Title: Many Worlds

Date: Oct 03, 2006 09:00 AM

URL: http://pirsa.org/06100002

Abstract: TBA

The many worlds theory takes unitary quantum mechanics, without collapse, to be a complete theory. To explain our experiences three additional observations are needed:

1. Given the pure quantum state of the universe, any subsystem of it can always be assigned a quantum state of its own, the relative state, which is in general mixed.

Let $\mathcal{H}$ be the Hilbert space of the universe, and suppose that the universe has a (pure) quantum state $|\Psi\rangle$. Consider a division of the universe into two subsystems $\mathcal{H} = \mathcal{H}_1 \otimes \mathcal{H}_2$. We can think of $\mathcal{H}_1$as a space associated with a given physical system, and $\mathcal{H}_2$ with the "rest of the universe". Take a basis $\{|\psi_i\rangle\}$ in $\mathcal{H}_1$ and a basis $\{|\phi_j\rangle\}$ in $\mathcal{H}_2$. The state of the universe $|\Psi\rangle$ can be written in terms of these bases

The state of the universe $|\Psi\rangle$ can be written in terms of these bases as:

$$|\Psi\rangle = \sum_{ij} \lambda_{ij} \, |\psi_i\rangle \otimes |\phi_j\rangle \qquad (1)$$

put

$$\mu_i = \sum_j |\lambda_{ij}|^2, \quad \mu_i \geq 0, \quad \sum_i \mu_i = 1 \qquad (2)$$

Define

$$|E_i\rangle = \sum_j \frac{\lambda_{ij}}{\sqrt{\mu_i}} |\phi_j\rangle \qquad (3)$$

then $|\Psi\rangle$ can be rewritten as:

$$|\Psi\rangle = \sum_i \sqrt{\mu_i} \, |\psi_i\rangle \otimes |E_i\rangle \qquad (4)$$

where the $|E_i\rangle$ need not be orthogonal nor form a basis, so the expansion (4) is not, in general, a bi-orthogonal decomposition. The relative state of the system 2 is the mixture on $\mathcal{H}_2$ given by $\rho_2 = \sum_i \mu_i |E_i\rangle\langle E_i|$, and each individual $|E_i\rangle$ is the state of the rest of the universe relative to the state $|\psi_i\rangle$ of the system. Everett calls each term $|\psi_i\rangle \otimes |E_i\rangle$ in the global superposition (4) a branch, or a

Adobe Acrobat ME - [ManyWorlds91.pdf]

2. In the many worlds theory environmental decoherence (see e.g. Joos, Zeh & Kiefer 2003) is the key to solving the so-called preferred basis problem (i.e. roughly the question why our experience is associated with some particular coarse grained states). It can be shown that decoherence yields coarse grained branches that are defined in terms of the decoherent states and this is just enough to explain our usual quasi-classical experience. (At least let's assume here that this is the case).

3. Probabilities: this is our subject. The major problem of the many worlds theory (as construed above) is how to account for the probabilistic content of standard quantum mechanics, that is, Born's rule. The problem arises because the Everett-DeWitt branching is unrelated to the quantum probability. In a finite

2. In the many worlds theory environmental decoherence (see e.g. Joos, Zeh & Kiefer 2003) is the key to solving the so-called preferred basis problem (i.e. roughly the question why our experience is associated with some particular coarse grained states). It can be shown that decoherence yields coarse grained branches that are defined in terms of the decoherent states and this is just enough to explain our usual quasi-classical experience. (At least let's assume here that this is the case).

3. Probabilities: this is our subject. The major problem of the many worlds theory (as construed above) is how to account for the probabilistic content of standard quantum mechanics, that is, Born's rule. The problem arises because the Everett-DeWitt branching is unrelated to the quantum probability. In a finite set of repeated measurements, any sequence of outcomes occurs with certainty, as long as the sequence has nonzero quantum amplitude. This includes sequences with relative frequencies that differ radically from the predictions of quantum mechanics. By contrast, the standard theory assumes the link to probability via the collapse postulate and Born's rule. Thus, there is a natural, built in, distinction between typical branches which are likely to occur, and deviant branches which are a-typical, have diminishing prob-

Adobe Acrobat ME - [ManyWorlds91.pdf]

that are defined in terms of the decoherent states and this is just enough to explain our usual quasi-classical experience. (At least let's assume here that this is the case).

3. Probabilities: this is our subject. The major problem of the many worlds theory (as construed above) is how to account for the probabilistic content of standard quantum mechanics, that is, Born's rule. The problem arises because the Everett-DeWitt branching is unrelated to the quantum probability. In a finite set of repeated measurements, any sequence of outcomes occurs with certainty, as long as the sequence has nonzero quantum amplitude. This includes sequences with relative frequencies that differ radically from the predictions of quantum mechanics. By contrast, the standard theory assumes the link to probability via the collapse postulate and Born's rule. Thus, there is a natural, built in, distinction between typical branches which are likely to occur, and deviant branches which are a-typical, have diminishing probability, and are rarely if ever observed. The problem in the many worlds theory is to account for this feature of the standard theory which explains our experience.

Adobe Acrobat ME - [ManyWorlds91.pdf]

File Edit Document Tools View Window Help

that are defined in terms of the decoherent states and this is just enough to explain our usual quasi-classical experience. (At least let's assume here that this is the case).

3. Probabilities: this is our subject. The major problem of the many worlds theory (as construed above) is how to account for the probabilistic content of standard quantum mechanics, that is, Born's rule. The problem arises because the Everett-DeWitt branching is unrelated to the quantum probability. In a finite set of repeated measurements, any sequence of outcomes occurs with certainty, as long as the sequence has nonzero quantum amplitude. This includes sequences with relative frequencies that differ radically from the predictions of quantum mechanics. By contrast, the standard theory assumes the link to probability via the collapse postulate and Born's rule. Thus, there is a natural, built in, distinction between typical branches which are likely to occur, and deviant branches which are a-typical, have diminishing probability, and are rarely if ever observed. The problem in the many worlds theory is to account for this feature of the standard theory which explains our experience.

Adobe Acrobat ME - [ManyWorlds91.pdf]

where $|\Phi_0\rangle$ is the 'ready' state of the apparata, then the Hamiltonian evolves the state so that after the N measurements the final state is the superposition

$$|\Psi^N\rangle = \sum_{i_1, i_2 \ldots i_N} \mu_{i_1}\mu_{i_2} \ldots \mu_{i_N} |\psi_{i_1}\rangle \otimes \ldots \otimes |\psi_{i_N}\rangle \otimes |\Phi_{i_1}\rangle \otimes \ldots \otimes |\Phi_{i_N}\rangle. \quad (6)$$

Where the $|\Phi_{i_k}\rangle$ are the pointer states (or the memory states) of the apparata, associated with the $|\psi_{i_k}\rangle$ states of the system. The apparata states are assumed to be of the kind described by decoherence theory.

Standard quantum mechanics implies, in virtue of the probabilistic collapse postulate, that the sequence of the outcomes is random with multinomial probability $|\mu_{i_1} \ldots \mu_{i_N}|^2$. In other words, the fact that a typical sequence of outcomes follows Born rule is a simple consequence of the law of large numbers of the classical theory of random variables.

However, in the many worlds theory the above sequence of measurements is completely described by the branching in the state $|\Psi^N\rangle$ (in 6)). This state is a superposition of K^N branches that in fact exhaust all the combinatorially possible arrangements of sequences of

Adobe Acrobat ME - [ManyWorlds91.pdf]

where $|\Phi_0\rangle$ is the 'ready' state of the apparata, then the Hamiltonian evolves the state so that after the N measurements the final state is the superposition

$$|\Psi^N\rangle = \sum_{i_1,i_2...i_N} \mu_{i_1}\mu_{i_2}...\mu_{i_N}|\psi_{i_1}\rangle \otimes ... \otimes |\psi_{i_N}\rangle \otimes |\Phi_{i_1}\rangle \otimes ... \otimes |\Phi_{i_N}\rangle. \quad (6)$$

Where the $|\Phi_{i_k}\rangle$ are the pointer states (or the memory states) of the apparata, associated with the $|\psi_{i_k}\rangle$ states of the system. The apparata states are assumed to be of the kind described by decoherence theory.

Standard quantum mechanics implies, in virtue of the probabilistic collapse postulate, that the sequence of the outcomes is random with multinomial probability $|\mu_{i_1}...\mu_{i_N}|^2$. In other words, the fact that a typical sequence of outcomes follows Born rule is a simple consequence of the law of large numbers of the classical theory of random variables.

However, in the many worlds theory the above sequence of measurements is completely described by the branching in the state $|\Psi^N\rangle$ (in 6)). This state is a superposition of K^N branches that in fact exhaust all the combinatorially possible arrangements of sequences of

Adobe Acrobat ME - [ManyWorlds91.pdf]

evolves the state so that after the N measurements the final state is the superposition

$$|\Psi^N\rangle = \sum_{i_1,i_2...i_N} \mu_{i_1}\mu_{i_2}...\mu_{i_N}|\psi_{i_1}\rangle \otimes ... \otimes |\psi_{i_N}\rangle \otimes |\Phi_{i_1}\rangle \otimes ... \otimes |\Phi_{i_N}\rangle. \quad (6)$$

Where the $|\Phi_{i_k}\rangle$ are the pointer states (or the memory states) of the apparata, associated with the $|\psi_{i_k}\rangle$ states of the system. The apparata states are assumed to be of the kind described by decoherence theory.

Standard quantum mechanics implies, in virtue of the probabilistic collapse postulate, that the sequence of the outcomes is random with multinomial probability $|\mu_{i_1}...\mu_{i_N}|^2$. In other words, the fact that a typical sequence of outcomes follows Born rule is a simple consequence of the law of large numbers of the classical theory of random variables.

However, in the many worlds theory the above sequence of measurements is completely described by the branching in the state $|\Psi^N\rangle$ (in 6)). This state is a superposition of K^N branches that in fact exhaust all the combinatorially possible arrangements of sequences of length N, and all of them are equally realized. There is no "natural" probability distribution on the set of branches.

the superposition

$$|\Psi^N\rangle = \sum_{i_1, i_2 \ldots i_N} \mu_{i_1}\mu_{i_2}\ldots\mu_{i_N} |\psi_{i_1}\rangle \otimes \ldots \otimes |\psi_{i_N}\rangle \otimes |\Phi_{i_1}\rangle \otimes \ldots \otimes |\Phi_{i_N}\rangle. \quad (6)$$

Where the $|\Phi_{i_k}\rangle$ are the pointer states (or the memory states) of the apparata, associated with the $|\psi_{i_k}\rangle$ states of the system. The apparata states are assumed to be of the kind described by decoherence theory.

Standard quantum mechanics implies, in virtue of the probabilistic collapse postulate, that the sequence of the outcomes is random with multinomial probability $|\mu_{i_1}\ldots\mu_{i_N}|^2$. In other words, the fact that a typical sequence of outcomes follows Born rule is a simple consequence of the law of large numbers of the classical theory of random variables.

However, in the many worlds theory the above sequence of measurements is completely described by the branching in the state $|\Psi^N\rangle$ (in 6)). This state is a superposition of K^N branches that in fact exhaust all the combinatorially possible arrangements of sequences of length N, and all of them are equally realized. There is no "natural" probability distribution on the set of branches.

Adobe Acrobat ME - [ManyWorlds91.pdf]

Where the $|\Phi_{i_k}\rangle$ are the pointer states (or the memory states) of the apparata, associated with the $|\psi_{i_k}\rangle$ states of the system. The apparata states are assumed to be of the kind described by decoherence theory.

Standard quantum mechanics implies, in virtue of the probabilistic collapse postulate, that the sequence of the outcomes is random with multinomial probability $|\mu_{i_1}...\mu_{i_N}|^2$. In other words, the fact that a typical sequence of outcomes follows Born rule is a simple consequence of the law of large numbers of the classical theory of random variables.

However, in the many worlds theory the above sequence of measurements is completely described by the branching in the state $|\Psi^N\rangle$ (in 6)). This state is a superposition of K^N branches that in fact exhaust all the combinatorially possible arrangements of sequences of length N, and all of them are equally realized. There is no "natural" probability distribution on the set of branches.

Consider two attempts to solve the probability problem in the many worlds interpretation. They follow in the footsteps of the classical approaches: Probability as relative frequency and probability as a degree of belief.

Adobe Acrobat ME - [ManyWorlds91.pdf]

Where the $|\Phi_{i_k}\rangle$ are the pointer states (or the memory states) of the apparata, associated with the $|\psi_{i_k}\rangle$ states of the system. The apparata states are assumed to be of the kind described by decoherence theory.

Standard quantum mechanics implies, in virtue of the probabilistic collapse postulate, that the sequence of the outcomes is random with multinomial probability $|\mu_{i_1}...\mu_{i_N}|^2$. In other words, the fact that a typical sequence of outcomes follows Born rule is a simple consequence of the law of large numbers of the classical theory of random variables.

However, in the many worlds theory the above sequence of measurements is completely described by the branching in the state $|\Psi^N\rangle$ (in 6)). This state is a superposition of K^N branches that in fact exhaust all the combinatorially possible arrangements of sequences of length N, and all of them are equally realized. There is no "natural" probability distribution on the set of branches.

Consider two attempts to solve the probability problem in the many worlds interpretation. They follow in the footsteps of the classical approaches: Probability as relative frequency and probability as a degree of belief.

Adobe Acrobat ME - [ManyWorlds91.pdf]

theory.

Standard quantum mechanics implies, in virtue of the probabilistic collapse postulate, that the sequence of the outcomes is random with multinomial probability $|\mu_{i_1}...\mu_{i_N}|^2$. In other words, the fact that a typical sequence of outcomes follows Born rule is a simple consequence of the law of large numbers of the classical theory of random variables.

However, in the many worlds theory the above sequence of measurements is completely described by the branching in the state $|\Psi^N\rangle$ (in 6)). This state is a superposition of K^N branches that in fact exhaust all the combinatorially possible arrangements of sequences of length N, and all of them are equally realized. There is no "natural" probability distribution on the set of branches.

Consider two attempts to solve the probability problem in the many worlds interpretation. They follow in the footsteps of the classical approaches: Probability as relative frequency and probability as a degree of belief.

Adobe Acrobat ME - [ManyWorlds91.pdf]

Standard quantum mechanics implies, in virtue of the probabilistic collapse postulate, that the sequence of the outcomes is random with multinomial probability $|\mu_{i_1}...\mu_{i_N}|^2$. In other words, the fact that a typical sequence of outcomes follows Born rule is a simple consequence of the law of large numbers of the classical theory of random variables.

However, in the many worlds theory the above sequence of measurements is completely described by the branching in the state $|\Psi^N\rangle$ (in 6)). This state is a superposition of K^N branches that in fact exhaust all the combinatorially possible arrangements of sequences of length N, and all of them are equally realized. There is no "natural" probability distribution on the set of branches.

Consider two attempts to solve the probability problem in the many worlds interpretation. They follow in the footsteps of the classical approaches: Probability as relative frequency and probability as a degree of belief.

Adobe Acrobat ME - [ManyWorlds91.pdf]

Standard quantum mechanics implies, in virtue of the probabilistic collapse postulate, that the sequence of the outcomes is random with multinomial probability $|\mu_{i_1}...\mu_{i_N}|^2$. In other words, the fact that a typical sequence of outcomes follows Born rule is a simple consequence of the law of large numbers of the classical theory of random variables.

However, in the many worlds theory the above sequence of measurements is completely described by the branching in the state $|\Psi^N\rangle$ (in 6)). This state is a superposition of K^N branches that in fact exhaust all the combinatorially possible arrangements of sequences of length N, and all of them are equally realized. There is no "natural" probability distribution on the set of branches.

Consider two attempts to solve the probability problem in the many worlds interpretation. They follow in the footsteps of the classical approaches: Probability as relative frequency and probability as a degree of belief.

Relative frequency: DeWitt (1970) see Hartle (1968) and others. Consider an actual infinite ensemble of systems, each associated with the state $|\phi\rangle$ in the Hilbert space $\mathcal{H}$. The infinite ensemble can be associated with the infinite tensor product $\mathcal{H}^{\infty} = \mathcal{H} \otimes ... \otimes \mathcal{H} \otimes ...$ and the state

$$|\phi^{\infty}\rangle = |\phi\rangle \otimes ... \otimes |\phi\rangle \otimes ... \tag{7}$$

Let $|\psi_k\rangle$ be the eigenstates of the operator $\mathcal{O}$ on $\mathcal{H}$. Define for positive integers N and k the operator P_k^N on $\mathcal{H}^N = \mathcal{H} \otimes ... \otimes \mathcal{H}$ (N copies) by

$$\mathcal{P}_k^N = \frac{1}{N} \sum_{i_1, i_2, \ldots i_N} \left(\sum_{j=1}^{N} \delta_{k,i_j} \right) |\psi_{i_1}\rangle \langle\psi_{i_1}| \otimes |\psi_{i_2}\rangle \langle\psi_{i_2}| \otimes ... \otimes |\psi_{i_N}\rangle \langle\psi_{i_N}| \tag{8}$$

The expression $\sum_{j=1}^{N} \delta_{k,i_j}$ gives the number of copies of $|\psi_k\rangle \langle\psi_k|$ in

Adobe Acrobat ME - [ManyWorlds91.pdf]

Relative frequency: DeWitt (1970) see Hartle (1968) and others. Consider an actual infinite ensemble of systems, each associated with the state $|\phi\rangle$ in the Hilbert space $\mathcal{H}$. The infinite ensemble can be associated with the infinite tensor product $\mathcal{H}^\infty = \mathcal{H} \otimes \ldots \otimes \mathcal{H} \otimes \ldots$ and the state

$$|\phi^\infty\rangle = |\phi\rangle \otimes \ldots \otimes |\phi\rangle \otimes \ldots \tag{7}$$

Let $|\psi_k\rangle$ be the eigenstates of the operator $\mathcal{O}$ on $\mathcal{H}$. Define for positive integers N and k the operator P_k^N on $\mathcal{H}^N = \mathcal{H} \otimes \ldots \otimes \mathcal{H}$ (N copies) by

$$\mathcal{P}_k^N = \frac{1}{N} \sum_{i_1, i_2, \ldots i_N} \left(\sum_{j=1}^{N} \delta_{k,i_j} \right) |\psi_{i_1}\rangle \langle \psi_{i_1}| \otimes |\psi_{i_2}\rangle \langle \psi_{i_2}| \otimes \ldots \otimes |\psi_{i_N}\rangle \langle \psi_{i_N}| \tag{8}$$

The expression $\sum_{j=1}^{N} \delta_{k,i_j}$ gives the number of copies of $|\psi_k\rangle \langle \psi_k|$ in the tensor product $|\psi_{i_1}\rangle \langle \psi_{i_1}| \otimes \ldots \otimes |\psi_{i_N}\rangle \langle \psi_{i_N}|$. Now, extend $\mathcal{P}_k^N$ to $\mathcal{H}^\infty$ by putting $\mathcal{R}_k^N = \mathcal{P}_k^N \otimes I \otimes I \otimes \ldots$. Then the operator $R_k^\infty = \lim_{N \to \infty} R_k^N$ on $\mathcal{H}^\infty$ exists in the strong limit. Hartle () proved that any state $|\phi^\infty\rangle$ of the type (7) is an eigenstate of R_k^∞ and

Adobe Acrobat ME - [ManyWorlds91.pdf]

Relative frequency: DeWitt (1970) see Hartle (1968) and others. Consider an actual infinite ensemble of systems, each associated with the state $|\phi\rangle$ in the Hilbert space $\mathcal{H}$. The infinite ensemble can be associated with the infinite tensor product $\mathcal{H}^\infty = \mathcal{H} \otimes \ldots \otimes \mathcal{H} \otimes \ldots$ and the state

$$|\phi^\infty\rangle = |\phi\rangle \otimes \ldots \otimes |\phi\rangle \otimes \ldots \tag{7}$$

Let $|\psi_k\rangle$ be the eigenstates of the operator $\mathcal{O}$ on $\mathcal{H}$. Define for positive integers N and k the operator P_k^N on $\mathcal{H}^N = \mathcal{H} \otimes \ldots \otimes \mathcal{H}$ (N copies) by

$$\mathcal{P}_k^N = \frac{1}{N} \sum_{i_1, i_2, \ldots i_N} \left(\sum_{j=1}^N \delta_{k, i_j} \right) |\psi_{i_1}\rangle \langle\psi_{i_1}| \otimes |\psi_{i_2}\rangle \langle\psi_{i_2}| \otimes \ldots \otimes |\psi_{i_N}\rangle \langle\psi_{i_N}| \tag{8}$$

The expression $\sum_{j=1}^N \delta_{k, i_j}$ gives the number of copies of $|\psi_k\rangle\langle\psi_k|$ in the tensor product $|\psi_{i_1}\rangle\langle\psi_{i_1}| \otimes \ldots \otimes |\psi_{i_N}\rangle\langle\psi_{i_N}|$. Now, extend $\mathcal{P}_k^N$ to $\mathcal{H}^\infty$ by putting $\mathcal{R}_k^N = \mathcal{P}_k^N \otimes I \otimes I \otimes \ldots$. Then the operator $R_k^\infty = \lim_{N \to \infty} R_k^N$ on $\mathcal{H}^\infty$ exists in the strong limit. Hartle () proved that any state $|\phi^\infty\rangle$ of the type (7) is an eigenstate of R_k^∞ and

$$\mathcal{R}_k^\infty |\phi^\infty\rangle = |\langle\psi_k|\phi\rangle|^2 |\phi^\infty\rangle \tag{9}$$

Adobe Acrobat ME - [ManyWorlds91.pdf]

Relative frequency: DeWitt (1970) see Hartle (1968) and others. Consider an actual infinite ensemble of systems, each associated with the state $|\phi\rangle$ in the Hilbert space $\mathcal{H}$. The infinite ensemble can be associated with the infinite tensor product $\mathcal{H}^\infty = \mathcal{H}\otimes...\otimes\mathcal{H}\otimes...$ and the state

$$|\phi^\infty\rangle = |\phi\rangle \otimes ... \otimes |\phi\rangle \otimes ... \tag{7}$$

Let $|\psi_k\rangle$ be the eigenstates of the operator $\mathcal{O}$ on $\mathcal{H}$. Define for positive integers N and k the operator P_k^N on $\mathcal{H}^N = \mathcal{H}\otimes...\otimes\mathcal{H}$ (N copies) by

$$\mathcal{P}_k^N = \frac{1}{N} \sum_{i_1, i_2, ... i_N} \left(\sum_{j=1}^{N} \delta_{k,i_j} \right) |\psi_{i_1}\rangle\langle\psi_{i_1}| \otimes |\psi_{i_2}\rangle\langle\psi_{i_2}| \otimes ... \otimes |\psi_{i_N}\rangle\langle\psi_{i_N}| \tag{8}$$

The expression $\sum_{j=1}^{N} \delta_{k,i_j}$ gives the number of copies of $|\psi_k\rangle\langle\psi_k|$ in the tensor product $|\psi_{i_1}\rangle\langle\psi_{i_1}| \otimes ... \otimes |\psi_{i_N}\rangle\langle\psi_{i_N}|$. Now, extend $\mathcal{P}_k^N$ to $\mathcal{H}^\infty$ by putting $\mathcal{R}_k^N = \mathcal{P}_k^N \otimes I \otimes I \otimes ...$. Then the operator $R_k^\infty = \lim_{N\to\infty} R_k^N$ on $\mathcal{H}^\infty$ exists in the strong limit. Hartle () proved that any state $|\phi^\infty\rangle$ of the type (7) is an eigenstate of R_k^∞ and

$$\mathcal{R}_k^\infty |\phi^\infty\rangle = |\langle\psi_k|\phi\rangle|^2 |\phi^\infty\rangle \tag{9}$$

Adobe Acrobat ME - [ManyWorlds91.pdf]

Relative frequency: DeWitt (1970) see Hartle (1968) and others. Consider an actual infinite ensemble of systems, each associated with the state $|\phi\rangle$ in the Hilbert space $\mathcal{H}$. The infinite ensemble can be associated with the infinite tensor product $\mathcal{H}^{\infty}=\mathcal{H}\otimes...\otimes\mathcal{H}\otimes...$ and the state

$$|\phi^{\infty}\rangle = |\phi\rangle\otimes...\otimes|\phi\rangle\otimes... \quad (7)$$

Let $|\psi_k\rangle$ be the eigenstates of the operator $\mathcal{O}$ on $\mathcal{H}$. Define for positive integers N and k the operator P_k^N on $\mathcal{H}^N=\mathcal{H}\otimes...\otimes\mathcal{H}$ (N copies) by

$$\mathcal{P}_k^N=\frac{1}{N}\sum_{i_1,i_2,...i_N}\left(\sum_{j=1}^{N}\delta_{k,i_j}\right)|\psi_{i_1}\rangle\langle\psi_{i_1}|\otimes|\psi_{i_2}\rangle\langle\psi_{i_2}|\otimes...\otimes|\psi_{i_N}\rangle\langle\psi_{i_N}| \quad (8)$$

The expression $\sum_{j=1}^{N}\delta_{k,i_j}$ gives the number of copies of $|\psi_k\rangle\langle\psi_k|$ in the tensor product $|\psi_{i_1}\rangle\langle\psi_{i_1}|\otimes...\otimes|\psi_{i_N}\rangle\langle\psi_{i_N}|$. Now, extend $\mathcal{P}_k^N$ to $\mathcal{H}^{\infty}$ by putting $\mathcal{R}_k^N=\mathcal{P}_k^N\otimes I\otimes I\otimes....$ Then the operator $R_k^{\infty}=\lim_{N\to\infty}R_k^N$ on $\mathcal{H}^{\infty}$ exists in the strong limit. Hartle () proved that any state $|\phi^{\infty}\rangle$ of the type (7) is an eigenstate of R_k^{∞} and

$$\mathcal{R}_k^{\infty}|\phi^{\infty}\rangle=|\langle\psi_k|\phi\rangle|^2|\phi^{\infty}\rangle \quad (9)$$

Adobe Acrobat ME - [ManyWorlds91.pdf]

ated with the state $|\phi\rangle$ in the Hilbert space $\mathcal{H}$. The infinite ensemble can be associated with the infinite tensor product $\mathcal{H}^{\infty}=\mathcal{H}\otimes...\otimes\mathcal{H}\otimes...$ and the state

$$|\phi^{\infty}\rangle=|\phi\rangle\otimes...\otimes|\phi\rangle\otimes... \tag{7}$$

Let $|\psi_k\rangle$ be the eigenstates of the operator $\mathcal{O}$ on $\mathcal{H}$. Define for positive integers N and k the operator P_k^N on $\mathcal{H}^N=\mathcal{H}\otimes...\otimes\mathcal{H}$ (N copies) by

$$\mathcal{P}_k^N=\frac{1}{N}\sum_{i_1,i_2,...i_N}\left(\sum_{j=1}^{N}\delta_{k,i_j}\right)|\psi_{i_1}\rangle\langle\psi_{i_1}|\otimes|\psi_{i_2}\rangle\langle\psi_{i_2}|\otimes...\otimes|\psi_{i_N}\rangle\langle\psi_{i_N}| \tag{8}$$

The expression $\sum_{j=1}^{N}\delta_{k,i_j}$ gives the number of copies of $|\psi_k\rangle\langle\psi_k|$ in the tensor product $|\psi_{i_1}\rangle\langle\psi_{i_1}|\otimes...\otimes|\psi_{i_N}\rangle\langle\psi_{i_N}|$. Now, extend $\mathcal{P}_k^N$ to $\mathcal{H}^{\infty}$ by putting $\mathcal{R}_k^N=\mathcal{P}_k^N\otimes I\otimes I\otimes....$ Then the operator $R_k^{\infty}=\lim_{N\to\infty}R_k^N$ on $\mathcal{H}^{\infty}$ exists in the strong limit. Hartle () proved that any state $|\phi^{\infty}\rangle$ of the type (7) is an eigenstate of R_k^{∞} and

$$\mathcal{R}_k^{\infty}|\phi^{\infty}\rangle=|\langle\psi_k|\phi\rangle|^2|\phi^{\infty}\rangle \tag{9}$$

where the eigenvalue $|\langle\psi_k|\phi\rangle|^2$ is just the quantum mechanical probability of the result $|\psi_i\rangle$ in the state $|\phi\rangle$. Therefore, the limit of

Adobe Acrobat ME - [ManyWorlds91.pdf]

can be associated with the infinite tensor product $\mathcal{H}^\infty = \mathcal{H}\otimes...\otimes\mathcal{H}\otimes...$ and the state

$$|\phi^\infty\rangle = |\phi\rangle \otimes ... \otimes |\phi\rangle \otimes ... \qquad (7)$$

Let $|\psi_k\rangle$ be the eigenstates of the operator $\mathcal{O}$ on $\mathcal{H}$. Define for positive integers N and k the operator P_k^N on $\mathcal{H}^N = \mathcal{H}\otimes...\otimes\mathcal{H}$ (N copies) by

$$\mathcal{P}_k^N = \frac{1}{N} \sum_{i_1,i_2,...i_N} \left(\sum_{j=1}^{N} \delta_{k,i_j} \right) |\psi_{i_1}\rangle \langle\psi_{i_1}| \otimes |\psi_{i_2}\rangle \langle\psi_{i_2}| \otimes ... \otimes |\psi_{i_N}\rangle \langle\psi_{i_N}| \qquad (8)$$

The expression $\sum_{j=1}^{N} \delta_{k,i_j}$ gives the number of copies of $|\psi_k\rangle\langle\psi_k|$ in the tensor product $|\psi_{i_1}\rangle\langle\psi_{i_1}| \otimes ... \otimes |\psi_{i_N}\rangle\langle\psi_{i_N}|$. Now, extend $\mathcal{P}_k^N$ to $\mathcal{H}^\infty$ by putting $\mathcal{R}_k^N = \mathcal{P}_k^N \otimes I \otimes I \otimes ...$. Then the operator $R_k^\infty = \lim_{N\to\infty} R_k^N$ on $\mathcal{H}^\infty$ exists in the strong limit. Hartle () proved that any state $|\phi^\infty\rangle$ of the type (7) is an eigenstate of R_k^∞ and

$$\mathcal{R}_k^\infty |\phi^\infty\rangle = |\langle\psi_k|\phi\rangle|^2 |\phi^\infty\rangle \qquad (9)$$

where the eigenvalue $|\langle\psi_k|\phi\rangle|^2$ is just the quantum mechanical probability of the result $|\psi_i\rangle$ in the state $|\phi\rangle$. Therefore, the limit of relative frequencies of each possible outcome of an $\mathcal{O}$ measurement

4 of 10 8.5x11 in

Adobe Acrobat ME - [ManyWorlds91.pdf]

$$|\phi^\infty\rangle = |\phi\rangle \otimes ... \otimes |\phi\rangle \otimes ... \qquad (7)$$

Let $|\psi_k\rangle$ be the eigenstates of the operator $\mathcal{O}$ on $\mathcal{H}$. Define for positive integers N and k the operator P_k^N on $\mathcal{H}^N = \mathcal{H} \otimes ... \otimes \mathcal{H}$ (N copies) by

$$\mathcal{P}_k^N = \frac{1}{N} \sum_{i_1, i_2, \ldots i_N} \left(\sum_{j=1}^{N} \delta_{k,i_j} \right) |\psi_{i_1}\rangle \langle \psi_{i_1}| \otimes |\psi_{i_2}\rangle \langle \psi_{i_2}| \otimes ... \otimes |\psi_{i_N}\rangle \langle \psi_{i_N}| \qquad (8)$$

The expression $\sum_{j=1}^{N} \delta_{k,i_j}$ gives the number of copies of $|\psi_k\rangle \langle \psi_k|$ in the tensor product $|\psi_{i_1}\rangle \langle \psi_{i_1}| \otimes ... \otimes |\psi_{i_N}\rangle \langle \psi_{i_N}|$. Now, extend $\mathcal{P}_k^N$ to $\mathcal{H}^\infty$ by putting $\mathcal{R}_k^N = \mathcal{P}_k^N \otimes I \otimes I \otimes ...$. Then the operator $R_k^\infty = \lim_{N \to \infty} R_k^N$ on $\mathcal{H}^\infty$ exists in the strong limit. Hartle () proved that any state $|\phi^\infty\rangle$ of the type (7) is an eigenstate of R_k^∞ and

$$\mathcal{R}_k^\infty |\phi^\infty\rangle = |\langle \psi_k | \phi \rangle|^2 |\phi^\infty\rangle \qquad (9)$$

where the eigenvalue $|\langle \psi_k | \phi \rangle|^2$ is just the quantum mechanical probability of the result $|\psi_i\rangle$ in the state $|\phi\rangle$. Therefore, the limit of relative frequencies of each possible outcome of an $\mathcal{O}$ measurement on identical systems in the state $|\phi\rangle$ is correctly predicted without reference to Born's rule, or so it seems.

Adobe Acrobat ME - [ManyWorlds91.pdf]

File Edit Document Tools View Window Help

200%

$$\mathcal{P}_k^N = \frac{1}{N} \sum_{i_1, i_2, \ldots i_N} \left(\sum_{j=1}^{N} \delta_{k,i_j} \right) |\psi_{i_1}\rangle \langle \psi_{i_1}| \otimes |\psi_{i_2}\rangle \langle \psi_{i_2}| \otimes \ldots \otimes |\psi_{i_N}\rangle \langle \psi_{i_N}| \quad (8)$$

The expression $\sum_{j=1}^{N} \delta_{k,i_j}$ gives the number of copies of $|\psi_k\rangle \langle \psi_k|$ in the tensor product $|\psi_{i_1}\rangle \langle \psi_{i_1}| \otimes \ldots \otimes |\psi_{i_N}\rangle \langle \psi_{i_N}|$. Now, extend $\mathcal{P}_k^N$ to $\mathcal{H}^\infty$ by putting $\mathcal{R}_k^N = \mathcal{P}_k^N \otimes I \otimes I \otimes \ldots$. Then the operator $R_k^\infty = \lim_{N \to \infty} R_k^N$ on $\mathcal{H}^\infty$ exists in the strong limit. Hartle () proved that any state $|\phi^\infty\rangle$ of the type (7) is an eigenstate of R_k^∞ and

$$\mathcal{R}_k^\infty |\phi^\infty\rangle = |\langle \psi_k | \phi \rangle|^2 |\phi^\infty\rangle \quad (9)$$

where the eigenvalue $|\langle \psi_k | \phi \rangle|^2$ is just the quantum mechanical probability of the result $|\psi_i\rangle$ in the state $|\phi\rangle$. Therefore, the limit of relative frequencies of each possible outcome of an $\mathcal{O}$ measurement on identical systems in the state $|\phi\rangle$ is correctly predicted without reference to Born's rule, or so it seems.

Adobe Acrobat ME - [ManyWorlds91.pdf]

on identical systems in the state $|\phi\rangle$ is correctly predicted without reference to Born's rule, or so it seems.

Problem: CIRCULARITY. The sequence $\{\mathcal{R}_i^N\}$ converges to $\mathcal{R}_i^\infty$ in the strong limit which is induced by the Hilbert space inner product. Born's rule is thus implicitly assumed when we identify the eigenvalues of $\mathcal{R}_i^\infty$ with the limiting frequency of typical sequences. DeWitt's argument is analogous to the attempt to apply the classical strong law of large numbers to define probability as the limit of relative frequencies. In this case too the set of badly behaving infinite sequences has measure zero, and the circularity stems from the identification of measure zero with probability zero. Similarly, in classical statistical mechanics the effort to define probability in terms of limiting relative frequencies suffers the same fate. Here the tool that is supposed to accomplish the task is the pointwise ergodic theorem.

Open problem: Is there a way to define "typical se-

Adobe Acrobat ME - [ManyWorlds91.pdf]

Problem: CIRCULARITY. The sequence $\{\mathcal{R}_i^N\}$ converges to $\mathcal{R}_i^\infty$ in the strong limit which is induced by the Hilbert space inner product. Born's rule is thus implicitly assumed when we identify the eigenvalues of $\mathcal{R}_i^\infty$ with the limiting frequency of typical sequences. DeWitt's argument is analogous to the attempt to apply the classical strong law of large numbers to define probability as the limit of relative frequencies. In this case too the set of badly behaving infinite sequences has measure zero, and the circularity stems from the identification of measure zero with probability zero. Similarly, in classical statistical mechanics the effort to define probability in terms of limiting relative frequencies suffers the same fate. Here the tool that is supposed to accomplish the task is the pointwise ergodic theorem.

Open problem: Is there a way to define "typical sequence" of outcomes without using probability? In the classical case there is a tradition that goes back to von Mises (Popper, Church, Wald, Martin-Löf) which attempts to do that for infinite sequences of outcomes.

Adobe Acrobat ME - [ManyWorlds91.pdf]

Problem: CIRCULARITY. The sequence $\{\mathcal{R}_i^N\}$ converges to $\mathcal{R}_i^\infty$ in the strong limit which is induced by the Hilbert space inner product. Born's rule is thus implicitly assumed when we identify the eigenvalues of $\mathcal{R}_i^\infty$ with the limiting frequency of typical sequences. DeWitt's argument is analogous to the attempt to apply the classical strong law of large numbers to define probability as the limit of relative frequencies. In this case too the set of badly behaving infinite sequences has measure zero, and the circularity stems from the identification of measure zero with probability zero. Similarly, in classical statistical mechanics the effort to define probability in terms of limiting relative frequencies suffers the same fate. Here the tool that is supposed to accomplish the task is the pointwise ergodic theorem.

Open problem: Is there a way to define "typical sequence" of outcomes without using probability? In the classical case there is a tradition that goes back to von Mises (Popper, Church, Wald, Martin-Löf) which attempts to do that for infinite sequences of outcomes.

Problem: CIRCULARITY. The sequence $\{\mathcal{R}_i^N\}$ converges to $\mathcal{R}_i^\infty$ in the strong limit which is induced by the Hilbert space inner product. Born's rule is thus implicitly assumed when we identify the eigenvalues of $\mathcal{R}_i^\infty$ with the limiting frequency of typical sequences. DeWitt's argument is analogous to the attempt to apply the classical strong law of large numbers to define probability as the limit of relative frequencies. In this case too the set of badly behaving infinite sequences has measure zero, and the circularity stems from the identification of measure zero with probability zero. Similarly, in classical statistical mechanics the effort to define probability in terms of limiting relative frequencies suffers the same fate. Here the tool that is supposed to accomplish the task is the pointwise ergodic theorem.

Open problem: Is there a way to define "typical sequence" of outcomes without using probability? In the classical case there is a tradition that goes back to von Mises (Popper, Church, Wald, Martin-Löf) which attempts to do that for infinite sequences of outcomes.

Adobe Acrobat ME - [ManyWorlds91.pdf]

5

Adobe Acrobat ME - [ManyWorlds91.pdf]

Bayes in many worlds Deutsch (1999), Wallace (2003, 2005), Saunders (2004, 2005), Greaves (2004) attempt derive the Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =:< |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

Adobe Acrobat ME - [ManyWorlds91.pdf]

Bayes in many worlds Deutsch (1999), Wallace (2003, 2005), Saunders (2004, 2005), Greaves (2004) attempt derive the Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =:< |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly)

Adobe Acrobat ME - [ManyWorlds91.pdf]

sical strong law of large numbers to define probability as the limit of relative frequencies. In this case too the set of badly behaving infinite sequences has measure zero, and the circularity stems from the identification of measure zero with probability zero. Similarly, in classical statistical mechanics the effort to define probability in terms of limiting relative frequencies suffers the same fate. Here the tool that is supposed to accomplish the task is the pointwise ergodic theorem.

Open problem: Is there a way to define "typical sequence" of outcomes without using probability? In the classical case there is a tradition that goes back to von Mises (Popper, Church, Wald, Martin-Löf) which attempts to do that for infinite sequences of outcomes.

Adobe Acrobat ME - [ManyWorlds91.pdf]

eigenvalues of $\mathcal{R}_i^\infty$ with the limiting frequency of typical sequences. DeWitt's argument is analogous to the attempt to apply the classical strong law of large numbers to define probability as the limit of relative frequencies. In this case too the set of badly behaving infinite sequences has measure zero, and the circularity stems from the identification of measure zero with probability zero. Similarly, in classical statistical mechanics the effort to define probability in terms of limiting relative frequencies suffers the same fate. Here the tool that is supposed to accomplish the task is the pointwise ergodic theorem.

Open problem: Is there a way to define "typical sequence" of outcomes without using probability? In the classical case there is a tradition that goes back to von Mises (Popper, Church, Wald, Martin-Löf) which attempts to do that for infinite sequences of outcomes.

in classical statistical mechanics the effort to define probability in terms of limiting relative frequencies suffers the same fate. Here the tool that is supposed to accomplish the task is the pointwise ergodic theorem.

Open problem: Is there a way to define "typical sequence" of outcomes without using probability? In the classical case there is a tradition that goes back to von Mises (Popper, Church, Wald, Martin-Löf) which attempts to do that for infinite sequences of outcomes.

Adobe Acrobat ME - [ManyWorlds91.pdf]

Bayes in many worlds Deutsch (1999), Wallace (2003, 2005), Saunders (2004, 2005), Greaves (2004) attempt derive the Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =: < |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly)

Adobe Acrobat ME - [ManyWorlds91.pdf]

Bayes in many worlds Deutsch (1999), Wallace (2003, 2005), Saunders (2004, 2005), Greaves (2004) attempt derive the Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =:< |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

$$V(|\phi\rangle, O, \Pi) = \sum |\langle\psi_i|\phi\rangle|^2 x_i \quad (10)$$

Adobe Acrobat ME - [ManyWorlds91.pdf]

File Edit Document Tools View Window Help

Bayes in many worlds Deutsch (1999), Wallace (2003, 2005), Saunders (2004, 2005), Greaves (2004) attempt derive the Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =:< |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

$$V(|\phi\rangle, O, \Pi) = \sum_i |\langle\psi_i|\phi\rangle|^2 x_i \tag{10}$$

Bayes in many worlds Deutsch (1999), Wallace (2003, 2005), Saunders (2004, 2005), Greaves (2004) attempt derive the Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =:< |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

$$V(|\phi\rangle, O, \Pi) = \sum_i |\langle\psi_i|\phi\rangle|^2 x_i \tag{10}$$

where the $|\psi_i\rangle$'s are the eigenstates of O, and $x_i = \Pi(|\psi_i\rangle)$ is the payoffs the agent receives in case the outcome of the measurement $\mathcal{O}$ is $|\psi_i\rangle$.

Adobe Acrobat ME - [ManyWorlds91.pdf]

Bayes in many worlds Deutsch (1999), Wallace (2003, 2005), Saunders (2004, 2005), Greaves (2004) attempt derive the Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =: < |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

$$V(|\phi\rangle, O, \Pi) = \sum_i |\langle\psi_i|\phi\rangle|^2 x_i \qquad (10)$$

where the $|\psi_i\rangle$'s are the eigenstates of O, and $x_i = \Pi(|\psi_i\rangle)$ is the payoffs the agent receives in case the outcome of the measurement $\mathcal{O}$ is $|\psi_i\rangle$.

Adobe Acrobat ME - [ManyWorlds91.pdf]

Bayes in many worlds Deutsch (1999), Wallace (2003, 2005), Saunders (2004, 2005), Greaves (2004) attempt derive the Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =:< |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

$$V(|\phi\rangle, O, \Pi) = \sum_i |\langle\psi_i|\phi\rangle|^2 x_i \tag{10}$$

where the $|\psi_i\rangle$'s are the eigenstates of O, and $x_i = \Pi(|\psi_i\rangle)$ is the payoffs the agent receives in case the outcome of the measurement $\mathcal{O}$ is $|\psi_i\rangle$.

2005), Saunders (2004, 2005), Greaves (2004) attempt derive the Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =: < |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

$$V(|\phi\rangle, O, \Pi) = \sum_i |\langle\psi_i|\phi\rangle|^2 x_i \tag{10}$$

where the $|\psi_i\rangle$'s are the eigenstates of O, and $x_i = \Pi(|\psi_i\rangle)$ is the payoffs the agent receives in case the outcome of the measurement $\mathcal{O}$ is $|\psi_i\rangle$.

Adobe Acrobat ME - [ManyWorlds91.pdf]

the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(<|\phi\rangle, O, \Pi>)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

$$V(|\phi\rangle, O, \Pi) = \sum_i |\langle\psi_i|\phi\rangle|^2 x_i \quad (10)$$

where the $|\psi_i\rangle$'s are the eigenstates of O, and $x_i = \Pi(|\psi_i\rangle)$ is the payoffs the agent receives in case the outcome of the measurement $\mathcal{O}$ is $|\psi_i\rangle$.

Adobe Acrobat ME - [ManyWorlds91.pdf]

File Edit Document Tools View Window Help

Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =:< |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

$$V(|\phi\rangle, O, \Pi) = \sum_i |\langle\psi_i|\phi\rangle|^2 x_i \tag{10}$$

where the $|\psi_i\rangle$'s are the eigenstates of O, and $x_i = \Pi(|\psi_i\rangle)$ is the payoffs the agent receives in case the outcome of the measurement $\mathcal{O}$ is $|\psi_i\rangle$.

Adobe Acrobat ME - [ManyWorlds91.pdf]

2005), Saunders (2004, 2005), Greaves (2004) attempt derive the Born probabilities from the non-probabilistic axioms of quantum theory and the non-probabilistic axioms of classical decision theory.

A quantum game is defined as an ordered triple $G =: < |\phi\rangle, O, \Pi >$ where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(< |\phi\rangle, O, \Pi >)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

$$V(|\phi\rangle, O, \Pi) = \sum_i |\langle\psi_i|\phi\rangle|^2 x_i \tag{10}$$

where the $|\psi_i\rangle$'s are the eigenstates of O, and $x_i = \Pi(|\psi_i\rangle)$ is the payoffs the agent receives in case the outcome of the measurement $\mathcal{O}$ is $|\psi_i\rangle$.

Adobe Acrobat ME - [ManyWorlds91.pdf]

where $|\phi\rangle$ is the pre-measurement (pure) state of the system, $\mathcal{O}$ is the observable measured, and Π is some payoff function from the set of measurement outcomes to the reals. Let $V(<|\phi\rangle, O, \Pi>)$ be the agent's expected payoff, which is a function from the set of games to the reals. The intended interpretation of V is that a rational agent prefers game G_1 to game G_2 just in case $V(G_1) > V(G_2)$. Assuming that V satisfies some further decision theoretic axioms (alledgedly) the authors claim to derive the following expected utility rule which is based on Born's rule:

$$V(|\phi\rangle, O, \Pi) = \sum_i |\langle\psi_i|\phi\rangle|^2 x_i \tag{10}$$

where the $|\psi_i\rangle$'s are the eigenstates of O, and $x_i = \Pi(|\psi_i\rangle)$ is the payoffs the agent receives in case the outcome of the measurement $\mathcal{O}$ is $|\psi_i\rangle$.

where the $|\psi_i\rangle$'s are the eigenstates of O, and $x_i = \Pi(|\psi_i\rangle)$ is the payoffs the agent receives in case the outcome of the measurement O is $|\psi_i\rangle$.

Adobe Acrobat ME - [ManyWorlds91.pdf]

File Edit Document Tools View Window Help

200%

6

6 of 10 8.5x11 in

Adobe Acrobat ME - [ManyWorlds91.pdf]

So what are the problems?

1. Philosophical question: what does it mean for an agent to have preferences when all the options are equally realized?

2. The devil is in the details. One major axiom of ALL authors is probabilistic and NOT decision-theoretic. Namely the non contextuality of probability. (Implicitly assumed by Deutsch, and explicitly by Wallace, who in one paper calls it Measurement Neutrality, and in another Equivalence)

Non Contextuality is a probabilistic assumption (not a rationality assumption) both in the classical and in the quantum framework.

It was called by Keynes a judgment of irrelevance. Consider a case of a flip of a coin and throw of a die. The 'standard model' is to take the probability space as the Cartesian product

$$X = \{HEADS, TAILS\} \times \{1, 2, 3, 4, 5, 6\}$$

Adobe Acrobat ME - [ManyWorlds91.pdf]

So what are the problems?

1. Philosophical question: what does it mean for an agent to have preferences when all the options are equally realized?

2. The devil is in the details. One major axiom of ALL authors is probabilistic and NOT decision-theoretic. Namely the non contextuality of probability. (Implicitly assumed by Deutsch, and explicitly by Wallace, who in one paper calls it Measurement Neutrality, and in another Equivalence)

Non Contextuality is a probabilistic assumption (not a rationality assumption) both in the classical and in the quantum framework.

It was called by Keynes a judgment of irrelevance. Consider a case of a flip of a coin and throw of a die. The 'standard model' is to take the probability space as the Cartesian product

$$X = \{HEADS, TAILS\} \times \{1, 2, 3, 4, 5, 6\}$$

and then to choose a probability distribution on the power set of X (we may assume that the outcomes are stochastically dependent). However, this model makes certain tacit assumptions. For example that the frequency of HEADS remains the same whether we throw

So what are the problems?

1. Philosophical question: what does it mean for an agent to have preferences when all the options are equally realized?

2. The devil is in the details. One major axiom of ALL authors is probabilistic and NOT decision-theoretic. Namely the non contextuality of probability. (Implicitly assumed by Deutsch, and explicitly by Wallace, who in one paper calls it Measurement Neutrality, and in another Equivalence)

Non Contextuality is a probabilistic assumption (not a rationality assumption) both in the classical and in the quantum framework.

It was called by Keynes a judgment of irrelevance. Consider a case of a flip of a coin and throw of a die. The 'standard model' is to take the probability space as the Cartesian product

$$X = \{HEADS, TAILS\} \times \{1, 2, 3, 4, 5, 6\}$$

and then to choose a probability distribution on the power set of X (we may assume that the outcomes are stochastically dependent). However, this model makes certain tacit assumptions. For example that the frequency of HEADS remains the same whether we throw

have preferences when all the options are equally realized?

2. The devil is in the details. One major axiom of ALL authors is probabilistic and NOT decision-theoretic. Namely the non contextuality of probability. (Implicitly assumed by Deutsch, and explicitly by Wallace, who in one paper calls it Measurement Neutrality, and in another Equivalence)

Non Contextuality is a probabilistic assumption (not a rationality assumption) both in the classical and in the quantum framework.

It was called by Keynes a judgment of irrelevance. Consider a case of a flip of a coin and throw of a die. The 'standard model' is to take the probability space as the Cartesian product

$$X = \{HEADS, TAILS\} \times \{1, 2, 3, 4, 5, 6\}$$

and then to choose a probability distribution on the power set of X (we may assume that the outcomes are stochastically dependent). However, this model makes certain tacit assumptions. For example that the frequency of HEADS remains the same whether we throw the die or not. So the marginals

have preferences when all the options are equally realized?

2. The devil is in the details. One major axiom of ALL authors is probabilistic and NOT decision-theoretic. Namely the non contextuality of probability. (Implicitly assumed by Deutsch, and explicitly by Wallace, who in one paper calls it Measurement Neutrality, and in another Equivalence)

Non Contextuality is a probabilistic assumption (not a rationality assumption) both in the classical and in the quantum framework.

It was called by Keynes a judgment of irrelevance. Consider a case of a flip of a coin and throw of a die. The 'standard model' is to take the probability space as the Cartesian product

$$X = \{HEADS, TAILS\} \times \{1, 2, 3, 4, 5, 6\}$$

and then to choose a probability distribution on the power set of X (we may assume that the outcomes are stochastically dependent). However, this model makes certain tacit assumptions. For example that the frequency of HEADS remains the same whether we throw the ... the marginals

Restore
Move
Size
Minimize
Maximize

have preferences when all the options are equally realized?

2. The devil is in the details. One major axiom of ALL authors is probabilistic and NOT decision-theoretic. Namely the non contextuality of probability. (Implicitly assumed by Deutsch, and explicitly by Wallace, who in one paper calls it Measurement Neutrality, and in another Equivalence)

Non Contextuality is a probabilistic assumption (not a rationality assumption) both in the classical and in the quantum framework.

It was called by Keynes a judgment of irrelevance. Consider a case of a flip of a coin and throw of a die. The 'standard model' is to take the probability space as the Cartesian product

$$X = \{HEADS, TAILS\} \times \{1, 2, 3, 4, 5, 6\}$$

and then to choose a probability distribution on the power set of X (we may assume that the outcomes are stochastically dependent). However, this model makes certain tacit assumptions. For example that the frequency of HEADS remains the same whether we throw the ... the marginals

6

Adobe Acrobat ME - [ManyWorlds91.pdf]

have preferences when all the options are equally realized?

2. The devil is in the details. One major axiom of ALL authors is probabilistic and NOT decision-theoretic. Namely the **non contextuality of probability.** (Implicitly assumed by Deutsch, and explicitly by Wallace, who in one paper calls it Measurement Neutrality, and in another Equivalence)

Non Contextuality is a probabilistic assumption (not a rationality assumption) both in the classical and in the quantum framework.

It was called by Keynes a judgment of irrelevance. Consider a case of a flip of a coin and throw of a die. The 'standard model' is to take the probability space as the Cartesian product

$$X = \{HEADS, TAILS\} \times \{1, 2, 3, 4, 5, 6\}$$

and then to choose a probability distribution on the power set of X (we may assume that the outcomes are stochastically dependent). However, this model makes certain tacit assumptions. For example that the frequency of HEADS remains the same whether we throw the ... the marginals

6

have preferences when all the options are equally realized?

2. The devil is in the details. One major axiom of ALL authors is probabilistic and NOT decision-theoretic. Namely the non contextuality of probability. (Implicitly assumed by Deutsch, and explicitly by Wallace, who in one paper calls it Measurement Neutrality, and in another Equivalence)

Non Contextuality is a probabilistic assumption (not a rationality assumption) both in the classical and in the quantum framework.

It was called by Keynes a judgment of irrelevance. Consider a case of a flip of a coin and throw of a die. The 'standard model' is to take the probability space as the Cartesian product

$$X = \{HEADS, TAILS\} \times \{1, 2, 3, 4, 5, 6\}$$

and then to choose a probability distribution on the power set of X (we may assume that the outcomes are stochastically dependent). However, this model makes certain tacit assumptions. For example that the frequency of HEADS remains the same whether we throw the die or not. So the marginals

Adobe Acrobat ME - [ManyWorlds91.pdf]

$$X = \{HEADS, TAILS\} \times \{1, 2, 3, 4, 5, 6\}$$

and then to choose a probability distribution on the power set of X (we may assume that the outcomes are stochastically dependent). However, this model makes certain tacit assumptions. For example that the frequency of HEADS remains the same whether we throw the die or not. So the marginals

$$P(\{HEADS\}) = \sum_{j=1}^{6} P(\{HEADS\} \times \{j\})$$

define the probability of HEADS, whether the die is rolled or not.

Imagine that you lived in a world where the frequency of HEADS is 0.5 when the die is not thrown, but when you start throwing the die it goes down to 0.3. In this case you will have to use a different model of the experiment with events like HEADS WHEN DIE ROLLED and TAILS WHEN DIE NOT ROLLED etc.

The judgment that our world is not like that is essentially empirical. Non-contextuality cannot be a principle of rationality.

Even less so in the many worlds interpretation because THERE ARE branches in which non-contextuality is empirically false, and

Adobe Acrobat ME - [ManyWorlds91.pdf]

However, this model makes certain tacit assumptions. For example that the frequency of HEADS remains the same whether we throw the die or not. So the marginals

$$P(\{HEADS\}) = \sum_{j=1}^{6} P(\{HEADS\} \times \{j\})$$

define the probability of HEADS, whether the die is rolled or not.

Imagine that you lived in a world where the frequency of HEADS is 0.5 when the die is not thrown, but when you start throwing the die it goes down to 0.3. In this case you will have to use a different model of the experiment with events like HEADS WHEN DIE ROLLED and TAILS WHEN DIE NOT ROLLED etc.

The judgment that our world is not like that is essentially empirical. Non-contextuality cannot be a principle of rationality.

Even less so in the many worlds interpretation because THERE ARE branches in which non-contextuality is empirically false, and there is no a priori reason to say that such branches are not typical.

Adobe Acrobat ME - [ManyWorlds91.pdf]

$$P(\{HEADS\}) = \sum_{j=1} P(\{HEADS\} \times \{j\})$$

define the probability of HEADS, whether the die is rolled or not.

Imagine that you lived in a world where the frequency of HEADS is 0.5 when the die is not thrown, but when you start throwing the die it goes down to 0.3. In this case you will have to use a different model of the experiment with events like HEADS WHEN DIE ROLLED and TAILS WHEN DIE NOT ROLLED etc.

The judgment that our world is not like that is essentially empirical. Non-contextuality cannot be a principle of rationality.

Even less so in the many worlds interpretation because THERE ARE branches in which non-contextuality is empirically false, and there is no a priori reason to say that such branches are not typical.

Adobe Acrobat ME - [ManyWorlds91.pdf]

So what are the problems?

1. Philosophical question: what does it mean for an agent to have preferences when all the options are equally realized?

2. The devil is in the details. One major axiom of ALL authors is probabilistic and NOT decision-theoretic. Namely the non contextuality of probability. (Implicitly assumed by Deutsch, and explicitly by Wallace, who in one paper calls it Measurement Neutrality, and in another Equivalence)

Non Contextuality is a probabilistic assumption (not a rationality assumption) both in the classical and in the quantum framework.

It was called by Keynes a judgment of irrelevance. Consider a case of a flip of a coin and throw of a die. The 'standard model' is to take the probability space as the Cartesian product

$$X = \{HEADS, TAILS\} \times \{1, 2, 3, 4, 5, 6\}$$

and then to choose a probability distribution on the power set of X (we may assume that the outcomes are stochastically dependent).

7 of 10 8.5x11 in