Jayme Tiomno: Relativity, gravity, cosmology, and the Marcel Grossmann Meetings

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Jayme Tiomno belonged to the 'founder's generation' of physicists in Brazil. He began working in relativity theory early in his career, at a time when it was not at all 'fashionable', through the influence of his early mentor, Mario Schenberg in São Paulo. When he went to graduate school in Princeton, in February 1948, his advisor there, John Wheeler, gave him a project in General Relativity, even though this was more than 4 years before Wheeler's 'turn' from nuclear and particle physics to field theory and gravitation.

Tiomno and Wheeler however soon discovered their mutual interest in meson decays, and Tiomno's Masters and PhD theses were on topics from particle physics, which remained his major field of interest for the following 20 years, during which he collaborated with Abdus Salam, among others. Only when he returned to Princeton in 1971, a refugee from the oppressive dictatorship in Brazil, did he again begin working in gravitation and field theory, having missed the 'golden age' initiated in part by Wheeler's group.

At the IAS, Tiomno experienced a renaissance of his interest in field theory, working with Remo Ruffini and others. He continued this work in the 1980's after he was able to return to the CBPF in Rio de Janeiro (which he had helped to found). His participation in the Marcel Grossmann Meetings was limited but significant.

Keywords: Physics Brazil; History of Physics; Marcel Grossmann Meetings; General Relativity; Gravitation

1. Introduction

Jayme Tiomno was born in Rio de Janeiro on April 16, 1920, the son of Russian-Jewish immigrants who had arrived in Brazil about 10 years earlier. There was nothing in his background that might suggest that he would become an eminent theoretical physicist. But his parents both valued education and saw to it that he and his siblings (an older brother, a twin sister, and two younger sisters) were all able to attend college. In the year of his birth, on Sept. 7, the Brazilian national holiday, the *Universidade do Rio de Janeiro* (URJ) was founded as the first real university in Brazil (as a collection of faculties and institutes combined from existing institutions).

After his childhood and youth spent in small cities in Minas Gerais, Tiomno's family returned in 1934 to Rio, where Jayme completed his *curso complementar* in medicine and then began studying medicine in 1938 at the *Universidade do Brazil* (UB – as the URJ was now called). In early 1939, Jayme was enrolled by his brother

for Natural History at the *Universidade do Distrito Federal* (UDF), a newer research university founded in the capital in 1935 by Anisio Teixeira, an eminent educator who was at the time Director of Education of the Federal District.

Fig. 1. (a) Jayme Tiomno, 1941. (b) Tiomno, Wheeler, Ruffini, 2001 (c) Mario Schenberg, 1937.

Tiomno qualified for the physics course, but was unable to study at the UDF because it was closed by the Vargas regime. Its physics curriculum was incorporated into the *Faculdade Nacional de Filosofia* (FNFi) and moved to the UB. Tiomno later had to decide between medicine and physics, and he chose the latter, graduating in 1941. Figure 1 shows Tiomno at age 21, when he graduated from the FNFi, and also 60 years later, with his Princeton mentor John Wheeler and his later collaborator Remo Ruffini, at Wheeler's 90th birthday in 2001; and Tiomno's first graduate mentor, Mario Schenberg, about the time Tiomno began his university career.

Tiomno entered military service, and was able to do some research with his mentor, the experimentalist Joaquim da Costa Ribeiro, and complete his *licenciatura* (teaching certificate) during the War. However, his real interest lay in theory, inspired by his Italian professor of theoretical physics, Luigi Sobrero (a former assistant of Levi-Civitá), and after the War, he obtained a fellowship to do graduate research at the Universidade de São Paulo (USP), in the department founded by Gleb Wataghin, under Wataghin's star pupil, the theoretician Mario Schenberg. The photo in Fig. 2 shows Tiomno's professors Sobrero and Costa Ribeiro as well as the teaching assistants in physics at the FNFi in May, 1942. Many of them later became noted scientists.

Tiomno spent most of 1946 at USP, studying hard to catch up in modern physics, to which he had hardly been exposed at the FNFi. After his fellowship ended, he returned to Rio in early 1947, but was then offered an assistantship with Mario Schenberg at USP, where he went in mid-year of 1947. He worked with Schenberg on formulating gravitation in Minkowski space, his introduction to relativity. The project was completed but never published, partly because relativity, and especially non-Einsteinian interpretations of gravitation, were hard to publish in 1948, and

Fig. 2. The teaching staff in physics at the FNFi, 1942. From left: Paulo Alcântara Gomes, Elisa Frota-Pessôa, Jayme Tiomno, Joaquim da Costa Ribeiro, Luigi Sobrero, Leopoldo Nachbin, José Leite Lopes, and Mauricio Matos Peixoto.

partly due to Schenberg's political difficulties, which forced him to go into exile in Europe in the following years.

Tiomno, in the meantime, on the recommendations of Schenberg and José Leite Lopes, was granted a fellowship for graduate work at Princeton by the U.S. State Department. He had to leave Brazil abruptly in early February 1948 to meet the starting deadline for his fellowship. In Princeton, he joined the group of John Archibald Wheeler, already a well-known theoretician, working in nuclear and particle physics. Nevertheless, Wheeler started Tiomno on a project involving point particles in GR (and eventually their gravitational-radiative damping). Tiomno was frustrated with the project and received little help from Wheeler (and from Einstein). Wheeler had already suggested this topic to Leopold Infeld, who in 1949 published the result with his assistant Alfred Schild.[1] By then, Tiomno and Wheeler had turned their interest to the pion-muon decay chain, and Tiomno spent the next 20 years working mainly in particle physics, apart from two collaborative projects with David Bohm – one a conformally-invariant formulation of the Dirac theory, which Tiomno only completed 12 years later; the other the inclusion of spin into Bohm's deterministic version of quantum mechanics (1955).

Fig. 3. John Wheeler and Jayme Tiomno in Princeton, Summer 1948.

When Wheeler (Fig. 3) left on sabbatical in June, 1949, Tiomno, with his fresh MSc degree, collaborated with Chen Ning Yang and David Bohm on weak-interaction physics and on relativistic quantum mechanics. He then began his PhD thesis work with Eugene Wigner as mentor. He finished his thesis in September 1950 and returned to São Paulo on October 10.

While still at Princeton, Tiomno also met Richard P. Feynman and Cécile Morette, and invited both to visit the newly-founded *Centro Brasileiro de Pesquisas Físicas* (CBPF) in Rio, which he had helped to plan and implement. He later also encouraged Bohm to apply (successfully) for the vacant chair of Advanced Physics in São Paulo (vacated by Gleb Wataghin when he returned to Italy in 1949). The young David Bohm is shown in Fig. 4, about the time that he completed his undergraduate studies.

Fig. 4. David Bohm, around 1940.

Figure 5 is a photo of a meeting at Princeton in early 1949, where several young Brazilian physicists conferred about the newly-founded CBPF in Rio, and met the Japanese theoretician Hideki Yukawa, on sabbatical in Princeton at the time. More information on Tiomno's life and career can be found in our recent biography.[2]

2. The development of gravitation, General Relativity and cosmology research after 1950

Modern gravitational physics dates from the early 20th century. Lorentz, Poincaré, Fitzgerald and others had speculated about applying the principle of relativity to electromagnetism (Maxwell theory). Albert Einstein realized the significance of those speculations and formulated his Special Relativity in 1905. Ten years later, with the help of Marcel Grossmann, he completed his General Theory of Relativity (GR), the modern theory of gravitation. After the early period from 1915–1925, when solutions to Einstein's field equations were found (e.g. by K. Schwarzschild, 1916: gravitational singularity; A. Einstein, 1917: closed, static universe; W. de Sitter, 1917: zero-density universe; A. Friedmann, G. Lemâitre, 1924/27: expanding

Fig. 5. A group of young Brazilians, together with Hideki Yukawa (behind, center), in Princeton, early 1949. César Lattes (behind, left), José Leite Lopes (below, center) and Jayme Tiomno (below, right) were the chief founders of the CBPF (Brazilian Center for Physics Research, Rio de Janeiro), which began operations about this time. At the upper right is Walter Schützer, and at lower left is Hervasio de Carvalho.

universe), Einstein began working on a unified theory of gravity and electromagnetism, and active work on GR decreased after about 1928. Some of the early contributors to GR theory are shown in Fig. 6.

In the period 1935–1955, Einstein published with N. Rosen, L. Infeld, B. Hoffmann, P. Bergmann, W. Pauli, V. Bargmann, and E.G. Strauss on some details of GR theory, and some other authors – notably J.R. Oppenheimer et al. (1939: collapse of stellar remnants) and K. Gödel (1949: stationary rotating homogeneous universe with timelike loops) also made important contributions. But only in the early 1950's did the 'great revival' of GR and its applications to relativistic astrophysics and cosmology begin, stimulated initially by J.A. Wheeler and his school (Princeton, University of Maryland, Caltech), and independently by Bryce DeWitt and Cécile Morette DeWitt (University of North Carolina, University of Texas), and in England by D.W. Sciama, C. Isham, R. Penrose, and S. Hawking (in London and Cambridge), and in the USSR by Y. Zel'dovitch, I. Novikov, and R. Sunyaev.

Fig. 6. (a) Karl Schwarzschild, ca. 1910. (b) Willem de Sitter. (c) Georges Lemâitre.

Tiomno's interest in field theory and GR was rekindled in 1966/67, when he spent a year as Associate of the ICTP (International Centre for Theoretical Physics) in Trieste (founded in 1964 by Abdus Salam, with Tiomno's active participation). While there, he reconnected with two Argentine physicists whom he had known earlier, in Rio and in London: Juan José Giambiagi and Carlos Guido Bollini. Their joint papers, especially 'A Linear Theory of Gravitation' (1970), mark Tiomno's revived interest in gravitation theory. Giambiagi, Tiomno and Bollini are shown in Fig. 7 while at the ICTP in 1966/67, and also shown are Jayme Tiomno with his wife Elisa Frota-Pessôa in Trieste at the same time. That interest was intensified during his stay in Princeton in 1971/72, after his blacklisting in Brazil by the military dictatorship. There, he interacted with Wheeler's now flourishing school. In the years 1972–75, he published 13 articles on gravitation and field theory. In addition to his two more senior collaborators, Remo Ruffini and Leonard Parker, his coauthors included the younger physicists C.V. Vishveshwara, Marc Davis, Jeffrey M. Cohen, Frank J. Zerilli, Robert M. Wald, and Reinhard A. Breuer. Many of those publications dealt with radiation – both electromagnetic and gravitational – from particles orbiting or falling into black holes; but they also included speculations on pulsars and the balance of forces on particles near black holes, as well as the possibility and properties of gravitational 'synchrotron radiation'. Figure 8 shows Tiomno and Elisa in Princeton in 1971, and also Tiomno's farewell letter to Wheeler upon leaving Princeton in June, 1972.

The text of Tiomno's letter to Wheeler when he left Princeton reads: *"We are leaving tomorrow, looking forward to a vague possibility of remaining in Rio. We were much pleased with our stay in Princeton. I have profited much from it and started a new phase of my career. Even the disagreeable dispute with a colleague has had a positive result to stress my friendship with you and to make me recover from the difficulty of writing papers. Here are some of them, which would not exist*

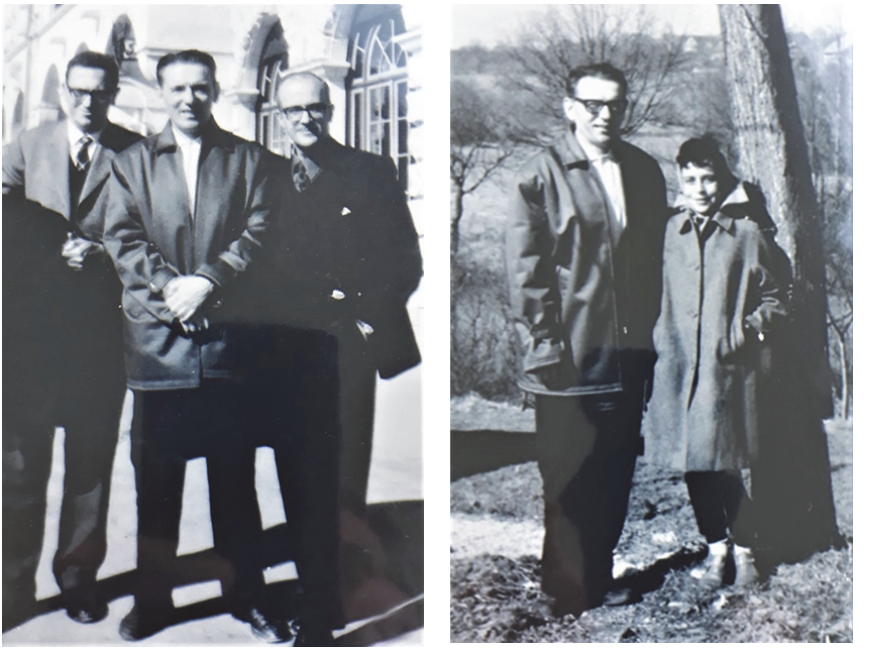
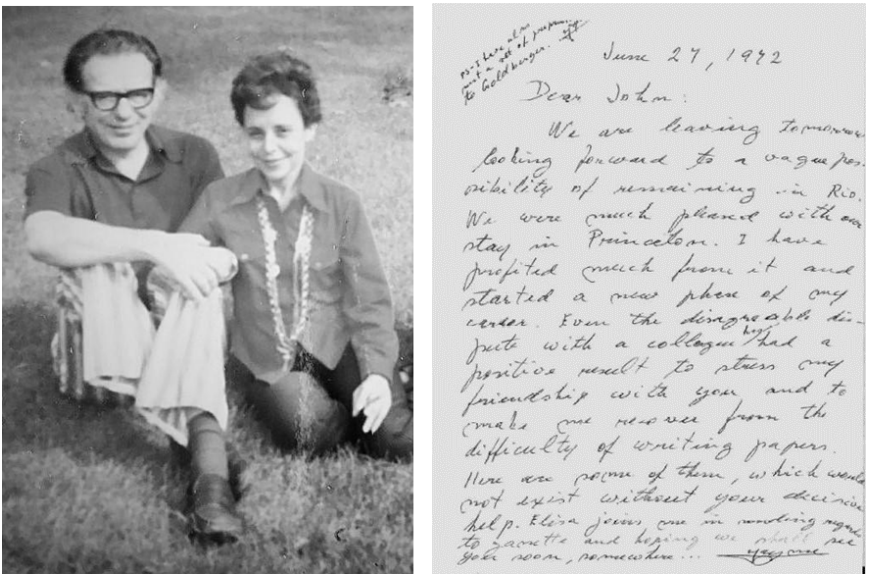


Fig. 7. (a) J.J. Giambiagi, J. Tiomno, C.G. Bollini, ICTP 1966. (b) Jayme Tiomno and Elisa Frota-Pessôa, ICTP 1966.

without your decisive help. Elisa joins me in sending regards to Janette and hoping we shall see you soon, somewhere . . . Jayme. PS. I have also sent a set of preprints to Goldberger."

We can only speculate on the precise details of the 'dispute' mentioned; it was probably a conflict over the publication of an article written jointly by Breuer, Ruffini, Tiomno and Vishveshwara (which appeared later in Phys. Rev. D. See Ref. 1 for more details).

After returning to Brazil in mid-1972, Jayme and Elisa were confronted with their continued blacklisting by the military dictatorship, which considered them to be 'subversive' (a charge which verges on the ridiculous, in retrospect). They could not even work at the private foundation CBPF, which they had helped to found and establish. Finally (after a Papal dispensation), they were given the opportunity to work at the Catholic University (PUC) in Rio de Janeiro, albeit with limited privileges. They remained there until after the Amnesty in 1979, and then still refused to beg for reinstatement to their university positions. Jayme finally rejoined the 'reformed' CBPF at the end of 1980; it was now an independent laboratory of the national science research funding agency CNPq. There, he became an honored and very active member of the faculty, retiring as 'Researcher emeritus' in 1992. For more information on the development of relativity and gravitation research after their 'rennaissance' in the 1950's, see the references.[3–5]



June 27, 1972

Dear John:

We are leaving tomorrow looking forward to a vague possibility of remaining in Rio. We were much pleased with our stay in Princeton. I have profited much from it and started a new phase of my career. Even the disagreeable dispute with a colleague had a positive result to strain my friendship with you and to make me recover from the difficulty of writing papers. Here are some of them, which would not exist without your decisive help. Elisa joins me in sending regards to Jeanette and hoping we shall see you soon, somewhere ...

Fig. 8. (a) Tiomno and Elisa, Princeton 1971. (b) Tiomno's 'farewell letter' to Wheeler, June 1972.

3. Tiomno's Scientific Work

Like Wheeler's scientific career, Tiomno's lifework can be divided into three distinct periods, although not so sharply:

– The first was his early work on relativity and particle physics, which extended from 1947 through about 1967. Highlights of this period were his work on the Weak Interaction (initially called the 'Universal Fermi Interaction', a term coined by Tiomno and C.N. Yang in 1949); his work on S-matrix theory and causality (with Walter Schützer; see Fig. 5); his prediction of the K* meson (with N. Zagury and A.L.L. Videira); and work on hyperons and global symmetry (with Abdus Salam).
– The second period began in the late 1960's and extended to around 1981. It was characterized by a shift in interest toward field theory, gravitation and cosmology, and was stimulated by collaborations with Giambiagi and Bollini as well as with his Princeton colleagues in 1971/72.
– The third period might be called his "eclectic phase", after he had returned to the CBPF in 1980, when he was involved in numerous projects relating to particle physics, Special Relativity, General Relativity, field theory, gravitation and cosmology, ending with his interest in relativistic rotating systems in the mid-1990's.

In the following, we give some selected examples of Tiomno's publications from the 1970's to the mid-1980's, as an illustration of the variety and the relevance of his work in his second and third periods.

3.1. *Some Selected Publications, 1970-1985*

(1) 'A Linear Theory of Gravitation', in: Lettere al Nuovo Cimento **3**, 65 (1970) (with C.G. Bollini and J.J. Giambiagi).
(2) 'Equivalence of Lorentz Transformations and Foldy-Wouthuysen Transformation for Free Spinor Fields', in: Physica **53**, 581–601 (1971).
(3) 'Electromagnetic Field of a Particle Moving in a Spherically-Symmetric Black-Hole Background', in: Lettere al Nuovo Cimento **3**, 211 (1972) (with R. Ruffini and C.V. Vishveshwara).
(4) 'Can Synchrotron Gravitational Radiation Exist?', in: Physical Review Letters **28**, 1352 (1972) (with Marc Davis, R. Ruffini and F. Zerilli).
(5) 'Pulses of Gravitational Radiation of a Particle Falling Radially into a Schwarzschild Black Hole', in: the Physical Review **D5**, 2932 (1972) (with Marc Davis and R. Ruffini).
(6) 'Maxwell Equations in a Spherically Symmetric Black-Hole Background', in: Lettere al Nuovo Cimento **5**, 851–855 (1972).
(7) 'Pair-Producing Electric Fields and Pulsars', in: the Astrophysical Journal **178**, 809 (1972) (with L. Parker).
(8) 'Polarization of Gravitational Synchrotron Radiation', in: Lettere al Nuovo Cimento **4**, 857 (1972) (with R.A. Breuer and C.V. Vishveshwara).
(9) 'Balancing of Electromagnetic and Gravitational Forces and Torque Between Spinning Particles at Rest', in: the Physical Review **D7**, 356 (1973).
(10) 'Gyromagnetic Ratio of a Massive Body', in: the Physical Review **D7**, 998 (1973) (with J.M. Cohen and R.M. Wald).
(11) 'Electromagnetic Field of Rotating Charged Bodies', in: the Physical Review **D7**, 992 (1973).
(12) 'Charged point particles with magnetic moments in General Relativity', in: Revista Brasileira de Física **8**, 350 (1978) (with Ricardo M. Amorim).
(13) 'On the relation between fields and potentials in non-abelian gauge fields', in: Revista Brasileira de Física **9**, 1 (1979) (with J.J. Giambiagi and C.G. Bollini).
(14) 'Singular potentials and analytic regularizations in classical Yang-Mills Equations', in: Journal of Math. Phys. **20**, 1967 (1979) (with C.G. Bollini and J.J. Giambiagi).
(15) 'Gauge field copies', in: Phys. Letters **83B**, 185 (1979) (with J.J. Giambiagi and C.G. Bollini).
(16) 'Wilson Loops and Related Strings for the instanton and its variational derivatives', in: Il Nuovo Cimento **59**, 412 (1980) (with C.G. Bollini and J.J. Giambiagi).
(17) 'Wilson Loops in Kerr Gravitation', in: Letters to Il Nuovo Cimento **81**, 13 (1981) (with C.G. Bollini and J.J. Giambiagi).
(18) 'Geodesic Motion and Confinement in Gödel's Universe', in: the Physical Review **D27**, 779 (1983) (with M. Novello and I.D. Soares).

(19) 'Gödel-type metric in Einstein-Cartan Spaces', in: Contributed Papers to the 10th International Conference on General Relativity and Gravitation, p. 507 (1983) (with A. Teixeira and J. Duarte).
(20) 'Homogeneity of Riemannian Spacetimes of Gödel type', in: the Physical Review **D28**, 1251 (1983) (with M. Rebouças).
(21) 'Pseudoscalar Mesons and Scalar diquarks—decay constants', in: Il Nuovo Cimento **81A**, 485 (1984) (with I. Bediaga, E. Predazzi, A.F.S. Santoro and M.H.G. Souza).
(22) 'Gravitational coupling of scalar and fermionic fields to matter vorticity: Microscopic asymmetries', in: Revista Brasileira de Física, Suppl. **14**, 372 (1984) (with I.D. Soares).
(23) 'Lifetimes in a quark-diquark system', in: Lettere al Nuovo Cimento **42**, 92–96 (1985) (with A.F.S. Santoro, I. Bediaga, M.G.H. Souza and E. Predazzi).
(24) 'On Experiments to detect possible failures of Relativity Theory', in: Foundations of Physics **15**, No. 9, pp. 945–961 (1985) (with W. Rodrigues).
(25) 'Gluon and qq mixing: [1440] system', in: Zeitschrift f. Physik **C30**, 493 (1985) (with A.C.B. Antunes, F. Caruso and E. Predazzi).
(26) 'Experiments to Detect Possible Weak Violations of Special Relativity', in: Physical Review Letters **55**, 143 (1985) (with A.K.A. Maciel).

Of special note are the publications that Tiomno himself listed as particularly important when he was nominated in 1995 for the Physics Prize of the Third-World Academy of Sciences (TWAS - an organization founded by Abdus Salam to complement the work of the ICTP). These include Items 1, 4, 9, 14, 16, 19, and 26 in the above list – and they illustrate how his interest in gravitation and field theory developed over the years.

4. ICRA and the MG Meetings. MG-X

The first international conference series to be initiated for the newly-revived field of General Relativity and Gravitation carried exactly that name – GR-1 was held at Chapel Hill, NC/USA in January 1957. It was organized by Bryce and Cécile (Morette) DeWitt, who had obtained positions at the University of North Carolina. In fact, it had a predecessor, a conference organized in Bern, Switzerland and held in July 1955 to celebrate the 50th anniversary of the initial publication of (Special) Relativity theory. It is often called 'GR-0', while later conferences in the series are listed as 'GR-1' etc. GR-2 took place in a former palace in Royaumont, near Paris, a location that was suggested by Cécile Morette DeWitt. Tiomno attended it, since he was in Europe at the end of his sabbatical year in London, 1958/59. This conference series continues today, now at three-year intervals, and GR-23 is scheduled for July 2022 in Beijing. Figure 9 shows Tiomno and Elisa in Paris in June 1959, at the end of their London stay, when he attended the Royaumont conference (GR-2). Tiomno also later published a paper in the proceedings of GR-10 (Item 19 in the above list).

Fig. 9. Jayme Tiomno and Elisa Frota-Pessôa in Paris, June 1959 (at the west end of the *Pont d'Iena*).

Another conference series was started in Dallas, TX/USA in 1963. It is called the 'Texas Symposia on Relativistic Astrophysics', and its initial motivation was to consider the newly-discovered Quasars in the light of relativity theory. This was the first time that the term 'Relativistic Astrophysics' was used publicly. An amusing account of the genesis of these conferences, which continue today at (usually) two-year intervals (the 31st is planned for December 2021 in Prague), was given by Engelbert L. Schucking, one of the original organizers from 1963, in *Physics Today* (August 1989, pp. 46-52).

In 1975, two of Tiomno's former collaborators, Abdus Salam and Remo Ruffini, founded the conference series 'Marcel Grossmann Meetings (on Recent Developments in Theoretical and Experimental General Relativity, Gravitation, and Relativistic Field Theories)', which should be familiar to the audience of this talk. Ruffini was at the time still officially at the Institute for Advanced Study in Princeton, but was on leave in 1975 as a visitor to the University of Western Australia (Nedlands)

and the University of Kyoto in Japan. The following year, he accepted a faculty position at the University of Catania, Sicily. Abdus Salam had been Head of the Department of Theoretical Physics at Imperial College London since 1957 (where Tiomno was one of the first visiting scientists, in the academic year 1958/59), and he became Director of the ICTP Trieste after its founding in 1964. The Centre offered a good platform for hosting the MG conferences, and the first two were held there in 1975 and 1979. MG-III, held in Shanghai in 1982, established the three-year interval still continued today. It was the result of the friendship between Remo Ruffini, who became Professor of Physics at his *alma mater*, the University of Rome 'La Sapienza' in 1978, and a Chinese visitor, Fang Li Zhi, whom he hosted in the late 1970's (cf. MG-XVI Awards Ceremony, Part 2). Later conferences in the series have been held in many cities on most of the continents.

Given his association with their founders and his own work in field theory, gravitation and cosmology, it was natural that Jayme Tiomno would have an interest in those meetings. But Tiomno, in spite of his close connection with the two founders of the MG conference series, did not attend the earlier MG meetings, both in Trieste; they took place during the 'leaden years' in Brazil, when he may not have been free to travel, and he had also not done any new, relevant research since leaving Princeton in 1972. By the time of MG-III, held in Shanghai/China in 1982, Remo Ruffini invited Mario Novello, from Tiomno's DRP Department at the CBPF, to participate in the meeting. Tiomno himself did not however attend the MG-III meeting; it was far from Brazil and perhaps difficult for him to obtain a visa.

Fig. 10. (a) Tiomno, Elisa and Mario Novello, 1991. (b) Tiomno with his last collaborator, Ivano Soares, in 1997.

In 1985, Ruffini and Abdus Salam, together with several other prominent scientists, founded the ICRA organization (International Center for Relativistic Astrophysics), based in Rome and Pescara, Italy (ICRANet). By 1985, Tiomno's time

had come, and he gave an invited paper on the LET–SRT controversy at MG-IV, held that year for the first time in Rome. Remo Ruffini and Abdus Salam were no doubt pleased to give him the opportunity to experience an MG conference, and Novello's enthusiasm also played an important role in convincing him to attend. After the meeting in Rome, Tiomno resumed his contacts with his former collaborators, and in 1994, the year of MG-VII, held in Stanford/CA, USA, he was a member of the 'Committee of the Americas', part of the international coordinating committee for the conference; but he again did not attend the meeting itself—by then, as *researcher emeritus*, he was reducing his overseas travel and participation in conferences, and encouraging some of his former students and collaborators to actively take over those functions, including Mario Novello and Marcelo Rebouças, among others.

Prior to the MG-X Meeting planned for 2003, the Brazilian physicists offered to host the conference at the CBPF, and Mario Novello served as chairman of its local organizing committee. At that meeting, the Institutional Award, presented at each conference to an outstanding institution in research and teaching, was given to the CBPF 'for its role as a teaching and research institution and as a place originating fundamental physics ideas in the exploration of the universe', and presented to its founders, César Lattes, José Leite Lopes, and Jayme Tiomno, who were all present.

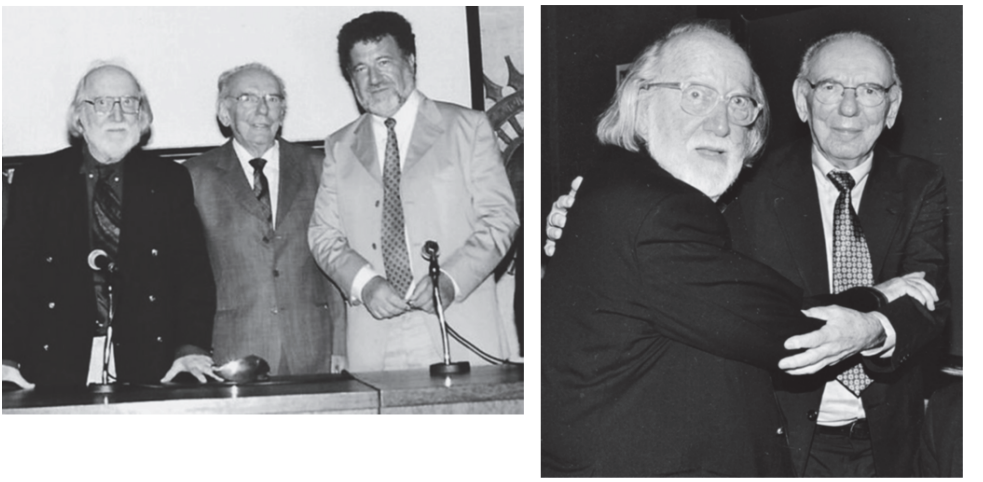


Fig. 11. (a) José Leite Lopes, Tiomno, and Remo Ruffini at the prize ceremony, MG-X, 2003. (b) Leite Lopes and Tiomno at MG-X in Rio, 2003.

That same year, ICRANet, the international networking arm of ICRA, was officially chartered. Ruffini needed at least three states to create it, and at the time, he had just two: the Vatican and Armenia. Brazil's membership in ICRANet was

also prepared at the 2003 Meeting, and Mario Novello later became its representative for Brazil (a post now occupied by Ulisses Barres de Almeida of the CBPF). Brazil formally agreed to join in 2005, and its membership was finalized in 2011.

Thus, although Jayme Tiomno himself was not strongly engaged in these meetings, his influence continues to be felt in them through the *Centro* that he helped to found, and through his former students and collaborators, who are actively involved in them, both scientifically and organizationally.

5. Conclusions

The three major strands of fundamental physics in the 20th century have wound their way through the decades, producing many offshoots and sometimes seeming to fuse into a single strand. They each experienced periods of hectic activity and rapid progress, and longer periods of relative neglect and apparent stagnation.

Particle physics reached its preliminary climax in the late 1970's with the formulation of the Standard Model of Particle Physics (combining the electroweak unified theory with quantum chromodynamics to describe three of the four fundamental interactions (weak, strong, electromagnetic); however leaving gravity out of the picture). In the intervening 40 years, the SMPP has been completed and perfected, but although no one really believes it to be the 'last word' on the microscopic world, the predicted 'new physics' beyond the SMPP has failed to appear, both experimentally and theoretically.

Gravitational physics has also produced the Standard Model of Cosmology (based on GR), and it has been enriched by many new discoveries and technical advances. But the SMC leaves many open questions and unsolved problems: dark matter, dark energy, inflation; and its fundamental constant, the Hubble constant, is currently the subject of conflicting measured values.

Fundamental quantum mechanics has given rise to a number of important offshoots: quantum optics, quantum information, quantum computing; but the interpretation of quantum mechanics is still elusive, as is its combination with gravity – quantum gravity.

Jayme Tiomno contributed significantly to all three of those major strands. But also, and for him more importantly, he contributed to the establishment and improvement of physics education and research in his native country, Brazil. This was his most serious goal during his long lifetime, and he made major contributions to its present success. The lesson to be learned from his lifelong efforts is that serious and honest work often leads to unexpected and lasting successes, even though it faces drastic obstacles and may appear hopeless at the time.

Acknowledgments

The author thanks Prof. Alfredo Tiomno Tolmasquim for much effort in the preparation of our joint book, reference,[2] upon which much of this article is based. Readers should consult it for many more references to original sources. Thanks are due also to Prof. Luis Carlos Bassalo Crispino, who was chairman of the session of MG-XVI where this paper was presented.

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