

# **Physics and Faith 4.**

**Rumors of a Designer  
Creator and Sustainer,  
Part III. The Ground of  
Physical Being in  
Quantum Physics**

# Introduction

In the last two sessions we have considered four contingencies or dependencies in the universe that are unexplained by physics, that might be considered "rumors" of God:

## **1. The laws of physics**

- *The Mystery of the Source of the Universe's Rationality.* Why is there an order, any rationality at all to the universe? Where does this order, rationality (the laws of Physics) come from?

# Introduction

**“the universe, in its rationale beauty and transparency, looks like a world shot through with signs of mind, and maybe, it's the "capital M" Mind of God we are seeing”**

- John Polkinghorne

# Introduction

## 1. The laws of physics

- *The Mystery of the Comprehensibility of the Universe's Rationality.* Why are these laws comprehensible to the human mind? And why should such laws appeal to our aesthetic sense of mathematical beauty and elegance?

**“ . . . there is some deep-seated relationship between the reason within (the rationality of our minds - in this case mathematics) and the reason without (the rational order and structure of the physical world around us). The two fit together like a glove.”**

- John Polkinghorne

# Introduction

## 1. The laws of physics

- *The Mystery of the Comprehensibility of the Universe's Rationality.*
- A Christian may speculate that this deep-seated relationship between the *reason within* and the *reason without* may be a reflection that human beings were made in the image and likeness of the source of that rationality, God.

# Introduction

2. The "boundary" of the universe at time = 0 (the "Big Bang") of classical cosmology

## The Penrose-Hawking Singularity Theorem

- proved that in all cosmological models based on General Relativity, a "singularity" at time = 0 is inevitable
- "singularity" at time = 0: the fabric of space and time is undefined, non-existent

Non-quantum physics (*General Theory of Relativity*) cannot explain what "caused" the universe to "appear" immediately after time = 0:

Contingency of the "boundary" at time = 0,  
the initial space-time singularity:  
*creatio ex nihilo?*

# Introduction

## **3. The Existence of All of Space-Time**

Why should we give any one "point" in space-time (the initial "singularity") any special significance?

Why is there something and not nothing?

What "breathes fire" into the equations and mathematical theories of physics (present or future) and makes the universe they describe manifest, real?

# Introduction

## 3. The Existence of All of Space-Time

**God is not a God of the edges, with a vested interest in beginnings. God is the God of all times and all places**

- John Polkinghorne

**"God is holding a fruitful, rationally beautiful world in being"**

- John Polkinghorne



# Introduction

## 4. The Anthropic Principle

The laws of physics and the "initial conditions" of the universe near time  $t = 0$  appear to be incredibly fine-tuned to produce life

The slightest deviations in the physical constants or the laws of physics would have resulted in a sterile universe devoid of stars and life

Why?

# Introduction

## 4. The Anthropic Principle

**Weak Anthropic Principle** asserts:

- these coincidences are *selection* effects.
- we live in a *privileged position* in the universe
- there are other universes (**Many Universes Hypothesis**), or other domains/parts of universe (for example, in the **Chaotic Inflation Model**) where the laws of physics or the initial conditions are different, and in which stars and life never developed

# Introduction

## 4. The Anthropic Principle

### Strong Anthropic Principle

- the apparent extraordinary "fine-tuning" is present because life is a *requirement* for the universe. Either:
  - the universe was "designed" for life to evolve (= a Rumor of a Designer)
  - conscious life is required for the universe to come into existence (**Observer Created Universe**)

# Introduction

When physics probes to understand the most basic constituents of matter, it reaches another boundary, a "ground" of physical being in quantum physics which is impenetrable to further probing

*Today's topic:*

## **5. The Ground of Physical Being in Quantum Physics**

# What is a Thing? What is Being?

**What is a thing?... It is striking that, of all the modern sciences, only quantum physics seems to have been obliged to face this issue directly**

- physicist C. J. Isham

# The Nature of Being in Quantum Physics

Atoms and subatomic particles are NOT the ultimate physical reality

Ultimate physical reality must be imagined as a "ground of being" teeming with latent potentialities, latent possibilities not yet actualized, not yet "real"

Our knowledge of these latent potentialities, latent possibilities is encoded in the quantum "wavefunction" or "state function"  $\Psi$  of a system

# The Nature of Being in Quantum Physics

The *act of measurement* seems to CAUSE one of the possibilities / potentialities in the "ground of being" to become actualized

- Out of the range of possibilities / potentialities, one possibility / potentiality becomes "real", and a "particle" (or "quantum") temporarily appears
- Physicists call this actualization of one of the latent possibilities / potentialities the **"collapse of the wavefunction"**

# The Nature of Being in Quantum Physics

The "ground of being" somehow "chooses" which particular possibility / potentiality is actualized when a measurement is done

We can predict only the **probability** of a particular "choice" occurring. Within the boundaries of the probability function, the "choice" made by the ground of beings appears to us as random

After measurement is done, the "particle" soon returns to the realm of latent potentialities, latent possibilities



# The Nature of Being in Quantum Physics

## Heisenberg Uncertainty Principle

The act of measurement does not bring into being a "classical particle" which has all its "properties" or "observables" fully defined

A **measurement / observation** only "brings into being" / "actualizes" a "particle" which has the **measured / observed** property or observable well-defined. Other properties or observables may remain "undefined," may still lie in the realm of latent possibilities / potentialities

# The Nature of Being in Quantum Physics

## Heisenberg Uncertainty Principle

*For example:*

Measuring for the observable "**position**" causes the wavefunction to collapse into a state which has a well-defined **position**

- the observable "**momentum**" however will still remain undefined, will still lie in the realm of latent possibilities

Measuring for the observable "**momentum**" causes the wavefunction to collapse into a state which has a well-defined **momentum**

- the observable "**position**" however will still remain undefined, will still lie in the realm of latent possibilities

This is the basis for the **Heisenberg Uncertainty Principle**

# The Nature of Being in Quantum Physics

It is generally no longer consistent to talk of individual entities possessing a value for an observable: it is more as if the property concerned is *latent* in the system until such time as an observation brings it into being. As John Bell has put it, "beables" are replaced by "observables," and the verb "to be" becomes "to be measured"

- physicist C. J. Isham

# Interpretations of the Meaning of Quantum Physics

The above "interpretation" of the meaning of quantum physics – that *the act of measurement itself causes a particular "observable" to become actualized / become "real"* -- is called the

**Orthodox or Copenhagen Interpretation**, and is the most widely accepted interpretation

# Interpretations of the Meaning of Quantum Physics

*Alternative Interpretations:*

## **Realist Interpretation**

- Quantum Physics is *incomplete*
- A system being measured must actually possess the value of the property being measured *before* the measurement is made
- There must be a "**hidden variable**" that remains to be discovered that will allow us to find what this value is before the measurement is done

# Interpretations of the Meaning of Quantum Physics

*Alternative Interpretations:*

**Realist Viewpoint** became untenable in **1964**, when J. S. Bell proved that *any* local hidden variable theory is logically incompatible with quantum physics

# Interpretations of the Meaning of Quantum Physics

*Alternative Interpretations:*

## **Many Worlds Interpretation**

- Each time we "collapse a wavefunction" through an act of measurement and observation, the universe is actually *fragmenting* into an unimaginable number of universes, each universe manifesting one of the possible latent potentialities, latent possibilities

# What is a Measurement?

What is required for an act to constitute a **measurement**, with the “power” to cause the “collapse of the wavefunction”?

*Suggestions:*

- A sufficiently large enough number of other quantum systems to make up a “macroscopic system” that is used for the measurement (e.g. a voltmeter, an eyeball)
- A conscious, self-aware mind



# What is a Measurement?

The suggestion that **measurement** or **observation** sufficient to cause the "collapse of the wavefunction" requires a *conscious, self-aware mind* has led to *speculations* of:

- an **Observer-Created** or **Participatory Universe** as an explanation for the **Strong Anthropic Principle**
  - the universe appears "designed" for life because only those possible universes with the potential for conscious, self-aware minds give rise to the observers needed for the universe to "concretize" or "actualize" itself

# What is a Measurement?

The suggestion that **measurement** or **observation** sufficient to cause the "collapse of the wavefunction" requires a *conscious, self-aware mind* has led to speculations of (*continued*):

- **The necessity of God**
  - The "observation" / "measurement" of a conscious, self-aware mind was necessary at the "Big Bang" for the "Big Bang" to become actualized, become real
  - God is also the "First Observer" or "Primal Observer"

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

1. Consider the **neutral pi meson** or **pion**  $\pi^0$ :
  - All subatomic particles have a property called "spin," (so called because it gives the particle behaviors as if it were spinning on a rotational axis). Spin is *conserved* in all particle interactions
  - A **pion**  $\pi^0$  has a "spin" of 0.
  - The **pion**  $\pi^0$  decays into an **electron**  $e^-$ , which can have "spin up" =  $+1/2$  or "spin down" =  $-1/2$ , and a **positron**  $e^+$ , which can also have a "spin up" =  $+1/2$  or a "spin down" =  $-1/2$ )

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

- Because spin is conserved, when a **pion**  $\pi^0$  decays, the total spin of the **electron e-** and **positron e+** it decays into must add up to the spin of the original **pion**  $\pi^0 = 0$
- if the **electron e-** has spin up =  $+1/2$ , then the **positron e+** must have spin down =  $-1/2$  and visa versa

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

2. Observe a **pion**  $\pi^0$  and watch it decay into an **electron e-** and a **positron e+**.
3. Let the **electron e-** and **positron e+** “fly” way off in opposite directions. Millions and millions of years pass – you have long died. The **electron e-** and **positron e+** are not being observed and so they return to the “ground of being,” to the realm of latent potentialities, latent possibilities not yet real, not yet actualized.

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

4. When the **electron e-** and **positron e+** are one million light years apart, millions and millions of years after the **pion  $\pi^0$**  from which they originated decayed, someone measures the spin on one of them -- say the **electron e-**. By the **Orthodox Interpretation:**
  - the latent potentialities of the **electron e-** includes the latent potentiality of being either spin up =  $+1/2$  or spin down =  $-1/2$

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

- When a measurement of the spin of the **electron e-** is made, one of the possible latent potentialities of the **electron e-** becomes actualized (the "wavefunction collapses"), and a spin up *or* spin down **electron e-** appears. Say the measurement yields an **electron e-** with spin up.
- *Instantaneously*, the spin of the **positron e+** one million light years away no longer has the latent potentiality of being spin up or spin down, but now has a fully determined spin – spin down!

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

## Einstein, Podolsky, Rosen:

- how can the **electron e-** *instantaneously* communicate to the **positron e+**, which is one million light year away, the message: "I've had my spin measured. I'm spin up," and "force" the **positron e+** to become spin down?
- this "spooky action-at-a-distance" is *preposterous*



# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

In **1982**, Aspect, Grangier and Roger at the University of Paris experimentally confirmed that the “preposterous” effect of the **EPR Paradox**, the "spooky action-at-a-distance" is physical reality.

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

## Einstein, Podolsky and Rosen ("Classical View"):

- considered the electron and positron to be *individual* particles. For the **electron e-** to determine the spin of the **positron e+**, it would have to exert some force on the positron to change it, to "cause" the positron to have a certain spin. This "force" would have to travel across the light years of distance between the electron and positron before it could effect the positron

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

## The Quantum Physics View (the "modern" view):

- The **electron e-** and **positron e+**, because they had "interacted" in their past through their origin from a **pion  $\pi^0$** , are never fully individual entities
- In the **EPR paradox** we see them behaving as a *single entity*. They have a *single wavefunction* which describes their *shared* latent potentialities, their *shared* latent possibilities.

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

## The Quantum Physics View (the "modern" view, *continued*):

- The measurement of the **electron's** spin collapses the entire “electron-positron” wavefunction and so actualizes one of the possible sets of properties for the *combined entity* of **electron e-** and **positron e+**.

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

## The Quantum Physics View (the "modern" view, *continued*):

The fact that the **electron e-** and **positron e+** are far removed from each other does not matter, for wavefunctions are *not* "local," are *not* tied to some location in space or time (= quantum "nonlocality"). The wavefunctions seem to exist *independently* of the dimensions of space and time

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

## The Quantum Physics View (the "modern" view, *continued*):

- In other words, there is a ground of physical reality that never "forgets" that the **electron e-** and **positron e+** share a common origin, and this memory is "nonlocal," is not tied to any location in space or time.

# Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”

Because the universe is filled with “particles” “interacting” all the time, particles are becoming “entangled” as joint entities all the time. Another name for **quantum "nonlocality"** is **"quantum entanglement."**

# **Quantum Nonlocality = Quantum Entanglement Einstein-Podolsky-Rosen (EPR) “Paradox”**

**The phenomenon of quantum entanglement imparts to the physical world a degree of holistic interdependence that contrasts strongly with the predominately atomistic concepts of Western Philosophy**

**- C. J. Isham**

**The EPR experiment shows that the subatomic world cannot be treated atomistically. There's an intrinsic interconnectedness that cannot be broken**

**- John Polkinghorne**



# Metaphysical Questions

What is the "realm" in which the "wavefunctions" = the latent possibilities, potentialities "exist"? What is the nature of their "being"?

How does this "ground of being" "remember" all the interactions between "particles" and what they shared? How can this "remembrance" be non-local, impervious to separations in time and space?

# Why Does the World Appear "Concrete" to Us?

If we do numerous measurements of an electron's "position" as it "rotates" around the nucleus of an atom (each measurement "collapsing the wavefunction" of the electron so that it becomes actualized and has a defined position at the time of the measurement), we find set of all position measurements forms a "cloud" ("electron cloud") around the nucleus. The electron can be *anywhere* in the cloud on two successive measurements

Why don't position measurements of Mars' rotation around the Sun form a "Mars cloud?"

# Why Does the World Appear "Concrete" to Us?

Why does the world appear to consist of distinct objects occupying distinct positions in a well-defined space-time?  
If nature is fundamentally a unity because of **quantum entanglement**, *why is it possible to know something without knowing everything?*

# Why Does the World Appear "Concrete" to Us?

The "separability" of nature is only *approximate*, but this approximate separability (the "classical" non-quantum world we observe macroscopically) is sufficient to *allow us to know something without knowing everything*

Physicist Hartle and Gell-Mann have calculated that the appearance of an approximately "classical world" is the result of a peculiar quantum state of the universe ("initial conditions") at the time of the Big Bang – another example then of the **Anthropic Principle**

# Other Issues for Theology

## Divine Action

Can God act "without being seen" by influencing the "collapse of the wavefunction" when we make a measurement or observation?

## An Open Universe

The exact value that results when a measurement or observation "collapses" the wavefunction can never be predicted. The universe is therefore inherently indeterminate. The future is unpredictably and inherently "open."

# Is Quantum Physics True?

**This theoretical failure to find a plausible alternative to quantum mechanics . . . suggests to me that quantum mechanics is the way it is because any small change in quantum mechanics would lead to logical absurdities. If this is true, quantum mechanics may be a permanent part of physics. Indeed, quantum mechanics may survive not merely as an approximation to a deeper truth, in the way that Newton's theory of gravitation survives as an approximation to Einstein's general theory of relativity, but as a precisely valid feature of the final theory**

- Steven Weinberg, in *Dreams of a Final Theory*

# References

- Quantum Cosmology and the Laws of Nature. Scientific Perspectives on Divine Action. Second Edition.** Robert John Russell, Nancey Murphy, and C. J. Isham, editors. Vatican Observatory Publications and the Center for Theology and the Natural Sciences, Berkeley, 1996. Distributed by University of Notre Dame Press
- Science and Theology: An Introduction.** John Polkinghorne, SPCK / Fortress Press, London / Minneapolis, 1998
- The Mind of God. The Scientific Basis for a Rational World.** Paul Davies. Touchstone. New York. 1992