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Physics and Space Science

Highlights

- Dark Spin Particles
- Gravitation Ever Since and Forever
- Electric Current Approach
- Solar Module on the Temperature

Discovering Thoughts, Inventing Future

VOLUME 21 ISSUE 3 VERSION 1.0

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On The Dependence of the Fill Factor of the Solar Module on the Temperature

By Aleksandr Ivanovich Kanareykin

Federal State Budgetary Educational Institution of Higher Education

Abstract- The work is devoted to the conversion and use of solar energy in solar panels. The article shows that one of the clue parameters for evaluating the efficiency of solar panels and photovoltaic cells, the fill factor decreases with increasing temperature. The issue of reducing the influence of the temperature factor on the efficiency of solar panels is also considered. Based on the research, the conclusion is given that the idling voltage should be as high as possible.

Keywords: *solar energy, solar battery, fill factor, temperature factor.*

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Keywords: solar energy, solar battery, fill factor, temperature factor.

I. Introduction

Solar energy is one of the most suitable options for generating electricity since it is inexhaustible, absolutely free (in terms of its availability), and environmentally friendly. [1-2].

Due to the need to develop hydrocarbon deposits in remote areas that do not have transport and energy infrastructure, the need to electrify the objects of the oil and gas transport system, autonomous power plants using resources of different physical nature are becoming increasingly relevant.

Renewable energy sources – wind and photovoltaic power plants-have future prospects. Their advantages are no need for fuel, a long service life, the possibility of long-term operation in automatic mode, sufficiently proven energy conversion technologies. The rapid development of wind power in recent years determines the practical interest in its use in autonomous power supply systems, including in the oil and gas industry.

There are also many works in the literature devoted to optimizing and increasing the efficiency of solar panels [3-9].

One of the key parameters for evaluating the efficiency of solar batteries and photovoltaic cells is the fill factor.

During operation, the solar battery operates 95% of the time in completely different conditions, with various illumination or temperature from the test conditions, which leads to a change in the operating point of maximum power. When the light is low or the temperature of the element is high, parasitic losses that occur in the solar cell have a great influence. As we have already determined above, a higher Fill Factor indicates a high quality of the element. Thus, when the external operating conditions change, relative to the test conditions, a solar battery with a high Fill Factor can be expected to be more efficient in the entire range of illumination and temperature, relative to a solar battery with a low Fill Factor, but with the identical declared efficiency and power.

A solar cell is an electronic device that directly converts sunlight into electricity. The light falling on the solar panel produces both current and voltage to generate electricity. This process requires, firstly, a material in which the absorption of light raises an electron to a higher energy state, and, secondly, the movement of this higher energy electron from the solar cell to the external circuit. The electron then dissipates its energy in the external chain and returns to the solar cell. Various materials and processes can potentially meet the requirements for the conversion of photovoltaic power. Still, in practice, almost all photovoltaic energy conversions use semiconductor materials in the form of a p-n junction. Like all other semiconductor devices, solar cells are sensitive to temperature. An increase in temperature reduces the bandgap of the semiconductor, thereby affecting most of the parameters of the semiconductor material. A decrease in the band gap of a semiconductor with an increase in temperature is associated with an increase in the energy of electrons in the material. Therefore, less energy is required to break the connection. In the semiconductor bandgap model, a decrease in the binding energy leads to a decrease in the band gap. Hence, an increase in temperature reduces the forbidden zone. In this regard, the question arises about the dependence of the fill factor on the temperature.

II. Materials and Methods

The paper uses the method of functional analysis.

III. Results

The fill factor is a parameter that, in combination with the no-load voltage and short-circuits current, determines the maximum power of the solar cell. The specified fill factor [10] is equal to

$$FF = \frac{2U_{mp}I_{sc} + 2U_{oc}I_{mp} - U_{mp}I_{mp}}{3U_{oc}I_{sc}} \quad (1)$$

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where U_{mp} is the voltage at the maximum power point, V; I_{mp} is the current at the maximum power, A; U_{oc} is the no-load voltage, V; I_{sc} is the short-circuit current, A.

The formula (1) includes four parameters that depend on the temperature. Let's consider each parameter.

In a solar cell, the most affected by an increase in temperature is the open-circuit voltage. The figure below shows the dependence of the volt-ampere characteristics of a solar cell on temperature (fig. 1).

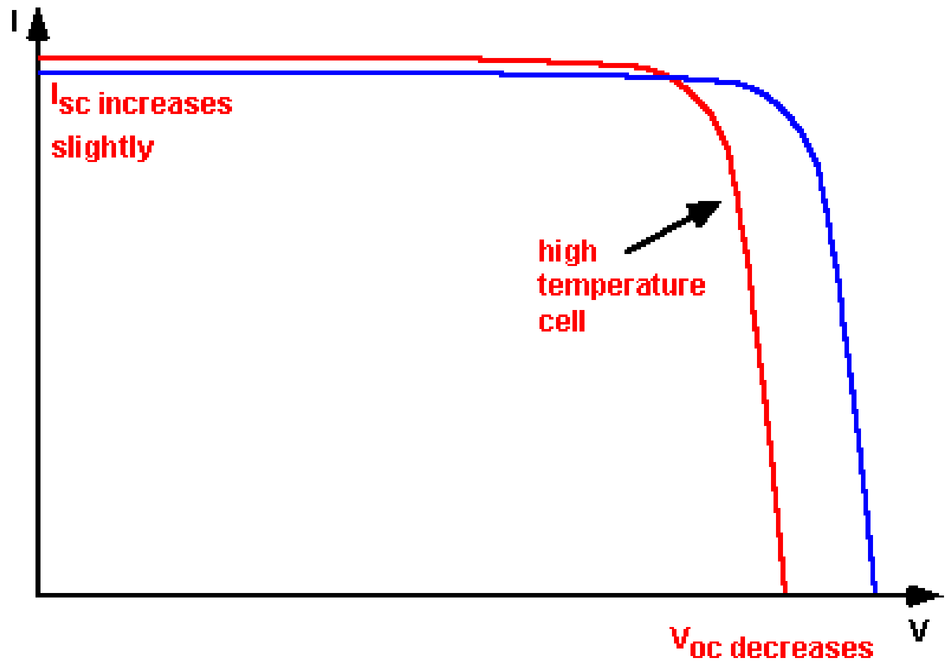

Figure 1: Influence of temperature on the volt-ampere characteristics of a solar cell

The short-circuit current, Isc, increases slightly with temperature as the bandgap energy decreases, and more photons have enough power to create pairs of electrons and holes. However, this is a small effect, and the temperature dependence of the short-circuit current for a silicon solar cell is usually zero. Most solar cells are silicon semiconductor photodiodes. Therefore, we will not take into account the change in current from temperature in the calculations.

For further research, we will simplify the formula (1). From the technical characteristics for solar modules, it follows that the short-circuit current is approximately 95% of the current at the maximum power point (I_{sc}=0.95 I_{mp}). Then

$$FF = 0{,}633 + \frac{0{,}35U_{mp}}{U_{oc}} \tag{2}$$

In turn, the voltage at the maximum power point is related to the no-load voltage by the following ratio.

$$U_{mp} = U_{oc} - \frac{nkT}{q}\ln\left(\frac{qU_{mp}}{nkT}+1\right) \tag{3}$$

where kT/q is the thermal voltage, n is the internal concentration of charge carriers.

Replace the no-load voltage in the expression (2)

$$FF = 0{,}633 + \frac{0{,}35}{1+\ln\left(\frac{qU_{mp}}{nkT}+1\right)^{\frac{nkT}{qU_{mp}}}} \tag{4}$$

To estimate the scope of the fill factor, we will perform a limit analysis of the resulting expression (4). To do this, we will introduce a constant *c*

$$\frac{qU_{mp}}{nk} = c \tag{5}$$

let's direct the temperature to zero and infinity. Since

$$\lim_{T\to 0}\ln\left(\frac{c}{T}+1\right)^{\frac{T}{c}} = 0 \tag{6}$$

$$\lim_{T\to\infty}\ln\left(\frac{c}{T}+1\right)^{\frac{T}{c}} = 1 \tag{7}$$

then the value of the fill factor FF lies in the range (0.808; 0.983).

Let's plot the functional dependence of the fill factor on the temperature (fig. 2). As can be seen, the filling coefficient decreases with increasing temperature.

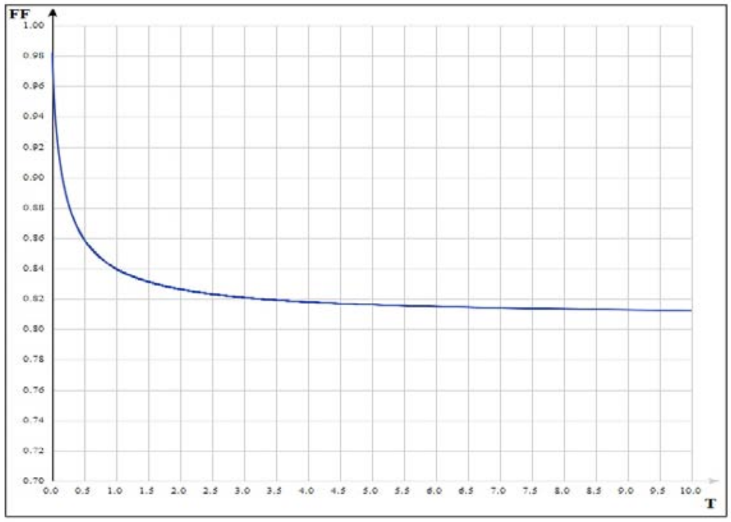

Figure 2: Graph of the dependence of the Fill Factor on the temperature

We will also conduct a study of the dependence of the fill factor on the voltage at the point of maximum power. To do this, consider the behavior of the expression located in the denominator of the fraction (4).

$$\ln\left(\frac{qU_{mp}}{nkT}+1\right)^{\frac{nkT}{qU_{mp}}} \tag{8}$$

Let's find the ratio for different values of voltages at the point of maximum power U_{mp}, making the necessary mathematical transformations.

$$\frac{\ln\left(\frac{qU_{mp2}}{nkT}+1\right)^{\frac{nkT}{qU_{mp2}}}}{\ln\left(\frac{qU_{mp1}}{nkT}+1\right)^{\frac{nkT_1}{qU_{mp1}}}}=\frac{U_{mp1}}{U_{mp2}}\log_{\left(\frac{qU_{mp1}}{nkT}+1\right)}\left(\frac{qU_{mp2}}{nkT}+1\right) \tag{9}$$

when $U_{mp2} > U_{mp1}$ this fraction decreases.

IV. Discussion

As follows from the obtained formula (4), the fill coefficient decreases with increasing temperature, since an increase in temperature reduces the band gap of the semiconductor, thereby affecting most of the parameters of the semiconductor material that is part of the solar cell.

The above equation (9) shows that the temperature sensitivity of a solar cell depends on the voltage of the open circuit of the solar cell, and solar cells with a higher voltage are less affected by temperature.

V. Conclusion

The work is devoted to the conversion of solar energy by solar panels into electric power. The article shows that one of the clue parameters for evaluating the efficiency of solar cells and photovoltaic cells, the fill factor decreases with increasing temperature, since an increase in temperature reduces the bandgap of the semiconductor, thereby affecting most parameters of the semiconductor material from which the solar panel is made. Also interesting is the result that the temperature sensitivity of a solar cell depends on the voltage of the open circuit of the solar cell, and the greater the no-load voltage, the less the influence of temperature.

When choosing solar panels, it is necessary that the no-load voltage is as high as possible to reduce the influence of the temperature factor. The obtained result can be useful for further engineering calculations and the production of solar modules.

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Gravitation ever Since and Forever

By Doron Kwiat

Abstract- This work presents a new approach to gravitation. Instead of seeing mass as a source of gravitation, the opposite is assumed here. Namely, gravitation has been there first and ever since. Masses were brought into the game later, following highly energetic interactions between electromagnetic fields (photons), with the gravitation field. These interactions resulted in photon annihilation and pair (or jets) production processes. Though pair production is forbidden kinematically in an empty space, it is allowed when the interaction of an incoming photon with gravitation field occurs. Quantum fluctuations in the gravitation field create very intense geometrical distortions in spacetime which in turn allows for photons to undergo momentum changes in favor of pair production processes.

Keywords: *gravitation; mass; planck length; quantization of space; quantization of time; quantum gravity; quantum fluctuations.*

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Gravitation ever Since and Forever

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The more mass created by these processes, the more is the distortion of the gravitation field and the more mutual attraction of masses to each other. This gradually leads to the accumulation of larger and larger masses.

Mass considerations, under general relativity, lead to Planck length. This in turn, brings to conclusion on quantization of space. Quantum fluctuations in space, lead us to the basic definition of time.

Keywords: gravitation; mass; planck length; quantization of space; quantization of time; quantum gravity; quantum fluctuations.

I. Introduction

Gravitation was discovered by Sir Isaac Newton, as published in the third volume of the Principia[1]. Newton proved that his laws of motion, together with the law of universal gravitation, explained the laws of planetary motion.

In 1915, Einstein had modified the concept and showed that gravitation is a field that becomes distorted under the presence of mass. Hence the force of gravitation is due to bending of the field lines of the gravitation field as a result of a nearby massive object.

General relativity, is the geometric theory of gravitation published by Albert Einstein and Marcel Grossman[2,3] in 1913. It is the basis for the description of gravitation in modern physics. General relativity describes gravity as a geometric property of four-dimensional spacetime. In particular, the curvature of spacetime is directly related to the energy and momentum of matter and radiation present.

In the search for quantization of the gravitational field, current assumption is that gravitation is mediated by quantum particles named gravitons, Gravitons are assumed to be the bosons which carry the gravitational force. Just like photons carry the electromagnetic force.

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They would be a microscopic phenomenon that will dominate quantum fluctuations at high intensity gravitation fields.

II. Mass

Mass as we know it is a collection of elementary particles (elementary particles may be massive or massless). Gravitation affects mainly cosmic objects because its effect falls off slowly with distance. Other forces (weak and strong) fall off rapidly with distance.

At short distances, the effects of the electromagnetic, weak, and strong forces shield off the effect of gravitation. Nevertheless, gravitational attraction affects both at small, as well as large distances. It affects stellar objects, as well as all elementary particles.

All elementary particles (see appendix) are either massive (with rest mass $m_0 > 0$), or massless (with rest mass $m_0 = 0$).

Massive elementary particles are fermions (Dirac particles).

Massless elementary particles are bosons.

An exception to these, is the massive weak bosons $W^{\pm}$, Z, and Higgs. But their half-lives are so short (of the order of 10^{-26} seconds), that their spatial existence is limited to distances of no cosmological effect. ($\sim 10^{-26}/3\text{x}10^{8} \approx 10^{-32}$cm, but still within the Planck distance).

Fermions are confined to 4 dimensions[12] and can never cross to an extension of our universe to higher dimensions.

All particles, including bosons, have to move, according to gravitational principles of general relativity, along with the gravitational geodesic 2-dimensional tensor $8^{\mu\nu}$:

$$ds^2 = dx_\mu dx_\nu 8^{\mu\nu}$$

Massless particles must, according to relativity, move at the speed of light c ($\approx 3\text{x}10^{8}$ m/sec). c is a universal constant.

The reason is that the mass m of a particle moving at speed v, is given by

$$m = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} m_0$$

and unless $m_0 \to 0$ where $v \to c$, m becomes infinite.

According to the confinement assumption[13], the universe is made of two sub-universes. All particles in one sub-universe (for instance, our universe) can never reach the other sub-universe (a parallel universe). Each

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of these sub-universes has 4 dimensions. One may point from one sub-universe, to the origin of the other (parallel) sub-universe, with the use of a 3-dimensional pointer which start point is at 3 coordinates of one sub-universe and its endpoint is at 3 coordinates of the second sub universe.

Therefore, the whole universe is an 11-dimensional universe (4+4+3).

The only common to both sub-universes is the gravitational field.
The universe is made of the so-called gravitation field.

a) What is Gravitation?

Since Newton, scientists believe that gravitation is caused by the presence of mass. Mass was considered to be the central source of the gravitational field. It is governed by a universal constant G ($=6.6743\times10^{-11}$ [Nm^2/Kg^2]), representing the magnitude of the force which falls off inversely proportional to the square of the distance from the mass center. It is also known[14] that this is only true for a distance greater than the radius of the mass and falls off linearly with the distance from outer radius of the mass to its center.

Attraction between masses is caused by gravitational forces.

Einstein has suggested that gravitational forces are the result of the distortion of gravitational field caused by the presence of mass.

Any particle moving in space, will simply follow the gravitational field lines along the geodesic.

Therefore, if field lines are bent, the object will behave as if a force is applied to it. Hence its trajectory in space appears to be that of a body under gravitational attraction.

Even moving massless elementary particles will be diverted from a free trajectory, and will appear to undergo such an attraction.

b) A new concept – gravitation is the source for everything

Our current concept says that mass is the source of gravitation and that the presence of mass creates distortion in the geodesic of space-time in our 4-dimensional universe.

One must ask. Is mass the source of gravitation? Is gravitation caused by the presence of mass? What if this assumption is wrong and one must change the concept?

One possibility is that gravitation has always been there. It is a field of 11 (and maybe more) dimensions, regardless of masses.

c) Assume, masses were introduced into the gravitational field after it was already there.

Once a mass is introduced somehow (by some mechanism that needs yet to be explained), it bends the gravitation field lines (see figure) and therefore creates the effect of attraction of other masses by gravitational field.

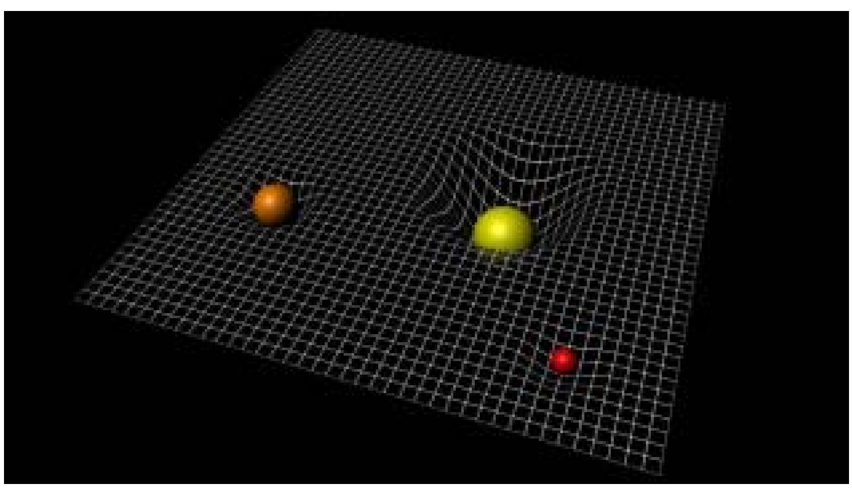

Figure 1: Spacetime curvature in the gravitation field caused by the presence of masses. ©European Space Agency

Once a mass is placed in this field, the field itself becomes curved (distorted) and any other object (massive or massless) passing in this distorted field is forced to move along this curved space field lines, as if being attracted by gravity.

Once the distorting mass is removed, the distortion disappears.

Notice that according to this concept, only inward distortion, negative curvatures ("valleys") are allowed. Otherwise, if by some mechanism (for instance, antigravitation) positive curvature ("hills") were allowed to occur, then we would have seen anti-gravity. Masses would then repel each other instead of attracting. If this was the case everywhere, our universe could never exist since all its mass would have eventually disappeared (dispersed) into infinity. Yet, a mixture of gravity and antigravity ("valleys" and "hills") is a possibility.

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When studying elementary particles, we learn that particles have properties like charge and spin, while their antiparticles have the same properties but of opposite signs. However, all massive elementary particles without exception have positive mass.

If, for some reason, there would be elementary particles with negative mass, we would see them bending the gravitational field in the opposite direction. Thus, creating "hills" (positive curvatures) instead of "valleys" (negative curvatures).

So far we have never observed such a phenomenon.

III. Quantum Gravity

The current theory of gravity is *general relativity*. Similarly, quantum mechanics explains matter, energy and causality. These two theories, one deterministic and the other probabilistic, both experimentally supported, have opened a major conceptual revolution in physics.

However, they appear to be incompatible: deterministic vs. probabilistic, large scale vs. microscopic scale.

The revolution opened by general relativity and quantum mechanics at the beginning of the 20th century is not concluded yet, and a new synthesis is required.

Quantum gravity, merging general relativity and quantum mechanics should be this new synthesis.

Contradictions in the known laws of nature require a theory that can resolve the clash between the laws of gravity and those of quantum mechanics.

Gravity and quantum mechanics have been developed and confirmed separately in countless experiments over the last century.

But when applied together they produce nonsense. Quantum mechanics is a probabilistic theory, whereas gravitation theory is deterministic, with no place for probabilities.

Quantum mechanics, though verified experimentally, relies on complex numbers representation and is unfortunately perceived by many as a magical, mysterious world of complex wave functions and Hermitian operators. It was shown[15], though that it is just a real-world representation, masked in complex representation. Though making the representation easier mathematically, it hides the true physics behind it. Instead of complex wave functions over a complex Hilbert space, and Hermitian operators, all can be represented by real wave functions in a real world and non-Hermitian operators.

Looking at the Schrodinger equation reveals that it is a description of two separate functions, coupled together.

This may give a clue to the real nature of elementary particles as being made of some form of coupled pairs of string-like fields.

Yet, classical gravitation, with general relativity, predicts a lower limit on space, below which classical mechanics fails. This lower limit as will later be proven is the so-called Planck distance.

A theory of quantum gravity would resolve these contradictions by applying the rules of quantum mechanics to effects below this lower limit of gravity. This willy endow the gravitational field with the randomness and uncertainty characteristic of quantization.

At first theorists thought there would be a simple fix: Just modify general relativity to allow the gravitational field to be in two places at once[4-9]. Physicists Richard Feynman[21] and Bryce DeWitt[22] developed such a theory in the 1960s, but they quickly realized that it worked only at small energies. In contrast, at high energies, when space-time becomes strongly curved, it produces infinite divergencies. This straight forward quantization, it turned out, is only an approximation to a more complete theory, one which should not suffer from the problem of infinities. It is this complete theory that physicists refer to as “quantum gravity.”

These first attempts at quantization break down when the gravitational force becomes very strong. This happens when large amounts of energy are compressed into a small region of space-time. Without a full theory of quantum gravity, one cannot understand what happens in the early universe.

Blackhole information loss problem is another strong indication that we need a theory of quantum gravity. As Stephen Hawking[11]demonstrated in 1974, quantum fluctuations of matter fields close to a black hole’s horizon lead to the production of particles, now called “Hawking radiation,” that make the black hole lose mass and shrink until nothing is left. Once the universe has cooled down sufficiently, black holes will evaporate, leaving behind nothing but radiation and (as will be soon argued) gravitation.

It is claimed, that this radiation carries no information besides its temperature. Information about what fell into the black hole is irretrievably destroyed during the evaporation.

Information that crosses the horizon is gone for good, which conflicts with quantum mechanics, which demands that information must be conserved. The information loss problem is a deep conceptual issue about the soundness of our theories.

Some phenomena where quantum gravity plays a major role are the microscopic structure of spacetime, early cosmology, black holes and astrophysical effects.

In the following, a short description of different approaches to solving quantum gravity are given. But for the moment, none of these offers a *complete* theory of quantum gravity and none of these have any experimental support. These theories are tentative at present.

IV. String Theory

String theory attempts to create a unified description of the physical world, where *all* physical entities are understood as manifestations of the energy states of a single object: a string.

Gravity emerges in this theory as one of the aspects of the dynamics of the string. String theory can be defined in terms of a perturbation expansion around a fixed spacetime. In this formulation certain infinities of perturbative quantum general relativity do not appear. However, when summed-up, the entire series appears to be divergent. A definition of string theory as a perturbation expansion is not sufficient for describing genuine quantum gravitational phenomena, which appear in the nonperturbative regime.

In this needed nonperturbative formulation, the characteristic features of quantum gravity become manifest: for instance, the lack of fixed background space and time and the resulting conceptual difficulties.

V. Loop Quantum Gravity and Spinfoams

Loop quantum gravity[26] is an attempt to find a quantum version of general relativity.

The theory is consistent with the other fundamental theories (such as the standard model). Still, it does *not* unify gravity as a manifestation of the dynamics of a single physical entity.

Loop quantum gravity is based on general relativity. It offers a precise mathematical description of quantum spacetime. The granular properties of space can be explicitly computed. The *area* and the *volume* of any physical surface of region turns out to be "quantized" just as the energy of a hydrogen atom. Corresponding discrete values that area and volume can take have been computed accordingly. The quantum states of physical space are described by labeled graphs called *spin networks*[25]. Each node of a spin network represents an elementary "quantum of space", and the links between these indicates who is next to who, building the spatial structure. The main incompleteness of the theory regards the relation between the Planck scale and macroscopic physics, and the consistency of its classical limit.

Related to loop quantum gravity is a covariant approach to quantum that goes under the name of *spinfoam formalism*[27]. This is sometimes presented as the path-integral, or, covariant (Lagrangian) version of the canonical (Hamiltonian) loop formalism[28].

VI. Noncommutative Geometry

Einstein's discovery is that gravity, which is a dynamical field, is the geometry of spacetime. Quantum mechanics teaches us that dynamical quantities are noncommutative. It is therefore, natural, to suspect that the mathematics needed to describe quantum spacetime is a noncommutative version of geometry. A number of different formulations of such a noncommutative theory of geometry are under study[29].

VII. Quantum Space and Quantum Time

Quantum gravity is expected to force us to further modifications of the concepts of *space* and *time*, in order to make them compatible with quantum theory. Quantum gravity should be the theory of a probabilistic "quantum space" and "quantum time". Building the mathematical language and the conceptual structure for making sense of such notions of quantum space and quantum time is the challenge for a quantum theory of gravity.

VIII. The Planck Scale

Simple dimensional arguments show that the physical phenomena where quantum gravitational effects become relevant are characterized by the "Planck length" $\ell_p = \sqrt{\frac{\hbar G}{c^3}} = 1.616x10^{-35}\, m.$

Here $\hbar$ is the Planck constant that governs the scale of the quantum effects, *G* is the Newton constant that governs the strength of the gravitational force, and *c* is the speed of light, that governs the scale of the relativistic effects. All are assumed to be universal constants.

The Planck length is extremely small ($1.616x10^{-33}$). Current technology is not yet capable of observing physical effects at scales that are so small (although several recent suggestions of how it could be possible, have appeared[45].) However, until genuine quantum gravitational phenomena are directly or indirectly observed, we cannot confirm or falsify any of the current tentative theories.

Where did masses come from?

Mass is energy. Assuming a completely flat gravitational field with no masses at all, the only energy around is either that stored in the gravitational field, or, energy moving around in the form of super energetic electromagnetic radiation (photons).

These photons may annihilate and convert to massive particles. One important rule in these annihilation-creation processes is that energy, momentum, charge, and spins, must be conserved.

Once created, these elementary particles start collapse under mutual gravitational attraction.

But how can a photon undergo annihilation process in an empty space? Momentum conservation rules forbid such a process!

Yet, in the presence of a strong gravitation field, this becomes possible[37]. But where does a strong gravitational field come from, when the field is flat as

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assumed to be the case in the early stage of the universe?

The answer may be in quantum fluctuations. If the field fluctuates, then the derivatives of the metric may be very high. This creates very strong local accelerations due to the local interactions between the passing energetic photons with the tremendous local distortions of the otherwise flat gravitational field. It is at this microscopic level that gravitons, the presumed carriers of the gravitation field come into action.

This phenomenon may allow for annihilation processes and the creation of massive particles.

IX. Photon-Gravitation Interaction

As described already[37-44], the interaction of a photon with gravitational field is possible. This interaction results in energy-momentum loss by the photon. The results are that annihilation process of an incoming photon into some massive pair production becomes possible. For instance, a photon graviton annihilation pair production process.

Since no charges nor spins have been yet introduced to this model of a universe, the most expected process to occur is the creation of Higgs bosons. The Higgs boson has mass (1.25 GeV/c^2) but neither spin nor charge. The Higgs boson's half-life is 1.56^{-22} sec. It decays into one of the following possible pairs: a Bottom-anti Bottom pair, a two W bosons, a two gluons, a Tau-antiTau pair, two Z bosons, two photons, Muon-antiMuon pair, or various other decays.

The following figure describes these processes:

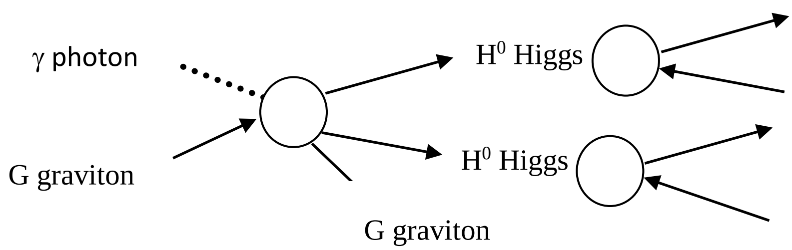

Figure 2: Photon annihilation Higgs pair production under graviton scattering

It will be therefore reasonable to presume that the earliest photon-gravity interactions were:

$$\gamma + grav.fluct. \rightarrow 2H^0 + \mathrm{G}$$

Here, *grav.fluct.* stands for gravitational fluctuations of some kind. For instance, interaction of photon with graviton has been analyzed recently[40,41]. It brought out the various features of the interaction between photons and gravitons that can be used in astrophysical observations[40,41,42,43].

Since gravitons are spin-2 particles, one must, in order to preserve spin, have an outgoing graviton in this photon-graviton scattering process[44].

The effective action for photons, developed there, demonstrates possible interactions between photons and gravitons at the quantum level. Thus, allowing with an outcome of a Jet of Higgs bosons as a result of gamma-graviton interaction.

If the gravitational field has always been there much before the introduction of masses, then how do one settle this the Big Bang theory?

The explosion of the early universe is just a phenomenon that involves masses. It of course has an effect on the distortion of the gravitational field. The early "valley" is gradually changing towards a flat manifold. Masses become less and less attracting (expanding universe). At a certain point, the flat universe will stop gravitation attraction completely (end of expansion).

Will the universe continue into an anti-phase? This means the distortion converts from flat to negative curvature (a hill) ? This will create the opposite effect of attraction and masses will start repelling each other. This may continue indefinitely (an endless dispersed universe), or, the flattening process may reach an end and stop at zero curvature.

At the point of zero curvature, gravitational forces stop altogether. Therefore, there are no pendulums or other repetitive processes available to measure time. The unavoidable conclusion is that time stops at that point and there is no meaning to physical processes anymore. This will mean the end of the universe as we know it.

The question remains though, is this a stable situation? Has the universe reached a stable equilibrium state?

Remember, all masses still exist. They are so far away from each other, that there are practically no gravitational forces between them.

During the process of expansion (cool down) energy must be released in the form of photons. The total energy of the universe must be conserved. Therefore, the equilibrium that was reached at the flattened state is unstable. The huge photon energy will prevent a steady state. Once this happens, some masses will start absorbing enough energy to increase their mass and so attraction will soon begin again and the universe will start collapsing again.

Gravitation is an 11-dimensional field in which everything is embedded (massive and massless particles).

Gravitation and mass co-exist in our universe. But which came first?
Were masses created after gravitation?
Suppose the opposite is true:

Masses came first, without the presence of gravitation. Gravitation emerged later on due the presence the masses.
Take the first mass created (if there are several, then pick one of them).

How can it create gravitation around it? If gravitational attraction is caused by bending of the gravitational field lines, this means that the first mass could not have attracted other masses. It did not have any field lines to bend.
This argument leads us to conclude:

1. Gravitational field was there before any masses were created.
2. This Primordial Gravitation field is the spacetime itself.
3. The concept of Vacuum should be abandoned, gravitation is the vacuum.
4. In the beginning there was gravitation field alone.
5. Gravitation is our spacetime grid.

Need that early gravitation field be flat? Not necessarily.

But assuming symmetry of space and with assumption on minimal energy state, it is the most reasonable assumption to be made.
Thus:

6. The Primordial gravitational field (spacetime) was flat and endless.

X. Spacetime Quantization

If one accepts the assumption that spacetime and gravitation field are the same, then quantization of gravity is quantization of spacetime.

This means that spacetime is an 11-dimensional grid, in which two 4-dimensional sub-universes co exist. Our universe and a parallel universe. Matter in one sub-universe is confined[9,10] in its 4-dimensional spacetime and can never reach the other sub-universe. However, the distortions in the gravitational grid are not confined. Hence, attraction of mass in our universe can result by distortion of the grid in the parallel universe.

We will not be able to measure the mass in the parallel universe causing the distortion, but we will be able to measure the gravitational effects.
We will refer to this phenomenon as "dark matter".

Why do we detect it only at very far galaxies? Probably, because the two sub-universes have departed already so much since their moment of creation, that their mutual effect expresses itself only at very far distances.

So where is, the long sought, quantization of spacetime?

One point which can be derived from general relativity and the constants of nature G, c, and h, is the quantum limit on mass density. This is dictated by dimensional analysis of the Planck's units and General Relativity. General relativity, therefore, leads to the quantization of gravity[11].

Simple dimensional analysis shows that quantum gravitational effects become relevant at the Planck length $\ell_p = \sqrt{\frac{\hbar G}{c^3}} = 1.616x10^{-35}$m. Here $\hbar$ is the Planck constant that governs the scale of the quantum effects, *G* is the Newton constant that governs the strength of the gravitational force, and *c* is the speed of light, that governs the scale of the relativistic effects. The Planck length is many times smaller than what current technology is capable of observing. Because of this, we have no direct experimental guidance for building a quantum theory of gravity.

Suppose there exists a quantum minimum for distance. We call it the Planck length and denote it by ℓ_p.

It is given by $\ell_p = \sqrt{\frac{\hbar G}{c}} = 1.616x10^{-35}$m.

Define in addition the Planck mass $m_p = \sqrt{\frac{\hbar c}{G}} = 2.176x10^{-8}\ \mathrm{Kg}$.

If this assumption is true, then the minimal spherical volume possible is $V = \frac{4\pi {\ell_p}^3}{3}$

Let m denote the mass of this minimal volume. Its density will be given by $\rho P =$

Since by assumption ℓ_p is the minimal possible length in nature, then for any mass m the density ρ_P is the maximum possible.

For a classical spherically symmetric object of mass m and radius R, the general relativistic limit gives[14]

$$d\tau = dt\sqrt{\left(1 - \frac{4\pi\rho G}{c^2}R^2\right)}$$

Since the expression in brackets must be real, we arrive at the restriction:

$$\rho \leq \frac{c^2}{4\pi G R^2}$$

For an object of any given mass m and radius R we have $\rho = \frac{m}{V} = \frac{3m}{4\pi R^3}$

Since for any mass m of radius R one must have $\rho = \frac{3m}{4\pi R^3} \leq \frac{c^2}{4\pi G R^2}$

The result is that for any mass m, of radius R, one must have $m(R) \leq \frac{Rc^2}{G}$

Obviously, the smaller the radius R, the smaller the allowed mass m.

Recall now, (by Planck's dimensionality analysis) that $\ell_p = \sqrt{\frac{\hbar G}{c}}$ and $m_p = \sqrt{\frac{\hbar c}{G}}$

Therefore

$$\mathrm{m} \leq \frac{\ell_p c^2}{G} = m_p$$

Hence, for any mass m, whose radius is ℓ_p

$$\mathrm{m} \leq m_p$$

And since

$$\rho = \frac{m}{V} \leq \frac{m_p}{V} = \rho_P$$

We have the result that ρ_P is the maximal possible density, namely Planck density.

In other words, for any given radius R, the mass m(R) becomes smaller and smaller with R. Still when one reaches the smallest possible radius ℓ_p, the mass must be smaller than the Planck mass m_p, and so, the density will always be smaller than the Planck density ρ_P.

One can reduce the radius R. Still, the density will never exceed the Planck density.

$$\lim_{R\to\ell_p} \rho(R) = \left(\frac{\ell_p}{R}\right)^3 \rho_P$$

Assume next, that the sphere has density $\rho(r)$, which varies with distance r from its center. Assume the sphere is of minimal possible radius ℓ_p.

We need to calculate the radius R of a quantized particle by its average normalized density to obtain a reduced average radius.

By comparing the integrated variable density over the Planck radius, to a volume, with constant density ρ_0 one obtains:

$$4\pi \int_0^{\ell_p} r^2\, \rho(r) dr = \frac{4\pi\rho_0 {\ell_p}^3}{3}$$

By definition, the average classical distance $\langle r^2 \rangle$ is given by the integral over the normalized density:

$$\langle r^2 \rangle \stackrel{\text{def}}{=} \frac{1}{\ell_p} \int_0^{\ell_p} r^2\, \rho(r)/\rho_0\, dr$$

Thus

$$4\pi\ell_p\rho_0\langle r^2 \rangle = \frac{4\pi\rho_0 {\ell_p}^3}{3}$$

and so

$$\langle r \rangle = \sqrt{\langle r^2 \rangle} = \frac{1}{\sqrt{3}}\ell_p$$

Hence, the actual measured classical radius R is given by

$$R = \langle r \rangle = \frac{1}{\sqrt{3}}\ell_p$$

The above result shows how the lower limit of the classical gravitation theory by Einstein, is related to the Planck length, which is a quantum phenomenon posed by the dimensional analysis of the universal constants.

Therefore, classical relativity and the relationship between the universal constants leads to the quantization of space.

XI. Quantization of Time

So far, it was shown that general relativity leads to the conclusion about quantization of space. Notice however, that by quantization of space we mean that space is a grid, just like in loop gravity.

This does not mean yet that quantum effects must take place. The only quantum effect so far was in the assumption, that it is a must, for the plausibility of photon annihilation and pair production processes to take place, even in the event of a flat primordial gravitation field.

Still, there remains a question – is time quantized?

Time is something we have based on repetitions. Be it the motion of stellar objects in orbits, or the motion of the pendulum. These are the origins of our concept of time and its measurement.

In modern days, we measure time by using atomic clocks. The second is defined as the duration of 9,192,631,770 cycles of radiation due to the transition between two energy levels of the ground state of the Cesium-133 atom, at rest at a temperature of absolute zero.

One way to assign time to processes is by averaging. For instance, measuring decay time or half-life time. In other words, one can measure <t> and this gives time a quantization aspect. Irrespective of how accurate our "time" measurement is, we will never be able to be accurate enough and there will always be an uncertainty in such measurement,

Obviously, in the absence of gravitation, there would be neither stellar nor pendulum repetitions. Therefore, in the absence of gravitation, time becomes meaning less to us.

The atomic decay process would only be possible if atoms existed. But as we assumed. Gravitation was there, as flat as Denmark, with no elementary particles present. Therefore, time did not exist.

Once we allow for quantum fluctuation to exist, then any passing photon would start the process of elementary particles creation, followed by gravitational attraction (caused by space distortion) and then time started ticking with the creation of repetitions.

We may thus assume that time was created by gravity and quantum. Without the two, time has no meaning.

XII. Conclusion

Gravitation is spacetime. It is the grid where everything occurs. When primordial electromagnetic energy hovers in this grid, interactions with this empty grid gives rise to the production of massive elementary particles. These interactions are allowed, because of the quantization of space. This quantization allows for very strong distortions in the fabric of the gravitation field, which in turn allows for the annihilation and pair production processes to occur. Most reasonable, because of symmetry reasons, these were Higgs particles to be produced first.

Without those quantum fluctuations, the otherwise gravitation field would have remained flat and hence no pair production could have taken place because kinematics and momentum conservation would forbid it.

Once elementary particles are created, they bend the gravitational fabric and start attracting each other. This process of mass accumulation went on and on and the masses have become large enough to create the cosmos as we know it.

Finally, only the coexistence of gravitation and quantum fluctuations could give time meaning.

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Appendix

a) Elementary particles

An elementary particle or a fundamental particle is a subatomic particle with no (currently known) substructure, i.e. it is not composed of other particles. Elementary particles include the fundamental fermions (quarks, leptons, antiquarks, and antileptons), which generally are "matter particles" and "antimatter particles", as well as the fundamental bosons (gauge bosons and the Higgs boson), which generally are "force particles" that mediate interactions among fermions. Ordinary matter is composed of atoms.

Subatomic constituents of the atom were first identified in the early 1930s; the electron and the proton, along with the photon, the particle of electromagnetic radiation.

Via quantum theory, protons and neutrons were found to contain quarks – up quarks and down quarks – now considered elementary particles.

b) Standard Model

The Standard Model includes members of several classes of elementary particles, which in turn can be distinguished by other characteristics, such as mass, electric charge, color charge, and spin.
All particles can be summarized as follows:

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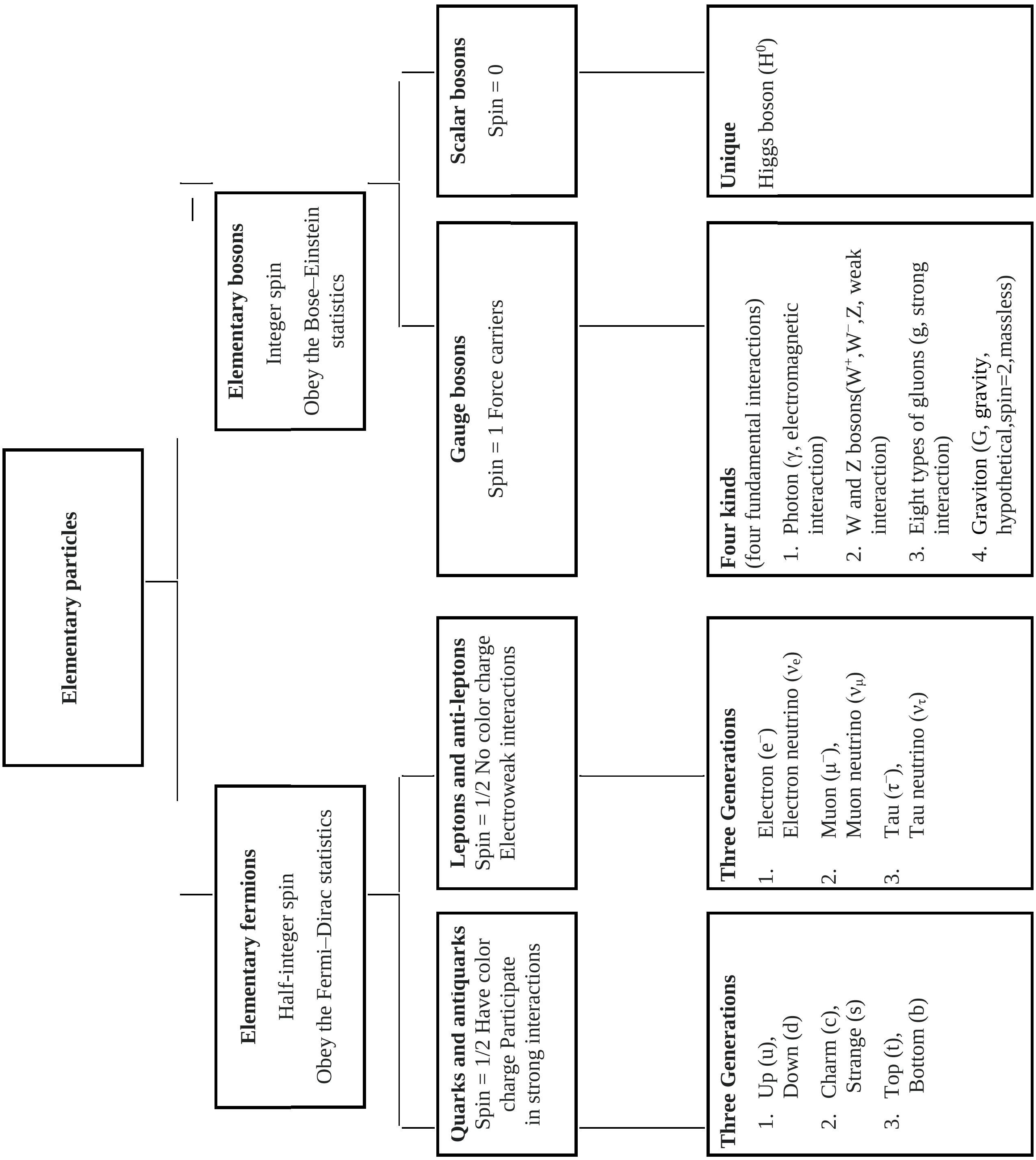
Elementary particles
Elementary fermions
Half-integer spin
Obey the Fermi–Dirac statistics
Elementary bosons
Integer spin
Obey the Bose–Einstein statistics
Quarks and antiquarks
Spin = 1/2 Have color charge Participate in strong interactions
Leptons and anti-leptons
Spin = 1/2 No color charge Electroweak interactions
Gauge bosons
Spin = 1 Force carriers
Scalar bosons
Spin = 0
Three Generations
1. Up (u), Down (d)
2. Charm (c), Strange (s)
3. Top (t), Bottom (b)
Three Generations
1. Electron (e^-) Electron neutrino (ν_e)
2. Muon (μ^-), Muon neutrino (ν_μ)
3. Tau (τ^-), Tau neutrino (ν_τ)
Four kinds
(four fundamental interactions)
1. Photon (γ, electromagnetic interaction)
2. W and Z bosons(W^+,W^-,Z, weak interaction)
3. Eight types of gluons (g, strong interaction)
4. Graviton (G, gravity, hypothetical,spin=2,massless)
Unique
Higgs boson (H^0)

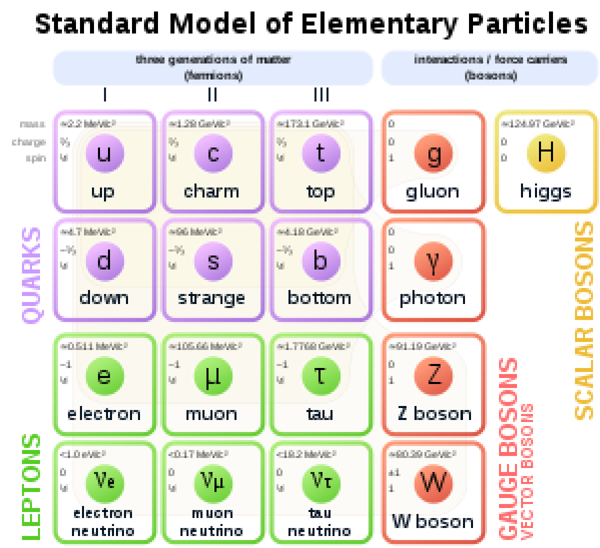

Figure 3: The Standard Model of elementary particles: Quarks in purple, Leptons in green and with the gauge bosons in the fourth column in red. Last in yellow is the Higgs boson

c) *Gauge boson*

Photons, W and Z bosons, gluons, and the hypothetical gravitons are gauge bosons. All known gauge bosons have a spin of 1; for comparison, the Higgs boson has spin zero. Therefore, all known gauge bosons are vector bosons.

Gauge bosons are different from the other kinds of bosons: first, fundamental scalar bosons (the Higgs boson); second, mesons, which are composite bosons, made of quarks; third, larger composite, non-force-carrying bosons, such as certain atoms.

In particle physics, a gauge boson is a bosonic elementary particle that mediates interactions among elementary fermions, and thus acts as a force carrier. Gauge bosons can carry any of the four fundamental interactions of nature.[1][2] Elementary particles, whose interactions are described by a gauge theory, interact with each other by the exchange of gauge bosons; usually as virtual particles.

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The Standard Model of particle physics recognizes four kinds of gauge bosons: photons, which carry the electromagnetic interaction; W and Z bosons, which carry the weak interaction; and gluons, which carry the strong interaction.

d) *Multiplicity of gauge bosons*

In a quantized gauge theory, gauge bosons are quanta of the gauge fields. Consequently, there are as many gauge bosons as there are generators of the gauge field. In quantum electrodynamics, the gauge group is $U(1)$; in this simple case, there is only one gauge boson, the photon. In quantum chromodynamics, the more complicated group $SU(3)$ has eight generators, corresponding to the eight gluons. The three W and Z bosons correspond (roughly) to the three generators of $SU(2)$ in electroweak theory.

e) *Massive gauge bosons*

Due to gauge invariance, gauge bosons are described mathematically by field equations for massless particles. Therefore, at a naïve theoretical level, all gauge bosons are required to be massless, and the forces that they describe are required to be long-ranged. The conflict between this idea and experimental evidence that the weak and strong interactions have a very short range, requires further theoretical insight.

According to the Standard Model, the W and Z bosons gain mass via the Higgs mechanism. In the Higgs mechanism, the four gauge bosons (of $SU(2)\times U(1)$ symmetry) of the unified electroweak interaction couple to a Higgs field. This field undergoes spontaneous symmetry breaking due to the shape of its interaction potential. As a result, the universe fluctuates around nonzero Higgs vacuum expectation value (VEV). This VEV couples to three of the electroweak gauge bosons (the Ws and Z), giving them mass; the remaining gauge boson remains massless (the photon). This theory also predicts the existence of a scalar Higgs boson, which has been observed in experiments.

f) Gravitons

The fourth fundamental interaction, gravity, may also be carried by a boson, called the graviton. In the absence of experimental evidence and a mathematically coherent theory of quantum gravity, it is unknown whether this would be a gauge boson or not.

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From Majorana Neutrino and Dark Neutrino v_0 to Dark Spin Particles

By ShaoXu Ren

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Abstract- In current theory of particle physics, the values of Casimir Operator, that is abbreviated to CO, of spin angular momentum for elementary particles are thought to be greater than zero. Both Majorana Neutrino ν and Majorana Antineutrino $\bar{\nu}$ are *all* with CO $\frac{+3\hbar^2}{4}$. Now the above limited region of CO is enlarged, this paper assumes that for the particles, the values of CO are still positive; for the antiparcles, however, the values of CO are negative. In this point of view, something similar is expected to happen in the case of Majorana Neutrino ν and Majorana Antineutrino $\bar{\nu}$. The Majorana Neutrino ν would be still with CO $\frac{+3\hbar^2}{4}$ and the Majorana Antineutrino $\bar{\nu}$ would be with CO $\frac{-3\hbar^2}{4}$. Further, leading to the possible existence of the so-called *Dark Neutrino*, *DN* or $\nu_0 . \nu_0$ is with CO $0\hbar^2$ that is the superposition of Majorana Neutrino ν_L(CO$\frac{+3\hbar^2}{4}$) and Majorana Antineutrino $\bar{\nu}_R$(CO$\frac{-3\hbar^2}{4}$). And ν_0 is the one-half spin fermion with zero-charge $0e$ and zero-CO $0\hbar^2$, which is a more neutral neutrino than Majorana neutrino. ν_0 is one kind of Peculiar Dark Spin Particles.

Keywords: majorana neutrino, dark neutrino, casimir operator, particle, antiparticle, left-handed neutrino, right-handed antineutrino, dark spin particles.

GJSFR-A Classification: FOR Code: 029999

FROMMAJORANANEUTRINOANDDARKNEUTRINOTODARKSPINPARTICLES

Strictly as per the compliance and regulations of:

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ShaoXu Ren

Abstract- In current theory of particle physics, the values of Casimir Operator, that is abbreviated to CO, of spin angular momentum for elementary particles are thought to be greater than zero. Both Majorana Neutrino ν and Majorana Antineutrino $\bar{\nu}$ are *all* with CO $\frac{+3\hbar^2}{4}$. Now the above limited region of CO is enlarged, this paper assumes that for the particles, the values of CO are still positive; for the antiparcles, however, the values of CO are negative. In this point of view, something similar is expected to happen in the case of Majorana Neutrino ν and Majorana Antineutrino $\bar{\nu}$. The Majorana Neutrino ν would be still with CO $\frac{+3\hbar^2}{4}$ and the Majorana Antineutrino $\bar{\nu}$ would be with CO $\frac{-3\hbar^2}{4}$. Further, leading to the possible existence of the so-called *Dark Neutrino*, *DN* or ν_0. ν_0 is with CO $0\hbar^2$ that is the superposition of Majorana Neutrino ν_L(CO $\frac{+3\hbar^2}{4}$) and Majorana Antineutrino $\bar{\nu}_R$ (CO $\frac{-3\hbar^2}{4}$). And ν_0 is the one-half spin fermion with zero-charge $0e$ and zero-CO $0\hbar^2$, which is a more neutral neutrino than Majorana neutrino. ν_0 is one kind of Peculiar Dark Spin Particles.

Keywords: *majorana neutrino, dark neutrino, casimir operator, particle, antiparticle, left-handed neutrino, right-handed antineutrino, dark spin particles.*

I. Introduction

What is the physical certification mark that distinguishes particles and antiparticles ? " When considering an electrically charged particle, say an electron, the difference between this particle and its antiparticle is evident: one has charge $-e$, the other $+e$. What happens when the particle is neutral? There is no general answer,......" then the graphic expression of *two states of a Majorana massive field* is given by G. Fantini, A. Gallo Rosso, V. Zema and F. Vissani [1], that indicates Majorana particle [2] is a neutrial charge massive fermion consist of two opposite charges, charge $-e$ and charge $+e$.

We see Majorana particle possesses a symmetrical picture shown in Table 1 and Figure 1. Here, the lefthand demonstrates the four states of a Dirac massive field, or a Dirac particle and a Dirac antiparticle. The righthand shows the two states of a Majorana massive field. Majorana particle is a neutrial fermion made of negative charge $-e$ and positive charge $+e$. , that called the *duality of charges*. All these particles mentioned are with the same CO $\frac{+3\hbar^2}{4}$ and with spin eigenvalues $+\hbar/2$ and $-\hbar/2$ respectively.

Being inspired, similar to Majorana did, this paper poses an assumption: Except the *duality of charges* of particle charge and antiparticle charge, maybe, there is another so-called *duality of Casimir Opertors* of positive Casimir Operator and negative Casimir Operator shown in Table 2 and Figure 2 .

In contrast with the lefthands of the two Figures, now, the four states of a DIrac massive field are replaced by a Majorana massive field, or replaced by a Majorana particle and a Majorana antiparticle, and at the same time, Majorana particle and a Majorana antiparticle are carry opposite CO each other.

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The righthands of the two Figures indicate: a *more neutrial* fermion that comprises *not only* positive charge $+e$ and negative charge $-e$, *but also* positive Casimir Operator $\frac{+3\hbar^2}{4}$ and negative Casimir Operator $\frac{-3\hbar^2}{4}$, than the Majorana Neutrino did. There are two dualities now the *more neutrial* fermion is so-called *Dark Neutrino*, *DN* or ν_0 that labelled with two physical quantities $0\,e$ and $0\,\hbar^2$.

Table 1: $0\,e \;=\; (-\,e) \;+\; (+\;e)$

	Charge	‖	Casimir Operator
Dirac particle	$-\,e$	‖	$\frac{+3\hbar^2}{4}$
— *Majorana Neutrino* —	— $0\,e$ — — —	— —	— $\frac{+3\hbar^2}{4}$ —
Dirac antiparticle	$+\,e$	‖	$\frac{+3\hbar^2}{4}$

$\Downarrow \qquad \Downarrow \qquad \Downarrow \qquad \Downarrow$

Table 2: $0\,\hbar^2 \;=\; (+\,\frac{3\hbar^2}{4}) \;+\; (-\,\frac{3\hbar^2}{4})$

	Casimir Operator	‖	Charge
Majorana Neutrino ν	$+\,\frac{3\hbar^2}{4}$	‖	$0\,e$
— *Dark Neutrino* ν_0 —	— $0\,\hbar^2$ —	— — — —	— $0\,e$ —
Majorana Antineutrino $\bar{\nu}$	$-\,\frac{3\hbar^2}{4}$	‖	$0\,e$

The following: schematics of Table 1 and table 2

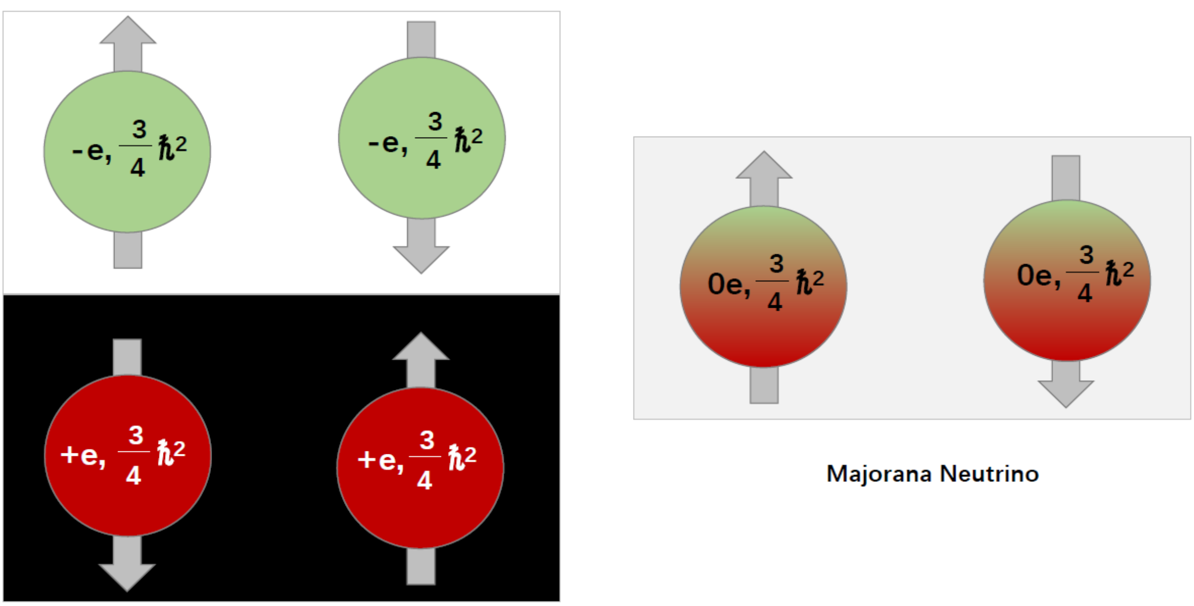

Figure 1: $0\,e \;=\; (-\,e) \;+\; (+\;e)$

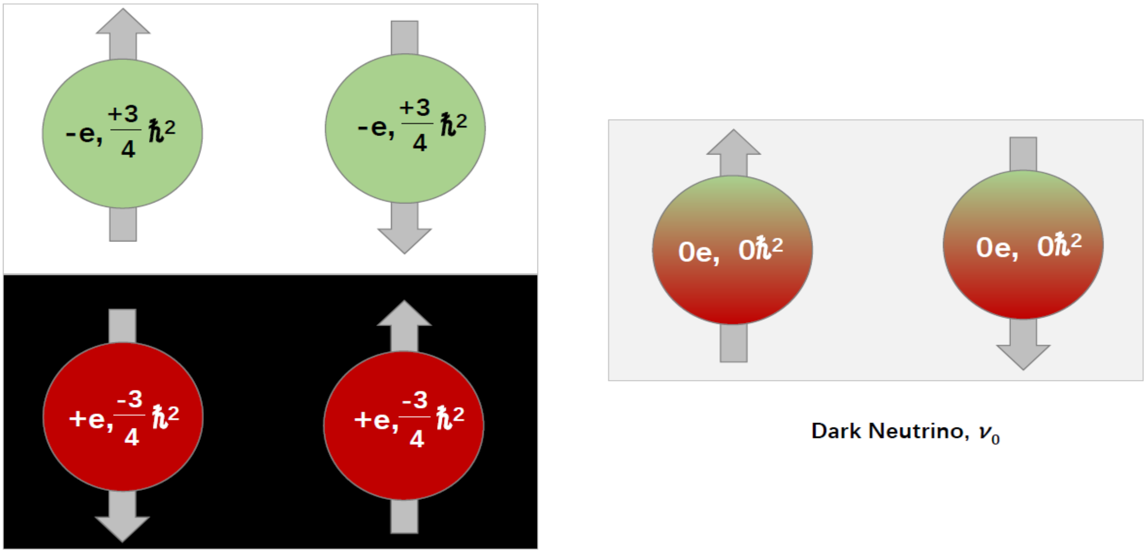

Figure 2: $0\,\hbar^2 \;=\; (+\frac{3\hbar^2}{4}) \;+\; (-\frac{3\hbar^2}{4})$

II. The Conditional Statements for Casimir Operators in Table. 2 and Figure. 2

The Casimir operator, a quantum operator, is the square sum $j^2 = j_1^2 + j_2^2 + j_3^2$ of three operator components of angular momentum $\vec{j}$. Due to the Hermiticity of angular momentum, the square sum always are $j^2 \geqq 0$, that is, the CO is a *positive* operator.

In particle physics Pauli matrices are positive operators, so the Casimir operators s^2 of spin 1/2 particles, $s_i = \frac{1}{2}\sigma_i$. $s^2 = \vec{s}\cdot\vec{s}$, are positive too. Pauli matrices are the constituents of Dirac equation, further, the solutions of Dirac equation naturally implies *a priori concept* (0) below

- $s^2(\text{particle, antiparticle}) = \vec{s}\cdot\vec{s} = \frac{+3\hbar^2}{4} = (\frac{1}{2})(\frac{1}{2}+1) \geq 0\hbar^2$ (0)

Formula (0) shows: In Table.1 and Figure.1, the *Spin* Casimir operators $s^2(e^-)$ and $s^2(e^+)$ of both *electron* and *positron* are all *positive* operators. further, (0) is suitable for $s^2(\nu)$ and $s^2(\overline{\nu})$ of *neutrinos* ν and *antineutrinos* $\overline{\nu}$ as well in current theory.

This paper bases on the assumption Table.2 and Figure.2, so we see formula (0) is merely the CO of spin 1/2 particles, and however, formula (1) is the CO of spin 1/2 antiparticles

- $s^2(\text{antiparticle}) = \vec{s}\cdot\vec{s} = \frac{-3\hbar^2}{4} = (\frac{i}{2})(\frac{i}{2}+i) < 0\hbar^2$ (1)

And the formula (2) is the CO of the peculiar *Dark Neutrino* ν_0

- $s^2(DN\ \text{Particle}) = \vec{s}\cdot\vec{s} = 0(0+1) = 0\hbar^2$ (2)

(1) and (2) really are two amusing questions, to find them, let us appeal to the math frame STS.

III. Spin Topological Space, STS (Complex Region)

Go back to Spin Topological Space, STS [3], this time we concern about another important concept: Casimir Operator π^2 of spin 1/2 particles.and spin 1/2 antiparticles.

Remind: the two dimension Hermitan spin matrix operators $\vec{s}=\frac{1}{2}\vec{\sigma}$ that appear in formula (0) are instead by the infinite dimension matrices $\vec{\pi}_{j,k}$, and 1st and 2nd Hermitan components s_1 and s_2 become *non-Hermitan* matrices π_1 and π_2.

Firstly, in order for the assumption (1) to be self-consistent, Spin Topological Coordinate should be extended from real region (j,k) to complex region $(j,b;k,d)$ (3) (4) below

■ Define the transformation

$$\pi_j^+ \Rightarrow \pi_{j,b}^+ = \pi_j^+ + ibI_{+1} \tag{3}$$

$$\pi_k^- \Rightarrow \pi_{k,d}^- = \pi_k^- + idI_{-1} \tag{4}$$

Imaginary numbers b and d now are introduced to raising operator π_j^+ and lowering operator π_k^- respectively.

Using $\pi_{j,b}^+, \pi_{k,d}^-$ to construct the spin angular momentum in complex region

$$\pi_{1\,;j,b\,,\,k,d} = \frac{1}{2}(\pi_{j,b}^+ + \pi_{k,d}^-) \tag{5}$$

$$\pi_{2\,;j,b\,,\,k,d} = \frac{1}{2i}(\pi_{j,b}^+ - \pi_{k,d}^-) \tag{6}$$

$$\pi_{3;j,b\,,\,k,d} = \frac{1}{2}(\pi_{j,b}^+\pi_{k,d}^- - \pi_{k,d}^-\pi_{j,b}^+) \tag{7}$$

$$= \pi_0(0) + \frac{1}{2}(j+k+1) + i\frac{1}{2}(b-d) \tag{8}$$

It can be shown, $\vec{\pi}_{j,b\,,\,k,d}$ still satisfies the commutative algebra rule (9), which is in accord with the Lie algebraic theory of infinite dimension matrix rotation group.

$$\vec{\pi}_{j,b\,,\,k,d} \times \vec{\pi}_{j,b\,,\,k,d} = i\vec{\pi}_{j,b\,,\,k,d} \tag{9}$$

Further, get the representation of invariant, Casimir Operator formula below

$$\pi_{j,b\,,\,k,d}^2 = \pi_{1\,;j,b\,,\,k,d}^2 + \pi_{2\,;j,b\,,\,k,d}^2 + \pi_{3\,;j,b\,,\,k,d}^2$$

$$= \frac{1}{4}\{\,(j-k)^2 - (b+d)^2 - 1\,\} + i\frac{1}{2}(j-k)(b+d) \tag{10}$$

■ The explicit expressions of Casimir Operators, which are in accordance with Table.2 and Figure.2, are given

For neutrino ν

$$j - k = \pm\frac{1}{\sqrt{2}}\sqrt{\frac{13}{\sqrt{10}} + 4}, \qquad b + d = \pm\frac{1}{\sqrt{2}}\sqrt{\frac{13}{\sqrt{10}} - 4} \tag{11}$$

For antineutrino $\bar{\nu}$

$$r - s = \pm\frac{1}{\sqrt{2}}\sqrt{\frac{7}{\sqrt{10}} - 2}, \qquad a + c = \mp\frac{1}{\sqrt{2}}\sqrt{\frac{7}{\sqrt{10}} + 2} \tag{12}$$

After substituting them into (10) obtain two pairs of conjugative CO between ν and $\bar{\nu}$

$$\pi^2_{j,b\,,\,k,d}(\nu) = \frac{+3}{4} + i\varphi = \frac{+1}{2}\left(\frac{+1}{2}+1\right)\left(1 + i10^{\frac{-1}{2}}\right)\hbar^2 \tag{13.1}$$

$$\pi^2_{r,a\,,\,s,c}(\bar{\nu}) = \frac{-3}{4} - i\varphi = \frac{+i1}{2}\left(\frac{+i1}{2}+i1\right)\left(1 - i10^{\frac{-1}{2}}\right)\hbar^2 \tag{13.2}$$

$$\pi^2_{j,b\,,\,k,d}(\nu) = \frac{+3}{4} - i\varphi = \frac{+1}{2}\left(\frac{+1}{2}+1\right)\left(1 - i10^{\frac{-1}{2}}\right)\hbar^2 \tag{14.1}$$

$$\pi^2_{r,a\,,\,s,c}(\bar{\nu}) = \frac{-3}{4} + i\varphi = \frac{+i1}{2}\left(\frac{+i1}{2}+i1\right)\left(1 + i10^{\frac{-1}{2}}\right)\hbar^2 \tag{14.2}$$

$$\frac{+3}{4} = 0.75, \qquad \varphi = \frac{3}{4\sqrt{10}} \simeq 0.237 \tag{15}$$

We see the real part, $\frac{+3}{4}$ and $\frac{-3}{4}$, of the above formulas are just the previous assumption (0) and (1), the Casimir operators for spin 1/2 particles and for spin 1/2 antiparticles repectively, which are what we except to be originally.

IV. Casimir Operator of DN, Dark Neutrino ν_0

For the implement of the progress of $(+\frac{3\hbar^2}{4}) + (-\frac{3\hbar^2}{4}) = 0\,\hbar^2$, ν_0 is written into the superposition of spin angular momentums $\vec{\pi}_{j,b\,,\,k,d}(\nu)$ and $\vec{\pi}_{r,a\,,\,s,c}(\bar{\nu})$ in complex region below

$$\pi^+(\nu_0) = \Pi^+_{j,b\,,\,r,a}(\nu + \bar{\nu}) = \frac{1}{2}\{\pi^+_{j,b}(\nu) + \pi^+_{r,a}(\bar{\nu})\} \tag{16}$$

$$\pi^-(\nu_0) = \Pi^-_{k,d\,,\,s,c}(\nu + \bar{\nu}) = \frac{1}{2}\{\pi^-_{k,d}(\nu) + \pi^-_{s,c}(\bar{\nu})\} \tag{17}$$

and

$$\vec{\Pi} \times \vec{\Pi} = i\vec{\Pi} \tag{18}$$

In much same way as discussed in section III by using (11) and (12), obtain an important formula below

$$\blacksquare \quad \Pi^2_{j,b\,,\,r,a\,;\,k,d\,,\,s,c}(\nu + \bar{\nu}) = \{\,0(0{+}1) \pm i\Phi\,\}\hbar^2 \tag{19}$$

Thus we have CO of DN

$$\pi^2_{w,e\,,\,z,f}(\nu_0) = \Pi^2(\nu + \bar{\nu}) = 0\hbar^2 \pm i\Phi\hbar^2 \tag{20}$$

where

$$\Phi = \tfrac{1}{8}(10^{\frac{+1}{2}} - 10^{\frac{-1}{2}}) \simeq 0.356 \tag{21}$$

and

$$w - z = \tfrac{1}{2}(10^{\frac{+1}{4}} + 10^{\frac{-1}{4}}) \tag{22}$$

$$e + f = \tfrac{1}{2}(10^{\frac{+1}{4}} - 10^{\frac{-1}{4}}) \tag{23}$$

We see the real part $0(0{+}1)\hbar^2$ of (20) is just the previous assumption (2), which is the CO of *Dark Neutrino* ν_0, and is in accord with the CO which appears in Table, 2, Figure 2. and formular (2).

V. THE SPIN THIRD COMPONENTS OF DN, DARK NEUTRINO ν_0

For convenience, in the following we take the imaginarys (ref.(8)) of the third components of neutrino ν and antineutrino $\bar{\nu}$ to be zero

$$b = d, \quad a = c \tag{24}$$

$$\blacktriangleright \quad \pi_{3;\,j,b\,,\,k,d}(\nu) = \pi_0(0) + \tfrac{1}{2}(j + k + 1) \tag{25}$$

$$\blacktriangleright \quad \pi_{3;\,r,a\,,\,s,c}(\bar{\nu}) = \pi_0(0) + \tfrac{1}{2}(r + s + 1) \tag{26}$$

Further obtain

$$\blacksquare \quad \Pi_{3;\,j,b\,,\,r,a\,;\,k,d\,,\,s,c}(\nu + \bar{\nu}) = \tfrac{1}{2}\{\pi_{3;\,j,b\,,\,k,d}(\nu) + \pi_{3;\,r,a\,,\,s,c}(\bar{\nu})\} \tag{27}$$

Thus we have CO of DN

$$\pi_{3;\,w,e\,,\,z,f}(\nu_0) = \Pi_3(\nu + \bar{\nu}) = \pi_0(0) + \tfrac{1}{2}(w + z + 1) \tag{28}$$

Where

$$w + z = \tfrac{1}{2}(j + k + r + s) \tag{29}$$

Applying above results to lead to two groups of solutions for (27): solution of integers (30) and solution of half-integers (31), and illustrated in Table. 3

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- $\Pi_3\{\nu + \bar{\nu}\} \quad = \ldots, +2, \quad +1, \quad 0, \quad -1, \quad -2, \ldots$ integers (30)
- $\Pi_3\{\nu + \bar{\nu},\} \quad = \ldots, \frac{+5}{2}, \frac{+3}{2}, \frac{+1}{2}, \frac{-1}{2}, \frac{-3}{2}, \frac{-5}{2}, \ldots$ half-integers (31)

Table 3: $\Pi_{3;\,j,b\,,\,r,a\,;\,k,d\,,\,s,c}(\nu + \bar{\nu})$

$\Pi^2(\nu + \bar{\nu})$ (19)	Antineutrino $\pi_{3;\,r,a\,,\,s,c}(\bar{\nu})$	$\frac{+5}{2}$	$\frac{+3}{2}$	$\frac{+1}{2}$	$\frac{-1}{2}$	$\frac{-3}{2}$	$\frac{-5}{2}$
Neutrino $\pi_{3;\,j,b\,,\,k,d}(\nu)$	$\Pi_3(\nu + \bar{\nu})$						
$\frac{+5}{2}$		$\frac{+5}{2}$	$+2$	$\frac{+3}{2}$	$+1$	$\frac{+1}{2}$	0
$\frac{+3}{2}$		$+2$	$\frac{+3}{2}$	$+1$	$\frac{+1}{2}$	0	$\frac{-1}{2}$
$\frac{+1}{2}$		$\frac{+3}{2}$	$+1$	$\frac{+1}{2}$	0	$\frac{-1}{2}$	-1
$\frac{-1}{2}$		$+1$	$\frac{+1}{2}$	0	$\frac{-1}{2}$	-1	$\frac{-3}{2}$
$\frac{-3}{2}$		$\frac{+1}{2}$	0	$\frac{-1}{2}$	-1	$\frac{-3}{2}$	-2
$\frac{-5}{2}$		0	$\frac{-1}{2}$	-1	$\frac{-3}{2}$	-2	$\frac{-5}{2}$

(19) and (30) construct a zero-spin boson (32). with one invariant Co of group representation

$$\Pi^2 = \{\, 0(0{+}1) \pm i\Phi \,\}\hbar^2 \quad \text{and} \quad \Pi_3 = \text{zero}, \pm\text{integers} \tag{32}$$

(19) and (31) construct ν_0 (33) which we have never seen such kind of representation of group before

$$\Pi^2 = \{\, 0(0{+}1) \pm i\Phi \,\}\hbar^2 \quad \text{and} \quad \Pi_3 = \pm\text{half-integers} \tag{33}$$

Where for (33) below

$$\Pi = \Pi(\nu + \bar{\nu}) = \pi(\nu_0) \tag{34}$$

Next following, using (20),(28) and (31) to research Dark Neutrino ν_0 in the case of $\nu = \nu_L$, Left-handed Neutrino and $\bar{\nu} = \bar{\nu}_R$, Right-handed Antineutrino. The more details are shown in Table 4 and section 5.

VI. Chiral Arrow ⇑ and Motion Arrow ↑ of ν_0

A particle is called *chiral* if it is distinguishable from its mirror image [4], Mark *chiral arrow* ⇑ is used to play the role in particle physics. The direction of the chiral arrows for particle and antiparticle are the same. Mark *motion arrow* $\uparrow$ is used to represent the direction of a particle momentum $\vec{p}$ that is aligned along with the z-axis.

Base on the two marks, $\Uparrow$ and $\uparrow$, we constructe Table.4 and Table.5 below

Table 4: Formation of DN with $\pi_3(\nu_0) = \frac{+1}{2}$

Diraction of motion $\vec{p}$ motion arrow	Left-handed Neutrino ν_L chiral arrow	$\pi_3(\nu_L)$ flavour	|	$\pi_3(\bar{\nu}_R)$ flavour	Right-handed Antineutrino $\bar{\nu}_R$ chiral arrow	Diraction of motion $\vec{p}$ motion arrow	|||	DN	$\pi_3(\nu_0)$
$\uparrow$	$\Downarrow$	$\frac{-5}{2}$	|	$\frac{+7}{2}$	$\Uparrow$	$\uparrow$	|||	$\uparrow$	$\frac{+1}{2}$
$\uparrow$	$\Downarrow$	$\frac{-3}{2}$	|	$\frac{+5}{2}$	$\Uparrow$	$\uparrow$	|||	$\uparrow$	$\frac{+1}{2}$
$\uparrow$	$\Downarrow$	$\frac{-1}{2}$	|	$\frac{+3}{2}$	$\Uparrow$	$\uparrow$	|||	$\uparrow$	$\frac{+1}{2}$
$\downarrow$ ♦	$\Uparrow$	$\frac{+1}{2}$ ♦	|	♦ $\frac{+1}{2}$	$\Uparrow$	♦ $\uparrow$	|||	0	$\frac{+1}{2}$
$\downarrow$	$\Uparrow$	$\frac{+3}{2}$	|	$\frac{-1}{2}$	$\Downarrow$	$\downarrow$	|||	$\downarrow$	$\frac{+1}{2}$
$\downarrow$	$\Uparrow$	$\frac{+5}{2}$	|	$\frac{-3}{2}$	$\Downarrow$	$\downarrow$	|||	$\downarrow$	$\frac{+1}{2}$
$\downarrow$	$\Uparrow$	$\frac{+7}{2}$	|	$\frac{-5}{2}$	$\Downarrow$	$\downarrow$	|||	$\downarrow$	$\frac{+1}{2}$

Table 5: Formation of DN with $\pi_3(\nu_0) = \frac{-1}{2}$

Diraction of motion motion arrow	Left-handed Neutrino ν_L chiral arrow	$\pi_3(\nu_L)$ flavour	|	$\pi_3(\bar{\nu}_R)$ flavour	Right-handed Antineutrino $\bar{\nu}_R$ chiral arrow	Diraction of motion motion arrow	|||	DN	$\pi_3(\nu_0)$
$\downarrow$	$\Uparrow$	$\frac{+5}{2}$	|	$\frac{-7}{2}$	$\Downarrow$	$\downarrow$	|||	$\downarrow$	$\frac{-1}{2}$
$\downarrow$	$\Uparrow$	$\frac{+3}{2}$	|	$\frac{-5}{2}$	$\Downarrow$	$\downarrow$	|||	$\downarrow$	$\frac{-1}{2}$
$\downarrow$	$\Uparrow$	$\frac{+1}{2}$	|	$\frac{-3}{2}$	$\Downarrow$	$\downarrow$	|||	$\downarrow$	$\frac{-1}{2}$
$\uparrow$ ♦	$\Downarrow$	$\frac{-1}{2}$ ♦	|	♦ $\frac{-1}{2}$	$\Downarrow$	♦ $\downarrow$	|||	0	$\frac{-1}{2}$
$\uparrow$	$\Downarrow$	$\frac{-3}{2}$	|	$\frac{+1}{2}$	$\Uparrow$	$\uparrow$	|||	$\uparrow$	$\frac{-1}{2}$
$\uparrow$	$\Downarrow$	$\frac{-5}{2}$	|	$\frac{+3}{2}$	$\Uparrow$	$\uparrow$	|||	$\uparrow$	$\frac{-1}{2}$
$\uparrow$	$\Downarrow$	$\frac{-7}{2}$	|	$\frac{+5}{2}$	$\Uparrow$	$\uparrow$	|||	$\uparrow$	$\frac{-1}{2}$

In the above two tables, the rotation orientation of these spin particles maybe clockwise or counterclockwise, which is discribed by their third components π_3 of spin angular momentum [5],[6]. The clockwise, corresponding to the postive value of π_3 and the counterclockwise to the negative values of π_3. Further, People usually provide: if $\vec{\pi}_3$ parallel to direction $\uparrow$ of its momentum $\vec{p}$, we speak of a particle with right-handed helicity, RH, and if $\vec{\pi}_3$ antiparallel to direction $\uparrow$ of its momentum $\vec{p}$, with left-handed hecility, LH. Remind $\vec{\pi}_3$ parallel chiral arrows $\Uparrow$.

In nature there are only right-handed antineutrinos and only left-handed neutrinos, so, we have $\nu \Rightarrow \nu_{\mathrm{L}}$ and $\bar{\nu} \Rightarrow \bar{\nu}_{\mathrm{R}}$ in Table.4 and in Table.5.

Cntinuing with the concept of Table 4 and Table 5, then Table.3 turns into Table.6

Table 6: Formation of DN ν_0 and Zero Spin from ν_{L} and $\bar{\nu}_{\mathrm{R}}$ with common CO$\{0(0+1) \pm i\Phi\}\hbar^2$

Diraction of motion $\vec{p}$ motion arrow	LH Neutrino ν_{L} chiral arrow	$\pi_3(\nu_{\mathrm{L}})$ flavour	|	$\pi_3(\bar{\nu}_{\mathrm{R}})$ flavour	RH Antineutrino $\bar{\nu}_{\mathrm{R}}$ chiral arrow	Diraction of motion $\vec{p}$ motion arrow	≡		DN $\pi_3(\nu_0)$ (33)	zero spin $\pi_3(zs)$ (32)
⋮	⋮	⋮	·	⋮	⋮	⋮		∘	∘ ∘ ∘ ∘	∘ ∘
$\uparrow$	$\Downarrow$	$-\frac{1}{2}$	—	$+\frac{7}{2}$	$\Uparrow$	$\uparrow$	≡	$\uparrow$	$+\frac{3}{2}$	
$\uparrow$	$\Downarrow$	$-\frac{1}{2}$	—	$+\frac{5}{2}$	$\Uparrow$	$\uparrow$	≡	$\uparrow$		$+1$
$\uparrow$	$\Downarrow$	$-\frac{1}{2}$	—	$+\frac{3}{2}$	$\Uparrow$	$\uparrow$	≡	$\uparrow$	$+\frac{1}{2}$	
$\uparrow$	$\Downarrow$	$-\frac{1}{2}$	—	$+\frac{1}{2}$	$\Uparrow$	$\uparrow$	≡	$\uparrow$		0
—	—	—	-	—	—	—	-	-	—	-
$\downarrow$	$\Uparrow$	$+\frac{1}{2}$	—	$-\frac{1}{2}$	$\Downarrow$	$\downarrow$	≡	$\downarrow$		0
$\downarrow$	$\Uparrow$	$+\frac{1}{2}$	—	$-\frac{3}{2}$	$\Downarrow$	$\downarrow$	≡	$\downarrow$	$-\frac{1}{2}$	
$\downarrow$	$\Uparrow$	$+\frac{1}{2}$	—	$-\frac{5}{2}$	$\Downarrow$	$\downarrow$	≡	$\downarrow$		-1
$\downarrow$	$\Uparrow$	$+\frac{1}{2}$	—	$-\frac{7}{2}$	$\Downarrow$	$\downarrow$	≡	$\downarrow$	$-\frac{3}{2}$	
⋮	⋮	⋮	·	⋮	⋮	⋮		∘	∘ ∘ ∘ ∘	∘ ∘

VII. DARK SPIN PARTICLES, DSP

DSP are spin particles that have yet to be observed in nature up to now, but are existing in math Spin Topological Space, STS. To give a succinct explanation account of DSP, we back to real region, spin topological coordinate (j, k) can help

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us describe spin particles and write down their group representations. In the following Tables, $\pi^2_{j,k}$ and $\pi_{3;j,k}$ are Casimir Operator and the third components of spin particles.

In Table 7 the values with underline are the spin eigenvalues of Bosons and Fermions, only those values are what we could explore and see in current theory and experiment now. Any other values without underline are the "spin-excited states " of Bosons and Fermions in STS.

Table 7: Bosons and Fermions

	$\pi^2_{j,k}$	$j-k$							
Boson	0	$+1$	(j,k)	$(+2,+1)$	$(+1,0)$	$(0,-1)$	$(-1,-2)$	$(-2,-3)$	$(-3,-4)$
A1	$0(0+1)$		$\pi_{3;j,k}$	$+2$	$+1$	$\underline{0}$	-1	-2	-3
Boson	2	$+3$	(j,k)	$(+3,0)$	$(+2,-1)$	$(+1,-2)$	$(0,-3)$	$(-1,-4)$	$(-2,-5)$
A2	$1(1+1)$		$\pi_{3;j,k}$	$+2$	$\underline{+1}$	$\underline{0}$	$\underline{-1}$	-2	-3
Boson	6	$+5$	(j,k)	$(+4,-1)$	$(+3,-2)$	$(+2,-3)$	$(+1,-4)$	$(0,-5)$	$(-1,-6)$
A3	$2(2+1)$		$\pi_{3;j,k}$	$\underline{+2}$	$\underline{+1}$	$\underline{0}$	$\underline{-1}$	$\underline{-2}$	-3
Boson	12	$+7$	(j,k)	$(+5,-2)$	$(+4,-3)$	$(+3,-4)$	$(+2,-5)$	$(+1,-6)$	$(0,-7)$
A4	$3(3+1)$		$\pi_{3;j,k}$	$\underline{+2}$	$\underline{+1}$	$\underline{0}$	$\underline{-1}$	$\underline{-2}$	$\underline{-3}$
Fermion	$\frac{3}{4}$	$+2$	(j,k)	$(+3,+1)$	$(+2,0)$	$(+1,-1)$	$(0,-2)$	$(-1,-3)$	$(-2,-4)$
B1	$\frac{1}{2}(\frac{1}{2}+1)$		$\pi_{3;j,k}$	$\frac{+5}{2}$	$\frac{+3}{2}$	$\underline{\frac{+1}{2}}$	$\underline{\frac{-1}{2}}$	$\frac{-3}{2}$	$\frac{-5}{2}$
Fermion	$\frac{15}{4}$	$+4$	(j,k)	$(+4,0)$	$(+3,-1)$	$(+2,-2)$	$(+1,-3)$	$(0,-4)$	$(-1,-5)$
B2	$\frac{3}{2}(\frac{3}{2}+1)$		$\pi_{3;j,k}$	$\frac{+5}{2}$	$\underline{\frac{+3}{2}}$	$\underline{\frac{+1}{2}}$	$\underline{\frac{-1}{2}}$	$\underline{\frac{-3}{2}}$	$\frac{-5}{2}$
Fermion	$\frac{35}{4}$	$+6$	(j,k) $A7$	$(+5,-1)$	$(+4,-2)$	$(+3,-3)$	$(+2,-4)$	$(+1,-5)$	$(0,-6)$
B3	$\frac{5}{2}(\frac{5}{2}+1)$		$\pi_{3;j,k}$	$\underline{\frac{+5}{2}}$	$\underline{\frac{+3}{2}}$	$\underline{\frac{+1}{2}}$	$\underline{\frac{-1}{2}}$	$\underline{\frac{-3}{2}}$	$\underline{\frac{-5}{2}}$

■ Regular Dark Spin Particles

Spin particles in Table 8 are called regular dark spin particles, due to their $\pi^2_{j\,k,}$ is connected to one of the values of their $\pi_{3j,\,k}$. Here the spin topological coordinate (j,k) of spin-1/3, spin-2/3 and spin-1/6, spin-5/6 are listed, the more details about others spin can be referred to author's works. The particles in Table 7 possess the same property.

Table 8: Regular Dark Spin Particles

	$\pi^2_{j,k}$	$j-k$							
	$\frac{7}{36}$	$\frac{+4}{3}$	(j,k)	$(\frac{+7}{3},\frac{+3}{3})$	$(\frac{+4}{3},\frac{0}{3})$	$(\frac{+1}{3},\frac{-3}{3})$	$(\frac{-2}{3},\frac{-6}{3})$	$(\frac{-5}{3},\frac{-9}{3})$	$(\frac{-8}{3},\frac{-12}{3})$
C1	$\frac{1}{6}(\frac{1}{6}+1)$		$\pi_{3;j,k}$	$\frac{+13}{6}$	$\frac{+7}{6}$	$\frac{+1}{6}$	$\frac{-5}{6}$	$\frac{-11}{6}$	$\frac{-17}{6}$
	$\frac{55}{36}$	$\frac{+8}{3}$	(j,k)	$(\frac{+11}{3},\frac{+3}{3})$	$(\frac{+8}{3},\frac{0}{3})$	$(\frac{+5}{3},\frac{-3}{3})$	$(\frac{+2}{3},\frac{-6}{3})$	$(\frac{-1}{3},\frac{-9}{3})$	$(\frac{-4}{3},\frac{-12}{3})$
C2	$\frac{5}{6}(\frac{5}{6}+1)$		$\pi_{3;j,k}$	$\frac{+17}{6}$	$\frac{+11}{6}$	$\frac{+5}{6}$	$\frac{-1}{6}$	$\frac{-7}{6}$	$\frac{-13}{6}$
	$\frac{4}{9}$	$\frac{+5}{3}$	(j,k)	$(\frac{+8}{3},\frac{+3}{3})$	$(\frac{+5}{3},\frac{0}{3})$	$(\frac{+2}{3},\frac{-3}{3})$	$(\frac{-1}{3},\frac{-6}{3})$	$(\frac{-4}{3},\frac{-9}{3})$	$(\frac{-7}{3},\frac{-12}{3})$
D1	$\frac{1}{3}(\frac{1}{3}+1)$		$\pi_{3;j,k}$	$\frac{+7}{3}$	$\frac{+4}{3}$	$\frac{+1}{3}$	$\frac{-2}{3}$	$\frac{-5}{3}$	$\frac{-8}{3}$
	$\frac{10}{9}$	$\frac{+7}{3}$	(j,k)	$(\frac{+10}{3},\frac{+3}{3})$	$(\frac{+7}{3},\frac{0}{3})$	$(\frac{+4}{3},\frac{-3}{3})$	$(\frac{+1}{3},\frac{-6}{3})$	$(\frac{-2}{3},\frac{-9}{3})$	$(\frac{-5}{3},\frac{-12}{3})$
D2	$\frac{2}{3}(\frac{2}{3}+1)$		$\pi_{3;j,k}$	$\frac{+8}{3}$	$\frac{+5}{3}$	$\frac{+2}{3}$	$\frac{-1}{3}$	$\frac{-4}{3}$	$\frac{-7}{3}$

■ Peculiar Dark Spin Particles

Spin particles in the next six tables are referred to peculiar dark spin particles, which are cataloged by different CO. The first three tables are with even number CO, and the last three tables with odd number.

Peculiar dark spin particles are *neither* Bosons, Fermions *nor* regular dark spin particles,

Compaire $\pi^2_{w,e\,,\,z,f}(v_0)$ (20), $\pi_{3;\,w,e\,,\,z,f}(v_0)$ (28) and $\Pi_3\{v+\bar{v},\}$ (31) with the Series $\frac{\pm1}{2}$ in Table 9, we see the former (complex region) is the extension of the latter (real region), the latter is the special case of the former. both of them are all with CO $0\hbar^2$ and $\pi_3{=}\frac{\pm1}{2},\frac{\pm3}{2},\frac{\pm5}{2},\ldots$ So DN v_0 is one kind of peculiar dark spin particles.

Table 9: $\pi^2_{j,k} = 0(0+1) = 0\hbar^2$, with $j-k=+1$

Series $\frac{+1}{2}$						
(j,k)	$(\frac{+5}{2},\frac{+3}{2})$	$(\frac{+3}{2},\frac{+1}{2})$	$(\frac{+1}{2},\frac{-1}{2})$	$(\frac{-1}{2},\frac{-3}{2})$	$(\frac{-3}{2},\frac{-5}{2})$	$(\frac{-5}{2},\frac{-7}{2})$
$\pi_{3;j,k}$	$\frac{+5}{2}$	$\frac{+3}{2}$	$\frac{+1}{2}$	$\frac{-1}{2}$	$\frac{-3}{2}$	$\frac{-5}{2}$
Series $\frac{+1}{3}$						
(j,k)	$(\frac{+7}{3},\frac{+4}{3})$	$(\frac{+3}{3},\frac{+1}{3})$	$(\frac{+1}{3},\frac{-2}{3})$	$(\frac{-2}{3},\frac{-5}{3})$	$(\frac{-5}{3},\frac{-8}{3})$	$(\frac{-8}{3},\frac{-11}{3})$
$\pi_{3;j,k}$	$\frac{+7}{3}$	$\frac{+4}{3}$	$\frac{+1}{3}$	$\frac{-2}{3}$	$\frac{-5}{3}$	$\frac{-8}{3}$
Series $\frac{+2}{3}$						
(j,k)	$(\frac{+8}{3},\frac{+5}{3})$	$(\frac{+5}{3},\frac{+2}{3})$	$(\frac{+2}{3},\frac{-1}{3})$	$(\frac{-1}{3},\frac{-4}{3})$	$(\frac{-4}{3},\frac{-7}{3})$	$(\frac{-7}{3},\frac{-10}{3})$
$\pi_{3;j,k}$	$\frac{+8}{3}$	$\frac{+5}{3}$	$\frac{+2}{3}$	$\frac{-1}{3}$	$\frac{-4}{3}$	$\frac{-7}{3}$
Series $\frac{+1}{6}$						
(j,k)	$(\frac{+13}{6},\frac{+7}{6})$	$(\frac{+7}{6},\frac{+1}{6})$	$(\frac{+1}{6},\frac{-5}{6})$	$(\frac{-5}{6},\frac{-11}{6})$	$(\frac{-11}{6},\frac{-17}{6})$	$(\frac{-17}{6},\frac{-23}{6})$
$\pi_{3;j,k}$	$\frac{+13}{6}$	$\frac{+7}{6}$	$\frac{+1}{6}$	$\frac{-5}{6}$	$\frac{-11}{6}$	$\frac{-17}{6}$
Series $\frac{+5}{6}$						
(j,k)	$(\frac{+17}{6},\frac{+11}{6})$	$(\frac{+11}{6},\frac{+5}{6})$	$(\frac{+5}{6},\frac{-1}{6})$	$(\frac{-1}{6},\frac{-7}{6})$	$(\frac{-7}{6},\frac{-13}{6})$	$(\frac{-13}{6},\frac{-29}{6})$
$\pi_{3;j,k}$	$\frac{+17}{6}$	$\frac{+11}{6}$	$\frac{+5}{6}$	$\frac{-1}{6}$	$\frac{-7}{6}$	$\frac{-13}{6}$

Table 10: $\pi^2_{j,k} = 1(1+1) = 2\hbar^2$, with $j-k=+3$

Series $\frac{+1}{2}$						
(j,k)	$(\frac{+7}{2},\frac{+1}{2})$	$(\frac{+5}{2},\frac{-1}{2})$	$(\frac{+3}{2},\frac{-3}{2})$	$(\frac{+1}{2},\frac{-5}{2})$	$(\frac{-1}{2},\frac{-7}{2})$	$(\frac{-3}{2},\frac{-9}{2})$
$\pi_{3;j,k}$	$\frac{+5}{2}$	$\frac{+3}{2}$	$\frac{+1}{2}$	$\frac{-1}{2}$	$\frac{-3}{2}$	$\frac{-5}{2}$
Series $\frac{+1}{3}$						
(j,k)	$(\frac{+10}{3},\frac{+1}{3})$	$(\frac{+7}{3},\frac{-2}{3})$	$(\frac{+4}{3},\frac{-5}{3})$	$(\frac{+1}{3},\frac{-8}{3})$	$(\frac{-2}{3},\frac{-11}{3})$	$(\frac{-5}{3},\frac{-14}{3})$
$\pi_{3;j,k}$	$\frac{+7}{3}$	$\frac{+4}{3}$	$\frac{+1}{3}$	$\frac{-2}{3}$	$\frac{-5}{3}$	$\frac{-8}{3}$
Series $\frac{+2}{3}$						
(j,k)	$(\frac{+11}{3},\frac{+2}{3})$	$(\frac{+8}{3},\frac{-1}{3})$	$(\frac{+5}{3},\frac{-4}{3})$	$(\frac{+2}{3},\frac{-7}{3})$	$(\frac{-1}{3},\frac{-10}{3})$	$(\frac{-4}{3},\frac{-13}{3})$
$\pi_{3;j,k}$	$\frac{+8}{3}$	$\frac{+5}{3}$	$\frac{+2}{3}$	$\frac{-1}{3}$	$\frac{-4}{3}$	$\frac{-7}{3}$
Series $\frac{+1}{6}$						
(j,k)	$(\frac{+19}{6},\frac{+1}{6})$	$(\frac{+13}{6},\frac{-5}{6})$	$(\frac{+7}{6},\frac{-11}{6})$	$(\frac{+1}{6},\frac{-17}{6})$	$(\frac{-5}{6},\frac{-23}{6})$	$(\frac{-11}{6},\frac{-29}{6})$
$\pi_{3;j,k}$	$\frac{+13}{6}$	$\frac{+7}{6}$	$\frac{+1}{6}$	$\frac{-5}{6}$	$\frac{-11}{6}$	$\frac{-17}{6}$
Series $\frac{+5}{6}$						
(j,k)	$(\frac{+23}{6},\frac{+5}{6})$	$(\frac{+17}{6},\frac{-1}{6})$	$(\frac{+11}{6},\frac{-7}{6})$	$(\frac{+5}{6},\frac{-13}{6})$	$(\frac{-1}{6},\frac{-19}{6})$	$(\frac{-7}{6},\frac{-25}{6})$
$\pi_{3;j,k}$	$\frac{+17}{6}$	$\frac{+11}{6}$	$\frac{+5}{6}$	$\frac{-1}{6}$	$\frac{-7}{6}$	$\frac{-13}{6}$

Table 11: $\pi_{j,k}^2 = 2(2+1) = 6\hbar^2$, with $j-k = +5$

Series $\frac{+1}{2}$						
(j,k)	$(\frac{+9}{2},\frac{-1}{2})$	$(\frac{+7}{2},\frac{-3}{2})$	$(\frac{+5}{2},\frac{-5}{2})$	$(\frac{+3}{2},\frac{-7}{2})$	$(\frac{+1}{2},\frac{-9}{2})$	$(\frac{-1}{2},\frac{-11}{2})$
$\pi_{3;j,k}$	$\frac{+5}{2}$	$\frac{+3}{2}$	$\frac{+1}{2}$	$\frac{-1}{2}$	$\frac{-3}{2}$	$\frac{-5}{2}$
Series $\frac{+1}{3}$						
(j,k)	$(\frac{+13}{3},\frac{-2}{3})$	$(\frac{+10}{3},\frac{-5}{3})$	$(\frac{+7}{3},\frac{-8}{3})$	$(\frac{+4}{3},\frac{-11}{3})$	$(\frac{+1}{3},\frac{-14}{3})$	$(\frac{-2}{3},\frac{-17}{3})$
$\pi_{3;j,k}$	$\frac{+7}{3}$	$\frac{+4}{3}$	$\frac{+1}{3}$	$\frac{-2}{3}$	$\frac{-5}{3}$	$\frac{-8}{3}$
Series $\frac{+2}{3}$						
(j,k)	$(\frac{+14}{3},\frac{-1}{3})$	$(\frac{+11}{3},\frac{-4}{3})$	$(\frac{+8}{3},\frac{-7}{3})$	$(\frac{+5}{3},\frac{-10}{3})$	$(\frac{+2}{3},\frac{-13}{3})$	$(\frac{-1}{3},\frac{-16}{3})$
$\pi_{3;j,k}$	$\frac{+8}{3}$	$\frac{+5}{3}$	$\frac{+2}{3}$	$\frac{-1}{3}$	$\frac{-4}{3}$	$\frac{-7}{3}$
Series $\frac{+1}{6}$						
(j,k)	$(\frac{+25}{6},\frac{-5}{6})$	$(\frac{+19}{6},\frac{-11}{6})$	$(\frac{+13}{6},\frac{-17}{6})$	$(\frac{+7}{6},\frac{-23}{6})$	$(\frac{+1}{6},\frac{-29}{6})$	$(\frac{-5}{6},\frac{-35}{6})$
$\pi_{3;j,k}$	$\frac{+13}{6}$	$\frac{+7}{6}$	$\frac{+1}{6}$	$\frac{-5}{6}$	$\frac{-11}{6}$	$\frac{-17}{6}$
Series $\frac{+5}{6}$						
(j,k)	$(\frac{+29}{6},\frac{-1}{6})$	$(\frac{+23}{6},\frac{-7}{6})$	$(\frac{+17}{6},\frac{-13}{6})$	$(\frac{+11}{6},\frac{-19}{6})$	$(\frac{+5}{6},\frac{-25}{6})$	$(\frac{-1}{6},\frac{-31}{6})$
$\pi_{3;j,k}$	$\frac{+17}{6}$	$\frac{+11}{6}$	$\frac{+5}{6}$	$\frac{-1}{6}$	$\frac{-7}{6}$	$\frac{-13}{6}$

Table 12: $\pi_{j,k}^2 = \frac{3}{4} = \frac{+1}{2}(\frac{+1}{2}+1)\hbar^2$, with $j-k = +2$

Series0						
(j,k)	$(\frac{+5}{2},\frac{+1}{2})$	$(\frac{+3}{2},\frac{-1}{2})$	$(\frac{+1}{2},\frac{-3}{2})$	$(\frac{-1}{2},\frac{-5}{2})$	$(\frac{-3}{2},\frac{-7}{2})$	$(\frac{-5}{2},\frac{-9}{2})$
$\pi_{3;j,k}$	$+2$	$+1$	0	-1	-2	-3
Series $\frac{+1}{3}$						
(j,k)	$(\frac{+17}{6},\frac{+5}{6})$	$(\frac{+11}{6},\frac{-1}{6})$	$(\frac{+5}{6},\frac{-7}{6})$	$(\frac{-1}{6},\frac{-13}{6})$	$(\frac{-7}{6},\frac{-19}{6})$	$(\frac{-13}{6},\frac{-25}{6})$
$\pi_{3;j,k}$	$\frac{+7}{3}$	$\frac{+4}{3}$	$\frac{+1}{3}$	$\frac{-2}{3}$	$\frac{-5}{3}$	$\frac{-8}{3}$
Series $\frac{+2}{3}$						
(j,k)	$(\frac{+19}{6},\frac{+7}{6})$	$(\frac{+13}{6},\frac{+1}{6})$	$(\frac{+7}{6},\frac{-5}{6})$	$(\frac{+1}{6},\frac{-11}{6})$	$(\frac{-5}{6},\frac{-17}{6})$	$(\frac{-11}{6},\frac{-23}{6})$
$\pi_{3;j,k}$	$\frac{+8}{3}$	$\frac{+5}{3}$	$\frac{+2}{3}$	$\frac{-1}{3}$	$\frac{-4}{3}$	$\frac{-7}{3}$
Series $\frac{+1}{6}$						
(j,k)	$(\frac{+8}{3},\frac{+2}{3})$	$(\frac{+5}{3},\frac{-1}{3})$	$(\frac{+2}{3},\frac{-4}{3})$	$(\frac{-1}{3},\frac{-7}{3})$	$(\frac{-4}{3},\frac{-10}{3})$	$(\frac{-7}{3},\frac{-13}{3})$
$\pi_{3;j,k}$	$\frac{+13}{6}$	$\frac{+7}{6}$	$\frac{+1}{6}$	$\frac{-5}{6}$	$\frac{-11}{6}$	$\frac{-17}{6}$
Series $\frac{+5}{6}$						
(j,k)	$(\frac{+10}{3},\frac{+4}{3})$	$(\frac{+7}{3},\frac{+1}{3})$	$(\frac{+4}{3},\frac{-2}{3})$	$(\frac{+1}{3},\frac{-5}{3})$	$(\frac{-2}{3},\frac{-8}{3})$	$(\frac{-5}{3},\frac{-11}{3})$
$\pi_{3;j,k}$	$\frac{+17}{6}$	$\frac{+11}{6}$	$\frac{+5}{6}$	$\frac{-1}{6}$	$\frac{-7}{6}$	$\frac{-13}{6}$

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Table 13: $\pi^2_{j,k} = \frac{15}{4} = \frac{+3}{2}(\frac{+3}{2}+1)\hbar^2$, with $j - k = +4$

Series0						
(j, k)	$(\frac{+7}{2}, \frac{-1}{2})$	$(\frac{+5}{2}, \frac{-3}{2})$	$(\frac{+3}{2}, \frac{-5}{2})$	$(\frac{+1}{2}, \frac{-7}{2})$	$(\frac{-1}{2}, \frac{-9}{2})$	$(\frac{-3}{2}, \frac{-11}{2})$
$\pi_{3;j,k}$	$+2$	$+1$	0	-1	-2	-3
Series $\frac{+1}{3}$						
(j, k)	$(\frac{+23}{6}, \frac{-1}{6})$	$(\frac{+17}{6}, \frac{-7}{6})$	$(\frac{+11}{6}, \frac{-13}{6})$	$(\frac{+5}{6}, \frac{-19}{6})$	$(\frac{-1}{6}, \frac{-25}{6})$	$(\frac{-7}{6}, \frac{-31}{6})$
$\pi_{3;j,k}$	$\frac{+7}{3}$	$\frac{+4}{3}$	$\frac{+1}{3}$	$\frac{-2}{3}$	$\frac{-5}{3}$	$\frac{-8}{3}$
Series $\frac{+2}{3}$						
(j, k)	$(\frac{+25}{6}, \frac{+1}{6})$	$(\frac{+19}{6}, \frac{-5}{6})$	$(\frac{+13}{6}, \frac{-11}{6})$	$(\frac{+7}{6}, \frac{-17}{6})$	$(\frac{+1}{6}, \frac{-23}{6})$	$(\frac{-5}{6}, \frac{-29}{6})$
$\pi_{3;j,k}$	$\frac{+8}{3}$	$\frac{+5}{3}$	$\frac{+2}{3}$	$\frac{-1}{3}$	$\frac{-4}{3}$	$\frac{-7}{3}$
Series $\frac{+1}{6}$						
(j, k)	$(\frac{+11}{3}, \frac{-1}{3})$	$(\frac{+8}{3}, \frac{-4}{3})$	$(\frac{+5}{3}, \frac{-7}{3})$	$(\frac{+2}{3}, \frac{-10}{3})$	$(\frac{-1}{3}, \frac{-13}{3})$	$(\frac{-4}{3}, \frac{-16}{3})$
$\pi_{3;j,k}$	$\frac{+13}{6}$	$\frac{+7}{6}$	$\frac{+1}{6}$	$\frac{-5}{6}$	$\frac{-11}{6}$	$\frac{-17}{6}$
Series $\frac{+5}{6}$						
(j, k)	$(\frac{+13}{3}, \frac{+1}{3})$	$(\frac{+10}{3}, \frac{-2}{3})$	$(\frac{+7}{3}, \frac{-5}{3})$	$(\frac{+4}{3}, \frac{-8}{3})$	$(\frac{+1}{3}, \frac{-11}{3})$	$(\frac{-2}{3}, \frac{-14}{3})$
$\pi_{3;j,k}$	$\frac{+17}{6}$	$\frac{+11}{6}$	$\frac{+5}{6}$	$\frac{-1}{6}$	$\frac{-7}{6}$	$\frac{-13}{6}$

Table 14: $\pi^2_{j,k} = \frac{35}{4} = \frac{+5}{2}(\frac{+5}{2}+1)\hbar^2$, with $j - k = +6$

Series0						
(j, k)	$(\frac{+9}{2}, \frac{-3}{2})$	$(\frac{+7}{2}, \frac{-5}{2})$	$(\frac{+5}{2}, \frac{-7}{2})$	$(\frac{+3}{2}, \frac{-9}{2})$	$(\frac{+1}{2}, \frac{-11}{2})$	$(\frac{-1}{2}, \frac{-13}{2})$
$\pi_{3;j,k}$	$+2$	$+1$	0	-1	-2	-3
Series $\frac{+1}{3}$						
(j, k)	$(\frac{+29}{6}, \frac{-7}{6})$	$(\frac{+23}{6}, \frac{-13}{6})$	$(\frac{+17}{6}, \frac{-19}{6})$	$(\frac{+11}{6}, \frac{-25}{6})$	$(\frac{+5}{6}, \frac{-31}{6})$	$(\frac{-1}{6}, \frac{-37}{6})$
$\pi_{3;j,k}$	$\frac{+7}{3}$	$\frac{+4}{3}$	$\frac{+1}{3}$	$\frac{-2}{3}$	$\frac{-5}{3}$	$\frac{-8}{3}$
Series $\frac{+2}{3}$						
(j, k)	$(\frac{+31}{6}, \frac{-5}{6})$	$(\frac{+25}{6}, \frac{-11}{6})$	$(\frac{+19}{6}, \frac{-17}{6})$	$(\frac{+13}{6}, \frac{-23}{6})$	$(\frac{+7}{6}, \frac{-29}{6})$	$(\frac{+1}{6}, \frac{-35}{6})$
$\pi_{3;j,k}$	$\frac{+8}{3}$	$\frac{+5}{3}$	$\frac{+2}{3}$	$\frac{-1}{3}$	$\frac{-4}{3}$	$\frac{-7}{3}$
Series $\frac{+1}{6}$						
(j, k)	$(\frac{+14}{3}, \frac{-4}{3})$	$(\frac{+11}{3}, \frac{-7}{3})$	$(\frac{+8}{3}, \frac{-10}{3})$	$(\frac{+5}{3}, \frac{-13}{3})$	$(\frac{+1}{3}, \frac{-16}{3})$	$(\frac{-2}{3}, \frac{-19}{3})$
$\pi_{3;j,k}$	$\frac{+13}{6}$	$\frac{+7}{6}$	$\frac{+1}{6}$	$\frac{-5}{6}$	$\frac{-11}{6}$	$\frac{-17}{6}$
Series $\frac{+5}{6}$						
(j, k)	$(\frac{+16}{3}, \frac{-2}{3})$	$(\frac{+13}{3}, \frac{-5}{3})$	$(\frac{+10}{3}, \frac{-8}{3})$	$(\frac{+7}{3}, \frac{-11}{3})$	$(\frac{+4}{3}, \frac{-14}{3})$	$(\frac{+1}{3}, \frac{-17}{3})$
$\pi_{3;j,k}$	$\frac{+17}{6}$	$\frac{+11}{6}$	$\frac{+5}{6}$	$\frac{-1}{6}$	$\frac{-7}{6}$	$\frac{-13}{6}$

Remind: For all the above tables mentioned, when transformation

$$(j,k) \;\Rightarrow\; (k,j)$$

lead to

$$j-k = +\Delta \;\Rightarrow\; j-k = -\Delta \quad \text{and} \quad \pi^2_{j,k} = \pi^2_{k,j}, \quad \pi_{3,j,k} = \pi_{3,k,j}$$

VIII. Conclusions

This paper suggests a possibility of the existence of DN, Dark Neutrino ν_0 which is the superposition of Majorana Neutrino ν_L (CO $\frac{+3\hbar^2}{4}$) and Majorana Antineutrino $\bar{\nu}_R$ (CO $\frac{-3\hbar^2}{4}$). ν_0 is a charge neutrial particle that could possess CO $0\,\hbar^2$ and half-integer eigenvalues $\frac{\pm 1\hbar}{2}\ \frac{\pm 3\hbar}{2},\ \frac{\pm 5\hbar}{2},\dots$ of the third component of its own, further we are in a dilemma as to judge the physical certification of spin particle ν_0, to be a Boson or to be a Fermion ?

The only most plsusible explanation is that ν_0 is a kind of dark spin particles.

The tables of section VII are the fundamental representations of spin particles in STS, which are heuristic and useful, the examples are given below:

The spin topological coordinates (j,k) of Fermion B1 of Table 7 are just the flavour quantum numbers of quarks in STS (isospin I=$\hbar/2$) which is the last column of Table 2 in [3]. The (j,k) of regular dark spin particles of Table 8 lead to the colour spectral line array of u quark, $u_{RGB} \equiv (u_R, u_G, u_B)$=($\frac{+2}{3}$, $\frac{+5}{3}$, $\frac{+11}{3}$) [3], then the definition of CSDF, Colour Spectrum Diagram of Flavour is ascertained.

The goal of this paper is mainly to explore the math properties of CO, Casimir Operator of angular momentum of spin particles in STS, and to show the roles of CO in distinguishing the identities between particles and antiparticles of particle physics. The spin-coupling of the third components of two spin particles, multi-body spin particles are rather complex, the difficulty can be seen from the discussions in section V and VI, here we see to ensure the harmony between the consistency of math discipline and reality of physical spin, is not an easy job. There are some critical concepts left are requested to be introduced, the relevant topics will be presented later.

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Four Subjects in Solar Physics from the Point of View of the Electric Current Approach

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Abstract- Four major subjects in solar physics, the heating of the corona, the cause of the solar wind, the formation of sunspots and the cause of solar flares, are discussed on the basis of the *electric current approach*, a sequence of processes consisting of power supply(dynamo), transmission (currents/circuits) and dissipation(high coronal temperature, solar wind, sunspots and solar flares). This is because the four subjects have hardly been considered in terms of the electric current approach in the past, in spite of the fact that these subjects are various manifestations of electromagnetic processes. It is shown that this approach provides a new systematic way of considering each subject; (1) the long-standing issue of the coronal temperature, (2) the long-standing problem on the cause of the solar wind, (3)the presence of single spots(forgotten or dismissed in the past) and its relation to unipolar magnetic regions and (4) the crucial power/energy source and subsequent explosive processes of solar flares. The four subjects are obviously extremely complicated and difficult subjects, but it is hoped that the electric current approach might provide a new insight in considering the four subjects.

Keywords: *coronal temperature solar wind sunspots solar flares.*

GJSFR-A Classification: *FOR Code: 020109*

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Four Subjects in Solar Physics from the Point of View of the Electric Current Approach

Syun-Ichi Akasofu

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Keywords: coronal temperature solar wind sunspots solar flares.

I. Introduction

In solar physics, there are at least four major issues.

1. Heating of the corona to more than 10^6 K,
2. Cause of the solar wind,
3. Process of the sunspot formation,
4. Cause of solar flares.

Each theory/observation was initiated by:

1. Observed high temperature of the corona (cf. Van de Hulst, 1953).
2. Theory of the solar wind (Parker, 1958).
3. Theory of the formation of sunspots (Babcock, 1961).
4. Theory of magnetic reconnection (Sweet, 1958).

Thus, the first two issues have been lasting at least a half-century. At the present time, there is no promising theory in both problems. The last two have widely-accepted theories, but there are serious contradictions (the presence of single spots, for example) and uncertainties (the process of energy source), respectively.

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Each of the above issue has respectively been studied by the following principle and premise.

1. The corona is heated by MHD waves from the photosphere.
2. The cause of the solar wind is based on the heated corona.
3. A pair of sunspots is caused by a rising magnetic flux tube.
4. Solar flares are caused by magnetic reconnection.

The present situation in each has been reviewed and summarized. Some of the recent reviews are:

1. All efforts of heating by MHD waves and others do not seem to succeed (cf. Van Doorsselaere et al., 2020).
2. All efforts of generating the solar wind do not seem to work (cf. Viall and Borovsky (2020).
3. The problem of the presence of single (unipolar) spots and the location of pairs of spots with respect to unipolar magnetic regions are not considered (Akasofu, 2021).
4. The theory of magnetic reconnection has been presumed to be the source of energy production process and has almost exclusively prevailed in the past. A number of simulation studies have been conducted. However, after the most extensive review based on multi-satellite observations and others, Fletcher et al. (2011) are uncertain about the role of magnetic reconnection as the energy source process.

On the other hand, in as early as 1967, under the title "*The second approach in cosmical electrodynamics*", Alfven (1967) emphasized the need for electric current approach in space plasma physics, as well as the magnetic field line approach. The electric current approach considers solar phenomena systematically as a sequence of processes, which consists of power supply (dynamo), transmission (currents/circuits) and dissipation (solar phenomena). He repeated this point later (Alfven, 1977, 1981,1986). By neglecting the particle and electric current aspects, he warned: "we deprive ourselves of the possibility of understanding some of the most important phenomena in cosmic plasma physics."

The four subjects are extremely complex and difficult. However, in spite of a great progress in observations, the above long standstill and/or stagnation in theoretical considerations on them seem to stem from what Alfven pointed out in the above.

In fact, there is one common weakness or lack in studying all the four subjects. It is the lack of considering them on the basis the electric current approach, which consists of a sequence of processes, power supply (dynamo), transmission (currents/circuits) and dissipation (observed phenomena).In fact, this sequence of processes is the basic way of studying electromagnetic phenomena. Many aspects of the four phenomena cannot quantitatively be explained without electric currents and electron flows.

Therefore, in this paper, the electric current approach is adopted in studying the four major subjects. It seems that this approach seems to provide a new way of considering them.

II. High Temperature of the Corona

The standard coronal temperature of $2x10^6$ K, corresponds to 170 ev, based on the ionization potential of highly ionized Fe ions. It seems to be difficult to find common plasma or wave processes from the photosphere to heat the corona to 10^6 K.

However, the ionization by energetic electrons is another possibility for the presence of highly ionized atoms and the high temperature of the corona (Stix, 2002), but the responsible process of the acceleration of electrons in the coronal environment has not been explored.

It is suggested that one ionization current system is a field-aligned current system along coronal magnetic loops, which consists of a photospherc dynamo process as the power supply for the field-aligned currents, because field-aligned *currents* are essential in developing a double layer, which is needed to accelerate both electrons and ions.

a) Power supply/ Dynamo and Circuit/currents

The dynamo process (V x B) is caused by a plasma flow across a magnetic field. The power of a dynamo is defined by the Poynting flux P (erg/s or w) bot phenomena is given by:

$$P = \int (E \times B)\bullet dS = V(B^2/8\pi)S,$$

where V and B dente the velocity of photospheric plasma flow and the magnetic field, respectively and S is the cross-section of the dynamo process (Figure 1a).

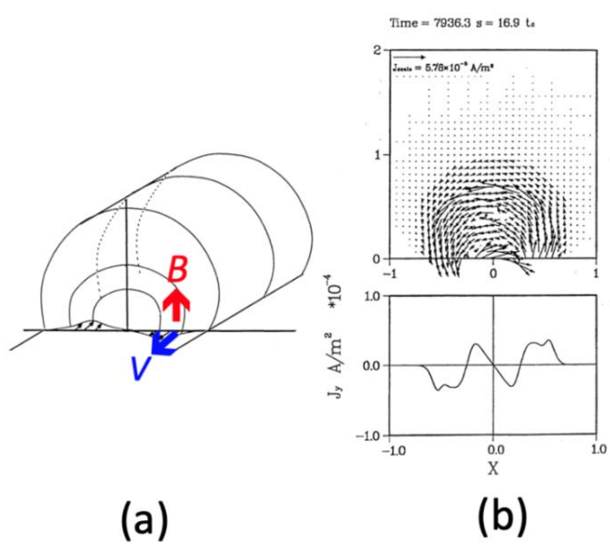

Figure 1: (a) The dynamo process in the photosphere for solar flares under a magnetic arcade. (b) The dynamo induced current system. The field-aligned currents occur along the magnetic arcade field lines(Choe and Lee, 1998; Courtesy of G. S. Choe).

Typical values of the parameters are:

Photospheric plasma speed V = 2.0 km/s,

Magnetic field intensity = B = 100 G,

S (cross-section) = k x d, k= lateral dimension (1.0 x 10^5 km), d = the depth (6.0 x 10^4 km),

P = 2.4 x 10^{27} erg/s.

This dynamo system is considered again in Section 6, because a similar dynamo power can supply the power for solar flares.

An example of the dynamo-induces field-aligned currents under a magnetic arcade is shown in Figure 1b, in which the dynamo process is considered with a set of B = 6 G and the speed V of 2 km/s along the neutral line under a typical magnetic arcade (cf. Choe and Lee, 1996); the intensity of field-aligned current is about 5 x 10^{-5} A/m^2(5 x 10 μA /m^2).

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b) Current/circuits: Double layer

In the past, a double layer was once considered for solar flares and its effect on coronal processes (Li et al., 2013, 2014). However, no estimate of the ionization rate by a double layer has made for a given current intensity and its possible potential drop along magnetic field lines. The presence of an electric field associated with the double layer along magnetic field lines for auroral processes was suggested by Alfven (cf. 1981, 1986) on the ground that magnetospheric electrons have to be accelerated to penetrate into the upper atmosphere and that the magnetospheric electric current system has to close itself (current continuity) by penetrating into the ionosphere at an altitude of 110 km from the magnetosphere.

The presence of the double layer (a U-shaped potential structure) in field-aligned currents is observationally well confirmed by several satellite observations in auroral research. The aurora is simply a result of this visible process.

In the earth's auroral conditions, various observed values related to the double layer are summarized by Karlsson (2012) and others: Field-aligned potential drops of the order of 6 KV or more, field-aligned currents of 10^{-1}-$10^{1}\mu A/m^2$, and the acceleration of magnetospheric electrons from 300 eV to 10KeV and more, an estimated thickness of the double layer 10 KV per 1 km, located between 0.5-2.0 Re above the ionosphere (Re = the earth's radius).

In the following, we estimate the ionization in the corona.

c) Dissipation (Ionization)

Neutral hydrogen atoms area major constituent in the middle height of the corona Aschwanden, 2005, his figure 1.19).The equation for the ionization rate q by a beam of energetic electrons in the ionosphere is given by (cf. Rees 1989):

$$q = F\, E\rho d / RE^2 \times 30 \text{ ev /cm}^3\text{ s.}$$

The ionization rate of the middle level of the coronaby field-aligned currents of 0.001 A/cm^2 (10^3mA/cm^2), supposing that the double layer provides of potential drop 1 KV:

F = electron flux (6.2×10^{11}/cm^2),

E = electron energy (1 Kev),

ρ = mass density (1.6×10^{-13}g = 10^{11}/cm^3 x 1.6×10^{-24} g),

d = length (10^9cm),

RE^2= effective range (5.6 g/cm^2),

q= 6.3×10^8/cm^{3}s.

Thus, it seems that the proposed field-aligned currents along magnetic loops can ionize hydrogen atoms and Fe atoms in the middle level of the corona.

III. Cause of the Solar Wind

Since all the attempts to produce the solar wind in the past have so far been based on the coronal heating or small-scale electromagnetic processes in the corona, it is very difficult to overcome the solar gravitational force. Thus, it may be worthwhile to consider other causes of the solar wind.

The process must be a large-scale bodily electromotive force (the Lorentz force, *J* x *B*) in order to lift the whole heliospheric plasma.

a) Solar unipolar dynamo

We suggest that the solar unipolar induction and the associated *electric currents* playan important role in generating the solar wind. The solar unipolar induction was considered by Alfven(1950, Chapter 3, p.5; 1977, 1981).However, the importance of the unipolar induction on the generation of the solar wind has not specifically been considered in the past.

b) Currents/circuit

The currents and circuits of the solar unipolar dynamo is shown in Figure 2a. In Alfven's model, the electric current flows out from the northern pole of the sun along the polar axis. After reaching the pole of the heliosphere, the current flows along the assumed spherical surface of the heliosphere to the equatorial plane (longitudinal current) and then flows back radially to the sun on the magnetic equator. On the equatorial plane, there is also the thin circular current, which is known as the equatorial current sheet. Both the radial current and the circular current on the equatorial current together generate spiral currents, which generate Parker's spiral field lines. The magnetic field produced by the longitudinal current is shown in Figure 2b (Akasofu et al., 1980).Alfven (1981) estimated the total current intensity to be 1.5×10^9 A.

The resulting electromotive force (*J* x *B*) must satisfy:

(1) The (*J* x *B*) force must have a significant outward component.

(2) The velocity of the solar wind is fairly uniform as a function of latitude during the solar minimum period.

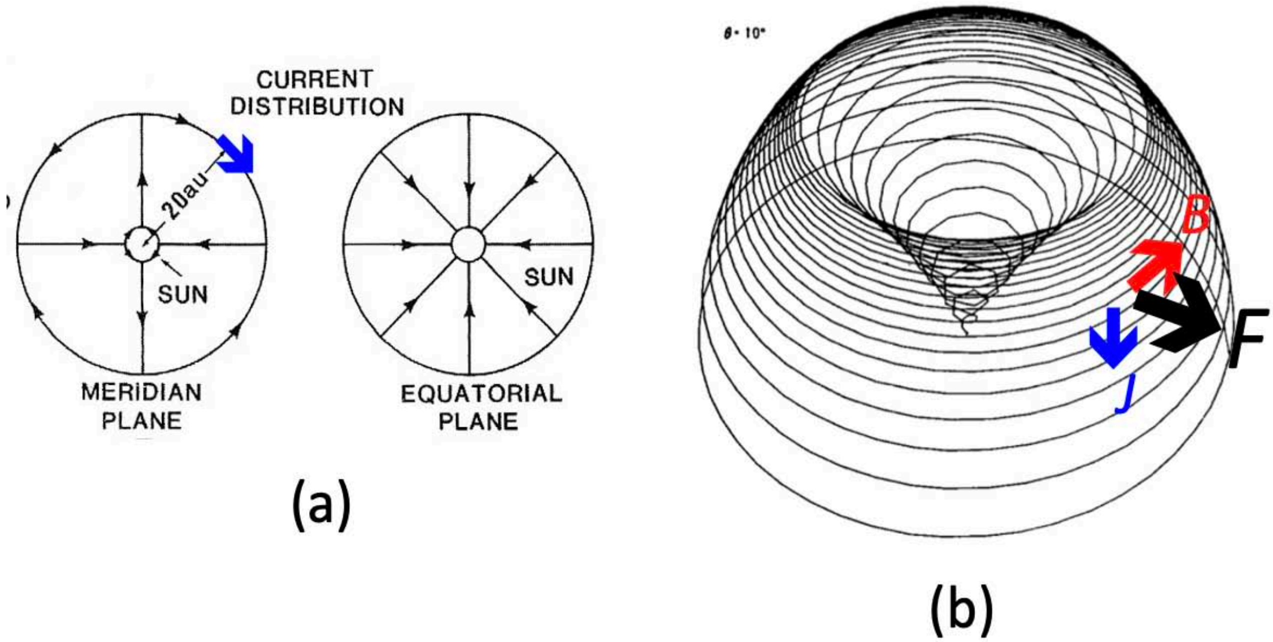

Figure 2: (a) The heliospheric current systembased on Alfven (1981), both the meridian and the top heliosphere views. (b) A magnetic field line generated mainly by the longitudinal current. It shows the electromotive force *F*, together with *J* and *B*.

c) Dissipation: Generation of the solar wind

Although the proposed (*J* x *B*) force is much greater than the solar gravitational force, it is difficult to lift the whole heliospheric plasma, if the longitudinal current is located only at the outer surface of the heliosphere or distributed uniformly in the heliosphere.

Lee and Akasofu (2021) considered that one third of the current flow on the spherical shell between r = 9.5-10.5 $R_\odot$ around the sun, not all from the top of the heliosphere; thus, in this shell, it is assumed that current I = 5×10^8 A (current density j $= 2.3 \times 10^{-11}$ A/m^2), magnetic field *B* $= 1.0 \times 10^3$nT, N = 100/cm^3 ($10^8/m^3$). The resulting acceleration a = *jB* = 1.4×10^2 m/s^2, compared with the solar gravity at 10 solar radii = 2.8m/s^2. The time for the solar wind with 500 km/s to move one solar radius T = 1.4×10^3s. Thus, the solar wind thus produced at 1 au is *V*= aT =*200 km/s* under the solar gravitation force.

Thus, it may be necessary to consider a large-scale (J x B) force for a cause of the solar wind

IV. Formation of Sunspots

Babcock (1961) proposed that sunspots appear as a positive and negative pair, when a thin magnetic flux tube below the photospheric surface emerges by magnetic buoyancy at the respective cross-sections, as shown in Figure 3a and 3b. Since then, the concept of the rising thin magnetic flux tube has prevailed until the present.

There are several serious morphological difficulties of this thin magnetic flux tube theory. They are:

(1) There are many single spots, often called isolated, independent, solitary spots or unipolar spots (the present theory indicates that spots should appear always as a (positive and negative) pair.

(2) Unipolar magnetic regions grow and decay with the sunspot cycle(what have been thought to be old active regions), so that they are one of the basic features of solar magnetism related to the sunspot cycle.

(3) *Positive* spots are formed in a *positive* unipolar region (vice versa) as a local coalescence of pores.

(4) A pair of clusters of spots (positive and negative) are formed *only* at the boundary of neighboring (positive and negative) unipolar regions, constituting the magnetic pair connection (the magnetic buoyancy suggests the occurrence of pairs at any location).

(5) It is difficult explain the Butterfly diagram (the pair can occur any place). These are difficult to explain by Babcock's theory.

Therefore, an entirely new morphological study may be needed on the formation of sunspots. A new morphology can be considered by synthesizing these observed facts.

In Figure 3c, as one of the basic facts, it may be noted that a single spot consists of several pores, not a single column of magnetic flux tube. The size of a single spot depends on the number and size of pores.

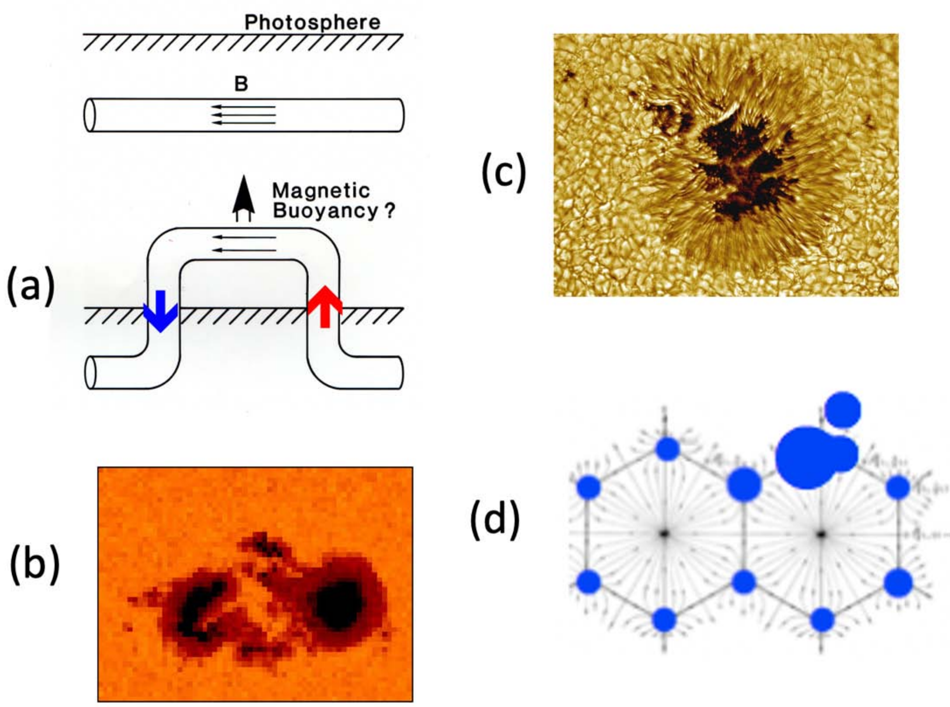

Figure 3: (a,b) The presently accepted theory of the formation of sunspots, in which a pair of spots (positive and negative) appears when an assumed magnetic flux tube rises from below the photospheric surface. (c) An example of single spots (NASA sunspot collection). (d) Photospheric convection cells with pores and single spots (assembly of pores); for the convection cells, see Clark and Johnson (1967).

This subsection deals with a new morphology of sunspots (Akasofu, 2021), before considering theoretical implications.

a) A new morphology

The first important clue in understanding the single (unipolar) spot was the presence of positive and negative unipolar magnetic regions (Akasofu, 2015). Figure 4a shows the distribution of magnetic fields on the solar disk. One can recognize that unipolar regions are weak positive and negative bands, aligned alternately in longitude, stretching well above the latitude of sunspots; there are also the northern and southern Polar Unipolar Regions. After examining the Kitt Peak solar magnetic maps during the three sunspot cycles (21, 22, 23), the first new findings are: (1)Unipolar regions are found to grow and decay with the sunspot cycle (Figure 5). (2) Unipolar regions are sometimes connected to the Polar Unipolar Regions. (3) Unipolar regions appear before sunspots at the beginning of a new sunspot cycle (Akasofu, 2021). Therefore, unipolar magnetic regions should be considered as one of the basic feathers of solar magnetism related to the sunspot cycle. In the past, they have been considered to be decaying active sunspot groups, which spread by the non-uniform rotation of the sun (Leighton, 1969).

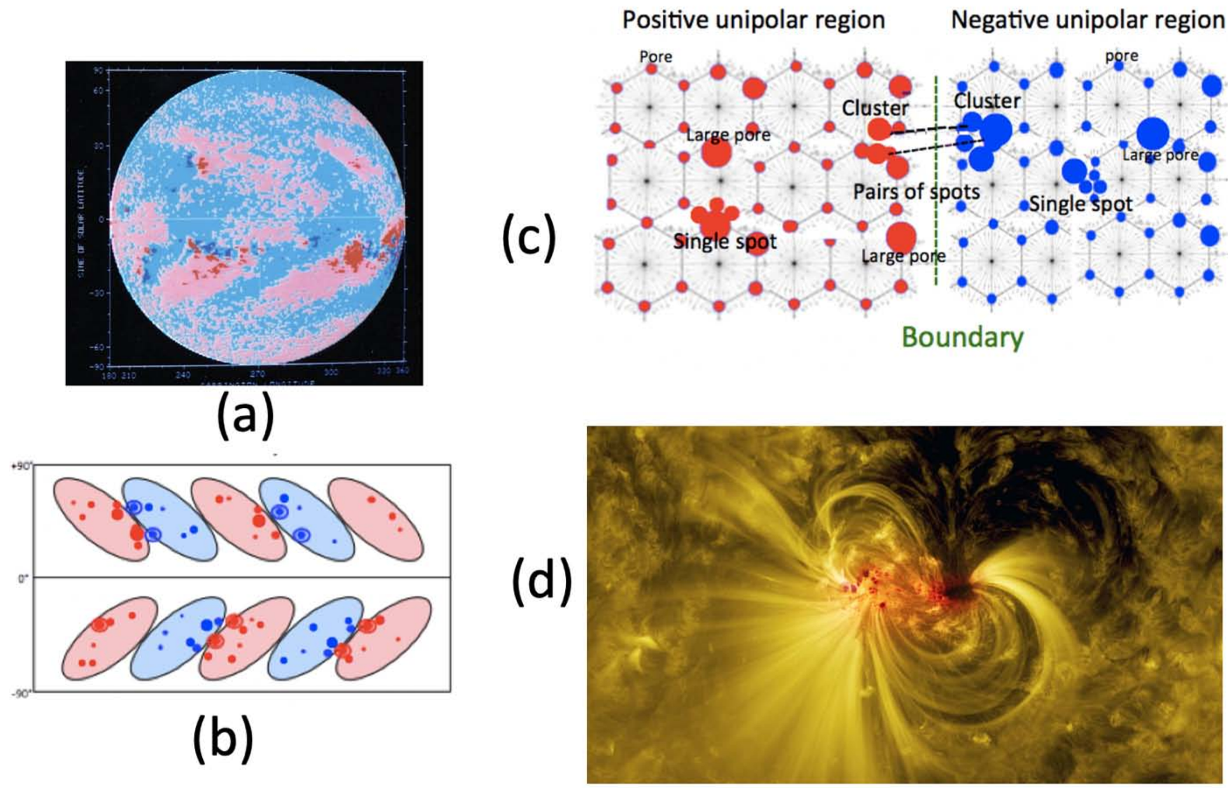

Figure 4: (a) A low resolution image of the distribution of magnetic fields on the solar disk. (b) A schematic illustration of the magnetic distribution on the solar disk, unipolar magnetic fields, concentrated fields (single spots, cluster of single spots (marked by a dot with circle and spots, which may be considered to be a pair of spots) in the network configuration. (c) A small section of the boundary of two unipolar regions with pores, single spots and clusters of spots forming a pair.(d) An example of pairs of spots; the left side is an assembly of small spots and right side perhaps two large spots (coalescence of single spots) and a few single spots (NASA Sunspot collection).

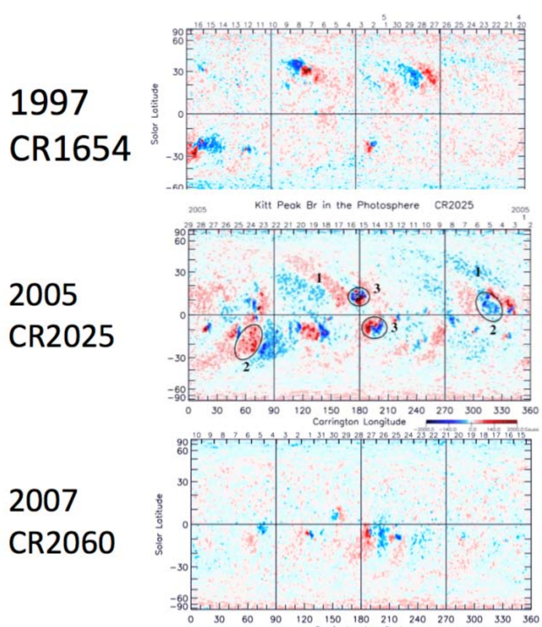

Figure 5: The distribution of magnetic fields on the photosphere, from the top, an early, middle and end epochs of the sunspot cycle, showing that unipolar regions grow and decay with the sunspot cycle.

In Figure 4a, there are also concentrated fields in unipolar regions; they are pores, single spots and clusters of spots.

The second important clue in Figure 4a is the fact *that positive single spots (red dots) are formed in a positive unipolar region (red region) and vice versa;* This feature is schematically shown in Figure 4b, which shows a summary of a study of the relationship between unipolar regions and single spots during three sunspot cycles (cf. Akasofu, 2015).

Figure 4c is a schematic enlarged view of a small portion of Figure 4a and 4b near the boundary of two unipolar regions, showing pores (dots), single spots (several dots together) and clusters of spots, forming a pair. Figure 4d shows an example of pair of clusters, constituting a pair across the boundary (a cluster consists of single spots).

b) Dynamo process/currents: Formation of single spots

The above morphological study requires a new way of considering the formation of sunspots, although a large number of studies based on the rising thin magnetic flux tube have been made in the past (cf. Solanki, 2003; Rempel, 2011).

We consider first the fact that the convective motions are always present in the photosphere. The convection cells are known to accumulate some magnetic fields along their boundaries (namely, local concentrations along the boundaries) because of irregularities of the convective motions, thus forming a network of pores, which appears as a uniform field from a global point (low resolution) of view (Figure 4a).

It is also known that these irregularities "coalesce" (not merging into single), forming pores, and then pores coalesce to form a single spot at some focal points of the boundary of the cells (McIntosh, 1981);this situation is schematically shown in Figures 3d and 5c.Parker (1992) considered vortex attraction for the coalescence. Thus, *a spot is not a simple column of magnetic flux.*

Based on the new facts in (a), it is proposed that the formation of single spots is a local coalescence and conversion of unipolar magnetic fields, namely *positive ones in a positive unipolar region (vice versa).*

Plasma motions are important in the formation of sunspots, not just the magnetic buoyancy in the thin tube theory. The local concentration can happen when a local convergence occurs; a powerful converging and downward flow down to the depth of 1.0 Mm was observed (cf. Zhao et al., 2001).

In a magnetic field, the local plasma convergence is associated with electromotive force ($V \times B$) and resulting current J. Kotov (1971) showed that there is a circular electric current around a small single spot of about 10^{12}A; Figure 6a. In fact, even Babcock's thin magnetic flux needs also a thin solenoidal current, which requires a plasma flow toward the central line of the tube and the resulting ($V \times B$) process.

In a large-scale view, considering the formation of a smallest spot (B=500 G, the radius 1.5 x10^3 km; Allen, 1955), the size of the converging area will be about 7 times of the area of a small spot by assuming the intensity of a unipolar region of 10G; this size corresponds to the size of large spots.

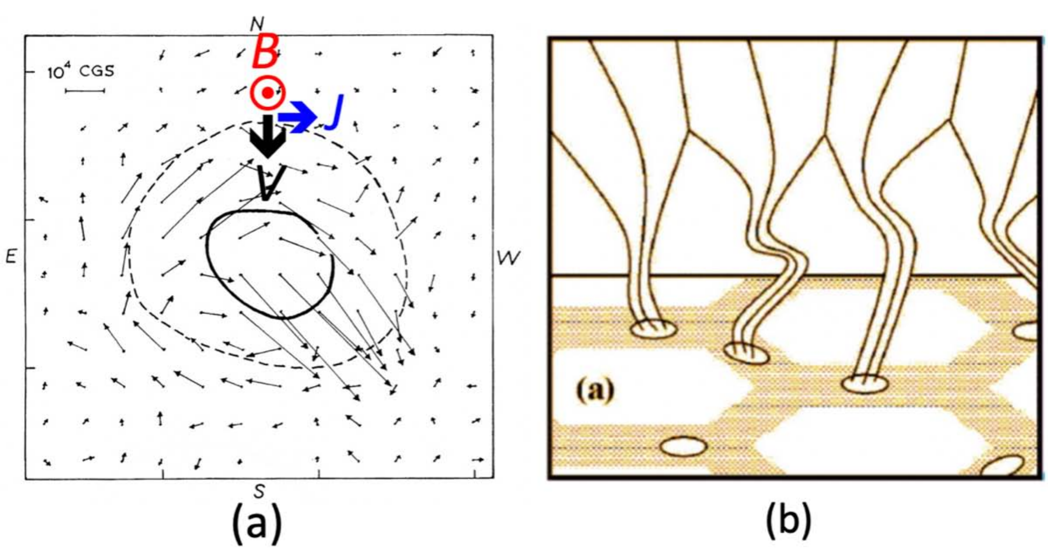

Figure 6: (a) Electric current around a single spot (Kotov,1971) with the electromotive force (VxB) and the current vector J. (b) The magnetic field above pores/single spots in the magnetic field network (taken from Canmer, 2009 for a different context)

The above process of a *local* photospheric convergence as the process of coalescence is expected to cause little change in the upper part of a unipolar region, and thus no magnetic flux adjustment with neighboring unipolar regions is needed; Figure 6b. This is perhaps only way to overcome the problems of

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unipolar magnetic spots; in the past, it has generally been assumed that single spots must have their counterpart somewhere, but without considering concretely the location.

Further, in the past, the formation of spots has hardly been discussed in terms of dynamo process and the associated *electric currents*. In considering a converging motion of plasmas for the dynamo process, it is important to know that there is also an outflow from the top of spots is well known as the Evershed flow (Bray and Loughhead, 1964; Solanki,2003).

c) Formation of pairs of spots

One of the most important new findings in the formation of pairs of spots in the above morphological study is that *a pair of clusters of spots is located only at the boundary of neighboring (positive and negative) boundary of unipolar regions.* They do not form in the middle of a unipolar region; Figures 4b and c; the thin tube theory considers only magnetic buoyancy, so that pairs of spots could appear in any place on the solar disk.

Figure 4c shows schematically a pair of two clusters, forming pairs of spots at the boundary of neighboring unipolar regions, in addition to the magnetic network of unipolar regions (positive and negative), pores, and single spots. Large spots (500-2000 G) are also known to be the coalescence of many single spots (McIntosh,1981).

Figure 4d shows an example of two clusters (pairs of spots) in each side of neighboring unipolar regions. The main feature in the left side shows a large number of single spots, while in the right side a large spot (actually, three coalesced single spots); the two clusters form a pair. An important point is that two clusters of spots across the boundary are not symmetric at all, so that it is unlikely that they are inherently connected as a tube under the photospheric surface; this is generally the case for the neighboring two clusters at the boundary.

In this view, single spots are the basic unit of sunspots, not a pair of spots.

Since pairs of spots form at the boundary of neighboring unipolar regions, it is expected that the magnetic connection between two active groups of single and large spots occurs in a way, by which Sheeley (1976) presented; on the basis of X-ray images of magnetic field lines, he described: "---these field lines usually interact by changing their flux linkage, much as they do in a vacuum". That is to say, for a given magnetic field distribution of two clusters at the boundary of neighboring unipolar regions, the magnetic connection between them may occur almost like in a potential field case.

The basic difference between the tube theory and the present morphological theory is that the present theory is developed on the basis of the *observed* magnetic records, while the tube theory is based on an *assumed* magnetic flux tube, which has so far *not been detected yet.*

d) Butterfly diagram

Any theory of the formation of sunspots must explain the equator ward shift of spots as the solar cycle advances, namely the Butterfly diagram. Since we are dealing with a new morphological theory (not the *assumed* equator ward winding of the thin magnetic flux tube), it is necessary to find a related *observed fact.* Howard and La Bonte (1980) found a large-scale latitudinal tortional oscillation, which shifts equator ward during each solar cycle; Figure 7. McIntosh (1981) showed that there occur sunspots and flare activities along the oscillation belt. Thus, there must be a close relationship between the boundaries of unipolar regions and the torsional oscillation belt. Note again Parker's vortex theory on the coalescence.

If sunspots were caused by a thin magnetic flux tube (thin solenoidal current) by magnetic buoyancy, sunspots would appear at any place and any time on the solar disk.

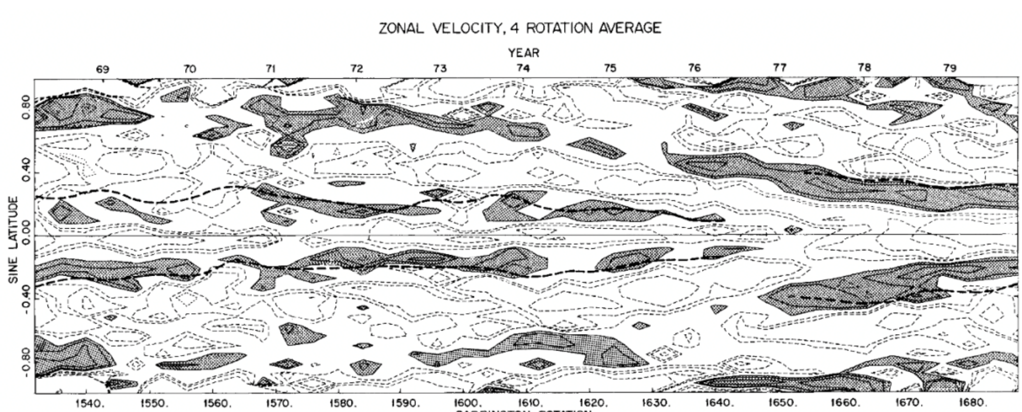

Figure 7: A large-scale tortional oscillation of the sun, which shits equator ward during each sunspot cycle (Howard and La Bonte, 1980).

e) Dissipation

When one observes a later stage of an active sunspot group, it appears as a scattered pores and single spots. Thus, the first stage of dissipation is a dispersing process of coalesced pores and single spots (see Bray and Loughhead, 1964; the βγtype in p.234) by the non-uniform rotation of the sun, rather than disintegration of a single magnetic flux tube. It is most likely that the ohmic loss will eventually dissipate individual scattered single spots.

The thin magnetic tube theory has several difficulties,(1) the presence of single spots; (2) the close relationship between single spots with unipolar magnetic regions; (3) the location of pairs of spots with the boundary of neighboring unipolar regions and (4) the Butterfly diagram. Thus, the formation of spots should be based on a new morphological theory of the formation of sunspots.

A study of sunspots is still an early phase of morphological study, so that a theoretical study here is very incomplete. As the first basic process of the formation of sunspot formation is a local convergence of unipolar regions, associated with electromotive force (*V* x *B*) and *current J* in the photosphere, forming pores and single spots. Pair of spots are formed *only* at the boundary of two unipolar regions, interacting with the large-scale torsional oscillations.

A single spot is the basic unit of spots, not a pair of spots.

V. Solar Flares

An explosive process depends generally on accumulated energy, which can be suddenly released. The theory of magnetic reconnection *presumes* that magnetic reconnection processes has such characteristics. Thus, unfortunately, magnetic reconnection has been presumed to be an explosive process for more than one-half century. Thus, the past efforts are concentrated in find plasma processes which could have the desired reconnection rate (explosive) under an anti-parallel magnetic configuration, but after several decades, there is so far no clear agreement on the rate and the produced amount of energy. Thus, there is even a possibility that magnetic reconnection is a result of flare processes, not the cause.

It may be recalled that after analyzing the reconnection theory, Parker (1963) concluded: "The observational and theoretical difficulties with hypothesis of magnetic field annihilation [magnetic reconnection] suggest that other alternatives for the flare must be explored."

Petschek (1964) appeared to be able to respond to Parker's criticism. However, after a most recent extensive review of observations, Fletcher et al. (2011), recalling Parker's criticism, mentioned that they are not certain about whether magnetic reconnection is the energy release process. *Thus, we are back to 1963.* Fletcher et al. (2011) noted also that because of the presumption, the supporting observations of the simultaneous occurrence of flares have the problem of confusing the cause-effect relationship. Thus, it is uncertain if magnetic reconnection is really the cause of solar flares. Further, there has been not much effort how the generated fast flow of plasma by magnetic reconnection can explain various flare phenomena. The Hα emission requires the knowledge of *electric currents.*

Another obvious possibility of an explosive energy source is to consider a loop current, which can accumulate needed magnetic energy (Alfven, 1950, 1981), but its possibility as the energy source was forgotten or not considered.

Here, we consider solar flares as a result of the sequence of processes, which begin with a dynamo process as the power supply and a current loop is the source of energy.

a) Dynamo and current/circuit

The basic mode of the dynamo of solar flares is an arcade-mode dynamo discussed Section 2. Figure 8a is the same as Figure 1a.

Plasma flows along the neutral line is about 1.6 km/s (Young et al., 2004) or much higher (cf. Min and Chae, 2002).

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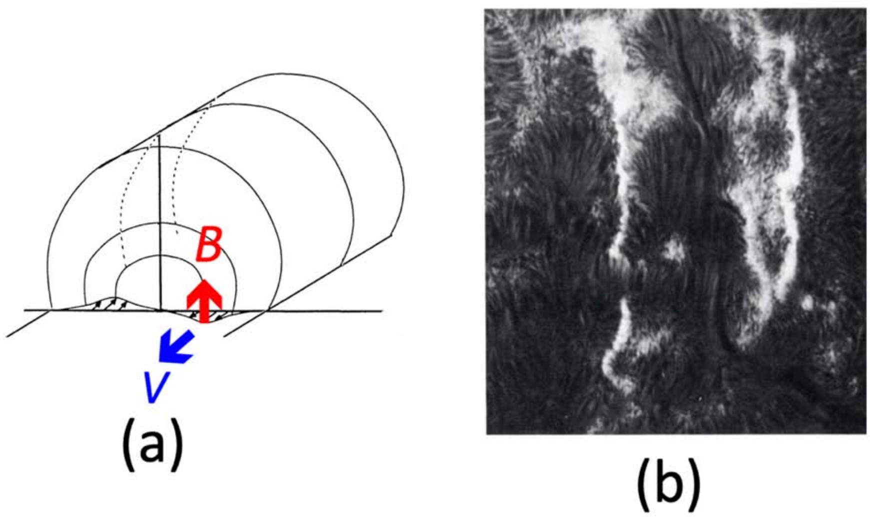

Figure 8: (a) The photospheric dynamo process under amagnetic arcade. (b) An example of spotless flares (Svestka, 1976).

b) Dissipation: Spotless flares

The dynamo under the arcade produces two-ribbon flares at the feet of the arcade, because the field-aligned currents along the arcade can excite chromospheric atoms. These flares are called spotless flares, because there is no sunspot around them. Actually, they occur more frequently than ordinary flares.

Although spotless flares are generally weak, they are the basic feature of flares driven by a dynamo process under the electric current approach. An active sunspot group provides regions of a stronger *B* field (see the power equation in Section 2), not sunspots themselves. The reason why intense flares tend to occur in an active sunspot group is due to this fact.

A significant part of the energy dissipation is associated with the Hα emission resulting from the enhancement of the field-aligned currents along the arcade magnetic field lines; it is about 10^{31} erg (Svestka,1976).Very energetic phenomena associated with flares, such as solar sub-cosmic rays, dissipate less energy in terms of the total energy budget.

c) Explosive process: The other dissipation

In addition to the magnetic field-aligned currents along the magnetic arcade, the dynamo process in the magnetic arcade model produces a loop current along the two-ribbon emission (Akasofu and Lee, 2019). It flows along the dark filament between the two ribbons, but above them (Figures9a and b).

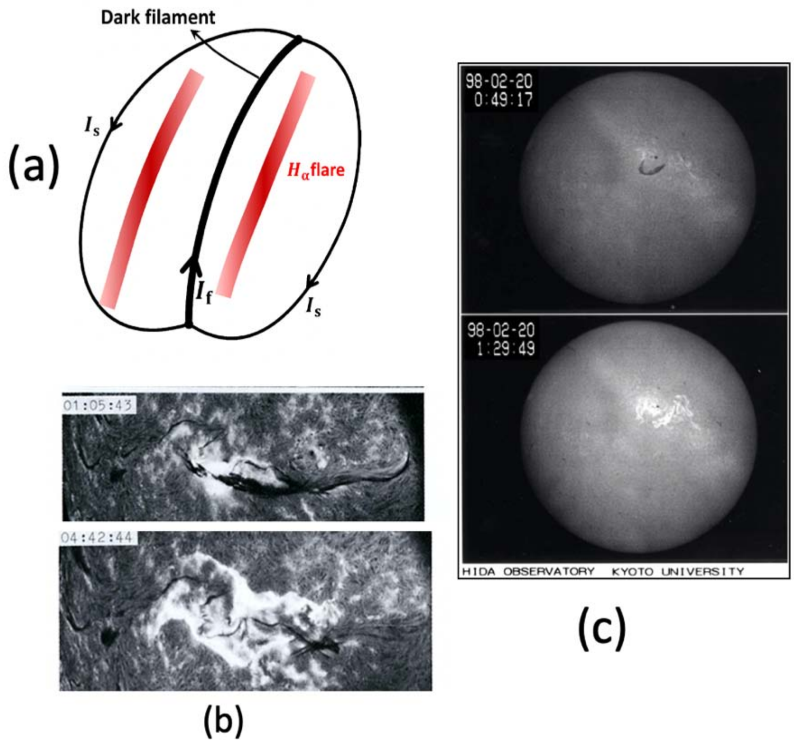

Figure 9: (a) The arcade dynamo generates another current between the two-ribbon flare, but above it. (b) Upper: an image just before flare onset; note the dark filament. Lower: the maximum epoch of a two-ribbon flare; note that the dark filament was blown away (Courtesy of E.Hiei, Norikura Solar Observatory). (c) An example of dispartion brusques (DB; Courtesy of E.Hiei, Norikura Solar Observatory)

The loop current has magnetic energy of $W = (1/2)\ I^2L$, where I and L denote the current intensity and inductance, respectively. For a typical vale $I = 10^{11}$ A (Chen and Krall, 2003) and L = 2000H (Alfven, 1981), $W = 10^{32}$ erg, so that the loop current along the dark filament can have enough energy for flares.

One of the ways to observe the energy accumulation is to examine magnetic shear (Wang et al., 1994); in his case, the shear increased for about 5 hours before flare onset, so that the power in this case is estimated to be 2.8×10^{26} erg/s (Akasofu and Lee, 2019); the speed of plasma estimated in this study is in agreement with the flow speed, 1.6 km/s, observed by Yang et al. (2004).

The reasons for emphasizing that the exploding loop current as the energy source of the explosive phase of solar flares is that the disappearance of the dark filament occurs at the time when the two-ribbon emission is greatly enhanced, flare onset (Figure 9b and c). This phenomenon is described in detail by Svestka (1967, p.229) as "*dispartions brusques*, (DB)"; DBs seem to occur in association with explosive feature and are likely to be caused by a current instability in the loop current. Indeed, Kurokawa et al. (1987) showed that the exploding prominence (the filament) has unwinding motions, indicating a reduction of the electric currents along the loop.

It is unfortunate that DBs are hardly considered today (perhaps, the attention has been focused only on magnetic reconnection).

Therefore, a magnetic arcade dynamo generates field-aligned currents along the arcade magnetic field lines, producing a two-ribbon flare and a loop current along the dark filament. The loop current in the dark filament has enough magnetic energy for flares. Therefore, the photospheric dynamo is likely to the power source of flares, and thus the loop current along the dark filament is another or a better source of the explosive energy than magnetic reconnection.

VI. Concluding Remarks

In this paper, the following suggestions are made for each of the four subjects on the basis of the electric current approach.

(1) Coronal heating: The photosphericdynamo and coronal magnetic loop *currents* for the ionization of the corona by energetic electrons.
(2) Solar wind: Solar unipolar induction, the associated circuit and *currents* for the electromotive force ($J \times B$) as adriving current system for the solar wind.
(3) Sunspot formation: The dynamo process of the photospheric convergence flow and associated *currents are crucial.*

(4) Solar flares: The photospheric dynamo under a magnetic arcade, and the resulting the field-aligned *current* along the arcade field lines produce the two-ribbon emission. The dynamo generates also the *current* loop along the filament for the explosive process.

It is hoped that these suggestions are useful in pursuing the four subjects and that the electric current approach will be considered in the future.

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- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

Color charges: Authors are advised to pay the full cost for the reproduction of their color artwork. Hence, please note that if there is color artwork in your manuscript when it is accepted for publication, we would require you to complete and return a Color Work Agreement form before your paper can be published. Also, you can email your editor to remove the color fee after acceptance of the paper.

Tips for Writing a Good Quality Science Frontier Research Paper

Techniques for writing a good quality Science Frontier Research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of science frontier then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

19. Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

20. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

21. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

22. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

23. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- o Single section and succinct.
- o An outline of the job done is always written in past tense.
- o Concentrate on shortening results—limit background information to a verdict or two.
- o Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

The Administration Rules

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

Please read the following rules and regulations carefully before submitting your research paper to Global Journals Inc. to avoid rejection.

Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.

Criterion for Grading a Research Paper (Compilation) by Global Journals

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals.

Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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