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

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Project Team

Professors

Alexandre Reily Rocha, Associate Researcher (4 hours), IFT-UNESP

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 Knegt López de Prado, Associate Researcher (4 hours), IB-USP

Victor Rivelles, Associate Researcher (4 hours), IF-USP

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)

Rafael Porto (Young Investigator – FAPESP)

Luana Sucupira Pedroza (FAPESP)

Ryo Suzuki (FAPESP)

Riccardo Sturani (Young Investigator – FAPESP)

Alberto Tonero (FAPESP)

Administrative support

Danilo Rodrigues Ramos, 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

In December 2014 and January 2015, the researchers Fabio Iocco (Stockholm) and Rafael Porto (IAS Princeton) joined the ICTP-SAIFR faculty as tenure track professors financed by a donation from the Simons Foundation (New York) and FAPESP Young Investigator fellowships. Fabio Iocco performs research in the subarea of astrophysics and dark matter detection, while Rafael Porto performs research in the subarea of effective field theorly appled to cosmology and gravitational waves. Together with FAPESP Young Investigator Riccardo Sturani and ICTP-SAIFR vice-director Rogerio Rosenfeld, the addition of these two new members greatly strengthened the cosmology group of ICTP-SAIFR.

In February 2015, two new international agreements were signed with the theoretical physics institutes IFT in Madrid, Spain and IPhT in Saclay, France. These agreements will help to finance the exchange of visitors between these institutes and ICTP-SAIFR. Also in February 2015, the ICTP-SAIFR organized the 3rd Joint Dutch-Brazil School in Theoretical Physics together with the Dutch Research School of Theoretical Physics. Lecturers included Fundamental Physics Prize winner Nima Arkani-Hamed (IAS Princeton) and Dirac Medal winner Cumrun Vafa (Harvard).

In May 2015, ICTP-SAIFR received a donation from a private individual which will be called the ICTP-SAIFR Isaas Raw Chair after the renowned Brazilian scientist who directed the Butantan Institute in Sao Paulo. This Chair will be used to partially sponsor a new faculty member of ICTP-SAIFR in the near future.

In July and October 2015, two FAPESP postdoctoral positions were filled with the selection of José Hugo García (UFRJ) and Ryo Suzuki (Oxford). Dr. García works in the field of condensed matter theory and uses approximations based on polynomial expansions and density functional theory to investigate the electronic and transport properties of disordered systems. Dr. Suzuki works in the field of integrability and studies gauge theories such as supersymmetric Yang-Mills using the AdS-CFT correspondence.

In October 2015, an agreement was signed by the director of Perimeter Institute (Waterloo, Canada) and the rector of UNESP involving the hiring in 2016 of a joint faculty member by ICTP-SAIFR and Perimeter Institute. This joint faculty member will spend up to 8 months per year at ICTP-SAIFR and 4 months per year at Perimeter, and will coordinate joint activities between the two institutes including a joint masters program involving the world-famous Perimeter Scholars International course at Perimeter. Students will be selected to this joint masters program through an exam at the end of a one-week international school for undergraduates organized at ICTP-SAIFR, and the first such school will be in July 2016 with information on the webpage http://sictp2.ift.unesp.br.

In November 2015, the General Conference of UNESCO in Paris formally approved ICTP-SAIFR as a Category 2 Institute of UNESCO. As a Category 2 Institute, ICTP-SAIFR will play the role of a regional centre for the South American

continent as a branch of ICTP in Trieste, which is a Category 1 Institute of UNESCO.

During 2015, the number of visitors, seminars, schools and workshops increased over the previous years. 119 visitors stayed for more than one week and more than 150 seminars and colloquia were presented. The ICTP-SAIFR organized activities in diverse areas of theoretical physics and complex systems. These activities included 9 international schools on the topics of mathematical biology, pathogen dynamics, theoretical physics, biophysics of proteins, Monte Carlo event generators, QCD and LHC Physics, gravitational waves, neutrinos, complex networks and applications to neuroscience, as well as 4 minicourses on energy landscapes in biophysics, numerical spectral methods, effective field theory and applications, and the functional renormalization group. Also, a 2 month-long program on particle physics was organized by Prof. Mariano Quirós (IFAE and ICREA, Barcelona) from October to December. Finally, there were weekly meetings in 2015 of a colloquium and three separate "journal clubs'' in the areas of string theory, particle physics and cosmology. These three 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. Besides these local activities, ICTP-SAIFR gave organizational support to the following two External Activities: First Peruvian School on High-Energy Physics and Cosmology in Lima, Peru (June 22-26) and the 6th ICTP Latin-America String School in Mexico City (October 26 – November 6).

The ICTP-SAIFR scientific council also approved 8 international schools to be held in 2016 at ICTP-SAIFR on the topics of mathematical biology, physics applications in biology, climate modeling, effective field theory, string theory, dark matter, spectroscopy in astrophysics and theoretical physics. In addition, a minicourse on the topic of numerical relativity will be given by Professors Luis Lehner (Perimeter Institute) and Frans Pretorius (Princeton University).

The activities of ICTP-SAIFR in 2015 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-SAIFR 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-SAIFR 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.

In publication [1] the pure spinor formalism is used to study a particular superstring tree-level scattering amplitude involving one closed string and N open string vertex operators in AdS^5xS^5 showing a relation with a d = 4, N = 4 harmonic superspace integral in terms of the supergravity and super-Yang-Mills superfields. Publication [2] shows that the pure spinor formalism for the superstring may have its origins in the quantization of a twistor-like constraint. In publication [3] the pure spinor and Green-Schwarz formalisms for the superparticle and superstring are obtained as different gauge-fixings of a purely bosonic classical action obtained by replacing the classical pure spinor with a projective pure spinor.

N = 2 supersymmetric Spin(n) gauge theory, with n − 2 hypermultiplets in the vector representation, is superconformal for any n > 2. These 4D gauge theories can be obtained by compactifying a 6D (2,0) theory of type D_N on a 4-punctured sphere. In publication [4] construct the corresponding Seiberg-Witten geometries, and discuss the strong-coupling S-dual realizations of the gauge theories. Publication [5] discusses the classification of 4D theories obtained from the compactification of the 6-dimensional E_6 (2,0) superconformal field theory, of type ADE, on a Riemann surface with codimension-2 defect operators at points on the surface. The effects of the presence of punctures twisted by a Z_2 outer automorphism is studied in publication [6]. In publication [7] a complete classification of 4D N=2 superconformal field theories is provided in terms of three-punctured spheres and cylinders.

The less-known particle type allowed by special relativity and quantum mechanics is the continuous spin particle. Along with usual massive and massless particles of integer and half-integer spins they constitute the irreducible representations of the Poincaré group. In publication [8] a gauge theory action for continuous spin particles is formulated in a spacetime enlarged by an extra coordinate. It is shown that the local symmetries are reducible in the sense that the parameters also have a local symmetry.

In publication [9] the equivalence theorem for integrable systems using two formulations of the Alday–Arutyunov–Frolov model is investigated and it is shown that the S-matrix is invariant under the field transformation which reduces the nonlinear Dirac brackets of one formulation into the standard commutation relations in the second formulation.

In publication [47] it is argued that one does not need to know the explicit solutions of the scattering equations in order to evaluate a given amplitude. The most general quantity consistent with SL(2, C) invariance that can appear in an amplitude that admits a scattering equation description is considered. This quantity depends on all cross ratios that can be formed from n points and we evaluate it for the first non-trivial case of n = 5. The combinatorial nature of the problem is captured through the construction of an appropriate generating function that depends on five variables. Publication [48] study the soft graviton theorem to show that the next to subleading order soft factor for gravity is universal at tree level in arbitrary dimensions.

Some aspects of the one-loop anomalous dimension of so(6)-singlet multi-trace operators in N = 4 $SU(N_c)$ Super Yang-Mills at finite N_c where discussed in publication [49].

a2. Condensed Matter

The advent of parallelized automated methods for rapid whole-genome analysis has led to an exponential drop in costs, thus greatly accelerating biomedical research and discovery. Third-generation sequencing techniques, which would utilize the characteristic electrical conductance of the four different

nucleotides, could facilitate longer base read lengths and an even lower price per genome. In publication [10] a quantum-classical hybrid methodology is proposed to quantitatively determine the influence of the solvent on the dynamics of DNA and the resulting electron transport properties of a prototypic sequencing device utilizing a graphene nanopore.

In publication [11] a density-functional microscopic model for soft tissues (STmod) is presented. The model is based on a prototype molecular structure from experimentally resolved type I collagen peptide residues and water clusters treated in periodic boundary conditions. The optimized geometry, binding and coupling energies, dipole moments, and vibrational frequencies are obtained. The results concerning the stability of the confined water clusters, the water-water, and water-collagen interactions were successfully correlated to some important experimental trends of normal and inflammatory tissues.

The formation of conducting channels of Ti_4O_7 inside TiO_2-based memristors is believed to be the origin for the change in electric resistivity of these devices. While the properties of the bulk materials are reasonably well known, the interface between them has not been studied up to now, mostly because of their different crystalline structures. In publication [12] a method to match the interfaces between TiO_2 and Ti_4O_7 and subsequently the band offset between these materials is obtained from density-functional-theory-based calculations. The results show that, while the valence band is located at the Ti_4O_7, the conduction band is found at the TiO_2 structure, resulting in a type-II interface. In this case, the Ti_4O_7 acts as a donor to the TiO_2 matrix.

The optical properties of novel heterolayered materials based on $MoTe_2$−InN for photovoltaic applications are studied using ab initio density functional theory calculations in publication [13].

One of the most important experimental probes in condensed matter physics is the electrical response to an external electrical field. In addition to the longitudinal conductivity, in specific circumstances, a system can present a transverse conductivity under an electrical perturbation. In publication [50] an efficient numerical approach to calculate the longitudinal and transverse Kubo conductivities of large systems using Bastin's formulation is developed and applied to calculate the conductivity tensor for the quantum Hall effect in disordered graphene and analyze the effect of the disorder in a Chern insulator in Haldane's model on a honeycomb lattice.

The study the the structure and dynamics of liquid water in contact with Pd and Au (111) surfaces using ab initio molecular dynamics simulations with and without van der Waals interactions was performed in publication [51], where it is shown that the structure of water at the interface of these two metals is very different.

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. For instance, if the new particles are color-neutral then it becomes more difficult to produce and detect them at the LHC. In publication [14] several models featuring colorless top partners were investigated and the conclusion is that the LHC will not be able to strongly disfavor naturalness, with mild tuning at the level of about one part in ten remaining allowed even with its full luminosity.

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 arising from the spontaneous breaking of a global symmetry. In publication [15] a model was developed that describes at a more microscopic level this process, inspired by a Nambu-Jona-Lasinio model used to describe chiral symmetry breaking in QCD. Starting from 4-fermi interactions, the Higgs boson appears as a bound state of these new fermions. Its mass is generated at 1-loop level because of the explicit breaking of the remnant global symmetry by the gauge and Yukawa interactions and it was computed. Constraints from electroweak precision measurements were taken into account.

Supersymmetric extensions of the SM find difficulties in reproducing the Higgs mass. In publication [16] extensions with Dirac gauginos were studied that can give rise to the measured Higgs mass without violating electroweak precision measurements.

Publication [52] discusses the discovery potential of light-by-light scattering at the Large Hadron Collider (LHC), induced by the Standard Model (SM) and by new exotic charged particles. The full four-photon amplitudes generated by any electrically charged particles of spins 1/2 and 1, including the SM processes involving loops of leptons, quarks and W bosons are implemented in the Forward Physics Monte Carlo generator. Model-independent bounds on massive charged particles, only parametrized by the spin, mass and "effective charge" Q_{eff} of the new particle are obtained. It is found that a new charged vector (fermion) with $Q_{eff} = 4$ can be discovered up to m = 700 GeV (m = 370 GeV) with an integrated luminosity of 300 fb^{-1} at the LHC.

One knows that the SM is incomplete since it can not account for the dark matter in the Universe. In publication [17] an extension of the SM with extra scalars and a Z_3 symmetry is proposed. A new mechanism for the generation of the dark matter abundance, called Self-Interacting Massive Particle (SIMP) is studied in this context, leading to values consistent with observations in the case of light dark matter in the hundreds of MeV range.

The AdS/CFT duality has been used to describe strongly coupled systems. In publication [18] the leptonic decay constants of the pion and its excitations with a 5-d holographic model for quantum chromodynamics are investigated. It is found that the leptonic decay constants of the excited states of the pion vanish in the chiral limit when chiral symmetry is dynamically broken. This nontrivial result is in agreement with a solid prediction of quantum chromodynamics. An extended partially conserved axial-vector current relation that includes the fields of the excited states of the pion is also obtained.

In publication [19] the production of a pair of D mesons in proton-antiproton collision using a meson-baryon model with special emphasis on the role played by the ψ(3770) resonance is investigated, resulting in cross sections in the range of 30–250 nb.

Motivated by discrepancies observed between lattice QCD simulations and quark models regarding the behavior of the pseudo critical temperature for chiral symmetry restoration as a function of the magnetic field B, the effects of a running the quark coupling constant G with temperature T and the magnetic field B is investigated in the context of the Nambu–Jona- Lasinio model (NJL) in publication [20]. It is found the NJL model can be brought in qualitative agreement with lattice QCD simulations.

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. Most of these tests probe the theory in the weak-field regime, and there are theoretical and experimental reasons to believe that GR should be modified when gravitational fields are strong and spacetime curvature is large. Testing General Relativity with present and future astrophysical observations is of great importance

and this topic was reviewed in publication [53]. One of the predictions of GR is the existence of gravitational waves, which are now being searched in terrestrial experiments such as the Laser Interferometer Gravitational-wave Observatory (LIGO) and VIRGO. We have researchers at SAIFR involved in these searches and publications [54], [55], [56], [57], [58] are related to various attempts to detect gravitational waves. Publication [59] deals with the details of the Advanced LIGO detector that recently started its operations.

The evolution of perturbations in dark matter is relatively easy to compute and leads to the formation of dark matter halos in the nonlinear regime. However, we observe galaxies and a model describing how galaxies are distributed in dark matter halos is necessary. In the so-called Halo Model, galaxies are hosted by dark matter halos, while the halos themselves are biased tracers of the underlying matter distribution. Measurements of galaxy correlation functions include contributions both from galaxies in different halos, and from galaxies in the same halo (the so-called one-halo terms). In publication [21] it is shown that, for highly biased tracers, the one-halo term of the power spectrum obeys a steep scaling relation in terms of bias. The steepness of these scaling relations is such that the one-halo terms can become key contributions to the n-point correlation functions, even at large scales. These results are interpreted through analytical arguments and semi-analytical calculations in terms of the statistical properties of halos.

Motivated by the arrival of large amounts of data, a renewed interest on analytic methods in Large Scale Structure (LSS) has resurfaced. These can be broadly classified in two categories. On the one hand, studying the impact of long-wavelength (IR) fluctuations on modes around the scale of baryon acoustic oscillations. On the other hand, considerable efforts have also been directed towards understanding the impact of short-wavelength (UV) perturbations. Their treatment is further complicated by the non-linear dynamics on short scales. The effective field theory (EFT) of LSS has emerged as a useful tool to parameterize the imprint of UV modes in long-distance observables. In publication [60] a non-perturbative equation for the large scale structure power spectrum of long-wavelength modes is derived. A simplified version of this non-perturbative equation is checked against existent numerical simulations, and good agreement is found within the expected uncertainties. Publication [61] studies soft limits of correlation functions for the density and velocity fields in the theory of structure formation.

The recent claim of B-modes in the cosmic microwave background pointing originating from gravitational waves generated during the inflationary epoch of the Universe was unfortunately overestimated due to dust contamination. Hence observations of the cosmic microwave background do not yet determine whether inflation was driven by a slowly-rolling scalar field or involved another physical mechanism. Publication [62] discuss the prospects of using the power spectra of scalar and tensor modes to probe the nature of inflation.

Probability density functions associated to random flights through two spaces of different dimensions emerge from the treatment of Boltzmann equation describing the Cosmic Microwave Background (CMB) temperature and polarization. Publication [22] studies random flights that start in a space of one given dimension and, after performing a definite number of steps, continue to develop in a space of higher dimension. It is shown that if the difference of the dimension of spaces is even, then the probability density describing the composite flight can be expressed as marginalizations of the probability density associated to a random flight in the space of less dimensions.

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. The consequences of this unstable phase for the background spacetime have not been addressed so far due to known difficulties concerning backreaction in semiclassical gravity. It seems reasonable to believe, however, that the quantum fluctuations will "classicalize" when they become large enough, after which backreaction can be

treated in the general-relativistic context. In publication [23], the emergence of a classical regime out of the quantum field evolution during the unstable phase is examined. By studying the appearance of classical correlations and loss of quantum coherence, it is shown that by the time backreaction becomes important the system already behaves classically. Consequently, the gravity-induced instability leads naturally to initial conditions for the eventual classical description of the backreaction. These results give support to previous analyses which treat classically the instability of scalar fields in the spacetime of relativistic stars, regardless of whether the instability is triggered by classical or quantum perturbations.

a5. Astrophysics

Here the highlight is the publication [63] in Nature Physics claiming evidence for dark matter in the inner part of the Milky Way from a detailed study of the rotation curve of our galaxy. Dynamical constraints on the dark matter distribution in the Milky Way were studied in publication [64], where a local dark matter density is estimated at $\rho_0 = 0.420+0.021-0.018\ (2\sigma)\pm0.025\ \mathrm{GeV/cm^3}$(including statistical and systematic errors), given some assumptions about the profile and velocity dispersion. Results of a new, non-parametric method to reconstruct the Galactic dark matter profile directly from observations were presented in publication [65]. The latest kinematic data to track the total gravitational potential and the observed distribution of stars and gas to set the baryonic component was used to infer the dark matter contribution to the circular velocity across the Galaxy. The radial derivative of this dynamical contribution was then estimated to extract the dark matter profile. Publication [66] puts constraints in Modified Newtonian Dynamics (MOND) models from Milky Way data.

A very active area of research is the role of magnetic fields in the astrophysical plasma. In publication [24] it was attempted to explain the observed radio and gamma-ray emission produced in the surroundings of black holes by employing a magnetically dominated accretion flow model and fast magnetic reconnection triggered by turbulence. This work puts fast magnetic reconnection events as a powerful mechanism operating in the core region near the jet base of black hole sources on more solid ground. Magnetic reconnection current sheets causing cosmic ray acceleration by a first-order Fermi process operating in the core region of galactic black hole binaries (or microquasars) were studied in publication [25]. Fast magnetic reconnection events can be a very powerful mechanism operating in the core region of microquasars and active galactic nuclei (AGNs). In publication [26] a comparison is made between two different fast magnetic reconnection mechanisms, namely, fast reconnection driven by anomalous resistivity (AR) and by turbulence. When driven by turbulence, not only their radio but also their gamma-ray emission can be due to magnetic power released by fast reconnection, which may accelerate particles to relativistic velocities in the core region of these sources. Thus the turbulent-driven fast reconnection model is able to reproduce very well the observed emission. The ambient magnetic field amplification in shock fronts of relativistic jets was applied to gamma-ray afterglows in publication [27]. In publication [28] it is shown that relativistic protons accelerated by magnetic reconnection in the core region of these sources may produce high energy (HE) neutrinos via the decay of charged pions produced by photomeson process. The diffuse flux of HE neutrinos was calculated and found that it can be associated with the IceCube recent results.

Large-scale, weakly collimated outflows are very common in galaxies with large infrared luminosities. In complex systems in particular, where intense star formation (SF) coexists with an active galactic nucleus (AGN), it is not clear yet from observations whether the SF, the AGN, or both are driving these outflows. In publication [29], a high-resolution three-dimensional hydrodynamical simulations with radiative cooling considering the feedback from both SF regions, including supernova (Type I and II) explosions and an AGN jet emerging from the central

region of the active spiral galaxy was performed. It was found that at scales within 1 kpc an outflow can be generally established considering intense nuclear SF only.

The Planck Collaboration results on the polarized thermal emission from Galactic dust are in publication [30].

a6. Complex Systems

São Paulo has experienced a severe drought during the last 2 years. Publication [31] suggests that this was worsened by a catastrophic regime shift in water reservoirs. The relation between rainfall and water accumulated in reservoirs comprises nonlinear feedbacks. It is shown that they may generate alternative equilibrium regimes, one of high water-volume, the other of low water-volume. Reservoirs can be seen as socio-environmental systems at risk of regime shifts, characteristic of tipping point transitions. A mathematical model is built that gives a mechanistic view of the dynamics and demonstrates that alternative stable states are an expected property of water reservoirs.

Network science has provided a large body of theoretical tools to investigate complex systems, from physics to social sciences and biology. Much work has been devoted to the study of networks' topological properties and dynamical processes on networks have been shown to depend sensitively on the network structure. More recently, the response of networks to external perturbations has also been investigated. Most of the networks found in nature are scale free, characterized by a power-law degree distribution and by the presence of nodes whose degree greatly exceeds the average. These special nodes, referred to as network hubs, are crucial for the structural integrity of many real-world systems, allowing for a fault tolerance behavior against random failures. Nevertheless, if the hubs are removed from the network by an intentional attack, the network might fragment into a set of isolated graphs. Thus, the presence of hubs represents at the same time the robustness and the "Achilles heel" of scale-free networks. In addition, network hubs can be detected and studied using numerous different graph measures, most of which express aspects of node centrality. Publication [32] gives exact statistical distributions for the dynamic response of influence networks subjected to external perturbations.

In publication [33] a binary dynamical process that is a representation of the voter model with two candidates and opinion makers is studied. The voters are represented by nodes of a network of social contacts with internal states labeled 0 or 1 and nodes that are connected can influence each other. The network is also perturbed by opinion makers, a set of external nodes whose states are frozen in 0 or 1 and that can influence all nodes of the network. The quantity of interest is the probability of finding m nodes in state 1 at time t. Here we study this process on star networks, which are simple representations of hubs found in complex systems, and compare the results with those obtained for networks that are fully connected. In both cases a transition from disordered to ordered equilibrium states is observed as the number of external nodes becomes small. For fully connected networks the probability distribution becomes uniform at the critical point. For star networks, on the other hand, the equilibrium distribution splits in two peaks, reflecting the two possible states of the central node. Approximate analytical solutions are obtained for the equilibrium distribution that clarify the role of the central node in the process.

The network structure of biological systems provides information on the underlying processes shaping their organization and dynamics. Publication [34] examined the structure of the network depicting protein interactions within the spliceosome, the macromolecular complex responsible for splicing in eukaryotic cells. It is shown that the interactions of less connected spliceosome proteins are nested subsets of the connections of the highly connected proteins. At the same time, the network has a modular structure with groups of proteins sharing similar interaction patterns. An adapted probabilistic model originally designed to

reproduce food webs was as successful in reproducing the structure of protein interactions as it is in reproducing interactions among species. The good performance of the model suggests affinity and specificity, partially determined by protein size and the timing of association to the complex, may be determining network structure. Publication [35] shows that Pleistocene megafaunal interaction networks became more vulnerable after human arrival, helping to understand why the megafauna died out in the Americas while persisting in Africa.

Predicting panic is of critical importance in many areas of human and animal behavior, notably in the context of economics. The recent financial crisis is a case in point. Panic may be due to a specific external threat or self-generated nervousness. Publication [36] shows that the recent economic crisis and earlier large single-day panics were preceded by extended periods of high levels of market mimicry—direct evidence of uncertainty and nervousness, and of the comparatively weak influence of external news. High levels of mimicry can be a quite general indicator of the potential for self-organized crises.

Organisms are often more likely to exchange genetic information with others that are similar to themselves. One of the most widely accepted mechanisms of RNA virus recombination requires substantial sequence similarity between the parental RNAs and is termed similarity-essential recombination. The study the dynamics of haplotype frequencies in populations evolving under similarity-essential recombination is the subject of publication [37]. In publication [38] the evolution of allele frequencies for infinitely large populations subjected to mutations and assortative mating is studied and the equilibrium solutions for arbitrary values of the mutation rate is obtained, providing a description of the dynamics on the basis of a bifurcation analysis.

The possibility of using a dynamic environment to achieve and optimize phase synchronization in a network of self-excited cells with free-end boundary conditions is addressed in publication [39].

a7. Mathematical Biology

Understanding the processes underlying community assembly has been a long-lasting challenge in community ecology. While niche-based, deterministic processes, such as environmental filtering and species interactions, have traditionally been seen as of foremost importance, consensus among ecologists now exists on the non-negligible role of neutral and stochastic processes, such as random extinctions and ecological drift, on community assembly. However, the strength of the influence of these two classes of processes is likely to vary in space and time depending on abiotic conditions as well as on taxonomic group. Given that habitat loss is considered the most important driver of the current biodiversity crisis, unraveling the processes underlying the effects of habitat loss is critical from both a theoretical and an applied perspective. Publication [44] unveils the importance of niche-based and neutral processes to species extinction and community assembly across a gradient of habitat loss, challenging the predictions of neutral models. The results obtained underscore the fundamental importance of pro-active measures to prevent human modified landscapes surpassing critical ecological thresholds.

In publication [46] the spatial dynamics of a population whose individuals go through life stages with very different dispersal capacities is studied. This is modeled through a system of partial differential equations of the reaction-diffusion kind, with nonlinear diffusion terms that may depend on population density and on the stage. In particular, in a situation akin to an invasion of the species in a new habitat it is found that the front of invasion is led by the most mobile adult class.

Ecological science contributes to solving a broad range of environmental problems. However, lack of ecological literacy in practice often limits application of this knowledge. In publication [45], a critical but often overlooked demand on ecological literacy is highlighted: to enable professionals of various careers to apply

scientific knowledge when faced with environmental problems.

Publication [40] studies the stress gradient hypothesis (SGH) that postulates how the balance between plant competition and facilitation shifts along environmental gradients, conducting field experiments along the most severe part of a coastal dune gradient in southeast Brazil to test the effect of stress on the intensity and importance of the net interactions between two tree species.

Publication [41] evaluates 10 statistical models for the distribution in tree diameter in natural forests. It was found which models provide best fits and under which sample properties (size, median, variance, skewness, and kurtosis).

By reviewing nearly 70 years of information on tree community surveys about the Atlantic Forest (AF), publication [42] shows that the total sampled area represents only 0.01 % of the AF remnants, showing how limited our knowledge is on AF structure.

Empirical studies in salt marshes, arid, and alpine systems support the hypothesis that facilitation between plants is an important ecological process in severe or 'stressful' environments. Coastal dunes are both abiotically stressful and frequently disturbed systems. Facilitation has been documented, but the evidence to date has not been synthesized. Publication [43] performs a systematic review with meta-analysis to highlight general research gaps in the study of plant interactions in coastal dunes and examine if regional and local factors influence the magnitude of facilitation in these systems.

b. Research related to visitors

During 2015, the ICTP-SAIFR hosted 49 short-term visitors who stayed less than one week and 117 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=7330
The research of some of the long-term visitors is described below:

Shota Komatsu – Perimeter Institute (1/1 – 31)
From December 2014 to January 2015, I participated in the program on Integrability, Holography and Conformal Bootstrap. During that period, I worked mainly on the non-perturbative formulation of three-point functions in the maximally supersymmetric Yang-Mills theory in four dimensions with Benjamin Basso, who also participated in the program, and Pedro Vieira, who was organizing the program. The ICTP-SAIFR provided wonderful environment for discussions and collaborations, and we finally suceeded in developing a novel non-perturbative to study the three-point functions (reference 1). I also conducted research on a related topic in collaboration with Didina Serban and Ivan Kostov, both of which were participants of the program (reference 2).

Reference 1: Structure Constants and Integrable Bootstrap in Planar N = 4 SYM Theory Benjamin Basso, Shota Komatsu and Pedro Vieira. http://arxiv.org/pdf/1505.06745.pdf

Reference 2: The hexagon in the mirror: the three-point functions in the SoV approach. Yunfeng Jiang, Shota Komatsu, Ivan Kostov, Didina Serban.
http://arxiv.org/abs/1506.09088

Frank Coronado – Perimeter Institute (1/1 – 3/2)
During my visit, I colaborated with my supervisor Pedro Vieira in a project in the framework of the computation of expectation values of null polygonal Wilson loops/ scattering amplitudes in the planar limit of N=4 supersymmetric gauge theory. Through the OPE decomposition, this computation of Wilson loops can be written as a correlation function of twist operators that geometrically correspond to null

pentagon loops. This computation has two parts: the dynamical part, that contains all the coupling dependence and the matrix part, that corresponds to the tensor structure of the pentagons due to the global SU(4) R-symmetry. The tensor structure is built up from tensor products of scalar fermions and gluons multiplets, that means the 6,4,1 representations of SU(4). Due to the various representation involved on this context the computations is cumbersome, so we decided to first work with a toy model for which we have only the fundamental representantion of SU(2). This we began in our visit to Ictp-saifr and by now we have achieved a complete understanding of how to systematically construct the matrix part for SU(2), currently we are working to extend this procedure for higher rank groups in special SU(4).

Lucía Gomez Cordova – Perimeter Institute (1/1 – 3/2)
During this visit I worked on the OPE approach for computing vacuum expectation values of null polygonal Wilson loops dual to scattering amplitudes in planar N=4 Super Yang Mills. In particular, my research was focused on extending this non-perturbative method to non-bosonic Wilson loops which accounts to studying all the possible helicity configurations in the amplitudes side. We proposed a concrete map between these helicity configurations and the so called "charged pentagons" and tested its validity using available data at weak coupling.

Fidel I. Schaposnik Massolo - Univ. de La Plata (1/5 - 30)
During my visit to ICTP-SAIFR I continued working on an ongoing project in collaboration with Pedro Vieira and Benjamin Basso. The goal of the project is to study the weak-coupling integrable structure of field insertions in light-like Wilson loops, and construct the n-particle wavefunctions that are required to check the factorization of the "pentagon transitions", which are the main building blocks of the bootstrap OPE approach to scattering amplitudes in N = 4 super Yang-Mills theory.

Matthew H. B. von Hippel – Perimeter Institute (1/6 – 2/28)
While at ICTP-SAIFR, I collaborated with Pedro Vieira and Benjamin Basso on building a numerical implementation of their OPE setup. Previous implementations had been limited to depicting exchanges of one or two excitations; our goal is to get up to eight, to allow for plots of scattering amplitudes for general kinematics and finite coupling.

João Caetano – Perimeter Institute (1/6 – 3/2)
During the visit, I have mostly worked on the subject of scattering amplitudes in N=4 Super Yang-Mills using integrability. Recently, we have proposed a formalism based on the OPE for scattering amplitudes to include external states with an arbitrary helicity. During my stay in ICTP-SAIFR we have performed several checks of our proposal and cleaned several technical aspects of the construction. We have also start writing a paper with these developments. Also, it was an opportunity to work on the project with the Post-doc Thiago Fleury of IFT/ICTP on the computation of three point functions in N=4 Super Yang-Mills.

Benjamin Basso – Perimeter Institute (1/11 – 2/28)
During my visit at ICTP-SAIFR I have been working on two different projects. - The first of these projects was done in collaboration with Joao Caetano, Lucia Cordova, Amit Sever and Pedro Vieira. It aimed at identifying and constructing the complete set of rules for building up the OPE integrands for gluon scattering amplitudes in planar N=4 SYM theory. Though this work is still under completion a lot of progress has been made during my visit at ICTP-SAIFR and it should appear soon on the arXiv. The second project was done in collaboration with Shota Komatsu and Pedro Vieira. It aimed at developing an integrable bootstrap for computing three-point functions in planar N=4 SYM theory. Almost all of this work was done at the time of

our visit at ICTP-SAIFR and it should appear soon on the arXiv.

Article 1: Structure Constants and Integrable Bootstrap in Planar N = 4 SYM Theory Benjamin Basso, Shota Komatsu and Pedro Vieira. http://arxiv.org/pdf/1505.06745.pdf

Article 2: OPE for all Helicity Amplitudes II. Form Factors and Data analysis Benjamin Basso, João Caetano, Lucía Córdova, Amit Server and Pedro Vieira. http://arxiv.org/pdf/1508.02987.pdf

Article 3: OPE for all Helicity Amplitudes. Benjamin Basso, João Caetano, Lucía Córdova, Amit Server and Pedro Vieira.
DOI: 10.1007/JHEP08(2015)018

Didina Serban – CEA, Paris (1/15 – 31):
After my arrival at SAIFR I have given a talk on my recent work with my collaborators Yunfeng Jiang, Ivan Kostov and Andrei Petrovskii "String Bits and the Spin Vertex" which proposes a novel approach to compute the three point function in the N=4 supersymmetric Yang-Mills theory at weak coupling. This approach is similar to that of the string vertex in string field theory, and our purpose is to implement the symmetry coming form integrability into the three point function. The final purpose is to characterize completely the correlation function at any coupling and for any operator, and compare with the result from string theory. This would give a refined check of the AdS/CFT correspondence at the level of correlation functions. During my stay I have investigated the possibility of implementing this program beyond the tree level, by deforming the super conformal algebra. I have also investigated some alternatives method to take the limit of large number of constituents, notably the method of separation of variables proposed by Sklyanin, both in su(2) and sl(2) sector.

Romuald Janik – Jagiellonian U., Krakow (1/20 – 2/1):
During my stay at ICTP-SAIFR I investigated the form-factor program in case of nondiagonal integrable quantum field theories. This investigation was done in view of the applications to the integrable approach to the string field theory vertex in AdS5xS5 which was introduced by Zoltan Bajnok and myself. Currently I am pursuing further research along these lines. I gave a seminar on the integrable approach to the light cone string field theory vertex and benefitted from numerous discussions with other participants of the program.

Diego Hernan Correa – Univ. de La Plata (1/25 – 2/5)
I have mainly focused on the study of Wilson loops in higher rank representations. Continuing in this way a collaboration initiaited with Diego Trancanelli and Fidel Schaposnik Massolo. More specifically we considered certain Wilson loops defined along lines with cusp angles whose vacuum expectation values can be exactly computed, either by supersymmetric localization or by resummation of ladder Feynman diagrams. We then look for classical D-brane solutions, dual to the aforementioned Wilson loops and try to verify the strong coupling limit of the exactly known vacuum expectation values. I have also prepared a blackboard talk "1-loop partition function for strings dual to cusped Wilson loops in ABJM" that I have delivered in the string theory journal club on the 30th of January of 2015.

Article: Cusped Wilson lines in symmetric representations. Diego H. Correa, Fidel I. Schaposnik Massolo, Diego Trancanelli.
DOI: 10.1007/JHEP08(2015)091

Nikolay Gromov – Kings College London (2/1 – 22)
During these 3 weeks I was working on the QSC formulation of the Cusp anomalous

dimension. The paper will appear soon.

Article 1: Quantum Spectral Curve and the Numerical Solution of the Spectral Problem in AdS5/CFT4. Nikolay Gromov, Fedor Levkovich-Maslyuk, Grigory Sizov
e-Print: **arXiv:1504.06640**

Article 2: NNLO BFKL Pomeron eigenvalue in N=4 SYM. Nikolay Gromov, Fedor Levkovich-Maslyuk, Grigory Sizov
e-Print: **arXiv:1507.04010**

Article 3: Quantum Spectral Curve for a Cusped Wilson Line in N = 4 SYM. Nikolay Gromov, Fedor Levkovich-Maslyuk
e-Print: **arXiv:1510.02098**

Manuel Cifuentes Valiente – Aarhus Univ, Denmark (2/3 – 3/14)
During my visit to ICTP-SAIFR I worked on the three body problem with ultracold atoms. In particular, the project envisions the observation of trimer Efimov states of bosons as ground states in special circumstances: strong three-body losses in an optical lattice give rise to an effective three-body constraint in which collapsed three-body bound states disappear from the spectrum (i.e. avoid the Thomas effect). The three-body constrain can be implemented with cold atoms as shown in [Daley, Taylor, Diehl, Baranov and Zoller, Phys. Rev. Lett. 102, 040402 (2009)]. I derived the integral equation by separation of the wave functions into Fadeev components, and obtained a simple kernel that is amenable to numerical treatments. The discussions with Marcelo Yamashita and Lauro Tomio were enlightening, and our collaboration is on the way. I will deliver a set of notes for them to study, and they will provide assistance with the numerical implementation of the equation solver, in which they are world-renowned experts. Apart from the obvious results regarding the binding energies of the trimers, the system at hand is regular due to the lattice discretisation and the absence of Thomas collapse. Therefore, the three-body parameter is NOT an input -- as it is for zero-range models -- but will come out as output and will be a measurable quantity. Moreover, there is a possibility of tuning, via changing the loss rates of the system, of the point where the first trimer appears, which is usually only tunable via changing the masses of the particles. We expect to have a draft of the manuscript in a few months time.

Ivan Kostov – Saclay (2/4 – 18)
During my visit at ICTP-SAIFR I worked on the computation of the three-point function in AdS/CFT using the formalism of separation of variables. This research will be will be hopefully finished and published later this year. I benefited from the discussions with Nicolai Gromov, Vladimir Kazakov, Jonathan Toledo and Pedro Vieira.

Vladimir Kazakov – ENS, Paris (2/4 – 3/3)
1. Work on the paper on principal chiral model. Exact solution at any N. large N limit under investigation
2. Seminar given at ICTP-SAIFR on this subject during my visit
3. Numerous fruitful discussions with P.Vieira, N.Gromov, N. Berkovits, B.Basso, J. Toledo, J. Caetano on correlators in N=4 SYM

Yubing Dong – Chinese Academy of Sciences (2/22 – 3/1)
I visited ICTP-SAIFR from Feb. 22nd to March 1st, 2015, hosted by Prof. Lauro Tomio. During the short period of the visit, I had several discussions with Prof. Lauro Tomio and Prof. Gastao Krein. We discussed something about future

collaborations between Brazil and China, and the few-body physics in quark model. I also gave a seminar entitled "Hadronic molecule scenario in a phenomenological approach" for hadronic physics people in ICTP-SAIFR. It was my first visit to Brazil and I also visited the Universidade Federal do ABC, Santo André. I spent one day there talked to the people there.

Claudio Dib – Federico Santa María Technical University, Valparaíso (3/4 – 4/16 and 8/15 - 22)
First visit: Collaboration with Rogerio Rosenfeld, Eduardo Ponton and Gero von Gersdof on the construction of a Left-Right symmetric model version of a composite pseudo-Golsdtone scenario for the 125 GeV Higgs. Left-right symmetric models have a reviving interest because they include right handed components of neutrinos as a requirement, and consequently neutrinos are naturally massive in the model. There are no papers yet, as this is the begining of this work, essentually the first two weeks of conversations. In addition to this work, I gave a talk at the thursday journal club of the group, where I presented several related works on neutrino models and detection, including my last works on the subject.

Second visit: Studies on neutrino physics: we studied specific topics on the detection of heavy sterile neutrinos at the LHC. Heavy sterile neutrinos are predicted in all models where the masses of the light neutrinos are explained by seesaw mechanisms. The original models predict masses around the GUT scale, far beyond the reach of production at colliders. However there are many alternative models, so called low-scale seesaw, where the heavy sector can be below the TeV scale, or even around the GeV scale. In our study we were interested in heavy neutrinos near or below the W boson mass (81 GeV), so that they can be produced in W decays produced at the LHC. Discussions with several people, especially those participating in the neutrino summer institute, have been helpful. This work is still ongoing. Studies on composite Higgs models: we are continuing the studies on this topic, in collaboration with members of the Institute (E. Ponton, R. Rosenfeld, G. von Gersdorf)

Article 1: Discovering sterile neutrinos lighter than Mw at LHC. Claudio O. Dib, C.S. Kim. DOI: 10.1103/PhysRevD.92.093009

George Rawitscher - University of Connecticut, USA (3/15 – 4/20)
The main purpose of my visit was to present 12 lectures on numerical computational methods, with emphasis on spectral methods. The lectures were based on research published in the last 10 years by G. Rawitscher, and the book by Lloyd N. Trefethen "Spectral Methods in MATLAB", (SIAM, 2000). One of the outcomes of these lectures is the preparation of a book "Practical guide to spectral computational methods in the Sciences". Professor Lauro Tomio and two students from the course are expected to be co-authors. Two book publishers have been contacted. The process is expected to take approximately one year. Research conversations with Drs. Tomio and Adhikari also took place. The topic was mainly computational methods for the calculation of Bose Einstein condensates, in the presence of long-ranged dipole-dipole interactions between the condensed molecules. So far no publications have resulted. Further updates of this summary are expected.

Mohab Abou Zeid - I.H.E.S, France (4/7 – 5/2)
I. Target space duality arises when one gauges a sigma model isometry, and then constrains the field strength of the corresponding gauge fields to vanish. For supersymmetric models formulated in superspace, the duality transformations can be studied while keeping (2,2) supersymmetry manifest. This was first done for the class of (conformally invariant) off-shell (2,2) supersymmetric sigma models which involve chiral superfields and twisted chiral superfields only and which admit

isometries. The generalisation of this target space duality for manifolds with almost product structures and to generalised complex manifolds is also possible and it has been the subject of renewed activity over the last decade. Moreover new (2,2) vector multiplets were obtained and used to gauge the isometry symmetries of the sigma models in superspace. The upshot is an explicit and manifestly supersymmetric description of target space duality for generalised Kaehler manifolds, by gauging the isometries of general (2,2) off-shell supersymmetric sigma models and following the usual procedure. In our work we generalise the construction to the superspace formulation of nonlinear sigma models with (2,1) and (2,0) heterotic supersymmetry. Motivated in part by their relation to the critical superstrings with (2,p) world-sheet supersymmetry, the geometry, isometry symmetries and gauging of such heterotic sigma models with manifest off-shell supersymmetry had been investigated in our earlier work on the subject. Their target space geometries and dynamics are very rich and include the generalised Kaehler geometries of the general (2,2) supersymmetric sigma models as special cases. The requirement of (2,p) supersymmetry restricts the admissible isometries to those that act holomorphically on chiral (2,p) superfields. However, the (2,1) and (2,0) matter multiplets are in many ways simpler to analyse and study than their (2,2) counterparts. For example, off-shell (2,p) supersymmetry requires the scalar and fermionic multiplets to be chiral and essentially determine the form of the vector multiplets as well. This contrasts with the (2,2) supersymmetric case, which admits many inequivalent representations. However, the general procedure which defines the dual pairs of general (2,p) models at the classical level is is locally the same as in the (2,2) cases. The conditions for conformal invariance and quantum equivalence of the dual pairs of (2,1) and (2,0) supersymmetric sigma models are currently under investigation, along with the details of the reductions from the generalised (2,2) superspaces relevant to generalised K"{a}hler geometry to the (2,p) heterotic superspaces (the reduction from (2,2) to (2,1) superspace has also been the subject of recent activity by other authors).

Ara Sedrakyan – Yerevan Physics Institute, Armenia (4/12 – 19)
During my visit I have given a seminar and discussed with various peoples the problems concerning to non-critical strings.

Nelson Merino – Pontificia Universidad Católica de Valparaíso (5/4 – 12)
I gave a talk titled "Expansion of Lie algebras and accidental symmetries in Lovelock theories". I had also the possibility to meet the group of ICTP-SAIFR Institute and in particular I had discussions with professors Berkovits, Nastase, Pereira and Pimentel.

Stefano Kovacs – Dublin Institute for Advanced Studies (5/16 – 6/15)
Article: On membrane interactions and a three-dimensional analog of Riemann surfaces. Stefano Kovacs, Yuki Sato, Hidehiko Shimada.
e-Print: **arXiv:1508.03367**

Encieh Erfani - Institute for Research in Fundamental Sciences, Tehran (06/02 – 12/02)
During my visit in the ICTP South American Institute for Fundamental Research IFT-UNESP under the ``TWAS 2015 Fellowship for Research and Advanced Training' from June 2 to November 28, 2015 I did the following activities. I profited the scientific atmosphere of the ICTP-SAIFR by participating in seminars, schools and workshops. I also visited other institutes in Brazil and presented my work. During my visit I finalized a paper which has been submitted to a journal. Encieh Erfani, Primordial Black Hole Formation from Particle Production during Inflation, arXiv: 1511.08470 submitted to JCAP The following research projects are in progress: Encieh Erfani, Primordial Black Holes Formation in Sheth-Tormen Formalism Encieh Erfani, Entropy Production by Primordial Black Holes Evaporation The following

visits were supported by the host institutes. 27 Oct. - 1 Nov., Observatorio Nacional, Rio de Janeiro, Brazil Oct. 14 - 16, Cosmo-ufes, Vitoria, Brazil Sep. 21 - 22, UNICAMP, Campinas, Brazil Schools and Workshops: Aug. 17 - 28, International Neutrino Summer School 2015, ICTP-SAIFR, Sao Paulo, Brazil Aug. 11 - 15, Workshop on Astrophysics and Relativity: Astro-GR 2015, ICTP-SAIFR, Sao Paulo, Brazil Aug. 3 - 11, School on Gravitational Waves: from data to theory and back, ICTP-SAIFR, Sao Paulo, Brazil Presentations: 23 Nov., Primordial Black Holes as Dark Matter, Dark Matter day in Sao Paulo, ICTP-SAIFR, Sao Paulo, Brazil 27 Oct., Primordial Black Holes Formation during Inflation, Observatorio Nacional, Rio de Janeiro, Brazil 16 Oct., Inflation and Dark Matter Primordial Black Holes, Cosmo-ufes, Vitoria, Brazil 22 Sep., Dark Matter Primordial Black Holes and Inflation, UNICAMP, Campinas, Brazil 18 June, Inflation and Dark Matter Primordial Black Holes, ICTP-SAIFR, Sao Paulo, Brazil 9 June, Inflation and Dark Matter Primordial Black Holes, IFUSP, Sao Paulo, Brazil

Douglas Singleton – Californica State University (7/2 – 8/24)
I did work on the time-dependent Aharonov-Bohm (AB) effect and the time-dependent Aharonov-Casher effect. For the AB effect I looked at the AB phase of a particle in the background of a plane electromagnetic wave. This work was submitted during my stay at ICTP has been accepted for publication. I am still finishing a paper on the time dependent AC effect which I hope to have ready fro submission by the end of September. I also am doing some work on gravitational baryogenesis with Prof. JAS Lima from USP. This work was begun in Sao Paulo and we should finish this work in 1-2 months.

Article: Aharonov-Bohm phase for an electromagnetic wave background. Max Bright, Douglas Singleton, Atsushi Yoshida.
DOI: **10.1140/epjc/s10052-015-3670-8**

Rodolfo Mario C. Roldan – University of Notre Dame (7/12 – 8/2)
I worked in two different projects during my visit to the ICTP-SAIRF: 1. With A. Natale (Volunteer professor at the IFT-UNESP) we defined the guidelines for our next project on dynamical chiral symmetry breaking and confinement. We want to apply the knowlege on QCK-like gauge theories and the its relation with confinement to other theories, using different groups and representations. Our goal is to compare our Analytical Schwinger-Dyson equation calculations using effective propagators with Lattice Field Theory calculations. 2. With F. Serna (PhD student at the IFT-UNESP) we are working on non-perturbative calculations on QED and QCD using Shwinger-Dyson equations. Our project is to calculate the electron g - 2 factor and compare it with the experimental result. Our goal is to find expressions to accurately truncate the four-point function when calculating the other Green functions. We hope that this study could help with the analytical calculation of the muon g - 2 factor which is one of the measurements not well understood in modern particle physics.

Syamal Dana - Indian Institute of Chemical Biology, Kolkata (8/31 – 10/22)
During my 2-months' visit (September-October, 2015), I collaborated with two groups, one consisting Hilda Cerdeira of the ICTP-SAIFR and Patrick Louodop Fotso, Postdoc Fellow of the IFT, and another group consisting Elbert E. Macau of the National Institute of Space Research. Our joint works mainly focussed on collective behaviours of complex dynamical systems. Results and future plans are discussed below: Cerdeira Hilda's group: (1) We worked on an issue of amplification and synchronization in two drive-response type coupled chaotic oscillators. We formulated a general coupling scheme which showed an interesting universal behaviour in this drive-response system. It establishes synchronization (generalized synchronization) and a predictable distance between the driver oscillator and the response oscillator, which is controllable. In fact, some of the response variables

are the amplified replica of their corresponding driver variables and one response variable maintains a distance although identical in amplitude and phase with the respective driver variable. The resultant effect is a distance that separates the response and the driver systems in a coherent motion. We observed that the effect is quite general and can be realized in many dynamical systems including a Jerk system and the Rössler system. The main point we intend to emphasize, in this work, is that a chaotic or periodic response oscillator (follower) in a state of coherent motion or synchrony with a chaotic driver (leader) maintains a desired distance and we are able to monitor it. Furthermore, we observe that the response system reacts to an external disturbance by moving to a new distance when an external short duration pulse is applied. This new distance depends upon the height and width of the external pulse. Interestingly, the response system stays at the new distance when the pulse is withdrawn. The response system can restore its original position by sending a message in the form of a short duration feedback pulse to the driver. The response system thus keeps a memory of the external pulse (height and width). We have tested this result in electronic circuit. We plan for further studies and a possible extension to a chain of coupled oscillators. It has an analogy with two flocks of birds following each other and maintaining a safe distance in the sky where they can readjust their distance as and when necessary (we can ignore the amplification aspect in this example). It is a very complex process, however, using example of two or arrays of dynamical system, we attempt a simplistic approach to understand some of the basic rules how flocks of birds fly in the sky with coherent movements and maintain/readjust a safe distance and also change directions. Our results seemed promising to develop a simple model for understanding the dynamics of movements of flocks of birds. However, we need further studies to make any conclusive statement which we planned for the future.

Flavia Sobreira – FERMILAB (10/1 – 20)
I have started a collaboration with Prof. Rogério Rosenfeld in Halo Occupation Distribution analysis using datas from Dark Energy Survey Collaboration. During the month I spent in the ICTP-SAIFR I created a outline for this new project and started creating a galaxy catalog to go on in the analysis.

Bruce Lehmann Sanchez Veja - Argonne National Lab (10/01 – 12/20)
I am developing a genetic algorithm to fit a general matrix in Mathematica and start a collaboration with Juan Montero.

Alessandro Codello – CP3 – Origins, Odense, Denmark (10/5 – 21)
Derivation and solution of the non–perturbative RG flow equations for the running self–energy and form factor for scalar theory with Z2 symmetry in d = 2, 3, 4. This study will is the natural generalization and continuation of the work done in arXiv:1504.00225. 2) The generalization of 1) to non–linear case, following previous work done in arXiv:1505.03119. 3) Heat kernel computation of the one loop beta functions for the Standard Model in presence of dimension six operators.

Germano Nardini - Institut de Física d'Altes Energies, Barcelona (11/9 – 12/8)
I spent around one month at the ICTP-SAIFR. Part of the time was dedicated to the attendance at the talks and the subsequent discussions. I also gave a talk covering the generation of gravitational waves from electroweak phase transitions and how to probe them by means of eLISA. In the following days several technical aspects of this subject were informally discussed. Besides the talks and group discussion, I had to partially keep working on projects that started before my visit. They included research on the detection of electroweakinos at colliders, probe of gravitational waves at eLISA, and electroweak baryogenesis in simple SM extensions. I furthermore discussed with Chee Sheng Fong about the feasibility of electroweak baryogenesis in the MSSM. The discussion was interesting but, at the moment, did lead to ideas that are sufficiently innovative and interesting to be perused. An

interesting idea was instead developed with Mariano Quiros and Mateo Garcia Pepin. It deals with a supersymmetry breaking mechanism that seems to be promising for what concerns LHC searches. The project is still under discussion and it will likely lead to a publication. In conclusion, I found this workshop of wide interest and for sure it was worth participating.

Jonas Enander - Stockholm University (11/15 – 29)
Together with Fabio Iocco, I have investigated how the observed baryonic distribution and rotation curves in the Milky Way constraints the possibility of non-Newtonian gravity. Furthermore, I participated in the Dark Matter Day on November 23th.

Stefan Pokorski - University of Warsaw, Poland (11/25 – 12/16)
My visit Nov 25-Dec 16 , 2015 I gave a seminar talk on „Discovering electroweakinos in (mini)-split supersymmetry" and a colloquium on „Flavour window to physics beyond the Standard Model". I participated in most of the activities of the workshop. With A. Belayev, we started a new project on investigating complementarity of direct detection and the LHC experiments in search for squezed chargino-neutralino spectra in supersymmetric models. With A. Belayev, R. Rosenfeld and A. Tonero, we started a new project on the WW and ZZ scattering as a portal to new physics.

Tony Gherghetta - University of Minnesota (11/27 – 12/4)
During my one week stay I gave two talks. The first was a seminar on the unnatural composite Higgs model which described my recent model and phenomenological study of a long-lived color triplet scalar. The second talk was a colloquium on the Higgs boson and naturalness, which outlined what we next expect to discover at Run 2 of the LHC. My seminar prompted discussions with Sasha Belyaev on possible effects of direct detection limits on the singlet dark matter predicted in the split composite Higgs model. I also discussed ways to realize a possible UV completion of the relaxion with Eduardo Ponton and Michele Redi. I also had discussions with Gero von Gersdorff on ways to improve the original relaxion model. Finally with Rogerio Rosenfeld and Gero von Gersdorff I had discussions about composite Higgs models, in particular discussing the similarities/differences between the usual partial compositeness approach to composite Higgs models versus the top condensation approach which relies on mass mixings with elementary fermions.

c. Organization of activities

During the year of 2015, the ICTP-SAIFR organized nine São Paulo International Schools for Theoretical Physics, two workshops, four minicourses, two Programs, one outreach event, the annual meeting of the steering committee and scientific council and weekly seminars, colloquia and journal clubs. The complete list of 2015 activities is on the webpage http://www.ictp-saifr.org/?page_id=6166, the list of weekly seminars and colloquia is on the webpage http://www.ictp-saifr.org/?page_id=7446, and the weekly journal clubs on particle physics and cosmology are on the webpages http://www.ift.unesp.br/users/matheus/partJC/ and https://sites.google.com/site/ictpsaifrjc/. Many of the activities were filmed using equipment donated by the ICTP in Trieste and the vídeos are available online on the associated webpages.

Besides the local activities, ICTP-SAIFR gave organizational support to the following External Activities: First Peruvian School on High-Energy Physics and Cosmology in Lima, Peru (June 22-26) and the 6th ICTP Latin-America String School in Mexico City (October 26 – November 6). The websites of these activities are http://www.ictp-saifr.org/epfaec2015 and http://www.ictp-saifr.org/lass2015, respectively.

c1. São Paulo International Schools

The nine São Paulo International Schools each lasted one to three weeks and were on the subjects of Mathematical Biology (January 5 - 11), Pathogen Dynamics, Climate and Global Change (January 12 – 23), Theoretical Physics (February 2 – 6), Biophysics of Protein Interaction (March 9 – 13), Monte Carlo on Event Generators (April 27 – 30), QCD and LHC Physics (July 22 – 31), Gravitational Waves (August 3 – 11), Neutrinos (August 17 -29), Complex Networks and Applications to Neuroscience (September 28 - October 16).

The schools were for mostly masters and PhD students, and those students not from São Paulo where 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://ictp-saifr.org/sis/mathbioIVViewAvaliacao.php
http://ictp-saifr.org/sis/pathogensViewAvaliacao.php
http://ictp-saifr.org/sis/dutch-brazilviewAvaliacao.php
http://ictp-saifr.org/sis/proteinviewAvaliacao.php
http://ictp-saifr.org/sis/mcViewAvaliacao.php
http://ictp-saifr.org/sis/qcdlhcviewAvaliacao.php
http://www.ictp-saifr.org/sis/gwavesviewAvaliacao.php
http://ictp-saifr.org/sis/neutrinoviewAvaliacao.php
http://ictp-saifr.org/sis/neuroscienceViewAvaliacao.php

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

c1A. Mathematical Biology (January 5 - 11)

The IV Southern-Summer School on Mathematical Biology (January 5 – 11) is described on the webpage http://www.ictp-saifr.org/mathbio4, and involved 1 lecturer and 47 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 biology and are supplemented with modelling exercises addressing mainly problems in ecology and epidemiology.

Topic and Lecturer:

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

c1B. Pathogen Dynamics, Climate and Global Change (Jan. 12 – 23)

The school on Pathogen Dynamics, Climate and Global (January 12 – 23) change is described on the webpage http://www.ictp-saifr.org/pathogens involved 8 lecturers and 33 participants. The school was aimed at students with with either strong interests in quantitative biology, or mathematicians and physicists interested in empirical non-linear systems. This activity provided an introduction to the basic underlying mathematical concepts used to study disease dynamics, their connections to climate systems, and the ecology and economics of land-use change.

Topics and Lecturers:

- Graciela Canziani (Universidad Nacional del Centro, Argentina)
- Andy P. Dobson (Princeton University, USA)
- Gabriela Gomes (Instituto Gulbekian de Ciência – IGC, Portugal)

- Aaron King (Univ. of Michigan, USA)
- Giulio De Leo (Stanford University, USA)
- Matteo Marsili (ICTP, Italy)
- Mercedes Pascual (University of Michigan, USA)
- Adrian Tompkins (ICTP, Italy)

c1C. Theoretical Physics (February 2 – 6)

The 3rd Joint Dutch-Brazil School on Theoretical Physics (February 2 – 6) is described on the webpage http://www.ictp-saifr.org/dutch-brazil and involved 3 lecturers and 69 participants. This school featured minicourses in the field of high-energy theoretical physics. The school was intended for graduate students and researchers of this field. This event was jointly organized with the Dutch Research School of Theoretical Physics (DRSTP).

Topics and Lecturers:

- Nima Arkani-Hamed (IAS Princeton) – Scattering Amplitudes and the Amplituhedron
- Jan de Boer (Univ. of Amsterdam) – Entanglement Entropy and its Uses
- Cumrun Vafa (Harvard Univ.) – Topological Strings and Supersymmetric Amplitudes

c1D. Biophysics of Protein Interactions (March 9 – 13)

The Minischool on Biophysics of Protein Interactions (March 9 – 13) is described on the webpage http://www.ictp-saifr.org/protein and involved 7 lecturers and 55 participants. The school presented different approaches to Coulomb systems in order to describe the electrostatic interactions in soft- and bio-matter. Attendants were invited to present their research activity in a poster session. The school was aimed graduate students and researchers in the fields of statistical mechanics, materials science, biophysics and nanobiotechnology.

Topics and Lecturers:

- Leandro Barbosa (USP-São Paulo, Brazil): Protein interactions as revealed by small-angle x-ray scattering
- Ralf Eichhorn (Nordita, Sweden): Theory of phoretic effects induced by the (counter-)ions in the system
- Yan Levin (UFRGS, Brazil): Introduction to statistical mechanics of charged systems
- Roland Netz (Freie Universität Berlin, Germany): Hydration and dielectric effects at surfaces
- Rudolf Podgornik (U. Ljubljana, Slovenia): Charge regulation and electrostatic interactions in proteins
- João Ruggiero Neto (UNESP-Rio Preto, Brazil): Electrostatic and non-electrostatic features in the interaction of lytic peptides with model membranes
- Fernando Luís Barroso da Silva (USP-Ribeirão Preto, Brazil): On the peculiar electrostatic effects observed in protein systems – a computational approach

c1E. Monte Carlo School on Event Generators (April 27 – 30)

The Monte Carlo School on Event Generators (April 27 - 30) is described on the webpage http://www.ictp-saifr.org/?page_id=6863 and involved 5 lecturers and 23 participants. This activity was organized as an external activity of ICTP-Trieste in collaboration with ICTP-SAIFR and the UNESP Nucleus of Scientific Computing (NCC). Through a series of lectures and hands-on practical tutorial sessions, this

activity provided a four day course of training in the physics and techniques used in modern Monte Carlo event generators for the Large Hadron Collider. The school was intended for advanced doctoral students and young postdocs.

Lecturers:

- Jon Butterworth (University College London, UK)
- Leif Lonnblad (Lund University, Sweden)
- Olivier Mattelaer (Durham University, UK)
- Andrzej Siodmok (CERN, Switzerland)
- David Grellscheid (ICTP-Trieste, Italy & Durham University, UK)

c1F. QCD and LHC Physics (July 22 – 31)

The School on QCD and LHC Physics (July 22 – 31) is described on the webpage http://www.ictp-saifr.org/qcdlhc and involved 7 lecturers and 41 participants. The activity discussed recent theoretical advances in predicting the scattering amplitudes produced at the LHC. Attendees were invited to present their research activities in a poster session and the school was aimed at younger postdoctoral fellows and graduate students in experimental high-energy physics.

Topics and Lecturers:

- Zvi Bern (UCLA, USA): On-shell methods
- Fernando Febres Cordero (Freiburg University, Germany): Higher-Order Calculations
- Claude Duhr (Université Catholique de Louvain, Belgium): Precision Higgs
- Daniel de Florian (FCEyN – Universidad de Buenos Aires, Argentina): Higher-Order Calculations
- Johannes Henn (IAS – Princeton, USA): Feynman Integrals
- David A. Kosower (Saclay, France): Higher-Order Calculations
- Stefan Prestel (SLAC, USA): Parton Showers
- Gavin Salam (CERN, Switzerland): Basics of QCD
- Andre Sznajder (UERJ, Brazil): LHC searches and Higgs results

c1G. Gravitational Waves (August 3 – 11)

The School on Gravitational waves: from data to theory and back (August 3 – 11) is described on the webpage http://www.ictp-saifr.org/gwaves and involved 6 lecturers, 2 speakers and 29 participants. The school presented a theoretical introduction to gravitational waves and their detection. The school was aimed at graduate students and researchers willing to acquire working knowledge in GW data analysis, physics and astrophysics.

Topics and Lecturers:

- Alessandra Buonanno (MPI Potsdam, Germany): Modeling gravitational waves: The analytical/numerical relativity interface
- Stefano Foffa (U. Geneva, Italy): Effective field theory methods to model astrophysical binaries
- Sergej Klimenko (U. Florida, USA): Detection of transient signals and coherent network algorithms in the gravitational waves data analysis
- Enrico Ramirez-Ruiz (U. California-Santa Cruz, USA): The Astrophysics of Compact Binaries
- Walter Del Pozzo (University of Birmingham, UK): Bayesian inference and gravitational wave observations
- Riccardo Sturani (IFT-UNESP / ICTP-SAIFR, Brazil): Match filtering methods in data analysis

Talks and Speakers:

- Odylio D. Aguiar (INPE & IF-USP, Brazil): Gravitational wave detection: what is new
- Rafael Porto (ICTP-SAIFR & IFT-UNESP, Brazil): The Kerr/EFT duality

c1H. International Neutrino Summer School (August 17 - 29)

The International Neutrino Summer School (August 17 – 29) is described on the webpage http://www.ictp-saifr.org/neutrino and involved 9 lecturers and 63 participants. The school dealt with all aspects of neutrino physics and lectures included experimental, phenomenological and theoretical developments. The school was aimed at young graduate or postdoctoral researchers in both theory and experimental neutrino areas.

Topics and Lecturers:

- Standard Model and Neutrino Mass Models: André de Gouvea (Northwestern University, USA)
- Neutrino Phenomenology: Boris Kayser (Fermilab, USA)
- Cosmology and Astrophysics: Pedro Holanda (IFGW-UNICAMP, Brazil)
- Accelerator Neutrinos: Kendall Mahn (Michigan State University, USA)
- Neutrino Cross Section: Kevin McFarland (University of Rochester, USA)
- Direct Mass Measurements: Susanne Mertens (LBNL, USA)
- Neutrino Detection: Kate Scholberg (Duke University, USA)
- Solar, Reactor & Atmospheric: Yifang Wang (IHEP-Beijing, China)
- Public Lecture: Marcelo Guzzo (IFGW-UNICAMP, Brazil)

c1I. Complex Networks and Applications to Neuroscience (Sept. 28 – Oct. 16)

The School on Complex Networks and Applications to Neuroscience (September 28 – October 16) is described on the webpage http://www.ictp-saifr.org/neuroscience and involved 12 lecturers, 4 speakers and 51 participants. The school covered current trends in the theory of complex networks and provided a detailed course on neuroscience.

Topics and Lecturers:

- Edson Amaro Jr (Hospital Israelita Albert Einstein, Brazil): Neuroimages techniques and mental illnesses
- Nuno M. de Araujo (Universidade de Lisboa):

  1. Percolation theory in complex networks

  2. Synchronization transitions in the Kuramoto model

  3. Structure and robustness of network infrastructures
- Stefano Boccaletti (CNR- Institute of Complex Systems – Florence -Italy, and the Italian Embassy in Israel) (by SKYPE): The Master Stability Function
- Javier M. Buldú (Center for Biomedical Technology & U.R.J.C., Madrid, Spain): Applications to Biology: from RNA to Brain Networks
- Mauro Copelli (Universidade Federal de Pernambuco, Brazil): Collective neuronal phenomena
- Ernesto Estrada (University of Strathclyde, U.K.): Structure of Complex Networks: From Graphs to Real Networks
- Jesús Gómez Gardeñes (Universidad de Zaragoza, Spain): Dynamical processes in networks
- Claudio Mirasso (IFISC, Universitat de les Illes Balears, Spain):
  1. Zero-lag and anticipated synchronization in neuronal circuits
  2. Information Processing with neuro-inspired delay-based nonlinear systems
- Vincenzo Nicosia (Queen Mary University of London, UK): Multilayer Networks

- Antonio Roque (Universidade de São Paulo at Ribeirão Preto, Brazil): An overview of single-cell and neural network models
- Adriano Tort (Universidade Federal do Rio Grande do Norte, Brazil):

  1. Detecting and tracking cell assemblies

  2. Cross-frequency coupling between brain rhythms
- Raúl Vicente (University of Tartu, Estonia): Analysis of neuronal data

Topics and Lecturers:

- Syamal Dana (Indian Institute of Chemical Biology – Kolkata, India): Chimera states in globally coupled network of oscillators
- Tiago Pereira (Imperial College London): Synchronization in Complex Networks: Structure and Dynamics
- Roberto Andrade (Universidade Federal da Bahia, Brazil): Recovering evolutionary history by complex network modularity analysis
- Ricardo Barros Sampaio (Fundação Oswaldo Cruz – Brasília, Brazil): Complex Network Analysis on Neglected Diseases: A Solution for Public Health

c2. Workshops

ICTP-SAIFR organized two workshops in 2015 on the subjects of Advanced Techniques for Scientific Programming and Management of Open Source Software Packages (13 – 24 April) and Gravitational Waves (August 11 -15). The purpose of these workshops was to discuss status, recent progress, perspectives in each of the fields mentioned.

c2A. Advanced Techniques for Scientific Programming and Management of Open Source Software Packages (13 – 24 April)

The curriculum activities focused on creating modular and reusable software frameworks with a scripting language interface and also covered modern collaborative software management tools. The webpage of the workshop is http://www.ictp-saifr.org/?page_id=6863 and speakers included:

- David Grellsheid (ICTP-Trieste, Italy & Durham University, UK)
- Ivan Girotto (ICTP-Trieste, Italy)
- Axel Kohlmeyer (Temple University, Philadelphia, USA)
- Jennifer Thompson (Durham University, UK)

c2B. Astrophysics and Relativity (Astro-GR 2015)

The workshop addressed crucial questions in the field of astrophysics and relativity, and focused on the interpretation of gravitational wave observations using electromagnetic astrophysics. The webpage of the workshop is http://www.ictp-saifr.org/astrogr and speakers and topics included:

- Tal Alexander (Weizmann Institute): Dynamically triggered supra-exponential growth of black hole seeds in the early universe
- Pau Amaro-Seoane (MPI-Potsdam): The astrophysics of emris Capture of compact objects by SMBHs
- Matthew Benacquista (University of Texas at Brownsville): Prospects for observing dynamically formed stellar mass black hole binaries with gravitational waves
- Tamara Bogdanovic (Georgia Tech): Can star disk collisions explain the missing red giant problem in the galactic center ?

- Jorge Cuadra (Pontificia Universidad Católica de Chile): Gas dynamics and SMBH accretion in the Galactic centre.
- Massimo Dotti (Bicocca University): Do MBH binaries coalesce*?*
- Zoltan Haiman & Daniel J. D'Orazio (Columbia University): Hydrodynamics of circumbinary disks and corresponding binary signatures
- Pablo Laguna (Georgia Tech): Stellar tidal disruptions for dummies
- Paola Leaci (U. La Sapienza, Rome): New prospects by the Advanced LIGO-Virgo Detector Network
- Ajith Parameswaran (International Centre for Theoretical Sciences): Measuring the energy and angular momentum lost by binary black holes into GWs
- Walter Del Pozzo (University of Birmingham): Testing General Relativity with GWs
- Bangalore Sathyaprakash (University of Cardiff): Undreamt by Einstein: Prospects in GW Astronomy and challenges
- Deirdre Shoemaker (Georgia Tech): From NR to GWs for BBHs
- John Veitch (University of Birmingham): Extracting astrophysics of neutron stars from compact binary GW observations
- Salvatore Vitale (Massachussets Institute of Technology): What can GWs tell us about black holes?

c3. Minicourses

The ICTP-SAIFR organized four minicourses in 2015 with invited lectures on different topics including Energy Landscapes in Biophysics, Numerical Spectral Methods, Effective Field Theory and Applications, Functional Renormalization Group. The topics, lecturers and webpages for these minicourses are:

1) March 8, Onuchic Minicourse on Energy Landscapes in Biophysics

   José Nelson Onuchic (Rice University, USA)

   Title: Energy Landscapes in Biophysics

   http://www.ictp-saifr.org/onuchic

2) March 18 – April 15, Rawitscher Minicourse on Numerical Spectral Methods

   George Rawitscher (University of Connecticut)

   Title: Numerical Spectral Methods for Solving Differential or Integral Equations

   http://www.ictp-saifr.org/rawitscher

3) August 3 - 6, Bedaque Minicourse on Effective Field Theory and Applications

   Paulo Bedaque (University of Maryland, USA)

   Title: Effective Field Theory and Applications

   http://www.ictp-saifr.org/bedaque

4) October 6 - 16, Codello Minicourse on the Functional Renormalization Group

   Alessandro Codello (CP3 – Origins, Odense, Denmark)

   Title: Functional Renormalization Group

   http://www.ictp-saifr.org/codello

C4. Program

In 2015, the Program on Particle Physics at the Dawn of the LHC13 (http://www.ictp-saifr.org/lhc13, October 19 – December 19) organized by Prof. Mariano Quirós (IFAE & ICREA, Barcelona) intended to discuss the status of the field and the possible impact of the LHC13 run. Participants in the program include:

- Alexander Belyaev (U. of Southampton, UK): Nov 22 – Dec 13, room 112
- Karim Benakli (Jussieu – Paris, France): Oct 26 – Nov 15, room 113
- J. Alberto Casas (IFT-UAM/CSIC – Madrid, Spain): Nov 2 -28, room 102
- Giacomo Cacciapaglia (U. de Lyon, France): Dec 12 – 20, room 116
- Antonio Delgado (U. of Notre Dame, USA): Oct 18 – 24, room 102
- Emilian Dudas (Ecole Polytechnique, France): Dec 12 – 18, room 102
- José Ramón Espinosa (IFAE & ICREA, Barcelona, Spain): Nov 12 – 30, room 115
- Tony Gherghetta (U. of Minnesota, USA): Nov 28 – Dec 4, room 102
- Germano Nardini (U. of Bern, Switzerland): Nov 9 – Dec 8, room 108
- Aurore Savoy Navarro (APC, CNRS/IN2P3, France): Nov 5 – Dec 7, room 116
- Stefan Pokorski (U. of Warsaw, Poland): Nov 25 – Dec 16, room 112
- Michele Redi (U. of Florence, Italy): Nov 15 – Dec 12, room 113
- Carlos Savoy (Saclay, France): Oct 20 – Dec 7, room 116
- Marc Thomas (U. of Southampton, UK): Nov 23 – Dec 4, room 113
- Mateo García (IFAE, Barcelona, Spain): Oct 12 – Dec 19, room 104

C5. Outreach event

The ICTP-SAIFR organized one outreach event in 2015 in collaboration with IFT-UNESP: a competition for undergraduate physics students held on October 31 in which winners were determined by a 3-hour exam. The title of the competition is 2015 Premio IFT-UNESP/ICTP-SAIFR para Jovens Físicos and the webpage with the names of the 5 winners is http://www.ictp-saifr.org/?page_id=10821

C6. Annual meeting of ICTP-SAIFR councils

The annual meeting of the ICTP-SAIFR Steering Committee and Scientific Council was held from February 9-10 and included closed meetings of the two councils.

The webpages of this meeting is http://www.ictp-saifr.org/?page_id=6216

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, Batavia

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 2015, weekly seminars and colloquia were regularly organized. There were 163 seminars and colloquia in 2015 and the complete list is on the webpage http://www.ictp-saifr.org/?page_id=7446. There were also weekly journal club meetings in particle physics and in cosmology, and the webpages for these journal club meetings are http://www.ift.unesp.br/users/matheus/partJC/ and https://sites.google.com/site/ictpsaifrjc/

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. Also, one of the IFT-UNESP technical assistants, Rafael Mascarenhas, has been dedicated to filming ICTP-SAIFR activities. In 2014, part of the space obtained from IFT on the first floor was divided into four new visitor offices for ICTP-SAIFR which can host up to nine visitors and, in 2015, sound-proof windows were installed in these offices.

The UNESP university is paying for four ICTP-SAIFR secretaries including our executive secretary, our accountant, our computer systems manager and an 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. Activity plan for the next period

In 2016, the ICTP-SAIFR will evaluate the progress of the two newly hired tenure-track fellows in astrophysics and cosmology and continue its search for a permanent researcher in the field of complex systems with biological applicaions. It also wiil hire a joint faculty member with Perimeter Institute (Waterloo) under the newly signed agreement, and begin the planning of a joint Masters program with Perimeter Institute involving a joint one-week school in July.

Confirmed scientific activities in 2016 which will be organized by ICTP-SAIFR include international schools and workshops on various topics including mathematical biology, physics applications in biology, climate modeling, effective field theory, next generation quantum materials, magnetic fields in hadron physics, string theory, dark matter, spectroscopy, particle physics and cosmology, econophysics and entrepeneurship. The list of 2016 activities confirmed up to now are on the webpage http://www.ictp-saifr.org/?page_id=9095 and include the activities:

School on Physics Applications in Biology
January 11-29, 2016

School on Effective Field Theory across Length Scales
February 22 – March 4, 2016

School on Fundamental Aspects of String Theory
May 23-31, 2016

School on Dark Matter
June 27 – July 9, 2016

Meetings/Programs/Workshops

2016 Meeting of Scientific Council and Steering Committee
February 1-2, 2016

Workshop on Next Generation Quantum Materials
April 4-8, 2016

Workshop on Magnetic Fields in Hadron Physics
May 9-13, 2016

VIII Workshop on String Field Theory and Related Aspects
May 31 – June 3, 2016

International Workshop on Particle Physics and Cosmology
July 11-15, 2016

Econophysics Colloquium 2016
July 27-29, 2016

Program on Particle Physics
October 3 – November 30, 2016

Symposium on ICTP-SAIFR and Science Policy in South America
November 7-8, 2016

Minicourses/Minischools

Joint ICTP-Trieste/ICTP-SAIFR Advanced School on Regional Climate Modeling over South America
February 15-19, 2016

Lehner/Pretorius Minicourse on Numerical Relativity
March 27 – April 2, 2016

School on Spectroscopy in Astrophysics and Laboratory Plasmas
July 8-9, 2016

IFT-Perimeter-SAIFR Journeys into Theoretical Physics
July 18-23, 2016

Brazilian Entrepeneurship Workshop for Scientists and Engineers
October 17-21, 2016

Prize Competition

2016 Prêmio IFT-UNESP/ICTP-SAIFR para Jovens Físicos
July 23, 2016

7. Use of Reserva Tecnica and Beneficios Complementares Funds

In 2015, the reserva tecnica and beneficios complementares funds were used for the following purposes:

a) Purchase of acoustic windows for the rooms of the first floor including evaluation by a specialist in acoustics: 23,555.00 reais

b) Purchase of security cameras: 2,920.00 reais

c) Purchase of the books "Cosmology and Particle Astrophysics", "Star as Laboratories for Fundamental Physics", "The Early Universe", "Statistical Data Analysis" and "Statistics for Nuclear and Particle Physicists": 1,136.80 reais

d) Purchase of white board for one of the offices of the first floor: R$ 499.00 reais

e) Purchase of a photographic camera for photos of ICTP-SAIFR activities: 539,10 reais

f) Per diem for research visit of Young Investigator Riccardo Sturani to University of Geneva: 3,000.00 reais

g) Reimbursement of hotel, ground transportation and health insurance for research visit of ICTP-SAIFR member Prof. Alexandre Reily to Nordita: 7,175.32 reais

h) Specialized Publication in The Astrophysical Journal Letters (The dark matter profile of the milky way, Miguel Pato & Fabio Iocco, April): 1,581.87 reais

i) Advertisement of ICTP-SAIFR activities and job openings in Physics Today (June 2015): 1,978.31 reais

j) Airfare and per diem for participation as a lecturer in the First Peruvian School on High-Energy Physics and Cosmology of ICTP-SAIFR member Prof. Eduardo Pontón to: 6,193.32 reais

k) Airfare, registration and visa for conference (Strings 2015) of ICTP-SAIFR director Prof. Nathan Berkovits to Bangalore (India): 4,264.04 reais

l) Airfare for conference (Geometric methods for quantum field theory) of ICTP-SAIFR director Prof. Nathan Berkovits to Villa de Leyva (Colombia): 2,830.66 reais

m) Airfare for participation as a lecturer in the 6th Latin American String School of ICTP-SAIFR director Prof. Nathan Berkovits to México: 3,373.54 reais

n) Per diem and registration fee for conference (LISHEP 2015) of ICTP-SAIFR vice-director Prof. Rogerio Rosenfeld to Manaus: 3,693.35 reais.

8a. 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. T. Azevedo, N. Berkovits, "Open-closed superstring amplitudes using vertex operators in AdS(5) x S-5", *Journal of High Energy Physics*, n° 2, p. 107, 2015.

2. N. Berkovits, "Twistor origin of the superstring", *Journal of High Energy Physics*, n° 3, p. 122, 2015.

3. N. Berkovits, "Origin of the pure spinor and Green-Schwarz formalisms", *Journal of High Energy Physics*, n° 7, p. 091, 2015.

4. O. Chacaltana, J. Distler, A. Trimm, "Seiberg-Witten for Spin(n) with spinors", *Journal of High Energy Physics*, n° 8, 2015.

5. O. Chacaltana, J. Distler, A. Trimm, "Tinkertoys for the E-6 theory", *Journal of High Energy Physics*, n° 9, p. 007, 2015.

6. O. Chacaltana, J. Distler, A. Trimm, "Tinkertoys for the twisted D-series", *Journal of High Energy Physics*, n° 4, p. 173, 2015.

7. O. Chacaltana, J. Distler, Y. Tachikawa, "Gaiotto duality for the twisted A(2N-1) series", *Journal of High Energy Physics*, n° 5, p. 075, 2015.

8. V. O. Rivelles, "Gauge theory formulations for continuous and higher spin fields", *Physical Review D*, vol. 91, n° 12, p. 125035, 2015.

9. A. Melikyan, E. Pereira, V. O. Rivelles, "On the equivalence theorem for integrable systems", *Journal of Physics a-Mathematical and Theoretical*, vol. 48, n° 12, p. 125204, 2015.

10. G. T. Feliciano, C. Sanz-Navarro, M. D. Coutinho-Neto, P. Ordejon, R. H. Scheicher, A. R. Rocha, "Capacitive DNA Detection Driven by Electronic Charge Fluctuations in a Graphene Nanopore", *Phys. Rev. Appl.*, vol. 3, n° 3, p. 034003, 2015.

11. E. T. Sato, A. R. Rocha, L. F. das Chagas Silva de Carvalho, J. D. Almeida, H. Martinho, "Molecular model for hydrated biological tissues", *Phys. Rev. E*, vol. 91, n° 6, p. 063310, 2015.

12. A. C. M. Padilha, A. R. Rocha, G. M. Dalpian, "DFT + U Simulation of the Ti 4 O 7 − Ti O 2 Interface", *Physical Review Applied*, vol. 3, n° 2, 2015.

13. C. E. P. Villegas, A. R. Rocha, "Elucidating the Optical Properties of Novel Heterolayered Materials Based on MoTe2-InN for Photovoltaic Applications", *J. Phys. Chem. C*, vol. 119, n° 21, p. 11886–11895, 2015.

14. G. Burdman, Z. Chacko, R. Harnik, L. de Lima, C. B. Verhaaren, "Colorless top partners, a 125 GeV Higgs boson, and the limits on naturalness", *Physical Review D*, vol. 91, n° 5, p. 055007, 2015.

15. G. von Gersdorff, E. Ponton, R. Rosenfeld, "The dynamical composite Higgs", *Journal of High Energy Physics*, n° 6, p. 119, 2015.

16. E. Bertuzzo, C. Frugiuele, T. Gregoire, E. Ponton, "Dirac gaugions, R symmetry and the 125 GeV Higgs", *Journal of High Energy Physics*, n° 4, p.

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8a2. Articles by ICTP-SAIFR Postdoctoral Associates

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9. First page of publications

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

12. Scientific reports of postdocs

See annexed file for scientific reports of

Nicolás Bernal, José Hugo García, Gero von Gersdorff, Chrysostomos Kalousios, Fabien Lacasa, Saeed Mirshekari, Luana Pedroza, Ryo Suzuki e Alberto Tonero.