

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



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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 postdocs, 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 postdocs. 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 Física 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. In addition to its permanent faculty members who are hired through IFT-UNESP, ICTP-SAIFR has a joint faculty member with Perimeter Institute (Waterloo) and two tenure-track faculty members who are funded by a donation from the Simons Foundation (New York) together with FAPESP Young Investigator fellowships. Furthermore, ICTP-SAIFR has obtained a private donation called the "Isaias Raw Chair" which will supplement the salary of a future professor, and a donation from the Instituto Serrapilheira to finance outreach activities and two outreach coordinators.

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 Brazil, 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 Brazil. 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 equipment installed with the guidance of the Perimeter Institute and ICTP Trieste audiovisual departments.

In addition to the research conducted by its members and visitors, the ICTP-SAIFR regularly organizes schools, mini-courses, 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 master's 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

Despite the onset of Covid-19 which disrupted activities from March-November of 2020, there were several highlights for ICTP-SAIFR during the past year. In November 2019, ICTP-SAIFR researcher Pedro Vieira was awarded the prestigious [2020 New Horizons in Physics Prize](#) by the Breakthrough Prize Committee “for profound contributions to the understanding of quantum field theory.” Pedro Vieira has a joint position with Perimeter Institute in Waterloo, Canada, and in March 2020, he was granted a 5-year FAPESP Excellence Chair in which he will spend 6 months each year at ICTP-SAIFR and six months at Perimeter.

In February 2020, ICTP-SAIFR researchers Riccardo Sturani and Ricardo Martinez-Garcia were approved in a concurso for permanent researchers at IFT-UNESP. Riccardo Sturani is an Italian physicist and key member of the LIGO-Virgo collaboration which was recently awarded the Nobel Prize for the detection of gravitational waves. He first came to ICTP-SAIFR in 2013 as a FAPESP Young Researcher, then went to IIP-Natal as a visiting professor, and returned to ICTP-SAIFR this year. Ricardo Martinez-Garcia is a Spanish physicist working on complex systems related to biodiversity and came to ICTP-SAIFR in 2019 with a Simons-FAPESP Young Investigator fellowship. In June 2020, Ricardo Martinez-Garcia was announced as one of [23 scientists](#) awarded with a researcher grant from the Serrapilheira Institute. Both Riccardo Sturani and Ricardo Martinez-Garcia are awaiting the relaxation of restrictions due to Covid-19 to begin their permanent positions at IFT-UNESP.

In July 2020, ICTP-SAIFR was awarded a [Covid-19 Innovation Grant](#) from the American Physical Society for its project “Modern Physics in the Latin-American Classroom”. Only 2 such grants were awarded out of 68 proposals, and the grant will fund the translation into Spanish by ICTP-SAIFR of classroom material on modern physics developed by Perimeter Institute. And in October 2020, ICTP-SAIFR director Nathan Berkovits was announced as recipient of the [2021 John Wheatley Award](#) for his “*exceptional leadership in fundamental physics research in South America.*” This award is granted every two years by the American Physical Society to honor physicists who have made contributions to the development of physics in countries of the third world.

Finally, in November 2020, Serrapilheira Institute approved a new initiative called the Serrapilheira/ICTP-SAIFR Research Training Program in Quantitative Biology which will be an annual six-month program organized by ICTP-SAIFR for master’s students from all areas of physical sciences who want to apply their quantitative skills in biological problems. The program will be held at IFT-UNESP and has been approved for 5 years with a commitment of 7.5 million reais from the Serrapilheira Institute. It is scheduled to begin in July 2021 with approximately 50 students selected from all regions of Brazil and 30 invited international lecturers every year.

With these advances during this last year, ICTP-SAIFR has consolidated its position as the leading research and training center in Latin America in the areas of high-energy physics and complex systems. In the area of high-energy physics, ICTP-SAIFR permanent researchers include Pedro Vieira (field theory), Rogerio Rosenfeld (cosmology and particle physics, current president of Brazilian Physical Society), Nathan Berkovits (string theory) and Riccardo Sturani (gravitational waves). ICTP-SAIFR also has 12 associated researchers in high-energy physics and exchange agreements with the leading international centers including CERN, Fermilab, Mainz ITP, Nordita, Perimeter, IFT-Madrid and CEA-Saclay. In July 2020, ICTP-SAIFR

organized for the second time the meeting of the [Latin American Strategy Forum for Research Infrastructure](#) which produced a document for funding agencies on priorities of the high-energy physics community in Latin America. And in June 2021, ICTP-SAIFR will organize the annual meeting of Strings 2021 for the first time in Latin America, which will be held online if necessary.

In the area of complex systems applied to biology and condensed matter, ICTP-SAIFR permanent researchers include Ricardo Martinez-Garcia (biodiversity), as well as associated researchers Roberto Kraenkel (mathematical biology, organizer of the Covid-19 Brazilian observatory and 10 editions of the ICTP-SAIFR Summer School on Mathematical Biology), Marcus Aguiar (evolutionary biology), Paulo Prado (ecology), Aline Ramires (condensed matter), Hilda Cerdeira (nonlinear dynamics), Alexandre Rocha (condensed matter), Leandro Aolita (quantum information) and Sadhan Adhikari (Bose-Einstein condensates). In addition to the new quantitative biology training program with the Serrapilheira Institute, ICTP-SAIFR has exchange agreements with the Princeton-CUNY Center for the Physics of Biological Function as well as a new agreement with the Interdisciplinary Center for Physics and Complex Systems in Palma de Mallorca. In 2020, ICTP-SAIFR hired three FAPESP postdoctoral fellows in complex systems including Gabriel Maciel (mathematical biology), Vivian Dornelas (biodiversity) and Krissia Zawadski (condensed matter). In addition, ICTP-SAIFR hosted Jose Nelson Onuchic, co-director of the NSF Center for Theoretical Biological Physics at Rice University, as a visiting researcher for six months in 2020. Finally, the ICTP-SAIFR international search committee interviewed candidates in 2020 for the second Simons-FAPESP fellowship and selected Pierre Ronceray, a French biophysicist with a prestigious postdoctoral position at Princeton University. Dr. Ronceray also received an offer of a research professor position in Marseille and has not yet decided if we will accept the offer from ICTP-SAIFR to start in 2021.

The 99 research publications of the last year in the areas of high-energy physics and complex systems are described below in section (a), and the various schools and workshops are described in section (c). Before the pandemic, ICTP-SAIFR organized international schools on high performance computing (Dec. 2-13, 2019), data science and machine learning (Dec. 16-20, 2019), mathematical biology (Jan. 12-18), community ecology (Jan. 19-25), and biophysics (March 9-15), a workshop on Infectious Disease Dynamics (March 2-4) which was held just before the pandemic and included international experts on Covid-19, and the 2020 meeting of the ICTP-SAIFR Steering Committee and Scientific Council (Feb. 3-4) which included participation for the first time of Luiz Davidovich (president of the Brazilian Academy of Sciences), Michael Green (new chair of the Scientific Council) and Hugo Aquilaniu (president of the Serrapilheira Institute).

After March, all ICTP-SAIFR activities were held online and included a one-week minicourse of Ashoke Sen (June 1-4), a one-week international workshop on string theory (June 8-12), a two-week international school on particle physics jointly organized with ICTP Trieste (June 22 – July 3), a one-week meeting of the Latin-American high-energy physics community to discuss research infrastructure (July 6-10), an international workshop on integrability (August 24-28), and a one-week school on holography (November 23-28). In December 2020, there will also be two online workshops on dark matter (December 2-4 and December 7-9) and a one-week workshop on observational cosmology (December 14-18).

In addition to these research and training activities, ICTP-SAIFR converted all of its outreach activities into online activities after March. These online activities attracted thousands of participants from all over Brazil as well as Portugal and Angola. For the general public, ICTP-SAIFR organized a biweekly presentation on Thursday evenings entitled ["Física em Casa"](#) with 16 online presentations by Brazilian

physicists working in Brasil and abroad and over 2000 participants. ICTP-SAIFR also developed a [Youtube library of interviews](#) of physicists and a [multimedia presentation](#) on astronomy in Brasil. For high-school students, the series of [Saturday morning minicourses](#) was continued online and expanded with minicourses on quantum mechanics (Pedro Vieira), particles (Ricardo Matheus), Covid (Roberto Kraenkel), relativity (George Matsas), astrophysics (Cecilia Cirenti), cosmology (Rogerio Rosenfeld), neutrinos (Marcelo Guzzo), waves (Nathan Berkovits), thermodynamics (Ricardo Martinez-Garcia), mathematical physics (Alberto Saa) and condensed matter (Aline Ramires). In addition, high-school teachers Lucas David and Felipe Santos presented [weekly online classes](#) to students on advanced topics in mathematics and physics. Finally, for high-school teachers, the workshops showing how to use Perimeter-based material on modern physics in the classroom were converted to [online sessions](#) offered 4 times per week. Over 100 of these online sessions were offered on Wednesdays and Fridays to over 2500 high-school teachers throughout Brazil. In addition, ICTP-SAIFR translated in 2019-2020 all 16 volumes of the Perimeter material into Portuguese and 8 volumes into Spanish which is available at <http://outreach.ictp-saifr.org/traducoes-para-sala-de-aula/>. With support from the American Physical Society, the remaining 8 volumes will be translated into Spanish in 2021 and workshops will be organized in Spanish for high-school teachers from other Latin-American countries.

Although these ICTP-SAIFR online activities attracted thousands of participants from all over the world, they cannot replace the essential role of schools and workshops organized by ICTP-SAIFR in the IFT-UNESP building. Especially for students, the direct interaction with researchers and other students in group activities cannot be replaced by virtual interactions on the computer. For this reason, several of the schools and workshops scheduled for 2020 were postponed until the second semester of 2021 and 2022 when normal activities are expected to be resumed. These postponed 2020 schools and workshops include a school and workshop on few-body systems, a school and workshop on density functional theory, a workshop on electromagnetic systems, a school and workshop on sociophysics, a school on data science and machine learning, a workshop on particle physics, a workshop on superconductors, a workshop on biological physics, and minicourses on topological matter and on condensed matter theory. These postponed activities from 2020 will be added to the already programmed 2021 activities and will fill the 2021-2022 calendar of ICTP-SAIFR activities.

Request to extend thematic project for an additional year:

Because of the postponement of several ICTP-SAIFR activities to 2021-2022 due to the pandemic, ICTP-SAIFR will be requesting an extension of the thematic grant for an additional year until November 30, 2022. Since the spending of ICTP-SAIFR for local and travel costs of visitors was drastically reduced in 2020 due to the pandemic, the only additional expense requested is the addition of 5 years of postdoctoral fellowships to the grant which will allow the extension of the 5 current postdoctoral fellows until November 30, 2022. Note that these 5 postdoctoral fellows are all in the beginning of their fellowships, and the extension of their stays until 2022 would have been normally requested with the renewal of the ICTP-SAIFR thematic grant which was expected to start on December 1, 2021. Their research sub-areas are complex systems (Gabriel Maciel), biological physics (Vivian Nunes), condensed matter (Kryssia Zawadski), integrable systems (Diego Medrano Jimenez) and observational cosmology (Martin de los Rios).

The activities of ICTP-SAIFR in 2020 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 various subareas of theoretical physics related to high-energy physics and complex systems. The publications involved research performed by principal and associated researchers, postdoctoral fellows, and visitors of ICTP-SAIFR. Various ICTP-SAIFR researchers are also members of international experimental collaborations such as the CMS detector at the LHC, the LIGO, and the Dark Energy Survey collaborations. In this period, ICTP-SAIFR researchers had a total of 99 publications and several of them will be described below.

a1. High Energy Physics

a.1.1. String theory, Field Theory and Integrability

A new ambitwistor string was constructed in [13]. This string theory is based on a ten-dimensional supertwistor model for the massless superparticle, and is shown to be equivalent to the RNS ambitwistor string in light-cone gauge. In [31], a generalization of the super-geometrical framework of NSR picture changing operators is developed for the pure spinor superstring formalism. And in [30], it is shown how to add spacetime-dependent terms in supersymmetric field theory actions and express the renormalization of these terms using cohomological invariants.

In [32] and [33], well-known problems in cosmology are addressed using the holographic cosmology framework in which holographic duality maps the cosmological theory to a simpler model in three-dimensional quantum field theory. In the first paper, a resolution of the flatness problem related to cosmological inflation is discussed and in the second paper, a solution of the cosmological constant problem is discussed.

The construction of consistent S-matrix amplitudes using the bootstrap method has been an extremely active research area. In [95], the construction of the S-matrix in massive two-dimensional theories with $O(N)$ symmetry is discussed and unitarity properties are analyzed using convex minimization. In [94], two-dimensional supersymmetrical models with either Z_2 or Z_4 symmetry are analyzed and the boundary of consistent S-matrices is shown to include well-known integrable models such as supersymmetric Sine-Gordon. And in [96], dual optimization methods are used to rule out inconsistent S-matrices in two dimensions and are applied to a gapped system with two stable particles of different masses.

A review and introduction to recent results on using integrability methods to compute supersymmetric Wilson loops in three-dimensional $ABJ(M)$ and related theories is presented in Ref [92].

a.1.2. Particle and Astroparticle Physics

Several investigations regarding the Standard Model of particle physics are being conducted at the LHC, where ICTP-SAIFR researchers take part in the CMS

collaboration [34-62]. Some of these works include: the first observation of the $t\bar{t}H$ process in a single Higgs boson decay channel with the full reconstruction of the final state ($H \rightarrow \gamma\gamma$) [34]; the first observation of the combined production of three massive gauge bosons (VVV with $V = W, Z$) in proton-proton collisions at a center-of-mass energy of 13 TeV [41]; and the observation of the $B_s^0 \rightarrow X(3872)\phi$ decay [52].

Such kind of investigations are also contemplated in a variety of other works by ICTP-SAIFR members, some of which were: the calculation of various η_c - nucleus bound state energies, which suggested new insight on the nature of strongly interacting systems [18]; an anomaly observed in the muon magnetic moment that cannot be accounted for in the Standard Model and insinuates that new measurements might give rise to a 5σ claim for physics beyond the Standard Model [77]; a review of the importance of Atomic Parity Violation (APV) to probing new physics using effective field theory [79].

a.1.3. Cosmology and Gravity

An important part of the research was dedicated to Black Holes either through the participation in the Laser Interferometer Gravitational-wave Observatory (LIGO) and Virgo Collaboration or in theoretical developments. Of particular importance is the detection of gravitational waves from the most massive binary black hole fusion so far, with a resulting black hole of roughly 150 Solar masses at a redshift of $z=0.8$ published in Physical Review Letters [88]. This event, called GW190521, defies the usual mechanisms of black hole formation through stellar evolution and may point to new mechanisms such as (multiple) stellar coalescences, or hierarchical mergers of lower-mass black holes in star clusters or in active galactic nuclei, as discussed in [87]. Also of interest is the detection of the event GW190814, a compact binary coalescence involving a ~ 23 Solar mass black hole and a compact object with a mass of ~ 2.6 Solar masses reported in [89]. No electromagnetic counterpart has been confirmed to date. The source has the most unequal mass ratio yet measured with gravitational waves, and its secondary component is either the lightest black hole or the heaviest neutron star ever discovered in a double compact-object system.

The observation of a compact binary coalescence of a light system with total mass ~ 3.4 Solar masses was reported in [90]. The mass parameters are consistent with the individual binary components being neutron stars. No electromagnetic counterpart was detected.

On the theoretical side, [85] compute the next-to leading effects of the so-called hereditary terms in the context of the two-body problem in general relativity, that comprise tail and memory, on the two-body dynamics, within effective field theory methods, including both dissipative and conservative effects. The conservative part is a new result and is an unavoidable ingredient for a derivation of the conservative two-body dynamics at fifth post-Newtonian order.

In [86] extracts information about the logarithmic contributions to the two-body conservative dynamics within the post-Newtonian (PN) approximation of general relativity. Renormalization group techniques are used to obtain the leading logarithmic terms to generic power n , and the infinite series is resummed in a closed form.

In a Physical Review Letters paper, [68] finds signatures of the quantum origin of fluctuations during the inflationary phase of the universe by looking at primordial

non-gaussianities.

There were several results from the Dark Energy Survey (DES) Collaboration. A key paper for the DES-Y1 analysis is the combination of cluster number counts and weak gravitational lensing described in [25]. The results were in disagreement with previous estimates of the amplitude of fluctuations and of the amount of matter. This may be caused by a faulty calibration of the mass-richness relation for clusters at small richness.

In [20], five candidates of periodically variable quasars were found, which can give rise to low-frequency gravitational waves. [21] reports the identification of a low-mass active galactic nucleus (AGN), DES J0218–0430, in a redshift $z = 0.823$ galaxy whereas [22] describes the discovery of 10 lensed quasars and 10 quasar pairs. [23] show that cluster radio loud AGNs are highly concentrated around cluster centres to $z \sim 1$ and [24] presents new optical spectroscopy of 16 extreme variability quasars (EVQs) that dimmed by more than 1.5 mag in the g band between the Sloan Digital Sky Survey (SDSS) and the Dark Energy Survey epochs (separated by a few years in the quasar rest frame). The 5-yr Dark Energy Survey Supernova Programme (DES-SN) is one of the largest and deepest transient surveys to date in terms of volume and number of supernovae. Identifying and characterizing the host galaxies of transients plays a key role in their classification, the study of their formation mechanisms, and the cosmological analyses. To derive accurate host galaxy properties, [26] creates depth-optimized coadds using single-epoch DES-SN images that are selected based on sky and atmospheric conditions.

Within the Halo Model of large scale structure, all matter is contained in dark matter halos. This simple yet powerful framework has been broadly applied to multiple data sets and enriched our comprehension of how matter is distributed in the Universe. In [27] this assumption is extended by allowing for matter to rest not only inside halos but also within cosmic voids and in between halos and voids. It is shown that this procedure eliminates the need to include low-mass structures on the normalization of large-scale terms, suggesting that halos and voids are complementary cosmic structures to effectively describe matter distribution on large scales of the Universe.

The sensitivity of the Javalambre Physics of the Accelerating Universe Astrophysical Survey (J-PAS) to tests of modified gravity models and time-varying dark energy equation-of-state was studied using Fisher matrix forecasts in [3], where it was found that it will provide the best constraints in the interval $z = 0.3-0.6$, thanks to the large number of ELGs detectable in that redshift range.

In [1] mock galaxy data from the VIMOS Public Extragalactic Redshift Survey (VIPERS) was used to test the performance of the Multi-Tracer Optimal Estimator (MTOE) as a tool to measure the monopoles of the power spectra of multiple tracers of the large-scale structure, finding that it provides more accurate measurements than the standard technique, independently of the tracer-selection strategy adopted, on both small and large scales. [2] discusses the effect that secondary halo bias has on the clustering of the central galaxy population using the improved IllustrisTNG300 magnetohydrodynamical cosmological simulation and it finds that there is a significant signal for galaxy size: at fixed halo mass, larger galaxies are more tightly clustered than smaller galaxies.

a.1.4. Astrophysics

We know that there is a supermassive black hole at the center of our galaxy - its discovery was recognized with the 2020 Nobel prize in Physics to Andrea Ghez. This

black hole has experienced a strong, unprecedented flare in May 2019 when its near-infrared luminosity reached much brighter levels than ever measured. [66] argues that an explosive event of particle acceleration to nonthermal energies in the innermost parts of the accretion flow—a nonthermal bomb—explains the near-infrared light curve. They discuss potential mechanisms that could explain this event such as magnetic reconnection and relativistic turbulence acceleration.

The Fermi Large Area Telescope (LAT) is a satellite measuring gamma-rays. In [64] nine years of Fermi-LAT data is used to systematically study the light curves of more than 2000 active galactic nuclei (AGN) included in recent Fermi-LAT catalogs in order to search for evidence of periodic emission in gamma-rays. They find 11 AGN, of which 9 are identified for the first time, showing periodicity at more than 4 sigma.

A new use of the likelihood ratio (LR) and a complementary supervised learning technique to associate gamma-ray blazars in Fermi-LAT data, based only on spectral parameters is proposed in [65], and a list with all blazar candidates of uncertain type associated by their method is provided.

[63] confirms the mini-halo in the massive strong cool core cluster PKS 0745–191 and discovers one in the massive cool core cluster MACS J1447.4+0827 based on new VLA observations. Furthermore, using a detailed analysis of all known mini-halos, they explore the relation between mini-halos and active galactic nucleus (AGN) feedback processes from the central galaxy. They indicate that mini-halos are directly connected to the central AGN in clusters, following previous suppositions.

The first detection of a very high-energy gamma-ray emission from the Crab Nebula was made by the Cherenkov Telescope Array (CTA), using a dual mirror Schwarzschild-Couder configuration at the ASTRI-Horn telescope, as reported by [14]. The ASTRI-Horn telescope was developed as a prototype for the CTA project, and this detection provides important validation for the use of dual-mirror systems in the next generation of Cherenkov telescopes.

A study that used data from H2O Southern GalacticPlane Survey (HOPS), [15] suggests that certain dense molecular regions of the Milky Way Galaxy likely to form high-mass stars may be associated with the Galactic bar potential x-1 orbits.

a.2. Complex Systems

a.2.1 Mathematical Biology

The employment of mathematical modeling has been crucial for the understanding of complex biological systems, including studies of population biology, ecology, and epidemiology. [28] derived new analytical expressions for encounter rates of interacting populations by exploring empirical evidence that pinpoints the limitations of most current interacting population theories. By comparing the predictions of the different models, it was concluded that neglecting realistic movement and perceptual behaviors can lead to systematic, non-negligible biases in encounter-rate predictions.

Ref [98] used methods inspired by evolutionary game theory and adaptive dynamics to study dispersal strategies of populations through heterogeneous environments. It was able to show that the behavioral strategy for movement at boundaries between different patches of landscapes is both globally evolutionarily

steady (ESS) and is a global neighborhood invader strategy (NIS).

A mathematical model developed for the population partitioning-process of the social amoeba *Dictyostelium discoideum* in [29] provided evidence of naturally occurring heritable variation in its loner behavior. The study motivates the investigation of potential implications for analogous behaviors from insects, vertebrates, and plants.

Ecological studies involving Brazilian fauna and flora were conducted in Ref [69-75].

Ref [76] analyzed the association between the transmission potential of SARS-CoV-2 and the decisions made by the municipal government of Florianópolis (Brazil) regarding social distancing, between February 1 and July 14, 2020. All of the decrees that maintained or loosened the distance measures were dissonant with the the tendency indicated by the time-dependent reproduction numbers (R_t) for a period of 14 days prior to each decree, which indicates a significant inconsistency between municipal measures of social distancing with epidemiological indicators at the time of each political decision. The COVID-19 pandemic has also been studied in the work of [9], which analyzed how the duration, start date and intensity of quarantine affect the height and position of the peak of the infection curve.

a.2.2. Condensed Matter

Ref [82] offers a detailed comparison of different methods applied in a study of the single impurity Anderson model. The techniques considered were the equations of motion method (EOM), the non-crossing approximation (NCA), the one-crossing approximation (OCA), and Wilson's numerical renormalization group (NRG). Such compilation allowed for a cost-benefit analysis of the different solvers that consider both numerical precision and computational performance.

A generalization of Anderson's theorem for superconductors developed in [80] provided a theoretical framework that naturally explains what protects Cooper pairs from strong scattering in complex superconductors.

A variety of studies concerning Bose-Einstein Condensates (BEC) in different configurations were conducted among Ref [4-6 and 8]. FORTRAN programs for solving the Gross-Pitaevskii equation for a harmonically trapped three-component spin-1 spinor BEC for a certain range of configurations were presented in [4], and [7] brings a review on solitons in an SO-coupled spin-1 spinor BEC in one, two, and three space dimensions.

A theoretical investigation by [83] showed that a device composed of a graphene sheet containing a nitrogen-terminated nanogap could successfully be used for DNA sequencing, with very high sensitivity and selectivity. The research also points that water plays a major role in electronic transport in nanoscopic tunneling devices.

a.2.3. Econophysics

[84] uses a path-integral formalism of statistical mechanics for pricing options using first-passage time problems involving both fixed and deterministically moving absorbing barriers under possibly non-Gaussian distributions of the underlying object. An analytical model for fixed or deterministically moving barrier options is presented and market prices of vanilla options are used to calibrate the model, and barrier option pricing arising from the model is compared to the price resulted from the relative entropy model.

a.2.4. Quantum information

[12] shows that Einstein-Podolsky-Rosen steering can be distilled, and exhibits the experimental protocol to do so, which outputs a perfectly correlated system in the asymptotic infinite-copy limit, and works well also in the non-asymptotic regime of few copies. The efficacy of the protocol is shown by using a hyperentangled photon pair encoding two copies of a two-qubit state.

Motivated by the speculated connection between topological and quantum entanglement, [91] shows that supersymmetry algebras can be used to construct large families of solutions of the spectral parameter-dependent generalized Yang-Baxter equation, presenting explicit examples and a general algorithm for arbitrary numbers of qubits. An improvement of that analysis is presented by [93], with the substitution of supersymmetry algebras for partition algebras, although the second method has limitations in obtaining all SLOOC classes of entangled states.

b. Research related to visitors

Due to COVID-19 the IFT-UNESP was closed in March which directly affected the number of visitors. Between December 2019 and March 2020, the ICTP-SAIFR hosted 10 short-term visitors who stayed less than four days, 28 middle-term visitors who stayed between five and fourteen days, and 12 long-term visitors who stayed more than two weeks. The complete list of visitors to ICTP-SAIFR can be found on the webpage <https://www.ictp-saifr.org/ictp-saifr-visitors-2020/>. The research of some of the visitors is described below:

Orlando Luis Pereyra Ravinez - Universidad Nacional de Ingeniería, Peru (01/12 - 08/12)

During my stay in SAIFR from 01 to 8 of the december 2019, I performed two types of researches in collaboration with professor Vicente Pleitez. In the first one it was necessary to confirm how the operator charge works in any $SU(n)$ extensions of the Standard Model for the cases Scalar, Vectorial and Spinorial. The charge operator appear in the literature and books but nobody explain how is assigned the electric charges values to the particles. From the phenomenology point of view we believe that this assignement was done by hand, but now we have a tool to do this directly. This work is develop by my doctoral student Eduardo Castillo under the advice of professor Pleitez and me. The second research, was a coordination for discuss some features of the preprint: Explicit parity violation in $SU(2)_L \otimes SU(2)_R \otimes U(1)_{B-L}$ models, especially in the chapter in which we present the conclusions. This work is performing by my other one doctoral student Henry Diaz, under the advice of professor Pleitez and me. We hope to send both articles this summer to arXiv, and next to PRD

Enrico Olivucci - Perimeter Institute, Canada (02/16 - 04/04)

At the ICTP SAIFR I have worked with Pedro Vieira and other members of the theoretical physics group, starting a project about the behavior of anomalous dimension of large spin operators in the Fishnet conformal field theory. We had numerous scientific discussions about Fishnet theory and the possible correlation functions to compute in order to compare the Fishnet theory with the $N=4$ SYM theory from which it can be obtained as a strong deformation. I have given a seminar at ICTP about my recent paper with S. Derkachov "Exactly solvable magnet of conformal spins in four dimensions" (PhysRevLett.125.031603). During my stay at ICTP I have spent a certain amount of time working on the follow up of this paper, by me and S. Derkachov. Furthermore I have taken part at the journal clubs of the group, held once or twice a week, and shortly after my departure I have myself given a talk.

c. Organization of activities

Between December 2019 and November 2020, the ICTP-SAIFR organized six São Paulo International Schools for Theoretical Physics, four workshops, one minicourse, weekly outreach events, seminars, colloquia and journal clubs. Due to COVID-19 several activities have been postponed to 2021-2022. The complete list of 2020 activities is on the webpage <https://www.ictp-saifr.org/2020-activities/> , the list of weekly seminars, colloquia and journal clubs is on the webpage <https://www.ictp-saifr.org/2020-research-seminars-and-activities/> . Activities, seminars and colloquia of December 2019 are described on “Past research seminars and activities” at <https://www.ictp-saifr.org/other-years-research-seminars-and-activities/> . Most of the activities were filmed and the videos are available online on the associated webpages.

c1. São Paulo International Schools

The six São Paulo International Schools were on the subjects of high performance computing (Dec. 2-13, 2019), data science and machine learning (Dec. 16-20, 2019), mathematical biology (Jan. 12-18), community ecology (Jan. 19-25), biophysics (March 9-15), and particle physics (June 22 - July 3). The schools were for mostly master’s and PhD students, and those students not from São Paulo were housed in a hotel in shared rooms. Due to COVID-19 the school on particle physics was held online. The students were asked to anonymously evaluate the schools, and the links to view their evaluations are:

<http://bit.ly/survey-hpc2019>
<http://bit.ly/survey-dmsl2019>
<http://bit.ly/survey-mathbio9>
<http://bit.ly/survey-ecology2020>
<http://bit.ly/survey-biophysics20>
<http://bit.ly/survey-spp2020>

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

c1A. 2nd Latin American School on Parallel Programming for High Performance Computing (Dec. 2-13, 2019)

The 2nd Latin American School on Parallel Programming for High Performance Computing (Dec. 2-13, 2019) is described on the webpage <https://www.ictp-saifr.org/hpc2019/> and involved 4 lecturers and 42 students. The goal of this activity was to teach scientists modern computer hardware and programming to provide a foundation for future computational research using High Performance Computing (HPC). Participants went through an intensive programme with focus on practical skills.

Lecturers:

- **Ivan Girotto** (ICTP-Trieste, Italy)
- **Axel Kohlmeyer** (Temple University, Philadelphia, US)
- **Gavin Pringle** (EPCC, Edinburgh, UK)
- **Silvio Luiz Stanzani** (NCC-UNESP/AI2, Brazil)

c1B. First School on Data Science and Machine Learning (Dec. 16-20, 2019)

The First School on Data Science and Machine Learning (Dec. 16-20, 2019) is described on the webpage <https://www.ictp-saifr.org/dsml2019/> and involved 7 lecturers, 3 tutors responsible for the hands-on activities and 58 students.

Participants learned the formalism of machine learning, starting from an introductory level and going through more advanced topics like computer vision, sequential and recursive learning, anomaly and outlier detectors, and generative models. The theoretical lectures were mixed with a set of hands-on sessions where participants were able to apply the concepts to solving real-world problems.

Lecturers:

- **Reinaldo A. C. Bianchi** (FEI, Brazil)
- **André Carlos Ponce de Leon Ferreira de Carvalho** (ICMC – USP, Brazil)
- **Anna Helena Reali Costa** (EP-USP, Brazil)
- **Alexandre Xavier Falcão** (IC-UNICAMP, Brazil)
- **Marcelo Finger** (IME-USP, Brazil)
- **João Paulo Papa** (FC-Unesp, Brazil)
- **Felipe Leno da Silva** (EP-USP, Brazil)

Hands-on activities:

- **Marcos C. S. Santana** (UNESP-Bauru, Brazil)
- **Davi Santos** (ICMC – USP, Brazil)
- **Italos E. S. de Souza** (UNICAMP, Brazil)

c1C. IX Southern-Summer School on Mathematical Biology (Jan. 12 - 18)

The IX Southern-Summer School on Mathematical Biology (Jan. 12 – 18) is described on the webpage <https://www.ictp-saifr.org/mathbio9> and involved 1 lecturer and 61 students. The school was aimed at students in Physics, Mathematics, Ecology and Epidemiology, having at least a basic knowledge of calculus and differential equations. Lectures covered the basics of population dynamics and are supplemented with modelling exercises addressing mainly problems in ecology, epidemiology and evolution.

Lecturers and Topics:

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

c1D. School on Community Ecology: from patterns to principles (Jan. 20-25)

The School on Community Ecology: from patterns to principles (Jan. 20-25) is described on the webpage <https://ictp-saifr.org/ecology2020> and involved 4 lecturers, 5 speakers and 95 participants. The school consisted of advanced courses on topics in the dynamics and structure of ecological communities, which aimed both at introducing students to up-to-date questions of the field as well as introducing useful mathematical tools. A particular focus was given to the emergence of macroecological patterns (“laws”) and to their connection to fundamental mechanisms.

Lecturers and Topics:

- **Stefano Allesina** (U. Chicago, USA): A tour of the Generalized Lotka-Volterra Model
- **Priyanga Amarasekare** (UCLA, USA): Non-linearity, variability and diversity: an integrative perspective
- **Otto Cordero** (MIT, USA): Microbial communities
- **William Bialek** (Princeton U., USA): Statistical physics of biological systems: From molecules to minds

Speakers and Topics:

- **Ricardo Martinez-Garcia** (ICTP-SAIFR/IFT-UNESP, Brazil): Ecological significance of imperfectly synchronized collective behaviors
- **Jacopo Grilli** (ICTP-Trieste, Italy): Laws of diversity and variation in microbial communities
- **Sara Mortara** (INMA – Jardim Botânico Research Institute, Brazil): Community ecology: From Patterns to the big four Processes
- **Marina C. Rillo** (University of Oldenburg, Germany): Species Competition: linking theory and data
- **Débora Princepe** (UNICAMP, Brazil): Modeling the Mito-nuclear Coevolution

c1E. APS & ICTP-SAIFR Young Physicists Forum on Biological Physics: from Molecular to Macroscopic Scale (March 9-15)

The APS & ICTP-SAIFR Young Physicists Forum on Biological Physics: from Molecular to Macroscopic Scale (March 9-15) is described on the webpage <http://ictp-saifr.org/biophysics20> , and involved 10 lecturers, 4 speakers and 67 participants. The school covered a broad spectrum of biophysical topics from highly charged, molecular Coulomb systems to the collective behavior of active particles and a broad spectrum of methodological approaches such as advanced constant-pH simulation techniques or recent developments in the foundations of non-equilibrium statistical physics.

Lecturers and Topics:

- **Leandro Barbosa** (USP-São Paulo, Brazil): Experimental techniques in structural biophysics
- **Fernando Barroso** (USP-Ribeirão Preto, Brazil): Peculiar electrostatic mechanisms observed in biomolecular systems and constant-pH simulations
- **Marko Djordjevic** (University of Belgrade, Serbia): A biophysical approach to modeling biological systems and bioinformatics
- **Ralf Eichhorn** (NORDITA, Sweden): Brownian motion and non-equilibrium statistical physics
- **Shaker Chuck Farah** (IQ-USP, Brazil): Proteins and nucleic acids: basic concepts and challenges?
- **Moyses Nussenzeig** (UFRJ, Brazil): Cell membrane biophysics with optical tweezers
- **Antonio Carlos Roque** (USP-Ribeirão Preto, Brazil): Neuronal networks (biological and artificial)
- **Erik Santiso** (NC State University, USA): Developing (macro)molecular models with SAFT- γ Mie
- **Eduardo Lima** (UERJ, Brazil): Ion-specific effects on biocolloidal systems
- **Julia Yeomans** (University of Oxford, UK): Challenges in active matter: connecting molecular and microscopic scales?

Speakers and Topics:

- **Philip Bucksbaum** (APS president – by video) – Opening remarks
- **Amy Flatten** (APS director of international affairs – by videoconference)
- **Carlos Brito Cruz** (FAPESP scientific director) – The American Physical Society and international research collaboration
- **Rogério Rosenfeld** (President of Brazilian Physical Society)

c1F. II Joint ICTP-Trieste/ICTP-SAIFR School on Particle Physics (June 22 – July 3)

The II Joint ICTP-Trieste/ICTP-SAIFR School on Particle Physics (June 22 – July 3) is described on the webpage <https://www.ictp-saifr.org/spp2020/> was held online and involved 7 lecturers and 140 participants. The school aimed at giving a detailed overview of particle physics, and covering important areas where recent progress has been made in the field.

Lecturers and Topics:

- **Masha Baryakhtar** (New York University, USA): Gravity wave probes from astrophysical sources

- **Zackaria Chacko** (University of Maryland, USA): Pontón Memorial Lecturer – New Physics Beyond the Standard Model
- **Francesco D’Eramo** (University of Padova, Italy): Dark Matter
- **Daniel Figueroa** (IFIC, Univ. Valencia, Spain): Gravity wave probes from stochastic sources
- **Riccardo Penco** (Carnegie Mellon University, USA): Effective Field Theories for Particle Physics and Beyond
- **Andrea Romanino** (SISSA, Italy): Standard Model and Flavor Anomalies
- **Rogério Rosenfeld** (IFT-UNESP/ICTP-SAIFR, Brazil): Early Universe for Particle Physics

c2. Workshops

ICTP-SAIFR organized 4 workshops on the subjects of mathematical modelling of infectious disease dynamics, string theory, research infrastructure for high energy physics and integrability. The purpose of these workshops was to discuss the status, recent progress and perspectives in each of the fields mentioned.

c2A. Workshop on Modelling of Infectious Diseases Dynamics (March 2-4)

This workshop aimed to bring together different groups of researchers in mathematical models in epidemiology and facilitate the emergence of new collaborations. It also featured a roundtable discussion on Covid-19 with international experts on the disease. The webpage of the workshop is <https://www.ictp-saifr.org/idd2020/> and speakers included:

Plenary talks:

- **Sara del Valle** (Los Alamos National Laboratory, USA): Real-time Data Fusion to Guide Influenza Forecasting Models
- **Marcelo Gomes** (FIOCRUZ/RJ, Brazil): Mathematical models for infectious diseases surveillance
- **Carrie Manore** (Los-Alamos National Laboratory, USA): Model-data Fusion and Forecasting for Mosquito-borne Diseases
- **Lisa White** (Oxford Dept. Medicine and Big Data Institute, UK): Malaria Elimination Trials and Simulations

Talks:

- **Lauren Castro** (Los-Alamos National Laboratory, USA): Using heterogeneous ecological data to predict properties of dengue outbreaks in Brazil
- **Rodrigo Malavazi Corder** (University of São Paulo, Brazil): Modelling the epidemiology of residual Plasmodium vivax malaria in a heterogeneous host population: a case study in the Amazon Basin
- **Renato Coutinho** (UFABC, Brazil): Detecting climate drivers of malaria using a causality criterion
- **Gabriel Fabricius** (INIFTA, Argentina): The dynamics of pertussis transmission: evaluating the impact of control measures through mathematical modeling
- **Claudia Pio Ferreira** (UNESP-Botucatu, Brazil): The role of intra and inter-hospital patient transfer in the dissemination of healthcare-associated multidrug-resistant pathogens
- **Andrea A. Gómez** (Centro de Estudios de Variabilidad y Cambio Climático (CEVARCAM, FICH-UNL) – CONICET, Argentina): Research topic: Infectious diseases and climate.
- **Sergio Oliva** (IME-USP, Brazil): Spatial-temporal dengue outbreaks: studies toward a warning system
- **Francisco Rodrigues** (University of São Paulo, Brazil): Machine Learning of Epidemic Processes in Networks
- **Gustavo Javier Sibona** (Universidad Nacional de Córdoba – CONICET, Argentina): Influence of individuals spatial dynamics in a SIRS model

Short talks:

- **Laís Alves** (Universidade de Brasília, Brazil): Time-series forecasting using recurrent neural

- networks and Takens' Theorem
- **Caroline Franco** (IFT-UNESP, Brazil): Data-driven investigation of Dengue and Malaria Dynamics in Brazil
- **Monicque Silva Pereira** (Secretariat of Infrastructure and Environment of São Paulo State, Brazil): Capybaras and Brazilian Spotted Fever – Technical Guidelines for Population Management in the State of São Paulo
- Helio Junji Shimozaoko (Biological Institute of São Paulo, Brazil): Evaluation of strategy control activities of Zoonotic Visceral Leishmaniasis using mathematical modelling

c2B. Workshop on Fundamental Aspects of String Theory (June 8-12)

This online workshop was jointly organized with the International Institute of Physics in Natal. In this activity, the status, recent progress and perspectives on string theory and related aspects were discussed. The webpage of the workshop is <https://www.ictp-saifr.org/string2020> and speakers included:

- **Tim Adamo** (Edinburgh University, UK) Scattering in chiral strong backgrounds
- **Eduardo Casali** (UC-Davis, QMAP, USA) Higher genus monodromy relations and color-kinematics
- **Subhrooneel Chakrabarti** (IMSc, Chennai and HBNI-Mumbai, India) Scattering of massive states in pure spinor formalism
- **Oswaldo Chandia** (Universidad Adolfo Ibáñez, Chile) The pure spinor b ghost in curved backgrounds
- **Kevin Costello** (Perimeter Institute, Canada) The Green- Schwarz string from 4d Chern-Simons
- **Harold Erbin** (Turin University, Alessandria and INFN, Italy) Algebraic structures of effective string field theory
- **Ted Erler** (ACSR Prague, Czech Republic) Mapping between Witten and lightcone SFTs
- **Yvonne Geyer** (Chulalongkorn University, Thailand) – Twistorial ambitwistor-strings: 2. Amplitude formulae
- **Nobuyuki Ishibashi** (Tsukuba University, Japan) SFT for noncritical strings revisited
- **Renann Lipinski** Jusinkas (Institute of Physics-Prague, Czech Republic) Chiral strings, the sectorized description and their integrated vertex operators
- **Hiroshige Kajjura** (Chiba University, Japan) Wondering about an open-closed correspondence
- **Sitender Kashyap** (Harish-Chandra Research Institute, India) Construction of covariant vertex operators in the pure spinor formalism
- **Shota Komatsu** (IAS Princeton, USA) The boundary state from Wilson loops
- **Matej Kudrna** (Institute of Physics-Prague, Czech Republic) SU(2) WZW model solutions in OSFT
- **Hiroshi Kunitomo** (Kyoto University and Yukawa Institute, Japan) Tree-level S-matrix of superstring field theory
- **Alok Laddha** (Chennai Math Institute, India) Dissection quivers, polytopes and scattering amplitudes
- **Carlo Maccaferri** (Turin University and INFN, Italy) Classical solutions and background independence in OSFT
- **Lionel Mason** (Oxford University, UK) Twistorial ambitwistor-strings: 1. Models
- **Toru Masuda** (ASCR-Prague, Czech Republic) 1/K in open string field theory
- **Hiroaki Matsunaga** (Institute of Physics and ASCR-Prague, Czech Republic) Path-integral and quantum A_∞ structure of quantum field theory
- **Anupam Mazumdar** (Groningen University, the Netherlands) Resolution of singularities in infinite derivative gravity
- **Ruggero Noris** (Turin Polytechnic and INFN, Italy) A simple solution for static backgrounds in cubic superstring field theory
- **Yuji Okawa** (Tokyo University Komaba, Japan) Gauge-invariant operators of open bosonic string field theory in the low-energy limit
- **Leonardo Rastelli** (YITP-Stony Brook, USA) Maximally supersymmetric RG flows in 4D and integrability
- **Ivo Sachs** (Munich University-LMU, Germany) Type II SUGRA from the spinning world line
- **Lorenz Schlechter** (Max Planck Institute-Munich, Germany) Bosonic string tachyon potentials from the $N=1$ point of view
- **Oliver Schlotterer** (Uppsala University, Sweden) Towards bases of worldsheet integrals for string amplitudes
- **Albert Schwarz** (University of California at Davis, USA) Scattering matrix and inclusive scattering matrix in QFT and string field theory
- **Ashoke Sen** (Harish-Chandra Research Institute, India) Divergent to complex amplitudes in two-dimensional string theory

- **Jim Stasheff** (North Carolina University, USA) Gauge field theory: deformations, obstructions and higher structure
- **Mritunjay Verma** (INFN-Naples and Naples University, Italy) Open-closed superstring field theory
- **Jakub Vosmera** (Institute of Physics and Charles University, Prague, Czech Republic) New results on localizing SFT effective actions
- **Xi Yin** (Harvard University, USA) D-instanton calculus in $c=1$ string theory
- **Barton Zwiebach** (MIT, USA) Hyperbolic string vértices

c2C. II Latin American Strategy Forum for Research Infrastructure: an Open Symposium for HECAP (July 6-10)

The goal of the online Symposium was to work towards establishing a regional consensus on the scientific objectives for each of the main topics of the submission tracks and to analyze the relevance of the proposed projects for the fulfillment of these objectives. A white paper was produced after the symposium which describes the priorities of the Latin-American high-energy physics community. The webpage of the workshop is <https://www.ictp-saifr.org/lasf4ri2020/> and speakers included:

- **O D Aguiar** (INPE, Brazil)
- **R Batista** (Radboud University, Netherlands)
- **N Bernal** (UAN, Colombia)
- **X Bertou** (Balseiro, Argentina)
- **R Camacho** (LPNHE, France)
- **E Carrera** (USFQ, Ecuador)
- **F Chierchie** (UNS, Argentina)
- **P Chimenti** (UEL, Brazil)
- **E Dal Pino** (IAG-USP, Brazil)
- **C Dobrigkeit** (UNICAMP, Brazil)
- **A Etchegoyen** (CNEA, Argentina)
- **J Fabris** (UFES, Brazil)
- **G O Garzón** (UBA, Argentina)
- **E Kemp** (UNICAMP, Brazil)
- **D G Lambas** (UNC, Argentina)
- **A Lepine-Szily** (IFUSP, Brazil)
- **D P R F Maltez** (UBA, Argentina)
- **J Molina** (UNA, Paraguay)
- **D Moreno** (UAN, Colombia)
- **G F Moroni** (FNAL, USA)
- **M G Munhoz** (IF-USP, Brazil)
- **I Nasteva** (UFRJ, Brazil)
- **H Nunokawa** (PUC-Rio, Brazil)
- **E Paolini** (UNS, Argentina)
- **F Queiroz** (IIP, Brazil)
- **M Rangel** (UFRJ, Brazil)
- **R Rosenfeld** (IFT-UNESP/ICTP-SAIFR, Brazil)
- **A C Rovero** (UBA, Argentina)
- **A R-Wolf** (JPL, USA)
- **C Sandoval** (UNAL, Colombia)
- **A Sanchez** (CERN, Switzerland)
- **E Segreto** (UNICAMP, Brazil)
- **J M Seixas** (UFRJ, Brazil)
- **I Sidelnik** (CONICET, Argentina)
- **G G Silveira** (UFRGS, Brazil)
- **V de Souza** (IFSC, Brazil)
- **A Sznajder** (UERJ, Brazil)
- **H Wahlberg** (UNLP, Argentina)

c2D. Integrability in Gauge and String Theory (IGST) (Aug. 24-28)

This online workshop aimed to bring the international community to discuss the scientific and organizational aspects of large-scale collaborations in astronomy and cosmology. The webpage of the workshop is <http://exact.ictp-saifr.org/> and

speakers included:

- **Fernando Alday** (U. of Oxford, UK): 6d (2,0) correlators and Quantum M-theory
- **Agnese Bissi** (Uppsala University, Sweden): Discussion Session on CFT
- **Andrea Cavaglia** (King's College London, UK): Discussion Session on Fishnet and QSC
- **Diego Correa** (U. Nacional de La Plata, Argentina): Wilson lines as 1d defects
- **Patrick Dorey** (Durham Univ., UK): Discussion Session on Sigma Models
- **Thiago Fleury** (IIP-UFRN, Brazil): Higher-Point Functions with Hexagonalization
- **Yifei He** (IPhT, France): Geometrical four-point functions in the 2d critical Q-state Potts model
- **Ben Hoare** (ETH Zurich, Switzerland): Sigma models with local couplings: a new connection between integrability and RG flow
- **Simon Caron Huot** (McGill University, Canada): Discussion Session on Amplitudes
- **Vladimir Kazakov** (ENS-Paris, France): Discussion Session on Matrix Bootstrap
- **Shota Komatsu** (IAS Princeton, USA): Discussion Session on Boundaries – PDF
- **Ivan Kostov** (U. of Paris-Saclay, France): Discussion Session on Hexagons
- **Gregory Korchemsky** (U. of Paris-Saclay, France): Octagons in planar N=4 super Yang-Mills
- **Charlotte Kristjansen** (Niels Bohr I., Denmark): Domain walls as integrable boundary states in N=4 SYM
- **Fedor Levkovich-Maslyuk** (ENS Paris, France): Separation of variables and scalar products at any rank: from spin chains to fishnet CFT
- **Henry Lin** (Princeton U., USA): Bootstrapping Matrices
- **Juan Maldacena** (IAS-Princeton, USA): Discussion Session on Black Holes and Integrability
- **Stefano Negro** (SUNY, USA): CDD deformations of $2+1$ Dimensional Integrable Quantum Field Theories
- **Leopoldo A. Pando Zayas** (University of Michigan, Ann Arbor, USA): Sub-leading microstate counting of AdS black hole entropy
- **Georgios Papathanasiou** (DESY, Germany): Integrable limits of scattering amplitudes
- **Silviu Pufu** (Princeton U., USA): Modular invariants in strongly-coupled N=4 super-Yang-Mills theory
- **Amit Sever** (Tel Aviv U., Israel): An Operator Product Expansion for Form Factors
- **David Skinner** (Cambridge U., UK): Ambitwistor Strings on AdS3 x S3
- **Evgeny Sobko** (U. of Southampton, England): Principal Chiral Model at Large N and the glimpse of a new String Theory
- **Bogdan Stefanski** (City University of London, UK): Chern Simons Origin of Superstring Integrability
- **Luigi Tizzano** (Stony Brook U., USA): Delayed Deconfinement and the Hawking-Page Transition
- **Arkady Tseytlin** (Imperial College London): Strong coupling expansion of circular Wilson loops and string theories in AdS5 x S5 and AdS4 x CP3 – PDF
- **Gustavo J. Turiaci** (UCSB, USA): Non-perturbative aspects of 2D gravity, matrix integrals, and the minimal string
- **Pedro Vieira** (Perimeter/ICTP-SAIFR, Canada/Brazil): Discussion Session on New Developments
- **Kostya Zarembo** (NORDITA, Sweden): Discussion Session on Strings
- **Deliang Zhong** (Tel Aviv University, Israel): Thermodynamic Bethe Ansatz for Fishnet CFT

c3. Minicourse

In 2020, ICTP-SAIFR organized the Online Minicourse on D-Instanton Perturbation Theory (June 1 – 4) with lectures by Fundamental Physics Prize winner, Ashoke Sen (Harish-Chandra Research Institute, India). He discussed the use of string field theory techniques to compute D-instanton correlation functions. The website of this activity is <https://www.ictp-saifr.org/string2020>.

c4. Outreach events

The ICTP-SAIFR organized 6 different types of outreach activities in 2020 aiming at different audiences. Due to COVID-19 some activities were converted to the online format, while other new online events were created. The format, topics and webpages for these events are:

- 1) Papos de Física

Papos de Física is a monthly outreach program of ICTP-SAIFR introducing current topics in theoretical physics to the general public in an informal setting. Due to COVID-19 the program was postponed and only one edition was held. The webpage for this program is <http://outreach.ictp-saifr.org/publico-leigo/papos-de-fisica/>. Topic covered during this meeting included:

- [5 de março – Barbara Amaral \(IFUSP\)- Tecnologias quânticas: será que o seu computador vai virar sucata?](#)

2) Ciência em Diálogo no IMS: Física e Arte

This outreach program involves a monthly series of presentations at the IMS featuring one scientist and one non-scientist who discuss a topic of common interest. Due to COVID-19 the program was postponed and only two editions were held. The webpage for the program is <http://outreach.ictp-saifr.org/dialogo/>. Topics covered during these meetings included:

- 1 de fevereiro: Reprise - *Ficção Científica*, com Antônio Xerxenesky (escritor) e Rodrigo Nemmen (IAG-USP)
- 6 de março: *Leonardo da Vinci*, com Rodrigo Naves (crítico de arte) e Deniol Tanaka (POLI-USP)

3) ICTP-SAIFR distinguished Public Lectures:

The goal of this program is to bring outstanding scientists to give talks to the general public on relevant topics in physics. Topic covered included:

- [January 23: Willian Bialek \(Princeton University\) – The physics of life: How much can we calculate?](#)

4) Física em Casa:

Physics at Home is a new outreach program of ICTP-SAIFR introducing current topics in theoretical physics to the general public in an online format. The webpage for the program is <http://outreach.ictp-saifr.org/fisica-em-casa/>. Topics covered during these meetings included:

- [7 de maio – De que é feito o Universo? com Rogério Rosenfeld \(ICTP-SAIFR/IFT-UNESP\) – junto com a Marcha Virtual pela Ciência](#)
- [21 de maio – Possível ou impossível com Pedro Vieira \(ICTP-SAIFR/Perimeter Institute\)](#)
- [4 de junho – Astronomia das ondas gravitacionais com Riccardo Sturani \(ICTP-SAIFR/IFT-UNESP/IIP-Natal\)](#)
- [18 de junho – Supercordas: sucessos e desafios com Nathan Berkovits \(ICTP-SAIFR/IFT-UNESP\)](#)
- [2 de julho – Sistemas Complexos: quando o todo é maior do que a soma das partes com Ricardo Martinez-Garcia \(ICTP-SAIFR/IFT-UNESP\)](#)
- [16 de julho – Aceleradores Cósmicos de Partículas: Buracos Negros e Jatos Supersônicos com Elisabete M. de Gouveia Dal Pino \(IAG-USP\)](#)
- [30 de julho – Neutrinos: O que são e para que servem? com Andre de Gouvêa \(Universidade de Northwestern\)](#)
- [13 de agosto – Um “POEMMA” – detector de partículas cósmicas ultra-energéticas com Angela V. Olinto \(Universidade de Chicago – EUA\)](#)
- [27 de agosto – Grafeno: a física na ponta de um lápis com Marcos Pimenta \(UFMG\)](#)
- [10 de setembro – Emaranhamento quântico e um novo paradigma para o processamento de informação com Rafael Chaves \(IIP-UFRN\)](#)
- [24 de setembro – Muito tempo atrás, numa galáxia muito, muito distante... com Eivaldo Moura Santos \(IFUSP\)](#)
- [8 de outubro – Física dentro do copo de água com Luana Pedroza \(UFABC\)](#)
- [22 de outubro – A Física na Diplomacia com Ernesto Mané \(físico e diplomata\)](#)
- [29 de outubro – Buracos Negros e o Nobel de 2020 com Rodrigo Nemmen \(IAG-USP\)](#)
- [5 de novembro – Supercondutividade: um fenômeno quântico macroscópico com Eduardo Miranda \(UNICAMP\)](#)
- [19 de novembro – Mudanças climáticas: investigando o passado para prever o futuro](#)

5) Minicourses for High-School Students:

This program involves several minicourses on topics of modern physics to high-school Students. Due to COVID-19 activities were held online. The webpage for the minicourses is <http://outreach.ictp-saifr.org/ensino-medio/minicurso/> and topics covered include:

- Aula inaugural – 07 de março- Pedro Vieira (ICTP-SAIJR & Perimeter Institute, Canadá)
- Introdução à mecânica quântica (on-line) – 21 de março a 18 de abril - Pedro Vieira (ICTP-SAIJR & Perimeter Institute, Canadá)
- Introdução à física de partículas (on-line) – 25 de abril a 23 de maio - Ricardo Matheus (IFT-UNESP)
- Aula especial “COVID-19 no Brasil: modelos do passado e do futuro” – 6 de junho - Roberto Kraenkel (IFT-UNESP)
- Introdução à física do espaço-tempo: relatividade geral e especial (on-line) – 13 de junho a 18 de julho - George Matsas (IFT-UNESP)
- Astrofísica relativística: uma visão geral sobre estrelas de nêutrons (on-line) – 1º de agosto - Cecília Chirenti (UFABC, Universidade de Maryland & NASA Goddard Space Flight Center)
- Física do universo: cosmologia (on-line) – 08 de agosto a 29 de agosto - Rogério Rosenfeld (ICTP-SAIJR/IFT-UNESP)
- Oscilações quânticas de neutrinos (on-line)- 05 de setembro - Marcelo Guzzo (IFGW – UNICAMP) & Marina Reggiani-Guzzo (doutoranda – Universidade de Manchester)
- Teoria ondulatória: da água às cordas (on-line) – 12 de setembro a 03 de outubro - Nathan Berkovits (ICTP-SAIJR/IFT-UNESP)
- Termodinâmica e introdução à mecânica estatística – 10 de outubro a 07 de novembro - Ricardo Martínez-García (ICTP-SAIJR/IFT-UNESP)
- Física matemática: de Newton à mecânica quântica – 14 de novembro a 28 de novembro - Alberto Saa (IMECC – UNICAMP)

Besides, Lucas David and Felipe Novaes, high-school teachers with FAPESP fellowships, complimented these minicourses with additional theoretical classes on mathematical tools used in physics, electricity and magnetism and activities such as measuring Planck’s constant using LEDs and calculation of dark matter in a galaxy. These classes were presented weekly on Saturdays and Tuesdays and initially taught at IFT and UFABC, and later held online. Links to the classes by Lucas David and Felipe Novaes are

<http://outreach.ictp-saifr.org/modulo-de-aulas-complementares-ift/>

<http://outreach.ictp-saifr.org/modulo-de-aulas-complementares-ufabc/>

6) Workshops for High-School Teachers

This program presents classroom methods for teaching modern physics concepts to high-school teachers using material developed by Perimeter Institute and translated and adapted by ICTP-SAIJR. In 2019 ICTP-SAIJR organized several activities in São Paulo and other states in Brazil, led by ICTP-SAIJR outreach coordinators Ana Luiza Sérgio and Lucas David. During this period, two weekend workshops were organized in São Paulo:

- [30 de novembro e 01 de dezembro: São Paulo – Nobel](#)
- [March 7-8 – Women and the Universe – São Paulo](#)

Due to the COVID-19 the workshops were converted to online meetings. The meetings were held 4 times per week, and over 100 meetings were held in 2020 with the active participation of over 2500 high-school teachers. Topics discussed at these online meetings in 2020 are described at <http://outreach.ictp->

saifr.org/ensino-medio/professores/fisica-de-fronteira-para-a-sala-de-aula-online/atividades-ja-realizadas/ and <http://outreach.ictp-saifr.org/ensino-medio/professores/fisica-de-fronteira-para-a-sala-de-aula-online/>

c5. Weekly seminars, colloquia and journal clubs

Between December 2019 and November 2020, weekly seminars and colloquia were regularly organized. There were 76 seminars and colloquia and the complete list is on the webpage <https://www.ictp-saifr.org/2020-research-seminars-and-activities/>. The list of the seminars of December 2019 are shown at <http://www.ictp-saifr.org/other-years-research-seminars-and-activities/>. There were also weekly journal club meetings in string theory, particle physics and cosmology.

c6. Annual meeting of Steering Committee and Scientific Council

On February 3-4, 2020, the ICTP-SAIFR steering committee and scientific council met to evaluate the activities of 2019 and to discuss the future plans and activities for 2021. The program is on the webpage <https://www.ictp-saifr.org/2020-meeting-of-steering-committee-and-scientific-council/> and the council members are listed on the webpages <http://www.ictp-saifr.org/steering-committee/> and <http://www.ictp-saifr.org/scientific-council/>.

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. Since January 2021, the computer systems manager position has been vacant with the departure of Lucas Sanches to Germany. The hiring of his replacement by UNESP has been delayed due to the pandemic.

Part of the institutional reserve técnica was used in 2019-2020 to substantially upgrade the recording equipment in the IFT-UNESP auditorium following the guidance of the Perimeter Institute audiovisual department.

6. Activity Plan for 2021

In 2021, the ICTP-SAIFR will continue and expand its research, outreach and training activities in all areas of theoretical physics. Depending on the pandemic scenario, activities during the first semester will be held online. Confirmed scientific activities in 2021 which will be organized by ICTP-SAIFR include international schools and workshops on topics including mathematical biology, ecology, biophysics, nonlinear systems, particle physics, theoretical condensed matter physics, quantum computation, few-body systems and data science and machine learning. The list of 2021 activities confirmed up to now include the activities:

São Paulo International Schools on Theoretical Physics

IV Joint ICTP-Trieste/ICTP-SAIFR School on Cosmology: Challenges for the Standard Cosmological Model
January 18-29, 2021

X Southern-Summer School on Mathematical Biology
February 21-28, 2021

School on Spatial Ecology: from individual movement to emergent patterns
March 1-6, 2021

Serrapilheira/ICTP-SAIFR Research Training Program in Quantitative Biology
July - December, 2021

Advanced School on Programmable Systems-on-Chip, Embedded Microcontrollers and their Applications
in Research and Industry
September 6-17, 2021

Joint ICTP-SAIFR/MITP Summer School on Particle Physics
September 13-24, 2021

[School on Critical Stability of Few-Body Quantum Systems](#)
October 4-8, 2021

[School on Applications of Nonlinear Systems to Socio-Economic Complexity](#)
October 25-27, 2021

School on quantum computation
November 16-26, 2021

2nd School on Data Science and Machine Learning
December 6-10, 2021

[School on DFT and Beyond: Electronic Structure Theory in the Era of Data-Driven Science](#)
February 14-25, 2022

Meetings/Programs/Workshops

Strings 2021
June 21-26, 2021

Meeting of ICTP-SAIFR Steering Committee and Scientific Council
June 27-29, 2021

Workshop on New Horizons in Quantum Correlated Materials
August, 2021

[Workshop on Critical Stability of Few-Body Quantum Systems](#)
October 11-15, 2021

[Workshop on Sociophysics: Social Phenomena from a Physics Perspective](#)
October 28-30, 2021

Tenth Anniversary of ICTP-SAIFR
November, 2021

Minicourses/Minischools

[Minicourse on the condensed matter theory of particle physics](#)
November 2021

[Minischool on Aspects of Topological Matter at Equilibrium and Out-of-equilibrium](#)
November 2021

Outreach

[Curso de Verão para Professores de Ensino Médio](#)

January 11-15, 2021

[Escola de Verão para Jovens Físicos](#)

January 18-23, 2021

[Papos de Física](#)

July – November, 2021

[Minicursos para Estudantes do Ensino Médio](#)

March – November, 2021

[Ciência em Diálogo: Física e Arte](#)

July – November, 2021

[Física Moderna para Professores do Ensino Médio](#)

March-November, 2021

[Física em Casa](#)

March-November, 2021

2021 IFT-Perimeter-SAIFR Journeys into Theoretical Physics

July 2021

Prêmio Jovens Físicos 2021

July 2021

7. Use of Reserva Técnica Funds

Between December 2019 and November 2020, the part of the reserva técnica funds related to “Custos de Infraestrutura Direta do Projeto” was used for the following purposes:

- a) Published advertisement of IT position: R\$ 300.00
- b) Design and printing of posters for announcements of Schools/Workshops activities: R\$ 1,839.50
- c) Post office expenses – delivery of School/Workshop posters: R\$ 3,904.60
- d) Service payment to Isabela Pereira for technical support in the transmission and recording of online events (authorized by FAPESP): R\$ 6,000.00
- e) Purchase of printer cartridge: R\$ 975.00
- f) Use of a service Email provider (Mailjet) to announce all ICTP-SAIFR activities and send newsletters: R\$ 1,732.02
- g) Use of Zoom platform for all ICTP-SAIFR online activities (authorized by FAPESP): R\$ 4,340.83

And the part of the reserva técnica funds related to “Benefícios Complementares” was used for the following purposes:

- a) Per diem for participation in the DESC (Dark Energy Science Collaboration) Meeting (January 20-24, 2020) of ICTP-SAIFR vice-

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)

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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 and direct doctoral students

See annexed file for scientific reports of

Vivian Dornelas, Leonardo Guerini, Andrea Guerrieri, Martin de Los Rios, Gabriel Andreguetto Maciel, Diego Medrano, Antonino Troja, Krissia Zawadzki, Cassiano Antonio Daniel, Lucas Nogueira de Sá Martins, João Victor Silva Rebouças.

10. Scientific reports of TT, EP and JC

See annexed file for scientific reports of

Adrianna Virmond, Artur Alegre, Cintia Cirillo, Felipe Novaes, Lucas Campos, Nelson Barrelo Jr., Isabela Pereira