Lee Smolin Five Great Problems and Their Solution without Ontological Hypotheses

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Solutions of Lee Smolin Five Great Problems from his book *The Trouble with Physics: the Rise of String Theory, the Fall of a Science, and What Comes Next* are described. These solutions are obtained only from the properties of probability without any ontological hypotheses.

Introduction

In his book [1] Lee Smolin, professor of Perimeter Institute, Canada, has formulated the following five problems which he named Great Problems:

> *Problem 1: Combine general relativity and quantum theory into a single theory that claim to be the complete theory of nature.*
>
> *Problem 2: Resolve the problems in the foundations of quantum mechanics, either by making sense of the theory as it stands or by inventing a new theory that does make sense. …*
>
> *Problem 3: Determine whether or not the various particles and forces can be unified in a theory that explain them all as manifestations of a single, fundamental entity. …*
>
> *Problem 4: Explain how the values of of the free constants in the standard model of particle physics are chosen in nature. …*
>
> *Problem 5: Explain dark matter and dark energy. Or if they don't exist, determine how and why gravity is modified on large scales. …*

Solution

Let us consider the free Dirac Lagrangian:

$$\mathcal{L} := \psi^{\dagger}\left(\beta^{[k]}\partial_k + m\gamma^{[0]}\right)\psi. \tag{1}$$

Here*

$$\beta^{[\nu]} := \begin{bmatrix} \sigma_\nu & 0_2 \\ 0_2 & -\sigma_\nu \end{bmatrix}, \gamma^{[0]} := \begin{bmatrix} 0_2 & 1_2 \\ 1_2 & 0_2 \end{bmatrix}$$

where σ_1, σ_2, σ_3 are the Pauli matrices.

Such Lagrangian is not invariant [2] under the SU(2) transformation with the parameter α:

$$\psi^{\dagger}U^{\dagger}(\alpha)\left(\beta^{[k]}\partial_k + m_1\gamma^{[0]}\right)U(\alpha)\psi$$
$$= \psi^{\dagger}\left(\beta^{[k]}\partial_k + (m\cos\alpha)\,\gamma^{[0]}\right)\psi,$$

the mass member is changed under this transformation.

Matrices $\beta^{[\nu]}$ and $\gamma^{[0]}$ are anticommutative. But it turns out that there exists a fifth matrix $\beta^{[4]}$ anticommuting with all these four matrices:

$$\beta^{[4]} := \mathrm{i}\begin{bmatrix} 0_2 & 1_2 \\ -1_2 & 0_2 \end{bmatrix}.$$

And the term with this matrix should be added to this Lagrangian mass term:

$$\underline{\mathcal{L}} := \psi^{\dagger}\left(\beta^{[k]}\partial_k + m_1\gamma^{[0]} + m_2\beta^{[4]}\right)\psi$$

where $\sqrt{m_1^2 + m_2^2} = m$.

Let $U(\alpha)$ be any SU(2)-matrix with parameter α and let $\mathbf{U}$ be the space in which $U(\alpha)$ acts. In such case $U(\alpha)$ divides the space $\mathbf{U}$ into two orthogonal subspaces $\mathbf{U}_o$ and $\mathbf{U}_x$ such that for every element ψ of $\mathbf{U}$ there exists an element ψ_o of $\mathbf{U}_o$ and an element ψ_x of $\mathbf{U}_x$ which fulfills the following conditions [3,4]:

1.
$$\psi_o + \psi_x = \psi,$$

2.
$$\begin{aligned} &\psi_o^{\dagger}U^{\dagger}(\alpha)\left(\beta^{[k]}\partial_k + m_1\gamma^{[0]} + m_2\beta^{[4]}\right)U(\alpha)\psi_o = \\ =\; &\psi_o^{\dagger}(\beta^{[k]}\partial_k + (m_1\cos\alpha - m_2\sin\alpha)\,\gamma^{[0]} + \\ &+ (m_2\cos\alpha + m_1\sin\alpha)\beta^{[4]})\psi_o, \end{aligned} \tag{2}$$

3.
$$\begin{aligned} &\psi_x^{\dagger}U^{\dagger}(\alpha)\left(\beta^{[k]}\partial_k + m_1\gamma^{[0]} + m_2\beta^{[4]}\right)U(\alpha)\psi_x = \\ =\; &\psi_x^{\dagger}(\beta^{[k]}\partial_k + (m_1\cos\alpha + m_2\sin\alpha)\,\gamma^{[0]} + \\ &+ (m_2\cos\alpha - m_1\sin\alpha)\beta^{[4]})\psi_x. \end{aligned} \tag{3}$$

In either case, m does not change.

I call these five ($\beta := \left\{\beta^{[\nu]}, \beta^{[4]}, \gamma^{[0]}\right\}$) anticommuting matrices *Clifford pentad*. Any sixth matrix does not anticommute with all these five.

There exist only six Clifford pentads (for instance, [5,6]): I call one of them (the pentad β) *the light pentad*, three (ζ, η, θ) — *the chromatic pentads*, and two ($\underline{\Delta}$, $\underline{\Gamma}$) — *the gustatory pentads*.

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*$0_2 := \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$, $1_2 := \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$, $\beta^{[0]} := -1_4 := -\begin{bmatrix} 1_2 & 0_2 \\ 0_2 & 1_2 \end{bmatrix}$, $k \in \{0, 1, 2, 3\}$, $\nu \in \{1, 2, 3\}$.

The light pentad contains three diagonal matrices ($\beta^{[\nu]}$) corresponding to the coordinates of 3-dimensional space, and two antidiagonal matrices ($\beta^{[4]}$, $\gamma^{[0]}$) relevant to mass terms (2,3) — one for the lepton state and the other for the neutrino state of this lepton.

Each chromatic pentad also contains three diagonal matrices corresponding to three coordinates and two antidiagonal mass matrices - one for top quark state and the other — for bottom quark state.

Each gustatory pentad contains a single diagonal coordinate matrix and two pairs of antidiagonal mass matrices [6] — these pentads are not needed yet.

Let* $\langle \rho_A \mathrm{c}, j_{A,\nu} \rangle$ be a 1+3-vector of probability density of a pointlike event A.

For any A the set of four equations with an unknown complex 4×1 matrix function $\varphi(x_k)$

$$\left\{ \begin{array}{c} \rho_A = \varphi^\dagger \varphi, \\ \dfrac{j_{A,\nu}}{\mathrm{c}} = -\varphi^\dagger \beta^{[\nu]} \varphi \end{array} \right|$$

has solution [3].

If† $\rho_A(x_k) = 0$ for all x_k such that $|x_k| > (\pi \mathrm{c}/\mathrm{h})$ then φ obeys the following equation [10]:

$$\begin{array}{l} \left(-\left(\partial_0 + \mathrm{i}\Theta_0 + \mathrm{i}\Upsilon_0\gamma^{[5]}\right) + \beta^{[\nu]}\left(\partial_\nu + \mathrm{i}\Theta_\nu + \mathrm{i}\Upsilon_\nu\gamma^{[5]}\right) + \right. \\ \left. \quad + 2\left(\mathrm{i}M_0\gamma^{[0]} + \mathrm{i}M_4\beta^{[4]}\right)\right)\varphi + \\ + \left(-\left(\partial_0 + \mathrm{i}\Theta_0 + \mathrm{i}\Upsilon_0\gamma^{[5]}\right) - \zeta^{[\nu]}\left(\partial_\nu + \mathrm{i}\Theta_\nu + \mathrm{i}\Upsilon_\nu\gamma^{[5]}\right) + \right. \\ \left. \quad + 2\left(-\mathrm{i}M_{\zeta,0}\gamma_\zeta^{[0]} + \mathrm{i}M_{\zeta,4}\zeta^{[4]}\right)\right)\varphi + \\ + \left(\left(\partial_0 + \mathrm{i}\Theta_0 + \mathrm{i}\Upsilon_0\gamma^{[5]}\right) - \eta^{[\nu]}\left(\partial_\nu + \mathrm{i}\Theta_\nu + \mathrm{i}\Upsilon_\nu\gamma^{[5]}\right) + \right. \\ \left. \quad + 2\left(-\mathrm{i}M_{\eta,0}\gamma_\eta^{[0]} - \mathrm{i}M_{\eta,4}\eta^{[4]}\right)\right)\varphi + \\ + \left(-\left(\partial_0 + \mathrm{i}\Theta_0 + \mathrm{i}\Upsilon_0\gamma^{[5]}\right) - \theta^{[\nu]}\left(\partial_\nu + \mathrm{i}\Theta_\nu + \mathrm{i}\Upsilon_\nu\gamma^{[5]}\right) + \right. \\ \left. \quad + 2\left(\mathrm{i}M_{\theta,0}\gamma_\theta^{[0]} + \mathrm{i}M_{\theta,4}\theta^{[4]}\right)\right)\varphi = \\ = \quad 0 \end{array}$$

with real
$\Theta_k(x_k)$, $\Upsilon_k(x_k)$, $M_0(x_k)$, $M_4(x_k)$, $M_{\zeta,0}(x_k)$, $M_{\zeta,4}(x_k)$, $M_{\eta,0}(x_k)$, $M_{\eta,4}(x_k)$, $M_{\theta,0}(x_k)$, $M_{\theta,4}(x_k)$
and with

$$\gamma^{[5]} := \left[\begin{array}{cc} 1_2 & 0_2 \\ 0_2 & -1_2 \end{array} \right].$$

*c = 299792458.

†h := 6.6260755 · 10^{-34}

The first summand of this equation contains elements of the light pentad only. And the rest summands contain elements of the chromatic pentads only.

This equation can be rewritten in the following way:

$$\begin{array}{l} \beta^{[k]}\left(-\mathrm{i}\partial_k + \Theta_k + \Upsilon_k\gamma^{[5]}\right)\varphi + \\ +(M_0\gamma^{[0]} + M_4\beta^{[4]} - \\ -M_{\zeta,0}\gamma_\zeta^{[0]} + M_{\zeta,4}\zeta^{[4]} - \\ -M_{\eta,0}\gamma_\eta^{[0]} - M_{\eta,4}\eta^{[4]} + \\ +M_{\theta,0}\gamma_\theta^{[0]} + M_{\theta,4}\theta^{[4]})\varphi = \\ = \quad 0 \end{array} \tag{4}$$

because

$$\zeta^{[\nu]} + \eta^{[\nu]} + \theta^{[\nu]} = -\beta^{[\nu]}.$$

This equation is a generalization of the Dirac's equation with gauge fields $\Theta_k(x_k)$ and $\Upsilon_k(x_k)$ and with eight mass members. The mass members with elements of the light pentad (M_0 and M_4) conform to neutrino and its lepton states. And six mass members with elements of the chromatic pentads conform to three pairs (up and down) of chromatic states (red, green, blue).

Let this equation not contains the chromatic mass nembers:

$$\left(\beta^{[k]}\left(-\mathrm{i}\partial_k + \Theta_k + \Upsilon_k\gamma^{[5]}\right) + M_0\gamma^{[0]} + M_4\beta^{[4]}\right)\varphi = 0. \tag{5}$$

If function φ is a solution of this equation then φ represents the sum of functions $\varphi_{n,s}$ which satisfy the following conditions [3, 62–71]:

n and s are integers;

each of these functions obeys its equation of the following form:

$$\left(\beta^{[k]}\left(\mathrm{i}\partial_k - \Theta_0 - \Upsilon_0\gamma^{[5]}\right) - \frac{\mathrm{h}}{\mathrm{c}}\left(\gamma^{[0]}n + \beta^{[4]}s\right)\right)\varphi_{n,s} = 0; \tag{6}$$

for each point x_k of space-time: or this point is empty (for all n and s: $\varphi_{n,s}(x_k) = 0$), or in this point is placed a single function (for x_k there exist integers n_0 and s_0 such that $\varphi_{n_0,s_0}(x_k) \neq 0$ and if $n \neq n_0$ and/or $s \neq s_0$ then $\varphi_{n,s}(x_k) = 0$).

In this case if $m := \sqrt{n^2 + s^2}$ then m is a natural number. But under the SU(2)-transformation with parameter α (2, 3): $m \to \left((n\cos\alpha - s\sin\alpha)^2 + (s\cos\alpha + n\sin\alpha)^2\right)^{0.5}$, $(n\cos\alpha - s\sin\alpha)$ and $(s\cos\alpha + n\sin\alpha)$ must be integers too. But it is impossible.

But for arbitrarily high accuracy in distant areas of the natural scale there exist such numbers m that for any α some natural numbers n' and s' exist which obey the following conditions: $n' \approx (n\cos\alpha - s\sin\alpha)$ and $s' \approx (s\cos\alpha + n\sin\alpha)$. These numbers m are separated by long intervals and determine the mass spectrum of the generations of elementary particles. Apparently, this is the way to solve Problem 4 because the masses are one of the most important constants of particle physics.

The Dirac's equation for leptons with gauge members which are similar to electroweak fields is obtained [4, p. 333–336] from equations (5, 6). Such equation is invariant under electroweak transformations. And here the fields W and Z obey the Klein-Gordon type equation with nonzero mass.

If the equation (4) does not contain lepton's and neutrino's mass terms then the Dirac's equation with gauge members which are similar to eight gluon's fields is obtained. And oscillations of the chromatic states of this equation bend space-time. This bend gives rise to the effects of redshift, confinement and asymptotic freedom, and Newtonian gravity turns out to be a continuation of subnucleonic forces [10]. And it turns out that these oscillations bend space-time so that at large distances the space expands with acceleration according to Hubble's law [7]. And these oscillations bend space-time so that here appears the discrepancy between the quantity of the luminous matter in the space structures and the traditional picture of gravitational interaction of stars in these structures. Such curvature explains this discrepancy without the Dark Matter hypothesis [8] (Problem 5).

Consequently, the theory of gravitation is a continuation of quantum theory (Problem 1 and Problem 3).

Thus, concepts and statements of Quantum Theory are concepts and statements of the probability of pointlike events and their ensembles.

Elementary physical particle in vacuum behaves like these probabilities. For example, according to doubleslit experiment [9], if a partition with two slits is placed between a source of elementary particles and a detecting screen in vacuum then interference occurs. But if this system will be put in a cloud chamber, then trajectory of a particle will be clearly marked with drops of condensate and any interference will disappear. It seems that a physical particle exists only in the instants of time when some events happen to it. And in the other instants of time the particle does not exist, but the probability of some event to happen to this particle remains.

Thus, if no event occurs between an event of creation of a particle and an event of detection of it, then the particle does not exist in this period of time. There exists only the probability of detection of this particle at some point. But this probability, as we have seen, obeys the equations of quantum theory and we get the interference. But in a cloud chamber events of condensation form a chain meaning the trajectory of this particle. In this case the interference disappears. But this trajectory is not continuous — each point of this line has an adjacent point. And the effect of movement of this particle arises from the fact that a wave of probability propagates between these points.

Consequently, the elementary physical particle represents an ensemble of pointlike events associated with probabilities. And charge, mass, energy, momentum, spins, etc. represent parameters of distribution of these probabilities. It explains all paradoxes of quantum physics. Schrödinger's cat lives easily without any superposition of states until the microevent awaited by everyone occurs. And the wave function disappears without any collapse in the moment when event probability disappears after the event occurs.

Hence, entanglement concerns not particles but probabilities. That is when the event of the measuring of spin of Alice's electron occurs then probability for these entangled electrons is changed instantly in the whole space. Therefore, nonlocality acts for probabilities, not for particles. But probabilities can not transmit any information (Problem 2).

Conclusion

Therefore, Lee Smolin's Five Great Problems do have solution only using the properties of probabilities. These solutions do not require any dubious ontological hypotheses such as superstrings, spin networks, etc.

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