X17 and the dark mark

Fabrizio Vassallo
facebook.com/fabrizio.vassallo.98

Recent developments in particle physics, astrophysics and cosmology seem to converge towards the recognition of the existence of the QCD axion. Moreover, a substantial equivalence between the X17 boson and the QCD axion has been proposed. A description of X17 is suggested as a particle composed of four preons, from a model described in previous articles of ours. The paper ends by pointing to a possible application of results related to braiding and fusion statistics to this model.

The QCD axion is a hypothetical elementary particle postulated by the Peccei-Quinn theory to resolve the strong CP problem [1].
In [2] it is suggested that the QCD axion, in the mass range of O(10 MeV), must possess properties that correspond, remarkably, to those possessed by the vector boson X17, whose existence has been recently proposed [3].
The existence of the axion is also one of the hypothesized explanations for the presence of black holes with a mass within the black hole mass gap, prohibited by current models [4].
Moreover, X17 can offer an explanation of the 511 keV line [5].
Further references on the subject and on possibly related anomalies can be found here [6].

A particle model from nonlinear dynamical systems theory

The logistic map [7]

$$x_{n+1} = r\, x_n (1-x_n) \qquad x_n \in [-0.5,1.5],\ r \in [-2,4]$$

is an example of a simple dissipative nonlinear dynamical system which shows a rich dynamical behavior. In particular, in Fig. 1 is plotted the bifurcation diagram of the map as the parameter r varies.

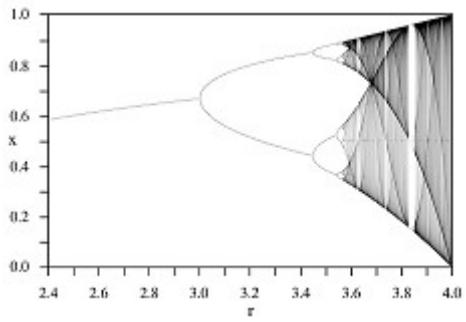

Fig. 1: Bifurcation diagram for the logistic map (from Wikipedia)

In [8] V. Manasson hypothesized a relation between the bifurcation diagram and the quantum numbers of some particles. This idea is connected with the phenomenon of the production of electron-positron pairs by high-energy photons [9].

In previous articles [10] we have proposed to extend Manasson's original idea and developed a toy model in which the bifurcations produce a hierarchy of particles, whose properties derive from the properties of the particles of the previous level of the hierarchy, recursively in a sense.

The level of the hierarchy after the electron-positron level is occupied by a particle we call “mark”.

As the electron derives from the photon that halves its spin and the electric charge appears, so the mark derives from the electron that halves its spin again and halves the electric charge. From this it follows that the mark has spin 1/4 and electric charge 1/2.
Furthermore, we postulate the appearance of a new quantum number, the “strong charge”, which in analogy to the spin of the photon (up and down), and to the electric charge of the electron-positron, can assume only two values, +1 and -1.

Our model is somewhat reminiscent of “digital physics” [11]: let's take as an example the next level of the hierarchy, characterized by the “supermark”.
This particle has 4 quantum numbers: “weak charge” ±1, “strong charge” ±1/2, electric charge ±1/4, spin ±1/8.
Any quantum number can be positive or negative, and can have a fractional value (only negative powers of two).

We assume also that the bifurcation processes leading from one level to the next level of the hierarchy mimic the dynamic behavior of Falaco solitons (which can be seen as half vortex rings).

“I propose (not yet supported by the mathematics) that the energy density and ‘torsion’ of space in this interaction can result in stable vortex pairs that are connected in the manner of Falaco solitons (Fig. 5). However, being vortices of a 3-D surface in 4-space, the connection is in time, not in space. It is a wormhole.” [12]. See also [13] for additional references.

Exotic statistics

The mark, having spin 1/4, obeys neither bosonic nor fermionic statistics.
Objects having similar characteristics have been studied in the literature: half-fermions, anyons, quartions, semions, plektons [14].
The study of exotic statistics can be traced back to Giovanni Gentile Jr. in 1940, and has been studied extensively [15].

As already mentioned, we assume that a pair of marks is created from an electron or from a positron, in analogy to the creation of electron-positron pairs from photons.

Our idea to justify the possibility of existence of particles with semifermionic statistics is that, in conjunction with this process of creating a pair of marks from an electron or a positron, a doubling of the dimensions of spacetime also takes place. The idea of variable spacetime dimensions is not new in the literature [16].
The mark can thus be described as an 8D particle, and we guess that this shift to higher dimensions [17] can lead to the possibility of realization of semifermionic statistics.

Superluminality

Since the photon is massless and timeless, in a certain sense it can be said that mass and time appear in conjunction with the creation of the electron-positron pair. We therefore assume that the principle

of dimensional doubling can also be applied to the dimensions of mass and time.
At the mark level, mass and time are no longer scalar but they are complex quantities, made up of a real and an imaginary part.
An imaginary mass suggests the possible presence of tachyonic fields [18] and opens up the possibility of using the advances made by researchers in the field [19].

A quantum of mass

M. H. Mac Gregor in [20] defines "a boson mass quantum $m_b = m_e/\alpha = 70.025$ MeV and a fermion mass quantum $m_f = (3/2)\ m_b = 105.038$ MeV", where $m_e = 0.511$ MeV is the electron mass. See also [21].

If to the mark is assigned a mass of $m_e/4\alpha = 17.5$ MeV, a composition of marks has the capability to recover the two quanta of mass defined by Mac Gregor, both as regards the mass and as regards the spin (a composition of semifermions can produce both bosons and fermions).

We argue that the only true bosons are gravitons and photons and that the only true fermion is the electron-positron. The other particles are pseudobosons and pseudofermions, composed of marks (or supermarks), and whose spin is the result of the sum of the spins possessed by the component marks.

In particular, we propose that X17 is composed of 4 marks, which in an "annihilation" process produce an electron-positron pair.
The fact that the mass of X17 is similar to the mass of a mark can be explained as follows: of the 4 component marks, only one has a "real" mass, which is roughly the one measured for the X17 boson.
The other 3 marks possess an "imaginary" mass, totally or almost totally.
Marks in this state can be defined as "dark" ones, and it is to these marks that the title of this article refers.

Braiding and fusion statistics

As a final observation, we note the visual similarity between fig. 2 of [22], regarding braiding and fusion statistics of the semion theory, and fig. 1 of [23], regarding the braiding of anyons.

This formal similarity, in our opinion, suggests that there could be also a substantial connection at the basis of the various proposals for the application of both braiding groups and the theory of anyons to the theory of particles in spacetime dimensions greater than 2+1 [24].

References

[1] Wikipedia Axion

Jihn E. Kim, Gianpaolo Carosi Axions and the Strong CP Problem

Y. Nakamura, G. Schierholz The QCD axion beyond the classical level: A lattice study

Jia Liu, Navin McGinnis, Carlos E.M. Wagner and Xiao-Ping Wang Challenges for a QCD axion at the 10 MeV scale

[2] D. S. M. Alves Signals of the QCD axion with mass of 17 MeV/c^2: Nuclear transitions and light meson decays

D. S. M. Alves, N. Weiner A viable QCD axion in the MeV mass range

[3] A.J. Krasznahorkay et al. Observation of Anomalous Internal Pair Creation in ^{8}Be: A Possible Signature of a Light, Neutral Boson

A.J. Krasznahorkay et al. New evidence supporting the existence of the hypothetic X17 particle

A.J. Krasznahorkay et al. A new anomaly observed in ^{4}He supports the existence of the hypothetical X17 particle

M. Viviani et al. The X17 boson and the ^{3}H(p,e^+e^-)^{4}He and ^{3}He(n,e^+e^-)4He processes: a theoretical analysis

Jonathan L. Feng et al. Protophobic Fifth Force Interpretation of the Observed Anomaly in ^{8}Be Nuclear Transitions

Jonathan L. Feng et al. Particle Physics Models for the 17 MeV Anomaly in Beryllium Nuclear Decays

Yu. M. Andreev et al. Search for pseudoscalar bosons decaying into e^+e^- pairs

NA64 Collaboration, E. Depero et al. Hunting down the X17 boson at the CERN SPS

C. Hati, J. Kriewald, J. Orloff and A.M. Teixeira Anomalies in ^{8}Be nuclear transitions and $(g-2)_{e,\mu}$: towards a minimal combined explanation

Jonathan Kriewald Explaining the (g −2)e,μ anomalies with the X17 boson

[4] Djuna Croon, Samuel D. McDermott, Jeremy Sakstein Missing in Action: New Physics and the Black Hole Mass Gap

Djuna Croon, Samuel D. McDermott, Jeremy Sakstein Missing in Axion: where are XENON1T's big black holes?

R. Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration) GW190521: A Binary Black Hole Merger with a Total Mass of 150 M⊙

Jeremy Sakstein, Djuna Croon, Samuel D. McDermott, Maria C. Straight, Eric J. Baxter Beyond the Standard Model Explanations of GW190521

Bruce Edelman, Zoheyr Doctor, Ben Farr Poking Holes: Looking for Gaps in LIGO/Virgo's Black Hole Population

Chase Kimball et al. Evidence for hierarchical black hole mergers in the second LIGO--Virgo gravitational-wave catalog

Horng Sheng Chia Probing Particle Physics with Gravitational Waves

[5] Yohei Ema, Filippo Sala, Ryosuke Sato Dark matter models for the 511 keV galactic line predict keV electron recoils on Earth

Lian-Bao Jia Explanation of the 511 keV line: cascade annihilating dark matter with the ^{8}Be anomaly

Lian-Bao Jia, Tong Li Interpretation of the Galactic gamma-ray excess with the dark matter indicated by ^{8}Be and ^{4}He anomalous transitions

[6] Fabrizio Tamburini, Ignazio Licata Can the periodic spectral modulations of the 236 SETI candidate Sloan Survey stars be due to Dark Matter effects?

Dario Buttazzo, Paolo Panci, Daniele Teresi, Robert Ziegler Xenon1T excess from electron recoils of non-relativistic Dark Matter

Haider Alhazmi, Doojin Kim, Kyoungchul Kong, Gopolang Mohlabeng, Jong-Chul Park and Seodong Shin Implications of the XENON1T excess on the dark matter interpretation

Peter Athron et al. Global fits of axion-like particles to XENON1T and astrophysical data

Amin Aboubrahim, Michael Klasen and Pran Nath Xenon-1T excess as a possible signal of a sub-GeV hidden sector dark matter

Matheus Hostert, Kunio Kaneta and Maxim Pospelov Pair production of dark particles in meson decays

Roberto Contino, Kevin Max, and Rashmish K. Mishra Searching for elusive dark sectors with terrestrial and celestial observations

Raghuveer Garani, Michele Redi, Andrea Tesi Dark QCD Matters

Bartosz Fornal, Benjamin Grinstein Dark Matter Interpretation of the Neutron Decay Anomaly

Bartosz Fornal, Benjamin Grinstein Neutron Lifetime Discrepancy as a Sign of a Dark Sector?

Bartosz Fornal, Benjamin Grinstein Neutron's Dark Secret

Fatemeh Elahi and Mojtaba Mohammadi Najafabadi Neutron decay to a non-Abelian dark sector

David McKeen, Maxim Pospelov and Nirmal Raj Cosmological and astrophysical probes of dark baryons

A. P. Serebrov, O. M. Zherebtsov Trap with ultracold neutrons as a detector of dark matter particles with long-range forces

Leanne D. Duffy and Karl van Bibber Axions as dark matter particles

D. Barducci, M. Fabbrichesi and E. Gabrielli Neutral hadrons disappearing into the darkness

Marco Fabbrichesi, Emidio Gabrielli, Gaia Lanfranchi The Dark Photon

Karim Ghorbani Light vector dark matter with scalar mediator and muon g-2 anomaly

A. Ahmidouch et al., A Direct Detection Search for Hidden Sector New Particles in the 3-60 MeV Mass Range

Zurab Berezhiani Neutron lifetime puzzle and neutron -- mirror neutron oscillation

Zurab Berezhiani Neutron lifetime and dark decay of the neutron and hydrogen

Paul Frederik Depta, Marco Hufnagel, Kai Schmidt-Hoberg Robust cosmological constraints on axion-like particles

Maria Paola Lombardo, Anton Trunin Topology and axions in QCD

Fabian Rennecke Higher topological charge and the QCD vacuum

Ryuichiro Kitano and Norikazu Yamada Topology in QCD and the axion abundance

Gonzalo Alonso-Álvarez and Joerg Jaeckel Exploring axionlike particles beyond the canonical setup

Luca Visinelli, Paolo Gondolo Dark Matter Axions Revisited

Giovanni Grilli di Cortona, Edward Hardy, Javier Pardo Vega and Giovanni Villadoro The QCD axion, precisely

Maurizio Giannotti, Igor G. Irastorza, Javier Redondo, Andreas Ringwald, Ken'ichi Saikawa Stellar Recipes for Axion Hunters

Luca Di Luzio, Maurizio Giannotti, Enrico Nardi, Luca Visinelli The landscape of QCD axion models

Shao-Feng Ge, Xiao-Dong Ma, Pedro Pasquini Probing the Dark Axion Portal with Muon Anomalous Magnetic Moment

Dongok Kim, Younggeun Kim, Yannis K. Semertzidis, Yun Chang Shin, Wen Yin Cosmic Axion Force

A. Nordt, S. Gerhard, D. H. H. Hoffmann, M. Kuster, D. Weber, K. Zioutas CAST-Probing Axions from the Core of the Sun

Ian Stern Axion Dark Matter Searches

David J. E. Marsh Axion Cosmology

M.S. Safronova, D. Budker, D. DeMille, D. F. Jackson Kimball, A. Derevianko, C. W. Clark Search for New Physics with Atoms and Molecules

Jonathan Engel, Michael J. Ramsey-Musolf, U. van Kolck Electric Dipole Moments of Nucleons, Nuclei, and Atoms: The Standard Model and Beyond

[7] Wikipedia Logistic map

[8] V. A. Manasson Are Particles Self-Organized Systems?

[9] Wikipedia Pair production, Electron–positron annihilation, Gamma ray

STAR Collaboration Measurement of e+e− Momentum and Angular Distributions from Linearly Polarized Photon Collisions

[10] F. Vassallo A Preon Model from Manasson's Theory

F. Vassallo A Preon Model from Manasson's Theory II

F. Vassallo Liberating Preons from Four Dimensions

F. Vassallo On a Possible Internal Structure of the Tau

[11] Wikipedia Digital physics

H. Pierre Noyes A Short Introduction to Bit-String Physics

David Deutsch, Chiara Marletto Constructor Theory of Information

Paola Zizzi Spacetime at the Planck Scale: The Quantum Computer View

D. R. Finkelstein Ur Theory and Space-Time Structure

Louis H. Kauffman Iterants, Majorana Fermions and the Majorana-Dirac Equation

Louis H. Kauffman Iterants, Fermions and the Dirac Equation

[12] A. Meulenberg Photon trapping and the transition to electrons in "Are electrons oscillating photons, oscillating “vacuum”, or something else? The 2015 panel discussion"

[13] R. M. Kiehn Falaco Solitons, Cosmic Strings in a Swimming Pool

Matti Pitkanen Robert Kiehn’s ideas about Falaco solitons and generation of turbulent wake from TGD perspective

Sofia Lambropoulou, Stathis Antoniou Topological Surgery, Dynamics and Applications To Natural Processes

Stathis Antoniou, Louis H. Kauffman, Sofia Lambropoulou Topological surgery in the small and in the large

Stathis Antoniou, Louis H. Kauffman, Sofia Lambropoulou Black holes and topological surgery

Stathis Antoniou, Louis H. Kauffman, Sofia Lambropoulou Topological surgery in cosmic phenomena

[14] A. Zee Semionics: a theory of superconductivity based on fractional quantum statistics

Luca Mezincescu, Paul K. Townsend Semionic Supersymmetric Solitons

Lincoln D. Carr and Laith H. Haddad Semions, Skyrmions, and a Zoo of Nonlinear Waves in the Nonlinear Dirac equation

Dmitri Sorokin The Heisenberg Algebra and Spin

Jens Mund The CPT and Bisognano-Wichmann Theorems for Anyons and Plektons in d=2+1

Ady Stern, Michael Levin Liberating anyons from two dimensions

Peter A. Horvathy, Mikhail S. Plyushchay, Mauricio Valenzuela Bosons, fermions and anyons in the plane, and supersymmetry

Luca Mezincescu, Paul K. Townsend 3D strings and other anyonic things

Diego Julio Cirilo-Lombardo Particle actions in the superspace, square root operators and quartions

Dmitrij P. Sorokin, Dmitrij V. Volkov D=(0|2) Dirac--Maxwell--Einstein Theory as a Way for Describing Supersymmetric Quartions

Mikhail S. Plyushchay Majorana equation and exotics: higher derivative models, anyons and noncommutative geometry

Sergey M. Klishevich, Mikhail S. Plyushchay, Michel Rausch de Traubenberg Fractional helicity, Lorentz symmetry breaking, compactification and anyons

D. Sorokin Hyperparticles, twistors and any spins

D.V. Volkov, D.P. Sorokin, V.I. Tkach On the Relativistic Field Theories with Fractional Statistics and Spin in D=(2+ 1), (3+ 1)

D.V. Volkov Quartions in Relativistic Field Theory

[15] Giovanni Gentile Jr., Osservazioni sopra le statistiche intermedie, Nuovo Cimento 17 (1940) 493

John C. Baez, Derek K. Wise, Alissa S. Crans Exotic Statistics for Strings in 4d BF Theory

Richard J. Szabo Topological Field Theory and Quantum Holonomy Representations of Motion Groups

Charis Anastopoulos Spin-Statistics Theorem and Geometric Quantisation

F.D.M. Haldane Fractional statistics in arbitrary dimensions: a generalizaton of the Pauli Principle

N. Read Nonabelian braid statistics versus projective permutation statistics

Jouko Mickelsson Current algebra and exotic statistics in 6 dimensions

Wladyslaw Marcinek Particles, Generalized Statistics and Categories

Wladyslaw Marcinek On Generalized Statistics and Interactions

Wladyslaw Marcinek Particles of generalized statistics, quantum logic and categories

Wladyslaw Marcinek On Generalized Quantum Statistics

[16] Hidezumi Terazawa Dimensional Transition of the Universe

Hidezumi Terazawa Space-Time Dimension of the Universe

Sung-Sik Lee A model of quantum gravity with emergent spacetime

Niayesh Afshordi, Dejan Stojkovic Emergent Spacetime in Stochastically Evolving Dimensions

[17] P. S. Bisht, Bimal Pandey, O. P. S. Negi Interpretations of Octonion Wave Equations

P. S. Bisht, O. P. S. Negi Super Symmetric Partners in T4- space

Luca Fabbri Polar analysis of the Dirac equation through dimensions

Merab Gogberashvili, Alexandre Gurchumelia Split Octonions and Triality in (4+4)-Space

Jens Koeplinger Nonassociative quantum theory on octooctonion algebra

E. A. Rauscher, R. L. Amoroso Complex Dimensional Geometries and Measurement

J. A. Nieto, M. Espinoza Dirac Equation in Four Time and Four Space Dimensions

M. Medina, J. A. Nieto, P. A. Nieto-Marín Cosmological Duality in Four Time and Four Space Dimensions

C. Aviles-Niebla, P. A. Nieto-Marin and J. A. Nieto Towards exterior/interior correspondence of black-holes

Juan Antonio Nieto, José Edgar Madriz Aguilar Aspects of (4+4)-Kaluza-Klein type theory

[18] Wikipedia Tachyonic field, Tachyon

[19] Erasmo Recami A homage to E.C.G.Sudarshan: Superluminal objects and waves (An updated overview of the relevant experiments)

Erasmo Recami Classical tachyons and possible applications

Luca Nanni Overcoming the Bradyon-Tachyon Barrier

Luca Nanni Space-Like Particle Production: an Interpretation Based on the Majorana Equation

Luca Nanni Dynamics of Neutrino Wave Packet in the Tachyon-like Dirac Equation

Luca Nanni Evanescent Waves and Superluminal Behavior of Matter

Luca Nanni Superluminal Tunneling of a Relativistic Half-Integer Spin Particle Through a Potential Barrier

Luca Nanni The Dynamics of the Wave Packet in the Majorana Equation

Luca Nanni Superluminal Neutrinos: Experimental Data and New Interpretative Theories

Luca Nanni Tachyonic Dirac Equation Revisited

Luca Nanni Production of Tachyonic Neutrino in Matter

Luca Nanni Particle Mass Oscillation through Tachyon Interaction

Luca Nanni On the Time-Like and Space-Like Components of Majorana Field

Luca Nanni Quantum Theory of Half-integer Spin Free Particles from the Perspective of the Majorana Equation

Fabrizio Tamburini, Ignazio Licata Majorana quanta, string scattering, curved spacetimes and the Riemann Hypothesis

Robert Ehrlich First results of the KATRIN neutrino mass experiment and their consistency with an exotic 3+3 model

Robert Ehrlich Tachyonic neutrinos and the neutrino masses

Guang-Jiong Ni Cosmic Ray Spectrum and Tachyonic Neutrino

U. D. Jentschura Dirac Hamiltonian with Imaginary Mass and Induced Helicity-Dependence by Indefinite Metric

Vo Van Thuan A superluminal formalism for Majorana-like lepton

Matej Pavšič Localized Propagating Tachyons in Extended Relativity Theories

Olexa-Myron Bilaniuk, E. C. George Sudarshan Particles beyond the light barrier

[20] M. H. Mac Gregor The top quark to electron mass ratio $m_t = 18\ m_e / \alpha^2$

[21] Paolo Palazzi Mass Rules, Shell Models and the Structure of Hadrons

V. V. Varlamov Lorentz group and mass spectrum of elementary particles

[22] Xie Chen, Fiona J. Burnell, Ashvin Vishwanath, Lukasz Fidkowski Anomalous Symmetry Fractionalization and Surface Topological Order

[23] Louis H. Kauffman Knot Logic and Topological Quantum Computing with Majorana Fermions

[24] Louis H. Kauffman, Samuel J. Lomonaco Braiding Majorana Fermions

Louis H. Kauffman, Samuel J. Lomonaco Braiding, Majorana fermions, Fibonacci particles and topological quantum computing

Louis H Kauffman, Peter Rowlands The Dirac Equation and the Majorana Dirac Equation

Giorgio Benedek Majorana Fermions in Condensed Matter, in Scientific Papers of Ettore Majorana, A New Expanded Edition, ed. Luisa Cifarelli 2020

C.W.J. Beenakker Search for non-Abelian Majorana braiding statistics in superconductors

R.S. Dunne A braided interpretation of fractional supersymmetry in higher dimensions

R.S. Dunne Intrinsic anyonic spin through deformed geometry

Yizhi You, Trithep Devakul, S. L. Sondhi, F. J. Burnell Fractonic Chern-Simons and BF theories

Davide Castelvecchi The strange topology that is reshaping physics

Janusz E. Jacak Confinement and fractional charge of quarks from braid group approach to holographic principle

Niels G Gresnigt Braided fermions from Hurwitz algebras

Niels G. Gresnigt Braids, normed division algebras, and Standard Model symmetries

Michael Atiyah, Matilde Marcolli Anyons in Geometric Models of Matter

Chenjie Wang, Michael Levin Braiding statistics of loop excitations in three dimensions

T. Asselmeyer-Maluga Braids, 3-manifolds, elementary particles: number theory and symmetry in particle physics

Aleksey Cherman, Srimoyee Sen, Laurence G. Yaffe Anyonic particle-vortex statistics and the nature of dense quark matter

Additional references

C.Pati, A.Salam, J.Strathdee Are quarks composite?

David Ritz Finkelstein Spin, Statistics and Space-Time

David Ritz Finkelstein, Heinrich Saller, Zhong Tang Beneath Gauge

J. A. Morgan Demonstration of the spin-statistics connection in elementary quantum mechanics

P. Ramadevi Exchange of identical particles in two dimensions

Zheng-Cheng Gu Neutrino as topological Majorana zero modes: the origin of three generations of neutrinos and their mass mixing

Zheng-Cheng Gu Fractionalized time reversal, parity and charge conjugation symmetry in topological superconductor: a possible origin of three generations of neutrinos and mass mixing

Niels G. Gresnigt A topological model of composite preons from the minimal ideals of two Clifford algebras

Niels G. Gresnigt Sedenions, the Clifford algebra Cl(8), and three fermion generations

Adam B. Gillard, Niels G. Gresnigt Three fermion generations with two unbroken gauge symmetries from the complex sedenions

Gia Dvali, Cesar Gomez, Slava Mukhanov Black Hole Masses are Quantized

Luis J. Boya, E. C. G. Sudarshan The Spin-Statistics Theorem in Arbitrary Dimensions

M. Pavsic, Erasmo Recami, W.A. Rodrigues Jr Electron structure, Zitterbewegung, and the new non-linear Dirac-like equation

Sergei Klishevich, Mikhail Plyushchay Zitterbewegung and reduction: 4D spinning particles and 3D anyons on light-like curves

Jonathan Hackett, Louis H. Kauffman Octonions

Jacob G. Foster, Berndt Müller Physics With Two Time Dimensions

Masud Chaichian, Archil B. Kobakhidze Mass hierarchy and localization of gravity in extra time

Recai Erdem, Cem S. Un Reconsidering extra time-like dimensions

S.I. Kruglov Pair production and solutions of the wave equation for particles with arbitrary spin

H.F. Dowker, R.D. Sorkin A Spin-Statistics Theorem for Certain Topological Geons

U. D. Jentschura and B. J. Wundt From Generalized Dirac Equations to a Candidate for Dark Energy

L. H. Kauffman Physical Knots and Particle Topology

E.C.G. Sudarshan, N. Mukunda Quantum Theory of the Infinite-Component Majorana Field and the Relation of Spin and Statistics

Chetan Nayak, Steven H. Simon, Ady Stern, Michael Freedman, Sankar Das Sarma Non-Abelian Anyons and Topological Quantum Computation

Frank Wilczek Majorana returns

Geoffrey Dixon Division Algebras: Family Replication

Cohl Furey Three generations, two unbroken gauge symmetries, and one eight-dimensional algebra

Paolo Budinich From the Geometry of Pure Spinors with their Division Algebras to Fermion's Physics

Shuichiro Teramachi Octonionic Higgs particles

Murod Abdukhakimov How Dirac and Majorana Equations Are Related

S. Esposito Searching for an equation: Dirac, Majorana and the others