements happen to be correlated instantaneously.
    - Everett (many-worlds) somehow choices of which world-line we're on.
- Notes that it may be fruitful to explore the exact value the Bell's Theorem violation, so try to get quantitative about it.

Caslav Brukner

He teases out three somewhat-independent qualities that draw us to local causal theories.

1. There exist causes that determine the outcomes of experiments that are made and what the outcomes would be if the experiments were made – in that sense, there is a '*reality*' to the system that is independent of our actually making the measurement.
2. Only *local* causes can influence the outcomes – that is, information traveling faster than the speed of light *can't* be a cause.
3. The experimenter's choice of what to measure is independent of the cause that determines what value would be measured – that is, we and the system are not ourselves entangled, we have 'freedom of choice.'

The violation of Bell's theorem means that one of these is wrong.

He thinks it's absurd for #3 to be wrong.

He's unimpressed by Bohm's pilot-wave approach to holding onto 'reality' and ditch locality by introducing a non-local influence, the pilot wave, since it's not been shown to predict anything new.

He points out that part of the difficulty people have is that, rather than focusing on the correlated system, they want to tease out the two sub-systems: the electron and the positron separately. His position is that we should think of a system not in terms of how many 'particles' make it up, but how many degrees of freedom it has, and thus how many 'bits' of information it takes to describe it.

Jeffrey Bub

Non-local correlations that are inconsistent with explanation by a shared cause. He discusses how one might go about trying to reproduce the outcomes of "PR box", which I take to mean a Podolsky Rosen box, i.e., of the EPR experiment. He suggests the best you can do is have Alice and Bob's teams share a set of rules as to how to respond to random number inputs, but even then you'll only reproduce ¾ of the EPR results. I didn't bother to try to follow his full thought experiment.

Arthur Fine

Local, noncontextual hidden-variables theories obey Bell's Inequality, which can also be phrased more generally as Clauser-Horne-Shimony-Holt (CHSH) inequalities for different numbers of degrees of freedom. That Quantum mechanics and experiment don't obey the inequalities tells us that they're not describable by such theories. He points out a truly alternative approach: maybe the joint probability of two incompatible measurements (corresponding to non-commuting operators in quantum) are simply 0 in nature, and must be left out of our otherwise-classical probabilistic models.

He points out that contextualism (any constraints placed on the hidden variables) and that the experiments still haven't got small enough uncertainties are two areas that need to be investigated.

Christopher Fuchs

Everything's connected. Unperformed experiments have no results. Bayesianism probabilities take more seriously that what is described as a state of knowledge about a system rather than a state of being of a system. This camp then disposes of the 'reality' of things that are unmeasured and is fine with the instantaneous change in knowledge about a spatially distributed system, they don't need non-local interactions.

Gian Carlo Gheridi

Not locally causal. His only argument is that Bell had intended/believed that local causality was the only underlying assumption in his derivation.

Shelly Goldstein

Non locality. Everett's Many-worlds model might avoid this, but it's unclear, since 'results' are illusionary – we're following different world trajectories (though that leave the question of why this trajectory). He too points out that hidden variables were more a product of locality than an input to Bell's derivation.

Daniel Greenberger

The correlation is pre-determined, not the individual result.

Lucian Hardy

Focusses on the experimental loop holes

- 1972 Freeman & Clauser – they had a very inefficient set-up (only captured a small fraction of the electron/positron pairs), and so had to assume that the fraction they did detect were an accurate / fair representation of the total population. They also chose the axis along which to measure the spins with enough time lag that a message could conceivably have gotten to the electron-positron pair before they separated.
- 1982 Aspect, Dalibard, Roger. They made the filters switch to address the latter problem; however, the switching was periodic and happened to be at just the right frequency so the filters were back to the original alignment by the time the particles got to the detectors. Later, Zeilinger & Gisin randomly switched their filters' axes
- 2001 Wineland had high enough efficiency to not have to make the fair-sampling assumption…much.
- 2008 High enough efficiency to no longer need to worry about the fair-sampling assumption. This was achieved by using entangled atoms rather than electrons. What's needed is this along with random filter selection / or selection too near the moment of measurement for information to get to the other particle.

Assuming loop holes are closed, would interpret that as meaning that space-time is not fundamental, but a result of "flattening" a "more connected graphical structure" – the 'our reality as a projection or hologram' interpretation.

Anthony Leggett

Notes that the qualities of a theory that *does* satisfy Bell's inequality are one of the following

1. Microscopic realism – each 'particle' carries with it its 'identity card' that determines the outcome of each experiment. This can be rephrased as 'even un-made experiments have real outcomes'
2. Einstein Locality – no communication faster than the speed of light.
3. Induction – things that happen later can influence what happened before.

One of these three must be wrong since experiments *don't* satisfy Bell's inequality. He says that 'popular' writers say #2 is violated, but most 'professional' physicists say #1 is violated. He suggests that #3 is worth exploring.

Tim Maudlin

Non-locality.

David Mermin

It tells us that correlated outcomes can't be attributed to correlated 'conditions' of the testing environment (hidden variables that inform both particles' measurements.) He says either it's got to be non-locality, but it's too much to ask that a single shared variable accounts for correlation of all possible measurements; or it could be simply that unperformed experiments have no conceivable results – unmade experiments are inconsistent with the ones that are made (if you measured x alignment, having well-defined y alignment is inconsistent). His preference is that asking for an explanation of what hasn't happened is unphysical (like Arthur Fine's and like the "orthodox" interpretation – the unmeasured property isn't something *to* be considered.)

Lee Smolin

Non-local interactions.

Anthony Valentini

Locality is violated. He too points out that determinism and hidden variables are consequences of locality, not separate inputs. He suggests that the future influencing the past and maybe many-worlds would work.

David Wallace

Notes that a "hardcore opperationalist" wouldn't care about Bell's work since theory matches experiment – job done. Super-luminal communication *seems* to be what the violation of Bell's theorem points to, but it could be instead be Everett's many-worlds interpretation with branchings propagating at light speed since *you* still can't *know* what the other experiment's outcome was until a time x/c later. If Everett's interpretation is wrong, then we need a faster-than-light theory that won't allow for unphysical causal loops.

Anton Zeilinger

Disproves local realism, counterfactual definiteness (things not measured still have definite values), standard logic, that the future doesn't influence the past, or that the universe isn't completely deterministic. The question is which – he prefers that local realism is broken.

Wojcrech Zurek

Two entangled particles *don't have* definite states of their own; the reality is in the entangled *system*. Mathematically, they can't be disentangled, so neither can they be conceptually disentangled.