

# ICTP-SAIFR Director's Report

## 1/12/2022-30/11/2023

Nathan Berkovits

# Project Team

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### **Administrative support:**

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- Humberto Neto, Executive Secretary (40 hours), ICTP-SAIFR/IFT-UNESP
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### 3 Summary of the Project's main goals

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

Throughout the world, the importance of this research has led to the creation of theoretical physics institutes which focus on research, on the training of graduate students and 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 São Paulo as a collaboration between the São Paulo Research Funding Agency (FAPESP), the International Centre for Theoretical Physics (ICTP-Trieste) - a category 1 institute of UNESCO, the São 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 its twelve years of 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, **Ricardo Sturani**, member of the LIGO-Virgo collaboration which was recently awarded the Nobel Prize for the detection of gravitational waves, and **Ricardo Martínez-García**, 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 began their permanent positions at IFT-UNESP in February 2022 as soon as the Covid-19 hiring restrictions were 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 2024, 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, minicourses, 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 from December 1, 2022 - November 30, 2023, ICTP-SAIFR initiated the new FAPESP thematic grant 2021/14335-0. As will be described below, highlights of this first year of the new grant included the hiring of a new Simons-FAPESP Young Investigator in the area of quantum chaos and 6 new postdocs, grants and prizes awarded to ICTP-SAIFR researchers in the areas of gravitational waves and quantitative ecology and complex systems, two long-term programs organized by ICTP-SAIFR with private funds, the signing of a new cooperation agreement between UNESCO and ICTP Trieste, the organization of dozens of international schools and workshops for graduate students and researchers including 5 satellite sessions broadcast live as part of the American Physical Society March and April meetings, and the expansion of outreach programs for high-school teachers and students as well as the general public. These accomplishments and others are described in the bimonthly scientific bulletins at <https://www.ictp-saifr.org/scientific-bulletins/>.

ICTP-SAIFR was recently awarded a renewal of its prestigious "Targeted Grant for Institutes" from the privately funded Simons Foundation (USA). This grant finances two generous Simons fellowships which are combined with FAPESP Young Investigator fellowships to attract top researchers to ICTP-SAIFR. In 2023, an international search committee was formed of world-leading researchers including Nobel laureate David Gross, a short list of 6 candidates was selected out of hundreds of applicants and interviewed at ICTP-SAIFR, and the Italian physicist Dario Rosa was chosen to receive one of the two Simons-FAPESP positions. Dario Rosa performs research on quantum chaos and was the research team leader of the Quantum Chaos group at the University of Science and Technology in Korea. Dario Rosa was also awarded a FAPESP Young Investigator Position in 2023 and will start his Simons-FAPESP position in January 2024. A call for the second Simons-FAPESP fellowship was opened in November 2023 with an application deadline of January 31, 2024. In addition, ICTP-SAIFR received hundreds of applications for its postdoctoral positions and hired 6 new postdocs in 2023 in the areas of cosmology, particle physics, astrophysics, complex systems, condensed matter physics and quantitative biology,

Previous Simons fellows and FAPESP Young Investigator fellows who were hired for permanent positions in 2022 at ICTP-SAIFR/IFT-UNESP are Riccardo Sturani and Ricardo Martinez-Garcia. Riccardo Sturani recently received a thematic grant from FAPESP for his research on gravitational waves and is a member since 2007 of the LIGO collaboration which received the Nobel Prize in 2017. In 2023, Ricardo Martinez-Garcia was awarded the prestigious 2023 Junior Science Prize from the Complex Systems Society (CSS) for his work on organizational dynamics in quantitative ecology and published a paper in Nature Communications on models of drifting ecosystems. Another FAPESP Young Investigator at ICTP-SAIFR, Danilo Liarte, also published a paper in 2023 in Nature Communications on the subject of jamming and strange metals. And in August 2023, ICTP-SAIFR/IFT-UNESP professor Hilda Cerdeira, who organizes ICTP-SAIFR schools every year, received the LANET prize for her contributions to non-linear dynamical systems and networks in Latin America.

In addition to its schools and workshops funded by FAPESP, ICTP-SAIFR organized two

long-term programs in 2023 with funding from private sources. In January-February, ICTP-SAIFR organized a two-month training program for 30 graduate students in Quantitative Ecology with funding from the Serrapilheira Institute. And in July, ICTP-SAIFR organized a 3-week program for 110 researchers from the Simons Bootstrap Collaboration with funding from the Simons Foundation and Perimeter Institute. The Simons Bootstrap Collaboration program was organized at the site of the old IFT-UNESP building in downtown São Paulo which is conveniently located next to hotels and restaurants. These long-term programs are very successful in bringing together researchers working on a similar topic, and more such programs are planned in the coming years.

In 2023, the original cooperation agreement between UNESP and the Abdus Salam International Centre for Theoretical Physics in Trieste which created ICTP-SAIFR in 2011 was updated and signed by the two institutions. The updated agreement included the description of new staff members financed by UNESP, new members of the steering committee including the president of Serrapilheira Institute, and the new private association Instituto Amigos do SAIFR created in 2021 to receive funds from private sources. On October 4, 2023, a Brazilian delegation including the president and CEO of FAPESP, Marco Antonio Zago and Carlos Américo Pacheco, and the director and vice-director of ICTP-SAIFR, Nathan Berkovits and Rogério Rosenfeld, visited Trieste to celebrate the signing.

In 2023, ICTP-SAIFR organized activities in various areas related to theoretical physics including 14 schools and minicourses for graduate students on the topics of quantitative ecology, light and cold atoms, cosmological phase transitions, CTA science, nonlinear dynamical systems, holography, non-equilibrium quantum systems, amplitudes in gauge and gravity theories, quantum chaos, epidemiology, mathematical modeling of governance, baryogenesis, lattice models in biology, and machine learning, as well as 9 workshops for researchers on the topics of quantum technologies, quantum gases, electron-ion collider physics, holography, strong electron correlations, bootstrap, gravitational waves, classical gravity and soft matter. In addition, ICTP-SAIFR organized in 2023 its annual scientific council meeting, two workshops on diversity and inclusion, and the sixth edition of the Perimeter-SAIFR-IFT school where the top undergraduate students from Latin America are chosen to participate in a joint Master's program with Perimeter institute in Canada. Finally, ICTP-SAIFR was invited to organize 5 satellite sessions on complex systems, quantum technologies, condensed matter physics, astrophysics and neutrino physics, which were broadcast live as part of the March and April annual meetings of the American Physical Society.

ICTP-SAIFR also organizes several types of online and in-person outreach activities for the general public, as well as activities for high-school teachers and students based on classroom material developed by Perimeter Institute and translated into Portuguese and Spanish by ICTP-SAIFR. In addition to public lectures by world-leading physicists such as David Gross, Juan Maldacena and Nima-Arkani-Hamed, ICTP-SAIFR initiated in 2023 a monthly presentation of films at the Bela Artes Cinema in São Paulo with discussions after the movie, a monthly pre-

resentation in a bar by a physicist, a cycle of lectures for the general public on a specific research topic, and continued its popular online book club meetings. For high-school teachers, ICTP-SAIFR continued its weekly online and in-person workshops in both Portuguese and Spanish which recently received accreditation from the Training School of Education Professionals of the State of São Paulo (EFAPE). And for high-school students, ICTP-SAIFR continued its program of Saturday morning minicourses taught by university professors, Saturday afternoon lectures by high-school teachers on advanced topics such as calculus, and initiated in 2023 a new program called "Physics Games" in which university professors visit public schools and present a short seminar followed by a competition based on answering questions about the seminar.

Subsections 4.1 - 4.3 below will describe the research publications, visitors and activities during this period, and subsection 4.4 will describe the increased budget request which is being submitted together with the report.

## 4.1 Research Related to Publications

The research conducted at ICTP-SAIFR during this period included various subareas of theoretical physics related to high-energy physics and complex systems. The publications involved research performed by principal and associated researchers, postdoctoral and direct-doctoral fellows, and visitors of ICTP-SAIFR. Various ICTP-SAIFR researchers are also members of international experimental collaborations such as the CMS particle detector at the LHC in Switzerland, the LIGO gravitational wave detector in the USA, and the Dark Energy Survey telescope in Chile. In this period, ICTP-SAIFR researchers had a total of 196 publications and several of them will be briefly described below.

### 4.1.1 High Energy Physics

#### String Theory

B-RNS-GSS formalism is a new approach for the first quantization of the superstring and, in [1], this formalism was defined in a curved heterotic supergravity background and nilpotence and holomorphicity of the BRST operator at the classical level was shown to imply the  $N = 1$   $D = 10$  supergravity equations for the background. In addition, in [2], it was shown that the relationship between  $D = 5$  holomorphic Chern-Simons and the RNS superstring is identical to the relationship between the pure spinor superstring and the constructed B-RNS-GSS superstring which has both  $N = 1$  worldsheet supersymmetry and  $D = 10$  spacetime supersymmetry.

Minimal coupling leads to problems such as loss of causality if one wants to describe charged particles of spin greater than one propagating in a constant electromagnetic background. To study this problem, [3] and [4] present a derivation of the equations of motion, and



the set of associated constraints, that describe the propagation in a flat space-time of massive states of spin 2 and 3/2, respectively. Finally, in [5], the first massive level of the open charged superstring was described in a flat four-dimensional spacetime, and it was shown how in the absence of an electromagnetic background the Rarita-Schwinger and Fierz-Pauli Lagrangians are recovered for spins 3/2 and 2, respectively.

## 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 [6–79]. As highlights we can list: (i) The first measurement of the azimuthal angular correlations of events produced exclusively with two jets in photon-lead interactions in a large momentum transfer, a process that is considered sensitive to the underlying nuclear gluon polarization, was presented in [13]. (ii) The first observation of the production of  $W^\pm W^\pm$  bosons from double parton scattering processes using same-sign electron-muon and dimuon events in proton-proton collisions at  $\sqrt{s} = 13$  TeV was reported in [27]. (iii) In [30] was presented the first search exploiting the vector boson fusion process to probe heavy Majorana neutrinos and the Weinberg operator. (iv) And the first direct search for exotic Higgs boson decays  $H \rightarrow \mathcal{A}\mathcal{A}$ ,  $\mathcal{A} \rightarrow \gamma\gamma$  in events with two photonlike objects was presented in [48]. The hypothetical particle  $\mathcal{A}$  is a low-mass spin-0 particle decaying promptly to a merged diphoton reconstructed as a single photonlike object.

On the theoretical side, the spontaneous breaking of a global  $U(1)$  symmetry (exact or approximate) leads to the appearance of axionlike particles (ALPs). These particles are among the best-motivated additions to the Standard Model (SM) particle content. In [80] were considered two specific classes of ALPs: *leptophilic* ALPs and Majoron, and for each class, the limits that the ArgoNeuT experiment can impose on its parameter space were studied.

## Cosmology, Astrophysics and Gravity

ICTP-SAIFR researchers are taking part in international collaborations to explore the cosmos, such as the Dark Energy Survey (DES), Dark Energy Spectroscopic Instrument (DESI), Cherenkov Telescope Array (CTA), 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 MiniJ-PAS surveys, the Laser Interferometer Gravitational-wave Observatory (LIGO), KAGRA and Virgo Collaborations.

Results from DES and DESI collaborations are described in [81–88], in particular, [86] reports measurement of the mean central optical depth of galaxy clusters via the pairwise kinematic Sunyaev-Zel’dovich effect with SPT-3G and DES. In [88], the matter density and

the dark energy equation of state were split to test the consistency of soft dark energy between background evolution and late growth of structures independent of the time scale.

Results from LIGO, VIRGO and KAGRA collaborations on gravitational waves are described in [89–91]. In particular [90] showed a search for gravitational-wave (GW) transients associated with fast radio bursts (FRB) detected by the Fast Radio Burst Project of the Canadian Hydrogen Intensity Mapping Experiment, and found no significant evidence of an association.

On the theoretical side, the contributions to the two-body scattering angle of a specific class of interactions involving the exchange of gravitational radiative degrees of freedom, including the nonlinear memory process and square of radiation reaction effects were computed in [92]. Such contributions provide in principle the last missing ingredients to compute the scattering angle at the fifth post-Newtonian and fourth post-Minkowskian order.

One of the most important collaborations in Astrophysics is the Cherenkov Telescope Array (CTA). In [93], the ICTP-SAIIR researchers Dal Pino and Nemmen, study the ability of the planned CTA to detect and identify hadronic PeVatrons. And [94] study the sensibility of the telescope array to TeV photon emission from the Large Magellanic Cloud. The report [95] presents a study of the CTA sensitivity for dark matter annihilation and decay searches using planned observations of the Milky Way dwarf spheroidal galaxies. Other results from the CTA collaboration are described in [96–101].

## 4.1.2 Complex Systems

### Mathematical Biology and Ecology

The employment of mathematical modeling has been crucial for the understanding of biological and ecological systems. During the last two years, mathematical modeling of the COVID-19 virus and vaccination methods in Brazil was especially important. In [102], a Bayesian statistical model was developed to estimate the number of deaths and hospitalizations averted by vaccination of older adults (above 60 years old) in Brazil. In [103], a discrete-time SEIR-like model was developed to estimate the potential impact of vaccinating children aged 5-11 years with mRNA-based COVID-19 vaccine in the context of omicron dominance.

Mathematical modeling also plays an important role in preserving biodiversity in ecosystems. In [104], a Lagrangian model was presented for drifting ecosystems that revealed a heterogeneity-driven enhancement of marine plankton blooms. In [105] the authors integrated theory and experiments to link local mechanisms and ecosystem-level consequences of vegetation patterns in drylands. In [106], analytical techniques and numerical simulations of empirical mutualistic networks were used to understand how ecological interactions affect the fitness of species.

Understanding the evolution of cooperation is a major question in Evolutionary Biology. [107] used an extended Game Theory model that analyzed a scenario in which a population of

cooperators and defaulters (*i.e.*, non-cooperators) both influences and depends on the availability of limited resources in an environment.

On the theoretical side, self-propelled particles (SPP), also referred to as self-driven particles, are used to describe autonomous agents, which convert energy from the environment into directed or persistent motion. [108] uses a model of SPP that spontaneously form multiple clusters to examine the average temporal evolution of many epidemics. Additionally, it was studied how this evolution is affected by the recovery of infested particles. Other results for SPP are in [109, 110].

## Condensed Matter Theory

The strange metallic regime across several high-temperature superconducting materials present numerous challenges to the classic theory of Fermi liquid metals. Recent measurements of the dynamical charge response of strange metals, including optimally doped cuprates, have revealed a broad, featureless continuum of excitations, extending over much of the Brillouin zone. Inspired by these observations, [111] investigated the phenomenology of bosonic collective modes and the particle-hole excitations in a class of strange metals by making an analogy to the phonons of classical lattices falling apart across an unconventional jamming-like transition associated with the onset of rigidity.

Quantum dots offer more possibilities than 2D and 3D systems to tune their electronic properties due to the enhanced effects of quantum confinement, making them potential candidates for many technological applications, including thermoelectrics. [112] uses density functional theory (DFT) and non-equilibrium Green's function formalism to investigate the electronic and thermoelectric properties of quantum dots in graphene nanoribbons under the presence of an applied gate voltage, and for different temperatures.

## 4.2 Research Related to Visitors

During this period, the ICTP-SAIFR hosted several long-term visitors. The research developed by 12 of these visitors is described below:

**Patrick Hervé Louodop Fotso** Dschang University (21/11/2022 - 22/01/2023)

During my visit to the ICTP-SAIFR, in collaboration with Prof. Hilda Alicia Cerdeira (IFT) and Prof. Fernando Ferreira Fagundes (USP), we worked on several manuscripts with the plan of submitting them to journals. They are:

- a) Two manuscripts on the topic of swarmalator, defined as systems of oscillators whose phase and spatial dynamics are coupled and that were used to describe the dynamics of some living systems. Their collective behavior presents simultaneous aggregation in space and synchronization in phase, which in turn leads, in some cases, to explosive

synchronization in a finite population as a function of the coupling parameter between the phases of the internal dynamics. This phenomenon is described using the order parameter and Hamiltonian formalism. Near the synchronization transition, the phase energy of the particles is represented by the  $XY$  model, and they undergo a transition that can be of the first order or second, depending on the distribution of natural frequencies of the internal dynamics of the swarmalators. Thus the first work main topic is the occurrence of the explosive synchronization in such systems.

- b) The second manuscript is dealing with the first - order transition of multi layers swarmalator within which the inter layers couplings are a combination of attractive and repulsive couplings. Thorough investigations have been done to bring out reasons or the route of transitions between some of the systems states. These analytical and numerical analysis are supported by some mathematical proofs. These two first works are planned to be submitted within two weeks to a month since we are in the last step reading, organization and language corrections.
- c) There are also works that we started such as the effect of history on the dynamics of coupled oscillators with the collaboration of Josue Tchouanti from Neuromod Institute in France, Fotso Fotso Yves from the department of Mathematics and Williams Pokam from the department of History both of the University of Dschang in Cameroon. the first manuscript could be submitted in February 2023.
- d) Finally, with my PhD students we submitted a paper to Communications in Nonlinear Science and Numerical Simulation entitled “Mobile oscillator network with amplification”. This work deals with the phenomenon of amplification in multilayer network of mobile systems whose nodes are constituted by a moving agent with an internal state (an oscillator).

**Oswaldo Chandia** Universidad Adolfo Ibañez (15/01/2023 - 21/01/2023)

Together with Nathan Berkovits and Joao Gomide we discuss the generalization to the type II string of our paper “B-RNS-GSS heterotic string in curved backgrounds”.

**Alexandre Homrich** Perimeter Institute (28/02/2023 - 20/03/2023)

Developed numerical algorithm to analytically continue CFT data of light cone operators in  $N = 4$  SYM. This helps to clarify the structure of CFT correlators in very Lorentzian regimes. We find evidence that, up to global symmetries, operators live in connected Riemann sheets as a function of spin: computing the low-lying spectrum is enough to recover the data of heavier operators provided one continue through branch-points.

Continued to develop research on detectors in conformal field theories and particle production in scattering experiments. Both observable provide us with non-trivial constraints imposed by causality and locality on the space of quantum field theories. During my visits at ICTP

I benefited from discussions with other world experts on both topics that were visiting for a conference.

**Katarzyna Jolana Budzik** Perimeter Institute (28/02/2023 - 20/03/2023)

During the visit I worked with Pedro Vieira and Harish Murali on a project concerning non-multigraviton operators in  $N = 4$  SYM at finite gauge group rank:

- we found the BPS operator (annihilated by the Beisert Hamiltonian) belonging to the non-multigraviton cohomology class.
- we found the BPS operators in multigraviton cohomology classes.
- we studied the  $1/2$ ,  $1/4$  and  $1/8$  BPS cohomology classes.
- we studied the form of multigraviton vs non-multigraviton operators for  $SU(2)$ .
- we compared the superconformal index with the multigraviton partition function.
- we studied the non-multigraviton eigenstate for other  $N$ .

I also gave a seminar on 16th of March on "Holomorphic twist of  $N = 1$  SYM".

**Nickolas Kokron** Stanford University (26/06/2023 - 12/07/2023)

The research visit was dedicated towards interactions with the cosmology group led by Professor Rogerio Rosenfeld with additional interactions with members of Professor Riccardo Sturani's group. Beyond active daily conversations and contributions (seminars, paper discussions) with members of the group I also worked directly on a project that is led by an IFT-UNESP Master's student, Abdias Aires Neto, advised by Professor Rosenfeld. I also continued my independent work on projects related to the statistics of large-scale structures in the Universe and benefited from the local expertise available at ICTP-SAIFR on the topic.

**Enrico Olivucci** Perimeter Institute (03/07/2023 - 15/07/2023)

My visit has been part of an established collaboration with Pedro Vieira (ICTP and Perimeter) and Thiago Fleury (IFT Natal) on the project "Light-cone correlators of Heavy operators in  $N = 4$  SYM via Integrability" and with Francesco Aprile (former ICTP, Univ. Complutense Madrid) about "Multipoint Fishnet integrals". The visit has coincided with the Simons Foundation's Bootstrap collaboration annual meeting, which I have attended (as well as all the mentioned collaborators). The work during my visit has consisted into scientific discussions with other participants of Bootstrap, related to the talks, and of focused discussion and scientific work with my collaborators. In particular, the visit helped to finalize the draft of an article with F. Aprile which is to appear soon.

**Andrea Leonardo Guerrieri** Perimeter Institute (13/06/2023 - 23/07/2023)

During my stay, I collaborated with Prof. Pedro Vieira on a project aiming at generalizing the S-matrix Bootstrap approach to multi-component amplitudes. In particular, thanks to my visit

and the in-person interaction, we could achieve a breakthrough and find suitable observables sensitive to multi-particle constraints. This allowed us to complete the first step in this very ambitious direction. We started writing the paper at ICTP, and we are going to publish it soon.

**Yin-Chen He** Perimeter Institute (05/07/2023 - 15/07/2023)

I gave two mini-courses, one at the Bootstrap 2023 workshop, the other at the Journey school. Also during the visit, I was working on the paper “Solving Conformal Defects in 3D Conformal Field Theory using Fuzzy Sphere Regularization”.

**Slava Rychkov** IHES-Paris (26/06/2023 - 15/07/2023)

I studied how the spectrum of the 3D Ising CFT can be obtained from the Exact Diagonalization of the transverse field Ising model on Icosahedron, once conformal perturbation theory corrections by the relevant and the leading irrelevant operators are taken into account.

**Aaron Zimmerman** U. of Texas (14/08/2023 - 18/08/2023)

I visited ICTP-SAIFR for one week. During this visit I primarily discussed gravitational wave data analysis techniques with other researchers. I did get some research ideas related to connecting black hole perturbations and geodesic theory to scattering amplitudes, but I have not developed these to any degree.

**Stefano Foffa** U. of Geneva (21/08/2023 - 01/09/2023)

I worked with Riccardo Sturani, Gabriel Almeida and Alan Muller in a revision of our recent paper “Conservative binary dynamics from gravitational tail emission processes” and prepared the ground for some follow-up and extension of such work. I had multiple interactions with other participants on various topics presented to the conference.

**Riccardo Gonzo** U. of Edinburgh (14/08/2023 - 01/09/2023)

I did some calculations related to how to derive spinning waveforms from amplitudes, as well as developing further a project on the analytic continuation between scattering and bound observables.

## 4.3 Organization of Activities

Between December 2022 – November 2023, ICTP-SAIFR organized nine São Paulo International Schools for Theoretical Physics, three minicourses, eight workshops, three programs, two meetings, and weekly outreach events, seminars, colloquia, and journal clubs. The complete list of 2023 activities is on the website <https://www.ictp-saifr.org/2023-activities/>, the list of weekly seminars, colloquia, and journal clubs is on the website <https://www.ictp-saifr.org/2023-research-seminars-and-activities/>.

Most of the activities were recorded and the videos are available online on the associated websites.

### 4.3.1 São Paulo International Schools

The eight São Paulo International Schools were on the subjects of light and cold atoms (March 6-17), CTA science (March 27-31), nonlinear dynamics, complex networks, information theory, and machine learning in neuroscience (May 22-26), holographic principle (June 5-13), non-equilibrium quantum many-body systems (June 26 – July 8), modern amplitude methods for gauge and gravity theories (July 24 – August 4), quantum chaos (August 21 – September 1), and mathematical modelling and governance (October 30 – November 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. The students were asked to anonymously evaluate the schools, and the links to view their evaluations are:

- [School on Light and Cold Atoms](#)
- [Latin-American School on CTA Science](#)
- [School on Nonlinear Dynamics, Complex Networks, Information Theory, and Machine Learning in Neuroscience](#)
- [Holography@25 School](#)
- [School on Emergent Phenomena in Non-Equilibrium Quantum Many-Body Systems](#)
- [School on Modern Amplitude Methods for Gauge and Gravity Theories](#)
- [School on Quantum Chaos](#)
- [School on Mathematical Modelling and Governance](#)

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

#### School on Light and Cold Atoms (March 6-17)

The School on Light and Cold Atoms (March 6-17) is described on the website <https://www.ictp-saifr.org/lca2023/> and involved 7 lectures and 56 participants. This school focused on training PhD students, postdocs, and outstanding master's students in the physics of optics and cold atoms, introducing them to the basic concepts and familiarizing them with the applications of modern technologies.

##### Lecturers and Topics:

- Philippe W Courteille (IFSC-USP, Brazil): *Basics on light-atom interaction, laser cooling and trapping.*

- Lucas Madeira (IFSC-USP, Brazil): *Numerical solutions of Schrödinger's equation applied to atomic physics.*
- Marcelo Martinelli (IFUSP – USP, Brazil): *Building quantum machines with light.*
- Gabriele Ferrari (University of Trento, Italy): *Bose Gases.*
- Eric Akkermans (Technion, Israel): *Mesoscopic physics of photons.*
- Joseph Thywissen (University of Toronto, Canada): *Optical lattices.*
- Frédéric Chevy (École Normale Supérieure-Paris, France): *BEC-BCS crossover.*

## **Latin-American School on CTA Science (May 22-26)**

The Latin-American School on CTA Science (May 22-26) is described on the webpage <https://www.ictp-saifr.org/cta2023/> and involved 5 lecturers, 3 speakers and 67 participants. At the school, students were familiarized with theoretical aspects of gamma-ray astronomy and learned through hands-on activities how to install the codes and familiarize themselves with numerical programs important for CTA science. The school had lectures on the following topics: numerical tools, dark matter, fundamental physics and multi-messenger.

### **Lecturers and Topics:**

- Ulisses Barres (CBPF, Brazil): *Multi-Messenger.*
- Elisabete Dal Pino (IAG-USP, Brazil): *Introduction to Astrophysics.*
- Manuel Meyer (University of Hamburg, Germany): *Fundamental Physics.*
- Gabrijela Zaharijas (University of Nova Gorica, Slovenia): *Dark Matter.*
- Francesco Longo (University of Trieste, Italy): *Experimental techniques.*

### **Seminars:**

- Rita de Cássia dos Anjos (UFPR, Brazil): *Supernovae Remnants and PeVatrons: Acceleration and Propagation.*
- Walter Max-Moerbeck (Universidad de Chile): *Introductions to Blazars.*
- Edivaldo Moura Santos (IFUSP, Brazil): *Prospects for AGN population studies with the CTA.*

## **School on Nonlinear Dynamics, Complex Networks, Information Theory, and Machine Learning in Neuroscience (May 22-26)**

This school for PhD students and young postdocs is described on the website <https://www.ictp-saifr.org/nld2023/> and involved 5 lecturers and 57 participants. The school aimed to improve knowledge of complicated neuroscience processes that occur at various scales. Nonlinear dynamics, complex networks, data analysis, information theory, and machine learning were the school's five main fields of study.



### Lecturers and Topics:

- Ana Amador (Universidad de Buenos Aires, Argentina): *Nonlinear dynamics of neuronal models with applications to bird song dynamics.*
- Cristina Masoller (Universitat Politecnica de Catalunya, Spain): *Time series analysis tools with applications to neuroscience.*
- Jesús Gomez-Gardeñes (Universidad de Zaragoza, Spain): *Complex networks and applications to neuroscience.*
- Osvaldo A. Rosso (Universidade Federal de Alagoas, Brazil): *Information theory tools for neuroscience applications.*
- Jordi Soriano (Universidad de Barcelona, Spain): *Structure-to-function relationship in neuronal cultures: applications to biological machine learning and reservoir computing.*

## Holography@25 School (June 5-13)

The school for PhD students, postdocs and outstanding Masters students is described on the website <https://www.ictp-saifr.org/holography25/> and involved 5 lecturers and 93 participants. The Holography@25 School included pedagogical lectures on tests and applications of holography and AdS-CFT. The lectures were 1.5 hours each, and in the afternoons there was a problem-solving session, in which the lecturers of the day were available to help students solve the assigned problems, as well as a Q&A session.

### Lecturers and Topics:

- Jan de Boer (Amsterdam University, Netherlands): *Black holes and AdS/CFT.*
- Aristomenis Donos (Durham University, UK): *Applications to condensed matter theory.*
- Carlos Hoyos (Oviedo University, Spain): *Holographic approach to QCD at large densities and compact stars.*
- Herman Verlinde (Princeton University, USA): *Formal aspects and tests.*
- Konstantin Zarembo (Nordita, Sweden): *Integrability and AdS/CFT.*
- Juan Maldacena (IAS-Princeton, USA): *Closing lecture*

## School on Emergent Phenomena in Non-Equilibrium Quantum Many-Body Systems (June 26 – July 7)

This two-week school organized from June 26 to July 7 provided lectures on non-equilibrium dynamics involving quantum many-body systems, bridging interdisciplinary boundaries between quantum information theory, condensed matter physics and high-energy physics. The school involved 5 lecturers and 38 participants. For a more detailed description see the website <https://www.ictp-saifr.org/neq2023/>

### Lecturers and Topics:

- Hannes Bernien (University of Chicago, USA): *Quantum Information Processing and Simulation with Rydberg Atom Arrays.*
- Darrick Chang (Institute of Photonic Sciences – ICFO, Spain): *Atom-Light Interactions as a Dissipative Spin Model.*
- Marcello Dalmonte (ICTP-Trieste, Italy): *Quantum Simulation of Lattice Gauge Theories.*
- Sebastian Diehl (University of Cologne, Germany): *Driven Open Quantum Systems — from Micro- to Macrophysics.*
- Joaquin Rodriguez-Nieva (Stanford University, USA): *Universal Prethermal Dynamics in Quantum Magnets and Fracton Fluids.*

## School on Modern Amplitude Methods for Gauge and Gravity Theories (July 24 – August 4)

The School on Modern Amplitude Methods for Gauge and Gravity Theories (July 24 – August 4) is described on the webpage <https://www.ictp-saifr.org/aggt2023/> and involved 6 lecturers and 62 participants. This two-week school provided students with techniques for computing scattering amplitudes which are not usually seen in standard courses. Selected students were invited to participate in the “Gravitational Waves Meet Amplitudes in the Southern Hemisphere” program.

### Lecturers and Topics:

#### 1<sup>st</sup> week

- Zvi Bern (UCLA, USA): *Generalized unitarity and loops.*
- Riccardo Sturani (ICTP-SAIFR/IFT-UNESP, Brazil): *Basics of gravitational waves.*
- Jaroslav Trnka (UC Davis, USA): *Overview of scattering amplitudes.*

#### 2<sup>nd</sup> week

- Nima Arkani-Hamed (IAS Princeton, USA): *Advanced topics in amplitudes.*
- Donal O’Connell (Edinburgh University, Scotland): *Double copy approach.*
- Radu Roiban (Pennsylvania State University, USA): *Gravitational waves from amplitudes.*

## School on Quantum Chaos (August 21 – September 1)

The School on Quantum Chaos (August 21 – September 1) is described on the website <https://www.ictp-saifr.org/qc2023/> and involved 7 lecturers and 33 participants. The two-week school was aimed at PhD students, postdocs and outstanding Master students and was divided into two parts. The first part provided a study of one- and many-body quantum chaos and applications based on random matrix theory and the semiclassical approach. The second part of the school focused on current aspects of research in the context of many-body quantum chaos.

### Lecturers and Topics:

#### 1<sup>st</sup> week

- Barbara Dietz (Institute for Basic Science (IBS), Republic of Korea): *Non-Relativistic and Relativistic Quantum Chaos*.
- Thomas Guhr (University of Duisburg-Essen, Germany): *Random Matrix Theory Applications from Single to Many-Body Quantum Chaos*.
- Martin Sieber (University of Bristol, UK): *Semiclassical Theory Approach in Quantum Chaos*.

#### 2<sup>nd</sup> week

- Alexander Altland (University of Cologne, Germany): *Quantum Chaos in the SYK model*.
- Horacio Pastawski (Universidad Nacional de Córdoba-CONICET, Argentina): *Dynamical Quantum Chaos in Many-Body Systems: An experimental quest for the origin of irreversibility from Loschmidt Echoes to Out of Time Order Correlators*.
- Dario Rosa (Institute for Basic Science (IBS), Republic of Korea): *Aspects of Many-Body Quantum Chaos*.
- Juan Diego Urbina (University Regensburg, Institute for Theoretical Physics, Germany): *The Semiclassical Approach to Discrete Quantum Fields and Many-Body Interference in Fock Space*.

## School on Mathematical Modelling and Governance (October 30 – November 3)

The School on Mathematical Modelling and Governance (October 30 – November 3) is described on the website <https://www.ictp-saifr.org/mmg2023/> and involved 4 lecturers and 28 participants. The school addressed how a complex systems approach modifies

our mathematical modeling; stochastic models and their relationships with deterministic models were critically examined, emphasizing the balance between mathematical accessibility and truth value.

#### Lecturers:

- Claudia Pio Ferreira (IBB – Unesp, Brazil).
- Marcelo Kuperman (CNEA-CONICET and Instituto Balseiro, Argentina).
- Christian E. Schaerer (FP-UNA, Paraguay).
- Hernan G Solari (FCEN-UBA & IFIBA-CONICET, Argentina).

#### Invited Talks:

- Silvio Funtowicz & Andrea Saltelli (University of Bergen, Norway): *Philosophy and politics of modeling*.
- Luísa Reis-Castro (USC, USA): *Field interventions using genetically modified *Aedes aegypti* mosquitoes in Brazil*.
- Ary Hoffmann (U. Melbourne, Australia): *Controlling insects*.
- Adrian Monjeau & Pedro Laterra (U. Patagonia & U. Buenos Aires, Argentina): *Management of complex ecosystems*.
- Antonieta Rojas de Arias (CEDIC, U. Asunción, Paraguay): *The rational use of resources to achieve sustainability*.

## 4.3.2 Workshops

ICTP-SAIFR organized workshops on the subjects of quantum technologies, low dimensional quantum gases, holography, classical gravity, strong electron correlations (inhomogeneities, frustration, and topology), gravitational waves, theoretical soft and condensed matter, diversity and inclusion in science and Boost STEM participation in underrepresented groups. The purpose of these workshops was to discuss the status, recent progress and perspectives in each of the fields mentioned.

### **SAIFR-Princípios Workshop on Low Dimensional Quantum Gases (March 19-22)**

This workshop took place at Instituto Princípios and the topics discussed included Bose-Einstein condensation, BEC-BCS crossover with fermionic atoms, quantum phase transitions, quantum gases in low dimensional geometries, and nonlinear waves in quantum fluids. The website of the workshop is <https://www.ictp-saifr.org/ldqg2023/> and the speakers included:

## Talks:

- Sadhan Adhikari (IFT-UNESP, Sao Paulo, Brazil): *Supersolids in Bose-Einstein condensates.*
- Vanderlei Bagnato (IFSC Sao Carlos, Brazil): *Characterization of a far from equilibrium BEC: from turbulence to scalability relations.*
- Jordi Boronat (UPC-Barcelona, Spain): *Quantum dipoles in two dimensions.*
- Monica Caracanhas (IFSC Sao Carlos, Brazil): *Superfluid vortex dynamics on curved surfaces.*
- Patricia Castilho (IFSC Sao Carlos, Brazil): *Townes soliton in a planar Bose gas.*
- Lauriane Chomaz (University of Heidelberg, Germany): *Exotic many-body states in dipolar quantum Bose gases of magnetic atoms.*
- Tobias Frederico (ITA-Sao Jose dos Campos, Brazil): *Few-boson limit cycles and discrete scale symmetry in integer and non-integer dimensions.*
- Randy Hulet (Rice University, Houston, USA): *Spin-charge separation with ultra-cold atoms.*
- Nathan Lundblad (Bates College, Maine , USA): *Studying ultracold bubbles in orbital microgravity with the NASA Cold Atom Laboratory.*
- Tommaso Macri (UFRN, Brazil): *The ubiquity of the quantum boomerang effect in Anderson-localized systems.*
- Anna Minguzzi (CNRS-Grenoble, France): *Persistent currents for ultracold fermions on a ring.*
- Nick Proukakis (Newcastle University, UK): *Criticality, quench dynamics and phase ordering in ultracold gases.*
- Francisco dos Santos (UFSCar, Sao Carlos, Brazil): *Bose-Einstein condensates and the thin-shell limit in anisotropic bubble traps.*
- Julian Schmitt (University of Bonn, Germany): *Compressibility and the equation of state of a two-dimensional optical quantum gas in a box.*
- Marzena Szymanska (University College London, UK): *Novel Non-equilibrium Phenomena in Quantum Fluids of Light.*
- Hugo Terças (IST-Universidade de Lisboa, Portugal): *Solitonic turbulence in low-dimensional quantum fluids.*
- Lauro Tomio (IFT-UNESP, Sao Paulo, Brazil): *Dynamical vortex production with periodic time-dependent perturbation applied to dipolar and non-dipolar BEC mixtures.*
- Silvio Vitiello (UNICAMP, Campinas, Brazil): *Ionic polaron in a degenerate Fermi gas.*

## Physics Opportunities at an Electron-Ion Collider 2023 (May 2-6)

The international conference POETIC 2023 on the future Electron Ion Collider (EIC) took place at Instituto Princípia. The conference included 17 international speakers from eight different countries who discussed topics such as quantum chromodynamics at high parton densities, physics beyond the Standard Model, and new developments in accelerator and detector technology. The website of the conference is <https://www.ictp-saifr.org/poetic2023/> and the speakers included:

### Talks:

- Arlene Aguilar (Unicamp, Brazil): *Dynamical mass generation in QCD.*
- Elke Aschenauer (Brookhaven National Lab, USA): *The electron-ion collider – A world wide unique collider to unravel the mysteries of visible matter.*
- Adnan Bashir (Universidad de Michoacán, Mexico): *Elucidating The Structure Of Pseudo-Scalar Mesons – Continuum Qcd Approach.*
- Shohini Bhattacharya (Brookhaven National Lab, USA): *Anomalies in Deep Virtual Compton Scattering.*
- Fabio L. Braghin (Federal University of Goias, Brazil): *Mixings in quarks/mesons and flavor content, vector meson coupling to axial current.*
- Wim Cosyn (Florida International University, USA): *Physics opportunities with light ions at the Electron-Ion Collider.*
- Aurore Courtoy (UNAM, Mexico): *Phenomenology of PDFs — uncertainty determination for the proton and the pion PDFs.*
- Tobias Frederico (Instituto Tecnológico de Aeronáutica, Brazil): *Light-Hadrons structure and dynamics in Minkowski space.*
- Adam Freese (University of Washington, USA): *Light front synchronization and the rest frame structure of hadrons.*
- Victor Goncalves (Universidade Federal de Pelotas, Brazil): *Seeking for saturation physics in inclusive and exclusive observables at the EIC.*
- Cedric Lorcé (École Polytechnique, France): *Relativistic spatial distribution of charge and magnetization.*
- Jamal Jalilian-Marian (Baruch College, USA): *One-loop corrections to single and double inclusive hadron production in DIS at small  $x$ .*
- Khépani Raya Montaña (University of Huelva, Spain): *From 1 dimensional distributions to GPDs.*
- Fernando Navarra (IF-USP, Brazil): *Leading Lambda production at the Electron Ion Collider.*

- Emmanuel de Oliveira (UFSC, Brazil): *Exclusive photo- and electroproduction of excited light vector mesons via holographic model.*
- Petja Paakkinen (University of Jyväskylä, Finland): *Heavy quarks and dijets as a probe of nuclear partons from LHC  $pA$  to  $\gamma A$  collisions in UPCs and at EIC.*
- Brian Page (Brookhaven National Lab, USA): *An Overview of Jets at the EIC.*
- Patrizia Rossi (Jefferson Lab, USA): *Jefferson Lab in the EIC era.*
- Farid Salazar (University of California Los Angeles, USA): *Gearing up for the precision era for gluon saturation.*
- Werner K. Sauter (Instituto de Física e Matemática – UFPel, Brazil): *Vector meson production at large  $t$  in  $eA$  collisions.*
- Fernando Serna (Universidad de Sucre, Colombia): *Meson Distribution Amplitudes from Bethe-Salpeter Wave Functions.*
- Fernanda Steffens (Bonn University, Germany): *PDFs, GPDs, and TMDPDFs from Lattice QCD.*
- Jun Takahashi (Unicamp, Brazil): *EXTREME Collaboration, a full hybrid model to simulate High Energy Heavy Ion Nuclear Collisions.*
- Anthony Thomas (University of Adelaide, Australia): *From the Quark and Gluon Structure of Nuclei to the Search for Dark Matter.*
- Giorgio Torrieri (Unicamp, Brazil): *Could collectivity exist in  $eA$  collisions?*
- Zhenyu Ye (University of Illinois in Chicago, United States): *AC-LGAD detectors for Spatial and Timing Measurements at the Electron-Ion Collider.*

## **Holography@25 (June 14-17)**

This workshop was held from June 14 to 17 and celebrated the 25th anniversary of the birth of AdS/CFT correspondence. During the workshop, several areas were covered, from formal aspects and proofs to applications in various areas, such as QCD and nuclear physics, condensed matter theory, black holes, information, chaos, complexity and integrability. The workshop presented new advances in all these areas of AdS/CFT correspondence. The website of the workshop is <https://www.ictp-saifr.org/holography25/> and the speakers included:

### **Speakers:**

- Matteo Baggioli (Shanghai Jiaotong University, China): *Holography with broken space-time symmetries and its transition into adulthood.*
- Nikolay Bobev (Leuven University, Belgium): *Large  $N$  Partition Functions, Holography, and Black Holes.*

- Nadav Drukker (King's College, London, UK): *Surface operators and holographic M2-branes.*
- Johanna Erdmenger (Wuerzburg University, Germany): *Geometric phases, von Neumann algebras and AdS/CFT.*
- Carlos Hoyos (Oviedo University, Spain): *Holographic baryonic matter without flavor branes.*
- Hai Lin (Southeast University, China): *Coherent states and high dimension operators in gauge/gravity correspondence.*
- Juan Maldacena (IAS, Princeton, USA): *Scaling similarity in large  $N$  quantum mechanics.*
- Dario Martelli (Turin University and INFN, Turin, Italy): *A spindle story: from AdS to equivariant localization and back.*
- Rob Myers (Perimeter Institute, Canada): *Complexity equals (Almost) Anything.*
- Niels Obers (Niels Bohr Institute, Denmark): *Non-relativistic corners in string theory and AdS/CFT.*
- Leopoldo Pando-Zayas (Michigan University, USA and ICTP, Trieste, Italy): *Logarithmic Corrections to the Entropy of AdS Black Holes.*
- Kostas Skenderis (Southampton University, UK): *Flat space limit of AdS/CFT for massive amplitudes.*
- Dam Thanh Son (Chicago University, USA): *Applied nonrelativistic conformal field theory.*
- Alessandro Tomasiello (Milan University and INFN Milan, Italy): *General bounds on Kaluza–Klein masses.*
- Herman Verlinde (Princeton University, USA): TBA
- Konstantin Zarembo (Nordita, Sweden): 't Hooft loops and integrability
- Dmitry Melnikov (International Institute of Physics – UFRN): *Entanglement and holographic states in Chern-Simons theory.*
- James Sparks (University of Oxford): *Equivariant localization in supergravity.*
- Diego Hernán Correa (Instituto de Física La Plata): *Wilson loops and integrability in Chern-Simons-matter theories.*

## **Workshop on Strong Electron Correlations in Quantum Materials: Inhomogeneities, Frustration, and Topology (June 19-23)**

The topics discussed in this workshop included equilibrium and non-equilibrium disordered metals and insulators, frustrate magnets, spin liquids, topological insulators, and correlated and topological superconductors. This activity was a natural continuation of a [workshop organized in 2018](#). The website of the workshop is <https://www.ictp-saifr.org/qm2023/> and the speakers included:



## Talks:

- Gabriel Aeppli (ETH Zürich, EPF Lausanne and Paul Scherrer Institute, Switzerland): *Mapping artificial and natural intelligence.*
- Carol Aguiar (UFMG, Brazil): *Quench dynamics of the Kondo effect.*
- Amir Caldeira (UNICAMP, Brazil): *Effective momentum-momentum coupling in a correlated electronic system: the diamagnetism of benzene.*
- Vanuildo S. Carvalho (UFG, Brazil): *Multipolar spin liquid in an exactly solvable model for  $J = 3/2$  moments.*
- Claudio Chamon (Boston University, USA): *Designing Topological Quantum Matter.*
- Wei Chen (PUC-Rio, Brazil): *Unification of topological invariants and topological markers.*
- Mucio Continentino (CBPF, Brazil): *Hybridization induced superconductivity in non-interacting chains.*
- Natanael Costa (UFRJ, Brazil): *The effects of randomness to charge-ordered systems.*
- Luis Gregório Dias (USP, Brazil): *Emergent parafermionic zero modes in fermionic systems.*
- Vlad Dobrosavljević (NHMFL & FSU, USA): *Disorder-dominated quantum criticality in moiré bilayers.*
- Rafael Fernandes (University of Minnesota, USA): *Inhomogeneous time-reversal symmetry-breaking in the superconducting state of  $\text{Sr}_2\text{RuO}_4$ .*
- Rebecca Flint (Iowa State University and Ames National Laboratory, USA): *Mobile Majorana Zero Modes in two-channel Kondo lattices.*
- Rafael S. Freitas (USP, Brazil): *Structural disorder and magnetic properties of geometrically frustrated magnets.*
- Elena Gati (Max Planck Institute for Chemical Physics of Solids, Germany): *Strain tuning of correlated (frustrated) magnets.*
- Wei Ku (Shanghai Jiaotong University, China): *Robustness of geometric frustration-induced localization and realization of homogeneous quantum Bose metal.*
- Caio Lewenkopf (UFF, Brazil): *Topological phase transitions in strongly disordered and amorphous systems.*
- Tobias Micklitz (CBPF, Brazil): *Observation of Topological Quantum Criticality.*
- Eduardo Miranda (UNICAMP, Brazil): *The domain wall between a Mott insulator and a metal is an anomalous metal.*
- Rajesh Narayanan (IIT-Madras, India): *A Cloaked Griffiths phase in a low dimensional superconductor.*
- Willian Natori (Institute Laue Langevin, France): *An exact chiral amorphous spin liquid.*

- Eduardo Novais (Universidade Federal do ABC): *Spectrum of Entanglement as a Dimensional Reduction Tool for studying Topological Insulators.*
- Thereza Paiva (UFRJ, Brazil): *Effects of lattice geometry on thermopower properties of the repulsive Hubbard model.*
- Rodrigo Pereira (IIP & UFRN, Brazil): *Boundary modes in fracton models.*
- Dragana Popovic (NHMFL & FSU, USA): *Nonequilibrium transport and thermalization in strongly disordered 2D electron systems*
- Victor Quito (Iowa State University and Ames National Lab, USA): *Unique signatures of electronic nematic liquids via nonlinear spectroscopy.*
- Srinivas Raghu (Stanford, USA): *New insights on the quantum Hall transition problem.*
- Daniel Reyes (Instituto Militar de Engenharia, Brazil): *Incommensurate charge density wave on multiband intermetallic systems.*
- Judit Romhányi (UC Irvine, USA): *Band-topology of triplet excitations.*
- Raimundo Rocha dos Santos (UFRJ, Brazil): *Phase diagram for the extended Hubbard model on a square lattice.*
- Hana Schiff (UC Irvine, USA): *Spin groups for weak spin-orbit coupling materials.*
- Eduardo Silva-Neto (Yale, USA): *Broken Symmetry States and Mysterious Superconductivity in Tetragonal Fe(Se, S).*
- Y. Soh (Paul Scherrer Institute, Switzerland): *Flat band and Weyl physics in ferromagnetic kagome lattices.*
- Matheus Sousa (PUC-RJ, Brazil): *Seeing topological charges by naked eyes.*
- Thaís Victa Trevisan (UC Berkeley, USA): *Nonlinear Hall effect induced by a quantum metric dipole in antiferromagnetic heterostructures.*
- Oskar Vafek (NHMFL & FSU, USA): *Interacting Hofstadter spectrum of twisted bilayer graphene.*
- Matthias Vojta (TU-Dresden, Germany): *Emergence of mesoscale quantum phase transitions in a ferromagnet.*
- Thomas Vojta (Missouri S&T, USA): *Controlling the stripe order in a diluted frustrated magnet.*

## **2023 Workshop on Classical Gravity (August 16)**

The goal of this workshop was to further stimulate activities in the Latin American community in research areas including fundamental gravity, astronomy and cosmology, and to award the [2023 ICTP-SAIFR Prizes for the best Latin-American thesis in Classical Gravity and Applications](#). The 2023 Classical Gravity Workshop was part of the [Gravitational Waves Meet Amplitudes in the Southern Hemisphere Program](#). The website of the workshop is <https://www.ictp-saifr.org/cgw2023/> and the speakers included:

### Speakers:

- Luis Lehner (Perimeter Institute, Canada): *Beyond General Relativity and the strongly gravitating/dynamical regime.*
- Guilherme Brando de Oliveira (UFES, Brazil): *The emergence of time in cosmological correlations.*
- David Camarena (UFES, Brazil): *Pushing the boundaries of modern cosmology: physics beyond the Copernican principle.*
- Luis Felipe Longo Micchi (UFABC, Brazil): *Prospective Sources of Gravitational Waves for Third-Generation Ground-Based Observatories.*

### Brazilian Workshop on Soft Matter (October 4-6)

This ICTP-SAIFR/SIRIUS workshop, organized from October 4-6, provided a platform to foster collaborations in the Brazilian soft matter community. The first two days of the workshop were held at IFT-UNESP in the city of São Paulo and the third day at the synchrotron accelerator Sirius in the nearby city of Campinas. The website of this workshop is <https://www.ictp-saifr.org/sm2023/>.

### Speakers:

- Jennifer Schwarz (Syracuse University, USA): *Using model active tissues containing active chromatin to test multi-scale hypotheses in organoids.*
- Luiz Roberto Evangelista (UEM, Brazil): *Fractional Calculus as a Tool for Applications in Soft Matter: Electrical Impedance Response of Liquid Crystals.*
- André Polloni (Anton Paar): *Exploring SAXS and USAXS to measure several properties of soft matter using small amounts of sample.*
- Hartmut Löwen (Heinrich Heine University Düsseldorf): *Self-propelled particles.*
- Ronald Dickman (UFMG, Brazil): *Phase Transitions in Active Matter.*
- Tomás Grigera (Universidad de La Plata, Argentina): *Critical dynamics of natural swarms.*
- Francisca Guzmán-Lastra (Universidad de Chile): *Controlling vertical transport driven by active carpets at viscosity interfaces.*
- Mathilde Champeau (UFABC, Brazil): *4D printing of hydrogels.*
- Watson Loh (UNICAMP, Brazil): *Soft core-shell nanoparticles with controlled architectures.*
- Kriss Leftwich (Xenocs): *Xeuss 3.0 Platform from Xenocs.*
- M. Lisa Manning (Syracuse University, USA): *Origin of rigidity in biological tissues.*
- Carolina Brito (UFRGS, Brazil): *Metastability in wetting phenomena.*
- Emanuela del Gado (Georgetown University, USA): *The hidden hierarchical nature of soft particulate gels.*
- Julien Chopin (UFBA, Brazil): *Tensional twist-folding and scrolling of sheets.*

## Increasing Diversity and Inclusion in Science (November 13-15)

The goal of this three-day workshop was to reorganize the scientific ecosystem to make it more inclusive and diverse. This is important not only because it constitutes a basic human right, but also because the great challenges that humanity faces require the joint effort of people of different backgrounds, viewpoints, and experiences. The website of the workshop is <https://www.ictp-saifr.org/diversity2023/> and involved 13 speakers and 40 participants.

### Plenary talks:

- Sônia Guimarães (Instituto de Tecnologia Aeronáutica, Brazil): *My Journey, Advocacy Work to Improve Brazilian Scientists Diversity.*
- Sendy Melissa Santos do Nascimento (Brazil): *Women in Colors.*
- Renata Wasserman (Universidade de São Paulo, Brazil): *Women in CS and IA: A personal perspective.*

### Talks:

- María Mayra de la Torre Martínez (Centro de Investigación en Alimentación y Desarrollo, Mexico): *How to write a paper/proposal.*
- Leslie Jimenez (Universidad de Chile): *Communicating science to different audiences: to whom? What for? How?.*
- Lorena Romero Salazar (Universidad Autónoma del Estado de México, Mexico): *Intellectual Property.*

### Discussion Panels:

- Gender and technology transition in Latin America:
  - Mariza Ferro (Universidade Federal Fluminense, Brazil).
  - Claudia López Moncada (Universidad Técnica Federico Santa María, Chile).
  - Camila Carneiro Dias Rigolin (Universidade Federal de São Carlos, Brazil).
  - Carleane Patricia da Silva Reis (Universidade de Santa Catarina, Brazil).
- Inclusion and diversity in science and technology: an initiative for equality and development
  - Claudia Matus Cánovas (Pontificia Universidad Católica, Chile) .
  - Maria Lúcia Santana Braga (CNPq, Brazil)).
  - Luciano Fabbri (Universidad Nacional de Rosario, Argentina).

## Proposals to Boost STEM Participation in Underrepresented Groups (November 16 -17)

The goal of this workshop was to discuss and present initiatives aimed at increasing the participation of underrepresented groups in STEM careers, with a focus of this 2-day event on Afro-Brazilian, indigenous and low-income populations. This activity was organized in the form of plenary talks and roundtable discussions, with the first day focusing on initiatives organized in the USA and Argentina, and the second day focusing on initiatives in Brazil. The website of this workshop is <https://www.ictp-saifr.org/boost2023/> and involved 10 speakers and 51 participants. The talks were in English and Spanish on the first day and Portuguese on the second day.

### Speakers:

- Young-Kee Kim (President-elect of American Physical Society, Univ. Chicago, USA): *APS activities: Enhancing inclusivity & embracing diverse perspectives.*
- Silvina Ponce Dawson (President-designate of the International Union of Pure and Applied Physics, Argentina): *The International Union of Pure and Applied Physics and its actions to increase inclusion and diversity in physics.*
- S. James Gates, Jr. (former president of American Physical Society, Univ. Maryland, USA): *Achieving the dream: My life in math and science, defying barriers and living diversity in STEM.*
- Valeria Viva (cofounder of XSTEM, Argentina): *STEM education at early stages for inclusion in Latin America.*
- Maria Lucia de Santana Braga (analista e membro da equipe do Programa Mulher e Ciência do CNPq, Brasil): *O Painel de Fomento em Ciência, Tecnologia e Inovação do CNPq e suas contribuições para a pluralidade na ciência.*
- Lazaro Cunha (diretor do Instituto Cultural Steve Biko e coordenador do projeto Oguntec, Brasil): *Programa Oguntec: uma experiência de ações afirmativas na educação científica de jovens negros e negras de escolas públicas da Bahia.*
- Rogerio Monteiro de Siqueira (EACH-USP, Brasil): *O programa de pós-doutorado para pesquisadoras e pesquisadores negros na USP: Histórico, perfil dos bolsistas, perspectivas de trabalho.*
- Celso Lins de Oliveira (FZEA-USP, Brasil): *As barreiras e a sub-representação negra na docência do Ensino Superior Brasileiro.*
- Marcelo Knobel (ex-reitor da Unicamp, Brasil): *Mesa redonda.*
- Rodrigo Capaz (Presidente da Sociedade Brasileira de Física, Brasil): *Mesa redonda.*

### 4.3.3 Minicourses

The ICTP-SAIFR organized three minicourses in 2023, on cosmological phase transitions and gravitational waves, modeling epidemics and behaviours, and lattice model and applications to biological problems. The topics, lecturers and websites for these minicourses are:

- 1) February 24 - March 3 – Minicourse on Cosmological Phase Transitions and Gravitational Waves – Benedict von Harling (IFAE-Barcelona, Spain)

This minicourse provided an introduction to phase transitions in the early universe and how they can produce stochastic gravitational waves that could be detected at current and future observatories. Several concrete models of particle physics were also presented and their prospects for discovery in gravitational wave observatories were discussed. The website of the minicourse is <https://www.ictp-saifr.org/cptgw2023/>.

- 2) October 16-20 – Minicourse on Modeling Epidemics and Behaviour – Ana Bento (Rockefeller Foundation, USA), Renato Coutinho (UFABC, Brazil), Roberto Kraenkel (IFT-UNESP, Brazil) and Joshua Weitz (University of Maryland, USA).

This minicourse provided students and early career researchers the opportunity to learn the principles of epidemic model development along with recent advances in the analysis of coupled dynamics of disease and behavior, methods for model data integration at scale and the current challenges in the use of mathematical models for pandemic prevention. The website of the minicourse is <https://www.ictp-saifr.org/meb/>.

- 3) November 27 – December 1 – Minicourse on Lattice models and applications to biological problems – Ricardo Martinez-Garcia (CASUS-HZDR, Germany & ICTP-SAIFR/IFT-UNESP, Brazil) and Luisa Ramirez (Johannes Gutenberg Univ., Mainz, Germany).

In this minicourse, the most common numerical and analytical techniques for the analysis of lattice models in biological and ecological contexts were introduced. Among the numerical approaches, the minicourse focused on Monte Carlo and Maximum Entropy methods. And using analytical techniques, different ways of inferring probability distributions of biological systems were described. The website of the minicourse is <https://www.ictp-saifr.org/lmabp/>.

## 4.3.4 Programs

### Serrapilheira/ICTP-SAIFR Training Program in Quantitative Ecology (January 9-March 3)

The Serrapilheira/ICTP-SAIFR Training Program in Quantitative Ecology (January 9-March 3) is described on the website <https://www.ictp-saifr.org/qecoprogram/>. The program trained young Brazilian scientists for world-class research on ecology using the qualitative 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 to solving cutting-edge problems in ecology. Lectures in all sub-fields of ecology were presented by international experts, and no previous knowledge of biology was required.

The two-month program focused on models and methods related to ecology. Topics included deterministic mathematical modeling, statistical models, computational methods for simulating and analyzing ecological models, quantitative foundations of ecological and evolutionary concepts, non-equilibrium dynamics in ecological systems, non-linearity, variability and diversity, evolutionary game theory and transitions, and metapopulation dynamics.

In addition to attending lectures and seminars by internationally renowned researchers, students in the program worked in small groups on a research project. The training program also included a series of transversal talks that are listed below.

#### Lecturers and Topics:

##### *Deterministic Mathematical Modeling.*

- Roberto Kraenkel (IFT-UNESP, Brazil)

##### *Statistical models: linking data to theory.*

- Paulo Inacio Prado (USP, Brazil)
- Diogo Melo (Princeton University, USA)
- Andrea Sanchez-Tapia (RLadies, The Carpentries and The Turing way)
- Paula Lemos Costa (University of Chicago, USA)

##### *Computational methods for simulating and analyzing ecological models.*

- Renato Coutinho (UFABC, Brazil)

##### *Quantitative Foundations of Ecological and Evolutionary concepts.*

- Joshua Weitz (Georgia Tech, USA)
- Stephen Beckett (Georgia Tech, USA)
- Jacopo Marchi (Georgia Tech, USA)

*Out of Equilibrium dynamics in Ecological Systems.*

- Karen C. Abbott (Case Western Reserve University, USA)

*Non-linearity, variability and diversity: an integrative perspective.*

- Priyanga Amarasekare (UCLA, USA)

*Evolutionary game theory and transitions.*

- Vitor Vasconcelos (University of Amsterdam, Netherlands)

*Metapopulation Dynamics.*

- Lisa C. McManus (University of Hawai‘i-Manoa, Hawai‘i)

### **Seminars:**

- Guilherme Longo (UFRN, Brazil): *Can we predict the future of Brazilian reefs?* (February 9).
- Lauren G. Shoemaker (University of Wyoming, USA): *A back and forth between experiments and modeling: from disease dynamics to plant ecology* (February 13).
- Vasilis Dakos (Université de Montpellier, France): *Anticipating ecological surprises: early-warning signals for tipping points* (February 15).
- Fernando Rossine (Harvard University, USA): *Emergent properties of microbial collectives mediate the effect of antimicrobial agents* (February 17).
- Theresa Ong (Dartmouth College, USA): *Coral halo patterns-geometry and consumer-resource interactions* (February 22).
- Luisa Gigante Carvalheiro (UFG, Brazil): *Using quantitative methods to evaluate and predict the ecological and socioeconomic consequences of global changes* (February 27).

### **Transversal Talks:**

- Maria Augusta Arruda (University of Nottingham, UK): *Talk about under-represented groups in Science* (February 10).
- Arthur Menezes and Yeraldi Loera (Princeton University, USA): *Graduate school application process* (February 14).
- David Medeiros and Rafael Lemos (Education USA): *How to get scholarships for your PhD program in the U.S.* (February 16).
- Fernanda Staniscuaski (UFRGS, Brazil): *Gender gap in Science* (February 24).
- Sarah Azoubel (Biology PhD and co-founder of the podcast 37 Graus and [cochicho.org](http://cochicho.org)): *The sound of science: how we mix science and storytelling in the podcast 37 Graus.*



## Bootstrap 2023 (June 26 – July 14)

Bootstrap 2023 was a 3-week program of the Simons Non-Perturbative Bootstrap Collaboration organized by ICTP-SAIFR at the Instituto Princípia in São Paulo from June 26 to July 14. Funded by the Simons Foundation, the objective of the collaboration is to solve strongly coupled quantum field theories by imposing consistency properties. Lectures were in the mornings, and afternoons were reserved for spontaneously organized discussions by the participants.

### Lecturers and Topics:

#### 1<sup>st</sup> week

- Petr Kravchuk: *Higher-twist operators in CFTs.*
- Alexandre Homrich: *Complex spin, light-ray operators, and integrability.*
- Victor Rodriguez: *A two-dimensional string cosmology.*
- António Antunes: *Coupled minimal models irrationally revisited.*
- Brandon Rayhaun: *Classification of Small 2D CFTs.*
- Liam Fitzpatrick: *Ising Field Theory in Lightcone Quantization.*
- Marten Reehorst & Benoit Sirois: *Bootstrapping frustrated magnets:  $O(n) \times O(2)$  model.*

#### 2<sup>nd</sup> week

- Petar Tadić: *The five-point bootstrap.*
- Joao Vilas Boas: *Conformal multi-Regge theory.*
- Nathan Benjamin: *High dimension operators for high dimension CFTs.*
- Tobias Hansen: *Bootstrapping the AdS Virasoro-Shapiro Amplitude.*
- Zechuan Zheng: *Numerical conformal bootstrap with Analytic Functionals and Outer approximation.*
- Harish Murali: *Following BPS black hole states in  $N$ .*
- Stefanos Kousvos: *On the spectrum of CFTs with Hypercubic global symmetry and the bootstrap.*
- Junchen Rong: *Classifying irreducible fixed points of five scalar fields in epsilon expansion.*
- Aike Liu: *Skydiving Algorithm: A Dynamical SDP Solver.*
- Jan Albert: *Bootstrapping pions and currents at large  $N$ .*

### 3<sup>rd</sup> week

- Scott Collier: *A TQFT for 3D Quantum Gravity*.
- Marco Meineri: *enormalization group flows in AdS and the bootstrap program*.
- Sidrip Pal: *Lightcone Modular Bootstrap and Tauberian Theory*.
- Henry Lin: *Bootstrap Bounds on D0 Brane Quantum Mechanics*.
- Giulia Fardelli: *Double Copy for Spinning Correlators in  $N = 2$  SCFTs*.
- Biswajit Sahoo: *Probing  $c$ -anomaly in 4D QFTs*.
- Connor Behan: *Analytics and Numerics for the Long-range Ising Model*.

## Gravitational Waves meet Amplitudes in the Southern Hemisphere (August 14 - September 1)

The central theme of this program was the application of particle physics methods to the calculation of processes relevant to gravitational-wave phenomenology. Both experts and younger theorists from three different communities were brought together: classical general relativity, effective field theories, and scattering amplitudes. The program was also useful for establishing contacts between theorists, observers, and LIGO-Virgo-KAGRA specialists. The website of the program is <https://www.ictp-saifr.org/gwa2023/>

### Lecturers:

- Fabian Bautista (IPhT Saclay, France): *Higher spins, the Teukolsky equation and super extrema Kerr Binary Systems*.
- Collin Capano (UMass at Dartmouth, USA): *Observational evidence for quasi-normal modes from astrophysical black holes*.
- John Joseph Carrasco (Northwestern University, USA): *From scattering to expansion, effective gravitational predictions via double-copy*.
- Fernando Febres Cordero (Florida State University, USA): *Numerical Techniques for Gravity Scattering Amplitudes*.
- Leonardo de la Cruz (IPhT Saclay, France): *Classical off-shell currents*.
- Stefano Foffa (University of Geneva, Switzerland): *Towards 5PN determination of conservative binary dynamics*.
- Riccardo Gonzo (University of Edinburgh, UK): *From classical scattering amplitudes to bound state observables*.
- Maria Haney (NIKHEF – Amsterdam, the Netherlands): *Waveform modeling for GW data analysis (1)*.
- Manfred Kraus (Mexico University, Mexico): *Spinning Black Holes from multi-loop Scattering Amplitudes*.

- David Kosower (Université Paris–Saclay, France): *Finite and Evanescent Feynman Integrals*.
- Luis Lehner (Perimeter Institute, Canada): *Beyond General Relativity and the strongly gravitating/dynamical regime*.
- Oliver Long (Max Planck Institute-Potsdam, Germany): *Self-force meets post-Minkowskian in the scattering regime*.
- Raissa Mendes (UFF, Brazil): *Effective action models for dynamical scalarization*.
- Guilherme Pimentel (Scuola Normale Superiore – Pisa, Italy): *The emergence of time in cosmological correlations*.
- Adam Pound (University of Southampton, UK): *Progress in gravitational self-force theory: recent advances in the small-mass-ratio limit*.
- Geraint Pratten (University of Birmingham, UK): *Waveform modeling for GW data analysis (2)*.
- Patricia Schmidt (University of Birmingham, UK): *Data analysis: hands-on session*.
- Riccardo Sturani (ICTP-SAIFR/IFT-UNESP, Brazil): *NRGR for the two-body problem: an overview*.
- Justin Vines (MPI for Gravitational Physics, Germany): *Scattering amplitudes for spinning black holes*.
- Mao Zeng (University of Edinburgh, UK): *Scattering amplitudes and the gravitational two-body problem*.
- Aaron Zimmermann (University of Texas – Austin, USA): *Introduction to Gravitational Wave Data Analysis*.

### 4.3.5 Meetings

#### APS-SAIFR Satellite March Meeting (March 20-22)

As part of the March Virtual Meeting on March 20-22, 2023, ICTP-SAIFR hosted three 2-hour sessions broadcast live to all participants, as well as a session for student presentations and postdocs. Graduate students and postdocs gave oral and/or poster presentations at the student-postdoc session. The website of the meeting is <https://www.ictp-saifr.org/aps-march23/>.

#### APS/ICTP-SAIFR Satellite Sessions:

- March 20: 14:00-16:00 (IFT auditorium) Condensed Matter Theory  
Organizer: Alexandre Reily Rocha (IFT-UNESP)
- March 20: 19:00-21:00 (IFT auditorium) Quantum Technologies  
Organizer: Marcelo Terra Cunha (Unicamp)

- March 21: 19:30-21:30 (online) Network Dynamics and Synchronization  
Organizer: Marcus Aguiar (Unicamp)

#### **ICTP-SAIFR Student-Postdoc Session:**

- March 20: 16:30-18:30 (IFT auditorium) Condensed Matter and Quantum Technologies  
Organizers: Alexandre Reily Rocha (IFT-UNESP) and Marcelo Terra Cunha (Unicamp)

### **APS-SAIFR Satellite April Meeting (April 26)**

As part of the April Meeting, ICTP-SAIFR hosted two sessions on Cosmology and Astrophysics/Neutrino Experiments broadcast live to all participants, as well as two sessions for student/postdoc presentations on cosmology/astrophysics/particle physics. The website of the meeting is <https://www.ictp-saifr.org/apsapril23/>.

#### **APS/ICTP-SAIFR Satellite Sessions:**

- April 26: 15:00-16:00 (IFT auditorium) Latin-American participation in Cosmology experiments  
Organizer: Rogerio Rosenfeld (ICTP-SAIFR/IFT-UNESP)
- April 26: 17:30-19:00 (IFT auditorium) Latin-American participation in Astrophysics/Neutrino experiments  
Organizer: Ettore Segreto (Unicamp)

#### **ICTP-SAIFR Student-Postdoc Sessions:**

- April 26: 13:30-14:30 (IFT auditorium) Cosmology  
Organizers: Rogerio Rosenfeld (ICTP-SAIFR/IFT-UNESP)
- April 26: 16:00-17:00 (IFT auditorium) Astrophysics and Particle Physics  
Organizers: Ettore Segreto (Unicamp)

## **4.3.6 Outreach Events**

The ICTP-SAIFR organized seven different types of online outreach activities in 2023 aiming at different audiences. The format, topics and websites for these events are:

### **Clube do Livro – Sci-SAIFR**

In this outreach program, a physicist uses a science fiction book to discuss with the audience the physics concepts behind it. The webpage for the program is <https://outreach.ictp-saifr.org/clube-do-livro/>, and the books discussed during 2023 meetings included:

- Alan Alves Brito (UFRGS): *Astro-Anstro-Lógicas* (março 02).
- Riccardo Sturani (ICTP-SAIFR/IFT-UNESP): *As cosmicômicas* (maio 04).
- Rafael Chaves (IFF UFRN): *Incerteza quântica* (junho 21).
- Marcia Rizutto (IFUSP): *Eu fui Veermer* (agosto 24).
- Raul Abramo (IFUSP): *Duna* (outubro 19).

## Ciência no Cinema

ICTP-SAIFR and the Petra Belas Artes Cinema promoted special sessions to discuss films related to physics with a public audience. In these sessions, researchers invited by the ICTP-SAIFR answered questions from the audience after the films. The website of this activity is <https://outreach.ictp-saifr.org/ciencia-no-cinema/> and the films discussed and the invited researchers this year included:

- *Oppenheimer* (July 25 & August 08): with Ivã Gugel (IFUSP), Gastão Krein (IFT-UNESP) and Lauro Tomio (IFT-UNESP).
- *Contact* (September 12): with Adriana Valio (CRAAM – Mackenzie).
- *Arrival* (October 17): with Jana Bianchi (translator) and Marcelo Munhoz (IFUSP).
- *Hidden Figures* (November 14): with Zélia Maria Da Costa Ludwig (UFJF).

## Ciclo de Palestras ICTP-SAIFR/Principia

In this series, ICTP-SAIFR and Instituto Principia organize a cycle of lectures for the general public by a distinguished researcher on a specific topic. The first set of lectures was presented from November 25 - December 16 by Rogério Rosenfeld (ICTP-SAIFR/IFT-UNESP) with the title "A Ciência do Cosmos: a evolução do conhecimento sobre o Universo." The website of this activity is <https://outreach.ictp-saifr.org/ciclo-de-palestras/>.

## Doses of Physics

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

## 6th Perimeter-SAIFR-IFT Journeys in Theoretical Physics (July 17-23)

The 6<sup>th</sup> edition of this school is described on the website <https://journeys.ictp-saifr.org/> and involved 4 lecturers and 90 participants. The top students from this school were invited to a joint Master's program at Perimeter and either IFT-UNESP or USP. The students

accepted to the joint program include Levy Bruno do Nascimento Batista (USP São Carlos), Francisco Divi (Balseiro Institute, Bariloche) and Matheus Balisa Pauliquevis (IF-USP São Paulo).

Lecturers and Topics:

- Nathan Berkovits (ICTP-SAIFR/IFT-UNESP, Brazil): *Introduction to Supersymmetry*.
- Juan Carrasquilla (Vector I./U. Waterloo/U. Toronto, Canada): *Machine Learning for Quantum Matter*.
- Yin-Chen He (Perimeter Institute, Canada): *Introduction to the Quantum Hall Effect*.
- Ricardo Matheus (IFT-UNESP, Brazil): *Open Problems in Particle Physics*.

## 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 website for the minicourses is <http://outreach.ictp-saifr.org/ensino-medio/minicurso/> and topics covered include:

- Rogério Rosenfeld (ICTP-SAIFR/IFT-Unesp): *Física do universo: cosmologia* (março 25 - abril 22).
- Pedro Vieira (ICTP-SAIFR/Perimeter Institute): *Relatividade* (maio 7-28).
- Alberto Saa (IMECC – Unicamp): *Os números complexos existem?* (junho 3-10).
- Roberto Kraenkel (IFT-Unesp): *A matemática no mundo* (agosto 12 - setembro 2).
- Raul Abramo (IFUSP): *História e Geografia do Universo* (outubro 21-28).
- Edivaldo Moura Santos (IFUSP): *Mensageiros cósmicos: raios cósmicos, neutrinos e raios gama* (novembro 11-18).

In addition, U. Porto and ICTP-SAIFR jointly organized the 3<sup>rd</sup> Summer School for Young Physicists. During this school, 36 talented high school students were selected to develop research projects created and supervised by 9 graduate students. Participants also attended the following seminars:

- Nathan Berkovits (ICTP-SAIFR/IFT-Unesp): *Supercordas: sucessos e desafios*.
- Caio Lewenkopf (UFF): *Revolução de eletrônica: o caminho da lei de Ohm ao domínio nanoscópio*.
- Roberto Kraenkel (IFT-Unesp): *Como a matemática ajuda a combater epidemias*.
- Ivone Albuquerque (IFUSP): *O mistério da matéria escura no universo*.

The website of this activity is <https://outreach.ictp-saifr.org/edv23/>. The fourth edition is planned for 2024 (see the website <https://outreach.ictp-saifr.org/escolaverao/>).

Furthermore, ICTP-SAI FR organized a one-week winter school for high school students. Topics included the two minicourses “A Mecânica Quântica e os novos materiais: metais, grafeno e os supercondutores” by Prof. Alexandre Reily Rocha (IFT-Unesp) and “Simulações computacionais de interfaces água/metal” by Luana Pedroza (UFABC), a programming course on Physics with Python by IFT-UNESP PhD students, and a lecture “Matemática básica para mecânica quântica” by Lucas David Feitosa Campos (Etec Albert Einstein, Colégio Santa Marcelina & ICTP-SAI FR). The winter school website is <https://outreach.ictp-saifr.org/cursodeinverno/>.

Clewton Fonseca, who is also a high-school teacher with FAPESP fellowship, teaches classes for high-school and middle-term students to prepare for the physics olympiad exams in Campinas: <https://outreach.ictp-saifr.org/programa-olimpiadas-cps/>, and William G C Oropesa (ICTP-SAI FR), who is a TT-5/FAPESP fellowship, does similar work with high school students, in São Paulo: <https://outreach.ictp-saifr.org/programa-olimp-so-paulo/>.

## Physics Games

Physics Games is an outreach program of ICTP-SAI FR introducing current topics in theoretical physics to students in middle school through entertaining games.

- In the first session of this program on March 21, Rogerio Rosenfeld (ICTP-SAI FR/IFT-UNESP) presented a short seminar on cosmology followed by a game based on the seminar. This activity was held at Etec Albert Einstein.
- In the second and third sessions (June 24 and August 26), for high-school students and teachers respectively, the activities were called “Physics missions”. In physics missions, participants in the game need to solve puzzles to unlock an “Escape Room”. In these editions, the topic was “Black Holes”. This activities were held at IFT-UNESP.
- In the fourth edition (October 23), Nathan Berkovits (ICTP-SAI FR/IFT-UNESP) presented a short talk, titled “What is light?”, followed by a Q&A game on the talk. This activity was held at CEU Heliópolis – Professora Arlete Persoli, an educational center in the south zone of São Paulo.
- In the last edition of the year (October 28) the physics games returned to the physics mission, in a session with the central topic of “Particle Accelerators”.

The website of this activity is <https://outreach.ictp-saifr.org/jogos-de-fisica/>.

## 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 2023 ICTP-SAIFR organized several online and seven onsite activities led by ICTP-SAIFR outreach coordinator Ana Luiza Sérgio.

The online meetings were held on Saturday, with the active participation of over 1000 high-school teachers from all over Latin America. Topics discussed at these online activities in Portuguese are described at <https://outreach.ictp-saifr.org/ensino-medio/professores/fisica-de-fronteira-para-a-sala-de-aula-online/> and in Spanish at <https://outreach.ictp-saifr.org/ensino-medio/professores/fisica-de-fronteira-para-a-sala-de-aula-online/espanol/>.

In addition, a one-week online summer school in Portuguese and Spanish on Cosmology was organized. The activities include minicourses based on Perimeter material translated into Portuguese and Spanish by ICTP-SAIFR and discussion sessions with different researchers. The website of this summer school is <https://outreach.ictp-saifr.org/cursoveraoprofessores/>.

The description of the in-person activities is in the website <https://outreach.ictp-saifr.org/ensino-medio/professores/>.

### 4.3.7 Weekly Seminars, Colloquia and Journal Clubs

In 2023, weekly seminars were regularly organized. There were 99 seminars and the complete list is on the website <https://www.ictp-saifr.org/2023-research-seminars-and-activities/>. There were also weekly journal club meetings in string theory, particle physics, cosmology and complex systems.

### 4.3.8 Annual Meeting of Steering Committee and Scientific Council:

On February 6-7, 2023, the ICTP-SAIFR scientific council met to discuss the activities planned for 2024. The council members are listed on the website <http://www.ictp-saifr.org/steering-committee/> and <http://www.ictp-saifr.org/scientific-council/>. The 2024 meeting of the steering committee and scientific council will be on February 18-21.



## 4.4 Request of Increase in Budget

Together with this report of the thematic grant, a modification of the budget is being requested to compensate the increase in airfares and hotel costs since the grant proposal was originally submitted in December 2021..

The original proposal of thematic grant 2021/14335-0 was submitted during the pandemic, and it was not anticipated that airfares and hotel costs would increase by more than 40 percent after the pandemic. This increase was acknowledged by FAPESP with the doubling of Benefícios Complementares and an increase of 35 percent in the allowed per diem from 555 reais to 745 reais. Because of this increase, ICTP-SAI FR expenses for travel and per diem during the first year of the grant has already used up more than 30 percent of the total 5-year budget for these expenses. For this reason, the proposal is being updated so that the typical cost of an international round-trip ticket is estimated at 1400 US dollars (instead of 1000 US dollars) and the number of diarias is increased by 35 percent so that the effective per diem is increased from 555 reais to 745 reais. This will imply an increase in the budget of 3.1 million reais, with an additional 1 million reais for travel and 2.1 million reais for per diem.

Note that the original 5-year budget for the project including fellowships is 17.6 million reais, so the requested supplement of 3.1 million reais is approximately 18 percent of the original budget. The quantity of 2025 ICTP-SAI FR activities that can be financed will depend crucially on this budget increase, so it would be very useful to know if this request will be approved before the ICTP-SAI FR 12th Anniversary Symposium on February 18-21, 2024 when the decision on 2025 activities will be made.

# 6 Activity Plan for 2024

In 2024, the ICTP-SAIFR will continue to expand its research, outreach and training activities in all areas related to theoretical physics. Confirmed scientific activities in 2024 which will be organized by ICTP-SAIFR are listed below and include international schools and workshops and programs on several topics which will take place both at IFT-UNESP and at the new installations of Instituto Principia. The list of 2024 activities planned up to now include the activities:

## São Paulo International School on Theoretical Physics

- School on Modeling Infectious Disease Dynamics (May 6-12).
- III Joint ICTP-SAIFR/ICTP-Trieste Summer School on Particle Physics (June 24-July 5).
- Second School on Dark Matter and Neutrino Detection (July 8-19).
- 2024 Perimeter-SAIFR-IFT Journeys into Theoretical Physics (July 22-28).
- Cosmological History: from Gravitational Waves to Exoplanets (July 29-August 9).
- School on Water: From the Anomalies to the Biological and Technological Applications (September 2-7).
- School on Active Matter (September 30-October 4).
- Second Quantum Computing School (October 7-18).
- School on Few-Body Physics (October 21-25).
- School on Biological Physics across Scales: Pattern Formation (November 11-22).
- Third School on Data Science and Machine Learning (December 2-6)

## Minicourses

- Minicourse on non-perturbative methods in QCD, quantum gravity and cosmology (May 13-31).

## Meetings/Programs/Workshops

- ICTP-SAIFR 12th Anniversary Celebration and 2024 Council Meetings (Feb. 18-21).
- APS/SAIFR Satellite March Meeting (March 3-8).
- APS/SAIFR Satellite April Meeting (April 3-6).
- [14th International Workshop on Neutrino-Nucleus Interactions \(NUINT 2024\)](#) (April 15-20).
- Workshop on Dynamical Processes on Complex Networks (May 13-17).
- Bootstrap meets Integrability (June 10-14).
- Integrability in Gauge and String Theory (IGST) (June 17-21).
- Witnessing Quantum Aspects of Gravity in a Lab (September 23-27).
- Third Brazilian Meeting of Science Communicators (November 15-17).
- Program on “Fundamental Physics meets Current and Future Facilities in Cosmology” (December 2-13).

## Outreach

- Escola de Verão para Estudantes de Ensino Médio (January 15-20).
- Curso de Verão para Professores de Ensino Médio (January 22-26).
- Minicursos para Estudantes de Ensino Médio (March-November).
- Física de Fronteira em Português (March-November).
- Física de Frontera en Español (March – November).
- Clube do Livro Sci-SAIFR (March – November).
- ICTP-SAIFR Módulos de Aulas (March – November).
- Ciclo de Palestras ICTP-SAIFR/Principia (March – November).
- Ciência no Cinema (January – December).

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