ICCA11

Ghent University

Waldyr Alves Rodrigues Jr.: Sketches on his Life and Work

S. Xambó & C. Lavor

UPC & Unicamp

9 August 2017

AGACSE 2015

1. Lavor
2. Alves
3. WARjr
4. Lewintan
5. Mrs Lewintan
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8. Zatloukal
9. Colapinto
10. Stockwell
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12. Todd
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16. Lasenby
17. Joan L.
18. Dorst
19. Bell
20. McClellan
21. Doran
22. Prodanov
23. Huang
24. Li
25. Klausen
26. Roosen
27. Taniçli
28. Burns
29. ??
30. Okamoto
31. Hitzer
32. Moya

N

Waldyr Alves Rodrigues Jr

Publicado por Universia en Investigadores

En el ámbito de la Física Matemática, el tratamiento de los fundamentos lógicos y matemáticos...

Más información

http://www.arbolmat.com/

N

- Plenary lecture: *Concept of the Lie derivative of spinor fields. A geometric motivated approach* (with Samuel WAINER)
- Summer School 1st lecture: *(Some) differential geometry and general relativity*.
- Summer School 2nd lecture: *Physical applications*.

GEOMETRIC ALGEBRA

E. ARTIN

Princeton University, Princeton, New Jersey

Wiley Classics Library Edition Published 1988

WILEY

INTERSCIENCE PUBLISHERS, INC., NEW YORK

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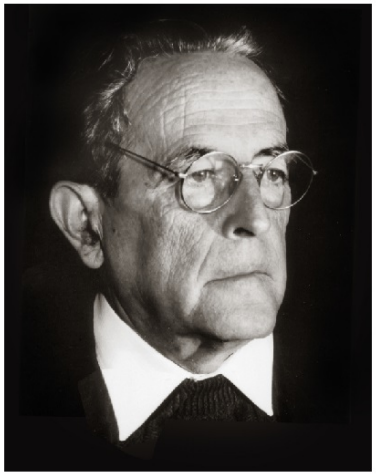
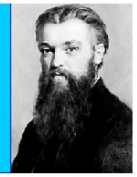


DIDACTICS OF MATHEMATICS

AS A MATHEMATICAL DISCIPLINE

UNIVERSIDADE DA MADEIRA, FUNCHAL, PORTUGAL

1-4 October, 2009



A Clifford perspective on Klein's Geometry

SEBASTIAN XAMBÓ

FACULTAT DE MATEMÀTIQUES I ESTADÍSTICA

UNIVERSITAT POLITÈCNICA DE CATALUNYA

08028 BARCELONA (SPAIN)

A JBSG, *in memoriam*

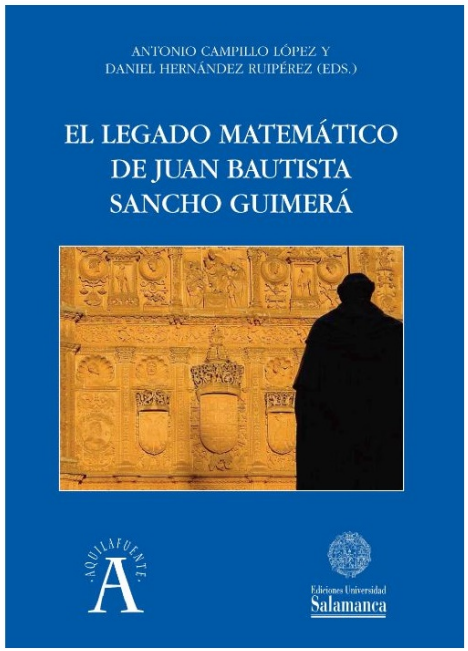
Escondidas sendas de la geometría proyectiva a la física cuántica

S. Xambó

UPC

4 abril 2014

S. Xambó (UPC) Escondidas sendas 4 abril 2014 1 / 49



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WARJr Work

- The PhD thesis in nuclear physics (Università di Torino, 1971, advisor Cesare Rosseti) and the first 25 papers of WARJr (1972-1986) are, in general terms, about particle physics and relativity theory (mainly SR).
- 1980: Moved from the Physics to the Mathematics Institute.
- Alcebiades Rigas asked him to deliver a series of lectures on relativity theory for MSc and PhD students. Suggested reference: R. K. Sachs & H. Wu, *General Relativity for Mathematicians* (1977).
- Less than a full success: Mathematicians complained of "low mathematical rigor" and physicists "did not understand basic deductions and calculations in the language of intrinsic differential geometry".

N

1927 W. Pauli: Zur Quantenmechanik des magnetischen electrons.

1928 P. A. M. Dirac: The quantum theory of the electron.

1935 R. Brauer, H. Weyl: Spinors in n dimensions.

1938 E. Cartan: *Leçons sur la théorie des spineurs*.

1948 H. C. Lee: On Clifford algebras and their representations.

1950 Y. Kawada,N. Iwahori: On the structure and representations of Clifford algebras.

1954 C. Chevalley: *The algebraic theory of spinors* (CW2).

1958 M. Riesz: *Clifford numbers and spinors*.

1859 R. Lipschitz (signed): Correspondence. *AM* **69**.

1964 M. Atiyah, R. Bott, A. Shapiro: Clifford modules.

1966 D. Hestenes: *Spacetime algebra*.

1967 D. Hestenes: Real spinor fields.

1969 I. R. Porteous: *Topological geometry* (especially Ch 13).

1975 D. Hestenes: Observables, operators, and complex numbers in the Dirac theory.

1976 G. Casanova: *L'algèbre vectorielle*.

1982: F. Brackx, R. Delanghe, F. Sommen: *Clifford analysis*.

1984 D. Hestenes & G. Sobczyk: *Clifford algebra to geometric calculus*.

1984 R. Penrose, W. Rindler: *Spinors and space-time*.

1987 I. Benn & R. Tucker: *An introduction to spinors and geometry with applictions in physics*.

1989 P. Budinich & A. Trautman: *The spinorial chessboard*.

- Launch of the **mathematical physics group** of IMECC-UNICAMP (Instituto de Matemática, Estatística e Computação Científica Unicamp).
- Discussions with colleagues lead to the study of **Clifford algebras and spinors**. Plans for applying these methods to mathematical physics problems.
- Advises several theses, including three defended in 1887:
  - Vera L. X. Figueiredo: *Estrutura Spinorial Em Variedades Lorentzianas*.
  - Adolfo Maia Jr.: *Potenciais Generalizados e Cargas Duais: Um Ensaio Sobre Monopolos Magnéticos*.
  - Marcio A. de Faria Rosa: *Aplicações de Fibrados Principais e Teorias de Espaço-Tempo e Algumas Teorias Físicas*.

"My main motivation for applying CLIFFORD algebras methods in physics came from a very simple observation: The main physical theories of the last century,

- MAXWELL *electrodynamics*,
- DIRAC's *theory of electron*, and
- EINSTEIN's *general relativity*

describe three different kinds of fields (electromagnetic, spinor and gravitational). In the usual presentation in textbooks, however, these fields are described by mathematical objects of different nature.

So, I asked myself [**Waldyr's dream**]: *If one wants to make a unified theory, the first thing one should try is to represent these fields as objects of the same mathematical nature."* (1.1.2017)

Volume 173, number 3 PHYSICS LETTERS B 12 June 1986

A SATISFACTORY FORMALISM FOR MAGNETIC MONOPOLES BY CLIFFORD ALGEBRAS ☆

Marcio A. DEFARIA-ROSA [a], Erasmo RECAMI [a,b,c] and Waldyr A. RODRIGUES Jr. [a]

[a] *Department of Applied Mathematics, State University at Campinas, 13100 Campinas SP, Brazil*
[b] *Dipartimento di Fisica, Università Statale di Catania, I-95129 Catania, Italy*
[c] *INFN, Sezione di Catania, I-95129 Catania, Italy*

Received 3 March 1986

The problem of electromagnetism with magnetic monopoles is approached by the physically interesting and mathematically powerful formalism of Clifford algebras, which provides a natural language for Minkowski space–time (*Dirac algebra*) and euclidean space (*Pauli algebra*). A lagrangian and hamiltonian formalism is constructed for interacting monopoles, which overcomes many of the long-standing difficulties that are known to plague the approaches developed till now.

As a consequence, we can decompose F in Pauli algebra *either* as $F = E + H$ (in which case H is a Pauli pseudo-vector), *or* as [2]

$$F = E + iH ,$$

in which case E and H are Pauli vectors.

[1] D. Hestenes, Space–time algebra (Gordon & Breach, New York, 1966);

[2] See e.g. E. Majorana, scientific manuscripts (ca. 1931), as reported in R. Mignani, E. Recami and M. Baldo, Lett. Nuovo Cimento 11 (1972) 568;

N

- 1992 Quintino Augusto Gomes de Souza: *Dirac Operators on Riemann-Cartan-Weyl Spacetimes and the Nature of the Gravitational Field* N
- 1992 José Ricardo Rezende Zeni: *Lorentz Transformations, Clifford Algebras and the Motion of Charged Particles*.
- 1993 Jayme Vaz Jr.: *A Álgebra do Espaço-Tempo, O Spinor de Dirac-Hestenes e A Teoria do Eletron*.
- 1999 José Emilio Maiorino: *Superluminal Solutions of the Relativistic Wave Equations and the Principle of Relativity*.
- 1999 Antonio Manuel Moya: *Formalisimo Lagrangiano para Campos Multivetorias*.
- 2000 Virginia Velma Fernandez: *Distortion and Rotation Extensors in the Gravitational Theories*.
- 2000 Alexandre Luis Trovon de Caravalho: *O Papel Algébrico dos Operadores Diferenciais no Formalismo Variacional*. N

- 1993: ICCA3 (Ghent)
- 1995: ICCA4 (Aachen)
- 1999: ICCA5 (Ixtapa-Zihuatanejo, México).
- 2001: ICCA6 (Cookville, Tennessee).
- 2005: ICCA7 (Toulouse)
- 2008: ICCA8 (**Campinas**)
- 2010: ICCA9 (Weimar)
- 2014: ICCA10 (Tartu)
- 2015: AGACSE 2015


8th International Conference on
Clifford Algebras
and their Applications
Mathematical Physics
Campinas 2008 May 26-30
"For geometry, you know, is the gate of science, and the gate is so low and small that one can only enter it as a little child."
Instituto de Matemática, Estatística
e Computação Científica
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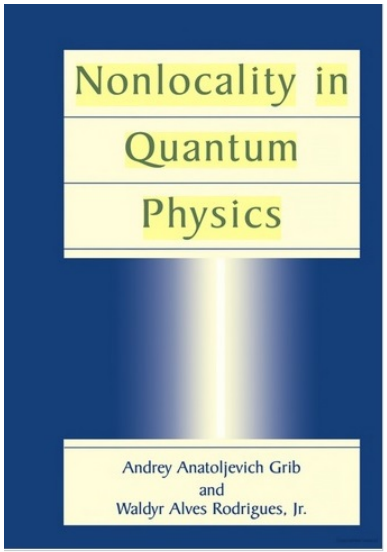
IMECC

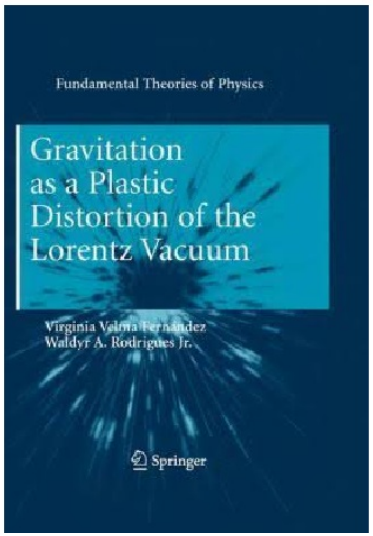
0 Waldyr Alves Rodrigues Jr. 1 Cassius Melo. 2 Hennie de Schepper. 3 Sirka Eriksson. 4 T. Santhanam. 5 William Baylis. 6 Artibano Micali. 7 ? 8 B Max P Escobar. 9 Jacques Helmstetter. 10 ? 11 Bernhard Jancewicz. 12 Jon Selig. 13 Douglas Lundholm. 14 ? 15 S. Tremblay. 16 D. Rochon. 17 ? 18 Klaus Gurlebeck. 19 Fred Brackx. 20 Wolfgang Sproessig. 21 Rafal Ablamowicz. 22 Matej Pavsic. 23 Anthony Lasenby. 24-27 ? 28 Eduardo Bayro Corrochano. 29 Paul Loya. 30 Jos Ricardo de Rezende Zeni. 31 ? 32 Jose Vergara. 33 ? 34 Alessandro Perotti. 35 ? 36 Marco Macias 37 ? 38 Rafael Leão. 39 Dimitrius Pinotsis. 40 Eduardo Alfonso Notte Cuello. 41 ? 42 Roldao da Rocha Jr. 43-45 ? 46 Juergen Tolksdorff. 47 David Hestenes. 48 Oliver Conradt. 49 Eckhardt Hitzer. 50 Francesco Toppan. 51 Zhanna Kuztetsova. 52 Stacey Staples. 53 Marek Czachor. 54 Jon Snygg. 55 Jayme Vaz Jr. 56 ? 57 Emilio Marmolejo Olea.

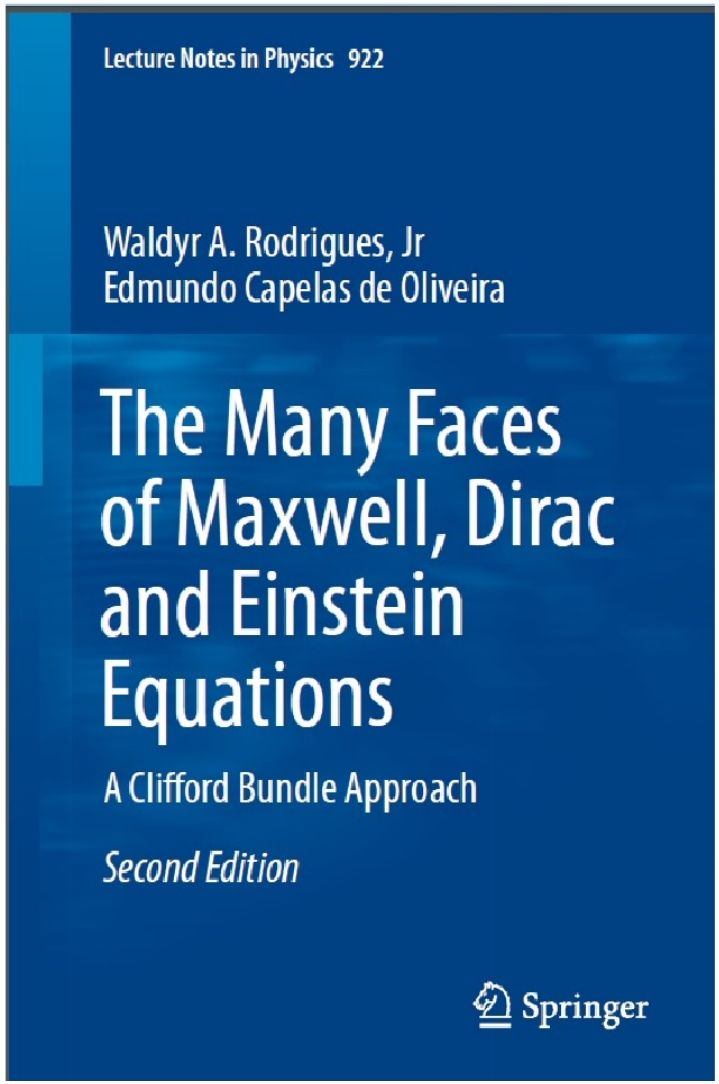
N

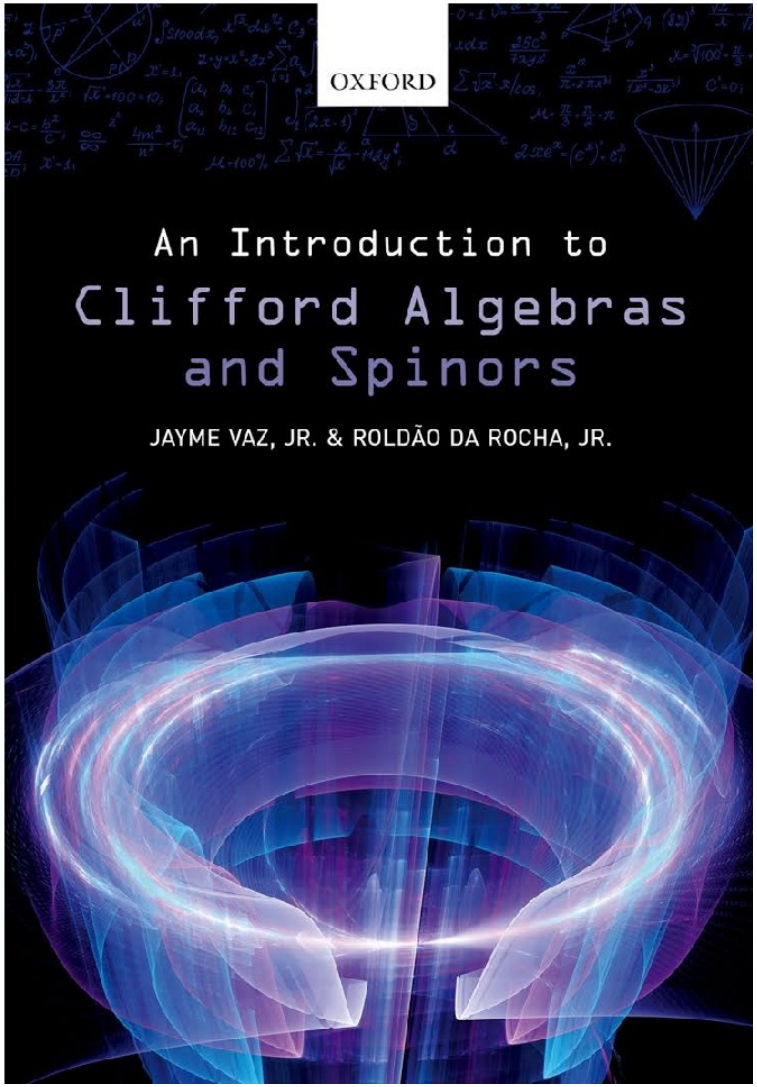
- 1990 (with E. C. de Oliveira): Dirac and Maxwell equations in the Clifford and spin-Clifford bundles. *International Journal of Theoretical Physics* **29**. MR1057506 (91d:53021)
- 1995 (with Q. A. G. de Souza and Y. Bozhkov): The mathematical structure of Newtonian spacetime: Classical dynamics and gravitation. *Foundations of Physics* **25**. MR1342391 (96f:53101)
- 1996 (with J. Vaz Jr. and M. Pavšič): The Clifford bundle and the dynamics of the superparticle. *Banach Center Publications* **37**. MR1442741 (98i:81091)
- 1997 (with J.-Y. Lu): On the existence of undistorted progressive waves (UPWs) of arbitrary speeds $0 \leqslant v < \infty$ in nature. *Foundations of Physics*, **27**. MR1452199 (98f:35144)
- 1999 (with A. A. Grib): *Nonlocality in Quantum Physics*. 225 p.

- 2004: Algebraic and Dirac–Hestenes spinors and spinor fields. *Journal of Mathematical Physics* **45**. MR2067593 (2006b:81113)
- 2004 (with R. A. Mosna): The bundles of algebraic and Dirac–Hestenes spinor fields. *Journal of Mathematical Physics* **45**. MR2067594 (2006b:81114)
- 2010 (with V. V. Fernández): *Gravitation as a plastic distortion of the Lorentz vacuum*. Foundamental Theories of Physics **168**. x + 153p. MR3012268
- 2012: The nature of gravitational field and its legitimate energy-momentum tensor. *Reports on Mathematical Physics* **69**.
- 2014 (with S. A. Wainer): A Clifford Bundle Approach to the Differential Geometry of Branes. *AACA* **24**.
- 2016 (with E. C. de Oliveira): *The Many Faces of Maxwell, Dirac and Einstein Equations* (2nd ed). LNiP **992**. xvi+587 p.









"I am proud to have formed a solid mathematical physics group at IMECC-UNICAMP and proud, e.g., that J. Vaz and R. da Rocha just published *An Introduction to Clifford Algebras and Spinors*" (2.1.2017)

- 1. Preliminairies [Tensor algebra].
- 2. Exterior algebra and Grassmann algebra.
- 3. Clifford, or geometric, algebra.
- 4. Classification and representation of the Clifford algebras.
- 5. Clifford algebras and associated groups [Lipschitz, Pin, Spin]
- 6. Spinors [Algebraic, classical and spinor operators].
- A. The standard two-component spinor formalism.

References to work of WARjr: Figueiredo-Oliveira-W-1990-2 [44], Vaz-W-1993-2 [54], W-Rocha-Vaz-2005 [124].

N

1. **Introduction**.
2. **Multivector and extensor calculus**. Fz-Moya-W-2001-2 [106]
3. **The hidden geometrical nature of spinors**. Chevalley-54, Benn-Tucker-87, Rocha-W-2006-1 [127].
4. **Some differential geometry**. DeRham-60, Sachs-Wu-77, Hestenes-Sobczyck-1984, Lawson-Michelsohn-89, Maia-Recami-W-Rosa-1990-1 [37], W-Oliveira-1990 [42], Fz-W-2010 [160], Leao-W-Wainer-2017 [184]
5. **Clifford bundle approach to the differential geometry of branes**. NotteCuello-W-Souza-2007 [147]
6. **Some issues on relativistic spacetime theories**. Weinberg-72, Matolcsi-W-1997-1 [89], W-Sharif-2001-2 [116], Giglio-W-2012-1 [166]
7. **Clifford and Dirac-Hestenes spinor fields**. Bleecker-81, Penrose-Rindler-1986, Naber-00, W-2004 [120], Oliveira-W-2004 [122] N

8. **Clifford algebra Lagrangian formalism in Minkowski spacetime**. Moya-Fz-W-2001-1 [104]
9. **Conservation laws on Riemann-Cartan and Lorentzian spacetimes**. Misner-Thorne-Wheeler-1973, Lasenby-Doran-Gull-1998, W-Souza-1993 [60], Bozhkov-W-1995 [72], Fz-Moya-W-2000 [103], NotteCuello-W-2009 [155], W-2012 [168], W-Wainer-2016-1 [178]. [149, 150]
10. **The DHE on a RCST and the meaning of active local Lorentz invariance**. W-Souza-Vaz-Lounesto-1996 [77]
11. **On the nature of the gravitational field**. Fz-W-2010 [160], W-2010 [161], NotteCuello-Rocha-W-2010 [162], W-2012 [168]
12. **On the many faces of Einstein equations**. Göckler-Schücker-87, Frankel-97, W-Oliveira-2004 [123]

N

13. **Maxwell, Dirac and Seiberg-Witten equations**. Campolattaro-80, W-2003 [118].
14. **Superparticles and superfields**. Daviau-93, Varadarajan-00, W-Souza-Vaz-1995 [74], W-Vaz-1998-2 [95], Grib-W-1999 [102]
15. **Maxwell, Dirac and Navier-Stokes equations**. FabioRodrigues-W-Rocha-2012 [171]
16. **Magnetic like particles and Elko spinor fields**. W-2003 [118], Rocha-W-2006-1 [127], Oliveira-W-Vaz-2014-2 [174]

A. **Principal bundles, vector bundles and connections**. Kobayashi-Nomizu-63.

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(From message 1/1/2017)

To sum up, what at first sight looked as fields of very different mathematical nature turned to be represented by objects of the same mathematical nature and their equations of motion can all be expressible in a form that looks the equation of motion of the others.

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- Maxwell and Dirac equations mathematically equivalent.
- Sub and superluminal phenomena.
- Einstein equation can be written as a Maxwell like equation.
- Poetical summary: I am not stating that these fields have the same physical ontology (in fact they do not), but its seems that GOD uses the same kind of mathematics in projecting these objects...

- 1992 and 1998: Zeferino Vaz Prize for Academic Merit (University of Campinas)
- 1995: Elected member of the Lódz Society of Sciences (Poland)
- 2010: Paul Sabatier Honor Medal (Paul Sabatier University)
- 2010: Elected member of the Russian Academy of Natural Sciences.
- 2012,...,2016: Editor in Chief of AACA (0.905 impact factor at end of his appointment)

1 Mrs. Krüger
2 Artibano Micali
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4 Mrs Nancy Hestenes
5 Mrs Alan Common
6 Mrs Paulina Mc Ewan
7 Sören Sprössig
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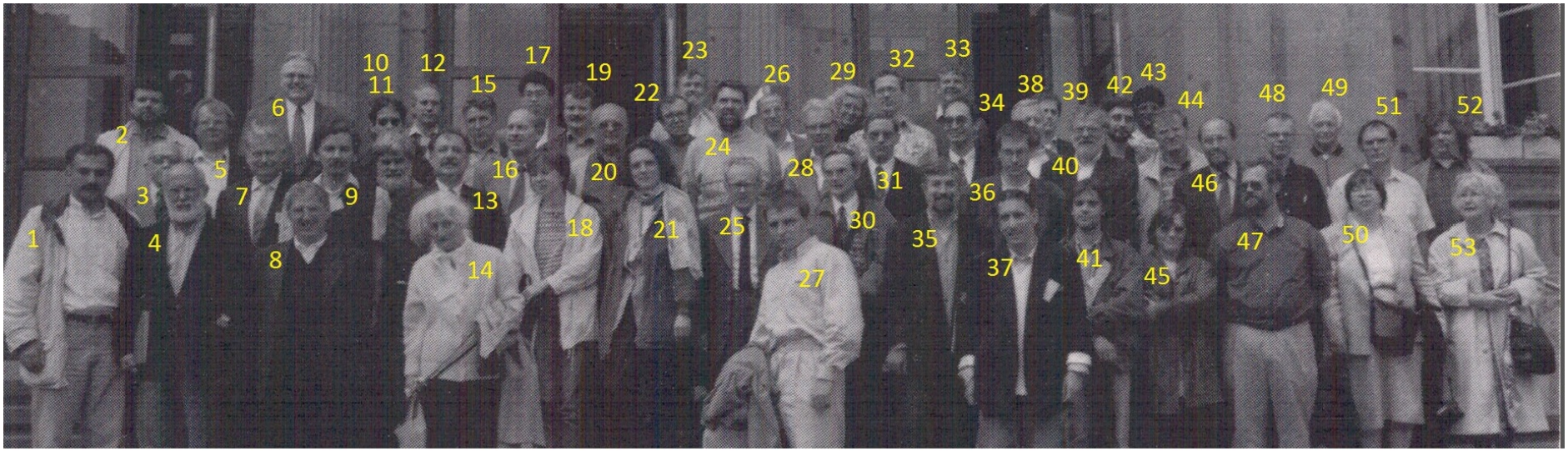

1 Hijazi
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4 Micali
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7 Lawrinowicz
8 Daviau
9 Vasilevski
10 Lufer
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42 Kisil
43 Somaroo
44 Sprössig
45 Cerejeiras
46 Malonek
47 Pezzglia
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50 Erikson-Biquet
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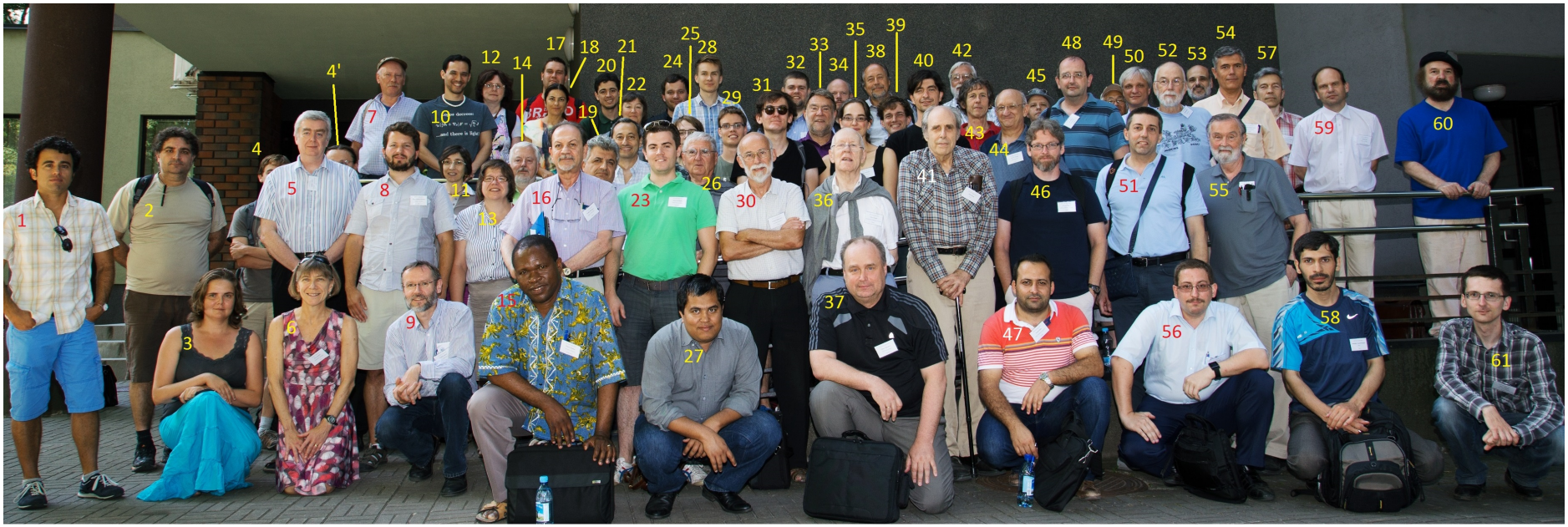
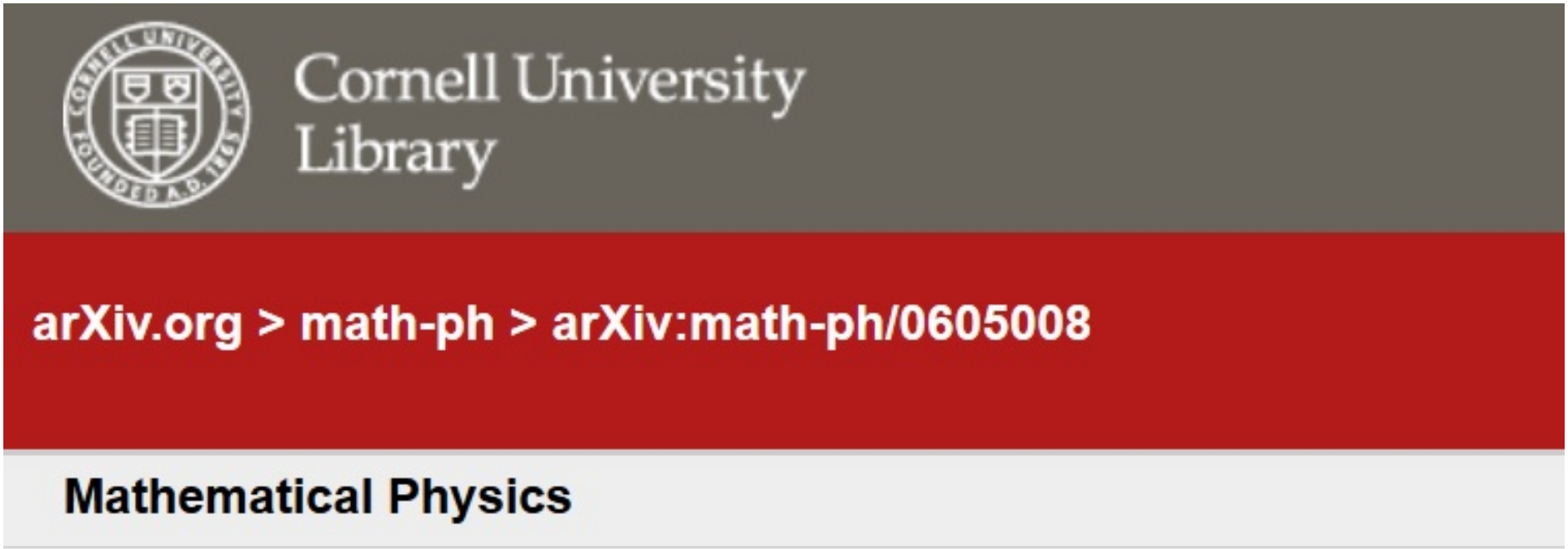


1 Dixan Pe a Pe a. 2 Antonio di Teodoro. 3 Olga Liivapuu. 4' Igor Kanatchikov. 5 Anthony Lasenby. 6 Joan Lasenby. 7 Valeriy Dvoeglazov. 8 Pierre Dechant. 9 Eckhard Hitzer. 10 Nicholas Okamoto. 11 Irene Sabadini. 12 Swanhild Bernstein. 13 Sirrka Lisa Erikson. 14 Klaus Guerlebeck. 15 Patrice Ntumba. 16 Waldy Rodrigues Jr. 17 Heikki Orelma. 18 Isabel Cação. 19 Daniel Alpay. 20 Kelvyn Brito. 21 Thierry Socrun. 22 Paula Cerejeiras. 23 Simon Kiefhaber. 24 Martin Reinhardt. 26 Claude Daviau. 27 Md. Raknuzzaman. 28 Vesa Vuojamo. 29 Tim Raeymaekers. 30 Jacques Helmstetter. 31 Hendrik De Bie. 32 Dimitry (from Weimar). 33 Fred Brackx. 34 Jaroslav Hrdina. 35 Hilde De Ridder. 36 Pierre Angles. 37 Viktor Abramov. 38 Helmut Malonek. 39 Lander Cnudde. 40 David Eelbode. 41 John Snygg. 42 Steven Lehar. 43 Charles Gunn. 44 Jose Vargas. 45 Paul Leopardi. 46 Stacey Staples. 48 Rolf Dahn. 49 Osamu Suzuki. 50 Oliver Conradt. 51 Francisco Colombo. 52 Alan Macdonald. 53 Alexander Trovon de Carvalho. 54 Ramon Gonzalez Calvet. 55 David Hestenes. 56 Uwe Kaehler. 57 Rimvydas Krasauskas. 58 Jalaledin Yousefi Koupaei. 59 Arturas Acus. 60 Carlos Castro. 61 Jaan Vajakas.

Yuri Bozhkov, WARJr, Pamela Ramos, Stylianos Dimas (24.2.2017)

Waldyr was member of the Scientific Council of the "Centro de Lógica, Epistemologia e História da Ciência da UNICAMP".



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arXiv.org > math-ph > arXiv:math-ph/0605008

Mathematical Physics

Conservation Laws on Riemann-Cartan, Lorentzian and Teleparallel Spacetimes

Waldyr A. Rodrigues Jr, Quintino A. G. de Souza, Roldao da Rocha

(Submitted on 3 May 2006 (v1), last revised 12 Jan 2008 (this version, v13))

Waldyr Alves Rodrigues Jr.

Projeto e Criação Multimídia IMECC-UNICAMP

Wer immer strebend sich bemüht,
den können wir erlösen (Goethe, *Faust*)

7th Conference on Applied Geometric Algebras in Computer Science and Engineering

University of Campinas (UNICAMP)
Campinas (São Paulo), Brazil

July 23-27, 2018

See you there!!

I want to begin by thanking Hennie de Schepper and the different committees, and especially to the scientific and organizing committees, for the invitation.

The idea of proposing to speak about the life and work of WARjr took form early in the June visit of Carlile Lavor, of the University of Campinas, to Barcelona. The visit had been planned almost one year ago with two main goals: helping him in the organization of AGACSE 2018 in Campinas (July 23-27) and to do some work in the applications of GA to various questions.

The main trail that has lead us to this point started, at least formally, with AGACSE 2015 (Barcelona, July 27-31; about seventy participants). P

[On return to slide, go to next one (AGACSE 2015) and, after a brief pause, go to the next].

This picture was taken in the evening of July 30, 2015. This subgroup gathered to go to the social dinner downtown. On the way it met Gaudi's dragon at the back of the Pedralbes Palace.

Several people in the picture are also present here at ICCA11, and I hope it brings good memories to them of those days in Barcelona.

The third on the left is WARjr. If not physically here, his presence will be in the mind and hearts of all in this conference, and in many others outside, particularly those that could not come to this ICCA, and I believe that this will continue for many years to come on account of his rich scientific legacy: works, research school (students and colleagues), and his remarkable quixotic stance against all sorts of windmills.

AGACSE 2015 was the first occasion, and sadly the last, for me to meet Waldyr in person. At the end of that week, many things had happened that were driven by him. Here are those that seem to me more relevant:

- He delivered three one-hour lectures, two in the Summer School and a plenary in the conference. I'll come back to this a little later.
- The Proceedings would be published in a special volume of AACA and the editors would be Josep Manel Parra, Ramon Gonzalez Calvet, and myself as EiC of the project. These proceedings were published early this year and you can see details of how the process evolved in the Preface written by Parra and myself. There we acknowledge in particular the decisive support of Waldyr at the beginning, and that of Rafal Ablamowicz afterwards.
- AGACSE 2018 would be organized in Campinas. Carlile Lavor, the leftmost in the picture, is the Chairman of the Organizing Committee.
- The Spanish Mathematical Society decided to include his profile in the portal that we colloquially call **ArbolMat**/MathTree (http://www.arbolmat.com/).

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In the slide you can see the titles of his three lectures. For now remark that the words emphasized in blue point to themes that have been among his constant research passions.

The picture was taken during his plenary lecture and it is the one featured in his ArbolMat profile.

[Let me insert a bried aside to say that since the beginnin of ArbolMat in 2011, we have published 68 profiles. An ArbolMat profile consists of a mention page (detail in the upper part of the slide) and a dossier on the academic evolution (accessed through "Otras informaciones"). I have taken the materials in Waldyr's profile as a core input for my talk. They were prepared in close collaboration with him in the last months of 2016 and early January of this year.

P

Please allow me to tell you briefly where was I before AGACSE 2015. We studied Emil Artin's *Geometric Algebra* in 1966-1967 at the FM of the UB, following lectures by Professor Juan Bautista Sancho Guimerá. He was as passionate about mathematics and physics as Waldyr, he also supervised many students (ten years in Barcelona, until 1972, and in Salamanca, where he moved in that year, until his death in 2012), and both could concentrate for hours on their current topic, but otherwise they were completely opposite in one respect: whereas Waldyr was always extremely diligent to publish, Sancho's ideas were only, for the most part, communicated orally to his students.

Front page of my slides *A Clifford view of Klein's Geometry* presented in a conference held in Funchal (Madeira) in 2009 and of my lecture in April 2014 in the Symposium in memoriam of Sancho. The title of the talk, and of the paper published in the Proceedings volume, was (in English) *Hidden pathways from projective geometry to quantum physics* with the third part devoted to geometric algebra.

The "hidden pathways" phrase points to the poem "Vida retirada/Secluded life" of Fray Luis de León, a XVI century Augustinian friar, theologian and academic admired by Sancho. After imprisonment for four years in Valladolid by the Inquisition, Fray Luis began his first class in Salamanca on 29 January 1577 with the words *Dicebamus hesterna die...* ("As we were saying yesterday...").

For the part on GA, I approached Manuel Parra and Ramon Gonzalez to seek their advice. This was just in the Spring before the Tartu ICCA and they managed –it was not that hard– to convince me to join them in organization of AGACSE 2015. I put all I could, institutionally and personally, for meeting that responsibility as best as possible. Among the many unexpected rewards of that decision I count having met Waldyr. So let us consider his work from a general perspective. P

The prestige of 'intrinsic differential geometry' at that time in relation to physics was based not only on its role in general relativity, but also because of the purely geometric formulation of gauge theories by means of fiber bundles (principal bundles with fiber a Lie group and the vector bundles associated to linear representations of that group). It seems clear that a key point for Waldyr's evolution was the fact that, in words of Andrej Trautman, "the definition of spinors on manifolds –unlike that of tensors– requires the use of fiber bundles".

Since the natural language for spinors is GA, the appeal at that point for trying to fuse the two languages must have had for Waldyr an irresistible appeal.

Let us consider the context in which this conception occurred by pointing out a few developments that concurred in it and which, for the most part, influenced the course of Waldyr thinking.

P

This was his fifth paper to be reviewed in MR, but the first with an authored review (Dominique Lambert):

1986 (with M. A. F. Rosa and E. Recami): A satisfactory formalism for magnetic monopoles by Clifford algebras. *Physics Letters B* **173**/3 (1986), 233-236. MR 87j:81267 (and MR 88c:81126, for Erratum 1987).

"The problem of electromagnetism with magnetic monopoles is approached by the physically interesting and mathematically powerful formalism of Clifford algebras, which provides a natural language for Minskowski space-time (Dirac algebra) and Euclidean space (Pauli algebra). A Lagrangian and Hamiltonian formalism is constructed for interacting monopoles, which overcomes many of the long-standing difficulties that are known to plague the approaches developed till now".

The most relevant references are

[1] Hestenes, *STA* (1966) and

[2] E. Majorana, *Scientific manuscripts* (ca. 1931).

The latter is quoted as follows: "... we can decompose F [the electromagnetic field] in Pauli algebra *either* as $F = E + H$ (in which case H is a Pauli pseudo-vector), *or* [2] as $F = \boldsymbol{E} + \mathbf{i}\boldsymbol{H}$, in which case $\boldsymbol{E}$ and $\boldsymbol{H}$ are Pauli vectors".

Note that Recami is the author of *Il caso Majorana* (Di Renzo Editore, Roma, 2001) and coeditor of *Ettore Majorana: Unpublished Research Notes on Theoretical Physics* (2009, 496 p), among other contributions *in memoriam* of Majorana. P

For a general reference on Cartan's geometries and variations thereoff, one commendable book is:

R. W. Sharpe, *Differential Geometry: Cartan's generalization of Klein's Erlangen Program*. GTM, Springer, 1997.

As Waldyr retired in 1998, he took no more students after the year 2000.

P

0 Waldyr. 2 Hennie de Schepper. 19 Fred Brackx. 20 Wolfgang Sprössig. 21 Rafal Ablamowicz. 22 Matei Pavsic. 23 Anthony Lasenby. 28 Eduardo Bayro. 47 David Hestenes. 49 Eckhard Hitzer. 55 Jayme Vaz.

P

[44] 1990 (with V. L. Figueiredo and E. C. de Oliveira): Clifford algebras and the hidden geometrical nature of spinors. *Algebras, Groups, and Geometries* **7**/2 (1990), 153-198. MR 92f:15015

[54] 1993 (with J. Vaz Jr.): Equivalence of Dirac and Maxwell equations and quantum mechanics. *International Journal of Theoretical Physics* **32**/6 (1993), 945-955. MR 94h:81051

[124] 2005 (with R. da Rocha and J. Vaz Jr.): Hidden consequence of active local Lorentz invariance. *International Journal of Geometric Methods in Modern Physics* **2**/2 (2005), 305-357.

This text does not replace P. Lounesto's *Clifford algebra and spinors* (2001, 2nd ed), and the common ground is approached quite differently.

P

(2) [106] Extensors. AACA

(3) Chevalley-54 and Benn-Tucker-87 already met before. [127] Where are ELKO spinor fields in Lounesto spinor field classification? MPL A.

(4) [37] Magnetic monopoles without string in the Kähler-Clifford algebra bundle: a geometrical interpretation. JMP. [42] Dirac and Maxwell equations in the Clifford and spin-Clifford bundles. JTP. [160] *Gravitation as a plastic distortion of the Lorentz vacuum*. [184] Concept of Lie derivative of spinor fields, a geometric motivated approach. AACA.

(5) [147] The square of the Dirac and spin-Dirac operators on a Riemann-Cartan space(time). RMP.

(6) [89] Spacetime model with superluminal phenomena. AGG. [116] Rotating frames in SRT: the Sagnac effect and related issues. FP. [166] Local inertial reference frames in Lorentzian and Riemann-Cartan spacetimes. AP.

(7) [120] Algebraic and Dirac-Hestenes spinors and spinor fields. JMP. [122] Dotted and undotted algebraic spinor fields in general relativities. IJMP D.

(8) [104] Lagrangian formalism for multiform fields on Minkowski spacetime. IJTP.

(9) [60] The Clifford bundle and the nature of the gravitational field. FP. [72] Mass and energy in geneeral relativity. GRG [103] Covariant derivatives on Minkowski manifolds. Ixtapa-Zihuatanejo (1999). [155] Freud's identity of differential geometry, the Einstein-Hilbert equations and the vexatios problem of the energy-momentum conservation in GR. AACA. [168] nature of the gravitational field and its legitimate energy-momentum tensor. RMP. [178] Notes on the conservation laws, equations of motion of matter, and particle fields in Lorentzian and teleparallel de Sitter space-time structures. AMP.

(10) [77] Dirac-Hestenes spinor fields on Riemann-Cartan spacetime. IJTP.

(11) [160] *Gravitation as a plastic distortion of the Lorentz vacuum*. [161] Killing vector fields, Maxwell equations and Lorentzian spacetimes. AACA. [162] Some thoughts on geometries and on the nature of the gravitational field. JPM. [168] Nature of the gravitational field and its legitimate energy-momentum tensor. RMP.

(12) [123] Clifford valued differential forms and some issues in gravitation, electromagnetism and "unified" theories. IJMP D.

(13) [118] The relation between Maxwell, Dirac, and the Seiberg-Witten equations. IJMMS.

(14) [74] Spinor fields and superfields as equivalence classes of exterior algebra fields. In Mathematics and its applications 321. [95] From electromagnetism to relativistic quantum mechanics. FP. [102] *Nonlocality in quantum physics*.

(15) [171] The Maxwell and Navier-Stokes that follow from Einstein equation in a spacetime ccontaining a Killing vector Field. AIP CP.

(16) [118] The relation between Maxwell, Dirac, and the Seiberg-Witten equations. IJMMS. [127] Where are ELKO spinor fields in Lounesto spinor field classification? MPL A. [174] Elko spinor fields and massive magnetic like monopoles. IJTP.

P

Years of hard work (with my students and some collaborators) realized that dream and in so doing we proved that the Maxwell and Dirac equations are mathematically equivalent (in a well defined sense) for all solutions of Maxwell equations for which one of the Poincaré invariants is not null.

Moreover, this result lead us to discover that all relativistic wave equations have three classes of (free boundary) solutions, namely, subluminal, luminal and superluminal. In particular the superluminal solutions (which are such that only finite aperture approximations can be realized in the physical world and for which the peak travels at superluminal velocity for a while until arriving at the front of the wave) possess longitudinal electric and/or magnetic components. This generated interest of Motorola which financed in 1999 a research project to develop an antenna to launch this kind of waves. This research has been the seed for the creation of a new research

institute in Campinas (von Braun Labs), started from my (pos-doc) student Dario Sassi THOBER in 2000.

But returning to the original program, I discovered that Einstein equation can be written as a Maxwell like equation (with a current term depending on the gravitational potential, that makes the equation a nonlinear one) and that such an equation (and thus Maxwell and Dirac equation) could be written as a Navier-Stokes like equation.

X-waves (message 2/1/2017). The experimental production of finite aperture approximations to superluminal waves (which can be launched in physical space by special antennas) have been demonstrate in several experiments done long ago (see some references in a new paper of mine that I am sending attached). Concerning the Motorola experiment, almost all the research was classified material(*). However, I am sending attached a note of the

Motorola news informing that the experiment realized at Motorola labs in May 2001.

As mentioned above, I am sending also to you a first draft of a paper that I wrote during last month (and which is in way to arXiv today). In one of the sections I describe the X-wave, how to generate finite aperture approximations and the reshaping phenomena. Hope you will enjoy it.

P

Waldyr, Edmundo Capelas de Oliveira and André Kock Torres Assis (Assissi, Itally, 1989). They were attending a conference in Peugia University. P

Maria Paula, Renata, Maria Larissa. On 15 July 2017, Maria Paula send me the following words (my translation):

"His love for my mother and for the children was clear, but the greatest love in his life was, without doubt, his granddaughter Olívia Sanchez, the daughter of Maria Larissa born on 12/7/2014.

His great passions were bying, reading and studying books. At 32, there has been no day in my life in which I did no see him with a book in his hands. Even when he was sick or in hospital, he always asked me to bring him a book and his glasses.

What was funny about him is that when I had doubts about something (especially in college), I would ask him a problem and he would give me at least 5 references on the subject of doubt... That is, I thought I was going to have my problem solved quickly with his help and I left even with more doubts...! On personal matters, however, he always gave his opinion quite succinctly and, again, made me think –never gave ready answers."

P

I want to express my gratitude to all the persons that have provided me advice or materials during the preparation of this work, and in particular to Manuel Parra, Maria Paula Grangeiro, Edmundo Capelas de Oliveira, Yuri Bozhkonv, Fabio Rodrigues (son of Waldyr), Samuel Wainer, and Hilde de Ridder (for providing me copies of two papers that I could not find in Barcelona).

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