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

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Host Institution: Instituto de Física Teórica-UNESP

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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 this 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.

To fulfill the need for such a theoretical physics institute in South America, the ICTP South American Institute for Fundamental Research (ICTP-SAIFR) was created in 2011 in Sao Paulo as a collaboration between the Sao Paulo Research Funding Agency (FAPESP), the International Centre for Theoretical Physics (ICTP-Trieste) - a category 1 institute of UNESCO, the Sao Paulo State University (UNESP), and the Instituto de Fisica Teórica (IFT-UNESP) in whose building it is located. The ICTP- SAIFR in South America was the first regional center of ICTP created outside of Trieste, and because of its success, the ICTP-Trieste has now created regional centers in the continents of Central America (Mexico), Africa (Ruanda), and Asia (China).

In this UNESP-ICTP-FAPESP collaboration, the role of UNESP is to provide the infrastructure of the IFT-UNESP building including an auditorium, a computer lab, and first floor office space, as well as provide the salaries of their two secretaries, one accountant, one computer technician, and up to five tenured research professors. The role of ICTP-Trieste is to provide organizational support to the secretaries, and financial support for visitors from other South American countries. And the role of FAPESP is to provide financial support for visitors, postdocs, and Young Investigators, and for the organization of schools and workshops.

Despite its brief existence, the ICTP-SAIFR has already established itself as a leading institute for theoretical physics. With the help of a world-class scientific council and international search committee, ICTP-SAIFR has been able to sign exchange agreements with the other leading theoretical physics institutes around the world and attract the top candidates for its faculty and postdoctoral positions. Its single tenured faculty member is Eduardo Ponton, a particle physicist who held a tenure-track position at Columbia University and received a competing offer from CEA-Saclay in Paris, and its current two tenure-track faculty members are Rafael Porto (cosmologist from Princeton) and Fabio Iocco (astrophysicist from Stockholm) who are funded by a donation of the Simons Foundation (New York) together with a Young Investigator grant from FAPESP. A second tenured ICTP-SAIFR faculty member will soon be hired through a joint agreement signed by Perimeter Institute (Waterloo) and UNESP in which the faculty member will spend 8 months/year at ICTP-SAIFR and 4 months/year at Perimeter and will coordinate a joint masters program for outstanding students from Latin America. Furthermore, ICTP-SAIFR has obtained a private donation called the "Isaias Raw Chair" which will supplement the salary of a future professor, and is actively pursuing other private donations from potential sponsors such as the Serrapilheira Institute.

Its postdocs and Young Investigators are selected from thousands of applications received through an online application process. Almost all received their PhD's at institutions outside Brasil, and many of these postdocs have already secured permanent faculty positions at other Brazilian institutions. So ICTP-SAIFR has been very successful at reversing the "brain drain" and attracting talented young physicists to Brasil. The main role of a theoretical physics institute is to foster the interchange of information between visiting and local researchers, and the ICTP-SAIFR has an active visiting program with over 150 visitors per year spending between one week and two months at the institute. There are weekly seminars and journal clubs in various subareas of theoretical physics, and the complete list of visitors and research seminars can be found on the ICTP-SAIFR webpage www.ictp-saifr.org. Research seminars are frequently recorded and made available online using ICTP Trieste equipment, and this recording equipment will be improved through the new agreement with Perimeter Institute.

In addition to the research conducted by its members and visitors, the ICTP-SAIFR regularly organizes schools, minicourses, workshops and programs for doctoral students and researchers in all areas of theoretical physics. The success of these activities has allowed the IFT-UNESP masters and doctoral programs to attract the top students in theoretical physics from all of South America, and to receive the top ranking of Brazilian graduate physics programs since 2011.

During the next five-year period, the ICTP-SAIFR intends to build on these recent accomplishments and continue to improve its research and organizational activities. Through its new agreement with Perimeter Institute involving a joint faculty member and a joint masters program, these activities will have an expanding impact and include outreach activities for high-school students and teachers, as well as for the general public. In addition to the support it receives from public institutions such as FAPESP and UNESP, ICTP-SAIFR is actively pursuing support from private institutions to consolidate its status as the premier theoretical physics institute in South America.

4. Accomplishments in the period

The number of current ICTP-SAIFR permanent researchers is relatively small, but

the goal is to gradually expand to include research in all subareas of theoretical physics. Although the current economic crisis has made it difficult for UNESP to open new permanent positions, the large number of visitors and associated researchers at ICTP-SAIFR allows it to organize activities and conduct research in a growing number of subareas.

In this year beginning December 2016, several new researchers came to ICTP-SAIFR working in different areas of theoretical physics. At the faculty level, Pedro Vieira (integrability and gauge theory) was hired by UNESP in February 2017 with a 2-year temporary professor position which he will occupy until a UNESP permanent position becomes available for him. Pedro Vieira is the coordinatator of the Perimeter-SAIFR agreement, and was awarded in 2015 the Gribov Medal for his research, which is a medal awarded every two years by the European Physical Society to an outstanding young theoretical physicist.

At the postdoc level, ICTP-SAIFR hired several new researchers with FAPESP fellowships including Ekaterina Karukes (February 2017, dark matter), José Herrera Diestra (June 2017, complex systems), Andrea Guerrieri (June 2017, integrability), Bithika Jain (September 2017, particle physics) and Antonino Troja (October 2017, cosmology). In addition, ICTP-SAIFR initiated in October 2017 a new two-year "Visiting Fellow" position for young faculty at other instutions in Latin America who would like to spend time at ICTP-SAIFR. Current visiting fellows include Riccardo Sturani (IIP Natal, gravitational waves), Farinaldo Queiroz (IIP Natal, astrophysics) and Mario Leandro Aolita (UFRJ, quantum information).

Furthermore, an ICTP-SAIFR search committee was formed in March 2017 to select the next two Simons-Fapesp fellows which is chaired by Peter Goddard (IAS Princeton) and with members Simon Levin (Princeton), William Bialek (Princeton), Marcus Aguiar (Unicamp), David Gross (KITP), Juan Maldacena (IAS Princeton) and Belita Koiller (UFRJ). One of these Simons-FAPESP positions will be in the area of complex systems with connections to biology, and the other position will be in any area of theoretical physics in which ICTP-SAIFR does not yet have a faculty member. After analyzing hundreds of applications, a short list of 12 candidates was selected in July 2017. Interviews were conducted in November 2017 for the position in theoretical physics, and interviews will be conducted in January 2018 for the position in complex systems. The expectation is that the two new Simons-FAPESP fellows will begin their positions in the second half of 2018.

The main physics research result during this year was the observation of gravitational waves coming from the collision of black holes and neutron stars which led to the 2017 Nobel Prize in Physics. In addition to visiting fellow Riccardo Sturani who is a member of the LIGO collaboration whose leaders were awarded the Nobel Prize, ICTP-SAIFR faculty includes Rogério Rosenfeld who is a member of the DES collaboration which visually observed the neutron star collision, Rafael Porto who performs theoretical analysis of black hole collisions using effective field theory, and Fabio Iocco who uses these astrophysical events to extract information about our universe such as the existence of dark matter.

Another major result during this year involved the development of new theoretical techniques to study the interactions of fundamental particles. This new approach is called the Nonperturbative Bootstrap and was awarded in 2017 a grant of several million dollars by the Simons Foundation http://bootstrapcollaboration.com/. ICTP-SAIFR faculty member Pedro Vieira is one of the principal investigators of this grant, and organized at ICTP-SAIFR the first Simons workshop on this topic from May 15 – June 16, 2017 with over 75 researchers. Pedro Vieira was also invited to give a plenary talk on his research at the annual Strings conference in June 2017.

In addition to these research activities, ICTP-SAIFR held several outreach activities in 2017. These included a monthly informal discussion in a bar called "Papos de Física" on different topics of theoretical physics, Saturday morning lectures for high-school students by ICTP-SAIFR faculty Pedro Vieira and Rogério Rosenfeld, a weekend workshop for high-school teachers organized in collaboration with Perimeter Outreach Director Greg Dick, and public lectures by distinguished professors including Mathias Zaldarriaga (IAS Princeton) and William Phillips (U. Maryland, 1997 Nobel Prize Laureate). Dozens of newspaper articles and online blogs were written on these activites by ICTP-SAIFR journalist Ivan Cardoso who was hired in March 2017 with a FAPESP scientific journalism fellowship. In addition, journalist Ivan Cardoso translated several pedagogical pamphlets of the Perimeter Institute into portuguese which will be made available for high-school teachers.

In 2017, a new international agreement with the Kavli Institute for Theoretical Physics was signed and several international agreements with other theoretical physics institutes were renewed. The complete list of international agreeements can be found at http://www.ictp-saifr.org/?page_id=2193. In February 2017, the first group of joint masters students with Perimeter Institute began their studies at the IFT in São Paulo. And in August 2017, they moved to Waterloo for the next 12 months to participate in the Perimeter Scholars International program. And in July 2017, the second edition of the IFT-Perimeter-SAIFR school was organized for the top undergraduate students from Latin America and 4 students were chosen to participate in the second group of the joint masters program.

On the ICTP-SAIFR scientific council, the terms of council members Barton Zwiebach (MIT, string theory) and Marcela Carena (U. Chicago/Fermilab, particle physics) expired in 2017. The two new members of the ICTP-SAIFR scientific council who began in 2017 are Eduardo Fradkin (U. Illinois, condensed matter theory) and Andre De Gouvea (Northwestern U., neutrino physics).

Between December 2016 and November 2017, the number of visitors, schools and workshops increased over the previous years. 181 visitors stayed for more than one week and more than 100 seminars and colloquia were presented. The ICTP-SAIFR organized activities in diverse areas of theoretical physics which included 7 international schools on the topics of mathematical biology, cold atoms, biological soft matter, AdS/CMT correspondence, bootstrap, cosmology, density functional theory and quantum information theory, 9 workshops on general relativity, solitons, dark matter, cosmology and gravitation, Cherenkov Telescope Array, quantum field theory and quantum gravity, cosmology and astrophysics, density functional theory and quantum information theory, condensed matter physics as well as 4 minicourses on pure spinor correlation functions, effective field theory of gravity, mathematica and machine learning. Also, a 5-week program funded by the Simons Foundation on the topic of the conformal bootstrap was held in May and June. Finally, there were weekly meetings in 2017 of a colloquium and four separate "journal clubs'' in the areas of string theory, particle physics, integrability and cosmology. These four journal clubs and colloquia discussed current research problems at the frontiers of scientific knowledge and included the participation of students and researchers both from IFT-UNESP and from other nearby universities.

The ICTP-SAIFR scientific council approved 8 international schools to be held in 2018 on the topics of mathematical biology, physics applications in biology, complex networks, particle physics, integrable models, dark matter and neutrino detection, entrepreneurship and gravitational waves. In addition, workshops will be organized on the topics of ecological networks, non-linear dynamics, gravity and holography, mathematical physics, condensed matter physics and cosmology.

The activities of ICTP-SAIFR in 2017 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

In the non-minimal pure spinor formalism of superstring consisten prescription to compute scattering amplitudes can be formulated with the so-called b-ghost field. In publication [8] a simplified b-ghost for the D=11 non-minimal pure spinor superparticle was constructed and shown to be nilpotent.

Solutions with knotted topological structures play an important role in various areas of physics. In publication [31] knotted solutions for electromagnetism and fluid dynamics and a map between these two theories was found under certain assumptions.

In publication [185] the grand partition function of N=4 super Yang-Mills theory is computed at one loop in the SU(2) sector with general chemical potentials and changes in the Hagedorn temperature are discussed.

The classification of irreducible unitary representations of the Poincaré group allow in principle for massless particles of continuous spin. Publication [150] shows that it is not possible to couple minimally such a particle to an abelian background gauge field.

The problem of quark confinement is an important unsolved issue. In publication [172] the quark-antiquark potential is computed in N=4 super Yang-Mills in the presence of a codimension-1 defect. In publication [173] a quantum mechanical supersymmetric integrable hamiltonian is constructed and the spectrum which contains entangled states is studied. The replica trick is used in publication [174] to compute the entropy of cylinder amplitude in string theory.

In publications [175] and [176], the non-perturbative bootstrap methods were combined with consistency properties coming from crossing and unitary to obtain bounds on the couplings of interacting field theories in two dimensions.

a2. Condensed Matter

One of the signatures of symmetry breaking in solids is the appearance of spatial fluctuations in some quantities that are known as Friedel oscillations. In materials such as graphene these oscillations are hidden due to a commensurability effect related to the fact that the wavelength of these oscillations are identical to the lattice spacing. In publication [151] it is shown how to improve the density functional theory, applied to carbon nanotubes as an example, to take this effect into account.

In publication [152], a study of DNA translocation through a graphene nanopore is studied using a methodology that combines quantum mechanics/molecular mechanics in a non-equilibrium Green's function framework to

simulate the electronic transport of nanoscopic devices in the presence of solvents.

In publication [177], the ground state of a three-dimensional quantum ball is studied in potentials with spontaneous symmetry breaking. In this background, the symmetric ground state is shown to dynamically evolve into a doubly-degenerate symmetry-breaking ground state. Under displacement, the doubly-degenerate ground state encounters an asymmetric Josephson oscillation.

a3. Particle and Astroparticle Physics

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

An exciting possibility that explains why the Higgs mass is light invokes a shift symmetry arising in the so-called composite Higgs models, which postulates that the Higgs boson is a pseudo-Nambu-Goldstone boson (pNGB) arising from the spontaneous breaking of a global symmetry. One signature of this class of models is the existence of a radial excitation associated with the breaking of the global symmetry. In publication [136] the signatures of this new particle, called "global Higgs", was studied in detail at the LHC.

In the absence of new particles one can use an effective lagrangian approach to parametrize new physics effects. In publication [13] a dimension six effective lagrangian is studied paying particular attention to unitarity violation in 2 to 2 scattering amplitudes.

Dark matter is another relevant topic since it has only been detected in astronomical measurements so far and is widely believed that dark matter is made of a new fundamental particle. The dark matter sector communicates with the observable sector through what is called mediator particles. In publication [141] a low mass Z' mediator is studied in the case of fermionic dark matter, deriving collider bounds on this particle. Collider limits on Z' arising from grand unification theories were studied in publication [142]. Next leading order corrections are used in publication [143] to improve the collider bounds on Z'. Publications [144, 145] propose and study a method to determine whether the dark matter is a Majorana particle using only direct detection data. Dark matter models usually require a parity-like symmetry to ensure the stability of the dark matter particle. Publication [146] studies a model with a non-supersymmetric parity arising from the spontaneous breaking of a gauge symmetry. Publication [147] studies the effects of the existence of a right-handed neutrino in the indirect detection of dark matter through its annihilation.

The Cherenkov Telescope Array (CTA) will be a new instrument for detecting gamma rays that can arise from dark matter annihilation. In publication [148] a comparison is made of the reach of CTA compared to the LHC in constraining dark matter models.

The origin of neutrino masses is still an open problem and publication [149] proposes a two Higgs doublet model with an extra abelian symmetry to address this issue.

The LHC continues to probe the physics of the Standard Model (SM) and to search for new phenomena beyond the Standard Model. In particular, the CMS collaboration has been very active in this area, as shown in publications [32-135]. After the discovery of the Higgs boson one of the priorities is to study its potential that gives rise to spontaneous symmetry breaking. In particular, the triple Higgs interaction has to be measured and this can be achieved in the measurement of double Higgs production. In publication [36] the search for double Higgs production with the b-b-tau-tau final state and a limit of 43 times the SM cross section was

established. In publication [32] constraints on anomalous quartic gauge boson self-interactions were obtained. Dark matter searches are conducted at the LHC by looking at events with missing energy. In publication [42] bounds on monophoton events were obtained. Top quark partners with exotic charges are predicted in many composite Higgs models and in publication [43] a search for these particles was conducted at CMS. Many searches for physics beyond the SM were conducted (supersymmetry, new resonances, dark matter, mini black holes, etc) but no new phenomena have been found yet and the SM has been confirmed with ever greater accuracy at the LHC.

The idea of holography has been applied in QCD in order to obtain non-perturbative results. In publication [18] it has been used to estimate electromagnetic form factors for charmed mesons. Publication [19] computes the masses and electroweak decay constants of charmed mesons using Schwinger-Dyson and Behte-Salpeter equations.

a4. Cosmology and Gravity

The 2017 Nobel Prize in Physics was awarded to physicists who proposed and led the Laser Interferometer Gravitational-wave Observatory (LIGO) collaboration for their *"decisive contributions to the LIGO detector and the observation of gravitational waves"*. A new window to the Universe is now open. Publications [153-160, 162-171] are all based on the Advanced LIGO ground-breaking results.

In publication [161], an effective field theory (EFT) approach is used to study the conservative dynamics of a two-body system at fourth post Newtonian order and at fifth order in Newton's constant. Ambiguities that appear in the 4^{th} post Newtonian calculations are addressed in publication [137]. Publication [165] addresses the issue of how well the properties of heavy binary black holes can be estimated in future detections by LIGO and Virgo. The impact of the matter distribution in the Universe along the path of a gravitational wave detected by future space-based interferometers such as LISA was studied in publication [166]. In publication [171] the use of gravitational waves to probe how compact binaries are formed is studied. The radiation reaction for spinning bodies in the EFT approach is computed for both spin-orbit and spin-spin effects in publications [138, 139]. In publication [140] the corrections to the gravitational binding energy of binary black holes are computed in analogy to the Lamb shift.

New results in Observational Cosmology are being obtained by mapping large areas of the sky measuring the redshift of a large number of galaxies either using photometry (such as the case of the Dark Energy Survey - DES) or spectroscopy (such as the Sloan Digital Sky Survey - SDSS). Publication [23] deals with detection of strong gravitational lensing systems in DES. One of these systems is used to study the dark matter distribution in the halo of a cluster of galaxies at redshift 1 in publication [24]. Publication [25] presents results of galaxy maps from the Milky Way to the distant Universe measured by SDSS-IV. A new quasar is presented in publication [26] and a model for a strongly lensed quasar is presented in publication [27].

The collapse of a collisionless self-gravitating system is studied both numerically and analytically in publication [28], where it is shown that the usual Vlasov-Poisson equation is inadequate to describe the system.

a5. Astrophysics

The existence of dark matter has so far been inferred only from astrophysical and cosmological observations. For instance, the distribution of dark matter in 36 dwarf galaxies from their rotational curves is the subject of publication [184]. In publication [14] a new software called *galkin* which compiles data from the Milky Way rotation curve is made available to the community. An estimate of

the dark matter density profile in the region of the Milky Way bulge is presented in publication [15]. The uncertainties in the model of our galaxy which are important for the direct and indirect detection of dark matter are carefully assessed in publication [16].

The prospects for the observation of supernova remnants with CTA are studied in publication [10] whereas a new method to identify active galactic nuclei in photometric surveys is proposed in publication [1]. In publication [11] a multi-wavelength analysis of the blazar OJ 287 is presented and compared to a binary supermassive black hole model. The impact of turbulence in the measurement of Faraday rotation maps used to estimate magnetic fields is the subject of publication [12].

a6. Complex Systems

The use of networks to model complex systems such as the banking system, electricity power grids and the internet has been greatly developed in the past decade. An interesting recent application is the modeling of epidemic outbreaks. In publication [183] a synthetic network with temporal structure in addition to topological ones is constructed to devise surveillance strategies designed to select signs for early detection of the outbreak of infectious diseases. In particular, the efficacy of the strategies are compared by measuring how long they increase the lead time in epidemic simulations.

A surprising new phenomenon in complex systems has been studied in the last decade: the symmetry breaking of a homogeneous synchronous state consisting of a large population of nonlocally coupled identical phase oscillators into two coexisting spatially extended coherent and noncoherent subpopulations, which are called chimera states. In publication [9] these states are found in the numerical simulation of an array of coupled Josephson junctions.

a7. Mathematical Biology

The mechanisms responsible for the origin of species, called speciation, is not yet understood. Among the important questions remaining to be answered is the role of geographical barriers and the number of genes involved in the evolution of reproductive isolation. Reproductive isolation between initially compatible individuals is a requirement for speciation. The case of sympatric speciation, where new species arise from a population inhabiting a single geographical region, is still controversial. In publication [2] it is shown that sympatric speciation can occur in a neutral scenario with assortative mating (mating preferentially within similar individuals) and finite genomes.

Ring species are groups of organisms dispersed along a ring-shaped region in such a way that the two ends of the population that meet after many generations are reproductively isolated. Publication [3] simulates the evolution of ring species using an agent-based speciation model. This model assumes that individuals become sexually isolated above a given genetic difference and incorporates exogenous and endogenous barriers, and it is used to assess the relative contribution of these barriers to ring species evolution.

Groups in nature can be formed by interactions between individuals, or by external pressures like predation. It is reasonable to assume that groups formed by internal and external conditions have different dynamics and structures. In publication [17] a computational model is proposed to investigate the effects of individual recognition on the formation and structure of animal groups.

The interaction between species can affect their co-evolution if they are linked by gene flow. The effects of the pattern of connections between communities and the number of communities on the coevolutionary dynamics between two species are studied in publication [5]. Publication [6] deals with the population

growth of two species that share the same predators, where a model is developed to predict the abundance ratio of competitor species based on changes of their habitat conditions. This model was able to predict the actual relative abundance of two species of marsupials.

The dynamics of populations with three different traits, called morphs, taking into account the genetics of the different morphs, is modeled in Publication [4] using a game-theoretic approach.

b. Research related to visitors

Between December 2016 and November 2017, the ICTP-SAIFR hosted 99 short-term visitors who stayed less than four days, 141 middle-term visitors who stayed between five and fourteen days, and 41 long-term visitors who stayed more than two weeks. The complete list of visitors to ICTP-SAIFR can be found on the webpage http://www.ictp-saifr.org/?page_id=14418
The research of some of the visitors is described below:

Denis Dalmazi and Elias Leite Mendonça – FEG-UNESP, Guaratinguetá (12/12-16/2016)

We have investigated massive spin-2 theories in D=2+1 dimensions. Both parity singlets (self-dual (SD) models) and parity doublets. We have developed new singlet and doublet models with WTDIFF (Weyl and transverse diffeomorphisms) symmetries. We have shown that the new SD models of second and third order in derivatives are related to each by means of master actions and Noether Gauge embeddings of local symmetries just like the usual SD models. The new models give rise to nonlinear completions: unimodular topologically massive gravity (singlet) and unimodular New Massive Gravity (doublet). We have found an argument which shows that the highest derivative term in both theories has more symmetry than the lowest term, therefore there is no improvement regarding renormalizability. Due to an "alternative master action" approach we have found new scalar-tensor TMG and NMG still under investigation. We have also investigated the soldering of the new singlets (in progress) of spin-2 and spin-3. We still have some difficulties with auxiliary fields but achieved soldering of the pure spin-3 sector.

Paper: Weyl and transverse diffeomorphism invariant spin-2 models in D=2+1; D. Dalmazi, A.L. dos Santos, S. Ghosh, E.L. Mendonça. Eur. Phys. J. C (2017) 77:620

DOI 10.1140/epjc/s10052-017-5189-7

Alessandro Georgoudis - Uppsala University (3/6-17)

The research performed during my visit of ICTP covered the calculation of p-integrals at 5 loops. This was achieved using the program developed by E. Panzer, Hyperint. This program can calculate only convergent integrals (in the sense that the divergence can be factorized in a Gamma function outside the parametric representation). For our calculation divergent integrals (where the divergent part can not be only factorized in a Gamma function that multiplies the integral in parametric representation) need to be computed and a method of regularization need to be used. The idea is to reduce, using integral by parts identities and dimensional shifting relations, a convergent integral in higher dimensions to a sum of divergent integrals in lower. Most of these divergent integrals would be already known from constrains and the remaining expression could be used to evaluate the missing divergent ones. The computation of these integrals is needed to complete the ongoing project with V. Goncalves of ICTP and R. Pereira of Uppsala University on 5 loop Konishi OPE coefficients in N=4SYM. During my stay I gave a JC Strings talk on "Different Spin Chains from Gauge Theory" covering the work I am doing with my supervisor at Uppsala University J. Minahan.

Submitted to JHEP: Konishi OPE coefficient at the five loop order. A. Georgoudis, V. Gonçalves, R. Pereira. (arXiv:1710.06419 [hep-th])

Karina Laneri – CNEA, Bariloche (3/26 – 4/1 & 9/16-22)

During my one week visit to ICTP-SAIFR we started discussing on different topics related with the actual scientific activities of the working group members: Dr. Roberto Kraenkel, Dr. Paulo Prado, Dr. Renato Coutinho and Brenno Cabella. After discussing and exposing on several topics we choose to work on three possible questions in the short term: 1) Malaria in northwestern Argentina. a) Fitting a time series of malaria cases using Partially observed Monte Carlo algorithms with a malaria model designed by the working group. b) Study of the causality between climatic variables and the

time series using statistical approaches without models. 2) Competition between two population species of tecamebas. The kinetics of growth of the two species exhibit very different behaviors due to competition. With an stochastic model designed by the working group we'll see if it's possible to generate the observed behaviors performing numerical simulations.

Ricardo Medina – Univ. Federal de Itajubá (4/24-28)

I did 2 things: 1) Attended Pedreo Vieira's Mathematica Minicourse: Paper Computations in Theoretical Physics done Efficiently ; 2) Participated in the Particle Physics Journal Club, giving the seminar "Graviton and gluon scattering from fisrt principles".

Marco Taoso – IFT-Madrid (5/4-14)

- Work on charged cosmic-rays and connection with gamma-rays
- Work on effective field theory for WIMP dark matter and comparison of different probes (direct, indirect and colliders).
- Participation to the South American Dark Matter Workshop: talk on "Bound state formation and Sommerfeld effect in dark matter models"
- Talk in the Journal Club of cosmology and astro-particle physics: "Confronting cosmic-rays models with gamma-rays observations."

Alex Geringer-Sameth – Imperial College London (5/3-12)

I worked with Fabio Iocco, Ekaterina Karukes, and Maria Benito to constrain the dark matter density profile of the Milky Way using observations of the Milky Way's rotation curve. We discussed the methodology of the project with a focus on the the statistical inference. We constructed mock data sets that will be used to test our methods and optimize them before applying them to the actual data and we discussed how to more properly incorporate systematic uncertainties and construct a good test statistic.

Lili Yang – UN Gorica, Slovenia (5/21-26)

I was invited by Prof. Fabio Iocco to visit ICTP-SAIFR from 22nd to 26th May. During the visit, I gave an talk about "The GeV excess at the Galactic Center" on Monday. It was about the recent publication from the Fermi collaboration who characterized the Fermi Galactic center (GC) GeV excess with 6.5 years of data from the Fermi Large Area Telescope. The GC is of particular interest as it would be expected to have the brightest signal from annihilation of weakly interacting massive dark matter particles. Based on the magnitude of the systematic uncertainties, conservative upper limits for the annihilation cross section as function of particle mass and annihilation channel is reported in the paper. During the stay, we made a training on the use of CLUMPY which is a dedicated and powerful to the calculation of astrophysical J-factor and gamma-ray and neutrino fluxes. Together, we tried to be familiar and solve problem related to dark matter study. Most importantly, we set up a pipeline for dark matter searching of the Large Magellanic Cloud in CTA. The point sources and extended sources in the region of interests are searched and studied with the data and observation from Ferim-LAT and HESS collaboration. The next step of the project is clear now.

Alessandro Cuoco – RWTH-Aachen (5/8 – 6/9)

I was visiting ICTP for 5 weeks from 8th May to 9th June 2017. -- The first weeks I have attended the "South American Dark Matter Workshop" giving a talk on "Dark Matter Constraints from cosmic ray observations with AMS-02". -- The second week I have been actually in Rio, attending the CTA collaboration meeting -- Third week i have been at the institute and discussed physics related to Dark Matter searches with CTA together with ICTP guest Lili Yang and ICTP members Fabio Iocco and Maria Benito. -- Fourth week I have attended the "South American cosmic ray school", although this was in USP, not ICTP, and discussed topics related to cosmic ray physics with Pasquale Blasi and Roberto Aloisio, also present at the school. --Fifth week I gave a Monday journal club seminar on "Dark Matter Searches in the Extra-Galactic gamma-ray sky". I also discussed with Fabio Iocco and Maria Benito regarding possible projects related to the uncertainties in the Dark Matter distribution in the Milky way and how to propagate these uncertainties to direct and indirect searches for Dark Matter.

Renato da Costa Santos - Univ. of Cape Town (7/29 – 8/18)

My visit was two fold: 1) To participate on the school On open problems in cosmology in the first two weeks, and 2) Move on in a project that I had started in collaboration with Horatiu Nastase one year ago. The visit was really successful in my opinion. During the school I had the opportunity to interact with people that are leading the theoretical cosmology nowadays. Since I've been trying to specialize on Large Scale Structure (LSS), it was really useful to have the opportunity to ask questions and be in touch with those people. I had also started a project in collaboration with Henrique Rubira, a master student, under the supervision of Marcos Lima, at USP university. Henrique is in touch with Rafael Porto from IFT/ICTP-SAIFR and we had already start computing the

two loops corrections to the LSS fluid in Lagrange space. The last three weeks I had devoted to figure out what was going wrong with my project in collaboration with Horatiu Nastase and his student, Heliudson. I had daily meetings with Heliudson and weekly meetings with Horatiu. In the last day we finally managed to understand why the numerical solution and the analytical attractor that we thought we had found weren't matching. A draft with the results we had obtained is in preparation and will come out on arXiv soon.

Sergei Ketov – Tokyo Metropolitan University (8/7-25)

I was conducting research in the supergravity-based cosmological inflation and reheating after inflation. I acknowledge useful discussions with N. Berkovits, H. Nastase, A. Mikhailov, R. Rosenfeld and Heliudson Bernardo. I gave a colloquium with the title "Starobinsky inflation", and also finished a research paper (see below), including my SAIFR-ICTP temporary affiliation, and acknowledgements.

To be submitted: Gravitino and Polonyi production in supergravity. A. Addazi, S.V. Ketov, M. Yu. Khlopov. (arXiv:1708.05393 [hep-ph])

Hisakazu Minakata - Univ. of Tokyo (8/25 – 9/2)

While visiting ICTP-SAIFR I continued to work on the topics I have been working in the last 2 years, namely the 3 neutrino mixing paradigm test, which may be carried out as leptonic unitarity test. Specifically, I am working to prepare the suitable framework of testing unitarity violation due to new physics at low energies, i.e., low compared to the electroweak scale. The concrete problem under study is to derive sterile-sector model independent, effective, and compact expressions of the oscillation probabilities in matter. In addition I gave a colloquium entitled "Neutrino Physics: still interesting because it is changing … How to complete the story?" in August 30, 2017. During the colloquium I was asked by several people many questions including the one by Nathan Berkovits who asked a very good questions (and far extended ones from what I covered) which in fact illuminated the points. My colloquium included the outcome of the research I engaged while visiting here. I discussed with Eduardo Pontón about possible reformulation of the conventional framework for describing unitarity violation at high energies. I attended a webinar talk by Rogerio Rosenfeld summarising the first year results of "Dark Energy Survey" (DNS) experiments in which he is involved. After his seminar I briefly discussed with him about the interpretation of apparent discrepancy of sigma_8, matter correlation at 3 M persec, between Planck CMB and DNS.

Jacopo Viti – UFRN (8/28 – 9/1)

I spent one week at the ICTP-SAIFR, mostly continuing working on applications of Logarithmic Conformal Field Theories to two-dimensional statistical mechanics models.

Kostas Skenderis – Univ. of Southampton (9/10-23)

During this visit I had a number of discussions with Horatiu Nastase about holographic cosmology.

Leandro Aolita – UFRJ (9/24 -10/2 & 10/27-29)

I attended a superb mini-course on machine learning for many-body physics. I discussed about my research on quantum information with the local researchers at ICTP-SAIFR; and, in addition, I also worked with the teachers of the machine learning mini-course from Perimeter institute about machine-learning enhanced quantum state tomography as well as Boltzmann machines as an efficient representation of many-body quantum states. After these discussions there are concrete possibilities for collaborations. Also, there are concrete possibilities for further work at ICTP-SAIFR. I don't doubt I will be coming back soon.

Wilton Kort-Kamp – Los Alamos National Lab. (10/22-29)

I presented three seminars while visiting ICTP-SAIFR about my recent research on topological two-dimensional materials, fluctuation-induced phenomena, and metamaterials for tailored light-matter interactions. Also, I have met and discussed with SAIFR professors about current topics in Condensed Matter physics.

Aline Ramires – ETH Zurich (10/26 – 11/4)

During the visit to ICTP-SAIFR, I gave two talks on the topic of unconventional superconductivity: one blackboard talk introducing the basic concepts on the field and how does it connect to my research interests; and one research talk with the application of the concept of "superconducting fitness" to some materials. I also gave a colloquium on the topic "Large-N: from a theoretical tool to the laboratory", which showed how some concepts originated in high energy physics are also found in condensed matter theory. During this visit, I also interacted with several members of IFT and ICTP-SAIFR, in particular with Alexandre Reily Rocha and Sadhan Kumar Adhikari, who also work on condensed matter systems, and George Matsas, who is interested in finding connections between gravity and condensed matter physics.

Jimmy Hutasoit – Institute Lorentz (10/22 – 11/2)

Gave 3 talks and had discussions with Nathan Berkovits, Rogerio Rosenfeld, Pedro Vieira and Fabio Iocco.

c. Organization of activities

Between December 2016 and November 2017, the ICTP-SAIFR organized seven São Paulo International Schools for Theoretical Physics, nine workshops, four minicourses, one Program, seven outreach events, and weekly seminars, colloquia and journal clubs. The complete list of 2017 activities is on the webpage http://www.ictp-saifr.org/?page_id=11739, the list of weekly seminars and colloquia is on the webpage http://www.ictp-saifr.org/?page_id=14420, and the weekly journal clubs on particle physics is on the webpage http://www.ift.unesp.br/users/particlesjc/. Activities, seminars and colloquia of december 2016 are described on "Past research seminars and activities" at http://www.ictp-saifr.org/?page_id=14451. Many of the activities were filmed using equipment donated by the ICTP in Trieste and the videos are available online on the associated webpages.

c1. São Paulo International Schools

The seven São Paulo International Schools were on the subjects of mathematical biology (Jan. 16-27), cold atoms (Jan. 30 – Feb. 10), biological soft matter (March 13-24), AdS/CMT correspondence (March 27 – April 7), bootstrap (May 22-29), cosmology (July 17-28), density functional theory and quantum information theory (October 23-26).

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

http://ictp-saifr.org/surveys/mathbio6/view.php
https://ictp-saifr.org/suveys/atom2017/view.php
http://ictp-saifr.org/surveys/softmatter2017/firstweek/view.php and
http://ictp-saifr.org/surveys/softmatter2017/secondweek/view.php
http://ictp-saifr.org/surveys/adscmt2017/view.php
http://www.ictp-saifr.org/surveys/bootstrap/view.php
http://www.ictp-saifr.org/surveys/cosmology17/view.php
http://www.ictp-saifr.org/surveys/DFTmQIT/view.php

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

c1A. Mathematical Biology (January 16 - 27)

The VI Southern-Summer School on Mathematical Biology (January 4 – 10) is described on the webpage http://www.ictp-saifr.org/mathbio6 and involved 5 lecturers and 79 students. The school was aimed at students in Physics, Mathematics, Ecology and Epidemiology, having at least a basic knowledge of calculus and differential equations. The first week was a basic course on population biology, which also included modelling exercises. The second week was an advanced school on up-to-date topics in ecology and

evolution.

Lecturers and Topics:

- **Roberto Kraenkel** (IFT-UNESP, Brazil): Introduction to Population Biology
- **Florence Débarre** (Collège de France – Paris, France): Evolution in spatially structured populations
- **Armita Nourmohammad** (Princeton University, USA): Evolution of molecular phenotypes: from gene regulation to immune system
- **Sergei Petrovskii** (University of Leicester, United Kingdom): Mathematical Theory of Biological Invasions
- **Andre de Roos** (University of Amsterdam, The Netherlands): Physiologically structured population models: from numerical techniques to ecological insight

c1B. School on Interaction with Light with Cold Atoms (Jan. 30 – Feb. 10)

The school on Interaction with Light with Cold Atoms (Jan. 30 – Feb. 10) is described on the webpage http://www.ictp-saifr.org/atom2017 involved 6 lecturers, 8 seminar speakers and 58 participants. The school covered topics including light scattering, cold and ultra-cold matter, quantum information and quantum optics.

Lecturers and Topics:

- **Jean-Michel Raimond** (Université Pierre & Marie Curie, France): Photons and Atoms
- **Jook Walraven** (Universiteit van Amsterdam, Netherlands): Quantum gases
- **Christof Weitenberg** (Universität Hamburg, Germany): Ultracold atoms in optical lattices
- **Luiz Davidovich** (Universidade Federal do Rio de Janeiro, Brazil): Quantum information with photons
- **James P. Shaffer** (University of Oklahoma, USA): Cold Rydberg systems
- **Claus Zimmermann** (Universität Tübingen, Germany): Cold molecules & Efimov physics

Seminar Speakers:

- Vanderlei S. Bagnato (IFSC-USP, Brazil): Quantum turbulence
- Philippe W. Courteille (IFSC-USP, Brazil): Atom-cavity interactions in the service of inertial sensing
- Alejandra Valencia (Univ. de los Andes, Colombia): Experimental quantum optics: a testbed for quantum measurement and quantum decoherence
- Emanuel A.L. Henn (IFSC-USP, Brazil): Ultracold Dipolar Gases
- Aldo P. Delgado Hidalgo (Univ. de Concepción, Chile): Quantum tomography
- Robin Kaiser (INLN – Nice, France): Coherence and diffusion in light-matter interaction
- Tommaso Macri (IIP-UFRN, Brazil): Quantum simulation with Rydberg atoms and dipolar systems
- José W. R. Tabosa (UFPE, Brazil): Nonlinear optics with cold atoms

c1C. School on Biological Soft Matter: from molecular interactions to engineered materials (March 13 – 24)

The School on Biological Soft Matter (March 13-24) is described on the webpage http://www.ictp-saifr.org/softmatter2017 and involved 13 lecturers and 43 participants. Topics covered in the first week included nucleic acids, proteins and electrostatic interactions, while bioengineering was the main theme of this activity in the second week.

Lecturers and Topics:

- 1st week

- **Leandro Barbosa** (USP-São Paulo, Brazil): The study of protein-protein interaction as seem by small-angle X-ray Scattering
- **Tal Danino** (Columbia U., USA):Synthetic Biology: From Microbial Genetic Circuits to New Therapies
- **Ralf Eichhorn** (NORDITA, Sweden): Dynamics on the micro-scale: Brownian motion and electrokinetic effects
- **Shaker Chuck Farah** (IQ-USP, Brazil): Proteins and nucleic acids: basic concepts and challenges?
- **Aatto Laaksonen** (Stockholm University, Sweden): Multiscale modeling of DNA
- **Samuela Pasquali** (U. Sorbonne Paris Cité, France): The physics of nucleic acids
- **Fernando Luís Barroso da Silva** (USP-Ribeirão Preto, Brazil): Peculiar electrostatic mechanisms observed in biomolecular systems
- **Frederico W. Tavares** (UFRJ, Brazil): The Electrostatic Effects in Colloid (and Protein) Thermodynamics

- 2nd week

- **Fernando Duda** (UFRJ, Brazil): Stimuli-responsive hydrogels
- **Hermes Gadelha** (York U., UK): Cell biology and its mathematical tales, from the cell's movement to its physiology
- **Greg Huber** (KITP/UCSB, USA): Terasaki Ramps: A Glimpse into the Geometrical Architecture of the Cell
- **Jair Koiller** (INMETRO, Brazil): A gentle introduction to the mathematics of microswimming
- **Ana Rosa Lopes Ribeiro** (UNIGRANRIO, Brazil): A biomimetic approach: from tissue regeneration to nanotoxicological models

c1D. School on AdS/CMT correspondence (March 27 – April 7)

The School on AdS/CMT correspondence (March 27 – April 7) is described on the webpage http://www.ictp-saifr.org/adscmt2017 and involved 6 lecturers and 71 participants. This school provided students with a panorama of current theoretical problems in condensed matter systems and the tools used to attack them, with a special emphasis on holographic techniques.

Lecturers and Topics:

- **Oscar Dias** (Southampton University, UK): GR with a view towards AdS/CMT
- **Sean Hartnoll** (Stanford University, USA): Black holes and strange metals
- **Hong Liu** (Massachusetts Institute of Technology – MIT, USA): Effective field theories for non-equilibrium systems
- **Shamit Kachru** (Stanford University, USA): Dualities and metallic criticality
- **David Tong** (University of Cambridge, UK): Progress in d=2+1 Field Theories
- **Jan Zaanen** (Leiden U., The Netherlands): Quantum field theory challenges in condensed matter physics

c1E. Simons Non-perturbative Bootstrap School (May 22 – 29)

The Simons Non-perturbative Bootstrap (May 22 - 29) is described on the webpage http://bootstrap.ictp-saifr.org/school/ and involved 4 lecturers and 73 participants. Topics covered during the school included an introduction to conformal field theories, the conformal bootstrap, the AdS/CFT correspondence and S-matrix bootstrap techniques.

Lecturers and Topics:

- **Zohar Komargodski** (Weizmann Institute of Science, Israel), **Silviu Pufu** (Princeton U., USA): Overview/Space of CFTs
- **Chris Beem** (U. Oxford, UK), **Miguel Paulos** (CERN, Switzerland): Bootstrap and Numerics
- **Tom Hartman** (Cornell U., USA), **Jared Kaplan** (Johns Hopkins U., USA): AdS3/CFT2
- **Balt Van Rees** (Durham U., UK): S-matrix Bootstrap

c1F. ICTP-Trieste/ICTP-SAIFR School on Open Problems in Cosmology (July 17 – 28)

The ICTP-Trieste/ICTP-SAIFR School on Open Problems in Cosmology (July 17 – 28) is described on the webpage http://www.ictp-saifr.org/cosmology17 and involved 6 lecturers and 84 participants. The school provided PhD students with a panorama of current theoretical problems in cosmology and future observational probes.

Lecturers and Topics:

- **Paolo Creminelli** (ICTP-Trieste): Introduction to Primordial Physics
- **Raphael Flauger** (UC San Diego, USA): Introduction to CMB Theory
- **Oliver Hahn** (Observatoire de la Côte d'Azur/Université de Nice, France) & **Rafael Porto** (ICTP-SAIFR/IFT-UNESP, Brazil): Introduction to LSS: Theory and Simulations
- **Julien Lesgourgues** (Universität Aachen, Germany): Introduction to CMB observations
- **Will Percival** (University of Portsmouth, USA): Introduction to LSS observations
- **Matias Zaldarriaga** (IAS Princeton, USA): Advanced topics for the study of LSS

c1G. School on Density Functional Theory and Quantum Information Theory (Oct. 23 – 26)

The School on Density Functional Theory and Quantum Information Theory (Oct. 23-26) is described on the http://www.ictp-saifr.org/DFTmQIT and involved 3 lecturers and 57 participants. During the school the fundamentas of DFT, QIT and its interface have been discussed.

Lecturers and Topics:

- **Giovanni Vignale** (University of Missouri, USA): Introduction to Static Density Functional Theory
- **Christian Schilling** (University of Oxford, UK): Quantum Information Theory
- **Irene D'Amico** (University of York, UK): Interface between Density Functional Theory and Quantum Information Theory

c2. Workshops

ICTP-SAIFR organized 9 workshops on the subjects of general relativity, solitons, dark matter, cosmology and gravitation, Cherenkov Telescope Array, quantum field theory and quantum gravity, cosmology and astrophysics, density functional theory and quantum information theory, condensed matter physics. The purpose of these workshops was to discuss status, recent progress and perspectives in each of the fields mentioned.

c2A. Workshop on Analytic Methods in General Relativity (Dec. 5 – 9, 2016)

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

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

c2B. Workshop on Solitons: Integrability, Duality and Applications (April 17-20)

The main discussions were oriented to non-linear phenomena in field theory, and Prof. Luiz Agostinho Ferreira (São Carlos) was honoured for his contributions to this area on the occasion of his 60th birthday. The webpage of the workshop is http://www.ictp-saifr.org/soliton2017 and speakers included:

- Abraham H. Zimerman – IFT-UNESP São Paulo, Brazil
- Adalto Rodrigues Gomes dos Santos - Universidade Federal do Maranhão, Brazil
- Alexis Roa Aguirre – Universidade Federal de Itajubá, Brazil
- Andrzej Wereszczynski -Jagiellonian University Krakov, Poland
- Árpád Luk-TU Delft, The Netherlands
- Carlos Naya – University of Durham, England
- Christoph Adam – University of Santiago de Compostela, Spain
- David Foster – Bristol University, England
- Fidel Schaposnik – La Plata University, Argentina
- Floris ter-Braak – Durham University, England
- Gabriel Luchini - UFES-Vitória, Brazil
- Gianni Tallarita – Universidad Adolfo Ibáñez, Chile
- Gustavo Moreira Simões – Universidade Federal Fluminense, Brazil
- José F. Gomes – IFT-UNESP São Paulo, Brazil
- Jutta Kunz – University of Oldenburg, Germany
- Kouichi Toda – Toyama Prefectural University, Japan
- Manu Paranjape – University of Montreal, Canada
- Marco Aurelio C. Kneipp – Universidade Federal de Santa Catarina, Brazil
- Nobuyuki Sawado – Tokyo University of Science, Japan
- Partha Guha – SN Bose Center Kolkata, India
- Paul Sutcliffe – University of Durham, England
- Pawel Klimas – Universidade Federal de Santa Catarina, Brazil
- Peter Forgacs – University of Tours, France
- Stefano Bolognesi – University of Pisa, Italy
- Steffen Krusch – University of Kent at Canterbury, UK
- Stephen Flood - University of Leeds, England
- Theodora Ioannidou – Aristotle University at Thessaloniki, Greece
- Wojtek J. Zakrzewski – University of Durham, UK
- Yuki Amari – Tokyo University of Science, Japan

c2C. South American Dark Matter Workshop (May 10 – 12)

During the workshop the latest developments in all theoretical and experimental branches of the search for Dark Matter had been discussed. The webpage of the workshop is http://www.ictp-saifr.org/DMw2017 and speakers included:

- Ivone Albuquerque (USP, Brazil)
- Gustavo Burdman (USP, Brazil)
- Alessandro Cuoco (RWTH Aachen, Germany)
- Graciela Gelmini (UCLA, USA)
- Manuel Meyer (KIPAC Stanford, USA)
- Tomer Volansky (Tel Aviv Univ., Israel)

c2D. IV CosmoSul – Cosmology and Gravitation in the Southern Cone (July 31 – August 2)

The 4th edition of this international workshop took place at ICTP-SAIFR and included seminars on various aspects of cosmology and gravitation including gravitational waves and observational tests of the late-time cosmic acceleration. One goal of this event is to promote collaborations among the various cosmology and gravitation groups of Argentina, Brazil, Chile and Uruguay. The webpage of the workshop is http://www.ictp-saifr.org/IVCosmoSul and speakers included:

- Jailson S. Alcaniz (ON-Rio de Janeiro, Brazil)
- Saulo Carneiro (UFBA-Salvador, Brazil)
- Luis P. Chimento (U. de Buenos Aires, Argentina)
- Júlio C. Fabris (UFES-Vitória, Brazil)
- Rodolfo Gambini (U. de la República, Uruguay)
- Ramón Herrera (PUC-Valparaíso, Chile)
- Gilberto M. Kremer (UFPR-Curitiba, Brazil)
- Osvaldo Moreschi (U. Nacional de Córdoba, Argentina)
- Joel Saavedra (PUC-Valparaíso, Chile)
- Winfried Zimdahl (UFES-Vitória, Brazil)

c2E. Hands-on meeting for junior CTA Brazil groups (Aug. 24-25)

The goal of this meeting was to bring together the "junior groups" working within CTA in Brazil, in order to share scientific and technical knowledge of the area. The webpage of the workshop is http://www.ictp-saifr.org/CTA2017 and participants included:

- Ulisses Barres de Almeida (CBPF Rio)
- Bruno Fontes (CBPF Rio)
- Bernardo Fraga (CBPF Rio)
- Luan Arbeletche (IFSC, USP)
- Humberto Martinez Huerta (IFSC, USP)
- Rodrigo G. Lang (IFSC, USP)
- Danielle Kaori Nakashima (IFSC, USP)
- Aion Viana (IFSC, USP)
- Manuela Vecchi (IFSC, USP)
- Fabio Cafardo (USP SP)
- Raniere Menezes (USP SP)
- Rodrigo Nemmen (USP SP)
- Maria Benito (ICTP-SAIFR)
- Fabio Iocco (ICTP-SAIFR)
- Ekaterina Karukes (ICTP-SAIFR)

c2F. Workshop on Infrared and Ultraviolet Problems in QFT and Quantum Gravity (Sept. 12-15)

This workshop covered recent advances in Quantum Field Theory and Quantum Gravity, with special emphasis on boundary conditions, symmetries, and the infrared and ultraviolet structures. The webpage of the workshop is

http://www.ictp-saifr.org/QFT2017 and speakers included:

- Filiberto Ares (Zaragoza)
- Manuel Asorey (Zaragoza)
- Steve Carlip (UC Davis)
- João Paulo Pitelli (Campinas)
- Amilcar Queiroz (Brasilia)
- Alberto Saa (Campinas)
- Ilya Shapiro (Juiz de Fora)

c2G. Informal Workshop on Cosmology and Astrophysics (Oct. 16-17)

The 12th edition of this annual international meeting was held at ICTP-SAIFR and topics included statistical methods, quantitative measures, high frequency trading, market dynamics, and simulations of financial and economic systems. The webpage of the workshop is http://www.ictp-saifr.org/cosmo-astro and speakers included:

- Raul Abramo (IF-USP)
- Guido D'Amico (CERN)
- Rafael Batista (Oxford U.)
- Paolo Creminelli (ICTP-Trieste)
- Marcus Lima (IF-USP)
- Rodrigo Nemmen (IAG-USP)
- Rogerio Rosenfeld (ICTP-SAIFR/IFT-UNESP)
- Antonino Troja (ICTP-SAIFR/IFT-UNESP)

c2H. Workshop Density Functional Theory meets Quantum Information Theory (Oct. 27 – 28)

The second edition of this workshop workshop hosted several seminars and informal discussions DFT, QIT and the interface between the two areas. The webpage of the workshop is http://www.ictp-saifr.org/wDFTmQIT and speakers included:

- Celso Villas Boas – Universidade Federal de São Carlos (UFSCar)
- Marcelo Terra Cunha – Universidade Estadual de Campinas (UNICAMP)
- Belita Koiller – Universidade Federal do Rio de Janeiro (UFRJ)
- Wilton de Melo Kort-Kamp - Los Alamos National Lab
- André Malvezzi – Universidade Estadual Paulista (FC-UNESP)
- Paulo Nussenzveig - Instituto de Física (USP)
- Marcos de Oliveira – Universidade Estadual de Campinas (UNICAMP)
- Raimundo Rocha dos Santos – Universidade Federal do Rio de Janeiro (UFRJ)
- Diego Guedes Sobrinho – Instituto Tecnólogico de Aeronáutica, São José dos Campos (ITA)
- Lauro Tomio – IFT (UNESP)
- Stefano Pittalis – Istituto Nanoscienze, Italy
- Anna Sanpera – Universitat Autònoma de Barcelona, Spain
- Roberto Serra – Universidade Federal do ABC (UFABC)
- Claudio Verdozzi – Lund University, Sweden

c2I. Post-Workshop on Condensed Matter Physics (October 28)

Afternoon of seminars on condensed matter physics. The webpage of the workshop is http://www.ictp-saifr.org/?page_id=16049 and speakers and topics included:

- **Aline Ramires** (ETH Zurich): The concept of Superconducting Fitness and its application to complex materials
- **Jimmy Hutasoit** (Leiden Univ.): Bogoliubov-Majorana gun: An on-demand single Bogoliubov quasiparticle source
- **Mario Leandro Aolita** (UFRJ): Certification of many-body quantum simulations
- **Mario Leandro Aolita** (UFRJ): Recently discovered stronger forms of quantum nonlocality
- **Wilton de Melo Kort-Kamp** (Los Alamos): Spontaneous emission control in new photonic materials

c3. Minicourses

The ICTP-SAIFR organized four minicourses in 2017, on on pure spinor correlation functions, effective field theory of gravity, mathematica and machine learning. The topics, lecturers and webpages for these minicourses are:

1) Dec. 1, 2016 – Feb. 1,2017 Movshev Minicourse on Pure Spinors

   Mikhail Movshev (SUNY at Stony Brook, USA)

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

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

2) March 13-24, Codello Minicourse on Effective Field Theory of Gravity

   Alessandro Codello (CP3 – Origins, Odense, Denmark)

   Codello used covariant heat kernel techniques to compute both the divergent and finite parts of the gravitational effective action in arbitrary spacetimes. Applications included computation of the leading corrections to the Newtonian potential as well as cosmological implications such as the possibility of unifying inflation and dark energy within the EFT approach.

   http://www.ictp-saifr.org/codello2017

3) April 24-28, Mathematica Minicourse: Paper Computations in Theoretical Physics done efficiently

   Pedro Vieira (Perimeter Institute & ICTP-SAIFR/IFT-UNESP)

   Pedro Vieira explained how to perform analytic symbolic computations using this program. Examples sent by students were used as basis for the lectures, and topics included how to simplify differential equations and compute Feynman diagrams.

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

4) Sept. 25-29, Minicourse on Machine Learning for Many-Body Physics

   This course introduced modern machine learning techniques for studying classical and quantum many-body problems encountered in condensed matter, quantum information, and related fields of physics. Topics covered included lattice models for statistical physics, Monte Carlo methods, supervised and unsupervised learning, neural networks, Boltzmann machines, and deep learning.

   Lecturers: Juan Felipe Carrasquilla (D-Wave Systems Inc., Canada) & Roger Melko (University of Waterloo & Perimeter Institute , Canada)

   Tutor: Lauren Hayward Sierens (Perimeter Institute, Canada)

   http://www.ictp-saifr.org/ML2017

C4. Program

In 2017, the Simons Program on Non-perturbative Bootstrap (http://bootstrap.ictp-saifr.org/ May 15 – June 16) locally organized by Vasco Gonçalves (ICTP-SAIFR/IFT-UNESP) and Prof. Pedro Vieira (Perimeter I. & ICTP-

SAIFR/IFT-UNESP) discussed new bootstrap methods for solving problems in strongly coupled quantum field theories. The program involved daily seminars with over 80 participants coming from institutes worldwide to participate in this Simons collaboration meeting led by Leonardo Rastelli (Stony Brook U., USA)

C5. Outreach event

The ICTP-SAIFR organized six outreach events in 2017 aiming at different audiences. The format, topics and webpages for these events are:

1) Papos de Física

Papos de Fisica is a monthly outreach program of ICTP-SAIFR introducing current topics in theoretical physics to the general public in an informal setting. The webpage for this program is http://www.ictp-saifr.org/papos16. Topics covered during these meetings included:

- Dec. 6, 2016 - Renata Funchal (FMA-USP) - Neutrinos: de quimeras a ases do Universo
- March 8 - Rodrigo Nemmen (IAG-USP) - 13 Maneiras de Morrer com um Buraco Negro
- April 4 - Adriana Valio (CRAAM - Universidade Presbiteriana Mackenzie) - Tudo o que você sempre quis saber sobre planetas em torno de outras estrelas
- May 15-17 - Papos de Física no Pint of Science Brasil 2017
- June 8 - João Penedones - Mecânica quântica: a pior teoria, exceto todas as outras
- Aug. 3 - Raul Abramo (IF-USP) - Afinal, o que está escrito nas estrelas?
- Sept. 14 - Nathan Berkovits - Teoria das Supercordas: Sucessos e problemas em aberto
- Oct. 5 - Alexandre R. Rocha - Grafeno: Como um material que não deveria existir levou ao prêmio Nobel?
- Nov. 9 – Horatiu Nastase: Líquidos e sólidos como hologramas de buracos negros

2) 2nd IFT-Perimeter-SAIFR Journeys into Theoretical Physics (July 10 – 15)

The 2nd journeys is described on the webpage http://www.ictp-saifr.org/journeys and involved 4 lecturers and 84 participants. The top students in this school were accepted to a joint master`s program where they will spend one year at Perimeter Institute (Waterloo) and one year at ICTP-SAIFR/IFT-UNESP. The students accepted to the joint program include Andre Nascimento Alcantara Pereira (UFMG, Brazil), David Jaramillo Duque (Universidad de Los Andes, Colombia), Diego García Sepúlveda (Universidad de Chile), Jairo Martín Rojas Huamaní (PUC-Peru) and Renato Gomes Pereira Souza (UFPE, Brazil**)**

Lecturers and Topics included:

- **Asimina Arvanitaki** (Perimeter): Fundamental Physics and Tabletop Experiments
- **Rob Myers** (Perimeter): Einstein's Gravity: Black Holes to Gravity Waves
- **Alexandre Reily Rocha** (IFT-UNESP): Topics in Condensed Matter and Molecular Theory
- **Rogério Rosenfeld** (ICTP-SAIFR/IFT-UNESP): Introduction to Cosmology

3) 2016 Prêmio IFT-UNESP/ICTP-SAIFR para Jovens Físicos (July 15)

ICTP-SAIFR organized in collaboration with IFT-UNESP a competition for undergraduate physics students held on July 15 in which winners were determined by a 3-hour exam. The webpage with the names of the 5 winners is http://www.ictp-saifr.org/premio2017

4) Minicourse on Relativity, Gravitation and Quantum Mechanics for High-School Students (Aug. 19 – Sept. 30)

In this minicourse, Pedro Vieira (ICTP-SAIFR/IFT-UNESP & Perimeter I.) introduced modern physics concepts from special relativity to quantum mechanics, and described research topics at the frontier of physics. The

webpage for this minicourse is http://sictp3.ictp-saifr.org/ensino-medio/minicurso/

5) Cutting-edge In-class Physics Resourses – Workshop for High-School Teachers (Sept. 16 – 17)

Gregory Dick (Perimeter I.) and Dave Fish (Perimeter I.) used hands-on activities to introduce wave-particle duality, dark matter, and particle physics to high-school teachers who also received a set of classroom-ready resources to share with their students. The webpage for this minicourse is http://sictp3.ictp-saifr.org/ensino-medio/perimeterw/

6) Minicourse Physics of the Universe for High-School Students (Oct 7-28)

In this minicourse, Rogerio Rosenfeld (ICTP-SAIFR/IFT-UNESP) discussed about the structure and evolution of the Universe. The webpage for this minicourse is http://sictp3.ictp-saifr.org/ensino-medio/minicurso/

C7. Weekly seminars, colloquia and journal clubs

Between December 2016 and November 2017, weekly seminars and colloquia were regularly organized. There were 150 seminars and colloquia and the complete list is on the webpage http://www.ictp-saifr.org/?page_id=10921. The list of the seminars of December 2016 are shown at http://www.ictp-saifr.org/?page_id=14451. There were also weekly journal club meetings in string theory, particle physics, integrability and cosmology.

5. Description of Institutional Support

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

The UNESP university is providing the salary for four ICTP-SAIFR secretaries including an executive secretary, an accountant, a computer systems manager and an executive manager. In April 2017, our previous executive secretary Nadia Rosa Roque moved to the USA, and our new executive secretary Vivian Vidal was hired. UNESP has also agreed to hire 5 permanent ICTP-SAIFR researchers, and the first permanent researcher (Eduardo Ponton) was hired in 2013 at the top researcher level.

6. Use of Reserva Tecnica Funds

Between December 2016 and November 2017, the part of the reserva tecnica funds related to "Custos de Infraestrutura Direta do Projeto" was used for the following purposes:

a) School/Workshop Posters printing for announcement of activities: R$ 4.094,00

b) Post office expenses – delivery of School/Workshop posters: R$ 9.849,70

c) Advertisement of postdocs positions at Physics Today: R$ 3.277,56

d) Purchase of desk, chair and drawers: R$ 1.238,16

e) Design of School/Workshop Posters: R$ 2.900,00

f) Purchase of equipment necessary for research activities and recording of research seminars (printer, computer, server, microphone): R$ 41.320,54

g) Airfare for Perimeter-ICTP-SAIFR Coordinator Pedro Vieira to Rio de Janeiro to participate in meeting with Instituto Serrapilheira Scientific Director Hugo Aguilaniu to discuss research partnership between the two institutes: R$ 929,36

h) Airfare for Perimeter-ICTP-SAIFR Coordinator Pedro Vieira to Rio de Janeiro to participate in meeting with Perimeter Outreach Director Greg Dick and professors at Colégio Pedro II (Rio de Janeiro) to discuss outreach project for high-school teachers: R$ 954,10

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

a) Airfare for ICTP-SAIFR director Nathan Berkovits to Boston (USA), Newark (USA) and London (UK) to collaborate with Cumrun Vafa (Harvard) in Cambridge, MA (USA), present a plenary seminar with the title "Twistors and the Superstring" at the meeting New Horizons in Twistor Theory (Jan 3-6) at Oxford Univ. (UK), and give a plenary lecture with the title "Review of the pure spinor formalism" at the meeting String Theory and Scattering Amplitudes (Jan. 9-13) in Stony Brook, NY (USA): R$ 3.769,32

b) Airfare for ICTP-SAIFR director Nathan Berkovits to Rio de Janeiro to participate in meeting with Instituto Serrapilheira Scientific Director Hugo Aguilaniu to discuss research partnership between the two institutes: R$ 929,36

c) Airfare for ICTP-SAIFR director Nathan Berkovits to Rio de Janeiro to participate in meeting with Perimeter Outreach Director Greg Dick and professors at Colégio Pedro II (Rio de Janeiro) to discuss outreach project for high-school teachers: R$ 954,10

d) Airfare for ICTP-SAIFR director Nathan Berkovits to Montevideo (Uruguay) to present a plenary talk entitled "Twistors and the Superstring" at Quantum Gravity in the Southern Cone VII (March 30-April 1): R$ 1.290,36

e) Airfare for ICTP-SAIFR director Nathan Berkovits to Boston (USA), Newark (USA) and London (UK) to collaborate with Cumrun Vafa (Harvard) and Edward Witten (Princeton) and to give a plenary lecture with the title "Relating the RNS and Pure Spinor Formalisms of the Superstring" at the meeting Supergravity, Strings and Dualities (April 28-29) at Imperial College (London, UK): R$ 5.056,86

f) Registration fee, airfare and per diem for participation in the workshop "Understanding cosmological observations" (July 30-August 11) of ICTP-SAIFR vice-director Rogerio Rosenfeld to Barcelona (Spain). Rogério presentend a short talk entitled "Covariance Matrix in the Dark Energy

Survey": R$ 12.000,00

7a. Articles in refereed scientific journals

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

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intracluster medium from simulated Faraday rotation maps II: the effects of instabilities feedback", *MNRAS*, vol. 465, p. 4866, 2017.

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8a2. Articles by ICTP-SAIFR Postdoctoral Associates

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8. First page of publications

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

9. Scientific reports of postdocs

See annexed file for scientific reports of

Jose Luis Herrera Diestra, Andrea Guerrieri, Bithika Jain, Ekaterina Karukes, Ryo Suzuki, Antonino Troja

10. Scientific reports of TT1 and JC-2

See annexed file for scientific reports of Ivan Nery Cardoso and Jaqueline Venturim