

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

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**Fapesp Project Number:** 2016/01343-7

**Project Period:** 01/12/2016 – 30/11/2022

**Period covered by this Report:** 01/12/2020 – 30/11/2021

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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.

In its brief existence, the ICTP-SAIFR has already established itself as the premier institute for theoretical physics in South America. Its international schools and workshops for graduate students and researchers are selected from online proposals every year by the ICTP Scientific Council and attract the top students and lecturers from all over the world to São Paulo. Since the creation of ICTP-SAIFR, the graduate physics department of IFT-UNESP has been awarded the highest rating from the national agency CAPES despite its relatively small size. And with the help of a world-class scientific council and international search committee, ICTP-SAIFR has been able to reverse the brain drain and attract the top candidates to its faculty and postdoctoral positions. Its faculty currently include **Director Nathan Berkovits**, winner of the [2009 TWAS Physics Prize](#) for his research in string theory and the [2021 John Wheatley Award](#) for ICTP-SAIFR's role in South America, **Vice-Director Rogério Rosenfeld**, member of the Dark Energy Survey collaboration and president of the Brazilian Physical Society from 2019-2021, **Pedro Vieira**, joint professor at Perimeter Institute and winner of the [2018 Sackler Physics Prize](#) and [2020 New Horizons in Physics Prize](#) for his research in quantum field theory, **Riccardo Sturani**, member of the LIGO-Virgo collaboration which was recently awarded the Nobel Prize for the detection of gravitational waves, and **Ricardo Martinez-Garcia**, winner of a Serrapilheira grant for his research in mathematical ecology, coauthor of the [December 2020 cover of Science](#), and elected in 2020 as an affiliated member to the Brazilian Academy of Science. Pedro Vieira is originally from Portugal and spends 6 months per year at IFT-UNESP with a [FAPESP São Paulo Excellence Chair](#), and Riccardo Sturani and Ricardo Martinez-Garcia came to Brazil from Italy and Spain as FAPESP Young Investigator Fellows and are expected to begin their permanent positions at IFT-UNESP in January 2022 as soon as the Covid-19 hiring restrictions have been relaxed.

Simons-FAPESP "tenure-track" professors and FAPESP postdocs with temporary positions at ICTP-SAIFR are annually selected through an online application process involving hundreds of applicants. For the postdoctoral positions, a final short list of candidates are interviewed by the ICTP-SAIFR faculty and associated researchers in the research area of the candidates. And for the Simons-FAPESP group leader positions, the final short list of candidates are invited to present seminars and are interviewed by members of the ICTP-SAIFR Scientific Council and International Search Committee consisting of distinguished professors including Nobel Prize winners. These ICTP-SAIFR fellowships have attracted many outstanding researchers to return or to immigrate to Brazil, reversing the brain drain. In 2022, two new Simons-FAPESP "tenure-track" professors will be selected in the areas of theoretical physics and biological physics.

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](http://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 related to 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. Over the next years, the ICTP-SAIFR intends to build on these recent accomplishments and continue to improve its research and organizational activities and consolidate its status as the premier theoretical physics institute in South America.

## 4. Accomplishments in the period

During the period of December 1, 2020 - November 30, 2021, all ICTP-SAIFR activities were held online because of the Covid-19 pandemic. Although this prevented direct in-person interactions between lecturers and students, it allowed global participation in ICTP-SAIFR's online activities which included several new innovative programs ideally suited for the Zoom online platform.

For graduate students, ICTP-SAIFR initiated in 2021 a program called "[Physics Discussions](#)" in which an on-line colloquium broadcast live on Youtube was combined with Zoom sessions before and after the colloquium in which only the lecturer and graduate students were invited to participate. ICTP-SAIFR also initiated in 2021 an [annual prize in Classical Gravity and Applications](#) for PhD students from Latin America. For researchers, ICTP-SAIFR organized [workshops](#) and [conferences](#) involving Zoom discussion sessions where hundreds of physicists from around the world watched pre-recorded seminars and met live to discuss the results. For high-school teachers, ICTP-SAIFR completed the translation of the Perimeter Institute pedagogical material into [Spanish and Portuguese](#) with support from the American Physical Society, and organized weekly workshops in both [Spanish](#) and [Portuguese](#) for teachers from all over Latin America where the Zoom breakout rooms were used to practice the classroom exercises. For high-school students, ICTP-SAIFR initiated an annual [one-week school](#) with the Univ. of Porto in which high-school students worked on research projects supervised by doctoral students. And for the general public, ICTP-SAIFR created new online material including [multimedia presentations](#) on astronomy and particle physics research groups in Brazil, a [Youtube channel](#) with interviews of visiting and local researchers, [biographies](#) of important Brazilian physicists, and short informative [Instagram videos](#) on modern physics topics.

There were several highlights during this period which are all described in the ICTP-SAIFR bimonthly [scientific bulletins](#). In December 2020, an article on plant competition by ICTP-SAIFR faculty member Ricardo Martinez-Garcia and collaborators was featured on the cover of [Science magazine](#). Also in December, Prof. Martinez-Garcia was elected to the Brazilian Academy of Science as an affiliated member.

In January 2021, the Simons Foundation in New York announced ICTP-SAIFR as one of the 3 winners of the [2021 Targeted Grants for Institutes](#) which involves a generous donation supporting two tenure-track Simons-FAPESP professors for 3 years. An [international search committee](#) was formed to evaluate candidates and it is expected that two new Simons-FAPESP faculty members will be chosen in 2022. Also in January, ICTP Associate member Hilda Cerdeira was awarded the 2021 Spirit of Abdus Salam Prize and ICTP Associated member Rafael Porto was awarded the Buchalter Cosmology Prize 2020.

In March 2021, ICTP-SAIFR director Nathan Berkovits was awarded together with ICTP-Trieste ex-director Fernando Quevedo the [2021 John Wheatley Prize](#) from the American Physical Society at their annual March meeting for contributing to the development of fundamental physics research in South America.

In May 2021, the Dark Energy Survey collaboration including ICTP-SAIFR vice-director Rogério Rosenfeld released its 3-year results on galaxy clustering and gravitational lensing which involved 30 interconnected papers.

In June 2021, the annual Strings meeting was organized for the first time in 35 years in Latin America by ICTP-SAIFR. The [two-week online meeting](#) attracted [2480 registered participants](#) and featured new interactive online formats such as informal discussions on various topics and a [Youtube event](#) for the general public with over 7500 views. Also in June, researchers of the LIGO-Virgo-KAGRA Collaborations including ICTP-SAIFR faculty member Riccardo Sturani announced the first observations of collisions between a black hole and a neutron star.

In July 2021, the first version of the [Serrapilheira/ICTP-SAIFR Training Program in Quantitative Biology and Ecology](#) was organized in a special one-month online version which featured 15 minicourses by distinguished biologists and physicists for graduate students from Latin America. The next version of this training program will be an in-person six-month program from July-December 2022 which will be repeated every year and coordinated by ICTP-SAIFR faculty member Ricardo Martinez-Garcia with financial support from the Serrapilheira Institute.

In August 2021, the editors of Physical Review Letters highlighted the paper "[Where is string theory in the space of scattering amplitudes](#)" written by ICTP-SAIFR faculty Pedro Vieira and collaborators on the subject of consistent theories of quantum gravity.

And in September 2021, the ICTP-SAIFR steering committee and scientific council met online to discuss future projects and directions of ICTP-SAIFR. New members of the steering committee include the UNESP rector, Pasqual Barretti, the FAPESP scientific director, Luiz Eugênio Mello, and the president-director of Serrapilheira Institute, Hugo Aguilaniu. In addition to approving the renewal of the MoU's with ICTP Trieste and Perimeter Institute, a new non-profit association called "[Friends of SAIFR Institute](#)" was created which will simplify the procedure for receiving private donations.

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), Rogério Rosenfeld (cosmology and particle physics), 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. ICTP-SAIFR is also the host of the newly formed [Latin-American Association for High-Energy, Cosmology and Astroparticle Physics](#) and is a partner of the new NSF-funded [Interamerican Network of Networks of QCD Challenges](#).

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.

The 119 research publications of this 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). During this period, ICTP-SAIFR organized international schools on cosmology (Jan. 18-29), quantitative biology and ecology (July 5-30), few-body quantum systems (Oct. 4-8) and systems-on-chip microcontrollers (Oct. 18-29), and international workshops on dark matter (Dec. 2-9), observational cosmology (Dec. 14-18), quantum mechanics (June 7-11), string theory (June 21-July 2), condensed matter (August 30 - Sept. 21), sociophysics (Oct. 18-22) and high-energy physics (Nov. 8-12).

In addition to these research and training activities, ICTP-SAIFR converted all of its outreach activities into online events which attracted thousands of participants from all over Brazil and Latin America. For the general public, ICTP-SAIFR organized a biweekly presentation on Thursday evenings entitled "[Física em Casa](#)" with 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, [multimedia presentations](#) on astronomy and particle physics in Brasil, [biographies](#) of important Brazilian physicists, and short informative [Instagram videos](#) on modern physics topics. For high-school students, the series of [Saturday morning minicourses](#) was continued online with minicourses on solid state physics (Aline Ramires), general relativity (Pedro Vieira), astrophysics (Cecilia Cirenti), atomic physics (Luana Pedroza), statistical mechanics (Ricardo Martinez-Garcia), dimensional analysis (George Matsas), particle physics (Ricardo Matheus), quantum mechanics (Alberto Saa), quantum computing (Gastao Krein), and cosmology (Rogerio Rosenfeld). In addition, high-school teachers Lucas David and Felipe Santos presented [weekly online classes](#) to students on advanced topics in mathematics and physics. Online discussion sessions between physicists and high-school students were held in "[Inspiring new generations of physicists](#)", and a [one-week school](#) with the Univ. of Porto was organized in which high-school students worked on research projects supervised by doctoral students. Finally, for high-school teachers, ICTP-SAIFR completed the [translation](#) of all 16 volumes of the Perimeter material into Portuguese and Spanish with support from the American Physical Society, and the workshops showing how to use Perimeter-based material on modern physics in the classroom were converted to weekly online sessions in [Spanish](#) and [Portuguese](#) with the participation of thousands of high-school teachers from all over Brazil and Latin America..

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 2021 were postponed until 2022 when normal activities are expected to be resumed. These postponed schools and workshops include a workshop on few-body systems, a school and workshop on density functional theory, a workshop on electromagnetic systems, a school 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

The activities of ICTP-SAIFR in 2021 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 119 publications and several of them will be described below.

### a1. High Energy Physics

#### a.1.1. String theory

String theory is at present the only known consistent theory of quantum gravity which allows the computation of graviton scattering amplitudes. In [117], the consistency properties of these graviton amplitudes were studied to determine where string theory sits in the space of all possible theories of quantum gravity. And in [116], the consistency properties of the most general field theories with both conformal invariance and supersymmetry were studied.

Over the last 20 years, superstring theory has been applied through the AdS-CFT correspondence to applications in gauge theory, condensed matter theory and cosmology. This correspondence requires studying the superstring in an Anti-de-Sitter background with Ramond-Ramond fields, and the only available formalism for the superstring in this background is the pure spinor formalism. In [16], the geometrical properties of this formalism was studied including its singularity structure. And in [19], the relation of this pure spinor formalism to the more conventional Ramond-Neveu-Schwarz formalism was explored and a manifestly spacetime supersymmetric version of the Ramond-Neveu-Schwarz formalism was constructed..

When the background is AdS<sub>5</sub>S<sup>5</sup>, the superstring is dual to a four-dimensional maximally supersymmetric version of QCD whose asymptotic states were studied in [119]. In [100], more general AdS<sub>5</sub>T<sup>1</sup> backgrounds were studied which are dual to the version of four-dimensional QCD with less supersymmetry. And in [99] and [101], integrable deformations of the AdS<sub>4</sub>CP<sup>3</sup> background were studied which is dual to three-dimensional field theories. Through this duality, the AdS<sub>4</sub>CP<sup>3</sup> background and its deformations are very useful for learning about condensed matter theories and is called the AdS-CMT correspondence whose properties were studied in [48]. The AdS-CFT correspondence can also be used to construct a cosmological model called "holographic cosmology", and [47] and [50] studied the implications of holographic cosmology for particle physics by investigating the presence of monopoles and the process of reheating in this model.



String theory is a two-dimensional field theory with worldsheet conformal invariance, and a deformation of this theory called the T-Tbar deformation produces interesting physical phenomena which can be related to nuclear physics. In [46] and [49], T-Tbar deformations of the Skyrme model and Heisenberg model for high-energy nucleon-nucleon scattering were investigated.

### a.1.2. Particle and Astroparticle Physics

The Standard Model (SM) of Particle Physics has been tested to great precision and searches for phenomena proposed by models beyond the SM were searched at the LHC. Also, the overwhelming astrophysical evidence for the existence of dark matter points to the incompleteness of the SM. ICTP-SAIFR researchers have been actively working on these important issues.

Results from the CMS collaboration working at the LHC were reported in [53-83]. As highlights we can list: the measurement of the electroweak diboson production cross sections at the LHC using leptonic decays Novaes[6], the observation of a new excited beauty-strange baryon [80], both published in Physical Review Letters, and the search for a heavy Higgs boson decaying into two lighter Higgs bosons in the  $\tau\tau b\bar{b}$  final state at 13 TeV [60].

On the theoretical side, several studies were conducted involving aspects of physics beyond the SM. [27] obtained unitarity constraints on axion-like-particles, [91] analyzed consequences of the recent muon ( $g-2$ ) results and [96] studied processes at a future muon collider. Aspects of dark matter models were discussed in [92, 93, 95].

Another research topic covered is related to the theory of strong interactions, QCD, in the works [37-40]. In particular, lattice QCD was used to constrain a model for strong interactions in [39].

### a.1.3. Cosmology and Gravity

ICTP-SAIFR researchers are taking part in international collaborations to explore the cosmos, such as the Dark Energy Survey (DES), the Rubin Observatory's Legacy Survey of Space and Time (LSST), the Javalambre Physics of the Accelerated Universe Survey (J-PAS) and the related S-PLUS and MiniJPAS surveys, the Laser Interferometer Gravitational-wave Observatory (LIGO), KAGRA and Virgo Collaborations.

In particular, the DES has released the analysis of its third year of data-taking which comprises the largest catalogs with position and shapes of  $\sim 100$  million objects. These results are shown in [41-45], and in particular the redshift estimation method is described [43], the weak lensing catalog used for the scientific results is the subject of [44] and the statistic methods to assess tensions in the comparison of different data sets are described on [42]. On the other hand, [107] present results for DES clustering of galaxies in harmonic space, whereas [106] proposes a method to incorporate baryonic modelling uncertainties in future LSST data.

A photometric redshift catalog for MiniJPAS survey was released in [5], results for the S-PLUS survey is the subject of [2] and a forecast for interacting dark energy for JPAS was published in [3]. On the more theoretical side, halo spin bias was studied in [1] and relativistic effects on the matter power spectrum were discussed in [4].

Results from LIGO, VIRGO and KAGRA collaborations on gravitational waves are described in [108, 110, 111, 112, 114]. In particular, [111] reports the observation of gravitational waves from two compact binary coalescences in LIGO's and Virgo's third observing run with properties consistent with neutron star-black hole (NSBH) binaries.

On the theoretical side, [109] studies the effect of scattering gravitational radiation off the static background curvature, up to second order in Newton constant. [113] revisits several aspects of the interaction of self-gravitating, slowly varying sources with their own emitted radiation within the context of post-Newtonian approximation to General Relativity using Effective Field Theory (EFT). Spin effects in gravitational radiation from inspiralling compact objects are studied in [84, 85].

#### a.1.4. Astrophysics

One of the most important future experiments in Astrophysics is the Cherenkov Telescope Array (CTA). ICTP-SAIFR researchers Dal Pino and Nemmen are members of CTA, with Dal Pino being a PI for a Fapesp Thematic Project focusing on the construction of the small antennas for the array. [22, 23] explore the sensitivity of CTA to probing fundamental physics with the propagation of gamma-rays and to a possible signal of dark matter coming from the center of our galaxy.

The acceleration mechanism of charged particles in astrophysical environments is related to the presence of strong magnetic fields and this effect has to be studied in numerical magneto-hydro-dynamical (MHD) simulations. These issues are investigated in [20, 21, 24, 25], including the production of high energy neutrinos in these processes [26].

The enormous black hole in the center of our galaxy can be studied with the gamma-ray observations of the instrument LAT in Fermi satellite (Fermi-LAT) and an imaging analysis was performed in [52]. Interestingly, the properties of our galaxy can also be used to test modified theories of gravity, as done on [32].

### 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. Regarding the pandemic and epidemiology in general, a variety of studies were made. [14] introduced an individual based model to describe the genetic evolution of a RNA-virus epidemic spreading. The P.1. variant, which started in Manaus, received the attention of [87], being ranked as one of the most transmissible among SARS-CoV-2 VOCs currently identified and potentially as transmissible as the posteriorly detected VOC B.1.617.2 (Delta variant). [33 and Prado] analyzed the impact of the same variant in Brazil and suggested a number

of science and health policies that might help to deal with new variants and possible new epidemics, while [88] argued in favor of a transdisciplinary approach towards science policies and that the pandemic might be good time to rethink such policies. Lastly, [36] studied cutaneous leishmaniasis cases using data provided by the Ministry of Health of Brazil from 2001 to 2017 and calculated incidence rates.

In the fields of population studies and ecology, mathematical biology was quite prolific during the last year among our researchers. [30] explored avenues to develop further a game theory based model, while [86] made a systematic comparison between two statistical approaches towards ecology called null hypothesis testing and information theory. [15] studied the Moran model to analyze the role of drifting and mutation on the diversity of a population in the absence of migration and natural selection. [28] analyzed a spatial Lotka-Volterra competition model and proposed that the creation of spatial patterns in population densities might suggest that long-range competition is a key driving force behind the rich diversity of species observed in natural ecological communities. Lastly, [118] used both numerical and analytical techniques to study the effect that disturbances in the ecological landscape exert on the spatial distribution of a population.

New models and methodologies were introduced as well. [31] introduced an asymmetric noisy voter model to study the joint effect of immigration and a competition-dispersal tradeoff in the dynamics of two species competing for space in regular lattices. Based on ecological succession theory as a case study, [90] proposed a new theoretical scheme for ecology with a more pluralistic and process-based theoretical approach. [29] introduced a new methodology called conditional distribution of encounters (CDE) which use model-based analysis to understand individual behaviors and the positive/negative encounters on higher level processes. And lastly, [89] jointly modelled the occurrences and co-occurrences of 1016 tropical tree species with abundance data from inventories of 574 localities in eastern South America in order to explore the influence of environmental filtering and limiting similarity.

### a.2.2. Quantum information

In the field of quantum information, three articles were published throughout 2021. [17] introduced the first observation of a quantum superposition of more than  $N = 2$  temporal orders, and demonstrated how it can be useful for efficient phase estimation. [18] made experiments that show the potential of exposure as a resource-theoretic transformation, showing inconsistencies between the traditional definition of multipartite steering and the widely accepted basic notion of locality. And the third article, [115], considered two-qubit Yang-Baxter operators and showed that their eigenvalues completely determine the non-local properties of the system, and also computed their entangling power and compared it with that of a generic two-qubit operator.

### a.2.3. Non-linear systems

In non-linear systems applied to wave physics, [35] studied the role of constant vorticity on weakly nonlinear surface gravity waves and introduced a new hierarchy of weakly nonlinear equations for surface gravity in finite depth in the presence of

constant vorticity  $\Omega$ . And [34] revisited Miles' theory of wave amplification by wind and extended it to the case of finite depth  $h$  and a shear flow with (constant) vorticity  $\Omega$ .

And in non-linear systems applied to Bose-Einstein condensation (BEC), [6] and [9] presented FORTRAN programs that solve the time-dependent nonlinear partial differential Gross-Pitaevskii (GP) equation for a trapped spinor BEC, with or without spin-orbit coupling, in one and two spatial dimensions. And [7] and [11] used the mean-field Gross-Pitaevskii equation for demonstrating, respectively, exotic stable quasi-two-dimensional solitons in a Rashba or a Dresselhaus spin-orbit (SO)-coupled state. While [8] demonstrated spontaneous spatial order in stripe and super-lattice solitons in a Rashba spin-orbit ferromagnetic BEC, [10] studied supersolid-like states in a quasi-two-dimensional trapped Rashba and Dresselhaus spin-orbit coupled condensate. Finally, [12] studied the formation of spin-1 symbiotic spinor solitons in a quasi-one- and quasi-two-dimensional ferromagnetic BEC.

#### a.2.4. Condensed matter theory

Emergent properties of complex systems in condensed matter theory were studied in several papers over the last year which can have important technological applications. [102] used different spectroscopies techniques to investigate the band alignment and the interfacial electronic coupling of van der Waals heterojunctions. [105] presented a theoretical and experimental review regarding aspects of Low-Dimensional-Materials-Based FET Immunosensors, focusing on devices that use LDMs (1D and 2D) as the sensing substrate. And [103] employed the density-functional theory-based tight-binding approach to study the impact on the geometry and electronic structure of phenylalanyl tryptophan nanotubes (PTNTs). An effective control of the structure and electronic properties of one-dimension PTNT can lead the way for potential medical and bioelectronic applications.

Finally, [104] dealt with the problem of simulating the properties of bulk water, which can be expensive and computationally demanding. The aim of the paper was to evaluate the errors that density functional theory (DFT)-based simulations routinely incur due to time- and size-scale limitations, and to offer a path to discriminate between model and convergence errors in these simulations.

### b. Research related to visitors

Due to COVID-19 the IFT-UNESP was closed since April 2020 which directly affected the number of visitors. In September 2021 IFT-UNESP was reopened to the community, with 30% of its capacity. Between December 2020-2021, the ICTP-SAIFR hosted 2 long-term visitors who stayed more than two weeks. The research developed during their visit is described below:

**Enrico Olivucci** – Perimeter Institute, Canada (10/17 - 12/15)

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.

**Jacob M. Abajian** - Perimeter Institute, Canada (11/22 - 12/18)

I have worked with Pedro Vieira and Francesco Aprile on a project focused on the calculation of correlation functions of very heavy operators in holographic Conformal Field Theories. We exactly calculated the structure constants of certain  $1/2$  BPS operators in  $\mathcal{N}=4$  supersymmetric Yang-Mills theory in 4d, and are working on extending the family of operators for which this calculation is done (both exactly and in the large  $N$  expansion). We also are working on calculating these structure constants holographically at large  $N$  in terms of the action of particular supersymmetric, asymptotically AdS geometries. As a first step towards this, we are working out how to calculate the two point function of very heavy operators in CFT's with a bulk gravitational limit in terms of a black hole geometry. The hope is that once we have understood this, we can then do the same for the supersymmetric bulk configurations and match with the result we got from CFT. This would provide an important further precision check of the AdS/CFT dictionary.

## c. Organization of activities

Between December 2020- December 2021, the ICTP-SAIFR organized four São Paulo International Schools for Theoretical Physics, ten workshops, and weekly outreach events, seminars, colloquia and journal clubs. Due to COVID-19 several activities have been postponed to 2022-2023. The complete list of 2021 activities is on the webpage <https://www.ictp-saifr.org/2021-activities/>, the list of weekly seminars, colloquia and journal clubs is on the webpage <https://www.ictp-saifr.org/2021-research-seminars-and-activities/>. Activities, seminars and colloquia of December 2020 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 recorded and the videos are available online on the associated webpages.

### c1. São Paulo International Schools

The four online São Paulo International Schools were on the subjects of cosmology (Jan. 18-29), quantitative biology and ecology (July 5-30), few-body quantum systems (Oct. 4-8) and systems-on-chip microcontrollers (Oct. 18-29). The schools were for mostly master's and PhD students. All lectures of the schools were filmed and the videos are available online on the school webpage.

#### c1A. IV Joint ICTP-Trieste/ICTP-SAIFR School on Cosmology: Challenges for the Standard Cosmological Model (Jan. 18-29)

The IV Joint ICTP-Trieste/ICTP-SAIFR School on Cosmology: Challenges for the Standard Cosmological Model (Jan. 18-29) is described on the webpage <https://www.ictp-saifr.org/cosmo2021/> and involved 6 lecturers and 593 applicants. Topics discussed included recent developments concerning tensions in the standard cosmological model, the modelling and testing of fundamental physics on nonlinear

scales and the use of gravitational waves to test cosmology.

Lecturers and Topics:

- **Fabian Schmidt** (Max Planck Institute for Astrophysics, Germany): Structure formation in the Universe
- **Yacine Ali-Haïmoud** (New York University, USA): Physics of the Cosmic Microwave Background
- **Valerie Domcke** (CERN, Switzerland): Inflation and the origin of perturbations
- **Dragan Huterer** (University of Michigan, USA): Cosmology from Large Galaxy Surveys
- **Chiara Caprini** (AstroParticle and Cosmology Laboratory, APC, Paris, France): Cosmology from Gravitational Waves
- **Pedro Ferreira** (Oxford University, UK): Testing Beyond LambdaCDM Models

### c1B. Serrapilheira/ICTP-SAIFR Training Program in Quantitative Biology and Ecology (July 5-30)

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 15 lecturers, 10 tutors responsible for the hands-on activities and 29 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.

The Serrapilheira/ICTP-SAIFR Training Program in Quantitative Biology and Ecology (July 5-30) is described on the webpage <https://www.ictp-saifr.org/qbioprogram/>. The program trained young Brazilian and other Latin American scientists for world-class research on biology and ecology using the quantitative methods of mathematics, physics, and computer science.

The training program was highly selective and involved students at the beginning of their graduate studies who have already developed quantitative skills and are interested in applying these skills in solving cutting-edge problems in biology and ecology. Lectures in all areas of biology and ecology were presented by international experts, and no previous knowledge of biology was required.

Because of the COVID-19 pandemic, the first edition of the program took place in a shorter online version

In addition to attending lectures by internationally renowned researchers, students in the program worked in small groups on a research project supervised by a postdoctoral mentor.

Lecturers and Topics:

- **Antonio Coutinho** (Instituto Gulbenkian de Ciência) – History of biological concepts
- **Oded Rechavi** (Tel Aviv U.) – Genetics, epigenetics and large datasets
- **Hanna Kokko** (U. of Zurich) – Evolutionary biology
- **Eva Nogales** (HHMI/U. California at Berkeley) – Molecular, structural and cell biology
- **Ingrid Lohmann** (U. of Heidelberg) – Developmental biology
- **Priyamvada Rajasethupathy** (The Rockefeller U.) – Neurobiology
- **Daniel Mucida** (Rockefeller U.) – Host-pathogen interactions and disease ecology and epidemiology
- **William Bialek** (Princeton U.) – Biophysics
- **Silvia De Monte** (ENS Paris/Max Planck Inst. for Evolutionary Biology) – Microbial ecology
- **Carla Staver** (Yale U.) – Ecology & Introduction to ecological theory
- **Corina E. Tarnita** (Princeton U.) – Game theory in ecology and evolution
- **Jordi Bascompte** (U. Zurich) – Community ecology and biodiversity, and ecological networks
- **Iain Couzin** (Max Planck Inst. of Animal Behavior) – Behavioral ecology
- **Max Rietkerk** (Utrecht U.) – Spatial ecology
- **Malin Pinsky** (Rutgers U.) – Climate change impacts of biodiversity + Conservation, management and decision-making

### c1C. School on Critical Stability of Few-Body Quantum Systems (Oct 4-8)

The School on Critical Stability of Few-Body Quantum Systems (Oct 4-8) is described on the webpage <https://www.ictp-saifr.org/school-on-critical-stability-of-few-body-quantum-system/s/> and involved 3 lecturers and 88 applicants. The lectures in the school will introduce basic few-body techniques understandable for advanced master's students.

Topics to be covered included Few-body techniques using coordinate space for bound and continuum states, Few-body techniques using momentum space for bound and continuum states, Universality in few-body systems and One- and two-dimensional systems

Lecturers:

- **Doerte Blume** (University of Oklahoma, USA)
- **Alejandro Kievsky** (Istituto Nazionale di Fisica Nucleare-Pisa, Italy)
- **Pascal Naidon** (RIKEN – Nishina Centre, Japan)

### c1D. Joint ICTP, SAIFR and UNESP School on Systems-on-Chip, Embedded Microcontrollers and their Applications in Research and Industry (Oct. 18-29)

The Joint ICTP, SAIFR and UNESP School on Systems-on-Chip, Embedded Microcontrollers and their Applications in Research and Industry (Oct 18-29) is described on the webpage <https://www.ictp-saifr.org/soc2021/> and involved 17 lecturers and 68 participants. The school will focused on the development of scientific instrumentation based on fully programmable Systems-on-Chip (SoC) and embedded microcontrollers. The aim was to provide appropriate methodological practices and key know-how to effectively take advantage of this technology for applications in research and industry.

Lecturers:

- CALLIGARIS Luigi, NCC UNESP, Brazil
- CASCADAN Andres, NCC UNESP, Brazil
- CICUTTIN Andres, ICTP, Italy

- CRESPO Maria Liz, ICTP, Italy
- DONDO Julio, Universidad Nacional de San Luis, Argentina
- FLORIAN SAMAYOA Werner, ICTP/UniTS, Italy
- GARCÍA ORDÓÑEZ Guillermo Luis, ICTP/UniTS, Italy
- GRIMA Eugenio, Italy
- MELO Rodrigo, Argentina
- MOLINA Romina Soledad, UNSL, Argentina & ICTP/UniTS, Italy
- MORALES ARGUETA Ivan, ICTP, Italy
- RINCON CALLE Fernando, Universidad de Castilla la Mancha, Spain
- SANDER Oliver, Karlsruhe Institute of Technology, Germany
- SILVA Agustin, UNMDP, Argentina & ICTP, Italy
- SISTERNA Cristian, Universidad Nacional de San Juan, Argentina
- SUTER Gustavo, Universidad Autonoma de Madrid, Spain
- VALINOTI Bruno, ICTP/UniTS, Italy

## c2. Workshops

ICTP-SAIJR organized workshops on the subjects of dark matter, observational cosmology, quantum mechanics, string theory, condensed matter and statistical mechanics, sociophysics, astrophysics, gravitational waves and astronomy. The purpose of these workshops was to discuss the status, recent progress and perspectives in each of the fields mentioned. In addition to the workshops, ICTP-SAIJR organized a memorial symposium in honor of Reuven Opher (IAG-USP).

### c2A. Reuven Opher Memorial Symposium (January 23)

Reuven Opher, Emeritus Professor at the IAG-USP, passed away on November 28, 2020. He was 88 years old and he has touched the lives of many people during his long career. This one-day Symposium honored Reuven's incredibly diverse career and brings together friends, colleagues, former students and family members to remember his accomplishments and his influence on their lives. The webpage of the workshop is <https://www.ictp-saifr.org/reuven/> and speakers included:

- Zulema Abraham
- José Carlos Neves de Araújo
- Yehoshua Felsteiner
- Vera Jatenco
- Jacques Lepine
- Michal Lipson
- Stephen Lipson
- George Matsas
- Merav Opher
- Elisabete Maria de Gouveia Dal Pino
- Rogerio Rosenfeld
- Ioav Waga
- Sarah White

### c2B. 3rd South American Dark Matter Workshop (Dec. 2-4, 2020)

The third edition of the South American Dark Matter Workshop continued the effort to project the South American community working on the subject in an international context, gathering experts from all the areas mentioned above in



order to discuss recent findings and prompt new collaborations. The webpage of the workshop is <https://www.ictp-saifr.org/dmw2020/> and speakers included:

- **Jorge Sanchez Almeida** (Instituto de Astrofísica de Canarias, Spain): *Principle of maximum entropy and cores in dwarf galaxies*
- **Carlos Argüelles-Delgado** (Harvard University, USA): *Searching for Signatures of Dark Matter Using High-Energy Neutrinos*
- **Nicolás Avalos** (Instituto Balseiro, Argentina): *The DMSQUARE Experiment*
- **Elisabetta Baracchini** (Gran Sasso Science Institute, Italy): *Directional Dark Matter searches with the CYGNO/INITIUM project*
- **Maria Benito** (National Institute of Chemical Physics and Biophysics (NICPB), Estonia): *Dark Matter in the Milky Way: distribution and uncertainties*
- **Nicolas Bernal** (Universidad Antonio Nariño, Colombia): *Self Interacting DM from Primordial Black Holes*
- **Gianfranco Bertone** (UvA Amsterdam, The Netherlands): *A new era in the search of Dark Matter*
- **Xavier Bertou** (C.A. Bariloche, Argentina): *The ANDES Deep Underground Laboratory*
- **Sushil Chauhan** (Panjab University Chandigarh, India): *Searches for DM with CMS*
- **Andrew Cheek** (Université catholique de Louvain, Belgium): *New insights into dark matter from EFT basics*
- **Marco Chianese** (GRAPPA, Amsterdam University, The Netherlands): *A Unique Multi-Messenger Signal of QCD Axion Dark Matter*
- **Arianna di Cintio** (Universidad de la Laguna- IAC, Spain): *Ultra Diffuse Galaxies*
- **Javier Conronado-Blazquez** (IFT-Madrid, Spain): *Unidentified gamma-ray sources*
- **Peter Denton** (Brookhaven National Laboratory, USA): *Ultralight Fermionic Dark Matter*
- **Malcolm Fairbairn** (King's College London, UK): *Astrophysical constraints on invisible dark matter*
- **Azadeh Fattahi** (Durham University, UK): *Build up of the MW stellar halo and connection to DM*
- **Sergio Gonzalez Fernandez** (BIST-Barcelona, Spain): *Searches for DM with ATLAS*
- **Giuliana Fiorillo** (U. di Napoli, Italy): *Direct Detection: a review of techniques and results*
- **Paddy Fox** (Fermilab, USA): *Status of theoretical candidates of DM*
- **Matheus Hostert** (University of Minnesota, USA and Perimeter Institute, Canada): *New signatures and opportunities with dark neutrino sectors*
- **Andrzej Hryczuk** (National Center for Nuclear Research, Poland): *Self interacting DM and H<sub>0</sub> tension*
- **Bradley Kavanagh** (Instituto de Física de Cantabria (IFCA), Italy): *Detecting Dark Matter around Black Holes with Gravitational Waves*
- **Rain Kipper** (University of Tartu, Estonia): *Lopsided galaxies*
- **Alexander Kish** (UH-Manoa, USA): *The DarkSide experiment for direct dark matter search with liquid argon*
- **Joachim Kopp** (U. Mainz, Germany): *DM at cosmological phase transition*
- **Rebecca Leane** (SLAC, USA): *Exoplanets Sub-GeV DM*
- **Jim Libby** (Indian Institute of Technology Madras): *The Dark Sector at Belle II*
- **Jack H. Lindon** (University of Birmingham, UK): *Search for invisible decays of the Higgs boson and Dark Matter interpretation*
- **Pedro de la Torre Luque** (University of Bari & INFN, Italy): *Uncertainties in antiprotons searches of Dark Matter*
- **Umberto Maio** (INAF – Italian National Institute of Astrophysics, Italy): *Early galaxy formation in dark matter cosmological models*
- **Martin Makler** (CBPF, Brazil): *Updates from the Coherent Neutrino-Nucleus Interaction Experiment – CONNIE*
- **Tessio Melo** (II-P/UFRN, Brazil): *XENON1T Anomaly: A Light Z'*
- **Julio Navarro** (U. of Victoria, Canada): *Going Non-Linear: Contrasting LCDM with observations of the internal properties of galaxies*
- **Kyle Oman** (Durham Institute for Computation Cosmology, UK): *An explanation for the diversity of dwarf galaxy rotation curves*
- **Leonardo Peres** (IF-UFRJ): *Perspectives for Boosted Dark Matter Analysis in DUNE*
- **Mihael Petac** (Laboratory Universe And Particles De Montpellier (LUPM), France): *Axisymmetric phase-space distribution for galactic DM: implications for direct searches*
- **Elena Pinetti** (University of Turin, Italy & Sorbonne University, France): *INTEGRAL X-ray subGeV*
- **Alexis Plascencia** (Case Western Reserve University, USA): *New Forces, Dark Matter and Electric Dipole Moments*
- **Chiara Poiré** (Universitat Politècnica de Valencia, Spain): *Dark Matter searches with ANTARES and KM3net*
- **Farinaldo Queiroz** (II-P/UFRN, Brazil): *Light DM, lithium and H<sub>0</sub>*
- **Peter Reimitz** (IFT-Heidelberg, Germany): *Hadronic footprint GeV DM*
- **Greg Rischbieter** (SUNY at Albany): *A Review of the LUX Dark Matter Experiment: Previous Analyses and Current Efforts*
- **Marcos Cardoso Rodriguez** (UFRRJ, Brazil): *Dark Matter in the SUSY B-L Model with three non-identical right handed neutrinos*

- **Ibrahim Safa** (Harvard University, USA): *DM with a Panopticon of Neutrino Detectors*
- **Miguel Sanchez-Conde** (IFT-Madrid, Spain): *Gamma Rays from MW dark satellites*
- **Juri Smirnov** (Ohio State University, USA): *New production mechanisms and search strategies for sub-GeV dark matter*
- **Anastasia Sokolenko** (Austrian Academy of Sciences, HEPHY, Austria): *Dark Particles in the IGM*
- **Tim Tait** (University of California-Irvine, USA): *DM Freeze-out Early confinement*
- **Paul Terman** (Texas A&M University, USA): *The Lightly Ionizing Particle Search in the LUX Detector*
- **Caner Unal** (Ben Gurion University, Israel): *PBH constraints from CMB and pulsar time arrays*
- **Manuela Vecchi** (U. Groningen, The Netherlands): *DM with AMS*
- **Aion Viana** (IFSC-USP, Brazil): *DM in the Galactic halo with SWGO*
- **Martin Vollmann** (Technische Universität München): *Theoretical developments on synchrotron searches for dark matter*
- **Tim Wolf** (MPI K, Heidelberg, Germany): *Latest results from the XENON1T detector*
- **Alfonso Zerwekh** (Universidad Técnica Federico Santa María, Chile): *Non-Abelian in the dark sector: opportunities for CTA*

## c2C. Workshop on New Trends in Dark Matter (Dec. 7-9, 2020)

The goal of the workshop was to bring together theorists and experimentalists to discuss searches, theories, results, opportunities, and, in general, new ideas for sub-GeV dark matter. It focused on models and regions in parameter space that are overlooked by the standard WIMP studies, and that may open a new window into the dark sector. The webpage of the workshop is <https://www.ictp-saifr.org/ntdm2020/> and speakers included:

- **Xiaoyong Chu** (HEPHY, Austria)
- **Miguel Escudero** (TUM, Germany)
- **Nicolás Fernández** (Illinois U., Urbana, USA)
- **Camilo Garcia-Cely** (DESY, Germany)
- **Hyun Min Lee** (Chung-Ang U., Korea)
- **André Lessa** (UFABC, Brazil)
- **Roberto Lineros** (Católica del Norte U., Chile)
- **Laura López-Honorez** (Brussels U., Belgium)
- **Gopolang Mohlabeng** (Brookhaven Natl. Lab., USA)
- **Sergio Palomares-Ruiz** (IFIC, Spain)
- **Carlos Pires** (Paraíba U., Brazil)
- **Diego Restrepo** (Antioquia U., Colombia)
- **James Unwin** (Illinois U., Chicago, USA)
- **Hardi Veermäe** (NICPB, Tallinn, Estonia)
- **Tomer Volansky** (Tel Aviv U., Israel)
- **Hai-bo Yu** (UC, Riverside, USA)
- **Tien-Tien Yu** (Oregon U., USA)

## c2D. Latin American Workshop on Observational Cosmology (Dec. 14-18, 2020)

This online workshop focused on the Latin American community working in different aspects of theoretical and observational cosmology. It covered topics such as: large-scale structure (theory and observations), gravitational lensing, tensions in cosmology, clusters, radio cosmology, dark matter and neutrinos, dark energy and modified gravity and machine learning techniques. The webpage of the workshop is <https://www.ictp-saifr.org/lawoc2020/> and speakers included:

- **Luca Amendola** (Heidelberg University, Germany)
- **Alexandra Amon** (Stanford University, USA)
- **Maria C. Artale** (University of Innsbruck, Austria)
- **Matteo Biagetti** (Institute for Fundamental Physics of the Universe, Italy)
- **Martin Crocce** (Institute of Space Sciences Barcelona, Spain)
- **Marian Douspis** (Institut d'Astrophysique Spatiale, France)
- **Alex DrlicaWagner** (Fermilab, USA)
- **Ginevra Favole** (EPFL, Switzerland)
- **Pedro Ferreira** (Oxford U., UK)
- **Carlos Frenk** (Durham University, UK)
- **Oliver Friedrich** (Kavli Institute for Cosmology Cambridge, UK)

- **Jaime E. ForeroRomero** (Los Andes University, Colombia)
- **Celine Gouin** (Institut d'Astrophysique Spatiale, France)
- **Christopher Hirata** (Ohio State University, USA)
- **Daniel Holz** (KICP & University of Chicago, USA)
- **Mustapha IshakBoushaki** (University of Texas at Dallas, USA)
- **Marc Kamionkowski** (Johns Hopkins University, USA)
- **Elisabeth Krause** (University of Arizona, USA)
- **Joseph Kuruvilla** ( Université ParisSaclay, France)
- **Martin Makler** (CBPF, Brazil)
- **Nicola Malavasi** (Institut d'Astrophysique Spatiale (IAS), Orsay, France)
- **Jorge Noreña** (PUC-Valparaíso, Chile)
- **Dante Paz** (IATE, Argentina)
- **Miguel Quartin** (UFRJ, Brazil)
- **Farinaldo Queiroz** (IIP/UFRN, Brazil)
- **Ariel Sanchez** (MPG, Germany)
- **Roman Scoccimarro** (New York University, USA)
- **Claudia Scoccola** (FCAGUNLP / CONICET, Argentina)
- **David Spergel** (Center for Computational Astrophysics, Flatiron Institute New York, USA)
- **Hideki Tanimura** (IAS, France)
- **David VallsGabaud** (CNRS Observatoire de Paris, France)
- **Licia Verde** (Institute of Cosmological SciencesBarcelona, Spain)
- **Benjamin Wandelt** (Institut Langrange de Paris, France)
- **Matías Zaldarriaga** (Institute for Advanced Studies Princeton, USA)

## c2E. Challenges for Witnessing Quantum Aspects of Gravity in a Lab (June 7-11)

This online workshop aimed to discuss various theoretical and experimental challenges to conceive the QGEM protocol in a lab that will require an unprecedented level of accuracy in witnessing the quantum nature of one of nature's weakest interactions. The webpage of the workshop is <https://www.ictp-saifr.org/ggem2021/> and speakers included:

- **Nancy Aggarwal** (Northwestern University, USA): *Room temperature optomechanical squeezing*
- **Markus Arndt** (University of Vienna, Austria): *Universal matter-wave interferometry: opportunity and challenges in probing quantum physics at the interface to gravity*
- **Markus Aspelmeyer** (University of Vienna, Austria): *Gravitational coupling of microscopic source masses: challenges for future quantum Cavendish experiments*
- **Peter Barker** (University College London, UK): *Charged levitated nano-oscillators for testing macroscopic quantum mechanics*
- **Chas Blakemore** (Stanford University, USA): *First search for new long range forces at the micron scale using optically levitated microspheres*
- **Sougato Bose** (University College London, UK): *Quantum Nature of Gravity in the Lab: Assumptions, Implementation and Applications on the Way*
- **Daniel Carney** (Lawrence Berkley lab, USA): *Theory implications from tabletop gravity experiments*
- **N.D. Hari Dass** (Institute of Mathematical Sciences – Chennai, India): *Simple experiments to probe parity violation in Gravitation, and their theoretical implications*
- **Brian D' Urso** (Montana University, USA ): *Magneto-Gravitational Trapping of SiC Particles Containing Si-Vacancy Centers*
- **Ron Folman** ( Ben Gurion University, Israel ): *Matter-wave interferometers on the atom chip*
- **Gerald Gabriele** (Northwestern University, USA): *One-Particle Quantum Cyclotron*
- **Andrew Geraci** (Northwestern University, USA): *Looking for "fifth forces", dark matter, and quantum gravity with optomechanical sensors*
- **Jan Harms** (Gran Sasso Institute, Italy): *Terrestrial gravity fluctuations in GW detectors*
- **Jack Harris** ( Yale University, USA ): *Measuring the higher-order phonon statistics in a nanogram volume of superfluid helium*
- **Timothy Kovachy** ( Northwestern University, USA): *Probing gravity nonlocally with macroscopically delocalized atom interferometers*
- **Claus Laemmerzahl** (University of Bremen, Germany): *Effects of space-time fluctuations on quantum systems*
- **Tongcang Li** (Purdue University, USA): *Ultrasensitive torque detection with an optically levitated nanoparticle*
- **Yair Margalit** ( MIT, USA ): *Towards testing quantum gravity using the full-loop Stern-Gerlach interferometer*
- **Ryan Marshman** ( University College London, UK ): *The design and use of Stern-Gerlach interferometry for Gravitational Experiments*

- **Samir Mathur** (Ohio State University, USA): *Contrasting the fuzzball and wormhole paradigms for resolving the black hole information paradox*
- **Anupam Mazumdar** (University of Groningen, The Netherlands): *Quantum test of Gravity by colliding Schrödinger's kittens*
- **David Moore** (Yale University, USA): *Progress towards the quantum measurement regime with optically levitated nanogram-scale masses*
- **Gavin Morley** (Warwick University, UK): *Levitating nanodiamond experiments towards a test of quantum gravity*
- **Cristian Panda** (Berkeley, USA): *Probing the interplay of quantum mechanics and gravity using a trapped atom interferometer*
- **Maulik Parikh** (Arizona State University, USA): *The Noise of Gravitons*
- **Igor Pikovski** (Stockholm University, Sweden): *Quantum optics at the interface with gravity*
- **Martin Plenio** (University of Ulm, Germany): *Towards Robust Interferometry with Massive Particles*
- **Simone Rijavec** (University of Oxford): *Decoherence effects in non-classicality tests of gravity*
- **Carlo Rovelli** (Aix-Marseille University, France): *What do the Gravitational Entanglement Lab Experiments Teach us about Quantum Spacetime*
- **Benjamin Stickler** (University of Duisburg-Essen, Germany): *Quantum rotations of nanoparticles*
- **Jacob Taylor** (NIST-Baltimore, USA): *Quantum information-driven tests of gravitationally-mediated entanglement*
- **Marko Toros** (University of Glasgow, UK): *Relative Acceleration Noise Mitigation for Nanocrystal Matter-wave Interferometry: Application to Entangling Masses via Quantum Gravity*
- **Hendrik Ulbricht** (University of Southampton, UK): *Probing gravity of quantum systems in the paradigm of levitated mechanics*
- **Vlatko Vedral** (Oxford University, UK): *Different degrees of reliability of lab-based tests of quantum aspects of gravity*
- **Kathryn Zurek** (Caltech, USA): *Observational consequences of quantum gravity in interferometers*

## c2F. Strings 2021 (June 21 - July 2)

Strings 2021 is an annual conference that brings together the entire string theory community. This online conference had over 2500 registered participants and included reviews of major developments in the field and specialized talks on specific topics, as well as several informal discussions involving two researchers and the conference participants. The webpage of the workshop is <https://www.ictp-saifr.org/strings2021/> and speakers included:

- Ofer Aharony (Weizmann Institute)
- Lara Anderson (Virginia Tech)
- Nima Arkani-Hamed (Institute for Advanced Study)
- Daniel Baumann (U of Amsterdam)
- Alek Bedroya (Harvard U)
- Jan de Boer (U of Amsterdam)
- Freddy Cachazo (Perimeter Institute)
- Simon Caron-Huot (McGill U)
- Horacio Casini (Centro Atómico Bariloche)
- Miranda Cheng (U of Amsterdam)
- Frank Coronado (McGill U)
- Kevin Costello (Perimeter Institute)
- Mirjam Cvetič (U of Pennsylvania)
- Atish Dabholkar (ICTP Trieste)
- Mykola Dedushenko (Stony Brook U)
- Lance Dixon (Stanford U)
- Michael Douglas (Stony Brook U)
- Sergei Dubovsky (New York U)
- Lorenz Eberhardt (Institute for Advanced Study)
- Netta Engelhardt (MIT)
- Matthias Gaberdiel (ETH Zurich)
- Sylvester James Gates Jr. (Brown U)
- Agash Goel (Princeton U)
- Jaume Gomis (Perimeter Institute)
- Eduardo Gonzalo (U Madrid)
- Rajesh Gopakumar (ICTS Bangalore)
- Mariana Grana (U Paris Saclay)
- Alba Grassi (U of Geneva and CERN)
- Michael Green (Cambridge U)
- David Gross (KITP/UC Santa Barbara)

- Alfredo Guevara (Harvard U)
- Yangrui Hu (Brown U)
- Kristan Jensen (U of Victoria)
- Clifford Johnson (U of Southern California)
- Shamit Kachru (Stanford U)
- Vladimir Kazakov (Ecole Normale Superieure)
- Igor Klebanov (Princeton U)
- Zohar Komargodski (Simons Center for Geom. and Physics)
- Shota Komatsu (CERN)
- Gregory Korchemsky (U Paris Saclay)
- Jonah Kudler-Flam (U Chicago)
- Suman Kundu (Tata Inst. for Fundamental Research)
- Hazel Mak (Brown U)
- Juan Maldacena (Institute for Advanced Study)
- Lionel Mason (Oxford U)
- Samir Mathur (Ohio State U)
- Alex May (U British Columbia)
- John McGreevy (UC San Diego)
- Thomas Mertens (Ghent U)
- Shiraz Minwalla (Tata Inst. for Fundamental Research)
- Sebastian Mizera (Institute for Advanced Study)
- Sameer Murthy (King 's College London)
- Jeff Murugan (U of Cape Town)
- Rob Myers (Perimeter Institute)
- Chiara Nappi (Princeton U)
- Sruthi Narayanan (Harvard U)
- Yuji Okawa (U of Tokyo)
- Hiroshi Ooguri (Caltech and Kavli IPMU)
- Leopoldo Pando-Zayas (U of Michigan)
- Shruti Paranjape (U of Michigan)
- Sabrina Pasterski (Princeton U)
- Silvia Penati (Milan Bicocca U)
- João Penedones (École Polytech. Féd. de Lausanne)
- Geoff Penington (UC Berkeley)
- Roger Penrose (Oxford U)
- Pavel Putrov (ICTP Trieste)
- Fernando Quevedo (Cambridge U)
- Mukund Rangamani (UC Davis)
- Leonardo Rastelli (Stony Brook U)
- Fabian Ruehle (Oxford U)
- Sakura Schafer-Nameki (Oxford U)
- Oliver Schlotterer (Uppsala U)
- John Schwarz (Caltech)
- Nathan Seiberg (Institute for Advanced Study)
- Ashoke Sen (Harish-Chandra Research Institute)
- Shu-Heng Shao (Institute for Advanced Study)
- Stephen Shenker (Stanford U)
- Gary Shiu (U of Wisconsin-Madison)
- Xavier Siemens (Oregon State U)
- Eva Silverstein (Stanford U)
- Dam Thanh Son (U Chicago)
- Douglas Stanford (Stanford U)
- Andy Strominger (Harvard U)
- Yuji Tachikawa (Kavli IPMU and U of Tokyo)
- Gregory Tarnopolsky (Carnegie Mellon U)
- Tomasz Taylor (Northeastern U)
- Gonzalo Torroba (Centro Atómico Bariloche)
- Erez Urbach (Weizmann U)
- Irene Valenzuela (Harvard U)
- Cumrun Vafa (Harvard U)
- Anastasia Volovich (Brown U)
- Gabriele Veneziano (CERN)
- Congkao Wen (Queen Mary U of London)
- Xiao-Gang Wen (MIT)
- Edward Witten (Institute for Advanced Study)
- Xi Yin (Harvard U)
- Ahmadullah Zahed (Bangalore Indian Inst. of Science)
- Ying Zhao (Institute for Advanced Study)
- Alexander Zhiboedov (CERN)
- Zhenghao Zhong (Imperial College)
- Barton Zwiebach (MIT)

## c2G. Workshop on Condensed Matter and Statistical Mechanics (August 30 - Sept. 21)

This online meeting featured a series of 8 seminars on condensed matter and statistical mechanics by 4 invited lecturers. The webpage of the workshop is

<https://www.ictp-saifr.org/condensedmatter2021/>

and the invited lectures included:

- **Danilo Liarte** (Cornell Univ.): Geometry, topology, and the complex emergent behavior of disordered materials
- **Danilo Liarte** (Cornell Univ.): Effective-medium theory and the universal behavior of disordered elastic systems
- **Jamir Marino** (Univ. of Mainz): Spatio-temporal control of correlations with non-local dissipation
- **Jamir Marino** (Univ. of Mainz): Criticality in driven open systems
- **Tiago Mendes Santos** (Max Planck Institute at Dresden): Machine learning many-body physics
- **Tiago Mendes Santos** (Max Planck Institute at Dresden): Quantum entanglement and unsupervised learning in many-body physics
- **Victor Quito** (Iowa State Univ.): Floquet-tuning correlated systems
- **Victor Quito** (Iowa State Univ.): Emergent symmetries in one-dimensional strongly disordered interacting systems

## c2H. Workshop on Sociophysics: Social Phenomena from a Physics Perspective (Oct. 18-22)

This online meeting brought together physicists and other scientists from all over the world to focus on open issues in social modelling and to identify the new directions in which this interdisciplinary field is evolving. The webpage of the workshop

is <https://www.ictp-saifr.org/workshop-on-sociophysics-social-phenomena-from-a-physics-perspective/> and speakers included:

- **Pablo Balenzuela** (Universidad de Buenos Aires, Argentina): *Analyzing mass media influence using natural language processing and time series analysis*
- **Guillaume Deffuant** (Lisc, France): *Group dominance or group hierarchies emerging from interplay between gossip and group prejudice*
- **Silvio Ferreira** (UFV, Brazil): *Echo chambers in Twitter debates on political debates in Brazil*
- **Jose Fernando Fontanari** (IFSC/USP, Brazil): *Wisdom of crowds: much ado about nothing*
- **Serge Galam** (SciPol, France): *What was right with my failed prediction of a 2020 second Trump victory?*
- **José Roberto Iglesias** (UFRGS, Brazil): *Growing inequality and wealth redistribution*
- **Marcelo Kuperman** (Centro Atómico Bariloche, Argentina): *The destructive effect of human stupidity: a revision of Cipolla's fundamental laws*
- **Fabiana Laguna** (Centro Atómico Bariloche, Argentina): *Optimal risk in a wealth exchange model: Agent dynamics from a microscopic perspective*
- **Francisco WS Lima** (UFPI, Brazil): *Majority-vote and Biswas-Chatterjee-Sen model on Complex Networks*
- **Alexandre Martinez** (USP-RP, Brazil): *Thermodynamics applied to game theory: study of the risk associated with cooperation in the Public Goods Games*
- **Hernán Makse** (City College, CUNY, USA): *How network theory and contact tracing can help to stop the Covid-19 pandemic*
- **Maxi San Miguel** (IFISC, UIB-CSIC, Spain): *Coevolution dynamics of opinion and social network*
- **Mauro Mobilia** (University of Leeds, UK): *How does homophily and heterophily shape the topology of preferred-degree networks?*
- **Yamir Moreno** (University of Zaragoza, Spain): TBA
- **Andrea Rapisarda** (University of Catania, Italy): *Investigating the role of talent and luck in getting success*
- **Fabiano Ribeiro** (UFLA, Brazil): *The Physics of Cities*
- **Viktoriya Semeshenko** (IIEP, Argentina): *The Network Structure of Inter-Industry Labor Mobility in Argentina*
- **José Soares-Andrade Jr** (UFC, Brazil): *Cracking urban mobility*

- **Katarzyna Sznajd-Weron** (Wroclaw University of Science and Technology, Poland): *"Private Truths, Public Lies" within agent-based modeling*
- **Raul Toral** (IFISC, UIB-CSIC, Spain): *The biased voter model*
- **Juan Alejandro Valdivia** (Universidad de Chile, Chile): *The complex traffic in cities under route optimization ... an example of transport over complex networks*

## c2I. SILAF AE XII3/4 (Nov. 8-12)

SILAF AE is a traditional event that gathers the Latin American community in High Energy, Cosmology and AstroParticle Physics, with the aim of discussing our current knowledge and the future perspectives in these areas. The webpage of the workshop is <https://www.ictp-saifr.org/silafae-xii-21/> and speakers included:

- **Ulisses Barres** (CBPF, Brazil): *The Southern Wide Field Gamma Ray Observatory (SWG O)*
- **Nicolás Bernal** (Antonio Nariño University, Colombia): *Dark Matter in the Time of Primordial Black Holes*
- **Enrico Bertuzzo** (USP, Brazil): *Relaxion physics*
- **Carla Bonifazi** (UFRJ, Brazil & ICAS, Argentina): *Detecting coherent elastic neutrino-nucleus scattering*
- **Hugo Camacho** (IFT-UNESP/ICTP-SAI FR, Brazil): *Cosmological results from the first three years of observations of the Dark Energy Survey*
- **Marcela Carena** (University of Chicago, USA): *Dark Matter Effects on the Early Universe and Muon g-2*
- **Claudio Dib** (Universidad Tecnica Federico Santa Maria, Chile): *Updates on the ANDES project*
- **Cora Dvorkin** (Harvard, USA): *Unlocking Dark Matter Physics out of Astrophysical Data Sets*
- **Nayara Fonseca** (ICTP-Trieste, Italy): *Theory of Deep Learning and Physics*
- **André de Gouvêa** (Northwestern University, USA): *Neutrino Physics News*
- **Cristiane Jahnke** (UNICAMP, Brazil): *Highlights and perspectives from the ALICE experiment*
- **Marta Losada** (NYU, USA & Abu Dhabi U., United Arab Emirates): *Constraining Baryogenesis in the Standard Model EFT with dim 6 terms using LHC Higgs physics and EDMs*
- **Camila Machado** (DESY, Germany): *On-shell amplitudes for effective theories*
- **Michelangelo Mangano** (CERN, Switzerland): *Physics at Future Circular Colliders*
- **Enrico Nardi** (INFN Frascati National Laboratories, Italy): *The axion: phenomenological implications and open theoretical problems*
- **Angela Olinto** (University of Chicago, USA): *Space Observatories for Ultrahigh Energy Astroparticles*
- **Massimo Passera** (University of Padova, Italy): *Muon g-2 and  $\Delta a$  connection*
- **Federico Sánchez** (CONICET, Argentina): *The Pierre Auger Observatory: results and perspectives*
- **Álvaro G. dos Santos Neto** (Universidade Federal do Triângulo Mineiro, Brazil): *LHCb latest results and new perspectives*
- **Ettore Segreto** (UNICAMP, Brazil): *DUNE Experiment*
- **Andres Guillermo Delannoy Sotomayor** (University of Tennessee, USA): *CMS updates*
- **Graziano Venanzoni** (INFN- Pisa, Italy): *First results from the Muon g-2 Experiment at Fermilab*
- **Song-Ming Wang** (Academia Sinica-Taipei, Taiwan): *ATLAS: recent results and future perspectives*
- **Matías Zaldarriaga** (Institute for Advanced Studies – Princeton, USA): *Effective Field Theory for Large Scale Structure*

## c2J. Reuven Opher Workshop on Challenges of New Physics in Space (Dec. 13-17)

This workshop, named after Reuven Opher, is continuing his efforts to showcase the work of the Brazilian community in the fields related to Cosmology, Gravity and Astrophysics. The webpage of the workshop is <https://www.ictp-saifr.org/ropher2021/> and speakers included:

- **Odylio D. Aguiar** (INPE): *Present and Near Future Gravitational Wave Observatories*
- **Ulisses Barres Almeida** (CBPF): *Southern Wide-Field Gamma-ray Observatory (SWG O)*
- **Orfeu Bertolami** (Universidade do Porto, Portugal): *Gravity UFOs*
- **João Braga** (INPE): *Localization of Bright Cosmic Explosions with the nanoMIRAX satellite*
- **Hugo Camacho** (IFT-UNESP/ICTP-SAI FR/LInEA): *Cosmology from the DES-Y3: baryon acoustic oscillations and the combination of clustering and weak lensing*

- **Renato Dupke** (ON): *J-PAS, miniJPAS and J-NEP: Current Status, Results and Perspectives*
- **Júlio Fabris** (UFES): *A Newtonian theory with variable G*
- **Diego A. F. Gonçalves** (USP): *CTA & Astri Mini-Array*
- **Gustavo Guerrero** (UFMG): *Modeling convection and dynamo in stellar interiors*
- **Jorge Horvath** (IAG-USP): *The supernova-neutron star connection*
- **Grzegorz Kowal** (EACH-USP): *Spontaneous magnetic reconnection*
- **Jacques Lepine** (IAG-USP): *An update of the LLAMA radio telescope project*
- **Germán Lugones** (UFABC): *Phase conversions in neutron stars: implications for stellar stability and gravitational wave physics*
- **Marcos Maia** (UnB): *Geometry at the Quantum Scale*
- **Martin Makler** (CBPF / U. Nacional de San Martin, Argentina): *Testing General Relativity at kiloparsec scales with gravitational lenses*
- **Valerio Marra** (UFES/INAF-Trieste, Italy): *The Copernican principle in light of the latest cosmological data*
- **Rodrigo Nemmen** (IAG-USP): *Fermi LAT observations of Sagittarius A\* and nearby galactic nuclei*
- **Merav Opher** (Boston University, USA): *Out Heliospheric Shield, a case of a Habitable Astrosphere: Open Science Questions*
- **Roderik Overzier** (ON): *The Giant Magellan Telescope and the first Cosmic Sources*
- **Mariana Penna-Lima** (UnB): *Legacy Survey of Space and Time and the Brazilian Participation Group*
- **Reinaldo Santos-Lima** (IAG-USP): *Turbulent transport of astrophysical magnetic fields*
- **Ilya Shapiro** (UFJF): *What quantum gravity can do for cosmology?*
- **Flávia Sobreira** (UNICAMP): *The Dark Energy Spectroscopic Instrument: updates*
- **Rafael da Silva de Souza** (Shanghai Astronomical Observatory, China): *The Cosmostatistics Initiative – Turning data into discoveries*
- **Riccardo Sturani** (IIP-UFRN): *Gravitational Wave Astronomy*
- **Adriana Valio** (Mackenzie): *The Impact of Stellar Activity on Exoplanet Habitability*
- **Carlos Alexandre Wuensche** (INPE): *21 cm Cosmology and the BINGO radio telescope*

#### c4. Outreach events

The ICTP-SAIFR organized 10 different types of online outreach activities in 2021 aiming at different audiences. The format, topics and webpages for these events are:

##### 1) Física em Casa:

Physics at Home is an 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:

- **4 de março – O Universo Não Conhecido e a Matéria Escura** com Ivone Albuquerque (IFUSP)
- **18 de março – Pedra-Papel-Tesoura-Lagarto-Spock** com Jeferson Arenzon (UFRGS)
- **8 de abril: Grafeno: da Física à Revolução Industrial** com Thoroh de Souza (Universidade Presbiteriana Mackenzie)
- **22 de abril: Do caos a ordem: materiais auto-construtores** com Cecília Leal (Universidade de Illinois)
- **6 de maio: Ondas gravitacionais: a nova luz** com Vitor Cardoso ( Instituto Superior Técnico, Lisboa)
- **20 de maio: ALICE no país das partículas, uma aventura pelo LHC** com Jun Takahashi (UNICAMP)
- **27 de maio: Qual o melhor modelo do Universo?** com Rogério Rosenfeld (ICTP-SAIFR/IFT-UNESP/LIneA)
- **3 de junho: Computador Quântico: para que serve e como construir um** com Fernando Brandão (Caltech)
- **17 de junho: O universo desconhecido: as novidades das ondas gravitacionais** com Cecília Chirenti (UFABC)
- **26 de agosto – Física e Arte: qual a relação?** com Marcia Rizzutto (IFUSP)
- **30 de setembro – A física quântica no nosso dia-a-dia** com Marco Moriconi (IF-UFF)
- **19 de outubro – Sistemas Complexos e o Prêmio Nobel de Física 2021** com Daniel Stariolo (IF-UFF)
- **28 de outubro – Einstein, agujeros negros, ondas gravitacionales y algunas otras cosas** com Gabriela González (Louisiana State University)



## 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 we had only two editions online. The webpage for the program is <http://outreach.ictp-saifr.org/dialogo/>. Topics covered during these meetings included:

- [Física e Ficção Científica](#)
  - 23 de fevereiro – Futuro – André Araújo (journalist) and Raul Abramo (IFUSP)
  - 25 de fevereiro - Viagens no tempo - Ana Rusche (writer) and Pedro Vieira (ICTP-SAIJR/IFT-UNESP/PI)
  - 26 de fevereiro - Multiversos - Cláudia Fusco (journalist) and Rogério Rosenfeld (ICTP-SAIJR/IFT-UNESP)
- [1 de dezembro: Super-heróis, com Cláudia Fusco \(journalist\) e Otaviano Helene \(IFUSP\)](#)

## 3) ICTP-SAIJR 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. On June 26, Sylvester James Gates Jr. (Brown U, president of American Physical Society) presented an online lecture for the general public entitled "[How to describe quantum gravity particles & physics from a starship](#)".

## 4) Ask a string theorist:

On June 27, ICTP-SAIJR organized the outreach event "[Ask a String Theorist](#)" in which the public was invited to send questions by Youtube chat in english or portuguese that were selected by a panel of journalists and answered by the Strings 2021 speakers. This recorded event on Youtube has more than 7700 views.

## 5) IV Curso de Astronomia

The Planetário Max Schreier (La Paz, Bolivia) and ICTP-SAIJR jointly organized an online minicourse on Astronomy for the general public using material translated into Spanish by ICTP-SAIJR: <http://outreach.ictp-saifr.org/iv-curso-de-astronomia-planetario/>

## 6) Clube do Livro – Sci-SAIJR:

In this outreach program, a physicist uses a science fiction book to discuss with the audience the physics concepts behind it. Pedro Vieira was the first speaker of this new outreach program and chose the book "The three body problem" from Cixin Liu to talk about chaos and gravity: <http://outreach.ictp-saifr.org/clube-do-livro/>

## 7) Doses of Physics

In this new outreach project of ICTP-SAIJR on Instagram, the journalist and TV news presenter Letícia Brito (TV UFG/ICTP-SAIJR) is producing a series of short weekly videos on physics for the general public (<http://outreach.ictp-saifr.org/doses-de-fisica/>). Topics covered include dark matter, gravitational waves, string theory, neutrinos and quantum mechanics.

## 8) Physics Pioneers in Brazil

The project Physics Pioneers in Brazil consists of biographies written on the inspiring careers of the scientists who shaped the current Brazilian physics landscape. The first biography describes the life of Sergio Mascarenhas who pioneered several research areas in Brazil including solid state physics, medical physics, molecular biophysics, neurophysics and soil physics. The second biography describes the life of Gleb Wataghin, a Russian-born theoretical physicist who emigrated first to Italy and then to Brazil to create in 1934 the first Brazilian physics department at the University of São Paulo. The texts are available at <http://outreach.ictp-saifr.org/pioneiros-da-fisica-brasileira/>

## 9) Minicourses for High-School Students:

This program involves several minicourses on topics of modern physics to high-school students which were held online every Saturday morning. The webpage for the minicourses is <http://outreach.ictp-saifr.org/ensino-medio/minicurso/> and topics covered include:

1. Introdução à relatividade especial e geral – 13 de março a 24 de abril - Pedro Vieira (ICTP-SAIFR & Perimeter Institute, Canadá)
2. Um passeio pela Astrofísica — destino: buraco negro – 1º e 8 de maio - Cecilia Chirenti (UFABC, Universidade de Maryland & NASA Goddard Space Flight Center)
3. Investigando o mundo quântico: de átomos a sólidos – 15 a 29 de maio - Luana Pedroza (UFABC)
4. Introdução à termodinâmica e mecânica estatística – 05 a 26 de junho - Ricardo Martinez-García (ICTP-SAIFR/IFT-UNESP)
5. O método científico e o número mínimo de unidades dimensionais para medir tudo – 12 a 16 de julho - George Matsas (IFT-UNESP)
6. Introdução à física de partículas – 31 de julho a 28 de agosto - Ricardo Matheus (IFT-UNESP)
7. Mecânica quântica: dos primórdios à atualidade – 04 a 25 de setembro - Alberto Saa (IMECC-UNICAMP)
8. O básico da computação quântica – 02 de outubro a 06 de novembro - Gastão Krein (IFT-UNESP)
9. Física do universo: cosmologia – 13 de novembro a 04 de dezembro - Rogério Rosenfeld (ICTP-SAIFR/IFT-UNESP)

In addition, U. Porto and ICTP-SAIFR jointly organized the 1st Summer School for Young Physicists. During this online school, 36 talented high school students were selected to develop research projects created and supervised by 9 graduate students. The website of this activity is <http://outreach.ictp-saifr.org/edv21/> and due to its huge success, a second edition is planned for 2022 (<http://outreach.ictp-saifr.org/escolaverao/>) and an extended program on research projects development will take place at ICTP-SAIFR next year (<http://outreach.ictp-saifr.org/programajc/>).

Another outreach program for high-school students called “Inspiring the next generation of physicists” presented the possible paths to becoming a physicist and aimed to inspire those interested in science to follow an academic career independently of gender, race and background. The first event was held online on June 1<sup>st</sup> (<http://outreach.ictp-saifr.org/inspirando01/>) and the second on September 1<sup>st</sup> (<http://outreach.ictp-saifr.org/inspirando/>).

In addition, Lucas David and Felipe Novaes, high-school teachers with FAPESP fellowships, complemented these minicourses with additional theoretical classes on mathematical tools used in physics, and organized activities such as measuring Planck's constant using LEDs and calculation of dark matter in a galaxy. These classes were presented weekly online on Saturdays and Tuesdays, and 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/>

#### 10) 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-SAIFR to Portuguese and Spanish. In 2021 ICTP-SAIFR organized several online activities led by ICTP-SAIFR outreach coordinators Ana Luiza Sério.

The meetings were held 4 times per week, and over 100 meetings were held in 2021 with the active participation of over 2500 high-school teachers. Topics discussed at these online meetings in Portuguese in 2021 are described at <http://outreach.ictp-saifr.org/ensino-medio/professores/fisica-de-fronteira-para-a-sala-de-aula-online/> and in Spanish at <http://outreach.ictp-saifr.org/ensino-medio/professores/fisica-de-fronteira-para-a-sala-de-aula-online/espanol/>

#### c5. Weekly seminars, colloquia and journal clubs

In 2021, weekly online seminars were regularly organized. There were 55 seminars and the complete list is on the webpage <https://www.ictp-saifr.org/2021-research-seminars-and-activities/>. There were also weekly journal club meetings in string theory, particle physics and cosmology. From January-July, 2021 ICTP-SAIFR also started a bi-weekly online colloquium/discussion for graduate students and researchers, the "Physics Discussions" (<https://www.ictp-saifr.org/physicsdiscussions/>). In addition to a 60-minute colloquium, the activity included 40 minutes of discussions of physics and career choices just for graduate students.

#### c6. Annual meeting of Steering Committee and Scientific Council

On Sept. 9 and 23, 2021, the ICTP-SAIFR steering committee and scientific council met online to discuss the activities during the pandemic and to discuss future directions for the center. 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.

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.

## 6. Activity Plan for 2022

In 2022, the ICTP-SAIFR will continue to expand its research, outreach and training activities in all areas related to theoretical physics. Depending on the pandemic scenario, activities during the first semester may be held online. Confirmed scientific activities in 2022 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 2022 activities planned up to now include the activities:

### **São Paulo International Schools on Theoretical Physics**

School on Quantum Computation  
March ?, 2022

[Serrapilheira/ICTP-SAIFR Training Program in Quantitative Biology and Ecology](#)  
July – December, 2022

Joint ICTP-SAIFR/MITP Summer School on Particle Physics  
September 12-23, 2022

[School on Applications of Nonlinear Systems to Socio-Economic Complexity](#)  
October 17-20, 2022

School on Atomic and Molecular Spectroscopy in Plasmas  
November, 2022?

Third School on Data Science and Machine Learning  
December, 2022

### **Meetings/Programs/Workshops**

Workshop on Representation Theory and Applications  
April 25-29, 2022

Workshop on New Horizons in Quantum Correlated Materials  
August, 2022

10th International Conference on Physics Opportunities at an Electron-Ion Collider  
2022

Workshop on New Directions of Fundamental Physics  
September 5-23, 2022

Workshop on Electromagnetic effects on multiparticle systems  
October 25-28, 2022

Workshop on Classical Gravity and Applications  
November 2022

**Outreach**

[II Curso de Verão ICTP-SAIFR para Professores de Física de Ensino Médio](#)  
January 15-21, 2022

[II Escola de Verão ICTP-SAIFR para Jovens Físicos](#)  
January 22-29, 2022

[IFT-Perimeter-SAIFR Journeys into Theoretical Physics](#)  
July, 2022

## 7. Data management

As explained earlier, almost all ICTP-SAIFR activities are recorded and the videos, together with pdf files of presentations, are posted online on the ICTP-SAIFR website of the activity. Links to the websites of 2021 activities can be found at <https://www.ictp-saifr.org/2021-activities/> . Also, the research articles described below can be accessed at the websites of the journals listed in the bibliography.

## 8. Use of Reserva Técnica Funds

Between December 2020-2021, the part of the reserva tecnica funds related to "Custos de Infraestrutura Direta do Projeto" was used for the following purposes:

- a) Design of online posters for announcements of Schools/Workshops activities: R\$ 2,482.90 (See SM-outra 003)
- b) Advertisement of postdoc positions at international magazines: R\$ 1,747.44
- c) Advertisement of online activities using online mailing system (mailjet): R\$ 2,682.22 (See SM-outra 003)
- d) Service payment to technician and specialized companies for technical support in the transmission and recording of online events: R\$ 24,585.00 (see SM-outra 010)
- e) Use of Zoom platform for all ICTP-SAIFR online activities: R\$ 8,679.11 (see SM-outra 010)
- f) Electronic devices ("material de consumo") for the Joint ICTP, SAIFR and UNESP School on Systems-on-Chip, Embedded Microcontrollers and their Applications in Research and Industry: R\$ 6,555.47 (see SM-outra 014)

And the part of the reserva tecnica funds related to "Benefícios Complementares" was not used.

## 9a. 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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## 9a2. Articles by ICTP-SAIFR Postdoctoral Associates

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## **10. First page of publications**

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

## **11. Scientific reports of postdocs and direct doctoral students**

**See annexed file for scientific reports of**

**Vivian Dornelas, Martin de Los Rios, Gabriel Andreguetto Maciel, Diego Medrano, Krissia Zawadzki, Cassiano Antonio Daniel, Lucas Nogueira de Sá Martins, João Victor Silva Rebouças e Ulisses Marques Portugal.**

## **12. Scientific reports of TT, EP and JC**

**See annexed file for scientific reports of**

**Artur Alegre, Ligia Pereira, Cintia Cirillo, Felipe Novaes, Lucas Campos**