

ICTP Instituto Sul-Americano para Pesquisa
Fundamental: um Centro Regional para Física
Teórica

Project Coordinator: Nathan Jacob Berkovits

Host Institution: Instituto de Física Teórica-UNESP

Fapesp Project Number: 2011/11973-4

Project Period: 01/12/2011 – 30/11/2016

Period covered by this Report: 31/12/2015 – 30/11/2016

Project Team

Professors

Luis Raul Abramo, Associate Researcher (4 hours), IF-USP
Marcus A. M. de Aguiar, Associate Researcher (4 hours), IF-UNICAMP
Carlos Alfonso Ballon Bayona, Associate Researcher (4 hours), IFT-UNESP
Nathan Jacob Berkovits, Project Coordinator (20 hours), IFT-UNESP
Gustavo Burdman, Associate Researcher (4 hours), IF-USP
Oscar Chacaltana Alarcon, Associate Researcher (4 hours), ICTP-SAIFR
Hilda Cerdeira, Associate Researcher (4 hours), IFT-UNESP
Roberto André Kraenkel, Associate Researcher (4 hours), IFT-UNESP
Gastão Krein, Associate Researcher (4 hours), IFT-UNESP
George E. A. Matsas, Associate Researcher (4 hours), IFT-UNESP
Elisabete Dal Pino, Associate Researcher (4 hours), IAG-USP
Eduardo Pontón, Associate Researcher (4 hours), ICTP-SAIFR/IFT-UNESP
Paulo Inácio de Knecht López de Prado, Associate Researcher (4 hours), IB-USP
Victor Rivelles, Associate Researcher (4 hours), IF-USP
Alexandre Reily Rocha, Associate Researcher (4 hours), IFT-UNESP
Rogerio Rosenfeld, Principal Investigator (20 hours), IFT-UNESP
Daniel Augusto Turolla Vanzella, Associate Researcher (4 hours), IFSC-USP

Postdoctorals associated to ICTP-SAIFR

Nicolás Bernal (FAPESP)
José Hugo García (FAPESP)
Gero von Gersdorff (FAPESP)
Fabio Iocco (Young Investigator – FAPESP)
Chrysostomos Kalousios (FAPESP)
Fabien Lacasa (FAPESP)
Saeed Mirshekari (FAPESP)
Alessandro Parisi (FAPESP)
Rafael Porto (Young Investigator – FAPESP)
Luana Sucupira Pedroza (FAPESP)
Ryo Suzuki (FAPESP)
Riccardo Sturani (Young Investigator – FAPESP)
Alberto Tonero (FAPESP)

Administrative support

Lucas Santos Sanches, Computer System Manager (40 hours), ICTP-SAIFR/UNESP
Lilia Faria, Financial Manager (40 hours), ICTP-SAIFR/UNESP
Nadia Rosa Roque, Executive Secretary (40 hours), ICTP-SAIFR/UNESP
Jandira Ferreira de Oliveira, Executive Manager (40 hours), ICTP-SAIFR/UNESP

3. Summary of the Project's main goals

Fundamental research in theoretical physics has historically led to developments in all areas of science. In addition to producing technological applications coming from a better understanding of the physical laws of the universe, fundamental research in theoretical physics has led to new methods of problem-solving which has revolutionized areas of mathematics, biology, computer science, economics, and other areas of study.

Throughout the world, the importance of fundamental research has led to the creation of theoretical physics institutes which focus on research, on the training of graduate students and post-docs, and on the organization of schools and workshops. Although these theoretical physics institutes have different structures and many are connected with public universities, they are all disconnected from undergraduate physics departments and have independent hiring policies and academic responsibilities from the rest of the university. Because of this autonomy, these theoretical physics institutes are able to attract the best researchers to their faculty. And because of the prestigious faculty and the organization of schools and workshops, these institutes are able to attract highly qualified graduate students and post-docs. As a result, the academic and research programs at these autonomous theoretical physics institutes increase the international impact of their host universities.

The establishment of a viable South American institute devoted to the fundamental aspects of theoretical physics is an urgent priority. One of the main roles of the International Center for Theoretical Physics (ICTP) in Italy is to promote scientific research in developing countries, and the establishment of such a center in South America has been promoted for several years by the ICTP leadership. In addition to promoting theoretical physics research in Brasil, this center would also have the responsibility of promoting research in less-developed countries of South America by hosting workshops and schools and having an active visiting program for students and researchers from other South American countries. In other words, this regional center would play the role of a mini-ICTP. In 2010, the new management of ICTP made the establishment of this South American regional center a high priority with the direct participation of the ICTP and named it the "ICTP South American Institute for Fundamental Research".

The association of the São Paulo State University (UNESP) with the International Center for Theoretical Physics (ICTP) to establish the ICTP South American Institute for Fundamental Research in São Paulo with funding from FAPESP has grown from the desire of UNESP to increase its international visibility and the ICTP desire to employ its expertise in the organization and running of this new South American regional center for theoretical physics.

The long-term goal for this new institute is to become a South American center of excellence in theoretical physics which will be comparable to theoretical physics institutes in the rest of the world and at the same level as the highly prestigious mathematics institute Instituto Nacional de Matematica Pura e Aplicada (IMPA) in Rio de Janeiro. Through an active visiting program involving Schools and Workshops, this center of excellence will elevate the level of theoretical physics in all of South America. With the assistance of the three institutions, namely ICTP, UNESP and FAPESP, the Steering Committee and Scientific Council and the Director will accomplish this mission through the following steps:

- Hiring five new permanent researchers with a reduced teaching load who will assist in the organization of the schools and workshops;
- Hiring a trained secretarial staff which will handle all non-scientific aspects;
- Supporting an active visiting program for South American students and researchers;
- Offering prestigious postdoctoral positions to highly qualified researchers;
- Organizing schools and workshops on focused topics throughout the year for South American students and researchers.

4. Accomplishments in the period

a. Main achievements during the five-year project

The ICTP South American Institute for Fundamental Research (ICTP-SAIFR) has now completed its fifth year of theoretical physics activities in Sao Paulo as a collaboration between the Sao Paulo Research Funding Agency (FAPESP), the International Centre for Theoretical Physics (ICTP) - a category 1 institute of UNESCO, the Sao Paulo State University (UNESP), and the Instituto de Fisica Teorica (IFT-UNESP) in whose building it is located. From November 6-8, 2016, ICTP-SAIFR celebrated this 5th anniversary with the Symposium on Advancement of Science in South America (www.ictp-saifr.org/fifth) featuring public lectures by a Nobel Prize laureate and the spokesperson of the LIGO gravitational wave observatory, plenary seminars on ground-breaking physics research by the leading young theoretical physicists, parallel research talks by the 60 distinguished ICTP-SAIFR associated members from across South America, and roundtable discussions with presidents of South American science funding agencies and directors and ex-directors of leading theoretical physics institutes including the Institute for Advanced Study in Princeton USA, the Kavli Institute for Theoretical Physics in Santa Barbara USA, the ICTP in Trieste Italy, and the Perimeter Institute in Waterloo Canada.

At this symposium, the various achievements of ICTP-SAIFR over the last 5 years were highlighted including its hiring of top researchers for its permanent and temporary positions, its organization of PhD schools and workshops with the participation of over 2500 graduate students and 1000 researchers, its international collaborations with leading theoretical physics institutes, and its outreach programs for high-school students and teachers. As evidence of these achievements, UNESP was ranked in 2016 by the Nature Index to be the most improved institution in Latin America over the last 4 years with explicit mention of ICTP-SAIFR, the Simons Foundation award donation of 60,000 US dollars per year to ICTP-SAIFR was recently renewed until December 2021, the UNESCO General Conference approved ICTP-SAIFR in November 2015 as a Category 2 Institute, and the new 5-year FAPESP thematic project was approved for the period of December 1, 2016 – November 30, 2021 with an increase in funding over the first 5-year project.

Although the number of ICTP-SAIFR faculty currently includes only 7 members (Nathan Berkovits, Rogério Rosenfeld, Eduardo Ponton, Pedro Vieira, Rafael Porto, Riccardo Sturani, Fabio Iocco), the research performed by these members and their postdocs and students has already yielded important results.

Over the last 5 years, perhaps the most important result in theoretical physics has been the discovery of gravitational waves by the LIGO collaboration (**Phys.Rev.Lett. 116 (2016) no.6, 061102**) which has opened a new window into astrophysical events and will undoubtedly soon lead to a Nobel Prize. ICTP-SAIFR is one of only two groups in Latin America that participated in this discovery, and

researcher Riccardo Sturani is chair of the LIGO subgroup dedicated to gravitational waveform modeling, and organizes the review of the codes used to test the search pipelines. In addition to Sturani's two postdocs who are involved with LIGO, ICTP-SAIFR faculty also includes researcher Rafael Porto who has made important contributions to theoretical aspects of gravitational waves through the use of effective field theory, and has recently written an invited Physics Report on this subject (**Phys.Rept.** **633 (2016) 1-104**).

Another important topic to which ICTP-SAIFR faculty have actively contributed is the search for dark matter. In **Nature Physics Letter 11 (2015) 245-248**, which was widely cited in the media (see for example, (<http://www.latimes.com/science/sciencenow/la-sci-sn-dark-matter-inner-milky-way-20150213-story.html>)), ICTP-SAIFR researcher Fabio Iocco was the first author of a paper showing convincing evidence for dark matter in the center of the Milky Way galaxy by analyzing rotation curve measurements and comparing with models of baryonic mass distributions.

In the area of particle physics, there have been few clues since the discovery of the Higgs boson for future directions. One possible clue is the relatively small mass of the Higgs boson which has led ICTP-SAIFR researchers Eduardo Ponton and Rogério Rosenfeld, together with collaborators such as Fermilab Theory director Marcela Carena, to conjecture that the Higgs boson is not a fundamental particle (e.g. **JHEP 1406 (2014) 159**). Another potential clue that has unfortunately disappeared was an apparent excess of photon-photon events, which led ICTP-SAIFR postdocs Gero Gersdorff and Silvain Fichet to propose a possible explanation in the widely cited paper **Phys.Rev.Lett.** **116 (2016) 23, 231801**.

In the area of string theory and integrability, AdS-CFT remains the most active research area with applications both to supersymmetric Yang-Mills theory as well as other strongly coupled field theories in condensed matter physics and heavy ion physics. ICTP-SAIFR researcher Pedro Vieira has pioneered new integrability methods involving string-like flux tubes to compute non-perturbative correlation functions in supersymmetric Yang-Mills (e.g. **JHEP 1508 (2015) 018**), and was awarded the 2015 Gribov Medal for his work. And ICTP-SAIFR researcher Nathan Berkovits has used twistors to construct new formulations of string theory (e.g. **JHEP 1403 (2014) 017**) which are more powerful for computing scattering amplitudes and, unlike other formulations, can be used in superstring backgrounds relevant to AdS-CFT.

In the area of complex systems with applications to biology, ICTP-SAIFR does not yet have any faculty members and a search committee including William Bialek (Princeton) is being formed now to select one of the next Simons-Fapesp tenure-track professors from this research area. However, there are ICTP-SAIFR associated researchers from IFT-UNESP who regularly organize ICTP-SAIFR activities in this area and have done important research over the last 5 years. Together with his postdoc, associated researcher Roberto Kraenkel developed a theoretical model to investigate the recent two-year drought in São Paulo, and created an online website with their theoretical predictions which was widely cited by the media (<http://g1.globo.com/sao-paulo/noticia/2015/05/pesquisadores-criam-metodo-para-prever-agua-no-cantareira.html>). And associated researcher Hilda Cerdeira used nonlinear dynamical methods to develop a device to predict epileptic seizures (www.epistemic.com.br) which has won numerous awards and is currently in development.

In addition to research, a main focus of ICTP-SAIFR activities over the last 5 years has been the training of PhD students from South America through international schools, minicourses, workshops and programs. These activities for

PhD students include all areas of theoretical physics, as well as in related areas of chemistry, biology and mathematics. Over 90 such activities have been organized over the last 5 years, with the participation of over 2500 graduate students with 1/2 from Brasil, 1/3 from other countries in South America, and 1/6 from other continents.

As a direct result of these activities, the IFT-UNESP graduate physics department rose to the top ranking of 7 by CAPES and now attracts the top theoretical physics graduate students from all of South America. This is despite the high cost of living in São Paulo and that IFT-UNESP has neither an undergraduate student program nor accommodations for students. In addition, ICTP-SAIFR has expanded its activities in 2016 to include outreach activities for high-school and undergraduate students which will be described in the next section. These outreach and training activities will surely have an effect on future generations of researchers in South America.

With these achievements, it is reasonable to affirm that ICTP-SAIFR is now the leading institute for theoretical physics in South America. Although there are several other theoretical physics institutes in South America such as the IIP in Natal (Brasil), CECS in Valdivia (Chile), ICAS in Buenos Aires (Argentina), none of them have the international scope in research and activities that ICTP-SAIFR has achieved in its brief 5-year existence.

b. Accomplishments in 2016

From March-October 2016, Perimeter Institute Dirac Professor Pedro Vieira visited ICTP-SAIFR from March-October 2016 as a visiting researcher as part of the new collaboration agreement with Perimeter Institute. Professor Vieira performs research in the area of integrability and gauge theory, and was awarded the 2015 Gribov Medal by the European Physical Society for his research. Following the recommendation of the ICTP-SAIFR International Search Committee, a proposal was submitted to the university to open a permanent position in the area of integrability in mathematical physics. Because of the current economic crisis, this permanent position has not yet been approved by the university council, however, Pedro Vieira recently was hired by UNESP as a temporary professor until the permanent position is opened.

Regarding the 5 permanent ICTP-SAIFR positions, the ICTP-SAIFR has filled one position in the area of particle physics (Eduardo Ponton) and has hired two tenure-track fellows in the areas of astrophysics (Fabio Iocco) and cosmology (Rafael Porto). These tenure-track candidates are supported by an award donation from the Simons Foundation (New York) together with a FAPESP Young Investigator fellowship, and the decision on opening permanent positions in the areas of these two tenure-track candidates will be made in December 2017.

With the assistance of the new collaboration with Perimeter Institute involving joint Perimeter professor Pedro Vieira, the ICTP-SAIFR greatly expanded its outreach activities in 2016 by organizing the school "1st IFT-Perimeter-SAIFR Journeys into Theoretical Physics", the workshop "Cutting-edge In-class Physics Resources" and the "Minicourse on Relativity, Quantum Mechanics and Gravitation". The IFT-Perimeter-SAIFR Journeys into Theoretical Physics School invited the top 100 undergraduate students from all over Latin America to participate in a one-week school with lecturers from Perimeter and IFT-UNESP. The 5 students receiving the top scores on an exam at the end of the school were accepted to a joint master's program where they will spend one year at Perimeter Institute in the

world-famous PSI program and one year at ICTP-SAIFR/IFT-UNESP. The "Cutting-edge Workshop" and the "Minicourse" are new outreach activities of ICTP-SAIFR for high-school teachers and students from greater Sao Paulo. In the Workshop which took place during the weekend of Sept. 17-18, Gregory Dick (Perimeter I.) and Glenn Wagner (Perimeter I.) used hands-on activities to introduce concepts of modern physics to high-school teachers who also received a set of classroom-ready resources to share with their students. The Minicourse for 90 high-school students met during six Saturday morning sessions in September-October with Pedro Vieira (ICTP-SAIFR/Perimeter I.) lecturing on modern physics concepts from special relativity to quantum mechanics.

Also, in June 2016, ICTP-SAIFR started a new monthly outreach program, "Papos de Física", introducing current topics in theoretical physics to the general public in a pub near Avenida Paulista. From July-December, researchers from ICTP-SAIFR and neighboring universities presented monthly seminars on Dark Matter, Gravitational Waves, the Holography, Particle Physics, and Neutrinos.

In 2016, a new international agreement was signed with the Mainz Institute for Theoretical Physics at Gutenberg University (Germany), while another was renewed with NORDITA. These agreements help to finance the exchange of visitors between these institutes and ICTP-SAIFR, similar to its other agreements with CERN, ICTP-Trieste, Fermilab, CEA-Saclay, IFT-Madrid and Perimeter.

In November 2015, the General Conference of UNESCO in Paris approved the proposal of ICTP-SAIFR to become a Category 2 Institute of UNESCO as a regional centre for the South American continent. In June 2016, UNESCO approved minor modifications to the proposal to make it consistent with the composition of the ICTP-SAIFR Steering Committee. The proposal is now awaiting the signature of the Brazilian Minister of Science and Communications which is expected to occur soon.

Research highlights in 2016 include the discovery of gravitational waves by the LIGO experiment with the direct participation of ICTP-SAIFR Young Investigator Riccardo Sturani and his ex-postdoc Saeed Mirshekari, and the publication in Nature Communications of an article on edge phonons in phosphorus with the participation of ICTP-SAIFR associated researcher Alexandre Rocha. Furthermore, the 2016 Nature Index ranked UNESP as the most improved institution in Latin America between 2012-2015 in high-quality research, and explicitly mentioned ICTP-SAIFR as playing an important role in this improvement.

In April 2016, the last FAPESP postdoctoral position on the previous grant was filled with the selection of Alessandro Parisi (U. L'Aquila, Italy). Dr. Parisi studies the dynamics of the two body problem in General Relativity with exact numerical tools and is working with Young Investigator Riccardo Sturani. The postdoctoral positions on the previous FAPESP grant will all finish in November 2016, and a search has already begun to fill the 12 postdoctoral fellowships on the new grant.

Also in April 2016, Lucas Santos Sanches was hired as the new computer systems manager of ICTP-SAIFR in replacement of Danilo Ramos. In addition to being responsible for the ICTP-SAIFR webpage and online applications, Lucas supervises the audiovisual recording and computer laboratory for ICTP-SAIFR activities and provides technical support to all ICTP-SAIFR researchers and visitors. His performance has been outstanding and Lucas was recently promoted from the job status of Junior Programmer to Programmer.

During 2016, the number of visitors, schools and workshops increased over the previous years. 213 visitors stayed for more than one week and more than 100 seminars and colloquia were presented. The ICTP-SAIFR organized activities in

diverse areas of theoretical physics. These activities included 7 international schools on the topics of mathematical biology, physics applications in biology, climate modeling, effective field theory, string theory, dark matter, astrophysics and laboratory plasmas, 14 workshops on quantum materials, hadron physics, string theory, mathematical physics, modeling of urban systems, interconnection of particle physics and cosmology, econophysics, 3-point correlation functions, entrepreneurship, dark matter, advancement of science in south America, mesoscopic systems, theoretical physics, general relativity as well as 1 minicourse on numerical relativity. Also, a 6-week program on particle physics was organized by Prof. Eduardo Pontón (ICTP-SAIJR/IFT-NESP) and Rogério Rosenfeld (ICTP-SAIJR/IFT-NESP) from October to November. Finally, there were weekly meetings in 2016 of a colloquium and four separate "journal clubs" in the areas of string theory, particle physics, integrability and cosmology. These four journal clubs and colloquia discussed current research problems at the frontiers of scientific knowledge and included the participation of students and researchers both from IFT-UNESP and from other nearby universities.

The ICTP-SAIJR scientific council approved 8 international schools to be held in 2017 on the topics of mathematical biology, cold atoms, soft matter, AdS/CMT correspondence, conformal bootstrap, cosmology, data science and quantum information theory. In addition, a 5-week program funded by the Simons Foundation on the topic of the conformal bootstrap will be organized by Professor Pedro Vieira (ICTP-SAIJR/Perimeter I.) and workshops will be organized on the topics of solitons, cosmology and gravitation.

The activities of ICTP-SAIJR in 2016 will be described below in more detail including:

- (a) research related to publications;
- (b) research related to visitors;
- (c) organization of schools, workshops, minicourses, outreach activities, meetings and seminars.

a. Research related to publications

The research conducted at ICTP-SAIJR during this period includes diverse areas of theoretical physics, as indicated by the publication list in item 8. Among the different subjects are string theory, field theory, integrability, condensed matter, particle physics, cosmology, general relativity, astrophysics, complex systems, and mathematical biology. These publications involved research performed by associate researchers, postdoctoral fellows and visitors of ICTP-SAIJR and will be highlighted below.

a1. String theory, Field Theory and Integrability

Although the conventional formalism for describing the superstring is the Ramond-Neveu-Schwarz (RNS) formalism developed in the 1970's, the RNS formalism is unable to describe backgrounds necessary for studying the AdS-CFT correspondence which relates weakly coupled gravity theories and strongly coupled gauge theories. For this background, one needs to use the pure spinor formalism for the superstring which contains manifest spacetime supersymmetry. The use of string techniques for computing scattering amplitudes is a topic of great interest.

In publication [9] a manifestly $N=1$ worldsheet supersymmetric action is

proposed for the superstring in an $AdS^5 \times S^5$ background in terms of the twistor superfields. This $AdS^5 \times S^5$ worldsheet action is a remarkably simple fermionic coset model and might be useful for computing superstring scattering amplitudes. In publications [51] and [52] some techniques in string theory were used to obtain results in scattering amplitudes.

In publication [34] the WKB approximation was used to analyse the tunnelling of a pulsating string in deformed Minkowski spacetime.

The renormalization group describes the evolution of couplings as a function of energy. An alternative to the perturbative calculation is the so-called Functional Renormalization Group, which was used in publications [77] and [78] to compute an effective action and correlation functions.

a2. Condensed Matter

Black phosphorus has recently emerged as a new layered crystal that, due to its peculiar and anisotropic crystalline and electronic band structures, may have important applications in electronics, optoelectronics and photonics. Despite the fact that the edges of layered crystals host a range of singular properties whose characterization and exploitation are of utmost importance for device development, the edges of black phosphorus remain poorly characterized. In publication [39] in Nature Communications, the atomic structure and behaviour of phonons near different black phosphorus edges are experimentally and theoretically studied using Raman spectroscopy and density functional theory calculations. Polarized Raman results show the appearance of new modes at the edges of the sample, and their spectra depend on the atomic structure of the edges (zigzag or armchair). Theoretical simulations confirm that the new modes are due to edge phonon states that are forbidden in the bulk, and originated from the lattice termination rearrangements. The anomalous temperature dependence of the band gap in this material was the subject of publication [42].

One of the challenges for next generation DNA sequencing is to have a robust, stable, and reproducible nanodevice. In publication [43] it is proposed how to improve the sensing of DNA nucleobase using functionalized graphene nanogap as a solid state device. Two types of edge functionalization, namely, either hydrogen or nitrogen, were considered. It was shown that the translocation process of nucleobases passing through the nanogap reduces the conductance by up to 3 orders of magnitude.

a3. Particle Physics

The Standard Model (SM) of Particle Physics has been frustratingly successful so far in describing the experiments performed by the LHC collaborations. One of the major unsatisfactory issues is the so-called naturalness problem: for the quantum corrections to Higgs boson mass to be "reasonable" one would expect new phenomena at the TeV scale. Since the LHC is almost closing this possibility, several extensions of the SM are being proposed that partially avoid this problem.

An exciting possibility that explains why the Higgs mass is light invokes a shift symmetry arising in the so-called composite Higgs models, which postulates that the Higgs boson is a pseudo-Nambu-Goldstone boson (pNGB) arising from the spontaneous breaking of a global symmetry. One signature of this class of models is the existence of a radial excitation associated with the breaking of the global symmetry. In publication [32] the properties of this new particle, called "global Higgs", was studied in detail for different models. In this class of models the

longitudinal components of the electroweak gauge bosons arise also as pNGB and hence their scattering can give information on the nature of the model, as studied in publication [79].

Dark matter is another relevant topic since it has only been detected in astronomical measurements so far and is widely believed that dark matter is made of a new fundamental particle. Publications [48] and [49] explore the possibility that this new particle has a strong self-coupling and study its consequences.

A new state of matter, the so-called quark-gluon plasma, can be achieved in high-energy collisions of heavy nuclei. In publications [18] and [25], some thermodynamical properties of quark matter were studied.

a4. Cosmology and Gravity

One century after its formulation, Einstein's general relativity (GR) has made remarkable predictions and turned out to be compatible with all experimental tests. One of the predictions of GR is the existence of gravitational waves. The first direct detection of gravitational waves, produced by the coalescence of binary black holes with masses of roughly 30 solar masses, was announced in February by the Laser Interferometer Gravitational-wave Observatory (LIGO). This detection, followed by another event soon afterwards, led to the opening of a new window to the Universe. Publications [57]-[69] are all based on the LIGO ground-breaking results.

The so-called Effective Field Theory approach, appropriate for nonperturbative problems such as the interaction of pions in Particle Physics, has been more recently used with relative success in different areas in Cosmology, such as inflation, the study of large scale structure of the Universe, the behavior of dark energy models and the emission of gravitational waves in binary systems. Publication [54] is a comprehensive review of these exciting developments.

Publication [1] deals with the advantages of including different tracers of cosmological perturbations in studying different cosmological models. The study of different probes is also important, as shown in publication [46], where a combination of cluster number counts and angular power spectrum is considered in the context of the Halo Model and Halo Occupation Distribution.

It has been shown that gravitational fields produced by realistic classical-matter distributions can force quantum vacuum fluctuations of some nonminimally coupled free scalar fields to undergo a phase of exponential growth. Publication [26] studies this instability in the spacetime of thin charged shells.

a5. Astrophysics

A very active area of research is the role of magnetic fields in the astrophysical plasma. In publication [29], for instance, three-dimensional relativistic magnetohydrodynamic was used to investigate the influence of radial density profile on the spatial development of the current-driven kink instability along magnetized rotating, relativistic jets. The results show the propagation of a helically kinked structure along the jet and relatively stable configuration for the lighter jets. The jets appear to be collimated by the magnetic field and the flow is accelerated due to conversion of electromagnetic into kinetic energy. Regions of high current density in filamentary current sheets are identified, indicative of magnetic reconnection, which are associated to the kink unstable regions and correlated to the decrease of the sigma parameter of the flow. It is found that fast magnetic reconnection may be driven by the kink-instability turbulence and govern the transformation of magnetic into kinetic energy thus providing an efficient way to power and accelerate particles in active galactic nuclei and gamma-ray-burst relativistic jets.

a6. Complex Systems

The concept of phase synchronization as proposed in 1996 by Rosenblum et al. has been widely used and proved experimentally when applied to time series. For coupled systems, phase synchronization has been extensively applied in the context of chemical and biological systems. In brain connectivity analysis, the phase synchronization phenomena can be considered a fundamental neural mechanism, responsible for supporting neural communication and neural plasticity and is probably relevant to many cognitive processes. In networks of neurons, the phase determines the degree of excitability of the neurons and influences the discharge times of cells. Consequently, phase relationships between brain regions affect the relative timing of action potentials in those regions. In publication [11] a novel way to estimate phase-lag synchronization in coupled systems is proposed. This approach was applied into two systems: a directed-coupled Rössler-Lorenz system and a network of Izhikevich neurons. For the former case, the phase-lag synchronization revealed an increase in complexity for the Lorenz subsystem components, when the coupling is activated. The opposite behavior was observed when the Izhikevich network was organized in a hierarchical way. These results point out to emergent synchronism related to causal interactions in coupled complex systems. Other neuronal networks were studied in publications [12] and [13], with applications to study epileptic seizures.

a7. Mathematical Biology

Despite the ongoing debate over the relative importance of randomness and environmental selection in determining the properties of organisms during evolution, stochastic processes are certainly an inherent property of living populations. In particular, random variation in the outcome of different life-history events collectively result in what is often summarized in the concept of "random genetic drift". Although its influence in large populations may be weak when compared to selection, its role can be decisive in the process of fixation of rare alleles and cannot be neglected in small populations. In population genetics, mutation and genetic drift are two inescapable sources of stochasticity with opposing effects regarding the maintenance of variation in the population. In publication [5], the stationary allele distribution for populations placed on regular networks is studied, where connected nodes represent potential mating partners. It is shown that the mutation threshold is sensitive to spatial structure only if the number of potential mates is very small. In this limit, the mutation threshold decreases substantially, increasing the diversity of the population at considerably low mutation rates.

It has been long recognized that evolutionary processes take place in space and time and that simple mean field approximations, where space is ignored, are unable to describe important aspects of their dynamics. A classic example is the phenomenon of pattern formation in host-parasite systems where the parasite can mutate, becoming more or less lethal. Whereas in a mean field approximation the dynamics would lead to the prevalence of the most lethal form and to the extinction of both hosts and parasites, in a spatial population only local patches of organisms disappear and are recolonized by hosts and less lethal forms of the parasite. In coevolutionary systems the spatio-temporal character of the dynamics appears to be equally important. Empirical observations indicate that patches of locally coadapted populations are short lived, being prone to mismatches, to extinctions and to constant invasion by other such local populations. Antagonistic interactions, such as predator-prey or host-parasite, are one of the principal forces of selection and can produce adaptations and counter-adaptations on the populations, leading to an arms race. In publication [7] an individual-based model is developed to

simulate the coevolutionary process in a predator-prey system using as inspiration the newt-snake system. Although the model has many assumptions and parameters, it is still an oversimplified version of the natural newt-snake system to allow for direct comparison between the results of simulations and the empirical data. The goal is to study the main qualitative features of the dynamics and, in particular, to understand the role of space in generating phenotypic mismatches. It is shown that evolution in this system exhibits a complex spatio-temporal dynamics of local extinctions and colonizations. While local populations of prey and predators tend to engage in an arms race and evolve closely balanced phenotypes, they can also go extinct. Moreover, since the population of prey is much more abundant than that of predators, groups of prey may become temporarily isolated from predators, decreasing the evolutionary pressure and lowering their toxic content. This, in turn, increase their reproductive ability, and make them potential colonizers of nearby extinct patches, leading to phenotypic mismatches.

b. Research related to visitors

During 2015, the ICTP-SAIFR hosted 127 short-term visitors who stayed less than one week and 213 long-term visitors who stayed more than one week. The complete list of short-term and long-term visitors to ICTP-SAIFR can be found on the webpage http://www.ictp-saifr.org/?page_id=10924
The research of some of the long-term visitors is described below:

Oswaldo Chandia – Univ. Adolfo Ibañez, Santiago, Chile (2/15-19)

I studied the construction of vertex operators in the holomorphic string invented by Berkovits two years ago.

Muruganandam Paulsamy - Bharathidasan University (4/10 – 6/10)

During the visit period, we have mainly focussed on the study of collective behaviors in a network of coupled nonlinear oscillators. In particular, by considering a network of nonlocally coupled Stuart-Landau oscillators subject to certain nontrivial sets of initial cluster sizes with appropriate initial conditions, we have explored the multicluster amplitude and oscillation death states. Apart from the above, we have studied the dynamics of certain relay coupled oscillators. Particularly, we have investigated the possibility of achieving synchronization in finite-time for a system of chaotic (Rossler-like) oscillators coupled through a relay unit. Further, we have also focussed on the study of the collective cohesive motion of certain jerk type chaotic systems, which can be used to mimic the flock of flying starlings. A manuscript has been prepared based on our study and already submitted for publication. Some preliminary results have been produced from our study on the multicluster oscillation deaths in a network of oscillators and also on the jerk dynamics. We are still continuing our works along these lines.

Aníbal Medina – Université Paris Saclay (5/2-6)

I gave a seminar at the ICTP-SAIFR on a possible interpretation for the then apparent excess in diphotons that had been measured at the LHC by both experiments ATLAS and CMS. The interpretation was based on a 5D warped scenario with a scalar Higgs localized in the bulk of the extra dimension and the radion playing the role of the new resonance providing the diphoton signal. I discussed some of my work with Prof. Eduardo Ponton and other members of the ICTP-SAIFR.

Shota Komatsu – Perimeter Institute (5/12 – 6/6 & 9/13 – 10/1)

I visited ICTP-SAIFR from May 12th to June 6th. The main purpose of the visit is to discuss with Pedro Vieira, who is the FAPESP-Perimeter Research Professor at ICTP-SAIFR. During the last visit, we, together with Benjamin Basso, found a new method to compute the three-point function in $N=4$ supersymmetric Yang-Mills theory. We are currently pushing that idea further and trying to establish an efficient method to compute a larger class of three-point functions. We could make important

progress during this visit and we hope to be able to publish a paper very soon. In addition to the project I described above, I spent some time discussing with Thiago Fleury, a postdoc in IFP, on the four-point functions of the same theory. The idea is to generalize the method described above and compute the four-point function directly. We performed several computations and so far it seems very promising.

Douglas Singleton – California State U. Fresno (6/2 – 7/28)

Below you will find papers that I published as a result of my work done partially or wholly at ICTP-SAIFR and which carries the ICTP-SAIFR affiliation.

Paper 1: Compact and extended objects from self-interacting phantom fields; V. Dzhunushaliev, V. Folomeev, A. Makhmudov, A. Urazalina, D. Singleton and John Scott

DOI: [10.1103/PhysRevD.94.024004](https://doi.org/10.1103/PhysRevD.94.024004)

Paper 2: The impact of particle production on gravitational baryogenesis; J.A.S. Lima, D. Singleton

DOI: [10.1016/j.physletb.2016.10.005](https://doi.org/10.1016/j.physletb.2016.10.005)

Paper 3: Global versus local — Mach's principle versus the equivalence principle; D. Singleton and S. Wilburn

DOI: [10.1142/S0218271816440090](https://doi.org/10.1142/S0218271816440090)

Paper 4: Time dependent electromagnetic fields and 4-dimensional Stokes' theorem; R. Andosca and D. Singleton

DOI: [10.1119/1.4962239](https://doi.org/10.1119/1.4962239)

Luis Martin Kruczenski – Purdue University (6/15-26)

During my visit I conducted the following activities 1) Participate and give a talk in the "Workshop on Mathematical Physics" (June 16 - June 17) organized by ICT-SAIFR. 2) Discuss with Prof. Pedro Vieira applications of the loop equation to lattice gauge theories. The loop equation proposed by Migdal and Makeenko attempts to describe gauge theories purely in terms of Wilson loops namely gauge invariant operators. New techniques suggest that such equation can be tractable in the lattice. 3) Discuss with Profs. Nathan Berkovits and Pedro Vieira applications of the new formalism discovered by Nathan Berkovits to quantize strings in AdS₅×S⁵ backgrounds. This new formalism can open the possibility of computing Wilson loops in perturbation theory on the string side of the AdS/CFT correspondence. We discuss classical solutions and how they will appear in the new formalism. All this work is in the initial stages but if any publication arises from them, ICT-SAIFR will certainly be acknowledged.

Ronaldo Batista – UFRN (6/22 – 7/18)

During my visit I have worked in a numerical code to solve Spherical Collapse model (in Cosmology) for the evolution for non-top-hat profiles in the presence clustering dark energy. This work is being developed for a long time and is now in its final stage. However, some technical questions had to be solved. In this sense, I have received very useful suggestions from Prof. Rogerio Rosenfeld and another visitor at the period, Prof. Valerio Marra. I hope this work will be finished in about a month. I also have started a work about the impact of dark energy perturbations in the context of σ_8 tension in collaboration with Prof. Rosenfeld and Prof. Marra. Some recent papers have claimed that clustering dark energy can decrease the value of σ_8 , while keeping the background cosmology identical to Λ CDM model. However we believe that some definitions regarding the mass functions in this kind of models have to be modified in order to make robust predictions. At the moment we are discussing such modifications. This work might demand more 3-4 months. In general, I have also benefited a lot from the interaction with other researchers that were also visiting the ICTP-SAIFR and/or attending its scientific events.

Sergio Palomares-Ruiz – IFIC-Valencia (6/23-30 & 7/9-17)

The main purpose of my visit to the ICTP-SAIFR was to collaborate with Nicolás Bernal. We discussed the possibility to further develop an idea we published a few years ago about detecting dark matter accumulated in the Sun by observing MeV neutrinos from the products of dark matter annihilations. Unlike the use of inverse beta decay as the detection reaction, we are considering the detection signature of neutrino-electron elastic scattering, which has a smaller cross section, but it is very directional. On the other hand, we are also considering improving some of the approximations made in the original work and update the results with new data. On the other hand, we also discussed a new idea. The minimum mass of structures that collapsed in the Universe (mainly dark matter) is determined by the time of kinetic decoupling of the dark matter particle. This minimum mass for halos has implications for cosmological dark matter annihilations. The smaller the mass (the earlier kinetic decoupling occurs), the larger the annihilation boost factor is.

We are considering scenarios in which kinetic decoupling could occur at a similar time as thermal decoupling, and hence, the minimum mass could be smaller than in standard scenarios. In addition, I gave a seminar on 'Subhalos internal structure and dark matter annihilation signals' and participated in the conference PPC 2016, giving a talk as well, 'High-energy neutrinos: An analysis of the 4-year IceCube data'.

Carolina Soledad Negrelli - Univ. de La Plata (7/16 - 23)

We have begun a collaboration with Dr, Fabio Iocco and his student María José Benito Castaño. We are testing the Modified Gravity Theory (MOG) proposed by Moffat using a data compilation of the rotation curve of the Milky Way. There is still a lot of work to do.

Leonard Todjihounde – I. of Mathematics and Physics, Benin (11/5 – 12/15)

My stay has been a great opportunity for me to learn about the recent developments on geometrical methods in physics. During my stay I participated in two workshops at ICTP-SAIFR : - 28.11 – 01.12 : New Physics in Space. - 05.12 – 09.12 : Analytical Methods in General Relativity. I had the opportunity to attend also some seminars at the Department of Mathematics of the University of Sao Paulo (USP) and we are in discussion to establish from next year a scientific cooperation between the " Institut de Mathematiques et de Sciences Physiques (IMSP)" in Benin and the Institute of Mathematics and Statistics of USP. It has been also an opportunity for me to have interesting discussions with many scientists from many scientific institutions of Brazil who participated in the workshops and seminars. My stay has been very fruitful and I thank warmly ICTP-SAIFR for inviting me and for its financial and logistical supports.

Emilio Trevisani - Univ. of Porto (7/13 – 8/10)

I worked on a project on the skeleton expansion for conformal field theories in collaboration with Vasco Gonçalves. This is a diagrammatic expansion around generalized free theory which uses as building blocks the exact two point function and the dressed cubic vertex. These building blocks are particularly convenient in order to study CFTs since they are determined by the two and three point functions, which are fixed by symmetry in terms of the CFT data (conformal dimensions and OPE coefficients). While usual Feynman diagrams are completely blind to conformal symmetry, the skeleton expansion makes explicit use of it by automatically resumming all the diagrams which would correct the propagator and the vertex. There are many possible directions and many open questions which we would like to clarify in this project. For example we would like to obtain some criteria to understand which is the landscape of theories which enjoys this convenient expansion. Also, more pragmatically, it would be interesting to focus on specific theories and to perform very high order perturbative computations of the CFT data.

Ekaterina Karukes – SISSA, Italy (10/15 – 12/31)

In two months of visiting ICTP-SAIFR I worked with Fabio Iocco's group on the extensions and improvement of the Milky Way rotation curve. As the first step of the extension of this rotation curve we included in the analysis the available data of the blue-horizontal-branch stars. Then this improved rotation curve was used to do the mass modelling of the Milky Way, where we were able to get useful information about Milky Ways's dark matter content. Finally, I would like to notice that this work should be followed up and some assumptions made in the analysis should be farther checked. Additionally, during my visit I finished the paper that I was working on before with prof. P. Salucci. This paper was accepted for publication in MNRAS.

Subir Ghosh – SISSA, Italy (11/2 – 12/23)

I collaborated with Professors Denis Dalmazi and Elias Mendonca of UNESP, Guaratingueta. We considered higher spin models in 2+1-dimensions that are closely related to (linearized version of) New Massive gravity. We exploited Master Action, Gauge Embedding and Soldering formalisms and have obtained non-trivial results.

c. Organization of activities

During the year of 2016, the ICTP-SAIFR organized seven São Paulo International Schools for Theoretical Physics, fourteen workshops, one minicourse, one Program, six outreach events, the annual meeting of the steering committee and scientific council and weekly seminars, colloquia and journal clubs. The complete list of 2016 activities is on the webpage http://www.ictp-saifr.org/?page_id=9095 the list of weekly seminars and

colloquia is on the webpage http://www.ictp-saifr.org/?page_id=10921, and the weekly journal clubs on particle physics is on the webpage <http://www.ift.unesp.br/users/particlesjc/>. Many of the activities were filmed using equipment donated by the ICTP in Trieste and the videos are available online on the associated webpages.

c1. São Paulo International Schools

The seven São Paulo International Schools were on the subjects of Mathematical Biology (January 4-10), Physics applications in Biology (January 11-29), Climate modeling (February 15-19), Effective Field Theory (February 22 - March 4), String Theory (May 23-31), Dark Matter (June 27 - July 9) and Astrophysics and Laboratory Plasmas (July 8-9).

The schools were for mostly masters and PhD students, and those students not from São Paulo were housed in a hotel in shared rooms. The students were asked to anonymously evaluate the schools, and the links to view their evaluations are:

<http://www.ictp-saifr.org/sis/mathbioVViewAvaliacao.php>

<http://www.ictp-saifr.org/sis/bioappViewAvaliacao.php>

<http://www.ictp-saifr.org/sis/climate2016ViewAvaliacao.php>

<http://www.ictp-saifr.org/sis/eftViewAvaliacao.php>

<survey.strings2016>

<survey.darkmatter2016>

<survey.spectroscopy2016>

All lectures of the schools were filmed and the videos are available online on the school webpage.

c1A. Mathematical Biology (January 4 - 10)

The V Southern-Summer School on Mathematical Biology (January 4 - 10) is described on the webpage <http://www.ictp-saifr.org/mathbio5> and involved 1 lecturer and 46 students. The school was aimed at graduate students in Physics, Mathematics, Ecology and Epidemiology, having at least a basic knowledge of calculus and differential equations. Lectures cover the basics of population dynamics and are supplemented with modelling exercises addressing mainly problems in ecology, epidemiology and evolution.

Topic and Lecturer:

- Roberto Kraenkel (IFT-UNESP, Brazil) - Introduction to Population Biology

c1B. School on Physics Applications in Biology (Jan. 11 - 29)

The school on Physics Applications in Biology (January 11 - 29) is described on the webpage <http://www.ictp-saifr.org/bioapp> involved 9 lecturers, 5 seminar speakers and 52 participants. The three-week school featured lectures by physicists who have made important contributions to different areas

of biological research. This activity covered topics on neuroscience, evolutionary dynamics, biophysics, collective behavior, pattern formation and optimization. The school was intended for graduate students and postdoctoral researchers in the physical and biological sciences.

Topics and Lecturers:

- Vijay Balasubramanian (University of Pennsylvania, USA): The Maps Inside Your Head — Diversity and Self-Organization of Neural Circuits
- William Bialek (Princeton University, USA): Precision and emergence in the physics of biological systems
- Eberhard Bodenschatz (Max Planck Institute – Göttingen, Germany): Pattern Formation in Biological Systems – from oscillations to spiral waves
- Ulf Dieckmann (International Institute for Applied Systems Analysis – IIASA, Austria): Complex Adaptive Systems at the Interface of Ecology and Evolution – Modeling Adaptation, Speciation and Biodiversity Dynamics
- Stanislas Leibler (IAS Princeton/Rockefeller University, USA): Microbial Population Dynamics
- Gabriel Mindlin (Universidad de Buenos Aires, Argentina): Nonlinear dynamics and biomechanics
- Jorge M. Pacheco (U. Minho, Portugal): The evolutionary dynamics of hematopoiesis in health and disease
- Francisco C. Santos (Universidade de Lisboa, Portugal): Cooperation and the Evolution of Collective Action
- Gustavo Stolovitzky (IBM Research and Icahn School of Medicine, USA): Introduction to Systems Biology of Cancer

Seminar Speakers:

- Silvina P. Dawson (Universidad de Buenos Aires, Argentina): Fluctuations and transport in cells and the information that can be extracted from optical experiments
- Celso Grebogi (Aberdeen University, UK): Compressive sensing based prediction of social and metabolic complex networks
- Flávia Maria Darcie Marquitti (IFGW – Unicamp, Brazil): Strategies in nature: using game theory to deal with different problems
- José N. Onuchic (Rice University, USA): From structure to function: the convergence of structure based models and co-evolutionary information
- Andre A. de Thomaz (IFGW -Unicamp, Brazil): Multimodal photonic platform to understand biological processes

c1C. Joint ICTP-Trieste/ICTP-SAIFR Advanced School on Regional Climate Modeling over South America (February 15 – 19)

The Joint ICTP-Trieste/ICTP-SAIFR Advanced School on Regional Climate Modeling over South America (February 15 – 19) is described on the webpage <http://www.ictp-saifr.org/climate2016> and involved 14 lecturers and 38 participants. This event included lectures and hands-on sessions on the theory of regional climate dynamics and regional climate change while providing a background on regional climate modeling studies focused on the South American region. The School was intended for early career scientists and advanced PhD students from developing countries, in particular South America.

Lecturers:

- Marcelo Barreiro (Universidad de la Republica, Uruguay)
- Iracema F.A. Cavalcanti (CPTEC, Brazil)
- Chou Sin Chan (CPTEC, Brazil)
- Erika Coppola (ICTP-Trieste, Italy)
- Santiago Cuadra (EMBRAPA, Brazil)
- Julio Pablo Fernandez (CPTEC, Brazil)
- Filippo Giorgi (ICTP-Trieste, Italy)
- Graziano Giuliani (ICTP, Italy)
- Marta Llopart (ICTP-Trieste, Italy)
- Laura Mariotti (ICTP-Trieste, Italy)
- Michelle Reboita (UNIFEI, Brazil)
- Rosmeri Porfirio da Rocha (Universidade de São Paulo, Brazil)
- Maria Elisa Silva (USP, Brazil)
- Silvina Solman (Universidad de Buenos Aires, Argentina)

c1D. School on Effective Field Theory across Length Scales (February 22 – March 4)

The School on Effective Field Theory across Length Scales (February 22 – March 4) is described on the webpage <http://www.ictp-saifr.org/eft> and involved 6 lecturers and 76 participants. This school provided an overview of the general concepts and principles underlying the construction of an EFT, illustrating these concepts and principles in concrete applications in different areas of physics. The school was intended for PhD students, postdocs and young researchers who are seeking expertise in EFTs.

Topics and Lecturers:

- Raphael Flauger (University of Texas- Austin, USA): EFT for strings
- Hans-Werner Hammer (Technical University of Darmstadt, Germany): EFT for cold atoms
- David Kaplan (University of Washington, USA): EFTs for strong interactions, nuclear physics, and fundamental symmetries
- Rafael Porto (IFT-UNESP & ICTP-SAIIFR, Brazil): EFT for gravitational waves
- Leonardo Senatore (Stanford University, USA): EFT for cosmology – large scale structures
- Ira Rothstein (Carnegie Mellon University, USA): General introduction on concepts in EFT

c1E. School on Fundamental Aspects of String Theory (May 23 - 30)

The School on Fundamental Aspects of String Theory (May 23 - 30) is described on the webpage <http://www.ictp-saifr.org/string2016> and involved 5 lecturers and 66 participants. This 8-day school on fundamental aspects of string theory covered advanced topics including superstring field theory, double field theory, topological strings, and duality symmetries. Participants were assumed to be familiar with quantum field theory, supersymmetry and basic properties of bosonic string and superstring theory.

Lecturers:

- Rajesh Gopakumar (ICTS-Bangalore, India): Topological strings II
- Kumar Narain (ICTP-Trieste, Italy): Topological strings I
- Martin Schnabl (Institute of Physics AS CR – Prague, Czech Republic): String field theory
- Ashoke Sen (Harish-Chandra Research Institute – Allahabad, India): Superstring perturbation theory
- Barton Zwiebach (Massachusetts Institute of Technology, USA): Double field theory

c1F. School on Dark Matter (June 27 – July 8)

The School on Dark Matter (June 27 – July 8) is described on the webpage <http://www.ictp-saifr.org/darkmatter2016> and involved 8 lecturers and 81 participants. The school aimed at making students familiar with all the aspects -astrophysical, cosmological, and particle physics- of the Dark Matter problem, both on the observational/experimental, and theoretical side. Students were trained both on the theory part, and with practical sessions in order to be able to participate to active research projects in the field by the end of the school.

Topics and Lecturers:

- Pasquale D. Serpico (LAPTh – Annecy-le-Vieux, France): Evidence of DM from Cosmology and Astrophysics
- Ravi Sheth (University of Pennsylvania – Philadelphia, USA): Formation of cosmic structures
- Eduardo Pontón (ICTP-SAIJR & IFT-UNESP): Collider tests of Dark Matter Model
- Manuela Vecchi (Instituto de Física de São Carlos – USP, Brazil): Cosmic Rays
- Eduardo Serra Cypriano (USP-São Paulo, Brazil): Gravitational Lensing
- Nassim Bozorgnia (GRAPPA – Amsterdam, The Netherlands): Direct detection of DM
- Francesca Calore (GRAPPA – Amsterdam, The Netherlands): Indirect detection of DM
- Fabio Iocco (ICTP-SAIJR & IFT-UNESP): Dark Matter in astrophysical structures

c1G. School on Spectroscopy in Astrophysics and Laboratory Plasmas (July 8 - 9)

The School on Spectroscopy in Astrophysics and Laboratory Plasmas (July 8 - 9) is described on the webpage <http://www.ictp-saifr.org/spectroscopy2016> and involved 6 lecturers and 28 participants. The school discussed the application of spectroscopic methods to astrophysical research topics.

Topics and Lecturers:

- Beatriz Barbuy (USP, Brazil) & Jorge Meléndez (USP, Brazil): Spectroscopy of cool stars
- Peter Beiersdorfer (Lawrence Livermore National Laboratory, USA): Modern techniques in plasma spectroscopy in astrophysics
- Claudio Mendoza (Western Michigan University, USA): High-resolution X-ray spectroscopy on the eve of Astro-H
- Alla Safronova (University of Nevada-Reno, USA): X-ray spectroscopy of Z-pinches
- Grazyna Stasinska (Observatoire Paris-Site de Meudon-LUTH, France): Problems of abundance determinations in emission-line nebulae

c2. Workshops

ICTP-SAIFR organized 14 workshops on the subjects of quantum materials, hadron physics, string theory, mathematical physics, modeling of urban systems, interconnection of particle physics and cosmology, econophysics, 3-point correlation functions, entrepreneurship, dark matter, advancement of science in south America, mesoscopic systems, theoretical physics and general relativity. The purpose of these workshops was to discuss status, recent progress and perspectives in each of the fields mentioned.

c2A. Workshop on Next Generation Quantum Materials (April 4 - 8)

Topics in the workshop included superconductivity, quantum magnetism, strongly correlated materials, electronic structure and topological systems. The webpage of the workshop is <http://www.ictp-saifr.org/quantum2016> and speakers included:

Superconductivity & Quantum Magnetism & Strongly Correlated Systems

- Eric C. e Andrade (IFSC – São Carlos, Brazil)
- Marcos Ávila (Universidade Federal do ABC, Brazil)
- Carlos Balseiro (Centro Atómico Bariloche, Argentina)
- Alberto Camjayi (Universidad de Buenos Aires, Argentina)
- Jose Hoyos (USP-São Carlos, Brazil)
- Caio Lewenkopf (Universidade Federal Fluminense, Brazil)
- Ana M. Llois (CONICET – Centro Atomico Constituyentes, Argentina)
- Eduardo Miranda (UNICAMP, Brazil)
- Philip W. Phillips (University of Illinois at Urbana-Champaign, USA)
- Tatiana G. Rappoport (Universidade Federal do Rio de Janeiro, Brazil)
- Eduardo Granado Monteiro da Silva (UNICAMP, Brazil)
- Luis Gregório Dias da Silva (USP – São Paulo, Brazil)
- Veronica Vildosola (CONICET – Centro Atomico Constituyentes, Argentina)

Electronic Structure

- Pablo Cornaglia (Centro Atómico Bariloche, Argentina)
- Emanuel Gull (University of Michigan, USA)
- Jan Kunes (Academy of Sciences Czek Republic)
- Richard Martin (Stanford University, USA)
- Francesco Sottile (European Theoretical Spectroscopy Facility (ETSF) – Paris, France)
- Lucas K Wagner (University of Illinois at Urbana-Champaign, USA)

Topological Systems

- Liliana Arrachea (Universidad de Buenos Aires, Argentina)
- Alejandro Lobos (Universidad de Rosario, Argentina)
- Gonzalo Usaj (Centro Atómico Bariloche, Argentina)

- Jan Zaanen (University of Leiden, The Netherlands)

High Pressure studies of strongly correlated materials

- Xiao-Jia Chen (HPSTAR – Beijing, China)
- Pascoal Pagliuso (UNICAMP, Brazil)
- Sandro Scandolo (ICTP-Trieste, Italy)
- Renata M Wentzcovitch (University of Minnesota, USA)

c2B. Workshop on Magnetic Fields in Hadron Physics (May 9 - 13)

The workshop discussed the role played by magnetic fields in hadron dynamics considering scenarios such as peripheral heavy ion collisions and compact astrophysical objects. The webpage of the workshop is <http://www.ictp-saifr.org/magnetic2016> and speakers included:

- Gunnar Bali (Universität Regensburg, Germany)
- Cesareo Dominguez (University of Cape Town, South Africa)
- Gergerly Endrödi (Universität Regensburg, Germany)
- Efrain J. Ferrer (University of Texas El Paso, USA)
- Eduardo Fraga (Universidade Federal do Rio de Janeiro – UFRJ, Brazil)
- Kenji Fukushima (Tokyo University, Japan)
- Luis Hernández (University of Cape Town, South Africa)
- Vivian de la Incera (University of Texas El Paso, USA)
- Ana Mizher (Universidad Nacional Autónoma de México – UNAM)
- Fernando Navarra (Universidade de São Paulo – USP, Brazil)
- Jorge Noronha (Universidade de São Paulo-USP, Brazil)
- Letícia Palhares (Universidade do Estado do Rio de Janeiro – UERJ, Brazil)
- Marcus Benghi Pinto (Universidade Federal de Santa Catarina – UFSC, Brazil)
- Alfredo Raya (Universidad de Michoacan, Mexico)
- Juan Cristobal Rojas (Universidad Católica del Norte, Chile)
- Angel Sánchez (Universidad Nacional Autónoma de México – UNAM)
- Norberto Scoccola (Comisión Nacional de Energía Atómica – CNEA, Argentina)
- Igor Shovkovy (Arizona State University, USA)
- Maria Elena Tejeda-Yeomans (Universidad de Sonora, Mexico)

c2C. VIII Workshop on String Field Theory and Related Aspects (May 31 – June 3)

The workshop included 22 seminars on string field theory and double field theory. The webpage of the workshop is <http://www.ictp-saifr.org/wstring2016> and speakers included:

- Gerardo Aldazabal (Centro Atómico Bariloche, Argentina)
- David Berman (Queen Mary College – U. London, UK)
- Lorian Bonora (SISSA – Trieste, Italy)
- Martin Cederwall (Chalmers University of Technology – Goteborg, Sweden)

- Ted Erler (Ludwig-Maximilians-Universität München, Germany)
- Rajesh Gopakumar (ICTS – Bangalore, India)
- Olaf Hohm (Massachusetts Institute of Technology, USA)
- Chris Hull (Imperial College London, UK)
- Nobuyuki Ishibashi (University of Tsukuba, Japan)
- Michael Kroyter (Holon Institute of Technology, Israel)
- Hiroshi Kunitomo (Kyoto University, Japan)
- Carlo Maccaferri (Turin University, Italy)
- Diego Marques (Universidad de Buenos Aires, Argentina)
- Lionel Mason (Oxford University, UK)
- Kumar Narain (ICTP-Trieste, Italy)
- Carmen Núñez (Universidad de Buenos Aires, Argentina)
- Yuji Okawa (University of Tokyo – Komaba, Japan)
- Ivo Sachs (Ludwig-Maximilians-Universität München, Germany)
- Martin Schnabl (Institute of Physics AS CR – Prague, Czech Republic)
- Ashoke Sen (Harish-Chandra Research Institute – Allahabad, India)
- Tomohiko Takahashi (Nara Women's University, Japan)
- Barton Zwiebach (Massachusetts Institute of Technology, USA)

c2D. Workshop on Mathematical Physics (June 16 – 17)

The workshop brought together mathematicians and physicists to discuss topics of mutual interest. This interdisciplinary workshop was a satellite workshop of the 31st International Colloquium on Group Theoretical Methods in Physics. The webpage of the workshop is <http://www.ictp-saifr.org/mathphys2016> and speakers and topics included:

- Yuly Billig (Carleton U., Canada) – Representation theory of Lie algebra of vector fields on a torus
- Jethro van Ekeren (UFF, Brazil) – Classification and construction of simple vertex algebras
- Laurent Freidel (Perimeter, Canada) – On the non-commutative geometry of compactified string
- Pedram Hekmati (IMPA, Brazil) – D-branes in orientifolds
- Reimundo Heluani (IMPA, Brazil) – On higher 1 point functions on the torus
- Martin Kruczenski (Purdue U., USA) – Wilson loops and minimal area surfaces in hyperbolic space
- Andrei Mikhailov (IFT-UNESP, Brazil) – BV formalism and string amplitudes
- Cristian Ortiz (IME-USP, Brazil) – Morita equivalence of vector bundles
- Pedro Vieira (Perimeter, Canada & ICTP-SAI FR, Brazil) – Bootstrapping massive quantum field theories
- Elizaveta Vishnyakova (IME-USP, Brazil) – Geometrization of graded manifolds
- Jorge Zanelli (CECS, Chile)
- Jian Zhang (IME-USP, Brazil) – Quantum determinants and quantum Pfaffians

c2E. Joint DACAS/ICTP-SAIFR Workshop on Modeling of Urban Systems (June 20 - 24)

The event included talks and collaborative sessions on how DACAS can help to address the specific challenges of Brazil's urban transformation. The webpage of the workshop is <http://www.ictp-saifr.org/dacas2016> and speakers included:

- Ana Lúcia C. Bazzan (Keynote speaker; Instituto de Informática-UFRGS, Brazil)
- Romulo Krafta (Keynote speaker; Faculdade de Arquitetura, UFRGS)
- Murilo da Silva Baptista (University of Aberdeen, UK)
- Shidan Cheng (Wuhan University, China)
- Christopher Doll (United Nations University, Japan)
- Rene Doursat (Manchester Metropolitan University, UK): Toward Engineering & Control of Self-Organization in Socio-Technical Systems
- Alexandros Gasparatos (University of Tokyo, Japan)
- Nils Goldbeck (Imperial College London, UK): Resilience of Interdependent Urban Infrastructure Systems in London
- Roberto Kraenkel (IFT-UNESP, Brazil)
- Jun Luo (Wuhan University, China)
- Nir Oren (University of Aberdeen, UK)
- Ulysses Sengupta (Manchester Metropolitan University, UK)

c2F. Xth International Conference on the Interconnection between Particle Physics and Cosmology - PPC 2016 (July 11 - 15)

This workshop is an international series starting in 2007 that brings together experts in the fields of Particle Physics and Cosmology to discuss recent advances in both areas. The webpage of the workshop is <http://www.ictp-saifr.org/ppc2016> and speakers and topics included:

- Nathaniel Craig (UCSB – Santa Barbara, USA): Physics Beyond the Standard Model After the First Year of LHC 13
- Silvia Galli (IAP Paris, France): Understanding tensions in the LCDM model
- Graciela Gelmini (UCLA – Los Angeles, USA): Direct detection of Dark Matter
- Claudia de Rham (Case Western Reserve University – Cleveland, USA): How light is gravity?
- Pasquale D. Serpico (LAPTh Annecy-le-Vieux, France): What can we learn from cosmic rays?
- Tracy Slatyer (MIT – Boston, USA): Indirect detection of Dark Matter
- Riccardo Sturani (ICTP-SAIFR & IFT-UNESP, Brazil): Gravitational wave detection by the first Advanced LIGO observation run
- Carlos Wagner (ANL – Chicago, USA): Perspectives on Particle Physics
- Federico Marinacci (MIT – Boston, USA): LambdaCDM cosmology below cluster scales: current results and challenges of state-of-the-art numerical simulations

c2G. Econophysics Colloquium 2016 (July 27 - 29)

The 12th edition of this annual international meeting was held at ICTP-SAIFR and topics included statistical methods, quantitative measures, high

frequency trading, market dynamics, and simulations of financial and economic systems. The webpage of the workshop is <http://www.ictp-saifr.org/econophysics2016> and speakers and topics included:

- Siew Ann Cheong (Nanyang Technological University): Financial Market Crashes Can Be Quantitatively Forecasted
- Andrea Rapisarda (INFN Sezioni di Catania – U. Catania, Italy): Financial markets, Self-organized criticality and Random strategies
- Constantino Tsallis (CBPF, Brazil): Universality in the Interoccurrence times in finance and elsewhere
- Fabio Caccioli (University College London, UK): Portfolio Optimization under Expected Shortfall: Contour Maps of Estimation Error
- Giacomo Livan (University College London, UK): Complexity driven collapses in large random economies
- Matheus Grasselli (McMaster University and Fields Institute, Canada): Macroeconomic modelling with heterogeneous agents: the master equation approach
- Rosário Mantegna (Central European University, Hungary): Trading networks at NASDAQ OMX Helsinki
- Suzy Moat (Warwick Business School, UK): Measuring economic behavior using online data
- Tiziana Di Matteo (King's College London, UK): Multiplex dependence structure of financial markets
- Tobias Preis (Warwick Business School, UK): Sensing human activity using online data

c2H. Workshop on 3-point functions in Gauge/String theories (Sept. 19 - 30)

The workshop hosted several seminars and informal discussions on different aspects of 3-point correlations in AdS/CFT, integrability and conformal field theory. The webpage of the workshop is <http://www.ictp-saifr.org/c123> and speakers included:

- Nathan Berkovits (ICTP-SAIIFR/IFT-UNESP, Brazil)
- João Caetano (Perimeter Institute, Canada)
- Frank Coronado (Perimeter Institute, Canada)
- Thiago Fleury (IFT-UNESP, Brazil)
- Vasco Gonçalves (ICTP-SAIIFR/IFT-UNESP, Brazil)
- Johannes Henn (JGU Mainz, Germany)
- Shota Komatsu (Perimeter Institute, Canada)
- Ivan Kostov (IPhT-Saclay, France)
- Charlotte Kristjansen (Niels Bohr Institute, Denmark)
- Tristan McLoughlin (Trinity College Dublin, UK)
- Raul João Pereira (Uppsala University, Sweden)
- Didina Serban (IPhT-Saclay, France)
- Amit Sever (Perimeter Institute, Canada)
- Alessandro Sfondrini (Humbolt University)
- Ryo Suzuki (ICTP-SAIIFR/IFT-UNESP, Brazil)
- Konstantin Zarembo (Nordita & Uppsala University, Sweden)

c2I. Entrepreneurship Workshop for Scientists and Engineers (Oct. 17 - 21)

The workshop consisted of lectures from invited national and international speakers, case studies, group discussions and role-playing sessions related to the commercialization of products. Topics include opportunity and value assessment, intellectual property (IP), basics of patenting, IP management and global IP protection, business plan fundamentals, technology readiness levels, invention to product, timelines and processes. The webpage of the workshop is <http://www.ictp-saifr.org/entrepreneurship> and speakers and panelists included:

- Richard Brooks (FD Solutions – London, UK)
- Carlos Henrique de Brito Cruz (FAPESP, Brazil)
- Maria Inez Fernandes Faraldo (UNESP-Botucatu, Brazil)
- Daniel Gurgel (Polifonia, Brazil)
- Fernando Galembeck (UNICAMP, Brazil)
- Dawood Parker (Melys Diagnostics, UK)
- Surya Raghu (ET Cube International, USA)
- Maria Valnice Boldrin Zanoni (UNESP – Araraquara, Brazil)
- Luciano Avalone Bueno (Telos Consulting)
- Fernando Galembeck (UNICAMP)
- Rafael Tadeu Luques (Kanaí)
- Rodrigo Fernando Costa Marques (Procell Biologics)
- Estácio Terui (TEY Eolic generator)

c2J. III Dark Matter day in São Paulo (Oct. 25)

The goal of this meeting was to bring together everybody -student, researcher, professor- who is active (or simply interested) in the field of Dark Matter, and and is somehow close to the state of São Paulo. By gathering together theorists, experimentalists and astrophysicists, we continue with this third edition in the path to create a functional DM community in South America. The webpage of the workshop is <http://www.ictp-saifr.org/dmday2016>.

c2K. ICTP-SAIFR 5th Anniversary Symposium: Advancement of Science in South America (Nov. 6 – 8)

To celebrate its 5th anniversary, ICTP-SAIFR organized a symposium of [public talks](#), [research seminars](#) and roundtable discussions with the participation of its [Steering Committee](#) and [Scientific Council](#), its [60 Associated Members](#) from South America, and several invited speakers. The webpage of the symposium is <http://www.ictp-saifr.org/fifth> and speakers and panelists included:

- Marcus A.M. de Aguiar (Unicamp, Brazil)
- Nathan Berkovits (Director of ICTP-SAIFR, Brazil)
- Miguel Ángel Blesa (Secretary for Planning of Mincyt, Argentina)

- Vanderlan Bolzani (Vice-President of SBPC and ACIESP, Brazil)
- Carlos Brito Cruz (Scientific Director of FAPESP, Brazil)
- Luiz Davidovich (President of Brazilian Academy of Sciences)
- Julio Cezar Durigan (Rector of Unesp, Brazil)
- Michael Duschenes (Perimeter managing director and chief operating officer, Canada)
- Herton Escobar (Science Journalist for Estadão and Director of USP Talks, Brazil)
- Peter Goddard (IAS Princeton, USA)
- Gabriela González (Spokesperson of LIGO, Louisiana State U., USA)
- David Gross (2004 Nobel Prize Laureate, KITP, USA)
- Mario Hamuy (President of Conicyt, Chile)
- Belita Koiller (President of Brazilian Physical Society)
- Karina Laneri (Centro Atomico Bariloche, Argentina)
- Juan Maldacena (IAS Princeton, USA)
- Moyses Nussenzveig (Univ. Federal do Rio de Janeiro, Brazil)
- Cristobal Petrovich (Univ. of Toronto, Canada)
- Eduardo Pontón (ICTP-SAIJR/IFT-UNESP)
- Fernando Quevedo (Director of ICTP, Italy)
- Antônio José Roque da Silva (Representative of CLAF and Director of LNLS, Brazil)
- Rogério Rosenfeld (Director of IFT-UNESP, Brazil)
- Neil Turok (Director of Perimeter Institute, Canada)
- Pedro Vieira (ICTP-SAIJR and Perimeter Institute, Canada)

c2L. Workshop on New Phenomena in Mesoscopic Systems (Nov. 14 – 15)

The workshop consisted of talks and informal discussion concerning recent developments in the physics of mesoscopic systems. Specific topics included the role of spin-orbit interactions, time reversal symmetry, spintronics, thermoelectricity, helical systems, topological insulators and Majorana states. The webpage of the workshop is <http://www.ictp-saifr.org/mesoscopic> and speakers included:

- Amnon Aharony (Ben Gurion U./Tel Aviv U., Israel)
- Irene D'Amico (University of York, UK)
- Esmerindo Bernardes (IFSC-USP, Brazil)
- Carlos Egues (IFSC-USP, Brazil)
- Ora Entin-Wohlman (Ben Gurion U./Tel Aviv U., Israel)
- Gerson J. Ferreira (U. Federal de Uberlândia, Brazil)
- Jiyong Fu (QuFu University, China and UnB, Brazil)
- Mariana M. Odashima (U. Federal de Uberlândia, Brazil)
- Fanyao Qu (UnB, Brazil)
- Tome M. Schmidt (U. Federal de Uberlândia, Brazil)
- Luis Gregório G. Dias da Silva (IF-USP, Brazil)

- Guilherme M. Sipahi (IFSC-USP, Brazil)
- Edson Vernek (U. Federal de Uberlândia, Brazil)

c2M. XIII Workshop on New Physics in Space (Nov. 28 – Dec. 1)

The New Physics in Space Workshop is a traditional biannual event widely known in the astronomical and cosmological communities in Brazil for providing an exceptionally efficient platform for inter-disciplinary discussions among theoretical physicists, cosmologists and astronomers. Now in its 13th edition, it was the venue for several talks on recent progress achieved in these fields. The webpage of the workshop is <http://www.ictp-saifr.org/space2016>

c2N. Workshop on Analytic Methods in General Relativity (Dec. 5 - 9)

The workshop gathered worldwide experts to discuss state-of-the-art computations of the dynamics of binary compact objects in Einstein's gravity. The webpage of the workshop is <http://www.ictp-saifr.org/gr2016> and speakers (*by skype) included:

- Leor Barack* (University of Southampton, UK)
- Luc Blanchet (Institut d'astrophysique de Paris, France)
- Thibault Damour* (IHES-Paris, France)
- Guillaume Faye (Institut d'astrophysique de Paris, France)
- Stefano Foffa (University of Geneva, Switzerland)
- Adam Leibovich (University of Pittsburgh, USA)
- Tanguy Marchand (Institut d'astrophysique de Paris, France)
- Pierpaolo Mastrolia* (U. of Padova, Italy)
- Maarten van de Meent (University of Southampton, UK)
- Rafael Porto (ICTP-SAIIFR & IFT-UNESP)
- Adam Pound* (University of Southampton, UK)
- Ira Rothstein (Carnegie Mellon University, USA)
- Gerhard Schaefler (Friedrich-Schiller-Universität Jena, Germany)
- Riccardo Sturani (International Institute of Physics – Natal, Brazil)
- Alexandre Le Tiec (Laboratoire de l'Univers et de ses Théories de l' Observatoire de Paris, France)

c3. Minicourses

The ICTP-SAIIFR organized two minicourses in 2016, on numerical relativity and pure spinors. The topics, lecturers and webpages for these minicourses are:

1) March 28 – April 1, Minicourse on Numerical Relativity

This course covered the fundamentals of solving Einstein equations numerically in strongly gravitating/dynamical regimes. Emphasis was on fundamentals to lay a solid foundation for venturing into Numerical Relativity. Topics covered included: Numerical Analysis for Partial Differential Equations, Formulations of Einstein equations, Hydrodynamics and basics of applications for Astrophysics, fundamental questions on General Relativity and

Holography. The webpage for this minicourse is <http://www.ictp-saifr.org/relativity2016> and lecturers included:

- Luis Lehner (Perimeter Institute -Waterloo, Canada)
- Vasileios Paschalidis (Princeton University, USA)
- Frans Pretorius (Princeton University, USA)

2) Dec. 2, 2016 – Feb. 8, 2017, Movshev minicourse on pure spinors

Mikhail Movshev (SUNY at Stony Brook, USA)

Title: Beta gamma systems on affine cones and local cohomology:
Computation of pure spinor correlation functions

<http://www.ictp-saifr.org/movshev>

C4. Program

In 2016, the Program on Particle Physics at the New Energy Frontier of 13 TeV (<http://www.ictp-saifr.org/tev13> Oct. 3 – Nov. 11) organized by Gustavo Burdman (USP), Oscar Eboli (USP), Eduardo Pontón (IFT-UNESP & ICTP-SAIFR), Mariano Quirós (IFAE-Barcelona), Rogério Rosenfeld (IFT-UNESP & ICTP-SAIFR) discussed the status of the field and the impact of the LHC13 run. Participants in the program include:

Name	Institution	Period of visit	Room Number	Extension
Carolina Arbeláez	U. Técnica Federico Santa María, Chile	Oct. 21 – Nov. 12	104	7890
Alexander Belyaev	U. of Southampton, UK	Oct. 24 – Nov. 11	112	7846
Diogo Buarque	Göttingen U., Germany	Nov. 7 – 11	108	7890
Antonio Delgado	U. of Notre Dame, USA	Oct 16 – 21	102	7882
Claudio Dib	U. Técnica Federico Santa María, Chile	Oct. 30 – Nov. 9	102	7882
Gero von Gersdorff	PUC-RJ, Brazil	Oct. 9 – 15	104	7848
Christophe Grojean	DESY, Germany	Nov. 1 – 6	102	7848
Matthias Neubert	Mainz U., Germany	Nov. 1 – 8	105	7848
David Pinner	Princeton University, USA	Oct. 2 – 8	102	7882
Giovanni Villadoro	ICTP-Trieste, Italy	Oct. 22 – Nov. 3	112	7846

C5. Outreach event

The ICTP-SAIFR organized six outreach events in 2016 aiming at different audiences. The format, topics and webpages for these events are:

1) Encontro de Universos – A meeting of Art and Science (March 22 - 24)

This meeting brought together scientists and artists from Sao Paulo which presented talks in the intersection of both areas. The webpage for this meeting is <http://www.ictp-saifr.org/artesci>

2) Papos de Física

Papos de Física is a new monthly outreach program of ICTP-SAIFR introducing current topics in theoretical physics to the general public in an informal setting. Topics covered during these meetings included Dark Matter (June 16 – Rogério Rosenfeld), Gravitational Waves (August 4 – Riccardo Sturani), Holography (September 1 – Pedro Vieira), Particle Physics (October 6 – Ricardo Matheus), Neutrinos (December 6 – Renata Funchal). The webpage for this program is <http://www.ictp-saifr.org/papos16>

3) I IFT-Perimeter-SAIFR Journeys into Theoretical Physics (July 18 – 23)

The I IFT-Perimeter-SAIFR Journeys into Theoretical Physics (July 18 – 23) is described on the webpage <http://www.ictp-saifr.org/journeys> and involved 5 lecturers and 87 participants. The top students in this school were accepted to a joint master's program where they will spend one year at Perimeter Institute (Waterloo) and one year at ICTP-SAIFR/IFT-UNESP. Francisco Vladimir C. Cigüenas (PUC-Lima, Peru) was the best student and obtained a score of 189/200 in the exam. The other students accepted to the joint program include Jairo Huamaní (PUC-Lima, Peru), Alexandre Homrich (USP São Paulo), Carlos Gustavo Rodriguez Fernandez (Univ. San Francisco de Quito, Ecuador) and Michael Morales Curi (UNI-Lima, Peru). Topics and Lecturers included:

- Freddy Cachazo (Perimeter): Unification of Quantum Mechanics and Special Relativity
- George Matsas (IFT) – Conceptual Introduction to Relativity: from special relativity to black holes
- Juan Pablo Paz (U. Buenos Aires) – Quantum Open Systems: Applications to quantum foundations and quantum information
- Eduardo Ponton (IFT) – The World of Elementary Particles Demystified
- Pedro Vieira (Perimeter and IFT) – Integrability

4) 2016 Prêmio IFT-UNESP/ICTP-SAIFR para Jovens Físicos (July 23)

ICTP-SAIFR organized in collaboration with IFT-UNESP a competition for undergraduate physics students held on July 23 in which winners were determined by a 3-hour exam. The webpage with the names of the 5 winners is <http://www.ictp-saifr.org/premio2016>

5) Minicourse on Relativity, Gravitation and Quantum Mechanics for High-School Students (Sept. 3 – Oct. 9)

In this minicourse, Pedro Vieira (ICTP-SAIFR/IFT-UNESP & Perimeter I.) introduced modern physics concepts from special relativity to quantum mechanics, and described research topics at the frontier of physics. The webpage for this minicourse is <http://sictp3.ictp-saifr.org/ensino-medio/minicurso/>

6) Cutting-edge In-class Physics Resources – Workshop for High-School Teachers (Sept. 17 – 18)

Gregory Dick (Perimeter I.) and Glenn Wagner (Perimeter I.) used hands-on activities to introduce wave-particle duality, dark matter, and particle

physics to high-school teachers who also received a set of classroom-ready resources to share with their students. The webpage for this minicourse is <http://sictp3.ictp-saifr.org/ensino-medio/perimeterw/>

C6. Annual meeting of ICTP-SAIFR councils

The 2016 and 2017 annual meetings of the ICTP-SAIFR Steering Committee and Scientific Council were held on February 1-2 and November 9 and included closed meetings of the two councils.

The webpages of both meetings are http://www.ictp-saifr.org/?page_id=9177 and http://www.ictp-saifr.org/?page_id=11764.

The names of the members of these councils are

Members of the Steering Committee:

Fernando Quevedo (chair) - ICTP director
Julio Cezar Durigan - UNESP rector
Carlos Brito Cruz - FAPESP scientific director
Jacob Palis - Brazilian Academy of Science president
Juan Maldacena - Representing South America

Members of the Scientific Council:

Peter Goddard (chair) - IAS Princeton
Seifallah Randjbar-Daemi - ICTP vice-director
Rogério Rosenfeld - IFT-UNESP director
Marcela Carena - Fermilab / Univ. Chicago
Marcel Clerc - Universidad de Chile, Santiago
Belita Koiller - UFRJ, Rio de Janeiro
Luis Lehner - Perimeter Institute, Waterloo
Gabriel Mindlin - University of Buenos Aires
Matias Zaldarriaga - IAS, Princeton
Barton Zwiebach - MIT, Cambridge

C7. Weekly seminars, colloquia and journal clubs

During 2016, weekly seminars and colloquia were regularly organized. There were 141 seminars and colloquia and the complete list is on the webpage http://www.ictp-saifr.org/?page_id=10921. There were also weekly journal club meetings in string theory, particle physics, integrability and cosmology.

5. Description of Institutional Support

The ICTP-SAIFR received generous support from both the Instituto de Física Teórica (IFT) and from the Universidade Estadual Paulista (UNESP). All professors and secretarial staff of the IFT have been extremely supportive of all ICTP-SAIFR activities, and the ICTP-SAIFR frequently uses the services of the IFT-UNESP driver and car.

The UNESP university is paying for four ICTP-SAIFR secretaries including our executive secretary, our accountant, our computer systems manager and a executive manager. UNESP has also agreed to hire 5 permanent ICTP-SAIFR researchers and the first permanent researcher (Eduardo Ponton) was hired in 2013 at the top researcher level.

6. Use of Reserva Tecnica Funds

In 2016, the part of the reserva tecnica funds related to "Custos de Infraestrutura Direta do Projeto" was used for the following purposes:

- a) School/Workshop Posters Impression for announcement of activities: 16,946,00 reais
- b) Post office expenses – delivery of School/Workshop posters: 9,074.00 reais
- c) Hiring of Translation service and Translator for ICTP-SAIFR Symposium: 6,200.00 reais
- d) Purchase of a photographic camera for recording activities: 3,287.80 reais
- e) Purchase of a microphone for recording activities: 770.00 reais
- f) Purchase of banner displayers for posters: 1,660.00 reais
- g) Airfare for participation as a plenary speaker in SILAF AE 2016 (Guatemala) of ICTP-SAIFR member Prof. Riccardo Sturani: 4,425.91 reais
- h) Airfare for participation as a plenary speaker in SILAF AE 2016 (Guatemala) of ICTP-SAIFR member Prof. Eduardo Pontón: 3,963.38 reais
- i) Airfare for participation as speaker in the ICTP-SAIFR Symposium of 2004 Nobel Prize David Gross: 19,577.97 reais

And the part of the reserva tecnica funds related to "Benefícios Complementares" was used for the following purposes:

- a) Airfare for conference (Strings at Dunes) of ICTP-SAIFR director Prof. Nathan Berkovits to Natal (Brazil): 981.25 reais
- b) Airfare for conference (Amplitudes 2016) of ICTP-SAIFR director Prof. Nathan Berkovits to Stockholm (Sweden): 471.02 reais
- c) Airfare for participation as a plenary speaker in SILAF AE 2016 (Guatemala) of ICTP-SAIFR director Prof. Nathan Berkovits: 4,343.11 reais
- d) Airfare and per diem for participation in the program "Theoretical Cosmology in the Era of Large Scale Surveys (period of visit: May 2-13, 2016)" of ICTP-SAIFR vice-director Prof. Rogerio Rosenfeld: 8,347.61 reais.
- e) Airfare for participation as a plenary speaker in SILAF AE 2016 (Guatemala) of ICTP-SAIFR vice-director Prof. Rogerio Rosenfeld: 4,419.36 reais.

7a. Articles in refereed scientific journals

8a1. Articles by ICTP-SAIFR Associate Researchers – they are presented following the order of the Project Team (item 2d)

1. L. R. Abramo, L. F. Secco, e A. Loureiro, "Fourier analysis of multitracer cosmological surveys", *Monthly Notices of the Royal Astronomical Society*, vol. 455, no 4, p. 3871–3889, feb. 2016.
2. M. Veronez e M. A. M. de Aguiar, "Topological structures in the Husimi flow", *Journal of Physics A: Mathematical and Theoretical*, vol. 49, no 6, p. 065301, feb. 2016.
3. D. M. Schneider, E. M. Baptestini, and M. A. M. de Aguiar, "Diploid versus haploid models of neutral speciation", *Journal of Biological Physics*, vol. 42, no 2, p. 235–245, mar. 2016.
4. A. Grigolo, T. F. Viscondiand M. A. M. de Aguiar, "Multiconfigurational quantum propagation with trajectory-guided generalized coherent states", *The Journal of Chemical Physics*, vol. 144, no 9, p. 094106, mar. 2016.
5. D. M. Schneider, A. B. Martinsand M. A. M. de Aguiar, "The mutation–drift balance in spatially structured populations", *Journal of Theoretical Biology*, vol. 402, p. 9–17, aug 2016.
6. K. M. Siqueira e M. A. M. de Aguiar, "Suppression of Fermi acceleration in composite particles", *Physica D: Nonlinear Phenomena*, vol. 331, p. 81–88, sept. 2016.
7. M. E. Nagai e M. A. M. de Aguiar, "Coevolution in sexually reproducing populations of predators and prey", *Ecological Modelling*, vol. 337, p. 168–175, oct. 2016.
8. A. Ballon-Bayona, G. Krein and C. Miller, "Decay constants of the pion and its excitations in holographic QCD", *Physical Review D*, vol. 91, no 6, mar. 2015.
9. N. Berkovits, "Untwisting the pure spinor formalism to the RNS and twistor string in a flat and AdS5 × S 5 background", *Journal of High Energy Physics*, vol. 2016, no 6, jun. 2016.
10. G. Burdman, O. J. P. Éboli and D. Spehler, "Signals of two universal extra dimensions at the LHC", *Physical Review D*, vol. 94, no 9, nov. 2016.
11. V. S. G. Martins, A. C. Rodrigues, H. A. Cerdeira and B. S. Machado, "Phase-lag synchronization analysis in complex systems with directed inter-relations", *The European Physical Journal Special Topics*, vol. 225, no 1, p. 41–49, feb. 2016.
12. A. C. Rodrigues, H. A. Cerdeira and B. S. Machado, "The influence of hubs in the structure of a neuronal network during an epileptic seizure", *The European Physical Journal Special Topics*, vol. 225, no 1, p. 75–82, feb. 2016.
13. E. B. Megam Ngouonkadi, H. B. Fotsin, P. Louodop Fotso, V. Kamdoum Tamba and H. A. Cerdeira, "Bifurcations and multistability in the extended Hindmarsh–Rose neuronal oscillator", *Chaos, Solitons & Fractals*, vol. 85, p. 151–163, apr. 2016.
14. K. Manikandan, M. Senthilvelan and R. A. Kraenkel, "Amplification of matter

- rogue waves and breathers in quasi-two-dimensional Bose-Einstein condensates”, *The European Physical Journal B*, vol. 89, no 2, feb. 2016.
15. K. Manikandan, M. Senthilvelan and R. A. Kraenkel, “On the characterization of vector rogue waves in two-dimensional two coupled nonlinear Schrödinger equations with distributed coefficients”, *The European Physical Journal B*, vol. 89, no 10, oct. 2016.
 16. N. Brambilla, G. Krein, J. Tarrús Castellà and A. Vairo, “Long-range properties of $1S$ bottomonium states”, *Physical Review D*, vol. 93, no 5, mar. 2016.
 17. S. Ghosh, C. E. Fontoura and G. Krein, “Mesonic Decay of Charm Hypernuclei Λ_c^+ ”, *EPJ Web of Conferences*, vol. 113, p. 05016, 2016.
 18. S. Ghosh, T. C. Peixoto, V. Roy, F. E. Serna and G. Krein, “Shear and bulk viscosities of quark matter from quark-meson fluctuations in the Nambu–Jona-Lasinio model”, *Physical Review C*, vol. 93, no 4, apr. 2016.
 19. G. Krein, “Leptonic decay constants of the pion and its excitations in holographic QCD”, *Journal of Physics: Conference Series*, vol. 706, p. 042004, apr. 2016.
 20. R. L. S. Farias, V. S. Timóteo, S. Avancini, M. B. Pinto and G. Krein, “Impact of a magnetic field on the thermodynamics of magnetized quark matter”, *Journal of Physics: Conference Series*, vol. 706, p. 052029, apr. 2016.
 21. R. A. Briceño et al. (G. Krein included), “Issues and Opportunities in Exotic Hadrons”, *Chinese Physics C*, vol. 40, no 4, p. 042001, apr. 2016.
 22. C. E. Fontoura, F. Krmpotić, A. P. Galeão, C. D. Conti and G. Krein, “Relativistic model for the nonmesonic weak decay of single-lambda hypernuclei”, *Journal of Physics G: Nuclear and Particle Physics*, vol. 43, no 5, p. 055102, jun. 2016.
 23. T. F. Caramés, C. E. Fontoura, G. Krein, K. Tsushima, J. Vijande and A. Valcarce, “Hadronic molecules with a D^- meson in a medium”, *Physical Review D*, vol. 94, no 3, aug 2016.
 24. B. El-Bennich, G. Krein, E. Rojas and F. E. Serna, “Excited Hadrons and the Analytical Structure of Bound-State Interaction Kernels”, *Few-Body Systems*, vol. 57, no 10, p. 955–963, oct. 2016.
 25. R. L. S. Farias, D. C. Duarte, G. Krein and R. O. Ramos, “Thermodynamics of quark matter with a chiral imbalance”, *Physical Review D*, vol. 94, no 7, oct. 2016.
 26. J. Santiago, A. G. S. Landulfo, W. C. C. Lima, G. E. A. Matsas, R. F. P. Mendes and D. A. T. Vanzella, “Instability of nonminimally coupled scalar fields in the spacetime of thin charged shells”, *Physical Review D*, vol. 93, no 2, jan. 2016.
 27. M. S. Nakwacki, G. Kowal, R. Santos-Lima, E. M. de Gouveia Dal Pino and D. A. Falceta-Gonçalves, “Features of collisionless turbulence in the intracluster medium from simulated Faraday Rotation maps”, *Monthly Notices of the*

Royal Astronomical Society, vol. 455, no 4, p. 3702–3723, feb. 2016.

28. G. Guerrero, P. K. Smolarkiewicz, E. M. de Gouveia Dal Pino, A. G. Kosovichev and N. N. Mansour, "ON THE ROLE OF TACHOCLINES IN SOLAR AND STELLAR DYNAMOS", *The Astrophysical Journal*, vol. 819, no 2, p. 104, mar. 2016.
29. C. B. Singh, Y. Mizuno and E. M. de G. D. Pino, "SPATIAL GROWTH OF CURRENT-DRIVEN INSTABILITY IN RELATIVISTIC ROTATING JETS AND THE SEARCH FOR MAGNETIC RECONNECTION", *The Astrophysical Journal*, vol. 824, no 1, p. 48, jun. 2016.
30. R. Santos-Lima, H. Yan, E. M. de Gouveia Dal Pino and A. Lazarian, "Limits on the ion temperature anisotropy in the turbulent intracluster medium", *Monthly Notices of the Royal Astronomical Society*, vol. 460, no 3, p. 2492–2504, aug 2016.
31. G. Guerrero, P. K. Smolarkiewicz, E. M. de G. D. Pino, A. G. Kosovichev and N. N. Mansour, "UNDERSTANDING SOLAR TORSIONAL OSCILLATIONS FROM GLOBAL DYNAMO MODELS", *The Astrophysical Journal*, vol. 828, no 1, p. L3, aug 2016.
32. S. Fichet, G. von Gersdorff, E. Pontón and R. Rosenfeld, "The excitation of the global symmetry-breaking vacuum in composite Higgs models", *Journal of High Energy Physics*, vol. 2016, no 9, sept. 2016.
33. R. A. F. Lima, H. C. Muller-Landau, P. I. Prado and R. Condit, "How do size distributions relate to concurrently measured demographic rates? Evidence from over 150 tree species in Panama", *Journal of Tropical Ecology*, vol. 32, no 03, p. 179–192, may 2016.
34. S. Giardino e V. Rivelles, "Tunnelling of pulsating strings in deformed Minkowski spacetime", *The European Physical Journal C*, vol. 76, no 5, may 2016.
35. C. E. P. Villegas, A. S. Rodin, A. Carvalho and A. R. Rocha, "Two-dimensional exciton properties in monolayer semiconducting phosphorus allotropes", *Phys. Chem. Chem. Phys.*, vol. 18, no 40, p. 27829–27836, 2016.
36. J. Prasongkit e A. R. Rocha, "Quantum interference effects in biphenyl dithiol for gas detection", *RSC Adv.*, vol. 6, no 64, p. 59299–59304, 2016.
37. S. Haldar, R. G. Amorim, B. Sanyal, R. H. Scheicher and A. R. Rocha, "Energetic stability, STM fingerprints and electronic transport properties of defects in graphene and silicene", *RSC Adv.*, vol. 6, no 8, p. 6702–6708, 2016.
38. S. Kogikoski et al. (A. R. Rocha included), "Multifunctional biosensors based on peptide–polyelectrolyte conjugates", *Phys. Chem. Chem. Phys.*, vol. 18, no 4, p. 3223–3233, 2016.
39. H. B. Ribeiro et al. (A. R. Rocha included), "Edge phonons in black phosphorus", *Nature Communications*, vol. 7, p. 12191, jul. 2016.

40. A. C. M. Padilha, H. Raebiger, A. R. Rocha and G. M. Dalpian, "Charge storage in oxygen deficient phases of TiO₂: defect Physics without defects", *Scientific Reports*, vol. 6, p. 28871, jul. 2016.
41. T. Andrade-Filho, T. C. Martins, F. F. Ferreira, W. A. Alves and A. R. Rocha, "Water-driven stabilization of diphenylalanine nanotube structures", *Theoretical Chemistry Accounts*, vol. 135, no 8, aug 2016.
42. C. E. P. Villegas, A. R. Rocha and A. Marini, "Anomalous Temperature Dependence of the Band Gap in Black Phosphorus", *Nano Letters*, vol. 16, no 8, p. 5095–5101, aug 2016.
43. R. G. Amorim, A. R. Rocha and R. H. Scheicher, "Boosting DNA Recognition Sensitivity of Graphene Nanogaps through Nitrogen Edge Functionalization", *The Journal of Physical Chemistry C*, vol. 120, no 34, p. 19384–19388, sept. 2016.
44. C. E. P. Villegas, A. R. Rocha and A. Marini, "Electron-phonon scattering effects on electronic and optical properties of orthorhombic GeS", *Physical Review B*, vol. 94, no 13, oct. 2016.
45. C. Englert, R. Rosenfeld, M. Spannowsky and A. Toner, "New physics and signal-background interference in associated $pp \rightarrow HZ$ production", *EPL (Europhysics Letters)*, vol. 114, no 3, p. 31001, may 2016.
46. F. Lacasa e R. Rosenfeld, "Combining cluster number counts and galaxy clustering", *Journal of Cosmology and Astroparticle Physics*, vol. 2016, no 08, p. 005–005, aug 2016.

8a2. Articles by ICTP-SAIFR Postdoctoral Associates

47. N. Bernal, C. S. Fong and N. Fonseca, "Sharing but not caring: dark matter and the baryon asymmetry of the universe", *Journal of Cosmology and Astroparticle Physics*, vol. 2016, no 09, p. 005–005, sept. 2016.
48. N. Bernal, X. Chu, C. Garcia-Cely, T. Hambye and B. Zaldivar, "Production regimes for Self-Interacting Dark Matter", *Journal of Cosmology and Astroparticle Physics*, vol. 2016, no 03, p. 018–018, mar. 2016.
49. N. Bernal e X. Chu, "Z 2 SIMP dark matter", *Journal of Cosmology and Astroparticle Physics*, vol. 2016, no 01, p. 006–006, jan. 2016.
50. J. H. Garcia e T. G. Rappoport, "Kubo–Bastin approach for the spin Hall conductivity of decorated graphene", *2D Materials*, vol. 3, no 2, p. 024007, may 2016.
51. C. Cardona e C. Kalousios, "Comments on the evaluation of massless scattering", *Journal of High Energy Physics*, vol. 2016, no 1, jan. 2016.
52. C. Cardona e C. Kalousios, "Elimination and recursions in the scattering equations", *Physics Letters B*, vol. 756, p. 180–187, may 2016.
53. D. Baumann, D. Green, H. Lee and R. A. Porto, "Signs of analyticity in single-field inflation", *Physical Review D*, vol. 93, no 2, jan. 2016.

54. R. A. Porto, "The effective field theorist's approach to gravitational dynamics", *Physics Reports*, vol. 633, p. 1–104, may 2016.
55. C. R. Galley, A. K. Leibovich, R. A. Porto and A. Ross, "Tail effect in gravitational radiation reaction: Time nonlocality and renormalization group evolution", *Physical Review D*, vol. 93, no 12, jun. 2016.
56. R. A. Porto, "The tune of love and the nature(ness) of spacetime: The tune of love and the nature(ness) of spacetime", *Fortschritte der Physik*, vol. 64, no 10, p. 723–729, oct. 2016.
57. B. P. Abbott et al. (R. Sturani included), "Binary Black Hole Mergers in the First Advanced LIGO Observing Run", *PHYSICAL REVIEW X* 6, 041015 2016.
58. B. P. Abbott et al. (R. Sturani included), "Improved Analysis of GW150914 Using a Fully Spin-Precessing Waveform Model", *PHYSICAL REVIEW X* 6, 041014 2016.
59. B. P. Abbott et al. (R. Sturani included), "Characterization of transient noise in Advanced LIGO relevant to gravitational wave signal GW150914", *Class. Quantum Grav.* 33 134001 (34pp) 2016.
60. B. P. Abbott et al. (R. Sturani included), "GW151226: Observation of Gravitational Waves from a 22-Solar-Mass Binary Black Hole Coalescence", *Class. Quantum Grav.* 33 134001 (34pp) 2016. *PRL* 116, 241103 2016.
61. B. P. Abbott et al. (R. Sturani included), "Properties of the Binary Black Hole Merger GW150914", *PRL* 116, 241102 2016.
62. B. P. Abbott et al. (R. Sturani included), "GW150914: First results from the search for binary black hole coalescence with Advanced LIGO", *Physical Review D*, vol. 93, no 12, jun. 2016.
63. B. P. Abbott et al. (R. Sturani included), "Directly comparing GW150914 with numerical solutions of Einstein's equations for binary black hole coalescence", *Phys. Rev. D* 94 064035 2016.
64. B. P. Abbott et al. (R. Sturani included), "Comprehensive all-sky search for periodic gravitational waves in the sixth science run LIGO data", *Phys. Rev. D* 94 042002 2016.
65. S. Adrián-Martínez et al. (R. Sturani included), "High-energy Neutrino follow-up search of Gravitational Wave Event GW150914 with ANTARES and IceCube", *Phys. Rev. D* 93 122010 2016.
66. B. P. Abbott et al. (R. Sturani included), "Search for transient gravitational waves in coincidence with short-duration radio transients during 2007–2013", *Phys. Rev. D* 93 122008 2016.
67. B. P. Abbott et al. (R. Sturani included), "Observing gravitational-wave transient GW150914 with minimal assumptions", *Physical Review D*, vol. 93, no 12, jun. 2016.
68. B. P. Abbott et al. (R. Sturani included), "Tests of General Relativity with GW150914", *Physical Review Letters*, vol. 116, no 22, may 2016.

69. B. P. Abbott et al. (R. Sturani included), "GW150914: Implications for the Stochastic Gravitational-Wave Background from Binary Black Holes", *Physical Review Letters*, vol. 116, no 13, mar. 2016.
70. B. P. Abbott et al. (R. Sturani included), "GW150914: The Advanced LIGO Detectors in the Era of First Discoveries", *Physical Review Letters*, vol. 116, no 13, mar. 2016.
71. J. Aasi et al. (R. Sturani included), "First low frequency all-sky search for continuous gravitational wave signals", *Physical Review D*, vol. 93, no 4, feb. 2016.
72. B. P. Abbott et al. (R. Sturani included), "ASTROPHYSICAL IMPLICATIONS OF THE BINARY BLACK HOLE MERGER GW150914", *The Astrophysical Journal*, vol. 818, no 2, p. L22, feb. 2016.
73. J. Aasi et al. (R. Sturani included), "Search of the Orion spur for continuous gravitational waves using a loosely coherent algorithm on data from LIGO interferometers", *Physical Review D*, vol. 93, no 4, feb. 2016.
74. B. P. Abbott et al. (R. Sturani included), "All-sky search for long-duration gravitational wave transients with initial LIGO", *Physical Review D*, vol. 93, no 4, feb. 2016.
75. B. P. Abbott et al. (R. Sturani included), "Observation of Gravitational Waves from a Binary Black Hole Merger", *Physical Review Letters*, vol. 116, no 6, feb. 2016.
76. B. P. Abbott et al. (R. Sturani included), "Prospects for Observing and Localizing Gravitational-Wave Transients with Advanced LIGO and Advanced Virgo", *Living Rev. Relativity*, 19, 1, 2016.
77. A. Codello, R. Percacci, L. Rachwał and A. Tonerò, "Computing the effective action with the functional renormalization group", *The European Physical Journal C*, vol. 76, no 4, apr. 2016.
78. Codello e A. Tonerò, "Renormalization group improved computation of correlation functions in theories with nontrivial phase diagram", *Physical Review D*, vol. 94, no 2, jul. 2016.
79. M. Fabbrichesi, M. Pinamonti, A. Tonerò and A. Urbano, "Vector boson scattering at the LHC: A study of the $W W \rightarrow W W$ channels with the Warsaw cut", *Physical Review D*, vol. 93, no 1, jan. 2016.

8. First page of publications

See two annexed files for publications of professors and postdocs on ICTP-SAIFR research team.

9. Scientific reports of postdocs

See annexed file for scientific reports of

Nicolás Bernal, José Hugo García, Chrysostomos Kalousios, Fabien Lacasa, Alessandro Parisi, Ryo Suzuki e Alberto Toneró.